The Ransome Book

HOW TO MAKE AND HOW TO USE CONCRETE

CAMPBELL

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CONCRETE

Written and Compiled by
H. COLIN CAMPBELL, C.E., E.M.
Director, Editorial Bureau,
Portland Cement Association

PRICE ONE DOLLAR

"Well-Mixed Concrete for Permanence."

RANSOME CONCRETE MACHINERY CO.
The Pioneer Builders of Concrete Machinery
115 BROADWAY — NEW YORK CITY
FACTORIES
DUNELLEN, N. J. READING, PA. OSHKOSH, WIS.

Form V

INTRODUCTION

In issuing this booklet the Ransome Concrete Machinery Company is making a departure from usual practice that it is hoped will be popular. The Ransome line of machinery and concreting equipment has been subordinated to those fundamental practices which govern success in the use of concrete. The thought is this: However good the machine may be, the concrete cannot be all that it should be unless the human element can be controlled. The machine cannot do that. This is up to the man on the job. Success in the use of concrete, as in the use of any other building material, lies in following well-established rules that have proved themselves the proper guide.

Concrete is too big a subject to be covered within the limited space of this booklet; but there have been gathered here useful data that are applicable to almost any and every kind of concrete work. Every page, it is believed, contains more than one reminder of the things that should be done but which are frequently overlooked or neglected.

Among many sources of information on the uses of concrete are the numerous booklets and pamphlets issued by the Portland Cement Association. All of these publications can be obtained for the asking, and a collection of them forms a valuable reference library on good concrete practice and the many popular uses of concrete. It is suggested that users of Ransome equipment will find much profitable information in the following, copies of which may be had free of charge by addressing the Portland Cement Association, 111 West Washington Street, Chicago:

Concrete Silos
Portland Cement Stucco
Concrete in the Country
Farmers' Handbook on Concrete Construction
Concrete Swimming and Wading Pools
Concrete Linings for Irrigation Canals
That Alley of Yours
Concrete Houses and Why to Build Them
Fundamentals of Reinforced Concrete Design
How to Maintain Concrete Roads and Streets
Recommended Specifications for Reinforced Concrete Design
Suggested Specifications for Concrete Floors
Why Build Fireproof?
Integral Curb for Concrete Pavement
Cement Stave Silos
Concrete Tile for Land Drainage
Protecting Concrete in Warm Weather
Concrete Grain Bins and Elevators
Bulk Cement
Concrete Ships
Facts Every One Should Know about Concrete Roads
Standard Specifications and Tests for Portland Cement
Specifications for Concrete Roads, Streets, and Alleys and Paving between Street Car Tracks.
Concreting in Cold Weather
Tennis Every Day on Concrete Courts
Concrete Septic Tanks
Concrete Fence Posts
Small Concrete Garages

Concrete Facts about Concrete Roads
Concrete Feeding Floors, Barnyard Pavements and Concrete Walks
Proportioning Concrete Mixtures and Mixing and Placing Concrete
Concrete Foundations
Concrete Troughs, Tanks, Hog Wallows, Manure Pits, and Cisterns
Concrete Sewers

This booklet falls short of what we want it to be. It could be made better if we had the suggestions of our many friends. We therefore invite suggestions and criticism as to how it may be made of greater value to you, so that in future editions we can endeavor to more nearly approach what is impossible to attain — perfection.

CONCRETE

HOW TO MAKE AND USE IT

GENERAL

Many persons are under the impression that Portland cement is the material most responsible for the success of concrete work. While it is true that a standard Portland cement should be used, it is nevertheless equally as important, and in some cases more important, that great care be taken in selecting and proportioning the aggregates, — that is, the sand and pebbles or broken stone which form the main bulk of concrete. Portland cement is manufactured after methods so exact that quality can be absolutely controlled. Any one should be able to realize the truth of this statement, because if Portland cement manufacturers did not make a product up to specification requirements they would soon be without a business.

All standard Portland cements when they leave the mill are of high quality. The only thing that can happen to them to render them worthless is improper care in storage. Portland cement is sensitive to water. If it were not it would not perform the function intended of it, — that is, bind the particles of sand and pebbles or broken stone together into what eventually becomes stone.

STORAGE REQUIREMENTS

Portland cement should never be piled on the ground out on the job, nor in any shed where it can absorb dampness. Only little moisture is necessary to spoil the cement. It will partly if not completely harden, due to this moisture, and that will make it unfit for use in a concrete mixture. Out on the job cement should be piled on boards and otherwise protected against sudden showers. On the average job only so much cement should be piled out of doors near the work as can be used within a definite period of hours or the working day. Any other quantity that may be necessary to keep near the job should be kept in a tight shed that will thoroughly protect it from moisture.

AGGREGATES

Many users of concrete think that bank-run gravel, meaning the natural mixture of sand or gravel with more or less foreign material as it comes from the gravel pit, is a suitable material for use in concrete. Concrete failures have resulted from using such unscreened material. It is not suitable for several reasons: It often contains more or less loam, clay, or similar foreign material. Sometimes the bank or deposit when opened for use is not stripped of the overlying soil, and as material is dug out of the face of the pit this soil falls down and becomes mixed with the bank material. Often the deposit contains clay or silt due to the manner in which the deposit was originally formed in nature.

No concrete can be stronger than the materials of which it is composed, and foreign material, like clay, loam, or silt, prevents the cement from coming in contact with the surfaces of the sand and pebble particles, thus they cannot be bonded together. In other words, such foreign material acts to adulterate the cement. Often, also, these foreign materials have some free chemical in them which acts injuriously upon the cement and prevents it from hardening.

Bank-run gravel usually contains twice as much fine material as coarse, while in the average concrete mixture these proportions should be about the reverse. The natural run of bank gravel contains about forty-five per cent of voids or air spaces. In order to fill these and make a dense concrete, the amount of sand should be about half the volume of pebbles. If more sand than this is used, as would be the case when the bank-run material is employed exactly as coming from the pit, it is necessary to use a much greater quantity of cement to fill up these voids or air spaces so as to give the concrete the desired strength. This, of course, is an uneconomical use of cement. The amount of cement used in an ideal mixture, as, for example, one sack of Portland cement, two cubic feet of sand and four cubic feet of pebbles or broken stone, is sufficient, when all have been thoroughly mixed with the proper amount of water, to coat every particle of sand, thus forming a sand-cement mortar which will practically fill all voids in the pebbles or broken stone, while voids in the sand are filled by the cement. If, however, these proportions are reversed by using twice as much sand as pebbles, the cement is naturally insufficient to coat the increased number of sand grains, not to mention fill the voids or air spaces in their volume. The result is a weak and porous concrete.

Mere inspection of a gravel bank will not tell any one whether the sand and pebbles are in correct proportions. As a matter of fact they hardly ever are. It is also true that no two loads of bank-run gravel are uniform in relative proportions of fine and coarse material, consequently the concrete made from such material is not uniform. By looking at an ordinary gravel bank one can see how in working or digging from the deposit the pebbles drift down the face, as it were, and become separated from the sand.

SCREEN BANK-RUN MATERIAL

To make good concrete, bank-run materials must be screened by separating them into at least two grades of material. The finer material, which is in the sand, is arbitrarily defined as that which will pass through a screen having four meshes to the linear inch. The coarser material, called pebbles, is that retained on such a screen and ranging in size from ¼ inch upward to particles as large as can conveniently be used on the job in question. The larger sizes will vary from ¾ inch for fence posts and other concrete products up to 1, 1¼ and 1½, or perhaps even 3 inches for work ranging from reinforced concrete floors and walls to heavy and massive foundations, where the 3 inch particles may be used if the volume of them is not in excess.

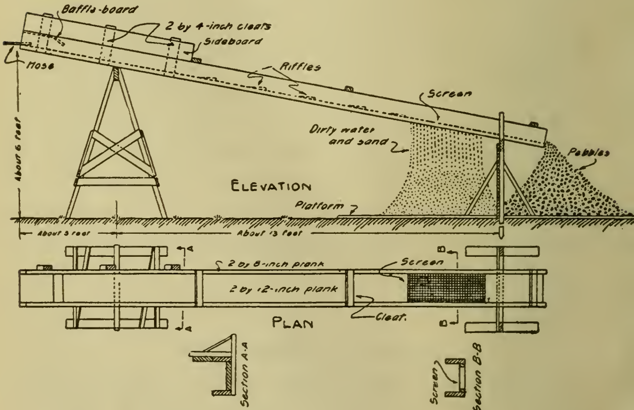
SCREENING PAYS

Many persons do not believe it is worth the trouble to separate bank-run material, and when specifications call for a 1:2:4 mixture they think that one volume of cement, or one sack of cement, to 6 cubic feet of the natural bank-run material is just the same thing. In a 1:2:4 mixture the 2 cubic feet of sand goes to fill the voids or air spaces in the 4 cubic feet of pebbles, so that one sack of cement, 2 cubic feet of sand, and 4 cubic feet of pebbles or broken stone properly mixed make about 4.5 cubic feet of concrete in place. On the other hand, 6 cubic feet of the natural bank-run material with one sack of cement will make little if any more than 6 cubic feet of compacted concrete. As between the 1:2:4 mixture and the 1:6 mixture the latter is about one third greater in volume, yet has no more cement in it than the other mixture, consequently cannot be so strong, cannot be dense, and hence cannot be water-tight. More often than otherwise a disregard of the essentials just stated is what produces the leaky concrete of which we frequently hear. It is true economy to screen bank-run material and reproportion the sand and pebbles in definitely measured volumes.

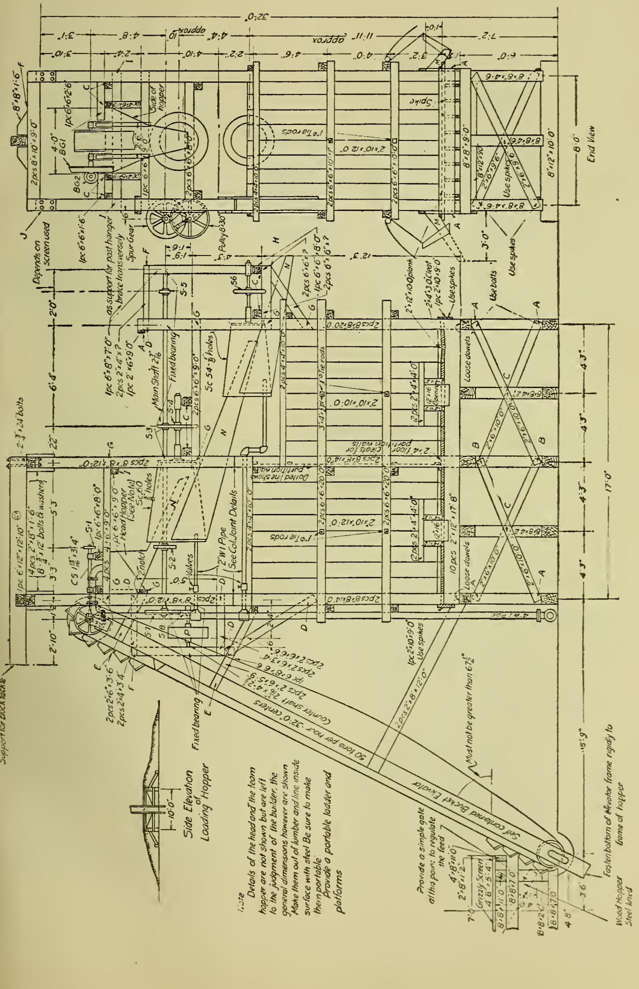
WASHING AGGREGATES

If aggregates contain more than a certain per cent of sand, loam, silt, or other foreign material, they should be washed before used in a concrete mixture. Specifications for concrete work sometimes vary in stating the amount of such foreign material that may be left in the aggregates. This does not mean that it is at all desirable that such material should be there, but it is generally believed that from three to five per cent will not, in most classes of concrete work, affect the final strength.

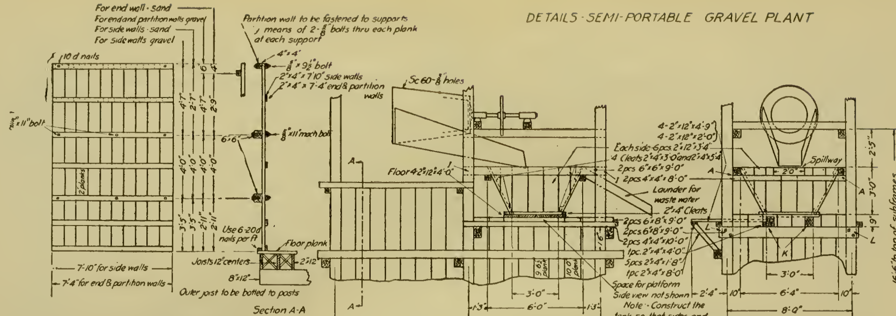
A number of methods can be employed to wash aggregates when necessary to do so. Washing troughs can easily be devised and such troughs can be made to combine the features both of washer and screen. A suggestion for such a washing device is shown in an accompanying sketch.



A simple washing trough with screen at the lower end, by means of which dirty bank-run material can easily be washed free from clay or other foreign material and the sand separated from the pebbles. The platform on which the sand and pebbles are discharged should be sloped slightly to cause the wash water to flow away freely.


Side Elevation of Loading Hopper
End View
Self contained Bucket Elevator
50 tons per hour 32'0" centers
Counter shaft
Must not be greater than 67½°
Provide a simple gate at this point to regulate the feed
Grizzly Screen
Wood Hopper Steel lined
Fasten bottom of elevator frame rigidly to frame of hopper
Support for block tackle
Depends on screen used
Spur Gear
Main Shaft
Fixed bearing
Head Hopper
Loose dowels
Use spikes
Use bolts
Note
Details of the head and the team hopper are not shown but are left to the judgment of the builder, the general dimensions however are shown
Make them out of lumber and line inside surface with steel Be sure to make them portable
Provide a portable ladder and platforms

DETAILS · SEMI-PORTABLE GRAVEL PLANT



PORTABLE WALL SECTION

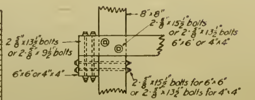
Note- The floor sections should be built similarly; merely lay the sections on the joists. For the partition wall use 2 · 5/8" bolts per plank at each girt support

Note · Construct the tank so that sides and floor are portable, use 3 · ½" x 8" or 10" bolts to fasten each wall section to top support

Side and End Elevations · Sand Settling Tank

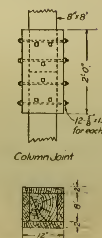
Note · This settling tank is to replace the 1/8" screen whenever the very fine grains of sand are not in excess

Symbol	Description
A	Use 2 - [illegible] - 11½" bolts with washers
B	" 2 - " - 13" " " "
C	" 1 - " - 13" " " "
D	" 2 - " - 13" " " "
E	" 2 - " - 6½" " " "
F	" nails " " "
G	" 2 - 5/8" - 13½" " " "
H	" 2 " " " "
I	" 2 " 13½" " " "
J	" 4 " - 13½" " " "
K	" 1 ¾" 17½" " " "
L	" 2 " - 15½" " " "
M	Bin Gates 12" x 16" Opening Steel
N	Steel Chutes
R	Wood Hopper Steel Lined
Note	Obtain standard sprockets etc near to the following sizes -
S-1	Sprocket - PD 9.72" T · 11 — Roller chain pitch ·2.61"
S-2	" " 22.98" " · 28 — 16' 6" long reqd
S-3	" " 9.12" " · 11 — Same pitch
S-4	" " 30.46" " · 36 — 14'· 9½" long
S-5	" 7.85" " · 9 — Same pitch
S-6	" " 24.55" " · 29 — 18'· 3" long
S-7	Spur Gear " 30.65" " · 76 Face 3"
S-8	Pinion " " 6.01" " 15 " 3"
P	Pulley - 8' x 30" requires 6" sgle leather belt
BG-1	Bevel Gear PD 31.44 T · 79 pitch 1¼" bore 2 7/16"
BG2	" " " 7.99 T · 20 " " " 1 15/16"
Sc·60	Gilbert Screen 60" Inner wearing skirt
Sc·54	" " 54" No wearing skirt

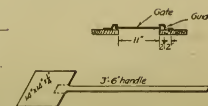


Girt Detail

Connections -
Use 2 5/8" bolts with washers for connecting timber 4" x 4" in cross section or larger, for lighter timbers use ½" bolts. Arrange to make all connections by means of bolts, use nails only on portable sections



Column Joint



Steel Gate for Settling Box

Symbol	Description
A	Use 2 - 5/8" - 11½" bolts with washers
B	" 2 - " - 13" " " "
C	" 1 - " - 13" " " "
D	" 2 - " - 13" " " "
E	" 2 - " - 6½" " " "
F	" nails " " "
G	" 2 - 5/8" - 13½" " " "
H	" 2 " " " "
I	" 2 " 15½" " " "
J	" 4 " - 13½" " " "
K	" 1 3/4" 17½" " " "
L	" 2 " - 15½" " " "
M	Bin Gates 12"x16" Opening - Steel
N	Steel Chutes
R	Wood Hopper - Steel Lined

