Radford's Estimating and Contracting

A Practical Manual of

UP-TO-DATE METHODS FOR RAPID, SYSTEMATIC, AND ACCURATE CALCULATION OF COSTS OF ALL TYPES AND DETAILS OF BUILDING CONSTRUCTION, TOGETHER WITH QUOTATIONS OF ORDINARY PRICES FOR LABOR AND MATERIALS, STANDARD SCHEDULES AND FORMS, LABOR-SAVING TABLES AND OTHER DATA USEFUL TO THE BUILDING TRADES

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Preface

ABILITY to figure accurately the cost of proposed construction is essential to the business success of the modern builder and contractor—an indispensable part of his necessary working capital, a passport to victory in competition, and a safeguard against loss. Up to the present time, however, the problem of making accurate and reliable estimates of cost has been the one great bugbear of the Building Trades in general. Estimates have been largely based on more or less skilful guesswork.

While it is a comparatively simple task to design a house, a barn, a bridge, or other structure, and even to build it complete in every detail, yet the all-important problem of determining beforehand what the finished work will cost has always been shrouded in uncertainty, so that the contractor's inability to forecast expense has made him timid and hesitating, and has caused the business of contracting in general to be looked upon as more or less a gamble surrounded with unmeasured risks to one and all concerned.

It is the purpose of RADFORD'S ESTIMATING AND CONTRACTING to teach the principles of scientific estimating—that is, to inculcate **systematic methods of procedure in figuring costs**, to show the reader the data necessary in every case, and explain how his particular problem is figured out on this basis. Prices are quoted, but in all cases they are provisional, depending on local conditions, for it is recognized that second-hand data such as specific quotations of prices are usually of little value for the reason that the conditions under which they hold good are rarely noted. Stress is accordingly laid on the far more important elements of **quantities** (for material) and **time** (for labor). If one knows, for example, how much material he will need on a job, how much excavating there is to do, etc., and how fast his men can be expected to do this work, an estimate of the cost then becomes easy.

It is as true of Estimating as of all other lines of activity, that men learn to do it by doing it, just as they learn to build houses by building them. Estimators are made, not born; and there is such a thing as developing an estimating faculty. So, while this work does not pretend to be a substitute for brains, nevertheless it embodies practical information based on the experience of well-known and successful contractors and builders in all parts of the country, as to the methods of estimating actually used by them in daily practice, on both large and small work.

Its systematic arrangement, broad range of contents, and multitude of useful, practical tables, will commend it to Contractors, Architects, Engineers, Carpenters, Cement Users, Masons, Plumbers, Decorators, Road and Bridge Builders, Steel Structural Workers, Sheet-Metal Workers, and the Building Trades in general.

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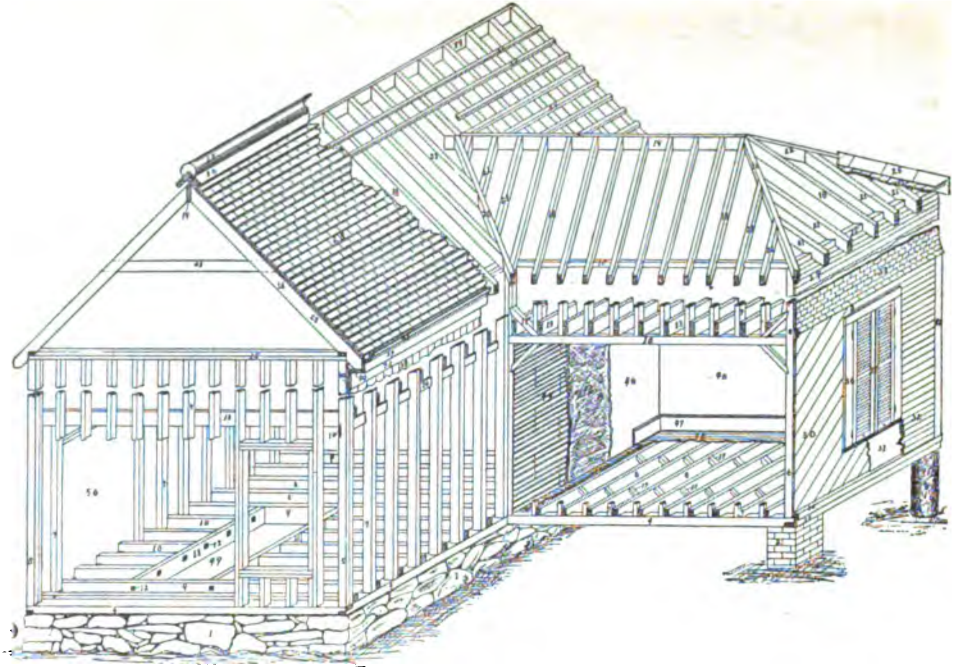


Fig. 1.—Chart Showing Structural Members of a Frame House.
For names of parts, see page 152.

RADFORD'S

Estimating and Contracting

General Principles of Estimating

At the very outset, we should understand—once and for all—that there is no such thing as a standard price for anything. Prices vary in different localities at the same time, and in the same locality at different times; and he who would figure costs of construction where it is necessary—as it always is— to purchase materials or labor, must acquaint himself with local market conditions in every case.

Nor is it possible to prescribe a form or scheme of estimating that will be everywhere and at all times applicable to any and all jobs whatsoever. For each example of construction is, in a certain sense, a job unto itself, involving factors which may vary infinitely with the endless variations of personality and sentiment, and which nothing in the universe can reduce to the monotonous uniformity of a universal rule or formula.

While, therefore, estimating is not an exact science in the sense in which physics and astronomy are exact sciences, wherein definite and precise results can be predicted from accurate and well-defined antecedents, and while any claim to reduce it to such form is merely "sounding brass and a tinkling cymbal," estimating is nevertheless founded on well-defined principles. The body of these principles constitutes the true Science of Estimating, which may therefore be defined simply as intelligent and systematic methods of procedure in the figuring of costs. It is the very antithesis of guesswork. And a knowledge of these principles, a mastery of these methods, is an absolute essential—in fact, it is the very foundation—of business success in all contracting and building operations. Without it, the modern builder and contractor is merely gambling against unknown odds.

One decorator, for example, will enter a room, glance at the walls, and immediately say, "I will paper that room for $5.00." Another will bring out his tape-measure or rule, and take measurements. He knows exactly how many rolls of paper will be needed; from records of his past experience, he can figure how many hours of labor will be needed for hanging the paper; and he knows the local wage-rate. From a business point of view, can anyone doubt, as between these two men, which one has adopted the safe and sane method of estimating? The one who figures carefully may not get the contract; but in nine cases out of ten he is better without it than at the other man's price. He knows why; the other man does not know; the owner may or may not know.

It is not unusual to find similar haphazard guesswork at play in figuring the basis on which bids are made, even on large construction jobs. It is no wonder, therefore, that many would-be contractors present their bids with fear and trembling, feeling that their action is merely a gamble, like betting on a horse-race. A knowledge of the factors determining costs, and the ability to apply this knowledge to the particular work at hand, would place their feet upon the solid rock.

To predict with accuracy what it will cost in time or money, or both, to accomplish work, is at best an exceedingly difficult task. To begin with, in out-of-door work the conditions are—many of them—speculative. We do not know the personalities of most of the men who are to be employed; we do not know how much rain or frost we shall have to contend with; and we are required to work under a contract many of the terms of which are vague, and some of them prohibitory. What wonder that estimates for the same work differ—and differ widely? There is a certain cost at which projected work is going to be done; but no two men will guess alike before the fact; and, after having guessed, no two men would come out with the same figures of performance on identically similar jobs, if it were possible to get together two identically similar jobs.

An ideal estimator should take into consideration all the conditions which affect costs, and should allow each condition to have just the correct influence upon his figures.

CONDITIONS AFFECTING COST

The conditions affecting the cost of construction work will naturally group themselves into three classes:

1. Those whose **quantitative** effect upon cost can be reasonably predicted.

2. Those of which the qualitative effect only can be determined in advance.

3. Those conditions the influence of which may be to increase or perhaps to decrease the cost above or below an assumed normal.

By way of example, (1) we can say in advance about how much more it will cost to haul bricks two miles along a known highway than to haul the same bricks only one mile along the same road; (2) we know that when we have to blast out a medium-hard shale, the work will cost more if the rock is full of seams and faults, with dikes of hard material, than if ordinarily regular in structure; but just how much more, or even nearly how much more, we cannot predict. Again, (3) the coming of a new superintendent upon the work will surely have an effect upon it, good or bad; but until he has been tried out, there is no telling which it will be. This last-mentioned fact accounts in large measure for the reluctance with which contractors let their old men go after they have run out of contracts.

In addition to the above, there are emergency and unforseen conditions that from time to time unexpectedly arise and make a carefully prepared estimate seem like a poor affair.

Obviously it is impossible, as we have already intimated, to eliminate absolutely all the elements of uncertainty in estimates. No matter how carefully we have proceeded, no matter how comprehensively we have "rounded up" the factors that may have a bearing on the final result, theoretically there will always remain at least some infinitesimal variations in our estimates from the standards of absolute truth and accuracy. The problem for us is how to make the closest estimate possible from the known facts. The most careful rules and the most elaborate system, if followed, would not reduce the art of estimating to an exact science It is not even possible to state with absolute accuracy what a job has cost after it is completed. How much more difficult, then, to forecast the cost before entering upon the work. It is no more possible to make an infallibly accurate estimate of the cost of anything, than it is to measure with unvarying accuracy the length of a beam, the height of a column, or the dimensions of a wall or floor. Much must depend upon the intelligence, the information, the aptitude, and—above all—the experience of the estimator; lastly, he must have the elusive and intangible but nevertheless positive and essential quality of judgment, without which all theory is helpless.

Fortunately, however, it is possible, no matter what the degree of complexity of the work, to estimate the cost with an accuracy close enough for practical purposes and with a sufficient marginal safety to provide against all danger of loss in bidding or in construction. It is possible, by the use of cumulative evidence, to reinforce a man's experience with the facts contributed by other men; and it is possible, by the presentation of correct theory, to show a man how to make his own experience of the most value with the least effort and fatigue. Such knowledge is the fundamental working capital of the successful bidder and contractor.

MEN WHO MAKE ESTIMATES

Estimates in general are made by three classes of men:

1. The **Engineer or Architect**, who makes them as the basis for designs, preliminary to obtaining contracts.
2. The **Contractor**, who undertakes to carry out the work.
3. The **man in the field**, who is carrying on the work.

The Engineer or Architect

The engineer or architect who makes his estimates as a guide to his client in deciding what work shall be planned, is usually in the position of the man who estimates without having to carry out the work himself; and he is always in great danger of making his estimates too low. The reasons for this are not generally appreciated. Some of them are as follows:

(a) His client is seldom willing to pay for a thorough investigation of the conditions that are to be met, it being assumed that since a contractor is willing to spend his own money in making an estimate on the chance of obtaining a profitable contract, the cost of estimating is so low that the engineer or architect can do it himself out of what he receives as his fee, and that it should therefore be a part of his office expenses. He cannot afford to make an extended investigation at his own expense, and thus fails to take into consideration many conditions which are more likely to increase the cost than to decrease it.

(b) As the business of the engineer or architect is to make designs, and as he is not particularly concerned with their execution except as an overseer, he seldom has actual experience of what it costs to do work, and is obliged to depend upon his records of contractors' bids on work of the class that he is contemplating. Since his figures on these bids are not in sufficient detail to make them applicable to his work except in a general way, he is at a serious disadvantage as compared with a contractor; and his disadvantage consists specifically in not having at hand a large number of facts which go to make up the contractor's cost. The engineer or architect seldom considers—because it has not been brought to his attention—the fact that the contractor must pay from 1 to 10 per cent of his pay-roll for liability insurance, and, after he has paid for liability insurance, he has such items as bad bills, lawsuits (outside of his liability insurance), discounts, and the like, all of which have to be taken care of by his average receipts. The estimating architect is therefore prone to make use of published data of costs, without adding anything for these special contingencies, thus frequently getting into serious trouble.

(c) The owner, or his representative, usually draws a contract which the contractor is expected to sign; and this contract contains clauses intended for the reasonable protection of the owner, but which are too often liable to result in an unreasonable hardship upon the contractor. The owner's engineer—be it said to the credit of the profession—is, in the large majority of cases, both fair-minded and unprejudiced; and it has long been a maxim of the engineering profession to give a contractor the benefit of any doubt as to the interpretation of any specific clauses. Often the man who draws a contract by way of insurance puts in clauses which are intended for protection against certain contingencies, but which may become operative in a number of other ways; and the contractor is obliged to put on a high price, rather than run the risk of large financial loss in the event of such clauses becoming operative. The following is a clause taken from the standard steel specifications of a large railroad:

"The Contractor shall so conduct his work as not to interfere in any way with the operations of the road or with the work of other contractors, or close any thoroughfare, by land or water, except by the special permission of the Chief Engineer. The erection shall be carried on with despatch, and in such manner as may be designated by the Chief Engineer."

This sort of clause, if enforceable, is one that makes the Chief Engineer the absolute arbiter or controller of the financial success or failure of the contractor on the work. To build a bridge on a railroad that is in full operation, in such manner as not to interfere in any way with the operations of the road, is one of those amusing inconsistencies that cost money. In all probability there never was yet a single instance in which a railroad bridge was built under traffic without in some measure interfering with the operations of the road. Such a clause as this means, of course, that the contractor must do his work with the minimum reasonable interference with the railroad; but it does not say so, and a contractor signing a contract with such a clause puts his head in a lion's mouth, and bids accordingly—often to the engineer's surprise and humiliation. Ambiguous specifications will force a careful contractor to bid high, and, by offering a reckle· contractor an inducement to bid low, will result in almost surely placing the contract where it will be inefficiently performed. The reckless contractor is not generally a good manager; and the careful contractor, if he gets the contract, will require more money than he would have been willing to work for had the specifications been precise.

(d) When work is done under national, state, or municipal authority, the law usually provides that the contract shall be let to the lowest responsible bidder; and everyone has an opportunity to bid. On private or railroad work, on the other hand, usually a selected number of contractors are invited to bid. In the former case, the architect or engineer has to guard against a contractor taking advantage of loose clauses, and must fortify himself—which he usually does—by making the terms as much one-sided as he can. The contractor who knows him personally, who knows the object for which the strict clauses were drawn and the extent to which they are to be enforced on the work, is thus enabled to make much lower prices than the man to whom the individual in charge is an entire stranger. This accounts for part of the large diversity of bids on any public work, and is a further reason why such bids, when published, are a very poor basis on which to make estimates.

The Contractor

In making estimates, the contractor is generally more expert than the owner's engineer or architect, because he is continually being confronted with the financial problem, and naturally makes more of a study of it; nevertheless his estimates are very difficult to make properly, for reasons among which are the following:

(a) The contractor rarely, if ever, receives compensation for his labor in preparing an estimate, and that labor is frequently very considerable; therefore he makes the estimate with as small a cost as possible to himself.

(b) The time within which the contractor must prepare his estimate is limited, and generally too much limited, so that he seldom has opportunity properly to investigate the conditions under which he is to bid.

(c) When ten men are to bid on one piece of work, it is manifestly unfortunate that each of the ten men should pay for an investigation which can as well be made by one; and yet it is seldom practicable for the bidders on a piece of work to combine and obtain all the information. For instance, in a job involving earth and rock work for foundations, unless the job is very large, the owner rarely makes sufficient test borings to determine thoroughly the existing field conditions; and yet the total cost of one investigation made by the owner would be very much less than the cost of all the investigations made by each contractor individually. The owner's point is that the successful contractor will make enough money to pay for the investigation; but it is almost never appreciated that when a contractor obtains a contract, he must make enough profit to pay for the investigation, not only on that contract, but for all those on which he has been unsuccessful as well; and the average of his bids must therefore be correspondingly higher than if it were the general practice among owners to furnish complete statistics when asking for bids.

The writer had occasion to bid on a large bridge for a municipality in West Virginia, on which almost no information from the municipality was forthcoming. Each contractor made an investigation more or less thorough, and was obliged to furnish his own design. The result was that over fifty bids, fifty investigations, and fifty designs were submitted, ranging from a minimum of about $40,000 to a maximum of about $140,000. All bids were rejected; and the municipality, reinforced and greatly benefited by the discussion that arose, re-advertised for bids. It is needless to add that the author did not bid again; but the question is: Who paid for all those estimates?

(d) After bidding upon work under a certain architect whom he knows, and whose attitude on certain clauses in his specifications he considers himself reasonably able to predict, the contractor may be confronted by a change of architects, and the new man may be more strict than the old. This is a danger more to be feared in long contracts than in short ones. In the former case, it is likely to be a very serious matter, and frequently offsets the advantage of having time thoroughly to organize and systematize the work.

Remedy. It will be noted that all of the causes for inaccurate estimates which have been pointed out above could be very largely remedied if two rules were rigidly adhered to by parties who ask for bids—namely:

First—Make specifications as specific as the limitations of language will permit.

Second—Obtain all available information before asking for bids, and furnish it to the contractors.

The Man in the Field

In order to reduce costs in the field, it is necessary to make estimates so as to know how the work is progressing. The field chief or superintendent frequently has to make estimates of the cost of work in progress.

Purposes of Estimates

The purposes of an estimate are to enable a contractor to know what it is going to cost in money or in time, or both, to carry out work. There is usually in contemplation a contract of one of the following forms: 1. **Lump Sum;** 2. **Unit-Price;** 3. **Cost plus a Fixed Sum;** 4. **Cost plus Percentage.**

1. **Lump Sum Contracts.** The first and oldest form involves the describing, by means of plans and specifications, what is to be done; and a guarantee by the contractor to perform all the work for a fixed consideration. After the contract is signed, it is up to the contractor to get the work done, and the owner is supposed to have no responsibility beyond making the specified payments. The contractor assumes all risk, and meets all difficulties whether foreseen or unforeseen.

2. **Unit-Price Contracts.** In the second form of contract mentioned above—the Unit-Price—the contractor receives an established price per yard, per pound, per ton, etc., and the owner assumes responsibility for the quantity. Since changes in plan involving increase or decrease of the amount of work are usually an accompaniment of most contracts after the contracts have been signed, this type admits of more elasticity than the first for meeting this condition.

3. **Cost plus a Fixed Sum Contracts.** Of late years, in order to permit of freedom in making changes without interfering with the liability of the parties, to save time, and for other reasons, the cost-plus-a-fixed-sum type of contract has come into vogue. Its advantage, among others, is that the contractor is under no risk, and therefore cannot be put out of business; and where the quantity and conditions cannot be determined beforehand, it has much merit. One argument against it, from the standpoint of the owner, is that the contractor, not having anything to lose, will not be likely to strive so hard for economy as he would if he guaranteed the price.

4. **Cost plus Percentage Contracts.** The fourth form of contract enumerated above—Cost plus Percentage—has long been used on railroad work, and usually provides that the contractor is to receive as his compensation and for his overhead charges a certain percentage of his pay-roll, with plant rental added. On this basis the contractor has nothing to lose; and the owner is at the disadvantage that the less the contractor's economy of operation, the greater is the contractor's financial gain, so that the contractor apparently has an incentive to wastefulness. Many contracts, especially on road work, require the contractor to maintain the finished work for a certain number of years. This places a peculiar hardship upon the contractor who is not expecting to remain long in that locality, thus eliminating the journeyman contractor. It requires, however, that he shall keep a considerable amount of money invested in plant at the call of that particular job, and therefore tends to impel a conservative man to bid high.

Warning. The man who is entrusted with the making of important estimates has resting upon him a large responsibility. His blunders may beggar him or his employer; yet too often cheap men of limited experience are employed on this work, and rules are accepted as substitutes for judgment. To the younger men of the engineering and contracting profession, it may seem that estimating is easy. Nothing could be farther from the truth. All that we can hope to do here is to boil down some of the gambling features of estimating, and place it upon a rational plane. To claim more would be dishonest and misleading. When a man says that he can safely estimate the cost of outside work within two per cent of performance, he may at once be written down as a fool or a liar. The difference in cost between a job that is run with ordinary methods and ordinary management, and the same job with proper cost analysis and thoroughly up-to-date-management, handled with push and snap, may easily be 30 per cent; and the claim of ability to guess within two or three per cent, without knowing a large number of the uncertain elements, is absurd. Therefore, in making use of our instructions, the reader must bear in mind that it is not attempted to predict what he or his organization will be able to do. Schedules are presented, covering most of the items on the main classes of work discussed in this treatise, the use of which should prevent many blunders of omission; but the reader must not understand that we claim to have given him a substitute for brains. He must use his own good judgment in every case.

GENERAL RULES FOR ESTIMATING

The successful estimator requires more than mere accuracy and quickness in figures. Experience and good judgment, familiarity with all the complicated details of the particular job in hand—these are factors of inestimable value, and they are qualities of an indefinable and intangible nature. The contractor should subscribe for the leading trade journals covering such portions of the construction field as he is interested in, and should keep an eye on **current prices and discounts.** He should also make it a practice in every case to file away his estimates, whether his bids based on them have been successful or not. If successful, he can compare his estimated costs with those of actual construction; and if unsuccessful, he can broaden his grasp of things by noting in what items his estimates have been too high or too low. In the preparation of future estimates, he will have at hand a great mass of data that will be of practical service. In every case, we repeat, he must acquaint himself with conditions, prices, and discounts current in the local market.

An estimator should rigidly adhere to the following general rules:

1. Make all estimates in the fullest possible detail.

2. Get together and classify all the available data before commencing to figure.

3. Use a carefully prepared standard schedule of items for the classification.

4. Go over the ground with great care—visiting the site of the work, if possible—to guard against the omission of items not provided for in the standard schedule.

5. Put down all the unit-quantities first; then all the unit-prices; and finally, make the arithmetical computations in such manner that you will not know even approximately the final results until all the figures have been thoroughly gone over and tabulated.

6. Check over the final results by every available means, such as contract prices on similar work, which are unsatisfactory as preliminary data. but which may be very useful as a check.

The reasons for these rules are as follows:

1. At first sight it would seem that it requires more labor and time on the part of the estimator to make estimates in elaborate detail than to make them in general. This, however, is not the case according to experience, since a much larger part of the detailed estimate can be done mechanically than when many of the items are lumped, and because the more elaborate the detail, the more confidence a man has in his own figures, and the faster he is able to work. When an estimate is made in careful detail, gaps in the available information become apparent; and in this way it is easy for an estimator to know just what information he lacks, and where the dangerous parts of his estimate are likely to be. Then, again, an estimate made in detail is much more easily checked by the subordinate or by the estimator's superior officers; and, when filed for reference, such an estimate is a document of great utility in future work. When the field costs are properly prepared, they can be used to check up the estimate for the work, in a way that is not possible if the estimate is not made in full detail.

2. It is a psychological fact—one based on the natural tendencies of the human mind—that if an estimate is made as the figures come in, it is impossible to obtain as good a grasp of the general problem as when the data are first collated, and the estimate then prepared on the data. While the estimates should be made in full detail, this does not mean that they should be made for different items of the work independently, since all parts of a piece of construction work are to a large extent dependent upon one another; and thus, if the estimated cost of one item is set down before the other items are known, their interdependence or mutual relations will not be appreciated and will not be allowed for in the estimate.

3. Rolling off a log is a difficult and elaborate feat com-

pared with forgetting items in an estimate; and it has been found, from wide experience, that **the best way to avoid omitting items is to start with a standard schedule.** To write a zero after an item that is not going to come into the estimate, takes practically no time; and the use of such a schedule in all cases is excellent insurance against blunders. A good plan is to have such schedules in stock, printed on sheets of coarse-ruled paper.

4. It is a sad fact that a great many estimates are made without the estimator ever seeing the work. This is utterly wrong; and it should be an invariable rule that the estimator must go over the ground, and go over it thoroughly; else it will be impossible for him to use the essential quality of judgment. Moreover, there is nothing like a physical view of the field for enabling a man to grasp all the details of the work. For this purpose, plans are of great assistance in the detailed analysis; but they are no substitute for a good look at the ground.

5. An estimate, to be accurate, should be **absolutely unbiased**; and where a question of judgment is involved, it is essential that the estimator make his figures without regard to what they will amount to in the grand total.

6. After the grand total has been computed, it should be checked; and the checks may throw some light upon erroneous items, which can then be corrected. The estimator's judgment will be a great deal more accurate if he works the problem out in detail first, than if he tries—perhaps sub-consciously, or without fully realizing the fact—to work to a desired or hoped-for result.

The practice of taking somebody else's contract price as a base of figuring, is very deceptive if you do not know what specifications he had, how he intended to do his work, what layout he anticipated, and what his financial arrangements were. All of these items are of the utmost importance in figuring the economics, or the financial features, of any particular piece of work. Conditions vary in places short distances apart; rates of wages vary in different parts of the country; specifications, and the interpretations of identical specifications by different engineers, vary greatly; the bid prices are frequently too low or much too high; the bid prices may be purposely "unbalanced"—that is, made abnormally high on certain items, and abnormally low on others, but always so as to offset one another and "even up" in the grand total; a unit-price for a large job is usually too low for a small job, on account of the falling percentages, or relatively lower rates, of overhead charges and superintendence on the larger jobs; a contractor well equipped with plant can usually bid lower than contractors not so equipped.

Hints for the Estimator

Don't forget that rates of wages are lowest in dull times and in winter, and highest in boom times and in summer.

Remember that an allowance for discounts is not operative when payment is delayed beyond the time limit.

Repairs on bargain-counter plant may be three times as great as on first-class new equipment.

Depreciation is affected by a multitude of conditions, and estimates of the amount for this item should not assume too high a figure for scrap value.

The interest on plant goes on whether the plant is working or not.

If the non-paying part of a job has to be done first, interest on the loss will run to the end of the contract.

In estimating the cost of transportation, give special attention to the character of available roads, the direction of the proposed traffic, and the time of year.

Insurance against accidents depends upon the riskiness, not to the plant, but to the men.

After making an estimate in detail, lay it aside for a day or two if possible, forget the figures, and then go over them again critically.

If someone else is going to carry on the work, take his personality into account in making an estimate of how much his work is going to cost.

Check up an estimate against average contract prices, selecting particularly contracts where the conditions are well known, and selecting the contract bids from firms of experience in the line of work in question.

Check over the bidding sheet to see that it compares with the estimate.

A long and big job can be estimated on more safely than a short and small one, since the accidental conditions on big work are more likely to balance themselves.

It is not wise for the contractor to figure on making money out of lawsuits, as he can generally make a good deal more money by doing construction work on a square basis than he can by providing a job for his lawyer.

The worst estimate made upon even assumed data is generally a good deal better than guess.

The cost of materials will vary from year to year. A study should be made of the characteristic fluctuations in prices, when figuring closely, in order that proper prices of materials can be determined for some time in advance.

QUANTITIES TO BE CONSIDERED

The estimator will generally have trouble when it comes to the **amount of work** to be done, this usually being roughly approximated, with the right to increase or decrease it later. A good method is to write down the maximum and minimum amounts that are likely to be involved. Clauses in the contract which enable the owner to change the contractor's quantities without changing unit-prices, should add something to the contractor's estimate, for the reason that there is one best plant, one best arrangement, one best organization, and one best outfit for every particular work. It has been shown that many of the conditions which affect the economy of the work are themselves affected by the quantities of work to be done; and any change on the part of the owner's mind affecting the quantity of work to be done, should—but rarely does—tend to increase or decrease the contractor's unit-price. In order to guard against such a contingency, the contractor should add something to his price by way of insurance. After an estimate has been made, it is a practice of many contractors to **unbalance** their bids. A great danger from this is that the work may have to be completed with quantities different from what were originally figured.

The kind and condition of the **equipment** available should be at hand, but is not often turned over to the estimator, unless he asks for it.

Frequently the name of the man who is going to **superintend** the work is not known in advance, and it should be established if possible.

The **general layout** of the work can be determined only by a personal inspection of the ground; and on this the estimator should make copious notes, having special reference to the distance of railroad connections, the distance of the railroad connection from shipping points of materials and supplies, the character of the country, the kind of water, and as many of the local conditions as can be reasonably and quickly noted.

He will find that the **time for completing** the contract will usually be determined by the business conditions. This ought to be ascertained with considerable care, because upon it depends the scale of the work.

State of the Labor Market. It is difficult to predict this two or three years in advance. In unfamiliar territory, if the padrone system is in use in the neighborhood, it is not difficult to obtain from the nearest padrone (importer of foreign labor) an estimate of how many men he can furnish, and then, by cutting the estimate in two, get somewhere near the probabilities. If it is necessary to board or transport the men, a provision for this should be made in the estimate.

Earth and Rock Work. This is perhaps one of the most important items, and one of the hardest to establish, because of the expense attendant upon the digging of test borings, making borings, etc. Personal inspection, where a man has had considerable experience, will go a long way toward helping out; but in earth and rock work a certain amount of boring is absolutely necessary for proper results.

Management. The method of managing should be understood before the estimate is to be made. If upon the work a bonus system and cost analysis are to be used, prices can be materially lower than when the ordinary day labor method is to be employed. Just how much lower, is a matter of judgment; but from past experience it may safely be said to range from about 10 to about 40 per cent—with 20 per cent as a safe average on general work.

If **electric power** is available, the fact should be carefully noted.

The **kind of supplies** readily available, and their cost on the work, should be estimated, not neglecting the water problem. The cost of coal of good quality will vary a great deal; and if a poor quality has got to be used, a very much larger amount should be allowed for than if the quality were good.

It is well to put the item **tools** in the estimate, as the estimator is more likely to know the proper kind and size of tools than the purchasing agent, and it serves as a useful reminder. Shovels of the proper size, for example, may not be locally purchasable on short notice.

Whether or not to work **night shift** can be determined by estimating the necessary daily output to complete the work in time; and if this daily output cannot be safely reached with the labor available by day, night shift must be figured on. If one night shift is employed, from 7 to 10 per cent should be added to the labor cost; while, if two night shifts are to be put on, 10 to 12 per cent of the unit labor cost should be added, since the output per man working night shift is likely to be from 15 to 20 per cent less than by day. Of course, judgment must be used here, depending upon the kind of work, conditions, etc. Night shifting in summer is a much simpler matter than in winter.

The **weather** is the greatest controlling factor, excepting in tunneling and on the interior parts of building to be done after the roof is on; and the probable number of working days on a short job cannot be estimated, except at considerable risk. Therefore, when the job is small, the unit-prices have to be assumed higher on this account than when the work is of long duration and the average weather counted on. When the work is to be done in an unfamiliar climate in the United States, the records of the Weather Bureau can be consulted, either by personal inspection or by writing to the Observer; and from these records the probable number of rainy days and days of excessive frost can be quite closely estimated if the work is to be of long duration. This should always be done as carefully as possible, since the weather is economically one of the most important field conditions to be considered.

A **working day** is a day, not a holiday, suitable for work. If the day is not a holiday, and is suitable for a working day, whether work is done or not, that day is a working day.

Amount of Capital Involved

Equipment. It is usually not difficult to estimate with reasonable accuracy how much plant will be necessary, provided that the working conditions are well established. Where drilling is to be done, the maximum and minimum average performance per drill must be determined from an inspection of the local conditions. It should be borne in mind that under ordinary working conditions from 10 to 20 per cent of the drilling equipment will be in the shop for repairs, and that a surplus of at least 15 per cent should be provided. Extra drills can easily be procured at comparatively short notice; but extra steam or air service cannot, and therefore a more liberal margin should be provided for the boilers and compressors than the actual number of drills to be taken on. Liberal allowance should be provided for pipe lines and for connections, whenever the work is to be done in cold weather.

For the process of loading, in the case of large jobs, the grab bucket, the steam shovel, or the derrick and skips are the logical types of equipment, with the advantages lying in the order named; and given the conditions and class of work, a fairly close approximation of the cost of equipment can be very rapidly made. It is necessary to be very careful to make a proper allowance for lost time.

Before deciding upon cost of transportation, it is necessary to have some approximate idea of the grades to be worked over; and in wagon work the assumed net load which can be safely handled upon the roads in their probable condition will determine this factor.

On large jobs, 10 per cent should be allowed for equipment undergoing repairs. In estimating, it is wise to figure on standard ordinary equipment wherever possible. Bear in mind that an engine cannot operate for many months without thorough overhauling.

One pick to every two shovels. The cost of tools per cubic yard handled is trifling.

A close estimate of the cost of temporary buildings can be made by roughly figuring the cubical contents necessary, then the amount of square feet of wall surface and partitions. The cost of a building should never be guessed at in a lump, as it depends upon the available material.

Cash Capital. On a good-sized piece of work, $200.00 for petty cash on a job is ordinarily ample to take care of express charges, etc. The amount of the pay-roll per month will depend upon the number of men employed; and when monthly settlements are made about two weeks after the end of the month, this amount will have to be "carried," so that about half or two-thirds of the average pay-roll for the entire job will have to be considered as continually losing interest.

This amount of capital to be considered available is in the nature of an insurance fund against emergencies; and the more risky the nature of the work, the larger it should be. Ordinarily the interest upon this is comparativly insignificant.

Storage. The contractor must make a list of the approximate amount of material to be kept continually on hand, which will vary with different classes of work and the facilities that must be provided for storage. Where a stock pile is to be used, the preliminary work of getting ready the ground, erecting a handling plant, etc., is a part of this item, which also includes the salary of the storekeeper, who looks after not only the storage of the material but also that of plant and supplies. The cost of rehandling material may be classified either as storage or as preparatory charges. The storekeeper, supplies, stationery, coal to warm the storehouse, as well as necessary material for labor, should not be forgotten. For the total cost of storage, 5 per cent of the actual value of small tools and material, ignoring storage of large plant on average construction work, is liberal.

Bonus or Discounts. This item depends largely upon the particular business followed. If the contractor is figuring to earn a bonus on the contract price by getting through before the time limit, such being provided in the contract, it should appear in the estimate; and, as offsetting this, what he can lose by delay should also appear in the estimate. Not long ago, one of the largest cities in the United States paid for a considerable amount of work in bonds at par, which several contractors, needing the money, sold at a discount of not far from 3 or 4 per cent, as it was not convenient for the city to raise the money on short notice. It is safe to say that this had not been figured on in their estimates.

Charity or Accidents. This is an item about which it is practically impossible to give advice in advance. The first part of it covers a good many sins and other things in contract work, while accidents are generally provided against, as far as possible, by insurance. Where the insurance companies refuse to insure, the contractor has got to provide against this item in the estimate somehow; and it is well to estimate the rate that the insurance companies would be likely to insure for if their rules did not prevent them from doing so, and to multiply this rate by about two.

A contractor is supposed to assume certain risks; but, as pointed out by Colonel Raban, of the Institution of Civil Engineers of Great Britain, it is another question whether all of the risks should be put upon the contractor. Risks from weather, the problems of handling men, and the general vagaries that go with all construction work, are probably the contractor's risk; but, when held up by strikes, or by eventualities that are not peculiar to his line of business, it seems unreasonable to shift these risks to the contractor's shoulders, and thus needlessly raise his estimate.

Depreciation. No other part of the estimator's task will call for the exercise of more careful judgment than the determination of the percentages of depreciation.

Fire Insurance. For brick buildings and for dwellings and their contents, the rate in the eastern part of the United States ranges from ¼ per cent to 1½ per cent for three years. For a plant such as in use in the Hudson River Trap Rock Quarries, the rate is from 2 to 2½ per cent per year. The rates vary widely with different localities and with different kinds of buildings or equipment insured; and where a general approximation is not sufficiently definite, the estimator will have to go to the nearest fire insurance agent, who, with the idea of getting business, will be so keen to furnish him with information as to make it a pleasure to ask for it.

Rent. This depends entirely upon the local conditions, and can be obtained by the writing of a postal card to some representative agent in the vicinity.

Interest. This may be ordinarily assumed as a fair average at 6 per cent per annum, or ½ per cent per month. In times of financial stress, or in certain parts of the United States where money is scarce, the rates will be higher than this. For a year or two after a panic, and on good collateral, money can often be borrowed for as low as 4 per cent.

Preparatory Costs. The best way to get a good estimate on the preparatory costs is to interview the man who is going to take charge of the job on the ground, and go over with him in detail how many men he is willing to undertake to get into full operation with, and how long it will take him to organize.

Advertising. This is an overhead charge depending upon the policy of the manager.

Repairs. The estimator must use his best judgment on this difficult and perplexing item.

Burglary Insurance. This, like fire insurance, will depend upon local conditions and the state of mind of the insurance companies. For private dwellings, the rates in some companies are $12.50 per thousand dollars per year, or 1¼ per cent per year. Where it is not thought advisable to purchase burglary insurance, the estimator should nevertheless realize that theft is possible if not likely, and it is wise to allow about 2½ per cent of the value of the constant stock of small tools and supplies on the work for this item.

Freight, Express, etc. This must depend upon the class of material handled, the distance to be hauled along the railroad, and the amount of competition between roads. It will be more in sparsely settled country than where there is much competition.

Bond. From a well-known indemnity company, in 1909, when a bond is in favor of New York City and is for 50 per cent or more of the contract price, ½ to 1 per cent of the bond is charged. When it is less than 50 per cent,

¼ of 1 per cent is charged. The minimum charge is $10.00. All other bonds cost ½ to 1 per cent of contract price. Bonds on contracts for furnishing supplies only (no labor) cost ¼ of 1 per cent of contract price.

ESTIMATED UNIT-COST

Hourly Direct Labor. From his general experience and what information he can gather from published data, the estimator is in a position to determine with fair accuracy between what limits he can reasonably expect to come on the item of direct labor, which is the fundamental labor charge and which ought to be nearly proportional to the actual amount of work accomplished.

Weekly and Monthly Labor. This can be selected as a percentage of the item above mentioned, and depends very largely upon the local conditions, number of men employed, etc. Where there is a large amount of plant, such as steam shovels, hoists, drills, etc., it may run as high as 15 per cent maximum. For average work it is likely to be about ⅜ of this.

Superintendence. This is likely to vary from 10 per cent to 20 per cent of the direct labor pay-roll. It will be more on small work, and less on large work. On large work, it is generally too small for true economy.

Materials. The amount of these to allow for can be figured from the plans of the finished work. A percentage, generally not less than 3, should be allowed for loss in handling, shortage in shipment, etc.

Supplies. Such as coal, oil, waste, etc. This item should be carefully gone into, and rates obtained when the work is large or far from a base of supplies.

Miscellaneous. It is a practice of many estimators to add from 5 per cent to 10 per cent to their estimate for miscellaneous and contingencies. The more the detail of the estimate, the less the necessity for a large amount for this item. Miscellaneous items can cover possible inefficiency of laborers, strikes, rise in rates of wages, or unforeseen contingencies. From 5 per cent to 20 per cent of estimated labor cost, is a fair allowance. It is an item used to insure against oversight or ignorance in making up an estimate. On materials the prices of which can be obtained before putting in a bid, there is no necessity for these.

Profit. The estimator can figure his grand total of cost, to which should be added a percentage for profit. On small work where the risk is large, this should be high; and on large work where the risk is small, it may be as low as 10 per cent when there is competition. The profit should not only take care of the risks of the business that cannot be or are generally not included in the above items; but it should also take care of the compensation to the stockholders, or to the contractor himself for his time and skill and risk in organizing the business and keeping it going. Thus, on certain work, 25 per cent or 30 per cent is not an excessive profit.

COST ANALYSIS

Only very few contractors who handle construction work have what, in plain words, might be called a truly "intelligent" idea of the actual cost of the same, until the work is finished and all accounts settled. Then they find, in a great many cases, that the work has either caused them a direct loss, or has earned but a small margin of profit.

The common lack of judgment in making up estimates of cost when submitting bids, may be laid to one or all of three things:

1. The comparative newness of the particular form of construction to the contractor;
2. The lack of system in making up estimates, thereby omitting important details;
3. The application of methods and costs which were successful in one locality or for one class of work, to another locality or to another class of construction.

If a search is made through the current engineering publications, it will soon be noticed that the ordinary contractor who wishes to build a residence or small building, using, say, concrete as the material of construction, is confronted with a mass of data and costs relating to such structures as dams, large retaining walls, city sewerage systems, and filtration plans, pavements in large quantity, and accounts of other massive construction, which do not fit his case at all, and which, in the majority of instances, would be ruinous if he used the figures given in making up his own bid or estimate of cost. It is true that similar work in the same locality, built under the same conditions as existent in previous structures, may be estimated with a reasonable degree of exactness; but successful contractors do not seem to have arrived at the stage yet where they are anxious to make known the means of their success, and allow their competitors to reap the result of their years of systematizing and well-remembered losses.

If the methods used by these successful contractors were closely investigated, the results would show that system was at the bottom of the whole matter. Carefully kept records of similar work, modified by the changes in the prices of materials and labor, form one guide-post in the path of successful estimating. A piece of work to be figured on should be carefully analyzed, separating each kind of material, each kind of labor, the amounts of all component parts, the likelihood of loss at any point during the construction, the cost of plant necessary, interest on money necessary to carry the contract, and all details which might in any way affect a fair profit on the work in hand.

The general scheme of such a system is outlined in a paper read before the American Society of Engineering Contractors by Mr. Gustave Kaufmann, and is broad enough to allow for variation in the method of handling details in each individual case. In regard to his system, Mr. Kaufmann says:

"The desirability of contractors throughout the country adopting a uniform system of keeping their accounts is very great. The main advantage is that gradually all engaged in contracting work will become familiar with what it actually costs them to do their work; and the very wide variation of bids which are now submitted at almost all lettings will eventually be done away with. It should prevent all but the most reckless from making proposals below cost. If these very desirable results are finally attained, the contractor's business will become a more stable one, and one in which banking houses especially would have more confidence than they have at present.

"The uniform system adopted should be simple, inexpensive to keep, and should have wide flexibility to permit its application to contracts of all kinds. The author has for a great many years been using a system deduced from the bookkeeping methods of our railroad companies, which he has found to be satisfactory in all respects.

"There are six general headings into which all contract work must be divided. They are as follows:

(a) Materials of Construction.
(b) Labor.
(c) Supplies.
(d) Plant.
(e) General Expense or Administration Charges.
(f) Profit.

"All general heads into which any contract is classified, such as excavation, concrete, masonry, etc., must be subdivided into such detail as may be desired, keeping constantly in mind the above headings.

"For the purpose of explanation, it is probably better to take an example of actual work. Let it be supposed that the construction of a reinforced concrete retaining wall is to be undertaken, the work to consist of excavation, concrete, and steel reinforcement. The heading **Excavation** would be divided as follows:

Labor—

1. Excavating in Trench.
2. Hoisting Excavated Material.
3. Trucking.
4. Back-filling.
5. Shoring and Sheeting.

Supplies—

6. Coal.
7. Oil.
8. Water.
9. Miscellaneous.

Plant—

10. Cost Delivered.
11. Maintenance.
12. Removal.

General Expense—

13. General Expense.

Profit—

Expenditures during the execution of the work would be distributed as Excavation Nos. 1, 2, 3, etc.

"**Concrete** could be divided as follows:

Materials of Construction—

1. Cement Delivered.
2. Sand Delivered.
3. Stone or Gravel Delivered.
4. Facing Material Delivered.
5. Lumber for Forms Delivered.
6. Cement Bags.

Labor—

7. Mixing Concrete.
8. Transporting Concrete.
9. Depositing Concrete.
10. Making Forms.

11. Erecting Forms.
12. Removing Forms.
13. Facing.

Supplies—

14. Coal.
15. Oil.
16. Water.
17. Miscellaneous.

Plant—

18. Cost Delivered.
19. Maintenance.
20. Removal.

General Expense—

21. General Expense.

Profit.

"**Steel Reinforcement** could be divided as follows:

Materials of Construction—

1. Bars Delivered.
2. Wire Delivered.

Labor—

3. Storing and Distributing Steel.
4. Bending Steel.
5. Placing Steel.

Supplies—

6. Miscellaneous.

Plant—

7. Cost Delivered.
8. Maintenance.
9. Removal.

General Expense—

10. General Expense.

Profit—

"It should be noted that in each of the above subdivisions the general headings are always included.

"The **General Expense** or **Administration Account** should be subdivided, for example, as follows:

General Expense—

1. Engineering.
2. Bookkeeper, Stenographer.
3. Timekeeper, Storekeeper.
4. Telephone, Stationery, Sundries.
5. Rentals.
6. Legal Expense.
7. Surety Bond.

8. Liability Insurance
9. Watchmen.
10. Interest and Discount.

"In preparing a bid for work of this character, the cost of each one of the above items should be carefully estimated with the best data available; and the charges for the general expense, plant, and profit should then be apportioned to the various items of the work as above indicated in accordance with their relative value. In this way the unit-price that should be submitted for the excavation, concrete, and steel reinforcement can be determined. If such a method of computing would be adopted by all competitors, then there would be but little variation in their bids, and surely the low bidder could not be very much too low. The method which is used by so many contractors at the present time, of jumping at the price that they should submit, is one that cannot be too strongly condemned.

"When the work is started, ledger accounts should be opened with each item as above enumerated.

"The general expense account should be kept separately with subdivisions as above suggested; and then, at intervals, by means of journal entries, should be transferred to the excavation, concrete, and reinforcement accounts, using the same percentages of the apportionment which were used in making the proposal. By simply adding up all the accounts of any one class and dividing them by the amount of work done, the cost of execution at any stage of the work can readily be determined.

"The books required for such a system of accounts are of the simplest character, and can be purchased at any stationery store. They consist of cash book, ledger, journal, and voucher book.

"The voucher system should be used. As is well known, under this system all bills and pay-rolls are inclosed in a blank, on the back of which is a place for distributing the amount to the proper accounts.

"If it is desirable to keep a running account with the parties with whom much business is done, their vouchers can be credited to them, charged to the voucher account, and placed among the paid vouchers.

"In the case of a contracting concern carrying on a number of contracts at the same time, ledger accounts should be started with the contracts themselves, each given a number and a subsidiary set of books kept for each contractor.

"In order to aid in the distribution of the pay-roll, a system of cards may be used, upon which are placed the amount of labor expended under each head for each day. This work is usually done by the assistant engineer from the reports of the timekeeper and the foreman of the various gangs. One set of cards is used for each week. These cards are very valuable for keeping track of labor costs, checking the pay-roll, and should, if properly kept up, prevent all disputes or padding of pay-rolls.

"As can be readily seen, the above system as outlined can be used for any kind of contract work, the headings being arranged to suit the work on hand. These headings can be subdivided to any refinement desired by the contractor.

"The system is very inexpensive, as it requires no elaborate forms and no more help than is usually required. As far as the author, aided by many years of experience, is able to judge, it meets all the requirements that a uniform system of accounts can need."

Cost Data from Experience

In order to show the importance of a carefully followed system in determining the actual costs of work, and to illustrate the care used in obtaining reliable data by some of the large and successful contracting companies, we are quoting the following from a paper read by Mr. Leonard C. Wason, President of the Abertlaw Construction Co., of Boston, Mass., before the National Association of Cement Users:

"The writer is going to give, in the course of this paper, some actual job costs of various parts of building construction from his own experience. This kind of data is usually guarded with the greatest of care from every interested or curious eye outside the firm possessing it, and often even from the trusted employee of the company. It is information usually known only to the manager or owners of a construction company, and kept by them under lock and key.

"A great many builders are taking up this type of construction (reinforced concrete) at the present time—some who are competent, many who are not. The novices underestimate the cost and difficulties of doing good work; hence they bid unreasonably low, lose money, and to some extent demoralize the true value of proper workmanship among architects, engineers, and their clients. In the writer's opinion there is no class of construction where more painstaking skill and often technical knowledge is required than in reinforced concrete. When well done, the resulting building is satisfactory to the owner beyond that obtained from any other material; and when poorly done, is the least desirable, even if not actually dangerous. Concrete is either good or bad. There is no half-way state, and the difference in cost of materials to the builder between perfect results and a dangerous structure is only 5 per cent. Therefore there is likely to be serious injury done to a rapidly growing industry by novices, either on account of ignorance, though coupled with honest, well-meaning intent, or through skimping a job on which the novice sees he is sure to lose money. Moreover, the older firms in the field have little to fear from the beginning, because so much depends on the personal ability as well as experience. With growing competition, improvements are constantly being developed. The standard of cost is not yet fixed, but is being reduced steadily. The desire of reducing the present wild bidding and having only intelligent competition, as well as saving some poor builder a loss he cannot afford, is the real inspiration of this paper.

"**Method of Collecting Data.** In order to have an intelligent understanding of the meaning of the figures hereinafter given, the method of collecting data will first be described.

"In making up an estimate of the cost of a building, in scaling the plans, it is found convenient to take off the volume of excavation and back-filling. The cubic feet of footings, foundations, and walls, the square feet of forms for walls of foundations and above grade, the linear feet of belt-courses, mouldings, cornices, etc. Also the size of special features of exterior treatment. Similarly, the superficial areas of column and floor forms are measured by themselves. Concrete of each different mixture is scaled off in cubic feet and totaled separately. Steel of each kind is taken off in pounds; granolithic finished surfaces, in square feet; and so on in detail; every item is measured.

"As the work progresses, it is desired to know weekly how the actual experience compares with the estimate, and, at completion, to compile correctly the costs of each item to compare with estimate and to aid in obtaining the true cost of future structures of a similar kind. The method of accounting was developed to fit the estimate.

"In the year 1898, daily time reports were designed, having a number of columns for ease in subdividing the time of the workman. At the head of each column, the timekeeper puts index numbers or letters to show the kind of work being done; and below, the actual time the men worked. On blank spaces at extreme right of the report, the timekeeper inserts in writing the amount of each kind of work done and the amounts of the principal materials used. The experience of eight years has required no change whatever in the principles first adopted. The only change in the forms has been to increase the number of vertical columns so that a larger number of subdivisions can be used without troubling the timekeeper to rewrite the names on another sheet. At the present time, ten vertical columns are used for recording time with the names of the workmen at the extreme left, two columns being left at the right for the rate per hour and the total amount. At the beginning of a job, written instructions are given as to how the work is to be subdivided into items in the reports."

A **standard method of classification** has been adopted as follows:

"The principal subdivisions are given a capital letter. Thus everything whatsoever relating to concrete masonry is given the index letter **M**; excavating of all kinds, including work incidental thereto, the letter **D**; all work connected with plant, the letter **F**; and so on, there being only six or seven subdivisions to indicate every building operation

"Vowels are used to indicate the kind of work. Thus the vowel combinations beginning with **a** all relate to form work, as: **a**, centering complete; when done by separate operations, **aa** is making, **ae** is setting, **ai** is straightening up or bracing, **ao** is removing after being used, and **au** is cleaning up and handling ready to be used again.

"All labor connected with mixing and placing concrete or with handling materials for same, goes under the head of **e**; all work in connection with plant, receiving, erecting, taking down, shipping, and repairing, is indicated by the vowel **i**. Thus **i** means receiving and setting up plant ready to work; **ia**, taking down, removing, and shipping; and **ie**, repairing.

"The consonants are used to indicate different parts of a structure in which certain work is done. Under classification **M**, **b** stands for footings; **c**, columns; **d**, foundations; **f**, floors; **g**, stairs, etc. Under classification **P**, **f** stands for boiler; **g**, for horizontal engine; **h**, for vertical hoisting engine; **l**, for elevator; **m**, for mixer, etc.

"Thus our timekeeper places at the head of a column when he is reporting concrete floors, for the placing of forms **Maaf**; for concrete, **Meaf**. If a mixer is being set up ready for work, the report would read **Pim**; and later, if it was repaired, it would be reported under **Piem**, etc.

"This is not so complicated to use as it may appear to read, and experience has proved that every man who knows enough to keep time can use the system with a few days' experience. The principle is to make the least amount of clerical work to the timekeeper on the job, as he has plenty of other work to do.

"In addition to subdivision of time as above set forth, it is the duty of the timekeeper to report the number of barrels of cement mixed in a day, which is usually done by the man in charge of the mixer counting the empty bags, and in addition the actual volume of concrete measured in place. From this, knowing the proportions, it is a very simple matter to obtain the amount of sand and stone used, and also to see if the right amount of cement is being used.

"Carpenter work on forms is reported by the number of square feet of surface in contact with the concrete erected. Thus, walls are measured two sides without deducting doors and windows, as it is usual to let the form work run straight across these unless it is impossible on account of mouldings, in which case the framing of the opening will cost as much as the form work omitted. Beam floors are measured around the perimeter of the beam and the flat surface of the panel, and around the perimeter of the girders. No deduction is made for the loss of area by the intersection of beams and girders, and small openings in the floor are not deducted. Anything as large as an elevator or stairway is usually deducted. Form work for columns is measured for entire area of surface contact between wood and cement, all four sides.

"The reports are made out on the job, daily, and sent to the office. The bookkeeper works these reports up into units of measurements, such as Cost of Labor per Cu. Ft. of Concrete, No. of Cu. Ft. of Concrete per Barrel of Cement, No. of Sq. Ft. of Form Work Erected, etc.; and from this it is easy to obtain the unit-costs. The bookkeeper can take the reports of four or five jobs, employing in the aggregate five or six hundred men, and in a single day work up the complete report for a week's time. Thus it will be seen that there is really little extra labor involved in the subdividing of reports into a useful form over merely reporting the time so that the pay-roll can be accurately made.

"Materials received on the job are reported on cards printed for the purpose, listing the principal materials which are reported, in order to save work of the timekeeper in reporting materials accurately.

"When a job is entirely completed, and the ledger account is closed, a master card is worked out, giving the complete history of the cost. On one side of the card are written the items which went into the original estimate, such as excavation, back-filling, footings, foundations, columns, floors, walls, stairs, etc., etc. In parallel columns is placed the actual amount of the estimate, with the actual experience, reduced to cost units such as cubic feet, square feet of form work, etc., and the percentage of profit or loss between the estimate and actual results.

"On the reverse side of the card the principal items are worked out more in detail. Thus form work is reduced to cost of labor, lumber and nails, wire or other sundries used in the forms, per sq. ft. of surface. Concrete is itemized into the superintendent's general labor; labor of mixing and placing; cost of cement, sand, stone; miscellaneous expenses, such as teaming, plant, and other general items, reduced to cu. ft. measurement, which makes the total cost of the concrete in place in each division of the building itemized for ready reference when making up future estimates on work of a similar character.

"It is well known that the costs of materials and labor in different parts of the country vary somewhat. Having the unit items all subdivided, as above stated, into their elementary parts, it is an easy matter, after determining the cost of materials in any locality, to make the exact corrections to the results obtained on a previous job. Similarly, when a difference in the rate per hour for wages is known, if the same efficiency is obtained from the men, it is very easy to make a correction; or, if the efficiency varies, judgment must be applied to determine the correct rate to use.

"It has been the writer's experience that, although the rate of wages and cost of materials vary somewhat in different parts of the country, the variations frequently offset one another so nearly that the sum total of the unit-cost obtained in one place may be used in another, very seldom needing correction. For instance, after careful investigation, a bid was recently made on a structure at San Juan, Porto Rico, using the same unit-costs as for a building in Boston. In the report that is given, the costs relate to strictly first-class material and workmanship in every case, as it has been the endeavor of the writer to establish and maintain one standard for all work. The variations in cost due to different mixtures of concrete can easily be allowed for by reference to tables given elsewhere (see section on 'Concrete Construction'). In general, would say that the stand-

ard mixture for all floors has been either 1:3:6 or 1:2:4, if the floor is subjected to extremely heavy loads and service. Walls are mixed 1:3:6, and columns usually 1:2:4; in some cases where they are very heavily loaded, a richer mixture is used. As these mixtures are common to nearly all construction, the costs here given may be applied with little danger of error from neglecting the mixture on any work.

TABLE I

Cost of Various Classes of Concrete Work

COST OF CONCRETE COLUMNS

Location	Forms per Square Foot				Concrete per Cubic Foot						
	Carpenter Labor	Lumber	Nails and Wire	Total	Concrete Labor	General Labor	Cement	Aggregate	Team and Miscell.	Plant	Total
Office building, Portland, Me.	.133	.039	.001	.173	.064	.004	.087	.084	.012	.022	.273
Coal pocket, Lawrence, Mass.	.057	.024	.001	.082	.166	.003	.073	.041	.008	.016	.307
Mill, Southbridge, Mass.	.097	.082	.002	.181	.073	.056	.107	.035	.027	.030	.328
Mill, Attleboro, Mass.	.093	.022	.001	.116	.110	.014	.062	.038	.013	.034	.271
Mill, Southbridge, Mass.	.080	.056	.001	.137	.108	.048	.100	.037	.013	.034	.340
Coal pocket, Hartford, Conn.	.098	.047	.002	.147	.089	.043	.069	.055	.017	.013	.286
Garage, Brookline, Mass.	.071	.051	.002	.124	.070	.028	.072	.058	.041	.020	.289
Warehouse, Portland, Me.	.118	.016	.001	.135	.087	.027	.087	.070	.039	.025	.335
Textile mill, Lawrence, Mass.	.061	.013	.001	.075	.095	.019	.109	.027	.018	.015	.283
Highest	.133	.082	.002	.181	.166	.056	.109	.084	.041	.034	.340
Lowest	.057	.013	.001	.075	.064	.003	.062	.027	.008	.013	.271
Average of 9	.082	.036	.001	.130	.096	.027	.085	.049	.021	.023	.301

COST OF BEAM FLOORS OF REINFORCED CONCRETE

Location	Forms per Square Foot				Concrete per Cubic Foot						
	Carpenter Labor	Lumber	Nails and Wire	Total	Concrete Labor	General Labor	Cement	Aggregate	Team and Miscell.	Plant	Total
Power House, Greenfield	.165	.107	.003	.275	.143	.020	.109	.101	.008	.016	.397
Tar well, Springfield	.064	.041	.002	.107	.076	.005	.026	.075	.013	.040	.335
Mills, Greenfield, Mass.	.106	.061	.004	.171	.077	.011	.109	.086	.007	.055	.345
Car barn, Danbury, Conn.	.044	.051	.001	.096	.128	.013	.086	.071	.011	.010	.319
Coal pocket, Lawrence, Mass.	.072	.039	.002	.113	.056	.004	.073	.041	.009	.019	.202
Mill, Southbridge, Mass.	.067	.062	.002	.131	.137	.029	.191	.051	.038	.014	.460
Mill, Attleboro, Mass.	.062	.032	.002	.096	.071	.023	.098	.062	.021	.055	.330
Bridge, Plymouth, Mass.	.047	.050	.001	.098	.078	.019	.100	.040	.027	.010	.274
Garage, Newton, Mass.	.104	.033	.002	.134	.116	.020	.121	.084	.038	.010	.394
Mill, Southbridge, Mass.	.057	.051	.001	.109	.119	.027	.132	.037	.013	.084	.362
Coal pocket, Hartford, Conn.	.060	.033	.001	.094	.047	.023	.081	.055	.017	.013	.236
Garage, Brookline, Mass.	.105	.038	.002	.145	.160	.032	.088	.058	.041	.020	.399
Filter, Lawrence, Mass.	.048	.032	.001	.081	.102	.016	.085	.054	.012	.032	.301
Storehouse, Chelsea, Mass.	.064	.043	.002	.109	.153	.035	.115	.068	.052	.020	.443
Warehouse, Portland, Me.	.037	.029	.001	.067	.186	.030	.096	.069	.043	.046	.470
Textile mill, Lawrence, Mass.	.045	.042	.001	.088	.130	.013	.071	.037	.025	.010	.286
Textile mill, Lawrence, Mass.	.053	.033	.001	.087	.116	.033	.194	.049	.035	.015	.442
Chapel, Portland, Me.	.053	.027	.002	.082	.100	.008	.127	.091	.041	.010	.377
Highest	.165	.107	.004	.275	.186	.035	.194	.101	.052	.055	.470
Lowest	.037	.027	.001	.067	.047	.004	.071	.037	.007	.010	.202
Average of 18	.070	.045	.002	.116	.111	.020	.106	.063	.025	.024	.354

COST OF FLAT SLAB FLOORS

Location	Forms per Square Foot				Concrete per Cubic Foot						
	Carpenter Labor	Lumber	Nails and Wire	Total	Concrete Labor	General Labor	Cement	Aggregate	Team and Miscell.	Plant	Total
Office building, Portland, Me....	.078	.039	.001	.118	.043	.004	.087	.084	.012	.022	.252
Fire station, Weston, Mass......	.067	.038	.003	.108	.103	.007	.092	.053	.026	.039	.320
Church, Boston, Mass............	.067	.037	.002	.106	.146	.017	.109	.072	.020	.010	.374
Highest..........................	.078	.039	.003	.118	.146	.017	.109	.084	.026	.039	.374
Lowest...........................	.067	.037	.001	.106	.043	.004	.087	.053	.012	.010	.252
Average..........................	.071	.038	.002	.111	.097	.009	.096	.070	.019	.024	.315

COST OF CONCRETE SLABS BETWEEN STEEL BEAMS

Location	Forms per Square Foot				Concrete per Cubic Foot						
	Carpenter Labor	Lumber	Nails and Wire	Total	Concrete Labor	General Labor	Cement	Aggregate	Team and Miscell.	Plant	Total
Bleachery, East Hampton.........	.054	.027	.002	.083	.092	.007	.137	.073	.012	.046	.367
Machine shop, Milton, Mass......	.087	.027	.003	.117	.090	.033	.114	.075	.016	.034	.362
Foundry, No. Britain, Conn......	.078	.046	.002	.126	.095	.021	.076	.078	.004	.022	.296
Stable, Boston, Mass............	.064	.012	.001	.077	.101	.019	.129	.070	.020	.015	.354
Residence, Milton, Mass.........	.110	.071	.003	.184	.105	.048	.132	.080	.053	.010	.428
Power house, Pittsfield, Mass....	.029	.030	.001	.060	.131	.008	.123	.068	.013	.010	.353
Laundry, Boston, Mass...........	.058	.024	.001	.083	.092	.021	.098	.089	.022	.010	.332
Prison, Portsmouth, N. H........	.068	.017	.001	.086	.073	.005	.208	.075	.006	.010	.377
Paper mill, Mittineague..........	.097	.071	.002	.170	.144	.033	.143	.062	.027	.010	.419
Power house, Quincy, Mass......	.047	.025	.001	.073	.073	.021	.159	.085	.064	.020	.422
School, Waltham, Mass..........	.029	.028	.001	.058	.138	.009	.102	.078	.018	.015	.360
Foundry, Providence, R. I.......	.028	.020	.001	.049	.084	.012	.114	.026	.026	.010	.272
Foundry, Providence, R. I.......	.043	.021	.001	.065	.111	.010	.128	.029	.029	.010	.317
Highest..........................	.110	.071	.003	.184	.144	.048	.208	.080	.064	.046	.428
Lowest...........................	.028	.012	.001	.049	.073	.005	.076	.026	.004	.010	.272
Average..........................	.061	.032	.002	.095	.102	.019	.128	.068	.024	.017	.359

COST OF BUILDING WALLS ABOVE GRADE

Location	Forms per Square Foot				Concrete per Cubic Foot						
	Carpenter Labor	Lumber	Nails and Wire	Total	Concrete Labor	General Labor	Cement	Aggregate	Team and Miscell.	Plant	Total
Fire Station, Weston, Mass.......	.116	.038	.004	.158	.100	.007	.069	.053	.026	.039	.294
Mill, Greenfield, Mass............	.062	.038	.002	.102	.060	.011	.084	.086	.007	.055	.303
Water works, Waltham, Mass...	.137	.024	.001	.162	.146	.007	.058	.057	.014	.047	.329
Coal pocket, Lawrence, Mass....	.118	.056	.002	.176	.042	.004	.073	.043	.009	.019	.190
Mill, Attleboro, Mass	.103	.024	.001	.128	.129	.018	.074	.048	.017	.043	.329
Coal pocket, Hartford, Conn......	.096	.047	.002	.145	.118	.052	.097	.055	.017	.013	.350
Filter, Lawrence, Mass	.046	.032	.901	.079	.046	.017	.083	.054	.012	.032	.244
Italian garden, Weston, Mass...	.101	.073	.002	.176	.102	.008	.105	.081	.019	.010	.325
Stable, Beverly, Mass............	.099	.030	.002	.131	.078	019	.071	.062	.018	.010	.258
Residence, North Andover, Mass.	.078	.016	.001	.095	.096	.014	.046	.050	.008	.010	.174
Observatory, Milton, Mass.......	.056	.038	.002	.096	.095	.012	.060	.187	.058	.005	.417
Office, Boston, Mass.............	.105	.030	.002	.137	.096	.033	.066	.114	.066	.005	.380
Tunnel, Boston, Mass............	.112	.045	.005	.162	.126	.016	.066	.106	.077	.005	.330
Hospital, Waltham, Mass.........	.058	.028	.001	.087	.089	.017	.034	.063	.023	.010	.236
Residence, Boston, Mass.........	.108	.036	.001	.145	.110	.015	.077	.069	.026	.005	.446
Coal pocket, Providence, R. I....	.087	.020	.001	.108	.052	.005	.102	.090	.015	.010	.274
Italian garden, Brookline, Mass.	.064	.027	.001	.092	.048	.011	.080	.071	.019	.010	.239
Highest..........................	.136	.073	.005	.176	.146	.052	.105	.187	.077	.055	.446
Lowest...........................	.046	.016	.001	.079	.042	.004	.034	.043	.007	.005	.174
Average of 17....................	.085	.036	.002	.128	.090	.016	.073	.076	.025	.019	.301

COST OF FOUNDATION WALLS

Location	Forms per Square Foot: Carpenter Labor	Lumber	Nails and Wire	Total	Concrete per Cubic Foot: Concrete Labor	General Labor	Cement	Aggregate	Team and Miscell.	Plant	Total
Filter, Warren, R. I.	.103	.048	.004	.155	.062	.037	.086	.068	.012	.031	.296
Tar well, Springfield	.071	.031	.002	.104	.040	.015	.094	.075	.013	.040	.277
Tunnel, New Bedford	.048	.045	.001	.094	.213	.019	.203	.092	.057	.015	.599
Filter, Exeter, N. H.	.124	.067	.002	.193	.064	.021	.071	.116	.034	.019	.325
Filter, Lawrence, Mass	.058	.042	.001	.101	.046	.017	.083	.054	.012	.032	.244
Theater, Portland, Me.	.081	.024	.003	.108	.112	.013	.073	.078	.003	.020	.303
Warehouse, Portland, Me	.053	.009	.001	.063	.040	.019	.060	.070	.029	.017	.235
Residence, No. Andover	.047	.019	.001	.067	.108	.006	.082	.045	.015	.010	.266
Filter, Lawrence, Mass.	.048	.035	.002	.085	.055	.006	.039	.027	.011	.010	.148
Residence, No. Andover	.065	.019	.001	.085	.087	.012	.072	.045	.013	.010	.239
Retain'g wall, Naugatuck, Conn.	.134	.047	.001	.182	.097	.018	.056	.032	.022	.010	.235
Hospital, Waltham, Mass	.048	.028	.001	.077	.043	.019	.038	.063	.026	.010	.199
Greenhouse, Brookline, Mass.	.032	.035	.001	.068	.051	.007	.078	.043	.013	.010	.202
Hotel, Brookline, Mass.	.037	.018	.001	.056	.043	.002	.080	.054	.010	.010	.199
Highest	.134	.048	.004	.193	.213	.037	.203	.116	.057	.040	.599
Lowest	.032	.009	.001	.056	.040	.002	.038	.027	.003	.010	.148
Average	.068	.033	.002	.103	.076	.015	.080	.062	.019	.017	.269

COST OF FOOTING AND MASS FOUNDATIONS

Location	Forms per Square Foot: Carpenter Labor	Lumber	Nails and Wire	Total	Concrete per Cubic Foot: Concrete Labor	General Labor	Cement	Aggregate	Team and Miscell.	Plant	Total
Power house, Greenfield	.119	.077	.002	.198	.065	.020	.098	.002	.008	.016	.299
Eng. foundation, Taunton, Mass.	.054	.025	.001	.080	.045	.002	.065	.048	.004	.017	.181
Head gates, Shawmut, Me.	.071	.043	.003	.117	.033	.001	.074	.099	.003	.014	.224
Canal, Lowell, Mass.	.039	.025	.001	.065	.025	.011	.080	.078	.004	.042	.240
Foundation, Provincetown	.069	.043	.002	.114	.039	.004	.073	.099	.011	.049	.275
Dam, Merrimack, N. H.	.066	.037	.003	.106	.081	.008	.090	.055	.008	.031	.273
Foundation, Boston, Mass.	.011	.006	.001	.018	.035	.004	.061	.072	.006	.010	.188
Eng. foundation, Boston, Mass.	.095	.039	.003	.037	.037	.013	.061	.084	.013	.015	.223
Gas holder, Springfield	.034	.031	.002	.067	.043	.001	.061	.068	.005	.010	.188
Foundation, Providence, R. I.	.016	.011	.001	.028	.051	.002	.047	.076	.010	.010	.196
Highest	.119	.077	.003	.198	.081	.020	.098	.099	.013	.049	.275
Lowest	.016	.006	.001	.018	.025	.001	.047	.043	.003	.010	.181
Average of 10	.057	.034	.002	.093	.045	.007	.071	.077	.007	.021	.229

COST OF STEEL

Location	Weight	Cost of Handling	Cost per Ton
Office building, Portland, Me.	324½ tons	$5,115.32	$15.76
Fire station, Weston, Mass.	8½ "	40.26	4.74
Mill, Chelsea, Mass	65¼ "	548.81	8.41
Coal bins, Dalton, Mass.	8⅝ "	61.75	7.26
Dam, Auburn, Me.	55 "	506.76	9.18
Filter, Warren, R. I.	19 "	102.59	5.40
Tank, Lincoln, Me.	8⅛ "	69.38	8.16
Tar well, Springfield	15½ "	59.21	3.82
Monument, Provincetown	24½ "	136.84	5.58
Mill, Greenfield	92¾ "	1,232.01	10.20
Machine shop, Milton, Mass.	20¼ "	177.16	8.75
Coal pocket, Lawrence, Mass.	28 "	461.16	16.47
Mill, Southbridge	58½ "	142.76	2.67
Mill, South Windham, Me.	293 "	3,079.60	10.51
Mill, Attleboro, Mass	49½ "	286.02	5.78
Garage, Newton, Mass.	20 "	86.55	4.33
Mill, Southbridge, Mass.	30 "	100.03	3.34
Coal pocket, Hartford, Conn.	195 "	2,316.60	11.88
Filter, Lawrence, Mass.	44⅛ "	112.84	2.54
Warehouse, Portland, Me.	62 "	462.99	7.47
Standpipe, Attleboro, Mass.	199⅛ "	1,547.00	7.75
Highest	....	....	16.47
Lowest	....	....	2.54
Average of 21	....	....	8.52

"Of course, it can be readily understood that in the large number of jobs which have entered into the averages given, there being as many as eighteen in the case of beam floors, different methods of conducting the work have been used, and many different foremen. Therefore, while the general average is doubtless safe for any work of an average character, some latitude may be allowed the judgment in determining whether any specific case is likely to be difficult, easy, or average. The writer has found quite a difference, for instance, in cost of identical work handled by different foremen, due to the personal equation of their painstaking supervision and ability.

"In Table I, only typical jobs are given, whose results are correctly known. The figures for the highest, lowest, and average totals in the fourth and last columns are taken from the vertical column in which they stand, and have no relation to the other figures in their horizontal line.

"By reference to the general average on form work in the tables of forms per square foot of surface contact—namely: columns, $.13; floors with reinforced concrete beams, $.116; flat floors without beams, $.111; short-span slabs between steel beams, including the fireproofing on the sides of the beams, $.095; walls exposed to view above ground, $.128; foundation walls, $.103; mass foundations, $.093—the writer believes all higher in price than usually believed to be a fair cost by the majority of builders. It is upon the success of handling forms that good results financially depend.

"In regard to concrete, labor is the variable item which must be carefully considered. Anyone of intelligence can make a careful estimate of the materials to be used; but note the average prices per cubic foot, of labor—namely, for columns, $.123; beam floors, $.131; flat floors, $.106; floors between steel beams, $.121; walls, $.106; foundations, $.091; and mass work in connection with buildings, $.052. Not until the last item is reached is a price obtained in experience which, according to the observation of the writer, the majority expect to obtain in building work in general.

"Many men who have had wide experience in handling large quantities of concrete in mass have at times attempted a lighter type of construction and been greatly surprised at the large expense connected therewith. It has come to the writer's notice a number of times, that men with this experience have added 50 to 100 per cent to the cost of mass work, and felt that they were amply covered for light structural work. The fallacy of this can be seen by a very recent experience of the writer's. In building a dam across the Connecticut river, about 5,500 cu. yds. of concrete were placed. Cement and aggregates were received on a bridge abutment 26 ft. above the river. Aggregates were dumped upon an inclined chute, where they were to be washed; and from the end of the chute, they fell into bins, from which they were drawn through measuring hoppers into a mixer, and dumped from this into tram-cars 4 feet above the water. The total expense for labor of washing, charging, mixing, and dumping into the cars, was only $.12 per cu. yd., and, for moving it in cars an average distance of 700 ft., dumping, and placing, was only $30 per cu. yd., or a total cost of $.0155 per cu. ft.

"The table of steel omits entirely the first cost of the material. After it is received at the site of the work in the shape sold by the manufacturer, these prices cover the cost of fabricating into units for columns or beams, bending the stirrups, placing, and all incidentals whatsoever prior to the actual embedding in concrete. In the case of the highest cost, a coal pocket, there was very limited storage space; 1¼-in. bars had to be bent diagonally so as to pass over the top of the support at columns; and there were numerous stirrups, all of which had to be made by hand. The job was too small to justify any mechanical arrangement for bending or for handling material. The next highest, an office building, Portland, Maine, there was a sufficient amount to require proper machinery. The hoops for columns were all welded. The vertical bars were all wired inside of these hoops. There was a mushroom head of bent and circular bars wired together at the top, and great numbers of long bars of small section spread in all directions over the floor. The lowest price, a filter at Lawrence, was made entirely of straight bars placed loose, the only expense being cutting them in a hand shear to length and placing them.

"Table II shows an exact copy of a master card, which gives the complete financial history of the job when it is finally completed. It will be seen that on some items a loss was incurred, as well as a profit on others, showing that it is difficult, even on work in which a company is fairly experienced, to reach the right price on everything; and also that when slight changes are made by the owner or architect, they often entail heavy loss, even though the changes appear to be extremely trivial. Take the case of the ex-

TABLE II
Typical Master Card of Cost Data

Job No. 747. Date, May 24, 1906. Mill, Tappan Bros., Attleboro, Mass.

	Proposal	Actual Cost	Per Cu. Ft.	Profit	Loss
Total	$35,164.55	$31,330.48	....	$3,834.07	....
Excavation	790.00	823.18	.021	....	$ 33.18
Footings and fr.	1,738.00	1,033.57	.187	704.43	....
			Per sq. ft.		
Exterior Walls	1,955.00	2,162.02	.190	....	207.02
Wall and fr. centers	1,520.00	3,630.08	.125	....	2,110.08
Floors, 6½ in. thick	8,883.00	6,544.16	.339	2,338.84	....
Roof, 5½ in. thick	2,869.00	1,713.51	.287	1,155.49	....
			Per lin. ft.		
Columns, 20x20 in.	832.00	676.65	1.470	155.35	....
Stairs	883.00	910.85	.912	....	27.85
			Per sq. ft.		
Tool surface	469.00	636.53	.056	....	167.53
Ornaments and cornice	348.00	164.33	....	183.67	....
Ventilators on roof	44.00	35.64	....	8.36	....
			Each.		
Set windows and door frames	852.00	729.99	2.19	122.01	....
			Per sq. ft.		
Interior partitions	1,770.25	1,656.35	.189	113.90	....
Bolts and iron work	253.00	257.06	....	....	4.06
Stair Railing and grill	387.00	654.00	....	....	267.00
			Per M.		
Screens and setting	1,086.00	835.12	52.17	250.88	....
2-in. spr. plank and laying	2,839.00	1,431.69	33.30	1,407.31	....
⅞-in. maple and laying	1,738.00	1,788.88	89.44	....	50.88
Motor shaft	379.50	533.19	98.89	....	153.69
Motor shaft found	98.00	70.07	....	27.93	....
Roofing and conductors	1,255.00	1,026.06	....	228.94	....
			Per sq. ft.		
Paving	1,009.00	647.54	.094	361.46	....
Retaining wall centers, per sq. ft.	....	....	.211	....	....
Retaining wall concrete, per cu. ft.	429.00	316.90	.175	112.10	....
Painting	400.00	375.00	....	25.00	....
Steel footings and walls	300.00	218.91	....	81.09	....
Plant, frt., etc.	1,860.00	2,271.73	....	....	411.73
Bond	100.00	120.00	....	....	20.00
Extras	77.80	67.97	....	9.83	....

ternal walls. The owners furnished the window-frames and sash, which were all of metal. The original design was for a frame with two sash, which could easily be put into a 6-in. wall. They later decided, for greater fire protection, to use four sash. This required an 8-in. wall instead of 6-in.; the form work on the inside had to be built inward, and the space under the windows paneled to save material. To save making a very narrow panel at the side of the window which would have cost more than the concrete saved, the space was filled up solid so that the columns appear to be wider than they were actually figured. This slight change, which did not appear great at the time, when the job was entirely complete caused the concrete on the walls to show an actual loss instead of profit, and made the form work cost more than twice what was originally estimated it should cost."

"Regarding the tooling of wall surfaces, it was originally planned to do this when the cement was less than ten days old; but, on account of the various changes, forms had to be left on a considerably longer time, and it was inconvenient to tool the surface until the cement was so thoroughly set that the cost of dressing was considerably greater than was first anticipated. Again, by reference to the ⅞-in. maple floor which was placed upon the concrete construction, a cost of $89.44 per M board feet will be observed; but additional repair work on floor after it was laid cost $248.50, or $12.42 per thousand. This was due to the fact that the owners did not deliver or set the window-sash at the time agreed, and therefore the maple floors lay exposed to the weather in the building for several weeks, swelled, and after laying, shrunk, leaving large cracks which the owners insisted on being filled before they would accept the work. These indicate how matters which appear trivial at the time may cause serious loss if overlooked.

"As seen from the large list of items entering into the estimate as given by this master card, there are various items of cost entering into the construction besides those which are enumerated. Nevertheless, the matter of the forms, steel, and concrete covers by far the largest proportion of the cost of a reinforced concrete structure; and the minor items are those which are peculiar to each individual case, and which any person can easily estimate for himself."

QUANTITY SYSTEM OF ESTIMATING

A Plea for a Better System of Estimating the Cost of Buildings

Abstract of an address delivered before the General Contractors' Association, of San Francisco, Cal., April 10, 1913, by G. Alexander Wright, Architect.

The ever-increasing amount of unproductive time, and usually money, which contractors are called upon to expend in gratuitously preparing quantities as well as prices, often for an owner's benefit, suggests that the time has arrived when all concerned should take up, and seriously consider, the possibility of adopting a modern and more sensible system of estimating, such, for example, as has been long in successful operation in older communities. Not a mere copying of such methods, for I advocate the creation of a standardized method of our own—an American system, practical above all things; a system that will be in line with our otherwise progressive building methods; a system that shall be clear and accurate, and that shall stand for square dealing between contractor and owner—in short, a system that shall give every man his due, no more and no less; one that will reveal to the bidder, at a glance, the actual quality of material and labor in a structure, in any individual trade.

When bidders are invited to submit bids they are theoretically asked, of course, to submit competitive prices; but, in actual practice, their bids are based upon competitive quantities, before the competition in prices commences—which, in my opinion, is as unjust to the contractor as it is ridiculous. A building can contain only a certain amount of material, and no amount of figuring by contractors against one another can make that quantitiy any more or any less. Where, then, is the sense in a dozen or more general contractors competing against one another in taking quantities? One or more bidders, through being hurried or being unable to take off the quantities accurately, leave something out. What happens? Their bids are consequently low, and the owner benefits, at the low bidder's expense, whilst the competent or more careful bidder loses the job, because his quantities are more accurate, or because there may have been room for uncertainty when figuring the plans and specifications.

Not long ago, a general contractor (whom I have known over twenty years) told me that if contractors figured to do competitive work just exactly as plans and specifications called for, a man would not get "one job in fifty." Now, if this is true—and personally I believe it is—there is something very rotten in our methods. In my judgment it lies in our antiquated estimating practices.

Those of us who know something of the unsatisfactory conditions under which bidders are often obliged to figure, time after time without result, have realized that hundreds of thousands of dollars in time and money are taken from contractors' pockets every year, simply because they do not, so far, limit competition between themselves to the matter of prices. They go on competing, and I suggest gambling, with one another as to the quantity of material a building will take; whereas I contend that that is a question of fact, and that competition in the quantities between contractors never can and never will, in any way, change the fact that a certain fixed quantity of material and labor is necessary to do every job. There can be no legitimate competition in taking off quantities of materials, except that unfortunate competition which bidders make themselves when they take off too much, or, as too often happens, too little.

The legitimate competition can come in only where one man can handle a job better than another, or one man may have some advantage over another in buying, and so forth. All this kind of competition is legitimate enough, but it must be obvious that no amount of figuring can reduce the real quantity of material which a building will take; and so my contention is that it would be proper and fair to **start all bidders figuring upon the same basis, by furnishing each with a schedule, or bill of quantities showing accurately and clearly the different quantities and kinds of materials which the bidder is invited to figure upon**; and even then there would be plenty of competition left, in placing profitable prices against each item.

Our present method (or rather, want of method) in estimating, and the rapid strides being made in construction, are, as I have said, forcing upon the contractor, more and more every year, an increasing waste of time and money in figuring out quantities. This senseless waste and competition cannot go on for ever. It has already brought men to bankruptcy all over the country, and has often prevented the making of a proper and legitimate profit among those who do succeed in keeping their heads above water.

This is a live question, and it deserves the earnest consideration of all contractors' associations and architectural societies from the Atlantic to the Pacific Coast.

No new or untried principle is involved. It is simply that **of a definite quantity of work for a definite amount of money.** In substance the owner says, "I want this quantity of work done. The drawings and specifications show you how this quantity of work is to be assembled or put together: Now, tell me how much money will this cost? I want you to do the quantity of work called for; no more, no less."

At present, the successful bidder often says, in effect, to an owner, "I will erect your building according to plans and specifications;" but—mentally—he says, "I do not figure that it will take as much flooring, concrete, plastering, or painting as my competitors think it will!" Let me ask, Is this a proper or fair competition between contractors themselves? Is it fair to their own interests? There is only one individual who stands to gain anything under such imperfect methods—the owner, and not always he.

It may be stated that the Quantity System is equally applicable to engineering works, such as railroad work, sewerage disposal schemes, canals, pumping stations, etc.

Before proceeding to a further consideration of this subject, I may be pardoned perhaps for expressing the opinion, after having had over twenty years' intimate experience with the workings of the Quantity System of estimating, and over another twenty years in San Francisco (without any such system), that I know of nothing in connection with the work of the contractor that would be more beneficial than the adoption of some equitable recognized system of estimating upon bills of quantities, and these latter would be equally valuable, whether sub-contracts were eventually let or not.

In the year 1909 a conference was held in Great Britain between the National Federation of Building Trade Employers, the Institute of Builders, and the London Master Builders' Association; and a resolution was adopted recommending contractors who were members of these powerful organizations to decline to bid in competition against one another unless bills of quantities were supplied for their use at the owner's expense. A deputation from these contractors' organizations afterwards attended before the principal body of architects, who promised to further the aims of the contractors as far as was within their power; and to-day the Quantity System is in full operation, not only in the case of private owners, but in all building work for government and municipal authorities, and upon the principle that it is impossible to obtain accurate bids without accurate quantities.

Now let us consider, for a moment, a few of the disadvantages of existing methods:

First—The time usually given for figuring is far too short for the accurate taking-off of quantities, in addition to the pricing and figuring-out of the many items. A bidder usually has contract work in progress, and other matters to be attended to during the daytime; other plans are to be figured by a certain time, and but little can be accomplished in the eight-hour working day; and so advantage must be taken of the night hours, sometimes all night, and even Sunday (as I happen to know), and any other time. Only those who have worked under these conditions and over blue-prints at night, hour after hour, taking off items, can appreciate the many difficulties, pitfalls, and liabilities to error through figuring against time after the real work of the business day is over. But the plans must be returned first thing in the morning, or the bid must be in by a certain hour the next day. Nothing but hurry—hurry—hurry. In not a few cases, more information is necessary; something is not quite clear. The plans and specifications do not agree on some point. Which is right? There is no time to find out, the only person who can enlighten you is asleep, perhaps; while the careful estimator is burning the midnight oil, and wrestling with problems which can be avoided and entirely eliminated under a more modern system of estimating.

Again, the careful bidder who honestly tries to get in all the items, and figures to do the work as called for, is frequently beaten by a less competent bidder who forgets something, or who, maybe, is willing to take a chance anyway in order to get the job. True, omissions in lists of materials are sometimes unavoidable, under existing methods, which unfortunately aim at speed rather than accuracy.

It is, to say the least, disappointing to a careful bidder on a large job to find his bid just above the lowest, and after the low man has signed up the contract, it develops that the painting, or some such item, was left out. This, however, could not occur with the Quantity System.

The competent bidder who gets in all his items today is usually under a disadvantage, unless he happens to be figuring against men of his own stamp. Meanwhile it would appear that the chances are in favor of the owner most of the time, and it seems to be a case of "Heads I win, tails you lose."

The existence of present conditions, whilst much to be regretted, is due to a blind continuance of early-day custom. It is in no way up to date or conductive to progress. It is entirely unsuited to modern construction and modern methods. The tallow candle, years ago, was a great invention, but how many of us would light our homes to-day by this method? And yet our estimating methods of to-day date from the same identical period as the tallow candle. Other countries have long ago graduated from such primitive methods; but we are content to stand still, and we are, in this respect, away behind the times. It seems to be almost inconceivable that shrewd business men are still willing to spend their time, all going over the same ground, figuring against one another on quantities, knowing all the time that they are all, save one (and sometimes even that one), simply wasting their time.

By the adoption of some sensible system, all this quantity taking could be done by one competent person.

The great difference we find in bids arises, in my opinion, not so much in the prices or money values placed against the quantities, as it does from errors in the quantities themselves, the accurate preparation of which calls for special training and continuous concentration of mind, which the busy contractor of to-day can seldom find time to acquire.

Now we shall investigate a **Bill of Quantities**, such as we are considering. What is it? And how is it used?

First of all, it is a document, handed free of expense to each bidder, lithographed or similarly duplicated, in order that all bidders' copies may be exactly alike. It will contain everything which it is essential for a contractor to know when making up a figure, with a separate section for each trade, such as excavation, concrete, brickwork, and so forth. A general summary is provided at the end of the bill, in which is entered the net cost of each trade; this summary is footed up, the profit the bidder expects to make is added, plus the cost of the quantities, the result being, of course, the amount of the bid.

The methods of measurement must conform to the standards used by each individual trade, and through the bill the greatest care is taken to have everything systemized; all cubic, square, and linear feet, and numbers of items, will be found all together under their respective heads. In this way, immediate reference may be made to any item required, even though the entire bill may contain hundreds of items; and so every item has its proper place—nothing is left to chance. Detail sketches also appear in the margins whenever necessary, to show a bidder at a glance what is required. These, as we know, are of more value to an estimator than the long written descriptions one sometimes finds in specifications. The keynete of the Quantity Surveyor is **accuracy.** In going through the drawings and specifications he has come across all those doubtful questions which always crop up when figuring under present methods. He will have taken them all up with the architect, and adjusted them, before the quantities are handed to bidders; so that everything is all plain sailing.

Nothing is "near enough" for a Quantity Surveyor—he scrutinizes every part of the work closely, clears up any doubts, or anything capable of a double interpretation; and his work leaves no loopholes for either the owner, the contractor, or the architect to take advantage of. The result is that it is seldom necessary for a bidder to ask questions of the architect when making up a figure. If he should wish to do so, probably he would be referred to the surveyor, who is familiar with every minute detail of the work.

Further, and right here, lies one of the greatest advantages of the Quantity System. It is not necessary, except in a general way, for a bidder to study the drawings and specifications at all, and he certainly does not have to figure them. He simply prices the bill of quantities; and, in these days of hurry and bustle, this is as much as a contractor can be expected to do for nothing. This enables the competent contractor (the one who has unit-prices at his finger ends) to make up a bid for, say, a $100,000 building in a few hours; and he has the satisfaction of knowing, when the unit-price is placed against each item, that nothing has been forgotten; in other words, he contracts to furnish only so much material and labor—and surely this is absolutely right in principle. Good reasons exist why the general contractor should have faith in his own judgment and accustom himself to price items in every trade that goes to make up the building business. It is the only consistent method of estimating for anyone who claims to be a general contractor. Experience has taught most competent men that it pays to do it. **The mere getting together of figures from sub-bidders, and footing up the totals of the lowest, is not estimating at all. That is mere schoolboy work.** However, I am led to believe that this is now the exception among general contractors in San Francisco, rather than the rule. **The ideal contractor is the one who makes up his own estimates,** and not he who is dependent, for any reason, upon sub-contractors, who thus become the real estimators. If every general contractor would keep a prime-cost book of all trades, and quantities were supplied to him, he would soon be in a position to give a fairly close figure upon any sized structure without first taking sub-bids; and this, I suggest, is the most consistent, satisfactory, and profitable method to pursue when bidding upon work as a whole; but of course it requires care and experience.

Further, one of the greatest arguments in favor of letting contracts as a whole is, of course, the fact that a general contractor has the ability to figure all trades in his own office, and that he knows how to, and will, supervise the work of sub-contractors, if any. If architects can be assured of this being done, it will be better for all concerned.

In general practice I believe the accuracy of the bill of quantities should be guaranteed. Such a document might well be made the basis of the contract, equally with the drawings and specifications; if this were done, the chief cause of disputes between owner and contrac.or would be removed.

This, I submit, is entirely logical and right—a certain quantity of work for a certain sum of money, the owner to determine the former, and the contractor to fix the latter.

It may be asked, Where are these competent surveyors to be found? And it would be a natural inquiry, as it is no part of the duty of architects to prepare such quantities. In fact, the relation of the architect to the contractor should preclude him from having anything to do with furnishing quantities. This should be attended to by a disinterested specialist—the Quantity Surveyor. In older countries, young men of education are now apprenticed to practicing surveyors, and it has become a recognized profession. Years ago these quantity surveyors frequently came from the ranks of the architects; others possessing the necessary education were possibly contractors, building superintendents, or estimators. I have known contractors' representatives who commenced life in the workshop, who, after securing the advantages of special training, made experienced and very competent quantity surveyors. There must be a beginning to everything; and doubtless there are many men in this country who, after some little training in the technique of this work, should make reliable quantity surveyors. The principal qualifications are honesty of purpose, and a knowledge of architecture and construction. The surveyor should be a neat draftsman and have actual experience in conducting building operations. He should possess the ability readily to detect discrepancies or conditions which might give rise to misunderstandings during construction; and, last but not least, the necessary mentality to act disinterestedly. He must do what is right in measuring, as between the contractor and the owner. The usual custom is for the architect to furnish the quantity surveyor with a set of the drawings and a draft specification; and the latter then commences work in his own offices. During this period the architect and surveyor are in frequent consultation, to the end that all uncertainties are cleared up and adjusted upon the drawings and specifications. In short, no effort is spared to obtain perfect clearness and accuracy before bidders commence figuring.

Such uncertainties are bound to crop up; they are unavoidable. They nevertheless perplex the contractor when he is figuring, and his foreman on the job, and create unnecessary trouble and sometimes bitter disputes; and then, in such cases, one of the parties to the contract is usually a loser.

Now that we have briefly considered the qualifications of a quantity surveyor, let us take note of what the preparation of a bill of quantities involves. It may well be said that during the last forty years it has been brought to a mathematical science; and yet it is really surprising what a vague idea exists concerning the methods, objects, and uses of the Quantity System. The fact remains, however, that, where the system has been adopted, responsible contractors refuse to figure without it. Some day that will be the attitude of contractors in this country—when they fully realize the folly of wasting their time and money in competing against one another on quantities as well as on prices.

But to return: Three distinct processes are involved, and each process calls for different operations.

First—**Taking off** and entering every item (or **dimension,** as it is called) upon the dimension sheets. This is always done in exactly the same order, in every building. No dimension, however small, is omitted; no guesswork of any kind is permitted. The exact location in the building of every dimension taken is carefully noted, and every figure or note is carefully preserved for future reference.

It is impossible to illustrate here the work in detail involved in taking off each trade, but the following may serve to show the general idea: Let us follow a surveyor for a moment in taking off his dimensions for a few items of, say, common brickwork. He always commences taking dimensions at the same point on each floor-plan; every length of wall from one angle to the next is measured separately, and the dimensions entered in "waste," as it is termed. We shall assume that it takes, say, 14 dimensions to go clear around a building. These 14 dimensions and their locations are permanently recorded, footed up, and the total linear feet is then placed immediately below this, and a line drawn across the column to separate it from the next item. The dimension is "squared;" that is, the number of square feet these figures represent is figured out; and, opposite to the total, we find a description, thus, for example: "21-inch wall of standard common brickwork laid up with lime mortar and Portland cement, gauged three to one, pointed with flat joints one side for whitewash, and raked out the other side for cementing."

In good practice it might be best to give the number of square feet superficial of wall, and give the thickness. The same method is adopted with each story, with its varying thicknesses of walls, every dimension being entered in precisely the same order, with its particular location noted.

Then we come to deduction of openings. Those with inside and outside reveals (as in the case of box-frame windows) are taken separately; door openings the same. Those of one size and one thickness of wall are "timesed," as we say, and entered in the dimension column, so: "Ddt. 9/3 feet 9 inches x 7 feet 13 inches, outside wall, fifth floor."

Then should follow an item, extra labor, "to so many 8-inch common brick segment arches in say three half-brick row-locks to 4-foot 6-inch openings with 3-inch rise in 8-inch wall, include for cutting skewbacks, etc., and for wood-turning piece and setting and striking." In case richer mortar was specified for arches, it would be so stated, and the proportions.

When rough cutting to brickwork is required, every square foot of it would be measured. Brickwork in footings or foundations, or walls below ground or at unusual heights, should be all segregated and given separately, with full descriptions.

Such items as the following are then taken by the square yard or square foot—namely, selected common brick facing. If joints are struck and cut (as face work), it is taken as a separate item, as should be the case with any portions that are to be pointed with special or colored mortar. Cementing by the square yard if on ordinary plain surfaces; but if in widths of 12 inches or under, then this is separated and taken by linear foot; should this work occur on circular surfaces, it would be so described, kept separate, and the radius given. Linear dimensions are taken of all rough splays and chamfers, flues, pointing to flashings, projecting courses, with the number of miters, splays, or stops in same; brick sills, with the returns, are numbered, if any. The labor of forming quoins, square or splayed, and (in certain cases) the linear feet of plumbing angles and reveals might be taken; also leveling up for joists, bond iron, and the like.

The foregoing applies to common brickwork, as before stated. Now, where "face" brick are used, the entire surface of such facing is measured by the square foot, including reveals and soffits (but openings deducted), the kind of mortar and the labor of pointing being given. Here would be taken such items as face arches. Fair cutting by the square foot on same principle as mentioned for common brickwork. Then come linear feet of each course, of which figured sketches should appear. Raking moldings or belts separate; then follow the number of external, internal, raking, skew, or other miters; also square ends, etc. (if any). All other linear feet items follow in their proper order, and then, in a similar way, concluding with numbered items, which would be described and (if necessary) sketched in the margin. I am aware that this is but a very elementary illustration of the detailed method of taking off; but the principle applies throughout every department, in every trade, from the excavator to the painter, but it would be too great an undertaking to go fully into details here in each case.

Surveyors' quantities are usually measured net, and it is so stated in the preamble of the bill—upon the understanding that the unit-price for each item is to be made by the contractor to cover trade customs, etc., which differ in each locality.

The before-mentioned dimension sheets are usually checked over with the drawings by a second person, and then all totals are abstracted; that is to say, they are transferred to **abstract sheets**, under separate headings. In this way many similar items of the same value are collected together and footed up and checked. This reduces the number of items appearing eventually in the finished bill, which is written directly from those abstract sheets; and any further sketches or descriptions necessary for the bidder to understand thoroughly what is required of copies of these bills are lithographed, or otherwise duplicated; and a copy is sent by the surveyor to the list of prospective bidders, whose names and addresses have been previously furnished him by the architect.

Some of the **advantages** of the Quantity System of estimating to the contractor are as follows:

1. Saving of time and money.
2. Greater precision in measuring.
3. No uncertainty as to interpretation of plans or specifications (the quantities should govern).
4. No visits to the architect's office when figuring, for explanations or otherwise.
5. No other work is contracted for except the quantity set forth in the quantities.
6. The contractor, if he so desires, can check up the quantities before signing a contract. In an American system of estimating, the quantities should, I think, form part of the contract.
7. No bidder can inadvertently leave out anything, and so in this way arrive at too low a figure.
8. Not having to spend time taking out his quantities,

the contractor has time to attend to more profitable business.

9. Systematically arranged bills of quantities duly priced (whether work has been secured or not), form excellent data for making future estimates.

Before an American system can be put into operation it will be necessary:

First—That a committee of representative contractors be selected to standardize a method of measurement to be universally followed by all contractors and architects.

Second—That competent men, mutually satisfactory to contractors and architects, be retained in such numbers as the volume of work may demand. These men, or quantity surveyors, could be placed under bond covering their competency and integrity until they have been proved and assured; such appointments to be permanent, except for good cause; the compensation of these surveyors to be fixed at a certain percentage upon the total of each estimate, each bidder, of course, adding this amount to his bid.

Third—I suggest, also, that a law be passed requiring that a bill of quantities be furnished (free of expense to bidders) upon all State and other public buildings. Such a law is actually in effect in the State of Pennsylvania, and has been since 1895. It does not, however, go quite far enough, as the quantities furnished have no guarantee as to their accuracy.

Fourth—In connection with the Quantity System I advocate the creation of a technical tribunal or court of arbitration where nothing but building suits and disputes shall be determined and adjusted. Such court should be presided over by a specially selected judge and at least two other persons of practical experience in the actual construction of buildings and in estimating the value of builders' work, and familiar with building trade methods, terms, processes, and customs. I maintain that such technical matters as building construction, values, etc., should not be decided solely by technical law, nor by laymen alone, however skilled in other ways, notwithstanding the custom of calling expert witnesses before them. I consider that it would be an advantage to disputants if a majority on the bench had a first-hand practical knowledge of building construction and methods, such as I have indicated, where technical disputes might be determined in a few days, once and for all, and without delays, which only tire the contractor out and thereby force him to accept a settlement more or less unjust from a practical standpoint.

I am hoping shortly to see a committee appointed in every building employers' organization in this country, to take up and seriously consider such matters as I have touched upon this evening. Nothing, in my judgment, will tend to elevate the building business and to promote a feeling of mutual confidence and respect between the architect, the contractor, and the owner more than the Quantity System of estimating, which, as I think I have shown, aims at absolutely square dealing between the man who pays for the structure and the man who builds it.

Construction Contracts

As the result of a great many centuries of experience, it has been found of advantage to do a very large percentage of the total business of the world by the contract method. In its essentials, this method consists of an agreement embodying the amount of the compensation to be paid, on the one hand, and the amount and quality of the performance, on the other. In the simplest forms of business, where there is a cash transaction to be carried out, a man can buy a horse or a suit of clothes, the transaction taking place by delivery, without what we are here considering as a formal contract; but, even in its simplest cases, there must be an understanding before the parties actually do business, and this understanding constitutes a contract.

When a man employs a carpenter to work for, say, $3.00 a day, the arrangement—whether verbal or written—under which the carpenter goes to work, usually means that he is to comply with the instructions of his employer as to what work he is to do and how he is to do it, in consideration of which he receives $3.00 per day; and the employer is under obligation to pay the $3.00, and to confine the nature of his instructions and requirements to the limits of the usual practice in his neighborhood and in the particular trade to which the man belongs. This is a contract in which the $3.00 per day is a **stipulated feature.** The **implied features** are one of the great troubles—and necessary troubles—in the economic administration of business of this kind, because, as a general thing, the parties in interest never have exactly the same idea of what the implied features are; and, moreover, it is frequently the case that the clauses in a written contract, as well as the intentions of the parties, are subject to differences in the interpretations that may be given them by different people.

There are two principal ways of looking upon a contract. It may be considered as a **legal instrument** pure and simple; or it may be considered as a **business arrangement,** entered into for the purpose of making money, by two or more parties, for their mutual financial benefit, but never for the exclusive benefit of either party, since the fundamental basis of the administration of business law is that a man shall not be obliged to enter into an agreement unless he considers it to his interest to do so. A contract cannot be properly considered under either of these points of view without taking into consideration the manner in which it must necessarily be affected by the other. In this discussion, the consideration of the contract as a business arrangement is made the fundamental one, and its legal status has been discussed only so far as it affects the practice in an economic sense.

Contract Defined. A construction contract is an agreement between parties to pay a certain compensation for certain valuable possessions or services, and may be for labor, material, money, or any valuable consideration. It may be in writing or simply a verbal understanding; but so long as it is an arrangement between the parties interested, and is understood by both or all of them to be such, it is a contract, and they are both or all equally bound by it.

Often it happens, in the case of written as well as verbal contracts, that, after unforeseen conditions have developed, the understanding of the parties may differ as to the meaning of certain clauses—their scope and the original intent when the contract was made. Furthermore, when a dispute arises, it may appear that when the contract was originally prepared the contractor had an entirely different idea from that held by the owner, as to what he (the contractor) was expected to do. In such case, unless it can be clearly shown that one of the parties was guilty of fraud—a criminal matter—the contract is sound and binding, and the meaning of the disputed clause is taken to be what its language would imply to an intelligent and unprejudiced third person. This third person may be a witness to a verbal agreement, or he may be one to whom a written contract is afterward submitted. Therefore, although the parties must both or all understand that they have an agreement in order that the contract shall be valid, yet one of the parties cannot abrogate it with impunity by claiming or proving that he has misunderstood the meaning of a part of it.

CLASSIFICATION OF CONTRACTS

There are three main classes of contracts for building construction in general use today. They are as follows:

(1) The **lump-sum contract**, where the contractor receives a certain amount of money for completing the work delivered in place.

(2) The **unit-price contract**, where the contractor receives so much money per thousand brick, per cubic yard of concrete, per pound of steel, etc.

(3) **The cost plus compensation contract,** which means that the owner advances the money, and the contractor supplies the managerial skill and organization.

These different kinds of contract, and all their complications, may be subject to a large number of various modifying clauses and restrictions on both sides; but, in general, almost any contract in use today for building construction in the United States may be classified under one or other of the above headings.

Essentials to the Contractor. Before taking up the classes and general structure of the contract in detail, it is important to consider the general features of the contract in their economic bearing. For this purpose we shall consider that there are two principal parties in interest, one of whom does the work—whom we shall call the **contractor,** and ordinarily designated as the **party of the first part;** and the other party, the **owner,** who advances the money and is to obtain possession of the completed work, and who is frequently designated the **party of the second part.**

From an economic standpoint, the essentials that the contractor requires, in order that the matter may be a satisfactory business venture for him, are as follows:

(a) Pay, regular and sufficient.

(b) Freedom from interference with the economic conduct of the work.

(c) Special privileges.

These we shall here discuss in this order.

Pay. A contractor in all forms of contracts except the third class indicated above (cost plus compensation), requires capital in order to pay his men, to pay for materials and supplies, and to support himself while the work is in progress and before he receives his money from the owner; but the amount of capital that he actually needs is by no means as great as the total cost of the work when completed. If the amount of work that a contractor has on hand, when ultimately completed, will cost $100,000, the amount of money that the contractor himself must have in the business may often be as low as $5,000, and is seldom higher than $15,000 or $20,000.

To understand this, let us see how the work actually proceeds. Upon completing the agreement, the contractor engages men to work for him, and he wants materials. The materials are ordered from the manufacturer or jobber upon an understanding whereby the contractor is to pay for them, let us say, 30 days after delivery upon the work; and the workmen are to receive their pay at the end of each week or month. Thus the contractor will not have to pay out anything in actual cash, except what might be called "petty cash items," until the first pay-day. On the first pay-day he will have to pay for the labor to date. At the end of the month the materials and supplies that were delivered when he first commenced operations will have to be paid for, but not material that has been delivered during the first month; therefore the actual work done to date, by the end of the month will represent a considerably larger amount of money than the contractor has had occasion to pay out for labor and materials, although the contractor is obliged ultimately to pay for these materials and labor from time to time as the payments become due.

Now, in the majority of contracts it is stipulated that the owner shall place with the contractor from time to time—usually from month to month—certain installments of the contract price, which installments will be as nearly as possible proportionate to the value of the work that the contractor has done, less a percentage (usually figured at 10 per cent or so) which is held up in order that the contractor may not be financially at liberty to stop the work and seek other employment to the detriment of the particular work covered by the contract in question.

It is evident that if the installments of the contractor's pay are not forthcoming when they are due, the contractor will not receive enough money to meet the payments that he has obligated himself to make for labor and materials; and conversely, it is clear that if the payments are made by the owner with proper regularity and are sufficient in amount to cover the contractor's expenses and obligations as they become due he (the contractor) will not be obliged to furnish money to "carry on the job." When work has been badly laid out in the beginning, so that through a mistake or otherwise the contractor is obligated for amounts in large excess of what he is obliged to pay out, the carrying charges may be very large; and if he is swinging a million dollars' worth of business on $100,000 capital, he may find himself at a comparatively early stage of the proceedings with most or all of his capital "tied up," and may be obliged to borrow more money at high rates of interest. He will therefore not only be losing interest on the money that he has himself invested in the business, but also be paying an additional interest on the money borrowed. When it is appreciated that this interest may easily be 6 per cent or more on the loan, and that his profits, which are his compensation for his own services, may not be more than 10 or 15 per cent on the contract price, it seems clear that insufficient and irregular payments are to be very carefully avoided.

Attention is here called to the hardships—often unnecessary hardships—that can be brought upon the contractor through the holding-up of his regular payments by the architect or engineer. Sometimes, when a contractor has not complied with the terms of the contract, and is seeking to do other work and make other money to the financial prejudice of the owner of the job on which he is employed, an architect has no right to authorize the regular payments until the contractor has lived up to his obligations; but, on the other hand, it is an injustice to the contractor to hold up a cerificate because the architect happens to be too busy to check the figures, or on a technical or finely drawn point which is not entirely justified by the cold facts. This injustice is not always a matter of consequence, but may result in serious complications if pushed too far.

The owner can have no objection to making payments regularly if the contractor carries out his part of the contract, for the reason that the owner knows beforehand when each payment ought to come due, and he is in a position to prepare himself against such time well in advance of its occurrence. Inasmuch as the partially completed structure belongs to the owner, he at all times has got value received for his money.

Freedom from Interference. The contractor undertakes to perform a certain specified act, or series of acts, or groups of acts, for a certain consideration; and it is of the highest economic importance to the contractor that he be not obliged to do things which he did not originally obligate himself to do or which he did not expect to do when he entered into the contract. If a contractor enters upon a piece of work with the idea of meeting the ordinary regular conditions that he can foresee, and if, suddenly, unforeseen difficulties develop which prevent him from executing the work as economically as he had originally planned, he is immediately in trouble, and he is in a position similar to that of a man who pays a good price for a cantaloupe and, after cutting it open, discovers it to be spoiled. As a matter of law, with the usual form of contract, if the contractor meets with difficulties which are not the fault of the owner in any way, and which the contractor ought to have foreseen himself, it is the contractor's fault, and he must bear the burden of it. On the other hand, if he is subjected to interference with the economic conduct of the work because of the actions of the owner, such privileges not having been granted to the owner in the contract, the owner is at fault, and in this case it is he who must bear the burden. There are, however, a great number of cases which do not come within either of these assumptions. For example, if the contractor meets with difficulties which are forced upon him by outside parties, or by what the lawyers term "the acts of God," the financial responsibility is often a very difficult one to determine.

In brief, the contractor is supposed to be able to foresee the ordinary conditions that will govern his work, and to make provisions for them in the terms of the contract which he signs; and to meet these conditions he is responsible. For unreasonable interference with him on his work, due to the owner, a contractor is not responsible. For outside conditions which are not foreseen in the contract and not of such ordinary occurrence that they should have been foreseen in the contract or by an intelligent estimator, and which, at the same time, are not imposed by the owner or anyone employed by him, there is usually room for question as to who must bear the responsibility.

Special Privileges. No two contracts can be exactly alike, because no two engineering or architectural purposes are exactly alike. Every piece of work has its own particular and peculiar features which require to be dealt with in a way particular and peculiar to that work; and therefore nearly every contract has clauses which are intended to guard against misunderstandings arising from special conditions. If these special conditions are expected to interfere with the right or the interest of the owner, the attempt is generally made to guard the owner's interest by introducing the special privileges that he may need; while, if the peculiar conditions are expected to affect the contractor detrimentally, he may insist upon certain special privileges for his protection.

The contractor may be allowed to use equipment belonging to the owner; he may be allowed to use the owner's property to store materials and supplies upon; he may be allowed special rates on materials sold to him by the owner; and he may be allowed special leeway as to when certain parts of the work ought to be completed—all of which special privileges are worth something to the contractor and are certain inducements to him to take the contract at a low figure; or they may be inducements to him to waive payments at certain times.

Essentials to the Owner. The owner, on his part, is under the economic necessity of obtaining most or all of the following valuable things as a result of his contract:

(a) Quantity of work.
(b) Quality of work.
(c) Time of completion.
(d) Special privileges.

Quantity of Work. In a construction contract, when the work has been completed, the owner is to have something that he did not have before; and the amount of what he is to have, secured for him by the contract, should be most carefully understood before the work is commenced. If the structure is to be built of concrete, the owner must receive enough cement, enough sand, enough stone, enough steel, and enough of all the various materials that are going into the structure, to justify him in his expenditure, or it will not be a financial success. Moreover, he must have the quantity that his original understanding with the contractor guarantees. His architect, for this purpose, lays out elaborate **plans**, showing in detail a very large portion of the finished work; and the **specifications**, which accompany the plans, and which are regularly made a part of the contract, are intended to insure, among other things, that there shall be no skimping in work below the understood and agreed-upon standard. In actual fact, as the practice runs today, it is not at all easy to guard against errors in and violations of the original arrangement in this regard. Take the simple case of cement, for example. The architect may specify that the concrete shall be made of a 1:3:5 mixture, meaning one part of cement, three of sand, five of stone. If the materials are specified as of these parts by weight, it will be difficult to enforce the rule with exactness, because of the ordinary difficulty of weighing upon the ground, and also because of the fact that these materials, except stone, weigh considerably more when they are wet than when they are dry. When, on the other hand—as is usually the case—the materials are specified by measure, there is room for misunderstanding, because the space which a given amount of sand or cement will take up depends to a considerable extent upon the degree to which it is packed. A packed barrel of Portland cement contains about 3.8 cubic feet, more or less, of cement; but, if sifted, the dry cement in one barrel may easily amount to considerably over 4 cubic feet; and, depending upon the way in which such a term of the specification is interpreted, will the owner get more or less material for his money.

Sometimes the contract may provide that the mixture is at the discretion of the contractor, and that the owner is satisfied if the finished concrete will pass certain tests, in which case there is less room for misunderstanding. Such practice, however, is not yet general in the United States.

A contract for structural steel work may be for a lump sum, or for so many cents per pound. If on the lump-sum basis, the owner is interested in receiving the number of pounds of material as covered by the plans. Now, it happens that the steel mills cannot roll the sections with absolute uniformity, and there is sometimes a difference of several per cent between the estimated standard handbook weight per foot of steel shapes and the actual weight of those steel shapes when shipped. The difference is caused by the variations in the adjustment of the rolls in which the material is made. In a case of this kind, it is generally conceded that variations in the estimated weight amounting to 2½ per cent are permissible, except in the case of such material as sheared plates more than 100 inches wide, in which case 5 per cent variation from the theoretical weight is ordinarily allowed. In a large piece of steel work, some of the material will be over-weight and some under-weight, so that in the long run the errors will tend in some degree to balance each other.

In the case of a brick building where the contract is upon the unit-price basis, there is likely to be some discussion as to what allowance must be made for the spaces of doors, windows, and other openings; and it is essential, in a contract of this kind, to specify carefully how the number of units of performance in the work shall be estimated or determined.

The owner is interested in the quantity of material and of labor entering into his structure, in so far as it affects the quality of the finished work, its durability, and serviceability. The distinction between quantity of labor as an asset to the owner, and quality of workmanship, is a fine one; but there is no question that the owner is entitled to the proper amount of material and the proper amount of labor necessary to make the structure what the two parties agreed upon when the contract was signed.

Quality of the Work. In addition to the amount, the owner is entitled to a certain quality of material and quality of labor; and here is one of the difficult problems that arise in all contract framing, and one which is worthy of careful study. As a general thing, what the parties have in mind when they sign the contract is that the material shall be of standard quality—the sort of quality that enters into a first-class job, the sort of quality that is readily obtainable at fair prices in the open market; but this understanding is so general and is subject to so many different interpretations, and the variation in interpretation is so great with different kinds of material, that it is exceedingly difficult to decide properly and equitably.

Take the common example of the ordinary red hard-burned brick. In the first place, the bricks made by different makers are of different sizes and of different shapes; and a big brick is worth more money than a small brick, other conditions being equal. A standard brick specification would require that a brick should show, when broken, a comparatively uniform structure, hard and somewhat glassy, and free from pebbles, cracks, cavities, and lumps; and yet, as a matter of fact, many a brick gets on the market which contains one or more pebbles the size of a hickory nut. An over-burned brick will be of a different size from an under-burned brick, and will have very different characteristics. Moreover, the art of brick-burning is such as not to admit at present of the most exact uniformity in the product. The bricks which are on the outside of the kiln will not receive as thorough a burning as the bricks toward the center of the fire; and therefore the finished product will necessarily show irregularity, and the justifiable range of irregularities is not easy to specify in terms of units. The owner is entitled to require upon inspection a quality which was standard when the contract was signed; and it is essential to the proper success of his part of the business that the standard quality be assured to him; but if the owner requires a quality which is higher than the standard and more difficult to obtain, the increase of usefulness thereby secured is usually not so great as the increase of cost involved.

It frequently happens that the owner changes his mind after the contract has been entered upon, as to what quality he wants in certain materials; and then, by an agreement with the contractor, he pays a certain amount for the privilege of changing the quality of the material. As a general thing, when so inserted, the cost of these extras to the contractor and also to the owner is greater than it would have been if they had been properly foreseen in the draft of the original contract. Sometimes a contractor takes advantage of the fact that the owner wants to change his mind, and exacts an exorbitant compensation for the extras, in which case the contractor makes money out of it. Making these extra charges on a larger number of items is one method of turning an unprofitable contract into a profitable one. It is nearly always strongly objected to by the owner, and is likely to lead to lawsuits.

The illustration of the red brick has been used above, because it is such a common article for construction purposes. Another type of article to which attention should be called in this connection, comes within the class of special fittings, hardware, etc. The standard quality of door-knob, for example, is a very difficult thing to decide on beforehand, or to agree upon afterward. There are so many different types of door-knobs, and so many different makers furnishing them, that sometimes the only way to solve this problem is to specify by catalogues and numbers. Then, if this particular manufacturer happens to have a surplus of orders and cannot deliver on time, the contractor has the excuse for delaying the work, that he could not get the special object specified by the owner, and the owner is in a quandary as to how to get what he wants without delay to his work in general.

The quality of the labor is still more difficult to contract for with accuracy than the quality of the material. When the contractor starts in on the contract, he may not have in his employ more than two or three of the men who are to work upon the job, but he undertakes to see that the work shall be performed in a "thoroughly workmanlike manner." The workmanlike manner of the human laborer in times of great business prosperity, when there is a job for every man, is a different matter from the workmanlike manner of the same man after he has resigned from the union or before he has joined it, when there are two men for every job. The owner is entitled unquestionably to receive the grade of work that the contract calls for; but how to specify in words that grade of work without room for a great deal of misunderstanding and subsequent trouble, is a problem that has not yet been generally solved except upon the understanding that the grade of work shall be in accordance with the established practice in the locality and at the time when the contract was signed or when the work is carried out.

The quality of the finished work, its appearance, its dimensions, its density, and its general resistance to outside forces, can often be pretty well defined, and this implies a certain quality of workmanship. On a piece of riveting work, for example, the owner on an ordinary contract should be reasonably entitled to have the riveting done by men of experience in this class of labor; and it might perhaps be a violation of his rights to have the contractor place upon the riveting work green men, training them as the work progresses. The contractor may claim that so long as the rivets fill the holes, are properly finished, are not burned, and cannot be found fault with on inspection, he is doing his part; and probably this is true, so long as the green gang does not take so much time upon the work as to interfere with the owner's rights.

Time of Completion. As a business proposition, the owner in the contract makes a stipulation that he is to receive his completed structure or certain parts of the completed structure at certain times. The contract for the structure is of more value to the owner if the structure is completed at a certain time than if it be delayed, for the reason that he makes his ordinary business plans and arranges his various business matters so that he can make use of the structure at the time specified. He does not expect to receive it sooner; and if he did receive it sooner, his other arrangements might not admit of its being any more valuable to him than if delivered later; while, if there is considerable delay, he may be put to a large monetary loss. Therefore he is entitled to receive the structure at the time agreed upon, provided that an extension of time is not agreed upon, or provided that the delay is not caused through the fault of the owner, or through an "act of God," so called, or through some other cause which is beyond the power of the contractor to prevent.

One of the causes most likely to produce a delay of this kind is a **strike.** Now, a strike may be caused by ignorance on the part of the contractor of proper methods of management. Men will sometimes strike while working for an ignorant contractor, whereas, if working for a successful manager, they would not strike under the same conditions. A contract such as we are now considering frequently includes a clause to the effect that a strike shall involve an extension of the contract time corresponding to the amount of the delay from the strike. It will be noticed that such a clause, while protecting the contractor in absolving him from the assumption of such risk, is a distinct disadvantage to the owner, who has no redress on that account if the strike takes place; and if a contractor finds that he is going to be delayed in the work, he can with very little trouble produce a strike. The time or duration of a strike may not be the same as the time of delay caused by such strike, and it is sometimes difficult to establish just what this time allowance ought to be.

Special Privileges. A railroad building a bridge on a contract will often require that the contractor shall so conduct his work as not to interfere "in any manner" with the regular passage of the trains that are operated by the railroad. This gives the railroad, or the "owner," the privilege of very considerably interfering with the work of the contractor at times in order to maintain its traffic in an uninterrupted way. Such a clause, when worded as above, is often ridiculous in its importance, because a contractor cannot build a bridge under traffic without requiring at least that the trains shall be slowed down. The owner may sometimes wish to have certain articles that he possesses, and for which he has special fondness, incorporated in the work —for instance, such as an ancestral mantel-piece of a particular grade of stone or a particular colored stone. Special features such as these are very frequently inserted by architects in order to obtain special artistic effects, and they unquestionably have a certain monetary value, which is very difficult to estimate in dollars and cents from the owner's point of view, but which may cost a very definite amount from the point of view of the contractor.

The owner will frequently decide upon asking certain privileges of this kind after the contract is well under way, and at a time when compliance with his wishes will involve a much greater hardship upon the contractor than would have been imposed had the privilege been settled upon originally. This forms an excellent reason—and too often an excellent excuse—for the contractor to demand a large extra compensation.

OBLIGATIONS OF A CONTRACT

Lump-Sum Contracts

Under the usual lump-sum form of contract, the owner agrees to furnish the following:

1. Money.
2. Plans and specifications.
3. General instructions, stakes, and layout.

The contractor furnishes:

1. Labor.
2. Materials.
3. Plant.
4. Supplies.
5. Organization.
6. Superintendence.
7. Experience.
8. Insurance, as to time.
9. Insurance, as to cost.

It will be noted that the owner furnishes something which is usually definite, and the proof of the furnishing of which is usually easy. By the dates on the checks or on the receipts, it is entirely feasible to establish just when the owner made the advance payments, and there is rarely much trouble as to whether or not the owner furnished a sufficiency of plans and specifications, stakes, and general instructions for the work, although at least one instance is on record of a lawsuit arising in which one of the principal grounds of contention was that the owner did not furnish a sufficiency of plans to enable the contractor to proceed.

While it is easy to establish the dates at which the owner has made payments, and their amounts, trouble may arise on a contract because the owner refuses to make payments, claiming that he is justified in withholding money, on the ground of something that the contractor has done. Now, the contractor, in furnishing each of the above nine items of value, supplies something which is not a definite medium of exchange, which cannot be specified with absolute precision, and the cost of which to the contractor may not be the same when he is ready to use it as it was when he signed the contract. Therefore the chances for misunderstanding as to the contractor's performance are very much greater than the chances as to the owner's performance; and this fact ought to be borne in mind by all owners, contractors, and architects, not only in preparing the contract, but in using ordinary common sense in its interpretation afterward.

Plant. The items of **labor** and **materials** have already been discussed. **Plant** is a factor in which there is a wide range of variation in efficiency and cost, and in general adaptability to different kinds of work. A contractor who has a small business of considerable variety must have a plant which is as adaptable as possible to different classes of work, so that when he finishes one piece of work of a certain type he can put the same plant on another piece of work of a different type without any large loss of efficiency. Such a plant will not operate as efficiently as one which is adapted to but one kind of work and which is made especially for that work. It therefore behooves the owner, before entering into a contract, to consider in general what sort of plant the contractor owns, which he intends to use on the particular work in hand.

Supplies, such as coal, oil, dynamite, etc., which are consumed in carrying on the work and which do not remain as part of the finished structure, do not particularly concern the owner as to their quality or amount; but they will have a considerable effect upon the contractor's efficiency. If they are not of proper quality, delays are likely to result, which the contractor may claim are not his fault. This is a danger that the owner has got to run, because it is not advisable for the owner, before signing a contract, to stipulate much as to the grade of supplies which the contractor is to use. Although there is no theoretical reason why it cannot be done, it would be unusual.

Organization. It is the contractor's duty to furnish the organization on the work—by which is meant the assembling of men of proper training to get the work carried on successfully. Some of this organization—namely, the Superintendent and Foremen—may be regularly carried upon the contractor's pay-rolls, and he may know exactly what they are capable of doing; and the owner may be able to get references as to the contractor's past performances, which will give him to understand just what he can expect from the contractor's employees of these grades. The great bulk of the organization, however, is likely to be engaged at the beginning of each job, and to some extent the owner must take a chance as to the results of this selection.

Men vary, and they vary greatly, in their individual efficiency. Under the ordinary system of handling outside work in use today, in taking on a number of men, there will be perhaps some very good workers, some fairly good workers, and some altogether bad workers. The general average of the workmen's performance is what the contractor figures on in making his estimate; and if he gets a certain man or gang of men better than the average, he is that much better off; if they are worse than the average, he is just that much the worse off. His chance of getting a combination that is pretty close to the average is greater on large jobs and in large communities where there are many men looking for work, than on small jobs or in small communities where there is not so much doing.

Therefore, the gambling chance as to the quality of workmen is greater in small communities on small jobs of work than vice versa, and this feature usually involves a larger contract price.

Superintendence. Superintendence of the work, to see that it goes smoothly and economically, is the special service which is expected of the contractor, and the one which the nature of his business makes him particularly fitted to render. He is supposed to know how to get the best foremen, and to see that they get the most out of their men; and his office is supposed to buy materials at the lowest prices. He may be seriously limited in his opportunity to get the best foremen for any particular piece of work, because in dull times, in order to reduce expenses, he discharges his idle men, and when business becomes lively again it is difficult to get good men at short notice. Many large contractors, therefore, keep a few of their good men over dull times; but this is done under the penalty of increasing the "overhead" charges, thus making it difficult to compete with small contractors on anything but large operations.

Some contractors are particularly skilful in handling certain kinds of labor, and have indifferent success with others. A manager accustomed to the type of bricklayers to be found in the New England States might have difficulty in getting satisfactory work out of negro labor in the South.

Some contractors can purchase materials and supplies more economically than others, because their credit is better, since the dealer will always quote better prices when he is sure of his money than when he is not; and some men have a natural gift as buyers which is not always possessed by other men equally clever as regards the handling of men.

It is clear that in furnishing superintendence or managerial skill, the contractor is delivering something which cannot be measured or estimated with much accuracy before commencing work, and not always afterward. If the contractor has a record as an efficient manager, and has in his employ some good men who are available for the work to be undertaken, he may be expected to manage or superintend the work efficiently, provided that his financial inducement to do so is sufficiently strong. This is supposed to be insured in the unit-price or lump-sum forms of contract, by having him guarantee the cost.

Experience. A contractor may be a good manager and may have an excellent organization, and he may have a very good plant and be able to obtain satisfactory labor—

all of these without being able to do efficient work. Unless his experience has been of the right kind to fit him for the particular work to be done, he is likely to have a good deal of trouble. For the best results, he requires to have had experience on the type of work in question. There are, for example, a great many "tricks of the trade" which are peculiar to a piece of brickwork, for the knowledge of which some experience seems to be necessary. In bricklaying the contractor employs a very high-priced class of labor for the actual laying of bricks; and he employs an entirely different class to act as helpers to keep the bricklayer supplied with material, to raise and move scaffolding, and, in general, to facilitate the brick problem. The management of the work so that the bricklayer can handle his bricks with a minimum of labor on his own part, can always find a brick at the right place when he reaches his hand for it, and not only find the brick there but find it in its proper position with the right side up so that the bricklayer standing upon his scaffolding is always at the proper position with regard to the growing wall—this kind of management is an art by itself. It is, moreover, a highly intricate art—one involving not only the ability to manage men well, but the ability to plan and foresee conditions that are likely to arise during the days' work. While this art can be studied scientifically, and a great deal can be learned about it that pertains to the economics of the subject, its efficient carrying-out requires practice.

In concrete construction the amount of material on the work is pretty rigidly limited by the plans and specifications, and the most variable feature is that of labor. This labor consists not only in the placing of the concrete itself, but in the making and setting of the forms; and it is likely to be the case in most work of this kind that the keynote of successful performance is experience and ability in handling these forms. Forms are generally made of wood that can be used again and again, and if properly treated, can be used much oftener than when improperly handled. The life of the forms is also very much governed by the manner in which they are designed and put together. To handle them properly upon the work and manage the general work so that they can be used to the best advantage, is an art entirely distinct from bricklaying, and one which seems to require a considerable amount of training and experience before it can be mastered. One reason for this is that heretofore no very thorough economic study of this subject has been made.

Another class of construction on which a contractor should have had special experience in order to insure his efficiency is that of **steel buildings.** Here the units to be handled are often very large and heavy. The handling of heavy weights economically by a small force of men and with the aid of derricks and other plant, is a peculiar art which comes only from practice. Sailors are generally good at this sort of work, and men who have not had experience in it are practically helpless when confronted by its problems. The iron worker as a laborer is in a class by himself. He is courageous and determined, strong and active, and under some circumstances requires considerable tact, as well as firmness, on the part of his manager. After the metal has been set up and bolted, it is necessary to rivet it together—which is a large item of cost; and here special experience will generally teach a manager how he can apply devices for pushing the work.

The contractor should have some experience of the locality in which he expects to work, since local ordinances are likely to vary a good deal, and the manner in which the laws are administered is also likely to vary a great deal in different localities. The local conditions of labor, besides, are likely to vary. One town may be pretty well unionized, and another not far away may contain a rather different class of labor and require different methods for pushing work. The prices of labor and material are not very different in New York City and in Brooklyn, just across the East River; yet prices obtained by contractors for doing work on Manhattan Island are considerably higher than those in the other Borough. This is due partly to these local conditions as above mentioned, and partly to the density of traffic on Manhattan Island and the difficulty of getting through the streets. A strange contractor cannot easily tell beforehand how much trouble he is going to have in unloading his wagons in the streets until he has been at least once "up against" the local ordinances.

Size of the Job. A man who is accustomed to handle small pieces of work is generally in the habit of doing a good deal of the field managing himself, and is not necessarily very strong in the organization line. He may be able to manage very efficiently a piece of work which requires a small number of workmen, but not be so good where the individual counts for less and the general business organization counts for more. If the bulk of his experience has been on works of small magnitude, he is not likely to be particularly good at the large ones; and on the other hand, if his work has been in the line of heavy construction, employing a good many men, he will usually not bid as low on a small piece of work as will a man who has had most of his experience in small jobs.

Insurance. In the old-fashioned form of contract, the contractor guarantees that he will do the work for so much money. This particular part of his contract is nothing else than a sort of insurance by which he undertakes to assume the risk of the work being more expensive than he originally figured. If it costs more, he loses; and if it costs less, he gains just that much—which, as has been indicated above, is an inducement to him to operate with economy. In practice, this works out in the following way: The contractor always either makes or loses, and frequently his bookkeeping methods are such that he does not know whether he has made a profit on the contract or whether he has actually lost unless the profit and loss should happen to run into a considerable amount. If he is generally successful in making substantial profits his business grows and he waxes prosperous; or if he makes a good many small losses, or one or two very large ones, the amount of capital at his disposal is not sufficient to enable him to stand the losses, and he fails. If he fails while the contract is at a critical stage, the owner is likely to lose money unless he is protected by a bond, and he is sure to lose in the matter of time for the completion of the work. The large contractor with a large capital is less likely, of course, to fail on a comparatively small contract than a small contractor, and the additional security in the way of insurance which this larger capital gives the owner is one reason why the owner is sometimes willing to accept a higher bid from a large contractor than he can obtain from a small one.

The insurance feature has a decided economic value from the standpoint of the owner, and is a tremendous risk from the standpoint of the small contractor. It will be noted that this insurance which the contractor provides is insurance as to cost and as to time, the former being by far the more dangerous to the contractor, and the latter sometimes of greater importance to the owner. These features will be considered more fully under the Cost plus Compensation Contract.

Unit-Price Contracts

The general bearing of the obligations of the parties to each other is very similar to that in the case of the lump sum contract, except that here the totals of the quantities are often not determined until the finish of the work. Any effect that this uncertainty may have upon the interests of the parties will properly influence the contract prices on the one hand, or the contractor's profit or loss on the other.

The case of structural steel work affords an excellent example of the workings of this feature upon the obligations and attitude of the parties. A great many steel structures are let upon the lump sum basis, and a very large number on that of the pound price. In either case the owner furnishes to the various bidders on the work plans and specifications in more or less detail, indicating the type, size, general strength, and character of construction. The bidders submit with their figures stress sheets, indicating how they propose to treat the various structural problems. On the basis of the quoted prices and the stress sheets submitted, a contractor is selected for the work, and a form of contract entered into with him. Before the work can be proceeded with, however, it is necessary that more elaborate detailed plans be prepared, and this is generally done by the contractor. He then proceeds along the lines indicated by the stress sheet. The details have to be approved by the owner's representative before actual construction commences. Now, it is clear that the more pounds of metal in the structure under the form of contract that we are now discussing, the greater will be the contractor's profit; whereas, the fewer the pounds of metal, the weaker the structure, and the less his profit. Since there are various ways of calculating the amount of metal necessary—column formulas, impact formulas, and various assumptions as to the performance of metal under stress made by different authorities, each of which assumptions will have to do with the amount of metal for a given amount of supporting power—there will be room for a variegated interpretation not only of the specifications but of the stress sheet; and it is the business of the owner's representative, the architect or engineer, to see to it that the detailed drawings do not call for an unnecessary amount of material at the owner's expense, while at the same time not imposing restrictions which will make the finished structure too weak. If the architect or engineer cut down the metal too much for agreement with the stress sheet, the contractor can very properly claim that he is entitled to sell the owner more material, on account of the provisions of the stress sheet, which then is a part of the contract.

In any steel structure, even with quite rigid specifications, there is room for the exercise of considerable judgment in designing the "connections" whereby the stress is transmitted from one main number to another or others. Where it is to the contractor's interest to supply an excess of material, he will generally show a desire to adhere to the best and safest and most conservative engineering practice. There is, then, the further complication that the weights of the material as actually shipped are likely to vary several per cent from the theoretical weights of the members called for in the stress sheet. The contractor is usually paid on the basis of the actual shipping weight of the steel. This feature has been more fully discussed above, under the caption "Quantity of Work."

The main distinction in the actual working results between the unit-price contract and the lump sum contract, is that in the former case the contractor demands the best engineering practice, whereas under the lump sum contract the owner is doing the fighting for good practice.

Cost plus Compensation Contract

Much has been heard of late years about this kind of contract, and a good deal of work has been done under it. So much uncertainty seems to obtain in the minds of most people concerning its true inwardness, and there is such a considerable diversity of opinion in the minds of different people as to what this form of contract really means to the owner as well as to the contractor, that it would be well to go into its analysis with some care. Under its provisions the owner pays the entire cost of the work, plus something to the contractor for his profit. In some forms of this contract, the contractor furnishes the money as he goes along, and the owner reimburses him from time to time for what he has paid out until the end of the job, when a final settlement is made; while in other forms the contractor O. K.'s all bills which are sent to the owner for payment, and the contractor does not handle any money at all. Even the pay-roll is settled by the owner sending his representative to the job on every pay-day and paying the men off on vouchers approved by the contractor or his representative.

It will be seen at once that this contract presents some particular advantages in certain localities and on certain classes of work, from the standpoint of all parties. On the other hand, it has certain peculiarities that do not immediately appear. Taking the same basis of analysis that we did in the consideration of the lump sum contract, we find that under the cost plus compensation form the owner furnishes the following items:

1. Money.
2. Insurance.
3. Plans and specifications.
4. Sketches and instructions.
5. Plant.
6. Labor.
7. Materials.
8. Supplies.

And the contractor furnishes:

1. Organization.
2. Superintendence.
3. Experience.

Money. The way in which the owner is going to make his payments is a point that has a great deal to do with the economical results of the work so far as the contractor is concerned. If the owner furnishes all the money from the beginning, the contractor does not have to tie up any capital in the work at all. The method followed by one well-known contractor of large experience has much to recommend it. In this case, when the work is started, the owner turns over to the contractor a sum of money which is intended to cover the cost for the first month or six weeks. This money is then deposited in a bank in a special account, against which the contractor is authorized to draw checks. Each check drawn, besides being in the usual form of banking check, contains the job number, the account number, and a complete list of all the items which are being paid for by that check. When the check comes back from the bank, it is filed with the papers for that particular job; and the owner can immediately, by going over the returned checks, see exactly how all the money was spent—for what accounts, in what manner, and at what time. Checks covering the pay-roll can be drawn either to the individual workmen or to a foreman or time-keeper, who accounts for his distribution of the men's pay.

Insurance. In contrast with nearly every other form of contract, under the cost plus compensation system the owner furnishes the insurance. Note that the contractor guarantees absolutely nothing. In the standard form of the "cost plus" contract, the contractor is not responsible for the time of completion; he is not responsible for the cost exceeding a certain amount; he gets no extra money if the cost is excessive or if he saves money; and, in short, the contractor has practically the minimum of interest in how he really does his work. The only real incentive that he has for making the work go expeditiously and economically, is his personal ambition and a desire to make or keep a good reputation for efficient work. He is on what might be called a peculiarly professional basis; and if the men strike on the work, if the men whom he has selected for directing the work mismanage it, if lightning strikes it, or if the work is held up by injunctions or lawsuits, either through his own negligence or through the negligence of his employees, he is not responsible, being simply the agent of the owner. The owner, on the other hand, guarantees that he will pay the bills when the contractor sends them in; that he will be responsible for all the errors and mistakes of the contractor so far as economic performance goes; and he further stands the damages when accidents which are not the fault of anybody in particular occur and cause considerable delay. He practically stands in the position of guaranteeing to himself that the contractor will do his work properly, and that no external agency will put the work back. If the contractor is slow, he is in the owner's employ, and the owner has no redress except to cancel the contract and let the contractor sue him for profits.

In order to mitigate some of this insurance that the owner has to stand, he is frequently accorded the right in the contract to require that the contractor shall take away from the job any foreman whom the owner considers to be incompetent. The trouble with this arrangement is that if the owner does order an incompetent foreman off the work, the contractor can be dilatory about providing another good foreman; and if the owner wishes to name a foreman, a contractor can say—and perhaps with logic—that he will not be responsible for any errors that the foreman selected by the owner makes. As he is not responsible anyway, it does not seem as if this would make much difference.

Plans and Specifications; Sketches and Instructions. These are furnished by the owner as in the lump-sum contract.

Plant. The contractors who do work on a "cost plus a fixed sum" basis, do not, as a general thing, own much plant themselves, and the owner is in the position of either purchasing or renting plant. If the contractor happens to own plant which he can turn over for this kind of work, he usually does so on a rental basis—so much per day or per month. This rental clause is really a separate contract by itself, since, after the renting has taken place, the plant is under the direct control of the owner through his agent, the contractor, and if accidents happen to it, the owner is responsible. Some contractors, particularly where the amount of plant involved is small, will agree in their contracts to furnish the necessary plant out of their own stock, the rental for plant, or compensation for its use, being waived. This feature is not so satisfactory from the owner's point of view as might at first appear, because the contractor is tempted to use a minimum amount of plant and one which may not be the most suitable for the work; and therefore, if the owner furnished or rented his own plant, it might be more suited to the particular class of work to be done and thus ultimately result to the economic advantage of the job.

Labor. Generally the contractor knows where he can find men to employ on the class of work to be done, and he engages the men as the representative or agent of the owner. When he pays them out of his own bank account from funds supplied by the owner in the first place, the contractor usually acts as paymaster; but in the case where the contractor is not to handle any money, the paymaster is outside of the contractor's organization entirely. Under this arrangement, the men learn immediately what kind of contract is being carried, and they are likely to get the idea that efficiency does not count much in the results of the work, and therefore are disposed to "soldier;" whereas, if they thought that they were working for the contractor, and the contractor's vital financial interest was at stake, they would be more inclined to expect to lose their places if they did not work well and rapidly.

Materials and Supplies. We have outlined above how the contractor buys the materials, and have called attention to the fact that the owner is usually given the privilege of furnishing materials himself if he thinks he can do so to advantage. At first sight it would appear that this protects the owner against graft; but it is not difficult to see how it would be possible for a dishonest contractor, after getting bids for materials, to accept upon delivery an inferior grade of materials and receive from the dealer furnishing them a rake-off for himself. Unless the owner put someone on the site to supervise the work with great care and inspect all materials as they came in, it would be difficult for him to prevent this. To be sure, this inspecting is the duty of the architect; but to inspect sufficiently well to provide against such contingencies would mean that specifications as to materials would have to be very accurately drawn in the first place, and, in the second place, that the architect would have to spend a great deal more time in inspecting than he is likely to spend. Where the contractor orders for the owner, he is practically in the position of a purchasing agent for materials, with all the advantages and disadvantages that ordinarily pertain to purchasing agents in general—with this difference, that, if the owner does not like the way he does his work, instead of discharging him as he does a purchasing agent, the owner has got to spend time and extra money and do the purchasing himself.

As against these things that the owner furnishes, we have the items that are supplied by the contractor:

Organization. This has been discussed above, and is not essentially different here, in its economic features, from the case of the lump sum and unit-price contracts. The contractor is seldom in a position to throw upon any particular piece of work an organization of his own, because, when this organization is good, it is occupied on other work and cannot come to a new position except with some injustice to the work already on hand. As a general thing, when the contractor is not busy, he cuts down his force to the very smallest possible minimum, in order to save himself from carrying expensive men without financial return; and then he has no one in his employ to throw upon new work. However, it is his business to keep in touch with men all over the country whom he can get for his work when he has work to do, and therefore, if he has had much experience, it is not difficult for him to get together in a comparatively short time an organization of men whom he knows something about personally, and in whom he feels that he and the men can have confidence.

Superintendence and Experience. A contractor under a "cost plus a fixed sum" contract may have had a good deal of experience in the particular line of work to be done, and yet this experience may have nothing to do with the work unless he have more incentive to economic performance than ordinarily obtains under such a form of contract. His own experience in the particular line involved may be of very little value to the owner. If his superintendent is inefficient, as sometimes happens, apparently the only redress that the owner has is to cancel the contract and allow the contractor to sue him for profits, which is a remedy that is sometimes worse than the disease. When the contractor has a great deal of work to do, he cannot put much of his time in supervising any one piece of it; and when he has not much to do, he generally spends most of his time looking for new propositions.

Other Forms of "Cost Plus" Contract. Sometimes, instead of the cost plus, a fixed sum contract, there is the cost plus percentage contract, in which the contractor receives 10 or 15 per cent of the actual cost of the work for his compensation and profit. Here, the more the work costs, the more the contractor gets as profit, and there is a positive premium upon inefficient work. The percentage basis—where the amount of work to be done was indefinite, and when, because of uncertainty in regard to the facts connected with the work, it was not desired to make up elaborate specifications—was used to a considerable extent ten or fifteen years ago. Today it is giving place to the cost-plus-a-fixed-sum form.

Examples of standard forms for contracts, proposals, bonds, etc., will be found in the section, "Miscellaneous Information and Tables," in the latter part of this volume.

Specifications

A properly drawn set of specifications, with accompanying plans, is a part of the contract as a legal instrument, and performs the function of elaborating just what specific things the contractor has to do and just how he has to do them. The specifications should contain a reference to the contract, and the contract should mention the specifications, in order that they shall be taken together as forming the parts of one entire agreement. So far as referred to, the specifications become constructively a part of the contract. While in ordinary practice the specifications are made a part of the contract, and are with it signed and sealed, they are not in the legal form of a contract, because the burden of performance falls entirely upon one party. In the contract the owner agrees to pay certain sums for the performance of certain work by the contractor; but, under the specifications, the owner is a passive party, and for that reason practically all clauses of the specifications are directed to the contractor and are statements of his duties. There are practically no clauses in the specifications that require anything of the owner.

General Faults. The man who draws up specifications finds himself between two difficulties. On the one hand, there is the probability of making a specification too verbose, too cumbersome, and too unwieldy; and on the other, in the attempt to eliminate this fault, there is the probability of leaving out something which might be desirable and which is necessary to make the instrument intelligible.

A common fault in the writing of these documents is caused by the desire of the writer to show those who are going to work under them his vast knowledge of the subject covered by the specifications. He puts in many things that are not necessary to the proper guidance of the contractor, and in many cases things that handicap the contractor in his work and bring about no compensating good. When this is the case, the contractor is liable to think that the specifications are antagonistic to his advantage, and he will act accordingly and be disposed upon the slightest pretext to attempt to "even up."

Another grave fault is the placing of too many restrictions upon those who are going to do the work. The contractor should be restricted as little as possible, the only requirements being that he must confine himself to good practice, and must, in the end, show proper and acceptable results.

The owner wants to get just as much for his money as possible—wants the best workmanship and materials because he is paying his good money for them—while the contractor, on the other hand, even though he may have no idea of skimping and no desire to skimp in any way, is working for his livelihood and wants to do the work as cheaply as may be consistent with acceptable performance, and so make as great a profit as possible.

If the specifications are clearly drawn when submitted to the contractor, he can make his bid accordingly; and no matter how severe the requirements may be, his bid will make allowances for the difficulties imposed by them. If, on the other hand, a specification is capable of several interpretations, or if it is stated in such a way that there are "holes in it," the contractor will be led to take chances in his bid. This is especially true if the contractor has done much work under the architect, and thus knows how closely or how loosely he will be held to the letter of the specifications. Bidding under such specifications works a hardship on the contractor who is unfamiliar with the architect. No matter how strict the specifications may be, and how well known to the contractor the architect's peculiarities are, the personal equation should have to be taken into consideration as little as possible. Remember that a well-defined specification is essential to a fair contract.

The following typical form of specifications for a frame dwelling of moderate cost, with heating and plumbing, is used by permission of the publisher, E. G. Soltman, 134 W. 29th St., New York City.

TYPICAL FORM OF SPECIFICATION FOR A FRAME HOUSE

If a brick dwelling is desired, see additional clauses at end of these specifications.

SPECIFICATIONS

Of labor and materials required in the erection and completion of a Frame Dwelling to be built for ....

....

.... Street, ... Town.
according to the plans drawn by ....,
Architect.

....

GENERAL

These specifications are intended to embrace all of the labor and materials necessary in the erection and completion of the building in all its parts, the whole to be comprised within any contract or contracts that may be made for the same. The entire work is to be constructed and finished in every part in a good, substantial, and workmanlike manner, according to the accompanying drawings and these specifications, to the full extent and meaning of the same, and to the entire approval and acceptance of the owner and architect. Each contractor is to provide all materials and labor necessary for the complete and substantial execution of everything described, shown, or reasonably implied, including all transportation, scaffolding, apparatus, and utensils requisite for the same, all materials, unless otherwise particularly specified, to be the best of their respective kind, and all workmanship to be that of skilled mechanics.

The work must conform to all building laws or ordinances applying to the locality, and the contractor is to obtain and pay for all permits, fees, &c.

The contractor is to lay out all work and give his personal superintendence to the same, and maintain at all times a competent foreman on the job. He is to execute the work with due diligence and expedition, and in co-operation with other mechanics. He is to give immediate attention to the directions of the architect, and will be held responsible for any variations from the drawings and specifications. He shall maintain and guarantee the stability of the work and repair any defective work for a period of one year after completion of the contract.

The following is a list of Drawings which accompany these specifications, and which form part thereof: Front Elevation, two Side Elevations, Rear Elevation, Plan of Cellar, First Floor Plan, Second Floor Plan, Roof Plan. Full size Details.

ALTERATIONS

It is also understood that the owner of the building and the architect shall have the right to make any alterations, additions, or omissions of work or materials herein specified, or shown on the drawings, during the progress of the building, that they may find necessary, and the same shall be acceded to by the contractor or contractors, and carried into effect without in any way violating or vitiating the contract. And the value of all such alterations, additions, or omissions shall be agreed upon in writing between the said owner and the contractor before going into execution. No extra work will be allowed without such written agreement.

CARE OF FINISHED WORK

Particular care must be taken by the contractor of all the finished work, as the building progresses, which work must be covered up and thoroughly protected from injury or defacement during the erection and completion of the building. Contractor shall make good any damage or defacements.

ADDITIONAL DRAWINGS, ETC.

There will also be furnished a complete set of scale and full-size detail drawings for all exterior and interior work, and used in connection with the above, show all dimensions in relation to the work which is to be represented by the Detail Drawings. Where figures are not given all drawings must be accurately followed and measured according to their scale. All writings and figures are to be considered a portion of these specifications, and must be followed and considered. Follow figures in preference to scale.

On the plans red expresses brick; yellow, wood; and blue, stone. The contractor shall not make any changes in the plans; in case an error should appear the contractor must refer the same to the architect. The specifications and drawings are the property of the architect, and must be returned to .... on the completion of the building.

MASON'S SPECIFICATIONS

Specifications of labor and material required in the Mason Work for a Frame Dwelling to be erected for .... according to plans and this specification by ...., Architect.

Excavation

Remove top soil from site of building and stack on premises where directed. Use again in grading.

The cellar is to be excavated to a clear depth of .... below the under side of first floor joists, and all excavations to be made .... inches larger than the dimensions given for the walls. Trenches for all exterior and interior foundations to be dug at least ...... below the cellar bottom, and all other excavations that are necessary to carry out the plans, such as cisterns, sewers, piers, steps,

chimneys, vaults, areas, and all other foundations, to be well and faithfully done. The earth to be filled in and packed against the cellar walls after the mortar is dry, and level with the bottom of the underpinning. Grade the excavated earth around and slope off the ground on all sides of the building and remove the surplus earth from the premises. All trees, dirt, rock or rubbish that may encumber the site of the building or interfere with the proper execution of the work to be removed. Protect the banks against caving and remove any water that may accumulate from any source whatever. Provide all necessary batter boards, stakes and lines. ....
....

Drains

All drain pipe used to be of the best quality .... straight, true, and of uniform bore, ... in sizes, etc., as marked on plans, and to be connected tightly with all necessary places, as indicated on plans. These pipes to be properly trapped, graded, and the joints cemented tight. Each trap to be provided with trap-screw or tight fitting cover, so it can be easily cleaned out if necessary. Make all joints clean and tight with Portland cement, and make perfectly smooth on inside of same. Also furnish in connection with the above all Y, U and T branches, and all cement inlets of the sizes to correspond with the plans. ....
....

Mortar Materials

All water lime to be fresh burned.

All quicklime for mortar and plaster to be fresh .... brand, well burned, in lumps, free from clinkers.

All Rosendale cement to be .... brand.

All Portland cement to be .... brand.

All sand to be clean and sharp grit sand.

All water lime mortar to consist of .... parts water lime and .... parts sand.

All quicklime mortar to consist of .... parts lime and .... parts sand. Lime to be thoroughly slaked.

All cement mortar to consist of .... parts .... cement, and .... parts sand. No cement mortar to be used after cement has once set, except as sand.

All common plaster mortar to consist of well slaked lime .... parts, clean sharp sand .... parts, thoroughly mixed. Long goat's hair or fibre to be added after lime is thoroughly slaked, but not before 24 hours have elapsed.

All lime putty must be worked through a fine wire mesh sieve before being mixed.

All stone mortar to be composed of one part fresh burned water lime and three parts of coarse, sharp sand, to be thoroughly mixed and manipulated ....
....

Foundations and Stone Walls

All footings, piers, foundations, and stone walls to be built to correspond with the sizes marked upon the plans. The stone used in the foundations to be of approved quarry stone, laid on quarry bed, the lower courses to be laid with extra large flat stone; all to be carefully bedded on their broadest faces, all laid in mortar, ... each layer well filled and flushed up on both sides and firmly bonded together. The foundations for steps, porch, piers, etc., to be built as above, and to extend at least three feet six inches below the grade. Level up carefully and bed the sill in .... cement mortar, and point up around it inside and out, and bed and point up around all cellar window frames. Leave all openings in walls where required for all drain, gas, or water pipes. Point up the walls on the outside as well as on the inside. Lay both faces of the wall to a line. ....
....

Face Stone Work

All face walls above grade to be laid with .... vertical and horizontal joints. All to be carefully set and bedded on their broadest faces, well bonded together and to the backing, and backed with stone of same quality as used in foundation. All well laid in .... mortar. The face stone to be pointed with .... mortar made in the best manner. ....
....

Cut Stone

All manner of cut stone represented on the drawings to be .... free from flaws and other

SPECIFICATIONS

imperfections impairing its durability, delivered at the ... ing properly fitted by the stonecutter with all ... drilling for anchors, etc. All water table to be of ... fine cut. The stonecutter will provide all dimension cut stone for all piers required by the plans of .... with dressed beds.

Brickwork

Use throughout the building good, sound, hard, burned brick. All brick used throughout the building to be laid up in the best and most workmanlike manner in mortar composed of .... and bonded once in every .... course.

If the brick are laid in warm, dry weather, they must be kept thoroughly wet; but should they be laid in damp or freezing weather, the brick must be kept perfectly dry.

Piers. All brick used in piers to be of .... well laid in .... mortar, all interstices ..... filled and thoroughly flushed up in every layer and f... bonded together. All piers and wall to be built as r... mented by the plans and of such dimensions as ma... thereon.

Chimneys. The chimneys must be built to corresp... with the dimensions indicated on the drawings. All flue... be carried up straight and true, independent of one... other and uniform throughout, with proper thimbles ... stoppers put in where required. (.........................

The withes in flues to be four inches thick and bonde... sides of chimney, and to extend in every case to to... chimneys. The smoke-flue for heating apparatus to be ... ried up from the cellar independent of all other flue... top of chimney. Place an 8-inch iron thimble in opening ... nected with the cellar. Build all openings for all fire pl... where required by the plans. Also carry all ash pit ... to bottom of cellar and leave arched openings connec... with cellar. Build all trimmer arches for hearths if any... required. Top out all chimneys above the roof with ... . brick, and as required by drawings. Li... flues with fire clay flue linings of sizes and shapes ... on plans, carefully set and joints made with fire c... Portland cement. All spaces around tile flues to be ... tight. ....

Beam Filling

Fill in on top of stone wall all around between and alongside of joists with hard-burned bricks .... courses wide and to the height of the underside floors. Fit the bricks tightly underneath the floor; thoroughly stop up all cracks and crevices, and lay up the whole in cement mortar ....

Lathing

All walls, partitions, ceilings, underside of stairs, and all studded and furred places to be lathed with the best .... laths, full thickness, and placed .... of an inch apart, and nailed on every stud. All joints must be broken every 10th lath, and all to be placed horizontally. Long, vertical joints will not be allowed, nor lath put on vertically to finish up to angles or corners. All lath at corners or angles must be nailed to solid furrings, and lath will not be allowed to run from one room to another behind studding. The lather must call upon the carpenter to fur and straighten all walls, ceilings, etc., and block and spike all studs together solidly at angles. In all cases lath below grounds to floor and behind all wainscotting. ....
....

Plastering

The walls and ceilings of all rooms and apartments throughout to be plastered with .... good coats of .... mortar, scratch coat, brown coat and .... finish. The scratch coat to be properly applied with sufficient force to secure good clinches. The browning coat to be screeded plumb and true. Finish coat to be .... Hard finish to be of white beach sand, lime putty and plaster of Paris trowelled hard and smooth. Sand finish to be floated. ....
....

Cellar Bottom

The cellar bottom must be levelled off; pack and settle it thoroughly and cover it flush and smooth with .... cement concrete .... inches deep, in three parts of clean, coarse, sharp gravel, and one part of good .... cement, and the entire surface to be floated up even and true with cement and sand equal parts. Around the sides of the main walls form gutters sufficient to carry all the water to the drain. Over the mouth of the drain place an iron strainer, and leave the whole job of work in good condition. ....

....

Cistern

(If cistern is to be boarded over, then use section under Carpenter's Specification, below.)

The cistern to be built as shown upon the plans .... feet deep, lined on the inside with a ...... inch brick wall, and plastered with Portland cement. Arch the cistern over the top, in a substantial manner, with a double row-lock arch. Thoroughly plaster on top of arch with cement mortar. Leave a manhole to connect with .... to be not less than twenty inches by two feet square. The cistern to be connected with house-leaders through .... Portland cement pipes, well cemented. A curved iron pipe with a .... draw-cock placed at the bottom of the cistern, emptying into an iron hopper. Thoroughly plaster the cistern on the inside with .... and leave perfectly water-tight. Place a 5-inch cast-iron overflow with hub connection in top of cistern where shown, and cement in tightly. ....

....

Filter

Build in cistern, as located on plans, a good brick filter.

....

Iron Work

All manner of iron work necessary to make the whole job of work complete to be done and finished in a satisfactory manner. Furnish all chimney braces where required, and all ash-pit openings to be provided with cast-iron doors properly fitted and secured and of sizes called for. ....

....

Provision for Heating

The .... must provide all stoves, salamanders, or other heating apparatus and keep the building thoroughly heated while the plastering is being done and until thoroughly dry. He will also provide all coal or other fuel for the use of same. ....

....

Signed, ...

....

CARPENTER'S SPECIFICATIONS

Specifications of labor and material required in the Carpenter Work for a Frame Dwelling to be erected for .... according to plans drawn by ...., Architect.

Enclosing studs, ...	inches	from	centers
First-floor joists, ...	"	"	"
Second-floor joists, ...	"	"	"
Attic-floor joists	"	"	"
...... " "	"	"	"
Rafters, ...	"	"	"
Dormer rafters, ...	"	"	"
Collar beams, ...	"	"	"
Partitions, ...	"	"	"
Partition heads, ...	"	"	"
Bearing partitions, ...	"	"	"

Window and Door studs, ...
Hips and valleys, ...
Ridges, ...
Plates, ...
Girths, ...
Posts, ...
Sills, ...
Bridging, ...
Braces, ...
Floor-beams ....

Porch and Veranda Timbers

Girders, ...	inches	from	centers
Joists, ...	"	"	"
Rafters, ...	"	"	"
Sills, ...	"	"	"

Sills, ...
Cedar posts, ...
....

And all other necessary timber required throughout the building to be of good, sound .... sawn true and square, free from sap, shakes, dry rot or other imperfections impairing its durability, and all timbers used throughout must be prepared and framed according to the plans, sections and details. All joists to have the crowning edge placed upwards and sized to proper widths. Also prepare and size all studding, etc. Cross bridge all joists at distances not exceeding 8 feet apart, with 2 x 3. The carpenter must size and fur the under side of all joists, and leave everything straight and true for the lather. All trimmers and headers must be framed double, and double all joists under all stud partitions, that do not bear upon partitions below; in no case allow less than 4 inches between chimney-breast and trimmers. Frame all trusses as per details for same. The height of stories as figured upon the drawings in every case is between timbers. Clear the building and premises at the completion of the work of all rubbish caused by building operations, and leave the building broom clean. ....

The carpenter must provide all temporary doors and sash to keep the building closed; he must also provide all temporary sash-boards, etc., and keep the building thoroughly closed in cold or freezing weather. Should the plastering be done in warm or summer weather, all windows must be tightly closed with good, strong sheeting secured with laths. ....

Frame

The house to be full frame, all frame-stayed and braced in the strongest manner; perfectly true and plumb, and in accordance with the framing drawings. ....
....

Gables

Place and frame all gables as per drawings. Where shingles are introduced they must be of uniform width. ....
....

Partitions

All partitions throughout the building to be set according to the plans. Bearing partitions on first floor must foot upon the girders below, and be capped on second story with plate for the reception of the joists. Bearing partitions on the second floor to foot upon the plate. The studs at angles to be thoroughly spiked together before being placed in position. All doors to be trussed over the top thoroughly and substantially. All partitions to be seized to a straight edge. Double all studs at sides and head of door and window openings. Put on grounds for finish throughout the building. ....
....

Sheathing

The building to be sheathed on the outside frame with good, sound ⅞ matched boards not to exceed 10 inches in width, nailed with two nails to every bearing. These boards

to be placed in frame horizontally with joints broken. ......
....

Roofs

Cover all the roofs, including those of porch, piazza, etc., with good hemlock boards, planed on one side to an even thickness, and well nailed to every rafter. All of the rough carpentry necessary to form the projection of eaves, as required for all cornices, gutters, etc., to be done in accordance with the plans and details. All to be composed of good, sound lumber, and put on in a good substantial manner. Build all secondary gutters required to carry sufficient water to tank in..
....

Cistern Cover

Cover the cistern over the top with 2-inch hemlock plank, and lap the joints with 1-inch boards; make thoroughly tight, and leave manhole, and cover the same with batten doors.
....

Lumber

The lumber used throughout to be of white pine unless otherwise specified. All of the exterior finishing lumber to be composed of .... lumber. All inside finishing lumber to be clear and dry, free from saps, shakes, or knots. ....
....

Exterior Finish

All of the exterior finish for corner boards, window and door casings, cornices, water tables, verandas, bands, sidings, and all manner of finish shown on plans and details, to be of lumber as above specified, and primed as soon as put up. The exterior surface of the building, where required by the plans, to be covered with .... face of white pine, as specified under the head of lumber.
....

Verandas

Construct all porches or verandas in strict accordance with the detail and working drawings prepared for the same. Form all mouldings required for all cornices, railings, columns, capitals, etc., with exactness, in conformity with the full-sized details and sections for same. ....
....

Cornices

All cornices to be constructed in accordance with the working drawings for same. All mouldings must be worked with exactness, and no stock mouldings will be allowed unless sanctioned by the architect. All gutters must be carefully graded to run all the water to the required outlets, all to be put up in a substantial manner. ....

Building Paper

The .... of the building and roof to be covered with .... ply building paper, well up on the sheathing boards, carried close up to all openings, joints well lapped and nailed. ....

....

Shingles

All roofs to be covered with the best quality of sawed pine shingles, ... inches long, laid 5 inches to the weather, and secured with at least two nails to every shingle. Start with double courses at eaves. Finish ridges with rebated ridge boards at least 6 inches wide.

....

Cutting for Pipes, etc.

The carpenter must do all cutting, casing, boxing, boring, etc., for pipes of all kinds, including plumbing, heating, water pipes, etc. Care must be taken not to cut off or weaken supporting timbers. In no case cut further than 2 feet from bearings nor more than 2 inches out of beam. Put up beaded casings in kitchen for the reception of all plumbing pipes, and case and box all pipes when required.

....

Floors

Lay throughout the entire building a good matched .... under flooring laid diagonally, securely nailed—joints on bearings only. Upon this floor lay all other floors of the various kinds specified. All floors, when not otherwise specified, to be of white pine, free from sap, shakes, black, unsound or loose knots, mill worked, tongued and grooved, ⅞-inch thick, not over .... inches wide, all well and blind nailed to every joist. The porch floors to be of white pine, 1⅛ inches thick and 2¼ inches face, the joints to be well laid in white lead. All floors required by the plans to be of lumber the best of the kind specified, all to be tongued and grooved, and all blind nailed to each joist, and all joints to be neatly smoothed up. Lay throughout the entire attic a good pine floor, free from loose or black knots, tongued and grooved, not over 5 inches wide, well and blind nailed.

The kitchen and pantry floors to be ....
....

The bath-room floor to be ....
....

The dining-room floor to be ....
....

The hall floor to be ....
....

Deafening

Deafen all floors where required with ....
....

Doors

All doors in the house, except where otherwise specified, to be made of .... free from sap, and must be in strict accordance with the drawings. Size of doors to be marked on floor plans for width, height, etc. All hardwood doors must be veneered and finished in a first-class manner. All doors to be made of the same kinds of wood as finish of rooms in which they face. Veneers to be not less than ¼-inch thick, laid on glued-up and white pine cores.
....

The front and vestibule doors, to be made as detailed, to be of .... inches thick ....
....

All inside doors to be ...., made of the best white pine, and to be .... inches thick. ....

The sliding doors to be made to correspond with the sizes marked on the plans, to be .... inches thick.
....

All doors marked on the plans as sash doors to have proper rebates for receiving glass, and suitable provisions for same with beads, etc. ....
....

All necessary dwarf doors to be provided where needed for all pantries, closets, sinks, etc., paneled or battened and beaded as the case may require, and as shown on scale details. All dwarf doors to be composed of clear white pine, and to be .... inches thick. ....
....

All outside and inside cellar doors, required by the plans, to be of kind known as batten doors, made of two thicknesses of ⅞ ceiling boards, hung to strong plank-cased frames. ....

....

Build all hatchway doors required by the plans of two thicknesses ⅞ lumber, and hang to a substantial frame-work with good wrought-iron strap hinges. Case the top of stone side walls in a good and substantial manner. Provide good plank stringers and steps to cellar, to be of 2-inch .... lumber. Furnish all flush rings to raise doors, and leave all complete. ....

....

All outside doors to be, as shown, of best white pine, to be .... inches thick, also make all other doors required by the plans and details in the most workmanlike manner.

....

The vestibule to have a .... floor laid on top of .... floor the same to be laid diagonally. The sides, soffits, and jambs to be finished with .... all to be paneled and moulded as shown by detail drawings ....

....

Hardware

Butts. The sliding doors to be hung on .... patent door hangers, the track boxed in as per furnished directions. Hang all doors throughout with loose pin butts of sufficient size to throw them clear of architraves. All doors over seven feet high to have three butts each. Butts on front doors to be ....
Butts on all inside doors to be ....
Butts on side and rear doors to be.........................

All dwarf doors throughout to have suitable butts to match other furniture, and all door butts to be loose pin. The cellar doors to have strong wrought-iron hinges, with hooks and staples, and all trap-doors, if any, to have the necessary flush-rings to raise..

....

Double-Acting Hinges. Place .... double-acting hinges on ....

....

Knobs, Roses and Escutcheons. The front and vestibule doors to have .... knobs, roses and escutcheons. All other outside doors to have ....

knobs, roses, etc. All inside doors to have .... knobs, roses, etc. Put suitable knobs on all dwarf-doors, press-doors, etc. ....

....

Locks. Front and vestibule doors to have a .... lock, with two keys, and to have .... front and striking plates. All other outside doors to have a good 4-inch lock with brass front and striking plates, and two keys. All principal doors inside to have a good 3½-inch mortise lock, with .... front and striking plates. Sliding doors to have locks with astragal fronts of .... and flush furniture of .... All small closets, presses, drawers, etc., to have suitable locks as approved. All door locks throughout to be mortise locks and of the best manufacture. ....

Sash Locks and Lifts. All sash locks throughout to be of .... Also all lifts to correspond with same. ....

....

Blind Hinges. The inside blinds to be hung on .... inch Berlin bronze parliament butts, and trimmed with shutter bars of same. The outside blinds to be hung on approved outside blind hinges and trimmed with appropriate appliances for fastening. ....

....

Wardrobe Hooks. Put two rows of wardrobe hooks in all clothes closets. All drawers to be trimmed with .... pulls, and all other hardware and trimmings to make the whole job of work complete, to be furnished of the best kind specified. ....

....

Bolts. All double doors to have sliding bolts at top and bottom, with levers and rods, all to be mortise bolts of suitable size, and to correspond with the other furniture of doors on which they are placed. The front .... door to have mortise bolts of .... All hardware and trimmings of all kinds throughout the building required, and not specially cited, to be furnished in conformity with other work where used. ....

Window Frames

All window frames constructed to correspond with the working drawings for the same. All to be made box frames and fitted for weights. All made of clear white pine well seasoned. Pulley stiles 1⅛ yellow pine oiled; ½-inch parting strip, 2-inch double sunk sill, inside and outside casings and staff beads. The cellar windows to be constructed in accordance with detail drawings for same. Put in ⅝-inch rods 3 inches apart placed upright. For sizes of glass see floor plans. Read first figure for width and second figure for height, thus 30x34. All windows shown on plans as box frames to have recessed pockets finished in accordance with the detail drawings for same. All window stop beads to be composed of the kind of wood used in finish of rooms in which they face. ....

Sash

The sash to be .... inches thick and hung on silver lake cords, weights and noiseless steel axle pulleys. Sash in cellar windows to be .... inches thick, and to be hung on back-flaps and secured with hooks and staples. All sash to have approved sash-locks and lifts. ....

Transoms

Transoms to be placed over .... doors, the sash to be glazed with .... glass, properly hung on reversible pivots, and operated by transom lifter.
....

Glass

The window sash to be glazed with .... glass, to be well-bedded, bradded, back puttied, and cleaned off. The cellar windows to have .... glass. Also provide and set all glass for all sash doors where shown on plans. All glass, where shown in front or side door panels, to be of .... glass. ....
....

Cathedral Glass. All cathedral glass to be furnished by
....
....
....

Blinds

The windows to have outside rolling blinds made of best white pine. ....
....

Interior Finish

All to be constructed, as required by the plans and details, with sound, clear, thoroughly seasoned, kiln-dried white pine, unless otherwise specified. All put up with neat, close joints, smoothed up, and well sand-papered with the grain.

Base to be put down in all apartments not wainscoted. Beads to be put on all corners, and rubber tipped door stops for all doors of wood to match finish of room. ....
....
The bathroom to be finished with ....
....
The kitchen, pantries, etc., to be finished with ....
....
The hall to be finished with ....
....
The front and back parlors to be finished with ....
....
The library to be finished with ....
....
Rooms over .... to be finished with
....
....

Stairs

All stairways to be built where located on plans. The main staircase to be built and supported on strong plank strings, the risers to be ⅞-inch and the treads 1⅛ inches thick, rebated and glued together. Dimensions in all cases for height of risers and width of treads to be measured from the building. The perpendicular space under the stairs to be finished with .... The soffit under stairs to be finished with .... The treads, risers, and platform of main stairs to be of .... All stairs must be put up after the plastering is dry. The attic and kitchen stairs built as required by the plans, of a good quality of stock. All cellar and outside stairs to be built on good, strong plank strings provided with plank steps of pine put up and thoroughly secured. ....
....

Newels, Rails, and Balusters

The newels, rails, and balusters and stringers to be of selected dry .... worked and moulded, carved, etc., in accordance with the detail drawings for same.
....

Closets

The closets to be fitted up with beaded cleats for the reception of wardrobe hooks. Also put up .... rows of shelves on .... sides, placed on beaded cleats.
....

Bathroom

Wainscot the walls of bath-room to the height of .... feet with narrow beaded ⅞-inch ceiling .... inches wide, and cap with neat beveled and moulded cap. Put up fascia boards for plumbing pipes to support W. C. tank. ....
....

Kitchen Pantry

The kitchen pantry to be fitted up with white pine shelves, to be placed on all available sides .... shelves on each side, to be of ⅞-inch lumber, with standard in center from bottom to top. Build a counter shelf 2 feet 4 inches high, and 20 inches wide, by 1⅛ inches thick, under which arrange for two closets enclosed with panel doors. Also put in .... drawers. Shelves on .... sides to be enclosed with panel doors, all to be properly fitted and trimmed. Also furnish all trimmings for the full and proper completion of the property. ....
....

China Closet

Fit up china closets with shelves; put in counter shelf two feet high and .... drawers underneath; furnish all trimmings for same. ....
....

Kitchen Sink

Ceil up for splash-back sixteen inches high over sink, with narrow beaded battens and caps same as wainscoting. .....
....

Wainscoting

Wainscot walls of kitchen, pantry, etc., with ⅞-inch beaded ceiling 3 inches wide, and cap with a neat beveled and moulded cap. All wainscoting to be .... feet high.
....

Mantels

Furnish and place where shown .... mantels to correspond with the detail drawings for same, to be of .....
....

Scuttle

Place a .... scuttle in roof connecting with .... to be properly tinned, well secured with proper fastenings, and made perfectly water tight. ....
....

Door Bell

Provide and install where required a good electric door bell, push button and plate to match other furniture of door. Put up bell where directed and provide batteries necessary.

....

Tank

The tank in ...., as shown on plans, to be constructed of pine; the bottom formed of 1x3 inch pieces of pine laid on edge and firmly nailed together. Build on top of the bottom so made with 1x4 inch pieces of pine laid flatways and well nailed together, the corners lapped alternately, the whole to be supported on strong timbers having a solid bearing. Double up all joists underneath tank and bridge thoroughly; also truss-brace all supporting partitions underneath. ....

Cold-Air Duct

Construct a frame of 2-inch plank, to be built in underpinning, where marked on plans, to admit cold air to furnace; cover with coarse wire netting; construct a cold air box from this opening to furnace and make air tight to suit the requirements. Put in a slide damper inside of cellar wall, and make the whole job complete. ....

....

Coal Bins

Build coal bins in cellar where indicated, fitted with slide openings and hopper. ....

....

Tinning

The angles, valleys, gutters, etc., of all roofs to be covered with the best IX roofing terne, with brand of maker on each sheet. Brand to be approved by architect .... Cover roofs with same brand I C terne plates. The gutters to be properly lined, and run the tin up under the shingles at least 10 inches; bring the tin over the face of the cornice and tack it down smoothly. All tinning throughout to be well locked, nailed and soldered in resin and made perfectly water-tight. Leaders of galvanized iron put as indicated on plans with all the necessary curves, breaks, bends, etc., to carry the water from the several roofs to the cistern. The leaders to be of .... inch calibre and thoroughly secured with hooks and carried to cistern; to be given proper fall, and hooked to joists with iron hooks. Flash around chimneys and walls with stepped cap flashing. Cap to lap at least 4 inches. All proper and necessary places to be flashed whether specified or not, and everything requisite to make all places water-tight must be done, all leaks to be stopped after other craftsmen, and everything left perfectly water-tight on the completion of the building. Cap all window casings, projecting cornices, returns, etc. ....

Galvanized Iron

Furnish all galvanized iron, 24 gauge, required by the plans ....

Signed,

....

....

PAINTER'S SPECIFICATIONS

Specifications of labor and material required for the Painting and Finishing of a Frame Dwelling to be erected by .... according to the plans drawn by ...., Architect.

All material used throughout the building to be furnished of the best quality, and all labor to be performed for the full and complete painting of the building. ....
....

Exterior

All the exterior wood and iron work must have .... good coats of .... colored as directed. Paint all the tin and galvanized iron work with .... coats best mineral paint. ....
....

Interior

All interior woodwork to be painted where required, must be well sand-papered, puttied, and rubbed down. All painted with .... good coats of .... in such colors or tints as may be directed. ....
....

Hardwood

All hardwood to be filled with the best paste or liquid filler, properly and evenly filling the grain of the wood by rubbing in and cleaning off thoroughly shortly after putting it on while wet; follow this with one coat of pure spirit .... shellac, and rub down with O or OO sand-paper; finish on this with .... coats of ....

..............., rubbed down with pumice and water to a dead and even surface, oiled and well wiped off. ....
....

Pine, etc., in Natural State

All the woodwork for .... to have one coat of pure spirit .... shellac, and .... coats of ...., treated and applied same as specified for hardwood. ....
....

Hardwood Floors, etc.

All hardwood floors and treads of stairs not to be painted or carpeted to be filled with properly prepared paste or liquid filler and finished with two coats of .... rubbed down with pumice and water, oiled and wiped off. All hard pine floors not painted or intended for carpets to to be given two coats of ....
....

Inside Blinds

Fill with best paste or liquid filler properly applied, and followed by one coat of pure spirit .... shellac, well rubbed down with sand-paper, and finish with .... rubbed down with pumice and water, oiled and wiped off. ....
....

Inside Front Doors

To be filled with the best filler properly applied, followed by one coat of pure spirit .... shellac, well rubbed down with sand-paper and finished with .... coats of ....
....

Inside Sashes

To be finished with ....
....

Memorandum

....
....

Signed,

....
....

HEATING SPECIFICATIONS

Specifications of labor and materials required in the Heating of a Frame Dwelling to be erected for ....
.... according to plans drawn by ....
.... Architect.

The specifications are intended to embrace the heating apparatus proper, together with all smoke pipes, tin hot-air pipes, register boxes, registers, wire netting and dampers, complete; also all cartage, transportation, and labor of every kind, excepting only mason and carpenter work. ....
....
....

Sizes of Pipes and Registers

First Story—The front hall is to have 12-inch pipe and 12x15 inch register. The parlor is to have 12-inch pipe and 12x15 inch register. The back parlor or living room to have 12-inch pipe and 12x15 inch register. The dining room is to have 12-inch pipe and 12x15 inch register. ....
....

Second Story—The chamber over dining room is to have 10-inch pipe and 10x14 inch register. The chamber over parlor is to have 10-inch pipe and 10x14 inch register. The chamber over kitchen is to have 9-inch pipe and 9x12 register. The chamber over back parlor or living room is to have 10-inch pipe and 10x14 inch register. The chamber over hall is to have 9-inch pipe and 9x12 inch register. The bathroom is to have 8-inch pipe and 8x10 inch register.

Each room is to have an independent hot air pipe, and all hot air pipes to be made double when they pass through floors or partitions or behind furrings. The pipes must be carefully arranged so that all may draw equally, with easy turns at every change in direction. All register boxes are to be made double; all tin work to be made of XX bright tin, and all woodwork within one inch of any hot air pipe, or sixteen inches of smoke pipe, to be protected with pieces of bright tin, securely nailed on. All registers are to be of ....
.... make, all to be placed where shown on plans, or as may be directed. All registers to be black japanned. ....

Cold-Air Duct

The cold-air duct to be furnished and built by the carpenter. Connect the cold-air duct with furnace with gal-

vanized iron at a sufficient distance from the furnace to render it fire-proof. ....
....

Regulator

Furnish and put on in the best manner .... automatic regulator, to act both upon the check-draught and the damper in the smoke-pipe, and leave all in complete working order. ....

Signed,

....

....

PLUMBER'S SPECIFICATIONS

Specifications of labor and materials required in the Plumbing and Gasfitting of a Frame Dwelling House for .... according to the plans drawn by .... Architect, and under his supervision and direction.

General Conditions

Before beginning work, the Plumber is to submit for approval and place on file at the office of the Board of Health of .... a copy of their specifications and accompanying drawings. The plumber is to do (or personally superintend the doing of) all the herein specified work promptly, as the progress of the building requires, and is to give proper authorities, at proper times, all requisite notice and obtain all necessary permits relating to such work. Also obtain official permits and license for temporary obstructions, and pay all proper fees for same; he is also to carry forward his work at all times, with the greatest reasonable rapidity.

When the specifications vary from, or conflict with, the drawings, the plumber is to be governed by the specifications.

All work is to comply with the ordinances of the city, and with the ordinances, rules and regulations of the Board of Health, and all such ordinances, rules and regulations applicable to plumbers, plumbing and drainage are considered a portion of these specifications.

The Architect and Plumbing Inspector are to have free access to the work at all times.

The Architect, or Plumbing Inspector, may cause the removal from the work of any incompetent workman, and reject any pipe, fixture, or piece of work which does not meet the requirements of these specifications, and all at the expense of the Plumber.

All necessary Mason's and Carpenter's work is to be furnished by the owner, without expense to the Plumbing contractor. The Plumber is not to cut wood work.

City Water in Yard

It to be brought from .... to a point inside of cellar wall. Through a .... This pipe to be laid 4 feet under ground. Digging and filling trench to be done by the Plumber.

Street Hose Attachment

Furnish and place on City Water Pipe, either in yard, or inside of front cellar wall, a ....
....

Soil Pipe and Branches

From front cellar wall a line of .... extra heavy cast iron soil pipe, is to be carried back to a point where necessary to receive upright lines of soil pipe and to the cistern overflow. This pipe to have a fall not less than .... inch to the foot. Where this line of pipe enters house end of the sewer in yard, place a .... running trap, with hand hole properly closed. On the house side of and near the water seal of this trap place a .... inch fresh air inlet pipe which is to rise .... feet above ground and to have an open turndown end. This opening to be carried away from any window.

A line of 4-inch .... cast iron soil pipe is to be carried from sewer in cellar up and through .... ft. .... above roof, and to have a .... top and ventilator ....
....

The soil pipe is to have the same diameter to the roof, and it may be greater, but never smaller above roof. All branches into the soil pipe must be Y branches. All points in the soil pipe must be made thoroughly tight by caulking with oakum and melted lead. All cast iron pipe, including both waste and air pipes, are to be of the best quality. These pipes are to be put up in the best manner by hooks, hangers or pipe rest. The mouths of all soil or vent pipes above the roof are to be located away from windows, chimney tops or ventilating shafts. Where these soil or vent pipes pass through roof, a water tight joint must be made by providing and fitting a flashing of ....

and to be securely fastened to roof. All joints between the cast iron pipes and the lead pipes are to be made with cast brass ferrules, of same size as the lead pipes, and soldered to the lead pipe by wiped joints, and caulked with melted lead and oakum into the cast iron pipes. When cast iron is in place and before fixtures are set or plastering begun make hydraulic test.

City Water in House

From cellar wall continue .... inch .... pipe to .... above first floor joist use .... inch .... pipe. Place a .... inch ...... stop and waste cock on city water pipe near cellar wall.

Lead Pipes

Support all lead pipes by metal tacks soldered to pipes and fastened with screws to boards put up by the carpenter. Use no hooks for fastening lead pipes. All joints between lead pipes are to be wiped joints. Keep hot and cold water pipes everywhere at least one-half inch apart. Run no lead pipes on outside walls, unless absolutely necessary. When pipes are liable to freeze, they must be properly protected.

Tank and Connections

Line a tank, on .... floor .... ft. long .... ft. wide .... ft. deep, furnished by owner ready for lining, with sheet .... of .... Wipe the seams and dot the sides 24 inches from center to center, place a .... inch cork and key in tank on supply to fixtures Connect the tank with the stop-cock by a .... inch .... lead pipe. This pipe to be carried to boiler in kitchen and from it branches are to be taken to all fixtures to be supplied with cold tank water.

To empty tank provide a .... inch T handle stop-cock connected to the bottom of tank and carried into ... . The tank is to be provided with a .... inch .... galvanized flow-pipe, and it is to be carried to cistern in cellar, or to nearest roof .... 26 iron .... Control supply to tank with Berkley ball float and valve. Supply range boiler and W. C. tanks from tank.

Boiler and Connections

Furnish a .... gall. heavy pressure .... boiler on stand, placed in kitchen. The boiler is to be supplied with water through a .... inch .... pipe, and is to be connected with water back of range, water back to be furnished by owner, through a .... inch .... brass pipe and brass couplings. A .... inch shut off cock is to be placed on supply pipe at top of boiler. Provide .... inch .... lead sediment pipe with a .... cock at bottom of boiler.

From the highest point in the hot water pipe return a .... lead to be connected to sediment pipe between cock and boiler. This pipe to act as a circulation pipe. Also from highest point in the hot water pipe run a .... inch .... pipe up to and over top of tank leaving end open for escape of steam. A separate line of .... inch .... pipe must be carried back from top of boiler, to supply hot water to the different fixtures.

Kitchen Sink and Pump

Furnish and place, as per plan .... sink. Connect sink to soil pipe by a .... inch .... lead pipe. This pipe to have .... inch .... lead trap, near sink. Supply sink with city water through a ...... inch .... pipe and .... faucet. Supply with hot water through a .... inch .... pipe and .... faucet. Furnish and set a No. .... pump on sink, pump to be connected to cistern in .... through a .... inch .... pipe ....

Wash Trays

Furnish and place a set of .... wash trays in, as per plan ....
The wash trays are to be connected to soil pipe by a .... inch lead pipe, and each to have a separate .... trap. If possible make an open connection over a slop hopper ....
Supply each wash tray with hot and cold water through .... inch .... lead branches from main lines of hot and cold water.

Butler's Pantry Sink

Furnish and place, as per plan .... Supply same with hot and cold water through .... inch .... lead branches, from main lines of hot and cold supply pipe. Place over the pantry sink 2 Nos. .... pantry cocks, one to be connected to each supply. Connect

pantry sink to main soil pipe, through a .... inch .... lead pipe, and place on this pipe near sink a .... lead trap ....
Sink to be provided with a plug and chain.

Water Closets

Furnish and place a .... water closet. Closet to ....
....
The closet to be supplied with .... water, through .... inch .... branches ....

Seat Ventilation

Run a .... inch .... pipe from beneath seat of each water closet upward to and through the roof .... ft. .... This pipe to have a .... inch .... ventilator on top of it. (This pipe may run near a chimney for heat if convenient.) One pipe must not ventilate more that one closet seat.

Bathtub

On .... floor, as per plan, furnish and set a .... bath tub. Supply bath tub with hot and cold water through .... inch .... pipe. Connect bath tub with soil pipe, through a .... inch .... lead pipe. This pipe to have placed in it a .... inch .... trap. .... The bath tub is to be furnished with a .... cock and nickel plated plug and chain.

Wash Basins.

Furnish and place, as per plan, ... marble slab, with countersunk face and moulded edges, slab to have .... inch wall plate. The slab is to be provided with a .... marble basin. The basin to have N. P. plug and chain and stay. Connect the basin, which is to be properly clamped and stayed to the slab, through a .... inch .... pipe, to the main soil pipe. This pipe to have placed in it, under the basin, a .... inch .... trap. This basin is to be supplied with hot and cold water through .... cock .... lead branches, and each branch to have a N. P. .... cock over basin. Set basin on N. P. .... brackets,

Slop Hopper

Furnish and set a .... slop hopper, as shown on plans, connect same to sewer through a .... inch soil pipe, and this pipe is to have .... inch trap underneath hopper, bell be cut off of hopper.

Force Pump

Furnish and set a .... one double acting .... with .... inch .... cylinder. Connect this pump to cistern through a .... inch .... lead suction pipe. This pipe to pass up and over cistern walls and to be provided with a ...... inch .... air cock. Connect pump to tank in attic through a .... inch .... lead pipe. This pipe to have on it at convenient place a .... cock for use in cellar.

Traps and Trap Ventilation

Each fixture herein specified and elsewhere provided for in regard to trap and trap ventilation is to have on its waste pipe, near fixtures, an independent trap. Every trap is to be easily accessible and ventilated by a .... pipe, having the same diameter as that of the trap. Each ventilating pipe, independently, or by entering a common ventilating pipe, is to enter the soil pipe, at least a foot above the waste opening of the highest fixture, or is to pass through roof enlarged (if smaller) to a diameter of 4 inches and to end high enough above the roof to insure a good draft, and these vent pipes must be placed remote from a window, chimney or ventilating shaft, and each separate vent pipe must be provided with a .... vent top. All vent connections over traps must be made of brass plain couplings (so that ventilating pipe can be removed and vent of trap closed when force pump is used to clear waste pipe.) If the vent pipe remains in place and is connected with other vent pipe, foul water may be forced up into common vent pipe whence it will flow into other fixtures.

How Traps Must be Ventilated

From a point close to the sewer side of each water closet, bathtub, basin, wash tray, butler sink, kitchen sink, ...trap, run a trap up and into either the main line of soil pipe, or into a main vent pipe. This pipe to enter main vent pipes at least one foot above the highest waste opening in building. Sizes of these vent pipes must be for all water closets, not less than 2 inches and for other fixtures, not less than the opening in the waste to be ventilated.

Waste Connections

Must be made into soil pipe, with brass ferrules wiped on to end of waste and properly caulked with melted lead and oakum.

Cistern Overflow

A .... inch pipe is to be carried from inside bottom of cistern, up and over the cistern wall and down to, with an open end over the cellar drain ....

Cellar Drain

Place under draw off cock, at cistern a .... inch half S, iron trap, to be connected into Y branch of sewer. The opening of this trap to be .... inches below top of grout, and provided with a .... by .... cellar hopper of .... iron.

Weight of Pipe

2 in. D.........lbs. to foot.			¾ in. A.........lbs. to foot.		
1 " D.........	"	"	1¼ " D.........	"	"
1 " A.........	"	"	1¼ " A.........	"	"
1½ " D.........	"	"	½ " A.........	"	"
1½ " A.........	"	"			

Other Fixtures

....

....

Gas Piping

Use good wrought iron gas piping of sizes required. No pipes less than ⅜-inch for fixture connections. The mains to be run as direct as possible, and so graded that any water gathering in pipe can be run out at a convenient point near the meter. ....
Secure all pipes in place with iron holdfasts. The pipes run to supply burners where indicated on plans by .... check. Nipples for fixtures to stand at right angles to wall surface, and must project 1¼ inches from same. The gas-pipes to be put in as required by the rules and regulations of the .... Gas Company. Put the joints together in red lead, all pipes to be capped, proven tight and caps left on. ....

....

....

To be done as per Rules and Regulations of Gaslight Co., and to be done at .... cents per foot.

Peppermint Test

When the fixtures are all on, the plumbing complete, and the water let into the pipes so the traps will be filled, then apply the peppermint test to the soil pipes in the house by means of putting into the soil-pipe on the roof an ounce of peppermint oil, followed by enough hot water to carry it through the soil-pipe to the cellar sewer. Should an odor be detected at any point of the plumbing throughout the house, the leakage is to be found and stopped, and the test applied again ....

Signed,

....

....

SPECIFICATIONS FOR A BRICK DWELLING

If specifications for a brick dwelling are desired, a special printed form may be obtained similar to that just shown for a frame dwelling. While the two sets of specifications are alike in most points, a few changes in detail are shown in the following clauses:

For a **brick dwelling**, the first part of the section headed "Brickwork" under the general heading of "Masons' Specifications" should be changed to read as follows:

Brickwork

"Use throughout the building good, sound, hard, well-burned brick. Refer to the plans and sections for thickness of walls. All brick used throughout the building to be laid up with mortar composed of .... mortar. All brick walls to be carried up straight, plumb and true at the same time, and all to be carried up to the exact height and leveled properly for the joists. If the brick are laid in warm, dry weather they must be kept thoroughly wet, but should they be laid in damp, freezing weather the brick must be kept perfectly dry. All joints must be flushed up solid and leave no empty spaces in the walls. Vertical channels for the reception of pipes for plumbing, heating or ventilating to be built in walls where necessary or where indicated on the plans. Turn relieving arches over all doors and windows, trimmer arches for hearths, and all other necessary places. Also build ledges for the support of floor timbers, if any are required. All door and window frames to be solidly bedded. All bricks to be well and thoroughly

bedded and tied in every sixth course and worked in regular bond. Point up close to all sills, copings and projections. Lay in Portland cement all projecting belting courses. After the walls are up, underpin all sills with suitable mortar. The contractor or contractors must provide all materials of every description for the proper execution of the brick work. The walls are to be kept covered in rainy weather and properly protected at all necessary times. The bricklayer must attend other craftsmen when necessary to properly back up and fill in behind their work. Beam fill in between all joists flush with inside face of brick wall. All of the exterior surface of front must be laid with the best ...., carefully bonded to backing. All street front brick must be laid from an outside scaffolding and neatly washed down with diluted acid on the completion of the brick work. All street front brick to be laid in ....
...."

The following sections on **brick arches, front brick,** and terra-cotta should also be added:

"**Brick Arches.** All brick arches, whether flat, segmental, or semicircular, to be laid in proper proportions of .... mortar and Portland cement. All arches called flat arches must have the bricks neatly cut and trimmed and to have a splay at side of arches not less than six inches and as determined by radius.

"**Front Brick.** The quality of front brick as cited above to be laid with ....
....

"**Terra-Cotta.** Furnish and set where required by the plans all terra-cotta ornaments and panels. To be of well burned and moulded .... terra cotta, in accordance with the full size drawings for same ....
...."

Under "Carpenter's Specifications," add the following section:

Wood Lintels

"The carpenter must provide and set all wood lintels of every description for all windows, doorways, and other necessary places. Lintels should not be less than 10 inches in depth and top cut to a segment arch. All lintels to have a bearing on walls of at least 4 inches. ....
...."

The sections headed "Frame" and "Sheathing" may be omitted in the case of a brick dwelling.

Preliminaries to Estimating

COST OF PLANS AND SPECIFICATIONS.

The "schedule of proper minimum charges and professional practice of architects" recommended by the Chicago Architects' Business Association is quite clear in its statement regarding cost of plans and specifications.

The architect's professional services consist of the necessary conferences; the preparation of preliminary studies, working drawings, specifications, large-scale and full-size detail drawings; and the general direction and supervision of the work—for which, except in special cases, the minimum charge is 6 per cent, based upon the total cost of the work complete.

Exceptions to this rate are as follows: Dwellings costing less than $10,000, 10 per cent; lofts not requiring special planning for machinery or arrangement, 5 per cent; additions and alterations to dwellings, 12 per cent; additions and alterations to business buildings, 10 per cent.

In case of discontinuance or abandonment of the work, the architect's charge shall be based upon an estimated total cost, which cost may be determined by the architect, by experts, or by the lowest bids of responsible contractors. "Total cost" is to be interpreted as the cost of all materials and labor necessary to complete the work, plus contractor's profits and expenses, as such cost would be if all materials were new and all labor fully paid, at market prices current when the work was ordered.

On furniture, monuments, decorative and cabinet work, and landscape architecture, it is proper to make a higher charge than above indicated.

The architect is entitled to compensation for articles purchased under his direction, even though not designed by him.

If an operation is conducted under separate contracts, rather than under a general contract, it is proper to charge a special fee in addition to the charges mentioned above.

Where heating, ventilating, mechanical, structural, electrical, and sanitary problems are of such a nature as to require the services of a specialist, the owner is to pay for such services in addition to the architect's regular commission. Chemical and mechanical tests and surveys, when required, are to be paid for by the owner.

Necessary traveling expenses are to be paid by the owner.

If, after a definite scheme has been approved, changes in drawings, specifications, or other documents are required by the owner, or if the architect be put to extra labor or expense by the delinquency or insolvency of a contractor, the architect shall be paid for such additional services and expense.

The architect's entire fee is itemized, and proportionate payments on account are due the architect, as the following items are completed:

Preliminary studies, one-fifth; general drawings, one-fifth; specifications, one-tenth; scale and full-size details, one-fifth; general supervision of the work, three-tenths.

Drawings and specifications, as instruments of service, are the property of the architect.

PREPARATION FOR ESTIMATING

The contractor or builder should be supplied with a complete set of plans, details, and specifications for the work in hand, and be allowed to have these plans and specifications in his possession long enough to take account of all details of the construction which he will be required to furnish. It is often the case that a builder is compelled to take his measurements from plans in an architect's office, with several other contractors of different trades examining the plans at the same time. This is a dangerous way to take quantities, since many details may be omitted in the general confusion.

The plans and specifications should be examined carefully, and all building materials needed from cellar to roof or from foundation to finished structure taken off and entered in carefully prepared lists. After that, the labor on different parts of the work should be divided into the individual operations needed in building the finished structure, and the cost of labor estimated at the current day wages for the workmen of that locality. Experience with a given class of workmen will serve as the best guide as to the amount of work performed per day by these men.

In making up lists of materials, allow for waste and for extras if any are needed. Look out for odd sizes of materials or fixtures, since odd or unusual forms of construction cost more than ordinary types.

Allow for accidents, and for work which may have to be replaced through carelessness of workmen or faulty materials. Also, allow for depreciation on tools and equipment used on a job, since these may be injured during the work, and repairs must be paid for.

Insurance on both property and men will add to the cost of the work, but is generally a cheap investment.

The profit to be cleared is to be added to the cost of all output, and should be sufficient to warrant the responsibility involved and the amount of capital used by the contractor. If only good day wages can be cleared, the contractor has gained no great advantage over his workmen.

Before the contractor files his bid, there are other things which should be noted, which may add to the general cost of the structure itself due to its location or the kind of ground on which it is to be built. These details do not appear on the plans, and can be determined only by a personal inspection of the site of the work.

Examination of Site. An examination of the location of the structure may show that additional expense will be incurred owing to one or more of the following points: The work may be located at a distance from the centers of supply, thus causing heavy freight or haulage charges which will add to the ordinary cost of the material used; there may be no opportunity for storing or piling materials, and these provisions may need attention; the distance from the storage to the work will affect the cost of handling the materials used; the condition of the approaches to the site will affect the ease with which materials may be brought to the work and taken away from it.

The general condition of the ground will determine the amount of excavation needed and the amount of filling to be done either before or after conclusion of the work. The nature of the soil to be handled, the underground conditions, amount of blasting necessary, amount of sheet-piling needed, the depth to firm soil or bed rock, together with any needed temporary protection of foundations and walls —all are of great importance in making up the final estimate on a piece of work.

General Costs

CLASSIFICATION OF COST FACTORS

Cost factors may be classified as general, special, and accessory.

General Costs. Costs of this class are common to construction in general, and embody such items as preparation of site for excavating; earth excavation; rock excavation; foundations and footings; together with overhead expense.

Special Costs. These costs include those involved in special constructions and for work which is not common to all classes of structures. This list of headings might be summed up as follows: Carpentry work; mill work; brickwork; stonework; cement and concrete work; reinforced concrete construction; concrete block construction; steel construction; mill building or slow-burning construction; fireproof construction; roof construction; waterproofing and damp-proofing; sidewalk, curb, and gutter construction; roads and pavements; bridges and culverts; sewers and conduits; etc.

Accessory Costs. These costs are made up of factors which are incidental or accessory to various types of construction. The following items might be considered under this heading: Sheet-metal work; plumbing; gas-fitting; electric wiring for heat, light, etc.; plastering; painting and decorating; paperhanging; glass and glazing; builders' hardware: elevators; ornamental iron work; vacuum cleaning installation; sound-deadening of partitions and floors; heating plant; cold storage plant; ventilating system; together with other items of a like nature.

PREPARATION OF SITE

The contractor will have to judge as to the cost of preparing the ground for excavating, since each problem will be an individual one. Some of the points that will have to be considered in this connection will be as follows: Leveling the ground; surveying; draining; removing any obstacles such as stumps or rocks; wrecking old buildings; plowing and scraping; construction of runways and driveways for carting materials; bracing, shoring, or under-pinning adjacent buildings; protection to adjoining property; staking out the work; etc.

He should also determine upon the number of teams needed to cart materials to and from the site, and the size and amount of plant equipment necessary for that particular job.

Ownership of materials on the site and their disposal should be clearly settled. Also the cost of water-supply during construction should be determined.

Demolition of Buildings. Since the exact procedure to be followed in removing an old building from its site preparatory to the construction of new work is not common knowledge, the following hints taken from an article by Mr. Owen B. Maginnis in the "National Builder" of December, 1909, may be of service:

As the building was commenced at the bottom, so it must be torn down by commencing at the roof; but it is usual first to remove all projecting ironwork, such as fire-escapes, cornices, leaders, balconies, or any detail which would cause all or any walls to overturn when torn down to beam level. Then chutes are constructed of wood, outside the walls, for the purpose of expeditiously and cleanly transferring all old plastering and debris to the waiting carts and wagons on the street below. Next, the tin or roof covering is carefully cut in sections, rolled, tied, and lowered with block and tackle to the street; next, the cornices and sashes and window frames are removed.

Most "demolishers" combine this occupation with the business of selling second-hand building materials, so that each and every detail is removed as far as possible intact and uninjured, so as to have a marketable value to be used again.

Brick chimneys are taken down before the roof boards are taken off; also all parapet walls, copings, and flashings, and the walls, too, to the level of the bottom edge of the roof beams. This being done, the stairs are taken out, if valuable, and replaced by rough ladders. Then the roof boards are leveled off with crowbars, bundled, and lowered; then the bridging knocked out; and finally the roof beams themselves, thus giving a safe opportunity to cut down the top story brick walls, which must not be thrown or barred down in heavy sections, but knocked apart with light hammers, course by course of bricks, as constructed.

It is usual first to take out all fixtures, such as trimmings, basins, plumbing, etc., before demolishing the brick and timber shell, so as to prevent injury; but this depends on their condition and value.

The walls must be closely watched; and if any show evidence of cracks, bulges, or unsafe conditions, they must be either shored or tied back with cables to guard against fall.

No materials should ever be thrown into the street, and a platform or roof should be erected over the sidewalk to guard pedestrians from injury by possible falling materials.

To keep down dust and make the debris shovable, a hose should be kept spraying the debris as it is piled; and not too much weight should be piled in one place, lest a floor be strained or overloaded. Collapses have occurred through neglect of this precaution.

Heavy girders, steel beams, and columns must be lowered with a derrick, windlass, and tackles, to save their condition and maintain safety. It is a serious error to drop a heavy weight on the floor of an old building, as the impact is liable to cause disaster.

It is better to pile stuff close to the walls of a building and not in the middle of the beams. Partitions, especially those running fore and aft, should be let remain in position until the beams above are ready for removal, to prevent the latter sagging.

All workmen should be careful not to drop tools or materials on those at work underneath.

When demolishing old wrought-iron or cast-iron structures, all details should be suspended from the derrick before cutting out rivets or removing bolts; besides, they can be at once lowered, thus avoiding delay.

EARTH EXCAVATION

Slope of Earthwork. It is often of value to know just where supports are necessary in excavation, in order that the earth forming the sidewalls of the excavation may not fall in and increase the cost of the work.

The following are values commonly given for the natural slope of different kinds of earth, the term "natural slope" meaning the angle which the earth or material may be expected to make with a horizontal line before particles of the earth or excavated material will begin to slide into the trench.

Loose peat	14	degrees
Wet clay	16	"
Moist sand	22	"
Vegetable earth	28	"
Dry sand	38	"
Shingle	39	"

Gravel	40	"
Firm peat	45	"
Rubble	45	"
Well-drained clay	45	"
Compact earth	50	"
Chalk	55	"

In case it is desired to know the height of perpendicular wall of earthwork (as in ditches) which will support itself for a short time without bracing, the following may be used as a guide:

Dry sand or gravel	1 ft. to 2 ft.
Ordinary earth	2 ft. to 3 ft.
Drained loam	5 ft. to 8 ft.
Clay	9 ft. to 12 ft.

In leaving earthwork in form of an embankment, it is not advisable to try to approach its natural slope when grading, but leave the lower part with a more gentle slope than the upper part. In clay, a slope of 1 to 1½ at the top of an embankment is often flattened to a 1 to 3 slope at the bottom, especially if the embankment is of considerable height. This same principle of changing slope applies to other materials as well.

The meaning of the term "slope of 1 to 3" as used, is that there is an increase of one foot of height in the sloping side of the embankment for each three feet of horizontal distance, or distance along the level ground, as shown in Fig. 2.

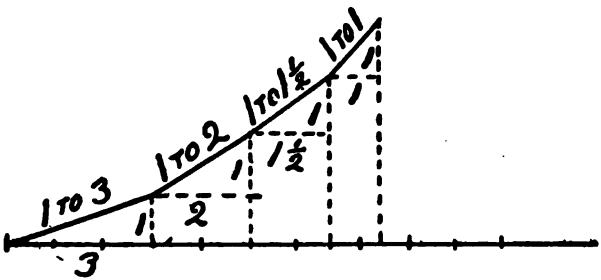


Fig. 2. Method of Stating Slopes.

The following will give a basis upon which to compare natural slopes of excavated materials in degrees with the commonly expressed "1 to 1," "1 to 3," etc., used in practice:

Slope of 1 to ½ equals angle of 63½ degrees with horizontal.
Slope of 1 to ¾ equals angle of 53 degrees with horizontal.

Slope of 1 to 1 equals angle of 45 degrees with horizontal.
Slope of 1 to 1¼ equals angle of 38⅝ degrees with horizontal.
Slope of 1 to 1½ equals angle of 33⅔ degrees with horizontal.
Slope of 1 to 1¾ equals angle of 29¾ degrees with horizontal.
Slope of 1 to 2 equals angle of 26¾ degrees with horizontal.
Slope of 1 to 3 equals angle of 18½ degrees with horizontal.
Slope of 1 to 4 equals angle of 14 1/5 degrees with horizontal.

Volume to Be Excavated. If the soil is of a light or unstable nature, and the specifications require that all foundations shall be carried down to what is called "hard-pan," or a solid layer of earth, without regard to depths given on the plans furnished by the designer, care should be taken in determining the depth at which this hard-pan lies. Test pits may be dug at different parts of the building site, or borings made, and the soil carefully examined as it is drawn out.

A large auger fitted to a long iron or steel shank will serve as a boring tool. In wet ground, a section of pipe should be driven first and the auger used in the pipe.

If the soil is firm and no further excavation is needed than that necessary to obtain the required depth of cellar or basement below grade, the number of cubic yards of earth to be removed may be found in the following manner:

Allow at least six inches additional excavation on all sides of the outside wall line. This permits inspection of the outside of the wall as the work progresses, and allows room for any exterior work necessary on the wall.

Then, allowing this 6-inch space all around, multiply the length of the excavation in feet by the breadth in feet, and this product by the distance in feet from grade to bottom of cellar or basement floor. To this number, add the volume of the trenches dug below the bottom of the cellar floor, which are to receive the footings, and divide the result by 27, the number of cubic feet in a cubic yard. The result will be the number of cubic yards of material to be removed, the cost of such removal varying per cubic yard with the amount to be removed, the distance to which it is taken, the quality of the soil, manner of handling, number of difficulties encountered, such as springs, ledges, etc., proper drainage in marshy land, bracing walls of neighboring buildings, season of year, and other local details which may differ in each particular case.

If the trenches needed for the footings are of any considerable depth, they should be figured separately, since the excavated material cannot be thrown easily from a trench over 6 feet in depth, but must be deposited on an intermediate platform and shoveled again from there and thrown out. As will readily be seen, this process involves extra cost.

Again, if there is any considerable amount of trench work to be done in connection with laying drains or pipes, this work will cost more per cubic yard than work on large areas. This is on account of the confined condition of the work in trenches as compared with the free working space of a larger area.

If ledges are encountered and blasting is necessary, the cost of excavating will be materially increased. Removal of water either from springs or marshy land will also require an extra amount to be added to the cost of handling the excavated material.

Bracing of foundations of neighboring buildings, or the use of sheet piling to prevent the caving of earth walls after the excavation is under way, will also add to the general expense.

Frozen earth is harder to work than the same material at more favorable seasons of the year, and prices per cubic yard which show a profit in the summer might cause a decided loss in freezing temperatures.

Each one of the above-mentioned points should be noted, together with any other local conditions, such as removal of rubbish, trees, etc., and careful consideration given same in making up the list of operations, the cost of which is to make up the estimated cost of the excavation.

The number of cubic yards of back-filling, or earth which is to be filled in around walls or cavities, should be carefully figured by determining the volume of the space to be filled, in a manner similar to that stated for finding the volume to be excavated.

If the surface of the building site is not level, or contains irregularities of any considerable size, the method illustrated in Fig. 3 may be employed for finding the volume to be excavated above the level of the bottom of the cellar floor.

Lay out the wall lines, and allow the 6 inches all around each side. Then divide the length and breadth into a number of equal parts each, as shown in Fig. 3, the number of these divisions depending on the irregularity of the ground. The volume of the material to be excavated may then be found by summing up the volumes of each of these small parts shown in Fig. 3, remembering that the volume of each

TABLE III

Number of Cubic Yards of Excavation per Foot of Depth in Spaces of Various Size

Length in Feet	WIDTH IN FEET 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
5	.37	.55	.74	.92	1.1	1.3	1.5	1.7	1.8	2.0	2.2	2.4	2.6	2.8	2.9	3.2	3.3
6	.44	.67	.89	1.1	1.3	1.5	1.8	2.0	2.2	2.5	2.7	2.9	3.1	3.3	3.5	3.8	4.0
7	.52	.78	1.04	1.3	1.6	1.8	2.1	2.3	2.6	2.8	3.1	3.4	3.6	3.9	4.1	4.4	4.6
8	.59	.89	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.5	3.8	4.1	4.4	4.7	5.0	5.3
9	.67	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0	4.3	4.7	5.0	5.3	5.7	6.0
10	.74	1.1	1.5	1.8	2.2	2.6	3.0	3.3	3.6	4.0	4.4	4.8	5.2	5.6	5.9	6.3	6.7
11	.82	1.2	1.6	2.0	2.4	2.8	3.3	3.7	4.1	4.5	4.9	5.3	5.7	6.1	6.5	6.9	7.3
12	.89	1.3	1.8	2.2	2.7	3.1	3.5	4.0	4.4	4.9	5.3	5.8	6.2	6.7	7.1	7.6	8.0
13	.97	1.4	1.9	2.4	2.9	3.4	3.9	4.3	4.8	5.3	5.8	6.2	6.7	7.2	7.7	8.2	8.7
14	1.04	1.6	2.1	2.6	3.1	3.6	4.1	4.7	5.2	5.7	6.2	6.7	7.2	7.8	8.3	8.8	9.3
15	1.1	1.7	2.2	2.8	3.3	3.9	4.4	5.0	5.5	6.1	6.6	7.2	7.8	8.3	8.9	9.4	10.0
16	1.2	1.8	2.4	3.0	3.6	4.2	4.7	5.3	5.9	6.5	7.1	7.7	8.3	8.9	9.5	10.0	10.6
17	1.3	1.9	2.5	3.1	3.8	4.4	5.0	5.7	6.3	6.9	7.5	8.2	8.8	9.4	10.0	10.7	11.3
18	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0	8.6	9.3	10.0	10.6	11.3	12.0
19	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7.0	7.7	8.4	9.1	9.8	10.6	11.2	12.0	12.7
20	1.5	2.2	3.0	3.7	4.4	5.2	5.9	6.7	7.4	8.1	8.9	9.6	10.4	11.2	11.8	12.6	13.3
21	1.6	2.3	3.1	3.9	4.7	5.4	6.2	7.0	7.8	8.5	9.3	10.2	10.9	11.6	12.4	13.2	14.0
22	1.6	2.4	3.3	4.0	4.9	5.7	6.5	7.3	8.1	9.0	9.8	10.6	11.4	12.2	13.0	13.8	14.6
23	1.7	2.6	3.4	4.3	5.1	6.0	6.8	7.7	8.5	9.4	10.2	11.0	11.9	12.8	13.6	14.4	15.3
24	1.8	2.7	3.6	4.5	5.3	6.2	7.1	8.0	8.9	9.8	10.6	11.5	12.4	13.3	14.2	15.1	16.0
25	1.8	2.8	3.7	4.6	5.5	6.5	7.4	8.3	9.2	10.2	11.1	12.0	12.9	13.8	14.8	15.7	16.6
26	1.9	2.9	3.9	4.8	5.8	6.7	7.7	8.7	9.6	10.6	11.6	12.5	13.5	14.4	15.4	16.4	17.3
27	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0
28	2.1	3.1	4.1	5.2	6.2	7.2	8.3	9.3	10.4	11.4	12.4	13.4	14.5	15.5	16.6	17.6	18.6
29	2.1	3.2	4.3	5.4	6.5	7.5	8.6	9.6	10.7	11.8	12.8	13.9	15.0	16.1	17.2	18.2	19.3
30	2.2	3.3	4.4	5.5	6.7	7.8	8.9	10.0	11.1	12.2	13.3	14.4	15.5	16.6	17.8	18.9	20.0

For widths of 19 to 30 ft., see remainder of table on page 125.

TABLE III—(Concluded)

Length in Feet	WIDTH IN FEET											
	19	20	21	22	23	24	25	26	27	28	29	30
5	3.5	3.7	3.9	4.1	4.3	4.4	4.6	4.8	5.0	5.2	5.4	5.5
6	4.2	4.4	4.7	4.9	5.1	5.3	5.5	5.8	6.0	6.2	6.4	6.7
7	4.9	5.2	5.4	5.7	6.0	6.2	6.5	6.7	7.0	7.2	7.5	7.8
8	5.6	5.9	6.2	6.5	6.8	7.1	7.4	7.7	8.0	8.3	8.6	8.9
9	6.3	6.7	7.0	7.3	7.7	8.0	8.3	8.7	9.0	9.3	9.7	10.0
10	7.0	7.4	7.8	8.1	8.5	8.9	9.2	9.6	10.0	10.4	10.7	11.1
11	7.7	8.1	8.5	9.0	9.4	9.8	10.2	10.6	11.0	11.4	11.8	12.2
12	8.4	8.9	9.3	9.7	10.2	10.6	11.0	11.5	12.0	12.4	12.8	13.3
13	9.1	9.6	10.1	10.6	11.0	11.6	12.0	12.5	13.0	13.5	14.0	14.4
14	9.8	10.4	10.9	11.4	11.9	12.4	13.0	13.4	14.0	14.5	15.0	15.5
15	10.6	11.2	11.7	12.2	12.8	13.3	13.9	14.4	15.0	15.6	16.1	16.6
16	11.2	11.8	12.4	13.0	13.6	14.2	14.8	15.4	16.0	16.6	17.2	17.8
17	11.9	12.6	13.2	13.8	14.4	15.1	15.7	16.4	17.0	17.6	18.2	18.9
18	12.6	13.3	14.0	14.6	15.3	16.0	16.6	17.3	18.0	18.6	19.3	20.0
19	13.4	14.0	14.8	15.5	16.2	16.9	17.8	18.3	19.0	19.7	20.4	21.1
20	14.0	14.8	15.5	16.3	17.0	17.7	18.5	19.2	20.0	20.7	21.4	22.2
21	14.8	15.5	16.3	17.1	17.8	18.6	19.4	20.2	21.0	21.7	22.5	23.3
22	15.5	16.3	17.1	17.9	18.7	19.5	20.4	21.2	22.0	22.8	23.6	24.4
23	16.2	17.0	17.8	18.7	19.5	20.4	21.3	22.1	23.0	23.8	24.6	25.5
24	16.9	17.8	18.6	19.5	20.4	21.3	22.2	23.1	24.0	24.9	25.7	26.6
25	17.6	18.5	19.4	20.4	21.3	22.2	23.1	24.0	25.0	25.9	26.8	27.7
26	18.2	19.2	20.2	21.1	22.1	23.0	24.0	25.0	25.9	26.9	27.8	28.8
27	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0	28.0	29.0	30.0
28	19.7	20.7	21.7	22.7	23.7	24.8	25.9	26.9	28.0	29.0	30.0	31.0
29	20.4	21.4	22.5	23.6	24.6	25.7	26.8	27.9	29.0	30.0	31.1	32.1
30	21.1	22.2	23.3	24.4	25.5	26.6	27.7	28.8	30.0	31.1	32.2	33.3

small part is equal to the area of the top in square feet, found by multiplying together the lengths of the division lines in feet on two sides which meet at a corner, and then multiplying this area by what is considered to be the average height in feet of this small part above the excavated level.

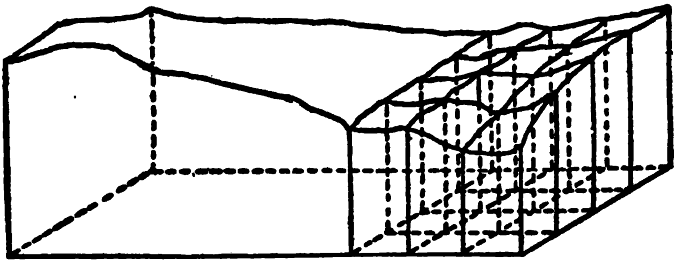


Fig. 3. Illustrating How to Estimate Volume of Excavation on an Irregular Site.

Table III may be used to advantage in calculating the amount of excavation in a given case per foot of depth. The value given in the table for a given length and width is to be multiplied by the depth in feet, in order to obtain the number of cubic yards in a given job. For instance, a cellar 25 feet by 30 feet top area, and 7 feet deep, would contain from the table 27.7x7, or 193.9 cubic yards of excavation.

Soil Test Borings with Augers. The borings detailed below were made in the City of Toronto in order to find the nature of the soil to a depth of from 30 to 70 feet. The ground passed through consisted mainly of blue clay, although seven borings were made in wet, sandy clay, and four were made in filled ground. The average depth of holes is shown in each case.

The borings were made with a 1½-inch carpenter's machine auger, welded to the end of a ¾-inch pipe. The ¾-inch pipe was cut in sections 6 feet long, and each length was added as it became necessary.

The auger was turned by two or three men at the surface, using wrenches. The heavier clay required three men to turn the auger. After the auger had bored from 8 to 12 inches, it had to be removed from the hole and cleaned, and then replaced in the hole and continued for another auger length.

The force consisted of one recorder and three laborers, each at $2.00 per day. The work was done at all seasons of the year, and no time was lost by any of the men.

The cost of blacksmith work and teaming amounted to about 5 per cent of the total cost; and the cost of material, such as augers, wrenches, and iron pipe, amounted to about ten per cent.

The following statements, taken from an article by A. C. D. Blanchard in the "Canadian Engineer" of July 30, 1909, show the general costs:

TEST BORINGS

Heavy Blue Clay with 10 Inches of Red Clay on Top

Number of holes	28
Total depth, ft.	709
Average depth of hole, ft.	25.3

Cost	Total	Per Ft.
Labor	$199	$0.281
Materials and blacksmith	34	0.048
Total	$233	$0.329

Made Ground

Number of holes	4
Total depth, ft.	90
Average depth of hole, ft.	22.5

Cost	Total	Per Ft.
Labor	$ 44	$0.488
Materials and blacksmith	5	0.066
Total	$ 49	$0.554

Fine, Running, Clayey Sand

Number of holes	36
Total depth, ft.	1,163
Average depth of hole, ft.	32.3

Cost	Total	Per Ft.
Labor	$293	$0.252
Materials and blacksmith	43	0.037
Total	$336	$0.289

Heavy Clay

Number of holes	7
Total depth,, ft.	152
Average depth of hole, ft.	21.7

Cost	Total	Per Ft.
Labor	$ 48	$0.315
Material and blacksmith	9	0.059
Total	$ 57	$0.374

Heavy Blue Clay

Number of holes	5
Total depth, ft.	160
Average depth of hole, ft.	32

Cost	Total	Per Ft.
Labor	$ 40	$0.250
Materials and blacksmith	6	0.038
Total	$ 46	$0.288

COST OF EXCAVATING

The unit of cost in excavation work is the cubic yard, or 27 cubic feet. The total cost of excavating and removing materials is made up of the following parts:

1. Loosening the material for the shovelers.
2. Loading material into carts or barrows.
3. Hauling or wheeling material away, including emptying and dumping.
4. Depositing and leveling in a workmanlike manner.
5. Necessary repairs to equipment, roads, etc., together with cost of general superintendence and depreciation of plant.

The price quoted is stated at so much per cubic yard of material in its original position. In connection with this rating, it should be noted that earth swells upon removal from its original position, and loosened materials occupy greater spaces according to the following relation:

Earth and clay, 25 per cent increase.
Sand and gravel, 50 per cent increase.
Broken stones and rock, 50 per cent increase.

When this same material, with the exception of rock, is dumped in another place or even filled into the same place, it will in time shrink from 10 to 15 per cent, depending upon whether the material is gravel or light, loose soil. In other words, if we have 100 cubic yards of back-filling to be done, if this material has to be excavated from a new piece of ground, it will require about 115 cubic yards of light soil measured in place to fill the 100 cubic yards of space so that it would be level after the soil has had plenty of time to settle into place.

Loosening for Removal. For loosening the material to be excavated, it is generally figured that 2 men with a plow and pair of horses will loosen from 25 to 30 cubic yards of heavy soil per hour; or, with ordinary loam, the same outfit will loosen from 40 to 60 cubic yards per hour. The cost per cubic yard will be found by dividing the sum of the labor costs of men and horses, the hire of the plow, together with all charges for repairs and extras, by the number of cubic yards of material loosened.

For instance, assume that the labor cost of the outfit is divided as follows:

2 men at $2.00 per 10-hour day........	$4.00
2 horses at $1.50 per 10-hour day.......	3.00
Plough at $0.50 per 10-hour day......	.50
Total	$7.50

Then, if in this 10-hour day, 250 cubic yards of heavy soil has been loosened, the cost per cubic yard has been:

$$\frac{750}{250} = 3 \text{ cents per cubic yard.}$$

If the loosening is done by men with picks, the following rates of work may be used as fair averages:

One man with a pick will loosen, per hour, about:
1¼ cubic yards of cemented gravel; or
1½ cubic yards of clay; or

2½ cubic yards of heavy soil; or
4 cubic yards of common loam; or
6 cubic yards of sandy loam.

The cost per cubic yard may be reached in any one of the above by dividing the rate of wages per hour by the number of yards of material loosened.

As extremes in the loosening of materials with a plow, we may consider the case of cemented gravel or stiff clay. These materials require three or four horses per plow, thereby increasing the cost. As an opposite to this case, sand requires but little loosening, and can in many instances be removed directly with a scraper. If dirt is to be simply removed to one side of the excavation, a scraper may be used to advantage with any light or loosely packed earth.

A good workman will dig and throw into a barrow the following quantities of material in a day of ten hours:

Common earth	8 to 10 cubic yards
Stiff clay or firm gravel..	5 to 6 cubic yards
Hard ground (picking necessary)	3 to 5 cubic yards

In excavating, a vertical throw is limited to 6 feet, and when a trench exceeds that depth, stages must be provided.

As an example of the cost of excavation in trenches where the depth exceeds 6 feet, the following will serve to show how such cost may be determined:

Assume a basis of 1 cubic yard of earth handled by one man in one hour, and a wage rate of 20 cents per hour. If the dirt requires but one handling, this cost per yard may be multiplied by the number of cubic yards, and we will have the cost of the work. Now the question will arise: How often will this dirt require to be handled?

