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ESTIMATING BUILDING COSTS

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CHARLES F. DINGMAN

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ESTIMATING BUILDING COSTS

BY

CHARLES F. DINGMAN

Architectural Engineer

THIRD EDITION
SEVENTH IMPRESSION

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ESTIMATING BUILDING COSTS

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PREFACE

During the years that have elapsed since the publication of the previous editions of this book, many important developments have taken place in the manner of doing construction work, particularly in the methods of handling excavation and related work, and these developments have dictated the entire revision of the relevant text.

In making the revision, it was considered advisable to cover much more completely the entire subject of earth handling and moving, so that the data given would be applicable to building operations of practically any scope and size, as well as to many construction operations other than building alone. The extensive treatment presented here was made possible by the cooperation of several manufacturers of excavating and transporting equipment, as well as by that of several men actually engaged in the work.

Recent developments in the handling and finishing of concrete have made it advisable to rewrite practically the entire text on that subject and to add much new material which was not included in the previous editions. Here, again, the cooperation of the manufacturers of materials and equipment, as well as that of several practical concrete men, has helped to make the text complete.

Entirely new chapters on plumbing and heating have been added. Although it is recognized that few general building contractors actually estimate their own plumbing and heating work, there are some who do. A knowledge of the methods of estimating plumbing and heating is bound to be helpful to any building estimator, while the man who is to specialize in estimating either or both of these branches will find here a method of analyzing work and estimating its cost that should be extremely useful.

CHARLES F. DINGMAN.

PALMER, MASS.,
September, 1944.

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CHAPTER 1

INTRODUCTION

The present volume is the result of about 40 years consideration as to the best method of presenting, to the ambitious young men in the building profession, the rudiments of the knowledge required to become competent estimators.

No single book can make a competent estimator of any man, and no claim is made that this book will accomplish that result, but a diligent study of the methods laid down and the principles expounded will develop the necessary habits of thought which, combined with practical experience and keen observation, will enable the student to become such an estimator.

The successful estimator is essentially a visualizer; he must be able to take a set of plans and specifications, with the quantity survey, and mentally see the several parts of the building put together. If he cannot do that, all the data available are not always sufficient to keep him from making an estimate that is far too low or far too high.

It is not intended that this book shall be primarily a "data book," though it necessarily contains a great deal of estimating data, much of it presented in tabular form. Nor is it intended that this book replace or supersede any of the many excellent reference books and handbooks that have been published for estimators' use.

Those books are essentially data books and are intended for use only by men who already possess a competent knowledge of estimating principles or who, in the capacity of appraisers or adjusters, want to arrive at figures very quickly.

This volume is intended for the less experienced man, to train him to analyze every construction job into its component parts, to apply his cost data, adjusted to existing conditions, to the several necessary operations and thus to calculate a price that will approach the actual cost of doing the work as closely as is humanly possible.

Naturally, in a work of this size, the treatment is not exhaustive, since entire volumes have been published on the subjects of earth and rock excavation alone, and similar volumes have been published on concrete work and brickwork. Carpenter work could well fill an equally large volume.

However, each subject has been treated at sufficient length to enable the reader to get a clear insight into the factors involved, their relative importance, and the methods to be employed in estimating their cost.

There are two general methods employed in preparing an estimate; one method is to summarize all of the costs involved in a unit quantity of the item under consideration, then to multiply the figures thus derived by the number of units. The other method is to calculate the total quantities of materials and labor needed to complete the operation and multiply by their individual costs to determine the total estimated cost of the operation.

The first method has the advantage of presenting the information in a form that makes it possible readily to adjust the estimate for reductions or increases in quantities, if any are made. It is probably the handier method for use by an experienced estimator whose training is such that he will be certain to include all the accessory costs in his unit prices.

For the student, the second method seems better and is used throughout the text, but it is well to form the habit of resolving all totals back to unit prices, as this affords an opportunity for a mental check on your work, a means of comparison with other estimates and a method of following the trend of costs in each department of work.

Such subjects as electrical wiring, mechanical equipment of buildings, and other specialties have not been included at all because it is not considered a safe practice for a builder to attempt to estimate those items himself. Sub-bids should always be secured from specialists in those lines, who will be competent to evaluate properly all specification requirements, as well as current market and labor conditions. No matter how competent a building estimator may be in his own field, it is not reasonable to expect him to have an intimate knowledge of the business of all of the specialists with whom he will have to deal.

It will be noted, in working out many of the examples in the text, that fractional quantities have been increased to full quantities and fractional hours to full hours. The present status of refinement in the methods of handling materials and administering labor on construction work is not such as to warrant too great a refinement in estimating methods, and the percentage of error thus introduced is not sufficiently large to affect the results of bidding.

Price lists have not been included in the text because it is deemed essential that the estimator in active practice should always obtain the current prices on all materials directly from his sources of supply, since he will thereby eliminate a very important source of error.

For instance, it might be very interesting to an estimator to have a price list of the various sizes of steel sash, together with information as to the manufacturers' methods of pricing. But there is no practical advantage in having the list, since prices change and local conditions affect sales policies and since there is seldom an occasion that does not allow time for obtaining prices directly from manufacturers or dealers.

One thing that this book attempts to accomplish is to induce estimators to pay more attention to the method of obtaining and recording data on the basis of production per man-hour rather than on that of the money cost per unit.

The possible production per man-hour is a reasonably constant quantity but money costs vary with every market change and, unless every condition is properly recorded, money costs reported for one operation may not be of any use in estimating the cost of a similar operation performed under different circumstances.

CHAPTER 2

EXCAVATING, GRADING, BRACING, HAULING

SECTION 1. MACHINE EXCAVATING

Methods of excavation on all kinds of construction work have changed so much during the past few years that an estimating procedure which would formerly produce accurate results is now of no use at all. Not long ago, practically all excavation on moderate-sized building construction jobs was done by hand, and an ordinary house-cellar excavation was a job of several days' duration. Present methods, using either a truck-mounted crane or a power shovel with motor trucks to dispose of the spoil, permit an excavation to be started in the morning and finished before noon.

With these newer methods in mind, an estimating procedure has been developed that is applicable to the wide variety of work encountered by a contractor having a modern equipment of power shovels, motor trucks and similar machinery. It formerly was customary to keep a record of what each job cost per unit in money and to use that cost as a basis for bidding on new work, but, because wage rates change and no two jobs are exactly alike, that method is no longer sufficiently accurate. The two principal fields of activity for an excavating contractor are road construction and building construction, and particular stress has been laid on those branches. It is obvious, however, that the same method of estimating may be applied to any other branch of construction work, provided due consideration be given to all local conditions which will govern the cost.

In keen competition, as has been in evidence on most of the larger recent contract lettings, a difference of a cent a yard in the estimated cost of digging may be an important factor in determining the award of a contract. This makes it necessary to know, as nearly as possible, exactly what it costs to get the earth out, but when it is realized that power shovels (whether steam, gasoline or diesel engine driven) seldom work up to their ultimate capacity, the importance of keeping accurate records as a basis for comparing new estimates with previous similar jobs is apparent. Carefully made time studies on actual work show that it would be possible to dig from two to four times as great a yardage with most power shovels as is claimed by the manufacturers in rating their shovels for hourly or daily capacity. This maximum yardage would, of course, be attainable only in a freely excavated material, by a very skillful operator, and with trucks or other disposal arrangements organized so as to cause no delays in shoveling.

The figures given here will be based, as nearly as possible, on conditions attainable on ordinary work, but it is necessary that any estimator, in adapting any estimating method to his own purposes, compile accurate performance records of his own equipment and operators and classify his data in accordance with the arrangement used here, so that comparison will be simplified. Actually, almost any power shovel working in loose material can handle three dipperfuls per minute, which would mean that the maximum capacities would be as in Table 1.

TABLE 1.—MAXIMUM CAPACITIES OF POWER SHOVELS

Rated size of shovel, cu yd	Capacity per minute, cu yd	Hours of work required per 100 cu yd
¾	2.25	0.75
1	3.00	0.56
1¼	3.75	0.45
1½	4.50	0.38
1¾	5.25	0.32
2	6.00	0.28

Based, however, on data collected from a wide variety of sources and from many different jobs, it appears that under the ordinary conditions of organization and operation on contract work, a sustained average of one dipperful per minute all during the working day is about the limit that can be expected, except in those rare instances where the spoil can be wasted without moving the shovel and without the intervention of trucks or other means of transportation. On the basis of one dipperful per minute for loose materials, and the appropriate reductions in capacity for other materials that experience has shown to be actual fact, Table 2 has been constructed. Among the causes of reductions in capacity are partially filled dippers, retarded digging motion and ineffectual movements of the dipper. While the first table expresses what might be done, the second table expresses the maximum efficiency upon which the estimator would dare to figure.

TABLE 2.—ACTUALLY DEVELOPED CAPACITIES OF POWER SHOVELS

Rated size of shovel, cu yd	Manufacturer's rating, cu yd per hr	Actual time required to dig 100 cu yd			
		Sand or loose loam	Medium soil	Heavy soil or clay	Hard pan
½	40	3.33	3.98	5.80	7.48
¾	60	2.25	2.77	4.04	5.05
1	80	1.68	2.00	3.03	3.77
1¼	100	1.35	1.61	2.42	3.06
1½	120	1.14	1.35	2.05	2.56
1¾	140	0.96	1.16	1.74	2.18
2	160	0.84	1.00	1.51	1.83

The number of hours given in Table 2 is based upon the assumption that the cut is being made into a bank deep enough to permit full digging motion of the dipper and full capacity per dipper. This can seldom be attained with a bank under 2 ft deep for the smaller shovels and 3 to 4 ft deep for the larger shovels. Thus, a shovel cannot do so well when digging the subgrade for a road as it can when digging out a bank. For shovels up to 1½ cu yd capacity, which are about as large as are used on ordinary construction work, the number of hours given in Table 2 should be increased in accordance with Table 3 for additional time in shallow banks or cuts.

TABLE 3.—ADDITIONAL TIME IN SHALLOW CUTS

For Depth of Cut, In.	Multiply Time in Table 2 by
18	1.20
12	1.50
6	2.25

The method for determining an hourly cost for any shovel will be developed later, but for the present it will be assumed, for convenience, that on the work in question the cost of shovels on the job would be as follows:

½ cu-yd shovel	$4 per hr
¾ cu-yd shovel	5 per hr
1 cu-yd shovel	6 per hr
1¼ cu-yd shovel	7 per hr
1½ cu-yd shovel	8 per hr

Then it follows that the cost of digging out 100 cu yd of material, using the quantities of time as indicated in Table 2, would be as shown in Table 4.

When the actual hourly rate for the shovel is known, the cost per 100 cu yd can, of course, be determined either directly by multiplying the number of hours in Table 2 by the rate or proportionally by comparing with the cost in Table 4, using the formula

$$\frac{\text{Actual hourly rate}}{\text{Rate in Table 4}} \times \text{cost in Table 4} = \text{actual cost}$$

Digging by other methods than power shoveling will be considered later on.

TABLE 4.—COST OF EXCAVATING 100 CU YD OF EARTH

Rated size of shovel, cu yd	Assumed cost per hour	Cost of digging 100 cu yd			
		Sand, loose loam or gravel	Medium soil	Heavy soil or clay	Hard pan
½	$4.00	$13.32	$15.92	$23.20	$29.92
¾	5.00	11.12	13.85	20.20	25.25
1	6.00	10.08	12.00	18.18	22.62
1¼	7.00	9.45	11.27	16.92	21.42
1½	8.00	9.12	10.80	16.40	20.48

SECTION 2. HAULING

After the material has been dug, the "spoil," as it is called, must be disposed of, and it often happens that the cost of disposal will be several times the cost of digging. In building construction, the spoil may be disposed of simply by dumping at some selected point or even by selling the earth to a purchaser who desires it for filling up some land which he may be developing but, on highway work, the price bid for excavation may have to include the delivery to a determined location and the spreading and compacting of it there.

In either case, the cost of hauling is a major item and, since motor trucks are most commonly used for that purpose, the cost of hauling by that means will be considered first. The speed at which the vehicle can move and the load which it can carry are, with the time taken for turning, loading and dumping, the factors which determine the cost of hauling. Materials as loaded into trucks "bulk" up and therefore weigh less and require more space than they do in their natural positions, but, as payment on unit price work is customarily based upon bank measurement, or measurement before excavating, it is necessary to base all costs on bank measurement. The materials encountered in excavation vary appreciably in weight. This, of course, affects the amount that can be handled in a load and that, in turn, affects the cost of hauling. The comparative weights of some of the materials frequently found in excavation are given in Table 5.

TABLE 5.—AVERAGE WEIGHTS OF EARTH

Type of earth	Lb per cu yd		Cu yd per ton
	Packed	Loose	Loose
Dry loam	2,700	2,160	0.92
Moist loam	2,700	2,430	0.83
Mud	3,240	.....	0.62
Gravel	2,970	2,700	0.74
Sand	3,240	2,700	0.74
Shale	4,320	2,700	0.74

With these weights, and allowing that trucks be loaded only to their rated capacities, the maximum yardage per trip would be as figured in Table 6. Of course, there are conditions under which a contractor may feel justified in overloading his trucks in order to reduce the cost per yard of excavation, even though he knows that eventually his present saving will all be used up in short life or increased maintenance cost of the equipment.

TABLE 6.—YARDAGE PER TRIP IN MOTOR TRUCKS

Rated capacity, tons	Yardage				
	Dry loam	Moist loam	Mud	Sand or gravel	Hard pan or shale
1	0.92	0.83	0.62	0.74	0.74
1½	1.36	1 25	0.93	1.11	1.11
2	1.86	1.66	1.24	1.48	1.48
3½	3.22	2.91	2.17	2.59	2.59
5	4.60	4.15	3.10	3.70	3.70

To make it possible to use these figures without division when estimating, they have been converted as in Table 7. Many offices are equipped with the key-driven types of computing machines, by which it is much simpler and quicker to multiply than it is to divide. It is well, therefore, to have all data arranged so that they may be used by multiplication only.

TABLE 7.—MOTOR TRUCK TRIPS PER 100 CU YD

Rated capacity, tons	Trips per 100 cu yd				
	Dry loam	Moist loam	Mud	Sand or gravel	Hard pan or shale
1	109	121	161	136	136
1½	74	80	108	91	91
2	54	61	81	68	68
3½	32	34	47	39	39
5	22	25	33	27	27

Obviously the time taken to turn around, load, dump, wait for place under the shovel, and all similar operations, is practically the same regardless of the length of the haul, except that where the haul is very short there is likely to be a bunching of trucks at the shovel. Proper organization of the job would mean the balancing of the number of trucks to the capacity of the shovel, and the costs here given are worked out on the basis of proper balance. It is also necessary that the size of the shovel and capacity of the trucks be in balance, so that, ordinarily, large trucks would be used where the shovel is large and the haul long, while smaller trucks would be used where the shovel is small and the haul short. Then, the average truckload would require 6 min for waiting, turning, backing in, loading and getting under way. Three minutes should cover the time required to turn, dump and start back. Truck speeds are greater now than formerly and may be safely figured at 5 mph on newly excavated surfaces, 10 mph on compacted surfaces, 15 mph on rolled subgrades, 25 mph on paved roads and 30 mph on concrete roads. At these speeds the time required to travel a given distance is as given in Table 8, in each case 0.15 hr has been added to cover the time taken in turning, backing, loading and dumping.

TABLE 8.—MOTOR TRUCK TIME IN HOURS PER TRIP

(1) Road surface	(2) Assumed speed, mph	(3) First ¼ mile	(4) Each additional ¼ mile	(5) First mile	(6) Each additional mile
New excavation....	5	0.20	0.05	0.35	0.20
Compacted surface.	10	0.175	0.025	0.25	0.10
Rolled subgrade....	15	0.167	0.017	0.216	0.060
Paved road........	25	0.16	0.01	0.19	0.04
Concrete.....	30	0.159	0.009	0.184	0.034

Since the kind of roadway or other surface over which the hauling must be done will have an important bearing on the cost, it is necessary to take into consideration the kind of surfaces to be traversed, as it might happen that part of the trip between the shovel and the dump could be made over good roads, while in other cases it might happen that all the trip would be over newly excavated or newly placed surfaces. On one road job recently estimated, the new line being a cutoff, it was found more economical to use the old road, which was still in good condition, than to drive over the new work except for short distances. Assuming an instance where the material could be taken from the shovel to the existing highway in less than ¼-mile distance, then 2 miles along a paved highway, and then ½ mile over compacted surface to dump, the time per trip would figure thus:

First ¼ mile, new excavation, from col. (3)	0.20 col. (4)	0.05
2 miles on paved road, from col. (6)......	0.08 col. (6)	0.08
Last ½ mile on compacted surface, from col. (6)........................	0.05 col. (6)	0.05
Time per trip......................	0.33 hr plus	0.18 hr

Assuming a rate of $3 per hour for a 5-ton truck, which rate is current in many places, the cost of hauling 100 cu yd of sand or gravel over the route just mentioned would be

27 trips @ 0.51 hr @ $3.00 per hr = $41.31

The method for determining the hourly cost of trucks will be developed later on.

SECTION 3. SPREADING AND TRIMMING

The necessity for any sort of spreading or trimming at the place of disposal is determined by the specifications under which the work is being done. Where the spoil is simply being used to fill up a hollow place, skillful handling of the trucks may practically eliminate the necessity for any spreading or trimming at the dump. On highway work, however, it is customary to specify that the spoil is to be spread and compacted at the point of delivery. A crawler-type tractor, with bulldozer attachment, is the most commonly used device for this purpose, since the crawler tread serves as a very efficient means of compacting the spoil as it is being spread by the bulldozer. The bulldozer attachment is really a large scraperlike blade, heavy enough to stand hard pushing. The capacity of such a machine varies with the thickness of layers allowed by the specifications, since thin layers, while affording a greater degree of compaction, will require a greater number of passages of the machine over the area being worked.

A 6-in.-thick layer is practically standard, though the first layer, when on soft or springy soil, may be made thicker, so as to afford a better bearing for the trucks and the spreading machinery. A bulldozer will spread 60 cu yd per hr, so that 1.67 hr of time will be required to spread each 100 cu yd excavated and delivered. Allowing an hourly rate of $3, the cost per 100 cu yd is then

$$1.67 \times \$3.00 = \$5.01$$

Rolling.—Frequently the specifications require that the earth, when used as filling, must be spread in layers and then rolled, but it has become customary not to insist upon the rolling if the crawler-type tractor is used in spreading. Rollers never work to full capacity on most jobs but, where one is required, it would be necessary to figure it for the same time and at the same rate as the bulldozer.

Unit Price.—When the estimator has determined the number of hours for which he will need a given machine, he must know how much that machine will cost per hour. So far in this section it has been assumed that unit hourly rates could be established for each piece of construction machinery and those rates applied to determine the costs per unit of work. As will be shown later, those rates can be established so as to cover the original cost of the machine, interest, depreciation, maintenance, operation, transportation, insurance and lost time. Of course, the rates will vary for each job and must be determined for each estimate, unless the equipment is hired at a flat rate per hour.

This method seems more satisfactory when bidding on work which is to be let on unit price bases than it would be to estimate those rather indeterminate costs and then distribute them over the yardage or other division into units. Taking the cost of digging sand or gravel with a 1-cu-yd shovel from Table 4 and the cost of transporting it as outlined in the discussion of Table 8, the cost per 100 cu yd would be

Digging	$10.08
Hauling	41.31
Spreading	5.01
Rolling	5.01
Overhead and profit, 10%	6.14
	$67.55

making 68 cents per cubic yard a fair price to bid on that item.

Scraper Work.—Where the cuts are comparatively shallow and the distances to be traveled are short, tractor-drawn scrapers show very favorable results. (The scraper is a scooplike device, made of heavy steel construction and equipped with a lever so that it may be dumped by the tractor operator from his seat.) This is especially so in building foundation work, when the depth of the cellar is not over 8 ft, the area covered is fairly large, and the spoil can be left in piles around the site. The information given in Table 9 is from actual timing on a limited number of operations and is as accurate as it is possible to get. Due allowance was made in the figures for turning, dumping and other causes of lost time.

TABLE 9.—TRACTOR-DRAWN SCRAPER EXCAVATION

Length of haul, ft	Hours per 100 cu yd	
	Loose material	Firm material
50	2.6	2.9
100	4.3	4.5
150	5.6	6.1
200	8.5	9.1

SECTION 4. TRENCHING

The cost of excavating with a trenching machine will vary with the width of the trench excavated, tending to become less per cubic yard as the width becomes greater. This is because the speed of operation is not necessarily reduced in proportion to the increased width of the trench. Table 10 has been constructed for use in figuring costs of trenches when they are of a sufficient length to warrant the use of a trenching machine. The ordinary trenching machine is simply an adaption of the bucket-type elevating conveyor. It is equipped for mobile operation along the trench and frequently has a belt conveyor discharging the excavated material to a spoil bank at the side.

TABLE 10.—EXCAVATING BY TRENCHING MACHINE

Width of cut, in.	Hours per 100 cu yd			
	Loam, sand or gravel	Medium soil	Heavy soil or clay	Stiff clay
10	7	8	11	14

Excavating with Loader.—For any loose material, such as sand or gravel, it is frequently possible to show great economy by the use of a creeper-mounted conveyor-type loader, as such a machine keeps crowding into the bank and has a practically continuous delivery. Allowing for the time taken in getting the trucks into position and moving them out of the way, the time required for digging 100 cu yd of material is 2.25 hr.

SECTION 5. EXCAVATION BY HAND

In building construction, hand excavation is coming more and more to be limited to trenches for footings or piping, and to pits for column footings, meters, traps or

TABLE 11.—HAND EXCAVATION, GENERAL WORK

Type of soil	Hours per 100 cu yd				
	Dry	Wet	Plowed or loosened	Trenches	Pier
Sand or loam.......	89	124	80	182	196
Ordinary medium soil.............	124	250	83	322	344
Heavy soil or clay..	222	333	106	416	435
Hard pan..........	250	400	118	500	526

similar utilities. In road work, it is coming to be limited to the excavation to be done in connection with the installation of sewers and drains and, even then, it is often possible to use the trenching machine. Table 11 indicates the time

TABLE 12.—PLOWING

Type of soil	Hours required to loosen 100 cu yd		
	Two-horse plow	Four-horse plow	Tractor plow
Topsoil	2.50	....	1.18
Ordinary medium soil	2.86	....	1.34
Heavy soil	3.00	....	1.45
Soft clay	5.00	....	2.22
Stiff clay	....	5.00	2.86

required for pick and shovel work, while the column headed "Plowed or loosened" indicates the decreased time necessary, and thus the saving to be made when the soil has been

TABLE 13.—WHEELING

Type of soil	Man-hours to move 100 cu yd			
	25 ft	50 ft	75 ft	100 ft
Sand or loam, dry	14	28	42	56
Sand or loam, wet	16	32	48	64
Medium soil, dry	15	30	45	60
Medium soil, wet	18	36	54	72
Heavy soil or clay, dry	17	34	51	68
Heavy soil or clay, wet	21	42	63	84
Hard pan	18	36	54	72

broken up by a plow, so that the laborer may devote his time to actual digging and have to do the minimum amount of picking.

The cost of the plowing must, of course, be included in the cost of excavating 1 cu yd of earth, and the cost of that operation is indicated by Table 12.

In some small work, such as cellars of small houses, and excavations for porch posts or walks, the excavated material might be conveyed to the place of disposal by means of wheelbarrows. Table 13 shows how the cost of such disposal would be estimated.

Backfilling.—On highway work, where backfilling around culverts or drains is of such a nature that the work can best be done by hand, and it is required that the filling be closely tamped in, the figures in Table 14 should be used.

TABLE 14.—BACKFILLING AND TAMPING BY HAND

Type of soil	Hours of laborer's time per 100 cu yd	
	Backfilling	Tamping
Sand or loam..........	40	80
Ordinary medium soil..	50	100
Heavy soil or clay......	66	132
Hard pan.............	70	140

Table 14 also covers such backfilling as would be done in connection with building construction, and, when cinders, gravel or crushed stone is required for all or part of the backfilling, the time required is the same as for sand. Frequently, in building construction, the tamping is avoided, and instead a stream of water under pressure, from a fire hose and nozzle, is employed to secure an even greater compaction of the fill than is possible with hand tampers. Most backfilling on highway work, except in connection with culverts, drains, catch basins and manholes, can be done with the bulldozer as discussed in the paragraphs headed Spreading and Trimming. Backfilling of long trenches, where the volume warrants it, can be done with a backfilling machine or a bulldozer, and, assuming that the material was left alongside the trench or is delivered there in quantities great enough to keep the machine working to capacity, Table 15 can be used to determine the cost. Table 15 can also be used to determine the cost when using a power shovel of the "excavator" type.

TABLE 15.—BACKFILLING BY MACHINE

Type of soil	Machine-hours per 100 cu yd	
	Backfiller	Excavator
Loam, sand or gravel...	3	3.5
Medium soil............	3.5	4
Heavy soil or clay.......	5	6

Hauling by Tractors and Wagons.—While the motor truck has practically displaced all other means of hauling on road construction, tractor-drawn dump wagons show very satisfactory results in some parts of the country. On building work, trucks are used almost exclusively. Depending upon the size and type of tractor used, the design of the wagons and the local conditions encountered, a tractor can satisfactorily move from one to three wagons. The wagons will not be the ordinary 1- and 2-cu yd type which can be pulled by horses, but will be of 7 or 8 cu yd capacity each and built heavily enough to stand the punishment they get by being pulled by the tractor over rough surfaces at fairly high speeds.

The speeds are lower than for truck hauling and it is seldom allowable to move such trains over roads which have already been improved. In figuring the length of haul at least 200 ft for each wagon in the train must be allowed for turning. On nearly level ground, the tractor must be big enough to deliver 30 hp per wagon hauled, and 40 to 45 hp per wagon will be needed where there are any steep grades encountered, as at dumps or borrow pits. The hourly cost of such a train will be found by adding the hourly cost of the tractor and the hourly cost per wagon for the number of wagons drawn. Table 16 shows the time required per trip and is based upon a maximum traveling speed of 10 mph. The time for the return trip is calculated from the column headed "Each additional 1,000 ft," as the loading, turning, dumping and waiting time has been included in the time figured for the first 1,000 ft.

TABLE 16.—HAULING BY TRACTOR AND DUMP WAGON

Make-up of train	Trips per 100 cu yd				
	Dry loam	Moist loam	Mud	Sand or gravel	Hard pan or shale
7 yd capacity, 1 wagon..	15	17	22	18	18
7 yd capacity, 2 wagons..	7.5	8.5	11	9	9
7 yd capacity, 3 wagons..	5	5.7	7.4	6	6
8 yd capacity, 1 wagon..	13	15	19	16	16
8 yd capacity, 2 wagons..	6.5	7.5	9.5	8	8
8 yd capacity, 3 wagons..	4.4	5	6.4	5.4	5.4

When the number of trips required to move a given quantity of spoil and the distance to the point of disposal are known, the total time can be readily determined by using Table 17.

TABLE 17.—TRACTOR TRAIN TIME IN HOURS PER TRIP

Make-up of train	First 1,000 ft	Each additional 1,000 ft
Tractor and 1 wagon........	0.225	0.075
Tractor and 2 wagons.......	0.300	0.075
Tractor and 3 wagons.......	0.375	0.075

Elevating Grader.—On comparatively shallow cuts, an elevating grader loading directly into trucks or wagons is a very satisfactory method of digging. Table 18 affords the means for figuring the cost, based upon the usual assumption that the job is well organized as to means of carrying the spoil away. It is noticeable here that the elevating grader produces its best results in comparatively loose soil and, because it is adapted only for shallow cutting, its field is in highway construction and not in building construction.

TABLE 18.—EXCAVATING BY ELEVATING GRADERS
(Hours per 100 cu yd)

Sand or loam	Medium soil	Heavy soil or clay	Hard pan gumbo
1.5	1.9	2.7	3.5

Truck-mounted Cranes.—For cellar excavations for small houses, especially where the soil is loose or free digging, the most satisfactory digging device thus far developed is a crane equipped with a clamshell bucket and mounted on a motor truck. One important feature of this equipment is its easy mobility, so that it can be used on one job in the morning and on another in the afternoon. Truck-mounted cranes have also shown very satisfactory results in water-main trenching and backfilling. Personally timed operations are the basis of Table 19, which may be used in figuring costs on excavating by crane.

TABLE 19.—EXCAVATION BY TRUCK-MOUNTED CRANE
(Hours per 100 cu yd)

Sand or loam	Medium soil	Clay	Mud
2.9	3.6	5.2	4.8

TABLE 20.—HAULING
(Hours required to move 100 tons over good earth roads—allowance made for loading and dumping)

	One-horse cart	Two-horse wagon	One-ton truck	Two-ton truck	Five-ton truck
¼ mile haul	74.0	33.6	16.8	8.3	4.0
½ mile haul	107.0	50.0	25.0	13.0	5.5
1 mile haul	164.0	80.0	35.2	17.4	7.0
1½ mile haul	244.0	110.0	46.4	22.6	9.0
2 mile haul	294.0	148.5	57.8	28.2	11.0

For other kinds of roads, multiply the times given above by these factors:

	Horse-drawn vehicle	Motor truck
Plowed ground	3.0	3.2
Poor dirt road	1.4	1.2
Hard gravel road	0.85	0.75
Good macadam road	0.80	0.70
Best concrete road	0.80	0.65

For other materials or commodities, multiply the time determined for 100 tons by these factors:

100 cu yd earth, sand or gravel	1.35
100 cu yd ¾-in. crushed trap rock	1.30
100 cu yd 1½-in. crushed trap rock	1.28
100 cu yd 1½-in. crushed limestone	1.18
100 cu yd ¾-in. crushed granite	1.25
100 cu yd 1½-in. crushed granite	1.20
100 cu yd crushed slag	1.00
100 bbl Portland cement	0.19
100 bbl lump lime (large)	0.15
100 bbl lump lime (small)	0.10
100M common bricks (dumped)	2.25
100M common bricks (piled)	2.35
100M face bricks (piled)	2.93
100M FBM* dressed hard pine timber	1.76
100M FBM soft pine timber	1.10
100M FBM douglas fir timber	1.67
100M FBM spruce or hemlock	0.93
100M FBM oak timber	1.58
100M FBM maple flooring	1.78
100M FBM hard pine flooring	1.40
100M FBM hard pine sheathing	1.36

* Feet board measure. A foot board measure is 1 sq ft, 1 in. thick. Lumber is customarily sold by the unit of 1M FBM.

Time for quantities other than 100 units can be determined by multiplying by the number of units and pointing off the proper number of decimal places.

Time for materials not listed here can be determined by using the tables of weights given under the several headings.

Cost of Operation, Power Drag Scrapers and Slackline Cableway Excavators.[1]—The information below is given for the benefit of those who are interested in an easy method of computing operating costs of drag scraper and slackline cableway machines.

Operating costs involve the following factors:

Labor.—Either a scraper or a cableway machine requires, if electric, oil or gasoline operated, the full time of one

[1] Courtesy of Sauerman Bros., Inc., Chicago.

man—the operator. (If steam operated add the full time of a fireman.) In addition the part-time service of one other man, a laborer, is necessary. This laborer's time will be used in oiling, shifting the line of operation, etc. His total time on the machine will amount to about one-third of the operating shift. These are the normal labor requirements and are the same regardless of the size of the machine. They apply to ordinary installations. Complicated installations such as movable towers will have greater labor requirements and in each instance these requirements will be peculiar to that particular job.

Fuel (or Power).—A 1-cu yd scraper or cableway machine will normally require the following fuel or power per hour of operation:

	Electric, KWH	Gasoline, gal	Oil, gal	Coal, lb
Power drag scraper.........	22	5	4	175
Slackline cableway excavator	30	8	6	200

(If machine is other than 1 cu yd, use above figures proportionately, *i.e.*, for a 2-cu yd machine double the above figures and for a ½-yd machine cut them in half.)

Maintenance.—This covers the replacement of wearing parts such as wire ropes, sheaves, teeth, etc., and the necessary oil, grease and waste. It has been found that the average cost for maintenance on power scrapers will average about 1¼ cents per cubic yard of excavated material and on a slackline cableway about 1½ cents per cubic yard.

On the basis of the foregoing and assuming certain fuel and labor costs, we give the following as an example of how to figure operating costs. You will understand that when you figure such costs you should use labor and fuel costs that are normal in your territory.

TABLE 21.—COST OF OPERATION, POWER DRAG SCRAPER AND SLACKLINE CABLEWAY EXCAVATOR

1 cu yd electrically operated drag scraper working an 8-hr day on an average haul of 150 ft, at which haul it will average 50 cu yd per hr		1 cu yd slackline cableway, electrically operated, working an 8-hr day on an average haul of 200 ft, at which haul it averages 44 cu yd per hr	
Operator, 8 hr @ $1.00 per hr	$ 8.00	Operator, 8 hr @ $1.00 per hr	$ 8.00
Laborer, 3 hr @ $0.30 per hr	0.90	Laborer, 3 hr @ $0.30 per hr	0.90
Electric current, 8 × 22 KWH @ $0.025 per KWH	4.40	Electric current, 8 × 30 KWH @ $0.025 per KWH	6.00
Maintenance, 400 yd @ $0.0125	5.00	Maintenance, 352 yd @ $0.015	5.28
	$18.30		$20.18
$18.30 divided by 400 cu yd, equals .046 per yd		$20.18 divided by 352 cu yd, equals .058 per yd	

If you will study the above figures you will find that they are conservatively figured yet they are remarkably low. Nevertheless there are many Sauerman machine owners who are consistently handling material at lower operating costs than those shown.

In making a comparison of the operating costs of scrapers and cableways with other types of excavating machines remember that scrapers and cableways are also conveyors and, in the case of the cableway, an elevator also. No other type of excavating machine will dig material and convey it several hundred feet. When comparing costs do not stop with the digging but figure on all of the costs necessary to dig the material and get to the desired dumping point. To the costs of other types of excavators add the costs of handling the material by wagons, trucks, cars, belts, bucket elevators, etc.

Output of Cable-scoop Type Excavators.[1]

Heil Hi-speed CABLE SCOOP
"Pay-yards Per Hour" Production
Model CF-600 Tractor, Scoop CT-15

ESTIMATED OUTPUT IN CUBIC YARDS OF "PAY DIRT" PER HOUR*

Length of haul one way, ft	Road conditions		
	100 per cent	80 per cent	60 per cent
600	300 cu yd	240 cu yd	180 cu yd
800	288	230	172
1,000	270	216	162
1,500	225	180	135
2,000	180	144	108
2,500	160	128	96
3,000	138	110	83
4,000	108	86	65
5,000	95	76	57

* Based on 12.5 cu yd pay load (50 sec loading time and 35 sec dumping and turning time) with 100 drawbar hp crawler tractor push-loading.

Explanation of road conditions

100% = good haul road; high gear output
80% = fair to good haul road; some third and fourth gear speed
60% = fair haul road; second and third gear loaded—third and fourth gear return

NOTE: The above figures are to be used only for estimating approximate production and, because of operating conditions over which the Heil Company has no control, are not guaranteed. Variations in soil conditions, grades and operator efficiency, etc., may so affect actual performance that yardage may exceed or fall below these quantities.

[1] Information furnished by courtesy of The Heil Company, Milwaukee.

Number of Hi-speed Cable Scoops (1) Push-loading Crawler Tractor Will Handle (60% Road Conditions)*

Maximum Haul in Feet One Way	Number of Hi-speed Scoops Push Tractor Will Load
600	2
600– 800	2
800–1000	3
1000–1500	4
1500–2000	5
2000–2500	6
2500–3000	7
3000–4000	8
4000–5000	10

* Based on use of 100 drawbar hp crawler tractor for push-loading.

PRODUCTION ESTIMATING DATA FOR TRACTOR-DRAWN HEIL CABLE SCRAPERS
(Pay yards per hour)
Model C-6 Heil cable scoop pulled by 45- to 60-hp crawler tractor
(no pusher tractors)

Haul one way, ft	Type of soil	Loaded on level ground		Loaded down 5% grade		Loaded down 10% grade	
		60-min hour	50-min hour	60-min hour	50-min hour	60-min hour	50-min hour
300	Sand or clay	70	58	84	69	89	74
	Earth	72	60	86	70	91	75
400	Sand or clay	60	52	72	63	77	68
	Earth	62	54	74	66	79	71
500	Sand or clay	55	46	66	55	71	60
	Earth	57	48	68	57	73	62
600	Sand or clay	48	40	57	48	62	53
	Earth	50	42	60	50	65	55
800	Sand or clay	38	32	42	35	46	39
	Earth	40	34	44	37	48	41
1,000	Sand or clay	35	30	38	33	42	37
	Earth	36	31	40	34	44	38
1,500	Sand or clay	20	16	22	17	25	19
	Earth	21	16	23	17	26	20

PRODUCTION ESTIMATING DATA FOR TRACTOR-DRAWN HEIL CABLE SCRAPERS.—(*Continued*)

Model C-8 Heil cable scoop pulled by 70- to 80-hp crawler tractor
(no pusher tractors)

Haul one way, ft	Type of soil	Loaded on level ground		Loaded down 5% grade		Loaded down 10% grade	
		60-min hour	50-min hour	60-min hour	50-min hour	60-min hour	50-min hour
300	Sand or clay	90	78	115	97	123	105
	Earth	93	80	117	98	125	106
400	Sand or clay	85	72	110	92	118	100
	Earth	90	76	112	93	120	101
500	Sand or clay	76	64	96	80	104	88
	Earth	80	68	98	82	106	90
600	Sand or clay	68	57	85	71	92	78
	Earth	70	58	88	72	95	79
800	Sand or clay	57	48	70	60	76	66
	Earth	60	50	72	61	79	67
1,000	Sand or clay	48	40	62	51	65	54
	Earth	50	42	63	51	66	55
1,500	Sand or clay	36	30	45	37	48	39
	Earth	38	31	46	38	49	40

Production Estimating Data for Tractor-drawn Heil Cable Scrapers.—(*Continued*)

Model C-10 Heil cable scraper pulled by 70- to 80-hp crawler tractor (no pusher tractors)

Haul one way, ft	Type of soil	Loaded on level ground		Loaded down 5% grade		Loaded down 10% grade	
		60-min hour	50-min hour	60-min hour	50-min hour	60-min hour	50-min hour
300	Sand or clay	112	92	125	105	140	120
	Earth	115	95	128	108	145	122
400	Sand or clay	98	82	110	93	130	108
	Earth	103	86	118	100	133	111
500	Sand or clay	92	78	106	88	125	104
	Earth	94	82	110	92	128	106
600	Sand or clay	87	73	98	82	115	96
	Earth	90	75	105	88	118	98
800	Sand or clay	75	65	85	72	99	83
	Earth	80	67	90	75	100	84
1,000	Sand or clay	67	56	75	64	88	73
	Earth	70	59	80	67	90	70
1,500	Sand or clay	54	45	60	50	68	58
	Earth	56	48	64	52	69	59

PRODUCTION ESTIMATING DATA FOR TRACTOR-DRAWN HEIL CABLE SCRAPERS.—(*Continued*)

Model C-15 Heil cable scoop pulled by 100-hp crawler tractor

Haul one way, ft	Type of soil	Loaded on level ground and no push tractor		Loaded down 5% grade and no push tractor		Loaded down 10% grade and no push tractor		Loaded on level ground with 100-hp push tractor	
		60-min hour	50-min hour	60-min hour	50-min hour	60-min hour	50-min hour	60-min hour	50-min hour
300	Sand	150	127	171	139	177	144	190	158
	Earth	159	136	182	150	186	155	193	161
	Clay	150	127	171	139	177	144	190	158
400	Sand	128	109	144	112	161	134	169	137
	Earth	138	112	161	128	168	136	173	141
	Clay	128	109	144	112	161	134	169	137
500	Sand	118	91	137	110	146	124	150	128
	Earth	120	93	146	119	155	134	157	136
	Clay	118	91	137	110	146	124	150	128
600	Sand	105	83	118	96	101	79	123	102
	Earth	109	88	122	101	107	86	128	107
	Clay	105	83	118	96	101	79	123	102
800	Sand	87	71	101	86	109	93	109	93
	Earth	91	75	105	90	113	97	113	97
	Clay	87	71	101	86	109	93	109	93
1,000	Sand	77	61	86	70	91	75	96	80
	Earth	80	64	91	75	96	80	102	86
	Clay	77	61	86	70	91	75	96	80
1,500	Sand	55	44	63	52	68	58	74	63
	Earth	57	46	67	57	73	62	78	67
	Clay	55	44	63	52	68	58	74	63

PRODUCTION ESTIMATING DATA FOR TRACTOR-DRAWN HEIL CABLE SCRAPERS.—(*Continued*)

Model C-18 Heil cable scoop pulled by 100-hp crawler tractor

Haul one way, ft	Type of soil	Loaded on level ground and no push tractor		Loaded down 5% grade and no push tractor		Loaded down 10% grade and no push tractor		Loaded on level ground with 100-hp push tractor	
		60-min hour	50-min hour	60-min hour	50-min hour	60-min hour	50-min hour	60-min hour	50-min hour
300	Sand	177	150	203	171	209	182	219	187
	Earth	187	161	214	182	219	187	225	193
	Clay	177	150	203	171	209	182	219	187
400	Sand	155	128	182	150	187	161	198	166
	Earth	166	139	193	161	198	166	203	171
	Clay	155	128	182	150	187	161	198	166
500	Sand	139	123	161	134	171	150	171	150
	Earth	144	128	171	139	182	155	182	155
	Clay	139	123	144	128	150	131	171	150
600	Sand	123	102	139	118	144	123	161	134
	Earth	130	107	144	124	150	126	166	139
	Clay	123	102	139	118	144	123	161	134
800	Sand	102	86	118	102	128	112	128	112
	Earth	107	91	123	105	131	116	131	116
	Clay	102	86	118	102	128	112	128	112
1,000	Sand	91	75	102	86	107	91	112	96
	Earth	96	80	107	91	112	94	116	98
	Clay	91	75	102	86	107	91	112	96
1,500	Sand	64	54	75	64	80	70	86	75
	Earth	66	56	80	70	83	73	88	77
	Clay	64	54	75	64	80	70	86	75
2,000	Sand	54	43	59	48	62	51	64	54
	Earth	54	43	59	48	62	51	64	54
	Clay	51	41	57	46	59	52	59	52

These figures are for estimating purposes only. The efficiency of the organization, the skill of the operator, the type of material and the general operation of the job will directly affect these yardage figures.

SECTION 6. ESTABLISHING HOURLY RATES

In the last analysis, on all competitive work the highest hourly rate that can be used in an estimate is the rate at which a given piece of equipment can be rented or hired, plus the wages of operator and the cost of fuel and lubricants, if those items are not included in the rental rate. For instance, careful calculation of all of the factors involved might show that $5 an hour is the correct rate for a ¾-cu yd gasoline-powered shovel, but, in a section where there are many shovels and not much work, owners of shovels might much rather have them working at $3 an hour than rusting in the yard. Then, $3 an hour is the maximum rate that can be figured on any job where that kind of competition prevails. In other words, the equipment renter really fixes the rate that a contractor can figure to charge a given job for the use of his own equipment.

Therefore, when estimating work, it is as important for the bidder to know the prevailing conditions and rates in a locality as it is to know what rate a piece of equipment rightfully should bring. If there are equipment rental companies operating in the vicinity, their rates will tend to fix the rates to be used in estimating costs.

A correct hourly rate to be used by a contractor owning his own equipment should cover

Interest on investment
Depreciation
Maintenance
Insurance
Fuel
Lubricants
Operation

The item of operation should not only include the wages of an operator during the time when a machine is productively employed, but also cover the cost of moving it from job to job as one is finished and another started. With such mobile equipment as trucks, the item of moving may be almost negligible, while the cost of moving a large shovel may be a matter of hundreds of dollars. Where equipment is owned for rental purposes, the rate charged must be made high enough to include a profit to the owner.

A satisfactory method for determining the cost of a ¾-cu yd gasoline shovel would be as follows:

TABLE 22.—ANNUAL COST OF POWER SHOVEL

Assumed actual cost of the machine		$10,000
Interest on investment @ 6 per cent	$ 600	
Depreciation @ 10 per cent	1,000	
Maintenance and repairs	400	
Insurance	20	
Annual items	$2,020	

Allowing for the customary amounts of lost time, bad weather, delays, moving, etc., the maximum productive time per year that can be obtained in most instances is 1,000 hr, so that the fixed charge per hour merely to own the machine is $2.02, and every hour's work done by that shovel should properly be charged for that amount. On this basis the rate that must be established per hour is as in Table 23.

TABLE 23.—HOURLY RATE FOR POWER SHOVEL

Annual expense (Table 22)	$2.02
Wages of operator	1.50
Fuel	0.40
Oil and grease	0.02
Moving to and from job	0.29
Liability and compensation insurance, 7 per cent of wages	0.11
Fair charge per hr, inclusive of profit or overhead expense	$4.34

The cost of moving to and from a job is variable, since it is determined by the length of time actually taken to do the job after getting to the site. Assuming, however, that it takes two trucks and a trailer all of one day to deliver the shovel and the same time to take it away and the job in question involves 20,000 cu yd of digging in stiff clay, then by Table 2 the approximate number of productive hours on the job will be 20,000 cu yd @ 4.04 per 100, or 808. The time taken to move a shovel to and from a job will vary greatly with the kind of roads traversed and the number of underpasses and other obstructions encountered, but average speed for fair roads can be figured at 5 mph, or 0.20 hr per mile, with an allowance of ½ hr for loading and for unloading, and 16 hr for dismantling and setting up.

Then the cost is as follows:

Time of two trucks and trailer, 8 hr each trip, or 16 hr in all:	
Trucks @ $5 per hr	$160
Trailer @ $3 per hr	48
Dismantling and setting up	24
	$232

which is to be spread over an estimated time of 808 productive hours, so that the average cost per hour is approximately 29 cents, as carried in Table 23. This is on the assumption that the trucks and trailers are used on the job or having a paying return load. Otherwise, the cost of the empty movements must be added into this cost. Although the actual figures given here might not apply in any particular instance, the same method could be used in connection with the governing data in order to determine the proper hourly rate to use in making any estimate.

Hourly Cost for Trucks.—Practically the same method is to be used in figuring the hourly cost of the trucks as was used for the shovel, except that the truck will move to and from jobs under its own power and that no time need be figured for dismantling and setting up. Assuming four years as the economical life of a truck, the annual cost would be as shown in Table 24.

TABLE 24.—ANNUAL COST OF MOTOR TRUCK

Assumed actual cost delivered		$6,000
Interest on investment @ 6%	$ 360	
Net depreciation @ 20%	1,200	
Maintenance and repairs	300	
Tire renewals	300	
Registration	50	
Insurance	100	
Annual cost	$2,310	

With the usual amounts of lost time for all of the various causes that prevent a truck from being used to its greatest capacity, it might be assumed that a truck could work 200 eight-hr days per year or a total of 1,600 hr; then the hourly cost would be as shown in Table 25. The annual charges per hour of work are found by dividing the annual cost by the assumed working time, or $2,310 by 1,600.

TABLE 25.—HOURLY COST OF MOTOR TRUCK

Annual charges	$1.44
Wages of driver	0.70
3 gal gasoline	0.48
Oil and grease	0.02
Compensation insurance	0.05
Cost per hr, exclusive of profit or overhead expense	$2.69

As in the case of the shovel, the estimator must always secure the actual figures which apply to the work upon which he is estimating and substitute them for the figures given in these tables.

Hourly Cost of Loader.—The manufacturers give the cost of creeper-model elevating loaders as $4,250, and on that basis Table 26 was constructed.

TABLE 26.—ANNUAL COST OF CREEPER-MODEL LOADER

Price quoted by manufacturer		$4,250.00
Interest @ 6%	$ 255.00	
Depreciation @ 25%	1,062.50	
Maintenance and repairs	250.00	
Insurance	20.00	
Annual cost	$1,587.50	

Because the loader can be used for loading aggregates during the time of concreting and for other purposes when no actual excavating is going on, it should be possible to develop at least 1,500 hr of productive work per year, giving a fixed hourly charge of $1.06, so that the hourly operating cost becomes as in Table 27.

TABLE 27.—HOURLY COST OF CREEPER-MODEL LOADER

Annual charges	$1.06
Operator	0.70
1½ gal gasoline	0.24
Oil and grease	0.02
Compensation insurance	0.05
Cost per hr, exclusive of profit and overhead expense	$2.07

It is possible to set up similar tables for every sort of construction equipment, and the estimator finds it necessary to compile his own tables covering the equipment with which he is dealing, in order that he may apply proper rates to the work upon which he intends to bid.

SECTION 7. ESTABLISHING A UNIT PRICE

In making a bid on a unit price basis, the essential thing is to determine just what work must be done under the given heading. In bidding on excavation for building construction, the excavating contractor would probably be required to do only the actual digging, transporting and disposing. The finding of a place for disposing of the spoil and the securing of permission to dump would be left entirely to the excavator, so that the distance the spoil must be transported could not be determined from the plans or specifications but only by making an actual examination of existing local conditions.

On highway work, however, the unit price for excavation will often include digging, transporting, spreading and compacting.

Since it is customary to pay on the basis of the measurement of the volume actually excavated, it is possible to construct the unit price without having to calculate the possible increases or decreases in bulk during handling, except when the bulking up of the spoil will mean that larger sized trucks are necessary to carry given quantities.

In the section headed Unit Price the method of calculating the unit price in one instance has been shown and, if the conditions under which the work must be done and the equipment available to do it are first determined, the price to use under any other set of conditions can be estimated.

If, as sometimes happens in building construction, the excavating contractor must protect the banks, a separate estimate, as will be explained in a later section, must be made of the cost of shoring and sheet piling. If the work is done on the basis of a unit price per cubic yard, then the cost of this additional work must be divided by the estimated number of cubic yards to be excavated and the result added to the unit price.

SECTION 8. ROCK EXCAVATION

In estimating the cost of rock excavation for buildings or for road construction, it is necessary to bear in mind that, while the principles to be used are the same as those for quarrying rock, the application is very different. For this reason the estimator must be careful not to use those data found in books on quarrying, which, while they are accurate for quarrying operations, are not based upon the conditions under which rock excavation for construction must be done. He must make sure that the proper adjustments are made to fit the conditions under which building construction and road building necessarily are done.

In quarrying, it is frequently possible to break out faces from 16 to 20 ft high and from 12 to 16 ft wide. This work involves comparatively high charges of explosives, while much building and road work must be done under such conditions that only rather light charges can be used. (In one instance, we had to blast out ledge rock within 6 ft of large plate-glass show windows, and we did it without cracking even one.)

Obviously, when light charges are used, a greater number of holes must be drilled to remove the same yardage of rock. Similarly, much rock excavation for road building or for building construction will involve comparatively shallow cuts and, as will presently be shown, the total amount of drilling to be done increases as the cut becomes shallow. Drilling is one of the major items making up the cost of rock excavation.

Hand Drilling.—Where the total amount of rock to be removed is very small, or where the conditions do not make it practicable to install power equipment, the drilling will be done by hand, using one of three methods: single hand drill, three-man or jumper drill, or churn drill.

The cost per linear foot of hole will vary with the method of hand drilling used, so it will be necessary to determine what method is most applicable. If only a small amount of rock is to be removed and the cut is not more than 1 ft deep, the single hand drill will be most practical but it cannot be used satisfactorily for greater depths. In almost all instances where the rock is fairly homogeneous in character and all drilling can be done vertically, the churn drill will prove most economical, but for seamy rocks, conglomerates and for all horizontal or inclined drilling, jumper

TABLE 28.—HAND DRILLING

Type of rock	Man-hours per 100 lin ft of hole		
	Churn, 1¾-in. hole	Jumper	Single hand, ¾-in. hole
Quartz	250	385	250
Sandstone	200	300	200
Limestone	120	180	120
Hornblende	167	245	167
Granite	133	200	133
Gneiss	133	200	133
Trap	180	240	180
Concrete	200	300	200

drilling must be used. Of course, power drills will be used where the volume of rock to be removed is sufficient to warrant the cost of transporting and installing the air compressor and drills.

Table 28 may be used in computing the cost of drilling in different kinds of rock. The time for jumper drilling is computed on the basis of having one holder and two strikers.

Since the drills have to be resharpened for approximately every 2 to 4 ft of depth and repointed for approximately every 10 to 20 ft of depth, it is necessary to add to the cost of each 100 ft of hole the following amounts for sharpening and repointing. The cost of the steel in hand drilling is generally taken care of in an item of "tools" carried in the estimate; in machine drilling it will be included in the hourly cost figured for each power drill. The hourly cost of sharpening will be made up of the wages of the blacksmith and helper, the rental charge on the forge, the cost of power if a power blower is used and the cost of the coal used.

TABLE 29.—SHARPENING AND REPOINTING DRILLS

Type of Rock	Hours per Unit (Blacksmith, Helper and Forge) per 100 Ft of Hole Drilled
Quartz	5.7
Sandstone	4.6
Limestone	2.8
Hornblende	3.8
Granite	3.0
Gneiss	3.0
Trap	4.2
Concrete	4.6

Machine Drilling.—For holes of any considerable depth, pneumatic drills of the tripod type will give most satisfactory results, but for most of the work encountered in moderate-sized building operations and for ordinary road work, the portable type of drill will answer every purpose and it can be used for drilling at almost any angle. The time required for drilling will be approximately the same with any machine but the hourly cost will be greater with larger machines than with smaller ones.

The cost per hour per drill will also vary with the type of air compressor used and with the number of drills being operated at once. Naturally, if the number of drills being operated is great enough to utilize the full capacity of the compressor, the amount of compressor time that must be charged to each drill will be less than when only one or two drills are used. While actual drilling speeds may run up to as much as four or more feet per minute, the time taken for changing drills, pumping out the hole, moving and resetting the machine cuts down the daily production to an average that is but a fraction of the maximum. Because the time taken in moving the drill is such a large

TABLE 30.—MACHINE DRILLING
(Hours for machine and driller per 100 lin ft of hole)

Type of rock	Depth of hole, ft						
	1	2	3	5	10	15	20
Quartz	30	25	21	17	15	14	13
Sandstone	25	17	14	13	12	11	10
Limestone	19	13	11	10	8	7	6
Hornblende	22	16	13	12	10	9	8
Granite	21	14	12	11	9	8	7
Gneiss	21	14	12	11	9	8	7
Trap	23	16	14	13	11	10	9
Concrete	25	17	14	13	12	11	10

part of the total time, shallow holes cost very much more per 100 lin ft than do deep ones, as indicated in Table 30. To the cost obtained from Table 30 must be added the cost of sharpening and repointing the drills, as indicated in Table 29.

Hourly Rate for Drills.—The annual cost per drill may be estimated approximately as follows, though, as with all other equipment, the estimator must use prices that actually apply to the machines that he expects to use on the work for which he is estimating.

TABLE 31.—ANNUAL COST OF ROCK DRILL

List price		$275.00
Interest @ 6%	$ 16.50	
Depreciation @ 30%	82.50	
Maintenance and repairs*	150.00	
Insurance	5.00	
Annual cost	$254.00	

* Includes steel for bits.

In computing the hourly rate, however, it is necessary to include a charge for the compressed air supplied by the compressor. This charge will vary with the size of the compressor and the number of drills it can supply. Assuming the case of a small gasoline-engine-driven compressor, with receiver mounted on the same chassis and automatically controlled so that one of the drill operators could give it whatever attention it required, then the annual cost may be computed thus:

TABLE 32.—ANNUAL COST OF AIR COMPRESSOR

Original cost		$450
Interest @ 6%	$ 27	
Depreciation @ 30%	150	
Maintenance and repairs	100	
Insurance	9	
Annual cost	$286	

On the assumption that the compressor could be used an average of 1,500 working hours per year, the hourly cost would be figured as follows:

TABLE 33.—HOURLY COST FOR COMPRESSOR

Annual charge	$0.19
6 gal gasoline @ $0.15	0.90
Oil and grease	0.07
	$1.16

TABLE 35.—MAXIMUM SPACING OF DRILL HOLES

Limestone	8 ft
Granite	5 ft
Gneiss	4 ft

Explosives.—The kind of explosive to be chosen is really a matter for the expert rockman to decide. In general, the harder and more brittle the rock, the faster the explosive that should be used in order to get a quick shattering action, such as is given by dynamites with high percentages of nitroglycerine. Softer and seamier rocks require the lifting action that is obtained by the slower burning explosives, such as black powder. Dynamite exerts from six to eight times the explosive force of gunpowder but it does not follow that only one-sixth to one-eighth the quantity will be required, if the proper explosive is chosen in each instance for the rock to be blasted. The amount of rock which can be removed with a pound of powder varies from 3 to 4 yd in open work down to ½ or ⅙ yd in tunnel work. The quantity of dynamite ordinarily required in the kind of excavation encountered in building construction or road work is given in Table 36.

TABLE 36.—EXPLOSIVE REQUIRED

Type of Rock	Dynamite, Lb per Cu Yd of Rock
Quartz	0.30 to 0.70
Sandstone	0.20 to 0.40
Limestone	0.75 to 1.00
Hornblende	0.20 to 0.80
Granite	0.20 to 0.80
Gneiss	0.60 to 0.80
Trap	0.20 to 0.70
Concrete	0.30 to 0.60

Estimating a Unit Price.—Assume that it is required to quote a unit price per cubic yard of granite rock excavation in a basement 60 ft wide, 100 ft long and 6 ft deep. Allowing 2 ft additional on each side and end for formwork which will be necessary when the foundation concrete work is installed, backfilling, etc., the total amount of excavation is evidently

$$\frac{64 \text{ ft} \times 104 \text{ ft} \times 6 \text{ ft}}{27} = 1{,}479 \text{ cu yd}$$

Since the proximity of other buildings would seem to make heavy blasting inadvisable, the estimate would be based upon taking the rock out in two 3-ft cuts. Then, spacing the rows three-fourths the depth of the cut apart, we get the rows of holes 2.25 ft apart and the holes 2.25 ft apart in the rows. Allowing for an extra row of holes at the end and an extra hole in each row, we find that we have 47 rows of 29 holes each or 1,363 holes, and at 7 ft deep each, allowing for the extra depth, we have 9,541 lin ft as the total length of holes to drill to make the two cuts, even though only half of them would be drilled for each cut.

From Tables 29, 30 and 34 we estimate as follows:

Drilling, 9,541 lin ft @ 12 hr per 100.. 1,444.92 hr, say 1,145
1,145 hr @ $1.25................. $1,431.25

$$\frac{\$1{,}432.25}{1{,}479 \text{ cu yd}} = \$0.96 \text{ per cu yd practically}$$

Sharpening and repointing
9,541 lin ft @ 3 hr per 100......... 286.23 hr, say 286 hr
286 hr @ $1.25.................. $357.50

$$\frac{\$357.50}{1{,}479 \text{ cu yd}} = \$0.24 \text{ per cu yd}$$

	Cost per Cu Yd
Drilling	$0.96
Sharpening and repointing	0.24
0.8 lb dynamite @ $0.15	0.12
Tamping and firing 0.2 hr	0.14
Caps, etc	0.03
Miscellaneous	0.05
Total for drilling and blasting	$1.54

To the cost given here must be added the cost of removing the rock after blasting and of hauling it away. This would be estimated as indicated in the section dealing with earth excavation. In estimating the cost of excavating and hauling, it is necessary to remember that the bulk of the rock will be approximately 1.7 times its measurement in place and the cost of excavating and hauling as estimated for earth must be multiplied by that factor to get the correct figure for rock excavation and removal. It may often be possible to sell the spoil from rock excavation, in which case the price could be reduced if this were known when bidding, or the contractor's profit increased if he found it practical later.

Pay Line.—On most unit price jobs it is customary to establish a "pay line," or point beyond which no allowance is made in computing the quantity of work done, even though the actual excavation necessarily goes beyond that line. The estimator then has to determine whether actual excavation is likely to exceed the amount paid for and adjust his figures accordingly.

SECTION 9. BRACING

Bracing used in ordinary building excavation may consist of wood, concrete or steel sheet piling. Concrete and steel sheet piling may be considered as specialties usually handled by organizations specializing in that class of work. The thickness of plank to be used for sheet piling and the spacing of waling strips and braces will have to be determined by calculating the load which the piling must retain. This is calculated after ascertaining the weight per cubic foot of the material and its angle of repose.

However, for excavations not over 10 ft deep, 2-in. plank with 6 by 6 wales not over 5 ft apart, the wales being supported by bracing not over 7 ft apart, will usually suffice.

For excavations 10 to 15 ft deep it is best to figure upon 3-in. plank with 8 by 8 wales, not over 3 ft apart near the bottom, and for 15 to 20 ft deep 4-in. plank should be used.

Wood sheet piling will seldom be found economical for depths greater than 20 ft.

Where union rules or other restrictions do not prevent it, the entire work of sheet piling can be done by handy laborers, provided they are directed by an experienced man. Where union rules require it, it will be necessary to allow for having certain parts of the work done by carpenters.

Production can be figured upon the following basis:

TABLE 37.—SHEET PILING

	Sq Ft per Man per Hr
Setting braces and driving piles:	
For first 10 ft of depth	10
From 10 to 15 ft deep	9
From 15 to 20 ft deep	7
Pulling piles and removing braces:	
For first 10 ft of depth	40
From 10 to 15 ft deep	35
From 15 to 20 ft deep	20

(Man-hours required per 100 square feet)

Depth	Setting braces and driving piles	Pulling piles and removing braces
First 10 ft	10.0	2.5
From 10 to 15 ft	11.2	2.9
From 15 to 20 ft	14.3	5.0
From 20 to 25 ft	17.0	7.5
From 25 to 30 ft	20.0	10.5

Although the men will work in a gang of two or four, the cost is to be figured upon the basis of the production per man.

The amount of material required for sheet piling will be determined by the number of times the piling can be used over again on the same job. On most moderate-sized jobs it will be advisable to provide enough plank and bracing to enclose the entire excavation at once.

Example.—To find the cost of sheet piling for an excavation 60 ft wide, 100 ft long and 10 ft deep. The plank will need to be at least 2 ft longer than the depth of the footing, that is, 12 ft long.

Distance around excavation 320 lin ft

320 lin ft by 12-ft plank by 2 in thick...	7,680 FBM, plank
Wales—3 lines 6 by 6's, 320 ft..........	2,880
Braces—6 by 6's, 45 each 8 ft, 10 ft, 12 ft.	4,050
Stakes—8 by 8, 45 each 6 ft............	1,485
	8,415 FBM, bracing

The area to be piled is

320 by 10 = 3,200 sq ft

3,200 ÷ 10 = 320 hr driving, etc.

3,200 ÷ 40 = 80 hr pulling

Fractional hours are here considered as full hours

7,680 FBM plank at $36 per M....................	$276.48
8,415 FBM bracing at $44 per M..................	370.26
	$646.74
Deduct 60 per cent for reuse value of lumber........	387.06
	$259.68
Spikes (estimated at 20 lb per M FBM bracing), 168 lb @ $0.05....................................	$ 8.40
Labor driving, 320 hr, @ $0.45....................	144.00
Labor pulling, 80 hr, @ $0.45......................	36.00
Contingencies, allow 5 per cent of labor cost.........	9.00
Insurance, allow 5 per cent labor cost...............	9.00
Net cost, exclusive of supervision, overhead and profit	$466.08

Caution.—All labor rates and material prices used in this text are arbitrarily assumed. The estimator should be careful to get the actual rates and prices that will be in effect for every job for which he makes an estimate.

Whenever possible, the necessary sheet piling and bracing should actually be designed by a competent engineer, then the amount of material to be purchased and handled can be figured more accurately.

Note also that the figures are on square-edged plank, which is the most practicable. If matched plank should be specified, 15 per cent must be added to the quantity of plank, and 10 per cent must be deducted from the amount driven or pulled per hour.

Whenever an estimate is made on the cost of excavating, a visit should be made to the place where the work is to be done, the following information obtained and proper allowances made in the figures:

Nature of soil
Disposal of topsoil
Disposal of other excavated material
Location of dump
Necessity for spreading at dump
Local rate for labor
Local price for teams or trucks, etc.
Cost of any permits required
Necessity for protecting sidewalk
Necessity for protecting pavements
Cost of watchman, if needed
Cost of maintaining lights, if needed
Cost of materials, if any are needed

It is necessary also to include in all estimates a proper amount for general supervision, traveling expenses, home-office expense and profit. These items will be referred to again in succeeding chapters, but attention is called to them here so that they will not be lost sight of.

CHAPTER 3

PLAIN AND REINFORCED CONCRETE WORK

SECTION 1. GENERAL

It was the intention in writing this text, in so far as it is practical to do so, to make each of the chapters complete in itself. However, there is hardly an operation in general building construction that is so unique that much that may be said of another operation will not apply to it as well.

For this reason, it will often be necessary for a student to master several different chapters before he will become really proficient in estimating the class of work covered by any one of them.

For instance, while this present discussion of the method of estimating the cost of concrete work will be rather lengthy, the student must also thoroughly master the chapters on excavating, brickwork and timber framing, if he would get the best results in this particular work.

It is well to adopt a uniform procedure when listing quantities for any kind of work, particularly for concrete work. The best method is to start at the beginning and list the different items in approximately the same order in which they will be constructed, thus: wall footing, pier footings, walls, piers, etc. It is also well to follow a regular system of setting down the dimensions, *viz.*, length first, width or thickness second, and height third.

This method will always make it practicable to know just what each figure means and will also facilitate the calculation of form quantities.

Formwork Important.—It hardly seems necessary, at this late date in concrete construction, to stress the importance of carefully figuring all formwork, either by the number of square feet of contact area or by the number of board feet of lumber to be used, and not by lumping the cost of formwork into the cost of a cubic yard of concrete.

As a general rule the contact area method is used because it gives very close results and is sufficiently accurate for all ordinary kinds of construction. For unusual work that would involve difficult, extra strong or intricate formwork, the design of the forms should be worked out before estimating and the cost carefully computed on the basis of the material to be used and the work to be done.

Construction men designate the quality of concrete by two methods. The first is by stating the proportions of the several ingredients of which it is composed. For instance, 1-2-4 gravel concrete designates a concrete composed of one part of portland cement, two parts of sand, and four parts of gravel. It is customary for the architect or engineer to specify whether gravel or crushed stone must be used as the coarse ingredient or "aggregate," or whether the choice is left to the contractor, and also the size that must be used. Sizes are designated by the size of the ring through which the particles will pass; as ¾-in., 1-in., and so on. The other method of designating quality, which is rapidly coming to be the only one used on important work, is by the compressive strength which the concrete must attain. That is, a 2,000-lb concrete must be so proportioned that when a sample of it is placed in a testing machine, after the concrete has attained an age of 28 days, it will be able to resist a crushing force of at least 2,000 lb per sq in. Proportioning for given strengths will be discussed later. Where the proportions of the several ingredients to be used in making concrete are specified by numerical rates, it is a simple matter to take a table and figure the costs of the ingredients. In fact, when no table is available, the cost may be approximated by remembering that

1-2-4 concrete takes approximately 6 bags of cement per yd
1-2½-5 concrete takes approximately 5 bags of cement per yd
1-3-6 concrete takes approximately 4 bags of cement per yd

and that each cubic yard of concrete made according to those ratios requires approximately ½ cu yd of sand and 1 cu yd of coarse aggregate. For accurate estimating, however, the quantities should be calculated on the basis of Table 38.