Note:- Obtain standard sprockets etc. near to the following sizes:-

S-1	Sprocket - P.D. 9.72" T=11	Roller chain, pitch=2.61"
S-2	" " 22.98" " =28	16'-6" long req'd.
S-3	" " 9.12" " =11	Same pitch
S-4	" " 30.46" " =36	14'-9½" long
S-5	" 7.85" " =9	Same pitch
S-6	" " 24.55" " =29	18'-3" long
S-7	Spur Gear " 30.65" " =76	Face 3"
S-8	Pinion " " 6.01" " 15	" 3"
P	Pulley - 8"x30" requires 6" sgle. leather belt	
B.G-1	Bevel Gear P.D. 31.44 T=79 pitch 1¼" bore 2 7/16"	
B.G.2.	" " " 7.99 T=20 " " " 1 15/16"	
Sc-60	Gilbert Screen 60" Inner wearing skirt	
Sc-54	" " 54" No wearing skirt	

BILL OF MATERIAL
FOR
SEMIPORTABLE GRAVEL PLANT

MACHINERY

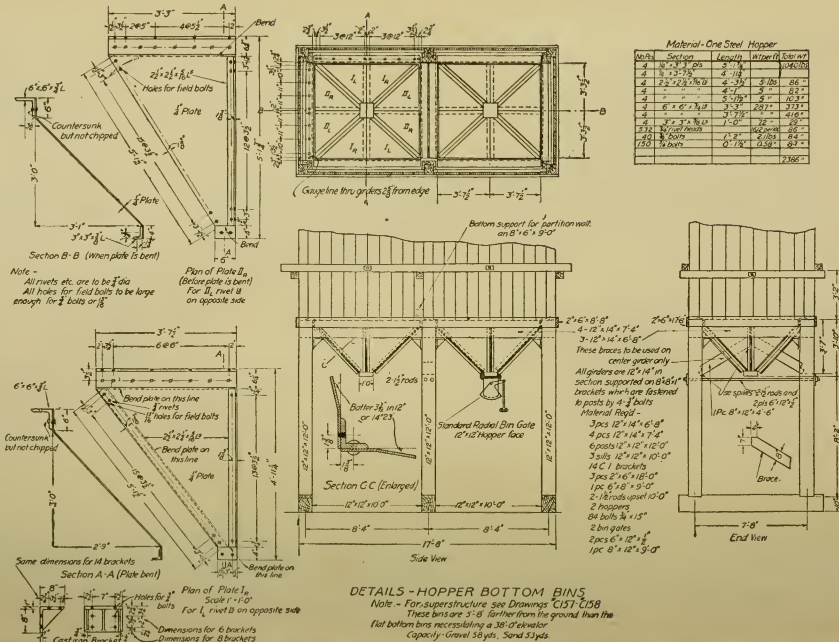
1 32′–0″ Incl. Bucket Elevator — 50 tons per hour
1 60″ Gilbert Screen, with inner skirt
1 54″ Gilbert Screen, no inner skirt
1 22′–2$\frac{7}{16}$″ turned shaft (approx. length)
6 fixed post bearings
1 3′–6″x1$\frac{15}{16}$″ dia. countershaft (approx. length)
1 4′–0″ x 2$\frac{7}{16}$″ dia. countershaft (approx. length)
6 sprockets, 1 spur gear and pinion (see Table)
70′-0″ S.B.R. 2.61″ pitch drive chain (approx.)
1 pulley 8″ face, 30″ dia.
2 steel screen chutes
1 wood steel-lined head hopper chute
1 wood steel-lined team hopper
1 8 H.P. gasoline engine
1 centrifugal pump (cap. 300 gals. per minute, disch. pipe 4″ dia.) and necessary pipe
1 10 H.P. gasoline engine for pump
4 bin gates—St'd Quadrant, 12″ x 16″
1 grizzly screen, 1¾″ □ openings (4′–8″ x 5′–4″)

FRAMING

No. Pcs.	*Dimensions*	*Material*	*Bd. Ft.*
	SUBFRAMES		
18	2″ x 6″ x 10′–0″	Y. P.	180
9	8″ x 8″ x 4′–2″	Y. P.	203
6	8″ x 8″ x 4′–6″	Y. P.	144
2	8″ x 8″ x 9′–0″	Y. P.	96
3	8″ x 12″ x 9′–0″	Y. P.	216
5	8″ x 12″ x 10′–0″	Y. P.	400
60	½″ x 6″ dowels	Steel	
4 lbs.	20d. nails		
12	⅝″ x 13″ bolts and washers		
16	⅝″ x 11½″ bolts and washers		
Floor	BINS		
6	2″ x 4″ x 16′–0″	Y. P.	64
2	2″ x 4″ x 12′–0″	Y. P.	16
5	1″ x 2″ x 14′–0″	Y. P.	12
2	2″ x 10″ x 9′–0″	Y. P.	30
18	2″ x 12″ x 10′–0″	Y. P.	360
10	2″ x 12″ x 18′–0″	Y. P.	360
11 lbs.	10d. nails		
	SIDE WALLS — GRAVEL		
16	2″ x 4″ x 7′–10″	Y. P.	83
20	2″ x 10″ x 12′–0″	Y. P.	400
9 lbs.	10d. nails		
	PARTITION AND END WALL — GRAVEL		
14	2″ x 4″ x 7′–4″	Y. P.	74
16	2″ x 12″ x 12′–0″	Y. P.	384
7 lbs.	10d. nails		
	END AND SIDE WALLS — SAND		
8	2″ x 4″ x 7′–4″	Y. P.	39
8	2″ x 12″ x 10′–0″	Y. P.	160
14	2″ x 4″ x 7′–10″	Y. P.	74
20	2″ x 10″ x 10′–0″	Y. P.	333
11½ lbs.	10d. nails		
		Carried forward	3,628

BILL OF MATERIAL
FOR
SEMIPORTABLE GRAVEL PLANT

No. Pcs.	Dimensions	Material	Bd. Ft.
	GIRTS AND POSTS	*Brought forward*	3,628
7	4″ x 4″ x 10′–0″	Y. P.	93
6	6″ x 6″ x 10′–0″	Y. P.	180
4	6″ x 6″ x 20′–0″	Y. P.	240
4	8″ x 8″ x 14′–0″	Y. P.	300
2	8″ x 8″ x 20′–0″	Y. P.	214
4	8″ x 8″ x 12′–0″	Y. P	256
46	⅝″ x 9½″ bolts and washers		
68	⅝″ x 11″ bolts and washers		
116	⅝″ x 13½″ bolts and washers		
48	⅝″ x 15½″ bolts and washers		
16	3″ x 4″ x ½″ plate		
2	1″ dia. steel rod—10′–0″		
4	1″ dia. steel rod—11′–2″		
2	1″ dia. steel rod—10′–7″		
	TOP FRAME		
2	2″ x 4″ x 3′–4″	Y. P.	4
1	2″ x 6″ x 12′–0″	Y. P.	12
2	2″ x 6″ x 14′–0″	Y. P.	28
3	2″ x 8″ x 12′–0″	Y. P.	48
4	4″ x 6″ x 9′–0″	Y. P.	72
2	4″ x 6″ x 1′–9″	Y. P.	7
6	6″ x 6″ x 8′–0″	Y. P.	144
4	6″ x 6″ x 9′–0″	Y. P.	108
1	6″ x 8″ x 14′–0″	Y. P.	56
1	6″ x 12″ x 13′–0″	Y. P.	78
2	8″ x 10″ x 9′–0″	Y. P.	120
	⅝″ BOLTS AND WASHERS		
	12 6½″; 4 11½″; 28 13″; 24 13½″; 4 15½″; 2 ¾″ x 24″		
	SETTLING TANK		
6	2″ x 4″ x 10′–0″	Y. P.	42
2	4″ x 4″ x 8′–0″	Y. P.	21
2	6″ x 6″ x 9′–0″	Y. P.	54
4	6″ x 8″ x 9′–0″	Y. P.	144
10	2″ x 12″ x 14′–0″	Y. P.	280
1	2″ x 12″ x 16′–0″	Y. P.	32
1 lb.	10d. nails		
	BOLTS AND WASHERS		
	6 ½″x8″; 6 ½″x10″; 8 ⅝″x15½″; 8 ¾″x15½″; 4 ¾x17½″		
	TEAM HOPPER		
2	4″ x 8″ x 11′–0″	Y. P.	60
4	8″ x 8″ x 2′–0″	Y. P.	43
4	8″ x 8″ x 7′–0″	Y. P.	149
2	8″ x 8″ x 11′–0″	Y. P.	118
9	2″ x 8″ x 12′–0″	Y. P.	144
2 lbs.	20d. nails		
		Total	6,675



Material - One Steel Hopper

No Pcs	Section	Length	Wt per ft	Total wt
4	¼"×3'3" pls	5'-1¼"		1040 lbs
4	¼"×3'-7½"	4'-11⅜"		
4	2½"×2½"×5/16" Ls	4'-3½"	5 lbs	86 "
4	" " "	4'-1"	5 "	82 "
4	" " "	5'-1½"	5 "	103 "
4	6"×6"×¾ Ls	3'-3"	28.7 "	373 "
4	" " "	3'-7½"	" "	416 "
4	3"×3"×⅜ Ls	1'-0"	7.2 "	29 "
532	¾" rivet heads		16.2 per 100	86 "
40	¾" bolts	1'-2"	2.1 lbs	84 "
150	¾" bolts	0'-1½"	0.58 "	87 "
				2386 "

DETAILS - HOPPER BOTTOM BINS

Note. - For superstructure see Drawings C157-C158
These bins are 5'-8" farther from the ground than the flat bottom bins necessitating a 38'-0" elevator
Capacity - Gravel 58 yds, Sand 53 yds.

DESIGN FOR WASHING PLANT

Accompanying drawings suggest details for a semiportable gravel-screening and washing plant. This has been designed with a view to producing 350 cubic yards of washed aggregates per day. An accompanying table gives a bill of lumber and a list of machinery estimated as necessary to build and operate this plant. Horsepower required will vary considerably, depending upon the design and capacity of the plant. Gasoline motive power is very convenient, economical, and adaptable. The particular advantages of the plant shown in this design are that preparation of sand and pebbles for use in concrete can be effectively done anywhere that necessity compels the use of a deposit that can be made suitable if the materials are washed and screened.

The quantity of water required to thoroughly wash and size sand and pebbles in a mechanical plant of this kind varies from one half to one gallon per minute per cubic yard of material prepared per day. That is, if the capacity of the plant is 500 yards of prepared material per day, water required per minute will vary from 250 to 500 gallons. Such wide range is due to variations in the amount and nature of the matter to be washed out. The general operation of preparing sand and pebbles for use as aggregate in concrete consists first of excavating the material from the bank or elevating it from the beds of streams, transporting it to the washing plant, where it is elevated to the hopper located directly above suitable screens, dumping it into these screens and playing upon the material water under pressure, which in connection with the agitation in the screens causes rolling and tumbling of materials and frees them of foreign matter.

Screens used in the commercial preparation of aggregates can be classified as gravity, reciprocating, and rotary. Experience has generally proven that gravity screening plants are not in all cases as satisfactory as other types in securing a product possessing all desirable qualities. This is due largely to the great variety of material found in different pits and often in different parts of the same pit. Reciprocating or vibrating screens generally give better results. Cylindrical screens are made by attaching perforated sheet metal or wire cloth to circular frames, the size of perforations being governed by the grading of output desired. To obtain material properly sized for some concrete construction involves coarse aggregate from $\frac{1}{4}$ to $1\frac{1}{2}$ inch and washed sand from $\frac{1}{4}$ inch to that which will be retained on a No. 100 mesh screen. Perforations are in most cases $1\frac{1}{2}$ inch round holes in the first conical screen, and $\frac{3}{8}$ inch diameter in the next screen. Material from the last screen should then be discharged into a settling tank. Wherever a grading of material is required which lies between $\frac{1}{4}$ and $\frac{1}{2}$ inch or $\frac{1}{4}$ and 1 inch the material must pass through a screen with 1 inch or $\frac{1}{2}$ inch perforations and be retained on a screen having $\frac{5}{16}$ inch perforations. It should be remembered that unless a very large percentage of the material ranges from

$\frac{1}{4}$ to $\frac{1}{2}$ inch or from $\frac{1}{4}$ to 1 inch, as it comes from the pit, the foregoing grading cannot be secured in the same operation that produces the coarse aggregate ranging from $\frac{1}{4}$ to $1\frac{1}{2}$ inch. When specifications refer to material retained on a $\frac{1}{4}$ inch wire mesh over a circular frame of suitable diameter. Testing-screens of this kind are held in a horizontal position when the material is screened through them, the screen being shaken by hand enough to cause the material under $\frac{1}{4}$ inch to pass through the openings; therefore the perforations or openings in screens used when washing or screening materials on a large scale must be of such diameter as will produce materials conforming to those obtained by the hand-screen test.

It will readily be seen that sand and some large aggregate can be made to pass over instead of through a $\frac{1}{2}$ inch mesh screen if the angle at which it is set and the speed of travel are made slow enough. Many materials have been used as aggregates in concrete construction. Various kinds of stone screenings are used at times in place of sand. In such cases the screenings should have the same sizing as would apply to natural sand.

The particles which may be considered as dust should be removed by washing or otherwise. A particular trouble sometimes encountered with stone screenings, especially from certain kinds of limestone, is that the particles themselves are coated with a very fine dust or powder which prevents the cement from coming in contact with them and sometimes causes considerable "balling up" of the mass in the mixer. The same holds true of some kinds of coarse limestone aggregates. If this trouble is encountered the aggregates should be washed.

GRADING OF AGGREGATES

Aggregates should be well graded. The reason for this can be illustrated in a simple way. If we draw a number of circles, say, one inch in diameter, touching one another, it will be seen that there are spaces among and between them in which smaller circles may be drawn. After these smaller circles have been drawn touching the larger ones, there still will be spaces in which still smaller circles may be drawn. These circles and the spaces correspond to the pebbles and the voids or air spaces in their bulk. It is necessary, therefore, that the larger particles predominate and that the grading of the materials be such with respect to the quantity of smaller particles contained in the bulk as to reduce these voids or air spaces to the lowest percentage. After they have been so reduced by the best grading possible, the sand voids or air spaces are filled by using the proper amount of cement.

Various tests may be made to determine the quantity or volume of voids or air spaces contained in any bulk of material. For great precision rather elaborate tests are necessary. Fairly accurate determinations may be made as follows:

FIRST METHOD

Weigh the vessel and then fill level full with water, then weigh again. Call the net weight of the water C. Say, for example, it proves to be 80 pounds. Remove the water, dry and fill the vessel level full with the aggregate. Weigh and call the net weight of the aggregate B. Say this is found to be 120 pounds. Then pour water slowly into the aggregate until the vessel is again level full of water. Weigh and call the net weight of the water and aggregate A. Say it is 160 pounds. Then the percentage of voids is 100 times the quantity $\frac{(A-B)}{C}$, or in this particular case 100 times $\frac{160-120}{80}$, = 100 times $\frac{40}{80} = \frac{4000}{80} = 4000 \div 80 = 50$, or 50% of voids.

In introducing the water into the vessel containing the aggregate care must be taken to prevent entrapping air. It is good practice, therefore, to apply the water all at one point along the side of the vessel. In determining the voids in sand or fine gravel the method of procedure outlined above, which answers for coarse aggregate, should be slightly modified. After determining the net weight of the water (C) and the net weight of the sand (B), instead of pouring water into the sand, the sand should be removed, the vessel filled about half full of water, and the sand poured into the water. The object of pouring the sand into the water is to expel the air, which is impossible if the order is reversed. As most sands have less than fifty per cent voids the water will overflow the vessel before it is level full of sand. When this point is reached care should be taken to keep the loss of fine particles down to a minimum. When the vessel is level full of sand and water and all the overflow of water carefully wiped off, the net weight of the sand and water is obtained and the voids determined as above, from the equation, per cent of voids = 100 times $\frac{(A-B)}{C}$.

SECOND METHOD

Procure two similar vessels with flat bottoms and vertical sides. Fill one level full with water and the other with the aggregate. Dip water from the vessel of water into the other until it appears on the surface, being careful not to spill any water. Measure the distance between the top of the vessel and the surface of the water. This distance divided by the total depth of the vessel and multiplied by 100 gives the per cent of voids in the aggregate. Say we have a vessel 18 inches deep and after the above operation the surface of the water is six inches below the top of the vessel. This would indicate a per cent of voids of $\frac{6}{18}$ times $100 = \frac{600}{18} = 33\frac{1}{3}\%$.

Proceed exactly as above when working with a coarse aggregate, but with sand start with one of the vessels empty and the other full of water. Dip a little less than one third of the water from the full vessel into the empty one and then pour the sand into the vessel containing the smallest amount of water until it is level full of sand. If the sand has more than one third voids, more water will have to be added; if less than one third voids it might be necessary to dip some of the water back into the other vessel. With this method care must be taken that no water is lost; always dip water from one vessel into the other, so that at the end all the water started with is in the two vessels. Measure and figure for voids exactly as above.