The first six feet of the trench may be dug with one handling, provided the top is thrown a considerable distance from the trench, leaving room close to the trench for the dirt which is lower down. After the trench is six feet deep, it will require another man to keep the dirt away on top; in this way the trench may be dug two feet deeper; and then, by placing a platform in the trench two or three feet below the top, the man in the trench can throw the dirt on the platform, and the top man can throw the dirt from the platform out of the trench. Thus, with two men, the trench can be dug about 5 feet deeper; then, by adding a third man, 5 feet more, which will reach the bottom. Now, as-

TABLE IV

Cubic Yards of Earth per Foot of Length in Ditches with Side Slopes of 1 Foot in 10

Bottom Width in Feet	DEPTH, IN FEET											
	4	5	6	7	8	9	10	12	14	16	18	20
2	0.36	0.48	0.60	0.72	0.86	0.99	1.15	1.46	1.80	2.19	2.59	2.96
2½	0.44	0.57	0.71	0.85	1.01	1.16	1.33	1.68	2.06	1.48	2.92	3.33
3	0.51	0.66	0.82	0.98	1.16	1.33	1.51	1.90	2.32	2.80	3.25	3.70
3½	0.58	0.76	0.93	1.11	1.30	1.49	1.70	2.12	2.59	3.10	3.58	4.07
4	0.66	0.84	1.04	1.24	1.45	1.66	1.88	2.34	2.84	3.40	3.91	4.44
4½	0.74	0.94	1.15	1.37	1.60	1.83	2.07	2.57	3.10	3.70	4.24	4.81
5	0.81	1.04	1.26	1.50	1.75	2.00	2.25	2.76	3.36	4.00	4.57	5.18

suming that the trench will have to be two feet wide at the top and perhaps for the first 11 feet, and about 18 inches for the last 5 feet, all the data necessary to calculate the cost of digging the trench in the first six feet are at hand: 1,200 cubic feet, or 44½ cubic yards nearly, at 20 cents per yard, would be $8.90. The next five feet will contain 1,000 cubic feet, or 37 yards. This, at 40 cents a cubic yard, as it takes two men to do the same work that one man did on top, would figure up to $14.80; and the last 5 feet would contain 750 cubic feet, or 28 yards nearly, at 60 cents, which would be $16.80, making a total of $40.50. To this add the use of platform and placing of same, which would be safe to put at $3.00. This, added to the $40.50, would be $43.50, which would be the total cost of excavation.

If the nature of the soil should require sheet-piling, this should be taken into account; also the extra width of trench due to the piling.

The problem of excavating the cellar should be taken up

TABLE V

Cubic Yards of Excavation per Foot of Length in Trenches

Width in Feet	DEPTH, IN FEET											
	4	6	8	10	12	14	16	18	20	22	24	26
2	0.30	0.44	0.59	0.74	0.89	1.04	1.18	1.33	1.48	1.63	1.78	1.93
2½	0.37	0.53	0.74	0.93	1.11	1.30	1.48	1.67	1.85	2.04	2.22	2.41
3	0.44	0.66	0.89	1.11	1.33	1.56	1.78	2.00	2.22	2.44	2.66	2.89
3½	0.52	0.78	1.04	1.30	1.56	1.82	2.07	2.33	2.59	2.85	3.11	3.37
4	0.59	0.89	1.18	1.48	1.78	2.07	2.37	2.67	2.96	3.26	3.55	3.85
4½	0.66	1.00	1.33	1.67	2.00	2.33	2.67	3.00	3.33	3.67	4.00	4.33
5	0.74	1.11	1.48	1.85	2.22	2.59	2.96	3.33	3.70	4.07	4.44	4.81
5½	0.82	1.22	1.63	2.03	2.44	2.85	3.26	3.67	4.07	4.48	4.89	5.30
6	0.89	1.33	1.78	2.22	2.66	3.11	3.55	4.00	4.44	4.89	5.33	5.78
6½	0.96	1.44	1.93	2.40	2.89	3.37	3.85	4.33	4.81	5.30	5.78	6.26
7	1.04	1.55	2.07	2.59	3.11	3.63	4.15	4.67	5.19	5.70	6.22	6.74
7½	1.10	1.66	2.22	2.77	3.33	3.89	4.44	5.00	5.55	6.11	6.67	7.22
8	1.18	1.78	2.37	2.96	3.55	4.15	4.74	5.33	5.92	6.52	7.12	7.70

in the same way. It will be necessary to have two units of value, one for a man and team, and one for a man alone, which has been already established. A team will walk about four miles an hour, and, with a suitable dump wagon, can haul four yards of dirt one-half mile in one hour. If a wage of 40 cents per hour is paid, there would be a cost of 10 cents a yard for hauling; and this, added to 20 cents for loading the wagons, would make a total cost per yard of 30 cents. This, multiplied by the number of yards in the cellar, would be the probable cost of excavation.

Work in trenches costs from 20 to 30 per cent more than digging over areas where the labor is not so closely confined.

Excavating with Drag-Scoop Scraper. Drag scrapers are made in three sizes having a capacity of 3, 5, and 7 cubic feet, respectively; but a scraper will not carry its rated capacity since it is not completely filled. Unless the soil is very loose and easily loaded, it is not safe to assume that each trip of the scraper will take much more than one-half of its rated capacity of solid earth.

For a 25-foot haul of earth, it will take about 1½ minutes to make one round-trip of the scraper. Where the large-size scraper is used, about 60 cu. yds. of earth can be removed per scraper in a 10-hour day. One man will hold and fill the scraper for two teams. One man on the dump will distribute and level the earth deposited by six teams. One foreman will be needed to look after the work. If the wages of workmen are $1.50 per day of 10 hours, and for foreman $2.50 per day, the costs for scraper work are given by Baker in "Roads and Pavements," as shown in Table VI.

TABLE VI

Cost of Moving Earth with Drag Scoop-Scraper

Cents per Cubic Yard

Items	25-ft. Haul		50-ft. Haul		100-ft. Haul		200-ft. Haul	
	Loose Earth	Hard Grnd.	Loose Earth	Hard Grnd.	Loose Earth	Hard Grnd.	Loose Earth	Hard Grnd.
Loosening	1.25	2.50	1.25	2.50	1.25	2.50	1.25	2.50
Filling scrapers	1.25	1.50	1.00	1.50	1.00	1.25	1.00	1.00
Hauling	5.83	6.50	7.00	7.70	8.75	9.62	10.00	11.00
Leveling	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Superintendence	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Wear and tear	0.25	0.38	0.33	0.50	0.42	0.63	0.53	0.80
Water boy	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Total cost	9.83	12.13	10.83	12.95	12.67	15.25	14.03	16.55

The 50-ft. haul shown in Table VI is based on a 50 cu. yd. quantity per scraper per day, with one scraper holder filling for three teams.

In the 100-ft. haul, each team will make the trip in about 2½ minutes, and the cost is based on a 40 cu. yd, quantity per day.

The 200-ft. haul is based on a 3½ minute time for trip, and a 35 cu. yd. quantity per day.

The cost of loosening given in Table VI is based on a team and plow at $5.00 per day with driver, and a capacity of 400 cu. yds. of loam per day.

Loading Material. If the excavated material is to be removed to any distance from the site from which it is taken, the loading of material into carts will be another item to be figured. When the number of men who are shoveling material is so regulated to the number of men picking or loosening and to the number of carts in use, that they do not have to wait for material to shovel or for carts to shovel it into, it is claimed that experience shows that 1 man will shovel into a cart the following quantities of loose material per hour:

2 cubic yards of loam or sand; or
1¾ cubic yards of heavy soil or clay; or
1 1/5 cubic yards of rock.

Removing Material. For small amounts and short distances of haul, either wheelbarrows, scrapers, or small dump-wagons may be used. For long hauls and large quantities, it may even pay to lay light rails and use a light car drawn by horses or by a light locomotive.

It is commonly considered that shovels are sufficient for small quantities of excavation where the distance which the earth has to be thrown is less than 12 feet on the horizontal or 6 feet vertical. Likewise, for distances under 200 feet, earth may be removed economically by shoveling into wheelbarrows and wheeling away.

For distances over 200 feet, wagons or wheeled scrapers should be used, unless large quantities of material are to be moved through long distances. The rates of economical haul are about as follows:

Drag scrapers, up to 150 feet.
Wheelbarrows, up to 200 feet.
Wheeled scrapers, up to 500 feet.
One-horse carts, up to 600 feet.
Two-horse carts, up to 1,000 feet.

For greater distances, the amount to be hauled should determine the method.

In computing time necessary for a team to haul a load from the excavation to the dumping place, it is customary to figure on about 5 minutes for a 1,000-foot haul, or about 200 feet per minute.

Another point to be considered is the capacity of the different types of equipment used in hauling away excavated materials. The following data, while, of course, merely approximate as representing the averages found in ordinary practice, will aid in determining how many loads will have to be carried from the excavation:

Wheelbarrow holds about 3 cu. ft.
One-horse dump-cart holds about 20 cu. ft.
Two-horse dump-wagon holds about 36 cu. ft.
Regular builder's cart holds about 27 cu. ft.
Drag scraper will remove from 4 to 7 cu. ft.
Wheeled scraper will remove from 10 to 18 cu. ft.
Small car will remove from 27 to 81 cu. ft.
A stone wagon will carry from 3 to 6 tons.
A single load of timber is about 50 cu. ft.
A single load of dressed lumber is 1,000 ft.

If it is desired to know the weights of material moved in connection with the above loading:

Top-soil earth weighs about 75 lbs. per cu. ft.
Sandy loam weighs about 90 lbs. per cu. ft.
Common earth weighs about 90 lbs. per cu. ft.
Mud weighs about 95 lbs. per cu. ft.
Clay weighs about 100 lbs. per cu. ft.
Dry sand weighs about 100 lbs. per cu. ft.
Wet sand weighs about 110 lbs. per cu. ft.
Gravel weighs about 110 lbs. per cu. ft.
Broken stone weighs about 100 lbs. per cu. ft.

The cost of picking up materials such as earth, sand, or stone, and hauling them a moderate distance in wheelbarrows, is about 20 to 25 cents per cubic yard. With wagons or carts, the cost is about 15 to 23 cents per cubic yard.

A man can easily wheel about 250 pounds in a barrow, and will walk about 15 miles per day of 10 hours. If wages are 15 cents per hour, the cost of wheeling earth is from 3 to 5 cents per cubic yard per 100 feet of haul. This price is based upon quantities and weights given in the tables above. The lower price applies when the runways are level and the men work hard.

Other materials could be figured in a similar manner.

Leveling or Spreading. If the excavated material is simply hauled away and dumped over some embankment, or deposited in piles, there is but little extra cost above the hauling cost. If the material is used in grading and has to be leveled or spread when it is dumped, an average value for the labor in spreading is about 1½ cents per cubic yard for either common or heavy soils. If labor is high in a locality, this may be increased to as high as 2¼ cents per cubic yard. It may possibly be better to form estimates on the basis of 75 cu. yds. handled per average man in a 10-hour day.

A scraper operated by a team, driver, and one helper, may spread as much as 500 cu. yds. per day.

Filling. Earth, material at hand, 20 cents to 50 cents per cubic yard.

A man can thoroughly tamp 25 cu. yds. in 6-inch layers in a 10-hour day.

Sheet-Piling. Where sheet-piling is needed in loose material, the amount to be added to the regular cost of excavating will be about 20 cents per cubic yard where shoring pieces are put in to a depth of 8 feet on about 4-foot centers in reasonably good ground; but where continuous surface is needed, the cost may be as high as $1.00 per cubic yard. For the worst cases, $3.00 per cubic yard.

Miscellaneous Charges. There are several expenses which are more or less of the nature of fixed charges, which must be added to the items already stated. These miscellaneous charges consist of necessary repairs to equipment, roads, etc., together with the cost of general superintendence, insurance, depreciation of plant, interest on invested capital, and all charges which cannot be placed directly under one of the headings used above.

In connection with the charges due to repairs on equipment, a common allowance is about ¼ of a cent per cubic yard; and an allowance of 1/10 of a cent per cubic yard will probably be sufficient for each 100 feet of distance that the material is hauled, as a charge for keeping cart roads in order.

The allowances for general superintendence, insurance, depreciation of plant, etc., vary with the circumstances in each case, and can be determined only from past knowledge of similar work, or by analyzing the charges which are at all likely to occur, summing up the detailed amounts to which values have been given according to the best information to be obtained, and dividing the total by the number of cubic yards to be excavated. The result will be the amount to add per cubic yard.

Profit. Now that the total cost of excavation per cubic yard of material has been determined, the contractor must add a certain amount in order that a profit shall result to pay him for his time and labor. This percentage will also, in a great many cases, be the means of saving the contractor from direct loss, unless he has added to his detailed estimate a certain percentage to cover the possibilities of loss from an excessive labor cost. This percentage to be added to the labor item will vary from 5 to 20 per cent of the labor estimate, depending upon local conditions.

While the percentage to allow for pure profit has caused a lot of discussion, it is commonly agreed that the size of the work, the financial risk incurred, together with local conditions, should largely determine this factor. From 10 to 15 per cent is a fair profit if all other expenditures are taken care of.

Costs on Large Work. The following excavating costs may prove of service as a guide to estimating on work where large quantities of material are to be removed:

In earth, large masses, above water, 25 to 50 cents per cubic yard; below water, for piers, $1.00 to $5.00 per cubic yard; in trench, earth, 50 cents to $1.00 per cubic yard; loose rock, $1.00 to $2.00 per cubic yard; hard rock, $1.00 to $3.00 per cubic yard.

Steam shovel work costs about 12 to 20 cents per cubic yard. In "Engineering Record" (Vol. 54, p. 732) some data are given from a paper by Mr. John C. Sessor on steam shovel work on the C., B. & Q. Railway. On one job of 251,711 cubic yards, 1,104 cubic yards was moved per 10-hour shift. The cost was as follows: Equipment, 1 cent; steam shovel service, 8.9 cents; temporary trestle, 3.6 cents; track and track work, 5 cents; supervision and engineering, 0.2 cent; total, 18.7 cents per cubic yard.

On another job of 188,240 cubic yards, 946 cubic yards was moved per 10-hour shift. The cost was as follows: Equipment, 1½ cents; steam shovel service, 9.6 cents; temporary trestle, 3.1 cents; track and track work, 4.2 cents; supervision and engineering, 0.3 cents; total, 18.7 cents per cubic yard.

The Illinois Central Railway estimate excavating in earth, in jobs below 50,000 cubic yards, to cost 25 cents per cubic yard, and in larger jobs 20 cents per cubic yard, adding in both cases 1 cent per cubic yard per 100-foot haul.

A committee report of the Roadmaster's and Maintenance of Way Association, published in the "Railroad Gazette" of Oct. 31, 1904, and in "Engineering News" of Oct. 27, 1904, gives the following as the cost of ditching cuts and widening embankments:

By wheelbarrows: 12.2 cents per cubic yard, plus 3.1 cents per cubic yard per 1,000-foot haul for common loam, or 7.3 cents extra in bad, wet material.

By push cars: 19.1 cents per cubic yard where material is unloaded by shovel, or 15.9 cents where unloaded by dumping box or similar arrangement, plus 33.4 cents per cubic yard per 5,000-foot haul.

By machine ditcher: 22 to 30 cents per cubic yard, the latter figure being for a 15-mile haul in loam. In wet or bad material, add about 4.5 cents per cubic yard.

The same report places the cost of team work with scrapers at 14 to 25 cents per cubic yard; and of ditching by casting, in fair digging, where one cast will place the material in suitable final location, at 10 cents per cubic yard.

ROCK EXCAVATION

Measurement

Rock excavation is commonly measured in place before loosening, and is paid for by the cubic yard of actual excavation. In sewer work and in tunnel work, no extra payment is made for excavation beyond certain definite boundary lines shown on the excavation plans, unless special arrangements have been made for payment in such cases. Care should be taken to note whether the contractor or owner is to pay for extra work caused by accidental slides of rock due to blasting.

In case of rock which is to be used for filling purposes in soft ground or near water, the contractor should remember that a liberal allowance should be made for rock which will disappear in the mud or be rolled away by the current. Where work of this kind is to be paid for by the cubic yard of material in place. there is a chance for loss.

If rock is to be excavated and measured by the cord, the method of piling the loose material will govern the measurement to a considerable extent. Where slabs are corded up carefully by hand, the pile will average about 30 per cent voids or holes. The meaning of the term "cord" should also be clearly defined, since a cord of wood is 128 cubic feet, but a cord of stone may mean 32 cubic feet.

Likewise, the term "perch" is a very indefinite quantity, as explained later under the head of "Stone Construction."

Drilling

Hammer Drilling. The common weight of hammer for one-hand drilling is 4½ pounds; for two-hand or three-hand, 10 pounds.

Where two-hand or three-hand drilling is done, a 1¼-inch or 1½-inch bit is commonly used for the starter. In this class of work, the extreme depth of hole is ordinarily not over 6 or 8 feet.

One man holding the drill and two men striking (three-hand drilling) is the most economical gang for ordinary work where hammer drilling is used.

Gillette states that on work where a 1½-inch starting bit is used, with one man holding the drill vertically and two men striking, the rate of drilling a 6-foot hole is about as follows:

Granite	7	foot depth in 9 hours
Trap	11	" " " " "
Limestone	16	" " " " "

Basing the cost of this drilling on a wage rate of $1.75 per day of 9 hours per man, the cost of drilling the above materials would be 75 cents per foot for granite; 48 cents per foot for trap; and 33 cents per foot for limestone.

The cost of sharpening drills will add about 8 cents per foot to the cost of drilling.

In plug and feather work in hard rock or granite, 60 holes, drilled, plugged, and feathered, should be considered as an average amount to expect of one man in an 8-hour day, each hole to be ⅝-in. diameter and 2½-in. deep.

Churn Drilling. For drilling vertical holes, churn drilling is cheaper than hammer drilling, except where the holes are small or very shallow. For deep holes in soft rocks, a churn drill operated by two or more men is a very effective means of drilling. The drill should be of good weight, since its action is due to the constant raising and dropping of the tool.

Trautwine gives the following rates of drilling 3-foot vertical holes, starting with a 1¾-inch bit. One man drilling with a churn drill will penetrate:

Solid quartz .... 4 ft. in 10 hours

Tough hornblende	6	"	"	"	"
Granite or gneiss	7½	"	"	"	"
Limestone	8½	"	"	"	"
Sandstone	9½	"	"	"	"

To determine cost per foot, divide rate of pay per hour by number of feet drilled per hour.

Machine Drilling. Gillette, in his work on "Rock Excavation," gives the following rule for determining the number of feet of hole (N) that can be drilled in a given time (a day or shift) when a power drill is used:

The total number of working minutes (S) in the shift or day should be divided by the sum of the following quantities: The number of minutes (n) actually required to drill one foot of hole; the average number of minutes (m) required to change bits, divided by length (f) of the feed screw of the machine in feet; the average number of minutes (s) required to shift the machine from one hole to the next, divided by the depth (D) of the hole in feet. Thus we have:

$$N = \frac{S}{n + \frac{m}{f} + \frac{s}{D}}$$

For example, in drilling holes 10 feet deep, let it be desired to find the number of feet drilled per shift of 10 hours. Assuming that 1 foot of hole can be drilled in 5 minutes, that 3 minutes are required to change bits, that the feed screw is 2 feet long, and that it takes 20 minutes to change the machine from one location to the next, then the above formula will give the number of feet (N) drilled per shift, as follows:

$$N = \frac{60 \times 10}{5 + \frac{3}{2} + \frac{20}{10}} = 70.5 \text{ feet, or, say,}$$

seven holes 10 feet deep.

The time to drill one foot of hole will vary with the kind of rock, the type of machine, the pressure of the air or steam, and the size of the drill. Average times for drilling different kinds of rock with a machine having a 3⅛-in. diameter cylinder (inside dimension), using air or steam at 70 pounds per square inch pressure, with a starting bit about 2¾ inches and a finishing bit about 1½ inches, are given as follows: Limestone, soft sandstone, and similar rocks, 3 minutes time per foot of depth; medium stones of same variety, 4 minutes per foot; hard sandstones and granites, 5 minutes per foot; very hard granites and hard trap rock, 8 minutes per foot; soft rocks that sledge badly 10 minutes per foot.

The average time needed to change bits will be from 4 to 8 minutes.

The average time needed to shift the machine from one hole to the next will vary from 12 minutes for moderate speed on level rock, to 40 minutes for setting up in a difficult place.

Cost of Sharpening Bits. In very hard rock, it will be necessary to sharpen bits about every 1½ feet of hole. In average rock, a bit may be used for about 2 feet of depth, while in soft rock 4 feet may be drilled without change. Under average conditions, one blacksmith and his helper will sharpen by hand about 140 bits a day, which will supply about six machines.

Blasting

The loosening of rock depends upon its hardness, and upon the number of natural seams it contains. The direction of the drilled hole as compared with the direction of the natural strata of the rock, is another factor which governs largely the success of a blast. A larger quantity of explosive is ordinarily required for rock of a soft or loose nature than for compact rocks.

Where black powder is used, it is usual to allow about ¾ of a pound of powder to each cubic yard of solid rock. If dynamite is used, an average estimate will be about 1 pound of dynamite to 8 or 10 cubic yards of rock. The quality of the dynamite will cause this quantity to vary to a considerable extent.

FOUNDATIONS AND FOOTINGS

Foundation Walls

Building codes commonly consider "foundation" walls as including all walls and piers built below the curb level, or nearest tier of beams to the curb, which serve as supports for walls, piers, columns, girders, posts, or beams. Such codes also specify that these foundation walls shall be built of stone, brick, Portland cement concrete, iron, or steel.

The costs of foundation walls, supposing that the minimum thicknesses were to be used, would be as follows:

TABLE VII

Thickness of Foundation Walls for Buildings of Various Heights

(No Building Code in Force)

Height of Building	Dwellings, Hotels, etc.		Warehouses	
	Brick	Stone and Concrete	Brick	Stone and Concrete
	Inches	Inches	Inches	Inches
Two stories	12 or 16	20	16	20
Three stories	16	20	20	24
Four stories	20	24	24	28
Five stories	24	28	24	28
Six stories	28	32	28	32

For 1 square foot of outside wall surface:

Stone work, 18" thick..............28 cents
Concrete, 8" thick..................20 cents
Brick, 12" thick ....25 cents

The above prices are necessarily approximate, and should be checked up in the locality where the work is to be figured on. The best way to check such results is to find the number of cubic feet contained in the proposed wall, by multiplying the thickness of each kind of material by the length around the wall, and then multiplying this result by the height desired. These dimensions should all be in feet. This gives the volume of the wall in cubic feet.

Then find the quantity of each material needed for each kind of wall, and multiply by the local cost per unit of same. To this add the local labor cost for putting each form of wall in place. The result will be the total cost of each kind of wall. If it is desired to find the cost of each per square foot of outside surface, divide each total by the product obtained by multiplying the distance around the wall by the height.

Detailed descriptions of similar methods of figuring are found in other places in this volume.

As a guide to be followed when no building code requires or specifies a certain thickness of foundation wall, Table VII may be taken as indicating the average current practice.

Proportions of Footings. The unit-bearing on foundations should be kept the same under all parts of continuous structures. Foundations should be designed to distribute the loads upon them uniformly.

Table VIII shows the bearing power of various soils, and may be used in determining size of footings for walls.

TABLE VIII

Bearing Power of Various Soils

KIND OF MATERIAL	Bearing Power in Tons Per Sq. Ft. Min.	Max.
Rock—the hardest—in thick layers of native bed	200	..
Rock equal to best ashlar masonry	25	30
Rock equal to best brick masonry	15	20
Rock equal to poor brick masonry	5	10
Clay on thick beds, always dry	4	6
Clay on thick beds, moderately dry	2	4
Clay, soft	1	2
Gravel and coarse sand, well compacted	8	10
Sand, compacted and well cemented	4	6
Sand, clean, dry	2	4
Quicksand, alluvial soils, etc	0.5	1

In general, footings for natural foundations should be made 1 ft. 6 in. or 2 ft. thick.

Footings for pile foundations should be made 3 ft. thick, with the pile head projecting 1 ft. into the concrete.

Depth of Footings. Wherever exposed to the action of frost, footings should be carried from 3 ft. to 5 ft. below ground level, depending on the latitude. Footings should be carried to the firmest foundation within reasonable reach.

Pile Foundations

Pile Spacing. Foundation piles should not be spaced closer than 2 ft. center to center in any direction, and at least 2 ft. 6 in. should be allowed in one direction.

Bearing Power of Piles. The maximum load carried by any pile should not exceed 40,000 pounds, or 600 pounds per square inch of its average cross-section. These limits apply to piles driven in firm soil to rock. Piles driven through loose, wet soil to solid rock or an equivalent bearing foundation, should be figured as columns with a maximum unit stress of 600 lbs. per square inch in the outer fibers.

Safe Load for a Pile. The safe load that a pile will support has been the subject of some experiments and much speculation; but no unfailing rule has been deduced. The formula that is in most common use for determining this safe load, is known as the Engineering News formula:

$$P = \frac{2\,W\,h}{s + 1}.$$

in which P is the safe load on the pile, and W is the of the hammer of the pile-driver, both being taken same unit, usually tons; h is the height in feet through which the hammer falls; and s is the penetration, in inches, of the pile under the last blow.

For example, if a hammer weighing 2,000 pounds, falling 20 feet, causes the pile to sink 1½ inches under the last blow, then the safe load by the formula will be:

$$P = \frac{2 \times 1 \times 20}{1\frac{1}{2} + 1} = 16 \text{ tons.}$$

Driving Wooden Piles. The cost of driving piles will vary with the nature of the soil and the method of driving the piles. Timber piles of good quality and average size may be driven for from 20 to 25 cents per foot of length, including the cost of the timber. This price applies to piles of about 10 inches average diameter and from 15 to 25 feet in length.

The variation from these prices may be as much as 25 per cent, or even more, when only a few piles are to be driven.

Driving Concrete Piles.—Owing to the difference in design of concrete piles, the cost of piles in place may vary from about 50 cents to $1.50 per foot of length, the lower price applying to piles of plain design and short lengths.

Concrete Blocks for Foundation Walls. For basements less than 12 feet in height, a wall 8 inches thick is sufficient for supporting an ordinary 2-story frame building. The size of the blocks is a matter of taste, but no block should be longer than four times its height, or shorter than one and one-half times its height. The best builders favor blocks that are twice as long as they are high. Crushed stone that passes a ¾-inch screen is used as aggregate where strength is desired, but may produce a rough appearing block.

Where concentrated loads rest on concrete block foundations, a few heavy, solid blocks should be used as a bearing.

EMPLOYERS' LIABILITY INSURANCE

Insurance against accident to both employees and outsiders, on work of normal risk, will cost about as follows:

Masonry	3	per cent of the pay-roll.
Ornamental iron work	3	" " " " "
Excavating (no blasting)	3	" " " " "
Carpentry	2.25	" " " " "
Private dwellings	1.85	" " " " "
Plumbing	1.25	" " " " "
Painting	1.25	" " " " "

When the risk is great, these items may run as high as 8 or 10 per cent. Insurance on building wrecking runs as high as 13 per cent.

On some reservoir pipe lines in New Jersey, the insurance was 2¾ per cent; and insurance of this kind has been obtained as low as 1 per cent, or even sometimes less, on such work as road construction where there was practically nothing that could happen. On aqueduct work with a rock tunnel, a rate less than 4 per cent has been obtained. In deep trench work, accidents to the men are likely to be frequent; and accident insurance companies, when the work is to be done in certain kinds of soil, will usually refuse to insure the men on this sort of contract.

Carpentry

RULES FOR GRADING LUMBER

The rules which govern the grading of the various kinds of lumber sold on the market are determined by the various lumber associations. These associations are composed of lumber-producing companies who are interested in a particular type of material, or group of materials.

Since the rules for grading are subject to change, it is advisable for contractors who are interested in a given product to send directly to the secretary of the lumber association dealing with that particular product, when the latest information in regard to grading is desired. The different associations publish small pamphlets containing these grading rules, which may be obtained free upon request.

The following list of addresses will be of service in obtaining copies of the various grading rules:

For **yellow pine**—The Yellow Pine Manufacturers' Association, St. Louis, Mo.

For **cypress** lumber and shingles—The Southern Cypress Manufacturers' Association, New Orleans, La.

For **hemlock, maple, beech, and birch**—The Northern Hemlock & Hardwood Manufacturers' Association, Wausau, Wis.

For **oak** flooring—Oak Flooring Bureau, Detroit, Mich.

For **Washington red cedar, western hemlock, and Oregon fir**—The West Coast Lumber Manufacturers' Association, Centralia, Wash.

For **white pine**—Northern Pine Manufacturers' Association, Lumber Exchange Bldg., Minneapolis, Minn.

For **red gum** and **sap gum**—Gum Lumber Bureau, Pullman Bldg., Chicago, Ill.

For **red cedar** shingles—Red Cedar Shingle Manufacturers' Association, Seattle, Wash.

For **redwood**—The Redwood Association, San Francisco, Cal.

For all **native hardwoods**—Hardwood Manufacturers' Association of the United States, Cincinnati, Ohio; or, the National Hardwood Lumber Association, Chicago, Ill.

For **Arkansas soft pine**—Arkansas Soft Pine Bureau, Chicago, Ill.

For additional information regarding grading rules and the properties of lumber, application should be made to the U. S. Department of Agriculture, Forest Service, Washington, D. C. This Department issues bulletins containing grading rules, and other valuable information in regard to all kinds of lumber.

STANDARD SIZES OF DRESSED LUMBER

As an example of the information which may be obtained from the literature of the lumber manufacturers' associations, the following list of standard sizes of dressed yellow pine lumber has been reproduced from a pamphlet issued by the Yellow Pine Manufacturers' Association, St. Louis, Mo.:

Finishing shall be dressed to the following: 1-in. S. 1 S. or 2 S. to 13/16; 1¼-in. S. 1 S. or 2 S. to 1 1/16; 1½ in. S. 1 S. or 2 S. to 1 5/16; 2-in. S. 1 S. or 2 S. to 1¾ in. 1x4 S. 4 S. shall be 3½ in. wide finished; 1x5 S. 4 S. shall be 4½ in. wide; 1x6—5½ in.; 1x7—6½ in.; 1x8—7½ in.; 1x9—8½ in.; 1x10—9½ in.; 1x11—10½ in.; 1x12—11¼ in.

The foregoing widths shall also apply to stock thicker than 1 in.

Molded Casing and Base. Shall be worked to ¾-in. as per patterns shown in Yellow Pine Manufacturers' Association Molding Book, 1908 edition.

Flooring. The standard of 1x3, 1x4, and 1x6 in. D. and better shall be worked to 13/16x2¼, 3¼, and 5¼ in.; 1¼-in. flooring shall be 1 3/32 in. thick; 1½-in. flooring to 1 11/32 in. thick, the same width and matching as 1-in. stock.

Drop Siding. D. and M. shall be worked to ¾x3¼ and 5¼-in. face, 4½ and 5½ over all. Worked shiplap, ¾x5-in. face, 5½ over all.

Ceiling shall be worked to the following: ⅜-in. ceiling, 5/16 in.; ½-in. ceiling, 7/16 in.; ⅝-in. ceiling, 9/16 in.; ¾-in. ceiling, 11/16 in. Same width as flooring. The standard working of ceiling shall be beaded center and edge with slight bevel on groove edge. The bead on all ceiling and partition shall be depressed 1/32 in. below surface line of piece.

Partition shall be worked to the following: ¾x3¼ and 5¼ in. Same standard for location of and size of bead as applies to ceiling.

Bevel Siding. To be made from stock S. 4 S. worked to 13/16x3½ and 5½ and resawed on a bevel.

Window and Door Jambs. Dressed, rabbeted and plowed as ordered.

Boards and Fencing. 1-in. S. 1 S. or 2 S. to 13/16 in.

Shiplap and Barn Siding No. 1 Common. 8, 10, and 12-in. shall be worked to 13/16x7⅛, 9⅛, and 11⅛ in.

D. and M. No. 1 Common 8, 10, and 12-in. Shall be worked to the following: 13/16x7⅛, 9⅛, and 11⅛ in.

Grooved Roofing. 10 and 12-in. S. 1 S. and 2 E. shall be worked to 13/16x9½ and 11¼.

Wagon Bottoms, unless otherwise ordered, shall be made in sets 38 and 42 in. face, and from stock 4 in. or over in width.

Standard thickness shall be 13/16 in.

Dimension shall be worked to the following: 2x4 S. 1 S. and 1 E. to 1⅝x3⅝ in.; 2x6 S. 1 S. and 1 E. to 1⅝x5⅝ in.; 2x8 S. 1 S. and 1 E. to 1⅝x7½ in.; 2x10 S. 1 S. and 1 E. to 1⅝x9½ in.; 2x12 S. 1 S. and 1 E. to 1⅝ by 11½ in. Dimension S. 4 S. ⅛-in. less than standard size S. 1 S. and 1 E.

Heavy Joists shall be worked to the following: 2x14, 2½, and 3x10, 12, and 14, S. 1 S. and 1 E., green, ¼-in. off side and ½-in. off edge. S. 4 S. ¼-in. off each face surfaced. Heavy joists, rough, green, must not be over ¼-in. scant in width or thickness.

Heavy Flooring. For 2 and 2½-in. matching, the thickness should be ⅜-in. less than the rough material. The tongue should be ⅝-in. thick and ⅜-in. long. For 3-in. and thicker matching, the tongue should be ¾-in. thick and ⅜-in. long, and the thickness of the stock should be ⅜-in. less than the rough material. The groove in heavy matchings should be 1/16-in. wider than the thickness of the tongue, and 7/16-in. deeper than the length of the tongue. Tongue and groove shall be located ¼ the thickness of the rough material from the bottom of the piece. In 2 in. and thicker material plowed for splines, the groove should be the same width and depth as is provided for in matching material of the same thickness.

Heavy Shiplap shall be worked to the same thickness as heavy flooring. The lap shall be ½ in. long, occupying one-half the finished thickness of the piece.

Timbers shall be worked to the following: 4x4 and larger S. 1 S. or S. & E., ⅜-in. off each face surfaced. S. 3 S. or S. 4 S., ¼-in. off each face surfaced.

Yellow Pine Plastering Lath. No. 1 should measure 2 in. in thickness to every five lath, green, the minimum thickness of any one lath shall not be less than 5/16 in. green, and should not be less than 1 7/16 in. in width, green, length 4 ft., 1⅝ in. thickness to every 5 lath, dry, and should not measure less than 1 5/16 in. in width, dry. Must not be more than ½ in. scant in length when dry.

No. 2 must not be less than 1¼ in. in width, ¼ in. thick, when dry, and not more than ¾ in. short in length.

Byrkit Lath. ¾x3½ and 5¼ in. wide, lengths, 4 ft. and upward.

Square Pickets. From 1½-in. stock shall be worked to 1 5/16x1 5/16, 3 and 4 ft. long, dressed on 4 sides and pointed. From 1¼-in. stock shall be worked to 1 1/16x1 1/16, 3 and 4 ft. long, dressed on 4 sides and pointed.

Flat Pickets. From 1x3 stock shall be worked to ¾x2¼, 3 and 4 ft. long, dressed on 4 sides and headed.

ACTUAL SIZES OF LUMBER

About 95 per cent of the southern yellow pine on the market is classified and graded according to the rules of the Southern Yellow Pine Manufacturers' Association, and runs from ¼ to ⅝-in. smaller in dimension than called for by its nominal size. Table IX gives the actual sizes of the various nominal sizes of yellow pine lumber as given by the above named association. Where the letters S-1-S-1-E are used, it means that the lumber is surfaced or planed on one side and one edge only, while S-4-S designates that the material is surfaced on all four sides.

If calculations for safe loads on beams have been made

TABLE IX

Actual Sizes of Lumber Dimensions, in Inches

(Southern Yellow Pine Manufacturers' Association)

For S1S1E

Breadth / Depth	2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
4 in.	1⅝x 3⅝	3⅝x 3⅝				
6 in.	1⅝x 5⅝	3⅝x 5⅝	5⅝x 5⅝			
8 in.	1⅝x 7½	3⅝x 7½	5⅝x 7½	7½x 7½		
10 in.	1⅝x 9½	3⅝x 9½	5⅝x 9½	7½x 9½	9½x 9½	
12 in.	1⅝x11½	3⅝x11½	5⅝x11½	7½x11½	9½x11½	11½x11½

For S4S

Breadth / Depth	2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
4 in.	1½x 3½	3½x 3½				
6 in.	1½x 5½	3½x 5½	5½x 5½			
8 in.	1½x 7½	3½x 7½	5½x 7½	7½x 7½		
10 in.	1½x 9½	3½x 9½	5½x 9½	7½x 9½	9½x 9½	
12 in.	1½x11½	3½x11½	5½x11½	7½x11½	9½x11½	11½x11½

TABLE X

Factors for Reducing Nominal Loads to Real Safe Loads

For S1S1E

Breadth	2 in.	4 in.	6 in.	8 in.	10 in.	12 in.
Depth 4 in.	67/100	74/100				
6 in.	71/100	8/10	82/100			
8 in.	71/100	82/100	9/10	9/10		
10 in.	73/100	84/100	9/10	92/100	93/100	
12 in.	75/100	85/100	92/100	93/100	94/100	94/100
For S4S						
4 in.	57/100	67/100				
6 in.	63/100	74/100	77/100			
8 in.	64/100	77/100	81/100	82/100		
10 in.	66/100	79/100	83/100	85/100	86/100	
12 in.	67/100	8/10	84/100	86/100	87/100	88/100

by using the full and rated size of timber, the load obtained for full-size cross-section should be multiplied by the factor corresponding to that size of section given in Table X.

For instance, the safe load for a 2 by 12-in. yellow pine joist 10 ft. long is 3,200 pounds when the joist is taken as full 2 by 12 in. From Table IX, we see that the actual size of this joist is only 1⅝ by 11½ in.; therefore the true load would be determined by multiplying 3,200 pounds by 75/100 as given in Table X. On this basis, the safe allowable load would be 2,400 pounds.

TO DETERMINE NUMBER OF FEET BOARD MEASURE IN TIMBER

A board foot is a piece of timber 12 in. long, 12 in. wide, and 1 in. thick. Thus a block of timber 12 in. square on the end, and 1 ft (12 in.) long, would contain 12 board feet. A simple rule for finding the number of board feet in a piece of timber is to multiply the end dimensions together, divide this product by 12, and multiply this answer by the length of the piece in feet.

Thus, a 2 by 12- in. joist 16 ft. long would contain

$$\frac{2\times12}{12}\times 16 = 32 \text{ board feet.}$$

Table XI gives the number of board feet in 1 ft. of length of common sizes of timber.

TABLE XI

Board Measure per Linear Foot of Length for Different Sizes of Timber

End Size, in Inches	Feet, Bd. Measure	End Size, in Inches	Feet, Bd. Measure	End Size, in Inches	Feet, Bd. Measure
1x2	.17	1¼x10	1.04	3x8	2.00
1x3	.25	1¼x12	1.25	3x10	2.50
1x4	.33	1½x2	.25	3x12	3.00
1x5	.42	1½x3	.37	3x14	3.50
1x6	.50	1½x4	.50	4x4	1.33
1x8	.67	1½x5	.62	4x6	2.00
1x10	.83	1½x6	.75	6x6	3.00
1x12	1.00	1½x8	1.00	6x8	4.00
1x14	1.17	1½x10	1.25	8x8	5.33
1x16	1.33	1½x12	1.50	8x10	6.66
1x18	1.50	2x4	.67	8x12	8.00
1x20	1.67	2x6	1.00	10x10	8.33
1¼x2	.21	2x8	1.33	10x12	10.00
1¼x3	.31	2x10	1.67	12x12	12.00
1¼x4	.42	2x12	2.00	14x14	16.33
1¼x5	.52	2x14	2.33	16x16	21.33
1¼x6	.62	3x4	1.00		
1¼x8	.83	3x6	1.50		

Lumber of any given width may be calculated from the table by adding together the board measure in two other sizes of the same thickness of material. For instance, a 2x16-in. timber will contain twice as many board feet as a 2x8-in. piece, or as much as a 2x12-in. and a 2x4-in. taken together.

Number of Board Feet in Logs

The hand book issued by the Forest Service on log rules, shows 45 different methods for measuring logs, each of which differs in some respects from the others. In the Southern and Central section of the country the rule most generally followed is the **Scribner-Doyle**, which is based on the number of square-edged inch boards of standard width a log will make; and in scaling by this rule, measurement is taken at the small end of the log inside of the bark. Or if it is a longer log to be cut in two before sawing, the measurement of both ends is taken and the average diameter of the two makes the scale measurement for the butt log.

There is a rule known as the **¾ rule**, said to be used in Maine, New Hampshire, and Massachusetts, the formula on which it is based being as follows: Deduct ¼ the diameter at the small end of the log inside of the bark, for saw kerf and slabs; square the remainder; multiply by the length of the log; and divide this last product by 12, for the contents of the log in board feet.

There is another rule known as the **Orange river rule**, which is used in Texas and based on the following: Multiply the square of the diameter of the small end of the log inside the bark by the length of the log, and divide the product by 30. The result is the contents in board feet.

All of these rules are based on the measurements taken at the small end of the log inside the bark. By keeping this in mind, and getting a copy of the table of rules followed by the purchaser of the timber, the amount of timber may be estimated easily before it is hauled.

Another rule is known as the **New Hampshire rule**. This rule is based on an imaginary cubic foot equal to about 1 4/10 times the standard cu. ft. The statutes of New Hampshire, 1910, give the law on this rule as follows:

"All round timber, the quantity of which is estimated by the thousand, shall be measured according to the following rules: A stick of timber 16 in. in diameter and 12 in. long shall constitute 1 cu. ft.; and the same ratio shall apply to any other size and quantity. Each cu. ft. shall constitute ten feet of a thousand board feet."

In the practical use of this rule it is customary to consider 115 cu. ft. equivalent to 1,000 ft., board measure, instead of 100 cu. ft., according to the wording of the statute. In this case, the diameter is taken at the middle of the log inside the bark. If the diameter is measured at the small end of the log, 106 cu. ft. are allowed for 1,000 board feet. The New Hampshire rule is also called the **Blodgett rule**.

SHRINKAGE OF TIMBER

Timber shrinks but very little lengthwise of the grain when drying, but crosswise the shrinkage may be quite considerable. The shrinkage varies considerably in different kinds of timber. The **soft woods**, such as pine, spruce, or cypress, shrink evenly, with but little cracking; but the **hard woods**, such as oak and hickory, are often subject to injury.

Table XII gives the approximate shrinkage of timber when drying in the open air.

TABLE XII
Approximate Shrinkage of Timber per Foot of Width in Drying

Kind of Wood	Shrinkage in Inches per Foot of Width	Kind of Wood	Shrinkage in Inches per Foot of Width
Ash	.60	Horse chestnut	.72
Basswood	.72	Locust	.72
Beech	.60	Maple	.60
Birch	.72	Oak	1.20
Box elder	.48	Pine, hard	.48
Cedar	.36	Pine, soft	.36
Cherry	.60	Poplar	.60
Chestnut	.72	Spruce	.36
Cypress	.36	Sycamore	.60
Elm	.60	Tamarack	.48
Hickory	1.20	Walnut	.60
Honey locust	.48		

ORDINARY LUMBER WASTE

In the use of ordinary lumber on walls, floors, ceilings, etc., the following percentages should be added to the actual measurement of the surface to be covered, in order to allow for lapping, matching, etc.:

Battens, 1x4, placed 6 in. on centers, only ⅝ of surface measure is needed.

Battens, 1x6, placed 8 in. on centers, only ¾ of surface measure is needed.

Ceiling will be same as flooring given below.

Flooring, 3-in. matched....................50%
Flooring, 4-in. 33%
Flooring, 6-in. 20%

(See also under Maple and Oak Flooring.)

Papers and felts are usually listed for enough less than the roll actually contains to allow for lapping.

Sheathing, common, laid horizontally on walls without openings 10%

Sheathing, common, laid horizontally on roofs without openings 10%

Sheathing, common, laid horizontally on dwellings with usual openings ....Nothing

Sheathing, common, laid diagonally on dwellings with usual openings 17%

Sheathing, tight, 6 in., laid horizontally....................20%

Sheathing, tight, 8 in., laid horizontally....................15%

Sheathing, tight, 10 in., laid horizontally....................12%

Sheathing, tight, 6 in., laid diagonally....................25%

Sheathing, tight, 8 in., laid diagonally....................17%

Sheathing, tight, 10 in., laid diagonally....................12%

Siding, drop 20%

Siding, lap, 4 in. to weather....................50%

Siding, lap, 4½ in. to weather....................33%

To estimate the quantity of sheathing or of shiplap, approximately, calculate the exact surface to be covered, deducting openings; then add the following percentages:

	Sheathing.	Shiplap.
For floors	1/7 or 15%	1/6 or 17%
For side walls	1/6 or 17%	1/5 or 20%
For roofs	1/5 or 20%	1/4 or 25%

HOUSE CHART

The object of the chart on page 8 is to give the names of various parts of a frame house. On account of the limited space, only one story and roof could be shown; but this does not matter much, as the second or third stories would be similar to the first.

To show as many of these various parts as possible, the house is arranged in a peculiar manner, parts being omitted here and there; while many parts are drawn larger than they should be, so as to show them clearly.

The main body of the house, toward the left, is the balloon-framed type; while the wing, toward the right, is of the braced-frame type. The names of the various parts are as follows:

1 Stone foundation.
2. Brick pier or pillar.
3. Post.
4. Sill.
5. Corner-post of balloon frame.

6. Corner-post of braced frame.
7. Studding.
8. First-story beams or joists.
9. Trimmer.
10. Tail-beam.
11. Header
12. Mortise-and-tenon joint.
13. Second-story beams or joists.
14. Ribbon or girt strip.
15. Plate.
16. Girt.
17. Bridging.
17½. Brace.
18. Common rafters.
19. Ridge.
20. Valley rafters.
21. Jack rafters.
22. Hip rafters.
23. Roof sheathing.
24. Purlins or shingle lath.
25. Flashing.
26. Ridge-board.
27. Ridge-roll.
28. Shingles.
29. Horizontal sheathing.
30. Diagonal sheathing.
31. Sheathing paper.
32. Clapboards or siding.
33. Shingle siding.
34. Water-table.
35. Pitched cap of water-table.
36. Window-frame.
37. Shutters or blinds.
38. Frieze.
39. Fascia.
40. Planceer or plancher.
41. Guttér.
42. Corner-board.
43. Collar beam.
44. Lath.
45. Rough plastering.
46. Finished plastering.
47. Baseboard.
48. Flooring.
49. Well-hole (for staircase).
50. Door opening.

BARN FRAMING

At first glance at the construction shown in Fig. 4, one would think such a frame a wilderness of timbers. As a matter of fact, however, the system is simple, and the number of names of different members or parts is not great. The accompanying list (p. 155) gives the names and sizes of the different numbered parts.

ESTIMATING LUMBER FOR BUILDINGS

In estimating material for buildings, it is often desirable to have some easy, quick, and reliable methods that will enable the contractor to arrive at a close, approximate cost without the necessity of going into all the details and making out lumber bills. As nearly all lumber is sold by board measure, it is apparent that an easy system of reducing linear feet of different-sized timbers to board measure is one thing needed. This is the case with sills, girders, and beams. The linear feet of such timbers in many plans can be de-

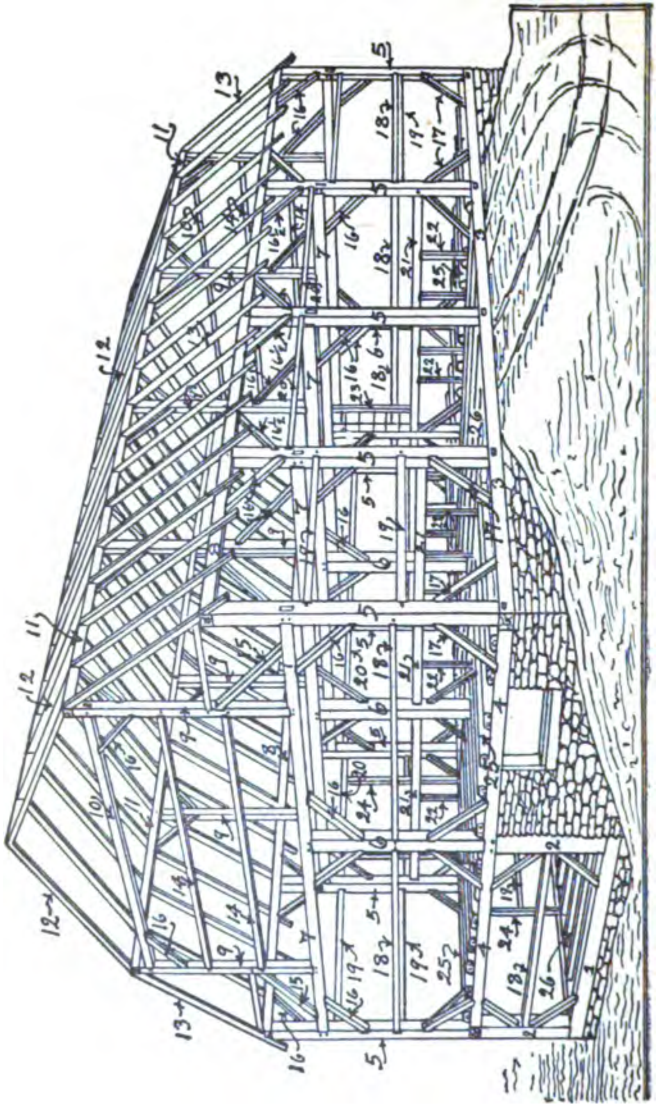


Fig. 4. General Framing Plan for a Heavy Timber Barn.

PARTS OF A HEAVY TIMBER BARN

	Name of Part	Size
1.	Basement sill	10 by 12 inches
2.	Basement posts	12 by 12 "
3.	Main sill	10 by 10 "
4.	Cross-sill	10 by 10 "
5.	Main post	8 by 8 "
6.	Center post	8 by 8 "
7.	Main beams	8 by 10 "
8.	Main plate	8 by 8 "
9.	Purlin posts	6 by 6 "
10.	Purlin beams	6 by 6 "
11.	Purlin plate	6 by 6 "
12.	Upper rafters	2 by 6 "
13.	Lower rafters	2 by 6 "
14.	Purlin girts	4 by 6 "
15.	Purlin braces	3 by 4 "
16.	3-ft.-run brace	3 by 4 "
16½.	2½-ft.-run brace	3 by 4 "
17.	3½-ft.-run brace	3 by 4 "
18.	End girts	4 by 6 "
19.	Side girts	4 by 6 "
20.	Door girts	4 by 6 "
21.	Breast girt	6 by 8 "
22.	Breast girt studs	3 by 4 "
23.	Ladder post	3 by 4 "
24.	Door posts	4 by 4 "
25.	Overlays, top and ends flatted to	6 "
26.	Sleepers	6 by 6 "

termined in a few minutes; then if these quantities can quickly be reduced to board measure, the cost can be figured without difficulty. Again, if the number of feet board measure for various kinds of framing is known, then the estimate of the cost of material for such work is quickly reached. For assisting in estimating the cost of material without making out a bill in detail, Table XIII will be of service.

TABLE XIII

Number of Feet Board Measure per Linear Foot, in Sills, Girders, and Beams

4x6 in.	2	ft. per linear foot
6x6 in.	3	" " " "
6x8 in.	4	" " " "
8x8 in.	5⅓	" " " "
8x10 in.	6⅔	" " " "
10x10 in.	8⅓	" " " "
10x12 in.	10	" " " "
12x12 in.	12	" " " "

TABLE XIV

Number of Feet Board Measure in a Square of Framing

Partitions (including plates)—

2x4 in. partitions set 16 in. O. C.	80 ft.
2x4 " " " 20 " " "	67 "
2x4 " " " 24 " " "	60 "
2x6 " " " 16 " " "	120 "
2x6 " " " 20 " " "	100 "
2x6 " " " 24 " " "	90 "

The framing of outside walls may be estimated the same as above.

Floors and Ceilings (allowing one joist in every square for doubling)—

2x4 in. set 16 in. O. C.	67 ft.
2x6 " " 16 " " "	100 "
2x8 " " 16 " " "	133 "
2x10 " " 16 " " "	167 "
2x12 " " 16 " " "	200 "
2x12 " " 12 " " "	240 "
2x14 " " 16 " " "	233 "
2x14 " " 12 " " "	280 "

Roofs (allowing one extra joist per square for cutting, etc.)—

2x4 in. set 16 in. O. C.	67 ft.
2x4 " " 20 " " "	53 "
2x4 " " 24 " " "	47 "
2x6 " " 16 " " "	100 "
2x6 " " 20 " " "	80 "
2x6 " " 24 " " "	70 "
2x8 " " 16 " " "	133 "
2x8 " " 20 " " "	107 "
2x8 " " 24 " " "	93 "

TABLE XV

Number of Feet Board Measure Required per Square, Allowing for Matching, etc.

8	in. shiplap	116 ft.
10	" "	125 "
2¼	" face matched flooring	133 "
3¼	" " " "	125 "
5¼	" " " "	120 "
6	" beveled siding	120 "
4	" " "	133 "
6	" drop "	120 "
8	" novelty "	116 "

TABLE XVI

Number of Shingles and Lath Required per Square

Shingles laid 4 in. to weather	1,000 per square
" 4½ " " "	900 " "
" 5 " " "	800 " "
Lath, per sq. yd	14
Per 100 sq. yds	1,400

ESTIMATING QUANTITIES OF NAILS

Table XVII will give the number of wire nails in pounds for various kinds of lumber, per thousand feet board measure, allowance being made for loss of covering surface due to lap or matching of material. The sizes given are as rated on the market.

If cut nails are used, add ⅛ to the number of nails as shown in the table.

Table XVII is based on the use of lumber cut to an average length of 12 ft., except in the case of ⅝-in. flooring, which is based on an average length of 6 ft.

Shingles, per 1,000, require 3½ pounds of 3d, or 5 pounds of 4d nails.

Lath, ordinary, per 1,000, studding spaced 12-in. centers, 10 pounds of 3d common wire nails. Studding spaced 16-in. centers, 8 pounds of 3d common wire nails.

Bridging, per set for 2x10 joists spaced 16-in. centers and 8 nails per set, will require 26 pounds of 8d common, or 38 pounds of 10d common wire nails per 1,000 linear ft. of bridging.

Furring, 1x2, will require 10 pounds of 10d nails, or 7 pounds of 8d nails, per 1,000 ft. of length.

TABLE XVII

Weight of Wire Nails Needed per 1,000 Feet of Lumber

Kind of Material	Distance Apart of Joist, or Studding Nailing Space in Inches	Number of Nails to Each Board each Nailing Space	Size of Nail	Pounds of Nails	Size of Nail	Pounds of Nails
1x4	12	2	8d com.	57	10d com.	84
1x4	16	2	8 "	43	10 "	65
1x4	24	2	8 "	30	10 "	45
1x6	12	2	8 "	38	10 "	56
1x6	16	2	8 "	29	10 "	43
1x6	24	2	8 "	20	10 "	30
1x8	12	2	8 "	28	10 "	42
1x8	16	2	8 "	22	10 "	32
1x8	24	2	8 "	15	10 "	23
1x10	12	2	8 "	23	10 "	34
1x10	16	2	8 "	17	10 "	26
1x10	12	3	8 "	34	10 "	51
1x10	16	3	8 "	26	10 "	39
1x10	24	3	8 "	18	10 "	27
1x12	16	3	8 "	22	10 "	32
1x12	24	3	8 "	15	10 "	23
2x6	16	2	20d com.	54	30d com.	75
2x6	24	2	20 "	37	30 "	53
2x8	24	2	20 "	28	30 "	40
2x10	24	3	20 "	34	30 "	48
2x12	24	3	20 "	28	30 "	40
3x6	24	2	40d com.	45	60d com.	70
3x8	24	2	40 "	34	60 "	52
3x10	24	3	40 "	41	60 "	63
3x12	24	3	40 "	35	60 "	54
Shiplap, 1x8	12	2	8d com.	32	10d com.	47
" " 1x8	16	2	8 "	25	10 "	36
" " 1x8	24	2	8 "	17	10 "	26
" " 1x10	12	2	8 "	25	10 "	37
" " 1x10	16	2	8 "	19	10 "	29
" " 1x10	24	2	8 "	13	10 "	20
" " 1x10	12	3	8 "	37	10 "	56
" " 1x10	16	3	8 "	29	10 "	43
" " 1x10	24	3	8 "	20	10 "	30
" " 1x12	12	3	8 "	30	10 "	45
" " 1x12	16	3	8 "	24	10 "	35
" " 1x12	24	3	8 "	16	10 "	25
Flooring, ⅜x2½	12	1	4d fin.	9	5d fin.	13
" 1x3	12	1	6d flg.	16	8d flg.	27
" 1x3	16	1	6d flg.	12	8d flg.	21
" 1x3	12	1	6d com.	28	8d com.	50
" 1x3	16	1	6 "	21	8 "	39
" 1x4	12	1	6d flg.	11	8d flg.	19
" 1x4	16	1	6 "	9	8 "	15
" 1x4	12	1	6d com.	19	8d com.	35

TABLE XVII—Continued

Kind of Material		Distance Apart of Joist, or Studding Nailing Space in Inches	Number of Nails to Each Board each Nailing Space	Size of Nail	Pounds of Nails	Size of Nail	Pounds of Nails
Flooring	1x4	16	1	6 com.	15	8 com.	27
"	1x6	12	1	6 "	12	8 "	23
"	1x6	16	1	6 "	10	8 "	18
"	1x6	24	1	6 "	7	8 "	12
"	1x6	12	2	6 "	24	8 "	46
"	1x6	16	2	6 "	20	8 "	36
"	1x6	24	2	6 "	14	8 "	24
"	1x8	12	2	8d com.	32	10d com.	47
"	1x8	16	2	8 "	25	10 "	36
"	1x8	24	2	8 "	17	10 "	26
Ceiling,	⅜x4	24	1	5d fin.	4	6d fin.	6
"	⅜x6	24	1	5 "	3	6 "	4
"	⅝x4	24	1	6d fin.	6	8d fin.	10
"	⅝x6	24	1	6 "	4	8 "	6
"	⅞x6	24	1	6d com.	7	8d com.	12
Siding,	½x4	16	1	6d com.	15	8d fin.	15
"	½x6	16	1	6 "	10	8 "	10
"	½x4	16	1	6d fin.	9	7d fin.	10
"	½x6	16	1	6 "	6	7 "	7

Framing studding will require 15 pounds of 10d, and 5 pounds of 20d nails, per 1,000 ft. of studding.

Framing joists will require approximately the following amounts of 20d nails per 1,000 feet:

Frame	buildings,	16-in.	centers	...............15 lbs.
"	"	12-in.	"	...............20 "
Brick	"	16-in.	"	...............10 "
"	"	12-in.	"	...............12 "

Finish, ⅞-in., will require about 20 pounds of 8d fin. nails per 1,000 feet, while 1¼-in. will require 30 pounds of 10d fin. nails per 1,000 feet.

Clapboards will require about 18 pounds of 6d box nails per 1,000 feet.

Table XVIII gives the approximate length and gauge number, as well as the approximate number per pound, for standard steel wire nails.

SATISFACTORY METHODS OF TAKING-OFF QUANTITIES

Some useful hints as to taking off quantities from plans were given by Mr. James Young in an address before the Carpenter Contractors' Association, of Cleveland, Ohio. The system followed by Mr. Young is of much interest, and is

TABLE XVIII

Standard Steel Wire Nails

Description.	Approximate Size of Wire Nails.	Approximate No. to the Pound.
3d fine	1⅛ in. No. 16	920
3d common	1¼ " " 14½	615
4d "	1½ " " 13	322
6d "	2 " " 12	200
8d "	2½ " " 10½	106
10d "	3 " " 9½	74
12d "	3¼ " " 9	57
16d "	3½ " " 8	46
20d "	4 " " 6	29
30d "	4½ " " 5	23
6d casing	2 " " 13	260
8d "	2½ " " 13	160
10d "	3 " " 11	108
4d finish	1½ " " 16	767
6d "	2 " " 14	359
8d "	2½ " " 13	214
10d "	3 " " 12	134
3d shingle	1¼ " " 13	429
6d flooring	2 " " 11	151
8d "	2½ " " 10	98
10d "	3 " " 9	66
4d box	1½ " " 15	550
6d "	2 " " 13	250

worthy of consideration. The suggestions were in part as follows:

"The first thing I do when figuring a job, is to give a general glance over the plans, elevations, and specifications. Then I turn to the basement plan, and take off the number of linear feet of girder and its size, whatever it may be; posts, if any; and these follow the date, name of architect, and owner, as my first entries. Then, turning to the first-floor plan, I take the amount of sill in linear feet, making an entry of that, and how the sill is composed. I take that measurement accurately, measuring the plan at its longest and widest square projection; thus, should the length be 58 ft. and the width 42 ft., we have 116 ft. and 84 ft., making the girth 200 ft. If there are any bays, I add 3 ft. for each bay.

"We have now not only the linear measurement for sill, but also for studding, sheathing, etc. Then I take the superficial area of the first floor for joisting, making the entry at whatever it may measure. For instance, first floor '1,950, 2 by 10 by 16 by 19,' thus indicating the number of square feet to be joisted, the size of the joist, the spacing, and the average length.

"I then turn to the second floor and do the same, making the same kind of entry, usually with some additions. For instance, there may be some bays or projections, which are only one story high, with girders running across at these openings. I take the amount of such girders and the size of bays or projections which stop at first floor, because, if they are not covered by the second-story joists, they must have ceiling joists. Then there may be one or more projections thrown out on the second floor, which are packed with mineral wool or otherwise treated. In addition, then, to the mere entry of joists for the second floor, I may have entries like these: '36 feet 6 by 10 girder, 115 ceiling joists, 130 feet 4 inches wool.' The fact of the entry of the wool carries with it the furring and sub-floors necessitated by its introduction. There may still remain other features on the second floor to be taken care of. The first floor may have a large living room, over which the joists are 2 in. wider than the balance of the house and set at 12-in. centers. I take the size of that room, and make an entry like this: 'extra on 24 by 32, 2 by 12, 12,' indicating that a portion of the second floor will have joist 2 by 12 set at 12-in. centers and 24 ft. long.

"Having thus taken care of the second floor, I then turn to the third floor or attic, and take the measurement of it. From the attic floor, I take the measurement of the roof and ceiling joists or collar-beams. Unless it is an absolutely plain, straight roof, I never measure it off the elevations, because I think I can measure a roof that is pretty well cut up much more accurately from the roof plan, and that in a fraction of the time required to measure each and every section or portion of roof as shown on the elevations. In the former case, I know that I have got full quantity of roof, while I might be doubtful if using the latter method.

"No matter at what pitch a roof is, it must bear some definite relation to the amount of plan area to be covered. The only thing necessary, then, is to find the various proportional relations that different pitches bear per square to the plan per square to be covered. Having determined that, you decide it is not only for one roof but for all time; you have then before you the simplest of propositions, and one that can be absolutely relied upon. But this does not dismiss the matter of roof. For instance, the measurement of your attic floor for joist does not go beyond your plate line, and your roof does. Then again, there may be a deck 16 by 20 ft. I believe it is better to make the entry '16 by 20 feet' than 'deck 320,' because the former entry gives not only the area of the deck but also the amount of deck-plate, and I think that it is particularly important to get a correct amount of the material that goes in a deck, because I quesion if the material in any other portion of a building costs as much to put in place.

"Having a deck, then, 16 by 20 ft., take 320 feet off from the measurement of your roof plan, and you have the amount on which to apply your proportional relation. I count the number of dormers in a roof, and allow so much additional per dormer, determining that amount at the time according to the kind of roof the dormers may have. One-half of the roof plan will give the amount of space required for collar beams, I believe, as accurately as it can be obtained in any other way, and there can surely be no method quicker.

"I then measure the cornices. The main cornice I measure from the attic plan, as it can be measured as accurately there, and more quickly than by taking it from four elevations. I usually make a price per foot on the cornice at that time, embracing that portion of roof which it takes to cover it. The gable cornice I measure from the elevations, also making a price per foot on it. Then I take the amount of dormer cornice. I also take the number of feet of hip for cant boards or hip shingles, as the case may be.

"I then turn to the walls. I already have the girth of the first floor. I take the girth of the second floor; and taking the mean between the two gives the girth for the total height. My entry would be thus: '200 feet of 2 by 5 by 22 stud and sheathing.' I then take the final covering, whatever it may be—siding, shingles, or timber work. If siding is used, I run my eye over the numbers of corners on the first and second floors, add them together, multiply by half the height, and I have the number of feet of corner-boards or mitered corner, as the case may be. I then measure the gables and dormers. I usually put higher price on gables and dormers than I do on the walls, because there is more waste and the work is slower.

"I then take water-table belting, if any, brackets, etc. I think it is well to put a price on these at the time, because it is difficult to make a note of them in such a way as to indicate their value. At this stage I go back to the attic plan, making the entry 'attic.' If a subfloor is used, I simply make the entry 'sub,' if it is laid straight; I follow the word 'sub' by the abbreviation 'diag.' if the floor is laid diagonally.

"I then measure the amount of finished floor, which is usually considerably less than the floor surface of the building, because the attic is usually studded in from the plate line. Then I take the number of linear feet of partition; the number of feet of base; the number of doors, height, style, and thickness; the number of windows to be cased; the number of closets, and how treated; the number of feet of cupboards; and whatever else appears on the first-floor plan.

"I then take the second floor in much the same way, the subfloor, the finished floor, paper, furring, wool, if any of these are called for. If bathrooms are marked 'tile,' I make an entry of so many feet of tile extra, because it costs considerably more to cut in floors between joists, fitting around pipes, than it does to lay it on top.

"In measuring partitions, I always measure those running one way of the building first, then measure those running the opposite way. I think one is more apt to get a correct measurement by so doing than if he tries to measure them irrespective of the way they run.

"Then I take the number of doors, window sides, closets plain, closets with drawers, the number of feet of cupboard, the number of mantels, medicine cases, towel closets, and whatever else may appear on the second-floor plan.

"If there is a room in hardwood, I take that by itself. If the hall is hardwood, I shall have an entry extra on 8 veneered doors, hall'; that implies that there must be jambs with hardwood edges and hardwood finish on one side; and then so many feet of hardwood base. I usually measure the hall by itself, in any case, because not infrequently it has a wood cornice, and you may not know whether it has or not until you are studying the three-quarter scale drawings.

"The first floor I treat somewhat differently. One very serious drawback to taking off quantities of interior work of the first floor is due to the fact that in many cases there is only one set of three-quarter scale interior drawings, and they are kept in the office, so that it is impossible to take off the work of any room intelligently.

"For a number of years, unless the three-quarter scale drawings accompany the plans, I have adopted the following method: After taking the partitions and floors, I take each room by itself, because the style of finish may differ very materially in the different rooms. An opening in one room may be cased for three or four dollars, while that of another may be worth ten dollars or more.

"My entries for these rooms, then, are as follows: 'Living room, birch, 3 door sides, 5 window sides, 70 ft. base or wainscot, 110 ft. picture mold or cornice, 16 ft. of alcove beam, 2 corner pilasters, mantel.'

"I take off each of the rooms and halls in this way, leaving two or three blank lines in my book between each room for the insertion of anything that appears on the interior drawings but not shown on the plans.

"Kitchens, pantries, store rooms, servants' dining room, and rear halls, I group the same as on the second floor, as invariably these are all of some one style. Then I take the number of feet of cupboards, and any other incidentals that may appear to be called for.

"I then take off the stairs. Rear stairs from basement to attic, I usually put a value upon as I look at them on the plans. The main stairs I usually make a diagram of as to position of the newel, the start of the rail, the shape of the first two or three risers, the width of the stair, number of landing posts, the number of feet of level rail, which, of course, includes the well-hole casing. The raking rail will run about a foot to the tread. I make the price after seeing the style on which the stairs are built. I rarely ever lump a main stairs at so much. I figure a stair itself at so much per step, according to its design and the wood of which it is built; so much for the newel and each of the landing posts; so much per foot of rail; and so much additional for each ramp or casing.

"After taking off the doors on the first floor and whatever work there is in the basement, I am done with the plans, so far as the interior work is concerned. I then turn to the elevations and take off the window-frames. While I already have the number, that does not enable me to make a price upon them, as their value may vary materially. This is my method, taking each elevation consecutively: I put down on my pad the number of common double-hung windows, and then look at those which are special; and on them I put a value. The entry in my book then will be like this: '40 common windows, specials, $215.'

"The only thing that is now left is porches and roofs and cornices of bays and balconies. Porches I take by the square foot—so many feet of floor and ceiling, so many feet of roof, so many linear feet of beams and cornice, so many posts, so many feet of rail, so many feet of lattice. Bay roofs and cornice I measure in with porch roofs and cornice, as they generally are of the same style and value. Balconies I take off as they may appear.

"Having now completed taking off my quantities, my one object is to get the amount of surface I have to cover on the exterior, and the nature of that covering; and in the interior, to get the quantity and kind of the various items that go to make the complete whole. After having done this, I read over the specifications carefully to see whether or not there may be something which I have overlooked in the more general reading at first.

"I have described the taking-off of quantities of a frame residence; taking off the quantities of a brick residence does not vary materially, although there is not so much to take off. There is one item which I always make an entry of on a brick residence which I do not make on a frame residence; and that is scaffolding.

MILLWORK

The term **millwork** is often used to include all material such as doors, door-frames, sash and window frames, transoms, moldings of various kinds, columns, capitals, cupboards, thresholds, stairs, hand-rails, newels, balusters, spindles, grills, mantels, consoles, chair and plate rails, wainscoting, base, screens, weather strips, etc. The prices of these various materials vary to so great an extent in different localities that it would be impossible to give any price list which would be of practical service in all instances. It is better for a contractor to make a list of the materials needed, and submit same to some dealer in millwork for an estimate on same. It would be well for a contractor to examine a catalogue containing descriptions of various types of millwork, in order to choose the type best suited in a given case. The price of millwork also varies with the quality of materials used in its construction, and the amount of decoration and type of finish used.

Labor quantities necessary in placing certain types of millwork will be found in the section devoted to Labor.

Doors

Doors may be obtained in stock sizes varying from 2 to 3 ft. in width, and from 6 ft. 6 in. to 7 ft. in height, and in 1⅛, 1⅜, and 1¾ in. in thickness. Doors 1⅛ in. thick are commonly used for closets, while the 1⅜-in. are generally used for all inside doors less than 3 ft. in width and 7 ft. in height. Outside doors and doors 3 ft. or over in width and 7 ft. in height, should be 1¾ in. thick.

Window-Sash

Sash are listed in stock thicknesses of 1⅛, 1⅜, and 1¾ in. The lighter types of sash are used in unimportant places or for small windows, while the 1⅜-in. thickness is used in small residence work. Common sash are made in stock sizes which will suit almost any purpose, and which are determined by the regular sizes of glass used. In reference to a given sash, it is called a 2, 4 or 8-light sash according to the number of lights of glass used. Sash are also referred to as "single" or "double" when used in a window. Single sash should be referred to as so many lights of glass of a certain size, giving the size of the glass and the size of the outside of the sash in order to make the description clear.

In ordering sash and doors, dimensions should be given in the order of width, length, and thickness of member. It is well, in ordering sash, to specify whether single-strength or double-strength glass is to be used.

Sash and doors may be shipped open or glazed as desired, but it is generally cheaper to have all glazing done at the mill.

Measuring Interiors for Millwork

In order to measure up millwork for interiors with any degree of accuracy, it is necessary that some definitely outlined plan be followed. The following scheme of taking measurements applied to the interior of an ordinary house three stories in height will be of service in this connection:

Top Floor. First, go to the top floor, which is the third in this instance, and start by taking the measurements of all the windows. The handiest and quickest method is to take the sash sizes. Having this, and knowing the construction of the frames furnished, there is a good basis to work on. In this case there might be one twin box frame, 2 ft. 5 in. by 4 ft. 6 in., one ¾ in. jamb, 1-in. center; one box frame, 2 ft. 9 in. by 5 ft. 2 in., 1¼-in.; one skeleton window-frame 2 ft. 7 in. by 5 ft. 2 in., 3¾-in. seat.

After having taken all the windows, proceed by taking the door sizes next. There may be an opening of 2 ft. 10 in. by 6 ft. 10 in. between the rough studs. This would mean a door of 2 ft. 8 in. by 6 ft. 8 in. A stud, which may be 3 in., would need a jamb of 4¾ in. Whatever the size of the rough opening is, make the door 2 in. less, and the jamb 1¾ in. wider in size, than the rough stud. Where plaster-boards are used, this would be too wide; but in such a case the right allowance for the jamb would be made by determining the thickness of the wall finish. If the opening for the door is irregular in width—as for example, 2 ft. 9 in.—then it is advisable to mark the studs with the correct size of the door which is to be furnished, so that there will be no mistake made by the carpenter when placing the jambs.

When taking the size of closet doors, make note of this fact, since in most cases closet doors are only 1⅛ in. thick, while others will probably be 1⅜ in. The trim on closet doors should be noted, since it is frequently different from the inside in cases where there is a cabinet head finish on the outside. Also measure the openings for switchbox doors, which are usually made the inside size of the box.

After taking doors, measure up the baseboards or base, taking closets separately, since in most cases they are different.

Next take the base blocks, if any are needed. Then corner-beads, stating how long, for some corners will not allow of a regular 4-ft. stock head being used. Sometimes it happens that the corner is not at right angles, which must be stated, and the correct angle noted.

In most cases there is a plaster railing inclosing the staircase on the top floor. If this wall is 4 in. thick, furnish a cap 5¾-in. wide, nosed on both edges, calculating a piece of molding the same kind as the base cap on each side of and under this nosed cap. These moldings should miter into the base cap.

Next measure the closets for shelving and hook-rail.

Then take steps and risers, nosing, and strings for the stairs leading down to the second floor. These are usually the box kind; also measure the wall rail.

Second Floor. Proceed with the second floor in the same manner as described above. It often happens that this floor has different kinds of wood in the different rooms, the front room being oak or chestnut, the bedrooms cypress or pine, and the bathroom poplar. It is advisable to mark on the plans the various kinds of finish to be used in the different rooms, so that there will not be so much chance of making mistakes. If there is a bay window on this floor, take note of the width of the space between the frames at the angles, for in many cases the regular trim is not wide enough, and a special trim must be made for these angles. If there is a window seat in this room, correct measurement must be taken of all angles, length, and depth, so that the seat will fit when sent to the job.

First Floor. The first floor is usually the hardest to measure up. Often there is a colonnade which joins into the staircase, therefore making accurate measurements necessary. If there is a paneled wainscot in the dining room, great care will have to be taken, or the panels will not fit. A circular bay window may also give trouble on this floor. If there is a paneled base or box seat, accurate measurement will be needed in this instance also. A definite plan should be used in taking measurements of this kind before proceeding.

The staircase may require the making of sketches in order to take down the scheme so that the stair man can readily understand what is meant. The one making measurements should be able to make a fairly good sketch, either with instruments or freehand, since he is often required to sketch outlines of some ornamental work that has many curved lines and moldings which must be duplicated exactly.

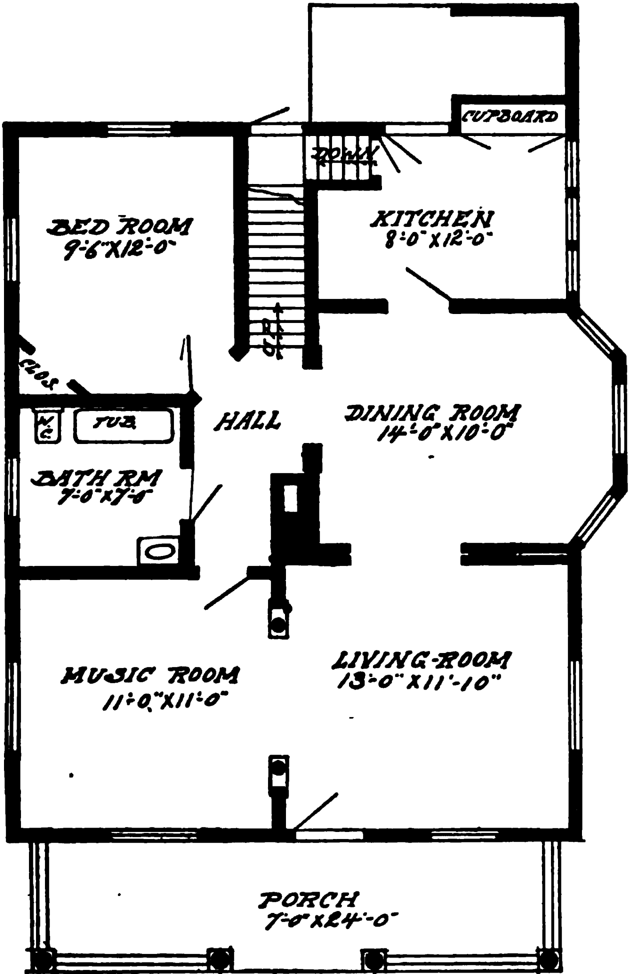
The data should be explicit in every respect, so that the man who writes out the cutting list for the mill can understand it thoroughly without asking a lot of questions in regard to details.

The plans and specifications for a job should be studied carefully before proceeding to take off interior quantities. In many cases, there are some changes made, either in the plans or in the specifications, which should be noted in the estimate or contract. This sheet of "extras" should be taken along with the plans, and a note made to see that there are no extras put into the job without being noted on the slips containing the measurements.

A handy book to use in taking down quantities is one having loose leaves that can be removed and placed on file upon completion of the measurements. Sheets about 5 by 7 in., and section-ruled are convenient in making sketches, and especially in taking measurements for staircases. A 4-ft. rule and steel tape will prove useful in ordinary work.

BILL OF MATERIALS

In order to form an intelligent estimate of the amount of materials needed for a piece of work, the plans and specifications must be carefully examined, and an itemized list made of the different materials going into the structure.



FIRST FLOOR PLAN

Fig. 5. Bill of Materials for Frame Dwelling.

An example of a bill of materials used in connection with the frame house shown in Plate I and Figs. 5 and 6, is given. This house was built of white pine, with inside finish of yellow pine stained dark oak. The first floor is of hardwood, with the exception of the kitchen. The cost of this house was $2,200—or $1,900, exclusive of heating, lighting, and bath. Following is a complete bill of all the material used:

Timber, Lumber, Lath, etc.

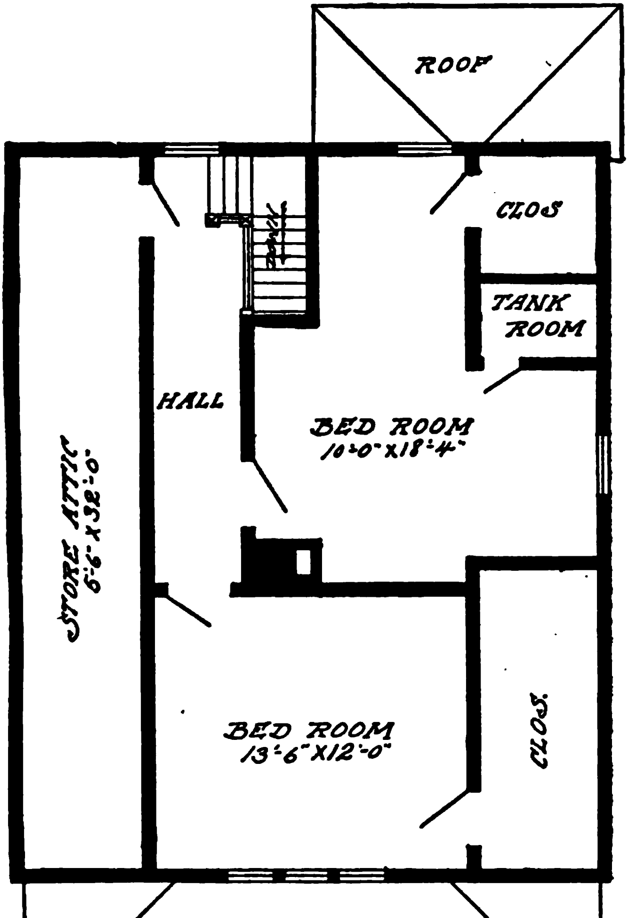
105—2x8x14 ft. No. 1 pine.
12—2x8x16 ft. No. 1 pine.
115—2x4x16 ft. No. 1 pine.
25—2x4x14 ft. No. 1 pine.
20—2x6x14 ft. No. 1 pine.
155—2x4x18 ft. No. 1 pine.
85—2x4x12 ft. No. 1 pine.
2—6x8x14 ft. No. 1 pine.
2—2x6x16 ft. No. 1 pine.
400 ft. No. 1 common pine S2S, 1x10x16.
300 ft. No. 1 common pine, S2S, 1x6x16.
5—1¼x10x12 C finish.
2—1¼x8x12 C finish.
3—1¼x6x12 C finish.
22—1x8x16 Sel. common S2S.
2—1x12x14 Sel. common S2S.
1—1x12x16 Sel. common S2S.
16—1x10x16 Sel. common S2S.
5—1x6x16 Sel. common S2S.
8—2x4x16 Sel. common S2S.
1—2x6x16 Sel. common S2S.
5—1x4x16 Sel. common S2S.
15½ M. red cedar shingles.
9¼ M. common No. 1 lath.
3,540 ft. No. 3 shiplap, 12-14-16.
2,000 ft. No. 2 pine sheathing, 12x14.
1,800 ft. flooring maple, oak, and yellow pine.
200 ft. porch flooring, ⅞x4x14, fir.
1,900 ft. 4 in. sugar pine lap siding.
600 ft. ⅝ in. yellow pine ceiling.
253 ft. 3¾ in. crown molding.
400 ft. 2¼ in. bed molding.
200 ft. ⅞x1¼ cove molding.
200 ft. screen molding.
100 ft. ⅞ quarter-mold.

Window and Door Frames

4 window-frames, 2-10x5-2.
2 window-frames, 1-10x5-2.
1 window-frame, 3-8x5-2.
1 window-frame, 4-0x5-2.
2 triple window-frames, 18 x20, 2 light.
3 frames, 20x24, 2 light.
1 frame, 20x20, 2 light.
2 outside door-frames, 3x7.
1 outside door-frame, 2-8x6-8.

Windows

6—18x20, 2-light D. S. windows.
2—18x28, 2-light D. S. windows.
1—26x20, 2-light D. S. windows.
1—40x28, 2-light D. S. windows.
2—44x32, 1-light D. S. windows.
4—30x28, 2-light D. S. windows.



SECOND FLOOR PLAN

Fig. 6. Bill of Materials for Frame Dwelling.

3—20x24, 2-light D. S. windows.
1—20x20, 2-light D. S. windows.
4—12x16, 2-light D. S. windows.

Doors and Trim

1 front door, 3x7x1¾, bevel plate glass 24x40.
1 door, 3x7x1¾.
1 door, 2-8x7x1⅜.
2 doors, 2-6x7x1⅜.
2 doors, 2-4x7x1⅜.
1 door, 2x7x1⅜.
2 doors, 2-6x6-6x1⅜.
3 doors, 2-4x6-6x1⅜.
1 door, 2x6-6x1¼.
1 door, 2-8x6-8x1⅜.
1 door, 5x7x1¾.
1 door-jamb, 8x7 ft.
1 door-jamb, 5x7 ft. 3 in.
1 door-jamb, 5x7 ft. 5 in.
1 door-jamb, 5x7 ft. 5½ in.
5 door-jambs, 2-8x7 ft. 5½ in.
2 door-jambs, 2-6x6-6 ft. 5½ in.
428 ft. base molding, No. 8420.
428 ft. base, No. 8421.
428 ft. shore, No. 8422.
560 ft. casing, No. 8310.
280 ft. embossed molding, No. 8413.
204 ft. cap molding, No. 8410.
180 ft. head casing, No. 8411.
180 ft. fillet, No. 8395.
50 base blocks, No. 2273.
48 ft. window-stool, No. 8267.
72 ft. window apron.
456 ft. window-stop, No. 8095.
4 porch columns, 8x8 ft., No. 1151.
2 colonnade posts, 5 ft. 6 in. base.
50 balusters, 1¾x24 in., No. 2151.
1 1¼x8 ft. yellow pine.
1 1x10 in. x 16 ft. yellow pine.
3 cupboard doors, 1-8x4 ft.
2 cupboard doors, 1-8x2-6.

Foundation, Plaster, and Chimney

9 cords stone.
96 cement blocks.
47 sacks plaster.
8 yds. sand.
11 bbls. lime.
1 bbl. cement.
1,100 brick.

Hardware

100 lbs. 10 d. wire nails.
122 lbs. 8 d. wire nails.
107 lbs. 20 d. wire nails.
9 lbs. 6 d. wire nails.
62 lbs. 3 d. gal. wire nails.
57 lbs. 3 d. fin. nails.
12½ lbs. 10 d. casing nails.
53 lbs. 8 d. casing nails.
23 lbs. 8 d. fin. nails.
25 lbs. 7 d. box nails.
13 inside door lock sets.
1 single sliding-door outfit, 5 ft. opening.
1 single sliding-door lock set.
1 doz. cupboard catches.
1 doz. sash-locks.
1 doz. drawer-pulls.
18 prs. door butts, 3½x3½.
1 doz. fancy box hinges.
3 doz. window springs.
1 pr. shelf brackets, 8x10.
1 pair shelf brackets, 10x12.

12 doz. ⅞ screws.
2½ lbs. 1 in. brads.
27 ft. valley tin, 14 in.
32 window tins.
176 tin shingles, 5x7.
19 8-ft. lengths ridge-roll.
50 wire screen, 24 in.
50 wire screen, 32 in.
2 screen doors, 3x7.
2 stovepipe thimbles.
7 10 ft. lengths eaves trough.
4 pieces outlet.
6 end caps.
8 eaves-trough elbows.
3 doz. eaves hangers.
5 pieces conductor pipe, 8 ft.
2 bundles sash-cord.
200 lbs. window weights.

Painting and Oiling

2½ lbs. putty.
1 lb. steel wool.
15 sheets sand paper.
1 gal. floor oil.
1 gal. floor varnish.
3 gal. interior varnish.
4 pints burnt turkey umber.
7 gal. linseed oil.
2 gal. turpentine.
7 gal. outside white paint, prime and trim.
4 gal. yellow stone paint for body.

Total cost of labor, including stone work, plastering, painting, oiling, carpenter, and excavating, $500.00.

COST OF FRAMING

Table XIX shows the cost of framing in different parts of a building, and states the amount of material needed for different spacing of members. The quantities and costs given are on the basis of 100 sq. ft. of surface of structure.

Table XIX is based upon labor charges at 40 cents per hour, or a charge of $8.00 per 1,000 ft. board measure for outside walls, ceilings, and floors; $9.00 per 1,000 ft. for partitions and plain roof framing; and $10.00 per 1,000 ft. for complicated roofs, hips, and valleys.

In this table, no allowance is made for sills and girders in the framing for floors, since sills and girders are not always required. If it is necessary to figure for them, they can be readily figured by the linear foot. A 6 by 6-in. timber has 3 ft. board measure per linear foot; a 6 by 8-in., 4 ft.; an 8 by 8-in., 5⅓ ft.; and the number of linear feet can be very readily found from any plan. Then the linear feet of the timber, multiplied by the board feet per foot, will give the feet board measure in the timber. This, multiplied by $8.00 per 1,000 feet, will give the cost of framing the same.

In the matter of partitions and outside walls, allowance has been made for plates, for it is always necessary to have these. Some allowance has also been made for waste in cutting.

TABLE XIX

Quantities and Costs of Framing per Square of 100 Square Feet

Size of Material in Inches, and Location	Board Feet per Square, 16" Centers	Labor Cost per Square, 16" Centers	Board Feet per Square, 12" Centers	Labor Cost per Square, 12" Centers
2x4, Outside Walls	80	$0.64	96	$0.77
2x6, " "	116	.93	140	1.12
2x4, Partitions	80	.72	96	.86
2x6, "	116	1.05	140	1.26
2x8, Floor Joists	110	.88	140	1.12
2x10, " "	140	1.12	180	1.44
2x12, " "	160	1.28	212	1.70
2x14, " "	190	1.52	245	1.96
3x12, " "	250	2.00	320	2.56
2x4, Ceiling Joists	60	.48	75	.60
2x6, " "	85	.68	110	.88
2x8, " "	110	.88	140	1.12
			Board Feet per Square, 24" Centers	Labor Cost per Square 24" Centers
2x4, Roof, Plain	60	.54	40	$0.36
2x6, " "	85	.77	60	.54
2x4, Roof, Hip and Valley	75	.75	50	.50
2x6, " " " "	106	1.06	70	.70

In figuring by this method, if one has the lumber bill made out so that he knows the amount of lumber to be framed, he can strike an average price per 1,000 feet, and figure the cost very easily and quickly.

Again, if the contractor does not care to take off the number of board feet of material, he can measure up the number of squares in a very few minutes, and ascertain the cost of labor by the square. He can also find the feet board measure by the square, and, from this, find the cost of material without the necessity of making out a bill. This method will be found handy in making estimates.

If carefully followed, this method will give the cost approximately correct. Then, if the estimator gets the job, he can make out the bill at his leisure, for the bill has to be made out for the lengths of lumber called for by the plan; but this detail is not necessary to determine the cost of the framing.

TYPICAL ESTIMATE FOR A FRAME HOUSE

The following estimate for a frame house is given as an example of the method to be followed in arriving at the probable cost of a piece of work. The plans of the building are shown in Figs. 7 to 10.

Specification

A brief specification for this design includes the following: Foundation walls and porch piers, up to level of first floor beams, are to be local stone 18 in. thick, laid up in Portland cement mortar. Cellar floor to be 2-in. Portland cement concrete.

Chimney to be brick, lined with 1-in. fire-clay tile.

Framing timber is to be all spruce, as follows: Girders, 8 by 12 in.; sills, 4 by 6 in.; studs and second floor ceiling beams, 2 by 4 in.; hips and ridge, 2 by 10 in.; rafters, 2 by 6 in.; sheathing, ⅞ by 6 or 8 in., tongued-and-grooved spruce; siding, from water-table to belt-course, 6-in. beveled siding; shingles, from belt to roof, cypress shingles; floors, ⅞ by 3½ in., tongued-and-grooved N. C. pine; exterior trim, all cypress (as detailed); interior trim, all cypress (as detailed); dining-room mantel, to be Colonial brick.

Plastering to be good-grade wall plaster.

House to be heated with hot-air furnace having separate pipe to each room.

Plumbing. Bathroom to have basin, closet, and bath. Kitchen to have sink, 2-compartment stone tubs, and small range. All fixtures to be porcelain enamel. Boiler to be

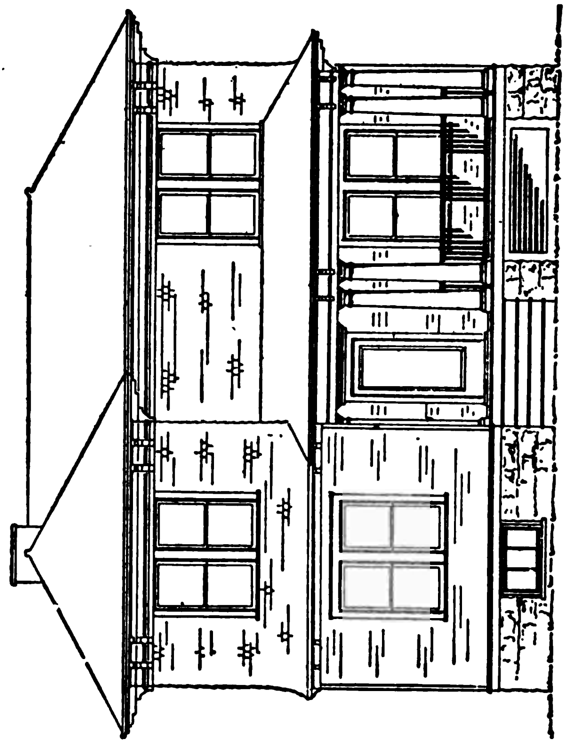
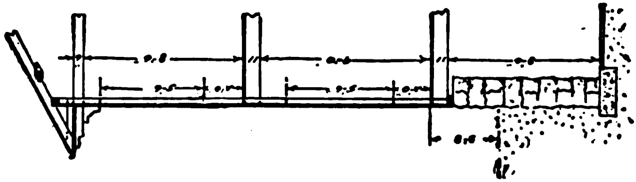
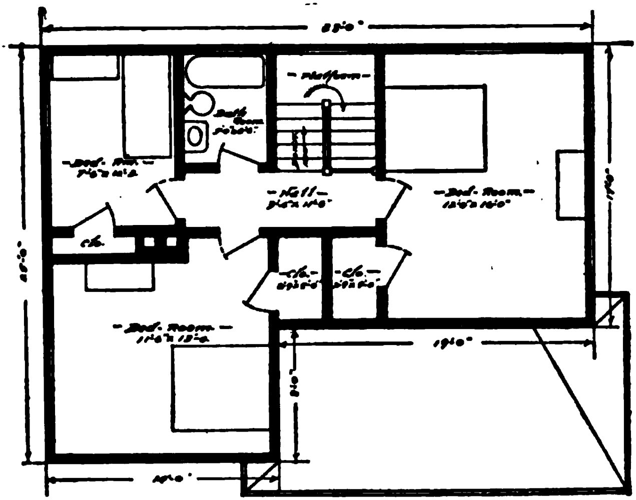
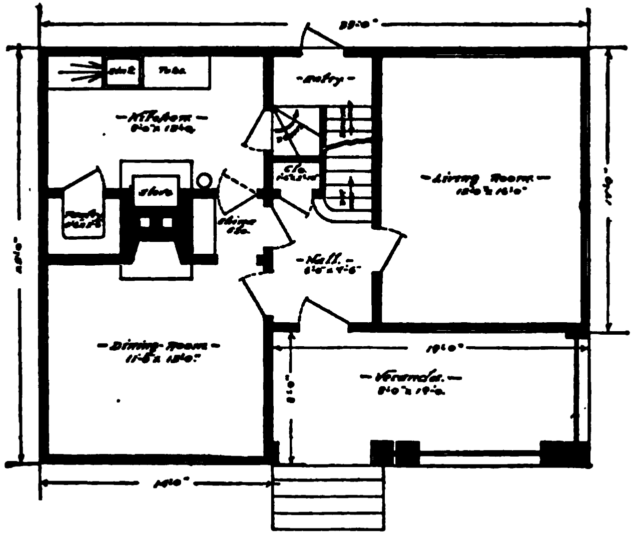


Fig. 7. Estimate on Frame House.





— Second — Floor — Plan. —



— First — Floor — Plan. —

Figs. 8 and 9. Estimate on Frame House.

Fig. 10. Estimate on Frame House.

35-gallon galvanized iron. Water system throughout to be of ¾-in. galvanized iron pipe.

Gas-Fitting. House to be piped with ½-in. pipe, with outlet for each room and cellar.

Metal Work. All roof shingles to be metal of standard approved make. Gutters to be galvanized-iron troughs with adjustable hangers. Leaders to be 3-in. corrugated galvanized iron.

All exterior woodwork (except wood shingles and soffits of roof) to have three coats of paint. Wood shingles to be stained. Soffits of roof to be varnished with two coats of spar varnish. Metal shingle roofs to have two coats of paint of dark tile color.

Estimate of Cost

	Labor	Material	Both
Excavation			
150 cu. yds. at 30c..............			$45.00
Footings			
(Concrete) 10 cu. yds.; Propor-			

	Labor	Material	Beth
- tion 1:2:4: Bbls. cement in 1 cu. yd., 1½............ $3.00			
Bbls. sand, 3............ .75			
Bbls. gravel, 6........... 2.00			
Cost of 1 cu. yd.......... $5.75		$57.50	
Labor, at $1.08 per cu. yd.	$10.80		$68.30
Stonework—37 perches			
1 perch stone............ $1.25			
½ bbl. cement, at $2.00.. 1.00			
1/6 load sand, at $1.75.... .29			
Material cost, 1 perch.... $2.54			
Material cost, 37 perches.......		$93.98	
½ day, mason............ 1.83			
¼ day laborer, at $2.00.. .50			
Labor cost of 1 perch..... $2.33			
Labor cost of 37 perches......	$86.21		$180.19
Bluestone—			
5 window-sills 4 ft. by 4 by 10 in., at 60c per ft...... $12.00			
1 window-sill, 2 ft. by 4 by 10-in., at 60c per ft........... 1.20			
$13.20		$13.20	
Labor setting, at 10c a ft......	$2.20		$15.40
Chimney and Fireplace—			
4,000 brick—			
Cost of labor, $9.00 per M....	$36.00	$39.32	
60. ft. 8 by 12 in. flue lining at 22c	$2.00	$13.20	
Chimney-cap	$1.00	$6.00	
Colonial brick mantel..........	$9.00	$20.00	$126.52
Cellar Floor—			
(Portland cement concrete) 56 sq. yds., at 60c...............	$11.20	$22.40	$33.60
Girder Columns—			
4 3-in. concrete-filled pipe columns	$3.00	$6.40	$9.40
Lathing and Plastering—			
586 sq. yds., at 40c............	$147.00	$88.00	$235.00

		Labor	Material	Both
Sheet Metal—				
105 ft. 3-in. leader at 15c..	$15.75			
5 elbows, at 30c..........	1.50			
50 conductor fasteners....	1.00			
136 ft. g. i. gutter........	24.00			
75 shanks and troughs....	4.00			
Nails	1.75			
	$47.95	$30.00	$47.95	
Flashing		$5.00	$5.00	
Metal shingles, 12. sq., at $5.00	$60.00			
130 ft. hip and ridge roll, at 7c	9.10			
	$69.10		$69.10	
Labor, at $2.25 per sq..........		$27.00		
Total for sheet metal......				$184.05
Heating—				
Steel furnace	$50.00			
Piping, cold-air box, and registers	40.00			
	$90.00		$90.00	
Labor		$30.00		$120.00
Plumbing and Gas-Fitting—				
Gas fixtures	$25.66			
1 2-section stone tub.....	25.00			
1 range with 24-gal. boiler.	60.00			
1 18 by 24-in. porcelain enamel sink with drain-board	27.00			
1 porcelain enamel basin..	20.00			
1 porcelain enamel siphonic closet	23.00			
1 4 ft. 6 in. porcelain enamel bathtub	30.00			
Pipes and fittings........	40.00			
	$250.66		$250.66	
Labor		$125.00		$375.66

	Labor	Material	Both
Carpenter Work—			
34 ft. girder, 8 by 10-in., 114 bd. ft.; 113 ft. sill, 4 by 6-in., 226 bd. ft.; 113 ft. plate, 4 by 4-in., 151 bd. ft.; 8 posts, 4 by 6-in., 22 ft., 352 bd. ft. Total, 843 bd. ft. at $30 per M...........		$25.30	
Labor, at $12 per M...........	$10.20		$35.50
Floors—Cost of a square of flooring:			
Joists 2 by 10-in., 16 in. O. C., equals 127 bd. ft., at $30 .... $3.75			
Labor 1.50			
Nails .... .10			
Flooring, 100 ft. N. C. pine at $50 .... 5.00			
Waste, ⅓ of stock........ 1.67			
Labor 1.50			
Nails, 5 lb., at 4c.......... .20			
Total, per sq.........$14.22			
Total squares first and second floor, 10 sq., at $14.22........	$30.00	$112.20	$142.20
Porch floor, 1½ sq.............	4.50	16.83	21.33
Roof—Cost 12 sq..................	70.00	96.80	166.80
Side Walls—			
18 sq., at $9.55................	54.00	117.90	171.90
Siding and Paper—			
9 sq., at $7.22................	20.00	45.00	65.00
Shingles and Paper—			
8 sq., at $6.50................	17.60	34.40	52.00
Inside Studding	16.00	20.00	36.00
Millwork—6 cellar windows........	3.00	17.10	20.10
Windows—First and second floors:			
Window-frame $1.20			
Sashes 1.75			
Weight .... .38			
Sash-cord .... .20			
Sash-fast .... .25			
Inside casing .... .70			
Stop-beads .... .28			
Labor, 8 hrs., 43¾c........ 3.50			
Cost window in place $8.26			
22 windows, at $8.26........	$77.00	$104.72	$181.72

Doors—Cost per door:	Labor	Material	Both
Door, 2 ft. 6 in. by 6 ft. 8 in. by 1⅜ in., price.........$2.40			
Frame 1.00			
Casings 1.33			
Threshold .... .15			
Nails .... .05			
Hardware 1.25			
Labor, 8 hrs., at 43¾c..... 3.50			
Cost of door in place......$9.68			
15 doors, at $9.68..............	$52.50	$82.70	$145.20
Front Door	4.00	18.73	22.73
Main stairs	15.00	20.00	35.00
Cellar stairs	5.00	7.40	12.40
Porch stairs	5.00	7.00	12.00
Porch columns—4 at $8............	8.00	24.00	32.00
Porch pilasters—2 at $6..........	4.00	8.00	12.00
Porch balustrade	3.50	3.50	7.00
Porch ceiling	8.00	7.00	15.00
Porch cornice—39 ft. at 75c......	8.00	22.00	30.00
Main roof cornice................	23.00	64.00	87.00
Belt-course—85 ft. at 15c........	5.00	7.75	12.75
Water-table—85 ft. at 15c........	5.00	7.75	12.75
Lattice—42 sq. ft., at 15c.......	3.30	3.00	6.30
Corner-boards	5.80	5.00	10.80
China closet	10.00	10.00	20.00
Picture mold—225 ft. at 5c.......	3.00	9.25	12.25
Base—300 ft. at 10c..............	15.00	15.00	30.00
Painting	160.00	40.00	200.00

Summary

Excavation	$ 45.00
Masonry	433.41
Carpentry and hardware...................	1,407.73
Sheet-metal work	184.00
Plastering	235.00
Plumbing and gas-fitting.................	375.66
Heating, hot-air	120.00
Painting	200.00
Total cost	$3,000.80

FORM FOR ESTIMATING CARPENTRY WORK

A form of estimate, arranged in systematic manner and complete in details, is of great value in determining the cost of a given piece of work. A form of this kind is reproduced below (pages 184-7).

The prices given for material and labor must not be considered as applying in all instances and locations, but will serve to show how such a form should be filled out in a similar estimate. Items may be added to or omitted from the list given as the work at hand demands. The scheme is intended to show a complete and systematized method of estimating carpentry, and the different branches usually comprised in the carpenter's bid.

WOOD FLOORING

Wearing Quality. The comparative life of the various woods used as flooring, under ordinary conditions, is indicated as follows, the floor of longest life being mentioned first:

1st, maple; 2d, beech and birch; 4th, oak, quarter-sawed; 5th, yellow pine, quarter-sawed; 6th, fir, quarter-sawed; 7th, oak, plain-sawed; 8th, yellow pine, plain-sawed; 9th, fir, plain-sawed; 10th, Norway pine; 11th, white pine.

Maple, Beech, and Birch Flooring

Grades. After years of experience, the manufacturers have found the designations: **Clear** (for the first grade), **No. 1** (for the second grade), and **Factory** (for the third grade), to be the most convenient and satisfactory to use in the manufacture, grading, and sale of their products; and architects are recommended to employ these established trade names in their specifications, in order to avoid disputes and misunderstandings. These grades should be referred to as **Association Grades.**

Clear has one face free of all defects that will impair its general appearance and durability; but the question of color and mild discoloration is not considered, and an occasional slight discoloration caused by the cross-piece used in piling the rough lumber during the process of air-seasoning is not classified as a defect.

No. 1 admits of tight, sound knots and slight imperfections in dressing, and the more prominent discolorations not admitted in the grade of Clear; and lays without waste.

Factory is of such a character as will lay and give a good serviceable floor for factory, warehouse, and kindred uses.

(Continued on page 187)

Estimate on Three-Story Store, Office and Apartment Building

(Carpenters' and Builders' Association of Chicago)

Size, 44'0"x50'0"—2,200 Area of 1 Floor.

Superficial Feet	Size		Quality and Location	Price Labor	Price Material	Total Labor	Total Material	
126	8/8		Posts in basement					
1,968	3/10	16"	Sized pine, joists 1st floor					
1,725	3/8	16"	" " " " "					
6,600	3/12	12"	" " " 2d "					
1,575	3/12	16"	" " " 3d "					
2,587	3/12	16"	" " " " "					
1,650	2/6	16"	Ceiling joists					
1,575	2/12	16"	Roof "					
2,587	3/12	16"	" "					
825	2/4	16"	Bridging					
6,600	1/6		S. I. S. floor sheeting					
2,750	6"		D. & M. roof "					
250	1/2		S. I. S. floor strips					
1,100	2/2		" " " " "					
400	4/6		Rough lintels					
2,400	1/2		S. I. S. furring and grounds					
4,500	2/4		Sized studding					
850	2/4-1/4		Basement partitions	12.50	24.00	$500.85	$961.63	
40,068								
Rear porches 750'-0" floors and roof				.15	.12½	112.50	93.75	
2,520	3"		Clear maple flooring	20.00	45.00	50.40	113.40	
3,850	3"		" red oak "	25.00	55.00	96.25	211.75	
175	12"		Shelving	25.00	35.00	4.38	6.12	
			51 linear feet store front (no glass)	3.00	8.00	153.00	408.00	
						$917.38		$1,794.65

Super-ficial Feet	Pieces	Quality and Location.	Price Labor	Price Material	Total Labor	Total Material
	7	Batten doors in basement	1.50	.	10.50	
	1	Door 2'8"x6'x1⅜" in basement	2.50	5.50	2.50	5.50
	1	Outside door to basement	2.50	6.25	2.50	6.25
	1	Rear entrance door and frame, store, 1st floor	4.25	10.00	4.25	10.00
	2	Side entrance doors 3'2"x7'2"x2¼" 1st floor	5.25	10.50	10.50	21.00
	2	Store entrance doors and transoms 3'-6"x7'-0"x2¼"	4.00	9.00	8.00	18.00
	1	Vestibule door 3'-2"x7'-2" and plain jamb.			4.25	11.50
	2	Inside doors 2'2"x6'-8"x1⅜"	3.75	6.50	7.50	13.00
	1	Plank frame window 2'-0"x5'-0"			1.25	3.50
	2	Box frame windows 2'-0"x2'x0"	2.50	4.00	5.00	8.00
	1	Box frame window 4'-0"x8'-0"			2.50	7.00
	25	Box frame windows on 2d and 3d floors	3.00	6.50	75.00	162.50
	5	triple windows on 2d and 3d floors	7.50	15.25	37.50	76.25
	9	Inside windows in office partitions	3.25	4.00	29.25	36.00
		Ceiling sash and frame, 3d floor			3.00	5.00
	4	Rear outside doors, frames, and transoms 1¾"	3.75	7.50	15.00	30.00
	17	Doors and transoms, 2d floor	4.50	8.50	76.50	144.50
	2	Entrance door and transoms to flats	4.50	8.80	9.00	17.60
	18	Doors, 3d floor	3.75	7.50	67.50	135.00
	1	Cased opening, 3d floor			1.50	3.50
	2	Pair doors to dining room, 3d floor	5.75	11.75	11.50	23.50
	2	Cased openings with columns, 3d floor	5.00	14.00	10.00	28.00
	2	Sideboards	10.00	45.00	20.00	90.00
	2	Hall trees	4.50	18.00	9.00	36.00

Superficial Feet	Pieces	Quality and Location.	Price Labor	Price Material	Total Labor	Total Material	
	4	Medicine and spice cases	1.50	4.50	6.00	18.00	
	2	Kitchen cupboards	5.00	18.00	10.00	36.00	
1000		Linear feet 3M 10" base	.08	.08	80.00	80.00	
600		Linear feet 3M 6" base	.06½	.05	39.00	30.00	
1000		Linear feet 2M picture mold	.03	.01½	30.00	15.00	
260		Linear feet cornice in dining room, reception hall, and corridors	.12	.09	31.20	23.40	
100		Linear feet plate rail, dining rooms	.10	.08	10.00	8.00	
150		Linear feet burlap strips, dining rooms	.04	.03	6.00	4.50	
400		Linear feet chair rail and burlap strips	.04	.03	16.00	12.00	
500		Linear feet ceiling strips in two parlors	.05	.03½	25.00	17.50	
	2	Mantle shelves	3.00	7.00	6.00	14.00	
170		Linear feet hook strips	.04	.02½	6.80	4.25	
		All labor on carpentry			$1,606.88		$1,154.25
							$1,606.88
	1	Main stairs—1st and 3d floor, $140					
	1	Outside stairs to basement, 18.00					158.00
		Rough hardware					120.00
		Bond and liability insurance					50.00
							$4,876.58
						Add 10% profit	487.65
							$5,364.23

Explanation of Method of Obtaining Quantities of Lumber

In ordering a bill of lumber, it is necessary to take off the lengths of joists, etc.; but in estimating, the following method will be found quicker and less liable to mistakes than the number of pieces and their different lengths.

Run the whole bill into lumber feet, and strike an average price for all rough lumber.

Thus: Take correct measure of floor area, say 44'-0" x 50'-0" = 2,200 sq. ft.

In joists, say	2" x 8"-16" c. c.	=	1	foot of lumber for one square foot of floor area
" " "	2" x 10"-16" c. c.	=	1¼	feet " " " " " " " " "
" " "	2" x 12"-16" c. c.	=	1½	" " " " " " " " " "
" " "	3" x 10"-16" c. c.	=	1⅞	" " " " " " " " " "
" " "	3" x 12"-12" c. c.	=	3	" " " " " " " " " "

In 2x4 studding with ceilings 10'-0", every running foot of partitions takes 10 ft. of lumber. This allows for pieces in firewalls, etc.

In bridging, add ⅓ of length of building to each continuous row.

Thus: 50' add 16' = 66', ⅔ of 66'. 2x4 bridging = 44 ft. of lumber.

In furring and grounds allow 3 feet of lumber for every running foot of furred wall; this allows for grounds, etc.

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*Allowance must be made for doubling under partitions, doubling for trimmers, and headers, extension into walls, lapping on girder, and waste.

Uses of Standard Grades. Clear, or first quality, is suitable for apartment buildings, churches, clubs, dancing floors, gymnasiums, hospitals, hotels, office buildings, public buildings, residences, roller skating rinks, schoolhouses, stores, and similar buildings.

Number one, or second quality, is a common grade. It is just as serviceable as clear, and equally as desirable when there is no objection to the appearance. It can be used in the same class of buildings as the clear grade, at a considerable saving in the cost of construction.

Factory, or third grade, is for use in factories, creameries, granaries, mills, warehouses, workshops, and in similar buildings where a low-priced floor is desired and where great wear is likely to occur.

Thickness and Face Widths. The Maple Flooring Manufacturers' Association issue the following list of thicknesses and face widths for maple, beech, and birch stock:

Thicknesses and Faces of Maple, Beech, and Birch Matched Stock

Standard Thickness	Faces	Grades
13/16″	1½″ 2″ 2¼″ 3¼″	Clear, No. 1, Factory
Special Thicknesses 1-1/16″ 1-5/16″ 1-11/16″	2″ 2¼″ 3¼″	Clear, No. 1, Factory
⅜″	⅞″ 1″ 1½″ 2″ 2¼″	Clear and No. 1 only
½″ ⅝″	1½″ 2″ 2¼″	Clear and No. 1 only

Standard Measurement

⅝″ and thicker, all faces, is measured ¾″ waste for matching.

½″ and thinner, all faces, is measured ½″ waste for matching.

Jointed flooring is measured as the rough lumber from which it is made, ½-in. being added to the face for waste in ripping and dressing to size. For example, 13/16 in. x 3½ in. is measured 1 in. x 4 in.

To Ascertain Quantity of Flooring Required. To ascertain the number of feet of flooring required to cover a given area, find the number of sq. ft. of floor space to be covered, and add thereto the following percentages:

Matched Stock	⅝" and 13/16" Thick	⅜" and ½" Thick
1½" face flooring	50%	33⅓%
2" face flooring	37½%	25%
2¼" face flooring	33⅓%	22½%
3¼" face flooring	24%	not made

Uses of Different Thicknesses and Faces of Flooring The 13/16-in. thickness of maple, birch, and beech flooring is most commonly used. This flooring can be laid directly on the joists, or on strips embedded in cement when the latter is used for fireproofing; but is more frequently laid on a subfloor. For ordinary purposes a subfloor of softwood boards laid diagonally is sufficient. These boards should be surfaced on one or both sides. This subfloor may be used for the work floor during the progress of construction, and the hardwood floor should not be laid until the building is dry.

In the case of warehouse or factory floors where greater strength and slow-burning construction are required, the subfloor should be made of matched softwood boards 1¾-in. thick.

If a floor is to be subjected to extraordinarily hard wear, a thickness of 1-1/16 in. is often used instead of the 13/16-in. hardwood flooring. The 13/16-in. thickness is suitable for ordinary purposes.

The ½-in. thickness of flooring is suitable for ordinary foot wear, and is used in apartment buildings, churches, clubs, offices, and similar buildings. It costs less than the 13/16-in. thickness; and if the subflooring is uneven, the ½-in. thickness will produce more satisfactory results than the ⅜-in.

The ⅜-in. flooring is the most popular thickness under 13/16-in. The sides and ends of the flooring are matched so that it can be laid with the nails entirely concealed. It is suitable for residences, apartment buildings, churches, etc., where appearance and service both count. A cheaper grade of 13/16-in. maple or beech flooring makes an ideal subfloor for the ⅜-in. thickness.

Faces. The 13/16-in. and ½-in. types of flooring are usually preferred in the 2¼-in. face, while the 1½-in. face is preferred in the ⅜-in. thickness. Narrower faces require a larger quantity of flooring to cover a given area, and the labor cost of laying is greater; but the resulting floor is worth the additional investment when appearance is desired. The wider faces usually cost less for material and labor.

Lengths. The standard lengths in the different grades of flooring as put out by the Maple Flooring Manufacturers' Association are as follows:

CLEAR—2 ft. to 16 ft. May contain what 2 ft. to 3½ ft. the rough lumber produces, up to 10 per cent.

NO. 1—1½ ft. to 16 ft. May contain what 1½ ft. to 3½ ft. the rough lumber produces, up to 25 per cent.

FACTORY—1 ft. to 16 ft. May contain what 1 ft. to 3½ ft. the rough lumber produces, up to 50 per cent.

Architects will find it more advantageous to specify and use the standard run of lengths in the different grades, instead of special long lengths, because lengths selected 4 ft. or 6 ft. and longer are much more expensive, without compensating benefits.

Weights. Approximate weights of maple, beech, and birch flooring, per thousand feet board measure, for use in estimating loads, may be taken as 2,100 pounds for 13/16-in. thickness; 1,800 pounds for ⅝-in., and 1,200 pounds for ⅜-in.

Nails for Hardwood Floors

It is necessary that proper nails be used in laying hardwood flooring, in order to prevent splitting the tongue and bruising the face. The Maple Flooring Manufacturers' Association suggests that the best results are obtained by using the following nails and spacing:

3-d. finishing nail for ⅜-in. thick, used 9 in. apart.

3-d. bung-head casing nail for ½-in. thick, used 12 in. apart.

4-d. bung-head casing nail for ⅝-in. thick, used 12 in. apart.

8-d. cut flooring brad for 13/16-in. thick, used 16 in. apart.

10-d. cut flooring brad for 1-1/16-in. thick, used 16 in. apart.

16-d. cut flooring brad for 1-5/16-in. thick, used 16 in. apart.

16-d. cut flooring brad for 1-11/16-in. thick, used 16 in. apart.

The 3 and 4-penny are wire nails, and, on account of the small gauge and medium length, are best adapted to thin flooring. The 8, 10, and 16-penny are steel-cut nails, manufactured especially for laying hardwood flooring.

Oak Flooring

The grades of oak flooring are generally divided into clear, quarter-sawed red or white, for use in high-class residences, hotels, apartments, and club houses.

Sap clear, select, quartered red or white, substituted for clear quartered where a dark finish is desired.

Clear, plain sawed red or white, for use in high-class residences, hotels, apartments, etc.

Select, plain-sawed red or white, for use in medium-priced residence, hotels, schools, etc.

No. 1 common, for use in cheap dwellings, stores, factories, etc.

Factory, for use in warehouses, cheap tenements, etc.

The standard thicknesses and widths of oak flooring are as follows: 13/16-in. thickness in 1½-in. face, 2-in. face, and 2¼-in. face; ⅜-in. thickness in 1½-in. face and 2-in. face.

In using oak flooring, the 1½-in. face makes a better, more serviceable, and handsomer floor than any other width. The shading of the figure of the wood may be blended to better advantage than when wider strips are used. The laying waste in the 13/16-in. by 1½-in. face is less than that with the 2-in. face, since in the 1½-in. face ½-in. is counted for the tongue and groove, whereas in the broader widths ¾-in. is counted. The cost per thousand is less than in the wider widths, which offsets additional cost for labor and laying.

The 2-in. and 2¼-in. faces are the widths more commonly used in 13/16-in. thicknesses; while in ⅜-in. thicknesses, either 1½-in. or 2-in. face is used as the conditions demand.

To Ascertain Quantity of Oak Flooring Required. For a given floor area, multiply the width of floor by the length to find the number of sq. ft.; then add the following percentages:

33⅓%	for	13/16"x1½"
37½%	for	13/16"x2"
33⅓%	for	13/16"x2¼"
33⅓%	for	⅜"x1½"
25%	for	⅜"x2"

The above figures are based on laying flooring straight across the room. Where there are bay windows or other projections to be cut around, allowance should be made for this cutting.

Tables XX to XXI, as compiled by the Nashville Hardwood Flooring Company, will be of use in determining quantities.

TABLE XX

Sizes and Methods of Bundling Oak Flooring

3/8 x 1½ in.	16 pieces to bundle	Counted 1 x 2 in.
3/8 x 2 in.	16 pieces to bundle	Counted 1 x 2½ in.
½ x 2 in.	12 pieces to bundle	Counted 1 x 2½ in.
5/8 x 2¼ in.	12 pieces to bundle	Counted 1 x 3 in.
13/16 x 1½ in.	8 pieces to bundle	Counted 1 x 2 in.
13/16 x 2 in.	8 pieces to bundle	Counted 1 x 2¾ in.
13/16 x 2¼ in.	8 pieces to bundle	Counter 1 x 3 in.
13/16 x 3 in.	6 pieces to bundle	Counted 1 x 3½ in.

To Change Surface Measure to Strip Count

3/8 x 1½ in. face	add 33⅓ per cent	to surface measure
3/8 x 2 in. face	add 25 per cent	to surface measure
½ x 2 in. face	add 25 per cent	to surface measure
5/8 x 2¼ in. face	add 33⅓ per cent	to surface measure
13/16 x 1½ in. face	add 33⅓ per cent	to surface measure
13/16 x 2 in. face	add 37½ per cent	to surface measure
13/16 x 2¼ in. face	add 33⅓ per cent	to surface measure
13/16 x 3 in. face	add 16⅔ per cent	to surface measure

Rules for Figuring Oak Flooring

Each bundle has the length stamped on it. After securing the linear feet bundle measure, use the following rule:

To Secure Strip Count

3/8 x 1½ in.	multiply by 2⅔
3/8 x 2 in.	" " 3⅓
½ x 2 in.	" " 2½
5/8 x 2¼ in.	" " 3
13/16 x 1½ in.	" " 1½
†13/16 x 2 in.	" " 2
13/16 x 2¼ in.	" " 2
13/16 x 3 in.	" " 1¾

To Secure Face Count

3/8 x 1½ in.	" " 2
3/8 x 2 in.	" " 2⅔
½ x 2 in.	" " 2
5/8 x 2¼ in.	" " 2¼
13/16 x 1½ in.	" " 1
13/16 x 2 in.	" " 1⅓
13/16 x 2¼ in.	" " 1½
13/16 x 3 in.	" " 1⅓

†On 2 in. face, after multiplying by 2, deduct 1-12.

1-1/16 in. and 1⅜ in. worked in 2¼ in. and 3 in. face on special orders. Figure as you would 13/16 in., adding ¼ for 1-1/16 in. and ½ for 1⅜ in.

TABLE XXI

Weights of Oak Flooring

5/16 in. parquetry strips	1,200 lbs. per 1,000 ft.
⅜ in. tongued-and-grooved	1,000 lbs. per 1,000 ft.
½ in. tongued-and-grooved	1,200 lbs. per 1,000 ft.
⅝ in. tongued-and-grooved	1,500 lbs. per 1,000 ft.
13/16 in. tongued-and-grooved	2,200 lbs. per 1,000 ft.
13/16 x 3 in. tongued-and-grooved	2,400 lbs. per 1,000 ft.

ESTIMATING COST OF FLOORS

A method of forming an estimate on the cost of floors per square of 100 sq. ft. is shown in the following outline. The prices for material are put in merely to indicate the scheme to be followed, while the labor is based on a wage of 40 cents per hour. A similar estimate could be made for any given locality. The floor estimated has 6 by 8-in. sills and 2 by 8-in. joists spaced 16 in. on centers.

Estimate for Floor

	Material	Labor
Framing lumber, 135 ft., at $25	$ 3.37	$1.00
Rough floor, laid diagonal, 120 ft., at $25	3.00	.85
Yellow pine finish floor, 4 in., 125 ft., at $38	4.75	1.80
Smoothing up, labor	...	1.75
Nails	.50	....
Paper between rough and finished floors	.25	.10
Totals	$11.87	$5.50
Total material and labor		$17.37

A bid based on the above estimate might range from $17.00 to $18.00.

It will be noticed that 120 ft. is figured in the rough floor to cover 100 sq. ft. The rough floor may be of 8-in. shiplap; and in such case one-fifth is added to make up for loss by waste in cutting. With the finish floor, one-fourth is added for the matching and waste in cutting.

The question might arise now, how much should be added to the above figures if the finish floor should be a 2¼-in. face oak floor, smoothed by scraping. The result is as follows:

	Material	Labor
135 ft. ⅞ by 2¼-in. face oak flooring at $80	$10.80	$3.00
Smoothing up, labor	....	2.75
Total	$10.80	$5.75

Now, the cost of the pine floor was $4.75, making a difference of $6.05 a square in the cost of the flooring material. The cost of laying and smoothing the pine floor was $3.55, making a difference of $2.20 in the labor. This makes the total difference for material and labor $8.25 per suare, the amount necessary to add for oak floors well finished up. This is equal to about 47 per cent of the total cost per square of the pine floor, and would bring the total cost of a square of oak floor up to $25.62.

The above figures are perhaps a little high, and it would probably be safe to figure at $25 for the square, or about 40 per cent more for the finished oak floor than for the pine.

None of the above figures include the filling and varnishing, or the profit for the contractor.

TABLE XXII

Allowable Floor Loads in Accordance with the Building Laws of Various Cities

LIVE LOADS FOR FLOORS IN DIFFERENT CLASSES OF BUILDINGS EXCLUSIVE OF THE WEIGHT OF THE MATERIALS OF CONSTRUCTION.	New York 1902	Chicago 1902	Phila-delphia 1902	Boston 1902	San Francisco 1906
	Pounds per Square Foot				
Dwellings, Apartment Houses, Hotels, Tenement Houses or Lodging Houses.	60	40	70	50	60
Office Buildings, (1st floor)..............	150	100	100	100	150
Office Buildings, (above 1st floor).......	75	100	100	100	75
Schools or Places of Instruction........	75			80	75
Stables or Carriage Houses..............	75	40* 100†			75
Buildings for Public Assembly.........	90	100	120	150	125
Buildings for ordinary stores, light manufacturing, and light storage.....	120	100	120		120
Stores for Heavy Materials, Warehouses and Factories..........................	150		150	250	250
Roofs—(Pitch less than 20 degrees).....	50	25	30	25¶	50
Roofs—(Pitch more than 20 degrees)....	30	25	30	25¶	30
Sidewalks..............................	300				300
Public Buildings except Schools........				150	

*Stables less than 500 sq. ft. in area.
†Stables over 500 sq. ft. in area.
¶Make proper allowance for wind at 30 lbs. sq. ft. horizontal.

ESTIMATE AND DETAIL OF CORNICE

A large number of houses are now being built with a wide cornice similar to that shown in Fig. 11. It is quite important that the carpenter and contractor should know somewhere near the cost of construction in such work. The following outline shows the method of figuring the material and labor separately, and in such a manner as to enable the contractor to arrive at approximate prices to suit his own locality. The moldings are taken from the Universal Molding Book, and the numbers and sizes are the same throughout the United States.

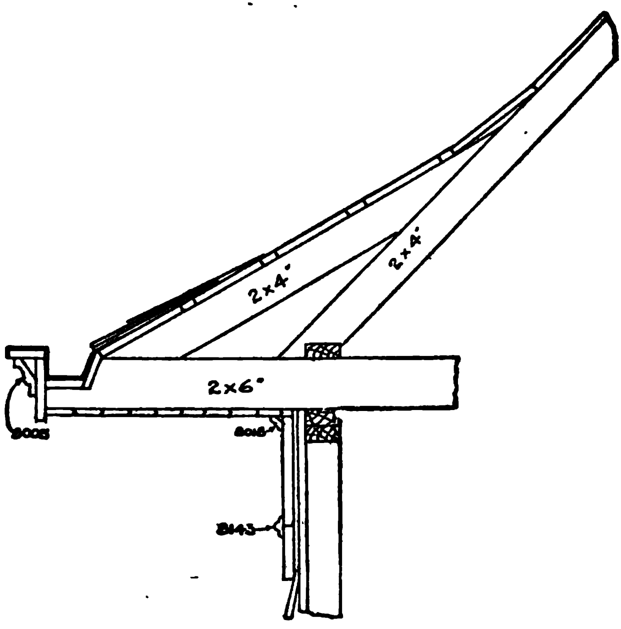


Fig. 11. Lumber Cornice Construction.

The object in the following outline is to figure this cornice by the linear foot, so that a contractor, in estimating, can find the linear feet of cornice the building will require, and then in a very few minutes find the quantity of each kind of material, and what the labor will be worth.

Wages will be figured at 40 cents per hour, but, if different in any locality, a proportional amount may be added or subtracted from the cost given here.

Estimate for Cornice.

	Material	Labor
Gutter cap, per linear foot	$0.01	$0.01¼
Bottom and side pieces	.02	.03
Crown mold	.02¼	.02
Plancher, 9 boards ⅝ by ¾-in. ceiling	.07½	.10
Bed mold	.01¾	.01¼
Frieze, 2 pieces	.07¼	.05
Band mold	.01¼	.01
Gutter tin	.17	....
Total	$0.40	$0.23½
Total, per linear foot, material and labor		$0.63½

Example—For a square house 24 by 30 ft. in size, a cornice of the design shown in Fig. 11 would be estimated as follows: The extreme projection of this cornice is 2 ft. 9 in.; therefore add 5 ft. 6 in. linear measure for each corner. For four corners, this would make 22 ft.; thus, the width and length doubled, plus 22 ft., would make the linear feet of the cornice. For the building in question, this would make 130 ft. net. For the estimate given above, 63½ cents, multiplied by 130, would give $82.55 as the total cost of cornice.

If the labor cost only is wanted, multiply 23½ cents by 130, which gives $30.55. For the cost of material alone, multiply 40 cents by 130, which will give $52.00.

The above figures do not include the framing; they are based on taking the roof all framed and ready for the cornice. The outside measurement is taken in all cases, so as not to run short on material. The prices given on the material are a little high, and just about enough to cover the waste in cutting.

In making out a bill of material for a job of this kind, about 8 per cent should be added for waste in cutting. For example, it would take just 130 ft. of crown mold to reach around the cornice if there were no waste; but since there is some waste in cutting crown molds, adding 8 per cent would give about 10 ft. additional, making 140 ft. to be ordered.

With the bed and band mold, it is slightly different, for these do not project from the building like the crown mold. If 8 per cent is added to the net linear feet around the building, there will be plenty for the job. This would make about 9 ft. to add to actual measurements around the building, thus making 117 ft.

For the ceiling, take the extreme outer measure, and multiply by the width of cornice at the point of ceiling, and then add ¼. This will cover the loss in the matching, and the waste in cutting.

The tin work is usually figured by the linear foot for material for gutters and the labor put in. A cornice of the kind just described will take tin 20 in. wide; and the cost will be about 17 cents per linear foot put in.

These figures are approximately correct, and may serve in estimating material and labor for cornice, even though differing from the design submitted.

CONSTRUCTION AND COST OF DORMER WINDOWS

The estimated cost, in detail, of the dormer, shown in Figs. 12 and 13, is as follows:

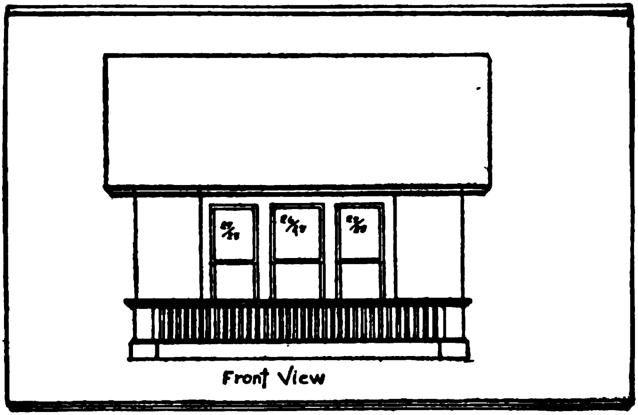


Fig. 12. Dormer Window Construction.

Estimate for Dormer Window

10 pcs. 2 by 4 by 18 16 pcs. 2 by 2 by 14 6 pcs. 2 by 4 by 12	408 ft. at $25..................	$ 10.20
400 ft. No. 2 Y. P. sheathing, $25....................		10.00
2,000 shingles, $3.50..............................		7.00
250 ft. ½ by 4-in. siding, $30......................		7.50
50 ft. 4-in. crown mold, 2c........................		1.00
48 ft. 2-in. bed mold, 1c..........................		.48
2 balcony newels, $1.50............................		3.00
20 ft. balcony rail, 6c............................		1.20

80 balusters, 1⅛ by 1⅛ by 18 in., 3c	2.40
20 ft. base, 5c	1.00
200 ft. ⅝ by 4-in. by 16 ft. for ceiling, 3c	6.00
60 linear ft. 1 by 4-in. fir finish	.75
1 triple window-frame	6.00

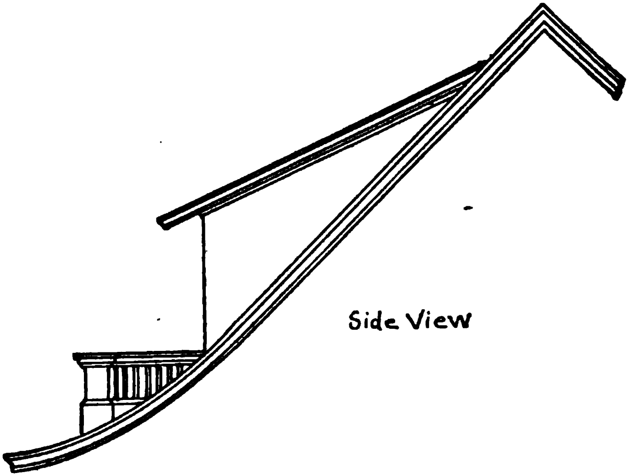


Fig. 13. Dormer Window Construction.

2 windows, 24 by 28, 2 lt., $1.60	3.20
1 window, 26 by 28, 2 lt	1.65
10 ft. window stool, 2c	.20
10 ft. window apron, 2c	.20
24 ft. window casing, 2c	.48
10 ft. head casing, 2c	.20
10 ft. cap mold, 2c	.20
10 ft. fillet, 1c	.10
42 ft. window stops, 1c	.42
84 flashing tins, 1½c	1.26
90 sq. ft. tin, balcony floor	9.00
Sash-cord, weights, and sash-locks	2.50
Carpenter work, 40 hours at 40c	16.00
Plastering sides and ceiling	9.00
Cost of painting	7.00
Total estimated cost	$107.94

In this estimate, no margin is added for incidentals. Nothing is figured for a floor in the room, because the floor is supposed to be there in the average building; but if a floor had to be put in, it would be necessary to figure it. No nails were figured, either—which goes to show very plainly that a dormer window of this kind and size is worth anywhere from $108 to $125, according to the general conditions likely to be met with in this kind of work. The figures given include finishing up the dormer, but not the entire room which might be back of the dormer and for which it is to furnish light.

TREADS AND RISERS FOR STAIRS

For general use in calculating the layout for stairs, the accompanying table, Fig. 14, will be found very handy and useful as a time-saver. The first row of figures running

Number of Risers	RISE OR RUN.																	
1	6½	6¾	7	7⅛	7¼	7⅜	7½	7⅝	7¾	7⅞	8	8¼	8½	9	9½	10	10½	11
2	1'1	1'1½	1'2	1'2¼	1'2½	1'2¾	1'3	1'3¼	1'3½	1'3¾	1'4	1'4½	1'5	1'6	1'7	1'8	1'9	1'10
3	1'7½	1'8¼	1'9	1'9⅜	1'9¾	1'10⅛	1'10½	1'10⅞	1'11¼	1'11⅝	2'0	2'0¾	2'1½	2'3	2'4½	2'6	2'7½	2'9
4	2'2	2'3	2'4	2'4½	2'5	2'5½	2'6	2'6½	2'7	2'7½	2'8	2'9	2'10	3'0	3'2	3'4	3'6	3'8
5	2'8½	2'9¾	2'11	2'11⅝	3'0¼	3'0⅞	3'1½	3'2⅛	3'2¾	3'3⅜	3'4	3'5¼	3'6½	3'9	3'11½	4'2	4'4½	4'7
6	3'3	3'4½	3'6	3'6¾	3'7½	3'8¼	3'9	3'9¾	3'10½	3'11¼	4'0	4'1½	4'3	4'6	4'9	5'0	5'3	5'6
7	3'9½	3'11¼	4'1	4'1⅞	4'2¾	4'3⅝	4'4½	4'5⅜	4'6¼	4'7⅛	4'8	4'9¾	4'11½	5'3	5'6½	5'10	6'1½	6'5
8	4'4	4'6	4'8	4'9	4'10	4'11	5'0	5'1	5'2	5'3	5'4	5'6	5'8	6'0	6'4	6'8	7'0	7'4
9	4'10½	5'0¾	5'3	5'4⅛	5'5¼	5'6⅜	5'7½	5'8⅝	5'9¾	5'10⅞	6'0	6'2¼	6'4½	6'9	7'1½	7'6	7'10½	8'3
10	5'5	5'7½	5'10	5'11¼	6'0½	6'1¾	6'3	6'4¼	6'5½	6'6¾	6'8	6'10½	7'1	7'6	7'11	8'4	8'9	9'2
11	5'11½	6'2¼	6'5	6'6⅜	6'7¾	6'9⅛	6'10½	6'11⅞	7'1¼	7'2⅝	7'4	7'6¾	7'9½	8'3	8'8½	9'2	9'7½	10'1
12	6'6	6'9	7'0	7'1½	7'3	7'4½	7'6	7'7½	7'9	7'10½	8'0	8'3	8'6	9'0	9'6	10'0	10'6	11'0
13	7'0½	7'3¾	7'7	7'8⅝	7'10¼	7'11⅞	8'1½	8'3⅛	8'4¾	8'6⅜	8'8	8'11¼	9'2½	9'9	10'3½	10'10	11'4½	11'1
14	7'7	7'10½	8'2	8'3¾	8'5½	8'7¼	8'9	8'10¾	9'0½	9'2¼	9'4	9'7½	9'11	10'6	11'1	11'8	12'3	12'10
15	8'1½	8'5¼	8'9	8'10⅞	9'0¾	9'2⅝	9'4½	9'6⅜	9'8¼	9'10⅛	10'0	10'3¾	10'7½	11'3	11'10½	12'6	13'1½	13'9
16	8'8	9'0	9'4	9'6	9'8	9'10	10'0	10'2	10'4	10'6	10'8	11'0	11'4	12'0	12'8	13'4	14'0	14'8
17	9'2½	9'6¾	9'11	10'1⅛	10'3¼	10'5⅜	10'7½	10'9⅝	10'11¾	11'1⅞	11'4	11'8¼	12'0½	12'9	13'5½	14'2	14'10½	15'7
18	9'9	10'1½	10'6	10'8¼	10'10½	11'0¾	11'3	11'5¼	11'7½	11'9¾	12'0	12'4½	12'9	13'6	14'3	15'0	15'9	16'6
19	10'3½	10'8¼	11'1	11'3⅜	11'5¾	11'8⅛	11'10½	12'0⅞	12'3¼	12'5⅝	12'8	13'0¾	13'5½	14'3	15'0½	15'10	16'7½	17'5
20	10'10	11'3	11'8	11'10½	12'1	12'3½	12'6	12'8½	12'11	13'1½	13'4	13'9	14'2	15'0	15'10	16'8	17'6	18'4
21	11'4½	11'9¾	12'3	12'5⅝	12'8¼	12'10⅞	13'1½	13'4⅛	13'6¾	13'9⅜	14'0	14'5¼	14'10½	15'9	16'7½	17'6	18'4½	19'3
22	11'11	12'4½	12'10	13'0¾	13'3½	13'6¼	13'9	13'11¾	14'2½	14'5¼	14'8	15'1½	15'7	16'6	17'5	18'4	19'3	20'2
23	12'5½	12'11¼	13'5	13'7⅞	13'10¾	14'1⅝	14'4½	14'7⅜	14'10¼	15'1⅛	15'4	15'9¾	16'3½	17'3	18'2½	19'2	20'1½	21'1
24	13'0	13'6	14'0	14'3	14'6	14'9	15'0	15'3	15'6	15'9	16'0	16'6	17'0	18'0	19'0	20'0	21'0	22'0
25	13'6½	14'0¾	14'7	14'10⅛	15'1¼	15'4⅜	15'7½	15'10⅝	16'1¾	16'4⅞	16'8	17'2¼	17'8½	18'9	19'9½	20'10	21'10½	22'11
26	14'1	14'7½	15'2	15'5¼	15'8½	15'11¾	16'3	16'6¼	16'9½	17'0¾	17'4	17'10½	18'5	19'6	20'7	21'8	22'9	23'10
27	14'7½	15'2¼	15'9	16'0⅜	16'3¾	16'7⅛	16'10½	17'1⅞	17'5¼	17'8⅝	18'0	18'6¾	19'1½	20'3	21'4½	22'6	23'7½	24'9

Fig. 14. Table Giving Number of Treads or Risers of Any Width for Any Size Space.

down the left-hand side represents the number of risers, while the first row running across the top represents either the rise or the width of the tread. Those in the following lines represent either the total rise or run for the number of risers shown in the opposite left-hand column.

Example—Suppose we wish to find the number of risers required in a stairway that is 10 ft. 5½ in. from floor to floor, and we desire to keep the risers as near 7½ in. as possible.

Take 7½ in the top line, and run down the column to the nearest figure to 10 ft. 5½ in. It is 10 ft. 7½ in., and is opposite 17 in the left-hand column. Therefore 17 represents the number of risers; but there is 2 in. left over. This must be divided into 17 parts, and one of these parts subtracted from each riser, which would be nearly ⅛ in. less than 7½ in.

Now look in the next column to the left. In this, the risers are 7⅜ in.; and for 17 risers, the total is found to be 10 ft. 5⅜ in., which is just ⅛ in. short. Thus the risers will be 7⅜ in., plus 1/17 of ⅛ in.

To find the run of the stairs, it must be remembered that there is always one less tread than there are risers. So take 16 in the left-hand column, and trace the figures to the right till you come to the column whose figures at the top represent the desired width of tread. Suppose it to be 9 in.; then it will be found that the run will be 12 ft. If the treads are 9½ in. wide, then the run will be 12 ft. 8 in., and so on for any desired width of tread. Usually there is some leeway in the run; that is, it is not confined to a certain space like the rise from floor to floor. Therefore, a few inches in the run of a straight flight of stairs does not usually make any difference, thus leaving it to the builder to select at once the width of tread desired. When this cannot be done, then the allotted space must be arrived at in the same manner as that given in the above for the risers. But after all, it should be remembered that, while the measurements can be accurately found by the aid of this table, its greatest utility is as a quick reckoner, in laying out the space and proper openings for the finished stair work. In that case it is not necessary to calculate down to the minuteness required in the building of the stairs.

FIGURING BUILDING DEPRECIATION

In a discussion of methods of figuring depreciation, held by the Cleveland Real Estate Board, Mr. D. H. Goldsmith made the following suggestions:

"Depreciation cannot be fixed by any absolute rule. Property depreciates in value from age, use, and occupancy and surroundings. Property occupied by tenants usually depreciates one per cent a year more than when occupied by the owner.

"Redwood lumber will last the longest, though it is not extensively used. White pine, spruce, birch, poplar, and oak come next, while yellow pine and hemlock are the shortest-lived. The kind of lumber used is the first consideration in figuring depreciation. North Carolina pine lacks strength, and warps badly. Southern pine, one of the classes of yellow pine is divided into two sub-classes—long-leaf and short-leaf pine. Short-leaf pine should be used for sheathing and interior work, as it is not so strong as long-leaf pine, the latter containing a lot of resin. Norway pine is practically extinct, yellow pine taking its place. Cypress is best for exterior work, especially that grown in Southern swamps, called 'red cypress.'

"Workmanship comes next. Next, much depends upon the owner. If he is dilatory about making needed repairs, naturally the depreciation is nearly double that of the owner who gives repairs immediate attention. The depreciation is also considerably less if repairs are properly made, rather than in a slipshod sort of way.

"Banks, in making appraisals for loans, base much of the value on the general appearance of a building—if well painted and in good condition. One banker informed me that his bank re-appraises all loans every three years, and that if the property looks neglected it demands that a payment on the loan be made. The general appearance of all the houses on the street also has an influence on the loan.

"That it is important that the owner do needed repairs, is evidenced by the following example: Six years ago my firm sold a 3-family frame dwelling to a widow for $6,900, bringing a rent of $828 annually. The property is located on a main street where land values have increased. We were given charge of this property, though never permitted by the owner to make needed repairs. The result was that when the property was put on the market, after the owner's death, the best offer obtainable was $5,300. We then pointed out to the administrator that some decorating, painting, and carpenter work would bring better results, for paint and paper cover a multitude of deficiencies, and apparently, at least to the casual observer, lessen the percentage of depreciation. These repairs cost about $200, though really $200 more should have been added. The result was we had an offer of $6,500 cash, or, in other words, an advance of $1,000 owing to some of the great depreciation being eliminated, which shows that repairs and depreciation go hand in hand.

"Where owners are negligent, the depreciation is great. If a porch floor commences to rot it is not long before nearly an entire new porch is needed. New stringers, post bases, etc., must be put in to make it safe again.

"In large cities, a frame dwelling occupied by the owner depreciates approximately from 2½ to 3 per cent a year. When occupied by a tenant, approximately 3 to 3½ per cent a year. On cheap frame tenements, about 50 per cent higher is a fair estimate. On frame barns used by the owner, 4½ to 5 per cent is a fair estimate. When used by tenant, 5½ to 6½ per cent, much depending upon the kind of tenant.

"On a poorly constructed dwelling, whether occupied by the owner or tenant, the depreciation is practically double. In smoke belts, the depreciation will be about 50 per cent higher than these figures. In small towns the figures are about the same, except that in towns where there is a great deal of soft coal smoke or acid fumes, 75 per cent should be added.

"The figured longevity of a frame dwelling is 30 years. At that age I have always figured that a house has depreciated about 80 per cent, the remaining 20 per cent being made up of sheeting, bill stuff, foundation, and interior finish. On the house built 20 years ago, I would figure the life as 40 years, lumber being better seasoned before using than at the present time, and more money was put into labor.

"Architectural changes, and people wanting different sizes of rooms, different style, more conveniences, newer patents, and the latest in plumbing and lighting fixtures, make 30 years now a fair basis on which to figure."

"Construction News" recently published the following data giving the average life of the different parts of a frame structure, and the percentage of annual depreciation on same:

Life of Parts, and Depreciation, in a Frame House

	Average Life.	Annual Depreciation.
Plastering	20 yrs.	5 per cent.
Painting, outside	5 "	20 " "
Painting, inside	7 "	14 " "
Shingles	16 "	6 " "
Cornice	40 "	2½ " "
Weather-boarding	30 "	3½ " "
Sheathing	50 "	2 " "
Flooring	20 "	5 " "

Flooring (entirely carpeted)	40	"	2½	"	"
Doors, complete	30	"	3½	"	"
Windows, complete	30	"	3½	"	"
Stairs and newels	30	"	3½	"	"
Base	40	"	2½	"	"
Inside blinds	30	"	3½	"	"
Building hardware	20	"	5	"	"
Outside blinds	16	"	5	"	"
Sills and first joists	15	"	4	"	"
Dimension lumber	50	"	2	"	"
Piazzas or porches	20	"	5	"	"

If this building had been built with brick walls, the average life of the brick would have been about 75 years with a depreciation of about 1 per cent. per year. The life of the plastering would be increased to about 30 years, with an annual depreciation of only 3½ per cent. The life of the sills and first-floor joists would be increased to 40 years, with 2½ per cent. depreciation per year; while the dimension lumber would have about the same life and yearly depreciation as the brick. Other materials would be rated about the same as in the case of the frame building.

STRENGTH OF BEAMS

For calculating strength of beams freely supported at ends, we may use the formula:

$$\frac{pI}{e} = M,$$

TABLE XXIII
Average Safe Working Unit-Stresses in Bending for Timber

	Pounds per Sq. In.
White oak	1,200
Southern long-leaf or Georgia yellow pine	1,200
Short-leaf yellow pine	1,000
Norway pine	800
Cypress	800
California spruce	800
Chestnut	800
Douglas fir	800
California redwood	750
White pine	700
Spruce	700
Eastern fir	700
Cedar	700
Hemlock	600

where p is the unit bending strength of the material in pounds per square inch (see Table XXIII); I is the moment of inertia of the beam cross-section; e is the distance from center of gravity of the beam section to the outer fibers at top or bottom (see Table XXIV for values of I and e); and M is the value of the greatest bending moment as given in Figs. 15 to 15c. All of these quantities should be expressed in pound and inch units.

This formula may be used to find the size of a beam necessary for a given load; to find the load which may be carried by a beam of a given size; or to find the degree of safety which exists in a beam of a given size which is carrying a given load.

Figs. 15 to 15c give the values of M, the maximum bending moment, for four common cases of beams and cantilevers. In each case, W is the total load on the member, in pounds; B is the weight of the beam itself, in pounds; w is the load per inch of length of beam; and a, b, and l are lengths as shown, in inches.

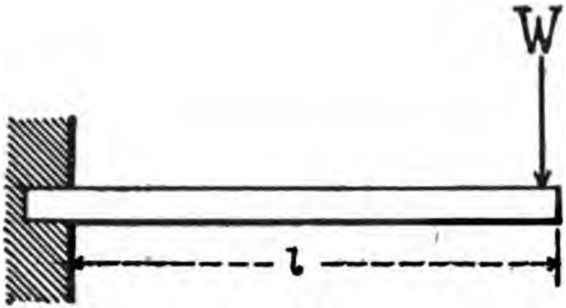
TIMBER COLUMNS

The following formula, called Johnson's parabolic column formula, is very useful in solving problems in regard to timber columns where the value of length divided by least width or thickness is not greater than 60. The ends are

TABLE XXIV

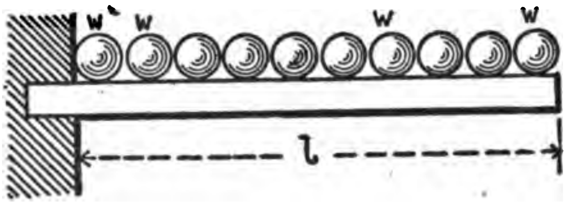
Values of I, e, and Areas of Cross-Section for Use with Common Structural Shapes Shown in Fig. 16

	A	B	C	D	E	F
I	$\frac{a^4}{12}$	$\frac{a^4-m^4}{12}$	$\frac{bh^3}{12}$	$\frac{bh^3-cg^3}{12}$	$\frac{d^4}{20}$	$\frac{d^4-n^4}{20}$
e	$\frac{a}{2}$	$\frac{a}{2}$	$\frac{h}{2}$	$\frac{h}{2}$	$\frac{d}{2}$	$\frac{d}{2}$
Area of Cross-Section	a^2	a^2-m^2	bh	bh−cg	$^{11}/_{14}\, d^2$	$^{11}/_{14}\, (d^2-n^2)$



$$M = Wl + \frac{Bl}{2}$$

Fig. 15. Cantilever with Single Load at End.



$$M = \frac{(W+B)l}{2}$$

Fig. 15A. Cantilever with Uniformly Distributed Load.

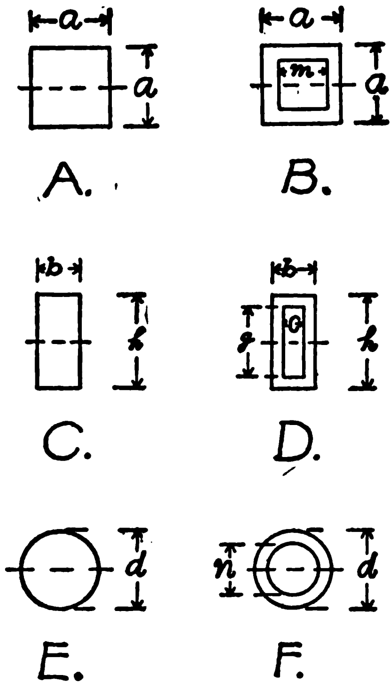
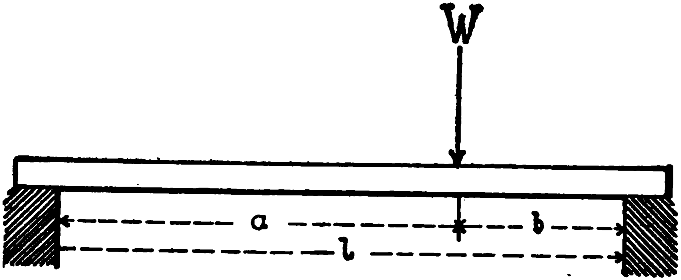


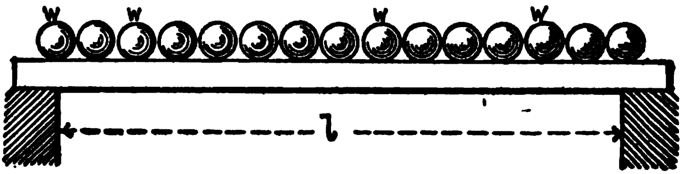
Fig. 16. Common Structural Shapes.

supposed to be flat, held firmly in place; and the load is to be exactly central. For convenience, the same formula is



$$M = \frac{a(2Wb + Bl - Ba)}{2l}$$

Fig. 15B. Freely Supported Beam with Concentrated Load.



$$M = \frac{(W+B)l}{8}$$

Fig. 15C. Freely Supported Beam with Uniformly Distributed Load.

given in four different ways, each way being for a different kind of timber.

For Georgia yellow pine columns—

$$\frac{W}{A} = 4{,}000 - \left[\frac{8}{10} \times \frac{1}{d} \times \frac{1}{d}\right]$$

For short-leaf yellow pine columns—

$$\frac{W}{A} = 3{,}300 - \left[\frac{7}{10} \times \frac{1}{d} \times \frac{1}{d}\right]$$

TABLE XXV

Final Crushing Strength of Building Materials
(Loads on Timber Applied in Direction of Grain)

MATERIAL	Short Column Under 12 Times Least Dimension	Columns over 12 Times Least Dimension
	Lbs. per Sq. In.	Lbs. per Sq. In.
White oak	5,000	7,000
White pine	3,500	5,500
Long-leaf or Georgia yellow pine	5,000	7,000
Douglas fir	4,500	5,700
Short-leaf yellow pine	4,500	6,000
Norway pine	4,000	5,000
Spruce and Eastern fir	4,000	6,000
Hemlock	4,000	....
Cypress	4,000	5,000
Cedar	3,500	5,500
Chestnut	4,000	....
California redwood	4,000	....
California spruce	4,000	....
Cast iron	80,000	70,000
Mild steel	60,000	50,000
Concrete (1:2:4 mixture)	2,000	....

For white oak columns—

$$\frac{W}{A} = 3{,}500 - \left[\frac{8}{10} \times \frac{1}{d} \times \frac{1}{d}\right]$$

For white pine and spruce columns—

$$\frac{W}{A} = 2{,}500 - \left[\frac{6}{10} \times \frac{1}{d} \times \frac{1}{d}\right]$$

In the above formulas, the value of W is the breaking central load, in pounds; A is the sq. in. of area of cross-section of column; l is the length of the column, in inches; and d is the least dimension of the cross-section of the column, in inches.

When there is occasion to use a factor of safety in solving for the working load, as is necessary in all design, divide both parts of the right-hand side of the formula by the factor desired, or leave the equation as it is, and divide the answer for W by the factor.

TABLE XXVI

Safe Unit-Loads for Hollow Round and Rectangular Cast-Iron Columns

(In pounds per square inch of cross-section of column)

Length, in Inches, Divided by Least Value of d	Round	Rectangular	Length, in Inches, Divided by Least Value of d	Round	Rectangular
8	9,259	9,433	23	6,020	6,684
9	9,082	9,293	24	5,814	6,494
10	8,888	9,140	25	5,614	6,305
11	8,688	8,983	26	5,420	6,120
12	8,475	8,811	27	5,233	5,940
13	8,257	8,635	28	5,050	5,764
14	8,032	8,446	29	4,875	5,592
15	7,806	8,257	30	4,706	5,424
16	7,576	8,064	31	4,543	5,260
17	7,347	7,867	32	4,386	5,102
18	7,117	7,670	33	4,235	4,947
19	6,892	7,468	34	4,090	4,797
20	6,666	7,272	35	3,951	4,655
21	6,447	7,076	36	3,817	4,515
22	6,230	6,877			

TABLE XXVII

Average Weight of Timber

Ash	42	lbs. per. cu. ft.
Chestnut	41	" " " "
Hemlock	25	" " " "
Hickory	53	" " " "
Maple	49	" " " "
Oak	32 to 48	" " " "
Pine, Norway	36	" " " "
Pine, white	25	" " " "
Pine, yellow, Northern	34	" " " "
Pine, yellow, Southern	45	" " " "
Spruce	25	" " " "
Walnut	48	" " " "

To find the weight of a board foot of these materials, divide the weight given by 12.

Table XXVIII gives the approximate weights of timber per 1,000 board feet.

TABLE XXVIII

Approximate Weight of Dry Lumber per 1,000 feet, Board Measure

Ash	3,500	lbs.
Chestnut	3,400	"
Hemlock	2,100	"
Hickory	4,400	"
Maple	4,100	"
Oak	4,000	"
Pine, Norway	3,000	"
" , white	2,100	"
" , yellow	3,000	"
Spruce	2,100	"
Walnut	4,000	"

CAST-IRON COLUMNS

Table XXVI contains values for the safe load in pounds per square inch of cross-section of hollow round and rectangular cast-iron columns, as recommended by Kidder's Architects' Pocket-Book. These unit-loads are based on a factor of safety of 8.

To find the total central load which may be carried by a column of a given size, multiply the area of the cross-section of the column by the corresponding unit-load taken from the table. The value d referred to in the table is the least exterior dimension of the column, in inches.

LABOR QUANTITIES IN CARPENTRY

A man will do approximately the following amounts of work in an 8-hour day in common frame buildings:

Base-boards, 1-member, fit	150	linear ft.
" " 2-member, "	125	" "
" " 3-member, "	100	" "

(These quantities are lowered by ⅛ after plaster is put in place.)

Boarding, rough barn work, putting on	1,000	bd. ft.
Bridging, place	40	pairs
Clapboards, cut and lay	250	sq. ft.
Cornices, including scaffolds (2 men)	160	linear ft.
Doors, fit and hang	8	" "
" 1-member casing, case	12	" "
" 2-member " "	8	" "
" fit locks in	12	" "

Flooring, 1"x4", matched, rough cheap work, lay about	700 sq. ft.
Flooring, 1"x6", matched, rough cheap work lay about	900 " "
Flooring, 4", better class of work........300 to	400 " "
" less than 4" ....200 to	300 " "
" hardwood, in small rooms, lay about	150 " "
" " end matched, in large rooms, lay about........	400 " "
" under, place in position............	1,000 " "
Joists, place in position about................	500 bd. ft.
Plaster grounds, place in position..............	400 linear ft.
Rafters, common, place in position............	400 bd. ft.
Sheathing, common, putting on...............	500 sq. ft.
" dressed and matched, putting on..	400 " "
" shiplap, putting on	400 " "
Shelving, pantry ....60 to	70 linear ft.
Shingles, cut and lay........................	1,500
Siding, common, cut and lay	300 sq. ft.
" drop, where joints are made	200 " "
" " window-casing and corner-boards placed over siding	350 " "
Stairs, box, number of risers in height........	6
Studding, place in position..................	500 bd. ft.
Wainscoting, ceiling	200 sq. ft.
" panel work, set up and finish (not make)	150 " "
Windows, 1-member casing, case	12
" 2-member " "	8
" 2-sash, fit and hang	10
Window frames, ordinary, set in place........	14
" " setting and fitting windows 3 to	8

Yellow Pine Construction

DATA FOR DESIGN AND CALCULATION

Since it is claimed that about one-third of the entire lumber output of the United States is Southern yellow pine, the data compiled and tabulated as given in the following pages of this section should be of value to the contractor. This material is reproduced by permission, from the handbook of the Yellow Pine Manufacturers' Association, written by Mr. Arthur T. North, Engineer, of Chicago, Ill.

SAFE LOADS ON YELLOW PINE BEAMS

The tables of **safe loads for yellow pine beams** (actual size) give the safe loads in pounds uniformly distributed for all usual spans, based upon an extreme fibre stress of 1,800 pounds per sq. in.; and the maximum safe load limited by resistance to the horizontal shearing stress along the neutral axis is based on a horizontal shearing stress of 175 pounds per sq. in. The tabular loads include the weight of the beam, which must be deducted to obtain the net external load it will safely carry.

The loads indicated **B** are the safe bending loads in pounds uniformly distributed corresponding to the extreme fibre stress of 1,800 pounds per sq. in.

To convert these loads for other stresses, proceed as follows:

Case I. To find the size of timber required for a given uniformly distributed load, span, and fibre stress—

f = Extreme fibre stress in pounds per sq. in.

For $f = 1{,}000$, given load × 1.8 = new load.
" $f = 1{,}200$, given load × 1.5 = new load.
" $f = 1{,}300$, given load × 1.4 = new load.
" $f = 1{,}400$, given load × 1.3 = new load.
" $f = 1{,}440$, given load × 1.25 = new load.
" $f = 1{,}500$, given load × 1.2 = new load.
" $f = 1{,}600$, given load × 1.13 = new load.
" $f = 1{,}700$, given load × 1.06 = new load.

Find the new load (indicated "**B**") in tables opposite the span; at head of column will be found the required size of beam.

Case II. To convert the loads indicated **B** for other fibre stresses—

f = extreme fibre stress in pounds per sq. in.
For $f = 1,000$, multiply tabular load by .555
" $f = 1,200$, multiply tabular load by .667
" $f = 1,300$, multiply tabular load by .722
" $f = 1,400$, multiply tabular load by .777
" $f = 1,440$, multiply tabular load by .800
" $f = 1,500$, multiply tabular load by .833
" $f = 1,600$, multiply tabular load by .888
" $f = 1,700$, multiply tabular load by .944

If a concentrated load is applied at the center of the span, the safe load is one-half the safe uniformly distributed load for the same span; if two equal concentrated loads are applied at the third-points of the span, the safe load (the sum of the two loads) is three-fourths the safe uniformly distributed load for the same span; two times the safe concentrated load applied at the center of the span is equivalent to the safe uniformly distributed load for the same span; one and one-half times the sum of two equal loads applied at the third-points of the span is equivalent to the safe uniformly distributed load for the same span.

The loads indicated **HS** are the safe uniformly distributed loads in pounds which are limited by the resistance to the horizontal shearing stress along the neutral axis of the beam, and are based on a horizontal shearing stress of 175 pounds per sq. in. These loads are the **maximum** safe uniformly distributed loads that can be applied to the beam for the spans given or for shorter spans.

The loads indicated **D** are the uniformly distributed loads in pounds which produce a deflection of one-thirtieth of an inch per foot of span and are based on a modulus of elasticity of 1,620,000 pounds per sq. in.

A concentrated load .625 times the uniformly distributed load, and applied at the center of the span, will produce the same deflection for the same span; a concentrated load divided into two equal units applied at the third-points of the span .734 times the uniformly distributed load, will produce the same deflection for the same span.

The deflections in inches indicated **DI** are the deflections produced with a load of 1,000 pounds uniformly distributed. The deflection in inches for any uniformly distributed load is obtained by multiplying the deflection indicated **DI** for the proper span, by the number of 1,000-pound units in the given load. For a concentrated load of 1,000 pounds applied at the center of the span, the deflection in inches is 1.6 times the deflection for a 1,000-pound load uniformly distributed over

TABLE XXIX

Safe Loads in Pounds Uniformly Distributed for Yellow Pine Beams

(Actual size)

Beams Supported at Both Ends

(The loads given include the weight of the beam)

Fibre stress 1,800 pounds per sq. in.; horizontal shearing stress, 175 pounds per sq. in.; modulus of elasticity, 1,620,000 pounds per sq. in.

HS indicates the maximum safe load uniformly distributed that can be applied to the beam, and corresponds to the horizontal shearing stress along the neutral axis.

B indicates the safe bending load uniformly distributed, and corresponds to the extreme fibre stress.

D indicates the load uniformly distributed that produces a deflection of one-thirtieth of an inch per foot of span.

D1 indicates the deflection in inches with a load of 1,000 pounds uniformly distributed.

L/30 indicates the deflection in inches which is one-thirtieth of an inch per foot of span.

Nominal Size		2x4	4x4	4x4		2x6	2½x6	3x6	4x6	6x6	L/30
Actual Size		1⅝x 3⅝	3⅝x 3⅝	3½x 3½		1⅝x 5⅝	2x¼ 5½	2¾x 5½	3⅝x 5⅝	5½x 5½	
Span in Feet											
3	HS	1372	3066	2856							.100
	D1	.0581	.0261	.0299							
4	B	1068	2382	2145	HS	2135	2887	3528	4760	7056	
	D	967	1876		D1	.0369	.0389	.0233	.0165	.0116	.133
	D1	.1379	.0618	.0711							
5	B	854	1905	1716	B	2056	2721	3326	4588	6655	
	D	619	1201	1382	D1	.0720	.0759	.0455	.0323	.0227	.166
	D1	.2693	.1206	.1388							
6	B	712	1588	1430	B	1714	2268	2773	3824	5546	
	D	430	834	960	D	1607	1523	2542	3584	5084	.200
	D1	.4651	.2083	.2398	D1	.1244	.1313	.0787	.0558	.0593	
7	B	610	1361	1225	B	1469	1944	2376	3277	4753	
	D	316	613	705	D	1180	1119	1867	2633	3735	.233
	D1	.7384	.3307	.3806	D1	.1977	.2085	.1250	.0886	.0625	
8	B	534	1191	1072	B	1285	1701	2079	2868	4159	
	D	242	469	540	D	904	857	1429	2016	2860	.266
	D1	1.1020	.4938	.5686	D1	.2950	.3112	.1866	.1323	.0932	
9					B	1143	1512	1848	2549	3697	
					D	714	677	1129	1593	2260	.300
					D1	.4202	.4431	.2657	.1883	.1327	
10					B	1028	1361	1663	2294	3327	
					D	578	548	915	1290	1830	.333
					D1	.5767	.6083	.3643	.2584	.1821	
11					B	935	1237	1512	2086	3025	
					D	478	453	756	1066	1513	.366
					D1	.7671	.8094	.4850	.3440	.2423	
12					B	857	1134	1386	1912	2773	
					D	402	381	635	896	1271	.400
					D1	.9950	1.0499	.6299	.4464	.3147	

the same span; for a concentrated load of 1,000 pounds divided into two equal units and applied at the third-points of the span, the deflection is 1.36 times the deflection for a 1,000-pound load uniformly distributed over the same span.

L/30 indicates the deflection in inches which is one-thirtieth of an inch per foot of span.

Sufficient bearing should be provided at the ends of the beams so that the allowable intensity of compression across the grain is not exceeded. This effect may be obtained by the use of metal or hardwood corbels or bearing plates arranged to provide a large bearing area against the softer wood.

TABLE XXIX—(Continued)

Nominal Size		2x8	2½x8	3x8	4x8	6x8	8x8	L/30
Actual Size		1⅝x7½	2¼x7½	2¾x7½	3¾x7½	5½x7½	7½x7½	
Span in Feet								
6	HS	2843	3937	4812	6562	9625	13125	.200
	D1	.0525	.0379	.0310	.0227	.0155	.0114	
7	B	2611	3617	4419	6027	8839	12053	.233
	D1	.0834	.0602	.0493	.0361	.0246	.0181	
8	B	2284	3165	3867	5274	7734	10547	
	D	2142	2966	3625	4944	7251	9888	.266
	D1	.1245	.0899	.0735	.0539	.0368	.0269	
9	B	2031	2813	3437	4688	6875	9375	
	D	1693	2344	2865	3906	5729	7813	.300
	D1	.1772	.1280	.1047	.0768	.0524	.0375	
10	B	1828	2532	3093	4219	6187	8437	
	D	1371	1898	2320	3164	4640	6328	.333
	D1	.2431	.1756	.1437	.1053	.0718	.0527	
11	B	1661	2302	2812	3835	5625	7670	
	D	1133	1569	1918	2615	3835	5230	.366
	D1	.3236	.2337	.1912	.1402	.0956	.0701	
12	B	1526	2110	2578	3516	5156	7031	
	D	952	1318	1612	2197	3223	4394	.400
	D1	.4202	.3035	.2481	.1821	.1241	.0910	
13	B	1406	1948	2380	3246	4759	6490	
	D	811	1123	1373	1873	2746	3744	.433
	D1	.5343	.3859	.3156	.2313	.1578	.1157	
14	B	1306	1809	2210	3014	4420	6027	
	D	700	968	1184	1615	2368	3229	.466
	D1	.6667	.4821	.3941	.2890	.1971	.1445	
15	B	1218	1688	2065	2813	4125	5625	
	D	609	844	1031	1406	2063	2812	.500
	D1	.8210	.5924	.4850	.3556	.2424	.1778	
16	B	1142	1582	1934	2637	3867	5273	
	D	536	742	906	1236	1813	2472	.533
	D1	.9950	.7188	.5887	.4416	.2942	.2158	

Fibre stresses should be modified for moving loads, impact, or other unusual conditions.

TABLE XXIX—(Continued)

Nominal Size.		2x10	2½x10	3x10	4x10	6x10	8x10	10x10	L/30
Actual Size.		1⅝x9½	2⅛x9½	2⅝x9½	3⅝x9½	5½x9½	7½x9½	9½x9½	
Span in Feet.									
8	HS	3601	4987	6097	8312	12190	16625	21056	.266
	D1	.0612	.0442	.0362	.0265	.0181	.0133	.0105	
9	B	3258	4512	5515	7521	11030	15041	19052	.300
	D1	.0872	.0630	.0515	.0378	.0257	.0189	.0149	
10	B	2933	4061	4963	6769	9927	13537	17146	
	D	2786	3858	4715	6430	9431	12860	16290	.333
	D1	.1196	.0864	.0707	.0518	.0353	.0259	.0209	
11	B	2666	3691	4512	6154	9025	12307	15588	
	D	2303	3189	3897	5315	7794	10629	13463	.366
	D1	.1592	.1149	.0941	.0690	.0470	.0345	.0273	
12	B	2444	3384	4136	5641	8273	11281	14289	
	D	1935	2679	3275	4466	6549	8931	11313	.400
	D1	.2067	.1493	.1221	.0896	.6108	.0448	.0353	
13	B	2256	3124	3818	5207	7636	10413	13190	
	D	1648	2283	2790	3805	5581	7610	9639	.433
	D1	.2630	.1898	.1553	.1139	.7765	.0569	.0449	
14	B	2095	2900	3545	4835	7091	9669	12248	
	D	1422	1968	2406	3281	4812	6561	8312	.466
	D1	.3282	.2371	.1939	.1422	.0970	.0711	.0561	
15	B	1955	2707	3309	4513	6618	9025	11431	
	D	1238	1715	2096	2858	4192	5716	7240	.500
	D1	.4133	.2915	.2386	.1750	.1193	.0875	.0691	
16	B	1833	2538	3102	4230	6205	8461	10716	
	D	1089	1507	1842	2511	3684	5024	6363	.533
	D1	.4898	.3539	.2895	.3124	.1447	.1062	.0838	
17	B	1725	2388	2920	3982	5840	7963	10086	
	D	964	1335	1632	2225	3263	4450	5637	.566
	D1	.5878	.4245	.3472	.2547	.1737	.1273	.1005	
18	B	1629	2256	2758	3760	5515	7521	9526	
	D	860	1191	1455	1985	2911	3969	5028	.600
	D1	.6977	.5038	.4124	.3023	.2061	.1512	.1193	
19	B	1544	2137	2612	3563	5225	7125	9025	
	D	772	1069	1306	1782	2613	3563	4513	.633
	D1	.8204	.5925	.4849	.3554	.2424	.1782	.1403	
20	B	1466	2030	2481	3384	4964	6768	8573	
	D	697	965	1179	1608	2358	3215	4073	.666
	D1	.9565	.6908	.5655	.4146	.2827	.2074	.1637	

TABLE XXIX—(Continued)

Nominal Size		2x12	2½x12	3x12	4x12	6x12	8x12	10x12	12x12	L/30
Actual Size		1⅝x 11½	2¼x 11½	2¾x 11½	3¾x 11½	5½x 11½	7½x 11½	9½x 11½	11½x 11½	
Span in Feet										
9	HS	4361	6037	7378	10062	14756	20125	25490	30856	
	D1	.0492	.0355	.0291	.0213	.0145	10.06	.0084	.0069	.300
10	B	4298	5951	7273	9919	14547	19837	25127	30417	
	D1	.0674	.0487	.0398	.0292	.0199	.0146	.0115	.0095	.333
11	B	3908	5409	6612	9017	13225	18034	22842	27652	
	D1	.0897	.0648	.0530	.0389	.0265	.0194	.0153	.0127	.366
12	B	3582	4959	6061	8266	12123	16531	20939	25348	
	D	3432	4752	5808	7921	11617	15842	20067	24292	.400
	D1	.1165	.0842	.0689	.0505	.0344	.0252	.0199	.0165	
13	B	3306	4577	5595	7630	11190	15259	19328	23398	
	D	2924	4050	4949	6750	9899	13499	17098	20698	.433
	D1	.1482	.1070	.0875	.0642	.0438	.0321	.0253	.0209	
14	B	3070	4250	5195	7085	10391	14169	17948	21727	
	D	2521	3490	4267	5820	8536	11639	14743	17847	.466
	D1	.1851	.1336	.1094	.0802	.0547	.0401	.0316	.0261	
15	B	2865	3968	4849	6613	9698	13225	16751	20278	
	D	2196	3042	3717	5070	7435	10139	12843	15547	.500
	D1	.2277	.1644	.1345	.0986	.0672	.0493	.0389	.0321	
16	B	2686	3719	4546	6199	9092	12398	15705	19011	
	D	1931	2673	3267	4456	6535	8911	11288	13664	.533
	D1	.2762	.1995	.1632	.1197	.0816	.0598	.0483	.0390	
17	B	2528	3500	4278	5835	8557	11669	14780	17892	
	D	1710	2368	2894	3947	5789	7894	9999	12104	.566
	D1	.3314	.2393	.1958	.1436	.0979	.0718	.0567	.0468	
18	B	2388	3306	4041	5510	8082	11021	13959	16898	
	D	1525	2112	2582	3521	5164	7041	8919	10796	.600
	D1	.4934	.2841	.2324	.1704	.1162	.0852	.0673	.0556	
19	B	2262	3132	3923	5221	7656	10441	13224	16009	
	D	1369	1896	2317	3160	4634	6319	8005	9690	.633
	D1	.4626	.3340	.2733	.2004	.1367	.1002	.0791	.0654	
20	B	2149	2975	3636	4959	7274	9918	12564	15209	
	D	1236	1711	2091	2852	4182	5703	7224	8745	.666
	D1	.5519	.3896	.3188	.2337	.1594	.1169	.0923	.0762	
21	B	2047	2834	3463	4724	6927	9446	11965	14485	
	D	1121	1552	1897	2587	3794	5173	6552	7932	.700
	D1	.6244	.4510	.3690	.2706	.1845	.1353	.1068	.0882	
22	B	1954	2705	3306	4509	6612	9017	11421	13826	
	D	1021	1414	1728	2357	3457	4714	5970	7227	.733
	D1	.7183	.5186	.4244	.3111	.2121	.1556	.1228	.1015	
23	B	1869	2587	3162	4313	6325	8625	10925	13225	
	D	934	1294	1581	2156	3163	4313	5463	6612	.766
	D1	.8208	.5925	.4849	.3556	.2424	.1778	.1403	.1159	
24	B	1791	2479	3031	4133	6061	8265	10469	12674	
	D	858	1188	1452	1980	2904	3961	5017	6073	.800
	D1	.9324	.6734	.5510	.4040	.2754	.2019	.1594	.1317	

TABLE XXIX—(Continued)

Nominal Size		2x14	2½x-14	3x14	4x14	6x14	8x14	10x14	12x14	14x14	L/30
Actual Size		1¾x 13½	2¼x 13½	2¾x 13½	3¾x 13½	5½x 13½	7½x 13½	9½x 13½	11½x 13½	13½x 13½	
Span in Feet 11	HS	5512	7087	8662	11812	17325	23625	29925	36225	42525	
	D1	.0515	.0401	.0328	.0240	.0164	.0120	.0095	.0078	.0067	.366
12	B	5316	6834	8353	11391	16710	22781	28856	34931	41006	
	D1	.0669	.0520	.0426	.0312	.0213	.0156	.0123	.0102	.0087	.400
13	B	4907	6308	7710	10515	15425	21028	26636	32244	37852	
	D1	.0850	.0661	.0541	.0397	.0271	.0198	.0156	.0129	.0110	.433
14	B	4556	5858	7159	9764	14323	19526	24734	29941	35148	
	D	4393	5649	6904	9415	13808	18829	23850	28871	33893	.466
	D1	.1062	.0826	.0676	.0496	.0338	.0248	.0170	.0162	.0137	
15	B	4253	5467	6682	9113	13368	18225	23085	27945	32805	
	D	3827	4921	6014	8201	12028	16401	20776	25150	29524	.500
	D1	.1306	.1016	.0831	.0610	.0415	.0305	.0241	.0198	.0169	
16	B	3987	5126	6264	8543	12532	17086	21642	26198	30754	
	D	3364	4325	5286	7208	10572	14416	18260	22105	25949	.533
	D1	.1585	.1233	.1009	.0740	.0504	.0370	.0292	.0241	.0205	
17	B	3753	4824	5896	8041	11790	16081	20369	24657	28945	
	D	2980	3831	4682	6385	9364	12770	16175	19580	22986	.566
	D1	.1902	.1497	.1210	.0887	.0605	.0444	.0350	.0289	.0246	
18	B	3544	4556	5568	7594	11140	15187	19237	23287	27337	
	D	2658	3417	4177	5695	8353	11391	14428	17465	20503	.600
	D1	.2254	.1756	.1437	.1053	.0718	.0527	.0416	.0343	.0292	
19	B	3358	4316	5275	7194	10554	14388	18225	22062	25898	
	D	2385	3067	3748	5112	7497	10223	12949	15675	18402	.633
	D1	.2655	.2065	.1689	.1239	.0845	.0619	.0489	.0404	.0344	
20	B	3190	4100	5012	6834	10026	13688	17313	20958	24604	
	D	2153	2768	3383	4613	6766	9227	11686	14147	16608	.666
	D1	.3097	.2408	.1971	.1445	.0985	.0723	.0570	.0471	.0401	
21	B	3038	3905	4773	6509	9549	13018	16489	19960	23432	
	D	1953	2511	3069	4184	6137	8369	10600	12831	15063	.700
	D1	.3585	.2788	.2281	.1673	.1141	.0836	.0660	.0545	.0465	
22	B	2900	3728	4556	6213	9114	12426	15740	19053	22367	
	D	1779	2288	2796	3813	5592	7625	9659	11692	13725	.733
	D1	.4122	.3206	.2623	.1923	.1311	.0962	.0759	.0627	.0534	
23	B	2774	3566	4358	5943	8718	11886	15055	18225	21394	
	D	1628	2093	2558	3488	5116	6977	8837	10697	12557	.766
	D1	.4710	.3663	.2997	.2198	.1498	.1099	.0867	.0717	.0610	
24	B	2658	3417	4176	5695	8355	11390	14428	17465	20503	
	D	1495	1922	2350	3204	4699	6407	8116	9825	11533	.800
	D1	.5351	.4162	.3405	.2497	.1703	.1249	.0986	.0814	.0694	
25	B	2552	3280	4009	5468	8021	10935	13851	16767	19683	
	D	1378	1772	2165	2952	4330	5905	7480	9054	10629	.833
	D1	.6048	.4704	.3849	.2822	.1924	.1411	.1114	.0920	.0784	
26	B	2454	3154	3855	5257	7712	10514	13318	16122	18926	
	D	1274	1638	2002	2730	4004	5460	6915	8371	9827	.866
	D1	.6804	.5292	.4329	.3175	.2165	.1588	.1253	.1035	.0882	
27	B	2363	3037	3712	5063	7427	10125	12825	15525	18225	
	D	1181	1519	1856	2531	3713	5062	6412	7763	9112	.900
	D1	.7619	.5926	.4848	.3555	.2424	.1778	.1403	.1159	.0987	
28	B	2278	2929	3579	4882	7161	9763	12367	14970	17574	
	D	1098	1412	1726	2354	3452	4707	5963	7218	8474	.933
	D1	.8498	.6609	.5407	.3965	.2704	.1983	.1565	.1293	.1101	

TABLE XXIX—(Continued)

Nominal Size		2x16	2½x16	3x16	4x16	6x16	$L/_{30}$
Actual Size		1¾x15½	2¼x15½	3¾x15½	3¾x15½	5½x15½	
Span in Feet							
13	HS	6328	8187	9947	13562	19890	
	D1	.0562	.0437	.0357	.0262	.0178	.433
14	B	6008	7723	9438	12870	18877	
	D1	.0702	.0546	.0446	.0327	.0223	.466
15	B	5608	7208	8809	12013	17618	
	D1	.0863	.0671	.0549	.0403	.0274	.500
16	B	5257	6757	8258	11262	16517	
	D	5091	6546	8001	10909	16001	.533
	D1	.1047	.0815	.0666	.0489	.0333	
17	B	4948	6360	7772	10599	15546	
	D	4510	5798	7087	9664	14174	.566
	D1	.1256	.0977	.0799	.0586	.0399	
18	B	4673	6006	4731	10010	14682	
	D	4023	5172	6322	8620	12643	.600
	D1	.1492	.1160	.0949	.0696	.0474	
19	B	4427	5690	6954	9484	13909	
	D	3610	4642	5673	7737	11347	.633
	D1	.1754	.1364	.1116	.0818	.0558	
20	B	4206	5406	6606	9009	13214	
	D	3258	4189	5120	6982	10241	.666
	D1	.2046	.1591	.1302	.0955	.0651	
21	B	4006	5148	6292	8580	12585	
	D	2956	3800	4644	6333	9289	.700
	D1	.2368	.1842	.1507	.1105	.0753	
22	B	3824	4914	6006	8190	12012	
	D	2693	3462	4232	5770	8463	.733
	D1	.2723	.2118	.1733	.1271	.0866	
23	B	3657	4701	5745	7834	11490	
	D	2464	3168	3872	5280	7743	.766
	D1	.3112	.2420	.1980	.1452	.0990	
24	B	3505	4505	5505	7508	11012	
	D	2263	2909	3556	4849	7112	.800
	D1	.3535	.2750	.2250	.1650	.1125	
25	B	3365	4325	5285	7208	10571	
	D	2085	2681	3277	4469	6554	.833
	D1	.3996	.3108	.2543	.1865	.1271	
26	B	3235	4159	5082	6930	10164	
	D	1928	2479	3030	4132	6060	.866
	D1	.4495	.3496	.2860	.2099	.1430	
27	B	3116	4004	4894	6674	9788	
	D	1788	2299	2810	3831	5619	.900
	D1	.5034	.3915	.3203	.2349	.1602	
28	B	3004	3861	4719	6435	9438	
	D	1663	2137	2622	3562	5225	.933
	D1	.5614	.4367	.3573	.2620	.1786	
29	B	2901	3728	4556	6214	9113	
	D	1550	1993	2436	3321	4871	.966
	D1	.6238	.4851	.3969	.2911	.1984	
30	B	2804	3604	4404	6006	8809	
	D	1448	1862	2276	3103	4551	1.000
	D1	.6905	.5371	.4394	.3222	.2197	

TABLE XXIX—(Continued)

Nominal Size		8x16	10x16	12x16	14x16	16x16	L/30
Actual Size		7½x15½	9½x15½	11½x15½	13½x15½	15½x15½	
Span in Feet							
13	HS	27125	34359	41590	48825	56056	
	D1	.0131	.0103	.0085	.0073	.0063	.433
14	B	25741	32605	39469	46334	53199	
	D1	.0164	.0129	.0107	.0091	.0079	.466
15	B	24025	40431	36838	43245	49652	
	D1	.0201	.0159	.0131	.0112	.0097	.500
16	B	22524	25829	34536	40542	46549	
	D	21820	27638	33457	39275	45094	.533
	D1	.0244	.0193	.0159	.0136	.0118	
17	B	21198	26851	32504	38157	43811	
	D	19328	24482	29636	34791	39945	.566
	D1	.0293	.0231	.0191	.0163	.0142	
18	B	20021	25359	30698	36037	41377	
	D	17240	21837	26435	31032	35630	.600
	D1	.0348	.0275	.0227	.0193	.0168	
19	B	18967	24025	29083	34141	39199	
	D	15473	19599	23725	27852	31978	.633
	D1	.0409	.0323	.0267	.0227	.0198	
20	B	18019	22824	27629	32434	37239	
	D	13965	17688	21412	25136	28860	.666
	D1	.0477	.0377	.0311	.0265	.0231	
21	B	17161	21736	26313	30889	35466	
	D	12666	16044	19422	22799	26177	.700
	D1	.0553	.0436	.0360	.0307	.0267	
22	B	16381	20749	25117	29485	33854	
	D	11541	14618	17696	20774	23851	.733
	D1	0635	.0502	.0414	.0353	.0307	
23	B	15668	19846	24025	28203	32382	
	D	10559	13375	16191	19006	21822	.766
	D1	.0726	.0573	.0473	.0403	.0351	
24	B	15015	19019	23024	27028	31033	
	D	9698	12283	14869	17456	20042	.800
	D1	.0825	.0651	.0538	.0458	.0418	
25	B	14415	18259	22103	25947	29791	
	D	8938	11320	13704	16087	18470	.833
	D1	.0932	.0736	.0608	.0518	.0451	
26	B	13861	17556	21235	24949	28645	
	D	8263	10466	12670	14873	17077	.866
	D1	.1049	.0828	.0684	.0583	.0507	
27	B	13347	16906	20466	24025	27584	
	D	7662	9706	11749	13792	15836	.900
	D1	.1174	.0927	.0766	.0652	.0568	
28	B	12870	16302	19735	23167	26599	
	D	7125	9025	10924	12825	14724	.933
	D1	.1310	.1034	.0854	.0728	.0634	
29	B	12427	15740	19054	23368	25682	
	D	6642	8413	10184	11952	13726	.966
	D1	.1456	.1149	.0949	.0809	.0704	
30	B	12012	15216	18419	21622	24826	
	D	6202	7862	9517	11172	12827	1.000
	D1	.1611	.1272	.1051	.0895	.0779	

TABLE XXIX—(Continued)

Nominal Size		2x18	2½x18	3x18	4x18	6x18	8x18	
Actual Size		1¾x17½	2¼x17½	2¾x17½	3¾x17½	5½x17½	7½x17½	L/30
Span in Feet								
15	HS	7147	9187	11228	15312	22459	30625	
	D1	.0599	.0466	.0382	.0279	.0191	.0143	.500
16	B	6699	8613	10527	14356	21055	28711	
	D1	.0728	.0566	.0463	.0339	.0231	.0169	.533
17	B	6305	8106	9908	13511	19816	27022	
	D1	.0873	.0679	.0555	.0407	.0278	.0204	.566
18	B	5954	7656	9356	12760	18715	25521	
	D	5790	7444	9098	12406	18195	24812	.600
	D1	.1036	.0806	.0659	.0483	.0329	.0242	
19	B	5641	7253	8865	12089	17730	24177	
	D	5196	6681	8165	11134	16330	22269	.633
	D1	.1219	.0948	.0775	.0569	.0388	.0284	
20	B	5359	6890	8421	11484	16844	22968	
	D	4690	6029	7369	10049	14738	20098	.666
	D1	.1422	.1106	.0904	.0663	.0452	.0332	
21	B	5104	6562	8020	10738	16042	21875	
	D	4254	5469	6684	9115	13368	18229	.700
	D1	.1646	.1280	.1047	.0768	.0523	.0384	
22	B	4872	6264	7656	10440	15312	20880	
	D	3876	4983	6090	8305	12180	16609	.733
	D1	.1892	.1472	.1204	.0883	.0602	.0441	
23	B	4660	5991	7323	9986	14647	19973	
	D	3546	4559	5572	7598	11144	15197	.766
	D1	.2162	.1643	.1376	.1009	.0688	.0504	
24	B	4466	5742	7018	9570	14036	19140	
	D	3257	4187	5118	6978	10235	13956	.800
	D1	.2456	.1911	.1563	.1146	.0782	.0573	
25	B	4287	5512	6737	9188	13475	18375	
	D	3001	3859	4716	6431	9433	12862	.833
	D1	.2777	.2159	.1767	.1296	.0883	.0648	
26	B	4122	5300	6478	8834	12957	17668	
	D	2775	3568	4361	5946	8721	11892	.866
	D1	.3123	.2429	.1987	.1457	.0994	.0729	
27	B	3970	5104	6238	8507	12477	17014	
	D	2573	3308	4043	5514	8087	11027	.900
	D1	.3498	.2720	.2226	.1632	.1113	.0816	
28	B	3828	4922	6015	8203	12031	16406	
	D	2392	3076	3760	5127	7520	10254	.933
	D1	.3902	.3034	.2482	.1820	.1241	.0910	
29	B	3696	4752	5808	7920	11616	15841	
	D	2230	2868	3505	4780	7010	9559	.966
	D1	.4334	.3371	.2758	.2022	.1379	.1011	
30	B	2573	4594	5314	7656	11229	15312	
	D	2085	2680	3275	4466	6550	8932	1.000
	D1	.4798	.3732	.3053	.2239	.1526	.1119	
31	B	3457	4445	5433	7409	10867	14818	
	D	1952	2510	3067	4183	6134	8365	1.033
	D1	.5294	.4117	.3369	.2470	.1684	.1235	
32	B	3349	4306	5263	7178	10527	14355	
	D	1832	2355	2879	3925	5757	7851	1.066
	D1	.5823	.4529	.3621	.2717	.1853	.1358	

TABLE XXIX—(Concluded)

Nominal Size		10x18	12x18	14x18	16x18	18x18		20x20	L/30
Actual Size		9½x 17½	11½x 17½	13½x 17½	15½x 17½	17½x 17½		19½x 19½	
Span in Feet									
15	HS	38790	46959	55125	63290	71456			.500
	D1	.0110	.0091	.0077	.0067	.0059			
16	B	36367	44024	51679	59336	66992	HS	88725	
	D1	.0134	.0111	.0094	.0082	.0073	D1	.0047	.533
17	B	34227	41434	48639	55845	63051	B	87234	
	D1	.0161	.0133	.0113	.0094	.0087	D1	.0056	.566
18	B	32326	39132	45938	52743	59549	B	82388	
	D	31428	38045	44661	51278	57894	D1	.0066	.600
	D1	.0191	.0157	.0134	.0117	.0103			
19	B	30624	37072	43520	49966	56414	B	78051	
	D	28207	34145	40084	46022	51961	D1	.0078	.633
	D1	.0224	.0185	.0158	.0137	.0122			
20	B	29094	35219	41344	47469	53594	B	74148	
	D	25457	30816	36175	41535	46894	D	72295	.666
	D1	.0262	.0216	.0184	.0160	.0142	D1	.0092	
21	B	27708	33542	39375	45208	51042	B	70618	
	D	23090	27951	32812	37673	42534	D	65574	.700
	D1	.0303	.0250	.0213	.0186	.0164	D1	.0107	
22	B	26449	32017	37585	43153	48721	B	67408	
	D	21039	25468	29897	34327	38756	D	59748	.733
	D1	.0348	.0288	.0245	.0213	.0189	D1	.0123	
23	B	25299	30625	35951	41277	46603	B	64477	
	D	19249	23301	27354	31407	35459	D	54665	.766
	D1	.0398	.0329	.0280	.0244	.0216	D1	.0140	
24	B	24245	29349	34453	39557	44661	B	61790	
	D	17678	21400	25122	28844	32566	D	50205	.800
	D1	.0452	.0374	.0318	.0277	.0245	D1	.0159	
25	B	23275	28175	33075	37975	42875	B	59319	
	D	16292	19722	23152	26528	30012	D	46269	.833
	D1	.0511	.0422	.0360	.0313	.0277	D1	.0180	
26	B	22379	27091	31803	36514	41226	B	57037	
	D	15063	18234	21406	24577	27749	D	42778	.866
	D1	.0575	.0475	.0405	.0353	.0312	D1	.0202	
27	B	21551	26088	30625	35162	39699	B	54925	
	D	13968	16909	19849	22790	25731	D	39668	.900
	D1	.0644	.0532	.0453	.0395	.0350	D1	.0227	
28	B	20781	25156	29531	33906	38281	B	52964	
	D	12988	15723	18457	21191	23925	D	36885	.933
	D1	.0718	.0594	.0506	.0440	.0390	D1	.0253	
29	B	20064	24289	28513	32737	36961	B	51137	
	D	12108	14657	17206	19755	22304	D	34385	.966
	D1	.0798	.0659	.0562	.0489	.0433	D1	.0281	
30	B	19396	23479	27562	31646	35729	B	49432	
	D	11314	13696	16078	18460	20842	D	32132	1.000
	D1	.0884	.0730	.0622	.0542	.0480	D1	.0311	
31	B	18770	22722	26673	30625	34577	B	47838	
	D	10596	12827	15057	17288	19519	D	30091	1.033
	D1	.0975	.0805	.0686	.0598	.0529	D1	.0343	
32	B	18184	22012	25840	29668	33496	B	46343	
	D	9944	12038	14131	16224	18318	D	28240	1.066
	D1	.1072	.0886	.0755	.0657	.0582	D1	.0377	

TABLE XXX

Maximum Bending Moments in Foot-Pounds for Yellow Pine Beams

(Actual Size)

Methods for calculating bending moments are shown in Fig. 15 to 15C.

Nominal Size	Actual Size	MAXIMUM BENDING MOMENT, IN FOOT-POUNDS					
		Fibre Stress 1200 lbs. per Sq. In.	Fibre Stress 1300 lbs. per Sq. In.	Fibre Stress 1400 lbs. per Sq. In.	Fibre Stress 1500 lbs. per Sq. In.	Fibre Stress 1600 lbs. per Sq. In.	Fibre Stress 1800 lbs. per Sq. In.
2 x 4	1⅝x 3⅝	356	385	415	444	474	534
4 x 4	3⅝x 3⅝	794	860	926	992	1058	1190
4 x 4	3½x 3½	715	774	834	393	953	1072
2 x 6	1⅝x 5⅝	857	928	1000	1071	1143	1285
2½x 6	2¼x 5½	1134	1228	1323	1417	1512	1701
3 x 6	2¾x 5½	1386	1501	1617	1732	1848	2079
4 x 6	3⅝x 5⅝	1912	2071	2231	2390	2549	2868
6 x 6	5½x 5½	2773	3004	3235	3466	3697	4159
2 x 8	1⅝x 7½	1523	1650	1777	1904	2031	2284
2½x 8	2¼x 7½	2110	2285	2462	2637	2813	3165
3 x 8	2¾x 7½	2578	2793	3008	3222	3437	3867
4 x 8	3¾x 7½	3516	3809	4002	4395	4588	5174
6 x 8	5½x 7½	5156	5585	6015	6445	6875	7734
8 x 8	7½x 7½	7031	7616	8202	8787	9373	10545
2 x10	1⅝x 9½	2444	2648	2851	3055	3259	3666
2½x10	2¼x 9½	3384	3666	3948	4230	4512	5076
3 x10	2¾x 9½	4136	4480	4825	5170	5515	6204
4 x10	3¾x 9½	5641	6110	6581	7050	7521	8461
6 x10	5½x 9½	8273	8962	9652	10341	11031	12409
8 x10	7½x 9½	11281	12221	13161	14100	15041	16921
10 x10	9½x 9½	14289	15480	16671	17862	19053	21435
2 x12	1⅝x11½	3582	3880	4179	4477	4776	5373
2½x12	2¼x11½	4958	5271	5784	6197	6610	7436
3 x12	2¾x11½	6060	6565	7070	7575	8080	9090
4 x12	3¾x11½	8266	8955	9644	10332	11021	12399
6 x12	5½x11½	12123	13133	14144	15153	16164	18185
8 x12	7½x11½	16531	17908	19286	20664	22041	24796
10 x12	9½x11½	20939	22683	24429	29174	27919	31408
12 x12	11½x11½	25348	27460	29572	31684	33796	38020
2 x14	1¾x13½	5316	5759	6202	6645	7088	7974
2½x14	2¼x13½	6834	7403	7972	8542	9112	10251
3 x14	2¾x13½	8353	9049	9745	10441	11137	12529
4 x14	3¾x13½	11391	12340	13289	14238	15188	17086
6 x14	5½x13½	16710	18102	19495	20887	22280	25065
8 x14	7½x13½	22781	24679	26578	28476	30375	34174
10 x14	9½x13½	28856	31261	33665	36071	38474	43284
12 x14	11½x13½	34931	37841	40753	43664	46775	52396
14 x14	13½x13½	41006	44423	47840	51257	54674	61508
2 x16	1¾x15½	7010	7594	8178	8762	9347	10515
2½x16	2¼x15½	9010	9760	10512	11262	12013	13515
3 x16	2¾x15½	11011	11928	12846	13763	14681	16516
4 x16	3¾x15½	15016	16267	17519	18770	20021	22524
6 x16	5½x15½	22023	23858	25693	27528	29363	33033

TABLE XXX—(Concluded)

Nominal Size	Actual Size	MAXIMUM BENDING MOMENT, IN FOOT-POUNDS					
		Fibre Stress 1200 lbs. per Sq. In.	Fibre Stress 1300 lbs. per Sq. In.	Fibre Stress 1400 lbs. per Sq. In.	Fibre Stress 1500 lbs. per Sq. In.	Fibre Stress 1600 lbs. per Sq. In.	Fibre Stress 1800 lbs. per Sq. In.
8 x16	7½x15½	30031	32533	35036	37538	40041	45046
10 x16	9½x15½	38039	41208	44379	47548	50719	57058
12 x16	11½x15½	46048	49885	53723	57560	61397	69072
14 x16	13½x15½	54056	58560	63065	67569	72075	81084
16 x16	15½x15½	62065	67237	72409	77581	82753	93097
2 x18	1⅝x17½	8932	9676	10421	11165	11909	13398
2½x18	2⅛x17½	11484	12441	13398	14355	15312	17226
3 x18	2⅝x17½	14036	15205	16375	17545	18715	21054
4 x18	3⅝x17½	19141	20736	22331	23926	25521	28711
6 x18	5½x17½	28073	30412	32752	35091	37431	42109
8 x18	7½x17½	38281	41471	44661	47850	51041	57421
10 x18	9½x17½	48489	52530	56571	60612	64652	72734
12 x18	11½x17½	58698	63590	68481	73373	78264	88047
14 x18	13½x17½	68906	74648	80390	86133	91875	103359
16 x18	15½x17½	79114	85706	92300	98892	105485	118671
18 x18	17½x17½	89322	96765	104209	111652	119096	133982
20 x20	19½x19½	123580	133878	144176	164475	164774	185370

YELLOW PINE COLUMNS

Formulae for determining the strength of columns, both of wood and steel, exist in untold numbers and are about evenly divided between those of a theoretical and an empirical nature. The formulae for wooden columns do not vary greatly in results when applied with a uniform fibre stress in compression; and it is obviously beyond the limits of this book to consider them all. For this reason, two formulae have been selected, upon which various tables are based, one being what is known as a "CURVED-LINE" FORMULA, and the other a "STRAIGHT-LINE" FORMULA.

Formulae

U. S. Department of Agriculture, Division of Forestry.

Bulletin No. 12.

$P = F\ (700+15c) \div (700+15c+c^2)$.
P—Ultimate strength in pounds per sq. in.
F—Ultimate crushing strength of timber.
c—L/d.
The above is a "curved-line" formula.

Winslow Formula

Unit-stress per sq. in. $= C\ (1 - L/80d)$.
C—Compressive strength per sq. in. with the grain.
L—Length in inches.
d—Least diameter, in inches.

(Continued on page 238)

TABLE XXXI

Safe Loads in Tons of 2,000 Pounds on Yellow Pine Columns

(Actual size)

Based on the formula of the U. S. Department of Agriculture, Division of Forestry.
Square end bearing and symmetrically loaded.

Nominal Size, Inches	Actual Size, Inches	Area Sq. In.	L/D	Length, in Feet	COMPRESSION PARALLEL TO THE GRAIN. Pounds per Square Inch. 1000	1100	1200	1300	1400	1500
6x6	5½x5½	30¼	17.5	8	11.50	12.65	13.80	14.95	16.10	17.25
"	"	"	21.8	10	10.34	11.37	12.40	13.44	14.47	15.51
"	"	"	26.2	12	9.29	10.22	11.15	12.08	13.01	13.94
"	"	"	30.5	14	8.39	9.23	10.07	10.91	11.75	12.59
8x8	7½x7½	56¼	12.8	8	23.76	26.13	26.13	30.88	33.26	35.63
"	"	"	16.0	10	22.11	24.32	26.53	28.74	30.95	33.16
"	"	"	19.2	12	20.48	22.52	24.57	26.62	28.67	30.72
"	"	"	22.4	14	18.95	20.84	22.74	24.63	26.53	28.43
"	"	"	25.6	16	17.52	19.27	21.02	22.77	24.52	26.28
"	"	"	28.8	18	16.28	17.90	19.53	21.16	22.79	24.42
"	"	"	32.0	20	15.06	16.56	18.07	19.57	21.08	22.59
10x10	9½x9½	90¼	10.1	8	40.29	44.32	48.35	52.38	56.41	60.44
"	"	"	12.6	10	38.29	42.12	45.95	49.78	53.61	57.44
"	"	"	15.2	12	36.21	39.83	43.45	47.07	50.69	54.31
"	"	"	17.7	14	34.06	37.46	40.87	44.27	47.68	51.09
"	"	"	20.2	16	32.08	35.29	38.50	41.71	44.92	48.13
"	"	"	22.7	18	30.19	33.21	36.23	39.25	42.27	45.29
"	"	"	25.3	20	28.32	31.15	33.98	36.81	39.64	42.47
12x12	11½x11½	132¼	8.3	8	61.02	67.12	73.22	79.32	85.43	91.53
"	"	"	10.4	10	58.70	64.57	70.44	76.31	82.18	88.05
"	"	"	12.5	12	56.21	61.83	67.45	73.07	78.69	84.31
"	"	"	14.6	14	53.68	59.04	64.41	69.78	75.15	80.52
"	"	"	16.7	16	51.11	56.22	61.33	66.44	71.55	76.66
"	"	"	18.8	18	48.60	53.46	58.32	63.18	68.04	72.90
"	"	"	20.9	20	46.20	50.82	55.44	60.06	64.68	69.30

TABLE XXXI—(Concluded)

Nominal Size, Inches	Actual Size, Inches	Area, Sq. In.	L/D	Length, in Feet	COMPRESSION PARALLEL TO THE GRAIN Pounds per Square Inch 1000	1100	1200	1300	1400	1500
14x14	13½x13½	182¼	7.1	8	85.75	94.32	102.90	111.47	120.05	128.62
"	"	"	8.9	10	83.19	91.51	99.83	108.15	116.47	124.79
"	"	"	10.7	12	80.46	88.50	96.55	104.59	112.64	120.68
"	"	"	12.4	14	77.66	85.43	93.19	100.96	108.72	116.49
"	"	"	14.2	16	74.63	82.09	89.55	97.02	104.48	111.94
"	"	"	16.0	18	71.62	78.78	85.94	93.11	100.27	107.43
"	"	"	17.8	20	68.61	75.47	82.33	89.19	96.05	102.91
16x16	15½x15½	240¼	6.2	8	114.57	126.02	137.48	148.94	160.40	171.86
"	"	"	7.7	10	111.95	123.14	134.34	145.53	156.73	167.92
"	"	"	9.3	12	108.95	119.84	130.74	141.63	152.53	163.42
"	"	"	10.8	14	105.80	116.38	126.96	137.54	148.12	158.70
"	"	"	12.4	16	102.34	112.57	122.80	133.03	143.27	153.51
"	"	"	14.0	18	98.83	108.71	118.59	128.48	138.36	148.24
"	"	"	15.5	20	95.49	105.04	114.59	124.14	133.69	143.24
18x18	17½x17½	306¼	5.5	8	147.45	162.19	176.94	191.68	206.43	221.17
"	"	"	6.9	10	144.55	159.00	173.46	187.91	202.37	216.82
"	"	"	8.2	12	141.48	155.62	169.77	183.91	198.06	212.21
"	"	"	9.6	14	138.11	151.92	165.73	179.54	193.35	207.16
"	"	"	11.0	16	134.29	147.72	161.15	174.58	188.01	201.44
"	"	"	12.3	18	130.76	143.83	156.91	169.98	183.06	196.13
"	"	"	13.7	20	126.78	139.46	152.14	164.82	177.50	190.18
20x20	19½x19½	380¼	5.0	8	184.23	202.65	221.07	239.50	257.92	276.34
"	"	"	6.2	10	181.37	199.50	217.64	235.78	253.92	272.06
"	"	"	7.4	12	178.15	195.96	213.78	231.59	249.41	267.22
"	"	"	8.6	14	174.53	191.98	209.43	226.88	244.33	261.79
"	"	"	9.8	16	170.73	187.80	204.87	221.95	239.02	256.09
"	"	"	11.1	18	166.54	183.19	199.85	216.50	233.16	249.81
"	"	"	12.3	20	162.37	178.60	194.84	211.08	227.32	243.56

TABLE XXXII

Maximum Spans for Yellow Pine Mill Floors.

(Actual thickness)

Made of matched and dressed plank.

Fibre stress 1,200, 1,300, 1,500, 1,600, and 1,800 pounds per sq. in.; modulus of rupture 1,620,000 pounds per. sq. in.
The SUM of the live load and the weight of the floor was used in calculating the spans.
In the line marked DEFLECTION, is given the span which has a deflection of one-thirtieth of an inch per foot of span

Nominal Thickness	Actual Thickness	Fibre Stress Pounds per Sq. In.	SPAN IN FEET — LIVE LOAD IN POUNDS PER SQUARE FOOT: 50 lbs.	100 lbs.	125 lbs.	150 lbs.	175 lbs.	200 lbs.	225 lbs.	250 lbs.	275 lbs.	300 lbs.	350 lbs.	400 lbs.
2"	1⅝"	1200	8′ 9″	6′ 4″	5′ 8″	5′ 3″	4′ 10″	4′ 6″						
"	"	1300	9′ 1″	6′ 7″	5′ 11″	5′ 5″	5′ 0″	4′ 9″						
"	"	1500	9′ 9″	7′ 1″	6′ 4″	5′ 10″	5′ 5″	5′ 1″						
"	"	1600	10′ 1″	7′ 4″	6′ 7″	6′ 0″	5′ 7″	5′ 3″						
"	"	1800	10′ 8″	7′ 9″	7′ 0″	6′ 5″	5′ 11″	5′ 7″						
"	"	Deflection	5′ 8½″	4′ 7″	4′ 3″	4′ 0″	3′ 10″	3′ 8″						
2½"	2⅛"	1200	11′ 3″	8′ 2″	7′ 5″	6′ 9″	6′ 4″	5′ 11″	5′ 7″	5′ 4″				
"	"	1300	11′ 9″	8′ 7″	7′ 9″	7′ 1″	6′ 7″	6′ 2″	5′ 10″	5′ 6″				
"	"	1500	12′ 7″	9′ 2″	8′ 3″	7′ 7″	7′ 0″	6′ 7″	6′ 3″	5′ 11″				
"	"	1600	13′ 0″	9′ 6″	8′ 6″	7′ 10″	7′ 3″	6′ 10″	6′ 6″	6′ 1″				
"	"	1800	13′ 10″	10′ 1″	9′ 1″	8′ 4″	7′ 8″	7′ 3″	6′ 10″	6′ 6″				
"	"	Deflection	7′ 5″	6′ 0″	5′ 7″	5′ 3″	5′ 0″	4′ 10″	4′ 8″	4′ 6″				
3"	2⅝"	1200	13′ 8″	10′ 1″	9′ 1″	8′ 4″	7′ 9″	7′ 3″	6′ 10″	6′ 6″	6′ 3″	6′ 0″	5′ 7″	5′ 2″
"	"	1300	14′ 3″	10′ 6″	9′ 6″	8′ 8″	8′ 1″	7′ 7″	7′ 2″	6′ 10″	6′ 6″	6′ 3″	5′ 9″	5′ 5″
"	"	1500	15′ 4″	11′ 3″	10′ 2″	9′ 4″	8′ 8″	8′ 2″	7′ 8″	7′ 4″	7′ 0″	6′ 8″	6′ 2″	5′ 10″
"	"	1600	15′ 10″	11′ 8″	10′ 6″	9′ 7″	8′ 11″	8′ 4″	7′ 11″	7′ 7″	7′ 2″	6′ 11″	6′ 5″	6′ 0″
"	"	1800	16′ 9″	12′ 4″	11′ 2″	10′ 3″	9′ 6″	8′ 11″	8′ 5″	8′ 0″	7′ 8″	7′ 4″	6′ 9″	6′ 4″
"	"	Deflection	9′ 0″	7′ 4″	6′ 11″	6′ 6″	6′ 2″	5′ 11″	5′ 8″	5′ 6″	5′ 4″	5′ 2″	4′ 11″	4′ 9″

TABLE XXXII—(Continued)

Nominal Thickness	Actual Thickness	Fibre Stress Pounds per Sq. In.	SPAN IN FEET — Live Load in Pounds per Square Foot: 50 lbs.	100 lbs.	125 lbs.	150 lbs.	175 lns.	200 lbs.	225 lbs.	250 lbs.	275 lbs.	300 lbs.	350 lbs.	400 lbs.
4″	3⅝″	1200	18′ 5″	18′ 8″	12′ 4″	11′ 5″	10′ 7″	10′ 0″	9′ 5″	9′ 0″	8′ 7″	8′ 3″	7′ 7″	7′ 2″
"	"	1300	19′ 2″	14′ 3″	12′ 11″	11′ 10″	11′ 0″	10′ 4″	9′ 10″	9′ 4″	8′ 11″	8′ 7″	7′ 11″	7′ 5″
"	"	1500	20′ 7″	15′ 4″	13′ 10″	12′ 9″	11′ 10″	11′ 2″	10′ 6″	10′ 0″	9′ 7″	9′ 2″	8′ 6″	8′ 0″
"	"	1600	21′ 3″	15′ 10″	14′ 4″	13′ 2″	12′ 3″	11′ 6″	10′ 11″	10′ 4″	9′ 11″	9′ 6″	8′ 10″	8′ 3″
"	"	1800	22′ 7″	16′ 9″	15′ 2″	13′ 11″	13′ 0″	12′ 2″	11′ 7″	11′ 0″	10′ 6″	10′ 1″	9′ 4″	8′ 9″
"	"	Deflection	12′ 3″	10′ 1″	9′ 5″	8′ 11″	8′ 6″	8′ 2″	7′ 10″	7′ 7″	7′ 4″	7′ 2″	6′ 10″	6′ 6″
5″	4⅝″	1200	22′ 10″	17′ 8″	15′ 7″	14′ 5″	13′ 5″	12′ 7″	11′ 11″	11′ 4″	10′ 10″	10′ 5″	9′ 8″	9′ 1″
"	"	1300	23′ 10″	17′ 11″	16′ 3″	14′ 11″	13′ 11″	13′ 1″	12′ 5″	11′ 10″	11′ 4″	10′ 10″	10′ 1″	9′ 5″
"	"	1500	25′ 7″	19′ 3″	17′ 5″	16′ 1″	15′ 0″	14′ 1″	13′ 4″	12′ 8″	12′ 2″	11′ 8″	10′ 10″	10′ 2″
"	"	1600	26′ 5″	19′ 11″	18′ 0″	16′ 7″	15′ 6″	14′ 7″	13′ 9″	13′ 1″	12′ 6″	12′ 0″	11′ 2″	10′ 6″
"	"	1800	27′ 9″	21′ 1″	19′ 1″	17′ 7″	16′ 5″	15′ 5″	14′ 7″	13′ 11″	13′ 4″	12′ 9″	11′ 10″	11′ 1″
"	"	Deflection	15′ 4″	12′ 9″	11′ 11″	11′ 3″	10′ 9″	10′ 4″	10′ 0″	9′ 8″	9′ 4″	9′ 1″	8′ 8″	8′ 4″
6″	5⅝″	1200		20′ 8″	18′ 9″	17′ 4″	16′ 2″	15′ 3″	14′ 5″	13′ 9″	13′ 2″	12′ 8″	11′ 9″	11′ 0″
"	"	1300		21′ 6″	19′ 6″	18′ 0″	16′ 10″	15′ 10″	15′ 0″	14′ 3″	13′ 8″	13′ 1″	12′ 2″	11′ 5″
"	"	1500		23′ 1″	21′ 0″	19′ 4″	18′ 1″	17′ 0″	16′ 1″	15′ 4″	14′ 8″	14′ 1″	13′ 1″	12′ 3″
"	"	1600		23′ 10″	21′ 8″	20′ 0″	18′ 8″	17′ 7″	16′ 7″	15′ 10″	15′ 2″	14′ 7″	13′ 6″	12′ 8″
"	"	1800		25′ 3″	23′ 0″	21′ 2″	19′ 10″	18′ 8″	17′ 8″	16′ 10″	16′ 1″	15′ 5″	14′ 4″	13′ 6″
"	"	Deflection		15′ 4″	14′ 5″	13′ 8″	13′ 0″	12′ 6″	12′ 1″	11′ 8″	11′ 4″	11′ 0″	10′ 6″	10′ 1″

TABLE XXXII—(Concluded)

Maximum Spans for Yellow Pine Mill Floors

(Actual thickness)

Made of matched and dressed plank.

Fibre stress 1,200, 1,300, 1,500, 1,600, and 1,800 pounds per sq. in.; modulus of rupture 1,620,000 pounds per sq. in. The SUM of the live load and the weight of the floor was used in calculating the spans.

In the line marked DEFLECTION, is given the span which has a deflection of one-thirtieth of an inch per foot of span.

Nominal Thickness	Actual Thickness	Fibre Stress Pounds per Sq. In.	SPAN IN FEET — LIVE LOAD IN POUNDS PER SQUARE FOOT											
			450 lbs.	500 lbs.	550 lbs.	600 lbs	650 lbs.	700 lbs.	750 lbs.	800 lbs.	850 lbs.	900 lbs.	950 lbs.	1000 lbs.
4"	3⅝"	1200	6' 9"	6' 5"	6' 1"	5' 10"	5' 8"	5' 5"	5' 3"	5' 1"				
"	"	1300	7' 0"	6' 8"	6' 4"	6' 1"	5' 10"	5' 8"	5' 6"	5' 4"				
"	"	1500	7' 6"	7' 2"	6' 10"	6' 7"	6' 4"	6' 1"	5' 11"	5' 8"				
"	"	1600	7' 9"	7' 5"	7' 1"	6' 6"	6' 6"	6' 3"	6' 1"	5' 11"				
"	"	1800	8' 3"	7' 10"	7' 6"	7' 2"	6' 11"	6' 8"	6' 5"	6' 3"				
"	"	Deflection	6' 3"	6' 1"	5' 11"	5' 9"	5' 7"	5' 5"	5' 4"	5' 2"				
5"	4⅝"	1200	8' 7"	8' 2"	7' 9"	7' 6"	7' 2"	6' 11"	6' 8"	6' 6"				
"	"	1300	8' 11"	8' 6"	8' 1"	7' 9"	7' 6"	7' 3"	7' 0"	6' 9"				
"	"	1500	9' 7"	9' 1"	8' 8"	8' 4"	8' 0"	7' 9"	7' 6"	7' 3"				
"	"	1600	9' 11"	9' 5"	9' 0"	8' 7"	8' 3"	8' 0"	7' 9"	7' 6"				
"	"	1800	10' 6"	10' 0"	9' 6"	9' 2"	8' 9"	8' 6"	8' 2"	7' 11"				
"	"	Deflection	8' 0"	7' 8"	7' 6"	7' 3"	7' 1"	6' 11"	6' 9"	6' 7"				
6"	5⅝"	1200	10' 5"	9' 10"	9' 5"	9' 0"	8' 8"	8' 5"	8' 1"	7' 10"	7' 7"	7' 5"	7' 3"	7' 1"
"	"	1300	10' 10"	10' 3"	9' 10"	9' 5"	9' 1"	8' 9"	8' 5"	8' 2"	7' 11"	7' 9"	7' 6"	7' 4"
"	"	1500	11' 7"	11' 0"	10' 7"	10' 2"	9' 9"	9' 3"	9' 1"	8' 10"	8' 6"	8' 4"	8' 1"	7' 11"
"	"	1600	12' 0"	11' 5"	10' 11"	10' 5"	10' 1"	9' 8"	9' 4"	9' 1"	8' 10"	8' 7"	8' 4"	8' 2"
"	"	1800	12' 9"	12' 1"	11' 7"	11' 1"	10' 8"	10' 3"	9' 11"	9' 8"	9' 1"	8' 10"	8' 10"	8' 8"
"	"	Deflection	9' 8"	9' 4"	9' 1"	8' 10"	8' 7"	8' 5"	9' 3"	8' 1"	7' 11"	7' 9"	7' 7"	7' 6"

TABLE XXXIII

Deflection in Inches with a Load of 1,000 Pounds Uniformly Distributed on Yellow Pine Mill Floors

(Actual size)

Made of matched and dressed plank.

In column headed L/₃₀, is given the deflection in inches which is one-thirtieth of an inch per foot of span.

For a concentrated load of 1,000 pounds applied at the center of the span the deflection is 1.6 times that given in the table.

Nominal Thickness	2 in.	2½ in.	3 in.	4 in.	5 in.	6 in.	L/₃₀
Actual Thickness	1⅝ in.	2⅛ in.	2⅝ in.	3⅝ in.	4⅝ in.	5⅝ in.	
Span in Feet							
4	.2072	.0926					.133
5	.4047	.1810	.0960	.0364			.166
6	.6993	.3127	.1659	.0630	.0303		.200
7	1.1104	.4966	.2634	.1000	.0481	.0267	.233
8	1.6572	.7413	.3932	.1493	.0719	.0399	.266
9	2.3601	1.0554	.5598	.2125	.1023	.0569	.300
10	3.2375	1.4478	.7679	.2916	.1404	.0780	.333
11	4.3090	1.9270	1.0221	.3881	.1868	.1039	.366
12		2.5017	1.3269	.5038	.2426	.1348	.400
13		3.1806	1.6870	.6406	.3084	.1714	.433
14		3.9727	2.1070	.8001	.3852	.2141	.466
15			2.5920	.9841	.4738	.2634	.500
16			3.1450	1.1943	.5750	.3196	.533
17				1.4325	.6897	.3834	.566
18				1.7004	.8187	.4551	.600
19				1.9999	.9629	.5353	.633
20				2.3326	1.1230	.6243	.666
21						.7227	.700
22						.8310	.733

STUD PARTITIONS

Table (Page 231), pertaining to stud partitions, gives the weight and board measure per lineal foot of partition in plan, including a single top and bottom plate of same size as the studs. To these weights should be added the weight of plastering or other wall covering.

TABLE XXXIV

Weight and Board Measure of Joist Construction

Board measure based on nominal size.
Weight based on actual size.
Add weight of ceiling, floor, and roof finish.

Nominal Size	Actual Size	Distance on Centers, Inches,	PER SQUARE FOOT OF SURFACE		
			Lineal Feet of Joist	Board Feet	Weight, Pounds
2x4	1⅝x3⅝	12	1.00	.66	1.63
“	“	16	.75	.50	1.22
“	“	20	.60	.40	.98
2x6	1⅝x5⅝	12	1.00	1.00	2.53
“	“	16	.75	.75	1.89
“	“	20	.60	.60	1.52
2x8	1⅝x7½	12	1.00	1.33	3.38
“	“	16	.75	1.00	2.53
“	“	20	.60	.80	2.03
“	“	24	.50	.66	1.70
2x10	1⅝x9½	12	1.00	1.66	4.28
“	“	16	.75	1.25	3.21
“	“	18	.66	1.11	2.85
“	“	20	.60	1.00	2.57
“	“	24	.50	.833	2.14
2x12	1⅝x11½	12	1.00	2.00	5.18
“	“	16	.75	1.50	3.88
2½x12	2⅛x11½	12	1.00	2.50	7.17
“	“	16	.75	1.875	5.38
3x12	2⅝x11½	12	1.00	3.00	8.76
“	“	16	.75	2.25	6.57
2x14	1⅝x13½	12	1.00	2.33	6.56
“	“	14	.857	1.997	5.61
“	“	16	.75	1.75	4.91
2½x14	2¼x13½	12	1.00	2.917	8.41
“	“	14	.857	2.50	7.21
“	“	16	.75	2.187	6.30
3x14	2⅝x13½	12	1.00	3.50	10.28
“	“	14	.857	3.00	8.81
“	“	16	.75	2.625	7.71
2x16	1⅝x15½	12	1.00	2.66	7.51
“	“	14	.857	2.85	6.43
“	“	16	.75	2.00	5.63
2½x16	2¼x15½	12	1.00	3.33	9.66
“	“	14	.857	2.857	8.28
“	“	16	.75	2.50	7.25
3x16	2⅝x15½	12	1.00	4.00	11.81
“	“	14	.857	3.428	10.12
“	“	16	.75	3.00	8.857
4x16	3⅝x15½	12	1.00	5.33	16.10
“	“	14	.857	4.57	13.80
“	“	16	.75	4.00	12.07

TABLE XXXV

Safe Loads on Stud Partitions

Weight and strength based on actual size board measure based on nominal size.

Add weight of plaster or ceiling.

Single plate top and bottom included, same size as studs.

SAFE LOAD BASED ON STUDS BEING BRIDGED AT CENTER.