TABLE 38.—QUANTITIES OF INGREDIENTS PER CUBIC YARD OF CONCRETE

Proportions	Cement, bags	Sand, cu yd	Stone or gravel, cu yd
1-1-2	11.	0.40	0.80
1-1½-3	7.5	0.52	0.78
1-2-3	7.0	0.52	0.78
1-2-4	6.0	0.44	0.89
1-2½-4	5.6	0.52	0.83
1-2½-5	5.0	0.46	0.92
1-3-6	4.2	0.47	0.94

Until recently, cement prices were always quoted on the basis of the barrel, containing 3.8 cu ft, but nowadays the bag, which is ¼ bbl or 0.95 cu ft, is becoming more and more to be the unit of sale. In ordinary work a bag is considered to be 1 cu ft of cement. Actually, the barrel as a container for cement had practically disappeared from the market as much as twenty years ago. Most cement bags used to be made of cloth. It was customary to add a charge of 10 cents per bag to the price quoted and the 10-cent charge was later refunded for each bag returned in good condition, with freight prepaid, to the cement company's mill. Paper bags are now used almost exclusively and, while a charge for them is necessarily included in the price of the cement, they are not returnable for rebate. On extremely large work, where equipment for handling and measuring will be available at the job, cement is shipped in bulk carloads, that is, unpackaged, and unloaded by suction conveyors.

There are tables available giving a much wider range of mixtures and also the theoretical variations in quantities due to variations in the sizes of stone comprising the aggregate, but, since few of these tables give any consideration to the shape of the aggregate, it seems that no actual gain in accuracy is made by the added refinement in figuring. Furthermore, when materials are purchased by volume, the accuracy of measurement is so low that any gain by such refined methods of estimating would be neutralized on the job. When materials are purchased by the ton, much more accurate estimating can be done, since the same quantity of material should then be received for the same amount of money in every instance. Table 39 gives the weights of the aggregates customarily used in concrete work.

TABLE 39.—WEIGHTS OF CONCRETE MATERIALS

Material	Cu yd per ton	Lb per cu yd
Sand	0.74	2,700
Gravel	0.74	2,700
¾-in. crushed trap rock	0.77	2,600
1½-in. crushed trap rock	0.785	2,550
1½-in. crushed limestone	0.85	2,360
¾-in. crushed granite	0.80	2,500
1½-in. crushed granite	0.832	2,400
Crushed slag	1.0	2,000

Since gravel and crushed trap rock are the most commonly used coarse aggregates, Table 40 has been constructed for calculating the cost of concrete directly when the prices are quoted on the basis of one ton.

TABLE 40.—QUANTITIES OF INGREDIENTS PER CUBIC YARD OF CONCRETE ON WEIGHT BASIS

Proportions	Cement, bags	Sand, tons	Tons of coarse aggregate		
			If gravel	If ¾ crushed stone	If 1½ crushed stone
1-1-2	11.	0.54	1.09	1.05	1.04
1-1½-3	7.5	0.70	1.06	1.0	1.0
1-2-3	7.0	0.70	1.06	1.0	1.0
1-2-4	6.0	0.60	1.19	1.12	1.11
1-2½-4	5.6	0.70	1.12	1.04	1.03
1-2½-5	5.0	0.61	1.23	1.18	1.17
1-3-6	4.2	0.62	1.28	1.22	1.21

Cement-water Ratio.—As previously stated it has, of late years, become the practice to specify the quality of concrete by the strength required rather than by the older method of definite proportions. This newer method enables the designer to determine the final characteristics of the concrete to be used and puts upon the contractor the responsibility for producing a concrete having those characteristics, and helps to make the estimator's job a little harder. The method is based upon a great number of tests by Prof. Duff A. Abrams which showed that the strength of concrete is greatest when just enough water is used to secure complete hydration of the cement and that any additional water reduces the ultimate strength that will be attained. Since a slight excess of water may be necessary in order to attain workability, the maximum degree of sloppiness that will be allowed is determined by specifying the maximum "slump" allowed; that is, how many inches a standard sample, made in the shape of a truncated cone, may slump down when the supporting form is removed.

When that method of specifying is used, the quantities of materials should be calculated from Table 41.

TABLE 41.—MATERIALS REQUIRED PER CUBIC YARD OF CONCRETE

(When specified according to cement-water ratio of strength control)

Designed 28-day strength, lb per sq in.	Bags of cement, using aggregate having maximum size of				
	¾ in.	1 in.	1½ in.	2 in.	2¼ in.
3- to 4-in. slump:					
1,500	4.7	4.2	4.0	3.6	3.4
2,000	5.8	5.2	4.8	4.4	4.1
2,500	7.1	6.3	5.8	5.4	4.9
5- to 8-in. slump:					
1,500	5.7	5.2	4.7	4.4	4.0
2,000	7.3	6.8	6.3	5.8	5.2
2,500	9.0	8.4	7.9	7.1	6.4
Tons of washed sand required for any strength or slump	0.39	0.50	0.53	0.54	0.61
Tons of coarse aggregate:					
If gravel	1.13	1.14	1.15	1.16	1.17
If trap rock	1.11	1.12	1.13	1.15	1.16
If aggregates are purchased by the cubic yard on the ordinary basis of damp and loose measurement, the following figures should be used:					
Sand, cu yd	0.41	0.52	0.54	0.56	0.63
Gravel, cu yd	0.99	1.00	1.00	1.01	1.01

TABLE 42.—STRENGTH OF CONCRETE* AS AFFECTED BY QUANTITY OF MIXING WATER

Maximum Number of Gal per Bag	Compressive Strength, Lb per Sq In. at 28 Days
7 –7½	2,000
6¼–6¾	2,500
5½–6	3,000
5¾–5¼	3,500

* As given by Prof. Duff A. Abrams.

As affected by use of 2 to 4 per cent calcium chloride in mixture:

Age of Concrete	Percentage of Normal
2 days	170
7 days	125
28 days	110
3 months	112
1 year	117
3 years	118

TABLE 43.—STRENGTH OF CONCRETE*

Proportions			Maximum slump permitted, in.	Assumed ultimate strength at 28 days, lb
Cement	Fine aggregate	Coarse aggregate		
1	2	4	6½	2,000
1	1½	3	8½	2,000
1	1½	3	6½	2,500
1	1	2½	8½	2,500
1	1	2½	6½	3,000
1	1	1½	8½	3,000

* As given in District of Columbia regulations.

So much of the literature that has been published on the cement-water ratio method of designing and controlling concrete mixes has stressed the savings in cement that may be made by the use of that method, while attaining high strengths in the concrete, as compared with the older methods of handling the proportioning, that there has developed a tendency among contractors estimating upon work to lose sight of the one critical condition upon which all water-cement ratio conclusions are based.

That condition is that the mixture must be plastic and workable. In other words, there must be enough water in the mix to insure thorough hydration of the cement, and enough cement to coat thoroughly all the particles of aggregate, no matter how large or how small they may be, and to permit the working of the mass into the forms so thoroughly that there will be no voids or "holidays" visible when the forms are removed.

The amount of cement which will be necessary to attain that degree of plasticity cannot be accurately foretold unless all the characteristics of the aggregates to be used are known in advance, but water can be substituted for cement in order to increase the plasticity, with a corresponding reduction in ultimate strength.

By setting a definite limit to the quantity of water which may be used per bag of cement, or the maximum slump which will be allowed in the test and the minimum compressive strength which will be accepted in the 28-day tests, the engineer can secure the kind of concrete which his design demands, but unless the contractor understands the effect of these specifications upon the amount of cement required to produce a cubic yard of concrete, he cannot prepare his estimates with certainty.

In Table 44 a comparison is shown of certain mixes, with the strengths assumed for them according to the Boston Building Law (which is one of the few building laws giving assumed strengths for various mixes of concrete), and mixes to attain equal strengths when designed according to the cement-water ratio method. The table is based upon the use of a coarse aggregate having a maximum size of 1 in. The quantities of cement for different sizes of aggregate would, of course, vary as indicated in the table, but the proportionate relationships between the last three columns in Table 41 would remain practically the same.

This table shows that, to obtain a concrete of a certain strength by the cement-water ratio method, equal to the strength assumed for a given mix by the old method, less cement will be required if conditions permit the use of concrete which will not slump more than 4 in., but when the conditions require a softer and more plastic mix, the same water-cement ratio being maintained, more cement

TABLE 44.—COMPARISON OF MIXES

Common designation of mix	Boston designation	Assumed strength, lb per sq in.	Bags of cement required per cu yd, water-cement basis		
			Old method	Permitted slump	
				3–4 in.	5–8 in.
1-1-2	1–3	3,300	10.0	8.8	12.2
1-1½-3	1–4½	2,800	7.4	7.1	9.6
1-2-4	1–6	2,200	5.84	5.66	7.4
1-2½-5	1–7½	1,800	4.76	4.7	6.2
1-3-6	1–9	1,400	4.04	3.9	4.9

will be required. Therefore, the conditions under which the concrete must be placed become an important factor in estimating the cost of the materials which will compose it.

It must also be noted that figures obtained from laboratory samples and tests cannot always be used as a basis for estimating the cost of producing concrete in the field. This is especially true when the sand used contains a large proportion of very fine material.

The greater the amount of fine material in the sand, the greater the amount of water required to wet it and also the greater the amount of cement required to surround it; therefore, to maintain a given cement-water ratio, a greater amount of cement will have to be added to produce a plastic mass.

A recently published bulletin gave the results of certain laboratory tests made with artificially graded sand and showed that high early and final strengths could be obtained when the entire procedure was under the control that can be maintained in a laboratory.

A comparison of the figures given in the bulletin mentioned, those given by Taylor and Thompson in their books, "Concrete, Plain and Reinforced" and "Concrete Costs," which have become the classics on this subject, and those likely to be attained under best actual job conditions is given in Table 45.

TABLE 45.—BAGS OF CEMENT REQUIRED PER CUBIC YARD—COMPARISON OF OTHER TABLES

As given in bulletin	Taylor and Thompson	Under job conditions
9	9.72–11.40	10.0–12.0
6.60	7.04– 8.36	7.4– 8.5
5.60	5.84– 7.04	6.5– 7.2

It should be noted that the figures given in the last two columns are not for producing concrete of any specified strength. The Taylor and Thompson tables are for producing concrete of certain proportions with aggregates having certain percentages of voids. The figures in the last column are as the contractor finds it when he checks up after the work is finished.

SECTION 2. SLAB WORK

While the cubic yard continues to be the unit used as a basis for payment in many instances, there are many classes of work in which it is simpler to estimate the superficial area than it is to convert the quantities into cubic yards, so if the work is to be done on a lump-sum basis, or on the basis of a square-foot or square-yard price, Table 46 can be used to determine the quantities of materials required.

For surface finishes, where mortar only, or granolithic, is to be used, Table 47 will apply. Granolithic is the kind

TABLE 46.—QUANTITIES FOR SLAB WORK

Concrete			Materials per 100 sq ft* (Multiply by 9 for quantities per 100 sq yd)					
Thickness, in.	Cu yd per 100 sq ft	Cu yd per 100 sq yd	1-2-4 Mix			1-3-6 Mix		
			C	*S*	*G*	*C*	*S*	*G*
1	0.31	2.78	1.86	0.14	0.23	1.30	0.15	0.29
1½	0.47	4.23	2.82	0.21	0.34	1.95	0.23	0.46
2	0.62	5.58	3.72	0.28	0.46	2.60	0.30	0.59
2½	0.78	7.02	4.68	0.35	0.57	3.25	0.37	0.73
3	0.93	8.37	5.58	0.42	0.69	3.90	0.45	0.87
3½	1.09	9.81	6.54	0.49	0.80	4.55	0.52	1.05
4	1.24	11.16	7.44	0.56	0.92	5.20	0.60	1.19
4½	1.40	12.60	8.40	0.63	1.03	5.85	0.67	1.33
5	1.56	14.04	9.36	0.70	1.15	6.50	0.75	1.47
6	1.88	16.92	11.28	0.84	1.38	7.80	0.90	1.78

* *C* = bags cement.
S = yards sand. Multiply by 1.35 to get tons.
G = yards stone or gravel. Multiply by 1.35 to get tons, if sand. Multiply by 1.30 to get tons, if ¾-in. stone. Multiply by 1.28 to get tons, if 1½-in. stone.

of surface made by adding ¼ in. washed gravel, or "grits," to the mortar mixture. It gives a rougher and more interesting texture, as well as a harder wearing surface.

TABLE 47.—QUANTITIES FOR CEMENT FINISH

Mix	Materials per 100 sq ft, 1 in. thick		
	Cement, bags	Sand, yd	Grits, yd
1-1	6.	0.23	
1-1½	4.76	0.72	
1-2	3.96	0.30	
1-2½	3.40	0.32	
1-3	2.96	0.33	
1-1-1	4.00	0.15	0.15
1-1-2	3.24	0.13	0.26

SECTION 3. MIXING

Ready-mixed Aggregates.—In many localities there are producers who are prepared to deliver aggregates mixed to contain the exact quantity of the several sizes of aggregate, from sand up to the largest size permitted, as required by the specifications. If ready-mixed aggregates are purchased on the volume basis, the amount to purchase will always be approximately the same as the total yardage of concrete to be produced, but, if they are purchased on the weight basis, the tonnage will be the sum of the tonnage computed for the sand and that computed for the coarse aggregate.

It is possible now, in most cities, to buy ready-mixed concrete, that is, concrete mixed at a central plant and delivered by trucks to the job, and "transit-mixed" concrete, where the mixing is completed in a mixing drum, mounted on a truck chassis. The drum revolves as the truck travels to the point of delivery.

Capacity of Mixer.—Since the concrete is charged or fed into the mixer in batches based on the number of bags of cement used, the time taken to produce a given quantity of concrete will be governed by the size of the batch and the time taken to mix a batch. Practically all of the modern mixers are capable of producing a batch of well-mixed concrete every minute, but it is seldom that any such

TABLE 48.—QUANTITIES PER 1-BAG BATCH OF CONCRETE

Nominal mix	Total volume charged in batch	Concrete, cu yd per batch	Batches per 100 cu yd
1-1-2	0.148	0.100	1,000
1-1½-3	0.204	0.134	746
1-2-3	0.223	0.143	700
1-2-4	0.259	0.167	598
1-2½-4	0.278	0.176	568
1-2½-5	0.315	0.200	500
1-3-6	0.371	0.232	432

pace can be maintained continuously under job conditions. Considering each bag of cement as the equivalent of 1 cu ft, Table 48 was constructed to show the amount of materials used per batch and the number of batches required to produce 100 cu yd of concrete.

From these figures it is evident that the mixer time required to produce 100 cu yd of concrete will be as in Table 49, in which it is assumed that the pace actually to be maintained is 30 batches per hour, or an average of one batch every 2 min.

Table 49.—Hours of Mixer Time per 100 Cu Yd

Nominal mix	1-bag batch	2-bag batch	4-bag batch
1-1-2	33.3	16.7	8.4
1-1½-3	24.9	12.5	6.3
1-2-3	23.3	11.7	5.9
1-2-4	19.9	10.0	5.0
1-2½-4	18.9	9.5	4.8
1-2½-5	16.7	8.4	4.2
1-3-6	14.4	7.2	3.6

The tabular time given is for 30 batches per hour.

Mixing Time, Min per Batch	Multiply Time Above By
1	0.5
3	1.5
4	2.0

If a half-bag mixer is used, it will require double the time required for a one-bag mixer, but it is advisable to figure not less than 3 min per batch.

Cost of Mixing.—The cost of mixing will be the total of the hourly cost of the mixer itself plus the cost of the time of the men required to operate and charge it. The number of men required to operate and charge a mixer will depend entirely upon the nature and organization of the work. A large road-building job may be so organized and equipped that all aggregates are delivered in exact batch quantities from the source of supply to the charging hopper of the mixer and no wheeling of aggregates at all will be done. In other instances, aggregates will be handled from stock piles to the mixer by trucks or carts. When this is done, the recovery from the stock piles is frequently done most economically by means of creeper-mounted loaders, though truck-mounted cranes with clamshell buckets are often used advantageously.

The method of computing the cost of loading by these machines was described in the discussion of the cost of excavating. For convenience, it seems better, in those cases where delivery is made by truck from the source of supply, to figure transporting costs as part of the delivered price of the material and, in all cases where stock piles will be used, to figure the cost to the stock pile as in the price of the material and all costs from the stock pile onward as parts of the cost of mixing.

On a small building job the hourly cost of the mixer will be a minor item in computing the cost of making concrete, since the crew charging and operating it will cost several times as much as the machine, but on a large highway contract the cost of the machine will be a controlling factor since the operating crew will be comparatively small.

Small Foundation Work.—In building house cellars and similar small structures, the stock piles will be kept comparatively close to the mixer and the distance from the mixer to the place of deposit will also be comparatively short. A one-bag mixer can be rented almost anywhere at not over $20 per week, and, assuming 40 hr of work per week, the cost per hour would be 50 cents. Detailed methods for calculating the hourly cost of mixers will be taken up later. The ordinary charging and operating gang for such a mixer would be

1 man shoveling sand
1 man shoveling stone
1 man wheeling sand

2 men wheeling stone
1 man operating mixer
1 man charging cement
1 man helping generally

so that the cost per hour for the charging and mixing operations would be as in Table 50.

Table 50.—Mixing Concrete for Small Jobs

Mixer	$0.50
7 laborers @ $0.35	2.45
1 operator	0.60
Fuel and lubricants	0.25
Compensation insurance	0.14
Total	$3.94

Thus, if the time required to mix 100 cu yd of 1-2-4 concrete (Table 49) is 19.9 hr, the cost of charging and mixing will be $78.41 per 100 yd or $0.78¼ per yd. To allow for the increased cost where the stock piles are not kept close to the machine, there should be added to the cost obtained from the table, 15 hr of laborers' time per 100 cu yd of material for each 25 ft beyond the first 25 ft from any stock pile to the mixer. Costs of distributing and depositing concrete will be discussed later.

Mixing on Larger Jobs.—On reinforced concrete buildings, and almost all the larger building jobs of concrete, the mixing plant will consist not only of the mixer itself, but also of a derrick and clamshell bucket or other means for recovering the stock from the piles, a batching plant for assuring accurate measurement of aggregates per batch and, where the cement-water ratio specification is in force, an inundator or other device for accurate regulation of the water content of each batch. This sort of plant greatly reduces the number of men required for wheeling and similar operations but requires a small number of higher grade men to operate the plant. Since the other items of equipment will be able to deliver materials faster than the mixer can handle them, the capacity of the whole plant will be that of the mixer.

When estimating work where it is known in advance what sort of plant will be used, the procedure is simply a matter of combining the hourly cost of operating each unit of the plant and from Table 49 determining the time to produce the concrete. For instance, the typical plant and crew on a very large reinforced concrete building might be as shown in Table 51.

TABLE 51.—MIXING PLANT FOR REINFORCED CONCRETE BUILDING

Unit	Cost per Hr
Elevating conveyor	$2.00
Batching plant	1.50
4-bag mixer	2.00
2 machine operators @ $1.00	2.00
1 batcher man	0.70
3 laborers @ $0.35	1.05
Compensation insurance	0.19
Total	$9.44

This sort of plant would be used where the incoming trucks could dump into a low hopper, from which the aggregates would be raised by the elevating conveyor to the batching plant and thence dumped into the mixer. The mixing cost per 100 cu yd of 1-2-4 would then be 4.8 × $9.44, or $45.31, and the cost per cubic yard $0.453. In other instances it might be necessary to construct storage bins, the cost of which should be separately calculated and, in the case of a unit price contract, distributed over the yardage to be placed. On a lump-sum contract the cost of the bins can be added directly into the total of the estimate, along with the other costs of temporary structures.

Mixing on Highway Work.—On most of the better organized highway jobs, the aggregates are either brought directly from the sources of supply in weighed quantities and dumped into the charging hopper or are recovered from stock piles and then dumped. In the first case, the mixing cost is only the time of the mixer and mixer crew, with insurance added, while in the second case it is that cost plus the cost of recovery and hauling. If a crane or derrick with a clamshell bucket is used for recovery, the cost of loading is to be figured as for excavating similar materials and, in any case, the hauling is to be figured as previously explained in the discussion of excavating costs. On a paving contract, with a modern mixer having a boom and a traveling bucket for distributing the concrete, a crew consisting of an operator and four laborers should handle all the work, so that the cost would be as in Table 52. In this instance, the cost would include the cost of depositing, so that the only further operation on the concrete would be the surface finishing, covering, wetting and similar treatments.

TABLE 52.—MIXING COST ON PAVING WORK

Unit	Cost per Hr
4-bag mixer	$2.00
Operator	1.00
4 laborers @ $0.35	1.40
Compensation Insurance	0.12
Total	$4.52

Since paving work is mostly 1½-3 mix, this would make the cost per 100 cu yd 6.3 × $4.52 = $28.48 or $0.285 per yard, plus the cost of getting the materials to the mixer.

SECTION 4. PLACING CONCRETE

The cost of placing concrete varies with every change in the conditions under which the work must be done. For ordinary small cellar jobs, it is sometimes practical to place the mixer on the bank alongside the forms and to discharge the concrete directly into its permanent location, moving the mixer from time to time as the work progresses. On many sidewalk and small paving jobs it is customary to use a mixer with a distributing spout so that no costs for wheeling are involved, the only placing costs being spreading, puddling or tamping and whatever surface treatments may be required. In most building work there will be considerable horizontal moving of the concrete, as well as hoisting, and a great variety of arrangements may be made for handling the work. Where the yardage is small, ordinary steel-bodied wheelbarrows, on wood frames, with a capacity of 2 cu ft, are most used. On larger work, two-wheeled buggies of 6 cu ft capacity are preferred.

Hoisting may be done either with barrows or carts on a platform elevator or by discharging from the mixer into an elevator bucket which dumps into a hopper above, whence the concrete is distributed by means of chutes or spouts. Because of the high first cost involved, it is seldom advisable to use a chuting or spouting plant unless the structure contains 2,000 or more cubic yards of concrete, but some form of hoist will be required where the lift is more than 15 ft, as the cost of making ramps to a greater height and the extra cost of pushing up long gradients will exceed the cost of installing and operating the hoist.

Where the depositing is to be done by barrows or carts, whether it is to be taken directly from the discharging chute of the mixer, from an elevated hopper or from the discharge end of chutes, the labor cost of moving, elevating and spreading may be calculated from Table 53, but the time of the elevator, chuting plant and similar parts of the equipment should be determined by taking the same number of hours of hoisting plant time as will be required of mixer time, for all concrete to be deposited above the level at which

TABLE 53.—LABOR COST OF DEPOSITING CONCRETE

Average distance to move concrete, ft	Man-hours per 100 cu yd			
	Wheeling in carts	Wheeling in barrows	Hoisting*	Spreading or puddling
25	20	30	25	25
50	35	45	35	25
75	50	60	50	25
100	65	80	65	25

* Add cost of hoist as explained in previous paragraph; the time in this column is for the laborers attending the hoisting plant.

elevating becomes necessary. This is so because, regardless of the ultimate capacity of the plant, unless it is undersize, it will have to be in use during all the hours when the mixer is delivering concrete that must be elevated. Of course, even where the hoisting plant is undersize, the last statement will hold true, but then the hoisting time will govern the mixing time, so that both will be increased.

The time given for wheeling will cover the necessary time taken for placing and moving plank runs.

SECTION 5. FINISHING CONCRETE SURFACES

Practically all concrete requires some surface treatment, either directly after depositing or after the concrete has become set and the forms have been removed. In highway work the customary treatment is a "screeding-off" followed by brooming while the concrete is still plastic. Then the concrete is allowed to attain its set, after which the surface is covered and kept moist by one means or another for several days. In building work, except in the case of floor slabs for which an integral surface is specified, surface treatment, other than striking off as nearly level as possible, will not be applied until after the concrete has become set and the forms removed.

The cost of the various finishes customarily employed on buildings can be determined from Table 54.

TABLE 54.—FINISHING CONCRETE SURFACES

Finish	Man-hours per 100 sq ft		
	Hand work		Pneumatic tool
	Laborers	Masons	
Cement wash	5		
Bush hammer	..	20	12
Crandalling	..	20	12
Picking	17	..	9
Rubbing	15	..	10

In highway work and other unit price work, the cost of finishing must be calculated on the basis of the yardage. Table 55 has therefore been constructed to show the amount of surface treatment required for each cubic yard, while Table 56 furnishes the means of calculating the cost of doing the work.

TABLE 55.—SURFACE TREATMENT PER CUBIC YARD

Thickness of Slab, In.	Area of Top Surface, Sq Ft
1	324
1½	216
2	162
2½	130
3	108
3½	91.5
4	81
4½	72.9
5	64.75
5½	59
6	54
7	46.5
8	40.5
9	36
10	32.4
11	29.25
12	27

TABLE 56.—HIGHWAY SURFACE TREATMENTS

Treatment	Time per 100 sq ft, hr	
	Laborer's time for hand work	Machine time if done mechanically
Screeding	5	0.045
Brooming	5	0.045

When the work is done mechanically, one man and the machine should be all that need be figured, so that the total cost for the operation, with the operator at 70 cents and the machine at $2, would be $2.70 per hr.

Thus, since a pavement averaging 7 in. thick has a superficial area of 46.5 sq ft per cu yd of concrete, and the cost of finishing 100 sq ft is 0.045 hr @ $2.70 or $0.12, then the amount that must be added to the unit price of each cubic yard to cover the surface treatments is

$0.12 × 0.465	$0.056
Compensation insurance	0.004
	$0.060

TABLE 57.—RIBBED CONCRETE FLOORS
(Quantities per 100 sq ft)

Construction	Width of rib	Cubic yards, concrete	Pounds, steel[1]	Pounds, steel[2]
6 plus 2	4	1.18	233	219
6 plus 2	5	1.24	233	219
8 plus 2	4	1.34	250	235
8 plus 2	5	1.41	250	235
10 plus 2	5	1.59	269	252
10 plus 2½	5	1.75	311	291
10 plus 3	5	1.91	349	327
12 plus 2	5	1.80	284	267
12 plus 2½	5	1.96	337	315
12 plus 3	5	2.12	371	347
12 plus 3	6	2.21	371	347

NOTE.—Weight of steel includes temperature rods at right angles to ribs but does not include weight of pans.

[1] Weight in this column figured on basis of f_s. 16,000, fc 650.
Weight in this column figured on basis of f_s. 18,000, fc 700.

TABLE 58.—MATERIALS FOR TAR CONCRETE

Size of Aggregate	Tar, Gal per Cu Yd
1- to 2½-in. crushed stone	6
¼- to 2½-in. crushed stone	9
Coarse-screened gravel	7
Fine-screened gravel	10
Sand (for dampproof course)	50 to 60

TABLE 59.—CONCRETE COLUMN QUANTITIES
(Cu yd per 100 lin ft)

Diameter, inches	Round column	Octagonal column	Square column
6	0.74	0.77	0.93
8	1.28	1.37	1.65
10	2.02	2.14	2.58
12	2.82	3.08	3.71
14	3.96	4.18	5.04
16	5.12	5.48	6.60
18	6.55	7.92	8.40
20	8.08	8.56	10.32
22	9.70	10.40	12.45
24	11.28	12.32	14.88
26	13.80	14.40	17.40
28	15.84	16.72	20.16

TABLE 60.—CONCRETE BEAM QUANTITIES
(Cu yd per 100 lin ft)

	Width in inches				
Depth	6	8	10	12	14
8	1.24	1.64	2.05	2.46	2.88
10	1.55	2.05	2.56	3.08	3.60
12	1.86	2.46	3.08	3.72	4.32
14	2.17	3.07	3.60	4.33	5.04
16	2.48	3.28	4.10	4.96	5.76
18	2.79	3.69	4.61	5.54	6.48
20	3.10	4.10	5.12	6.16	7.20
22	3.41	4.51	5.64	6.80	7.92
24	3.72	5.92	6.16	7.44	8.64

TABLE 61.—CONCRETE PLAIN SLAB QUANTITIES

Thickness, inches	Quantity	Thickness, inches	Quantity
1	0.31	6½	2.04
1½	0.47	7	2.20
2	0.62	7½	2.35
2½	0.78	8	2.50
3	0.93	8½	2.65
3½	1.09	9	2.80
4	1.24	9½	2.95
4½	1.40	10	3.10
5	1.56	10½	3.25
5½	1.72	11	3.40
6	1.88	11½	3.56
		12	3.71

SECTION 6. FORMS

In actual construction of a building, it is necessary to build the forms for all of the structural concrete before the concrete itself can be put into place. The estimator, however, generally finds it more feasible to estimate the cost of the concrete first and then to estimate the cost of the forms to contain it. The quantity surveyor takes off the quantities of concrete work and formwork practically simultaneously. When concrete is used in paving, whether of roads, streets, walks or floors, the cost of the formwork is an almost negligible part of the entire cost, but in reinforced concrete building construction the cost of the forms will often exceed the cost of the concrete. On almost any reinforced concrete building, the area of the forms will average from 50 sq ft per cu yd of concrete upward, and using these nominal figures:

1 cu yd concrete in place	$8
50 sq ft forms @ 18 cents	$9

it is seen that the forms are the major item. Of course these prices will vary, and the average area of the forms will vary, but it is evident that it is just as important to figure forms accurately as it is to figure the concrete accurately. On unit price work it will frequently be necessary to figure the cost of the forms separately and then divide the cost by the yardage of concrete, in order to be able to quote a correct price per cubic yard, since there is seldom a separate item for forms in the bid.

There are several different methods of figuring forms, but it seems most satisfactory to figure all building work on the basis of the number of square feet of "contact" area, that is, the area of surface of forms that will be in actual contact with the concrete, since construction of forms can be fairly well standardized on that basis, except that round column forms are best estimated by a unit price per column. In fact, there are companies who make a business of delivering, erecting and dismantling steel forms for round concrete columns. They frequently quote a lump-sum price to cover all of the columns in a given building. Recent figures have been from $14 to $20 per column. For bridges and many other kinds of heavy construction work, the first procedure is to work out a design for the forms, parts of which will undoubtedly be in steel, and then to estimate the cost of making, erecting, stripping and dismantling.

The standardized types of forms that can be used for ordinary building work can seldom be used in bridge construction and there the design of the forms calls for as nice a degree of engineering skill as does the design of the bridge itself.

Forms in Building Construction.—Since most of the types of forms used in reinforced concrete building construction have become pretty well standardized, it has been practicable to work out tables covering the materials and the labor needed for making and erecting them, as well as the costs of stripping or removing. For certain kinds of floor slab work it is possible to sublet the making, erecting and stripping of forms to companies specializing in that work. Recent figures on multistoried buildings have averaged 18 cents per square foot of contact area.

Where organized labor is employed, it may be necessary to have practically all the work of form building done by carpenters. Otherwise, a great deal of the work can be done by handy laborers, with consequent saving in cost. The estimator should always determine what parts of the work can be done by laborers.

Wall Forms.—Except in those instances where it is specified that heavier stock should be used, it is customary to build wall forms of 7/8-in. boards, supported by 2 × 4 studding 24 in. on centers. Of course, the studs must be firmly braced and tied to prevent bulging or misalignment. Walls higher than 8 ft should have the studs closer together. Where conditions make it practicable, wall forms are best built in panels and then erected. The materials required for 100 sq ft of forms in the ordinary types of construction are as given in Table 62.

TABLE 62.—MATERIALS FOR CONCRETE FORMS
(Quantities per 100 sq ft)

Material	Footings	Walls	Piers	Steps	Sills, lintels, etc.
FBM boards	115	115	120	120	120
FBM	80	78	80	80	60
Lb nails	8	8	8	8	7
Lb tie wire	...	5			

The actual cost of materials used in forms will vary with the number of times that the forms can be used. In small house construction, the materials used for building the foundation forms will almost always be used up as underflooring, roof boarding, studding, etc., so that if a proper charge is made in the estimate for cleaning, the cost of the lumber can be considered as saved without much additional depreciation. It is more customary, however, to make a further deduction of at least 30 per cent to cover waste due to short pieces that may not be reused, breakage and similar causes. Thus, if it be estimated that the cost of new material per 100 sq ft of forms is $6.62, and the salvage value of the lumber is 70 per cent of $5.80 (which is the total cost except for the nails and wire), or $4.06, then the cost of that part of the value of the materials which was consumed by their use in the forms is $2.56.

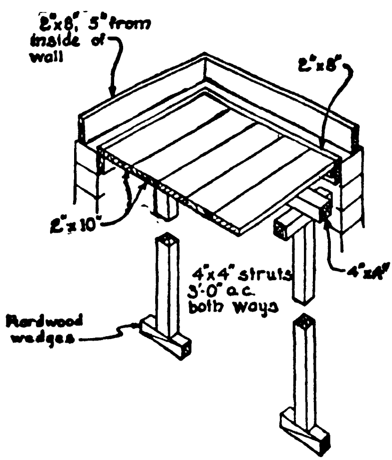

FIG. 1.—Forms for solid concrete floors. (*Courtesy Portland Cement Association.*)

Caution must be used in figuring the material for the other parts of the building not to omit the cost of the form materials, on the theory that they are left over from the foundation work and therefore do not cost anything. In this instance, only the depreciation is included in the foundation estimate, so the balance of the cost, as well as the full cost of additional materials required, must be included in the carpenter work estimate. Where forms can be reused several times on the same job, it will generally be necessary to add some new materials for repairs, extra bracing and other purposes, for each additional time the stock is used. If the forms could be used three times, the cost each time they were used would be figured as follows:

Cost of material for first use	$6.62
Add 15% for new material for second use.	0.99
Add 15% for new material for third use	0.99
Total	$8.60
Residual value of salvage, if used for blocking and similar purposes, 20% of first cost of lumber only	$1.19
Net cost of three uses	$7.41
Net cost of each use	$2.47

Beam, Girder and Column Forms.—Forms for the structural parts of a building, other than the walls and slabs, require a much greater amount of bracing and shoring, as is indicated in Table 63.

TABLE 63.—MATERIALS FOR BEAM, GIRDER AND COLUMN FORMS

Material	Quantity per 100 sq ft	
	Beams and girders	Square or rectangular columns
Boarding, FBM	115	145
Bracing, etc., FBM	265	235
Nails, lb	18	10
Bolts, etc., lb	...	50

In addition to the materials named in the table, it will be necessary to make an estimate of the total number of linear feet of bevel strips, reversed moldings and similar items which must be introduced in order to produce whatever ornamental profiles may be required by the plans.

Slab Forms.—The design of the slab forms to be used will vary with the type of construction. For any solid concrete slab, it will be necessary to build a tightly floored form, but any of the ribbed, domed or cored types can be built on open forms. Tight forms are customarily built of ⅞-in. or 1¼-in. boarding, while open forms are more frequently made with 2-in. planking and the domes or cores

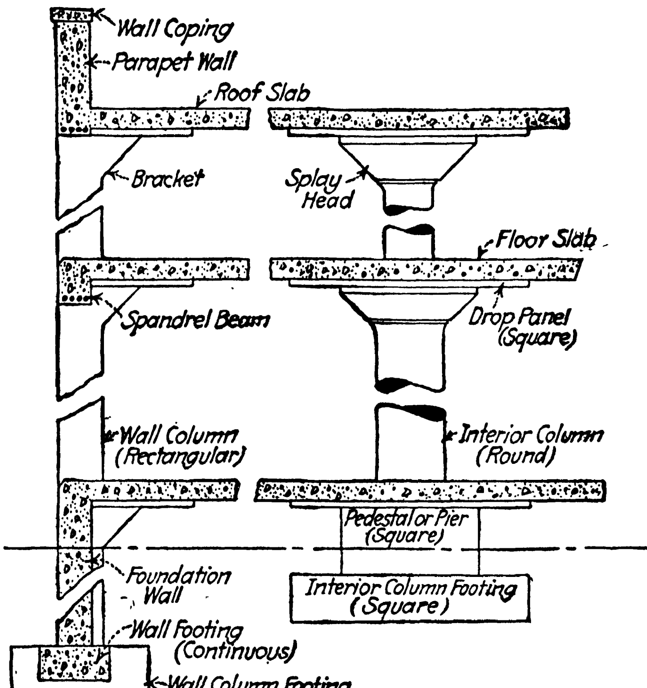

FIG. 2.—Typical reinforced concrete details.

are supported on the planking. Tables 64 to 66 indicate the amount of material required for the first use of each kind of forms, and Table 67 indicates the factor to be used for each use of the forms, where the construction is such that the forms may be reused on the same building.

TABLE 64.—MATERIALS FOR FORMS FOR COMBINATION SLABS (Hollow tile or gypsum and concrete)

Type of construction	Quantities per 100 sq ft				
	Spacing of joists	Spacing of posts	Plank, FBM	Timber, FBM	Nails, lb
4 + 2	58	72	110	170	6
4 + 2½	58	72	110	170	6
5 + 2	56	66	110	182	7
5 + 2½	56	66	110	182	7
6 + 2	56	66	110	182	7
8 + 2	52	60	110	198	8
8 + 2½	52	60	110	198	8
10 + 2	50	54	110	212	9
10 + 2½	50	54	110	212	9
10 + 3	50	54	110	212	9
12 + 2	48	48	110	230	10
12 + 2½	48	48	110	230	10
12 + 3	48	48	110	230	10

TABLE 65.—MATERIALS FOR FORMS FOR SOLID SLABS

Thickness of slab, in.	Quantities per 100 sq ft		
	Boarding, FBM	Timber, FBM	Nails, lb
3	115	245	7
4	115	245	7
5	115	255	8
6	115	255	8
7	115	265	9
8	115	265	9

TABLE 66.—MATERIALS FOR FORMS FOR RIBBED SLABS
(Using permanent or removable steel cores or pans)

Construction	Plank, FBM	Timber, FBM	Nails, lb
6 + 2	102	160	5
8 + 2	102	172	5
10 + 2	102	184	6
10 + 3	102	186	6
12 + 2	102	196	7
12 + 3	102	198	7

Slabs on metal lumber and steel joists will not require any formwork, since the reinforcing fabric or lath will serve as a form during the setting of the concrete.

TABLE 67.—FORMS FOR MULTISTORIED BUILDINGS*

Height of building, stories	Speed					
	1 week per story			2 weeks per story		
	Beams, girders	Columns	Slabs	Beams, girders	Columns	Slabs
1	1.0	1.0	1.0	1.0	1.0	1.0
2	1.3	1.3	1.3	1.0	1.0	1.0
3	1.28	1.12	1.44	0.8	0.7	0.9
4	1.76	1.08	1.44	0.7	0.6	0.9
5	0.85	0.68	1.20	0.5	0.4	0.7
6	0.74	0.58	1.14	0.45	0.35	0.7
7	0.72	0.56	1.12	0.42	0.32	0.6
8	0.58	0.41	0.96	0.36	0.26	0.6
9	0.56	0.39	0.94	0.35	0.25	0.5
10	0.48	0.36	0.75	0.34	0.24	0.5
11	0.48	0.33	0.45	0.32	0.22	0.3
12	0.48	0.33	0.45	0.32	0.22	0.3

* To determine the average quantity per use on a building of a given height, multiply the quantity of lumber required for one use of the forms, as determined by Tables 63, 64, 65 and 66, by the factor in this table.

Thus, if it be determined that the total contact area for forms in a 12-story building be as follows:

Beams and girders	20,000 sq ft
Columns	6,000 sq ft
6-in. slabs	60,000 sq ft

and it is intended to prosecute the work at an average speed of one story every two weeks, then the lumber required for the forms would be figured thus:

Boarding			
Beams and girders	20,000 × 1.15 × 0.32	7,360	
Columns	6,000 × 1.45 × 0.22	1,914	
6-in. slabs	60,000 × 1.15 × 0.30	20,700	
		29,974	FBM
Timber			
Beams and girders	20,000 × 2.65 × 0.32	16,960	
Columns	6,000 × 2.35 × 0.22	3,102	
6-in. slabs	60,000 × 2.55 × 0.30	45,900	
		65,962	FBM

or an average of 1.12 FBM stock per square foot of contact area.

The nails, of course, would not be reused, so the quantity would be

Beams and girders	20,000 × 0.18	3,600
Columns	6,000 × 0.10	600
Slabs	60,000 × 0.08	4,800
		9,000 lb

The bolts for the columns would be reused and their quantity would be

$$6,000 \times 0.50 \times 0.22 = 660 \text{ lb}$$

Labor Costs on Forms.—All well-organized jobs are now equipped with power saws to handle practically all the cutting in connection with the making of forms, but on

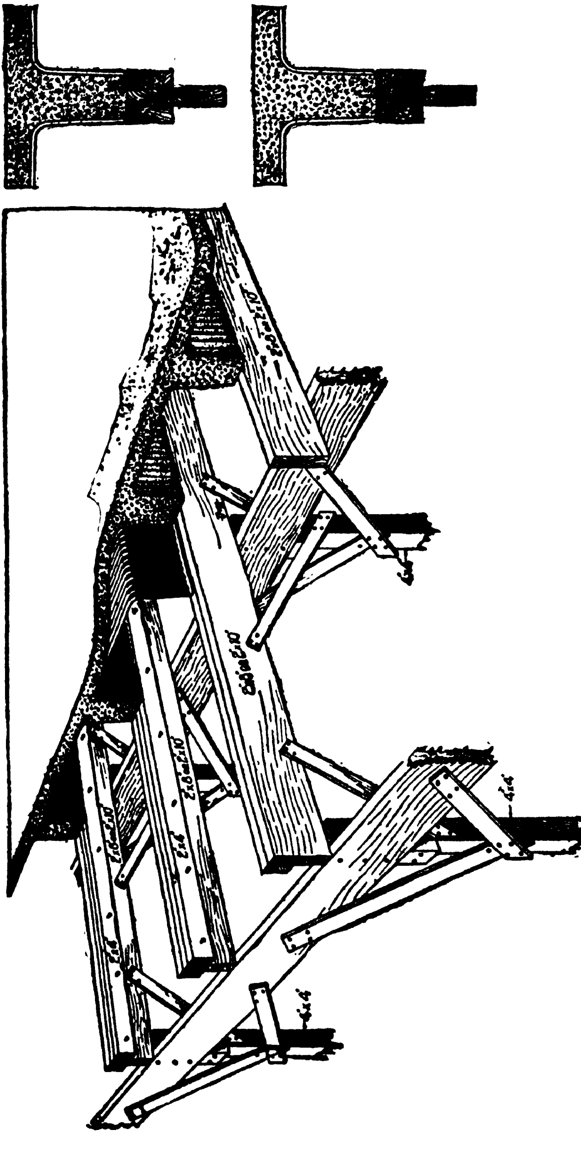

FIG. 3.—Forms for ribbed concrete floors. (*Courtesy Berger Manufacturing Co.*)

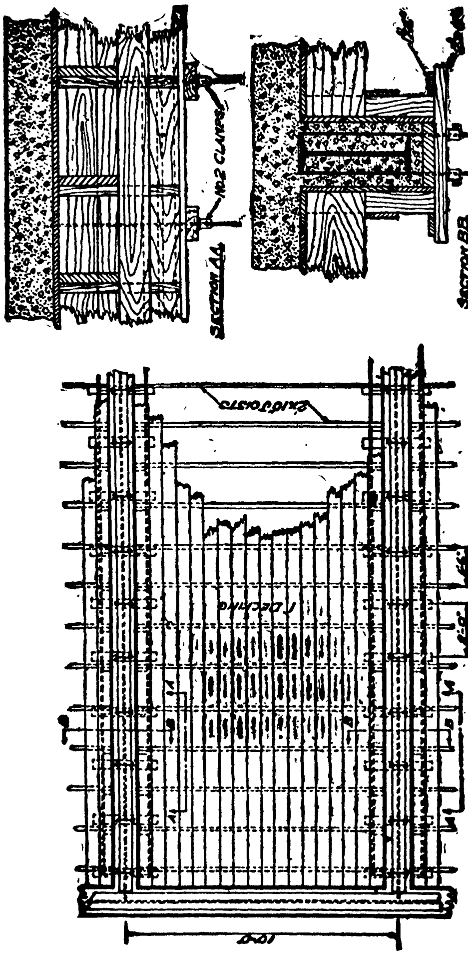

FIG. 4.—Floor forms supported on steel construction. (*Courtesy Universal Form Clamp Co.*)

small foundation jobs it may not always be practicable to get the power installed in time to use it, so the estimator should be prepared to figure the job according to the conditions under which it will probably have to be done. On reinforced concrete construction, the estimator will make a careful study of the plans to see if it will be possible to make up the forms in semipermanent panels, which can be used over again without complete remaking for each use. Where such panels can be used, it will only be necessary to figure the making up cost once, and the stripping and re-erecting cost for the succeeding uses. The tables which follow have been worked out for use in estimating the labor costs on form making and erecting for building construction and similar work where standardized types of forms can be used. Where specially designed forms are required, it is recommended that the methods which will be developed later for figuring costs of heavy timber work, planking and structural steel be used. Tables can be worked out as well to apply the labor costs directly to the quantities of forms as expressed in contact area as they can to apply them to the quantity of lumber used. In this instance they have been constructed on the basis of the quantities of materials.

TABLE 68.—LABOR ON FOUNDATION FORMS

Type of form		Hours per 1M FBM total stock			
		Make	Erect	Strip	Total
Footings	carpenter	13.0	2.6	...	15.6
	laborer	5.0	5.0	5.0	15.0
Walls	carpenter	15.5	7.7	...	23.2
	laborer	7.7	7.7	7.0	22.4
Piers	carpenter	20.0	7.7	...	27.7
	laborer	7.7	7.7	7.0	22.4
Steps	carpenter	35.0	8.0	...	43.0
	laborer	7.8	8.0	8.0	23.8
Platforms	carpenter	32.0	7.0	...	39.0
	laborer	7.8	7.0	7.0	21.8

In each instance, the cost of the carpenter's time and the laborer's time must be added together in order to get the total cost. Thus, to compute the cost of 100 sq ft of wall forms, the procedure is as follows:

Materials (from Table 62)		
115 FBM boards @ \$26.00 per M	\$2.99	
78 FBM studs @ 36.00 per M	2.81	
8 lb nails @ \$0.02½	0.20	
5 lb wire @ 0.06	0.30	\$ 6.30
Labor (from Table 68)		
23.2 × 0.193 = 4.5 hr carpenter @ \$1.00	\$4.50	
22.4 × 0.193 = 4.3 hr laborer @ 0.50	2.15	\$ 6.65
Total		\$12.95

To this total must be added the cost of compensation insurance unless a separate item is carried for insurance in the summary or general conditions section of the estimate, and the salvage value of the lumber should be deducted.

TABLE 69.—LABOR ON FORMS IN REINFORCED CONCRETE CONSTRUCTION

Type of form		Hours per M FBM total stock			
		Make	Erect	Strip	Total
Beams, girders, columns, etc.	carpenter	17.0	5.2	...	22.2
	laborer	5.2	5.2	8.0	18.4
Slabs	carpenter	17.0	5.2	...	22.2
	laborer	5.2	5.2	7.0	17.4
Walls and partitions	carpenter	15.5	7.7	...	23.2
	laborer	7.7	7.7	7.0	22.4
Stairs	carpenter	22.5	7.5	...	30.0
	laborer	7.8	7.8	8.0	23.6

In every instance where the forms cannot be used again without remaking, the labor should be figured as though the forms were being used only once, even though the stock is figured as explained in connection with Table 67. Thus, taking the instance mentioned there, and the material quantities from Tables 63 and 65, the labor quantities would be as follows:

Carpenters		
Beams and girders...	20,000 × 3.8 × 22.2 per M	1,687.2
Columns............	6,000 × 3.8 × 22.2 per M	506.2
6-in. slabs..........	60,000 × 3.7 × 22.2 per M	4,928.4
		7,121.8
	7,121.8 hr @ $1.00 = $7,121.80	
Laborers		
Beams and girders...	20,000 × 3.8 × 18.4 per M	1,398.4
Columns............	6,000 × 3.8 × 18.4 per M	419.5
6-in. slabs..........	60,000 × 3.7 × 17.4 per M	3,862.8
		5,680.7
	5,680.7 hr @ $0.50 = $2,840.35	

$7,121.80
2,840.35
$9,962.15

or an average of $0.115 per sq ft.

If it had been possible to make panels and use them three times, then the labor would have been considerably less and it would be better to figure in this manner:

Making forms			
Columns, beams and girders		560	
	8,670 × 3.8 × 17. per M		
Slabs	20,000 × 3.7 × 17. per M	1,258	
		1,818	
	1,818 hr @ $1.00		$1,818.00
Laborers			
Columns, beams and girders		171.3	
	8,670 × 3.8 × 5.2 per M		
Slabs	20,000 × 3.7 × 5.2 per M	384.8	
		556.1	
	556.1 hr @ $0.50		278.25
Erecting and stripping forms			
Carpenters			
Columns, beams and girders		513.8	
	26,000 × 3.8 × 5.2 per M		
Slabs	60,000 × 3.7 × 5.2 per M	1,154.4	
		1,668.2	
	1,668.2 hr @ $1.00		1,668.20
Laborers			
Columns, beams and girders		1,304.2	
	26,000 × 3.8 × 13.2 per M		
Slabs	60,000 × 3.7 × 12.2 per M	2,708.4	
		4,012.6	
	4,012.6 hr @ $0.50		2,006.30
			$5,770.75

or an average of $0.068 per sq ft.

TABLE 70.—LABOR ON FORMS FOR COMBINATION AND RIBBED SLABS

Type of form		Hours per M FBM total stock		
		Make and erect	Strip	Re-erect after first use
Combination slabs	carpenter	15		
	laborer	..	3.8	11.4
Ribbed slabs	carpenter	21	...	7.0
	laborer	10	4.0	6.0

In using Table 70, as in previous instances, add the cost of the laborers' time to the cost of the carpenters' time. Figure the cost of making and erecting once for as great an area as will have to be covered at once, then the cost of re-erecting for the balance of the area and the cost of stripping for the entire area.

Paper Tubes as Forms.—A recent development is the use of heavy paper tubes for foundation pier and short column forms. Stock sizes are from 8 in. to 13½ in. inside diameter and the thickness of the spirally wound paper wall is generally ¼ in. The cost is but a few cents per linear foot and the labor cost of installation is very small. In foundation work, it is frequently possible to backfill around the form and, as there is no salvage value in the tube, no expense of stripping is involved. Sufficient experience has not yet been had to compile tables of actual costs but, in general, it may be said that the cost of foundation pier forms of this type will be about one-fourth that of wooden forms of similar size.

SECTION 7. REINFORCING STEEL

Accurate estimating of the labor costs of installing reinforcing steel is perhaps one of the most difficult tasks which confront the estimator. First, there is such a wide variety of schemes for distributing the steel that it is almost impossible to develop a set of standard time allowances for the various operations. Then, there is the fact that, while most of the work of installing reinforcing steel could readily be done by handy laborers, union regulations generally require it to be done by structural ironworkers or by metal lathers. It has actually been proved on many jobs that handy laborers will install more steel per hour than will mechanics, and that just as accurately.

Quantities.—Surveying the quantities of reinforcing steel is rather a tedious task because of the great number of pieces that must be considered in order to build up the tonnage. This is especially true where there is no uniformity in the design of the several structural members. On the other hand, some engineers standardize the several parts of a design so well that the same units are repeated frequently and thus considerable time can be saved in surveying quantities. To facilitate the quantity surveying, several tables have been prepared which enable the estimator to calculate the tonnage of steel in the principal members directly from their lengths or from the areas of slabs, but, where great accuracy is desired, it is much better to list all bars and calculate their weights.

Occasionally, engineers will indicate the cross-sectional area of steel required, leaving the contractor to select the bars which will give that area, and Table 72 indicates the area per bar and per foot with a given spacing of bars. Manufacturers of reinforcing bars have now reduced the number of sizes to 11 standards and the tables are based on those sizes.

When using Table 71, it is necessary always to include one additional row of bars across the end of each space surveyed. For ribbed slab or combination hollow tile and concrete construction it is necessary to multiply the quantity in the column for the proper spacing by the number of bars specified per joist or per rib. Where the reinforcing is laid in two directions, as is frequently the case in highway

TABLE 71.—WEIGHTS OF REINFORCING RODS
Lb per 100 sq ft

Nominal size, in.	Weight, lb per lin ft	Spacing, in.							
		4	5	6	8	12	16	20	24
¼ round	0.17	51	40.4	34	25.5	17.0	12.8	10.1	8.5
⅜ round	0.38	114	91.2	76	57	38.0	28.5	22.8	19
½ round	0.68	204	163.2	136	102	68.0	51	40.8	34
½ square	0.86	258	206.4	172	129	86.0	64.5	51.6	43
⅝ round	1.06	318	254.4	212	159	106	79.5	63.6	53
¾ round	1.52	456	364.8	304	228	152	114	109.2	76
⅞ round	2.07	621	596.8	414	310.5	207	155.8	149.2	103.5
1 round	2.70	810	648	540	405	270	205.5	162	135
1 square	3.44	1,032	705.6	688	516	344	258	126.4	129
1⅛ square	4.35	1,305	1,044	870	652.5	435	326.3	261	163.2
1¼ square	5.37	1,611	1,288.8	1,074	805.5	537	402.8	322.2	210.4

construction, double the quantity taken from the table will be required if the rods are the same size in both directions. If a larger size is used in one direction than the other, then

TABLE 72.—AREAS OF REINFORCING RODS

Nominal size, in.	Area per bar, sq in.	Area, sq in. per ft of width Spacing, in.							
		4	5	6	8	12	16	20	24
¼ round	0.05	0.15	0.12	0.10	0.075	0.05	0.038	0.03	0.025
⅜ round	0.11	0.33	0.264	0.22	0.165	0.11	0.083	0.066	0.055
½ round	0.20	0.60	0.48	0.40	0.30	0.20	0.15	0.12	0.10
½ square	0.25	0.75	0.60	0.50	0.375	0.25	0.188	0.15	0.125
⅝ round	0.31	0.93	0.744	0.62	0.465	0.31	0.233	0.186	0.155
¾ round	0.44	1.32	1.056	0.88	0.66	0.44	0.33	0.264	0.22
⅞ round	0.60	1.80	1.44	1.20	0.90	0.60	0.45	0.36	0.30
1 round	0.79	2.37	1.888	1.58	1.185	0.79	0.593	0.472	0.395
1 square	1.00	3.00	2.40	2.00	1.50	1.00	0.75	0.60	0.50
1⅛ square	1.27	3.81	3.128	2.54	1.905	1.27	0.953	0.782	0.635
1¼ square	1.56	4.68	3.744	3.12	2.34	1.56	1.17	0.936	0.78

the quantities for each size, as taken from the table, are to be added together. In all instances where special types of fittings are not specified, it will be necessary to add 2 per cent to the cost of the rods to cover tie wire, etc.

Labor on Bar Reinforcement.—Most of the data that have previously been published on the cost of fabricating and placing reinforcing steel will be found of little real assistance in estimating, since they consist principally of average costs per ton. To be of maximum benefit to an estimator, data should be so arranged that he can apply them directly to the problem in hand. Some of the data which have been published, having been translated into the cost in hours per ton, are reproduced in Table 73.

TABLE 73.—PUBLISHED DATA ON REINFORCING STEEL

Kind of work	Labor, hr per ton		
	Bending and fabricating	Placing	Total
Buildings	..	..	31
Bridge superstructure	..	..	86
Bridge piers	..	..	42
Dams	..	..	36
Slab rods	16	12	28
Stirrup	40	16	56
Spiral	70	20	90
Beam bars	16	19	35

Tables 73 to 75 and 77 are based on a wide range of data and may be used for all ordinary figuring. In making them it was assumed that mechanics would be employed in fabricating, that they would be equipped with proper tools and that either handy laborers or mechanics would do the installation. No allowance was made for restrictions on output, such as are in force in many metropolitan sections at present. Since it is now the custom to have the suppliers of reinforcing steel make a lump-sum bid on all of the reinforcing steel cut to length, bent and fabricated, leaving only the erection to the contractor, it will seldom be necessary for the estimator to concern himself with cutting and bending costs. The figures which are given in Table 74 are lower than those in Table 73 but, when compared with the average prices per ton quoted by those subcontractors who specialize in the installation of reinforcing steel, they check very closely.

TABLE 74.—REINFORCING STEEL IN BUILDINGS

Size of bars, inches		Labor, hr per ton	
		Bending	Placing
Spirals	1/4	70	16
	3/8	40	16
	1/2	35	16
Stirrups	1/4	26	18
	3/8	24	16
	1/2	22	14
Beams, columns, and stairs	1/2 and 5/8	10	12
	3/4 and 7/8	8	10
	1 and over	6	9
Walls	1/2 and 5/8	5	12
	3/4 and 7/8	4.5	7.5
	1 and over	4	4.5
Slabs	1/2 and 5/8	5	8
	3/4 and 7/8	4.5	5.5
	1 and over	4	4

Even these figures can be reduced somewhat under favorable conditions, but it is not advisable to pare an estimate any closer for ordinary competitive bidding. In addition to the time taken for the placing of reinforcing rods, it is necessary to include in the estimate a sufficient amount to take care of all the costs of placing "chairs," inserts and other fittings, and these items commonly consume more time than is allowed for them. Because of the great number and variety of such special items, it is practically impossible to make up tables that are at all complete.

The best practice seems to be to allow 4 hr per 100 of all inserts that must be located very exactly and 2 hr per 100 for all spacers and chairs.

Mesh and Fabric Reinforcements.—Experience has shown that practically all forms of mesh and fabric reinforcements can be placed much more economically by laborers than by mechanics. The figures which are given in this article are based upon what is ordinarily accomplished where no restrictions are in force. These reinforcements are divided into two general classes, and the sizes and weights within those classes are pretty well standardized by all manufacturers. These classes are the expanded types, which are delivered in sheets, and the fabric types, which are delivered in rolls. Prices on these materials are customarily quoted on the basis of 100 sq ft and their sizes and

TABLE 75.—TYPES OF EXPANDED METAL REINFORCING MESH*

Style	Weight, lb per sq ft	Width of sheets, short way of mesh, ft and in.	Length of sheets, long way of mesh, ft
306	0.20	6	8 and 12
308	0.27	6	8 and 12
310	0.34	4	8 and 12
3125	0.42	5–6	8 and 12
315	0.51	7	8, 10 and 12
3126	0.60	6	8, 10 and 12
320	0.68	5–6	8, 10 and 12
325	0.85	4–3	8, 10 and 12
330	1.02	7	8, 10 and 12
335	1.19	6	8, 10 and 12
340	1.36	7	8, 10 and 12
345	1.53	6–3	8, 10 and 12
350	1.70	5–9	8, 10 and 12
354	1.83	5–6	8, 10 and 12
360	2.04	4–9	8, 10 and 12
365	2.19	4.3	8, 10 and 12

* An allowance of 5 per cent over actual areas should be made for laps.

TABLE 76.—STANDARD STYLES OF ELECTRICALLY WELDED FABRIC*

Spacings of wires, in.		Gauge number		Section areas, sq in. per ft		Weight per 100 sq ft
Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	
2	16	1	7	0.377	0.018	138.9
2	16	2	8	0.325	0.015	119.4
2	16	3	8	0.280	0.015	103.6
2	16	4	9	0.239	0.013	88.5
2	16	5	10	0.202	0.011	74.6
2	16	6	10	0.174	0.011	64.7
2	16	7	11	0.148	0.029	54.8
3	16	2	8	0.216	0.015	82.6
3	16	3	8	0.187	0.015	72.0
3	16	4	9	0.159	0.013	61.4
3	16	5	10	0.135	0.011	51.8
3	16	6	10	0.116	0.011	45.1
3	16	7	11	0.098	0.009	38.1
3	16	8	12	0.082	0.007	31.7
4	16	3	8	0.140	0.015	56.1
4	16	4	9	0.120	0.013	47.9
4	16	5	10	0.101	0.011	40.4
4	16	6	10	0.087	0.011	35.2
4	16	7	11	0.074	0.009	29.7
4	12	8	12	0.062	0.009	25.5
4	12	9	12	0.052	0.009	21.8
4	12	10	12	0.043	0.009	18.6
4	12	12	12	0.026	0.009	12.6
4	12	5	5	0.101	0.034	48.4
4	12	6	6	0.087	0.029	41.6
4	12	7	7	0.074	0.025	35.4
4	12	8	8	0.062	0.021	29.6
6	12	0	6	0.148	0.029	65.3
6	12	2	2	0.108	0.054	59.4
6	12	3	3	0.093	0.047	51.2
6	12	4	4	0.080	0.040	43.8
6	12	5	5	0.067	0.034	37.0
6	12	6	6	0.058	0.029	31.8
6	12	7	7	0.049	0.025	27.0
6	8	12	12	0.017	0.013	11.1
6	6	4	4	0.080	0.080	57.8
6	6	5	5	0.067	0.067	48.8
6	6	6	6	0.058	0.058	42.0
6	6	7	7	0.049	0.049	35.7
6	6	8	8	0.041	0.041	29.9
6	6	9	9	0.035	0.035	25.0
6	6	10	10	0.029	0.029	20.7

* An allowance of 5 per cent over actual areas should be made for laps.

weights can be determined from Tables 75 and 76. Where the price quoted is for other than delivery at the site of the work, the cost of hauling can be computed in the manner outlined in the article on that subject.

TABLE 77.—PLACING MESH REINFORCING

Reinforcement	Hours per 100 sq ft		
	On roads	Over wood forms	Over joists or metal lumber
Expanded metal	0.5	0.4	0.45
Fabric	0.6	0.5	0.55

Ribbed and Domed Systems.—The metal pans or domes which are used as cores in several systems of reinforced concrete floor construction are more properly to be considered as forms than as reinforcement, but since they are generally placed by the same crew that places the reinforcing steel, the method of estimating the cost of their installation is indicated here. There are two types in general use, those which remain permanently in place and those which are later removed. Where the concrete ceiling will not be concealed by lathing and plastering, or some other construction, the removable type will generally be used, and the permanent type will generally be used where the concrete will be concealed.

In the permanent types, provision is frequently made to attach the ribbed metal lath for the ceiling directly to under edges of the pans, thus reducing the number of operations required to complete the building, because the lath may be placed directly upon the wood forms and then the pans put in place and clamped. This clamping operation consumes some time but does not cost so much as it would to install hangers and then fasten the lath on later. The labor cost of installing these cores can be determined from Table 78. The material cost should be obtained from the manufacturer or dealer and, where removable cores are used, they can ordinarily be rented on the basis of a lump-sum price for the job, thus obviating the necessity for making a permanent investment in equipment that may not be in constant use. In getting prices on cores of any type, it is advisable to have the manufacturer or dealer examine the plans and make a lump-sum bid. Where that is not feasible, the estimator can make his own schedule.

TABLE 78.—PLACING DOMES AND PANS

Work	Hr per 100 Sq Ft
Placing pans on forms	4
Placing pans over ribbed lath	4.5
Placing domes	4.5
Removing pans	2

Since the customary width of the pans is 20 in. and the width of the ribs 4 in., it follows that 1 lin ft of pan will be required for each 2 sq ft of slab, except for the spaces at the ends of the spans, which are to be cast solid in concrete. If the width of the ribs is 5 in., the number of linear feet of pans would then be only 48 per cent of the number of square feet of slabs. Making allowance for the solid areas at the ends of the spans, one manufacturer recommends that 43 per cent of the slab area be used as the number of linear feet of pans required. In the schedule sent for prices, the number of closures required for the ends should be stated and also the number of spacers, which is one for each 6 sq ft of floor or practically 17 for each 100 sq ft. In two-way construction, where domes are used, they should be scheduled by number, which with 4-in. ribs and 20-in. domes would be 23 per cent of the area covered. One spacer will be required for each dome.

SECTION 8. SPECIAL PROCESSES

It was intended to include in this edition detailed information as to the costs of all of the recently developed and, in some instances, patented processes for placing and finishing concrete, but it was found that the proprietors of the processes were either reluctant to give out the data that were desired or that the information which was available could not be readily integrated into the form required. However, some valuable data were obtained and are given in the following paragraphs.

Soil-cement Roads.—These roads, a relatively new development, are coming into use in connection with housing developments and other projects where the site development operations are frequently included in the building contract. The information here given will enable one to estimate the cost of such roads. The figures are based upon data supplied by North American Cement Company.

	Materials required per 100 sq yd				Labor required per 100 sq yd		
	Cement, bags	Water, gal	Screenings, tons	Tar, gal	Equipment operator	Truck driver	Laborer
Pavement 6 in. thick, 10% cement content	45	382	..	..	2.5	3.8	2.5
Bituminous mat	..	...	3	17	0.5	1	1

plus foreman, timekeeper, etc., and
0.42 hr offset disc harrow
0.42 hr tooth harrow
2.52 hr 1½-ton trucks
1.68 hr cultivator
0.42 hr plow
1.26 hr sprayer trucks
0.42 hr motor patrol type grader
0.84 hr sheep foot rollers
0.84 hr rollers

Not all the equipment will be constantly in use but it must be kept at the job for use as needed.

Vacuum Process.—The following is quoted from a government specification:

a. Vacuum processed concrete (contractor's option):

(1) General. The contractor may if he so desires use the vacuum concrete process to extract excess water and compact the concrete. Should the contractor elect to take advantage of this option, he must provide a concrete that shall meet the strength requirements specified herein for 28-day tests. Strength of concrete will be determined by vacuum processed test cylinders.

(2) Proportions. If the vacuum process is used, provisions of this section in reference to mixing and proportioning shall govern with the exception that the cement content may be reduced by ½ bag or 47 lb per cu yd, provided that the strength of the concrete is maintained as specified in paragraph (1) above.

(3) Vacuum Process.

(a) Vacuum process shall be used in addition to internal vibrating. After the concrete mix has been placed and screeded, this processing shall be utilized to compact the concrete with a pressure of 1,000 lb per sq ft, and to extract excess water from the concrete so that immediately after processing the concrete shall be reduced to a no-slump consistency.

(b) To achieve this result it will generally require approximately one minute of processing time per inch depth of slab. If necessary, in the opinion of the contracting officer, the period of processing and/or pressure used shall be increased or decreased as directed by the contracting officer.

(c) The contractor shall arrange the placing and screeding of the concrete so that the vacuum processing begins not later than 45 min after pouring has commenced.

(d) The forms may be removed when the concrete has attained a strength of 2,000 lb per sq in. as determined by vacuum processed cylinder tests.

The following information as to costs was derived from data furnished by the manufacturers of the equipment used:

Labor required for vacuum processing 1,000 sq ft of concrete surface:

1.06 hr cement finisher*

* Laborers could do the work but for union restrictions.

0.67 hr laborers
0.53 hr pump operator.
plus 6.70 hr finisher for hand finishing or, if Whiteman rodding and finishing machines are used,
0.04 hr machine and operator rodding and
0.25 hr machine and operator finishing.

Of course, the proper charge must be made for the machine.

CHAPTER 4

BRICKWORK

SECTION 1. MATERIALS

While the Common Brick Manufacturers' Association has adopted a standard size, 8 in. long by 3¾ in. wide by 2¼ in. high, to be used for all common building bricks and for face bricks, it will probably be many years before the bricks actually used will approach uniformity in size.

Bricks sold in different parts of the country vary materially in size, and in New England alone we find them ranging in cubical contents from 60 cu in. to 76 cu in., or a variation of over 25 per cent.

As long as these differences in size endure, it is evident that no arbitrarily assumed figure, such as 21 bricks or 22½ bricks to the cubic foot of wall, can be correct except by some lucky chance that the bricks delivered happen to average either 68 or 64 cu in. in size and that they are to be laid with ¼-in. joints.

Inaccurate Methods.—Such a method, when used in estimating the cost of large quantities of brickwork, is too inaccurate for closely competitive bidding. On the other hand, when securing quotations on bricks, it is no trouble to ascertain the average cubical contents of the bricks and to adjust the estimate accordingly.

Table 79 was prepared for the purpose of determining the number of bricks required and also for determining which of two or more competing makes of bricks would prove cheaper to use at the prices which might be quoted.

Tables 80 and 81 are to be used in conjunction in order to determine the total number of bricks and quantity of mortar needed to complete a given piece of brickwork.