THIRD METHOD

Carefully measure the capacity of the vessel. Say, for example, it takes ninety small measures of water to fill the vessel level full. Empty out the water, fill the vessel with the aggregate, and then note how many small measures of water can be poured into the aggregate until the vessel is again level full of water. Suppose it requires thirty small measures to do this — then the per cent of voids is equal to one hundred times the result obtained by dividing the number of small measures of water added to the aggregate by the number of small measures of water required to fill the vessel; or, in this case 100 times $\frac{30}{90} = \frac{3000}{90} = 33\frac{1}{3}\%$ voids.

When using this method to determine the voids in sand or fine aggregate first place a given number of small measures of water in the vessel, say a few less than one third the number required to fill the vessel, then pour the sand slowly into the water. If you are able to fill the vessel with sand without bringing water to the surface add enough measures of water to do this; or if on the other hand you have started with too much water, dip out enough so that the vessel may be filled with sand without causing the water to overflow. Note how many measures of water you started with and how many were added or dipped out and obtain the per cent of voids as pointed out.

FOURTH METHOD

The following method of determining voids applies to sand only and is probably the best. Fill the vessel with sand and let the net weight of sand equal B. Fill the same vessel with water and let the net weight of the water equal A. Then the per cent of voids equals 100 $\frac{(A \times 2.65)-B}{A \times 2.65}$ equal 100 times $\frac{2.65A-B}{2.65A}$.

Of the above methods for determining voids in coarse aggregate the first is the most accurate, but approximate results may be obtained with the others, the value of the determination depending upon the care with which the work is done. At least three determinations for voids should be made and the result averaged.

When deciding upon a mixture bear in mind that a first-class concrete requires that the cement be a little more than sufficient to fill the voids in the sand and that the cement and sand mortar must a little more than fill the voids in the gravel or stone. This means that if the sand at hand contains thirty-three per cent of voids, one cubic foot of cement (one sack, ninety-four pounds) can be mixed with two and one half cubic feet of sand, and if the gravel or stone has forty-five per cent of voids, the mixture of one sack of cement and two and one half cubic feet of sand can be mixed with four cubic feet of gravel or stone. Such a mixture will make a good concrete, but if an exceptionally strong, dense concrete is desired, the mixture — with the aggregates referred to — should be one sack of cement to two cubic feet of sand and three cubic feet of pebbles or stone.

MISCELLANEOUS AGGREGATES

Various kinds of stone or rock and substitutes for them are used in concrete work. Different authorities have given slightly varying opinions as to the order of preference in which certain materials used as aggregates stand. The following table gives the principal kinds that have been considered, in the order in which they are generally valued:

Trap Rock	100
Granite	90
Quartz Gravel	90
Hard Limestone	80
Soft Limestone	75
Slag	75
Slate	60
Shale	55
Cinder	50

Just why slate and shale should be considered it is hard to say, since both of these materials are of a form that makes them particularly unsuited for use as concrete aggregate. The particles are flat and elongated, and regardless of how well mixed with the sand-cement mortar of a concrete mixture, cannot be made to produce a dense concrete. Late tests seem to show that slag stands higher up in the list than credited in the above table. Slag in this case means slag from blast furnace operations in smelting iron ore. Nearly all other slags are unsuited for use as concrete aggregate because of the excessive quantity of free chemicals they contain and the injurious effect these will have upon the cement.

FIRE RESISTANCE OF AGGREGATES

Another thing should be borne in mind in connection with aggregates. Concrete is a great fire-resisting material, partly because the cement itself in process of manufacture has been subjected to very high heat. However, the cement alone will not safeguard the concrete if the aggregates of which it is composed are not in themselves of a fire-resisting nature. Trap rock and slag, from the very nature of their origin, have been subjected to high heat, and are therefore good fire-resisting aggregates. Some gravels have good fire-resisting qualities.

Granite, though hard, may easily be affected by intense heat because it tends to burst or crack. Some limestones are soft and become converted into lime, which, as every one knows, is made by burning limestone. Trap rock is regarded as one of the ideal aggregates. It is hard, and breaks into shapes that make a dense concrete.

For roads and pavements which from the nature of their use are subjected to heavy traffic and impact, the aggregates should be tough and wear resisting.

Cinders are used to some extent in concrete work where lightness rather than strength is required, as in some reinforced concrete floors. Cinders, however, make a porous concrete. Whenever used they should be free from ash and particles of unburned coal.

SIZE OF AGGREGATES

The maximum size of coarse aggregate is determined by the thickness of the section in which used. Aggregate particles should always be less than half the thickness of the wall or section being placed. A maximum of one third such dimension is probably best. In some cases this maximum cannot be used, because the reinforcing that must be embedded in the concrete and the position of such reinforcing prevent the use of such large particles. It is difficult to cause concrete containing too large particles of aggregate to settle well around reinforcing and everywhere adhere or bond to it.

MIXING WATER

A very good rule to observe in connection with water used for mixing concrete is that it be equal in quality to drinking water. It should be clean, free from vegetable and animal matter, and should not contain acid or alkali. If water containing alkali is used, the result is usually a formation on the concrete of a whitish deposit called efflorescence. If alkali is present in excessive quantities it may affect the final strength of the concrete.

PROPORTIONING CONCRETE MIXTURES

USUAL METHODS

For very accurate work concrete is proportioned after determinations have been made in a laboratory or otherwise to ascertain the exact quantities of each ingredient which should be used, or which is necessary to make the mixture as dense and strong as possible, that is, as free from voids or air spaces. On much work such exact methods are not followed. Proportioning is ordinarily done by volume. One of the commonest mixtures used is the 1:2:4 mixture, which is largely employed for most reinforced concrete work. Some modification of proportions is necessary, depending upon the kind of work and the grading of the materials used. For example, if there is lack of uniformity in grading of the sand or pebbles, or both, and the work must be water-tight, then a 1:2:3 mixture is much safer than a 1:2:4. A table of mixtures commonly used in certain classes of work follows:

TABLE OF RECOMMENDED MIXTURES

1:1:1 Mixture for

The wearing course of two-course floors subject to heavy trucking, such as occurs in factories, warehouses, on loading platforms, etc.

1:1:1½ Mixture for

The wearing course of two-course pavements, in which case the pebbles or crushed stone is graded from ¼ to ½ inch.

1:2:3 Mixture for

Reinforced concrete roof slabs.

One-course concrete road, street, and alley pavements.

One-course walks and barnyard pavements.

One-course concrete floors.

Fence posts.

Sills and lintels without mortar surface.

Watering troughs and tanks.

Reinforced concrete columns.

Mine timbers.

Construction subjected to water pressure, such as reservoirs, swimming pools, storage tanks, cisterns, elevator pits, vats, etc.

1: 2: 4 Mixture for

Reinforced concrete walls, floors, beams, columns, and other concrete members designed in combination with steel reinforcing.

Concrete for the arch ring of arch bridges and culverts; foundations for large engines causing heavy loading, some impact and vibration.

Concrete work in general subject to vibration.

Reinforced concrete sewer pipe.

1: 2½: 4 Mixture for

Silo walls, grain bins, coal bins, elevators, and similar structures.

Building walls above foundation when stucco finish will not be applied.

Walls of pits or basements subject to considerable exposure to moisture but practically no direct water pressure.

Manure pits, dipping vats, hog wallows.

Backing of concrete block.

Base of two-course road, street, and alley pavements.

1:2½:5 Mixture for

Walls above ground which are to have stucco finish.

Base of two-course sidewalks, feeding floors, barnyard pavements, and two-course plain concrete floors.

Abutments and wing walls of bridges and culverts, dams, small retaining walls.

Basement walls and foundations for ordinary conditions where water-tightness is not essential.

Foundations for small engines.

1:3:6 Mixture for

Mass concrete, such as large gravity retaining walls, heavy foundations and footings.

1:1½ Mixture for

Inside plastering of water tanks, silos, and bin walls, where required, and for facing walls below ground when necessary to afford additional protection against the entrance of moisture.

Back plastering of gravity retaining walls.

1:2 Mixture for

Scratch coat of exterior plaster (cement and stucco).

Facing block and similar concrete products.

Wearing course of two-course walks, floors subjected only to light loads, barnyard pavements, etc.

1:2½ Mixture for

Intermediate and finish stucco coats.

Fence posts when coarse aggregate is not used.

1:3 Mixture for

Concrete block when coarse aggregate is not used.

Concrete brick.

Concrete drain tile and pipe when coarse aggregate is not used.

Ornamental concrete products.

QUANTITIES OF MATERIALS REQUIRED FOR VARIOUS MIXTURES OF MORTAR AND CONCRETE

Mixture	Materials for One-Bag Batch			Resulting Volume in Cubic Feet		Quantities of Cement, Sand, and Pebbles or Stone required for One Cubic Yard of Compacted Mortar or Concrete				
	Cement in Sacks	Sand cu. ft.	Pebbles or Stone cu. ft.	Mortar	Concrete	Cement in Sacks	Sand cu. ft.	Sand cu. yd	Stone or Pebbles cu. ft.	Stone or Pebbles cu. yd.
1:1½	1	1.5		1.75		15.5	23.2	.86		
1:2	1	2.0		2.1		12.8	25.6	.95		
1:2½	1	2.5		2.5		11.0	27.5	1.02		
1:3	1	3.0		2.8		9 6	28.8	1.07		
1:2:3	1	2.0	3.0		3.9	7.0	14.0	.52	21.0	.78
1·2:4	1	2.0	4.0		4.5	6.0	12.0	.44	24.0	.89
1:2½:4	1	2.5	4.0		4.8	5.6	14.0	.52	22.4	.83
1:2½:5	1	2.5	5.0		5.4	5.0	12.5	.46	25.0	.92
1:3:6	1	3.0	6 0		6.4	4.2	12.6	.47	25.2	.94

MIXING CONCRETE

Concrete is mixed either by hand or machine. However, on jobs of any size today hand mixing is no longer thought of because of the labor involved, and also because machine mixing is certain to produce more uniformly mixed concrete. There are many kinds of concrete mixers, but broadly speaking these may be classified as continuous and batch mixers.

Continuous mixers, as the name implies, are those into which the separate materials are continuously fed and from which there is an uninterrupted stream of mixed concrete discharged. The idea of the continuous mixer is good, but in practice such mixers are not reliable. Difference in moisture in the sand, as well as packing of the cement in the bin or hopper in which contained, is likely to cause varying quantities of the materials to be discharged, and therefore the resulting concrete will not be uniform.

BATCH MIXERS

Engineers now almost invariably specify that concrete be mixed in one of the batch types of mixers. This means a mixer into which the separately measured quantities of materials are dumped and the mixing completed before another supply of materials is put in the machine. Ransome mixers are all of the batch type and are recognized as the highest class of machines in their particular field. Every size and kind of mixer may be found in the Ransome line, each having its own particular merits with special reference to some particular class of work for which it is most suitable.

MEASURING MATERIALS

The most convenient way of measuring the sand and pebbles or broken stone is to set a bottomless box or frame holding a definite number of cubic feet of material into a metal wheelbarrow and then fill this box to the required depth or level. Otherwise some type of wheelbarrow particularly devised for measuring aggregates may be used. It is well to determine by one or two test batches the amount of water necessary to produce the required consistency, then as long as the aggregates being used are the same in quality and moisture content the same measured volume of water may be used for each batch, thus resulting in concrete of uniform consistency. If the moisture in the sand varies or if more porous aggregates must be used, it then becomes necessary to adjust the volume of water used for each batch.

CONSISTENCY OF MIXTURES

By far too much concrete is mixed either too wet or too dry. Rarely is just the right amount of water used. In times past the greatest fault of concrete construction was dry concrete. In later days and at the present time the fault is concrete that is too wet — actually sloppy mixtures. For most classes of work the correct amount of water is that which will produce a concrete of "quaky" or jelly-like consistency. Less water can sometimes be used for foundation concrete where the section is massive or where the wall need not be water-tight, but the quaky consistency is preferable wherever possible to use it.

QUANTITY OF WATER

In hand mixing, batches should not be larger than can be conveniently mixed on the platform, nor should the batches ever be larger than can be placed within thirty minutes after mixing. Water is one of the essential ingredients of a concrete mixture. A certain quantity is necessary to accomplish the chemical change that takes place in the cement when combined with water. For ease of working, a little in excess of the best quantity necessary may be added to make the mass a little more plastic. There are differences between the opinions that engineers and contractors have as to the correct amount of water to be used in concrete mixtures, and as to the effect which variations in the quantity of water have on the strength and other properties of concrete. The amount of water which gives concrete of maximum strength results in a mix which is too stiff to be conveniently used in most work. For example, in plants where concrete block, drain tile, and sewer pipe are manufactured, it is desirable for profitable output to use a mix containing less water than that which gives maximum strength. This permits molds to be removed within a short time and hence increases the output of the plant.

The exact amount of water necessary for the maximum strength of concrete varies with the method of handling and placing concrete. The proper quantity of water will vary with the quantity of cement and the size and grading of the aggregates and somewhat on the nature of the aggregates. The water required for a sand and crushed stone aggregate is not greatly different from that required for a sand and cement mixture, providing the aggregates are similarly graded. If the aggregates are soft or porous a somewhat greater quantity of water will be necessary. The principal difficulty in attempting to state a specific quantity of water for any mixture is due to the fact that moisture content and physical characteristics of the aggregates vary. An approximation that will help to a decision is given in the accompanying table.

Mix		Approximate Mix as Usually Expressed			Water Required (Gallons per Sack of Cement)	
Cement	Volume of Aggregate after Mixing	Cement	Aggregate			
			Fine	Coarse	Minimum	Maximum
1	5	1	2	4	6	6½
1	4½	1	2	3	5¾	6¼
1	4	1	1½	3	5½	6
1	3	1	1¼	2½	5	5½

Others have stated the quantity of water required in a slightly different way. The quaky or jelly-like consistency can usually be obtained by using water in the proportion of one gallon to one cubic foot of concrete in place. Some uses of concrete require wetter mixtures than are described by the word quaky, but never should the quantity of water be such as to produce the sloppy consistency which may better be described, perhaps, as one which when handled on a shovel causes the pebbles to separate from the sand-cement mortar.

TIME OF MIXING

Of late years the tendency has been to increase the time of mixing. This is a very desirable trend. Experiments have proved conclusively that increasing the time of mixing very greatly influences the strength of the resulting concrete. Of course there is a limit to the length of time which can be devoted to mixing with true economy to the work in question, but all concrete would be better if mixed for one and one half minutes than one minute or less. Frequently a few more turns of the drum will produce the required consistency, which is often obtained at a sacrifice of strength of the concrete by using more water than needed and reducing the time of mixing.

Before water is added to the materials in the drum it should be given a few revolutions to thoroughly mix the materials while dry. Then the required amount of water should be added and the drum revolved for a specified time or a specific number of revolutions. Many mixers have attached to them a water tank by means of which a measured quantity of water for each batch may be added to the dry materials.

Care should be taken not to place more materials in the drum than recommended by the manufacturers, as proper mixing cannot then be accomplished. When the batch has been completely mixed its volume in the drum should not represent more than one third of the total cubic capacity of the drum. Many contractors fail to understand mixer capacity. They do not realize how much greater is the volume of unmixed materials as they lie in the drum before it has been revolved than the resulting volume of concrete. This is a simple matter and can readily be understood by recalling statements previously made with reference to the voids in the various materials. Until the measured materials have been mixed they represent a volume corresponding to the total number of cubic feet of the several materials measured separately; that is, until mixed a 1:3:5 mixture has nine cubic feet of materials. Just as soon as mixing begins, however, the distribution of the smaller sized particles amongst the larger ones commences to fill the voids or air spaces in the mass and considerably reduces its volume.

FORMS FOR CONCRETE

GENERAL

When a batch of concrete is mixed, it must be placed in some kind of a form or mold that will give it the desired shape. Practically every class of concrete work requires form construction, the only exception to this being that sometimes concrete for a foundation may be placed in a trench without forms, providing the excavation walls are firm and self-supporting. For work above ground and for concrete objects in general some kind of forms or molds are necessary.

TYPES OF FORMS

In the average run of concrete work wood forms are used. For work such as circular tanks, silos, and other circular structures, there are various types of metal forms on the market devised with special reference to the classes of work above mentioned. There are also various types of so-called form systems, most of which are patented and involve metal forms. Because of the fact that no two concrete structures are rarely, if ever, exactly alike, wood forms are used more often than metal forms. Sometimes where an exceptionally smooth surface finish is desired, and it is also advisable to prolong the life of the forms so they may be used repeatedly on similar portions of different buildings, they are lined or covered inside with thin sheet steel.

REQUIREMENTS OF WOOD FORMS

Depending upon the nature of the work, its massiveness, and hence the volume of concrete to be supported, forms are made of lumber varying from one inch to two or three inches in thickness. This refers to the form sheathing itself. Braces, studs, and posts to which sheathing is nailed may be two by four inches, two by six inches, or any similar dimensions that will withstand the loads or strains that will be brought upon forms by the concrete in place before it has hardened and become self-supporting.