Nominal Size	Actual Size	Distance on Centers, Inches	Height, Feet	PER LINEAR FOOT OF PARTITION		
				Safe Load, Pounds	Weight, Pounds	Board Feet
2x4	1⅝x3⅝	12	8	3723	16.30	6.66
"	"	"	10	3180	19.56	8.00
"	"	"	12	2631	22.82	9.33
"	"	16	8	2793	13.04	5.33
"	"	"	10	2385	15.50	6.33
"	"	"	12	1974	18.75	7.66
2x6	1⅝x5⅝	12	8	5767	25.30	10.00
"	"	"	10	4926	30.56	12.00
"	"	"	12	4076	35.42	14.00
"	"	16	8	4326	20.24	8.00
"	"	"	10	3699	24.03	9.50
"	"	"	12	3057	27.88	11.00
2½x6	2⅛x5½	12	8	9079	34.30	12.50
"	"	"	10	8250	41.16	15.00
"	"	"	12	7422	48.02	17.50
"	"	16	8	6808	27.44	10.00
"	"	"	10	6187	32.59	12.00
"	"	"	12	5566	37.73	13.75
3x6	2⅝x5½	12	8	11823	42.00	15.00
"	"	"	10	10992	50.40	18.00
"	"	"	12	10175	59.80	21.00
"	"	16	8	8868	33.60	12.00
"	"	"	10	8244	39.90	14.25
"	"	"	12	7630	46.20	16.50
2x8	1⅝x7½	12	8	7692	33.80	13.33
"	"	"	10	6570	40.56	16.00
"	"	"	12	5436	47.32	18.66
"	"	"	14	4315	54.08	21.33
"	"	16	8	5769	27.04	10.66
"	"	"	10	4927	32.11	12.66
"	"	"	12	4077	37.18	14.66
"	"	"	14	3236	42.25	16.66
2½x8	2⅛x7½	12	8	12382	46.80	16.66
"	"	"	10	11252	56.16	20.00
"	"	"	12	10122	65.52	23.33
"	"	"	14	9008	74.88	26.66
"	"	16	8	9286	37.44	13.33
"	"	"	10	8439	44.46	15.83
"	"	"	12	7591	51.48	18.33
"	"	"	14	6756	58.50	20.83
3x8	2⅝x7½	12	8	16124	57.20	20.00
"	"	"	10	14990	68.64	24.00
"	"	"	12	13877	80.08	28.00
"	"	"	14	12743	91.52	32.00
"	"	16	8	12093	45.76	16.00
"	"	"	10	11242	54.34	19.00
"	"	"	12	10408	62.92	32.00
"	"	"	14	9557	71.50	25.00

(*Continued from page 223*)

This formula is proposed by Mr. Benj. E. Winslow, Mem. Am. Soc. C. E.[1] taken from Winslow's Tables (McGraw-Hill) and is a "straight-line" formula which has many practical working advantages and was incorporated in the Chicago Building Ordinance passed December 5, 1910.

The work performed by wooden columns in buildings is under such simple and direct conditions of loading with square end bearings that the consideration and use of the more complicated theoretical formulae is not justified. The above formula has been extensively and satisfactorily used.

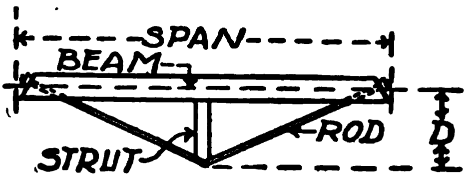


Fig. 17. Single-Strut Trussed Beam.

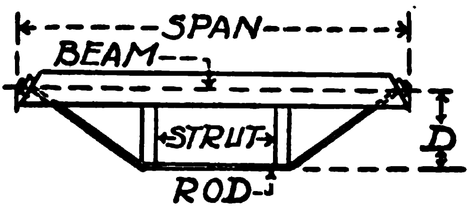


Fig. 18. Double-Strut Trussed Beam.

TRUSSED BEAMS

Tables XXVI to XL give the safe load in pounds uniformly distributed on trussed beams supported at both ends. Tables XXXVI and XXXVII are for single-strut trussed beams as shown in Fig. 17; while Tables XXXVIII to XL are for double-strut trussed beams as shown in Fig. 18, the upper load for each depth of beam being for one rod of size designated, and the lower load being for two rods.

The loads given will develop the safe strength of the rods, which is assumed at 14,000 pounds per sq. in., the rods not upset, and the area of the rod at the base of the thread being assumed as the net area. The loads given for two rods are double those given for one rod, as the loads are based on the strength of the rods. The timbers of standard sizes are pro-

TABLES XXXVI and XXXVII

Safe Load in Pounds, Uniformly Distributed, on Single-Stru t Trussed Beams Supported at Both Ends

The upper loads and timber sizes are for one rod; the lower, for two rods.

Diam. Rod	"D" in inches	SPAN 16 ft.			SPAN 18 ft.		
		LOAD	SIZE OF BEAM	SIZE OF STRUT	LOAD	SIZE OF BEAM	SIZE OF STRUT
1"	15	3,958 7,916	3¼x 7½ 3¼x 9½	3½x3½ 3½x3½	3,524 7,048	3¼x 7½ 3¼x 9½	3½x3½ 3½x3½
	21	5,471 10,942	5½x 7½ 5½x 9½	3½x3½ 3½x3½	4,897 9,794	5½x 7½ 5½x 9½	3½x3½ 3½x3½
	27	6,941 13,882	5½x 7½ 5½x 9½	3½x3½ 3½x3½	6,214 12,428	5½x 7½ 5½x 9½	3½x3½ 3½x3½
	33	8,344 16,688	5½x 7½ 5½x 9½	3½x3½ 3½x3½	7,490 14,980	5½x 7½ 5½x 9½	3½x3½ 3½x3½
1¼"	15	6,425 12,850	5½x 7½ 5½x 9½	3½x3½ 3½x3½	5,721 11,442	5½x 7½ 5½x 9½	3½x3½ 3½x3½
	21	8,881 17,762	5½x 7½ 5½x11½	3½x3½ 3½x3½	7,948 15,896	5½x 7½ 5½x11½	3½x3½ 3½x3½
	27	11,266 22,532	5½x 9½ 5½x11½	3½x3½ 3½x5½	10,087 20,174	5½x 9½ 5½x11½	3½x3½ 3½x3½
	33	13,544 27,088	5½x 9½ 5½x13½	3½x3½ 3½x5½	12,157 24,314	5½x 9½ 5½x13½	3½x3½ 3½x5½
1½"	15	9,322 18,644	5½x 9½ 5½x13½	3½x3½ 3½x3½	8,301 16,602	5½x 9½ 5½x13½	3½x3½ 3½x3½
	21	12,886 25,772	5½x 9½ 5½x13½	3½x3½ 3½x5½	11,533 23,066	5½x11½ 5½x13½	3½x3½ 3½x5½
	27	16,347 32,694	5½x11½ 5½x15½	3½x3½ 5½x5½	14,636 29,272	5½x11½ 5½x15½	3½x3½ 3½x5½
	33	19,653 39,306	5½x11½ 5½x15½	3½x3½ 5½x5½	17,640 35,280	5½x13½ 5½x15½	3½x3½ 5½x5½
1¾"	15	12,567 25,134	5½x11½ 7½x13½	3½x3½ 3½x5½	11,190 22,380	5½x11½ 7½x11½	3½x3½ 3½x5½
	21	17,371 37,742	5½x11½ 7½x13½	3½x3½ 5½x5½	15,047 30,094	5½x13½ 7½x13½	3½x3½ 3½x5½
	27	22,037 44,074	5½z15½ 7½x15½	3½x5½ 5½x7½	19,730 39,460	5½x15½ 7½x15½	3½x5½ 5½x5½
	33	27,493 54,986	5½x15½ 7½x15½	3½x5½ 5½x7½	23,780 47,560	5½x15½ 7½x15½	3½x5½ 5½x5½

Diam. Rod	"D" in inches	SPAN 20 ft.			SPAN 22 ft.		
		LOAD	SIZE OF BEAM	SIZE OF STRUT	LOAD	SIZE OF BEAM	SIZE OF STRUT
1"	16	3,378 6,756	3¼x 7½ 3¼x 9½	3½x3½ 3½x3½	3,074 6,148	3¼x 7½ 3¼x 9½	3½x3½ 3½x3½
	24	5,032 10,064	5½x 7½ 5½x 9½	3½x3½ 3½x3½	4,580 9,160	5½x 7½ 5½x 9½	3½x3½ 3½x3½
	32	6,598 13,196	5½x 7½ 5½x 9½	3½x3½ 3½x3½	6,026 12,052	5½x 7½ 5½x 9½	3½x3½ 3½x3½
	40	8,106 16,212	5½x 7½ 5½x11½	3½x3½ 3½x3½	7,424 14,848	5½x 7½ 5½x11½	3½x3½ 3½x3½
1¼"	16	5,483 10,966	5½x 7½ 5½x 9½	3½x3½ 3½x3½	4,990 9,980	5½x 7½ 5½x 9½	3½x3½ 3½x3½
	24	8,168 16,336	5½x 9½ 5½x11½	3½x3½ 3½x3½	7,434 14,868	5½x 9½ 5½x11½	3½x3½ 3½x3½
	32	10,710 21,420	5½x 9½ 5½x13½	3½x3½ 3½x5½	9,781 19,562	5½x 9½ 5½x13½	3½x3½ 3½x3½
	40	13,158 26,316	5½x11½ 5½x13½	3½x3½ 3½x5½	12,050 24,100	5½x11½ 5½x13½	3½x3½ 3½x5½
1½"	16	7,956 15,912	5½x 9½ 5½x13½	3½x3½ 3½x3½	7,240 14,480	5½x 9½ 5½x13½	3½x3½ 3½x3½
	24	11,852 23,704	5½x11½ 5½x15½	3½x3½ 3½x5½	10,787 21,574	5½x11½ 5½x15½	3½x3½ 3½x5½
	32	15,541 31,082	5½x11½ 5½x15½	3½x3½ 3½x5½	14,192 28,384	5½x11½ 5½x15½	3½x3½ 3½x5½
	40	19,093 38,186	5½x13½ 7½x15½	3½x5½ 5½x5½	17,485 34,970	5½x13½ 7½x15½	3½x5½ 5½x5½
1¾"	16	10,725 21,450	5½x13½ 7½x13½	3½x3½ 3½x5½	9,760 19,520	5½x13½ 7½x13½	3½x3½ 3½x3½
	24	15,977 31,954	5½x13½ 7½x15½	3½x3½ 3½x5½	14,542 29,084	5½x13½ 7½x15½	3½x3½ 3½x5½
	32	20,950 41,900	5½x15½ 7½x15½	3½x5½ 5½x5½	19,132 38,264	5½x15½ 7½x15½	3½x3½ 5½x5½
	40	25,748 51,496	7½x15½ 9½x15½	3½x5½ 5½x7½	23,571 47,142	7½x15½ 9½x15½	3½x5½ 5½x5½

Diam. Rod	"D" in inches	SPAN 20 ft. Load	SPAN 20 ft. Size of Beam	SPAN 20 ft. Size of Strut	SPAN 22 ft. Load	SPAN 22 ft. Size of Beam	SPAN 22 ft. Size of Strut
1"	16	4,016 8,032	3¾x 7½ 3¾x 7½	3½x3½ 3½x3½	3,660 7,320	3¾x 7½ 3¾x 7½	3½x3½ 3½x3½
	24	5,890 11,780	3¾x 7½ 3¾x 9½	3½x3½ 3½x3½	5,391 10,782	3¾x 7½ 3¾x 9½	3½x3½ 3½x3½
	32	7,589 15,178	3¾x 7½ 3¾x 9½	3½x3½ 3½x3½	6,992 13,984	3¾x 7½ 3¾x 9½	3½x3½ 3½x3½
	40	9,188 18,376	3¾x 7½ 3¾x 9½	3½x3½ 3½x3½	8,500 17,000	3¾x 7½ 3¾x11½	3½x3½ 3½x3½
1¼"	16	6,520 13,040	5½x 7½ 3¾x11½	3½x3½ 3½x3½	5,940 11,880	5½x 7½ 3¾x11½	3½x3½ 3½x3½
	24	9,561 19,122	5½x 7½ 3¾x11½	3½x3½ 3½x3½	8,750 17,500	5½x 7½ 3¾x11½	3½x3½ 3½x3½
	32	12,317 24,634	5½x 9½ 5½x11½	3½x3½ 3½x3½	11,394 22,788	5½x 9½ 5½x11½	3½x3½ 3½x3½
	40	14,913 29,826	5½x 9½ 3¾x13½	3½x3½ 3½x3½	13,796 27,592	5½x 9½ 3¾x13½	3½x3½ 3½x3½
1½"	16	9,460 18,920	5½x 9½ 5½x11½	3½x3½ 3½x3½	8,620 17,240	5½x 9½ 5½x11½	3½x3½ 3½x3½
	24	13,873 27,746	5½x 9½ 5½x11½	3½x3½ 3½x3½	12,697 25,394	5½x 9½ 5½x11½	3½x3½ 3½x3½
	32	17,873 35,746	5½x11½ 5½x13½	3½x3½ 3½x5½	16,468 32,936	5½x11½ 5½x13½	3½x3½ 3½x5½
	40	21,640 43,280	5½x11½ 5½x13½	3½x3½ 3½x5½	20,019 40,038	5½x11½ 5½x13½	3½x3½ 3½x5½
1¾"	16	12,752 25,504	5½x11½ 5½x13½	3½x3½ 3½x3½	11,620 23,240	5½x11½ 5½x13½	3½x3½ 3½x3½
	24	17,702 35,404	5½x11½ 7½x13½	3½x3½ 3½x5½	17,116 34,232	5½x11½ 7½x13½	3½x3½ 3½x5½
	32	24,094 48,188	7½x11½ 5½x15½	3½x3½ 3½x5½	22,200 44,400	7½x11½ 5½x15½	3½x3½ 3½x5½
	40	29,172 58,344	7½x11½ 5½x15½	3½x3½ 5½x5½	27,087 54,174	7½x11½ 5½x15½	3½x3½ 5½x5½

Diam. Rod	"D" in inches	SPAN 24 ft. Load	SPAN 24 ft. Size of Beam	SPAN 24 ft. Size of Strut	SPAN 26 ft. Load	SPAN 26 ft. Size of Beam	SPAN 26 ft. Size of Strut
1"	18	3,777 7,554	3¾x 7½ 3¾x 7½	3½x3½ 3½x3½	3,493 6,986	3¾x 7½ 3¾x 9½	3½x3½ 3½x3½
	26	5,347 10,694	3¾x 7½ 3¾x 9½	3½x3½ 3½x3½	4,757 9,514	3¾x 7½ 3¾x 9½	3½x3½ 3½x3½
	34	6,851 13,702	3¾x 7½ 3¾x 9½	3½x3½ 3½x3½	6,362 12,724	3¾x 7½ 3¾x 9½	3½x3½ 3½x3½
	42	8,227 16,454	3¾x 7½ 3¾x11½	3½x3½ 3½x3½	7,678 15,356	3¾x 7½ 3¾x11½	3½x3½ 3½x3½
1¼"	18	6,131 12,262	5½x 7½ 3¾x11½	3½x3½ 3½x3½	5,670 11,340	3¾x 9½ 3¾x11½	3½x3½ 3½x3½
	26	8,679 17,358	5½x 7½ 5½x11½	3½x3½ 3½x3½	8,046 16,092	3¾x 9½ 5½x11½	3½x3½ 3½x3½
	34	11,120 22,240	5½x 9½ 5½x11½	3½x3½ 3½x3½	10,327 20,654	5½x 9½ 5½x11½	3½x3½ 3½x3½
	42	13,354 26,708	5½x 9½ 3¾x13½	3½x3½ 3½x3½	12,463 24,926	5½x 9½ 3¾x13½	3½x3½ 3½x3½
1½"	18	8,895 17,790	5½x 9½ 5½x11½	3½x3½ 3½x3½	8,227 16,454	5½x 9½ 5½x11½	3½x3½ 3½x3½
	26	12,593 25,186	5½x 9½ 5½x11½	3½x3½ 3½x3½	11,675 23,350	5½x 9½ 5½x11½	3½x3½ 3½x3½
	34	16 136 32,272	5½x11½ 5½x13½	3½x3½ 3½x3½	14,985 29,970	5½x11½ 5½x13½	3½x3½ 3½x3½
	42	19,377 38,754	5½x11½ 5½x13½	3½x3½ 3½x5½	18,084 36,168	5½x11½ 5½x13½	3½x3½ 3½x5½
1¾"	18	11,991 23,982	5½x11½ 5½x13½	3½x3½ 3½x3½	11,091 22,182	5½x11½ 5½x13½	3½x3½ 3½x3½
	26	16,976 33,142	5½x11½ 7½x13½	3½x3½ 3½x5½	15,739 31,478	5½x11½ 7½x13½	3½x3½ 3½x3½
	34	21,752 43,504	7½x11½ 5½x15½	3½x3½ 3½x5½	20,201 40,402	5½x13½ 5½x15½	3½x3½ 3½x5½
	42	26,121 52,242	7½x11½ 5½x15½	3½x3½ 3½x5½	24,378 48,756	5½x13½ 7½x15½	3½x3½ 3½x5½

TABLE XL

Safe Load in Pounds, Uniformly Distributed, on Double-Strut Trussed Beams Supported at Both Ends

The upper loads and timber sizes are for one rod; the lower, for two rods.

Diam. Rod	"D" in inches	Span 28 ft. Load	Span 28 ft. Size of Beam	Span 28 ft. Size of Strut	Span 30 ft. Load	Span 30 ft. Size of Beam	Span 30 ft. Size of Strut
1"	18	3,250 6,500	3¾x 9½ 3¾x 9½	3½x3½ 3½x3½	3,039 6,078	3¾x 9½ 3¾x 9½	3½x3½ 3½x3½
	26	4,626 9,252	3¾x 9½ 3¾x 9½	3½x3½ 3½x3½	4,333 8,666	3¾x 9½ 3¾x 9½	3½x3½ 3½x3½
	34	5,958 11,916	3¾x 9½ 3¾x 9½	3½x3½ 3½x3½	5,581 11,162	3¾x 9½ 3¾x 9½	3½x3½ 3½x3½
	42	7,217 14,434	3¾x 9½ 3¾x11½	3½x3½ 3½x3½	6,781 13,562	3¾x 9½ 3¾x11½	3½x3½ 3½x3½
1¼"	18	5,275 10,550	3¾x 9½ 3¾x11½	3½x3½ 3½x3½	4,935 9,870	3¾x 9½ 3¾x11½	3½x3½ 3½x3½
	26	7,509 15,018	3¾x 9½ 5½x11½	3½x3½ 3½x3½	7,033 14,066	3¾x 9½ 5½x11½	3½x3½ 3½x3½
	34	9,671 19,342	5½x 9½ 5½x11½	3½x3½ 3½x3½	9,059 18,118	3¾x11½ 5½x11½	3½x3½ 3½x3½
	42	11,714 23,428	5½x 9½ 5½x11½	3½x3½ 3½x3½	11,118 22,236	3¾x11½ 5½x11½	3½x3½ 3½x3½
1½"	18	7,654 15,308	5½x 9½ 5½x11½	3½x3½ 3½x3½	7,158 14,316	5½x 9½ 5½x11½	3½x3½ 3½x3½
	26	10,895 21,790	5½x 9½ 5½x11½	3½x3½ 3½x3½	10,206 20,412	5½x 9½ 5½x11½	3½x3½ 3½x3½
	34	14,033 28,066	5½x11½ 5½x13½	3½x3½ 3½x3½	13,145 26,290	5½x11½ 5½x13½	3½x3½ 3½x3½
	42	16,998 33,996	5½x11½ 5½x13½	3½x3½ 3½x5½	15,972 31,944	5½x11½ 5½x13½	3½x3½ 3½x3½
1¾"	18	10,318 20,636	5½x11½ 5½x13½	3½x3½ 3½x3½	9,650 19,300	5½x11½ 5½x13½	3½x3½ 3½x3½
	26	14,687 29,374	5½x11½ 5½x15½	3½x3½ 3½x3½	13,758 27,516	5½x11½ 5½x15½	3½x3½ 3½x3½
	34	18,917 37,834	5½x13½ 5½x15½	3½x3½ 3½x5½	17,720 35,440	5½x13½ 5½x15½	3½x3½ 3½x5½
	42	22,914 45,828	5½x13½ 7½x15½	3½x3½ 3½x5½	21,531 43,062	5½x13½ 7½x15½	3½x3½ 3½x5½

portioned to these loads, allowing a safe bending fibre strain of 1,800 pounds per sq. in.; and in no case will the crushing strain exceed 1,000 pounds per sq. in.

The washers at ends of rods should have the following areas to provide sufficient bearing on the timbers:

¾-in. diameter rod= 4.6 sq. in. area.
⅞-in. diameter rod= 6.5 sq. in. area.
1 -in. diameter rod= 8.5 sq. in. area.
1⅛-in. diameter rod= 9.9 sq. in. area.
1¼-in. diameter rod=13.8 sq. in. area.
1⅜-in. diameter rod=16.5 sq. in. area.

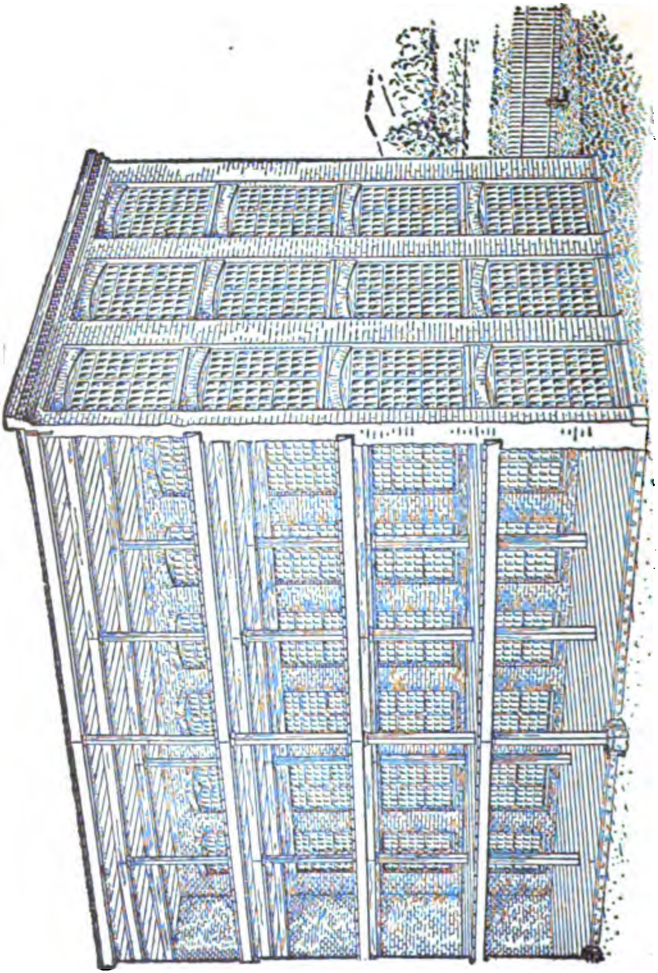


Fig. 19. Standard Mill Construction—General Framing Plan.

1⅛-in. diameter rod=20.1 sq. in. area.
1⅝-in. diameter rod=23.5 sq. in. area.
1¾-in. diameter rod=27.1 sq. in. area.

Where double rods are used, the washers must have twice the areas given above and be made of steel or wrought-iron plates of sufficient thickness not to bend or shear.

It is understood that these beams are secured against lateral deflection by floors, roofs, or other means.

The nuts on the rods should not be screwed up too hard, as any initial strain produced by this means reduces the effective strength for the applied load by the amount of this initial strain.

STANDARD MILL CONSTRUCTION

The succession of heavy fire losses each year is the penalty which this country is paying for the erection of light, cheap, and poorly designed buildings. The cost of fire insurance is a direct yearly tax on the building and its occupants. It is the duty of those responsible for the design of buildings, to plan them so that this tax may be the smallest possible, and this can be done often without any great increase in the cost of the building itself.

According to tests made by the Boston Insurance Engineering Experiment Station, it has been clearly shown that, all things considered, the **mill** or **slow-burning** type of construction is to be recommended for most factory and warehouse buildings. In cases where the contents will be extra inflammable and very great loss to life and property is at risk, the extra expense of the thoroughly fireproof reinforced concrete structure is warranted.

In order that there shall be no misunderstanding of what is meant by **mill construction**, we shall say that it consists in disposing the timber and plank in heavy solid masses so as to expose the least number of corners or ignitable projections to fire. Also, it consists in separating every floor from every other floor by **fire stops**.

The essential features of standard mill construction are illustrated in Fig. 19, and are briefly as follows:

1. The walls should be of brick or concrete block, at least 1 ft. thick (16 in. for best work) in top story, and increased in thickness at lower floors to support additional load. The pilastered wall has many advantages, and is often preferred to the plain wall. Window and door arches should be of brick; window and outside door-sills and underpinning, of granite or concrete.

2. The roofs should be of 3-in. pine plank, spiked directly to the heavy roof timbers and covered with 5-ply tar and gravel roofing. Roofs should pitch ½ to ¾ in. per foot. An incombustible cornice is recommended when there is exposure from neighboring buildings.

3. Floors are best made of spruce plank 4 in. or more in thickness according to the floor loads, spiked directly to the floor timbers and kept at least ½ in. clear of the face of the brick walls. In floors and roof, the bays should be 8 to 10½ ft. wide; and all plank two bays in length, laid to break joints every 4 ft., and grooved for hardwood splines. Usually top floor of birch or maple is laid at right angles to the planking; but the best mills have a double top floor—the lower one of soft wood laid diagonally upon the plank, and the upper one laid lengthwise. This latter method allows boards in alleys to be easily replaced when worn; and the diagonal boards brace the floors, reduce vibration, and distribute the floor load even better than the former method.

Between the planking and the top floor should be two or three layers of heavy tarred paper, laid to break joints, and each mopped with hot tar or similar material to produce a reasonably water-tight as well as dust-tight floor.

Rapid decay of basement or lower floors of mills makes it desirable, whenever wood is not absolutely necessary, to provide cement floors for these places. If wooden floors are required, crushed stone, cinders, or furnace slag should be spread evenly over the surface, and covered with a thick layer of hot tar concrete, on which is often laid tarred felt, well mopped with hot tar or asphalt. On this a floor of 2-in. seasoned plank should be pressed, nailed on edge without perforating the waterproofing under it, and the hardwood top floor boards nailed across the plank. Cement concretes, it is claimed, promote decay of wood in contact with them. If extra support is required for heavy machinery, independent foundations of masonry should be provided.

4. In regard to timbers and columns, it should be remembered that all woodwork in standard construction, in order to be slow-burning, must be in large masses that present the least surface possible to a fire. No sticks less than 6 in. in width should be used, even for the lightest roofs; and for substantial roofs and floors, much wider ones are needed. Timbers should be of sound Georgia pine; and for sizes up to 14 by 16 in., single sticks are preferred; but timbers 7 or 8 by 16 in. are often used in pairs, bolted together without air-space between. They should not be painted, varnished, or

filled for three years, because of danger of dry-rot; and an air-space should be left in the masonry around the ends, for the same reason. Timbers should rest on cast-iron plates or beam boxes, in the walls, and on cast-iron caps on the columns.

Beam boxes are of value, as they strengthen the walls when floor loads are heavy and distance between windows small; they facilitate the laying of the brick and the handling of the beams; and there is less possibility of breaking away the brick in putting the beams in place. They also insure a proper air-space around beams.

Columns should be set on pintles, which may be cast in one piece with the cap, or separately, as preferred. Columns of cast-iron are preferred by some engineers, and, when the building is equipped with automatic sprinklers, have proved satisfactory, but are not so fire-resisting as timber. Wrought-iron or steel columns should not be used unless encased with at least 2 in. of fireproofing.

One of the most important features of slow-burning construction is to make each and every floor continuous from wall to wall, avoiding holes for belts, stairways, or elevators to the utmost extent possible, so that a fire may be confined to the floor where it starts. No well-informed mill owner, engineer, or builder, therefore, will fail to locate elevators and stairs, as well as main belts, in brick towers or in sections of a building cut off by incombustible walls from all the rooms of a factory. Openings in these walls should be provided with fire-doors, preferably self-closing. These should be hung on heavy, inclined, solid steel rails at least 3½ in. by ⅜ in., and balanced by a weight held by a fusible link.

In modern practice all belts and ropes which may be used for transmission of power to the various rooms are placed in incombustible vertical belt-chambers, from which the power is transmitted by shafts through the walls into the several rooms of the factory. There should be no unprotected or unguarded openings in the inner walls of this belt-chamber.

TRUSS CONSTRUCTION

The principle of a truss is theoretically a number of straight bars joined near their ends by flexible joints, and arranged so that all their internal stresses are sustained by its members, and only the vertical pressures (the weights of the truss and its load) are transmitted to its abutments. Trusses differ from solid beams inasmuch as the weight of the truss and its load may be regarded as divided into portions which are concentrated at the joints between the members, and which act through the centers of gravity of their cross-sections. So placed, the stresses caused by them could not act transversely of the members, as in a beam, causing secondary stresses, but must act **longitudinally** of the members, and must be uniformly distributed over their entire cross-sectional areas. This is the distinguishing feature of all trusses; while in a solid beam, when it bends under its load or its own weight, all the fibres above the neutral axis are compressed, and all those below are extended, the resulting change of length in each fibre being proportional to the distance of the fibre from the neutral axis.

Most of the trusses in common use consist of two long members, called **chords**, extending the entire length of the span, and connected by web members, which are sometimes all inclined and sometimes alternately vertical and inclined. Inclined web members are called **diagonals**, such web members being known as **ties** and **struts**. A member sustaining tension is called a **rod** or **tie**; and one sustaining compression is called a **strut** or **post**; while one capable of sustaining both tension and compression is called a **tie strut**.

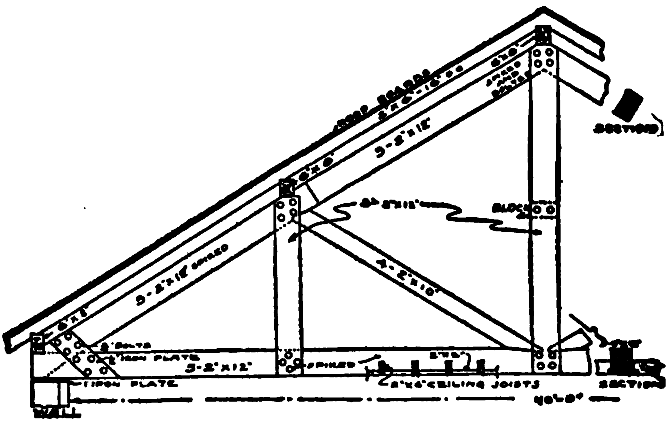


Fig. 20. Cheap Plank-Framed Truss.

Plank-Framed Truss. A plank-framed truss is very popular where a cheap truss is wanted to support a roof of say 40-ft. span, as for a hall. Fig. 20 shows a well-designed built-up truss of satisfactory and at the same time cheap construction, for such a purpose. The wind and snow load on a roof of this kind is a factor that has to be considered. Such trusses will prove amply safe for a 40-ft. span. They shall be set in 16-ft. bents. The expensive large-dimension timbers are not used, the different members being built up of 2 by 10 and 2 by 12-in. pieces, spiked together to break joints as specified on the drawing.

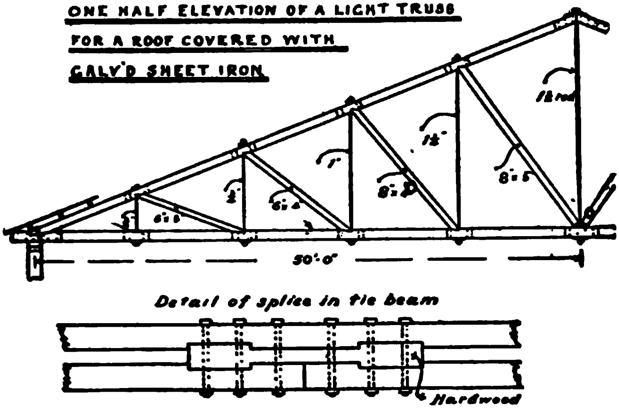


Fig. 21. Light Truss for 100-Foot Span.

Light Truss for 100-Foot Span. In designing trusses of wide span such as those used to support temporary roofs of light construction, the same principle of triangulation is carried out as for very small trusses. Carpenters sometimes overlook this; and, in their amazement at the width of span, trying to arrange framing adequate to the task, lay out a series of members not a truss at all, but a number of quadrilateral panels which offer little resistance to change of form, and which would easily be racked by an extra force acting on one side, such as a gale of wind.

Fig. 21 shows a good form for a long-span truss. For the bottom chord (tie-beam), two pieces of 9-in. by 4-in., at least, will be necessary. The splicing of the pieces to obtain length enough for the span will reduce the sectional area considerably, and must be allowed for. The system of tension rods and struts must be carried out carefully as to joints. The blades or rafters (top chords) should be of two pieces of 8-in. by 3-in., blocked and bolted together at frequent intervals. The sizes of the other members are shown in the diagram. It is very much better to use iron rods for all the tension members as shown. If wood is used, straps and bolts at top and bottom of each member will be required, to hold up the weight of tie-beam and thrust of strut. If the rods are upset at the ends, and a plus thread cut upon them, slightly smaller iron can be used.

It is usual to allow on trusses of this description a camber of half an inch for every ten feet of span. Five inches may seem a lot for this truss, but is none too much when the number of joints is considered.

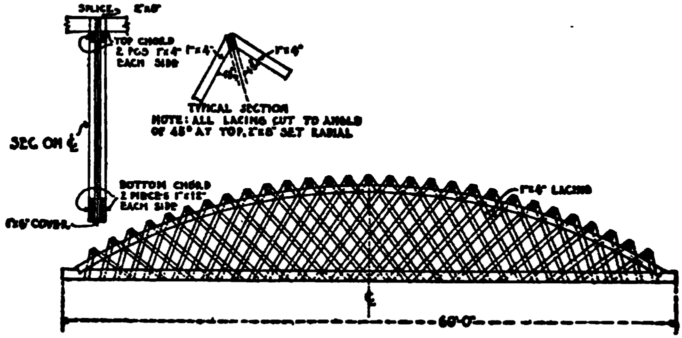


Fig. 22. Lattice Truss for Long Spans.

A Lattice Truss. A cheap truss for broad spans is the **lattice truss,** built up out of light timbers which can be had in any lumber yard. It is easily constructed. Fig. 22 shows such a truss of 60-ft. span. No unsightly rods are required to keep the side walls from spreading, since, in this form of truss, the truss itself acts as a tie, and, when properly anchored, there can be no tendency to crowd the walls out. Six trusses, exclusive of the ends, will be sufficient for a building 80 ft. long, which would call for a spacing a little less than 12 ft. on centers.

The covering for this form of roof may be of almost any of the roofing materials, aside from the gravel-coated, as the inclines at the sides are too steep to stand for any great length of time the wind and wash that the gravel roof would be subjected to.

Roof Construction

Types of Roofs. Figs. 23 to 28 show types of roofs used in ordinary construction. The "lean-to" or "shed" roof shown in Fig. 23 is the simplest type to build. An extreme case of this roof would be the ordinary flat roof having but small slope.

Fig. 24 shows the common "pitch" or V-shaped roof. This is easily built and of relatively low cost.

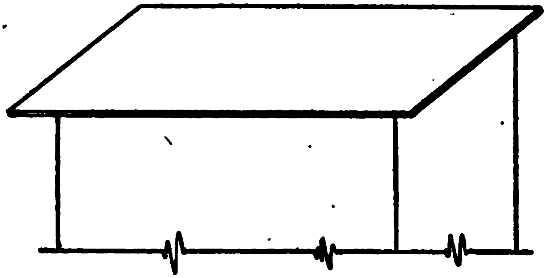


Fig. 23. Shed Roof.

The "gambrel" roof, shown in Fig. 25, gives more space for the same span than the pitch roof, and is used where attic room is a feature. A special type of the gambrel roof is the "mansard" roof, the difference lying in the slope of the first pitch.

The "hip" roof shown in Fig. 27 slopes back at the ends as well as at the sides. When this type of roof has a flat

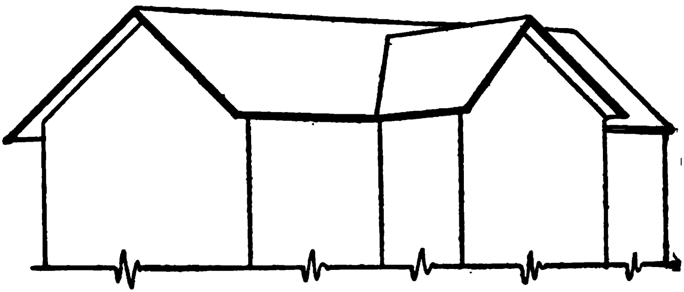


Fig. 24. Pitch Roof.

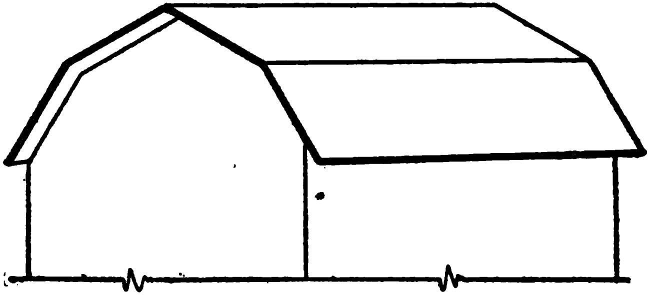


Fig. 25. Gambrel Roof.

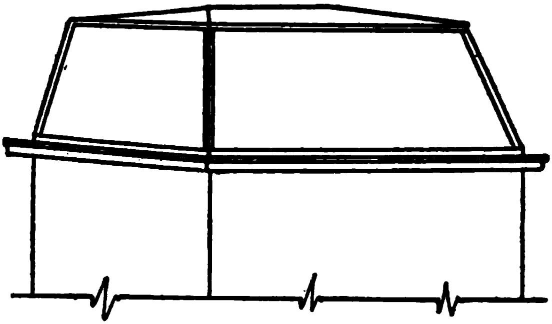


Fig. 26. Mansard Roof.

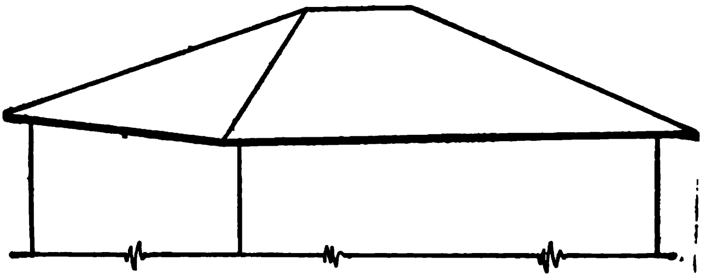


Fig. 27. Hip Roof.

top as shown in Fig. 26, it is called a "deck" roof. A hip roof is cheaper than a roof with gables, and a deck roof is still cheaper for buildings over 30 feet in width.

Slopes or Pitches of Roof. The "pitch" of a roof is the angle of slant between the rafters and a horizontal plane. A common way of expressing this quantity is to give the ratio of the rise of ridge to the span of walls, or the rise of the rafters in inches for each foot of half-span. For instance:

Two-thirds pitch	= 16	inches	rise	in	1	foot	horizontal
Half-pitch	= 12	"	"	"	"	"	"
One-third pitch	= 8	"	"	"	"	"	"
One-fourth pitch	= 6	"	"	"	"	"	"

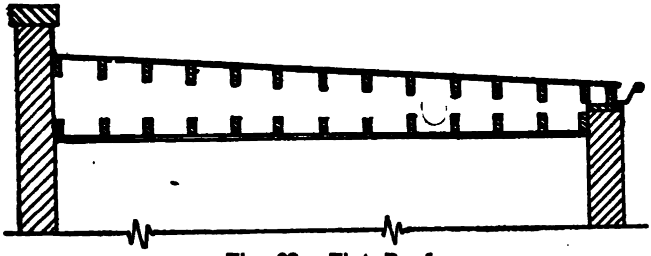


Fig. 28. Flat Roof.

The lowest pitches for safety, giving fall in inches per foot horizontal, in shingle, slate, and tile roofs, are as follows:

Shingles, cedar, 4½-in. gauge	6 inches
Shingles, cypress, 4½-in. gauge	6 inches
Shingles, asbestos, 5-in. gauge	6 inches
Slate, 8x16x3/16 inches, 6½-in. gauge	5 inches
Slate, diminishing courses	5 inches
Tile, Spanish, 5½-in. gauge	12 inches
Tile, shingle, 5-in. gauge	12 inches
Tile, interlocking	6 inches
Tile, metal, tin painted	6 inches
Tile, metal, copper	6 inches

Life of Roofing Materials. The average number of years of service of various kinds of roofing materials may be judged from the following:

Cedar shingles will last from 12 to 15 years; cypress shingles, 30 years or more; painted tin, about 25 years; while slate, asbestos shingles, and tiles are practically permanent.

SHINGLE ROOFS

Size of Shingles. Ordinary roofing shingles vary in width from 2½ to 14 inches. They are 16 inches long, and about 5/16 inch in thickness at the butt. Such shingles are put up in bundles of four to the thousand, where a "thousand" common shingles is the equivalent of 1,000 shingles 4 inches wide. Cypress shingles are about 18 inches long, and 7/16 inch thick at the butt.

Dimension singles are either 4, 5, or 6 inches in width, and may be obtained with the butt sawn to various patterns.

Method of Laying Shingles. The amount of a shingle which is exposed to the weather will depend upon the slope of the roof and the kind of shingle. Where the rise of the roof is 8 or 10 inches to the foot, cedar shingles should be laid 4 to 4¼ inches to the weather. If the rise is between 10 and 12 inches to the foot, they should be laid 4¼ to 4⅝ inches to the weather; but on steeper roofs they may be laid 4½ to 5 inches to the weather.

In wall work, cedar shingles may be laid 5 inches to the weather.

In roof work, the first course at the eaves is generally a double course; but the other courses are laid single. The courses of shingles should be lapped so that about one-third of the length of the shingle will be exposed, and each course should be laid so as to break joints at least 1 inch. Each shingle is secured by two threepenny nails placed about 8 inches from the butt of the shingle.

Cost of Shingle Work. Table XLI shows the number of square feet of roof covered by 1,000 shingles when laid with different exposures to the weather.

TABLE XLI

Covering Capacity of Shingles

Exposure to Weather	Number of Square Feet of Roof Covered by 1,000 Shingles		Number of Shingles Required for 100 Square Feet of Roof	
	4 In. Wide	6 In. Wide	4 In. Wide	6 In. Wide
Inches				
4	111	167	900	600
4¼	118	177	847	565
4½	125	188	800	534
5	139	208	720	480
5½	153	230	650	437
6	167	250	600	400
7	194	291	514	343
8	222	333	450	300

In the above table no allowance has been made for waste. On plain work, allow about 6 per cent for waste; and on irregular work, such as hip roofs or where there are dormer windows, allow 10 per cent.

If 5-inch dimension shingles are to be estimated, the following rule may be followed:

For 4 inches to the weather, multiply the width (5 inches) by the exposure (4 inches), and divide 14,400 (sq. in. in 100 sq. ft.) by this product. The result will be the number of shingles required for 100 square feet of surface.

$$5 \times 4 = 20 \text{ square inches;}$$

$$\frac{14{,}400 \text{ (sq. in. in 100 sq. ft.)}}{20 \text{ sq. in.}} = 720 \text{ shingles in 100 sq. ft.}$$

If it is desired to know how many square feet of surface will be covered by 1,000 5-inch dimension shingles laid 4 inches to the weather, multiply the width of shingles (5 inches) by the exposure (4 inches), and this again by 1,000; then divide this product by 144, the number of square inches in a square foot.

$$5 \times 4 \times 1{,}000 = 20{,}000 \text{ sq. in. in 1,000 shingles;}$$

$$\frac{20{,}000 \text{ sq. in.}}{144 \text{ (sq. in. in 1 sq. ft.)}} = 139 \text{ sq. ft. covered by 1,000 shingles.}$$

The percentage for waste as indicated above should be allowed in both of these cases.

$$720 \times 1.06 = 763 \text{ shingles (plain work); and}$$

$$1{,}000 - 60 \text{ (6 per cent. of 1,000)} = 940$$

$$940 \times 5 \times 4 = 18{,}800$$

$$\frac{18{,}800}{144} = 130 \text{ sq. ft. covered by 1,000 shingles, allowing 6 per cent for waste.}$$

Other percentages of waste may be figured in this same manner.

The labor charge should be based on 1,500 to 2,000 shingles per man in an 8-hour day on plain work, or 1,000 shingles per day on irregular wark.

The cost of nails may be estimated by allowing 5 pounds of threepenny or 7½ pounds of fourpenny nails for each thousand shingles.

SLATE ROOFS

Slate is mined along the Blue Ridge Mountains in Pennsylvania, Virginia, Maryland; also in Vermont and New York. By far the greater bulk of the output used in the United States comes from these regions. Naturally the cost of slate varies in different parts of the country, according to freight rates.

As a general principle, it may be said that, since the advance in the price of lumber and shingles, a slate roof can be put on for about the same as, or a little more than, a first-class shingle roof.

Slate comes in various colors, generally classified under the trade terms, Black, Sea Green, Mottled, Unfading Green, Unfading Red. The last two are mined in rather limited quantities, and are naturally the highest in price.

Where it is desired to produce a fancy effect, sometimes green or red slate, or both, are used in black slate roofs to produce geometrical and other patterns. Ornamental effects are also produced with slate all of the same color, by trimming the exposed corners, either in every layer or in layers at certain intervals.

Sizes of Slate. The sizes of slate vary from 6 by 12 inches up to 24 by 44 inches. The common sizes in general use vary from 6 by 12 inches to 12 by 18 inches. The sizes best adapted to plain work are the large varieties such as 12 by 16 in. or 12 by 18 in. For roofs with small sections of area, the smaller slates are used to better advantage.

Table XLII gives the common sizes of slates and the number required per square of 100 sq. ft., when a 3-inch lap is used.

Fig. 29 shows the method of determining the lap, gauge, and bond in slate work.

The thickness of slate varies from ⅛ to ⅜ inch, but the usual sizes are full 3/16 inch in thickness.

Rules for Measurement. The following are the standard rules for measuring slate work:

For Plain Roof—Measure the length of the roof, and multiply by the length of the rafter.

For Roof with Hips, Valleys, Gables, Dormers, etc.—Measure each section through the center, and multiply by length of rafters; and in addition to the actual surface of roof, measure the length of all hips and valleys, allowing 1 ft. width for these; also add in, for the first or eave course, measuring what this course shows to the weather, and multiplying by the length of eaves to get the area. In some localities this rule is not adhered to strictly, but hips and valleys are always measured wherever slate is used.

The extra measure on eave course is to compensate for lost time in starting and laying the under-course at the eave, which does not show or count in the surface measure. The extra measure on hips and valleys is intended to compensate for extra labor and loss of material in cutting, fitting, and laying same.

No deduction is made for dormer windows, skylights, chimneys, etc., unless they measure more than 4 ft. square. If more than 4 ft. square and less than 8 ft. square, one-half

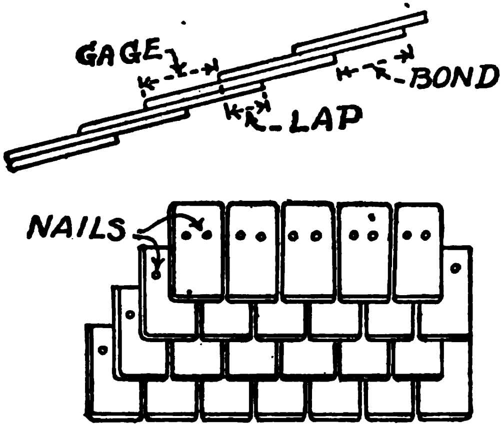


Fig. 29. Lap, Gauge, and Bond in Slate Roofing.

is to be deducted. If more than 8 ft. square, deduct the whole. The reason for not deducting the whole of all openings, is the extra work in cutting and fitting the slate and putting in the finishings. Hips and valleys on spires are measured extra, same as above. If hips are mitered and flashed, they should be charged for extra. If ridge-roll is put on, it is charged extra. Gutters, valleys, and all flashings are charged extra.

It should always be remembered, in measuring roofs, that if the pitch of the roof is the same, size of building and projections the same, the mere fact that there are hips and valleys does not add to the surface of the roof. As an example: Two buildings of the same size may be roofed—one with plain pitch and gable roof (that is, two plain sides); and the other may have four hips, four gables, and eight valleys. If both roofs are the same pitch, the roofs will measure exactly the same, and two measures are all that are necessary in measuring either—that is, the length of one eave and the length over both rafters, except that the extra measure on hips and valleys would have to be added on the cut-up roof.

Method of Laying Slate. Slate may be laid either on regular sheathing, or on roofing strips 2 to 3 inches wide and 1 to 1¼ inches thick, fastened onto the rafters of the building at a distance apart corresponding to the gauge of the slate.

Where sheathing is used, a layer of tarred roofing felt or waterproofed paper is placed over the sheathing to act as a cushion for the slate.

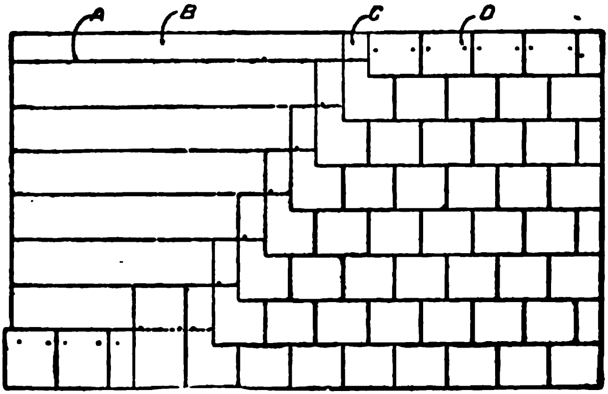


Fig. 30. Usual Method of Marking Headlines, Previous to Laying Slate.

Slating is started at the eaves, working upward, and laid with a 3-inch lap. That is, the top slate of the third course above, will overlap by 3 inches the slate of the first course below, as shown by Fig. 30. For this reason the eave course is only a little longer than half the length of the slate put on the rest of the roof. This is frequently accomplished by laying the slate in the eave course lengthwise. The lower end of this eave course slate should extend about 1⅛ inches or so beyond the eaves, and the course of slate should end flush with this edge, thus producing a double layer.

In this manner there is a double layer of slate all over the roof, and a threefold layer near and over the horizontal joints. As to vertical joints, the rows always break bonds.

A good practice is to trace out, with a carpenter's pencil or chalk, the lines along the roof surface where the various courses are to be nailed to the rafters or the sheathing, as shown by Fig. 30.

In order to allow the second course, the one above the eave course, and naturally all the following courses, to lie right, it is well to nail a cant strip along the eave before starting to slate.

Each slate is fastened with two 3d. or 4d. nails; the holes therefor being punched by the roofer on the premises or else at the quarry. A foot-power slate-punching machine will punch the nail-holes and at the same time trim the cor-

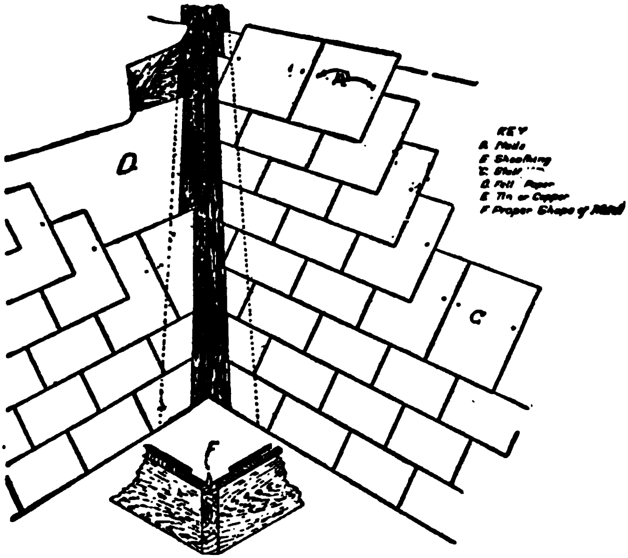


Fig. 31. Method of Slating in Open Valley.

ners. These machines are easily portable, and are frequently carried around to the various building premises by the slater. The holes are naturally so located as to allow for the 3-inch lap, no matter what the size of the slate, and placed about 1 inch from the side edges.

The nails should not be driven perfectly tight; this is so as not to interfere with the elasticity of the slate roof. Owing to its many small component pieces, it adapts itself readily to the vibrations of the wind, the sagging of the building, etc.

Of course the nail must not be allowed to project above the surface of the slate, in which case it would damage the overlying slate. Galvanized or copper nails are preferable, owing to their weather resistance.

As the courses of slate approach the ridge, a slight variation in lap is permissible so as to finish at the ridge without cresting.

The ridges and valleys of a slate roof are generally of metal. Flashings should extend well in under the slate to keep out the possible "back-flow" of water from heavy rains. Fig. 31 shows method of slating in open valley.

The top course of slate on the ridge, as well as the slate for 2 or 3 feet from gutters and at least 1 foot from valleys and hips, should be set in elastic cement.

Cost of Slate Roofs. The cost of slates will vary with

TABLE XLII
Number of Slates and Nails for 100 Square Feet of Roof

Size Inches	Exposure when Laid Inches	Number to 100 Sq. Ft., 3-In. Lap	Weight of Galvanized Nails Pounds		Spacing of Lath
14x24	10½	98	4d	1⅜	10½
12x24	10½	114		1⅝	10½
12x22	9½	126		1¾	9½
11x22	9½	138		2	9½
12x20	8½	141		2	8½
10x20	8½	170		2⅜	8½
12x18	7½	160	3d	1⅞	7½
10x18	7½	192		2¼	7½
9x18	7½	213		2½	7½
12x16	6½	185		2⅛	6½
10x16	6½	222		2½	6½
9x16	6½	246		3	6½
8x16	6½	277		3⅛	6½
10x14	5½	261		3	5½
8x14	5½	327		3¾	5½
7x14	5½	374		4¼	5½
8x12	4½	400		4⅝	4½
7x12	4½	457		5¼	4½
6x12	4½	533		6	4½
8x10	3½	514		5⅞	3½
7x10	3½	588		6¾	3½
6x10	3½	686		7⅞	3½

To determine the number of pieces to a square of any size slate not given, first deduct 3 inches from the length; divide this by 2; multiply by the width of slate; and divide the result into 14,400.

For example, for 20x10-in. slate, we should calculate as follows: 20 — 3 = 17; 17 ÷ 2 = 8½; 8½ × 10 = 85; 14,400 ÷ 85 = 170 pieces required per square.

the locality where bought, and the size, color, and quality of material. Medium sizes cost the most, while the larger and smaller sizes cost the least. The cheapest roof is made from the larger sizes.

The labor charge may be based upon 1½ to 2 squares of slate per day of 10 hours per man.

Where elastic cement is used, the cost of that part of the roof which is laid in cement will be increased $1.50 or $2.00 per square.

Table XLII shows the sizes of slate and the number of pieces per square of roof; the exposure to the weather on the roof when laid with standard 3-inch lap; the quantity of nails needed per square; and the spacing of lath used in laying.

TABLE XLIII

Weight of Slate Required for One Square of Roof

Length in Inches	Weight in Pounds, per Square, for the Thickness.							
	⅛ in.	3/16 in.	¼ in.	⅜ in.	½ in.	⅝ in.	¾ in.	1 in.
12	480	725	968	1450	1938	2420	2900	3870
14	460	688	920	1370	1845	2300	2760	3685
16	445	668	890	1336	1785	2230	2670	3568
18	435	650	870	1305	1740	2175	2608	3480
20	425	638	850	1276	1705	2130	2555	3408
22	418	625	836	1255	1675	2094	2508	3350
24	412	616	825	1238	1655	2066	2478	3307
26	408	610	815	1222	1630	2039	2445	3265

TABLE XLIV

Weight of Slate per Square Foot

Thickness (In.)	⅛	3/16	¼	⅜	½	⅝	¾	1
Weight (Lbs.)	1.80	2.70	3.62	5.47	7.25	9.06	10.9	14.5

TIN ROOFING

Kinds and Sizes of Plates. Tin plates for roofing are made by coating flat iron or steel sheets with tin or with an amalgam of lead and tin. The tin-coated plates are referred to as **bright tin plate**; and these coated with the mixture or amalgam are called **terne plate.** Terne plates should not be used on a roof if corrosive gases are present in the air.

TABLE XLV—Flat-Seam Tin Roofing—Number of 14x20-In. Sheets Required to Cover Various Areas.

A sheet of 14 by 20-in. with ½-in. edges measures, when edged or folded, 13 by 19 in., or 247 sq. in.; but its covering capacity when joined to other sheets on the roof is only 12½ by 18½ in., or 231.25 sq. in. In the following all fractional parts of a sheet are counted a full sheet.

No. of square feet	100	110	120	130	140	150	160	170	180	190	200
Sheets required	63	69	75	81	88	94	100	106	112	119	125
No. of square feet	210	220	230	240	250	260	270	280	290	300	310
Sheets required	131	137	144	150	156	162	169	175	181	187	193
No. of square feet	320	330	340	350	360	370	380	390	400	410	420
Sheets required	200	206	212	218	224	231	237	243	249	256	262
No. of square feet	430	440	450	460	470	480	490	500	510	520	530
Sheets required	268	274	281	287	293	299	305	312	318	324	330
No. of square feet	540	550	560	570	580	590	600	610	620	630	640
Sheets required	337	343	349	355	362	368	374	380	386	393	399
No. of square feet	650	660	670	680	690	700	710	720	730	740	750
Sheets required	405	411	418	424	430	436	442	448	455	461	467
No. of square feet	760	770	780	790	800	810	820	830	840	850	860
Sheets required	474	480	486	492	499	505	511	517	523	530	536
No. of square feet	870	880	890	900	910	920	930	940	950	960	970
Sheets required	542	548	554	561	567	573	579	586	592	598	604
No. of square feet	980	990									
Sheets required	610	617									

A box of 112 sheets 14" x 20" laid in this way will cover 180 square feet.

Flat-Seam Tin Roofing—Number of 28x20-In. Sheets Required to Cover Various Areas

The flat seams edged ½ in. take 1½ in. off the length and width of the sheet. The covering capacity of each sheet is therefore 26½ by 18½, or 490.25 sq in

No. of square feet	100	110	120	130	140	150	160	170	180	190	200
Sheets required	30	33	36	39	42	45	47	50	53	56	59
No. of square feet	210	220	230	240	250	260	270	280	290	300	310
Sheets required	62	65	68	71	74	77	80	83	86	89	92
No. of square feet	320	330	340	350	360	370	380	390	400	410	420
Sheets required	94	97	100	103	106	109	112	115	118	121	124
No. of square feet	430	440	450	460	470	480	490	500	510	520	530
Sheets required	127	130	133	136	139	141	141	147	150	153	156
No. of square feet	540	550	560	570	580	590	600	610	620	630	640
Sheets required	159	162	165	168	171	174	177	180	183	186	188
No. of square feet	650	660	670	680	690	700	710	720	730	740	750
Sheets required	191	194	197	200	203	206	209	212	215	218	221
No. of square feet	760	770	780	790	800	810	820	830	840	850	860
Sheets required	224	227	230	233	235	238	241	244	247	250	253
No. of square feet	870	880	890	900	910	920	930	940	950	960	970
Sheets required	256	259	262	265	268	271	274	277	280	282	285
No. of square feet	980	990	1000								
Sheets required	288	291	294								

A box of 112 sheets 28" x 20" laid in this way will cover 381 sq. ft.

The two common sizes of tin plates are 14 by 20-in. and 20 by 28-in. Although tin sheets are made in several thicknesses, the two common gauges are the IC, or No. 29 gauge, weighing 8 ounces to the square foot; and the IX, or No. 27 gauge, weighing 10 ounces to the square foot. The standard weight of a box of 112 sheets of the 14 by 20-in. size, is 108 pounds for the IC plates, and 136 pounds for the IX.

Methods of Laying Tin Roofing. There are two general methods of laying a tin roof. The **flat seam** method has the sheets of tin locked into each other at the edges, with the seam either flattened and fastened with tin cleats, or nailed firmly and soldered water-tight. In flat roof work, the tin should be locked and soldered at all joints, and should be held in place by tin cleats.

Flat seams are used on roofs of less than one-third pitch, while the roofing sheets should be of the 14 by 20-in. size. In flat seam work, 1-in. barbed and tinned roofing nails should be used, spaced not over 6 inches apart.

Standing seams are used on steep roofs, or on roofs over one-third pitch. In this type of seam, the sheets are double-seamed and soldered together into a long strip that will reach from eaves to ridge. The "upstands" for the standing seams are left on the up-an-down sides, parallel to the slope of the roof. These are interlocked and held in place by cleats, but are not soldered.

Before laying the tin, one or two layers of tar paper should be placed over the sheathing.

The under side of all sheets should be painted before laying. A paint for this purpose may be made in the proportion of 10 pounds of Venetian red and 1 pound of red lead to 1 gallon of pure linseed oil.

Cost of Tin Roofing. Tables XLV and XLVI show the covering capacities of roofing tin, using flat and standing seams, for both the 14 by 20-in. and the 20 by 28-in. sizes. Table XLIX gives the cost of roofing material per square foot of roof when tin is of a given price per box. These tables are reproduced by courtesy of the N. & G. Taylor Company, of Philadelphia, Pa.

Tin in Rolls. For the convenience of roofers and for rush orders, tin is put up in rolls 14, 20, or 28 inches wide. Each roll contains 108 sq. ft. (about 63 linear feet, 28x20-in. sheets laid 20 in. wide). The tin is painted one side or both sides as wanted, with good metallic brown paint. Seams are carefully soldered by hand.

TABLE XLVI—Standing-Seam Tin Roofing—Number of 14x 20-In. Sheets Required to Cover Various Areas

The standing seams, edged 1¼ in. and 1⅛ in. take 2¾ in. off the width; and the flat cross-seams, edged ⅜ in. take 1⅛ in. off the length of the sheet. The covering capacity of each sheet is, therefore, 11¼ by 18⅞, or 212.34 sq. in. In these tables fractional parts have been counted as a full sheet.

No. of square feet..........	100	110	120	130	140	150	160	170	180	190	200
Sheets required............	68	75	82	89	95	102	109	116	123	129	136
No. of square feet..........	210	220	230	240	250	260	270	280	290	300	310
Sheets required............	143	150	156	163	170	177	184	190	197	204	211
No. of square feet..........	320	330	340	350	360	370	380	390	400	410	420
Sheets required............	218	224	231	238	245	251	258	265	271	279	285
No. of square feet..........	430	440	450	460	470	480	490	500	510	520	530
Sheets required............	292	299	306	312	319	326	333	340	346	353	360
No. of square feet..........	540	550	560	570	580	590	600	610	620	630	640
Sheets required............	367	374	379	387	393	401	407	414	421	428	435
No. of square feet..........	650	660	670	680	690	700	710	720	730	740	750
Sheets required............	441	447	455	462	468	475	482	489	495	501	509
No. of square feet..........	760	770	780	790	800	810	820	830	840	850	860
Sheets required............	515	523	529	536	543	550	557	563	570	577	584
No. of square feet..........	870	880	890	900	910	920	930	940	950	960	970
Sheets required............	590	597	604	611	618	623	630	637	644	651	658
No. of square feet..........	980	990	1000								
Sheets required............	665	672	679								

A box of 112 sheets 14" x 20" laid in this way will cover 165 sq. ft.

Standing-Seam Tin Roofing—Number of 28x20-In. Sheets Required to Cover Various Areas

The standing seams take 2¾ in. off the width, and the flat cross-seams, edged ⅜ in., take 1⅛ in. off the length of the sheet. The covering capacity of each sheet is, therefore, 25¼ by 18⅞ in., or 463.6 sq. in. In these tables fractional parts are counted as full sheets.

No. of square feet..........	100	110	120	130	140	150	160	170	180	190	200
Sheets required............	32	35	38	41	44	47	50	53	56	59	62
No. of square feet..........	210	220	230	240	250	260	270	280	290	300	310
Sheets required............	65	68	71	74	77	80	84	87	90	94	97
No. of square feet..........	320	330	340	350	360	370	380	390	400	410	420
Sheets required............	109	103	106	109	112	115	118	121	125	128	132
No. of square feet..........	430	440	450	460	470	480	490	500	510	520	530
Sheets required............	134	137	141	144	147	150	153	156	159	162	165
No. of square feet..........	540	550	560	570	580	590	600	610	620	630	640
Sheets required............	168	171	174	177	180	184	187	190	193	196	199
No. of square feet..........	650	660	670	680	690	700	710	720	730	740	750
Sheets required............	202	205	208	211	214	218	221	224	227	230	233
No. of square feet..........	760	770	780	790	800	810	820	830	840	850	860
Sheets required............	236	239	242	245	249	252	255	258	261	265	268
No. of square feet..........	870	880	890	900	910	920	930	940	950	960	970
Sheets required............	271	274	277	280	283	286	289	292	296	299	302
No. of square feet..........	980	990									
Sheets required............	305	308									

A box, 112 sheets, 28" x 20", will cover 360 square feet.

Sheets 14 by 20-in. can be laid either the long or short way. The best roof is made by laying the sheets the 14-in. way; similarly, in laying 28 by 20-in., always lay the 20-in. way, i. e., the short dimension crosswise.

TABLE XLVII

Tin in Rolls, or Gutter Strip

Number of sheets required per lineal foot for 20-in. and 28-in. widths.

Feet	Width 20	Width 28	Feet	Width 20	Width 28	Feet	Width 20	Width 28	Hundred Feet	Width 20	Width 28
1	1	1	35	16	23	69	31	44	2	89	128
2	1	2	36	16	23	70	32	45	3	134	192
3	2	2	37	17	24	71	32	45	4	178	256
4	2	3	38	17	24	72	32	46	5	223	320
5	3	4	39	18	25	73	33	47	6	267	384
6	3	4	40	18	26	74	33	47	7	312	444
7	4	5	41	19	27	75	34	48	8	356	512
8	4	5	42	19	27	76	34	48	9	401	576
9	4	6	43	20	28	77	35	49	10	445	640
10	5	7	44	20	28	78	35	50	11	495	704
11	5	7	45	20	29	79	36	50	12	540	768
12	6	8	46	21	29	80	36	51	13	585	832
13	6	9	47	21	30	81	36	52	14	630	896
14	7	9	48	22	31	82	37	52	15	675	960
15	7	10	49	22	31	83	37	53	16	720	1024
16	8	11	50	23	32	84	38	54	17	765	1088
17	8	11	51	23	33	85	38	54	18	810	1152
18	8	12	52	24	33	86	39	55	19	855	1216
19	9	12	53	24	34	87	39	55	20	900	1280
20	9	13	54	24	34	88	40	56	21	945	1344
21	10	14	55	25	35	89	40	57	22	990	1408
22	10	14	56	25	36	90	40	57	23	1035	1472
23	11	15	57	26	36	91	41	58	24	1080	1536
24	11	16	58	26	37	92	41	59	25	1135	1600
25	12	16	59	27	38	93	42	59	26	1170	1664
26	12	17	60	27	38	94	42	60	27	1215	1738
27	12	18	61	28	39	95	43	61	28	1260	1792
28	13	18	62	28	40	96	43	62	29	1305	1856
29	13	19	63	28	40	97	44	62	30	1350	1920
30	14	19	64	29	41	98	44	63	31	1395	1984
31	14	20	65	29	41	99	44	64	32	1440	2048
32	15	21	66	30	42	100	45	64	33	1485	2112
33	15	21	67	30	43				34	1530	2176
34	16	22	68	31	43				35	1575	2240

TABLE XLVIII

Cost of Tin in Rolls, or Gutter Strip

Labor, solder, paint, rosin, and other materials not included.

Cost per box, (28″ x 20″)	$10.00	$11.00	$12.00	$13.00	$14.00	$15.00
Cost per lineal foot, 28″ wide	.05714	.06285	.06856	.07426	.07998	.08569
Cost per lineal foot, 20″ wide	.04032	.04435	.04838	.05241	.05644	.06047
Cost per box, (28″ x 20″)	$16.00	$17.00	$18.00	$19.00	$20.00	
Cost per lineal foot, 28″ wide	.09149	.09711	.10282	.10853	.11424	
Cost per lineal foot, 20″ wide	.06450	.06853	.07256	.07659	.08062	

A box of 112 sheets in	28-inch roll	will cover	175 linear feet.
"	"	"	20	"	"	248	"	"
"	"	"	14	"	"	350	"	"
"	"	"	10	"	"	496	"	"

TABLE XLIX

Cost of Tin for Standing-Seam Roofing

Size of sheets, 28 by 20 inches.

When tin costs per box......	$6.00	$6.50	$7.00	$7.50	$8.00	$8.50	$9.00	$9.50	$10.00	$10.50
S. S. Roofing costs per sq. ft..	.0162	.0175	.0189	.0202	.0216	.0230	.0243	.0256	.0270	.0283
When tin costs per box........	11.00	11.50	12.00	12.50	13.00	13.50	14.00	14.50	15.00	15.50
S. S. Roofing costs per sq. ft....	.0297	.0310	.0324	.0337	.0351	.0364	.0378	.0391	.0404	.0418
When tin costs per box........	16.00	16.50	17.00	17.50	18.00	18.50	19.00	19.50	20.00	20.50
S. S. Roofing costs per sq. ft...	.0432	.0446	.0459	.0473	.0486	.0500	.0513	.0526	.0540	.0553
When tin costs per box........	21.00	21.50	22.00	22.50	23.00	23.50	24.00	24.50	25.00	
S. S. Roofing costs per sq. ft..	.0567	.0580	.0594	.0607	.0621	.0634	.0648	.0661	.0675	

The above estimates do not include cost of laying.

The cost, using 14 by 20-in. sheets, will amount to about 25 per cent more than the cost using 28 by 20-in. size, owing to the greater number of seams; hence more tin, solder, cleats, and work are necessary.

Labor in Placing Tin. Two good average workmen will put on and paint about 3 squares of tin roofing in a day of 8 hours. In measuring up work, skylights or other openings under 100 sq. ft. in area are not deducted, since the work of laying around these openings will offset the saving in material.

Where 28 by 20-in. tin sheets are laid with flat seams, an allowance of 5 pounds of solder, 1 pound of rosin, and 1 to 1½ pounds of roofing nails should be made per square of roof. If 14 by 20 in. sheets are used, allow about 7½ pounds of solder per square of roof.

TAR AND GRAVEL ROOFS

Tar and gravel roofing is made by placing a layer of sheathing paper, then several layers of roofing felt on the sheathing, and firmly nailing in place. On temporary structures three coats are often used; but in regular construction not less than four layers are used, and often five or six. The sheets of felt are lapped and laid so as to break joints at all parts of the roof. The laps are mopped with tar and securely cemented together. Finally the entire surface is covered with a thick coating of hot tar, which is then covered with a layer of clean gravel that has been screened through a ⅝-in. mesh screen.

Laying Tar and Gravel Roofs. Since the details of laying tar and gravel roofing vary to a considerable extent, only one plan will be outlined. This method is suggested by the Barrett Manufacturing Company, and is frequently referred to as the "Barrett Specification":

Over the entire roof shall be laid a 5-ply coal-tar pitch felt and slag or gravel roof to be constructed as follows:

The rosin-sized sheathing paper to be used shall weigh not less than 6 pounds per 100 square feet.

The felt shall weigh not less than 14 pounds per 100 square feet, single thickness.

The pitch shall be the best quality of straight-run coal-tar pitch distilled directly from American coal-tar; and there shall be used not less than 120 pounds (gross weight) per 100 square feet of completed roof.

The nailing shall be done with threepenny barbed wire roofing nails driven through tin discs.

The slag or gravel shall be of such a grade that no particles shall exceed ⅝ inch or be less than ¼ inch in size. It shall be dry and free from dust or dirt. In cold weather it must be heated immediately before using. Not less than 300 pounds of slag or 400 pounds of gravel shall be used per 100 square feet.

The materials shall be used as follows:

First, lay one thickness of rosin-sized sheathing paper, lapping each sheet 1 inch over the preceding one, and nailing only so often as may be necessary to hold in place until covered with the tarred felt; and the nailing may be omitted entirely if practicable.

Over the rosin-sized sheathing, lay two full thicknesses of tarred felt, lapping each sheet 17 inches over the preceding one, and nailing along the exposed edges of the sheets only so often as may be necessary to hold the sheets in place until the remaining felt can be applied.

Over the entire surface of the felt thus laid, spread a uniform coating of pitch mopped on. Then lay three full thicknesses of felt, lapping each sheet 22 inches over the preceding one, and nailing, as laid, every three feet, not more than 10 inches from the upper edge.

When the felt is thus laid and secured, mop with pitch the full width of 20 inches under each lap. Then spread over the entire surface of the roof a uniform coating of pitch, into which, while hot, embed slag or gravel.

When this roof is to be laid over hydraulic cement concrete, as in fireproof construction, omit the rosin sheathing paper, and in its place coat the concrete with hot pitch.

Pitch of Tar and Gravel Roofs. In hot climates, a gravel roof should not have a pitch of less than ⅜ or more than ¾ inch to the foot; while in cold or damp climates the pitch should be from ⅝ to 1 inch per foot.

Cost of Tar and Gravel Roofs. The quantities of material used, and the cost of labor, will depend upon the method employed in laying a roof. The amounts of paper, felt, tar, and gravel for the Barrett type of roof may be taken from the preceding specifications, while other specifications require from 8 to 10 gallons of tar and about 1/6 of a cubic yard of gravel for each 100 square feet of roof.

To comply with the Barrett specifications, the materials needed for each 100 square feet of completed roof are approximately as follows:

Sheathing paper	108 square feet
Tarred felt	80 to 85 pounds
Pitch	120 to 160 pounds
Gravel	400 pounds
or	
Slag	300 pounds

In estimating the felt needed, the average weight is practically 15 pounds per 100 sq. ft., single thickness; and about 10 per cent additional is required for laps.

In estimating pitch, the weather conditions and expertness of the workmen will affect the amount necessary for the moppings and to properly embed the gravel or slag.

CORRUGATED STEEL ROOFING

The regular sizes of corrugations on standard sheets are 3, 2½, 1¼, ⅝, and 3/16-inch. These distances are measured from center to center of corrugations. The standard sheets, of all widths of corrugation, are made so that the distance between centers of the outer corrugations is about 24 inches. The sheets with 2½-in. corrugations are 28 in. wide before corrugating, and 26 in. after. These sheets will cover a width of 24 in. with a side lap of one corrugation, and about 21½ in. with a side lap of two corrugations.

Standard lengths of sheets vary from 5 to 10 feet by 6-inch lengths. The 8-foot length is the one most commonly used.

Method of Laying Corrugated Steel. Corrugated steel may be laid on sheathing, nailing strips, directly on purlins properly spaced, or on a steel framework. Where sheathing or

TABLE L

Number of Square Feet of Corrugated Sheets to Cover 100 Square Feet of Roof

End Laps	1 in.	2 in.	3 in.	4 in.	5 in.	5½ in.
	Sq. Feet	Sq. Feet	Sq. Feet	Sq. Feet	Sq. Feet	Sq. Feet
Side lap, 1 corrugation	110	111	112	113	114	115
" " 1½ corrugations	116	117	117	119	120	121
" " 2 corrugations	123	124	125	126	127	128

TABLE LI

Weight, in Pounds, of Corrugated Iron or Steel Plates per 100 Square Feet

Corrugations.	⅝-in.		1¼-in.		2½-in.		3-in.	
Gauge	Painted	Galvanized	Painted	Galvanized	Painted	Galvanized	Painted	Galvanized
16	...	...	...	...	271	286	271	286
18	...	...	...	...	217	232	217	232
20	...	...	170	185	163	178	163	178
21	...	...	156	171	150	165	150	165
22	...	...	142	157	136	151	136	151
23	...	...	128	143	123	138	123	138
24	114	129	114	129	110	124	110	124
25	100	115	100	115	96	111	96	111
26	86	101	86	101	83	98	83	98
27	79	94	79	94	76	91	76	91
28	72	87	72	87	68	85	68	85

timber construction is used, 8-penny barbed roofing nails 2½ inches long may be used for fastening the sheets. If steel framework is used, the sheets may be held in place by means of nailing strips fastened to the steel, by clinch nails, by clips and bolts, or by straps made of No. 18 gauge steel, ¾-in. wide, held in place by two 3/16-in. stove bolts ⅝-in. long.

When sheets are nailed in place, a nail is placed at every alternate corrugation at the ends of the sheets, and about 8 in. apart at the sides.

Clinch nails, straps, and clips are placed from 8 to 12 in. apart at the ends of the sheets; while the side laps are held by rivets spaced about 8 in. apart for roof work, and about 24 in. apart in sides of buildings.

The laps of sheets should be at least 6 in. at the ends in roof work, and 4 in. for work on the sides of building.

Cost of Corrugated Steel Roofs. Tables L and LI show the number and weight of corrugated sheets of different size per square of 100 sq. ft. of roof; while Table LII may be used to determine the number of nails needed to lay a given area of roof after the number of sheets of metal are known and the number of nails per sheet estimated.

Labor on roofs may be estimated on the basis of 10 squares of roof per day of 10 hours for one man and his helper.

Galvanizing sheet iron adds about 2½ ounces to its weight per square foot. Black sheets weigh about 2 pounds less per 100 square feet than painted sheets.

TABLE LII

Number of Barbed Roofing Nails in One Pound

Size	Length In Inches	Number in One Pound	Size	Length in Inches	Number in One Pound
4d	1½	340	16d	3½	40
6d	2	200	20d	4	30
8d	2½	100	30d	4½	20
10d	3	60	40d	5	17
12d	3½	50	50d	5½	12
14d	3½	50	60d	6	10

Where steel frame and corrugated sheets are used, the following will be of use in determining the size of nails and number of pounds needed: For 2 by 2-in. angles, use 4-in. clinch nails, 48 nails per pound; for 2½ by 3-in. angles, use 5-in. clinch nails 38 nails per pound; for 3½ by 3½-in. angles, use 6-in. clinch nails, 32 nails per pound.

When rivets are needed for closing the side laps, copper rivets weighing about 6 pounds per 1,000 rivets, or soft galvanized iron rivets weighing about 7 pounds per 1,000 rivets, may be used.

SHEET STEEL SIDING

Table LIII shows the approximate weights of various kinds of steel siding per square of 100 square feet.

TABLE LIII

Weight, in Pounds, of Steel Siding per 100 Square Feet

Gauge of Metal	Plain Brick, Rock Face Brick and Stone		Beaded		Weatherboard	
	Painted	Galvanized	Painted	Galvanized	Painted	Galvanized
24	..	..	110	125	119	135
26	77	91	83	98	89	106
27	71	85	76	91	82	98
28	64	78	70	85	75	91

TABLE LIV

Weight, in Pounds, of Flat Steel Sheets, per 100 Square Feet

Number of Gauge	Thickness (Inches)	Black Sheets	Galvanized Sheets
16	.063	250	266
18	.050	200	216
20	.038	150	166
22	.031	125	141
24	.025	100	116
26	.019	75	91
28	.016	63	79

In figuring costs for placing, two men will lay from 800 to 1,200 square feet in a 9-hour day on plain surfaces.

TILE ROOFS

Terra-cotta and concrete roofing tiles are made in a great many styles and sizes. Glass tiles are also made for use as skylights in roof construction, and are laid in with the other tiles as a part of the roof covering. Among the tiles in common use are plain tile, book tile, pan tile, Spanish tile, and Ludowici tile.

Method of Laying Roof-Tile. Tiles may be laid on plank sheathing, steel members, or on a concrete roof. The method of laying tiles on a solid surface is similar to that described for slate roof construction.

If tiles are laid without sheathing or an under covering surface, either a porous tile should be used where surface condensation may occur, or a special anti-condensation roof

TABLE LV

Standard Gauge for Sheet and Plate Iron and Steel

Number of Gauge	Approximate Thickness in Inches	Weight per Square Foot in Pounds	Number of Gauge	Approximate Thickness in Inches	Weight per Square Foot in Pounds
0000000	1-2	20.	17	9-160	2.25
000000	15-32	18.75	18	1-20	2.
00000	7-16	17.50	19	7-160	1.75
0000	13-32	16.25	20	3-80	1.50
000	3-8	15.	21	11-320	1.38
00	11-32	13.75	22	1-32	1.25
0	5-16	12.50	23	9-320	1.13
1	9-32	11.25	24	1-40	1.
2	17-64	10.63	25	7-320	.88
3	1-4	10.	26	3-160	.75
4	15-64	9.38	27	11-640	.69
5	7-32	8.75	28	1-64	.63
6	13-64	8.13	29	9-640	.56
7	3-16	7.5	30	1-80	.50
8	11-64	6.88	31	7-640	.44
9	5-32	6.25	32	13-1280	.41
10	9-64	5.63	33	3-320	.38
11	1-8	5.	34	11-1280	.34
12	7-64	4.38	35	5-640	.31
13	3-32	3.75	36	9-1280	.28
14	5-64	3.13	37	17-2560	.27
15	9-128	2.81	38	1-160	.25
16	1-16	2.50			

lining should be used under the tiles. A glazed tile is more likely to condense moisture than are porous tiles.

There are some special features that should be noted in regard to the proper framing of a roof and its preparation to receive the tile. Rafters should be at least 2 by 6 in., and spaced 24 in. on centers or closer according to length of span. Sheathing should be securely nailed, and should be either of ⅞-in. common lumber laid tight and well joined together, or of matched and dressed sheathing securely fastened. Roof pitch may be as low as one-fourth (provided slope is not of extreme length), and from that to the vertical.

Before the tile are laid, entire roof should be carefully covered with one layer good roofing felt, laid to lap 2 inches in every course, and turned up against the sides of building at least 4 inches. If building has a box or cornice gutter, felt should lap over top of metal at least 4 inches, and the same at valleys. After felt is so laid, same should be stripped with good white pine plastering lath, laid parallel, true, and straight, to facing board at eaves. The top edge of first line of lath should be 12 inches above the lower edge of facing board or starting strip; and thereafter not less than 12 in. nor more than 12¼-in. space allowed from the top edge of the next above and parallel. The tile hook over these strips;

and each tile is fastened with a 7-penny galvanized or copper wire nail.

All ridge boards should extend 3 inches above top of sheathing, and hip boards 2½ inches, both to be of ⅞-in. common lumber. Facing board or starting strips at eaves under bottom end of tile will extend up above the top edge of sheathing 1⅝ inches. In all cases facing boards at gable ends should be flush with the sheathing.

In some cases an open roof construction is used—that is, with no sheathing under the tile. In that case there must be a space of 12 inches between the lower edge of the lowest purlin to top edge of the purlin next above it, and thereafter a space of not less than 12 inches nor more than 12¼ inches between the top edge of each purlin and the top edge of the purlin next above it. These purlin strips should be ⅞-in. by 2-in. or over, the bottom strip 1¼ inches higher than the strip next above it—that is, 2⅜ inches by ⅞ inch. In this construction the hip and ridge strips should be the same as if building were sheathed.

Cost of Tile Roofs. The size and covering of a given kind of tile should be obtained from the catalogue of the manufacturer of the tile.

Plain terra-cotta roofing tiles are commonly 10½ in. long, 6¼ in. wide, and ⅝ in. thick. These tiles are laid with one-half exposed to the weather. The weight of plain tiles varies from 2 to 2½ pounds.

The labor on ordinary tile roofs may be estimated on the basis of 300 square feet of roof for one man and his helper, per day of ten hours.

SPECIAL SHINGLE ROOFS

Asphalt Shingles. Asphalt shingles are about 8 inches wide and 12¾ inches long. In laying them, but 4 inches of the length is exposed to the weather. When the shingles are laid, they form three thicknesses of material, and four thicknesses where nailed.

These shingles are made especially for all classes of residences or public buildings where either wood, slate, or tile shingles might be used. They are made in four colors—gray, green, red, and slate.

Asphalt shingles are uniform in size and thickness, and can be laid quickly and easily. They are packed one-quarter square to the case, which weighs 50 pounds when filled. One square covers 100 square feet of roof, with allowance made for all laps.

Two ½-in. head roofing nails in each shingle are used in laying. These nails are placed 4½ inches from the lower end of the shingle, and just under the edge of the shingle above it.

Asbestos Shingles. A combination of asbestos and Portland cement has been produced, which, when made up in the form of shingles, furnishes a roof that is absolutely fireproof. Simple exposure to the elements causes the shingles to become better, tougher, and harder as time goes on.

Another good point for these shingles is that they do not need paint or any attention, as the elements take better care of asbestos shingles than any paint or dressing.

They are usually applied in the French, or diagonal, method. Shingles for a finished roof laid in this manner, weigh about 250 pounds to the square. This lightness, with its accompanying efficiency, renders them peculiarly adaptable to lighter forms of construction. They may be obtained in a great variety of sizes, styles, and prices.

A common size is 12 by 12 inches, ⅛ inch in thickness. This size will lay about 155 shingles to the square of 100 square feet.

The labor charges on asbestos shingles will be from one-half to two-thirds those for wood shingles.

Cement Shingles. Portland cement shingles are made in a great variety of shapes and sizes. Most types contain some kind of wire or expanded metal reinforcement to give strength to the shingle.

These shingles are nailed to the roof in a manner similar to that used in laying slate.

Quantities required will depend upon the type of shingle used, and should be obtained directly from the manufacturer of that particular brand.

CONCRETE ROOFS

Information in regard to the quantities and cost of material needed in a given case will be found in the section on Concrete Construction. The data necessary for figuring cost of forms and labor will also be found in the same section.

ROOF FLASHINGS

Flashings are for use in places where leaks are likely to occur, such as in valleys, around chimneys, dormers, skylights, and where walls of one building or part of a building join another. This flashing consists of strips of tin, copper, zinc, or lead, laid over the roofing material in such a manner that water from the roof is prevented from getting under the roofing.

Counter-flashings are made of lead or zinc, laid between courses of brick or masonry, and turned down over the regular flashing.

In **shingle roofs**, the flashings are made of IC tin or 14-ounce zinc, used with 3-pound or 4-pound lead counter-flashing.

In **slate roof** work, the flashing should consist of 14-ounce zinc or 16-ounce copper. Sheet lead should always be used for counter-flashings where same are embedded in masonry.

In **tar and gravel** roof work, the flashings are formed by turning up the roofing felt 4 inches against the vertical surface, and covering with an 8-inch wide strip of felt laid with one-half of its width on the roof. The upper edge of this strip is fastened to the vertical surface by wooden strips securely nailed. The felt strip is then pressed down into the angle formed by the roof and the vertical wall, and firmly cemented to the roof with hot pitch.

Cost of Roof Flashings. Flashings are measured by the number of square feet contained.

In shingle work, the valley flashings are 14 inches wide, while the length will depend upon the length of the valley. Chimneys, sides of dormers, and all intersections are flashed with tin cut so as to turn up 3½ inches on the vertical and 3 inches on the roof. Where tin shingles are used for flashing at the intersection of a roof with a vertical surface, they should not be less than 7 by 6⅝ inches in size.

Lead counter-flashings should be of such size that they will extend 1 inch into the masonry, and reach down over the other flashing to within 1 inch of the roof.

In slate work, the zinc or copper flashings should be 18 or 20 inches wide for valleys and 7 inches wide for vertical intersections, allowing 3½ inches for turning up.

Labor costs may be figured on the basis of 400 sq. ft. of valley work per day of 8 hours for 2 men. These two men will also put in place 400 linear feet of ordinary flashing, or about 150 square feet of flashing and counter-flashing.

Sheet Lead Work. No sheet lead should be laid in greater length than 10 or 12 feet without a dip to allow for expan-

TABLE LVI

Weight of Sheet Lead

Thickness in inches....	1-24	1-20	1-18	1-16	1-14	1-12	1-10	1-9	1-7	9-64	1-6	3-16	1-5
Pounds, per Sq. Ft....	2½	3	3⅓	4	4½	5	6	7	8	9	10	11	12

TABLE LVII

Weight, in Pounds, Zinc per Sheet

(RICHEY'S BUILDING FOREMAN'S POCKETBOOK)

U. S. Standard Gauge	M. & H. Zinc Gauge	24x84 In.	26x84 In.	28x84 In.	30x84 In.	32x84 In.	34x84 In.	36x84 In.	40x84 In.	42x84 In.	46x84 In.	48x84 In.	52x84 In.
28	8	8.4	9.1	9.8	10.5	11.2	11.9	12.6	14.0	14.7	16.1	16.8	18.2
26–27	9	9.4	10.2	10.9	11.7	12.5	13.3	14.1	15.6	16.4	18.0	18.8	20.3
25	10	10.5	11.4	12.3	13.1	14.0	14.9	15.7	17.5	18.4	20.1	21.0	22.7
24	11	12.6	13.7	14.7	15.8	16.8	17.8	18.9	21.0	22.0	24.0	25.2	27.3
23	12	14.7	15.9	17.1	18.4	19.6	20.8	22.0	24.5	25.7	28 2	29.4	31.8
22	13	16.8	18.2	19.6	21.0	22.4	23.8	25.2	28.0	29.4	32.2	33.6	36.4
21	14	18.9	20.5	22.0	23.6	25.1	26.8	28.3	31.5	33.1	36.2	37.8	40.9
20	15	21.0	22.7	24.5	26.2	28.0	29.7	31.5	35.0	36.7	40.2	42.0	45.5

Zinc gauge can be maintained only approximately.

sion. In roof and gutter work, 7-pound lead should be used; in hip and ridge work, 6-pound; and for flashings, 4-pound.

TABLE LVIII

Weight of Sheet Copper

(Association of Copper Manufacturers of the United States)

Stubbs' Gauge (nearest number)	Thickness in Decimal Parts of 1 Inch	Ounces per Square Foot	WEIGHT IN POUNDS				
			Sheet 14x48 In.	Sheet 24x48 In.	Sheet 30x60 In.	Sheet 36x72 In.	Sheet 48x72 In.
35	.0054	4	1.16	2.	3.12	4.50	6
33	.0081	6	1.75	3.	4.68	6.75	9
31	.011	8	2.33	4.	6.25	9.00	12
29	.013	10	2.91	5.	7.81	11.25	15
27	.016	12	3.50	6.	9.37	13.50	18
26	.019	14	4.08	7.	10.93	15.75	21
24	.022	16	4.66	8.	12.50	18.00	24
23	.024	18	5.25	9.	14.06	20.25	27
22	.027	20	5.83	10.	15.62	22.50	30
21	.032	24	7.00	12.	18.75	27.00	36
19	.043	32	9.33	16.	25.00	36.00	48
18	.054	40	11.66	20.	31.25	45.	60
16	.065	48	14.00	24.	37.50	54.	72
15	.075	56	16.33	28.	43.75	63.	84
14	.086	64	18.66	32.	50.00	72.	96
13	.095	70	....	35.	55.	79.	105
12	.109	81	....	40.50	63.	91.	122
11	.120	89	....	44.50	70.	100.	134
10	.134	100	....	50.	78.	112.	150
9	.148	110	....	55.	86.	124.	165
8	.165	123	....	61.	96.	138.	184
7	.180	134	....	67.	105.	151.	201
6	.203	151	....	75.50	118.	170.	227
5	.220	164	....	82.	128.	184.	246
4	.238	177	....	88.50	138.	199.	266
3	.259	193	....	96.	151.	217.	289
2	.284	211	....	105.50	165.	238.	317
1	.300	223	....	111.50	174.	251.	335
0	.340	253	....	126.50	198.	285.	380

One cubic foot of copper weighs 558.12 pounds.

CORNICE WORK

Brick cornices are measured as solid wall of a size equal to the height and projection of the cornice. All thicknesses of wall are to be measured to the nearest half-brick above actual width.

In measuring for **sheet metal cornices**, find the girth of the cornice by measuring the exact outline of the front, following the curve of all moldings and adding the top distance back to the wall, besides that part allowed for joining to wall at top and bottom; and multiply by the length of the cornice. To this should be added all end trusses, dentils, brackets, and all extra work. Details of this kind will have to be determined from catalogues or from a local sheet-metal worker.

Stucco cornice work is measured by the square foot when composed of plain members or panel work.

Carved moldings are measured by the linear foot. Ordinary moldings less than 12 inches in girth are measured by the linear foot; but, if over 12 inches, they are measured by the square foot of surface. Internal angles and miters are provided for by adding 1 foot to the length of the cornice, and 2 feet are added for external angles.

In **wood cornice work**, the cornice usually consists of several members. Simple cornices consist of from 3 to 5 members, although the 5-member cornice is the most common and consists of a planceer, fascia, frieze, and crown and bed molding.

In measuring the amount of material required for a cornice, multiply the length of the cornice in feet, by the combined width of the planceer, fascia, and frieze, in feet. The lengths of the bed and crown molding should be taken off separately in linear feet, and treated as separate quantities. An allowance of about one-eighth should be added to each kind of material, to make up for waste.

In estimating **labor quantities on wood cornice**, the following details will be of service: For gable roofs, two average men will put on in a 9-hour day 80 feet of cornice with 10-in. planceer, 9-in. frieze, and 4-in. fascia; 75 feet with 12-in. planceer, 10-in. frieze, and 4-in, fascia; 60 feet with 16-in. planceer, 12-in. frieze, and 4-in. fascia; or 48 feet with 20-in. planceer, 14-in. frieze, and 5-in. fascia.

For **hip roofs**, two men will put on 75 feet of cornice with 16-in. planceer, 18-in. frieze, and 4-in. fascia; 65 feet with 20-in. planceer, 22-in. frieze, and 4½-in. fascia; 50 feet with 24-in. planceer, 28-in. frieze, and 5-in. fascia; 40 feet with 28-in. planceer, 32-in. frieze, and 5½-in. fascia; 30 feet with 32-in. planceer, 34-in. frieze, and 6-in. fascia.

Crown molding may be estimated at the following rate: Two men in a 9-hour day will put on 800 feet of 2-in., flat; 500 feet of 4-in., spring; 450 feet of 5-in., spring; 350 feet of 6-in., spring; 300 feet of 7-in., spring; or 250 feet of 8-in. spring.

Flat bed molding may be put on at the rate of 800 feet for 1½-in.; 750 feet for 2-in.; 700 feet for 3-in.; or 500 feet for 4-in.

In cornice work around octagon towers or semi-octagon bay windows or verandas, the labor charge should be increased from one-quarter to one-half; while in circular or curved work, the labor charge will be increased as much as one and one-half times that charged for plain work.

Miters on wood cornices may be estimated on the basis of 2 hours labor for one man; while **brackets** will vary from 10 minutes to 1 hour for putting in place, depending upon the type of bracket and the amount of trim.

On **metal cornices**, one man and his helper will put on about 40 linear feet of ordinary stock patterns; but with elaborate work this quantity may be diminished by one-half.

Data for estimating on **brick cornice work** will be found in the section on Brick Construction. The cost of laying brick in cornices will be about double that for plain work.

GUTTERS AND DOWNSPOUTS

Gutters and downspouts are usually made of galvanized iron, but often gutters are made in the form of a lumber trough lined with sheet metal. Lead, tin, or zinc may be used for this purpose. Where the side of a gutter touches a wall, the side should be turned up at least 6 in. against the wall and covered with an apron. If gutters are formed along the eaves, the gutter metal should be turned up against the roof boards for at least 10 inches and securely nailed.

The slope of gutters should be about ⅛-in. for each foot of length.

Sizes of Gutters and Spouts. A way to determine the size of downspouts for a roof is given in the following:

2-in. pipe will drain 3½-in. gutter 12 ft. long.
3-in. pipe will drain 3½-in. gutter 12 to 25 ft. long.
3-in. pipe will drain 4-in. gutter 25 to 35 ft. long.
4-in. pipe will drain 5-in. gutter 35 to 45 ft. long.
5-in. pipe will drain 6-in. gutter 45 to 55 ft. long.
6-in. pipe will drain 7-in. gutter 55 to 65 ft. long.
7-in. pipe will drain 8-in. gutter 65 to 75 ft. long.

The American Bridge Company recommends that roofs up to 50 ft. span be provided with 6-in. gutters with a 4-in. downspout every 40 ft.; that roofs from 50 to 70 ft. in span be provided with 7-in. gutters with a 5-in. downspout every 40 ft.; and for roofs from 70 to 100 ft. in span, an 8-in. gutter with 5-in. downspout every 40 ft.

Labor costs on this class of work may be estimated on the basis of 200 feet of ordinary gutter in a day of 9 hours for 2 men. These two men would also line about 150 sq. ft. of box gutter in a 9-hour day.

Two men will average about 300 feet of downspout in a 9-hour day.

In taking off quantities for the above labor, double all angles and elbows.

STEEL CEILINGS

In measuring ceilings, the surface to be covered is taken as the surface between the walls of the room, unless special care is needed. In careful work, the flat part of the ceiling is first measured; and all cornice work, coves, corners, etc., are taken off separately, in linear feet.

The plates for ceilings are generally about 24 by 24 in. but may come in 96-in. lengths.

Furring strips should be estimated separately from the ceiling material, but corner brackets and nails are furnished with the ceiling material.

Labor costs of putting up metal ceilings may be figured on the basis of 300 to 400 sq. ft. of ceiling, with cornice, etc., for 2 men in a 9-hour day; while on plain work on large surfaces, these quantities may be doubled.

PAINTING ROOF WORK

Data for estimating cost of painting or staining roofs will be found in the section on Painting and Decorating.

TABLE LIX

WEIGHTS OF ROOFING MATERIALS

Material	Weight in Pounds per Square Foot
Asphalt on felt, without sheathing	2
Ceiling, ordinary lath and plaster	6 to 8
Ceiling, stamped steel	2
Ceiling, wood, ¾-in	2½
Composition, 3-ply	1
Concrete, per 1-inch thickness of slab	13
Copper, sheet	1 to 1½
Felt, roofing, 2 layers	½
Gravel and felt, without sheathing	8 to 10
Iron, corrugated, No. 18	2½
Iron, corrugated, No. 20	2
Iron, corrugated, No. 24	1¼
Iron, flat, galvanized	1 to 3½
Lead, sheet	4 to 8
Sheathing, hemlock, 1-in. thick	2
Sheathing, spruce, 1-in. thick	2

Sheathing, yellow pine, 1-in. thick	4	
Sheathing, white pine, 1-in. thick	3	
Shingles, wood, cedar	1½	
Shingles, wood, cypress	2½	
Shingles, metal, tin, painted	1	
Shingles, metal, copper	1½	
Skylight, glass, 3/16 to ½-in., with frames	4	to 10
Slate, 3/16 to ¼-in	7	to 9
Slate, diminishing courses	12	
Steel, standing seam	1	
Tar and gravel, 4-ply	5½	
Tar and gravel, 5-ply	6	
Tiles, corrugated	8	to 10
Tiles, flat	15	to 20
Tiles, Ludowici	8	
Tiles, on concrete slabs	30	to 35
Tiles, pan	10	
Tin, on felt	1	
Tin, without sheathing	½	to 1
Zinc, sheet	1	to 2

Concrete Construction

The exact cost of concrete work in any case is governed by local conditions. In reinforced concrete, the design, the loading for which it must be adapted, the price of cement, the cost of obtaining suitable sand and broken stone or gravel, the price of lumber for forms, the wages of the laborers and carpenters, are all factors entering into the estimate. Reinforced concrete is largely laid by common labor, so that high rates for skilled laborers affect it less than many other building materials.

Sometimes the gravel and sand for a piece of work can be found at or near the site, thus greatly reducing cost.

Extra hazardous work should have something added to the estimated cost, to allow for the risk taken by the contractor. Work that must be finished in a short time should have the estimate increased, especially if a penalty attaches for failure to complete by a specified time. If the season is a poor one for the class of work, still more expense is liable to be incurred. Erecting bridges over streams in flood time may be attended with serious difficulties and expensive delays.

Large contracts, as a rule, cost less per unit than small ones. The placing and removing of the contractor's plant on a job often requires considerable time. If the magnitude of work does not justify bringing labor-saving machinery to the site, the extra labor will make the smaller job more expensive. Large orders of materials may be placed at lower rates than small ones.

Where labor is the principal item of cost in any work, less certainty can be expected in the estimate of the cost, whereas materials that are regularly manufactured should vary but little in cost.

There are some general rules that will be found very useful in making a rough estimate of the cost of structures and checking against large errors in more careful estimates:

"In making up an estimate of the cost of a building, in scaling the plans, it is found convenient to take off the volume of excavation and back-filling. The cubic feet of footings, foundations, and walls, the square feet of forms for walls of foundations and above grade, the linear feet of belt-courses, moldings, cornices, etc. Also the size of special features of exterior treatment. Similarly, the superficial areas of column and floor forms are measured by themselves. Concrete of each different mixture is scaled off in cubic feet, and totaled separately. Steel of each kind is taken off in pounds. Granolithic finished surfaces in square feet; and so on in detail, every item is measured."

Excavation and back-filling have been treated in the sections on Earth and Rock Excavation in the chapter on General Costs.

CONCRETE FOOTINGS

The dimensions of all footings for foundations may be taken directly from the plans of the structure. These sizes should have been carefully figured by the architect or designer according to the load to be carried and the stability of the soil which is to support this load. The common bearing pressures of various soils are shown in Table VIII.

For footings of rectangular cross-section, the number of cubic yards of concrete needed may be found by multiplying the length of the footing by the width, and this value by the thickness, all dimensions taken in feet; then divide this product by 27, the number of cubic feet in a cubic yard.

If the footing is stepped, the total cubic contents may be found by adding together the volume of each stepped section; or by multiplying the length of the footing by the average width, and this value by the depth, and dividing the result by 27. This same method may also be applied to footings with slanting sides, or those having a certain amount of "batter."

In case of soft soil, or where the footings are to be aided in their efforts to support the loads resting upon them by the use of concrete piles, the volume of concrete in cubic yards necessary for these piles may be obtained in the following manner: Multiply together the sectional area of the pile in square feet, the length in feet, and the number of piles of a given size, and divide the result by 27.

CONCRETE FOUNDATIONS AND WALLS

The length, thickness, and height of all foundations and walls may likewise be obtained directly from the plans. The total amount of each grade of concrete, if a different mixture is used in different parts of the work, should be figured by the method just outlined for footings, and made note of.

If walls vary in thickness at different heights in the structure, figure the contents of each belt of wall around the structure, and add together all the quantities of like mixture. Pilasters or belt courses may be figured separately, and added to the totals.

All openings such as doors, windows, etc., should be deducted from the surface of the wall in figuring, so as to get the actual cubic contents of the wall.

Any trimmings, projections, or depressions on or in the face of the wall should be considered separately, and added into the total of the mixture of which they are composed.

A rough rule for labor on reinforced walls is to allow one man one day for each cubic yard of concrete. This should take care of the placing of concrete and reinforcement.

MEASURING CONCRETE CONSTRUCTION WORK

The following rules of measurement have been adopted by the Chicago Contractors' and Masons' Association, the Chicago Architects' Business Association, and the Western Society of Engineers:

1. **Excavation of Cellars and Basements.** Excavation to be measured and computed by the actual amount of material displaced. If unit price is based upon loose measurement, add 40 per cent to actual bank measurement, except if consisting of sand and gravel, when only 20 per cent will be added. If rehandling becomes necessary, same to be done at a special price agreed upon in addition to the above.

2. **Excavation of Trenches and Pits.** Excavation of trenches, pier holes, or pits, when more than 3 ft. wide, to be computed on actual contents when less than 5 ft. deep.

When less than 3 ft. wide, excavation of trenches, pier holes, or pits to be computed on actual contents if less than 2 ft. deep.

If more than 2 ft. deep, compute contents of trench on basis of 3-ft. width, even though same is narrower.

If less than 2 ft. in depth, estimate actual width.

For pits and pier holes more than 2 ft. deep and less than 12 sq. ft. in area, estimate area of same on basis of 12 sq. ft. multiplied by depth of same down to 5 ft.; and for more than 5 ft. deep, estimate on same basis as given below for additional depth of trenches, with the same percentages of increase added:

Add 75 per cent to actual contents of excavation of trenches, pier holes, or pits, for depths between 5 and 10 ft.; add 150 per cent, for depths between 10 and 15 ft.; add 225 per cent for depths between 15 and 20 ft.; add 300 per cent for depths between 20 and 25 ft.; add 375 per cent for depths between 25 and 30 ft.; add 450 per cent for depths between 30 and 35 ft.; and so on, adding 75 per cent accumulative for every 5 ft. additional depth.

3. **Back-Filling and Grading.** Soil required for back-filling or grading to be measured by computing, from cross-sectioning, cubic contents of area to be filled or graded.

4. Sheet-piling and lagging to be estimated per thousand feet of lumber required. Kind of lumber to be specified.

5. Shoring of earth banks to be done at unit price per square foot of shored surface of bank.

6. Pumping or bailing, when required, to be done at special price, in addition to excavation unit price, as the excavation rules are based on dry work; this, however, does not apply to rain or storm water.

7. **Concrete Foundations.** Foundations for walls to be measured actual contents, when made with square and level offsets.

Footings with sloping or beveled offsets less than 30 per cent from the horizontal, multiply area of base by greatest height of footing. This applies to piers also, except when courses in pier foundations are less than 12 ft. in area, when 1 cu. ft. will be added for each corner for every foot in height of such course.

8. Foundations for all projections (such as chimney breasts, pilasters, buttresses, or flues) connected with walls, to be measured actual contents contained therein, and 1 cu. ft. added thereto for each corner for every foot in height.

9. Recesses and slots in foundations to be measured solid, and, in addition thereto, allow 2 cu. ft. for every foot in height or length.

10. Arches in foundations. Multiply length of chord at spring arch by height from chord to extrados by thickness of arch, and add to wall measurement. Height of arch-ring equal to thickness of wall.

11. Circular or polygon foundations to be figured at double actual contents.

12. For wall 14 ft. or less in height, 24 in. or more in thickness, use the actual thickness as basis in computing volume. For walls less than 24 in. in thickness, add one-half the difference between the actual thickness and 24 in. in computing the volume. If walls are more than 14 ft. in height between doors, add to cubic contents 15 per cent for every additional 4 ft. in height, on accumulative scale, as given for trench excavation.

13. For circular walls of radius sufficiently large to obvi-

ate the necessity of using specially prepared lumber for forms, add one-fifth of length to girth of wall, and figure cubic contents on the same basis as prescribed for external and division walls (paragraph 12).

14. For battered or sloping walls, estimate contents on same basis as for external and division walls, and add one-half of contents of wedge or batter to same when narrower on top than 24 in. See paragraphs 12 and 17.

Intersection and division walls, 24 in. thick or less (bonded together in any manner not abutting), to be measured as slot or recess. When thicker, add 1 ft. to length of wall for every intersection.

15. In retaining walls reinforced with beams, columns, or girders, figure concrete casing a minimum thickness of 12 in. from outside edge of steel on side next to earth bank, and 6 in. from outside edge of steel on opposite side; that is, compute wall 1 ft. 6 in. thicker than width of steel.

For all other retaining walls, compute on same basis as for external walls (paragraphs 12 and 17).

No deduction in cubic contents of concrete to be made for metal imbedded in same.

16. Hollow walls to be at special rates.

17. For each corner of wall more or less than 90 degrees, add 1 ft. 6 in. to girth length of walls in measuring.

The term "corner" is used for salient angles of walls, and "angle" for re-entering angles.

18. All plain projections, such as chimney breasts, piers connected with walls, and pilasters, to be measured actual contents contained therein, and 1 cu. ft. added for each corner for every foot in height.

19. Independent plain square piers to be measured by same rule; that is, add 1 cu. ft. for each corner for every foot in height. For plain polygon or round piers, add 4 cu. ft. for each foot in height.

20. Recesses and slots to be measured solid; in addition thereto, allow 2 cu. ft. for every foot in height or length.

21. In vaults, multiply length of chord at spring of arch by height from chord to extrados, by thickness of arch.

In walls, find contents of arch by same rule, and add same to wall measurement as called for in paragraph 10.

In sewers and tunnel arches, multiply length of extrados by thickness of arch.

22. **Openings with Frames Built In.** Deduct contents of windows, doors, and other openings, measuring from jamb to jamb and from top of sill to spring of arch, and add 2 ft.

of wall for each jamb for every foot in height of opening when plank frames are used; if box frames are used, add 4 ft. of wall for each jamb for every foot in height.

23. **Openings without Frames.** Deduct contents of openings, same to be measured from top of sill to spring of arch, and shortest distance between concrete jamb for width; and add for each jamb 2 ft. of wall for every foot in height of opening.

Circular, oval, or other special-shaped openings to be figured at special price.

24. **Chimney Breasts, Flues, and Pilasters.** All flues or hollows in chimneys or walls less than 2 ft. in area, figure solid and add 2 cu. ft. for every foot in height. All flues and hollows in chimneys or walls from 2 to 4 ft. in area to be measured solid. When larger, deduct one-half contents of flue.

Detached portions of chimneys in buildings, and plain chimney tops above roof, to be measured solid, and 1 cu. ft. to be added for each corner for every foot in height.

25. Detached chimney stacks to be figured at special rates.

26. No deductions allowed for omissions of concrete for cut stone, terra-cotta, or other trimmings, bond blocks, timber, joists, or lintels.

All ornamental or molded work in cornices, gutters, belt or sill courses, etc., to be figured at special rates.

27. Cutting and patching of joists, girder, or other holes, slots, panels, recesses, etc., to be paid for on basis of time and material required.

28. When ordered by owner, architect, engineer, or superintendent in charge of work, to rack or block in consequence of delay of delivery of iron, steel, stone, terra-cotta, or other material, that concrete work which may connect with such racking or blocking shall be measured as extra work, as follows: Increase girth length of such line by one-half, and multiply by thickness of wall.

29. **Concrete Floors on Soil and Tile Arches.** Floors to be measured by the superficial surface between outside walls of building. No deductions to be make for floor sleeps, conduits, pipes, drain, or division or partition walls. No deduction to be made for any piers, columns, chimney breasts, pilasters, or other projections of walls, of 10 ft. or less in area.

30. **Caissons.** Owing to grillage in caissons being left at different heights in same building, unit price for caissons will be computed on excavated contents, including necessary

wood-lagging and rings for same. Cubic contents of excavation of caissons to be computed from top of first set of lagging to bottom of caissons and from outside to outside of lagging. If steel or any other special casing is required, same to be paid for additional at special unit price per pound.

31. Area of bottom of bell to be multiplied by height of bell to neck for cubic contents.

32. For caissons 7 ft. or more in diameter, estimate actual contents from outside to outside of lagging.

For caissons from 7 ft. to 6 ft. 6 in., inclusive, add 5 per cent to actual contents.

For caissons under 6 ft. 6 in. to 6 ft., inclusive, add 15 per cent to actual contents.

For caissons under 6 ft. to 5 ft. 6 in., inclusive, add 25 per cent to actual contents; under 5 ft. 6 in. to 5 ft., add 35 per cent; under 5 ft., add 50 per cent to actual contents.

33. If compressed air is required, same to be paid for in addition to the above.

34. If rings are ordered left in caissons, same to be paid for additional at unit prices per pound.

35. Pumping and bulkheading to be paid for at additional price.

36. No deduction to be made for cubic contents of metal imbedded in concrete.

Concrete for filling of caissons to be computed on actual contents per cubic foot of concrete, but no deduction to be made for any metal imbedded in same.

37. **Reinforced Concrete Work—Reinforced Walls.** Compute concrete on same basis as specified in sections 12 and 17 for external and division walls, and add to same cost of reinforcing metal put in place. If, through changes or revisions, cutting of reinforcing metal delivered or ordered becomes necessary, estimate the full length of such bars or metal fabric, and add to same cost of cutting and fitting required. Reinforcing metal to be computed on unit price per pound or square foot. No deductions to be made in estimating cubic contents of concrete for any metal imbedded in same, such as wire netting, expanded metal, bars, beams, columns, etc.

38. **Columns.** Measuring of plain, uniform-size columns to be covered by the paragraph (19) relating to piers.

39. Capitals, cap, brackets, panels, molding, or other ornamental or molded work to be figured at special rate.

40. **Girders, Floor-Beams, or Other Drop Projections below Floor-Slab.** For projections named in this paragraph, add for

each corner and angle to cubic contents 1 cu. ft. for each foot in length. For each chamfered or rounded corner or angle, add ½ cu. ft. for each foot in length in addition to the above.

41. Floor and roof slabs to be estimated on same basis as called for in paragraph 29 for floors on soil, and at a minimum thickness of 6 in. Less than 6 in. in thickness will be computed as 6 in.

42. No deductions to be made in floor area for openings of less than 20 sq. ft. For larger openings, after deducting full area of opening, add one superficial foot to floor area for each foot in length of girth of opening, and 1 cu. ft. extra for each corner or angle.

43. For pits, baskets, or other depressions in floor, add one superficial foot to the area of walls and floor of same for each foot in length of each corner and angle.

44. Setting of fascias, frames, pipes, sleeves, bolts, rods, clamps, etc., imbedded in concrete, to be paid for additional at special price.

45. **Floor Base and Coves.** Floor base and coves to be estimated at special price per linear foot, with 1 foot added to length of same for each corner and angle. For base or cove around round columns, estimate three times girth of column; and for square or polygon columns, add 1 foot for each corner to girth of same.

46. Concrete stairs to be estimated per square foot area of face of treads and risers. Stair landings and platforms between floors to be same unit price per foot as stairs.

47. Curbs and roofs of skylights to be estimated on same basis as called for in sections 40 and 41, except that quantities for same shall be doubled.

48. Sidewalks laid on soil to be estimated same as floor-slab, paragraph 29, with special unit price.

CONCRETE WALL CONSTRUCTION

Cellar Walls

In estimating quantities of materials needed for cellar walls in ordinary dwelling construction, Table LX, compiled by the Atlas Portland Cement Company, gives information for three heights of basement.

The cost of cementing the bank walls of cellars generally amounts to about 65 cents per square yard for a coat ½ inch thick. Hicks states in his "Estimator's Pocket-Book" that 1 bushel of cement and 2 bushels of sand will cover 3½ square yards of wall 1 inch thick, 4½ square yards ¾ inch thick, or

TABLE LX

Thicknesses of Walls, and Quantities of Materials for Different Heights of Basement

Proportions: 1 part Portland cement to 2½ parts sand to 5 parts gravel or stone

Height of Basement	Depth of Foundat'n below Ground Level	Thickness of Wall at Bottom	Thickness of Wall at Top	Cement per 10 ft. of Length of Wall	Sand per 10 ft. of Length of Wall	Gravel or Stone per 10 ft. of Length of Wall
Feet	Feet	Inches	Inches	Bags	Cubic Feet	Cubic Feet
6	4	6	6	6	14½	29
8	6	10	8	12	29	58
10	8	15	10	24	57	114

6½ square yards ½ inch thick. Arthur in his "Building Estimator" considers that 37 cents per square yard is a fair price for a ¾-inch coat of 1:3 cement mortar on the sloping sides of hard earth cellars. He states that the material required for 100 square yards of surface is 4 barrels of cement and 2¼ cubic yards of sand. For a ½-inch rough coat of 1:2½ cement mortar on brick walls, 23 cents is said to be a fair price. If floated, the cost will be about 30 cents per square yard. The materials needed in such work are 3 barrels of cement and 1¼ cubic yards of sand for 100 square yards of surface.

Superstructure Walls

A contractor engaged in wall construction where metal forms were used and concrete raised to a height of 20 feet above grade, recorded his experience to the following effect: With concrete placed with wheelbarrows, the cost of mixing, form work, and placing concrete in 12-inch walls, was about 4½ cents per square foot of wall, or about $1.21½ per cubic yard of concrete.

A 1:3:5 mixture of concrete would cost as follows per barrel of cement used:

1 bbl. cement @ $1.50	$1.50
.44 cu. yd. sand @ $1.50	.66
.74 cu. yd. stone @ $1.50	1.11
1 lb. of reinforcing steel @ $0.02	.02
Total	$3.29

Allowing 1¼ cu. yds. of loose material for each cubic yard of concrete, this would make about 28.2 cu. ft. of concrete at a cost of about 11½ cents per cu. ft. for materials.

The total cost of materials and labor for one square foot of wall 12 in. thick, would then be 11½ cents plus 4½ cents, or 16 cents.

Allowance must be made for staging if of any but the simplest form.

A finish coat applied to the surface of the monolithic wall can be applied with a uniform and smooth surface for about 2½ cents per square foot of exposed concrete.

These costs may be slightly under the rates prevailing in some localities.

Mr. Milton D. Morrill states that he has used a mixture composed of 1 part cement, 2 parts sand, and 4 parts gravel, laid in a 6-in. wall, at $5.40 per cu. yd. Cost of materials was as follows:

1¼ bbls. cement	$1.50
½ cubic yard of sand	.60
1 cubic yard of gravel	1.50
	$3.60

To this was added the cost of erecting and removing steel forms, at 1 cent per sq. ft. of wall surface, thus making the cost of forms per cubic yard of concrete $1.10, taking the surface area of both sides of the wall.

Also the cost of handling the concrete by the spouting method was figured to be 70 cents per cu. yd.

This made a total cost, for materials and labor, of $5.40 per cu. yd. of concrete in place.

The cost of finishing walls where metal forms are used is given as 1 cent per sq. ft., which includes the floating and brush coating.

CONCRETE FLOOR CONSTRUCTION

Since the thicknesses and sizes of floors are indicated on the drawings, the cubic contents of the floor-slab, the finishing coat, beams or girders for supporting floor, and all other necessary details, may be obtained directly from the plans. Generally the main body of the slab is of a different mixture of concrete from the top surface; therefore each should be taken separately from the drawings and figured.

Beams and girders may be figured by multiplying the area of cross-section of each size of beam or girder, in square feet, by the number of linear feet of that particular size of beam or girder used in the structure, and dividing this result by 27. The final result will be the number of cubic yards of concrete needed for each particular size of beam or girder in the structure.

If the floors are of the slab type, such as used in the "Mushroom" or "Spider-Web" system, the contents of each floor in cubic yards may be found by simply multiplying the length of floor in feet by the width in feet, then multiplying this result by the thickness in feet, and dividing by 27.

If any material other than concrete is used—such, for example, as hollow tiles, which are employed to lighten floors in fireproof construction—the volume occupied by the material should be deducted from the total volume of the floor.

Cinder concrete, when used for fireproofing or deadening purposes, should be figured separately.

Granolithic or terrazzo work in floors should also be taken off in a separate amount, since it comes under a different rating, both in materials and in labor. In work of this kind it is common to state the number of square feet of surface to be laid, as well as the amount of material needed.

An approximate rule for labor on ordinary floors is to allow one man one day for each 1⅛ cu. yds. of concrete.

Cellar Floors. The cost of cellar floors of concrete will depend upon the thickness of the floor-slab and the kinds of concrete used. In determining amounts of materials, Table LXI will be of service:

TABLE LXI

Materials for 100 Square Feet of Concrete Floor

	Base, 1:2½:5 Mixture						Wearing Coat, 1:2 Mixture					
	Thickness, Inches						Thickness, Inches					
	2½	3	3½	4	4½	5	½	¾	1	1¼	1½	2
Cement, Bbls.	1.10	1.30	1.50	1.78	1.99	2.21	0.56	0.85	1.13	1.41	1.69	2.26
Sand, Cu. yd.	0.40	0.47	0.55	0.63	0.70	0.78	0.16	0.24	0.32	0.40	0.47	0.64
Stone, Cu. yds.	0.80	0.94	1.10	1.26	1.40	1.56						

The costs for laying concrete cellar floors will be about the same as for sidewalks of the same thickness, except in the case of very large basements. The cost of laying will be about 25 cents per sq. yd. less than for sidewalks.

In small work, a gang consisting of one finisher at $5.00 per day, and five laborers at $2.00 per day, will lay about 700 sq. ft. of floor surface in a 10-hour day. This estimate is based on a floor consisting of a 4-inch base laid on a cinder bed and having a ¾-inch wearing coat, the mixtures of concrete being as given in Table LXI.

With cement at $2.00 per barrel, sand at $1.00 per cu. yd., and broken stone at $1.50 per cu. yd., the cost of a floor of this type would be about $1.25 per sq, yd. for materials and labor.

A cheap floor for light use is made by laying 1 inch of coarse gravel and stone chips on a solid earth bottom, and covering with an upper coat of 1:3 cement mortar ½ in. thick. This type of floor is not so satisfactory as a heavier type of construction, but costs only 60 to 75 cents per sq. yd.

Terrazzo Flooring. Terrazzo or Venetian flooring is of the granolithic type, with polished surface, the body consisting chiefly of an aggregate of irregularly shaped angular fragments of white or colored marble, granite, or other suitable stone. These are embedded in a matrix of neat cement paste; and, after the material has been spread, the pattern is brought out by rubbing and polishing, which exposes the aggregate.

As compared with other types of permanent flooring, the relatively low cost of terrazzo is shown by the following comparative statement of costs:

Marble mosaic flooring	60 to 75 cents per sq. ft.
Ceramic tile flooring	35 to 50 " " " "
Terrazzo flooring	20 to 30 " " " "

In order to figure the cost, an allowance of about 6 pounds of aggregate and 3 pounds of cement should be made to the sq. ft. of 1-in. flooring. To this must be added the cost of labor, from mixing to a final polish, which is about 8 cents per sq. ft. This, of course, will vary in different localities, but the price given is figured on a basis of labor of one foreman at $5.00 per day, and common labor at $2.00 per day.

Granolithic Finish on Concrete Floors. The following figures of cost for the finished surface of granolithic concrete floors are average results obtained by an experienced Boston construction company:

For a 1-in. finished floor surface laid integral with and at the same time as the structural concrete, finishers being paid 50 cents and laborers 20 cents per hour, the costs for 100 square feet of finished surface were as follows:

Finisher's time	$1.00 to $1.30
Mixing and placing concrete	.42
Cement, 1 11-100 bbls., at $1.40 per bbl	1.56
Sand, 3½ cu. ft., at $1.00 per cu. yd	.12
Fine stone, 3½ cu. ft., at $2.00 per cu. yd	.25
	$3.65

If laid after the structural concrete has set, and not integral with it, the total cost of the floor will be about $1.50 more per 100 sq. ft.

If finished surface is reinforced with ¼-in. steel bars 12 in. on centers to prevent cracking, add 40 cents extra labor for mixing and placing concrete, and 30 cents extra labor for finishing—or 70 cents per 100 sq. ft. For placing steel, add 50 cents per 100 pounds, with cost of steel about $3.00 per 100 pounds at the job.

CONCRETE COLUMNS AND PILASTERS

When columns are of the same size of cross-section from top to bottom, their cubic contents may be found in the same manner as already explained for walls and floors. Multiply the area of cross-section, in sq. ft., by the length in feet, and divide by 27. If all the columns of one floor are of the same length and size, the total quantity of concrete needed will, of course, be found by multiplying the volume of one column by the number of columns on that floor.

If a column is plain in design, but of variable cross-section, the volume may be found by multiplying the area of the average cross-section in square feet by the length.

If a shell of concrete is used to protect an iron column, the volume of concrete needed per column may be found by subtracting the volume of the iron column from the volume of the finished column.

When bases or caps are used, they should be figured separately, and added to the volume of the plain column. Ornamental work and bands should be treated likewise.

An approximate labor basis for column work is to allow one man one day for each one-half cu. yd. of concrete placed.

The volume of **pilasters** may be obtained separately, figuring each size of pilaster as a column separate from the wall of which it is a part; or a part of the thickness of the pilaster may be figured in in getting the volume of the wall itself, and the projecting portion figured separately and added to the total.

Curtain walls may be figured as a vertical slab, dividing the product of the three dimensions (length, breadth, and thickness), in feet, by 27, in order to get the contents in cubic yards. The volume of all openings of any considerable size should be deducted. Projections or ornamental work should be figured separately, and added or deducted, as the case may be.

Belt-Courses, Cornices, and Exterior Ornamentation. All work which projects from the flat surface of the wall or pilaster should be figured separately, and added to the volume already obtained. Often it is difficult to find the exact cubic contents of irregular work, but this difficulty may be largely overcome by dividing the irregular-shaped body into a number of small, regular-shaped parts, and adding the volumes of these.

If belt-courses or cornices are of a different material from that used in the walls, make a separate note of each kind of material, and consider same individually in making up the estimate.

Since, in many kinds of material, belt-courses, cornices, sills, lintels, etc., are measured and priced at a certain price per linear foot of a certain size, especially where the above are furnished as separate members to be placed in the structure during the progress of the work, it is well to take from the plans the number of linear feet of cornice, belt-courses, etc., and note each kind of material, together with the size of cross-section and number of linear feet needed.

Care should be taken when figuring monolithic work, to recognize the extra cost for form work which will necessarily accompany any deviation from the plain flat surface of the ordinary wall. Costs for such work cannot be standardized to take care of all cases; and the contractor is forced to use his judgment, basing his cost on a careful analysis of the actual materials and labor necessary in producing the change in the form, and adding this increase in cost to the original plain construction cost.

STAIRS AND STEPS

In determining the materials needed for stairs and steps, a careful study of the plans will show that a division into simple parts is possible. For flying steps or stairs, the stringers may be figured by finding the section area and length. The volume of material needed for one step may be multiplied by the number of steps, and the total volume determined by adding the volume needed for the stringers.

In cast steps, or steps where a coarser grade of concrete is to be faced with a richer mixture, care should be taken to separate the volumes of the two grades of concrete, since there is a difference in the cost of each.

A rule for labor costs on stairs and steps is to allow one man one day for each ¾ cu. yd. of concrete used. It is sometimes stated that two men working together will average 1 cu. yd. of concrete per day on stairs or steps, including the building of forms.

CHIMNEYS AND SMOKESTACKS

The simplest manner of determining the volume of concrete needed in constructing a chimney or smokestack is as follows:

If chimney is of one thickness from bottom to top, find the cubic contents of the chimney figured as solid, and subtract from this result the cubic contents of the inside, or open part, of the chimney, also figured as solid. For example, if a chimney is to be built 25 feet high with 8x12-inch flue, walls 4 inches thick, the outside dimensions of the chimneys will be 16x20 inches. We shall, therefore, need from the above:

$$\frac{16}{12} \times \frac{20}{12} \times 25 = 55.6 \text{ cu. ft.}$$

less

$$\frac{8}{12} \times \frac{12}{12} \times 25 = 16.7 \text{ cu. ft.}$$

or

$$55.6 - 16.7 = 38.9 \text{ cu. ft.}$$

$$\frac{38.9}{27} = 1.44 \text{ cu. yds. of concrete.}$$

If the chimney or smokestack is of different thicknesses, or of different sizes of cross-section, at various parts of its height, divide the entire height into sections (of equal thicknesses if possible), and figure each section separately, adding the various results for the total.

Ornamental work of any kind at top of chimney will have to be figured separately, and added on to give total.

SIDEWALKS AND CURBS

Quantities of materials needed for sidewalks and curbs are determined in the same general way as already outlined. The specifications and plans according to which the work is to be performed, will give all sizes of slabs, thickness of top coat, base, and sub-base, together with the mixture to be used in each layer. From these dimensions, the number of cubic yards of each kind of concrete may be obtained; and from a table of mixtures, such as Tables LXXXI and XC, the amounts of materials may readily be figured.

The number of cubic yards of cinders or other material for sub-base, is figured in the same manner as you would figure a thick floor-slab.

Curbs are figured by separating the volumes of coarser mixture of concrete used from the facing mixture, and determining quantities as for sidewalks.

Careful attention should be paid to plans and specifications in both of the above cases, since a difference in the quality of the mixture used in figuring, from that specified, may make quite a considerable difference in the ultimate cost.

Costs are generally given at a certain price per square foot or square yard of surface of walk; but to obtain same correctly, the exact quantities of materials used must be determined, or the exact conditions governing the construction upon which the price was based must be known. It is even safer, then, to detail the cost in each individual case and obtain your own standards.

In getting together the quantities which go to make up the costs of sidewalk and curbing work, **drainage** should not be forgotten. If broken stone or tile drains are to be laid, include excavation for same, together with amounts of material needed.

The following estimate of a 6-ft. wide walk will serve as a guide in forming similar estimates:

Work consisted of a 4-in. base slab of 1:2½:5 concrete laid on an 8-in. cinder fill, and finished with a ¾-in. top coat of 1:1½ cement mortar. The stone for the concrete ranged in size from ¼ to ¾-in. The sand was a good grade of lake sand passing a ¼-in. screen. Mixing was done by hand.

Material Cost

Basis of 100 square feet of walk surface.

Cement, 2.5 barrels, @ $2.00 per barrel........	$5.00
Sand, .77 cubic yard, @ $1.00 per cu. yd.	.77
Broken stone, 1.11 cubic yards, @ $1.50 per cu. yd.	1.66
Cinders, 2.7 cubic yards, @ $0.50 per cu. yd.....	1.35
Total cost of materials per 100 square feet..	$8.78

Labor Cost.

One finisher @ $5.00 per day..................	$ 5.00
Five laborers @ $2.00 per day................	10.00
Cost per 100 sq. ft. on basis of 700 sq. ft. laid per 10-hour day	2.14
Total cost for labor and materials per 100 sq. ft.	10.92

This makes the cost of the work, without forms, about 11 cents per sq. ft. for this type of slab.

A barrel of Portland cement should contain 380 pounds net. One operator states that if work is well tamped, a barrel will yield the following for sidewalk work:

	Cement	Sand	Gravel	Thickness	Per Bbl.
Concrete course............	1	1	6	3 inch	
Top course...............	3	5	.	1 inch	52 sq. ft.
				4 inch walk	
Concrete course............	1	1	6	3¼ inch	
Top course...............	3	5	.	¾ inch	55 sq. ft.
				4 inch walk	
Concrete course............	1	1	6	3½ inch	
Top course...............	3	5	.	1 inch	49 sq. ft.
				4½ inch walk	
Concrete course............	1	1	6	4 inch	
Top course...............	3	5	.	1 inch	42 sq. ft.
				5 inch walk	
Concrete course............	1	1	6	4½ inch	
Top course...............	3	5	.	1½ inch	31 sq. ft.
				6 inch walk	
Concrete course............	1	1	6	6½ inch	
Top course...............	3	5	.	1½ inch	24 sq. ft.
				8 inch walk	

See also section on Sidewalks, Curbs, and Gutters.

CONCRETE REINFORCEMENT

Measurements. The quantity of steel or other reinforcing material may be obtained directly from the plans of the work, and should be separated into lots of a given size and length of bar. In this way the number of pounds of steel needed may be made up easily from a table giving weights per foot of lengths for bars of different sizes. Also, any sizes which are not base may be indicated and figured as "extra."

Expanded metal or wire cloth should be figured by determining the number of square feet of the material needed, and the gauge of the metal or the wires, as the case may be. Manufacturers' catalogues contain the weight per square foot of the various sizes, and the prices for same.

If stirrups are used in beam or girder work, note whether they are fastened to the longitudinal rods or not; and, if fastened, note method of fastening.

Unit-frames should be figured by themselves, and prices may be obtained directly from the manufacturers.

Do not overlook the material needed for wiring together reinforcing rods where they cross; and be sure to allow for labor in connection with same.

A record of the number of bars of different sizes which are to be bent, cut, or worked over in any manner, will be of great service in estimating the total cost of reinforcement. For this purpose we reproduce a form of **Material Sheet** as used by the Northwestern Expanded Metal Co.

If the contractor is fortunate enough to have access to a complete schedule of shapes, dimensions and weights, which is sometimes drawn up to accompany plans when submitted to bidders, his work will be simplified.

Or, if the amount of steel needed is specified as a percentage of volume of the concrete which is reinforced, the following rule may be used:

If the reinforcement is 1 per cent of the volume of the concrete (the concrete only which contains reinforcement), there will be 1-100 of 27 cu. ft. of steel needed for each cu. yd. of concrete, or 27-100 of a cu. ft. Since a cu. ft. of steel weighs about 490 pounds, the amount of steel needed per cu. yd. of concrete to be reinforced will therefore be:

$$\frac{27}{100} \times 490 = 132.3 \text{ pounds.}$$

TABLE LXII

Weight of Steel Needed per Cubic Yard of Reinforced Concrete

Quantity of steel indicated as a certain percentage of volume of concrete.

Per Cent of Steel	Lbs. Steel, per Cu. Yd.	Per Cent of Steel	Lbs. Steel, per Cu. Yd.
.25	33.1	.80	105.8
.30	39.7	.85	112.4
.35	46.3	.90	119.0
.40	53.0	.95	125.7
.45	59.5	1.00	132.3
.50	66.1	1.05	139.0
.55	72.8	1.10	145.5
.60	79.4	1.15	152.1
.65	86.0	1.20	158.7
.70	92.6	1.25	165.4
.75	99.2		

Care should be taken, in connection with the above table, not to confound the percentage of steel given in the first column with the percentage of steel when stated in terms of the sectional area of a beam or slab. The term "1 per cent of reinforcement" is used in formulas for figuring the strength of beams, but is used as a percentage of the sectional area of the beam above the center of the reinforcing rods, and not of the whole cross-section of beam. Therefore, even with plain, straight bars extending throughout a beam, there would be a considerable difference between the two percentages.

Material Sheet for Steel Reinforcement

JOB NO.................. Date..............................19....
Estimated for...
Structure...
Designer..
Cost given F. O. B. Cars..
Destination
....

Estimated by............ Checked by............ Approved by..........
Address...
....................City........................State...................
Address...
Remarks...
....

Location of Steel No. Number and Size of Sheets Pieces of Bars, Rods, etc.	Expanded Metal		Lath		Bars		Rods		Unit Price	Shipping Weight Lbs.	Freight Rate (cwt.)	Cost F.O.B. Factory	Freight	Cost F. O. B. Destination	Cu. Ft. Concrete
	No.	Sq. Ft.	Ga.	Sq. Yds.	Size	Lin. Ft.	Diam.	Lin.Ft.							

Table LXII shows the weight of steel needed per cubic yard of reinforced concrete, for percentages of volume varying from ¼ of 1 per cent up to 1¼ per cent.

As an aid in determining the weight of steel needed when sizes and lengths of rods or bars are known, or when gauges or ratings of metal fabric are stated, several accompanying tables have been prepared. If these do not include the material used, figures of a similar sort may be obtained from the manufacturer from whom the product was purchased. Various types of deformed bars are illustrated in Plate II.

TABLE LXIII

Weights of Round and Square Bars

Thickness or Diameter (Inches)	Square Bars (Lbs. per ft.)	Round Bars (Lbs. per ft.)
1/16	.013	.010
⅛	.053	.042
3/16	.119	.094
¼	.212	.167
5/16	.333	.261
⅜	.478	.376
7/16	.651	.511
½	.850	.688
9/16	1.076	.845
⅝	1.328	1.043
11/16	1.607	1.262
¾	1.913	1.502
⅞	2.608	2.044
1	3.400	2,670
1⅛	4.303	3.380
1¼	5.312	4.172
1½	7.650	6.008
1¾	10.404	4.178
2	13.600	10.680

Manner in Which Reinforcement is Sold. All steel rods and bars are sold from what is called a base price. This base price covers all rods or bars from ¾-in. diameter up to 3 1/16-in. diameter. On bars less than ¾-in. diameter, there is what is called a size differential, which is a charge of a fractional part of one cent a pound above the base price.

The present differentials for sizes are given as follows:

¾-inch bar		Base	
11/16 " "	$0.05	per	cwt.
⅝ " "	.05	"	"
9/16 " "	.10	"	"
½ " "	.10	"	"
7/16 " "	.20	"	"
⅜ " "	.25	"	"
5/16 " "	.35	"	"
¼ " "	.50	"	"

The above list of differentials is based on plain material.

There is also what is known as a **shearing differential**. This is a cost of .05 cent per pound extra on all bars less than 5 ft. in length.

A **quantity differential** is an extra charge of .15 cent per pound for shipments from the mill of less than 2,000 pounds of material.

The actual cost of material at the work is made up of the above quantities, together with the freight rate from the mill to the point of delivery, and the cost of hauling to the site.

TABLE LXIV

Weights of Deformed Bars

RANSOME TWISTED BAR

Size (Inches)	Lbs. per Ft.	Area (Square Inches)
¼	.212	.063
½	.850	.250
⅝	1.32	.320
¾	1.91	.563
⅞	2.6	.765
1	3.4	1.00
1¼	5.3	1.563

CUP BARS

Size (Inches)	Lbs. per Ft.	Size (Inches)	Lbs. per Ft.
⅜	.48	⅞	2.65
½	.86	1	3.46
⅝	1.35	1⅛	4.38
¾	1.95	1¼	5.41

JOHNSON OR CORRUGATED BARS

Size (Inches)	Lbs. per Ft.	Area (Square Inches)
¼	.24	.06
½	.85	.25
⅝	1.33	.39
¾	1.91	.56
⅞	2.60	.77
1	3.40	1.00
1¼	5.31	1.56

DIAMOND BARS

Size (Inches)	Lbs. per Ft.	Area (Square Inches)
½	.85	.25
⅝	1.33	.39
¾	1.91	.56
⅞	2.60	.76
1	3.40	1.00
1¼	5.31	1.56

TWISTED LUG BARS

Size (Inches)	Lbs. per Ft.	Area (Square Inches)
¼	.222	.063
½	.87	.250
⅝	1.35	.391
¾	1.94	.563
⅞	2.64	.766
1	3.45	1.00
1¼	5.37	1.56
1½	7.70	2.25

Steel bars for reinforcement, ¾-in., 20 feet long, may be unloaded from box cars and placed on ground beside car for as low as 32 cents per ton; but where rods are carried 300 ft. and piled on racks in steel shed, the cost may be as high as $3.00 per ton. These costs are based on common labor at 17½ cents per hour, and foreman at 30 cents per hour.

The prices of steel reinforcing bars (July, 1913), are as

TABLE LXV

Sizes and Weights of Expanded Metal

Size of Mesh—Width					Area Sq. In. per 12 In. Width	Weight. Lbs. per Sq. Ft.
⅜ in.	¾ in.	1½ in.	2¼ in.	3 in.		
Expanded Metal Numbers						
			05-2¼	05-3	.05	.17
	10-¾	10-1½	10-2¼	10-3	.10	.34
	15-¾	15-1½	15-2¼	15-3	.15	.51
20-⅜	20-¾	20-1½	20-2¼	20-3	.20	.68
	25-¾	25-1½	25-2¼	25-3	.25	.840
		30-1½	30-2¼	30-3	.30	1.02
			35-2¼	35-3	.35	1.185
			40-2¼	40-3	.40	1.36
Regular Lengths—Feet					Stock Widths—Feet	
8	8	8	8 12	8 12	2, 4, 6, 8 2, 3, 4, 6, 8	

Only the 3-inch mesh should be used for reinforcement. The smaller meshes are used for screens, fencing, and for reinforcing roofing tile.

Waste and cutting charged for lengths or widths not shown in table.

First two figures in number give area in square inches per 12-inch width. Other figures give width of mesh.

TABLE LXVI

Sizes and Weights of Kahn Rib Metal

Size, Number	Weight Lbs. per Sq. Ft.	Area Sq. In. per 12-Inch Width
2	2.13	.54
3	1.43	.36
4	1.08	.27
5	.87	.22
6	.72	.18
7	.62	.15
8	.55	.14

---

follows: Base sizes, shipment from Pittsburgh stock, 1.95 cents per lb.; New York stock, 2.25 cents; Chicago stock, 2.05 cents. These prices are for large lots.

Other quotations, with card of extra charges for small lots or odd sizes, will be found in the section on Steel Construction.

The **cost of reinforcement** of concrete work will vary greatly with the percentage of steel used, the amount of work necessary to put the steel in a condition ready to be placed in the concrete, whether unit-frames or separate bars are used, the market price of steel, and many other conditions which cannot be covered by any one price elastic enough to fit all conditions.

We have already outlined carefully the method of determining the weight of steel needed in a structure, and have provided tables covering the more common forms of reinforcement. It now remains for the contractor to determine the weights and sizes of the steel needed, and apply the current market price to same. As cautioned before, remember that sizes other than base are rated at a higher price per pound. The standard size of rod on which a base price is assumed is ¾ inch. For sizes below ¾ inch, an extra price is charged according to the rate card.

The cost of deformed rods will run from ⅓ cent to 1 cent per pound more than the cost of plain rods, except in the case of the twisted Ransome bar, which is stated to cost only about 1/10 to 1/5 cent extra per pound for twisting the square bars.

Godfrey, in his work on Concrete, states that structural steel used as reinforcement for concrete costs about 2½ cents per pound in place. Other engineers state that for plain work such as retaining walls, arches, and ordinary structures, the cost of putting in steel alone is from ¼ to ½ cent per pound, and in building work may run as high as 1 cent per pound. It is also stated that where some form of unit-frame reinforcement is used, the cost will be from ⅓ to ½ more than where the ordinary bar reinforcement is used.

In keeping records of the cost of work containing reinforcement, be sure to separate the concrete which is to be reinforced from the plain concrete, if the cost of steel used is desired in terms of the number of cubic yards of concrete reinforced.

FORMS FOR CONCRETE WORK

The cost of forms may be stated in one of three ways:

1. In cents per cubic yard of concrete used.
2. In cents per square foot of concrete surface to which the forms are applied.

3. In cents per 1,000 feet, board measure, of lumber used in constructing the forms.

It is common practice to state the cost of forms in cents per cubic yard of concrete, giving the cost of lumber and labor separately.

An analysis of the cost of forms should be taken in such a manner as to include the first cost of the lumber per 1,000 feet, board measure; the number of times that this lumber is used; together with the labor costs of framing, setting up, and taking down the forms each time that they are used, and expressed in dollars and cents per 1,000 feet, board measure. In making future estimates on work of a similar nature, this method of figuring may be used to great advantage, especially if the number of square feet of concrete surface covered by the forms was noted and made a part of the memoranda.

Many advocate the scheme of filing a sketch showing the detailed construction of the form upon which a certain price was based.

The following method is often advocated as a guide in estimating the amount of lumber needed for forms:

Lumber for Forms. Knowing the time limit within which the work must be completed, find the number of cubic yards of concrete that must be laid in one day, allowing a fair percentage of time for delay in the progress of the work. Knowing the dimensions of the work, find the number of thousand feet, board measure, of forms required to encase and support in place the amount of concrete which must be placed each day. Determining from experience, or from the specifications of the work, the number of days that the forms must be left in place on each part of the work, a fair estimate of the amount of lumber needed will result.

The amount of water used in the concrete plays quite an important part in the length of time needed for setting, since a "dry," well-rammed mixture will often set hard enough for the forms to be removed in 12 hours after the placing of the concrete. A "wet" or "sloppy" concrete would require more lumber for the job on account of the slowness in hardening of the concrete.

Cold weather has the same effect in delaying the setting of the concrete, and should also be considered in figuring costs of forms.

For work where there is any bending action or transverse strain, or where loads of any kind are likely to be placed upon the structure, the forms must necessarily be left in place for a considerable length of time. In this class of work more lumber would be required than in plain wall work, in order that the work might progress without interruption.

Different conditions of materials, climate, season of year, together with the class of structure and its use, determine largely the amount of capital which will have to be tied up in forms.

The following statements in regard to the length of time that forms should be left in place are only approximate. Inspection by the architect or engineer in charge is to be recommended in all cases before forms are removed by the contractor.

Walls in mass work—1 to 3 days, or until the concrete will bear pressure of the thumb without indentation.

Thin walls—in summer, 2 days; in cold weather, 5 days.

Short-span slabs up to 6 ft. span—in summer, 6 days; in cold weather, 2 weeks.

Beams and girders and long-span slabs—in summer, 10 days or 2 weeks; in cold weather, 3 weeks to 1 month. If shores are left without disturbing them, the time of removal of the sheeting in summer may be reduced to 1 week.

Columns—in summer, 2 days; in cold weather, 4 days, provided girders are shored to prevent appreciable weight reaching columns.

Conduits—2 or 3 days, provided there is not a heavy fill upon them.

Arches—small size, 1 week; large, with heavy dead load, 1 month.

It is policy to lay out the form scheme for a structure in advance; and from this plan the number of sq. ft. of concrete surface to be covered may readily be figured by applying the common rules for figuring areas. The sizes of struts and supporting members are determined by the ordinary rules of design, and the entire quantity reduced to board measure, or the equivalent number of linear feet of material 12 in. wide and 1 in. thick.

In arranging this plan for the construction of forms, lay out as much of the work as possible in sections or panels, which may be used a number of times without tearing apart. This will not only save the material from the wear and tear resulting from dismembering, but will cut down the cost of handling in the structure.

TABLE LXVII

Safe Strength of Wood Struts in Forms for Floor Construction

POUNDS PER SQ. IN. OF CROSS-SECTION

Length of Strut	3 x 4 in.	4 x 4 in.	6 x 6 in.	8 x 8 in.
14 ft.		700	900	1,100
12 ft.	600	800	1,000	1,200
10 ft.	700	900	1,100	1,200
8 ft.	850	1,050	1,200	1,200
6 ft.	1,000	1,200	1,200	1,200

Cost of Forms

As previously stated, the cost of forms may be quoted at a certain price per cubic yard of concrete enclosed, or at so much per square foot of surface covered by the forms.

The cost of forms varies with the type of structure and the amount of irregularity in the surface to be supported. On ordinary wall work the cost of rough plank forms may be as low as 50 cents per cu. yd. of concrete for a wall 3 ft. thick. This price includes both labor and lumber, with both sides of the wall supported. For buildings of symmetrical design, the cost of forms for walls, including lumber and labor on forms, may be as low as 9 to 12 cents per sq. ft. of surface of forms; but if these forms can be used only once, the price may be doubled.

For plain work such as dams and retaining walls, the cost of framing and erecting forms will be about $7.00 per thousand feet, board measure; while the cost of tearing down in order to move will amount to about $2.00 per thousand in addition. If the forms are built in panels, to be used over and over again, the cost of moving to a new location may be as low as 60 cents per thousand feet, board measure.

Gillette, in his "Handbook of Cost Data," has given a rule for determining the cost of plain forms for piers and retaining walls, which should prove of value. The rule is based on the assumption that 2-in. planks are used for the forms, and that each square foot of face requires 40 per cent as much material to hold it in place. This assumption would allow 40/100 of 2 board feet, or 8/10 of a board foot of bracing and 2 board feet of planks, for each sq. ft. of surface covered. The price of lumber is taken as $25.00 per thousand board feet, and the forms are figured to be used 4 times.

This rule states that the cost of forms per cu. yd. of wall for plain work may be estimated by dividing the set price of $3.80 by the product obtained by multiplying the thickness of the wall in feet by the number of times the forms are to be used, and adding to this the result obtained by dividing $1.20 by the thickness of the wall in feet.

The first part of this empirical rule is supposed to give the cost of the lumber needed; and the second part, the cost of the labor for taking down and erecting.

If building work is to be figured, the above data—which relate to wall construction—will be of little service, since a greater percentage of supporting lumber will be needed, the cost of framing same will be more, and the forms in many instances will have to be left in place for a longer time than in ordinary wall work, thereby requiring a greater outlay for lumber.

The most satisfactory way to estimate the cost of forms for a particular piece of work is to measure up the amount of lumber needed as outlined above under "Lumber for Forms," taking care that enough material is figured on so that the forms will be rigidly supported. Then allow $6.00 to $8.00 per thousand feet of lumber, board measure, for framing and erecting. This will apply fairly close in simple work.

The costs for removing and changing forms have already been given.

A check on the estimate thus formed would be to have a carpenter estimate on the cost of framing, and see if his estimate compared favorably with the price given above.

Reference to Tables I and LXVIII will show a variation in the cost of forms, depending on their location in the structure.

As an example of the labor connected with the above-mentioned cost of forms and centering, we quote an answer to an inquiry made as to the cost of labor on building walls consisting of piers 2 ft. square, with 8-inch curtain walls between, the reinforcement consisting of an ordinary type of deformed bar:

"The labor cost in concrete form building is a very uncertain figure, as no two men do the same amount of work per day. I have had a squad of carpenters and helpers who would build forms for 24 by 24-in. columns at less than 10 cents per foot height; and, again, I have seen it cost as much as 35 cents per foot. Then, conditions make a wide difference; and I recall an instance where forms cost as much as 70 cents per cu. ft. of concrete, as no form could be used over again in stories higher up. The side-wall forms are worth from 6 to 20 cents per sq. ft. for labor; but it is all guesswork, for even the nature of the lumber

TABLE LXVIII.
Cost of Various Classes of Concrete Work

Kind of Structure	Average Cost of Forms per Square Foot				Average Cost of Concrete per Cubic Foot						
	Carpenter Labor	Lumber	Nails and Wire	Total	Concrete Labor	General Labor	Cement	Aggregate	Teams and Misc.	Plant	Total
	$	$	$	$	$	$	$	$	$	$	$
Building Walls (Above Grade) Average of 17 Structures.........	.085	.036	.002	.128	.090	.016	.073	.076	.025	.019	.301
Footing and Mass Foundations Average of 10 Structures.........	.057	.034	.002	.093	.045	.007	.071	.077	.007	.021	.229
Foundation Walls Average of 14 Structures.........	.068	.033	.002	.103	.076	.015	.080	.062	.019	.017	.269
Beam Floors of Reinforced Concrete Average of 18 Structures.........	.070	.045	.002	.116	.111	.020	.106	.063	.025	.024	.354
Flat Slab Floors Average of 3 Structures..........	.071	.038	.002	.111	.097	.009	.096	.070	.019	.024	.315
Concrete Columns Average of 9 Structures..........	.082	.036	.001	.130	.096	.027	.085	.049	.021	.023	.301
Concrete Slabs Between Steel Beams Average of 13 Structures........	.061	.032	.002	.095	.102	.019	.128	.068	.024	.017	.359

Cost of handling steel for reinforcement (Average of 21 structures) was $8.52 per ton.

affects the labor cost data; besides, you must remember that the cost of forms is always the big item in reinforced concrete, and until we have a system of changeable forms it always will be. I recall an instance where a contracting firm underestimated the cost of forms $28,000 on a building which they contracted to build for the sum of $230,000. In fact, their estimate as to cost of forms was only $17,000, and the total cost amounted to $45,000.

"The cost of labor per cu. yd. for reinforced work of sizes given will be as follows: First-story columns, $2.35 per yard; walls, $2.75 per yard. Second-story-columns, $2.66 per yard; walls, $3.00 per yard; and so on up. These figures are based on machine-mixing and elevator."

Experience Cost Data. Table LXVIII shows a detailed consideration of the costs of reinforced concrete construction work. The steel cost given at the end of the table applies only to cost of putting in place, and does not cover purchase price. These costs were obtained from a very large corporation engaged exclusively in reinforced concrete work and employing as superintendents and foremen experienced, skilled men. The average contractor handling occasional jobs cannot hope to reach these figures except under very favorable circumstances.

The costs of concrete work given in Table I were compiled by Mr. L. C. Wason, and represent results obtained from careful observation over a long period.

Table LXX will be found of value as an actual record of the cost of various classes of concrete work as carried out during the year 1907 by a prominent contracting company for one of the large Eastern railway systems in the United States.

Mr. Edward F. Godfrey, also on the basis of wide observation, gives the following costs:

Portland cement concrete, in **large mass**, easily deposited, $4.00 to $7.00 per cubic yard. Walls requiring difficult forms, $6.00 to $8.00 per cubic yard. Tunnels, etc., $10.00 to $12.00 per cubic yard.

Reinforced concrete, including steel, usually costs from $10.00 to $20.00 per cubic yard. Concrete should be estimated at $5.00 to $10.00 per cubic yard in place; steel, about 2.5 cents per pound in place (plain structural steel); forms

TABLE LXIX

Concrete Factories vs. those of Wood or Brick

Approximate Yearly Cost of Insurance per $100

Exposures, none; area not large; good city department; no private fire apparatus except such as pails and standpipes

Class of Structure	All Concrete		Brick Mill Construction or Open Joists.		Wood Mill Construction or Open Joists.		Add for brick or wood bldgs. in small towns and cities without best of water and fire departments.
	Bldg.	Contents	Bldg.	Contents	Bldg.	Contents	
General Storehouse	20c.	45c.	60c.	100c.	100c.	125c.	25c.
Wool Storehouse..........	20c.	35c.	40c.	60c.	75c.	100c.	25c.
Office Building..........	15c.	30c.	35c.	50c.	100c.	125c.	25c.
Cotton Factory...........	40c.	100c.	100c.	200c.	200c.	300c.	50c.
Tannery..................	20c.	40c.	75c.	100c.	100c.	100c.	25c.
Shoe Factory.............	25c.	80c.	75c.	100c.	150c.	200c.	50c.
Woolen Mill..............	30c.	80c.	75c.	100c.	150c.	200c.	50c.
Machine Shop.............	15c.	25c.	50c.	50c	100c.	100c.	25c.
General Mercantile Bldg.	35c.	75c.	50c.	100c	100c.	150c.	25c.

NOTE—These costs are based on the absence of automatic sprinklers and other private fire protective appliances of the usual completely equipped building. They are not schedule rates, but may be an approximation to actual costs under favorable conditions based on examples in various parts of the country.

TABLE LXX

Costs for Various Classes of Railway Concrete Work

Class of Work	Year	Total Yardage of Concrete	Total Yardage of Excavation	No. Jobs	Average Yardage of Concrete per Job	Average Yardage of Excavation per Job	Average: Driving Foundation Piles, per Pile ($)	(¢)	Average: Excavation per Cu. Yd. of Excavation ($)	(¢)	Average: Concreting per Cu. Yd. of Concrete ($)	(¢)
Bar Top Culv'ts and H. W. Crossings	1907	26151.8	17973.0	46	568.0	389.0	2	87	1	88	1	71
Bar Top Culv't & H. W. Xing Ext'ns	1907	122.3	110.0	2	61.1	55.0			1	51	2	35
Piers and Abutments	1907	28434.0	24059.0	34	836.0	707.0	2	81	1	82	1	63
Pier and Abutment Extensions	1907	71.9	70.0	1	71.9	70.0				92	1	36
Building Foundations	1907	2462.4	3077.0	11	224.0	280.0	1	11	1	40	2	38
Pedestals	1907	665.1	751.0	6	110.8	125.2			1	24	1	97
Turntables, Trans. Tables, etc	1907	2159.9	6750.0	7	308.5	964.0	1	86	1	01	1	78
Retaining Walls	1907	222.5	945.0	1	222.5	945.0				58	1	10
Floor Slabs	1907	227.1		2	113.6						2	39
Arches	1907	7520.0	3556.0	5	1504.0	711.2	2	60	3	08	1	33
Arch Extensions	1907	154.3	168.0	1	154.3	168.0			1	81	1	89
Special Reinforced Jobs	1907	477.4	2480.0	3	238.7	1240.0				62	1	78
Average for all Jobs	1907	73139.0	64841.0	127	576.0	511.0	2	70	1	79	1	70

5 to 10 cents per square foot. The unit-cost of concrete will depend upon the difficulty of handling and placing.

Cement finish, mortar ½-in. thick, 50 to 80 cents per sq. yd.

As a comparison with the costs given by Mr. Godfrey, Mr. Trautwine in his "Engineers' Pocket-Book" gives the following prices for concrete work:

For **mass work** such as breakwaters, fortifications, etc., $5.00 to $7.00 per cu. yd. of concrete in place. May run as low as $4.00 or as high as $8.00.

For **retaining walls, foundations,** etc., prices vary with difficulties met with in construction, and run from $4.00 to $16.00 per cu. yd. of concrete in place. Many instances show the price to be between $6.00 and $9.00. Reinforced walls cost from $3.00 to $10.00 more than plain walls.

For **building work,** the costs for plain work average between $6.00 and $12.00 per cu. yd. of concrete in place, while reinforced work costs between $10.00 and $20.00 per cu. yd., and is sometimes priced even as high as $27.00 per cu. yd.

Small arches, such as used in culvert work, under 30-ft. span, cost from $5.00 to $10.00 per cu. yd.

TABLE LXX—(Concluded)

Cost of Labor: Concrete Forms: Per Cu. Yard Neat Work		Per Sq. Yard Form Surface	Total Per Cu. Yard Concrete Excl. of Exc. Fdn. Piles, Moving and Spec. Items		Total Per Cu. Yard of Concrete Excl. of Fdn. Piles and Special Items		Average Amount of Material: Ft. B. M. of Lumber Used: Coffer Dam Per Cu. Yd. of Footing		Concrete Forms Per Cu. Yd. Neat Work		Concrete Forms Per Sq. Yd. Form Surface		Crushed Stone Per Cu. Yd of Concrete	Sand or Gravel Per Cu. Yd. of Concrete	Sacks Cement Per Cu. Yd. Concrete: In Footing		In Neat Work		In Cover		Average Total Cost of Materials Per Cu. Yd. Concrete Excl. of Special Items		Average Total Cost of Concrete Per Cu. Yard. Excl. of Fdn. Piles and Special Items	
1	63	42	2	11	3	58	14	3	22	0	14	7	98	51	4	34	4	58	5	16	3	12	6	70
	84	46	3	01	5	68	9	0	2	5		9	91	84	3	63	4	82	5	88	2	79	8	47
	65	53	2	06	3	78	38	5	17	7	14	5	82	57	4	38	4	64			3	14	6	82
1	66	39	1	80	3	47	40	8	8	9	5	3	59	68	3	56	4	53			2	78	6	25
	46	36	3	48	5	28			36	8	9	2	90	73	5	51	5	82			3	75	9	03
	71	33	2	81	3	87	7	1	25	0	11	5	86	59	4	16	4	50			2	87	6	74
	87	35	2	24	5	55	33	2	20	4	8	3	90	61	4	62	4	58			3	29	8	84
	61	20	1	43	4	82			33	7	11	1	81	58	3	65	4	35			2	81	7	13
1	16	21	3	54	3	87			83	0	15	1	74	55					5	58	5	20	9	07
1	33	91	2	30	4	02	25	2	24	5	16	7	99	50	4	45	4	54	5	12	3	25	7	27
	86	40	2	03	4	69	19	4	24	0	13	6	86	44	4	40	5	40			3	30	7	99
5	20	85	4	03	7	57			105	0	19	2	76	61	6	02	6	16			4	83	11	90
	36	52	2	27	4	04	24	3	22	6	13	7	90	54	4	44	4	60	5	17	3	20	7	24

COST OF CEMENT AND AGGREGATES

The factors which combine to form the cost of the materials of which concrete is composed are: Cost of cement; cost of sand; cost of crushed stone, gravel, slag, or cinders.

Cement. The cost of cement will vary with the locality in which it is to be used, and also with the kind of cement used. The present market prices (July, 1913), for Portland cement are as follows:

New York—$1.58 per bbl. delivered within lighterage limits, or 95 to 98 cents per bbl. in bulk at the mill; Boston—$1.72 per bbl.; Chicago—$1.20 per bbl., some large orders at $1.10. The charge of 10 cents each for sacks (or 40c. per bbl.) is rebated on return of sacks in usable condition.

These prices vary with the amount bought, and freight charges will also depend upon this same quantity. Cement is packed for shipment in paper bags, cloth sacks, or wooden barrels. A barrel of Portland cement contains 380 lbs. of cement, and the barrel weighs 20 lbs., making 400 lbs. in all. The content of a tightly packed barrel of Portland cement varies from 3 to 3 8/10 cubic feet.

A barrel of so-called "Western" natural cement contains about 265 lbs. of cement, and the barrel itself weighs 15 lbs.; but a barrel of Rosendale or other "Eastern" natural cement contains 300 lbs. of cement, and the barrel weighs about 20 lbs.

Although we have referred above to the weights of a barrel of the two cements, Portland and natural, the common unit of measurement, especially for shipment, is the bag. The ordinary barrel of Portland cement contains 4 bags, while a barrel of "Eastern" natural cement contains only 3 bags. "Western" natural runs 2 sacks per barrel. In work of considerable magnitude, it is not uncommon to buy cement in barrels, or even in bulk.

The charges for packing vary slightly with the method in which the product is placed on the market. A charge of 10 cents is common for each sack, which is rebated if the bags are returned clean and in good condition. Cement in barrels is about 10 cents per barrel higher than bulk cement; while that in paper bags costs about 5 cents per barrel in excess of the charge for bulk material.

The statement as to the number of cubic feet of Portland cement in a barrel as given above, refers to a packed barrel. When the cement is dumped from the barrel and loosened up, it swells considerably, and increases about ¼ in volume as compared with its original packed condition. A common assumption is that a bag of Portland cement contains 1 cu. ft. This assumption is rather crude, but will suffice for rough work.

The costs in Table LXXI are based on the following constants:

Cement (vol. 3.8 cu. ft.) delivered on job, per bbl., net $1.75
Broken stone (21 cu. ft. equals 1 ton), per ton........ 1.50
Sand, per cu. yd.. 1.20
Gravel (containing stone and sand in right proportions), per cu. yd. 1.15
Labor (foreman, common and miscellaneous), .06 cu. ft., or, per cu. yd. 1.62

With common labor at 17½ cents, and foreman at 30 cents, per hour, 6 men will unload 600 bags of cement from a car in 3 hours, where the cement is passed directly from car to storage shed. Since this amount is equal to 150 barrels, the unit cost per barrel is about 2 cents.

If unloaded by wheelbarrows and wheeled a distance of 100 feet, the cost will probably be about 5 cents per barrel.

Weights of the various materials used in concrete, together with the weights of various concrete mixtures, will be found also in the general tables of weights of substances.

TABLE LXXI
Data Regarding Cost of Various Mixtures of Concrete
(Aberthaw Construction Company)

Ratio. Volume of Cement, Sand, Stone	Volume of a Batch in Place (Cu. Ft.)	Barrels of Cement per Cu. Yard	Cost of Cu. Ft. Broken Stone Concrete	Cost of Cu. Ft. Gravel Concrete
1 : ½ : 1	6.8	3.97	$0.37	$0.34
1 : 1 : 2	9.7	2.79	.314	.274
1 : 1½ : 3	12.6	2.14	.283	.237
1 : 2 : 4	15.6	1.73	.264	.214
1 : 2½ : 5	19.0	1.42	.246	.195
1 : 3 : 6	22.8	1.18	.23	.179
1 : 3½ : 7	26.6	1.02	.219	.169
1 : 4 : 8	30.4	.89	.210	.160
1 : 4½ : 9	34.2	.79	.205	.154
1 : 5 : 10	38.0	.71	.200	.149
1 : 5½ : 11	41.8	.65	.195	.145
1 : 6 : 12	45.6	.59	.192	.141

Sand and Gravel. The cost of sand may vary from 50 cents a cubic yard up to $2.00 or over, depending upon the cost of labor, amount of labor necessary to produce a given amount of sand free from rocks or pebbles, the distance that the sand has to be hauled or shipped, the number of times that it has to be handled before reaching its destination, and the cost of preparing for proper use in concrete.

A common price for sand, in cities, is about $1.00 per cubic yard, delivered; but this is only fairly approximate. If sand is to be bought by the load, a careful stipulation should be made as to the exact size of the load as measured in cubic feet. A 1-horse load of sand generally contains about 22 cu. ft., while 2-horse loads vary from 1¼ to 2 cu. yds. It is commonly considered that 1¼ cu. yds. is a fair load, 1½ cu. yds. a good load, and 2 cu. yds. a large load. The weight of a cubic yard of dry sand is generally taken to be 2,700 pounds.

Some of the component parts which go to make up the total cost of a cubic yard of sand on the job are indicated as follows:

Cost of building sand in bank is about 20 to 25 cents a cu. yd. This same sand on board a car would cost from 40 to 50 cents a cu. yd. The freight charges for hauling this sand 50 miles are about 75 cents a cu. yd. The cost of hauling from the cars in teams is about 25 to 50 cents a cu. yd. Therefore it may be seen that there is no standard price for sand, since the cost of same will vary with any of the above named quantities and according to the number of them which must be considered before the sand is at the place where it is to be used.

The same conditions may be applied to gravel with a slight change in the figures. Gravel in bank is worth from 15 to 20 cents per cu. yd., while on cars this price is raised to 35 or 40 cents. The freight for a 50-mile run is the same as that for sand, 75 cents per cu. yd. The cost of hauling by teams from the cars is from 25 to 50 cents per cu. yd. The usual price of gravel delivered when supply is near by, is about $1.00 per cu. yd.

If it is desired to estimate the cost of sand from a bank in a locality near the structure, same may be done by following this plan:

Add together the cost of the sand per cu. yd. in the bank, the cost of loading into wagons per cu. yd., the cost of hauling per cu. yd., and the cost of washing.

It is estimated that a good workman will load 20 cu. yds. of sand into wagons per 10-hour day, while a slower man may only average 15 cu. yds. per day. Better figure on a 15-cu. yd. basis. Divide the amount paid for labor by the number of cu. yds. loaded, and the result is one factor of the total cost—the **cost of loading** per cu. yd.

The cost of **team hauling** is about 26 cents per mile of haul. If 1 cu. yd. makes a load, add 26 cents per cu. yd. for each mile of haul; or, figure at a rate of ½ cent for each 100 feet of haul.

Allow for **lost time** of team while loading and dumping. This will ordinarily amount to about 5 cents per cu. yd. The above costs are based upon team hire at 35 cents per hour, and a rate of travel of 2½ miles per hour. Since the sand is only hauled one way, the expense of the total trip must be charged to the cost of the sand.

Where sand and gravel may be unloaded directly from the car to the storage pile, the cost of shoveling will vary from 6 to 10 cents per cu. yd., with an average price of 8 cents. This is based on common labor at 17½ cents, and foreman at 30 cents, per hour.

The cost of sand in Chicago (July, 1913), is $1.15 per cu. yd. in carload lots, f. o. b. Chicago.

If sand has to be washed before it can be used, the **cost of washing** may be figured as follows: For sand washed by the use of a single-inclined platform fitted with cleats to act as stops for the sand, figure a cost of from 15 to 30 cents per cu. yd., depending upon the cost of water used in washing.

If a pair of boxes or platforms are used so that one can be washed while the other is emptied, one man can wash about 30 cu. yds. of sand in a 10-hour day. The cost per cu. yd. for labor in washing will be this man's wages, divided by the number of yards washed. To this price must be added the cost of shoveling the washed sand from the platform or tank which is not being used. This cost will be about 10 cents per cu. yd., depending on the rate of day wages paid. Any extra handling or shoveling of the material should be considered, since many times these little points make a great difference in the cost of a material.

Broken Stone. The cost of broken stone is a varying quantity, depending upon the locality in which the stone is to be used. If the stone is to be purchased from the nearest dealer or from the nearest crusher, determine the cost of the material per cu. yd. at the plant or at the dealer's, and add costs of transportation and hauling. If stone requires handling other than that required to load onto cars or wagons, and then hauling from cars to place where stone is to be used, add an allowance for each handling.

If the contractor undertakes to furnish his own stone from a local quarry, he must figure the cost of quarrying, crushing, and hauling. Since these costs vary so greatly with the quality of stone handled, no set price can be given.

Examples are stated where limestone has been quarried and crushed as low as 53 cents per cu. yd. of 2-in. size stone, while other cases using the same kind of rock will show higher costs. It is often stated that a fair price for quarrying and crushing limestone is about 75 cents per cu. yd., exclusive of quarry rent and the costs for labor necessary to remove the earth from the rock so as to get at the latter. To this price must be added the cost of handling and hauling.

Another instance, where quartzite was quarried and crushed for concrete work, showed a cost of $1.00 per cu. yd. at the crusher. An extra charge of 50 cents per cu. yd. was made for hauling the crushed rock 2½ miles.

Instances are given where trap rock has been crushed in large quantities for as low a price as 50 cents per cu. yd., including the quarry cost; but this is too low to figure for ordinary work, and $2.00 a cu. yd. is not an extraordinary price for crushed trap rock.

If stone is to be broken by hand, an ordinary laborer will

TABLE LXXII

Voids in Pebbles and Broken Stone

Sizes of Aggregate: Passing a ring of... / Held by a ring of...	2.4 in. / 1.6 in.	1.6 in. / 0.8 in.	0.8 in. / 0.4 in.	Voids (Per Cent) in Round Pebbles	Voids (Per Cent) in Broken Stone
Parts Tested	1	0	0	40.0	53.4
" "	0	1	0	38.3	51.7
" "	0	0	1	41.7	52.1
Mixtures Tested.....	1	1	0	35.3	50.5
" "	1	0	1	35.6	47.1
" "	0	1	1	37.9	49.5
" "	1	1	1	35.5	47.8
" "	4	1	1	34.5	49.2
" "	1	4	1	36.6	49.4
" "	1	1	4	38.1	48.6
" "	8	0	2	34.1	....

TABLE LXXIII

Percentage of Voids in Coarse Aggregates

Weight per Cubic Foot	Gravel	Sandstone	Limestone, Medium Soft	Limestone, Medium Hard; Sandstone, Hard	Granite, Blue Stone, Limestone, Hard	Granite, Hard; Trap, Medium	Trap, Hard
70 lbs.	57	53	55	57	58	60	61
75 "	54	50	52	54	55	57	59
80 "	51	47	49	51	52	54	56
85 "	48	43	46	48	50	51	53
90 "	45	40	42	45	47	48	50
95 "	42	37	39	41	44	46	47
100 "	39	33	36	38	41	43	45
105 "	36	30	33	35	38	40	42
110 "	33	26	29	32	35	37	39
115 "	30	23	26	29	32	34	36
120 "	27	20	23	26	29	31	34
125 "	24	16	20	23	26	28	31
130 "	20	13	17	20	23	26	28
135 "	17	10	13	17	20	23	25
140 "	14	6	10	14	17	20	23

break about 2 cu. yds. of limestone into 2-in. sizes in a day of 10 hours.

The above prices for crushed rock do not consider the interest and depreciation of plant, nor the cost of moving same if necessary. A fair price for a 9 by 15-in. crusher plant with rotary screen, portable bins, 15-h. p. engine, and 20-h. p. boiler, is in the neighborhood of $2,200.

A quarry plant consisting of 2 steam drills, a 15-h. p. steam boiler, necessary piping, and tools, will cost about $1,200.

The labor cost of setting up and dismantling such a crusher plant as just described, together with hauling the plant for two or three miles, is about $75.

The amount of crushed stone which can be loaded into a wagon per day depends upon the size of the stone and upon the material upon which it rests. In shoveling from an elevated pile where the shovel has to cut its way among the stones, a man can handle about 14 cu. yds. of loose 2-in. stone in a 10-hour day. If this same size of stone is shoveled from the ground where it rests upon the earth, about 12 cu. yds. per 10-hour day may be shoveled. If this stone is dumped upon a wood platform or platform faced with sheet metal, this rate will be considerably increased. Small stone under ¾-in. size may be handled easily without a platform.

About 1 cu. yd. of crushed stone is a fair load for a team.

The cost of broken stone in Chicago (July, 1913), is $1.15 per cu. yd., f. o. b. Chicago. In New York, at the same time, it cost 90c. to $1.00 per cu. yd. for full cargo lots of 500 cu. yds., delivered at the docks.

Voids in Coarse Aggregates. Table LXXII, compiled by M. Feret, shows the percentage of voids to be found in round pebbles and broken stone of different sizes, and also in mixtures of different sizes of each of these aggregates.

Table LXXIII shows the percentage of voids in coarse aggregates as determined by weight per cubic foot.

Weight of Crushed Stone. One cu. ft. of loose measured broken trap stone weighs about 90 pounds. A cu. ft. of broken stone, well shaken down, weighs about 100 pounds.

TABLE LXXIV

Compression Strength of Portland Cement Concrete

MIXTURE	AGE 1 MONTH		AGE 6 MONTHS	
	PERCENTAGE OF VOIDS IN BROKEN STONE OR GRAVEL		PERCENTAGE OF VOIDS IN BROKEN STONE OR GRAVEL	
	40%	45%	40%	45%
	Strength in Lbs. per Sq. Inch		Strength in Lbs. per Sq. Inch	
1 : 1½ : 3	2,720	2,750	3,680	3,700
1 : 2 : 4	2,400	2,450	3,200	3,300
1 : 2½ : 5	2,100	2,200	2,800	2,950
1 : 3 : 6	1,900	1,950	2,600	2,650
1 : 4 : 8	1,500	1,550	2,000	2,100

These values should be used with a factor of safety in construction.

A cubic foot of crusher-run stone also weighs about 100 pounds.

COST OF GRAVEL CONCRETE

The comparison given on page 313, of costs of gravel and crushed stone concrete was made in a paper read by Mr. Arthur B. Henson before the Architects' Business Association of Chicago, Ill. The materials were washed gravel and crushed limestone in combination with torpedo sand. The greater bulk of gravel concrete is due to the fact that gravel, on account of its rounded particles, averages 7½ per cent less voids than crushed stone.

COST OF MANUFACTURE OF CONCRETE

As the prices of labor and materials not only vary considerably in different localities, but are constantly shifting in the same locality, the reader will understand that it is impossible to give any quotations of prices that will be reliable as of permanent or universal application. Any quotations given must be taken merely as proportionate, to be used in comparison with known quantities and methods.

Mr. Edward Godfrey in his volume on Concrete says: "Cost estimates must be based on unit-values. The accuracy of the estimate will often depend upon the particular unit at which the estimate starts. The cost per unit will depend upon the particular plant or equipment employed and its fitness to handle the work most economically.

"The plant or equipment needed to do a piece of work should be selected with a view to the size of the work and the time in which it is to be finished. Large equipment cannot, in general, be used economically on a small job, and small equipment cannot be used economically on a large job. The size, for example, of a concrete plant, should be such that its normal daily capacity is about equal to the amount of concrete that it is desired to turn out per day. For maximum economy, a plant should be employed continuously. If stops must be made to wait for forms to be put in readiness, or for other causes, the concrete will cost more than if the work of the concrete mixing can be carried on continuously.

"For small concrete jobs, such as pavement work, hand mixing is more economical. Small batches may be mixed with a hoe or shovels in a box. Half-yard batches should be mixed on a platform by at least two men with shovels. The platform may be made of a steel plate or of boards placed with close joints on a frame.

CARLOAD DELIVERY

Limestone Concrete—1:2:4

Stone, 100 cu. yds., @ $1.00	$100.00
Sand, 50 cu. yds., @ $1.00	50.00
Cement, 175 bbls., @ 85 cents	148.75
*108.5	$298.75
	2.75…

Gravel Concrete—1:2:4

Gravel, 100 cu. yds., @ $1.00	$100.00
Sand, 50 cu. yds., @ $1.00	50.00
Cement, 175 bbls., @ 85 cents	148.75
108.5 + 7½% = 116.64	$298.75
	2.56

Limestone concrete cost	2.75⅓ per cu. yd.
Gravel concrete cost	2.56 per cu. yd.
Savings on materials	0.19⅓ per cu. yd.
7% cost of handling and mixing, figured at $1.85 per cu. yd.	0.12 9-10 per cu. y…
Total saving	0.32 7-30 per cu. y…

TEAM DELIVERY

Limestone Concrete—1:2:4

Stone, 100 cu. yds., @ $1.50	$150.00
Sand, 50 cu. yds., @ $1.50	75.00
Cement, 175 bbls., @ $1.00	175.00
108.5	$400.00
	3.68…

Gravel Concrete—1:2:4

Gravel, 100 cu. yds., @ $1.50	$150.00
Sand, 50 cu. yds., @ $1.50	75.00
Cement, 175 bbls., @ $1.00	175.00
116.64	$400.00
	3.42 9…

Limestone concrete cost	$3.68 2-3 per cu. …
Gravel concrete cost	3.42 9-10 per cu. …
Saving on materials	$0.26 11-30 per cu. …
7% cost of handling and mixing, figured at $1.85 per cubic yard	$0.12 9-10 per cu…
Total saving	$0.39 8-30 per c…

* Number of cubic yards of concrete 1:2:4 produced by abo… cles, according to "Taylor & Thompson," voids 47½%, 108.5.

"A typical gang, mixing and laying one-half cubic yard batches, is the following: 1 foreman, 2 men delivering sand and stone, 1 man delivering cement, 2 men mixing, 2 men delivering concrete, 1 man tamping. At $3.00 per day for the foreman, and $1.50 per day for each of the other men, the cost per day of the gang is $15.00. The gang should turn out about 20 to 25 cubic yards per day. This is a cost of 75 to 60 cents per cubic yard for labor.

"A typical gang for mixing and laying by hand cubic yard batches, is as follows: 1 foreman, 3 men delivering sand and stone, 1 man delivering cement, 4 men mixing, 3 men delivering concrete, 2 men tamping. The cost of this gang at the same wages as above is $22.50 per day. They should turn out about 40 cubic yards per day, making the cost of labor 56 cents per cubic yard.

"The above examples give about average conditions, and show the cost of labor on hand-mixed concrete in heavy work where mixing and laying can go on continuously. If labor is cheap (and efficient), the unit-cost may be less, and vice versa. If materials can be deposited for easy handling, as when they are laid close to the mixing board and need only to be measured, the unit-cost will be reduced accordingly; whereas long hauls or high lifts, either before or after mixing, will add to the cost very materially. If the gang cannot be continuously employed, costs may be two or three times as much as the above. Concrete deposited in narrow forms will also cost more per cubic yard than in massive work.

"With mechanical mixers, the cost of mixing concrete will be less than by hand-mixing, though the extra cost of skilled workers to run the engine and mixer helps to balance the costs. Batch mixers should turn out about 20 batches per hour."

On small jobs—even those requiring as much as several hundred cubic yards of concrete—it is ordinarily much cheaper and more expedient to mix by hand. This is, of course, especially true where only a small crew—say two to four men—are available for the mixing, and where the work is often interrupted or frequent moving is necessary.

On large jobs it is more economical to mix by machinery, and this is the method generally adopted. The economy of machine mixing, on large jobs, depends to some extent on the use of labor-saving appliances in handling the raw materials and the finished mixture. Wheelbarrow work in delivering materials to the mixer and carrying away the concrete to where it is deposited, will make the cost relatively high in

TABLE LXXV

Proportions of Aggregates Giving Maximum Density with Varying Mixtures of Cement and Sand

Voids in Stone (Per Cent)	Proportions of Mortar									
	1:1	1:2	1:2½	1:3	1:3½	1:4	1:4½	1:5	1:5½	1:6
	Proportions of Stone									
20	5	10	12½	15	17½	20	22½	25	27½	30
21	4¾	9½	12	14¼	16⅔	19	21½	23¾	26¼	28½
22	4½	9	11⅓	13⅔	16	18¼	20½	22¾	25	27¼
23	4⅓	8⅔	10⅞	13	15¼	17⅓	19½	21¾	24	26
24	4	8⅓	10⅜	12½	14⅝	16⅔	18¾	20⅞	23	25
25	4	8	10	12	14	16	18	20	22	24
26	3¾	7⅔	9⅝	11½	13½	15⅓	17⅓	19¼	21⅛	23
27	3⅔	7⅓	9¼	11	13	14¾	16⅔	18½	20⅓	22¼
28	3½	7⅛	9	10¾	12½	14¼	16	17⅞	19⅝	21⅜
29	3½	7	8⅝	10⅓	12	13¾	15½	17¼	19	20⅔
30	3⅓	6⅔	8⅓	10	11⅔	13⅓	15	16⅔	18⅓	20
31	3¼	6½	8	9⅝	11¼	13	14½	16	17¾	19⅓
32	3	6¼	7¾	9⅜	11	12½	14	15⅝	17¼	18¾
33	3	6	7½	9	10⅝	12	13⅝	15⅛	16⅔	18⅛
34	3	6	7⅓	8¾	10¼	11¾	13¼	14¾	16¼	17⅝
35	2⅞	5¾	7⅛	8½	10	11½	12⅞	14¼	15¾	17⅛
36	2¾	5½	7	8⅓	9¾	11	12½	14	15¼	16⅔
37	2⅝	5⅜	6¾	8	9½	10¾	12⅛	13½	14⅞	16¼
38	2⅝	5¼	6⅝	8	9¼	10½	11⅞	13⅛	14½	15¾
39	2½	5	6⅜	7⅝	9	10¼	11½	12¾	14	15⅜
40	2½	5	6¼	7½	8¾	10	11¼	12½	13¾	15
41	2½	4⅞	6	7⅓	8½	9¾	11	12¼	13⅜	14⅝
42	2⅜	4¾	6	7⅛	8⅓	9½	10¾	12	13	14¼
43	2⅓	4⅝	5¾	7	8⅛	9⅓	10½	11⅝	12¾	14
44	2¼	4½	5⅔	6¾	8	9	10¼	11⅓	12½	13⅝
45	2¼	4½	5½	6⅔	7¾	8⅞	10	11	12¼	13⅓
46	2⅛	4⅓	6⅜	6½	7⅝	8⅝	9¾	10⅞	12	13
47	2⅛	4¼	5⅓	6⅜	7½	8½	9½	10⅝	11¾	12¾
48	2	4	5¼	6¼	7¼	8⅓	9⅜	10⅜	11½	12½
49	2	4	5	6⅛	7⅛	8⅛	9⅛	10¼	11¼	12¼
50	2	4	5	6	7	8	9	10	11	12
51	2	3⅞	5	6	6⅞	7⅞	8⅞	9¾	10¾	11¾
52	2	3⅞	4¾	5¾	6¾	7⅔	8⅝	9⅝	10½	11½
53	2	3¾	4¾	5⅔	6⅝	7½	8½	9½	10⅜	11¼
54	1¾	3⅔	4⅝	5½	6½	7⅜	8⅓	9¼	10¼	11
55	1¾	3⅝	4½	5½	6⅜	7¼	8¼	9	10	11
56	1¾	3½	4½	5⅓	6¼	7⅛	8	9	9¾	10¾
57	1¾	3½	4⅜	5¼	6⅛	7	8	8¾	9⅝	10½
58	1¾	3½	4⅓	5⅛	6	7	7¾	8⅝	9½	10⅓
59	1⅔	3⅜	4¼	5	6	6¾	7⅝	8½	9⅓	10¼
60	1⅔	3⅓	4	5	5¾	6⅔	7½	8⅓	9⅛	10

any case, which will be greatly reduced if the mixer can be fed by gravity from bins, and the concrete dumped into hauling cars. On small jobs, however, the saving in hand labor is usually more than offset by the cost of the mixing plant and its maintenance and operation. The relative cost of the two methods usually depends on local circumstances, and these must be taken into consideration in each particular case.

Proportions of Aggregates for Maximum Density

Table LXXV, compiled by Albert Moyer, shows the proportions of aggregates which will give maximum density with a minimum of cement. The voids in the stone, and the economic proportions of cement to sand which will give the density and plasticity of mortar required on the particular concrete job, should first be determined; and the table may then be applied to show the amount of coarse aggregate to be used.

For example, suppose that a mortar mixture of 1 part cement to 2½ parts sand is decided upon, and that the available coarse aggregate contains 33 per cent of voids. Then, looking at the table, starting at 33 in the void column at the left, and passing over to the right until we come to the proportion column headed 1:2½, we find 7½, which is the number of parts of stone to be added to the 1:2½ mortar mixture.

Richness of Mixture. When classified according to relative richness in cement, concrete mixtures are distinguished under four different headings—namely, **Rich, Medium, Ordinary,** and **Lean.**

Rich Mixture.—A 1:2:4 concrete—that is, a mixture containing ingredients in the proportion of 1 barrel (4 bags) of packed Portland cement just as it comes from the manufacturer, to 2 barrels (7.6 cubic feet) of loose sand, to 4 barrels (15.2 cubic feet) of loose gravel or broken stone—would be called a **rich mixture.**

Medium Mixture. A 1:2.5:5 concrete—that is, in the proportions of 1 barrel (4 bags) Portland cement, to 2.5 barrels (9.5 cubic feet) loose sand, to 5 barrels (19 cubic feet) loose gravel or broken stone—would be called a **medium mixture.**

Ordinary Mixture. A 1:3:6 concrete—that is, in the proportions of 1 barrel (4 bags) Portland cement, to 3 barrels (11.4 cubic feet) loose sand, to 6 barrels (22.8 cubic feet) loose gravel or broken stone—would be called an **ordinary mixture.**

Lean Mixture. A 1:4:8 concrete—that is, in the proportions of 1 barrel (4 bags) Portland cement, to 4 barrels (15.2 cubic feet) loose sand, to 8 barrels (30.4 cubic feet) loose gravel or broken stone—would be called a **lean mixture.**

Quantities for Batch Mixing. Tables LXXVIII and LXXIX, compiled by Percy H. Wilson and Clifford W. Gaylord, show the quantities for a 2-bag batch. A 3-bag batch will require half

TABLE LXXVI

Approximate Mixtures Adaptable to Various Classes of Work

Rich, 1:2:4; Medium, 1:2.5:5; Ordinary, 1:3:6; Lean, 1:4:8

(A. S. Johnson)

Kind of Work	Mixture	Consistency
Abutments	Rich to Ordinary	Medium
Arches	Rich to Medium	Medium
Backing for Masonry	Lean	Medium to Dry
Beams, Reinforced	Rich to Medium	Very Wet
" Plain	Rich to Medium	Very Wet to Medium
Cisterns	Rich to Medium	Very Wet to Medium
Columns, Reinforced	Rich	Very Wet
Conduits, Water	Rich	Very Wet
Coping	Rich to Medium	Medium
Culverts, Reinforced	Medium to Ordinary	Medium
" Plain	Medium to Ordinary	Medium
Driveways	Same as Sidewalks	
Fence Posts	Rich	Very Wet to Medium
Floors, Reinforced	Rich to Ordinary	Very Wet to Medium
" Ordinary Ground	Medium to Ordinary	Medium
Footings	Ordinary to Lean	Medium
Foundations, Heavy Vibrating Machinery	Rich	Very Wet to Medium
" Ordinary Machinery	Medium	Medium
" Thin Walls	Rich to Medium	Very Wet to Medium
" Thick Walls	Medium to Lean	Medium to Dry
Girders, Reinforced	Rich to Medium	Very Wet
" Plain	Same as Beams	
Gutters	Same as Sidewalks	
Pavements	Same as Sidewalks	
Piers	Rich to Ordinary	Medium
Reservoirs	Rich to Medium	Very Wet to Medium
Roof Slabs	Medium to Ordinary	Medium
Sewers, Reinforced	Rich to Medium	Medium
" Plain	Medium	Medium
Sidewalks (Base)	Medium to Ordinary	Medium to Dry
" (Sub-Base)	Ordinary to Lean	Medium to Dry
Silos	Rich to Medium	Very Wet to Medium
Tanks	Rich to Medium	Very Wet to Medium
Walls, Dwelling Houses	Rich to Medium	Very Wet to Medium
" Large Buildings (Compression and Tension)	Rich to Medium	Very Wet to Medium
" Large Buildings (Compression Only)	Medium to Ordinary	Medium
" Massive	Medium to Ordinary	Medium
" Retaining	Medium to Ordinary	Medium
" Thin Foundations	Rich to Medium	Very Wet to Medium
" Tunnel	Medium to Ordinary	Medium

as much more of each ingredient; a 4-bag batch, just double the amount; and so on. If the aggregates used are sand and crushed stone or gravel, use Table LXXVIII; if natural-bank sand and gravel already mixed, use Table LXXIX.

From these tables the quantities required for batches of any size can easily be calculated in the manner above described. They will simply be increased or diminished in proportion with the cement.

If the number of cubic yards of concrete is known, and the cement is in barrels instead of bags, Table LXXX will be

TABLE LXXVII

Proportions of Cement, Sand, and Stone for Different Percentages of Voids in Sand and Stone

Voids in Sand (Per Cent)	Parts of Cement	Parts of Sand	Voids in Stone (Per Cent): 36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
			Parts of Stone														
19	1	3.5	7.5	7.5	7.5	7.0	7.0	7.0	6.5	6.5	6.5	6.5	6.0	6.0	6.0	6.0	6.0
20	1	3.5	7.0	7.0	7.0	7.0	6.5	6.5	6.5	6.5	6.0	6.0	6.0	6.0	5.5	5.5	5.5
22	1	3.0	7.0	6.5	6.5	6.5	6.5	6.0	6.0	6.0	6.0	5.5	5.5	5.5	5.5	5.5	5.0
24	1	3.0	6.5	6.0	6.0	6.0	6.0	6.0	5.5	5.5	5.5	5.5	5.5	5.0	5.0	5.0	5.0
26	1	3.0	6.0	6.0	6.0	5.5	5.5	5.5	5.5	5.0	5.0	5.0	5.0	5.0	5.0	4.5	4.5
27	1	2.5	6.0	6.0	5.5	5.5	5.5	5.5	5.0	5.0	5.0	5.0	5.0	4.5	4.5	4.5	4.5
28	1	2.5	5.5	5.5	5.5	5.5	5.5	5.0	5.0	5.0	5.0	5.0	4.5	4.5	4.5	4.5	4.5
29	1	2.5	5.5	5.5	5.5	5.0	5.0	5.0	5.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.5
30	1	2.5	5.5	5.5	5.0	5.0	5.0	5.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.0	4.0
31	1	2.5	5.5	5.0	5.0	5.0	5.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.0	4.0	4.0
32	1	2.5	5.0	5.0	5.0	5.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.0	4.0	4.0	4.0
33	1	2.5	5.0	5.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.0	4.0	4.0	4.0	4.0	4.0
34	1	2.5	5.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0
35	1	2.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5
36	1	2.0	4.5	4.5	4.5	4.5	4.5	4.5	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5
37	1	2.0	4.5	4.5	4.5	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5
38	1	2.0	4.5	4.5	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.5
39	1	2.0	4.5	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.5	3.5
40	1	2.0	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5
41	1	2.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
42	1	2.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.0	3.0

found useful, as it shows the quantities of cement and aggregates in one cubic foot of concrete of varying mixtures.

For example, suppose the work consists of a concrete silo requiring in all 935 cu. ft. of concrete, of which 750 cu. ft. is to be 1:2:4 concrete, and 185 cu. ft. is to be 1:3:6 concrete.

TABLE LXXVIII

Quantities of Materials, and Resulting Amount of Concrete, for a Two-Bag Batch

Aggregates—Sand and Broken Stone or Screened Gravel

Mixture	Quantities of Material Required			Amount of Concrete Obtained	Size of Measuring Boxes (Inside Dimensions)		Water for Medium Wet Mixture
	Cement	Sand	Stone or Gravel		Sand	Stone or Gravel	
	Bags	Cu. Ft.	Cu. Ft.	Cu. Ft.			Gallons
1:2:4	2	3¾	7½	8½	2' x 2' x 11¼"	2' x 4' x 11¼"	10
1:3:6	2	5⅝	11¼	12	2' x 3' x 11¼"	3' x 4' x 11¼"	13½

TABLE LXXIX

Quantities of Materials, and Resulting Amount of Concrete, for a Two-Bag Batch

Aggregate—A Natural Mixture of Sand and Gravel

Mixture	Proportions by Parts		Quantities of Material Required		Amount of Concrete Obtained	Size of Measuring Boxes (Inside Dimens'ns)	Water for Medium Wet Mixture
	Cement	Natur'l Mixture of Sand and Gravel	Cement	Natur'l Mixture of Sand and Gravel			
			Bags	Cu. Ft.	Cu. Ft.		Gallons
1:2:4	1	4	2	7½	8½	2' x 4' x 11¼"	10
1:3:6	1	6	2	11¼	12	3' x 4' x 11¼"	13½

TABLE LXXX

Ingredients in One Cubic Foot of Concrete

Mixture	Quantities of Materials		
	Cement	Sand	Stone or Gravel
1 : 2 : 4	.058 bbl.	.0163 cu. yd.	.0326 cu. yd.
1 : 3 : 6	.041 bbl.	.0174 cu. yd.	.0348 cu. yd.

Also enough sand and cement is needed to paint the silo inside and outside, in all 400 sq. yds. of surface, with a 1:1 mixture of sand and cement. One cu. ft. of 1:1 mortar will paint about 15 sq. yds. of surface, and requires 0.1856 barrel of cement and 0.0263 cu. yd. of sand. Then we have:

Cement—

750 cu. ft. of 1:2:4 concrete	is	750×.058 =	43.5 bbls.
185 cu. ft. of 1:3:6 concrete	is	185×.041 =	7.6 "
Painting	is	$\frac{400}{15}$×.1856=	4.9 "
Total cement			56.0 bbls.

Sand—

750 cu. ft. of 1:2:4 concrete	is	750×.0163=	12.25 cu. yds.
185 cu. ft. of 1:3:6 concrete	is	185×.0174=	3.25 " "
Painting	is	$\frac{400}{15}$×.0263=	.75 " "
Total sand			16.25 cu. yds.

Stone or Gravel—

750 cu. ft. of 1:2:4 concrete	is	750×.0326=	24.5 cu. yds.
185 cu. ft. of 1:3:6 concrete	is	185×.0348=	6.5 " "
Total stone or gravel			31.0 cu. yds.

Thus the necessary quantities of materials are: 56 bbls. of Portland cement; 16¼ cu. yds. of sand; 31 cu. yds. of stone or gravel.

It is always wise to order two or three extra barrels of cement, if the dealer is at considerable distance, as this avoids any possible trouble that a shortage might cause.

Measuring According to Voids. As an approximate guide to the use of Table LXXVII and other tables, where a determination of voids has been made, it may be pointed out that 45 per cent voids in the coarse aggregate would indicate the average conditions, and would be about what is found in broken stone with dust screened out; 40 per cent voids would correspond to gravel or mixed stone and gravel; 50 per cent voids would indicate poor grading, as in an aggregate screened to uniform size; while 30 per cent voids and under would indicate an aggregate graded with great care.

Where voids have been determined in both sand and coarse aggregate, the upper part of Table LXXXII, which may be taken as representing average conditions, will be found useful.

Where the voids are the same as in the upper part of Table LXXXII, but the cement is measured loose in a box after dumping from a barrel, the quantities should be determined from the lower part of the table, as under such conditions a barrel of cement yields 4.4 cu. ft. of loose cement:

TABLE LXXXI

Amount of Material Required for One Cubic Yard Rammed Concrete of Varying Mixture

Mixture			Stone, 1-inch and under, dust screened out			Stone, 2½-inch and under, dust screened out			Stone, 2½-inch, with most small stone screened out			Gravel, ¾-inch and under		
			Cement, Bbls.	Sand, Cu. Yds.	Stone, Cu. Yds.	Cement, Bbls.	Sand, Cu. Yds.	Stone, Cu. Yds.	Cement, Bbls.	Sand, Cu. Yds.	Stone, Cu. Yds.	Cement, Bbls.	Sand, Cu. Yds.	Gravel, Cu. Yds.
1	1.0	2.0	2.57	0.39	0.78	2.63	0.40	0.80	2.72	0.41	0.83	2.30	0.35	0.74
1	1.0	2.5	2.29	0.35	0.70	2.34	0.36	0.89	2.41	0.37	0.92	2.10	0.32	0.80
1	1.0	3.0	2.06	0.31	0.94	2.10	0.32	0.96	2.16	0.33	0.98	1.89	0.29	0.86
1	1.0	3.5	1.84	0.28	0.98	1.88	0.29	1.00	1.88	0.29	1.05	1.71	0.26	0.91
1	1.5	2.5	2.05	0.47	0.78	2.09	0.48	0.80	2.16	0.49	0.82	1.88	0.42	0.73
1	1.5	3.0	1.85	0.42	0.84	1.90	0.43	0.87	1.96	0.45	0.89	1.71	0.39	0.78
1	1.5	3.5	1.72	0.39	0.91	1.74	0.40	0.93	1.79	0.41	0.96	1.57	0.36	0.83
1	1.5	4.0	1.57	0.36	0.96	1.61	0.37	0.98	1.64	0.38	1.00	1.46	0.33	0.88
1	1.5	4.5	1.43	0.33	0.98	1.46	0.33	1.00	1.51	0.35	1.06	1.34	0.31	0.91
1	2.0	3.0	1.70	0.52	0.77	1.73	0.53	0.79	1.78	0.54	0.81	1.54	0.47	0.73
1	2.0	3.5	1.57	0.48	0.83	1.61	0.49	0.85	1.66	0.50	0.88	1.44	0.44	0.77
1	2.0	4.0	1.46	0.44	0.89	1.48	0.45	0.90	1.53	0.47	0.93	1.34	0.41	0.81
1	2.0	4.5	1.36	0.42	0.93	1.38	0.42	0.95	1.43	0.43	0.98	1.26	0.38	0.86
1	2.0	5.0	1.27	0.39	0.97	1.29	0.39	0.98	1.33	0.39	1.03	1.17	0.36	0.89
1	2.5	3.5	1.45	0.55	0.77	1.48	0.56	0.79	1.51	0.58	0.81	1.32	0.50	0.70
1	2.5	4.0	1.35	0.52	0.82	1.38	0.53	0.84	1.42	0.54	0.87	1.24	0.47	0.75
1	2.5	4.5	1.27	0.48	0.87	1.29	0.49	0.88	1.33	0.51	0.91	1.16	0.44	0.80
1	2.5	5.0	1.19	0.46	0.91	1.21	0.46	0.92	1.26	0.48	0.96	1.10	0.42	0.83
1	2.5	5.5	1.13	0.43	0.94	1.15	0.44	0.96	1.18	0.44	0.99	1.03	0.39	0.86
1	2.5	6.0	1.07	0.41	0.97	1.07	0.41	0.98	1.10	0.41	1.03	0.98	0.37	0.89
1	3.0	4.0	1.26	0.58	0.77	1.28	0.58	0.78	1.32	0.60	0.80	1.15	0.52	0.72
1	3.0	4.5	1.18	0.54	0.81	1.20	0.55	0.82	1.24	0.57	0.85	1.09	0.50	0.75
1	3.0	5.0	1.11	0.51	0.85	1.14	0.52	0.87	1.17	0.54	0.89	1.03	0.47	0.78
1	3.0	5.5	1.06	0.48	0.89	1.07	0.49	0.90	1.11	0.51	0.93	0.97	0.44	0.81
1	3.0	6.0	1.01	0.46	0.92	1.02	0.47	0.93	1.06	0.48	0.97	0.92	0.42	0.84
1	3.0	6.5	0.96	0.44	0.95	0.98	0.44	0.96	1.00	0.45	1.01	0.88	0.40	0.87
1	3.0	7.0	0.91	0.42	0.97	0.92	0.42	0.98	0.94	0.42	1.05	0.84	0.38	0.89
1	3.5	5.0	1.05	0.56	0.80	1.07	0.57	0.82	1.11	0.59	0.85	0.96	0.50	0.76
1	3.5	5.5	1.00	0.53	0.84	1.02	0.54	0.85	1.06	0.56	0.89	0.92	0.48	0.78
1	3.5	6.0	0.95	0.50	0.87	0.97	0.51	0.89	1.00	0.53	0.92	0.88	0.46	0.80
1	3.5	6.5	0.92	0.49	0.91	0.93	0.49	0.92	0.96	0.51	0.95	0.83	0.44	0.82
1	3.5	7.0	0.87	0.47	0.93	0.89	0.47	0.95	0.91	0.49	0.98	0.80	0.43	0.85
1	3.5	7.5	0.84	0.45	0.96	0.86	0.45	0.98	0.88	0.47	1.01	0.76	0.41	0.87
1	3.5	8.0	0.80	0.42	0.97	0.82	0.43	1.01	0.81	0.45	1.04	0.73	0.39	0.89
1	4.0	6.0	0.90	0.55	0.82	0.92	0.56	0.84	0.95	0.58	0.87	0.83	0.51	0.77
1	4.0	6.5	0.87	0.53	0.85	0.88	0.53	0.87	0.91	0.55	0.90	0.80	0.49	0.79
1	4.0	7.0	0.83	0.51	0.89	0.84	0.51	0.90	0.87	0.53	0.93	0.77	0.47	0.81
1	4.0	7.5	0.80	0.49	0.91	0.81	0.50	0.93	0.84	0.51	0.96	0.73	0.44	0.83
1	4.0	8.0	0.77	0.47	0.93	0.78	0.48	0.95	0.81	0.49	0.98	0.71	0.43	0.86
1	4.0	8.5	0.74	0.45	0.95	0.76	0.46	0.96	0.78	0.47	1.01	0.68	0.42	0.88
1	4.0	9.0	0.71	0.43	0.97	0.73	0.44	1.01	0.75	0.45	1.04	0.65	0.40	0.89
1	5.0	9.0	0.66	0.50	0.90	0.67	0.52	0.93	0.70	0.53	0.96	0.61	0.46	0.83
1	5.0	10.0	0.62	0.47	0.95	0.63	0.48	0.96	0.65	0.50	1.00	0.57	0.43	0.87

TABLE LXXXII

Ingredients in One Cubic Yard of Concrete
(H. P. Gillette)

Sand voids 40 per cent. Stone voids 45 per cent. Barrel of Portland cement containing 3.65 cu. ft. of paste. Barrel specified 3.8 cu. ft.

Proportions by Volume	1:2:4	1:2:5	1:2:6	1:2.5:5	1:2.5:6	1:3:4
Bbls. cement per cu. yd. concrete.......	1.46	1.30	1.18	1.18	1.00	1.25
Cu. yds. sand " " " "	0.41	0.36	0.33	0.40	0.35	0.53
Cu. yds. stone " " " "	0.82	0.90	1.00	0.80	0.84	0.71
Proportions by Volume	**1:3:5**	**1:3:6**	**1:3:7**	**1:4:7**	**1:4:8**	**1:4:9**
Bbls. cement per cu. yd. concrete.......	1.13	1.05	0.96	0.82	0.77	0.73
Cu. yds. sand " " " "	0.48	0.44	0.40	0.46	0.43	0.41
Cu. yds. stone " " " "	0.80	0.88	0.93	0.80	0.86	0.92

Proportions by Volume	1:2:4	1:2:5	1:2:6	1:2.5:5	1:2.5:6	1:3:4
Bbls. cement per cu. yd. concrete.......	1.30	1.16	1.00	1.07	0.96	1.08
Cu. yds. sand " " " "	0.42	0.38	0.33	0.44	0.40	0.53
Cu. yds. stone " " " "	0.84	0.95	1.00	0.88	0.95	0.71
Proportions by Volume	**1:3:5**	**1:3:6**	**1:3:7**	**1:4:7**	**1:4:8**	**1:4:9**
Bbls. cement per cu. yd. concrete.......	0.96	0.80	0.82	0.75	0.68	0.64
Cu. yds. sand " " " "	0.47	0.44	0.40	0.40	0.44	0.42
Cu. yds. stone " " " "	0.78	0.88	0.93	0.80	0.88	0.95

From the above table it will be seen that the following rule can be deduced: Add together the number of parts, and divide this sum into 10; the quotient will be approximately the number of barrels per cubic yard. Thus, for 1:2:5 concrete, the sum of the parts is 8, and 10÷8=1.25 barrels of cement per yard, which is approximately equal to 1.30, the amount called for by the table.

Hand Mixing and Placing

If it is desired to analyze the cost of manufacture and placing of concrete, the following approximate prices for different divisions of the process will be of service:

With men working under a good foreman, the loading of sand, stone, and cement into wheelbarrows will cost about 18 cents per cu. yd. of concrete. Wheeling materials will cost about 6 cents per cu. yd. of concrete when the supply piles are not over 50 feet from the mixing board. The actual mixing of the concrete will cost about 5 cents per cu. yd. for each turn given to the mixture. The loading of the concrete into wheelbarrows ready to wheel to the place where it is to be used will cost about 15 cents per cu. yd. Wheeling the concrete will cost the same as wheeling the materials given above. Dumping the concrete costs about 6 cents per cu. yd., while 20 cents per cubic yard is a fair price for a concrete which is moderately wet. If the concrete is to be lifted or hoisted above the level at which it could be easily wheeled in barrows, an extra charge should be allowed.

The above prices are figured on the basis of $1.50 per 10-hour day for laborers. To the above costs must be added a proportionate part of the wages of the foreman, if one is hired extra. If the foreman is paid $3.00 per day and 30 cu. yds. of concrete are mixed and placed in a particular piece of work, the charge to be added per cu. yd. is 10 cents.

Although an example has been cited, showing where 13 laborers under a foreman mixed and deposited 40 cu. yds. of concrete per day at a cost of 56 cents per cu. yd., other instances taken from similar conditions and at the same scale of wages could be mentioned where 16 men under a foreman mixed and deposited only 27 cu. yds. of concrete per day at a cost of $1.00 per cu. yd.

In each of the above instances the costs are for labor only, and do not consider materials. With inexperienced men or under difficult circumstances, these costs may be nearly doubled.

Therefore the uncertainty of using published data when figuring on work is made clear. It is far better to divide the manufacture and placing of the concrete into its component parts, and apply to each operation a fair estimate for your locality, knowing the capabilities of your men and the manner in which they work.

We suggest the following divisions for a fairly close estimate, where the mixing and placing are to be done by hand:

(a) Loading from stock piles.
(b) Wheeling cement, sand, and stone to mixing boards.
(c) Cost of labor for mixing.
(d) Loading mixed concrete into wheelbarrows.

(e) Wheeling to place to be used.
(f) Dumping into place.
(g) Spreading and ramming concrete.
(h) Cost of superintendence.

As a check on your own detailed estimate, the approximate figures given above may be used for the sake of comparison.

If the concrete has to be wheeled not over 50 feet, four experienced men should be able, on an average, to mix by hand and wheel to the place of deposit about 10 four-bag batches of 1:3:6 concrete in 10 hours. And since, from Table LXXVIII, one 4-bag batch will make 24 cu. ft. of concrete, the four men should mix and wheel in this period of time about 240 cu. ft. of concrete, or $240 \div 27 = 8.8$ cu. yds. This estimate, however, is for the very simplest kind of concreting, and makes no allowance for the labor of supplying materials to the mixing platform or for building forms.

Machine Mixing

If the contractor decides to invest capital in a plant for mixing and placing concrete, or if he only purchases a mixer, he should not lose sight of the fact that the cost of his concrete is to be increased by a certain percentage made up in part of the interest on his invested capital, and in part of the depreciation in value of the plant which comes with use. Another point which he should not lose sight of is that the cost of repair to the plant, the cost of moving same from place to place, and the cost of labor and supplies necessary to operate the plant, should also be charged up to the work in hand in order to obtain a fairly correct estimate of what a certain piece of work has cost him.

The actual cost of machine mixing is not a great factor in making up the total cost of the labor on the concrete. In the previous detailed statement of approximate costs, it will be seen that the cost of actually mixing the concrete by hand is given as 5 cents for each turn of the mixture per cubic yard, which is only one part of a total cost per cubic yard amounting to about $1.00. Thus it will be seen that the manner in which the materials are brought to the mixer and taken away again, together with the cost of ramming and spreading, is the true controlling factor.

If we consider the actual cost of machine mixing, the style and size of mixer used will be of great importance. Prices with various types of machines vary from 2 cents up to 15 cents per cu. yd. An average price for rough estimating is often taken at 10 cents per cu. yd. for mixing alone.

Taylor and Thompson state that on account of incidental expenses and delays caused in mixing concrete by machinery and hoisting to place, it is not safe to figure on a price of less than $1.50 to $2.00 per cu. yd. of concrete as the cost of labor for simply mixing and placing the concrete under ordinary conditions. Prices even higher than these are often quoted, based on actual experience.

An estimate on the **cost of power** for hoisting concrete where the concrete is dumped directly from the machine into a self-dumping conveyor or bucket and then hoisted to place, is about 5 cents per cubic yard.

The cost of **superintendence** over a plant for small and average-sized jobs is commonly considered to be about 10 per cent of the cost of the labor per cubic yard of concrete mixed and placed. This should be added to the actual labor cost.

Where concrete can be dumped from the mixer into wheelbarrows or carts and hauled or wheeled directly to the work, the cost of hoisting can be omitted and the cost of wheeling as previously given substituted in its place.

Since there can be no standard price given for the mixing or placing of concrete by machinery, on account of the variation in conditions in each particular piece of work and with the special apparatus used, it is better to make a careful analysis of each operation which goes to make up the process in each separate case, and then sum up the individual costs.

The trade catalogues of the different manufacturers give sizes and capacities of their machines, and these firms will quote prices upon application.

If it is desired to determine the depreciation on a plant, a fairly good method is to determine beforehand the price that a similar plant can be bought for second-hand. That will help to determine roughly the value of machine work as compared with hand work.

Cost of Finishing Concrete Surfaces

Reliable data and costs in connection with methods of surface treatment are difficult to obtain. Another difficulty is that in many of the processes in use it makes a great deal of difference whether the concrete is one day old or a week old. Take, for instance, the **Quimby process.** This process of wall finish is quite extensively used in Philadelphia. The method consists in using boards of such width for the forms that each board will extend upwards through a space covered by one course of the concrete. These boards have small triangular strips of wood nailed along each edge, so that when the forms are in place, two strips will come together and form a seam in the surface.

As the forms are removed from work which is already in place, they are carried up, and make a new course above. As soon as the lower forms can safely be removed, the concrete surface is scrubbed with an ordinary scrubbing brush and water, and then washed off with a hose. Generally this washing may be done on the day following the placing of the concrete, but depends largely upon the season of the year and the rapidity with which the concrete sets. If the concrete has set too hard for ordinary scrubbing brushes to remove the film of cement and expose the aggregate, it may be necessary to use a wire brush, or even, in extreme cases, a brick with scouring sand.

If the scrubbing is done when the cement is still fairly soft, one man can scrub about 100 sq. ft. of surface per hour; but if the concrete has set hard, it may take a day to scour the same area.

Grout or cement washes are often applied as a finish on concrete work. The cost of applying same with a brush on vertical surfaces is a varying quantity, depending upon the smoothness of the surface. An estimate of from 8 to 12 squares per day per man for one coat will not be far out of the way.

The cost of the grout may be determined from the mixture used. A 1 cement to 2 sand mixture is a fair one, and should be mixed to about the consistency of whitewash. If the grout is to be brushed on, all ridges should be rubbed off and all holes filled before the grout is applied.

If a mortar facing is to be used in the forms, the cost may be determined by figuring the cost of the special mixture separate from the other concrete, and estimating that 8 squares per day may be scoured by one man when the surface is fairly fresh.

The cost of removing **efflorescence** from walls by the use of scrubbing brushes and dilute hydrochloric acid is generally figured at about 20 cents per sq. yd. of surface on plain work. On fancy work, or work which is irregular in design, this price may run as high as 60 cents per sq. yd. Care should be taken to keep walls thoroughly wet while cleaning with acid solutions, to prevent the acid from entering the concrete. An example is stated in Gillette and Hills' "Concrete Construction," where the cost of removing efflorescence with wire brushes without acid ran as high as $2.40 per sq. yd. of surface.

A finish which approaches the scheme of the Quimby finish is produced by using rounded pebbles between 1½ and 2 inches in the smallest diameter, in place of the usual crushed stone for the surface layer in the forms. Before the concrete has set hard, the surface is brushed until about one-half of the surface of the pebbles is uncovered. The cost of this style of finish applied to concrete which was 24 hours old was found in one instance to be about 60 cents per sq. yd. of surface treated.

If a **colored finish** is desired, the same may be obtained by the use of colored aggregates, by the use of a coating or paint, or by mixing coloring matter with the cement.

Table LXXXIII indicates the mineral coloring materials which may be used for giving various colors and tints of cement mortar, and the proportions of coloring matter to cement.

TABLE LXXXIII

Materials Used in Coloring Mortars

Color	Mineral	Pounds Color to 100 Pounds Cement	Pounds Color to Barrel of Cement
Gray	Germantown Lamp Black	¼ to ½	2
Black	Manganese Dioxide	12	48
Black	Excelsior Carbon Black	2	00
Blue	Ultramarine	5 to 6	20
Green	Ultramarine Green	6	24
Red	Iron Oxide	6 to 10	24
Bright Red	Pompeian or English Red	6	24
Sandstone	Red-Purple Oxide of Iron	6	24
Violet	Violet Oxide of Iron	6	24
Brown	Roasted Iron Oxide or Brown Ocher	6	24
Yellow or Buff	Yellow Ocher	6 to 10	24

Table LXXXIV gives other information in connection with the coloring of mortar, and should prove of service.

It is not uncommon to finish the surface of concrete work by **bush-hammering or tooling**. Costs for this class of work vary greatly; and, contrary to conditions where the surface is to be scrubbed, the concrete should be from 30 to 60 days old before it is worked.

The cost of bush-hammering is ordinarily considered to be about 1½ to 3 cents per sq. ft. when wages are 15 cents per hour. This is based on the rate of 10 sq. ft. of surface worked per hour for a good laborer. Costs are given in

TABLE LXXXIV

Coloring of Cement Mortar

Dry Material Used.	Weight of Dry Coloring Matter to 100 Lbs. Cement				Cost of Coloring Matter. Per Lb. Cents.
	½ lb.	1 lb.	2 lbs.	4 lbs.	
Lamp Black	Light Slate	Light Gray	Blue Gray	Dark Blue Slate	15
Prussian Blue	Light Green Slate	Light Blue Slate	Blue Slate	Bright Blue Slate	50
Ultramarine Blue		Light Blue Slate	Blue Slate	Bright Blue Slate	20
Yellow Ocher	Light Green	Pinkish Slate		Light Buff	8
Burnt Umber	Light Pinkish Slate		Dull Lavender Pink	Chocolate	10
Venetian Red	Slate, Pink Tinge	Bright Pinkish Slate	Light Dull Pink	Dull Pink	2½
Chattanooga Iron Ore	Light Pinkish Slate	Dull Pink	Light Terra Cotta	Light Brick Red	2
Red Iron Ore	Pinkish Slate	Dull Pink	Terra Cotta	Light Brick Red	2½

some instances as high as 26 cents per sq. ft. for high-class work.

If pneumatic tools are used with a special point for concrete work, from 400 to 500 sq. ft. of surface may be covered per day. This will often run as low as 200 sq. ft. per day when common laborers are employed.

Another form of tooled finish is obtained by removing the forms while the concrete is still fairly green, and picking the surface with a light pick or tool. It is estimated that a laborer will pick over about 100 sq. ft. of surface per day.

Cost of Waterproofing

Covering capacities, or amounts to be used per unit of concrete, are stated by the manufacturers of standard compounds. If one of the standard integral preparations is to be used, all that is necessary is to determine the amount of the preparation needed for the amount of concrete which is to be waterproofed, and knowing the price of the compound per pound or per gallon from the nearest dealer, add same to the cost of the plain concrete.

For instance, suppose that it is decided to use a dry compound, or powder, which is to be added to the cement when mixing the concrete. If the directions are to use 2 per cent (by weight) of the powder to each barrel of cement, this would mean to use 2/100 of 400 pounds, or 8 pounds of the compound. If this particular compound sells for 12 cents per pound, the added cost to the concrete per barrel of cement used would be 96 cents. This same line of reasoning may be applied to other cases as easily as above.

If a surface method of waterproofing is to be used, there will be an additional cost of applying the compound. This cost will depend to a considerable extent on the condition of the wall surface. A rough, porous surface will soak up more of the material used, and will be harder to cover.

In estimating the labor of applying surface compounds, it is often figured that a fair workman will cover about 8 squares a day, using the liquid as a paint. The covering capacity of liquid compounds is commonly given as being from 100 to 150 sq. ft. of surface per gallon. Two-coat work is necessary in nearly all cases, the first coat requiring a larger amount of material and labor than the second.

Concerns who manufacture the various compounds now on the market are always glad to furnish an estimate of the amount of their product needed for a given piece of work, and also to approximate the cost of applying same.

As an example, the manufacturers of one compound which is used as a paint publish the following information in regard to their product:

"The material costs $1.85 per gallon; and, with labor at 60 cents per hour, 8 squares of 100 sq. ft. may be applied in an 8-hour day. A gallon will cover a square and a half, one coat."

Detailed examples showing cost of applying soap and alum washes for waterproofing purposes, are not easy to obtain, but should be fairly approximated from the results following: On a reservoir in which about 132,000 sq. ft. of surface was covered with two coats of soap solution and two coats of alum solution, each wash applied alternately at intervals of 24 hours, 900 pounds of Olean soap were required, mixed in the ratio of ¾ pound of soap to 1 gallon of water, and 210 pounds of alum mixed in the ratio of ½ pound of alum to 4 gallons of water. This would indicate about ¾ pound of soap per 100 sq. ft. of surface to be covered, and about 1/6 of a pound of alum. Two men applied these solutions with 10-inch brushes, other men bringing the pails of material to them ready for application. According to the statement given in connection with this job, the two men applied four coats of solution, two of soap and two of alum, to the bottom and sloping sides of this reservoir in 8½ days.

This seems to be a very rapid rate of work, and is probably due to the fact that the operation really consisted in spreading the solution over a ground surface with no lifting of the materials as in the case of a wall or overhead work.

Where a surface has practically to be "painted" with the solutions, 8 to 12 squares a day per man would probably be a closer estimate for labor.

A Sylvester mortar has been made by mixing 3 pounds of powdered alum with each bag of cement and using water in which 1¼ pounds of light-colored soft soap is dissolved in each 15 gallons used. This mortar is mixed 1:2, and applied in two separate coats, making a sheet about ½ inch thick. The cost of such a mortar will exceed the cost of an ordinary mortar by about 60 cents per barrel of cement used. It is figured that about 2 pounds of soap and 12 pounds of alum are needed per barrel of cement.

Hydrated Lime in Concrete. Hydrated lime increases the water-tightness of concrete. Effective proportions of hydrated lime for water-tight concrete were found by Mr. Sanford E. Thompson to be as follows:

One part Portland cement; 2 parts sand; 4 parts stone; add 8 per cent hydrated lime.

One part Portland cement; 2½ parts sand; 4½ parts stone; add 12 per cent hydrated lime.

One part Portland cement; 3 parts sand; 5 parts stone; add 16 per cent hydrated lime.

These percentages are based on the weight of dry hydrated lime to the weight of dry Portland cement.

CEMENT BLOCK CONSTRUCTION

Table LXXV, based on figures furnished by Mr. J. A. Smith, and published in "Cement Era," gives valuable information concerning the use of hollow cement blocks in building.

In order to show the profits to be made by the manufacture of concrete blocks, a block machine company submits the following:

1 barrel cement	$1.50
10 cu. ft. clean sand, 3½ cts	.35
16 cu. ft. stone or gravel, 4½ cts	.72
Materials for 55 blocks cost	$2.57

There are 960 cubic inches in a block 6x8x20, or, material for one block, 4½ cents.