TABLE 79.—NUMBER OF BRICKS REQUIRED TO LAY 1 CU FT OF WALL

Average volume of one brick in cubic inches	¼-inch joint	5/16-inch joint	⅜-inch joint	½-inch joint
60	23.7	22.4	21.1	18.6
61	23.5	22.1	20.8	18.4
62	23.3	21.9	20.4	18.2
63	23.0	21.7	20.0	18.0
64	22.4	21.3	19.9	17.8
65	22.2	21.1	19.8	17.6
66	21.9	20.8	19.6	17.4
67	21.6	20.6	19.3	17.2
68	21.3	20.3	19.0	17.0
69	20.9	20.0	18.8	16.8
70	20.6	19.7	18.6	16.6
71	20.5	19.5	18.5	16.4
72	20.3	19.2	18.2	16.2
73	20.0	18.9	17.9	16.0
74	19.8	18.7	17.7	15.8
75	19.5	18.4	17.5	15.6
76	19.1	18.2	17.3	15.4

TABLE 80.—VOLUME OF MORTAR REQUIRED TO LAY 1,000 BRICKS, CU YD

(12-in. wall basis. Full joints on outside. Interior vertical spaces open)

Average volume of one brick in cubic inches	Cubic yards mortar required			
	¼-inch joint	5⁄16-inch joint	⅜-inch joint	½-inch joint
60	0.28	0.35	0.42	0.56
61	0.28	0.34	0.41	0.55
62	0.27	0.33	0.40	0.53
63	0.26	0.33	0.39	0.52
64	0.29	0.35	0.41	0.57
65	0.28	0.35	0.41	0.55
66	0.28	0.35	0.41	0.55
67	0.26	0.33	0.39	0.52
68	0.31	0.35	0.42	0.61
69	0.30	0.37	0.43	0.59
70	0.28	0.35	0.42	0.56
71	0.29	0.36	0.43	0.57
72	0.28	0.35	0.42	0.56
73	0.29	0.36	0.43	0.57
74	0.29	0.36	0.43	0.57
75	0.30	0.37	0.45	0.58
76	0.31	0.39	0.46	0.68

If all vertical spaces are filled solid with mortar, the above quantities must be increased 25 per cent.

Valuable Catalogue Information.—Several years ago a builders' supply dealer issued a catalogue and included in it some tables of valuable information. Among them was one giving the amount of materials required to make the necessary mortar to lay 1M bricks.

For a mixture of 1 part cement, 1 part lime putty, and 3 parts sand, the catalogue gave the quantities as

0.36 bbl lime
0.75 bbl cement
0.32 yd sand,

which was based upon ⅜-in. mortar joints.

Comparing the table with the actual results reported from jobs upon which similar mortar and width of joint had been specified, the quantities used were found to be as follows:

	Job 1	Job 2	Job 3	Job 4
Barrels lime	0.94	0.65	0.50	0.81
Barrels cement	0.53	0.57	0.37	0.19
Yards sand	0.43	0.55	0.47	0.49

It will be noticed that none of the jobs completed furnished a very good check upon the figures given in the catalogue.

The small quantity of cement used on Job 4 is explained by the use of a local gray lime, rich in alumina, which produces a very strong mortar even when the major portion of the specified quantity of cement is replaced by lime.

Variations in Lime.—The variation in the amount of lime used on the other three jobs is probably explained by the difference in the "bulking" capacities of the different brands of lime used. For instance, three different brands show a production of putty of 2.50, 2.62, and 2.75 times the amount of dry lump lime, and authorities writing on the subject given an even wider variation. From the above, it would seem that, to get the actual proportions called for in the specifications, the quantity of dry lime used should never be more than 40 per cent of the quantity of cement used.

However, the great tendency is to exceed the specified amount of lime whenever possible because it produces a smoother working mortar, which means a saving in labor cost of bricklaying even though the cost per cubic yard of mortar may be slightly increased.

Regardless of the amount of the cementing materials used, the quantity of sand used is what determines the quantity of mortar produced and the figures indicate a variation of practically 28 per cent between Job 1 and

Job 2. Put in other figures, Job 1 used 400 cu in. of sand per cubic foot of wall, while Job 2 used 510 cu in. of sand per cubic foot of wall.

If the sand contained 33 per cent of voids, 3 cu ft of sand and 1 cu ft of cement should produce 3 cu ft of mortar even if no lime were used; but, as the sand usually used will average from 40 to 50 per cent of voids, the addition of a cubic foot of lime-putty cannot increase the total volume beyond 3.70 to 3.80 cu ft. In other words, the total volume of mortar cannot be over 1.27 times the amount of sand purchased. In actual practice, because of waste, shrinkage and other losses, the total quantity of mortar produced is very likely to be slightly less than the total amount of sand purchased.

TABLE 81.—QUANTITY OF INGREDIENTS PER CU YD OF MORTAR

In the proportions column, cement is given first, lime-putty second, and sand third.

Proportions	Barrels cement	Barrels of dry lump lime		Cubic yards loose sand
		180-pound basis	280-pound basis	
1–1–3	2.28	1.21	0.78	0.94
1–1–2	3.02	1.58	1.03	0.91
1–1½–3	2.28	0.61	0.39	0.94
1–1½–2	3.02	0.80	0.52	0.91
½–1–3	1.19	1.21	0.78	1.00
½–1–2	1.76	1.58	1.03	0.99
1–3 with 10 per cent lime-putty	2.28	0.13	0.08	0.94
½ with 10 per cent lime-putty	3.02	0.17	0.12	0.91

Even when the amount of mortar per thousand bricks is determined accurately for a given size of bricks, it will be absolutely accurate only for a given thickness of wall. For instance, if 1M bricks laid in a 12-in. wall required 0.55 cu yd of mortar, varying the thickness of wall would affect the quantity of mortar approximately as follows:

	Per cent	Cubic yard
8-inch wall	94	0.51
12-inch wall	100	0.55
16-inch wall	103	0.565
20-inch wall	105	0.58
24-inch wall	107	0.59

These differences are small, it is true, and on a small building would average up so as to balance one another, but, if costs were reported for a job having all 12-in. walls and those costs were used for estimating another one having all 24-in. walls, the difference might be appreciable. If a cubic yard of mortar costs $12, then the mortar for a thousand bricks in a 12-in. wall would cost $6.60 and in a 24-in. wall it would cost $7.08. On 1,000M bricks this difference would be $480, well worth taking into consideration.

None of these tables has been carried beyond the second decimal place. It is not believed that the accuracy attainable in scaling plans and computing quantities, or the accuracy attainable in measuring materials on construction work, will warrant any greater refinement.

Some of the figures in Table 80 may seem inconsistent at first sight, but, by comparing these figures with those in Table 79, and noting the volume of wall produced by 1,000 of a given size of bricks, the apparent inconsistency will be explained.

Table 82, furnished by New England Lime Company, is included here for comparison with Table 81 and may be used by those who prefer it, instead of Table 81.

TABLE 82.—QUANTITY OF MATERIALS REQUIRED FOR MASONRY MORTAR

Granular finishing lime—pulverized finishing lime granulated masonry lime—waterproof masonry lime
(Granulated or pulverized)
Quicklime @ 90 cu ft lime putty per ton

Proportions by volume			Quantity of materials required					
			For 1 cu yd of mortar			To lay 1M brick (17 cu ft)		
Lime putty	Cement	Sand	Lime, lb	Cement, bags	Sand, cu yd	Lime, lb	Cement, bags	Sand, cu yd
1	0	3	200	0	1	126	0	0.63
3	1	12	150	2¼	1	94	1 42	0.63
2	1	9	133	3	1	84	1.89	0.63
1½	1	7½	120	3 6	1	75	2.27	0.63
1	1	6	100	4½	1	63	2.83	0.63
½	1	4½	67	6	1	42	3 78	0 63
0	1	3	0	9	1	0	5.67	0.63
10 %*	1	3	20	9	1	12	5 67	0.63
15 %*	1	3	30	9	1	19	5 67	0.63

* Based on volume of cement required. No allowance for waste.

First quality lump lime—All-purpose pulverized lime
Quicklime @ 70 cu ft lime putty per ton

Proportions by volume			Quantity of materials required					
			For 1 cu yd of mortar			To lay 1M brick (17 cu ft)		
Lime putty	Cement	Sand	Lime, lb	Cement, bags	Sand, cu yd	Lime, lb	Cement, bags	Sand, cu yd
1	0	3	257	0	1	162	0	0.63
3	1	12	193	2¼	1	121½	1.42	0.63
2	1	9	171½	3	1	108	1.89	0.63
1½	1	7½	154	3.6	1	97	2.27	0.63
1	1	6	128½	4½	1	81	2.83	0.63
½	1	4½	86	6	1	54	3.78	0.63
0	1	3	0	9	1	0	5.67	0.63
10 %*	1	3	26	9	1	16	5.67	0.63
15 %*	1	3	39	9	1	24	5.67	0.63

* Based on volume of cement required. No allowance for waste.

TABLE 82.—QUANTITY OF MATERIALS REQUIRED FOR MASONRY MORTAR.—(*Continued*)

Finishing hydrated lime—Masons' hydrated lime
Waterproof masons' hydrated lime
Hydrated lime @ 46 cu ft lime putty per ton

Proportions by volume			Quantity of materials required					
			For 1 cu yd of mortar			To lay 1M brick (17 cu ft)		
Lime putty	Cement	Sand	Lime, lb	Cement, bags	Sand, cu yd	Lime, lb	Cement, bags	Sand, cu yd
1	0	3	391	0	1	246	0	0.63
3	1	12	239½	2¼	1	185	1.42	0.63
2	1	9	261	3	1	164	1.89	0.63
1½	1	7½	235	3 6	1	148	2.27	0.63
1	1	6	195½	4½	1	123	2.83	0.63
½	1	4½	130½	6	1	82	3.78	0.63
0	1	3	0	9	1	0	5.67	0.63
10 %*	1	3	39	9	1	25	5.67	0.63
15 %*	1	3	59	9	1	37	5.67	0.63

* Based on volume of cement required. No allowance for waste.

SECTION 2. LABOR

In the previous section, dealing with the cost of the materials which are used in brickwork, it was shown why it is possible for there to be such great differences in two or more estimates submitted for the same piece of work.

Figures were presented to show the number of bricks of varying sizes required to lay up 1 cu ft of wall and the amount of the mortar materials required for each 1,000 bricks of the size selected.

In the present section there will be presented a method of figuring the cost of brickwork labor. This method is the one that I have been using for years in my own work, and it has given highly satisfactory results.

The ideal method of estimating the cost of brickwork would be one which was worked out in as much detail as the method evolved by Taylor and Thompson for figuring the cost of concrete as presented in their book, "Concrete Costs."

Such a method would involve the finding and tabulation of the necessary unit-times for each such operation as picking the bricks from the pile, loading hods or wheelbarrows, delivering to scaffold, picking up, turning, placing, spreading mortar, cutting the joint, pointing, raising the line, plumbing corners and jambs, as well as a number of other operations.

Such a method would be very interesting from a theoretical viewpoint and might reasonably be used as means from which to develop more improved methods of handling brickwork, with ultimate reduction in cost.

Competitive Methods.—However, present competitive methods of doing business, as well as present labor conditions, make it impracticable to use such detailed methods, while good business demands that the method of estimating shall be one that gives a figure which will very closely approximate the actual cost of doing the work.

If, even considering the limited time usually allowed for the preparation of bids, the estimator could determine exactly the conditions under which the work will be conducted and the methods that will be used, he might be justified in using minutely detailed methods of estimating.

Often the estimator will have very little to do with the actual conduct of the work after a contract is closed, so the best that he can do is to exercise his good judgment as to the most desirable method of handling the work and estimate accordingly.

The method which has been outlined herein is intended to be sufficiently detailed for all practical purposes and yet not to be too theoretical. Certainly it is much better than the ordinary method of "sizing up" a job and setting a price per thousand bricks on that basis.

The quantities which have been set down herein as a normal hourly production for different classes of work were determined after a careful study of all the published literature, as well as by collating a great mass of personal experience data.

TABLE 83.—MASONS' TIME REQUIRED IN BRICKLAYING

Type of brickwork	Time required, in hr per 1M brick*	
	Using lime mortar	Using cement mortar
Common brickwork:		
Joints struck 1 side walls 3 ft 0 in. thick and over	4.0	4.8
2 ft 4 in. to 2 ft 8 in. thick	4.8	5.3
1 ft 8 in. to 2 ft 0 in. thick	5.3	5.9
1 ft 4 in. thick	5.9	6.7
1 ft 0 in. thick	6.7	8.0
0 ft 8 in. thick	7.8	9.0
Backing stonework	7.8	9.0
Face brickwork:		
Running bond, plain-cut joints	10.5	11.2
V-joints	13.5	14.2
Raked out	13.5	14.2
Raked out and struck smooth	14.7	15.4
Flemish bond, plain-cut joints	14.7	15.4
V-joints	16.0	16.7
Raked out	19.3	20.0
Raked out and struck smooth	20.5	21.2
Rodded	21.5	22.2

* The following costs, as required by the individual job, must be added:
Horse scaffolding, 3.5 hr laborers' time per 100 lin ft.
Pole scaffolding, 14.0 hr laborers' time per 100 lin ft.
Transporting, add 0.9 hr laborers' time for each 40 ft of horizontal travel, beyond the first 40 ft, from stock pile to point where bricks are laid.
Culling, 3.0 to 5.0 hr per 1,000 bricks.
Hoisting, 0.15 hr elevator time per M bricks per story.
Washing down, 1.0 hr mason and 0.5 hr laborer per 100 sq ft.
Pointing inside faces of walls, 1.5 hr mason and 0.5 hr laborer per 100 sq ft.

Table 83 gives the average production that may be expected from competent bricklayers working under average conditions:

If there be more than the usual number of openings in the wall, or if there be many pilasters that require plumbing, an allowance of 5 min of bricklayer's time for each linear foot of plumbing should be made.

If joints on both sides of the wall must be struck, the production will be about 10 per cent less than the figures given above.

At present the actual production in the New England states will only run about 85 per cent of the tabular figures, but the proper kind of management should succeed in getting 100 per cent of those figures.

Other special and fancy bonds will decrease the production, as also will the introduction of many pilasters, openings, paneling, etc.

Laborers' Work.—The number of laborers, or tenders, required is, of course, determined by the number of bricks being laid, the distance the bricks must be moved, necessity of culling bricks and other factors. The ratio may be anywhere from four laborers to each five bricklayers up to three laborers to one bricklayer.

TABLE 84.—LABORERS' TIME REQUIRED IN BRICKLAYING

Work	Time Required, Hr
Mixing mortar	2.25 per cu yd
Wheeling mortar	2 per cu yd per 100 ft
Wheeling bricks*	2.20 per M per 100 ft
Carrying bricks in hods	4 per M per 100 ft
Unloading and piling bricks	2 per M
Culling bricks	3 to 5 per M, depending upon quality of bricks and stringency of inspection
Erecting pole staging	0.14 per 100 lin ft, including removal
Erecting horse staging	2 per 100 sq ft of wall, including removal

* Includes loading into barrows and dumping onto scaffold.

The information given in Table 84 will be helpful in determining the number of laborers necessary.

It has not been attempted to include figures here for the great variety of patented scaffolds. The estimator who has

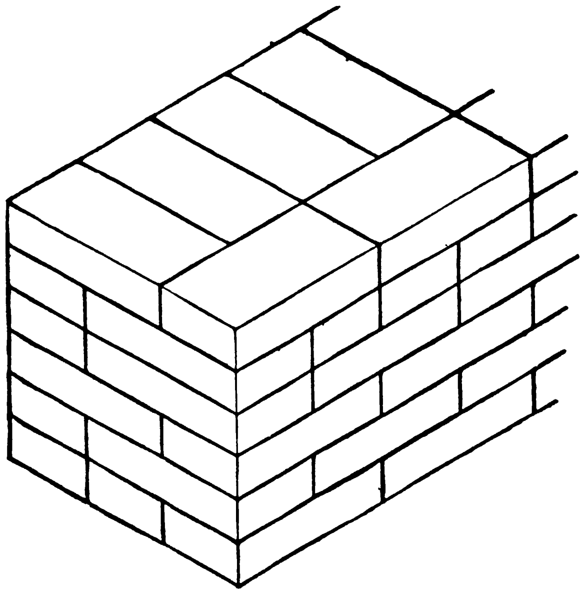

FIG. 5.—Twelve-inch brick wall—common bond.

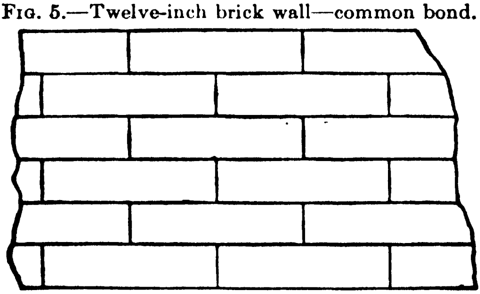

FIG. 6.—Common or running bond.

occasion to figure on their use usually can get the necessary information from the manufacturers or from persons who have used them.

On buildings having a skeleton frame greater convenience in operation and some economy in cost can be attained through the use of swinging and other types of patented scaffolding. In most instances, these scaffolds are owned

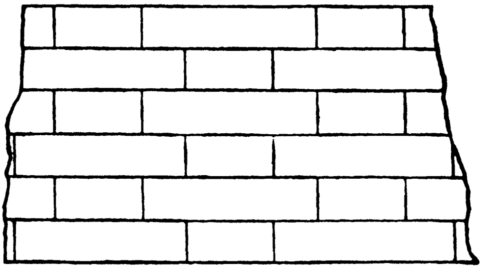

FIG. 7.—Flemish bond.

by companies who install them on a rental basis, and, where there seems to be an opportunity to use such a scaffold, it is recommended that a proposal be obtained from the nearest company or agency engaged in that work.

TABLE 85.—ACTUAL SIZES OF FACE BRICKS

	Length	Thickness	Width	Area of side, square inches	Volume, cubic inches	Average per square foot of wall
Standard.....	8.00	2.25	3.75	18.00	67.5	7
Selected sand struck.....	8.00	2.27	3.53	18.16	64.10	7.10
Water struck.	7.95	2.23	3.61	17.70	64.0	7.20
"Harvard"...	8.10	2.275	3.825	18.40	70.5	6.80
Pressed......	8.00	2.25	3.875	18.0	69.8	7
Enamelled....	8.125	2.25	4.00	18.3	73.2	6.90

SECTION 3. EXAMPLES

As previously stated, the quantities given herein are the average of a great number of published data and con-

TABLE 86.—HEIGHT OF SOLID AND IDEAL BRICKWORK BY COURSES.*—(*Courtesy Common Brick Manufacturers' Association*)

Number of courses	⅜-inch joints				½-inch joints				⅝-inch joints				¾-inch joints		Number of courses
	Brick flat		Brick on edge		Brick flat		Brick on edge		Brick flat		Brick on edge		Brick flat		
	Feet	Inches	Feet	Inches	Feet	Inches	Feet	Inches	Feet	Inches	Feet	Inches	Feet	Inches	
1	..	2⅝	..	4⅛	..	2¾	..	4¼	..	2⅞	..	4⅜	..	3	1
2	..	5¼	..	8¼	..	5½	..	8½	..	5¾	..	8⅜	..	6	2
3	..	7⅞	1	0⅜	..	8¼	1	0¾	..	8⅝	1	1⅛	..	9	3
4	..	10½	1	4½	..	11	1	5	..	11½	1	5½	1	0	4
5	1	1⅛	1	8⅝	1	1¾	1	9¼	1	2⅜	1	9⅞	1	3	5
6	1	3¾	2	0¾	1	4½	2	1½	1	5¼	2	2¼	1	6	6
7	1	6⅜	2	4⅞	1	7¼	2	5¾	1	8⅛	2	6⅝	1	9	7
8	1	9	2	9	1	10	2	10	1	11	2	11	2	0	8
9	1	11⅝	3	1⅛	2	0¾	3	2¼	2	1⅞	3	3⅜	2	3	9
10	2	2¼	3	5¼	2	3½	3	6½	2	4¾	3	7¾	2	6	10
11	2	4⅞	3	9⅜	2	6¼	3	10¾	2	7⅝	4	0⅛	2	9	11
12	2	7½	4	1½	2	9	4	3	2	10½	4	4½	3	0	12
13	2	10⅛	4	5⅝	2	11¾	4	7¼	3	1⅜	4	8⅞	3	3	13
14	3	0¾	4	9¾	3	2½	4	11½	3	4¼	5	1¼	3	6	14
15	3	3⅜	5	1⅞	3	5¼	5	3¾	3	7⅛	5	5⅝	3	9	15
16	3	6	5	6	3	8	5	8	3	10	5	10	4	0	16
17	3	8⅝	5	10⅛	3	10¾	6	0¼	4	0⅞	6	2⅜	4	3	17
18	3	11¼	6	2¼	4	1½	6	4½	4	3¾	6	6¾	4	6	18
19	4	1⅞	6	6⅜	4	4¼	6	8¾	4	6⅝	6	11⅛	4	9	19

20	4	4½	6	10½	4	7	7	1	4	9½	7	3½	5	0	20
21	4	7⅛	7	2⅝	4	9¾	7	5¼	5	0⅜	7	7⅞	5	3	21
22	4	9¾	7	6¾	5	0½	7	9½	5	3¼	8	0¼	5	6	22
23	5	0⅜	7	10⅞	5	3¼	8	1¾	5	6⅛	8	4⅝	5	9	23
24	5	3	8	3	5	6	8	6	5	9	8	9	6	0	24
25	5	5⅝	8	7⅛	5	8¾	8	10¼	5	11⅞	9	1⅜	6	3	25
26	5	8¼	8	11¼	5	11½	9	2½	6	2¾	9	5¾	6	6	26
27	5	10⅞	9	3⅜	6	2¼	9	6¾	6	5⅝	9	10⅛	6	9	27
28	6	1½	9	7½	6	5	9	11	6	8½	10	2½	7	0	28
29	6	4⅛	9	11⅝	6	7¾	10	3¼	6	11⅜	10	6⅞	7	3	29
30	6	6¾	10	3¾	6	10½	10	7½	7	2¼	10	11¼	7	6	30
31	6	9⅜	10	7⅞	7	1¼	10	11¾	7	5⅛	11	3⅜	7	9	31
32	7	0	11	0	7	4	11	4	7	8	11	8	8	0	32
33	7	2⅝	11	4⅛	7	6¾	11	8¼	7	10⅞	12	0⅜	8	3	33
34	7	5¼	11	8¼	7	9½	12	0½	8	1¾	12	4¾	8	6	34
35	7	7⅞	12	0⅜	8	0¼	12	4¾	8	4⅝	12	9⅛	8	9	35
36	7	10½	12	4½	8	3	12	9	8	7½	13	1½	9	0	36
37	8	1⅛	12	8⅝	8	5¾	13	1¼	8	10⅜	13	5⅞	9	3	37
38	8	3¾	13	0¾	8	8½	13	5½	9	1¼	13	10¼	9	6	38
39	8	6⅜	13	4⅞	8	11¼	13	9¾	9	4⅛	14	2⅝	9	9	39
40	8	9	13	9	9	2	14	2	9	7	14	7	10	0	40
41	8	11⅝	14	1⅛	9	4¾	14	6¼	9	9⅞	14	11⅜	10	3	41
42	9	2¼	14	5¼	9	7½	14	10½	10	0¾	15	3¾	10	6	42
43	9	4⅞	14	9⅜	9	10¼	15	2¾	10	3⅝	15	8⅛	10	9	43
44	9	7½	15	1½	10	1	15	7	10	6½	16	0½	11	0	44
45	9	10⅛	15	5⅝	10	3¾	15	11¼	10	9⅜	16	4⅞	11	3	45
46	10	0¾	15	9¾	10	6½	16	3½	11	0¼	16	9¼	11	6	46
47	10	3⅜	16	1⅞	10	9¼	16	7¾	11	3⅛	17	1⅜	11	9	47
48	10	6	16	6	11	0	17	0	11	6	17	6	12	0	48
49	10	8⅝	16	10⅛	11	2¾	17	4¼	11	8⅞	17	10⅜	12	3	49
50	10	11¼	17	2¼	11	5½	17	8½	11	11¾	18	2¾	12	6	50
60	13	1½	20	7½	13	10	21	3	14	4½	21	10½	15	0	60
70	15	3¾	24	0¾	16	0½	24	9½	16	9¼	25	6¼	17	6	70
80	17	6	27	6	18	4	28	4	19	2	29	2	20	0	80
90	19	8¼	30	11¼	20	7½	31	10½	21	6¾	32	9¾	22	6	90
100	21	10½	34	4½	22	11	35	5	23	11½	36	5½	25	0	100

* Based on standard brick 2¼ × 3¾ × 8 in. Height from bottom of mortar joint to bottom of mortar joint.

siderable personal experience. Actual production will vary very widely in different parts of the country and at different times.

Every estimator in active practice should have his own data book, covering the experience of his own organization, and those data will reflect the skill of the workmen employed as well as the organizing and executive ability of the foremen, superintendent, and higher officials.

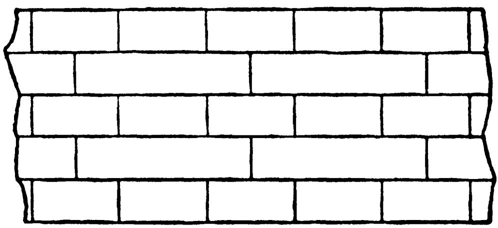

FIG. 8.—English bond.

However, by substituting the proper quantities and taking due account of all local conditions, this method of estimating may be used for practically every job.

Example 1.—As a typical example, we may take the case of an ordinary brick mill building, four stories high, with interior brick walls enclosing the stairways. We will assume that the dimensions are 80 ft by 200 ft and the thickness of the walls as follows:

	Exterior, inches	Interior, inches
First story.........	20	16
Second story.......	16	12
Third story.........	16	12
Fourth story.......	12	12

Figuring the quantity of bricks by the usual method, and deducting all openings, we find that the job will require about 641M bricks, distributed as follows:

164M in 20-in. walls on first story
29M in 16-in. walls on first story
139M in 16-in. walls on second story
139M in 16-in. walls on third story
22M in 12-in. walls on second story
22M in 12-in. walls on third story
126M in 12-in. walls on fourth story

The method of computing the amount of mortar materials required was explained in the previous chapter and will not be repeated here. This is to be an estimate of the labor cost only, and it will be assumed that the materials have been purchased for delivery at the site.

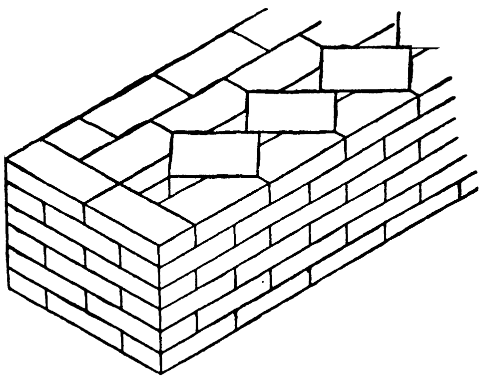

FIG. 9.—Common bond, clipped headers.

It will also be assumed that the stocks of lime, cement, sand and bricks will be disposed about 25 ft away from the building and that a steam elevator will be used.

Rates of pay are assumed as follows:

Bricklayers.	$1.50 per hr
Laborers.	0.70 per hr

Elevator—Flat rate of $20 per day, including engineman, fuel, raising for additional stories, etc.

Horse scaffolding will be used throughout, working from the floor construction, and the outside bricks will be laid "overhand."

From the method outlined in the previous section, we find that about 266 cu yd of mortar will be required, to be used as follows:

86 cu yd on the first story
65 cu yd on the second story
65 cu yd on the third story
50 cu yd on the fourth story

Because a job of this size will hardly tax the full capacity of the elevator, the cost of hoisting need not be figured separately for each floor but can be covered by a single item, as will be apparent later. Where a building is very high or the number of bricklayers great enough to use the full capacity of the elevator, it is well to estimate the amount of materials to be hoisted to the various heights and to figure accordingly.

From the locations of the piles and the dimensions of the building, it will be seen that the greatest horizontal distance that materials will be transported on the job is about 305 ft and the average about 165 ft.

Laborer's time (from Table 84)		
26,880 sq ft wall to scaffold @ 2 hr per 100.......	537.6	
260 cu yd mixing mortar @ 2.25 hr..............	585.0	
260 cu yd transporting mortar 165 ft @ 2 hr per 100 ft......................................	858.0	
641M transporting bricks 165 ft @ 2.2 hr per 100 ft	3,468.0	
26,880 sq ft washing down @ 0.5 hr per 100.......	134.4	
Total......................................	5,583	hr
Bricklayers' time (from Table 83)		
164M bricks in 20-in. walls @ 5.9 hr.............	967.6	
307M bricks in 16-in. walls @ 6.7 hr.............	2,056.9	
170M bricks in 12-in. walls @ 8 hr..............	1,360.0	
26,880 sq ft washing down @ 1 hr per 100........	268.8	
Total......................................	4,653.3	hr

Assuming that there will be 20 bricklayers at work, the job would require slightly more than 29 days of 8 hr each but, allowing for bad weather, and other interruptions, it would be well to allow a total of 35 days.

Then

5,583 hr laborers @ \$ 0.70		\$ 3,908.10
4,654 hr bricklayers @ \$ 1.50		6,981.00
35 days foreman @ \$16.00		560.00
Total for direct pay roll		\$11,449.10
Plus compensation insurance	8.0	
unemployment insurance	3.7	
Social Security tax	1.0	
	12.7%	1,454.04
and assuming that the elevator will be required for 28 days @ \$20.00		560.00
		\$13,463.14

or approximately \$20.96 to lay 1M bricks.

Extra Cost.—No attempt has been made to discuss, in the example just given, such items as cutting and grinding

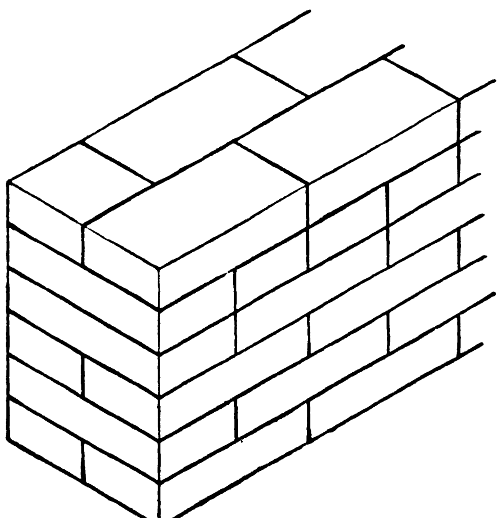

FIG. 10.—Eight-inch brick wall—common bond.

bricks for arches, building quoins or ornamental cornices, though proper allowance should be made for each such item made necessary by the design of the work. However, it is almost impossible to set down any figures which will be of real value without examining the design in each

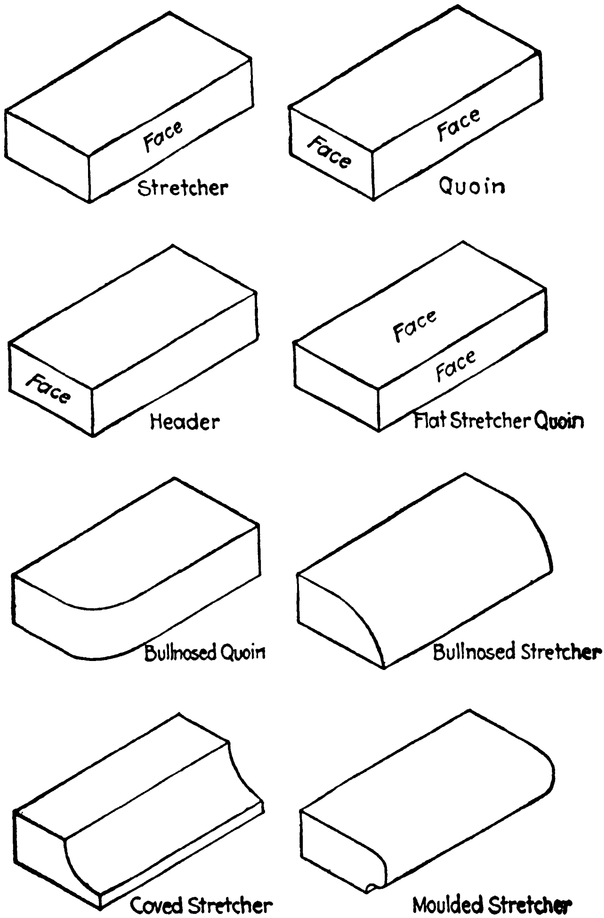

FIG. 11.—Some special-shaped bricks.

instance. A fair allowance is 0.17 hours of bricklayers' time for each brick that must be cut and ground and 0.17 hours of bricklayers' time for each running foot of each projecting or corbelled course. These amounts are to be added to the total cost of the work.

Shorter Method.—A much shorter method of estimating and one which, while it is neither so accurate nor so detailed as the one just outlined above, may be used when estimating time is limited, is given in the following paragraphs.

The job which we have just been considering may be called a "fair average" of what comes to the contractor who specializes in industrial buildings, and it brings out the following facts:

The total number of hours of bricklayers' time, exclusive of the time of foreman and the time spent in washing down exterior walls, is 4,384.5, and the average number of bricks to be laid in each of those hours is 146, or 1,168 for an 8-hr day.

The total number of hours of laborers' time, exclusive of cleaning down, is 5,448.6, or, in other words, practically 10 hours of laborers' time for each 8 hr of bricklayers' time. Allowing for the foreman and elevator, we get the daily job cost for each bricklayer as follows:

8	hr bricklayer	@ $ 1.50	$12.00
10	hr laborer	@ 0.70	7.00
0.08	day foreman	@ 16	1.28
0.03	day elevator	@ 20	0.60
Total			$20.88

On a day's production of 1,168 bricks laid, this would equal $17.88 per thousand.

It must be remembered, however, that if we were using this latter method in actual practice, we should probably assume some arbitrary figure for the daily production, such as 1,100, 1,200, 1,300 or 1,400 bricks laid, and should then get the following costs per thousand, respectively, $18.91, $17.40, $16.06 or $14.91.

While the relative number of hours for the two classes of men will vary but little over a wide range of sizes of mill-type buildings, the daily production will vary widely and should always be calculated as closely as circumstances will permit.

The amount of foreman's time and elevator time will be governed largely by the number of men that can be employed and that number, in turn, by the size of the building and other conditions, and these two items may vary as much as 50 cents to $1 per M in the cost of the bricks.

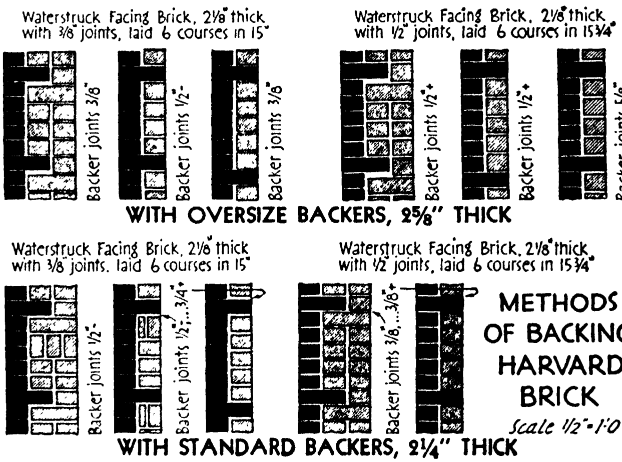

FIG. 12.—Methods of backing face bricks.

Whichever method of figuring is used, the cost of culling bricks for facing, when such is necessary, must be added. Of course, in all instances, the actual rates of wages which will prevail on the job to be estimated must be used in making up the figures.

Example 2.—Where pressed or face bricks are used or in any case where overhand laying of the outside facing will not be permitted, it will be necessary to figure upon two scaffolds, an inside scaffold of the "horse" type for laying the backing and an outside scaffold of the pole or swing type for laying the facing.

When pressed bricks are used, their added weight, and the greater care required in handling them, will reduce the number which can be handled by laborers in a given time to only two-thirds or three-fourths of the number of common bricks which could be handled in the same time.

For instance, if the building under consideration had been faced on one side and one end with pressed bricks, the total quantities involved would then have been as follows:

69M pressed bricks
82M common bricks in 20-in. walls
234M common bricks in 16-in. walls
211M common bricks in 12-in. walls
45M common bricks in 8-in. walls

and the estimated time for laying them will be as follows:

69M pressed bricks @ 11.2 hr	773 hr
82M common bricks in 20-in. walls @ 5.9 hr	484 hr
234M common bricks in 16-in. walls @ 6.7 hr	1,568 hr
211M common bricks in 12-in. walls @ 8 hr	1,688 hr
45M common bricks in 8-in. walls @ 9 hr	405 hr
Total	4,918 hr

The cost of the laborers attending the bricklayers, assuming that the locations of stock piles with reference to the work are as before, will be changed only by the added time normally necessary on account of the greater care needed in handling pressed bricks (this equals 1.7 hr per 1M bricks) and the labor necessary for the construction of the outside pole scaffolds, of which 3,080 lin ft, requiring 14 hr per 100 lin ft, or 431 hr time, will be required.

CHAPTER 5

STONEWORK, CEMENT BLOCK WORK, ARCHITECTURAL TERRA COTTA

SECTION 1. STONE FOUNDATIONS. RUBBLE STONE

While it is true that stone foundation work has been almost entirely superseded by concrete in many parts of the country, it is essential that the well-informed estimator be familiar with the methods of figuring its cost.

It is also improbable that the time will ever come when there will not be some call for high-grade jobs of rubblestone work, because no other form of construction can produce the same variety of artistic effects.

Since the range of sizes and shapes of stones available for rubblestone work will vary widely, and hardly any two lots of stone will work out alike, it is not practicable to develop as detailed, or as accurate, a method of estimating rubblestone work as is practicable for cut stonework, brickwork, or concrete work.

This makes it necessary to resort more to the method of assumptions than when estimating brickwork or concrete, but nevertheless the estimator should strive to accumulate all the experience data that he can, taking care to record his data so that they can readily be used for the purpose of estimating those features of any new work that are comparable with similar features of previous work.

Every estimator will do well to record the cost, in man-hours, of the various operations on any rubble stone job coming under his observation and to compare it with the information contained in this section.

In some parts of New England, it is quite usual to build stone foundations from old stone fence walls and, when this is done, the question of estimating the cost of obtaining the stones is very simple.

In other cases, when it is necessary to obtain the stones from the field, the cost can only be obtained by determining, as nearly as possible, the necessary time required to assemble them into piles and load them into the carts or wagons, and this time will be determined by the frequency or scarcity of stones in the field that are suitable for use in the work.

Where the stones can be taken from a gravel pit or from a fence wall and the sizes are such that they can be loaded by hand, the following figures may be used:

TABLE 87.—HANDLING STONES

Type of stone	Labor hours per cu yd	
	From pit to wagon or truck	From old stone fence walls to wagon or truck
Small round cobbles or boulders.	0.72	0.66
Large round cobbles or boulders.	0.78	0.70
Small split stones..........	0.67	0.60
Large split stones.............	0.73	0.65

NOTE.—Figure hauling as in Table 20, Chap. 2, on basis of 2,600 lb per cu yd or 0.78 cu yd per ton. Where wheeling is necessary, add 1 hr per cu yd per 100 lin ft of distance wheeled.

Allowance for Openings.—When figuring the quantity of stone and mortar required, allowance may be made for the various openings in the wall and the actual cubical contents taken but, when figuring the cost of the labor, it is well to remember that stonemasons who take rubblestone work by subcontract usually insist upon measuring entirely around the outside of the foundation and not allowing for any ordinary openings.

They usually also insist upon figuring upon a minimum thickness of 18 in., no matter what the actual thickness of the wall may be.

This is done because there are practically no available data as to the cost of building jambs and corners, so the assumption is made that the saving by reason of the openings will

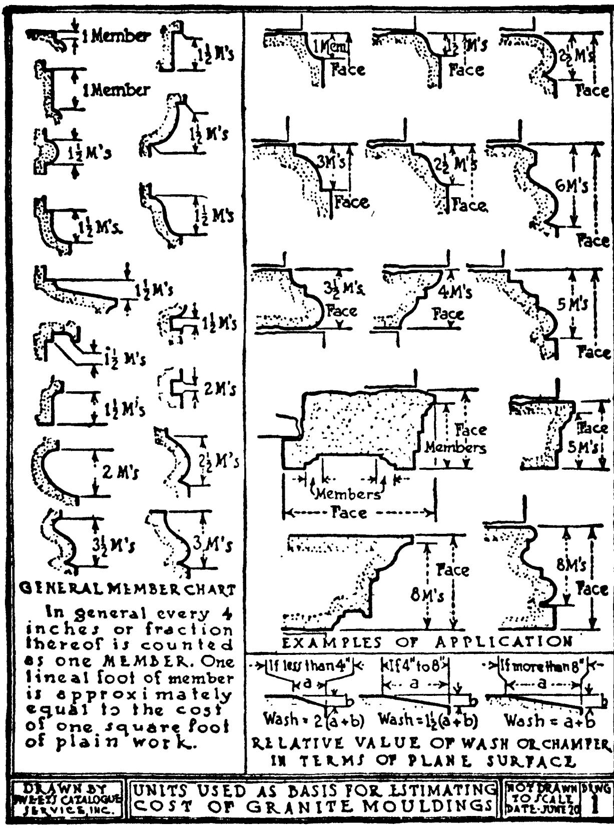

FIG. 13.—(*Courtesy National Building Quarries Association.*)

balance the added cost of the jambs and corners. It is also assumed by the masons that it takes just as long to build a wall 12 in. thick as it does to build a wall 18 in. thick, because of the greater care required in selecting stones and plumbing the wall.

The discussion of the cost of producing mortar for brickwork, given in Chapter 4, applies equally to the cost of producing mortar for stonework, whether it be rubblestone or cut stone.

Scaffolding for all walls over 4 ft in height must be figured as explained in Chap. 4 and added to the costs obtained from this chapter.

It was formerly the custom to pay for stonework by the perch, and that unit is still in vogue in many parts of the country, but just what constitutes a perch seems to be subject to some disagreement. The most commonly accepted definition is 16.5 sq ft of 18-in. wall, or 24.75 cu ft. For this reason the cubic yard is recommended as the most satisfactory unit for use in figuring rubblestone work.

In the section on stone setting we go into a great deal of detail as to the methods to be employed in estimating the cost of setting cut stone, ashlar facings, and other ornamental work, as well as the use of hand and power derricks in stone setting.

However, estimators are called upon to figure stone foundations in which it is necessary to split the stones and square them roughly for laying, either in coursed or random ashlar or in cobweb rubble.

Of course, the more nearly rectangular in shape the stones are, the less mortar will be required for laying with a given thickness of joint and the amount required will also be less as the size of the individual stones increases.

Tables 88, 89 and 90 will give the time necessary to prepare the stones and lay them.

When the individual stones run much over ½ cu ft each, it will be necessary to set them with a derrick. For most ordinary work a hand derrick will give very efficient service, but on large operations a power derrick can be employed.

In another chapter the methods used in figuring the charge for power equipment are discussed, so it is only necessary for the present to consider the cost of the direct labor, foreman, water boy, etc.

TABLE 88.—BUILDING STONE WALLS
(Using 1- and 2-man stone)

Time and mortar	Required per cu yd			
	Wall 18 to 30 in. thick		Wall 30 to 48 in. thick	
	Flat split stone	Cobbles	Flat split stone	Cobbles
Masons, hr	2.5	6.25	1.75	5.25
Laborers, hr	2.5	5.25	2.5	5.25
Mortar, cu yd	0.26	0.30	0.26	0.30

NOTE.—Figure scaffolding as indicated for brickwork. Figure extra wheeling, when more than 40 ft from stock pile to work, as indicated for handling stones.

TABLE 89.—PREPARING STONE

Preparation	Cutters' time per 100 sq ft of surface prepared, hr	
	Freestone	Granite
Hammered faces	80.0	100.00
Beds and builds	40.0	50.00
Fine hammering	200.0	250.00

NOTE 1.—Add cost of rough stone, figured at proper price per ton or yard. (See Table 98.)

NOTE 2.—For jobs of fine stonework, prices should always be obtained from quarries or yards equipped to deliver the stone at the site of the work, ready for setting.

In addition to the actual cost of laying the stones in the wall, a very important item in the cost of stonework is that of pointing the exposed areas, and, since the kind and

TABLE 90.—LAYING WALLS OF PREPARED STONES

Time and mortar	Required per cu yd of wall			
	Cobweb rubble	Random ashlar	Coursed ashlar	
			Courses up to 18 in. high	Courses 20 to 32 in. high
Masons, hr	6.25	7.0	6.0	5.25
Laborers, hr	4.75	5.0	6.0	5.25
Mortar, cu yd	0.15	0.15	0.15	0.20

NOTE.—Figure scaffolding as for brickwork. Figure extra wheeling, when more than 40 ft from stock pile to work, at 2 hr per cu yd per 100 lin ft.

TABLE 91.—POINTING STONE WALLS

Type of work	Time required, hours per 100 sq ft	
	Mason	Laborer
Flat stonework, joints raked out	5.0	1.67
Small cobble work, joints raked out	5.0	1.67
Large cobble work, joints raked out	3.33	1.12
Random ashlar	3.33	1.12
Cobweb rubble, joints raked out	3.33	1.12
Coursed ashlar	3.33	1.12
Cobweb rubble, smoothed joints	5.0	1.67
Random ashlar, smoothed joints	5.0	1.67
Coursed ashlar	5.0	1.67
Cobweb rubble, ribbon joints	10.0	3.33
Random ashlar, ribbon joints	10.0	3.33
Coursed ashlar, ribbon joints	10.0	3.33

quality of work demanded vary greatly, the cost varies accordingly. Table 91 gives the data necessary for computing the cost of the labor.

Example.—Assume that the foundation for a church building is to be 80 ft long, 40 ft wide and 10 ft high. The first 6 ft from the bottom of the wall to grade are to be ordinary flat stonework, but from grade to top is to be coursed granite ashlar. The outside walls above grade are to be pointed smooth and the inside face from bottom to top is also to be pointed smooth. The wall is to be 2 ft thick.

The flat stones are available on the lot but the granite is delivered at a railroad station a mile away. The mortar materials are furnished at the job, which is quite a usual practice in some sections of the country where stonework is sublet by general contractors to men who specialize in stone setting.

The wages per hour are

Masons	$1.50
Laborers	0.70

The quantities involved are evidently as follows:

Perimeter of wall equals 240 lin ft. The flat stonework is therefore 240 ft by 2 ft by 6 ft or 2,880 cu ft, say 107 cu yd, and the ashlar is 240 ft by 2 ft by 4 ft or 1,920 cu ft, say 72 cu yd of ashlar. The area to be pointed is

Inside, 224 ft by 4 ft	896 sq ft
Outside, 240 ft by 4 ft	960 sq ft
While the area of rubble to be pointed is 224 ft by 6 ft	1,344 sq ft
Making the total area to be pointed	3,200 sq ft

The time required will be as follows:

Masons, laying flat stone 107 yd @ 2.5	267.5 hr
laying ashlar 72 yd @ 6	432
pointing 3,200 sq ft @ 5 hr per 100	160
Total	859.5 hr, say 860
Laborers, on flat stone, same as masons	267.5 hr
on ashlar, same as masons	432
on pointing, @ 1.67 per 100 sq ft	53.5
on pole scaffolding 240 lin ft @ 14 hr per 100	33.6
Total	786.6 hr, say 787

From Table 20, assuming good macadam road, a two-ton truck, and a weight of 170 lb per cu ft for the granite, we get the hauling time as follows:

1,920 cu ft × 170 lb equals 326,400 lb or 168.2 tons

which would figure out thus:

0.70 × 17.4 hr × 1.682 equals 20.49 hr, say 21

and at 4 hr per 100 cu ft for loading the truck and the same amount for unloading, we would have

19.2 × 8 or 153.6 hr, say 154

Summarizing:

860 hr masons' time @ $1.50	$1,290.00
787 hr laborer's time @ $0.70	550.90
21 hr truck's time @ $3.00	63.00
154 hr laborers' time loading, etc.	107.80
Total	$2,011.70

which equals practically $10.30 per cu yd exclusive of the hauling, loading and unloading, and $0.96 per cu yd for those items; or, on a cubic-foot basis, practically 40 cents and 3½ cents respectively.

To the cost just found must be added any premium which it may be necessary to pay to one of the masons for acting as foreman, the cost of compensation insurance, moving scaffolding to and from the job, overhead expense and profit, all as explained in earlier examples in this book.

From the tables it is evident that 38.4 cu yd of mortar will be required, and a complete estimate of the cost of the work would include all of the costs above, the cost of the mortar materials and the price of the granite at the depot.

SECTION 2. CEMENT BLOCK WORK

The most common size of block used is 8 in. thick, 16 in. long and 8 in. high, and it weighs from 50 to 60 lb, depending upon the percentage of core voids and the density of the concrete used. Blocks 12 in. long and 8 in. high, as well as other shapes, are also used but not so extensively as the 16- by 8-in. size.

In addition to the "stretcher" blocks, it is necessary to have corner and jamb blocks, as well as lintels. On the better jobs, short stretchers will be provided to make closures.

Various methods of organizing are used for cement block work, but the most satisfactory method seems to be to have a helper for each mason, to assist in lifting the blocks onto the wall, and one man to mix mortar and serve it to each two masons.

Additional men will be required to bring the blocks from the piles and distribute them along the wall, since the helper cannot be expected to handle them for a greater distance than 10 ft without delaying the mason.

Makers of cement block machinery and dealers in the blocks consider about 260 blocks, including jambs and corners, to be a fair amount to lay in an 8-hr day. The figures in Table 92 are more conservative.

TABLE 92.—LAYING CEMENT BLOCKS

Work	Time, in Hr per 100 Blocks
Mason	3.8
Helper	3.8
Mortar-man	1.9
Wheelers (per 100 ft distance to pile)	0.8
Loading or unloading trucks, laborers' hr	0.5
Add for each lin ft of corner or jamb to plumb, masons' hr	0.06
Add for each lin ft of ornamental projecting corners, masons' hr	0.05
Mortar, cu yd	0.2

This table will hold good for walls up to 12 ft in height, but, since cement block walls are seldom used for buildings having a greater story height, it is not necessary to compile a table for greater heights. When the building is more than one story high, allowance must be made for elevating, as explained in brickwork.

The time for loading onto or unloading from wagons or trucks is given in the table, and, knowing the weight of the blocks, you can compute the cost from the knowledge you have gained in studying the previous chapters.

Examples.—Assume that we have a building 200 ft long, 70 ft wide and 12 ft high, with 48 steel-sash each 6-0 by 8-6, two doors 10-0 by 10-0, and three doors 3-0 by 7-0, and we wish to compute the labor cost of laying the blocks.

The wall area is evidently:

(2) by 200 = 400		
(2) by 70 = 140		
540 lin ft by 12 ft high		6,480
less		
(48) by 6-0 by 8-6	2,448	
(2) by 10-0 by 10-0	200	
(3) by 3-0 by 7-0	63	2,711
		3,769

Disregarding the thickness of the joints 3,769 × 144 ÷ 128 = 4,240 blocks required

Assume laborers' rate	$0.45 per hr
Assume masons' rate	0.90 per hr

Blocks delivered by trucks to site and unloaded 100 ft from working point.

For each 100 blocks the time to be consumed at the job is, therefore, as follows:

Laborers:

	Hours		
Unloading	0.5		
Wheeling	0.8		
Mortar-man	1.9		
Helper	3.8		
	7.0	@ $0.45	$3.15
Mason:	3.8	@ $0.90	3.42
Cost to lay 100 blocks			$6.57

But we must add the cost of plumbing the corners and jambs, which is

	Linear Feet	
4 corners @ 12 ft	48	
96 window jambs @ 8½ ft	816	
4 door jambs @ 10 ft	40	
6 door jambs @ 7 ft	42	
	946 @ 0.06 =	56.76 hr
4,240 blocks laid @ $6.57 per 100		$278.57
57 hr time plumbing corners, etc. @ $0.90		51.30
Total labor cost		$329.87

If we use a mortar made of 1 part cement, 3 parts sand and 10 per cent lime putty, the cost of the mortar materials would be figured as follows:

2.28 barrels cement @ $2.80	$6.38	
0.08 barrels lime @ $4	0.32	
0.94 cu yd sand @ $1.25	1.18	
Per cu yd	$7.88	
4,240 blocks @ 0.2 cu yd per 100 = 8.48 cu yd		
8.48 cu yd @ $7.88		$66.82

The cost of scaffolding is figured as indicated in Chapter 4.

TABLE 93.—WEIGHTS OF CEMENT BLOCKS

Thickness, inches	Cinder blocks		Sand concrete blocks	
	Pounds per square foot	Square feet per ton	Pounds per square foot	Square feet per ton
8	40	50	70	28.6
12	70	28.6	105	19
			Pounds per block	Blocks per ton
8	..	....	60	33.4
12	..	....	85	23.6

SECTION 3. MAKING CEMENT BLOCKS

No attempt is made here to cover completely the method of estimating the cost of producing the blocks, since they are usually made in factories and delivered to the job at a fixed price per block. However, a few words on the subject will not be inappropriate.

The cost of making the blocks varies widely with the equipment used; thus of two apparently prosperous plants, one, using mechanical tampers, mechanical conveyors, industrial cars, etc., with a gang of eight men, working 9 hr per day, turns out an average of 3,300 dry-tamped blocks per day. The other plant, with all hand operations and a gang of three men at work, turns out 700 similar blocks per week.

Assuming a labor rate of 45 cents per hour, which is probably higher than actually paid, their costs would be as follows:

Mechanical plant, 8 by \$0.45 by 9 ÷ 3,300 = 1 cent per block
Hand plant, 3 by \$0.45 by 9 by 6 days ÷ 700 = 10.41 cents per block

The cost of the materials used depends entirely upon the mix used, and most block-makers are not very definite in stating what mix they use. However, this may be roughly estimated by assuming that the usual mix is not much higher than 1 to 5, which requires 1.20 bbl of cement and 1 yd of sand per cubic yard.

Thus:

1.20 bbl cement @ \$2.80	\$3.36
1 cu yd sand @ \$1.25	1.25
1 cu yd mortar will cost	\$4.61

Since each block of the size under consideration contains 704 cu in. of mortar, a yard will make 27 times 1,728 ÷ 704 = 66.2 blocks, which would mean that the material cost of each block would be approximately 7 cents.

Assuming usual overhead costs, the comparison of the two plants will be as follows:

	Mechanical Plant	Hand Plant
Materials....................	0.07	0.07
Direct labor..................	0.01	0.104
Overhead (50 per cent of labor)	0.005	0.05
Total......................	0.085	0.224

Whenever occasion requires the making of an estimate of the cost of producing cement blocks, it is essential to get complete data as to the equipment available, mixture to be used, size and cross section of blocks and all other factors which affect the cost.

Care should also be taken to differentiate between dry-tamped blocks and wet-poured blocks.

SECTION 4. ARCHITECTURAL TERRA COTTA

In estimating the cost of setting all sorts of ornamental work, as well as natural stone ashlar, the cubic foot seems to be the most satisfactory unit of calculation and as a basis in figuring architectural terra cotta, though others figure it by the square foot of surface area and some by the ton. The individual block seems to be the most satisfactory unit for figuring cement block work.

Architectural terra cotta is essentially a manufactured product and the matter of estimating the cost of production is no more within the province of the construction estimator than is estimating the cost of producing any other manufactured article.

It is true that the man who has carefully kept the data as to the cost of terra cotta on previous jobs is in a position to approximate the cost of similar jobs in the future. However, the price of terra cotta is varied by so many factors, such as finish, amount of ornament, number of times any piece is duplicated, color, etc., as well as manufacturing conditions and transportation costs, that it is always wise to get a definite quotation based upon the plans and specifications in every case.

Such a quotation may or may not include all necessary anchors. If it does not, then it is necessary to secure a list of those anchors from the manufacturers, or from the architect or the plans, and secure a price for them. When a lump price for the anchors is not obtainable, their weight can readily be calculated by the tables in structural steel handbooks and their cost estimated at the current price for builders' wrought-iron work.

Terra Cotta Like Cut Stone.—Setting architectural terra cotta is an operation very similar to setting cut-stone work, except that its lighter weight usually obviates the necessity for using derricks with terra cotta and, in those sections where the trades are separated, terra cotta is more usually set by bricklayers than by stone setters. When any fitting is necessary at the job that also is done by bricklayers, generally by those who are particularly expert in the work, rather than by stonecutters.

On work involving a large amount of terra cotta, it is well to make sure that the price made by the manufacturer includes the cost of necessary fitting to take care of any inaccuracies in the dimensions of the several pieces. It is hardly practicable for the builder to estimate the cost of fitting, since it may be absolutely nothing on one job and run to several hundred dollars on another and similar job.

When scaling quantities of terra cotta from plans, it is necessary to take the full "squared" size of all moldings, projections, capitals, columns, and similar members and multiply the dimensions into cubic feet. On that basis, the average weight will be between 70 and 75 lb per cu ft and the cost of hauling may be figured accordingly.

The cost of the scaffold, when figured separately, may be computed according to the data given in the discussion of brickwork. There will be many times when the terra cotta will be laid from the same scaffold as that used for the bricklaying, so no separate item need be made.

The cost of handling the terra cotta from car to truck, truck to wheelbarrows, to the building, sorting and distributing it, as well as setting and cleaning down, may be computed from Tables 94, 95, and 96.

TABLE 94.—UNLOADING TERRA COTTA
(Labor hours per 100 cubic feet)

From car to truck	3
From truck to barrow	3
Wheeling 100 ft	3
Sorting and distributing	8
Elevating, per story, time of elevator	1

NOTE 1.—Figure hauling on basis of Table 20, using 75 lb per cu ft, or 28 cu ft per ton.

NOTE 2.—In estimating terra-cotta quantities, take greatest dimension in each direction.

TABLE 95.—SETTING AND BACKING TERRA COTTA
Required per 100 cu ft

	Setting terra cotta	Backing with bricks
Mason, hours	8	8
Laborer, hours	10	4
Mortar, cubic yard	0.16	
Bricks	....	80

TABLE 96.—CLEANING AND POINTING TERRA COTTA
Time, hr per 100 sq ft of exposed surface

	New work		Old work	
	Washing down	Pointing	Cleaning	Pointing
Mason, hours	1.5	1.5	2.0	2.0
Laborer, hours	0.75	0.75	1.0	1.0

NOTE.—To the cost of setting and pointing must be added the cost of unloading and distributing and the cost of such scaffolding as may be necessary.

SECTION 5. CUT STONEWORK

As with architectural terra cotta, the production of cut stone has becone a manufacturing proposition and is seldom undertaken by a general contractor.

We shall therefore limit ourselves to discussing how to estimate the cost of installing the stone in the building, as that is all that the building estimator generally finds it necessary to estimate himself.

Usually when there is any appreciable amount of stone to be used in a building, the companies bidding on it will name a lump-sum figure for all of the stone required. They will also give their estimate of the number of cubic feet to be set, thus relieving the general contractor of the necessity of scaling the quantities again, unless he desires to check the figures.

TABLE 97.—UNLOADING CUT STONE
Labor hr per 100 cu ft

	By hand	By hand derrick	By power derrick or crane
Car to truck or wagon	4.0	3.0	2.5
Truck or wagon to barrow	4.0	3.0	2.5
Wheeling in barrows per 100 linear feet	3.0		
Elevating, per story,[1] time of elevator	3.0		

[1] This figure applies only where the stone is used on upper stories and is raised to the floor by elevator instead of being lifted directly to its location by derrick.

There are many items of stonework, such as sills, lintels, pier caps, chimney caps, steps, bondstones, etc., upon which it is possible to secure unit price lists in many localities, and when this is possible, it is well to be equipped with such lists and use them in estimating, even though the figures may be checked by sub-bids.

When using such lists, it is well to be very careful to make sure that the list covers exactly the same sizes, kinds of finish, etc., that are called for by the plans and specifications, as it is possible that there may be a very appreciable variation otherwise.

When any special work or ornamentation at all is required, it is very necessary to get special prices.

The cubic foot, as previously stated, is the most convenient unit for use in figuring stonework but, of course, the number of cubic feet that can be handled in a unit period of time will be determined by the size and weight of the individual pieces, their shape, and their position in the work.

Such items as sills, lintels, steps, pier caps, etc., are usually set by hand, one or more laborers assisting the mason as may be required, but when ashlar facing is used, or when very much ornamental work, such as columns, cornices, etc., is included, it is customary to use a small hand derrick or a breast derrick.

Profitable Use of Derrick.—Where the individual pieces are heavy, or where the total quantity to be handled runs into several thousand feet, it may be profitable to use a power derrick. However, this should be studied carefully, because it often develops that the mason will not handle the stone rapidly enough to pay the added cost of the power equipment and the men to run it, to say nothing of the cost of installation, fuel and removal.

The information given in Chaps. 2 and 4 will enable the estimator to figure the cost of hauling, scaffolding, elevating, etc. The cost of loading and unloading will be determined by the facilities available (see Table 97).

If the stones are large, and no derrick is available for moving them from the car to truck and truck to building, the cost will naturally be higher than where the unloading facilities are good or the stones small.

Tables 98 to 101 contain the information necessary for the preparation of an estimate on any ordinary work.

TABLE 98.—WEIGHTS OF BUILDING STONES

Stone	Lb per cu ft	Cu ft per ton
Granite	170–172	11.7
Limestone	144–160	12.5–13.9
Sandstone	147–164	12.2–13.4
Bluestone	147–151	13.2–13.4
Marble	168	11.9
Gneiss	168	11.9
Slate	171–175	11.4–11.7

TABLE 99.—SETTING CUT STONE
Hr per 100 cu ft

	Masons	Laborers	Derrick[1]
Hand work:			
Sills, lintels, etc	30.0	30.0	
Ashlar	12.0	20.0	
Small cornices, etc	20.0	30.0	
Using hand derrick:			
Sills, lintels, etc	24.0	24.0	
Ashlar	10.0	20.0	
Small cornices, etc	15.0	30.0	
Using power derrick:			
Heavy foundation stone	4.0	32.0	4.0
Ordinary ashlar	8.0	48.0	4.0
Ornamental work	12.0	36.0	4.0

[1] This rate to include cost of derrick, power, and operator.

NOTE.—For heavy stonework, figure pole scaffolding at 1.5 times the cost of scaffold for brickwork.

Most architectural stonework must be laid in non-staining mortar, the composition of which is usually definitely specified by the architect. It is becoming customary to use white portland cement as the binding principle in

TABLE 100.—MORTAR FOR CUT STONEWORK
Cu yd per 100 cu ft stone

	Setting	Pointing	Parging
Heavy foundations	0.10	0.03	
Thin ashlar	0.15	0.05	0.15
Sills, lintels, etc	0.15	0.05	0.15
Ornamental work	0.13	0.04	0.13

TABLE 101.—CLEANING AND POINTING CUT STONE
Time required, hr per 100 sq ft of exposed surface

	New work		Old work	
	Washing down	Pointing	Cleaning	Pointing
Mason	2.0	2.0	3.0	3.0
Laborer	1.0	1.0	1.5	1.5

nonstaining mortars, and when this is done, the tables given in the chapter on brickwork can be used in figuring the cost of the mortar, taking due account of the fact that the price of white cement is very much higher than that of the standard gray color.

The quantity of mortar required can be calculated from Table 100.

Beside the cost of hauling, labor, elevating and mortar, it is necessary to include the cost of all anchors and clamps that are specified, being careful to note the number and kind as well as the material of which they are to be made and to get proper prices for them.

After the setting has been completed it will be necessary to wash the work down, using no acid for most stones, and the cost of such cleaning is to be calculated as in Table 101.

On work which has been exposed to weather for many years, particularly in communities where much soft coal is used, an ordinary washing down, even with a strongly alkaline wash, will not restore the stone to a satisfactory appearance.

It is then necessary to resort to the use of a sandblast and the work is usually done by "stone renovators" rather than by builders.

Example 1.—Assuming for example a building front, to have a granite grade course and a limestone-ashlar facing with the usual amount of ornamental work, such as pilasters, caps, bases, cornices, etc.

The bill of quantities, using the method mentioned in the discussion of architectural terra cotta, and taking the "squared" dimensions of all members, is assumed as follows:

	Cubic Feet
Granite grade course	120
Limestone ashlar	720
Sills and lintels	150
Ornamental features	600
Total	1,590

Assume that the stone is to be delivered f.o.b. cars at the railroad station, one mile from the job over good hard roads, there is ample room at the work to pile the stone, but as the building is three stories high, it will be necessary to hoist our stones by a power derrick which will be located at a point that will serve the entire front and obviate the necessity for relocating during the work.

To calculate the cost of bringing the stone from the railroad to the building, use Table 98.

The total weight is, therefore

120 cu ft granite @ 170 lb	20,400
1,470 cu ft limestone @ 160 lb	235,200
	255,600 lb

or 127.8, say 128 tons.

Using a 2-ton truck, we find from Table 20, that the cost per 100 tons will be 17.4 × 0.75 or 13.05 hr per 100 tons, equaling 16.70 hr, say 17 hr for 128 tons.

The time for unloading at car and from truck at site, at 4 hr per 100 cu ft for each of those operations, will total 127 hr.

The cost of the derrick engineer will be included in the flat rate for the derrick and figured into the setting as indicated on page 139.

From Table 99, we estimate the setting time as follows:

Ashlar work, including sills, grade course, etc., 990 cu ft:	
Mason @ 8 hr per 100 cu ft	79.2
Laborers @ 48 hr per 100 cu ft	475.2
Derrick @ 4 hr per 100 cu ft	39.6
Ornamental work, 600 cu ft:	
Mason @ 12 hr per 100 cu ft	72
Laborers @ 36 hr per 100 cu ft	216
Derrick 6 hours per 100 cu ft	36
Cleaning and pointing, 1,800 sq ft (from Table 101):	
Mason @ 4 hr per 100 sq ft	72
Laborers @ 2 hr per 100 sq ft	36
Pole scaffolding, laborers	15

Summary

Truck, 17 hr @ $3.50			$ 59.50
Laborers, unloading, etc	127.2		
setting ashlar	475.2		
setting ornament	216		
cleaning, etc	36		
scaffold	15		
Total	869.4		
say 870 hr @		$ 0.70	609.00
Masons, setting ashlar	79.2		
setting ornament	72		
cleaning, etc	72		
Total	223.2		
say 223 hr @		$ 1.50	334.50
Derrick on ashlar	39.6		
on ornament	36		
Total	75.6 hours		
say 9½ days @		$20.00	190.00
			$1,193.00

which equals 75 cents per cu ft.

Example 2.—To find the cost of setting the same job by hand, if conditions make that practicable, using a breast derrick and working from the floors as the building goes up, the method is as follows.

Figure the trucking, loading and unloading as before. It is necessary to figure now on the cost of the time needed to put the stones on the elevator, elevate them, take them off again, and distribute them on the upper floors. Assuming 360 cu ft of stone on the first story, we have 1,230 cu ft to elevate to the upper stories, and the distance to handle it will be taken as 100 lin ft, therefore, 1,230 cu ft @ 3 hr per 100 equal 36.9 hr. The time required for setting, from Table 99, will be as follows:

	Masons' time	Laborers' time
270 cubic feet sills, lintels, grade course, etc.	81	81
720 cubic feet ashlar	86.4	144
600 cubic feet ornament	120	180
Totals	287.4	405

The cost of the cleaning, pointing and scaffolding will be as before.

SUMMARY

Trucking cost as before		$ 59.50
Laborers, unloading	127.2	
wheeling	36.9	
setting	405	
cleaning, etc	36	
scaffold	15	
Total	620.1	
	say 620 hr @ $ 0.70	434.00
Masons, setting	288	
cleaning, etc	72	
Total	360 hr @ $ 1.50	540.00
Elevator, from Table 97,		
360 cu ft on first story	0	
400 cu ft on second story	12	
830 cu ft on third story	50	
Total	62 hr	
	say 8 days @ $20.00	160.00
		$1,193.50

In each of these examples the compensation insurance, moving of equipment to and from the job, general supervision, overhead costs and profit should be added in order to determine the correct price to charge for the work.