Norway pine, spruce, and southern pine are the most generally used and economical form lumbers. Short leaf pine also makes good form sheathing. If spruce can be obtained it is probably the best material to use for studs, braces, joists, and posts, as it is tough under bending strains. Hemlock is too coarse grained for sheathing and splits easily, so is not reliable for heavy frame work. The hard woods, such as oak, are too high priced and too difficult to work economically.

Form lumber should be free from imperfections, such as shakes, rot, and knots, especially where the appearance of the finished work is of importance. Unplaned lumber will do where the concrete surface is to be hidden from view, but planed lumber is always best because of the smoother surface finish that can be secured on the concrete and also because the concrete will stick less to the forms. Air-seasoned lumber is better than kiln dried. The latter will swell and bulge at joints, while if the lumber is green it will shrink very quickly in drying out, after forms are made, thus opening cracks through which water carrying cement will leak out when the concrete is placed. Lumber dressed on both sides and edges may sometimes be necessary, because it is very important that sheathing boards be of uniform thickness; otherwise when nailed to the studs the inside face of forms will be very irregular and this irregularity will be reproduced in the concrete surface, making it unsightly. Tongued and grooved materials and what is known as shiplap are often used for form sheathing. Beveled edge stock has its advantages, because if the lumber swells the edges will slip past each other without causing warping or bulging of the boards. Beveled edge stuff is usually cheaper, because there is less waste in manufacturing at the mill.

SAFE LOAD FOR STUDS OR POSTS

Posts and studs for supporting forms must be strong and stiff enough to hold them in true line and to prevent sagging under the load of concrete. The maximum safe load for wood posts of various lengths and sections is given below. Knowing the length of post, total weight of concrete and forms to be supported, and the economical number of posts, the load per post can readily be determined. It should be remembered that a corner post carries over one fourth of the load carried by a side post and that a side post carries one half the load of an inside post.

TABLE I

Maximum Safe Load in Pounds for Wood Columns

Length in ft.	4 in.	6 in.	8 in.
5	9,400		
6	8,800		
7	8,200		
8	7,500	20,700	
9	6,800	19,800	
10	6,300	18,900	37,700
11		17,900	36,400
12		17,000	35,200
14		15,100	32,700
16			30,200
18			27,600
20			25,100

EXAMPLE:

Flat slab 14 feet by 17 feet 8 inches, weighing approximately 60,000 pounds, 16 post can be spaced economically in four rows of 4. There will be 4 corner posts, 8 side posts, and 4 inside posts—16 posts.

4 corner posts carry load of 1 inside post	=1
8 side posts carry load of 4 inside posts	=4
4 inside posts carry load of 4 inside posts	=4
Number posts of equal load	9

Maximum load per post $= \frac{60,000}{9} = 6,666$ lb.
Length of post 6 feet 0 inches.

From the table we find one 4 by 4 inch post 6 feet long will carry safely a load of 8,800 pounds. Since no timbers of less than 4 by 4 inches should be used, this size will be adopted.

PLANNING FORMS ECONOMICALLY

Considerable economy in form work results from carefully planning the forms before cutting lumber. Often form units can be planned that will serve repeated use on similar portions of structures other than the one for which first made. Any such forethought given the planning of forms will therefore result in final economy. For some work but little cutting may be required. Stock lengths can be used and ends allowed to hang over without causing any inconvenience on the job. Also, if the forms are planned so that few nails will be necessary to hold them together, less damage will be done to lumber when knocked apart than if tightly nailed together. Often screws can be used to decided advantage instead of nails.

Bolts, clamps, and various kinds of ties can also be used on some types of forms, thus making any permanent fastenings entirely unnecessary. Such devices where they can be used make form lumber last longer. The forms or the lumber can be reassembled for other forms, serving repeated use on a number of structures and thus reducing the cost of form work on each job. Waste of lumber in concrete form work results often from allowing carpenters unfamiliar with concrete work to make the forms. For important jobs quite a different kind of carpenter skill is required than is usually possessed by a carpenter whose experience has been on fine permanent structures built throughout or largely of wood. The experienced form carpenter bears in mind that forms can be designed so that some if not most of the lumber can be used again. Therefore he is careful to avoid unnecessary cutting and other damage to lumber.

COST OF FORM WORK

Straight walls and flat floors usually require the simplest types of forms. In normal times such forms can often be built for from $10 to $20 per thousand feet board measure of lumber. If there are many corners, openings, offsets, projections, and similar irregularities, to be molded in the concrete surface or section, there must be more cutting of lumber, which will correspondingly increase the cost of forms. In normal times form lumber can be obtained for from $25 to $30 per thousand feet board measure. The longer it can be used the less the amount of its original cost will be charged to any one job.

As has been mentioned, economy in cost of forms can often be brought about by planning unit sections so far as possible, that is, panels which can be reset on the same job in similar position without alteration. This is especially true in plain wall construction, beams, floor slabs, and columns. There are on the market a number of types of unit forms for various classes of construction. These permit building both solid (monolithic) and hollow walls. Among the common types of unit forms are those used for silos, arches, sewers, and box culverts. Many of these are adjustable so as to permit being used for structures of the types mentioned, having different dimensions.

WETTING OR GREASING FORMS

After forms are set up and firmly braced in position they should be either wet down or slightly greased with a mixture of linseed oil and kerosene, or some other application, so that concrete will not stick to them. Each time after use the forms should be thoroughly cleaned, and before again used should be wet down or wiped with oil immediately before concrete is placed in them.

IMPORTANCE OF BRACING FORMS

Some failures of concrete work have had their origin in faulty form construction. This is particularly true of floors and arches. Form studs or supports were not strong enough to hold the load of concrete, and a gradual settlement or change in position of forms while the concrete has been undergoing early hardening produced small cracks in the concrete. These naturally increase in size just as soon as the structure is loaded, and frequently failure has followed. This leads up to the subject of form removal.

FORM REMOVAL

Concrete failures have resulted from too early removal of forms. It should be remembered that concrete hardens quite differently under different weather and temperature conditions. Moist, warm weather is most favorable to the rapid hardening of concrete. Cold weather retards hardening greatly, depending upon the degree of cold. For example, it might be safe to remove forms in from twenty-four to forty-eight hours from some piece of work in warm weather, while it might be necessary to leave forms in place for two or three weeks in cold weather. It is particularly important not to remove forms from concrete that is to be self-supporting, such as floors, roof slabs, and arches, until all possibility of failure has passed. Forms may often be removed from vertical walls within twenty-four hours after the last concrete was placed, but forms for arch rings, roof slabs, and floors may have to be left in place for a week or several weeks to make certain that the concrete has properly hardened so as to be able to support not only its own weight but that of any load that may be placed upon it immediately after forms are removed. No specific rule can be laid down for the time which must elapse before forms may safely be removed. This is something which only experience and good judgment can determine.

REINFORCING CONCRETE

PRINCIPLES OF REINFORCING

It is presumed that those who will read this book know why concrete is reinforced, therefore the subject will not be discussed at length; an outline of the principles will be sufficient. Concrete is relatively weak in tension or in resisting strains that tend to pull it apart. It is also weak in resisting bending strains. In bearing loads that are placed directly upon it, concrete is very strong, that is, it has a great compressive strength. To take advantage of concrete's full compressive strength, regardless of how the material may be used in any portion of a building, it is necessary to embed steel in it to resist bending or pulling strains, that is, strains of tension. Each concrete structure is the subject of a particular design, so, except as relates to some standard sections or portions of fixed dimensions, it is not possible to lay down definite rules for reinforcing concrete.

LOCATION OF REINFORCEMENT

In every use of reinforcement it is necessary that the material be placed in the concrete at some particular point or location to secure its full effectiveness. In a beam, for example, the reinforcement is placed along its lower section, sufficiently embedded in the concrete to prevent injury from severe exposure to fire, for instance. Usually from one to one and a half inches of such protection is all that is necessary. The principal thing to observe when placing reinforcing is to make sure that its location in the forms with reference to the position that it is to occupy in the finished concrete work is exactly in accordance with the position shown on the engineers' or designers' plans from which the contractor is working. This is necessary for several reasons — protection against fire, for example — but principally because the engineer or designer has calculated that the quantity and size of steel specified will best accomplish its purpose in the location shown for it on the plans. Therefore in placing concrete for reinforced work it is very important that the steel when laid in position in the forms shall not be displaced when the concrete is deposited.

Bars and mesh used for reinforcement can be blocked up into proper position by placing beneath them small cubes of concrete which may afterward be left in the work. If wood blocks are used for the same purpose, they should subsequently be removed and the space which they occupied be filled with a good, rich sand-cement mortar.

MATERIALS USED AS REINFORCEMENT

Various materials are used for reinforcing concrete, that is, steel is used in various forms. There are plain, round, and square rods, twisted square rods, and various other types of round and square rods that are in different ways deformed, so to speak, when they are manufactured. They have lugs or projections molded in their surface, the idea of this deforming being to increase the mechanical bond between the concrete and steel. In some cases deformed bars may be best, as they are a safeguard when concrete has not everywhere been puddled or spaded to place around the bars, as it should be; also, when for any reason the consistency of the concrete is drier than would be best. In some cases mechanically deformed bars are a safeguard against slight variations in the workmanship or placing concrete. If, however, concrete is of correct consistency, and is sufficiently rich in cement, the natural bond between concrete and plain round or square rods is enough to take advantage of the safe elastic limit of the steel. For most work round, square, or twisted square rods or bars are satisfactory and most commonly used because easiest to obtain.

EXPANDED METAL AND MESH FABRIC

Other types of reinforcing used largely for certain classes of work, such as floor and wall construction, roof slabs, and for ground work for stucco, are the various deformed or expanded sheet metals, steel wire mesh, and similar fabrics. Most of these reinforcing materials have unusual merits if properly used, and they also have a wide range of use. In a great many cases some one of the fabrics or expanded metals can be substituted for steel rods or bars, providing the net sectional area of the materials substituted is equivalent to that of the rods or bars.

Generally speaking, the average contractor need consider but one grade of reinforcing steel. This can be obtained direct from any of the steel companies or through dealers in the usual variety of building materials. It should be remembered that there is a great variation in steel, that is, there are many grades of it. Some steel is quite like wrought iron, while others may be compared with cast iron as regards brittleness. This should lead one to realize that not all steel is suitable for reinforcing concrete. Reinforcing steel should meet certain specifications which have been laid down by engineering societies, notably the American Society for Testing Materials. Such steel ranges in tensile strength from 55,000 to 70,000 pounds per square inch. The stocks of steel often carried by hardware stores, and particularly by local blacksmith shops, are not of the desired quality for reinforcement in concrete. When steel of a certain tensile strength or having other particular qualities is called for in a specification the contractor or builder should make certain that the material he is using meets the requirements set forth.

CARE OF REINFORCEMENT BEFORE USE AND ON THE JOB

Reinforcing steel or other reinforcing materials must be handled on the job properly. The steel must be placed exactly where it belongs in the concrete. Care should be taken to see that before placed all loose rust or mill scale is removed from it by brushing with wire brushes or pickling in a weak acid bath and then washing thoroughly with clean water; also that it is not covered wholly or in part with oil or grease. Any of the foregoing will prevent good bond or adhesion between concrete and steel.

Reinforcing material should not be bent suddenly. Various types of machines are on the market intended for use in cutting, bending, and otherwise shaping reinforcing bars according to the requirements of plans. Reinforcing for many members of buildings are often furnished completely assembled so that they can be readily set up in the forms. Bending has all been done properly and this leaves but little work to do on the job. If bars must be bent on the job, proper machines should be used for the purpose and the bending should be done steadily and gradually, so that the steel is not subjected to sudden jerks or twists that might tend to start a fracture at the point where bent and thus weaken the reinforcement.

CONVENIENT CONCRETE ESTIMATING TABLES AND EXAMPLES

For convenience, concrete is usually mixed in batches, each requiring one sack of cement. The following table shows the cubic feet of sand and pebbles (or crushed stone) to be mixed with one sack of cement to secure mixtures of the different proportions indicated in the first column. The last column gives the resulting volume in cubic feet of compacted mortar or concrete.

TABLE No. I

MIXTURES			MATERIALS			COL. IN CU. FT.	
Cement	Sand	Pebbles or Stone	Cement in Sacks	Sand cu. ft.	Pebbles or Stone cu. ft.	Mortar	Concrete
1	1.5		1	1.5		1.75	
1	2		1	2		2.1	
1	3		1	3		2.8	
1	1.5	3	1	1.5	3		3.5
1	2	3	1	2	3		3.9
1	2	4	1	2	4		4.5
1	2.5	4	1	2.5	4		4.8
1	2.5	5	1	2.5	5		5.4
1	3	5	1	3	5		5.8

The following table gives the number of sacks of cement and cubic feet of sand and pebbles (or stone) required to make one cubic yard (twenty-seven cubic feet) of compacted concrete proportioned as indicated in first column.

TABLE No. II

MIXTURES			QUANTITIES OF MATERIALS		
Cement	Sand	Pebbles or Stone	Cement in Sacks	Sand cu. ft.	Stone or Pebbles cu. ft.
1	1.5		15.5	23.2	
1	2		12.8	25.6	
1	3		9.6	28.8	
1	1.5	3	7.6	11.4	22.8
1	2	3	7	14	21
1	2	4	6	12	24
1	2.5	4	5.6	14	22.4
1	2.5	5	5	12.5	25
1	3	5	4.6	13.8	23
1	3	6	4.2	12.6	25.2

EXAMPLE I

How much cement, sand, and pebbles will be required to build a feeding floor 30 by 24 feet, 5 inches thick?

Multiplying the area (30 by 24) by the thickness in feet gives 300 cubic feet, and dividing this by 27 gives $11\frac{1}{9}$ cubic yards as the required volume of concrete. A one-course floor should be of 1:2:3 mixture. Table II shows that each cubic yard of this mixture required 7 sacks of cement, 14 cubic feet of sand, and 21 cubic feet of gravel or stone. Multiplying these quantities by the number of cubic yards required ($11\frac{1}{9}$) gives the quantities of material required (eliminating fractions) as 78 sacks of cement, 156 cubic feet of sand, and 233 cubic feet of pebbles or stone. As there are 4 sacks of cement in a barrel, and 27 cubic feet of sand or pebbles in a cubic yard, we shall need a little less than 20 barrels of cement, 6 cubic yards of sand, and 9 cubic yards of pebbles or stone.

EXAMPLE II

How many fence posts 3 by 3 inches at the top, 5 by 5 inches at the bottom, and 7 feet long can be made from one sack of cement? How much sand and pebbles will be needed?

Fence posts should be of a 1:2:3 mixture. Table I shows the volume of a one-sack batch of this mixture to be $3\frac{9}{10}$ cubic feet. The volume of one concrete post, found by multiplying the length by the average width and breadth in feet (7 by $\frac{1}{3}$ by $\frac{1}{3}$) is $\frac{7}{9}$ cubic foot. By dividing $3\frac{9}{10}$ by $\frac{7}{9}$ we find that five posts can be made from 1 sack of cement when mixed with 2 cubic feet of sand and 3 cubic feet of pebbles.

EXAMPLE III

What quantities of cement, sand, and pebbles are necessary to make 100 unfaced concrete blocks, each 8 by 8 by 16 inches?

The product of height, width, and thickness, all in feet ($\frac{2}{3}$ by $\frac{2}{3}$ by $\frac{4}{3}$) gives $\frac{16}{27}$ cubic foot as the contents of a solid block. As the air space is usually estimated as $33\frac{1}{3}$ per cent, the volume of concrete in one hollow block will be $\frac{2}{3}$ or $\frac{16}{27}$ or $\frac{32}{81}$ cubic foot; in 100 blocks the volume of concrete will be $\frac{3200}{81}$ or $39\frac{1}{2}$ cubic feet, which being divided by 27 gives a little less than $1\frac{1}{2}$ cubic yards. Unfaced concrete block should be of $1:2\frac{1}{2}:4$ mixture. Table II shows that each cubic yard of this mixture requires $5\frac{6}{10}$ sacks of cement, 14 cubic feet of sand, and $22\frac{4}{10}$ cubic feet of pebbles. Multiplying these quantities by the number of cubic yards required ($1\frac{1}{2}$) gives the quantities of material required as $8\frac{2}{5}$ sacks of cement, 21 cubic feet of sand, and $33\frac{3}{5}$ cubic feet of gravel.

EXAMPLE IV

How many 6 foot hog troughs 12 inches wide and 10 inches high can be made from 1 barrel of cement?

Use a 1:2:3 mixture. Table I shows the volume of a 1 sack batch of this mixture to be $3\frac{9}{10}$ cubic feet. As there are 4 sacks in 1 barrel, a barrel of cement would be sufficient for four times $3\frac{9}{10}$, or $15\frac{6}{10}$ cubic feet of concrete. The product of the three dimensions, all in feet, gives the volume of one trough as 5 cubic feet. However, approximately 30 per cent of this volume is in the open water basin or inside of the tank, leaving $3\frac{5}{10}$ cubic feet as the solid contents of concrete in one trough. Dividing $15\frac{6}{10}$ by $3\frac{5}{10}$, we find that 4 troughs (and a fraction over) can be made from 1 barrel of cement when mixed with 8 cubic feet of sand and 12 cubic feet of pebbles.