Count 500 blocks per day—

TABLE LXXXV

Comparison of Cost of 100 Concrete Blocks of Various Sizes, Laid in Wall, with the Equivalent Amount of Common Brick

Blocks Made of 1:3:4 Mixture with ½-inch Facing of 1:2

Size	Gravel		Sand		Cement		Labor		Profit	Total Price 100 Blocks in Wall	Number Brick Displaced by 100 Blocks	Cost of Brick at $14 per M Laid in Wall	Saving on Every 100 Blocks by Use of Concrete
	Amount	Cost	Amount	Cost	Amount	Cost	Making	Laying					
8x 8x16 in.	1.05 yd.	$1.05	0.79 yd.	$0.79	2.02 bbls.	$3.04	$2.75	$3.00	$4.00	$14.68	1,333	$18.67	$ 4.04
8x10x16 in.	1.40 "	1.40	1.06 "	1.06	2.62 "	3.94	3.00						
8x12x16 in.	1.68 "	1.68	1.27 "	1.27	3.08 "	4.62	3.25	4.00	4.00	18.82	2,000	28.00	9.18
8x 8x24 in.	1.62 "	1.62	1.23 "	1.23	3.12 "	4.68	4.00	5.00	5.00	21.63	2,000	28.00	6.47
8x10x24 in.	2.02 "	2.02	1.53 "	1.53	3.80 "	5.70	4.25						
8x12x24 in.	2.43 "	2.43	1.82 "	1.82	4.46 "	6.70	4.50	7.00	6.00	28.50	3,000	42.00	13.50

500 blocks at 10½ cts. each..........................$52.50
Materials, 4½ cts. per block..................$22.50
Labor, three men, 10 hrs., 20 cts. hr......... 6.00
Curing, delivering to job, 1½ cts............. 7.50
$36.00

Profit for one day $16.50

TABLE LXXXVI

Data Regarding Concrete Blocks

Kind of Block	Size with Mortar Joints	Net Size of Blocks	Net Weight in Lbs.	Cubic Inches over All	Cubic Inches Material	Cubic Inches of Voids	Per Cent of Voids	Displacement of Brick
Hollow	8 x 8 x 16 in.	7¾ x 8 x 15¾ in.	50	976.	658.	318.	32.58	14.22
Hollow	8 x 10 x 16 in.	7¾ x 10 x 15¾ in.	68	1220.6	882.48	337.12	27.61	17.77
Hollow	8 x 12 x 16 in.	7¾ x 12 x 15¾ in.	82	1464.7	1057.83	406.87	27.77	21.33
Hollow 4-in. Course	4 x 8 x 16 in.	3¾ x 8 x 15¾ in.	25	472.50	318.64	153.86	32.58	7.11
Hollow 4-in. Course	4 x 10 x 16 in.	3¾ x 10 x 15¾ in.	34	590.62	427.5	163.12	27.61	8.88
Hollow 4-in. Course	4 x 12 x 16 in.	3¾ x 12 x 15¾ in.	41	708.75	511.88	196.87	27.77	10.66
Solid Veneer	8 x 4 x 16 in.	7¾ x 4 x 15¾ in.	37	488.25	488.25			7.11
Hollow	8 x 8 x 24 in.	7¾ x 8 x 23¾ in.	84	1472.5	1025.10	447.40	30.38	21.33
Hollow	8 x 10 x 24 in.	7¾ x 10 x 23¾ in.	104	1840.62	1275.08	565.50	30.72	26.66
Hollow	8 x 12 x 24 in.	7¾ x 12 x 23¾ in.	122	2208.75	1524.97	683.78	30.95	32.
Hollow 4-in. Course	4 x 8 x 24 in.	3¾ x 8 x 23¾ in.	42	712.50	496.02	216.48	30.38	10.66
Hollow 4-in. Course	4 x 10 x 24 in.	3¾ x 10 x 23¾ in.	52	890.62	616.95	273.67	30.72	13.33
Hollow 4-in. Course	4 x 12 x 24 in.	3¾ x 12 x 23¾ in.	61	1068.75	737.89	330.86	30.95	16.
Solid Veneer	8 x 4 x 24 in.	7¾ x 4 x 28¾ in.	56	736.25	736.25			10.66

Displacement of brick is based on common brick, 2¼x4x 8 in., allowing ¼ in. for mortar joints.

It is often figured that blocks for a 10-in. wall will cost about 16 cents per sq. ft. of wall surface out of the wall.

Table LXXXVI, compiled by the Ideal Concrete Machinery Company, gives valuable data regarding the sizes, necessary raw materials, and equivalent brick displacement of the blocks made by their machines.

The same company has made a comparison between the use of concrete blocks and brick for buildings, and bases this comparison on the following details:

If a man were to build a house or a residence of bricks, and he desired to substitute blocks for bricks, he would find that where he would build a 2-brick wall, he would substitute 12-in. blocks; and if he would build a wall 1½ bricks thick, 8-in. hollow blocks.

The 8x8x16-in. block, including the joint, covers 128 sq. in. wall surface, and consequently one square foot of wall surface would require 1.12 blocks. One square foot of wall surface of the brick wall would require 21 bricks. It will therefore take 54 blocks 8x8x16-in. to substitute 1,000 bricks in a wall 1½ bricks thick.

The price for laying these 8x8x16-in. blocks, which weigh about 50 lbs. each, should not exceed 5 cents each.

Cost for laying 1,000 bricks, average not less than....	$ 5.00
Cost for laying 54 blocks at 5 cts..................	2.70
Saving in laying the equivalent of 1,000 bricks......	$ 2.30
Purchase price for bricks will average for face bricks and common not less than	14.00
Cost of manufacturing 54 blocks, for labor and material, at 9¾ cts. each............................	5.30
Saving in cost for the equivalent of 1,000 bricks, using blocks	$ 8.70
Of, if we figure the total saving for material and laying, this saving will be for each 54 blocks, substituting the 1,000 bricks, $2.30 for laying, $8.70 for material ....Total,	$11.00

Suppose now we were to build a two-story residence, about 40x40 feet, of bricks. The outside walls would require about 90,000 bricks; and by substituting the hollow blocks for the bricks, there would, on the outside walls alone, according to above calculations, be saved $990.00, and a proportional amount might be saved on the partitions.

Finally, it must be considered that if the blocks are well made with a facing of 1 cement and 2 sand, and particularly if 1 to 2 per cent of waterproofing filler—which will increase the cost of the block ¼ cent only—is mixed in the facing material, the cost of lathing and furring, and also the rough coat of plaster, can be saved.

A mason should lay from 2 to 3 blocks in the wall in the same time it takes him to lay 14 bricks of the equal of but one block. A common mason will lay one hundred 8x8x16-in. blocks per day, but a first-class one will do better. The cost of laying cement blocks will vary with the class of work desired. We find upon investigation that prices vary as to the laying of blocks in the wall. They can be laid as cheap as 2 cents each, but we prefer to make a conservative estimate by placing the average cost at 5 cents per block. Contractors figure the cost of laying a common brick at $5.00 per M. under ordinary conditions.

This company states that an average value for 8x8x16-in. blocks, in the above instance, is about 9¾ cents each. Their method of arriving at this cost is based on the following data, the unit-price to be adjusted for various localities:

One block, including joint, of 8x8x16-in., has 32.6 per cent. voids, and contains 0.39 cubic foot of material; consequently one cu. yd. of mixed material will make about 69 blocks 8x8x16-in.

It is recommended to use a mixture for the facing, of 1 cement and 2 sand; and for the balance of the block, 1 cement, 2 sand, and 3 gravel, in which the pebbles for the gravel do not exceed ¾ inch diameter.

The material necessary to prepare 1 cu. yd. of mixture is approximately 1.54 lbs. of cement, 0.47 cu. yd. of sand, and 0.73 cu. yd. of gravel, being sufficient for 69 blocks.

For manufacturing 100 blocks there are needed 2.24 bbls. cement, 0.68 cu. yd. sand, and 1.06 cu. yds. gravel, which, at the following prices, will amount to:

2.24 bbls. of best Portland cement at $2.25 per bbl......	$5.05
0.68 cu. yd. of sand at $1.25 per cu. yd................	.85
1.06 cu. yd. of gravel at $1.50 per cu. yd................	1.59
Cost of material for 100 blocks 8x8x16-in..............	$7.49

In manufacturing these blocks, some claim that two laborers of ordinary intelligence can do all the work incident to the manufacture, and can with ease turn out 200 blocks a day. On this basis, for one man $1.50, and for the other $2.00 per day:

Cost for labor for 100 blocks $1.75
Incidentals $1 per day, or for 100 blocks............... .50

Cost of labor for 100 blocks 8x8x16-in.................$2.25
Or total for material and labor for 100 blocks........ 9.74

It must be considered that the above calculations are made for a capacity of 200 blocks a day; and that if several machines are operated and power mixer employed, and where, on account of larger consumption, the ram material can be had cheaper, the manufactured block will be cheaper.

Additional information in regard to blocks is furnished by the Lansing Co., and shown in Table LXXXVII.

Number of Blocks Required

In estimating the number of blocks required, the simplest method to pursue is to figure out the superficial or face area of the building. First, multiply the length around the building (in feet) by the height of the wall (also in feet); let us call this quantity A. Find the surface of gables by multiplying width of gable by its height, and dividing by 2; call this quantity B. Find the surface of each opening by multiplying its width by its height, and add together all the areas of the openings; call this quantity C. Then add together the quantities A and B, and subtract from their sum the quantity C. The result will be the net or actual face surface to be covered with the blocks (in square feet). Divide this by 100 by simply pointing off two figures at the right, and this will give the number of squares of 100 feet each to be covered.

Then turn to Table LXXXVIII, and multiply your number of squares by the number in the right-hand column opposite the size of block to be used. The result will be the number of blocks needed for the building.

For example, suppose the superficial area to be covered is 1,525 square feet. This will be 15.25 squares of 100 feet each. If the blocks are to be 8x8x16-in., find this size in the left-hand column of the table, and look across to the right, where you will find the number 112. Then $112 \times 15.25 =$ 1,708, which is the number of blocks required.

Cost of Concrete Blocks

The following example of cost calculation is based on conditions that may be regarded as approximately standard:

The facing mixture is 1 part Portland cement to 2 parts coarse, sharp, clean sand; and the body of the block 1 part cement to 2 parts sand and 3 parts gravel or broken stone,

TABLE LXXXVII
Concrete Block Data

Plant Number	Capital Required One Outfit	Concrete Mixture Used	Cost of Mixing per Block	Number of Men Employed	Blocks Made per Day per Man	Number of Days Sprinkled	Number Laid by Mason and Helper per Day	Cost of Laying Blocks per Block
1	......	1 : 4	3½–4c	3	50	7	....	....
2	......	1 : 4	....	3	..	5	100	....
3	$2,500	1 : 4	5c	2	40	10	100–150	5c
4	......	1 : 3½	6/10c mach.	11	60	5	100–150	....
5	......	1 : 4½	....	3	34	7	....	....
6	2,000	1 : 4½	....	3	30	10	....	5–7c
7	......	1 : 4	....	4	40	7	....	....
8	......	1 : 3	....	3	35	28	....	....
9	1,000	1 : 4	1½c	4	40	4	....	....
10	1,200	{1 : 1 {1 : 4	2c	3	50	6	90	7½–9c
11	500 up	1 : 4	....	6	65	5	75–125	7c
12	1,500	1 : 4	....	3	40	8	125	4½c
13	1,500	1 : 4	3c	4	45	8	125–150	6c
14	1,500	1 : 4	....	3	50	6	80–100	5c
15	2,000	1 : 4	2c mach.	3	33	4	....	....
16	1,000	1 : 4	7/10c mach.	6	47	....	120	7c
17	1,000	1 : 4	....	3	46	5	....	....
18	1,000	1 : 4	....	5	50	10	100	....
19	2,000	1 : 3½	....	2	50	....	150	8c
20	1,500	1 : 5	1½c	3	45	7	....	....
21	1,500	1 : 5	....	3	45	10	....	....

TABLE LXXXVIII
Concrete Block Data

Size of Block: Height x Width x Length	Solid Blocks: Weight of Block (lbs.)	Solid Blocks: No. per bbl. Cement at 1:5	Solid Blocks: No. per Cu. Yd.	Hollow Blocks: Weight of Block (lbs.)	Hollow Blocks: No. per bbl. Cement at 1:5	Hollow Blocks: No. per Cu. Yd.	No. of Blocks per Square of 100 Feet
8 x 8 x 16	73	34	48	50	49	71	112
8 x 10 x 16	92	27	33	67	37	71	112
8 x 12 x 16	109	22	32	80	31	44	112
4 x 8 x 16	35	68	99	24	100	144	224
4 x 10 x 16	44	54	79	32	70	109	224
4 x 12 x 16	53	44	66	39	63	91	224
8 x 4 x 16	37	68	95	....	....	....	112
8 x 8 x 24	112	22	31	77	32	45	75
8 x 10 x 24	140	18	25	92	25	33	75
8 x 12 x 24	166	15	21	112	21	31	75
4 x 8 x 24	54	46	65	37	66	94	150
4 x 10 x 24	67	36	52	46	52	76	150
4 x 12 x 24	79	36	44	55	44	68	150
8 x 4 x 24	55	44	63	....	....	....	75

The figures given in the above table for the weight of hollow blocks and the number produced from one barrel of cement, can, of course, be taken as only approximate, since the size of the air-space in different blocks varies. It ranges from about 27 to about 32 per cent, or averages about 30 per cent, of the total space occupied by the block.

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the gravel or broken stone to range in size from one-fourth to three-fourths of an inch in diameter.

One barrel cement contains 3¾ cubic feet.

One cubic yard contains 7¼ barrels.

One cubic yard of sand and 3⅝ barrels of cement will give a 1:2 mixture of cement and sand.

One cubic yard of sand and gravel and 1½ barrels of cement will give a 1:5 concrete mixture.

For manufacturing 100 blocks 8x8x16-in. in size, there are needed 2.24 barrels of cement, 0.68 cu. yd. of sand, and 1.06 cu. yds. of gravel or broken stone. The cost of making 100 blocks will therefore be approximately as follows:

2.24 bbls. best Portland cement at $2.00 per bbl.	=$4.48
0.68 cu. yd. sand at $1.00 per cu. yd.	= .68
1.06 cu. yds. gravel or broken stone at $1.50 per cu. yd.	= 1.59
Cost of labor for 100 blocks	= 1.75
Incidentals for safe margin per 100 blocks	= .50
Total cost of 100 blocks 8x8x16 in.	=$9.00

The above figures are conservative estimates of cost for materials and labor. They may vary to a greater or less degree, depending on the locality—distance from sources of supply, local labor conditions, etc.

Ordinarily blocks cost less than common brick. For comparison of cost with brick construction, the following figures showing the equivalent number of brick displaced by blocks of various sizes, will be found of help:

Size of Block with Mortar Joints.	Equivalent No. of Brick Displaced.
8x 8x16 in.	14.22
8x10x16 in.	17.77
8x12x16 in.	21.33
4x 8x16 in.	7.11
4x10x16 in.	8.88
4x12x16 in.	10.66
8x 4x16 in.	7.11
8x 8x24 in.	21.33
8x10x24 in.	26.66
8x12x24 in.	32.00
4x 8x24 in.	10.66
4x10x24 in.	13.33
4x12x24 in.	16.00
8x 4x24 in.	10.66

Cost of Special Facing for Blocks. Many times it is desired to use a special facing on concrete blocks, and, in connection with same, the Thompson Architectural Company publish the following data:

Highest grade, light color.		2 to 1 Mixture.
100 lbs. M. C. sand	$0.40	Equals 1⅛ cu. ft. tamped, and will cover 48 sq. ft. surface, ⅜ in. thick, or 2.14 cts. per sq. ft.
50 lbs. white cement	.63	
	$1.03	

Regular block facing, light.
100 lbs. M. C. sand.....$0.40
40 lbs. white cement.. .50
——
$0.90

2½ to 1 Mixture.
Will cover 45 sq. ft. surface, ⅝ in. thick at a cost of 2 cts. per sq. ft.

Reg. block facing, medium.
100 lbs. M. C. sand.....$0.40
30 lbs. white cement.. .38
10 lbs. gray cement... .04
——
$0.82

2½ to 1 Mixture.
Will cover 45 sq. ft. surface, ⅝ in. thick at a cost of 1.82 cts. per sq. ft.

Reg. block fac'g, med. dark.
100 lbs. M. C. sand.....$0.40
20 lbs. white cement.. .25
20 lbs. gray cement... .08
——
$0.73

2½ to 1 Mixture.
Will cover 45 sq. ft. surface, ⅝ in. thick at a cost of 1.62 cts. per sq. ft.

Regular block facing, dark.
100 lbs. M. C. sand....$0.40
40 lbs. gray cement... .16
——
$0.56

2½ to 1 Mixture.
Will cover 45 sq. ft. surface, ⅝ in. thick at a cost of 1.26 cts. per sq. ft.

Allowing 10 per cent for overrunning estimate, one ton of special facing sand will face approximately one thousand 8x8x16-in. blocks. The above prices are average sand carloads; cement, retail. In some localities where freights are high, and materials are purchased in small quantities, the cost would be more; in others, less.

Another form of estimate is that the cost of white cement on the basis of $5.00 per barrel is nearly 2¼ cents for each 8x8x16-in. block, and about 3⅜ cents for each 8x8x24-in. block.

White sand will cost about 1 cent for the 8x8x16-in. blocks, and 1½ cents for the 8x8x24 in. blocks.

The above estimate is on a basis of a facing mixture of 1 part cement and 2 parts sand, with the facing ½-in. in thickness.

CEMENT BRICK CONSTRUCTION

In regard to the cost of making cement brick, which may vary in localities, one can figure this cost from the following data, for each thousand brick.

Mixture	Cement	Sand
A 1:3 brick takes	3.8 barrels and	1.7 cu. yds.
A 1:4 brick takes	3.05 barrels and	1.8 cu. yds.

A 1:5 brick takes 2.55 barrels and 1.9 cu. yds.
A 1:6 brick takes 2.18 barrels and 2 cu. yds.
A 1:7 brick takes 1.9 barrels and 2 cu. yds.

The size of the standard cement brick is 8¼x4x2 inches. A brick of this size contains 66 cu. in. and has an average weight of 5 pounds.

It requires 26.2 bricks of standard size to make 1 cu. ft., and 707 standard brick to make 1 cu. yd.

The number of bricks of standard size required in walls, allowance being made for waste, is as follows:

1	sq.	ft.	of	wall, 1	brick	thick	will	require	14	brick.
1	"	"	"	" 1½	"	"	"	"	21	"
1	"	"	"	" 2	"	"	"	"	28	"
1	"	"	"	" 2½	"	"	"	"	35	"
1	"	"	"	" 3	"	"	"	"	42	"

One bricklayer, with a helper, will lay 1,500 brick in a day of 10 hours when working on an ordinary wall. In face or front work, he will lay from 1,000 to 1,200.

The number of brick of standard size required per sq. yd. in sidewalk work is 38, provided they are placed flatwise. If placed edgewise, the number required is 73; and when placed endwise, 149 are required.

CEMENT STUCCO EXTERIORS

Cement stucco walls, when used with ordinary frame construction, may be built either as independent slabs, or by using the stucco as a veneer coat over a sheathed framework.

Framing. The framework of studding for a stucco house is of the ordinary "balloon" type. Studding 2 by 4-in., spaced 12 in. on centers, is used. These studs should run entirely from the foundation sill to roof-plate, without any intervening horizontal grain in the wood. At two points between the foundation and eaves—midway between floors will do—the studding should be braced with 2 by 3-in. bridging, placed horizontally, but with the faces of the bridging inclined in alternate directions in adjacent spaces, as shown in Fig. 32. Foundations should be built a few inches above grade, and a cement water-table placed at grade, so as to keep the stucco up away from the ground. This water-table should project 2 or 3 in. from the face of the stucco surface.

Floor-joists are supported by 1 by 6-in. strips let into the studding at the proper height and firmly nailed.

Sheathed Walls. Where sheathing is desired, and a veneer coating of stucco is to be used, the sheathing should be sound and dry, ⅞-in. thick, and from 5 to 6 in. in width. The boards are nailed diagonally across the studding, in order to increase the stiffness of the structure. Over the sheathing should be fastened two thicknesses of a good grade of heavy waterproof building paper. This paper assists in keeping in the warmth in the building, and also protects the wood sheathing from rot due to dampness.

Furring. Where rods or crimped furring are used, painted or galvanized material should be provided. The size should be such as to allow a ¼-in. space at least between the metal

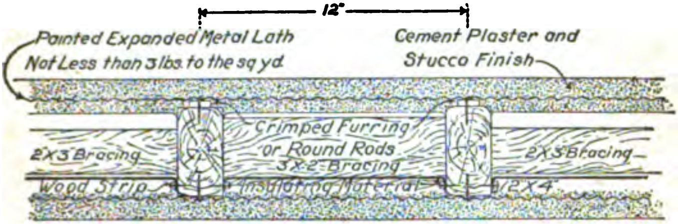

Fig. 32. Wall Section Showing Detail of Stucco Construction as Recommended by the Associated Metal Lath Manufacturers.

and wood, but not over ½-in. This furring should be fastened along the face of the studding with No. 14 gauge galvanized staples. These staples should be placed about 5 in. apart, and should be of sufficient length to go through the metal and astride of furring strips into the wood at least 1 in. When furring is fastened to metal uprights or members, galvanized wire should be used.

Lathing. Metal fabric of some type is now stapled onto the furred uprights. Although these sheet materials are usually specified by gauge, the true gauge of the sheets of metal from which the manufactured material is made may have been changed to a considerable extent. It is better to specify both the gauge and the weight per square yard of material. The weights are given in catalogues of manufacturers, and may be depended upon very closely. Painting adds but little to the weight of the sheets, while galvanizing adds from .75 lb. to .90 lb. per sq. yd., according to the gauge and type of material. When galvanized sheets are used, care should be taken to see that the galvanizing was done after all other manufacturing processes had been completed.

The sheets of reinforcement should be fastened horizontally;. that is, rib materials should have the ribs run across the studding, and expanded metal should be placed with the long dimension of the mesh horizontal. In expanded metal, the dip of the strand should be inward and downward, away from the workman, so that a perfect key can be formed. Grounds should allow at least ⅝-in. over face of steel. Edges of sheets should lap about the width of mesh, and no more, simply to make the sheets stiff; and the meshes should nest.

For best results, a sheet material weighing not less than 3 pounds per sq. yd. should be used, fastened horizontally, as described above, over the furring strips on the 12-in. spaced studs. The sheets of metal between furring strips should be tied with No. 18 gauge galvanized wire. Excellent results have been reported in cases where a sheet material of No. 24 gauge and weighing 3¼ pounds per sq. yd. was used.

If a metal corner-bead is not used, there should be 6-in. strips of metal lath bent around the corners and stapled over the side lathing, unless the sheets of side lath as applied are bent around the corners and fastened. A combination of corner-bead and strips of lath is often recommended.

Mixtures of Materials Used. Three-coat plastering is generally recommended where a considerable thickness of material is to be placed. The first and second coats should be of good thickness, and the finishing coat should be thoroughly waterproofed. The object is to use a Portland cement mortar with as little lime in it as will make it work properly. Clean, long, winter cattle hair, or clean fiber should be used for binding the under coats.

For the first and second coats the following mixtures have been recommended as giving good results:

(1) Lime mortar made by mixing 2 barrels of hydrated lime; 1 yard of clean, sharp sand free from loam; and 4 bushels of cattle hair. This mixture should be made up at least 3 days before using.

(2) Cement mortar made by mixing 1 part of Portland cement with 2 parts of clean, sharp sand free from loam. This mortar is mixed in small batches as used.

The lime mortar and cement mortar should be mixed and tempered separately. When used, equal parts of mixture, (1) and (2), are measured carefully, and mixed well together.

The finish coat should contain no lime; and if a lighter color is desired, white Portland cement should be used. A waterproofing compound of some kind should be mixed with the finishing coat. This compound should be used exactly as specified by the manufacturer.

Often a mixture of 1 part Portland cement and 2½ parts coarse sand is used as a finishing coat; and sometimes a part of the sand is replaced by an equal amount of small pebbles or stone screenings passing a ¼-in. screen and free from dust.

To insure an even color on this completed job, the ingredients should be thoroughly mixed dry until the mass has an even color; then add water until the proper consistency is reached. Care should be taken not to use too much water so that more ingredients will have to be added to thicken the mixture. Do not mix a greater quantity of cement plaster than can be applied before the cement begins to set. Plaster should never be used after it has once begun to harden, but should be thrown away.

Applying the Plaster. The first coat should be of such a thickness that it will cover the metal lath or fabric and fill the meshes. As soon as this coat has hardened sufficiently, it should be scratched at right angles and at about 45 degrees to the horizontal. The scratcher used should not cut a sharp line in the plaster, but should form grooves with ridges on the sides, so as to present a rough surface for the following coat.

The second and all following coats should be applied after the preceding coat has hardened, but preferably before it has had time to dry out. Each coat should be brought to a true, plane surface, and, with the exception of the finishing coat, should be scratched in the same way as the first coat.

Immediately before placing any coat of plaster, the preceding coat should be thoroughly drenched with water, and then covered with a grout coating of neat cement mixed with water to the consistency of thick cream. A calcimining brush may be used for this purpose. The coat of plaster should then be put on the wall before this grout wash has had time to dry.

The number of coats of plaster will depend upon the location and finish desired. Two coats are sometimes used, but more often three or more coats will give better results. It is often specified that no coat shall be more than ½-in. thick, regardless of the thickness of wall desired. The different coats are known as the **first or scratch coat, intermediate coat, and finish coat.** Three-coat work is recommended in nearly all cases, and is seen to be necessary in many, especially where thick work is desired. Smooth or float finishes are more satisfactory in 3-coat than in 2-coat work. It is very difficult to straighten a wall properly in a second coat and float it to a good surface at the same time.

The thickness of stucco exteriors varies in different instances from ¾-in. to 1½-in., depending upon the type of building and the kind of sheet steel reinforcement used. Where a wall is to be back-plastered, the backing coat adds about ¾-in. to the total thickness of reinforced slab.

Finishes. The last coat of stucco work may be finished smooth, pebble-dash, or rough-cast. The smooth coat is applied in the usual manner and is floated and troweled to a smooth finish. Objections to this type of surface are that variations of color show readily, and that cracks are more likely to occur, due to troweling.

Pebble-dash finish consists of small pebbles about ½-in. in size, which are mixed into a paste of Portland cement mortar and thrown on the wall with a trowel or wooden paddle. A mixture of 5 parts mortar to 1 part pebbles, by volume, is said to give good results. The work should be started at the top and confined to a space of about 6 sq. ft. per man; and it should be continuous so that one patch of plaster may not dry before the spaces adjoining are covered.

Waterproofing. It is claimed by some architects and engineers that a small percentage of hydrated lime mixed with the cement mortar produces a stucco which is practically waterproof. A frequent specification calls for a mixture of 1 part Portland cement, 2½ parts clean, medium-grained sand, and 10 to 15 per cent of hydrated lime. This percentage is based upon the amount of cement used in the mixture.

Stucco on Brick, Stone, Tile, etc. When cement stucco is to be used on stone, brick, concrete, or terra-cotta wall surfaces, either as a first finish or as a means of covering up deterioration of materials, care should be taken to clean the surface to be plastered and remove all loose particles of material, before applying the stucco. In brick or stonework, all loose mortar should be removed from the joints, and joints raked out to a depth of ½ to ¾-in. After the surfaces and joints are cleaned, the wall should be thoroughly wetted until it is saturated to such a degree that no water will be taken from the cement coating which is to be applied. A brush or hose may be used in wetting the wall.

The method of plastering to be followed is similar to that already described. The first coat should be put onto the wall while it is wet, and plastered on thickly enough to cover all irregularities in the wall surface.

Where expense will permit, it is good policy to cover stone and brick walls with metal lath furred out by steel rods or ¼-in. metal furring strips fastened to wooden plugs driven into the joints of the masonry, or held by galvanized staples 2-in. by No. 9 gauge driven into the mortar joints. This furring should be placed on about 12-in. centers.

Cost of Exterior Plastering, or Stucco

There are three popular finishes for exterior work—**Float, Rough-Cast, and Pebble-Dash.**

Float finish is two-coat work, and is, therefore, the cheapest of the three. It is best adapted to surfaces of small area.

Rough-Cast and Pebble-Dash are applied in the third coat and are to be had in great variety of texture and color.

Cost depends largely on the location of the work, the amount of scaffolding required, and the handling of the door and window trim. The Northwestern Expanded Metal Company claim that it should not, however, exceed an average of $1.50 per sq. yd. of surface plastered complete; and in small towns and on the farm, where nearly all of the labor involved in putting on the lath and getting ready for the plasterer is done by the owner, it should be much less. This company has a record of work having been done as low as 62 cents per sq. yd.

Other sources of information give the price of 3-coat work on expanded metal lath as $1.25 to $1.75 per sq. yd. when work is put on in panels, but only from 85 cents to $1.00 per sq. yd. for plain, straight work. These prices include putting on the lath and all materials, but do not include the cost of staging.

CEMENT MORTAR

The area which one barrel of Portland cement in various mixtures will cover with coating of varying thickness, is shown as follows:

Proportions	Thickness of Coating	Yield in Sq. Ft.
1 Cement, 1 Sand	1 in.	67
	¾ in.	90
	½ in.	134
	¼ in.	268
1 Cement, 2 Sand	1 in.	104
	¾ in.	129
	½ in.	208
	¼ in.	416
1 Cement, 3 Sand	1 in.	140
	¾ in.	187
	½ in.	280
	¼ in.	560

The quantities of cement and sand required for 100 sq. ft. of surface, with various mixtures and thicknesses of mortar, are shown in the accompanying table:

TABLE LXXXIX
Cement and Sand for 100 Sq. Ft. of Plaster

PROPORTIONS	Thickness	Barrels Cement	Cubic Yards Sand
One part cement. Two parts sand.	1 in.	.96	.28
	¾ in.	.72	.21
	½ in.	.48	.14
	¼ in.	.24	.07
One part cement. Three parts sand.	1 in.	.67	.31
	¾ in.	.50	.23
	½ in.	.33	.15
	¼ in.	.17	.08

TABLE XC
Quantities of Materials for One Cubic Foot of Cement Mortar

MIXTURE	Cement	Sand
	Barrel	Cubic Yard
1 : 1½	0.15	0.03
1 : 2	0.12	0.03
1 : 2½	0.11	0.04

The amount of water to be used may be taken as that indicated in Table XCI, which shows the percentage of water required for a 1:3 mixture. This percentage will vary, where different cements are used, according to the percentage that may be necessary for giving normal consistency to the neat cement paste.

TABLE XCI
Percentage of Water for Standard Sand Mortars

Neat	One Cement Three Standard Ottawa Sand	Neat	One Cement Three Standard Ottawa Sand
15	8.0	27	10.0
16	8.2	28	10.2
17	8.3	29	10.3
18	8.5	30	10.5
19	8.7	31	10.7
20	8.8	32	10.8
21	9.0	33	11.0
22	9.2	34	11.2
23	9.3	35	11.5
24	9.5	36	11.5
25	9.7	37	11.7
26	9.8	38	11.8

For example, if the neat cement requires 18 per cent of water for normal consistency, then 8.5 per cent of water will be needed for the 1:3 mortar mixture. The percentages of water indicated are percentages by weight, being based on the weight of the dry material.

COST OF SMALL CONCRETE DAM

Where a small dam is to be built not more than 6 feet above the bed of a stream, Fig. 33 and Table XCII will prove of value in estimating quantities of material needed.

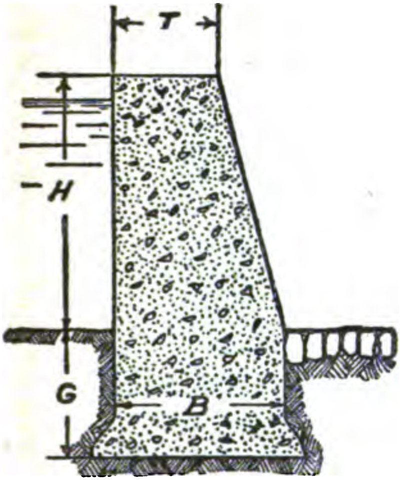

Fig. 33. Section Showing Design of Concrete Dam.

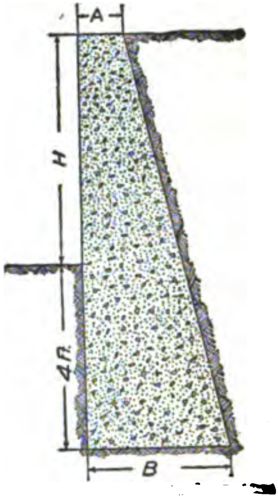

Fig. 34. Section Showing Design of Simple Gravity Retaining Wall.

(Courtesy of Atlas Portland Cement Company.)

RETAINING WALLS

The quantity of materials needed for retaining walls is figured in the same manner as indicated for foundations and walls, care being taken to keep separate the quantity of each mixture of concrete. The volume of excavation should be found by the method already explained, and figured according to the costs given on page 127.

Fig. 34 shows a simple form of retaining wall. The quantities of materials needed for constructing this style of wall in different heights and sizes are given in Table XCIII.

CONCRETE TANKS

Heidenreich gives the cost of reinforced concrete tanks built of light dimensions but of rich material, resting on the ground, and without roof, approximately as in Table XCIV.

TABLE XCII

Dimensions for Small Dams, and Quantity of Materials for Different Heights of Dam

Proportions: 1 part Portland cement, to 2 parts sand, to 4 parts gravel or stone

Height above Bed of Stream	Depth below Bed of Stream	Thickness at Base	Thickness at Top	Amount of Materials per Foot of Length of Dam		
				Cement	Sand	Gravel or Stone
Feet H	Feet G	Feet B	Feet T	Bags	Cu. Ft.	Cu. Ft.
1	1½	1	1	½	¾	1½
2	1½	1	1	1	1½	3
3	1½	2	1½	1¾	4	8
4	2	2	1½	2¾	5	10
5	2	2½	1½	3½	6¾	13½
6	2	3	1½	4½	8¾	17½

TABLE XCIII

Dimensions of Retaining Walls, and Quantity of Materials for Different Heights of Wall

Proportions: 1 part Portland cement, to 2½ parts sand, to 5 parts gravel and stone.

Height of Wall above Ground H	Total Height of Wall	Thickness at Base B		Thickness at Ground Level		Thickness at Top A	Amount of Materials per One Ft. Length of Wall		
							Cement	Sand	Gravel or Stone
Feet	Feet	Ft.	In.	Ft.	In.	Inches	Bags	Cu. Ft.	Cu. Ft.
2	6	2	2	1	6	10	1¾	4½	9
3	7	2	5	1	7½	10	2½	5½	11
4	8	2	9	1	11	12	3	7	14
5	9	3	2	2	1	12	3½	9	19
6	10	3	6	2	4½	15	4¾	11½	23
7	11	3	10	2	8	18	6	14	28
8	12	4	2	2	10	18	7	16½	33

Note—A large single load of sand or gravel is about 20 cubic feet. A large double load of sand or gravel is about 40 cubic feet.

TABLE XCIV—Cost of Concrete Tanks

Capacity in Gallons	Cost per Gallon
1,000	6¼ cents
2,000	5 "
5,000	4¼ "
10,000	3¼ "
20,000	3 "
100,000	2 "

CONCRETE FENCE-POSTS

In estimating the cost of cement posts, first find the number of cubic inches in the size of post to be made. Then determine the mixture of cement and aggregates to be used. If we decide to use a 1:2½:4 mixture, 1 barrel of cement will produce about 20 cu. ft. of concrete. Twenty cu. ft. of concrete, reduced to cubic inches, is:

$$20 \times 1{,}728 = 34{,}560 \text{ cubic inches.}$$

Divide this number by the number of cubic inches of concrete in the desired post, and the result will be the number of posts which may be made from 1 barrel of cement and the stated quantity of aggregates. Adding to the above cost about 6 cents for reinforcement, and 5 cents for labor, the result will be the cost of an ordinary fence-post, not counting the cost of the mold.

The cost of concrete fence-posts will vary with the size of the post, cost of materials in a given locality, and the cost of labor.

The following estimate based upon the manufacture of 20 posts measuring 6 by 6 in. at the bottom, 6 by 3 in. at the top, and 7 ft. long, from one cu. yd. of 1:2½:5 concrete, will serve as a guide:

1.10 bbls. of cement at $2.00	$2.20
.42 cu. yd. of sand at $1.00	.42
.83 cu. yd. of gravel at $1.00	.83
Materials for 1 cu. yd. of concrete	$3.45
Concrete for 1 post	$0.17
28 feet of .16-in. steel wire at 3 cents per pound.	.06
Total cost of concrete and metal for 1 post	$0.23

Allow an average charge of 7 cents to cover cost of mixing concrete, molding, handling, and cost of molds, making a total of 30 cents per post.

Another estimate on 1,000 concrete fence-posts 9 ft. long, 4 by 4 in. at the top, and 4 by 6 in. at the base, showed that these posts cost about 65 cents each. The concrete mixture was composed of 1 part Portland cement, and 2 parts stone screenings ranging in size from dust to ¼-in. Each post was reinforced with four ¼-in. Johnson corrugated bars, one in each corner. Cement cost $2.00 per barrel; screenings, 75 cents a cu. yd.; and reinforcing steel, 3½ cents a pound.

Two men at $2.00 per day could produce about 40 posts per day. These men also mixed the concrete, and moved and watered the posts.

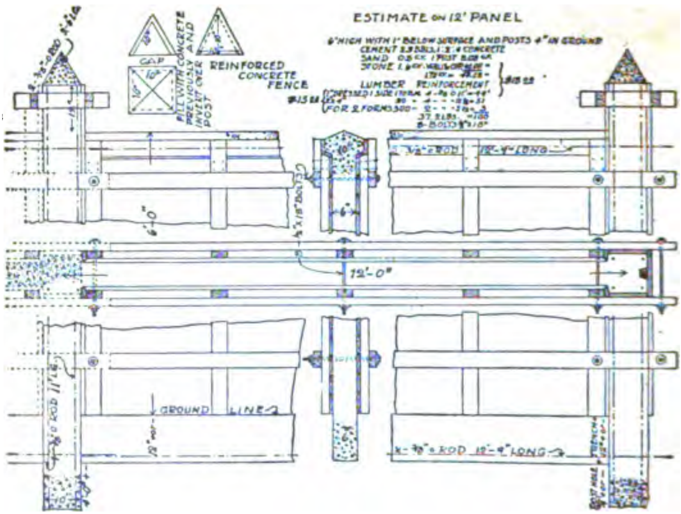

Fig. 35. Solid Cast Concrete Fence, Showing Forms and Reinforcement. Designed by G. H. Derrick, Pulaski, Va.

SOLID CAST CONCRETE FENCE

Fig. 35 shows details of a cast concrete fence and the forms for making same, as well as an estimate of material for a 12-ft. panel of enclosure.

The concrete mixture was of 1 part Portland cement, 2 parts sand, and 4 parts crushed stone. The reinforcement consists of fcur ⅜-in. diameter steel rods placed near the corners of the post and extending throughout its full length. Two ⅜-in. diameter rods are placed near the base, as shown, to prevent vertical cracks. Two other similar rods are placed in the coping. Both sets of horizontal rods extend a few inches into the next section, as shown.

A panel of enclosure wall 12 ft. long and 6 ft. high, with 12 in. of concrete below grade, and posts 4 ft. in the ground, will contain about 1¾ cu. yds. of 1:2:4 concrete, and is said to cost about $1.50 per running foot, depending, of course, on the extent of the job and the local cost of material, labor, etc. The cost of two sections of lumber forms is stated to be about $15, and they can be used for a considerable length of time if made properly and coated with some kind of lubricant to prevent the concrete from sticking to them. Different heights of fence may be built from the same forms, by taking off or adding to the bottom as the case may be.

REINFORCED CONCRETE LINE POLES

Trolley and transmission line poles made by the Fort Wayne & Wabash Valley Traction Co. were stated to cost as follows:

Trolley poles 32 ft. long, 10 in. square at a section 8 ft. from the bottom, and 6 in. square at the top, were reinforced with eight ⅝-in. twisted steel rods. One of these poles contained 22½ cu. ft. of 1:3:3 gravel concrete and 122 pounds of steel. This pole weighed 3,300 pounds, and cost $7.50 at the gravel pit.

Transmission poles 42 ft. long, 12 in. square at a section 8 ft. from the bottom, and 6 in. square at the top, were reinforced with eight ½-in. twisted steel bars, four of which were 32 ft. long, and four 42 ft. long. Each pole contained 29 cu. ft. of concrete, 242 pounds of reinforcing bars, and 21 pounds of steps. The weight of these poles was 4,400 pounds, and they cost $13.00 each.

CONCRETE DRAIN-TILE AND SEWER-PIPE

The following figures, which are only approximate, are based on a mixture of 4 parts of sand to 1 part of cement. Placing sand at $1 per yard, cement at $2 per barrel, and labor at $2 per day, we have the data given in Table XCV.

Table XCVI shows the comparative weights and cost of concrete and cast-iron pipes from 1 ft. up to 4 ft. diameter; it is based on the price of $7 per cu. yd. for concrete, and 3¼ cents per lb. for cast-iron pipes. The thicknesses for concrete pipes of various diameters have been taken as approximately proportional to the thickness of cast-iron pipes of the same diameter, the 4-ft. pipes being used as a basis for calculation.

The first cost of concrete pipes at the place of manufacture would, according to the table, be less than 1/12th of the cost of cast-iron pipes. The cost of transportation and of installing the concrete pipes would, on account of the greater weight and greater number of pieces, probably be very nearly double the cost for cast-iron pipes. On account of the lack of reliable data regarding this cost, it is very difficult to give a fair comparative estimate of the cost of the two styles of culverts in place. However, since transportation and installation of iron pipes is but a small proportion of the cost of the completed culverts, it is evident

TABLE XCV

Concrete Tile and Sewer Pipe Data

Size of Tile	Thickness	Cost Sand	Cost Cement	Cost Labor
12-Inch	1¼-inch	$0.02	$0.12	$0.06
14-Inch	1⅜-inch	0.025	0.16	0.065
16-Inch	1½-inch	0.035	0.20	0.075
18-Inch	1⅝-inch	0.04	0.22	0.085
20-Inch	1¾-inch	0.05	0.25	0.10
22-Inch	1⅞-inch	0.06	0.30	0.11
24-Inch	2-inch	0.07	0.35	0.15
30-Inch	2½-inch	0.09	0.53	0.20
36-Inch	3-inch	0.13	0.70	0.30
40-Inch	3½-inch	0.16	0.80	0.36

Size of Tile	Cost One Tile 24 Ins. Long	Cost per Ft.	Day's Work for 3 Men
12-Inch	$0.20	$0.10	100 tile
14-Inch	0.25	0.125	90 tile
16-Inch	0.31	0.155	80 tile
18-Inch	0.345	0.172	70 tile
20-Inch	0.40	0.20	60 tile
22-Inch	0.47	0.235	50 tile
24-Inch	0.57	0.285	40 tile
30-Inch	0.82	0.41	25 tile
36-Inch	1.13	0.565	20 tile
40-Inch	1.32	0.66	16 tile

TABLE XCVI

Relative Thickness, Weight, and Cost of Cast-Iron Pipe and Concrete Pipe

Size and Kind of Pipe		Thickness	Weight per Lin. Ft.	Cost per Lin. Ft.
12-in.,	cast-iron	0. 33/64 In.	75 Lbs.	$ 2.44
	concrete	2.0 "	88 "	0.16
18-in.,	cast-iron	0. 47/64 "	167 "	5.43
	concrete	3.0 "	220 "	0.36
24-in.,	cast-iron	1.0 "	250 "	8.13
	concrete	4¼ "	420 "	0.68
30-in.,	cast-iron	1 1/16 "	334 "	10.86
	concrete	4½ "	602 "	0.88
36-in.,	cast-iron	1⅜ "	450 "	14.63
	concrete	4⅝ "	676 "	1.10
42-in.,	cast-iron	1⅝ "	600 "	19.50
	concrete	5⅝ "	960 "	1.55
48-in.,	cast-iron	1 7/16 "	725 "	23.56
	concrete	6.0 "	1,131 "	1.82

that the cost of a concrete pipe culvert in place would be but a small fraction of the cost of a cast-iron pipe culvert of the same diameter, provided the pipes were hauled only moderate distances.

CONCRETE SIDEWALKS, CURBS, AND GUTTERS

See section on "Sidewalks, Curbs, and Gutters."

CONCRETE BRIDGES AND CULVERTS

See section on Bridges and Culverts.

CONCRETE RAILROAD TIES

A report issued by the Maintenance of Way Department of the Galveston, Harrisburg & San Antonio Railroad, relating to costs of the "Percival" concrete tie is as follows:

Size of tie, 9½ in. face, 9 in. deep, and 8 ft. long. The ends of the base are made oval for 3 ft., with an average bearing of 5 in. under the rail. The center of the tie is cut away for about 2 ft. The matrix contains 3 cu. ft., 55½ cu. in. The weight per tie is 445 pounds. Each tie is reinforced with four corrugated steel bars—three ½-in. bars near the upper face of the tie, and one ¾-in. bar in the base.

The concrete was composed of 1 part Portland cement, 1 part sand, and 4 parts crushed sand rock. The concrete was hand-tamped in the molds, and was exposed to moisture for 10 days.

The following detailed costs were reported:

Cost per Tie

Ties, complete	$1.8500
Freight and labor, distributing	.0239
Stripping track	.1832
Installing	.1532
Total	$2.2103

Detailed Cost of Handling and Installing 100 Ties

Unloading and distributing ties:		
1 hour's work train service	$ 1.46	
6 laborers 1 hour at $1.25 per day	.75	
1 foreman 1 hour at $55 per month	.18	
		$ 2.39
Stripping track and taking out old ties:		
11 laborers 1 day at $1.50 per day	$16.50	
1 foreman ⅓ day at $85 per month	.91	
1 foreman ⅓ day at $55 per month	.59	
1 timekeeper ⅓ day at $30 per month	.32	
		18.32

Installing 100 concrete ties:		
9 laborers 1 day at $1.50 per day	$13.50	
1 foreman ⅙ day at $85 per month	.91	
1 foreman ⅙ day at $55 per month	.59	
1 timekeeper ⅙ day at $30 per month	.32	
		15.32
Resurfacing track and dressing ballast:		
12 laborers 1 day at $1.50 per day	$18.00	
1 foreman ⅙ day at $85 per month	.91	
1 foreman ⅙ day at $55 per month	.59	
1 timekeeper ⅙ day at $30 per month	.33	
		19.83
Total		$55.86

CONCRETE PILES

Ordinary concrete piles cost from 60 cents to $1.00 per linear foot when driven. Special types cost from $1.00 to $1.50 per linear foot. For small quantities of piles made at one time, the cost of ordinary piles may run as high as $1.65 per linear foot.

The cost of concrete piles, as compared with that of wood piles, was brought out in a striking manner during the erection of the new buildings of the United States Naval Academy at Annapolis, Md. Calculations showed that by using concrete piles a saving of over $27,000, or more than 50 per cent of the cost of wood piles, could be effected. The various factors which tended toward the economy resulting from the substitution of concrete piles, are thus stated by Walter R. Harper, inspector in charge of the work: 2,193 wood piles were replaced by 885 concrete piles; 4,542 yards of excavation was reduced to 1,038 yards, saving 2,504 yards; and 3,250 yards of concrete footing was reduced to 986 yards, thus saving 2,264 yards. Shoring and pumping, which would have cost $4,000 had wood piles been used, were entirely eliminated.

Table XCVII shows a detailed statement of the comparison.

The saving in the cost of foundations by the use of concrete piles was $27,458.18, or more than half the original cost of the foundations as designed with wood piles.

COST OF CONCRETE SILOS

Tables XCVIII and XCIX, compiled by the Universal Portland Cement Company, give an interesting comparison of costs of both monolithic and block silos of various sizes and built in different localities.

TABLE XCVII

Comparative Cost of Wood and Concrete Piles

Wood Piles

2,193 piles, at $9.50	$20,835.50	
4,542 cubic yards excavation, at $0.40	1,816.80	
3,250 cubic yards concrete, at $8.00	26,000.00	
5,222 lbs. I-beams, at $0.04	208.88	
Shoring and pumping	4,000.00	
Total cost		$52,861.18

Concrete Piles

855 piles, at $20.00	$17,100.00	
1,038 cubic yards excavation, at $0.40	415.00	
986 cubic yards concrete, at $8.00	7,888.00	
Shoring and pumping	....	
Total cost		25,403.00
Difference in cost		$27,458.18

The following costs given per ton of capacity of silo, are taken from these tables:

Average Cost of Silos

	Per Ton of Capacity Monolithic	Block
Illinois	$2.83	$2.44
Michigan	2.31	3.21
Wisconsin	2.10	3.36
Minnesota	2.26	3.34
Average cost of all silos, capacity 100 tons or less	2.89	3.52
Average cost of all silos, capacity 100 to 200 tons	2.38	2.88
Average cost of all silos, capacity more than 200 tons	2.18	
Average cost of all silos	2.30	3.11

Labor Required for Silos

The following estimate of labor required to construct monolithic silos is based on experience in a large number of cases, the materials being mixed by hand. The labor here given is approximate, and does not include that required to haul materials:

Silos	8 ft. diameter	10 to 14 days (4 hrs. per day)	4 men
"	12 " "	10 to 16 " " " "	4 men
"	16 " "	10 to 16 " " " "	4 to 5 men
"	20 " "	10 to 20 " " " "	5 men
"	22 " "	12 to 20 " " " "	5 men

TABLE XCVIII

Cost of Monolithic Silos

Silo No.	Diameter in ft.	Height in ft.	Capacity in tons	Entire Cost	Cost per ton of capacity	Location
1	16	37	161	$ 525	$ 3.26	Belvidere, Illinois
2	16	44	207	695	3.36	Carlton, "
3	15	30	105	400	3.81	Downer's Grove, "
4	16	32	131	500	3.82	Downer's Grove, "
5	20	40	282	550	1.95	Dundee, "
6	20	40	282	720	2.56	Dundee, "
7	12	27	58	241	4.15	Effingham, "
8	18	40	228	620	2.62	Elburn, "
9	18	40	228	620	2.62	Elburn, "
10	20	40	282	680	2.41	Elburn, "
11	20	40	282	680	2.41	Elburn, "
14	16	40	180	550	3.05	Kaneville, "
15	17	42	218	650	2.98	Lake Forest, "
16	17	42	218	650	2.08	Lake Forest, "
17	18	46	277	650	2.35	Marengo, "
18	18	36½	200	409	2.09	Pingree Grove, "
20	18	34	181	490	2.70	St. Charles, "
21	16	30	119	405	3.40	St. Charles, "
22	20	40	282	680	2.41	St. Charles, "
23	18	38	212	575	2.72	St. Charles, "
24	12	38	94	300	3.19	St. Jacob, "
25	18	40	228	550	2.41	Wheaton, "
26	24	50	550	...	....	
27	24	50	550	1600	.97	Winslow, "
28	24	50	550	...	....	
29	20	40	282	500	1.76	Coldwater, Michigan,
30	20	40	282	500	1.76	Coldwater, "
32	14	45	165	306	1.87	Eau Claire, "
33	14	46	170	400	2.35	Eau Claire, "
34	12½	36	95	163	1.72	Eau Claire, "
35	14	36	118	200	1.70	Eau Claire, "
36	..	..	55	190	3.45	Grandvill , "
37	11	28	51	105	2.06	Hudsonville "
38	14	28	83	250	3.00	Kalamazoo, "
39	12	30	67	250	3.72	Kalamazoo, "
42	14	30	91	130	1.43	Lansing, "
43	14	32	100	169	1.69	Lansing, "
44	18	40	228	550	2.41	Marquette, "
45	14	40	138	295	2.14	Parma, "
46	14	40	138	300	2.18	Parma, "
47	12	36	87	230	2.64	Parma, "
48	12	36	87	240	2.75	Parma, "
49	12	36	87	300	3.45	Parma, "
50	14	47	175	300	1.72	Sodus, "
57	20	45	330	550	1.67	Cedarburg, Wisconsin,
58	20	45	330	550	1.67	Cedarburg, "
61	16	30	120	500	4.16	Elkhorn, "
64	16	40	180	275	1.53	Hudson, "
65	14	52	190	600	3.16	Irma, "
66	14	36	118	175	1.48	Lake Geneva, "
68	14	36	118	293	2.48	Madison, "
71	16	30	120	260	2.16	New Richmond, "
72	16	30	120	260	2.16	New Richmond, "
73	16	37	161	199	1.24	New Richmond, "
74	13	30	79	168	2.13	Roberts, "
75	16	30	120	114	.95	Roberts, "
76	16	30	120	180	1.50	Roberts, "

TABLE XCVIII—(Concluded)

Silo No.	Diameter in feet	Height in feet	Capacity in tons	Entire cost	Cost per ton of capacity	LOCATION
77	16	30	120	177	1.47	Roberts, Wisconsin
78	16	38	167	195	1.17	Roberts, "
79	14	35	114	325	2.85	Walworth, "
80	14	28	83	400	4.80	Walworth, "
81	60	40	2250	2500	1.11	Waukesha, "
85	14	29	87	115	1.32	Jordan, Minnesota
89	20	32	205	380	1.85	Owattona, "
90	14	28	83	214	2.58	Rose Creek, "
93	16½	33	144	475	3.30	Wheaton, "
94	20	40	282	500	1.77	Centerville, Indiana
95	16	38	167	500	2.99	Fort Wayne, "
96	16	40	180	550	3.05	Huntington, "
97	14	30	91	340	3.74	Oil City, "
102	16	40	180	344	1.91	Roanoke, Missouri
103	16	32	131	315	2.40	Springfield, "
104	12	30	67	250	3.72	High Bridge, Kentucky
105	18	38	211	204	.97	West Paint Lick, "
106	12	24	49	145	2.96	Fort Collins, Colorado
107	12	24	49	165	3.36	Fort Collins, "
108	17	38	190	400	2.10	Iowa City, Iowa
110	18	40	228	600	2.64	Warren, Pennsylvania

TABLE XCIX

Cost of Concrete Block Silos

Silo No.	Diameter in feet	Height in feet	Capacity in tons	Entire cost	Cost per ton of capacity	LOCATION
12	16	38	167	$ 450	$ 2.70	Kaneville, Illinois
13	16	44	207	450	2.18	Kaneville, "
31	12	32	74	163	2.20	Coloma, Michigan
40	12	30	67	138	2.06	Lansing, "
41	12	38	94	180	1.92	Lansing, "
51	8	37	40	227	5.70	Sodus, "
52	12	30	67	300	4.48	Sodus, "
53	12	30	67	180	2.70	Zeeland, "
54	10	20	36	110	4.20	Zeeland, "
55	10	28	42	160	3.80	Zeeland, "
56	10½	28	45	170	3.78	Zeeland, "
59	16	34	143	340	2.38	East Troy, Wisconsin
60	14	35	114	300	2.64	East Troy, "
62	14	30	91	450	4.95	Elkhorn, "
63	18	33	174	400	2.30	Elkhorn, "
67	12½	38	100	500	5.00	Lake Geneva, "
69	16	32	131	410	3.13	New Richmond, "
70	16	32	131	410	3.13	New Richmond, "
82	16	42	193	550	2.83	Austin, Minnesota
83	16	30	119	400	3.36	Claremont "
84	16	32	131	400	3.05	Claremont, "
86	14	32	100	312	3.12	Litchfield, "
87	14	32	100	380	3.80	Northfield, "
88	14	32	100	375	3.75	Northfield, "
92	14	32	100	225	2.25	Stillwater Jct, "
98	20	60	530	750	1.42	Delaware, Ohio
99	14	40	138	420	3.04	Greenfield, "
100	12	33½	80	250	3.12	Lorain, "
101	12	30	67	200	2.98	Marysville, "
109	16	34½	146	475	3.25	Butler, Pennsylvania

TABLE C

Approximate Capacity of Round Silos, in Tons

Diameter is shown at top of column, and depth at left

Height of Silo.	Inside Diameter of Silo, in Feet; and Capacity, in Tons (2,000 lbs.)										
	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.	19 ft.	20 ft.
Feet	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
20	26										
21	28										
22	30	36									
23	32	39									
24	34	41	49								
25	36	43	52								
26	38	46	55	64							
27	40	49	58	68							
28	42	51	61	71	83						
29	44	54	64	75	87						
30	47	56	67	79	91	105					
31	49	58	70	83	96	110					
32	51	62	74	86	100	115	131				
33	53	65	77	90	105	121	138				
34	56	68	80	94	109	126	143	162			
35	58	70	84	98	114	132	149	169			
36	61	73	87	102	118	136	155	176	196		
37	63	76	90	106	123	142	161	183	204		
38	66	79	94	110	128	148	167	191	212	237	
39	68	82	97	115	133	154	174	198	221	247	
40	70	85	101	119	138	160	180	205	229	256	280
41	72	88	105	124	143	166	187	211	236	262	291
42	74	91	109	128	148	172	193	218	244	270	300
43			113	133	154	179	201	225	252	280	310
44			117	137	159	184	207	233	261	289	320
45					165	191	215	240	269	298	330
46					170	197	222	247	277	307	340
47							229	254	285	316	350
48							236	261	293	325	361
49									301	334	371
50									310	344	382

Add 5 feet to height indicated, to allow for settling of silage.

TABLE CI

Cement, Sand, and Stone Required for Walls of Monolithic Silos

Thickness of walls, 6 inches. Continuous doors, 2½ feet wide. Proportions for concrete, 1:2½:4.

(For silos with non-continuous doors a slightly greater quantity of materials is necessary)
(Universal Portland Cement Company)

Ht. of Silo	Bbls. of Cement Required for given inside diameter in ft.								Cu. Yds. of Sand Required for given inside diameter in ft.								Cu. Yds. of Gravel Required for given inside diameter in ft.							
ft.	8	10	12	14	16	18	20	22	8	10	12	14	16	18	20	22	8	10	12	14	16	18	20	22
20	12.6	16.0	19.0	22.6	25.4	....	....	....	4.6	5.8	7.0	8.4	9.3	....	....	....	7.4	9.4	11.2	13.3	15.2	....	....	....
22	13.8	17.7	21.0	24.9	28.0	32.0	....	....	5.1	6.5	7.7	9.0	10.2	11.6	....	....	8.2	10.4	12.4	14.8	16.5	18.8	....	....
24	15.1	19.2	22.8	27.1	30.7	35.0	38.5	....	5.6	7.0	8.6	9.9	11.2	12.7	14.1	....	8.9	11.4	13.5	16.0	18.2	20.6	22.8	....
26	16.3	21.0	24.8	29.3	33.0	37.8	41.8	....	6.0	7.7	9.1	10.7	12.1	13.7	15.3	....	9.6	12.4	14.7	17.4	19.6	22.2	24.8	....
28	17.6	22.3	26.6	31.5	35.5	40.6	44.9	49.7	6.5	8.2	9.7	11.6	13.0	14.8	16.4	18.1	10.4	13.3	15.8	18.7	21.0	24.0	26.5	29.4
30	18.9	24.0	28.8	33.8	38.2	43.4	48.0	53.5	6.9	8.7	10.5	12.3	14.0	15.8	17.5	19.5	11.1	14.2	17.0	19.8	22.8	25.5	28.5	31.5
32	20.1	25.7	30.7	36.0	40.5	46.0	51.4	57.0	7.4	9.4	11.2	13.1	14.8	16.9	18.7	20.7	11.8	15.0	18.0	21.3	24.0	27.3	30.3	33.6
34	21.4	27.1	32.3	38.3	43.4	49.0	54.3	60.0	7.8	10.0	11.8	14.0	15.8	17.9	19.9	22.0	12.6	16.1	19.2	22.5	25.5	29.0	32.0	35.5
36	22.6	28.7	34.3	40.4	45.8	52.0	57.5	64.2	8.3	10.5	12.5	14.8	16.8	19.0	21.0	23.4	13.3	17.0	20.3	24.0	27.2	30.6	34.0	38.0
38	23.9	30.3	36.2	42.8	48.7	55.0	60.8	67.5	8.8	11.1	13.3	15.7	17.8	20.1	22.2	24.6	14.1	18.0	21.5	25.4	28.7	32.5	35.9	39.7
40	25.1	31.7	37.8	44.5	50.6	57.5	64.0	71.3	9.2	11.6	14.0	16.4	18.6	21.2	23.6	26.1	14.8	18.8	22.4	26.4	30.0	34.0	38.0	42.0
42	....	33.5	40.0	47.4	53.7	60.5	67.5	74.6	....	12.3	14.7	17.2	19.5	22.1	24.6	27.3	....	19.9	23.8	28.0	31.7	35.6	40.0	44.1
44	....	....	41.8	49.6	55.8	65.3	71.0	78.7	....	....	15.3	18.1	20.4	22.9	26.0	28.8	....	....	24.8	29.2	33.0	38.4	41.8	46.4
46	....	....	....	51.8	58.6	66.5	74.0	81.6	....	....	....	18.9	21.4	24.4	27.0	29.8	....	....	....	30.6	34.7	39.3	43.5	48.0
48	....	....	....	....	61.2	69.8	76.6	85.7	....	....	....	....	22.3	25.5	28.0	31.4	....	....	....	....	36.0	41.0	45.0	50.5
50	....	....	....	....	....	71.6	80.0	89.0	....	....	....	....	...	26.3	29.6	32.6	....	....	....	....	....	42.8	47.2	52.6

TABLE CII

Number of Concrete Blocks Required for Silo Construction

Whole block, 16 in. long (outside), 8 in high; half block, 8 in. long (outside), 8 in. high.

(Universal Portland Cement Company)

Inside Diameter of silo	8 ft.	10 ft.		12 ft.		14 ft.		16 ft		18 ft.		20 ft.		22 ft.
Size of Block	Whole	Whole	Half	Whole	Half	Whole	Half	Whole	Half	Whole	Half	Whole	Half	Whole
20 ft.	600	720	30	870	30	1020	30	1140	30	....	..	....	..	....
22 "	660	792	33	957	33	1122	33	1254	33	1419	33	....	..	....
24 "	720	864	36	1044	36	1224	36	1368	36	1548	36	1728	36	....
26 "	780	936	39	1131	39	1326	39	1482	39	1677	39	1872	39	....
28 "	840	1008	42	1218	42	1428	42	1596	42	1806	42	2016	42	2226
30 "	900	1080	45	1305	45	1530	45	1710	45	1935	45	2160	45	2385
32 "	960	1152	48	1392	48	1632	48	1824	48	2064	48	2304	48	2544
34 "	1020	1224	51	1479	51	1734	51	1938	51	2193	51	2448	51	2703
36 "	1080	1296	54	1566	54	1836	54	2052	54	2322	54	2592	54	2862
38 "	1140	1368	57	1653	57	1938	57	2166	57	2451	57	2736	57	3021
40 "	1200	1440	60	1740	60	2040	60	2280	60	2580	60	2880	60	3180
42 "	....	1512	63	1827	63	2142	63	2394	63	2709	63	3024	63	3339
44 "	....	....	..	1914	66	2244	66	2508	66	2838	66	3168	66	3498
46 "	....	....	..	....	..	2346	69	2622	69	2967	69	3312	69	3657
48 "	....	....	..	....	..	....	..	2736	72	3096	72	3456	72	3816
50 "	....	....	..	....	..	....	..	....	..	3225	75	3600	75	3975

TABLE CIII

Size and Spacing of Vertical Reinforcement for Monolithic Silos

Height of Silo in Feet	For Silos 10' to 13' Inside Diameter: Spacing in Inches for ½" Mild Steel Bars and Number of Bars Used	For Silos 10' to 13': Spacing in Inches and Number of Strands Used for Different Gauges of Steel Wire — Gauge No. 000	Gauge No. 2	Gauge No. 5	Gauge No. 8	For Silos 14' to 17' Inside Diameter: Spacing in Inches for ½" Mild Steel Bars and Number of Bars Used	For Silos 14' to 17': Spacing in Inches and Number of Strands Used for Different Gauges of Steel Wire — Gauge No. 000	Gauge No. 2	Gauge No. 5	Gauge No. 8	For Silos 18' to 20' Inside Diameter: Spacing in Inches for ½" Mild Steel Bars and Number of Bars Used	For Silos 18' to 20': Spacing in Inches and Number of Strands Used for Different Gauges of Steel Wire — Gauge No. 000	Gauge No. 2	Gauge No. 5	Gauge No. 8
25' and under	1-30"	1-36"	1-19"	3-36"	3-22"	....	....	....	....	....	....	....	....	....	....
25' to 30'	1-19"	1-24"	2-25"	3-23"	6-28"	1-25"	1-30"	2-23"	3-31"	6-36"	....	....	....	....	....
30' to 35'	2-26"	1-16"	3-36"	6-32"	9-29"	1-15"	1-24"	2-24"	3-22"	6-28"	....	....	....	....	....
35' to 40'	2-19"	2-24"	3-15"	6-23"	12-28"	2-27"	1-16"	3-26"	6-32"	9-30"	1-17"	1-21"	2-22"	3-21"	6-36"

TABLE CIV

Size and Spacing of Horizontal Reinforcement Around Monolithic Silos

Distance in Feet Measured from Top of Silo	For Silos 10' to 13' Inside Diameter: Spacing in Inches for ½" Mild Steel Bars and Number of Bars Used	For Silos 10' to 13': Spacing in Inches and Number of Strands Used for Different Gauges of Steel Wire — Gauge No. 000	Gauge No. 2	Gauge No. 5	Gauge No. 8	For Silos 14' to 17' Inside Diameter: Spacing in Inches for ½" Mild Steel Bars and Number of Bars Used	For Silos 14' to 17': Spacing in Inches and Number of Strands Used for Different Gauges of Steel Wire — Gauge No. 000	Gauge No. 2	Gauge No. 5	Gauge No. 8	For Silos 18' to 20' Inside Diameter: Spacing in Inches for ½" Mild Steel Bars and Number of Bars Used	For Silos 18' to 20': Spacing in Inches and Number of Strands Used for Different Gauges of Steel Wire — Gauge No. 000	Gauge No. 2	Gauge No. 5	Gauge No. 8
0' to 5'	1-18"	1-18"	1-18"	1-16"	1-12"	1-18"	1-18"	1-18"	1-13"	1-11"	1-18"	1-18"	1-18"	1-12"	1-9"
5' to 10'	1-18"	1-18"	1-16"	1-11"	1-7"	1-18"	1-18"	1-14"	1-9"	1-5"	1-18"	1-18"	1-12"	1-7"	2-9"
10' to 15'	1-15"	1-18"	1-12"	1-7½"	2-9"	1-14"	1-16"	1-9"	1-6"	2-7"	1-12"	1-15"	1-8"	2-9½"	3-9"
15' to 20'	1-14"	1-17"	1-9"	1-6"	3-10"	1-11"	1-12"	1-7"	2-8½"	3-8"	1-9"	1-11	1-6"	2-7½"	3-6½"
20' to 25'	1-11"	1-14"	1-7"	2-9"	3-8"	1-9"	1-10"	1-5½"	2-7"	3-6"	1-7"	1-9"	1-4½"	3-8½"	3-5½"
25' to 30'	1-9"	1-11"	1-6"	2-7½"	3-7"	1-7"	1-8"	1-4½"	2-5½"	3-5"	1-6"	1-7"	1-4"	3-7½"	3-4½"
30' to 35'	1-8"	1-10"	1-5"	2-6½"	3-6"	1-6"	1-7"	1-4"	3-7½"	3-4½"	1-5"	1-6"	1-3½"	3-6"	3-4"
35' to 40'	1-7"	1-8"	1-4½"	2-5½"	3-5"	1-5"	1-6"	1-3½"	3-6½"	3-4"	1-4½"	1-5"	1-3"	3-5½"	3-3½"

TABLE CV

Horizontal Reinforcement for Block Silos

Showing size of wire or steel rod to be used between successive courses of blocks 8 inches high

Feet from top of silo	DIAMETER OF SILO						
	8 ft.	10 ft.	12 ft.	14 ft.	16 ft.	18 ft.	20 ft.
0—4	No. 6	No. 6	No. 6	No. 6	No. 6	[illegible] inch	[illegible] inch
4—8	No. 6	No. 6	No. 6	No. 6	No. 6	[illegible] inch	[illegible] inch
8—12	No. 6	No. 6	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch
12—16	No. 6	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch
16—20	No. 6	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch
20—24	No 6	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch
24—28	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch
28—32	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch
32—36	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch
36—40	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch
40—44	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] ichn	[illegible] inch	[illegible] inch	[illegible] inch
44—48	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch
48—50	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch	[illegible] inch

The wire gauges indicated in Tables CIII and CIV are those of the American Steel & Wire Company.

TABLE CVI

Dimensions and Capacities of Silos

Number of Cows in Herd	Feed for 180 Days				Feed for 240 Days			
	Estimated Tonnage of Silage Consumed	Size of Silo: Diameter	Size of Silo: Height	Corn Acreage Required at 15 Tons to Acre	Estimated Tonnage of Silage Consumed	Size of Silo: Diameter	Size of Silo: Height	Corn Acreage Required at 15 Tons to Acre
	Tons	Feet	Feet	Acres	Tons	Feet	Feet	Acres
10	36	10	25	$2\frac{2}{5}$	48	10	31	$3\frac{1}{5}$
12	43	10	28	3	57	10	35	4
15	54	11	29	4	72	11	36	5
20	72	12	32	5	96	12	39	$6\frac{2}{5}$
25	90	13	33	6	120	13	40	8
30	108	14	34	$7\frac{1}{5}$	144	15	37	10
35	126	15	34	$8\frac{2}{5}$	168	16	38	11
40	144	16	35	10	192	17	39	13
45	162	16	37	11	216	18	39	$14\frac{2}{5}$
50	180	17	37	12	240	19	39	16
60	216	18	39	$14\frac{2}{5}$	288	20	40	19
70	252	19	40	17	336	—	—	—

Masonry Construction

STONE MASONRY

Measurement of Masonry. There are no universally adopted rules for measuring stone masonry, and the custom in each locality must be ascertained before bidding upon or measuring up work of this kind. The most satisfactory manner of measuring stone is by the **cubic yard.** To find the number of cubic yards contained in a wall or pile of stone, measure the length, height, and thickness of the wall or pile, obtaining all three **dimensions in feet and fractions of a foot.** Multiply these three quantities together, and divide the product by 27, the number of cu. ft. contained in 1 cu. yd. Suppose, for example, the measurements to be: Length, 92 ft.; height, 13 ft. 6 in. ($13\frac{1}{2}$ ft.); thickness, 16 in. ($1\frac{1}{3}$ ft.). Then we have: $92 \times 13\frac{1}{2} \times 1\frac{1}{3} \div 27 = 61\frac{1}{3}$ cu. yds.

The **cord,** or 128 cubic feet, is sometimes used, but has no advantage over the cubic yard as a unit of measurement.

The **perch,** which is also used as a measure of stone or stonework, is often misleading, on account of the varying value of a perch in different localities. This value may range all the way from $16\frac{1}{2}$ to 25 cu. ft., depending upon the custom in the particular locality.

It is easier to build a straight, plain wall than one containing corners or curves; and for this reason the number of cu. ft. in a wall is not an exact index of the worth of such work. One way of allowing for such extra work is to count the openings for windows and doors as solid, thus adding to the actual number of cu. ft. in the wall. Another rule sometimes adopted is to take out the openings, and add 1 cu. ft. for each linear foot of corners to be finished, including the vertical sides of windows and doors.

For example, let Fig. 36 represent the plan and elevation of the front of a small building to be measured. According to the first rule, the volume is:

$$(8+25) \times 12 \times 1\tfrac{1}{2} = 594 \text{ cu. ft.}$$

By the second rule, it is:

$$594 - (4+18+48) \times 1\tfrac{1}{2} + 12 \times 6 + 32 = 593 \text{ cu. ft.}$$

If the extras for the corners be counted 18 in. thick, the result will be 52 cu. ft. more, or 645 cu. ft.

If the corners are in foundations under ground, they are usually left so rough that no allowance is made for building them.

Usually openings not wider than twice the thickness of the wall are measured as solid; and some allowance is agreed upon as extra to be added for building corners, curves, or other unusual work.

It is seen from the above example, that as much as ten per cent of the total volume may depend upon the method adopted in the measurement. Accordingly, care should be taken that all parties concerned are, from the first, acquainted with the practice to be adopted.

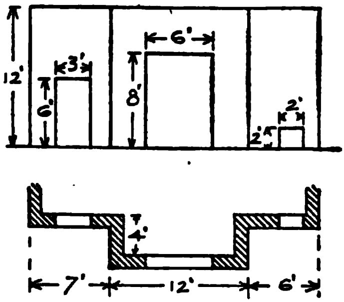

Fig. 36. Measuring Masonry in a Small Building.

Cost of Stone. The cost of stone is subject to so many changes and to so many local conditions, that nothing more than a very general statement can be made concerning it.

A large part of the total cost of stone as used in building, is the expense incurred in **cutting** the stone. Within the past few years, the following prices for sawing stone have been quoted: Sandstone, 8 to 10 cents; limestone, 15 to 18 cents; marble and granite, 25 to 35 cents—all per sq. ft. It costs nearly $5.00 to quarry a cu. yd. of granite, split to three dimensions. If split in random sizes, the cost is perhaps $4.00. Granite broken out by very heavy blasts, to be afterwards used in this form or to be split into regular shapes, is sometimes quarried as cheaply as 50 cents or less per cu. yd. Bedford limestone costs from $1.50 up per cu. ft., ready for the wall.

The cost of **rough stone** for use in bridges and foundation work ranges from $2.75 to $3.00 per cu. yd. **Ashlar** is about the same price; but **coping stone** varies from $3.00 to $3.50 per cu. yd. **Cut ashlar** varies from $3.25 to $4.00, while **cut coping** is worth from $4.00 to $4.75 per cu. yd.

In the Eastern States a fair estimate for **granite** may be taken as follows:

Blocks 3 ft. square and under, $1.50 per cu. ft.

Over 3 ft. up to 3 ft. 6 in., $1.70.

From 3 ft. 6 in. up to 4 ft., $1.90.

Flagstones are estimated as costing between 20 and 70 cents per sq. ft. of top surface.

Rough backing stone for bridge and foundation work costs from $2.00 to $2.50 per cu. yd.; while **cut backing** for cut coping and ashlar work costs from $2.60 to $3.25 per cu. yd.

Cost of Stonework. For rough work, such as foundations, common **rubble stone** is estimated at about 10 to 12 cents per cu. ft. out of the wall, and about 20 to 24 cents per cu. ft., including mortar and labor, laid in the wall. The lower

TABLE CVII

Cost of Various Kinds of Stonework

Random rubble, per cu. ft.	30 to 36c
Coursed rubble, per cu. ft.	56 to 60c
Coursed rock face, per sq. ft. of face	75c
Cost of setting ashlar, per sq. ft. of face	20c
Jamb stone and faced openings, per sq. ft.	75c
Backing, per cu. ft.	20 to 25c
Curbing (4"x24" granite), per linear foot	50c
Flagstone,	
2 in. x 3 ft. x 5 ft., per sq. ft.	13c
3 in. x 3 ft. x 5 ft., per sq. ft.	15c
4 in. x 5 ft. x 5 ft., per sq. ft.	35c
5 in. x 8 ft. x 10 ft., per sq. ft.	70c
Door sills, 8 in. x 12 in., clean cut, per linear foot	$1.40
Window sills, 4 in. x 8 in., clean cut, per linear foot.	55c
Window sills, 5 in. x 8 in., clean cut, per linear foot.	75c
Window sills, 5 in. x 12 in., clean cut, per linear foot.	90c
Water-table, 8 in. x 12 in., per linear foot	$1.45
Coping, 3 in. x 18 in., rock face, per linear foot	40c
Coping, 4 in. x 21 in., rock face, per linear foot	60c
Coping, 4 in. x 21 in., clean cut, per linear foot	$1.30
Lintels, 4 in. x 10 in., clean cut, per linear foot	75c
Lintels, 8 in. x 12 in., per linear foot	$1.25

price applies to walls 18 in. and over in thickness; while the higher price is for 12 to 16-in. walls. Double-faced walls may even run as high as 36 cents per cu. ft.

The above prices are only for rough work. Work laid in courses and nicely faced will cost more, but varies in price with the locality.

One man with a helper will lay from 90 to 150 cu. ft. of stone in a ten-hour working day, depending on the class of work.

As a guide to the probable cost of different types of stonework in place, Table CVII may be used with a fair degree of correctness.

For bluestone **door-sills**, 8x12 in., clean cut, allow $1.25 per linear foot. For **window-sills** 5x12 in., clean cut, allow 85 cents per linear foot; while 4x8 and 5x8 cost about 50 and 70 cents per linear foot respectively.

Clean cut bluestone **lintels** cost about 65 cents per linear foot for the 4x10-in. size; while the 8x12-in. size costs about $1.20 per linear foot.

Water-table, clean cut, is estimated at about $1.30 per linear foot.

The prices for bluestone **coping** are about as follows:

4x21-in., clean cut, $1.20 per linear foot.

4x21-in., rock-face edges and top, 50 cents per linear foot.

3x15-in., rock-face edges and top, 30 cents per linear foot.

3x18-in., rock-face edges and top, 35 cents per linear foot.

These prices are for cut bluestone only, but may be used as an approximate basis for comparison of the costs of other stone. This comparison will have to be left to the judgment and experience of the contractor, as it involves quantities which vary not only with each piece of work but with the locality.

The cost of **setting the stonework used** must be added to the above prices, and may be fairly estimated as 10 cents per linear foot for water-tables and ground work such as steps, and at about 6 cents per linear foot for window-sills and work of a similar nature.

In speaking of the work of stonecutters, the Building Trades Pocket-Book states that a stonecutter can cut about 6 sq. ft. of granite per day, 8 sq. ft. of bluestone, and about 10 sq. ft. of Ohio sandstone or Indiana limestone. These figures are for 8-cut patent-hammered work.

For rock-face ashlar, beds worked 3 in. from face, a workman can dress from 25 to 28 sq. ft. of random ashlar per day, and from 18 to 20 sq. ft. of coursed ashlar.

In figuring cut stone, allow about 25 per cent for waste.

The cost of dressing limestone, with a bush hammer or tooth chisel, is about 25 cents per sq. ft. of dressed surface.

The cost of fine-pointing the beds and the joints of sandstone is about 13 cents per sq. ft., where ½-in. joints are to be laid. In one instance the cost of cutting sandstone to ½-in. joints for work on bridge piers, was $2.65 per cu. yd.

The cost of cutting granite for beds and joints is stated to be about 33 cents per sq. ft. of surface; pean-hammered, 50 cents per sq. ft.; plain face, from 65 cents to $1.10, depending upon whether 6-cut or 12-cut.

For setting coursed ashlar, allow from 35 to 50 sq. ft. per day for a mason and helper.

One man will cut from 1 to 2 sq. ft. per day on cornice work, measuring length and girth.

An average workman will carve about 1 sq. ft. of surface per day on average work, after the stone has been surfaced.

On cobblestone work with recessed joints and two finished surfaces, one mason and helper will lay about ½ cu. yd. in one day.

On work above reach, one man should be allowed for each eight workmen for putting up scaffolding.

Mortar for Masonry. Table CVIII indicates the amount of cement mortar required for laying one cu. yd. of masonry of various kinds.

The manner of using Tables CVIII and CIX is shown in the following problem: How many barrels of Portland cement and cu. yds. of sand will be required for laying 100 cu. yds. of rubble masonry in 1:3 cement mortar?

From Table CVIII it is seen that the minimum amount of mortar needed per cu. yd. of masonry is .33 cu. yd. In Table CIX it is seen that 1 cu. yd. of 1:3 cement mortar requires 2 bbls. of cement and .9 cu. yd. of sand. Therefore, .33 cu. yd. of mortar would require about ⅔ of a barrel of cement and .3 cu. yd. of sand. Multiplying these quantities by 100, since there are 100 cu. yds. of masonry to be laid, the result is 67 bbls. of cement and 33 cu. yds. of sand.

Amount of Water. Allow 50 to 60 gallons of water per cu. yd. of stonework.

TABLE CVIII

Amount of Mortar Required for a Cubic Yard of Masonry

Kind of Masonry	Mortar, Cu. Yd.	
	Minimum	Maximum
Ashlar, 12 in. courses, 1/4 in. joints	.06	.08
Ashlar, 18 in. courses, 1/4 in. joints	.03	.04
Ashlar, 12-to 20 in. courses, 3/8 to 1/2 in. joints	.07	.08
Ashlar, 20 to 32 in. courses, 1/4 to 3/8 in. joints	.05	.06
Brickwork (bricks of standard size, 8 1/4x4x2 1/4 in.), 1/8 in. joints	.10	.15
1/4 to 3/8 in. joints	.25	.35
1/2 to 5/8 in. joints	.35	.40
Concrete, clean stone, without gravel or screenings	.50	.55
Rubble, course, not dressed	.33	.40
Rubble, roughly dressed	.25	.30
Squared-stone masonry, 12 in. courses and 3/4 in. joints	.20	.25
Squared-stone masonry, 18 in. courses and 3/4 in. joints	.12	.15

TABLE CIX

Quantities of Materials per Cubic Yard of Cement Mortar

Proportions		Materials		
Cement	Sand	Barrels Portland	Cement (Packed) Western	Sand, Cubic Yard
1	0	7.1	6.4	.0
1	1	4.2	3.7	.6
1	2	2.8	2.6	.8
1	3	2.0	1.8	.9
1	4	1.7	1.5	.95
1	5	1.3	1.1	.97
1	6	1.2	1.0	.98

TABLE CX
Safe Bearing Loads on Masonry

Material		Pounds per Square Inch of Area
Granite	Cap stone	700
	Squared stonework	350
Sandstone	Cap stone	350
	Squared stonework	175
	Rubble stonework, lime mortar	80
	Rubble stonework, cement mortar	150
Limestone	Cap stone	500
	Squared stonework	250
	Rubble stonework, lime mortar	80
	Rubble stonework, cement mortar	150

BRICK CONSTRUCTION
Classification of Brick

Bricks are classified (1) according to the manner of molding; (2) according to the place they occupy in the kiln during burning; and (3) according to their shape or the use to which they are to be put.

(1) When distinguished according to the manner of molding, bricks are named:

Soft-mud brick, made of very wet mud;

Stiff-mud brick, made of mud with less water;

Dry-pressed brick, made of clay containing 4 to 6 per cent. of moisture;

Re-pressed brick, made by re-forming partially dried brick made of soft mud, or brick made of stiff mud; mostly applied to the stiff-mud product.

(2) In the old-style kilns the bricks were not all burned alike. Those adjacent to the fire were over-done; those farthest away from the fire were under-done; and only the intermediate portion were satisfactory. This condition led to the adoption of the names:

Arch-brick, or those forming the top of the firing-place of the kiln.

Soft or salmon brick, or those named from the lack of color or hardness.

Body brick, or those taken from the middle of the kiln.

Mercantile brick are brick well burned, but not graded as to color or degree of hardness.

Hard kiln-run brick are meant to be all suitable for outside work.

In the kilns of modern design, the heat is well distributed throughout the whole mass, and the above terms are not now so appropriate as formerly.

(3) The form and the use for which the brick are intended, make the following terms suitable:

Face brick, or those of best appearance as to uniformity of color and dimension, and thus suitable for outside walls. The term is especially used to designate pressed or repressed brick.

Ornamental brick are nearly always made by the dry-press process; and this is the name given to all brick differing from the standard shape.

Compass brick, or those having one edge shorter than the other. They are used in building curves on which the length of the brick is a part of the circumference.

Feather-edge brick, or **Voussoir brick,** those similar to compass brick, but having one edge thinner than the other. They, also, are used in building arches.

Paving brick, or **vitrified blocks,** usually larger than ordinary bricks, used in paving streets.

Sidewalk brick are extra hard-burned brick from good clay, or small paving brick.

Sewer brick, or common brick of better grades, so regular in form as to be suitable for building sewers. They must also be low in absorption.

TABLE CXI

Thickness of Brick Walls, Chicago Building Ordinance, for Residences, Tenements, Hotels, and Office Buildings

(Thickness given in inches)

Number of Stories	Basement	Stories											
		1st	2d	3d	4th	5th	6th	7th	8th	9th	10th	11th	12th
Basement and One-Story	12	8											
" " Two-Story	12	12	8										
" " Three-Story	16	12	12	8									
" " Four-Story	20	16	16	12	12								
" " Five-Story	20	16	16	16	12	12							
" " Six-Story	20	20	16	16	16	12	12						
" " Seven-Story	24	24	20	20	16	16	12	12					
" " Eight-Story	24	24	24	20	20	16	16	12	12				
" " Nine-Story	28	24	24	20	20	20	16	16	12	12			
" " Ten-Story	28	24	24	24	20	20	20	16	16	12	12		
" " Eleven-Story	28	28	24	24	24	20	20	20	16	16	12	12	
" " Twelve-Story	32	28	28	24	24	24	20	20	20	16	16	12	12

Brick Building Construction

Table CXI indicates the required thickness of brick walls in the different stories of residences, tenements, hotels, and office buildings, according to the Building Ordinances of the City of Chicago, Ill.

Table CXIII gives a summary of requirements of the Building Ordinances of various cities in the United States, as to the thickness of brick walls for mercantile buildings and public stables, and (except in Chicago) for all buildings over five stories in height.

Table CXII may be taken as a guide to the proper thickness, at the different stories, for residence walls of varying height and length.

TABLE CXII

Number of Stories of Different Thicknesses in Residence Walls of Various Heights and Lengths

Height of Wall	Length of Wall	Number of Stories of Different Thickness					
		28 in.*	24 in.*	20 in.*	16 in.*	12 in.*	8 in.*
Feet	Feet						
100	45	......	......	2	3	Remainder	......
	80	......	2	2	2	"	......
	Over 80	1	2	2	2	"	......
90	45	......	......	2	2	"	......
	70	......	1	2	2	"	......
	Over 70	1	2	1	2	"	......
80	40	......	......	1	2	"	......
	60	......	......	2	2	"	......
	Over 60	......	1	2	2	"	......
70	40	......	......	......	2	"	......
	55	......	......	1	2	"	......
	Over 55	......	1	2	1	"	......
60	30	......	......	......	1	"	......
	50	......	......	......	2	"	......
	Over 50	......	......	1	2	"	......
50	30	......	......	......	......	Below top story	Top story
	45	......	......	......	1	"	"
	Over 45	......	......	1	1	Remainder	......
40	35	......	......	......	......	Below upper two stories	Upper stories
	Over 35	......	......	......	1	Below top story	Top story
30	35	......	......	......	......	Below upper two stories	Upper stories
	Over 35	......	......	......	......	Below top story	Top story
25	30	......	......	......	......	......	All
	Over 30	......	......	......	......	Below top story	Top story

*See statement on page 375 as to the method of considering thickness of building walls.

TABLE CXIII

Thickness of Brick Walls for Mercantile Buildings and Public Stables, and, except in Chicago, for All Buildings over Five Stories in Height

(Thickness given in inches)

Height of Building	Stories 1st	2d	3d	4th	5th	6th	7th	8th
Two Stories								
Boston	16	12						
New York	12	12						
Chicago	12	12						
Minneapolis	12	12						
St. Louis	18	13						
Denver	13	13						
San Francisco	17	13						
New Orleans	13	13						
Three Stories								
Boston	20	16	16					
New York	16	16	12					
Chicago	16	12	12					
Minneapolis	16	12	12					
St. Louis	18	18	13					
Denver	17	17	13					
San Francisco	17	17	13					
New Orleans	13	13	13					
Four Stories								
Boston	20	16	16	16				
New York	16	16	16	12				
Chicago	20	16	16	12				
Minneapolis	16	16	12	12				
St. Louis	22	18	18	13				
Denver	21	17	17	13				
San Francisco	17	17	17	13				
New Orleans	18	18	13	18				
Five Stories								
Boston	20	20	20	20	16			
New York	20	16	16	16	16			
Chicago	20	20	16	16	16			
Minneapolis	20	16	16	12	12			
St. Louis	22	22	18	18	13			
Denver	21	21	17	17	13			
San Francisco	21	17	17	17	13			
New Orleans	13	13	18	13	13			
Six Stories								
Boston	24	20	20	20	20	16		
New York	24	20	20	20	16	16		
Chicago	20	20	20	16	16	16		
Minneapolis	20	20	18	16	16	12		
St. Louis	26	22	22	18	18	13		
Denver	26	21	21	17	17	13		
San Francisco	21	21	17	17	17	13		
New Orleans	22	13	18	18	13	13		
Seven Stories								
Boston	24	20	20	20	20	20	16	
New York	28	24	24	20	20	16	16	
Chicago	20	20	20	20	16	16	16	
Minneapolis	20	20	20	16	16	16	12	
St. Louis	26	26	22	22	18	18	13	
Denver	26	21	21	21	17	17	17	
New Orleans	22	22	18	18	18	18	13	
Eight Stories								
Boston	28	24	20	20	26	20	20	16
New York	32	28	24	24	20	20	16	16
Chicago	24	24	20	20	20	16	16	16
Minneapolis	24	20	20	20	16	16	16	12
St. Louis	30	26	26	22	22	18	18	18
Denver	30	26	21	21	21	17	17	13
New Orleans	22	22	22	18	18	18	13	18

TABLE CXIII—(Concluded)

Height of Building	Stories											
	1st	2d	3d	4th	5th	6th	7th	8th	9th	10th	11th	12th
Nine Stories												
Boston	28	24	24	20	20	20	20	20	16			
New York	32	32	28	24	24	20	20	16	16			
Chicago	24	24	24	20	20	20	16	16	16			
Minneapolis	24	24	20	20	20	16	16	16	12			
St. Louis	30	30	26	26	22	22	18	18	18			
Denver	30	26	26	21	21	21	17	17	17			
Ten Stories												
Boston	28	28	24	24	20	20	20	20	20	16		
New York	36	32	32	28	24	24	20	20	16	16		
Chicago	28	28	24	24	24	20	20	20	16	16		
Minneapolis	24	24	24	20	20	20	16	16	16	12		
St. Louis	34	30	30	26	26	22	22	18	18	18		
Denver	30	30	30	26	21	21	21	17	17	17		
Eleven Stories												
Boston	36	32	32	28	28	24	20	20	20	20	16	
New York	36	36	32	28	28	24	24	20	20	16	16	
Chicago	28	28	24	24	24	20	20	20	16	16	16	
St. Louis	34	34	30	30	26	26	22	22	18	18	18	
Denver	30	30	26	26	26	21	21	21	17	17	17	
Twelve Stories												
Boston	36	36	32	32	28	28	24	20	20	20	20	16
New York	40	36	36	32	32	28	24	24	20	20	16	16
Chicago	28	28	28	24	24	24	20	20	20	16	16	16
St. Louis	34	34	34	30	30	26	26	22	22	18	18	18
Denver	30	30	30	26	26	26	21	21	21	17	17	17

Sizes and Weights of Building Bricks. On account of the variation in different localities, there is no standard size of brick. In the **New England States**, the size of a brick is about 7¾ by 3¾ by 2¼ in., while in the **Western States** the common size is about 8⅛ by 4⅛ by 2 in. The western brick give wall thicknesses of about 9, 13, 18, and 22 in. for thicknesses of 1, 1½, 2, and 2½-in. bricks. A **hard-burned** brick, or one which was located near the arch of the kiln in which the bricks were burned, will generally be from ⅛ to 3/16 in. smaller than one of the softer (or **salmon**) bricks of the outer layers in the kiln.

Pressed bricks, or bricks which are intended for use in face work of buildings or in prominent places, are generally more uniform in size, the most common size being 8⅜ by 4⅛ by 2⅜ in. A form of pressed brick called a **Roman brick** is 12 by 4 by 1½ in.

The sizes adopted by the National Brickmakers' Association in 1899 were as follows:

Common brick	8¼x4 x2¼ in.
Face brick	8⅜x4 x2⅜ in.
Paving brick	8½x4 x2½ in.
Roman brick	12 x4 x1½ in.
Fire-clay brick	9 x4½x2½ in.

The sizes of enameled brick vary from the English size of 9x4½x3 in. to the size of the standard American brick.

All bricks should be sorted into different thicknesses for first-class work.

The weight of brick varies with the make and size. A common brick will weigh from 4 to 4½ pounds, while pressed brick weigh from 5 to 5½ pounds. Paving bricks weigh from 6 to 7 pounds each; and fire-clay bricks, about 7 pounds each.

The weight of brickwork per cu. ft. varies both with the quality of brick and with the thickness of mortar joints. A fair average value for common bricks laid in lime mortar is about 120 pounds per cu. ft. When laid in cement mortar, 1 cu. ft. of common brickwork weighs about 130 pounds. Paving brick weigh about 160 pounds per cu. ft.

Some authorities consider that 112 pounds per cu. ft. is plenty to allow for the weight of brickwork; and it is often stated upon that basis, that the weights of brickwork per sq. ft. of wall surface for different thicknesses of wall are as given on page 403. The terms "9-inch wall," "13-inch wall," etc., may be used in some localities as 8-inch wall, 12-inch wall, etc., figuring the wall thickness as if made up of whole bricks and half-bricks.

Safe Bearing Loads on Brickwork

In laying brickwork, the lower bricks are subjected to the weight of all brickwork above the lower courses, together with weights of roof, floors, etc., and should be figured to see if their strength is sufficient to carry these pressures. Common brick in lime mortar will hold about 100 lbs. per sq. in:; when laid in cement mortar, about 200 lbs. per sq. in. Hard-burnt and paving bricks laid in cement mortar will hold about 200 to 250 lbs. per sq. in.

Strength of Brick Piers. The results shown in Table CXIV indicate that both the strength of the individual bricks and that of the mortar are factors in the strength of columns. As it is the weakest part that fails, it is evident economy to have the strength of the various parts nearly the same.

Labor in Laying Brickwork

Since the price of labor and the length of working day vary so greatly in different parts of the country, no attempt will be made to give absolute prices for labor in laying brickwork. Instead of actual figures, there will be given the number of bricks that an average workman should be able

TABLE CXIV

Summary of Tests of Brick Columns
(Average values)

Reference	Characteristics of Columns	Average Unit-Load (Lbs. per Sq. In.)	Ratio of Strength of Column to Strength of Brick	Crushing Strength of 6-in. Mortar Cubes (Lbs. per Sq. In.)	Ratio of Strength of Column to Strength of Cubes
	SHALE BUILDING BRICK				
A	Well laid, 1:3 Portland cement mortar 67 days..	3,365	.51	*2,870	1.17
B	Well laid, 1:3 Portland cement mortar 6 months	3,950	.37	....	....
C	Well laid, 1:3 Portland cement mortar eccentrically loaded, 68 days.....	2,800	.26	....	....
D	Poorly laid, 1:3 Portland cement mortar, 67 days..	2,920	.27	*2,870	1.66
E	Well laid, 1:5 Portland cement mortar, 65 days..	2,225	.21	1,710	1.30
F	Well laid, 1:3 Natural cement mortar, 67 days..	1,750	.16	305	5.75
G	Well laid, 1:2 Lime mortar, 66 days..........	1,450	.14	....	....
	UNBURNED CLAY BRICK				
	Well laid, 1:3 Portland cement mortar, 63 days..	1,060	.27	*2,870	.37

*Average value based on 13 tests of 1:3 Portland cement mortar cubes 60 days old.

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to lay in a given length of time on a stated class of work. Knowing local rates of wages and hours in a working day, the contractor should be able to judge with a fair degree of correctness as to the probable cost of the work in hand.

In wall construction, there are generally allowed from 1 to 1½ laborers for each brick mason. These men provide the mason with all necessary material, and leave it in a place convenient for use. The wages of these laboring men, added to the wages of the brick masons, and divided by the number of thousand brick laid in the wall in a day, would give the cost of laying per thousand.

The following list of different types of work, indicating the actual number of bricks that can fairly be expected to be laid per day by the average workman, will be of service in estimating. An average man will lay:

1,200 bricks in plain wall in 8-hour day.
2,000 bricks in heavy work in 8-hour day.
1,800 bricks in arches in 9-hour day.
3,500 bricks in sewers in 8-hour day.
7,000 bricks in pavements in 10-hour day.
600 bricks in small chimneys in 9-hour day.
450 bricks in pressed work in 8-hour day.
400 bricks in veneer work in 8-hour day.

One man will mix mortar by hand for five bricklayers.

In brick veneer work, one man and helper will lay about 600 common brick per day, or from 300 to 400 pressed brick. In the case of **molded or fancy brickwork,** one man and his helper will lay from 100 to 200 bricks per day, depending on the design of the work.

In fireplace work, one mason and his helper will lay up about 2 ft. per day in case of average-size fireplace built of plain pressed brick. This time includes placing of firebrick backing. An average hearth will take about ½ day, while a tile hearth requires about 1¼ days. Double time is needed in case of a fancy brick fireplace.

Cost of Brickwork

Although attention has been called to the fact that the cost of bricks and brickwork will vary in different localities, the following prices may be used for rough estimates:

Brick, common, $6.00 to $10.00 per cu. yd. Cost of lime mortar per cu. yd. of brickwork, about 60 cents; of cement mortar, $1.00 to $2.00.

On the basis of $7.25 per thousand for red brick, $2.50 per barrel for cement, $1.25 per barrel for lime, $1.25 per cubic yard for sand, assuming a mason at 65 cents per hour, with help at 37½ cents per hour, to lay 1,200 bricks in 8 hours, a brick wall 13 in. thick will cost about 40 cents per superficial foot. With pressed brick face, the cost will be about 50 cents per superficial foot.

For close figuring, the methods given below in detail should be followed:

Measurement of Brickwork

It is customary to estimate brickwork by the thousand brick contained in the wall. As many parts are not open to inspection, it is clearly not possible to determine the number by actual count, and recourse must be had to measurement.

The methods of measuring brickwork in walls and in construction work vary with different contractors and in different parts of the country. Many use a rough rule of measuring around the walls, multiplying this measurement by the height, and then multiplying by the number of bricks contained in a square foot of wall of the thickness to be used. They make no allowance for windows, doors, or openings of any kind, of an area less than about 80 sq. ft., since they claim that the labor necessary around such openings will offset the saving in the bricks that are not used.

As a means of compensating for this seemingly large estimate on the amount of brickwork, some contractors do not allow extras for arches, pilasters, etc.

If deductions are made for openings larger than 80 square feet, contractors using the above method generally measure the width as 2 ft. less than the actual width. A rule among some contractors is to figure all walls as solid, and then make an allowance for mortar.

Another method in common use—and one which seems to be a little more rational and conservative, while not claiming to be exact—is to measure the actual wall surface, deducting all openings over 2 feet square, measuring the corners only once for brick walls, and then multiplying by 7½ for a 4-in. wall; by 15 for an 8 or 9-in. wall; by 22½ for a 12 or 13-in. wall; by 30 for a 16 or 18-in. wall; by 38 for a 20-in. wall; and by 45 for a 24-in. wall. The results of such a procedure will give the approximate number of "eastern" brick in the wall. Deduct about 1/5 the number if "western" brick are used. Table CXV may be used to advantage in figuring by this method.

In the Western States the terms **wall measure** and **kiln count** are often heard. "Wall measure" is simply a common trade rule and is not exact. Amounts of brickwork are calculated by the arbitrary rule of 22½ bricks per sq. ft. of wall surface for a 12-in. wall just referred to and as shown in Table CXV. This method is often insisted upon by workmen as the basis for computing labor in laying brickwork. Contractors often use this method of estimating number of bricks in figuring cost of brickwork, and then do not figure for cost of mortar; allowing the extra number of bricks figured over the number actually needed for the wall, to take the place of the cost of the mortar and possibly a part of the labor. If bricks were ordered by this rule, there would be a greater number than needed for the work.

TABLE CXV

Number of Common Bricks Required for Walls of Different Thicknesses

Surface Area of Wall	Number of Bricks Needed for Thickness of					
(Square Feet)	4 Inches	8 Inches	12 Inches	16 Inches	20 Inches	24 Inches
1	7	15	23	30	38	45
2	15	30	45	60	75	90
3	23	45	68	90	113	135
4	30	60	90	120	150	180
5	38	75	113	150	188	225
6	45	90	135	180	225	270
7	53	105	158	210	263	315
8	60	120	180	240	300	360
9	68	135	203	270	338	405
10	75	150	225	300	375	450
20	150	300	450	600	750	900
30	225	450	675	900	1,125	1,350
40	300	600	900	1,200	1,500	1,800
50	375	750	1,125	1,500	1,875	2,250
60	450	900	1,350	1,800	2,250	2,700
70	525	1,050	1,575	2,100	2,625	3,150
80	600	1,200	1,800	2,400	3,000	3,600
90	675	1,350	2,025	2,700	3,375	4,050
100	750	1,500	2,250	3,000	3,750	4,500
200	1,500	3,000	4,500	6,000	7,500	9,000
300	2,250	4,500	6,750	9,000	11,250	13,500
400	3,000	6,000	9,000	12,000	15,000	18,000
500	3,750	7,500	11,250	15,000	18,750	22,500
600	4,500	9,000	13,500	18,000	22,500	27,000
700	5,250	10,500	15,750	21,000	26,250	31,500
800	6,000	12,000	18,000	24,000	30,000	36,000
900	6,750	13,500	20,250	27,000	33,750	40,500
1,000	7,500	15,000	22,500	30,000	37,500	45,000

"Kiln count" means the actual number of bricks needed for the work, or the number to be purchased. If kiln count is used, mortar will have to be figured separately, as no allowance is made. The size of brick should always be specified in figuring. For standard bricks, 8¼x4x2¼ in., 17 is the number usually estimated as occupying 1 sq. ft. of 12-in. wall when joints are thick, that is, between ⅜ and ½-in., or 18 when ¼-in. joints are used.

Sometimes the actual wall contents are measured in cubic yards of volume, and the following plan used. For common brick 8¼x4x2¼ in. in size, allow 500 bricks to a cu. yd. of wall when ⅜-in. mortar joints are used. In work where thin joints are used—as, for example, in fronts, where a ⅛-in. joint may be used—it is better to figure on about 580 bricks for a cu. yd. of wall.

When asking for bids on work, it is well to specify just how the measurement of the quantity shall be made; and the following rule is often recommended as fair and tending to prevent controversy:

Divide the total number of superficial feet of wall surface of a given thickness by 160, and multiply the result by the number of brick widths the wall is thick. The result will be the number of thousand of brick contained.

This rule is based on the fact that a 4-in. wall contains about 1,000 brick to 160 superficial feet, if the joints be ¼ in. thick.

For example, a 12-in. wall 40 ft. long and 20 ft. high would contain (40×20÷160)×3=15 thousand bricks.

While the above rule gives the number of brick to be purchased for the wall, another arbitrary rule for the payment of the masons is sometimes adopted:

Count 7½ bricks for each superficial foot of wall for each half-brick (half-length of brick) thickness of wall.

In the same example as above, this would give 40×20×7½×3=18 thousand bricks as a basis of payment for the labor.

The allowance for openings is not a uniform practice, but may be fairly well established by custom in any given city. These customs must be consulted in letting or computing such work.

Hollow walls are generally figured as solid.

Arches are figured from the spring; and pillars or columns may be figured as a wall of length equal to the width and height of the pillar, and of thickness equal to the third dimension of same.

When stonework, such as sills, caps, etc., is set by the brickmason, no deduction is made for same in figuring brickwork for walls. The same conditions apply to ashlar work when placed by the bricklayers.

An allowance of 5 or 6 per cent should be made on all figured amounts of brickwork to make up for loss and breakage. A common rule in fancy bricklaying is to add 50 per cent to the figured number of bricks, or allow 1½ bricks for each one actually estimated.

A method of measuring footings together with walls, is to add the width of the projections of the footing on each side of the wall to the height of the wall, and figure as indicated above for an ordinary wall.

TABLE CXVI

Number of Bricks Required in Brick Piers

(Standard Size of Brick, 8¼×4×2¼ Inches)

Size of Pier (Inches)	Number of Bricks per Foot of Height	Size of Pier (Inches)	Number of Bricks per Foot of Height	Size of Pier (Inches)	Number of Bricks per Foot of Height
8¼x 8½	9	22 x22	62	35 x52½	238
8¼x13	14	22 x26½	75	39½x39½	200
8¼x17½	19	22 x30½	86	39½x44	224
8¼x22	23	22 x35	100	39½x48	244
		22 x39½	112	39½x52½	268
13 x13	22			39½x57	290
13 x17½	29	26½x26½	90		
13 x22	37	26½x30½	104	44 x44	250
13 x26½	45	26½x35	120	44 x48	270
		26½x39½	134	44 x52½	296
17½x17½	40	26½x44	150	44 x57	320
17½x22	50			44 x61	345
17½x26½	60	30½x30½	120		
17½x30½	69	30½x35	138	48 x48	296
17½x35	79	30½x39½	154	48 x52½	324
		30½x44	172	48 x57	350
		30½x48	188	48 x61	376
		35 x35	158	48 x65½	400
		35 x39½	178		
		35 x44	198		
		35 x48	218		

If using western brick, size, 8½x4⅛x2½ in., deduct 1/5 from the number of brick indicated in Table CXVI.

In figuring the number of bricks needed for piers of considerable size, and where the bulk of the mortar used in the joints will prove a considerable factor, it would be safer to figure the cubic contents of the pier in cu. ft., and divide by 27 to reduce to cu. yds. Then apply the rule of 500 bricks to a cu. yd. as already given.

Measurement of Old Brick. Old brick, uncleaned and rough from the building and dumped in a pile, will average about 9 bricks to the cu. ft., or about 111 cu. ft. to the thousand brick. If stacked on the outside, and the interior of the stack filled promiscuously, they will average about 11 bricks to the cu. ft., or about 91 cu. ft. to the thousand brick.

If cleaned and closely stacked, an average will be about 17 bricks to the cu. ft., or about 59 cu. ft. to the thousand brick. If the bricks are cleaned and stacked on the outside, but the interior of the pile filled promiscuously, an average will be about 13 bricks to the cu. ft., or about 77 cu. ft. to the thousand bricks.

Mortar for Brickwork

After the number of bricks which are to be laid is estimated, the amount of materials needed for mortar may be found from Table CXVII and from the statements given below. The amount of sand, lime, or cement depends on the richness of the mortar and the thickness of the joints.

Table CXVII gives the necessary amount of sand and cement to lay 1,000 bricks with joints about ⅜ inch thick.

TABLE CXVII
Mixing Table for Mortar for Laying 1,000 Bricks

Mortar	Lime Barrels	Cement Barrels	Sand Cubic Yards
Lime 1	1		
Sand 3			0.5
Portland Cement................ 1		1.5	
Sand 3			0.5
Natural Cement................. 1		1.5	
Sand 3			0.5
Portland Cement................ 1	1		
Lime 1		1	
Sand 3			0.5

Stated otherwise, a cu. yd. of brick masonry with ½-in. joints requires rather more than ⅓ cu. yd. of mortar. If the joints are ¼ in. thick, ¼ cu. yd. of mortar will be sufficient to lay a cu. yd. of brickwork. When joints are only ⅛ in. thick, ⅛ cu. yd. of mortar will be required to a cu. yd. of brickwork.

A barrel of lime will make 2¼ barrels (or .3 cu. yd.) of lime paste. A barrel of this paste, with 3 barrels of sand, will make 3 barrels of lime mortar. A barrel of unslaked lime is sufficient for 6¾ barrels of 1:3 mortar.

If laid in 1:2 cement mortar with ⅜-in. joints, 1,000 brick will require about 1⅛ barrels of cement and 2⅜ barrels of sand. With ¼-in. joints, 1,000 brick will require about 1 barrel of cement and 2 barrels of sand.

If laid in 1:3 cement mortar, with ⅜-in. joints, 1,000 bricks will require about 1 1/9 barrels of cement and 3⅛ barrels of sand. With ¼-in. joints, 1,000 bricks will require about ¾ of a barrel of cement and 2¼ barrels of sand.

The cost will vary with the prices of above materials in different localities.

Colors for Lime Mortar. Mortar colors generally are purchased in the form of dry powders. These powders are mixed first wtih the dry sand; then the cold slaked lime or putty is added, and the mass thoroughly mixed again. Hot lime should not be used when mixing colors.

When spread joints are used, 1,000 brick will require about 50 pounds of red, brown, or buff coloring, or about 45 pounds of black. If buttered joints are used, 1,000 brick will require about 40 pounds of red, brown, or buff, or about 35 pounds of black coloring material.

Where colored mortar is to be used, the amount of coloring will depend somewhat on the shade required, and it is advisable to estimate on about 50 pounds per 1,000 brick. The coloring material, sand, and lime should all be carefully measured, so as to keep the same proportions throughout the entire work.

With the cost of the coloring materials and the extra work of mixing and measuring, it is estimated that colored mortar on small jobs will cost from $3.00 to $4.00 extra per 1,000 bricks.

Colored Cement Mortar. Table LXXXIV gives quantities of coloring material needed for Portland cement mortar.

Number of Brick in a Wall

Table CXV will be of service in determining the number of common bricks 8¼x4x2¼ in. in size which are needed for walls of ordinary thickness.

For example, suppose that we wish to find from the table the number of bricks in a wall 125 ft. long, 15 ft. high, and 12 in. thick. This wall contains 125×15=1,875 square feet.

For 1,000 sq. ft. of 12-in. wall, the table gives....22,500 brick
For 800 sq. ft.....................................18,000 brick
For 70 sq. ft....................................... 1,575 brick
For 5 sq. ft.. 113 brick

Total 1,875 sq. ft. requires total of.........42,188 brick

This same method can be applied to any size of wall, by simply breaking up the total number of sq. ft. in the wall into parts which are given in the table, and then adding these parts for the final result. This final result is in what is called "wall measure," and not actual number of brick.

It should be noticed, in using this table, that the thicknesses of wall are given in multiples of 4 inches, or the width of one brick. By adding the thickness for mortar joints, it can be readily seen what column so-called 13-in. walls, 17½-in. walls, etc., will fall under.

For actual number, or "kiln count," multiply this number by 17, and divide by 22½.

Short Method of Estimating Brick for Footings. When "standard" size brick 8¼x4x2¼ in., are used in footings with offsets of 2 ins. for each course used, Table CXVIII, based upon the calculation here shown, may be used.

TABLE CXVIII
Number of Common Bricks in Footings

Thickness of Wall (Inches)	Number of Courses Used in Footing	Number of Bricks per Foot of Length in Footing
8	2	10½
12	3	22½
16	4	38
20	5	60
24	6	85½

Fig. 37 shows an 8-in. wall resting upon a footing consisting of 2 courses of brick laid with offsets of 2 in. There are 3½ bricks shown when looking at the end of this footing. If we stood around on the side of the footing, we should see the ends of 3 bricks 4 in. wide for each foot length of side of footing. Multiplying the number of bricks shown in the end view, by the number shown per foot of length in the side view, we have: 3½×3=10½ bricks per foot length of footing.

With other thicknesses of wall, thicker footings are needed; but the same plan for finding number of bricks per foot length of footing may be used.

For sizes of brick other than that on which Table CXVIII is based, the figures there given will be varied to some extent.

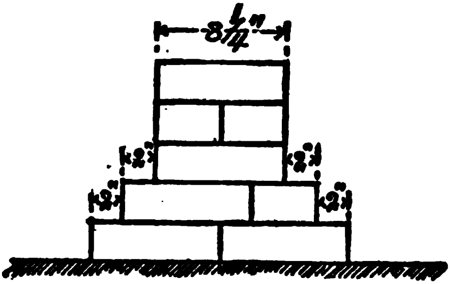


Fig. 37. Brick Footing with 2-Inch Offsets.

Bricks Required for a Chimney

If it is desired to obtain a fairly close estimate as to the number of bricks necessary for a plain chimney, one of the methods described below may be used.

If it is figured that 5 courses of brick laid in a chimney will make 1 ft. of height, taking into account the thickness of the mortar joints, and that 5 bricks in a course will make a flue 4×8 in., then 5×5=25 bricks would be necessary for 1 ft. of height of a chimney with a 4x8-in. flue.

For a flue 8x8 in., 6 bricks would be needed in each course, or 30 bricks for 1 ft. of height.

For a flue 8x12 in., 7 bricks would be needed in each course, or 35 bricks for 1 ft. of height.

For a flue 12x12 in., 8 bricks would be needed in each course, or 40 bricks for 1 ft. of height.

By remembering the size of a common brick, and with the aid of a sketch of the cross-section of the flue desired, no matter whether it is a single, double, or triple-flue chimney, the above method of figuring the number of brick needed for any chimney, square or oblong in section, may be used. The method of procedure consists in finding the number of bricks necessary to enclose the area desired, and then multiplying by 5 to get the number of bricks per foot of height of chimney.

For example, suppose it is desired to find the number of bricks needed for a plain chimney 25 ft. high and having 2 flues 8x8 in., and 1 flue 8x12 in.

Lay out a diagram like Fig. 38, and we find that 15 brick are needed for a course. Then, 15×5=75 brick needed per foot of height of chimney, figuring 5 courses of brickwork per foot of length. And, 75×25=1,875 brick, the approximate total number needed for the chimney.

If fancy designs are used, a special allowance must be made for the same, depending wholly upon the design desired.

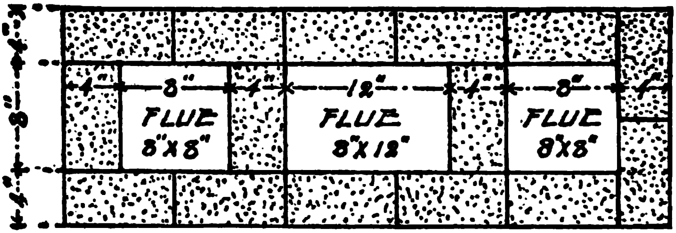


Fig. 38. Section of Brick Chimney with Three Flues.

A simple method of figuring for single flues is as follows:

Find the number of cu. ft. in the chimney by multiplying the area (in sq. ft.) of cross-section of the chimney considered as solid, by the height in feet; and subtract the contents of the flues as indicated in the following:

For an 8-in. flue, subtract one-half the length of the flue in feet.

For a 12-in. flue, subtract the length of the flue in feet.

For an 18-in. flue, subtract 2¼ times the length of the flue in feet.

For a 24-in. flue, subtract 4 times the length of the flue in feet.

Multiply this answer by 22½, and the result will be the number of bricks required.

Table CXIX gives sizes and weights of common sizes of flue-linings.

Fire-clay stove thimbles may be obtained in sizes varying from 4 to 12 in. in diameter, and from 4½ to 12 in. in length. These thimbles are made ¼-in. larger than measure, to receive stovepipe.

Table CXX shows sizes of chimney flues for different sizes of buildings.

Square tile for flue linings are sized and listed commercially from outside dimensions; round tile, from inside dimensions.

TABLE CXIX

Approximate Weights, Dimensions, etc., of Fire-Clay Flue-Linings

Square or Round Corners
(In two-foot lengths)

Outside Measure	Weight per Foot	Outside Measure	Weight per Foot
4½x 8½ in.	14 lbs.	8½x13 in.	28 lbs.
4½x13 in.	20 lbs.	8½x18 in.	45 lbs.
4½x18 in.	40 lbs.	13 x13 in.	38 lbs.
7½x 7½ in.	15 lbs.	13 x18 in.	57 lbs.
8½x 8½ in.	18 lbs.	18 x18 in.	75 lbs.

Round Flues
(Without Sockets)

Inside Measure	Weight per Foot	Inside Measure	Weight per Foot
6 in.	15 lbs.	20 in.	87½ lbs.
7 in.	17½ lbs.	21 in.	....
8 in.	20 lbs.	22 in.	....
9 in.	25 lbs.	24 in.	125 lbs.
10 in.	27½ lbs.	27 in.	....
12 in.	32½ lbs.	30 in.	220 lbs.
15 in.	55 lbs.	33 in.	....
18 in.	70 lbs.	36 in.	....

TABLE CXX

Sizes of Flues for Buildings of Various Sizes

Capacity of Building (Cubic Feet)	Brick	Tile, Square (Outside Dimensions)	Tile, Round (Inside Dimensions)
Up to 20,000	8x12 in.	8½x13 in.	10 in.
20,000 to 40,000	12x12 in.	13 x13 in.	12 in.
40,000 to 70,000	12x16 in.	13 x18 in.	15 in.
70,000 to 100,000	16x16 in.	18 x18 in.	18 in.
100,000 to 150,000	16x24 in.	....	......
150,000 to 250,000	24x24 in.	....	......

Table CXXI, compiled by Edward Richmond Pierce, indicates the approximate sizes of chimney-flues for steam and hot-water heating in residences and other buildings.

TABLE CXXI

Approximate Sizes of Chimney Flues for Steam and Hot-Water Heating in Residences and Other Buildings

Direct Radiation†		Size of Flue	
Steam (Sq. Ft.)	Water (Sq. Ft.)	Round	Square
250	400	8 in. diam.	8 x 8
300	500	8 in. diam.	8 x 8
400	700	8 in. diam,	8 x 8
500	850	10 in. diam.	8 x 12
600	1,000	10 in. diam.	8 x 12
700	1,200	10 in. diam.	8 x 12
800	1,350	12 in. diam.	12 x 12
900	1,500	12 in. diam.	12 x 12
1,000	1,700	12 in. diam.	12 x 12
1,200	2,100	12 in. diam.	12 x 12
1,400	2,400	14 in. diam.	12 x 16
1,600	2,700	14 in. diam.	12 x 16
1,800	3,000	14 in. diam.	12 x 16
2,000	3,400	14 in. diam.	12 x 16
2,200	3,700	16 in. diam.	16 x 16
3,000	5,100	16 in. diam.	16 x 16
3,500	5,900	18 in. diam.	16 x 20
5,000	8,500	18 in. diam.	16 x 20

†Note—When a considerable amount of "indirect" radiation is to be used, increased boiler capacity is necessary; and in many cases such demands require a larger chimney-flue for the same number of square feet of radiation used.

HOW TO ESTIMATE BRICKWORK FOR A RESIDENCE

Figs. 39 to 43 show elevations and plans of a substantial modern brick dwelling-house of 7 rooms, with bath, reception hall, and basement. We shall now endeavor to show the method of procedure to be followed in estimating the number of bricks needed for this house.

Two methods of figuring will be given—first, the wall measure, or number of bricks on which estimate of cost is figured, in which connection Table CXV is used; and second, the kiln count, or actual number of bricks bought and used, figured on a basis of 17 bricks to the cu. ft. when laid in wall. If the rule of 500 to the cu. yd. is used, a little larger number of bricks will be needed. If pressed brick is figured, with thin joints in surface work, 17 bricks to the cu. ft. will be a little low. The rule of 580 to the cu. yd. or 20 to the cu. ft. will be nearer.

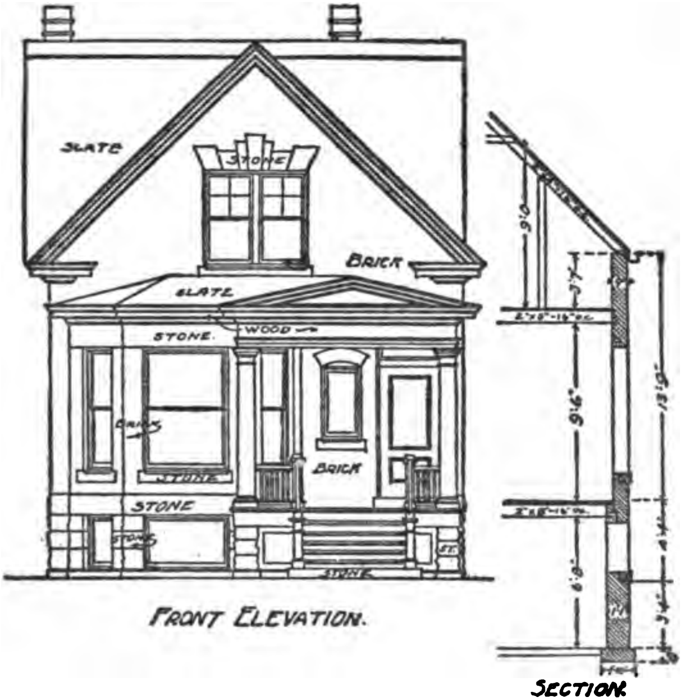


Fig. 39. Estimating for a Brick House.

We shall divide the work into parts:

1. All brickwork below top of the first-floor joists;
2. Brickwork above top of first-floor joists;
3. Chimneys;
4. Deduct all openings of over 2 sq. ft., and all stonework.

Brickwork below Top of First-Floor Joists

Footing. The length around the foundation wall is about

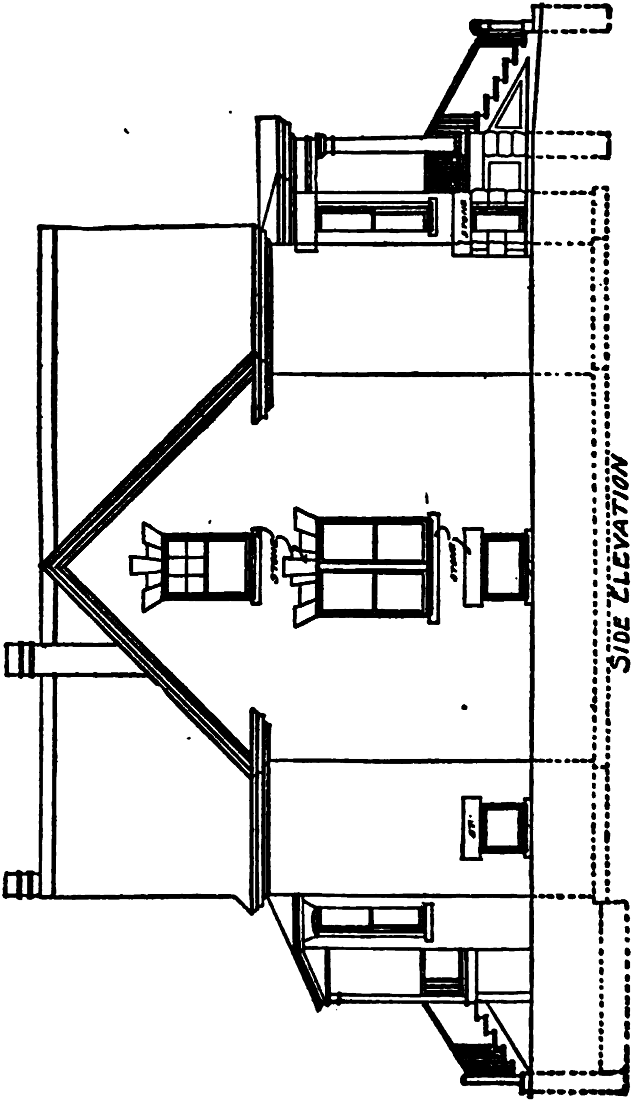


Fig. 40. Estimating for a Brick House.

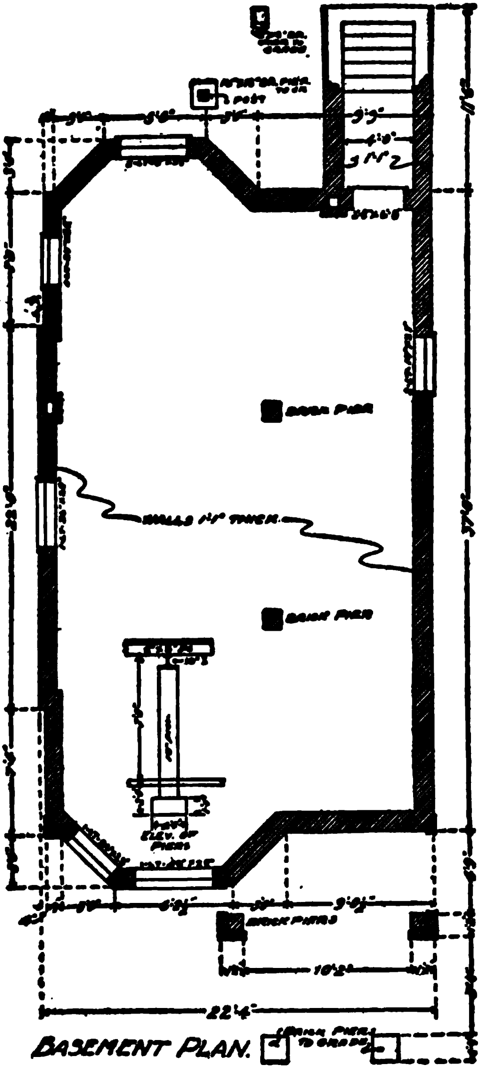


Fig. 41. Estimating for a Brick House.

121 ft. Thickness of footings, 8 in., or ⅔ ft.; width, 1 ft. 10 in., or 22 in. Then we have:

121×⅔=81 sq. ft. of wall surface in footings.

This will be figured under the 20-in. column in Table CXV since it is 5 bricks thick, with ½ in. allowed for each of 4 joints.

From table for 20-in. wall,

80 sq. ft.=3,000 bricks
1 sq. ft.= 38 bricks

For footings, 3,038 bricks

Basement Wall. Wall is 13-in. thick, and 7½ ft. high to top of first-floor joists. Length around wall is 121 ft.

121×7½=908 sq. ft. of wall surface in basement.

From table for 12-in. wall,

900 sq. ft.=20,250 bricks
8 sq. ft.= 180 bricks

Total for basement, 20,430 bricks

Deducting the following window space, allowing 8 in. additional width to windows, and 10 in. additional depth for size of frame opening:

1 space 36"x38"=1,368 sq. in.
1 space 54"x38"=2,052 sq. in.
2 spaces 32"x38"=2,432 sq. in.
1 space 44"x38"=1,672 sq. in.
1 space 40"x38"=1,520 sq. in.

Total, 9,044 sq. in..

Dividing this by 144, the numoer of sq. in. in a sq. ft.:

$$\frac{9,044}{144} = 63 \text{ sq. ft. of 12-in. wall,}$$

which from the table is equivalent to 1,418 bricks.

Also, deducting for basement door,

3 ft. × 7 ft.=21 sq. ft.

and 21 sq. ft. of wall surface of 12-in. wall. from the table, is equivalent to 473 bricks.

Total number of bricks to deduct is:

1,418+473=1,891.

Thus we have:

20,430—1,891=18,539 bricks needed in basement wall.

Area-Way Walls. Two walls 11½ ft. long by 6 ft. high and 13 in. thick.

2×11½×6=138 sq. ft. of wall surface.

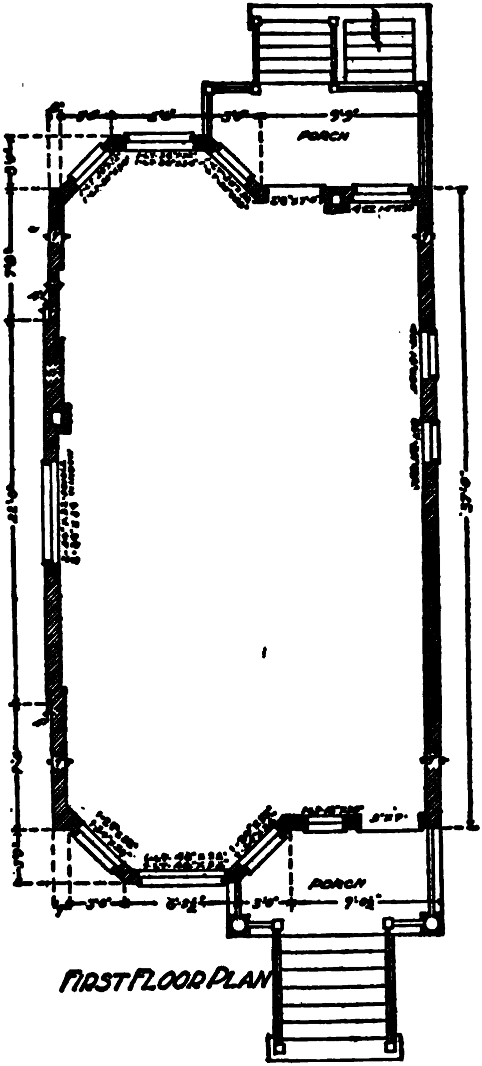


Fig. 42. Estimating for a Brick House.

From table for 12-in. wall,

100 sq. ft.=2,250 bricks
30 sq. ft.= 675 bricks
8 sq. ft.= 180 bricks

Total, 3,105 bricks in area-way walls.

Piers. The following piers are called for by the plans:

2 16-in. square brick piers at front, 7 ft. high.
2 16-in. square brick piers at front, 4 ft. high.
2 13-in. square brick piers in cellar, 7⅓ ft. high.
1 16-in. square brick pier at rear, 4 ft. high.
1 8x12-in. brick pier at rear, 4 ft. high.

Figuring these as walls either 12 or 16 in. thick as the case may be, we have:

7'×1⅓'×2=19 sq. ft. of wall surface in 2 piers, 16 in thick.

From table for 16-in. wall,

10 sq. ft.=300 bricks
9 sq. ft.=270 bricks

Total, 570 bricks

Also,

4'×1⅓'×2=11 sq. ft. of wall surface in 2 piers, 16 in. thick.

From table for 16-inch wall,

10 sq. ft.=300 bricks
1 sq. ft.= 30 bricks

Total, 330 bricks

Also,

7⅓'×1'×2=15 sq. ft. of wall surface in 2 piers, 12 in. thick.

From table fo: 12-in. wall,

10 sq. ft.=225 bricks
5 sq. ft.=113 bricks

Total, 338 bricks

Also,

4'×1⅓'=5½ sq. ft. (nearly) of wall surface 16 in. thick.

From table for 16-in. wall,

5 sq. ft.=150 bricks
½ sq. ft.= 15 bricks

Total, 165 bricks

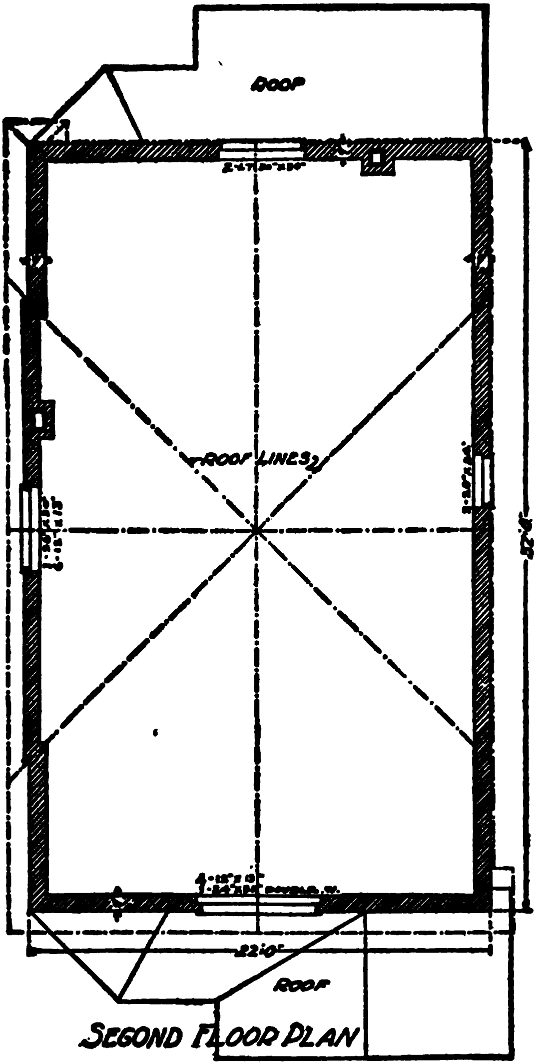


Fig. 43. Estimating for a Brick House.

For the 8x12-in. pier, figure it as a wall 12 in. thick, ft. high, and $\frac{2}{3}$ ft. long:

$4' \times \frac{2}{3}' = 3$ sq. ft. (nearly) of wall surface 12 in. thick. From table for 12-in. wall,

3 sq. ft.=68 bricks.

Adding together the various totals for the piers, we have:

Total number of bricks in piers=570+330+338+165+68= 1,471 bricks.

For total number of bricks in footings, basement walls, area-way walls, and piers, we have:

3,038+18,539+3,105+1,471=26,153 bricks.

This is wall measure, and not actual number of bricks.

If the actual number of bricks is desired, we should proceed as follows:

Find the actual cubic contents of all brickwork, and multiply the result by 17—that is, by the number of bricks contained in a cu. ft. of wall with ordinary mortar joints.

The cubic contents will be figured as follows:

Footings—

$121' \times \frac{2}{3}' \times 1\frac{2}{3}' = 133$ cu. ft.

Walls—

$121' \times 7\frac{1}{2}' \times 1' = 908$ cu. ft.

Subtracting $(63+21) \times 1 = 84$ cu. ft. for door and windows, we have:

908—84=824 cu. ft.

Area-Way—

$11\frac{1}{2}' \times 6' \times 1' \times 2 = 138$ cu. ft.

Front Piers—

$7' \times 1\frac{1}{3}' \times 1\frac{1}{3}' \times 2 = 25$ cu. ft.

$4' \times 1\frac{1}{3}' \times 1\frac{1}{3}' \times 2 = 14$ cu. ft.

Basement Piers—

$7\frac{1}{2}' \times 1' \times 1' \times 2 = 15$ cu. ft.

16-Inch Pier at Rear—

$4' \times 1\frac{1}{3}' \times 1\frac{1}{3}' = 7$ cu. ft.

8x12-Inch Pier at Rear—

$4' \times 1' \times \frac{2}{3}' = 2\frac{2}{3}$, or 3 cu. ft.

Total cubic contents,

133+824+138+25+14+15+7+3=1,159 cu. ft.

Allowing 17 bricks to the cubic foot, we have:

$1{,}159 \times 17 = 19{,}703$ bricks

as the actual number of bricks needed below the first floor.

If we wish to check up the wall measure, which was

26,153, by applying the rule of $22\frac{1}{2}$ bricks per cu. ft. of wall, we find:

$$1{,}159 \times 22\tfrac{1}{2} = 26{,}078 \text{ bricks,}$$

which is very close to the figure found by the use of Table CXV.

Bricks in Walls from Top of First-Floor Joists to Roof

Since the method of procedure has now been outlined, we shall go directly to the house plans for our dimensions in each case, and proceed with less detail.

Side Walls—

$$37 \text{ ft.} \times 13\tfrac{3}{4} \text{ ft.} = 509 \text{ sq. ft.}$$

From table for 8-inch wall,

500 sq. ft. = 7,500 bricks
9 sq. ft. = 135 bricks

Total, 7,635 bricks

Multiplying this by 2 for 2 walls, we have:

$$2 \times 7{,}635 = 15{,}270 \text{ bricks.}$$

Add for gables on sides:

$$22' \times 11' \times \tfrac{1}{2} = 121 \text{ sq. ft.}$$

(Area of a triangle is equal to one-half the product obtained by multiplying the length of base by the height.)

From table for 8-inch wall,

100 sq. ft. = 1,500 bricks
20 sq. ft. = 300 bricks
1 sq. ft. = 15 bricks

Total, 1,815 bricks

Multiplying this by 2 for 2 gables,

$$1{,}815 \times 2 = 3{,}630 \text{ bricks}$$

Then,

$$15{,}270 + 3{,}630 = 18{,}900 \text{ bricks.}$$

Deducting openings in walls, making same allowance as before,

1 space 36″×58″ = 2,088 sq. in.
2 spaces 28″×58″ = 3,248 sq. in.
1 space 66″×76″ = 5,016 sq. in.
1 space 44″×62″ = 2,728 sq. in.

Total, 13,080 sq. in.

$$\frac{13{,}080}{144} = 91 \text{ sq. ft. of wall surface.}$$

From table for 8-inch wall,

90 sq. ft.=1,350 bricks
1 sq. ft.= 15 bricks

Total, 1,365 bricks

Deducting 1,365 from 18,900, we have:

18,900—1,365=17,535 bricks.

This is wall measure for the side walls of building.

For the front and rear end walls, the figuring will be done as follows:

End Walls—Front—

Deduct thickness of side walls, which has already been figured in in getting number of bricks in side walls.

20½'×13¾'=282 sq. ft.

with gable,

½×22'×11'=121 sq. ft.

403 sq. ft.

Deducting front bay window opening in wall,

12'×10'=120 sq. ft.

283 sq. ft.

Deducting also front door opening,

3⅓'×7⅓'= 25 sq. ft.

258 sq. ft.

1 space, 24×40"= 960 sq. in.
1 space, 66"×62"=4,092 sq. in.

5,052 sq. in.

$$\frac{5{,}052}{144}=35 \text{ sq. ft.}$$

258—35=223 sq. ft.

Add for bricks in front bay window:

Length around front bay=14½ ft.
Height=10 ft.
14½'×10'=145 sq. ft.

Deduct window openings,

1 space 54"×76"=4,104 sq. in.
2 spaces 32"×76"=4,864 sq. in.

8,968 sq. in.

$$\frac{8{,}968}{144}=62 \text{ sq. ft.}$$

145—62=83 sq. ft. of wall surface.

Adding 223 sq. ft. of surface in front wall and 83 sq. ft. in front bay, we have:

223+83=306 sq. ft.

From table for 8-inch wall,

200 sq. ft.=3,000 bricks
100 sq. ft.=1,500 bricks
6 sq. ft.= 90 bricks

Total, 4,590 bricks

for front end wall of house.

Rear Wall—

20½′×13¾′=282 sq. ft.;

with gable,

½×22′×11′=121 sq. ft.

403 sq. ft.

Deducting rear bay window opening in wall,

11′×10′=110 sq. ft.

293 sq. ft.

Deducting also rear door,

3′×7⅓′= 22 sq. ft.

271 sq. ft.

and deducting window openings,

1 space, 36″×70″=2,520 sq. in.
1 space, 38″×70″=2,660 sq. in.

5,180 sq. in.

$$\frac{5{,}180}{144}=36 \text{ sq. ft.}$$

271—36=235 sq. ft. of wall surface.

Add for bricks in rear bay window:

Length around rear bay=14 ft.
Height= 9 ft.

14′×9′=126 sq. ft

Deduct window openings,

2 spaces, 28″×76″=4,256 sq. in.
1 space, 44″×76″=3,344 sq. in.

7,600 sq. in.

$$\frac{7{,}600}{144} = 53 \text{ sq. ft.}$$

$$126 - 53 = 73 \text{ sq. ft.}$$

Adding 235 sq. ft. of surface in rear wall, and 73 sq. ft. of surface in rear bay, gives:

$$235 + 73 = 308 \text{ sq. ft.}$$

From table for 8-inch wall,

200 sq. ft. =	3,000 bricks
100 sq. ft. =	1,500 bricks
8 sq. ft. =	120 bricks
Total,	4,620 bricks

for rear end wall of house.

Total Wall Measure above First Floor—

Sides	17,535
Front	4,590
Rear	4,620
	26,745 bricks

To determine kiln count, or actual number of bricks, we may, as before, find the actual cubic contents of the walls above the top of the first-floor joists, and then multiply by 17. Or we may multiply the above "wall measure" number, 26,745, by 17, and divide by 22½.

$$\frac{26{,}745 \times 17}{22\frac{1}{2}} = 20{,}207 \text{ bricks, "kiln count."}$$

As a matter of interest and as a check on the work, we shall go back and add up the cubic contents of the walls above the top of the first-floor joists.

From the previous work,

Side walls, sq. ft. = (509+121) × 2 =	1,260
Deducting openings, sq. ft.,	91
	1,169
Front wall, sq. ft.,	306
Rear wall, sq. ft.,	308
Total,	1,783 sq. ft.

Multiplying this wall surface by the thickness, 8 in. or ⅔ ft.,

$$1{,}783 \times \tfrac{2}{3}' = 1{,}189 \text{ cu. ft.}$$

Applying the rule of 17 bricks to the cu. ft., we have:

$$1{,}189 \times 17 = 20{,}213 \text{ bricks, "kiln count,"}$$

which checks approximately with the previous result.

Chimneys—

One chimney $33\frac{1}{2}$ ft. high., with 8x12-in. flue:

From page 385 we see that for an 8x12-in. flue 35 bricks are needed for each foot of height:

$$33\frac{1}{2} \times 35 = 1{,}173 \text{ bricks.}$$

One chimney $33\frac{1}{2}$ ft. high with 8x8-in. flue:

From page 385 we see that for an 8x8-in. flue 30 bricks are needed for each foot of height:

$$33\frac{1}{2} \times 30 = 1{,}005 \text{ bricks.}$$

Total for 2 chimneys:

$$1{,}173 + 1{,}005 = 2{,}178 \text{ bricks.}$$

If it is desired, these figures may be checked by the chimney rule given on page 386.

Adding the numbers of bricks determined from the previous calculations, we find that the following bricks are needed:

Wall Measure—

Basement and footings	26,153
Above first floor	26,745
Chimneys	2,178
	55,076

Kiln Count—

Basement and footings	19,703
Above first floor	20,207
Chimneys	2,178
	42,088

A nearer approximation may be reached by deducting the volume of the cut stone shown in the plans. The walls thus far have been figured as solid brick, with no notice taken of the stone.

Cut Stone—Front —

Piers:

$$14'' \times 4'' \times 30'' = 1{,}680 \text{ cu. in.}$$
$$9'' \times 4'' \times 30'' = 1{,}080 \text{ cu. in.}$$

Front Wall:

1 piece,	$9'' \times 4'' \times 30'' = 1{,}080$ cu. in.
1 piece,	$6'' \times 4'' \times 30'' = 720$ cu. in.
1 piece,	$6'' \times 4'' \times 30'' = 720$ cu. in.
1 piece,	$12'' \times 4'' \times 30'' = 1{,}440$ cu. in.
1 piece,	$12'' \times 4'' \times 30'' = 1{,}440$ cu. in.
1 piece,	$9'' \times 9'' \times 30'' = 2{,}430$ cu. in.
1 piece,	$75'' \times 4'' \times 12'' = 3{,}600$ cu. in.
1 piece,	$51'' \times 4'' \times 12'' = 2{,}448$ cu. in.

1 piece,	51"×4"×12"=2,448 cu. in.
1 sill,	60"×5"× 5"=1,500 cu. in.
2 sills,	39"×5"× 5"=1,950 cu. in.
1 sill,	30"×5"× 5"= 750 cu. in.
1 sill,	44"×5"×10"=2,200 cu. in.
1 sill (2d story),	72"×5"× 5"=1,800 cu. in.

1 flat arch, 72"×4"×18" (average height)=5,184 cu. in.
(Deduct stone water-table if there is one.)

Side Walls:

1 sill,	32"×5"× 5"= 800 cu. in.
1 sill,	42"×5"× 5"=1,050 cu. in.
1 sill,	36"×5"× 5"= 900 cu. in.
1 sill,	66"×5"× 5"=1,650 cu. in.
1 sill,	36"×5"× 5"= 900 cu. in.
2 sills,	28"×5"× 5"=1,400 cu. in.
1 sill,	44"×5"× 5"=1,100 cu. in.
1 flat arch,	72"×4"×18"=5,184 cu. in.
1 flat arch,	54"×4"×15"=3,240 cu. in
1 lintel,	52"×4"×12"=2,496 cu. in.
1 lintel,	42"×4"×12"=2,016 cu. in.
1 lintel,	48"×4"×12"=2,304 cu. in.

Rear Wall:

1 sill,	40"×5"×10"=2,000 cu. in.
1 sill,	38"×5"× 5"= 950 cu. in.
1 sill,	36"×5"× 5"= 900 cu. in.
2 sills,	28"×5"× 5"=1,400 cu. in.
1 sill,	44"×5"× 5"=1,100 cu. in.
1 sill,	40"×5"× 5"=1,000 cu. in.

Adding to determine the total volume of stonework, we find the result to be:

62,860 cu. in.

Dividing this by 1,728, the number of cu. in. in a cu. ft.:

$$\frac{62,860}{1,728}=36 \text{ (nearly) cu. ft.}$$

By the rule of 22½ bricks to the cu. ft., we should deduct:

$$22\frac{1}{2}\times 36=810$$

bricks from the "wall measure" of 55,076 bricks.

Or, by the rule of 17 bricks to the cu. ft., we should deduct:

$$17\times 36=612$$

bricks from the "kiln count," or actual number used, of 42,088.

This would leave the final result as follows:

Wall Measure ....54,266 bricks
Kiln count ....41,476 bricks

Allowing 5 per cent for breakage on each of the above amounts, we have:

$$54{,}266+\frac{5}{100}\times 54{,}266=56{,}979 \text{ bricks}$$

$$41{,}476+\frac{5}{100}\times 41{,}476=43{,}549 \text{ bricks}$$

These are the approximate numbers needed according to the two methods of figuring. In practice these numbers would probable be treated as 57 thousand and 44 thousand.

No attempt has been made here to separate the various kinds of brick, as the intention is to show the method of obtaining the number of standard 8¼x4x2¼-in. bricks which are needed. By applying the same methods, the number of each kind of brick in a house where several qualities are used may be found.

On large jobs of brickwork, it is often usual for the contractor to specify a minimum size for the bricks so as to guard against losses from estimating that a certain number of bricks will build a certain number of cubic feet of wall.

Thickness of mortar joints is also a quantity to be figured on in determining actual number of brick. This point was referred to on page 382.

Data Concerning Brickwork

The weight of brick walls, at 112 pounds per cubic foot, is:

9-in. wall	84	pounds per superficial foot
13 " "	121	" " " "
18 " "	168	" " " "
22 " "	205	" " " "
26 " "	243	" " " "

A load of sand or mortar is a cubic yard.

Sand weighs from 80 to 115 pounds per cubic foot, or 1 to 1½ tons per cubic yard.

A cu. yd. of mortar requires a cu. yd. of sand, and equals 30 hodfuls.

No 8-in brick wall should be over 14 ft. in height.

Flemish bond costs more to lay than plain or English bond.

The waste of brick in good material is about 2 per cent for ordinary work; in soft or salmon, as much as 5 per cent.

The space occupied by 1,000 bricks when carefully stacked, is about 56 cu. ft.

It is often estimated that a bricklayer's hod will hold about 20 bricks, or about 100 pounds weight. This type of hod is generally about 8 in. on a side, and 20 to 22 in. in length.

A mortar hod which is about 12 in. on a side, by 22 in. long, will hold about 1/30 of a cu. yd. of mortar.

Walls that are a brick-length thick are often called 9-in. walls.

A 13-in. wall is a brick-length, plus its width, plus the thickness of a mortar joint.

A 17-in. wall has a thickness equal to the length of two bricks, with the mortar joint.

Comparative Cost of Frame and Brick Construction

The question of comparative costs is one which the contractor or builder often has to face; and, unless experience has given him the desired knowledge, he is often troubled as to how to proceed in the matter. As an example, we shall show an approximate method of determining the difference in cost between an ordinary frame residence, the same size of house in brick veneer construction, and the same in solid brick.

On account of the roof, foundations, floors, windows, doors, all interior finish, etc., being practically the same in each house, we shall confine ourselves to a comparison of the costs of the walls in each form of construction.

In the brick construction, the costs of stonework such as sills and lintels will have to be added.

If stonework is used for porches in the construction of a brick house, this cost also will have to be added. These prices may be estimated from the data already given under "Cost of Stonework."

The difference in cost of plain wall construction for the three forms of construction is approximately as follows:

Frame Construction

(Per square yard of finished wall surface)

Dimension lumber, 8 ft. B. M., at 4c per ft. (in wall)....	$0.32
Sheathing, 10 ft. B. M., at 4c per ft. (in wall)..........	.40
Siding, 12 ft. B. M., at 4½c per ft. (in wall)............	.54
Building paper, put on, per yard.......................	.03
Painting, two coats, per yd............................	.18
Plastering, three coats, per yard......................	.26
Total, per sq. yd..................................	$1.73

Brick Veneer Construction

(Based on cost of face brick at $21.00 per 1,000)

Dimension lumber, 8 ft. B. M., at 4c per ft. (in wall)	$0.32
Sheathing, 10 ft. B. M., at 4c per ft. (in wall)	.40
Building paper, put on, per yd	.03
63 face brick, at 3½c each (in wall)	2.21
Plastering, three coats, per yd	.26
Total, per sq. yd	$3.22

Solid Brick Construction

(12-in. wall)

63 face brick, at 3½c each (in wall)	$2.21
126 common brick, at $14 per 1,000 (in wall)	1.76
Furring walls, per yard	.06
Plastering, three coats, per yd	.26
Total, per yd	$4.29

The above figures will give a fair idea of the comparative **wall costs.** Of course, the percentage of the total cost of these different houses will not be directly proportional to these above costs, since the latter are only a part of each total. By adding to each one of these the cost of floors, roof, interior finish, etc., divided by the total number of square yards of wall surface, we would then be in a position to give a comparative estimate on the total cost of the forms of construction. This percentage of the total cost is often figured as being 20 to 25 per cent greater for veneer construction than for the frame, and about 40 per cent greater than the frame for the solid brick construction.

BRICK CISTERNS

Table CXXII will be found of service in estimating the number of bricks required in circular brick cisterns with open tops. If an arched top is used, the number of additional bricks required may be estimated by determining the number of square feet of top of a given thickness, and then using Table CXV for walls.

In the excavation part of Table CXXII, 6 in. has been added to the outside diameter of brickwork, in order to provide plenty of room for laying bricks.

To use Table CXXII, multiply the number of bricks in column corresponding to the diameter and thickness of wall desired, by the depth of the cistern; and add the number required for the bottom. To reduce the capacity of the cistern to barrels, divide contents in gallons by 31.5.

TABLE CXXII

Number of Bricks Required for Cisterns per Foot of Height of Wall

Inside Diameter of Cistern, in Feet	Thickness of Side Walls, in Inches	Number of Bricks in Side Wall	Number of Bricks in Bottom, Laid Flat	Square Feet of Plaster on Side Walls	Square Feet of Plaster on Bottom	Contents of Cistern, in Gallons	Cubic Feet of Excavation Required
4	4	84	50	12.5	12.5	94	21
4	8	180	50	12.5	12.5	94	27
5	4	104	80	15.7	19.6	147	30
5	8	220	80	15.7	19.6	147	37
6	4	124	110	18.8	28.2	212	40
6	8	260	110	18.8	28.2	212	48
7	4	145	154	22.0	38.4	288	52
7	8	300	154	22.0	38.4	288	62
8	4	165	200	25.0	50.0	376	66
8	8	340	200	25.0	50.0	376	76
9	8	400	255	28.2	63.5	476	92
9	12	610	255	28.2	63.5	476	104
10	8	450	312	31.4	78.5	588	110
10	12	672	312	31.4	78.5	588	122
11	12	735	380	34.5	95.0	711	143
12	12	800	450	37.5	113.0	846	165
13	12	865	530	40.8	133.0	992	189
14	12	924	616	44.0	154.0	1152	216
15	12	990	705	47.0	176.0	1322	240
16	12	1050	800	50.0	200.0	1504	270

Rectangular cisterns may be figured by determining the number of sq. ft. of wall surface and the thickness of wall, then determining the number of bricks from Table CVX.

The size of a rectangular cistern for a given capacity may be found from Table CXXIV. The dimensions given are for inside measurements of cistern.

PRESSED CEMENT BRICK

Table CXXIII will be found useful in estimating the quantities and cost of materials required for the manufacture of pressed cement brick.

TABLE CXXIII
Material Required for 1,000 Pressed Cement Brick

Parts of sand to one of cement	1.	2.	3.	4.	5.	6.	7.
Cement, barrel (380 pounds net)	6.30	4.25	3.	2.5	2.	1.5	1.40
Cement, pounds	2,400.	1,610.	1,150.	910.	750.	643.	562.
Sand, cu. yd. (basis of 110 lbs. cu. ft.)	.88	1.10	1.16	1.22	1.25	1.29	1.32
Cost of materials required per 1,000 brick, at prices below for cement and sand	....	....	....	....	....	....	....
Local cost of Portland cement per barrel	....	....	....	....	....	....	....
Local cost of sand per cubic yard	....	....	....	....	....	....	....

In the above table, the cost spaces (per 1,000 brick) are left vacant so that they may be filled in by the contractor or builder for his own locality.

For example, if a 1:3 brick is desired, with cement at $1.20 per barrel, and sand at $1.00 per cubic yard, the above table shows that approximately 3 barrels of cement and 1.16 cubic yards of sand will be needed. Therefore the approximate cost per 1,000 bricks will be:

$$3 \times \$1.20 + 1.16 \times \$1.00 = \$4.76$$

FIRE BRICK

Fire brick are a special form of brick which are used in places where high temperatures are common. A common instance is in the lining of furnaces or fire-boxes under boilers, or as a backing and side walls in fireplaces. The common size for fire brick is 9x4½x2½ in.

Since the common use of fire brick is practically limited to places where they are exposed to great heat, they should be laid in a mortar made from fire clay.

Although fire clay in itself does not have the holding properties of a lime or cement mortar, and is really used to fill up irregular spaces between the fire bricks, the addition of a small amount of lime (about 1 part in 100 by volume), when

TABLE CXXIV

Capacity of Rectangular or Square Cisterns

(In U. S. gallons per foot of depth)

Width, in Feet	LENGTH, IN FEET 4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12
4	120	135	150	165	180	194	209	224	239	254	269	284	299	314	329	344	359
4½		151	168	185	202	219	236	252	269	286	303	320	337	353	370	387	404
5			187	206	224	243	262	281	299	318	337	355	374	393	411	430	449
5½				226	247	267	288	309	329	350	370	391	411	432	453	473	494
6					269	292	314	337	359	382	404	426	449	471	494	516	539
6½						316	340	365	389	413	438	462	486	511	535	560	583
7							367	393	419	445	471	497	524	550	575	602	628
7½								421	449	477	505	533	561	589	617	645	673
8									479	509	539	569	598	628	658	688	718
8½										540	572	604	636	668	700	731	762
9											606	640	673	706	741	774	808
9½												675	711	746	782	817	853
10													748	785	823	860	898
10½														825	864	903	943
11															905	946	987
11½																989	1032
12																	1077

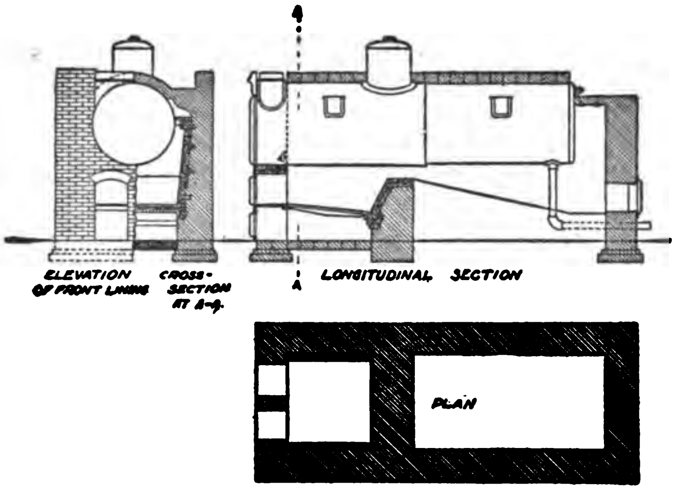


Fig. 44. Tubular Boiler in Brick Setting.

TABLE CXXV

Materials Required for Brickwork of Tubular Boilers

(Boilers with Full Front—Single Setting)

Boilers	Common Brick	Fire Brick	Sand Bushels	Cement (Bbls.)	Fire Clay Pounds	Lime (Bbls.)
30 in. x 8 ft.	5,200	320	42	5	192	2
30 in. x 10 ft.	5,800	320	46	5½	192	2¼
36 in. x 8 ft.	6,200	480	50	6	288	2½
36 in. x 9 ft.	6,600	480	53	6½	288	2¾
36 in. x 10 ft.	7,000	480	56	7	288	3
36 in. x 12 ft.	7,800	480	62	8	288	3¼
42 in. x 10 ft.	10,000	720	80	10	432	4
42 in. x 12 ft.	10,800	720	86	11	432	4¼
42 in. x 14 ft.	11,600	720	92	11¼	432	4½
42 in. x 16 ft.	12,400	720	99	12½	432	5
48 in. x 10 ft.	12,500	980	100	12½	590	5¼
48 in. x 12 ft.	13,200	980	108	13½	590	5½
48 in. x 14 ft.	14,200	980	116	14½	590	5¾
48 in. x 16 ft.	15,200	980	124	15½	590	6
54 in. x 12 ft.	13,800	1,150	108	13¾	690	5½
54 in. x 14 ft.	14,900	1,150	117	15	690	6
54 in. x 16 ft.	16,000	1,150	126	16	690	6¼
60 in. x 10 ft.	13,500	1,280	108	13½	768	5½
60 in. x 12 ft.	14,800	1,280	118	14¾	768	6
60 in. x 14 ft.	16,100	1,280	128	16	768	6½
60 in. x 16 ft.	17,400	1,280	140	17½	768	7
60 in. x 18 ft.	18,700	1,280	148	18¾	768	7½
66 in. x 16 ft.	19,700	1,400	157	19¾	840	8
66 in. x 18 ft.	21,000	1,400	168	21	840	8¼
72 in. x 16 ft.	20,800	1,550	166	20¾	930	8½
72 in. x 18 ft.	22,000	1,550	175	22	930	9

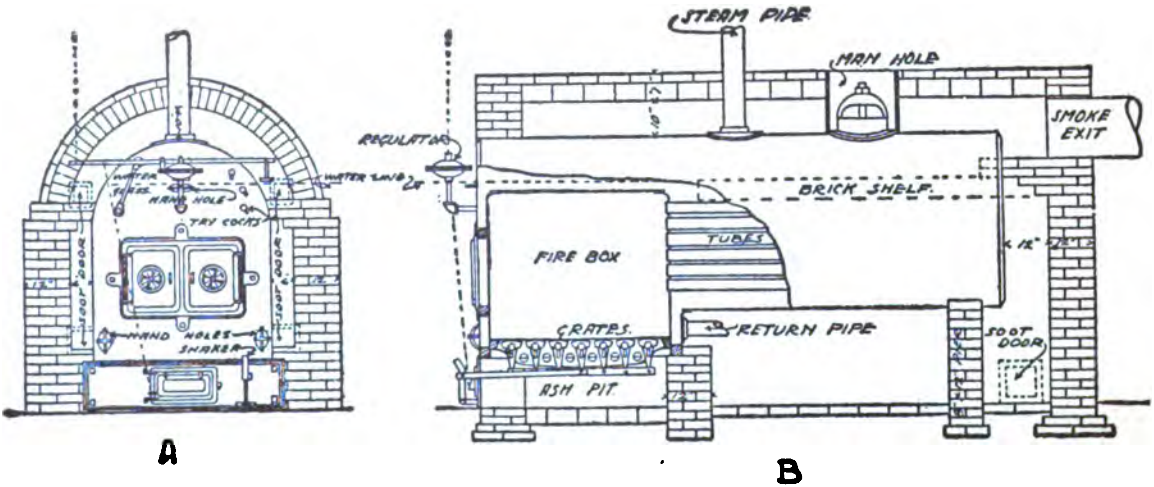


Fig. 45. Estimating Brick Setting for a Firebox Boiler.

A—Front elevation and section, showing brickwork; B—Side view, showing longitudinal section.

mixing the paste or mortar for laying the bricks, will form a vitrified bond between the bricks, thereby holding them in place. A final coat of thin fire clay is brushed onto the work, and a gentle heat applied to drive out moisture, before subjecting to high temperatures.

It is claimed that about 700 pounds of fire clay are needed for 1,000 fire brick. The cost of fire clay is approximately as follows: Dry powder, $1.50 per ton, delivered on cars; calcined fire clay, $3.00 to $4.00 per ton.

For puddle, $1.50 per cu. yd., delivered.

BOILER SETTINGS

Figs. 44 and 45 show the ordinary forms of boiler settings. That shown in Fig. 44 is for the ordinary form of tubular boiler with what is known as a full front, or a cast-iron front which extends the full width of the boiler and from the floor to the top of the brick setting.

Table CXXV gives an estimate of the materials required for various sizes of tubular boilers with full fronts.

Fig. 45 shows an ordinary form of horizontal tubular boiler, with firebox in front end. This form of boiler is used quite extensively for heating purposes.

Table CXXVI gives approximate number of brick required for 8-in. and 12-in. walls.

BRICK SEWERS

See Sewers and Conduits.

BRICK PAVING

See Roads and Pavements.

TILE WORK

Table CXXVII gives not only the shape and size of many of the common tiles, but also the number of each kind required to fill exactly one sq. ft. of space. An allowance of a small number should be made for breakage and losses.

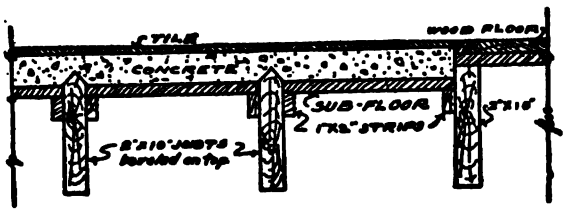


Fig. 46. Section of Tile Floor Laid on Wood Joists.

For example, if we have a section of tile wainscoating 8 ft. long and 5 ft. high, composed of oblong white tiles 6x1½

TABLE CXXVI

Number of Brick Required for Firebox Boilers (Single Setting)

Boiler	8-in. Walls	12-in. Walls
30 in. x 6½ ft.	1,650	2,400
30 in. x 7½ ft.	1,820	2,600
30 in. x 8½ ft.	1,980	2,900
36 in. x 7½ ft.	2,250	3,200
36 in. x 9 ft.	2,500	3,600
36 in. x 10½ ft.	2,880	4,000
42 in. x 8½ ft.	2,880	4,000
42 in. x 10 ft.	3,400	4,500
42 in. x 11½ ft.	3,900	5,100
48 in. x 10½ ft.	3,600	4,900
48 in. x 12 ft.	3,850	5,400
48 in. x 13½ ft.	4,200	5,800
54 in. x 14 ft.	5,200	6,900
54 in. x 16½ ft.	5,500	7,500

in. in size, and a border along the top made from blue and white triangular, or diagonal, tile 6x6 in. in size, to find the number of tiles needed for this piece of work, we proceed as follows:

The area to be covered by the oblong tiles is 8 ft. long and 4½ ft. high.

$$8 \times 4\frac{1}{2} = 36 \text{ sq. ft.}$$

There are 144 sq. in. in one sq. ft.; therefore,

$$36 \times 144 = 5{,}184 \text{ sq. in.}$$

Now, since 1 oblong tile, size 6x1½ in. contains $6 \times 1\frac{1}{2} = 9$ sq. in., the exact number of tiles needed for the part 8 ft. long below the border, is:

$$\frac{5{,}184}{9} = 576 \text{ tiles.}$$

Better make this 600, to allow for loss and breakage.

Now that we have seen the principle involved in this calculation, we shall explain the method of using Table CXXVII and see if the results check in value. From our figures above we have 36 sq. ft. below the border. This space is to be filled with 6x1½-in. tiles. From the table, the number of

TABLE CXXVII

Number of Tiles Required per Square Foot of Area to be Covered

Shape of Tile	Size in Inches	Number in Square Foot
Square	6 x 6	4
Diagonal ½	6 x 6	8
Square	4¼ x 4¼	8
Diagonal ½	4¼ x 4¼	16
Square	3 x 3	16
Diagonal ½	3 x 3	32
Square	2⅛ x 2⅛	32
Diagonal ½	2⅛ x 2⅛	64
Square	1½ x 1½	64
Diagonal ½	1½ x 1½	128
Square	1 1/16 x 1 1/16	128
Diagonal ½	1 1/16 x 1 1/16	256
Square	2 x 2	36
Square	1 x 1	144
Oblong	6 x 4	6
Oblong	6 x 3	8
Oblong	6 x 2	12
Oblong	6 x 1½	16
Oblong	6 x 1	24
Oblong	4½ x 2¼	16
Oblong	4½ x 1 1/16	32
Oblong	3 x 1½	32
Oblong	3 x 1	48
Oblong	2¼ x 1 1/16	64
Octagon	6 x 6	4½
Octagon Diagonal ½	6 x 6	9
Octagon Square ½	6 x 6	9
Octagon Square ¼	6 x 6	18
Hexagon	6 x 3	10⅔
Hexagon Long ½	6 x 3	21⅓
Hexagon Short ½	6 x 3	21⅓
Octagon	3 x 3	18
Hexagon	6 x 5 3/16	6
Hexagon Diagonal ½	6 x 5 3/16	12
Hexagon Square ½	6 x 5 3/16	12
Pentagon	5 3/16 x 2⅝	14
Octagon	4¼ x 4¼	9
Octagon Diagonal ½	4¼ x 4¼	18
Octagon Square ½	4¼ x 4¼	18
Oblong	3 x ½	96
Oblong	6 x ½	48
Hexagon	4½ x 2¼	21
Hexagon Short ½	4½ x 2¼	42
Hexagon Long ½	4½ x 2¼	42
Square	½ x ½	576
Oblong	6 x ¾	32
Hexagon	3 x 3 7/16	18
Hexagon Diagonal ½	3 x 3 7/16	36
Hexagon Square ½	3 x 3 7/16	36
Oblong	3 x ¼	192
Hexagon	2 x 2 5/16	41
Hexagon Diagonal ½	2 x 2 5/16	83
Hexagon Square ½	2 x 2 5/16	83
Oblong	9 x 3	5⅓
Oblong	6 x 4½	5⅓
Oblong	1 5/16 x ½	256
Oblong	5 x 10	2
Hexagon	2 9/16 x 2 15/16	31
Hexagon Diagonal ½	2 9/16 x 2 15/16	62
Hexagon Square ½	2 9/16 x 2 15/16	62
Hexagon	1¾ x 2	54
Hexagon Diagonal ½	1¾ x 2	108
Hexagon Square ½	1¾ x 2	108
Triangle	3	37
Half Triangle	3	74
Triangle	1 11/16	109
Half Triangle	1 11/16	219
Triangle	1 5/16	249
Half Triangle	1 5/16	298

6x1½-in. oblong tiles which are necessary to cover one sq. ft. of surface is 16. Therefore,

$$36 \times 16 = 576 \text{ tiles required.}$$

This result checks with our first figures.

For the border of diagonal tiles, we have an area 8 ft. long by ½ ft. high which is to be filled.

$$8 \times \tfrac{1}{2} = 4 \text{ sq. ft.}$$

From the table (second line from top), we find that we shall need 8 diagonal 6x6-in. tiles per sq. ft. Therefore,

$$4 \times 8 = 32 \text{ tiles required for border.}$$

Better make this 40, to allow again for loss and breakage. This would mean 20 blue and 20 white diagonal tiles.

This same principle may be used in figuring other sizes of walls, and in using other sizes of tiles.

Steel Construction

GENERAL ANALYSIS OF STEEL COSTS

An itemized review of costs in steel structural work comprises the following headings:

(a) The weights of the various standard sections used in the main members.

(b) The weights of different kinds of sections and materials used in the details of fittings, such as connection angles, separators, plates, tie-rods, etc.

(c) The costs of each of the above, taking careful note of extra charges for sizes other than base, extras for work done on the material at the mill, and extras for small quantities of a given material.

(d) Any extra shop costs in preparing material for erection.

(e) Cost of shop painting.

(f) Cost of erecting, or putting material in place in structure.

(g) Cost of finish on material.

(h) Miscellaneous costs, such as drafting room expenses, freight and haulage, traveling expenses, profit, etc.

In making up the estimate of cost of material in the main members, the sizes, lengths, and weights per foot of length may be taken directly from the general drawings, and then the cost determined as detailed under c, above.

Sizes and weights of details may be determined from the details drawings, each kind or shape of material being listed separately, and an addition of 1.55 cents made to the base price of each for each 100 pounds as referred to on page 425 under heading of "Mill Extras." Standard connections and separators for use with I-beams and channels may be purchased from the various steel companies, who issue tables giving sizes and weights to be used in figuring these products.

In estimating the cost of riveted girders or columns, the weight of the plain structural shapes and plates of which the member is made up is taken; and then an extra price per pound is added, to cover the cost of mill work, rivets, and assembling. According to Mr. Frank E. Kidder, this extra will be about as follows:

Light channel or Z-bar columns..................1½c per lb.
Heavy channel or Z-bar columns............... .1¼c per lb.
Plate girders, 24 to 48 inches deep..............1¼c per lb.
Box girders, 24 to 48 inches deep................1¼c per lb.
Box girders, 48 to 60 inches deep............1 1/10c per lb.

A list of extras to be added to the price of plain beams and channels is given on page 425. These are commonly referred to as mill extras.

COST OF STEEL STRUCTURES

In bidding on a structure, the bid may be for a lump sum to complete the work, or for so much per ton, or for so much per pound. In any case, the contractor will not directly estimate it that way himself. He will take into account and figure on the ten or twelve costs which go to make up the total, and will then transform them into the lump sum bid or the unit-price.

Raw Material and Mill Work

The raw material means the various shapes just as they come from the rolls. These vary in price in different years, and at different periods of the year. They also vary in price according to the size and kind of shape. Since these variations in price are due chiefly to the varying costs of ore and cast iron or billets, there is a certain price for various shapes called **base price**; and to this must be added the so-called **card extras** for a particular shape, in order to get the price per pound for that particular shape.

The base price will be found in standard trade papers covering the steel structural field. The card extras are issued at certain intervals by the manufacturers, and can be had for the asking. Any dealer in hardware can get you one. Sometimes one-half the card extras are to be added to the base price. For example, suppose the base price was 1.87½ cents per pound, and the card extra for 24-inch I-beams was 0.10 cent. The price for 24-inch I-beams would be 1.87½+0.10=1.97½ cents per pound.

In cutting material in the mills, a ⅜-in. variation is allowed. That is, if you order a plate 18 ft. 7½ in. long, it may come to you 18 ft. 7⅞ in. long, or 18 ft. 7⅛ in. long. So, in ordering material, it is ordered longer than the finished length, in order that it will be correct if the mills happen to cut it ⅜ inch shorter. If longer than the ordered length, it can be cut again after it reaches the shops.

No shop work will be done on angles and plates at the mills, but they will do a certain amount on I-beams and channels. The work they will do on I-beams and channels is punching the same or different-sized holes in various parts, cutting and bending, and painting and fitting connection angles on the ends. It is often cheaper to have the mills do such work as the above, and then have the material shipped directly to the site of the proposed structure, thus saving some freight and all handling at the shops.

The mills issue cards stating the cost for performing the different operations as given above. This cost is in cents per pound of beam worked upon. It costs just as much to have one hole punched in the web of a 20-in. 65-pound I-beam 30 feet long, as it would to have 1,000 holes punched. A beam such as the above weighs 65×30=1,950 pounds; and it costs 15 cents per hundred pounds, or 19.5×15=$2.93, to punch as many holes as are wanted in the web of that beam. The card showing these extras and their cost may be had by addressing any rolling mill company. The cost varies from 15 cents to $1.55 per hundred pounds, according to the amount of work done.

Cost of Material

The following prices taken from "Iron Age," July, 1913, will give an idea of the variation in the cost of steel and iron in some of their different forms as used in construction work, and also of the change in price due to size or peculiarities of manufacture. It is advisable for every contractor to obtain the card spoken of on page 416, so that he may confine himself to what are termed **base sizes** wherever possible.

Finished Iron and Steel f. o. b. Pittsburgh

Freight rates from Pittsburgh in carloads, per 100 lbs.; New York, 16c.; Philadelphia, 15c.; Boston, 18c.; Buffalo, 11c.; Cleveland, 10c.; Cincinnati, 15c.; Indianapolis, 17c.; Chicago, 18c.; St. Louis, 22½c.; Kansas City, 42½c.; Omaha, 42½c.; St. Paul, 32c.; Denver, 84½c.; New Orleans, 30c.; Birmingham, Ala., 45c.; Pacific Coast, 80c. on plates, structural shapes, and sheets No. 11 and heavier; 85c. on sheets Nos. 12 to 16; 95c. on sheets No. 16 and lighter; 65c. on wrought pipe and boiler tubes.

Structural Material. I-beams, 3 to 15 in.; channels, 3 to 15 in.; angles, 3 to 6 in. on one or both legs, ¼ in. thick and over, and zees, 3 in. and over, 1.45c. to 1.50c. Extras on other shapes and sizes are as follows:

Extras	Cents per 100 lbs.
I-beams over 15 in.	$0.10
H-beams over 18 in.	.10
Angles over 6 in. on one or both legs	.10
Angles, 3 in. on one or both legs, less than ¼ in. thick as per steel bar card, Sept. 1, 1909	.70
Tees, structural sizes (except elevator, hand rail, car-truck and conductor rail)	.05
Angles, channels and tees, under 3 in. wide, as per steel bar card, Sept. 1, 1909	.20 to .80
Deck beams and bulb angles	.30
Hand rail tees	.75
Cutting to lengths, under 3 ft., to 2 ft. inclusive	.25
Cutting to lengths, under 2 ft., to 1 ft. inclusive	.50
Cutting to lengths, under 1 ft.	1.55

No charge for cutting to lengths 3 ft. and over.

Steel Bars. Base, 1.25c. See table of extras for other sizes.

Iron Bars. Base, 1.35c. See table of extras for other sizes.

Plates. Tank plates, ¼ in. thick, 6¼ in. up to 100 in. wide, 1.45c. to 1.50c., base, net cash, 30 days. Following are stipulations prescribed by manufacturers, with extras:

Rectangular plates, tank steel or conforming to manufacturers' standard specifications for structural steel dated February 6, 1903, or equivalent, ¼ in. and over on thinnest edge, 100 in. wide and under, down to but not including 6 in. wide, are base.

Plates up to 72 in. wide, inclusive, ordered 10.2 lbs. per sq. ft., are considered ¼-in. plates. Plates over 72 in. wide must be ordered ¼ in. thick on edge, or not less than 11 lbs. per sq. ft., to take base price. Plates over 72 in. wide ordered less than 11 lbs. per sq. ft. down to the weight of 3-16 in. take the price of 3-16 in.

Allowable overweight, whether plates are ordered to gauge or weight, to be governed by the standard specifications of the Assocation of American Steel Manufacturers.

Extras	Cents per 100 lbs.
Gauges under ¼ in. to and including 3-16 in.	$0.10
Gauges under 3-16 in. to and including No. 2	.15
Gauges under No. 8 to and including No. 9	.25
Gauges under No. 9 to and including No. 10	.30

Gauges under No. 10 to and including No. 12	.40
Sketches (including straight taper plates) 3 ft. and over	.10
Complete circles, 3 ft. in diameter and over	.20
Boiler and flange steel	.10
"A. B. M. A." and ordinary firebox steel	.20
Still bottom steel	.30
Marine steel	.40
Locomotive firebox steel	.50
Widths over 100 in. up to 110 in., inclusive	.05
Widths over 110 in. up to 115 in., inclusive	.10
Widths over 115 in. up to 120 in., inclusive	.15
Widths over 120 in. up to 125 in., inclusive	.25
Widths over 125 in. up to 130 in., inclusive	.50
Widths over 130 in.	1.00
Cutting to lengths, under 3 ft., to 2 ft. inclusive	.25
Cutting to lengths, under 2 ft., to 1 ft. inclusive	.50
Cutting to lengths, under 1 ft.	1.55

No charge for cutting rectangular plates to lengths 3 ft. and over.

Sheets. Makers' prices for mill shipments on sheets of U. S. Standard gauge, in carload and larger lots, on which jobbers charge the usual advance for small lots from store, are as follows, f. o. b. Pittsburgh, terms 30 days net, or 2 per cent cash discount in 10 days from date of invoice:

Blue Annealed Sheets

	Cents per lb.
Nos. 3 to 8	1.70
Nos. 9 to 10	1.75
Nos. 11 and 12	1.80
Nos. 13 and 14	1.85
Nos. 15 and 16	1.95

Box Annealed Sheets, Cold-Rolled

Nos. 10 and 11	1.90 to 2.00
No. 12	1.90 to 2.00
Nos. 13 and 14	1.95 to 2.05
Nos. 15 and 16	2.00 to 2.10
Nos. 17 to 21	2.05 to 2.15
Nos. 22 and 24	2.10 to 2.20
Nos. 25 and 26	2.15 to 2.25
No. 27	2.20 to 2.30
No. 28	2.25 to 2.35
No. 29	2.30 to 2.40
No. 30	2.40 to 2.50

Galvanized Sheets of Black Sheet Gauge

Nos. 10 and 11	2.35 to 2.50
No. 12	2.45 to 2.60
Nos. 13 and 14	2.45 to 2.60
Nos. 15 and 16	2.60 to 2.75
Nos. 17 to 21	2.75 to 2.90
Nos. 22 and 24	2.90 to 3.05
Nos. 25 and 26	3.05 to 3.20
No. 27	3.20 to 3.35
No. 28	3.35 to 3.50
No. 29	3.50 to 3.65
No. 30	3.65 to 3.80

Rivets. Button-head structural rivets, $2.00 per 100 pounds, Pittsburgh.

Cove-head boiler rivets, $2.10 per 100 pounds, Pittsburgh.

All of the above prices are for **large lots** of material. If small quantities are ordered, an extra charge is made, which is added to the base price. A card or list published by the mills or issued by jobbers usually gives this additional price to be considered. This point is shown under "Quantity Differentials" in the accompanying **jobber's card of extras.**

Standard Steel Classification

Extras are given in cents per pound.

ROUNDS TO 7 5/16 IN.—SQUARES TO 5 IN.

3/4 to 3 1/16	inches		Base
5/8 to 11/16	inch	.10c.	extra
1/2 to 9/16	inch	.20c.	"
7/16	inch	.40c.	"
3/8	inch	.50c.	"
11/32	inch	.60c.	"
5/16	inch	.70c.	"
9/32	inch	.80c.	"
1/4	inch	1.00c.	"
15/64	inch	1.50c.	"
7/32	inch	2.00c.	"
3/16	inch	2.50c.	"
3 1/8 to 3 9/16	inches	.15c.	"
3 5/8 to 4 1/16	inches	.25c.	"
4 1/8 to 4 9/16	inches	.30c.	"
4 5/8 to 5	inches	.40c.	"
5 1/8 to 5 1/2	inches	.50c.	"
5 5/8 to 6	inches	.75c.	"
6 1/8 to 6 1/2	inches	1.00c.	"
6 5/8 to 7 5/16	inches	1.25c.	"

For intermediate sizes, the next higher extra to be charged in all cases.

Flat Bars and Heavy Bands

1 to 6	in. x	3/8 to 1	in.		Base
1 to 6	in. x	1/4 to 5/16	in.	.20c	extra
11/16 to 15/16	in. x	3/8 to 3/4	in.	.40c	"
11/16 to 15/16	in. x	1/4 to 5/16	in.	.50c	"
9/16 to 5/8	in. x	3/8 to 1/2	in.	.60c	"
9/16 to 5/8	in. x	1/4 to 5/16	in.	.70c	"
1/2	in. x	3/8 to 7/16	in.	1.00c	"
1/2	in. x	1/4 to 5/16	in.	1.20c	"
3/8	in. x	1/4 to 5/16	in.	2.00c	"
1 1/8 to 6	in. x	1 1/16 to 1 5/16	in.	.10c	"
1 1/8 to 6	in. x	1 1/4 to 1 1/2	in.	.20c	"
1 1/4 to 6	in. x	1 5/8 to 2 1/4	in.	.30c	"
3 1/2 to 6	in. x	3 to 4	in.	.40c	"

For intermediate sizes, the next higher extra to be charged in all cases.

Above extras not applicable on Steel Tires.

Light Bars and Bands

1 1/2 to 6	in. x Nos. 7, 8, 9 and 3/16 in.	.40c	extra
1 1/2 to 6	in. x Nos. 10, 11, 12 and 1/8 in.	.60c	"
1 to 1 7/16	in. x Nos. 7, 8, 9 and 3/16 in.	.50c	"
1 to 1 7/16	in. x Nos. 10, 11, 12 and 1/8 in.	.70c	"
13/16 to 15/16	in. x Nos. 7, 8, 9 and 3/16 in.	.70c	"
13/16 to 15/16	in. x Nos. 10, 11, 12 and 1/8 in.	.80c	"
11/16 to 3/4	in. x Nos. 7, 8, 9 and 3/16 in.	1.00c	"
11/16 to 3/4	in. x Nos. 10, 11, 12 and 1/8 in.	1.20c	"
9/16 to 5/8	in. x Nos. 7, 8, 9 and 3/16 in.	1.20c	"
9/16 to 5/8	in. x Nos. 10, 11, 12 and 1/8 in.	1.30c	"
1/2 in. x Nos. 7, 8, 9 and 3/16 in.		1.30c	"
1/2 in. x Nos. 10, 11, 12 and 1/8 in.		1.50c	"
7/16 in. x 7/32 in.		1.80c	"
3/8 in. x Nos. 7, 8, 9 to 3/16 in.		1.90c	"
3/8 in. x No. 10 and 1/8 in.		2.40c	"

For intermediate sizes, the next higher extra to be charged in all cases.

Half-Ovals

3/8 to 4 in. x 7/32 to 1/2 in	.50c	extra
2 1/2 x 5/8 in. (special)	.50c	"
1/4 x 3/16 in.	.80c	"
5/8 x 5/32 and 3/16 in	1.00c	"
3/16 x 3/32 in	1.30c	"
3/16 in. x No. 13	1.80c	"
1/2 x 1/8 in	1.30c	"
7/16 x 7/32 in	2.10c	"
3/8 x 3/32 to 5/32 in	2.50c	"

Half-Rounds

3/8 to 2 in.	.50c	extra
1/4 in.	.80c	"
5/8 and 11/16 in	1.00c	"
1/2 in.	1.30c	"
7/16 in.	2.10c	"
3/8 in.	2.50c	"
5/16 in.	2.60c	"

Ovals

1/4 to 1 1/2 inches	.30c	extra
3/8 inch	.50c	"
5/16 inch	.60c	"
1/4 inch	.80c	"

For intermediate sizes, the next higher extra to be charged in all cases.

Hexagons

1/4 to 2 5/16 inches	.30c	extra
5/8 to 11/16 inch	.50c	"
1/2 to 9/16 inch	.70c	"
7/16 inch	1.10c	"
3/8 inch	1.30c	"
5/16 inch	1.50c	"

For intermediate sizes, the next higher extra to be charged in all cases.

Channels

1½ inches and wider, but under 3 inches, x 3/16 inch and heavier....	.20c	extra
1½ inches and wider, but under 3 inches, x ⅛ inch................	.30c	"
1½ x 1½ inches x ⅛ inch (special)....	.40c	"
1 to 1¼ inches x 3/16 inch and heavier.	.30c	"
1 to 1¼ inches x ⅛ inch..............	.40c	"
⅞ x ⅛ inch and 11/64..................	.50c	"
⅞ x 7/64 inch.........................	.70c	"
¾ x ⅛ inch............................	.60c	"
¾ x 3/32 inch.........................	.80c	"
⅝ x ⅛ inch............................	2.20c	"

For intermediate sizes, the next higher extra to be charged in all cases.

Angles

1½ x 1½ inches and wider, but under 3 inches, x 3/16 inch and heavier.	.20c	extra
1½ x 1½ inches and wider, but under 3 inches, x ⅛ inch.............	.30c	"
1 x 1 to 1¼ x 1¼ inches x 3/16 inch and heavier...................	.30c	"
1 x 1 to 1¼ x 1¼ inches x ⅛ inch..	.40c	"
⅞ x ⅞ inch x 3/16 inch	.40c	"
⅞ x ⅞ inch x ⅛ inch	.50c	"
¾ x ¾ inch x 3/16 inch...............	.50c	"
¾ x ¾ inch x ⅛ inch	.60c	"
3 inches on one or both legs by less than ¼ inch thick.............	.70c	"

Prices quoted on application for special sizes.

For intermediate sizes, the next higher extra to be charged in all cases.

Tees

1½ x 1½ inches and wider, but under 3 inches, x ¼ inch and heavier	.20c	extra
1½ x 1½ inches and wider, but under 3 inches, x 3/16 inch............	.40c	"
1¼ x 1¼ inches x ¼ inch and heavier	.40c	"
1¼ x 1¼ inches x 3/16 inch............	.50c	"
1 x 1 inch x 3/16 inch	.60c	"
1 x 1 inch x ⅛ inch	.70c	"

Prices quoted on application for special sizes.

For intermediate sizes, the next higher extra to be charged in all cases.

Quantity Differentials

All specifications for less than 2,000 lbs. of a size will be subject to the following extras, the total weight of a size ordered to determine the extra, regardless of length and regardless of exact quantity actually shipped.

Quantities less than 2,000 lbs., but not less than 1,000	.30c	extra
Quantities less than 1,000 lbs..................	.70c	"

Extras for Cutting to Specified Lengths

Hot Sawing or Shearing to lengths over 24 in........	.10c
Hot Sawing or Shearing to lengths 12 in. to 24 in., inclusive	.20c
Machine cutting to lengths over 24 in................	.20c
Machine cutting to lengths 12 in. to 24 in., inclusive....	.40c
For Machine cutting to lengths less than 12 in., extra will be furnished on application, but will not be less than	.60c

Exceptions

No charge will be made for Hot Sawing or Shearing to lengths of 5 ft. and over.

Shearing or Hot Sawing to lengths under 12 in. will be quoted on application.

Rounds and Squares in extreme lengths will be subject to an extra charge.

Straightening and Centering

Machine Straightening	.20c

Extra for Machine Straightening and Centering will be furnished on application.

Mill Extras for Rolled Steel Beams and Channels

	Extras per 100 lbs.
Beams, plain, 15-inch and smaller	
Channels, plain, 15-inch and smaller	
18-inch, 20-inch, and 24-inch Beams	$0.10
Extras for Work, to be Added to Base Price per Pound of Beams and Channels.	
1. Plain punching one size hole in web only	$0.15
2. Plain punching one size hole in one or both flanges	.15
3. Plain punching one size hole in either web and one flange or web and both flanges	.25
4. Plain punching each additional size hole in either web or flanges, web and one flange, or web and both flanges	.15
5. Plain punching one size hole in flange, and another size hole in web of the same beam or channel	.40
6. Punching and assembling into girders	.85
7. Coping, ordinary beveling, including cutting to exact length, with or without punching, including the riveting or bolting of standard connection angles.	.35
8. For riveting or bolting shelf angles or cover-plates to beams, channels or angles	.50
9. For painting or oiling one coat with ordinary oil or paint	.10
10. Cambering beams and channels and other shapes for ships or other purposes, bending or other unusual work	Shop Rates
11. For cutting to length with less variation than plus or minus ⅜"	.15
12. For fittings, whether loose or attached, such as angle connections, bolts and separators, tie-rods, etc.	1.55

Tie-rods in all cases where estimated upon in connection with beams or channels to be classified as fittings.

Prices for Small Lots

The quotations given below are for small lots, as sold from stores in New York City by merchants carrying stocks.

As there are many consumers whose requirements are not sufficiently heavy to warrant their placing orders with manufacturers for shipment in carload lots from mills, these prices are given for their convenience.

IRON AND STEEL

Bar Iron and Soft Steel Bars

	Per lb.
Refined iron:	
1 to 1⅞ in., round and square	2.05c
1½ to 4 in. x ⅜ to 1 in.	2.05c
1½ to 4 in. x ¼ to 5/16 in.	2.25c
Burden's H. B. & S. bar iron, base price	3.15c
Burden's Best bar iron, base price	3.35c
Norway bars	3.60c
Soft steel:	
¾ to 3 in., round and square	2.05c
1 to 6 in. x ⅜ to 1 in.	2.05c
1 to 6 in. x ¼ and 5/16 in.	2.20c

Rods—⅝ and 11/16 ....2.15c
Bands—1½ to 6 x 3/16 to No. 8.........................2.35c

Shapes

Beams and channels—3 to 15 in.........................2.15c
Angles:
- 3 in. x ¼ in. and larger.............................2.15c
- 3 in. x 3/16 in. and ⅛ in 2.55c
- 1½ to 2½ in. x ⅛ in.................................2.30c
- 1½ to 2¾ in. x 3/16 in. and thicker.................2.20c
- 1 to 1¼ in. x 3/16 in.................................2.30c
- 1 to 1¼ x ⅛ in...2.35c
- ⅞ x ⅛ in...2.45c
- ¾ x ⅛ in..2.50c
- ⅝ x ⅛ in..3.70c
- ½ x 3/32 in...4.75c

Tees:
- 1 in. x 1 x ⅛ in.......................................2.60c
- 1¼ in. x 1¼ in. x 3/16 in.............................2.45c
- 1½ to 2½ x ¼ in.......................................2.25c
- 1½ to 2½ x 3/16 in...................................2.35c
- 3 in. and larger.......................................2.25c

Tank Plates—Steel

¼ in. and heavier.......................................2.15c
3/16 in. 2.25c
No. 8 ....2.45c

Sheets

Blue Annealed

No. 10 ....2.65c
No. 12 ....2.70c
No. 14 ....2.75c
No. 16 ....2.85c

Box Annealed—Black

	One pass, C. R. soft steel Per lb.	R. G. cleaned Per lb.
Nos. 18 to 20	2.90c	....
Nos. 22 and 24	2.95c	3.45c
No. 26	3.00c	3.55c
No. 27	3.05c	3.65c
No. 28	3.10c	3.75c
No. 29	3.30c	....
No. 30	3.50c	....

Galvanized

	Per lb.
Nos. 12 and 14	3.35c
No. 16	3.45c
Nos. 18 and 20	3.60c
Nos. 22 and 24	3.75c
No. 26	3.90c
No. 27	4.05c
No. 28	4.20c
No. 30	4.60c

No. 28, 36 in. wide, 10c higher.

Corrugated Roofing, Galvanized

2½ in. corrugations, 10c per 100 lb. over flat sheets.

Corrugated Roofing, Painted

2½ in. corrugations.

No. 22	Per 100 sq. ft.	$4.75
No. 24	Per 100 sq. ft.	3.75
No. 26	Per 100 sq. ft.	2.85
No. 28	Per 100 sq. ft.	2.50

Genuine Iron Sheets

Galvanized

Nos. 22 and 24	Per lb.	5.75c
No. 26	Per lb.	6.50c
No. 28	Per lb.	7.25c

Where jobbers sell in small lots and cutting is desired, it is common to add an extra price for such service. A card of extras, issued by Joseph T. Ryerson & Son, of Chicago, Ill., is here reproduced (see top of page 428).

Although attention has been called to the practice of allowing a variation ⅜ inch either way from the ordered length in figuring the cut length of a member, it might be well to state that the variation may be kept within even smaller limits if desired; but the mills charge an extra price for so doing, on account of the additional care requisite in adjusting the machinery and supervising the mill processes. In view of the fact that a ⅜-in. variation from ordered length is allowable in the cutting done at the mills, it is good practice, when ordering beams which are to abut against other members at each end, to make due allowance for this possible variation from the measurements specified. This precaution is not necessary for beams which are built into masonry or brickwork, since in this case there is little difficulty in fitting the beam to its end connections.

WAREHOUSE CUTTING EXTRAS

(Joseph T. Ryerson & Son, Chicago, Ill.)

	3' and Over	2' to 3'	1' to 2'	6" to 1'	4" to 6"	2" to 4"
Beams and Channels, 3" and over	$0.00	$0.15	$0.30	$0.85	$1.40	$2.30
Zees	.00	.15	.30	.85	1.40	2.30
Tees 3" and over	.00	.15	.30	.85	1.40	2.30
Angles 2 x 2 x 3/16 and over	.00	.05	.10	.20	.35	.50
Plates, rectangular:						
For length	.00	.05	.10	.20	.35	.50
Splitting plates, 10c extra.						
Sketch	.10	.10	.10	.10	...	...
Checkered	.30	.30	.30	.50	...	...
Sheets, No. 10 gauge	.25	.25	.25	.45	...	...
Sheets, No. 12 gauge	.30	.30	.30	.50	...	...
Sheets, No. 14 gauge	.35	.35	.35	.55	...	...
Sheets, No. 16 gauge	.40	.40	.40	.60	...	...
Splitting Stock Sheets, No. 10 to No. 16, 10c extra.						
Flats, 1 lb. per ft. and over to 1" thick, incl.	.30	.30	.30	.50	.65	.80
Rounds, 1 lb. per ft. and over to 2" thick, incl.	.30	.30	.30	.50	.65	.80
Squares, 1 lb. per ft. and over to 3" thick, incl.	.30	.30	.30	.50	.65	.80
Angles, 1 lb. per ft. and over to 2x2x1/4", incl.	.30	.30	.30	.50	.65	.80
Flats, under 1 lb., per ft.	.25	.25	.40	.85	1.40	2.30
Rounds, under 1 lb., per ft.	.25	.25	.40	.85	1.40	2.30
Squares, under 1 lb., per ft.	.25	.25	.40	.85	1.40	2.30
Angles, under 1 lb., per ft.	.25	.25	.40	.85	1.40	2.30
Flats, over 1" in thickness	.25	.25	.40	.85	1.40	2.30
Rounds, over 2" diam.	.25	.25	.40	.85	1.40	2.30
Squares, over 3"	.25	.25	.40	.85	1.40	2.30
Tees, under 3"	.25	.25	.40	.85	1.40	2.30
Channels, under 3"	.25	.25	.40	.85	1.40	2.30
Rails	.25	.25	.40	.85	1.40	2.30
Billets / Bands / Reinforcing Bars	Prices on Request					

Also, if there are likely to be changes made in the plans, order material of a length sufficient to meet these changes.

Be sure to allow a little leeway in the width of plates forming the web of built-up girders. It is better to have them a half-inch narrower than the distance from back to back of angles, than to have to shear off that half-inch.

Also, allow for a milling cut wherever surfaces or edges have to be faced or finished.

Above all, stick to standard shapes and sizes, and avoid specials wherever possible.

Drafting and Shop Costs

The drafting cost on I-beams and channel work does not exceed 50 cents per ton when a good draftsman is employed on it. For a general average, $1.00 a ton is about right. Building-truss and plate-girder work should not run higher than $2.00 to $3.00 per ton, although some runs as high as $8.00 a ton. As a general rule, the lighter the work and the more difficult, the higher the cost. Some work on a dome where the heaviest angles were 3 by 3 by 5/16 in., and where much curved work was necessary, ran up as high as $15.00 a ton.

The shop cost for cutting, punching, assembling, and riveting, runs about as follows:

Column work ....$14.00 to $20.00 per ton
Truss and Girders ....$12.00 to $25.00 per ton

According to Mr. M. S. Ketchum, for lots of six members ordered at the same time, the costs of fabrication are as shown in Table CXXVIII.

TABLE CXXVIII

Shop Costs of Steel Columns and Trusses

(Prices based on orders of six members)

Type of Member	Member Consists of	Weight of Members (Pounds)	Shop Cost per Pound (Cents)
Column	2 channels and 2 plates, or 2 laced channels	600 to 1,000	[illegible]/10 to 7/10
Column	4 angles, laced		[illegible]/10 to 1 [illegible]/10
Column	2 channels and 1 I-beam, or 3 channels		[illegible]/10 to [illegible]/10
Column	Single I-beam / Single angle		[illegible]/10
Column	Z-bar		[illegible]/10 to [illegible]/10
Column	Plain cast	500 to 2,500	1½ to [illegible]/10
Riveted Roof Truss (ends of members cut off at right angles)	Ordinary form of truss	1,000	1 [illegible]/100 to 1 [illegible]/100
Riveted Roof Truss (ends of members cut off at right angles)	Ordinary form of truss	1,500	[illegible]/10 to 1
Riveted Roof Truss (ends of members cut off at right angles)	Ordinary form of truss	2,500	[illegible]/100 to [illegible]/100
Riveted Roof Truss (ends of members cut off at right angles)	Ordinary form of truss	3,500 to 7,500	[illegible]/10 to [illegible]/100
Pin-Connected Trusses	....	....	Add 1-10 to 2-10 cent per pound to above prices for riveted trusses

The cost of shop work alone on plate-girders for floor and traveling cranes varies according to the size, detail, and number put through the shop at the same time, from 6/10 cent to 1 3/10 cents per pound.

The total cost of an eye-bar is made up by adding the cost of the metal and the cost of shop work or labor on same. This shop work cost varies from 1 2/10 to 1 8/10 cents per pound for small bars from 2½x¾ in. to 3x¾ in. in section and from 16 to 30 ft. long; while large bars ordered in large quantities may be made at a price ranging from 5/10 to 8/10 cent per pound.

Cost of Erection

Erection expenses are variable, depending upon the class of work, and must be figured separately for each case. The following costs are taken from data compiled by Mr. Edward F. Godfrey, and are thought to be good average values:

Erection of plain structural work costs $9.00 to $10.00 per ton; of framework of office buildings, $10.00 to $12.00 per ton; of mill buildings, $11.00 to $15.00 per ton. Complicated work of many small parts and light tonnage, such as angles and tees for roof tile, may run as high as $28.00 to $30.00 per ton to erect. Bridge truss work will cost $15.00 to $20.00 per ton. These figures include furnishing falsework, also the painting.

The driving of field rivets costs from 5 cents to 20 cents each, depending upon the accessibility of the rivets and the number of times that scaffolds must be moved in a day. A riveting gang costs about $8.00 a day. For ordinary work, 12 cents per rivet is a good average.

The hire of an engine and derrick is about $30.00 per week. That of an engine and concrete mixer is about the same. This does not include any men to operate the same.

The cost of furnishing clips and rivets and putting up corrugated iron, is about $2.00 per square of 100 sq. ft.

Other authorities state that with wages for skilled labor at $3.50 and common labor at $2.00 per 9-hour day, the cost of erecting the steel work on small mill or manufacturing buildings will be about $10.00 per ton if the trusses are riveted and all other connections are bolted.

The erection of corrugated steel siding varies in cost from 75c to $1.00 per square of 100 sq. ft.

The erecting of heavy steelwork in machine shops and similar buildings where all steel is riveted, will cost about $9.00 per ton, including the labor of painting but not the cost of paint.

In small buildings where all connections are bolted, the erection costs will be about $6.00 per ton.

Cost of Finishing Work

Cleaning, Painting, and Galvanizing. Any mud, dirt, or rust which may adhere to steel work should be removed by the use of wire brushes, steel scrapers, or sand-blast; and in the case of plain, ungalvanized material, two or more coats of good paint should be applied. The surface should be clean before the application of the first coat, in order that the paint may adhere.

The first coat usually consists of red lead mixed in oil in the proportion of about 33 lbs. of dry red lead to a gallon of oil. When brushed out by the ordinary workman, one gallon will cover about 400 sq. ft. of surface, one coat. Red lead paint is best prepared from day to day, and should be used only as an under or first coat.

Before applying the finishing coat, all bolt and rivet-heads, together with the edges and corners of structural shapes, should be given an extra coat of paint in order sufficiently to cover those parts which may have received a light coat on the first application or been abraded in handling. A week later, the finishing coat may be applied. This finishing coat should consist of pure linseed oil and a finely ground, stable, and non-injurious pigment. Graphite in linseed oil is often used, and gives good results. Often lampblack is mixed with the graphite. Bone black is frequently an ingredient. Asphalt paints seem to withstand the action of gases successfully, and are used to a considerable extent.

The painting of structural work costs about $1.00 per ton for each coat; while the cost if galvanizing is about $20.00 per ton.

Allowance for Profit. This varies with the competition, and with the amount of work on hand in the shop. If work is plentiful, and men who wish employment are plentiful, the profit can be made low. If the shop is running full, and men are scarce, the profit can be made large, as it does not matter much if the contract is lost; and if it is awarded, then some of the other work may be delayed and the contract worked on. On the other hand, if work is scarce, and the men are almost out of work in the shop, but prospects look bright, it would be policy to take the work at a very small profit, or at none at all, or even at a small loss, in order to keep from laying off good men who might leave for other places and thus seriously inconvenience the output of the plant when work "picks up."

Ordinarily 15 per cent may be added for profit. If conditions are favorable during the contract, more than this may be realized. If adverse conditions occur, even this profit may vanish. The same estimator should confine his estimates to as few classes of work as possible, and success will be more certain.

Other Costs. Bolts and spikes are to be counted up, and estimated at the current market prices. **Freight** varies with the distance of the structure from the shop. **Traveling** and **bidding** expenses vary with the distance of the agent from the place where the letting of the contract is done, when he is notified from the home office; and also with the character of the town in which the contract is let. Two days' hotel expenses is a fair amount for the estimate. **Haulage**

TABLE CXXIX

Number of Rivets in 100 Pounds

(Dimensions given in inches)

Length Rivets	Diameter of Rivets											
	⅛	3/16	¼	5/16	⅜	7/16	½	⅝	11/16	¾	⅞	1
½	17,500	15,900	8,000	5,100	3,200	1,900	....	....	....	....	....	....
⅝	16,000	13,800	7,000	4,500	2,900	1,800	....	....	....	....	....	....
¾	14,400	12,200	6,300	4,100	2,378	1,476	1,103	642	....	....	....	....
⅞	13,500	10,900	5,700	3,700	2,190	1,371	1,030	604	....	....	....	....
1	12,600	9,800	5,200	3,400	2,034	1,280	968	571	400	345	....	....
1⅛	11,600	9,000	4,700	3,100	1,898	1,200	910	541	382	322	208	....
1¼	10,800	8,300	4,400	2,900	1,780	1,129	862	514	365	311	206	....
1⅜	10,000	7,600	4,100	2,700	1,675	1,066	815	489	350	295	204	....
1½	9,800	7,100	4,000	2,500	1,582	1,010	776	462	335	284	201	....
1⅝	8,700	....	3,800	2,300	1,498	960	740	446	324	275	199	132
1¾	8,100	6,800	3,500	2,200	1,424	914	707	428	311	266	192	128
1⅞	....	....	3,400	2,000	1,356	872	672	411	302	257	185	124
2	....	5,600	3,000	1,900	1,295	834	648	395	293	249	178	120
2⅛	....	....	....	....	1,238	800	623	381	285	240	172	116
2¼	....	5,000	2,800	1,800	1,187	768	599	367	277	233	167	112
2⅜	....	....	....	....	1,139	738	577	354	269	226	162	108
2½	....	4,600	2,500	1,700	1,095	711	556	343	261	219	157	104
2⅝	....	....	....	....	1,052	687	537	332	253	212	152	100
2¾	....	4,200	2,300	1,600	1,017	662	519	321	245	206	148	96
2⅞	....	....	....	....	982	636	503	311	237	201	144	92
3	....	3,900	2,200	1,400	949	611	487	302	230	196	140	88
3¼	....	3,600	2,000	1,300	890	581	459	285	218	186	132	85
3½	....	3,400	1,900	1,200	837	548	433	270	208	177	126	82
3¾	....	3,200	1,800	1,175	791	519	411	257	198	168	120	79
3⅞	....	....	....	....	....	....	395	250	195	165	119	....
4	....	3,000	1,700	1,100	749	400	390	244	189	161	115	77
4¼	....	....	1,600	1,050	700	....	372	233	180	155	110	75
4½	....	....	1,500	1,000	650	....	355	223	172	149	105	73
4¾	....	....	1,475	925	625	....	339	214	166	143	101	71
5	....	....	1,400	900	600	....	325	205	160	136	97	69
5¼	....	....	1,350	850	575	....	312	197	154	131	94	67
5½	....	....	1,300	825	550	....	300	190	149	127	91	65
5¾	....	....	1,250	775	525	....	289	183	144	123	88	63
6	....	....	1,200	750	500	....	279	177	139	118	85	61
6¼	....	....	....	....	....	....	....	171	135	114	82	59
6½	....	....	....	....	....	....	....	165	131	110	79	57
6¾	....	....	....	....	....	....	....	160	127	107	77	55
7	....	....	....	....	....	....	....	155	123	104	75	53
7¼	....	....	....	....	....	....	....	150	119	100	73	51
7½	....	....	....	....	....	....	....	146	116	97	71	49
7¾	....	....	....	....	....	....	....	142	113	94	69	47
8	....	....	....	....	....	....	....	138	110	92	67	45

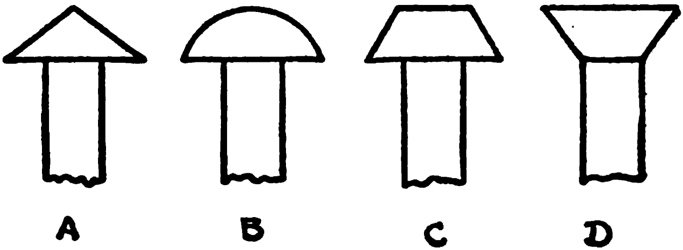
may be estimated at 25 cents per ton-mile—that is, per ton hauled one mile.

RIVETS

If the weight of the rivets is desired, find the number and size of rivets needed from the drawings, and determine their weight from table given in the mill books or from Table CXXIX. An estimate of 2 per cent for rivets is often added to the weight of built-up structural work.

Size of Rivets.—The following rules may aid in determining size of rivets: For plates less than ½-in. thick, use a rivet whose diameter is twice the thickness of plate. For plates ½-in. and ⅝-in. in thickness, use a rivet whose diameter is one and one-half times the thickness of the plate, while 1-in. diameter holes should be used for ⅞-in. and 1-in. plates.

The length of a rivet before clinching is generally given as equal to the thickness of the plates, plus 2½ times the diameter of the rivet.



Common Forms of Rivet Heads.

A—Steeple; B—Round; C—Cone; D—Countersunk.

The above figure shows the common forms of rivet-heads. The measure of countersunk head rivets is over all. All other styles are measured from under the head. Boiler rivets less than 1 in. long are ½ cent per pound extra. Tank rivets 7/16 in. in diameter and less are sold at a list price, and subject to discount.

CONDITIONS AFFECTING COST OF WORK

Current prices for which similar work is being done in localities situated about the same distance from the source of supply, afford a sound basis upon which to gauge the cost of work. If only a rough approximation is desired, it is best to use as a basis the unit-cost of work in place, rather than to analyze the elements that go to make up the cost, such as material, labor, freight, hauling, profit, etc.

The contractor's profit is an elastic factor, depending upon the size of the work, the risk, and many other considerations. The cost of manufacture is variable. Some shops can make heavy work cheaper than others, while others can handle light work more economically.

It is not the purpose here to analyze the cost in shops and mills, so much as to give more general data for determining the probable cost of ordinary building and bridge work, as well as to point out some of the special cases where costs are apt to be more or less than the average. Average costs will prevail near the railroads and within radii of 50 or 100 miles of the commercial centers. Freight rates average about ¾ cent to 1½ cents per ton-mile. Long pieces requiring several cars and not weighing enough to load them to their normal capacity, will cost more per ton than materials that can be shipped in full carloads. Partial carloads are charged at a minimum carload rate—say one-half of the capacity of the car. Where more than one car is required, one car is charged at this minimum rate, and each other car at one-half of this amount, if the actual weight of the material shipped is not over that total.

Extra hazardous work should have something added to the estimated cost, to allow for the risk taken by the contractor. Work that must be finished in a short time should have the estimate increased, especially if a penalty attaches for failure to complete by a specified time. If the season is a poor one for the class of work, still more expense is liable to be incurred. Erecting bridges over streams in flood-time, for example, may be attended by serious difficulties and expensive delays.

Large contracts, as a rule, cost less per unit than small ones. The placing and removing of the contractor's plant on a job often requires considerable time. If the magnitude of work does not justify bringing labor-saving machinery to the site, the extra labor will make the smaller job more expensive. Large orders of materials may be placed at lower rates than small ones.

Where labor is the principal item of cost in any work, less certainty can be expected in the estimate of the cost, whereas materials that are regularly manufactured should vary but little in cost.

Under average conditions, it is often estimated that structural steel will cost from 3 to 5 cents per pound, erected and painted.

The cost of steel framing, per cubic foot of building, is about 2½ cents.

WEIGHT OF STEEL USED IN BUILDING

The following weights of steelwork are often used in estimating steel frame buildings of moderate height. The weight of steel per square foot of floor area of building may be approximated as follows:

Hotels and flat buildings without exterior steel frames. 9 lbs.
Same with exterior frames.............................14 lbs.
Office buildings without exterior steel frames.........15 lbs.
Same with exterior frames.............................24 lbs.
Warehouses and storage buildings without exterior steel frames ....18 lbs.
Same with exterior frames.............................30 lbs.

In manufacturing plants the approximate weight of steelwork estimated on the basis of the number of square feet of ground surface covered is as follows:

Blacksmith shops, paint shops, etc....................10 lbs.
Foundries ....20 lbs.
Machine shops ....25 lbs.

The above values should be used only in approximating prices.

WORKING UNITS FOR STEEL STRUCTURAL DESIGN

In calculating necessary sizes for steel members, and figuring other details of design, the units given in Table CXXX will be found of great service.

TABLE CXXX

Factors of Safety and Allowance Stress in Steel Structures

Ultimate strength of medium steel, 60,000 lbs. per sq. in.

Class of Work	Class of Stress	Factor of Safety	Allowable Working Stress
Buildings..........	Dead and Live Load	3	20,000 lbs. per sq. in.
Highway Bridges...	Dead Load	2.4	25,000 " " " "
	Live Load	4.8	12,500 " " " "
Railroad Bridges...	Dead Load	3	20,000 " " " "
	Live Load	6	10,000 " " " "

IRON CASTINGS

If cast-iron columns are to be used in construction work, use stock sizes wherever possible. In case a special pattern has to be made for column, cap, or base, the price of same when ready for the building will depend largely on the first cost of the pattern itself and upon the number of pieces cast. Patterns are costly, and should be estimated on by an experienced pattern-maker. The white pine from which they are made will cost about $80.00 per thousand board feet, but the labor is a varying quantity.

If the weight of cast work is desired, same may be obtained either by experiment or by calculation. When the pattern is available, the weight of a casting may be obtained by measuring the amount of water displaced in a tank when the varnished pattern is placed just beneath the surface of the water, and then multiplying this displacement in cu. in. by 26/100 of a pound, the weight of a cu. in. of cast iron. An old rule is to multiply the weight of the pattern by 18 to obtain the weight of the casting.

The most accurate rule is to find the actual cubic content of the piece to be used, and multiply this volume (in inches) by .26. The result will be the weight of the casting in pounds.

In case of a hollow column, find the volume of the column figured as solid, and subtract the volume of the hollow part. This will leave the actual cubic contents of the metal in the hollow column. For brackets, flanges, etc., figure the cubic contents, and add to the volume of the shaft itself. This sum, multiplied by .26 for each cu. in. of volume, will give the weight of column.

The following prices may serve as an approximate guide where a local price for castings is not easily obtained:

Cast Iron. Pig iron, $14.00 to $17.00 per long ton, depending on location. In general building work, 1.75 to 2.25c per lb. Castings for footings, manhole covers, and outside work, 1.60 to 1.90c per lb. Intricate castings, 3 to 6c per lb., depending upon size of the order and shape of pattern.

TABLE CXXXI

Cost of Bridge Steel Work and Floors

Span	Type	Cost Per Foot of Span			Per Cent Cost of Renewal of Timber Work Per Year
		Steel	Floor System	Total	
45	Pl. girder	$25.00	$ 3.00	$28.00	1.1
60	Pl. girder	30.00	3.00	33.00	0.9
85	Pl. girder	39.00	3.00	42.00	0.7
100	Pony lattice	38.00	6.00	44.00	0.7
100	Lattice	29.00	10.00	39.00	0.8
125	Lattice	35.00	10.00	45.00	0.7
150	Pin	36.00	12.00	48.00	0.6
175	Pin	41.00	12.00	53.00	0.6
200	Pin	46.00	12.00	58.00	0.5
250	Pin	60.00	12.00	72.00	0.4

COST OF STEEL BRIDGE WORK AND FLOORS

The floors of railroad bridges (unless constructed with buckle-plates or similar material, on which the regular ballast roadbed is carried) are largely of timber, which has a relatively short life. In general it may be estimated that the wooden portion of such a floor will last about ten years in the northern part of the United States, decreasing to about six in the Southern States.

Table CXXXI gives some estimated costs of **bridge steel work and railroad bridge floors** for different spans, for the sake of comparison.

Heating and Ventilating

HEATING PLANT

Heat Units. Heat, like electricity, is a form of energy, and therefore must be measured by the results it produces.

A **heat unit** (B. T. U.) is the quantity of heat required to raise the temperature of 1 lb. of water 1 degree. Heat manifests itself as a form of motion, and motion requires work to produce it; therefore the relation between heat and work is definite.

Unit of Work. Work is measured by the results due to its performance—for instance, the raising of a given weight a given number of feet. One pound weight raised one foot high, is one **foot-pound.** This is the unit of work; and one heat unit will raise 778 lbs. weight 1 foot high; therefore the mechanical equivalent of heat is 778 foot-pounds; and 33,000 lbs. raised 1 foot high in one minute of time=one **horsepower.**

In estimating the number of heat units required to raise the temperature of the air in a building a given number of degrees, it is necessary to know the number of cu. ft., or number of pounds weight, of air at constant pressure that will require to be heated. This result could be easily arrived at if the specific heat of air were the same as that of water; but as it is not, it will be necessary to ascertain the ratio between the two. The specific heat of water is taken at 1. The specific heat of air is .238; that is, if 1 heat unit will raise the temperature of 1 lb. of water 1°, .238 heat units will raise the temperature of 1 lb. of air 1°. The volume, in cu. ft., of 1 lb. of air at any temperature can be found by the following formula:

$$V = \frac{T+R}{2.71p},$$

where T=Temperature by thermometer.
R=Absolute temperature=460°.
P=Pressure, Barometer at 30 inches.
V=Volume in cu. ft.

Example—

Let T=40°; P=14.7 lbs. Then,

$$V = \frac{40+460}{2.71 \times 14.7} = 12.6 \text{ cu. ft.} = 1 \text{ lb. wt. of air at } 40°.$$

To raise the temperature of 12.6 cu. ft. of air 1° requires .238 heat units; and to raise its temperature 30° (40° to 70°) will require 30 times .238=7.14 heat units.

Although cu. ft. of space is not so important a factor in heating calculations as sq. ft. of wall surface, still it is very convenient for an approximate estimate of the quantity of heat (number of heat units) that will be required to heat a building containing a given number of cu. ft. of space.

Mr. Richey, Supt. U. S. Public Buildings, says:

"Under ordinary conditions one horse-power will heat approximately, in:

Brick dwellings in blocks, as in cities	15,000 to 20,000 cu. ft.
Brick stores, in blocks	10,000 to 15,000 cu. ft.
Brick dwellings, exposed all sides	10,000 to 15,000 cu. ft.
Brick mills, shops, factories, etc.	7,000 to 10,000 cu. ft.
Wooden dwellings, exposed	7,000 to 10,000 cu. ft.
Foundries and wooden shops	6,000 to 10,000 cu. ft.
Exhibition buildings, largely glass	4,000 to 15,000 cu. ft."

To develop one horse-power requires $\frac{33,000}{778}=43$ heat units per minute, nearly; and knowing this factor, and the cu. ft. of space to be heated, the size and capacity of the heating plant, whether a hot-air furnace, or a hot-water or steam heating system, may be estimated.

The value of fuel is estimated by the number of heat units generated by its combustion. From the formula and example already given, the total number of heat units needed to raise the temperature of a given number of cu. ft. of air to any desired temperature can be easily estimated.

Specific Heat. Another factor to be considered in calculating the heat producing and radiating capacity of any heating system, is the **specific heat** of the materials used in the building. The specific heat of any substance is the ratio of the number of heat units required to raise the temperature of a given weight of that substance 1°, to the number of heat units required to raise an equal weight of water 1°. Table 1 gives the specific heat of ordinary building materials and other substances directly connected with heating systems.

TABLE 1

Specific Heat of Various Substances

Substance	Specific Heat
Water	1.000
Air, at constant pressure	.2375

Air, at constant volume	.1689
Cast iron	.1298
Wrought iron	.1138
Soft steel	.1165
Glass	.1977
Oak wood	.57
Plaster	.2
Masonry	.2159
Brickwork	.1950
Pine wood	.667
Birch wood	.48
Stones, generally	.21

Although specific heat is not shown by the thermometer, still it must be considered in calculating the required capacity of a heating plant. Especially does this apply to buildings in which the application of the heat is intermittent—that is, where heat is used through the day, but during the night the rooms are allowed to cool, thus creating a condition daily requiring the expenditure of an extra amount of heat in rewarming the walls. Practice and experiment show that a heating plant operating under such conditions should have at least 30 per cent. more capacity than would be required to heat the same building properly provided the temperature of all the rooms were maintained continuously at a certain standard, say 70° inside, with an outside temperature of zero.

Exposure, whether on north side (the side of prevailing winds) or on south side (only slightly exposed) is another feature to be considered in these calculations. To sum up—when heat is shut off at night and building allowed to partly

TABLE 2

Required Air Changes per Hour in Various Classes of Buildings

Kind of building	Changes per Hour
Residences having loose windows	2
Churches, except small audience rooms	4
Small churches and other assembly rooms	5 to 6
Office building, rooms above grade	1
General basement	4
Heating plant	10
Factories having no mechanical ventilation	1
Factory buildings, having large doors from out side, opened frequently	4

cool, heat in walls is dissipated, and must be replaced each time building is to be heated; whereas, if an even temperature is maintained throughout the 24 hours, the loss of heat by absorption and dissipation through walls is greatly decreased.

LOSS OF HEAT FROM BUILDINGS

This occurs owing to filtration of air through walls; direct transmission through walls, doors, and windows; passage of air up and out through foul-air flues, etc. Ordinarily the air in a room, or rooms will change about once each hour, assuming all doors and windows to be closed. The American Society of Heating & Ventilating Engineers recommend air changes per hour for various classes of buildings, as indicated in Table 2.

Loss of heat by filtration through walls and leakage of air around doors and windows, depends upon the kind of material of which the walls are built, and the character of the workmanship; and the determination of this loss is largely a matter of judgment. Loss of heat by direct transmission through walls, windows, etc., and the passing of the air through foul-air flues, is easily determined, and depends upon the number of times per hour that the volume of air in the room or building is changed; also on whether the building is allowed to cool at night, or is kept heated continuously.

Other factors to be considered in estimating loss of heat from a building are the different ways of cooling. There are three; (a) by **radiation**, (b) by **conduction**, (c) by **convection**.

Radiation of heat follows the same laws as the radiation of light does. A body of a higher temperature will always radiate heat to the body of lower temperature, and the number of heat units thus given off will depend upon (a) difference in temperature between the two bodies; (b) material composing the radiating surface; (c) substance through which the heat passes; and (d) sq. ft. of radiating surface. Table

TABLE 3

Radiating Power of Various Bodies

Expressed in heat units given off per sq. ft. per hour for a difference of one degree. (Peclet.)

Substance	Heat Units
Water	1.085
Copper, polished	.0327
Sheet iron	.0920
Glass	.595
Cast iron, rusted	.648
Building stone, plaster, wood, brick,	.7358
Woolen stuffs, any color	.7522

3 shows the radiating power of various substances directly or indirectly connected with the heating of buildings.

Table 3 is useful mainly in calculating required number of sq. ft. of radiating surface for properly heating a room or building.

Loss of Heat by Conduction. This will depend upon the type of conductor through which the heat passes, the difference in temperature between the two sides of the plate or wall, and thickness of wall. Table 4 gives the conducting power of various building materials, expressed in heat units.

TABLE 4

Conducting Power of Various Materials

Expressed in number of heat units transmitted per sq. ft. per hour by a plate 1 in. thick, the surface on the two sides of the plate differing in temperature by one degree. (Peclet.)

Substance	Heat Units
Copper	515.0
Iron	233.0
Lead	113.0
Stone	16.7
Glass	6.6
Brick work	5.6
Plaster	3.7
Pine wood	.76
Sheep's wool	.323

Heat lost by direct passage of air through foul-air flues depends upon: (a) height of flue: (b) excess of temperature of air in flue above external air: (c) area in sq. ft., or fraction thereof, of flue.

Table 5 shows the approximate quantity of air in cu. ft. per minute that will pass a flue having an area of .5 sq. ft., and governed by conditions indicated regarding height and temperature.

Convection Losses. Calculations of losses of heat by convection are complicated, and space will not permit here an elaborate discussion of the subject. These losses are entirely independent of the kind of material composing the body from which heat is lost, but they are affected by the shape or form of the surface.

For instance, the amount of heat lost per sq. ft. by a cylindrical surface differs from the amount lost from a spherical surface. In the radiator of the ordinary type, the loss of heat by contact with fluid currents (as of air)—or convection, as it is termed—represents one-half the total amount of heat

TABLE 5

Number of Cu. Ft. of Air that will Pass per Minute through a Flue Having an Area of ½ Sq. Ft.

Height of Flue in Ft.	Size of Flue 6"x12"—Area .5 Sq. Ft.												
	Excess of Temperature in Flue Above Temperature of External Air.												
	10°	15°	20°	25°	30°	40°	50°	60°	70°	80°	90°	100°	150°
	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.
30 ft.......	94	115	132	148	160	175	197	217	237	257	279	297	363
40 ft.......	108	132	153	171	187	216	242	262	282	302	322	342	419
50 ft.......	121	148	171	191	209	242	271	296	320	345	365	383	469

distributed by the radiator. This is owing to shape of radiator columns. The balance of the heat leaving the radiator is distributed by radiation.

Problems in Heat Losses. Table 6 and Problems 1 and 2 are presented in order to show loss of heat, or rather waste of fuel, that may be charged directly to the practice of allowing the temperature of a building to drop during the night, and then reheating it the next morning. No account is taken of the extra quantity of fuel consumed in bringing the temperature of the heating plant up to normal conditions each morning. Table 6 is calculated on the basis of an increase of 70° in temperature. If, instead of 70°, the required increase is but 25, 35, or 40°, as the case may be, the number of heat units required would be lessened in proportion.