It is to be noted that, in this instance, the cost of hand setting and power derrick setting figure out to almost exactly the same amount so that, other considerations being equal, it would probably be advisable to set the stone with the hand derrick, rather than go the trouble of bringing another derrick to the building, arranging for power if it were not practicable to use the same power as already in the building for the elevator, and then removing that equipment at the completion of the work.

This is not an invariable rule, yet it is not at all unusual for a job of this size, as the economy resulting from power equipment does not become effective until much larger quantities of stone are handled.

In *Engineering News-Record* of March 13, 1919, I described an instance where we completed some heavy repair work on a stone dam for less than $4,000 with a hand derrick, though the estimates of our competitors, who contemplated the use of power equipment, ran as high as $39,000.

That was an exceptional instance. It happened during a period of coal shortage, the nearest railroad was over 2 miles away and the conditions and the site were such that the cost of installing a steam engine would have been equal to the total cost of operating the hand derrick.

CHAPTER 6

FIREPROOFING AND FIREPROOF CONSTRUCTION

SECTION 1. GENERAL

Fireproof construction, or more properly speaking fire-resistive construction, divides itself into three general types: terra cotta, gypsum and concrete.

Brickwork is, of course, a form of fire-resistive construction; in fact, it is the best known form, and also the most effective form of terra-cotta fire-resistive construction.

Terra-cotta and gypsum constructions are largely used for walls, floors, partitions and roofs and are usually placed by masons.

Concrete fireproofing is, however, usually placed by laborers, and since the same general methods apply as for other forms of concrete work, it was more fully discussed in Chap. 3.

Hollow-tile Fireproofing.—The term fireproofing, as here used, includes all those forms of hollow terra-cotta building material that are commonly used, such as flat and segmental floor arches, roof arches, "book" tile, beam, girder and column covering, wall and partition tile and furring tile.

In taking off quantities of tile required for any piece of work it is necessary to make some allowance for breakage in handling and in cutting to fit around openings, against jambs, etc. It is impossible to lay down any exact rules for figuring the breakage. It may vary all the way from 1 to 10 per cent but a good method is to allow 3 per cent breakage for areas having no openings, no deductions for openings under 10 sq ft, one-half of openings from 10 to 21 sq ft, deduct full opening if over 21 sq ft, and add enough tile to go once around the opening.

Practically all forms of hollow-tile fireproofing can be figured and bought by the square foot or by the piece. In buying by the piece, only one 12 by 12 tile is required, no matter what the thickness, per square foot, but 1½ tiles are required of the 8 by 12 size.

"Book" tile, which are used for roofs where no heavy loads are to be carried, and are so called because their "tongue and groove" cross section makes them resemble large books, usually come in 12 by 24 size, so that each tile will lay 2 sq ft. They are placed upon a structural steel frame consisting of angles and tees, and therefore no formwork or centering is required.

Furring tile usually come in the "split" form, *i.e.*, a block resembling a partition block which is scored in such a manner that it can readily be split into two halves, each of which is a furring tile.

Figuring Flat Arches.—When figuring flat or segmental arches for estimating purposes, it is sufficient to take from the plans the number of square feet to be covered but, when listing tile for shipment to the work, it is necessary to compute carefully the number of skewbacks, key blocks, voussoirs, soffit tile, girder shoes, etc., that will be required.

The literature issued by the manufacturers of terra-cotta fireproofing contains such a wealth of information on that subject that it is unnecessary to encumber these pages with a repetition of it.

However, it is essential that care should be taken to figure upon exactly the kinds of tile in each case that the specifications require; dense, porous or semiporous, smooth-faced, scored, etc.

In earlier chapters we have discussed very thoroughly the cost of hauling and, knowing the weight of the various kinds of tiles likely to be used, it is a simple matter to determine the number that can be handled in a load.

The cost of loading and unloading is not a simple matter, since there is a variety of weights to be considered and since it is possible for a man to handle a tile weighing 30 lb about as quickly as one weighing 20 lb.

The following tables provide the necessary data for estimating loading and unloading costs, hauling, etc.

Split furring tile weigh the same per *block* as a partition block of twice the thickness.

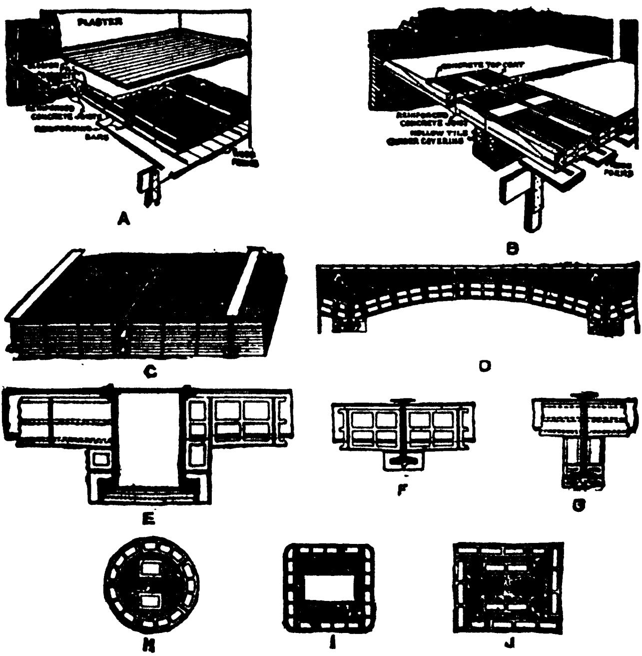

FIG. 14.—Terra-cotta fireproof construction. (*Courtesy National Fireproofing Company.*)

A, *B*, combination hollow tile and concrete floor construction. *C*, end construction flat arch. *D*, segmental arch. *E*, *F*, *G*, beam and girder protection. *H*, round column covering. *I*, *J*, square column covering.

However, the weights given in the table are average or standard weights and may vary appreciably in different localities. Care should therefore be taken to determine whether these weights apply when buying fireproofing by weight.

The cost of building scaffolds for partition work can be determined on the basis of one scaffold builder for each four masons; and for wall furring, one scaffold builder for each three masons.

The cost of making and handling the mortar is, of course, the same as for the same grade of mortar when used for brickwork.

NOTE.—The best results in hollow-tile construction are obtained with a strong cement mortar to which enough lime putty has been added to make it spread very freely. This works better than a lime and cement mortar made in the ordinary way.

TABLE 102.—WEIGHTS OF HOLLOW TILE

Thickness, inches	Load bearing wall tiles		Partitions		Book tile	
	Pounds per square foot	Square feet per ton	Pounds per square foot	Square feet per ton	Pounds per square foot	Square feet per ton
2	..	..	12	166	12	166
3	..	..	14	143	14	143
4	..	..	16	125	16	125
5	..	..	19	105		
6	29	68	22	91		
7	..	..	25	80		
8	34	59	30	66		
9	..	..	33	61		
10	40	50	35	57		
12	52	38	40	50		
	Segmental floor arches		End construction, flat arches		Side construction, flat arches	
6	27	74	..	..	27	74
8	33	61	27	74	29	68
9	..	..	31	64	36	55
10	..	..	33	61	39	51
12	..	..	38	53	44	45

TABLE 103.—LAYING HOLLOW TILES

Hours of masons' time, per 100 sq ft*

Thickness, inches	Partitions	Furring	Segmental arches	Flat arches
2	4.0	3.0		
3	4.5	4.0		
4	4.5			
5	4.5			
6	5.0	...	3.0	4.0
7	5.0			
8	5.5	...	4.0	5.0
9	6.0			
10	6.5	...	...	6.0
12	7.0	...	...	7.0

NOTE.—Time for partitions, furring, and walls is based upon the use of tiles 12 × 12 × t, if tiles 8 × 8 × t are used, the time must be increased 25 per cent.

Laborers' time

Thickness, inches	First 40 feet of horizontal distance, stock pile to work	Each additional 40 feet	Time of elevator per story
2	1.70	0.40	0.05
3	1.70	0.40	0.05
4	1.75	0.45	0.10
5	1.80	0.50	0.15
6	1.85	0.55	0.20
7	1.90	0.60	0.25
8	1.95	0.65	0.30
9	2.00	0.70	0.35
10	2.10	0.75	0.40
12	2.25	0.85	0.50

* Add laborers' time, as given below, plus the cost of scaffolding as determined from p. 108, also elevator time as indicated.

In figuring costs it is necessary to include scaffold building, mortar making, tending, and, for floor systems, building forms or "centering" and removing forms.

Where metal strips or other forms of ties are specified in partition work, add 1 hr of mason's time per 100 sq ft.

Where nails must be driven into brick walls to act as anchors for furring, add 4 hr of masons' time per 100 nails, which will usually be spaced about 25 nails to the 100 sq ft of furring.

In some localities it is practicable to have the laborers set the soffit tiles under the beams when putting up the forms, but bricklayers are inclined to object to the practice.

NOTE.—Where "lip" skewbacks are not used, one soffit tile will be required for each linear foot of steel beams.

Where the girders are to be fireproofed it will usually require two shoe tiles, or girder tiles, and one soffit tile for each linear foot of girder.

Beside that, when the girders extend more than 3 in. below the bottoms of the beams, it will be necessary to figure upon sufficient partition tile or hollow bricks to fill the space between the top of the shoe tile and the under side of the floor construction.

TABLE 104.—LAYING HOLLOW-TILE SPECIALTIES

Hours of Masons' time

Thickness, inches	Per 100 square feet		Per 100 linear feet	
	Round column	Square column	Soffit tile	Shoe tile
2	2.0	2.5		
3	2.5	3.0		
4	3.0	3.5		
..	...	...	1.5	1.5

NOTE.—Add laborers' time and hoisting time as before.

TABLE 105.—CENTERING FOR HOLLOW-TILE ARCHES
Required per 100 sq ft

	Segmental arches	Flat arches		Add for raised skews
		Center hung	Side hung	
FBM timber. .	80	100	80	20
FBM plank. . .	80	210	210	
FBM boards. .	145			
Hours, laborers.	5	5	4.5	0.5
Hours, carpenters.	2.5			

NOTE.—Laborers' time includes removal of forms. When forms can be reused, material and carpenters' time need be figured only once.

TABLE 106.—MORTAR REQUIRED
(Cubic yards per 100 square feet)

Inches	Furring	Partitions, column covering, book tile	Floor construction
2	0.07	0.10	
3	0.09	0.12	
4	....	0.14	
5	....	0.15	
6	....	0.17	0.17
7	....	0.20	0.20
8	....	0.23	0.23
9	....	0.26	0.26
10	....	0.29	0.29
11	....	0.33	0.33
12	....	0.36	0.36

Table 106 is figured upon the basis of an average thickness of joints of ½ in. It would be possible to construct a table giving the amount of mortar for any thickness of joints but, since the edges of the tiles are seldom straight, it is not practicable to maintain an exactly even joint and this table is, therefore, as nearly correct as working conditions warrant.

Load-bearing tiles are used for outside wall construction as well as bearing partition construction, to take the place of brickwork. They are usually faced on the outside by

TABLE 107.—LOAD-BEARING TILE

Size	Weight per square foot	Hours of masons' time per 100 square feet	Cubic yards mortar per 100 square feet
6 by 12 by 12	29	6	0.26
8 by 12 by 12	34	7	0.30
10 by 12 by 12	40	7.5	0.38
12 by 12 by 12	52	8	0.45

TABLE 108.—INTERLOCKING WALL TILE[1]

Thickness	Quantities per 100 square feet of wall			
	Tiles	Bonding tiles	Cubic yards mortar	Hours masons' time
8-inch tile wall	210	..	0.30	9
8-inch backing to brick wall	180	..	0.25	8.5
12-inch tile wall	320	..	0.45	14
16-inch tile wall	400	70	0.63	21
21-inch tile wall	530	..	0.75	24

[1] (Weight of 1 tile = 17 pounds. Corner tiles, 2 required for each linear foot of corner. Jamb tiles, 1 required for each linear foot of jamb. Bonding tiles, 0.7 piece for each square foot of 16-inch wall.)

stucco, but sometimes smooth-faced blocks are used that require no other finish.

The cost of handling these tiles, except mason's time in laying, may be calculated from Table 103 by increasing the times given for partitions by 10 per cent.

Interlocking tiles have come into very general use and are now made by licensees in many parts of the country. These licensees are glad to furnish much more detailed information as to the use of interlocking tiles than is given here, but Tables 103 and 108 give all the necessary information for figuring the cost of handling and laying.

For each linear foot of jambs or corners, add 0.10 hr masons' time.

Figure cost of handling, unloading, etc., in the same manner as for an equal number of 4-in. partition blocks.

NOTE.—The time for foremen on all hollow-tile work should be figured by the method previously indicated in connection with brickwork.

SECTION 2. FORMS OR CENTERING

In fireproofing the term "centering" is probably in more general use than is the term "forms," though both have practically the same meaning.

However, for hollow-tile floor arches of all types, it is most usual to use forms which are merely assembled from 2-in. scaffold planks and "stringers," hung from the steel floor framing by means of adjustable wrought-iron hangers. The work is usually done by laborers.

For combination hollow-tile and concrete construction, it is usual to build up the form of planking which, because of the longer spans used, must be supported at regular intervals by "shores" or posts. The work may be done either by carpenters or handy laborers.

For reinforced concrete or cast-in-place gypsum construction, it is usual to build a tightly constructed form of boards, supported by joists, posts, or other members as may be necessary. This work is almost invariably done by carpenters.

Centering for Hollow-tile Arches.—Centering for flat arches is a very simple form of construction, particularly where the ceiling surface is kept level and carried on the line formed by the under surface of the skewbacks.

Stringers, usually built of two pieces of 2 by 6 timber, separated by 1-in. blocking at fairly close intervals, are usually used, though some builders use single stringers.

The stringers are hung from the beams by wrought-iron hangers, ¾-in. round rods being used, which are fitted with clips to attach to the upper flanges of the beams. Adjustment in length of the hangers is provided by a screw thread and nut at the top.

Scaffold planks are then laid across the stringers to form the surface upon which the tiles are laid and which supports the tiles until the mortar in the joints has set and the arches become self-supporting.

When the specifications require that the arches must be cambered (usually the amount will not exceed ½ in.), additional stringers must be provided over the tops of the beams and the lower hangers supported at the center of the span. Then the skewbacks or soffit tiles can be set at the beams, and the hangers drawn up in the middle so as to give the required camber. This is termed "center-hung centering."

Centering for segmental arches is made as for flat arches, but, in addition, arch forms consisting of segmental ribs, cut to proper cross section and covered with 1-in. strips, are placed on top of the planking in order to give the curved shape to the arch.

As it is customary in steel-framed buildings to keep the spans between beams as uniform as possible, very little cutting of the lumber is necessary, and it should be possible to use all of the lumber over at least four times.

The figures in Table 105 are the amount of lumber needed for one time. The cost of the material actually used will be found by dividing the quantity given by the number of times it can be used. This number cannot be determined without knowing the conditions under which the work is to be done.

For instance, in building a four-story building and pushing the work with any speed at all, the builder would probably put in enough forms for the first and second floors. Then the first-floor forms would be reused on the third floor and roof, the second-floor forms would be reused on the fourth floor. This is an average use of two and one-half times.

If he had no further use for them as centering, he could then credit the planks to the job at their depreciated value as secondhand scaffold planks and the stringers as so much wood.

On the other hand, if he were constantly installing hollow-tile arches, the stringers should have a very long life, and the depreciation chargeable to any particular contract would be very small.

The hangers should last indefinitely, so it is entirely a matter of judgment as to what proportion of their cost should be charged to any job.

When using Table 105 it is necessary first to figure the cost of getting the lumber to the site of the work, unless it is bought delivered on the job.

The time given for carpenters is that required for cutting out the arch ribs and attaching the "lagging."

SECTION 3. GYPSUM FIREPROOFING

In general, the laying of precast gypsum fireproofing, such as solid or hollow partitions, furring, etc., is an operation very similar to the laying of corresponding shapes of terra-cotta hollow tile, but the work will ordinarily proceed much more rapidly because the nature of the material, as well as its lighter weight, makes practicable the use of much larger units and the partition tiles are usually made 12 by 30 in., so that 2½ sq ft of partition can be laid at one operation.

Another reason why faster work can be done with gypsum fireproofing is the much more regular shape of the units.

Being cast and not burned, gypsum partitions are not subject to any shrinking or warping that will draw them from their intended shapes.

Greater Speed with Gypsum.—Because of the greater speed of laying, more scaffold men will be required to keep the same number of bricklayers busy than would be the case with hollow tile and an average of one scaffold builder for each mason is a fair basis for figuring.

The cost of handling gypsum partitions may be figured on the basis of Table 109.

The cost of laying and the amount of mortar required can be determined directly from the proper columns of Tables 109 and 110, but it should be remembered that either "patent plaster" or "prepared mortar" are used with gypsum partitions. Portland cement mortar will not properly bond gypsum construction.

Table 110 gives the quantities of materials needed to produce a cubic yard of mortar, and the cost of mixing this mortar may be figured as explained in the discussion of brickwork.

TABLE 109.—GYPSUM FIREPROOF PARTITIONS

Thickness, inches	Weight per square foot	Square feet per ton	Hours masons' time per 100 square feet	Cubic yard mortar per 100 square feet
2 solid	10	200	3.0	0.06
3 hollow	10	200	3.0	0.07
3 solid	13	154	3.5	0.07
4 hollow	13	154	3.5	1.00
5 hollow	17.2	117	4.0	1.20
6 hollow	19	106	4.5	1.40

NOTE.—Figure scaffolding as for brickwork. Figure laborers' time and elevating time at 0.80 time given for plain hollow tile of equal thickness.

TABLE 110.—MORTAR FOR GYPSUM PARTITIONS

Proportions	Material per cu yd mortar	
	Patent mortar, tons	Sand, cu yd
1:2	0.40	0.94
1:2½	0.36	0.96
1:3	0.32	1.00

SECTION 4. COMBINATION HOLLOW TILE AND CONCRETE

Floor Construction.—Because the number of different types or "systems" of combination hollow-tile and concrete floor constructions is very great and because some of them are covered by patents and can only be installed by licensees under such patents, no attempt will be made to make this discussion cover every form of construction in general use. Only the "standard" types can be covered here, but the same principles can be used for any other system when the details of it are known.

Such books as "Concrete Engineers' Handbook," by Hool and Johnson (McGraw-Hill Book Company, Inc.), "Useful Data" (Corrugated Bar Co., Kalman Steel Co., Successors) and the literature issued by National Fireproofing Co. and other manufacturers of hollow tile contain all of the information needed by the engineer who would determine the requisite thickness of the tiles, thickness of top course and amount of reinforcing steel.

In Chap. 3 we discussed the methods to be used in estimating the costs of the materials needed to make concrete of given proportions, as well as the cost of mixing that concrete and placing concrete under most of the conditions likely to be encountered in ordinary building construction.

The same principles are to be used in estimating the cost of the concrete used in combination hollow-tile and concrete construction and the quantity of concrete can readily be determined by reference to the specified requirements for thickness of tile and thickness of top slab, if any.

Since tiles 12 in. wide, separated by a "rib" or "joist" 4 in. wide, is almost the universal type, it is evident that

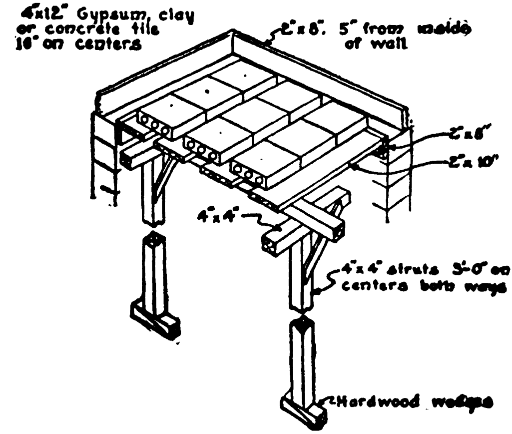

FIG. 15.—Forms for combination floors. (*Courtesy Portland Cement Association.*)

the joists are always 16 in. center to center and, therefore, each square foot of floor contains three-fourths the amount of concrete in 1 lin ft of "joist," plus the amount of concrete in 1 sq ft of top slab.

Thus, a construction of 6-in. tiles, with a 2-in. top slab, will contain the following quantities in each 100 sq ft of floor:

	Cubic Feet
75 tiles, 6 by 12 by 12	
75 lin ft 6-in. × 4-in. joists	12.5
Top slab (2-in. × 12-in. × 12-in.) × 100	16.7
	29.2 cu ft = 1.08 cu yd

Table 111 gives the concrete quantities for a variety of constructions (the tile quantity is always 75 where the

TABLE 111.—COMBINATION HOLLOW-TILE AND CONCRETE FLOORS

Construction	Cubic yards concrete per 100 square feet floor	Hours labor placing tiles per 100 square feet floor
4 plus 2	0.944	3
4 plus 2½	1.104	3
5 plus 2	1.025	3
6 plus 2	1.106	3.5
8 plus 2	1.268	4
8 plus 2½	1.428	4
10 plus 2	1.43	5
10 plus 2½	1.59	5
10 plus 3	1.74	5
12 plus 2	1.592	5.5
12 plus 2½	1.752	5.5
12 plus 3	1.902	5.5

NOTE.—Figure cost of placing concrete as indicated in Chap. 3. See Table 117 for two-way construction.

Figure cost of forms as indicated below.

Number of blocks for 12-in. wide tiles and 4-in. wide joists is always 75 per 100 sq ft.

TABLE 112.—FORMS FOR COMBINATION TILE AND CONCRETE FLOORS

Thickness of tile, inches	Spacing of joists, inches	Spacing of posts, inches	FBM, Lumber per 100 square feet	Labor, hours per 100 square feet		
				Assemble and erect	Strip	Re-erect
4	58	72	280	4.2	1.1	3.1
5	56	66	286	4.3	1.1	3.2
6	56	66	286	4.3	1.1	3.2
8	52	60	292	4.4	1.2	3.3
10	50	54	300	4.5	1.2	3.4
12	48	48	310	4.7	1.2	3.5

width of joists is 4 in.) and the quantities for any other construction may be determined by following the method given above. In the table an allowance of 5 per cent has been made in the joists to provide for the additional concrete used at the ends of the rows of tile, over the supports.

The cost of getting the tiles into the building can be estimated from the information given in Tables 102 and 103.

Placing the tiles on the forms, which can almost always be done by laborers, is an item that must not be overlooked and can be calculated from Table 111.

Reinforcing Steel.—Because this form of construction is not ordinarily used for heavy live loads, it is not customary to use complicated reinforcement.

The most common method is to use one or two bars in each rib, either or both of which may be bent up at supports. Where the rods are carried across a support, care must be taken to figure in the necessary added length of rod and its weight. Also the weight of transverse reinforcement, if any be used.

The weight of the steel may be calculated by counting the number of rods, then multiplying them by their length and weight per foot or the method indicated in Table 113.

TABLE 113.—REINFORCING RODS

Nominal size inch	Weight per linear foot		Pounds per 100 square feet	
	Round bar	Square bar	One round bar per joist	One square bar per joist
½	0.67	0.85	51	64
⅝	1.05	1.35	79	102
¾	1.52	1.91	114	143
⅞	2.06	2.64	155	198
1	2.67	3.40	200	255
1⅛	3.41	4.30	256	322
1¼	4.20	5.35	315	403

Always add 5 per cent to the computed quantity of steel, in order to take care of waste due to cutting, bending, etc.

Because stirrups, and similar members, are not regularly used in hollow-tile and concrete constructions, the cost of forming and installing them will be fully covered in the next chapter, which takes up the entire subject of reinforced concrete work.

Steel in Cut Lengths.—It is the custom to purchase the steel cut to scheduled lengths so the only costs that are incurred at the site are bending and placing.

This work can just as readily be done by any handy men, after a little training, but union regulations in many sections require reinforcing steel to be placed by structural steel erectors or metal lathers.

Table 114 gives the production that may be expected from men of ordinary skill under good supervision.

TABLE 114.—REINFORCING STEEL
(Time in labor hours)

Bar sizes inch	Bending per 100 eighth or quarter bends	Placing 100 bars		
		Under 10 feet long	10 to 20 feet long	20 to 30 feet long
½ or under........	1	4.50	5.75	7
¾ and ⅞........	1.33	5.25	6.75	8.25
1.................	1.67	6.25	8	9.75
1¼ and 1⅛.......	2	7.50	9.75	11.50

Forms.—For a "one-way" type of floor construction, open forms, similar to those used for ordinary hollow-tile floor construction, except that supporting "shores" or posts will be required, will suffice. In fact, it is only necessary that the planks should be spaced so as to come under the "joists" or ribs and to extend a sufficient distance on either side to support the tiles.

For a "two-way" construction, however, unless some form of "channel tiles" are used, it will be necessary to construct a solid floor of formwork, as for a straight reinforced concrete slab.

Except for the item of forms, the instruction given here for estimating "one-way" constructions will apply for "two-way" constructions, if proper allowance is made for the difference in quantities.

A good type of form construction consists of 2 by 8 planks, one under each "joist," resting on 4 by 6 joists, supported by 4 by 4 posts. There will also be the necessary amount of bracing and bolsters and short planks, or pedestals, under the lower ends of the posts.

Table 115 gives the necessary information for determining the number of joists and posts required, and 25 per cent should be added to the quantity thus calculated in order to take care of the bracing, bolsters and pedestals.

TABLE 115.—FORM JOISTS AND POSTS

Type of construction	Spacing of joists in inches	Spacing of posts in inches
4 + 2	58	72
4 + 2½	58	72
5 + 2	56	66
5 + 2½	56	66
6 + 2	56	66
8 + 2	52	60
8 + 2½	52	60
10 + 2	50	54
10 + 2½	50	54
10 + 3	50	54
12 + 2	48	48
12 + 2½	48	48
12 + 3	48	48

Salvage values are to be determined upon the same basis as that already outlined for centering for hollow-tile construction.

Example.—Thus, to support a floor construction consisting of 10-in. tile and 4-in. by 10-in. concrete joists with a 2½-in. top, over an area 25 by 100 ft, would necessitate the use of the following form lumber, the clear story height being assumed as 12 ft:

	FBM
Planks (25-ft length not being a stock length in most places, we must use a 14-ft and a 12-ft length).	
2 × 8: 75 pieces, 12 ft; 75 pieces, 14 ft	2,600
Joists (25 ft divided by 50 in. plus 1 joist) = 7 rows.	
4 × 6: 35 pieces, 20 ft long	1,400
Posts (7 rows joists, 100 ft long, 1 post each 54 in., plus 1 post in each row) = 161 posts.	
4 × 4: 161 pieces, 12 ft long	2,576
Braces, etc. (25 per cent of joists and posts)	944
	7,520

which equals practically 3 FBM per sq ft of floor construction.

The total time required for handling this material, after delivery to the site, may be calculated from Table 116. The time is given there in labor hours, to be divided by the estimator among carpenters and laborers as local conditions may require, but the work is not beyond the skill of good laborers.

TABLE 116.—LABOR ON FORMS

Assembling and erecting	15 hr per M FBM
Stripping	6 hr per M FBM
Re-erecting	11 hr per M FBM

TABLE 117.—TWO-WAY COMBINATION HOLLOW-TILE ANI, CONCRETE FLOOR CONSTRUCTION

Type of constructio	Cubic yards concrete per 100 square feet of floor	Hours labor placing tiles per 100 square feet of floor
4 plus 1½	0.92	2.2
4 plus 2	1.43	2.2
5 plus 0	0.74	2.4
5 plus 1	1.05	2.4
5 plus 2	1.36	2.4
6 plus 1	1.18	2.7
6 plus 2	1.50	2.7
6 plus 2½	1.66	2.7
7 plus 1	1.37	3.0
7 plus 2	1.68	3.0
8 plus 1	1.52	3.4
8 plus 2	1.83	3.4
9 plus 1	1.66	3.8
9 plus 2	1.99	3.8
10 plus 2	2.14	4.2
12 plus 2	2.30	4.6

NOTE.—For tiles 12 × 12 × *d*, with concrete ribs 4 in. thick between, figure 56 tiles per 100 sq ft.

Figure mixing and placing of concrete as previously explained. Figure forms as for one-way construction, adding 10 per cent to the amount of lumber and the labor time.

CHAPTER 7

TIMBER FRAMING

SECTION 1. GENERAL

When the writing of this text was considered, the paucity of the published data available regarding the cost of timber framing was astonishing. True, a great deal of information has been published, but it is all on the basis of the cost per M FBM.

If all designers used the same details in mill construction, for instance, then a figure per M FBM for that type would have a real value. But costly experience has shown that the only safe way to determine the probable cost of a sizable job of mill construction is to determine the several operations that must be performed on each stick and to estimate them separately.

This is not so formidable a task as it sounds. There are generally a great number of sticks all exactly alike in every mill construction building. That is, on any floor most of the columns will be alike, most of the inner rows of floor timbers will be alike and most of the outer rows of floor timbers will be alike.

Therefore, having found the cost for one stick, it is only necessary to multiply it by the number of similar sticks.

In a recent instance of a building, the cost of framing was figured on the basis of figures taken from previous experience and those figures also very closely approximate certain previously published cost figures. The estimate was

2 carpenters, 8 hr each @ $0.85..........	$13.60
3 laborers, 9 hr each @ $0.45............	12.15
To frame 2M FBM....................	25.75
Estimated cost per M..................	13.88

The actual cost was over $20 per M and the job superintendent claimed that the number of operations on each stick made it impossible for him to show a lower cost.

Note that the term "framing," as used so far, includes the actual framing operations as well as the operations of erecting, and most published data follow the same plan. Experience has shown that it is wiser to estimate the cost of those two distinct operations separately. If one gets into the habit of figuring each distinct operation separately, he will find that the temptation to "lump" and guess is greatly lessened and that his estimates more nearly approach actual costs.

Use your "costs per thousand" as a check on your detailed figures, if you like, but be sure to study the details.

You have already learned how to compute the cost of hauling materials when the weight is known, so if you know the weights of the various kinds of building lumber, you can readily figure the cost of hauling it from a car or yard to the work. Table 118 gives that information.

Table 118.—Weights of Timber

Timber	M FBM per ton		Lb per M FBM	
	Rough	Dressed	Rough	Dressed
Yellow pine...	0.455	0.57	4,400	3,500
Chestnut......	0.657	0.70	3,050	2,850
Red oak......	0.455	0.57	4,400	3,500
White oak.....	0.39	0.44	5,108	4,600
Spruce........	0.71	0.748	2,800	2,680
Hemlock......	0.71	0.748	2,800	2,680

Note.—Very complete tables of the weights of many kinds of timber and lumber may be found in the "Southern Pine Manual," the handbook of the Southern Pine Manufacturers' Association, and the "Pocket Companion" published by Carnegie Steel Co.

Of course, the cost of handling varies greatly, depending upon whether the lumber is taken from a boxcar, a gondola, or a flatcar, or whether it is taken from a pile. The type of trucks or wagons used also have an effect upon the cost; for instance, the "roller-dump" type of trucks and wagons used in many places can be unloaded in less than a minute, while other types require a very appreciable time of unloading.

Costs of handling timber from cars to trucks may be figured from Table 119.

TABLE 119.—AVERAGE COSTS ON UNLOADING TIMBER AND LUMBER FROM CAR

(Labor hours per M FBM)

	From flat-car	From gondola car	From box-car
Heavy mill timbers	1.0	1.5	1.0
House framing	0.4	0.5	0.5
Floor and roof plank	0.6	0.7	0.7
Boards	0.4	0.5	0.5
Flooring	0.7	0.8	0.8

Unloading from truck to pile will be two-thirds of the time required from flatcar to truck.

SECTION 2. MILL CONSTRUCTION

Scaling the quantities for a mill-construction building is a comparatively simple operation, but estimating the cost is not so simple, since, on a carpenter's wage rate of $1.25 per hour, the cost per M FBM may easily vary from $12.50 to over $36.00.

This is all explained by the variation in details; one designer uses joint bolts to provide a crosstie for the building, another uses dog irons, another depends entirely upon the lag bolts in the column caps.

Some designers use cast-iron pintles to carry the load of an upper column to the capital of the column below, while other designers permit the column itself to come down into the capital.

TABLE 120.—FRAMING MILL TIMBERS
(Hours of carpenters' time per cut)

	Thickness of timber, inches				Any size
	8	10	12	16	
Crosscutting, per inch of depth	0.04	0.05	0.06	0.07	
Ripping, per linear foot	0.14	0.16	0.20	0.28	
Chamfering, per linear foot	....	....	....	....	0.02
Drilling ¾-inch or smaller holes	....	....	0.02		
Drilling 1-inch holes	....	....	0.03		
Drilling 1½-inch holes	....	....	0.04		
Cutting mortise for knee brace	....	....	....	....	0.30
Cutting V notch for pintle	0.22	0.26	0.30	0.42	
Cutting square notch for post	0.25	0.30	0.35	0.50	
Cutting mortise for joint bolt	0.10	0.12	0.15	0.20	
Cutting notch for hook plate	0.12	0.15	0.18	0.20	

All of these variations in design introduce operations which must be considered when estimating. Table 120 gives the time in hours of carpenters' time for a number of different operations. Where the operation, such as cross-cutting, requires two men, proper allowance has been made in the table so that the figures may be used without change.

The figures in the table include an allowance to cover the time of shifting the boring machine and other tools, as well as moving the sticks into working position, turning them as required, and also moving the stick out of the way when framing is completed.

Example.—An example of the method of figuring the cost of framing is as follows:

The floor beams in a certain silk mill are 10 by 18's 24-0 long. They are carried on duplex hangers at one end and on hook plates at the other. The table takes in sizes only as high as 16 in., so we will make proportionate allowances where necessary.

	Hour
Plumb cut at girder end	0.90
Fire cut at wall end	0.90
Notch for hook plate	0.15
Chamfering 2 under corners, 22 ft each	0.88
	2.83
	@ $1.125 = $3.18

Each stick contains 360 FBM, therefore the cost of framing 1M FBM would be $8.83 for the floor beams.

The girders are 10 by 18's, 16-0 long, carrying a beam on each side every 8 ft, the beams being supported by hangers which are let into the sides of the girders by two holes. The girders have a plumb cut on each end. The cost is, therefore,

	Hour
Plumb cuts at both ends	1.80
Drilling 4 holes for beam hangers, holes 4 in. deep	0.16
Drilling 4 holes for dog-irons	0.04
Chamfering 2 under edges	0.56
	2.56
	@ $1.125 = $2.88

Each stick contains 240 FBM, so the cost per M is evidently $12 for the girders.

The columns are 10 by 10's, 12-0 long, requiring only square cuts at top and bottom to fit into iron bases and caps. Their cost is:

	Hour
2 square cuts	1.00
Chamfering 40 lin ft	0.80
	1.80 @ $1.125 = $2.03

Each column contains 100 FBM, so the cost is evidently $20.30 per M for the columns.

This brings out one of the most dangerous features of the usual method of figuring on the basis of an assumed average hourly production or a cost per thousand feet. The columns, though each of them requires considerably less work on it than each of the floor beams requires, cost more than twice as much per thousand feet.

This is simply because the columns each contain less than half as many board feet as the beams do. This same condition exists throughout most jobs; for instance, a 6 by 6 column will contain only one-fourth as much material as a 12 by 12 column, yet the cost of framing it will probably be more than half as much as the cost of framing the 12 by 12. This will result in a cost per thousand that will be twice as high for the small sticks as for the large ones.

This same mill has a truss roof on the top story. Each truss contains:

Chords	6 by 8	1/22-0	1/26-0	192
Rafters	6 by 8	2/24-0	......	192
Struts	6 by 6	2/ 8-0	2/ 7-0	90
	4 bv 6	2/ 6-0	......	24
				498

The labor cost of assembling one truss will be:

	Hour
End cuts on chords and rafters	1.92
End cuts on struts	2.16
Boring chord and rafter for 4 end bolts	0.22
Boring chord and rafter for 5 truss rods	0.20
Boring chord for 12 splice bolts	0.18
Notching chord and rafter for struts	3.00
Notching chord and rafter for rods, etc	3.50
Bolting up truss	2.00
	13.18
	@ $1.125 = $14.83

Since the truss contains 498 FBM, the cost per M FBM is evidently $29.78.

Erecting Timber.—So far we have only figured the cost of framing. We must still estimate and add in the cost of the erection.

The cost of erection is a very variable item and will depend upon the equipment available, the height to which the timber must be raised above ground, the distance between timbers, and whether or not most of the work can be done by common laborers instead of carpenters.

While framing timber is very properly a carpenter's job, there is no good reason why practically all of the work of erection cannot be done by good laborers, working under a competent carpenter foreman. However, in certain districts, the unions may enforce regulations requiring that the work be done by carpenters.

For most mill jobs, the best sized gang will consist of eight men, using a hand-powered "wheel-derrick" and working as follows:

1 foreman,
4 laborers operating the derrick,
1 laborer tending guy line,
1 carpenter putting the timber in place,
1 laborer helping the carpenter.

Such a gang can handle timbers containing up to 400 FBM each, at the following speeds:

TABLE 121A.—ERECTING TIMBER
(Time for full gang, as above)

Shifting derrick horizontally	2 ft per min
Raising timber vertically	3 ft per min
Setting timber in place	Average 5 min

TABLE 121B.—ERECTING MILL TIMBERS
(Average in hours per M FBM)

	Beams	Columns	Trusses
Carpenters	3.0	10.0	4.8

Add to the carpenters' time, the following:

	For each 100 feet of horizontal travel	For each 10 feet of vertical lift
Laborers[1]	3.5	3.5

[1] Union rules may make it necessary for this work to be done in all or part by carpenters.

These unit times contain a sufficient allowance to cover the ordinary small delays that occur in a day's work but do not provide for any major contingencies.

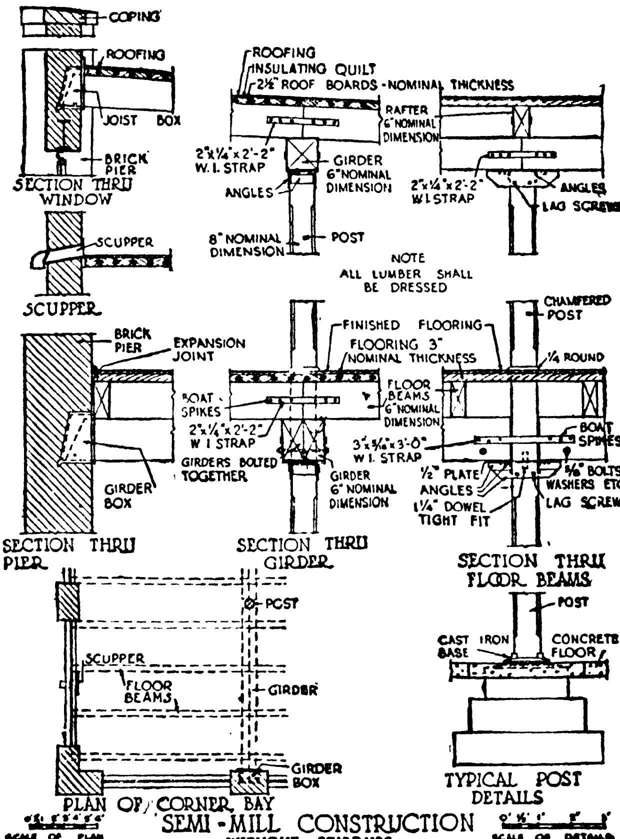

FIG. 16.—Mill-construction details. (*Courtesy National Lumber Manufacturers' Association.*)

Individual timbers containing over 400 FBM are seldom encountered in ordinary mill construction (though we once handled a mill in Paterson, N. J., with timbers of 1,728

FBM each, which is very exceptional) and the cost of erection per stick will advance practically one and one-half times its proportionate size beyond 400 FBM.

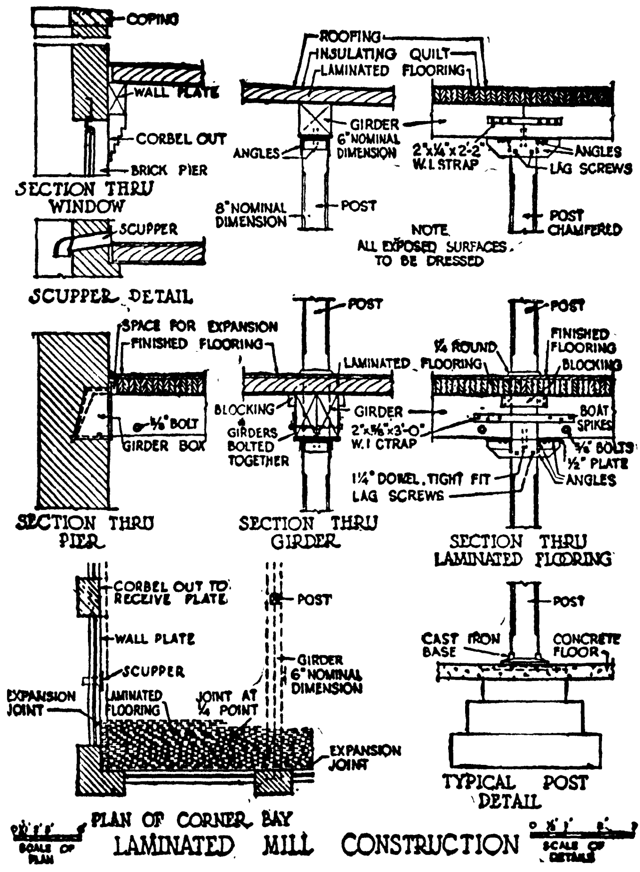

FIG. 17.—Mill-construction details. (*Courtesy National Lumber Manufacturers' Association.*)

On the other hand, it takes practically as long to erect smaller timbers, until their size gets down below 200 FBM each, so the cost of erection per thousand feet becomes less as the size of the individual sticks increases, until it reaches 400 ft per stick, after which it again advances.

In multistoried buildings there will usually be a steam engine or electric motor on the job for use in raising other

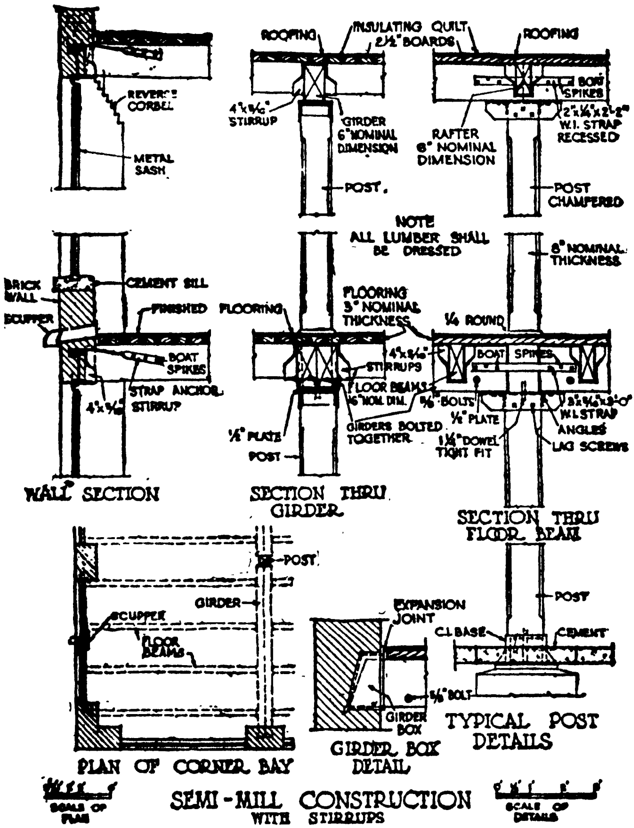

FIG. 18.—Mill-construction details. (*Courtesy National Lumber Manufacturers' Association.*)

materials and it can also be employed in getting the timber onto the upper floors, whence it can be erected by the hand-powered derrick. In some cases the entire erection is handled by a power derrick, but I believe the instances where this can be done economically are comparatively few.

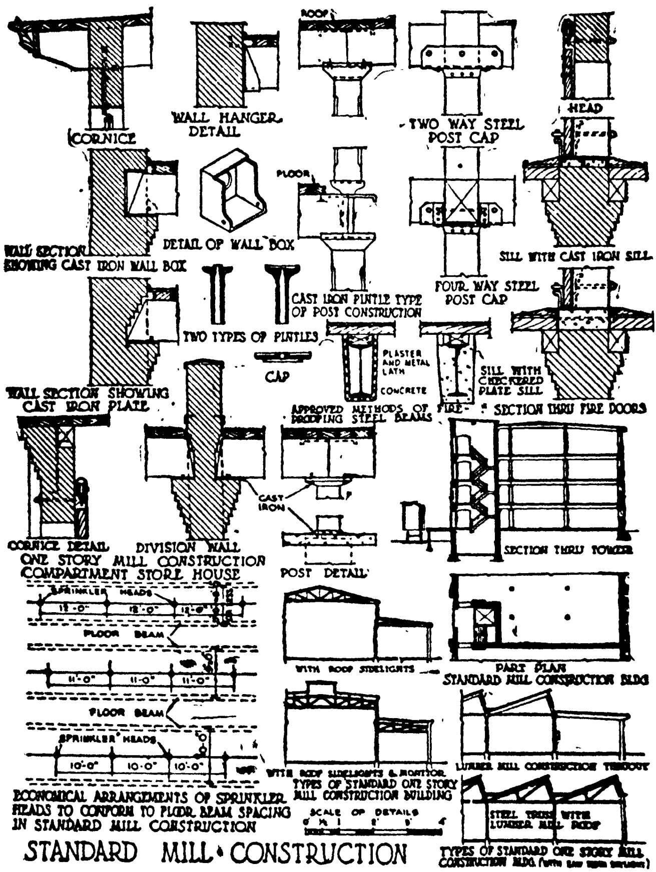

Fig. 19.—Mill-construction details. (*Courtesy National Lumber Manufacturers' Association.*)

Where the hoisting engine is employed to lift the timbers onto the floors, it is usual to wrap the line around the winch. Working this way will require two men on the ground to "load" the timber, two men on top to "unload," one man to tend the winch and the engineer to operate the derrick.

Such a gang should "load" and "unload" in a total of 3 min and should handle loads averaging 800 FBM at a speed of 12 vertical feet per minute.

Applying these figures to the building under consideration, we get the following costs:

COST OF "WHEEL-DERRICK" GANG PER HOUR

Foreman	$1.25
6 laborers @ $0.45	2.70
Carpenter	1.12½
(Average 0.634)	$5.07½

COST OF "POWER HOIST" GANG PER HOUR

Foreman (working)	$1.25
3 laborers @ $0.45	1.35
Guyman	0.50
Engineer	1.00
Engine	1.00
(Average 0.734)	$5.10

ERECTING SECOND-STORY TIMBERS (from first floor)

Timbers are 8 ft center to center

	Minutes
Shifting derrick	4
Raising timber	4
Setting timber	5
	13 min = 0.22 hr

The third- and fourth-story timbers will take the same length of time to erect, plus the time taken to bring them to the floors from which they are erected.

Thus third-story timbers will require the time of the "power hoist" gang for each "load" as follows:

	Minutes
Load and unload	3
Hoist	1
Total	4 min or 0.07 hr

The fourth-story timbers will require 1 additional minute of hoisting time, making 5 min, or 0.084 hr.

The cost of erecting, exclusive of hoisting, is therefore:

For beams, 0.22 hr × \$5.07½ ÷ 360 = \$ 3.10 per 1,000
For columns, 0.22 hr × \$5.07½ ÷ 100 = \$11.17 per 1,000
For girders, 0.22 hr × \$5.07½ ÷ 240 = \$ 4.65 per 1,000

From their sizes it can be seen that two beams or three girders will just about make a "load" for the hoist. The columns could be hoisted eight at a time, so far as weight is concerned, but their shape makes it unlikely that more than four will be handled at once. Therefore the third-story hoisting cost will be:

For beams or girders, 0.07 hr × \$5.10 ÷ 720 = \$0.50 per 1,000
For columns, 0.084 hr × \$5.10 ÷ 400 = \$1.08 per 1,000

In handling the trusses, the time for shifting the derrick will be the same as before, but even though each truss contains only 498 FMB, the time taken in hoisting and erecting it, because of its size and shape, will be twice as long as for a stick, and the time placing it three times as long. Since all the trusses go on one level, we can figure them as follows:

	Minutes	
Hoisting-gang time:		
Load and unload	6	
Hoisting 36 ft	6	
	12 min or 0.20 hr	
	@ \$5.10 =	\$1.02

	Minutes	
Wheel-derrick gang:		
Shift derrick as before	4	
Raising truss	12	
Setting truss	15	
	31 min or 0.51 hr	
	@ \$5.07½ =	2.60
	Total...	\$3.62

which equals \$7.27 per 1,000

NOTE.—For convenience sake, it might have been better, as well as cheaper, to hoist the individual parts of the truss to the top floor and then assemble and erect them there. Where the element of time does not make it necessary to have the trusses ready to erect as soon as the walls can receive them, it will usually be found most economical to assemble them on the floor from which they are erected.

Summarizing the cost computed thus far, we get the following costs per M FBM:

	Framing	Hoisting	Erecting	Total
Beams:				
2nd floor.........	9.09	....	3.10	12.19
3rd floor.........	9.09	0.50	3.10	12.69
4th floor.........	9.09	0.60	3.10	12.79
Girders:				
2nd floor.........	12.00	....	4.65	16.65
3rd floor.........	12.00	0.50	4.65	17.15
4th floor.........	12.00	0.60	4.65	17.25
Columns:				
1st floor.........	20.30	....	11.17	31.47
2nd floor.........	20.30	0.89	11.17	32.36
3rd floor.........	20.30	1.08	11.17	32.55
Trusses............	29.78	2.04	5.23	37.05

Liability and compensation insurance, as well as overhead items and contingencies must, of course, be added to these figures. It must also be remembered that we have only figured the cost after the timber was delivered to the site of the work and that the cost of delivery must be computed separately.

Since, counting the working foreman as a carpenter, the usual average throughout such a job as this would be 1½ laborers to a carpenter, a much more usual method of figuring is as follows:

1 carpenter, 8 hr @ $1.12½........................	$ 9.00
1½ laborer, 8 hr @ $0.45........................	5.40
Cost to handle 1M FBM........................	$14.40

TABLE 122.—MILL FRAMING TIMBERS
(Feet board measure per stick)

Size	Lengths, feet								Any length
	12	14	16	18	20	22	24	26	
6 × 6	36	42	48	54	60	66	72	78	L[1] × 3.0
6 × 8	48	56	64	72	80	88	96	104	4.0
6 × 10	60	70	80	90	100	110	120	130	5.0
6 × 12	72	84	96	108	120	132	144	156	6.0
6 × 14	84	98	112	126	120	154	168	182	7.0
6 × 16	96	112	128	144	160	176	192	208	8.0
8 × 8	64	74.7	85.4	96	106.7	117.4	128	138.7	5.333
8 × 10	80	93.4	106.7	120	133.4	146.7	160	173.4	6.67
8 × 12	96	112	128	144	160	176	192	208	8.0
8 × 14	112	130.7	149.4	168	186.7	205.4	224	242.7	9.333
8 × 16	128	149.4	170.7	192	213.4	234.7	256	277.3	10.67
8 × 18	144	168	192	216	240	264	288	312	12.0
10 × 10	100	116.7	133.4	150	166.7	183.4	200	216.3	8.333
10 × 12	120	140	160	180	200	220	240	260	10.0
10 × 14	140	163.4	186.7	210	233.4	256.7	280	303.4	11.667
10 × 16	160	186.7	213.4	240	266.7	293.4	320	346.7	13.333
10 × 18	180	210	240	270	300	330	360	390	15.0
10 × 20	200	233.4	266.7	300	333.4	366.7	400	432.7	16.6 67
12 × 12	144	168	192	216	240	264	288	312	12.0
12 × 14	168	196	224	252	280	308	336	364	14.0
12 × 16	192	224	256	288	320	352	384	416	16.0
12 × 18	216	242	288	324	360	396	432	468	18.0
12 × 20	240	280	320	360	400	440	480	520	20.0
12 × 22	264	308	352	396	440	484	528	572	22.0
12 × 24	288	336	384	432	480	528	576	624	24.0
14 × 14	196	228.7	261.4	294	326.7	359.4	392	424.7	16.333
14 × 16	224	261.4	298.7	336	373.4	410.7	448	485.4	18.667
14 × 18	252	294	336	378	420	462	504	546	21.0
14 × 20	280	326.7	373.4	420	466.7	513.4	560	606.7	23.333
16 × 16	256	298.7	341.4	384	426.7	469.4	512	554.7	21.333
16 × 18	288	336	384	432	480	528	576	624	24.0
16 × 20	320	372.4	426.7	480	533.4	586.7	640	693.4	26.667
18 × 18	324	378	432	486	540	594	648	702	27.0
18 × 20	360	420	480	540	600	660	720	780	30.0
20 × 20	400	466.7	533.4	600	666.7	733.4	800	866.7	33.333
24 × 24	576	672	768	864	960	1,056	1,152	1,248	48.0

[1] L = length in feet.

This figure is to include framing, hoisting and erecting. To get the average for the building we have been studying we will figure as follows:

Second story:	
13,000 FBM beams @ $12.19	$ 158.47
2,200 FBM girders @ $16.65	36.63
900 FBM columns @ $31.47	28.32
Third story:	
13,000 FBM beams @ $12.69	164.97
2,200 FBM girders @ $17.15	37.73
900 FBM columns @ $32.36	29.12
Fourth story:	
13,000 FBM beams @ $12.79	166.27
2,200 FBM girders @ $17.25	37.95
900 FBM columns @ $32.55	29.30
Trusses:	
9,000 FBM @ $37.05	333.45
57,300 FBM @ average of $17.84	$1,022.21

This would indicate that, in this instance, the error by the use of the short method is practically 25 per cent, since the actual average daily production is only about 800 FBM, instead of 1M FBM as figured. However, the amount of this error would vary with each job. If there had been no trusses in this instance, the short method would have given a result that would be approximately the same as that obtained by the longer method. This simply indicates the necessity of separating the different classes of work, no matter which method of estimating is used.

In Chap. 10, the use of a truck-mounted crane for erecting structural steel is discussed. The same principles apply to its use for erecting timber.

SECTION 3. BUILDERS' IRONWORK

Computing the quantities of builders' ironwork is ordinarily a very simple operation; the exact method to be used depends largely upon the kinds of ironwork called for.

For instance, if any of the ready-made or patented types of joist hangers, beam boxes, column caps, column bases and similar members are called for, the simplest method is to make a list of the various items required and get a price on the list, either from a catalogue or price list or by inquiry of persons dealing in such goods.

When the ironwork consists of members made up of ordinary sizes of rod, bar, or flat iron, the weight can easily be computed by means of the tables in such handbooks as Bethlehem or Carnegie Pocket Companion, or if no handbooks are available, all of the various sizes can be figured to the equivalent of 1-in. square bar, which weighs 3.40 lb per lin ft, and the total weight thus readily calculated.

Manufacturers of such ironwork will usually be glad to give a unit price per pound of lists sent them for price, or a unit price per piece on each of the various items.

Where castings of any ordinary types, such as bases, caps, bearing plates, pier plates, etc., are used, unless a price per piece can readily be obtained, the contents of each piece in cubic inches should be calculated, and since a cubic foot of cast iron weighs 450 lb, the weight of the piece will be found by multiplying its contents by 450 and dividing by 1,728. Many estimators simply divide the cubic contents by four and consider the result near enough for all practical purposes. See also Appendix A.

A bricklayer with a laborer will set a base plate, 16 in. square and weighing 100 lb, in an average time of ½ hr and will take practically the same time for one of half that weight, while a beam bearing plate weighing 40 lb should not require over 10 min.

With masons' time at $1.25 per hour and laborers' time at 60 cents per hour, the costs would be as follows:

Setting 100-lb base	0.0083 per lb
Setting 50-lb base	0.0165 per lb
Setting 40-lb base	0.0065 per lb
Average	0.0101 per lb

It is hardly practicable to set up a table giving the unit times required for all of the different items of cast iron that might be used, but the information just given should enable you to figure the cost as closely as necessity may require.

The time necessary for setting those items of ironwork that are placed by carpenters and which require boring and lag bolting can be computed from Table 120, by figuring the time necessary to do all the boring required and adding 1½ times that amount to cover the cost of bolting and assembling.

SECTION 4. HOUSE CONSTRUCTION

The work of framing and erecting the timber portions of houses and similar buildings is usually a very simple oper-

TABLE 123.—HOUSE FRAMING
(Time in carpenter hours per 100 pieces)

Joists	Fire-cutting (hours)	Square-cutting (hours)
2 by 8	16	14
2 by 10	18	16
2 by 12	24	22
3 by 10	25	22
3 by 12	30	27
3 by 14	35	32
Rafters	Main rafters	Jack and cripple rafters
2 by 6	14	18
2 by 8	16	20
2 by 10	18	22
Wall studs, plates same	Cutting both ends and notch for ribbon	Halving for splices, add
2 by 4	10	3
2 by 6	12	4

ation, since practically the only items involving any complicated work are stairs, bay windows, roofs and dormers.

Because house framing is so simple, the most usual method is to compare the building being estimated with some previous job, and then assume a comparative cost per M FBM for the new work. This method is usually very satisfactory, but sometimes apparently slight variations in

TABLE 123.—HOUSE FRAMING.—(*Continued*)

Partition studs, caps and sills same	Cutting both ends
2 by 3	7
2 by 4	8
2 by 6	9
Main sills, halving only	
4 by 6	50
6 by 6	75
6 by 8	100
Hips and valleys, 1½ times adjoining rafters	
Bridging	2

the framing will make disproportionately large increases in the cost.

For this reason the same analytical method as outlined for mill construction should be used to determine the unit prices which will be used in a house-construction estimate for the framing, using the data in Table 123, while for the erection the data given in Table 126 should be used.

TABLE 124.—HOUSE FRAMING

(Average number hours carpenters' time per 1,000 feet board measure)

Joists		Fire cutting	Square cutting	Notching
2 × 8	10 feet	9	8	11
	12	8	7	10
	14	7	7	10
	16	6	6	9
2 × 10	12 feet	9	8	11
	14	8	7	10
	16	7	6	10
	18	6	6	9
2 × 12	14 feet	12	11	14
	16	10	9	13
	18	8	7	10
	20	7	7	10
	22	7	6	9
3 × 10	14 feet	13	12	15
	16	11	10	14
	18	9	8	11
	20	8	7	10
	22	8	7	10
3 × 12	14 feet	16	15	20
	16	14	13	16
	18	12	11	14
	20	10	9	13
	22	10	9	13
	24	9	8	11
3 × 14	16 feet	17	16	20
	18	14	13	16
	20	12	11	14
	22	12	11	14
	24	10	9	13

NOTE.—Common rafters take same time as fire cutting joists of same size. Jack and cripple rafters take 1.3 × time for fire cutting. Hips and valleys take 2.0 × time for fire cutting.

It should be noted that the times given in Table 123 are for spruce, hemlock or other soft wood and they should be increased as follows if hardwood framing timber is used:

For hard pine add 20 per cent to tabular time
For chestnut add 25 per cent to tabular time
For oak add 30 per cent to tabular time

TABLE 125.—STUD PARTITIONS

Studs	Spacing, inches	Height, feet	FBM per 100 linear feet[1]	Average carpenter hours per 100 linear feet[2]
2 × 4	12	8	799	12
		10	934	13
		12	1,067	14
	16	8	667	10
		10	767	11
		12	867	12
2 × 6	12	8	1,200	19
		10	1,400	22
		12	1,600	25
		14	1,900	30
	16	8	1,000	16
		10	1,150	19
		12	1,300	21
		14	1,550	25

[1] Includes studs, sill, plate and bridging.
[2] Includes erecting in buildings one to four stories high. If studs are cut on power saw, multiply time × 0.70 and add cost of saw at 3 hr per 1M FBM.

In using Table 123, note particularly that the cost of framing a stick is really independent of the length of the stick, so the cost of 1M FBM will increase as the length of the pieces decreases.

An example of the working out of this point is as follows.

Assuming a carpenters' wage rate of \$1.12½ per hour the cost of framing 2 by 6 rafters would be

	Pieces per M
$26.30 per M for 6-ft lengths	167
13.15 per M for 12-ft lengths	84
11.34 per M for 14-ft lengths	72
9.92 per M for 16-ft lengths	63

It can readily be seen that the use of this method eliminates the necessity of guessing how much should be added to the estimate for dormers, bay windows, and similar features involving a great number of short sticks, since by counting the number of individual pieces required, and figuring the cost on that basis, we have made the necessary allowance in the labor column and need only extend the materials at the proper price into the materials column.

TABLE 126.—ERECTING HOUSE FRAMING
(Carpenters' time, hours per M FBM)

	Hours
Setting joists on masonry wall	9
Setting joists on main sill	11
Setting joists on girts or ribbons	12
Setting wall studs, including plates	7
Setting 2-story partition studs	7
Setting 1-story partition studs	11
Bridging joists	9
Bridging partitions	9
Setting ceiling beams	12
Setting main rafters	12
Setting jack and cripple rafters	17
Setting hips and valleys	17

In most cases it will be practicable to substitute from one-fourth to one-third of laborers' time for the carpenters' time given above, since a great deal of the work consists merely of handling and passing the lumber to the carpenters.

The figures given in this chapter are for all hand work and do not include anything for the time of a foreman in laying out cuts. It is assumed that a template will be made in each instance where there is an appreciable number of sticks to be cut to the same pattern and the figures are based accordingly.

Where other than square-end cuts, or fire cuts, are required, the time for laying out a cut may be as high as half the time required for making the cut but, with a template, this cost should be distributed over so many pieces that the charge per stick is negligible.

TABLE 127.—HOUSE FRAMING TIMBERS
(Feet board measure per stick)

Sizes	Lengths (feet)								Any length
	10	12	14	16	18	20	22	24	
2 × 4	6.7	8	9.4	10.7	12	13.4	14.7	16	L[1] × 0.667
2 × 6	10	12	14	16	18	20	22	24	1.0
2 × 8	13.4	16	18.7	21.4	24	26.7	29.4	32	1.333
2 × 10	16.4	20	23.4	26.7	30	33.4	36.7	40	1.667
2 × 12	20	24	28	32	36	40	44	48	2.0
2 × 14	23.4	28	32.7	37.4	42	46.7	51.4	56	2.333
3 × 4	10	12	14	16	18	20	22	24	1.0
3 × 6	15	18	21	24	27	30	33	36	1.5
3 × 8	20	24	28	32	36	40	44	48	2.0
3 × 10	25	30	35	40	45	50	55	60	2.5
3 × 12	30	36	42	48	54	60	66	72	3.0
3 × 14	35	42	49	56	63	70	77	84	3.5
4 × 4	13.4	16	18.7	21.4	24	26.7	29.4	32	1.333
4 × 6	20	24	28	32	36	40	44	48	2.0
4 × 8	26.7	32	37.4	42.7	48	53.4	58.7	64	2.67
4 × 10	33.4	40	46.7	53.4	60	66.7	73.4	80	3.333
4 × 12	40	48	56	64	72	80	88	96	4.0
4 × 14	46.7	56	65.3	74.7	84	93.3	102.7	112	4.67

[1] L = length in feet.

Machine Work.—It is not possible to give as many data as desirable on the use of power saws and power drills. It is doubtful that the old types of power saws, requiring fixed locations, would show any economy at all on small-sized jobs, and on large jobs their economy is entirely a matter of organizing the work so that the cost of handling the stock to and from the machine does not eat up any possible saving due to the use of the machine.

On the other hand, with the many types of portable equipment now available, appreciable savings can be made, though it is seldom that the savings will equal the optimistic claims of their manufacturers or dealers.

TABLE 128.—LENGTHS OF RAFTERS AND AREAS OF PITCHED ROOFS

Nominal pitch	Rise, inches per foot	Rafter length		Hip or valley	Area
		$L \times$	$W \times$	$L \times$	$A \times$
¼	6	1.12	0.56	1.53	1.12
⅓	8	1.20	0.60	1.59	1.20
⅜	9	1.25	0.63	1.63	1.25
½	12	1.42	0.71	1.76	1.42
⅝	15	1.60	0.80	1.91	1.60
¾	18	1.80	0.90	2.09	1.80

NOTE.—W = width of building over plates, or over cornice if rafters extend into cornice. $L = \frac{1}{2}W$, A = product of horizontal dimensions. This applies whether roof is gabled, hipped or otherwise arranged.

TABLE 129.—HIGH SCAFFOLDS

(For interiors of churches, theaters, etc.)

For each 12 ft of height, allow 0.4 FBM per sq ft of area covered.

For each square foot of floor area covered, allow 2.0 FBM plank.

Figure 50 per cent salvage.

Figure 16 hr carpenter labor per M FBM for erecting.

Figure 3 hr laborers' time per M FBM for dismantling.

Making proper allowances for the current required for operation, changing wiring and other incidental expenses, it is safe to figure that the cost of work done with portable power tools of proper size and design will not exceed 70 per cent of the cost of straight hand work.

Therefore, when figuring on the use of a power saw or drill, the time given for hand work should be multiplied by

0.70 to get the time in hours of the men using the machines and performing the same operations.

Teco Connections.—The following information as to this recent development in timber construction is included by the courtesy of the Timber Engineering Co.:

Man-hours required for fabrication assembly and erection of wood trusses employing the Teco system of construction. (Prepared by Mr. E. S. Lank, Structural Engineer for Timber Engineering Co.)

These figures are applicable only to trusses employing split ring connectors. It should be further noted that the following relations are not intended for use with nailed, bolted or glued construction. The following relations may be used without correction only if there is sufficient material to warrant use of templates and production line of fabrication.

The expression for total man-hours including fabrication, assembly and erection may be given as follows:

Man-hours per thousand board feet

$$= Q + \left(\frac{\text{No. of patterns per M FBM}}{10}\right) + \left(\frac{\text{No. of pieces per M FBM}}{A}\right) + \left(\frac{\text{No. of Holes per M FBM}}{B}\right) + \left(\frac{\text{No. of grooves per M FBM}}{C}\right)$$

Two members should be considered as the same pattern if they are congruent. Further, if they are identical except for being of the opposite hand they should be considered of the same pattern.

Each structural member before assembly shall be considered as a piece in counting number of pieces involved. It is recommended that filler blocks that are not precisely cut to length and have only one bolt hole be tallied as ½ piece.

The total number of holes involved shall be the sum of all the holes in individual structural members before assembly, except single holes in filler blocks that are not used for transfer of primary stresses be tallied as ½ hole.

It is assumed in the following table that a proper ratio between mechanics and unskilled labor is maintained for each operation in fabrication, assembly and erection.

The table includes man-hours required for erection using power rigs to hoist trusses. If a manual gin pole rig is used additional man-hours will be necessary.

Supervision and layout time are to be added to the labor shown in the equation.

Description of labor and fabricating facilities	Truss detail	*Q*	*A*	*B*	*C*
Labor skilled in fabrication, assembly and erection of Teco trusses; modern woodworking equipment; roller tables should be provided on fabrication line	Simple (single connectors at each overlapping area except chord splices); one size of bolt and connector used throughout (*R*)	14	20	100	70
	Average (not more than 3 connectors used at each overlapping area except chord splices); one size of bolt and connector used throughout (*S*)	16	17	90	60
	Complex (scarfing of members required at some joints, more than one size of bolt or connector used within same design); more than 3 connectors used at overlapping area within joint (*T*)	20	15	80	50
Carpenter labor experienced in Teco fabrication; power machinery	Simple (*R*)	17	17	90	60
	Average (*S*)	19	15	80	50
	Complex (*T*)	22	12	64	40
Semiskilled labor under proper supervision; portable field machinery	Simple (*R*)	18	15	80	50
	Average (*S*)	21	12	64	40
	Complex (*T*)	24	10	55	35

CHAPTER 8

BOARDING, PLANKING, SHINGLING

SECTION 1. PLANKING

While 1M FBM is undoubtedly the proper unit to use in calculating the quantities of materials required for all such items as floor and roof planking, flooring, siding, sheathing, etc., the square, or 100 sq ft, is the handiest unit to use when figuring the labor cost, and that unit has been used in all cases in this chapter.