PLACING CONCRETE

GENERAL

The hardening which takes place when cement and water are combined is noticeable within a very short time after a batch of concrete has been mixed. For this reason concrete should be deposited as quickly as possible after mixing. No concrete should be used when it is thirty minutes or more old.

METHODS OF PLACING

Methods of placing necessarily vary in accordance with the class of work and the condition under which it is being carried on. Concrete should be deposited in a layer or layers of uniform depth, as for instance when a foundation wall is being built, or arrangements should be made to fill up one section of the forms at a time, provision being made at one end of the section to join the next one to it so a water-tight joint will result.

Concrete for pavements and for floors on the ground is generally dumped from wheelbarrows or, in the case of highway pavements, is placed by a spout or by means of a boom and bucket. In street and highway pavement work the subgrade should be thoroughly sprinkled before concrete is placed, so that the concrete will not be robbed of water.

Where the only surface finish required is that obtained from contact with the forms, the concrete should be spaded with some chisel-edged tool used next to form faces so as to force back coarse particles of aggregate and allow the fine sand-cement mortar to come next to the form, thus producing a smoother, denser, and hence water-tight surface.

Where surfacing mixtures are used it is necessary to place the facing mixture a little in advance of the back or center of the work either by hand or by means of a metal septum. Then the septum is withdrawn and the center mass consolidated by tamping or spading so that it will thoroughly unite with the facing mixture. To best accomplish this the two mixtures should be of as nearly the same consistency as possible.

Care should be taken not to dump concrete into the forms through too great a height. If it is dropped more than 6 or 8 feet the materials are likely to separate somewhat in falling and this will cause pebble pockets in the work.

Much poor concrete work has been done by placing concrete through spouts. In such cases elevators are run up towers, the concrete dumped into a hopper connected with the spout and allowed to flow down through the spout into place. The object of such placing is to make one central plant distribute concrete over as large an area as possible without changing the location of the central plant frequently. Spouts are frequently made to cover too wide a range, with the result that they lie at too flat an angle and then too much water is used in the mixture to make the concrete travel in the spout. Spouting concrete into place permits rapid and economical placing, but the concrete must not be sloppy. Care should therefore be taken never to set spouts at a flatter angle than will carry concrete of the right consistency. This is usually about twenty-five degrees.

Concrete is also placed by compressed air. The Ransome Concrete Machinery Co. manufactures a pneumatic placing machine for this purpose which has special efficiency in that it both mixes the concrete and places it with force at the right consistency, thus practically doing away with the need of tamping or spading in the forms.

Concrete should not be placed in layers deeper than will permit firmly consolidating it with concrete previously placed. Nor should the operation of placing be interrupted so that concrete previously placed has commenced to harden before that subsequently placed is put upon it. If such is the case the two layers cannot be made to unite thoroughly. Such conditions produce construction seams in the work, which not only weaken it but are quite likely to be the cause of leakage. When necessary to discontinue concreting before forms are filled, as at the end of the day, for instance, the top of the concrete last placed in the forms should be roughened by scratching it with a stick to prepare for a good bond with the concrete that is to be placed later. Immediately before resuming concreting the surface of the old concrete should be well scrubbed and washed with a broom and water, and painted with a mixture of cement and water of about the consistency of thick cream, this being done immediately before placing new concrete.

Arrangements should be made wherever possible to carry on continuously the concreting of tanks, silos, reservoir walls, and any concrete work that has to be water-tight, so as to prevent the construction seams mentioned. However, on some work it is necessary to suspend concreting each day. Then the work should be left roughened in the forms and treated as previously described. On tank work some have found it advisable to embed at or along the center line of the concrete section a strip of tin or sheet iron half into the concrete just placed, and half exposed preparatory to being covered with concrete the next day. Just before resuming work this metal strip as well as the old concrete should be painted with the creamy cement-water paint previously mentioned.

PROTECTING THE FINISHED WORK

Proper protection of concrete after placed is of the utmost importance. Concrete mixtures may have been properly proportioned, may have been mixed to the correct consistency, and may have been properly placed, yet if the concrete is allowed to dry out or in any other way lose the water which was combined with it, the cement is deprived of the ingredient necessary to hardening, hence the concrete will lack strength and water-tightness.

The hardening of concrete is not a drying process, as some people suppose. If concrete after being placed is left exposed to sun and wind much of the water necessary to its hardening is lost by evaporation. Protection is especially necessary on floors and walls where considerable surface area is exposed. It is not so necessary on mass work, since such work is to a certain extent self-protecting. Floors, walks, pavements, and like work should be protected by a covering of moist earth or some other moisture-retaining material. This should be kept wet for several days, when it may be removed and the concrete allowed to harden naturally. The ideal conditions for hardening of concrete are warmth and moisture. When these two conditions are present the concrete hardens most uniformly. An illustration of this is seen in the practice of ponding or flooding concrete road pavements immediately after they have hardened sufficiently to permit covering with water.

Thin wall sections may be given part of the protection needed by leaving forms in place a day or two longer than ordinarily would be necessary and wetting down the entire work several times daily.

Silo and tank walls should be protected by hanging canvas cloth over them and keeping this wet. Stucco should be protected in the same manner. Indeed a great deal of the hair-cracking in stucco work is due to the almost universal practice of omitting protection against sun and wind immediately after the work is finished.

Until contractors and others realize the full importance of these protective measures there will be more or less concrete work that will be the subject of unjust criticism as far as concrete itself is concerned.

CONCRETING IN COLD WEATHER

Many concrete contractors now keep their plant operating practically twelve months a year by taking precautions in their concrete work to observe practice that makes concreting in cold weather just as successful as that done in warm weather.

The principles underlying the success of concrete work done in cold weather are the following:

Sand and pebbles or broken stone used must be free from frost or lumps of frozen materials. If there is frost or frozen lumps in the materials they must be thawed out.

Sand and pebbles or broken stone and mixing water must be heated. Cement forms only a small bulk of the materials in a batch of concrete and need not be heated.

It is necessary to mix, place, and protect the concrete, so that early hardening will be complete before the work is exposed to freezing temperatures.

Sand and pebbles, or broken stone, and mixing water should be heated so that the concrete when placed has a temperature of seventy-five to eighty degrees.

Adding common salt to the mixing water will prevent freezing of concrete that has not hardened. There is a limit to the quantity of salt which may be used, however, as an excess will affect the final strength of the concrete. Salt is not desirable, as it simply lowers the freezing point of the mixing water. It does not supply what is most needed — heat and warmth. It delays instead of hastens hardening of the concrete.

Some sands and pebbles or broken stones are injured by too much heat. Temperature not exceeding 150 degrees Fahrenheit will generally be high enough when heating these materials.

Concrete must be placed immediately after mixing, so that none of the heat will be lost before placing in the forms.

Metal forms and reinforcing steel should be warmed before placing concrete. Snow and ice and frozen concrete remaining on the forms from preceding work should be removed. Forms can be warmed by turning a jet of steam against them or by wetting with hot water.

Unless the work is protected immediately after placed it will lose much of the heat. Canvas covering, sheathing, housing in the work, or hay or straw properly applied, will furnish protection for some work. Small oil or coke burning stoves or salamanders are used to supply the necessary heat in enclosed structures.

Temperatures which may not be low enough to freeze the concrete may delay its hardening for some time. Concrete placed when the temperature is low and remains low for some time afterward will not be safe under load as soon as though placed during warmer weather.

Concrete which freezes before early hardening has been completed may not be permanently injured if after thawing out it is not again exposed to freezing until hardened. However, it is best to protect the concrete as soon as placed, so that it will not freeze. Alternate freezing and thawing at comparatively short intervals will seriously damage concrete that has not hardened. Forms must not be removed from concrete work done during cold weather too early. This applies to any concrete work regardless of season, but is particularly important in cold weather concreting.

Frozen concrete sometimes very closely resembles concrete that has thoroughly hardened. When frozen concrete is struck with a hammer it will often ring like properly hardened concrete. Work should be carefully examined before removing forms. The flame of a blowtorch, a steam jet, or hot water applied to the concrete will show whether it is merely frozen or has hardened. If frozen, heat will soften it by thawing the water contained in it.

PLACING CONCRETE UNDER WATER

Sometimes concrete must be placed under water. In such cases the methods must be such that the ingredients will not be separated. Some kind of a spout or a large pipe must be used to carry the concrete to a point near the bottom of the water, the pipe being gradually withdrawn as the concrete is built up. Otherwise large buckets are used which are lowered to and opened at the place of deposit. Concrete to be placed under water should not be mixed too wet. Difficulty often experienced with placing concrete under water comes from lack of care to prevent separation of cement and aggregates. Concrete cannot be thrown on the surface of the water and allowed to settle through it, because separation of materials is then certain.

One common and practical method of placing under water is to provide a closed rectangular wood chute or circular metal one, called a tremie. This is placed with one end extending into the water to the foundation in such a manner as to prevent concrete from flowing out while the chute is being filled with concrete. When entirely filled, it is raised slightly, thereby permitting the concrete to distribute itself and at the same time permit additional concrete being placed in the chute, so that depositing is continuous and the entrance of water to the chute prevented. In large work a closed bucket with hinged bottom is often used. When the bucket reaches the bottom, or foundation, its bottom is released and the concrete falls into position.

Concrete has been placed by first filling sacks which were lowered through the water to the foundation. This, however, is not good practice, as good bond cannot be secured through different parts of the foundation. When the concrete is to be deposited from the air by a receptacle lowered into the water, it should be mixed dry enough so when the gate or trap door of the bucket is opened the material will be discharged in a mass. Sometimes cofferdams are used to prevent current where the concrete is deposited. The water should always be kept quiet. The surface of the concrete under water must be kept as nearly level as possible to avoid the formation of pockets which will retain sediment or silt. Freshly deposited concrete should not be disturbed. If the concrete is not deposited continuously, all sediment should be removed from the surface of the concrete by pumping or otherwise before resuming additional concreting.

ACTION OF SEA WATER ON CONCRETE

Opinions on this subject often seem contradictory. However, extensive investigation of the subject has proved that the success of concrete in sea water depends largely, if not entirely, upon certain well defined practice. Concrete must be dense, reinforcing steel must be placed far enough from the surface so that sea water will not come in contact with it and start oxidization or rusting which will eventually cause bursting of the concrete on the face. Rich mixtures should be used throughout, otherwise a rich facing mixture should be placed simultaneously with the mass concrete. Where disintegration of concrete in sea water has been observed it has generally been proved that the concrete lacked density, also that disintegration was more marked between high and low water marks, indicating that the salts in the sea water entered the pores of the lean concrete and caused rupture by crystallizing when the water evaporated.

The United States Bureau of Standards, Technologic Paper No. 12, says:

> The disintegration of cement structures when placed in contact with sea water is a phenomenon which has attracted the attention of cement manufacturers and cement users almost from the first time that such material was used for marine construction. There are cement structures which have withstood the action of sea water for years, and probably will continue to do so, yet there are structures which have failed; and it is also possible in the laboratory by artificial solutions to destroy almost completely a briquette, or cube, or cylinder made of cement mortars or concrete. The cause of this disintegration is not certain, though it is almost universally believed that it is the reaction of sulphate of magnesia of the sea water with the lime of the cement (formed during the setting) and the alumina of the aluminates of the cement,

resulting in the formation of hydrated magnesia and calcium sulpho-aluminate, which crystallizes with a large number of molecules of water.

The other constituents both of the sea water and the cement are usually considered of little effect, though lately attention is being drawn to the fact that both sodium chloride and magnesium chloride rapidly attack the silicates.

Portland cement mortar or concrete, if porous, can be disintegrated by the mechanical forces exerted by the crystallization of almost any salt in its pores, if a sufficient amount of it is permitted to accumulate and a rapid formation of crystals is brought about by drying; and as larger crystals are formed by slow crystallization, there would be obtained the same results on a larger scale, but in greater time, if slow drying were had. Porous stone, brick, and other structural materials are disintegrated in the same manner. . . .

Properly made Portland cement concrete, when totally immersed, is apparently not subject to decomposition by the chemical action of sea water.

While these tests indicated that Portland cement concrete exposed between tides resisted chemical decomposition as satisfactorily as the totally immersed concrete, it is felt that actual service conditions were not reproduced, and therefore further investigation is desirable. . . .

Marine construction, in so far as the concrete placed below the surface of the water is concerned, would appear to be a problem of method rather than materials, as the concrete sets and permanently hardens as satisfactorily in sea water as in fresh water or in the atmosphere, if it can be placed in the forms without undue exposure to the sea water while being deposited.

CONCRETE FLOORS

GENERAL

Concrete floors are a type of pavement. Sometimes they are laid on the ground, and in others, as in reinforced concrete buildings, are aboveground. Concrete floors have in instances been cause for complaint. One of the common objections to them is that under heavy traffic they "dust" more or less. Dusting is the result of neglect to observe one or more of the fundamental requirements of concrete construction. Usually the concrete mixtures are either too wet or too dry. In the first case, finishing operations must be gone through several times in order to give the floor the desired finish. Repeated troweling draws too much fine cement to the surface. This takes the wear, and not being so resistent to wear as aggregate particles, comes off and causes the dust spoken of. Too dry a mixture lacks the quantity of water needed to transform the cement chemically, so that it will act as the firm, durable binder which it really is when properly used.

CAUSES OF DUSTING

The common causes of dusting of concrete floors are:

Too fine, dirty, or otherwise unsuitable sand.

Too little cement in the mixture.

Too much time allowed to elapse between mixing and finishing.

Troweling at several intervals after hardening has commenced.

The use of driers, and, finally

Neglect to protect the floor (keep it moist) for several days after concreting has been finished.

TYPES OF FLOORS

Like other pavements, concrete floors may be either one or two course. If the floors are to be subjected to heavy wear, one-course construction with hard, tough aggregates is best. In other respects concrete floor construction is not unlike that followed in building concrete walks, roads, or other concrete pavements. In one-course construction a 1:2:3 mixture is used throughout. In two-course construction a 1:3:5 concrete is used for the base, while the top or wearing course consists of a 1:1½ or 1:2 mixture. Much of the trouble in two-course work comes from not placing the wearing course immediately after the base is placed. Another cause of trouble is that the top coat is usually placed too wet. It should be mixed stiff enough so that the mixture will have to be scraped from the buckets or wheelbarrows. Other objections that have been advanced against concrete floors have to do with their disintegration in some plants where manufacturing solutions of various kinds are spilled on them. Concrete floors will not withstand strong acids, but such floors are used successfully in dairies, creameries, soap factories, salt works, etc. General experience seems to prove that inasmuch as dense concrete is practically impervious, none of the ordinary industrial solutions will injure a concrete floor if it is built so that maximum density of concrete is secured. Concrete floors, especially aboveground, should be water-tight. The principles of water-tight construction have been given elsewhere. They consist merely of properly proportioned mixtures placed at the right consistency and proper protection of the concrete for several days after the work has been finished.

CONCRETE WALKS

The principles of concrete floor construction apply to concrete walks. Frequently concrete walks are made too thin; also, they are frequently laid on poorly drained soil, then upheaval, due to freezing of water retained beneath the slabs, will mar the appearance of the walk, if not destroy it in part. Walks, floors, and pavements laid on the ground should be on a firmly compacted soil. If drainage is not good, a sub-base of clean material well compacted may be necessary, but in such cases the sub-base must be drained by tile lines, otherwise it will act merely as a sump to collect and retain water which will then prove as disastrous as were the whole area undrained.

Specifications for concrete floors, walks, roads, streets, and alleys, issued by the Portland Cement Association, and obtainable on request without cost, go into details of several classes of pavement construction, so these details will not be given here.

CONCRETE TANKS

Concrete is used most successfully in constructing many kinds of tanks, employed not only as containers for various liquids but as silos, grain bins, coal pockets, and similar structures, all of which can be regarded as tanks.

Tanks which are to hold liquids must, of course, be water-tight. It is best that concreting on them be continuous, to prevent construction seams which might cause leakage. Each tank must be reinforced in accordance with its capacity, so that no standard rules can be laid down for the quantity or spacing of reinforcing material in any such structure.

Tanks can be either cylindrical or rectangular. The same principles of concrete practice apply to the small concrete watering trough or tank on the farm as apply to the large water storage standpipe or reservoir. Properly proportioned mixtures, proper consistency, careful spading in forms, and protection of the finished work are all vital to success. Small watering troughs and tanks, such as used on the farm, usually have the inside faces battered or sloped so as to relieve pressure from ice if the water should freeze. Tanks of large capacity can be built more economically if circular in shape than if square or rectangular. Less material, both concrete and reinforcing, is required in circular structures than in those of other shape of like capacity. Many types of silo forms are particularly adapted to the construction needs of grain bins, water tanks, standpipes, and similar concrete structures.

Reinforcing of tanks must be properly calculated and the material must be correctly placed. Probably many tank failures have been due to improper reinforcing or to the use of unsuitable reinforcing materials. For example, old chain, wire rope, and similar materials are not suited for tank reinforcement, as they cannot be accurately placed in the forms nor kept in proper position while placing concrete. However strong such reinforcing material may be in itself, effectiveness of it is not secured when used in reinforced concrete tanks or similar structures. For the smaller classes of concrete tanks steel rods or mesh fabric may be used, but in large grain bins and elevators and similar tanks suitable sizes of steel rods and bars must be used. Leaky water tanks result from mixtures lean in cement or improperly proportioned mixtures, concrete placed too dry or too wet, and neglect to protect the concrete from drying out after the work is finished.