A glance at Table 1 will show the quantity of heat, expressed in heat units, or fractions thereof, required to increase by one degree the temperature of one pound of any given material used in the construction of the average building. Experiments and investigations prove that the loss of heat in the manner previously described—namely, by absorption and transmission through walls of buildings, is practically the same, regardless of material used in construction. Masonry and concrete walls, if solid, will absorb and dispense a fixed quantity of heat; while wooden buildings have an air-space between inner and outer walls, which is a valuable factor in the retention of the heat, owing to the fact that air is a poor conductor. Of course, thin walls of any type of construction will lose more heat during a given time than thick walls will.

Problems—Assume outside temperature at 0° F.; inside temperature to be 70° F.; weather conditions, calm, no wind blowing; heat to be maintained continuously.

(1). Assume a brick building described as follows: Average thickness of walls, 1½ ft.; total exposure, 4,350 sq. ft.; total cu. ft. of brickwork=4,350×1.5=6,525. Allow 120 lbs. weight per cu. ft.; total wt.=6,525×120=783,000 lbs. Allow for wt. of wood work, inside finish, etc., 42,282 lbs. Allow for wt. of plaster, 18,792 lbs. Air, 64,600 cu. ft., which, at .08 lb. per cu. ft., weighs 5,168 lbs. Wt. of glass and other appurtenances included in wt. of walls. How many units of heat will be required to raise temperature of air in this building from 0° to 70°? Reference is made to Table 1.

(2) How many pounds of coal will require to be burned in order to produce the above quantity of heat, and effect this change in temperature of the building within 3 hours' time?

TABLE 6

Specimen Calculation of Necessary Heat Units for Warming a Brick House

Material	Weight (Lbs.)	Specific Heat of		Heat Units
Brick walls	783,000×	.1950	×70°=	10,687,950
Wood work	42,282×	.5	×70°=	1,479,800
Plaster	18,792×	.2	×70°=	263,088
Air (in building)	5,168×	.2375	×70°=	85,918
				12,516.756
Add 15 per cent. for furniture, etc.			=	1,877,513
Total number of heat units required.............			=	14,394,269

The answer to Problem 2 will depend upon kind of coal used, and number of heat units contained in each pound wt. of same. To facilitate calculations of this kind, Table 7 is given, showing heating values of various American coals.

Assume the coal being used in the heating plant, to have a heat value of 15,070 heat units per lb. Total number of heat units required=14,394,269. Then number of lbs. coal required=14,394,269÷15,070=955 lbs.

This process can be applied to any size, or type of heating system, whether the medium for applying the heat be steam, hot water, or warm air.

(3) How many heat units must be developed in order to maintain a constant temperature of 70° in a building; outside temp.=0°? Air changes per hour=2.

This problem relates directly to size and capacity of plant. Therefore it is necessary to sum up total losses of heat from all sources.

For convenience these losses may be expressed in heat units per sq. ft. of surface exposed to heat on one side, and cold on the other. Losses due to changes of air at 2-hour intervals, will be expressed in heat units per cu. ft. of air, taking, first, loss by filtration of air through walls, partly opened doors, and other passages, which have a direct bearing upon the number of times per hour that the air is changed.

There are approximately 13 cu. ft. of air in 1 pound; and if .2375 heat unit will raise its temperature 1°, one heat unit will heat 13÷.2375=54.7, or, in round numbers, 55 cu. ft. of air 1°.

Using this number as a constant, the number of heat units required to heat a given number of cu. ft. of air may be found by Formula 1:

$$B.\ T.\ U. = \frac{V \times C \times D}{55} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where B. T. U=No. of heat units.
C=No. of air changes per hour.
V=Volume in cu. ft. to be heated.
D=Degrees difference between temp. of outside air, and air in room.
55=Cu. ft. of air heated 1° by 1 heat unit.

Example—Let V=64,600; C=2; D=70°. Then,
B. T. U=64,600×2×70÷55=164,436.

TABLE 7

Approximate Heating Values of Various American Coals

Kind of Coal	Heating Value per Lb., in Heat Units
Anthracite—	
Northern coal field	13,160
East Middle coal field	13,420
West Middle coal field	12,840
Southern coal field	13,220
Semi-Bituminous—	
Broad Top, Pa.	14,820
Cambria County, Pa.	14,450
Cumberland, Md.	14,400
Pochantas, Va.	15,070
New River, W. Va.	15,220
Bituminous—	
Connellsville, Pa.	14,050
Pittsburgh, Pa.	13,410
Jackson County, Ohio	13,090
Hocking Valley, Ohio	12,130
Scott County, Tenn.	13,700
Big Muddy, Ill.	12,420
Mt. Olive, Ill.	10,490
Missouri	12,230

Loss of Heat due to window surface depends upon the kind of window, also the velocity of the wind. For present purposes, the average velocity of wind may be taken at 12½ miles per hour, at which rate the loss of heat per sq. ft. of single-thick common glass=1.09 B. T. U per degree of difference in temperature between outside and inside air. For double windows, the loss would be about half the above amount.

Example—Assume a "single window" surface of 300 sq. ft. Temp. difference=70°. What is the loss in heat units per hour through this window surface with a wind velocity of 12½ miles per hour? B. T. U.=1.09×300×70=22,890. Total loss in 2 hours=22,890×2=45,780 B. T. U.

Heat for Ventilation. In addition to losses of heat thus far listed, a large proportion of heat passes off with the air required for ventilation, which finds an outlet through the ventilating flues. This loss may be estimated by using Formula 2:

$$\text{B. T. U}=\frac{V\times D}{55}\qquad\text{(2)}$$

Where V=Volume of air passing per min., in cu. ft.
D=Difference in temp. between outside air, and air in ventilating flue.
55=Cu. ft. of air heated 1° by 1 heat unit.

Reference to Table 5 shows that 271 cu. ft. of air will escape per minute through a 6×12-in. flue 50 ft. high, when excess of temp. in flue is 50° above outside air. Assume two such flues for the building under discussion. Total volume of air escaping in this manner per hour, then, will=271×2×60=32,520 cu. ft. This would effect a change of air in the building in a little over 2 hours. Applying Formula 2, we have the following values: V=271 cu. ft.; D=50°. Then,

B. T. U.=271×2×60×50÷55=29,564.

Total loss in 2 hours=29,564×2=59,128 heat units.

Summing up we have:

Heat loss due to filtration through walls, etc.	164,436 B.T.U.
Heat loss through window surface	45,780 "
Heat loss due to ventilation	59,128 "
Total heat to be supplied each 2 hours	269,344 "

Prof. R. C. Carpenter, in "Heating and Ventilation of Buildings," gives the following general formula for finding number of heat units required per hour to replace losses.

$$h=(.02nC+G+\tfrac{1}{4}W)t,$$

where, n=Number of changes per hour;
C=Volume of room, in cu. ft.;
G=Area of window surface, in sq. ft.;
W=Area of exposed wall surface, in sq. ft.;
t=Difference in temp. outside and inside air.

Taking same building, let n=2; C=64,600 cu. ft.; G=300 sq. ft.; W=4,350 sq. ft.; and t=70 degrees. Then,

$$h=(64,600\times.02\times2+300+\frac{4,350}{4})\times70=278,040 \text{ B. T. U.}$$

These results agree very closely.

Considerable space has been devoted to an explanation of the use of the heat unit (B. T. U.) in calculations for sizes and capacities of heating plants, for the reason that by its use such calculations may be greatly simplified, and made to apply to any and all systems of heating. The heat required to heat a given sized building can be measured in heat units; likewise the heat units contained in a pound of any particular variety of coal can be ascertained. It is then an easy matter to make these two important factors balance each other by a correctly designed heating plant; one that has the capacity to burn the required weight of coal with the proper degree of combustion.

RADIATING SURFACE

Square feet of radiation required for steam or hot-water heating depends upon; (a) number of heat units required to produce, and maintain continuously the desired temperature in the room or rooms to be heated. (Rules and formula for calculating this have already been given.) (b) Kind of system employed, for heating. (c) Pressure carried. (d) Altitude above sea level. The last is an important factor, as, for instance, water at sea level boils at 212° F., while at an altitude of 500 ft. the boiling point is 211°; at 1,000 ft., 210°; and so on—thus decreasing in the ratio of 1° for each 500 ft. increase in altitude. At 10,000 ft. above sea level, water boils and steam is generated at a temperature of 192° F.

Since the number of heat units released per hour per sq. ft. of radiating surface depends upon the temperature of the heating medium within the radiator, it is evident that increase of altitude calls for either a proportionate increase of radiating surface, or a correspondingly higher pressure of steam.

Three kinds of radiation are in use—**direct, indirect, and direct-indirect.**

The term **radiating surface** means the number of sq. ft. of iron (wrought or cast) directly in contact with the heating medium (steam or hot water), assuming the iron to have a flat surface.

Tables 8 to 12 show sq. ft. of radiating surface per section in various sizes of cast-iron radiators. The total sq. ft.

in any size radiator given in the tables can easily be calculated from these tables, which have been supplied by the McCrum-Howell Co., of New York.

TABLE 8
Single-Column Radiator
Steam and Water

Width of section across top 5¼, and legs, 5 1/16 in. Width at middle, 4⅛ in.

Number of Sections	*Length 2½ Inches per Section.	HEATING SURFACE—SQUARE FEET						
		45 Inches High, 3½ Square Feet per Section.	38 Inches High, 3 Square Feet per Section.	32 Inches High, 2½ Square Feet per Section.	26 Inches High, 2 Square Feet per Section.	23 Inches High, 1⅔ Square Feet per Section.	20 Inches High, 1½ Square Feet per Section.	18 Inches High, 1½ Square Feet per Section.
2	5	7	6	5	4	3⅓	3	3
3	7½	10½	9	7½	6	5	4½	4½
4	10	14	12	10	8	6⅔	6	6
5	12½	17½	15	12½	10	8⅓	7½	7½
6	15	21	18	15	12	10	9	9
7	17½	24½	21	17½	14	11⅔	10½	10½
8	20	28	24	20	16	13⅓	12	12
9	22½	31½	27	22½	18	15	13½	13½
10	25	35	30	25	20	16⅔	15	15
11	27½	38½	33	27½	22	18⅓	16½	16½
12	30	42	36	30	24	20	18	18
13	32½	45½	39	32½	26	21⅔	19½	19½
14	35	49	42	35	28	23⅓	21	21
15	37½	52½	45	37½	30	25	22½	22½
16	40	56	48	40	32	26⅔	24	24
17	42½	59½	51	42½	34	28⅓	25½	25½
18	45	63	54	45	36	30	27	27
19	47½	66½	57	47½	38	31⅔	28½	28½
20	50	70	60	50	40	33⅓	30	30
21	52½	73½	63	52½	42	35	31½	31½
22	55	77	66	55	44	36⅔	33	33
23	57½	80½	69	57½	46	38⅓	34½	34½
24	60	84	72	60	48	40	36	36
25	62½	87½	75	62½	50	41⅔	37½	37½
26	65	91	78	65	52	43⅓	39	39
27	67½	94½	81	67½	54	45	40½	40½
28	70	98	84	70	56	46⅔	42	42
29	72½	101½	87	72½	58	48⅓	43½	43½
30	75	105	90	75	60	50	45	45
31	77½	108½	93	77½	62	51⅔	46½	46½
32	80	112	96	80	64	53⅓	48	48

*Add ½-inch for each bushing, to get total length measurement of radiator.

Rules for Estimating Radiating Surface

A simple rule ordinarily applicable to steam or hot-water heating systems is called the 2, 20, and 200 rule. This rule, when applied to steam heating, allows 1 sq. ft. of radiation

TABLE 9

Two-Column Radiator
Steam and Water

Width of section across top and legs, 8 3/16 in.; width at middle, 7⅛ in.

Number of Sections	*Length 2½ Inches per Section.	HEATING SURFACE—SQUARE FEET						
		45 Inches High, 5 Square Feet per Section.	38 Inches High, 4 Square Feet per Section.	32 Inches High, 3⅓ Square Feet per Section.	26 Inches High, 2⅔ Square Feet per Section.	23 Inches High, 2⅓ Square Feet per Section.	20 Inches High, 2 Square Feet per Section.	18 Inches High, 2 Square Feet per Section.
2	5	10	8	6⅔	5⅓	4⅔	4	4
3	7½	15	12	10	8	7	6	6
4	10	20	16	13⅓	10⅔	9⅓	8	8
5	12½	25	20	16⅔	13⅓	11⅔	10	10
6	15	30	24	20	16	14	12	12
7	17½	35	28	23⅓	18⅔	16⅓	14	14
8	20	40	32	26⅔	21⅓	18⅔	16	16
9	22½	45	36	30	24	21	18	18
10	25	50	40	33⅓	26⅔	23⅓	20	20
11	27½	55	44	36⅔	29⅓	25⅔	22	22
12	30	60	48	40	32	28	24	24
13	32½	65	52	43⅓	34⅔	30⅓	26	26
14	35	70	56	46⅔	37⅓	32⅔	28	28
15	37½	75	60	50	40	35	30	30
16	40	80	64	53⅓	42⅔	37⅓	32	32
17	42½	85	68	56⅔	45⅓	39⅔	34	34
18	45	90	72	60	48	42	36	36
19	47½	95	76	63⅓	50⅔	44⅓	38	38
20	50	100	80	66⅔	53⅓	46⅔	40	40
21	52½	105	84	70	56	49	42	42
22	55	110	88	73⅓	58⅔	51⅓	44	44
23	57½	115	92	76⅔	61⅓	53⅔	46	46
24	60	120	96	80	64	56	48	48
25	62½	125	100	83⅓	66⅔	58⅓	50	50
26	65	130	104	86⅔	69⅓	60⅔	52	52
27	67½	135	108	90	72	63	54	54
28	70	140	112	93⅓	74⅔	65⅓	56	56
29	72½	145	116	96⅔	77⅓	67⅔	58	58
30	75	150	120	100	80	70	60	60
31	77½	155	124	103⅓	82⅔	72⅓	62	62
32	80	160	128	106⅔	85⅓	74⅔	64	64

*Add ½ inch for each bushing, to get total length measurement of radiator.

to each 2 sq. ft. of glass and door surface in a room; 1 sq. ft. of radiation for each 20 sq. ft. of "exposed wall surface;" and 1 sq. ft. of radiation for each 200 cu. ft. of contents or air-space, it being understood that the temperature in the room is to be maintained at 70° while external temp. is 0°. For hot-water heating, add 60 per cent to amount of radiation as figured for steam; and when it is necessary to provide

TABLE 10
Three-Column Radiator
Steam and Water

Width of section across top and legs, 9⅞ in.; width at middle, 9 in.

Number of Sections	*Length 2½ Inches per Section.	HEATING SURFACE—SQUARE FEET: 45 Inches High, 6 Square Feet per Section.	38 Inches High, 5 Square Feet per Section	32 Inches High; 4½ Square Feet per Section.	26 Inches High, 3¾ Square Feet per Section.	23 Inches High, 3 Square Feet per Section.	20 Inches High, 2¾ Square Feet per Section.	18 Inches High 2¾ Square Feet per Section.
2	5	12	10	9	7½	6	5½	5½
3	7½	18	15	13½	11¼	9	8¼	8¼
4	10	24	20	18	15	12	11	11
5	12½	30	25	22½	18¾	15	13¾	13¾
6	15	36	30	27	22½	18	16½	16½
7	17½	42	35	31½	26¼	21	19¼	19¼
8	20	48	40	36	30	24	22	22
9	22½	54	45	40½	33¾	27	24¾	24¾
10	25	60	50	45	37½	30	27½	27½
11	27½	66	55	49½	41¼	33	30¼	30¼
12	30	72	60	54	45	36	33	33
13	32½	78	65	58½	48¾	39	35¾	35¾
14	35	84	70	63	52½	42	38½	38½
15	37½	90	75	67½	56¼	45	41¼	41¼
16	40	96	80	72	60	48	44	44
17	42½	102	85	76½	63¾	51	46¾	46¾
18	45	108	90	81	67½	54	49½	49½
19	47½	114	95	85½	71¼	57	52¼	52¼
20	50	120	100	90	75	60	55	55
21	52½	126	105	94½	78¾	63	57¾	57¾
22	55	132	110	99	82½	66	60½	60½
23	57½	138	115	103½	86¼	69	63¼	63¼
24	60	144	120	108	90	72	66	66
25	62½	150	125	112½	93¾	75	68¾	68¾
26	65	156	130	117	97½	78	71½	71½
27	67½	162	135	121½	101¼	81	74¼	74¼
28	70	168	140	126	105	84	77	77
29	72½	174	145	130½	108¾	87	79¾	79¾
30	75	180	150	135	112½	90	82½	82½
31	77½	186	155	139½	116¼	93	85¼	85¼
32	80	192	160	144	120	96	88	88

*Add ½ inch for each Bushing to get total length measurement of Radiator.

for a wider range of temperature, 1½ per cent of radiation should be added for each degree below zero.

"Exposed wall surface" means the entire outside surface of the room to be heated.

Square feet of radiation required for each room should be calculated separately.

To demonstrate above rule, take as an example the living room of a certain residence. First, assume window sur-

TABLE 11
Four-Column Radiator
Steam and Water

Width of section across top and legs, 13 in. Width at middle, 12 3/16 in.

Number of Sections	*Length 2½ Inches per Section.	HEATING SURFACE—SQUARE FEET						
		45 Inches High, 9 Square Feet per Section.	38 Inches High, 8 Square Feet per Section.	32 Inches High, 6⅔ Square Feet per Section.	26 Inches High, 5⅓ Square Feet per Section.	23 Inches High, 4⅔ Square Feet per Section.	20 Inches High, 3½ Square Feet per Section.	18 Inches High, 3½ Square Feet per Section.
2	5	18	16	13⅓	10⅔	9⅓	7	7
3	7½	27	24	20	16	14	10½	10½
4	10	36	32	26⅔	21⅓	18⅔	14	14
5	12½	45	40	33⅓	26⅔	23⅓	17½	17½
6	15	54	48	40	32	28	21	21
7	17½	63	56	46⅔	37⅓	32⅔	24½	24½
8	20	72	64	53⅓	42⅔	37⅓	28	28
9	22½	81	72	60	48	42	31½	31½
10	25	90	80	66⅔	53⅓	46⅔	35	35
11	27½	99	88	73⅓	58⅔	51⅓	38½	38½
12	30	108	96	80	64	56	42	42
13	32½	117	104	86⅔	69⅓	60⅔	45½	45½
14	35	126	112	93⅓	74⅔	65⅓	49	49
15	37½	135	120	100	80	70	52½	52½
16	40	144	128	106⅔	85⅓	74⅔	56	56
17	42½	153	136	113⅓	90⅔	79⅓	59½	59½
18	45	162	144	120	96	84	63	63
19	47½	171	152	126⅔	101⅓	88⅔	66½	66½
20	50	180	160	133⅓	106⅔	93⅓	70	70
21	52½	189	168	140	112	98	73½	73½
22	55	198	176	146⅔	117⅓	102⅔	77	77
23	57½	207	184	153⅓	122⅔	107⅓	80½	80½
24	60	216	192	160	128	112	84	84
25	62½	225	200	166⅔	133⅓	116⅔	87½	87½
26	65	234	208	173⅓	138⅔	121⅓	91	91
27	67½	243	216	180	144	126	94½	94½
28	70	252	224	186⅔	149⅓	130⅔	98	98
29	72½	261	232	193⅓	154⅔	135⅓	101½	101½
30	75	270	240	200	160	140	105	105
31	77½	279	248	206⅔	165⅓	144⅔	108½	108½
32	80	288	256	213⅓	170⅔	149⅓	112	112

*Add ½ inch for each Bushing to get total length measurement of Radiator.

face to approximate 46 sq. ft. Allowing 1 sq. ft. of radiation per 2 sq. ft. of glass will require 46 ÷ 2 = 23 sq. ft. of radiation to balance heat loss due to this source.

Second, as to exposed wall surface, assume dimensions of exposed wall to be 17 ft. along one side, and 15 ft. across the end. Ceiling is 10 ft. high. Then, 17+15×10=320 sq. ft. From this, deduct the 46 sq. ft. of glass and door surface, which will leave 320—46=274 sq. ft. of exposed wall

TABLE 12
Six-Column Radiator
Steam and Water

Width of section, 12¼ in. at top; at middle, 12 in.; and width across feet, 13 in.

Number of Sections	*Length 3 Inches per Section.	HEATING SURFACE—SQUARE FEET: 20 Inches High, 6 Square Feet per Section.	18 Inches High, 5⅓ Square Feet per Section.	16 Inches High, 4⅔ Square Feet per Section.	14 Inches High, 4 Square Feet per Section.	13 Inches High, 4 Square Feet per Section.
2	6	12	10⅔	9⅓	8	8
3	9	18	16	14	12	12
4	12	24	21⅓	18⅔	16	16
5	15	30	26⅔	23⅓	20	20
6	18	36	32	28	24	24
7	21	42	37⅓	32⅔	28	28
8	24	48	42⅔	37⅓	32	32
9	27	54	48	42	36	36
10	30	60	53⅓	46⅔	40	40
11	33	66	58⅔	51⅓	44	44
12	36	72	64	56	48	48
13	39	78	69⅓	60⅔	52	52
14	42	84	74⅔	65⅓	56	56
15	45	90	80	70	60	60
16	48	96	85⅓	74⅔	64	64
17	51	102	90⅔	79⅓	68	68
18	54	108	96	84	72	72
19	57	114	101⅓	88⅔	76	76
20	60	120	106⅔	93⅓	80	80
21	63	126	112	98	84	84
22	66	132	117⅓	102⅔	88	88
23	69	138	122⅔	107⅓	92	92
24	72	144	128	112	96	96
25	75	150	133⅓	116⅔	100	100
26	78	156	138⅔	121⅓	104	104
27	81	162	144	126	108	108
28	84	168	149⅓	130⅔	112	112
29	87	174	154⅔	135⅓	116	116
30	90	180	160	140	120	120
31	93	186	165⅓	144⅔	124	124
32	96	192	170⅔	149⅓	128	128

*Add ½ inch for each Bushing to get total length measurement of Radiator.

Allowing 1 sq. ft. of radiation for each 20 sq. ft. of exposed wall surface, calls for, 274÷20=14 sq. ft. of radiation to balance loss of heat due to this source.

Third, as to amount of radiation required for actual heating of the room. Dimensions of the room are 17 by 15 by 10 ft., which, multiplied together, show the volume to be 2,550 cu. ft. Allowing 1 sq. ft. of radiation for each 200 cu. ft. of contents, results in 2,550÷200=13 sq. ft. of radiation, which is the amount actually required to heat the cubic contents of this room.

This gives a total of 23+14+13=50 sq. ft. of radiation necessary to heat the room to 70° with steam at 2 lbs. pressure in zero weather.

Adding 60 per cent to 50 sq. ft. will give 80 sq. ft. as the amount of radiation required in case hot water, instead of steam, is used as the heating medium.

In making this estimate of radiation required for the living room, all fractions have been counted as 1 sq. ft., and the same plan may safely be followed in calculations for other rooms.

Table 13 serves to illustrate a practical method of estimating the total number of sq. ft. of radiation required for a 2-story residence building. The radiating surface required for each room is estimated separately. This table is cal-

TABLE 13

Schedule of Radiation

FIRST FLOOR

ROOMS	Sq. Ft. Glass	Sq. Ft. of Wall (Except Glass)	Contents (Cu. Ft.)	Sq. Ft. of Radiation, Steam	Per Cent Added for Hot Water	Sq. Ft. of Radiation, Hot-Water Heating
Vestibule	21	39	180	13	50	20
Reception Hall	33	221	2975	43	60	68
Living room	46	274	2550	50	60	80
Dining room	40	100	2560	38	60	61
Library	38	122	1490	32	60	51
Kitchen	28	192	1560	32	50	48
Toilet room	8	52	270	8	50	12
Pantry	14	116	400	15	50	23
SECOND FLOOR						
Family room	35	190	1350	35	60	56
Family bedroom	33	66	1098	25	50	38
Alcove	15	120	504	17	50	26
Guest room	25	128	1521	27	50	41
Chamber	18	125	1350	22	50	33
Servants' room	18	153	810	22	55	34
Hall	24	147	945	24	50	36
Bathroom	8	46	486	10	70	17
Totals in Sq. Ft.				413		644

culated on the basis of the 2, 20, and 200 rule. The dimensions of the different rooms are not given, as these factors are easily obtained by measuring the rooms. The table is given as a guide to be followed by the estimator in calculating the heating surface necessary in each room. The "range of temperature" is assumed to be 70°—that is, interior air to be 70°, with an outside temperature of zero. The figures given are adapted to the use of any standard make of cast-iron radiator.

Another rule, which may be termed a "rule of thumb," giving an approximate estimate of the sq. ft. of radiation required for heating various types of buildings, is condensed in Table 14. The numbers given represent the cu. ft. of air in the room or building that 1 sq. ft. of radiation will heat. These numbers are to be used as constants for dividing the cubic contents of the room, the quotient showing the sq. ft. of radiation required.

TABLE 14

Approximate Heating Capacity of 1 Sq. Ft. of Radiation

	Cu. Ft.
Living room, with large glass exposures (2 or 3 windows)	40
Bath room under same conditions	40
Living room with large glass surface (1 or 2 exposures)	50
Living room with fair amount of glass (1 exposure)	60
Sleeping rooms	55 to 70
Halls	50 to 70
Schoolrooms	60 to 80
Churches and public Assembly Halls	65 to 100
Factories and Shops	75 to 150

Example—Living room with large glass surface (1 or 2 exposures.) Contents in cu. ft. = 2,550. Sq. ft. of radiation required = 2,550 ÷ 50 = 51 sq. ft.

This result is practically the same as that shown in Table 13, where 50 sq. ft. is given as the amount of radiation required for the same room.

These rules are given for **direct** steam radiation, steam at 2 lbs. gauge pressure, which is the usual rating; and difference between temperatures of steam in radiators and air in rooms ranging from 140° to 150°.

For **indirect** radiation, add 25 per cent, and for **direct-indirect**, add 50 per cent, to sq. ft. of radiation. If hot water is used as the heating medium, add 33⅓ per cent to sq. ft. of radiation required for direct steam.

Baldwin's rule for estimating the radiating surface required is adapted to the various conditions of pressure and temperature encountered in steam, or hot-water heating. This rule is as follows:

Divide the difference between the temperature at which the room is to be kept and the coldest outside temperature, by the difference between the temperature of the steam in the radiator and that at which the air in the room is to be kept. The quotient will be the sq. ft. of radiating surface to be allowed for each sq. ft. of equivalent glass surface.

By "equivalent glass surface" is meant the wall surface divided by 4, plus the glass surface.

In using these various rules, certain factors called **factors for exposure** are to be used. For instance, 20 to 30 per cent should be added when the room or building has a north or

TABLE 15

Properties of Steam for Heating

Radiation based upon capacity of direct-acting 3-column cast-iron radiator. Pressures and temperature shown are calculated for altitudes not higher than 500 feet above sea level.

Gauge Pressure at Boiler (Lbs. per Sq. In.)	Temp. of Steam in Boiler (Degrees F.)	Temp. of Steam in Radiator (Degrees F.)	Heat Units Transmitted per Sq. Ft. of Radiation per Hour	Degrees Difference between Temp. of Radiator and Temp. of Air in Room
0	212	201	216	131
1	215	204	218	134
2	219	208	220	138
3	222	210	224	140
4	224	212	227	142
5	227	215	232	145
6	229	220	239	150
7	234	223	244	153
8	235	224	246	154
9	237	226	247	156
10	240	228	251	158
11	242	230	253	160
12	244	232	255	162
15	249	239	270	169
20	259	247	295	177
25	267	258	310	188
30	275	266	333	196

northwestern exposure, and the winds are severe. For a building heated only in the day time, and permitted to cool at night, add 20 per cent; for a building heated only occasionally—as, for instance, a church or assembly hall—add 40 to 50 per cent.

Pressures and Temperatures

In all calculations for size and capacity of a steam heating system, the pressure under which the system is to be operated must be taken into account if accurate results are desired.

Table 15 shows pressures and temperatures of steam at various stages from 0 up to 30 lbs. The same table shows number of heat units transmitted per hour per sq. ft. of radiation, at the various temperatures.

Temperature of air in room is assumed to be 70°. No reference to outside temperature.

The use of Table 15 for estimating required sq. ft. of radiation necessitates the use of the heat unit. Such calculations will give more accurate results, and are also better adapted to all conditions of pressure and temperature.

Knowing the total loss in heat units per hour from the building, the sq. ft. of radiation required to balance this loss may be easily calculated for any of the pressures given in the table, by the following rule (assuming radiation to be direct):

Divide total loss in heat units per hour from the building, by the number of heat units transmitted per hour per sq. ft. of radiating surface at the difference in temperature between air in building and steam in radiators. As an example, take the building previously referred to, in which total heat loss from all sources in 2 hours' time was found to be 269,344 B. T. U. One-half of this number, $\frac{269,344}{2} = 134,672$, the number of heat units lost per hour, which must be supplied direct from the radiators.

Assuming gauge pressure at boiler to be 2 lbs., how many sq. ft. of radiation will be required to balance this loss? Reference to Table 15 shows that with boiler pressure at 2 lbs. gauge; and a difference of 138° between temperature of air in room and of steam in radiator, there will be 220 heat units transmitted per hour per sq. ft. of radiating surface. Therefore, total heating surface required will be:

$$\frac{134{,}672}{220} = 613 \text{ sq. ft.}$$

Estimated by the 2, 20, and 200 rule, the amount of radiation required is 78 sq. ft. more, as shown by the following calculation:

Assume, glass and door surface = 300 sq. ft.
exposed wall surface = 4,350 sq. ft.
cubic contents =64,600 cu. ft.

Then radiation required will be as follows:

$$\text{For glass and door surface} = \frac{300}{2} = 150 \text{ sq. ft.}$$

$$\text{For exposed wall surface} = \frac{4{,}350}{20} = 218 \text{ sq. ft.}$$

TABLE 16

Length of Pipe Giving One Square Foot of Radiating Surface

Size of Pipe	Length per sq. ft.	Size of Pipe	Length per sq. ft.
1 inch	36 inches	3½ inch	12 inches
1¼ inch	28 inches	4 inch	11 inches
1½ inch	24 inches	4½ inch	10 inches
2 inch	20 inches	5 inch	9 inches
2½ inch	16 inches	6 inch	8 inches
3 inch	13 inches	8 inch	6 inches

TABLE 17

Expansion of Wrought-Iron Pipe

Temperature of the Air when the Pipe is Fitted.	Length of Pipe when Fitted.	Length when Heated to the Temperatures Indicated Below.						
		160°	180°	200°	215° 1 Lb. Steam.	265° 25 Lbs. Steam.	297° 50 Lbs. Steam.	338° 100 Lbs. Steam.
Deg. Fahr.	Ft.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
Zero (0°)	100	100+1.28	100+1.44	100+1.60	100+1.72	100+2.12	100+2.31	100+2.70
32	100	100+1.02	100+1.18	100+1.34	100+1.47	100+1.78	100+2.12	100+2.45
64	100	100+ .77	100+ .93	100+1.09	100+1.21	100+1.61	100+1.87	100+2.19

For cubic contents $= \frac{64,600}{200} = 323$ sq. ft.

Total radiation required $= 691$ sq. ft.

TABLE 18.

Square Feet of Radiating Surface of Pipe per Linear Foot.

On all lengths over 1 ft., fractions less than tenths are added to, or dropped.

Length of Pipe (in feet)	SIZE OF PIPE ¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.
1	.275	.346	.434	.494	.622	.753
2	.5	.7	.9	1.	1.2	1.5
3	.8	1.	1.3	1.5	1.9	2.3
4	1.1	1.4	1.7	2.	2.5	3.
5	1.4	1.7	2.2	2.4	3.1	3.8
6	1.6	2.1	2.6	2.9	3.7	4.5
7	1.9	2.4	3.	3.4	4.4	6.3
8	2.2	2.8	3.5	3.9	5.	6.
9	2.5	3.1	3.9	4.4	5.6	6.8
10	2.7	3.5	4.3	4.9	6.2	7.5
11	3.	3.8	4.8	5.4	6.8	8.3
12	3.3	4.1	5.2	5.9	7.5	9.
13	3.6	4.5	5.6	6.4	8.1	9.8
14	3.8	4.8	6.1	6.9	8.7	10.5
15	4.1	5.2	6.5	7.4	9.3	11.3
16	4.4	5.5	6.9	7.9	10.	12.
17	4.7	5.9	7.4	8.4	10.6	12.3
18	5.	6.2	7.8	8.9	11.2	13.5
19	5.2	6.6	8.3	9.4	11.8	14.3
20	5.5	6.9	8.7	9.9	12.5	15.
21	5.8	7.3	9.1	10.4	13.	15.8
22	6.	7.6	9.6	10.9	13.7	16.5
23	6.3	8.	10.	11.3	14.3	17.3
24	6.6	8.3	10.4	11.9	14.9	18.
25	6.9	8.6	10.9	12.3	15.6	18.8
26	7.1	9.	11.3	12.8	16.2	19.5
27	7.4	9.4	11.7	13.3	16.8	20.3
28	7.7	9.7	12.2	13.8	17.4	21.
29	8.	10.	12.6	14.3	18.	21.8
30	8.3	10.4	13.	14.8	18.7	22.5
31	8.5	10.7	13.5	15.3	19.3	23.3
32	8.8	11.1	13.9	15.8	19.9	24.1
33	9.1	11.4	14.3	16.3	20.5	24.8
34	9.4	11.7	14.7	16.8	21.2	25.6
35	9.6	12.1	15.2	17.3	21.8	26.3
36	9.9	12.5	15.6	17.8	22.4	27.
37	10.2	12.8	16.1	18.3	23.	27.8
38	10.5	13.2	16.5	18.8	23.7	28.5
39	10.7	13.5	16.9	19.3	24.3	29.3
40	11.	13.8	17.4	19.8	24.9	30.1
41	11.3	14.2	17.8	20.3	25.5	30.8
42	11.5	14.5	18.2	20.8	26.1	31.6
43	11.8	14.9	18.7	21.3	26.8	32.3
44	12.1	15.2	19.1	21.8	27.4	33.1
45	12.4	15.6	19.5	22.2	28.	33.8
46	12.7	15.9	20.	22.7	28.6	34.6
47	12.9	16.3	20.4	23.2	29.2	35.3
48	13.2	16.6	20.8	23.7	29.9	36.1
49	13.5	17.	21.3	24.2	30.5	36.8
50	13.8	17.3	21.7	24.7	31.1	37.6

TABLE 18—(Concluded)

Length of Pipe (in Feet)	SIZE OF PIPE					
	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.
1	.916	1.175	1.455	1.739	1.996	2.25
2	1.8	2.4	2.9	3.5	4.	4.5
3	2.7	3.5	4.4	5.2	6.	6.8
4	3.6	4.7	5.8	7.	7.	9.
5	4.6	5.8	7.3	7.7	10.	11.3
6	5.5	7.	8.7	10.5	12.	13.5
7	6.4	8.2	10.2	12.1	14.	15.8
8	7.3	9.4	11.6	13.9	16.	18.
9	8.2	10.6	13.1	15.7	18.	20.3
10	9.1	11.8	14.6	17.4	20.	22.6
11	10.	12.9	16.	19.1	22.	24.9
12	11.	14.1	17.4	20.9	24.	27.1
13	11.9	15.3	18.9	22.6	26.	29.4
14	12.8	16.5	20.3	24.3	28.	31.6
15	13.7	17.6	21.8	26.1	30.	33.9
16	14.6	18.8	23.2	27.8	32.	36.1
17	15.5	20.	24.7	29.5	34.	38.4
18	16.5	21.2	26.2	31.3	36.	40.6
19	17.4	22.3	27.6	33.1	38.	42.9
20	18.3	23.5	29.1	34.8	40.	45.2
21	19.2	24.7	30.5	36.5	42.	47.4
22	20.2	25.9	32.	38.3	44.	49.7
23	21.1	27.	33.5	40.	46.	52.
24	22.	28.2	34.9	41.7	48.	54.2
25	22.9	29.3	36.4	43.5	50.	56.4
26	23.8	30.5	37.8	45.2	52.	58.6
27	24.7	31.7	39.3	47.	54.	61.
28	25.6	32.9	40.7	48.7	56.	63.2
29	26.6	34.1	42.2	50.4	58.	65.5
30	27.5	35.3	43.6	52.1	60.	67.7
31	28.4	36.4	45.1	53.9	62.	70.
32	29.3	37.6	46.5	55.6	64.	72.2
33	30.2	38.8	48.	57.4	66.	74.4
34	31.1	40.	49.5	59.1	68.	76.7
35	32.	41.1	50.9	60.8	70.	79.
36	33.	42.3	52.4	62.6	72.	81.3
37	33.9	43.5	53.8	64.3	74.	83.5
38	34.8	44.6	55.2	66.	76.	85.8
39	35.7	45.8	56.7	67.8	78.	88.
40	36.6	47.	58.2	69.5	80.	90.2
41	37.6	48.2	59.6	71.3	82.	92.5
42	38.5	49.4	61.1	73.	84.	94.8
43	39.4	50.6	62.5	74.8	86.	97.
44	40.3	51.7	64.	76.5	88.	99.3
45	41.2	52.9	65.5	78.2	90.	101.6
46	42.2	54.	67.	80.	92.	103.8
47	43.	55.2	68.4	81.7	94.	106.
48	43.9	56.4	69.8	83.5	96.	108.4
49	44.8	57.6	71.2	85.1	98.	110.5
50	45.8	58.7	72.7	87.	100.	112.8

The difference between the two results is only 691—613= 78 sq. ft., proving that the 2, 20, and 200 rule is a safe one to follow.

PIPE AND FITTINGS

Table 16 shows length of pipe of different sizes required to furnish 1 sq. ft. of radiating surface.

The data given in Table 18 are useful chiefly in the designing of pipe coils for heating factories and similar buildings. As an example, assume a space in one corner of a factory building which requires to be heated by a 5-pipe corner coil, one branch of which is to be 10 ft. and the other branch 15 ft. long. The dimensions of the space to be heated are about as follows: Width, 16 ft.; length, 25 ft.; height, 16 ft.

Cubic contents of space to be heated will be 16×25×16= 6,400 cu. ft. What size of pipe should be used in building the coil?

Since the number and length of pipes in each branch of the coil are restricted to certain figures, first find total length of pipe to be used, size of pipe to be 1½-in.

1 branch, 5 pipes 10 ft. long = 50 ft.
1 branch, 5 pipes 15 ft. long = 75 ft.

Total = 125 ft.

TABLE 19

Size of Main for Single-Pipe Steam Heating—Direct Radiation

For Indirect Radiation the mains should be 1½ times larger than for direct radiation.

Sq. Ft. of Radiation	Length of Main, in Feet						Return
	20	40	80	100	200	300	
	Size of Pipe, in Inches						
100	1	1	1¼	1¼	1½	1½	Return, one size smaller than flow pipe.
200	1	1½	1½	1½	2	2	
300	1½	1½	2	2	2	2½	
400	1½	2	2	2	2½	2½	
500	1½	2	2½	2½	2½	3	
600	2	2	2½	2½	3	3	
700	2	2	2½	2½	3	3	
800	2	2½	2½	3	3½	3½	
1000	2½	2½	3	3	3½	4	
1200	2½	2½	3	3½	4	4	
1400	2½	3	3½	3½	4	4½	
1600	3	3	3½	3½	4	4½	
1800	3	3	3½	4	4½	5	
2000	3	3½	4	4	4½	5	
2500	3½	4	4	4½	5	5½	
3000	3½	4	4½	5	5½	6	
3500	4	4½	5	5½	6	7	
4000	4	4½	5	5½	6	7	

Reference to Table 18 shows that in 10 ft. of 1½-in. pipe there are 4.9 sq. ft. of radiating surface; then radiating surface in 10-ft. branch = 4.9 × 5 = 24.5 sq. ft.

Sq. ft. of surface in 15 ft. of 1½-in. pipe = 7.4; then radiating surface in 15 ft. branch = 7.4 × 5 = 37 sq. ft.

Total radiating surface in two branches = 24.5 + 37 = 61.5 sq. ft.

By referring to Table 14, it will be seen that for heating factories and shops 1 sq. ft. of radiation is allowed for each 75 to 150 cu. ft. of space to be heated. As there are 6,400 cu. ft. of space to be heated, and 61.5 sq. ft. of radiating surface, the number of cu. ft. per sq. ft. of radiation $= \frac{6,400}{61.5} = 104$, which is a good average.

Direct Hot-Water Radiation for Zero Weather. Table 20 shows number of cu. ft. of space heated by 1 sq. ft. of direct radiation.

Low-Pressure Steam Heating

There are two systems of low pressure steam heating in common use—the **one-pipe** and the **two-pipe** systems.

Heating Greenhouses. The glass exposure is practically the sole cause of heat loss. Assume a greenhouse 100 ft. long by 20 ft. wide; it will contain about 2,600 sq. ft. of glass. To heat this greenhouse to a temperature of 50° to 60° will require 1 sq. ft. of radiation to 3 sq. ft. of glass, or $\frac{2,600}{3}$

TABLE 20

Hot-Water Heating—Direct Radiation

RESIDENCE BUILDINGS	Cu. Ft. of Space Heated by 1 Sq. Ft. of Direct Radiation
Living rooms, one side exposed	25 to 30
Living rooms, two sides exposed	25 to 27
Living rooms, three sides exposed	20 to 25
Sleeping rooms	30 to 35
Halls and bathrooms	20 to 30
Vestibule	35 to 40
PUBLIC BUILDINGS	
Offices	30 to 40
Schoolrooms	30 to 40
Factories and stores	40 to 60
Assembly halls and churches	60 to 100

= 866 sq. ft. of radiating surface. This will require 866 linear feet of 4-in. pipe, or 946 ft. of 3-in. pipe, or 1,060 ft. of 2½-in. pipe, or 1,485 ft. of 2-in. pipe, or 1,730 ft. of 1½-in. pipe. These figures are obtained from Table 22, which gives the factors for ascertaining amount of surface needed with any size pipe from 1½-in. to 4-in.

TABLE 21
Indirect Hot-Water Heating Data

Ft. of Heating Surface (Water)	Area of Cold-Air Supply (Sq. In.)	Area of Hot-Air Flue (Sq. In.)	Size of Register (In.)
26	36	48	8x12
52	54	72	9x12
78	72	96	10x12
104	90	120	12x15
130	108	144	12x19
156	126	168	14x22
182	144	192	14x24
208	162	216	16x20
234	180	240	16x24
260	198	264	20x20
286	216	288	20x24
312	234	312	20x24

TABLE 22
Heating of Greenhouses

For Zero Weather	Temp. of House 50° to 60°	Temp. of House 60° to 70°
Sq. ft. of glass heated by 1 sq. ft. of surface	3	2.25
Sq. ft. of glass heated by 1 linear ft. of 4-in. pipe	3	2.25
Sq. ft. of glass heated by 1 linear ft. of 3-in. pipe	2.75	2.10
Sq. ft. of glass heated by 1 linear ft. of 2½-in. pipe	2.25	1.80
Sq. ft. of glass heated by 1 linear ft. of 2-in. pipe	1.75	1.30
Sq. ft. of glass heated by 1 linear ft. of 1½-in. pipe	1.50	1.20

In measuring glass surface, take actual glass, and its equivalent in outside wall or exposed surface.

For heating ordinary greenhouses, 2-in. wrought-iron pipe will give the most satisfactory results. For heating green-

TABLE 23

Size of Mains to be Used for Different Distances from the Boiler—Hot Water Heating

Sq. Feet Radiation	At Heater	15 Feet	30 Feet	45 Feet	60 Feet	75 Feet	90 Feet	100 Feet
50	1	1	1¼	1¼	1¼	1¼	1¼	1¼
75	1¼	1¼	1¼	1¼	1¼	1¼	1½	1½
100	1½	1½	1½	1½	1½	1½	1½	2
150	1½	2	2	2	2	2	2	2
200	2	2	2½	2½	2½	2½	2½	2½
300	2½	2½	2½	2½	2½	3	3	3
400	2½	2½	3	3	3	3	3	3
500	3	3	3	3	3	3½	3½	3½
600	3	3	3½	3½	3½	3½	3½	4
700	3½	3½	3½	3½	4	4	4	4
800	3½	3½	4	4	4	4	4½	4½
900	3½	4	4	4	4	4½	4½	4½
1000	4	4	4	4½	4½	4½	4½	4½
1200	4	4	4½	4½	5	5	5	5
1500	4½	4½	5	5	5	6	6	6
2000	5	6	6	6	6	6	7	7
2500	6	6	6	6	7	7	7	7
3000	6	6	7	7	7	7	8	8
3500	6	7	7	7	8	8	8	8
4000	6	7	7	8	8	8	8	9
5000	7	8	8	8	9	9	10	10

The above table will be a guide to the fitter in proportioning mains and branches for hot water.

houses having less than 2,000 sq. ft. of glass, hot water is recommended. For large greenhouses, steam is best.

The same general plan of piping may be used for steam as for hot water, except that, for steam, one-third less surface will be sufficient to produce the desired heat.

Table XXV is a comparison of the one pipe, and two pipe systems of steam heating.

TABLE 24

Pressure of Water in Pounds Due to Height in Feet

Feet Head	Pressure per Sq. In.	Feet Head	Pressure per Sq. In.	Feet Head	Pressure per Sq. In.
1	0.43 lbs.	35	15.16 lbs.	70	30.32 lbs.
5	2.16 "	40	17.32 "	75	32.48 "
10	4.33 "	45	19.49 "	80	34.65 "
15	6.49 "	50	21.65 "	85	36.82 "
20	8.66 "	55	23.82 "	90	38.98 "
25	10.82 "	60	25.99 "	95	41.15 "
30	12.99 "	65	28.15 "	100	43.31 "

TABLE 25

Amount of Direct Radiation that a Main Will Supply in One-Pipe and Two-Pipe Steam Heating

Amount of Direct Radiation Sq. Ft.	One-Pipe Work In.	Two-Pipe Work In.
40 to 50	1	¾ x ¾
100 to 125	1¼	1 x ¾
125 to 250	1½	1¼ x 1
250 to 400	2	1½ x 1¼
400 to 650	2½	2 x 1½
650 to 900	3	2½ x 2
900 to 1250	3½	3 x 2½
1250 to 1600	4	3½ x 3
1600 to 2050	4½	4 x 3½
2050 to 2500	5	4½ x 4
2500 to 3600	6	5 x 4½
3600 to 5000	7	6 x 5
5000 to 6500	8	7 x 6
6500 to 8100	9	8 x 6
81000 to 100000	10	9 x 6

In hot-water heating systems the relative sizes of the flow and return pipes should be the same. Table 26 shows the number of sq. ft. of radiation that can be supplied by hot-water mains in sizes from 1½-in. to 6-in. The smallest size pipe that is practicable in hot-water heating is 1½-in.

TABLE 26

Sizes of Hot-Water Mains, and Amount of Radiation Supplied

Sizes of Mains	Amount of Radiation Supplied
1½-in.	125 to 175 sq. ft.
2-in.	175 to 300 sq. ft.
2½-in.	300 to 475 sq. ft.
3-in.	475 to 700 sq. ft.
3½-in.	700 to 950 sq. ft.
4-in.	950 to 1,200 sq. ft.
4½-in.	1,200 to 1,575 sq. ft.
5-in.	1,575 to 1,975 sq. ft.
5½-in.	1,975 to 2,375 sq. ft.
6-in.	2,375 to 2,850 sq. ft.

FITTINGS FOR STEAM AND HOT-WATER PIPES

Long-turn or long-radius fittings will greatly aid circulation and reduce friction in a system of piping, and should be used wherever possible, especially in hot-water heating.

A steam main should have a pitch of at least ½-in. for

TABLE 27

Number and Sizes of Branches that Mains Will Supply

Sizes of Mains	Number and Sizes of Branches
1-in.	2—¾-in. branches
1¼-in.	2—1-in. branches
1½-in.	2—1¼-in branches
2-in.	2—1½-in. branches
2½-in.	2—1½-in. and 1—1¼ in. branches
2½-in.	1—2-in. and 1—1¼-in. branch
3-in.	1—2½-in. and 1—2-in. branch
3-in.	2—2-in. and 1—1½-in. branches
3½-in.	2—2½-in. branches
3½-in.	1—3-in. and 1—2-in. branch
3½-in.	3—2-in. branches
4-in.	1—3½-in. and 1—2½-in. branch
4-in.	2—3-in. branches
4-in.	4—2-in. branches
4½-in.	1—3½-in. and 1—3-in. branch
4½-in.	1—4-in. and 1—2½-in. branch
4½-in.	6—2-in. branches
5-in.	1—4-in. and 1—3-in. branch
5-in.	1—4½-in. and 1—2½-in. branch
5-in.	8—2-in. branches
6-in.	1—3-in. and 2—4-in. branches
6-in.	4—3-in. branches
6-in.	10—2-in. branches
7-in.	1—6-in. and 1—4-in. branch
7-in.	3—4-in. and 1—2-in. branches
8-in.	2—6-in. and 1—5-in. branches
8-in.	5—4-in. and 2—2-in. branches

TABLE 28

Sizes of Drip-Pipes for Mains of Various Lengths

Sizes of Steam Mains	Length of Steam Main, in Feet			
	1 to 100	100 to 200	200 to 400	400 to [illegible]
	Size of Drip Pipe			
0 to 2-in.	½-in.	½-in.	½-in.	¾-in.
3-in.	½-in.	¾-in.	¾-in.	1 -in.
4-in.	¾-in.	¾-in.	1 -in.	1¼-in.
5-in.	¾-in.	1 -in.	1¼-in.	1½-in.
6-in.	1 -in.	1¼-in.	1½-in.	1½-in

every 10 ft. of length; and branches should have a pitch of 1 in. for every 5 linear ft.

Care should be exercised to secure as near a perfect alignment as possible in the running of pipes; and pockets should be avoided.

When absolutely necessary to make a direct rise for the purpose of increasing head-room, or to pass an obstruction, a small **bleeder pipe**, ⅜-in. or ½-in., should be tapped into the lowest point of the pocket thus formed in order to carry off the condensation.

A check-valve should always be placed in the return, near the boiler, when radiators are located near the water level of the boiler. If the water level of the boiler shows a disposition to fluctuate, it may be kept steady by connecting a pipe called an **equalizing pipe** from the steam dome, or top of the boiler to one of the return openings, below the water line of the boiler; or it can be connected to the main, near the boiler, and tapped into the return pipe near its entrance into the boiler. Check-valves should always be located in the horizontal portion of the return, and as near the boiler as possible.

Branches should be taken from the top of the main, or they may be taken at an angle of 45°. They should be run with a pitch up from main to riser.

Where reductions in size of main are made, **eccentric tees or couplings** should be used. If this is not done, it will be necessary to run **heel-drips** from each reduction to the wet return.

Main return for a two-pipe system should increase in size as branch returns enter it. It should be maintained one size smaller than the supply pipe corresponding.

When a drip is connected into a **dry return, a loop or trap** should be inserted to prevent short-circuiting of the steam, which would block return water.

This precaution is not necessary with **wet returns**. Table 27 shows the number and sizes of branches that a main of a given size will supply.

Doubling the diameter of a pipe increases its capacity four times.

The sizes of drip pipes required for steam depend not alone upon the size of main to be dripped, but also upon the length, as may be seen by reference to Table 28.

Expansion Tanks

In hot-water heating systems, an **expansion tank** should always be provided, for the reason that when the water has reached boiling point (212° F.) it has also increased in volume so that it occupies a space 5 per cent greater than it did at 40°.

The expansion tank should have a capacity sufficient to contain from 1/20 to 1/30 of the total volume of water contained in the entire system, and it should be located, if possible, where there is no danger from freezing.

It should be placed at such a height as to bring the bottom of the tank at least 24 in. above the highest radiator in the system.

If there is no increase in pressure due to expansion, a vent-pipe may be run from the tank, connecting its highest point with the outside air. The pressure on the heating system will then depend upon the height of the water level in the tank, each foot in height corresponding to .43 lb. pressure per sq. in.

These tanks should be made of boiler steel, double-riveted, caulked, and galvanized, and tested to 200 lbs. hydraulic pressure. They should be tapped, top and bottom, for 1-in. overflow and expansion pipe, the latter to be connected to the system in such a manner as to conduct the surplus water into the bottom of the tank. A 1-in. connection for a filling attachment should be made on the side, near the top of tank, and a 12-in. water gauge glass should be connected on the side near the bottom.

If it is desired to maintain a pressure in excess of atmospheric pressure, the vent-pipe may be closed, and a safety-valve attached which will open when the pressure reaches the desired point.

TABLE 29

Dimensions and Capacities of Expansion Tanks

Size (Inches)	Capacity (Gallons)	Square Feet of Radiation
10x20	8	250
12x20	10	300
12x30	15	500
14x30	20	700
16x30	26	950
16x36	32	1,300
16x48	42	2,000
18x60	66	3,000
20x60	82	5,000
22x60	100	6,000

A slight increase in pressure on the system will also increase the boiling temperature of the water, thus making it possible to maintain a higher temperature throughout the entire system. For instance, at 5 lbs. pressure, the temperature at boiling point is 228°; and at 10 lbs. pressure, boiling temperature is 240°. Table 29 gives the dimensions in inches, and capacity in gallons, of expansion tanks for various amounts of hot-water radiation.

The capacity, in gallons, of any size cylindrical tank may be found by the following simple rule: Square the diameter of the tank, in inches; then multiply by length of tank, in inches, and this product by the constant .0034. Result = No. of U. S. gallons.

Pipe Coverings

The amount of heat losses that take place from uncovered steam or hot-water mains, has already been discussed. All losses of this character may be prevented, in large measure, by the use of a **good pipe covering**, thus effecting a saving in cost of fuel, and in many instances making it possible to use a smaller size of boiler. All piping in the boiler room should be covered; also all distributing pipes, except radiator connections. Results of tests made by Prof. Cooley, of the University of Michigan, show that, for pres-

TABLE 30

Relative Insulating Values of Various Pipe Coverings

MATERIAL OF COVERING	Thickness of Covering (Inches)	Relative Insulating Value
Non-Sectional Coverings—		
Two layers asbestos paper, 1 in. hair felt, and 1 thickness of canvas	....	1.000
Two layers asbestos paper	....	.263
Sectional Coverings—		
Mineral wool	.94	.952
Asbestos sponge	1.12	.920
Asbestos felt	1.35	.923
Hair felt	1.45	.960
Molding Coverings—		
Asbestos	1.23	.803
Magnesia	.94	.915
Magnesia and asbestos	1.12	.879
Asbestos and wool felt	1.12	.910
Wool felt	1.16	.904
Wool felt and iron with air-space	....	.828

TABLE 31

Standard Dimensions of Wrought-Iron Welded Steam, Gas and Water Pipe

*Diameter.				Circumference							
Nominal Internal, inches.	Actual External, inches.	Actual Internal, inches.	Thickness, inches.	External, inches.	Internal, inches.	Internal Area, square inches.	Length of Pipe Per Square Foot of External Surface, feet.	Square Feet of Surface Per Foot in Length.	Nominal Weight Per Foot, pounds.	Number of Threads Per Inch of Screw.	Inside Diameter, inches.
1/8	.405	.27	.068	1.272	.848	.0578	9.44	.106	.24	27	1/8
1/4	.54	.364	.088	1.696	1.144	.1041	7.075	.141	.42	18	1/4
3/8	.675	.494	.091	2.121	1.552	.1917	5.657	.177	.56	18	3/8
1/2	.84	.623	.109	2.639	1.957	.3048	4.547	.220	.84	14	1/2
3/4	.105	.824	.113	3.299	2.589	.5333	3.637	.275	1.12	14	3/4
1	1.315	1.049	.134	4.131	3.292	.8626	2.904	.344	1.67	11 1/2	1
1 1/4	1.66	1.38	.14	5.215	4.335	1.496	2.301	.434	2.24	11 1/2	1 1/4
1 1/2	1.9	1.611	.145	5.969	5.061	2.038	2.01	.497	2.68	11 1/2	1 1/2
2	2.375	2.067	.154	7.461	6.494	3.356	1.608	.621	3.61	11 1/2	2
2 1/2	2.875	2.468	.204	9.032	7.753	4.784	1.328	.753	5.74	8	2 1/2
3	3.5	3.067	.217	10.996	9.636	7.388	1.091	.916	7.54	8	3
3 1/2	4.	3.548	.226	12.566	11.146	9.887	.955	1.047	9.	8	3 1/2
4	4.5	4.026	.237	14.137	12.648	12.73	.849	1.178	10.66	8	4
4 1/2	5.	4.508	.246	15.708	14.162	15.961	.764	1.309	12.49	8	4 1/2
5	5.563	5.045	.259	17.477	15.849	19.99	.687	1.456	14.5	8	5
6	6.625	6.065	.28	20.813	19.054	28.888	.577	1.734	18.76	8	6
7	7.625	7.023	.301	23.955	22.063	38.738	.501	1.996	23.27	8	7
8	8.625	7.982	.322	27.096	25.076	50.04	.443	2.256	28.18	8	8
9	9.625	8.937	.344	30.238	28.076	62.73	.397	2.520	33.7	8	9
10	10.75	10.019	.366	33.772	31.477	78.839	.355	2.814	40.	8	10
11	11.75	11.	.375	36.914	34.558	95.033	.325	3.076	45.	8	11
12	12.75	12.	.375	40.055	37.7	113.098	.299	3.338	49.	8	12

sures under 5 lbs., **hair felt** is the most effective non-conductor; but when used for higher pressures, it chars, and breaks down. The same may be said of **wool felt coverings.**

Table 30 shows the relative insulating value of various kinds of pipe covering, taking a covering composed of asbestos paper, hair felt, and canvas as a standard.

It should be noted that if the material composing the covering is a good conductor, its heat-insulating power is lessened by increasing the thickness beyond a certain limit.

Table 32 is for the purpose of estimating the number of smaller size pipes that will be required to equal in capacity a pipe of larger size. For instance, take a 1-in. pipe. How many pipes of this size will be required to equal in capacity one 3½-in. pipe?

Starting at the left-hand column in the table, under the heading "Size of Pipe," trace in a horizontal direction from "1-in." toward the right, until, under the heading "3½-in.," it will be seen that the required number is 11. Similarly, the capacity of a 3-in. pipe is found to be 8.5 times the capacity of a 1-in. pipe. In practice it would be necessary to use nine 1-in. pipes for equalizing in capacity one 3-in. pipe.

COMMERCIAL GRADES OF PIPE

Pipe for steam and hot-water heating is put on the market in three grades of thickness: (1) **Standard wrought-iron welded pipe** (see Table 31), tested to a pressure of 250 lbs. per sq. in.; (2) **Extra strong;** (3) **Double extra strong.** The "standard' is the grade used principally for heating purposes. "Extra strong" and "double extra strong" pipe are always shipped without threads or couplings, unless otherwise specified. Each length of standard pipe, when shipped is provided with threads on both ends, and one coupling. The lengths range from 16 to 24 ft.

All **fittings**, except **couplings** and **nipples**, are made of malleable or cast iron, the latter being preferable for heating systems.

Flange unions should be used on all pipe exceeding 2 in. in diameter.

Three types of **valves** are used in steam and hot-water heating—namely, **globe valves, gate valves,** and **check valves.** When a globe valve is placed in a horizontal steam pipe, it should always be placed with the stem in a horizontal position, as it presents less resistance to the flow of the

TABLE 32

Equation of Pipes

Size of Pipe	¾-in.	1-in.	1¼-in.	1½-in.	2-in.	2½-in.	3-in.	3½-in.	4-in.	4½-in.	5-in.	6-in.
½-in.	1.7	2.8	4.9	6.6	11.	15.9	24.	32.	41.	52.	65.	94.8
¾-in.		1.6	2.6	3.8	6.2	8.6	13.8	18.	23.	30.	37.	54.1
1 -in.			1.7	2.3	3.8	5.5	8.5	11.	14.	18.	23.	33.5
1¼-in.				1.3	2.2	3.1	4.9	6.6	8.	10.	13.	19.3
1½-in.					1.6	2.3	3.6	4.8	6.2	7.7	9.7	14.2
2- in.						1.4	2.2	2.9	3.8	4.7	5.3	8.6
2½-in.							1.5	2.	2.6	3.3	4.1	6.
3- in.								1.3	1.7	2.1	2.7	3.9
3½-in.									1.2	1.6	2.	2.9
4- in.										1.2	1.6	2.1
4½-in.											1.2	1.8
5- in.												1.4

steam and condensed water in that position than it does when the stem is set in a vertical position.

Globe valves should not be used in hot-water systems. Gate valves are to be preferred for water pipes. Check valves must be installed in places where it is necessary that the flow shall be continually in one direction, and where there is danger of a reverse flow. A check valve should always be placed in the return as near the boiler as possible.

VACUUM HEATING SYSTEMS

In the systems of heating already discussed, the pressure is carried either at atmospheric or higher pressure, and the boiling temperature of the water is 212° or higher. If a heating system, piped along practically the same lines as those hitherto discussed, is equipped with the proper apparatus for exhausting all the air, and keeping it exhausted, from the interior of boilers, pipes, and radiators, thus producing a vacuum within the system, the boiling point of the water will be reduced, and steam will be generated at a much lower temperature. This is termed the **vacuum heating system.** It is more economical in the use of fuel than a system in which pressure is maintained above atmospheric pressure, for the reason that in pressure systems a large portion of the fuel is consumed in driving the air from pipes and radiators against the pressure of the atmosphere; whereas, in the vacuum system, all the air is automatically removed from every part of the system, and the steam is permitted to circulate freely at a high velocity, thus making every sq. ft. of radiation available. In some systems operated on this principle, a **vacuum pump** is employed for the purpose of removing the air, also the water of condensation, from pipes and radiators. In other systems of vacuum heating the condensation of the steam in the radiators is utilized to produce a vacuum by taking advantage of the great difference in volume between steam and the water from which it is produced. For instance, if 1,600 cu. in. of steam at atmospheric pressure be condensed, the water of condensation will occupy a space of but 1 cu. in., and if no air leaks exist in the system, the result will be a vacuum.

In order that a heating system of this kind may be successfully operated, it is necessary to provide each radiator with an **automatic air-valve** which will open and close by the contraction and expansion of some material. There are many different types of these valves. Some of them use air confined within a small float which is caused to rise by the expansion of the confined air when heated, and, in rising, closes the outlet, thus preventing the escape of steam after the air in the radiator has all been exhausted. In due course, more air will accumulate in the radiator, owing to the condensation of the steam; the air in the float will contract from cooling, and this will again open the small air discharge valve, thus permitting the air in the radiator to be again expelled, and fresh steam to take its place.

In other types of automatic air-valves the discharge is opened and closed by the contraction and expansion of a curved metallic strip. The valve remains open, thus permitting the escape of air until the curved strip becomes nearly equal in temperature to that of the steam. The heat serves to increase the length of the strip, and it bends out sufficiently to close the air discharge. A drip pipe removes any water of condensation escaping from the air-valve.

Paul System. In what is known as the **Paul System**, now largely used, an automatic air-valve is attached to each radiator, and at any point where air is liable to collect in the returns. These valves are connected by means of small air-pipes with an **air-exhauster** located in the boiler room. The air-valves permit the passage of air, but no water can escape through them.

This system may be operated on the single-pipe gravity plan; and it has the advantage over the ordinary one-pipe system, of keeping all the air continually exhausted, so that the steam will in fact be sucked or drawn through the pipes, instead of being forced through. The exhauster may be operated by steam, gas, electricity, or water; the last-mentioned being usually employed with low-pressure systems.

The cost of operating the exhauster for a system containing 4,500 ft. of radiation, need not exceed 3 cents a day; and since a much better circulation is maintained by this system than when the air discharges into the rooms against the pressure of the atmosphere, the radiators are more effective, and it is claimed that a saving of 15 to 20 per cent in fuel is thereby made possible.

Vapor Heating System. In the so-called vapor heating system the piping is practically the same as in the vacuum system, except that the hot-water type of radiator is employed, in which the flow is connected to the upper portion of the radiator at one end, and the discharge is connected to the lower portion at the opposite end. The radiator is thus heated from the top down; and special forms of valves called **graduated valves** are used, whereby the admission of vapor to the radiator may be controlled so as to heat just as much of the radiator surface as is desired.

This may be one-quarter, one-half, three-quarters, or the entire surface. The heating medium is the vapor which rises from the surface of the water in the boiler when at or near the boiling point; and it circulates throughout the system under very light pressure.

The methods employed for expelling the air from radiators and flow pipes are similar to those already described in connection with the vacuum system.

In some cases vapor heating systems are installed in such a manner that either steam, of low pressure, or vapor can be used as the heating medium, and a range in temperature thus secured which runs from 90° to 240° F., the latter being the temperature of steam at 10 lbs. gauge pressure.

Accelerated Hot-Water Heating System. One of the principal objections to hot-water heating systems in which more or less pressure is maintained by the use of expansion tanks and valves connected therewith, is the liability of the valves to stick and thus allow the pressure to increase to the point of danger.

In order to overcome this objection, and insure safety in operation, a device known as the **Honeywell generator** may be placed on the return line, and connected to the expansion line, by means of which it is possible to maintain a pressure of 10 lbs. on the system with perfect safety.

In this device mercury is the active agent employed for regulating the pressure. The mercury is contained in a bottle-shaped casting, to one side of which the expansion line is connected. The top of this casting is connected by a pipe to an elliptical-shaped casting above it. The connecting pipe extends down into the bottle-shaped casting to near the bottom,—and, inside this connecting pipe, is a secondary or circulating pipe of small size extending slightly above the connecting pipe into the elliptical top compartment.

The action of the device is as follows: Assuming no pressure on the system, the mercury will lie at the bottom of the lower casting. When pressure forms in the system, it acts upon the mercury in the generator, tending to drive it upwards through the small inner pipe. By the time the pressure has reached 10 pounds, the mercury is overflowing into the top compartment, whence it finds its way into the large connecting pipe; and, owing to the difference in weight between it and the hot water, the mercury continues circulating down and up in the tubes, while at the same time it has been lowered to a point at the bottom of the generator below the open end of the connecting pipe, thus allowing the water from the system to pass upward through this pipe into the top compartment, and thence into the expansion tank.

Other **pressure-regulating devices** using mercury as the sealing agent, are the **Milwaukee heat generator**, and another, known as the **Mercury heat generator**, designed for use in connection with hot-water heating. It is claimed for the accelerated hot-water heating system, that, owing to the available range of temperatures in connection therewith, the sq. ft. of required radiation as ordinarily calculated may be reduced a considerable amount; also, that the size of piping may be lessened by its use.

The usual plan is to estimate the radiation by the ordinary method, and then deduct 10 or 15 per cent if the accelerated hot-water system is to be employed. The sizes of mains for this system may be found by the following rule:

Let size of main supplying the riser or radiator connection farthest from the boiler be two sizes larger than this riser or connection. From this point, work toward the boiler, increasing the area of the main to an amount sufficient to equal or slightly exceed the combined areas of radiator valves to be supplied. All branches to radiators are to be of the same size as the connection or riser they are designed to feed. Radiators employed in accelerated hot-water heating, are, as a rule, tapped for smaller connections than in the ordinary open method. Table 33 shows tapping of radiators for various amounts of radiation with accelerated hot-water heating systems.

TABLE 33

Tapping of Radiators in Accelerated Hot Water Heating Systems

Sq. Ft. of Radiation	Sizes of Radiator Tapping	Sq. Ft. of Radiation	Sizes of Radiator Tapping
30	½-in.	100 and over	1 -in.
30 to 75	¾-in.	50	½-in.
75 and over	1 -in.	50 to 125	¾-in.
40	½-in.	125 and over	1 -in.
40 to 100	¾-in.		

Connection to an indirect radiator in the basement, or to a basement ceiling coil or wall radiator, should be taken from a riser at a point near the ceiling of the first floor, in order that a positive circulation of water may be maintained through the basement radiator by the pressure of the water due to the head or height.

BOILERS FOR HEATING PLANTS

Boilers designed for heating purposes alone, are in a class separate and distinct from boilers designed to supply steam for power only, or for a combination power and heating system. Heating boilers intended for low-pressure systems (2 lbs. and under) are usually constructed of hollow cast-iron sections, of various patterns according to the ideas of the builders, the object being to present as many sq. ft. of heating surface as possible to the action of the heat.

Cast iron has proved itself to be the best material for the construction of this type of sectional boiler. This is owing to the ability of cast iron to withstand the action of rust.

Sectional boilers for heating are built in two general forms—namely, the **round vertical** and the **horizontal rectangular** shape. The round boiler is built up of hollow cast-iron cylindrical sections or rings laid one on top of the other, and connected by means of either screw nipples, or push nipples, thus permitting a free circulation of the water. The firebox is at the bottom, and the sections are so designed as to present bafflers or projections of their surfaces into the interior flue or passageway leading from firebox to smoke-flue. These projections, being a part of the boiler, and filled with water, form additional heating surface, and they also serve to baffle or retard the heated gases on their way to the chimney, thus utilizing more of the heat value of the fuel.

The horizontal boiler is built up of a series of vertical sections, the usual shape of which is in the form of an inverted U. These are placed side by side, the lower portions of the legs, or waterways being connected to headers running along each side of the boiler, near the bottom, into which the returns from the heating system are conducted. The water for heating is taken from the top of the boiler, or from a header connected with the top portions of the sections. The furnace is in front, below; and the upper portions of the sections are equipped with bafflers in the same manner and for the same purpose as those described in

TABLE 37

Vertical, Cylindrical-Shaped Non-Sectional Boilers for Steam Heating

Height of Boiler to Top of Outlets, inches.	Outside Diameter, inches.	Inside Diameter of Firepot, inches.	Height of Water Line, inches.	Number of Steam Outlets and Inlets.	Size of Steam Outlets, inches.	Size of Return Inlets, inches.	Diameter of Smoke Pipe, inches.	Capacity, Direct Radiation, square feet.
47	27	16	42	2	2½	2½	8	225
52	27	16	47	2	2½	2½	8	250
57	27	16	52	2	2½	2½	8	275
48	31	20	43	2	2½	2½	8	325
54	31	20	49	2	2½	2½	8	375
60	31	20	55	2	2½	2½	8	425
48	35	24	43	2	3	3	8	500
54	35	24	49	2	3	3	8	550
60	35	24	55	2	3	3	8	600
66	35	24	61	2	3	3	8	700
54	40	28	49	2	4	4	9	850
60	40	28	55	2	4	4	9	925
66	40	28	61	2	4	4	9	1000
54	44	32	49	2	5	5	10	1100
60	44	32	55	2	5	5	10	1200
66	44	32	61	2	5	5	10	1300

TABLE 38

Horizontal, Rectangular, Sectional Boilers for Hot-Water Heating

Number of Sections.	Size of Grate, inches.	Height to Top of Header, inches.	Length with Smoke Box, inches.	Width with Return Manifolds, inches.	Diameter of Smoke Pipe, inches.	Number and Size of Outlets, inches.	Number and Size of Return Inlets, inches.	Capacity, Direct Radiation, square feet.
6	44 x 40	80	60	74	18	2-5	2-5	4950
7	44 x 48	80	68	74	18	2-6	2-6	5950
8	44 x 56	80	76	74	18	2-6	2-6	6925
9	44 x 64	80	84	74	18	2-6	2-6	7925
10	44 x 72	80	92	74	20	2-8	2-8	8900
11	44 x 80	80	100	74	20	2-8	2-8	9900
12	44 x 88	80	108	74	20	2-8	2-8	10900

TABLE 39

Vertical, Cylindrical-Shaped Sectional Boilers for Hot-Water Heating

Number of Sections.	Diameter of Grate. Inches.	Height of Boiler to Top of Flange, inches.	Outside Diameter, inches.	Diameter of Smoke Pipe, inches.	Number and Size Branch Outlets, inches.	Single Outlet and Inlet Diameter, inches.	Capacity, Direct Radiation, square feet.*
5	16	47	20	7	2-1½	..	300
5	19	51	23	7	2-2	..	425
5	20½	54	25	8	4-2	3½	550
5	23½	57	28	9	4-2	4	800
5	27	64	33	10	6-2	5	1100
6	27	69	33	10	6-2	5	1200
5	30	65	36	11	8-2	5	1425
6	30	70	36	11	8-2	5	1550
5	34	67	40	12	8-2	6	1950
6	34	72	40	12	8-2	6	2150

TABLE 40

Vertical, Cylindrical-Shaped, Sectional Boilers for Hot-Water Heating

Height of Heater to Top of Dome, inches.	Outside Diameter of Heater, inches.	Diameter of Firepot, inches.	Number of Sections.	Number and Size of Outlets, inches.	Number and Size of Return Inlet, inches.	Diameter of Smoke Pipe, inches.	Capacity, Direct Radiation, square feet.
51	34	16	4	3-2	3-2	8	400
56	34	16	5	3-2	3-2	8	500
61	34	16	6	3-2	3-2	8	525
51	38	20	4	3-2½	3-2½	8	625
56	38	20	5	3-2½	3-2½	8	750
61	38	20	6	3-2½	3-2½	8	825
53	42	24	4	3-3	3-3	9	900
59	42	24	5	3-3	3-3	9	1025
65	42	24	6	3-3	3-3	9	1150
55	46	28	4	3-3½	3-3½	10	1250
61	46	28	5	3-3½	3-3½	10	1400
67	46	28	6	3-3½	3-3½	10	1575
55	50	32	4	3-4	3-4	11	1650
61	50	32	5	3-4	3-4	11	1900
67	50	32	6	3-4	3-4	11	2075

TABLE 41

Horizontal Firebox Boilers—Dimensions, Capacities, etc.

Diameter of shell............In.	30	30	30	36	36	36	42	42	42	48	48	48	54	54
Length over all.............Ft.	6½	7½	8½	7½	9	10½	8½	10	11½	10½	12	13½	14	16½.
Size of grate................In.	24x26	24x32	24x38	30x32	30x38	30x44	36x38	36x44	36x50	42x44	42x50	42x56	48x56	48x62
Fire doors {Single............In.	12x18	12x18	12x18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fire doors {Double...........In.	.....	.....	.....	14x24	14x24	14x24	14x24	14x24	14x24	18x30	18x30	18x30	18x30	18x30
Diam. of smoke pipe.........In.	16	16	16	18	18	18	20	20	20	22	22	22	24	24
Steam Tappings {Supply...........In.	3	3	4	4	4	4	6	6	6	6	6	6	7	7
Steam Tappings {Return...........In.	2½	2½	3	3	3	3	4	4	4	4	4	5	5	5
Water tappings, supply and return...................In.	2-4	2-4	2-4	2-5	2-5	2-5	2-5	2-6	2-6	2-6	2-6	2-7	2-7	2-7
Capacity Steam direct radiation.................Sq. Ft.	900	1000	1200	1400	1700	2100	2200	2500	2900	3200	3800	4400	4900	5800
Capacity water direct radiation ....Sq. Ft.	1400	1600	1900	2200	2700	3400	3500	4000	4600	5100	6100	7000	7800	9300
Height brick work, above floor ....In.	71	71	71	78	78	78	86	86	86	92	92	92	99	99
Height water line, above floor, In.	49	49	49	54	54	54	59	59	59	63	63	63	64	64
Floor space, length..........Ft.	8½	9½	10½	9½	11	12½	10½	12	13½	12½	14	15½	16	18½
Floor space, width...........Ft.	5½	5½	5½	6	6	6	6½	6½	6½	7	7	7	7½	7½

ing different capacities, are made with a section of less interior heating surface, to provide for the smaller rating.

Greater capacity in sectional boilers may be obtained by adding extra sections. It is always good practice to install a boiler having a capacity at least 25 per cent greater than is called for in the specifications. This refers to direct radiation. For indirect radiation, the reserve capacity should be 50 per cent.

The boiler referred to in Table 37, although cast-iron, has not as many sections as those previously described, the lower half consisting of a double cylinder casting having a large water space surrounding the firebox.

It should be noted that the ratings given in connection with boilers for either steam or hot-water heating are based upon the assumption that sufficient radiation will be installed to heat the building properly, and that the flue or chimney will be of sufficient capacity to supply the proper draft for the boiler furnace.

Firebox Boilers

In many cases it is more convenient to install **firebox boilers** of the regular pattern for supplying steam for heating buildings. Boilers of this type should be constructed of the best open-hearth, mild steel having a tensile strength of 60,000 lbs. per sq. in.

These boilers are built either **vertical** or **horizontal.** The latter type is the better adapted for heating systems.

Thickness of the sheets should be not less than ¼ in.; a thickness of 5/16 in. is better.

The front and back ends of boilers of the horizontal type rest on brick piers, and the boiler should be encased in brick setting, having deflecting baffles of brick in the smoke chamber at the back end, arranged in such a manner as to divert the hot gases in their course from the boiler flues to the chimney, and to cause them to return under and around the shell of the boiler, and thus act upon all portions of the heating surface before their final exit to the open air.

Table 41 gives dimensions and capacities of horizontal firebox boilers of various sizes; also complete specifications relative to installation.

It should be noted that these boilers are adapted for either steam, or hot-water heating, and the ratings given in Table 41 are based upon a standard for steam of 2 lbs. pressure at boiler, although 10 lbs. may be carried with safety.

For hot-water heating, the mean temperature of the water as it leaves the boiler is 180° F.

Boiler Horse-Power

Although the term **horse-power** is an unsatisfactory unit of measurement for rating the capacity of a boiler, still by its use it is possible to arrive at an approximate estimate of boiler capacities, and it may be safely used in calculating dimensions of boilers designed for use in buildings where the power plant and the heating system are combined.

A **boiler horse-power** as defined by the American Society of Mechanical Engineers is "the evaporation of 30 lbs. of water from a feed-water temperature of 100° F., into steam at 70 lbs. gauge pressure; or the evaporation of 34½ lbs. of water from and at a temperature of 212° F. into steam at atmospheric pressure." Using the sq. ft. of heating surface of the boiler as one factor, and the total weight of water evaporated per hour as the other, if it is found that the evaporation equals 2.3 lbs. of water per hour per sq. ft. of heating surface, then 15 sq. ft. of heating surface will be required for the production of one horse-power, as follows: $34.5 \div 2.3 = 15$. Or, if the evaporation equals 3 lbs. of water per sq. ft. of heating surface, the number of sq. ft. of heating surface required per horse-power equals $34.5 \div 3 = 11.5$.

To convert a pound of water at 212° temperature into steam at atmospheric pressure and 212° temperature, requires 965.7 heat units; therefore, heat units required to produce one boiler horse-power $= 965.7 \times 34.5 = 33{,}317$ per hour.

COMBINED POWER AND HEATING SYSTEMS

In many cases, especially in large buildings, the heating system is combined with some form of power system (for electric lighting, refrigerating machinery, or pumps), steam being supplied from a common source. The plan to be followed in the installation of a system of this kind will depend upon the method to be pursued in its operation.

First—In case the heating of the building requires the greater portion of the steam, the boilers supplying this steam will be operated on low pressure, the steam passing directly from boilers to heating mains. One or more high-pressure boilers are also installed for the purpose of supplying steam to the engines or pumps, and the exhaust from these, after passing through an oil separator, is carried into the heating mains also, the pressure on the exhaust being determined by the pressure carried in the heating system.

Second—If operated entirely as a high-pressure system, the boilers will all be high-pressure; and the bulk of the steam, being required for power, will pass directly to the engines, whence it is exhausted into the heating mains. A by-pass, with reducing valve, is carried from the live steam main to the heating main; and if at any time the exhaust should fail to maintain the required pressure on the heating main, the reducing valve opens automatically, and the deficiency is made up with live steam from high-pressure main. When the heating pressure is again up to standard, the reducing valve automatically closes, either partly or altogether.

The engine exhaust pipe should always be provided with a back-pressure valve opening to the atmosphere, in order to prevent the accumulation of excessive pressure on the exhaust.

Either method of operation requires the installation of one or more high-pressure boilers, depending upon the size and requirements of the building.

Table 42 shows specifications for **high-pressure horizontal tubular boilers** of various capacities, designed to carry 100 lbs. working pressure. Table 43 is for 125 lbs.

In Tables 42 and 43, the radiating capacities given are based upon the assumption that all mains and returns are to be counted as radiation. If a horizontal smoke-pipe or breeching leads to the stack, it must be 15 to 25 per cent larger, the increase depending upon length of pipe and number of elbows, or turns it makes before reaching the stack.

Water-Tube Boiler

The object sought for in this type of boiler is safety in connection with power. Modern engineering demands high pressures; and, as one result of this demand, the **water-tube boiler** has been developed to a high degree of perfection.

The usual type of construction is: one or more steam drums built of the best boiler steel, according to specifications for high pressures. To the ends are connected water legs of large capacities. These are in some cases made of the same material as the steam drum or shell; and in other cases, they consist of tubes. In either type, these water legs are always connected at the bottom by a series of tubes exposed to the heat of the furnace. Circulation of the water is, as a rule, very good through these tubes, water legs, and the lower portion of the steam drum; and steam gen-

TABLE 42

High Pressure Horizontal Tubular Boilers—Dimensions, Capacities, Etc.

Working pressure, 100 lbs.

Horsepower	10	12	15	20	25	25	30	35	35	40	40	45	50	50
Capacity, direct radiation, Sq. Ft.	800	1000	1200	1200	2000	2226	2500	3100	3300	3600	4000	4500	5000	5500
Diameter of shell ... In.	32	34	36	36	36	42	42	42	44	44	48	48	48	54
Length of tubes ... Ft.	7	7	8	10	12	10	12	14	12	14	12	14	16	12
Size of tubes (regular) ... In.	3	3	3	3	3	3	3	3½	3	3½	3	3½	4	3
Number of tubes	20	22	24	24	24	39	39	28	42	30	44	32	26	52
Thickness of shell ... In.	¼	¼	¼	¼	¼	¼	¼	¼	¼	¼	9/32	9/32	9/32	5/16
Thickness of heads ... In.	⅜	⅜	⅜	⅜	⅜	⅜	⅜	⅜	⅜	⅜	7/16	7/16	7/16	7/16
Diameter of dome ... In.	16	16	18	18	18	20	20	20	24	24	24	24	24	27
Height of dome ... In.	16	18	20	20	20	24	24	24	24	24	24	24	24	30
Width of grate ... In.	32	34	36	36	36	42	42	42	44	44	48	48	48	54
Length of grate ... In.	36	36	36	36	42	36	42	48	42	42	36	42	48	42
Heating surface, with regular tubes ... Sq. Ft.	149	162	201	251	301	379	459	462	488	492	515	528	570	603
Diameter of stack ... In.	14	16	16	16	16	18	18	18	22	22	24	24	24	26
Length of stack ... Ft.	24	24	28	28	35	35	35	40	35	40	40	40	45	40
Gauge of steel in stack	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Size lever safety-valve or steam supply ... In.	1½	1½	1½	2	2½	2½	2½	2½	2½	2½	3	3	3	3
Size blow-off cock ... In.	2	2	2	2	2	2	2	2	2	2	2½	2½	2½	2½
Size check and stop valves ... In.	¾	¾	¾	¾	¾	1	1	1	1	1	1¼	1¼	1¼	1¼
Size steam-gauge ... In.	5½	5½	5½	5½	5½	5½	5½	5½	5½	5½	5½	5½	6	6
Size steam opening ... In.	4	4	4	4	5	5	5	5	5	6	6	6	6	6
Size return opening ... In.	3	3	3	3	4	4	4	4	4	5	5	5	5	5

TABLE 43

High-Pressure Horizontal Tubular Boilers—Dimensions, Capacities, Etc.

Working pressure, 125 lbs.

Nominal horse power	50	55	60	70	70	85	100	100	115	125	150
Capacity, direct radiation, Sq. Ft.	4000	4700	5000	5600	6400	7200	8000	8500	9600	10500	12000
Diameter of shell, In.	48	48	54	54	60	60	60	66	66	72	72
Length tubes, Ft.	14	16	14	16	14	16	18	16	18	16	18
Number tubes	24	24	36	36	44	44	44	54	54	70	70
Thickness shell, In.	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$
Thickness heads, In.	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
Number braces each head above tubes	11	11	10	10	15	15	15	15	15	22	22
Number through braces below tubes	2	2	2	2	2	2	2	2	2	4	4
Size steam opening, In.	6	6	6	6	6	6	6	7	7	8	8
Size return opening, In.	5	5	5	5	5	5	5	6	6	7	7
Length grate, In.	48	54	48	54	48	54	60	54	60	54	60
Width grate, In.	48	48	54	54	60	60	60	66	66	72	72
Diameter stack, if vertical, In.	24	24	26	26	28	28	28	32	32	36	36
Length of stack, Ft.	40	40	45	45	45	50	50	55	55	60	60
Pop safety valve, In.	3	3	3	3	3	3	3½	3½	3½	4	4
Check and stop valves, In.	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½
Size blow-off valve, In.	2½	2½	2½	2½	2½	2½	2½	2½	2½	2½	2½
Size steam gauge, In.	6	6	6	8½	8½	8½	8½	8½	8½	8½	8½

erates rapidly. Since the bottom of the drum is exposed to the furnace heat, the water must also be maintained in the drum at a certain height, and still leave sufficient steam space. The pressures carried by these boilers are usually 200 to 225 lbs. per sq. in.

Feed-Water Heaters

The great benefits derived from heating the feed water before it enters the boiler; and the economy in fuel thereby attained when exhaust steam is utilized for this purpose, are beyond question, and need not here be discussed.

Table 44 gives dimensions and other details of feed-water heaters designed for power and heating plants of from 50 to 3,000 horse-power.

TABLE 44
Feed-Water Heaters
("Kewanee" Type)

Horse Power.	Diameter, inches.	Height. inches.	Exhaust. inches.	Hot Water, inches.	Cold Water, inches.	Shipping Wgt., pounds.
50	24	72	3	1½	¾	900
100	24	78	3	2	1	1000
150	30	78	4	2	1	1200
200	30	84	6	2½	1¼	1300
250	30	90	6	2½	1¼	1350
300	30	96	6	3	1½	1450
400	36	96	6	3½	1½	1800
500	36	102	6	3½	2	1950
600	42	108	7	4	2	2300
750	42	120	7	4	2½	2500
900	42	132	7	4	2½	2700
1000	48	132	8	5	2½	3400
1250	48	138	8	5	2½	3800
1500	54	132	8	5	3	4400
1750	54	138	8	5	3	4700
2000	54	144	8	6	3	5000
2500	60	168	10	6	3½	6000
3000	60	192	10	6	3½	6600

HOT-AIR HEATING AND VENTILATING SYSTEMS

Hot-air furnaces may be constructed either of cast iron or of steel, there being very little difference between the merits of the two materials for this purpose. While cast iron is less sensitive to the action of rust when the furnace stands idle during the summer, it is more easily broken by shrinkage strains than steel is, and, when very hot, it may be slightly permeable to the furnace gases, and thus increase the danger from noxious fumes. The danger from this source, however, is slight, because, if the furnace is properly proportioned, the temperature need not exceed 300° or 400° F., and for this condition, the difference in the heating power of cast iron and steel is a negligible quantity. On the other hand, cast iron, owing to its rough surface, is a better medium for giving off heat than wrought iron or steel.

Since air takes up heat much more slowly than does water or steam, the **ratio of heating surface to grate surface** should be more than that usually employed in steam heating, which latter varies from 20 to 45, averaging about 32; while ratio of air-heating surface to grate surface in hot-air furnaces varies from 20 to 50, the average being 35.

Each sq. ft. of heating surface may be assumed to give off 1,000 to 1,500 B. T. U. per hour. A furnace should be so proportioned that the temperature of air leaving it will not exceed 180° F., and in selecting a furnace, it is best to have 25 to 50 per cent more heating capacity in the furnace than the building is rated at. Builders rate their furnaces at, or at about, their maximum capacity, the rating being expressed as number of cu. ft. of building volume the furnace will heat.

General Form of Hot-Air Furnace

The same principles that apply in the construction of furnaces for steam and hot-water heating, may also, with a few modifications, be applied to the installation of hot-air furnaces. It is essential that the shell of the furnace be tight; otherwise products of combustion may enter the air passages.

A furnace may be set in a chamber surrounded by brick walls. A better setting is a metallic casing consisting of two sheets of metal, the outer one of galvanized iron. These sheets are placed far enough apart to allow a filling of asbestos between them, or, as in some cases, simply an air-space serves as the insulation. Ample space is provided between the casing and the sides of the furnace proper for the passage of the heated air. A **dumping or shaking grate** which can be quickly cleaned, should be used.

There should be 1 sq. ft. of grate surface for each 30 to 50 sq. ft. of heating surface in the furnace.

Regulation of the draft should be made available from the first floor of the building.

Heated air requires more moisture than cold air does to maintain the proper degree of saturation; for instance, one pound of air at 32° F. will hold in the form of vapor .003 lb. of water; but at 150° temperature, it will hold .22 lb., or about 70 times as much moisture. For this reason, every furnace should be provided with a water-pan in which water may be kept for increasing the moisture in the air as it is distributed to the various rooms. A good plan is to fit each pipe leaving the furnace, with a trough or pan inside, for containing water from which the heated air may take up its moisture in passing.

Cold-Air Supply. The cold-air supply for the furnace consists of a passageway or duct of wood, metal, or masonry, leading from a point beneath the furnace casing or near its bottom to the outside air, usually on that side of the building which is subject to the prevailing winds. This cold-air passageway or duct should be provided with a damper for regulating the supply. In all cases there should be a screen over the outer end, to prevent the admission of foreign matter; and doors should be arranged so that it can be cleaned periodically. The cross-section of the cold-air duct should be 80 per cent of the sum of the sectional areas of all the hot-air pipes leading from the furnace to various parts of the building.

Leaders and Flues for Heating Air. Leader pipes, taken from near the top of the furnace casing, are usually round, made of bright tin, and, when running horizontally, should have an ascending pitch of at least .75 inch to the foot. These pipes should have as few and as easy turns as possible, and should not be placed in the outside walls. The vertical flues, or **risers**, are rectangular in shape, made in dimensions to fit in the partitions, and are connected at the bottom with the horizontal leaders, whence they extend to the various floors.

In calculations for dimensions of risers, the velocity of the heated air for the first floor may be taken at 3 to 4 ft. per second; for the second floor at 4 to 5 ft. per second; for third floor and above, at 5 to 6 ft. per second. These flues should be double-walled, having an air-space or asbestos between the walls.

Registers. The dimensions of the registers should be calculated on the basis of an air velocity of 2 to 3 ft. per second on the first floor, and 3 to 4 ft. per second on floors above. The effective area of ordinary registers is about 50 per cent of actual outside area.

Air in principal rooms should be changed 5 times per hour in hot-air heating systems. H. B. Carpenter, before the Society of Heating and Ventilating Engineers (see Transactions, Vol. 5, p. 77), gives rules as follows for finding cu. ft. of air passing per minute through pipes.

For first floor, area of pipe in sq. in. × 1.25.

For second floor, area of pipe in sq. in. × 1.66.

For third floor, area of pipe in sq. in. × 2.08.

Table 45 gives sizes of openings, and areas of registers, for hot-air systems of various capacities.

TABLE 45

Hot-Air Registers

Size of Opening, Inches	Effective Area, Sq. In.	Diam. Round Pipe, Inches	Size of Opening, Inches	Effective Area, Sq. In.	Diam. Round Pipe, Inches
4½x6½	20	5.1	10x20	132	13.0
4x 8	21	5.2	12x12	96	11.1
4x10	26	5.8	12x14	112	11.9
4x13	34	6.6	12x15	120	12.4
4x15	40	7.2	12x16	128	12.8
4x18	48	7.8	12x17	136	13.2
6x 6	24	5.6	12x18	144	13.5
6x 8	32	6.4	12x19	152	13.9
6x 9	36	6.7	12x20	160	14.3
6x10	40	7.2	12x24	192	15.6
6x14	56	8.5	14x14	130	12.8
6x16	64	9.1	14x16	149	14.8
6x18	72	9.6	14x18	168	14.9
6x24	96	11.1	14x20	186	15.5
7x 7	32	6.4	14x22	205	16.2
7x10	52	8.2	15x25	250	17.8
8x 8	42	7.4	16x16	170	14.7
8x10	53	8.2	16x20	213	16.5
8x12	64	9.6	16x24	256	18.1
8x15	80	10.1	18x24	288	19.2
8x18	96	11.2	20x20	267	18.5
9x 9	54	8.2	20x24	320	20.2
9x12	72	9.6	20x26	347	21.0
9x13	78	10.0	21x29	406	22.7
9x14	84	10.3	24x24	384	22.1
10x10	66	9.2	24x32	512	25.5
10x12	80	9.1	27x27	486	25.0
10x14	93	10.9	27x38	684	29.5
10x16	107	11.7	30x30	600	27.7
10x18	120	12.4	.....	...	....

Table 46 shows required proportions of flues, grate area and heating surface.

TABLE 46

Proportions of Flues, Grate Area, and Heating Surface in Hot-Air Heating

	1st Floor		2d Floor		Furnace	
Contents of Room Cu. Ft.	Hot-Air Flue Diam., In.	Foul-Air Flue Diam., In.	Hot-Air Flue Diam., In.	Foul-Air Flue Diam., In.	Grate Area, Sq. In.	Heating Surface, Sq. Ft.
500	6	6	6	6	25	5
1,000	8	8	7	7	50	10
1,500	9	9	8	8	75	15
2,000	10	10	9	8	100	20
2,500	11	11	10	9	125	25
3,000	12	12	11	9	150	30
3,500	13	13	11	10	175	35
4,000	14	14	12	10	200	40
5,000	16	16	14	12	250	50
6,000	17	17	15	12	300	62.5
8,000	20	20	18	14	350	80
10,000	24	24	20	16	400	100

It is assumed in the above table, that:
Temperature of outside air=0°;
Temperature of air entering rooms=160°;
Temperature of air in rooms=70°;
Changes of air in rooms, 3 per hr.
Velocity of air in hot-air flues, 1st floor, 3 ft. per second.
Velocity of air in hot-air flues, 2d floor, 4 ft. per second.
Velocity of air in foul-air flues, 1st and 2d floors, 3 ft. per second.
Proportion of grate surface to heating surface, 1 to 30.
Lbs. of coal burned per sq. ft. of grate surface per hr.= 3 lbs.

MECHANICAL HEATING AND VENTILATION

Mechanical or fan heating consists in first driving the cold air over heated surfaces, and thence into the rooms to be warmed. The general arrangement of this system of heating consists of one or more rotary fans located in what is called the tempering room. The fan is driven by an electric motor, or by a gas or steam engine; and its function is, first, to draw the outside, cold air through temporary coils, into the tempered air-chamber, and then force the air through a series of heating coils into the hot-air chamber.

From this chamber, the air, at a temperature of 130° to 140°, is allowed to pass to the various rooms as required.

When used for ventilation only, the air is delivered by the fan directly from the tempered air-chamber to the rooms, the heating of the rooms being done by direct radiation. The temperature of the air as it leaves the ventilating fan ranges from 60° to 70°.

In some systems the fan is made to perform the double function of heating and ventilating the building. This is known as the **double-direct** system, and is the mechanical system in most extensive use. In this system the heating surface is concentrated near the fan, and a flue or passage is provided directly over it for hot air, and another passage around it for cool air. These two flues are kept separate for some distance, but join at the bottoms of the vertical flues leading to the rooms.

Regulating dampers are arranged in the rooms in such a manner that the admission of ventilating air, and the throttling of heated air, or vice versa, are entirely under control of the occupants of the rooms.

Heating Coils. The heating surface employed in this system is usually built of inch pipe set vertically into a cast-iron base and connected at top with return bends, although the box coil, or any form of indirect radiating surface can be used. The heaters should be designed to afford free circulation of the steam, and a ready removal of the water of condensation.

A heating surface will emit from 600 to 1,000 B. T. U. per sq. ft. per hour, and should average 1 sq. ft. for every 13 to 15 cu. ft. of air heated from 0° to 120° F. per minute.

TABLE 47

Dimensions and Capacities of Heater Coils—Fan Heating

Lineal feet capacity of 1-inch pipe.	Connections. Steam.	Connections. Drip.	Connections. Bleeder.	Net air space in sq. ft.	Size of fan. Regular Disc.	Size of fan. Steel Plate.
200	2 "	1 "	¾"	5.4	30	80
300	2 "	1 "	¾"	7.6	36	90
400	2 "	1¼"	¾"	10.7	42	100
525	2 "	1¼"	1 "	14.3	48	110
650	2 "	1½"	1 "	17.7	54	120
825	2½"	1½"	1 "	22.2	60	140
1,175	2½"	1½"	1 "	31.	72	160
1,525	3 "	2 "	1¼"	40.	84	180
2.025	3 "	2 "	1¼"	52.5	96	200

The heater should be designed so as to allow ample area for the passage of air through, between the coils, at a velocity of about 1,200 feet per minute. Tempering coils should be not less than 12 pipes deep.

Table 47 gives dimensions and capacities of heater coils designed for use in connection with the fan system of heating. Sizes of fans are also given, the information having been supplied by the American Blower Company. Table 48 gives detailed information relative to dimensions and capacities of fans, together with motive power.

TABLE 48

Dimensions, Capacities, and Motive Power of Fans

FAN WITH STEEL-PLATE HOUSING.

Size of Fan. Inches.	Diameter of Wheel.	Diameter of Shaft.	Size of Pulley. In.	Inlet.		Outlet.		Size of Engine Cylinder In.		Weights.		
				Diameter.	Area in Sq. In.	Size. In.	Area in Sq. In.	Single.	Double.	Fan Only.	Single Engine.	Double Engine.
70	42	2 3/16	14 × 8 1/2	26	530	24 × 24	576	4 × 4	3 × 3	1000	1290	1330
80	48	2 3/16	16 × 8 1/2	30	706	26 1/2 × 26 1/2	702	4 × 4	3 × 3	1300	1590	1690
90	54	2 3/16	18 × 10 1/2	34	907	30 × 30	900	5 × 5	4 × 4	1690	2190	2190
100	60	2 [illegible]	20 × 10 1/2	38	1134	34 × 34	1156	6 × 6	5 × 5	2000	2640	2890
110	66	2 [illegible]	22 × 10 1/2	42	1385	37 × 37	1369	6 × 6	5 × 5	2500	3140	3390
120	72	2 [illegible]	24 × 12 1/2	46	1661	41 × 41	1681	7 × 7	6 × 6	3000	3870	4300
140	84	3 3/16	28 × 12 1/2	53	2206	47 1/2 × 47 1/2	2256	..	7 × 7	4000	5600	5700
160	96	3 3/16	32 × 12 1/2	60	2827	53 1/2 × 53 1/2	2862		7 × 7	5200	6800	6900

Size of Air-Ducts. Sizes and capacities of air-ducts are to be determined by the velocity of the air passing through the ducts. For main ducts of large dimensions, the velocity of the air may be 1,500 ft. per minute. For branch mains, the velocity varies from 800 to 1,000 ft.; it should not exceed 1,000 ft. per minute.

The velocity in flues leading to the various rooms depends upon their size, but should range from 600 to 800 ft. per minute. In case the size of these ducts is very small, the velocity is often reduced to 400 ft. per minute.

At the registers, the velocity should not exceed 300 ft. per minute, unless the registers are very large, and so located that the current of air issuing from the register does not directly strike the occupants of the room. In such installations the velocity of the issuing air may be as high as 500 ft. per minute.

If these proportions for air velocities are adhered to in the installation of a system of mechanical heating and ventilation, the resistance will be from .3 to .6 ounce pressure for the system.

Protection from Fire. Where hot-air or steam pipes pass up through partitions near woodwork, there is always more or less danger of fire, the extent of the danger depending upon the insulation of the heat conductors, the proximity of these conductors to woodwork, and the methods pursued in the installation of the system. Various cities and municipalities have in force various laws regulating the installation of heating plants; but one of the best rules—if not the best—to be observed when installing a plant, is to **properly insulate all heat conductors.** This rule is not only safe, but it is also on the side of economy.

Plumbing

Under this general term is included:

(1) The water supply to the building, and its proper distribution to the various fixtures; the proper arrangement of all traps and vent lines; the installation of apparatus for heating the water for culinary purposes, and the proper installation of all plumbing fixtures, together with such mechanical appliances as house, and fire pumps, suction and supply tanks, besides other apparatus connected with the use of water.

(2) No less important than the water supply is the proper drainage of all waste matter from the building; and this also is a portion of the plumber's duty.

Notwithstanding the importance of the plumber's work, it is as a rule given very little attention by the average architect in the preparation of plans and specifications. The plans may show a toilet-room located here, a sink there, lavatories scattered promiscuously about; and there may be a few lines on the basement plan to indicate the general direction of the sewer, but seldom more. It therefore falls to the lot of the plumber to figure, if he can, how to reach the various fixtures with his lines. He must also find the best locations he can for water-heaters, pumps, and tanks; also where to install the risers and vent lines. The incomplete nature of the drawings is very often recompensed, to some extent, by carefully outlined specifications, although these may at the same time be inadequate and indefinite, abounding in such terms as "pipes of ample size," "valves satisfactory to the architect," "water-heater of sufficient capacity," etc., thus placing upon the plumber practically the entire responsibility for the designing and proper working of the system.

WHAT PLUMBING PLANS SHOULD SHOW

The plumbing for a building should be so indicated in the drawings and described in the specifications as to cover everything required, and so clear and concise as to be readily understood by the average plumbing contractor. The positions of all mechanical appliances in connection with the plumbing should be clearly shown, upon whatever floor plan such appliance may be located. All runs of piping through basement, together with the size of same, should be concisely indicated in the basement drawing. House traps, bell traps, area drains, sump pits, conductor lines, etc., should be located beyond dispute. Branches to risers, with size plainly indicated, together with location of such risers, should be shown; and valves and stop-cocks should be plainly indicated.

In addition to the plumbing lines shown on the plans, there should be prepared a riser diagram showing the serving of each and every fixture on each floor of the building. This riser diagram should show clearly all water lines, waste lines, soil lines, vent lines, fire lines, etc., at each and every floor throughout the building, giving the relative position and arrangement of the waste and vent lines for each fixture, with the sizes of all lines plainly designated. Pipes of the various characters can be indicated by different kinds of broken or dotted lines, with a properly arranged index on the drawing, showing the kind of service each line performs.

Where there are groups of fixtures, and where it is desirable to show connections to pumps, house tanks, filters, etc., it is advisable to prepare, on a larger scale than is ordinarily used, a detailed drawing showing the exact arrangement of all piping, together with all fittings, joints, valves, traps, etc.; but where the plumbing is ordinary straight and simple work, such detailed drawing may be omitted.

The specifications should indicate in the clearest possible manner the quality of the materials to be used, and the method of installation.

The location, size, depth, and general direction of the street sewer, if there is any, should be clearly described; and if there is no street sewer, the final disposition of the sewage should be given in detail.

The location and size of the city water main from which the water supply is to be taken should be plainly stated, along with the water pressure at source of supply. This information can be obtained in any well-regulated municipality, where it is always kept on file. The specification should list accurately the number of each style of fixtures to be located on each floor of the building, and should give such an accurate and detailed description of such fixtures and the trimmings as to leave no doubt as to what is desired.

SEWER AND CONNECTIONS

The first thing to be considered in the layout of a plumbing job is the sewer and connections.

The sewer is usually constructed of salt-glazed vitrified sewer-pipe, laid to an even grade, joints made with Portland cement and clean, sharp sand (1 part cement to 2 parts sand), all joints to be carefully swabbed on the inside after making.

Connections to main sewer should be made with a Y; or, if main sewer has no Y connection, the entrance to the sewer should be made in such a manner that the sewage will strike at an angle in the direction of flow in the main sewer. From the main sewer, the branch for the building should continue with a gradual incline up to the same, and should terminate at a point not less than 5 ft. from the building, from which point it is to be extended into the building with cast-iron soil pipe, preferably the "Extra Heavy" grade.

Sewer Traps and Ventilation

The utility of a house, main, or intercepting trap in the sewer line is a question that has called forth considerable discussion, both for and against, and both sides have their good and bad points. The Building Department of the City of New York specifies that "an iron running trap must be placed on the house drain near the wall of the house, and on the sewer side of all connections—except a drip-pipe, where one is used. If placed outside the house, or below the cellar floor, it must be made accessible in a brick manhole, the walls of which must be 8 in. thick, with an iron or flagstone cover. When outside the house, it must never be less than 3 ft. below the surface of the ground."

Whether a trap is used or not, the soil stack (or stacks) should always extend up to and through the roof. It should never be connected to a chimney. No steam exhaust, boiler blow-off, or drip-pipe should be connected with the house drain or sewer. Such pipes should first discharge into a proper condensing tank; and from this a connection to the house sewer outside the building should be provided. In low-pressure systems the condensing tank may be omitted, but the waste connection should be as above required. When rain-leaders or downspouts are connected to the sewer, the proper size of pipe may be determined from table 1, which is based on an average rainfall. All leaders should be trapped at the base.

TABLE 1

Size of House Drains for Carrying Rain Water

Size of Pipe	¼-inch fall Per foot	½-inch fall Per foot
5-in.	3,700 sq. ft.—roof area	5,500 sq. ft.—roof area
6-in.	5,000 sq. ft.—roof area	7,500 sq. ft.—roof area
7-in.	6,900 sq. ft.—roof area	10,000 sq. ft.—roof area
8-in.	11,600 sq. ft.—roof area	13,600 sq. ft.—roof area
9-in.	11,600 sq. ft.—roof area	17,400 sq. ft.—roof area

An easy rule to remember in this connection is to allow 1 sq. in. pipe area for each 250 sq. ft. of roof area. A cistern overflow should never be connected into the house sewer if it can be avoided, as there always exists the possibility of the sewer choking or clogging up, and backing up into the cistern. When a cistern overflow must go into the sewer, there should be a trap and vent pipe inserted in the pipe leading to the sewer.

Sizes of House Sewers

House sewers and house drains should be at least 4 in. in diameter where water-closets discharge into them. Where rain water discharges into them, the house sewer and house drain, up to the leader connections, should conform to the sizes indicated in Table 1. Full-size Y and T branch fittings for hand-hole clean-outs should be provided.

It is good practice to run the sewer pipe one size larger than the soil-pipe that discharges into it, owing to the greater frictional resistance of the clay sewer pipe. For instance, if the soil-pipe is 4 in. in diameter, the sewer should be 5 in., but no larger unless other soil-pipes discharge into it, in which case its internal area should be such as to insure its being able to carry away the total discharge when it is flushed or nearly so. It is better, however, to install a size that will be flushed, or nearly so, by the water flowing through it, than to install a size so large that the water passing through it reaches only part way up the sides, since in the latter case there is a tendency to allow the floating matter to adhere, and in time the accumulation may cause a stoppage.

Care should be exercised, that the house drain be not given too much incline toward the street sewer, as there is danger that the water may travel so rapidly as to run ahead of the solid matter, allowing the latter to be deposited in the pipe to present an obstruction to the next discharge. An average velocity of 276 ft. per minute in the flow of the sewage will carry all matter from the sewer. Ordinarily, a fall of ¼ in. per foot is more than ample.

Sewage is carried along in the pipes only by flotation. It is therefore very important that the size of pipe, and velocity of flow be calculated correctly.

Table 2 shows the fall or pitch required for various sizes of sewers, the average velocity of flow to be 276 ft. per minute.

TABLE 2

Fall Per Foot, Giving Flow of 276 Feet Per Minute in Various Sizes of Sewers

Size of Sewer	Fall or Pitch Required
2-in.	1 ft. in 20 ft.
3-in.	1 ft. in 30 ft.
4-in.	1 ft. in 40 ft.
5-in.	1 ft. in 50 ft.
6-in.	1 ft. in 60 ft.
7-in.	1 ft. in 70 ft.
8-in.	1 ft. in 80 ft.
9-in.	1 ft. in 90 ft.
10-in.	1 ft. in 100 ft.

Fresh-Air Inlet

A fresh-air inlet should be installed in connection with, the main trap, for the purpose of relieving the air-pressure that may accumulate in the system, and to create a current

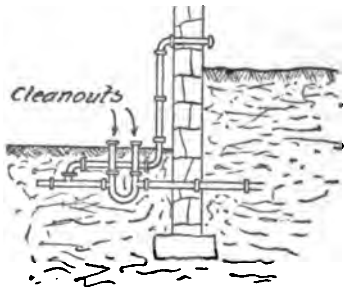


Fig. 1. Installing a Trap and Fresh-Air Inlet.

of fresh air throughout the entire system of piping. The fresh-air inlet should be installed at a point a short distance beyond the trap, so as to avoid the possibility of the water seal becoming frozen in the winter, and also to decrease the evaporation that will occur if the inlet is introduced directly into the hub or top of the trap. It is good practice to use a trap with hubs for double vent, as this will allow clean-outs to be placed on both sides of the water seal, and afford free access to the sewer for cleaning purposes. Fig. 1 illustrates this method of installing a trap and fresh-air inlet.

Roughing In

At this point a few words may well be said regarding the proper method of handling soil-pipe. The best way to cut soil-pipe is with a narrow, sharp-pointed chisel and a medium-weight hammer. This gives better results to the average mechanic than the use of three-wheel cutters, on account of the liability to crack the pipe, which is very easily done with the cutters because of the pipe not being of uniform thickness throughout, and because with the cutters this variation in thickness cannot be so easily detected as with the hammer and chisel, the ear being of great assistance in determining where the pipe is thick and thin. Lay the pipe on the floor, and place a narrow piece of wood under the place marked for cutting. The pipe should be marked with chalk entirely around at the place where it is to be cut. Then use the chisel and hammer. Filing a groove around the pipe where it is to be cut is not necessary, since the chisel will make a clean, square cut if properly used.

Table 3 gives the weights per foot, of soil-pipe and vent-pipe of various diameters.

TABLE 3.

Weight of Soil-Pipe and Vent-Pipe

Weights per Linear Foot

Diameters	"Extra Heavy"	"Standard"
2-in.	5½ pounds	3½ pounds
3-in.	9½ pounds	4½ pounds
4-in.	13 pounds	6½ pounds
5-in.	17 pounds	8½ pounds
6-in.	20 pounds	10½ pounds
7-in.	27 pounds	14 pounds
8-in.	33½ pounds	17 pounds
10-in.	45 pounds	23 pounds
12-in.	54 pounds	33 pounds

Soil-Pipe Joints

All joints should be made with picked oakum and molten lead, and must be gas-tight. Twelve ounces of fine, soft pig lead for each inch in the diameter of the pipe, is the proper proportion to use at each joint. Table 4 gives the correct quantities of lead and oakum, for making joints with various sizes of soil and vent pipes.

TABLE 4

Lead and Oakum Required for Soil-Pipe Joints

Size of Pipe	Lead per Joint	Oakum per Joint
2 inch.............	1½ pounds	3 ounces
3 "	2¼ "	6 "
4 "	3 "	7 "
5 "	3¾ "	8 "
6 "	4½ "	9 "

The proper method of making a soil-pipe joint is to carefully pack the same with oakum, and leave a space of 1¼ inches for the lead. The oakum must be calked tightly before pouring in the lead. If the pipe has not been cut exactly square across, care must be taken that none of the oakum is driven into the pipe to present an obstacle to the flow

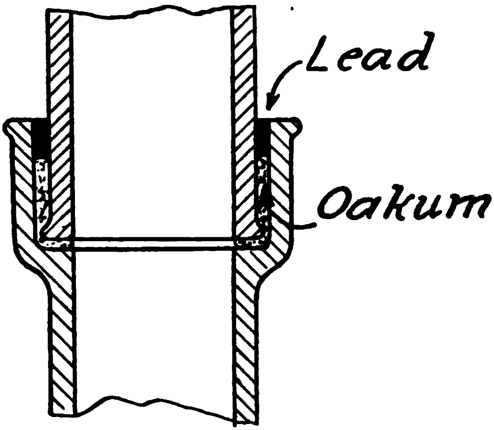


Fig. 2. Soil-Pipe Joint.

of waste matter, and in time cause a stoppage. The joint must then be poured with the hot lead, in one pouring; and after the lead has cooled, it should be calked tight with the proper calking chisels and a light hammer, bearing in mind that every blow of the hammer creates a pressure on the hub which may crack the hub unless the operation is carefully done. The joint should always be run full at one pouring; if this is not done, the lead should be picked out and the joint poured again.

Pouring lead in an upright joint is a very simple matter; but a horizontal joint requires different handling, and recourse is had to a joint-runner made of asbestos, which clamps around the pipe in such a manner that it leaves an opening on top for the pouring of the lead. Clay or putty may be used for this purpose, but are makeshifts and very unsatisfactory.

Fig. 2 shows a sectional view of a properly constructed soil-pipe joint.

If there is dampness in the joints, placing some pulverized rosin in the hub before pouring will be beneficial. The lead should always be hot; and none but lead free from solder or other metals should be used, in order to avoid cracking the hubs when calking.

Piping System

Following is a list of the different pipes with which the plumber must deal in the installation of a job of plumbing. The proper function of each pipe is also given.

Drain-pipes, which are horizontal and receive the discharge from the vertical or upright pipes.

Soil-pipes, which receive the discharge from the closets.

Waste-pipes, which receive the discharge from fixtures other than closets.

Vent-pipes, which relieve the air pressure on the system, prevent siphonage, and create a circulation of air throughout the system.

Water-pipes, which supply water to the various fixtures.

Table 5 gives minimum diameters of soil and waste pipes.

TABLE 5

Minimum Allowable Diameter of Soil-Pipe and Waste-Pipe

	Diameter
Main soil-pipe	4 in.
Main soil-pipe for water-closets on 5 or more floors	5 in.
Branch soil-pipe	4 in.
Main waste-pipe	2 in.
Main waste-pipe for kitchen sinks, 5 or more floors	3 in.
Branch waste-pipe for laundry tubs	1½ in.
When set in ranges of 3 or more tubs	2 in.
Branch waste-pipe for kitchen sinks	2 in.
Branch waste-pipe for urinals	2 in.
Branch waste-pipe for other fixtures	1½ in.

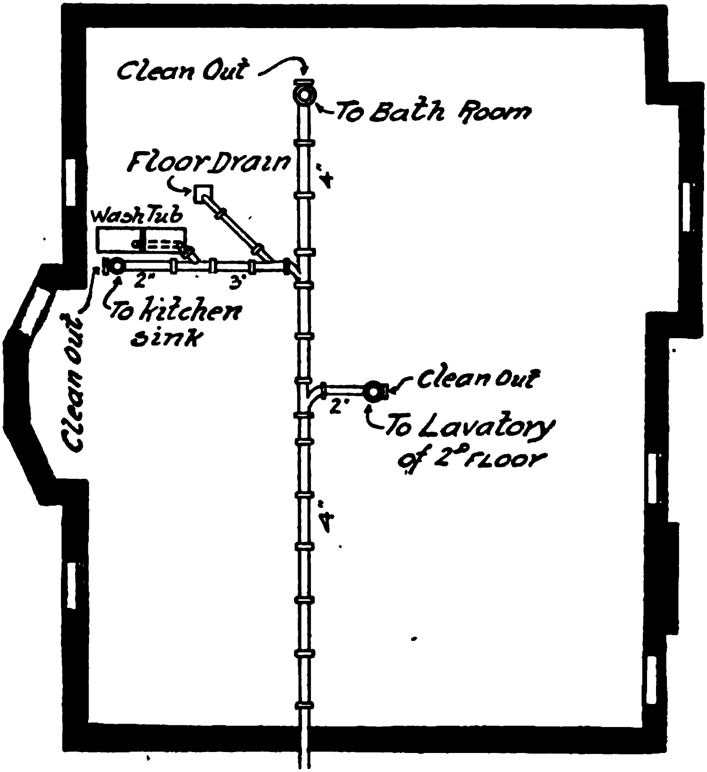


Fig. 3. Basement Roughing-In Plan.

Let Figs. 3, 4, and 5 represent respectively, the basement, first-floor, and second-floor plans of a building in which the plumbing is to be installed. Assume the following to be a list of the fixtures required.

Basement	1 Two-part Wash-Tray. 1 Floor Drain.
First Floor	1 Sink. 1 Forty-Gallon Range Boiler. 1 Lavatory.

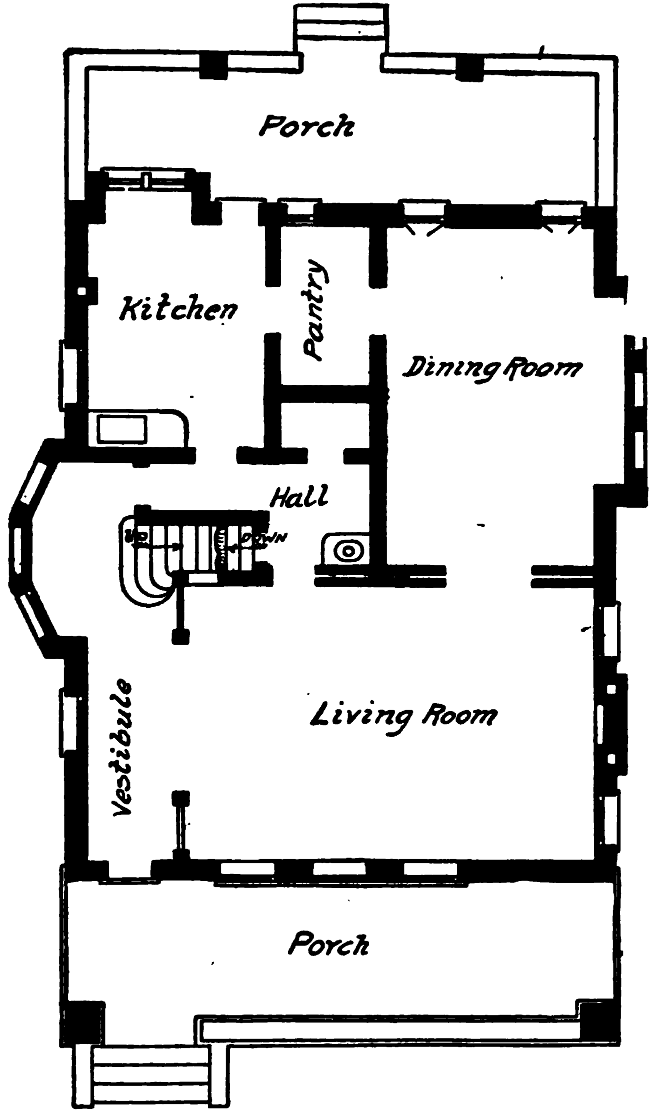


Fig. 4. First-Floor Plan of Residence.

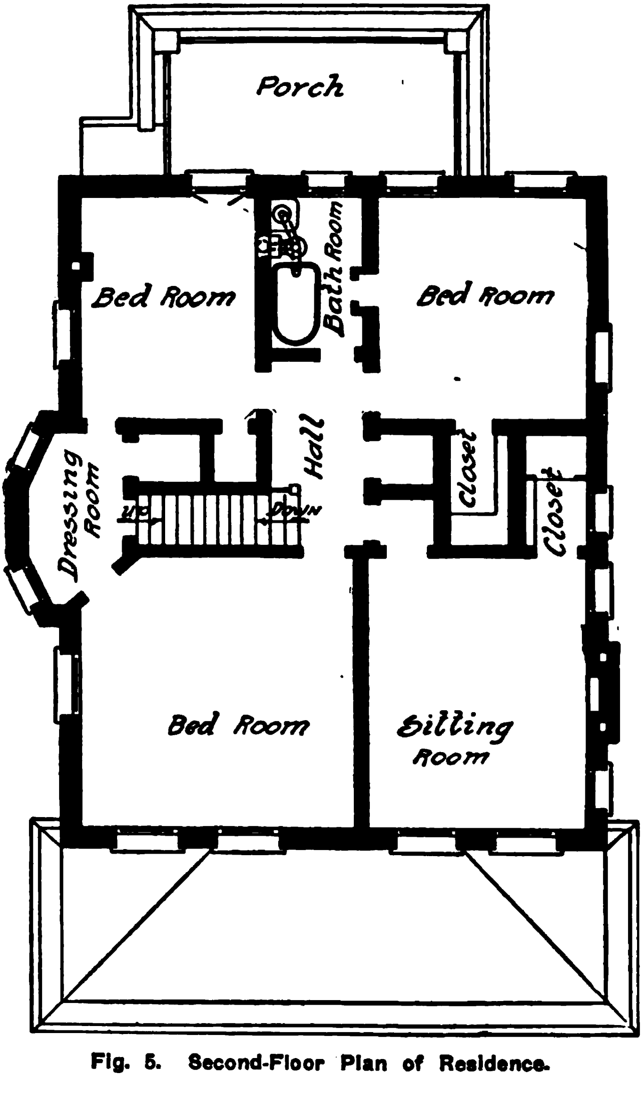


Fig. 5. Second-Floor Plan of Residence.

Second Floor	1 Lavatory. 1 Bathtub. 1 Water-Closet.

First will come the roughing-in measurements of the various fixtures, in order to so locate the pipes that they will be in exactly the right places when the floors are down and the plastering done. These measurements should always be entered in a small memorandum book for future reference.

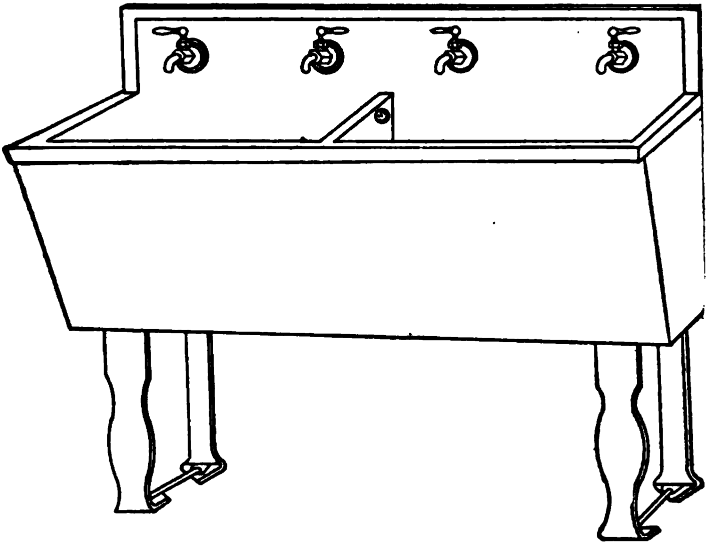


Fig. 6. Wash-Trays or Laundry Tubs.

The wash-trays—or laundry tubs, as they are sometimes called—are of the style shown in Fig. 6, with rough brass continuous waste and trap as in Fig. 7; and are to be supplied with hot and cold water through Fuller bibbs, as shown in Fig. 6.

The floor drain is like that shown in Fig. 8.

The kitchen sink is of the type illustrated in Fig. 9, with nickel-plated trap, with waste to floor and vent to wall, and nickel-plated Fuller bibbs.

The range boiler is shown in Fig. 10. It is to be erected on a stand (Fig. 11), and connected to the kitchen range, and also to a gas heater as shown in Fig. 12.

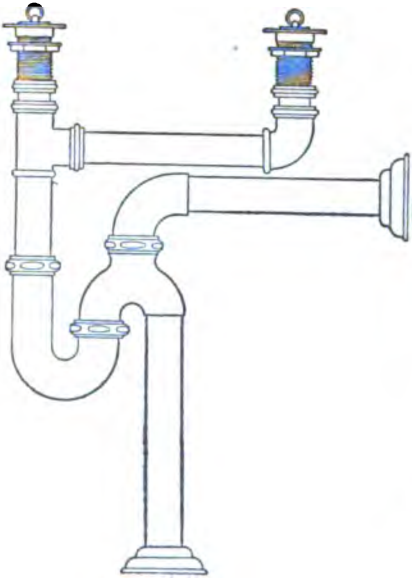


Fig. 8. Floor Drain.

Fig. 7. Continuous Waste and Trap from Wash-Trays.

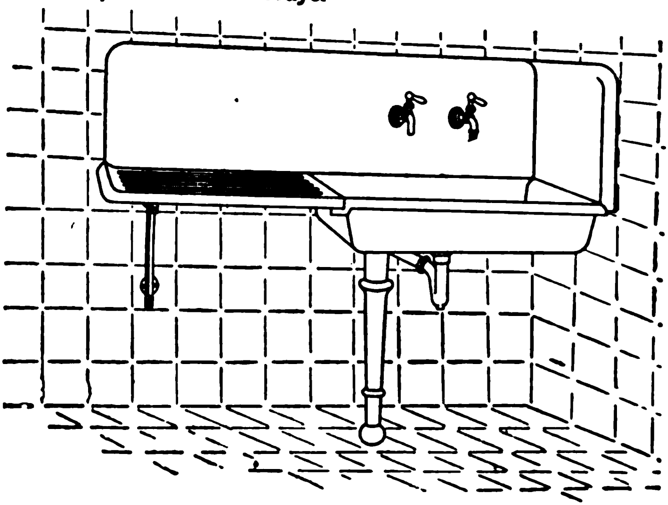


Fig. 9. Kitchen Sink.

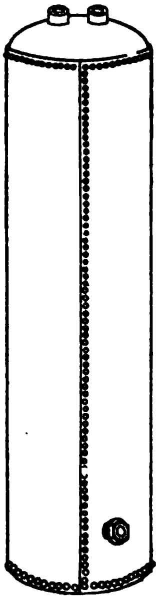


Fig. 10. Range Boiler.

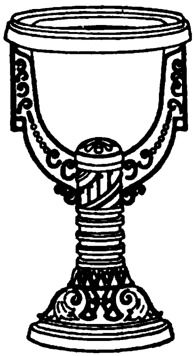


Fig. 11. Stand for Range Boiler.

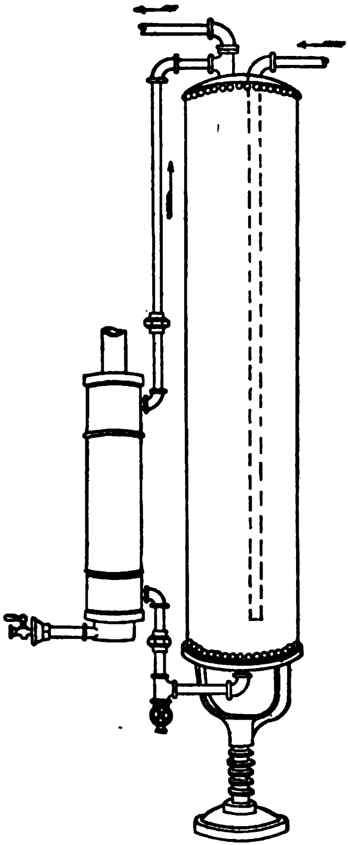


Fig. 12. Range Boiler Connected to Gas Heater.

The first-floor lavatory (Fig. 13) is fitted with nickel-plated Fuller basin corks, and nickel-plated trap to wall.

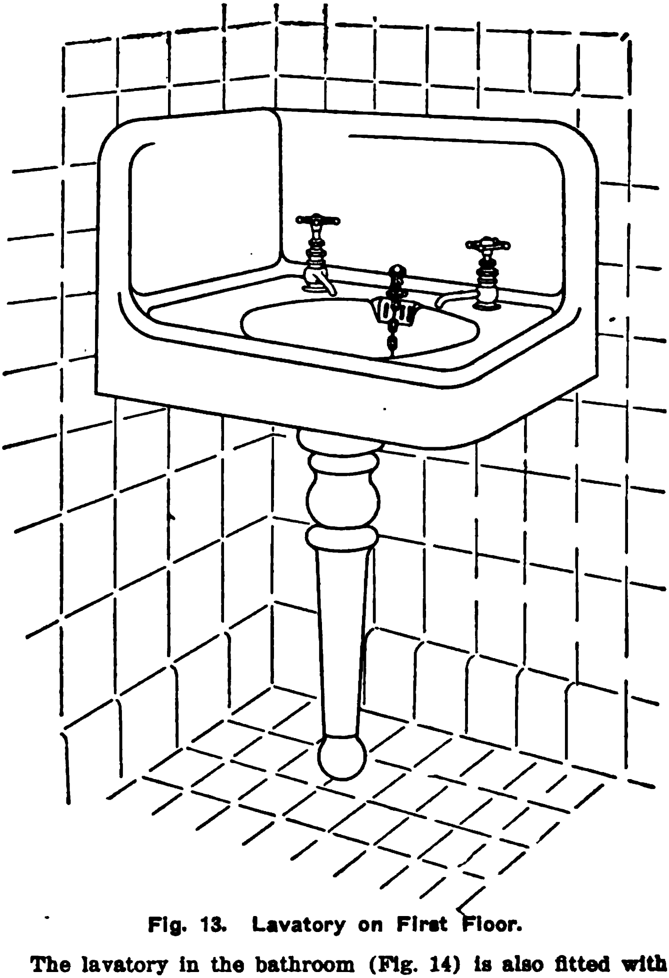


Fig. 13. Lavatory on First Floor.

The lavatory in the bathroom (Fig. 14) is also fitted with nickel-plated Fuller corks, and nickel-plated trap to wall.

The bathtub is a 5-ft. tub of the type shown in Fig. 15.

The closet is of the low-tank type illustrated in Fig. 16.

Having looked over the fixtures and noted the roughing-in measurements, a start can be made on the vertical pipe work.

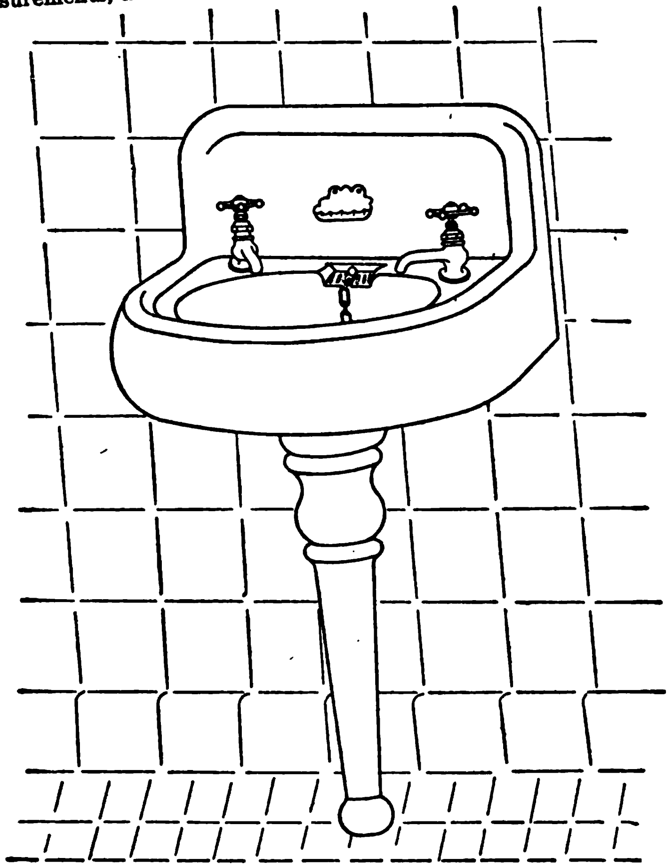


Fig. 14. Bathroom Lavatory.

Vertical Pipe Work

Fig. 17 is an elevation of the sink and wash-tray stack, which can be installed at once. Into the bend in the drain-pipe that is looking up, first calk a 2-in. Y; and in the outlet of this Y, calk a 2-in. clean-out plug with brass cover and square head, for the purpose of clearing the pipe at any time a stoppage may occur. Continuing to the basement ceiling, place a 2-in. Y for the sink waste. It may be necessary to use an offset here—that is, change direction, and carry the piping along to where it will be in position to pass up directly through the first-floor partition. Then, continuing upwards to a point about five feet above the first floor, place a 2-in. tapped tee (see Fig. 18) for the vents from the kitchen sink and the wash-trays; and then continue on up to and through the roof, enlarging the pipe to 4 inches just below the roof, and placing a roof-flashing at the roof.

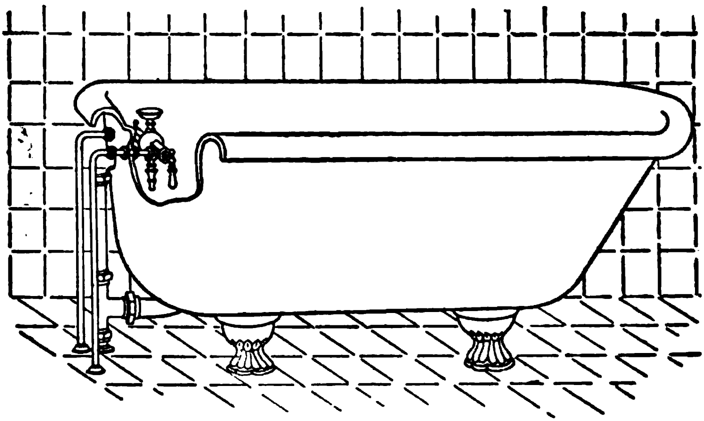


Fig. 15. Bathtub.

There are a number of different styles of roof-flashings, any one of which may be used, provided it will prevent the water from leaking through and provided it has good wearing qualities. By enlarging the pipe to 4 inches where it goes through the roof, the danger of the pipe becoming closed with hoar frost is avoided. This same precaution applies to any soil or vent stack carried through the roof.

The next step will be to get in the waste and vent-pipes. For the sink waste there will be required a 2x1½-in. brass ferrule, and about two feet of 1½-in. lead pipe. After wiping the lead to the ferrule, calk same into the Y left for that purpose, after bending the lead pipe to the proper place to receive the sink trap.

Into the tapped tee which was left for the vents, screw a 2x1½x1½-in. tee with nipple of right length, and drop out of the side opening to the basement for the wash-trays, and out of the end opening to the sink. Here are needed for the sink, and also for the trays, a 1½-inch female soldering

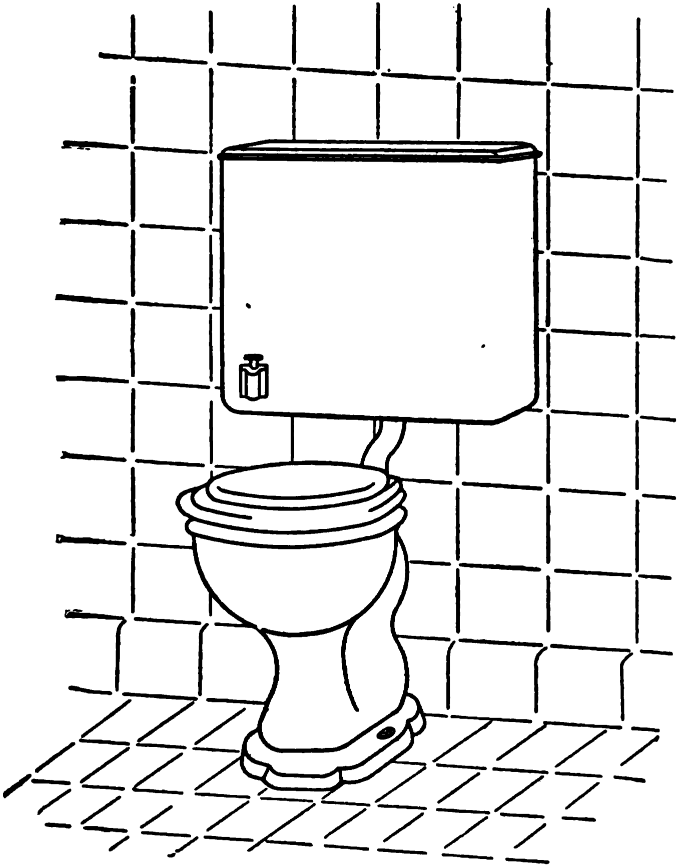


Fig. 16. Low-Tank Type of Water-Closet.

nipple, and about 15 inches of 1½-in. lead pipe. After wiping the necessary joints, screw the pieces onto the pipe, after bending the same to the proper angle. Then, close the ends so that the job can be tested, which will complete this stack until time for setting the fixtures.

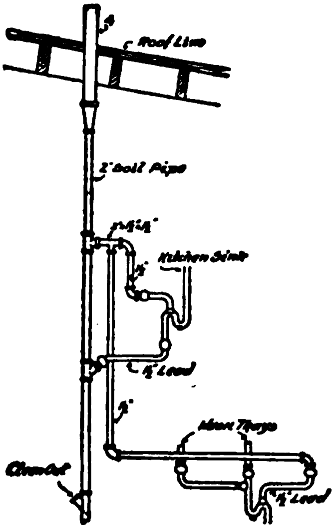


Fig. 17. Sink and Wash-Tray Stack.

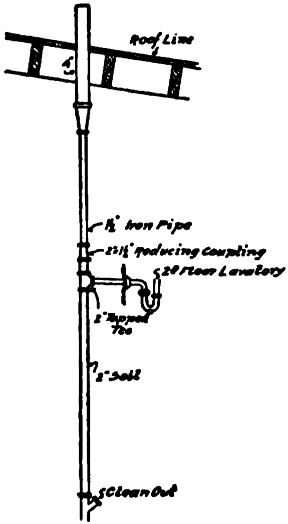


Fig. 18. Stack Elevation for First-Floor Lavatory.

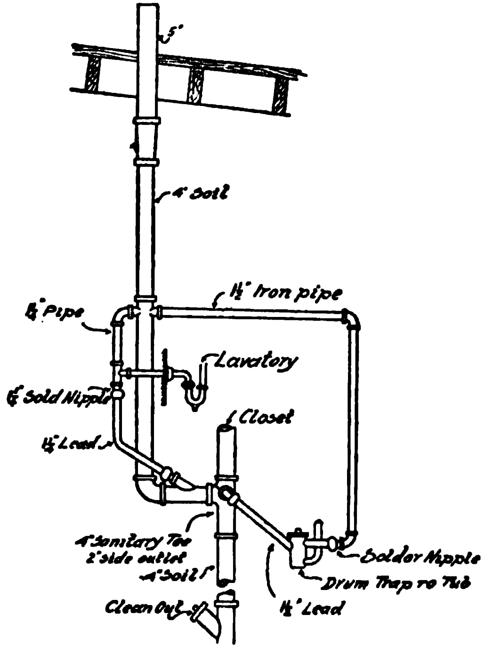


Fig. 19. Stack Elevation for Bathroom.

It will be seen that when setting these fixtures, it will be necessary to wipe a joint between the vent-pipe now in, and the vent-pipe from the traps; and this connection will leave plenty of "spring" in the piping for expansion and contraction. In some localities the connection between the vents in the wall and the trap vents is made by means of **slip joints**, with a rubber gasket to make the joint tight and allow for expansion and contraction. Various authorities differ regarding this subject. It would appear, however, that a well-made slip joint would be an advantage in this respect.

The next work will be on the wash-tray waste, which will require to be of the same style as the waste for the sink, and the end brought through the basement floor for future connection. In some cases, a **slip-joint nut** (Fig. 20) is used.

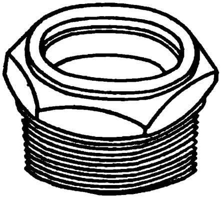


Fig. 20. Slip-Joint Nut.

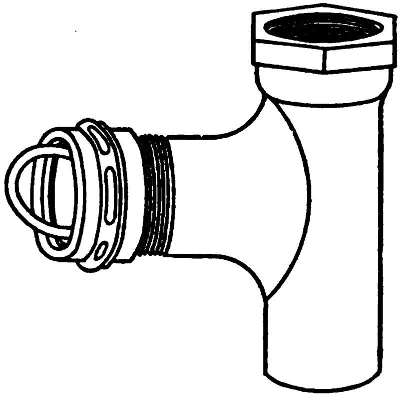


Fig. 21. Vent Tee.

Fig. 21 shows a type of **vent tee** that is extensively employed. This can be obtained with both ends intended for connection to iron pipe, instead of the form shown, which is for lead waste-pipes and iron vent-pipes. The part that receives the pipe from the trap has a long, threaded shank, which can be cut off to suit the job it is being used on; and this is a very good feature. See Fig. 21.

The next work in order will be to rough-in the stack for the first-floor lavatory. This will be commenced by calking in a Y with clean-out, as was done on the sink stack: then continue to basement ceiling, where it may be necessary to use an offset, as before, to get back into the partition.

At the proper height, place a tapped tee, 2x2x1¼ in., with a nipple in the 1¼-in. opening which will extend ½-in. through the plaster. This will allow the use of a slip-joint nut (Fig. 20) when connecting up the lavatory.

In the top of this tee, calk a 2x1½-in. reducing coupling, and extend up to a point just below the roof with 1½-in. iron pipe. At this point, screw on a 2x1½-in. coupling to calk into a 2x4-in. increaser, and use a short piece of 4-in. soil-pipe to extend through the roof, with necessary roof-flashing.

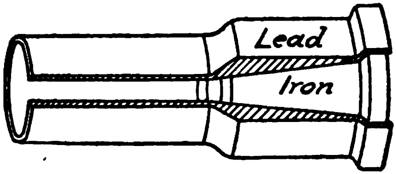


Fig. 22. Ferrule for Connecting Bath Waste to Closet Tee.

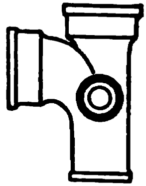


Fig. 23. Closet Tee.

This manner of roughing-in is termed continuous venting. It is preferable to venting on the sink and wash-trays, since, with this style, there is not the chance for the vent-pipe to choke up, which is apt to occur with the sink style of venting.

The vent work on this job will be done with black iron pipe, and cast-iron fittings. Galvanized pipe and fittings are sometimes used; sometimes black pipe and galvanized fittings; and sometimes, again, galvanized pipe and black cast-iron fittings. In some cases, black pipe coated inside with asphaltum and having recessed drainage fittings is used. In any case, provision should be made for cleaning the vent-pipes at times when needed. When a vent is taken from the top, or crown of a trap, grease will accumulate in the vent-pipe, and in time will choke it up entirely; and this is where "continuous" venting has the advantage.

The question as to what kind of material shall enter into the roughing-in of the job, will be largely governed by local rulings where there is an Inspector, and the work will require inspection and testing before being covered up. Whether an inspection is necessary or not, however, all work should be tested before being covered up.

Next proceed to rough-in the stack for the bathroom. First calk-in a clean-out plug into a Y, the same as for the other two stacks, and then continue up to the bathroom. Here will be required a sanitary tee with a 2-in. opening in the side to receive the bath waste. There should be a 4x2-in. Y in the side opening of the tee, for the lavatory waste. Continuing over to the partition, and extending upwards, insert two tapped tees for the bath and lavatory vents, and then continue up to a point just below the roof, where the pipe should be enlarged to 5 in. and extended through the roof, with the necessary roof-flashing.

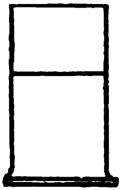


Fig. 24. Straight Brass Ferrule.

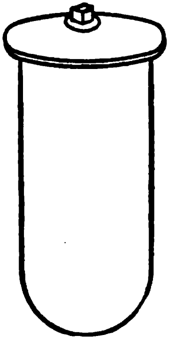


Fig. 25. Drum Trap Used on Bath Waste.

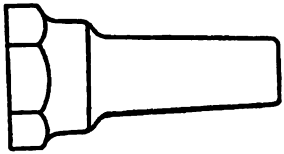


Fig. 26. Solder Nipple Used on Vent Work.

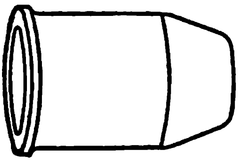


Fig. 27. Tapered Brass Ferrule.

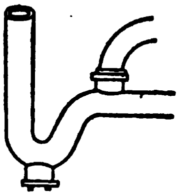


Fig. 28. Style of Trap Often Used on Bathtubs.

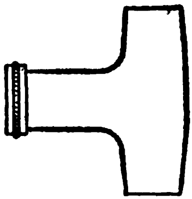


Fig. 29. Tee for Continuous Venting with Lead Waste and Vent Pipes.

All the soil-pipe in the stacks may be "Extra Heavy" and the vents "Standard" pipe; or all may be "Standard." The specifications usually cover this point.

In the top of the 4-in. sanitary tee, a combination lead ferrule, should be calked, as shown in Fig. 22, and this will receive the discharge from the water-closet. Fig. 18 shows the stack elevation for the first-floor lavatory.

Fig. 19 shows the stack elevation for the bathroom. Ordinarily the closet opening would be in the side of the 4-in. sanitary tee; but in this case the opening will be in the top, owing to the fact that the first-floor partition is not directly under the bathroom partition, and requires an offsetting of the pipe-work between the ceiling and the floor. In the side opening of the closet tee, connect the bath waste, which will require a 2-in. ferrule like that shown in Fig. 22, or in Fig. 24, some 1½-in. lead waste-pipe, a 4x8-in. drum trap (Fig. 25) for the waste-pipe, a short piece of 1½-in. lead pipe, and a 1½-in. brass solder nipple (Fig. 26). The waste from the tub will branch into the drum trap at a point near the bottom; and the outlet to the soil-pipe will be taken out at a point near the top, but just below the vent branch.

The wiping on the bath waste can be done before setting the same in place, with the exception of the joint where the solder nipple (Fig. 26) screws onto the vent-pipe already roughed-in, and this can be wiped after the work is set in place. The screw-top on the bath trap makes it easily accessible for cleaning purposes.

In the side opening of the 4x2-in. Y which is to run into the closet tee, place a 2x1¼-10-in. lead ferrule (Fig. 22), which will require a wiped joint to connect it to the lead vent and waste-pipe which is already roughed-in.

Fig. 23 shows the closet tee used on this installation; and, minus the side opening, this is the fitting ordinarily used.

Fig. 24 shows a straight brass ferrule; and Fig. 27 shows a tapered brass ferrule, reducing down to the size of the waste-pipe used.

Fig. 26 shows the solder nipple used on the vent work; this is made with either male or female threading.

Fig. 25 shows the drum trap used on the bath waste. The top, being a trifle larger than the body of the trap, will cover up the hole in the floor, and make a neat finish.

Fig. 28 shows another style of trap that is used extensively on bathtubs.

Fig. 29 shows another form of tee that can be used for the continuous style of venting where lead is used for both waste and vent pipes.

Fig. 30 shows a new method of joining the closet to the soil system, to be used instead of the putty joint that has commonly been employed. This makes a very sanitary job, and insures a tight joint at this connection, which is by no means certain when putty is used. The brass flange is slipped over the 4-in. lead pipe extending through the floor for the closet connection; and then the pipe is sawed off at the proper distance to allow it to be flanged over into the brass floor-flange and then soldered. The graphite gasket is next placed in position, and the closet is ready to be screwed in place.

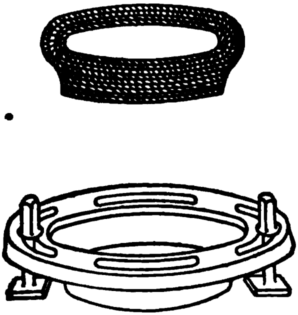


Fig. 30. Graphite Gasket Closet Connection to Soil System.

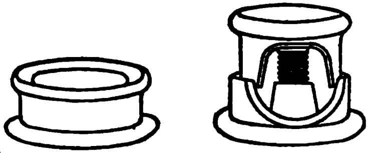


Fig. 31. Device for Steadying Bathtub on Uneven Floor.

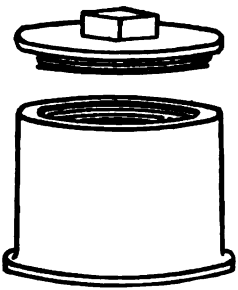


Fig. 32. Clean-Out Plug.

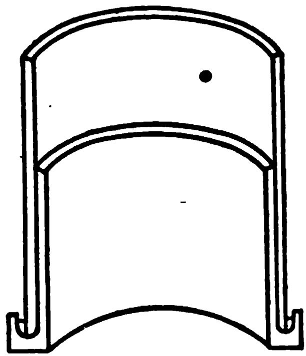


Fig. 33. Type of Ferrule for Waste Pipes; Small Joint is poured.

In some instances when the bathtub is set in place, it is found that it will not set firmly, but has a rocking motion due to the unevenness of the floor. The device shown in Fig. 31 will be found very useful to remedy this trouble, and is inexpensive.

Fig. 32 shows the clean-out plug which is placed at the foot of the different stacks for cleaning purposes. This has

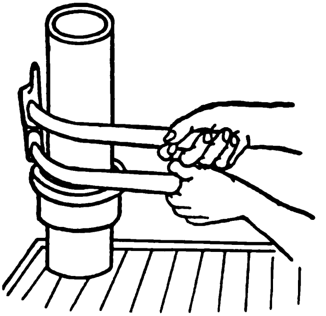


Fig. 34. Special Tools for Calking Joints in Corners.

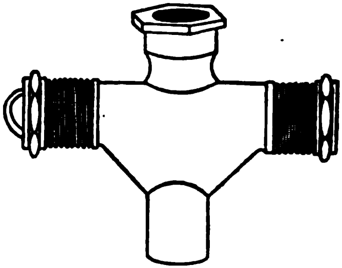


Fig. 35. Waste and Vent Fitting for Two Fixtures Set Back to Back.

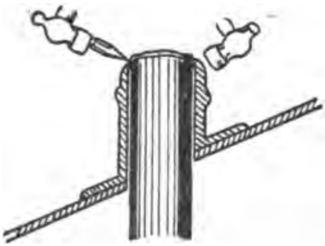


Fig. 36. Roof Flashing.

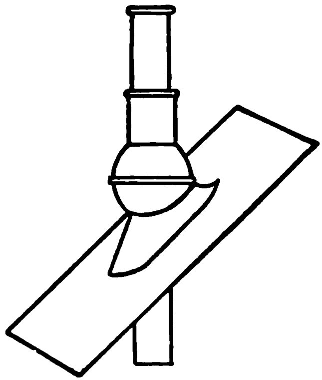


Fig. 38. Roof Flashing.

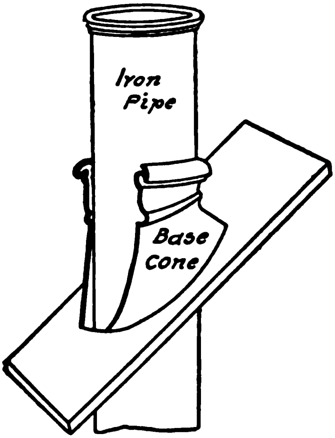


Fig. 37. Roof Flashing.

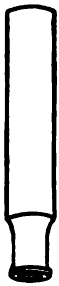


Fig. 39. Increaser.

an iron body, and a brass screw; the latter is easily removed should occasion require it.

Fig. 33 shows another type of ferrule for waste-pipes. It is used by inserting the ferrule into the lead pipe, and pouring the small joint as shown.

There will be times when soil-pipe joints will be encountered in corners where it will be a hard matter to get at them to calk them properly with the ordinary tools. In this case, the tools shown in Fig. 34 will be found very useful.

Fig. 35 shows a waste and vent fitting that can be used where two fixtures are set back to back.

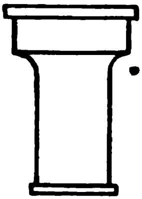


Fig. 40. Increaser.

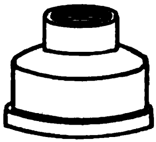


Fig. 41. Increaser Tapped for Screw Pipe.

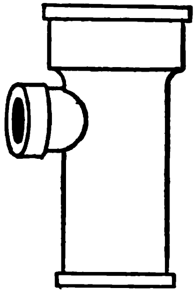


Fig. 42. Tapped Tee.

Figs. 36, 37, and 38 show various styles of roof-flashings.

Figs. 39 and 40 shows various styles of increasers, which are used at a point just below the roof. They can be obtained either to calk-in as shown, or with the bottom end tapped for iron pipe to screw in. An increaser tapped for screw-pipe is shown in Fig. 41.

Fig. 42 shows one style of tapped tee.

Fig. 43 shows a brass bath trap that is used where the waste work is all wrought iron—or, as it is sometimes called, the "Durham" system.

Soil-Pipe Sizes Allowed by Various Cities

Municipal regulations ordinarily govern the sizes of soil-pipe that are allowed to be installed in towns and cities of any considerable size. The regulations in some of the leading American cities are indicated in the following:

Baltimore, Md.; Buffalo, N. Y.; Chicago, Ill.; Cincinnati, Ohio; Denver, Col.; Detroit, Mich.; Minneapolis, Minn.; New Haven, Conn.; Omaha, Neb.; St. Joseph, Mo.; San Francisco, Cal.

Minimum diameter, 4 in.

Allegheny, Pa.; Pittsburgh, Pa.; Scranton, Pa.

For 1 to 4 water-closets, not less than 4 in.
For 4 to 8 water-closets, not less than 6 in.

Jersey City, N. J.

For 1 and less than 10 water-closets, with other fixtures, 4 in.
For 10 and less than 20 water-closets, with other fixtures, 5 in.
For 20 or more water-closets, with other fixtures, 6 in.

Milwaukee, Wis.

For 4 water-closets, 4 in.
For 10 water-closets, 5 in.
For 25 water-closets, 6 in.
For over 25 water-closets, 8 in.

Newark, N. J.; Paterson, N. J.

For main soil-pipe, 4 in.
For main soil-pipe for water-closets on 5 or more floors, 5 in.
For main soil-pipe for tenements or factories, 5 in.

New Orleans, La.

For 1 to 5 water-closets, 4 in.
For more than 5 water-closets, 5 in.
In buildings over 5 stories, and having more than 8 water-closets, 6 in.

Philadelphia, Pa.

For 1 to 6 water-closets, 4 in.
For 7 to 12 water-closets, 5 in.
For 13 to 20 water-closets, 6 in.
If building is 5 up to 12 stories high, 5 in.
If building is more than 12 stories high, 6 in.

Cleveland, Ohio; Columbus, Ohio

The maximum number of fixtures connected to pipe of various sizes is indicated as follows:

Size Pipe	Soil and Waste		Soil-Pipe Alone	
	Branch	Main	Branch	Main
4-in.	48	96	12	24
5 "	96	192	24	48
6 "	168	336	42	84
7 "	280	560	70	140
8 "	420	840	105	210
9 "	580	1,160	145	290
10 "	800	1,600	200	400
11 "	1,060	2,120	265	530
12 "	1,420	2,840	355	710

Washington, D. C.

For 1 to 12 water-closets, 4 in.
For 13 to 35 water-closets, 5 in.
For 26 to 40 water-closets, 6 in.

Toledo, Ohio

For main soil-pipe from 6 water-closets or bathrooms, 4 in.
For main soil-pipe from 6 to 10 bathrooms or water-closets, 5 in.

Rochester, N. Y.

For 1 to 30 fixtures, 4 in.
For 30 to 50 fixtures, 5 in.
For 51 or more fixtures, 6 in.
One water-closet is counted as 2 fixtures; one tub, or sink, etc., is counted as 1.

St. Paul, Minn.

For main soil-pipe, not less than 4 in.
For main soil-pipe for water-closets on 5 or more floors, 5 in.
For main soil-pipe from more than 10 bathrooms, 6 in.

3-foot urinal trough or wash-sink, or 1 bath, basin, sink, or small fixture, is counted as 1 fixture; and 1 water-closet, pedestal urinal, or slop hopper, is counted as 2 fixtures.

The above shows the sizes used in daily installations in various cities where local rulings govern, and all work is tested and inspected before being covered up by the other trades.

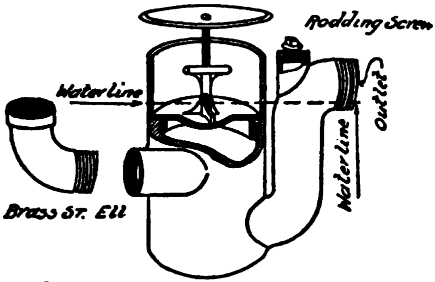


Fig. 43. Brass Bath Trap for Wrought-Iron Waste Work.

WATER SERVICE PIPES

The main in the street is usually tapped by the local Water Company; and either the connecting pipe is run to the curb line by the Company, or else the plumber takes it at the point of connection. The kind of piping is governed by local rulings. In some sections of the country it is customary to run lead pipe to the curb, and then either lead or iron on into the building. Other places require only a short section of lead pipe at the main, usually about 18 in. in length; and from this point on into the building the pipe may be iron.

In any case, iron pipe should never be connected directly to the corporation cock (as the cock that is screwed into the water main is termed), on account of the rigid connection being liable to breakage from settling, either of the main, or of the earth over the service. For a similar reason the service pipe into the building should never be laid in the same ditch with the sewer line, unless a shelf of earth is left alongside the sewer ditch, on which the water service can be laid, and which will insure a good foundation for it. Many a plumber has had to dig up the service pipe after it has been in but a short time, to repair a leak in it caused through settling of the dirt.

The service pipe should be laid below the frost line, and carried as directly as possible to the building. Where the service pipe enters the building, it should be provided with a good, serviceable **stop and waste cock**, placed at a point easily reached by the occupants of the building in case the water should require shutting off at any time on account of leaks, bursting of pipes, etc.

The water service pipes should be put in place before the plastering is done or the bathroom floor is laid.

Starting the cold-water line at the front wall where the service enters, and rising to the ceiling, run this pipe directly to the bathroom riser, where a stop and waste cock should be placed so that the bathroom can be shut off independently of the other portions of the system.

In making this run, tees should be put in at proper intervals to provide connections for the other fixtures.

The bathroom line is carried up to underneath the floor of the bathroom, where it branches to the tub, closet, and lavatory. The nipples of these branches are left extending through the floor at the proper places, being capped for testing purposes and to prevent dirt getting into the pipe.

Next extend the first-floor lavatory supply to the proper point, placing a stop and waste cock on this line also.

It is next in order to extend the branch that supplies the laundry tubs, sink, and hot-water boiler, placing stops on the wash-tray and sink lines, but placing the stop for the range boiler at the top of the boiler. This will cut off the entire hot-water supply for the house; and separate stops can be placed on the various hot-water lines to the fixtures, if desired. The hot water for the bathroom can be either extended to the ceiling and carried across to the bathroom, or it can be taken to the cellar and carried up alongside the cold-water line. The hot lines, after leaving the boiler, can be run about the same as the cold-water supplies; but on both lines there must be a definite place to which the pipes will drain, in case it is desired to empty the entire system of water.

In connecting up the range boiler (see Fig. 12) with the cold supply, a piece of pipe usually extending to within six inches of the bottom of the boiler—known as a **boiler tube**—should be screwed into the boiler coupling to which the cold-water supply is connected, for the purpose of carrying the cold water down nearly to the bottom of the boiler. The object of this is to avoid chilling the hot water, which leaves the boiler by a pipe at the top alongside the cold water inlet pipe. This cold-water pipe should always have a small hole drilled in it at a point about one inch below the top of the boiler, to prevent the possibility of the water being siphoned out of the boiler, which might occur in case the supply were shut off for any reason. This vent-hole in the cold inlet pipe should be about ⅛-in. in size, and should always be turned away from the hot supply, or it will throw a spray of cold water directly across the hot water leaving the boiler; and it may be difficult to determine why a job that is to all outward appearance piped correctly will nevertheless not give a good supply of hot water.

In some cases, it is required that the job shall be supplied with soft water. This calls for the use of a **water lift**; and the soft water can be either pumped to an attic tank, or pumped directly into the system. There are a number of water lifts or motors on the market, operated either by electricity or by water-power. In the electrically operated lift, the necessary wiring will be installed, and the soft water end will be connected by a suction pipe to the cistern, and a discharge pipe to the attic tank or directly to the system of piping through the building. In the case of a lift operated by water-power, the cold city water should be connected at the opening marked for it on the lift; and the waste water can be discharged to the sewer or run to the kitchen sink (if an attic tank is used), in which case the lift will pump water whenever cold water is drawn at the sink. The discharge and suction on the soft water end should be connected up as before described.

Where the soft water is discharged directly into the piping, it is necessary to place a compression tank in the discharge line. This is usually a 30-gallon range boiler, which acts as a cushion for the pump or lift to work against, and insures a steady flow at the faucets when water is drawn. If such a tank were not installed, the water would come in a sputtering stream as the lift delivered it into the pipe system.

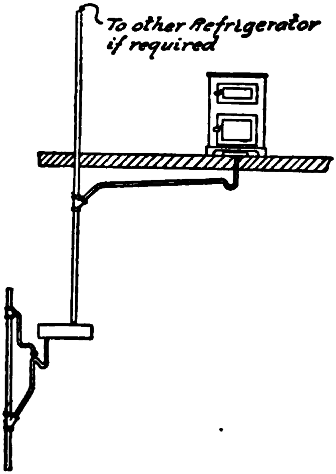


Fig. 44. Refrigerator Waste Connection to Sink.

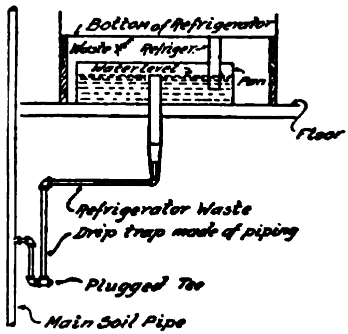


Fig. 45. Refrigerator Waste Connection to Soil-Pipe.

In some cases where an attic tank is used for the storage of soft water, a ball-cock, similar to the one used for regulating the supply to the water-closet flush-tank, is placed on the soft-water supply to the tank, being set to limit the supply to a certain height of water in the tank. When any water is drawn from the tank, the lift will replace it, and the supply will then be shut off by the action of the ball-cock.

Refrigerator wastes should never be connected directly to any sewer or drain-pipe, but should discharge into a sink indirectly, as per Fig. 44; or into soil-pipe, as per Fig. 45. The use to which the refrigerator is put demands that unusual care be taken in disposing of the waste water. The piping should be provided with clean-outs wherever there is a possibility of a stoppage occurring from the sawdust, etc.

used in packing the ice; and the pipe should be run in such a manner that it can be readily taken down and cleaned if a stoppage occurs which cannot be cleared from the clean-outs.

It is not usually necessary to vent refrigerator traps, since the water does not enter the piping, as it does from other fixtures, in a large volume, but only as the ice melts, and there is little possibility of any siphonage occurring.

Waste-pipes from refrigerators should be galvanized iron, with ends well reamed. The trap used at the soil-pipe in Fig. 45 may be made out of pipe and fittings. The end of the waste pipe from the refrigerator extends down into the pan (Fig. 45); and the waste to sewer connected toward the top of the pan will leave a place for the dirty matter from the ice to collect, and this can be removed frequently, being thus prevented from entering the waste-pipe. By making the trap seal at the soil-pipe about 6 to 8 in. in depth, there will be little danger of this trap being siphoned from the discharge of fixtures on the line above; and even if this did occur, the dripping from the ice would soon seal the trap again.

TESTING THE PLUMBING

After a job has been roughed-in, and before being covered up, it should be thoroughly tested, to obviate the necessity for any tearing-up of floors or removal of plaster in order to locate and repair leaks that may show up after the fixtures are set.

There are several different methods employed in testing plumbing installations, the principal ones being the **water test, smoke test,** and **peppermint test,** details of which need not be given here.

A careful inspection of the material as it is being put in place, will save much trouble at times, as it is an easy matter to detect cracked pipes or fittings by tapping them with a hammer. The difference in sound between good and defective material is easily detected by the ear after a little practice.

Local rulings generally prescribe the form of test to be applied to plumbing installations. Many plumbers, where there are no local rulings requiring or regulating tests, test all their work for their own satisfaction, and are then in a position to guarantee absolutely with some degree of satisfaction, all the work they install.

The added cost for testing does not amount to a very large item; and it gives the plumber the advantage of an added prestige when it becomes known to his customers—both the customers he already has, and prospective ones—that any job he does must be right to his own satisfaction before he is ready to turn it over to his customers; and this will soon increase his list of clients. There is only one way to do work, and that is to do it right.

USEFUL TABLES, RULES, ETC.

The experience of practical plumbers has resulted in the accumulation of a great mass of useful information which has been embodied in the convenient form of ready tables, concise practical rules, etc. We now present such portions of this accumulated fund of information as will be found of greatest practical value in calculating for ordinary plumbing work.

TABLE 6

Carrying Capacity of Sewer Pipes, in Gallons per Minute, with Varying Fall in Inches per 100 Feet

Size of Pipe	Fall per 100 Feet, in Inches							
	1 in.	2 in.	3 in.	6 in.	9 in.	12 in.	24 in.	36 in.
3 inch	13	19	23	32	40	46	64	79
4 "	27	38	47	66	81	93	131	162
6 "	75	105	129	183	224	258	364	450
8 "	153	216	265	375	460	527	750	923
9 "	205	240	355	503	617	712	1,006	1,240
10 "	267	378	463	755	803	921	1,310	1,613
12 "	422	596	730	1,033	1,273	1,468	2,076	2,554
15 "	740	1,021	1,282	1,818	2,224	2,464	3,617	4,467
18 "	1,168	1,651	2,022	2,860	3,508	4,045	5,704	7,047
24 "	2,396	3,387	4,155	5,874	7,202	8,303	11,744	14,465
27 "	4,407	6,211	7,674	10,883	13,257	15,344	21,771	26,622
30 "	5,906	8,352	10,223	14,298	17,714	20,204	28,129	35,513
36 "	9,707	13,769	16,816	23,763	29,284	33,722	47,523	58,406

TABLE 7

Discharge of Sewer Pipes

Grade of 1 Foot in 100 Feet

Diameter of Pipe	Discharge Cubic Feet per Second	Discharge Gallons per Second
4 inches	0.16	1.2
6 "	0.49	3.7
8 "	1.11	8.3
9 "	1.53	11.48
10 "	2.05	15.33
12 "	3.4	25.5
15 "	6.29	47.2
18 "	10.37	77.8
20 "	13.85	103.9

Capacity of Sewer Pipe. The carrying capacity, in gallons per minute, of sewer pipe laid at various grades, is shown in Table 6.

Discharge of Sewer Pipes. Table 7 shows the discharge from various-sized sewer pipes laid on a grade of 1 foot in 100 feet.

TABLE 8

Dimensions and Weights of Galvanized-Iron Range Boilers

Capacity of Boiler	Sizes	Weight, "Standard"	Weight, "Extra Heavy"
30 gallons........	12x60 inches	78 lbs.	100 lbs.
40 "	14x60 "	96 "	120 "
52 "	16x60 "	126 "	152 "
63 "	16x72 "	150 "	175 "
66 "	18x60 "	166 "	180 "
82 "	20x60 "	200 "	215 "
100 "	22x60 "	245 "	270 "
120 "	22x72 "	285 "	315 "

Sizes of Galvanized-Iron Range Boilers. The dimensions and weights of both "Standard" and "Extra Heavy" galvanized-iron range boilers are given in Table 8.

Miner's Inch. A Miner's inch of water about equals a flow of 12 United States gallons per minute.

Sheet Lead. The weight and thickness of sheet lead are indicated in Table 9.

TABLE 9

Weight and Thickness of Sheet Lead

Weight per Square Foot	Thickness
8 lbs.	[illegible] in.
7½ "	[illegible] "
6 "	[illegible] "
5 "	[illegible] "
4 "	[illegible] "
3 "	[illegible] "

Brass Piping. Table 10 gives the weight per linear foot of brass pipe of standard iron pipe sizes.

To Find Centers between Fittings. To find the length of piping required to connect fittings where offsets occur—that is, to determine the distance between fittings, center to center—multiply the length of the offset, in inches, by the factors indicated as follows:

For 60-degree	or 1/6	bends,	multiply by	1.1547
" 45-	" 1/8	"	" "	1.4142
" 30-	" 1/12	"	" "	2.00
" 22½-	" 1/16	"	" "	2.61
" 11¼-	" 1/32	"	" "	5.12
" 5⅝-	" 1/64	"	" "	10.22

For example, suppose that it is desired to know the length between centers, of two 45-degree ells, when the offset is 2 ft.

Since 2 ft. = 24 in., the solution of the problem will be as follows:

$$24 \times 1.4142 = 33.9 \text{ in. nearly.}$$

In practice the above result would be called 34 in., which, allowing off for the ells, would be the length of pipe required. Reference to Fig. 46 will make this clear.

TABLE 10
Weight of Brass Pipe
Iron Pipe Sizes

Size of Pipe	Weight Per Linear Foot	Size of Pipe	Weight Per Linear Foot
⅛ in.	.25 lb.	2 in.	4.0 lbs.
¼ "	.43 "	2½ "	5.75 "
⅜ "	.62 "	3 "	8.30 "
½ "	.9 "	3½ "	10.9 "
¾ "	1.25 lbs.	4 "	12.7 "
1 "	1.7 "	4½ "	13.9 "
1¼ "	2.5 "	5 "	15.75 "
1½ "	3.0 "	6 "	20.8 "

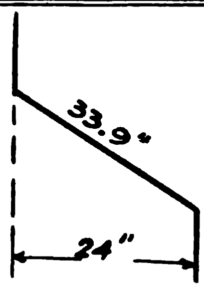


Fig. 46. Piping Calculation at Offset.

Capacity of Storage Tanks. As a basis for figuring the size of storage tank required, take the average amount of water used daily by one person, which is as follows:

Washing dishes ....1 gallon per person daily.
House cleaning ....2 " " " "
Washing clothes ....3 " " " "
Toilet purposes and bathing..9 " " " "
Drinking .... ¼ " " " "
In food .... ¼ " " " "
Water closet ....9½ " " " "
Total average of 25 gallons per person per day.

TABLE 11
Dimensions and Capacities of Wrought Steel Tanks

DIMENSIONS	CAPACITY	AVERAGE WEIGHT
5 by 24 inches.......	120 gallons	300 pounds
6 " 24 "	145 "	330 "
7 " 24 "	170 "	360 "
8 " 24 "	200 "	420 "
5 " 30 "	185 "	450 "
6 " 30 "	220 "	500 "
7 " 30 "	257 "	550 "
8 " 30 "	300 "	600 "
10 " 30 "	375 "	700 "
6 " 36 "	325 "	700 "
7 " 36 "	375 "	800 "
8 " 36 "	425 "	900 "
10 " 36 "	530 "	1,000 "
8 " 42 "	600 "	1,250 "
10 " 42 "	725 "	1,500 "
12 " 42 "	850 "	1,750 "

Table 11 gives dimensions and other data pertaining to storage tanks, and in this connection it is well to explain that:

Tanks up to 6 by 22 in. are tapped 1 in.
Tanks up to 10 by 30 in. are tapped 1½ in.
Tanks above 10 by 30 in. are tapped 2 in.

TABLE 12
Barometric Pressure at Different Altitudes, with Equivalent Head of Water, and Practicable Suction Lift of Pumps

ALTITUDE	BAROMETRIC PRESSURE	EQUIVALENT HEAD OF WATER	PRACTICABLE SUCTION LIFT OF PUMP
At sea level..........	14.7 lbs. per sq. in.	33.95 feet	25 feet
¼ mile, or 1,320 ft...	14.02 " " " "	32.38 "	24 "
½ " " 2,640 " ...	13.33 " " " "	30.79 "	23 "
¾ " " 3,960 " ...	12.66 " " " "	29.94 "	21 "
1 " " 5,280 " ...	12.02 " " " "	27.76 "	20 "
1¼ " " 6,600 " ...	11.42 " " " "	26.38 "	19 "
1½ " " 7,920 " ...	10.88 " " " "	25.18 "	18 "
2 " " 10,560 " ...	9.88 " " " "	22.82 "	17 "

TABLE 13

Velocity and Volume of Discharge per Minute of Different-Sized Sewers

DIA.	180 FT. PER MIN. 3 FT. PER SEC.		270 FT. PER MIN. 4½ FT. PER SEC.		360 FT. PER MIN. 6 FT. PER SEC.		540 FT. PER MIN. 9 FT. PER SEC.	
	FALL	GAL.	FALL	GAL.	FALL	GAL.	FALL	GAL.
3 in.	1 ft. in 69 ft.	54	1 ft. in 30.4 ft.	81	1 ft. in 17.2 ft.	108	1 ft. in 7.6 ft.	162
4 in.	1 ft. in 92 ft.	96	1 ft. in 40.8 ft.	144	1 ft. in 23 ft.	192	1 ft. in 10.2 ft.	288
6 in.	1 ft. in 138 ft.	216	1 ft. in 61.2 ft.	324	1 ft. in 34.5 ft.	432	1 ft. in 15.3 ft.	648
9 in.	1 ft. in 207 ft.	495	1 ft. in 92 ft.	742.5	1 ft. in 51.7 ft.	990	1 ft. in 23 ft.	1485

For example, a 6-in. sewer, laid to a grade of 1 ft. in 61.2 ft., will have a velocity of 270 ft. per minute, or 4½ ft. per second, and will discharge 324 gallons per minute. Other grades and discharges can be similarly figured from the table.

The friction loss caused by ells and valves in pipe work can be calculated from the data given in Table 14.

TABLE 14

Friction Equivalent of Ells and Globe Valves in Lengths of Straight Pipe

DIAMETER OF PIPE	ELL IN FEET OF PIPE	GLOBE VALVE IN FEET OF PIPE
¾ inch............	3 feet	4 feet 0 inches
1 "	4 "	5 " 0 "
1¼ "	5 "	7 " 0 "
1½ "	6 "	8 " 0 "
2 "	7 "	10 " 0 "
2½ "	8 "	12 " 6 "
3 "	10 "	15 " 0 "
3½ "	12 "	17 " 6 "
4 "	14 "	20 " 0 "
4½ "	15 "	22 " 6 "
5 "	17 "	25 " 0 "
6 "	20 "	30 " 0 "
7 "	24 "	35 " 0 "
8 "	27 "	40 " 0 "
9 "	30 "	45 " 0 "
10 "	34 "	50 " 0 "
12 "	40 "	60 " 0 "
14 "	47 "	70 " 0 "

If, for example, it is desired to know the friction loss in a line of piping, caused by 2 ells and 1 valve, the size of pipe being 4-in., by referring to Table 14 it will be seen that one 4-in. ell is equivalent in friction to 14 ft. of pipe, and the 2 ells would therefore mean 28 ft., which, with 20 ft. for the valve, would make a total friction equivalent of 28+20 feet, or a total friction loss equal to the friction loss in 48 ft. of 4-in. pipe.

PROCESS OF SOLDERING

The object of soldering is to unite two portions of the same metal, or of different metals, by means of a more fusible metal or metallic alloy applied when melted, and known by the name of solder. The parts which are to be joined must be thoroughly clean and free from oxides or tarnish. Surfaces may be scraped, filed, scoured, or treated with acids to prepare them for soldering. The edges of the joint must fit well, and be treated with a flux to aid in the operation.

Kinds of Solder. Solders are known as **hard solders** and **soft solders.** Since "soft" soldering is the more common form, we shall devote our attention to this process. Soft solders, also called **tin solders,** or **white solders,** consist of readily fusible metals or alloys, and do not possess much strength. They are easy to handle, on account of the ease with which they are melted. Soft solders are composed of tin, lead-tin, and alloys of tin, lead, and bismuth. Plumbers solder, also called **half-and-half,** is made of 1 part tin and 1 part lead. This solder melts at 370 degrees F., and is used for wiped joints, etc. Ordinary solder for general use with a soldering-bit is made of 5 parts tin and 3 parts lead, and melts at 350 degrees F. Other variations of these mixtures are used with the addition of bismuth for blowpipe work.

Fluxes. No one flux can be assigned to any one metal as being peculiarly adapted to that metal for all purposes. In many cases the nature of the solder used determines the flux. The fluxes generally used in the soft soldering of metals are powdered resin or a solution of chloride of zinc—alone, or combined with sal ammoniac.

A common method of applying resin in soldering is to powder the resin, and apply it to the work by means of a swab consisting of a small tin or wooden handle to which a tuft of cotton or a few folds of cloth have been fastened. If a liquid resin solution is desired, the resin may be dissolved in alcohol, thus making a sort of varnish. This preparation when applied to the surface to be soldered, dries out, leaving a thin coat of resin just where it is desired.

Ordinary acid solution may be made by placing 3 parts of hydrochloric acid and 1 part of water in a lead, glass, or wooden vessel, then slowly adding small pieces of zinc as long as any action of the acid on the zinc can be observed. Always put in more zinc than the acid will dissolve, and allow the solution to stand several hours. A test should then be made to see that there is sufficient water in the solution. To make this test, a small quantity of the solution is removed to a clean dish, and a bit of clean new zinc is dropped in. Now add a few drops of water, and see if any chemical action upon the zinc follows the addition of the water. If there is any action, the original solution should be diluted with water until further addition does not have effect upon the zinc. Pour off the clear part of the liquor for use. Care should be taken in this process, since considerable heat is present.

A variation on the ordinary acid solution is obtained by dissolving the zinc in three quarts of common muriatic or hydrochloric acid without the water mentioned in the previous solution. After the acid has dissolved all the zinc possible, pour off the clear liquid as before, and add a solution made by dissolving 6 ounces of sal ammoniac in a pint of warm water. Also, add 4 ounces of chloride of tin which has been dissolved in another pint of water. These quantities will make 1 gallon of solution, but may be cut down proportionately for smaller quantities. The combination of solutions will be a little cloudy, but may be cleared by the addition of a few drops of the hydrochloric acid. Be careful not to add any more acid than is necessary to clear the solution. The advantage of this solution is that it will not spatter when the bit is applied to it, and also will allow the use of a poorer grade of solder.

Soldering with Bit. See that all surfaces to be soldered are clean and free from any material which will prevent the solder from sticking. Old work should be brightened by scraping, filing, or rubbing with emery cloth. For small work, the solder is applied to the bit instead of to the work. A small amount of solder may be picked up on the tinned part of the hot soldering bit to the place which is to be soldered. If the surfaces are clean and properly fluxed, the solder from the bit will readily flow over them and adhere solidly.

When large work is to be soldered, as in the case of seams in a tin roof, it is necessary to feed the solder onto the seam by melting the bar of solder on the top of the hot bit as it is moved along the seam.

Soldering Bits. Soldering bits are usually made of copper, and are "tinned" on the point. To "tin" a bit, the tool should be heated hot enough to melt solder easily; the point of the tool quickly filed bright, and then rubbed through a mixture of solder and sal ammoniac spread on a piece of tin. This action will provide a thin coating of solder over the point of the bit.

Bits should not be heated too hot, nor should they be used too cold to produce smooth work. The bit should be just hot enough to melt the solder readily. Bits should be kept well tinned at all times for good work.

A gasoline blow-torch or a charcoal furnace is best for heating the bit. Heating in a soft coal fire causes the tinning to vanish very quickly.

Gasfitting

Ordinary wrought-iron or steel pipe, such as is used for water or steam, is suitable for all kinds of illuminating gas.

Tables of dimensions and various other details pertaining to the subject of pipes, are given in the section on "Heating and Ventilation." Galvanized malleable iron fittings are to be preferred for gas, and should be used rather than plain iron.

Before a pipe is placed in position it should be thoroughly cleaned out by a blast of air blown through it under pressure.

The supply pipe connecting with the street main, and extending to the building, should never be less than 1-in. pipe. This pipe should be laid with an incline toward the street main, as there is always more or less condensation of the gas, the result being the formation of a liquid which should be allowed to find its way into the street main.

In fact the whole system of gas piping in a building should be so arranged that any condensed gas will flow back in the system toward the street main.

Drip-pipes in a building should always be avoided. The supply main should rest on a solid foundation of blocks; and before the trench in which it lies is filled up, it should be tested for leaks.

In fact, the whole system of gas piping should be proved to be air-tight and gas-tight under a pressure of air that will raise a column of mercury 12 in. high in a glass tube. This is equal to about 6 lbs. pressure per sq. in.

In making the test, all outlets should be capped, or plugged. Any good pressure gauge will answer, but a mercury gauge is best. If the pipes are tight, the mercury will not drop a particle; but if there is the least leak the mercury will show it. The system of piping should remain under test in this manner for at least one-half hour. It is a good plan to paste a piece of white paper on the glass tube just on a level with the mercury, to mark its height when the pressure is on.

Where possible it is best to test each floor of piping separately. After the test is made, and while the pressure is still on, loosen the cap on each outlet separately, and notice if the pressure goes down as each one is loosened. This will show if all the pipes are clear, or if there are obstructions in any of them.

The test on the pipes should be repeated just before the plastering is commenced, and again when it is finished.

Center pipes should rest on a solid support fastened to the floor timbers near their tops. The pipe should be securely fastened to the support to prevent lateral movement. The drop-pipes must be perfectly plumb, and should pass through guides fastened near the bottoms of the timbers. This will keep them in position despite the assaults of lathers, masons, and other workmen.

In the absence of explicit directions to the contrary, the outlets for brackets should, as a rule, be at a height of 5 ft. 6 in. from the floor, except in halls and bathrooms, where it is customary to place them 6 ft. from the floor. The nipples located at these points should project not more than ¾ in. from the face of the plastering. As lath and plaster together are usually ¾ in. in thickness, the nipples should project 1½ in. from the face of the studding.

Drop center pipes should project 1½ in. below the furring, or timbers if there be no furring, and if it is known that there will be no stucco or center-pieces used. Where center-pieces are to be used, or where there is a doubt as to whether they will be or not, then the drop pipes should be allowed to project about 12 in. below the furring.

All pipes being properly fastened, the drop pipe can be safely taken out, and cut to the right length when the gas fixtures are put on.

Gas pipes should never be placed on the bottoms of floor timbers that are to be lathed and plastered, for the reason that they would be practically inaccessible in cases of leakage, or when alterations are desired; and, in addition to this objection, the gas fixture would be insecure.

Following is an extract from specifications published by the Denver Gas & Electric Company, which are of particular interest to the gasfitter.

"Always use fittings in making turns; do not bend pipe. Do not use unions in concealed work; use long screens, or right and left couplings. Long runs of approximately horizontal pipe must be firmly supported at short intervals, to prevent sagging."

Table 15 gives the correct sizes of pipes for different lengths; also number of burners which can be supplied from the various sizes and lengths of pipe.

TABLE 15

Required Sizes of Pipe, and Number of Burners Supplied

Greatest No. of Feet to be Run	Size of Pipe	Greatest No. of Burners Supplied	Greatest No. of Feet to be Run	Size of Pipe	Greatest No. of Burners Supplied
20 ft.	⅜-in.	2	150 ft.	1½-in.	70
30-ft.	½-in.	4	200 ft.	2-in.	140
50 ft.	¾-in.	15	300 ft.	2½-in.	225
70 ft.	1-in.	25	400 ft.	3-in.	300
100 ft.	1¼-in.	40	500 ft.	4-in.	500

Table 16 shows sizes of connections that should be left for the meter.

TABLE 16

Sizes of Connections for Meter

No. of Lights	Size of Connection	No. of. Lights	Size of Connection
3	¾-in.	60	2-in.
5	¾-in.	100	2-in.
10	1¼-in.	150	2½-in.
20	1¼-in.	200	2½-in.
30	1½-in.	250	3-in.
45	1½-in.	300	4-in.

Electric Wiring

For Light, Heat, and Power

The following abstract of Rules of the "National Electric Code" is furnished by the Inspection Department of the Associated Factory Mutual Fire Insurance Companies:

RULES OF THE NATIONAL ELECTRICAL CODE

Contracts. It is advised that all contracts for electrical work contain the following clauses:

No fittings shall be used which are not listed in the latest edition of Approved Electrical Fittings, issued by the Inspection Department of the Associated Factory Mutual Fire Insurance Companies.

Generators. Generators should be located in clean, dry places, away from combustible materials; and a light location rather than a dark one is always preferable. It is not desirable to place them in the work-rooms of a plant where combustible material abounds, as in the ordinary textile mill, though they may sometimes be so located if properly cut off from the main room by a dust-tight plank partition. A location suitable for a first-class steam engine is none too good for a generator.

A solid foundation is necessary for smooth running. The generator frame should, where possible, rest on timber supports, and should be fastened to them by lag screws or bolts which do not pass through in such a way as to electrically connect the frame with the ground. Two parallel timbers are preferable to a four-sided framework, which encloses a place under the machine that is difficult to keep clean.

Motors. The use of voltages above 550 in rooms where manufacturing processes are being carried on is rarely advisable or necessary, and will be approved only when every possible safeguard has been provided. Plans for such installations should be submitted to the Inspection Department before work on them is begun.

Direct-current motors and alternating-current motors with brushes should be so located or enclosed, especially in dusty or linty places, that inflammable material or flyings cannot accumulate around them and become ignited by serious sparking at the brushes. Similar protection should also be provided in wet places, as most electrical machinery is injured by continued exposure to moisture.

Alternating-current induction motors of the type without brushes can be safely located in almost any part of a textile plant without being enclosed, being generally no more dangerous than any other piece of machinery running at the same speed.

. For light work, direct-current motors which have all of the working parts enclosed in an iron case are on the market, and these "enclosed" motors may be treated in the same way as induction motors without brushes.

Where an enclosure around the whole motor is provided, it should include the starting rheostat or auto-starter, as well as the main switch and fuses or circuit-breaker, and should, if possible, be of such a size as will permit the attendant to enter it and easily get at any part of the apparatus. It should preferably be made largely of glass, so as to keep the motor in full view of the attendants, thus promoting cleanliness and making it possible to quickly discover any derangement. It should also be thoroughly ventilated, in order to prevent undue heating of the electrical machinery.

Where a motor is permitted to be used in a dusty or linty place without being enclosed, or if the enclosure provided for it is too small to include anything else, the rheostat or auto-starter, and the main switch and fuses or circuit-breaker, should be placed in a dust-tight, moisture-proof cabinet of approved construction. Similarly, in wet places, these accessories should be protected from moisture in a cabinet which is thoroughly moisture-proof.

Many A. C. motors are protected by oil-immersed circuit-breakers rather than fuses; and, as these circuit-breaker cases, as well as the auto-starter cases, are usually made dust-and moisture-proof, no further enclosure is generally necessary.

Switchboards. Switchboards should be made of slate or marble, supported on metal frames, and should be located well away from combustible materials. They should always be open at the sides; and a space of at least 12 inches should be left between the floor and the board, and 3 feet, if possible, between the ceiling and the board, in order to lessen the danger of communicating fire to the floor or ceiling, and to prevent the formation of a partially concealed space, very liable to be used for the storage of rubbish, oily waste, etc.

The instruments should be neatly arranged, and the wiring on the back should be laid out in a careful and workmanlike manner.

It is recommended that all live parts, such as bus-bars and other conductors, be protected against accidental contact as far as practicable by suitable insulation, which shall be "flame-proof" or "slow-burning" and designed to withstand a reasonable amount of abrasion. The chances of accidental short-circuit, and arcing at these points may thereby be greatly reduced. Insulated cable for bus-bars and connections is excellent for this purpose. However, the conductors could be wrapped or taped if this should be found more convenient; but this method should never be used unless it can be done well. Special precautions might also be necessary with either method if applied to high-voltage switchboards.

In addition to the usual measuring instruments and other apparatus, the switchboard should contain reliable devices for testing for grounds.

Dynamo Room Wiring. Since there are generally a considerable number of wires brought close together in this room, particularly in the vicinity of the switchboard, the use of a "slow-burning" insulation is of great importance; and attention is therefore called to the paragraph below on Inside Wiring. As automatic sprinkler protection is not always advisable in dynamo rooms, the necessity for reducing as far as possible the chances of a fire at this point is at once evident. The desirability of fireproof construction throughout the dynamo room is especially emphasized.

Special care should be exercised in rigidly supporting and thoroughly insulating the wires from generator to switchboard, as the main cut-outs are usually on the switchboard, and a short-circuit between these wires would, therefore, be likely to burn out the armature.

Outside Wires. All outside lines should be carefully laid out through factory yards, so as not to interfere with fire streams or ladders, a definite plan being determined upon before work is commenced. Many wiremen are very careless about this matter, and, if not cautioned, will run the wires in the easiest way, regardless of looks or safety.

Wherever a high-voltage circuit enters the factory yard from a distant station, outside emergency switches should be so placed that in case of fire or other accident the current can be quickly and safely cut entirely out of the yard. Telephone or call-bell service from the factory to the power station is not usually sufficiently reliable to make these switches unnecessary. Lightning arresters should be provided on all wires which are liable to receive lightning discharges.

Fire Lights. It is a good plan, where possible, to arrange in yards and buildings, on circuits entirely out of the way of ladders or fire streams, a few lights which may be thrown on at the time of a fire when the main lights are off, enabling firemen to move about quickly and safely.

Such lights can generally be best arranged on entirely separate circuits, and will often be useful for repair work and for lighting the help into and out of the mill, when the main lights are off. These circuits may take current from a small, separate generator, driven by an independent engine or water-wheel; or from outside lines; or possibly from a storage battery, so isolated from the main buildings as not to be affected by a fire in them.

Transformers. Where transformers are to be connected to high-voltage circuits, the Inspection Department should always be consulted before work is begun or the apparatus is purchased, as it is necessary in many cases, for best protection to life and property, that the secondary system be permanently grounded, and this cannot be done unless provision is made for it when the transformers are built.

Transformers should always be located outside of buildings, unless special permission is given to put them inside. In general, it is dangerous to locate transformers with oil-filled cases inside, as it is entirely possible for a break-down of insulation to ignite the oil, which may result in a very stubborn fire. For the same reason, the placing of these transformers on roofs is also objectionable.

Even transformers which are not oil-cooled may contain a considerable amount of combustible material which, if ignited, would make a hot fire, especially if the cases are ventilated, as is customary with these types of transformers. Moreover, a burn-out in the windings may cause dense smoke, which might easily be mistaken for a fire and cause fire streams to be thrown into the building, with a resultant water damage. They can, therefore, be permitted inside of buildings only after the circumstances have been carefully considered and the necessary safeguards provided.

Inside Wiring. Rubber-covered wire must be used in all damp places; while rubber-covered or varnished cambric-covered wire must be used in all conduit, molding, or concealed work, and throughout all systems on which the voltage exceeds 550.

For open work in dry places where the voltage is not over 550, rubber-covered wire may be used if desired, but slow-burning weather-proof wire fulfills every requirement for such work—in fact is preferable—and is less expensive. This wire has special merit for use in linty and dusty places, for lint does not readily adhere to the hard, smooth, outer surface, as is the case with wires having a weather-proof braid on the outside which in warm rooms becomes sticky. Moreover, what little lint may collect upon it can be easily brushed off, so that, when "sweeping down," there is much less liability of breaking the insulators or badly deranging the wires.

Where of necessity a considerable number of "open" wires are brought close together—as, for example, about the ordinary distributing switchboard—either the wires should have the slow-burning insulation as just described, or, if a rubber or varnished cambric insulation is necessary, it should be protected by a heavy, slow-burning outer braid.

The weather-proof and rubber insulations in common use contain a large amount of inflammable material, which ignites easily and produces a fierce fire and dense smoke. It is therefore desirable to reduce, as far as possible, the amount of this inflammable material, and to surround it with a tight, slow-burning cover to prevent rapid combustion. To still further reduce the amount of combustible material, the porcelain insulators by which the wires are held in place may be supported on an iron frame.

Before beginning work, the circuits should be carefully mapped out, and the work so planned as to secure the very simplest arrangement. The wiring should then be put up in a neat manner, and should present a thoroughly workmanlike appearance.

In many cases far too little attention is given to this matter while the work is in progress, the result being a general disappointment to all interested in the plant, especially to those who understand what a really first-class job of wiring looks like. This disappointment is probably felt by nobody more than by the owner, when he realizes that with reasonable care and common sense a better and undoubtedly safer equipment could have been installed at practically the same expense.

In mill work, "open" wiring securely supported on porcelain insulators is generally best. Mains of No. 8 B. & S. gage wire and larger are usually most conveniently carried through space from timber to timber and supported at each timber only. Smaller wires thus supported would be liable to be broken, and should therefore be wrapped around the beams or carried through them in holes bushed with porcelain; or they may be fastened to strong running-boards, well put up. The idea is to have the wires so rigidly supported on proper insulators that, even if they were bare, the insulation of the system would be perfect. All joints should be securely made and then carefully soldered and taped.

Wires should be carefully protected where liable to be deranged or injured, as in passing from story to story up side walls or columns, or near belts, or over shelves and similar places where anything is likely to be piled against them. Excellent protection can be secured by carrying them through iron pipe, first reinforcing the insulation of each wire by enclosing it in flexible insulating tubing, unless the wire is double-braided rubber, or varnished cambric-covered, in which case the insulating tubing is unnecessary. An approved fitting should be provided at each end of the pipe to prevent the wires resting on sharp edges.

On A. C. systems, the two or more wires of the same circuit should be run in the same pipe to avoid induction effects. Even on D. C. systems this arrangement is best, as then the expense and inconvenience of rewiring is avoided when it is desired to change such systems to alternating current, which frequently happens. Protection may also be obtained by strong wooden boxing, with a slanting top to keep out dirt, the holes through which the wires enter the top being bushed with short porcelain tubes.

The use of incandescent lamps in series on constant-potential systems is not approved where the voltage of the circuit is over 250.

Switches. Knife-switches should be enclosed in cabinets in all dusty or linty places, or when so located that persons would be liable to come in contact with the bare live parts. Up to 250 volts and 30 amperes, approved indicating snap-switches are considered preferable for use on lighting circuits.

Cut-Outs. Link fuses are not advised for general use about a factory and will not be approved unless mounted on slate or marble bases made to conform to specifications for cut-outs, and enclosed in dust-tight, fireproofed cabinets. The ordinary porcelain link-fuse cut-outs are not permissible. Approved plug and cartridge fuses may be used almost anywhere in the ordinary manufacturing plant without the enclosing cabinet, such cabinets being necessary only in specially hazardous places, or where persons would be liable to come in contact with the bare live parts. These fuses of the enclosed type are strongly recommended for general use.

In 1903 the enclosed fuse was standardized by a special committee of the underwriters in consultation with the fuse manufacturers. This was found necessary in order to secure an interchangeable fuse for any given capacity, regardless of the make. This feature had heretofore been sadly lacking, and the result had been great inconvenience, or the use of dangerous substitutes, such as fuse wire, wire nails, etc. The great advantages of an interchangeable fuse are evident, and it is urged that the National Electrical Code Standard fuse be used generally.

Rosettes. Either fused or fuseless rosettes may be used as desired. With fuseless rosettes the number of 16-candle-power lamps per circuit should not exceed 12, and for convenience the branch cut-outs should be located over alleys or in other readily accessible places. With fused rosettes, 30 or 40 lamps could be placed on one circuit if desired; but it is better practice to have a smaller number, so that the blowing of the fuse at a branch cut-out will not extinguish so many lights.

Flexible Cord. With the exception of wet rooms, storehouses, and specially hazardous rooms of textile mills and the like, approved flexible cord may be used for all pendants which hang freely in the air. If the lamp is to be moved about, so that the cord is liable to come in contact with surrounding objects, reinforced flexible cord like that described below for Portable Lamps should be provided.

Either the two insulated conductors which form the cord should be carefully knotted together, or else an approved device should be used in both socket and rosette, so as to prevent any strain from coming on the small binding screws in these fittings.

Portable Lamps. In this class of work the fittings are subjected to much hard usage, and the very best possible construction is therefore necessary. Instead of the ordinary flexible cord made for pendant lamps, a special cord having an extra covering of rubber, reinforced by a tough outer braid, should be used.

The cord should be securely fastened to the wall or ceiling by a cleat or split knob near the point at which it connects to the rosette or supply wires, so that no strain can come on this connection. It should also be knotted inside the socket, as explained above under "Flexible Cord." An approved metal shell socket with an outlet threaded for ⅜-inch pipe should be used, so that the whole cable may be drawn into the socket and still permit the use of a proper socket bushing.

The cord of pendants which do not hang free in air, or which are liable to come in contact with near-by objects. should also be of the reinforced type.

The bulb of an incandescent lamp, when used in a factory, frequently becomes hot enough to ignite paper, cotton, and similar readily ignitible materials; and in order to prevent it from coming in contact with such materials, as well as to protect it from breakage, every portable lamp should be surrounded with a substantial wire guard. Many of the lamp-guards now on the market are very flimsy and utterly worthless.

Waterproof Pendants. For incandescent lamps in wet places, approved waterproof sockets should be used. These sockets should be suspended by separate, stranded, rubber-covered wires, soldered to the socket leads and also to the overhead wires. Where the pendant is over 3 ft. long, the wires should be twisted together. The entire weight of the pendant should be borne by cleats or some other independent means, in order to prevent any strain on the connection to the overhead wires.

Arc-Lamps. "Enclosed arc" lamps having tight inner globes may, in general, be used wherever desired, although in Especially Hazardous Places it is believed that the incandescent lamp makes the safer light and is generally as satisfactory. Its use in these rooms is therefore recommended in preference to the arc-lamp. Any switches attached to arc-lamps, or resistance coils used with them, must be so arranged and protected that dust cannot gather around them and become ignited by a spark from the switch or by overheating of the resistance or magnet coils. Each lamp or series of lamps must be protected by a separate cut-out, and the lamps may be grouped, and controlled by switches as desired.

As a matter of regulation, it is not advisable to have a very large number of lamps controlled by one switch, as annoying momentary fluctuations in the voltage of the generator may result when the switch is closed or opened.

In general, the use of arc-lamps in series on constant-potential systems should be avoided if possible. However, if other arrangements of circuits are impracticable, this may be permitted on low-voltage circuits where the conditions are favorable.

Especially Hazardous Places. For incandescent lamps in the more hazardous places, an excellent pendant can be secured by using reinforced flexible cord and a keyless socket with an outlet threaded for ⅜-in. pipe and properly bushed, as advised for Portable Lamps. The cord should be securely supported from the ceiling by a porcelain cleat or split knob, and the two conductors should then be separated and soldered to the overhead circuit. The regular Waterproof Pendant could also be used. As far as possible, cutouts should not be located in these rooms; but, if this cannot be avoided, they should be of the plug or cartridge type, and should be enclosed in dust-tight wooden cabinets of approved construction. If it is desired to control the lights from points in these rooms, it should be done by snap-switches, which should be either enclosed in dust-tight cabinets or located where lint and flyings cannot accumulate around them.

Storehouses. The best and safest light for storehouses is the incandescent lamp. Special care should be taken to so locate and protect the wires that the handling of storage in the building could never derange them. The pendants should be of the type advised above for Especially Hazardous Places. The cut-outs and switches should be grouped and enclosed in dust-tight wooden cabinets of approved construction. Strong lamp-guards should be provided, as advised for Portable Lamps.

Telephone, Call Bell, and Similar Circuits. The arrangement of these wires should be as carefully planned as that of the lighting or power circuits. They should be so placed as never to be in the way of fire streams or ladders. Where possible, the signal wires about the yard should be kept entirely away from lighting or power circuits. This avoids the liability of the two systems crossing if breaks occur, and dangerous currents being conducted into buildings over wires ordinarily considered harmless.

Where the arrangement is of necessity such that crosses might occur if wires broke, protectors should be provided near the point where the signal wires enter each building. Protectors should also be provided on all foreign lines, such as public telephone or fire-alarm wires, and on all private lines which are liable to receive lightning discharges.

MEASUREMENTS FOR ELECTRIC WIRING

The lengths and sizes of wire required for main and branch circuits in any system of wiring for light, heat, or power, are determined by the location of the **centers of distribution.** These are the particular points in a building where the cut-out cabinets are located, and from which the branch circuits are led off. Theoretically the center of distribution should bear the same relation to the circuit that the center of gravity bears to any given mass or body. Therefore, in laying out an installation, every effort should be made to so locate the distributing centers that the load may be as evenly divided as possible, and at the same time have each distributing center located where it will be easily accessible.

Measurements for **length of wire** required for each branch circuit are to be taken from the center of distribution for that circuit to the farthest lamp or motor that is to be supplied with current through it, and this distance, multiplied by 2 for a 2-wire circuit, or by 3 for a 3-wire circuit, will equal total length of wire required. Allowance must also be made for bends and splicing.

Size of Wire

This will depend upon:

(a) Value of current to be carried.

(b) Distance, or extreme length of wire.

(c) Drop of potential allowed.

Table I, showing the allowable carrying capacity of copper wires and cables of 98 per cent conductivity, according to the standard adopted by the American Institute of Electrical Engineers, must be followed in placing interior conductors.

The **drop of potential** varies from 2 to 2½ per cent when current is taken from public mains, and from 3 to 5 per cent in case current is generated in or near the building by a private generating station.

WIRING METHODS AND CALCULATIONS

Three methods of inside wiring and current distribution are shown in Figs. 1, 2, and 3. In Fig. 1 the service mains are run to the main distributing center M, from which four main circuits run to the different floors of the building. The rules of the National Code require that no wire for inside wiring shall be of smaller size than No. 14 B. & S. gage, except under certain special conditions. The number of lamps allowed on each branch circuit is twelve 16-c.-p., or six 32-c.-p. The average incandescent lamp consumes 3½ watts per candle-power; and, in order to ascertain the correct sizes of wire for main and branch circuits, it is necessary to know: First, the maximum value of the current that will be required at any time in case the system should be

TABLE 1

Allowable Carrying Capacities of Copper Conductors

B. & S. G.	Table A. Rubber Insulation. Amperes.	Table B. Other Insulations. Amperes.	Circular Mils.
18	3	5	1,624
16	6	8	2,583
14	12	16	4,107
12	17	23	6,530
10	24	32	10,380
8	33	46	16,510
6	46	65	26,250
5	54	77	33,100
4	65	92	41,740
3	76	110	52,630
2	90	131	66,370
1	107	156	83,690
0	127	185	105,500
00	150	220	133,100
000	177	262	167,800
0000	210	312	211,600
Circular Mils.			
200,000	200	300	
300,000	270	400	
400,000	330	500	
500,000	390	590	
600,000	450	680	
700,000	500	760	
800,000	550	840	
900,000	600	920	
1,000,000	650	1,000	
1,100,000	690	1,080	
1,200,000	730	1,150	
1,300,000	770	1,220	
1,400,000	810	1,290	
1,500,000	850	1,360	
1,600,000	890	1,430	
1,700,000	930	1,490	
1,800,000	970	1,550	
1,900,000	1,010	1,610	
2,000,000	1,050	1,670	

The lower limit in Table 1 is specified for rubber-covered wires, to prevent gradual deterioration of the high insulations by the heat of the wires, but not from fear of igniting the insulation. The question of drop is not taken into consideration in the table.

For insulated aluminum wire, the safe carrying capacity is 84 per cent of that given in Table 1 for copper wire with the same kind of insulation.

The carrying capacity of Nos. 16 and 18 B. & S. gage wire is given, but no smaller than No. 14 is to be used except under specially favorable conditions.

worked to full capacity (this will determine the size of the main or service wires); second, the wire composing each branch circuit should have a carrying capacity sufficiently large to enable it to carry the full amount of current required by the lamps or motors connected with it.

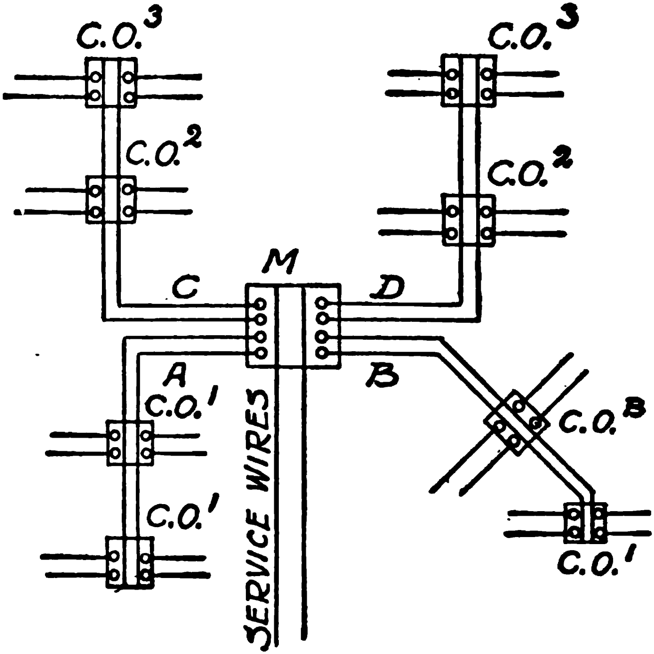


Fig. 1. Wiring System of a 3-Story and Basement Building

Referring to Fig. 1, we may assume it to represent a plan of the wiring system of a 3-story and basement building.

C. O. B. is the basement cut-out, from which two circuits run. C. O. 1 represent 3 cut-outs and 6 circuits for the first floor; C. O. 2 represent 2 cut-outs and 4 circuits on the second floor; and C. O. 3 represent 2 cut-outs and 4 circuits on the third floor. As there are 16 branch circuits, the maximum number of 16-C. P. incandescent lamps which this system could carry would equal $16 \times 12 = 192$ lamps.

Allowing a current consumption of 55 watts per lamp, which is at the rate of about 3½ watts per candle-power, the total number of watts consumed=192×55=10,560; and if the voltage is 110, which is the usual rate for incandescent lamp service, the amperes or volume of current required will= 10,560÷110=96 amperes. Therefore the value of the current to be carried by the service wires from the street mains to the main center of distribution M. will=96 amperes at 110 volts.

The size of wire required for the service can be calculated as follows: Assuming the distance from point of connection with street mains to center of distribution M, to be 100 ft., and loss of current to be 2 per cent. This will require 200 ft. of wire, and 2 per cent of 110=2.2. The sectional area in circular mils (C. M.) of the required wire is found by using Formula I, as follows:

$$C.\ M. = \frac{I \times L \times 10.8}{v} \qquad \ldots\ldots (1)$$

Where I=Current in amperes ....= 96
L=Total length of wire in feet.................=200
v=Volts lost ....= 2.2
10.8=A constant=number of ohms resistance of a piece of copper wire 1 ft. long, and having a cross-section of 1 mil.

Then,

$$C.\ M. = \frac{96 \times 200 \times 10.8}{2.2} = 94{,}254,$$ which is the cross-sectional area required for the service wires. Referring to Table 1, it will be seen that it is necessary to use Number O wire. Although this size wire has a larger cross-section (105,500 C. M.) than is required, still it is much better to use wire having too large a carrying capacity than too small, which would be the case if No. 1 (the next smaller size) were used.

Another method of calculating the size of wire may be used when the resistance in ohms per foot is known.

In this method use Formula 2:

$$R = \frac{1{,}000v}{I \times L} \qquad \ldots\ldots (2)$$

where the same values apply that are used in Formula 1—namely, I=amperes; L=total length of wire, in feet; v= volts lost. Then,

$$R = \frac{1{,}000 \times 2.2}{96 \times 200} = .114$$ ohms, which is the resistance per 1,000 feet in length of the required wire. By reference to Table 2 (Dimensions of Copper Wire), it will be seen in the column headed "Ohms per 1,000 Ft.," that the nearest approach to this is .102 ohm, which is the resistance per 1,000 feet of No. O wire.

Branch Circuits. Starting at main distributing center M, assume the total length of wire required for circuit A to be 80 ft. From cut-outs C. O. 1 are carried 4 lighting circuits, each carrying twelve 16-C. P. lamps, making 4×12=48 lamps, each consuming ½ ampere, or a total of 48÷2=24 amperes of current at 110 volts potential, to be supplied. Using Formula 1, and allowing the same drop (2 per cent), we have:

$$C.\ M. = \frac{24 \times 80 \times 10.8}{2.2} = 9{,}425$$

Referring to Table 1, the column headed "Circular Mils" shows the nearest approach to this number is 10,380; and a glance to the left shows that this is the number of C. M. in a cross-section of No. 10 wire. As the lengths and carrying capacities of circuits A, B, C and D are practically the same, it will be seen that No. 10 wire is the proper size to be used in the four branch circuits, while the total length of this size of wire required will depend upon conditions, and the number of unavoidable deviations from a straight line in running the wire.

Lighting Circuits. From each cut-out box there are two lighting circuits leading in the directions desired. Taking one of the circuits leading from cut-out C. O. B., if we assume the distance from this box to the center of distribution of this circuit to be D feet, and allow for a drop of 2 volts in potential, the size wire required may be found by Formula 3:

$$C.\ M. = \frac{I \times 2D \times 10.8}{2} \quad \text{........................(3)}$$

where I=amperes required for 12 lamps=6
D=Distance in feet=48

Then

$$C.\ M. = \frac{6 \times 96 \times 10.8}{2} = 3{,}110$$

and according to Table 1 the next highest number above this is 4,107, which is the sectional area in circular mills, of No. 14 wire, which is the proper size of wire to use on this circuit; and as the circuit just under consideration is a fair sample of all the lighting circuits in the building, we may safely calculate on using No. 14 wire on these circuits.

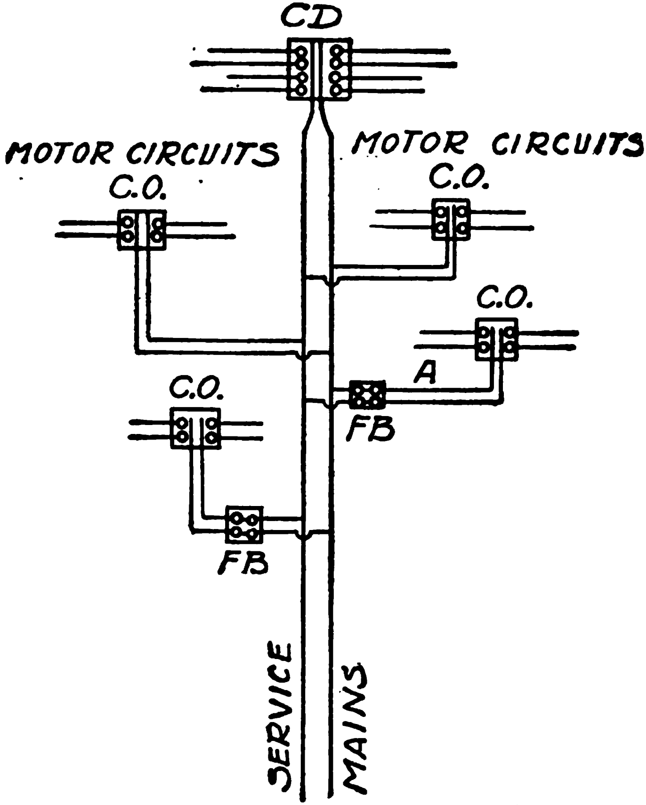


Fig. 2. Plan for Wiring a Factory Building.

Light and Power Circuits. Fig. 2 shows a plan for wiring a factory building in which current is to be supplied for both lighting and power.

In this system, 4 branch circuits are taken off the service mains at intervals, before these mains enter the last center of distribution at C. D.

It will be noted that the service mains are retained at full size from the point of their connection with the street mains to the main cut-out box C. D. In this plan of wiring there are 8 branch lighting circuits, and 4 branch circuits for supplying current to motors. Four of the branch lighting circuits are supplied with current from the service mains before the latter reach the distributing center C. D., and the remaining four radiate from that center.

The motor branch circuits are connected to the service mains between the branch lighting circuits and distributing center C. D.

Fig. 2 shows the building as wired on the 2-wire system, and the first problem will be to find what size wire will be required for the service mains.

The total current, in watts, to be carried by the service mains will be:

For—96 incandescent lamps of 16 C. P., rated at 55 watts each=5,280 watts for lamps.

For— 4 motors, 5 horse-power each—total 20 horse-power—746 watts per H. P., making a total of 746×20=14,920 watts for the motors.

And, 5,280+14,920=20,200 watts.

Since the voltage is to be 110, the number of amperes of current to be carried will be $\frac{20,200}{110}$ =184.

Allowing for a drop of 3 per cent, what will be the required size, in circular mils, of the service mains, assuming the distance to be 150 ft. from connection with the street mains to the last center of distribution C. D.?

Using Formula 1, we have:

$$C.\ M. = \frac{I \times L \times 10.8}{v}$$

where I=Current, in amperes ....=184

L=Total length of wire, in ft.=150×2...........=300

v=Volts lost=110×.03 ....= 3.3

Then,

$$C.\ M. = \frac{184 \times 300 \times 10.8}{3.3}\quad 180,655 \text{ circular mils,}$$

and by reference to Table I it will be seen No. 0000 wire will be required.

As the branch lighting circuits in this system are similar to those shown in Fig. 1, and each is to carry practically the same amount of current, it will not be necessary to enter into details regarding the size of wire required, except that we might assume one Circuit B) as extending to a greater length than the rest. We may assume the center of distribution for Circuit A to be located at a distance of 175 ft. from the point of connection with service mains. This would mean that the length of wire required would be $175 \times 2 = 350$ feet, which would require a larger wire.

The size may be found as follows: Assuming that there are to be 2 lighting circuits leading from the cut-out box, each circuit to carry 12 lamps (total, 24 lamps) consuming ½ ampere per lamp, or 12 amperes of current in all; and the loss or drop in voltage=2 volts. Then,

$$\text{C. M.} = \frac{12 \times 350 \times 10.8}{2} = 22{,}680 \text{ circular mils}$$

as the required cross-section of wire for this branch circuit.

By reference to Table I, it will be seen that No. 6 wire, which has a cross-sectional area of 26,250 C. M. is the only size that will come near meeting the requirements.

If we allow a drop of 3 volts in this circuit, which is almost 3 per cent, the circular mils required will=15,120, and No. 8 wire may be used.

Fuse-boxes (F. B.) can be inserted as shown in the branch circuits. Then in case of a short-circuit across the contacts on the cutout boxes, the smaller fuse will blow.

This arrangement also makes it possible to disconnect any distributing center for purposes of testing, without interfering with the other centers.

Motor Leads or Branch Circuits. Following is an extract from the National Code regarding this subject:

"The motor leads or branch circuits must be designed to carry a current at least 25 per cent greater than that for which the motor is rated, in order to provide for the inevitable occasional overloading of the motor and the increased current required in starting, without over-fusing the wires; but where the wires under this rule would be over-fused, in order to provide for the starting current, as in the case of many of the A. C. motors, the wires must be of such size as to be properly protected by these larger fuses."

In the wiring system illustrated in Fig. 2 there are 4 motors, each having a capacity of 5 H. P., which are to be supplied with current. The following values may be used for calculating size of mains for supplying a number of small motors, as in the case of Fig. 2:

110 volts..........	7.5	amperes	per	horse-power.
220 volts..........	3.75	"	"	"
500 volts..........	1.65	"	"	"

The distance from point of connection of the motor branch circuits with the service mains, to their respective centers of distribution, may be assumed to be 100 ft.; and the size of wire required for these two circuits will therefore be:

$$C.\ M.\ \frac{I \times L \times 10.8}{v}$$

As each of these two circuits is to supply current for two 5-H. P. motors, it will be necessary, first, to ascertain the value of current, in amperes at 110 volts potential, that will be required. According to the rule just given, which allows 7.5 amperes per horse-power for 110-volt motors, the value of I for two motors=7.5×10=75 amperes. The total length (L) of wire required will be 100×2=200 ft.; and the loss to be allowed (v) is 4 per cent=110×.04=4.4 volts. Then,

$$C.\ M. = \frac{75 \times 200 \times 10.8}{4.4} = 36{,}818 \text{ circular mils}$$

Referring to Table 1, it will be seen that No. 4 wire comes next highest in cross-sectional area. Therefore it must be used.

If a loss of 5 per cent were allowed, the required C. M. cross-section would be 29,454, which is slightly less than is contained in No. 5 wire.

In this calculation no allowance is made for the 25 per cent additional current referred to at the beginning of this section.

Another method of calculating the size of wire for these circuits is as follows:

One horse-power will require the consumption of 746 watts, electrical energy; and, there being 10 H. P. to be developed, the total number of watts=746×10=7,460, which, at 110 volts potential, will reqnire 7,460÷110=68 amperes of current. This represents the value of I, and the loss being same as before:

$$C.\ M. = \frac{68 \times 200 \times 10.8}{4.4} = 33{,}381,$$

to which must be added 25 per cent, making a total of 41,726 circular mils.

Reference to Table I will show that No. 4 wire can be used under this calculation also.

The size of wire forming the circuits that lead from the cut-out boxes directly to the motors, is obtained in the same manner. As an example, we may calculate the size of wire for one of these circuits, assuming the motor to be 5-H. P. and located at a distance of 50 ft. from its distributing center.

Allowing 7.5 amperes per H. P., value of $I = 7.5 \times 5 = 37.5$. The value of $L = 100$ ft.; and there is to be a drop of 2 volts. Then,

$$C.\ M. = \frac{37.5 \times 100 \times 10.8}{2} = 20{,}250,$$

to which must be added 25 per cent for safety, making a total of 25,312 circular mils; and according to Table I, No. 6 wire will come nearest to meeting the requirements.

Size of Wires for Direct-Current Motors. Referring to Table 2, the column headed "Size of Wire, Branches" gives sizes of wires for branches and for mains supplying one motor, and is based on the 25 per cent overload demanded by the rule of the National Code. The column headed "Size of Wire, Mains" gives size of wire to be used for mains; but in no case must the size of these mains be less than that required for the 25 per cent overload on the largest motor such mains supply.

The question of drop, or loss of voltage is not taken into consideration in the tables which herein given.

Table 2, indicating sizes of mains and branches for D. C. motors, is taken from the rules and regulations of the Department of Electricity, Chicago, Ill.

Three-Wire System. This system of wiring requires but 3 wires to carry the same amount of current that would require 4 wires in the 2-wire system; and it also permits doubling of the initial voltage of the system, thus reducing the volume or amperes one-half, which allows the use of smaller wires. In this system, 3 mains are carried through the district, and a potential difference of 220 to 230 volts is maintained between the two outside wires.

TABLE 2

Sizes of Mains and Branches for Direct-Current Motors

Horse Power	110 Volts			220 Volts			
	Full load Current	Size of Wire Mains	Size of Wire Branches	Full load Current	Size of Wire Mains	Size of Wire Branches	Ohms per 1,000 Feet
1	8	14	14	4	14	14	2.628
2	15	12	10	8	14	14	2.628
3	23	10	8	12	14	12	1.653
4	30	8	6	15	12	10	1.040
5	38	6	6	19	10	10	1.040
7.5	56	4	3	28	8	6	.411
10	75	3	1	38	6	6	.411
12.5	94	1	0	47	5	4	.259
15	113	0	00	56	4	3	.205
17.5	131	00	000	65	4	2	.163
20	150	00	0000	75	3	1	.129
25	188	0000	C. M. 250000	94	1	0	.102
30	225	C. M. 250000	350000	113	0	00	.081
35	263	300000	400000	131	00	000	.064
40	300	350000	500000	150	00	0000	.051
45	338	400000	600000	169	000	C. M. 250000	.064
50	375	500000	700000	188	0000	250000	.051
55	413	600000	800000	206	0000	300000	.051
					C. M.		Resistance per Foot
60	450	600000	800000	225	250000	350000	.0000431
65	488	700000	900000	244	300000	350000	.000036
70	525	800000	1000000	263	300000	400000	.000036
75	563	800000	1100000	281	350000	500000	.0000308
80	600	900000	1300000	300	350000	500000	.0000308
85	638	1000000	1400000	319	400000	500000	.000027
90	675	1100000	1500000	338	400000	600000	.000027
95	713	1200000	1600000	356	500000	600000	.0000215
100	750	1300000	1700000	375	500000	700000	.0000215
125	938	1700000	2- 900000	469	700000	900000	.0000155
150	1125	2- 800000	2-1100000	563	800000	1100000	.0000135
200	1500	2-1300000	2-1700000	750	1300000	1700000	.0000083
250	1875	2-1700000	3-1300000	938	1700000	2- 900000	.0000063
300	2250	3-1300000	3-1700000	1125	2800000	2-1100000	.0000038

The third wire, called the neutral wire, lies half-way between the others in potential. By proper connections, the motors can thus be supplied at 220 volts, while the lamps are operated at 110 volts. Incandescent lighting circuits can be maintained from either outside wire, to the neutral wire.