In figuring the cost of the material necessary to lay a given area of planking, or boarding, due allowance must be made for the waste due to matching, cutting of ends, cutting out bad spots, etc.

If the planks for any piece of work can be ordered directly from the mill and if the spacing between supports is uniform, it is often possible to purchase plank so that practically the only waste will be that due to matching.

However, materials purchased from yard stocks are always subject to an overrun of 5 per cent, and due allowance must be made for this overrun when estimating. For instance, in a factory which required 100M FBM of floor and roof planking, all might be needed in 20-ft lengths. If plank were ordered from a yard that did not have enough 20-ft pieces and added 21- or 22-ft pieces to make up the quantity, the purchaser would have to pay for that useless overlength up to a total of 5M FBM. Therefore, when estimating, be sure to determine whether stock will have to be purchased from yards and make allowance accordingly.

Side waste, from matching, is a very uncertain quantity in planking, since it varies with the width of the plank. If it is known in advance that it is possible to get all planks of a given width, one could estimate accordingly, but the increase in price when all plank of one width are specified will usually overbalance any possible saving.

Since matching takes $\frac{3}{4}$ in. from the width of a plank, it is evident that the percentage of side waste must be as follows:

	Per Cent
Planks 4 in. wide	$18\frac{3}{4}$
Planks 6 in. wide	$12\frac{1}{2}$
Planks 8 in. wide	$9\frac{3}{8}$

An ordinary lot of random width floor or roof plank will not average over 6 in. wide, so it is well to allow at least $12\frac{1}{2}$ per cent for the side waste.

If the distances between supports are not uniform, or if those distances are not such that readily obtainable lengths of plank can be used, then additional allowance must be made for end waste on that account.

In most markets, planks are available in lengths varying by multiples of 2 ft, from 12 ft upward. This means that, no matter what the actual length of plank required, the user must buy and pay for planks of the next larger length in even feet.

Thus, for an actual length of, say, 18 ft 4 in., he would have to buy 20-ft planks and waste the difference, or 9.3 per cent.

Adding this end waste of 9.3 per cent to a side waste of 12.5 per cent we would have a total waste of 21.8 per cent or practically 22 per cent, which must be added to the estimate.

When splines are used, which is seldom the case with plank of a nominal thickness less than 4 in., their cost is determined by allowing 1 ft of spline for each linear foot of plank.

Thus, if the plank average 4 in. wide, the total linear feet of splines will be three times the total area of planking; if 6 in. wide, twice the area; if 8 in. wide, $1\frac{1}{2}$ times the area, and so on.

Various tables have been published for computing the quantities of nails or spikes required for floor and roof planking, but most of these tables give quantities very much smaller than will actually be used.

Ordinarily, spikes used in planking should not be much shorter than ½ in. less than twice the nominal thickness of the plank, thus:

For 4-in. plank use 7-in. spikes, figure 9 to the pound.
For 3-in. plank use 60d spikes (6 in. long), figure 12 to the pound, or
For 3-in. plank use 50d spikes (5½ in. long), figure 15 to the pound.
For 2-in. plank use 16d spikes (3½ in. long), figure 51 to the pound.

The number required will be determined by allowing two nails, or spikes, for each plank on each bearing. Thus planks 6 in. wide, 20 ft long, on 10-ft bearings, would require six nails per plank or 0.6 nails per square foot or 60 nails per square.

On this basis the quantities would be as follows:

Table 130.—Nails Required

		Per square, pounds	Per 1,000 FBM, pounds
4-inch plank.........	6-foot supports	11.2	28
	8-foot supports	8.4	21
	10-foot supports	6.7	17
	12-foot supports	5.6	14
3-inch plank.........	6-foot supports	8.4	28
	8-foot supports	6.2	21
	10-foot supports	5.0	17
2-inch plank.........	4-foot supports	2.8	14
	6-foot supports	2.0	10
	8-foot supports	1.4	7
	10-foot supports	1.1	6

These are the actual quantities required but, because of the many wastes that occur on every job, it is always well to allow an increase of 50 per cent of the computed quantities when estimating.

Whenever the conditions are such that the planks can be ordered of a very few lengths, that will work without further cutting, it is well to buy them "butted to exact length."

Dealers make an extra charge for butting but their charge is usually small as compared with the cost of butting on the job, even though power saws are available.

Having figured the cost of landing the planks at the level at which they are to be laid, as previously explained, we now have only to figure the cost of placing, including the setting in of splines, when specified, and the cost of spiking.

The cost of placing plank, because of the inconvenience in working and moving around, naturally increases as the plank span increases. On the other hand, since the number of nails per bearing is usually the same, the cost of nailing or spiking increases as the distance between bearings decreases.

For all practical purposes, therefore, the same cost may be figured for all reasonable variations in plank-span length.

TABLE 131.—LABOR HOURS PER 100 SQUARE FEET

Nominal thickness, inches	Tongue and grooved	Splined	Laminated
2	3		
3	3.5	4.5	
4	...	5	7
5	...	5.5	8
6	...	6	9

The column for splined plank includes the time necessary for placing the splines.

The time in Table 131 is given entirely in labor hours because local conditions will determine what portion of the work can advantageously be done by laborers and what portion must be done by carpenters. Beyond the butting of the plank, however, there is really very little work connected with the laying of plank that requires the skill of the carpenter.

SECTION 2. FLOORING, BOARDING, SHEATHING

In the previous discussion of the cost of timber framing, you have become familiar with the cost of transporting lumber to the site of the work and of placing it on the level at which it is to be used, and no repetition is necessary here.

The same general principles apply to the application of flooring, boarding, sheathing, ceiling, etc., as apply to the laying of floor and roof planking, but in these present items a greater number of factors affect the amount of waste involved and the amount and quality of the labor required.

If we always knew in advance that our lumber would be as good as we expect it to be and our architects no more exacting than we read their specifications to be, it is probable that we could figure upon a less proportion of waste material and a greater production per man-hour.

Under present market conditions, and with present grading rules, we are always likely to have to do a great deal of cutting out and rejecting, which means waste of material and added cost for labor.

In preparing Table 132, all these conditions have been given consideration and allowance made accordingly. In figuring, it is assumed that the estimator will always consider small openings as part of the area to be covered, making no allowance for the saving and, in the cases of irregular or badly broken up areas, he will make a judicious addition to the figured allowances for labor and for waste material.

TABLE 132.—FLOORING, SHEATHING, ETC.
(Carpenter hours per 100 square feet)

	Time	Add percentage of waste required	Nails, pounds
3¼ face NC or fir flooring.	2.8	15	4.5 (on underfloor)
2¼ face NC or fir flooring.	3.0	30	5.5 (on underfloor)
3¼ face NC or fir flooring.	3.3	20	4.5 (on joists)
2¼ face NC or fir flooring.	2.5	30	5.5 (on joists)
2¼ face oak............	3.0	30	5.5 (on underfloor)
2¼ face beech, birch or maple	2.8	30	5.5 (on underfloor)
1 × 6 underfloor on joists.	1.7	15	2.0
1 × 8 underfloor on joists.	1.5	15	1.7
1 × 6 underfloor on joists.	2.2	25	2.0 diagonal
1 × 8 underfloor on joists.	2.0	25	1.7 diagonal
1 × 6 roofers on sidewall studs..................	2.4	15	2.0
1 × 8 roofers on sidewall studs..................	2.2	15	1.7
*1 × 6 roofers on flat roof.	2.2	15	2.0
*1 × 8 roofers on flat roof.	2.4	15	1.7
*1 × 6 roofers on pitched roof..................	2.6	25	2.2*
*1 × 8 roofers on pitched roof..................	2.8	25	1.9*
Narrow ceiling on sidewalls	3.5	25	2.0
Narrow ceiling on ceiling..	4.0	25	2.0
Narrow clapboards on walls	4.0	25	2.0
Wide clapboards on walls.	2.5	25	1.6

* Add 1 hr to total figures for each 10 lin ft of hips, valley and ridges in the roof and 1½ FBM waste lumber for each linear foot of hip, valley and ridge.

SECTION 3. SHINGLING

While the square seems to be the most convenient unit for use in figuring the items just discussed, shingles can better be figured by the thousand.

This is true because, even though the number of squares must be taken off the plan in order to compute the quantity of shingles required, it takes just as much labor to lay a thousand shingles with a 4-in. exposure to the weather as with a 5-in. exposure, yet the area covered will be materially less.

Shingles, as delivered, vary in width but are counted on the basis of 4 in. wide, so the actual number of pieces in a bundle is immaterial but the charge is for a quarter-thousand.

Shingles are usually made 16 or 18 in. long but, since the exposure to the weather is what governs the quantity used, the length makes no difference in the number required but will make a difference in the cost, because the 18-in. shingles cost more per thousand.

Also, because of the greater lap afforded, they make a warmer house.

Shingles on roofs are laid 4, 4½ or 5 in. to the weather, on sidewalls they may have as much as 10-in. exposure and sometimes are laid with the courses alternating, first a course of narrow exposure, then one of wide exposure.

Since the shingles average 4 in. in width, when laid 4½ in. to the weather, each shingle covers 18 sq in. and 8 shingles cover 1 sq ft. Upon this basis we may calculate our table as below.

The usual method of figuring the labor, as given in most handbooks, is to take a certain figure for "plain roofs" and another one for "fancy roofs," but that hardly seems definite enough, so the following method is recommended.

To these figures it is necessary to add 10 min time for each linear foot of door or window casing or similar trim against which the shingles must be fitted, and also 20 min time for each linear foot of ridge hip or valley.

TABLE 133.—SHINGLES REQUIRED PER 100 SQUARE FEET

Exposure, inches	Number required	Nails required, pounds
4	900	3.9
4½	800	3.5
5	720	3.3
6	600	2.7
7	515	2.3
8	450	2.0
9	400	1.8
10	360	1.6

TABLE 134.—LABOR PER 1,000 SHINGLES

	Carpenter Time, Hours
On straight roofs	3.5
On curved surfaces	5.0
On side walls	4.0

With these additions, the figures given in Tables 133 and 134 will be large enough to cover erecting and taking down the usual amount of scaffolding.

With the great variety of asphalt, and other forms of proprietary shingles that are now on the market, it is hardly practicable to prepare a table that would cover them all, but the following figures will prove helpful:

TABLE 135.—LABOR PER 100 SQUARE FEET

	Carpenter Time, Hours
Asphalt strip shingles	2
Asphalt twin shingles	2.25
Asphalt single shingles	2.75

SECTION 4. FURRING AND GROUNDS

No attempt will be made here to discuss the cost of affixing the many kinds of patented furrings and "spot" grounds. The manufacturers of most of such articles have collected data on their cost of installation and are glad to furnish information at any time. When using such information, however, it is necessary to be sure that it is in such form that it can be applied to the problem in hand.

Some strip furring is figured by the square, which is all right if the proper allowances are made for waste, etc., but, since furring is often sold on the basis of the number of linear feet, I recommend that method of figuring.

Knowing the spacing, it is a simple matter to calculate the number of linear feet required, and then an allowance of at least 10 per cent should be added to cover end waste on strips, short pieces, cross strips, etc.

The labor can readily be figured by means of Table 136.

TABLE 136.—FURRING
(Carpenters' time per 1,000 linear feet)

	On joists	On T. C. tile	On gypsum tile	On brick
1 by 2........	7	11	10	13
2 by 2........	8	13	12	15
2 by 3........	8.5	14	13	17

The figures for furring on brick are based upon the assumption that plugs have already been placed in the wall. If wood plugs must be inserted, add 6 hr to the figures given in the table.

The item of grounds affords more opportunities of guesswork than almost any other item in the carpenter's estimate. This is true because few people take the time to compute the quantities required or make any actual effort to find what it really costs to affix grounds.

Care should be taken to include grounds for every kind of wood trim that is to be attached in plastered rooms and to study the detailed drawings carefully to find out just how much grounding is necessary.

Ordinarily, the following figures should be used:

Base, 2 lin ft grounds per lin ft.
Chair rail, 2 lin ft grounds per lin ft.
Picture mold, 1 lin ft grounds per lin ft.
Casings, 1 lin ft grounds per lin ft.

The labor may be calculated from Table 137.

TABLE 137.—GROUNDS
(Carpenters' time per 100 lin ft)

	Hours
On brick	5
On terra cotta	4.5
On gypsum	4.5
On wood	4

If plugging of brick walls must be done, then the same allowances must be made as for furring.

CHAPTER 9

FINISHED CARPENTER WORK

SECTION 1. GENERAL INSTRUCTIONS

It is hardly within the province of this chapter to attempt to give a detailed explanation of the method of figuring the cost of millwork materials, since that is the manufacturer's job rather than the construction estimator's, but it will be in order to suggest the methods to be used in taking off quantities and securing prices.

If the materials required are all of stock sizes and patterns, it is a simple matter to make a complete list of the items required, price them from a catalogue and discount sheet, or send the list to dealers and have them quote on it.

If the material is only partly of stock patterns, part of it can be priced from the catalogue as above, or all of it sent out for prices, but if the patterns are at all unusual, it is always best to have the mill estimator take his own quantities directly from the plans.

When sending out lists for prices, it is well to transcribe all those parts of the specifications that describe the kind, size or quality of members required. Also note carefully every given dimension of all of the different members required.

For instance, window frames should have dimensions given for outside casing, pulley stile, head casing (also whether square or segment head), parting, beads, sills, etc., and a complete description of pulleys if any are to be installed.

Sash should have dimensions given for thickness and width of stiles and rails, kind of glass and number of lights.

Doors should be completely described by size, thickness, number of panels and material and, if possible, accompanied by sketch.

Window trim should have dimensions and descriptions of inside casings, head casings, stops, stools, aprons, also false jambs, backbands, scotia, etc., if required.

There are many methods of procedure used in taking off and listing the quantities but the one that is simplest and most readily checked is as follows:

After having made all of the notes referred to above, make headings, thus:

Basement:
- Door frames
- Window frames
- Doors
- Sash
- Stair treads
- (Other items, if any)

After each heading, put down the number and size of each required, then proceed with the

First floor:
- Door frames
- Window frames
- Doors, exterior
- Doors, interior
- Sash
- Door jambs
- Door trim
- Window trim
- Base
- Chair rail
- Picture mold
- Beam casings
- Beam soffits
- Stair rail
- Balusters
- Newels
- Treads
- Risers
- Etc.

Door and window trim are listed by writing down the number of "sides" required. A "side" consists of a complete set of material necessary to trim one side of an opening; thus, an inside door requires two sides of trim, while an outside door or a window requires only one side. Door jambs are listed by the "set."

If the description previously mentioned is given, any mill estimator will be able to calculate the cost of a side of door trim or a side of window trim and will quote accordingly.

Because of the allowances that must be made for waste, few mills will make any difference in the price of a side of trim for a door 2 ft 6 in. by 6 ft 6 in. and one for a door 2 ft 0 in. by 7 ft 0 in. In fact, unless you ordered the casings cut to length and made up in "cabinet trim," you would probably receive them in 7-ft or 14-ft lengths where mitering is not required and 16-ft lengths if the trim is to be mitered at the head.

Where the builder is willing to take the extra trouble incurred in handling the materials at the work, he can often buy his millwork more cheaply by simply ordering a sufficient number of linear feet of casings, stops, plinth, backbands, window stools, etc.

Stairs, pantries, cupboards and mantels should be fully described and sketches sent whenever possible.

For approximate estimating, the simplest method is to price frames, doors and sash from catalogues, then, if the items are such that they cannot readily be priced in that way, calculate each member into "molding-inches" and price it at the prevailing price per 100 lin ft per "molding-inch."

A molding-inch is the equivalent of a piece 1 in. square and 1 ft long, and is figured upon the basis of the full size of stock from which the molding must be made.

Get the prices for different woods from a reliable mill and calculate the quantities by multiplying the dimensions of each member thus a $\frac{3}{4}$ by $4\frac{3}{4}$ casing must be cut from a 1 by 5 board, therefore, it equals 5 molding-inches. Follow this method through for each member.

When listing millwork be careful to note whether any priming coat is to be applied or if any back-painting is to be done at the shop and, when ordering, be sure that

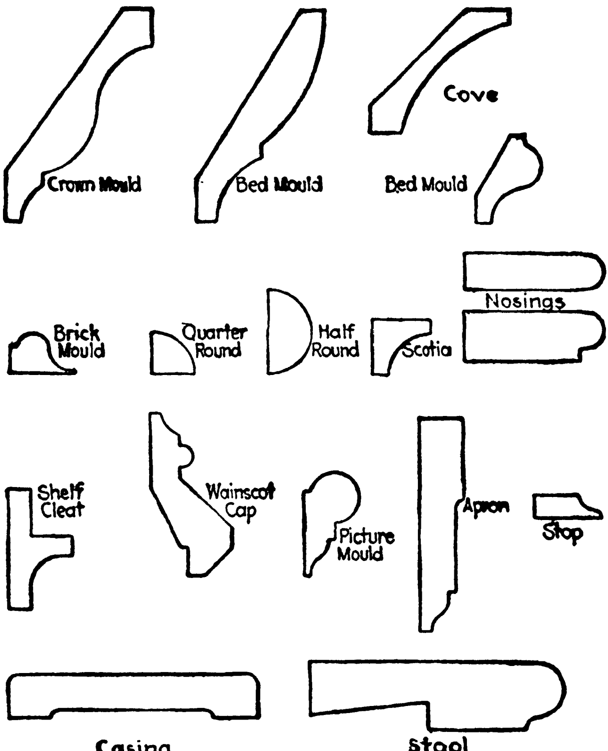

FIG. 20.—Standard wood moldings.

no priming coat is put on any surfaces which are to be stained instead of painted.

SECTION 2. INTERIOR WORK

You are now ready to attack the labor estimate, and can use the following figures in computing the cost:

TABLE 138.—INTERIOR WOODWORK
(Hours carpenter time per 100 linear feet)

	Soft wood	Hard pine	Oak	Mahogany or gum
Base	4.5	5.7	6.2	6.8
Base-mould	1.7	2.1	2.4	2.6
Floor-mould	1.5	1.9	2.1	2.3
Chair-rail	4.0	5.0	5.5	6.0
Wainscot-cap	3.8	4.8	5.3	5.8
Picture mould	3.5	4.4	4.8	5.4
Beam casings	4.5	5.7	6.2	6.8
Beam soffits	4.5	5.7	6.2	6.8
Beam cornice[1]	5.0	6.3	6.9	7.5
Panel stiles[1]	7.0	8.8	9.7	10.5
Panel mouldings[1]	7.0	8.8	9.7	10.5
Plate rail	6.5	8.1	9.0	9.8
Plate rail-apron	6.5	8.1	9.0	9.8

NOTE.—To obtain these results, one laborer will be required for each four carpenters; therefore, an allowance of 1 hour of laborers' time should be added for each four hours of carpenters' time.

[1] Add 5 min for each miter required.

The amount of time indicated in these tables, for the several kinds of work, is sufficient to cover all direct labor from the time the materials are delivered inside of the building.

It requires practically as long to perform the work on a smaller opening as it does on one up to 3 ft 0 in. by 7 ft 0 in., but, when the openings are larger, the weight of the materials to be handled becomes so great and the amount of work to be done is so much that the time allowances must be increased proportionately.

One hour of laborers' time should be added for each 8 hr of carpenters' time on stairwork. Because of the nature of the work, the mechanics do not handle as great a volume of material as when on other forms of interior woodwork.

TABLE 139.—DOORS AND WINDOWS AND TRIM
(Hours per single opening 3 feet 0 by 7 feet 0 or less)

	Soft woods	Hard pine	Oak	Mahogany or gum
Fit sash	2.0	2.5	3.0	
Attach weights and cord	1.0	1.0	1.0	
Attach weights and chain	1.25	1.25	1.25	
Attach sash fasts	0.2	0.2	0.2	
Attach flush lifts	0.3	0.4	0.4	
Attach bar lifts	0.2	0.2	0.2	
Attach pole socket	0.2	0.2	0.2	
Install stops with adjusters	0.5	0.5	0.5	0.7
Install stops with screws	0.4	0.4	0.4	0.6
Install false jambs	1.5	2.0	2.2	3.0
Install casing, stool and apron	2.0	2.5	2.5	3.0
Fit door	2.0	1.5	1.8	2.0
Attach butts (per pair)	0.6	0.8	0.9	1.2
Attach spring butts	1.5	1.7	1.8	2.5
Attach floor hinge	2.0	2.2	2.5	3.0
Attach flush bolts	1.0	1.2	1.5	2.0
Attach cremorne bolts	1.5	1.7	1.8	2.5
Set jambs	0.5	0.5	0.8	0.8
Plant on stops	0.8	0.8	0.9	1.3
Set casings	2.5	2.9	3.5	3.9
Set back bands	1.0	1.2	1.5	2.0
Set plinths	1.0	1.2	1.5	2.0
Add for mitered heads	0.5	0.5	0.6	1.0
Set cap mould	0.5	0.5	0.5	1.0
Attach mortise lock	1.0	1.2	1.5	2.5
Set transom	1.5	1.7	1.8	2.5
Install transom catch	0.6	0.8	0.9	1.2
Install transom operator	1.0	1.2	1.5	2.0

NOTE.—To obtain these results, one laborer will be required for each four carpenters; therefore, an allowance of 1 hour of laborers' time should be added for each 4 hours of carpenters' time.

TABLE 140.—STAIRWORK
(Hours of carpenters' time)

	Soft woods	Hard pine	Oak	Mahogany or gum
Housing out stringers (per tread and riser)	0.5	0.6	0.7	0.9
Fitting plain rabbeted treads.	0.3	0.4	0.5	0.8
Fitting plain plowed risers	0.3	0.4	0.5	0.8
Cutting open stringers (per tread and riser)	0.4	0.5	0.6	0.8
Miter return on end of open stairs treads	0.3	0.4	0.5	0.7
Placing scotia, per 100 feet	2.5	3.0	3.5	4.5
Placing skirt mould, per 100 feet	3.0	3.5	4.0	5.0
Placing skirt board, per 100 feet	5.5	6.7	7.2	7.8
Placing baluster rail, each 10 feet	3.0	3.0	3.5	4.0
Placing wall rail, each 10 feet.	1.0	1.0	1.5	2.0
Placing balusters each	0.1	0.1	0.1	0.2
Setting newels each	1.0	1.0	1.5	2.0

NOTE.—Figure all rough carriages for stairs, also all rough stairs, such as are sometimes used for cellar stairs, according to the method delineated for timber framing, but be sure to make allowances for each carriage, or stringer, each tread and each riser and necessary cuts.

so a smaller number of laborers may be employed than on trim.

It is obviously impracticable to list here all of the various fittings and fixtures that might be introduced under the heading of Interior Woodwork, but there are very few instances where the work to be done cannot be analyzed into its component operations. The cost can then be calculated from the information given in Tables 138 to 141.

Care must always be taken to see that sufficient grounds or blocking have been provided properly to secure all interior woodwork and all of those items should be included

TABLE 141.—MISCELLANEOUS INTERIOR WOODWORK
(Hours of carpenters' time)

	Soft woods	Hard pine	Oak	Mahogany or gum
Placing 4-ft. high "made-up" panelled wainscot, per 100 linear feet	15.0	15.0	17.0	21.0
Ditto 6 feet high	17.0	17.0	19.0	28.0
Ditto 8 feet high	19.0	19.0	21.0	30.0
Fitting and hanging cupboard doors	0.6	0.7	0.7	1.0
Setting drawer cases	1.5	1.5	1.5	2.0

in the estimate under their proper headings, as previously explained.

Where the finish is specified to be hand-smoothed or "bench-sanded," the allowances included in Table 142 must be included in the estimate. Be sure to include as many sides or edges of the member as are to be exposed.

TABLE 142.—SANDING INTERIOR FINISH
(Hours of carpenters' time per 100 square feet)

	Plain	Moulded
Hard woods	1.25	1.50
Soft woods	1.00	1.25

NOTE.—Members under 6 in. wide should be counted as 6 in. and all wider than 6 in. should be counted as a foot wide, or when the actual width is greater than a foot, then their actual width. This is because it takes about as much time to handle a narrow piece as it does to handle a wide one.

Nails.—It would be futile to attempt to compile an accurate schedule to indicate the number of nails required for the various operations included in interior wood work, but an allowance of 2 lb of nails for each 100 lin ft of casing, stool, apron, moldings, etc., will cover all that are actually used, as well as those that are usually wasted.

SECTION 3. EXTERIOR WORK

TABLE 143.—EXTERIOR WOODWORK
(Hours of carpenters' time per 100 linear feet)

Box cornices, each member	3.0
Open cornices, for each molding cut between rafters	5.0
Corner boards and water table	3.5
Placing false rafters (each)	0.5
Placing porch posts (each)	2.0

NOTE.—The same allowances should be made for the extra cost of miters and for laborers' time as given in Table 139.

TABLE 144.—DOOR AND WINDOW FRAMES
(Hours of carpenters' time per unit)

	Masonry wall	Stud wall
Setting single door frames	1.75	1.50
Setting double door frames	2.75	2.50
Setting single window frames	1.25	1.00
Setting double window frames	1.75	1.50
Setting triple window frames	2.75	2.50

These costs include necessary bracing, plumbing, attaching anchors, etc.

SECTION 4. WALLBOARD

Of late, there has come onto the market a great variety of wallboards, made from wood pulp, vegetable fibers or other by-products and some of gypsum or asbestos and cement. Some of these are used principally for their insulating value, some for decorative value, and some merely because they are inexpensive.

Most such boards are made in 48-in. width and in lengths of 6, 7, 8, 8½, 9, 10 and 12 ft. This makes it practicable to apply the boards to either 12-in. or 16-in. spacing of studding and in one piece for the full height of a wainscot or wall with almost no cutting. This avoidance of cutting on the job is important, since the nature of the materials makes cutting with a saw slow, and it is extremely difficult to make neat cuts.

Joints are frequently covered with wood batten strips, or with batten strips of the same material as the boards, but cut in the factory to the proper width and sometimes chamfered.

The following figures will apply to almost any of these boards now on the market:

TABLE 145.—MANUFACTURED WALLBOARDS

Wallboard		Approximate weight, lb per 100 sq ft	Carpenter labor, hr per 100 sq ft, Stud spacing 16 in. c.c.	12 in. c.c.
Cellular fiberboard	3/32 in. thick	38	3.75	5.
	5/32 in. thick	63	3.90	5.3
	3/16 in. thick	68	4.	5.4
Compressed fiberboard	3/8 in. thick	51	4.5	6.
	1/2 in. thick	68	4.75	6.4
Plywood	1/4 in. thick	63	5.	6.7
	3/8 in. thick	100	5.5	7.4
	3/4 in. thick	200	5.5	9.3
Asbestos-cement 3/16 in. thick		171	8.	10.
Gypsum 3/8 in. thick		400	3.5	4.

CHAPTER 10

STRUCTURAL STEEL AND IRONWORK, STEEL SASH

SECTION 1. STRUCTURAL STEEL

If this book were intended for the use of workers in structural steel and ironworks, we should take up in detail the subject of the costs of the various items of shopwork that enter into the preparation of steel and ironwork for buildings.

This book, however, is intended primarily for the use of general contract estimators and will therefore cover only those portions of the work handled by a builder.

Of course, on jobs involving a large tonnage of steel, the builder will prefer to sublet the erection, either to the company furnishing the steel or to someone who specializes in steel erection and who will have the necessary equipment of engines, derricks, riveting machinery, etc.

In estimating the cost of erection, the same care should be taken as when figuring to furnish the material, except that no count need be taken of shop rivets, nor need any mention be made of such strictly shop items as coping beams, etc.

Of course, in making a list of steel for pricing or purchase, it will be necessary to describe all punching, coping, shop riveting, etc., to be done on each piece.

When listing for estimating, or for purchasing, keep the following facts in mind:

Wall-bearing beams always require steel or cast-iron bearing plates under each end, and nearly always have an anchor of some sort as well.

Beams framing into other beams, or into girders, require connection angles and bolts, or rivets, at all connections.

Girders, lintels, grillages, and other members made up of more than one unit require bolts and separators to hold them in proper assembly.

Trusses are often shipped in sections and, therefore, require bolting up and sometimes riveting in the field.

Even though seldom indicated on small-scale plans, trusses usually require gusset plates at the connections between the several members.

Many of the items mentioned here are frequently omitted from the drawings but are covered by some general clause in the specifications that requires the contractor to furnish everything necessary to make a complete job. This is manifestly unfair, but since contractors continue to bid for and accept work on that basis, it is a condition with which we must contend.

When no sizes are given for these various sundries, the estimator must assume that they are the standard sizes for the conditions. Every estimator who has frequent occasion to figure on steelwork should, therefore, provide himself with a copy of some such handbook as that issued by Carnegie or Bethlehem Steel Company, or American Institute of Steel Construction, which gives complete data on all standard construction.

When listing steel for purchase, the items should be set down in some such manner as follows:

STEEL FOR JONES BLOCK, BONDSVILLE, MASS.

First story:

Three 12-in. 31.8-lb I-beams, 19 ft 8 in. long (wall bearing)
Five 10-in. 25.0-lb I-beams, 19 ft 8 in. long (wall bearing)
Six standard bearing plates for 12-in. 31.8-lb I-beams
Ten standard bearing plates for 10 in. 25-lb I-beams
Ten lintels, each consisting of
 Three 4 × 4 × ⅜ angles, 5 ft 8 in. long, loose
Five lintels, each consisting of
 Two 10-in. 15-lb channels, 8 ft 8 in. long
 Two standard separators for same
 Two 10 × 12 × ½ bearing plates

Second story:

Six 10-in. 25-lb I-beams, 20 ft 4 in. long (wall bearing)

Four 9-in. 21-lb I-beams, 8 ft 0 in. long (wall bearing. One end standard; connection on other)

Two 10-in. 25-lb I-beams, 20 ft 4 in. long (wall bearing, punched for connection of 9-in. 21-pound I-beam, 8 ft from each end)

Ten lintels, each consisting of

Three 4 × 4 × 3/8 angles, 5 ft 8 in. long, loose

Three lintels, each consisting of

Two 8-in. 11.25-lb channels, 8 ft 8 in. long

Two separators for same

Two 8 × 8 × 3/8 bearing plates

Such a list would give a practical steel man a fair picture of what was required, but if it were used in taking off steel quantities from a large set of plans, for the purpose of figuring erection only, quite a bit of time would be consumed just in writing down items.

For figuring erection, the following method is as complete as needed and gives the same results.

First floor beams,

(3) × 19 ft 8 in. × 31.8 lb

(5) × 19 ft 8 in. × 25.0 lb

Six bearing plates at 31.0 lb

Ten bearing plates at 17.0 lb

Lintels,

(30) × 5 ft 8 in. × 9.8 lb

(10) × 8 ft 8 in. × 15.0 lb

Ten separators, including bolts at 8.1 lb

Ten bearing plates at 17 lb

Second-story beams,

(8) × 20 ft 4 in. × 25.0 lb

(4) × 8 ft × 21.0 lb

Twenty bearing plates at 17 lb

Four connections at 13 lb

Lintels,

(30) × 5 ft 8 in. × 9.8 lb

(6) × 8 ft 8 in. × 11.25 lb

Six separators at 5.9 lb

Six bearing plates at 6.8 lb

Field bolts,

Second floor, 4 connections at 4 = 16 bolts.

If preferred, the parentheses and multiplication signs may be omitted and quantities tabulated thus:

Name	Number	Length,		Weight per foot, pounds	Total
		Feet	Inches		
Beams...........	8	20	4	25	4,066
Beams...........	4	8	0	21	672
Bearing plates.....	20	..	..	17 (each)	340
Connections.......	4	..	..	13 (each)	52

And this affords an opportunity to note that of a total weight of only 5,130 lb, 392 lb, or practically 8 per cent of the total, is in items that are often omitted from the plans but which must be purchased and installed by the contractor. Some estimators make a practice of listing only the members shown and then allowing 10 or 15 per cent for sundries.

After calculating the weight of material to be handled, it is necessary to figure the cost of getting it to the work, unless it is purchased for delivery at the site, and of erecting it in place.

Sizes of individual members, as well as facilities for handling, have such a marked effect upon the cost of handling that it is very difficult to set down general rules for estimating that would cover every case, but the data presented here are on the side of safety and may be used with confidence.

There is no reason why practically all of the steelwork in wall-bearing buildings cannot be erected by ordinary laborers, when under competent supervision, except that union rules do not permit it. However, in many districts union rules are not effectually enforced and laborers do the erection.

It is important to know, when figuring on work of any size, whether it can be handled by laborers or not, as the difference in wage rates will make an appreciable difference in the cost per ton.

Of course, setting up the derrick and similar work should always be done by a competent man.

When no crane is available at the point of unloading from cars, it will be necessary to set up a derrick to handle the steel, unless the amount to be handled is so small that it is thought advisable to handle it by some less convenient means, and proper allowance should be made for setting up and taking down this unloading derrick.

The actual hauling cost can be estimated from the information given in Chap. 2.

Allowance must also be made for the cost of setting up and taking down the derrick used at the building, as well as for moving it, from time to time.

For such operations as erecting trusses over one-story buildings, heavy individual girders and similar members, a gin pole is often preferable to a derrick.

Riveting.—When pneumatic hammers are used to drive rivets, an allowance of at least 40 hr must be made for installing and removing the compressor and reservoir, and the hoisting engineer will also receive additional pay at the rate of one-half his regular pay for taking care of the compressor.

TABLE 146.—MISCELLANEOUS OPERATIONS[1]

	Erect	Move 20 feet horizontally	Raise 2 stories vertically	Take down
Gin-pole	40	15	..	10
Guy-derrick	60	20	60	20
Breast-derrick	10	3	5	3

[1] (Time in man-hours. Where local conditions will permit, an average of 1 foreman, 1 tradesman and 3 laborers make a good gang; elsewhere figure 1 foreman to 4 tradesmen.)

TABLE 147.—UNLOADING, ERECTING STRUCTURAL STEEL
(Man-hours per ton)

	Unloading	Erecting
Wall-bearing beams.....	2	8
Skeleton construction...	2	6.5
Roof trusses............	2.5	14.0
Roof purlins............	2.5	16.0

TABLE 148.—RIVETING AND BOLTING
(Man-hours per 100 units)

	Bolts	Hand driven rivets	Air driven rivets
Wall bearing construction.........	5		
Trusses and purlins..............	7	17	9
Skeleton construction............	7	13	7

TABLE 149.—AREA OF STRUCTURAL STEEL
(Approximate number of square feet of surface per ton of steel)

Floor beams, etc.........................	250
Heavy girders and columns................	200
Trusses and purlins......................	400

TABLE 150.—PAINTING STRUCTURAL STEEL

	Gallons paint per coat per ton	Hours time per coat per ton
Floor beams, etc................	0.5	1.0
Heavy girders and columns.......	0.4	0.8
Trusses and purlins..............	0.8	1.6

Using the figures given in the tables, an average skeleton framed building, having 200 tons of structural steel, on eight tiers, would figure out as follows:

The gang is assumed to consist of

1 foreman	$1.50
1 engineer (1½ × $1.33 rate)	2.00
4 ironworkers @ $1.00	4.00
Total	$7.50 per hr or
Average	$1.25 per man-hour.

	Hours	
From Table 96		
Unload 200 tons @ 2 hr	400	
Erect 200 tons @ 6.5 hr	1,300	
From Table 95		
Set up derrick	60	
Lift three times	180	
Take down	20	
Set up and take down derrick at freight yard	80	
From Table 97		
10,000 air-driven rivets @ 7 hr per 100	700	
Total	2,740 hr @ $1.25	$3,425.00
Compensation insurance, 8 per cent		274.00
Hauling, 2 miles on hard road, 5-ton truck 2 × 9 × 0.75 = 13.5 hours @ $3.50		47.25
Insurance on hauling @ 3 per cent		1.42
Allowing for rainy days and other delays, approximately 45 days will be required for the work. Allowing $10 per day for fixed charges on equipment, fuel and lubricants		450.00
Moving equipment to and from job		50.00
Total for 200 tons		$4,247.67
Average cost per ton		$ 21.24

to which must be added general supervision, overhead and profit in order to determine the rate to be charged.

The number of rivets was assumed in this instance; in actual practice it should always be determined carefully from the plans.

Since it is quite customary to include the field coats of paint on structural steel in the erection subcontract, it is necessary to make a figure on that item also.

As ½ gal of paint and 1 hr of painters' time (skilled painters are not generally employed for this work, handymen being used) will be required for each 250 sq ft of surface, per coat, the cost per ton will be as follows:

1 hr painter	$0.60	
½ gal paint @ $1.50	0.75	
Cost per 250 sq ft	$1.35	or
Per ton for heavy girders, etc	$1.18	
Floor beams, etc	$1.35	
Trusses and purlins	$2.16	

Welding.—Arc welding of structural steel is rapidly coming into use and it is, therefore, essential that an estimator should have some knowledge of the procedure to use in estimating its cost.

Naturally, though the tonnage to be handled in a welded frame will be considerably less than that required for a riveted frame for the same sized building, the cost of actual erection will be practically the same per ton in either case.

Steel for welded frames is not generally painted at the shop and it is, therefore, necessary that two field coats be applied. The method of estimating painting is as outlined above, allowance being made for the additional field coat.

In a welded job, instead of counting the rivets to be driven, it is necessary to determine, from a survey of the plans, the size and length of the welds required.

Table 151, compiled from information courteously supplied by Westinghouse Electric and Manufacturing Co., may be used in estimating field costs of welding. Due allowance has been made in the table for the lost time incidental to all construction operations, but it is to be remembered that the amount of information available as to welding costs is as yet very small and that more information will constantly become available, as the experience in this branch of the work becomes more extensive, and the estimator should therefore constantly seek to increase his fund of knowledge on the subject.

Overhead expenses, supervision, insurance and the usual incidentals should be added to these costs as explained for other branches of work in this book.

TABLE 151.—ARC WELDING OF STRUCTURAL STEEL

Size of fillet	Units required per 100 linear feet of weld			
	Pounds electrode	KWH power	Hours welder	Hours helper
3/16 inch	24	45	9	3
1/4 inch	44	70	14.5	4.9
5/16 inch	68	100	20	6.7
3/8 inch	96	140	26.5	8.9

NOTE.—Electric-motor-driven welder weighs about 1,600 pounds crated. Gas-engine-driven welder weighs about 1,800 pounds crated.

The annual charge for depreciation, interest and maintenance is estimated at 45 per cent for the electric driven machine and 60 per cent for the gas engine driven machine, both based upon original purchase price.

SECTION 2. STEEL JOISTS

A comparatively recent development in fire-resistant floor construction is the use of lightweight steel beams or joists, either of the solid rolled type or the trussed open-web type. Over these joists, which may be spaced from 12 to 30 in. on centers, is placed a covering of metal lath, which acts both as centering or forms and reinforcement of the 2- or 2½-in. concrete floor slab.

The underside of the floor construction is generally protected by metal lathing and plastering in the ordinary manner.

The common practice is for the manufacturer of or dealer in the joists to give a lump-sum figure for all of the joists and top lath required for a given job, and also to state the

TABLE 152.—WEIGHTS OF STEEL JOISTS PER SQUARE FOOT (Including accessories) in Fire-resistive Floor Construction

(Courtesy Kalman Steel Company)

Joist depth, inches	Clear span		Weight of joists per square foot of floor for live loads shown				
	Feet	Inches	40 pounds	50 pounds	60 pounds	75 pounds	100 pounds
8	12	0	2.1	2.1	2.2	2.4	2.8
8	14	0	2.5	2.7	3.0	3.4	3.9
8	16	0	3.2	3.6	3.9	4.2	5.1
10	14	0	2.2	2.3	2.5	2.8	3.4
10	16	0	2.7	2.9	3.2	3.5	4.2
10	18	0	3.1	3.5	3.7	4.3	5.0
10	20	0	3.9	4.2	4.6	5.2	6.1
12	16	0	2.6	2.6	2.7	3.0	3.5
12	18	0	2.8	3.1	3.5	3.9	4.4
12	20	0	3.3	3.6	3.9	4.4	5.2
12	22	0	3.8	4.2	4.5	5.0	6.1
12	24	0	4.6	5.0	5.4	6.0	7.0
14	22	0	3.6	3.9	4.2	4.7	5.6
14	24	0	4.2	4.7	5.2	5.7	6.8
14	26	0	4.7	5.2	5.6	6.2	7.3
14	28	0	5.2	5.8	6.1	6.9	8.3
16	26	0	4.7	4.7	5.2	5.6	6.7
16	28	0	4.9	5.4	5.9	6.6	8.0
16	30	0	5.7	6.4	7.0	7.6	9.2
16	32	0	6.5	6.9	7.6	8.6	10.0

NOTE.—Floor construction consists of 2-in. concrete slab on metal lath over steel joists and metal lath and plaster ceiling. The dead load is assumed at 40 lb per sq ft plus 25 lb for partitions and floor finish, making a total of 65 lb per sq ft.

Designed in accordance with the Specifications of the Steel Joist Institute.

weight of the materials which the contractor will have to handle.

For convenience in estimating, Table 152 is included. It enables one to compute the approximate tonnage of steel joists for any ordinary job. The weight of the lath can, of course, be readily determined from the specifications, since it is customary to specify it by the weight per square yard.

Cartage costs can be figured as for any other material.

Erection costs can be figured on the following basis:

Joists, 15 hr per ton.
Top lath, 30 hr per 100 sq yd.

Where it is required that joists must be spot-welded to the supporting girders, figures should be obtained from someone having the necessary equipment for such work or an allowance of 4 hr per 100 welds included.

SECTION 3. STEEL SASH

While there are several makes of steel sash on the market, all ordinary factory type side-wall sash are made to the same dimensions, the glass sizes being

10 × 16,
12 × 18,
14 × 20,

for the full lights, the dimensions of lights in ventilators being 1 in. less on the outer edge, or frame, of the ventilator.

Thus, a six-light ventilator, consisting of two rows of three lights each, would be arranged thus:

13 × 19	14 × 19	13 × 19
13 × 19	14 × 19	13 × 19

NOTE.—Standard size of glass 14 by 20. (See Fig. 22.)

This variation of size need not be considered when taking off quantities for estimating or securing prices, but should be kept in mind when listing glass for purchase or shipment, unless it is planned to do the trimming at the building.

Different manufacturers used to have their own systems of denominating the various sizes of sash made by them but that used by the Detroit Steel Products Company is the simplest and a list made on that basis will be perfectly clear to other manufacturers when embodied in a request for prices or an order for shipment.

In that system,

10 × 16 sized lights are listed as X
12 × 18 sized lights are listed as Y
14 × 20 sized lights are listed as Z
16 × 22 sized lights are listed as P

The first figure written down is the number of lights in the width of the sash, the second figure is the number of lights high, the third figure is the number of ventilators, the fourth figure is the number of lights in each ventilator, and the fifth figure is the number of rows under the ventilator.

Thus, a list reading

3 sash—Z47–141
5 sash—Z47–144
2 sash—X55–161
2 sash—Y55

would mean

3 sash for 14 by 20 glass, 4 lights wide, 7 lights high, 1 4-light ventilator, 1 row up from bottom
5 sash, same size, 1 4-light ventilator, 4 rows of lights below ventilator
2 sash, for 10 by 16 glass, 5 lights wide, 5 lights high, 1 6-light ventilator, 1 row up from bottom
2 sash for 12 by 18 glass, 5 lights wide, 5 lights high, no ventilators

When vertical or horizontal mullions are required, a proper notation should be made of them as, for instance, three windows, each consisting of three units 55-161 and 2 vertical mullions.

Catalogues of the sash manufacturers give full particulars as to over-all dimensions of all units.

Because sash prices vary constantly with the steel market and with other causes, it is not wise to use published

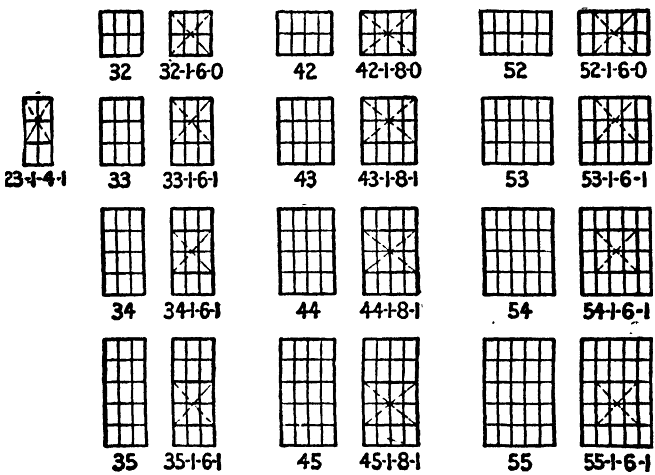

FIG. 21.—Industrial steel slash.

STANDARD WINDOW OPENINGS

No. of lights	Wide	High
2 lights	2′ 5⅝″	3′ 5⅝″
3 lights	3′ 8″	5′ 2″
4 lights	4′ 10⅜″	6′ 10⅜″
5 lights	6′ 0¾″	8′ 6¾″

GLASS SIZES

The 14″ × 20″ glass size occurs only in stationary portion of windows. All lights at top and bottom of ventilators must be 1 inch shorter and all lights at sides of ventilators must be 1 inch narrower than in stationary portion of window.

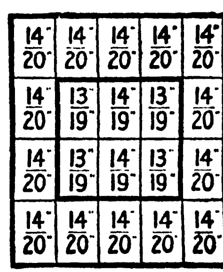

FIG. 22.—(*Courtesy General Fireproofing Company.*)

price lists as a basis for estimating. A list should always be made and sent out for prices, or else the plans should be sent and a lump-sum quotation received.

Where the work consists entirely of single units of steel sash, particularly in brick or cement-block walls, it is generally more economical for the builder to do his own erection, but where large openings are filled with "multiple-unit" sash, the trained organizations employed by the sash

·GLASS SIZES

NOTE: LIGHTS IN VENTILATORS (NOT LETTERED) ARE "A" SIZE · 8" x 12" GLASS

	GLASS SIZE	CUT FROM
A	8" x 12"	STOCKED
B	8 11/16" x 12 5/8	STOCKED
C	8 11/16" x 12"	STOCKED
D	8 11/16" x 11 3/4"	STOCKED
E	10" x 12"	R
F	11 3/16" x 11 3/4"	R
G	TEMPLATE	C
H	TEMPLATE	M
J	TEMPLATE	M
K	TEMPLATE	R
L	TEMPLATE	D
M	11 1/4" x 16 1/2"	STOCKED
N	TEMPLATE	M
O	8 11/16" x 10 1/2"	D
P	8 11/16 x 11 3/16	D
R	11 3/16 x 12 5/8"	STOCKED
S	11 3/16" x 12"	R
T	11 3/16" x 10 1/2"	R
U	11 3/16 x 11 3/16	R
V	8" x 10"	A
BB	8 3/8" x 12 5/8"	STOCKED
CC	8 3/8" x 12"	STOCKED
LL	8" x 9 1/8"	A
MM	TEMPLATE	D

LIGHTS NOT STOCKED ARE CUT IN FIELD FROM STOCK SIZE GLASS INDICATED

NOTES

VC = VENTILATOR IN CENTER

TYPES MARKED R-L CAN BE FURNISHED EITHER RIGHT HAND AS SHOWN OR LEFT HAND

THE HANDING OF A CASEMENT IS DETERMINED BY THE LOCATION OF HINGES ON THE VENTILATOR WHEN VIEWED FROM THE OUTSIDE. A CASEMENT WITH VENTILATOR HINGED AT THE RIGHT IS RIGHT HAND. ONE WITH THE VENTILATOR HINGED AT THE LEFT IS LEFT HAND.

NOTE: TYPES SHOWN SHADED ARE CARRIED IN STOCK. OTHER TYPES ARE STANDARD.

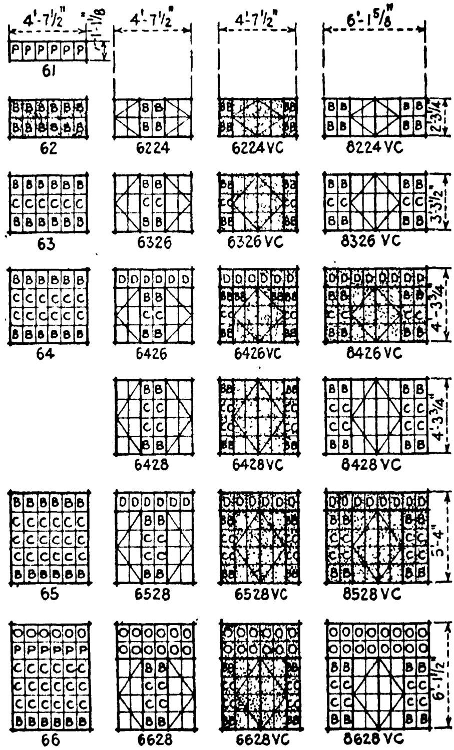

FIG. 23.—Standard steel casements. (*Courtesy Detroit Steel Products Co.*)

companies can show greater efficiency and it is always wise to get the sash companies' erection figures when possible.

In brick walls, it is practicable to set small sash in place (as is done with wood window frames) and to build the brickwork up to the sash, but in concrete walls it is always necessary to leave rebates in the jambs and to set the sash later.

After the sash are set it is necessary to point or caulk around them, which is rather an expensive job, so now a

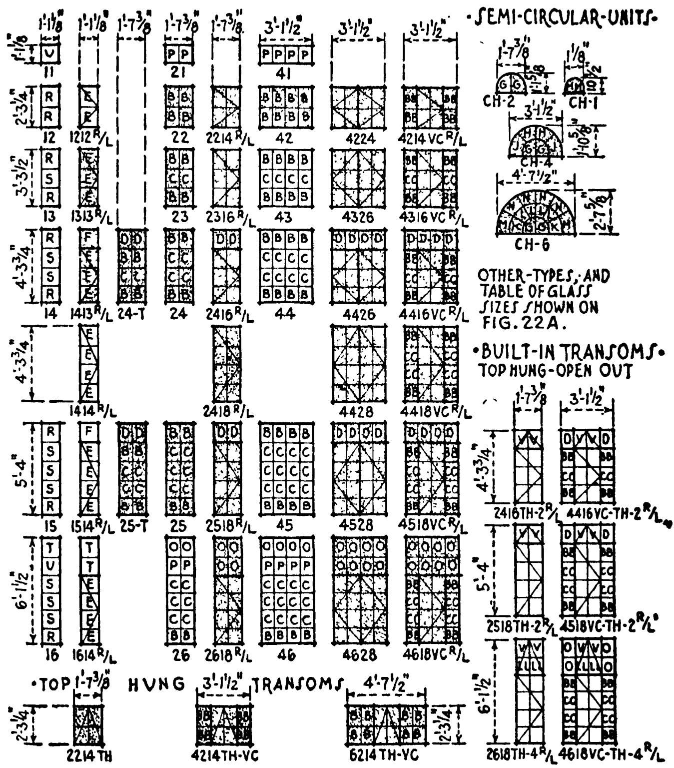

FIG. 24.—Standard steel casements. (*Courtesy Detroit Steel Products Co.*)

patented metal rebate strip is being introduced which obviates this pointing.

Costs of erecting steel sash can be determined from the following tables:

TABLE 153.—ERECTING STEEL SASH
(Hours per 100 square feet)

	Personal observation	As reported by manufacturers
Single unit side wall sash	8.0	3.5
Multiple-unit side wall sash	10.0	4.4
Monitor sash	11.0	4.4
Casements	15.0	
Double hung windows	30.0	

TABLE 154.—POINTING STEEL SASH

	Hr per 100 lin ft
Brick jambs	2.5
Concrete jambs	4.0

The erection of single-unit sash can be handled by any men who are competent to determine when they are plumb and straight, but multiple-unit and monitor sash are best handled by ironworkers who are experienced in setting sash.

Pointing of jambs is claimed by masons as their work but can readily be done by handy laborers.

SECTION 4. GLASS AND GLAZING

Estimating quantities of glass for steel-sash work is a very simple operation, since there is such a limited range of glass sizes likely to be used and since the operation of listing the sash gives us a check on the total number of lights required.

Thus, the simple multiplication of the number of units of each denomination by the first two figures of the denomination gives the number of lights.

For instance, the item reading

3 sash—Z47–141
5 sash—Z47–144
2 sash—X55–161
2 sash—Y55

would be extended thus:

	Lights
14 × 20 glass (3) × 4 × 7	84
(5) × 4 × 7	140
	224
10 × 16 glass (2) × 5 × 5	50
12 × 18 glass (2) × 5 × 5	50
Total	324

If the glass is all of one kind, and if no distinction need be made of the sizes for ventilators, the quantities thus taken will be all that are required.

If, however, as is usual, the first two rows of glass are some grade of clear glass and the other rows are some grade of obscure glass, the necessary distinctions will have to be made in the list.

Care should be taken to specify exactly the same grades of glass in the list as are called for in the specifications, as the substitution of glass only one grade poorer might create considerable trouble.

Glass manufacturers publish a list giving the stock sizes of all kinds of window glass, the number of lights packed in a box and the price per light or per box. These prices are

TABLE 155.—GLAZING STEEL SASH
(Hours of glaziers' time per 100 lights)

Glass size	Side walls		Monitors	
	Summer	Winter	Summer	Winter
10 by 16	7	8	8	9
12 by 18	7	8	8	9
14 by 20	8	9	9	10
16 by 22	8	9	9	10
24 by 32	.	.	24	27
24 by 46	.	.	26	29
24 by 58	.	.	28	32
24 by 70	.	.	30	36

subject to large discounts which vary considerably and it is essential either to get a price on your own glazing list or the latest discounts from the standard list.

A similar list is published for plate glass and it gives the details as to cost of beveling, etc.

I have been told that the union rules in some districts limit the number of lights that may be glazed in steel-sash work to 100 per working day but I have seen expert men put in 200 or more lights day after day. Table 155 is a safe one to follow since the error, if any, is on the side of safety.

TABLE 156.—PUTTY

(Pounds of putty per 100 lights glass)

8½ by 11	60	16 by 22	112
9 by 13	68	24 by 32	170
10 by 16	80	24 by 46	210
12 by 18	88	24 by 58	256
14 by 20	100	24 by 70	280

NOTE.—For glazing in steel sash, "steel-sash putty" should be used. It is furnished by the manufacturer of the sash at a price usually less than the cost of preparing it locally.

CHAPTER 11

LATHING, PLASTERING AND STUCCO WORK

SECTION 1. WOOD LATHING

Until we get a great many more people to learn the plasterer's trade, plasterers will continue in much greater demand than the available supply, and every building boom, or near boom, is going to see competition among builders for the plasterers that can be had. This always results in sending wages up and daily production down.

As long as such conditions last, any data submitted for the purpose of estimating plastering costs must be used with a great deal of judgment and due consideration of all existing local conditions.

The same remarks apply, though probably not with equal force, to metal lathing and furring.

Wood lathing, on the other hand, is usually paid for at an agreed price per 100 or 1,000 laths, so the lather has a definite incentive to do a good day's work. And, if the price be known in advance, the estimator need only determine the number of laths needed and multiply it by the price to determine the labor cost of the work.

Since the laths themselves are purchased by the thousand, Table 158 will give all the information needed, after the area to be covered has been determined.

The time given is for skilled lathers. When lathers are not available and the lathing is done by carpenters, the time must be increased from 25 to 33⅓ per cent, depending upon the skill of the men employed.

Right here it is well to mention that trade practices in many communities affect the methods to be used in surveying quantities of lathing and plastering. For instance,

TABLE 157.—WEIGHTS OF WOOD LATHS
(Per bundle of 100 laths)

	Spruce		Hard pine	
	Green, pounds	Dry, pounds	Green, pounds	Dry, pounds
1 × 32	17.9	12.8	29.2	20.8
1 × 48	27.5	19.5	45.0	31.8
1⅛ × 48	40.5	29	66.0	47.5
1½ × 48	45.5	32.5	74.0	53.0
1⅝ × 48	52.5	35	85.5	57.0

TABLE 158.—WOOD LATHING

Kind of lath	Nailing centers, inches	Lath per square yard	Pounds nails per 1,000 lath	Hours time per 1,000 lath
1 inch wide, 32 inches long.....	12	26.0	9	4.75
1 inch wide, 32 inches long.....	16	26.0	7	4.50
1 inch wide, 48 inches long.....	12	19.5	14	5.25
1 inch wide, 48 inches long.....	16	19.5	10	5.0
1⅛ inches wide, 48 inches long	12	19.0	14	5.25
1⅛ inches wide, 48 inches long	16	19.0	10	5.0
1½ inches wide, 48 inches long	12	14.5	14	5.25
1½ inches wide, 48 inches long	16	14.5	10	5.0

in certain sections no opening less than 21 sq ft is deducted; in others, openings under 2 ft in width are not deducted and one-half of all wider openings is deducted. Sometimes curved work is charged at double the price of flat work. Every estimator should familiarize himself with the practices in the sections in which he works and govern himself accordingly when considering work to be sublet or when undertaking work on a unit-price basis.

The data included in this discussion are, however, intended for the man who intends to employ the plasterers, lathers and laborers himself and wishes to estimate accordingly. He should take off actual net areas, and make the necessary additions for corners and other items, as will be explained later.

Sometimes, plasterboards are used as an effective substitute for the lath and for the first coat of plaster. In figuring it should be remembered that the boards are made 16 by 32 in. and 16 by 48 in., so as to be suited for 12- or 16-in. nailings, and, therefore, each sheet contains only 3.55 or 5.33 sq ft instead of a full square yard.

TABLE 159.—APPLYING PLASTERBOARD OR GYPSUM LATH*

Thickness, inches	Pounds per square yard	Pounds nails per square yard		Hours† per square yard	
		12-inch nailing	16-inch nailing	12-inch nailing	16-inch nailing
¼	11.4	0.19	0.15	0.09	0.08
⅜	17.0	0.20	0.16	0.11	0.10
½	22.6	0.21	0.17	0.14	0.13

* Prices for plasterboard or gypsum lath are quoted on the basis of 1,000 sq ft.

† In many places, plasterboard is applied by carpenters, regardless of whether it is finished by plastering or painting.

SECTION 2. METAL FURRING AND LATHING

There is such a wide variety of kinds of metal lath that it is hardly practicable to tabulate accurately the unit-time costs of installing every kind of lath under all different conditions.

Figuring the cost of the lath itself is a simple matter, since it is only necessary to take off actual quantities of surfaces to cover and add the following allowances for waste.

Plain surfaces, add 5 per cent
Beams, pilasters, etc., add 10 per cent
Cornices, add 20 per cent
Domed and groined work, add 25 per cent

Since quotations can be readily obtained on the kinds of laths required, it is only necessary to multiply the quantity by the price.

The labor, however, will vary with the difficulty of handling the materials. Naturally, a heavier gauge cannot be manipulated as handily as a light-gauge lath, and various types of expanded lath, even of the same gauge, will vary materially in their ease of manipulation.

For all ordinary work on wood furring, the following figures may be used, and 1 lb of staples should be included for each 20 sq yd of lath.

TABLE 160.—METAL LATH ON WOOD FURRING
(Hours per 100 square yards)

	Spacing of studs or furring		Percentage of lath to be added for waste
	12 inches	16 inches	
Flat ceilings	14	10	5
Walls and partitions	12	9	5
Simple coves	24	18	10
Simple cornices	26	20	20
Elaborate cornices	30	..	25
Beams and girders	28	22	10
Panel or arch ceilings	16	..	10
Domed or groined ceilings	18	..	25

NOTE.—The time here will allow for the ordinary plank scaffolds needed for rooms not more than 9 ft high. For high ceilings, the cost should be figured as indicated in Table 129.

Where metal furring is required, except in the case of "self-furring" lath, it is necessary to calculate the amount of furring material separately, as it may vary from 5 lb to the square yard in the case of comparatively simple cornice work up to 15 lb to the square yard in the case of heavy hung ceilings.

In doing this, it is necessary to take off all hangers, cross-bars and longitudinal bars and to figure their total weight by the method explained for builders' wrought-iron work, being sure to add 15 per cent for waste in cutting, bending, etc., and extend it at the current price per pound.

The labor cost of placing the material may be calculated from Table 161.

Table 161.—Metal Lath on Metal Furring

	Placing furring, hours per 100 pounds	Pounds[2] steel furring per yard	Placing lath,[1] hours per 100 square yards	
			16 inch spacing	12 inch spacing
Simple beams	8	7.5	20	26
Heavy beams	9	7.5	24	30
Heavy cornices	9	7.5	26	32
Panelled ceilings	8	9	14	18
Groined ceilings	12	12	16	20
Domed ceilings	12	11	16	20
Flat ceilings (clipped)	8	7	14	18
Flat ceilings (hung)	9	9	14	18
Partitions	3	8	11	14
Partitions (wood studs)	....	....	10	13
Walls	5	3.0	11	14
Coves	8	7.5	20	26

[1] Allow same percentages for waste as in previous table. Scaffolding same as for wood furring.

[2] This figure should be used only for approximate estimating. Accurate figures can be made after examining specifications in each instance. In some cities, weight and spacing of hangers and furring are governed by building code.

SECTION 3. PLASTERING

There is practically no limit to the number of different kinds and qualities of plaster finishes that may be obtained, each with a varying labor and material cost, and there is also a wide range of manufactured products available, each of different covering capacity and varying cost of application.

Manifestly, it will be impossible to discuss thoroughly all of these finishes in this text, so we shall endeavor to treat only those which are in most general use.

Right here it may be well to add a word of caution to the estimator. It is not at all unusual to find a clause in specifications stating that the work must be done in strict accordance with all state and local regulations.

In certain places, local custom provides that not less than two coats of plaster must be applied, while in one state there is a law requiring that all plastering must consist of "scratch, brown and finish coats."

So, even though good mechanics can do a good job with only one coat on "Rocklath" or similar board, or even though the specifications require only one or two coats, it is necessary to figure upon putting on the number required by the regulations.

The man who has to estimate the cost of plastering should familiarize himself with all of the various kinds of plaster available in his market, their cost, covering capacity, workability, etc., so that he may make the most intelligent use of the information contained in this section.

In using the tables which follow, keep in mind that they include the cost of all ordinary scaffolding, but when the walls are over 12 ft high, it is usual to have the carpenters build a staging, which is often left in place for the use of the painters, or decorators, later.

Be sure that the estimate includes such staging under the proper heading.

If the patent plaster is bought in the prepared form, requiring no further addition of sand but simply mixing with water, a reduction of 1 hr of laborers' time may be made in any of the figures in Table 162 for scratch and browning coats.

When using the table to prepare an estimate on a piece of plastering, be sure to take the proper figures for each

TABLE 162.—LABOR COSTS ON PLAIN PLASTERING
(Hours of masons' time per 100 square yards)[1]

Base	Scratch Coats		
	Patent plaster	Lime plaster	Portland cement[2]
Brick or hollow tile	4.5	4.5	5.0
Concrete	5.5	5.5	...
Wood lath	4.75	5.0	5.5
Metal lath	5.25	5.5	6.0
Ribbed metal lath	6.5	7.0	7.5
	Browning coats		
Scratch coat	7.0	7.5	9.0
Brick or hollow tile	7.5	8.0	9.5
Plaster board	7.0	7.5	9.0
	Finishing coats		
	On browning coat	On plaster board[3]	
White skim	8.5	9.0	
Hard finish	9.5	10.0	
Sanded white	10.0	10.5	
Floated sand	11.0	11.5	
Keenes cement	12.5	13.0	
Caen stone	40.0		

NOTE.—Allow 0.15 hr elevator time per 100 yd of plaster per story for all above first story.

[1] To find the cost per square yard for any job, add together the cost of each of the coats specified. Allow the same number of hours of laborers' time as indicated for masons. This will cover mixing and serving mortar and building of scaffolds where room is not over 9 feet high. For high-ceilinged rooms, see cost of scaffolds in Table 129.

[2] Finishing coats of portland cement plaster cannot be applied practicably to base coats of gypsum plasters.

[3] Finishing coats directly on plasterboard are not recommended, but are sometimes used in cheaper construction.

of the coats required and add them together to get the total labor cost.

All of the figures in the table are for an ordinary "good" job of plastering. It is possible to reduce the time required, except for scratch coats, very appreciably if a good job is not wanted, but it is well to ascertain definitely what will be expected before cutting prices.

Do not forget to figure the cost of elevator or hoist when estimating for a multistoried building.

SECTION 4. ORNAMENTAL WORK

If any of the ornament required is such that it cannot be "run" in the ordinary manner, it is necessary to secure

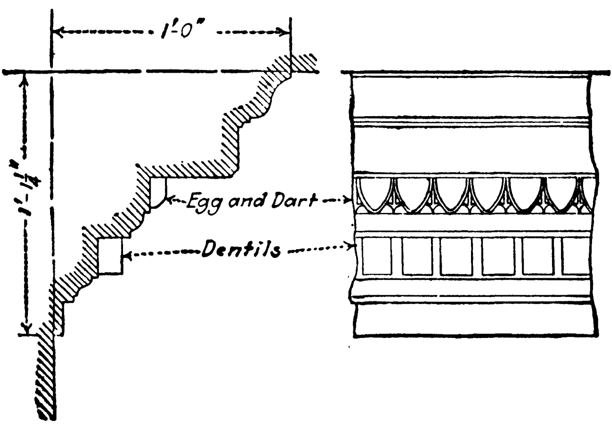

FIG. 25.—Plaster cornice.

a price from a shop having facilities for making plaster casts. These include dentils, egg-and-dart ornament, wreaths, etc., and must be planted onto the cornices or other members which they ornament.

An allowance of 1 hr of plasterers' time should be included for each 3 lin ft of "planted-on" ornaments and each 2 sq ft of panels, bas-reliefs or similar ornaments. This covers the setting only and does not include any part of the cost of modeling or casting.

In figuring the labor cost of all ordinary "run" work, such as coves, moldings and rails, the simplest method that is at all accurate is to measure the girth of the member, including all the moldings and figure it on the basis of the "developed" area. It should be remembered, however, that it takes as much time to run a molding of 8 in. girth as it does one of 12 in. girth, so the girth should always be figured in full feet, when fractional dimensions occur. The full length should be taken, doubling for all corners and miters, and the resultant area forms the estimating quantity.

TABLE 163.—RUNNING ORNAMENTAL PLASTER
(Time per 100 square feet measured full girth of members)

	Plaster	Keenes cement	Portland cement
Masons	20	24	48
Laborers	8	8	8

TABLE 164.—RULING TO IMITATE TILING
(Time per 100 square feet)

	Plaster	Keenes cement	Portland cement	Caen stone
Masons	3	4	3	10
Laborers	¼	¼	¼	2

TABLE 165.—MISCELLANEOUS ORNAMENTAL WORK

	Mason's Time, Hr per 100 Lin Ft
Planting on panel strips and moldings	34
Planting on bas-reliefs, etc	50
Running corners and arrises	8

NOTE.—Portland cement finishes, whether of white or gray cement, cannot be applied over any sort of gypsum undercoats. This is sometimes overlooked by specification writers and has often cost contractors appreciable sums of money because, while the finish will appear at first to be holding firmly, in a short time it will entirely separate itself from the backing.