TYPES OF SILOS

Concrete is used for silos in the form of monolithic construction, concrete block, and cement staves. The last two types of construction are essentially masonry work. The success of block and stave silos depends entirely upon the care used in making and laying the particular units. Concrete block and cement stave silos are both excellent structures if the block and staves have been made according to good concrete practice. Block and staves should both be steam cured. Concrete silos are a form of tank, and to preserve the contents should be made water-tight and airtight. This can readily be secured by using the proper mixture properly placed.

Accompanying tables will be found convenient for estimating quantities of materials, also as a guide for reinforcing silos of various sizes both with mesh reinforcing and with rods.

CAPACITY OF ROUND SILOS IN TONS

Inside Height of Silo in feet.	INSIDE DIAMETER OF SILO											
	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.	19 ft.	20 ft.	22 ft.
24	34	41	49	57	67	76	86	98	110	122	...	...
25	36	43	52	60	71	80	91	104	116	129	143	...
26	38	46	55	64	75	85	97	110	123	137	152	...
27	40	49	58	68	79	90	102	116	130	145	160	...
28	42	51	61	71	83	95	109	122	137	152	169	205
29	44	54	64	75	87	100	114	128	144	160	178	216
30	47	56	67	79	91	105	119	135	151	168	187	226
31	49	59	70	83	96	110	125	141	158	176	196	237
32	51	62	74	86	100	115	131	148	166	184	205	248
33	53	65	77	90	105	121	137	155	174	192	215	260
34	56	68	80	94	109	126	143	162	181	200	224	271
35	58	70	84	98	114	132	149	169	189	209	234	282
36	61	73	87	102	118	136	155	176	196	218	243	293
37	63	76	90	106	123	142	161	183	204	227	252	305
38	66	79	94	110	128	148	167	190	212	236	262	316
39	68	82	97	115	133	154	173	197	220	245	272	328
40	70	85	101	119	138	160	180	204	228	255	282	340
41	72	88	105	124	143	166	187	211	236	262	291	352
42	74	91	109	128	148	172	193	218	244	270	300	363
43	...	...	113	133	154	179	201	225	252	280	310	375
44	...	...	117	137	159	184	207	233	261	289	320	387
45	...	...	...	...	165	191	215	240	269	298	330	399
46	...	...	...	...	170	197	222	247	277	307	340	412
47	...	...	...	...	...	...	229	254	285	316	350	424
48	...	...	...	...	...	...	236	261	293	325	361	436
49	...	...	...	...	...	...	...	...	301	334	371	449
50	...	...	...	...	...	...	...	...	310	344	382	462

TABLE OF DIMENSIONS AND MATERIALS FOR ROOFS FOR SILOS WITH DIAMETERS 8 FEET TO 22 FEET

Diameter of Silo	Vertical Rise	Volume of Conc. in cu.yds	Cement Required barrels	Sand Required cu. yds.	Stone Required cu. yds.	¼ Inch Reinforcing Rods		
						No. of Rods Required	Stock Length of Rods	No. of Lbs. of Rods
10 ft.	2½ ft.	1.60	2.80	.80	1.20	31	12 ft.	62
12 ft.	3 ft.	2.20	3.80	1.10	1.70	33	16 ft.	88
14 ft.	3½ ft.	2.90	5.00	1.50	2.20	45	16 ft.	120
16 ft.	4 ft.	3.80	6.60	2.00	2.90	87	10 ft.	146
18 ft.	4 ft.	4.50	7.8	2.60	3.50	93	12 ft.	187
20 ft.	4 ft.	5.40	9.4	2.80	4.20	107	12 ft.	226
22 ft.	4 ft.	6.40	11.1	3.30	4.90	113	14 ft.	265

TABLE OF MATERIALS FOR SILO FOOTING AND FLOORS

Silo in ft.	Cu. Yds.	Footings			1:2:3 cu. yds	Floors			Footings and Floor		
		Cement bbls.	Sand yds.	Gravel yds.		Cement bbls.	Sand yds.	Gravel yds.	Cement bbls.	Sand yds.	Gravel yds.
10	2.44	2.83	1.27	2.10	.70	1.22	.36	.54	4.05	1.63	2.64
12	2.91	3.38	1.51	2.50	1.07	1.86	.56	.82	5.24	2.07	3.32
14	3.37	3.91	1.75	2.90	1.51	2.63	.79	1.17	6.55	2.54	4.07
16	3.84	4.45	2.00	3.30	2.04	3.55	1.06	1.57	8.00	3.06	4.87
18	4.31	5.00	2.24	3.70	2.64	4.59	1.37	2.03	9.59	3.61	5.73
20	4.77	5.53	2.48	4.10	3.32	5.78	1.73	2.56	11.31	4.21	6.06
22	5.24	6.08	2.72	4.51	4.04	....	....	....	....	....	....

TABLE OF TRIANGLE MESH REINFORCEMENT

Feet from Top	Inside Diameter of Silo													
	10 feet		12 feet		14 feet		16 feet		18 feet		20 feet		22 feet	
	Layers	Style No.	Layers	Style No.	Layers	Style No.	Layers	Style No.	Layers	Style No.	Layers	Style No.	Layers	Style No.
0 to 9	1	6	1	6	1	6	1	6	1	6	1	6	1	6
9 to 12	1	6	1	6	1	6	1	6	1	6	1	6	1	6
12 to 15	1	6	1	6	1	6	1	6	1	6	1	4	1	4
15 to 18	1	6	1	6	1	6	1	4	1	4	1	4	1	4
18 to 21	1	6	1	6	1	4	1	4	1	4	1	4	1	4
21 to 24	1	6	1	4	1	4	1	4	1	4	1	4	1	4
24 to 27	1	4	1	4	1	4	1	4	1 each	4 & 6	1 each	4 & 6	2	4
27 to 30	1	4	1	4	1	4	1 each	4 & 6	1 each	4 & 6	1 each	4 & 6	2	4
30 to 33	1	4	1	4	1 each	4 & 6	1 each	4 & 6	1 each	4 & 6	1 each	4 & 6	2	4
33 to 36	1	4	1	4	1 each	4 & 6	1 each	4 & 6	1 each	4 & 6	2	4	2	4
36 to 39	1	4	1 each	4 & 6	1 each	4 & 6	1 each	4 & 6	2	4	2	4	2	4
39 to 42	1	4	1 each	4 & 6	1 each	4 & 6	2	4	2	4	2	4	2	4
42 to 45	1 each	4 & 6	1 each	4 & 6	1 each	4 & 6	2	4	2	4	2	4	2	23
45 to 48	1 each	4 & 6	1 each	4 & 6	2	4	2	4	1 each	4 & 23	2	23	2	23
48 to 51	1 each	4 & 6	1 each	4 & 6	2	4	2	4	1 each	4 & 23	2	23	2	23
51 to 54	1 each	4 & 6	2	4	2	4	2	4	1 each	4 & 23	2	23	2	23
54 to 57	1 each	4 & 6	2	4	2	4	1 each	4 & 23	1 each	4 & 23	2	23	2	23
57 to 60	1 each	4 & 6	2	4	2	4	1 each	4 & 23	1 each	4 & 23	2	23	2	23
Floor	1	6	1	6	1	6	1	6	1	6	1	6	1	6
Roof	2	6	2	6	2	6	2	6	2	4	2	4	2	4

CEMENT — SAND — STONE — REQUIRED FOR WALLS OF MONOLITHIC SILO

Thickness of Walls, 6 in. Continuous Doors, 2½ ft. wide. Proportions of Concrete, 1:2½:4

Height of Silo feet	Barrels of Cement required for given inside diameter in feet						Cubic yards of Sand required for given inside diameter in feet						Cubic yards of Gravel required for given inside diameter in feet					
	10	12	14	16	18	20	10	12	14	16	18	20	10	12	14	16	18	20
26	20.41	.....	.....	.....	.....	.....	7.49	.....	.....	.....	.....	.....	12.04	.....	.....	.....	.....	.....
28	21.38	26.51	.....	.....	.....	.....	8.06	9.73	.....	.....	.....	.....	12.96	15.64	.....	.....	.....	.....
30	25.55	28.40	33.25	.....	.....	.....	8.64	10.42	12.20	.....	.....	.....	13.89	16.75	19.61	.....	.....	.....
32	25.12	30.29	35.47	40.64	.....	.....	9.22	11.11	13.02	14.91	.....	.....	14.82	17.88	20.93	23.98	.....	.....
34	26.69	32.18	37.68	43.17	48.68	.....	9.79	11.80	13.83	15.84	17.86	.....	15.74	18.98	22.23	25.47	28.72	.....
36	28.24	34.07	39.89	45.77	51.54	57.37	10.36	12.50	14.64	16.77	18.91	21.05	16.66	20.10	23.53	26.97	30.41	33.84
38	29.82	35.86	42.12	48.26	54.40	60.55	10.94	13.19	15.45	17.71	19.96	22.22	17.59	21.22	24.85	28.47	32.09	35.72
40	31.39	37.85	44.33	50.80	57.27	63.73	11.52	13.89	16.26	18.64	21.01	23.38	18.52	22.33	26.15	29.97	33.78	37.60
42	.....	39.74	46.55	53.33	60.13	66.94	.....	14.58	17.08	19.57	22.06	24.56	.....	23.44	27.46	31.46	35.47	39.48
44	.....	41.64	48.76	55.88	62.99	70.11	.....	15.28	17.89	20.50	23.11	25.72	.....	24.57	28.77	32.96	37.16	41.36
46	.....	43.53	50.99	58.42	65.86	73.29	.....	15.97	18.71	21.44	24.16	26.89	.....	25.68	30.08	34.46	38.85	43.25
48	.....	45.43	53.21	60.95	68.72	76.48	.....	16.67	19.52	22.36	25.21	28.06	.....	26.80	31.38	35.96	40.54	45.12
50	.....	47.33	55.41	63.50	71.59	79.67	.....	17.37	20.33	23.30	26.27	29.33	.....	27.92	32.68	37.46	42.23	47.00
52	.....	.....	57.63	66.04	74.45	82.86	.....	.....	21.14	24.23	27.32	30.40	.....	.....	34.00	38.96	43.92	48.89
54	.....	.....	59.84	68.58	77.31	86.04	.....	.....	21.96	25.16	28.37	31.57	.....	.....	35.30	40.46	45.61	50.76
56	.....	.....	62.06	71.11	80.18	89.20	.....	.....	22.77	26.09	29.42	32.74	.....	.....	36.61	41.95	37.30	52.64
58	.....	.....	64.27	73.66	83.04	92.42	.....	.....	23.58	27.02	30.47	33.91	.....	.....	37.92	43.45	48.99	54.52
60	.....	.....	66.50	76.20	85.90	95.60	.....	.....	24.40	27.96	31.52	35.08	.....	.....	39.22	44.95	50.68	56.40

Graphic chart showing method of choosing horizontal reinforcing of round rods for a monolithic silo. The amount of reinforcing will vary with the height and diameter of the silo.

TABLE SHOWING NUMBER OF CONCRETE BLOCKS REQUIRED

Whole Blocks 16 in. long (outside), 8 in. high   Half Blocks 8 in. long (outside), 8 in. high.
Door 3 ft. 10 in. wide between blocks.

Inside Diameter of Silo	10 feet		12 feet		14 feet		16 feet		18 feet		20 feet		22 feet	
Size of Block	Whole	Half	Whole	Half	Whole	Half	Whole	Half	Whole	Half	Whole	Half	Whole	Half
Height														
26	897	39	......	......	......	......	......	......	......	......	......	......	......	......
28	966	42	1155	42	......	......	......	......	......	......	......	......	......	......
30	1035	45	1238	44	1463	44	......	......	......	......	......	......	......	......
32	1104	48	1320	48	1560	48	1776	48	......	......	......	......	......	......
34	1173	51	1423	50	1658	50	1887	51	2117	50	......	......	......	......
36	1242	54	1485	54	1755	54	1998	54	2241	54	2511	54	......	......
38	1311	57	1568	56	1853	56	2109	57	2369	56	2651	56	2907	57
40	1380	60	1650	60	1950	60	2220	60	2490	60	2790	60	3160	60
42	......	......	1733	62	2048	62	2331	63	2615	62	2999	62	3213	63
44	......	......	1815	66	2145	66	2442	66	2739	66	3069	66	3366	66
46	......	......	1898	68	2243	68	2553	69	2864	68	3209	68	3519	69
48	......	......	1980	72	2340	72	2664	72	2988	72	3348	72	3672	72
50	......	......	2063	74	2438	74	2775	75	3113	74	3488	74	3825	75
52	......	......	......	......	2535	78	2886	78	3277	78	3627	78	3978	78
54	......	......	......	......	2633	80	2997	81	3362	80	3767	80	4131	81
56	......	......	......	......	2730	84	3108	84	3486	84	3906	84	4284	84
58	......	......	......	......	2828	86	3219	87	3611	86	4046	86	4435	87
60	......	......	......	......	2925	90	3330	90	3735	90	4185	90	4590	90

TABLE GIVING HORIZONTAL REINFORCEMENT FOR BLOCK SILOS, SHOWING SIZE OF WIRE OR ROUND RODS TO BE USED BETWEEN EACH 8 INCH COURSE OF BLOCKS

Feet from top of Silo	Diameter of Silo in feet							
	8	10	12	14	16	18	20	22
0– 4	No. 6	No. 6	No. 6	1/4″	1/4″	1/4″	1/4″	1/4″
4– 8	No. 6	No. 6	No. 6	1/4″	1/4″	1/4″	1/4″	1/4″
8–12	No. 6	No. 6	1/4″	1/4″	1/4″	1/4″	3/8″	3/8″
12–16	No. 6	1/4″	1/4″	3/8″	3/8″	3/8″	3/8″	3/8″
16–20	1/4″	1/4″	3/8″	3/8″	3/8″	3/8″	3/8″	3/8″
20–24	1/4″	3/8″	3/8″	3/8″	3/8″	3/8″	3/8″	3/8″
24–28	3/8″	3/8″	3/8″	3/8″	3/8″	1/2″	1/2″	1/2″
28–32	3/8″	3/8″	3/8″	3/8″	1/2″	1/2″	1/2″	1/2″
32–36	3/8″	3/8″	3/8″	1/2″	1/2″	1/2″	1/2″	1/2″
36–40	3/8″	3/8″	3/8″	1/2″	1/2″	1/2″	1/2″	5/8″
40–44	3/8″	3/8″	1/2″	1/2″	1/2″	1/2″	5/8″	5/8″
44–48	3/8″	3/8″	1/2″	1/2″	1/2″	5/8″	5/8″	5/8″
48–52	3/8″	1/2″	1/2″	1/2″	1/2″	5/8″	5/8″	5/8″
52–56	3/8″	1/2″	1/2″	1/2″	5/8″	5/8″	5/8″	5/8″
56–60	3/8″	1/2″	1/2″	1/2″	5/8″	5/8″	5/8″	5/8″

TABLE GIVING LINEAL FEET OF TRIANGLE MESH REINFORCEMENT

Height of Silo	Inside Diameter of Silo			
	10 feet	12 feet	14 feet	16 feet
24 feet	333 Style No. 6	347 Style No. 6 40 Style No. 4	347 Style No. 6 89 Style No. 4	336 Style No. 6 151 Style No. 4
27 feet	343 Style No. 6 34 Style No. 4	357 Style No. 6 77 Style No. 4	357 Style No. 6 132 Style No. 4	346 Style No. 6 204 Style No. 4
30 feet	353 Style No. 6 64 Style No. 4	367 Style No. 6 114 Style No. 4	367 Style No. 6 178 Style No. 4	405 Style No. 6 253 Style No. 4
33 feet	363 Style No. 6 95 Style No. 4	377 Style No. 6 150 Style No. 4	420 Style No. 6 221 Style No. 4	468 Style No. 6 302 Style No. 4
36 feet	373 Style No. 6 125 Style No. 4	387 Style No. 6 190 Style No. 4	476 Style No. 6 264 Style No. 4	527 Style No. 6 355 Style No. 4
39 feet	383 Style No. 6 159 Style No. 4	433 Style No. 6 227 Style No. 4	529 Style No. 6 310 Style No. 4	586 Style No. 6 404 Style No. 4
42 feet	393 Style No. 6 189 Style No. 4	483 Style No. 6 264 Style No. 4	582 Style No. 6 353 Style No. 4	596 Style No. 6 506 Style No. 4
45 feet	434 Style No. 6 220 Style No. 4	530 Style No. 6 300 Style No. 4	638 Style No. 6 396 Style No. 4	606 Style No. 6 604 Style No. 4
48 feet	477 Style No. 6 250 Style No. 4	570 Style No. 6 340 Style No. 4	648 Style No. 6 485 Style No. 4	619 Style No. 6 706 Style No. 4
51 feet	518 Style No. 6 281 Style No. 4	626 Style No. 6 377 Style No. 4	658 Style No. 6 571 Style No. 4	629 Style No. 6 808 Style No. 4
54 feet	558 Style No. 6 314 Style No. 4	636 Style No. 6 450 Style No. 4	668 Style No. 6 660 Style No. 4	639 Style No. 6 906 Style No. 4
57 feet	599 Style No. 6 345 Style No. 4	646 Style No. 6 527 Style No. 4	678 Style No. 6 746 Style No. 4	649 Style No. 6 959 Style No. 4 53 Style No. 23
60 feet	642 Style No. 6 375 Style No. 4	656 Style No. 6 600 Style No. 4	688 Style No. 6 835 Style No. 4	659 Style No. 6 1008 Style No. 4 102 Style No. 23
Floor	38 Style No. 6	48 Style No. 6	68 Style No. 6	87 Style No. 6
Roof	96 Style No. 6	134 Style No. 6	182 Style No. 6	240 Style No. 6

NOTE. Use 38 in. widths of mesh and lap 2 in. or use 42 in. widths and lap 6 in. Reinforcement furnished only in rolls 150 ft., 200 ft. and 300 ft. long.