An examination of Table 2 will show the saving in copper that is effected by supplying D. C. motors with 220 volts potential. Take, for instance, a D. C. motor of 10 H. P. using current at 110 volts. In this case a No. 3 wire is required for the mains; but when current is supplied at 220 volts, No. 6, wire, just one-half the size of No. 3, can be used.

Fig. 3 shows a plan for wiring a building for light and power on the 3-wire system. The same number of motor and lighting circuits are to be supplied with current as are shown in Fig. 2. It will be noticed that the motor leads run from the two outside service mains to their respective centers of distribution, while the branch circuits for lighting connect to one outside wire and the neutral wire.

For the purpose of calculating size of wire required for the service mains in this system, we may assume distances and lengths of wire to be practically the same as given in connection with Fig. 2—namely, 150 ft. from point to point of connection of service mains with the street mains, to last center of distribution (C. D.), from which two motor circuits lead. The same amount of power is to be developed by the motors; but in this case the motors are to use current at 220 volts. The same number of lamps will be supplied with current at 110 volts as are mentioned in connection with Fig. 2.

Using the same methods of calculation, we have: Total current, in watts, required by the 96 lamps at 55 watts each $=96\times55=5,280$ watts, consequently, amperes for the lamps will be $5,280\div110=48$.

The four motors will require the same number of watts as in the previous installation (14,920); but, since they are now to be supplied with current at 220 volts, the amperes will be reduced just one-half; thus $14,920\div220=68$ amperes; whereas the amperes required for the motors in Fig. 2 $=14,920\div110=136$. The service mains in Fig. 3 will therefore carry: For lamps, 48 amperes; for motors, 68 amperes; making a total of $48+68=116$ amperes of current, instead of 184 as in Fig. 2.

Using Formula 1, we may now calculate size of wire required for the two outside wires, allowing the same percentage of drop (3); but as the value of I is only three-fifths as great as in the case of Fig. 2, the value of v will be increased by two-fifths, making $v=4.6$. Then,

$$\text{C. M.}=\frac{116\times300\times10.8}{4.6}=81{,}704=\text{No. 1 wire,}$$

which is less than half the circular mils required in Fig. 2. To this must be added the neutral wire, which, for outside work, may be much smaller than the two main wires. Inside of buildings, however, it is safest to have the neutral of the same size as the other wires.

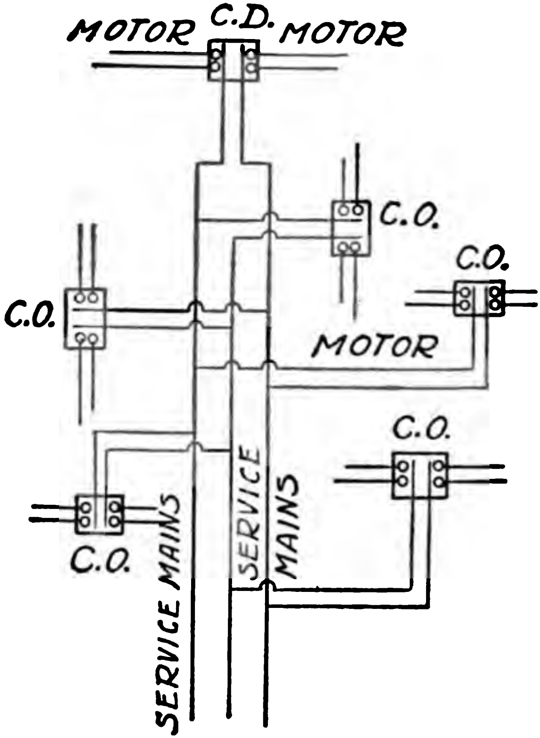


Fig. 3. Plan for Wiring Factory Building on the Three-Wire System.

Ordinarily the total cost of wire for a 3-wire system is calculated to be ⅝ of that for a 2-wire system of the same capacity.

In calculating sizes of leads and branch circuits for motors operating on 220 volts, as in Fig. 3, use same methods as for figuring size of service wires, leaving out the neutral. In actual practice, these calculations need not often be made,

(Continued on page 566)

TABLE 3

Wiring Data for 110-Volt Circuits

Top Figures in Each Column the Percentage of Loss; Those Below, the Size of Wire B. & S. Gauge.						Top Figures in Each Column are the Number of Amperes; Those Below, the Distance in Feet.																		
2	3.15	5	6.3	8	10	2	4	6	10	15	20	25	30	40	50	60	80	100	125	150	200	250	300	350
....	....	....	....	....	500000	127315	63657	42438	25463	16975	12731	10185	8187	6365	5092	4243	[illegible]	2546	2037	1697	1273	1018	849	727
....	....	....	....	500000	400000	101850	50925	33960	20370	13580	10185	8148	6790	5093	4074	3395	2546	2037	[illegible]	1358	1018	815	679	....
....	....	....	500000	400000	300000	76380	38190	25460	15276	10184	7638	6111	5092	3819	3055	2546	1910	1527	1222	1018	763	611	....	....
....	....	500000	400000	300000	0000	53880	26940	17960	10776	7181	5388	4311	3592	2694	2155	1796	1347	1077	862	718	538	....	....	....
....	....	400000	300000	0000	000	40410	20205	13470	8082	5458	4041	3233	2744	2020	1616	1372	1010	808	647	538	....	....	....	....
....	500000	300000	0000	000	00	33883	16942	11295	6777	4517	3388	2711	2258	1694	1355	1129	822	677	542	452	....	....	....	....
....	400000	0000	000	00	0	26880	13440	8960	5377	3584	2688	2151	1792	1344	1075	896	672	587	430	....	....	....	....	....
500000	300000	000	00	0	1	21310	10655	7103	4262	2841	2131	1705	1420	1065	852	710	532	426	341	....	....	....	....	....
400000	0000	00	0	1	2	16900	8450	5633	3380	2253	1690	1352	1126	845	676	523	422	338	....	....	....	....	....	....
300000	000	0	1	2	3	13400	6700	4166	2680	1786	1340	1072	893	670	536	447	335	....	....	....	....	....	....	....
0000	00	1	2	3	4	10605	5302	3535	2121	1413	1060	848	706	530	424	353	....	....	....	....	....	....	....	....
000	0	2	3	4	5	8130	4215	2810	1686	1124	813	675	562	423	337	281	....	....	....	....	....	....	....	....
00	1	3	4	5	6	6685	3342	2228	1337	890	668	535	445	334	267	....	....	....	....	....	....	....	....	....
0	2	4	5	6	7	5300	2650	1766	1060	706	534	424	353	265	212	....	....	....	....	....	....	....	....	....
1	3	5	6	7	8	4220	2110	1406	844	562	422	338	281	211	....	....	....	....	....	....	....	....	....	....
2	4	6	7	8	9	3330	1665	1110	666	441	333	266	222	....	....	....	....	....	....	....	....	....	....	....
3	5	7	8	9	10	2640	1320	880	528	352	264	211	....	....	....	....	....	....	....	....	....	....	....	....
4	6	8	9	10	11	2095	1047	698	419	278	209	....	....	....	....	....	....	....	....	....	....	....	....	....
5	7	9	10	11	12	1660	830	553	333	221	....	....	....	....	....	....	....	....	....	....	....	....	....	....
6	8	10	11	12	13	1320	660	440	264	176	....	....	....	....	....	....	....	....	....	....	....	....	....	....
7	9	11	12	13	14	1045	522	348	209	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
8	10	12	13	14	15	830	415	276	166	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
9	11	13	14	15	16	655	327	218	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
10	12	14	15	16	....	525	263	175	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
11	13	15	16	....	....	412	206	137	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
12	14	16	....	....	....	330	165	111	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
13	15	....	....	....	....	263	131	87	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
14	16	....	....	....	....	206	103	68	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
15	....	....	....	....	....	165	82	55	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
16	....	....	....	....	....	131	65	43	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

One 16-C. P. 55-watt incandescent lamp = ½ ampere. One H. P. = 7.5 amperes. One 2,000-C. P. constant-potential arc-lamp = 5 amperes.

TABLE 4
Wiring Data for 220-Volt Circuits

Top Figures in Each Column the Percentage of Loss; Those Below the Size of Wire B. & S. Gauge.						The Top Figures in Each Column are the number of Amperes: Those Below the Distance in Feet.																			
2	3.15	5	6.3	8	10	2	4	6	10	15	20	25	30	40	50	60	80	100	120	160	200	250	300	350
......	......	......	......	......	500000	254630	127315	84877	50926	33950	25463	20370	16975	12731	10185	8487	6766	5092	4243	3183	2546	2037	1697	1455
......	......	......	......	500000	400000	203700	101850	67900	40740	27160	20370	16295	13580	10185	8147	6790	5092	4073	3395	2546	2036	1629	1357	
......	......	......	500000	400000	300000	152775	76387	50924	30555	20370	15275	12222	10183	7637	6111	5091	3819	3055	2546	1910	1528	1222	....	....
......	......	500000	400000	300000	0000	107780	53890	35926	21556	14370	10778	8622	7185	5389	4311	3592	2695	2155	1796	1348	1077	....	....	....
......	......	400000	300000	0000	000	85450	42725	28483	17090	11393	8545	6836	5696	4272	3418	2848	2136	1709	1424	1068	....	....	....	....
......	500000	300000	0000	000	00	67745	33872	22581	13549	9032	6774	5420	4516	3387	2710	2258	1679	1355	1129	839	....	....	....	....
......	400000	0000	000	00	0	53770	26885	17923	10751	7170	5377	4302	3585	2688	2151	1792	1344	1075	896	....	....	....	....	....
500000	300000	000	00	0	1	42020	21310	14206	8524	5682	4262	3410	2841	2131	1705	1420	1065	852	710	....	....	....	....	....
400000	0000	00	0	1	2	34055	17027	11351	6811	4540	3405	2724	2270	1702	1360	1135	851	681	..	....	....	....	....	....
300000	000	0	1	2	3	26570	13285	8856	5314	3542	2657	2125	1777	1328	1062	885	664	....	....	....	....	....	....	....
0000	00	1	2	3	4	21255	10627	7085	4251	2834	2125	1700	1417	1062	850	708	....	....	....	....	....	....	....	....
000	0	2	3	4	5	16855	8427	5618	3371	2247	1685	1348	1123	842	614	562	....	....	....	....	....	....	....	....
00	1	3	4	5	6	13365	6682	4455	2673	1782	1336	1050	891	668	525	....	....	....	....	....	....	....	....	....
0	2	4	5	6	7	10560	5280	3520	2112	1413	1060	848	706	530	424	....	....	....	....	....	....	....	....	....
1	3	5	6	7	8	8405	4202	2801	1681	1120	840	672	560	420	....	....	....	....	....	....	....	....	....	....
2	4	6	7	8	9	6665	3332	2221	1333	888	666	533	444	....	....	....	....	....	....	....	....	....	....	....
3	5	7	8	9	10	5275	2637	1758	1055	703	527	422	....	....	....	....	....	....	....	....	....	....	....	....
4	6	8	9	10	11	4190	2095	1396	838	558	419	....	....	....	....	....	....	....	....	....	....	....	....	....
5	7	9	10	11	12	3325	1662	1108	665	443	....	....	....	....	....	....	....	....	....	....	....	....	....	....
6	8	10	11	12	13	2635	1317	878	527	351	....	....	....	....	....	....	....	....	....	....	....	....	....	....
7	9	11	12	13	14	2090	1045	696	418	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
8	10	12	13	14	15	1655	827	551	331	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
9	11	13	14	15	16	1315	657	438	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
10	12	14	15	16	......	1050	525	350	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
11	13	15	16	......	......	828	414	276	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
12	14	16	......	......	......	657	336	219	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
13	15		......	......	......	526	263	175	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
14	16		......	......	......	414	207	138	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
15	......	......	......	......	......	329	164	100	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
16	......	......	......	......	......	265	132	88		....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

One 16-C. P. 55-watt incandescent lamp = ¼ ampere. One H. P. = 3.75 amperes. One 2,000-C. P. constant-potential arc-lamp = 2⅓ amperes.

TABLE 5

Wiring Data for 500-Volt Circuits

Top Figures in Each Column the Percentage of Loss; Those Below the Size of Wire B. & S. Gauge.						The Top Figures in Each Column are the Number of Amperes: Those Below the Distance in Feet.																
2	3.15	5	6.3	8	10	2	4	6	10	15	20	25	30	40	50	60	80	100	120	150	170	200
......	......	......	......		500000	578700	289350	192900	115740	77160	57870	46296	38580	28935	23148	19290	14467	11574	9645	7716	6800	5787
......	......	......		500000	400000	460645	230822	153550	92129	61420	46064	36852	30710	23032	18426	15355	11516	9213	7677	6142	5420	4606
......	......	......	500000	400000	300000	347220	173610	115740	69444	45296	34723	27777	22648	17361	13888	11324	8680	6944	5662	4629	4085	3472
......	......	500000	400000	300000	0000	244950	122475	81650	48990	32660	24495	19595	16330	12247	9797	8165	6123	4898	4082	3266	2882	2449
......	......	400000	300000	0000	000	194215	97107	64738	38843	25895	19421	15537	12947	9710	7768	6473	4855	3884	3236	2589	2285	....
......	500000	300000	0000	000	00	154025	77012	51341	30805	20536	15402	12322	10268	7701	6161	5134	3850	3080	2567	2054	....	....
......	400000	0000	000	00	0	122210	61105	40736	24442	16293	12221	9775	8146	6110	4887	4073	3055	2443	2036	....	....	....
500000	300000	000	00	0	1	96405	48202	32135	19281	12854	9640	7712	6427	4820	3856	3213	2410	1928	1606	....	....	....
400000	0000	00	0	1	2	76565	38282	25521	15313	10208	7656	6125	5104	3828	3062	2552	1914	1531	....	....	....	....
300000	000	0	1	2	3	60915	30457	20305	12183	8122	6091	4873	4061	3045	2436	2030	1522	....	....	....	....	....
0000	00	1	2	3	4	48310	24155	16103	9662	6441	4831	3864	3220	2415	1932	1610	....	....	....	....	....	....
000	0	2	3	4	5	38282	19140	12760	7656	5104	3828	3062	2552	1914	1531	1276	....	....	....	....	....	....
00	1	3	4	5	6	30457	15228	10152	6091	4061	3045	2436	2030	1522	1218	....	....	....	....	....	....	....
0	2	4	5	6	7	24155	12077	8051	4831	3220	2415	1932	1610	1207	966	....	....	....	....	....	....	....
1	3	5	6	7	8	19140	9570	6380	3828	2552	1914	1531	1276	957	....	....	....	....	....	....	....	....
2	4	6	7	8	9	15229	7614	5076	3045	2030	1522	1218	1015	....	....	....	....	....	....	....	....	....
3	5	7	8	9	10	12077	6039	4026	2415	1610	1207	978	....	....	....	....	....	....	....	....	....	....
4	6	8	9	10	11	9570	4785	3190	1914	1276	957	....	....	....	....	....	....	....	....	....	....	....
5	7	9	10	11	12	7639	3819	2546	1527	1018	....	....	....	....	....	....	....	....	....	....	....	....
6	8	10	11	12	13	6039	3019	2013	1207	805	....	....	....	....	....	....	....	....	....	....	....	....
7	9	11	12	13	14	4785	2392	1595	957	....	....	....	....	....	....	....	....	....	....	....	....	....
8	10	12	13	14	15	3819	1910	1273	763	....	....	....	....	....	....	....	....	....	....	....	....	....
9	11	13	14	15	16	3019	1510	1005	....	....	....	....	....	....	....	....	....	....	....	....	....	....
10	12	14	15	16	......	2392	1195	797	....	....	....	....	....	....	....	....	....	....	....	....	....	....
11	13	15	16	......	......	1910	950	636	....	....	....	....	....	....	....	....	....	....	....	....	....	....
12	14	16	......	......	......	1510	755	503	....	....	....	....	....	....	....	....	....	....	....	....	....	....
13	15	......	......	......	......	1195	597	398	....	....	....	....	....	....	....	....	....	....	....	....	....	....
14	16	......	......	......	......	950	475	316	....	....	....	....	....	....	....	....	....	....	....	....	....	....
15	......	......	......	......	......	755	377	252	....	....	....	....	....	....	....	....	....	....	....	....	....	....
16		......	......	......	......	597	298	199	....	....	....	....	....	....	....	....	....	....	....	....	....	....

One H. P. = 1.49 amperes. When lights are used, the lamps are put in series.

TABLE 6

Cost per Mile of Triple-Braid Weather-Proof Solid Copper Conductor at 10 to 20 Cents a Pound

(5 per cent. allowed for sag and waste.)

Circ. Mils. and B & S Nos.	*Weight per Mile	Wt. Mile Plus 5%	AMOUNT IN DOLLARS PER MILE AT THE DIFFERENT PRICES PER POUND 10c	11c	12c	13c	14c	15c	16c	17c	18c	19c	20c
2,000,000	37000	38850	$3885	$4274	$4662	$5051	$5439	$5828	$6216	$6605	$6993	$7382	$7770
1,750,000	32700	34335	3434	3777	4120	4464	4807	5150	5494	5837	6180	6524	6867
1,500,000	28400	29820	2982	3280	3578	3877	4175	4473	4771	5069	5368	5666	5964
1,250,000	23800	24990	2499	2749	2999	3249	3499	3749	3998	4248	4498	4748	4998
1,000,000	19400	20370	2037	2241	2444	2648	2852	3056	3259	3463	3667	3870	4074
750,000	14900	15645	1565	1721	1877	2034	2190	2347	2503	2660	2816	2973	3129
600,000	11800	12390	1239	1363	1487	1611	1735	1859	1982	2106	2230	2354	2478
500,000	10000	10500	1050	1155	1260	1365	1470	1575	1680	1785	1890	1995	2100
450,000	9100	9555	956	1051	1147	1242	1338	1433	1529	1624	1720	1815	1911
400,000	8200	8610	861	947	1033	1119	1205	1292	1378	1464	1550	1636	1722
350,000	7100	7455	746	820	895	969	1044	1118	1193	1267	1342	1416	1491
300,000	6200	6510	651	716	781	846	911	977	1042	1107	1172	1237	1302
250,000	5200	5460	546	601	655	710	764	819	874	928	983	1037	1092
0000	4220	4431	443	487	532	576	620	665	709	753	798	842	886
000	3450	3623	362	399	435	471	507	543	580	616	652	688	725
00	2760	2898	290	319	348	377	406	435	464	493	522	551	580
0	2240	2352	235	259	282	306	329	353	376	400	423	447	470
1	1735	1822	182	200	219	237	255	273	292	310	328	346	364
2	1425	1496	150	165	180	194	209	224	239	254	269	284	299
3	1090	1145	115	126	137	149	160	172	183	195	206	218	229
4	900	945	95	104	113	123	132	142	151	161	170	180	189
6	610	641	64	71	77	83	90	96	103	109	115	122	128

*Manufacturers' standard approximate weights.

TABLE 7

Cost per Mile of Triple-Braid Weather-Proof Stranded Copper Conductor at 10 to 20 Cents a Pound

(5 per cent. allowed for sag and waste.)

Size B. & S. Gauge	*Wt. per Mile	*Wt. Mile Plus 5%	**AMOUNT IN DOLLARS PER MILE AT THE DIFFERENT PRICES PER POUND 10c	11c	12c	13c	14c	15c	16c	17c	18c	19c	20c
0000	4050	4253	$425	$468	$510	$553	$595	$638	$680	$723	$766	$808	$851
000	3320	3486	349	383	418	453	488	523	558	593	627	662	637
00	2650	2783	278	306	334	362	390	417	445	473	501	529	557
0	2150	2258	226	246	271	294	316	339	361	384	406	429	452
1	1670	1754	175	193	210	228	246	263	281	298	316	333	351
2	1370	1439	144	158	173	187	201	216	230	245	259	273	288
3	1050	1103	110	121	132	143	154	165	176	188	199	210	221
4	865	908	91	100	109	118	127	136	145	154	163	173	182
6	590	620	62	68	74	81	87	93	99	105	112	118	124
8	395	415	41.50	45.65	49.80	54	58	62	66	71	75	79	83
10	280	294	29.40	32.34	35.28	38.22	41.16	44.10	47.07	49.98	53	56	59
12	185	194	19.40	21.34	23.28	25.22	27.15	29.10	31.07	32.98	34.92	36.86	38.80
14	130	137	13.70	15.07	16.44	17.81	19.18	20.55	21.92	23.29	24.66	26.03	27.40
16	105	110	11.00	12.10	13.20	14.30	15.40	16.50	17.60	18.70	19.80	20.90	22.00
18	85	89	8.90	9.79	10.68	11.57	12.46	13.35	14.24	15.13	16.02	16.91	17.80
20	65	68	6.80	7.48	8.16	8.84	9.52	10.20	10.88	11.56	12.24	12.92	13.60

*Manufacturers' standard approximate weights. **Amounts less than $50.00 are given to nearest cent.

TABLE 8

Sizes of Wire for Single-Phase Motors

Horse-Power	110 VOLTS Full Load Current	110 VOLTS Size of Wire	220 VOLTS Full Load Current	220 VOLTS Size of Wire
1	12	12	6	14
2	28	8	11	12
3	33	4	16	10
4	44	4	22	8
5	53	2	26	6

TABLE 9

Sizes of Wires for Three-Phase Motors

Horse Power	220 VOLTS			440 VOLTS		
	Full Load Current	Size of Wire, Mains	Size of Wire, Branches	Full Load Current	Size of Wire, Mains	Size of Wire, Branches
1	3	14	14	2	14	14
2	5	14	14	3	14	14
3	8	14	12	4	14	14
4	10	14	12	5	14	14
5	13	12	10	6	14	14
7.5	19	10	8	10	14	12
10	26	8	6	13	12	10
12.5	32	8	5	16	12	10
15	38	6	4	19	10	8
17.5	45	6	3	22	10	8
20	51	5	3	26	8	6
25	64	4	1	32	8	5
30	77	3	0	38	6	4
35	90	2	00	45	6	3
40	102	1	00	51	5	3
45	115	0	000	58	4	2
50	128	0	0000	64	4	1
55	141	00	0000	70	3	1
60	154	000	c. m. 250	77	3	0
65	166	000	300	83	2	0
70	179	000	300	90	2	00
75	192	0000	350	96	1	00
80	205	0000	350	102	1	00
85	218	c. m. 250	400	109	1	000
90	230	250	500	115	0	000
95	243	300	500	122	0	0000
100	256	300	500	128	0	0000
125	320	400	700	160	000	c. m. 250
150	384	500	900	192	0000	350
200	512	700	1.300	256	c. m. 300	500
250	640	1.000	1,800	320	400	700
300	768	1,300	2-900	384	500	900

Column headed "Size of Wire, Branches" gives size of wire for branches for mains supplying one motor, and is based on 50% overload.

Column headed "Size of Wire, Mains" gives size of wire to be used for mains, but in no case must the size of these mains be less than that required for the 50% overload on the largest motor such main supplies.

The question of drop is not taken into consideration in Table 9.

as it is much easier to refer to the tables presented on the following pages (especially Tables 3, 4, and 5), from which can be determined, almost at a glance, the proper sizes of wire for carrying various amounts of current in amperes, different distances in feet, at various percentages of loss. These tables are calculated on safe carrying capacity for the different sizes of wire. Distances in feet are to center of distribution. Table 1 should always be consulted before making a selection of wire. This table is taken from the rules of the National Board of Fire Underwriters, and is therefore standard.

ELECTRIC ILLUMINATION

Table X shows the coefficients of diffusion for various colored interior walls and ceilings.

TABLE 10

Coefficients of Diffusion for Colored Walls and Ceilings

Color of Walls	Percentage of Light Reflected
White wallpaper	70 to 80%
Yellow wallpaper	35 to 40%
Emerald green	about 18%
Black paper	about 5%
Deep blue paper	about 3%
Black velvet	about .4 of 1%

It is evident from Table 10 that in estimating number of lamps required for lighting a building, it is necessary to know the color of the interior decorations.

In estimating candle-power on the basis of volume in cu. ft. of halls, rooms, etc., Table 11 will be of service.

TABLE 11

Candle-Power Required for Lighting Interiors per Cubic Foot Volume of Space

(Walls and ceilings of medium tint.)

Kind of Building	C. P. Required per Cu. Ft. of Space
Public Hall	.055 candle-power
Legislative Hall	.052 " "
Church	.022 " "
Opera House	.035 " "
Theatre	.020 " "
Drawing Room	.018 " "

Example—Assume the volume of space in a public hall to be 20,000 cu. ft. The required illumination in C. P. $=20{,}000 \times .055 = 1{,}100$ C. P.

The quantity of light required per cu. ft., as already intimated, will also depend upon color of walls, ceilings, etc. The figures given in Table 11 assume walls and ceilings to be of a medium tint, neither too dark nor too light. Shades and globes also absorb a certain amount of light, making it necessary in certain cases to increase the figures here given, so as to allow for this loss.

Table 12 will be found helpful in calculating illumination by means of enclosed arc-lamps.

TABLE 12

Illumination by Enclosed Arc-Lamps

Kind of Space to be Illuminated.	Sq. Ft. to be Allowed per Lamp of 2,000 Candle-Power.
Open areas	20,000 sq. ft.
Railroad stations	14,000 " "
Machine shops	2,000 " "
Foundries	5,000 " "
Thread and Textile mills	2,000 to 4,600 " "
Train sheds	12,600 to 14,400 " "

In estimating candle-power according to floor space of rooms to be lighted, assuming ceilings to be of the usual height for residence buildings, calculate number of sq. ft. of floor space in each room; then for each 100 sq. ft. allow:

For good illumination, 2 16-C. P. incandescent lamps.
For very bright light, 3 16-C. P. " "
For brilliant light, 4 16-C. P. " "

AUTOMATIC CUT-OUTS—(FUSES AND CIRCUIT-BREAKERS)

All Voltages—Constant Potential Systems

Extracts from General Rules—National Electrical Code:

a. Automatic cut-outs must be placed on all service wires, either overhead or underground, as near as possible to the point where they enter the building, and inside the walls, and arranged to cut off the entire current from the building.

The purpose of such cut-outs is to make sure that the wires inside a building cannot be subjected to a current larger than they can safely carry. They are absolutely necessary when taking current from a public plant, as the fuses in the mains are often changed without regard to the size of the wires in the buildings.

b. Must be placed at every point where a change is made in the size of wire, unless the cut-out in the larger wire will protect the smaller.

For 3-wire D. C., or single-phase systems, the fuse in the neutral wire, except that called for under Section d, may be omitted, provided the neutral wire is properly grounded.

It will frequently be found necessary to provide cut-outs where taps are taken from large mains. In such cases, if the clamps on the cut-outs are not sufficiently large and strong to give a firm and secure connection, a short length of smaller wire may be soldered to the main wire and then carried directly to the cut-out, which should be located as near as possible to the point of connection with the mains. Special care should be taken to guard these leads from accident, as they may not be properly protected by the fuses in the main circuit.

c. Must be in plain sight, or enclosed in an approved cabinet and readily accessible. They must not be placed in the canopies or shells of fixtures.

Link fuses may be used only when mounted on slate or marble bases, and must be enclosed in dust-tight, fireproofed cabinets, except on switchboards.

d. Must be so placed that no set of incandescent lamps requiring more than 660 watts, whether grouped on one fixture or on several fixtures or pendants, will be dependent upon one cut-out. Special permission may be given in writing by the Inspection Department having jurisdiction, for departure from this rule in the case of large chandeliers, stage borders, and illuminated signs.

The above rule shall also apply to motors when more than one is dependent on a single cut-out.

The idea is to have a small fuse to protect the lamp socket and the small wire used for fixtures, pendants, etc. It also lessens the chances of extinguishing a large number of lights if a short-circuit occurs.

Unless fused rosettes are used, the fuses in the branch cut-outs should not have a rated capacity greater than 6 amperes on 110-volt systems, and 3 amperes on 220-volt systems.

If ceiling rosettes are used—either fused or fuseless—there must be a separate one for each pendant and they must be supported independently of the overhead wires.

SWITCHES

a. Switches must be placed on all service wires, either overhead or underground, immediately at a point where they enter the building and within 7 ft. of the floor. Provided, however, service switches may be located away from where wires enter buildings, when space where said wires enter is used for purposes such that the location of cut-out therein would increase the fire hazard, in which case the wires must be encased in standard continuous conduit, from a point outside the building to the point where the switch is installed. The switch required by this section must be so placed as to be protected by cut-out.

Service cut-out and switch must be arranged to cut off current from all devices including meters.

b. Must always be placed in dry, accessible places, and be grouped as far as possible.

In risks having private plants, the yard wires running from building to building are not generally considered as service wires, so that cut-outs would not be required where the wires enter buildings, provided that the next fuse back is small enough to properly protect the wires inside the building in question.

Up to 250 volts and 30 amperes, approved indicating snap-switches are advised in preference to knife-switches on lighting circuits.

ELECTRIC HEATERS

a. Must be protected by a cut-out, and controlled by indicating switches. Switches must be double-pole where the device controlled requires more than 660 watts of energy.

b. Must never be concealed, but must at all times be in plain sight. Special permission may be given in writing by the Electrical Department for departure from this rule.

c. Flexible conductors for smoothing irons and sad irons, and for all devices requiring over 250 watts, must have a standard insulation and covering.

d. For portable heating devices, the flexible conductors must be connected to a standard plug device, so arranged that the plug will pull out and open the circuit in case any abnormal strain is put on the flexible conductor. This device may be stationary, or it may be placed in the cord itself. The cable or cord must be attached to the heating apparatus in such manner that it will be protected from kinking, chafing, or like injury at or near the point of connection.

e. Smoothing irons, sad irons, and other heating appliances that are intended to be applied to inflammable articles, such as clothing, must conform to the above rules so far as they apply. They must also be provided with an approved stand, on which they should be placed when not in use.

f. Stationary electric heating apparatus, such as radiators, ranges, plate warmers, etc., must be placed in a safe location, isolated from inflammable materials, and be treated as sources of heat.

g. Must each be provided with name-plate, giving the maker's name and the normal capacity in volts and amperes.

LIGHTNING ARRESTERS

a. Must be provided on each wire of every overhead circuit connected with the station.

b. Must be located in readily accessible places, away from combustible materials, and as near as practicable to the point where the wires enter the building.

Station arresters should generally be placed in plain sight on the switchboard.

Kinks, coils, and sharp bends in the wires between the arresters and the outdoor lines, must in all cases be avoided as far as possible.

c. Must be connected to a thoroughly good and permanent ground connection by metallic strips or wires having a conductivity not less than that of a No. 6 B. & S. gage copper wire, which must be run as nearly in a straight line as possible from the arresters to the ground connection.

Ground wires for lightning arresters must not be attached to gas pipes within the buildings.

Whenever lightning is discharged through an arrester, the generator current tends to follow the discharge current, as the heat of the latter volatilizes a little of the metal and forms between the points a bridge of metal vapor, which quite readily conducts electricity. The arrester must be so designed as to break this arc, as otherwise the generators may be injured and the service interrupted. The arrester itself would also probably be injured, and might not then afford protection against a second discharge.

SIGNALING SYSTEMS

The requirements for signaling systems including wiring for telephone, telegraph, district messenger, and call-bell circuits, fire and burglar alarms, and all similar systems, are as follows:

a. Outside wires should be run in underground ducts or strung on poles, and as far as possible should be kept off buildings. They must not be placed on the same cross-arm with electric light or power wires, and should not occupy the same duct, manhole, or handhole of conduit systems with such wires.

b. When outside wires are run on same pole with electric light or power wires, the distance between the two inside pins on each cross-arm must not be less than 24 inches.

Should be placed on lower cross-arms.

c. Where wires are attached to the outside of buildings they must have an approved rubber insulating covering; and, on frame buildings, or frame portions of other buildings, shall be supported on glass or porcelain insulators, or knobs.

d. The wires from last outside support to the cut-outs or protectors must be of copper, and must have an approved rubber insulation.

Must be provided with drip loops immediately outside the building, and at the entrance.

e. Wires must enter building through approved non-combustible, non-absorptive, insulating bushings sloping upward from the outside.

INTERIOR CONDUITS

a. No conduit tube having an internal diameter of less than ⅝ in. shall be used. With lined conduit, this measurement is to be taken inside the metal tube.

b. Must be continuous from outlet to outlet or to junction-boxes, and the conduit tube must properly enter, and be secured to all fittings.

c. Must first be installed as a complete conduit system, without the conductors.

d. Must be equipped at every outlet with an approved outlet box or plate.

e. Metal conduits, where they enter junction-boxes, and at all other outlets, etc., must be provided with approved bushings, fitted so as to protect the wire from abrasion, except when such protection is obtained by the use of approved nipples, properly fitted in the boxes or other devices.

f. The metal of the conduit must be permanently and effectively grounded.

g. Junction-boxes must always be installed in such a manner as to be accessible.

h. All elbows or bends must be so made that the conduit or lining of same will not be injured. The radius of the curve of the inner edge of any elbow must not be less than 3½ in. Must not have more than the equivalent of four quarter-bends from outlet to outlet, the bends at the outlets not being counted.

Finished conduit to have weight per hundred feet not less than that given in Table 13.

TABLE 13

Dimensions and Weight of Conduits

Trade Size (Inches)	Approx. Inter. Diameter (Inches)	Min. Th'kness of wall (Inches)	Wt. per 100 Ft. (Pounds)
½	.62	.100	75
¾	.82	.105	104
1	1.04	.125	152
1¼	1.38	.135	209
1½	1.61	.140	250
2	2.06	.150	350
2½	2.46	.200	535
3	3.06	.210	710

MOLDINGS FOR ELECTRIC CONDUCTORS

Wooden Moldings

a. Must have, both outside and inside, at least two coats of waterproof material, or be impregnated with a moisture-repellent.

b. Must be made in two pieces, a backing and a capping, and must afford suitable protection from abrasion. Must be so constructed as to thoroughly encase the wire, be provided with a tongue not less than ½ in. in thickness between the conductors, and have exterior walls which under grooves shall not be less than ⅜ in. in thickness, and on the sides not less than ¼ in. in thickness.

Metal Moldings

c. Each length of such molding must have marker's name or trade-mark stamped in the metal, or in some manner permanently attached thereto, in order that it may be readily identified in the field.

d. Must be constructed of iron or steel with backing at least .05 in. in thickness, and with capping not less than .04 in. in thickness, and so constructed that when in place the raceway will be entirely closed; must be thoroughly galvanized, or coated with an approved rust preventive, both inside and out, to prevent oxidation.

e. Elbows, couplings, and all other similar fittings must be constructed of at least the same thickness and quality of metal as the molding itself, and so designed that they will both electrically, and mechanically secure the different sections together.

TUBES AND BUSHINGS

a. Construction. Must be made straight and free from checks or rough projections, with ends smooth and rounded to facilitate the drawing-in of the wire, and prevent abrasion of its covering.

b. Material and Test. Must be made of non-combustible insulating material, which, when broken and submerged for 100 hours in pure water at 70° F. (21° C.) will not absorb over ½ of 1 per cent of its weight.

c. Marking. Must have the name, initials, or trade-mark of the manufacturer stamped in the ware, so that inspectors may know who is responsible for defective fittings.

d. Sizes. Dimensions of walls and heads must be at least as great as those given in Table 14.

TABLE 14

Dimensions of Walls and Heads of Tubes and Bushings

Diameter of Hole (Inches)	External Diameter (Inches)	Thickness of Wall (Inches)	External Diameter of Head (Inches)	Length of Head (Inches)
5/16	9/16	1/8	13/16	1/2
3/8	11/16	5/32	15/16	1/2
1/2	13/16	5/32	1 3/16	1/2
5/8	15/16	5/32	1 5/16	1/2
3/4	1 3/16	7/32	1 11/16	5/8
1	1 7/16	7/32	1 15/16	5/8
1 1/4	1 13/16	9/32	2 5/16	5/8
1 1/2	2 3/16	11/32	2 11/16	3/4
1 3/4	2 9/16	13/32	3 1/16	3/4
2	2 15/16	15/32	3 7/16	3/4
2 1/4	3 5/16	17/32	3 13/16	1
2 1/2	3 11/16	19/32	4 3/16	1

An allowance of 1-64 in. for variation in manufacturing will be permitted, except in the thickness of the wall.

CALCULATING CURRENT REQUIRED

All calculations for quantity of current required to develop a given horse-power; to supply a certain number of lumens, or foot-candles, per sq. ft. of surface, or cu. ft. of volume; or to generate a given number of heat units, are based upon the kilowatt-hour.

Examples—For Power—30-H. P. 220-volt motor?

Allow 746 watts per horse-power:

$$\text{Kilowatts} = \frac{30 \times 746}{1,000} = 22.38$$

For Light—One hundred 55-watt incandescent lamps?

$$\text{Kilowatts} = \frac{100 \times 55}{1,000} = 5.5$$

For Heat—One kilowatt-hour=3,440 heat units
=1⅓ horse-power.

ELECTRIC GAS LIGHTING

Electric gas lighting, unless it is of the same frictional system, must not be used on the same fixture with the electric light.

Plastering

Plasterer's work may consist of either interior or exterior plastering on wood lath, metal lath, patent lath, sheathing lath, plaster-boards, or wall-boards, or directly on brick, tile, stone, or concrete walls and other surfaces.

In order to produce good work, the surfaces must be rigid and capable of holding the plaster; and only the best of materials, put on in a careful manner, must be used.

MATERIALS USED

The common materials used in making plaster are lime, Portland cement, natural cement, hydrated lime, patent or hard plasters, plaster of Paris, Keene's cement, pulp and fiber plasters, hair or fiber, sand, and water.

MEASUREMENT OF PLASTER WORK

Details in the measurement of plaster work vary in different parts of the country. The ordinary unit of measurement on plain surfaces, such as walls and ceilings, is the **square yard.** The allowances necessary in measuring surfaces and quantities must be clearly understood for a given locality. The cost will vary with the price of materials and labor, and also with the number of coats used and the type of finish.

The **standard rules for measurement** of plastering, adopted by the Employing Plasterers' Association of Chicago, Ill., are as follows:

"**Lath and plastering** to be measured by the superficial yard, from floor to ceiling for walls, and from wall to wall for ceilings.

"In rooms containing one or more horizontal angles between the floor and ceiling line, the ceiling to be measured from wall to wall, as though all walls were vertical, for contents of ceiling; and from floor to highest point of ceiling, for height of wall.

"**Openings** in plastering to be measured between grounds. No deductions to be made for openings of 2 ft. or less in width. One-half of contents to be deducted for openings 2 ft. or more in width. The contents on all store front openings to be deducted, and the contractor to be allowed 1 ft. 6 in. for each jamb by the height.

"All beams or girders projecting below ceiling line to have one foot in width by total length added for each internal and external angle.

"**Corner-Beads, Arches, etc.** All corner angles of more or less than 90 degrees, beads, quirks, rule joints, and moldings, to be measured by the linear foot on their longest extension, and one foot for each stop or miter.

"Length of **cornices** to be measured on walls. Plain cornices of 2 ft. girth or less, to be measured on walls by the linear foot. Plain cornices exceeding 2 ft. girth to be measured by the superficial foot. Add 1 linear foot to girth for each stop or miter. Enriched cornices (cast work), by the linear foot for each enrichment.

"Arches, corbels, brackets, rings, center pieces, pilasters, columns, capitals, bases, rosettes, bosses, pendants, and niches, by the piece. Ceiling or frieze plates over 8 in. wide, by the sq. ft.

"**Columns** to be measured by the linear foot for plain plastered columns.

"**Cement wainscot** to be measured by the sq. ft., openings to be allowed as for plain plaster.

"**Grounds** for various classes of work to be as follows, unless expressly specified to the contrary:

Grounds for 2-coat lath work........................ ⅞-in.
Grounds for 3-coat lath work........................ 1-in.
Grounds for 3-coat metal lath work.................. ⅝-in.
Grounds for 3-coat metal lath work on ½-in. iron framing ....1⅛-in.
Grounds for 3-coat metal lath work on 1-in. iron furring.1⅝-in.
Grounds for hard mortar metal lath work............. ⅝-in.
Grounds for hard mortar metal lath work, on ½-in. iron furring ....1⅛-in.
Grounds for 2-coat work on brick or tile............. ⅝-in.
Grounds for hard mortar lath work................... ¾-in.

Where metal lath is spoken of, it applies to all wire or metal lath.

"In accordance with agreements between the International Operative Plasterers' Union and the American Brotherhood of Cement Finishers, it is agreed that plasterers shall claim and do all exterior and interior plastering, whether of stucco, cement, or any patent material, when done in and by the usual methods of plastering, including the covering of all walls, ceilings, soffits, piers, columns, or any part of a construction of any sort, when any part of a construction is covered with any plastic material in the usual methods of plastering.

"In accordance with agreements between the International Operative Plasterers' Union and the Ceramic, Mosaic & Encaustic Tile Layers' and Helpers' International Union, it is agreed that on all walls and ceilings upon which a foundation or base coat is put on by the plasterers, ample room shall be allowed for a final coat of not less than ⅝-in., to be put on by the tile layers, to act as a binder and regulator for the float coat upon which the tile is placed.

"It is also agreed that the plasterers shall use only sand and cement in the preparation of walls for the work as above stipulated.

"It is also agreed that this shall not interfere with the right of the tile layers to do the scratch coating on small jobs of one or two ordinary-sized bathrooms. No scratch coating shall be put on except by mechanics of either trade.

"Patching of plastering after other mechanics shall not be done as a part of the contract price."

Other rules for measurement allow one-half the area of openings for ordinary doors and windows, while some make no allowance for openings of less than 7 sq. yds. Returns of chimney-breasts and pilasters, and all strips less than 12 in. wide, are measured as full 12 in.

In closets, the actual measurements are increased by one-half; and if shelves are in place before plastering, the actual measurement is doubled.

For soffits of stairs, raking ceilings, or places difficult to reach, the actual measurements are increased by one-half.

Round corners and arrises are measured by the linear foot.

Circular or elliptical work should be charged at double measurement.

SUPPORTS FOR PLASTER

Wood Lath. The best wood for laths is white pine, although spruce is used to a great extent. Yellow pine should not be used, on account of the pitch which it contains. Half-green laths are best for use, although dry laths may be wet before using.

Wood laths vary in dimensions; but the common size is 1⅜ in. wide, ¼ in. thick, and 4 ft. long. This length allows proper nailing to studding spaced either 12 or 16 in. on centers.

In nailing, the laths should have a nail to each bearing, and often two nails are required at the ends of each lath. In ceiling work, five nailings to a lath is preferred.

The spacing of laths for ordinary lime mortar should be about ⅜-in. in the clear, and about ¼-in. for patent or hard plasters. Joints in lath work should be broken about every sixth lath.

When laths rest on a bearing surface over 2 in. in width, strips of wood should be placed under the lath so as to allow a space for keying the plaster.

Wood laths are sold by the thousand, in bundles usually containing 100 laths. One thousand laths, if dry, will weigh about 500 pounds, but if wet or green will weigh about double this amount.

Quantity estimates may be based on about 1.500 laths of standard size for each 100 sq. yds. of surface. This allows for a moderate number of angles, brackets, etc. Where work is divided into small or irregular surfaces, this quantity may vary considerably.

A good lather will average about 1,500 laths per 8-hour day; but this quantity may vary from 1,200 to 2,000, depending on the men and the shape of the surfaces worked on.

About 10 pounds of threepenny nails will be required for each 100 sq. yds. of wood lath.

Plaster-Board. Many varieties of patented wall-boards are to be found on the market. These boards are used in the place of wood or metal lath, and are of service as a fireproof covering or for sound-deadening.

Sizes of any particular board may be obtained from the literature of the manufacturer, together with directions for applying same to walls. A common size for plaster-board is 32 by 36 in. Thicknesses vary from ¼ to ½ in., but the standard board weighs about 1½ pounds per sq. ft.

In using plaster-board, the grounds will vary from ¾-in. for boards ¼-in. thick to not less than ⅞-in. for a board ⅜-in. thick. The boards are nailed directly to the studding, furring strips, or joists, with the plastering side out. The center of the board is nailed first, and the edges last. A space of ¼-in. is left between boards, and each edge of the board must have a bearing on the nailing piece of at least ¾-in.

In applying on wood studding or joists, use 1¼-in., 11½ gauge, 7/16-in. head, smooth wire nails set 4-in. apart, with each nail driven in firmly.

On ceilings where leveling is required, ⅞-in. by 2-in. furring strips should be used, set on 8 or 12-in. centers.

Boards should not be wet before applying plaster.

Metal Lath. There are many kinds of metal lath on the market, varying from wire lath made from woven wire reinforced with rods or V-shaped strips, to sheets of expanded sheet steel either of the plain type or of the ribbed and perforated type. The sizes of rolls and sheets of these materials vary to such an extent that it is necessary to consult the catalogues of the manufacturers in order to determine the number of rolls or bundles of a given kind of material needed.

One pound of ⅞-in. wire staples will fasten on about 10 sq. yds. of wire or metal lath.

Sheathing Lath. A combination of wood sheathing and lath is often used for holding plaster. This lath is made by special machinery from pine, hemlock, cypress, and poplar in 4, 6, and 8-in. widths, and in the same lengths as flooring. The edges are either tongued-and-grooved or square.

The face of the lath is recessed so as to form a clinch for plaster applied to the surface.

Grounds for Plastering. Grounds for ordinary lime plaster are usually ¾ to ⅞-in. in depth. For hard wall plaster, common depths are ¾-in. for wood lath; ½ or ⅝-in. for brick or tile; ⅝-in. over face of wire or metal lath; and ¾-in. for wall-board.

Where pulp or fiber plaster is used, ⅝-in. should be allowed for both lath and plaster. This will leave ¼-in. for mortar after lath is on.

It is always good policy to set grounds about ⅛-in narrower than the finished work, so as to allow for the thickness of the finish coat.

PATENT PLASTERS

There are a great number of **patent or hard wall plasters** on the market, sold under various names. The composition of these plasters is nearly the same, the hardness depending upon the proportion of plaster of Paris or prepared gypsum used in their manufacture. These plasters give good satisfaction and make a hard, durable job. For quick work, or for use in cold weather, they are preferable to lime plaster, as they will set and harden much more rapidly.

When any of the hard finishes are used, the plasterer will generally try to work **lime putty** in along with the hard finish, to make it work smoother and easier. This may be permitted to the extent of about 15 per cent lime by volume.

The covering capacity of the different patent plasters varies from 90 to 150 sq. yds. per ton of plaster. In estimating on this class of work, it is advisable to follow the quantities given by the manufacturer of the kind of plaster used.

TWO-COAT PLASTER WORK

Two-coat plastering—known as drawn work—consists of a first layer of plaster containing hair or fiber, applied as a **base coat**, followed immediately with a **brown coat**—these two layers constituting in reality a single coat. A **finish** or **skim coat** is applied as soon as the 2-layer under-coat has dried out. If the plaster is to be placed on brick or tile, the base coat, or first layer of the under coat, may be omitted, and only the brown and finishing coats used.

THREE-COAT PLASTER WORK

Where three-coat **dry work** is used, each coat is dried out before the following coat is applied. A **scratch coat, brown coat,** and **finish coat** are used.

In work on metal lath, the first coat must be thin so as to stick and form a good surface, and also so that it may be pushed through the lath to form a good key.

PORTLAND CEMENT PLASTER

For methods, quantities, costs, and coloring materials, see page 340.

LIME PLASTERING

Lime. Lime is sold in most of the Eastern cities, by the **barrel** weighing 200 pounds net. If shipped in bulk, it is generally sold by the **bushel**. A bushel of lime is figured as 80 pounds, or 2½ bushels to the barrel.

A barrel of the best lime will swell to about 2 3/5 the bulk of the unslaked lime. It is generally estimated that a barrel of lime will make about 8 cu. ft. or 20 pails of **lime paste or putty.**

Experience has shown that the best mortar is made by mixing 1 part lime paste to 2 parts sand.

Three-Coat Work. The first or **scratch coat** is made up of first-quality lump lime, clean, sharp bank sand, and the best quality of clean, long cattle hair, mixed in the proportion of 5⅓ barrels of sand and 1½ bushels of hair to each cask or 200 pounds of lump lime. All materials are stacked in the rough for at least 7 days before using.

The second or **brown coat** is made up in the same manner as the scratch coat, except that 6½ barrels of sand and ½ bushel of hair are used to each 200 pounds of lime. This second coat should be leveled and floated so as to be true at all points.

The third coat may be either a **white or putty coat or sand finish.** If a white coat is used, it is made up of lime putty and equal parts of plaster of Paris and marble dust, or lime putty and some kind of hard wall plaster. This coat is thoroughly troweled and brushed to a hard, smooth surface.

Where a sand finish is desired, the materials consist of lime putty and clean, washed beach sand, floated with a wooden or cork-faced float to an even surface. The surface finish should be of a texture similar to that of No. 1 sand-paper.

A **skim coat** is often used as a finishing coat and is similar to the sand finish described above, except that the surface is finally gone over with a brush and small trowel until the surface becomes hard and polished.

Two-Coat Work. In two-coat work, the first or scratch coat described in three-coat work, is brought nearly to the grounds, and carefully straightened to receive the finishing coat.

The finish or skim coat in two-coat work is made up of nearly equal parts of lime, sand, and plaster of Paris.

Hydrated Lime. Hydrated lime is simply pure lime in a powdered form—thoroughly slaked and screened when obtained in the commercial form. It is handled and treated as pure lime. In the preparation of putty it must be thoroughly soaked and cured for 12 to 24 hours, the same as putty made from lump lime. The use of hydrated lime saves the cost and labor of slaking and running off lump lime.

Keene's Cement. This material is made by re-calcining plaster of Paris after soaking it in a solution of alum. It is used in work on wainscots, caps, bases, and also as a hard finish.

The first coat is made up of 1 part cement, 1 part lime paste, and 3 parts sand.

The second coat is made up of 1 part cement, 1 part lime paste, and 4 parts sand.

For first coat work, 1 ton of Keene's cement will coat about 475 sq. yds. In brown coat and white hard finish, 1 ton will cover about 300 sq. yds. In first and second coat work, 1 ton will cover about 350 sq. yds.

If Keene's cement is used for brown coat, and Keene's finish on expanded metal lath, 100 sq. yds. of surface will require 550 pounds of cement, 5½ bushels of lime, 2 cu. yds. of sand, and 2 bushels of hair for the brown coat, with 300 pounds of cement and 1 bushel of lime for the finishing coat.

Lafarge Cement. Lafarge cement is often used for outside stucco work. It should be mixed as follows:

First coat, 1 part cement, 3 parts sand, 25 per cent lime paste, and sufficient hair.

Second coat, 1 part cement, 2 parts sand, and 10 per cent lime paste.

One barrel of cement and 3 barrels of sand will cover about 34 sq. yds. ⅝-in. thick.

One barrel of cement and 2 barrels of sand will cover about 25 sq. yds. ⅝-in. thick.

Mixing and Estimating Quantities for Plaster Work

For **scratch coat work**, 350 pounds of hydrated lime and ¾ cu. yd. of screened sand should cover 100 sq. yds.

For **second coat**, 200 pounds of hydrated lime and ½ cu. yd. of screened sand should cover 100 sq. yds.

For **float finish**, 300 pounds of hydrated lime and ¼ cu. yd. of screened sand should cover 100 sq. yds.

For **stone mortar**, add 200 pounds of hydrated lime to ⅝ cu. yd. of screened sand.

For **brick mortar**, add 250 pounds of hydrated lime to ⅝ cu. yd. of screened sand. This quantity should lay from 1,000 to 1,200 brick.

For **cement mortar**, use 100 pounds of Portland cement, 150 pounds of hydrated lime, and ⅝ cu. yd., of screened sand.

For waterproofing concrete blocks, 15 to 20 per cent of hydrated lime based on the weight of Portland cement used will give good results when mixed with the other materials used.

Plaster Tables. Tables 1 to 10 show the estimator the number of sq. yds. of plaster required on rooms of different sizes. These tables cover several thousand rooms of varied dimensions, and each table has been verified and can be relied upon as correct. The numbers in the left-hand column and across the top designate the width and length of the room (in feet), while the height of ceiling is indicated at the top of the various tables. The number of sq. yds. indicated, of course, includes only side walls and ceilings, not the floor surface.

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Example: To obtain the number of sq. yds. in a room 12x15x7 ft. Turn to the table giving measurement of rooms with 7-ft. ceilings; follow down the column of figures on the

(Continued on Page 593)

TABLE 1

Number of Square Yards and Feet of Plastering in Various-Sized Rooms

Ceilings—7 Feet High

(Copyright, 1900, by United States Gypsum Co.)

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3	10.3	12.2	14.1	16.0	17.8	19.7	21.6	23.5	25.4	27.3	29.2	31.1	33.0	34.8	36.7	38.6	40.5	42.4	44.3	46.2
4	12.2	14.2	16.2	18.2	20.2	22.2	24.2	26.2	28.2	30.2	32.2	34.2	36.2	38.2	40.2	42.2	44.2	46.2	48.2	50.2
5	14.1	16.2	18.3	20.4	22.5	24.6	26.7	28.8	31.0	33.1	35.2	37.3	39.4	41.5	43.6	45.7	47.8	50.0	52.1	54.2
6	16.0	18.2	20.4	22.6	24.8	27.1	29.3	31.5	33.7	36.0	38.2	40.4	42.6	44.8	47.1	49.3	51.5	53.7	55.8	58.2
7	17.8	20.2	22.5	24.8	27.2	29.5	31.8	34.2	36.5	38.8	41.2	43.5	45.8	48.2	50.5	52.8	55.2	57.5	59.8	62.2
8	19.7	22.2	24.6	27.1	29.5	32.0	34.4	36.8	39.3	41.7	44.2	46.6	49.1	51.5	54.0	56.4	58.8	61.3	63.7	66.2
9	21.6	24.2	26.7	29.3	31.8	34.4	37.0	39.5	42.1	44.6	47.2	49.7	52.3	54.8	57.4	60.0	62.5	65.1	67.6	70.2
10	23.5	26.2	28.8	31.5	34.2	36.8	39.5	42.2	44.8	47.5	50.2	52.8	55.5	58.2	60.8	63.5	66.2	68.8	71.5	74.2
11	25.4	28.2	31.0	33.7	36.5	39.3	42.1	44.8	47.6	50.4	53.2	56.0	58.7	61.5	64.3	67.1	69.8	72.6	75.4	78.2
12	27.3	30.2	33.1	36.0	38.8	41.7	44.6	47.5	50.4	53.3	56.2	59.1	62.0	64.8	67.7	70.6	73.5	76.4	79.3	82.2
13	29.2	32.2	35.2	38.2	41.2	44.2	47.2	50.2	53.2	56.2	59.2	62.2	65.2	68.2	71.2	74.2	77.2	80.2	83.2	86.2
14	31.1	34.2	37.3	40.4	43.5	46.6	49.7	52.8	56.0	59.1	62.2	65.3	68.4	71.5	74.6	77.7	80.8	84.0	87.1	90.2
15	33.0	36.2	39.4	42.6	45.8	49.1	52.3	55.5	58.7	62.0	65.2	68.4	71.6	74.8	78.1	81.3	84.5	87.7	91.0	94.2
16	34.8	38.2	41.5	44.8	48.2	51.5	54.8	58.2	61.5	64.8	68.2	71.5	74.8	78.2	81.5	84.8	88.2	91.5	94.8	98.2
17	36.7	40.2	43.6	47.1	50.5	54.0	57.4	60.8	64.3	67.7	71.2	74.6	78.1	81.5	85.5	88.4	91.8	95.3	98.7	102.2
18	38.6	42.2	45.7	49.3	52.8	56.4	60.0	63.5	67.1	70.6	74.2	77.7	81.3	84.8	88.4	92.0	95.5	90.1	102.6	106.2
19	40.5	44.2	47.8	51.5	55.2	58.8	62.5	66.2	69.8	73.5	77.2	80.8	84.5	88.2	91.8	95.5	99.2	102.8	106.5	110.2
20	42.4	46.2	50.0	53.7	57.5	61.3	65.1	68.8	72.6	76.4	80.2	84.0	87.7	91.5	95.3	99.1	102.8	106.6	110.4	114.0
21	44.3	48.2	52.1	55.8	59.8	63.7	67.6	71.5	75.4	79.3	83.2	87.1	91.0	94.8	98.7	102.6	106.5	110.4	114.3	118.2
22	46.2	50.2	54.2	58.2	62.2	66.2	70.2	74.2	78.2	82.2	86.2	90.2	94.2	98.2	102.2	106.2	110.2	114.2	118.2	122.2
23	48.0	52.2	56.3	60.4	64.5	68.6	72.1	76.8	81.0	85.1	89.2	93.3	97.4	101.5	105.6	109.7	113.8	118.0	122.1	126.2
24	50.0	54.2	58.4	62.6	66.8	71.1	75.3	79.5	83.7	88.0	92.2	96.4	100.6	104.8	109.1	113.3	117.5	121.7	126.0	130.2

The amount indicated includes side walls and ceilings

TABLE 2

Number of Square Yards and Feet of Plastering in Various-Sized Rooms

Ceilings—7 Feet 6 Inches High

(Copyright, 1900, by United States Gypsum Co.)

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3 ...	11.0	13.0	15.0	17.0	19.0	21.0	23.0	25.0	27.0	29.0	31.0	33.0	35.0	37.0	39.0	41.0	43.0	45.0	47.0	49.0
4 ...	13.0	15.1	17.2	19.3	21.4	23.5	25.6	27.7	29.8	32.0	34.1	36.2	38.3	40.4	42.5	44.6	46.7	49.8	51.0	53.1
5 ...	15.0	17.2	19.4	21.6	23.8	26.1	28.3	30.5	32.7	35.0	37.2	39.4	41.6	43.8	46.1	48.3	50.5	52.7	55.0	57.2
6 ...	17.0	19.3	21.6	24.0	26.3	28.6	31.0	33.3	35.6	38.0	40.3	42.6	45.0	47.3	49.6	52.0	54.3	56.6	59.0	61.3
7 ...	19.0	21.4	23.8	26.3	28.7	31.2	33.6	36.1	38.5	41.0	43.4	45.8	48.3	50.7	53.2	55.6	58.1	60.5	63.0	65.4
8 ...	21.0	23.5	26.1	28.6	31.2	33.7	36.3	38.8	41.4	44.0	46.5	49.1	51.6	54.2	56.7	59.3	61.8	64.4	67.0	69.5
9 ...	23.0	25.6	28.3	31.0	33.6	36.3	30.0	41.6	44.3	47.0	49.6	52.3	55.0	57.6	60.3	63.0	65.6	68.3	71.0	73.6
10 ...	25.0	27.7	30.5	33.3	36.1	38.8	41.6	44.4	47.2	50.0	52.7	55.5	58.3	61.1	63.8	66.6	69.4	72.2	75.0	77.7
11 ...	27.0	29.8	32.7	35.0	38.5	41.4	44.3	47.2	50.1	53.0	55.8	58.7	61.6	64.5	67.4	70.3	73.2	76.1	79.0	81.8
12 ...	29.0	32.0	35.0	38.0	41.0	44.0	47.0	50.0	53.0	56.0	59.0	62.0	65.0	68.0	71.0	74.0	77.0	80.0	83.0	86.0
13 ...	31.0	34.1	37.2	40.3	43.4	46.5	49.6	52.7	55.8	59.0	62.1	65.2	68.3	71.4	74.5	77.6	80.7	84.8	87.0	90.1
14 ...	33.0	36.2	39.4	42.6	45.8	49.1	52.3	55.5	58.7	62.0	65.2	68.4	71.6	74.8	78.1	81.3	84.5	87.7	91.0	94.2
15 ...	35.0	38.3	41.6	45.0	48.3	51.6	55.0	58.3	61.6	65.0	68.3	71.6	75.0	78.3	81.6	85.0	88.3	91.6	95.0	98.3
16 ...	37.0	40.4	43.8	47.3	50.7	54.2	57.6	61.1	64.5	68.0	71.4	74.8	78.3	81.7	85.2	88.6	92.1	95.5	99.0	102.4
17 ...	39.0	42.5	46.1	49.6	53.2	56.7	60.3	63.8	67.4	71.0	74.5	78.1	81.6	85.2	88.7	92.3	95.8	99.4	103.0	106.5
18 ...	41.0	44.6	48.3	52.0	55.6	59.3	63.0	66.6	70.3	74.0	77.6	81.2	85.0	88.6	92.3	96.0	99.6	103.3	107.0	110.6
19 ...	43.0	46.7	50.5	54.3	58.1	61.8	65.6	69.4	73.2	77.0	80.7	84.5	88.3	92.1	95.8	99.6	103.4	107.2	111.0	114.7
20 ...	45.0	49.8	52.7	56.6	60.5	64.4	68.3	72.2	76.1	80.0	84.8	87.7	91.6	95.5	99.4	103.3	107.2	111.1	115.0	118.8
21 ...	47.0	51.0	55.0	59.0	63.0	67.0	71.0	75.0	79.0	83.0	87.0	91.0	95.0	99.0	103.0	107.0	111.0	115.0	119.0	123.0
22 ...	49.0	53.1	57.2	61.3	65.4	69.5	73.6	77.7	81.8	86.0	90.1	94.2	98.3	102.4	106.5	110.6	114.7	118.8	123.0	127.0
23 ...	51.0	55.2	59.4	63.6	67.8	72.1	76.3	80.5	84.7	89.0	93.2	97.4	101.6	105.8	110.1	114.3	118.5	122.7	127.0	131.2
24 ...	53.0	57.3	61.6	66.0	70.3	74.6	79.3	80.5	84.7	89.0	93.2	97.4	101.6	105.3	113.6	118.0	122.3	126.6	131.0	135.8

The amount indicated includes side walls and ceilings

TABLE 3

Number of Square Yards and Feet of Plastering in Various-Sized Rooms

Ceilings—8 Feet High

(Copyright, 1900, by United States Gypsum Co.)

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3 ...	11.6	13.7	15.8	18.0	20.1	22.2	24.3	26.4	28.5	30.6	32.7	34.8	37.0	39 1	41.2	43.3	45.4	47.5	49.6	51.7
4 ...	13.7	16.0	18.2	20.4	22.6	24.8	27.1	29.3	31.5	33.7	36.0	38.2	40.4	42 6	44.8	47.1	49.3	51.5	53.7	56.0
5 ...	15.8	18.2	20.5	22.8	25.2	27.5	29.8	32.2	34.5	36.8	39.2	41.5	43.8	46 2	48.5	50.8	53.2	55.5	57.8	60.2
6 ...	18.0	20.4	22.8	25.3	27.7	30.2	32.6	35.1	37.5	40.0	42.4	44.8	47.3	49 7	52.2	54.6	57.1	59.5	62.0	64.4
7 .	20.1	22.6	25.2	27.7	30.3	32.8	35.4	38.0	40.5	43.1	45.6	48.2	50.7	53 3	55.8	58.4	61.0	63.5	66.1	68.9
8 ..	22.2	24.8	27.5	30.2	32.8	35.5	38.2	40.8	43.5	46.2	48.8	51.5	54.2	56 8	59.5	62.2	64.8	67.5	70.2	72.8
9 ..	24.3	27.1	29.8	32.6	35.4	38.2	41.0	43.7	46.5	49.3	52.1	54.8	57.6	60 4	63.2	66.0	68.7	71.5	74.3	77.1
10 ..	26.4	29.3	32.2	35.1	38.0	40.8	43.7	46.6	49.5	52.4	55.3	58.2	61.1	64 0	66.8	69.7	72.6	75.5	78.4	81.3
11 ..	28.5	31.5	34.5	37.5	40.5	43.5	46.5	49.5	52.5	55.5	58.5	61.5	64.5	67 5	70.5	73.5	76.5	79.5	82.5	85.5
12 ..	30.6	33.7	36.8	40.0	43.1	46.2	49.3	52.4	55.5	58.6	61.7	64.8	68.0	71 1	74.2	77.3	80.4	83.5	86.6	89.7
13 ..	32.7	36.0	39.2	42.4	45.6	48.8	52.1	55.3	58.5	61.7	65.0	68.2	71.4	73.6	77.8	81.1	84.3	87.5	90.7	94.0
14 ...	34.8	38.2	41.5	44.8	48.2	51.5	54.8	58.2	61.5	64.8	68.2	71.5	74.8	78 2	81.5	84.8	88.2	91.5	94.8	98.2
15 ...	37.0	40.4	43.8	47.3	50.7	54.2	57.6	61.1	64.5	68.0	71.4	74.8	78.3	81 7	85.2	88.6	92.1	95.5	99.0	102.4
16 ...	39.1	42.6	46.2	49.7	53.3	56.8	00.4	64.0	67.5	71.1	74.6	78.2	81.7	85 3	88.8	92.4	96.0	99.5	103.1	106.6
17 .	41.2	44.8	48.5	52.5	55.8	59.5	03.2	66.8	70.5	74.2	77.8	81.5	85.2	88 8	92.5	96.2	99.8	103.5	707.2	110.8
18 . .	43.3	47.1	50.8	54.6	58.4	62.2	66.0	69.7	73.5	77.3	81.1	84.8	88.6	92 4	96.2	100.0	103.7	107.5	111.3	115.1
19 ...	45.4	49.3	53.2	57.1	61.0	64.8	68.7	72.6	76.5	80.4	84.3	88.2	92.1	96 0	99.8	103.7	107.6	111.5	115.4	119.3
20 ...	47.5	51.5	55.5	59.5	63.5	67.5	71.5	75.5	79.5	83.5	87.5	91.5	95.5	99.5	103.5	107.5	111.5	115.4	119.5	123.5
21 ...	49.6	53.7	57.8	62.0	66.1	70.2	74.3	78.4	82.5	86.6	90.7	94.8	99.0	103 1	107.2	111.3	115.4	119.5	123.6	127.7
22 ...	51.7	56.0	60.2	64.4	68.8	72.8	77.1	81.3	85.5	89.7	94.0	98.2	102.4	106 6	110.8	115.1	119.3	123.5	127.7	132.0
23 ...	53.8	58.2	62.5	66.8	71.2	75.5	79.8	84.2	88.5	92.8	97.2	101.5	105.8	110 2	114.5	118.8	123.2	127.5	131.8	136.2
24 ...	56.0	60.4	64.8	69.3	73.7	78.2	82.6	87.1	91.5	96.0	100.4	104.8	109.3	113 7	118.2	122.6	127.1	131.5	136.0	140.4

The amount indicated includes side walls and ceilings

TABLE 4

Number of Square Yards and Feet of Plastering in Various-Sized Rooms

Ceilings—8 Feet 6 Inches High

(Copyright, 1900, by United States Gypsum Co.)

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3..	12.3	14.5	16.7	19.0	21.2	23.4	25.6	27.8	30.1	32.2	34.5	36.7	39.0	41.2	43.4	45.6	47.8	50.1	52.3	54.5
4..	14.5	16.8	19.2	21.5	23.8	26.2	28.5	30.8	33.2	35.5	37.8	40.2	42.5	44.8	47.2	49.5	51.8	54.2	56.5	58.8
5..	16.7	19.2	21.6	24.1	26.5	29.0	31.4	33.8	36.3	38.7	41.2	43.6	46.1	48.5	51.0	53.4	55.8	58.3	60.7	63.2
6..	19.0	21.5	24.1	26.6	29.2	31.7	34.3	36.8	39.4	42.0	44.5	47.1	49.6	52.5	54.7	57.3	59.8	62.4	65.0	67.5
7..	21.2	23.8	26.5	29.2	31.8	34.5	37.2	39.8	42.5	45.2	47.8	50.5	53.2	55.8	58.5	61.2	63.8	66.5	69.2	71.8
8..	23.4	26.2	29.0	31.7	34.5	37.3	40.1	42.8	45.6	48.4	51.2	54.0	56.7	59.5	62.3	65.1	67.8	70.6	73.4	76.2
9..	25.6	28.5	31.4	34.3	37.2	40.1	43.0	45.8	48.7	51.6	54.5	57.4	60.3	63.2	66.1	69.0	71.8	74.7	77.6	80.5
10..	27.8	30.8	33.8	36.8	39.8	42.8	45.8	48.8	51.8	54.8	57.8	60.8	63.8	66.8	69.8	72.8	75.8	78.8	81.8	84.8
11..	30.1	33.2	36.3	39.4	42.5	45.6	48.7	51.8	55.0	53.1	61.2	64.3	67.4	70.5	73.6	76.7	79.8	83.0	86.1	89.2
12..	32.2	35.5	38.7	42.0	45.2	48.4	51.6	54.8	58.1	61.3	64.5	67.7	71.0	74.2	77.4	80.6	83.8	87.1	90.3	93.5
13..	34.5	37.8	41.2	44.5	47.8	51.2	54.5	57.8	61.2	64.5	67.8	71.2	74.5	77.8	81.2	84.5	87.8	91.2	94.5	97.8
14..	36.7	40.2	43.6	47.1	50.5	54.0	57.4	60.8	64.3	67.7	71.2	74.6	78.1	81.5	85.0	88.4	91.8	95.3	98.7	102.2
15..	39.0	42.5	46.1	49.6	53.2	56.7	60.3	63.8	67.4	71.0	74.5	78.1	81.6	85.2	88.7	92.3	95.8	99.4	103.0	106.5
16..	41.2	44.8	48.5	52.2	55.8	59.5	63.2	66.8	70.5	74.2	77.8	81.5	85.2	88.8	92.5	96.2	99.8	103.5	107.2	110.8
17..	43.4	47.2	51.0	54.7	58.5	62.3	66.1	69.8	73.6	77.4	81.2	85.0	88.7	92.5	96.3	100.1	103.8	107.6	111.4	115.2
18..	45.6	49.5	53.4	75.3	61.2	65.1	69.0	72.8	76.7	80.6	84.5	88.4	92.3	96.2	100.1	104.0	107.8	111.7	115.6	119.5
19..	47.8	51.8	55.8	59.8	63.8	67.8	71.8	75.8	79.8	83.8	87.8	91.8	95.8	99.8	103.3	107.8	111.8	115.8	119.8	123.8
20..	50.1	54.2	58.3	62.4	66.5	70.6	74.7	78.8	83.0	87.1	91.2	95.3	99.4	103.5	107.6	111.7	115.8	120.0	124.1	128.2
21..	52.3	56.5	60.7	65.0	69.2	73.4	77.6	81.8	86.1	90.3	94.5	98.7	103.0	107.2	111.4	115.6	119.8	124.1	128.3	132.5
22..	54.5	58.8	63.2	67.5	71.8	76.2	80.5	84.8	89.2	93.5	97.8	102.2	106.5	110.8	115.2	119.5	123.8	128.2	132.5	136.8
23..	56.7	61.2	65.6	70.1	74.5	79.0	83.4	87.8	92.3	96.7	101.2	105.6	110.1	114.5	119.1	123.4	127.8	132.3	136.7	141.2
24..	59.0	63.5	68.1	72.6	77.2	81.7	86.3	90.8	95.4	100.0	104.5	109.1	113.6	118.2	122.7	127.3	131.8	136.4	141.0	145.5

The amount indicated includes side walls and ceilings

TABLE 5

Number of Square Yards and Feet of Plastering in Various-Sized Rooms
Ceilings—9 Feet High

(Copyright, 1900, by United States Gypsum Co.)

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3..	13.0	15.3	17.6	20.0	22.3	24.6	27.0	29.3	31.6	34.0	36.3	38.6	41.0	43.3	45.6	48.0	50.3	52.6	55.0	57.3
4..	15.3	17.7	20.2	22.6	25.1	27.5	30.0	32.4	34.8	37.3	39.7	42.2	44.6	47.1	49.5	52.0	54.4	56.8	59.3	61.7
5..	17.6	20.2	22.7	25.3	27.8	30.4	33.0	35.5	38.1	40.6	43.2	45.7	48.3	50.8	53.4	56.0	58.5	61.1	63.6	66.2
6..	20.0	22.6	25.3	28.0	30.6	33.3	36.0	38.6	41.3	44.0	46.6	49.3	52.0	54.6	57.3	60.0	63.5	65.4	68.0	70.6
7..	22.3	25.1	27.8	30.6	33.4	36.2	39.0	41.7	44.5	47.3	50.1	52.8	55.6	58.4	61.2	64.0	66.7	69.5	72.3	75.1
8..	24.6	27.5	30.4	33.3	36.2	39.1	42.0	44.8	47.7	50.6	53.5	56.4	59.3	62.2	65.1	68.0	70.8	73.7	77.6	79.5
9..	27.0	30.0	33.0	36.0	39.0	42.0	45.0	48.0	51.0	54.0	57.0	60.0	63.0	66.0	69.0	72.0	75.0	78.0	81.0	84.0
10..	29.3	32.4	35.5	38.6	41.7	44.8	48.0	52.0	54.2	57.3	60.4	63.5	66.6	69.7	72.8	76.0	79.1	82.2	85.3	88.4
11..	31.6	34.8	38.1	41.3	44.5	47.7	51.0	54.2	57.4	60.6	63.8	67.1	70.3	73.5	76.7	80.0	83.2	86.4	89.6	92.8
12..	34.0	37.3	40.6	44.0	47.3	50.6	54.0	57.3	60.6	64.0	67.3	70.6	74.0	77.3	80.6	84.0	87.3	90.6	94.0	97.3
13..	36.3	39.7	43.2	46.6	50.1	53.5	57.0	60.4	63.8	67.3	70.7	74.2	77.6	81.1	84.5	88.0	91.4	94.8	98.3	101.7
14..	38.6	42.2	45.7	49.3	52.8	56.4	60.0	63.5	67.1	70.6	74.2	77.7	81.3	84.8	88.4	92.0	95.5	99.1	102.6	106.2
15..	41.0	44.6	48.3	52.0	55.6	59.3	63.0	66.6	70.3	74.0	77.6	81.3	85.0	88.6	92.3	96.0	99.6	103.3	107.0	111.6
16..	43.3	47.1	50.8	54.6	58.4	62.2	66.0	69.7	73.5	77.3	81.1	84.8	88.6	92.4	96.2	100.0	103.7	107.5	111.3	115.1
17..	45.6	49.5	53.4	57.3	61.2	65.1	69.0	72.8	76.7	80.6	84.5	88.4	92.3	96.2	100.4	104.0	107.8	111.7	115.6	119.5
18..	48.0	52.0	56.0	60.0	64.0	68.0	72.0	76.0	80.0	84.0	88.0	92.0	96.0	100.0	104.0	108.0	112.0	116.0	120.0	124.0
19..	50.3	54.4	58.5	62.6	66.7	70.8	78.0	79.1	83.2	87.3	91.4	95.5	99.6	103.7	107.8	112.0	116.1	120.2	124.3	128.4
20..	52.6	56.8	61.1	65.3	69.5	73.7	78.0	82.2	86.4	90.6	94.8	99.1	103.3	107.5	111.7	116.0	120.2	124.4	128.6	132.8
21..	55.0	59.3	63.6	68.0	72.3	76.6	81.0	85.3	89.6	94.0	98.3	102.6	107.0	111.3	115.6	120.0	124.3	128.6	134.3	137.3
22..	57.3	61.7	66.2	70.6	75.1	79.5	84.0	88.4	92.8	97.3	101.7	106.2	111.6	115.1	121.5	124.0	128.4	132.8	137.3	141.7
23..	59.6	64.2	68.7	73.3	77.8	82.4	87.0	91.5	95.1	100.6	105.2	109.7	114.3	118.8	123.4	128.0	132.5	137.0	141.6	146.2
24..	62.0	66.6	71.3	76.0	80.6	85.3	90.0	94.6	99.3	104.0	108.6	113.3	118.0	122.6	127.3	132.0	136.6	141.3	146.0	150.6

The amount indicated includes side walls and ceilings

TABLE 6

Number of Square Yards and Feet of Plastering in Various-Sized Rooms

Ceilings—9 Feet 6 Inches High

(Copyright, 1900, by United States Gypsum Co.)

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3..	13.6	16.1	18.5	21.0	23.4	25.8	28.3	30.7	33.2	35.6	38.1	40.5	43.0	45.4	47.8	50.3	52.7	55.2	57.6	60.1
4..	16.1	18.6	21.2	23.7	26.3	28.8	31.4	34.0	36.5	39.1	41.6	44.2	46.7	49.3	51.8	54.4	57.0	59.5	62.1	64.6
5..	18.5	21.2	23.8	26.5	29.2	31.8	34.5	37.2	39.8	42.5	45.2	47.8	50.5	53.2	55.8	58.5	61.2	63.8	66.5	69.2
6 .	21.0	23.7	26.5	29.3	32.1	34.8	37.6	40.4	43.2	46.0	48.7	51.5	54.3	57.1	59.8	62.6	65.4	68.2	71.0	73.7
7..	23.4	26.3	29.2	32.1	35.0	37.8	40.7	43.6	46.5	49.4	52.3	55.2	58.1	61.0	63.8	66.7	69.6	72.5	75.4	78.3
8..	25.8	28.8	31.8	34.8	37.8	40.8	43.8	46.8	49.8	52.8	55.8	58.8	61.8	64.8	67.8	70.8	73.8	76.8	79.8	82.8
9..	28.3	31.4	34.5	37.6	40.7	43.8	47.0	50.1	53.2	56.3	59.4	62.5	65.6	68.7	71.8	75.0	78.1	81.2	84.3	87.4
10..	30.7	34.0	37.2	40.4	43.6	46.8	50.1	53.3	56.5	59.7	63.0	66.2	69.4	72.6	75.8	79.1	82.3	85.5	88.7	92.0
11..	33.2	36.5	39.8	43.2	46.5	49.8	53.2	56.5	59.8	63.2	66.5	69.8	73.2	76.5	79.8	83.2	86.5	89.8	93.2	96.5
12..	35.6	39.1	42.5	46.0	49.4	52.8	56.3	59.7	63.2	66.5	70.1	73.5	77.0	80.4	83.8	87.3	90.7	94.2	97.6	101.1
13 .	38.1	41.6	45.2	48.7	52.3	55.8	59.4	63.0	66.5	70.1	73.6	77.2	80.7	84.3	87.8	91.4	95.0	98.5	102.1	105.6
14 .	40.5	44.2	47.8	51.5	55.2	58.8	62.5	66.2	69.8	73.5	77.2	80.8	84.5	88.2	91.8	95.5	99.2	102.8	106.5	110.2
15..	43.0	46.7	50.5	54.3	58.1	61.8	65.6	69.4	73.2	77.0	80.7	84.5	88.3	92.1	95.8	99.6	103.4	107.2	111.0	114.7
16..	45.4	49.3	53.2	57.1	61.0	64.8	68.7	72.6	76.5	80.4	84.3	88.2	92.1	96.0	99.8	103.7	107.6	111.5	115.4	119.3
17..	47.8	51.8	55.8	59.8	63.8	67.8	71.8	75.8	79.8	83.8	87.8	91.8	95.8	99.8	103.8	107.8	111.8	115.8	119.8	123.8
18..	50.3	54.4	68.5	62.6	66.7	70.8	75.0	79.1	83.2	87.3	91.4	95.5	99.6	103.7	107.8	112.0	116.1	120.2	124.3	128.4
19..	52.7	57.0	61.2	65.4	69.6	73.8	78.1	82.3	86.5	90.7	95.0	99.0	103.4	107.6	111.8	116.1	120.3	124.5	128.7	133.0
20..	55.2	59.5	63.8	68.2	72.5	76.8	81.2	85.5	89.8	94.2	98.5	102.8	107.2	111.5	115.8	120.2	124.5	128.8	133.2	137.5
21..	57.6	62.1	66.5	71.0	75.4	79.8	84.3	88.7	93.2	97.6	102.1	106.5	111.0	115.4	119.8	124.3	128.7	133.2	137.6	142.1
22..	60.1	64.6	69.2	73.7	78.3	82.8	87.4	92.0	96.5	101.1	105.6	110.2	114.7	119.3	123.8	128.4	133.0	137.5	142.1	146.6
23 .	62.5	67.2	71.8	76.5	81.2	85.8	90.5	95.2	99.8	104.5	109.2	113.8	118.5	123.2	127.8	132.5	137.2	141.8	146.5	151.2
24..	65.0	69.7	74.5	79.3	84.1	88.8	93.6	98.4	103.2	108.0	112.7	117.5	122.3	137.1	131.8	136.6	141.4	146.2	151.0	155.7

The amount indicated includes side walls and ceilings

TABLE 7

Number of Square Yards and Feet of Plastering in Various-Sized Rooms

Ceilings—10 Feet High

(Copyright, 1900, by United States Gypsum Co.)

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3..	14.3	16.8	19.4	22.0	24.5	27.1	29.6	32.2	34.7	37.3	39.8	42.4	45.0	47.5	50.1	52.6	55.2	57.7	60.3	62.8
4	16.8	19.5	22.2	24.8	27.5	30.2	32.8	35.5	38.2	40.8	43.5	46.2	48.8	51.5	54.2	56.8	59.5	62.2	64.8	67.5
5	19.4	22.2	25.0	27.7	30.5	33.3	36.1	38.8	41.6	44.4	47.2	50.0	52.7	55.5	58.3	61.1	63.8	66.6	69.4	72.2
6	22.0	24.8	27.7	30.6	33.5	36.4	39.3	42.2	45.1	48.0	50.8	53.7	56.6	59.5	62.4	65.3	68.2	71.1	74.0	76.8
7	24.5	27.5	30.5	33.5	36.5	39.5	42.5	45.5	48.5	51.5	54.5	57.5	60.5	63.5	66.5	69.5	72.5	75.5	78.5	81.5
8..	27.1	30.2	33.3	36.4	39.5	42.6	45.7	48.8	52.0	55.1	58.2	61.3	64.4	67.5	70.6	73.7	76.8	80.0	83.1	86.2
9..	29.6	32.8	36.1	39.3	42.5	45.7	49.0	52.2	55.4	58.6	61.8	65.1	68.3	71.5	74.7	78.0	81.2	84.4	87.6	90.8
10..	32.3	35.5	38.8	42.2	45.5	48.8	52.2	55.5	58.8	62.2	65.5	68.8	72.2	75.5	78.8	82.2	85.5	88.8	92.2	95.5
11..	34.7	38.2	41.6	45.1	48.5	52.0	55.4	58.8	62.3	65.7	69.2	72.6	76.1	79.5	83.0	86.4	89.8	93.3	96.7	100.2
12..	37.3	40.8	44.4	48.0	51.5	55.1	58.6	62.2	65.7	69.3	72.8	76.4	80.0	83.5	87.1	90.6	94.2	97.7	101.3	104.8
13..	39.8	43.5	47.2	50.8	54.5	58.2	61.8	65.5	69.2	72.8	76.5	80.2	83.8	87.5	91.2	94.8	98.5	102.2	105.8	109.5
14..	42.4	46.2	50.0	53.7	57.5	61.3	65.1	68.8	72.6	76.4	80.2	84.0	87.7	91.5	95.3	99.1	102.8	106.6	110.4	114.2
15..	45.0	48.8	52.7	56.6	60.5	64.4	68.3	72.2	76.1	80.0	83.8	87.7	91.6	95.5	99.4	103.3	107.2	111.1	115.0	118.8
16..	47.5	51.5	55.5	59.5	63.5	67.5	71.5	75.5	79.5	83.5	87.5	91.5	95.5	99.5	103.5	107.5	111.5	115.5	119.5	123.5
17	50.1	54.2	58.3	62.4	66.5	70.6	74.7	78.8	83.0	87.1	91.2	95.3	99.4	103.5	107.6	111.7	115.8	120.0	124.1	128.2
18	52.6	56.8	61.1	65.3	69.5	73.7	78.0	82.2	86.4	90.6	94.8	99.1	103.3	107.5	111.7	116.0	120.2	124.4	128.6	132.8
19	55.2	59.5	63.8	68.2	72.5	76.8	81.2	85.5	89.8	94.2	98.5	102.8	107.2	111.5	115.8	120.2	124.5	128.8	133.2	137.5
20	57.7	62.2	66.6	71.1	75.5	80.0	84.4	88.8	93.3	97.7	102.2	106.6	111.1	115.5	120.0	124.4	128.8	133.3	137.7	142.2
21	60.3	64.8	69.4	74.0	78.5	83.1	87.6	92.2	96.7	101.3	105.8	110.4	115.0	119.5	124.1	128.6	133.2	137.7	142.3	146.8
22..	62.8	67.5	72.2	76.8	81.5	86.2	90.8	95.5	100.2	104.8	109.5	114.2	118.8	123.5	128.2	132.8	137.5	142.2	146.8	151.5
23	65.4	70.2	75.0	79.7	84.5	89.3	94.1	98.8	103.6	108.4	113.2	118.0	122.7	127.5	132.3	137.1	141.8	146.6	151.4	156.2
24..	68.0	72.8	77.7	82.6	87.5	92.4	97.3	102.2	107.1	112.1	114.8	116.6	121.7	131.5	136.4	141.3	146.2	151.1	156.0	160.8

The amount indicated includes side walls and ceilings

TABLE 8

Number of Square Yards and Feet of Plastering in Various-Sized Rooms

Ceilings—10 Feet 6 Inches High

(Copyright, 1920, by United States Gypsum Co.)

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.	15.0	17.6	20.3	23.0	25.6	28.3	31.0	33.6	36.3	39.0	41.6	44.3	47.0	49.6	52.3	55.0	57.6	60.3	63.0	55.6
4.	17.6	20.4	23.2	26.0	28.7	31.5	34.3	37.1	39.8	42.6	45.4	48.2	51.0	53.7	56.5	59.3	62.1	64.8	67.6	70.4
5.	20.3	23.2	26.1	29.0	31.8	34.7	37.6	40.5	43.4	46.3	49.2	52.1	55.0	57.8	60.7	63.6	66.5	69.4	72.3	75.2
6.	23.0	26.0	29.0	32.0	35.0	38.0	41.0	44.0	47.0	50.0	53.0	56.0	59.0	62.0	65.0	68.0	71.0	74.0	77.0	80.0
7.	25.6	28.7	31.8	35.0	38.1	41.2	44.3	47.4	50.5	53.6	56.7	59.8	63.0	66.1	69.2	72.3	75.4	78.5	81.6	84.7
8	28.3	31.5	34.7	38.0	41.2	44.4	47.6	50.8	54.1	57.3	60.5	63.7	67.0	70.2	73.4	76.6	79.8	83.1	86.3	89.5
9.	31.0	34.3	37.6	41.0	44.3	47.6	51.0	54.3	57.6	61.0	64.3	67.6	71.0	74.3	77.6	81.0	84.3	87.6	91.0	94.3
10.	33.6	37.1	40.5	44.0	47.4	50.8	54.3	57.7	61.2	64.6	68.1	71.5	75.0	78.4	81.8	85.3	88.7	92.2	95.6	99.1
11.	36.3	39.8	43.4	47.0	50.5	54.1	57.6	61.2	64.7	68.3	71.8	75.4	79.0	82.5	86.1	89.6	93.2	96.7	100.3	103.8
12.	39.0	42.6	46.3	50.0	53.6	57.3	61.0	64.6	68.3	72.0	75.6	79.3	83.0	86.6	90.3	94.0	97.6	101.3	105.0	108.6
13.	41.6	45.4	49.2	53.0	56.7	60.5	64.3	68.1	71.8	75.6	79.4	83.2	87.0	90.7	94.5	98.3	102.1	105.8	109.6	113.4
14.	44.3	48.2	52.1	56.0	59.8	63.7	67.6	71.5	75.4	79.3	83.2	87.1	91.0	94.8	98.7	102.6	106.5	110.4	114.3	118.2
15.	47.0	51.0	55.0	59.0	63.0	67.0	71.0	75.0	79.0	83.0	87.0	91.0	95.0	99.0	103.0	107.0	111.0	115.0	119.0	123.0
16.	49.6	53.7	57.8	62.0	66.1	70.2	74.3	78.4	82.5	86.6	90.7	94.8	99.0	103.1	107.2	111.3	115.4	119.5	123.6	127.7
17	52.3	56.5	60.7	65.0	69.2	73.4	77.6	81.8	86.1	90.3	94.5	98.7	103.0	107.2	111.4	115.6	119.8	124.1	128.3	132.5
18.	55.0	59.3	63.6	68.0	72.3	76.6	81.0	85.3	89.6	94.0	98.3	102.6	107.0	111.3	115.6	120.0	124.3	128.6	133.0	137.3
19	57.6	62.1	66.5	71.0	75.4	79.8	84.3	88.7	93.2	97.6	102.1	106.5	111.0	115.4	119.8	124.3	128.7	133.2	137.6	142.1
20	60.3	64.8	69.4	74.0	78.5	83.1	87.6	92.2	96.7	101.3	105.8	110.4	115.0	119.5	124.1	128.6	133.2	137.7	142.3	146.8
21	63.0	67.6	72.3	77.0	81.6	86.3	91.0	95.6	100.3	105.0	109.6	114.3	119.0	123.6	128.3	133.0	137.6	142.3	147.0	151.6
22.	55.6	70.4	75.2	80.0	84.7	89.5	94.3	99.1	103.8	108.6	113.4	118.2	123.0	127.7	132.5	137.3	142.1	146.8	151.6	156.4
23.	68.3	73.2	78.1	83.0	87.8	92.7	97.0	102.5	107.4	112.3	117.2	122.1	127.0	131.8	136.7	141.6	146.5	151.4	156.3	161.2
24.	71.0	76.0	81.0	86.0	91.0	96.0	101.0	106.0	111.0	116.0	121.0	126.0	131.0	130.0	141.0	140.0	151.0	156.0	161.0	166.0

The amount indicated includes side walls and ceilings

TABLE 9

Number of Square Yards and Feet of Plastering in Various-Sized Rooms

Ceilings—11 Feet High

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3..	15.6	18.4	21.2	24.0	26.7	29.5	32.3	35.1	37.8	40.6	43.4	46.2	49.0	51.7	54.5	57.3	60.1	62.8	65.6	68.4
4..	18.4	21.3	24.2	27.1	30.0	32.8	35.7	38.6	41.5	44.4	47.3	50.2	53.1	56.0	58.8	61.7	64.6	67.5	70.4	73.6
5..	21.2	24.2	27.2	30.2	33.2	36.2	39.2	42.2	45.2	48.2	51.2	54.2	57.2	60.2	63.2	66.2	69.2	72.2	75.2	78.2
6..	24.0	27.1	30.2	33.3	36.4	39.5	42.6	45.7	48.8	52.0	55.1	58.2	61.3	64.4	67.5	70.6	73.7	76.8	80.0	83.1
7..	26.7	30.0	33.2	36.4	39.6	42.8	46.1	49.3	52.5	55.7	59.0	62.2	65.4	68.6	71.8	75.1	78.3	81.5	84.7	88.0
8..	29.5	32.8	36.2	39.5	42.8	46.2	49.5	52.8	56.2	59.5	62.8	66.2	69.5	72.8	76.2	79.5	82.8	86.2	89.5	92.8
9..	32.3	35.7	39.2	42.6	46.1	49.5	53.0	56.4	59.8	63.3	66.7	70.2	73.6	77.1	80.5	84.0	87.4	90.8	94.3	96.7
10..	35.1	38.6	42.2	45.7	49.3	52.8	56.4	60.0	63.5	67.1	70.6	74.2	77.7	81.3	84.8	88.4	92.0	95.5	99.1	102.6
11..	37.8	41.5	45.2	48.8	52.5	56.2	59.8	63.5	67.2	70.8	74.5	78.2	81.8	85.5	89.2	92.8	96.5	100.2	103.8	107.5
12..	40.6	44.4	48.2	52.0	55.7	59.5	63.3	67.1	70.8	74.6	78.4	82.2	86.0	89.7	93.5	97.3	101.1	104.8	108.6	112.4
13..	43.4	47.3	51.2	55.1	59.0	62.8	66.7	70.6	74.5	78.4	82.3	86.2	90.1	94.0	97.8	101.7	105.6	109.5	113.4	117.3
14..	46.2	50.2	54.2	58.2	62.2	66.2	70.2	74.2	78.2	82.2	86.2	90.2	94.2	98.2	102.2	106.2	110.2	114.2	118.2	122.2
15..	49.0	53.1	57.2	61.3	65.4	69.5	73.6	77.7	81.8	86.0	90.1	94.2	98.3	102.4	106.5	110.6	114.7	118.8	123.0	127.1
16..	51.7	56.0	60.2	64.4	68.6	72.8	77.1	81.3	85.5	89.7	94.0	98.2	102.4	106.6	110.8	115.1	119.3	123.5	127.7	132.0
17..	54.5	58.8	63.2	67.5	71.8	76.2	80.5	84.8	89.2	93.5	97.8	102.2	106.5	110.8	115.2	119.5	123.8	128.2	132.5	136.8
18..	57.3	61.7	66.2	70.6	75.1	79.5	84.0	88.4	92.8	97.3	101.7	106.2	110.6	115.1	119.5	124.0	128.4	132.8	137.3	141.7
19..	60.1	64.6	69.2	73.7	78.3	82.8	87.4	92.0	96.5	101.1	105.6	110.2	114.7	119.3	123.8	128.4	133.0	137.5	142.1	146.6
20..	62.8	67.5	72.2	76.8	81.5	86.2	90.8	95.5	100.2	104.8	109.5	114.2	118.8	123.5	128.2	132.8	137.5	142.2	146.8	151.5
21..	65.6	70.4	75.2	80.0	84.7	89.5	94.3	99.1	103.8	108.6	113.4	118.2	123.0	127.7	132.5	137.3	142.1	146.8	151.6	156.4
22..	68.4	73.3	78.2	83.1	88.0	92.8	97.7	102.6	107.5	112.4	117.3	122.2	127.1	132.0	136.8	141.7	146.6	151.5	156.4	161.3

The amount indicated includes side walls and ceilings

TABLE 10

Number of Square Yards and Feet of Plastering in Various-Sized Rooms

Ceilings—12 Feet High

(Copyright, 1900, by United States Gypsum Co.)

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3.	17.0	20.0	23.0	26.0	29.0	32.0	35.0	38.0	41.0	44.0	47.0	50.0	53.0	56.0	59.0	62.0	65.0	68.0	71.0	74.0
4.	20.0	23.1	26.2	29.3	32.4	35.5	38.6	41.7	44.8	48.0	51.1	54.2	57.3	60.4	63.5	66.6	69.7	72.8	76.0	79.1
5.	23.0	26.2	29.4	32.6	35.8	39.1	42.3	45.5	48.7	52.0	55.2	58.4	61.6	64.8	68.1	71.3	74.5	77.7	81.0	84.2
6.	26.0	29.3	32.6	36.0	39.3	42.6	46.0	49.3	52.6	56.0	59.3	62.6	66.0	69.3	72.6	76.0	79.3	82.6	86.0	89.3
7.	29.0	32.4	35.8	39.3	42.7	46.2	49.6	53.1	56.5	60.0	63.4	66.8	70.3	73.7	77.2	80.6	84.4	87.5	91.0	94.4
8.	32.0	35.5	39.1	42.6	46.2	49.7	53.3	56.8	60.4	64.0	67.5	71.1	74.6	78.2	81.7	85.3	88.8	92.4	96.0	99.5
9.	35.0	38.6	42.3	46.0	49.0	53.3	57.0	60.6	64.3	68.0	71.6	75.3	79.0	82.6	86.3	90.0	93.6	97.3	101.0	104.6
10.	38.0	41.7	45.5	49.3	53.0	56.8	60.6	64.4	68.2	72.0	75.7	79.5	83.3	87.1	90.8	94.6	98.4	102.2	106.0	109.7
11.	41.0	44.8	48.7	52.6	56.5	60.4	64.3	68.2	72.1	76.0	79.8	83.7	87.6	91.5	95.4	99.3	103.2	107.1	111.0	114.8
12.	44.0	48.0	52.0	56.0	60.0	64.0	68.0	72.0	76.0	80.0	84.0	88.0	92.0	96.0	100.0	104.0	108.0	112.0	116.0	120.0
13.	47.0	51.1	55.2	59.3	63.4	67.5	71.6	75.7	79.8	84.0	88.1	92.2	96.3	100.4	104.5	108.6	112.7	116.8	121.0	125.1
14.	50.0	54.2	58.4	62.6	66.8	71.1	75.3	79.5	83.7	88.0	92.2	96.4	100.6	104.8	109.1	113.3	117.5	121.7	126.0	130.2
15.	53.0	57.3	61.6	66.0	70.3	74.6	79.0	83.3	87.6	92.0	96.3	100.6	105.0	109.3	113.6	118.0	122.3	126.6	131.0	135.3
16.	56.0	60.4	64.8	69.3	73.7	78.2	82.6	87.1	91.5	96.0	100.4	104.8	109.3	113.7	118.2	122.6	127.1	131.5	136.0	140.4
17.	59.0	63.5	68.1	72.6	77.2	81.7	86.3	90.8	95.4	100.0	104.5	109.1	113.6	118.2	122.7	127.3	131.8	136.4	141.0	145.5
18.	62.0	66.6	71.3	76.0	80.6	85.3	90.0	94.6	99.3	104.0	108.6	113.3	118.0	122.6	127.3	132.0	136.6	141.3	146.0	150.6
19.	65.0	69.7	74.5	79.3	84.1	88.8	93.6	98.4	103.2	108.0	112.7	117.5	122.3	127.1	131.8	136.6	141.4	146.2	151.0	155.7
20.	68.0	72.8	77.7	82.6	87.5	92.4	97.3	102.2	107.1	112.0	116.8	121.7	126.6	131.5	136.4	141.3	146.2	151.1	156.0	160.8
21.	71.0	76.0	81.0	86.0	91.0	96.0	101.0	106.0	111.0	116.0	121.0	126.0	131.0	136.0	141.0	146.0	151.0	156.0	161.0	166.0
22.	74.0	79.1	84.2	89.3	94.4	99.5	104.6	109.7	114.8	120.0	125.1	130.2	135.3	140.4	145.5	150.6	155.7	160.8	166.0	171.1

The amount indicated includes side walls and ceilings

left until you come to 12, then follow the figures to the right until you come to the figures directly under the figure 15 at the top of the page; the answer is 62 sq. yds. When the half-foot comes in the dimensions of a room, both ways, take the next largest number on one side. When it comes on one side only, add one yard, and it will be close.

Quantities of Materials for Plaster Work. For 100 sq. yds. of 3-coat lime plaster work **on wood lath**, allow 10 bushels of lime, 42 cu. ft. of sand, 15 pounds of hair, and 100 pounds of plaster of Paris.

For scratch and brown coat only, omit the plaster of Paris, and deduct 2 bushels of lime.

For sand finish on scratch and brown coat, omit the plaster of Paris, and add 14 cu. ft. of sand.

For 2-coat work **on brick, stone, or terra-cotta walls**, deduct 2 bushels of lime, and use 100 pounds of plaster of Paris.

In white coat work, 90 pounds of lime, 50 pounds of plaster of Paris, and 50 pounds of marble dust will be needed for each 100 sq. yds.

In skim coat work, 1 barrel of lime, 1 barrel plaster of Paris, and 1 barrel sand will cover about 140 sq. yds.

Hard wall plasters vary from 90 to 150 sq. yds. per ton of plaster.

Pulp or fiber plaster vary from 130 to 170 sq. yds. per ton of plaster.

Cattle hair comes in bags containing one bushel of loose material, and weighing 6 or 7 pounds.

Two-coat drawn work requires about 1,000 pounds of hard wall plaster and finish, and 2 yards of sand, for each 100 sq. yds.

Three-coat dry work requires about 1,600 pounds of plaster and finish, and about 2½ cu. yds. of sand for each 100 sq. yds.

Three-coat work on metal lath requires about 2,200 pounds of plaster and finish, and about 3 cu. yds. of sand for each 100 sq. yds.

For Portland cement quantities, see page 345.

Labor Costs in Plaster Work. In 2-coat work, two plasterers and one laborer will require about 12 hours for 100 sq. yds., while 18 hours will be needed for the same number of men on 3-coat work.

Allow about 6 hours of time for a laborer in fixing up the mortar beds and preparing mortar.

For ordinary cornice work, allow about 40 linear feet per man per 8-hour day.

In outside work with Portland cement plaster, 1 man and 1 helper will cover about 50 sq. yds. of 2-coat work in an 8-hour day.

Pebble-dash work costs about double the price of ordinary work.

One plasterer and helper will do any of the following work in an 8-hour day:

Put on 75 sq. yds. of one-coat finished work, using ⅝-in. grounds.

Put on 100 sq. yds. of second coating.

Put on 100 sq. yds. of hard finish.

Painting and Decorating

Paint is a mixture made from finely divided solid substances, held in suspension in a liquid which is termed the **vehicle**, and capable of being spread upon the surface to which it is to be applied, by means of a brush or spraying apparatus. The different solids which are used in paint making are termed **pigments**. They do not become paint until they are mixed with the thinner vehicle; thus white lead, zinc white, ocher, Prussian blue, and Venetian red are all pigments, but they do not become paint until they have been mixed with linseed oil, turpentine, or other vehicle.

Paint may either be mixed by the painter himself, or it may be obtained already mixed in two different forms—in one as a tinted paste to which the painter adds thinners, as his judgment dictates; or in the other, already thinned and prepared for immediate application. The latter are known as **mixed paints**, or **ready-mixed.**

Ingredients of Paint. The principal white base pigments are **white lead** and **zinc white.** Besides these there are several white pigments which are variously regarded as **inert** pigments, or as **extenders.** Among these are **barytes, whiting,** and **gypsum.**

White lead, one of the oldest known pigments, is the hydrated carbonate of lead, and is of varying composition, no absolute formula being recognized. White lead unites with linseed oil to form an inelastic, insoluble lead soap, and this property gives it one of its greatest values as a pigment.

Sublimed white lead, which is used to a considerable extent in mixed paint making, is not the true white lead, but is a lead sulphate that is white in color and is produced by a fire process.

Zinc white, or oxide of zinc, is made by blowing a current of air through molten zinc. It is free from the poisonous qualities which render white lead objectionable for an indoor paint, and is not acted on by sulphur or gases which darken white lead. Zinc white spreads much more rapidly than white lead, but does not cover so well, so that it will require four coats or even more of zinc white to hide a surface as well as three coats of white lead. It is very seldom used alone on exterior work, but almost invariably in combination with lead or some other white base.

Barytes, or sulphate of barium, is a native rock, which is very finely ground and is used as an inert extender of paint. It has no affinity for linseed oil, and absolutely no covering power. Four coats of barytes mixed with linseed oil will not hide a surface to which it is applied, and the film is practically transparent. The same is true of **silica**, which is another so-called "inert pigment."

Whiting (pulverized chalk, calcium carbonate) is lighter in weight than barytes, and possesses a decided affinity for linseed oil. Mixed with oil in a paste form, it becomes putty. It has very little covering power in itself.

Linseed oil, the oil expressed from the seed of the flax, is remarkable from the fact that it unites with oxygen to dry to a waterproof film. It is this fact, that it is a drying oil, that gives it its great value in paint. Linseed oil is adulterated wtih various mineral oils, rosin oil, corn oil, and fish oil. The first named are the most common adulterants.

Turpentine is the distilled sap of the long-leafed pine. It is used to make paint more fluid, and hence to make it spread easier. It dries by evaporation, leaving a slight, gummy residue. Owing to its price it is likely to be adulterated with the lighter mineral oils.

Benzine, a petroleum distillate, is also used for diluting paint, and dries by evaporation without residue.

Driers are oxidizing agents introduced into paint to promote rapidity of drying. They are usually salts of lead or salts of manganese. In this country they are ordinarily found in liquid form; but in England, paste driers are usually employed.

Kinds of Paint Mixtures. Mixtures of color are of three kinds, and may be termed **oil**, **flatting**, and **distemper**. The first is bright and glossy; the second is perfectly flat or dead (without gloss); and the third is like the second in effect, but without its durability.

The chief body in oil and flatting color is white lead; but in distemper or water-color, whiting is substituted.

The three ordinary vehicles in mixing are oil for oil color, turpentine for flatting, and water for distemper. In addition to these for insuring the drying of the mixtures, patent drier is used in oil color, japanner's gold-size and varnish in flatting, and glue size in distemper.

It would probably not be denied by anyone that a better paint can be made in a well-equipped factory than by any individual at home or in a small shop. Many ready-mixed paints are of the very best quality, but many are of poor quality, made of cheap materials, and at the same time are sold with extravagant claims and at high prices. A very good rule to follow in purchasing mixed paints is to buy nothing which does not bear the name of the manufacturer. If the manufacturer's name does not appear on the label, this is very good presumptive evidence that he is not particularly proud of his product.

The most expensive paints are generally white paints or very light tints. The reason for this is that there are comparatively few white pigments which have covering power —that is, the property of hiding the surface of the material painted. Samples of dry white lead and of dry whiting look much alike. Both are white powders, and a thin layer of each appears to be practically opaque. If, however, the two pigments are mixed in oil, the whiting is quite transparent, while the white lead is opaque. All of the cheaper white pigments are more or less transparent in oil, and are therefore deficient in covering power. White lead, zinc white, sublimed white lead, zinc lead, and lithopone are practically the only white pigments which have good covering power in oil. These pigments are all rather expensive, and as they are heavy, it takes quite a large amount to make a paint.

Of the dark shades, there are a number of cheaper pigments which have very good covering power. It may be quite safely stated that for a white paint that really covers, some one or more of the white pigments just enumerated must be used. For a dark brown, however, a good covering can be obtained with an iron oxide pigment, which is very much cheaper. Therefore, for such paints there is no reason for using an expensive lead or zinc pigment.

COST OF WHITE PAINTS

The United States Department of Agriculture has published data throwing some useful light on the subject of the cost of paints:

"A vehicle for outside paint of the best quality will generally consist of from 90 to 95 per cent of linseed oil, and from 10 to 5 per cent of japan drier. A good japan drier has about the same specific gravity as linseed oil, and each may be considered to weigh about 7¾ pounds to the gallon. Of course, the prices of all paint materials vary; but at the present time linseed oil sells for approximately 90 cents a gallon, and a good grade of japan can be bought for $1.60. In making up paints, the drier should be mixed with the larger portion of the oil before adding the pigment. Using the prices and weights just given for linseed oil and japan drier, the liquid portion of a paint will cost about 95 cents a gallon, or 12¼ cents a pound. White lead, both dry and in the form of paste, costs approximately 7 cents a pound, zinc white approximately 8 cents a pound, and the other white pigments which cover well will not differ very much from these two in price. A gallon of white lead paint will weigh from 21 to 22 pounds. Fourteen pounds of dry white lead and 7¼ pounds of vehicle will make a gallon of paint; and at the prices quoted, the cost would be about $1.87; 15 pounds of paste lead and 6¼ pounds of vehicle will make a gallon of paint, costing $1.82; 9½ pounds of white zinc and 5¾ pounds of the paint vehicle will make a gallon of zinc white paint, costing about $1.46.

"Of course, these prices are based on an assumed cost for the ingredients, and to make an exact estimate it would be necessary to know the exact prices of the different materials entering into the paint. Many painters insist that a paint composed entirely of white lead, linseed oil, and drier is the best. Others contend that a mixture of white lead and zinc white is the best; and still others say that a mixture of these pigments with the cheaper white pigments which have slight covering power makes a better paint than the expensive pigments alone. It is probably true that a mixture of lead and zinc is superior to either pigment by itself; and also that the addition of a small amount of so-called inert pigments (silica, whiting, barytes, china-clay, etc.) has no injurious effect on the paint, and may even be beneficial. The addition of a large amount, however, of such pigments will give a paint deficient in covering power, and the addition should have the effect of cheapening the product. There is no reason why any mixed paint should cost per gallon more than a paint made entirely of white lead, oil, and the necessary drier. By ascertaining the market price of white lead and linseed oil, the buyer should be able to calculate the maximum price for a mixed paint.

COST OF COLORED PAINTS

"Tinted paints, at least those of light tint, consist practically of white paint, with the addition of a small amount of coloring matter. The coloring materials used in tinting are not uniform, and it is not possible, therefore, to give exact directions for producing a particular shade, since the amount of color used will depend upon the individual characteristics of the particular lot on hand.

"In Table 1 is given the composition of several tinted paints, and also of bright red, bright green, and black. The composition of individual lots of paint of any of these tints or colors might vary considerably from that given, and the table is only illustrative of the materials from which these different kinds of paints may be made.

"An estimate of the cost of the raw materials entering into the different formulae is also included. The total cost per gallon does not make any allowance for labor or for containers, but is based solely upon the cost of the raw materials, assuming that white lead and sublimed white lead cost 7 cents a pound, white zinc 8 cents, and the other white pigments (barium sulphate, china-clay, whiting, and asbestine) 1 cent a pound. The price of the coloring material is given separately for each paint. These prices for the raw materials are a fair approximation of the retail price at the present time.

"In calculating the cost of paints per gallon, it is assumed

TABLE 1
Composition and Cost of Tinted and Colored Paints

Data.	Tints.						Colored paints		
	Gray.	Buff.	Yellow.	Drab.	Blue.	Brown.	Red.	Green.	Black.
Percentage composition:									
Vehicle	42.4	43.0	45.0	41.0	43.0	49.0	57.0	34.0	65.0
White lead			13.0			12.0			
Zinc white	21.0	21.0	25.0	21.0	22.0	24.0	2.0		
Sublimed white lead	27.0	29.0		26.0	27.0				
Barium sulphate	2.0		5.0	2.0	2.0	5.0	25.0	49.0	
China-clay	5.0			4.0	4.0				
Whiting							11.0		
Ground slate									26.0
Asbestine	1.0	1.0	1.0	1.0	1.0	1.0			
Color	.6	6.0	11.0	5.0	1.0	9.0	5.0	17.0	9.0
Total pigment	56.6	57.0	55.0	59.0	57.0	51.0	43.0	66.0	35.0
Nature of color	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Weight in pounds per gallon:									
Total	14.7	14.8	14.1	15.2	14.8	13.4	11.6	16.4	10.0
Pigment	8.32	8.44	7.76	8.97	8.44	6.83	4.99	10.82	3.50
Vehicle	6.38	6.36	6.34	6.23	6.36	6.57	6.61	5.58	6.50
Cost per pound, dollars:									
Color	0.06	0.04	0.05	0.05	0.30	0.05	0.78	0.19	0.10
Total pigment	.065	.069	.066	.065	.070	.066	.103	.056	.033
Cost per gallon, dollars:									
Pigment	.541	.582	.512	.583	.591	.451	.514	.606	.118
Vehicle	.782	.779	.777	.763	.779	.805	.810	.684	.793
Total	1.32	1.36	1.29	1.35	1.37	1.26	1.32	1.29	.91

[1] Bone black; tuscan red; ultramarine blue.
[2] Umber and ocher.
[3] Golden ocher.
[4] Ocher and bone black.
[5] Prussian blue.
[6] Bone black; venetian red; chrome yellow.
[7] Para-red.
[8] Five-sixths chrome yellow, one-sixth Prussian blue.
[9] Carbon.

that the vehicle in all cases is the same as that above described, and it is valued at 12¼ cents a pound.

"An inspection of the table shows that there is comparatively little difference in the cost of the materials entering into these paints, with the exception of black paint, which is considerably cheaper than any of the others. The red paint is colored by an expensive color, para red, costing 73 cents a pound; the rest of the pigment, however, is cheap; and it will be noticed that the paint weighs only 11.6 pounds per gallon, whereas some of the others weigh much more.

"For dark shades of brown or red, there is probably nothing which is as cheap as the oxide of iron pigments. These vary very much in shade, giving both browns and dull reds. A pigment, that gives a very satisfactory reddish brown and contains about 40 per cent of iron oxide, makes a satisfactory paint containing approximately 56 per cent pigment and 44 per cent vehicle, the vehicle being very much the same as that used in a first-class white paint. Such a paint will weigh about 13.5 pounds to the gallon, which, therefore, will contain 7.56 pounds of pigment and 5.94 pounds of vehicle. This pigment is cheap, generally costing not more than 1 or 1½ cents per pound. The pigment in a gallon of this paint, therefore, would cost approximately 10 cents, and the 5.94 pounds of vehicle about 73 cents, giving a cost of 83 cents for the gallon of paint.

"An inspection of these figures shows that the expensive part of this paint is the vehicle and not the pigment. A paint of this character is a very good material to apply either to wood or iron. There are more expensive paints, however, frequently used on iron to protect it from rusting, the most popular being red lead and linseed oil. This material undoubtedly affords very good protection, but it is also expensive. A red-lead paint cannot be made and kept as most other paints can. The red lead itself causes the oil to dry, and no additional drier is necessary. In fact, red lead should not be mixed until just before it is used. A paint made of 70 per cent of red lead and 30 per cent of linseed oil will weigh about 19.8 pounds to the gallon. A gallon of paint, therefore, will contain 13.86 pounds of red lead, which costs about 8 cents a pound, making the cost of the pigment in a gallon of this paint approximately $1.11. The 30 per cent of linseed oil will weigh 5.94 pounds, and a gallon of linseed oil 7.75 pounds, costing about 90 cents at the present time, or 11.5 cents a pound. The oil in the paint will cost, then, about 68 cents, and a gallon of red-lead paint would cost $1.79, as compared with 83 cents for a gallon of oxide of iron paint. These two paints will cover about the same area of clean iron; and, while somewhat better service might be expected from the red-lead paint, it is more than twice as expensive as the iron-oxide products."

MATERIALS FOR OUTSIDE PAINTING

A good mixed paint should be composed, in the main, of white lead, zinc white, and the necessary coloring matter, thinned with pure raw linseed oil of good quality, with the addition of such pure turpentine and driers as may be necessary. The best quality mixed paints always bear the name of some reputable paint manufacturer. The best thing to do, in selecting a mixed paint, is to look carefully at houses that have been painted with it for several years, and note whether the paint is scaling off in blotches or is cracking and peeling badly. If a paint has been found to give good service, it is then safe to use it.

Some mixed paint manufacturers make special paint for **priming.** This is often an inferior grade of ocher, which is objectionable because it has a tendency to throw off the subsequent coats of paint. While the regular mixed paints may be used for a priming coat on new wood by adding from one-half to an equal volume of pure raw linseed oil, as a rule it would be very much better to prime with pure white lead and linseed oil, using the mixed paint on the second and third coats. If the mixed paint is found to be too thick, pure raw linseed oil should be used for priming. **Boiled oil** should not be used.

Pure white lead can be readily used for the priming coat, as it needs no special knowledge of color mixing to prepare it. For 100 pounds of white lead in oil, it would be necessary to use 4 gallons of raw linseed oil, half a gallon of pure turpentine, and one pint best liquid driers to thin it. A 25-pound keg would require one-fourth of these quantities, and would make about 2½ gallons of paint. In breaking up and thinning down the lead, it should first be put into a keg or tub large enough to contain the lead and all the thinners. The driers should be mixed in with the oil, and the oil added gradually to the lead paste, stirring and working it up thoroughly by means of a wooden paddle. After the lead and oil have been thoroughly incorporated, the turpentine should be added. The addition of a very little lampblack in oil, say not over a half to one pound to 100 pounds of white lead, will tint the priming a light lead color, and aid in covering up any discolorations in the wood due to sap or weather stains. After the lead and oil have been mixed as above directed, the paint should be strained through a fine wire sieve, to remove any skins or lumps. The paint should be mixed the day before using, if possible; and should the house be a large one, requiring a good deal of paint, it is well to mix only half the quantity required. This will avoid any loss from the paint skinning over, if bad weather comes up to delay the work when partly completed.

Before the work is primed, all knots and sappy places should be coated with strong orange shellac varnish.

After the work has been primed, all nail holes and cracks should be thoroughly puttied up with pure whiting and linseed oil putty. This should be well worked in with a putty knife, and any excess of putty scraped off the surface to prevent a lump. Pure putty is difficult to obtain, but it can be bought. It will cost probably three cents or more a pound, but is far superior in every way to the cheaper grades that can be bought for as low as 1½ cents.

Although the autumn is usually considered to be the best season of the year for painting, because the paint dries slower than in summer time and the sun is not sufficiently hot to cause blisters, good painting can be done at any time of year, provided due care is used.

What Not to Do. The following precautions must be employed at any season: No painting should be done on a damp surface; and if there has been rain, dew, or frost, work should not be begun until the sun has thoroughly dried off all moisture. If the air is dry, and the surface to be painted is dry, a very good job can be done in very cold weather. Ample time must be allowed between coats for the under coats to be thoroughly dry. At least 48 hours, and preferably a week, should be given.

In using mixed paints in cold weather, it is well to add half a gallon of turpentine to five gallons of mixed paint on the first coat, and one quart of turpentine to five gallons of paint on the last coat. If necessary, a small quantity of best liquid drier may be added; but, as a rule, mixed paints contain enough drier to make this unnecessary. The paint requires to be brushed out thoroughly in cold weather.

Best Brushes to Use. The best brush to use for outside painting is the "6-0" (six-naught) round or oval brush—also known as the "pound brush"—for the body color, and the "5-0" brush for the trimming colors. Two "sash tools" are also needed, one for the trim color and one for the sash color.

The 6-0 brush is recommended because it is the only shaped brush which has sufficient elasticity to thoroughly brush the paint out into a very thin film. It is impossible, with a flat brush, to get into the corners as well as with a round brush, nor can the color be rubbed out so thoroughly.

Good brushes are an expensive item in painting, and it is economy to buy none but the best. Brushes made from white bristles command a somewhat higher price than those made from gray or black bristles of the same quality, although there is no reason why the darker brushes should not be just as good. A round brush made with a hollow center is more elastic than one made with a solid center, and is therefore preferable. The bristles are set in cement, and are firmly bound by being wrapped with wire in the round brushes, or being enclosed in metal in the flat brushes.

Brushes of excellent quality are made in which the bristles are set in rubber and then bound in a hard rubber ferrule. These are somewhat more expensive than the ordinary brushes, but are supposed to wear longer.

Besides the brushes already mentioned, the painter wants a "duster," which is used for removing any surface dust or loose dirt from the wood before painting.

The wall brush is generally used just as it is made, while the round brush is usually "bridled" or bound with twine, or with a metal or patent bridle, which serves to shorten the working length of the bristles and make them more elastic.

Covering Knots. It is essential for the durability of the paint, that all knots or sappy places in the wood shall be coated with some material which will seal up the resinous matter within the wood and prevent it from causing blisters or otherwise destroying the paint. The best material known for the purpose is pure orange shellac. This is better than bleached shellac, since the latter has lost much of its strength owing to the chemicals employed in bleaching. A wood alcohol shellac, although inferior to one made by dissolving the shellac in grain alcohol, is good enough for covering these knots and sappy places. It is the practice of some painters to shellac knots before priming, but other experienced painters maintain that better results are obtained by priming first.

Use of Thin Coats. Paints should always be applied in thin coats well brushed out. No greater mistake can be made than the use of heavy coats of paint, although it is the custom of many architects to specify "good, heavy coats." Heavy coats almost invariably cause blistering or wrinkling of the paint skin, and will not last as long as thinner coats. The old practice of making the priming coat thin, and then following it up with two or more coats of paint mixed moderately stout and well brushed out till they were thin on the surface, largely accounted for the durability of the painting of a generation ago. Three thin coats of paint will give 50 per cent more wear than two heavy coats, although less material is used in the three coats.

Thickness of a Coat of Paint. A gallon of paint mixed to a proper brushing consistency and well brushed out will cover at least 600 sq. ft., and will make a film 2/1,000 in. thick. To get a more correct idea of how thick this would be, note that a newspaper sheet is about 3/1,000 in. thick. Therefore, a coat of paint is only ⅔ as thick as a sheet of newspaper. If there is an excess of oil in the lead, it will spread over much more than 600 sq. ft., giving a much thinner film and less pigment to protect the oil than if the paint had been properly mixed.

Using Putty. All cracks and nail-holes must be thoroughly filled with putty, in order to make a firm and solid foundation for the subsequent coats of paint. This puttying is usually done after the priming, but some painters prefer to putty before priming. The putty should be made from the best grade of bolted whiting, mixed with pure raw linseed oil. Very little pure putty is sold commercially, and much trouble results from the use of putty made from marble dust and kerosene or containing these materials. The saving effected on a house by the use of cheap putty is so slight that the pure should always be insisted on.

VARNISHES

Kind of Varnishes. Varnishes are of two classes—**oil varnishes** and **spirit varnishes.** The first are made from certain resins known in the trade as "varnish gums" (although, strictly speaking, they are not gums) and linseed oil, and thinned with spirits of turpentine. (Cheaper grades of varnish are made from ordinary "rosin" (the resin of the long-leafed pine), and are sometimes thinned with benzine. Within recent years considerable tung or China wood oil has been used in the manufacture of certain grades of varnish. Oil varnishes dry or harden by the chemical change of the linseed oil contained in them to form linoxyn by combining with the oxygen of the air.

Spirit varnishes are made by dissolving the resin or other substance (resins are chiefly used) in a volatile liquid, such as alcohol or spirits of turpentine. When a varnish of this kind is spread over any surface, it dries or hardens by the evaporation of the volatile liquid, and the resin is then left spread over the surface in a thin film, the liquid simply having served as a mechanical means for spreading.

Preparation of Wood Surface for Varnishing

In very many cases where complaints are made of the poor work done by the finishers or the poor results obtained from the use of a certain varnish, the cause will be found to lie in the unfavorable conditions under which the work has been done. Often, before the carpenters, plumbers, or plasterers have finished their work, the painter is urged to rush the work as fast as possible. The air is full of dust; the building is seldom heated, and the temperature is allowed to fall at night; the second coat of varnish follows as soon as the first is "set," and before it has a chance to become thoroughly dry. The carpenters seldom leave the woodwork in good condition for the painter. He finds it far from smooth, requiring both scraping and sandpapering, marred by pencil marks, dented by misdirected blows from the hammer, greasy from the fingers of plumbers and others, etc.

To do a first-class job of hardwood finishing, all the other work should be completed before the room is turned over to the finishers. The rooms should then be thoroughly swept out, and the floors sponged off or wiped off with a damp cloth and allowed to become perfectly dry. The sash should be fitted and in place, and the doors hung; and both doors and windows should be closed to prevent draughts. An even temperature of about 70° should be maintained night and day. Wherever possible, doors should be taken from their hinges and laid flat on a pair of trestles while varnishing, in order to flow a more even coat. The door openings, in this case, can be closed with light frames covered with building paper or cloth to prevent dust and cold air coming into the room. Unless these precautions are taken, and unless ample time is given, a first-class job of hardwood finishing is impossible.

It must be remembered that there is an important difference between painting and varnishing. Whereas paint should be applied in a thin coat, thoroughly brushed out with a rather stiff bristle brush in order to work it into the pores of the wood, varnish should be flowed on in a heavy coat, and, when applied, should be allowed to level itself out. The luster and beauty of the varnish depend largely upon the depth or thickness of the film, and it naturally follows that a heavier coating can be applied to a level surface than upon a vertical one. Very few varnishes will stand crossing, but they should be applied in parallel strokes with the grain of the wood, using a wide, chisel-edged camel's hair or elastic bristle varnish brush. There is no economy in using any but the very best brushes that can be bought.

In preparing the surface, all pencil marks must be cleaned off. Greasy stains should be removed; ammonia is excellent for this, but it requires subsequent washing off, and, since it can be used only on such woods as do not contain tannic acid, as it darkens oak, mahogany, etc., gasoline or naphtha is probably more generally satisfactory. Hammer dents in the surface can sometimes be obliterated by soaking well with water and holding a heated flatiron in front of the dented spot. All plane marks must be carefully obliterated by means of steel scrapers, and finally the wood must be made perfectly smooth by means of sandpaper or steel wool. Extra care must be taken in doing this to avoid rounding off the edges of moldings and other sharp corners. Finally, every particle of fine sand and wood dust must be carefully dusted off, and the surface left perfectly smooth and clean.

If the wood is an open-grained wood, it will need to be filled with a paste filler. If the wood is to be stained, the filler should be colored the appropriate tone. The staining is usually done before the wood is filled.

After the paste filler has been applied and become dry, a thin coat of shellac should be given to the whole surface in order to produce a smooth, non-porous surface. Shellac being expensive, a liquid filler is often substituted; and in this case care should be taken to select one of good quality, made with a pigment base and a good varnish, and thinned with turpentine. There is so much adulterated shellac on the market to-day, cut with wood alcohol, that many finishers now prefer to start at once with the varnish coats instead of using a shellac or liquid filler surfacer. In any case where there is danger of moisture penetrating through the wood from behind, shellac should be avoided. Under no circumstances should oil be used as a primer.

After the work has been filled, all nail-holes, cracks, or other defects should be puttied up. This is a matter requiring the most careful judgment. All wood darkens in time; and if the putty is tinted to match the new woodwork, in the course of five or six months every nail-head and every crack will show out against the darker ground. It is best to make the putty three or four shades darker than the wood at the start.

Finishing Floors

The first thing necessary in order to obtain a good job of floor finishing, is to get a perfectly smooth surface. Until recently the only way to do this was the tedious, back-breaking method of planing and scraping, the latter being done usually with the edge of a freshly cut piece of glass. When the cutting edge wears down, a fresh piece must be taken. Sandpaper, bent over a flat wooden block, is also used to cut down any roughnesses or raised grain. Steel wool is preferable for this purpose, on account of the greater rapidity with which it cuts. While this method is still very generally practiced, modern invention has come to the aid of the floor finisher and has produced a planing machine or surfacer that is pushed across the floor like a lawn mower.

The first operation is filling the wood. Oak and other open-grained woods require filling with a paste filler; and while many painters laugh at the idea of a paste filler upon such woods as yellow pine and maple, experienced floor finishers say that a better job can be done by using paste filler as a surfacer. The method of using is to apply the filler to a strip, say six or eight boards wide, running the entire length of the room. Use a short, stiff brush, and apply across the grain. By the time this strip has been completed, the filler will probably have set sufficiently to rub. It must not be rubbed before setting, or it will be rubbed off the wood; nor must it be allowed to set too hard, or it will be impossible to rub it at all or even to scrape off the filler. When the strip has set just enough, it must be rubbed well into the grain of the wood with burlap, always rubbing across the grain of the wood. After the filler has been thoroughly rubbed, any surplus material must be carefully wiped off with a soft rag. Before anything further can be done, the filler must be given time to dry—not less than 24 hours, and preferably two days.

If the natural color of the floor boards is not satisfactory they should be stained before filling, and the filler should be colored with pigment ground in oil to bring it to the same color tone.

If there are cracks or nail-holes in the floor, they must next be filled, in order to make a smooth and perfectly uniform surface. This filling may be done by using a pure whiting and linseed oil putty, tinted to match the floor boards; or it may be done better with a whiting and white lead putty made by mixing one part of white lead in oil with two or three parts of bolted whiting and enough coach varnish to make a stiff paste. This putty will resist moisture; and, when dry and hard, it may be sandpapered or rubbed. For large cracks, an excellent unshrinkable putty can be made by soaking blotting paper in boiling water until it forms a pulp, then mixing it with glue dissolved in water. To this, bolted whiting is added in sufficient quantities to make a fairly stiff paste, and thoroughly kneaded. This paste must be pressed into the cracks and smoothed off with a putty knife.

For those who do not care to make their own putty, there are excellent prepared crack-fillers on the market.

Wax Finishing. By far the best material for finishing hardwood floors is wax, although this involves a little more trouble to keep in good condition. It gives a smooth, satiny luster, without the glaring effect of new varnish, and is not marred by heel-prints such as varnish is subject to. When wax grows dim, it can readily be polished again.

Some painters advocate the application of the wax directly upon the paste filler, but the best practice is first to give one or two thin coats of pure shellac varnish. Where a slight darkening of the tone of the wood is no objection, orange or brown shellac is preferable to the bleached, since it is stronger. Shellac should be cut with grain alcohol, and not with wood alcohol. It is especially adapted where a hard and quick-drying undercoat is required. On a close-grained wood where a paste filler has not been used, either a thin coat of a first-class liquid filler, or a coat of one part of linseed oil to which from five to ten parts of turpentine have been added, should be given before applying the shellac. Unless there is an undercoating of some kind, it is very difficult to apply the shellac so that it does not show laps. Even then it requires skill and rapidity of work. In shellacking a floor, the plan of following down a space one or two boards wide should always be followed. The shellac coat should be put on before the oil or liquid filler coat is absolutely dry.

After shellac has become dry, the wax, in paste form is applied with a rag or a brush, and, after a short time, is brought to a polish by means of a weighted brush or by rubbing with a cloth. Only a very thin coat of wax is necessary, a very little more being occasionally added.

Quite a large number of specially prepared floor-polishing waxes are on the market, and care should be taken to select a material of this kind that will give a hard polish and will not remain soft and sticky. It was the softness of the old-fashioned beeswax and turpentine that caused the almost endless labor needed to keep floors in perfect condition. Modern wax finishes are made by combining beeswax or paraffine with some of the fossil waxes, or from the latter alone, giving a much harder surface. In general, the wax which has the highest melting point is best for the manufacture of floor waxes, because it is the hardest after application. Carnauba wax has a high melting point (185° F.), and may be used alone as a floor wax by melting it in a suitable kettle and thinning it with spirits of turpentine so that in cooling it has the consistency of soft tallow. In this condition it can be applied with a large brush.

Two coats of wax on a new floor are better than one—the first coat being required to fill up, and the second to give luster—although, if sufficient polish is obtained by the first coat, the second will be found unnecessary.

The preparation of wax finish is attended with so much risk from fire that it should be undertaken only over a water bath. Even then it is wiser for the ordinary painter to buy the prepared wax than to undertake to make it.

Varnish Finish. A large number of floor varnishes are on the market. These varnishes, as a rule, are designed to harden over night. The surface should be prepared in the same way as for wax finish; and after the filler is bone dry, two or more coats of varnish should be applied. If desired, the varnish may be rubbed to a dead surface with pumice stone and kerosene. Practically every varnish will show heel marks, and will mar white by use. When the surface becomes worn, the old varnish requires to be either scraped off or removed with a varnish remover before a new coat of varnish can be applied, while with a wax all that is necessary to restore the surface to a good condition is to apply a little more wax and use the polishing brush.

When a waxed floor gets dirty and shabby, it can be cleaned down to the shellac with turpentine, and rewaxed at a small cost. It is well to give a special caution against using a wax finish over a varnish coating, since the wax will soften up the varnish and cause trouble.

Oil Finish. A very satisfactory finish for rooms that have hard wear, such as schoolrooms, stores, and rooms in public buildings, is first to fill the floors, and then give them two thin coats of shellac, finally applying a very thin coat of paraffine oil or of a rubbing and polishing oil with a brush or a rag, and thoroughly wiping off any surplus remaining on the surface. This oiling should be repeated every few days, according to the amount of wear that the floor gets. This same treatment is specially adapted for kitchen floors, dining rooms, and other floors in private houses that are subject to hard wear. It is also well adapted to the cheaper floors, such as yellow pine or spruce. If mud has been tracked on the floor, it should first be mopped up with water, and this should be allowed to dry before oiling. One advantage of the oiled floor is that it is ready for use as soon as the oiling is finished. This same method of oiling can be used over a varnished floor, and will preserve it from marring.

Besides paraffine oil, crude petroleum may be used, or any of the so-called polishing oils or furniture polishes. Such oils can be made from machine oil or sweet oil and oil of lemon.

Painted Floors. A floor finish not in such general use as it deserves is the painted floor. Paint has the advantage of hiding inferior floor boards and being cheap. There are a number of special floor paints on the market for use on kitchen floors and other rooms having a good deal of wear. These paints are made so as to dry over night, and as a rule are fairly satisfactory. However, there are many rooms of a better class for which these cheaper mixed paints are unsatisfactory. For these rooms, the floors should be primed with pure white lead and linseed oil, tinted with a small percentage of lampblack (not over 2 per cent), and followed by two coats of paint of the desired color. The last coat should be mixed with turpentine to dry flat; and when it is thoroughly dry, the floor may be given two coats of good floor varnish. This will give a floor that can be kept in good condition for a long time by aid of the floor oil described above. Instead of finishing with a varnish coat, the last coat of paint may be left in full gloss, provided it can be given ample time for drying, say at least a week. This will give an excellent floor so far as durability is concerned, but it will not have as good an appearance as a painted and varnished floor.

A painted floor can be made quite ornamental by the use of a stenciled border, which should be put on before the varnish coats. The most appropriate designs are those which resemble mosaic work in their effects, or interlacing strap-work. When the colors are properly chosen, care being taken to avoid glaring contrasts, a painted and stenciled floor is fully as effective as a hardwood floor; and it possesses one distinct advantage in that it can be adapted to any decorative color scheme desired for the room.

A floor that is grained, especially one grained in oak, has one of the most durable finishes that can be given, requiring very little attention other than wiping up with a damp cloth or mop. If well done, it is fully as effective as a hardwood floor.

For figuring cost of floor finishing, see date given below under head of "Estimating Cost of Painting."

STAINS

The principal varieties of stains are oil stains, water stains, alcohol or spirit stains, acid and alkali stains, pigment or wiped stains, wood dyes, and the fuming process. The color of open-grained woods, like oak, ash, chestnut, etc., may be modified by coloring the paste filler by adding some pigment to it. In addition to the above methods of staining, all of which are used by the painter and hardwood finisher, there are large quantities of stains sold that are intended principally for the use of the amateur who wants to stain and finish in one operation and who does not possess the mechanical skill or technical knowledge needed to use a true stain. There are two classes of stains of this kind. The first, known as "varnish stains," consist of varnish mixed with some dry pigment ground in it. These varnish stains require constant stirring while using, to prevent the pigment from settling out or the color from running streaky. Such stains are suitable only for household work, touching up chairs and the like that have become disfigured and rubbed, or finishing some small article, and are entirely unsuitable for finishing the woodwork of a new house.

Another class of single-operation stains and varnishes, consists of varnish that has been colored with aniline dyes. These have the advantage of being uniform in color, since there is no pigment to settle out; but as all aniline colors are more or less fugitive, it is likely that these new-varnish stains would fade more or less on exposure to strong light. Their greatest disadvantage is that they dry so quickly that it is difficult to avoid showing laps when used on broad surfaces like door panels.

SHINGLE STAINS

A good shingle stain may be made by using pure white lead (in oil), strong chrome green (in oil), raw umber, and a little lampblack, mixed until the desired shade is reached. thinning with boiled linseed oil and a little japan. To 1 quart of this paint, add, for dipping purposes, 5 quarts creosote oil; and for application with the brush, mix 1 quart of the oil paint and 3 quarts of creosote oil. A common estimate is that 3½ gallons of stain will be sufficient for 1,000 shingles, dipping two-thirds of the shingle.

Covering Capacity of Shingle Stains. The following estimate of covering capacity of shingle stain is based on the average cedar shingle, size 4 by 16 in.

One gallon of stain will cover 150 sq. ft. one brush coat, or 100 sq. ft. two brush coats.

Two and one-half to 3¾ gallons of stain will dip 1,000 shingles. Two-thirds of length of shingle to be dipped.

Three gallons of stain will dip and brush-coat 1,000 shingles in some cases.

The covering capacity of creosote bleaching oil is about one-fifth less than the above figures.

FILLERS

Fillers for use in painting or finishing woods consist of liquid and paste types.

Liquid fillers are sometimes used as first coats on close-grained woods where cheapness is desired and where shellac is considered too expensive. These fillers are not intended for use on open-grained woods, as they are not fillers in the strict sense of the word. They are merely intended for use as a first coat, and will not fill the grain of such woods as oak, ash, chestnut, etc. This type of filler should not be used for first coats in finishing floors or on fine natural wood finishing.

The covering capacity of liquid fillers varies from 250 to 400 sq. ft. per gallon.

Paste fillers vary in consistency according to the kind of wood to be filled, the more open-grained woods requiring the filler to be heavier in body than the close-grained woods. For instance, walnut and mahogany are open-grained woods, but are not nearly so open-grained as ash, oak, or chestnut; therefore the filler used on walnut or mahogany need not be so heavy as that for the other kinds of wood named.

The following rule for reducing paste fillers is often used: For oak, chestnut, ash, and other very coarse-grained woods, use 7 to 9 pounds of filler to the gallon. For walnut, mahogany, butternut, and other similar grained woods, a mixture of 6 pounds of paste filler to the gallon may be used.

The covering capacity of paste filler reduced for use is about 300 sq. ft. to the gallon on work in which there is no waste.

PAINTING CONCRETE

The amount of surface covered by a gallon of oil paint on concrete depends upon the degree of porosity of the concrete and the character of the paint used. As a rough approximation for ordinary smooth concrete walls made from a fairly rich mixture of materials, it may be estimated that one gallon of paint will cover about 250 sq. ft. for the first coat; 500 sq. ft. for the second coat; and 650 sq. ft. for the third coat.

PAINTING TIN

In painting sheet tin, scrape off all resin that may adhere to joints, and then thoroughly wash the surface with benzine, so as to remove all grease and dirt. Then apply red lead and linseed oil paint for the first coat. White lead and ocher should never be used.

Quantities necessary for painting tin roofs may be found by the use of Table 2.

PAINTING GALVANIZED IRON

There is generally much difficulty experienced in getting paint to adhere firmly to galvanized iron; and various experiments are tried to overcome the trouble. The United States Government has adopted a plan that seems to be satisfactory. The specifications compel the use of vinegar for washing surfaces preparatory to painting. This roughens or corrodes the surface, and gives the paint better adhesion.

Quantities of materials needed for a given surface may be found from Table 2.

LIQUID BRONZE

A bronze paint thinned with turpentine or benzine, and containing a little varnish as a binder, will cover about 800 sq. ft. per gallon.

If "banana liquid" is used, the covering capacity will be about 700 sq. ft. per gallon.

Where bronze powder is used, one ounce of powder will cover about 25 sq. ft. of surface.

The above quantities are for surface of average smoothness.

Finishing Radiators. One of the most durable finishes for radiators and steam pipes that are exposed to great heat is **aluminum bronze**, mixed to a consistency of paint in the so-called "banana liquid." This is a solution of celluloid in amyl acetate, and is very explosive if brought in contact with fire; hence it should never be used in a room lit by gas or lamps, or in which a fire may be burning. It has a very peculiar and pungent odor which is disagreeable to many people, but which passes off within a day or two. Bronzes thinned with this medium hold their color well, and stand exposure to the weather. It may be used with gold, copper, and colored bronzes, as well as with aluminum; but the latter is the most durable, especially when subjected to great heat, as in the case of radiators, besides presenting a very pleasing appearance.

For painted radiators and steam pipes, zinc white should be used as the base, and it should be colored with some pigment not easily affected by the heat. For a light buff, Italian sienna may be used, lightened, if desired, with permanent yellow (zinc yellow). For other tints, such colors as ultramarine blue, drop black, burnt sienna, red oxide or Tuscan red, Indian red, yellow ocher, chrome red, or madder lake may be used; but on no account should chrome yellow, chrome green, Prussian blue, or other colors affected by heat be selected. The zinc white should be of the best quality, ground in damar varnish. If only zinc white ground in linseed oil can be obtained, it should be washed with turpentine to draw off the surplus oil. The colors should be ground in japan. When the proper tint has been obtained, it should be thinned with turpentine to a creamy consistency, and a good pale baking varnish added to give a glossy surface. The pipes should be painted when fairly cool, and steam should not be turned on until the paint is dry and hard to the touch.

Testing Linseed Oil. The simplest tests for the purity of linseed oil are the smell and the taste. Good, raw linseed oil should be of a light yellow color; a greenish oil usually indicates that it has been made from unripe seed and is not fit for use in first-class paint. Pure linseed oil, when first placed on the tongue, has a bland taste, turning afterward to slightly bitter and rasping. The presence of either rosin or mineral oil as an adulterant gives a decidedly nauseating taste. A few drops of pure linseed oil rubbed briskly between the palms of the hands should have only the characteristic odor of flaxseed; a faint odor of rosin indicates adulteration with rosin oil, while an odor of machine oil shows the presence of mineral oil. If there is a sweet, mealy smell of fish or menhaden oil, it is very difficult to disguise when the oil is heated; but fish oil is little used as an adulterant.

If a drop of the suspected oil is placed on a piece of black japanned tin or on a sheet of glass painted black on the other side, the presence of mineral oil will be detected by a bluish iridescence or bloom, when held in a strong light, sometimes extending as a ring beyond the drop of oil.

A simple test is to make a freezing mixture of ice and salt, placing a small portion of the suspected oil in it, with the bulb of a thermometer in the oil. If the oil congeals to a solid or butter-like consistency at a temperature higher than eighteen degrees below zero, it is not pure linseed oil, but may contain an excess of water, or may be adulterated with rosin oil (freezing point 6° F.), or with rape seed oil, which is apt to come from imperfectly cleaned seed and which freezes at 25° F. Fish oil has a still higher freezing point, 32°., or that of water.

Another simple test is to take a white glass bottle about 3 in. high, and pour in oil to a depth of about 2 in. Add 3 or 4 drops of sulphuric acid, and shake.

If the mixture becomes a very dark brown, thick, syrup-like substance in a few minutes, the oil is linseed. If it does not change quickly, let it stand over night; and if there is linseed oil in the mixture, it will form the syrup at the bottom of the bottle. By measuring the height of the syrup at the bottom of the bottle, the percentage of adulteration may be determined.

Testing White Lead. White lead, purchased in unbroken packages bearing the name of any reputable corroder, is reasonably certain to be pure. Occasionally it may contain a trifle of silver or of uncorroded blue lead, either of which renders the white lead off-color. But when white lead is offered under fancy names, either branded with a jobber's or grinder's name, or with no firm name, and especially when it is offered at less than the current market quotations for white lead, one may feel certain that it is a so-called "combination" lead, or a mixture of white lead, zinc white, and barytes.

To test white lead in oil for purity, scoop a small hole in a piece of charcoal, and place in it a portion of the lead about the size of a small pea. A gas flame, or the flame of a spirit lamp, is then directed upon it by means of a blowpipe. The lead must be held in the point of the flame, and a steady blast must be maintained. A minute or two should reduce the white lead to a button of metallic lead, provided it is free from adulteration. If any zinc, barytes, whiting, clay, or silica be present—even if only 5 or 10 per cent—no metallic button can be formed, but the substance left will be a whitish, yellow, or gray cinder-like mass.

To test white lead for the presence of barytes (the most usual adulterant), place about 20 grains in a test tube, which should be filled about half full of dilute nitric acid. Pure white lead will completely dissolve, with some effervescence, while barytes will remain as an insoluble precipitate in the bottom of the tube.

The oil may be removed from white lead ground in oil, by placing it on blotting paper and saturating it with benzine or gasoline, which is then allowed to evaporate.

White lead, however, may be pure, yet of inferior quality, owing to imperfect corrosion or to lack of care in its manufacture. A good white lead should be reasonably white, with a very slight yellow tone as distinguished from the dead white of zinc white. The quick-process leads, as a rule, are whiter than those made by the old Dutch process. A dark, somewhat gray color indicates imperfect corrosion. The lead should be of good density and not too oily, but should be ground so as to "string out" when taken up from the keg with a paddle. Lead of this character does not break up so readily as a "short" lead, and is much more durable for outside work.

ESTIMATING COST OF PAINTING

Estimate Systematically. It is very easy to overlook something, and the only safe way to avoid it is to go about the matter systematically, taking room by room, if the work is interior, and exercising equal care to measure and include all surfaces to be covered if the work is exterior. A book should be ruled for estimating so as to show the superficial measurements, the number of square feet, and the allowances or corrections, so that the last column shows the equivalent number of square feet of plain surface. The different kinds of wood and the different classes of workmanship should, of course, be kept entirely separate, in order to avoid confusion.

The most important thing for a painting contractor to do is to keep a record of cost of every job, giving in tabulated form an exact statement of the number of hours work and the amount of materials required. These are things that every contractor must find out for himself, because the methods of handling work in different localities are different, and each man must fix his own prices.

The careful painter does not guess at heights, lengths, or the areas of surfaces, but measures everything carefully with a rule or tape. All measurements and calculations should be checked for accuracy, and also to see that nothing has been omitted in taking off the measurements.

MEASUREMENTS FOR PAINTING

When both **ends** and both **sides** of a building are of the same size, it is necessary to measure one end and one side only; then double these dimensions, and multiply their sum by the height to the eaves. If the building is of irregular outline or is cut up considerably, it is best to run the line completely around the building, taking care to press it into all the angles. In this way, the circumference is obtained, which, if multiplied by the height to the eaves, gives the number of sq. ft. of area in the wall surface to be covered.

Next, measure the **gables**. The areas of gables may be found by multiplying the height by the width of the end of the house, and dividing the result by 2. If both gables of the building are alike, multiply the area of one gable by 2.

Porches and verandas, dormer windows, bay windows, cornices, and other additions to a building must be measured separately, and noted in a different place on the estimate sheet, since the labor rate on these items will be different from that on flat surfaces of large area.

Plain work on cornices, verandas, etc., is often figured by the linear foot instead of by the surface area. Fancy lattice-work or large capitals on columns will have to be estimated in each individual case.

Dormer windows, bay windows, etc., may be estimated by the lump sum for each one, remembering that the location of the dormer will make the labor cost higher than on straight walls.

Gutters and downspouts may be estimated by the linear foot. On small jobs, it is not difficult to estimate the time needed for this class of work. The amount of surface to be covered may be obtained from tables of areas, provided the dimensions of the spouts and gutters are known.

No deduction has been made for **window and door open-**

ings in figuring surfaces to be covered. Wall spaces are usually measured solid, and it is estimated that the time spent in cutting around sashes, frames, etc., is as much as would be required in painting a smooth surface the size of the openings.

If there are a great many small openings, or if there are a large number of small lights to be cut around, an additional charge of one or two cents per sq. yd. should be made.

If the **roof** is to be painted or stained, the number of sq. ft. of surface in the roof should be measured. A pitch roof may be measured from the ground by measuring off a space on the end of the building at an angle equal to the roof angle. The length of the side of the angle parallel to the roof line, multiplied by the length of the roof, will give the area of one side in plain work or with gables and dormers of the same pitch.

Store fronts should first be measured as in the case of other surfaces. Then double, triple, or quadruple this measurement, according to the amount of work on the front. The height of a front or surface must be taken into consideration, and the amount of difficulty to be met in placing ladders, hanging stages, etc. Large fluted columns with ornamental tops, fancy cornice, frieze, etc., may require that the measurements be tripled in order to arrive at a proper labor cost.

Prices of labor and materials vary greatly in different parts of the country, and these are the main items to be taken into consideration. The conditions and surroundings of each individual job must be considered in attempting to fix a cost. If the surface to be painted is peeling, blistered, or in a bad condition which requires much scraping or burning off, the cost of the work will be higher. If a job is located at some distance from the shop, the cost of hauling equipment and materials to and from the job must be added.

Official Rules for Measuring

In order to give some basis by which estimates for painting work could be intelligently made, the National Association (now the International Association) of Master House Painters and Decorators appointed a committee, about the year 1892, to devise a system of measurements which would be practicable for the entire country. This committee took two years to perform its work, and finally reported at the convention held in Baltimore, February, 1894, giving a very practical system whereby all classes of work were reduced to a basis of square yards of plain painting. For example, lattice-work, when painted on one side only, is to be measured by multiplying three times the height by the length.

Some of the more important rules of the system of measurement are given in the following:

Outside Measurements

Clapboarded walls—Add one sq. ft. to each sq. yd. of measurement to allow for under edges of boards.

Flat brick, wood, cement, or stone walls—Measure height by width, and add area of openings.

Cornices (if plain)—Multiply the length by 1½ times the girth; on high buildings, where the walls are not to be painted, by 4 times the girth.

Bracket cornices—The length to be measured by from 3 to 8 times the girth, according to ornamentation and height above ground.

Outside blinds—Multiply the height by twice the girth for stationary, and by three times the girth for rolling slat blinds. Height by twice girth for shutters.

Door-frames—If 6 in. or less in girth, the girth to be counted as 1 ft., and allow double girth for all in excess of 6 in., multiplying by the length all around.

Doors—Batten doors, add 1 in. to girth for each bead or batten, and measure square. Paneled doors, double the area. Measure edges twice on account of lock face and butts.

Window-sash—If plain, measure the height by 1½ times the width; if fancy, by 3 times the width.

Balustrades—Take 4 times the height of one side, with the top surface of upper and lower rail added, and multiply by the length of the baluster rail.

Columns—When plain, multiply the height by 1½ times the girth; when fluted, by twice the girth, pressing the tape into the flutes.

Capitals—Multiply the height by from 3 to 10 times the girth.

Tin roofs—Measured square.

Plain or beaded sheathing ceilings—Multiply twice the length by the width, adding 1 in. to the width for each bead.

In **dipping shingles**, estimate at 400 sq. ft. for each 1,000 shingles.

Floors—Square measurement.

Chimneys, conductors, spouts, barge boards, crestings—Four times the girth multiplied by the length.

Inside Measurements

Ceilings—If washed and tinted, double surface. If washed, sized, and tinted, 3 times the surface.

Walls—Make no allowance for openings if the finish is of hardwood, and allow one-half the area of openings if the finish is to be painted. If walls to be washed and tinted, add one-fourth to surface measurement, and make no deduction for openings.

Interior wood finish—If from 4 to 6 in. in girth, count as 1 ft.; 12 and 18 inches, count as 3 ft. Add 1 ft. to the perpendicular height for **corner blocks**.

Baseboard—Allow not less than 1 ft. for height; and when base and molding exceed 10 in., count them as 15.

Paneled dadoes—Two or three times the area.

Painted floors—One and one-half times the area; double area for hardwood floors. Parquet floors, from 3 to 5 times the area.

Moldings less than 4 in. in width, and separated from other finish, to be counted as 1 ft.

Doors, window-frames, columns, etc.—The same rules as for outside measurements.

To the above measurements might be added the following:

Iron gratings, screens, or bars—Measure area of surface covered, and multiply by 4 or 6 as the case demands.

Hand-rails, buttresses, stairs, and steps—Multiply surface measurement by 2.

Skylights—Multiply surface measurement by four.

Iron Fences—Fancy cast-iron work, 4 times the height of one side multiplied by length. Bar or pipe work, circumference of pipe multiplied by length of fence.

Board or picket fences—Twice the height of rails or pickets, and girth of same, multiplied by the length of fence with circumference of posts added.

Domes and cupolas—Multiply the girth at the base by the greatest height, and this result by 3.

Spires—If plain boarded, multiply the greatest girth by double the height.

Single doors—Measure as 35 sq. ft. for each side, including trim.

Interior side of windows—Same as for single doors.

Wall decoration—See under "Calcimine," p. 625.

Woodwork in bad condition, add from one-tenth to one-half to the measurements given above.

Quantities of Materials for Painting

Where the contractor has learned by experience to judge reasonably well as to the time required for doing a given piece of work, then the labor and material may be figured separately. It then becomes needful to know the average covering capacity of white lead or such other paint as may be used. This depends very much on the condition of the surface to be covered and its degree of absorption, as well as on the particular material employed and the fineness to which it is ground.

In figuring from plans the painter not only needs to look over the specifications for his own work, but he must also examine carefully the specifications for other mechanics, since often there are items called for which do not appear on the plans, but which require painting or hardwood finishing. Sometimes the mantels are furnished by the owner ready-finished from the factory, while at other times the painter must finish them. It is well to read carefully the specifications for the plasterer, the plumber, and the steam-fitter. Among other things that the painter should carefully consider are the kinds of wood for interior finish; the kinds of wood for the floors, and whether they are to be finished; whether the cellar woodwork is to be finished by the painter, or whether he has whitewashing to include in his estimate. Who is to finish the radiators? Is the kitchen sink to be bronzed with aluminum? And the same of the outside of the sink. What walls, if any, are to be calcimined or frescoed? Are there wood or plaster cornices to be finished? Look out for wainscots, kitchen dressers, pantry fittings, seats, or other wood fittings requiring finishing.

Covering Capacity. For white lead, under average conditions of surface, the area (in sq. ft.), divided by 18, will give approximately the number of pounds of white lead in oil that will be needed to do a good 3-coat job of painting. The area (in sq. ft.), divided by 200, will give approximately the number of gallons of white lead paint that will be required to do the work, two coats. There would be very little difference in the number of gallons of any good mixed paint that would be needed.

One pound of **paint** will cover from 3½ to 4 sq. yds. of wood for the first coat, and from 4½ to 6 sq. yds. for each additional coat; on brickwork, it will cover about 3 sq. yds. for the first coat and 4 sq. yds. for the second coat.

One pound of **putty**, on an average, will be sufficient for about 20 sq. yds. of wall or ceiling where stopping (filling cracks, etc.) is needed.

One pound of wax will cover about 125 sq. ft. of surface.

One pound of glue, mixed with two gallons of water, for sizing, will cover about 100 sq. yds. of surface.

One gallon of ready-mixed paint will cover 250 to 300 sq. ft. of wood surface one coat, or 175 to 225 sq. ft. two coats, or 125 to 150 sq. ft. three coats.

One gallon of paint, emerald green, will cover about 25 sq. yds.

One gallon of paint, yellow, will cover about 44 sq. yds.

One gallon of paint, stone color, will cover about 44 sq. yds.

One gallon of paint, white, will cover about 44 sq. yds.

One gallon of paint, zinc white, will cover about 50 sq. yds.

One gallon of paint, prime color, will cover about 50 sq. yds.

One gallon of paint, black, will cover about 50 sq. yds.

One gallon of paint, green, will cover about 45 sq. yds.

One gallon of paint, bronze green, will cover about 75 sq. yds.

One gallon of mixed paint will cover from 25 to 30 sq. yds. on stonework; 80 to 90 sq. yds. on ironwork; and 40 to 50 sq. yds. on plaster.

One gallon of mixed paint will cover about 125 sq. ft. of brickwork for the first coat, or about 300 sq. ft. for the second coat.

One gallon of shellac will cover 700 to 750 ft., one coat.

One gallon of water stain will cover 650 sq. ft. on open-grained woods; 750 sq. ft. on close-grained woods, and about 500 sq. ft. on soft woods.

One gallon of spirit stain will cover about ½ the capacity of water stains.

One gallon of oil stain will cover about 600 sq. ft. on either hard or soft woods.

For shingle stains, see page 612.

One gallon of paste filler reduced for use will cover about 300 sq. ft.

One gallon of liquid filler, hard oil finish, or varnish will generally cover from 350 to 400 sq. ft. for first coat, and from 400 to 500 sq. ft. for subsequent coats.

One gallon of enamel will cover about 260 sq. ft. on plaster, one coat.

One gallon of varnish remover will treat about 150 sq. ft.

For bronze paint, see page 613.

In estimating per square of surface covered, the following proportions are often followed:

Where lead and oil primer is used, new woodwork requires 3¾ pounds of white lead, 1 quart linseed oil, and a little under ½ pint of turpentine per square (100 sq. ft.) of work. If used on common brickwork, 8¼ pounds of white lead, ½ gallon of linseed oil, and a little over ½ pint of turpentine per square.

Coats other than priming coats require 2½ pounds of white lead, 1 pint of linseed oil, and ⅛ pint of turpentine per square for woodwork, and 3½ pounds of white lead, 1 quart of linseed oil, and ¼ pint of turpentine per square on common brickwork.

Labor Quantities for Painting

An average workman will do approximately the following amounts of work in an 8-hour day:

Shellacking knots, 450 sq. yds.

Puttying defects, 250 sq. yds.

Sizing plaster walls, 250 sq. yds.

Filling woodwork with paste filler, 65 sq. yds. on common work, or 25 sq. yds on high-class work.

Lead and oil, priming coat, 80 to 100 sq. yds.

Lead and oil, second coat, 80 sq. yds.

Outside blinds, 8 pairs, first coat; and 10 pairs, second coat.

Dipping shingles, 8,000 dipped ⅝ of length.

Staining shingles, one coat with brush, 100 sq. yds.

Varnishing, varies from 30 sq. yds. on balusters and similar work, to 90 sq. yds. on plain, flat surfaces such as floors.

Graining, about 25 sq. yds.

On residence work, about 30 sq. yds. per 8-hour day for 3-coat **exterior** work, including shellacking knots, puttying defects, and cornice and porch work.

Interior shellacking, 70 sq. yds., one coat.

Rubbing down work, about 30 sq. yds.

Applying liquid filler, from 50 to 100 sq. yds., depending upon the class of work.

Mineral paint, on small surfaces with angles, 80 sq. yds.; on large surfaces, 150 sq. yds.

Lead and oil paint on plaster, 125 sq. yds.

Cleaning work for painting, 40 sq. yds. on plain work.

Painting on Metal. As regards the surface of structural steel covered by a gallon of paint, there is much difference of opinion among experts, some putting it at 300 or 400 sq.

TABLE 2

Average Covering Capacity of Paints per Gallon, on Metal

Kind of Paint	Gallons of Oil Used	Pounds of Pigment Used	Amount of Paint Resulting from Mixture		Covering Capacity	
			Gallons	Pounds	1 Coat	2 Coats
Asphalt, black.	1 (turp.)	17¼	4	30	520 sq. ft.	300 sq. ft.
Graphite, ground in oil.	1	12½	2	20½	625 sq. ft.	350 sq. ft.
Iron oxide, powdered.	1	8	1 1/5	16	600 sq. ft.	350 sq. ft.
Iron oxide, ground in oil. . . .	1	24¾	2 3/5	32¾	625 sq. ft.	375 sq. ft.
Lead, red, powdered.	1	22½	1 2/5	30 2/5	625 sq. ft.	375 sq. ft.
Lead, white, ground in oil . .	1	25	1¾	33	500 sq. ft.	300 sq. ft.
Linseed oil (no pigment) . . .	1	. . . .	. . . .	. . . .	875 sq. ft.	. . . .

ft., others as high as 1,000 or 1,200 sq. ft. The fact is that any paint can be brushed out by a skilled workman into an exceedingly thin film, while ordinary work will give a coating at least twice as thick. In general it is not wise to estimate more than 500 or 600 sq. ft. of surface to the gallon, one coat. Varnish paints cover less than oil; but, if well made, they are more durable.

Table 2 will give a general idea of the quantities of materials needed for different kinds of paints on metals, together with covering capacities for one-coat and two-coat work.

Painting Structural Work. Mr. Edward Godfrey gives, in Table 3, a great quantity of useful data in regard to the covering capacity and cost of paint on metal bridge and other steel structural work.

Buildings—12 lbs. iron averages 1 sq. ft. surface. Add 10 per cent for corrugations in corrugated iron.

Steel Riveted Pipe—Add 3 per cent for laps.

Painter's Cost Record. The National Lead Company of New York publish a form of record blank which is very useful in determining the cost of a piece of work, and which, if properly filled out, will show the amount of profit realized. A sample of this blank, with properly filled-in items, is here reproduced (see p. 628).

CALCIMINE

Measurements. In measuring rooms for decorating, measure ceilings as solid, and side walls as actual area less ½ of all openings.

To Apply Calcimine

Use a flat wall brush 5 to 7 in. in width, and apply material with a sweeping, slanting stroke, half-perpendicular in motion. Make a downward sweep slightly curved so that the material flows easily and leaves no brush marks. Apply in strips double the width of the brush.

Tint the ceiling first, beginning at the side-wall angle, working back and forth the narrowest way of the room. Begin side-wall work at ceiling angle, and work down to base-board in strips double the width of the brush.

Covering Capacity of Calcimine. As a basis for estimating quantities of material needed in a given case, one pound of dry calcimine will cover the following average areas:

Stone	24 to 40 sq. ft.
Soft, unpainted bricks	25 to 40 " "
Rough, unpainted boards	25 to 40 " "

(Continued on page 628)

TABLE 3

Painting Steel Structural Work

Span (Ft.)	Weight (Lbs.)	Area (Sq. Ft.)	GALLONS PAINT REQUIRED, 1ST AND 2D COATS.									
			Iron Oxide		Red Lead		White Lead		Graphite		Asphalt	
			1st	2d	1st	2d	1st	2d	1st	2d	1st	2d
Single Track Railway Bridge—												
80	60,000	4,800	10	7	7	5	10	7	10	7	16	10
100	85,000	6,800	14	10	10	7	14	10	14	10	23	14
120	112,000	8,960	18	13	13	9	18	13	18	13	29	18
140	150,000	12,000	24	17	17	12	24	17	24	17	40	24
160	185,000	15,000	30	21	21	15	30	21	30	21	50	30
180	226,000	18,080	36	26	26	18	36	26	36	26	60	36
200	270,000	21,600	43	31	31	22	43	31	43	31	72	43
220	319,000	25,530	51	36	36	25	51	36	51	36	85	51
240	375,000	30,000	60	43	43	30	60	43	60	43	100	60
260	429,000	34,320	69	49	49	35	69	49	69	49	115	69
280	490,000	39,200	78	56	56	39	78	56	78	56	130	78
300	555,000	44,500	89	63	63	45	89	63	89	63	148	89

Buildings—12 lbs. iron averages 1 sq. ft. surface. Add 10 per cent for corrugations in corrugated iron.
Steel Riveted Pipe—Add 3 per cent for laps.

TABLE 3—(Concluded)

Span (Ft.)	Weight (Lbs.)	Area (Sq. Ft.)	GALLONS PAINT REQUIRED, 1ST AND 2D COATS									
			Iron Oxide		Red Lead		White Lead		Graphite		Asphalt	
			1st	2d	1st	2d	1st	2d	1st	2d	1st	2d
Highway	**Bridge—**											
20	1,800	400	1	¾	¾	½	1	¾	1	¾	1½	1
40	5,200	800	1½	1¼	1¼	1	1½	1¼	1½	1¼	3	1½
60	10,200	1,400	3	2	2	1½	3	2	3	2	5	3
80	16,800	2,200	4½	3	3	2¼	4½	3	4½	3	7	4½
100	25,000	3,000	6	4¼	4¼	3	6	4¼	6	4¼	10	6
120	34,800	3,800	7½	5½	5½	4	7½	5½	7½	5½	13	7½
140	46,200	5,400	11	8	8	5½	11	8	11	8	18	11
160	59,200	8,000	16	12	12	8	16	12	16	12	27	16
180	73,800	10,000	20	14	14	10	20	14	20	14	33	20
200	90,000	12,000	24	17	17	12	24	17	24	17	40	24
220	107,800	15,000	30	21	21	15	30	21	20	21	50	30
240	127,200	18,000	36	25	26	18	36	26	36	26	60	36
260	148,200	21,000	42	30	30	21	42	30	42	30	70	42
280	170,800	24,000	48	35	35	24	48	35	48	35	80	48
300	195,000	28,000	56	40	40	28	56	40	56	40	90	56
*	*	*	*	*	*	*	*	*	*	*	*	*
Covering capacity of 1 gal. (sq. ft.).			500	700	700	1000	500	700	500	700	300	500
Price per gallon.			$0.50	....	$1.25	....	$0.85	....	$0.70	....	$0.40	....
Cost per 100 sq. ft.			.10	$0.07	.18	$0.13	.17	$0.12	.14	$0.10	.13	$0.08
Times renewed in 20 years.			10		3		5		7		60	
Cost per 100 sq. ft. for 20 years.			$1.70		$0.92		$1.45		$1.68		$12.60	

RECORD BLANK

Contract No. 25 Made Jan. 2, 1912 With Geo. Smith

Description Three story house at 11 Ashton Ave.

Remarks Repaint, 2 coats, "Dutch Boy" white lead & linseed oil

Commenced Jan. 5, 1912 Finished Jan. 23, 1912

Date		Labor (Day's Work)	White Lead (Pounds)	Linseed Oil (Gallons)	Turpentine (Gallons)	Drier (Pints)	Colors (Pounds)	Cartage	
Jan	5	3	100	4	1/2	1	1 1/2	1	00
	6	3							
	10	2 1/2	50	2		1	1		
	11	2	100	3	1				75
	12	3							
	13	1	75	2					50
	19	4	100	3	1	1	1 1/2		75
	20	4	50	2		1/2			
	23	2 1/2						1	00
Totals		25	475	16	2 1/2	3 1/2	4	4.00	

Recapitulation

Contract Price			$200
Labor	25 days @ $3.50	87.50	
White Lead	475 pounds, 8¢	38.	
Linseed Oil	16 gallons, 80¢	12.80	
Turpentine	2 1/2 " " 70¢	1.75	
Drier	3 1/2 pints, 22¢	.77	
Colors	4 pounds	1.20	
Cartage		4.00	$146.02
Overhead Charges	15 per cent	21.90	167.92
Net Profit			$32.08
Per Cent. of Net Profit	about 19 per cent		

Hard, unfinished bricks ....40 to 65 sq. ft.
Smooth, unpainted boards ....50 to 75 " "
Smooth, painted boards ....60 to 80 " "

Average areas covered by 1 gallon of mixed calcimine are as follows: Hard plaster walls, 270 sq. ft.; wood, 225 sq. ft.; brick, 180 sq. ft.

For necessary quantities of sizing, see page 622.

Labor Costs of Calcimine Work

An average workman, using a 5-in. calcimine brush, will cover the following areas in one hour:

Brick wall	20 sq. yds.
Rough wall	22 " "
Ceiling (from step-ladder)	25 " "
Smooth wall	38 " "
Flat surface	40 " "

For labor costs in sizing, see page 623.

WHITEWASHING

A recipe for whitewash, issued by the Lighthouse Board of the Treasury Department, said to be very good for outdoor exposure, is as follows:

Slake half a bushel of unslaked lime with boiling water, keeping it covered during the process. Strain it, and add a peck of salt dissolved in warm water; three pounds of ground rice put in boiling water and boiled to a thin paste; half a pound of powdered Spanish whiting; and a pound of clear glue, dissolved in warm water. Mix these well together, and let the mixture stand for several days. Keep the wash thus prepared in a kettle or portable furnace; and when used, put it on as hot as possible, with painters' or whitewash brushes.

To Clean Whitewash from a Ceiling. Take 3 pints of flour and beat it thoroughly in cold water; then pour boiling water into it until cooked. Dissolve one pound of alum in hot water, and pour in the paste. Use the paste quite thick. Apply to the ceiling with a whitewash brush, being sure to cover the ceiling thoroughly; then close the room, and let it stand over night. In the morning the bits of lime left clinging to the ceiling are easily scraped off. Be sure to carry everything from the room before commencing work as the lime falls to the floor.

Glass and Glazing

There are several different kinds and grades of glass manufactured for use in building construction. Among the different kinds used are **plate glass, sheet glass, ornamental and colored glass, figured rolled glass, wire glass, prismatic glass, and skylight glass.**

PLATE GLASS

Plate glass is the highest grade of window glass. It is cast in large sheets on a flat table, and then polished. This glass is manufactured in sheets of different sizes, some as large as 12 ft. wide by 16 ft. long. The average thickness of plate glass is from ¼ to 5/16 in. Large plates are made ½-in. thick.

WINDOW GLASS

Sheet glass, or common **window glass,** is so named on account of the method of manufacture. The glass is first blown in the form of a cylinder, then cut along the side of the cylinder and flattened on a stone. This method of manufacture causes a wavy appearance in the product, which readily distinguishes it from plate glass.

Grades of Window Glass. Window glass is made in three different grades, in both **single strength and double strength,** the grading of the glass depending upon its color and brilliancy, and the presence or absence of flaws in the material. The best quality is rated as **AA,** the second as **A,** and the third as **B.** The **AA** grade is supposed to be of very fine quality and free from flaws, while the **A** grade is the one commonly used. **B** grade glass is used in cellar windows, factories, greenhouses, or other places where the quality of the glass is not an important question.

Stock Sizes of Window Glass. The regular stock sizes of window glass vary in width, by inches, from 6 to 16 in., and then, by increases of 2 in., up to 60 in. The length or height of these sizes varies from 8 in. up to 90 in. in the different sizes of single- and double-strength glass. The exact size of glass may be obtained from a list of standard sizes and prices of same, which may be obtained from any jobber.

The thickness of ordinary window glass is about 1/16 in. for single-thick or single-strength glass, but double-thick or double-strength glass is nearly ⅛-in. thick.

Mode of Setting. Ordinary window glass is held in place by means of small triangular pieces of thin tin which measure about ¼-in. on a side, and finally by a strip of putty The tin points hold the glass in place until the putty has hardened. Large lights of glass require more points than small ones, but a good rule is to space the points about 6 in apart.

The amount of putty required for a given job may be estimated approximately on the basis of 1 pound of putty for each 25 linear feet around edge of glass.

The number of points needed may be determined from the rule given above, knowing the number of linear feet of edge of glass.

Method of Selling Glass. Window glass is sold by the box containing about 50 sq. ft. of glass. The number of panes per box will depend upon the size of the pane.

If it is desired to find the number of boxes of window glass of a given size necessary for a job, divide 50 multiplied by 144, by the result obtained by multiplying the width of the pane by its length. This will give the number of panes of glass per box. The total number of panes needed, divided by the number of panes per box, will give the number of boxes to be ordered.

For example, suppose that it is desired to find how many boxes of glass would be needed to furnish glass for 12 windows consisting of 4 panes of glass, each 13 by 28 in.:

$$\frac{50 \times 144}{13 \times 28} = 20 \text{ (nearly).}$$

Thus it is seen that 1 box of glass contains 20 panes. If 48 panes are needed, 3 boxes of glass would have to be ordered, or 2 boxes and 8 extra panes. If 3 boxes were ordered, there would be a liberal allowance for breakage, and there would be some left over. If exactly enough glass was ordered to fill the job, there would be danger of a shortage due to breakage.

WIRE GLASS

Wire glass may be obtained as plain glass, either polished or rough, or as ribbed, prism, or figured patterns. The thickness of wire glass is ¼-in. or about ⅜-in. Rough, ribbed and figured wire glass may be obtained in widths up to and including 44 in. Figured glass may be obtained in lengths up to 110 in.; and rough and ribbed patterns, up to 144 in. Prism wire glass is about ⅜-in. thick, and comes in widths up to and including 42 in., and in lengths up to 144 in.

PRISM GLASS

Prism glass comes in sizes up to 60 inches high, and in lengths up to 138 inches.

FIGURED GLASS

Figured glass is made in a variety of patterns which are designated by name or numbers by the manufacturers. One side of this type of glass is smooth, and the other rough. The thickness may be either ⅛ or 3/16 in.; while widths of pane may be 30, 40, or 42 in. The lengths of panes may be up to about 100 in.

SKYLIGHT GLASS

Skylight glass may consist of prism or wire glass, fluted or rough plate glass, or clear double-thick glass. The prism or wire glass is the best for use in skylights, with fluted or rough plate glass as a second choice. If double-thick clear glass is used, lights may be from 16 to 30 in. long by 9 to 15 in. wide. A 1½-in. lap should be used at joints.

Table 4 gives the thickness and weight per sq. ft. for fluted or plate glass for skylights. If a lap of 1½ in. is allowed at the joints, the covering area of the glass will be diminished as indicated.

TABLE 4
Weights and Covering Capacities of Skylight Glass

Size of plate	12x48 in.	15x60 in.	20x100 in.	94x156 in.
Thickness	3/16 in.	¼ in.	⅜ in.	½ in.
Area of plate	4 sq. ft.	6.25 sq. ft.	13.8 sq. ft.	101.8 sq. ft.
Covering capacity of plate allowing 1½ in. joints	3.87 sq. ft.	6.09 sq. ft.	13.6 sq. ft.	100.8 sq. ft.
Weight	2½ lbs. per sq. ft.	3½ lbs. per sq. ft.	5 lbs. per sq. ft.	7 lbs. per sq. ft.

The weights of other thicknesses of plate or fluted glass are approximately as follows:

⅛-in. .... 2 pounds per sq. ft.
⅝-in. .... 8½ " " " "
¾-in. ....10 " " " "

PUTTY

Putty is made by mixing Spanish whiting reduced to a fine powder, with raw linseed oil, and kneading into a stiff paste. If hard putty is desired, turpentine may be substituted for a part of the oil. **Soft putty** is made by mixing 10 pounds of whiting and 1 pound of white lead with the necessary amount of boiled linseed oil, adding to it half a gill of the best salad oil. The salad oil prevents the white lead from hardening, and keeps the putty soft so that it will stick to the glass at all times.

Protection of Putty. In glazing, sashes must first be primed before being puttied; otherwise the wood will draw the oil out of the putty, and cause it to shrink and fall out. Putty on sashes should also be covered with a good coat of paint to protect it from the air, or it will shrink and get loose, as the oil dries out of it through contact with the air.

Figuring Cost of Glazing

Builders should procure price lists and discounts on all kinds and grades of glass from their nearest jobber or dealer. It is impossible to quote standard prices on glass, on account of the constant fluctuations which occur on the market. While the **list** price of glass may remain a constant quantity through a long period of time, the **discounts**—which really determine the price of the glass—change very frequently.

In figuring the cost of glass of a given size, knowing the list price and the discount, the following data will be useful:

Discounts are usually stated as "90 per cent and 20 per cent," or as "90 and 10 and 5." This method of stating discounts is interpreted as 90 per cent discount allowed off the stated list price, and then additional discounts off this reduced price as indicated. For example, if the list price of a box of 10 by 14-in. double strength A grade window glass is $37.50, and the discount is quoted as "90 and 20," the price would be found as follows:

$$\$37.50 \times .90 = \$33.75$$

Subtracting this from $37.50, the remainder is $3.75. Then,

$$\$3.75 \times .20 = \$0.75$$

Subtracting this from $3.75, the remainder is $3.00, the final cost of the glass.

If the discount is given as "90, 10, and 5 per cent," a similar procedure is followed, only the reduction is carried one step additional in calculation, so that 5 per cent is deducted from the second reduced price—making the final price, in this case, $3.21.

Odd Sizes of Glass. Where fractional parts of inches or sizes of glass in odd inches are used, the cost of the glass should be figured on the basis of the next higher even inch size of glass.

Fancy shapes or odd sizes of sheets should be figured on the basis of the cost of the pane of glass necessary to furnish the size of shape desired.

Labor Costs in Glazing

Labor quantities in glazing are very uncertain. The mill worker who spends his time at this special line of work on sash, can do more in an hour than can the man who has only an occasional job of this kind. The type of window, size of glass, and size of putty fillet needed, will also affect the time unit.

An approximate estimate may be based upon 1/6-hour per sq. ft. of glass area per glazier, where the glass is in fairly large sheets on new work. In old work, about 2/5 of an hour should be allowed per sq. ft. per man.

In measuring this work, the dimensions must be taken between the rabbets, and all irregular panes should be measured according to the extreme dimensions each way.

Paperhanging

KINDS OF WALLPAPER

Wallpapers may be classified as follows:

(1) Papers printed with distemper colors;
(2) Papers printed with oil colors;
(3) Hand-block printed papers;
(4) Machine-printed papers.

Hand-printed papers are in many ways superior to the machine-printed article, but usually cost about twice as much.

Wallpapers printed in distemper colors generally fade.

Papers printed in oil colors always darken and acquire a yellow tone; and allowance should be made for this when the woodwork of the room is painted.

A **flock wallpaper** has a raised pattern of flock.

A **satin paper** is one whose ground or pattern is polished.

A **frieze** is a narrow paper of special design for the top portions of a room.

A **dado** is a paper specially designed for the lower part of the walls of a room, and for the sides of staircases. A dado should be 3 ft. 6 in. from the floor to the top of the border; if the dado is kept too high, it gives the room a walled-in appearance. Staircase and hall dadoes generally run a little higher than those in rooms. Friezes and dadoes, as a rule, are used only in first-class work.

Borders can generally be had of any width.

Marble block papers, to look well, should be hung very carefully. They are now generally sent out lined, and very often varnished ready for use.

Common or pulp paper is a wallpaper whose body is of the general surface or ground color.

MEASUREMENTS FOR PAPERING

The methods of measurement vary to a considerable extent in different localities. Some measure all walls as solid, without deductions for ordinary openings, except in the case of double doors, etc.; while others deduct one-half of a single roll of paper for each ordinary door or window.

Another method is to measure all surfaces carefully, and deduct actual openings, allowing a little for waste. No deduction is usually made for a border where used, since the extra paper allowed will help to make up for the loss in matching, trimming, etc.

If there are large openings in a room, or if a high baseboard, a wide frieze, or a dado is used, allow for these quantities in taking the surface to be covered. It is always policy to allow a little more paper than is actually needed for the wall surface to be covered.

Figuring Number of Rolls Required

A single roll of ordinary wallpaper is 8 yds. long by 18 in. wide; and a single roll of ingrain, felt, or cartridge paper is 8 yds. long by 30 in. wide. A single roll of one-strip border is 8 yds. long by 18 in. wide. A single roll of two-strip border is the same length and width, and contains therefore 16 yards of border. Common wallpaper is put up in double rolls; and ingrain, felt, or cartridge paper is put up in triple rolls. Prices are quoted on single rolls.

To determine the quantity of paper required to cover a room, divide the surface area (sq. ft.) to be covered by 30, which will give a fairly approximate estimate of the number of single rolls of common paper required, with allowance made for trimming and matching.

If the paper is 36 in. wide, one-half the above number of rolls will be required.

If the paper is 30 in. wide, and 8 yds. long, two-thirds of the above number will be needed.

As an example, suppose that it is desired to find the number of single rolls of paper needed for a room 12 by 15 ft. with a 10-ft. ceiling; also the number of rolls of border required.

The distance around the room is 54 feet. The wall surface, therefore, is 54x10. This area, divided by 30, gives 18 rolls of common paper needed.

If there were two doors and three windows of ordinary size in this room, an allowance of 20 sq. ft. for each opening might be made. This would bring the surface area down to 440 sq. ft., with a corresponding decrease in the quantity of paper needed, to 15 rolls.

Since the distance around the room is 54 ft. (or 18 yds.), and a 2-strip roll of border contains 16 yds. of border, 1⅛ rolls of border would be needed.

If the ceiling of this room was to be papered also, there would be 180 sq. ft. of surface to be covered, which would require 6 rolls of common paper, or 3 rolls of 36-in. wide paper.

The waste to be allowed for trimming and matching will approximate 1 roll in every 8 single rolls.

One gallon of paste should be allowed for each 9 rolls of ordinary paper.

Table 5 will give the approximate number of single rolls of common paper needed for rooms of different size and different heights of ceiling.

TABLE 5

Single Rolls of Common Paper Needed for Rooms of Various Sizes

(Ceilings not included)

Distance Around Room in Feet	HEIGHT OF ROOM			
	9 Ft.	10 Ft.	11 Ft.	12 Ft.
20	6	7	8	8
25	8	9	10	10
30	9	10	11	12
35	11	12	13	14
40	12	14	15	16
45	14	15	17	18
50	15	17	19	20
55	17	19	21	22
60	18	20	22	24
65	20	22	24	26
70	21	24	26	28
75	23	25	28	30
80	24	27	30	32
85	26	29	32	34
90	27	30	33	36
95	29	32	35	38
100	30	34	37	40
105	32	35	39	42
110	33	37	41	44
115	35	39	43	46
120	36	40	44	48
125	38	42	46	50
130	39	44	48	52
135	41	45	50	54
140	42	47	52	56
145	44	49	54	58
150	45	50	55	60

TABLE 6

Quantity of Wallpaper and Border Required for Various-Sized Rooms

(Papering of ceilings not included)

Dimensions of Room (In Feet)	Height of Ceiling, Ft.	Number of Doors	Number of Windows	Rolls of Paper	Yards of Border
7 x 9	8	1	1	6	11
7 x 9	9	1	1	7	11
7 x 9	10	1	1	8	11
7 x 9	12	1	1	10	11
8 x 10	8	1	1	7	12
8 x 10	9	1	1	8	12
8 x 10	10	1	1	9	12
8 x 10	12	1	1	11	12
9 x 11	8	1	1	8	14
9 x 11	9	1	1	10	14
9 x 11	10	1	1	11	14
9 x 11	12	1	1	13	14
10 x 12	8	1	1	9	15
10 x 12	9	1	1	10	15
10 x 12	10	1	1	11	15
10 x 12	12	1	1	13	15
11 x 12	8	2	2	8	16
11 x 12	9	2	2	9	16
11 x 12	10	2	2	10	16
11 x 12	12	2	2	13	16
12 x 13	8	2	2	8	17
12 x 13	9	2	2	10	17
12 x 13	10	2	2	11	17
12 x 13	12	2	2	14	17
12 x 15 or 13 x 14	8	2	2	10	18
12 x 15 or 13 x 14	9	2	2	11	18
12 x 15 or 13 x 14	10	2	2	13	18
12 x 15 or 13 x 14	12	2	2	15	18
13 x 15	8	2	2	10	19
13 x 15	9	2	2	11	19
13 x 15	10	2	2	13	19
13 x 15	12	2	2	16	19
14 x 16	9	2	2	12	20
14 x 16	10	2	2	14	20
14 x 16	12	2	2	17	20
14 x 18	9	2	2	13	22
14 x 18	10	2	2	15	22
14 x 18	12	2	2	19	22
15 x 16	10	2	2	15	21
15 x 17	12	2	2	19	22

Table 6, taken from the New York "Newsdealer," gives estimated quantities of wall paper and border required for rooms of various sizes.

Deduct one-half roll of paper for each ordinary door or window extra—size 4 by 7 ft.

Labor Costs in Paperhanging

A paperhanger will paste and hang about 1⅛ rolls of paper per hour.

Where new walls are to be papered, it is safe to allow ⅛ hour for each roll of paper, for preparing wall surface to receive paper.

Where wallpaper is to be removed before putting on new paper, labor costs will depend on the difficulty found in each case. An average value would be ½ hour per roll of paper.

Time required in all work varies according to care taken, and also with the quality of the paper used. Common, cheap papers are difficult to hang well, as they are likely to tear with their own weight when saturated with paste.

Where walls are papered in two heights, as in the case of a room with a dado rail, the cost of hanging is increased about 15 per cent.

For ceilings, add about ¼ hour extra per roll.

Builders' Hardware

The term "Builders' Hardware" today covers all metallic mechanical fittings used in building construction. Nails, screws, and bolts are used to hold together integral parts to form the whole. Locks, latches, catches, bolts, and hooks are used to hold temporarily some adjustable member of a construction in a fixed place for a certain purpose. Hinges and butts are used as a means of easily moving, by a swinging motion, some part of a structure which it is convenient to have in various positions. Escutcheons, push-plates, etc., form a protection from wear to the member on which they are used.

It is useless to try to describe standards in builders' hardware, since manufacturers of the same article use different patterns and even different materials for producing the same effect. For example, locks, butts, and hinges may be made in various proportions and shapes, each having its distinctive object and merit; while, again, each type may be made of a variety of metals such as cast iron, wrought iron, wrought steel, brass, or bronze, the cost varying with both the type and the metal.

The articles of builders' hardware used in an ordinary residence may be divided into the following classes:

1. Fittings for doors, blinds, and shutters;
2. Fittings for windows and transoms;
3. Miscellaneous fittings.

FINISHES FOR HARDWARE

Finishes for hardware vary all the way from a coat of ordinary paint up to gold plating. The cheaper forms of butts, locks, hooks, etc., are japanned. This process gives a satisfactory wearing coat which looks well and is a good protection against rust. When plain hardware is to be used, it is commonly buffed by the use of a rapidly revolving emery wheel. The finer the wheel, the higher the grade of surface. Very bright surfaces are produced by the use of a cloth wheel saturated with rouge.

When iron or steel hardware is used, it should be protected in some manner from the effects of rust. Japans, lacquers, and even paints or varnishes are used for this purpose. Plating with copper, brass, or bronze is effective, and even dipping in a copper solution or in molten tin is resorted to as a protective coating.

The **Bower-Barff process** is one of the best finishes for indoor hardware, but is not suitable for exposed outdoor work. The process consists in a chemical change in the outer surface of the iron or steel, effected in a high-temperature furnace. The result is a permanent, lustrous black color which needs no additional protective coating. While this finish is almost unexcelled for interior work, yet, when exposed to the action of dampness in unprotected locations, rust forms in the small pits which are liable to occur during the process, and spots develop which in time cause the skin of the finish to flake off around the spots, thus leaving the metal unprotected.

For cast or wrought brass or bronze, the natural surface polished or subjected to the action of a sand-blast forms an attractive finish. In places where wear and handling are not excessive, a coat of colorless lacquer may be given to prevent tarnishing. Fancy finishes are given to brass and bronze by the application of chemical solutions which, instead of coloring the surfaces, really discolor them. These finishes do not wear well when handled.

Gold and silver plating are used in some cases in high-class work for parlors, libraries, halls, etc. Gold-plating, varying in thickness according to the use of the article plated, is a permanent finish which requires no care or cleaning.

For plated articles which are handled but little, a thickness known as **single plate** is all that is necessary. For knobs, handles, etc., a thickness known as **triple plate** should be used.

Silver-plating wears well, but should be used only on plain surfaces which can be cleaned easily. The action of sulphurous gases tarnishes silver, and articles coated with such a plating are subject to constant attention.

INDICATING SIZE OF BUTTS

Ordinary butts used in building are square when open. When special forms are designated in catalogues—as a 3 by 2½, for instance—it means that the butt is 3 inches high by 2½ inches wide when open. **The first figure indicates height.** The common sizes for interior doors are the 4 to 5-inch sizes; while for heavier doors or entrance doors, the 5 to 6-inch sizes are used. In some cases where a light hinge would be sufficient to carry a door, but where the finish around the

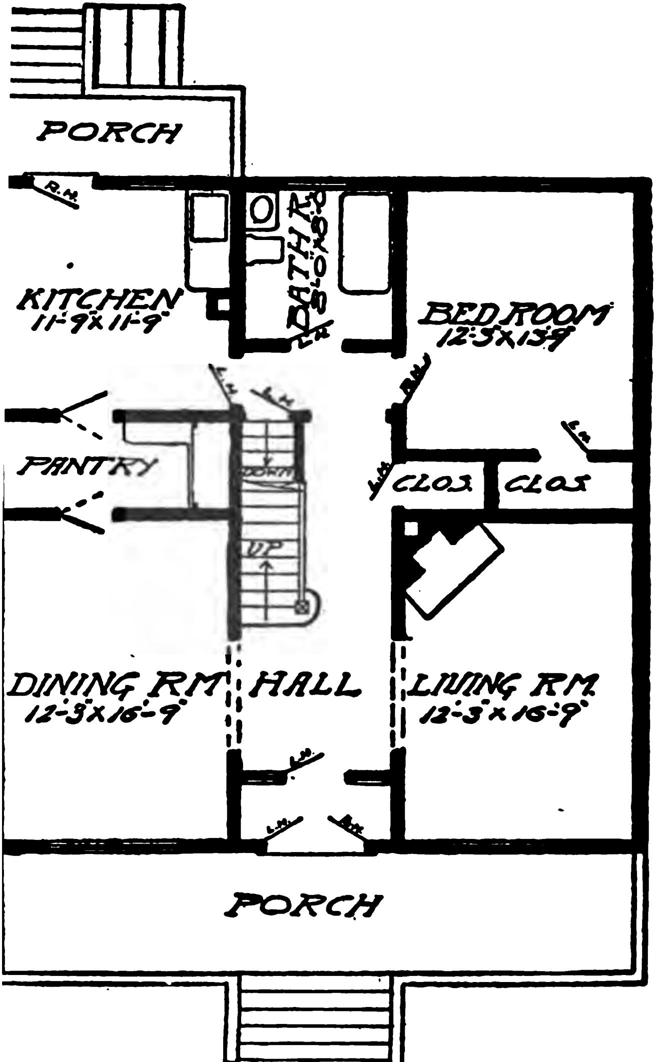

Fig. 1. First-Floor Plan of a House, Illustrating Distinction between "Right-Hand" and "Left-Hand" Doors.

door prevents it from swinging clear back against the wall, it may be necessary to use a larger butt in order to allow the knuckles to project out far enough so that the door when opened will not strike. The rule is to allow the knuckles to project a little more than one-half the distance from the surface of the hanging stile, where the hinge is attached, to the surface of the finish on the casing on the knuckle side of the door.

LOCKS FOR USE ON DIFFERENT TYPES OF DOORS

One of the largest and oldest lock-manufacturing concerns recommends the following locks for various parts of the house:

For main floor swinging doors, 4 or 4½-in. 2-bolt knob locks.

For sliding doors, 5½-in. locks, containing dead-bolt, and a pull to withdraw door.

For bedroom doors, a 5-in, 3-bolt knob lock, the third bolt being a thumb-bolt operated from the inside; or, for cheaper construction, a 4-in. 2-bolt knob lock, with separate thumb-bolt if wanted.

In case of **communicating rooms,** a thumb-bolt operated from the opposite side of the door may take the place of the dead-bolt in the 3-bolt knob lock.

Closet doors may have a 4-in. 2-bolt knob lock, with trim on both sides or only on the outside, as depth of closet will permit.

Basement and attic doors may have 3½ or 4-in. mortise locks of a cheaper grade than used in other parts of house.

Bathroom doors may have any form of good knob lock, but should be fitted with a thumb-bolt either as a part of or separate from the lock.

HAND OF A DOOR

The terms **right-hand** and **left-hand** are used in designating butts and locks. And a few words of explanation will be in place.

Fig. 1 shows a floor-plan of a house, with the doors marked **R. H.** for right hand, and **L. H.** for left hand, as the case may be. The rules which govern the marking of this diagram are as follows:

The hand of a door is determined from the outside, this being the street side in case of an entrance door; the hall or corridor side, for a room door; and the room side, for a closet or clothes-press door.

In the case of a door between two communicating rooms, the outside is the side from which the butts are not visible when the door is closed.

If, when standing outside a door as explained above, the hinges or butts are on the right-hand side, it is a right-hand door; if on the left side, it is a left-hand door.

SELECTING AND BUYING HARDWARE

When it comes to the selection of the hardware for a building, the question as to whether cheap, medium, or high-grade material shall be used depends largely upon the character of the building, and whether it is for private use or for sale or renting purposes. If for private use, the difference in cost between a cheap grade of hardware and a medium grade, with some of the more important articles such as locks or butts of high grade, will be more than offset in the long run by the wearing qualities of the goods. Broken hardware, aside from the replacing value, is often expensive and troublesome to renew.

Care should be taken in choosing the types of locks, butts, etc., used, as the general finish of the building should determine largely the size and design to be purchased. Catalogues of the different manufacturers usually explain in detail the finishes and characteristics of their different articles, and it is considered to be good policy to use the line of some reputable concern throughout. This insures harmony in design, and prevents confusion in fitting pieces in their proper places.

If possible, procure samples of each article to be used, and examine carefully before buying. The experience of an architect who has handled the same line of goods in other buildings is valuable. See the actual articles under similar circumstances, if possible, and note the conditions of wear and appearance.

When listing the hardware needed, a careful list should be made, containing the name of each article, the quantity desired, any necessary features it must possess which are out of the ordinary, and its exact location in the building. Costs may now be easily arrived at by making up this list in the cheap-grade, medium-grade, and high-grade qualities. Then, by finally deciding upon a combination of articles from the three lists, the cost may be kept within desired bounds.

A plan of each floor of the building showing locations of doors, windows, closets, etc., may be used to advantage in connection with such a list as that just mentioned. Each door or window should be given a number which will serve to locate the hardware on the list when tagged with a similar number. It is good policy to give each different article on the list a number to designate what the article is, and whether it is for a door, window, transom, miscellaneous, etc.

In the following example, articles for doors are numbered from 1 to 30; for windows, from 30 to 50; and miscellaneous, from 50 upwards. First-floor doors are numbered from 100 to 150; first-floor windows, from 150 to 190; and closets and cupboards, from 190 to 200. Second-floor doors are numbered from 200 to 250, etc.

On the plan, at each door, window, closet, or other place where hardware is needed, insert the number standing for the article needed at that place. In that way the number of pieces of each article desired can be readily counted up on the plans.

The plans shown in Plate III are marked in the way indicated. From the list of articles following, numbered as suggested, a quantity sheet has been made up. This sheet is only approximate, as its sole object is to show the method to be followed.

Hardware for Doors

1—Loose-pin, wrought steel, Bower-Barffed, butts with tip, 4 in. by 4 in.

2—Loose-pin, wrought steel, Bower-Barffed, butts with tip, 2 in. by 2 in.

3—Knob-latches, R. H.

4—Knob-latches, L. H.

5—Knob-latches, stopwork and pass key, R. H.

6—Knob-latches, thumb-bolt, R. H.

7—Knob-latches, thumb-bolt, L. H.

8—Knob-latches, dead-bolt, R. H.

9—Knob-latches, dead-bolt, L. H.

10—Brass knobs.

11—Mineral knob.

12—Jet knob.

13—Chain-bolt.

14—Double-acting butts.

15—Push-plate.

16—Heavy iron bolt.

17—Push-button for electric bell.

18—T-hinge, 14 in.

QUANTITY SHEET

Number of Door	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Notes
Basem't Door	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1	
Area way Door	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	1	..	
101	3	..	..	..	1	..	..	..	..	1	..	..	1	..	..	..	1	..	..	..	
102	3	..	..	1	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	
103	3	..	..	..	..	..	..	..	1	..	..	1	..	..	..	..	..	..	..	..	Reverse Bevel Latch
104	3	..	..	..	..	..	..	..	1	..	..	1	..	..	..	..	..	..	..	..	Reverse Bevel Latch
105	3	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	
106	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	
107	3	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	
108	3	..	..	..	..	..	..	..	1	..	..	1	..	..	..	1	1	..	..	..	
109	3	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	Reverse Bevel Latch
										Pairs		Pairs		Pairs				Pairs			
201	3	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	
202	3	..	..	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	
203	3	..	..	1	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	Reverse Bevel Latch
204	3	..	..	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	
205	3	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..	..	
206	3	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	Reverse Bevel Latch
Total	45	..	5	2	1	1	2	..	3	1	..	13	1	1	1	2	2	2	1	1	

No. of Window	31	32	33	34	35	36	37	38	39	..	..	..	..	..	..	..	..	..	..	..	
6 Cellar Windows	12	..	..	..	6	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
Scuttle	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
150	..	4	..	2	..	..	1	15	4	..	..	..	..	..	..	..	..	..	..	..	
151	..	4	2	..	..	..	1	15	4	..	..	..	..	..	..	..	..	..	..	..	
152	..	4	2	..	..	..	1	15	4	..	..	..	..	..	..	..	..	..	..	..	
153	..	4	2	..	..	..	1	15	4	..	..	..	..	..	..	..	..	..	..	..	
154	..	4	2	..	..	..	1	15	4	..	..	..	..	..	..	..	..	..	..	..	
155	..	4	..	2	..	..	1	15	4	..	..	..	..	..	..	..	..	..	..	..	
250	..	4	2	..	..	..	1	15	4	..	..	..	..	..	..	..	..	..	..	..	
251	..	4	2	..	..	..	1	15	4	..	..	..	..	..	..	..	..	..	..	..	
252	..	4	2	..	..	..	1	15	4	..	..	..	..	..	..	..	..	..	..	..	
253	..	4	2	..	..	..	1	15	4	..	..	..	..	..	..	..	..	..	..	..	
254	..	4	2	..	..	..	1	15	4	..	..	..	..	..	..	..	..	..	..	..	
Total	12	44	18	4	6	8	11	165	44	..	..	..	..	..	..	..	..	..	..	..	
								Feet													

Location	51	52	53	54	55	56	57	58	59	60	2	..	..	..	..	..	..	..	..	..	
Pantry	12	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	
Bath Room	..	..	..	..	6	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	
190	..	..	1	..	..	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	
191	..	1	..	..	..	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	
192	..	..	1	..	..	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	
193	..	1	..	..	..	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	
194	..	..	1	..	..	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	
195	..	1	..	..	..	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	
196	..	..	1	..	..	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	
197	..	1	..	..	..	..	..	..	..	Pair	3	..	..	..	..	..	..	..	..	..	
Back Entry	..	..	..	..	..	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
Chamber Closets	..	..	..	..	..	..	24	24	..	..	..	..	..	..	..	..	..	..	..	..	
Total	12	4	4	..	6	6	24	24	1	1	24	..	..	..	..	..	..	..	..	..	

19—Padlock and chain.
20—Heavy iron thumb-latch.

Hardware for Windows

31—Fast-pin, plain steel butts, 3 in. by 3 in.
32—Pulleys, 2 in. on running face.
33—Sash-lifts, hook.
34—Sash-lifts, handle.
35—Cellar window fastener.
36—Wire hook and eye.
37—Sash-lock.
38—Sash-cord.
39—Sash-weights.

Miscellaneous Hardware

51—Drawer-pulls.
52—Cupboard spring catches.
53—Elbow catches.
54—Loose-pin butts, with tips, 3 in. by 3 in.
55—Towel hooks.
56—Coat hooks.
57—Wardrobe hooks.
58—Wire closet hooks.
59—Toilet-paper holder.
60—Hinges for flour bin.

TYPICAL SCHEDULE FOR ORDERING HARDWARE

The accompanying schedule of hardware is typical for use in a modern residence. This schedule is designed to help the carpenter, the architect, and the hardware trimmer. It contains the information required to make a perfect working list of goods. It is suggested that the carpenter, the architect, and the hardware trimmer adopt this schedule as a regular form. If the order has to be sent in to the hardware manufacturer, it cannot be supplied correctly unless most of this information is sent in with the order.

Schedule of Hardware for Typical Residence

First Floor

Dull brass finish on front of double-acting door to pantry and on front of door from hall to rear hall; Bower-Barff finish on rear part.

1 single 1¾-in. front entrance sash door, 3 ft. by 7 ft. 6 in., rt. 26-in. glass.

1½ prs. brass butts, 4½ by 4½, dull brass finish.

1 push button to match.
1 set cyl. front door lock; knobs and escutcheons, Change A.
Note: Change A refers to pattern of key for lock.

1 sgl. 1¾-in. vest. sash door, 3 ft. by 7 ft. 6 in., rt. hd. 26-in. glass.
1½ prs. steel butts, 4½ by 4½, dull brass finish.
1 set cyl. vest. lock; knobs and escutcheons; Change A.

1 double sliding door, hall to parlor, 6 ft. by 7 ft. 6 in. opening.
3 sliding door pulls, dull brass finish.
6 cup escutcheons; no keyholes.

1 1¾-in. door, hall to coat closet, 2 ft. 6 in. by 7 ft.
1 pr. steel butts, 4 by 4, dull brass finish.
1 set 1-tumbler locks; knobs and escutcheons.

1 1¾-in. door, hall to back hall.
1 pr. butts, 4 by 4, Bower-Barff finish.
1 set thumb-bolt lock, knobs, and escutcheons; dull brass and Bower-Barff. Thumb-piece in front hall so servant is locked in servant's portion of the house.

1 1¾-in. double-acting door, dining room to butler's pantry.
1 set spring hinges, dull brass and Bower-Barff.
1 push-plate, dull brass finish.
1 push-plate, Bower-Barff finish.
1 door holder, Bower-Barff finish.
1 mortise thumb-bolt, dull brass finish.
Thumb-piece in dining-room to lock against servants.

1 1¾-in. door, kitchen to pantry.
1 pr. butts, 4 by 4, Bower-Barff finish.
1 set 1 tumbler lock, knob and escutcheons, Bower-Barff finish.

1 single-sliding door, hall to dining room, 3 ft. by 7 ft. 6 in. opening.

1 1¾-in., kitchen to basement.
1 pr. butts, 4 by 4, Bower-Barff finish.
1 set 1 tumbler lock, knob and escutcheon, Bower-Barff finish.
1 mortise thumb-bolt.

1 1¾-in. rear entrance door to kitchen.
1½ pr. butts, 4 by 4, Bower-Barff finish.
1 set 3-tumbler locks, knobs and escutcheons, plain bronze and Bower-Barff.
1 cyl. rim night latch. Change B.
1 door-fast.

Note: Change B is to differ from, yet to be passed by Change A, which are alike.

1 pr. 1¾-in. open-in French doors, porch to living room, open 90 degrees, 2 ft. by 7 ft. 6 in.
 3 pr. brass butts, 4½ by 4½, dull brass finish.
 2 lever extension bolts on edge, 12-in. and 18-in. rod.
 1 set thumb-bolt lock, 1⅝-in. backset; lever with oval rosette; outside knob with 2½-in. rosette, and thumb-knob inside for 2½-in. stiles with T astragal.

1 pr. 1¾-in. open-in French doors, porch to dining room, open 180 degrees, 2 ft. by 7 ft. 6 in.
 3 pr. brass butts, 4½ by 6, dull brass finish.
 2 flush extension bolts on face of door, 12-in. and 18-in.
 1 set thumb-bolt lock, 1⅝-in. backset; lever with oval rosette; outside knob with 2½-in, rosette, and thumb-knob inside for rabbet ½-in. deep, stiles 5-in. between glass.
 The above lock can be put in upside down, so hand of door need not be noted.

1 pr. 1¾-in. open-out French doors, 2 ft. by 7 ft. 6 in.
 3 pr. brass pin galvanized butts and screws, 4½ by 4½.
 2 flush extension bolts on face of door, 12-in. and 18-in., dull brass finish.
 1 set thumb-bolt lock, 2-in. backset, lever and oval rosettes both sides of door, with thumb-knob inside for 2½-in. stiles, with T astragal on outside.

1 pr. 1¾-in. open-in French windows on dining room, 2 ft. by 7 ft. 6 in.; open 90 degrees.
 3 pr. butts, brass, 4½ by 4½.
 1 Cremorne bolt, dull brass finish, 7 ft. 6 in. long, knob in middle.

1 single 1¾-in. open-in casement sash, dining room, 18-in. glass; open 90 degrees.
 1 pr. brass butts, 3½ by 3½ in.
 1 ring handle, fast with wide strikes.
 1 adjuster, 12-in. rod, stool depressed ⅝ in. and stool 2½ in. wide.

1 single 1¾-in. open-in casement sash, 18-in. glass; open 180 degrees.
 1 pr. Stanley parliament loose-pin butts, 6-in., dull brass.
 1 fast, as above.
 1 adjuster, as above.

1 pr. 1¾-in. open-in recessed casement sash; open 90 degrees.

2 pr. Stanley parliament loose-pin butts, 6 in.
2 flush-bolts, 6-in., having ⅝-in. angle.
1 fast, as above.
2 adjusters, as above.
1 single 1¾ open-out casement sash.
1 pr. brass-pin galv. butts, 3½ by 3½.
1 ring handle, fast with narrow strikes.
1 adjuster.
1 double-hung sash, front.
1 Diamond sash-fast, dull brass.
2 bar sash-lifts, dull brass.
1 jimmy-proof ventilating sash-stop.
1 double-hung sash, rear.
1 Diamond sash-fast, Bower Barff.
2 bar lifts.
1 jimmy-proof ventilating sash stop.
1 book-case, living room; 1 pr. 1⅛ doors; 2 single 1⅛ doors.
7 pr. butts, 2½ by 2.
1 elbow catch.
1 cabinet lock, ⅝-in. backset, right-hand for double door.
2 cabinet locks, ¾-in. backset, ½ right, for single glass door.
2 cabinet locks, 1¼-in. backset, ½ right, for panel door.
5 key-plates.
5 knobs for doors.
8 drawer-knobs for small drawers.
4 drop-handles for large drawers.
1 buffet, dining room; hardware similar to that for book-case above.
Cases, butler's pantry.
Butts, 3 by 3, on bin, hinged at bottom.
Butts on doors, 2½ by 2, Bower-Barff finish.
Elbow catches, japanned.
Cupboard turns, Bower-Barff finish.
3-ft. pieces Stanley rail, ¾-in.
Sheaves, No. 110 and screws on sliding doors.
Flush lifts, on sliding doors.
Drawer-pulls, on drawers and bin.
1 icing door on rear porch.
1 pr. galv. butts, 3½ by 3½, galv. screws.
1 flat-key night latch, reverse latch-bolt.
1 door-pull.

Second Floor

Dull brass in hall and chambers; nickel in bath; Bower-Barff in servants' part.

1 1¾-in. door, front hall to servants' hall.

1 pr. steel butts, 4 by 4, Bower-Barff finish.
1 set thumb-bolt lock, Bower-Barff knob and escutcheon, rear; octagon glass knob and thumb-knob in front hall.
1 1¾-in. door, hall to bath.
1 pr. butts, 4 by 4, nickel-plated.
1 set thumb-bolt lock octagon glass knobs; thumb-knob inside, key-plate outside.
Note: Thumb-knob spindle cut off to half the thickness of door, and the plug key is an emergency key from outside.
1 1¾-in. door, hall to chamber.
1 pr. butts, 4 by 4, dull brass finish.
1 set thumb-bolt lock, octagon glass knob; thumb-knob inside; key-plate on outside.
1 1⅜-in. closet door.
1 pr. butts, 4 by 4, dull brass finish.
1 set 3-tumbler lock, octagon glass knobs and key-plates.
1 1⅜-in. communicating door between chambers.
1 pr. butts, 4 by 4, dull brass.
1 set thumb-bolt lock, octagon glass knobs and thumb-knobs each side of door.
2 1⅜-in. doors from 2 chambers to 1 closet between same.
2 pr. butts, 4 by 4, dull brass.
2 sets thumb-bolt lock, octagon glass knob and thumb-knob one side of door.
Note: Put thumb-knob on chamber side of door.
2 1⅜-in. doors from 2 chambers to closet having wash-bowl in same.
Use same hardware as above.
1 1 ⅜-in. door to wash-bowl closet.
1 pr. butts, 4 by 4, dull brass finish.
1 set mortise latch, octagon glass knob with closet spindle inside.
1 1⅜-in. mirror door to wardrobe, 3-in. stile.
1 pr. butts, 4 by 4, dull brass finish.
1 set mortise latch, 1½-in. backset, knob as above.
1 1⅜-in. door, servants' part.
Same trimmings as kitchen.
Windows of all kinds.
No jimmy-proof sash-stops except over roofs.
1 single sliding communicating door, chamber to bath.
1 door-pull.
1 cup escutcheon, nickel; no keyhole.
1 cup escutcheon, dull brass; no keyhole.
1 Corbin ventilating bolt, nickel finish, No. 1408.

1 Corbin ventilating bolt, dull brass finish, No. 1408.
Put these bolts in the side of the near stile, and the plate on the sliding door stop.
1 wardrobe in chamber; 1 pr. 1⅛-in. doors; drawer below.
3 pr. butts, 3 by 3½, dull brass.
1 elbow catch at top.
1 bolt at bottom, 3-in.
1 half-mortise cupboard latch; 1-in. baskset and thumb-knob.
2 drawer handles.
1 medicine case.
1 pr. butts, 2½ by 2, nickel.
1 half-mortise cupboard latch; 1-in. backset and thumb-knob.
1 linen case, having drop fronts and 36-in. drawers.
Butts, 2½ by 2, dull brass finish.
Forge catches and screws, No. 11, two to each drop.
Drawer knobs, 1⅛-in., one to each drop.
Stanley desk slides, No. 430, 7½-in., one to each drop.
Drawer handles, two to each drawer.
1 1⅜-in. secret panel door.
1 pr. Soss hinges.
1 mortise latch in the jamb, no knob is required.
1 electric opener No. 151 in the door.
1 push-out spring No. 79 in door.
1 Mite push-button No. 63, located in some hidden place.
If secret door extends down to the floor and the base board is attached to the door, Soss hinges cannot be used. Use No. 53 Sargent sash-center; place it on the inside of the door about 3 in. from hinge edge.
Miscellaneous.
Base-knobs.
Floor door-stops.
Window and sliding door-stop screws and washers.
Coat and hat hooks.

SPECIFICATIONS FOR HARDWARE

Specifications for hardware generally form a part of the general specifications, but may be omitted and the selection reserved by the owner or architect. There are a great many plans governing the specifications when inserted, among which are the following:

1. Hardware specified definitely;
2. Hardware covered by a fixed allowance;

3. Hardware covered by allowing a fixed sum per opening.

Forms of specifications should be drawn up by an architect who is familiar with such papers. Contracts for furnishing the hardware, either by the contractor or by a dealer or manufacturer, may be obtained in blank form ready to fill in. These are carefully worded and cover the legal side of the transaction.

SIMPLE FORM OF CONTRACT

For small buildings, when the quantity and value of hardware involved is small, the following brief form may be used:

Contract for Furnishing Hardware

Contract made this ...... day of .... 19..., between ...., Owner, and ....,.........., Contractor. The Contractor agrees to furnish, and to deliver at ...., all of the hardware stated below, according to instructions, drawings, and specifications made by ...., Architect, for the sum of .... $......... The hardware covered by this contract is as follows:

(Here insert specifications.)

The owner agrees to pay the Contractor the said amount of ...., $......, as follows: .... The Contractor agrees that all hardware covered by this contract shall be of standard quality, material, and finish; that delivery of the same, complete, shall be made within .... weeks from the date when he shall have received all necessary instructions and detailed information; and that the decision of the Architect as to any and all questions relating thereto shall be final and binding upon the Contractor.

Sidewalks, Curbs, and Gutters

The common types of sidewalks consist of Portland cement concrete, bricks, asphalt, cinders, or gravel.

WIDTH OF WALK

The width of walks varies to some extent with their location. On residence streets in small cities, walks are generally from 4 to 6 ft. wide. For business streets and streets solidly built up with large buildings, walks will average 8 or 10 ft. in width, and in some cases even more.

SLOPE OF SURFACE OF WALKS

The surface of walks should have a slope varying from 1 in. in 3 ft. to 1 in. in 5 ft., depending upon the kind of walk. Smooth walks, like concrete, should have a slope of about 1 in. in 5 ft. of width, while the steeper slope is used on walks with a rough surface. The lower edge of hard-surface walks should be at least 2 in. above the ground level at the side of the walk, in order to allow perfect drainage for the surface.

CONCRETE SIDEWALKS

The ordinary type of concrete sidewalk should consist of a well-drained, porous sub-base or foundation; a base; and a wearing or surface coat, as shown in Fig. 1. The sub-base

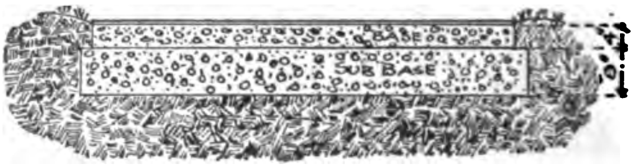

Fig. 1. Cross-Section of Cement Walk, Showing Various Parts.

or foundation is needed to provide a firm bed under the slab, so that it will be supported evenly at all points, thus preventing the formation of cracks in the slab due to unequal support at different places in the walk. This bed should be made not less than 6 in. deep, and of porous material, so that it can be easily drained in order to prevent collection of surface water under the slab and a resulting upheaval from the action of frost. In localities where the soil is sandy and easily drained, the sub-base is often done away with, and the concrete base placed directly upon a well-compacted excavation. The base, or slab proper, is composed of a medium mixture of concrete, and provides the body and strength of the walk. This base should be at least 4 in. thick.

The wearing coat is composed of a richer mixture of cement and sand, or cement and screenings, and is used as a covering for the main slab. For ordinary use, 1 in. is a common thickness. This covering serves two purposes: It resists wear to better advantage than the slab proper, and allows the application of a better finish on the surface of the walk.

In describing the construction of a cement sidewalk, let us begin with the sub-base and work up. The first step is to excavate to a depth of 11 in.—or more, if necessary—to provide for perfect drainage; ram and tamp the ground thoroughly and evenly; and partly fill the excavation with clean, large cinders, screened gravel, broken stone, or brick-bats, any of which should pass a 4-in.-mesh screen and be collected upon a 1-in. screen. The depth of this bed should be such that about 5 in. will be left above the filling to receive the walk. Tamp this drainage foundation well and evenly, wetting thoroughly while tamping. The bottom of

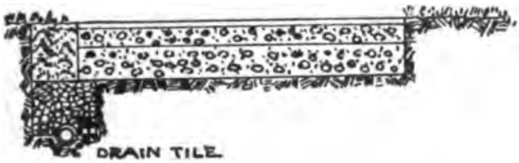

Fig. 2. Drainage of Foundation by Use of Ditch and Tile Drain.

the excavation made for this foundation should have a slope towards the curb of about ½ in. to the foot, in order to allow the water which may collect at the bottom of the trench to drain to one side of the trench, where it may be removed, either by a series of stone drains placed every 10 or 12 ft., or by means of a stone-filled ditch and tile drain, as shown in Fig. 2. A ditch of the type shown in Fig. 2 should be about 12 in. square and provided with 4-in. drain-tile. Care should also be taken to see that no roots of trees lie near bottom of foundation.

If the excavation trench contains any soft or spongy places, these should be removed, and the holes filled with firm material and packed solidly. When the ground on which the sidewalk is to be placed is uneven, and parts of the walk are constructed upon filled ground, care should be taken in making these fills. The filling material should be placed and tamped in layers about 6 in. thick, and in no case exceeding 10 in. in thickness. This fill should also extend at least 1 ft. beyond the borders of the foundation of the walk, to provide a support for the edge of the walk. The slope given to the sides of the fill is about 1 ft. rise to 1½ ft. horizontal extension.

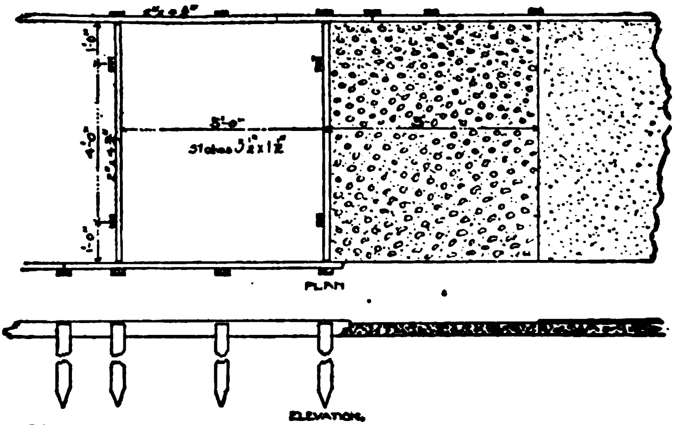

Fig. 3. Layout for Lumber Forms in Ordinary Sidewalk Construction.

After the foundation is completed, steel or lumber forms are placed as shown in Fig. 3 and Plate IV. These forms are used as an outline of the concrete part of the sidewalk, and serve to hold the base and wearing coat in place until the concrete has hardened sufficiently to hold its shape. The side parts of the forms should be made of such height that the top edge of the form may be used as a guide to the top grade of the finished walk. The side of the forms nearer the curb side of the walk should be set lower than the inner side, so as to allow a drainage slope of about ¼ in. to the foot across the width of the walk. The partitions shown in the figures should be placed in such a manner that no dimension of the base slab will be greater than 6 ft., and so that no individual slab will contain more than 36 sq. ft.

In the steel type of form, the cross-partitions are held in place by end-holding devices, and are adjustable for different lengths of slab. When lumber forms are used, it is common practice to hold the sides and partitions in place by stakes driven into the ground on the side opposite to that touched by the concrete, as shown in Fig. 3. All forms should be clean and free from old concrete.

When the forms have been placed and lined up to the proper slope and direction of the walk, metal forms should be smeared with some form of mineral oil or anti-sticking compound, and lumber forms should be wetted before the concrete for the base is poured into place. This concrete consists of a mixture of 1 part Portland cement, 2½ parts sand, and 5 parts broken stone of a quality described later in Paragraph 2 and 3 of the "Specifications for Cement Sidewalks." This concrete should be handled rapidly and in the manner described in Paragraph 30 of the Specifications. Where steel forms are not used, a steel parting strip, for separating individual slabs of the walk, may be used to advantage.

In some types of steel forms, the metal parting strip is left in place until that part of the sidewalk is completed and has taken on its initial set. Then, when the metal strips are removed, a clean joint ⅛ in. wide is left, extending through the entire thickness of the concrete. This joint provides for expansion and contraction, and allows each slab to become a separate member in itself. No large expansion joints are needed in such a walk. When lumber forms are used, and the concrete of each part of the walk is placed by using the end of the neighboring slab as a form, although distinct joints may exist, they are not of sufficient size to allow for expansion. In such a case, a ½-in. expansion joint should be left at intervals of 50 ft., and filled with paver's pitch or some like material, as described in Paragraphs 21 and 22 of the Specifications.

As soon as a part of the base is laid, it should be covered with canvas or tar paper to protect it from dirt or from too rapid drying out. After each batch of concrete is used in placing the base, and before the base has commenced to harden, the wearing coat should be placed and finished. This necessitates the mixing of small batches of concrete of not over 1 cu. yd. when placing the base, in order to be able to use all of the concrete mixed before the first slabs laid have hardened too much to receive the wearing coat with safety. The size of the batch will be regulated by the number of full slabs which may be filled in completely before the first slabs begin to harden, since it is not good policy to leave off placing concrete at a point between the dividing strips. If part of a batch of concrete is left over from one lot of slabs, do not use it on the next if it shows perceptible hardening or drying out. A small amount of concrete saved in this way may ruin the job.

When placing the wearing coat, care should be taken to see that the top surface of the base is fresh, clean, and damp. Any part which has set should be taken up and put down again new for best results. As specified, this surface coat consists of 1 part of Portland cement and not more than 2 parts of fine aggregate, such as sand or screenings. A thickness of about ¾ in. or 1 in., for ordinary work, is placed on the base, and leveled down with a straight-edge to bring all parts of the surface to grade. The finish is applied as described in Paragraph 36 of the Specifications.

Care must be taken not to trowel this wearing coat to such an extent that neat cement will be flushed to the surface. The result, in that case, would be the formation of hair-cracks and crazing.

Where lumber forms are used, it is customary to locate the joints in the base by marking the side forms. In this way the joints are usually located when cutting through the wearing surface in the process of finishing. Care should be taken to see that these cuts extend through the entire slab.

Always end a day's work at the end of a slab. An exterior joint will mean a crack at that point at some later time.

Do not allow any part of the walk to bear directly against any solid body, such as stone curb, building, post, manhole rim, etc. Leave about ¼ in. between the sidewalk slab and such bodies. This space may be obtained during construction by the use of thick tar paper or felt, waterproofed with any of the reliable waterproof paints; and such precautions may prevent disastrous cracks due to expansion and contraction of the neighboring bodies because of temperature changes.

Where a sidewalk is exposed to severe wearing conditions, the base should be made at least 6 in. thick, and the wearing coat 1 in. or over in thickness. At crossings, the wearing coat should be 1½ in. or over.

As soon as finished, the walk should be kept covered with canvas or tar paper to protect it from the rays of the sun and from the wind, in order that the concrete may not dry out too quickly. This covering should be weighted down, and raised a few inches so as not to touch the surface of the walk. After the concrete has set hard, the walk may be sprinkled two or three times a day for a week or more. Some builders use a covering of sand, removing it when the walk has thoroughly hardened. Such a covering gives good protection, if of sufficient depth. The sand tends to hold the moisture in the concrete and thus aid the process of hardening.

If a color other than the natural color of concrete is desired, lampblack or mineral colors may be mixed dry with the materials for forming the wearing coat. Proportions of mineral colors range from 2 to 5 per cent of the weight of the cement used, depending upon the intensity of color desired.

The difficulty met with in the use of colors is to maintain a uniform color throughout the job. Lampblack is probably more commonly used than any other color, giving different shades of gray according to the amount used. For instance, in the case of a 1:2 mortar, the addition of one-half pound of dry lampblack to 100 pounds of cement will give a light slate color to the work; one pound will give a light gray color; two pounds, a blue gray; and four pounds will produce a dark blue slate color. A color best suited to a particular piece of work should be obtained by experiment with small quantities made up into trial specimens, before being applied to the real construction.

Specifications for Cement Sidewalks.