TABLE 166.—PLASTERING MATERIALS
(Quantities per 100 square yards)

	Cubic yard, sand	Barrel, lime	Bushel, hair	Ton, patent plaster	Ton, plaster of Paris	Barrel, Portland cement
Lime scratch:						
On wood	0.63	1.5	1.5			
On metal	0.80	1.9	1.9			
On brick	0.46	1.0	1.0			
On board	0.46	1.0	1.0			
On tile	0.46	1.0	1.0			
Patent scratch:						
On wood	0.50	...	...	0.25		
On metal	0.65	...	...	0.32		
On brick, etc	0.38	...	...	0.20		
On gypsum lath	0.50	...	...	0.12		
Wood pulp scratch	.....	...	...	0.35		
Portland scratch	1.20	0.7	1.5	....	.....	4.6
Lime mortar brown	0.875	1.5	1.0	....		
Patent brown	0.70	...	...	0.35		
Wood pulp brown	.....	...	...	0.50		
Portland brown	1.20	0.7	1.0	....	.....	4.6
Finish coats:						
Skim	.....	1.5	...	....	0.015	
Hard	.....	1.5	...	....	0.04	
Sanded white	0.25	0.5	...	....	0.10	
Sand floated	0.25	0.5	...	....	0.10	
Keenes	.....	0.5	...	....	0.25[1]	
Caen stone	.....	...	...	....	1.25[1]	
Portland cement	0.62	0.5	...	....	.....	1.6

NOTE.—To get the cost per square yard of plaster, figure the total of the materials needed for each coat and add together.

[1] Figure at the special higher price for these materials instead of plaster of Paris.

SECTION 5. STUCCO

The operations involved in stucco work are essentially the same as those involved in interior plastering and, like plastering, it is impracticable to give complete cost data for all kinds within the limits of such a book as this.

The best results in stucco work are, however, usually obtained by workmen who specialize largely in that branch of the work and who have developed a technique that enables them to produce a quality of work far beyond that of the all-round plasterer.

Beside the ordinary kinds of cement-stucco, there are numerous patent or proprietary preparations on the market and, as with plasters, the estimator should obtain all possible data upon their use, covering capacity and workability from the manufacturers, as well as from persons who have used the preparations.

It is well to remember that, while they are undoubtedly actuated by motives of the purest intent, manufacturers are likely to be very optimistic about the cost of using their products, and sometimes results in actual practice are disappointing.

When getting information as to costs of applying different proprietary preparations, it is well to ask for details as to the quantity applied in a given time-period per man and the number of coats required, and it should also be noted that some of these preparations require an especially prepared base for their successful use. Costs in dollars or cents per square yard are not very helpful unless all surrounding conditions are known.

Portland cement-stucco is the most common stucco in general use (though magnesite stuccos are rapidly increasing in popularity) and it is probably also the most adaptable, since it can be applied to almost any lath or masonry base, except that it can seldom be applied successfully to a concrete surface that has not been thoroughly roughened and washed.

Knowing the base to which the stucco is to be applied and the number of coats required by the specifications, you can readily calculate the quantities of materials needed for any ordinary stucco job from Table 166.

Where the surface is to be enriched or "enlivened" by the use of pebbles or crystals, it is necessary to add the cost of those materials, which are usually sold by the 100 lb or by the ton by people specializing in that line.

For fine grit or crystals, allow 5 lb per sq yd.

For ¼-inch pebbles, allow 20 lb per sq yd.

Intermediate sizes require proportionate amounts.

NOTE.—White portland cement is much more expensive than ordinary gray cement and white sand sometimes costs as much per bushel as ordinary sand does per yard.

The labor costs of the scratch and brown coats, as may be required, can readily be calculated from the column in Table 163 headed "Portland cement."

Table 167 gives the data for figuring the cost of a variety of finish coats, which are to be added to the cost of the rough coats.

TABLE 167.—LABOR COSTS ON STUCCO FINISH COATS
(Hours per 100 square yards)

	Masons	Laborers	Tons grit or crystals for dash
Plain finish	12	9	
Sand float	15	11	
Coarse pebble dash	16	12	1.0
Fine pebble dash	16	12	0.25
Slap dash	15	11	
Broomed	15	11	

NOTE.—For portland cement-stucco, figure materials as for cement plaster. See Table 166. For patent stuccos, get covering capacities from manufacturers. Figure scratch and browning coats, when required, as in Table 162. Figure scaffolding as for brickwork.

CHAPTER 12

PAINTING AND PAPER HANGING

SECTION 1. GENERAL

As a general rule, because of the fact that the labor items in a painting estimate will amount to a great deal more in money than the material items will, and because the labor required to work around an opening is at least as much as that which would be required if there were no opening, painters do not deduct openings when making estimates.

It is also quite customary to consider each linear foot of wood trim, when the actual width is a foot or less, as a square foot, because there is very little difference in the time required to cover a member a foot wide and a narrower one.

On the other hand, there is a great difference in the amount of paint that will be used by different workmen, depending upon how thoroughly they will brush out the paint, and a day's work will also vary greatly with different men.

SECTION 2. MATERIALS

Of late, it has become more and more customary for architects to specify well-known brands of ready-prepared paints because they feel more certain of the results they will obtain than if they depend upon the painter's own judgment in mixing and preparing the paint.

However, a great deal of paint is still mixed on the job or in the painter's shop, and the estimator should have a clear idea of the amounts of the ingredients needed to prepare a given quantity of paint.

Table 169 has been prepared for that purpose.

TABLE 168.—COVERING CAPACITY OF PAINTS

Nature of surface	Priming coat		Other coats	
	Gallons per 100 square feet	Square feet per gallon	Gallons per 100 square feet	Square feet per gallon
Smooth boards	0.2	500	0.143	700
Clapboards	0.222	450	0.159	630
Plaster	0.2	500	0.143	700
Brick	0.25	400	0.222	450
Stucco	0.235	425	0.2	500
Concrete	0.235	425	0.2	500

NOTE.—New stucco or concrete surfaces must have their causticity neutralized. This can be done by the application of one coat of 1 to 9 solution of zinc sulphate in water.

TABLE 169.—PAINT INGREDIENTS
(To make 10 gallons)

Paint	Linseed oil, gallons	Turpentine, gallons	Drier, pints	White lead, pounds	Enamel varnish, gallons
White primer	5.25	2.0	1.5	100	
Second coat	5.0	1.3	1.3	129	
Finish coat	5.75	0.2	1.5	143	
Inside finish:					
Primer	4.5	2.3	1.7	114	
Second coat	4.3	1.4	2.1	143	
Full gloss finish	...	...	...	30	9
Egg-shell	0.4	5.0	...	167	
Dead-flat finish	...	5.2	...	173	

NOTE.—To produce shades or colors add 3 to 15 pounds pigment to those quantities.

The area of surface that can be covered by a given quantity of paint depends, assuming that the same care is given in brushing out, upon the porosity of the surface, and also upon the temperature.

Of course, the first coat applied to any surface will be absorbed (except in the cases of metal surfaces) much more rapidly than the succeeding coats and thus a greater amount of paint is required for the first coat than for the succeeding coats.

Mixed paint weighs approximately 15 lb per gal.

White lead weighs approximately 36 lb per gal.

In addition to the quantities of paints and varnish required, approximately 1 lb of putty must be used to each 1,000 sq ft of surface.

TABLE 170.—COVERING CAPACITY OF VARNISHES, STAINS, ETC.

	Hardwood		Softwood	
	Gallons per 100 square feet	Square feet per gallon	Gallons per 100 square feet	Square feet per gallon
Water-stain	0.143	700	0.167	600
Alcohol stain	0.25	400	0.286	350
Oil stain	0.182	550	0.182	550
Paste filler	0.333	300	0.333	300
Varnish	0.167	600	0.167	600
Shellac	0.143	700	0.143	700
Aniline stain	0.154	650	0.222	450
Floor varnish	0.2	500	0.2	500
Liquid filler	0.222	450	0.222	450
Kalsomine (on plaster)	.....	...	0.67	150

Where rubbing down is specified, the following materials are necessary, for each 1,000 sq ft of surface.

5.6 lb crude petroleum
1.2 gal kerosene
3.5 lb powdered pumice
10 lb waste

SECTION 3. LABOR

There is very little agreement in published data as to the amount of surface that a painter should cover in a day's work. Some books give as wide a variation as from 20 to 180 sq ft per hour.

Of course, such data are obtained by taking the average of entire jobs, rather than by recording the performance on each different kind of work. Obviously, some kinds of work require a great deal more time than others, and the proper procedure is to determine the production that may fairly be expected.

In Table 171 the quantities given are those that can reasonably be considered as a fair average production.

TABLE 171.—LABOR ON PAINTING
(Hours per 100 square feet per coat or operation)

	Priming coats	Finishing coats
Outside woodwork	0.5	0.45
Clapboards	0.55	0.5
Outside trim	0.6	0.48
Filling interior trim	1.3	
Staining interior trim	0.6	
Sand papering trim	1.3	
Rub down trim	1.3	
Varnish trim	....	0.67
Enamelling trim	....	0.85
Calcimining plaster	0.3	0.6
Painting brickwork	0.9	0.7
Painting plaster	0.9	0.7
Painting concrete	0.9	0.7
Oiling brickwork	0.9	0.7
Filling floors	0.7	
Waxing floors	....	0.5
Polishing floors	....	1.0
Varnishing floors	....	0.5
Staining floors	0.6	
Stencilling	....	5.0

This may seem to be rather a brief method of treating the entire subject of estimating the cost of painting, yet there is hardly any ordinary specification that will be encountered by a building contractor that cannot be resolved into its component parts and estimated by means of the tables given in this chapter.

Example.—Assume a building for which the following areas to be covered have been computed:

14,000 sq ft 2 coats mill-white on ceilings
6,500 sq ft 3 coats mill-white on brick walls
2,400 sq ft 2 coats graphite paint on steel sash
1,800 sq ft 2 coats white paint on cornices
14,000 sq ft 2 coats cement coating on floors

The cost of the materials would be as follows:

140 squares × 0.2.......	28	gal mill-white for first coat on plank
140 squares × 0.143.....	20	gal mill-white for second coat on plank
65 squares × 0.25......	16.25	gal mill-white for first coat on brick
65 squares × 0.222.....	14.5	gal mill-white for second coat on brick
	14.5	gal mill-white for third coat on brick
Total................	93.25	gal, say 94 gal mill-white

24 squares steel sash × 0.2 × 2 coats, 9.6 gal, say 10 gal of graphite paint.

18 squares × 0.2........	3.6 first coat
18 squares × 0.143......	2.6 second coat
	6.2, say 7 gal white paint on cornice
140 squares × 0.235.....	33 first coat
140 squares × 0.2.......	28 second coat
	61 gal cement coating on floors

Labor:	Squares		
Woodwork, ceilings	140		
Cornices	18		
	158	× 0.5	79 hr priming
		× 0.45	72 hr finishing
Brickwork	65	× 0.9	59 hr priming
		× 0.7	46 hr second coat
		× 0.7	46 hr third coat
Steel sash (2 ×)	24	× 0.4	19 hr
Cement floor	140	× 0.9	126 hr first coat
		× 0.7	98 hr second coat
Total			545 hr

SUMMARY

94 gal mill-white @ $1.75	$164.50
10 gal graphite paint @ $2.25	22.50
7 gal white paint @ $2.50	17.50
61 gal cement coating @ $1.50	91.50
545 hr labor @ $0.85	463.25
Insurance	23.72
Contingencies, brushes, etc	50.00
Cost	$832.97

Under ordinary circumstances, the profit to be added by the painting contractor should bring this figure up to about $1,000.

SECTION 4. PAPER HANGING

On new work, it is necessary to prepare the plastered walls by giving them a coat of glue sizing before applying the wallpaper. The amount of size required will vary with the smoothness and porosity of the wall, but average quantities are

0.10 gal size per 100 sq ft
0.25 hr labor per 100 sq ft

The ideal method of paying for paper and paper hanging is on the basis of the number of rolls actually required and used. It is then only necessary to calculate the number of rolls of each kind of paper required and to multiply by the proper prices per roll.

Prices of paper vary all the way from 15 cents to several dollars per roll and it is, therefore, necessary to get the correct prices for the papers specified.

A single roll is 18 in. wide by 24 ft long.
A double roll is 18 in. wide by 48 ft long.
Some high-grade papers are made 30 in. wide by 15 ft long.

For all ordinary purposes, the best method of estimating the number of rolls required is to multiply the perimeter of the room by its net height (from top of baseboard to border or ceiling) and then deduct the net size of any doors and windows.

Dividing the area thus calculated by 36 sq ft, we get the net number of standard single rolls required.

If the paper has no figured pattern, 5 per cent should be added.

If the paper has a large figured pattern, 15 per cent should be added.

These additions will cover necessary waste in trimming and matching.

Ceiling areas are figured in the usual manner and the number of rolls determined by dividing as above.

The number of rolls that can be applied in a day's work depends a great deal upon the weight of the stock and somewhat upon the pattern; the figures given in Table 172 cover ordinary conditions.

TABLE 172.—PAPER HANGING
(Hours per single roll)

	Light	Medium	Heavy
Walls	0.2	0.3	0.4
Ceilings	0.25	0.35	0.5
Gallons paste per roll	0.08	0.13	0.17

Borders are figured by the linear yard and a given length of border will require the same amount of labor as a corresponding length of wallpaper.

CHAPTER 13

ROOFING AND SHEET METAL, DAMPPROOFING AND WATERPROOFING

SECTION 1. COMPOSITION ROOFING

There are as many different kinds of composition roofings as there are manufacturers of roofing felts and cements, and each varies slightly from the other in the amount and cost of materials, as well as the labor cost of application. It is, therefore, practically impossible to discuss each kind of roof in detail.

However, there are a few well-established types and a discussion of them will develop the method of estimating so that, by an examination of the specifications in each case, the estimator can determine the quantities of materials and labor required.

Those general types are

Tar and gravel, or tar and slag
Asphalt
Asbestos

The common unit of measurement of roofs is the square of 100 sq ft and all of the quantities are given here on that basis.

All of these types of roofs are usually applied by companies who specialize in roofing and who are prepared to guarantee their work watertight for periods ranging from 5 to 20 years, depending upon the thickness of the roof applied.

Some of these roofs are only applied by the manufacturers, while others, the Barrett for instance, are applied by approved roofing contractors and guaranteed and bonded by the manufacturers of the materials.

The tables which follow give the quantities of materials required for 1 square of roof.

TABLE 173.—TAR AND GRAVEL ROOFS
(Labor and materials per square on wood decks)

	Pounds, rosin-sized paper	Pounds, felt	Pounds, pitch	Pounds, gravel[1]	Hours, labor
3-ply	5	45	75	400	1.25
4-ply	5	60	100	400	1.50
4-ply (Barrett)	5	60	125	400	1.75
5-ply	5	75	125	400	1.75
5-ply (Barrett)	5	75	150	400	2.25
(Labor and materials per square on concrete decks)					
3-ply	..	45	110	400	1.50
4-ply	..	60	135	400	1.75
4-ply (Barrett)	..	60	175	400	2.00
5-ply	..	75	150	400	2.00
5-ply (Barrett)	..	75	200	400	2.50
5-ply (Irvin)	..	75	180	400	2.50

NOTE.—Increase the labor by 0.125 hr for each 12 ft beyond the first 25 ft which the materials must be hoisted. Winter work will increase the labor by 20 per cent of the figures in the table.

[1] If slag is used, only 300 lb will be required.

TABLE 174.—ASPHALT ROOFS
(Labor and materials per square on wood decks)

	Pounds, rosin-sized paper	Pounds, felt	Pounds, asphalt	Hours, labor
2-ply	..	55	60	1.25
3-ply	..	70	90	1.50
4-ply	..	85	120	1.75
5-ply	5	75	120	2.00

NOTE.—For concrete decks, omit any rosin-sized paper and add 10 pounds asphalt primer. The notes under Table 173 apply to this table as well.

TABLE 175.—ASBESTOS ROOFS
(Labor and materials per square on wood decks)

	Pounds, asbestos felt	Pounds, asphalt	Hours, labor
3-ply	60	82	1.50
4-ply	73	90	1.75

For promenade tile roofs, add to the cost of the roof membrane the cost of the tiles, hoisted onto the roof, plus the following:

TABLE 176.—PROMENADE TILE ROOFS

	For 6 × 9 tiles	For 6 × 6 tiles
Pounds, roofing composition	300	300
Hours, roofers' time	8	10
Hours, laborers' time	8	8

Prices on the pitch, felt, asphalt and asbestos will usually be quoted on the basis of a ton, while the slag or gravel will be quoted either by the ton or the cubic yard.

The cost of hauling the materials from the railroad to the site of the work can be calculated as explained for other materials in previous chapters and, besides including the insurance, an item of 5 per cent of the net cost should be included to cover miscellaneous items such as mops and small contingent expenses.

SECTION 2. SLATE AND ASBESTOS SHINGLES

Roofing slates are sold by their producers at certain prices per square (sufficient slate to lay 100 sq ft with standard 3-in. lap) and extra charges are made for punching and countersinking.

There is a wide variety of kinds, sizes and grades of slates and prices vary, according to recent lists, from $6 to $24 per square for slates of ordinary thickness, and up to $70 per square for slates 1½ in. thick.

As a general rule, larger sizes of slates cost less per square than the same grade in smaller sizes and, because of the smaller number required, the labor is also less.

The estimator who has occasion to figure upon slate roofs should obtain current price lists from the producers and

TABLE 177.—SLATE ROOFS
(Time given includes labor for placing felt under slates)

Size, inches	Number per square	Pounds nails per square	Slater's time per square	Helper's time per square
6 × 10	695	6.25	3.3	2.0
12	534	5.30	3.1	2.0
7 × 12	457	4.70	2.7	2.0
14	374	3.75	2.6	2.0
8 × 10	514	4.00	2.7	2.0
12	400	3.80	2.6	2.0
14	328	3.25	2.6	2.0
16	277	2.75	2.6	2.0
9 × 14	295	3.00	2.6	2.0
16	247	2.50	2.5	1.8
18	214	2.10	2.5	1.8
10 × 14	262	2.60	2.9	2.0
16	222	2.25	2.7	2.0
18	192	1.90	2.5	1.8
20	170	1.75	2.5	1.8
12 × 16	185	1.80	2.6	1.8
18	160	1.60	2.5	1.8
20	142	1.50	2.5	1.8
22	127	1.25	2.4	1.5
24	115	1.20	2.4	1.5
14 × 20	121	1.25	2.4	1.5
22	105	1.10	2.1	1.5
24	98	1.00	2.0	1.5

NOTE.—Add 0.5 hour slaters' time for curved surfaces.

Add 0.34 hour slaters' time per linear foot for all hips and valleys.

should also keep informed as to the differentials that are charged on less than carload orders, as well as the extras for punching and countersinking.

Ordinary slates will average 650 lb per square and cartage can be figured on that basis. An average of ½ hr laborers' time will cover the cost of unloading from car to truck and ⅓ hr from truck or wagon.

The times given in the table are sufficient to include all ordinary scaffolding but an addition of ½ hr per square must be made for all curved surfaces and ⅓ hr per lin ft for all hips and valleys.

Asbestos shingles are made in a variety of sizes and colors, and hip and ridge rolls of the same material are usually used. If the shingles are laid in "American" style, the cost of laying will be the same as for similar sizes of slate, but if they are laid in the "hexagon" or "diagonal method" the number used will be less and a saving of ½ hr slaters' time and ¼ hr helpers' time will be made.

Wood shingles and asphalt shingles are discussed in Chap. 8.

SECTION 3. TILE ROOFS

Cement-tile roofs of the "Federal" and "American" types are usually laid by the manufacturers under a guaranty and, since prices vary greatly with conditions, the estimator should always submit the roof plan and specifications directly to the manufacturers for their estimates.

Clay-roofing tiles may either be installed directly by the manufacturers or their representatives, or sold to the roofing contractor and installed by him. Flat, or "promenade," tile were discussed in Section 1.

Clay tiles are made in "Spanish," "Mission," "Shingle" and "Imperial" types, and special ridge rolls, hip rolls, finials, starters, etc., are made for each type. This makes it necessary either to list the pieces carefully or to send the plans to the manufacturers and have them make a price on the entire lot.

The labor of laying and handling will be 1.5 times that of similar sizes of slates and the cartage is figured on the basis of 1,000 lb per square for ⅜-in. shingle tile, 1,350 lb per square for ½-in. shingle tile, 800 lb per square for Spanish or mission tile.

All tile roofs (except those types which attach directly to steel purlins) must be laid over a course of 40-lb asphalt felt.

Spanish and mission tiles also require 90 ft of 1 by 2 furring strips and 14 laths per square.

Shingle tiles require the laths but not the furring strips.

SECTION 4. METAL ROOFS

Tin plates are furnished in a variety of grades, dependent upon whether the base stock is steel or charcoal iron, and upon the quality and weight of the coating. Prices are quoted by the box, which contains 112 sheets of one of the following sizes, the last two being the most commonly used:

10 × 20
14 × 20
20 × 28

The roof may be laid either with flat or standing seams.

The cost of a comparatively flat tin roof may be figured on the basis of Table 178, but no deductions should be made for small openings.

TABLE 178.—TIN ROOFS
(Materials required per square)

	14 by 20 size tin	20 by 28 size tin
Sheets tin	62	29
Pounds solder	8	5
Pounds nails	4	3
Pounds rosin	1	1
Pounds charcoal	2	2
Hours labor	7	5

Painting of the underside of the sheets, as well as cartage of materials to the work, must be estimated according to the methods previously explained and added to the estimate.

If standing-seam roofs are specified, the items of solder, rosin and charcoal are omitted from the estimate but the quantities of tin are:

	14 by 20 size	20 by 28 size
Seams on short edge.............	66	31
Seams on long edge..............	68	32

Copper roofing is always specified by the weight in ounces per square foot of the sheet copper to be used and the weight of material is thus readily figured. Five per cent will cover the waste on all ordinary copper roofing and the labor and other items will be the same as for tin.

Stamped metal shingles, tin-plate, galvanized or copper, require the same amount of labor as for slate shingles of corresponding sizes and, in addition, both sides of the tin shingles must be painted, as must also the upper side of the galvanized shingles, though the painting of exposed surfaces may be included in the painters' specifications.

SECTION 5. SHEET-METAL WORK

Ordinarily, gutters, leaders, hip roll, ridge roll and finials are purchased ready-made from manufacturers and it is only necessary for the builder to obtain prices on them and to calculate the cost of erection.

Gutters will be made of tin, copper, galvanized iron or zinc and will require bending to shape and installation. The specifications will determine the kind and weight of material, as well as its width, to be used. The same remarks apply to flashing.

After finding the cost of the materials, the labor cost of installation can be determined by figuring that a mechanic and helper will erect 15 lin ft an hour of hanging gutters, leaders, hip roll, ridge roll, base flashing or cap flashing.

Stepped flashing around chimneys and in similar locations can be figured on the basis of 6 lin ft per hour.

To attempt to cover the estimating of all such items of sheet-metal construction as cornices, skylights, windows, etc., would demand an entire volume in itself. Therefore, no attempt is made to discuss them here, and the estimator is advised always to secure a figure from a manufacturer who is properly equipped to turn out the work.

SECTION 6. DAMPPROOFING, CAULKING

The common methods of dampproofing consist essentially of painting the concrete or masonry surfaces with a waterproof or water-resisting paint or compound. Dampproofing is distinguished from waterproofing in that dampproofing is not intended to resist water pressure.

Most dampproofing paints have an asphaltic base and their covering capacity varies greatly with their consistency (which in turn varies greatly with the temperature) and the roughness of the surface to which they are applied.

TABLE 179.—DAMPPROOFING
(Asphaltic compounds or paints)

Nature of surface	Average covering capacity		Hours required	
	Gallons per 100 square feet	Square feet per gallon	To cover 100 square feet	Apply 1 gallon
Rough concrete	1.33	75	1.33	1.0
Smooth concrete	0.80	125	0.96	1.2
Brickwork	1.33	75	1.33	1.0
Hollow-tile	1.67	60	1.67	1.0
Stone	0.80	125	1.20	1.5
Wood	0.40	250	0.56	1.4

At temperatures of 60° Fahrenheit and upward, the figures in Table 179 will apply for most of the compounds, but at lower temperatures the covering capacity will decrease rapidly and few of them can be satisfactorily applied at all when the temperature is below freezing.

Dampproof paints can be applied by any laborer with sufficient intelligence to make sure that the entire surface is covered.

Example.—Required, the cost of dampproofing 1,000 sq ft of brickwork, with a compound costing $1.80 per gal and labor at 50 cents per hour.

Compound, $1.80 × 13.3	$23.94
Labor, 0.50 × 13.3	6.65
	$30.59
Allow for brush, etc	$1.50
Insurance on pay roll	0.30
Contingencies	1.90
	$34.29

Caulking.—Ordinary caulking of door and window frames may be figured on the following basis:

Labor	4½ hr per 100 lin ft
Oakum	¼ bale per 100 lin ft
Mineral caulking compound	2 gal per 100 lin ft

SECTION 7. WATERPROOFING

Waterproofing methods fall into three general classes, as follows:

Membrane waterproofing, consisting of a number of plies of saturated felt or burlap, coated over and between with pitch or asphalt.

Integral waterproofing, consisting of the addition of waterproofing materials to the cement or the mixing water that is used for making concrete.

Plaster coating, consisting of the application of a coat from ½ in. thick upward, of waterproofed cement plaster to the brick or concrete walls and floors.

Some of the waterproofings in the last two classes are applied only by the manufacturers, or their representatives, and it is always necessary to get their figures.

The other preparations are sold by the pound or gallon and the amount to be used varies with each compound, so it is necessary to obtain detailed information in each case, and estimate accordingly.

Usually the amount to be used is a certain number of pounds per bag of cement, and the procedure for estimating is the same as outlined in Chap. 3, but precaution must be taken to estimate the cost of caring for water as mentioned below.

The engineer or architect should specify the number of plies of felt or burlap to be used, when membrane waterproofing is required, also the weight per square of the felt or burlap, the kind of composition to be used for coating, and the number of pounds of coating per 100 sq ft per application.

Since there will be one coating of pitch or asphalt on each side of each ply of the membrane, it is evident that there will always be one more coating than the number of plies.

Thus, if 7-ply waterproofing is required, with 40-lb coating per application, each square would require,

320 lb composition and
770 sq ft felt or burlap,

10 per cent being allowed for lapping and waste, and, if the felt weighs 26 lb per square, its weight would be 220.2 lb.

In computing the area to be covered, it is necessary to include all bends, angles, returns and keyways before adding the percentage for waste.

The labor of applying the waterproofing will require an average of 0.8 hr per square for each ply of membrane and the same amount for each coating of composition.

Thus, the 7-ply waterproofing mentioned above would require:

	Hours	
For placing felt, 7 piles @ 0.8	5.6	
For placing composition, 8 coatings @ 0.8	6.4	
	12.0	
And at 75 cents per hr this would be		$9.00
Adding 302 lb composition @ $35 per ton		5.29
201 lb felt @ $19 per ton		1.91
Insurance		0.45
Contingencies, including mops and fuel		2.25
Net cost per square		$18.90

Thus, the calculation of the cost of the actual waterproofing is a very simple matter, but the cost of caring for water during construction is often a much more serious matter than is the application of the waterproofing, and it is practically impossible to give any rules that may be followed.

For this reason, it is recommended that all waterproofing problems be referred to one of the subcontractors specializing in that work, whose experience has taught him how to cope with almost any conditions that may be encountered.

CHAPTER 14

INTERIOR MARBLE WORK, TILING, AND TERRAZZO

SECTION 1. INTERIOR MARBLE WORK

In preparing a bill of quantities for interior marble work it is necessary to list individual pieces, so far as practicable, and otherwise to give the number of linear feet for such items as base, or square feet for such items as wainscot or flooring, and to give as complete a description as is possible. For instance, toilet partitions should be described by giving:

Name of kind of marble specified
Thickness and dimensions of slabs
Finish on sides
Finish on edges and corners
How slabs are supported
Description of hardware, if to be included

Marble base should be described by giving:

Name of kind of marble specified
Thickness and height of base
Length of individual pieces, when possible
Finish
Molding or chamfering, if any
Method of setting
Number of return ends required

Each other item in the list should be described with at least as much detail, so that the manufacturer may estimate intelligently the cost of preparing the stone for the building, as it is hardly to be supposed that a builder will have facilities for taking the marble in blocks, sawing it and polishing it, even though he might be prepared to set it after delivery.

When marble is purchased from a producer, there are likely to be charges for crating and boxing, and, in less than carload shipments, trucking charges at the shipping end as well as freight charges, and the estimator must see that his estimate covers every one of these costs.

Marble averages 168 lb per cu ft in weight, which means an average weight of 14 lb per sq ft for each inch of thickness of slabs, and when crated for shipment it is necessary to include 2 lb per sq ft to cover the weight of the crates.

In figuring the labor costs of setting, after delivering to the site, all base and similar members should be considered at least 1 ft wide, and pieces wider than 1 ft should be counted to the next foot; fractional square feet in any slabs should be considered as a full square foot; molded members should be figured as indicated above for base, and where more than 1 in. thick, the area should be multiplied by the thickness.

Having thus determined the total area of marble to be set, Table 180 may be used to calculate the cost.

TABLE 180.—SETTING INTERIOR MARBLE
(Hours per 100 square feet)

	Setter	Helper
Floor tiles	17	17
Stair treads	19	19
Wainscot	19	19
Base, dado cap, etc	23	23
Partitions, 1-inch thick	20	20
Partitions, 2-inches thick	23	23
Heavy rails, balusters, etc	23	23
Curved work	23	30

NOTE.—In making an estimate on setting marble work, at least 5 per cent should be allowed to cover such items as plaster of paris, brass wire for anchors, and similar necessities which cannot readily be estimated by quantities.

SECTION 2. SLATE WORK

It is not necessary to discuss the costs of setting slate work at any great length since the costs given in the previous section apply equally to this item.

However, practically all of the large producers of slate issue price lists and discount sheets giving the cost of practically every size of slabs used in building construction.

SECTION 3. FLOOR TILING

Practically all kinds of floor tiling are laid upon a concrete base, 2 or more inches in thickness, and sometimes reinforced by a layer of "chicken wire," or other form of wire fabric.

The cost of this concrete base course can be estimated from the data given in the tables on plain concrete work in Chap. 3.

The variety of kinds, sizes and shapes of floor tiles is endless. They are made round, square, hexagonal, and have been made elliptical; they range in size from 1 in. to 1 ft or more; they are made in white, as well as almost every conceivable range of colors, and are laid in one color, or in mosaics to resemble tapestries, in geometrical designs, and in plain fields.

Naturally, it is almost impossible to give figures upon which to base estimates to cover each kind of tiling, laid in rooms of every size, with or without borders.

Small sizes of "ceramic" tiles, up to 1⅝ in., whether plain pattern or mosaic, are usually mounted on paper, so that the actual building up of the pattern is not done at the building. However, the tile setter must match up the several sheets of the field and the border, as well as space them out so that the design properly covers the area.

Larger tiles are set individually and, where there is no other tile work in the building, quarry tiles are often set by bricklayers.

Beside the labor indicated in Table 181 below, it is necessary to include the cost of a 1-in. layer of one-half cement mortar, in which the tiles are set.

On small jobs, such as single bathrooms, it will be necessary to include an item to cover the time consumed in sending men to and from the work.

TABLE 181.—LAYING TILE FLOORS
(Hours per 100 square feet)

	Setter	Helper
Small ceramics: Plain field	8	8
Mosaic pattern	10	10
Border	10	10
2-inch hexagon	14	14
2- or 3-inch square	16	16
4 × 4-inch quarry or "encaustic"	14	14
6 × 6-inch quarry or "encaustic"	13	13
9 × 9-inch quarry or "encaustic"	10	10

SECTION 4. WALL TILING

In estimating the labor cost of wall tiling it is necessary to consider each individual item, such as base, ornamental frieze, cove or cap, as though it were 1 ft wide and to figure the field of the wainscot at its actual area. Beads and exterior angle tile should be figured as 2 sq ft each.

Of course, for purchasing, it will be necessary to list the exact number of each kind of piece required.

The metal-lath and cement-plaster backing that will be required for all wall tiling can be estimated as outlined in the section on plastering, taking care to use the proper labor rate for a tile setter and remembering that you will always need a helper for every setter.

TABLE 182.—SETTING WALL TILES
(Hours per 100 square feet)

	Setter	Helper
6 × 3 tile, small rooms	17	17
large rooms	10	10
6 × 6 tile, small rooms	16	16
large rooms	9.5	9.5

SECTION 5. TERRAZZO FLOORS

In the tables on Cement Floors in Chap. 3 we gave the necessary information for figuring the cost of mixing and placing the bed of cement required for a terrazzo floor.

Having determined the cost of preparing and placing the bed to comply with specification requirements, we have but to calculate the cost of the necessary marble chips, their placing in the floor, and the final rubbing and polishing.

The chips will average 7½ lb to the square foot and the rubbing cost will be determined by the nature of the work and whether it is done by hand. Hand rubbing will average 20 hr per 100 sq ft.

Machine work will reduce the number of hours required on floors by one-third and on base by one-half.

CHAPTER 15

FOUNDATION WORK

SECTION 1. WOOD PILING

The customary method of paying for wood piles is by the linear foot of pile actually driven, but sometimes a price per pile is quoted. The piling contractor may buy the piles either at a price per stick or a price per foot.

Specifications usually all for minimum diameters of butt and tip, maximum variation from straightness and the kind of wood.

It is also customary to specify that the piles shall be driven until a certain bearing value is reached.

On large operations, the probable length of piling that will be required is determined in advance by driving test piles at several different points on the lot and ordering accordingly.

To make fairly close estimate for bidding purposes, it is necessary to examine the plans and compute the time that will probably be consumed in moving the driver, as well as that actually consumed in driving, and to this must be added all of those additional costs which include:

Delivering and setting up driver
Purchase price of piles
Cost of delivering and unloading
Cost of distributing them on the site
Cutting off after driving
Removing discarded butts
Fixed charges on driver
Removing driver from work
Contingencies
Profit

For the purpose of the general contractor, the following information will suffice.

An ordinary "land" driver will require a gang consisting of

1 foreman
1 engineman
6 laborers

and they should be able to unload and set up the driver in 3 days and dismantle and ship it in 2 days. This means that, regardless of the number of piles to be driven, the job must carry the cost of the full gang for 5 days. It must also carry the full fixed charge on the driver, which would probably be at least $25 per day, from the time it leaves the yard until it returns, and an additional charge for fuel and supplies, probably $10 for every active day.

In ordinary work, an average of 108 ft of piles can be driven per working hour but the character of the soil may be such as to reduce this figure by half.

If the total number of linear feet of piles be known, the number of hours required to drive them can thus be determined, and the cost computed.

An additional allowance of 1½ hr laborer's time per pile must be made for cutting off butts after driving.

SECTION 2. CONCRETE PILES

As a general rule, no one but a concrete-piling specialist should attempt to estimate on any concrete-piling job, because practically all of that work is done by the owners of or licensees under one or another of a very limited number of patents.

However, if the operation is one for which precast piles may be bought and used, the cost of driving may be figured in the same manner as for wooden piles, except that a maximum of 50 ft per hr is all that can be driven.

SECTION 3. CAISSONS

Here again we encounter a line of work that belongs strictly to the specialist and, though it might be practicable to get up figures covering a wide variety of conditions, it is almost impossible to put them in such shape that they would be safe for use by any but experienced men.

However, for ordinary open caissons, for which the design has been prepared, the following method will prove satisfactory.

Estimate the cost of materials for building the caissons and the concrete for filling them, as explained in previous chapters.

Estimate the cost of building the caissons by the methods outlined in Chaps. 7 and 8 on Carpenter Work and add 50 per cent.

Estimate the cost of excavating by the methods outlined in Chap. 2 on Excavating and add 10 per cent, plus 1 hr laborer's time per cubic yard for hoisting.

Estimate the cost of mixing concrete in the usual manner, but add 50 per cent to the cost of placing it, plus 1 hr laborer's time per cubic yard.

CHAPTER 16

CEMENT-GUN WORK

It is seldom practicable to apply Gunite in layers much over ⅜ in. thick and it is, therefore, necessary to figure on as many coats, each ⅜ in. thick, as will be necessary to build up the specified thickness, and also the necessary labor for finishing the final coat.

Scaffolds will have to be built for all operations that cannot be handled by a man standing on the floor or ground and their cost should also be figured as previously outlined.

For most cement-gun work the organization will consist of

1 foreman
1 nozzleman and helper
3 laborers loading gun
1 engineer

while rental charges must be figured to cover the cement gun and the air compressor with its motive power and its fuel.

Such an organization can cover an average of 300 sq ft per coat per hour and the additional cost of floating or otherwise finishing the final coat will be estimated on the same basis as that outlined for sand-finish plaster.

The material can be estimated by the table for an equivalent thickness of "top coat" in the section on plain concrete work and by adding 30 per cent to the quantity of sand, since that amount will be lost by sand rebounding from the surface to which the Gunite is applied.

Using the cement gun as a sand blast, with the same organization, about 100 sq ft of steel or concrete surfaces can be cleaned in an hour and about 0.4 cu yd of sand will be required per 100 sq ft.

CHAPTER 17

SHORT-CUT METHODS OF ESTIMATING

SECTION 1. GENERAL

To the best of my knowledge, the methods of preparing preliminary estimates for mill buildings as outlined in this chapter, were first proposed by Charles T. Main, engineer, of Boston, Massachusetts, in a paper which he presented at a meeting of the New England Cotton Manufacturers' Association, April 28, 1904.

The method outlined is vastly superior to any attempt to estimate contents by the square-foot or cubic-foot method and its greater accuracy well compensates for the added time required for its use.

The superiority of this method lies in the fact that it takes into consideration the variation in the ratio of floor area to wall area that takes place with every increase in the size of a building or any change in its shape.

An exaggerated comparison, but one that brings out forcibly the principle involved, is as follows:

Dimensions	Area	Length of wall	Ratio of length of wall to area of floor
1 by 1	1	4	4 to 1
100 by 100	10,000	400	4 to 100
2 by 1	2	6	3 to 1
200 by 100	20,000	600	3 to 100
3 by 1	3	8	2⅔ to 1
300 by 100	30,000	800	2⅔ to 100

However, like the "cubic foot of contents" or "square foot of area" method, the method given here is suitable only for approximate estimating and is not a safe method to use for bidding.

But, if this method is used with the proper care, always working out unit prices on the basis of up-to-date costs, there should be no trouble in quickly making an approximate estimate on any reasonably standard building and the estimate should fall within the range of the figures actually submitted in competition.

SECTION 2. MILL BUILDINGS

Assuming the following data as approximately the average, or standard, of mill buildings in a given territory,

TABLE 183

Height of building in stories	Thickness of brick walls in inches									
	Outside walls					Inside walls				
	1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th
1	12	..	..	..	..	12				
2	16	12	..	..	..	12	12			
3	16	12	12	..	..	12	12	18		
4	20	16	12	12	..	16	12	12	8	
5	24	20	16	12	12	20	16	12	12	12

we can proceed to set up a series of unit costs of a linear foot of wall construction and a square foot of floor or roof construction.

Floor timbers, 12 by 16, LLYP, 8–0 center to center
Floor planking, 4 in., LLYP, splined
Roof planking, 3 in., LLYP, splined
Roof timbers, 8 by 14, LLYP, 8–0 center to center
Roof covering, 5-ply tar and gravel
Finished floors, 13/16 maple

Floors on earth, 4-in. Tar-rok, 3-in. hemlock plank and 1³⁄₁₆ maple, or 3-in. concrete base course and 1-in. top-coat
Foundation, concrete, 4 in. thicker than wall it supports and 4–0 total height from top of footing to top of water table
Footing course, concrete, 10 in. thick by width 8 in. greater than foundation course
Story heights, 12–0 floor to floor
Wall thickness, as per table

Now, assuming that we have found, by the methods outlined in previous chapters, that we may use the following as average costs:

Bricks, delivered to the site, per M	$22.00
Mortar, per 1M bricks	4.00
Labor, per 1M bricks	26.00
Insurance, etc	2.60
Profit	5.40
Cost of bricks in walls, per M	$60.00

and allowing 21 bricks to the cubic foot, the cost per square foot of wall will be as follows:

TABLE 184

8-in. wall	$0.84
12-in. wall	1.26
16-in. wall	1.68
20-in. wall	2.10
24-in. wall	2.52

and, therefore, a linear foot of all would be figured as follows:

TABLE 185.—UNPIERCED WALLS

Height of building	Outside walls	Inside walls
1 story	$ 15.12	$15.12
2 story	35.28	30.24
3 story	50.40	40.32
4 story	75.60	60.48
5 story	105.84	85.68

The figures just given are for unpierced walls, but most mill buildings have fairly large windows at regular intervals. Since steel sash are popular at present, let us consider that each 8-ft bay of the building is lighted by a standard steel sash Y-55-161.

The size of the opening is, therefore, 5 ft 2¾ in. by 7 ft 8¾ in., or 40.4 sq ft, and we will assume its cost to be

Sash	$ 8.50
Erection	2.50
Glass	12.50
Glazing and putty	3.00
Pointing	1.50
Stone sill and setting	4.00
Profit and insurance, etc	4.00
	$36.00

Since the bays are 8 ft 0 in. from center of window to center of window and the story heights are 12 ft, each bay, or panel, of wall will contain 96 sq ft, consisting of

40.4 sq ft of window and
55.6 sq ft of brickwork

from which we calculate that a bay of 12-in. wall would cost

For window, as before	$ 36.00
55.6 sq ft wall @ $1.26	70.06
	$106.06

or practically $13.20 per lin ft.

TABLE 186.—PIERCED WALLS (STEEL SASH)

Height of Building	Cost per Linear Foot of Wall
1 story	$13.25
2 story	29.43
3 story	42.68
4 story	61.77
5 story	83.68

A similar table can be prepared for varying lengths of bays and kinds and sizes of windows, and the estimator who has frequent occasion to furnish preliminary estimates can well afford to utilize any spare time that he may have in preparing a series of such tables to cover the variety of conditions he most frequently encounters.

Foundations.—From the assumptions previously made, it is evident that the foundation sizes will be as follows:

TABLE 187.—FOUNDATIONS

Building height	Footing course	Foundation course	Cubic yard concrete per linear foot	Cubic yard excavation per linear foot
(For outside walls)				
1	2–0 by 0–10	1–4 by 4–0	0.26	0.5
2	2–4 by 0–10	1–8 by 4–0	0.32	0.55
3	2–4 by 0–10	1–8 by 4–0	0.32	0.55
4	2–8 by 0–10	2–0 by 4–0	0.39	0.6
5	3–0 by 0–10	2–4 by 4–0	0.44	0.65
(For inside walls)				
1	2–0 by 0–10	1–4 by 4–0	0.26	0.5
2	2–0 by 0–10	1–4 by 4–0	0.26	0.5
3	2–0 by 0–10	1–4 by 4–0	0.26	0.5
4	2–4 by 0–10	1–8 by 4–0	0.32	0.55
5	2–8 by 0–10	2–0 by 4–0	0.39	0.6

Since the height of the footing and foundation courses is taken to be the same in all cases, we shall always require practically 10 sq ft of forms to each linear foot of wall.

Assuming that, by the methods outlined in previous chapters, excavation, either backfilled or wasted, costs $1 per cu yd; concrete, in place, costs $16 per cu yd; and forms cost 16 cents per sq ft, we can construct another table, as follows, allowing for profit and insurance:

TABLE 188.—COST OF FOUNDATION

Building height	Per linear foot outside walls	Inside walls
1	7.15	7.15
2	8.30	7.15
3	8.30	7.15
4	9.65	8.30
5	10.60	9.65

Floor Constructions.—Floors resting directly upon the earth will not have any parts of the structural frame included in their cost, but must bear all of the cost of removing topsoil, grading, cinder or gravel fill, or similar items.

Assuming the square of 100 sq ft as the basis of calculation for this type of floors, we may use the following figures:

Concrete floor:

Excavating topsoil 3.7 cu yd @ $1.00	$ 3.70
Leveling subgrade	2.00
2.09 barrels cement @ $3.20	6.69
0.70 cu yd sand @ $1.50	1.05
0.85 cu yd gravel @ $2.50	2.13
Labor on base and top courses	9.00
Insurance and profit	3.00
Cost per square	$27.57

or, 28 cents per sq ft

Tar-rok, hemlock and maple floor:

Including grading sublet for about	$15.00
300 FBM hemlock plank @ $45	13.50
Labor placing plank	3.00
Floor paper	0.50
130 FBM maple @ $90 per M	11.70
Labor placing maple flooring	4.00
Nails, etc	0.50
Insurance and profit	5.00
Cost per square	$53.20

or, practically, 54 cents per sq ft.

Floor constructions, as well as roof constructions, which are supported by the structural frames must bear the cost of their share of the structural frame, and it therefore becomes easier to figure the cost on the basis of the bay or panel, instead of the square.

In order not to make our list of units unduly complicated we will make certain assumptions which, while not absolutely true, give fairly close results.

We will assume the spacing of beams to be 8 ft 0 in. center to center, the spacing of columns longitudinally to be 18 ft 0 in. center to center, the average column to be 10 by 10, 12 ft 0 in. long, the average share of column footing to each story to be equal to one 24 by 24 by 18 footing.

Then, for one bay, we must allow

0.9 cu yd excavation @ $1		$0.90
0.23 cu yd concrete @ $0.16		3.68
12 sq ft forms @ $0.16		1.92
1 10 × 10/12–0 column,	100 FBM	
1 12 × 16/18–0 beam,	288 FBM	
4-in. plank,	662 FBM	
	1,050 FBM average $70	73.50
Miscellaneous iron, pintles, etc., 200 lb		10.00
Splines 216 lin ft @ 1 cent		2.16
Nails and paper		1.50
Labor on timber @ $18		6.98
Labor on plank @ $4		5.76
167 FBM maple @ $90		15.03
Labor placing maple flooring		5.76
Insurance and profit		20.00
Cost per panel of 144 sq ft		$147.19

or practically $1.03 per square foot.

For the roof construction, we would allow the same figures for the first three items, but must take into consideration the overhang of the roof and the cost of the cornice.

Since the corner panels of the roof carry overhang and cornice on two sides, while the center panels do not carry either, we are safe in figuring each panel as though it carried an 18-in. overhang and full cornice on one side, which also means that our timber must be figured as 20 ft long; thus,

Excavation, concrete, forms		$ 6.50
Column,	100 FBM	
1 8 × 14/20 beam,	187 FBM	
3-in. plank,	552 FBM	
	839 FBM @ $70	58.73
Misc. iron (hangers, etc.)		10.00
Splines, nails, etc		2.60
Labor on timber @ $18		5.16
Labor on plank		5.76
Roofing (sublet for $15 per square)		21.00
Insurance and profit		14.00
Cost per panel		$123.75

or, practically 86 cents per sq ft of building, disregarding the overhangs.

Miscellaneous Items.—By the usual methods, we may estimate the cost of such items as flights of stairs, and find that the average will be about $180 per flight for ordinary mill stairs and $235 per flight for an outside iron fire escape.

From previous experience, we can determine an average cost per fixture for the plumbing, and this will probably be about $100.

Painting costs vary widely, depending upon the amount of work that is required and the kinds of materials to be used, but an allowance of 5 per cent of the combined costs of the mason and carpenter work will be sufficient for a preliminary estimate.

Ornamental stone trim, tile floors and similar items should be figured on the basis of prices paid for similar recent jobs and added to the figures determined according to this method.

Profit and insurance have already been included, but an additional allowance of 10 per cent should be added to the estimate to include any incidentals that would otherwise be overlooked.

Assume that a request has been received for a preliminary estimate to cover a cotton mill. It is to be five stories high, to be of standard mill construction and is 400 ft long, 60 ft wide, divided by a cross wall at the middle of the length, and each end of each floor has a stair enclosure 12 by 16 ft and a toilet room enclosure of the same size, with six fixtures in each.

The length of the outside walls is evidently 920 ft; the length of the inside walls is

	Feet
Cross walls	60
Partition walls (4) by 28	112
	172

ESTIMATE

1.	172 lin ft fdtn of 5-story inside wall @ $9.65	$ 1,659.80
	920 lin ft fdtn of 5-story outside wall @ $10.60	9,752.00
2.	172 lin ft 5-story inside wall @ $85.68	14,736.96
	920 lin ft 5-story outside wall @ $83.68	76,985.60
3.	24,000 sq ft Tar-rok, hemlock and maple floor @ $54	12,960.00
4.	96,000 sq ft standard floor @ $1.03	98,880.00
5.	24,000 sq ft standard roof @ $0.86	20,640.00
6.	Painting 5 per cent of items 2–3–4–5	11,210.10
7.	Stairs 8 flights @ $180	1,440.00
8.	Plumbing 60 fixtures @ $100	6,000.00
9.	Contingencies	25,986.00
	Total	$280,250.46

which equals $2.34 per square foot of floors or $0.195 per cubic foot of building. If the principal units have been correctly calculated upon the basis of current prices, the figure should invariably come between the highest and lowest figures submitted when the plans are sent out for actual competitive bids.

SECTION 3. REINFORCED CONCRETE BUILDINGS

Reinforced concrete buildings generally fall into one of two general types, flat-slab construction and beam-and-girder construction but, because the flat-slab construction is rapidly superseding the beam-and-girder type for industrial buildings, we shall attempt to draw up figures only for the first type.

There are several different "systems" of flat-slab construction, but for equal spans and equal loadings the costs do not vary a great deal, so only one set of figures will be needed for preliminary estimating.

The three important factors governing the costs of reinforced concrete factory buildings are the live floor load, which determines the slab thickness, the percentage of steel, and the column spacing.

Column spacings will be found to vary appreciably. However, a dimension of 20 ft 0 in. center to center is sufficiently standard to warrant its use in determining slab thicknesses and steel percentages, and in estimating from them the approximate costs per square foot of slab.

From the "Concrete Designers' Manual," by Hool and Whitney (McGraw-Hill Book Company, Inc., New York City), we get the following quantities of steel and concrete for slabs (including dropheads), designed according to the recommendations of the American Concrete Institute:

TABLE 189.—FLAT-SLAB FLOORS
(Panel size 20 by 20 feet)

Live load per square foot, pounds	Concrete per square foot, cubic foot	Reinforcing steel per square foot, pounds
100	0.65	2.53
150	0.65	3.27
200	0.70	3.70
250	0.74	4.00
300	0.81	4.30
350	0.86	4.55

TABLE 190.—AVERAGE SIZES OF COLUMNS

Height of building in stories	Diameters of interior columns					Thickness of exterior columns (width assumed 16 inches)				
	1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th
1	12	..	..	..	..	12				
2	14	12	..	..	..	12	12			
3	16	14	12	..	..	14	12	12		
4	18	16	14	12	..	16	14	12	12	
5	20	18	16	14	12	16	16	14	12	12

NOTT.—In actual designs the column sizes would vary with changes in load, and a tabulation might well be made of column dimensions and steel areas for each floor loading given above, but for the purpose of illustrating the method one set of figures will suffice.

For the purposes of preliminary estimating we can assume that each column base will require the following quantities:

TABLE 191.—COLUMN FOUNDATIONS

	Concrete, cubic yards	Forms, square feet	Steel, pounds	Excavation, cubic yards
5-story wall column.......	1.2	44	171	4.0
4-story wall column.......	1.1	44	130	4.0
3-story wall column.......	1.0	41	90	3.3
2-story wall column.......	0.9	39	60	3.0
1-story wall column.......	0.7	39	50	3.0
5-story interior column...	3.1	60	294	9.0
4-story interior column...	2.3	52	216	7.1
3-story interior column...	2.1	44	150	5.5
2-story interior column...	0.9	28	96	2.5
1-story interior column...	0.7	20	54	1.9

Since the side walls carry no load, the wall footings need only be strong enough to support the first-story walls. They will also serve to prevent frost from working under the floors.

We therefore assume a footing wall, 12 in. thick and 4 ft 0 in. high, running around the building between the wall column foundations.

Each story will be assumed to have an 8-in. brick curtain wall, 3 ft 0 in. high, cement sills, and steel sash from sill to spandrel beam of slab above.

The top story will also have a parapet wall 3 ft 0 in. high with cement coping.

Assuming that we have found by previous calculation that the prices used are correct for existing markets and local conditions, we may proceed to set up our table of unit prices as follows:

Cost of floor slab for 150-lb live load:	
0.65 cu ft = 0.024 cu yd concrete @ $16	$0.384
1 sq ft forms	0.20
3.27 lb steel @ $0.05	0.164
Grandolithic finish	0.062
Insurance and profit	0.10
Cost per square foot	$0.91
Cost of roof slab:	
0.024 cu yd concrete @ $16	$0.384
Forms	0.20
2.53 lb steel	0.127
5-ply roof	0.15
Insurance and profit	0.099
Cost per square foot	$0.96
Cost of 5-story interior column:	
9 cu yd excavation @ $1	$ 9.00
60 sq ft footing forms @ $0.20	12.00
7 cu yd concrete @ $16	112.00
60 lin ft column forms @ $1.50	90.00
942 lb steel @ $0.05	47.10
Insurance and profit	35.90
	$306.00

Cost of 1 lin ft of exterior wall:

0.4 cu yd excavation @ $1	$ 0.40
0.15 cu yd footing concrete @ $16	2.40
8 sq ft footing forms @ $0.20	1.60
18 sq ft 8-in. brick wall @ $0.84	15.12
5 lin ft sill @ $1	5.00
1 lin ft coping @ $1.50	1.50
40 sq ft windows @ $0.80	32.00
Insurance and profit	7.38
	$65.40

Cost of one 5-story exterior column:

4 cu yd excavation @ $1	$ 4.00
416 sq ft forms @ $0.20	83.20
4.3 cu yd concrete @ $16	68.80
570 lb steel @ $0.05	28.50
Insurance and profit	22.50
	$207.00

NOTE.—We count corner columns as two wall columns each and deduct the wall columns to determine the total length of wall.

Now, suppose that the inquirer who asked for the estimate on the mill building wanted to know what a building of the same size, but of reinforced concrete in the construction just discussed, would cost.

Estimate:

1. 38 interior columns @ $306	$ 11,628.00
2. 50 exterior columns @ $207	10,350.00
3. 853 lin ft outside walls @ $65.40	55,786.20
4. 10,320 sq ft 8-in. brick inside walls @ $0.84	8,668.80
5. 24,000 sq ft concrete first floor @ $0.28	6,720.00
6. 96,000 sq ft reinforced floors @ $0.91	87,360.00
7. 24,000 sq ft reinforced roof @ $0.96	23,040.00
8. Painting	10,200.00
9. Stairs, 8 flights @ $300	2,400.00
10. Plumbing, as before	6,000.00
11. Contingencies	22,215.00
Total	$244,368.00

which equals $2.04 per square foot of floors or 17 cents per cubic foot, which is less than the cost of the mill building on the basis of the figures used.

This same method can be carried out for any type of work. A set of figures might easily be made up covering side walls, floors, partitions and roofs of houses, but it must always be remembered that the figures reached are approximate only and that their value, even for that purpose, depends upon the care with which they are compiled and the correctness of the prices used.

CHAPTER 18

PLUMBING ESTIMATES

SECTION 1. GENERAL

Procedure.—The first operation to be performed when estimating on a plumbing contract of any reasonable size is to secure a list of all of the fixtures required and to secure prices on them from the manufacturers or their representatives. If the specifications are so worded that competing makes of fixtures may be used, prices should be obtained from all manufacturers whose fixtures are of the grade and quality specified.

Caution must, however, be used not to base a bid on a quotation from a manufacturer whose fixtures would not prove acceptable to the architect or to any other person having authority to accept or reject. When a certain manufacturer's fixtures are specified by name, and the words "or equal" follow the names specified, it will generally be found that the architect reserves to himself the right to determine what constitutes equality, and the bidder is under the necessity of inquiring whether a brand proposed by him is considered the equal of the brand originally specified.

On most Federal government work it is customary to specify plumbing fixtures by numbers which refer to the United States Government Master Specifications for Plumbing Fixtures. The manufacturers who are interested in furnishing fixtures for government buildings are familiar with the requirements and can quote from a list sent them.

General Conditions.—The plumbing estimator is also under obligation to study the conditions of the general contract, to determine if it is so worded that a plumbing contractor would be bound by it. He must study the general clauses in the plumbing specifications and learn to what extent the plumbing contractor will be held responsible for the compliance of the design of fixtures with the

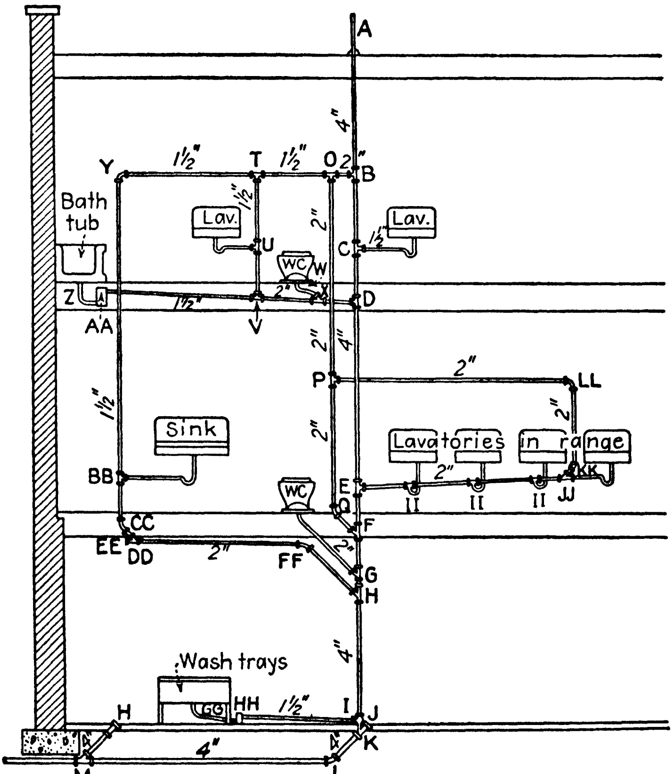

FIG. 26.—Soil and vent lines.

various laws and ordinances governing a plumbing installation in a given locality.

Regulations.—For instance, making a complete and proper plumbing installation in certain places would involve a knowledge of

Local plumbing regulations
Local building regulations
Rules of state board of labor and industries
Rules of state board of public safety
Rules of state board of health

and, perhaps, still other requirements.

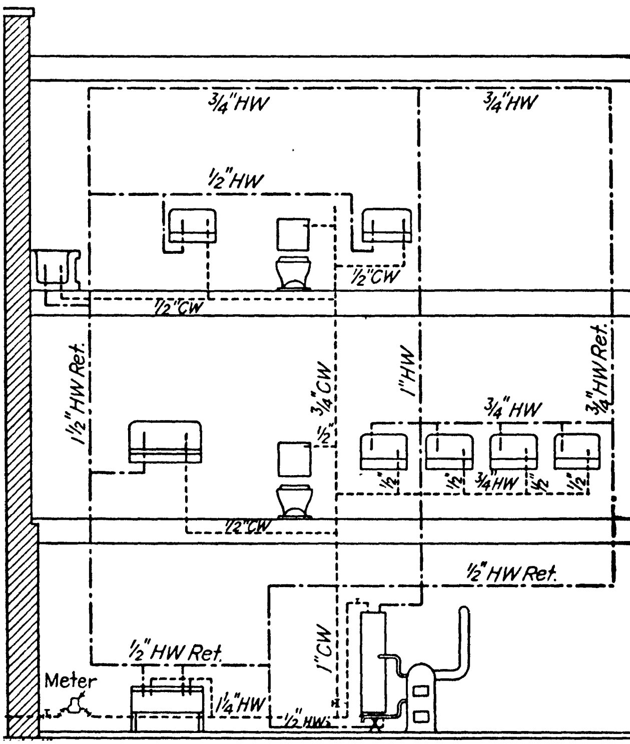

FIG. 27.—Hot- and cold-water piping.

It may properly be supposed that it is the function of the architect or engineer to determine what the requirements are, but these vary greatly and not every architect or engineer will take the time to make a thorough study of the requirements in every locality for which he might design a building. Therefore, it is not at all unusual to insert in the specifications a general clause requiring that the plumbing contractor make the installation comply with the laws, rules and regulations of any authority having jurisdiction.

Thus, it might be that while a fixture of a certain catalogue or plate number were specified, it could not be installed because it did not comply with certain regulations regarding local venting, trapping, size of waste pipe or some other detail.

In the matter of the number of fixtures, also, there might be a violation of regulations, though the plumbing contractor is not very often held responsible for this detail. In some oil-company work, however, the specifications leave it entirely to the contractor to determine how many fixtures will be required, whether cesspools or septic tanks are necessary, and many other details, so that only a contractor who is thoroughly familiar with local conditions can make a really intelligent bid.

On some small projects, when current prices are known, or if the estimator is in possession of price lists and current discount sheets, it would not be necessary to send out fixture lists for prices, but ordinarily the best results are obtained by sending the list out and getting a lump-sum price for a specific project.

Items to Be Listed.—With the fixture list out of the way for the time being, the next step is to take off, from the plans, as complete a list of all other items as is possible. This list will include

Soil pipe
Vent pipe
Iron water pipe
Brass water pipe
Fittings for each of above kinds of pipe
Copper water pipe
Lead pipe (if any)
Traps

Vents
Cleanouts
Valves
Hydrants
Pits

and any other devices or equipment which may be specified or which may be necessary in order to make the work comply with all rules and regulations.

Special Items.—While such items as the installation of septic tanks and of tile pipe drains, outside of the building line, are frequently handled by the mason contractor, the plumbing contractor must determine whether they are to be included in his estimate or not. If they are, he should either prepare his own estimate or secure an estimate from a mason contractor and include it with his bid.

The plumbing contractor must also determine what connections he must make or provide for other kinds of equipment or work to be installed in the structure. He will frequently have to provide a water connection for the heating system and also provide for disposal of the water collected by the roof drainage system.

On a well-designed building, the plumbing plans will be on separate sheets from the architectural or structural plans of the building, and all of the piping will be shown in detail, with sizes marked on each run, and the location of all valves and other details clearly indicated. It then becomes a simple matter of being able to read the plans and scale off the quantities in order to determine the amount of piping to be done.

On the smaller buildings, however, it is customary to show not much more than the locations of the several fixtures and to leave it to the plumbing contractor to determine the sizes and locations of the piping required. In these instances, it is well to make a rough sketch when estimating, note on it the piping as it will probably be installed, and make the estimate of quantities from it.

Permits and Fees.—In every instance it is important to ascertain what permits must be obtained and what fees must be paid. Practically every municipality makes a charge for entering a sewer and also charges for the cost of making the connection and replacing the paving. In certain places sewer connections can only be made by licensed and bonded drain layers. Where such rules apply, it is better to get the estimate from the drain layer for his part of the work than to attempt to estimate it oneself.

Water departments and water companies frequently bring the water to a shutoff at the property line without cost, and the plumber takes the work from there on.

Gas companies generally continue their piping directly to the meter but make a fixed charge per foot of pipe from the property line to the meter.

SECTION 2. SURVEYING PLUMBING QUANTITIES

Scheduling.—Surveying or scheduling the quantities of plumbing fixtures is, as previously indicated, not generally a complicated procedure, since a schedule of plumbing fixtures, listed by plate number, is frequently made a part of the specifications.

Where such a schedule is furnished, it is only necessary for the plumbing estimator to make a careful comparison of the schedule with the plans to be certain that plans and specifications are in agreement. Where they are not in agreement, inquiry must be made of the architect or engineer to determine whether plans or specifications are to govern, and the request for prices and the estimate must be made accordingly.

Where such a schedule is not furnished, or where the information in the schedule is not given by plate numbers in such a manner as to be complete, the estimator must make his own schedule and, in listing, should take off as complete data as possible.

Data Required.—The following are some of the data required for the different types of plumbing fixtures customarily encountered in buildings:

Water-closet combinations:
Bowl, whether siphon-action
Siphon-jet
Washdown or
Nonfreezing type
Whether locally vented or not and, if so, how
Seat, whether wood
Composition or
Wood covered with composition
If wood, what kind and color
If other material, what kind and color
Whether open or closed at front
Whether cover is required
Kind and finish of hinge, if specified
Tank, whether high or low type
Whether wood or china
If wood, how lined
Type of flushing mechanism, if specified
Flushometer or flushing valve, if specified, kind and size
Piping, if exposed in room, with exposed portion plated
Valves, if shutoff is required on supply line
Lavatories: whether enameled iron
Solid porcelain
Marble or other material
Whether pedestal or
Wall type
Whether for recess,
Angle or
Straight wall
Whether singly or
In groups
Size and shape
Size and type of waste
Whether pop-up, chain or otherwise
Kind of traps
Faucets, type and material
Supply pipes, size and material
Bathtubs, size
Whether enameled iron or
Solid porcelain or
Other material

Whether free standing, or for angle or recess
Waste, type and size
Faucets, type and size
Whether shower head is required, if so
Type and size
Kind of curtain
Supply pipes, size and kind
Accessories, if any
Whether access doors or panels are required and must be furnished by the plumbing contractor

Kitchen sinks, size
Whether enameled iron
Porcelain
Slate, or
Other material
If enameled iron, whether required to be acidproof
Type of back
Apron
Ends
Legs
Drainboard, if any
Size and type of faucets
Waste
Trap

Drinking fountains, whether wall or free standing type, or merely attached to other fixture
Method of delivery of water
Whether uniced, iced or electrically refrigerated

Urinals, whether wall or standing
Singly or in groups
Size
Material
Method of flushing
Size and kind of supply pipe
Size and kind of waste pipe

Janitors' or slop sinks, size
Material
Whether provided with flushing arrangement
Size and kind of supply pipe
Size and kind of waste pipe
Size and kind of faucets

Wash trays, type and size
  Whether enameled iron
    Slate, alberene or porcelain
  Whether singly or in groups
  Types of supports
  Covers, if any
  Size and kinds of faucets
  Size and kind of wastes
  Size and kind of traps
  Size and kind of supply pipes
  Size and kind of waste pipes

There may also be other items that are especially required in connection with certain fixtures and, of course, such items must be noted when asking for prices. The fixtures named above are not by any means the only ones that will be found in buildings, but the items listed will give the estimator a good idea of what to look for in connection with any project upon which he may be estimating.

Specialties.—There will also be many other items to be included in the plumbing work, and these items are frequently considered as not coming in the classification of plumbing fixtures. In fact, many of them are made by manufacturers who specialize in one or more of the items mentioned and who make none of the usual fixtures.

Frequently, however, a jobber will handle both the regular fixtures and the special items and will quote prices on both.

Some of these special items, and the features to be particularly noted in connection with them, are

Area drains, type and size
Floor drains, type and size
  Whether trapped or not
  Whether brass or other special top is required
Stall drains, same as for floor drains
Grease traps, type and size
Sand traps, type and size
Refrigerator drains, type and size or if ordinary copper pan can be used

Roof water drains (these are frequently installed by the roofing contractor but, when not, then note type and size)
Hose or sill cocks, size and kind
  Whether nonfreezing or not
  Finish
Water heaters, size and kind
  Whether coal or gas fired or connected to heating plant
  Thermostatic control, if any
Hot-water tanks, size and kind,
  Whether copper, brass or steel
  Whether for any specified pressure
  Type of relief valve or other protection
Water coolers, size and kind
  Whether iced or electrically refrigerated

Special Equipment.—Electrical or mechanical dishwashers may also be included in the plumbing work, in which case they may be either separately installed devices or integral parts of the kitchen sink.

In hotel and restaurant installations it is customary to have a great number of devices for cooking and preparing food, but these are generally furnished under the kitchen-equipment contract and the plumber makes only the necessary supply and waste connections.

So, too, in hospitals, such items as sterilizers will be included, but the installation will be by the hospital-equipment contractor and the plumbing contractor will supply only the connections.