TABLE GIVING LINEAL FEET OF TRIANGLE MESH REINFORCEMENT

Height of Silo	Inside Diameter of Silo		
	18 feet	20 feet	22 feet
24 feet	368 Style No. 6 173 Style No. 4	337 Style No. 6 254 Style No. 4	362 Style No. 6 279 Style No. 4
27 feet	433 Style No. 6 229 Style No. 4	409 Style No. 6 319 Style No. 4	372 Style No. 6 419 Style No. 4
30 feet	502 Style No. 6 285 Style No. 4	484 Style No. 6 381 Style No. 4	382 Style No. 6 558 Style No. 4
33 feet	568 Style No. 6 343 Style No. 4	556 Style No. 6 443 Style No. 4	392 Style No. 6 698 Style No. 4
36 feet	636 Style No. 6 399 Style No. 4	566 Style No. 6 570 Style No. 4	402 Style No. 6 837 Style No. 4
39 feet	646 Style No. 6 513 Style No. 4	576 Style No. 6 697 Style No. 4	412 Style No. 6 977 Style No. 4
42 feet	656 Style No. 6 628 Style No. 4	586 Style No. 6 824 Style No. 4	422 Style No. 6 1116 Style No. 4
45 feet	666 Style No. 6 739 Style No. 4	596 Style No. 6 951 Style No. 4	432 Style No. 6 1116 Style No. 4 140 Style No. 23
48 feet	676 Style No. 6 798 Style No. 4 59 Style No. 23	606 Style No. 6 951 Style No. 4 127 Style No. 23	442 Style No. 6 1116 Style No. 4 279 Style No. 23
51 feet	686 Style No. 6 853 Style No. 4 115 Style No. 23	619 Style No. 6 951 Style No. 4 254 Style No. 23	452 Style No. 6 1116 Style No. 4 419 Style No. 23
54 feet	696 Style No. 6 909 Style No. 4 173 Style No. 23	629 Style No. 6 951 Style No. 4 381 Style No. 23	465 Style No. 6 1116 Style No. 4 558 Style No. 23
57 feet	706 Style No. 6 968 Style No. 4 229 Style No. 23	639 Style No. 6 951 Style No. 4 508 Style No. 23	475 Style No. 6 1116 Style No. 4 698 Style No. 23
60 feet	716 Style No. 6 1023 Style No. 4 285 Style No. 23	649 Style No. 6 951 Style No. 4 635 Style No. 23	485 Style No. 6 1116 Style No. 4 837 Style No. 23
Floor	102 Style No. 6	125 Style No. 6	154 Style No. 6
Roof	300 Style No. 4	328 Style No. 4	400 Style No. 4

NOTE. Use 38 in. widths of mesh and lap 2 in. or use 42 in. widths and lap 6 in. Reinforcement furnished only in rolls 150 ft., 200 ft., and 300 ft. long.

RECOMMENDED PRACTICE FOR THE CONSTRUCTION OF MONOLITHIC CONCRETE SILOS

The following brief summary of construction requirements for monolithic concrete silos will serve as a guide for specifications.

EXCAVATION

Excavations should be to firm bearing soil always below possible frost penetration. Roots, sod, or any other perishable material must be removed. Soft, spongy spots should be excavated and refilled with well-compacted gravel.

BACK FILLING

When back filling is necessary it should be done after the footings have been completed and have thoroughly hardened and the walls have been finished to ground line. Provisions for draining the silo and for filling and emptying a tank, if such is to be built upon the top, should be provided for by inserting the necessary plumbing. Requirements for cement and aggregates have been stated elsewhere and these apply to silo construction. Quality of reinforcement has also been described in another section. Wire mesh may be used instead of rods but should be equal in cross-sectional area to the rods for which substituted. It should be lapped not less than four inches on vertical laps and not less than eighteen inches on horizontal laps, all laps being securely wired together.

FORMS AND FOOTINGS

All silos are now usually built by using some one of the several excellent commercial forms now on the market. Wall footings should be of such width that pressure on the soil will not exceed 3,000 pounds per square foot. For silos not over 40 feet high a footing 1 foot thick and 2 feet wide will usually be sufficient.

MIXTURES

Wall footings should be a 1:3:5 mixture. Walls proper should be a 1:2½:4. Roofs, floors, and walls, and floors of tanks should be a 1:2:3 mixture. A quaky consistency is best.

PLACING CONCRETE AND STEEL REINFORCEMENT

If steel rods are used the verticals should be embedded not less than one foot in the concrete footings. If wire mesh is used, the lower six inches of the first layer and the lower one foot of the verticals should be embedded in the concrete footings. Concrete should be well spaded next to the forms to secure a smooth surface. Walls should be uniformly six inches thick. Reinforcing should be placed midway between inner and outer surfaces of the wall and thoroughly embedded. At doorway openings the horizontal bars, or if mesh is used, the horizontal wires, should be bent around vertical bars alongside the doorways.

It is best that concreting of silos be continuous, but frequently this is not practicable. When necessary to discontinue work on the walls, as at night, the concrete should be left rough so that a good bond may be easily secured between fresh concrete and that previously placed. Sometimes a strip of sheet steel or galvanized iron is partly embedded in the concrete, and when concreting is resumed this as well as the surface of the old concrete is well washed, then painted with a cement grout paint before concreting is continued.

When a tank is to rest on top of the silo walls the first section of the tank wall should be placed at the same time as the floor, so as to prevent a leak at the point where the tank starts. Care should be taken not to remove forms from beneath the tank floor slab until all possibility of collapse has passed. Each tank of this kind is a subject of special design depending upon the capacity.

If concreting is done in warm weather the concrete should be protected while hardening by frequent sprinkling or by some protective covering that will prevent rapid drying. If the work is done in cold weather protection should be given to prevent injury to the concrete from freezing, according to methods described elsewhere.

ROOFS

Many concrete buildings fall short of what they should be. They are finished with some kind of a roof other than concrete. Flat roofs are the simplest type of concrete roofs to build. They are particularly suited to small farm buildings and other small structures.

Concrete roofs must be properly designed. To a certain extent tables can be used for slabs of various thicknesses and span where only small buildings are involved. For larger buildings, involving greater spans, roofs must be designed for the particular structure.

The following table shows thickness of slab required for concrete roofs or roof slabs of various dimensions from four feet square up to sixteen feet square:

TABLE I

THICKNESS OF ROOF SLABS IN INCHES

Width in Ft. between Center Lines of Walls	Length of Roof in Feet between Center Lines of Walls						
	4 ft.	6 ft.	8 ft.	10 ft.	12 ft.	14 ft.	16 ft.
4 feet	2 in.	2 in.	2½ in.	2½ in.	2½ in.	2½ in.	2½ in.
6 feet	....	2½ in.	2½ in.	2½ in.	3 in.	3 in.	3 in.
8 feet	....	....	3 in.	3½ in.	3½ in.	3½ in.	4 in.
10 feet	....	....	....	3½ in.	4 in.	4½ in.	4½ in.
12 feet	....	....	....	....	4 in.	4½ in.	5 in.
14 feet	....	....	....	....	....	5 in.	5½ in.
16 feet	....	....	....	....	....	....	6 in.

Load = weight of roof + 50 pounds per square foot.

The following table shows the amount of cement, sand, and pebbles or broken stone required for roofs of various area and thickness:

TABLE II

CEMENT, SAND, AND STONE OR PEBBLES

Required for Concrete Slab Roofs. Proportions for concrete 1:2:3. Each cubic yard of 1:2:3 concrete requires about 1.74 barrels of cement, .52 cubic yards of sand, and .77 cubic yards of stone.

			WIDTH OF SLAB IN FEET (BETWEEN EAVES)						
			4	6	8	10	12	14	16
Sacks of Cement (1 sack = 1 cu. ft.)	Length of Roof in feet between eaves	4	0.7	2.0	......	......	......	......	......
		6	1.0	......	......	......	......	......	......
		8	1.7	2.6	4.2	......	......	......	......
		10	2.2	3.3	6.1	7.6	......	......	......
		12	2.6	4.7	7.3	10.4	12.5	......	......
		14	3.0	5.5	8.5	13.7	16.4	21.2	......
		16	3.5	6.2	10.1	14.4	20.8	26.7	33.3
Cubic feet of Sand	Length of Roof in feet between eaves	4	1.4	......	......	......	......	......	......
		6	2.1	3.9	......	......	......	......	......
		8	3.4	5.2	8.3	......	......	......	......
		10	4.3	6.5	12.1	15.2	......	......	......
		12	5.2	9.4	14.6	20.8	25.0	......	......
		14	6.1	10.9	17.0	27.3	32.8	42.5	......
		16	6.9	12.5	20.2	28.8	41.6	53.4	66.6
Cu. feet of Stone or Pebbles	Length of Roof in feet between eaves	4	2.1	......	......	......	......	......	......
		6	3.1	5.9	......	......	......	......	......
		8	5.1	7.8	12.5	......	......	......	......
		10	6.5	9.8	18.2	22.7	......	......	......
		12	7.8	14.0	21.8	31.2	37.4	......	......
		14	9.1	16.4	25.5	41.0	49.1	63.7	......
		16	10.4	18.7	30.3	43.2	62.4	80.1	99.8

The following table shows the size and spacing of reinforcing rods for roof slabs of various dimensions:

TABLE III

SPACING OF REINFORCING RODS IN INCHES

Width in Ft. between Center Lines of Walls	Length of Roof in Feet between Center Lines of Walls							
	4 ft.	6 ft.	8 ft.	10 ft.	12 ft.	14 ft.	16 ft.	Size Steel
4 feet...	12 in. 12 in.	$9\frac{1}{4}$ in. 24 in.	8 in. 36 in.	8 in. 36 in.	8 in. 36 in.	8 in. 36 in.	8 in. 36 in.	¼ in. Rd. Rods.
6 feet...	....	6 in. 6 in.	$4\frac{3}{4}$ in. 12 in.	4 in. 36 in.	4 in. 36 in.	4 in. 36 in.	4 in. 36 in.	¼ in. Rd. Rods.
8 feet...	....	....	11 in. 11 in.	$9\frac{1}{2}$ in. 22 in.	9 in. 36 in.	$7\frac{3}{4}$ in. 36 in.	$7\frac{1}{4}$ in. 36 in.	⅜ in. Round Rods.
10 feet...	....	....	....	$8\frac{3}{4}$ in. $8\frac{3}{4}$ in.	$7\frac{3}{4}$ in. 16 in.	7 in. 27 in.	$6\frac{1}{2}$ in. 36 in.	⅜ in. Round Rods.
12 feet...	....	....	....	....	$6\frac{1}{2}$ in. $6\frac{1}{2}$ in.	$5\frac{3}{4}$ in. 12 in.	$5\frac{1}{4}$ in. 16 in.	⅜ in. Round Rods.
14 feet...	....	....	....	....	....	$5\frac{1}{4}$ in. $5\frac{1}{4}$ in.	$4\frac{1}{2}$ in. $8\frac{3}{4}$ in.	⅜ in. Round Rods.
16 feet...	....	....	....	....	....	....	4 in. 4 in.	⅜ in. Round Rods.

NOTE—Upper figures are for cross reinforcement; lower figures for long reinforcement

Load = weight of roof + 50 pounds per square foot.

The following example shows method of using the three tables preceding:

EXAMPLE. Required, the thickness of slab, amount of concreting materials, spacing of lateral and transverse reinforcement, and the amount of reinforcing rods, for the flat slab roof of a building 12 feet by 14 feet in outside dimensions, with 12 inch eaves on all sides. The size of the roof slab between the center lines of walls will be 13 feet 6 inches by 11 feet 6 inches. Referring to Table I, we run down the vertical column at the left to the smaller dimension of the slab, which in this case is 11 feet 6 inches. As this dimension is not given in the table we take the next larger, which is 12 feet. Running across horizontally to the larger dimension of the slab (13 feet 6 inches) we find that this is not given in the table, but that we must take 14 feet. In the square directly below 14 feet, and horizontally opposite 12 feet, we find the required thickness of the roof to be 4½ inches. By reference to Table II the quantities of materials required are easily obtained. The size of the roof over the eaves is 14 feet by 16 feet. The table is divided into three parts showing respectively the amounts of cement, sand, and pebbles required for roofs of various sizes. The upper portion of the table gives the number of sacks of cement required and those below it give the number of cubic feet of sand and pebbles or stone necessary. By referring to the table we find that the roof will require about 25 sacks of cement, 53 cubic feet of sand, and 79 cubic feet of pebbles or stone.

The spacing of the reinforcing rods is shown in Table III. As the roof is 11 feet 6 inches by 13 feet 6 inches between center lines of walls, the next larger dimension shown in the table should be used. These are 12 feet by 14 feet. By running down the left hand vertical column to 12 feet, then running across horizontally to the 14 foot column, we find that cross reinforcement (running parallel to the short sides of the house) should be 5¾ inches apart, and the longitudinal rods (running the long way of the house) 12 inches apart. Round or square $\frac{3}{8}$ inch rods should be used, as shown in the column to the right of the table. The roof being 16 feet long and 14 feet wide, over eaves, will require thirty-four $\frac{3}{8}$ inch rods 14 feet long, parallel to the short sides, and seventeen $\frac{3}{8}$ inch rods 16 feet long, parallel to the long side.

NOTE. The foregoing data and tables are taken from "Small Farm Buildings of Concrete," issued by the Universal Portland Cement Company, to whom acknowledgment is hereby made.

FIELD PRACTICE IN CONCRETE PAVEMENT CONSTRUCTION

SPECIFICATIONS

The history of concrete pavements in the United States dates from 1894, in which year several blocks were paved with concrete in the city of Bellefontaine, Ohio. For a number of years thereafter this pioneer work attracted no particular attention, nor was any considerable progress made in the use of concrete as a pavement for roads, streets, or alleys. Within the past three or four years the yardage has increased by leaps and bounds until, on the first of January, 1918, there were between 8,000 and 9,000 miles of concrete roads, streets, and alleys in the United States.

In the past three or four years also there has been marked progress in standardizing methods of concrete pavement construction. The best practice has perhaps been brought to light as a result of two National Conferences on Concrete Road Building, combined with concerted work on the part of the American Concrete Institute, the American Society for Testing Materials, and the Portland Cement Association. As a result there are standard specifications for concrete roads, streets, and alleys that embody practice based on extensive experience, which if followed is certain to insure that the resulting pavement will have no superior, if an equal. The latest of these specifications are those adopted by the American Concrete Institute in 1917, which can be obtained from the Portland Cement Association, 111 West Washington Street, Chicago, free of charge. They should be used as a basis for any other specifications covering the class of concrete work to which they apply.

TYPES OF CONCRETE PAVEMENTS

In general there are but two types of concrete pavements — one-course and two-course. The first consists of one mixture of concrete — a relatively rich one, such as a 1:2:3 — laid at one operation to the required thickness on the prepared roadbed or subgrade.

The second consists of a base and wearing course, the first of a leaner mixture on which is laid immediately after the base has been placed and before it has commenced to harden, a top or wearing course of a rich mixture. Where suitable materials are obtainable either on the site of the work or convenient to it, one-course construction is to be preferred. As a rule, two-course construction is used only where local materials lack sufficient toughness and wear resistance to withstand the impact or abrasion of traffic. Then the local materials are used in the less important base and the relatively small amount of higher grade materials necessary for the top or wearing course are shipped in.

OBJECT OF SPECIFICATIONS

Specifications for any work go into the details of the various materials to be used and the methods of using them. Concrete for concrete pavements, such as roads, streets, and alleys, like concrete for any other work, is composed of Portland cement, aggregates, and water. The volume of cement required in the construction of concrete roads represents about one sixth of the total of the materials used. Portland cement is subject to rigid specifications, and while specifications for concrete roads, streets, and alleys require that tests of sand and stone be made of those materials when used in pavement work, rarely is the attention given to these important materials that should be required. The mistaken impression is too generally prevalent that any sand or stone mixed with Portland cement will make good concrete. Without fear of contradiction it may be said that the majority of unsatisfactory concrete paving jobs are due to the use of inferior aggregates; and much of the inferiority may be found in the sand. Since the strength of concrete depends entirely upon the character of the materials used, it is highly important that the sand be composed of hard grains. When it is of grains of uniform size, more cement is required to obtain the same strength than where the grains range in size from the finest permissible to ¼ inch. The sand should not contain vegetable matter or other similar impurities, as the presence of such results in defective bond between cement and aggregates and consequently in weak concrete. Vegetable matter, if present, may through chemical action prevent the setting of the cement. Road contractors should not only welcome tests upon sand made by the engineer, but should be prepared to make them on their own account. They effect a direct saving in the end.