The following specifications were presented at the annual convention of the National Association of Cement Users in Kansas City, Mo., in March, 1912, and are considered to represent the best current practice. The reader will see that the directions included are sufficient for the intelligent carrying-out of a piece of work.

1. **Cement.** The cement shall meet the requirements of the Standard Specifications for Portland Cement of the American Society for Testing Materials and adopted by this Association.

2. **Fine Aggregate.** Fine aggregate shall consist of sand, crushed stone, or gravel screenings, graded from fine to coarse, and passing when dry a screen having ¼-in. diameter holes; shall be preferably of siliceous material, clean, coarse, free from dust, soft particles, loam, vegetable or other deleterious matter; and not more than 3 per cent shall pass a sieve having 100 meshes per linear inch. Fine aggregate shall be of such quality that mortar composed of 1 part Portland cement and 3 parts fine aggregate by weight, when

made into briquettes, will show a tensile strength at least equal to the strength of 1:3 mortar of the same consistency, made with the same cement and Standard Ottawa sand. In no case shall fine aggregate containing frost or lumps of frozen materials be used.

3. **Coarse Aggregate.** Coarse aggregate shall consist of inert materials, such as crushed stone or gravel, graded in size, retained on a screen having ¼-in. diameter holes; shall be clean, hard, and durable; free from dust, vegetable or other deleterious matter; and shall contain no soft, flat, or elongated particles. In no case shall coarse aggregate containing frost or lumps of frozen material be used. The maximum size of coarse aggregate shall be of such size as to pass a 1¼-in. ring.

4. **Natural Mixed Aggregates.** Natural mixed aggregates shall not be used as they come from the deposit, but shall be screened and remixed, to agree with the proportions specified.

5. **Sub-Base.*** Only clean, hard, suitable material, not exceeding 4 in. in the largest dimension, shall be used.

When a sub-base is not required, eliminate Paragraphs 5 and 10 (a).

Unless paragraph 10 (a) is eliminated, 10 (b) is void.

6. **Water.** Water shall be clean, free from oil, acid, alkali, or vegetable matter.

7. **Coloring.** If artificial coloring material is required, only mineral colors shall be used.

8. **Reinforcing Metal.** The reinforcing metal shall meet the requirements of the Standard Specifications for Steel Reinforcement adopted March 16, 1910, by the American Railway Engineering Association.

Sub-Grade

9. **Slope.** The sub-grade shall have a slope toward the curb of not less than ⅛ in. per foot.

10. **Depth.** (a) The sub-grade shall not be less than 11 inches below the finish surface of the walk;

(b) The sub-grade shall not be less than 5 inches below the finished surface of the walk.

11. **Preparation.** All soft and spongy places shall be removed, and all depressions filled with suitable material, which shall be thoroughly compacted in layers not exceeding 6 in. in thickness.

12. **Deep Fills.** When a fill exceeding 1 ft. in thickness is required to bring the work to grade, it shall be made in

*Note—When a sub-base is required, eliminate Paragraph 10 (b).

a manner satisfactory to the engineer. The top of all fills shall extend beyond the walk on each side at least 1 ft., and the sides have a slope not greater than 1 on 1½.

13. **Drainage.** When required, a suitable drainage system shall be installed and connected with sewers or other drains indicated by the engineer.

Sub-Base

14. **Width and Thickness.** On the sub-grade shall be spread a suitable material, as heretofore stated, which shall be thoroughly rolled or tamped to a surface at least 5 in. below the finished grade of the walk. On the fills the sub-base shall extend the full width of the fill, and the sides shall have the same slope as the sides of the fill.

15. **Wetting.** While compacting the sub-base, the material shall be kept thoroughly wet, and shall be in that condition when the concrete is deposited.

Forms

16. **Materials.** Forms shall be free from warp, and of sufficient strength to resist springing out of shape.

17. **Setting.** The forms shall be well staked or otherwise held to the established lines and grades, and their upper edges shall conform to the established grade of the walk.

18. **Treatment.** All wood forms shall be thoroughly wetted, and metal forms oiled before depositing any material against them. All mortar and dirt shall be removed from forms that have been previously used.

Construction

19. **Size of Slabs.** The slabs or independently divided blocks, when not reinforced, shall have an area of not more than 36 sq. ft., and shall not have any dimension greater than 6 ft. Larger slabs shall be reinforced as hereinafter specified.

20. **Thickness of Walk.** The thickness of the walks should not be less than 5 in. for residence districts, and not less than 6 in. for business districts.

21. **Width and Location of Joints.** A ½-in. expansion joint shall be provided at least once in every 50 ft.

22. **Joint Filler.** The expansion joint filler shall be a suitable elastic waterproof compound that will not become soft and run out in hot weather, nor hard and brittle, and chip out in cold weather.

23. **Protection of Edges.** Unless protected by metal, the upper edges of the concrete shall be rounded to a radius of ½ in.

Measuring and Mixing

24. **Measuring.** The method of measuring the materials for the concrete, including water, shall be one which will insure separate uniform proportions at all times. A sack of Portland cement (94 pounds net) shall be considered 1 cu. ft.

25. **Machine Mixing.** When the conditions will permit, a machine mixer of the type that insures the uniform proportioning of the materials throughout the mass shall be used. The ingredients of the concrete or mortar shall be mixed to the desired consistency, and the mixing shall continue until the cement is uniformly distributed and the mass is uniform in color and homogeneousness.

26. **Hand Mixing.** When it is necessary to mix by hand, the materials shall be mixed dry on a water-tight platform until the mixture is of uniform color, the required amount of water added, and the mixing continued until the mass is uniform in color and homogeneousness.

27. **Retempering.** Retempering, that is, remixing mortar or concrete that has partially hardened, with additional water, will not be permitted.

Two-Course Walks

Base

28. **Proportions.** The concrete shall be mixed in the proportion of 1 sack of Portland cement, 2½ cu. ft. fine aggregate, and 5 cu. ft. coarse aggregate.

29. **Consistency.** The materials shall be mixed wet enough to produce a concrete of a consistency that will flush readily under slight tamping, but which can be handled without causing a separation of the coarse aggregate from the mortar.

30. **Placing.** After mixing, the concrete shall be handled rapidly, and the successive batches deposited in a continuous operation, completing individual sections. Under no circumstances shall concrete be used that has partially hardened. The forms shall be filled, and the concrete struck off, and tamped to a surface the thickness of the wearing course below the established grade of the walk. After the concrete has been thoroughly tamped against the cross-forms, they shall be removed, and the material for the adjoining slab deposited, so as to preserve the joint. Workmen shall not be permitted to walk on the freshly laid concrete; and if sand or dust collects on the base, it shall be carefully removed before the wearing course is applied.

31. **Reinforcing.** Slabs having an area of more than 36 sq. ft., or having any dimension greater than 6 ft., shall be

reinforced with wire fabric or with plain or déformed bars. The cross-sectional area of metal shall amount to at least 0.041 sq. in. per linear foot. The reinforcing metal shall be placed upon and slightly pressed into the concrete base immediately after the base is placed. Reinforcing metal shall not cross joints, and shall be lapped sufficiently to develop the strength of the metal.

Wearing Course

32. **Proportions.** The mortar shall be mixed in the manner hereinbefore specified, in the proportion of 1 sack Portland cement, and not more than 2 cu. ft. of fine aggregate.

33. **Consistency.** The mortar shall be of a consistency that will not require tamping, but which can be easily spread into position.

34. **Thickness.** The wearing course of the walk in residence districts shall have a minimum thickness of ¾ in., and in a business district a minimum thickness of 1 in.

35. **Placing.** The wearing course shall be placed immediately after mixing, and in no case shall more than 50 minutes elapse between the time the concrete for the base is mixed and the time the wearing course is placed.

36. **Finishing.** After the wearing course has been brought to the established grade, it shall be worked with a wood float in a manner that will thoroughly compact it. When required, the surface shall be troweled smooth, but excessive working with a steel trowel shall be avoided. The slab markings shall be made in the wearing course directly over the joints in the base, with a tool which will completely separate the wearing course of adjacent slabs. If excessive moisture occurs on the surface, it must be taken up with a rag or mop, and in no case shall dry cement or a mixture of dry cement and sand be used to absorb this moisture or to hasten the hardening. Unless protected by metal, the surface edges of all slabs shall be rounded to a radius of about one-half inch.

37. **Coloring.** If artificial coloring is used, it must be incorporated with the entire wearing course, and shall be mixed dry with the cement and aggregate until the mixture is of uniform color. In no case shall the amount of coloring used exceed 5 per cent of the weight of the cement.

One-Course Walk

The general requirement of the Specifications covering two-course work will apply to one-course work, with the following exceptions:

38. **Proportions.** The concrete shall be mixed in the pro-

›n of 1 sack Portland cement to 1½ cu. ft. of fine ag- te, and 3 cu. ft. of coarse aggregate passing a 1-in. ring.

. **Placing and Finishing.** The form shall be filled, the ete struck off, and the coarse particles forced back from urface, and the work finished in the usual way.

. **Reinforcing.** When a single-course walk is to be rein- l, the metal shall be placed 2 in. from the finished sur- The minimum amount of metal shall be as specified in ;raph 31.

Protection

. **Treatment.** When completed, the work shall be kept and protected from traffic and the elements for at least days, and shall not be opened to traffic until the en- r so directs.

Temperature below 35 Deg. F. If at any time during :ogress of the work the temperature is, or in the opinion ə engineer will within 24 hours drop to 35 deg. F., the and aggregates shall be heated, and precautions taken otect the work from freezing, for at least 5 days. In se shall concrete be deposited upon a frozen sub-grade b-base.

Equipment Needed for Sidewalk Work

ır hand work on small jobs, the articles needed are: a g board; runways to and from the same; a measuring or proportioning sand and aggregates; a No. 3 square- shovel for each man, wheelbarrows, at least two being sary for quick work (sheet-iron body preferred); a rake; ter barrel; water buckets, 2-gallon size; and a sand ı, made by nailing a piece of ¼-in.-mesh wire screen. y 5 ft. in size, to a frame made of 2 by 4-in. lumber.

ıe tools needed for work upon the walk itself will con- ıf a tamper, straight-edge, wood float, mason's trowel. :hing trowel, edger, jointing tool, and line or dotting if specified. These tools may be obtained with long ort handles as the workman prefers.

ıe batch will be mixed on a wooden platform known :oncrete board. For two men, this should be 9 ft. by 10 : a 2-bag batch, or 12 by 10 ft. for a 4-bag batch. Make : of 1-in. boards 10 ft. long, surfaced on one side, using ! by 4-in. by 9-ft. cleats to hold them together. The s are so laid as to enable the shoveling to be done with, ıot against, the cracks between the boards. The boards be drawn up close in nailing, so that no cement grout will run through while mixing. If tongued-and-grooved boards are available, so much the better. Knotholes may be closed by nailing a strip across them, on the under side of the board. Often 2-in. planks are used in making concrete boards, but these are unnecessarily heavy, and very cumbersome to move.

The concrete board is usually best placed as close as possible to the forms in which the concrete is to be deposited, but local conditions must govern this point. Choose a place giving plenty of room, near the storage piles of sand and stone (or gravel). Block up the concrete board level, so that the cement grout will not run off on one side, and so that the board will not sag in the middle under the weight of the concrete.

Make the runways for the wheelbarrows of good, strong plank 2 to 3 in. thick and 10 to 12 in. wide. They should be of liberal width—say at least 20 in. wide if lifted much above the ground—as this feature will help greatly to lighten and quicken the work.

COST OF CONCRETE WALKS

Figures indicating the cost of different types of sidewalks, and data for calculating quantities of material needed for their construction, compiled by the Information Bureau of the Universal Portland Cement Company, are as follows:

The cost of cement walk will vary with the cost of materials and labor, and with the experience of the men doing the work; also with the location of the walk, the amount of walk to be placed at one time, and its width. The cost of materials given below includes delivery on the work.

Two-Course Sidewalk. Experience shows that a gang of six men can lay between 600 and 800 sq. ft. of walk in a day of ten hours; and 700 sq. ft. is considered as a day's work in arriving at these figures. This estimate is based on a 6-ft. walk, having 9-in. cinder sub-base, 4¼-in. base consisting of 1 part cement, 2½ parts sand, and 5 parts crushed stone, covered with a ¾-in. top of 1 part cement and 1½ parts sand. The stone ranged in size from ¼ to ¾ in. and contained 45 per cent voids. A good grade of coarse sand passing a ¼-in. screen was used. The sand contained 33 per cent voids. The mixing was done by hand.

LABOR (TWO-COURSE)

One finisher at $5.00 per day	$ 5.00
Five laborers at $2.50 per day	12.50
Total cost of labor (700 sq. ft.)	$17.50

Total cost of labor per 100 sq. ft.		$ 2.50

MATERIALS (TWO-COURSE)

Cement 2.5 barrels at $1.50 per barrel.......	$ 3.75	
Stone 1.21 cu. yds. at $1.50 per cu. yd. ...	1.82	
Sand .80 cu. yd. at $1.25 per cu. yd. ...	1.00	
Cinders 2.7 cu. yds. at $0.50 per cu. yd.	1.35	
Total cost of materials per 100 sq. ft. ...		7.92
Total cost of laying 100 sq. ft.		$10.42

It should be noted that this estimate provides for a walk where an excavation for the sub-base was necessary. No addition was made for cost of forms or equipment depreciation.

One-Course Sidewalk. The cost of placing one-course work is probably less than for the two-course; but, for comparison, the labor and cost of materials have been considered the same and the calculations made accordingly.

LABOR (ONE-COURSE)

One finisher at $5.00 per day	$ 5.00	
Five laborers at $2.50 per day	12.50	
Total cost of labor for 700 sq. ft.	$17.50	
Total cost of labor per 100 sq. ft.		$ 2.50

MATERIALS (ONE-COURSE)

Cement 2.42 barrels at $1.50 per barrel......	$ 3.63	
Stone 1.08 cu. yds. at $1.50 per cu. yd. ...	1.62	
Sand .73 cu. yds at $1.25 per cu. yd. ...	.91	
Cinders 2.7 cu. yds. at $0.50 per cu. yd. ...	1.35	
Total cost of materials per 100 sq. ft. ..		$ 7.51
Total cost of laying 100 sq. ft.		$10.01

Concrete Sidewalk on Limestone Flags

In some of the business districts of our larger cities, the old limestone flags are fast wearing out making replacement necessary. A great deal of expense may be saved, provided the flags are of sufficient thickness, by laying a mortar top, not less than 2 in. thick, directly upon the limestone. It is necessary to clean the surface thoroughly by chipping, and anchor a steel plate to the flags for the curb edge. The application of a cement-granite screenings top completes the work, and has proven successful in several instances.

Sidewalk Calculations

Number of cubic yards of concrete in 100 sq. ft. of sidewalk:

3 in. thick=0.926;	4½ in. thick=1.389;
3½ in. thick=1.080;	5 in. thick=1.543;
4 in. thick=1.235;	¾ in. thick=0.232;
4¼ in. thick=1.312;	1 in. thick=0.309;

Assuming 1 sack cement=1 cu. ft., 1 cu. yd. of concrete requires for:

Mixture	Bbls. Cement	Cu. Yds. Sand	Cu. Yds. Gravel
1:1½:3	1.91	0.42	0.85
1:2 :3	1.74	0.52	0.77
1:2 :4	1.51	0.45	0.89
1:2½:4½	1.31	0.48	0.87
1:2½:5	1.24	0.46	0.92
1:3 :5	1.16	0.52	0.86
1:1	4.88	0.72	
1:1½	3.87	0.86	

Example—Two-course sidewalk 400 ft. long, 5 ft. wide, 4¼-in. base mixture 1:2½:5, ¾-in. top mixture 1:1½.

Area sidewalk—400x5=2,000 sq. ft.

Base—

Cubical contents—20.00x1.312=26.2 cu. yds.

26.2 { x 1.24=32½ barrels cement
x 0.46=12 cu. yds. sand
x 0.92=24 cu. yds. gravel

Top—

Cubical contents—20.00 x .232=4.64 cu. yds.

4.64 { x 3.87=18 barrels cement
x 0.86= 4 cu. yds. sand

Total—

32½+18=50½ barrels cement
12 + 4=16 cu. yds. sand
24 + 0=24 cu. yds. gravel

Example: One-course sidewalk as above 400 ft. long, 5 ft. wide, 4½ in. thick, mixture 1:2:3.

Area sidewalk—400 x 5=2,000 sq. ft.

Cubical contents—20.00 x 1.389=27.8 cu. yds.

27.8 { x 1.74=48.3 barrels cement
x 0.52=14.5 cu. yds. sand
x 0.77=21.4 cu. yds. gravel

Average Costs for Estimating

Concrete sidewalks, finished with mortar of sand and cement, granite screenings and cement, etc., 10 to 25 cents per sq. ft. Mortar finish alone, 5 to 15 cents per sq. ft.

A common contract price for concrete sidewalks, small jobs, is 15 to 20 cents per sq. ft. Large paving work can be done at an actual cost of about 10 cents per sq. ft.

BRICK WALKS

Brick walks are used in a great many localities, and, if properly constructed, are cheap and durable.

The construction of a brick sidewalk consists of an excavation from 8 to 10 in. deep, depending upon the condition of the soil, care being taken that all soft material is removed, and that the subgrade is made parallel to the surface of the finished walk. The foundation used in this excavation consists of a layer of clean, course sand, fine gravel, or cinders which furnish a firm support for the bricks. This material should be thoroughly rolled or tamped so as to compress it into a firm layer. Where gravel or cinders are used, a layer of sand from 1½ to 2 in. deep is placed in the excavation on top of the fill, to serve as a cushion for supporting the bricks.

The bricks used in this class of work are hard-burned, with plane, parallel surfaces and sharp, right-angled edges. The bricks are laid either with the large surface up for light traffic, or set on edge where heavy traffic is to be met. The method of laying the pattern of the brickwork may be varied in design, and a pleasing effect may be obtained by introducing different colored bricks if desired. The side of the walk is protected by laying a row of bricks on edge to form a border. Joints between bricks should be thin to prevent weeds and grass from growing up in the walk.

In laying the bricks, it is customary to place 2 by 4 timbers along each side of the foundation, lined up so that the top edges are flush with the top of the finished walk. The 2-in. layer of sand is then placed on the foundation, and leveled off parallel to the surface of the finished walk. The bricks are then laid by men standing on the bricks already in position, so as not to disturb the sand cushion ahead of the work in progress. The surface of the finished walk is then carefully and thoroughly rammed or tamped so as to settle all of the bricks into the sand cushion and form a level surface at the top. The final operation consists in sprinkling a layer of fine, dry sand over the top of the walk, and allowing about ¼-in. of sand to remain on the top surface to be worked into the joints by traffic.

The **cost of brick sidewalks** will be made up in detail of the following points: Cost of excavation and preparation of bed; cost of bricks per thousand; cost of sand and material for filling in foundation, and cost of labor in placing materials. The cost of excavation and preparation of bed will be found in the section on "Excavation" earlier in this volume. The number of bricks needed to lay a square yard of sidewalk will be found in Table 1 in the section on "Roads and Pavements." The cost of labor in placing the sand cushion and laying the bricks will be about 5 cents per sq. yd. of top surface.

ASPHALT WALKS

The construction of asphalt sidewalks is practically the same as that for asphalt pavements described on page 702 in the section on "Roads and Pavements," except that the foundation does not need to be so heavy, nor the wearing coat so thick. A soft mixture of asphalt is used in the wearing coat, since this coat is not required to bear heavy loads such as would come upon a pavement. The softer the mixture so long as it is suitable for working purposes, the better for use in sidewalk work, and the longer its life. This type of walk is unsuitable for locations where walks are used but little, since cracks which form from the contraction and expansion of the walk are not closed again by the effects of travel.

The cost of an asphalt walk consisting of a concrete base 3 in. thick and an asphalt wearing coat 1 in. thick, is about $1.00 per sq. yd., exclusive of the cost of grading or preparation for laying.

One ton of prepared rock-asphalt will cover about 26 sq. yds. 1 in. thick where grit is not used, and about 33 sq. yds. when about 25 per cent of grit is mixed in with the asphalt. Other thicknesses of wearing coat would be estimated in proportion to the above amounts.

A skilled workman will lay from 12 to 15 sq. yds. of asphalt pavement or sidewalk per hour.

CINDER WALKS

Cinder walks are constructed by excavating a trench 6 in. or more in depth, and filling same with a layer of cinders in which the larger particles are well embedded in the body of the fill. The fill is then flooded and tamped thoroughly to embed the smaller particles in the larger. The surface of a walk of this kind is given considerable crown, and small gutters are needed at the sides to provide drainage. Cinder walks are not considered to be so satisfactory as gravel or other similar types of walks.

GRAVEL WALKS

Gravel walks are serviceable where traffic is light, and where a cheap type of walk is desired. The construction of a gravel walk consists of an excavated trench about 5 in. deep, with bottom of trench parallel to surface of the finished walk. The lower part of a walk of this kind consists of 3 or 4 in. of crushed stone or gravel of small dimensions, which is rolled into place with a heavy roller in a manner similar to that followed in the construction of a macadam road. The wearing surface consists of about ½ in. of fine gravel or torpedo sand having grains not over ¼-in. in dimension. The edges of the finished surface should be about ½-in. below the adjoining lawn-surface when finished.

In clayey soils, it may be necessary to excavate a deeper trench, and lay a foundation bed of cinders upon which the crushed stone or gravel is placed.

CURBS AND GUTTERS

Since concrete is fast becoming the material used in curb and in curb-and-gutter construction, the data embodied in the following specifications will form a basis for determining the necessary points of design for standard types of construction. Figs 4 and 5 show these standard types for both plain curb and combined curb and gutter.

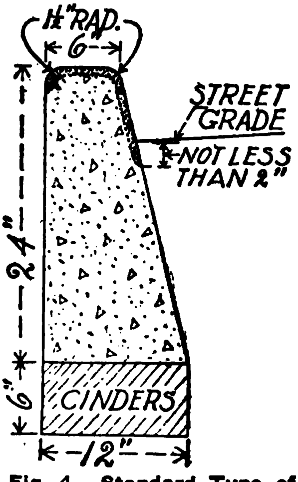

Fig. 4. Standard Type of Concrete Curb.

PROPOSED REVISED STANDARD SPECIFICATIONS FOR CONCRETE CURB, AND CONCRETE CURB AND GUTTER

Presented to the National Association of Cement Users, December, 1912

MATERIALS

1. **Cement.** The cement shall meet the requirements of the Standard Specifications for Portland Cement of the American Society for Testing Materials and adopted by this Association.

2. **Fine Aggregate.** Fine aggregate shall consist of sand, crushed stone or gravel screenings, graded from fine to coarse, and passing when dry a screen having ¼-in. diameter holes; shall be preferably of silicious material, clean, coarse, free from dust, soft particles, loam, vegetable or other deleterious

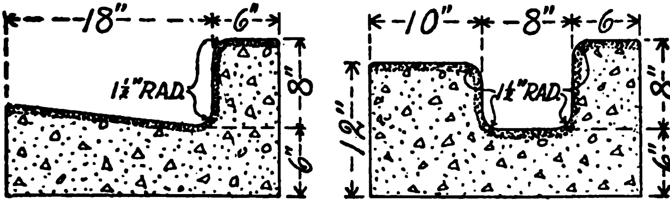

Fig. 5. Standard Types of Combined Curb and Gutter.

matter; and not more than 3 per cent shall pass a sieve having 100 meshes per linear inch. Fine aggregate shall be of such quality that mortar composed of 1 part Portland cement and 3 parts fine aggregate by weight, when made into briquettes, will show a tensile strength at least equal to the strength of 1:3 mortar of the same consistency made with the same cement and Standard Ottawa sand. In no case shall fine aggregate containing frost or lumps of frozen material be used.

3. **Coarse Aggregate.** Coarse aggregate shall consist of inert materials such as crushed stone or gravel graded in size, retained on a screen having ¼-in. diameter holes; shall be clean, hard and durable, free from dust, vegetable, or other deleterious matter, and shall contain no soft, flat, or elongated particles. In no case shall coarse aggregate containing frost or lumps of frozen material be used. The maximum size of coarse aggregate shall be such as to pass a 1¼-in ring.

4. **Natural Mixed Aggregate.** Natural mixed aggregates shall not be used as they come from the deposit, but shall be screened and remixed to agree with the proportions specified.

5. **Sub-Base.** Only clean, hard, suitable materials, not exceeding 4 in. in the largest dimension shall be used.

6. **Water.** Water shall be clean, free from oil, acid, alkali, or vegetable matter.

7. **Coloring.** If artificial coloring material is required, only mineral colors shall be used.

SUB-GRADE

8. **Depth below Grade.** (a) **Concrete Curb.** When a sub-base is required, the sub-grade shall not be less than 30 in. below the established grade of the curb.

(b) **Concrete Curb and Gutter.** When a sub-base is required, the sub-grade shall not be less than 11 in. below the established grade of the gutter.

9. **Preparation.** All soft and spongy places shall be removed, and all depressions filled with suitable material which shall be thoroughly compacted in layers not exceeding 6 in. in thickness.

10. **Deep Fills.** When a fill exceeding 1 ft. in thickness is required to bring the work to grade, it shall be made in a manner satisfactory to the engineer.

11. **Drainage.** When required, a suitable drainage system shall be installed and connected with sewers or other drains indicated by the engineer.

SUB-BASE

12. **Thickness.** (a) **Concrete Curb.** On the sub-grade shall be spread a material as hereinbefore specified, which shall be thoroughly rolled or tamped to a surface at least 24 in. below the established grade of the curb.

(b) **Concrete Curb and Gutter.** On the sub-grade shall be spread a material as hereinbefore specified, which shall be thoroughly rolled or tamped to a surface at least 6 in. below the established grade of the gutter.

13. **Wetting.** While compacting the sub-base, the material shall be kept thoroughly wet, and shall be in that condition when the concrete is deposited.

FORMS

14. **Materials.** Forms shall be free from warp and of sufficient strength to resist springing out of shape.

15. **Setting.** The forms shall be well staked or otherwise held to the established lines and grades, and their upper edges shall conform to the established grade of the curb or curb and gutter.

16. **Treatment.** All wood forms shall be thoroughly wetted, and metal forms oiled, before depositing any material against them. All mortar and dirt shall be removed from forms that have been previously used.

CONSTRUCTION

17. **Dimension of Curb.** The section of the curb shall conform with that shown in Fig. 4. The thickness at the base shall not be less than 12 in., and at the top not more than 6 in., with a batter on the street side of 1 to 4.

18. **Dimensions of Curb and Gutter.** The sections of the combination curb and gutter shall conform with that shown in Figure 5. The depth of the back of the curb shall not be less than 12 in., and the depth of the face not less than 6 in. The breadth of the gutter shall not be less than 16 in., nor more than 24 in.

19. **Size of Sections.** The curb and gutter shall be divided into sections not less than 5 nor more than 8 ft. long by some method which will insure the complete separation of the sections.

20. **Section at Street Corners.** The construction of the combination curb and gutter at street corners shall conform with that shown in Figure 5. The radius of the curb shall not be less than 6 ft.

21. **Width and Location of Joints.** A ½-in. expansion joint shall be provided at least once in every 150 ft.

22. **Joint Filler.** The expansion joint filler shall be a suitable, elastic, waterproof compound that will not become soft and run out in hot weather, nor hard and brittle and chip out in cold weather.

23. **Protection of Edges.** Unless protected by metal, the upper edges of the concrete shall be rounded to a radius of ½ in.

MEASURING AND MIXING

24. **Measuring.** The method of measuring the materials for the concrete, including water, shall be one which will insure separate uniform proportions at all times. A sack of Portland cement (94 lbs. net) shall be considered 1 cu. ft.

25. **Machine Mixing.** When the conditions will permit, a machine mixer of a type which insures the uniform proportioning of the materials throughout the mass, shall be used. The ingredients of the concrete or mortar shall be mixed to the desired consistency, and the mixing shall continue until the cement is uniformly distributed and the mass is uniform in color, and homogeneous.

26. **Hand Mixing.** When it is necessary to mix by hand, the materials shall be mixed dry on a water-tight platform until the mixture is of uniform color and the required amount

of water added, and the mixing continued until the mass is uniform in color, and homogeneous.

27. **Retempering**—that is, remixing mortar or concrete that has partially hardened with additional water—will not be permitted.

TWO-COURSE CURB AND CURB AND GUTTER

Base

28. **Proportions.** The concrete shall be mixed in the proportion of 1 sack Portland cement, 2½ cu. ft. fine aggregate, and 5 cu. ft. coarse aggregate.

29. **Consistency.** The materials shall be mixed wet enough to produce a concrete of a consistency that will flush readily under slight tamping, but which can be handled without causing a separation of the coarse aggregate from the mortar.

30. **Placing.** After mixing, the concrete shall be handled rapidly, and the successive batches deposited in continuous operation completing individual sections. Under no circumstances shall concrete be used that has partially hardened. The gutter forms shall be filled, and the concrete struck off and tamped to a surface the thickness of the wearing course below the established grade of the gutter. The concrete for the curb shall be placed and tamped so as to permit of the application of the required wearing course to the face and top so as to bring the work to the established line and grade of the curb. The work shall be executed in a manner which will insure perfect joints between abutting sections. Workmen shall not be permitted to walk on freshly laid concrete; and, if sand or dust collects on the base, it shall be carefully removed before the wearing course is applied.

Wearing Course

31. **Proportions.** The mortar shall be mixed in the manner hereinbefore specified in the proportion of 1 sack Portland cement and not more than 2 cu. ft. of fine aggregate.

32. **Consistency.** The mortar shall be of a consistency that will not require tamping but which can be easily spread into position.

33. **Thickness.** The wearing course of the gutter and top and face of the curb shall have a minimum thickness of ¾ in.

34. **Placing.** The wearing course shall be placed immediately after mixing, and in no case shall more than 50 minutes elapse between the time the concrete for the base is mixed and the time the wearing course is placed.

35. **Finishing.** After the wearing course has been brought

to the established line and grade, it shall be worked with a wood float in a manner which will thoroughly compact it. When required, the surface shall be troweled smooth, but excessive working with a steel trowel shall be avoided. The section markings shall be made in the wearing courses directly over the joints in the base, with a tool which will completely separate the wearing courses of adjacent sections. If excessive moisture occurs on the surface, it must be taken up with a rag or mop; and in no case shall dry cement or a mixture of dry cement and sand be used to absorb this moisture or to hasten the hardening. The edge of the curb on the street side, and the intersection of the curb and gutter, shall be rounded to a radius of about 1½ in. All other edges shall be rounded to a radius of ⅜ in. unless protected by metal.

36. **Coloring.** If artificial coloring is used, it must be incorporated with the entire wearing course, and shall be mixed dry with the cement and aggregate until the mixture is of uniform color. In no case shall the amount of coloring used exceed 5 per cent of the weight of the cement.

ONE-COURSE CURB AND ONE-COURSE CURB AND GUTTER

The general requirements of the specifications covering two-course work will apply to one-course-work, with the following exceptions:

37. **Proportions.** The concrete shall be mixed in the proportion of 1 sack Portland cement and not more than 2 cu. ft. of fine aggregate, and 3 cu. ft. of coarse aggregate passing a 1-in. ring.

38. **Placing and Finishing.** The forms shall be filled, the concrete struck off, and the coarse particles forced back from the surface, and the work finished in usual way.

Protection

39. **Treatment.** As soon as the concrete has hardened sufficiently to prevent being pitted, it shall be sprinkled with clean water, and kept wet for at least 4 days. The work shall not be opened to traffic until the engineer so directs.

40. **Temperature below 35 Degrees F.** If at any time during the progress of the work, the temperature is, or in the opinion of the engineer will within 24 hours drop to 35 degrees F., the water and aggregates shall be heated and precautions taken to protect the work from freezing for at least 5 days. In no case shall concrete be deposited upon a frozen sub-grade or sub-base.

COST OF CURBS AND GUTTERS

The cost of curbs and combined curbs and gutters depends upon the cross-section of the work and the materials used. It is very difficult to give a price which is of any real value, on account of this great variation.

The labor cost on curb and combined curb and gutter will vary from 10 to 15 cents per linear foot where finishers are paid $5.00 and laborers $2.50 per day.

The cost of materials can be determined by finding the number of cu. ft. of volume in a given length of the curb, or curb and gutter, and then determining the quantity of cement, sand, and gravel or crushed stone needed from a table of quantities similar to that given in the section on "Concrete Construction."

A rough estimate for concrete curb, and curb and gutter, as just described would be from 25 to 50 cents per linear foot.

Prices for other kinds of curbing will vary about as follows:

Sandstone and limestone, 50 cents to $1.00 per linear foot, in place.

Bluestone, $1.00 to $1.50 per linear foot, in place.

Granite, $1.00 to $2.50 per linear foot, in place.

Curved curbs, in stone, 20 per cent to 10 per cent extra.

Resetting curb, 10 to 50 cents per linear foot.

Roads and Pavements

Estimating the cost of roads and pavements is a rather uncertain procedure, unless the contractor has had experience in this particular line of work. Even then, soft earth or excavations and fills of uncertain character may prove troublesome and a matter of considerable extra expense. The local costs of labor and materials prove to be just as important in road building or street paving and improvement as in any other form of construction, and will largely govern the cost of the work in any case. For this reason, the costs which follow must be regarded only in the light of an aid in determining other actual costs for any given job.

The roads and pavements which are here treated consist of the following types: **Earth roads, macadam roads, and stone, brick, wood block, concrete, asphalt, and cobblestone pavements.**

PREPARATION OF ROADBED

The method of determining the amount of earth to be excavated or moved, may be determined by the method of measurement given in the section on Excavation. Also, amounts of earth which may be handled by shovels, wheelbarrows, or scrapers may be found in the same section, together with labor costs for removing materials.

EARTH ROADS

Earth roads are the cheapest in first cost, but may require considerable expenditure in maintenance. This type of road is intended for light traffic, and demands constant attention in order that it may be kept in good shape. A properly constructed earth road must have a surface so graded that drainage of water will be from the center of the road to the sides. The effect of water standing on the surface of earth roads is to produce a soft condition which soon destroys the road for easy service. A road constructed in low ground may require **under-drainage** as well as side **drainage**, for best results. In fact, any soil in which ground water comes within 4 or 5 feet of the surface will be benefited by a system of under-drainage.

The best and cheapest method of securing **under-drainage** is to lay a line of porous tile 3 or 4 feet deep on one or both sides of the roadway. The size of the tile will depend upon the quantity of water to be carried away. The tile are laid with their ends in contact, care being taken to adjust them until the ends fit reasonably close. If it is feared that water will wash in at the open ends of the tile, the joints may be covered with tarred paper or some similar material, to prevent the entrance of foreign matter. There is little danger of this condition if the tile are laid with a very slight fall, and if a free outlet is provided. A fall of about 3 inches per 100 feet of length is the lowest that should be allowed for good working conditions in the tile.

If side ditches are used to carry the water away from the roadway, they should be of such a grade as to carry it rapidly and entirely away from the roadside. Such ditches do not need to be deep, but should have a broad, flaring side toward the road, to prevent accident in case a vehicle should be crowded to the extreme side of the road. The outside bank of the ditch should have sufficient slope to prevent the earth caving in. This ditch should have a free outlet at the end, to provide a means of disposing of the water.

If the road is built in an excavated space, care must be taken to provide a ditch on each side of the road, so that the water will not run down into the middle of the road.

No attempt should be made to carry water long distances in side ditches, but frequent outlets should be made which discharge into natural water-courses.

The crown of the road should be at least ½ in. to 1 ft. for the slope from the center of the road to the side; and should not be more than 1 in. to a foot at the same location. A proper crown can be easily and cheaply made by the use of a road machine or scraping grader. The crown should be greater on steep grades than on level portions of the road, since on the grade the line of steepest slope is not perpendicular to the length of the road, and consequently the water travels in an oblique direction in getting down from the center of the road.

The width of the right of way varies considerably, but is usually between 40 and 66 ft. In the case of a 40-ft. right of way, 28 ft. are used for ditches and wheelway, and the remainder reserved for footpaths at the sides. For a 66-ft. right of way, 54 ft. are used for ditches and roadway, and the remainder for footpaths.

The side slopes of the earth for use in different locations and soils may be found in the section on Earth Excavation earlier in this volume, together with costs of moving earth, shrinkage of earthwork, and labor quantities in connection with the handling of soil or earth.

MACADAM ROADS OR PAVEMENTS

A macadam pavement is one built by placing small fragments of stone in an excavated space, and compacting them into a solid mass. This type of road derives its name from John Loudon Macadam, a famous English builder of broken stone roads. According to present practice, the term "macadam" is not altogether appropriate when used for a broken stone road, but should strictly be used to designate the foundation or lower courses of a stone road composed entirely of small fragments.

The construction of macadam roads and pavements consists, first, in excavating subgrade similar to that just described for earth roads. This subgrade must be well drained by tile drains or side ditches. Two forms of constructing the roadway are in common use—**surface construction** and **trench construction.** Surface construction consists in placing a layer of broken stone upon the earth road, and leaving it to be compacted by the travel which passes over the road. Where this form of construction is employed, some stone such as limestone is used for the top coating, since a soft stone will pulverize and thus produce a binding agency between the small particles of rock. The trench form of construction consists of the excavated type referred to above, with the excavation filled with the broken stone.

Madacam roads consist of two or more layers of crushed stone, the first being placed directly upon the earth roadbed. The size of stone used depends upon the hardness and toughness of the stone, and upon the kind of traffic. The harder and tougher the material, the smaller may be the size of particles used. The stones in the top course should be larger for heavy traffic than for light traffic, in order that they may not be ground into powder. The bottom course of a macadam road built of soft stones is often limited to fragments of 3 to 4 in. in largest dimensions; but, if of hard stone, the size may be reduced to 2 to 2½ in. The top course is usually composed of stones 1 to 2 in. in size for heavy traffic, and ½ to 1 in. in size for light traffic. These particles should be of hard, tough rock.

The subgrade should be rolled before placing the stone, to prevent the particles from being forced into the earth. **The lower course** of stone should be rolled to compact it so that the pieces will not move under traffic. The top course should be rolled to pack it tightly and bind the pieces into place so that they may not be knocked out by the horses' feet. Care should be taken to sprinkle the rock during rolling so as to work the binding material into the crevices, making the surface water-tight. Since the stone is put on in two or three layers, each course should be thoroughly rolled before the next is added. The rolling should be done from both sides of the road, toward the center, and should continue until the stone ceases to creep in front of the roller, and until the macadam is firm under the foot.

The width of a macadam road or pavement varies in different localities, while 10 to 12 feet may be given as an average for country roads. A width of 16 feet will be sufficient unless there is considerable rapid traffic.

The amount of the crown will vary with the location of the road and the grade. The average slope is about 1 in. to 1 ft. as the fall from the center of the road towards the ditch.

STONE BLOCK PAVEMENTS

Stone block pavements are used where traffic is heavy. The material from which the blocks are made should be hard enough to stand the abrasive action of travel, and tough enough to prevent fracture by impact which comes upon such pavements. The materials which have been used for paving blocks are **granite, trap, sandstone,** and **limestone,** granite being the most frequently used.

The foundation for a stone block pavement consists of a layer of concrete stone placed upon a prepared earth excavation, and covered with a sand cushion about 2 in. thick. This cushion is used to bed the blocks, and to bring each top to a uniform surface.

The blocks are made of sound, durable stone of as near one color as possible. These blocks are laid with their long dimensions across the street, except at street intersections; and should be placed in straight rows, with as thin joints as possible. Each course should be of uniform width and depth, and the bond in different courses should be at least 3 in., or as near a half-block as possible.

After the blocks are in place, they should be rammed or tamped until they come to a uniform bearing and even surface. Imperfect or broken blocks should be removed and replaced with perfect blocks.

After the ramming is completed, the joints are swept full of pebbles. The size of the pebbles will vary from ¼ to ¾ in. in the case of ordinary stone pebbles. These pebbles are tamped down with a bar having a chisel-shaped end, and the joints filled again with pebbles, and again tamped. The final filling of the joints is completed by spreading fine sand over the pavement and allowing traffic to work it into the joints, or by pouring hot tar, or a mixture of tar and asphalt, over the pavement. The tarred joint makes a better pavement, and provides a waterproof condition. The quantity of tar required to fill the joints varies from 1 to 3½ gallons per square yard of pavement surface, according to the size of the joints and the condition of the pavement in general.

BRICK AND BLOCK PAVEMENTS

In the construction of brick pavements, the sub-foundation should be prepared in the same manner as for the construction of any street. The earth should be graded, and compacted to a smooth surface conforming to the grade of the finished street. A layer of concrete consisting of broken stone or gravel mixed with sand or finer particles of sand or gravel should be laid to a thickness of 4, 5, or 6 inches on top of this compacted earth. The amount of water to be used in this concrete should be such that the surface of the concrete itself may be made smooth, but at the same time able to stand at a grade conforming with that of the finished street.

A layer of compressed sand 2 in. thick should be spread on top of the finished concrete to form a cushion upon which to lay the brick. This layer of sand may be compacted to a uniform density by the use of an ordinary lawn roller weighing 300 pounds, and by the use of a template with a steel face which will cut the sand to an exact 2-in. uniform depth. This sand cushion furnishes a uniform and ample support to the surface of the brick, and at the same time affords sufficient resiliency both to protect the brick from chipping and the cement filler from breaking, due to vibrations of the impact or to the weight of the load to which it is to be subjected.

The brick should be placed on edge along this cushion with the best edge up; then rolled with a 5-ton roller, bringing the surface of the bricks to a perfect plane. After the bricks are laid, a space from 1 to 1½ inches in width, and to a depth of the brick, should be provided along the curb by placing a board that may be finally withdrawn. This produces a space in which pitch may be poured to serve as a cushion for the contraction and expansion of the pavement occurring during the seasons of extreme heat or cold.

The whole pavement is then made into a monolithic form by carefully filling all the joints with a mixture of grout composed of 1 part Portland cement and 1 part fine, sharp sand. This mixture must be so applied that the sand and cement shall be held in place in the proportion named and to the full length of the joints. This is done by mixing the grout filler in small batches not exceeding one sack of cement and an equal amount of sand, in a box standing on legs of uneven length, so that during the mixing process the wet mixture will continually run back to the low end of the box while being turned over with a hoe.

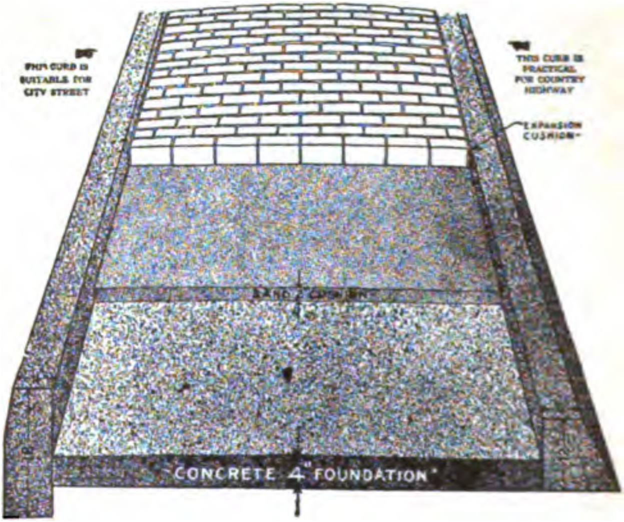

Fig. 1. Cross-Section of Street Paved with Brick, as Recommended by the National Paving Brick Manufacturers' Association.

The grout mixture is lifted out with a scoop shovel, and deposited upon the street a shovelful at a time, and then swept into the joints immediately. The joints should thus be filled full, and flush with the surface of the pavement. A rattan or fiber broom is used in the application of the first coat of grout, while a squeegee is used in the application of the final coat.

The finished pavement should be protected from heat and cold; and a slow setting of the filling grout should be brought about by spreading a thin layer of sand over the surface. In extremely hot weather this coating of sand should be wet by sprinkling. The boards along the curb should be withdrawn at this time, and the space left filled with the material used for the expansion cushion.

A pavement built in this way will last in perfect condition without a penny of repair for about 35 years, in an entirely satisfactory condition for travel.

The bricks used for paving are about 8½ x 4 x 2½ in. in size. Another size of brick, commonly called a **block**, is 9 x 4 x 3 in.

The method of laying brick pavements is illustrated in Fig. 1, which shows also two types of curbing—one for city streets (on left), and one suitable for country roads (on right).

The cost of a brick pavement with pitched joints such as shown in Fig. 1 is about $2.60 per sq. yd.; while the cost of the curbing as shown on the left, is about 45 cents per linear foot.

In determining the number of brick necessary for paving any desired area, Table 1 will be found of assistance.

TABLE 1

Covering Capacity of Paving Brick

Size of Brick	Number Required for Each Square Foot		Size of Brick	Number Required for Each Square Foot	
	Laid on Edge	Laid Flat		Laid on Edge	Laid Flat
2 x4 x8 in.	9	4.5	3 x4½x9 in.	5.4	3.6
2¼x4¼x8¼ in.	7.8	4.1	4 x4 x8 in.	4.5	4.5
2½x4½x8½in.	6.8	3.8	4 x4 x9 in.	4	4
2½x4½x9 in.	6.4	3.6	4½x4½x8½in.	3.8	3.8
3 x4 x8 in.	6	4.5	4½x4½x9 in.	3.6	3.5
3 x4½x8½in.	5.7	3.8			

Cost of Brick and Block Pavements

The following items are to be taken into consideration in figuring costs in this connection:

Cost of grading street..................15 to 50c per cu. yd.
Average value in easy soil and moderate cuts ....20 to 30c per cu. yd.
Dressing off subgrade and loading material into wagons ....2½ to 3c sq. yd.
Rolling with horse roller, longitudinally....0.1 to .15c sq. yd.
(With interest on investment in roller per year, may be as high as ½ to 1c sq. yd.)

Rolling with steam roller, longitudinally and transversely, without interest, depreciation, or storage .... ½c sq. yd.

Cost of 4-inch course of concrete:

Materials .... 30c sq. yd.

Labor .... 4 to 6c sq. yd.

*Price of brick per thousand, at kiln........... $7.00 to $15.00

(Size 2½ x 4 x 8½ in.) Average......... 8.00 to 10.00

Cost per sq. yd., exclusive of freight......... 43 to 54c

Price of repressed blocks per thousand, at kiln...... .... $12.00 to $14.00

(Size 3 x 4 x 9 in.)

Cost per sq. yd., exclusive of freight.......... 55 to 65c

Cost of hauling and piling on side of street (haul of 1 mile; three wagons with each team)...... $1.00 per 1,000

Brick, 4 in. of brick on 3 in. of sand, 65 to 85 cents per sq. yd.; 4 in. of brick on 6 in. of natural cement concrete and 1½-in. cushion of sand, $1.20 to $1.60 per sq. yd.; sidewalks, 2 in. of brick on sand, 50 to 80 cents per sq. yd.

The following analysis of the cost of brick paving is taken from "Engineering News," July 24, 1902:

"The following is a summary of the cost of paving with brick laid on edge, wages being 25 cents per hour for pavers and 15 cents for laborers:

†Number of bricks set by 1 man per day:

Average man ...... 10,000 to 12,000 (small) in 10 hrs.

Expert .... 15,000 (small) in 10 hrs.

Average man .... 8,000 to 10,000 (large) in 10 hrs.

Expert .... 10,000 to 12,000 (large) in 10 hrs.

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*In estimating freight, a brick

2 x4x8 inches weighs about 5 pounds.

2½x4x8½ inches weighs about 7 pounds.

3 x4x9 inches weighs about 9 pounds.

Loss in broken and rejected bricks, from 2 to 4 per cent.

†Prof. Ira O. Baker, in "Roads and Pavements," says: "The organization of a paving gang is usually about as follows:

1 Man in charge of spreading the sand cushion..........	$ 2.50
1 Helper on the sand cushion..........................	1.50
6 Men wheeling blocks from wagons....................	9.00
4 Men setting blocks..................................	10.00
1 Man sweeping pavement and filling joints with sand..	1.50
1 Foreman in general charge...........................	5.00
Total per day of 10 hours..........................	$29.50

"This gang should at least lay 1,000 square yards in 10 hours."

Cost of filling joints in a brick pavement:

With sand ....2c sq. yd.
With tar ....10 to 12c sq. yd.
With Portland cement grout, mixed in small lots ....10 to 12c sq. yd.
With Portland cement grout, uniform brick, thin joints ....9 or 10c sq. yd.

Cost of expansion joints:

1 gal. tar at 8c for each 5 or 6 sq. yds. of pavement ....1½c sq. yd.

Add, also, cost of administration, tools, profits, etc.

If brick blocks are piled at side of street, add 2 or 3 cents per square yard.

The prices of labor and material will vary from the above according to the locality, and this outline may be changed to suit local conditions.

Other estimates taken from various sources give the following costs, which may be used in checking details local estimates:

Brick work only, 15 to 20 cents per square yard.

COST OF BRICK PAVING

	Cost per Square Yard
57 "pavers" at $10 per M	$0.57
Hauling 1⅛ miles over earth roads	.06
Laying pavers, including labor of grouting	.08
0.18 cu. ft. = 1/150 cu. yd. of grout*	.05
1/36 cu. yd. sand cushion at $1.08 cu. yd	.03
Plank to protect concrete	.01
Total net cost	$0.80
Add about 19 per cent for profit	.15
Contract price	$0.95

"To this, of course, must be added the cost of grading and cost of concrete foundation."

Table 2 may be used in computing the number of bricks required for top course of pavement.

WOOD BLOCK PAVEMENTS

Good practice demands that creosoted wood blocks be laid upon foundation of a solid, non-flexible material such as concrete, of sufficient depth to accommodate the traffic to which it will be subjected. Upon this solid foundation, which is gen-

*1 part Portland cement to 2 parts sand.

TABLE 2

Number of Bricks Required for One Square Yard of Pavement Top Course

The upper number in each case is for ⅛-in. joints, and the lower for ¼-in. joints.

(Prof. Ira O. Baker.)

Length of Brick (Inches)	Thickness of Brick, in Inches										
	1⅞	2	2⅛	2¼	2⅜	2½	2⅝	2¾	2⅞	3	4
7¾ ..	82.1	77.6	73.2	69.8	65.8	62.8	59.7	57.5	54.9	52.7	39.9
	76.2	72.0	68.0	64.8	61.8	58.9	56.4	54.0	52.0	49.8	38.1
7⅞ ..	81.1	76.2	72.0	68.0	64.8	61.8	58.9	56.4	54.0	52.0	39.3
	75.3	70.8	67.2	63.9	60.8	58.1	55.4	53.1	51.1	49.1	37.6
8	80.1	75.3	70.8	67.2	63.9	60.8	58.1	55.4	53.1	51.1	38.7
	74.1	69.8	66.1	62.9	60.0	57.0	54.4	52.5	50.8	48.4	36.9
8⅛ ..	78.5	74.1	69.8	66.1	62.9	60.0	57.1	54.4	52.5	50.4	38.1
	72.8	58.9	65.1	62.0	59.2	56.4	53.8	51.6	49.7	47.7	36.4
8¼ ..	77.1	72.8	58.9	65.1	62.0	59.2	56.4	53.8	51.6	49.7	37.6
	72.0	67.9	64.2	61.1	58.1	55.5	52.9	50.8	48.9	47.0	35.9
8⅜ ..	76.2	72.0	67.9	64.2	61.1	58.1	55.5	52.9	50.8	48.9	37.0
	70.8	66.8	63.2	60.0	57.4	54.7	52.3	50.0	48.2	46.3	35.3
8½ ..	75.4	70.8	66.8	63.2	60.0	57.4	54.7	52.3	50.0	48.2	36.5
	69.7	65.8	62.3	59.2	56.6	53.8	51.4	49.3	47.5	45.7	34.8
8⅝ ..	74.1	69.7	65.8	62.8	59.2	56.6	53.8	51.4	49.3	47.5	36.0
	68.9	64.8	61.4	58.4	55.9	53.1	50.6	48.7	46.8	45.1	34.4
8¾ ..	73.2	68.9	64.9	61.4	58.4	55.9	53.1	50.0	48.7	46.8	35.4
	67.9	63.8	60.6	57.6	54.9	52.6	50.0	48.0	46.1	44.4	34.0
8⅞ ..	72.0	67.9	63.8	60.6	57.6	54.9	52.5	50.8	48.0	46.0	35.0
	67.1	63.2	59.7	56.8	54.2	51.6	49.3	47.3	45.5	43.7	33.4
9	71.2	67.1	68.2	59.7	56.8	54.2	51.6	49.3	47.2	45.5	34.5
	66.1	62.8	58.9	56.1	53.6	51.0	48.7	46.8	44.9	43.1	33.0
10 ...	64.1	60.3	58.6	53.8	51.2	48.9	46.6	44.5	42.6	41.0	31.1
	59.7	56.1	52.9	50.6	48.3	45.9	44.1	42.2	40.5	38.9	29.7

erally 5 or 6 in. in depth, a cushion coat of either a lean mortar or dry sand is spread to a thickness varying from ½ to 1½ in., depending upon the grade and crown of the street. Fig. 2 shows a section of street where block pavement is used.

The object of a cushion coat is to absorb the shock of impact applied by horses or vehicles passing over the blocks. The joints between the blocks should be filled with any one of the following fillers: tar, asphalt, a mixture of the two, or sand. The most common and least expensive filler used is sand, but a tar filler is and has been used with great success in St. Louis and other cities.

The best practice, however, in laying wood blocks is to lay them with tight joints. This is done by laying a plank alongside of every tenth transverse row or so, and hammering the blocks into straight lines and as close together as possible. It is obvious that this method of laying demands even more or heavier expansion joints than the open method.

The customary method of laying **expansion joints** is to place a strip of wood 1 by 6 in. directly against the curb, and resting, edge down, on the sand cushion. The blocks are then laid against this strip of wood. When the street has been paved from curb to curb, these strips are removed, and the remaining space filled with some tar or bituminous compound which has been prepared for the purpose.

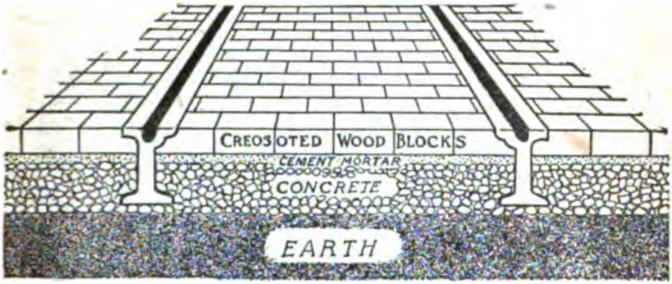

Fig. 2. Section of Street Paved with Creosoted Wood Blocks.

These transverse joints alone are not sufficient to guarantee a good street. Expansion along the short axis of the block or in the direction of the street (longitudinally) must be provided for. The fact that the expansion of the blocks is less in this direction than across the street, as was just shown, makes it necessary to provide only occasional transverse joints. Common practice uses a 1-in. joint at 100 or 200-ft. intervals, depending somewhat upon the grade and other local factors.

CONCRETE PAVEMENTS

An analysis of the vital points which unite to produce a satisfactory concrete pavement, might result in the following divisions:

1. A thoroughly compacted sub-foundation, cleared from any material which may afterward change its shapè or condition.
2. A porous, well-drained foundation, rolled or thoroughly compacted to receive the concrete base-slab.
3. A base-slab of first-class Portland cement concrete of a thickness sufficient to stand the type of traffic common to the street.
4. A wearing surface or layer of concrete composed of a

TABLE 3

Cost of Yellow Pine Creosote Block Pavement in Various Locations

The amount of creosote used for impregnating blocks usually ranges from 16 to 20 lbs. per cu. ft. of wood. Blocks laid with grain vertical.

State	City	Extent Paved	Time Laid	Cost Repair	Initial Cost	Dim. of Block (In.)
N. Y.	Borough of Manhattan	10 or 11 miles	5 yrs.	none	Wood Bl. $3.34 sq. yd. Asphalt Bl. 2.70 " Asphalt 2.13 " Granite 3.14 "	8 to 10 x 3 to 4x4
N. Y.	Jamestown	1 block	5 yrs.			3x4
N. Y.	Poughkeepsie	2 sts.	1 yr.	none	½ more	3½x8½x8
N. Y.	Geneva	1 st.	10 yrs.	nominal	40% more	4x4–6 to 10
Ohio	Toledo	12 sts.	from 1 to 9 yrs.	none	Wood $2.80 sq. yd. Brick 1.75 " Asphalt 2.00 "	4x4 and 3x3
Ohio	Cincinnati	17 sts.	20 mo.	none	Wood Bl. 2.60 " Asphalt 1.50 " Granite Bl. 3.00 "	3½x6 to 8½x3
Ohio	Delaware	1 st. or 7,300 sq. yds.	1 yr.	none	Brick .80 " Asphalt Bl. 1.65 " Wood 1.68½ "	3x3, 5 & 8 long
Md.	Baltimore	12 sts. or 33,592 sq. yds.	first in 1902	none	Wood Bl. $3.00 to 3.73 " Granite 3.39 to 3.95 " Asphalt 1.74 to 2.00 " Vit. Brk. 2.12 to 2.35 " Bitulithic 2.14 to 2.48 " Asphalt Bl. 1.99 "	3x8x3½ deep
Mich	Detroit	5.26 miles or 89,123 sq. yds.	first in 1905	none	3½-in. Creo. Bl. 1.73 " Brick .85 "	3x6 to 8x3½
Ind.	Mishawaka	none				
Pa.	Easton	1 st.	Nov. 1909		Brick 2.25 " Wood 3.25 "	4x4x6 to 9
Pa.	Harrisburg	1 st.	5 yrs.	very little	50% greater	
Conn.	Hartford	1 st.	since 1902	nothing		Standard Creo. Resinate

TABLE 3—(Continued)

State	City	Extent Paved	Time Laid	Cost Repair	Initial Cost	Dim. of Block (In.)
Pa.	Philadelphia	14 blocks Market st.				
Mo.	St. Louis.	4 sts. and number of crossings	7 yrs. 3 yrs.	none	Wood Bl. $2.75 " Bitulithic 2.15 " Asphalt 2.00 " Vit. Brick 1.90 "	
Tex.	Dallas	1 st.	2 yrs.	none	Pine Bl. 3.30 " Brick or Bit. 2.30 "	4x4x8
Tex.	Houston	1 strip, test	9 mo.	none	Much higher.	8x2¾x3½
Iowa.	Ft. Dodge	1 st.	Nov. 1909	none	Wood Bl. 2.34 " Asphalt 2.00 " Brick 2.14 "	3 in. block
Mich	Grand Forks	2 sts.	16 mo.	none	About 60c sq. yd. more than over brick.	3 in. block
Ga.	Atlanta	5 sts. and bridges	4 or 5 years	none on st., slight on bridges	$2.46 to $3.29 sq. yd.	3x3½x8
Ala.	Mobile	170,000 sq. yds.	5 yrs.	none	Brick $1.90 sq. yd. Bitulithic 2.05 " Asphalt 1.75 " Wood 2.00 "	3x4x8
Ark.	Pine Bluff	1 st.	just laid		Brick 2.15 " Macadam 1.60 " Creo. Bl. 2.20 "	3x4, 5 to 10 in.
Fla.	Pensacola	9 sts. or 85,000 sq. yds.	just completed		Block 2.22 " Brick 1.97 "	4x6x3 deep
Ky	Lexington	⅝ mile	from 4 to 7 yrs.	none ex. R. R. tracks	Present prices about same.	4x4x8 & 3x4x8 & 6
Conn.	New Haven	5 sts.	2 yrs.	none	None higher except granite bl. and rock asph.	3x3½
Iowa.	Des Moines	5,000 sq. yds.	1 yr.	none	75c per sq. yd. higher.	6x8x3½
Ky.	Winchester	1 block	1906	none		
Ky.	Louisville	3 blocks or 1,380 sq. yds.	1909	none	Wood Bl. $2.56 sq. yd. Vit. Brick 1.85 " Asphalt 1.98 " Includes 6 in. Port. cem. found'n.	3½x4x6 to 10 long

TABLE 3—(Concluded)

State	City	Extent Paved	Time Laid	Cost Repair	Initial Cost	Dim. of Block (In.)
Kan.	Wichita.	1 st., contract				3 in. block
Wis.	La Crosse.	1 st.	1907	none	Granite Macadam....$1.12 sq. yd. Brick. .... 2.10 " Creo. Bl. .... 2.61 "	3x3 & 4 to 10 long
Mass.	Boston.	Tremont, st., etc.	10 yrs.	none	Favorably.	8x4x4 & 9½x3x8
Mo.	Kansas City	2 short sts. and 2 bridges				
N. J.	Hoboken	12 blocks on 10 sts.	1908		Higher.	8 to 4 wide 8 to 3½ deep
Ill.	Chicago	11.43 miles	1903		Y. P. blk. $3.05 sq. yd.	3½ to 4 deep 3¾ to 4 wide 5 to 10 long
Ind.	Indianapolis	23 miles	12 yrs.	3%	¼ more.	4 in. deep 3 in. wide
Minn.	Minneapolis	20,600 yds.	8 yrs	none	50 to 75c over asph.	4x4x6 to 12

standard quality of Portland cement and carefully selected aggregates.

5. An elastic membrane coating to prevent chipping and to reduce glare.

6. Use only the best quality of clean, carefully selected and graded materials, and see that the workmanship is in keeping with the materials.

Various types of concrete pavements are in use today, some of which are patented. In the more common methods of construction, the mixed concrete is laid in blocks or sections and finished at once, or a thoroughly rolled body of stone is flushed with a thin cement grout and rolled down to a solid and compact mass. In other types, a special top dressing of tar and sand is used. There is one instance on record where the pavement consists of 2-in. concrete cubes laid in a bed of sand on a rolled stone foundation. The cracks between the blocks are swept full of sand. This produces a very cheap form of pavement, and its wearing qualities are watched with interest. Where the wear is not excessive, the top layer of concrete is often omitted, and the base layer troweled to a smooth finish.

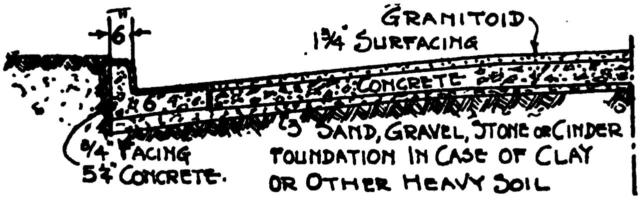

Fig. 3. Standard Section of Blome Granitoid Pavement.

Where the soil is sandy or composed largely of gravel, the concrete base may be laid without additional foundation. Otherwise a layer of compacted and flooded sand, gravel, or stone must be used, as shown in Fig. 3. Expansion joints are cut through blocking and surface, both at the sides of the pavement and extending across the width. These joints are filled with a patented preparation. The surface is finally finished by grooving with special apparatus, so that a paving block effect is produced. The grooves form rectangles about 4½ inches by 9 inches in size.

The Rudolph S. Blome Company recommends the following mixtures of concrete for use in bases and wearing surfaces: The base to be composed of 1 part Portland cement, 3 parts sand, and 4 parts crushed limestone, trap rock, or clean gravel. Stone shall be clean and not more than 1½ inches nor less than ¼ inch in any dimension. Concrete to be machine-mixed, and shall be mixed at least five times before removal from the mixer. The wearing surface to be composed of 2 parts Portland cement and 3 parts clean crushed granite, trap rock, hard stone, boulders, or gravel, with all dust removed. Fifty per cent of this crushed material should be ¼-inch in size; thirty per cent ⅛-inch in size; and twenty per cent 1/16-inch in size. The Blome pavement consists of a 5¼-inch layer of concrete base, laid on a rolled and prepared bed and covered with a 1¾-inch wearing coat of richer concrete.

A form of concrete pavement patented by the Hassam Paving Company is laid in the form of a grouted macadam street. The sub-grade is thoroughly compacted and covered with a layer of broken stone to a depth of 6 inches. This layer of stone conforms to the grade and contour of the street in such a manner that a constant thickness is maintained at all points. This layer of stone is then thoroughly rolled down to place, and grouted with a 1:2 Portland cement and sand grout. All voids in the layer of stone are filled with the grout, and the mass rolled with a heavy roller until the grout flushes to the surface at all parts. A thin finishing coating of pea stone is then spread on the top of this base, and grouted and rolled as before.

An interesting type of concrete pavement is found at Ann Arbor, Michigan. This pavement is constructed by the ordinary mixing and depositing method, and consists of a base layer 5 inches thick, composed of a mixture of 1 part Portland cement and 8 parts sand and gravel, covered with a top layer 2 inches thick, composed of a 1:2 mixture of Portland cement and sand.. When the concrete is partially set and is dry, a thin coating of tar, or other product of similar nature, is spread over the surface of the pavement. Before this tar is dry, it is covered with a uniform layer of clean, sharp sand. All joints are filled flush with the pavement surface with pitch or tar and sand. It is stated that this form of concrete pavement is proving very satisfactory. The color is such that glare is done away with, since the pavement resembles street asphalt. Noise and reflection of heat are lessened; expansion joints disappear from view, and are protected on the edges from chipping; and should cracks appear in the pavement surface, they can easily be hidden by an application of the tar and sand.

During the construction of concrete pavements, too great care cannot be taken to see that each step in the process is finished in a complete manner. The subsoil should be properly shaped, graded, and compacted by rolling with a roller weighing not less than 10 tons. All old timbers and similar matter should be removed, all soft spots filled with sand or gravel, and a properly drained and compacted bed prepared to receive the base. The concrete may be hand-mixed where the size of the job will not warrant the use of a mixer. Machine-mixed concrete will generally be of a better quality. The consistency of the mixture should be fairly dry, but wet enough so that the mortar will come to the surface by ramming slightly. The operation of mixing and placing both the base concrete and wearing surface should be carried on as quickly as possible. In some instances a strip is laid across the whole width of a street, and in others only in the center. The wearing coat should be placed before the base has had time to set, and finished by grooving or brushing as soon as it is hard enough. Where joints are to be made between concrete which has set and new work, care should be taken to see that the old work is clean, that it presents a vertical surface at the joint, and that it is thoroughly wet.

The use of expansion joints at the curbs and across the roadway at intervals of about 25 feet, is common practice. The curb joints are about 1 inch in thickness, while those crossing the pavement are about ½ inch wide. This joint extends clear through the concrete, and is filled with an asphalt or tar filler. Half way between these 25-foot expansion joints, there should be a contraction joint. This contraction joint is only about ⅛ inch in width, and extends clear through the concrete. Curbs should be placed before any pavement work is commenced.

TABLE 4

Offsets for Crowning Streets of Various Widths

Width of Roadway between Curbs	Crown	Distance from Center of Roadway	Vertical Offset	Distance from Center of Roadway	Vertical Offset
Feet	Inches	Feet	Inches	Feet	Inches
24	3	4	1/3	8	1 1/3
30	4	5	4-9	10	1 7-9
36	5	6	5-9	12	2 2-9
48	6	8	2/3	16	2 2/3
60	8	10	8-9	20	3 5-9

Table 4, taken from data published by the Atlas Portland Cement Company, shows a method for producing the crown or curve to a pavement, necessary for proper drainage to the curbs. Longitudinal drainage will have to be provided either by grading the street or by changing the crown at intervals. A longitudinal grade of 4 inches in 100 feet of length of pavement should carry away water from a concrete pavement.

The scheme in connection with Table 4 is to lay out a template or line of stakes by first locating a level line at the proper height of the center of the finished pavement above the curbs; then dividing the distance between the center of the street and curbs into thirds, and laying off a certain ordinate or vertical distance downwards from the reference line. For instance, in the case of a 24-foot roadway with a 3-inch crown, the two stakes to be driven or points to be located on a template at the one-third points near the center of roadway, should be placed at a distance of ⅓-inch below the level string or straight edge of board. Likewise the points on the two-thirds points should be located 1⅓ inches downward from the reference line.

In connection with the details of construction in the case of ordinary concrete pavements, it may be well to refer to the proportions commonly adopted, use of expansion and contraction joints, etc. Proportion used in mixing the concrete base vary from a 1:2:5 mixture up to a 1:3:7 mixture, depending upon the nature of the traffic. A 1:3:6 mixture is claimed to give a good foundation in ordinary cases. The thickness of a base composed of this mixture should be 5 or, better, 6 inches.

The wearing surface may be of a 1:2 mixture of cement and sand, or a combination of cement, sand, and fine crushed rock. Several mixtures of this nature are referred to in this article, and it is claimed that they are giving satisfaction.

PROPOSED REVISED STANDARD SPECIFICATIONS FOR CONCRETE ROADS AND STREET PAVEMENTS

Presented to the National Association of Cement Users, December, 1912

MATERIALS

1. **Cement.** The cement shall meet the requirements of the Standard Specifications for Testing Materials, and adopted by this Association (Standard No. 1).

2. **Fine Aggregate for Concrete.** Fine aggregate shall consist of sand, crushed stone, or gravel screenings grade from fine to coarse, and passing, when dry, a screen having

¼-in. diameter holes; shall be preferably of silicious material, clean, coarse, free from dust, soft particles, loam, vegetable or other deleterious matter; and not more than 3 per cent shall pass a sieve having 100 meshes per linear inch. Fine aggregate shall be of such quality that mortar composed of 1 part Portland cement and 3 parts fine aggregate, by weight, when made into briquettes, will show a tensile strength at least equal to the strength of 1:3 mortar of the same consistency made with the same cement and Standard Ottawa sand. In no case shall fine aggregate containing frost or lumps of frozen material be used.

3. **Aggregate for Wearing Course.** The aggregate shall consist of screened gravel or stone screenings from granite or other close-grained durable rock, sufficiently hard to scratch glass, free from loam or other deleterious matter, mixed in the proportion of 3 parts passing a ½-in. ring and retained on a screen having ¼-in. diameter holes and retained on a screen having 50 meshes per linear inch. In no case shall aggregate for wearing course containing frost or lumps of frozen material be used.

4. **Coarse Aggregate for Concrete.** Coarse aggregate shall consist of inert materials such as stone or gravel, graded in size, retained on a screen having ¼-in. diameter holes; shall be clean, hard and durable, free from dust, vegetable, or other deleterious matter, and shall contain no soft, flat, or elongated particles. In no case shall coarse aggregate, containing frost or lumps of frozen material be used. The maximum size of the coarse aggregate shall be such as to pass a 1½-in. ring.

5. **Natural Mixed Aggregate.** Natural mixed aggregates shall not be used as they come from deposits, but shall be screened and remixed to agree with the proportions specified.

6. **Sub-Base.** Only clean, hard, suitable material, not exceeding 4 in. in the largest dimensions, shall be used.

7. **Water.** Water shall be clean, free from oil, acid, alkali, or vegetable matter.

8. **Coloring.** If artificial coloring matter is required, only mineral colors shall be used.

9. **Reinforcing Metal.** The reinforcing metal shall meet the requirements of the Standard Specifications for Steel Reinforcement adopted March 16, 1910, by the American Railway Engineering Association.

SUB-GRADE

10. **Section.** The subgrade shall have a rise at the center of not more than 1/100 the width of the pavement.

11. **Depth.** (a) The subgrade shall not be less than 12 in. below the finished surface of the pavement.

(b) The subgrade shall not be less than 6 in. below the finished surface of the pavement.

12. **Preparation.** All soft and spongy places shall be removed, and all depressions filled with suitable material which shall be thoroughly compacted in layers not exceeding 6 in. in thickness.

13. **Deep Fills.** When a fill exceeding 1 ft. in thickness is required to bring the pavement to grade, it shall be made in a manner satisfactory to the engineer.

14. **Drainage.** When required, a suitable drainage system shall be installed and connected with sewers or other drains indicated by the engineer.

Note—When a sub-base is required, eliminate Paragraph 11-b. When sub-base is not required, eliminate Paragraph 6, 11-a, 15, and 16. Unless 11-a is eliminated, 11-b is void.

15. **Thickness.** On the sub-grade shall be spread a material as hereinbefore specified, which shall be thoroughly rolled and tamped to a surface at least 6 in. below the finished grade of the pavement.

16. **Wetting.** While compacting the sub-base, the material shall be kept thoroughly wet, and shall be in that condition when the concrete is deposited.

FORMS

17. **Materials.** Forms shall be free from warp and of sufficient strength to resist springing out of shape.

18. **Setting.** The forms shall be well staked or otherwise held to the established lines and grades, and their upper edges shall conform to the established grade of the pavement.

19. **Treatment.** All wood forms shall be thoroughly wetted and metal forms oiled before depositing any material against them. All mortar and dirt shall be removed from forms that have been previously used.

EXPANSION JOINTS

20. **Width and Location.** Expansion joints not less than ¼ in. nor more than ½ in. in width shall be placed across the street or road, not more than 25 ft. apart. When a curb or combination curb and gutter is used, a ½-in. joint

shall be placed between it and the pavement. All expansion joints shall extend through the entire thickness of the pavement.

21. **Joint Filler.** The expansion joint filler for open joints shall be a suitable bitumen that will not become soft in hot weather or hard and brittle in cold weather. Expansion joints may also be formed by inserting during construction, and leaving in place, a total thickness of ¼ in. of tarred paper or tarred felt.

22. **Protection of Edges.** When required by the engineer in charge, the concrete at the expansion joints shall be protected with metal. Unless protected by metal or filled with tarred paper or felt, the upper edges of the concrete shall be rounded to a radius of ⅜ in.

MEASURING AND MIXING

23. **Measuring.** The method of measuring the materials for the concrete, including water, shall be one which will insure separate uniform proportions at all times. A sack of Portland cement (94 pounds net) shall be considered 1 cu. ft.

24. **Machine Mixing.** When the conditions will permit, a machine mixer of a type which insures the uniform proportion of the materials throughout the mass, shall be used. The ingredients of the concrete or mortar shall be mixed to the desired consistency, and the mixing shall continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous.

25. **Hand Mixing.** When it is necessary to mix by hand, the materials shall be mixed dry on a water-tight platform until the mixture is of uniform color, the required amount of water added, and the mixing continued until the mass is of uniform color and homogeneous.

26. **Retempering.** Retempering, that is, remixing mortar or concrete that has partially hardened, with additional water, will not be permitted.

TWO-COURSE PAVEMENT

Base

27. **Proportions.** The concrete shall be mixed in the proportion of 1 sack Portland cement, 2½ cu. ft. fine aggregate, and 5 cu. ft. coarse aggregate.

28. **Consistency.** The materials shall be mixed with sufficient water to produce a concrete of a consistency such that mortar will flush to the surface under light tamping, but

which can be handled without causing a separation of the coarse aggregate from the mortar.

29. **Placing.** After mixing, the concrete shall be handled rapidly into place and successive batches deposited in a continuous operation, completing sections between expansion joints without the use of intermediate cross-forms or bulkheads. Concrete shall not be used that has partially hardened. The concrete shall be well tamped to a surface the thickness of the wearing surface below the established grade of the pavement. Workmen shall not walk on freshly laid concrete; and if sand or dust collects on the base, it shall be removed before the wearing course is applied.

30. **Reinforcing.** On streets more than 20 ft. wide not having car tracks, the pavement shall be reinforced with wire fabric or with plain or deformed bars. The cross-sectional area of metal shall amount to at least 0.041 sq. in. per foot measured parallel to the axis of the street, and at least 0.025 sq. in. per foot measured perpendicular to the axis of the street. The reinforcing metal shall be placed upon and slightly pressed into the concrete base immediately after the base is placed. Reinforcing metal shall not cross expansion joints, and shall be lapped sufficiently to develop the strength of the metal.

WEARING COURSE

31. **Proportions.** The mortar shall be mixed in the manner hereinbefore specified in the proportion of 1 sack Portland cement and not more than 2 cu. ft. of aggregate for wearing course.

32. **Consistency.** The mortar shall be a consistency that will not require tamping, but which can be easily spread into position with a template or straight-edge.

33. **Thickness.** The wearing course of the pavement in residence districts shall have a minimum thickness of 1½ in., and in business districts a minimum of 2 in. in thickness.

34. **Placing.** The wearing course shall be placed immediately after mixing, and in no case shall more than 50 minutes elapse between the time the concrete for the base is mixed and the time the wearing course is placed.

35. **Finishing.** After the wearing course has been brought to the established grade with a template or straight-edge, it shall be worked with a wood float in a manner to thoroughly compact it and produce a comparatively smooth surface, free from depressions or inequalities of any kind. The

finished surface of the concrete shall not vary more than ¼ in. from a 2-ft. straight-edge placed upon the concrete in any position.

36. **Coloring.** If artificial coloring is used, it must be incorporated with the entire wearing course, and shall be mixed dry with the cement and aggregate until the mixture is of uniform color. In no case shall the amount of coloring used exceed 5 per cent of the weight of the cement.

ONE-COURSE PAVEMENT

The general requirements of the specifications covering two-course work will apply to one-course work, with the following exceptions:

37. **Proportions.** The concrete shall be mixed in the proportion of 1 sack Portland cement to not more than 2 cu. ft. of fine aggregate (paragraph 2) or aggregate for wearing course (paragraph 3), and 3 cu. ft. of coarse aggregate passing a 1-in. ring.

38. **Placing and Finishing.** The concrete shall be placed and finished as provided for under "Two-Course Pavement," "Base" and "Wearing Course" respectively.

39. **Reinforcing.** When a one-course pavement is reinforced, the metal shall be placed at the middle of the section. The minimum amount of metal shall be as specified under "Two-Course Pavement."

Crown

40. **Amount.** All types of concrete pavement shall be given a rise or crown at the center of at least 1/100, but not more than 1/75, of the width of the pavement. A portion of this crown may be obtained by increasing the thickness of the pavement at the center rather than by laying a pavement of uniform thickness on a crowned subgrade or sub-base.

Protection

41. **Treatment.** As soon as the concrete has hardened sufficiently to prevent being pitted, the surface of the pavement shall be sprinkled with clean water and shall be kept wet for at least 4 days. Concrete pavement on roads shall be covered as soon after finishing as it is possible to do so without damaging the surface, with at least 2 in. of dirt, which shall be kept wet for at least 4 days. Before covering with dirt, the pavement shall be sprinkled with water as above specified. The pavement shall not be open to traffic until the engineer so directs.

42. **Temperature Below 35 Degrees.** If at any time during the progress of the work the temperature is, or in the opinion of the engineer will, within 24 hours drop to 35 degrees F., the water and aggregates shall be heated and precautions taken to protect the work from freezing for at least 5 days. In no case shall concrete be deposited upon a frozen subgrade or sub-base.

Shoulders

43. **Construction.** On streets where the pavement does not occupy the full width of the street, and on roads, a gravel or crushed stone shoulder at least 2 ft. wide shall be constructed on each side of the pavement. The surface of the shoulders shall have a slope away from the pavement of 1½ in. per foot, and a thickness for the 2-ft. width adjoining the concrete, at least equal to the minimum thickness of the concrete.

Wearing Surface Bitumen and Fine Aggregate

44. **Construction.** Where a wearing surface of bitumen and fine aggregate is used, it shall preferably be placed upon a one-course pavement, constructed as hereinbefore specified, but may be used also on two-course work.

45. **Expansion Joints.** Before applying the bitumen to the concrete, all open expansion joints shall be filled as hereinbefore specified. Where required by the engineer in charge, concrete at the expansion joints shall be protected with metal.

46. **Bitumen.** The bitumen shall be of a quality specified by the engineer.

47. **Placing Wearing Surface.** After the concrete has hardened for at least 7 days, the thoroughly cleaned dry surface of the pavement shall be covered with hot bitumen applied with a sprinkling wagon designed for the purpose, or with suitable hand-sprinkling cans. The hot bitumen shall immediately be evenly distributed over the concrete by brushing with suitable brooms, and then covered with the requisite amount of fine aggregate (paragraph 3).

48. **Amount of Bitumen and Fine Aggregate.** Approximately ½ gallon of bitumen shall be applied per sq yd of pavement and approximately 1 cu. yd. of fine aggregate shall be applied per 150 sq. yds. of pavement.

Protection

49. **Open to Traffic.** The pavement shall not be open to traffic until the engineer so directs.

Concrete Pavement Calculations

The accompanying data, taken from a pamphlet on "Concrete Pavements, Sidewalks, Curb, and Gutter," published by The Universal Portland Cement Co., will be useful in de-

Width of Concrete	Sq. Yards per 100 ft.
9 feet	100
12 feet	133⅓
14 feet	155 5/9
16 feet	177 7/9
18 feet	200
20 feet	222 2/9

To obtain cubic yards of concrete required for pavement

4	inch thick multiply area in square yards by 4/36, or	0.11111
5	inch thick multiply area in square yards by 5/36, or	0.13889
6	inch thick multiply area in square yards by 6/36, or	0.16667
7	inch thick multiply area in square yards by 7/36, or	0.19444
8	inch thick multiply area in square yards by 8/36, or	0.22222
1½	inch thick multiply area in square yards by 1/24, or	0.04167
2	inch thick multiply area in square yards by 1/18, or	0.05556

Assuming 1 sack cement = 1 cu. ft., 1 cu. yd. of concrete requires:

Mixture	Bbls. Cement	Cu. Yds. Sand	Cu. Yds. Gravel
1:1½:3	1.91	0.42	0.85
1:2 :3	1.74	0.52	0.77
1:2 :4	1.51	0.45	0.89
1:2½:5	1.24	0.46	0.92
1:3 :5	1.16	0.52	0.86
1:1½	3.87	0.86	
1:2	3.21	0.95	

Examples

Example No. 1: Road or pavement 1500 feet long, 18 feet wide, one-course, 7 inches thick, mixture 1:1½:3.

15 (length in hundred feet) 200 (number of square yards per 100 feet length) 0.19444 (number of cubic yards per square yard area) = 583.32 cubic yards of concrete.

583.32 { 1.91 = 1111 barrels cement; 0.42 = 245 cubic yards sand; 0.85 = 496 cubic yards gravel }

Example No. 2: Road or pavement 1500 feet long, 18 feet wide; two-course; base 6 inches thick, mixture 1:3:5, top 1½ inches thick, mixture 1:1½.

Base—

15 x 200 x 0.16667 = 500.01 cubic yards

500.01 { 1.16 = 580 barrels cement; 0.52 = 260 cubic yards sand; 0.86 = 430 cubic yards gravel }

Top—

15 x 200 x 0.04167 = 125.01 cubic yards

125.01 { 3.87 = 484 barrels cement; 0.86 = 108 cubic yards sand }

Total—

580 + 484 = 1064 barrels cement
260 + 108 = 368 cubic yards sand
430 + 0 = 430 cubic yards gravel

termining quantities of materials needed wherever concrete is used as a pavement, or as a base for other pavement materials. The table of mixtures and quantities given in the section on Concrete Construction in another part of this volume, will also be of service.

ASPHALT PAVEMENTS

As commonly understood, the term "asphalt pavement" means a pavement composed of sand or crushed stone held together by a binder of asphalt. In America the term is ordinarily applied to a comparatively thin layer of sand held together by asphalt, and laid upon a bed of concrete.

Construction of Asphalt Pavements

The concrete base for an asphalt pavement should consist of a mixture of 1 part Portland cement, 2 to 3 parts sand, and 5 to 6 parts of broken stone, depending upon the degree of richness desired. For heavy city traffic, the concrete base is usually 6 in. thick, while for light traffic it is sometimes made 4 in. thick. The proper thickness will depend upon the kind of traffic, the mixture of concrete used, and the bearing power of the soil upon which the pavement is placed.

Sometimes an old pavement of broken stone, brick, or cobblestones is used as a foundation for an asphalt pavement. Such foundations give good results when care is taken that the surface is perfectly clean and dry when the asphalt wearing coat is laid.

When placing a coating of asphalt upon a concrete foundation, care should be taken to see that the concrete is thoroughly dry before the asphalt mixture is put in place, since the generation of steam caused by placing hot asphalt on a damp concrete base will produce blisters and disintegration of the wearing coat.

The binder course consists of a layer about 1½ in. thick, of broken stone cemented together with asphaltic paving cement, and rolled in place while hot. The object of this binder course is to hold the top wearing coat and the foundation or base together.

The broken stone used in this course is screened so as to pass a 1-in. mesh screen; and after being heated, not more than 5 or 10 per cent should pass a No. 10 screen.

The asphaltic cement is the same as that used for the wearing coat, except that it is mixed much softer before application. Each cubic foot of stone in the binder course requires about seven pints of cement for satisfactory results. Each fragment of stone should be thoroughly coated with the cement, and all of the cement should be used.

The binder course is sometimes omitted, and a thin **cushion coat** used in its place. This cushion coat is usually from ½ to 1 in. thick, and composed of material of the same composition as the wearing coat, except that it contains a little more cement.

The **wearing coat**, or **top coat**, is composed of sand and asphaltic cement in about the proportions of 10 parts of cement to 90 parts of sand. The sand should be clean and sharp, and composed of grains not easily crushed and of varying size. Enough asphaltic cement should be used to fill the voids in the compacted sand so as to hold the sand together to the best advantage; but only enough cement to fill the voids should be used.

In laying the wearing coat, the mixed cement and sand is brought to the work in wagons or carts at a temperature of about 280° F. It is dumped upon the binder or cushion course, and evenly spread over the surface with rakes or shovels. Care should be taken to see that no foreign material is mixed in with the paving mixture. The depth of this wearing coat should be such that the thickness after rolling will be about 2 in. The amount of compression during rolling is usually to about three or four tenths of the thickness of the mixture when first deposited.

The first compression of the mixture is made with hand-rollers and tamping irons. Gutters, joints, and all edges and angles which cannot be reached with the rollers, should be finished by hand with hot tamping and smoothing irons.

After the first compression is given, some material such as natural hydraulic cement should be dusted over the surface of the asphalt so as to give it a pleasing color, and to prevent adhesion of the roller during the second compression. The second compression is made by use of a steam roller weighing about 5 or 6 tons, followed by a roller weighing 10 or 12 tons in some cases. Often the 5 or 6-ton roller is the only one used. For wide streets, the pavement should be rolled across the street as well as lengthwise, and the rolling should be kept up until the roller leaves no mark in the material. The final rolling usually requires about 5 hours for each 1,000 sq. yds. of paving surface.

The top of the binding coat should also be perfectly dry when the wearing coat is laid, to prevent the formation of steam as already referred to.

TABLE 5

Average Cost of Asphalt Pavements in 42 Cities in 1900, Including only, Base, Binder, and Wearing Surface

Compiled by F. V. E. Bardol, Chief Engineer, Buffalo, N. Y. (Taken from "Roads and Pavements," by Prof. Ira. O. Baker.)

CITIES	Average Price per Sq. Yd.	Guarantee Years	Foundation: Thickness	Foundation: Proportions	Foundation: Kind of Cement	Cost of Foundation Materials: Cement, Bbl.	Cost of Foundation Materials: Sand, Cu. Yd.	Cost of Foundation Materials: Bk. St., Cu. Yd.	Cost of Foundation Materials: Concrete, Cu. Yd.	Thickness Binder	Thickness Topping	Hours per Day	Wages per Day
Altoona, Pa.	$2.47	5	6	1:2:5	Nat.	$0.80	$1.55	1.68	$4.20	1	1½	10	$1.60
Atlanta, Ga.	2.83	10	6	1:2:4	"	1.00	.75	1.25	4.50	1½	1½	10	1.00
Baltimore, Md.	2.18	5	6	1:3:5	"	1.00	.75	1.50	3.30	1½	2	8	1.66
Boston, Mass.	3.25	10	6	1:3:7	Port.	2.50	1.80	1.70	4.50	1½	1½	9	1.75
Brooklyn, N. Y.	3.15	10	5	1:3:6	"	2.20	.77	1.60	5.63	1	2	8	1.50
Buffalo, N. Y.	2.20	10	6	1:2:5	Nat.	.70	1.25	1.10	3.30	1½	2	8	1.50
Chattanooga, Tenn.	2.68	5	6	1:2:5	"	....	....	....	....	....	2½	....	....
Cincinnati, O.	2.05	5	6	1:2:6	"	.60	.75	1.35	2.60	½‖	2	10	1.50
Cleveland, O.	2.17	10	6	1:2:4	"	....	....	....	....	1	2	....	....
Columbus, O.	2.20	10	6	1:2:4	"	.80	1.00	1.10	3.00	1	2	10	1.50
Denver, Colo.	2.13	5	6	1:2:4	"	1.25	.50	2.00	4.50	1	2	8	1.60
Des Moines, Ia.	1.96	7	4½	1:2:4	"	....	.40	1.25	....	1.	1½	10	1.75
Erie, Pa.	2.30	10	6	1:2:5	"	....	....	....	....	1½	1½	....	....
Fort Wayne, Ind.	2.40	10	6	1:2:5	"	....	.65	1.15	....	1½	2	10	1.50
Grand Rapids, Mich.	1.59	10	6	1:2:5	"	.70	.40	1.00	....	1	2	10	1.50
Kansas City, Mo.	2.12	10	5	1:2:5	"	....	.80	1.00	....	1½	1½	8	1.40
Lafayette, Ind.	2.00	10	6	1:2:6	....	....	....	....	4.00	1	1½	10	1.50
Los Angeles, Cal.	1.80	No	6	1:3:6	Port.	2.50	.40	1.00	6.00	No.	2	10	2.00
Milwaukee, Wis.	1.85*	5	6	1:2:5	Nat.	.55	.65	1.10	....	1	2	10	1.50
Minneapolis, Minn.	....	....	6	1:2:5	"	.80	.55	1.85	3.00	1	2	8	1.75
Montreal, Que.	3.25	10	6	1:3:4	Port.	2.84	.75	1.25	6.00	½	2½	10	1.25
Newark, N. J.	2.03	10	6	1:3:7†	P.& N.	....	....	....	....	1½	2	....	....
New Orleans, La.	2.50	5	6	1:3:7	Port.	....	2.02	2.02	8.00	1½	2	10½	1.50
Newport News, Va.	2.03	10	6	1:2:5	Nat.	.95	.50	2.20	4.80	1½	1½	10	1.25

TABLE 5—(Concluded)

CITIES	Average Price per Sq. Yd.	Guarantee Years	Foundation: Thickness	Foundation: Proportions	Foundation: Kind of Cement	Cost of Foundation Materials: Cement, Bbl.	Cost of Foundation Materials: Sand, Cu. Yd.	Cost of Foundation Materials: Bk. St., Cu. Yd.	Cost of Foundation Materials: Concrete, Cu. Yd.	Thickness Binder	Thickness Topping	Hours per Day	Wages per Day
New York, N. Y.	2.56	10	6	1:3:6	Port.	2.50	.45	....	5.84	1.	2	8	2.00
Omaha, Neb.	2.11	5	6	1:2:5	Nat.	.80	.70	1.40	5.00	1½	1½-2	10	1.75
Peoria, Ill.	1.96	5	6	1:1½:4	"	.55	1.00	1.50	4.50	1	1½	10	1.62
Philadelphia, Pa.	2.37	5-10	6	1:3:6	P.& N.	....	....	....	....	1	2	..	....
Pittsburgh, Pa.	2.44	5	6	1:2:4	Nat.	.70	.65	1.70	....	1	2	9-10	1.55
Providence, R. I.	2.65	5	6	1:2:6	Port.	2.20	.63	2.00	5.10	1½	1½	10	1.62
Rochester, N. Y.	2.11	10	6	1:2:4	Nat.	.70	1.00	1.10	4.00	1	2	8	1.50
San Antonio, Tex.	1.99	10	6	1:2:4	"	1.50	1.00	.75	4.40	No	2	8	1.50
San Francisco, Cal.	1.89	No	6	1:2½:7	Port.	2.88	.70	1.38	5.18	No.	2½	9	2.00
Scranton, Pa.	2.20	10	6	1:3:7	"	1.90	1.00	1.25	4.20	1½	1½	10	1.50
Spokane, Wash.	2.29	10	4	1:3:6	"	4.50	.70	.98	7.65	1½	2	8	1.80
St. Paul, Minn.	2.55	10	6	1:2:4	Nat.	....	....	....	3.00	1	2	10	1.62
Syracuse, N. Y.	2.22	5	6-8	1:2:5‡	"	....	....	....	....	....	....	..	1.62
Toledo, O.	1.96	5	6	1:2:5	"	....	....	....	....	1	2	10	1.50
Toronto, Ont.	2.75	10	6	1:3:6	Port.	2.24	.79	1.60	5.70	¾	2½	9	1.62
Utica, N. Y.	2.35	10	5	1:2:5	Nat.	.85	.85	1.25	4.00	1	2	8	1.50
Washington, D. C.	1.79	5	6	1:2:5	"	.70	.40§	1.25§	3.50	1½	1½	8	1.20
Winnipeg, Man.	1.79	..	4½	1:3:6	Port.	3.75	1.00	1.10	5.74	1½	1½-2	9	1.65

* Including grading. † Also 1:3:5. ‡ Also 1:3:6. ‖ Cushion course. § Not including haul.

COBBLESTONE PAVEMENTS

Records of the cost of laying cobblestone pavement in the city of Baltimore, Md., show results which are tabulated in Table 6.

TABLE 6

Cost of Cobblestone Pavements
Baltimore, Md.

		Cost per Square Yard
Stones at $1.60 per perch of 2,800 lbs.		$0.29
Paving sand at 60 cents per cu. yd., delivered		.20
Labor laying and ramming:		
1 Foreman at $3.00 for 8 hrs.	$ 3.00	
4 Pavers at $3.00 for 8 hrs.	12.00	
2 Rammers at $2.00 for 8 hrs.	4.00	
6 Laborers at $1.66 for 8 hrs.	10.00	
Total for 200 sq. yds.	$29.00	.14
Total cost per sq. yd., exclusive of administration, tools, and profits		$0.63

COMPARATIVE VALUES OF DIFFERENT PAVEMENTS

Table 7 shows the results of an investigation by the United States Department of Agriculture, of the subject of wood paving in the United States.

TABLE 7

Comparative Values of Different Pavements

Pavement qualities.	Percentage.	Granite.	Asphalt (sheet).	Brick.	Macadam.	Creosoted wood.
Cheapness (first cost)	14	4.0	6.5	7.0	14.0	4.5
Durability	20	20.0	10.0	12.5	6.0	14.0
Ease of maintenance	10	9.5	7.5	8.5	4.5	9.5
Ease of cleaning	14	10.0	14.0	12.5	6.0	14.0
Low traction resistance	14	8.5	14.0	12.5	8.0	14.0
Freedom from slipperiness (average of conditions)	7	5.5	3.5	5.5	6.5	4.0
Favorableness to travel	4	2.5	4.0	3.0	3.0	3.5
Acceptability	4	2.0	3.5	2.5	2.5	4.0
Sanitary quality	13	9.0	13.0	10.5	4.5	12.5
Total number of points	100	71.0	76.0	74.5	55.0	80.0
Average cost per square yard, laid, 1905	...	$3.26	$2.36	$2.06	$0.99	$3.10

Favorableness to travel is dependent chiefly upon smoothness and freedom from dust and mud, secondarily upon the qualities composing "Acceptability."

Acceptability includes noise, reflection of light, radiation of heat, emission of unpleasant odors, etc. It chiefly concerns the pedestrian and the adjoining resident.

Cost per square yard includes concrete, but not excavation, curbing, etc.; except for macadam, which is not usually laid on concrete.

COST OF STREET IMPROVEMENTS

Valuable cost data for contractors in street improvement work are found in the annual report of the Chief Engineer of the Board of Estimates and Apportionment of New York City for 1910.

Table 8 gives the unit-prices used for estimating purposes by the engineers of the five boroughs composing Greater New York. These prices are averages figured on the basis of all estimates submitted between May 21 and December 31, 1910.

TABLE 8
Unit-Prices of Street Improvement Work in New York City

Items	Boroughs				
	Manhattan	Brooklyn	The Bronx	Queens	Richmond
Sheet asphalt,* per sq. yd.	....	$0.95	$1.55	.....	....
Asphalt block,* per sq. yd.	$2.50	1.70	1.90	$1.80	....
Granite block,* per sq. yd.	....	2.75	2.30	.....	....
Wooden block,* per sq. yd.	....	....	2.25	.....	....
Bituminous macadam, per sq. yd.	....	....	1.25	.....	....
Concrete, per cu. yd.	6.00	5.05	6.20	5.90	$6.00
Earth excavation, per cu. yd.	1.00	.42	.33	.35	.59
Rock excavation, per cu. yd.	2.00	....	1.60	3.00	....
Filling, per cu. yd.	.50	.47	.35	.48	....
Cement curb, per lin. ft.	....	.50	....	1.00	.60
Bluestone curb, per lin. ft.	1.00	1.00	.85	.90	1.00
Cement walk, per sq. ft.	....	.15	....	22	....
Bluestone flagging, per sq. ft.	.30	.28	.28	.28	....
Bridgestone, per sq. ft.	....	....	.60	.72	....
Engineering and inspection, per cent.	4.8	4.5	9.2	5.0	9.7

*Excluding concrete base.

It will be noticed that the unit-prices for what is apparently the same kind of work in the different boroughs show a wide range of variation. These different prices cannot be due entirely to varying conditions, but are probably owing to different standards of work.

MISCELLANEOUS PAVEMENT COSTS

The following data as to the cost of asphalt and macadam roads, compiled by Mr. Edward F. Godfrey, will be of interest in connection with the subject of pavement costs. While the prices given are seen to vary from amounts given in other places, such values should be used in the sense of a guide rather than as an exact figure for any given case.

Stone blocks—on broken stone base, $1.50 to $2.00 per sq. yd.

Stone blocks on concrete base, $2.00 to $3.50 per sq. yd.

An analysis of the labor cost of stone block paving, based on data in "Engineering News," is as follows:

Cost of Block Paving

	Per Sq. Yard
Loading and unloading, inclusive of lost team time	$0.10
Hauling 1 mile	.05
Distributing blocks	.03
Laying	.06
Filling joints	.06
Foreman at 40 cts. per hr., 30 sq. yds	.13
Two water and errand boys	.07
Total labor	$0.50

Cost of Medina Block Pavement

	Per Sq. Yard
1/3 cu. yd. street excavation	$0.15
6 in. concrete foundation	.50
1-18 cu. yd. sand cushion in place at $1.08	.06
Medina block (6 in.) f. o. b. Albion, N. Y.	1.15
Freight to Rochester	.07
Unloading, hauling and laying	.30
1.5 gallons tar at 10 cts. a gallon	.15
1-50 cu. yd. sand for joints	.02
Total	$2.40
Add for contractor's profit	.25
Total cost	$2.65

Asphalt—In 44 cities in North America, the cost of asphalt paving, including 4 to 6 in. of concrete, varied between $1.43 and $3.25 per sq. yd. It is estimated that the cost of guarantee for the first five years is 3 cents per yard, and for the second five years is 15 cents per yard. The Congressional appropriation bill allowed $1.80 per sq. yd. to be paid for asphalt pavements in Washington, D. C.

Asphalt block—$2.00 to $2.50 per sq. yd.

The division of the cost of asphalt pavements is about as follows: 2½ in. of surface, 67 cents per sq. yd.; 2 in. of binder, 13 cents per sq. yd.; 6 in. of Portland cement concrete, $1.00. Total, $1.80 per sq. yd.

Macadam—The actual cost, with stone free at the quarry, of laying macadam pavement (5-in. layer, large-sized stone, rolled; 2½ to 3-in. layer of medium-sized stone, sprinkled and rolled; about ¾-in. of fine screenings, sprinkled and rolled) was 42 cents per square yard. The average weight of stone was 3 tons per sq. yd.

Macadam, stone free at quarry, 8 in. depth, 40 to 50 cents per sq. yd.; including cost of stone, 8 in. depth, 60 to 90 cents per sq. yd.; 12 in. depth, 90 cents to $1.30 per sq. yd.

Cobblestone—80 cents per sq. yd.

Wooden blocks—4-in. creosoted yellow pine blocks on 1 in. of sand over 6 in. of natural cement concrete, $2.25 to $2.35 per sq. yd. Cost of 4-in. creosoted yellow pine blocks, f. o. b. cars, about $1.70 per sq. yd.

Brick—Brickwork only, 15 to 20 cents per sq. yd.

Brick, 4 in. of brick on 3 in. of sand, 65 to 85 cents per sq. yd.; 4 in. of brick on 6 in. of natural cement concrete and 1½-in. cushion of sand, $1.20 to $1.60 per sq. yd.; sidewalks, 2 in. of brick on sand, 50 to 80 cents per sq. yd.

City street paving—Cost of street paving in 30 cities in Wisconsin per sq. yd.: asphalt, $1.80 to $2.19; brick, $1.00 to $2.19; macadam, 25 cents to $1.30; wood block, 60 cents to $1.97.

All-concrete roadway paving has been found in several cities to cost 14 to 18 cents per sq. ft. At Jackson, Mich., some street paving having 3 in. of gravel, 6 in. of 1:8 cement and gravel, 4 in. of 1:3 cement and ½-in. crushed granite, mixed quite wet, cost 18 cents per sq. ft.

Bridges and Culverts

BRIDGES

Classification of Bridges in General. A bridge is a structure which furnishes a passageway from one side of an opening or depression to the other side. A bridge may be needed to cross a valley, gulch, stream, canal, road, or railway track. If the bridge is supported at the two ends only, it is said to be a bridge of one **span**, and the end supports are called **abutments**; if the bridge has one or more intermediate supports, it is a bridge of two or more spans, and the intermediate supports are known as **piers**. The abutments and piers compose the **substructure**; and the remainder of the bridge, the **superstructure**. The superstructure may be of any one of several forms, and bridges are classified accordingly, as **beam bridges, arch bridges, and suspension bridges**. The difference in the types is in the manner in which the structures carry the loads that come upon them, and, consequently, in their external form.

Beam bridges are described in the word beam, which signifies a member under a bending stress, having compression in the top, and tension in the bottom. Beam bridges are the most generally used, and are particularly adapted for short spans, although the modern steel truss bridge is a beam bridge.

Arch bridges carry the load in direct compression throughout the arch ring, and transmit the pressure downward and outward against the abutment.

Suspension bridges are designed to support the loads that come upon them, by means of ropes or cables which are either fastened to the banks above the ends of the bridge, or laid over towers and anchored in the ground. This type of bridge has made it possible to span tremendous distances, but is not very desirable for ordinary lengths.

Steel Bridges

Use of Steel Bridges Trusses. Since 1854 the metal bridge truss has been in general use for all spans from 10 to 15 ft. up to several hundred feet. The huge Firth of Forth bridge in Scotland, and the Quebec bridge crossing the St. Lawrence river near Quebec, have spans of about 1,800 feet.

Steel bridges may be considered as **trussed beams**. A **truss** is a combination of members which take stresses in direction of their length only. Another definition, perhaps, is that a truss is a combination of tension and compression members.

Two or more trusses constitute a bridge. The trusses constituting a bridge are connected by a system of beams on which the load is carried. This is the **floor system** of the bridge, and has no purpose except to carry the loads to the trusses.

Classes of Steel Bridges. Steel bridges, like beams, may be divided into **continuous, simple,** and **overhanging.** In the case of overhanging bridges, there may be one or both ends overhanging. Such bridges are called **cantilever bridges,** from the fact that the overhanging end is a cantilever. Other classes of bridges are the **suspension, swing, rolling-lift,** and **trunnion-lift.**

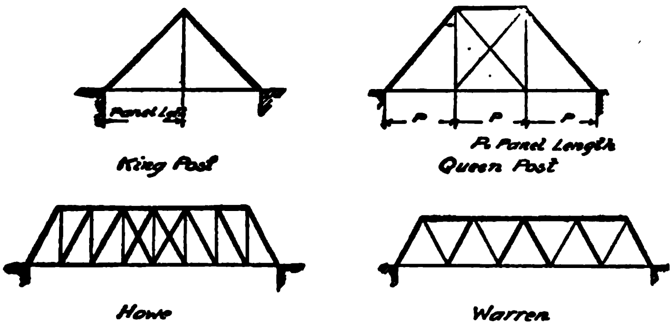

Fig. 1. Classes of Bridge Trusses.

Probably 95 per cent of all steel bridges built are of the simple type—that is, having each end resting on a support. The simplest forms are the **king-post** and **queen-post trusses** (Fig. 1). Since the panel length—that is, the distance between any two joints—is limited to about 20 ft., the greatest spans of these classes of bridges are 40 and 60 ft. respectively.

Other classes of simple trusses are the **Howe, Warren, Pratt, Camel Back, Baltimore,** and **Petit.** The first three and the last were named after their inventors; the fourth, because of its humped back; and the fifth, because the Baltimore Bridge Works was it first builder. The camel back is frequently called the **bowstring.**

The limiting economical span for a simple truss is between 300 and 500 ft., according to the class. The Pratt is built to a greater extent than any of the others, probably 85 per cent of all simple trusses being of the Pratt type. The

Petit and Baltimore are for long spans only—say from 250 to 500 ft. The rolling-lift and trunnion-lift are the outcome of the attempt to do away with the old swing bridge or drawbridge. The latter was costly, and also had a pier in the center; and this, especially in narrow streams, was a great obstruction to navigation.

The rolling- and trunnion-lifts have their foundations and supports on the banks, the full width of the stream being available for navigation. These bridges are balanced about their rolling or trunnion centers, by huge counterweights of cast-iron blocks or masses of concrete, and are opened or closed by a pull or push on the operating strut, which is usually supplied with power from electric motors in a small house.

Continuous bridges have the same objections as continuous beams. A slight settlement of the trusses causes the stresses to be greater than computed. They are not used in this country, except in a very few cases.

Cantilevers and suspension bridges should be used for long spans only, or where their form offers ease of erection. They are very uneconomical for .short spans. Their special use is for spans of about 500 to 1,800 ft. for cantilevers, and 1,000 to 3,000 ft. for suspension bridges.

In Fig. 1, the heavy lines indicate compression members, while the light lines indicate tension members. In simple trusses, the top chord is always in compression, and the bottom chord always in tension.

In warm weather a steel bridge is slightly longer than in cold weather, and any change of temperature causes it to change in length. If both ends were fixed, the strusses in the bridge would change considerably from those computed on the basis of the loads, and may in extreme cases cause danger. One end should be fixed to the support, and the other end should either be on rollers or on a planed plate so that it may move backwards and forwards when the temperature changes.

Cost of Bridge Steelwork. See section on "Steel Construction" for costs of fabrication and erection of steelwork.

Cost of Painting Bridges. See section on "Painting."

CONCRETE BRIDGES

Girder and Slab Bridges

Girder and slab bridges are known as beam bridges ,and carry the loads which come upon them by their resistance to bending. They are extensively used for short spans and for low, shallow crossings. These bridges are very interesting as examples of the advantages of reinforced concrete construction, because it is only the use of the steel reinforcement that makes it possible for them to resist the bending stresses which the applied loads and their own weight bring upon them. The reinforcement is only an assistance and improvement in the case of an arch bridge; in the case of a beam bridge, it is the essential feature.

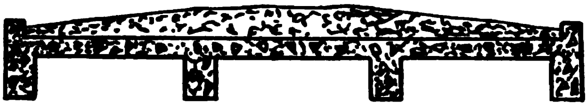

Fig. 4. Cross-Section of a Concrete Girder Highway Bridge.

The difference between a girder bridge and a slab bridge of reinforced concrete, is shown by Figs. 4 and 5.

The flat slab bridge is the simplest to design and construct, and also proves to be the most economical in materials when used for spans up to about 20 ft. For spans from 20 to 35 ft. or thereabouts, the girder type is the best to use. Beams longer than 35 ft. are rarely built; an arch is generally used for such spans.

Fig. 5. Cross-Section of a Concrete Slab Highway Bridge.

Highway Girder and Slab Bridges. Highway bridges are of the greatest practical utility and importance, and the number required in the present state of civilization is extremely large. Good bridges are as necessary as good roads for the advancement of a district, and reinforced concrete is an ideal material for a "good bridge." A concrete bridge is reasonably cheap in first cost, requires the minimum of maintenance, and will last indefinitely. For a structure to be maintained by a public body, as highway bridges usually are, the fewer repairs that are required the better.

Portland cement should always be used for concrete highway bridge construction, because it is stronger and more reliable and hardens more quickly than natural cement.

The cement should be of a standard brand, not liable to expansion or disintegration, fine, and of uniform quality. It should be free from lumps, and should be stored in a dry place.

For the aggregates in concrete, the sand should be clean and coarse, or a mixture of coarse and fine, the coarse predominating. It should be free from clay, loam sticks, organic matter, and other impurities.

Screenings or crusher dust from broken stone may be substituted for sand by altering the proportions so as to give a dense mixture and the same relative volume of aggregates.

Gravel, when used, should be composed of clean pebbles free from any foreign matter, and containing no clay or any materials adhering to the pebbles.

It should be screened to remove the sand, and should be mixed afterwards in the proper proportions. However, if by tests the gravel runs in the proportions of 2½ to 3 sand, to 4 or 5 parts pebbles, it can be used without screening.

Broken stone should consist of pieces of hard, durable rock, such as limestone or conglomerate.

The water should be clean and free from acids or strong alkalis.

Steel for reinforcement should be of high tensile strength, and of such shape as to form a firm mechanical bond with the concrete.

In mixing concrete for highway bridges or culverts, proportions should be used to give the densest concrete with the maximum strength of the concrete.

The mortar mixture of sand and cement is generally 3 parts sand to 2 parts cement; yet mixtures of 2½ to 3 parts sand to 1 part cement will give a mortar that is dense and for practical purposes as good on small bridges and culverts as stronger mixtures.

The stone aggregate should not be more than twice that of sand; and in most cases the proportion of 4 parts stone will generally make the most desirable mixture, as it allows sufficient mortar to cover all the stone and leaves no rough spots on the surface.

"Mix well" and "mix wet" will cure many faults, so-called, in working with concrete.

Exposed surfaces of concrete may be made sufficiently smooth by spading, so as to force the stones back from the surface, allowing the mortar to crowd to the face. The forms should be sufficiently tight to prevent mortar running out. With these precautions, surfaces can be obtained that require very little patching or plastering to make a neat job.

The forms should be made of lumber sufficiently strong to hold itself in line without an excess of bracing, and not bulge or be thrown out of line by the workmen filling them. All exposed surfaces should be made with dressed lumber, with all joints neatly fitted. The lumber best adapted for building the forms is 2x6-in. stuff, with 4x4-in. for the stays.

The handiest ties are ½-in. bolts of a length necessary to hold the forms together. Bolting the forms requires few nails, and makes a form that can be taken down easily.

The handiest ties are ½-in. bolts of a length necessary to hold the forms together. Bolting the forms requires few nails, and makes a form that can be taken down easily.

The time necessary to leave the forms in place varies considerably with the weather; but under ordinary conditions, wing wall and culvert wall forms can be removed in 3 days. Slabs of not more than 6-ft. may be removed in 5 days. Longer spans and arches up to 40 ft. require not less than 10 days of good drying weather.

In freezing weather, the forms should be left in place as long as possible.

Classes of Loading

A large manufacturer of reinforcing materials much used in bridge construction gives the following three classes of loadings for highway bridges:

Class No. 1—Light highway specification answering the purposes of ordinary county traffic where the heaviest load may be taken as a 12-ton road-roller. Uniformly distributed load, 100 pounds per sq. ft.

Class No. 2—Heavy highway specification, designed for localities where heavy road-rollers, up to 20 tons, and electric cars of a maximum weight of 40 tons, must be provided for. Uniformly distributed load, 125 pounds per sq. ft.

Class No. 3—City highway specification, designed for heavy concentrated loads and large interurban cars. This classification should be adopted for all city work; the weight of the maximum car has been taken as 60 tons. Uniformly distributed load, 150 pounds per sq. ft.

CONCRETE BRIDGES

Cost of Girder and Slab Types

The following data and diagrams in regard to the cost of concrete bridges of the girder and slab types were presented by Mr. B. H. Piepmeier in a paper read before the Illinois Society of Engineers and Surveyors:

The purpose of this paper is to develop a ready means of ascertaining the approximate number of cubic yards of concrete in a completed structure of the through girder or slab type, of known span, height of abutments, and length of wings, as well as to develop a means of making preliminary estimates of the cost of completed structures without calculating the quantities in detail.

Before proceeding, it may be well first merely to outline in a general way the slab and the girder bridges as designed by the Illinois Highway Commission, and give a few dimensions, that the types of bridges under consideration may be understood.

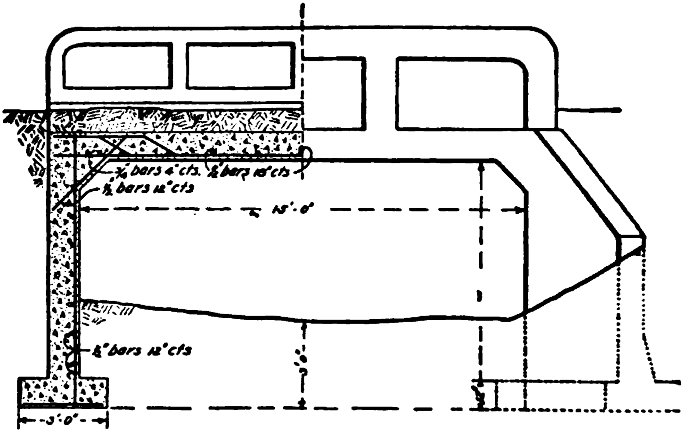

Fig. 4. Standard Bridge of 15-Foot Span, Illinois State Highways.

Slab Bridges. For reinforced abutments for slab bridges, the main wall is made 12 inches thick from top to bottom, the steel reinforcing being placed on the stream side, and the percentage of steel increased as the height increases. The abutments rest on an 18-in. reinforced footing, which is made of sufficient size to allow but 3,000 lbs. per square foot bearing on the foundation. When a soft foundation is encountered, this same size footing is usually sufficient to permit the proper spacing of the required number of piles.

The reinforced wings for slab bridges are of the standard cantilever type, the base being 33 per cent of the total height. The wing wall proper is 12 in. thick for heights up to 16 ft.

For greater heights, the base of the wall increases in proportion to the height. Nearly all wings for this type of bridge have a drop of 18 in. to 5 ft. at the end, to conform to the 2 to 1 slope on the sides of the road. The cantilever type of wing for extreme heights has been found much more satisfactory than the buttress type, as the increased thickness at the base and the large percentage of steel do not equal the extra cost of forming necessary for the buttress type.

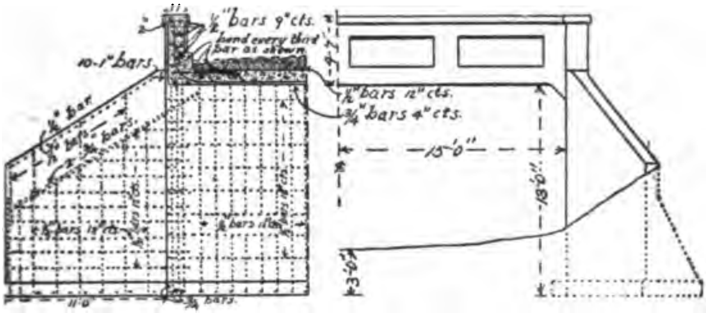

Fig. 5. Standard Bridge of 30-Foot Span, Illinois State Highways.

Reinforced concrete slab bridges are designed with various roadways ranging from 16 ft. upward. The side rails usually average 8 in. thick and 3½ ft. high. On this type of bridge the slab and the side rails come flush with the back of the abutment walls. The top of the wings comes up along the outside of the rails to catch the side slope on the road. In determining the thickness of the slab, its entire dead load is considered, the load of the cushion wearing surface, and a 24-ton engine live load. Excluding temperature stress, the steel is figured at 12,000 lbs. per square inch; the compression in the concrete is assumed at 800 lbs. per square inch.

Girder Bridges. For the reinforced abutments for girder bridges, the general type is the same as that for slab bridges, with the exception that all abutment walls proper are 18 in. thick, and the width of base for the wings is 40 per cent of the total height. The extra thickness in the abutments is for bearing of the girders. The extra width of base under the wings is for stability, as the wing walls are cut away from the abutment walls proper by a 1-in. partition to allow for expansion of the superstructure. They can therefore receive no support from the slab bridges. The wings on this type of bridge also come up on the sides of the girders, and drop several feet at the ends to follow the general side slopes on the road.

The reinforced concrete girder superstructures are designed with roadways from 16 to 30 ft. The roadway usually required is 16 to 20 ft. The side girders average from 4 to 6 ft. in height, and 16 to 30 in. wide on top. On the side girders they are heavy, depressed panels to lighten the web and to give the proper appearance to the finished bridge. The floor and side girders on this type of bridge also extend to the back side of the abutment wall. The floor-slab is designed to carry its own dead load, the cushion wearing surface, and a 24-ton engine live load. The side girders are designed to carry the entire dead load of the superstructure, plus a live load of 125 lbs. per square foot on the roadway, or a 24-ton engine, whichever gives the greater moment.

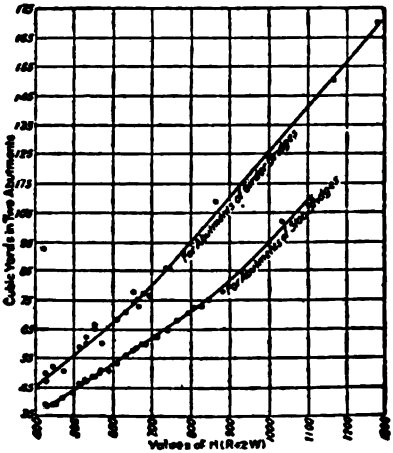

Fig. 6. Yardage in a Pair of Reinforced Concrete Abutments.

Abutment Diagram. For the purpose of determining offhand the approximate yardage in a pair of reinforced concrete abutments for either slab or girder bridges, Fig. 6 has been prepared, and is applicable within the specific cases used. For abutments of slab bridges, 40 different designs were taken from the files of the Commission, and the number of cubic yards in the two abutments of each design was plotted against H (R+2W), where H is the distance from the finished roadway to the bottom of the footings, R is the clear roadway of the slab bridge, and W is the length of one wing measured on the stream side. R was taken as the clear roadway of the bridge, as this figure is always secured at the preliminary inspection of the bridge site. W, the length of the wing, can always be assumed in the field or computed in the office, knowing first the general conditions of the bridge site.

It will be noticed that the number of cubic yards in the two abutments varies approximately as the height of the abutments; also, that the maximum deviation from the curve does not exceed 2 cu. yds., and more often it is less than 1 cu. yd. In fact, for heights of abutments up to about 16 ft., or where H (R+2W) does not exceed 900, the quantities so plotted follow practically a straight line, and might be represented by the straight line formula, cubic yards =0.09 [H (R+2W)] — 1.37, which often is convenient when the curve sheet is not at hand.

For a particular bridge, suppose the distance from the crown of finished roadway to bed of stream is 10 ft., and the footing should be carried 4 ft. below bed of stream. Then H=14 ft. Now assume the wings are each to be 13½ ft. long, and that the finished bridge will have a 16-ft. clear roadway. We have now H (R+2W)=600, the value to be read at the bottom of Fig. 6.

It will be seen, by locating the point on the curve and going across to the left-hand side, that there are about 53 cu. yds. in the two abutments. Where the quantity at the bottom of the figure exceeds 900, we readily see that the curve begins to rise above the straight line. This is expected, as abutments exceeding 16 ft. in height have the base of the wings spread, to allow for the proper percentage of steel. This extra width of base is added to the back of the wing wall by a batter, the batter extending up from the footing 4 to 8 ft., according to the height of the wall. This batter does not extend to the top of the wall, as the drop at the end of the wing would increase its thickness at the end, and this does not give the best appearance to the finished bridge. The abutment walls remain 12 in. thick up to 21 ft. high; and from there on, the thickness increases as the height. The slight variation from the curve in solving specific cases may be attributed to the difference in the angle of the wing with respect to the abutment, and the difference in width of footing for bearing. The more nearly the direction of the wing approaches a parallel with the center line of the road, the higher will be the wing at the end, thereby increasing the number of cubic yards; but as the corner formed by the intersection of the abutment wall and wing is measured twice, these two quantities tend to compensate each other.

For the reinforced abutments on girder superstructures, 25 designs were taken from the files of the Commission, and the number of cubic yards in the two abutments plotted against H (R+2W), the notation being the same as before.

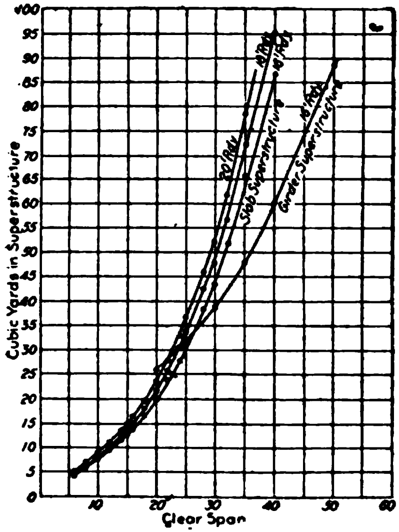

Fig. 7. Yardage in Superstructures.

It is to be noted here that the number of cubic yards is somewhat greater than the number of yards in the abutments for slab bridges. This is due to the extra thickness of the abutment walls proper, to give the desired bearing, and the extra width of footings under the wings. It will be noted on this curve, that some of the specific cases used had a wide variation from the mean. This can be attributed to the fact that some of the abutments had extremely long wings that were level on top, and also the different lengths of spans require a little different width of footing under abutments to take the required bearing. A curve of this kind could not take into account all of these conditions; and, while several points fall several yards off the curve, the mean is close enough for the purpose that it is to meet.

For a particular case, take the same dimensions that were considered before: Clear roadway, 16 ft.; height, 14 ft.; and length of wings, 13½ ft. We now have 600 to read off at the bottom of Fig. 6. Getting the intersection with the curve for girder spans, we find that the two abutments contain 67 cu. yds. instead of 53 cu. yds. in case of the slab span, a difference of 14 cu. yds. in favor of the slab bridge. Fig. 6, then, is a ready means for comparing the substructures of the two types of concrete bridges and determining the approximate number of cubic yards in each.

Superstructure Diagram. The next thing of importance is to determine the number of cubic yards in the superstructures of the two types of bridges. For this, Fig. 7 has been prepared, and is applicable for the flat-top type of bridge up to 50 ft. in span. For slab superstructures, 48 designs of different roadways and spans were taken from the files of the Commission; and the total number of cubic yards in the superstructure was plotted against the clear span length, the curves drawn through the points having 16, 18, and 20 ft. roadway. The three curves will meet the requirements of the majority of highway bridges. Occasionally a special case arises, such as a skew or extra wide roadway; and then it is necessary to make special computations to determine the number of cubic yards.

For a specific case, assume a bridge to have a 30-ft. clear span and 16-ft. roadway. We readily see the number of cubic yards to be about 43.2.

We may wish to consider for the same site the 30-ft. girder type with 16-ft. roadway. Here we see that the number of cubic yards is about 38.6, or a difference of 4.6 cu. yds. in favor of the girder superstructure. But you will notice for the same height substructure the difference in all cases is in favor of slab bridges. If it should happen that for a single span the girder bridge and the slab bridge should have the same yardage, an advantage still rests with the slab type, as it has been found that contractors usually bid more favorably on this type. There is also another very important point in favor of the slab type. If for any reason there should be any defective material placed in the rail, or poor alignment in its construction, it can be torn down and replaced without disturbing the floor, even after the falsework has been taken down.

Cost Diagram. Having found the expression that is the measure of the number of cubic yards in the abutments and superstructures of concrete slab and girder bridges, the next step is to combine the quantities with a unit-price, that we may determine the approximate cost of each type. For this purpose, Fig. 8 has been prepared.

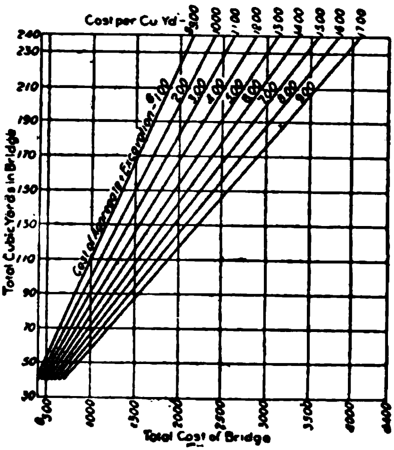

Fig. 8. Cost of Bridge Complete.

It has been found from the cost data of a large number of slab and girder type concrete bridges built under the supervision of the Illinois Highway Commission, that it is possible to get a very close figure on each individual item that goes to make up the cost of the bridge—(1) the cost at the bridge site of sufficient cement to make 1 cu. yd. of 1:2½:4 concrete; (2) the cost of the necessary lumber for forming 1 cu. yd.; (3) the cost of reinforcing steel per cubic yard of concrete; (4) the labor cost in mixing and placing 1 cu. yard. of concrete; (5) the cost of sufficient aggregate to make 1 cu. yd. of concrete; (6) the cost per cubic yard of concrete for making the necessary excavation to start the concrete of the footings. The two items that largely control the cost of a structure of this kind are the excavation and the necessary aggregate for the concrete. We find that the cost per cubic yard of concrete for cement, forms, reinforcing steel, and the mixing and placing, have narrow limits in their variation.

It therefore appears possible that some definite quantities may be fixed to the first four items, and a curve plotted for the last two, combining them in such a way that the total cost may be readily determined after we have learned the number of cubic yards in the bridge.

The cost at the bridge site of sufficient cement to make 1 cu. yd. of concrete for a 1:2½:4 mixture may vary from $1.75 to $2.10. While the price of cement, the distance it has to be hauled, and the amount required for some aggregates, vary slightly, the extreme variation would not be over 20 cents per cubic yard from the average. From a general average of all cost data on this item, it would seem that we are probably safe in choosing for cement about $1.90 per cubic yard of concrete.

The cost of forms includes all the necessary falsework, bracing, and form lumber for completing the bridge. While this item varies somewhat for different localities, and will vary again where the contractor can use some of his old lumber, it will fall between the limits of 75 cents and $2.50. Experience has shown that about $1.50 for the ordinary type of bridge is usually sufficient, and might well be chosen for this cost curve.

The reinforcing steel varies from 50 lbs. per cubic yard for substructures to 170 lbs. per cubic yard for superstructures—or an average of about 110 lbs. for the two combined. This steel, delivered at the bridge site under ordinary conditions, and bent ready for placing in the structure, will cost about $2.10.

The item for mixing and placing concrete might vary from $1.50 per cubic yard for crushed rock concrete mixed by hand, to possibly as low as 40 cents for gravel concrete mixed by machinery. This item should also provide for the necessary work in spading the concrete next to the form and securing the desired finish. In spite of the possible wide variation, we find the cost of this item varies but little from the fixed amount of $1.25.

While all these quantities given above may seem somewhat in doubt as to their reliability, yet experience has determined that they are not far from the correct figures for normal conditions on the average bridge.

The item of excavation, which includes also cribbing, sheet-piling, pumping, and all necessary work to start the concreting of the footings, has been found from the cost data on file to vary from 50 cents to $5 per cubic yard of total concrete in the bridge. The 50 cents per cubic yard is found only in some very favorable cases and on the smaller spans, where there is practically no cribbing, sheeting, or pumping [illegible] per cubic yard [illegible] where cribbing, [illegible] are necessary. Quite [illegible] is due to [illegible] in charge. [illegible] with ex- [illegible] and with [illegible] to estimate [illegible] purposes.

[illegible] delivered [illegible] the price [illegible] favorable con- [illegible] aggregate [illegible] per cubic yard [illegible] the cost [illegible] per cubic [illegible] railroad sta- [illegible] gravel or [illegible] miles into

[illegible] Fig. 8 [illegible] com- [illegible] conditions [illegible] aggregate at [illegible]

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[illegible]

veloped for the deck girder, the through girder, floor-beam type, or the arch, and would prove of equal service to the highway engineer.

REINFORCEMENT TABLES FOR GIRDER AND SLAB BRIDGES

Tables 1, 2, and 4 will give the amounts of steel and size of members for different spans of highway bridges. The type of reinforcement used is indicated at the head of each table.

TABLE 1
Data for Trussed Bar Reinforcement
SLAB BRIDGE

SPAN	Thickness of Slab	Kahn Bars		Cup-Bars	
		Size	Spacing	Size	Spacing
4 Ft.	6 In.	½x1½ In.	12 In.	3 In.	24 In.
6 Ft.	6 In.	½x1½ In.	8 In.	⅜ In.	24 In.
8 Ft.	7 In.	¾x2 7/16 In.	12 In.	⅜ In.	24 In.
10 Ft.	8 In.	¾x2 7/16 In.	11 In.	⅜ In.	24 In.
12 Ft.	9 In.	¾x2 7/16 In.	10 In.	⅜ In.	24 In.
14 Ft.	10 In.	¾x2 7/16 In.	9 In.	⅜ In.	24 In.

Cup bars are placed over and at right angles to Kahn bars.

TABLE 2
Data for Trussed Bar Reinforcement
GIRDER BRIDGE

SPAN IN FT.	OUTSIDE BEAMS					CENTER BEAMS				
	SIZE	KAHN BARS				SIZE	KAHN BARS			
		STANDARD SHEARED		CENTER SHEARED			STANDARD SHEARED		CENTER SHEARED	
		No	SIZE	No	SIZE		No.	SIZE	No.	SIZE
12	10x16″	2	¾x2 7/16″	1	¾x2 7/16″	12x16″	2	1 x3″	1	¾x2 7/16″
14	10x16″	2	¾x2 7/16″	*1	1 x3″	12x16″	2	1x3″	1	1 x3″
16	10x18″	2	1 x3″	1	¾x2 7/16″	12x18″	2	1 x3″	*1	1¼x2¾″
18	12x18″	2	1 x3″	1	¾x2 7/16″	14x18″	2	1¼x2¾″	1	1 x3″
20	12x20″	2	1 x3″	1	1 x3″	14x20″	2	1¼x2¾″	1	1¼x2¾″
22	12x22″	2	1 x3″	1	1 x3″	14x22″	2	1¼x2¾″	1	1¼x2¾″
24	12x22″	2	1¼x2¾″	1	¾x2 7/16″	14x22″	2	2 x3½″	1	1 x3″
26	12x24″	2	1¼x2¾″	1	1 x3″	14x24″	2	2 x3½″	1	1 x3″
28	12x26″	2	1¼x2¾″	1	1 x3″	14x26″	2	2 x3½″	1	2 x3½″
30	12x28″	2	1¼x2¾″	1	¾x2 7/16″	16x28″	2	2 x3½″	1	2 x3½″
32	12x30″	2	1¼x2¾″	1	¾x2 7/16″	16x30″	2	2 x3½″	1	2 x3½″
34	14x30″	2	2 x3½″	1	1 x3″	16x30″	3	2 x3½″	2	¾x2 7/16″
36	14x32″	2	2 x3½″	1	1 x3″	16x32″	3	2 x3½″	3	¾x2 7/16″
38	14x34″	2	2 x3½″	1	1 x3″	18x34″	3	2 x3½″	2	1 x3″
40	14x36″	2	2 x3½″	1	¾x2 7/16″	18x36″	3	2 x3½″	2	¾x2 7/16″

*Bars full length.

Floor-Slab—6 in. thick, reinforced with ½x1½in. Kahn bars spaced 12 in. centers, and ⅜-in. Cup bars spaced 16 in. centers.

necessary. On the other hand, the cost of $5 per cubic yard of concrete is caused by a soft, seepy soil where cribbing, sheet-piling, and excessive pumping are necessary. Quite often the wide variation in the item for excavation is due to poor management on the part of the foreman in charge. This item, therefore, may vary considerably; but with experience with the excavation that is to be handled and with the type of bridge that is to be built, one is able to estimate this item sufficiently close for all practical purposes.

It will be seen that the cost of the aggregate delivered to the bridge site is the second item determining the price per cubic yard of concrete. Under the most favorable conditions with respect to location of a satisfactory aggregate supply, it would likely cost at least 50 cents per cubic yard to haul it to the mixing plant. On the other hand, the cost of aggregate at the bridge site might exceed $4 per cubic yard, as the structure may be isolated from a railroad station, and it may be necessary to ship in either gravel or crushed rock and sand, besides hauling it several miles into the country.

In the light of the wide range on these two items, Fig. 8 has been prepared to give the total cost of the bridge complete, including profit to the contractor under conditions where the cost of excavation, plus the cost of aggregate at the bridge site, might vary from $1 to $9.

For a specific case, we shall assume that a concrete bridge has 120 cu. yds. of concrete. We shall next investigate the condition of the foundation, and assume the cost for completing this part of the work, and express it as so much per cubic yard of concrete. We then approximate the cost of delivering at the bridge site the necessary aggregate to make 1 cu. yd. of concrete. For convenience let us say that these two quantities amount to $3 per cubic yard of concrete. Entering Fig. 8 with 120 cu. yds. at the left-hand side, and following this across to the $3 curve, or the $11 per cubic yard, which is the same thing, and then to the bottom of the figure, we find the cost of the bridge complete to be $1,300. The total cost per cubic yard of concrete is shown at the top for aid in determining the unit-price.

From the figures heretofore given, we are able to determine approximately the number of cubic yards in either the slab or the through girder type of bridge, besides having a ready means of determining the probable cost. While the curves here developed apply only to the slab and through girder types of bridges, similar curves might readily be developed for the deck girder, the through girder, floor-beam type, or the arch, and would prove of equal service to the highway engineer.

REINFORCEMENT TABLES FOR GIRDER AND SLAB BRIDGES

Tables 1, 2, and 4 will give the amounts of steel and size of members for different spans of highway bridges. The type of reinforcement used is indicated at the head of each table.

TABLE 1

Data for Trussed Bar Reinforcement

SLAB BRIDGE

SPAN	Thickness of Slab	Kahn Bars		Cup-Bars	
		Size	Spacing	Size	Spacing
4 Ft.	6 In.	½x1½ In.	12 In.	3 In.	24 In.
6 Ft.	6 In.	½x1½ In.	8 In.	⅜ In.	24 In.
8 Ft.	7 In.	¾x2 7/16 In.	12 In.	⅜ In.	24 In.
10 Ft.	8 In.	¾x2 7/16 In.	11 In.	⅜ In.	24 In.
12 Ft.	9 In.	¾x2 7/16 In.	10 In.	⅜ In.	24 In.
14 Ft.	10 In.	¾x2 7/16 In.	9 In.	⅜ In.	24 In.

Cup bars are placed over and at right angles to Kahn bars.

TABLE 2

Data for Trussed Bar Reinforcement

GIRDER BRIDGE

SPAN IN FT.	OUTSIDE BEAMS					CENTER BEAMS				
	SIZE	KAHN BARS				SIZE	KAHN BARS			
		STANDARD SHEARED		CENTER SHEARED			STANDARD SHEARED		CENTER SHEARED	
		No	SIZE	No	SIZE		No.	SIZE	No.	SIZE
12	10x16″	2	¾x2 7/16″	1	¾x2 7/16″	12x16″	2	1 x3″	1	¾x2 7/16″
14	10x16″	2	¾x2 7/16″	*1	1 x3″	12x16″	2	1x3″	1	1 x3″
16	10x18″	2	1 x3″	1	¾x2 7/16″	12x18″	2	1 x3″	*1	1[illegible]x2[illegible]″
18	12x18″	2	1 x3″	1	¾x2 7/16″	14x18″	2	1[illegible]x2[illegible]″	1	1 x3″
20	12x20″	2	1 x3″	1	1 x3″	14x20″	2	1[illegible]x2[illegible]″	1	1[illegible]x2[illegible]″
22	12x22″	2	1 x3″	1	1 x3″	14x22″	2	1[illegible]x2[illegible]″	1	1[illegible]x2[illegible]″
24	12x22″	2	1[illegible]x2[illegible]″	1	¾x2 7/16″	14x22″	2	2 x3[illegible]″	1	1 x3″
26	12x24″	2	1[illegible]x2[illegible]″	1	1 x3″	14x24″	2	2 x3[illegible]″	1	1 x3″
28	12x26″	2	1[illegible]x2[illegible]″	1	1 x3″	14x26″	2	2 x3[illegible]″	1	2 x3[illegible]″
30	12x28″	2	1[illegible]2[illegible]″	1	¾x2 7/16″	16x28″	2	2 x3[illegible]″	1	2 x3[illegible]″
32	12x30″	2	1[illegible]x2[illegible]″	1	¾x2 7/16″	16x30″	2	2 x3[illegible]″	1	2 x3[illegible]″
34	14x30″	2	2 x3[illegible]″	1	1 x3″	16x30″	3	2 x3[illegible]″	2	¾x2 7/16″
36	14x32″	2	2 x3[illegible]″	1	1 x3″	16x32″	3	2 x3[illegible]″	3	¾x2 7/16″
38	14x34″	2	2 x3[illegible]″	1	1 x3″	18x34″	3	2 x3[illegible]″	2	1 x3″
40	14x36″	2	2 x3[illegible]″	1	¾x2 7/16″	18x36″	3	2 x3[illegible]″	2	¾x2 7/16″

*Bars full length.

Floor-Slab—6 in. thick, reinforced with ½x1½in. Kahn bars spaced 12 in. centers, and ⅜-in. Cup bars spaced 16 in. centers.

TABLE 3

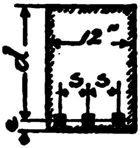
Values of Depth to Steel, Area of Steel, and Spacing of Steel Rods or Bars in Girders and Slabs, for Different Values of the Bending Moment

Formulas—

$$d = \sqrt{\frac{M}{1559}}$$

$$a = .0111 \times 12 \times d$$

Formulas based on allowable unit stresses of 750 lbs. per sq. in. on concrete and 13,500 lbs. per sq. in. on steel. 50% must be added to Live Load moments.



e=1¼ in. for ½ in. sq. bars
e=1½ in. for ¾ in. sq. bars
e=2 in. for 1 in. sq. bars

When S is less than 4 times dimension of bar a double row must be used.

Resisting Moment in thousands in.-lbs.	d (in.) Depth to Steel	a(sq.in.) Area of Steel per Foot Width	Spacing c to c for ¾ in. Sq. Bars	Spacing c to c for ½ in. Sq. Bars	Spacing c to c for 1 in. Sq. Bars
14	3	.40	16⅞	7½	30
19	3½	.47	14⅜	6⅜	26
25	4	.53	12¾	5½	22½
31	4½	.60	11¼	5	20
39	5	.67	10	4½	18
47	5½	.73	9¼	4	16½
56	6	.80	8½	3¾	15
66	6½	.86	7⅞	3½	14
76	7	.93	7¼	3¼	13
88	7½	1.00	6¾	3	12
100	8	1.06	6¼	2⅞	11¼
113	8½	1.13	6	2⅝	10½
126	9	1.20	5½	2½	10
141	9½	1.27	5¼	2⅜	9½
156	10	1.33	5	2¼	9
172	10½	1.40	4⅞	2⅛	8½
189	11	1.47	4⅝	2	8⅛
206	11½	1.53	4⅜	....	7⅞
224	12	1.60	4¼	....	7½
244	12½	1.67	4	....	7¼
264	13	1.73	3⅞	....	7
284	13½	1.80	3¾	....	6⅝
306	14	1.86	3⅝	....	6½
328	14½	1.93	3½	....	6¼
350	15	2.00	3⅜	....	6
400	16	2.13	3¼	....	5½
452	17	2.26	3	....	5¼
505	18	2.40	....	....	5
563	19	2.53	....	....	4¾
624	20	2.66	....	....	4½
688	21	2.80	....	....	4¼
755	22	2.93	....	....	4
823	23	3.06	....	....	4
897	24	3.20	....	....	3¾
975	25	3.33	....	....	3⅝
1,054	26	3.46	....	....	3½
1,139	27	3.60	....	....	3⅜
1,221	28	3.73	....	....	3¼
1,311	29	3.86	....	....	3⅛
1,404	30	4.00	....	....	3
1,499	31	4.13	....	....	3
1,593	32	4.26	....	....	2⅞
1,700	33	4.40	....	....	2¾
1,802	34	4.53	....	....	2⅝
1,910	35	4.66	....	....	2⅝
2,020	36	4.79	....	....	2½
2,135	37	4.93	....	....	2½
2,256	38	5.06	....	....	2⅜

TABLE 4

Data for Bar and Expanded Metal Reinforcement
GIRDER BRIDGE

Span in Feet	Outside Girders: Size of Girders (Ins.)	Outside Girders: No. and Size of Bars-Ins	Outside Girders: No Exp. Metal Web	Inside Girders: Size of Girders (Ins.)	Inside Girders: No. and Size of Bars-Ins	Inside Girders: No. Exp. Metal Web
12	8 x 12 x 17	{2– [illegible]″ {1– [illegible]″	10–3	10 x 17	2– [illegible]″	30–3
14	10 x 13 x 18	4– [illegible]″	10–3	10 x 18	3–[illegible]″	30–3
16	10 x 14 x 20	3– [illegible]″	15–3	10 x 20	3–[illegible]″	30–3
18	10 x 15 x 21	4– [illegible]″	15–3	12 x 21	3–1″	35–3
20	10 x 16 x 23	4– [illegible]″	20–3	12 x 23	3–1″	35–3
22	12 x 18 x 25	5– [illegible]″	25–3	12 x 25	2–1[illegible]″	40–3
24	12 x 18 x 26	4– [illegible]″	25–3	12 x 26	{2–1[illegible]″ {1– [illegible]″	40–3
26	12 x 19 x 27	3–[illegible]″	25–3	14 x 27	3–1[illegible]″	40–3
28	12 x 20 x 28	5– [illegible]″	30–3	14 x 28	{2–1[illegible]″ {2–1″	40–3
30	12 x 21 x 29	{2–1″ {1– [illegible]″	35–3	14 x 29	{3–1[illegible]″ {2– [illegible]″	40–3
32	12 x 22 x 30	3–1″	35–3	16 x 30	4–1″	40–3
34	12 x 23 x 31	4– [illegible]″	40–3	16 x 31	{3–1[illegible]″ {2–1″	40–3
36	12 x 24 x 33	{2–1″ {2– [illegible]″	40–3	16 x 33	{4–1[illegible]″ {1– [illegible]″	40–3
38	12 x 24 x 34	4–1″	40–3	18 x 34	5–1[illegible]″	40–3
40	12 x 25 x 35	3–1[illegible]″	40–3	18 x 35	{4–1[illegible]″ {2–1″	40–3

Cost of Through Girder Concrete Highway Bridges

The costs shown in Table 5 were given in a paper read by A. N. Johnson, State Highway Engineer of Illinois, before the Illinois Society of Surveyors and Engineers. The bridges referred to were of the through girder type, with the bridge floor supported by the two side girders. The mixture of concrete used consisted of 1 part Portland cement, 2½ parts sand, and 4 parts coarse aggregate.

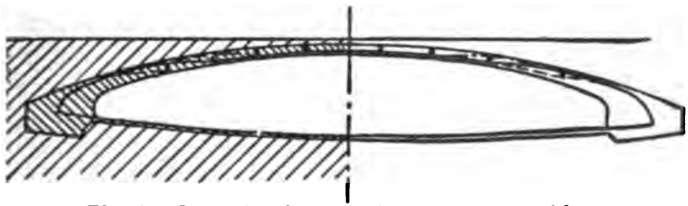


Fig. 9. Cross-Section of Highway Arch Bridge.

HIGHWAY ARCH BRIDGES

Highway arch bridges are usually low and flat, and vary in span length from 20 to 100 ft. The ordinary type consists

TABLE 5

Cost Data of Reinforced Concrete Bridges Built in 1909

Name	Clear Opening (feet)	Roadway (feet)	Height of Abutments (feet)	Substructure: Concrete in Cu. Yds.	Substructure: Steel in Pounds	Superstructure: Concrete in Cu. Yds.	Superstructure: Steel in Pounds	Total Concrete in Cu. Yds.	Total Steel in Pounds	Cost per Cu. Yd.: Cement	Stone	Sand	Gravel	Forms	Steel in Place	Mixing Placing Concrete	Excavating Per Cu. Yd. Concrete	Total Cost Per Cu. Yd. Concrete
Hamel	7	18	7	22.71	650	6.91	670	29.62	1,520	$1.35	$2.44	$0.61	....	$1.50	$1.16	$1.61	$1.28	$ 9.85
Heckle	8	20	14	61.74	2,927	7.42	741	69.16	3,668	1.81	0.77	0.80	....	1.71	0.81	1.50	0.41	7.87
Kresting	10	16	14	46.55	1,652	11.45	1,041	58.00	2,693	1.51	....	1.06	$2.05	1.59	0.80	1.16	1.16	9.83
Stahlburtt	12	14	..	....	....	....	....	16.00	1,800	1.30	3.22	0.32	....	3.07	2.41	0.95	....	10.23
Geo. Schreiner	12	16	9.5	35.60	1,290	11.85	1,223	47.45	2,513	1.85	....	....	1.19	2.16	1.53	1.23	1.09	9.05
Cronkhite	12	18	12.5	52.87	1,926	17.13	1,554	70.00	3,480	1.46	....	0.86	1.72	2.39	0.84	1.46	2.16	10.39
West Avery	13	16	8.5	37.60	....	34.20	4,120	71.80	4,120	2.25	....	....	1.00	1.70	1.28	0.80	1.09	8.12
Carr	14	16	12	33.28	1.027	13.31	1,924	46.59	2,951	1.74	2.61	1.10	....	1.37	1.12	1.77	0.50	10.22
Thompson	14	16	15	27.07	724	14.93	1,647	42.00	2,371	2.05	2.71	1.46	....	2.50	1.26	1.21	1.79	12.50
Town Line	14	19	8.5	34.74	1,892	17.38	1,928	54.85	3,820	1.34	3.06	0.76	....	1.01	1.72	0.84	1.06	9.80
Joe Hatter	14	16	9	23.74	700	14.93	1,647	38.67	2,347	1.56	1.64	0.72	....	1.44	1.44	2.05	1.00	9.85
Feldmans	14	16	22	139.00	10,633	15.44	1,688	154.44	12,321	1.48	1.99	0.65	....	2.33	1.39	1.95	2.91	14.25
Phillips	14	16	11	29.82	790	13.31	1,926	43.13	2,716	1.74	2.78	1.22	....	1.56	1.24	1.93	0.81	11.81
Funk	14	16	9	26.96	879	14.93	1,647	41.89	2.526	1.68	1.06	0.61	....	2.10	1.48	1.16	1.07	9.79
Derichson	16	16	12	38.84	1,400	21.28	2,454	60.12	3,854	1.56	2.45	1.09	....	3.82	1.51	1.00	2.49	14.52
John Lawson	16	16	11	37.52	1,546	21.28	2,454	58.80	4,000	1.61	2.50	1.11	....	2.47	1.25	1.09	1.69	11.72
Stillwell	16	16	7.5	30.35	546	21.28	2,454	51.63	3,000	1.30	1.30	0.35	....	0.96	1.34	0.82	0.43	6.54
Calvert No. 1-6	17-19	..	..	....	....	....	....	48.37	6,307	1.72	....	0.78	1.38	1.36	2.64	0.96	0.47	9.78
Scotts	19	16	12.5	....	....	....	....	84.26	6.050	1.74	1.92	0.29	1.20	2.30	1.44	1.50	0.96	11.94
Edw. Peterson	20	16	15	92.21	1,845	25.12	3,910	117.33	5,755	1.44	....	....	0.85	1.36	1.04	1.26	2.80	9.86
Lamb	20	16	18	56.79	1,428	25.12	3,910	81.91	5,338	1.57	0.88	0.40	0.28	1.74	1.37	1.27	1.45	9.86
Fuller	20	16	18	60.05	1,955	25.12	3,910	85.17	5,865	1.68	1.75	0.36	0.70	1.51	1.57	1.10	1.18	9.63
Dog Bridge	20	16	18	91.68	4,325	25.12	3,910	116.80	8,235	2.34	....	....	0.96	1.37	1.52	0.90	1.23	8.82
Lillis Creek	20	16	15.5	64.97	2,760	25.12	3,910	90.09	6,670	2.30	1.93	0.06	2.42	2.96	1.61	2.72	2.68	17.51
Phillips	20	16	14.5	39.55	1,501	25.12	3,910	64.67	5,411	1.25	....	....	1.96	0.88	1.78	0.86	0.50	7.52
Sornberger	22	16	14	60.55	2,484	30.29	5,006	91.24	7,490	1.96	....	....	1.65	2.57	2.34	1.07	1.00	10.90
Creamery Cr.	24	16	8.5	32.10	1,194	30.89	5,006	62.99	6,200	2.31	....	....	1.91	1.97	1.96	0.73	1.52	10.88
White	25	16	11.5	38.35	1,355	26.18	5,416	64.53	6,771	1.62	0.49	....	1.66	2.73	2.48	2.07	1.67	12.70
Slough	25	16	7	60.12	1,906	26.18	5,416	86.30	7,352	1.45	2.12	0.94	....	2.91	2.75	0.90	0.31	10.66
McConkey	25	14	12	44.62	1,799	24.20	5,085	68.82	6,884	1.37	2.97	1.47	....	2.57	1.90	1.14	1.13	12.06
Drl. Stassen	30	16	11	51.62	1,849	41.61	6,786	93.23	9,635	1.48	1.88	2.24	....	1.84	2.48	1.76	1.85	[illegible]
McNair	34	16	12	59.30	2,390	62.70	11,044	122.00	[illegible]	1.70	....	....	1.48	2.95	[illegible]	0.90	1.10	[illegible]
Schorber	35	16	15	71.40	2,766	52.40	[illegible]	123.80	11,718	1.90	1.48	0.14	0.78	1.84	[illegible]	1.09	0.78	[illegible]
Roper	35	16	10	57.40	[illegible]	52.40	[illegible]	109.80	11,499	1.58	0.90	1.41	2.06	1.41	[illegible]	[illegible]	[illegible]	[illegible]
Stockland	40	16	12	71.60	3,212	[illegible]	12,784	135.94	15,997	1.47	1.49	0.47	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	40	16	16	84.22	3,271	[illegible]	[illegible]	134.08	13,196	1.70	....	0.70	2.42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Boyd	50	16	18	72.75	[illegible]	66.00	14,172	138.75	16 600	2.35	....	....	1.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mud Creek	60	16	16	109.00	[illegible]	97.07	[illegible]	206.07	[illegible]	1.81	1.50	1.11	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

of an arch-barrel and spandrel walls, with an earth filling between the walls. Ornamental concrete parapets are often used, although ordinary gaspipe railing is very common. The width of these bridges ranges from 14 ft. for small creek crossings, to 60 ft. or over for structures carrying city streets.

Fig. 9 gives a cross-section of a highway arch bridge. This bridge was built in 1904, at Yorktown, Indiana. It has a span of 95 ft.; a rise of 11 ft. 1 in.; a height of opening of 15 ft. 7 in., and crown thickness of 26 in. The roadway is 16 ft. wide. The arch-rods are ¾ in. square, spaced 6 in. The parapets are monolithic concrete, 18 in. by 3 ft. high. The design was made for a 20-ton roller, or 200 pounds per sq. ft.

For ordinary highway construction where long spans are required, and where heavy loads such as traction engines and their accompanying machines or heavy earth-fills will occur, an arch of this type is especially suitable. The construction has all the strength of the masonry arch, with much greater elasticity. In case of settlement of the abutments, the reinforcing steel will take strains that would cause large cracks in ordinary masonry.

In cities and towns where it is necessary to have the streets cross a stream, the reinforced concrete arch not only insures strength and stability, but is capable of such varied artistic treatment that it is being almost universally adopted in municipal work.

CONCRETE ARCH BRIDGES

Mr. George P. Carver, in his handbook on Reinforced Concrete, gives the accompanying detailed estimates of concrete arch bridges of 50, 75, and 100-ft. span, 28 ft. wide, from which he has prepared a curve of costs to be used in roughly estimating such structures for interurban railroad use:

SPAN, 50 FT.; WIDTH, 28 FT.

Steel, 27,700 lbs., at 2½ cents	$ 692.50
Steel placing, 27,700 lbs., at 1 cent	277.00
Form work at $1 per cu. yd	370.00
Cement, 481 bbls., at $2	962.00
Sand, 185 cu. yds., at $1	185.00
Stone, 370 cu. yds., at $2	740.00
Mixing and placing 370 cu. yds. at $1.50	555.00
	$ 3,781.50
Incidentals, add 15 per cent	567.22
	$ 4,348.72
Profit, add 10 per cent	434.87
	$ 4,783.59

SPAN, 75 FT.; WIDTH, 28 FT.

Steel, 38,000 lbs., at 2½ cents	$ 970.00
Placing steel, 38,800 lbs., at 1 cent	388.00
Form work at $1 per cu. yd	740.00
Cement, 962 bbls., at $2	1,924.00
Sand, 370 cu. yds., at $1	370.00
Stone, 740 cu. yds., at $2	1,480.00
Mixing and placing 370 cu. yds. at $1.50	555.00
	$ 6,982.00
Incidentals, add 15 per cent	1,047.30
	$ 8,029.30
Profit, add 10 per cent	802.93
	$ 8,832.23

SPAN, 100 FT.; WIDTH, 28 FT.

Steel, 38,800 lbs., at 2½ cents	$ 970.00
Placing steel, 55,650 lbs., at 1 cent	556.50
Form work at $1 per cu. yd	1,008.00
Cement, 1,310 bbls., at $2	2,620.00
Sand, 504 cu. yds., at $1	504.00
Stone, 1,008 cu. yds., at $2	2,016.00
Mixing and placing 1,008 cu. yds., at $1.50	1,512.00
	$ 9,607.75
Incidentals, add 15 per cent	1,441.16
	$11,048.91
Profit, add 10 per cent	1,104.89
	$12,153.80

Table 6 gives some of the dimensions and costs of a number of arches. In the case of single arch spans, the cost per square foot is computed from face to face of abutments and out to out of railings.

Specifications for Design of Concrete Bridges

Bureau of Surveys, Department of Public Works, Philadelphia, Pa.

Data for Calculation. The structure shall be proportioned to carry the dead load—consisting of the weight of the struc-

TABLE 6
Dimensions and Costs of Concrete Arch Bridges

Place	Over	Total Length Bridge	Arch Spans	Width	Rise of Arch	Total Cost	Cost per Sq. Ft.	Date Erected
Pine Road, Phila.	Pennypack Creek	....	2a 25'4¾"	34'3¾"	6'6"	$ 8,662	$ 4.94	1893
Neuhansel, Hungary	Neutra	....	6a 55'9½"	19'8"	3'8½"	13,700	2.00	1893
Richmond Av., Syracuse	Harbor Brook	....	12'0"	49'0"	2'6"	2,000	3.40	1894
Eden Park, Cincinnati	Park Ave.	....	70'0"	32'0"	10'0"	7,130	3.15	1895
Stockbridge	Housatonic	....	100'0"	7'6"	10'0"	1,475	2.00	1895
Belleville, Ill	Richmond Creek	....	40'0"	52'0"	7'0"	10,500	3.90	1895
Topeka	Kansas River	693'0"	5a 125'0" 2a 110'0" 2a 97'6"	40'0"	....	125,000	4.50	1896
Green and Goat Islands	Niagara	371'0" 198'0"	2a 103'6" 1a 110'0" 2a 50'6" 1a 55'0"	40'0"	....	102,070	4.50	1900
Indianapolis	Fall Creek	....	6a 74'0"	65'0"	9'6"	105,340	8.70	1900
Washington	Rock Creek	....	80'0"	27'0"	15'0"	17,500	8.10	1901
Wabash Co., Ind.	....	....	25'0"	16'0"	....	573	1.45	1902
Forest Park, St. Louis	....	....	45'0"	45'0"	....	10,600	5.20	1902
I. C. R. R.	Big Muddy River	483'0"	3a 140'0"	34'2"	30'0"	125,000	7.60	1901-3
Plainwell, Mich.	Kalamazoo River	446'0"	7a 54'0"	25'0"	8'0"	19,900	1.80	1903
Saley St., Brooklyn	Prospect Ave	125'0"	85'0"	60'0"	....	21,800	4.30	19—
Munich	Grunwald	720'0"	2a 230'0"	30'0"	42'0"	65,000	3.10	1904
Connecticut Av., Washington	....	1,341'0"	2a 82'0" 5a 150'0"	52'0"	41'0" 75'0"	850,000	12.20	1905
16th St., Washington	Piney Branch	272'0"	125'0"	25'0"	39'0"	42,731	6.25	1905
Dayton	Great Miami	588'0"	69'0"-88'0"	56'0"	....	123,170	3.70	1904
Park Ave., Newark	Branch Brook Pk.	243'7"	132'0"	74'0"	10'2"	84,000	4.70	1905
Connington, Viaduct	....	600'0"	10a 50'0"	16'0"	16'0"	52,200	5.43	1903
Greensburg, Ind.	Clifty Creek	....	80'0"	16'0"	12'0"	2,695	2.10	....
Wayne St., Peru	Wabash River	500'0"	6a 75' to 100	30'0"	15'0"	36,900	2.46	....
Wabash, Ind.	Charley Creek	....	2a 75'0"	30'0"	18'0"	7,000	1.56	....
Muncie, Ind.	....	....	38'0"	16'0"	7'6"	640	1.21	....
Bangor, Me	....	90'0"	46'7¾" 38'2"	40'0"	8'7" 7'6"	6,500	1.80	....
Sandy Hill	....	1,025'0"	15a 60'0"	35'8"	....	72,000	2.00	....
Walnut Lane, Phila.	....	585'0"	233'0"	60'0"	....	262,000	7.50	....
Maryborough, Queensland	....	613'0"	a 80'0"	22'8"	4'0"	75,000	5.40	....
Lansing, Mich.	Grand River	....	120'0"	52'10"	23'0"	31,000	4.90	....

Data Sheet for Reinforced Concrete Bridge

NORTHWESTERN EXPANDED METAL CO., CHICAGO, ILL.

No.................. Date.................................19....

Bridge to be erected at ....

Nearest R. R. station.................on.................R. R. Reinforcement to be shipped via..................................

Name and address of inquirer ....

Kind of bridge. Slab {Yes. No. Girder {Yes. No. Arch {Yes. No.

Number of spans............Clear span, face to face of abutments,............ft..........in. Overall width.............ft.............in.

Clear width between railings............ft.............in. Railing to be Concrete {Yes No Wood {Yes. No. Iron {Yes. No.

Remarks ....

....

....

Width of roadway......ft.........in. {If there will be sidewalks width of roadway is distance from curb to curb.} Sidewalk widths {Right.........ft.........in. Left ....ft.........in.

Gutter.........in. deep (The right side is the side on the right hand when facing down stream.)

HEIGHTS ABOVE BOTTOM OF FOOTINGS. (Send with this sheet a profile of the bridge site if a survey has been made. Make sketch in this space and on back of sheet.)

To top of wall or railing. ....ft............in.
To top of macadam or paving.........ft............in.
To top of earth fill..................ft............in.
To top of concrete..................ft............in.
To high water mark..................ft............in.
To ordinary water mark.............ft............in.
To low water mark..................ft............in.
To bottom of stream................ft............in.
Footings should go......ft.........in. below low water level.

Pavement will be......in. thick of..............on..............foundation......in. thick on......in. of earth at middle of span.

Heaviest load will be { Farm Wagon, weighing loaded.................................; Threshing outfit, weighing.................................; ....Ton Road Roller.................................; ....Ton Electric car................................. } Cross out all but the heaviest load to be carried.

If Electric R. R. will use bridge, track will be { Single ....; Double .... } and will occupy { Right..................; Middle ....; Left .... } Part of roadway.

Character of foundation..

....

....

....

Remarks ....

....

....

....

....

....

(Use other side of this sheet if necessary.)

tural material, driveway, and sidewalk formation, rails, curbs, and railings—and one of the following classes of live load:

A uniformly distributed load over the entire surface, including driveway and sidewalks, as follows:

For spans up to 75 ft., 100 pounds per sq. ft.

For spans over 75 ft. and not over 150 ft., 90 pounds per sq. ft.

For spans over 150 ft., 80 pounds per sq. ft.

Sidewalk brackets, joists, and floor to be proportioned for a local loading of 110 pounds per sq. ft.

A concentrated moving load as follows:

For bridges with permanent pavement on metal deck, a load of 40 tons equally distributed on four wheels spaced 20 ft. between axles, and 6 ft. gauge.

The following weights are to be used in computing the dead load:

Concrete, 140 pounds per cu. ft.

Binder coat, 135 pounds per cu. ft.

Granolithic pavement, 140 pounds per cu. ft.

Asphalt wearing surface, 87 pounds per cu. ft.

Granite block paving, 6 in. in depth, 80 pounds per sq. ft.

Vitrified brick paving, 4 in. in depth, 50 pounds per sq. ft.

Woodwork, 4 pounds per foot, board measure.

Comparative Costs of Small Railroad Bridges

In order to determine the most economical type of structures for short-span railway bridges, the costs of four different designs were computed for span lengths of from 10 to 35 ft. The four types of structures which were estimated are as follows:

A—I-beam span with standard open wooden floor.

B-1—I-beams imbedded in concrete and ballast floor.

B-2—Concrete ballast floor supported on I-beams.

C—Reinforced concrete slab with ballast floor.

The spans were figured for the total dead loads and a Cooper's E-50 live load. The unit allowed stresses in the steel beams were 8,000 lbs. per sq. in. for live load, and 16,000 lbs. per sq. in. for dead load. The allowed unit-stresses in the concrete slabs were 750 lbs. per sq. in. in the concrete, and 13,500 lbs. per sq. in. in the steel, for dead load; and 500 lbs. per sq. in. in the concrete, and 9,000 lbs. per sq. in. in the steel, for live load.

The steel beams were estimated to cost 2¾ cents per pound; the reinforcing steel, 3 cents per pound; the concrete, 35 cents per cu. ft., or $9.50 a cu. yd. The ballast

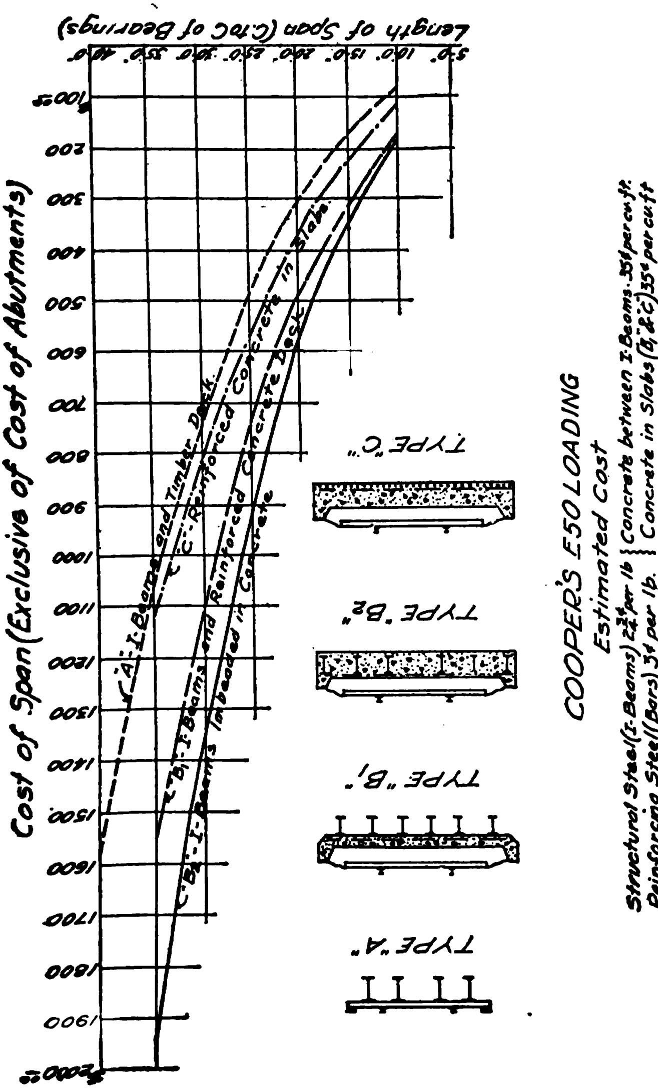


Fig. 10. Curves Showing Costs of Various Types of Short-Span Bridges.

and floor were estimated at $1.50 per linear foot, and the wooden floor at $3.60 per linear foot.

The costs for each of the four designs for the various spans were plotted as shown in Fig. 10. The spans are laid off on one axis; and the costs in dollars for the structure, exclusive of abutments, are laid off on the other axis. Fig. 10 shows also the cross-sections of the four types considered. An inspection of the curves will show the following:

1. The I-beam spans with the open wooden floor are the cheapest.

2. The reinforced concrete slabs are only slightly more expensive than the Type A spans, and cheaper than Types B-1 and B-2.

3. The Type B-2 spans, I-beams imbedded in concrete, are the most costly construction.

4. The difference in cost between the Type A and Type C spans does not increase as the span length increases.

5. The difference in cost between the Type C and Type B spans increases rapidly as the span length increases.

It will be noticed that a slight change in the relative costs of the steel and concrete in the various types will affect relative positions of the curves. The costs used are indicated to be average, and therefore the curves indicate the economy of the various types of spans in the average case. It is entirely possible, however, that under certain conditions the cost of concrete may be so low that the Type C spans will be cheaper than the Type A spans.

Abutments and Piers

Design of Abutments. The supports at each end of a bridge are known as **abutments.** An abutment serves a number of purposes: it furnishes a resting-place for the end of the span; it distributes the weight of the bridge over the foundation; and it prevents the bank from running out into the stream at the end of the bridge.

It is the object of bridge engineers to plan abutments which will fulfill these requirements and at the same time be as economical as possible to construct; and every man who may be called upon to assist in bridge-building should understand this object if he expects to do his part of the work intelligently.

The first step in the design of an abutment is to provide a resting-place for the **pedestals** which carry the bridge-span. These pedestals are made sufficiently large to prevent the crushing of the material of the top of the abutment, or bridge-seat, under the load of the bridge. After the size of the bridge-seat has been determined, the area and depth of the **foundation course** is calculated, the actual dimensions depending on the nature of the underlying soil, which is known from preliminary investigations. The third and last step is to provide for the **embankment** behind the abutment in such a way that it will not encroach on the clear waterway or opening under the span. There have been a number of abutment types developed to accomplish this object, among which are: **wing-abutments, Tee-abutments, U-abutments, arch abutments**, and a number of special types.

Bridge Piers. It has always been the endeavor of bridge-builders to make the clear span of their structures as large as possible; but since the cost of a bridge increases very rapidly as the span is made longer, it is customary to cross only the smaller streams and valleys without the use of intermediate supports between abutments. When a bridge is supported at some point between the abutments, the supporting structure is known as a **bridge pier** or **tower.** Towers are used only for high viaducts and short spans, and are seldom placed in mid-stream; piers are far more common.

From its definition it will be seen that a pier has to carry the vertical weight of the bridge and its traffic; it usually is placed in mid-stream, and must be able to resist the action of moving water and ice, and it must give the bridge an anchorage to prevent its overturning as a result of wind or vibration. To accomplish these ends, a pier must have compressive strength, massiveness, and weight, and be designed for stability and bearing power. The civil engineer has these objects in view when he is planning the piers for a particular bridge; and a knowledge of his methods, as well as of the ways and means of getting the required results, should be of value to the construction man who carries out the work in the field.

The first problem—to design the pier with sufficient compressive strength and footing area to transmit the load to the foundation and spread it sufficiently to prevent settlement—is attacked as follows:

The part of the total weight of the bridge superstructure —trusses, girders, bracing, floor, etc., as well as the load of the trains, cars, vehicles, and people—which can possibly come on the piers, is computed. The steel or cast-iron **shoes** or **pedestals** which rest on the top of the pier are then made large enough to distribute this load so as not to exceed the safe compressive strength of the material of which the pier is constructed. The size of the top of the pier—or the bridge-seat, as it is technically known—is governed by the size and position of these bridge pedestals. The dimensions of the pier are usually increased from the top downward, by sloping or "battering" the sides until the top of the footing course is reached. Footing course is the name given to the lowest part of the structure, and is the layer of masonry resting directly on the foundation. The bottom of the pier must be placed at such a depth below the surface of the ground or bed of the stream as will insure a firm foundation and safety from the effects of frost and the scouring action of the current.

The total weight of the bridge coming on the bridge-seat, together with the weight of the pier itself, constitute the total load on the foundation; and the area of the base of the pier must be made large enough to distribute this pressure according to the safe supporting power of the particular foundation. The nature of the foundation is ascertained before the design is made, and the supporting power in tons per sq. ft. is estimated. In many cases it is found necessary to use piles or more extreme precautions to give the pier a sufficiently firm foundation.

The second requirement for the design of a pier is that it should be able to resist the action of running water or moving ice and debris. Water will have little effect on a masonry pier unless it manages to undermine the footings; and this will not occur if the precautions mentioned in the preceding paragraph are taken. Floating ice and wreckage, however, constitute a formidable menace to the stability of a bridge; and for this reason it is well to have as few piers as possible exposed to the current. Such piers as are exposed should be made massive, well founded to prevent sliding, and shaped to obstruct the current as little as possible and deflect the logs or ice that may be thrown against them. For this reason, piers have their long dimension parallel to the stream, are made as narrow as possible, and are provided with a rounded or pointed cut-water or starling at the upstream end. The nose is often reinforced with old rail, steel bars, or cast-iron plate.

The final requirement for a well-designed pier—stability against overturning—is usually supplied for ordinary heights if the precautions mentioned above have been taken. In the case of a high pier, however, it is often necessary for the engineer to make additional calculations in view of possible overturning.

Bridge piers have been built of piles, timber frames filled with stone, metal cylinders filled with concrete, brick, and stone masonry, but are now generally constructed of concrete, which is an ideal material to answer all the requirements.

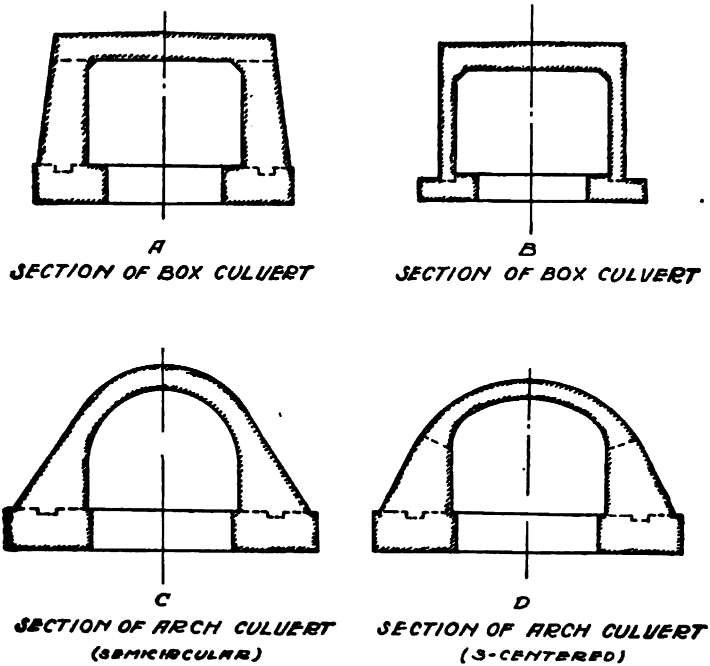


Fig. 11. Culvert Sections.

For piers of average height, plain concrete is all that is required; but for the center piers of swing-bridges, and for piers of extreme height, it has been found economical in many cases to use reinforced concrete and to make the piers hollow.

The cost of abutments and piers will vary in each particular design, but may be estimated approximately by determining the quantity of materials needed from the plans, and determining the cost of placing from the rules already given under "Concrete Construction."

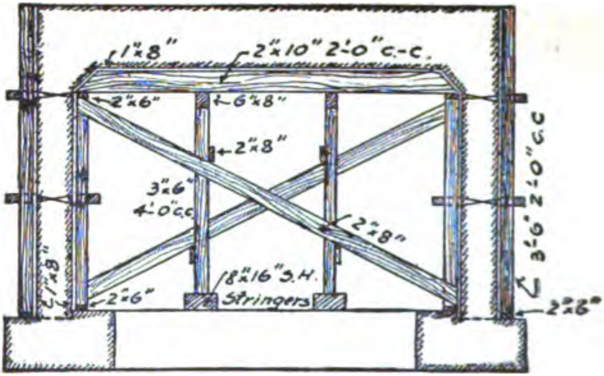


Fig. 12. Section of Concrete Box Culvert, Showing Forms.

REINFORCED CONCRETE CULVERTS

The difference between a culvert and a bridge is not very clearly marked. A large culvert may be called a small bridge, and a small bridge is but little different from a culvert. The two structures may best be distinguished by their purpose—a bridge being intended as a crossing over a stream or gulch, while a culvert is needed to allow a creek or ditch to pass under a road. A culvert serves as a drain or conduit, and is covered by the road embankment; for this reason it must be composed of a material which will

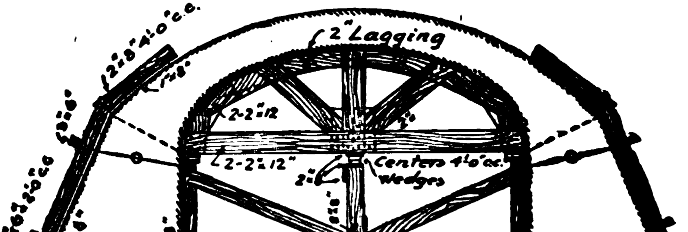


Fig. 13. Cross-Section of Concrete Arch Culvert, Showing Forms.

not rot under the most adverse conditions of alternate wet and dry periods.

Bridges are often built of considerable lengths, when an embankment with a small culvert would be much more desirable because of the greater stability and permanence of the crossing and the reduced cost of repairs and renewals.

There are three distinct types of culverts: **Box-culverts,** which are rectangular in section; **arch culverts,** which have arched tops and in some cases arched floors; and **pipe culverts,** which are circular or elliptical in section.

Box culverts (see Fig. 11, **A** and **B**, and Fig. 12) were formerly built of wood or stone, and later of concrete, with covers of old rails; but reinforced concrete is now the standard construction. Arch culverts (see Fig. 11, **C** and **D**, and Fig. 13) are built of concrete, either plain or reinforced, the more modern material having replaced stone masonry.

Culvert pipes of cast iron, corrugated sheet steel, and vitrified clay, are still used; but concrete has invaded this field also, and is perhaps more extensively used today than any other material for culvert construction. In some instances it is combined with the sheet metal, the latter being used as as form for the bore and left in place after the concrete is filled in.

Table 7 gives figures from which to make estimates, giving the necessary thickness of top, bottom, and side walls for various-sized culverts, the amount of material needed, etc. These figures are for culverts 18 ft. long. On longer or shorter ones, make estimates in proportion.

The costs of completed culverts as here estimated are figured on cement at 65 cents per hundred pounds, and gravel at $1 per yard. The cost of this kind of concrete work

TABLE 7

Data for Estimating on Culvert Construction

Diameter of Culvert Inches	Waterway Squared Inches	Thickness Bottom Inches	Thickness Sides Inches	Thickness Top Inches	Cubic Feet Sand Required	Pounds Cement Required	Width to Dig Ditch Inches	Complete Cost
8	6x8.87	3	4	4½	30	465	16	$ 5.40
11	10x9.50	3	4	5	36	558	19	6.84
13	12x11.60	3	5	6	48	744	23	8.64
15	12x14 75	4	5	6	50	915	25	10.62
19	16x17,72	4½	5½	6½	85	1317	30	15.80
22	19x20	4½	5½	6½	90	1806	33	16.20
27	24x23.75	5	6	7	124	1922	39	22.82
33	24x41	5	6	7	165	2557	48	28.70
46	36x57 50	6	7	8	255	3962	62	40.80

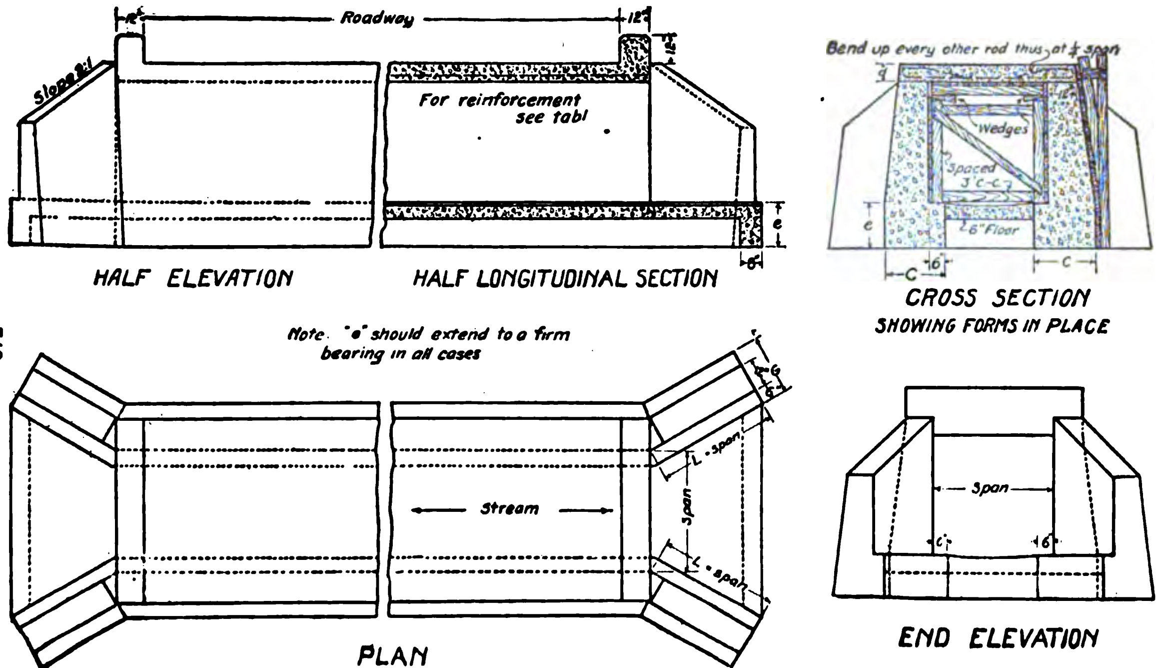


Fig. 14. Typical Design of Reinforced Concrete Box Culvert.

is close to 18 cents per cu. ft. of concrete used; and, as cement in the proportions mentioned does not increase the bulk of gravel, to estimate the cost of any sized culvert completed, multiply the estimated amount of gravel, in cu. ft., by 18—this will give you the cost complete. Multiply by 11 to get the cost of cement; by 7 for cost of material on the ground and placed.

The figures in the table are made on a basis of 18-ft. culverts, with coping to extend two feet from waterway through culvert, and concrete in proportion of 1 part cement to 6 parts gravel or sand.

Box Culverts

Tables 8 to 11, compiled by the Information Bureau of the Universal Portland Cement Company, give dimensions of parts, and quantities of materials needed, in the case of box culverts with different heights of fill.

Arch Culverts

Tables 12 and 13, also compiled by the Information Bureau of the Universal Portland Cement Company, give sizes and quantities of materials needed in case of plain concrete arch culverts up to 8 ft. in span.

TABLE 8

Data for Culvert Construction

Wing Wall Dimensions—Flat-Top Culvert

(To be used with Tables 9, 10, and 11)

Span	Height = Span + Floor Thickness	L = Span	G	Depth of Apron	Amount of Materials, Including Apron, Guard Rail, and Floor Between Wing Walls			
					Concrete Cu. Yds.	Cement Bbls.	Sand Cu. Yds.	Gravel Cu. Yds.
3′-0″	3′- 6½″	3′-0″	1′- 8″	Minimum depths 18″. Should be carried to bottom of footings in all cases.	3.5	4.7	1.6	3.2
3′-6″	4′- 1 ″	3′-6″	1′-10″		4.3	5.4	2.0	4.0
4′-0″	4′- 7½″	4′-0″	2′- 0″		5.8	7.2	2.7	5.4
4′-0″	5′- 2½″	4′-6″	2′- 0″		7.1	8.9	3.3	6.6
5′-0″	5′- 9 ″	5′-0″	2′- 3″		8.6	10.7	4.0	8.0
5′-6″	6′- 3½″	5′-6″	2′- 3″		10.4	13.0	4.8	9.6
6′-0″	6′-10 ″	6′-0″	2′- 6″		12.8	16.0	5.9	11.8
7′-0″	7′-11½″	7′-0″	2′- 9″		17.4	21.8	8.0	16.0
8′-0″	9′- 1 ″	8′-0″	3′- 0″		25.6	32.0	11.8	23.6

Concrete—1:2½:5.

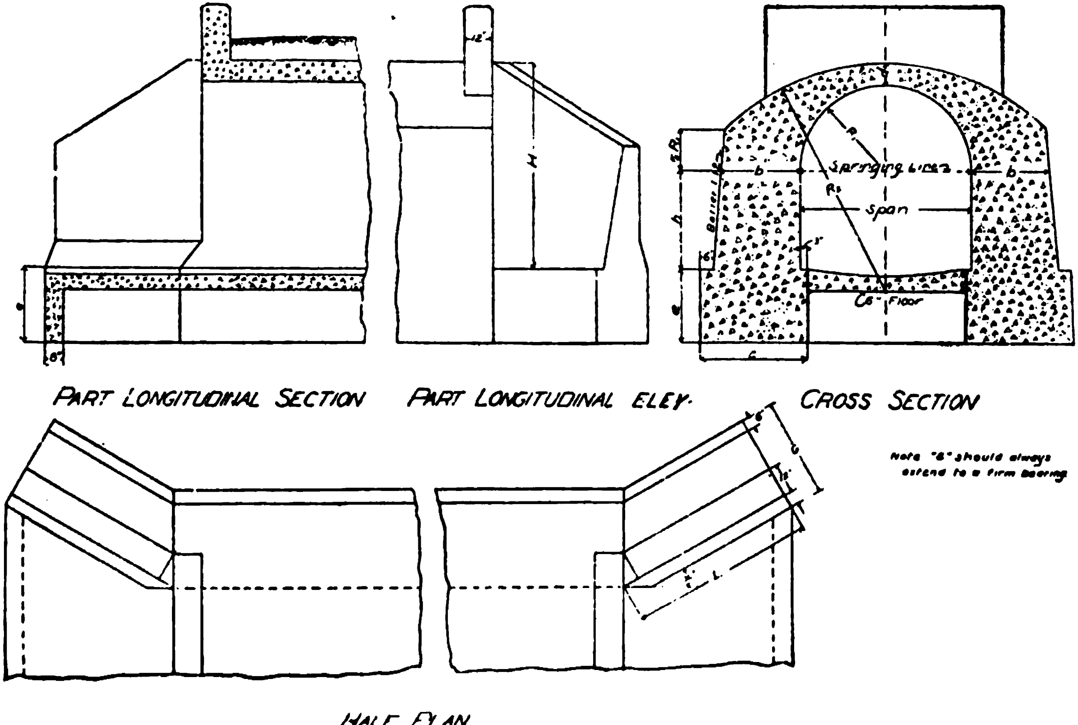


Fig. 15. Typical Design of Plain Concrete Arch Culvert.

TABLE 9

Data for Culvert Construction

Flat-Top Culvert, 2-Foot Fill, Computed for 24-Ton Roller

Span	Height	Slab Thickness "d"	Slab: Concrete Below Steel	Slab: Reinforcement: Tension: Size	Slab: Reinforcement: Tension: Spacing	Slab: Reinforcement: Temperature: Size	Slab: Reinforcement: Temperature: Spacing	Side Walls: C	Side Walls: e	Materials—Per Foot of Length Exclusive of Wing Walls: Steel lbs.	Materials: Concrete Cu. Yds.	Materials: Cement Bbls.	Materials: Sand Cu. Yds.	Materials: Gravel Cu. Yds.
3′–0″	3′–0″	6 ″	1 ″	½″	6 ″	½″	12″	1′– 8″	To extend to firm foundation in all cases. Assumed as 18″ to figure quantities.	8.0	.65	.835	.30	.60
3′–6″	3′–6″	6½″	1 ″	½″	5½″	½″	12″	1′–10″		9.3	77	.99	.35	.71
4′–0″	4′–0″	7 ″	1 ″	½″	5 ″	½″	12″	2′– 0″		12.2	89	1.15	41	.82
4′–6″	4′–6″	7½″	1 ″	½″	4½″	½″	12″	2′–2″		14.6	.97	1.25	.45	.89
5′–0″	5′–0″	8 ″	1 ″	½″	4 ″	½″	12″	2′– 5″		17.3	1.08	1.39	.50	.99
5′–6″	5′–6″	8½″	1 ″	½″	4 ″	½″	12″	2′– 7″		17.3	1.32	1.70	.61	1.21
6′–0″	6′–0″	8½″	1 ″	⅝″	6 ″	⅝″	12″	2′– 9″		20.6	1.49	1.91	.68	1.37
7′–0″	7′–0″	9½″	1¼″	⅝″	5½″	⅝″	12″	3′– 2″		27.0	1.79	2.30	.82	1.65
8′–0″	8′–0″	10 ″	1¼″	⅝″	5 ″	⅝″	12″	3′– 6″		32.0	2.20	2.83	1.01	2.02

Concrete—For slab, 1:2:4; for side walls, 1:2½:5. Steel—Soft round rods.

TABLE 10

Data for Culvert Construction

Flat-Top Culvert, 6-Foot Fill, Computed for 24-Ton Roller

Span	Height	Slab Thickness "d"	SLAB					SIDE WALLS		MATERIALS PER FOOT OF LENGTH EXCLUSIVE OF WING WALLS				
			Concrete Below Steel	REINFORCEMENT										
				TENSION		TEMPERATURE								
				Size	Spacing	Size	Spacing	C	e	Steel Lbs.	Concrete Cu. Yds.	Cement Bbls.	Sand Cu. Yds.	Gravel Cu. Yds.
3'-0"	3'-0"	6½"	1 "	½"	5½"	½"	12"	1'- 8"	18" to figure quantities.	9.3	.66	.85	.30	.60
3'-6"	3'-6"	7 "	1 "	½"	5 "	½"	12"	1'-10"		10.8	.78	1.03	.36	.71
4'-0"	4'-0"	7½"	1 "	½"	4½"	½"	12"	2'- 0"		13.5	.89	1.15	.41	.82
4'-6"	4'-6"	8 "	1 "	½"	4 "	½"	12"	2'- 2"	To extend to a firm foundation in all cases. Assumed as	15.6	.98	1.27	.45	.90
5'-0"	5'-0"	8½"	1 "	⅝"	6 "	⅝"	12"	2'- 5"		17.8	1.09	1.41	.50	1.00
5'-6"	5'-6"	9 "	1¼"	⅝"	5½"	⅝"	12"	2'- 7"		22.0	1.33	1.72	.61	1.22
6'-0"	6'-0"	9½"	1¼"	⅝"	5 "	⅝"	12"	2'- 9"		26.2	1.51	1.95	.70	1.39
7'-0"	7'-0"	11 "	1¼"	⅝"	4½"	⅝"	12"	3'- 2"		32.0	1.83	2.36	.84	1.68
8'-0"	8'-0"	12 "	1¼"	¾"	6 "	¾"	12"	3'- 6"		38.0	2.26	2.92	1.04	2.08

Concrete—For slab, 1:2:4; for sidewalls, 1:2½:5. Steel—Soft round rods.

TABLE 11

Data for Culvert Construction

Flat-Top Culvert, 10-Foot Fill, Computed for 24-Ton Roller

Span	Height	Slab Thickness	Concrete Below Steel	SLAB — Reinforcement — Tension — Size	Tension — Spacing	Temperature — Size	Temperature — Spacing	Side Walls — C	Side Walls — e	Materials Per Foot of Length Exclusive of Wing Walls — Steel Lbs.	Concrete Cu. Yds.	Cement Bbls.	Sand Cu. Yds.	Gravel Cu. Yds.
3′–0″	3′–0″	6½″	1 ″	½″	5½″	½″	12″	1′– 8″	To extend to a firm foundation in all cases. Assumed as 18″ to figure quantities.	9.3	.66	.85	30	.61
3′–6″	3′–6″	7 ″	1 ″	½″	5 ″	½″	12″	1′–10″		10.8	.78	1.03	.35	.72
4′–0″	4′–0″	7½″	1 ″	½″	4½″	½″	12″	2′– 0″		13.5	.90	1.16	.41	.83
4′–6″	4′–6″	8½″	1 ″	⅝″	6 ″	⅝″	12″	2′– 2″		15.6	99	1.28	45	.91
5′–0″	5′–0″	9 ″	1¼″	⅝″	5½″	⅝″	12″	2′– 5″		20.8	1.11	1.44	51	1.02
5′–6″	5′–6″	9½″	1¼″	⅝″	5 ″	⅝″	12″	2′– 7″		23.9	1.34	1.73	.62	1.23
6′–0″	6′–0″	10 ″	1¼″	⅝″	5 ″	⅝″	12″	2′– 9″		23.9	1.53	1.98	.70	1.40
7′–0″	7′–0″	11½″	1¼″	⅝″	4 ″	⅝″	12″	3′– 2″		35.4	1.85	2.39	.85	1.70
8′–0″	8′–0″	13 ″	1½″	¾″	5½″	¾″	12″	3′– 6″		41.0	2.29	2.96	1.03	2.10

Concrete—For slab, 1:2:4; for sidewalls, 1:2½:5. Steel—Soft round rods.

TABLE 12

Data for Culvert Construction

Plain Concrete Arch Culvert

Span	Crown d	Springing Line b	R1	h	C	e	Materials Per Foot at Length			
							Concrete Cu. Yds.	Cement Bbls.	Sand Cu. Yds.	Gravel Cu. Yds.
3'	6"	2'- 5"	1'-6"	2'-0"	3'- 4"	To extend to a firm foundation in all cases. Assumed as 18" to figure quantities.	1.13	1.5	.52	1.04
3'-6"	6"	2'- 7"	1'-9"	2'-0"	3'- 6"		1.27	1.7	.58	1.16
4'-0"	6½"	2'- 8"	2'-0"	2'-6"	3'- 8"		1.41	1.8	.65	1.30
4'-6"	7 "	2'- 8"	2'-3"	2'-6"	3'- 8"		1.50	2.0	.69	1.38
5'-0"	7½"	2'- 9"	2'-6"	3'-0"	3'- 9"		1.59	2.1	.73	1.46
5'-6"	8 "	2'- 9"	2'-9"	3'-0"	3'- 9"		1.71	2.3	.79	1.58
6'-0"	8½"	2'-10"	3'-0"	3'-0"	3'-10"		1.93	2.6	.89	1.78
7'-0"	9 "	3'- 0"	3'-6"	3'-6"	4'- 0"		2.32	3.1	1.07	2.14
8'-0"	10 "	3'- 2"	4'-0"	4'-0"	4'- 3"		2.72	3.7	1.25	2.50

Concrete—For arch-ring, 1:2:4; for abutments, 1:2½:5.

TABLE 13

Data for Culvert Construction

Plain Concrete Arch Culvert—Dimensions of Wing Walls and Amount of Materials, Including Guard-Rails, Floor, and Apron

(To be used with Table 12)

Span	Height H	L	G	Concrete Cu. Yds.	Cement Bbls.	Sand Cu. Yds.	Gravel Cu. Yds.
3'	4'-0"	3'-0"	2'-0"	3.8	4.72	1.75	3.50
3'-6"	4'-3"	3'-6"	2'-0"	4.2	5.21	1.93	3.86
4'-0"	5'-0"	4'-0"	2'-2"	6.9	8.55	3.18	6.36
4'-6"	5'-7"	4'-6"	2'-4"	8.8	10.91	4.05	8.10
5'-0"	6'-1"	4'-6"	2'-6"	10.2	12.64	4.69	9.38
5'-6"	6'-5"	5'-0"	2'-7"	11.1	13.77	5.11	10.22
6'-0"	6'-8"	5'-0"	2'-9"	12.8	15.87	5.88	11.76
7'-0"	7'-9"	5'-6"	3'-0"	14.3	17.73	6.57	13.15
8'-0"	8'-10"	6'-0"	3'-5"	18.3	22.70	8.43	16.86

Sewers and Conduits

A **sewerage system** consists of:

1. A **trunk or main sewer.** This is built of sufficiently large capacity to carry away all waste waters, and liquid filth containing fecal and other polluting matters, from a given district the boundaries of which are prescribed.
2. **Lateral Sewers.** Each one of these serves the particular street under which it lies. These lateral sewers are connected with, and discharge into the trunk sewer.

A sewerage system may also include:

3. An **intercepting sewer.** This is built large enough to enable it to collect and carry away the sewage from a number of trunk sewers to the point of final discharge. Where a stream of water is available, the intercepting sewer, toward the latter end of its course, is built parallel with the stream, until it reaches the place of discharge.
4. A **relief sewer.** In many cities the continued increase in population and in manufacturing causes such an increase in the volume of sewage to be removed that in course of time the capacity of the original sewer becomes overtaxed. In such cases a **relief sewer** is built, generally parallel with the old sewer, and sharing its work.

The various **functions of a sewerage system** are: (1) To carry away all sewage, such as household waste waters, liquid and fecal matter, etc. (2) To carry away from manufacturing establishments all waste waters, and other liquid trade wastes containing organic or inorganic waste products that are objectionable and a menace to public health. (3) To carry away storm water, not only from the roofs of buildings, but also from the surface of the streets. (4) In many cases the sewerage system is utilized for the purpose of draining areas beyond the limits of those directly served, when it is found that such areas can be conveniently drained in this manner.

When a sewerage system serves all the purposes here enumerated it is termed a **combined sewerage system.** If, on the other hand, the system serves only to remove sewage and trade wastes in liquid form, and from which all storm water and other waste products are excluded, it is called a **separate sewerage system.** Under these conditions it is in many instances necessary to install a system of storm sewers in connection with other drains and conduits, for the express purpose of removing storm water from the streets.

CAPACITY OF A SEWERAGE SYSTEM

The capacity of a system of sewers which it is proposed to install in a given locality, will depend, of course, upon the greatest volumes of sewage and other liquids which the system will be called upon to remove at any time; and this is to be calculated from the maximum rates of discharge from all the various sources connected with the system. The periods of time when these maximum rates of discharge are liable to occur, must also be taken into account in designing the system. Another very important factor in connection with the design and installation of a sewerage system, and one which must be accurately known, is the volume of water supplied by the waterworks pumping system.

Of course, a portion of the water supplied by the pumping system is used in boilers, also a portion is used for sprinkling lawns, and for other purposes which do not contribute to the volume of sewage to be carried away; but, as a general thing, the volume of sewage will very nearly equal the volume of water supplied by the pumping works. The average daily per capita consumption of water—which is the quantity of water used per day for each person living within the boundaries of the town or city to be served—is usually taken as the basis for determining the volume of sewage to be provided for in the design of a sewerage system. However, in order to insure a satisfactory service, and to provide for fluctuations, there should be added from 70 to 100 gallons per capita. As will be seen from the accompanying table, the per capita consumption of water in different cities varies greatly. This variation is due to several causes, principal among which is the percentage of water that is metered to consumers. Those cities showing the largest percentage of metered service generally show the smallest per capita consumption of water, while those cities showing a small percentage of meter service, and in some cases none at all, usually show the largest per capita consumption of water.

Local conditions, and the nature of the manufacturing industries of a city, control to a large degree the volume of trade wastes to be removed by the sewerage system.

Ground Water. Another factor that must be taken into account in estimating the capacity of a sewerage system

TABLE 1

Water Consumption in Various Cities.

City	Year	Population	Consumption per Capita (Galls. Daily)	Percentage of Metered Service
Philadelphia, Pa.	1905	1,438,000	227	1
St. Louis, Mo.	1908	685,000	101	7
Minneapolis, Minn	1907	300,000	59	71
Cincinnati, Ohio	1905	340,400	130	12
Milwaukee, Wis.	1907	360,000	93	96
Pittsburgh, Pa.	1907	296,000	230	
Detroit, Mich.	1906	377,500	160	9
Newark, N. J.	1904	290,000	105	42
Chicago, Ill.	1904	1,962,000	203	2
Toronto, Ont.	1907	287,000	118	
Kansas City, Mo.	1905	250,000	73	46
Watertown, N. Y.	1908	27,000	157	
Laurence, Mass.	1907	78,000	45	89
Springfield, Mass.	1907	83,000	120	51
Wilmington, Del.	1908	90,000	98	28
Fall River, Mass.	1905	106,600	41	97
Lowell, Mass.	1907	96,300	57	74
Rochester, N. Y.	1905	181,700	86	41
St. Paul, Minn.	1905	178,000	56	38
Worcester, Mass.	1905	128,100	75	95
Hartford, Conn.	1908	116,000	61	98
Providence, R. I.	1907	225,700	72	88
Indianapolis, Ind	1905	196,000	82	10
Louisville, Ky	1905	226,500	81	8
Denver, Col.	1908	200,000	218	
Boston, Mass.	1907	612,600	157	5
Washington, D. C.	1908	339,400	192	15
Cleveland, Ohio.	1907	501,000	117	89
Buffalo, N. Y.	1905	401,000	324	3
New York, N. Y.	1909	4,629,310	116	

is the amount of ground water which the system will be called upon to dispose of. Ground water is the water that finds its way into the sewer through leaky walls, joints, etc. The amount of this water will depend upon the quality of the work done in building the sewer. If a sewer could be built perfectly water-tight, there would be no ground water to dispose of; but as it is hardly possible, and is not desirable, to have a sewer absolutely water-tight, particularly in localities where the land is flat, there will always be more or less ground water to be removed. The amount will depend upon: (a) the character of the workmanship done in the building of the sewer; and (b) the diameter and length of the sewer. When a reasonable effort is made to build a system of sewers water-tight, the amount of ground water that finds its way into the laterals through leakage is variously estimated at from 10,000 to 50,000 gallons per mile per day; while in trunk sewers, being larger, the quantity may be taken at 100,000 gallons (and even more) per mile per day. Of course there are certain seasons of the year when this amount may be doubled, or even quadrupled, for short periods of time.

Storm Flow. The volume of water due to heavy rainstorms is probably one of the most important factors to be considered in the designing of a system of sewers, since the water due to this source usually appears in very large quantities within comparatively short periods of time, and, as a consequence, the capacity of the sewer is taxed to the utmost. Should this capacity be too small, the result will be a flooding of basements, and general inconvenience, besides liability of endangering the health of the community.

These remarks apply more especially to a combined sewerage system, which, as has already been explained, must remove both the house drainage, and the water from the streets.

The volume of water directly due to storm flow depends largely upon the character of the street pavement, and the rapidity with which the water from the streets reaches the sewers. If the streets are well paved with a material which is generally impervious to water and which throws off within a short time practically all the water that falls upon it, the volume of water reaching the sewers during a heavy storm is apt to test their ability to the utmost to remove and dispose of it. The nature of the climate, and the rapidity with which the rain sometimes falls, are further factors to be taken into consideration. Also the character of the area to be drained. If this area is compact, tending to bring the maximum rates of discharge from all portions into the sewer at practically the same time, it will be necessary to figure carefully on this phase of the problem. Another feature that affects to a large extent the volume of storm water to be carried away, is whether or not the area to be drained is covered by buildings and pavements, for the reason that, if such is the case, practically all the rain water falling upon such area will find its way to the sewer.

Various **formulae** are in use for calculating the volume of water directly due to storm flow; but there are several important elements omitted in some of these formulae, which are therefore not considered. These are the shape of the area to be drained, the general arrangement of the sewers composing the system, and the lengths of time required for the various flows to reach the different gratings or inlets to the sewerage system. There are, however, some formulae that take these elements into account. The formula most generally used is known as **McMath's formula** for determining the maximum amount of rain water to be removed by a sewerage system. This formula is as follows:

$$Q = CR\sqrt{SA^{4}}$$

in which:

Q=Quantity, in cubic feet.

C=Proportion of rainfall that will eventually reach the sewers after deducting losses by evaporation, absorption, and retention.

R=Number of cu. ft. of water per second falling upon an acre of surface. Equivalent to inches per hour.

S=Mean surface grade, feet per thousand.

A=Area, in acres.

The value of C is taken at 0.9 for all areas covered by roofs and pavements which are practically impervious to water. For uncovered or naked areas composed of sandy or gravelly soil, C=0.1; and where the soil is of a clayey nature, or but slightly penetrable by water, C=0.2.

As a rule the area for which a sewerage system is to be designed is partly covered and partly uncovered; and with a proper application of these two factors, the coefficient for the total area can be ascertained.

Trautuine gives the following formula for calculating the rate at which rain water reaches sewers, culverts, conduits, etc.

$$\left\{\begin{matrix}\text{Cu. ft. per}\\ \text{sec., per}\\ \text{acre, reach-}\\ \text{ing sewer}\end{matrix}\right\} = \left\{\begin{matrix}\text{A coeffi-}\\ \text{cient ac-}\\ \text{cording to}\\ \text{judgment}\end{matrix}\right\} \times \left\{\begin{matrix}\text{Ave. cu. ft. of}\\ \text{rainfall per sec.}\\ \text{per acre during}\\ \text{heaviest fall}\end{matrix}\right\} \times \sqrt[4]{\frac{\text{ave. slope of ground in ft. per 1,000 ft.}}{\text{No. of acres drained.}}}$$

The coefficient for paved streets is given as 0.75; for ordinary cases, 0.625; for suburbs with gardens, lawns, and macadamized streets, 0.31. Note that 1 in. of rainfall per hour may be taken as equivalent to 1 cu. ft. per second per acre.

Example—Assume:

Area to be drained=2,000 acres (about 3 sq. miles).
Average slope=5 ft. per 1,000 ft.
Maximum rainfall=2.5 in. per hour.

Coefficient=0.625.

According to the above formula, the rate at which the rain water would reach the mouth of a sewer at the lower end of the 2,000 acres would be:

$0.625 \times 2.5 \times \sqrt[4]{\frac{5}{2000}} = 0.625 \times 2.5 \times .225 = .35$ cu. ft. per second per acre.

Therefore the total volume would be:

$$.35 \times 2{,}000 = 700 \text{ cu. ft. per second.}$$

To ascertain the required area of a sewer, when the total volume of water to be discharged per second is known, proceed as follows:

$$A = \frac{W}{V}$$

Where W=No. of cu. ft. discharged per second.
V=Velocity of water, in ft. per second.
A=Area of sewer, in sq. ft.

In the case under discussion the total volume of water discharged per second was found to be 700 cu. ft. Assume velocity to be 5 ft. per second, which practice has demonstrated to be as high a velocity as can be allowed with safety. Then

$$A = \frac{700}{5} = 140 \text{ sq. ft.}$$

As the area of a sewer 13.5 feet in diameter is 143 sq. ft., this would allow a margin of 3 sq. ft.

Old sewers built on irregular grades often have short sections where the computed capacity is less than for sections above. Within certain limits, sewers will act under pressure at such places; and the carrying capacity of the sewer as a whole will be represented by the average capacity of a section of some length.

From the foregoing it is to be seen that, the capacity of a separate sewerage system may be calculated largely from the daily per capita water consumption; but in the case of a combined system, the volume of storm water must also be carefully considered. In fact, the capacity of the combined system should be gauged by the maximum amount of storm water it will be called upon to remove within a given time. In many instances the final outlet of the system, unless correctly planned, may greatly lessen its capacity to remove the quantity of sewage it is designed for. This is owing to the danger of the outlet becoming submerged wholly or in part, during a rainy period. Especially is this the case when the final dischage is into a stream that has a high flood level relative to the district or area to be served by the sewer.

When the sewer outlet is thus submerged frequently, or is allowed to remain submerged for any length of time, the main sewer will become filled with deposits, a condition which should be guarded against as closely as possible. Where the probabilities are that the outlet will be frequently submerged, a pumping station should be installed for the purpose of elevating the sewage above the flood level, the outlet, itself being closed by gates while the pumps are working. These pumps should have a working capacity of at least 25 per cent more than the maximum flow of sewage, in order that they may be able to handle all the sewage during the time that the gates are closed.

TABLE 2

Approximate Weights, Dimensions, etc., of Vitrified Sewer Pipe.

"STANDARD" PIPE.

Calibre	Thickness	Weight per Foot	Depth of Socket	Annular Space
3 inch	½ inch	7 lbs.	1½ inch	¼ inch
4 "	½ "	9 "	1⅝ "	⅜ "
5 "	⅝ "	12 "	1¾ "	⅜ "
6 "	⅝ "	15 "	1⅞ "	⅜ "
8 "	¾ "	23 "	2 "	⅜ "
9 "	13/16 "	28 "	2 "	⅜ "
10 "	⅞ "	35 "	2⅛ "	⅜ "
12 "	1 "	45 "	2¼ "	½ "
15 "	1⅛ "	60 "	2½ "	½ "
18 "	1¼ "	85 "	2¾ "	½ "
20 "	1⅜ "	100 "	3 "	½ "
21 "	1½ "	120 "	3 "	½ "
22 "	1⅝ "	130 "	3 "	½ "
24 "	1⅝ "	150 "	3¼ "	½ "
27 "	2 "	224 "	4 "	¾ "
30 "	2⅛ "	252 "	4 "	¾ "
33 "	2¼ "	310 "	5 "	1¼ "
36 "	2½ "	350 "	5 "	1¼ "

"DOUBLE-STRENGTH" PIPE.

Calibre	Thickness	Weight per Foot	Depth of Socket	Annular Space
15 inch	1¼ inch	75 lbs.	2½ inch	½ inch
18 "	1½ "	118 "	2¾ "	½ "
20 "	1⅝ "	138 "	3 "	½ "
21 "	1¾ "	148 "	3 "	½ "
22 "	1⅞ "	157 "	3 "	½ "
24 "	2 "	190 "	3¼ "	½ "
27 "	2¼ "	265 "	4 "	¾ "
30 "	2½ "	290 "	4 "	¾ "
33 "	2⅝ "	335 "	5 "	1¼ "
36 "	2¾ "	375 "	5 "	1¼ "

PIPE WITH DEEP AND WIDE SOCKETS.

"Standard."

Calibre	Thickness	Weight per Foot	Depth of Socket	Annular Space
4 inch	½ inch	10 lbs.	2 inch	½ inch
5 "	⅝ "	12 "	2½ "	⅝ "
6 "	⅝ "	16 "	2½ "	⅝ "
8 "	¾ "	25 "	2¾ "	⅝ "
10 "	⅞ "	37 "	2¾ "	⅝ "
12 "	1 "	45 "	3 "	⅝ "
15 "	1⅛ "	70 "	3 "	⅝ "
18 "	1¼ "	90 "	3¼ "	⅝ "
20 "	1⅜ "	115 "	3½ "	⅝ "
21 "	1½ "	130 "	3⅝ "	⅝ "
22 "	1⅝ "	145 "	3¾ "	⅝ "
24 "	1⅝ "	150 "	4 "	⅝ "

"Double Strength."

Calibre	Thickness	Weight per Foot	Depth of Socket	Annular Space
15 inch	1¼ inch	75 lbs.	3 inch	⅝ inch
18 "	1½ "	118 "	3¼ "	⅝ "
20 "	1⅝ "	138 "	3½ "	⅝ "
21 "	1¾ "	148 "	3⅝ "	⅝ "
22 "	1⅞ "	157 "	3¾ "	⅝ "
24 "	2 "	190 "	4 "	⅝ "

MATERIALS FOR SEWER CONSTRUCTION

The most common material used, up to the present time for sewers of 24-in. diameter and under, is vitrified tile. In some instances, it is used in sewers of 36-in. diameter.

The accompanying table (2) gives the approximate weights, dimensions, and other details in connection with "standard" and also "double-strength" sewer pipe, from 3 in. up to 36 in. in diameter.

BRICK SEWERS

Brick sewers on slopes that produce greater velocities than 7 to 8 ft. per second wear rapidly on the bottom. A slope of more than 6 ft. per 1,000 ft. will produce such velocities in sewers of 48-in. diameter; and a slope of 4 ft. in 1,000 ft. will produce the above named velocities in 72-in. sewers.

The materials required for the construction of brick sewers can be determined by use of Tables 3 and 4 for circular sewers, and Table 5 for egg-shaped sewers.

The cost of brickwork laid in sewers ranges from $10 to $15 per cubic yard.

Table 7, compiled by G. H. Brown and published in "Municipal Engineering," shows the number of brick required for circular sewers with different thicknesses of joints.

TABLE 3

Materials Required for Circular Sewers One Foot in Length and Four Inches or One Ring Thick

(Brick 8¼x4x2¼ Inches)

Diameter of Sewer, feet	2	2½	3	3½	4	5
Number of Bricks	42	53	63	73	83	105
Barrels of Cement per 100 linear feet	9	11	13	15	17	20
Barrels of Sand per 100 linear feet	18	22	26	30	34	40

TABLE 4

Materials Required for Circular Sewers One Foot in Length and Eight Inches or Two Rings Thick

(Brick 8¼x4x2¼)

Diameter of Sewer, feet	2	2½	3	3½	4	5	6	8	10
Number of Bricks	115	150	170	195	215	260	[illegible]	[illegible]	[illegible]
Barrels of Cement per 100 linear feet	17	19	22	25	27	34	40	[illegible]	75
Barrels of Sand per 100 linear feet	34	38	44	50	54	[illegible]	80	120	[illegible]

TABLE 5

Materials Required for Egg-Shaped Sewers One Foot in Length and Eight Inches or Two Rings Thick

(Brick 8¼x4x2¼ Inches)

Inside Dimensions, feet	2x3	2¼x3⅜	2⅓x3½	2½x3¾	2⅔x4	3x4½	3½x5¼	4x6	5x7½
Number of Bricks	145	160	170	178	185	205	235	260	315
Barrels of Cement per 100 linear feet	19	21	22	23	25	27	34	38	41
Barrels of Sand per 100 linear feet	38	42	44	46	50	54	68	76	82

Table 6 gives least velocities and grades for drain pipes and sewers in cities, in order that they may under ordinary circumstances keep themselves clean, or free from deposits.

TABLE 6

Velocities and Grades in Sewage Drainage (Wicksteed)

Diameter in Inches	Velocity in Feet per Minute	Grade 1 in.	Grade—Feet per mile
4	240	36	146.7
6	220	65	81.2
7	220	76	69.5
8	220	87	60.7
9	220	98	53.9
10	210	119	44.4
11	200	145	36.7
12	190	175	30.2
15	180	244	21.6
18	180	294	18.0
21	180	343	15.4
24	180	392	13.5
30	180	490	10.8
36	180	588	9.0
42	180	686	7.7
48	180	784	6.8
54	180	882	6.0
60	180	980	5.4

Flush-Tanks. Table 9 gives the number of common-sized bricks required for the construction of flush-tanks of various sizes.

TABLE 7

Number of Brick in Circular Sewers

(Size of brick, 2½x4x8½ inches. Joints ¼ inch, except between rings ⅜ inch)

Inside Diameter (Inches)	1 Ring	2 Rings	3 Rings
24	37.6	89.0	155.0
30	47.0	108.0	183.0
36	56.4	126.9	211.4
42	65.8	145.8	239.8
48	75.0	164.0	267.0
54	84.6	183.1	296.1
60	94.0	202.0	324.0
66	103.0	220.5	351.5
72	112.8	240.0	380.0
78	122.0	258.0	408.0
84	131.6	276.6	436.6
90	141.0	296.0	465.0
96	150.0	312.0	490.0

(Size of brick 2½x4x8½ inches. Joints ⅜ inch, except between rings ½ inch)

Inside Diameter (Inches)	1 Ring	2 Rings	3 Rings
24	35.4	84.0	146.0
30	44.2	101.7	172.7
36	53.1	119.4	199.0
42	62.0	137.2	225.7
48	70.8	154.8	252.3
54	79.7	172.7	278.7
60	88.5	190.5	305.5
66	97.5	208.5	332.5
72	106.0	226.0	359.0
78	115.0	244.0	386.0
84	124.0	261.0	411.0
90	133.0	279.0	438.0
96	141.5	296.5	464.5

Table 8, gives quantities of cement, sand, and of cement mortar for sewer-pipe joints, for each 100 ft. of sewer, (Portland cement, 375 lbs. net per bbl.).

TABLE 8

Cement, Sand, and Cement Mortar for Sewer Pipe Joints

Prepared by J. N. Hazlehurst, C. E.

Size of Pipe, Inch	Length, Feet	Mortar, Cubic Yards	PROPORTIONS: 1 CEMENT TO 1 Sand: Cement, Barrels	1 Sand: Sand, Cubic Yards	1 Sand: No. Ft. to Bbl. Cement	2 Sand: Cement Barrels	2 Sand: Sand, Cubic Yards	2 Sand: No. Ft. to Bbl. Cement
6	2½	0.003	0.01248	0.00201	803	0.00855	0.00252	1168
8	2½	0.038	0.15806	0.02546	633	0.10830	0.03192	923
10	2½	0.058	0.24128	0.03886	410	0.16530	0.04872	605
12	2½	0.089	0.37024	0.05963	270	0.25365	0.07476	394
15	2½	0.123	0.51268	0.08241	195	0.35055	0.10332	285
18	2½	0.167	0.69472	0.11189	144	0.47595	0.14018	210
20	2½	0.237	0.98592	0.15879	101	0.67545	0.19908	148
24	2½	0.299	1.24384	0.20033	80	0.85215	0.25116	117
27	3	0.492	2.04672	0.32964	49	1.40220	0.41328	71
30	3	0.548	2.27968	0.36716	44	1.56180	0.46032	64
36	3	0.849	3.53184	0.56883	29	2.41965	0.71316	41

TABLE 9

Number of Bricks in Flush-Tanks

(12-Inch Walls—Brick 8¼x4x2¼ Inches)

Inside Diameter (Feet)	Depth, in Feet: 5	6	7	8	9
4	1,124	1,344	1,560	1,780	2,000
5	1,417	1,680	1,940	2,200	2,460
6	1,820	2,440	3,060	3,680	4,300

Manholes. Table 10 gives the number of common-sized bricks required in manholes construction.

TABLE 10

Number of Bricks in Manholes

Inside Diameter (Feet)	Height, in Feet: 4	5	6	7	10	12	15	20
3½	677	835	980	1,125	1,555	1,845	2,279	3,007
4	740	880	1,030	1,180	1,625	1,948	2,410	3,180
4½	830	1,040	1,190	1,370	1,910	2,270	2,826	3,730

FARM DRAINAGE

A system of farm drainage may be laid out by placing a main ditch as near the center line of the field as possible, and then having side drains enter this from various directions. These side drains should reach out to all portions of the field that need drainage service.

TABLE 11

Acres Drained by Different-Sized Drain-Tile

(Tile laid at different grades—Grade indicated in ft. per 100 ft.)

GRADE PER 100 FT.	SIZE OF TILE													
	4″	5″	6″	7″	8″	10″	12″	14″	15″	16″	18″	20″	24″	30″
.05	13	23	36	53	74	129	204	299	290	418	561	730	1152	2012
.06	14	25	39	58	81	141	223	327	356	454	614	800	1261	2203
.07	15	27	43	63	87	153	241	354	421	494	664	864	1363	2380
.08	16	29	46	67	94	163	258	378	450	529	693	923	1457	2545
.10	18	32	51	75	105	182	288	423	503	591	710	1032	1629	2845
.12	20	36	56	81	114	199	315	463	551	647	869	1130	1753	3114
.15	23	40	62	92	129	223	353	518	616	724	971	1264	1995	3485
.20	26	46	72	106	148	258	408	598	712	836	1122	1460	2304	4024
.30	31	55	88	130	182	315	499	733	871	1025	1373	1787	2821	4923
.50	41	72	114	167	234	408	644	947	1125	1324	17,5	2308	3643	6364
1.00	57	104	161	234	330	576	910	1336	1594	1870	2510	3266	5158	9000
1.50	72	125	195	290	405	705	1115	1635	1950	2270	3070	4000	6305	11015
2.00	82	144	228	334	468	816	1090	1894	2250	2648	3550	4616	7296	12728

Approximate figures, based on 36 in. annual rainfall.

Another system often used consists in locating the various branch lines parallel with each other, and finally converging near the outlet, gridiron fashion. Soil water enters the tile, both between the abutting joints, and through the porous walls. It is neither necessary, nor desirable to leave a space between the ends of the tiles that water may enter, as such space gives free passage for roots, sediment, etc., to enter and clog up the tile.

Cost of Tile Drainage

Drainage outlets constructed for a farm or a district cost various sums per acre of land, depending upon the nature of the outlet and of the area in the district benefited. The price for excavating a large ditch varies from 8 to 14 cents per cu. yd. This may make the cost per acre as low as $1 or, in exceptional cases, $15 or more. Not many outlets, however, cost over $4 for every acre of land drained. Of course, if an adequate outlet is already present, this part of the expense is eliminated.

The cost of tile drainage is influenced by the price of tile, the transportation expenses from the factory to the farm, the cost of digging the ditch, laying and priming the tile, and filling the ditch. The price of tile varies with the section in which it is manufactured. In Ohio, Indiana, Illinois, and Iowa, where most of it is made and where the competition is strongest, the price is the lowest. In the East, where the manufacturers sell just low enough to compete with the delivered price in the Middle West, the cost is higher. Southern prices are practically the same as in the East; while in the far West, tile are higher than in any other part of the country. Most factories sell tile by the thousand feet. In the Middle west, the following prices of the various sizes prevail:

Size	Price per 1,000 Feet
4-inch	$13 to $16
5-inch	18 " 23
6-inch	24 " 34
7-inch	34 " 48
8-inch	48 " 60
10-inch	60 " 110
12-inch	90 " 150

Prices in the East and South are about 50 per cent in excess of these, while in the far West they are about 70 per cent higher.

The expense of transportation is determined by the distance tile are shipped, and the cost of hauling them from the station to the farm.

Digging the ditch and laying and priming the tile, are usually figured as one operation. This is done either at so much per rod, or by the day, the former being the more common practice. The price of the work and the amount accomplished per day are affected by the size and depth of the tile, the character of the soil, and the skill of the workmen. The work is cheapest in the Middle West, while higher rates prevail in the East and South. A skilled workman—one who digs rapidly and is capable of making the bottom—generally earns from $2 to $3.50 a day. Unskilled laborers may be secured for $1 to $1.50 a day. On ordinary soils in the Middle West, the average capacity of a good workman with a 3-ft. ditch, and not over 5-in. tile, is 10 rods a day. In the East and South, sometimes, on account of the character of the soil, the capacity of a man is from 4 to 8 rods, with the same depth and the same size of tile. An average price in the Middle West for a 3-ft. ditch is from 25 to 30 cents per rod with 4- or 5-in tile, 35 to 40 cents for 6-in, and 50 cents for 8-in. For ditches deeper than 3 ft., the price usually increases at the rate of 1 cent per rod for every additional inch in depth. Ordinarily, however, the price is figured on the average depth of the entire ditch. The ditch can be filled with a plow for 3 cents per rod, and sometimes for 2 cents. When done by hand or with a scraper, it is much more than this.

The cost of drainage per acre will, in addition to these factors, depend on the tile required. If laterals are laid 100 ft. apart, it will take 436 tile for every acre, in addition to the tile needed for the main and sub-mains. If 4-in. tile at $20 per thousand, including transportation, are used, the tile would cost $8.72. The cost of digging the ditch and laying and priming the tile, at 30 cents per rod, would be $7.93; and the filling, at 3 cents per rod, 79 cents. Thus the cost per acre, exclusive of the mains, sub-mains, and outlets, totals $17.44. With closer laterals or larger tile, of course, the cost will be greater. However, where land does not require thorough drainage, the maximum benefits may be obtained with an expenditure of $7 or $8 per acre. The cost of drainage is therefore a problem in itself, and must be determined for the locality in which it is done.