In garages, where the ordinary type of low-pressure overhead washer is used, the plumbing contractor will probably make the entire installation, but where the high-pressure type is used, the pump may be installed by the manufacturer and the supply connection may be made by the plumber.

In stables and cow barns, many of the fixtures may be furnished and installed under an equipment contract, leaving only the connections for the plumbing contractor, or the entire installation may be made part of the plumbing contract.

Medicine cabinets and bathroom accessories, such as towel racks, soap holders, grab rails and toilet-paper holders, while more properly belonging to other divisions of the work, are frequently included in the plumbing specifications and should be noted when so required. Personal hygiene cabinets, which require hot- and cold-water supply, as well as overflow connections, are properly a part of the plumbing work.

SECTION 3. ROUGHING

Definition.—By the term "roughing" we understand all of the work to be done by the plumber, preparatory to the installation of the fixtures. It includes

Soil, waste and vent lines
Hot- and cold-water supply lines
Lead work

Plans.—Except where completely detailed plumbing plans, such as those mentioned in Section 1, have been furnished, it is almost impossible for anyone but a practical plumber, or a man competent to design a plumbing layout, to make an accurate schedule of the quantities of piping and other items necessary to complete the roughing.

As previously suggested, such a man would take the plans and specifications and from them he would roughly lay out the entire installation so that he could schedule the lengths and sizes of pipes required and could note approximately the sizes and locations of the various fittings. Whenever possible, however, the plumbing estimator should get from the designer of the building all of the information required as to the sizes of piping and the location of traps, cleanouts, valves and fittings.

When such information is available, it is merely a matter of careful scaling and recording to make a complete schedule of the piping and of all accessories.

Of course, even where detailed plumbing plans are furnished, it is frequently necessary to show much of the work in a diagrammatic manner and is not practicable to show all features to correct scale. The estimator must then use especial care to get the correct lengths of pipe runs from the architectural plans or other data.

It is in the roughing, particularly, that local regulations may have a marked effect on the amount of work to be done. Therefore, if the plumbing plans do not contain diagrams clearly showing the method of wasting and venting from each fixture, the estimator should determine from the appropriate authority just how it must be done and be governed accordingly.

Soil and Vent Piping.—Soil pipe is almost always cast iron, with caulked and leaded joints, although steel or wrought-iron pipe, with screw joints, is used in some localities. The same would apply to vent pipe.

Soil and vent piping should be listed by linear feet, stating the size and whether standard or extra heavy, and if any particular requirements are given as to leading or caulking of joints, they should be noted.

The specials and fittings to be encountered in soil and vent piping will include

Quarter bends
Eighth bends
Y's
Tees
Increasers
Reducers
Traps
Double Y's
Double tee-Y's
Cleanouts

each of which should be scheduled separately by giving the sizes of pipe that they are to fit. In the case of branches, *i.e.*, Y's and tees, the size of the main line should be written first, followed by the size of the branch; as 6 × 4 tee, meaning a 4-in. tee branch from a 6-in. main pipe.

Branches may also be of special types, such as

3-way elbow
Reducing 3-way elbow
Long turn tee-Y
Double tee-Y
Double Y
Offset

Traps should always be listed by the type required, as

S traps
Half-S traps
Running traps
P traps
California P traps
Backwater valves or traps

Cleanouts may be installed in Y or tee branches at the ends of runs or in the bottoms of traps. They will usually be in the form of brass screw plates let into the end of the branch or into a boss on the bottom of the trap.

It is sometimes provided that main traps, or cleanouts, must be installed in concrete or masonry pits, under floors, with pit covers of iron to provide access to them. Where the construction of the pit or the furnishing or installation of the cover is included in the plumbing, note must be taken of it in preparing the estimate.

Leader connections also are frequently included in the plumbing contract and should be scheduled where so indicated.

Water Piping.—Water piping, whether of iron, steel, brass or copper, should be listed in linear feet, giving the sizes required and the material of which the pipe is made, and all fittings should be listed as for soil and vent pipes. The fittings to be encountered in water piping may include

Elbows, 45, 60 or 90 deg
Drop elbows
Side-outlet elbows
Reducing elbows
Tees

Reducing tees
Four-way tees
Crosses

It will also be necessary to include unions where shown, or where it is evident that the piping cannot be assembled by working continuously in one direction. All shutoff valves, check valves and similar accessories should be separately scheduled.

Pipe Insulation.—Quite frequently, hot- and cold-water pipes, and especially ice-water pipes, are insulated. Hot-water pipes are insulated to prevent loss of heat, cold-water pipes to prevent the "sweating" caused by condensation of atmospheric moisture on the pipes, and ice-water pipes to prevent both "sweating" and the increase of the temperature of the water in the pipes.

When pipe insulation is specified, the number of linear feet of each size of pipe and the kind of insulation, whether hair felt, wool felt, asbestos, etc., should be noted.

If the fittings are to be insulated, plastic insulation will probably be required and then the fittings so insulated should be listed and the quantity of insulation computed from Table 209 in Section 4.

Lead Work.—Lead work, in present-day plumbing, consists principally of the traps or bends placed under water-closet combinations, traps under bathtubs and occasionally under sinks, lavatories, and wash trays. In some installations, however, lead supply pipes will convey the cold water to many fixtures and the waste pipes from sinks, lavatories, and wash trays to the nearest soil stack may be of lead.

Lead pipe should, of course, be listed by linear feet, giving the size required, and any particular specifications as to material and separate items should be made of

Traps, stating kind
Ready-made bends
Wiped joints

To figure the cost of lead pipe, it is customary to convert the total quantity required into pounds, as the price is quoted on the pound basis. (See Table 197, page 301.)

Where lead pipes or bends join iron piping, it is customary to use a brass ferrule. If ordinary plain ferrules are to be used, they should be listed by the internal diameter on the taper end. If union type of ferrules are to be used, the diameter of the larger end should be written first; thus a 2 × 1¼ ferrule is used for joining 1¼-in. lead pipe to 2-in. iron soil pipe.

Tile Piping.—Tile pipe, when part of the plumbing contract, should be listed by the number of linear feet of each size, and all fittings and specials of each size should be listed.

Particular care should be taken to note whether the pipes are to be laid on planks or boards, or directly upon the earth; whether they are to be all or partly surrounded with broken stone, gravel or cinders, or simply backfilled with earth; and whether a layer of hay or other material is to cover the pipes. Where hub-joint pipe is used, and where it is part of the sanitary plumbing system, it is most usual that the pipes be laid directly upon the earth and backfilled with earth.

Where butt-joint pipe is used, or where hub-joint pipe is used as subsoil, or underdrainage, the other methods of laying and backfilling may be used.

Excavation.—Excavation and backfilling should always be scheduled in cubic yards, figuring a trench about 18 in. wide for depths of less than 3 ft, and 2 ft wide for depths of 3 to 6 ft. The number of yards is, of course, determined by multiplying the length of the trench in feet by the width of the trench in feet (as 16 in. equal 1⅓ ft) by the depth of the trench to the underside, or "invert," of the pipe in feet and dividing the result by 27.

When well tamped, the quantity of backfill will nearly equal the quantity of excavation and, in ordinary instances, the cost of disposing of the surplus will be about the same as the cost of backfilling, so a separate item need not be made for material carted away. In many instances, it will be found that the specifications require the mason or general contractor to do the excavation without cost to the plumbing contractor, and then that work need not be figured as part of the plumbing.

General Items.—In connection with the survey of quantities, items should be made of all permits, tests, bonds, guaranties, or special insurance policies that may be required.

SECTION 4. ESTIMATING PLUMBING COSTS

Having completed the survey of the quantities, and having in hand prices on the several materials, fittings, and fixtures required, we may now make an estimate of the cost.

The tables which follow are to be used in calculating the labor costs, which should always be kept separate from the material costs, and both combined as will be later indicated.

Most of these tables have the amount of time figured as based upon the amount of time required to accomplish one hundred units of work. That method facilitates figuring costs by means of key-driven calculating machines, as it does not require dividing as does the usual method where the amount of work done per hour is tabulated.

Excavation.—Where the excavation is part of the plumbing contract the cost should be figured as indicated in Chap. 2.

Tile Piping.—When tile piping for sewer connections, underdrains, or drains from leaders is included in the plumbing contract, Table 192 should be used in figuring the cost. Ordinarily, a good handyman under competent supervision can lay the drains, but in many localities the work is done by masons and, in others, local ordinances require the work to be done by licensed drain layers. Many cities require all connections to sewers to be laid by licensed drain layers.

The figures given in the table can be used for all ordinary jobs of tile-pipe work encountered by a plumber and include such work as the service connection to the sewer, and a line from a building to a cesspool or septic tank.

TABLE 192.—LAYING TILE UNDERDRAINS

Size of pipe, in.	Time per 100 lin ft*			
	Agricultural tile		Hub-joint tile	
	Layer	Helper	Layer	Helper
3	9	9	16	16
4	9	9	16	16
5	..	..	16	16
6	..	..	18	18
8	..	..	18	18
10	..	..	20	20
12	..	..	22	22

* In figuring labor, consider each special or fitting as equal to 3 lin ft.

Table 210 gives the quantities of cement and sand required for laying sewers and drains.

Cost of taking up and replacing pavements or of making the actual connection to a public sewer are not given here, as it is customary for each municipality to establish fixed charges for street openings and sewer connections, and this information should be obtained locally. Most cities also require a cash deposit or a bond to cover future settling of backfill in the trenches.

Cast-iron Pipe Work.—Practically all municipalities having any plumbing regulations require that soil or drain pipe laid underground within the building or within 10 ft outside of the walls shall be of cast-iron pipe. Extra heavy pipe is required in many instances, but most smaller communities still permit the use of standard weight pipe.

Table 193 is to be used in figuring the labor required for installation.

TABLE 193.—INSTALLING CAST-IRON UNDERGROUND DRAINS

Size of Pipe, In.	Time, per Gang of One Plumber and One Helper,* to Install 100 Lin Ft,† Hr
3	17
4	20
5	22
6	25
8	33

* Excavation and backfilling by others.

† In figuring labor on cast-iron piping, consider each fitting or special as equal to one 5-ft length of straight pipe.

TABLE 194.—ERECTING SOIL AND VENT STACKS

Size of pipe, in.	Time per gang of one plumber and one helper* to install 100 lin ft†	
	Cast iron	Wrought iron or steel
2	13	17
3	15	22
4	17	25
5	20	
6	25	
8	34	

* Cutting and patching of woodwork, and masonry or concrete work, by others.

† Consider each cast-iron fitting or special as equal to 5 ft of pipe and each wrought-iron or steel fitting or special as equal to 8 ft of straight pipe.

In all cast-iron work, it is necessary to figure in the cost of the lead and oakum for the joints, though the hours of labor already given include the time necessary for making the joints. Keeping in mind that each 5-ft length of pipe requires one joint and each fitting or special requires two or more joints, as the case may be, Table 195 may be used to calculate the quantities of lead and oakum:

TABLE 195.—LEAD AND OAKUM

Size of pipe, in.	Quantity per joint	
	Lead, lb	Oakum, lb
3	4	0.15
4	6	0.2
5	8	0.22
6	10	0.25
8	12	0.3

While it is customary to purchase wrought-iron and steel pipe by the linear foot, and while prices on cast-iron soil pipe are sometimes quoted by the linear foot, cast-iron pipe is frequently bought by the ton. Table 196 affords a means for converting feet into pounds.

TABLE 196.—WEIGHT OF CAST-IRON SOIL PIPE

Size of pipe, in.	Lb per lin ft, including hubs	
	Standard	Extra heavy
2	3.6	5.5
3	5.2	9.5
4	7	13
5	9	17
6	11	20
8	17	34
10	23	45
12	33	54

Water Piping.—Depending upon local conditions, the quality of the available water supply, or the judgment of the designer, the water piping in an installation may be of wrought iron, steel, copper or brass for concealed work, and lead pipe, nickel or chromium-plated brass pipe for exposed work; or combinations of different piping may be used, as iron or steel for concealed cold-water piping and brass for concealed hot-water piping. Especial care should be taken to figure on the kind of piping specified, as prices may vary considerably.

Flexible copper piping is coming into use for repair and replacement work but is seldom encountered in new work.

While it is customary to figure the cost of other kinds of water piping by the linear foot, lead pipe is best converted to a pound basis for the purpose of estimating the material cost, though the labor is figured on the linear foot basis.

Table 197 gives the means for converting lengths of lead pipe into pounds.

TABLE 197.—WEIGHTS OF LEAD PIPE

Size of pipe, in.	Lb per ft		
	Light	Medium	Strong
1	2.5	3.3	4.0
1¼	3.0	3.8	4.8
1½	4.0	5.0	6.0
1¾	4.5	5.5	6.5
2	5.0	7.0	8.0
3	6.2	9.0	12.0
4	8.0	10.0	16.0

Labor costs of installation should be calculated on the basis of Table 198. Some estimating books advise figuring the piping as straight lengths and adding 70 or 75 per cent to the pipe cost to cover the cost of the fittings and a like amount to the labor cost to cover the added cost of installing the fittings, but the method given in the note accompanying the table seems to be a more satisfactory method, even though it may require the expenditure of a little more time on the part of the estimator.

Cutting and Threading.—While the labor times given in Table 198 include the time taken to cut, thread and

TABLE 198.—INSTALLING WATER PIPE

Size of pipe, in.	Time per gang of one plumber and one helper* per 100 lin ft			
	Steel or wrought iron	Copper or brass	Nickel or chromium plated	Lead
¾	9	11	14	8
1	10	12	15	8
1¼	12	14	18	10
1½	12	14	18	10
2	14	17	21	12
2½	20	23	30	
3	22	25	33	
3½	25	28	38	
4	30	34	40	

* Cutting and patching of woodwork, carpentry, or masonry by others.

NOTE.—Consider each special or fitting as equal to 8 ft of straight pipe. Do not list nickel- or chromium-plated pipe separately where it is included as part of a fixture or combination, as the figures given in later tables for installation include the labor of installing the exposed supplies and wastes.

TABLE 199.—CUTTING AND THREADING PIPE

Size of Pipe, In.	Time per Gang of One Plumber and One Helper to Cut and Thread 100 Ends, Hr
¾	3.3
1	4.
1¼	4.3
1½	4.5
2	6.
3	12.
4	22.
6	32.

make up all joints in the ordinary run of piping work, there are occasions when it may be necessary to make up an estimate separately on the cost of cutting and threading pipe. Table 199 is prepared for that purpose.

Roughing In.—Most books giving labor costs on plumbing installations include a table showing the time required to install all fittings and connections between the vertical stacks and the fixtures, exclusive of the installation of the fixtures. This work is termed "roughing in." Since the amount of roughing to be done will vary in accordance with local or specific requirements on wasting and venting, it seems more accurate to determine just what must be done at each fixture and to use the tables already given to determine the amount of labor.

However, for those who prefer to use the other method, Table 200 is given.

TABLE 200.—ROUGHING IN FIXTURES, EXCLUSIVE OF VERTICAL STACKS

	Time for a Gang of One Plumber and One Helper, Hr
3-piece bathroom C. I. soil pipe, G. I. pipe for hot and cold water	20
Kitchen or pantry sink, including back vent	10
Wash trays, pair	12
Slop sink	8

Gas Piping.—The safest method for figuring the cost of gas piping is to use Table 198 as a basis for determining the amount of labor required, considering any piping smaller than ¾-in. in size as requiring the same amount of labor as ¾-in.

Since plans seldom give the sizes of gas piping required, it is necessary for the estimator to learn from the local building authority or gas company just what the requirements are. Table 201, taken from the building code of the city of Springfield, Mass., is quoted here as typical.

TABLE 201.—GAS PIPING

The size of pipe used shall not be less, nor the length greater, to the number of outlets stated than those specified in the following table, except that if the number of outlets is not more than half the stated maximum, the length of the run may be increased 50 per cent:

Diameter of pipe, in.	Greatest length allowed, ft	Greatest number of fixture outlets	Greatest number of ranges or range boilers
3/8	10	2	0
1/2	30	6	0
3/4	60	20	1
1	80	35	2
1 1/4	120	60	8
1 1/2	160	100	16
2	200	200	24
2 1/2	300	300	36
3	450	450	48
4	600	600	85

No riser from a meter shall be less than 3/4-in. pipe.

The supply pipe for a gas range, water heater or gas log shall not be smaller than 3/4 in., and all gas ranges and heaters shall have a straightway valve or cock on service pipe above the floor.

It is also to be noted that many building codes now require that all gas water heaters, gas stoves, gas logs and gas ranges must be provided with vents or flues. These may be part of the plumbing work or may be included in the sheet-metal contract or masonry contract.

Setting Fixtures.—After the estimate of the time required for all roughing in has been made, whether by the short method given in Table 199 or the more detailed method previously recommended, it is necessary to prepare an estimate of the cost of installing the fixtures after their actual delivery to the building.

Because of the great variety of types and designs in any given class of fixtures, it is impossible to make up a perfectly accurate table of costs that would be complete in every particular. Fixtures vary in weight and in many other details which have a bearing on the cost, but the figures in Table 202 may be used with confidence in all but the most unusual installations.

In multistoried office buildings, hotels and apartment houses there will, of course, be an added cost for elevating and distributing the fixtures to the several floors. Actual costs for elevating will vary greatly with the conditions existing on any given building, but an allowance for 2 hr of helper's time per fixture for each 10 stories above the third should prove ample, and to it should be added ⅙ hr of elevator time per fixture for each 10 stories above the

TABLE 202.—SETTING FIXTURES

	Time of Gang of One Plumber and One Helper per Fixture, Hr
Water-closet combination	5
Water closet with local vent	6
Pedestal lavatory	8
Wall-type lavatory	5
Lavatories in ranges	4
Ordinary bathtub	5
Shower head	4
Porcelain bathtub	10
Recess bathtub	10
Kitchen sink	5
Slop sink	5
Pantry sink	6
Wash trays, pair	10
Range boiler	6
Water meter	6
Sill cock	3
Hanging urinal	5
Standing urinal	7
Wall-type drinking fountain	5
Pedestal-type drinking fountain	8
Drinking fountain in lavatory	2
Hose reel	3

third. This allowance should cover all waiting time of the elevator.

Marble and Slate Work.—Marble and slate work are not properly parts of the plumbing contract but occasionally they are found specified along with the plumbing. The best procedure is, of course, to get a sub-bid from a reliable contractor in those lines, but when that is not either practicable or desirable, the labor cost can be estimated from the data given in Table 180 in Chap. 14 and the prices on the materials can be obtained from the shop or manufacturer.

SECTION 5. MISCELLANEOUS PLUMBING DATA

Sources.—The tables and other data presented in this chapter have been collected from many sources, and acknowledgment is here made to the several manufacturers who have permitted the use of material from their catalogues and other advertising literature.

While the handbooks prepared by the manufacturers of plumbing materials and supplies contain a great deal of valuable and interesting information, an effort has been made here to include only as much of such matter as will prove directly helpful for the purpose of estimating costs.

Prices.—Where list prices are quoted in the tables, or elsewhere in the text, it is to be noted that they are the current list prices at the time of writing and, therefore, approximate only. The estimator should always communicate with the manufacturers or dealers to obtain the latest prices and discounts.

Pipe Sizes.—For the convenience of the estimator in preparing his own sketch, in those instances where detailed plans and specifications have not been furnished, the following excerpts from the Building Code of the City of Springfield, Mass., are quoted as being typical of the requirements in moderate-sized cities.

TABLE 203.—SIZE OF SOIL AND WASTE STACK

The required size of a soil or waste stack shall be independently determined by the total fixture units of all fixtures connected to the stack in accordance with the following tables:

Waste stacks

No. of fixtures	Diameter of stack, in.	Maximum length, ft
1– 8	1½	60
9–18	2	75
19–36	2½	105

Soil and waste stacks

No. of fixture units	No. of water closets or equivalent	Diameter of stack, in.	Maximum length, ft
37– 72	1– 12	3	150
73– 300	13– 50	4	225
301– 720	51–120	5	300
721–1080	121–180	6	400
1081–1920	181–320	8	600

FIXTURE UNITS AND EQUIVALENTS

The following table based on the rate of discharge from a lavatory as a unit shall be employed to determine fixture equivalents:

	Fixture Units
One lavatory	1
One kitchen sink	1½
One bathtub	2
One laundry tray	3
One combination fixture	3
One urinal	3
One shower bath	3
One floor drain	3
One slop sink	4
One water closet	6

TABLE 204.—VENT PIPES

Vent pipes for other than water-closet traps shall be not less than 1½ in. in diameter if 35 ft or less in length, and increase 1 in. in diameter for each additional 35 ft in length or fraction thereof.

Branch vent pipes from single fixtures or group of fixtures shall be combined in accordance with the following table:

2 1½-in. vent branches into one 1½-in. pipe
3 1½-in. vent branches into one 2-in. pipe
3 2-in. vent branches into one 2-in. pipe
4 2-in. vent branches into one 3-in. pipe

TABLE 205.—RAIN LEADERS

The size of rain leaders required shall be in accordance with the following table:

Area of Roof, Sq Ft	Size of Leaders, In.
Up to 300	2
301– 1,800	3
1,801– 3,600	4
3,601– 5,500	5
5,501–10,000	6

Supply Pipe.—Most building codes are not at all definite in specifying the sizes of pipes that must be used to convey cold water to the several plumbing fixtures in an installation. A few codes give requirements on parts of the hot-water piping.

Proportioning the size of supply pipes is, therefore, largely a matter of experience and judgment. The designer is governed by the local pressure available, the number of fixtures likely to be used at one time, and other considerations. Tables 206 and 207 give what may be considered to be minimum requirements.

The service pipe and the risers or branches from it should be proportioned so that no pipe serves a greater number of fixtures than allowed by Table 207, except where local regulations limit the size of service allowed to any one building.

TABLE 206.—SIZES OF SUPPLY PIPES TO FIXTURES

Fixture	Single fixture	Groups of 3	Groups of 4 to 6
Tank-type water closet	½	¾	1
"Flushometer" closet	1½	2	2½
"Flushometer" urinal	1	1¼	1½
Tank-type urinal	½	¾	1
Sink	¾	1	1¼
Showers or bathtubs	½	¾	¾
Lavatories	½	¾	¾
Hot-water heater	¾ and up, depending upon capacity		

TABLE 207.—SIZES OF WATER SERVICES AND RISERS

Size of Pipe, In.	Maximum Number of Fixtures
¾	3
1	9
1¼	20
1½	32

In any instance, the size of any service pipe must be not less than the next size above the largest pipe branching from it, and each branch should be at least one size larger than the largest fixture supply branching from it.

TABLE 208.—CANVAS AREAS FOR PIPE COVERING

Pipe size, in.	Ambler Featherweight Woolfelt and other types, same thickness, sq ft			Keasbey & Mattison Company's 85% Magnesia and High Temperature Coverings, sq ft				
	½ in. thick	¾ in. thick	1 in. thick	Standard thickness	Double standard thickness	1½ in. thick	2 in. thick	3 in. thick
½	0.482	0.613	0.744	0.688	1.2292	1.0145	1.2763	1.7971
¾	0.537	0.668	0.799	0.753	1.2926	1.0799	1.3417	1.8660
1	0.607	0.737	0.868	0.818	1.3583	1.1454	1.4072	1.9300
1¼	0.697	0.828	0.959	0.917	1.4558	1.2436	1.5054	2.0283
1½	0.760	0.891	1.021	0.964	1.5054	1.2926	1.5545	2.0782
2	0.844	1.016	1.146	1.177	1.7667	1.4235	1.6854	2.2092
2½	1.015	1.146	1.277	1.307	1.9000	1.5545	1.8164	2.3400
3	1.179	1.310	1.440	1.471	2.0630	1.7181	1.9800	2.5034
3½	1.310	1.440	1.544	1.604	2.1925	1.8490	2.1108	2.6340
4	1.440	1.570	1.702	1.781	2.3725	1.9800	2.2420	2.7650
4½	1.570	1.702	1.833	1.917	2.5034	2.1108	2.3725	2.8960
5	1.719	1.850	1.980	0.063	2.6500	2.2580	2.5200	3.0434
6	1.997	2.128	2.259	1.360	2.9430	2.5525	2.8145	3.3380
7	2.259	2.389	2.520	2.683	3.3380	2.8145	3.0762	3.5992
8	2.520	2.650	2.782	2.943	3.5992	3.0762	3.3380	3.8607
9	2.782	2.913	3.043	3.240	3.8941	3.3707	3.6326	4.1560
10	3.077	3.208	3.338	3.537	4.1558	3.6326	3.8941	4.4180
12	3.600	3.730	3.793	4.098	4.908	4.098	4.385	4.908
14	3.928	4.058	4.189	4.450	5.236	4.450	4.712	5.236
16	4.450	4.582	4.713	4.974	5.759	4.974	5.236	5.759

TABLE 209.—QUANTITY OF CEMENT NEEDED TO COVER FITTINGS

(Keasbey & Mattison Company's 85% Magnesia Cement*)

Pipe size, in.	Approximate quantity of cement needed, lb												
	Regular ells			Long-radius ells and tees			Standard flanged joint		Extra-heavy flange		Globe valve		
	1-in.	2-in.	3-in.	1-in.	2-in.	3-in.	1-in.	2-in.	2-in.	3-in.	1-in.	2-in.	3-in.
1	0.4	1.2	2.5	0.8	2.0	4.0	2.0	9.7	9.7	20	1.5	3.0	6
1¼	0.5	1.4	2.8	0.9	2.2	4.5	2.1	10.1	10.1	21	1.7	3.5	6.5
1½	0.6	1.7	3.3	1.0	2.7	5.0	2.2	10.6	10.5	22	2.0	4.0	7
2	1.0	2.2	4	1.2	3.2	6.0	2.7	11.5	11.5	23.3	2.8	5	8.5
2½	1.2	2.8	5	1.7	4	7.4	3.2	12.5	12.7	25	3.2	6	9.7
3	1.4	3.2	6	2.0	5	8.7	3.6	13.5	14.3	27	40.	7.2	11.3
3½	1.7	4	7	2.5	5.8	10.2	4	14.3	16	28	4.8	8.3	13.0
4	2.0	4.8	8.2	3.0	7	12	4.3	15.2	17.5	30	5.4	9.4	14.5
4½	2.4	5.6	9.6	3.4	8	13.4	4.7	16	19	33	6.2	10.6	16.5
5	2.8	6.3	11	4.0	9	15.2	5	17	20.6	35	7.0	12	19
6	3.6	8	13.3	4.3	12	19.5	6	19	24	40	8.2	15	23.5
7	4.3	9.5	15.8	6.7	14.6	24.5	7	21	27	45	10.0	17.8	29
8	5	11	18.3	8.1	17	29.3	7.8	22.7	30.2	50	11.5	20.8	34.5
9	6.3	14	22.2	9.7	21.5	35.0	8.6	24.5	33.3	55	13.0	25.2	41
10	7.6	16	26	11.6	25.5	41	9.3	26.5	36.6	60	14.5	30	48
12	10.0	21	33.8	16.0	34.0	55	11	30	43	70	18.5	39	62

* For Ambler Asbestos Cement multiply quantity indicated by 2. For Velvet Asbestos Cement multiply quantity indicated by 2½.

Note.—For standard cross add 25 per cent to the amount required for a long radius elbow.

Tile Pipe.—The prices quoted in Table 210 are given by courtesy of Robinson Clay Products Company, of New York, and the quantities of sand and cement required were computed by the author.

TABLE 210.—PRICES OF SEWER PIPE

Size of pipe, in.	List price per lin ft	Approximate weight per lin ft	Cement, bags per 100 lin ft	Sand, cu yd per 100 lin ft
3	$0.30	7	0.14	0.014
4	0.30	9	0.16	0.016
5	0.45	12	0.20	0.022
6	0.45	15	0.27	0.028
8	0.70	23	0.34	0.036
9	1.05	28	0.48	0.05
10	1.05	35	0.58	0.06
12	1.35	45	0.70	0.075
15	1.80	60	1.15	0.11
18	2.50	85	2.00	0.22
20	3.00	100	2.52	0.26
22	4.00	130	2.80	0.29
24	4.50	140	3.06	0.30

FITTINGS

Each 4 times price 1 ft pipe same size:
- Elbows 12 in. and smaller
- Curves
- Slants
- Branches 2 ft long with inlets 12 in. and smaller
- Increasers
- Reducers

Each 5 times price 1 ft pipe same size:
- Branches 3 ft long with inlets 12 in. and smaller
- Branches double 2 ft long with inlets 12 in. and smaller

Each 6 times price 1 ft pipe same size:
- Branches 27 in. to 36 in. inc., with inlets 15 in. and larger
- Branches double 3 ft long with inlets 12 in. and smaller

Each 7 times price 1 ft pipe same size:
- Branches up to 24 in. inc., with inlets 15 in. and larger

Each 8 times price 1 ft pipe same size:
- Elbows 15 in. and larger
- Branches double 3 ft long with inlets 15 in. and larger
- Traps 10 in. and smaller

Each 13⅛ times price 1 ft pipe same size:
  Traps 12 in.
Each ½ price 1 ft pipe same size
  Stoppers 3 in. to 15 in.
Each ⅗ pipe 1 ft pipe same size:
  Channel pipe per ft
Pipe 1 ft long same price as 2-ft lengths

It is to be noted that prices on tile sewer and drainpipes are subject to discounts varying from 50 to 80 per cent, so the prices given should not be used without first learning the discount applying at the time and place where the work is to be done.

SECTION 6. TYPICAL PLUMBING ESTIMATE

Approximate Estimates.—When it is desired to obtain an approximate estimate on the cost of a given plumbing installation, there are several different methods that may be used, but since they all only roughly approximate the probable actual cost, they should never be used as the basis of a bid or proposal.

The most common method of approximate estimating is to count up the number of fixtures of all kinds and to multiply the total by an assumed average price per fixture installed. This figure may vary from about $75 for the crudest sort of an installation up to $400 or $500 for the plumbing of a very high grade residence.

To show, however, how far from accurate such an approximate figure may be, it is to be noted that the several bids submitted by plumbing contractors bidding on one post-office building varied from less than $150 to over $200 per fixture.

An estimator who wishes to use this method of approximate estimating, even as a check on his regular estimating, should carefully tabulate all the bids he can get, separating them into the different classes of buildings, and make up average costs per fixture for each class of buildings.

The data thus obtained will, of course, be helpful in telling a prospective client the range of prices in which he could expect the bid to be, or for roughly checking estimates.

Another method of approximate estimating is to set opposite each fixture the list prices quoted by the manufacturer, then figure the discount to get the net price, and to the total add a percentage to cover the materials for the roughing and all labor and incidentals.

This percentage will, of course, vary greatly with the local labor rates and the prices on piping and other materials and can be determined only by careful tabulation and comparison of previous bids. When based upon carefully compiled data, this is probably the most accurate method that is available preparing approximate estimates.

Bidding Estimates.—Estimates made for the purpose of filing a bid or proposal must, of course, be made as accurately as it is practicable to make them, since a bid made too high will result in failure to get the desired contract, while a bid made too low may result in a serious monetary loss to the contractor.

Taking Fig. 26, which is a diagram showing the arrangement of soil, waste and vent connections necessary to make an installation complying with the plumbing rules of the city of Springfield, Mass., an estimator would proceed about as follows:

Taking off the fittings, which are identified on the sketch by letters as indicated below, and scaling the lengths of piping, the quantities and cost of the materials for the portion of the work indicated would be

A Flashing to make watertight connection at roof. Only the pipe should ordinarily be included in the plumbing contract, as the flashing would be done by the roofing and sheet metal contractor.
B 4 × 2 cast-iron tee
C 4 × 1½ cast-iron tee
D 4 × 2 cast-iron tee
E 4 × 2 cast-iron tee
F 4 × 2 cast-iron Y
G 4 × 2 cast-iron Y

H	4 × 2 cast-iron Y
I	4 × 1½ cast-iron tee
J	Brass cleanout screw
K	4 × 4 cast-iron Y
L	4-in. cast-iron 45-deg elbow
M	4 × 4 cast-iron Y
N	Brass cleanout screw
O	2 × 2 cast-iron tee
P	2 × 2 cast-iron tee
Q	2-in. cast-iron 45-deg elbow
R	2-in. lead bend
S	2-in. brass ferrule
T	1½ × 1½ wrought-iron tee
U	1½ × 1½ wrought-iron tee
V	2 × 1½ wrought-iron tee
W	2-in. lead bend
X	2-in. brass ferrule
Y	1½-in. wrought-iron 90-deg elbow
Z	1½-in. lead bend
AA	Lead traps, with brass cleanout screw, nickeled floor plate
BB	1½ × 1½ wrought-iron tee
CC	1½-in. wrought-iron 90-deg elbow
DD	2 × 1½ cast-iron Y
EE	Leaded-in plug
FF	2-in. cast-iron 45-deg elbow
GG	2-in. lead bend
HH	Lead trap
II	2 × 1½ cast-iron tees
JJ	2 × 2 cast-iron Y
KK	2-in. cast-iron 45-deg elbow
LL	2-in. cast-iron 90-deg elbow

Summary of Materials

50 lin ft	4-in.	cast-iron soil pipe	@ $0.27	$13.50
45 lin ft	2-in.	cast-iron soil pipe	@ 0.12	5.40
3	4 × 2	cast-iron tees	@ 3.60	10.80
3	4 × 2	cast-iron Y's	@ 4.25	12.75
1	4 × 1½	cast-iron tee	@ 3.60	3.60
1	4 × 1½	cast-iron Y	@ 4.25	4.25
2	4 × 4	cast-iron Y's	@ 3.85	7.70

1	4-in. cast-iron 45-deg elbow		@ $2.30	$ 2.30
2	2 × 2 cast-iron tees		@ 0.80	1.60
1	2 × 2 cast-iron Y		@ 0.95	0.95
1	2 × 1½ cast-iron Y		@ 1.05	1.05
4	2 × 1½ cast-iron tee		@ 1.05	4.20
3	2-in. cast-iron 45-deg elbows		@ 0.57	1.71
1	2-in. cast-iron 90-deg elbow		@ 0.57	0.57
Lead	22 4-in. joints @ 6	132		
	34 1½- and 2-in. joints @ 3.5	119		
		251 lb	@ 0.08	20.08
Oakum	22 4-in. joints @ 0.15	3.3		
	34 1½- and 2-in. joints @ 0.12	4.1		
		7.4 lb	@ 0.11	0.81
60 lin ft	1½-inch wrought-iron pipe		@ 0.27½	16.50
3	1½ × 1½ wrought-iron tees		@ 0.45	1.35
2	1½-in. wrought-iron 90-deg elbows		@ 0.27	0.54
2	1½-in. cast-lead traps, brass cleanouts		@ 1.35	2.70
3	2-in. lead bends		@ 1.00	3.00
1	1½-in. lead bend		@ 0.66	0.66
2	2 × 2 ferrules		@ 0.28	0.56
2	Cleanout screws		@ 1.00	2.00
1	Plug		@ 1.00	1.00
	Gross cost of materials			$119.58
	* Average discount 15%			17.94
	Net cost of materials			$101.64

* When individual discounts are known, do not use an average, but figure the individual discounts on the items to which they apply.

The hot- and cold-water supply are not shown in Fig. 26, because it was desired not to complicate the drawing by more lines than necessary; however, on the basis of Table 205, we find that the piping should be as in Fig. 27, from which we get the following quantities and cost:

10 lin ft 1¼-in. wrought-iron pipe	@	$0.23	$ 2.30
19 lin ft 1-in. wrought-iron pipe	@	0.17	3.23
33 lin ft ¾-in. wrought-iron pipe	@	0.115	3.80
32 lin ft ½-in. wrought-iron pipe	@	0.085	2.72
24 lin ft 1-in. brass pipe	@	1.06	25.44
48 lin ft ¾-in. brass pipe	@	0.78	37.44
90 lin ft ½-in. brass pipe	@	0.59	53.10
Iron fittings			
2 1¼-in. unions	@	0.80	1.60
4 1¼-in. elbows	@	0.26	1.04
1 1¼ × 1 reducing coupling	@	0.10	0.10
1 1¼ × 1 tee	@	0.34	0.34
3 1-in. elbows	@	0.17	0.51
1 1 × ¾ reducing coupling	@	0.10	0.10
1 1 × ½ tee	@	0.22	0.22
1 ¾ × ½ reducing coupling	@	0.10	0.10
6 ¾ × ½ tees	@	0.20	1.20
4 ½ × ½ tees	@	0.18	0.72
6 ½-in. elbows	@	0.11	0.66
Brass fittings			
1 1 × ½ tee	@	1.85	1.85
1 1 × 1 tee	@	1.50	1.50
6 1-in. elbows	@	1.45	8.70
2 ¾ × ½ reducing couplings	@	0.75	1.50
3 ¾ × ½ tees	@	1.30	3.90
1 ¾ × ¾ tee	@	1.05	1.05
1 1 × ¾ double-branch tee	@	1.85	1.85
11 ½-in. elbows	@	0.56	6.16
7 ½ × ½ tees	@	0.80	5.60
1 1-in. hose bibb			1.25
1 1-in. stop and waste cock			1.25
1 ½-in. swing check valve			1.75
1 1¼-in. gate valve			5.50
Gross price on pipe and fittings			$176.48
Less 15% discount			26.47
Net price on pipe and fittings			$150.01

For a fixture list we will take

1	5-ft recess pattern bathtub, list price	$160.00
6	wall-type lavatories @ $17.50, list price	105.00
2	siphon-jet closet combinations @ $35.50, list price	71.00
1	kitchen sink, list price	16.00
1	pair wash trays, list price	18.00
1	domestic hot-water heater, list price	40.00
1	copper storage tank, list price	40.00
	Gross cost of fixtures	$450.00
	Average discount 20%	90.00
	Net cost of fixtures	$360.00

NOTE: The list prices on fixtures used here are arbitrarily assumed and are not to be used in making any actual estimate.

Labor Costs.—Taking the figures given in Tables 193 and 198, we proceed as follows to determine the cost of the soil and vent lines:

16 ft 4-in. cast-iron pipe, plus	
3 fittings @ 5 ft; total of 31 ft @ 20 hr per 100	6.2 hr
34 ft 4-in. cast-iron pipe stacks, plus	
8 fittings @ 5 ft; total of 74 ft @ 17 hr per 100	12.6 hr
45 ft 2-in. cast-iron soil pipe, plus	
12 fittings @ 5 ft; total of 105 ft @ 13 hr per 100	13.7 hr
60 ft 1½-in. wrought-iron pipe, plus	
5 fittings @ 8 ft; total of 100 ft @ 14 hr per 100	14. hr
10 lead fittings @ 8 ft; total of 80 at @ 12 hr per 100	9.6 hr
	56.1 hr

Wages of plumber	$1.00 per hr
Wages of helper	$0.50 per hr
Wages per gang	$1.50 per hr

56.1 hr @ $1.50 = $74.85

By the same tables, the cost of installing the supply lines will be:

Iron									
10 ft	1¼-in.	pipe and	9 fittings	equal	82 ft	@	12 hr per 100	.....	9.9
19 ft	1-in.	pipe and	7 fittings	equal	75 ft	@	10 hr per 100	.....	7.5
33 ft	¾-in.	pipe and	7 fittings	equal	89 ft	@	9 hr per 100	.....	8
32 ft	½-in.	pipe and	10 fittings	equal	112 ft	@	9 hr per 100	.....	10.1
Brass									
24 ft	1-in.	pipe and	11 fittings	equal	112 ft	@	12 hr per 100	.....	13.5
48 ft	¾-in.	pipe and	6 fittings	equal	96 ft	@	11 hr per 100	.....	10.6
90 ft	½-in.	pipe and	19 fittings	equal	242 ft	@	11 hr per 100	.....	26.6
									86.2

86.2 hr @ $1.50 = $129.30

From Table 202 the cost of setting the fixtures would be

Recess bathtub		10 hr
4 lavatories in range	@ 4	16 hr
2 lavatories	@ 5	10 hr
2 water closets	@ 5	10 hr
1 sink		5 hr
1 pair wash trays		10 hr
1 domestic hot-water heater		5 hr
1 storage tank		6 hr
		72 hr @ $1.50 = $108.00

SUMMARY

	Labor	Materials
Soil and vent lines....................	$ 74.85	$101.64
Supply lines..........................	129.30	150.01
Fixtures..............................	108.00	360.00
Tests 16 hr time......................	24.00	....
Miscellaneous.........................	10.00	5.00
Sewer connection and permit...........	Town	100.00
Water connection and permit...........	Company	50.00
Compensation insurance, 5% of labor...	....	17.31
	$346.15	$783.96

Total in labor column	$ 346.15	
Total in materials column	783.96	
Overhead expense 6%	68.00	
Hauling	25.00	
Profit 10%	122.36	
Bid	$1,345.47	Say $1,346.00

Considering the water-heating outfit as one fixture, we have a total of 12 fixtures, so that the average cost per fixture installed, in this instance, would be $112.17, which is a rather low average for present prices.

It is to be noted, however, that the arrangement of the fixtures was such as to make feasible a comparatively simple piping layout. Variations in the piping layout and in the choice of fixtures would tend to increase the cost. The method of estimating would always be the same, but the prices of all materials and the rates of wages must be varied to fit each particular instance.

Estimate on a Government Building.—The figures which follow are those which were recently made on the plumbing work on a Federal post-office building to be erected in the eastern part of Massachusetts.

The fixtures to be installed were listed as follows in the specifications, the numbers following the names of fixtures refer to the United States Government Master Specification for Plumbing Fixtures, mentioned in Section 1.

The other quantities used in the estimate are as they were surveyed from the plumbing plans.

Schedule of Fixtures

Basement

3 water closets, No. 48 EF
1 urinal, No. 18 VF
2 lavatories, No. 20 RV
3 lavatories, No. 20 RVB
1 shower fixture, No 50 MV
1 water heater and hor. storage tank, No. 100 HP
2 fire-hose racks
1 sink, No. 36 CI

First Floor

3 water closets, No. 48 EF
1 urinal, No. 18 VF
3 lavatories No. 20 RV
3 lavatories No. 20 RVB
1 slop sink No. 24 SCIG
2 fire-hose racks
2 electric drinking fountains

Second Floor

8 water closets, No. 48 EF
3 urinals, No. 18 VF
5 lavatories, No. 20 RV.
9 lavatories, No. 20 RVB.
1 slop sink, No. 22 VG.
1 slop sink, No. 24 SCIG.
2 shower fixtures, No. 49 MV.
1 fire-hose rack.
2 electric drinking fountains.

The underground portion of the soil and vent lines was specified to be of extra-heavy cast-iron pipe, while all of the other soil, waste and vent piping was specified to be screw-joint galvanized iron and steel piping The two kinds of piping, with their fittings, are here estimated separately, as follows:

Soil, Waste and Vent Lines

120 ft	2-in. XHCI pipe underground	@ $0.40	$ 48.00
131 ft	3-in. XHCI pipe underground	@ 0.62	81.22
602 ft	4-in. XHCI pipe underground	@ 0.84	505.68
162 ft	5-in. XHCI pipe underground	@ 1.10	178.20
28 ft	6-in. XHCI pipe underground	@ 1.30	36.40
32 ft	8-in. XHCI pipe underground	@ 2.20	70.40
20 ft	10-in. XHCI pipe underground	@ 3.60	72.00
10	2-in. 90-deg elbows	@ 0.40	4.00
5	2-in. 45-deg elbows	@ 0.45	2.25
11	2 × 2 Y's	@ 1.20	13.20
14	3 × 3 Y's	@ 1.80	25.20
5	3-in. 90-deg elbows	@ 0.40	2.00
5	3-in. 45-deg elbows	@ 0.45	2.25
22	4 × 4 Y's	@ 2.52	55.44
4	4 × 4 tees	@ 2.52	10.08
4	4 × 2 Y's	@ 2.52	10.08
15	4-in. 90-deg elbows	@ 0.50	7.50
20	4-in. 45-deg elbows	@ 0.55	11.00
1	4-in. double-branch tee	@ 3.32	3.32
5	4 × 3 Y's	@ 2.52	12.60
4	5 × 5 Y's	@ 3.30	13.20
4	5 × 4 Y's	@ 3.30	13.20
1	5 × 2 Y	@ 3.30	3.30
1	5-in. 45-deg elbow	@ 0.75	0.75
2	6 × 6 Y's	@ 3.90	7.80
2	6 × 4 Y's	@ 3.90	7.80
1	6-in. 45-deg elbow	@ 0.90	0.90
3	8 × 8 Y's	@ 6.60	19.80
2	8 × 6 Y's	@ 6.60	13.20
1	8 × 4 Y	@ 6.60	6.60
2	8-in. 45-deg elbows	@ 3.10	6.20
1	10 × 4 Y	@ 10.80	10.80
5	3-in. running traps	@ 5.50	27.50
4	3-in. area cesspools	@ 7.50	30.00
1	4-in. back-water valve		20.00
1	3-in. gate valve		36.00
1	3-in. floor drain	@ 6.00	6.00
46	Cleanout screws	@ 1.00	46.00
			$1,419.87
	Average discount 45%		638.94
	Net		$ 780.93

The jointing materials were figured as follows:

		Lead, Lb	Oakum, Lb
81	2-in. joints	162	12
79	3-in. joints	316	12
227	4-in. joints	1,362	45
47	5-in. joints	376	10
16	6-in. joints	160	4
16	8-in. joints	192	5
6	10-in. joints	132	2
		2,700	90

2,700 lb lead @ 7¢ net	$189.00
90 lb oakum @ 9¢ net	8.10
	$197.10

The labor on this portion of the work was figured as follows:

120 ft 2-in pipe plus 26 fittings equals 250 ft @ 17 hr per 100	42.5
131 ft 3-in. pipe plus 22 fittings equals 241 ft @ 17 hr per 100	41.
602 ft 4-in. pipe plus 73 fittings equals 967 ft @ 20 hr per 100	193.4
162 ft 5-in. pipe plus 10 fittings equals 212 ft @ 22 hr per 100	46.7
28 ft 6-in. pipe plus 5 fittings equals 63 ft @ 25 hr per 100	15.8
32 ft 8-in. pipe plus 8 fittings equals 72 ft @ 33 hr per 100	23.8
20 ft 10-in. pipe plus 1 fitting equals 25 ft @ 40 hr per 100	10.
	373.2

373.2 hr @ .1.85 = .690.42

The stacks of screw-joint pipe were estimated as follows:

Soil, Waste and Vent Stacks

232 ft	1¼-in. galvanized screw-joint pipe in stacks, etc.	@$ 0.27½	$ 63.80
324 ft	2-in. galvanized screw-joint pipe in stacks, etc.	@ 0.37	119.88
138 ft	3-in. galvanized screw-joint pipe in stacks, etc.	@ 0.76½	105.57
940 ft	4-in. galvanized screw-joint pipe in stacks, etc.	@ 1.09	1,024.60
8	1½-in. 90-deg elbows	@ 0.33	2.64
5	1½-in. 45-deg elbows	@ 0.39	1.95
9	2-in. 90-deg elbows	@ 0.52	4.68
8	2-in. 45-deg elbows	@ 0.62	4.96
8	2 × 2 Y's	@ 0.75	6.00
3	2 × 2 tees	@ 0.68	2.04
7	3 × 3 Y's	@ 1.90	13.30
8	3-in. 90-deg elbows	@ 1.30	10.40
8	3-in. 45-deg elbows	@ 1.55	12.40
1	3 × 2 Y	@ 1.90	1.90
2	3 × 2 tees	@ 1.90	3.80
4	4 × 4 tees	@ 2.65	10.60
11	4 × 2 Y's	@ 3.45	37.95
9	4 × 4 Y's	@ 3.45	31.05
2	4 × 2 tees	@ 3.45	6.90
37	4-in. 45-deg elbows	@ 2.85	105.45
22	4-in. 90-deg elbows	@ 2.35	51.70
3	2-in. traps	@ 7.00	21.00
3	3-in. T traps	@ 16.00	48.00
3	3-in. lead bends for roof water connections	@ 1.60	4.80
8	4-in. lead bends for roof water connections	@ 2.40	19.20
3	3 × 3 brass ferrules	@ 0.42	1.26
8	4 × 4 brass ferrules	@ 0.50	4.00
	Total		$1,719.83
	Average discount 40%		687.93
	Net		$1,031.90

Labor on these stacks was figured thus:

232 ft	1½-in. pipe and	13 fittings equal	336 ft	@ 17 hr per 100	57.2
324 ft	2-in. pipe and	28 fittings equal	548 ft	@ 17 hr per 100	93.2
138 ft	3-in. pipe and	35 fittings equal	418 ft	@ 22 hr per 100	92.0
940 ft	3-in. pipe and	101 fittings equal	1,748 ft	@ 25 hr per 100	437.0
					679.4

679.4 hr @ $1.85 = $1,256.89

The fire lines were to be of galvanized iron and the hot- and cold-water lines were to be of either copper or brass, and were figured as follows:

208 ft	2-in. galvanized fire lines	@	\$ 0.37	\$ 76.96
13	2-in. galvanized 90-deg elbows	@	0.52	6.76
2	2 × 2 tees	@	0.68	1.36
1	3 × 2 tee	@	1.90	1.90
5	2 × 1¼ tees	@	0.68	3.40
958 ft	½-in. brass or copper piping	@	0.77	737.66
890 ft	¾-in. brass or copper piping	@	1.02	907.80
222 ft	1-in. brass or copper piping	@	1.50	333.00
138 ft	1¼-in. brass or copper piping	@	2.06	284.28
282 ft	1½-in. brass or copper piping	@	2.50	705.00
304 ft	2-in. brass or copper piping	@	3.45	1,048.80
176 ft	2½-in. brass or copper piping	@	5.25	924.00
36 ft	3-in. brass or copper piping	@	7.05	253.80
82	¾ × ½ tees, brass or copper	@	1.30	106.60
70	¾ × ¾ tees, brass or copper	@	1.05	73.50
1	1 × 1 tee, brass or copper	@	1.50	1.50
1	1 × ¾ tee, brass or copper	@	1.85	1.85
3	1¼ × ½ tees, brass or copper	@	2.65	7.95
2	1¼ × ¾ tees, brass or copper	@	2.65	5.30
2	1¼ × 1 tees, brass or copper	@	2.65	5.30
2	1½ × ½ tees, brass or copper	@	3.50	7.00
2	1½ × 1¼ tees, brass or copper	@	3.50	7.00
2	1½ × 1½ tees, brass or copper	@	2.80	5.60
2	2 × 1½ tees, brass or copper	@	5.25	10.50
2	2 × 2 tees, brass or copper	@	4.20	8.40
2	2½ × 2 tees, brass or copper	@	9.75	19.50
2	3 × ¾ tees, brass or copper	@	15.80	31.60
5	3 × 2 tees, brass or copper	@	15.80	79.00
2	3 × 3 tees, brass or copper	@	12.75	25.50
40	½-in. 90-deg elbows	@	0.56	22.40
22	¾-in. 90-deg elbows	@	0.75	16.50
2	1-in. 90-deg elbows	@	1.10	2.20
2	1¼-in. 90-deg elbows	@	1.55	3.10
12	1½-in. 90-deg elbows	@	2.00	24.00
2	2-in. 90-deg elbows	@	3.00	6.00
2	2½-in. 90-deg elbows	@	5.50	11.00
2	3-in. 90-deg elbows	@	9.00	18.00
5	¾-in. wall hydrants	@	7.50	37.50
1	1¼-in. regulating valve	@	25.00	25.00
8	½-in. gate valves	@	1.65	13.20
12	¾-in. gate valves	@	2.05	24.60
4	1-in. gate valves	@	2.80	11.20
2	1¼-in. gate valves	@	3.70	7.40
6	1½-in. gate valves	@	5.00	30.00
10	2-in. gate valves	@	7.30	73.00
4	3-in. gate valves	@	19.00	76.00
				\$6,081.92
	Average discount 55%			3,345.06
	Net			\$2,736.86

The labor on the water piping was figured thus:

208 ft 2-in. galvanized	piping plus	20 fittings equal	360 ft @ 14 per 100.......	50.4
958 ft ½-in. brass	piping plus	48 fittings equal	1,342 ft @ 11 per 100.......	147.6
890 ft ¾-in. brass	piping plus	191 fittings equal	2,418 ft @ 11 per 100.......	266.0
222 ft 1-in. brass	piping plus	6 fittings equal	270 ft @ 12 per 100.......	32.4
138 ft 1¼-in. brass	piping plus	11 fittings equal	226 ft @ 14 per 100.......	31.7
282 ft 1½-in. brass	piping plus	14 fittings equal	294 ft @ 14 per 100.......	41.2
304 ft 2-in. brass	piping plus	16 fittings equal	432 ft @ 17 per 100	73.5
176 ft 2½-in. brass	piping plus	4 fittings equal	208 ft @ 23 per 100.......	47.9
36 ft 3-in. brass	piping plus	16 fittings equal	164 ft @ 25 per 100.......	41.0
				731.7

731.7 hr @ \$1.85 = \$1,353.64

All water lines, except certain pipes exposed in rooms, were insulated. The insulation was figured as follows:

820 ft sectional insulation ½-in. pipe	@ \$0.22......	\$180.40
810 ft sectional insulation ¾-in. pipe	@ 0.24......	194.40
200 ft sectional insulation 1-in. pipe	@ 0.27......	54.00
138 ft sectional insulation 1¼-in. pipe	@ 0.30......	41.40
282 ft sectional insulation 1½-in. pipe	@ 0.33......	93.06
304 ft sectional insulation 2-in. pipe	@ 0.36......	109.44
176 ft sectional insulation 2½-in. pipe	@ 0.40......	70.40
1,200 lb plastic insulation on fittings	@ 0.01¾ ...	21.00
		\$764.10
Discount 50%..................................		382.05
		\$382.05

The labor applying this insulation was figured thus:

2,730 ft pipe @ 5 hr per 100.............	136.5
1,200 lb plastic @ 6 hr per 100..........	72
	208.5

208.5 hr @ \$1.85 = \$385.73

The fixtures were quoted at a lump-sum price of \$2,689.00 and the setting of the fixtures was figured thus:

14 water closets	@ 5 hr..............	70 hr
5 urinals	@ 7 hr..............	35 hr
25 lavatories	@ 5 hr..............	125 hr
3 shower fixtures	@ 4 hr..............	12 hr
1 sink	@ 5 hr..............	5 hr
3 slop sinks	@ 5 hr..............	15 hr
5 fire-hose racks	@ 3 hr..............	15 hr
4 electric drinking fountains	@ 5 hr..............	20 hr
1 water heater and storage tank	@ 9 hr..............	9 hr
Total....................................		306 hr

306 hr @ \$1.85 = \$566.10

The estimate was then summarized as follows:

	Labor	Materials
Sewer permit and connection	\$ Town	\$ 125.00
Water permit, connection, meter	Company	150.00
Underground lines	690.42	780.93
Lead and oakum	above	197.10
Soil and vent stacks	1,256.89	1,031.90
Water piping	1,353.64	2,736.86
Insulation	385.73	382.05
Fixtures	566.10	2,689.00
Incidentals, 5%	213.00	....
Insurance, 5% of pay roll	....	229.50
Miscellaneous trucking, etc.	125.00	....
	\$ 4,590.78	\$8,322.34

Total in labor column	\$ 4,590.78
Total in materials column	8,322.34
Overhead and profit	1,421.00
	\$14,334.12

The electrical connections to drinking fountains and all excavation were to be done by others.

With 61 fixtures to be furnished and installed, we have an average of \$305.00 per fixture, which is a high price for an ordinary installation but a fair price for such a job as this, with a high grade of fixtures, a circulating system of hot-water supply and the fixtures distributed over a wide area of building instead of being in groups directly over one another.

CHAPTER 19

HEATING ESTIMATES

SECTION 1. GENERAL

The preparation of estimates on heating installations involves the same procedure as the preparation of estimates for plumbing work, but the amount of detail involved is likely to be much greater.

There are several general classes of heating installations, as, hot-air, hot-water, vapor and steam. Each installation may be complicated by the addition of a ventilating system and by the inclusion of many patented or special devices intended to secure greater efficiency or better performance.

Specifications.—A method of specifying the steam or hot-water heating system for small- and moderate-sized installations which until recently was very much in vogue but is now, happily, becoming less prevalent, was simply to require that it should be of sufficient capacity to heat all of the rooms to a given temperature of 65 or 70°F., when the outside temperature is at zero.

This practice, of course, takes the design of the heating plant out of the hands of the architect or the heating and ventilating engineer, where it belongs, and places it in the hands of the heating contractor. The better equipped contractors may have the engineering organization and ability to produce a design that will meet the actual needs of the project, but a more customary practice is to pass the problem on to the manufacturers of boilers and radiation, and get them to make an estimate of the amount of radiation and the size of the boiler.

This method means, too, that the estimator does not really have a fair chance to do his work, since the bidders are not competing to submit the best bid on a specific piece of work but are really competing on the basis of who will guarantee the least expensive installation. And, of course, once an installation is made and paid for, it is easier to ascribe its shortcomings to faulty operation than it is to compel the contractor to make expensive changes in the work.

Because this method of specifying still has some vogue, methods for determining the required amount of radiation are given on pages 330 to 336 inclusive.

Correct Method.—The proper method, which is used by all competent designers, is to work out the heating and ventilating plans with at least as much detail as is used on any other portion of the building construction and to have all bidders competing on the same requirements, so that the bids submitted shall be truly competitive.

Of course, on installations of any size or complexity, the architect should properly call in a competent heating and ventilating engineer who will employ his specialized knowledge to make certain that the installation is designed to be adequate, efficient and properly balanced.

Such a designer will work out every detail, from the size and height of the chimney flue to the final bronzing of the radiators, because even the color of the bronzing used has a bearing on the final efficiency of radiation.

Where complete plans have been worked out, the procedure for estimating steam, vapor and hot-water heating follows closely that outlined for estimating plumbing work, taking due account of the differences in the nature of the piping and in the types of accessories to be used.

Hot-air Systems.—While the number of the older type of hot-air heating installation tends to become smaller in some parts of the country, there is an increasing number of "pipeless" and "one-pipe" heaters being installed in small stores, small houses, and other buildings which either are not broken up into rooms or are so arranged that the circulation of air through the building can be easily provided for.

Estimating such installations is a comparatively simple process and the methods developed in succeeding chapters will be found especially valuable.

Costs.—As in the previous sections of this work, labor costs are given in man-hours, or more properly "gang-hours," required to complete a unit or a hundred units of each kind of work.

The figures given are, as nearly as possible, for average conditions and can be safely used except where unusual conditions apply. Wherever possible, however, each estimator should make a practice of compiling his own data and comparing them with published data, so that his estimates may become more and more accurate when applied to the men with whom the estimator works and the local conditions under which the work is done.

Of course, labor-union restrictions may have a bearing on the amount of work which can be accomplished and the estimator should always be informed as to them.

Laws and Ordinances.—The estimator should also become familiar with the local laws, ordinances, rules and regulations to determine in what manner they will affect costs and, when plans and specifications require that work be done to comply with such regulations, he must be able to make certain that he has included all of the items which become necessary by that stipulation.

In some states there are laws governing the temperatures to be maintained and the amount of ventilation to be supplied in schools, churches, auditoriums, theaters, factories and other buildings. Quite frequently, two or more departments or bureaus will have jurisdiction over the same building, so it is necessary to ascertain to what extent the contractor is to be liable for the compliance of the design with these requirements.

SECTION 2. PROPORTIONING HEATING PLANTS

As stated in the previous chapter, the design of a heating plant is properly the work of a heating and ventilating engineer rather than of an estimator. However, because proper plans and specifications are not always furnished with requests for an estimate or bid, the estimator must be prepared to approximate the amount of radiation required and to prepare a tentative design upon which he can base his estimate.

The methods which are outlined in this chapter are presented through the courtesy and cooperation of the manufacturers whose names are mentioned, but the data so presented are not to be construed as a complete course in the engineering of steam or hot-water heating plants.

Old Method.—A method that was formerly in use among many heating contractors was to compute the total contents of a building in cubic feet, using outside dimensions, and then to divide by some arbitrary figure to get the total amount of direct radiation required. To compensate for the heat loss in risers and other piping, the required boiler rating was taken as twice that of the amount of direct radiation. The radiation was proportioned among the several rooms on the basis of their contents. The divisors used in this method were as given in Table 211.

TABLE 211.—APPROXIMATE RADIATION REQUIRED

Type of building	Divisor for steam radiation	Divisor for hot-water radiation
Frame house, northern section....	40	24
Frame house, middle section......	50	30
Brick house, northern section.....	50	30
Brick house, middle section.......	60	36
Office building..................	60	36
Hotel..........................	60	36
Factory........................	80	48

The figures thus obtained also have a value in checking the total amount of radiation obtained by the more detailed method given below.

When using the method just outlined, estimates are frequently made on the basis of a total cost, covering all labor and materials, of from $1.50 for steam to $2 for hot water per square foot of total radiation.

More Detailed Method.—The following method, given by United States Radiator Corporation, is quoted by their permission:

Because of different conditions surrounding the installation of a heating apparatus, it is impossible to give any set rule that can be accepted, without modification, for all kinds of buildings to be heated. It is necessary to take into consideration all of the conditions in and around any building, and additions or deductions made to suit the requirements, no matter what rule may be used for figuring.

Nearly all rules are based on 2 to 5 lb steam pressure and a temperature of 180° for water, as indicated at the boiler when the outside temperature is at zero. When systems are designed for heating with a lower temperature at the boiler (vapor, vacuum, etc.) it is necessary to provide additional radiation in accordance with best practice for different systems.

Many contractors make the error of installing too little radiation. A little extra surface will give greater economy and insure a first-class working system.

If direct-indirect radiation is to be used, 25 per cent should be added to the radiation necessary for direct heating. If indirect radiation is to be used, 50 per cent should be added to the amount of radiation necessary for direct heating. In schools, churches, etc., where ventilation is required, it is necessary to use some special rule for ventilating to obtain indirect surface.

Before determining the size of boiler required, all special forms of heating surface should be made the equivalent of direct radiation.

The amount of radiation computed for steam should be multiplied by 1.65 to determine the quantity of water radiation required.

The following rule has been found to give good results, but is not guaranteed. By using this rule and providing for additional radiation on the cold sides of a building and making allowance for poor construction, loose-fitting windows, doors, etc., good results will be obtained.

For Steam and Water Heating

This rule is based on outside temperature at zero and inside temperature at 70° for walls 12 in. thick. Corrections should be made for varying conditions as stated below.

C = contents in cubic feet.
W = exposed wall in square feet.
G = glass (windows and doors) square feet.
R = radiation in square feet.

Steam

$$\frac{(6C) + (80W) + (300G)}{1{,}000} = R$$

Water

$$\frac{(6C) + (80W) + (300G)}{600} = R$$

Example: A given room has 50 sq ft of glass, 220 sq ft of wall and 1,800 cu ft of space. Substituting the figures in place of letters in formula above:

$$\frac{(6 \times 1{,}800) + (80 \times 220) + (300 \times 50)}{1{,}000}$$

$$= \frac{10{,}800 + 17{,}600 + 15{,}000}{1{,}000} = 43.4 \text{ sq ft steam radiation.}$$

$$\frac{10{,}800 + 17{,}600 + 15{,}000}{600} = 72.3 \text{ sq ft hot-water radiation.}$$

Corrections for Varying Temperatures and Local Conditions

Add 1 per cent of radiation for each degree below zero outside or above 70° inside. Subtract 1 per cent for each degree above zero outside or below 70° inside.

Residences

For halls and dining rooms, use $10C$.
For bathrooms, use $20C$.
For bedrooms, use $5C$.

Exposures

Rooms on sides of prevailing winds should have radiation increased 10 per cent. Walls exposed to unheated rooms and spaces use $40W$.

Table 212.—Inside Temperatures Required

Public buildings	68–72°
Stores	60–70°
Shops and factories	60–65°
Residences and schools	70°
Bathrooms	80°
Hospitals	72–75°
Offices	70°
Paint shops	80°
Operating rooms	98°

Having determined the amount of radiation required for each room, the sizes and lengths of risers and other piping can be determined by Tables 214 and 215. The boiler to be chosen will be the one listed which comes nearest to having a margin of about 10 per cent over the total area of direct radiation or its equivalent, plus the radiating area of all exposed piping.

Boiler Rating.—The American Radiator Company gives the following figures as the amounts to be added to the direct radiation to take care of losses through piping, in computing the size of boiler required:

Table 213.—Computing Boiler Rating Required

Actual Area for Which Radiation Is Required, Sq Ft	Recommended Increase, Per Cent
100– 300	70–80
300– 450	65–70
450– 700	60–65
700–1,250	35–60
1,250–4,000	50

Note.—Where the rating of the boiler is given as the "net area of installed radiation," it is not necessary to make these increases, as allowance has already been made for them in computing the size of the boiler.

The United States Radiator Corporation also gives the following figures on the external areas of pipe:

TABLE 214.—EXTERNAL AREAS OF PIPES

Pipe Size, In.	External Area, Sq Ft per Lin Ft
¾	0.275
1	0.346
1¼	0.434
1½	0.494
2	0.622
2½	0.753
3	0.916
4	1.175
5	1.455
6	1.739
7	1.996
8	2.257

TABLE 215.—NUMBER OF BRANCHES SUPPLIED BY ONE LARGE PIPE

Size of Main Pipe, In.	No. and Size of Branches Supplied							
1							2	¾ in.
1¼							2	1 in.
1½							2	1¼ in.
2							2	1½ in.
2½	2	1½ in. and	1	1¼ in., or	1	2 in. and	1	1¼ in.
3	1	2½ in. and	1	2 in., or	2	2 in. and	1	1½ in.
3½	2	2½ in., or	1	3 in. and	1	2 in., or	3	2 in.
4	1	3½ in. and	1	2½ in., or	2	3 in., or	4	2 in.
4½	1	3½ in. and	1	3 in., or	1	4 in. and	1	2½ in.
5	1	4 in. and	1	3 in., or	1	4½ in. and	1	2½ in.
6	2	4 in. and	1	3 in., or	4	3 in., or	10	2 in.
7	1	6 in. and	1	4 in., or	3	4 in. and	1	2 in.
8	2	6 in. and	1	5 in., or	5	4 in. and	2	2 in.

TABLE 216.—PROPORTIONING SINGLE-PIPE STEAM MAINS
(United States Radiator Corp.)

Radiation, sq ft*	Total length of main, feet: 20 — Diameter, in.	Total length of main, feet: 40 — Diameter, in.	Return diam., in.
100	1½	1½	1
200	1½	1½	1¼
300	2	2	1¼
400	2	2	1¼
500	2½	2½	1¼
600	2½	3	1½
700	2½	3	1½
800	3	3	1½
1,000	3	3½	2
1,200	3½	4	2
1,400	3½	4	2
1,600	4	4	2½
1,800	4	5	3
2,000	4	5	3
2,500	5	5	3
3,000	5	5	3
3,500	5	6	3
4,000	5	6	3½
5,000	6	7	4
6,500	8	8	5

* Reduce all radiating surface to equivalent in direct surface.

With the data given in this chapter, and a working knowledge of steam and hot-water heating practice, a reasonably accurate design can be made for the heating plant in any moderate-sized house, store building or other comparatively simple building.

In the sections which follow, the methods for estimating the cost of such an installation, or any other heating installation, will be developed.

SECTION 3. SURVEYING HEATING QUANTITIES

With complete plans and specifications in hand, the surveying of most of the quantities for a heating estimate is not especially difficult. It does, however, require some practical knowledge of the methods of work and a great deal of careful attention to see that no items are overlooked.

Boilers.—On an ordinary job, when well planned, the first item would be the boiler, which should be listed by

Maker's name
Number and rating
Accessories required, such as gauges and other items not furnished with the boiler

Where other hand-fired coal is to be used, the kind and type of stoker or burner should be listed.

If the boiler requires a brick setting, included in the heating contract, note should be made of it, together with particulars as to the kinds of bricks specified.

On the larger installations, using high-pressure boilers with complicated settings, it is better practice to get a sub-bid from a contractor specializing in boiler settings than it is to attempt to estimate it oneself.

Direct Radiation.—When listing radiation for purchase, it is necessary to make a detailed schedule giving the pattern required, number of sections, height, area, etc.

Where different prices apply for radiation of different heights, it is necessary when estimating to segregate the amounts of radiation of different heights but when, as at present, manufacturers are quoting a single price per square foot for all sizes of radiation, it is necessary to know only the total amount of radiation required.

Some architects and engineers include, in their specifications, a complete schedule of all of the radiators required, but a more customary method is to indicate it by locations in the plans. In many cases, the basement or first-story plan will indicate the length and location of the horizontal mains, and the risers will be indicated by slanting lines off to the sides.

When that is done, the radiators on the upper stories will be shown diagrammatically in connection with the risers which supply them.

A recommended method of listing direct radiation for estimating purposes is to have one column in which are noted the locations of all radiators and an adjoining column in which are noted their sizes in square feet of radiation.

The first column can then be used to give the total number of radiators, which is necessary in figuring costs of setting, as well as the valves and accessories, and the second column can be used to determine the total quantity of radiation.

Indirect Radiation.—When indirect cast-iron radiation is used, the same procedure is to be followed as for direct radiation, except that the individual sizes, when listed, will be given on the basis of the number of square feet per section of radiator instead of by giving the height of the radiators.

The registers, housings, duct work, etc., used in connection with indirect radiation will be discussed later.

Heat and Vent Units.—The several forms of combined heating and ventilating units now coming into increasing vogue are specified generally by their capacity in cubic feet of air per minute.

The types known as unit heaters are most frequently specified by a catalogue or plate number, but sometimes by their capacity in Btu per hour under given conditions.

Pipe Radiation.—This type of radiation should be listed by the number of linear feet of each size of pipe. Of course, each coil will be all of one size of pipe, but different coils may use different sizes. When the necessary information is given, it should be noted in the quantity listed whether the coil is made up with return bends or manifolds or multiple-branch tees at one or both ends.

Where the length of pipe is not given but the number of square feet of radiation is given, the length of pipe required to give that number of square feet can be determined from Table 214.

Piping.—The process of scheduling the number of linear feet of piping for all hot-water and steam heating installations will be very similar to that for plumbing work, except that while there may be a wider range of sizes of piping there will probably be fewer different kinds of piping.

Steam piping in the larger sizes and for higher pressures may be put together with flanged joints, instead of screw joints, and this should be noted when scheduling.

Except in straight one-pipe installations it will be necessary to have return lines from all radiators, and these should be noted as carefully as supply lines.

In heating work, many of the changes in direction may be made with long radius bends of pipe, instead of with elbows. All such bends should be noted by giving size of pipe, length of bent portion, and whether it is a quarter-bend, half-bend, return-bend or expansion loop.

Some expansion loops are made with straight pipes and fittings, and these should be scheduled as ordinary pipe and fittings.

Fittings.—Fittings encountered in heating piping should be scheduled as previously outlined for plumbing work. Among the fittings to be scheduled in heating are

Elbows
Tees
Crosses
Y branches or laterals
Branch tees or manifolds
Double-branch elbows
Side-outlet tees
Reducers
Bushings

Fittings for flanged piping should be listed separately from those for screw-joint piping.

The bushings where branches enter the radiators are ordinarily supplied with the radiator and need not be listed separately.

Accessories.—Among the accessories that may be included in a heating system and that should be listed separately are

Valves
Radiator valves
Union elbows for return ends of hot-water radiators
Radiator brackets
Radiator enclosures
Radiator shields
Direct-indirect enclosures
Radiator feet or pedestals
Air valves on radiators
Air valves on mains
Floor and ceiling plates
Gauges (steam, altitude, vacuum)
Damper regulators
Traps
Thermostats
Water feeders
Water gauges
Draw-off cocks
Safety valves
Expansion tanks
Water circulators
Sliding expansion joints
Hangers
Roller supports
Clay conduit
Etc.

Steam gauges, vacuum gauges, air valves, safety valves and water gauges (or water columns) are not found in hot-water installations, while altitude gauges, expansion tanks and water circulators are found only in hot-water installations.

On all automatically fired installations, whether the fuel be oil, gas or coal, it is customary to include devices to dampen or extinguish the fire when the water becomes too low or when pressure or temperature becomes too high. These devices are generally included in the cost of the burner or stoker work but may sometimes have to be furnished by the heating contractor.

In listing heating accessories, as much detail as possible should be given as to

Maker's name
Style
Size
Finish

and any other characteristics that may be specified.

Insulation.—It is customary to insulate all boilers, and also all steam piping passing through spaces which it is not desired to heat. The amount of insulation required to cover a boiler varies with the type and make of boiler and can best be determined from the data given in the manufacturers' catalogues.

Practically all manufacturers give either the number of pounds of insulation required or the number of square feet of surface to be covered. The quantity of asbestos cement needed will vary from $3\frac{1}{3}$ lb per sq ft in the best grades to 6 or 7 lb per sq ft in the cheaper grades.

Jacketed boilers require no additional insulation, as the insulation is contained within the jacket.

Bronzing.—Where the painting or bronzing is to be done by the heating contractor, it is a comparatively simple matter to total the area of direct or direct-indirect radiation and to add to it the area of exposed piping.

The area of the piping, the lengths having already been scheduled for the purpose of determining the cost of pipe and insulation, can readily be determined from Table 214.

Indirect radiation and concealed piping will ordinarily be neither painted nor bronzed, but the specifications should be carefully examined to see if any such treatment is required.

SECTION 4. ESTIMATING HEATING COSTS

It is not amiss to repeat the admonition that the use of this or any other handbook will not make a successful estimator. Success will come from a proper appreciation and use of the methods outlined and data given in this book, accompanied by constant and painstaking observation of work under way and the collection of new data.

The essential procedure which this book attempts to teach is that of breaking up of every job into its component parts and estimating them with the greatest degree of accuracy that is possible, rather than of attempting to estimate by generalizations and short cuts.

Approximate Methods.—Mention has been made of one method of making an approximate estimate on a steam or hot-water heating job. Another method, somewhat more accurate but still only applicable for small and simple one-pipe steam jobs, is to list the

Price of the boiler
Cost of radiation at current price per square foot
70% of cost of boiler and radiation to cover piping and accessories
1 day of time of fitter and helper per radiator
Cost of compensation insurance
Social Security and Unemployment taxes
Overhead expense
Profit

For a small two-pipe steam job or a hot-water job, the 70 per cent for piping and accessories should be increased to 100 per cent and the time to 1½ days of fitter and helper per radiator.

Detailed Method.—The more satisfactory method of estimating is to figure the labor separately on each portion of the work and the materials separately from the latest current prices for each. The following paragraphs outline the procedure for the purpose of determining the amount of labor required.

Boilers.—Under ordinary conditions, an allowance of one hour of time of a fitter and helper, per section, will cover the cost of setting up any sectional cast-iron boiler up to 32 in. wide.

However, for a rule that will apply safely to all boilers of the general type, and that will allow for variations in weight and other factors, it is better to figure as in Table 217.

TABLE 217.—SETTING UP CAST-IRON BOILERS

Time of 1 fitter and 1 helper, hr	Steam rating, sq ft	Water rating, sq ft
4 for first	600	1,100
1 for each additional	200	320

Insulation.—The labor cost of applying insulation can be determined from Table 218.

TABLE 218.—INSULATING BOILERS AND PIPING

	Time, Hr
Plastic insulation per 100 sq ft, 1¼ in. thick	16
Plastic per 100 lb	2.7–6
Sectional per 100 lin ft pipe, 3 in. or under	5
Sectional per 100 lin ft pipe, 4, 5, or 6 in	6

Information regarding the area to be covered or the actual amount of insulation required for the boiler should always be obtained from the manufacturer, as the quantity will vary greatly among different boilers for the same rating.

Brick Settings.—Where a brick setting is required, it is essential to obtain the number of fire bricks and the number of common bricks required. This information should be obtained directly from the manufacturers. Building estimators' handbooks frequently give the number of bricks required for boilers of various sizes, but on investigation it will be found that the tables of quantities have been compiled with some particular make or type of boiler in mind and that the figures are not applicable to other types.

If it is not convenient to obtain a sub-bid from a mason contractor to do all of the brickwork in connection with the boiler setting, the cost may be estimated by referring to Chap. 4.

Piping.—The labor cost of installing the piping can be calculated from Table 219.

TABLE 219.—STEAM AND HOT-WATER PIPING

Pipe Size, In.	Time per Gang (Fitter and Helper) per 100 Lin Ft of Pipe, Hr
1	9
1¼	10
1½	12
2	14
2½	17
3	20
3½	23
4	26
4½	28
5	30
6	36

Consider each special or fitting as equal to 8 lin ft of the same size as straight pipe. Consider each bend as equal to six times the length of the same size of straight pipe. The time in this table includes the installation of floor and ceiling plates.

Flanged Work.—The above table is for screw-joint work. Flanged work will take approximately twice as much time as the same size of pipe in screw-joint work. It is not likely that much flanged work will be encountered in the smaller sized piping.

Radiation.—The labor cost of setting up radiators, which includes the time necessary to bring them into place, install and connect the radiator valve and air valve, is calculated from Table 220.

In multistoried office buildings, hotels and apartment houses, add 2 hr of helper's time and ⅓ hr of elevator time for each 100 sq ft of radiation for each 10 stories above the third.

Accessories.—The following table gives the average time necessary for setting up the accessories ordinarily encountered.

TABLE 220.—INSTALLING RADIATION

Radiation	Time per gang (1 fitter and 1 helper) per unit, hr	
	1-pipe work	2-pipe work
Direct radiators:		
Up to 80 sq ft	1.5	2
Up to 100 sq ft	2	2.5
Each additional 20 sq ft	0.25	0.3
Direct-indirect casings	4	4
Indirect radiators:		
Per section	....	0.5
Unit ventilators	....	8
Unit heaters	....	3
Pipe coils	Figure as in Table 219	
Branch tees	Figure each connection as one fitting, in accordance with Table 219	

TABLE 221.—INSTALLING ACCESSORIES

Accessories	Time per Gang (1 Fitter and 1 Helper) per Unit
Air valves on mains	1
Vacuum vapor pump, etc	60
Automatic expansion tank	9
Alternating receiver	18
Hot-water heater	12

Gate valves, check valves and similar items will take the same time as allowed in Table 219 for 10 ft of straight pipe of the size in which they are installed.

Electrical Connections.—Estimates on the cost of electrical connections required for oil burners, stokers, unit ventilators, unit heaters, etc., should always be obtained from electrical contractors, as local conditions may cause a wide variation in the cost of such work.

Bronzing or Painting.—Having determined the total area of radiation to be covered, the cost can be estimated from Table 222.

TABLE 222.—BRONZING RADIATORS

Quantities and time per 100 sq ft of surface per coat

Aluminum bronze powder	0.17	lb
Other bronze powders	0.34	lb
Bronzing liquid	0.34	qt
Labor, by hand	1.5	hr
Labor, with spray gun	1	hr

Welding.—While welding of certain parts of the material used in a steam heating job that cannot be done on the job has been in vogue for sometime, there is a tendency being developed to have some of the field work done by portable electric welding outfits. This development is yet too new to afford many definite data, but Table 151, compiled from information furnished by Westinghouse Electric and Manufacturing Company, which will be helpful in estimating costs, has been included in Chap. 10.

TABLE 223.—CIRCUMFERENCE OF PIPES

Pipe Size, In.	Circumference, In.
¾	3.3
1	4.13
1¼	5.22
1½	6.0
2	7.5
2½	9.0
3	11.0
3½	12.6
4	14.14
5	17.5
6	20.81
8	27.10
10	33.8

The estimate which follows is one that was prepared for the heating installation to go in the same Federal building as that for which the plumbing estimate is given in Chap. 18.

The installation is a vacuum heating system. The painting and bronzing of radiators and exposed piping are in other parts of the contract. There is no brickwork to be done by the heating contractor.

The schedule of radiation, as taken from the heating plans, is as shown on page 348.

INSTALLING RADIATORS

73 radiators	80 sq ft and under	@	1.50...	109.5
9 radiators	80 to 100 sq ft	@	2.00...	18
2 radiators	100 to 120 sq ft	@	2.25...	4.5
4 radiators	120 to 140 sq ft	@	2.50...	10
12 radiators	140 to 160 sq ft	@	2.75...	33
				175.0 hr

175.0 hr @ $1.85 = $323.75

SCHEDULE OF RADIATION

Radiators	Area each	Totals	Size of valve
1	14	14	1
1	18	18	1
1	19	19	1
3	22	66	1
1	28	28	1¼
1	30	30	1¼
4	33	132	1¼
1	36	36	1¼
7	38	266	1¼
1	40	40	1¼
9	41	369	1¼
4	44	176	1¼
7	46	322	1¼
6	49	294	1¼
2	52	104	1¼
1	55	55	1¼
1	58	58	1¼
3	60	180	1¼
2	68	136	1½
1	71	71	1½
2	72	144	1½
3	74	222	1½
3	77	231	1½
8	80	640	1½
1	84	84	1½
1	89	89	1½
5	93	465	1½
2	94	188	1½
2	112	224	2
4	130	520	2
12	150	1,800	2
100		7,021	

7,021 sq ft @ $0.38	$2,667.98
Less 25% discount	666.99
	$2,000.99

Piping and Accessories

Pipe		
2,216 ft ¾ in.	@ $ 0.11½	254.84
738 ft 1 in.	@ 0.17	125.46
1,604 ft 1¼ in.	@ 0.23	368.92
230 ft 1½ in.	@ 0.27½	63.25
568 ft 2 in.	@ 0.37	210.16
116 ft 2½ in.	@ 0.58½	67.86
110 ft 3 in.	@ 0.76½	84.15
92 ft 3½ in.	@ 0.92	84.64
122 ft 4 in.	@ 1.09	132.98
196 ft 5 in.	@ 1.48	290.08
44 ft 6 in.	@ 1.92	84.48
Tees		
20 ¾ × ¾	@ 0.13	2.60
7 1 × 1	@ 0.17	1.19
30 1¼ × 1¼	@ 0.26	7.80
4 1¼ × ¾	@ 0.29	1.16
17 1½ × 1½	@ 0.33	5.61
2 1½ × 1¼	@ 0.37	0.74
4 2 × 2	@ 0.52	2.08
10 2 × 1½	@ 0.57	5.70
4 2 × 1¼	@ 0.57	2.28
8 2½ × 2	@ 0.90	7.20
3 2½ × 1¼	@ 1.00	3.00
6 3 × 2	@ 1.45	8.70
9 3 × 1½	@ 1.45	13.05
9 3 × 1¼	@ 1 45	13.05
10 3½ × 2	@ 2.20	22.00
2 3½ × 2½	@ 2.20	4.40
3 4 × 2½	@ 2.65	7.95
4 4 × 2	@ 2.65	10.60
8 4 × 1¼	@ 2.65	21.20
21 5 × 2	@ 4.70	98.70
16 5 × 1¼	@ 4.70	75.20
2 6 × 1½	@ 6.60	13.20
1 6 × 2	@ 6.60	6.60
1 6 × 5	@ 6.60	6.60
Eccentric reducers		
1 6 × 5	@ 3.75	3.75
2 5 × 4	@ 3.15	6.30
2 4 × 3½	@ 1.40	2.80
2 3½ × 3	@ 1.10	2.20
2 3 × 2½	@ 0.75	1.50
90-deg. elbows		
564 ¾ in.	@ 0.10	56.40
160 1 in.	@ 0.13	20.80
134 1¼ in.	@ 0.20	26.80

Piping and Accessories.—(*Continued*)

49 1½ in.	@ $ 0.25	$ 11.25
88 2 in.	@ 0.40	35.20
13 2½ in.	@ 0.72	9.36
14 3 in.	@ 1.00	14.00
5 3½ in.	@ 1.50	7.50
4 4 in.	@ 1.80	7.20
5 5 in.	@ 3.25	16.25
8 6 in.	@ 4.65	37.20
Check valves		
1 1 in.	@ 1.60	1.60
Valves		
4 2 in.	@ 4.75	19.00
Drain valve		
1 ¾ in.	@ 1.75	1.75
Gate valves		
14 1 in.	@ 2.50	35.00
7 1¼ in.	@ 3.50	24.50
5 1½ in.	@ 5.00	25.00
11 2 in.	@ 7.50	82.50
8 2½ in.	@ 13.50	108.00
2 3½ in.	@ 26.50	53.00
2 5 in.	@ 120.00	240.00
3 6 in.	@ 170.00	510.00
Combination traps		
113	@ 6.00	678.00
Radiator valves		
6 1 in.	@ 4.50	27.00
48 1¼ in.	@ 5.75	276.00
28 1½ in.	@ 7.30	204.40
18 2 in.	@ 12.00	216.00
Floor and ceiling plates		
296	@ 0.22	65.13
		$4,932.82
	Average discount 55%	2,713.05
		$2,219.77

In estimating the hours of labor required for the piping and accessories listed above, valves and traps were considered as the equivalent of fittings. The figures obtained were as follows:

Labor on Piping and Accessories

2,216 ft ¾-in.	pipe and 698 fittings	equal 7,800	@ 9 hr per 100	702
738 ft 1-in.	pipe and 188 fittings	equal 2,242	@ 9 hr per 100	201.8
1,604 ft 1¼-in.	pipe and 223 fittings	equal 3,388	@ 10 hr per 100	338.8
230 ft 1½-in.	pipe and 102 fittings	equal 1,046	@ 12 hr per 100	125.5
568 ft 2-in.	pipe and 235 fittings	equal 2,448	@ 14 hr per 100	342.7
116 ft 2½-in.	pipe and 32 fittings	equal 372	@ 17 hr per 100	63.2
110 ft 3-in.	pipe and 40 fittings	equal 430	@ 20 hr per 100	86
92 ft 3½-in.	pipe and 21 fittings	equal 260	@ 23 hr per 100	59.8
122 ft 4-in.	pipe and 25 fittings	equal 322	@ 26 hr per 100	83.7
196 ft 5-in.	pipe and 46 fittings	equal 564	@ 30 hr per 100	169.2
44 ft 6-in.	pipe and 16 fittings	equal 172	@ 36 hr per 100	61.9
				2,234.6

2,234.6 hr @ $1.85 = $4,134.01

Insulation

180 sq ft 1½-in. air cell block insulation on breeching	@ $1 05	$ 189.00
2,400 lb plastic insulation on boilers	@ 0.01¾	42.00
12,000 lb plastic insulation on fittings	@ 0 01¾	210.00
400 ft sectional insulation on ¾-in. pipe	@ 0 24	96.00
318 ft sectional insulation on 1-in. pipe	@ 0.27	85.86
480 ft sectional insulation on 1¼-in. pipe	@ 0.30	144.00
70 ft sectional insulation on 1½-in. pipe	@ 0.33	23.10
408 ft sectional insulation on 2-in. pipe	@ 0 36	146.88
110 ft sectional insulation on 3-in. pipe	@ 0.45	49.50
92 ft sectional insulation on 3½-in. pipe	@ 0.50	46.00
122 ft sectional insulation on 4-in. pipe	@ 0 60	73.20
196 ft sectional insulation on 5-in. pipe	@ 0.70	137.20
44 ft sectional insulation on 6-in. pipe	@ 0.80	35.20
		$1,277.94
Discount 50%		638.97
		$ 638.97

The labor on the insulation was figured thus:

180 sq ft block insulation @ 4 hr per 100...........	7.2
12,400 lb plastic insulation @ 4 hr per 100............	496
1,786 lin ft 3-in. and under sectional @ 5 hr per 100...	89.3
454 lin ft 6-in. and under sectional @ 6 hr per 100...	27.2
	619.7

619.7 hr @ $1.85 = $1,146.44

The boilers and remaining items were figured as follows:

30 ft trench cover and frame	@ $	1.50	$ 45.00
2 steel smokeless boilers, each 4,746 sq ft rating	@	677.50	1,355.00
16 ft 28 × 28 steel breeching			64.00
2 dampers			24.00
1 ash hoist			185.00
2 vacuum pumps, complete			550.00
2 vacuum gauges			20.00
2 steam gauges			26.00
2 safety valves			24.00
Miscellaneous boiler trimmings, etc.			40.00
			$2,333.00

The labor cost of installing these items was figured thus:

Boilers and trimmings	52 hr
Trench cover	15 hr
Vacuum pumps	120 hr
Breeching	8 hr
Ash hoist	8 hr
	203 hr

203 hr @ $1.85 = $375.55

The summary follows:

	Labor	Materials
Radiation	$ 323.75	$2,000.99
Piping and accessories	4,134.01	2,219.77
Insulation	1,146.44	638.97
Boiler, pumps, etc	375.55	2,333.00
Totals	$5,979.75	$7,192.73
Total in labor column		$ 5,979.75
Total in materials column		7,192.73
Compensation insurance 5%		298.99
Haulage		150.00
Contingencies		200.00
Overhead and profit		2,052.00
Total		$15,873.47

On the basis of 7,021 sq ft of radiation, this would equal $2.04 per sq ft average.

SECTION 5. VENTILATING AND SHEET-METAL WORK. HOT-AIR HEATING

Quantities.—When the heating system is to be combined with a ventilating system the sheet-metal work required for ventilating ducts and shafts must be estimated separately, either giving the length in feet of each size of duct or shaft, or else reducing the quantities to the number of pounds of metal required.

In hot-air heating, the number of sizes of ducts required is small and their arrangement is comparatively simple, so it is customary to make the estimate entirely on the basis of the number of linear feet of duct and the number of specials for branches, if any.

The best practice for the larger work is to convert all of the quantities of metal into pounds and to estimate on that basis. An allowance of 10 per cent, added to the computed quantities, will cover the necessary laps and reinforcements. If all curves and bends are figured as straight ducts along their outside dimension, the extra weight so included will be ample to cover waste due to the necessary irregular cutting.

A separate list should, of course, be made of all

Intake screens and louvers
Dampers
Registers
Exhaust vent heads and hoods
Motors
Fans
Switches

and other equipment to be included in the system.

Weights of Ducts and Pipe.—The weight of round ducts and piping may be taken directly from Table 224. In this table allowance has been made for laps, trimmings, rivets and solder.

TABLE 224.—WEIGHTS OF GALVANIZED-IRON PIPE
(*Courtesy, United States Radiator Corp.*)
(In Pounds per Running Foot)

Diam. of pipe, in.	Gauge of iron				
	No. 24	No. 22	No. 20	No. 18	No. 16
5	1¾	2	2½	3⅜	4
6	2⅛	2½	3	4	4¾
7	2½	3	3½	4⅝	5½
8	2⅞	3⅜	4	5¼	6¾
9	3¼	3¾	4½	5⅞	7
10	3½	4	5	6½	7⅝
11	3¾	4¼	5½	7	8¼
12	4	4⅝	6	7½	9
13	4¼	5⅛	6½	8⅜	10
14	4⅝	5½	7	8	11
15	5	6	7½	9⅝	12
16	5½	6½	8	10¼	13
18	6	7¼	9	11½	14¼
20	6½	8	10	12¾	15½
22	7¼	8¾	11	14	16¾
24	8	9⅝	12	15¼	18½
26	8¾	10½	13	16½	20
28	9½	11⅜	14	18	21½
30	10	12¼	15	19⅜	23
32	....	13⅛	16	20¾	24⅝
34	....	14	17	22	26¼
36	....	15	18	23¾	27⅞
38	....	16	19	24½	29½
40	....	17	20	26¼	31¼
42	....	....	21	28	33
44	....	....	22	29¾	35
46	....	....	23	31½	37
48	....	....	24	33¼	39
50	....	....	25	35	41
52	....	....	26	36¾	43
54	....	....	27	38½	45
56	....	....	28	40¼	47
58	....	....	29	42	49
60	....	....	30	43¾	51

For rectangular pipe and ducts, the weight per linear foot is to be determined from Table 225.

TABLE 225.—UNITED STATES STANDARD GAUGE FOR STEEL AND IRON PLATES AND SHEETS

Gauge number	Weight, lb per sq ft	
	Black	Galvanized
16	2.5	2.7
18	2.0	2.2
20	1.5	1.7
22	1.25	1.4
24	1.00	1.17
26	0.75	0.91

For instance, if a duct is 24 by 48 in. in size and to be made of 18-gauge galvanized metal, the perimeter of the duct would be twice 2 ft plus twice 4 ft or 12 ft, or an area of 12 sq ft of metal per linear foot.

At 2.2 lb per sq ft, as in Table 225, and allowing for laps and reinforcements, the weight per linear foot would be

2.2 lb × 12 sq ft............	26.4
plus 10 per cent.............	2.64
Total weight..............	29.04 lb per lin ft

Labor Costs.—The great variety of sizes of piping or ducts that would be used in even a moderate-sized ventilating system, as, for instance, a school building, make it difficult to obtain detailed data or the labor costs of forming and installing the sheet-metal work.

This may explain why, except in districts where several contractors work somewhat together to establish a reasonable price basis, there is such a wide variety in the prices bid for a specific job. For all work that would be encountered in the average run of installations, the following figures may be used:

TABLE 226.—SHEET-METAL WORK IN VENTILATING

Work	Time of 1 Mechanic and 1 Apprentice or 2 Mechanics, Hr per 1,000 Lb of Metal*
Shop work	32
Erection	26

* Figure each elbow, damper or bend as equivalent to four feet of the same size duct in which it occurs. Add this quantity to the total quantity of metal actually required, in order to compute the necessary labor.

Where labor conditions permit, much of the hoisting and similar work, included under the heading of Erection, may be done by laborers.

Accessories.—The various other items to be installed may be figured in accordance with Table 227, but all mechanical and electrical features and specialties will ordinarily be installed either by the manufacturers or by persons specializing in those lines.

Estimates should always be taken on all such items, as any attempts to guess at or approximate costs may result in serious errors in a bid.

TABLE 227.—MAKING AND INSTALLING ACCESSORIES IN VENTILATING SYSTEM

Accessories	Time for 1 mechanic and 1 helper or 2 mechanics, hr	
	Shopwork	Erection
Louvers and frames per sq ft	12	12
Registers per sq ft	..	2
Vent heads and hoods per 100 lb	10	12
*Ready-made ventilators per 100 lb	..	12
†Machinery per 1,000 lb	..	15

* Get weights of ventilators from manufacturers' catalogues.

† Get installed prices from manufacturers whenever possible. Otherwise, get weights from manufacturers.

Warm- and Hot-air Heating.—Many of the types of warm- and hot-air furnaces now on the market are being installed by direct representatives of the manufacturers. These manufacturers are, or should be, in possession of accurate data as to the costs of installing the several sizes of their furances and accessories.

For general work, the cost of the ducts, pipes or stacks required for any warm- or hot-air installation can be figured on the basis of the preceding paragraphs.

The installation of the furnace and its casing may be figured on the basis of 2 hr time of mechanic and helper for each 100 lb or fraction thereof of the combined weight of furnace and casing as given in the manufacturers' catalogues.

CHAPTER 20

SUMMARY

SECTION 1. SUB-BIDS

A diligent study of the preceding chapters should give the student a grasp of all the subjects covered, and, with a reasonable amount of practical experience, he should be prepared to do all of the estimating usually required in the office of a general building contractor.

It is true that there are many building contractors who make a practice of taking every item in detail from the plans, even though it is their practice to sublet a great deal of the work, but it is believed that it is easier and safer always to get reliable sub-bids on every item that will eventually be sublet.

In cases of emergency, when no sub-bids are available, the builder must be prepared to estimate many items of subcontractors' work. Even so, it is well to remember that, no matter how complete his knowledge of the subject may be, the man actually engaged in a particular line has much greater opportunities for keeping up to date than any builder has, both as regards labor and material prices and conditions in the trade. Furthermore, if the sub-bidder is reliable, his figure will stand and relieve the general contractor of any further concern as to its correctness.

On the other hand, if he always deals fairly with all his sub-bidders, he will find very few occasions when he will not be able to get all the sub-bids he needs.

Needless to say, fairness requires that a sub-bidder whose figure is used to make up a successful bid should be awarded the subcontract without further question and without "dickering."

The practice of "shopping around" after a contract has been awarded, in order to let subcontracts at lower figures than those of the sub-bidders whose figures were used, is a very pernicious one. Besides making the sub-bidders suspicious of all general contractors, it encourages them to add large percentages to their figures for the sole purpose of "knocking off" later on.

Thus, a general contractor who is known to be a "shopper" may lose valuable opportunities because all the sub-bids he receives will be so high as to throw his own bid out.

If a contractor must shop around after receiving contracts, then he should estimate every item himself and take his own chances of being able to sublet for less than his estimate.

The methods to be used in getting sub-bids will vary with the size of the job, location and local conditions.

When competition for the general contract is fairly open, as in the case of most public buildings, plans will be on exhibition at all of the general contractors' offices and all sub-bidders will have access to them at one office or another.

In such instances it is only necessary to send out postal card requests to the several sub-bidders who are known to be actively interested in the lines of work to be included.

On small jobs, or jobs for which the competition is more restricted, it is usually necessary to invite sub-bids from people with whom the builder usually deals and sometimes to take the plans and specifications to them.

With the stated purpose of securing fair competition for bidders on construction of public works, the following amendment to the Massachusetts law was adopted in 1939. It applies to all cities and towns in Massachusetts and has been used very largely in other parts of New England. Whether it will accomplish its avowed purpose remains yet to be determined.

(*A*) . . .

(*1*) Bids from general contractors shall be for the complete project as specified and shall include the names of all principal and such minor subcontractors as are designated in the proposal form, and the general contractor shall be selected on the basis of such bid.

(*2*) Each bid shall be divided into two items:

Item 1, covering all the work of the general contractor, being all work not covered in item 2.

Item 2, covering the work of such subcontractors, and the estimates therefor, as are listed in the proposal form for general contractors, attached thereto.

(*B*) All principal and such minor subcontractors as are designated in the proposal form shall deliver or mail to the awarding authority record copies of all bids sent by them to the general contractor. All such bids shall be in sealed envelopes, plainly marked on the outside with the subcontractor's name, and shall also have marked on the outside the name or names of bidders they include in their bids for any portion of the work, involving labor and materials. All bids shall be delivered or mailed to the awarding authority, and mailed to the general contractor, by twelve o'clock noon at least two days before the date for receipt of general contract proposals. The date and time limit for receipt of such bids shall be stated in each section of the specifications. No recorded sub-bids shall be opened by the awarding authorities until after the selection of the general contractor.

No sub-bid shall be considered in the final selection of sub-bidders, as hereinafter described, except those filed with the awarding authority as above provided.

Each sub-bidder shall endorse the copy of his bid filed with the awarding authority as follows: "The above proposal is being sent to the following general bidders:..................

....

The proposal may not be used by any other general contractor without the consent of the undersigned," and sign such copy.

(*C*) The names of all sub-bidders who filed their bids with the awarding authority shall be mailed on date of receipt to the general contractors bidding on the project and no sub-bidder not included on such list shall be used by the general contractor in his bid.

(*D*) If after the selection of the general contractor, it be decided to consider subcontractors other than the ones named by the general contractor in his proposal, the awarding authority, architect and engineer, or any one or more of them, and the selected general contractor shall jointly consider the names of all proposed sub-bidders and their amounts, as given in the general contractor's proposal. Any agreement to substitute the name of a subcontractor other than the one named in the general contractor's proposal shall cause an adjustment of contract price at the net difference in accordance with the sub-bidders of record filed with the awarding authority. The subcontractors so selected shall be notified of their selection within twenty-four hours thereafter by the awarding authority.

(*E*) If a subcontractor who has been selected and included in the general contract fails to sign the subcontract within ten days after notice of selection, the awarding authority, architect and engineer, or any one or more of them, and the general contractor shall select, from the sub-bidders who have conformed to the bidding procedure, the next lowest bidder at the amount named in such sub-bid, and the total contract price shall be revised in accordance with the change in figures as submitted.

The awarding authority shall reserve the right to reject all sub-bids on any item or items; provided, that it is agreed by and between the bidders and the awarding authority that none of such bids represents the bid of a person or firm competent to perform the work as specified, or that only one such bid was received and that the price is not reasonable for acceptance without competition. If a rejection of a sub-bid occurs, new bids shall be requested on such item or items as may have been rejected, which shall in no way affect the other sub-bidders who have conformed to the prescribed bidding procedure.

(*F*) If a general bidder customarily performs with his own employees any sub-trade or trades listed in item two of the proposal, he may submit a sub-bid proposal on the form as herein required of all regular subcontractors, with an endorsement controlling its use, and shall also submit his name and amount for such work in his own proposal for the general work under item two. Such submission by the selected general contractor shall be considered on a par with sub-bids filed with the awarding authority by sub-bidders who customarily perform such work, and selection shall be made as provided above in (*E*). No such sub-bid by a general bidder shall be considered, however, unless the general bidder can show, to the satisfaction of the awarding authority, that he does customarily perform such work, and is qualified to do the character of work required by the specifications.

Draft of Proposal Form

To. . . . . (awarding authority)
. . . .

(*a*) The undersigned proposes to furnish all the labor and materials required for the construction of. . . . .
. . . .
on. . . . .
street, ... (city), Massachusetts, for . . . . (owner) in accordance with the accompanying specifications and plans prepared by . . . . (name), of . . . . (address), for the sum specified below, subject to additions and deductions according to the specifications and in all respects according to the terms thereof.

(*b*) The undersigned agrees that if within. . . .days from the day named for delivering the proposal to the awarding authority, notice that this proposal will be accepted by the awarding authority shall be mailed to him at the business address given below, or shall be delivered to him, he will, within ten days thereafter, deliver to the awarding authority where directed a contract properly executed in (triplicate, or otherwise) on the forms annexed with such changes therein as shall have been made by the awarding authority prior to the time named for delivery of this proposal, together with a bond of a surety company satisfactory to the awarding authority in the sum of. per cent of the contract price, the premium for which is to be paid by the contractor and is included in the contract price.

(*c*) The proposed contract sum is. . . . . dollars ($. . . . .).

(*d*) The subdivision of the proposed contract sum is as follows:

Item 1. The work of the general contractor, being all work other than that covered by the following item 2. . . . . dollars ($. . . . .).

Item 2. Sub-bids as follows:

	Bidder.	Amount.
(1)	. . . .	$. . . . .
(2)	. . . .	. . . .
(3)	. . . .	. . . .
Etc.	. . . .	. . . .
Total of item 2		$. . . . .

The undersigned agrees that the list of sub-bidders represent bona fide bids based on the plans and specifications, made in good faith to the bidder, and are hereby submitted and that, if the undersigned is awarded the contract, they will be used for the work indicated, at the amounts stated, if satisfactory to the awarding authority as provided in article......of the general conditions.

The undersigned agrees that if he is selected as general contractor he will promptly confer with the awarding authority on the question of sub-bidders and that the awarding authority may substitute for any sub-bids listed above, the names and amounts of sub-bids as submitted for this work and filed with the awarding authority, as required by the notice to bidders, against whose standing and ability the undersigned makes no objection, and that he will use all such finally selected sub-bidders at the amounts so named and be in every way as responsible for them and their work as if they had been originally named in this proposal, the total contract price being adjusted to conform thereto.

Bidder ....

Address ....

Proposal Form

(*Sub-bidder*)

To..................................(general contractor)

....

(*a*) The undersigned proposes to furnish all the labor and materials required for the completion of all the work specified under the sub-heading...................................

.....................Paragraphs No....................

to No..............., inclusive, in accordance with the plans and specifications prepared by.......................

for (name or other description of building) located on.........

street................................city,........state,

for.......................................owner, for

the contract sum of...........................dollars

($....................).

The undersigned further agrees to be bound to the general contractor by the terms of the general conditions, drawings and specifications, and to assume toward him all the obligations and responsibilities that he, by those documents, assumes toward the owner.

The undersigned offers the following information as evidence of his qualification to perform the work as bid upon according to all the requirements of the plans and specifications.

1. Have been in business under present business name ....years.
2. Ever failed to complete any work awarded?.............
3. List one or more recent buildings with names of general contractor and architect on which you served as sub-contractor for work of similar character as required for the above named building.

Building Contractor	Architect contract
(a)	Amount your Contract
(b)	
(c)	

4. Bank Reference:

Note: The sub-bidder may add the following information in filing copy of his bid with the awarding authority. If such information is not so submitted, it shall be understood that his proposal is available for use with whatever general contractor is selected.

The above proposal is being sent to the following general bidders:

....

....

....

The proposal may not be used by any other general contractor without the consent of the undersigned.

Respectfully submitted,

....

Section 44D. If any provision of sections forty-four A to forty-four C inclusive, or the application of such provision to any person or circumstance, shall be held invalid or unconstitutional, the remainder of said sections, or of any section, subsection, sentence, clause or phrase thereof, or the application of such provision to any person or circumstance other than that as to which it is held invalid or unconstitutional, shall not be affected thereby.

Approved August 12, 1939.

SECTION 2. VISITING THE SITE

In the discussion of the cost of excavating, we gave a list of information to be obtained when visiting the site of any work upon which a bid is being made.

In addition to the items mentioned there, be sure to get the local prices on any materials available for use in the work, costs of carting, sub-bids from near-by bidders when possible, and information as to any local rules or regulations which may have a bearing upon the figures.

Many architects and engineers put clauses in contracts that require the builder to comply with all local regulations, even though not recited in the specifications.

Such a clause as this might make the sidewalk protection, or even the working staging, cost twice as much as would otherwise be figured; it might make it necessary to put an extra coat of paint on the steelwork, or an extra coat of plaster on the walls and ceilings, or do a lot of expensive firestopping that had not been considered at all.

There are also rules regarding the use of streets and alleyways that may affect costs and, in times of labor shortages, the fact that another large operation is going on near by may cause labor costs to mount high, either through increased wages or decreased production.

The availability of and rates at suitable boarding places will also affect the readiness of men to go to a given location, and it may be necessary at times to provide quarters and commissary for them. It is a very rare occurrence when a job commissary pays its own cost, so the loss on the commissary must be figured as part of the cost of doing the work.

SECTION 3. MAKING UP THE ESTIMATE

The number of different forms used for estimating is almost as great as the number of contractors who make estimates. Some use stock forms, some use specially ruled and printed forms, some use loose sheets and some use books.

Some contractors combine the unit labor and material prices before multiplying by the quantity, but I prefer to keep a separate column of labor costs and one of material costs.

A construction company with which I was associated for a time used a book made up of quadrille-ruled sheets with a dollars-and-cents column at the right and left hand sides of each page, one book of about 30 pages being used for each estimate. The "take-off" or survey of quantities was made in the middle of the page and extended to totals for each subject. After calculating the unit labor and material prices for each item, the extension of the labor cost was made into the left hand column, and that of the material cost was made into the right hand column, all the prices on each side which made up any subhead of the estimate were then added up, a double blue-pencil line was ruled under each total, and this transcribed onto the summary page.

The summary might appear something like this:

Name of Job
Location
Architect or Engineer Date

Labor		Materials
$ 1,500.00	Preliminaries (page 3)..............	$ 500.00
1,925.00	Excavation and grading (page 5)....	....
2,750.00	Concrete and forms (page 9)........	3,950.00
5,675.00	Brickwork (page 12)...............	9,250.00
....	Plastering (sub-bid), (page 13)......	5,500.00
1,800.00	Rough carpentry (page 15)..........	3,650.00
2,230.00	Finish carpentry (page 17)..........	4,575.00
....	Roofing and sheet-metal work (sub-bid) 18..........................	1,550.00
....	Plumbing (sub-bid) 19.............	2,500.00
....	Heating (sub-bid) 20...............	5,000.00
....	Wiring (sub-bid) 21................	900.00
....	Allowances.......................	500.00
$15,880.00		$37,875.00

Total labor........................	$15,880.00
Materials..........................	37,875.00
	$53,755.00
10 per cent profit.................	5,375.00
Bid................................	$59,130.00

Such a method has the advantage of not carrying a running total from page to page, and it is thus possible to make changes or corrections in any page without having to erase the total on all of them. To be sure that all subtotals are carried into the summary, all the blue-underlined figures should be added together directly from the individual sheets to see that they equal the total in the summary.

It has been found helpful to recapitulate all totals thus:

		Per cent
1. Preliminaries........	$ 2,000.00	3.7
2. Direct labor.........	14,380.00	26.7
3. Materials............	21,425.00	40.0
4. Sub-bids.............	15,450.00	28.7
5. Allowances..........	500.00	0.9
	$53,755.00	100.0

This recapitulation affords an opportunity to compare various portions of the present estimate with previous estimates and sometimes to show up a difference that might otherwise be overlooked. It is helpful in cases of sharp competition where the bidder wants to figure a smaller percentage of profit on such items as sub-bids and allowances, but to retain the full percentage on such items as labor.

In making up the estimate, when a sub-bid is used, it is customary to write in the name of the sub-bidder, together with any pertinent information, on one of the pages, and then carry the figure into the summary like any other figure but to make a notation as indicated.

Ordinary journal paper, which has two sets of dollars-and-cents columns on the righthand side, can be used, one column for labor items and the other for materials and sub-bids

Summary of Estimate

Building Date
Location
Architect
Stories in height Ground area
Floor area Contents
(See Sheet 2 for dimensions and calculation)

	Sheet	Labor	Materials
General conditions			
Excavation, earthwork, drains			
Plain concrete work, inc. forms			
Reinforced concrete work, inc. forms			
Brickmason's work			
Furring, lathing, plastering			
Millwork and trim, screens, weatherstrips			
General carpenter work (except forms)			
Kalamcined and metal windows and doors			
Storefronts and plate glass			
Structural steel, ornamental and miscellaneous iron, bronze			
Iron and steel bucks, trim and specialties			
Lockers, cabinets, metal partitions			
Linoleum, rubber, cork, etc			
Terrazzo, marble, tile, slate			
Roofing and sheet metal work			
Elevators, dumbwaiters, lifts			
Waterproofing and damp-proofing			
Demolition and shoring			
Plumbing, heating, ventilating, sprinklers			
Wiring, fixtures, clock systems			
Painting and decorating			
Totals		$	$

Recapitulation

General conditions	
Ordinary pay roll	
Allowances	
Materials	
Construction subs	
Mechanical subs	
Estimated net cost..................	$
Estimated profit....................	$
Recommended bid..................	$

General Conditions

	Labor	Materials
Pay for plans, extra blueprints, etc.......		
Bond..................................		
Liability and compensation insurance.....		
Fire insurance..........................		
Superintendent.........................		
Timekeeper............................		
Watchman..............................		
Job engineer...........................		
Temporary buildings and toilet..........		
Temporary light and heat...............		
Temporary enclosures...................		
Temporary elevator.....................		
Survey and batters.....................		
Permits and fees.......................		
Use of tools and equipment.............		
Transp. of tools and equipment..........		
Small tools............................		
Sidewalk protection....................		
Photographs...........................		
Sampling and tests.....................		
Clean and remove rubbish...............		
Water for building purposes............		
Telephone service and tolls.............		
Traveling expense......................		
Social Security and unemployment insurance............................		
Totals............................		

SECTION 4. REMINDER LIST

Some contractors use a reminder sheet, containing a list of items usually entering into the construction of buildings, and the estimator may check off each item as he figures it. These reminder lists are helpful, but have the disadvantage that it is impossible to prepare one that will be complete. Also, an estimator might depend too much upon the list and neglect to scan the plans and specifications carefully for little notes and inconspicuous clauses. The following will be found helpful but is not exhaustive.

Excavation, Earthwork, Drains

Clearing site
Removal and protection of trees and shrubbery
Building fences, roads, ramps
Scraping loam
General excavation and disposal of spoil
Trench and pier excavation
Wet excavation and pumping
Drilling, blasting and rock excavation
Backfilling
Sand, gravel or cinder filling
Agricultural or Akron tile drains
Manholes and catch basins
Cesspools and dry wells
Excavation for service connections and for other trades
Rough grading
Finish grading
Sodding, seeding and planting

Plain Concrete Work

Concrete footings and walls
Piers and steps
Floors, walks, drives, curbing
Thresholds, sills, coping, caps
Dressing exposed surfaces
Granolithic finish
Hardening and special finishes
Curb bars
Forms for concrete

Integral waterproofing
Sleeper filling and roof grading

Reinforced Concrete Work

General and special mixes
Wall and column footings, walls, columns, beams, girders, spandrels, floor and roof slabs
Stairs
Integral and applied finishes
Ornamental work, sills, lintels, pilasters, columns, coping, balusters, rails
Steel and wood forms
Reinforcing rods, mesh, lath
Stationary or removable pans and domes
Chairs, ties, inserts, sleeves and accessories
Trimmer arches
Protecting structural steel
Grouting columns, bases and lintels
Setting up and taking down concreting plant

Brickmason's Work

Common, hollow, face, fire, paving, enameled, glazed, ground or molded bricks
Culling bricks
Brick hearths and facings
Cleaning, pointing, oiling
Wall ties and plugs
Interior and exterior scaffolding
Brick veneering
Parging
Boiler setting
Hollow-tile walls, backing, floor construction, partitions, roofing, furring, column-, beam- and girder-covering
Glazed-tile walls and partitions, special shapes
Cement, cinder or slag blocks
Flue linings
Chimney pots or caps
Firestopping
Rubble masonry
Cut granite, bluestone, limestone, sandstone, marble
Cast stone

Stone paving and flagging
Architectural terra cotta
Tile inserts

Furring, Lathing, Plastering

Metal furring on walls and ceilings
Metal lath, stapled, wired or clipped to supports
Lathing for solid partitions
Wood lathing
Gypsum board lathing
Fiberboard lathing
Corner beads and cornerite
Two- and three-coat plastering
Special finishes and textures
Keene's cement work
Caenstone work
Scagliola
Portland cement stucco
Magnesite stucco
Ornamental work cast in shop
Ornamental work run in place
Modeling
Scaffolding
Patching after other trades

Millwork and Trim, Screens, Weather Strips

Exterior finish, cornices, columns and pilasters, water table, corner boards, dormer trim
Interior finish, door and window jambs and trim, base, chair rail and picture mold, paneling, beam casings, wainscoting, stairs
Cabinetwork
Access panels
Wardrobes
Closets and cedar linings
Folding partitions
Folding stairs
Store-front work, counters, shelving
Flagpoles
Blackboards, bulletin boards and trim for same
Radiator enclosures

Wood or metal screens
Weather strips
Window shades

General Carpenter Work

Scaffolding for other trades
Jobbing for other trades
Grounds, sleepers and screeds
Wall and ceiling furring
Miscellaneous blocking and furring, wood bricks
Door bucks
Protect stonework
Framing of floors, walls, roofs, dormers, partitions
Boarding of walls, floors and roofs
Siding, clapboarding, shingling
Insulating
Finishing floors
Parquetry
Nails and rough hardware
Paper, felt and quilting
Finishing hardware
Temporary floors and stairs
Firestopping

Kalamein and Metal Windows and Doors

Hollow metal doors and windows
Kalameined doors and windows
Smoke screens
Underwriters' doors
Fire shutters
Metal access doors and panels
Overhead doors
Hatchway doors
Steel rolling doors
Bronze doors
Vault doors
Steel cellar sash
Steel factory-type sash
Steel monitor sash
Steel projected windows
Steel casement windows
Steel double-hung windows

Screens
Operating devices
Special hardware

Store Fronts and Plate Glass

Metal-covered work
Drawn metalwork
Special finishes
Ventilating devices
  Jambs
  Sills
  Muntins
  Transom bars
Polished plate glass
Special transom glass
Art and leaded glass
Mirrors
Glass for steel sash
Glass for doors, etc.

Structural Steel, Ornamental and Miscellaneous Iron, Bronze

Structural steel
  Erection
  Riveting
  Welding
  Painting
Cast iron
Concrete-filled columns
Miscellaneous bolts and anchors
Stairs
Railings
Fire escapes
Balconies
Gratings
Finials
Stable fittings
Pipe railings
Ladders
Safety treads
Door and window guards
Woven wire work

Column guards
Bank and vault work
Jail and cell work
Revolving doors
Ash hoists and sidewalk doors
Vault lights and frames
Fireplace throats, ash dumps and cleanout doors
Manhole and cesspool covers
Coal chutes, garbage and package receivers
Steel joists and bridging
Nailer joists
Steel decking

Iron and Steel Bucks, Trim, Specialties

Steel bucks
Steel trim, base, picture molding, capping

Lockers, Cabinets, Metal Partitions

Steel lockers
Steel shelving and bins
Built-in steel furniture
Medicine cabinets
Steel toilet partitions
Steel shower partitions
Steel office partitions

Linoleum, Rubber, Cork

Treads
Floors
Molded bases
Wainscots
Thresholds
Nosing strips
Cork bulletin boards
Cork insulation

Terrazzo, Marble, Slate, etc.

Floors
Wainscots, base, cap rails, trim
Molded specials
Dividing strips
Stairs and nosings

Balustrades
Sills and nosings
Borders and paneling
Garden and hall furniture

Roofing and Sheet-metal Work

Composition roofing
Tar and gravel roofing
Asphalt roofing
Asbestos roofing
Metal roofing
Canvas roofing
Slate roofing
Plastic slate roofing
Tile roofing
Guaranty
Insulation under roofing
Roof water outlets, gutters, conductors
Flashing, ridging
Snow guards, finials, weather vanes
Cornices, spandrels and ornamental work
Skylights
Interior sheet-metal work
Laundry chutes
Stamped metal ceilings

Elevators, Dumbwaiters, Lifts

Elevators and enclosures
Automatic elevators
Coin elevators
Plate drops
Dumbwaiters
Sidewalk elevators
Mail chutes
Fuel lifts
Differential hoists
Escalators
Greasing lifts (for garages)

Waterproofing and Dampproofing

Integral compounds (unless included in concrete)
Membrane waterproofing

Applied coats of waterproofed concrete or mortar
Applied dampproofing
Tar concrete work
Tarred sand leveling course
Caulking

Demolition and Shoring

Tearing out present construction
Supporting present construction
Underpinning and protecting adjoining structures
Sheet piling and bracing banks

Plumbing, Heating, Ventilating, Sprinklers

Permits and fees
Service connections
Cesspools (if in plumbing contract)
Water supply, pumps, wells, tanks
Water closets, urinals, sinks, lavatories
Bidets, lavatories, drinking fountains, baths, showers, foot baths
Thermostatic valves
Soil and waste piping, traps, vents
Domestic boilers
Refrigerator drains
Floor and roof drains
Cellar drainer
Boilers
Single or double piping
Valves, air valves, checks, gauges
Return pump
Radiators
Expansion tank
Stoker and ash remover
Oil burners
Air washers or humidifiers
Ventilating ducts or units
Dampers, registers, grilles
Insulating piping and boiler
Bronzing pipes and radiators
Gas piping
Range, water heater, storage, refrigerator
Sprinkler system

Storage and pressure tanks
Alarm valves
Fire-hose reels
Fire curtain
Fire standpipes

Wiring, Fixtures, Clock Systems

Service connections
Meter and panel boards
Transformers
Wiring and conduits
Switches, light and power outlets, floor and wall plugs
Connections to heating and ventilating system
Lighting fixtures
Bell, annunciator and speaking-tube systems
Interior phone systems
Conduits for telephone wiring
Radio wiring
Electric clocks, program clocks and master-clock systems
Refrigerators, ranges
Vacuum-cleaner systems
Oil-burner connections
Lightning protection

Painting and Decorating

Back painting and priming
Exterior painting
Interior painting
  Staining, filling
  Varnishing
  Kalsomining
  Waxing
  Canvas and burlap
  Papering
  Decorating

Special Items

Diving
Boring
Caisson work
Subaqueous foundations

Piling, wood, steel or concrete
Cold-storage work
Coal-handling equipment
Cash-carrier systems
Package conveyors and carrier systems
Kitchen equipment
Laboratory equipment
X-ray equipment
Hospital equipment
Restaurant equipment

SECTION 5. PRELIMINARIES AND OVERHEAD ITEMS

Among the most difficult items to calculate correctly in a building estimate are some of the items usually included as overhead or preliminaries.

This is because many of them, such as

Superintendent's salary
Timekeeper's salary
Watchman's salary
Temporary heat and
Commissary loss

are dependent entirely upon the length of time occupied in constructing the building, rather than upon the quantities of materials involved.

In previous chapters the method to be used in calculating the cost of the foreman for a given item of the work has been indicated. Practically the same method must be used to figure the total time required to complete the entire structure, making due allowance for the time when two or more parts of the work will proceed concurrently, in order to calculate the salaries of superintendent, timekeeper, clerks and watchman with any degree of accuracy. Even then unforeseen delays will often spoil all the calculations.

Such items as office building, sheds, storehouses, sidewalk, bridges and fences are best figured by making little pencil sketches of them and calculating the labor and materials involved.

If portable office buildings are used, it is necessary to figure only the transportation; and if standardized sheds are developed the problem will be just that much simpler.

The premium on a surety bond is always a fixed percentage (usually 1½ per cent) of the total amount of the contract, regardless of whether the indemnity is 25 or 100 per cent of the contract.

Insurance is figured on the pay roll, as indicated in previous chapters, and the rates vary but are always included in the policies, so that they can readily be determined.

SECTION 6. EQUIPMENT

Even if a builder owns his equipment, it is constantly being worn out or becoming obsolete, so he is entitled to figure into his estimate an amount which would enable him to keep it in repair, to retire his investment or replace his equipment as needed and to make a reasonable profit on his investment.

Rental rates vary greatly. Some contractors figure a flat charge per day or week from the time equipment leaves the storehouse until it returns. Others have one rate for active time and another for idle time, but in all cases, transportation both ways should be included.

A typical equipment rental list follows:

Terms of Rental Charges and What Tools Are Supposed to Include

1. Where prices per week are not inserted they are indefinite and are subject to special agreements.

2. No tools are to be rented for less than one week unless special agreement.

3. Tools and machinery are to be shipped from jobs or storehouses in good repair and complete with parts and fittings ready to run and are to be returned to other jobs or storehouses in good repair, allowing for reasonable wear and tear. If necessary to buy parts at the job to make the tools or machinery ready to run, same is to be charged to

Description	Rent per week	Description	Rent per week
		Concrete mixer, ¼ yard	$15.00
Derrick 40 to 60 feet	$12.00	Bantam mixer with gas engine	12.00
Derrick 60 to 90 feet	15.00	Concrete carts	1.00
Stiff-leg derrick	12.00	Scale box iron	2.00
Hand derrick, small	5.00	Scale box wood	1.00
Hand derrick, large	8.00	Circular saw table	2.00
Breast derrick	2.00	Band saw	1.00
Wheel derrick	2.00	Buzz planer	1.00
Four-leg derrick	2.00	Six-foot swing saw	1.00
Gin poles	2.00	Chain hoists 2 or 3 ton	3.00
Hoisting engines 3D	18.00	Chain hoists 5 ton	4.00
Hoisting engines 2D	13.00	Barrett jacks	1.00
Hoisting engines 1D	8.00	Screw jacks	0.50
Skeleton engines 3D	11.00	Albany jacks	1.00
Skeleton engines 2D	9.00	Norton jacks	1.00
Skeleton engines 1D	5.00	Bed-screw jacks	0.50
Flat cars, 24-inch and 36-inch gauge	2.00	One-horse, 2-wheel dump carts	
Koppel car	2.00	Two-horse, 4-wheel wagons	3.00
1½-yard 2-way dump car	3.00	"Chocolate drop"	10.00
4-yard dump car	4.00	Quarry bar	10.00
Dray, 10 ton	10.00	Quarry bar, 4-inch, 2½-inch	
Pile driver	......	Elevator platform, small	1.00
Steam sheet pile hammer, 4-inch	9.00	Steam sheet pile hammer, 6-inch	12.00
Bolt cutting machine	1.00	Timber dollies	0.50
Pipe cutter	1.00	Timber truck, 2-wheel	0.50
Gas cutting machine	6.00	Truck, 4-wheel	2.00
Blacksmith kit and forge	1.50	Air compressors, 8 inches by 8 inches	15.00
Riveting kit and forge	1.50	Air compressors, 22 inches by 13 inches by 16 inches	40.00
Cableways 1,000 feet	60.00	Air compressors, 19 inches by 12 inches by 16 inches	35.00
Hand-drills, press	0.50	Lights, carbic	1.50
Rock-drills, tripod	10.00	Winch	2.50
Jack hammer drills	6.00	Industrial R. R.	
Electric boring drills	5.00	Electric motors, 5 horsepower	
Ratchet drills	0.50	Electric motors, 10 horsepower	
Concrete mixer, ⅓ yard	25.00	Pump, 10-inch discharge, belted	10.00
Concrete mixer, ¾ yard	22.00	Pump, 8-inch discharge, belted	8.00
Concrete mixer, ½ yard	20.00	Pump, 6-inch discharge, belted	6.00
Independent swingers	5.00	Pump, 6-inch discharge	12.00
Locomotive boilers, 50 horsepower	15.00	Pump, 5-inch discharge	10.00
Vertical boilers, 18 horsepower	7.00	Pump, 4-inch discharge	8.00
Vertical boilers, 20 horsepower	12.00	Concrete surfacer	8.00
Stone crushers, 9 by 16 inches	20.00	Power grindstone	1.00
Stone crushers, 24 by 13 inches	30.00	Rowell chimney hoist	5.00
Stone crushers, 20 by 10 inches	25.00	Portable houses	3.00
Stone crushers, 28 by 12 inches	40.00	Lead furnace on wheels	2.00
Stone crusher bin, portable, 30 ton	6.00	Staging clamps	0.02
Cement gun	30.00	Putlogs patent	0.04
Blasting battery	2.00	Plow, root, six-horse	4.00
Concrete dump carts	2.00	Plow, root, four-horse	3.00
Clamshell buckets	10.00	Punch, hand-screw	1.00
Orange peel buckets	10.00	Rod bender	1.00
Concrete spouting outfits		Ram, hydraulic	1.00

Description	Rent per week	Description	Rent per week
Roofer's kit	5.00	Pump, 12-inch discharge, belted	12.00
Drag scrapers	0.50	Car unloaders	1.00
Drag scrapers, two-wheel	2.00	Sharpening machine	18.00
Electric motors, 20 horsepower		Vises	0.50
Electric motors, 40 horsepower		Scows, 3 feet by 30 feet by 8 feet	5.00
Electric motors, 50 horsepower		Shears, McLane	0.50
		Tents, 12 by 14	2.00
Electric motors, 60 horsepower		Tents with flies, 12 by 14	3.00
		Tents, 10 by 10	1.50
Electric motors, 75 horsepower		Tents with flies, 10 by 10	2.00
		Taps and dies sets	0.50
Engine, vertical, 8	6.00	Typewriter	
Engines, horizontal, 25 horsepower	12.00	Bolt threading machine	0.50
		Leveling instrument	1.00
Engines, horizontal, 20 horsepower	10.00	Motor truck, 5-ton	
		Motor truck, 4-ton	
Engines, horizontal, 40 horsepower	15.00	Motor truck, 3-ton	
		Motor truck, 1½-ton	
Diving suits, complete	24.00	Concrete bucket, ¾-yard	2.00
Pump, pulsometer	10.00	Concrete bucket, 1-yard	2.00
Pump, diaphragm hand	5.00	Concrete bucket, 1½-yard	3.00
Pump, hand	2.00	Concrete bucket, 2-yard	3.00
Pump, gasoline 3-inch	8.00		

user. (Tool and Maintenance Account.) The jobs to pay the expense of repairs or breakage while on their job.

4. The jobs to pay for transportation both ways.

5. On all contracts, the rental of tools or machinery to commence when they are set up and ready to run, and to continue, until they are taken down or shipped, unless we are notified by the user's representative that they are no longer needed, in which case the rental stops on the day of notification.

Rental charges on tools and machinery to other than contractor's own jobs to commence when they are taken from storehouses or jobs and to continue until returned, unless otherwise agreed.

6. Stone crushers are to be complete with elevator and screen. Bins for large crushers to be furnished by the job. Portable bins on separate rental. Motive power on separate rental. Contractor is to replace worn-out jaws with new.

7. Steam or air drills to have 15 ft of hose and to be replaced by us when worn out. Drills to be kept in repair at the jobs. Drill steel to be charged to the job and taken back at its market value at the close of the job.

8. Derricks are to be complete with fittings, blocks, and a reasonable amount of guy wire and clips for guy derrick.

9. Hoisting engines are to be shipped complete with fittings and fall lines ready to connect with derrick. Fall lines to be replaced by contractor when worn out, if used with reasonable care.

10. All pumps to be complete with 16 ft of suction pipe or hose and foot valve and 10 ft of pipe for discharge.

Diaphragm pumps are to include the suction hose 16 ft long, and to be replaced by contractor when worn out.

Additional pipe or hose over 16 ft is to be charged to the job, and taken at the close of the job at its market value.

APPENDIX A

MATHEMATICS

Practical quantity surveying and estimating do not require a knowledge of the higher mathematics, but they do require a thorough understanding of the principles of mensuration, as well as of the conventional signs and symbols used by architects and engineers in designating the kinds of materials and other features on their plans.

While the surveying of some quantities involves only the counting of units, and some involves only the taking of linear measurements, by far the greater portion consists of finding areas and volumes. The following rules cover practically every problem of this sort that will be encountered.

Sombols Used in the Rules.

L = length
B = breadth
D = depth or thickness
d = diameter
r = radius
n = number of sides

Rule

1. Area of rectangular figure $= L \times B$
2. Area of triangle $= \dfrac{L \times B}{2}$
3. Area of circle $= d^2 \times 0.7854$ or $r^2 \times 3.1416$
4. Area of ellipse = long diameter × short diameter × 0.7854
5. Area of sphere $= d^2 \times 3.1416$
6. Area of hemispherical dome $= d^2 \times 1.5708$
7. Area of trapezoid $= B \times$ one-half sum of parallel sides
8. Area of any regular polygon = length of one side $\times\ n$ × one-half perpendicular distance from side to center

9. Area of ring = area of outer circle minus area of inner circle
10. Area of any irregular polygon: divide the figure into triangles, calculate, and add their areas.
11. Area of sides of a pyramid = perimeter at base × one-half slant height

NOTE.—The slant height must be that at the middle of a side and not along the edge joining two sides.

12. Area of sides of frustrum of pyramid = the sum of top and bottom perimeters × one-half the slant height
13. Area of convex surface of cone = $\frac{\text{area of base}}{\text{radius of base}} \times$ slant height or circumference of base × one-half the slant height
14. Area of sides of frustrum of cone = (radius at top plus radius at bottom) × slant height × 3.1416
15. Contents of rectangular solid = $L \times B \times D$
16. Contents of cone = area of base × one-third height
17. Contents of pyramid = area of base × one-third height
18. Contents of frustrum of cone or pyramid = (area of base, plus area of top, plus 4 × area of plane midway between top and base) × one-sixth height
19. Contents of sphere = $d^3 \times 0.5236$
20. Contents of cylinder = area of end × L
21. Contents of prism = area of end × L
22. Length of circumference of circle = $d \times 3.1416$
23. Length of circumference of ellipse = (square root of one-half of sum of squares of both diameters) × 3.1416

NOTE.—This is an approximate rule that is in general use and gives fairly accurate results. There is no simple rule in use that gives the exact length.

24. Length of hypotenuse of triangle = the square root of the sum of the squares of base and altitude
25. Length of side of square inscribed in circle = $d \times 0.7071$

NOTE.—The factor 3.1416 is sometimes represented by the Greek letter pi (π).

In each case where a portion of the rule is enclosed in parentheses, that portion should be worked before multiplying by the factor outside of the parenthesis.

Abbreviations.—The abbreviations recommended for use in expressing quantities when surveying quantities and in estimating are as follows:

in.	inches or inch
ft	feet or foot
yd	yards or yard
lin ft	linear feet
square	an area of 100 square feet
sq	square
□	square
sq ft	square feet
□′	square feet
sq yd	square yards
□ yd	square yards
cu ft	cubic feet
Δ′	cubic feet
cu yd	cubic yards
Δ yd	cubic yards
M	1,000
FBM	feet board measure
#	number, when written before numerals
#	pounds, when written after numerals
lb	pound or pounds
bbl	barrel or barrels
φ	round (usually, in reference to rods)

Linear dimensions are customarily expressed thus: 6′ 2″ equals 6 feet 2 inches.

Multipliers.—The following multipliers are to be used when calculating by means of key-operated machines:

Converting	Multiply by
Cubic inches to cubic feet	0.00058
Cubic feet to cubic yards	0.03704
Cubic feet to gallons	7.4805
Cubic feet to FBM	12.0
Cubic inches to gallons	0.0044
Cubic inches to FBM	0.007
Square inches to square feet	0.007
Square feet to square yards	0.1111
Cubic inches to pounds steel	0.284
Cubic inches to pounds iron	0.261
Cubic inches to pounds copper	0.319

Lumber.—W in inches $\times$ B in inches $\times$ L in feet $\times$ 0.0833 = feet board measure

Steel.—W in inches $\times$ B in inches $\times$ L in feet $\times$ 3.40 = pounds

APPENDIX B

RECOMMENDED READING

The estimator who would be thoroughly informed as to the many and various phases of his profession will do well, in addition to collecting all available experience data that come to him in the course of his own work, or which he can obtain through a reading of periodicals and by conversations with others in the same and allied lines of work, to obtain as many as possible of the books listed below and to familiarize himself with their contents.

ARTHUR, WILLIAM, "New Building Estimators' Handbook," U. P. C. Book Co., New York.

BARNES, FRANK E., "Estimating Building Costs," McGraw-Hill Book Company, Inc., New York.

CARVER, WILLIAM, "Brick, How to Build and Estimate," Common Brick Manufacturers' Association, Cleveland, Ohio.

CONNOR, FRANK L., "Labor Costs on Construction," Gillette Publishing Company, Chicago.

DINGMAN, CHARLES F., "Plan Reading and Quantity Surveying," McGraw-Hill Book Company, Inc., New York.

GILLETTE, HALBERT P., "Handbook of Construction Cost," Gillette Publishing Company, Chicago. "Handbook of Construction Equipment," Gillette Publishing Company, Chicago. "Handbook of Cost Data," Gillette Publishing Company, Chicago. "Earthwork and Its Cost," Gillette Publishing Company, Chicago. "Rock Excavation, Methods and Cost," Gillette Publishing Company, Chicago.

GILLETTE and DANA, "Cost Keeping and Management Engineering," Gillette Publishing Company, Chicago.

GILLETTE and HILL, "Concrete Construction, Methods and Cost," Gillette Publishing Company, Chicago.

HOOL and JOHNSON, "Handbook of Building Construction," McGraw-Hill Book Company, Inc., New York.

KNOWLES, MORRIS, "Industrial Housing," McGraw-Hill Book Company, Inc., New York.

MULLIGAN, JOHN A., "Handbook of Brick Masonry Construction," McGraw-Hill Book Company, Inc., New York.

PAINTING AND DECORATING CONTRACTORS OF AMERICA, "Price Guide," Peoria, Illinois.

PARK, KENNETH F., "Principles of Modern Excavation and Equipment," R. G. LeTourneau, Inc., Peoria, Illinois.

PULVER, HARRY E., "Construction Estimates and Costs," McGraw-Hill Book Company, Inc., New York.

TAMBLYN, GORDON, "Building Labor Estimator," Gordon Tamblyn, Denver, Colorado.

TAYLOR and THOMPSON, "Concrete Costs," John Wiley & Sons, Inc., New York.

TRAUTWINE, JOHN C., "Civil Engineers' Pocket Book," John C. Trautwine, Philadelphia.

UNDERWOOD, G., "Estimating Construction Costs," McGraw-Hill Book Company, Inc., New York.

WALKER, FRANK R., "The Building Estimators Reference Book," Frank R. Walker, Chicago.

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