Miscellaneous Information and Tables

WAGE TABLES

Table 1 (p. 766) shows a method of calculating wages without using the ordinary method of multiplication. The table will read directly for certain numbers of hours and rates of wage; but almost any combination of hours and rates of pay may be obtained from the table by simple addition. Thus the table may be used as a means of determining amounts first-hand, or may be used to check calculations made by multiplication. Several examples will be given to show the method of using the table.

If, for example, it is desired to find the amount due for 6 days work of 8 hours per day at 50 cents per hour, the 48-hour column will show $24.00 if the 50-cent line is read across the table.

What would be the amount due for 8 hours work at 37½ cents per hour?

Finding the 8-hour column at the top of the table, refer to the left-hand column under 20, 17, and ½. Tracing these lines across to the 8-hour column, it is seen that the amounts to be added together are $1.60, $1.36, and .04, making a total of $3.00.

If it is desired to find the amount due for 52½ hours at 62½ cents, the method to be followed would be to divide the 52½ hours into 50, 2 and ½. Also divide the 62½ into 50, 12, and ½. Place a rule, blotter, piece of paper, or anything with a straight edge, on the 50 cents per hour line at the left, and, reading across the table, set down on a piece of paper the values under 50 hrs. ($25.00), 2 hrs. ($1.00), and ½ hr. (.25); then, placing the rule on the 12 cents per hour line, read the values under 50 hrs. $6.00, 2 hrs. (.24), and ½ hr. (.06); next read the same values along the ½ cent per hour line—50 hrs. (.25), 2 hrs. (.01), and ½ hr. (.00). Adding these different amounts, the result is $32.81.

Rate of Wages per Hour in Different Building Trades

Table 2, compiled by E. M. Craig, Secretary of the Builders' Association, Chicago, Ill., shows the rates of wages, per hour, being paid (July 1, 1913) in the building trades in various cities of the United States and Canada.

TABLE 1

Data for Calculating Amount of Wages Due for Work

Rate per Hour in Cents	Number of Hours ¼	½	¾	1	2	3	4	5	6	7	8	9	10	20	30	40	48	50	54	60
¼	....	....	....	....	.01	.01	.01	.01	.02	.02	.02	.02	.03	.05	.08	.10	.12	.13	.14	.15
½	....	....	....	.01	.01	.02	.02	.03	.03	.04	.04	.05	.05	.10	.15	.20	.24	.25	.27	.30
¾	....	....	.01	.01	.02	.02	.03	.04	.05	.05	.06	.07	.08	.15	.23	.30	.36	.38	.41	.45
10	.03	.05	.08	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00	2.00	3.00	4.00	4.80	5.00	5.40	6.00
11	.03	.06	.08	.11	.22	.33	.44	.55	.66	.77	.88	.99	1.10	2.20	3.30	4.40	5.28	5.50	5.94	6.60
12	.03	.06	.09	.12	.24	.36	.48	.60	.72	.84	.96	1.08	1.20	2.40	3.60	4.80	5.76	6.00	6.48	7.20
13	.03	.07	.10	.13	.26	.39	.52	.65	.78	.91	1.04	1.17	1.30	2.60	3.90	5.20	6.24	6.50	7.02	7.80
14	.04	.07	.11	.14	.28	.42	.56	.70	.84	.98	1.12	1.26	1.40	2.80	4.20	5.60	6.72	7.00	7.56	8.40
15	.04	.08	.11	.15	.30	.45	.60	.75	.90	1.05	1.20	1.35	1.50	3.00	4.50	6.00	7.20	7.50	8.10	9.00
16	.04	.08	.12	.16	.32	.48	.64	.80	.96	1.12	1.28	1.44	1.60	3.20	4.80	6.40	7.68	8.00	8.64	9.60
17	.04	.09	.13	.17	.34	.51	.68	.85	1.02	1.19	1.36	1.53	1.70	3.40	5.10	6.80	8.16	8.50	9.18	10.20
18	.05	.09	.14	.18	.36	.54	.72	.90	1.08	1.26	1.44	1.62	1.80	3.60	5.40	7.20	8.64	9.00	9.72	10.80
19	.05	.10	.14	.19	.38	.57	.76	.95	1.14	1.33	1.52	1.71	1.90	3.80	5.70	7.60	9.12	9.50	10.26	11.40
20	.05	.10	.15	.20	.40	.60	.80	1.00	1.20	1.40	1.60	1.80	2.00	4.00	6.00	8.00	9.60	10.00	10.80	12.00
30	.08	.15	.23	.30	.60	.90	1.20	1.50	1.80	2.10	2.40	2.70	3.00	6.00	9.00	12.00	14.40	15.00	16.20	18.00
40	.10	.20	.30	.40	.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	4.00	8.00	12.00	16.00	19.20	20.00	21.60	24.00
50	.13	.25	.38	.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	10.00	15.00	20.00	24.00	25.00	27.00	30.00
60	.15	.30	.45	.60	1.20	1.80	2.40	3.00	3.60	4.20	4.80	5.40	6.00	12.00	18.00	24.00	28.80	30.00	32.40	36.00

APPROXIMATE COST OF HOUSES

An ordinary house, 26 by 40 ft. on the ground, and 30 ft. from the bottom of the cellar floor to the top of the roof, would contain 1,040 sq. ft. or 31,200 cu. ft. An architect, figuring roughly on such a house, would place the cost at about $3.00 a sq. ft. or 10 cents a cu. ft. The house in either case would figure out about $3,120. This, of course, is based upon plain inside work, without any fancy equipment. It would include sufficient windows and doors to make the house light and comfortable. The rooms would be of the ordinary standard size for such a cottage, and the whole work fully up to grade. It would represent the ordinary good house, such as we find constructed in great numbers in different parts of the country.

The price of lumber and labor in some localities might make it possible to bring this price down. It is possible to build such a house, with two stories plastered and the third story or attic left unfinished, at a cost of 9 and possibly 8 cents a cu. ft.; but to secure this, some of the comforts and conveniences of the ordinary house would have to be omitted. There could be a saving made in the quality of the lumber, shingles, hardware, and plaster; but it would hardly be wise to adopt such a course unless the inferior material used was plainly stated to the owner in advance. Frequently owners who know nothing about the quality of building materials are deceived by architects and builders who dishonestly say that the cheaper house is "just as good." It is wiser to be frank with the owner, and explain patiently the difference in the work. In the end the reputation of the builder will be safer.

On the other hand, to run the price up to 12 or 15 cents a cu. ft. is just as easy. That means more comforts in the interior, more elaborate trim, superior grade of walls and ceilings, and better equipment generally. The tendency of some to save by decreasing the size of a house, is a mistake too often made. Other things being equal, the larger a house is built, the less it will cost per cu. ft. Large, commodious rooms are more to be desired than small, cramped ones. Unless more elaborate trim and equipment are placed in the larger house, its cost should show a relative decline per cu. ft. over the small structure. With no more angles, bay windows, doors, and roof hips to build, the cubic foot cost is increased only so far as actual plain work is

(*Continued on page 774*)

TABLE 2

Rates of Wages, per Hour, in the Building Trades in Various Cities, July 1, 1913

City.	Masons and Bricklayers	Structural Iron Setters	Ornamental Iron Setters	Plasterer	Lathers	Hoisting Engineers	Tile Setters	Plumbers	Steam Fitters	Steam Fitters Helpers	Gas Fitters	Carpenter
Aberdeen, S.D.	65¢			60¢	3½¢ per yd.			55¢	50¢	25¢	40¢	40¢
Albany, N.Y.	65¢	50¢	37½¢	65¢	60¢	$24 per wk.	50¢	60¢	60¢	30¢	37½¢	50¢
Atlanta, Ga.	45¢	62½¢	50¢	45¢	30¢	35¢	45¢	50¢	45¢	20¢	35¢	30¢
Baltimore, Md.	M.56¼¢ BL.62½	62½¢	62½¢	62½¢	50¢	50-62½¢	62-72½¢	50¢	43¾¢	25¢	43¾¢	37½-43¾¢
Birmingham, Ala.	70¢	62½¢	62½¢	62½¢	55¢	56¼¢	70¢	75¢	75¢	30¢	75¢	52½¢
Boston, Mass.	65¢	56¼¢	62½¢	65¢	$2.75-$3 per M 60¢ hr.	60 to 75¢	68¾¢	62½¢	50¢	25¢	50¢	55¢
Buffalo, N.Y.	M.55¢ BL.65¢	60¢		60¢	45¢	$24 per wk.	$4 a day	$4.50 a day	$4.50 a day	$1-2 a day		45 & 50¢
Cheyenne, Wyo.	M.62½¢ BL.75¢	50¢	56¼¢	75¢	4½¢ per yd.	50¢		75¢	75¢	37½¢	75¢	55¢
Chicago, Ill.	75¢	68¢	65¢	75¢	71⅞¢	75¢	75¢	75¢	75¢	40¢	75¢	65¢
Cincinnati, Ohio.	M.60¢ BL.70¢	62½¢	54 to 56¼¢	68¾¢		$5.00 a day	62½¢	62½¢	52½¢	29¼¢	62½¢	50¢
Cleveland, Ohio.	65¢	65¢	65¢	62½¢	62½¢	45 to 65¢	65¢	62½¢	62½¢	31¼¢	62½¢	50¢
Columbus, Ohio.	M.67½¢ BL.70¢	65¢	35 to 40¢	60¢	$2.50 per M	35¢	62½¢	56¼¢	56¼¢	25¢	56¼¢	50¢
Dallas, Texas.	M.62½¢ BL.87½	56¼¢	56¼¢	75¢	62½¢	50¢	75¢	68¾¢	68¾¢	30¢	68¾¢	55¢
Dayton, Ohio.	M.40¢ BL.67½¢	30 to 50¢	40 to 60¢	60¢	$2.50 per M	55¢	45¢	55¢	55¢		55¢	35 to 45¢
Denver, Col.	M.62½¢ BL.75¢	56¼¢	25 to 50¢	75¢	50 to 56¼¢	56¼¢	62½¢	62½¢	62½¢	21⅞ to 31¼¢	62½¢	60¢
Des Moines, Ia.	70¢	50¢	50¢	70¢	60¢	40¢	62½¢	62½¢	62½¢	25¢	62½¢	55¢
Detroit, Mich.	50 to 65¢	25 to 40¢	30 to 50¢	45 to 68¢	35 to 50¢	30 to 40¢	50 to 55¢	35 to 56¢	30 to 56¢	22 to 25¢	30 to 45¢	30 to 45¢
Duluth, Minn.	M.60¢ BL.75	50¢	50¢	62½¢	50¢	50¢	50¢	62½¢	60¢	31¼¢	62½¢	45-50¢
East St. Louis, Ill.	70¢	65¢	65¢	70¢	65¢	75¢	62½¢	75¢	75¢	37½¢	72¢	62½¢
Edmonton, Canada	70¢	45¢		70¢	$3.00 per M	$3.50 a day		60¢	60¢	35¢	60¢	55¢
Evansville, Ind.	M.60¢ BL.65¢	60¢	60¢	65¢	40¢	63¢	56¢	50¢	50¢	25¢	50¢	45¢
Galveston, Tex.	$7.00 per day	60¢	60¢	75¢	$5.00 a day	$4.00 a day	62½¢	65¢	65¢	35¢	62½¢	$4.00 a day

CITY	STONE CUTTERS	MARBLE CUTTERS AND SETTERS	PAINTERS	SHEET METAL WORKERS	ELECTRICAL WORKERS	ROOFERS	CEMENT FINISHERS	ELEVATOR CONSTR'ORS	PIPE COVERERS	LABORERS & HOD CARRIERS	REMARKS.
ABERDEEN, S.D.	40¢		35 to 40¢	40 to 45¢	40¢					25¢	
ALBANY, N.Y.	62½	62½¢	50¢	50¢	60¢	50¢	65¢			L. 25¢ H.C. 35¢	
ATLANTA, GA.	GRAN. 43¾ SOFT 50¢	CUT 50 SET 62½	30¢	40¢	40¢	35¢	45¢	45¢		15¢	CUTTERS, SETTERS & IRON-WORK'RS 8 HRS. ROOFERS 10 HRS. OTHERS 9 HRS
BALTIMORE, MD.	50¢	62½¢	37½-43¾	40¢	43¾¢	40¢		56¼¢	43¾¢	L. $1.75-2.00 H.C. $2.50	
BIRMINGHAM, ALA.	50¢	62½¢	45¢	55¢	68⅔¢	55-35¢	50¢	55¢		30¢	
BOSTON, MASS.	GRANITE 45⅝¢	50-56¼¢	50¢	45-55¢	37½ to 56¼¢	COMP. 28-43¾ SLATE 55¢	62½¢	56¼¢	50¢	L. 25¢ H.C. 30-40¢	PLASTERER' LABORER 41½¢ METAL ROOFERS 55¢
BUFFALO N.Y.	60¢	CUT. $4.25 DAY SET. 50¢	$3.50 A DAY	40-45¢	56¼¢	REMARKS	40 to 60¢	$4.00 A DAY		L. 22½-25¢ H.C. 25¢	ROOFERS,- TIN 37½-45¢ SLAG & GRAVEL 25-40¢ SLATE 50¢
CHEYENNE, WYO.	62½¢	62½¢	56¼¢	62½¢		62½¢			37½¢	L. 25-31¼¢ H.C. 43¾¢	
CHICAGO, ILL.	62½¢	68¾¢	65¢	65¢	75¢	65¢	65¢	65¢	62½¢	40¢	MARBLE SETTERS ASKING 75¢ PIPE COVERERS ASKING 67½¢
CINCINNATI, OHIO.	56¼¢	43¾¢	50¢	40 to 45¢	50 to 55¢	40 to 45¢	50¢	45 to 50¢		L. 25¢ H.C. 25 to 32¢	LABORERS WORK 9 HRS., OCT. 1, '13.
CLEVELAND, OHIO.	60¢	62½¢	45¢	45¢	57½¢	REMARKS	50¢	55¢	42½¢	L. 25¢ H.C. 31¼¢	ROOFERS - GRAVEL 25 to 60¢ SLATE 55¢ METAL 45 to 50¢
COLUMBUS, OHIO.	56¼¢	62½¢	40¢	31¼-40⅝¢	35¢	40¢	45¢	45¢		L. $2.00 A DAY H.C. 37½¢	ORNAMENTAL IRON WORK 9 HRS.
DALLAS, TEXAS.	62½¢	62½¢	43¾¢	50¢	50¢	25¢		50¢		L. 25¢ H.C. 30¢	WAGES SAME AS 1912 EXCEPT BRICK-LAYERS & CARPENTERS.
DAYTON, OHIO.	56¼¢	SET. 45¢	40¢	30¢	45¢	30¢	35¢			L. 20¢ BRICK 40 MORTAR 42½¢	PLASTERERS & CARPENTERS WORK 9 HRS. LABORERS 10 HRS.
DENVER, COL.	62½¢	CUT. 35 to 46⅞ SET 62½¢	50¢	56¼¢	37½ to 50¢	37½¢	68¾¢	30 to 56¼¢	37½¢	L. 37½ to 40¢ H.C. 37½ to 43¾¢	
DES MOINES, IA.	56¼¢	62½¢		50¢	30 to 60¢	55¢	59⅜¢	40¢	45¢	25¢	
DETROIT, MICH.	45 to 62½¢	CUT 33 to 40 SET. 45 to 62½	30 to 45¢	27½ to 45¢	30 to 50¢	GRAV. 25-28 SLATE 28-40	25 to 60¢	30 to 50¢	28 to 55¢	L. 18 to 25¢ H.C. 22½ to 35¢	HOURS IN TRADES VARY FROM 8 TO 10
DULUTH, MINN.	50¢	50¢	47½¢	47½¢	45⅝¢	45¢	45¢	50¢		L. 25¢ H.C. 30¢	
EAST ST. LOUIS, ILL.	56¼¢	CUT 30¢ SET 62½¢	55¢	56¼¢	65¢	55¢	60¢		37½¢	L. 25¢ BRICK 42½ MORTAR 45¢	
EDMONTON, CANADA	65¢	CUT 40¢	50¢	55¢	40 to 60¢	45¢	70¢			L. 30¢ H.C. 35¢	
EVANSVILLE, IND.	57¢	63	50¢	40¢	40¢	50¢		40¢	50¢	L. 20 to 25¢ H.C. 30¢	
GALVESTON, TEX.	62½¢	62½¢	$4.00 A DAY	$4.00 A DAY	$4.25 A DAY	37½¢	62½¢	37½¢	50¢	L. $2.00 A DAY H.C. 31¼¢	

TABLE 2—(Continued)

Rates of Wages, per Hour, in the Building Trades in Various Cities, July 1, 1913

City.	Masons and Bricklayers	Structural Iron Setters	Ornament'l Iron Setters	Plasterer	Lathers	Hoisting Engineers	Tile Setters	Plumbers	Steam Fitters	Steam Fitters Helpers	Gas Fitters	Carpenter
Grand Rapids, Mich.	M. 40 to 60¢ BL. 65¢	50¢		55¢	50¢	$2.50 to 3.50	60¢	50¢	50¢	35-40¢	50¢	35 to 45¢
Hartford, Conn.	65¢	50¢	50¢	65¢	50¢	45¢	65¢	55¢	54¢	28¢	55¢	50¢
Indianapolis, Ind.	75¢	65¢	65¢	62½¢	55¢	60¢	62½¢	62½¢	62½¢	31¼¢	Work done by plumber	50¢
Canton, Ohio.	M. 56¼¢ BL. 65 to 75¢	65¢		50¢	35¢		32 to 40¢	55 to 60¢	60¢	25¢		27½ to 40¢
Jacksonville, Fla.	BL 62½¢	43¾ to 50¢		56¼ to 62½¢	37½¢	31¼¢		56¼¢	56¼¢	31¼¢	37½¢	34⅜ to 37½¢
Kansas City, Mo.	M. 62½¢ BL. 75¢	62½¢	62½¢	75¢	50 to 56¼¢	70¢	75¢	68¾¢	68¾¢	31¼¢	68¾¢	55¢
Los Angeles, Cal.	M. $5.50 a day BL. 75¢	38⅞¢	44⅗¢	75¢	$2.25 per M	37½¢	50 to 62½¢	56¼¢	56¼¢	31¼¢	56¼¢	50¢
Louisville, Ky.	M. 55¢ BL. 65¢	27½-35¢	25 to 30¢	65¢	55¢	35 to 50¢	56¼¢	60¢	50¢	25¢		45¢
Lowell, Mass.	M. 43¾¢ BL. 60¢	27½-35¢	40¢	50¢	40¢	$18.00 per wk.	60¢	50¢	50¢	25¢	50¢	40-45¢
Memphis, Tenn.	M. 65¢ BL. 75¢	62½¢	62½¢	75¢	Wood 50¢ Metal 62½¢	50¢	62½¢	62½¢	62½¢	33¼¢	62½¢	50¢
Milwaukee, Wis.	67½¢	65¢	65¢	65¢	53⅛¢	62½¢	62½¢	62½¢	56¼¢	31⅞¢	62½¢	47½¢
Minneapolis, Minn.	65¢	40 to 50¢	56¼¢	70¢	4¢ per yard	45¢	62½¢	56¼¢	50-56¼¢	28⅛¢	42½ to 56¼¢	40 to 55¢
Montreal, Can.	M. 50¢ BL. 55¢	35¢	30¢	50-55¢	Wood 45¢ Metal 50¢	25¢	45¢	35-40¢	35-40¢	15¢	35-40¢	35-42½¢
Newark, N. J.	65¢	56¼ to 62½¢	56¼ to 62½¢	65¢	50¢	71⅞¢	56¼¢	62½¢	56¼ to 60¢	30¢	62½¢	50¢
New Orleans, La.	62½¢	50¢	50¢	50¢	50¢	50¢	62½¢	56¼¢	56¼¢	17½¢	50¢	35 to 45¢
New York, N. Y.	M. 60¢ BL. 70¢	62½¢	62½¢	68¾¢	62½¢	75¢	68¾¢	68¾¢	68¾¢	37½¢	68¾¢	62½¢
Oklahoma, Okla.	75¢	56¼¢	50¢	75¢	50¢	50¢	62½¢	62½¢	62½¢	35¢	50¢	45¢
Omaha, Neb.	70¢	58¾¢	58¾¢	75¢	50¢	$5.00 per day	62½¢	$30 for 44 hrs.	$30-44 hrs.	30¢	$30-44 hrs.	55¢
Peoria, Ill.	70¢	62½¢	62½¢	75¢	50¢	62½¢	67½¢	62½¢	56¼¢	31¼¢		55¢
Philadelphia, Pa.	M. 55¢ BL. 62½¢	60¢	30¢	62½¢	Wood $2.50-3.25 Metal 56¼¢	50¢	62½¢	43¾¢	43¾¢	25¢	43¾¢	50¢
Pittsburgh, Pa.	M. 55¢ BL. 70¢	52½¢	52½¢	62½¢	46⅛¢	62½¢	62½¢	62½¢	56¼¢	30¼¢	62½¢	55¢
Pittston, Pa.	M. 45¢ BL. 50¢			45¢	$2.00 per M			40⅝ to 68¾¢	40⅝ to 68¾¢	28⅛¢	30 to 35¢	28 to 37½¢

CITY	STONE CUTTERS	MARBLE CUTTERS AND SETTERS	PAINTERS	SHEET METAL WORKERS	ELECTRICAL WORKERS	ROOFERS	CEMENT FINISHERS	ELEVATOR CONSTR'ORS	PIPE COVERERS	LABORERS & HOD CARRIERS	REMARKS.
GRAND RAPIDS, MICH.	50¢		35 to 45¢	35 to 40¢	35 to 40¢	37½-43¾¢	25-45¢			L. 22½-30¢ H.C. 25-30¢	CARPENTERS, PAINTERS, CEMENT & LABORERS WORK 9 HOURS.
HARTFORD, CONN.	65¢	65¢	45¢	45¢	40¢	45¢	54¢	50¢	28¢	L. 25¢ H.C. 37½¢	
INDIANAPOLIS, IND.	56¼¢	SET 62½¢	47½¢	47½¢	47½¢	20-30¢	50¢		45¢	L. 25¢ H.C. 40 to 42½¢	
CANTON, OHIO.	65¢		27 7/10 to 35¢	30 to 35¢	33⅓¢		30 to 40¢			35¢	SLATERS 9 HOURS 42½¢
JACKSONVILLE, FLA.		SETTERS 62½ to 75¢	34 3/8 to 37½	37½¢	45 to 50¢	37½¢		50¢	56¼¢	L. $1.50 H.C. $1.50-1.75	
KANSAS CITY, MO.	56¼¢	CUT 56¼¢ SET 62½¢	50¢	57½¢	62½¢	30 to 35¢	62½¢	62½¢	37½¢	L. 20 to 30¢ H.C. 37½¢	PAINTERS ON STRIKE FOR 60¢ HR. LABORERS WORK 8 TO 10 HOURS.
LOS ANGELES, CAL.	56¼¢	50¢	43¾¢	50¢	43¾¢	43¾¢	62½¢	38 3/8 to 55 5/9¢	50¢	L. 34 3/8¢ H.C. 37½¢	PLASTERER' LABORER 50¢ HR.
LOUISVILLE, KY.	50¢	50¢	45¢	40¢	40¢	40¢	40¢	40¢	39 4/9¢	L. 17½ to 20¢ H.C. 38¢	STRUCTURAL IRON & CEMENT FIN WORK 10 HRS. MARBLE CUT. 9 HRS.
LOWELL, MA.	60¢		35¢	40 5/8¢	$18.00 PER WK	25 to 30¢				L. 20¢ H.C. 35¢	
MEMPHIS, TENN.	65¢	56¼¢	50¢	50-60¢	45¢	50-60¢	62½¢	40¢	50¢	L. 17½¢ H.C. 30¢	
MILWAUKEE, WIS.	56¼¢	CUT $4.50 DAY SET. 62½¢	50¢	45¢	45¢	40-50¢	40-50¢			35¢	ROOFERS WORK 10 HOURS.
MINNEAPOLIS, MINN.	56¼¢	56¼¢	45 to 50¢	45¢	45¢	35¢	35 to 40¢			28 1/8¢	
MONTREAL, CANADA	50¢	40¢	30-35¢	35¢	22½-35¢	20-27½¢	35-40¢			25-30¢	MASONS WORK 9 HRS. CEMENT 10 H
NEWARK, N.J.	$4.00 to $5.00 BLUE $5.50	CUT 45 to 50 SET 62½¢	47½¢	60¢	56¼¢	SLATE 60¢ COMP. 40¢	60 to 65¢	50¢	56¼¢	L. 25 to 30¢ H.C. 35¢	STEAM FITTERS PROBABLE INCREASE TO 62½¢ HOUR.
NEW ORLEANS, LA.	45 to 50¢	CUT 45 to 50¢ SET 50 to 56¼	37½¢	35 to 45¢	$3.60 A DAY	30¢	45¢			L. 15¢ H.C. 30¢	
NEW YORK, N.Y.	56¼ to 68¾¢	68¾¢	43¾¢	62½¢	56¼¢	METAL 62½¢ COMP. 50¢	62½¢	66¢	59 3/8¢	L. 33¢ H.C. 37½¢	
OKLAHOMA, OKLA.	62⅓¢	72½¢	50¢	50¢	50¢	40¢	60¢	62½¢	62½¢	L. 25¢ H.C. 35¢	
OMAHA, NEB.	58¾¢	68¾¢	50¢	42½ to 52½¢	50¢	40 to 50¢	INSIDE 60¢ OUTSIDE 50¢	45 to 50¢	50¢	L. 25 to 30¢ H.C. 35¢	
PEORIA, ILL.	50¢	67½¢	47½¢	45¢	50¢	40¢	50¢			L. 34 3/8¢ H.C. 37½¢	MARBLE SETTERS & LABORERS STRIKING FOR AN INCREASE.
PHILADELPHIA, PA.	50¢	CUT. 40¢ SET. 60¢	40¢	45¢	40¢	45¢	45¢	56¼¢	37½¢	37½¢	
PITTSBURGH, PA.	55¢	62½¢	55¢	55¢	57½¢	50¢		62½¢		L. 20 to 25¢ H.C. 25 to 37½¢	CARPENTERS ARBITRATING INCREASE TO 60¢ HOUR.
PITTSTON, PA.	45¢	45¢	30 to 35¢	35 to 40¢	35 to 45¢	METAL 35 to 40¢	45¢			L. $1.65-$2.00 H.C. $2.00-$2.25	SOME CARPENTERS AND PAINTERS WORK 9 HOURS.

TABLE 2—(Concluded)

Rates of Wages, per Hour, in the Building Trades in Various Cities, July 1, 1913

City	Masons and Bricklayers	Structural Iron Setters	Ornamental Iron Setters	Plasterer	Lathers	Hoisting Engineers	Tile Setters	Plumbers	Steam Fitters	Steam Fitters Helpers	Gas Fitters	Carpenter
Portland, Ore.	M. 70¢ BL. 75¢	75¢	$3.50 a day	75¢	62½¢	50¢	75¢	75¢	75¢	37½¢	75¢	$4.50 per day
Providence, R.I.	M. 50¢ BL. 65¢	55¢	55¢	65¢	50¢	55¢	65¢	60¢	50¢	35¢	60¢	50¢
Racine, Wis.	65¢			65¢	50¢			62½¢	62½¢	25¢	31¼¢	50¢
Reading, Pa.	M. 45¢ BL. 65¢	30 to 40¢	27 to 35¢	42½¢	Wood $1.90 M. Metal 30¢	35¢	50¢	40 to 42⅞¢	40¢	20¢	40 to 42⅞¢	40¢
Richmond, Va.	M. 43¾-62½ BL. 62½-70¢	35 to 50¢	35 to 50¢	33⅓¢	$1.70 per M.	35 to 50¢	55¢	45 to 50¢	45 to 50¢	20 to 25¢	45 to 50¢	33⅓ to 37½¢
Rochester, N.Y.	65¢	56¼¢	56¼¢	65¢	$2.25 per M.		55¢	50¢	50¢		50¢	50¢
Salt-Lake City, U.	M. 62½¢ BL. 75¢	62½¢	62½¢	75¢	62½¢	56¼¢	75¢	75¢	75¢	40¢	75¢	62½¢
San Antonio, Tex.	BL. 87½¢	62½¢		75¢				56¼¢				45¢
San Francisco, Cal.	$7.00 per day	62½¢	62½¢	87½¢	75¢	75¢	75¢	75¢	75¢	37½¢	75¢	62½¢
Scranton, Pa.	M. 50¢ BL. 60¢	56¼¢	50¢	55¢	50¢	35¢	50¢	50¢	50¢	25¢	45¢	47½¢
Seattle, Wash.	75¢	62½¢	62½¢	75¢	62½¢	Steam 62½ Electric 56¼	68¾¢	68¾¢	68¾¢	37½	56¼¢	
Sioux City, Ia.	M. 75¢ BL. 85¢	70¢		75¢	65¢	45¢	70¢	60¢	60¢	35¢	60¢	50¢
St. Louis, Mo.	M. 70¢ BL. 75¢	65¢	65¢	75¢	68¾¢	Single 75¢ Double 87½¢	62½¢	66¼¢	75¢	37½¢	66¼¢	62½¢
St. Paul, Minn.	M. 55¢ BL. 65¢	50¢	50¢	62½¢	Wood 4¢ a yard Metal 55¢	55¢	62½¢	62½¢	56¼¢	25¢	62½¢	40 to 50¢
Tacoma, Wash.	M. 62½¢ BL. 75¢	56¼¢	37½-46⅞¢	75¢	$2 & 2.25 per M.	43¾¢	68¾¢	37½ to 68¾¢	37½-56¼¢	12½-31¼¢	43¾¢	43¾-50¢
Toledo, Ohio.	BL. 65¢	60¢		62½¢	55¢	45¢	40-60¢	56¼¢	56¼¢	31¼¢	56¼¢	45¢
Toronto, Canada.	55¢		25-36¢	52½¢	42¢	35¢	45 to 62½¢	45¢	45¢	17¢	45¢	42¢
Troy, N.Y.	60¢			60¢	50¢		60¢	60¢	60¢		60¢	45¢
Washington, D.C.	66⅔¢	50¢	50¢	62½¢	$2.85 per M.	62½¢	50¢	50¢	50¢	28⅛¢	50¢	50¢
Wilmington, Del.	M. 45¢ BL. 55¢	50¢	50¢	50¢	45¢	40¢	55¢	40¢	40¢	30¢	40¢	40¢
Winnepeg, Can.	70¢	50¢	40¢	65¢	56¼¢	50¢	57½¢	55¢	55¢	25¢	55¢	50¢

CITY	STONE CUTTERS	MARBLE CUTTERS AND SETTERS	PAINTERS	SHEET METAL WORKERS	ELECTRICAL WORKERS	ROOFERS	CEMENT FINISHERS	ELEVATOR CONSTR'ORS	PIPE COVERERS	LABORERS & HOD CARRIERS	REMARKS.
PORTLAND, ORE.	70¢	62½¢	50¢	$4.50 A DAY	50-62½¢	37½¢	$5.00 to $6.00	50¢		L. $2.50-$3.00 H.C. 50¢	CARPENTERS & SHEET METAL ASK INCREASE 50¢ A DAY. ELECTRIC'N 9 HR
PROVIDENCE, R.I.	50¢	CUT 50¢ SET. 65¢	50¢	50¢	50¢	45¢	55¢		50¢	L. 25¢ H.C. 27½¢	
RACINE, WIS.			50¢	47½¢	45¢	45¢				L. 32¢ H.C. 35¢	SCALE USED, SAME AS 1912
READING, PA.	50¢	CUT. 30¢ SET. 45¢	33-35	32¢	30 & 35¢	SLATE 40¢	$2.50 to $3.50	40¢	25¢	L. $1.75 to $2.40 H.C. 34¢	NEARLY ALL TRADES WORK 9 HR. CEMENT FINISHERS WORK 10 HRS.
RICHMOND, VA.	50¢	55¢	33⅓ to 35	40¢	33⅓¢	44¢	40¢	35 to 45¢		L. 15 to 20¢ H.C. 25¢	SCALE USED, SAME AS 1912
ROCHESTER, N.Y.	56¼¢	CUT. 56¼¢ SET. 55¢	46⅞¢	46⅞¢	50¢	37½¢	37½¢	50¢	37½¢	L. 25 & 28¢ H.C. 30¢	
SALT-LAKE CITY, U.	62½¢	62½¢	62½¢	57½¢	56¼¢	50¢	62½¢			L. 31¼¢ H.C. 50¢	
SAN ANTONIO, TEX.	62½¢		45¢		56¼¢					L. 21⅞ to 25¢	
SAN FRANCISCO, CAL.	SAND. 70 GRANITE 62½	CUT. 56¼¢ SET. 62½¢	56¼¢	68¾¢	62½¢	75¢	75¢	62½¢	50¢	L. 31¼ BRICK 50 PLAS. 62½	PIPE COVERERS ASKING FOR INCREASE FROM $4 TO $5.00
SCRANTON, PA.	50¢		42½¢	42½	47¢	45¢				L. 20¢ H.C. 25¢	LABORERS WORK 9 HRS.
SEATTLE, WASH.	70¢	62½¢	56¼¢	56¼¢	62½¢	50¢	62½¢	56¼¢	$6.50 DAY	L. $2 TO 3.50 H.C. $4.00	
SIOUX CITY, IA.	70¢	CUT 50¢ SET 70¢	45¢	40¢	50¢	50¢		80¢	30¢	L. 30¢ H.C. 40¢	
ST. LOUIS, MO.	56¼¢	CUT. 30 to 45¢ SET. 62½¢	57½¢	60¢	65¢	55¢	60¢	65⅝¢	62½¢	L. 20 to 37½¢ BRICK 47½ MAR 50	MARBLE HELPERS 34⅜¢ STONE H. 40¢
ST. PAUL, MINN.	56¼¢	CUT 32½-50¢ SET. 62½¢	50¢	40¢	30 to 47¢	GRAV 30-35 SLATE 40-45	50¢	25 to 35¢	27½ to 40¢	L. 22½¢ H.C. 30 to 35¢	HOISTING ENG., ELEVATOR CON., ROOFERS & LABORERS WORK 10 HRS.
TACOMA, WASH.	70¢	CUT. 44⅜¢ SET 62½¢	50-55¢	56¼¢	50¢	25-40¢	43¾-62½¢	45-50¢		L. 19-25¢ H.C. 50¢	GAS FITTERS & MARBLE CUTTERS WORK 9 HRS. LABORERS 10 HRS.
TOLEDO, OHIO.	56¼¢	SET 40-60¢	40¢	37½-42½¢	43¾¢	40-60¢	50¢		22½-25¢	L. 25-35¢ H.C. 33-35¢	
TORONTO, CANADA	55¢	CUT. 35¢ SET. 50¢	35¢	37½¢	40¢	30-40¢	45¢	30-45¢	$9.00 to 20.00 PER WEEK	L. 25-30¢ H.C. 30¢	STRUCTURAL-IRON STRIKING FOR 50¢ PER HR. PLAST'LAB. ASK 40¢ HR
TROY, N.Y.	50¢	CUT 50¢ SET. 50 to 60	45¢	45¢			60¢			L. 25¢ H.C. 30¢	
WASHINGTON, D.C.	50¢	56¼¢	50¢	50¢	55¢	50¢	45¢	56¼¢	47¢	L. 18¾¢ H.C. 28¼¢	
WILMINGTON, DEL.	50¢	CUT 50¢ SET. 60¢	40¢	37½ & 40¢	35 & 40¢	35 & 40¢	50¢	40 & 50¢	40¢	L. $1.75 & $2.00 H.C. 35¢	SCALE SAME AS 1912
WINNEPEG, CAN.	65¢	CUT 45¢ SET. 56¼¢	42½¢	43¢	35 to 50¢	35¢	40¢	40¢	40¢	L. 25¢ H.C. 30¢	IRON MEN, PAINTERS & ROOFERS WORK 9 HRS. LABORERS 10 HRS.

concerned. Figuring on a house of the above size, and of another 40 by 50, with the same interior trim and equipment, should demonstrate to an owner that a commodious house is the better investment where land is ample and unrestricted.

Porches, piazzas, and elaborate plumbing and heating systems are the luxuries which most house-owners stumble upon, and they invariably blame the builder in the end for what they consider exorbitant cost. Estimates of different kinds of plumbing and heating should therefore be made separately, so that the owner can get just what he contracts for. Here, too, honesty of representation is the wisest policy for the builder or architect. It is a fatal mistake to recommend an inadequate heating plant for a building, simply for fear that a higher-priced one will frighten the owner. If, after a free, dispassionate presentation of the facts, the owner wishes to adopt the cheaper system, the risk is his and not that of the builder or designer.

While estimates on a simple small cottage may thus vary from $3 to $5 per sq. ft., omitting porches, a brick house can be built for prices ranging from $5 to $6 per sq. ft. A fair brick veneer might be constructed for $4 per sq. ft., omitting porches, and finishing off only the first and second floors, with a fair cellar floor and walls. Bricks of the better class have advanced in price so that a house built ten or even five years ago at a cost of $10,000 would more than likely cost $13,000 today. The cubic contents of a brick house can be estimated at 14 to 22 cents per cu. ft. These figures represent the extremes. A house costing 22 cents per cu. ft. should have rather elaborate equipment and finish, while one constructed at a cost of only 14 cents would have to be skimped in many ways. The quality of the bricks used, and the current wages of masons in the particular locality, are factors which enter greatly into the question, and must be settled in each individual case.

Comparative Cost of Stone, Brick, and Wood Houses

Combinations of brick and lumber naturally increase the difficulty of advance estimates. A house with brick walls, but a shingle roof and wooden bay windows, should cost a little less than a house of bricks throughout, but much depends upon the number of angles and curves in the structure. Where the house is designed on plain lines so that the turning of many corners is avoided, the cost can be kept within reasonable limits. A brick-veneer house is a very satisfactory structure, and this combination is being used very extensively.

A stone house costs the most; and it is only by combining stone with wood that economy can be obtained so as to bring the final cost of the stone house anywhere near that of the brick one. One of the factors in stone houses is the cost of handling the heavy blocks. While a brickmason can handle his bricks easily without machinery, or a carpenter can depend almost entirely upon hand power for putting his frames together, the workman with stone must resort more or less to hoists and derricks to get his heavy blocks in position. There is apparently no way to overcome this difficulty, and stonemasons cannot facilitate their work by any device. The cost of rough stone, even in the most favorable locations, is in advance of bricks, and the cost of construction does not vary much from year to year. With the combination of lumber with stone, however, some very handsome houses have been constucted at 22 to 25 cents per cu. ft.

Stucco work is popular. This is combined with many kinds of materials. Stucco and shingles on a wooden frame have proved very satisfactory in some towns, and at a cost of 20 cents per cu. ft. A stone house of equal refinement and construction would probably cost upward of 30 cents per cu. ft. Houses of stucco on frame, costing 25 cents per cu. ft. are quite common, but local conditions may increase or decrease this cost.

A brick and plaster house is another improved method of construction that gives very pleasing and durable effects. With walls of frame, sheathed and veneered with brick and stucco, a house can be constructed for 20 cents per cu. ft. if the lines are plain and simple and no elaborate inside trim is attempted. A brick and plaster house costing 24 cents per cu. ft. permits of some rather elaborate interior trim and equipment.

It will be seen from the foregoing that the question of estimating in a rough way on the relative cost of different types of houses is one that depends upon local conditions, the price of labor, and the character of the interior trim, the heating and plumbing systems, and other equipments. Nevertheless, with a little care, a builder or architect can give his client an estimate that will in the end approximate quite closely the actual cost; but to do this, he must study modern conditions and changes closely and carefully.

RELATIVE COSTS OF DIFFERENT TYPES OF CONSTRUCTION IN DIFFERENT PARTS OF THE COUNTRY

Assuming a certain type of house, built at a certain cost, and located in a certain section of the country, it will be interesting as well as helpful to the estimator on houses of every type built anywhere, to know just how much another house built from the same plans would cost anywhere else whether the same or other types of material were used. A comparative statement of costs of this nature, compiled by Mr. H. W. Butterfield, was recently published in "House and Garden."

The house selected as a basis of comparison was an ordinary, good, substantial house, including all the conveniences and arrangements suitable for the average family without any special features or elaborate details, of thorough construction, built of first-class materials, and complete with the exception of the lighting fixtures, which will range from about $50 up to any amount one is willing to pay.

Plans and specifications for this house were sent to architects in different typical sections of the country, with the request that they submit estimates of cost for such a house if built in their locality from various materials. Their replies were carefully averaged; and the figures, both lump and per cu. ft., are tabulated as follows:

Cost of Typical House

New York City (suburban)	$4,300.00
Per cubic foot frame	17 cents
Per cubic foot brick	21½ cents
Per cubic foot stone	22½ cents
Stucco on metal lath	18 cents

Vicinity of **Philadelphia,** 10 per cent to 15 per cent less than near New York.

Maine	$3,400.00
Per cubic foot frame	14 cents
Per cubic foot brick	17 cents
Per cubic foot stone	20 cents
Stucco on metal lath	15 cents

In the **Southern New England States,** the cost would be slightly in excess of the above.

Middle South (Kentucky, Maryland, etc.)	$3,000.00
Per cubic foot frame	10 to 12 cents
Per cubic foot brick	12 to 14 cents
Per cubic foot stone	15 to 20 cents
Stucco on metal lath	11 to 14 cents

Chicago (vicinity of) $3,800.00
Per cubic foot frame ....15 to 16 cents
Per cubic foot brick .... 18 cents
Per cubic foot stone .... 20 cents
Stucco on metal lath ....16 to 17 cents

Middle Western States (such as Ohio, Michigan, Iowa, and Wisconsin) ......$2,550.00 to $4,000.00
Per cubic foot frame ....10 to 17 cents
Per cubic foot brick ....12½ to 20 cents
Per cubic foot stone ....16 to 25 cents up
Per cubic foot stucco on metal lath.......... ....12 to 18 cents up

Pacific Coast (Northwest) ......$2,000.00 to $3,200.00
Per cubic foot frame.............8½ to 13 cents
Per cubic foot brick ....9½ to 14 cents
Per cubic foot stone ....14 to 16 cents
Per cubic foot stucco on metal lath 9 to 14 cents

Colorado (average) ....$3,100.00 to $3,200.00
Per cubic foot frame .... 12 cents
Per cubic foot brick .... 14 cents
Per cubic foot stone .... 15 cents
Per cubic foot stucco on metal lath.... 13 cents

Southwest (Arizona and New Mexico)........... ....$2,900.00 to $3,000.00
Per cubic foot frame .... 12 cents
Per cubic foot brick ....13½ to 14 cents
Per cubic foot stone .... 16 cents
Per cubic foot stucco on metal lath.......... ....13½ to 14 cents

Analyzing these figures, we find that building costs are highest in New York and vicinity, and lowest in the Pacific Coast Northwest.

Labor and Materials are the two great dominating factors in these sections—as, in fact, they are everywhere. In some places, labor plays the more important part, wages being high and hours short.

In the vicinity of New York City, union labor is well organized and the mechanics receive the maximum wage for the minimum number of hours. In central and western New York State, carpenters and masons get a modest wage, and some materials, requiring a long haul, are expensive. The lumber sections of the Northwest and some parts of the South give a plentiful supply of cheap material; and where labor's demands are not high at the same time, we find here the most favorable conditions in which to build cheaply.

Prices, however, may vary in each section. An example in illustration of this is found in two houses built recently—one in Flushing, Long Island, N. Y., and the other in New Jersey. On Long Island the cost was 10 per cent less than in New Jersey. Transportation had much to do with this variation. The distance material is hauled is a strong factor in determining its cost to the consumer. It is therefore always wiser, apart from aesthetic reasons, to build with native materials.

BUILDING COSTS IN CITIES

As regards cost of building construction, New York City stands first, with San Francisco second, among American cities. In the latter, the high rates are due to the conditions that govern the labor market; in the former, the difficulties are due to complexity of building laws.

In discussing this subject and that of simplifying legal building requirements, a writer in a recent issue of the "Record and Guide" gives some rather intersting figures showing the cost per cu. ft. of construction in several of the leading cities. In New York City, construction is about 2 cents a cu. ft. higher than in San Francisco; while in San Francisco, construction costs run from 12 to 15 cents more than in other cities similarly situated with regard to shipping and railroad facilities. As a matter of fact, construction in both New York and San Francisco should be lower than in Chicago, Denver, and New Orleans, yet the range of cost for average buildings in American cities is as shown in the accompanying table:

Construction Costs in Various Cities

City	Cents per Cubic Foot
New York (Greater), N. Y.	23 to 28
San Francisco, Cal.	21 to 26
Chicago, Ill.	20 to 25
Boston, Mass.	20 to 23
Pittsburgh, Pa.	20 to 22
New Orleans, La.	19 to 20
Oakland, Cal.	18 to 21
Denver, Col.	18 to 19
New Haven, Conn.	18 to 19
Philadelphia, Pa.	16 to 18

From the above it is apparent that the local operator in Greater New York has to pay more for the legal requirements imposed upon his contractor than do operators in other cities, due allowance being made for the fact that union wages are higher in New York and in San Francisco than they are in any other city.

RELATIVE COST OF BUILDING MATERIALS

The report of the Committee on Fire Protection of the Boston Chamber of Commerce included some very interesting figures on the comparative cost of frame and brick construction for dwelling houses. The conclusion was that the slightly greater cost of brick, which averaged under 10 per cent more than frame, was more than offset in a few years by the lesser cost of maintenance and insurance and by the greater comfort and durability of the structure. The report says that when lumber was cheap and brick was more expensive than now, the idea became general that the cost of brick as compared with frame was almost prohibitive; and this continues, although the conditions have changed so radically that the cost is now little more and the ultimate cost is less.

The purpose of the investigation was to encourage the use of brick and non-combustible interior construction for the purposes of fire prevention, and this form of building was very strongly urged by the report. Bona fide bids were secured from five different contractors of good reputation on the cost of the construction of dwellings of brick, wood, cement, and hollow blocks, the houses to be the same in every particular except the outer walls. Bids were secured on a modern, 8-room house of good design and excellent arrangement, such as is frequently built in and about large cities; and on these bids of the five contractors varied comparatively little. Accordingly the average was taken as a fair test of the practical cost, the contractors including their profits in all cases. The average bid for the various types was as follows, the second column showing the percentage of excess cost of each type over the clapboard type:

Clapboard	$6,759.95	.0
Shingles	6,868.80	1.6
10-in. brick wall, hollow	7,372.48	9.1
12-in. brick wall, solid	7,641.00	13.0
Stucco on hollow block	7,187.65	6.3
Brick veneer on hollow block	7,483.16	10.7
Stucco on frame	6,952.90	2.9
Brick veneer on boarding	7,226.44	6.9
Brick veneer on studding	7,153.98	5.8

The committee corresponded with contractors in various parts of the country in making up its report, and found from them that brick buildings were commonly estimated to cost

10 per cent more than frame, while brick-veneered buildings could be put up in many sections for 5 per cent more than the cost of frame buildings, the difference in cost being usually more than offset by the lessened insurance premium. In the same way, estimates were secured on annual cost of maintenance, including depreciation, for frame and brick dwellings; and it was found that the frame dwellings cost 26 per cent more for maintenance and depreciation than the brick dwellings.

METHODS OF RAPID ESTIMATING

Very often it is desirable and important to be able to give a quick but fairly accurate estimate on some proposed piece of work for which nothing but "rough idea" sketches are provided. To assist the contractor to this end, particulars of work already carried out by him are of the utmost importance, and a form of record like that shown in Table 3 is recommended.

As it is usually only in buildings of small size that contractors are called upon to tender without quantities, these remarks apply only to such structures. In dealing with No. 3 column in the record, the number of cu. ft. is arrived at by multiplying the length of the building by the breadth, and then by the height from bottom of footings to half-way up roof, disregarding buttresses, chimney stacks, dormers, etc.. The ordinary cubing is assumed to include drainage of average extent and character, and average-priced grates, mantels, and finishings. But, as the price per cubic foot is of small value unless one knows the character of the building, the contractor should insert, in the space left for "Remarks" (10), particulars of finishings, materials, and any unusual features there may be. Boundary walls, entrance gates, and such like should be excluded, and the price of them stated in the remarks. Other elements which affect the price per cubic foot are very small or very large rooms, the utilization of the roof space for rooms, etc. Small buildings cost more per cubic foot than large ones, the finishings being of similar character.

No. 4 column in the record indicates a very useful item, and may be arrived at either by squaring each floor, including walls, or by measuring each room, also areas of passages and stairs, and adding to the total 1/5 of the whole for walls and waste.

In No. 6, the brickwork is all reduced the sq. yd. 9-in thick, including half-brick partitions; but a note should be

TABLE 3

Builder's or Contractor's Record Card

X Name of Work	1 Contract Price Exclusive of Boundary Walls, Fencing, Etc.	2 Actual Cost	3 Price per Cubic Foot at Contract Price	4 Number of Squares	5 Cost per Square at Contract Price	6 Number of Rooms	7 Price per Room	8 Number of Yards of Brickwork	9 Cost per Yard of Brickwork	10 Remarks

made as to whether there is much stud partitioning, and whether the openings are particularly large or numerous.

Having the particulars before him, the contractor is in a position to arrive at least at a closely approximate value of a building of average size, character, and finish, and may adopt either of the four following methods: (a) At so much per cubic foot; (b) at so much per square; (c) at so much per room; (d) so much per yard of brickwork.

Of these methods, a (column 3) is perhaps the most common, the measurements being taken from the bottom of footings to half-way up the roof. Yet in some respects it is the least satisfactory, chiefly on the ground that the figures dealt with are large, and any miscalculation must necessarily result in a mistake of some magnitude.

For instance—apart from an actual error in the figures—in case of a pair of semi-detached houses of 40,000 cu. ft. the pair, the difference between 11 cents and 12 cents per cu. ft. would be $400, which is too large a margin to play with. Given the information of the above-mentioned record, the most satisfactory method on the whole is b (column 5). The pair of houses of 40,000 cu. ft. might contain 8 squares on each floor in each house, a total of 32 for the pair, which, at the price of $4,800 for the pair, is $150 a square. It is clear that by this method a mistake has not so serious results as by method a. In the case of a contractor pricing at either $145 or $155 a square, the result does not mean a severe loss on one side, nor destroy his chance of the job on the other. Furthermore, there is a better opportunity of adjustment of price by adding to or deducting from the price per square.

In dealing with outbuildings of one story, it is best to cube these, figuring the main building only by the square. Boundary walls, fencing, and entrance gates must, of course, be kept separate in each case; and, as these are usually simple and easily measured, there is no difficulty about this.

Sometimes it is the case that the house which is bid on is, on the whole, of ordinary materials and finish; but has in connection with it one or two troublesome or expensive particulars—perhaps a dining or drawing room finished with somewhat costly fittings or with carved work. The simplest way is undoubtedly to treat the whole by the square, and add a sum for the particular items.

Method c (column 7) cannot be considered so satisfactory as the price per square method just given. It is obvious that the size of the rooms is of the first importance. Some contractors who always arrive at their price by means of this method, are guided almost exclusively by the size of the ground-floor rooms. Having a certain price for these rooms of average size and height, they vary the price per room, according as the rooms differ from a given standard. They contend that the size of the upper rooms is necessarily governed by that of the lower rooms. The particulars necessary for estimating by this method are the same as those for estimating by the square, and the same remarks apply generally.

The last method, **d** (column 9), is very simple and very useful; and given, as already stated, similar materials and finish, there is a very close connection between the price and the number of yards of brickwork. The only thing to be noted is whether the amount of stud partition is unusually large. It might be argued that the number of yards of brickwork would be no guide in the case of buildings of irregular outline; that if the house were made square, the brickwork, at least in the external walls, might be the same in both cases, yet in the case of the square house the space enclosed would be larger, with more floor area, and therefore of greater cost.

In answer to that, there are these conditions: For its size, the house with the irregular outline, has a larger proportion of external wall and external facing; the roof would be likely to be more expensive in labor; more cutting of brickwork and roofing would be required—all of which would compensate for the extra floor space, etc.; and the balance would thus be restored.

The various methods that have just been mentioned, can be used only for the purpose of arriving at an approximate price, though this price may approximate very closely the value of the work. They cannot, of course, be said to compare for reliability with the proper and correct "taking off" the quantities of the materials and labor required.

COST OF BUILDINGS PER CUBIC FOOT

The cost of buildings is often estimated at a certain price **per cubic foot of contents**, basing this cubical measurement on the length, multiplied by the width, and then by the average height, measuring from the bottom of basement to the mean or average height of a flat roof, or to the height of the finished portion of the attic in case of a pitch roof. All measurements are to the outside of walls and foundations. Vaults and spaces under sidewalks are measured as a part of the basement.

While the following costs will serve as a guide in estimating, it should be remembered that they are approximations at the best, and will be affected by local prices of labor and materials.

Frame dwellings with shingle roof, pine floors and trim, two coats of paint inside and out, without heat or plumbing, cost about 10 cents per cu. ft.

Same with hardwood floors in hall and parlor, with heat and fair plumbing, about 11 cents per cu. ft.

Same with hardwood floors and trim on first floor, pine floors and trim on second floor, heat and plumbing, good quality of materials, about 15 cents per cu. ft.

Brick dwellings of same character as for frame above, add about 2 cents per cu. ft. for each case.

Flat buildings or **apartments of frame construction,** with shingle or composition roof, hardwood floors and trim, good plumbing, and with furnace, of good-quality material, cost about 12 cents per cu. ft.

Flat buildings of **brick construction** cost from 15 to 30 cents per cu. ft., depending upon the style of architecture, quality of material, brick or stone front, etc.

Churches and school buildings cost about 12 cents per cu. ft. for frame, 14 cents for brick, and 25 cents for stone.

Stores cost about the same as flat buildings given above.

Fireproof flats, office buildings, and **factories** cost from 25 to 60 cents per cu. ft., depending upon the detail of building and type of construction.

Theaters cost about 40 cents per cu. ft.

Mill construction for factories and warehouses costs about 10 cents per cu. ft.

Barns, small or medium-sized, cost about 10 cents per cu. ft., stalls and bins complete. For **brick construction,** add about 2 cents per cu. ft.

COST OF FIREPROOF WALLS

The costs of various hollow-tile fireproof walls in comparison with those of ordinary construction, are indicated in Table 4, compiled by the Pennsylvania Fireproofing Co.

AVERAGE DIMENSIONS OF HOUSEHOLD FURNITURE

Beds—Single, 2 ft. 8 in. to 3 ft. 6 in. wide.

Three-quarter, 4 ft. to 4 ft. 6 in. wide.

Double, 4 ft. 6 in. to 5 ft. wide.

Length of beds will vary from 6 ft. 6 in. to 6 ft. 8 in., inside measurement.

TABLE 4

Cost of Hollow-Tile Exterior Walls

Per square of 100 sq. ft.

With Exterior Cement Stucco and Interior Plaster Complete		With Exterior Plain and Interior Plaster Complete		Without Exterior Stucco or Interior Plaster—Tile Keyed Ready for Plasterer	
Wall	Cost	Wall	Cost	Wall	Cost
6 in.	$23.85	6 in.	$18.35	6 in.	$15.50
8 in.	27.10	8 in.	21.60	8 in.	18.75
10 in.	30.85	10 in.	25.35	10 in.	22.50
12 in.	32.35	12 in.	26.85	12 in.	24.00
15 in.	36.35	15 in.	30.85	15 in.	27.00
16 in.	39.35	16 in.	33.85	16 in.	29.50

Hollow Tile with Exterior Brick Veneer

Cost per square of 100 sq. ft.

Tile used for this purpose sometimes called "Backing-up Block." (Tile with keyed surfaces ready for direct application of plaster. Includes exterior stone trim.)

Thickness of Wall	Face Brick Veneer	Common Brick Veneer
8 in.	$38.50	$26.80
10 in.	42.00	30.30
12 in.	45.25	33.55
14 in.	49.00	37.30
16 in.	50.50	38.80

Partition Walls—Hollow Tile Ready for Plaster

3 in.	$10.50	5 in.	$12.80	7 in.	$14.50
4 in.	11.00	6 in.	13.10	8 in.	17.00

Outside walls, WOOD FRAME construction throughout, painted exterior, plastered interior, including all labor and finish, is stated to cost about $18.50 per square.

Billiard tables—4 ft. by 8 ft., 4 ft. 2 in. by 9 ft., and 5 ft. by 10 ft.

Bureaus—Body 3 ft. 5 in. wide, 1 ft. 6 in. deep, 2 ft. 6 in. high; or 4 ft. wide, 1 ft. 8 in. deep, 3 feet high.

Carving tables—3 ft. high.

Chairs—These vary greatly in size, so that no average can be given which would be of any practical use.

Cheval glasses—5 ft. high by 1 ft. 8 in. wide; 5 ft. 6 in. high by 2 ft. wide; 6 ft. 4 in. high by 3 ft. 2 in. wide.

Chiffonieres, 3 ft. wide, 1 ft. 8 in. deep, 4 ft. 4 in. high.

Commodes—1 ft. 6 in. square on top, and 2 ft. 6 in. high.

Couches—2 ft. 6 in. wide, 6 ft. 8 in. long.

Pianos—Baby grand, 3 ft. 1 in. high, 4 ft. 5 in. wide, 6 ft. long. **Parlor grand**, 3 ft. 4 in. high, 5 ft. wide, 7 ft. 8 in. long. **Upright**, 4 ft. 5 in. high, 2 ft. 4 in. wide, 5 ft. 2 in. long.

Sideboards—4 ft. to 6 ft. long, and from 20 to 26 in. deep.

Wardrobes, 8 ft. high, 2 ft. deep, 4 ft. 6 in. wide; or 6 ft. 9 in. high, 1 ft. 5 in. deep, 3 ft. wide.

Washstands—2 ft. 7 in. high, 1 ft. 6 in. wide, 3 ft. long.

AVERAGE DIMENSIONS OF BATHROOM AND KITCHEN FIXTURES

Bathtubs—Enameled iron, roll-rim, with sloping end, lengths 4, 4½, 5, 5½ and 6 ft.; width 30 to 34 in.

Kitchen sinks—Cast-iron, enameled, 16 by 24 in., 18 by 30 in., 18 by 36 in., 20 by 30 in., 20 by 36 in., 24 by 50 in.
Cast-iron, plain, up to 32 by 56 in., or 28 by 78 in.
Steel, up to 20 by 40 in.
Porcelain, 20 by 30 in., 23 by 36 in., 24 by 42 in.
Average depth of above sizes, 6 in.

Laundry tubs—Slate or soapstone, length of two-part tub, 4 ft. and 4 ft. 6 in.; length of three-part tub, 6 ft., 6 ft. 6 in., and 7 ft. Width of tubs, 2 ft. Depth of tubs, 16 in.

Range boilers—12 in. diam. for 30-gal. size; 14 in. for 40-gal. size; and 16 in. for 52- and 63-gal. size.

Slabs, Marble, for wash-basins—20 by 24 in., 20 by 30 in., 22 by 28 in., 24 by 30 in. All slabs 1¼ in. thick.

Slop sinks—Cast-iron, 16 by 16 in., 16 by 20 in., 18 by 22 in., 20 by 24 in. All sizes 12 in. deep.

Wash-basins—Crockery, round bowls, 10, 12, 14, and 16 in. diam. Oval bowls, 14 by 17 in., and 15 by 19 in.
Enameled iron, 16 by 20 in. with 11 by 14-in. basin; 18 by 21 in. with 11 by 15-in. basin; 18 by 24 in. with 12 by 15-in. basin. Height of back, 10½ in.

Waterclosets—Width of bowl, 13 in.; width of seat, 16 in.; height from floor to seat, 17 in.; distance from wall to front of seat, 23 in.

ABBREVIATIONS FOR ESTIMATORS

The following list of abbreviations will be found useful in making up an estimate. Others of a like nature may be originated by the estimator, for use in his particular line of work.

A

a. b. .... as before
L .... angle
asb. .... asbestos
av. .... average

B

bbl. .... barrel
bd. & jt. ...... bed and joint
bd. & pt. ...... bed and point
b. f. .... box frame
bldg. .... building
b. m. .... board measure
bn. .... battens
b. p. .... brick piers
b. s. .... both sides
b. v. .... brick veneer

C

c. .... cent or cents
cal. .... calsomine
c. b. .... common brick
c. bl. .... cement blocks
c. to c. ...... center to center
[................... channel

ch. ....chimney
c. i. ....cast iron
cir. ....circular
c. m. ....cement mortar
cmt. ....cement
col. ....column
com. ....common
con. ....concrete
con. p. ....concrete piers
c. p. ....candle power
cor. ....corner
corr. ....corrugated
cr. st. ....crushed stone
cu. ft. or c. f. ....
.........cubic foot or feet
cu. in. or c. i. ....
......cubic inch or inches

D

dbl. ....double
ddt. ....deduct
d. h. ....double hung
dia. ....diameter
diag. ....diagonal
dist. ....distemper
d. p. c. ....damp-proof course
d. s. ....double-strength
dsp. ....downspout
d. & m. dressed and matched
d. m. & b........dressed,
......matched, and beaded

E

est. ....estimate
ex. ....excavating
ex. met. ....expanded metal

F

f. b. ....face brick
fd. ....foundation
f. e. ....feather edge
f. o. b. ....free on board
foot. ....footings
f. p. ....fireplace
fr. ....furring
frd. ....framed
f. & h. ....fill and haul away
f. & r. ....fill and ram

G

g. ....grain
gal. ....gallon
galv. ....galvanized
g. i. ....galvanized iron

H

H. ....H-section
h. p. ....horse-power
h. r. ....hand-rail
h. w. ....hard wall

I

I ....I-section
in. ....inch

L

lab. ....labor
lin. ft. ....linear foot or feet
l. m. ....lime mortar
l. p. ....lath and plaster

M

m. ....measure
M. ....thousand
matl. ....material
m. b. ....matched boards
mold. ....moulding
mult. ....multiply
m. w. ....mineral wool

N

n. c. ....natural cement
no. ....number
N. p. ....Norway pine

O

O ....round or diameter
o. c. ....on centers
O. f. ....Oregon fir
O. G. ....ogee style

P

p. ....paint
p. b. ....paving brick
pcs. ....pieces
P. c. ....Portland cement
p. d. ....pebble-dash
p. f. ....plain face
pl. ....plastering

Q

q. s. ....quarter-sawed

R

r. c. ....red cedar
reb. ....rebated
rein. ....reinforcing
rel. arch......relieving arch
r. i. ....rolled iron
r. o. ....red oak
r. o. & p. ..rake out and point
r. w. ....redwood

S

S-1-S....surfaced on one side
S-2-S...surfaced on two sides
S-4-S...surfaced on four sides
S-1-S-1-E.....surfaced on one side and one edge
s. c. ....surface coat
seg. ....segmental
s. g. ....straight-grained
shg. ....shingles
sh. l. ....short length
sk. ....sack
sl. ....slate
sq. ....square or squares
sq. ft. or s. f...............
........square foot or feet
s. s. ....single-strength
sto. ....stucco
sub. ....sub-floor
sup. ....superficial
surf. ....surface

T

t. & g. ..tongued-and-grooved
t. & grav. ....tar and gravel
tl. ....tile
T. p. ....Texas pine
t. rf. ....tin roof
tr. ....transom

V

v. ....varnish
v. g. ....vertical grain

W

w. i. ....wrought iron
win. ....window
w. l. ....wood lath
w. o. ....white oak
w. p. ....white pine
wpr. ....waterproofing or waterproof
wsct. ....wainscot

X

X ton. ....cross-tongue

Y

yd. ....yard
y. p. ....yellow pine

Miscellaneous

′ ...foot or feet, as (1′, 2′, 3′, etc.)
″ ..inch or inches (as 1″, 2″, 3″, etc.)
1ce ....once
2ce ....twice
1 b. ....one brick
2 b. ....two bricks

FORMS OF CONTRACTS

The following standard forms of contract will be of service to the architect, builder, or contractor who wishes a carefully arranged contract for use in any particular type of construction. The standard forms shown are copyrighted, 1911, by the American Institute of Architects, Washington, D. C., and are here reproduced by express permission of E. G. Soltman, dealer in drawing materials, of New York City, sole licensee for publication.

Invitation to Submit a Proposal

Office of Architect

Dear Sir: You are invited to submit a proposal for

....

Drawings, Specifications and other information may be procured from this office on and after......................

....

All documents must be returned to this office...........

To be entitled to consideration, the Proposal must be made upon the form provided, which must be fully completed in accordance with the accompanying Instructions to Bidders and must be delivered to this office not later than

....

Very truly yours,

....

Architect.

.... 19....

Instructions to Bidders

(Standard Form of the American Institution of Architects)

Proposals, to be entitled to consideration, must be made in accordance with the following instructions:

a. Proposals shall be made upon the form accompanying these instructions, and all blank spaces in the form shall be fully filled; numbers shall be stated both in writing and in figures; the signature shall be in long hand; and the completed form shall be without interlineation, alteration, or erasure.

b. Proposals shall not contain any recapitulation of the work to be done.

c. Proposals shall be delivered to the Architect enclosed in an opaque, sealed envelope addressed to him, marked "Proposal," and bearing the title of the work and the name of the Bidder.

d. No oral, telegraphic, or telephonic proposals or modifications will be considered.

Should a Bidder find discrepancies in or omissions from the drawings or documents, or should he be in doubt as to their meaning, he should at once notify the Architect, who will send a written instruction to all bidders. Neither Owner nor Architect will be responsible for any oral instructions.

Before submitting a proposal, bidders should carefully examine the Drawings and Specifications, visit the site of work, fully inform themselves as to all existing conditions and limitations, and shall include in the Proposal a sum to cover the cost of all items contemplated by the Contract.

The competency and responsibility of bidders and of their proposed sub-contractors will be considered in making the award. The Owner does not obligate himself to accept the lowest or any other bid.

(Here follows a blank Standard Form of Agreement, as given below.)

Standard Form of Proposal

(American Institute of Architects)

.... 19....

....

Architect.

Dear Sir:

Having carefully examined the Instructions to Bidders, the General Conditions of the Contract and the Specifications entitled (Here insert the caption descriptive of the work as used therein) and the Drawings similarly entitled numbered...............
.... as well as the premises and the conditions affecting the work, the Undersigned proposes to furnish all materials and labor called for by them for (Here insert, in case all the work therein described is to be covered by one contract, "the entire work." In case of a partial contract insert name of the trade or trades to be covered and the numbers of the pages of the Specifications on which the work is described).

....

....

in accordance with the said documents, for the sum of .... Dollars ($........) and to execute a contract for the above work, for the above stated compensation in the form of the Agreement, shown in Instructions to Bidders, provided that he be notified of the acceptance of this proposal within .... days of the time set for the submission of bids.

GENERAL CONDITIONS OF THE CONTRACT AND OF THE SPECIFICATIONS

Brief Description of the Work

The work consists of that called for by the Drawings and Specifications entitled (Here insert the caption descriptive of the work as used in the form of Proposal, in the Specifications and upon the Drawings.)

....

hereinafter called the Owner, and is to be executed to the satisfaction of, under the supervision of and in accordance with the Drawings and Specifications prepared by

....

acting as and in these Contract Documents called the Architect.

Identification of Documents

The Drawings and Specifications forming a part of these contract Documents are the following:

....

....

In these General Conditions the Owner, the Contractor, and the Architect are treated as if each were of the singular number and masculine gender. Where the words written notice or notice in writing are used, such notice shall be deemed to have been duly served if delivered in person to the individual or to a member of the firm or to an officer of the corporation for whom it is intended, or if delivered at the last address of the said individual, firm, or corporation known to him who gives the notice.

Drawings and Specifications

Article 1. The Agreement, the General Conditions of the Contract, the Specifications, and the Drawings, with all notes made thereon before the signing of the Agreement, are the documents forming the Contract. Copies of all these documents signed by the parties, or identified by the Architect as provided in the Articles of Agreement, shall remain in the custody of the Architect and shall be produced by him at his office on demand of either party.

Article 2. The documents forming the Contract are complementary, and what is called for by any one shall be as binding as if called for by all. They are intended to include all detail of labor and material reasonably necessary for the proper execution of the work. Should they disagree the Architect shall determine which quantity or quality of the work is to be furnished. Where reference is made to approval of work, material, fixtures, etc., such approval, unless otherwise distinctly stated, is to be understood as that of the Architect.

Article 3. The Contractor, if required, shall prepare, in consultation with the Architect, a schedule fixing the latest dates at which the various detail drawings and decisions will be required for the proper conduct of the work, and the Architect will from time to time, as necessary, furnish such detail and working drawings, which shall be true developments of the scale drawings. The work shall be executed in conformity therewith, and with such instructions, directions and explanations, not inconsistent therewith, as may from time to time be given by the Architect.

Article 4. The Architect will furnish to the Contractor, free of cost to him, one copy of each full size detail drawing, and two copies of all other drawings and of the Specifications. If additional copies are desired they may be obtained at the cost of reproduction. The Contractor shall keep in good order upon the work one copy of the Specifications and one of each Drawing, and the Architect and his representatives shall have free access to such copies.

Article 5. Figured dimensions shall be followed in preference to measurements by scale; and larger scale drawings shall take precedence over those at smaller scale.

Article 6. The Drawings and Specifications furnished by the Architect shall be used for this work only. As instruments of service they are the property of the Architect, and shall be returned to him. Any models furnished under this Contract, or by the Owner, are the property of the Owner and shall be disposed of as directed by him.

Article 7. The Contractor shall furnish to the Architect at proper times all shop and setting drawings or diagrams which the Architect may deem necessary in order to make clear the work intended or to show its relation to adjacent work of other trades. The Contractor shall make any changes in such drawings or diagrams which the Architect may require, and shall submit two copies of the revised prints to the Architect for his identification, one copy to be returned to the Contractor, the other to be filed by the Architect. In submitting such shop and setting drawings the Contractor shall in writing specifically call the attention of the Architect to every change from the Architect's Drawings or Specifications. The Architect's identification on the revised prints shall not relieve the Contractor of entire responsibility for his own errors and for changes not so pointed out in writing. Any models or templates submitted shall be changed as required until satisfactory to the Architect.

Materials and Workmanship, and their Inspection

Article 8. No one unskilled in the work which he is given to do shall be employed, and all work shall be executed in a skillful and workmanlike manner. Should the Architect deem any one employed on the work incompetent or unfit for his duties, and so certify, the Contractor shall dismiss him, and he shall not again, without the Architect's permission, be employed on the work.

Article 9. All materials unless otherwise specified, shall be new and of the best quality of their respective kinds.

Article 10. The Contractor shall at all times maintain proper facilities and provide safe access for inspection to all parts of the work, and to the shops wherein the work is in preparation. Where the Specifications require work to be specially tested or approved it shall not be tested or covered up without timely notice to the Architect of its readiness for inspection and without his approval thereof or consent thereto. Should any such work be covered up without such notice, approval or consent it must, if required by the Architect, be uncovered for examination at the Contractor's expense.

Article 11. When required the Contractor shall provide all facilities and labor necessary for a complete re-examination of work under suspicion, and if the Architect decides that the work is defective, the Contractor shall bear the expense of re-examination and replacement. If not found defective, such expense shall be credited to the Contractor as extra work.

Article 12. The Contractor, upon receiving from the Architect written notice and within such reasonable time as may be named therein, shall remove from the premises all materials, whether worked or unworked, and take down and remove all portions of the work, condemned by the Architect as unsound or improper or as in any way failing to conform to the Contract; and the Contractor shall promptly replace and re-execute his own work in accordance with the Contract and without expense to the Owner, and shall bear the expense of making good all work of other contractors destroyed or damaged by such removal, or replacement.

If the Contractor does not remove such condemned or rejected work and materials within the time limited by the notice, the Owner may remove them and may store the material at the expense of the Contractor. If the Contractor does not pay within ten days after such removal by the Owner the expense of such removal, the Owner may at any time thereafter upon ten days' written notice sell such materials at auction or at private sale. The Owner shall account to the Contractor for the proceeds of such sale, after deducting all expense of removal and storage.

Article 13. Except when authorized in writing by the Owner through the Architect, neither the clerk of the works nor a superintendent, even though employed by the Owner, has authority to add to or deduct from the work called for under the Contract, or to make any changes therein.

Financial Relations

Article 14. The Contractor, when required shall furnish to the Architect, upon a blank form provided or approved by him, a correct statement, showing the estimated cost of each part of the work as subdivided in the Specifications, the total equaling the contract price. This statement shall be for the use of the Architect at his discretion, in preparing estimates for payments on account.

Article 15. At least one week before each payment falls due the Contractor shall submit to the Architect a requisition therefor and shall, if required, submit therewith an itemized statement of the quantities and cost and proportionate share of profit of work performed to the termination of the period to be covered by the payment. Such statement shall be made in form provided or approved by the Architect; but it shall not be binding as against his judgment.

Article 16. The acceptance by the Contractor of the payment of the final certificate shall constitute a waiver of all claims against the Owner under or arising out of this Contract.

Article 17. The Contractor shall make good, without cost to the Owner, any omissions from his work or negligence in connection therewith or any improper materials or defective workmanship or consequences thereof of which he may in writing be notified within one year of the date of the final certificate, but this general guarantee shall not act as a waiver of any specific guarantee for another length of time set elsewhere in the Contract Documents.

Within the period of general or special guarantee, no certificate given, nor payment made under the Contract, nor partial nor entire occupancy of the premises by the Owner, shall be construed as an acceptance of defective work or of improper material or as condoning any negligence or omission.

Article 18. The Architect may withold or nullify any certificate or reduce the amount thereof, if, in his opinion, violation of the Contract exists after the Contractor has been duly notified to correct the same, or if he have knowledge of lien against the premises under this Contract, and such certificates may be withheld until such violation is corrected to the satisfaction of the Architect, or such lien is discharged or satisfactorily bonded.

Article 19. If, in the opinion of the Architect, it is not expedient to correct injured work, or work not done in accordance with the Contract, the Owner may deduct the difference in value between the work involved and that called for by the Contract, together with a fair allowance for damage, the amount of which shall be determined by the Architect, subject to arbitration.

Article 20. The Owner may, without invalidating the Contract, make changes by altering adding to or deducting from the work in the manner hereinafter provided. No claim for an extra charge for such changes shall be valid unless such work is done in pursuance of a formal written order therefor from the Owner or from the Architect acting under the authorization of the Owner, and no bill for extra work of any kind will be audited by the Architect or paid by the Owner unless it be rendered in accordance with the terms of such formal written order. Unless otherwise expressly agreed all such work shall be executed under the conditions of the original Contract.

Article 21. Should the Contractor deem any work which he is called upon to perform, whether by instruction, by detail drawings or otherwise, to be extra to the Contract, he shall give the Architect written notice thereof before proceeding to execute it, and in any case within two weeks of receiving such instructions or drawings or otherwise being called upon to perform such work, and failure so to do shall constitute a waiver of all claim for extra payment on account of it. Should the Architect decide that no extra work is involved, the Contractor may appeal to arbitration before commencing the work, but in any case he shall proceed with it if so ordered.

Article 22. Should the Architect determine that any alterations in, addition to or deductions from, the work covered by the Contract affect the contract price, then their value shall be determined in one or more of the following ways, as may be selected by the Owner:

(A) By Unit Prices named in the Contract or subsequently agreed upon, in which case the Architect shall make the award, subject to arbitration.

(B) By Cost and Percentage or Cost and a Fixed Fee, under special order in writing, in which case the Contractor shall keep a true and correct account of the net cost of labor and materials, rendering to the Architect, at required intervals, detailed statements and vouchers, and the Architect shall award an amount as cost and profit, subject to arbitration.

(C) By Estimate and Acceptance in a lump sum.

(D) In case an agreement as to price cannot be reached or in case the Owner should refuse to employ any of the above methods, the Architect may, with the authority of the Owner, by a special order in writing, direct the work to proceed and the Contractor shall forthwith proceed and leave the price to be settled by arbitration.

Article 23. Where the Contractor is thus specially ordered in writing by the Owner or Architect to do additional work not covered by unit prices, or by estimate and acceptance in a lump sum, the Contractor or his duly authorized agent shall, unless directed to the contrary by the Architect, prior to doing such work, notify the superintendent or, in his absence, the Architect, stating his intention to enter upon such work, and not later than the next day thereafter he shall deliver to the superintendent or Architect as directed a written memorandum, in duplicate, giving in detail the amount of materials and labor incorporated in the claim for the day, together with his proper compensation therefor. Failure on the part of the Contractor so to notify the superintendent or Architect or to deliver the memorandum relative to the day's work shall be construed as a waiver of any and all claims therefor. The duplicate copy of the above mentioned memorandum will be returned to the Contractor as soon thereafter as possible, with a duly certified approval, disapproval or correction, and all bills for extra work shall be rendered on the basis of these approved daily memoranda.

Article 24. Neither the Contractor nor any sub-contractor, materialman, nor any other person shall file or maintain a lien, commonly called a mechanic's lien, for materials delivered for use in, or work done in, the performance of this Contract, and the right to maintain such lien by any or all of the above named parties is hereby expressly waived, except in the event of the failure or refusal of the Owner to pay the amount called for by any certificate of the Architect, within ten days of the date of its tender to the Owner for payment. Then, and in such case only, shall any of the above named parties have the right to file and maintain a mechanic's lien.

Payment shall not become due unless at the time of each payment the Contractor, if so required, and in any event at the time of final payment, shall deliver to the Owner a satisfactory release of all liens against the premises on the part of all persons who have delivered materials for use in, or work done in, the performance of this Contract in respect of all such work or material covered by the payment in question. At the last payment, such releases shall include that of the Contractor himself. If at any time there shall be evidence of any lien or claim for which, if established, the Owner or the premises might be made liable, and which would be chargeable to the Contractor, the Owner shall have the right to retain out of any payment then due, or thereafter becoming due, an amount sufficient to indemnify himself for such lien or claim until the same shall have been effectually discharged or bonded. If, because of the Contractor's negligence or default, any such lien or claim shall remain unsatisfied after all payments are made, the Contractor shall refund to the Owner all moneys that the latter may be compelled to pay in discharging such lien or claim.

Artic e 25. The Contractor shall set aside to be expended as the Architect shall direct the amount of each cash allowance required by the Contract. The Contractor shall expend and pay such allowance at such times and in such amounts, and to and in favor of such persons and upon such work as the Architect may in writing direct, and the Contractor shall make sub-contracts with such parties for furnishing such materials and labor, and he shall assume the same responsibility for their work as for other portions of his work. But no such sub-contractor shall be employed upon the work against whom the Contractor shall make objection which the Architect considers reasonable, or who will not enter into an agreement with the Contractor upon conditions consistent with those of this Contract.

Except where specifically provided to the contrary, all cash allowances shall be for the actual net cost to the Contractor of labor and material only, exclusive of office or other expenses or profit; i. e., the Contractor in making up his bid shall add such sum for expenses and profit on account of cash allowances as he deems proper, and no demand for expenses or profit other than those included in the contract sum shall be allowed by the Architect. Cash allowances shall be payable by the Contractor without discount or deduction or by the Owner directly, if he so elect. All bills for labor and materials under such allowances shall be submitted to the Architect for his approval. Proper credit or debit shall be made in the contract price, according to the difference between the total cost of such material and labor, and the total of cash allowances named in the Agreement or Specification, and any credit balance may be deducted from the contract price or applied by written order of the Architect in payment for additional work done by the Contractor on formal written order.

Article 26. Unless specifically provided otherwise in the Agreement the Owner and the Contractor shall each protect his own interest against loss or damage by fire, pending full performance by the Contractor of the work hereunder and full payment therefor by the Owner. For the purpose of maintaining fire insurance as far as concerns this Contract the Owner's interest at any time shall be held to amount to the sum of all payments which he shall have made to the

Contractor on account of this Contract. For the same purpose, the Contractor's interest shall be held to consist of any and all insurable value under and pertaining to this Contract not above defined as "Owner's interest." Loss or damage by fire shall not affect the rights and obligations of either party under this Contract, except that in such event the Contractor shall be entitled to reasonable extension of time for the performance of this Contract, as provided under Article 28, "Contractor's Claim for Extension of Time." The Contractor shall upon written notice from the Owner immediately proceed with the reinstallation of work damaged or destroyed, and the Owner shall make payments to the Contractor on account of reinstallation upon certificates of the Architect issued on the same principles as govern payments during its original construction as provided in the Agreement. Should the Owner and the Contractor fail to agree on the total amount thus to be paid, such amount shall be subject to arbitration.

Article 27. Should the Owner claim damages for delay in the completion of the work, the Architect, it, in his opinion, any damages be payable, shall make an award, and shall write the amount thereof across the face of the final certificate as "amount to be deducted from the face hereof for delay in completion of the work," but such amount shall be subject to arbitration. Thereupon the Architect's services in this matter shall terminate, except as provided under Article 38.

Article 28. Should the Contractor be delayed in the prosecution or completion of the work by the act, neglect or default of the Owner, or of anyone employed by the Owner, or by fire, or by general strikes or for any other reason deemed sufficient by the Architect, then the time fixed in the Agreement for the completion of the work shall be extended for a period equivalent to the time lost by reason of any and all the causes aforesaid. Such extension of time shall be determined and fixed by the Architect. (Subject to arbitration.) But no such allowance shall be made unless a claim therefor is presented in writing to the Architect within forty-eight hours of the occurrence of such delay.

Article 29. Should the Owner fail to provide all labor and materials, not included in this Contract, but essential to the conduct of this work, in such manner as not to delay its reasonable progress, or should the Contractor be damaged by any act or omission of the Owner, the right of the Contractor to compensation for the damage suffered, whether in the form of unusual or protracted services or otherwise, and the amount of such compensation shall be determined and awarded by the Architect (subject to arbitration); but no such allowance shall be made unless a claim therefor is made in writing or by telegraph to the Architect within forty-eight hours of the occurrence of such damage.

Article 30. Should the Contractor or any person directly or indirectly employed by him cause damage to the material, apparatus or executed work of any other contractor employed by the Owner on the work, or cause damage by way of delay or otherwise to such other contractor, such other contractor shall in writing notify the Owner, through the Architect, of the fact within forty-eight hours of the occurrence of such damage and should the two contractors be unable to reach a settlement within ten days thereafter the Owner shall debit the Contractor in the amount that the Architect shall decide to be just and shall credit that amount to the other contractor. (Subject to arbitration.) Should the Contractor sustain damage to his apparatus or materials or executed work by reason of delay or otherwise at the hands of some other contractor he shall in similar manner notify the Owner, and should the two contractors be unable to reach a settlement within ten days thereafter the Owners shall credit the Contractor in the amount that the Architect shall decide to be just, and shall debit that amount to the other contractor. (Subject to arbitration.) The Contractor shall in final settlement accept, or permit the deduction of, the amount determined by the Architect or by arbitration. The terms of Article 38, entitled "Arbitration," shall in all ways control any arbitration held under this paragraph, save that each contractor shall name an arbitrator or that they may agree on a single arbitrator, the Owner in either case naming none.

Article 31. The Contractor shall save harmless and indemnify the Owner from every claim or demand which may be made by reason of—

1. Any injury to person or property sustained by the Contractor or by any person, firm or corporation employed directly or indirectly by him upon or in connection with his work, however caused, except as provided by Article 29.

2. Any injury to person or property sustained by any person, firm or corporation, caused by any act, neglect, default or omission of the Contractor or of any person, firm or corporation directly or indirectly employed by him upon or in con-

nection with his work, whether the said injury or damage occur upon or adjacent to the work.

And the Contractor at his own cost, expense and risk shall defend any and all actions, suits or other legal proceeding that may be brought or instituted against the Owner on any such claim or demand, and pay or satisfy any judgment that may be rendered against the Owner in any such action, suit or legal proceeding or result thereof.

Article 32. Should the Contractor by his own fault or negligence delay the completion of the work, thereby necessitating unusual or protracted services or expenses on the part of the Architect or the clerk of the works, the Owner shall be entitled to retain from the amount otherwise to become due to the Contractor, an amount sufficient to reimburse them for such protracted or unusual services or expenses. (Subject to arbitration.)

Article 33. Should the Contractor become insolvent, or at any time, except in case of a general strike, refuse or fail to supply a sufficiency of properly skilled workmen or of materials of the proper quality, or fail in the performance of any of his obligations under the Contract, such refusal or failure being certified by the Architect to both Owner and Contractor as sufficient ground for such action, the Owner shall be at liberty, without prejudice to any other right or remedy he may have, to provide, after giving the Contractor three days' written notice, any such labor or materials, and to deduct the cost thereof from any money then due or thereafter to become due to the Contractor under the Contract.

Article 34. If the Architect shall certify to both Owner and Contractor that such refusal or failure is sufficient ground for such action, the Owner shall also be at liberty, without prejudice to any other right or remedy he may have, after giving the Contractor three days' notice, to terminate the employment of the Contractor for said work, and for the purpose of completing the work, to enter upon the premises and take possession thereof, and of all materials, tools and appliances thereon, and to employ any other person or persons to finish the work, and to provide the materials therefor. In case of such discontinuance of the employmnt of the Contractor, he shall not be entitled to receive any further payment until the said work shall be wholly finished, at which time, if the unpaid balance of the amount to be paid shall exceed the expenses incurred by the Owner in finishing the work, including proper compensation to the Architect for his additional service in connection therewith, such excess shall be paid by the Owner to the Contractor. But if such expense shall exceed such unpaid balance, the Contractor shall pay the difference to the Owner. The expense incurred by the Owner as herein provided, either for furnishing materials or for finishing the work, and any damage incurred through such default, shall be audited and certified by the Architect.

Article 35. Should the Owner fail to pay to the Contractor any sum named in a certificate of the Architect as due from the Owner to the Contractor within ten days of its presentation to the Owner in person or at his last known address, the Contractor may give him written notice of such failure, and should he within a further period of five days fail to pay the said sum, or if the work should be stopped under an order of any Court of Law for a period of three months through no action or fault of the Contractor or of any one directly or indirectly employed or instigated by him, then the Contractor shall be at liberty to terminate this Contract by notice in writing given to the Owner and the Architect and to recover from the Owner payment for all work executed, and for any loss he may have sustained upon any plant or material supplied or purchased for the purpose of this Contract and for reasonable profit and damages.

Should the Owner fail to pay the sum named in any certificate of the Architect within ten days of its presentation to him or at his last known address, the Contractor shall receive, in addition to the sum named in the certificate, interest thereon at the rate of five per cent per annum until the payment of such certificate.

Article 36. The Contractor shall under no circumstances assigns this Contract without the written permission of the Owner.

Article 37. The Owner reserves the right to let contracts other than this one in connection with this work.

Article 38. In any case in which an appeal to arbitration is permitted under this Contract, the Owner or Contractor may demand arbitration by filing with the Architect, within ten days of the receipt of the decision from which he appeals, a written notice of such demand, sending at the same time a copy thereof to the other party to the Contract. In case no such notice be filed within ten days, both parties shall lose the right of appeal and the decision of the Architect shall stand as final. In case such notice be filed three disinterested arbitrators shall be chosen, one by the Owner, one by the Contractor and the third by these two arbitrators, and the difference or dispute shall be submitted to them for arbitration. Should the party filing notice fail to choose an arbitrator within ten days of filing such notice, his right to arbitration shall lapse, and the decision of the Architect shall stand as final. Should the other party fail to choose an arbitrator within ten days of the filing of the notice, then the Architect shall appoint an arbitrator who, with the other arbitrator, shall choose a third. Should either party refuse or neglect to supply the arbitrators with any papers or information considered necessary by them and demanded in writing, the arbitrators are empowered by both parties to take ex parte proceedings.

The arbitrators shall act with promptness. The decision of any two of them shall be binding on both parties hereto. The decision of the arbitrators upon any question subject to arbitration under the terms of this Contract shall be a condition precedent to any right of legal action by either Owner or Contractor.

The arbitrators, if they deem that the case demands it, are authorized to award to the party whose contention is sustained such sums as they shall deem proper for the time, expense and trouble incident to the appeal, and this sum may be named in cases where the claim is set aside in whole, or as an addition to or deduction from the amount of the principal award. The arbitrators shall assess the costs and charges of the arbitration upon either or both parties, in such proportion as the arbitrators shall deem just.

In lieu of the three arbitrators hereinbefore provided for, the parties may by mutual agreement name a single arbitrator, and in such case the provisions of this Article shall otherwise apply.

The Architect

Article 39. Save only in cases in which an appeal to arbitration is permitted by these General Conditions, the final decision of all questions arising under this Contract shall be made and given by the Architect, and both the Owner and the Contractor shall be bound thereby, and such decision shall be a condition precedent to any right of legal action by either Owner or Contractor.

Article 40. The parties to the Contract recognize the Architect as the interpreter of the Contract Documents, and in that capacity he is to define their true intent and meaning. He is not the agent of the Owner except in structural emergencies (Article 41) and except when in special instances he is authorized by the Owner so to act.

Article 41. The Architect has authority to stop the progress of the work whenever, in his opinion, such stoppage may be necessary to insure the proper execution of the Contract. In an emergency affecting the safety of life or of the structure or of adjoining property, he is hereby empowered to act as the Owner's agent, and, if he so elect, to make such changes or to order such work, extra to the Contract or otherwise, as may in his opinion be advisable.

Article 42. In case of the termination of the employment of the Architect or his successors, the Owner shall appoint a capable and reputable Architect, whose duties and authority under the Contract shall be those of the former Architect.

The Contractor

Article 43. The Contractor, if required, shall prepare, in consultation with the Architect, a schedule fixing dates for the beginning of manufacture and installation of materials and for the completion of the various parts of the work.

Article 44. The Contractor, unless otherwise expressly provided, shall furnish and install all material and shall furnish all labor, water, apparatus, light and power necessary for the complete, prompt and satisfactory execution of the work and for properly connecting and co-ordinating his work with that of other contractors.

Article 45. The Contractor shall confine the storage of materials and operations of his workmen to the limits indicated by law, ordinances, permits or by the Architect, and shall not unnecessarily encumber the premises with his materials.

Article 46. The Contractor shall submit in writing the names and references of all proposed sub-contractors to the Architect who shall have the right to reject such as he deems unsatisfactory, and the Contractor shall not sublet any portion of the work without the written permission of the Architect. Such permission shall not, however, relieve the Contractor from responsibility for the conduct and work of his sub-contractors.

Article 47. The Contractors in subletting any part of the work shall make contracts by which his sub-contractors shall be bound by the terms of these Contract Documents as far as applicable to the work sublet. He shall properly direct and control his sub-contractors being responsible for the correlation of his own work and that of his sub-contractors. Should the Contract Documents assign certain responsibilities to sub-contractors the Contractor is not thereby relieved of such or of any responsibilities for the entire work or any part thereof. The Contractor shall promptly transmit to his sub-contractors all Drawings and Specifications bearing on their work.

Article 48. The Contractor shall afford other contractors employed by the Owner every reasonable facility for the storage and introduction of their materials and for erection of their work.

Article 49. The Contractor shall keep a competent general foreman and any necessary assistants, satisfactory to the Architect, in charge during the progress of the work. The general foreman shall not be changed except with the consent or at the instance of the Architect. The foreman shall represent the Contractor in his absence, and all directions as to the conduct of the work given to him shall be as binding as if given to the Contractor, provided that on request such directions be given in writing.

Article 50. The Contractor shall not do any work without proper drawings or instructions, and shall, at his own expense, replace any work wrongly executed, whether from lack of such drawings or instructions or otherwise.

Article 51. The Contractor, as a part of his services, shall give personal supervision to the work, and he shall carefully study and compare all Drawings, Specifications and other information given to him by the Architect, as to figures, materials and methods of construction, using therein the skill and experience for which he receives compensation under this Contract, and shall immediately report to the Architect for rectification any error, inconsistency or omission therein which he shall discover.

Article 52. The Contractor shall measure work already in place, to insure the proper execution of his subsequent work, or for the information of the Architect; and should any discrepancy between the executed work and the drawings be discovered, he shall report it at once to the Architect.

Article 53. The Contractor shall, at his own expense, obtain for the Owner all necessary permits and licenses, except permanent easements, give all necessary notices, pay all fees required by law, and comply with all laws, ordinances, rules and regulations relating to the work, and to the preservation of the public health and safety. If the Drawings and Specifications are at variance therewith, he shall so notify the Architect in writing, stating the effect of such compliance upon the contract price.

Article 54. The Contractor shall furnish, within a reasonable time, whenever required, and in the manner directed, reports showing the progress and status of the work at the building and in the shops.

Article 55. The Contractor shall, when required, produce satisfactory evidence to show the kind and quality of materials used, and furnish duplicate labeled samples of materials and workmanship, with sufficient information, for the Architect's approval, and the materials furnished shall have the same character, finish, color and texture as the approved samples, and the workmanship shall be equal to that of the samples.

Article 56. The Contractor shall pay all royalties and license fees, and shall save the Owner harmless from loss or annoyance on account of suits or claims of any kind for violation or infringement of any letters patent or patent rights by the Contractor or any one directly or indirectly employed by him or by reason of the use by him or them of an art, machine, manufacture or composition of matter on the works in violation or infringement of such letters or rights.

Article 57. The Contractor shall not allow waste material or rubbish caused by his employes to accumulate in or about the premises, but shall promptly remove the same and at the completion of the work he shall thoroughly remove all his rubbish from and about the building, and all tools, scaffolding and surplus materials, and shall leave his work thoroughly cleaned and ready for use. In case of dispute the Owner will remove the rubbish and charge the cost of work to the contractors pro rata.

Article 58. The Contractor shall promulgate and enforce rules to prevent, and it shall be his duty to prevent:

1. The lighting of open fires upon the premises, in or dangerously near the building.
2. Smoking within the building after the roof is on.
3. The erection on or about the premises of any sign, billboard or other advertisement by the Contractor or his subcontractors, except by written permission of the Architect.
4. The loading of any part of the structure with a weight greater than it is calculated to bear.

Article 59. The Contractor shall cover and protect his materials and work from damage by the elements, or from any other cause, in a manner satisfactory to the Architect and shall efficiently maintain such covering and protection.

Article 60. The Contractor shall, at his own expense, make good, to the Architect's satisfaction, any damage to his work from the action of the elements, or any other cause, except such damages as are contemplated in Article 19.

Article 61. The Contractor shall do all cutting, fitting or patching of his work that may be required to make its several parts come together properly and fit it to receive or be received by work of other contractors, shown upon, or reasonably implied by, the Drawings and Specifications for the completed structure, and he shall make good after them, as the Architect may direct. But the Contractor shall not endanger the stability of the structure or any part thereof by cutting or digging or otherwise, and shall not in any way cut or alter the work of any other contractor, save with the consent and under the direction of the Architect.

Article 62. The Contractor shall maintain such insurance as will adequately protect him and the Owner from claims for damages for personal injuries, arising directly or indirectly from operations under this Contract, and he shall be liable to the Owner for failure to maintain such insurance, and shall, if required by the Owner, submit the policies to him for approval.

Article 63. If any part of the Contractor's work is dependent for its proper execution or for its subsequent efficacy or appearance on the character or condition of associated or contiguous work not executed by him, the Contractor shall examine such associated or contiguous work and shall report to the Architect in writing any imperfection therein or any conditions that render it unsuitable for the reception of his work. In case the Contractor proceeds without making such written report, he shall be held to have accepted such other work and the existing conditions and shall be responsible for any defects in his own work consequent thereof, and shall not be relieved of the obligation of any guarantee because of any such imperfection or condition.

APPENDIX TO THE GENERAL CONDITIONS OF THE CONTRACT

In many cases the sixty-three Articles printed will not include all necessary General Conditions of the Contract. The Architect will then add to them such others as he deems wise.

Many architects include in their General Conditions one or more of the subjects named below. It would seem that many of these should appear in the specifications for the various trades, and that others, though suited for inclusion in the General Conditions, are not invariably needed. These subjects are:

Watchmen, Heating during Construction, Protection and Care of Trees and Shrubs, Protective Coverings in general, Vault Permit, Sidewalks, Fences, Ladders, Temporary Stairways, Scaffolding, Sheds, Sanitary Conveniences, Offices and their Furniture, Telephone, Temporary Wiring and Electric Lights, Lanterns, Temporary Enclosures from Weather, Keeping Building and Cellar free from Water, Chases, Photographs, Checking by Surveyor and his Certificate, Contractor to Work Overtime if Required, Time of Completion of the Essence of the Contract, Earthquake Insurance, Owner to furnish Survey, Contractors to Lay Out the Work, Giving Lines and Levels, Owner's Contingent Policy of Accident Insurance, Bracing Building during Construction, Damage to Adjoining Property by Movement or Settlement, Stoppage of Work in Freezing Weather, etc.

Liens

Owing to the diversity of the lien laws in the several States, it is impracticable to draft an article suited for use in all, but it is thought that Article 24 is of very general applicability. In certain States it is necessary as a bar to liens, that the Agreement, or at least the lien clauses of the Contract, be publicly filed or recorded.

Fire Insurance

The scheme for effecting and settling insurance, described in the following paragraph, has had much consideration. As it has not been tried in practice it is thought wiser to include in the body of the General Conditions the shorter form, but the following is presented for the consideration of members, as possibly preferable under certain conditions, and as having the approval of the representatives of the National Board of Fire Underwriters. The "Trustee" hereinafter mentioned may, of course, be agreed upon at the time of the signing of the Contract, or subsequently named by the Architect.

The Owner shall maintain fire insurance upon the building in all stages of construction, and upon all materials in or about the premises, not including Contractor's tools and appliances, to the full amount of the Architect's estimate of the value of the building, so far as completed, and of such materials. The policies shall be taken out in the name of the Owner "for account of whom it may concern, upon their joint and several interests in" the building and materials described. The loss, if any, shall be made adjustable with the Owner, and payable to a Trustee to be named by the Architect. Within ten days after the occurrence of any loss covered by the policies, the Contractor shall deliver to the Owner a complete schedule of (1) labor and materials necessary for rebuilding, restoring and replacing the work or the materials destroyed or damaged, and (2) their true value, together with a sworn statement that such schedule and valuation are full and correct. All moneys paid for losses under the policies shall be held by the Trustee aforesaid for distribution to the Owner, the Contractor and all other persons having insurable interests in building or in materials upon the premises, as their interests may be determined. The Trustee shall disburse the insurance moneys in accordance with the agreement reached by the Owner, the Contractor and other persons having insurable interests under this policy, or as determined by arbitration; but he shall make payments to contractors only upon the Architect's certificates of reinstallation of the work. If the Owner, the Contractor and the other persons interested in the insurance should fail to agree upon a distribution, the matter shall be referred to arbitration, as provided in Article 38 of the General Conditions, the Owner appointing one arbitrator, the Contractor and the other persons having insurable interests appointing a second arbitrator, and these two appointing a third. The Contractor agrees that if the Owner maintains insurance as above provided, he will not make upon the Owner any claim for loss through fire beyond the Contractor's interest under the policies of insurance maintained by the Owner under this Article. In case of fire the Contractor shall not be released or relieved in any way from the obligation to complete the work under contract, notwithstanding the cost of so doing may exceed the contract price, or the amount recovered as his share of the insurance; and the Contractor shall proceed with the work forthwith, and without awaiting a decision as to the distribution of insurance money, and shall make good all his work or materials destroyed or damaged. All fire insurance policies upon the building or upon materials upon the premises shall be kept in the custody of the Architect and shall be open to inspection by the Owner, the Contractor and others having insurable interests. Upon the request of any person having an insurable interest under such policies, the Architect shall deliver to such person a certificate setting forth briefly the terms and the amounts of the policies, and the facts so far as they are within the personal knowledge of the Architect, upon which such person claims an insurable interest.

If the Owner fails to maintain insurance as provided in this Article, the Contractor may terminate the Contract; but the Contractor may terminate the Contract, under this provision, only at a time when building and materials are not insured as provided in this Article. If the Contractor or any sub-contractor takes out fire insurance upon his interest in the building or in materials upon the premises, he shall not have, while such insurance is in force, any right to participate under any policy taken out by the Owner.

A Suggested Clause Relative to Payments

When the system of monthly payments is adopted, the following form may be used in filing the blank in Article 4 of the Agreement. "On or about the .... day of each month, ... per cent of the value, proportionate to the amount of the Contract, of labor and materials wrought into the building up to the first day of that month, as estimated by the Architect, less the aggregate of previous payments. On the satisfactory completion of the entire work, a sum sufficient to increase the total payments to .... per cent of the value of the work, and .... days thereafter the balance due under the Contract."

STANDARD FORM OF AGREEMENT OF THE AMERICAN INSTITUTE OF ARCHITECTS

This form is to be used only with the Standard General Conditions of the Contract. In it Owner, Contractor and Architect are treated as of the singular number and masculine gender.

This Agreement made the .... day of ....
in the year Nineteen Hundred and ....
by and between ....
hereinafter called the Contractor and ....
.... hereinafter called the Owner

Witnesseth, that the Contractor and the Owner for the considerations herein named agree as follows:

Article 1. The Contractor agrees to provide all the materials and to perform all the work shown on the Drawings and described in the Specifications entitled (Here insert the caption descriptive of the work as used in the Proposal, Specifications, General Conditions and upon the Drawings.)

....

....

prepared by ....

.... acting as, and in these Contract Documents entitled the Architect, and to do to the satisfaction of the Architect everything required by the Drawings, Specifications and General Conditions.

Article 2. The Contractor agrees to complete the work by and at the following time or times, to wit:

....

....

and to pay or allow the Owner as liquidated damages, the sum of .... ($............) for each day thereafter, Sundays and legal holidays not included, that the work remains uncompleted.

Article 3. The Owner agrees to pay the Contractor in current funds for the performance of the Contract .... ($............) subject to additions and deductions as provided in the General Conditions of the Contract.

Article 4. The Owner agrees to make payments on account of this Contract on the certificate of the Architect, as follows:

....

....

In no case, however, shall the Contractor be entitled to a payment which, in the judgment of the Architect, will leave the balance withheld insufficient to complete the work.

Article 5. The Contractor and the Owner agree that the Drawings with all notes now thereon, the Specifications and the General Conditions of the Contract are, together with this Agreement, the Documents forming the Contract, and that the said Drawings, Specifications and General Conditions are as fully a part of the Contract as if hereto attached or herein repeated; and that should the Contractor and the Owner fail to sign them the identification of them by the Architect shall be binding on both parties.

....

....

....

The Contractor and the Owner for themselves, their successors, executors, administrators and assigns, hereby agree that they will in all ways be bound by the Documents forming the Contract, and that they will abide by and will promptly and fully carry out all decisions given thereunder, and that they will fully perform all of the convenants and agreements therein contained, in witness whereof they have hereunto set their hands and seals, the day and year first above written.

In Presence of

....

....

......................(Seal)

....

....

......................(Seal)

(This Agreement is not intended to diminish the use of the Uniform Contract, the publication of which is continued by the American Institute of Architects and the National Association of Builders. This Agreement is issued in two styles, identical in wording: One, Style A, is intended for carbon duplication, the other, Style B, is intended for reproduction by blue-printing. This is Style A.)

STANDARD FORM OF BOND OF THE AMERICAN INSTITUTE OF ARCHITECTS

Know all Men by these Presents: That we (Here insert the name and address of the Contractor.)

....

.... hereinafter called the Principal, and

....

.... and

....

.... and

....

hereinafter called the Surety or Sureties are held and firmly bound unto

....

hereinafter called the Owner, in the sum of ....

.... ($............)

for the payment whereof the Principal and the Surety or Sureties bind themselves, their heirs, executors, administrators, successors and assigns, jointly and severally, firmly, by these presents.

Whereas, the Principal has, by means of a written Agreement, dated ....

entered into a contract with the Owner for

....

a copy of which Agreement is hereto annexed;

Now, Therefore, the Condition of this Obligation is such that if the Principal shall faithfully perform the Contract on his part, and satisfy all claims and demands incurred for the same, and fully indemnify and save harmless the Owner from all cost and damage which he may suffer by reason of failure so to do, and shall fully reimburse and repay the Owner all outlay and expense which the Owner may incur in making good any such default, then this obligation shall be null and void; otherwise it shall remain in full force and effect.

Provided, however, that no suit, action or proceding by reason of any default shall be brought on this Bond after .... months from the day on which the final payment under the Contract is made; and that service of writ or process commencing any such suit, action or proceeding shall not be made after such date.

And Provided, that any alterations which may be made in the terms of the Contract, or in the work to be done under it, or the giving by the Owner of any extension of time for the performance of the Contract, or any other forbearance on the part of either the Owner or the Principal to the other shall not in any way release the Principal and the Surety or Sureties, or either or any of them, their heirs, executors, administrators, successors or assigns from their liability hereunder, notice to the Surety or Sureties of any such alteration extension or forbearance being hereby waived.

Signed and Sealed this .... day of ....
19...

In Presence of

....	....................(Seal)
....	....
....	....................(Seal)
....	....
....	....................(Seal)
....	....
....	....................(Seal)

THE UNIFORM CONTRACT

Form of Contract Adopted and Recommended for General Use by the American Institute of Architects and the National Association of Builders.

This Agreement, made the ....day of .... in the year one thousand nine hundred and .... by and between ....
.... party of

the first part (hereinafter designated the Contractor), and .... party of the second part (hereinafter designated the Owner), **Witnesseth** that the Contractor , in consideration of the agreements herein made by the Owner , agree with the said Owner as follows:

Article I. The Contractor shall and will provide all the materials and perform all the work for the ....

....

.... as shown on the drawings and described in the specifications prepared by

....

Architect, which drawings and specifications are identified by the signatures of the parties hereto, and become hereby a part of this contract.

Art. II. It is understood and agreed by and between the parties hereto that the work included in this contract is to be done under the direction of the said Architect, and that his decision as to the true construction and meaning of the drawings and specifications shall be final. It is also understood and agreed by and between the parties hereto that such additional drawings and explanations as may be necessary to detail and illustrate the work to be done are to be furnished by said Architect, and they agree to conform to and abide by the same so far as they may be consistent with the purpose and intent of the original drawings and specifications referred to in Art. I.

It is further understood and agreed by the parties hereto that any and all drawings and specifications prepared for the purposes of this contract by the said Architect are and remain his property, and that all charges for the use of the same, and for the services of said Architect, are to be paid by the said Owner.

Art III. No alterations shall be made in the work except upon written order of the Architect; the amount to be paid by the Owner or allowed by the Contractor by virtue of such alterations to be stated in said order. Should the Owner and the Contractor not agree as to amount to be paid or allowed, the work shall go on under the order required above, and in case of failure to agree, the determination of said amount shall be referred to arbitration, as provided for in Art XII of this contract.

Art IV. The Contractor shall provide sufficient, safe and proper facilities at all times for the inspection of the work by the Architect or his authorized representatives;

shall, within twenty-four hours after receiving written notice from the Architect to that effect, proceed to remove from the grounds or buildings all materials condemned by him, whether worked or unworked, and to take down all portions of the work which the Architect shall by like written notice condemn as unsound or improper, or as in any way failing to conform to the drawings and specifications, and shall make good all work damaged or destroyed thereby.

Art. V. Should the Contractor at any time refuse or neglect to supply a sufficiency of properly skilled workmen, or of materials of the proper quality, or fail in any respect to prosecute the work with promptness and diligence, or fail in the performance of any of the agreements herein contained, such refusal, neglect or failure being certified by the Architect, the Owner shall be at liberty, after three days' written notice to the Contractor , to provide any such labor or materials, and to deduct the cost thereof from any money then due or thereafter to become due to the Contractor under this contract; and if the Architect shall certify that such refusal, neglect or failure is sufficient ground for such action, the Owner shall also be at liberty to terminate the employment of the Contractor for the said work and to enter upon the premises and take possession, for the purpose of completing the work included under this contract, of all materials, tools and appliances thereon, and to employ any other person or persons to finish the work, and to provide the materials therefor; and in case of such discontinuance of the employment of the Contractor .... shall not be entitled to receive any further payment under this contract until the said work shall be wholly finished, at which time, if the unpaid balance of the amount to be paid under this contract shall exceed the expense incurred by the Owner in finishing the work, such excess shall be paid by the Owner to the Contractor ; but if such expense shall exceed such unpaid balance, the Contractor shall pay the difference to the Owner . The expense incurred by the Owner as herein provided, either for furnishing materials or for finishing the work, and any damage incurred through such default, shall be audited and certified by the Architect, whose certificate thereof shall be conclusive upon the parties.

Art. VI. The Contractor shall complete the several portions, and the whole of the work comprehended in this Agreement by and at the time or times hereinafter stated, to wit:

....

....

Art. VII. Should the Contractor be delayed in the prosecution or completion of the work by the act, neglect or default of the Owner , of the Architect , or of any other contractor employed by the Owner upon the work, or by any damage caused by fire or other casualty for which the Contractor .... not responsible, or by combined action of workmen in no wise caused by or resulting from default or collusion on the part of the Contractor , then the time herein fixed for the completion of the work shall be extended for a period equivalent to the time lost by reason of any or all the causes aforesaid, which extended period shall be determined and fixed by the Architect ; but no such allowance shall be made unless a claim therefor is presented in writing to the Architect within forty-eight hours of the occurrence of such delay.

Art. VIII. The Owner agree to provide all labor and materials essential to the conduct of this work not included in this contract in such manner as not to delay its progress, and in the event of failure so to do, thereby causing loss to the Contractor , agree that .... will reimburse the Contractor for such loss; and the Contractor agree that if .... shall delay the progress of the work so as to cause loss for which the Owner shall become liable, then .... shall reimburse the Owner for such loss. Should the Owner and the Contractor fail to agree as to the amount of loss comprehended in this Article, the determination of the amount shall be referred to arbitration as provided in Art. XII of this contract.

Art. IX. It is hereby mutually agreed between the parties hereto that the sum to be paid by the Owner to the Contractor for said work and materials shall be ....

....

subject to additions and deductions as hereinbefore provided, and that such sum shall be paid by the Owner to the Contractor , in current funds, and only upon certificates of the Architect, as follows:

....

....

The final payment shall be made within .... days after the completion of the work included in this contract, and all payments shall be due when certificates for the same are issued.

If at any time there shall be evidence of any lien or claim for which, if established, the Owner of the said premises might become liable, and which is chargeable to the Contractor , the Owner shall have the right to retain out of any payment then due or thereafter to become due an amount sufficient to completely indemnify .... against such lien or claim. Should there prove to be any such claim after all payments are made, the Contractor shall refund to the Owner all moneys that the latter may be compelled to pay in discharging any lien on said premises made obligatory in consequence of the Contractor default.

Art. X. It is further mutually agreed between the parties hereto that no certificate given or payment made under this contract, except the final certificate or final payment, shall be conclusive evidence of the performance of this contract, either wholly or in part, and that no payment shall be construed to be an acceptance of defective work or improper materials.

Art. XI. The Owner shall during the progress of the work maintain insurance on the same against loss or damage by fire, ... the policies to cover all work incorporated in the building, and all materials for the same in or about the premises, and to be made payable to the parties hereto, as their interest may appear.

Art. XII. In case the Owner and Contractor fail to agree in relation to matters of payment, allowance or loss referred to in Arts. III or VIII of this contract, or should either of them dissent from the decision of the Architect referred to in Art. VII of this contract, which dissent shall have been filed in writing with the Architect within ten days of the announcement of such decision, then the matter shall be referred to a Board of Arbitration to consist of one person selected by the Owner , and one person selected by the Contractor , these two to select a third. The decision of any two of this Board shall be final and binding on both parties hereto. Each party hereto shall pay one-half of the expense of such reference.

....

....

The said parties for themselves, their heirs, successors, executors, administrators and assigns, do hereby agree to the full performance of the covenants herein contained.

In Witness Whereof, the parties to these presents have hereunto set their hands and seals, the day and year first above written.

In Presence of (Space for signatures)

BUILDERS' UNIFORM SUB-CONTRACT

A Form of Contract between Builders, Based upon the Requirements of the Uniform Contract Approved by the American Institute of Architects and the National Association of Builders.

This Agreement, made the .... day of .... in the year one thousand nine hundred and .... by and between .... party of the first part (hereinafter designated the Sub-Contractor *), and .... party of the second part (hereinafter designated the Contractor *), **Witnesseth** that the Sub-Contractor , in consideration of the agreements herein made by the Contractor , agree with the said Contractor as follows:

Article I. The Sub-Contractor shall and will provide all the materials and perform all the work for the .... as shown on the drawings and described in the specifications prepared by .... Architect for said building.

Art. II. It is understood and agreed by and between the parties hereto that the work included in this contract is to be done under the direction of the said Architect , and that .... decision as to the true construction and meaning of the drawings and specifications shall be final. It is also understood and agreed by and between the parties hereto that such additional drawings and explanations as may be necessary to detail and illustrate the work to be done are to be furnished by said Architect , and they agree to conform to and abide by the same so far as they may be consistent with the purpose and intent of the original drawings and specifications referred to in Art. I.

....

....

Art III. No alterations shall be made in the work except upon written order of the Contractor ; the amount to be paid by the Contractor or allowed by the Sub-Contractor

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*A Partnership Firm, Company, or Corporation can avoid writing the "S" throughout the entire contract, by NOT adding it here.

by virtue of such alterations to be stated in said order Should the Contractor and Sub-Contractor not agree as to amount to be paid or allowed, the work shall go one under the order required above, and in case of failure to agree, the determination of said amount shall be referred to arbitration, as provided for in Art. XII of this contract.

Art. IV. The Sub-Contractor shall provide sufficient, safe and proper facilities at all times for the inspection of the work by the Contractor , the Architect or their authorized representatives; shall, within twenty-four hours after receiving written notice from the Contractor to that effect, proceed to take down all portions of the work, and remove from the grounds or buildings all material, whether worked or unworked, which the Architect shall condemn as unsound or improper, or as in any way failing to conform to the drawings and specifications, and shall make good all work damaged or destroyed thereby.

Art. V. Should the Sub-Contractor at any time refuse or neglect to supply a sufficiency of properly skilled workmen, or of materials of the proper quality, or fail in any respect to prosecute the work with promptness and diligence, or fail in the performance of any of the agreements herein contained, the Contractor , with the approval of the Architect , shall be at liberty, after .... days' written notice to the Sub-Contractor , to provide any such labor or materials, and to deduct the cost thereof from any money then due or thereafter to become due to the Sub-Contractor under this contract; and if such refusal, neglect or failure is sufficient ground for such action, the Contractor shall also be at liberty to terminate the employment of the Sub-Contractor for the said work and to enter upon the premises and take possession, for the purpose of completing the work included under this contract, of all materials, tools and appliances thereon, and to employ any other person or persons to finish the work, and to provide the materials therefor; and in case of such discontinuance of the employment of the Sub-Contractor .... shall not be entitled to receive any further payment under this contract until the said work shall be wholly finished, at which time, if the unpaid balance of the amount to be paid under this contract shall exceed the expense incurred by the Contractor in finishing the work, such excess shall be paid by the Contractor to the Sub-Contractor ; but if such expense shall exceed such unpaid balance, the Sub-Contractor shall pay the difference to the Contractor . The expense incurred by the Contractor as herein provided, either for furnishing materials or finishing the work, and any damage incurred through such default, shall be chargeable to the Sub-Contractor .

Art. VI. The Sub-Contractor shall complete the several portions, and the whole of the work comprehended in this Agreement by and at the time or times hereinafter stated, to wit:

....

....

Art. VII. Should the Sub-Contractor be delayed in the prosecution or completion of the work by the act, neglect or default of the Owner , of the Architect , of the Contractor , or of any person employed by the Contractor upon the work, or by any damage caused by fire or other casualty for which the Sub-Contractor .... not responsible, or by combined action of the workmen, in no wise caused by or resulting from default or collusion on the part of the Sub-Contractor , then the time herein fixed for the completion of the work shall be extended for a period equivalent to the time lost by reason of any or all causes aforesaid; but no such allowance shall be made unless a claim therefor is presented in writing to the Contractor within forty-eight hours of the occurrence of such delay.

Art. VIII. The Contractor agree to provide all labor and materials essential to the conduct of this work not included in this contract in such manner as not to delay its progress, and in the event of failure so to do, thereby causing loss to the Sub-Contractor , agree that .... will reimburse the Sub-Contractor for such loss; and the Sub-Contractor , agree that if .... shall delay the progress of the work so as to cause loss for which the Contractor shall become liable, then .... shall reimburse the Contractor for such loss. Should the Contractor and Sub-Contractor fail to agree as to amount of loss comprehended in this Article, the determination of the amount shall be referred to arbitration as provided in Art. XII of this contract.

Art. IX. It is hereby mutually agreed between the parties hereto that the sum to be paid by the Contractor to the Sub-Contractor for said work and materials shall be ......

....

....

subject to additions and deductions as hereinbefore provided, and that such sum shall be paid by the Contractor to the Sub-Contractor in current funds, as follows:

....

....

The final payment shall be made within .... days after the completion of the work included in this contract.

Art. X. It is further mutually agreed between the parties hereto that no payment made under this contract, except the final payment, shall be conclusive evidence of the performance of this contract, either wholly or in part, and that no payment shall be construed to be an acceptance of defective work or improper materials.

Art. XI. The Contractor shall during the progress of the work maintain insurance on the same against loss or damage by fire, ... the policies to cover all work incorporated in the building, and all materials for the same in or about the premises, and to be made payable to the parties hereto, as their interest may appear.

The Sub-Contractor agree to indemnify the Contractor against all claims or demands for damage arising from accidents to persons or property occasioned by the said Sub-Contractor or .... employes, and the Contractor agree to indemnify the Sub-Contractor against all claims or demands for damage arising from accidents to persons or property occasioned by the said Contractor or .... employes, during the performance of this contract.

Art. XII. In case the Contractor and Sub-Contractor fail to agree in relation to matters of payment, allowance or loss referred to in Arts. III or VIII of this contract, or fail to agree under the stipulations in Art. VII of this contract, then the matter shall be referred to a Board of Arbitration to consist of one person selected by the Contractor , and one person selected by the Sub-Contractor , these two to select a third. The decision of any two of this Board shall be final and binding on both parties hereto. Each party hereto shall hereto pay one-half of the expense of such reference.

....

The said parties for themselves, their heirs, successors, executors, administrators and assigns, do hereby agree to the full performance of the covenants herein contained.

In Witness Whereof, the parties to these presents have hereunto set their hands and seals, the day and year first above written.

In Presence of

(Space for signatures)

FORM OF CONTRACT FOR BUILDING

(Eugene Dietzgen Co., Chicago, Ill.)

This Agreement, Made and entered into this .... day of .... A. D. Nineteen Hundred and .... by and between .... Contractor , part of the first part, and .... Owner , part of the second part:

Witnesseth, That the said part of the first part, for and in consideration of the payments to be made to .... by the said part of the second part as hereinafter provided, do hereby covenant, contract and agree to .... agreeable to the plans, drawings and specifications made by .... Architect , in a good, substantial and workmanlike manner, to the satisfaction of and under the direction of the Superitnendent. And said part of the first part also do agree to find, provide and furnish such Materials of such kinds, qualities and descriptions as shall be fit, proper and sufficient for completing and finishing all the work or works mentioned ....

Time to be extended only in case of general strike .... And said part of the second part, for and in consideration of said part of the first part strictly performing the covenants and agreements as above specified, by and at the times mentioned, and to the entire satisfaction of .... Superintendent , do hereby agree to pay to the said part of the first part the sum of .... Dollars, on certificates of Superintendent , as the work progresses, to-wit: .... per cent of the estimated value of same .... and the remaining amount within .... days after faithful completion and acceptance of all the work.

It is Agreed by said parties, that the .... per cent agreed to be reserved shall be held by the proprietor as security for the faithful completion of the work, and may be applied under the direction of the Superintendent , in the liquidation of any damages under this contract; also furnishing, whenever requested, to the part of the second part, a release from any liens or right of lien.

It is further agreed that the specifications and drawings form a part of this agreement, and are intended to co-operate, so that any works exhibited in the drawings and not mentioned in the specifications, or vice versa, are to be executed the same as if they were mentioned in the specifications and set forth in the drawings, to the true intent and meaning of said drawings and specifications, without any extra charge whatsoever.

It is also further agreed that the said part of the second part may make any alterations, deviations, additions, or omissions from the aforesaid plans, drawings, and specifications, or either of them, which .... shall deem proper, and the said Architect shall advise, without affecting or making void this Contract, and in all such cases the said Architect shall value or appraise such alteration, and add to or deduct from the amount herein agreed to be paid to the said part of the first part the excess or deficiency occasioned by such alteration.

It is further agreed that in case any difference of opinion shall arise between said parties in relation to the contract, the work to be performed under it, or in relation to the plans, drawings and specifications hereunto altered, the decision of .... the Architect , shall be final and binding on all parties hereunder, or, if preferred, the decision of an umpire selected by two men, one of whom is appointed by the owner and the other one by the contractor, shall be final and binding on all parties hereunder.

It is further agreed that all payments made on work during its progress, on account of the contract, shall in no case be construed as an acceptance of the work executed; but the Contractor shall be liable to all the conditions until the work is accepted as finished, and all the plans, details, elevations and sections of each and every kind are returned to the Architect , before the final certificate is given.

It is further agreed, should the Contractor fail to finish the work at or before the time agreed upon .... shall pay to or allow the proprietor by way of liquidated damages, the sum of .... dollars per diem for each and every day thereafter the said work shall remain incomplete.

It is further agreed that the Contractor, at his own proper cost and charges, is to provide all manner of materials and labor, implements, scaffolding, moulds, models and cartage of every description for the due performance of the several erections.

It is further agreed that the owner shall not in any manner be answerable or accountable for any violation of the city ordinances, or for any loss or damage that shall or may happen to said work or materials, or any part or parts thereof respectively, or for any of the materials and other things used and employed in finishing and completing the same. (Loss or damage by fire excepted.)

In Witness Whereof, The said parties of these presents have hereunto set their hands and seals the .... day and year first above written.

Contractor : Part of the First Part.

..............................**(Seal)**

..............................**(Seal)**

Owner : Part of the Second Part.

..............................**(Seal)**

..............................**(Seal)**

Witness:

....

....

SHORT FORM OF PROPOSAL FOR WORK

The following form of letter—which, when formally accepted, constitutes a contract—may be used as a guide when small jobs or repair work are to be done. One of the regular forms of contract, as already given, should be used for work of any considerable amount or importance.

Chicago, Ill., ... 1913

Mr. ....

No. .... Ave.,

Chicago, Ill.

Dear Sir:

I hereby propose to do work as follows on your property situated at No. .... Ave., Chicago, Ill.: Construct a rear porch according to sketch agreed upon between us and described in detail of construction as follows:

2x6-inch joists spaced 16 inches on centers, placed parallel with the rear wall and frame flush between 6x8-inch girders resting on 12-inch brick piers of a suitable height.

Floor of porch to be covered with ⅞x4-inch quarter-sawed hard pine flooring, matched and blind-nailed, and tightly strained. Edges of floor to be rounded with a cove underneath. Finish under the floor and in front of the piers with wide white pine casings, and fill in the spacing between the piers with diagonal lattice work ¼ by 1⅛ inches, with 1⅛-inch spaces and 1⅛ by 7-inch beveled base.

Posts for porch are to be 4x4-inch straight, well-seasoned yellow pine. Posts to support a 4x8-inch girder.

Rafters to be 2x6 inches, with 2x8-inch hips.

Porch roof to be fastened to rear wall by four ¾-inch bolts, 14 inches long, fitted with 4-inch square washers.

Bottom of rafters to be furred for level ceiling and ceiled with ¾x4-inch center beaded ceiling, with ⅞-inch quarter-round around edges.

Plate to be boxed to form a false beam. Cornice to be finished with 4-inch crown mold, 4-inch fascia, 10-inch plancceer, and 2½x⅞-inch bed mold. Locate gutter back of crown mold. Bottom of gutter to have a fall of 1½ inches to outlet.

Roof and gutter to be covered with tin.

Space between posts to be filled with plain balusters 1⅝ inches square, set 4 inches on centers, and 2 feet 6 inches long. Top and bottom rails to be made of beveled 2-inch by 4-inch white pine stock.

Build steps to porch on 2x10-inch plank carriages, 16 inches on centers, resting at the bottom on a concrete slab. Treads to be 1¼ inches thick, risers 1-inch, rounded noses, returned at the ends with cove underneath.

Strings to be cased with ⅞-inch stock, and filled in to ground with lattice work same as under porch.

All work to be done in a proper and workmanlike manner for the sum of .... dollars, and same to be due and paid in cash when work is complete.

I am to supply all required materials, tools, etc.

Trusting that this will prove satisfactory, and awaiting your further orders, I remain

Yours very truly,

....

ACCEPTANCE

I hereby approve and accept the above proposition, and instruct you to proceed with the work with all possible speed.

Signed ....

Dated ....

BLANK FORMS OF ESTIMATE

In addition to the detailed forms of estimate which have already been shown, the following blank forms of general estimate are given:

Blank Form for Estimate

Estimate for ....

Date ...., 19....

Kind of Structure ....

1. Excavating .... $........
2. Foundations and piers..................................
3. Cement work ....
4. Drains ....
5. Grouting ....
6. Chimneys ....
7. Flue linings ....
8. Cut stone ....
9. Brick ....
10. Lumber ....
11. Roofing ....
12. Mill work ....
13. Cupboards ....
14. Stairs ....
15. Heavy hardware ....
16. Trim hardware ....
17. Tin work ....
18. Galvanized iron work ....
19. Iron work ....
20. Lathing ....
21. Plastering ....
22. Plumbing ....
23. Cesspool or sewer connection..................................
24. Carpenter work ....
25. Cresting ....
26. Electric wiring ....
27. Gas fitting ....
28. Heating plant ....
29. Mantles, tiling, grates..................................
30. Painting ....
31. Glass ....
32. Screens ....
33. Grading ....
34. Incidentals ....

....

Total .... $........

BLANK FORM FOR ITEMIZED ESTIMATE

Following is a blank form for estimating, and checking on estimates, with schedule of items ordinarily entering into house construction:

BUILDING ESTIMATE

Town .... State .... Date .... 19...
Owner's Name. ....
Address...
Contractor. ....
Address...
Size of Building. .... Height of Cellar. ....
Kind of Building. .... " " First Story. ....
Style of Finish. .... " " Second Story. ....
No. of Rooms. .... Outside Studding. ....
No. of Doors. .... Estimated Cost $. ....
No. of Windows. .... Actual Cost $. ....

No.	Names and Kind	Size	Length	Board Feet
	Sills			
	Side sills			
	End sills			
	Middle sills			
	" sills			
	Cross-sills			
	Trimmers			
	Main Posts			
	" "			
	Center posts			
	Door posts			
	Basement posts			
	Girts			
	Main girts			
	Side girts			
	Tie girts			
	Joists			
	First floor			
	Second floor			
	Third floor			
	Ceiling joists			
	Porch joists			

Studding

	Side studding			
	Gable studding			
	Partition studding			
	Braces			
	Plates			
	Porch plates			
	Bay window plates			

Roof Timbers

	Common rafters			
	Hip rafters			
	Valley rafters			
	Jack rafters			
	Trusses			
	Purlin plates			
	Collar beams			

Sheathing

	Outside walls			
	Roof sheathing			
	Gutters			
	Floor lining			
	Shiplap (sometimes used for sheathing)			

Shingles

	Dimension shingles			

Siding

	Beveled siding			
	Cove siding			
	Barn siding			

Battens

	⅞ Ogee battens			
	½-inch battens			

Furring

	1 x 1 inch			
	2 x 2 inch			

Fencing

......	4 inch	......	......	......
	6 inch			

Paper

......	Straw board	......	......	......
	Tarred paper			

7-8 Finish

......	Outside base	......	......	......
......	Bay window finish	......	......	......
......	Porch finish	......	......	......
......	Cornice	......	......	......
......	Brackets	......	......	......
......	Stair risers	......	......	......
......	Jamb casings	......	......	......
......	Pantry shelves	......	......	......
	Closet shelves			

1 1-4 Finish

......	Outside casings	......	......	......
......	Corner boards	......	......	......
......	Jamb casings	......	......	......
......	Porch finish	......	......	......
......	Bay window finish	......	......	......
......	Scroll work	......	......	......
......	Stair steps and stringers	......	......	......
	Outside steps			

2 Inch Finish

......	Door sills	......	......	......
......	Window sills	......	......	......
......	Jamb casings	......	......	......
......	Brackets	......	......	......
......	Cellar stairs	......	......	......

1 3-8 Finish

......	Outside casings	......	......	......
	Outside steps			

1-2 Inch Finish

......	Panels	......	......	......
	Drawer bottoms			

Flooring 7-8 x

......	Main floor	......	......	......
......	Kitchen floor	......	......	......
......	Dining room floor	......	......	......
	Porch floors			

Ceiling 7-8 x

......	Porch ceilings	......	......	......
......	Panels	......	......	......
......	Wainscoting	......	......	......
......	Lining partition	......	......	......
......	Flooring pine	......	......	......
......	Flooring oak	......	......	......
......	Flooring maple	......	......	......
......	⅜ Ceiling	......	......	......
......	⅝ Ceiling	......	......	......
......	⅞ Ceiling	......	......	......
......	⅞ Pine finish	......	......	......
......	1⅛ Pine finish	......	......	......
......	Oak finish	......	......	......
......	Poplar finish	......	......	......

Mill Work

......	Common window frames	......	......	......
......	Cellar window frames	......	......	......
......	Cottage front frames	......	......	......
......	Outside door frames	......	......	......
......	Cellar door frames	......	......	......
......	Attic frames	......	......	......
......	Inside door jambs	......	......	......
......	Cellar sash	......	......	......
......	Cellar doors	......	......	......

......	Front doors	......	......	......
......	Doors	......	......	......
......	Transoms	......	......	......
......	Base, 8 inch	......	......	......
......	Base, 10 inch	......	......	......
......	Casing, 5 inch	......	......	......
......	Plinth blocks	......	......	......
......	Center blocks	......	......	......
......	Corner blocks	......	......	......
......	Common doors	......	......	......
......	Front doors	......	......	......
......	Sliding doors	......	......	......
......	Closet doors	......	......	......
......	Transom sash	......	......	......
......	Window sash	......	......	......
......	Cellar sash	......	......	......
......	Outside blinds	......	......	......
......	Brackets	......	......	......
......	Gable finish	......	......	......
......	Crown moldings	......	......	......
......	Bed moldings	......	......	......
......	Base moldings	......	......	......
......	Band moldings	......	......	......
......	Cove moldings	......	......	......
......	Quarter-round	......	......	......
......	Lattice	......	......	......
......	Door stops	......	......	......
......	Window stops	......	......	......
......	Parting stops	......	......	......
......	Window stools	......	......	......
......	Watertable	......	......	......
......	Wainscoting cap	......	......	......
......	Thresholds	......	......	......
......	Corner beads	......	......	......

......	Porch posts	....	....	....
......	Porch spindles	....	....	....
......	Porch railing	....	....	....
......	Landing posts	....	....	....
......	Stair rails	....	....	....
......	Porch rails	....	....	....

Hardware and Sheet Metal

......	20d Nails	....	....	....
......	16d Nails	....	....	....
......	12d Nails	....	....	....
......	10d Nails	....	....	....
......	8d Nails	....	....	....
......	6d Nails	....	....	....
......	3d Coarse	....	....	....
......	3d Fine	....	....	....
......	10d Finish	....	....	....
......	8d "	....	....	....
......	6d "	....	....	....
......	4d "	....	....	....
......	3d "	....	....	....
......	Door butts	....	....	....
......	Cupboard butts	....	....	....
......	Strap hinges	....	....	....
......	Mortise locks	....	....	....
......	Mortise latches	....	....	....
......	Rim locks	....	....	....
......	Rim latches	....	....	....
......	Front door locks	....	....	....
......	Sliding door locks	....	....	....
......	Door hangers	....	....	....
......	Transom lifts	....	....	....
......	Flush bolts	....	....	....
......	Mortise bolts	....	....	....

......	Cupboard catches	......	......	......
......	Sinks	......	......	......
......	Shelf brackets	......	......	......
......	Blind hinges	......	......	......
......	Sash bolts	......	......	......
......	" pulleys	......	......	......
......	" locks	......	......	......
......	" lifts	......	......	......
......	" weights	......	......	......
......	" cord	......	......	......
......	Wardrobe hooks	......	......	......
......	Door stops	......	......	......
......	Sand paper	......	......	......
......	Roofing	......	......	......
......	Window caps	......	......	......
......	Hip shingles	......	......	......
......	Flashing	......	......	......
......	Valley tin	......	......	......
......	Gutters	......	......	......
......	Conductors	......	......	......
......	Flue thimbles	......	......	......
......	Flue stops	......	......	......

Recapitulation

......	Yards excavations $	......	......	......
......	Foundations	......	......	......
......	Perches of stone	......	......	......
......	Brick chimneys	......	......	......
......	Lumber	......	......	......
......	Carpenter work	......	......	......
......	Mill work	......	......	......
......	Hardware	......	......	......
......	Tinwork	......	......	......
......	Iron work	......	......	......
......	Yards plastering	......	......	......

	Plumbing			
......	....	....	....	....
	Gas fitting			
......	....	....	....	....
	Steam fitting			
......	....	....	....	....
	Yards painting			
......	....	....	....	....
	Incidental expenses			

MISCELLANEOUS DATA FOR READY REFERENCE

The following miscellaneous data may frequently be found of value for ready reference in solving problems, making estimates, etc.

1,728 cu. in. make 1 cu. ft.

27 cu. ft. make 1 cu. yd.

1 lb.=27.681 cu. in. of distilled water.

1 gal. of water at 62° F. weighs 8.336 lbs.

A cu. ft. contains 7.48 gals. at 62° F.

To find the diameter of a circle, multiply circumference by .31831.

To find circumference of a circle, multiply diameter by 3.1416.

To find area of a circle, multiply square of diameter by .7854; or multiply radius (one-half diameter) by circumference, and divide product by 2.

To find the surface of a ball, multiply square of diameter by 3.1416.

To find side of square approximately equal in area to a given circle, multiply diameter by .8862.

To find cubic inches in a ball, multiply cube of diameter, in inches by .5236.

Doubling the diameter of a pipe increases its capacity four times.

One ton of coal is equivalent to two cords of wood for steam purposes.

There are 9 sq. ft. of heating surface to each sq. ft. of grate surface.

A cubic foot of water weighs 62½ lbs.

Each nominal horse-power of a boiler requires 30 to 35 lbs. of water per hour.

A horse-power is equivalent to raising 33,000 lbs. one ft. per minute, or 550 lbs. one ft. per second.

To find the **capacity** (U. S. gallons) **of cylindrical tanks,** square the diameter, expressed in inches, multiply by the length, and by .0034.

To find the **thickness of steel to be used in hollow cylinders under tension,** such as pipe lines, etc., multiply the specified working pressure in pounds by the radius of the cylinder in inches, then by the factor of safety, and divide the result obtained by the tensile strength of the steel, multiplied by the percentage efficiency of the riveted joint employed.

Boiler Horse-Power—The evaporation of 30 lbs. of water per hour, from a temperature of 100° F. into steam at 70 lbs. gauge pressure.

One pound of water evaporated from and at 212° is equivalent to 965.7 British Thermal Units.

To find the number of **sq. ft. of heating surface in tubes,** multiply the number of tubes by the diameter of a tube in inches, by its length in feet, and by .2618.

To find the **bursting and safe working pressure of a boiler shell,** multiply the tensile strength of material by the thickness of the plate. Then multiply the result so found by the efficiency of the joint, and divide by the radius of the boiler. This will give the bursting pressure. The bursting pressure, divided by the factor of safety, will give the safe working pressure. The factor of safety of 5 has been generally accepted by eminent engineers and boilermakers.

The average consumption of coal for steam boilers is 12 lbs. per hour for each sq. ft. of grate surface.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column, in feet, by .434.

Steam rising from water at its boiling point (212 degrees) has a pressure equal to the atmosphere (14.7 lbs. to the sq. in.).

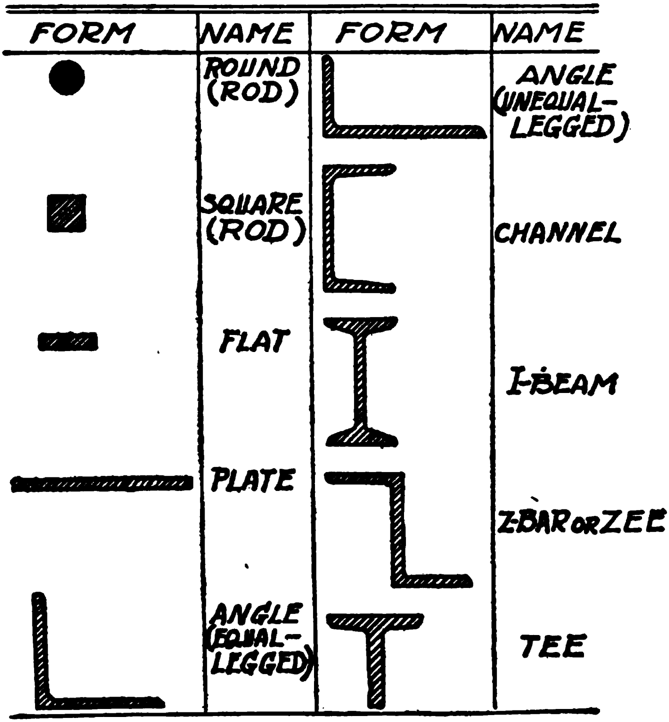
To evaporate 1 cu. ft. of water requires the consumption of 7½ lbs. of ordinary coal, or about 1 lb. of coal to 1 gallon of water.

To estimate the quantity of sheeting or of shiplap, calculate the exact surface to be covered, deducting openings; then add the following percentages:

	Sheeting	Shiplap
For floors	1/7, or 15 per cent	1/6, or 17 per cent
For sidewalls	1/6, or 17 per cent	1/5, or 20 per cent
For roofs	1/5, or 20 per cent	1/4, or 25 per cent

For trench machine work, from $7.00 to $10.00 a day should ordinarily be added for rental. Also add the cost of the sheeting, plank, and pumping. In estimating the cost of trenching work, look out for the boulders.

Common shapes of structural steel are illustrated as follows:



Common Shapes of Structural Steel.

CUBICAL CONTENTS OF ROOMS

Tables 5 to 9, compiled by the Chicago Heater & Supply Co., give the contents, in cu. ft., for various-sized rooms with different heights of ceiling.

TABLE 5

Cubical Contents of Rooms 25x20 Ft. and Smaller
(Ceilings 8 ft. high)

Ft	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	15½	16	16½	17	17½	18	18½	19	20
5½	176	198	220	242																												
6	192	216	240	264	288																											
6½	208	234	260	286	312	338																										
7	224	252	280	308	336	364	392																									
7½	240	270	300	330	360	390	420	450																								
8	256	288	320	352	384	416	448	480	512																							
8½	272	306	340	374	408	442	476	510	544	578																						
9	288	324	360	396	432	468	504	540	576	612	648																					
9½	304	342	380	418	456	494	532	570	608	646	684	722																				
10	320	360	400	440	480	520	560	600	640	680	720	760	800																			
10½	336	378	420	462	504	546	588	630	672	714	756	798	840	882																		
11	352	396	440	484	528	572	616	660	704	748	792	836	880	924	968																	
11½	368	414	460	506	552	598	644	690	736	782	828	874	920	966	1012	1058																
12	384	432	480	528	576	624	672	720	768	816	864	912	960	1008	1056	1104	1152															
12½	400	450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1260														
13	416	468	520	572	624	676	728	780	832	884	936	988	1040	1092	1144	1196	1248	1300	1352													
13½	432	486	540	594	648	702	756	810	864	918	972	1026	1080	1134	1188	1242	1296	1350	1404	1456												
14	448	504	560	616	672	728	784	840	896	952	1008	1064	1120	1176	1232	1288	1344	1400	1456	1512	1568											
14½	464	522	580	638	696	754	812	870	928	986	1044	1102	1160	1218	1276	1334	1392	1450	1508	1566	1624	1682										
15	480	540	600	660	720	780	840	900	960	1020	1080	1140	1200	1260	1320	1380	1440	1500	1560	1620	1680	1740	1800									
15½	496	558	620	682	744	806	868	930	992	1054	1116	1178	1240	1302	1364	1426	1489	1550	1612	1874	1736	1798	1860	1922								
16	512	576	640	704	768	832	896	960	1024	1088	1152	1216	1280	1344	1408	1472	1536	1600	1664	1728	1792	1856	1920	1984	2048							
16½	528	594	660	726	792	858	924	990	1056	1122	1188	1254	1320	1386	1452	1518	1584	1650	1716	1782	1848	1914	1980	2046	2112	2178						
17	544	612	680	748	816	884	952	1020	1088	1156	1224	1292	1360	1428	1496	1564	1632	1700	1768	1836	1904	1972	2040	2108	2176	2244	2312					
17½	560	630	700	770	840	910	980	1050	1120	1190	1260	1330	1400	1470	1540	1610	1680	1750	1820	1890	1960	2030	2100	2170	2240	2310	2380	2450				
18	576	648	720	792	864	936	1008	1080	1152	1224	1296	1368	1440	1512	1584	1656	1728	1800	1872	1944	2016	2088	2160	2232	2304	2376	2448	2520	2592			
18½	592	666	740	814	888	962	1036	1110	1184	1258	1332	1406	1480	1554	1628	1702	1776	1850	1924	1998	2072	2146	2220	2294	2368	2442	2516	2590	2664	2738		
19	608	684	760	836	912	988	1064	1140	1216	1292	1368	1444	1520	1596	1672	1748	1824	1900	1976	2052	2128	2204	2280	2356	2432	2508	2584	2660	2736	2812	2888	
19½	624	702	780	858	936	1014	1092	1170	1248	1326	1404	1482	1560	1638	1716	1794	1872	1950	2028	2106	2184	2262	2340	2418	2496	2574	2652	2730	2808	2886	2964	
20	640	720	800	880	960	1040	1120	1200	1280	1360	1440	1520	1600	1680	1760	1840	1920	2000	2080	2160	2240	2320	2400	2480	2560	2640	2720	2800	2880	2960	3040	3700
21	672	756	840	924	1008	1092	1176	1260	1344	1428	1512	1596	1680	1764	1848	1932	2016	2100	2184	2268	2352	2436	2520	2604	2688	2772	2856	2940	3024	3108	3192	3360
22	704	792	880	968	1056	1144	1232	1320	1408	1496	1584	1672	1760	1848	1936	2024	2112	2200	2288	2376	2464	2552	2640	2728	2816	2904	2992	3080	3168	3256	3344	3520
23	736	828	920	1012	1104	1196	1288	1380	1472	1564	1656	1748	1840	1932	2024	2116	2208	2300	2392	2484	2576	2668	2760	2852	2944	3036	3128	3220	3312	3404	3496	3680
24	768	864	960	1056	1152	1248	1344	1440	1536	1632	1728	1824	1920	2016	2112	2208	2304	2400	2496	2592	2688	2784	2880	2976	3072	3168	3264	3360	3456	3552	3648	3840
25	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	4000

TABLE 6

Cubical Contents of Rooms 25x20 Ft. and Smaller

(Ceilings 8½ ft. high)

Ft.	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	15½	16	16½	17	17½	18	18½	19	19½	20
5½	187	210	234	257																													
6	204	230	255	281	306																												
6½	221	249	276	304	332	359																											
7	238	268	297	327	357	387	417																										
7½	255	287	319	351	383	414	446	478																									
8	272	306	340	374	408	442	476	510	544																								
8½	289	325	361	397	434	470	506	542	578	614																							
9	306	345	382	421	459	497	536	574	612	650	689																						
9½	323	363	404	446	485	525	565	606	646	686	727	767																					
10	340	382	425	468	510	553	595	638	680	723	765	808	850																				
10½	357	402	446	491	536	580	625	669	714	759	803	848	893	937																			
11	374	421	467	514	561	608	655	701	748	796	842	888	935	982	1029																		
11½	391	440	489	538	587	635	684	733	782	831	880	929	978	1026	1075	1124																	
12	408	459	510	561	612	663	714	765	816	867	918	969	1020	1071	1122	1173	1224																
12½	425	478	531	584	638	691	744	797	850	903	956	1009	1063	1116	1169	1222	1275	1328															
13	442	497	552	608	663	718	774	829	884	939	995	1050	1105	1160	1216	1261	1326	1381	1437														
13½	459	516	574	631	689	746	803	861	918	975	1033	1090	1148	1205	1262	1319	1377	1434	1492	1549													
14	476	536	595	655	714	774	833	893	952	1012	1071	1131	1190	1250	1309	1369	1428	1488	1547	1607	1666												
14½	493	555	616	678	740	801	863	924	986	1048	1109	1171	1233	1294	1356	1417	1479	1541	1602	1664	1726	1787											
15	510	574	637	701	765	829	893	956	1020	1084	1148	1211	1275	1339	1403	1466	1530	1594	1658	1721	1785	1849	1913										
15½	527	593	659	725	791	856	922	988	1054	1120	1186	1252	1318	1383	1449	1515	1581	1647	1713	1779	1845	1910	1976	2042									
16	544	612	680	748	816	884	952	1020	1088	1156	1224	1292	1360	1428	1496	1564	1632	1700	1768	1836	1904	1972	2040	2108	2176								
16½	561	631	701	771	842	912	982	1052	1122	1192	1262	1332	1403	1473	1543	1613	1683	1753	1823	1893	1964	2034	2104	2174	2244	2314							
17	578	650	722	795	867	939	1012	1084	1156	1228	1301	1373	1445	1517	1590	1662	1734	1806	1879	1951	2023	2095	2168	2240	2312	2384	2457						
17½	595	669	744	818	893	967	1041	1116	1190	1264	1339	1413	1488	1562	1636	1711	1785	1859	1934	2008	2083	2157	2231	2306	2380	2454	2529	2601					
18	612	689	765	842	918	995	1071	1148	1224	1301	1377	1454	1530	1607	1683	1760	1836	1913	1989	2066	2142	2219	2295	2372	2448	2525	2601	2678	2754				
18½	629	708	786	865	944	1022	1101	1179	1258	1337	1415	1494	1573	1651	1730	1808	1887	1066	2044	2123	2202	2280	2359	2437	2516	2595	2673	2752	2831	2909			
19	646	727	807	888	969	1050	1131	1211	1292	1373	1454	1534	1615	1696	1777	1857	1938	2019	2100	2180	2261	2342	2423	2503	2584	2665	2746	2826	2907	2988	3068		
19½	663	746	829	912	995	1077	1160	1243	1326	1409	1492	1575	1658	1740	1823	1906	1989	2072	2155	2237	2321	2403	2486	2569	2652	2735	2818	2901	2984	3066	3149	3232	
20	680	765	850	935	1020	1105	1190	1275	1360	1445	1530	1615	1700	1785	1870	1955	2040	2125	2210	2295	2380	2465	2550	2635	2720	2805	2890	2975	3060	3145	3230	3315	3400
21	714	803	893	982	1071	1160	1250	1339	1428	1517	1607	1696	1785	1874	1964	2053	2142	2231	2321	2410	2499	2588	2678	2767	2856	2945	3035	3124	3213	3302	3392	3481	3570
22	748	842	935	1029	1122	1216	1309	1403	1496	1590	1683	1777	1870	1964	2057	2151	2244	2338	2431	2525	2618	2711	2805	2898	2992	3086	3179	3273	3366	3460	3553	3647	3740
23	782	880	978	1075	1173	1271	1369	1466	1564	1662	1760	1857	1955	2053	2151	2248	2346	2444	2542	2639	2737	2835	2933	3030	3128	3226	3324	3421	3519	3617	3715	3812	3910
24	816	918	1020	1122	1224	1326	1428	1530	1632	1734	1836	1938	2040	2142	2244	2346	2448	2550	2652	2754	2856	2958	3060	3162	3264	3366	3468	3570	3672	3774	3876	3978	4080
25	850	956	1063	1169	1275	1381	1488	1594	1700	1806	1913	2019	2125	2231	2338	2444	2550	2656	2763	2869	2975	3081	3188	3294	3400	3506	3613	3719	3825	3931	4038	4144	4250

TABLE 7

Cubical Contents of Rooms 25x20 Ft. and Smaller

(Ceilings 9 ft. high)

Ft.	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	15½	16	16½	17	17½	18	18½	19	20
5½	198	223	248	272																												
6	216	243	270	297	324																											
6½	234	263	293	322	351	380																										
7	252	284	315	347	378	410	441																									
7½	270	304	338	371	405	439	473	506																								
8	288	324	360	396	432	468	504	540	576																							
8½	306	344	383	421	459	497	536	574	612	650																						
9	324	365	405	446	486	527	567	608	648	689	729																					
9½	342	385	428	470	513	556	599	641	684	727	770	812																				
10	360	405	450	495	540	585	630	675	720	765	810	855	900																			
10½	378	425	473	520	567	614	662	709	756	803	851	898	945	992																		
11	396	446	495	545	594	644	693	743	792	842	891	940	990	1040	1089																	
11½	414	466	518	569	621	673	725	776	828	880	932	983	1035	1087	1139	1190																
12	432	486	540	594	648	702	756	810	864	918	972	1026	1080	1134	1188	1242	1296															
12½	450	506	563	619	675	731	788	844	900	956	1013	1069	1125	1181	1238	1294	1350	1406														
13	468	527	585	644	702	761	819	878	936	995	1053	1111	1170	1229	1287	1346	1404	1463	1521													
13½	486	547	608	668	729	790	851	911	972	1033	1094	1154	1215	1276	1337	1397	1458	1519	1580	1640												
14	504	567	630	693	756	819	882	945	1008	1071	1134	1197	1260	1323	1386	1449	1512	1575	1638	1701	1764											
14½	522	587	653	718	783	848	914	979	1044	1109	1175	1240	1305	1370	1436	1501	1566	1631	1697	1762	1827	1892										
15	540	608	675	742	810	878	945	1013	1080	1148	1215	1282	1350	1418	1485	1553	1620	1688	1755	1823	1890	1958	2025									
15½	558	628	698	767	837	907	977	1046	1116	1186	1256	1325	1396	1465	1535	1604	1674	1744	1814	1883	1953	2023	2093	2162								
16	576	648	720	972	864	936	1008	1080	1152	1224	1296	1368	1440	1512	1584	1656	1728	1800	1872	1944	2016	2088	2160	2232	2304							
16½	594	668	742	817	891	965	1040	1114	1188	1262	1337	1411	1485	1559	1634	1708	1782	1856	1931	2005	2079	2153	2228	2302	2376	2450						
17	612	689	765	842	918	995	1071	1148	1224	1301	1377	1453	1530	1607	1683	1760	1836	1913	1989	2066	2142	2219	2295	2372	2448	2525	2601					
17½	630	709	788	866	945	1024	1103	1181	1260	1339	1418	1496	1575	1654	1733	1811	1890	1969	2048	2126	2206	2284	2363	2441	2520	2599	2678	2756				
18	648	729	810	891	972	1053	1134	1215	1296	1377	1458	1539	1620	1701	1782	1863	1944	2025	2106	2187	2268	2349	2430	2511	2592	2673	2754	2835	2916			
18½	666	749	833	916	999	1082	1166	1249	1332	1415	1499	1582	1665	1748	1832	1915	1998	2081	2165	2248	2331	2414	2498	2581	2664	2747	2831	2914	2997	3080		
19	684	770	855	941	1026	1112	1197	1283	1368	1454	1539	1625	1710	1796	1881	1967	2052	2138	2223	2309	2394	2480	2565	2651	2736	2822	2907	2993	3078	3164	3249	
19½	702	790	878	965	1053	1141	1229	1316	1404	1492	1580	1667	1755	1843	1931	2018	2106	2194	2282	2369	2457	2545	2633	2720	2808	2896	2984	3071	3159	3247	3335	
20	720	810	900	990	1080	1170	1260	1350	1440	1530	1620	1710	1800	1890	1980	2070	2160	2250	2340	2430	2520	2610	2700	2790	2880	2970	3060	3150	3240	3330	3420	3600
21	756	851	945	1040	1134	1229	1323	1418	1512	1607	1701	1796	1890	1985	2079	2174	2268	2363	2457	2552	2646	2741	2835	2930	3024	3119	3213	3308	3402	3497	3591	3780
22	792	891	990	1089	1188	1287	1386	1485	1584	1683	1782	1881	1980	2079	2178	2277	2376	2475	2574	2673	2772	2871	2970	3069	3168	2267	3366	3465	3564	3663	3762	3960
23	828	932	1035	1139	1242	1346	1449	1553	1656	1760	1863	1967	2070	2174	2277	2381	2484	2588	2691	2795	2898	3002	3105	3209	3312	3416	3519	3623	3726	3830	3933	4140
24	864	972	1080	1188	1296	1404	1512	1620	1728	1836	1944	2052	2160	2268	2376	2484	2592	2700	2808	2916	3024	3132	3240	3348	3456	3564	3672	3780	3888	3996	4104	4320
25	900	1013	1125	1238	1350	1463	1575	1688	1800	1913	2025	2138	2250	2363	2475	2588	2700	2813	2925	3038	3150	3263	3375	3488	3600	3713	3825	3938	4050	4163	4275	4500

TABLE 8
Cubical Contents of Rooms 25x20 Ft. and Smaller
(Ceilings 9½ ft. high)

Ft.	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	15½	16	16½	17	17½	18	18½	19	20
5½	209	235	261	287																												
6	228	256	285	313	342																											
6½	247	277	308	339	370	401																										
7	266	299	332	365	399	432	465																									
7½	285	320	356	391	427	463	498	534																								
8	304	342	380	418	456	494	532	570	608																							
8½	323	363	403	444	484	524	565	605	646	686																						
9	342	384	427	470	513	555	598	641	684	726	769																					
9½	361	406	451	496	541	586	631	676	722	767	812	857																				
10	380	427	475	522	570	617	665	712	761	807	855	902	950																			
10½	399	448	498	548	598	648	698	748	798	847	897	947	997	1047																		
11	418	470	522	574	627	679	731	783	836	888	940	992	1045	1097	1149																	
11½	437	491	547	600	655	710	764	819	874	928	982	1030	1092	1147	1201	1256																
12	456	513	570	627	684	741	798	855	912	969	1026	1083	1140	1197	1254	1311	1368															
12½	475	534	593	653	712	771	831	890	950	1009	1068	1128	1187	1246	1306	1365	1425	1484														
13	494	556	617	679	741	802	864	926	988	1049	1111	1173	1235	1296	1358	1420	1482	1543	1606													
13½	513	577	641	705	769	833	897	961	1026	1090	1154	1218	1282	1346	1410	1474	1539	1603	1667	1731												
14	532	598	665	731	798	864	931	997	1064	1130	1197	1263	1330	1396	1463	1529	1596	1663	1729	1795	1862											
14½	551	619	688	757	826	895	964	1033	1102	1170	1239	1308	1377	1446	1515	1584	1663	1721	1790	1859	1928	1907										
15	570	641	712	783	885	926	997	1068	1140	1211	1282	1353	1425	1496	1567	1638	1710	1781	1852	1923	1995	2066	2137									
15½	589	662	736	807	883	957	1030	1104	1178	1251	1325	1398	1472	1546	1619	1693	1767	1840	1914	1997	2061	2135	2209	2282								
16	608	684	760	836	912	988	1064	1140	1216	1292	1368	1444	1520	1596	1672	1748	1824	1900	1976	2152	2128	2204	2260	2356	2432							
16½	627	706	783	862	940	1018	1097	1175	1254	1332	1410	1489	1567	1645	1724	1802	1881	1959	2037	2116	2194	2272	2351	2429	2508	2586						
17	646	726	807	888	969	1049	1130	1211	1292	1372	1453	1534	1615	1695	1776	1857	1938	2018	2099	2180	2261	2341	2422	2503	2584	2664	2745					
17½	665	748	831	914	997	1081	1163	1246	1330	1413	1496	1579	1662	1745	1828	1911	1995	2078	2161	2244	2327	2410	2493	2576	2660	2743	2826	2909				
18	684	769	855	940	1026	1111	1197	1282	1368	1453	1539	1624	1710	1795	1881	1966	2062	2137	2223	2318	2394	2479	2565	2650	2736	2821	2907	2992	3078			
18½	703	790	878	966	1054	1142	1230	1318	1406	1493	1581	1669	1757	1845	1933	2021	2109	2196	2284	2372	2460	2548	2636	2724	2912	2899	2987	3075	3163	3251		
19	722	812	902	994	1083	1173	1263	1353	1444	1534	1624	1714	1806	1895	1986	2075	2166	2256	2346	2436	2527	2617	2707	2797	2888	2978	3068	3158	3249	3339	3429	
19½	741	833	926	1018	1111	1204	1297	1389	1482	1574	1667	1759	1852	1945	2037	2130	2223	2315	2408	2500	2593	2686	2778	2871	2964	3056	3149	3241	3334	3427	3519	
20	760	855	950	1045	1140	1235	1330	1425	1520	1615	1710	1805	1900	1995	2090	2185	2280	2375	2470	2565	2660	2755	2850	2945	3040	3135	3230	3325	3420	3515	3610	3800
21	798	897	997	1097	1197	1296	1396	1496	1596	1695	1795	1895	1995	2094	2194	2295	2394	2493	2593	2693	2793	2892	2992	3092	3192	3291	3391	3491	3591	3690	3790	3990
22	836	940	1045	1149	1254	1358	1463	1567	1672	1776	1881	1985	2090	2194	2299	2403	2507	2612	2717	2821	2926	3030	3135	3239	3344	3448	3553	3657	3762	3866	3971	4180
23	874	983	1092	1201	1311	1420	1529	1638	1748	1857	1967	2075	2185	2294	2403	2512	2622	2731	2840	2949	3059	3168	3277	3386	3496	3605	3714	3823	3933	4042	4151	4370
24	912	1026	1140	1254	1368	1482	1596	1710	1824	1938	2052	2166	2280	2394	2508	2622	2736	2850	2964	3078	3192	3306	3420	3534	3648	3762	3876	3990	4104	4218	4332	4560
25	950	1068	1187	1306	1425	1543	1662	1781	1900	2018	2137	2256	2375	2493	2612	2731	2850	2968	3087	3206	3325	3443	3562	3681	3800	3918	4037	4156	4275	4393	4512	4750

TABLE 9

Cubical Contents of Rooms 25x20 Ft. and Smaller

(Ceilings 10 ft. high)

Ft.	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	15½	16	16½	17	17½	18	18½	19	20
5½	220	248	275	303																												
6	240	270	300	330	360																											
6½	260	293	325	358	390	423																										
7	280	315	350	385	420	455	490																									
7½	300	338	375	413	450	488	525	563																								
8	320	360	400	440	480	520	560	600	640																							
8½	340	383	425	468	510	553	595	638	680	723																						
9	360	405	450	495	540	585	630	675	720	765	810																					
9½	380	428	475	523	570	618	665	713	760	808	855	903																				
10	400	450	500	550	600	650	700	750	800	850	900	950	1000																			
10½	420	473	525	578	630	683	735	788	840	893	945	998	1050	1103																		
11	440	495	550	605	660	715	770	825	880	935	990	1045	1100	1155	1210																	
11½	460	518	575	633	690	748	805	863	920	978	1035	1093	1150	1208	1265	1323																
12	480	540	600	660	720	780	840	900	960	1020	1080	1140	1200	1260	1320	1380	1440															
12½	500	563	625	688	750	813	875	938	1000	1063	1125	1188	1250	1313	1375	1438	1500	1563														
13	520	585	650	715	780	845	910	975	1040	1105	1170	1235	1300	1365	1430	1495	1560	1625	1690													
13½	540	608	675	743	810	878	945	1013	1080	1148	1215	1283	1350	1418	1485	1553	1620	1688	1755	1823												
14	560	630	700	770	840	910	980	1050	1120	1190	1260	1330	1400	1470	1540	1610	1680	1750	1820	1890	1960											
14½	580	653	725	798	870	943	1015	1088	1160	1233	1305	1378	1450	1523	1595	1668	1740	1813	1885	1958	2030	2103										
15	600	675	750	825	900	975	1050	1125	1200	1275	1350	1425	1500	1575	1650	1725	1800	1875	1950	2025	2100	2175	2250									
15½	620	698	775	853	930	1008	1085	1163	1240	1318	1395	1473	1550	1628	1705	1783	1860	1938	2015	2093	2170	2248	2325	2403								
16	640	720	800	880	960	1040	1120	1200	1280	1360	1440	1520	1600	1680	1760	1840	1920	2000	2080	2160	2240	2320	2400	2480	2560							
16½	660	743	825	908	990	1073	1155	1238	1320	1403	1485	1568	1650	1733	1815	1898	1980	2063	2145	2228	2310	2393	2475	2558	2640	2723						
17	680	765	850	935	1020	1105	1190	1275	1360	1445	1530	1615	1700	1785	1870	1955	2040	2125	2210	2295	2380	2465	2550	2635	2720	2805	2890					
17½	700	788	875	963	1050	1138	1225	1313	1400	1488	1575	1663	1750	1838	1925	2013	2100	2188	2275	2363	2450	2538	2625	2713	2800	2888	2975	3063				
18	720	810	900	990	1080	1170	1260	1350	1440	1530	1620	1710	1800	1890	1980	2070	2160	2250	2340	2430	2520	2610	2700	2790	2880	2970	3060	3150	3240			
18½	740	833	925	1018	1110	1203	1295	1388	1480	1573	1665	1758	1850	1943	2035	2128	2220	2313	2405	2498	2590	2683	2775	2868	2960	3053	3145	3238	3330	3423		
19	760	855	950	1045	1140	1235	1330	1425	1520	1615	1710	1805	1900	1995	2090	2185	2280	2375	2470	2565	2660	2755	2850	2945	3040	3135	3230	3325	3420	3515	3610	
19½	780	878	975	1073	1170	1268	1365	1463	1560	1658	1755	1853	1950	2048	2145	2243	2340	2438	2535	2633	2730	2828	2925	3023	3120	3218	3315	3413	3510	3608	3705	
20	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	4000
21	840	945	1050	1155	1260	1365	1470	1575	1680	1785	1890	1995	2100	2205	2310	2415	2520	2625	2730	2835	2940	3045	3150	3255	3360	3465	3570	3675	3780	3885	3990	4200
22	880	990	1100	1210	1320	1430	1540	1650	1760	1870	1980	2090	2200	2310	2420	2530	2640	2750	2860	2970	3080	3190	3300	3410	3520	3630	3740	3850	3960	4070	4180	4400
23	920	1035	1150	1265	1380	1495	1610	1725	1840	1955	2070	2185	2300	2415	2530	2645	2760	2875	2990	3105	3220	3335	3450	3565	3680	3795	3910	4025	4140	4255	4370	4600
24	960	1080	1200	1320	1440	1560	1680	1800	1920	2040	2160	2280	2400	2520	2640	2760	2880	3000	3120	3240	3360	3480	3600	3720	3840	3960	4080	4200	4320	4440	4560	4800
25	1000	1125	1250	1375	1500	1625	1750	1875	2000	2125	2250	2375	2500	2625	2750	2875	3000	3125	3250	3375	3500	3625	3750	3875	4000	4125	4250	4375	4500	4625	4750	5000

WEIGHT OF MATERIALS

The approximate weight per cubic foot of materials commonly used in construction, is as follows:

Metals

Material	Weight per Cubic Foot
Bronze	552 lbs.
Copper	550 "
Iron, Cast	450 "
Iron, Wrought	480 "
Lead	712 "
Steel, Structural	490 "

Masonry

Material	Weight per Cubic Foot
Asphalt	130 lbs.
Bluestone	160 "
Brick in lime	120 "
Brick in cement	130 "
Cement, Portland	90 "
Concrete	150 "
Gneiss	160 "
Granite	165 "
Gravel	120 "
Limestone	170 "
Marble	165 "
Sandstone	145 "
Slate	170 "
Terra-cotta	110 "
Tile	115 "

Weight of a bag of natural cement, about 94 lbs.

Weight of a bag of Portland cement, about 94 lbs.

A bbl. of natural cement=3 bags, and weighs about 282 lbs.

A bbl. of Portland cement=4 bags, and weighs about 380 lbs.

A cu. ft. of loose measured broken trap stone weighs about 90 lbs.

A cu. ft. of broken stone, well shaken down, weighs about 100 lbs.

A cu. ft. of crusher-run stone weighs about 100 lbs.

A cu. ft. of cinder concrete averages 110 lbs.

A cu. ft. of conglomerate concrete averages 130 lbs.

A cu. ft. of gravel concrete averages 150 lbs.

A cu. ft. of limestone concrete averages 148 lbs.

A cu. ft. of sandstone concrete averages 143 lbs.

A cu. ft. of trap concrete averages 155 lbs.

Loose, unrammed concrete weighs from 5 to 25 per cent less than when well tamped.

One cubic foot of anthractite coal weighs about 58 pounds.

One cubic foot of bituminous coal weighs from 47 to 50 pounds.

TABLE 10

Specific Gravity of Stone

Trap, Boston, Mass	2.78
Trap, Duluth, Minn	2.8 to 3.0
Trap, Jersey City, N. J	3.03
Trap, Staten Island, N. Y	2.86
Gneiss, Madison Ave., N. Y	2.92
Granite, New London, Conn	2.66
Granite, Greenwich, Conn	2.84
Granite, Vinalhaven, Me	2.66
Granite, Quincy, Mass	2.66
Granite, Barre, Vt	2.65
Limestone, Joliet, Ill	2.56
Limestone, Quincy, Ill	2.51 to 2.57
Limestone (oolitic), Bedford, Ind.	2.25 to 2.45
Limestone, Marquette, Mich	2.34
Limestone, Glens Falls, N. Y.	2.70
Limestone, Lake Champlain, N. Y.	2.75
Sandstone, Portland, Conn	2.64
Sandstone, Haverstraw, N. Y.	2.13
Sandstone, Medina, N. Y	2.41
Sandstone, Potsdam, N. Y	2.60
Sandstone (grit), Berea, O	2.12

TABLE 11

Specific Gravity of Common Minerals and Rocks

Apatite	2.92—3.25
Basalt	3.01
Calcite, $CaCO_3$	2.5 —2.73
Cassiterite, SnO_2	6.4 —7.1
Cerusite, $PbCO_3$	6.46—6.48
Chalcopyrite, $CuFeS_2$	4.1 —4.3
Coal, anthracite	1.3 —1.84
Coal, bituminous	1.2 —1.5
Diabase	2.6 —3.03
Diorite	2.92
Dolomite, $CaMg(CO_3)_2$	2.8 —2.9
Feldspar	2.44—2.78
Felsite	2.65
Galena, PbS	7.25—7.77
Garnet	3.15—4.31
Gneiss	2.62—2.92
Granite	2.55—2.86
Gypsum	2.3 —3.28
Halite (salt), NaCl	2.1 —2.56
Hematite, Fe_2O_3	4.5 —5.3
Hornblende	3.05—3.47
Limonite, $Fe_2O_3(OH)_6$	3.6 —4.0
Limestone	2.35—2.87
Magnetite, Fe_3O_4	4.9 —5.2
Marble	2.08—2.85
Mica	2.75—3.1
Mica Schist	2.5 —2.9
Olivine	3.33—3.5
Porphyry	2.5 —2.6
Pyrite, FeS_2	4.83—5.2
Quartz, SiO_2	2.5 —2.8
Quartzite	2.6 —2.7
Sandstone	2.0 —2.78
Sandstone, Medina	2.4
Sandstone, Ohio	2.2
Sandstone, Slaty	1.82
Shale	2.4 —2.8
Slate	2.5 —2.8
Sphalerite, ZnS	3.9 —4.2
Stibnite, Sb_2S_3	4.5 —4.6
Syenite	2.27—2.65
Talc	2.56—2.8
Trap	2.6 —3.0

Table 12 shows the weights of aggregates of varying specific gravity and having different percentages of voids:

THERMOMETER SCALES

A thermometer is an instrument for indicating the intensity (not quality) of heat. The thermometer scale upon which the intensity of the heat is indicated, is an arbitrarily chosen scale. The two scales in most general use are the **Fahrenheit** and the **Centigrade**.

TABLE 12

Weights of Aggregates of Varying Specific Gravity and Percentages of Voids

Specific Gravity	Weight in Pounds per Cu. Ft.	Weight in Pounds per Cu. Yd.	Weight in Pounds per Cu. Yd. when Voids are				
			30%	35%	40%	45%	50%
1.0	62.355	1,684	1,178	1,094	1,010	926	842
2.0	124.7	3,367	2,357	2,187	2,020	1,852	1,684
2.1	130.9	3,536	2,475	2,298	2,121	1,945	1,768
2.2	137.2	3,702	2,593	2,408	2,222	2,037	1,852
2.3	143.4	3,872	2,711	2,517	2,323	2,130	1,936
2.4	149.7	4,041	2,828	2,626	2,424	2,222	2,020
2.5	155.9	4,209	2,946	2,736	2,525	2,315	2,105
2.6	162.1	4,377	3,064	2,845	2,626	2,408	2,189
2.7	168.4	4,545	3,182	2,955	2,727	2,500	2,273
2.8	174.6	4,714	3,300	3,064	2,828	2,593	2,357
2.9	180.9	4,882	3,418	3,174	2,929	2,685	2,441
3.0	187.1	5,051	3,536	3,283	3,030	2,778	2,526
3.1	193.3	5,219	3,653	3,392	3,131	2,871	2,609
3.2	199.5	5,388	3,771	3,502	3,232	2,963	2,614
3.3	205.8	5,556	3,889	3,611	3,333	3,056	2,778
3.4	212.0	5,724	4,007	3,721	3,434	3,148	2,862
3.5	218.3	5,893	4,125	3,830	3,535	3,241	2,947

The Fahrenheit scale is used most generally in domestic, commercial, and industrial fields. Its lowest point, zero (0°), designates the lowest point to which mercury will fall in a tube when surrounded by a mixture of salt and ice. The point at which water freezes—called the **freezing point** (32°)—is noted, and the point at which water boils under normal conditions is noted as 212°; the distance between is divided into 180 equal divisions called **degrees**.

The Centigrade scale is divided into 100 equal divisions called **degrees** between the freezing point of water (0°) and its boiling point (100°) under normal conditions. These points and divisions are calibrated or marked upon a glass tube containing mercury, the expansion of which by heat indicates the number of degrees, or the temperature.

The distance from 32° (freezing point) to 212° (boiling point), or 180° Fahrenheit, is equal to the distance 0° (freezing point) to 100° (boiling point) on the Centigrade scale; or each degree on the Fahrenheit thermometer is 100/180 or 5/9 of a degree on the Centigrade. Therefore to convert Fahrenheit temperatures to Centigrade temperatures, it is necessary to subtract 32 (degrees), and multiply by 5/9. To convert Centigrade temperatures to Fahrenheit temperatures, multiply by 9/5, and then add 32 (degrees).

Temp. C. = (Temp. F. — 32°) 5/9.

Temp. F. = (Temp. C × 9/5) + 32°.

TABLE 13

Estimated Weight of a Cubic Foot of Dry Lumber

Kind of Wood	Lbs. per Cu. Ft.	Kind of Wood	Lbs. per Cu. Ft.
Alder	50	Juniper	35
Apple	50	Lancewood	45
Ash	47.5	Larch	35
Beech	44	Ligmum Vitae	83.3
Birch	44	Logwood	57
Boxwood	62	Mahogany (Honduras)	35
Butternut	24	Mahogany (Spanish)	54
Cedar (American)	35.6	Maple	48
Cedar (West Indian)	47	Oak, Live	66
Chestnut	39	Oak, Red	45
Cherry	44	Oak, White	52
Cork	15	Pine, Pitch	41
Ebony	79	Pine, Red or Norway	37
Elm	38	Pine, White	25
Fir (New England)	35	Pine, Yellow	34
Fir (Norway spruce)	32	Poplar	28.5
Fir, White	36	Rosewood	45.5
Gum, Blue	53	Satinwood	55.3
Hackmatack	37	Spruce	25
Hazel	58	Sycamore	37
Hemlock	25	Tamarack	24
Hickory (Pig nut)	50	Teak	47
Hickory (Shell bark)	43	Walnut	42
Holly	48	Walnut, Black	32
Hornbeam	47	Willow	33
Ironwood	71		

TABLE 14

Weight of Dry Lumber, in Pounds per 1,000 Feet, Board Measure

Kind of Wood	Pounds per 1,000 Feet Board Measure
White Pine—	
2-in., rough or S1E	2,500
2-in. S1S1E, S4S or D&M	2,200
3-in. and 4x4-in. to 8x8-in.	3,000
Battens, O. G.	1,500
Boards, common, rough	2,400
Boards, common, S1S or S2S	2,000

Ceiling, ⅜-in.	800
Fencing, rough	2,400
Fencing, S1S or S2S	2,000
Finish, S1S or S2S	2,000
Lath, ⅜-in.	500
Shingles	250
Shiplap and D. & M.	1,800
Siding, drop	1,800
Roofing, grooved	1,800

Cypress—

Rough, 2-in. and under	3,000
" , 2½ and 3-in	3,500
Battens, O. G., 2-in.	500
Battens, O. G., 2½-in.	600
Battens, O. G., 3-in.	700
Ceiling, ⅞-in.	2,300
Ceiling, ⅝-in.	1,600
Ceiling, ½-in.	1,300
Ceiling, ⅜-in.	1,000
Flooring, ⅞-in.	2,300
Lath, fence, ⅝-in.	900
Lath, plaster, ⅜-in.	500
Pickets, D. & H., ⅞x2½x4-ft.	1,800
Pickets, D. & H., 1¼x1¼x4-ft.	1,600
Shingles, all grades	300
Siding, bevel, ½-in.	1,000

Pacific Coast Lumber—

California sugar pine, 1-in., rough	2,200
California redwood, 1 to 2-in., rough	2,500
California redwood, 1 to 2-in., S1S	2,200
California redwood, 1 to 2-in., S2S	2,000
Cedar shingles, A	200
Oregon fir, 1-in., rough	2,200
Washington red cedar, 1-in., rough	2,300
Washington red cedar, 1-in., dressed	2,000

Yellow Pine—

	Short-Leaf	Long-Leaf
Base, moulded	2,000	2,100
Boards, common	3,200	3,400
" " S1S or S2S	2,500	2,700
Ceiling, ⅜-in.	1,000	1,000
" ½-in.	1,300	1,300
" ⅝-in.	1,500	1,600
" ¾-in.	1,800	1,900

Finish, rough	3,200	3,400
" , S1S or S2S	2,500	2,700
" , 1-in. S2S	2,500	2,600
" , 1, 1¼, 1½, and 2-in., rough	3,100	3,400
" , 1¼, 1½, and 2-in., S2S	2,700	2,800
Flooring, 13/16-in.	2,000	2,200
Flooring, grooved	2,400	2,600
Shiplap, D. & M.	2,300	2,500
Siding, from 1-in. stock	1,000	1,000
" " 1¼-in. stock	1,250	1,400
2x4, 2x6, and 2x8-in., rough	3,200	3,400
2x10 and 2x12-in., rough	3,200	3,400
2x14 and 3x12-in., rough	3,700	3,900
4x4-in., and over, rough	4,000	4,300
2x4, 2x6, and 2x8-in., S1S1E	2,500	2,700
2x10 and 2x12-in., S1S1E	2,600	2,800
2x14 and 3x12-in., S1S1E	3,200	3,600
4x4-in. and ever, S1S1E	3,200	3,400

Norway Pine—

	Pounds per 1,000 Feet Board Measure
Lumber, rough	2,700
" , dressed	2,300
" , D. & M.	2,000
Timbers, heavy, rough	2,800

TABLE 15

Weights of Merchandise

(M. S. Ketchum)

Commodity	Wt. in Lbs. per Cu. Ft.	Commodity	Wt. in Lbs. per Cu. Ft.
Wool in bales	5 to 28	Caustic soda	88
Woolen goods	13 to 22	Barrel starch	23
Baled cotton	12 to 43	" lime	50
Cotton goods	11 to 37	" cement	73
Rags in bales	7 to 36	" plaster	53
Paper	10 to 69	" lard oil	34
Wheat	39 to 44	Rope	42
Corn	31	Box tin	278
Oats	27	Box glass	60
Baled hay and straw	14 to 19	Crate crockery	40
Bleaching powder	31	Bale leather	16 to 23
Soda ash	62	Sugar	45
Box indigo	43	Cheese	30

TABLE 16

Weight and Strength of Rope

(Godfrey's Tables)

Size in Circumference	Size in Diameter	Weight of 100 Ft.	Strength of Manila Rope, in Pounds, (Sisal Rope about 25 per cent less)	Tarred Hemp Rope; Weight of 100 Ft.
3/8	1/8	30	300	....
1/2	3/16	35	540	....
3/4	1/4	45	780	54
1	5/16	55	1,000	69
1 1/8	3/8	65	1,280	73
1 1/4	7/16	75	1,560	86
1 1/2	1/2	85	2,250	98
1 3/4	9/16	110	3,060	135
2	5/8	140	4,000	162
2 1/4	3/4	170	5,000	214
2 1/2	13/16	200	6,250	263
2 3/4	7/8	240	7,500	290
3	1	275	9,000	347
3 1/4	1 1/16	325	10,500	400
3 1/2	1 1/8	360	12,250	455
3 3/4	1 3/16	410	14,000	526
4	1 1/4	460	16,000	620
4 1/4	1 3/8	510	18,000	719
4 1/2	1 7/16	585	20,250	781
4 3/4	1 1/2	640	22,500	870
5	1 5/8	720	25,000	932
5 1/2	1 3/4	835	30,250	1,190
6	1 7/8	1,050	36,000	1,400
6 1/4	2	1,150	39,000	1,525
6 1/2	2 1/8	1,250	42,250	1,688
7	2 1/4	1,425	49,000	1,906
7 1/2	2 3/8	1,700	56,250	2,188
8	2 9/16	2,000	64,000	2,562
8 1/2	2 3/4	2,300	72,250	2,875
9	2 7/8	2,650	81,000	3,312
9 1/2	3	3,000	90,250	3,625
10	3 3/16	3,400	100,000	4,187
11	3 1/2	4,000	118,000	5,094
12	3 3/4	4,700	135,000	5,938
13	4 1/4	5,650	156,000	7,060
14	4 7/8	6,500	211,000	8,190
15	5 1/2	7,500	230,000	9,438

The **working strain** is about one-third to one-seventh of the **breaking strain**. The minimum diameter of the pulley should be from 30 to 40 times the diameter of rope to be used.

Weights of rope are liable to vary either way.

WEIGHT OF CASTINGS

Table 17 is very useful for determining the weight of any casting before it is made, by simply weighing the pattern. It should be noted that the weight of the core prints, if any, should be deducted.

TABLE 17

Proportionate Weight of Castings to Weight of Patterns

A Pattern Weighing One Pound Made of	Cast Iron	Brass.	Copper	Bronze.	Bell Metal.	Zinc.
Pine or Fir	16	15.8	16.7	16.3	17.1	13.5
Oak	9	10.1	10.4	10.3	10.9	8.6
Beech	9.7	10.9	11.4	11.3	11.9	9.1
Linden	13.4	15.1	16.7	15.5	16.3	12.9
Pear	10.2	11.5	11.9	11.8	12.4	9.8
Birch	10.6	11.9	12.3	12.2	12.9	10.2
Alder	12.8	14.3	14.9	14.7	15.5	12.2
Mahogany	11.7	13.2	13.7	13.5	14.2	1.2 1
Brass	0.85	0.95	0,99	0.98	1.0	10.8

PRESERVATIVE TREATMENT OF LUMBER

Cheap grades of lumber may be made to compare with better grades in point of service by treating the lumber by some one of the preservative processes now used. A common method is the absorption of creosote or zinc chloride, or a combination of the two, thereby filling the pores of the wood with material which will withstand the action of moisture or decay. When properly treated, woods like cottonwood, willow, sycamore, and low-grade pine will outlast untreated cedar and oak, thereby increasing the value of the cheaper woods so that they will compare favorably with the more expensive grades of timber.

Impregnation with creosote has been highly cheapened by the introduction of the open-tank system, which can be installed very cheaply, especially if an old boiler is used for the tank. A tank with a bottom area of 12 sq. ft. will be of a capacity sufficient for treating 40 or 50 6-in fence-posts a day, but double this number if two runs per day are made.

This process is especially favorable in the treatment of fence-posts, railroad ties and even for ordinary lumber which is to be exposed to decaying influences. In the treatment of fence-posts the absorption of creosote per post is about as follows:

Ash, hickory, red oak, elm, and maple...	.4 gallon
Douglas fir	.6 "
Sycamore, cottonwood, lodge-pole pine....	.7 "

Since the price of creosote varies in different parts of the country, the cost of treatment for any given number of posts will have to be determined for a given locality. Fence-posts, if properly treated, should give service for at least 20 years. A rough estimate of cost would be 4 cents per post where creosote is 10 cents per gallon, or 15 cents per post where creosote is 27 cents per gallon, as in the case of the Rocky Mountain States.

When zinc chloride is used, about ½ pound of dry zinc is required per cu. ft. of wood; while if the creosote process is used, 2 to 12 pounds of creosote are required per cu. ft. of wood, depending upon the degree of absorption. In the zinc chloride process, the cost of treating a 7 by 9-in. by 8-ft. railroad tie is about 17 cents when zinc chloride costs 4 cents per gallon; or $4.10 per thousand, board measure, in the treatment of lumber. When creosote is 7 cents per gallon, various processes of treatment for railroad ties will cost from 26 to 46 cents per tie; or $6.00 to $11.00 per thousand feet, board measure, for timber or lumber.

TABLE 18

Standard Sizes of Plate-Iron Washers

(Trautwine)

Diameters (Inches)		Thickness (Bir. Wire Gauge)	Number in Pound	Diameters (Inches)		Thickness (Bir. Wire Gauge)	Number in Pound
½	¼	18	450	2	13/16	10	10.1
⅝	5/16	16	210	2¼	15/16	9	8.6
¾	5/16	16	139	2½	1 1/16	9	6.2
⅞	⅜	16	112	2¾	1¼	9	5.2
1	7/16	14	68	3	1⅜	9	4.0
1¼	½	14	43	3½	1½	9	2.8
1⅜	9/16	12	26	...	...	..	....
1½	⅝	12	22.5	...	...	..	....
1¾	11/16	10	13.1	...	...	..	....

SPEEDS OF CUTTING TOOLS FOR WOOD AND METAL

Conditions vary to so great an extent in different kinds of work, and with different materials, that it is difficult to give an exact speed for a given tool, which will be of best advantage at all times. The following speeds are necessarily approximate, and should be treated as such in any work. The only safe way to gauge the proper speed for a given tool in a given class of work, is to obtain a list of cutting speeds from the manufacturer of that particular tool.

The matter of speeds of circular saws and of woodworking machinery, is a very delicate and often a dangerous proposition, and should be determined only by the directions of the manufacturer. There is no general rule for the speed of saws of a given diameter, since saws even of the same diameter take different speeds, according to the gauge, quality, temper, style of teeth, timber to be cut, etc. It is often stated that circular saws should be run at such a speed that the teeth will travel between 9,000 and 10,000 linear feet per minute.

Table 19, indicating the speeds of circular saws, will give an approximate idea of the revolutions per minute for saws of different sizes.

TABLE 19

Speeds of Circular Saws

Size of Saw (Inches, Diam.)	Revolutions per Minute	Size of Saw (Inches, Diam.)	Revolutions per Minute
8	4,300	24	1,450
10	3,500	26	1,300
12	2,900	28	1,200
14	2,500	30	1,150
16	2,100	32	1,100
18	1,900	34	1,000
20	1,700	36	950
22	1,600		

Table 19 is figured on a peripheral speed of 9,000 ft. per minute; but saws for portable mills are usually run at a speed of about 450 revolutions per minute, and saws for steam feed mills from 600 to 900 revolutions per minute.

These values, as cautioned above, should be looked upon only as approximate, and treated with suspicion until verified by the manufacturer of the saw.

For **band saws** it is often stated that for wheels up to three feet in diameter, 4,000 ft. per minute linear speed is considered to be adequate for soft and medium woods; while for hardwood, about 3,500 ft. per minute. For band saws with wheels over three feet in diameter, speeds may be increased.

In **planer and jointer work**, opinions seem to differ according to the type of machine used; but it seems to be fairly well agreed, that in either machine the cutting edge should travel at a speed of from 4,000 to 6,000 ft. per minute.

The criticism given above in regard to consulting the manufacturer as to the proper revolutions per minute will apply as well to **emery wheels** as to saws.

Table 20, based upon a peripheral speed of 5,500 ft, per minute, will give an approximate idea of the proper revolutions per minute at which emery wheels of different diameters should be run.

TABLE 20

Safe Speed of Emery and Corundum Wheels

Diameter of Wheel (Inches)	Revolutions per Minute	Diameter of Wheel (Inches)	Revolutions per Minute
4	5,250	12	1,750
5	4,200	14	1,500
6	3,500	16	1,300
7	3,000	18	1,175
8	2,625	20	1,050
9	2,325	22	950
10	2,100	24	875

For **metals**, the speed of the cutting point or edge of the tool will vary according to the kind of metal to be cut, kind of steel used in making the given tool, depth of cut to be taken, and amount of feed taken by the tool at each revolution. An average cutting speed for planing steel is 20 ft. per minute; and, for planing cast iron, 26 ft. per minute. The speed for turning and for milling soft steel, or wrought iron, is about 48 ft. per minute. Soft brass is often cut at the rate of 120 ft. per minute. These speeds refer to the use of tools made from **ordinary steel**.

Where **high-speed steel** is used for making the tools, these cutting speeds may be increased; but same should be governed by the directions issued by the manufacturer of the particular brand of steel used. With some brands of steel, a cutting speed as high as 175 ft. per minute may be used on mild steel, where a cut not to exceed ⅛ in. in depth and a feed of 3/64 in. are used. Generally better results are obtained with much lower speeds. As the depth of cut and feed is increased, less reduction in speed is required with the high-speed steels as compared with ordinary tools.

Table 21 will give an idea of the speed, depth of cut, and feed often used with high-speed steels.

TABLE 21

Speeds for High-Speed Steel Lathe Work

Metal	Cutting Speed Ft. per Minute.	Depth of Cut	Feed	Weight Removed per minute.
Mild Steel	145	1/16 inch	1/16 inch	5.8 lbs.
" "	45	[illegible] "	1/8 "	7 "
" "	100	1/16 "	1/16 "	3.9 "
" "	50	[illegible] "	1/8 "	10.4 "
" "	80	[illegible] "	1/8 "	14 "
" "	72	[illegible] "	1/16 "	5 "
" "	72	[illegible] "	1/16 "	7 "

CARE OF BELTS

The main care the average belt gets in small woodworking institutions is to have new lacings put in when the old ones wear, and to have a piece cut out and the belt made tighter when it fails to pull its load. Belts running on a moderate load do not need a great deal of attention; still a little attention is worth while, as one not only gets better service out of the belt, but increases its life and usefulness.

Belts should be run as slack as possible—that is, just tight enough to do their work with a fair factor of safety, and no more. There are more belts ruined by being unnecessarily tight than are worn out in actual service. Keep the surface of the belt in good shape and it will not have to be so tight as when left unattended.

If a leather belt in use gets dirty from an accumulation of dust, oil, etc., take the time and trouble to clean it. To cut the grease and loosen the dirt, use a mixture made of 3 parts of benzine, naphtha, or gasoline, and 1 part of turpentine. If the use of this mixture is prohibited in the shop because of the danger of fire, explosions, etc., use the turpentine alone to loosen the grease. After the belt is clean and dry, apply a light coat of some good belt dressing, or, in the absence of that, a little castor oil or tallow. The majority of mineral and vegetable oils are injurious to belts, and should not be used. In common practice, however, they are used quite extensively; in fact, it is not unusual in most shops to take lubricating oil and pour same on belts that seem to be in need of limbering up. But this is not good practice.

The mixture mentioned is for cleaning leather belts and should not be used on **rubber belts**, since it will cut the rubber. Rubber belts may be cleaned with a little soap and water; but use it sparingly so as not to injure the belt.

To make a rubber belt more pliable and cause it to stick to the pulleys better, moisten it lightly on the inside with boiling linseed oil. Animal oils or grease should not be used on rubbed belts.

In the **lacing of belts** there are so many different methods, and their claims for superiority are so confusing and generally so obscure, that study of them becomes more tiresome

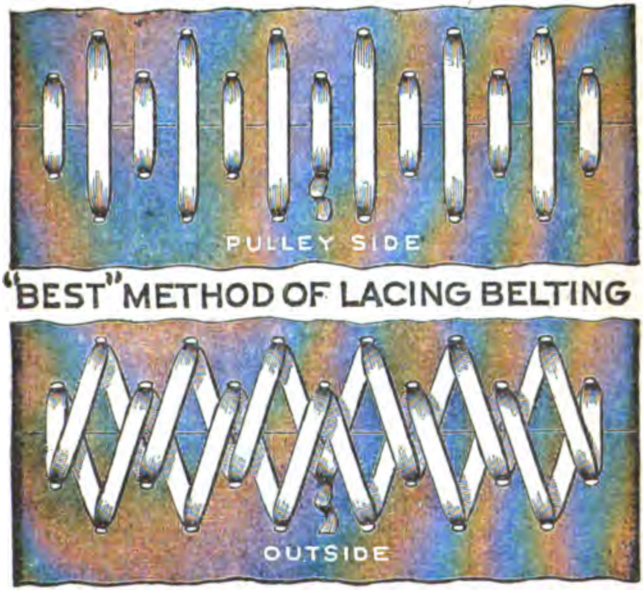


Fig. 2. Approved Method of Lacing Belts.

than enlightening. Fig. 2 shows what one of the leading belt manufacturers considers to be the best method of lacing.

When there is trouble in threading the end of the lace leather through the holes, try lighting a match and burning the end of the lace leather with it. A little burning will usually make the end hard and stiff so that it will serve as a sort of needle point and can readily be pushed through the holes. Of course, the part of the lace string that is burned is ruined and will have to be cut off.

Table 22 shows the spacing for holes in lacing belts.

TABLE 22

Spacing of Holes for Lacing Belts

Width of Belt (Inches)	Punch first row of holes from ends of belt	Punch second row of holes from ends of belt	Centers of outer holes on the row nearest the ends of the belt to be distant from each edge of the belt	Size of lace leather to be used
2 to 4	3/8 in.	3/4 in.	3/8 in.	3/16 in.
6 to 8	1/2 "	1 "	1/2 "	1/4 "
10 to 12	5/8 "	1 1/4 "	5/8 "	5/16 "
14 to 16	3/4 "	1 1/2 "	3/4 "	3/8 "
18 to 20	7/8 "	1 3/4 "	7/8 "	7/16 "
22 to 24	1 "	2 "	1 "	1/2 "

GLUING EMERY TO WOOD OR METAL

A cement having great holding power in gluing emery to wood or metal, is made by melting together equal parts of shellac, white resin, and carbolic acid (in crystals), adding the carbolic acid after the shellac and resin have been melted.

TO KEEP TOOLS FROM RUSTING

Take two ounces of tallow and one ounce of resin; melt together, and strain while hot to remove the specks in the resin. Apply a slight coat on the tools with a brush, and this will keep off rust for any length of time.

TO PREVENT GLUE FROM CRACKING

Glue frequently cracks because of the dryness of the air in rooms warmed by stoves. The addition of a little chloride of calcium to glue will prevent this disagreeable tendency to cracking. Chloride of calcium has such powers of absorption that it attracts enough moisture to prevent the glue from cracking.

Table 24 will be found useful in reducing linear measurements in inches and fractions of inches to their decimal equivalents in feet.

It indicates the equivalent, in decimals of a foot, for 1/64 in., and for every increase of 1/64 in. in linear measurements up to 1 ft. For example, suppose we wish to find the value of 2⅝ in. expressed as a decimal of a foot. Reading down the column headed "2"" till we come to the cross-line marked "5-8" at the left, we find .2188. Thus,

2⅝ in.=.2188 ft.

TABLE 23

Heat and Power Equivalents

UNIT	EQUIVALENT VALUE IN OTHER UNITS
1 H. P. per hour=	.746 K. W. hour. 1,980,000 ft.-lbs. 2,545 heat units. 273,740 K. G. M. .175 lb. carbon oxidized with perfect efficiency. 2.64 lbs. water evaporated from and at 212° F. 17.0 lbs. water raised from 62° F. to 212° F.
1 H. P.=	746 Watts. .746 K. W. 33,000 ft.-lbs. per minute. 550 ft.-lbs. per second. 2,545 heat units per hour. 42.4 heat units per minute. .707 heat unit per second. .175 lb. carbon oxidized per hour. 2.64 lbs. water evaporated per hour from and at 212° F.
1 Heat Unit 1 (B. T. U.)=	1,055 Watt seconds. 788 ft.-lbs. 107.6 kilogram meters. .000293 K. W. hour. .000393 H. P. hour. .0000688 lb. carbon oxidized. .001036 lb. water evaporated from and at 212° F. A unit of heat (British thermal unit) is the quantity of heat required to raise 1 pound of water 1° Fahr. in temperature, at sea level.
1 Heat Unit per sq. ft. per minute=	.122 Watt per sq. inch. .0176 K. W. per sq. foot. .0236 H. P. per sq. foot.
1 lb. carbon oxidized with perfect efficiency=	14,544 heat units. 1.11 lbs. anthracite coal oxidized. 2.5 lbs. dry wood oxidized. 21 cubic feet illuminating gas oxidized. 4.26 K. W. hours. 5.71 H. P. hours. 11,315,000 ft.-lbs. 15 lbs. water evaporated from and at 212° F.
1 lb. water evaporated from and at 212° F.=	.283 K. W. hour. .379 H. P. hour. 965.2 heat units. 103,000 K. G. M. 1,019,000 Joules. 751,300 ft.-lbs. .0664 lb. of carbon oxidized perfectly.

TABLE 24—Equivalents, in Decimals of a Foot, for Inches and Fractions of Inches
(Calculated for each 1-64th in. difference, up to 1 ft.)

Inch	0″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″
0	0	.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167
1-64	.0013	.0846	.1680	.2513	.3346	.4180	.5013	.5846	.6680	.7513	.8346	.9180
1-32	.0026	.0859	.1693	.2526	.3359	.4193	.5026	.5859	.6693	.7526	.8359	.9193
3-64	.0039	.0872	.1706	.2539	.3372	.4206	.5039	.5872	.6706	.7539	.8372	.9206
1-16	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
5-64	.0065	.0898	.1732	.2565	.3398	.4232	.5065	.5898	.6732	.7565	.8398	.9232
3-32	.0078	.0911	.1745	.2578	.3411	.4245	.5078	.5911	.6745	.7578	.8411	.9245
7-64	.0091	.0924	.1758	.2591	.3424	.4258	.5091	.5924	.6758	.7591	.8424	.9258
1-8	.0104	.0937	.1771	.2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	.9271
9-64	.0117	.0951	.1784	.2617	.3451	.4284	.5117	.5951	.6784	.7617	.8451	.9284
5-32	.0130	.0964	.1797	.2630	.3464	.4297	.5130	.5964	.6797	.7630	.8464	.9297
11-64	.0143	.0977	.1810	.2643	.3477	.4310	.5143	.5977	.6810	.7643	.8477	.9310
3-16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
13-64	.0169	.1003	.1836	.2669	.3503	.4336	.5169	.6003	.6836	.7669	.8503	.9336
7-32	.0182	.1016	.1849	.2682	.3516	.4349	.5182	.6016	.6849	.7682	.8516	.9349
15-64	.0195	.1029	.1862	.2695	.3529	.4362	.5195	.6029	.6862	.7695	.8529	.9362
1-4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
17-64	.0221	.1055	.1888	.2721	.3555	.4388	.5221	.6055	.6888	.7721	.8555	.9388
9-32	.0234	.1068	.1901	.2734	.3568	.4401	.5234	.6068	.6901	.7734	.8568	.9401
19-64	.0247	.1081	.1914	.2747	.3581	.4414	.5247	.6081	.6914	.7747	.8581	.9414
5-16	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
21-64	.0273	.1107	.1940	.2773	.3607	.4440	.5273	.6107	.6940	.7773	.8607	.9440
11-32	.0286	.1120	.1953	.2786	.3620	.4453	.5286	.6120	.6953	.7786	.8620	.9453
23-64	.0299	.1133	.1966	.2799	.3633	.4466	.5299	.6133	.6966	.7799	.8633	.9466
3-8	.0312	.1146	.1979	.2812	.3646	.4479	.5312	.6146	.6979	.7812	.8646	.9479
25-64	.0326	.1159	.1992	.2826	.3659	.4492	.5326	.6159	.6992	.7826	.8659	.9492
13-32	.0339	.1172	.2005	.2839	.3672	.4505	.5339	.6172	.7005	.7839	.8672	.9505
27-64	.0352	.1185	.2018	.2852	.3685	.4518	.5352	.6185	.7018	.7852	.8685	.9518
7-16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
29-64	.0378	.1211	.2044	.2878	.3711	.4544	.5378	.6211	.7044	.7878	.8711	.9544
15-32	.0391	.1224	.2057	.2891	.3724	.4557	.5391	.6224	.7057	.7891	.8724	.9557
31-64	.0404	.1237	.2070	.2904	.3737	.4570	.5404	.6237	.7070	.7904	.8737	.9570
1-2	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
33-64	.0430	.1263	.2096	.2930	.3763	.4596	.5430	.6263	.7096	.7930	.8763	.9596
17-32	.0443	.1276	.2109	.2943	.3776	.4609	.5443	.6276	.7109	.7943	.8776	.9609
35-64	.0456	.1289	.2122	.2956	.3789	.4622	.5456	.6289	.7122	.7956	.8789	.9622
9-16	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
37-64	.0482	.1315	.2148	.2982	.3815	.4648	.5482	.6315	.7148	.7982	.8815	.9648
19-32	.0495	.1328	.2161	.2995	.3828	.4661	.5495	.6328	.7161	.7995	.8828	.9661
39-64	.0508	.1341	.2174	.3008	.3841	.4674	.5508	.6341	.7174	.8008	.8841	.9674
5-8	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
41-64	.0534	.1367	.2201	.3034	.3867	.4701	.5534	.6367	.7201	.8034	.8867	.9701
21-32	.0547	.1380	.2214	.3047	.3880	.4714	.5547	.6380	.7214	.8047	.8880	.9714
43-64	.0560	.1393	.2227	.3060	.3893	.4727	.5560	.6393	.7227	.8060	.8893	.9727
11-16	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
45-64	.0586	.1419	.2253	.3086	.3919	.4753	.5586	.6419	.7253	.8086	.8919	.9753
23-32	.0599	.1432	.2266	.3099	.3932	.4766	.5599	.6432	.7266	.8099	.8932	.9766
47-64	.0612	.1445	.2279	.3112	.3945	.4779	.5612	.6445	.7279	.8112	.8945	.9779
3-4	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792
49-64	.0638	.1471	.2305	.3138	.3971	.4805	.5638	.6471	.7305	.8138	.8971	.9805
25-32	.0651	.1484	.2318	.3151	.3984	.4818	.5651	.6484	.7318	.8151	.8984	.9818
51-64	.0664	.1497	.2331	.3164	.3997	.4831	.5664	.6497	.7331	.8164	.8997	.9831
13-16	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
53-64	.0690	.1523	.2357	.3190	.4023	.4857	.5690	.6523	.7357	.8190	.9023	.9857
27-32	.0703	.1536	.2370	.3203	.4036	.4870	.5703	.6536	.7370	.8203	.9036	.9870
55-64	.0716	.1549	.2383	.3216	.4049	.4883	.5716	.6549	.7383	.8216	.9049	.9883
7-8	.0729	.1562	.2396	.3229	.4062	.4896	.5729	.6562	.7396	.8229	.9062	.9896
57-64	.0742	.1576	.2409	.3242	.4076	.4909	.5742	.6576	.7409	.8242	.9076	.9909
29-32	.0755	.1589	.2422	.3255	.4089	.4922	.5755	.6589	.7422	.8255	.9089	.9922
59-64	.0768	.1602	.2435	.3268	.4102	.4935	.5768	.6602	.7435	.8268	.9102	.9935
15-16	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948
61-64	.0794	.1628	.2461	.3294	.4128	.4961	.5794	.6628	.7461	.8294	.9128	.9961
31-32	.0807	.1641	.2474	.3307	.4141	.4974	.5807	.6641	.7474	.8307	.9141	.9974
63-64	.0820	.1654	.2487	.3320	.4154	.4987	.5820	.6654	.7487	.8320	.9154	.9987

TABLE 25
Circumferences and Areas of Circles

OF ONE INCH.				OF INCHES OR FEET.					
Fract.	Dec.	Circ.	Area	Dia	Circ.	Area.	Dia.	Circ.	Area.
1-64	.015625	.04909	.00019	1	3.1416	.7854	64	201.06	3216.99
1-32	.03125	.09818	.00077	2	6.2832	3.1416	65	204.20	3318.31
3-64	.046875	.14726	.00173	3	9.4248	7.0686	66	207.34	3421.19
1-16	.0625	.19635	.00307	4	12.5664	12.5664	67	210.49	3525.65
5-64	.078125	.24545	.00479	5	15.7080	19.635	68	213.63	3631.68
3-32	.09375	.29452	.00690	6	18.850	28.274	69	216.77	3739.28
7-64	.109375	.34363	.00939	7	21.991	38.485	70	219.91	3848.45
1-8	.125	.39270	.01227	8	25.133	50.266	71	223.05	3959.19
9-64	.140625	.44181	.01553	9	28.274	63.617	72	226.19	4071.50
5-32	.15625	.49087	.01917	10	31.416	78.540	73	229.34	4185.39
11-64	.171875	.53999	.02320	11	34.558	95.033	74	232.48	4300.84
3-16	.1875	.58905	.02761	12	37.699	113.1	75	235.62	4417.86
13-64	.203125	.63817	.03241	13	40.841	132.73	76	238.76	4536.46
7-32	.21875	.68722	.03758	14	43.982	153.94	77	241.90	4656.63
15-64	.234375	.73635	.04314	15	47.124	176.71	78	245.04	4778.36
1-4	.25	.78540	.04909	16	50.265	201.06	79	248.19	4901.67
17-64	.265625	.83453	.05542	17	53.407	226.98	80	251.33	5026.55
9-32	.28125	.88357	.06213	18	56.549	254.47	81	254.47	5153.
19-64	.296875	.93271	.06922	19	59.690	283.53	82	257.61	5281.02
5-16	.3125	.98175	.07670	20	62.832	314.16	83	260.75	5410.61
21-64	.328125	1.0309	.08456	21	65.973	346.36	84	263.89	5541.77
11-32	.34375	1.0799	.09281	22	69.115	380.13	85	267.04	5674.50
23-64	.359375	1.1291	.10144	23	72.257	415.48	86	270.18	5808.80
3-8	.375	1.1781	.11045	24	75.398	452.39	87	273.32	5944.68
25-64	.390625	1.2273	.11984	25	78.540	490.87	88	276.46	6082.12
13-32	.40625	1.2763	.12962	26	81.681	530.93	89	279.60	6221.14
27-64	.421875	1.3254	.13979	27	84.823	572.56	90	282.74	6361.73
7-16	.4375	1.3744	.15033	28	87.965	615.75	91	285.88	6503.88
29-64	.453125	1.4236	.16126	29	91.106	660.52	92	289.03	6647.61
15-32	.46875	1.4726	.17257	30	94.248	706.86	93	292.17	6792.91
31-64	.484375	1.5218	.18427	31	97.389	754.77	94	295.31	6939.78
1-2	.5	1.5708	.19635	32	100.53	804.25	95	298.45	7088.22
33-64	.515625	1.6199	.20880	33	103.67	855.30	96	301.59	7238.23
17-32	.53125	1.6690	.22166	34	106.81	907.92	97	304.73	7389.81
35-64	.546875	1.7181	.23489	35	109.96	962.11	98	307.88	7542.96
9-16	.5625	1.7671	.24850	36	113.10	1017.88	99	311.02	7697.69
37-64	.578125	1.8163	.26248	37	116.24	1075.21	100	314.16	7853.98
19-32	.59375	1.8653	.27688	38	119.38	1134.11	101	317.30	8011.85
39-64	.609375	1.9145	.29164	39	122.52	1194.59	102	320.44	8171.28
5-8	.625	1.9635	.30680	40	125.66	1256.64	103	323.58	8332.29
41-64	.640625	2.0127	.32233	41	128.81	1320.25	104	326.73	8494.87
21-32	.65625	2.0617	.33824	42	131.95	1385.44	105	329.87	8659.01
43-64	.671875	2.1108	.35453	43	135.09	1452.20	106	333.01	8824.73
11-16	.6875	2.1598	.37122	44	138.23	1520.53	107	336.15	8992.02
45-64	.703125	2.2090	.38828	45	141.37	1590.43	108	339.29	9160.88
23-32	.71875	2.2580	.40574	46	144.51	1661.90	109	342.43	9331.32
47-64	.734375	2.3072	.42356	47	147.65	1734.94	110	345.58	9503.32
3-4	.75	2.3562	.44179	48	150.80	1809.56	111	348.72	9676.89
49-64	.765625	2.4054	.45258	49	153.94	1885.74	112	351.86	9852.03
25-32	.78125	2.4544	.47937	50	157.08	1963.50	113	355.	10028.75
51-64	.796875	2.5036	.49872	51	160.22	2042.82	114	358.14	10207.03
13-16	.8125	2.5525	.51849	52	163.36	2123.72	115	361.28	10386.89
53-64	.828125	2.6017	.53862	53	166.50	2206.18	116	364.42	10568.32
27-32	.84375	2.6507	.55914	54	169.65	2290.22	117	367.57	10751.32
55-64	.859375	2.6999	.58003	55	172.79	2375.83	118	370.71	10935.88
7-8	.875	2.7489	.60132	56	175.93	2463.01	119	373.85	11122.02
57-64	.890625	2.7981	.62298	57	179.07	2551.76	120	376.99	11309.73
29-32	.90625	2.8471	.64504	58	182.21	2642.08	121	380.13	11499.01
59-64	.921875	2.8963	.66746	59	185.35	2733.97	122	383.27	11689.87
15-16	.9375	2.9452	.69029	60	188.50	2827.43	123	386.42	11882.29
61-64	.953125	2.9945	.71349	61	191.64	2922.47	124	389.56	12076.28
31-32	.96875	3.0434	.73708	62	194.78	3019.07	125	392.70	12271.85
63-64	.984375	3.0928	.76097	63	197.92	3117.25	126	395.84	12468.98

TABLE 26

Upset Screw Ends for Round and Square Bars

Diameter of Round or Side of Square Bar Inches	Round Bars				Square Bars			
	Diam. of Upset Screw End Inches	Diam. of Screw at root of Thread Inches	Threads per Inch No.	Excess of Effective Area of Screw End Over Bar Per Cent	Diam. of Upset Screw End Inches	Diam. of Screw at root of Thread Inches	Threads per Inch No.	Excess of Effective Area of Screw End Over Bar Per Cent
1/2	3/4	.620	10	54	3/4	.620	10	21
9/16	3/4	.620	10	21	7/8	.731	9	33
5/8	7/8	731	9	37	1	.837	8	41
11/16	1	.837	8	48	1	.837	8	17
3/4	1	837	8	25	1 1/8	.940	7	23
13/16	1 1/8	.940	7	34	1 1/4	1.065	7	35
7/8	1 1/4	1.065	7	48	1 3/8	1.160	6	38
15/16	1 1/4	1.065	7	29	1 3/8	1.160	6	20
1	1 3/8	1.160	6	35	1 1/2	1.284	6	29
1 1/16	1 3/8	1.160	6	19	1 5/8	1.389	5 1/2	34
1 1/8	1 1/2	1.284	6	30	1 5/8	1.389	5 1/2	20
1 3/16	1 1/2	1.284	6	17	1 3/4	1.490	5	24
1 1/4	1 5/8	1.389	5 1/2	23	1 7/8	1.615	5	31
1 5/16	1 3/4	1.490	5	29	1 7/8	1.615	5	19
1 3/8	1 3/4	1.490	5	18	2	1.712	4 1/2	22
1 7/16	1 7/8	1.615	5	26	2 1/8	1.837	4 1/2	28
1 1/2	2	1.712	4 1/2	30	2 1/8	1.837	4 1/2	18
1 9/16	2	1.712	4 1/2	20	2 1/4	1.962	4 1/2	24
1 5/8	2 1/8	1.837	4 1/2	28	2 3/8	2.087	4 1/2	30
1 11/16	2 1/8	1.837	4 1/2	18	2 3/8	2.087	4 1/2	20
1 3/4	2 1/4	1.962	4 1/2	26	2 1/2	2.175	4	21
1 13/16	2 1/4	1.962	4 1/2	17	2 5/8	2.300	4	26
1 7/8	2 3/8	2.087	4 1/2	24	2 5/8	2.300	4	18
1 15/16	2 1/2	2.175	4	26	2 3/4	2.425	4	23
2	2 1/2	2.175	4	18	2 7/8	2.550	4	28
2 1/16	2 5/8	2.300	4	24	2 7/8	2.550	4	20
2 1/8	2 5/8	2.300	4	17	3	2.629	3 1/2	20
2 3/16	2 3/4	2.425	4	23	3 1/8	2.754	3 1/2	24

ENGLISH AND METRIC SYSTEMS

English Measures of Length

12 inches = 1 foot.
3 feet = 1 yard.
5½ yards = 1 rod.
40 rods = 1 furlong.
8 furlongs = 1 sta. mile.
3 miles = 1 league.

English Square Measure

144 sq. inches = 1 sq. foot.
9 sq. feet = 1 sq. yard.
30¼ sq. yards = 1 sq. rod.
40 sq. rods = 1 rood.
4 roods = 1 acre.
640 acres = 1 sq. mile.

English Cubic Measure

1,728 cub. in. = 1 cub. foot.
27 cub. ft. = 1 cub. yard.
2,150.42 cub. in. = 1 standard bushel.
1 cubic foot = about ⅘ of a bushel.
128 cu. ft. = 1 cord (wood).
40 cub. ft. = 1 ton (shpg.).
268.8 cub. in. = 1 standard gallon

English Measure of Heat Quantities

1 kilogram caloric = 3.968 British thermal units (B. T. U.).
1 pound caloric = 1.8 British thermal units (B. T. U.).
1 British thermal unit (B. T. U.) = 0.555 pound caloric.
1 British thermal unit (B. T. U.) = 0.252 kilogram caloric.

METRIC SYSTEM

Prefixes of Multiples and Sub-Multiples of Meter, Liter, and Gram

Deka = 10
Hecto = 100
Kilo = 1,000
Deci = 0.1
Centi = 0.01
Milli = 0.001

10 millimeters = 1 centimeter.
10 centimeters = 1 decimeter.
10 decimeters = 1 meter.
10 meters = 1 dekameter.
10 dekameters = 1 hectometer
10 hectometers = 1 kilometer.

METRIC EQUIVALENTS

Linear Measure

1 centimeter = 0.3937 in.
1 decimeter = 3.937 in. = 0.328 ft.
1 meter = 39.37 in. = 1.0936 yards.
1 dekameter = 1.9884 rods.
1 kilometer = 0.62137 mile.
1 in. = 2.54 centimeters or 0.254 meter
1 ft. = 3.048 decimeters or 0.3048 meter
1 yard = 0.9144 meter.
1 rod = 0.5029 dekameter.
1 mile = 1.6093 kilometers.

Surface or Square Measure

1 sq. centimeter = 0.1550 sq. in.
1 sq. decimeter = 0.1076 sq. ft.
1 sq. meter = 1.196 sq. yds.
1 are = 3.954 sq. rods.
1 hektar = 2.47 acres.
1 sq. kilometer = 0.386 sq. mile.
1 sq. inch = 6.452 sq. centimeters.
1 sq. foot = 9.2903 sq. decimeters.
1 sq. yard = 0.8361 sq. meter.
1 sq. rod = 0.2529 are.
1 sq. acre = 0.4047 hektar.
1 sq. mile = 2.59 sq. kilometers.

Measure of Volume and Capacity

1 cu. centimeter = 0.061 cu. in.
1 cu. decimeter = 0.0353 cu. ft.
1 cu. meter, 1 ster = 1.308 cu. yards; 0.2759 cord.
1 liter = 0.908 quart dry; 1.0567 quarts liq.
1 dekaliter = 2.6417 gallons; .135 peck.
1 hektoliter = 2.8375 bushels.
1 cu. inch = 16.39 cu. centimeters.
1 cu. foot = 28.317 cu. decimeters.
1 cu. yard = 0.7646 cu. meter.
1 cord = 3.624 sters.
1 quart dry = 1.101 liters.
1 quart liq. = 0.9463 liter.
1 gallon = 0.3785 dekaliter.
1 peck = 0.881 dekaliter.
1 bushel = 0.3524 hektoliter.

Weights

1 gram = 0.03527 ounce.
1 kilogram = 2.2046 lbs.
1 metric ton = 1.1023 English tons of 2,000 lbs.
1 ounce = 28.35 grams.
1 lb. = 0.4536 kilogram.
1 English ton = 0.9072 metric ton.

TABLE 27

Weight and Strength of Chain

(Godfrey's Tables)

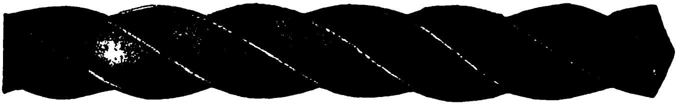
Nominal Diameter of Wire (Inches)	Description	Specification		
		Maximum Length of 100 Links (Inches)	Weight per Foot (Pounds)	Breaking Weight (Pounds)
1/4	Straight-link chain...	102	0.70	3,200
5/16	" " " ..	114 3/4	1.10	5,000
3/8	" " " ..	114 3/4	1.60	7,200
3/8	Crane chain........	113 5/8	1.60	8,280
7/16	Straight-link chain...	127 1/2	2.07	9,800
7/16	Crane chain.........	126 1/4	2.07	11,270
1/2	Straight-link chain...	153	2.50	12,800
1/2	Crane chain.........	151 1/2	2.60	14,720
5/8	Straight-link chain...	178 1/2	4.08	20,000
5/8	Crane chain.........	176 3/4	4.18	23,000
3/4	Straight-link chain...	204	5.65	28,800
3/4	Crane chain.........	202	5.75	33,120
7/8	" "	252 1/2	7.70	45,080
1	" "	277 3/4	9.80	58,880
1	Straight-link chain...	280 1/2	9.80	51,200
1 1/8	Crane chain.........	303	12.65	76,520
1 1/4	" "	353 1/2	15.50	92,000
1 1/2	" "	416 5/8	22.50	132,480
1 3/4	" "	479 3/4	30.00	180,320
2	" "	555 1/2	39.00	235,520

Crane chains of wrought iron. Straight link chains of either wrought iron or steel.

Proof test = 1/2 breaking weight.

Working load = 1/3 breaking weight.

Modern Frame Dwelling.
For bill of materials, see page 168.

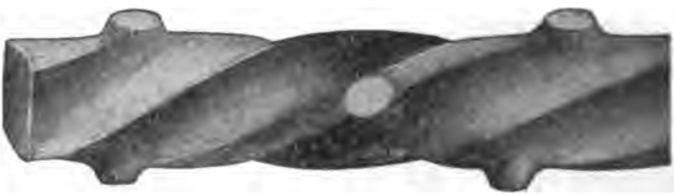


Ransome Twisted Bar.

Cup Bar.

Johnson or Corrugated Bar.

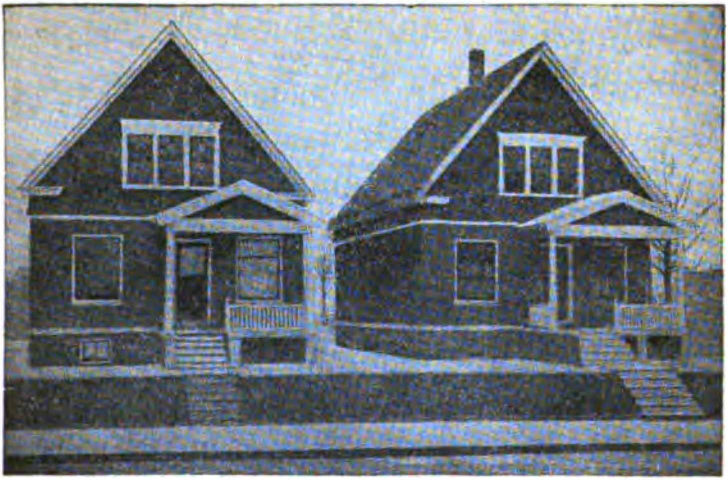
Diamond Bar.



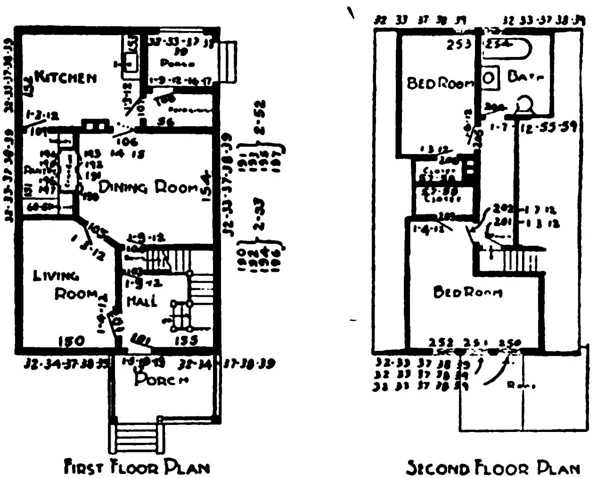
Twisted Lug Bar.

Types of Deformed Bars.

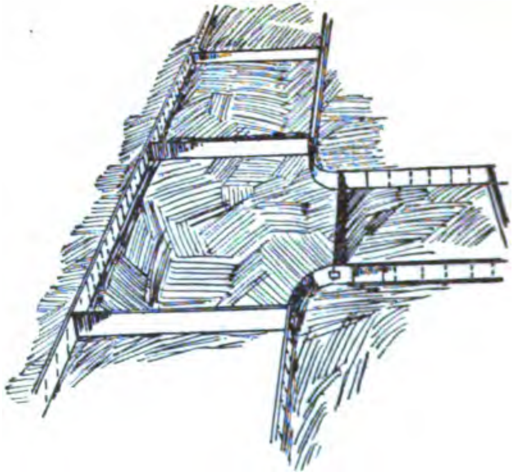
PLATE II—Estimating and Contracting.

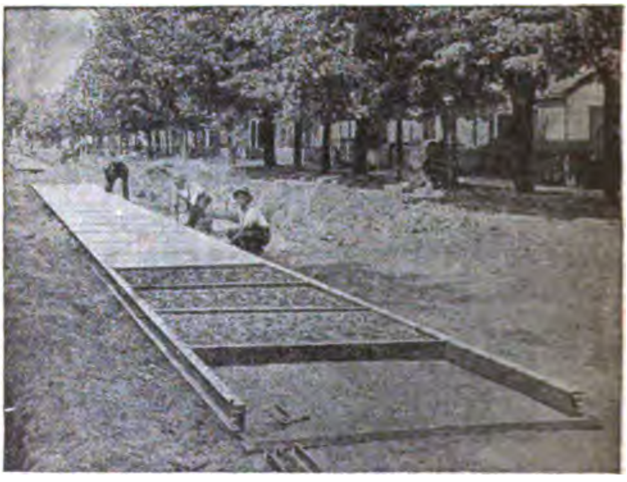


Workingmen's Houses Built of Solid Reinforced Concrete.



House Plans Showing Layout of Hardware Items Needed.





Concrete Sidewalk Construction, Using Steel Forms.

PLATE IV—Estimating and Contracting.

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