COLORIMETRIC TEST FOR ORGANIC IMPURITIES IN SAND

Until recently there were no simple, reliable tests that could quickly be made by the contractor. Within the past year, however, there has been developed by Duff A. Abrams, Professor in Charge of the Structural Materials Research Laboratory, Lewis Institute, and Oscar E. Harder, Chemist, Structural Materials Research Laboratory, a simple method for detecting organic impurities in sand. A simple colorimetric test may be used for detecting the presence of organic impurities of a humous or vegetable nature in sand. This test was fully described in a bulletin entitled "Colorimetric Tests for

Organic Impurities in Sand" that was issued by the Structural Materials Research Laboratory in 1917. Copies of this publication can be obtained from the Portland Cement Association. But the simple application of these tests to field practice differs slightly from the method applied in the laboratory, principally in that comparisons are made with definite color standards.

METHOD FOR FIELD TEST

The field test consists of shaking the sand thoroughly in a dilute solution of sodium hydroxide (NaOH) and observing the resultant color after the mixture has been allowed to stand for a few hours. Fill a 12-ounce graduated prescription bottle to the $4\frac{1}{2}$-ounce mark with the sand to be tested. Add a 3 per cent solution of sodium hydroxide until the volume of the sand and solution, after shaking, amounts to 7 ounces. Shake thoroughly and let stand for twenty-four hours. Observe the color of the clear liquid above the sand. A good idea of the quality of the sand can be formed earlier than twenty-four hours, although this period is believed to give best results.

If the solution resulting from this treatment is colorless or has a light-yellowish color the sand may be considered satisfactory in so far as organic impurities are concerned. On the other hand, if a dark-colored solution of a color deeper than that indicated by Plate 2 is produced the sand should not be used in high-grade work such as is required in roads and pavements or in building construction. Sands showing color as dark as Plate 3 may be used in unimportant concrete work. Sands showing colors darker than Plate 3 should never be used for concrete. Plate 5 represents the color of the solution obtained with an unusually dirty sand or from a sample of soil high in loam. A small quantity of material of this kind would make a sand unsuitable for use in concrete.

While it is not practicable to give exact values for the reduction in strength corresponding to the different colors of solution, the tests made thus far show this relation to be about as follows:

Color Plate Number	Reduction in Compressive Strength of 1:3 Mortar at Seven and Twenty-eight Days Per Cent
1	None
2	10– 20
3	15– 30
4	25– 50
5	50–100

Washing sands has the effect of greatly reducing the quantity of organic impurities present. However, even after washing, sands should be examined in order to determine whether the organic impurities have been reduced to harmless proportions.

APPARATUS

The following list includes sufficient apparatus for making five field tests at a time:

Five 12-ounce graduated prescription bottles.

Stock of 3 per cent solution of sodium hydroxide (dissolve 1 ounce of sodium hydroxide in enough water to make 32 ounces).

This material can be purchased at most drug stores at a cost of about one dollar.

SUMMARY

Experience and tests have shown that it is the presence of organic impurities of a humous nature that is responsible for most defective sands. The colorimetric test furnishes a simple and inexpensive method for detecting the presence of such impurities. The test made in the manner described above will be found useful for:

(1) Prospecting for sand supplies.
(2) Checking the cleanness of sand received on the job.
(3) Preliminary examination of sands in the laboratory.

This test is now being used by a large number of testing laboratories, engineers, and contractors in passing on the suitability of sands for use in concrete.

In certain instances the test has been made the basis of specification requirement for sand.

It is much easier to detect unclean stone or gravel than it is to detect unclean sand. The colorimetric tests for sand will, however, reveal cleanliness or the reverse with accuracy.

TESTING COARSE AGGREGATES

Stone or pebbles used as coarse aggregate also should be subjected to careful inspection and test. Coarse aggregate is required to successfully withstand the abrasive action and impact imposed by traffic. Soft stone or stone containing soft particles will not stand up under heavy traffic. Flat stones in the surface of a road do not have sufficient embedment. They are easily broken or torn out by traffic, thus leaving a pothole. Where the dimensions of stone exceed 1½ inches it is sometimes difficult to obtain an even surface and more work is required with the template when striking off to the desired contour. A graded stone with particles ranging from coarse to fine is economical if mortar required to obtain a strength equal to that of stone not so graded is used. Where aggregates are dirty, but suitable in other respects, arrangements should be made to wash them before using in the concrete mixtures. Specification requirements prohibit the use of crusher-run stone, bank-run gravel, or artificially prepared mixtures of coarse and fine aggregate.

PROPORTIONING

All materials entering into concrete should be accurately proportioned. Successful concrete pavement work requires uniformity of mixture which cannot be obtained with bank-run gravel or crusher-run stone. In most gravel pits the sand exceeds the pebbles or broken stone by twice. Concrete mixtures in which such aggregate is used produce weak concrete due to excess mortar. A road surface showing neat cement at one point, mortar at another and aggregate at another will not wear evenly. Screening and separating fine and coarse aggregates and reproportioning them in correct volumes results in economy in the use of cement.

MIXING WATER

Mixing water must be clean, free from oil, acid, alkali, or vegetable matter. A large quantity of water is required in concrete road construction. It has to be used, first, for wetting down the subgrade, during rolling, again wetting it prior to placing concrete; also to supply the boiler of the mixer and to make the concrete mixture itself, and finally must be used for sprinkling or ponding after the concrete has been placed and finished to insure proper hardening. Before submitting a bid for concrete road work the contractor should thoroughly investigate the source of water supply. The water equipment requires a two-inch pipe of sufficient length to reach at least half way between the source of supply. It should have a capacity of at least fifty gallons per minute. To avert excess expense occasioned by delay from irregular water supply, the contractor should have an additional pump so that if one breaks down the other can immediately be put in commission. The pipe line should be laid with hose connections about every two hundred feet. A blow-off valve or compensating tank should be placed on the high point of the line to prevent bursting when the pump is working and no water is being used.

GRADING

Before concrete for pavements can be laid there must be a properly prepared roadbed or subgrade. It has been proved that many of the cracks which develop in concrete pavement are due to settlement, poor drainage, or other unstable conditions of the roadbed or subgrade, so that too much care cannot be taken to properly prepare the surface on which concrete is to be laid. Fills must be allowed to finish all settlement before placing concrete. They should also be made by placing the material in layers of uniform thickness and rolling compactly with a ten-ton or heavier roller until reduced to the utmost compactness.

DRAINAGE

It is well known that stability of railroad roadbeds depends more largely upon good drainage than any other one fundamental of construction. Drainage is equally important in construction of the subgrade or roadbed for concrete pavement. If the foundation on which the slabs rest is not thoroughly drained so that no water will be retained beneath the slabs, then it is certain that there will be heaving and consequent cracking of the concrete due to freezing and expansion of the retained water. Drainage of the surface of concrete roads and streets is provided for by crowning the surface, this being done by striking off with a template cut to the required contour. Alley pavements are usually dished, that is, are lower in the center than at the sides, or have, as is said, an inverted crown. In this way the surface drains quickly, while the pavement serves also the purpose of a gutter.

HANDLING MATERIALS ON THE JOB

Cement is shipped in paper bags and cloth sacks. The cost of the packages is included in the price of cement. The cloth sacks will be redeemed by the manufacturer if returned in good condition. Therefore it is necessary that workmen be properly instructed as to care of sacks out on the job. By permitting workmen to carelessly or purposely destroy or damage sacks by cutting them with a knife or shovel, or by allowing them to use sacks for knee pads, aprons, etc., a loss is incurred of ten cents or more for every sack so used. On large jobs proper care of sacks warrants assigning one or more men to have entire charge of shaking and bundling them properly for shipment. Cement is purposely made sensitive to moisture. It therefore must be so stored before use that it cannot be injured by dampness. A tight building with a tight floor raised sufficiently above ground so that free circulation of air can take place around the piles is necessary. On the job there should never be more than one day's supply piled along the work, and it should never be piled on the ground, but on board platforms, so that in case of a sudden shower it can be quickly covered with tarpaulins and thus protected against injury. Aggregates are usually distributed in piles along the subgrade, sand on one side, crushed stone or pebbles on the other. An accompanying table shows the quantities of materials required for a concrete pavement of the width and thickness indicated and will be found convenient when estimating quantities of aggregates to be distributed along the work.

QUANTITIES OF MATERIALS REQUIRED FOR LINEAR FOOT OF CONCRETE PAVING FOR THE WIDTHS AND THICKNESSES AT SIDES AND CENTER AS SHOWN

Width (feet)	Thickness Side and Center (inches)	CEMENT (bbls.)		SAND (cubic yards)		ROCK OR PEBBLES (cubic yards)	
		1:2:3	1:1½:3	1:2:3	1:1½:3	1:2:3	1:1½:3
9	6–7	0.32	0.35	0.10	0.08	0.14	0.16
16	6–8	0.63	0.68	0.19	0.15	0.28	0.30
18	6–8	0.71	0.77	0.21	0.17	0.32	0.34
20	6–8½	0.82	0.90	0.24	0.20	0.36	0.40
24	6–9	1.01	1.10	0.30	0.24	0.45	0.49

Quantities based on the assumption of 45% voids in the coarse aggregate.

To prevent possibility of dirt or refuse becoming mixed with the aggregates, some contractors have a supply of planks to lay on the roadbed so that aggregates can be dumped upon them. Frequently planks are laid on the roadbed or subgrade to enable loaded wagons being driven along without cutting up the subgrade. In handling broken stone which is dumped directly on the ground ballast forks should be used to prevent dirt being shoveled up with the aggregate. Care should also be taken when shoveling sand from the piles that they are not thoroughly cleaned up, because to do so would cause dirt to be shoveled up also.

JOINTS

Joints are placed in concrete pavements to provide for volume changes in the concrete owing to variations in moisture content and in temperature. Engineers are not in thorough accord as to the distance which such joints should be spaced from each other. Some are disposed to omit a made joint entirely, knowing that the concrete will eventually crack, due to contraction at certain intervals, thus providing such "joints" as are needed. However, these are not straight across the pavement, therefore are unsightly and are also more difficult to keep in good repair because of their irregular edges. For this reason a made joint is preferable. Engineers are also not in accord as to whether joints should be protected or unprotected; that is, whether there should be placed in the concrete at each end of every slab a metal protection plate with joint filler material between or whether the plate should be omitted and merely a prepared joint filler used. In general, joints should not exceed $\frac{1}{4}$ or $\frac{3}{8}$ of an inch in width. Wider joints are likely to suffer increased wear due to impact of steel-tired wheels crossing them. The strips of fiber matrix and bitumen used for joint filler come in convenient form. They are easy and economical to handle and are shipped the required thickness. They are also easy to install, contain sufficient bitumen to seal the surface and protect the edges of the concrete, and there is no pulling of templates, all of which makes for economy and warrants the adoption of this type of joint filler. When metal protection plates are used, care should be taken in placing the installation device, the plates and the filler cut to the proper crown. When the unprotected joint is used the filler should be allowed to extend about ½ inch above the finished pavement surface so that traffic will iron it out and thus help to more completely seal the joint. Steel protection plates are set in place by an installing device. These differ somewhat for the different types of plates. In some cases they may be used as a template to test the correctness of the pavement crown. Where plates are used it is very necessary that they be carefully set and that the pairs be of the same curvature. If they are not, the joints will be low or high or in some respect uneven, owing to the inequalities in the plates forming the pair.

PLACING CONCRETE

Before concrete is placed on the prepared subgrade, the foundation should be well sprinkled to prevent the soil from absorbing water from the concrete mixture. Concrete paving mixers are equipped either with a chute or with boom and bucket for depositing the concrete. Either type properly used will give satisfactory results, but where a mixer with chute is used care must be taken not to attempt to distribute concrete over such an area that it is necessary to have the chute lie at a flat angle, thus tempting the contractor to use too wet a concrete so that the mixture will flow down the chute readily and into place. This objection is not common to types of mixers having the drum mounted so high that the chute never need lie at an angle less than twenty-two to twenty-five degrees.

In planning paving work the greatest progress will be made if things are so arranged that the mixer can travel up grade. This allows laborers to wheel materials downhill to the mixer and also helps the finishers, as any excess water from the concrete will run away from them onto portions of the pavement that have hardened. If the mixer is working down grade, materials must be hauled uphill to it, and this makes harder work, not to mention more unsatisfactory conditions for finishing. Contractors should know in advance of commencing work the exact lines and grades upon which they are to work. Such information can be obtained only from the engineer's grade stakes which designate the outline of the proposed pavement. These are set as a convenience to the contractor as well as a guide to the engineer when checking up the work while under construction. Stakes are often accidentally destroyed or obliterated, but they should be carefully replaced.

HANDLING EXCESS MATERIAL

Rather than haul away all excess material it is economical to leave sufficient at the roadside to cover the surface cf the concrete with at least two inches of earth for protection while curing, unless provisions can be made and water is available in required quantity to adopt the ponding method of curing. If excess material in quantities sufficient to use as protection for the finished work is not left along the roadside it becomes necessary to rehandle the required amount of earth covering. Such material can be hauled away more readily and economically after the road has been open to traffic, as the highway is then paved.

FINISHING CUTS AND FILLS

There is a tendency upon the part of the laborers to leave slopes of embankments concave and those of cuts convex. It is more economical to construct slopes properly at first than to go back and attempt to make adjustments to work not properly done in the first instance. The final dressing of slopes should be commenced in sufficient time so that slopes and shoulders can be completed simultaneously.

SHOULDERS

Shoulder material should be such as to permit of compacting by light roller only. The material should be self-draining and should possess sufficient stability to prevent rutting. The practice has been adopted in many places of making earth shoulders and seeding them to grass. The resulting sod makes not only an attractive shoulder but one that can hardly be washed out. Of course this is not practicable on narrow concrete pavements, since then shoulders must be of a material that will stand up when passing traffic turns off the pavement and onto the shoulder. An old bituminous macadam road makes good shoulder material. Gravel or stone containing some clay also makes good shoulders.

The common tendency today is to build wider concrete pavements. The minimum should be eighteen feet, because vehicles are larger and the wider road permits traffic to pass safely without reducing speed.

FORMS

Wherever the stretch of concrete pavement to be built is a mile or more in length it is economy to use as side forms a stiff steel channel. There are several types manufactured for the purpose. If wood forms are used they will render longer service if capped with angle irons. This also stiffens them and allows the template to be worked easily along their tops. A warped wooden form is difficult to stake to line and grade, and therefore increases the labor cost and results in a wavy road. The forms must be the same depth as the concrete at the edges. If too deep, extra work is required in digging a trench to set them. If not deep enough they must be blocked up at an increased cost, and as the easiest method of doing this is to use stones, mortar runs from the concrete under the forms and is wasted. Many forms are not properly constructed. Frequently, too, the joints in forms on opposite sides of the road are placed directly opposite each other instead of being staggered, as are the joints of rails on the railroad.

Of the accompanying sketches, the upper shows the method of supporting side forms to grade, which is easily applied. It will be noticed that 2 by 2 inch

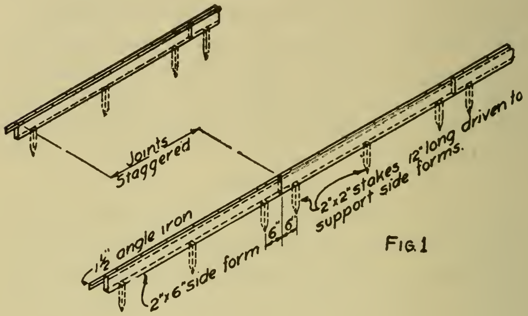


FIG. 1

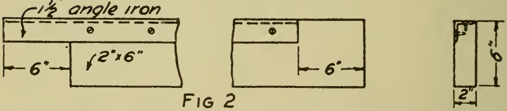


FIG 2

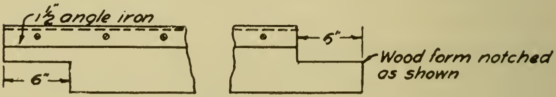


FIG 3

wood stakes about 12 inches long are driven along the line of the side forms to the elevation of the bottom of the form. These stakes of course are intended merely to support the side form to the proper elevation, other stakes being driven in the regular way for the purpose of holding the forms in line. It will be seen also that the joints in the side forms are staggered to prevent a wave being formed across the road in case form joints are low.

The next sketch shows details of wood side form construction. The angle iron cap shown extends six inches beyond the end of the form to insure that adjacent forms are maintained at the same elevation. A slight modification of this is shown in the next sketch. This method will prevent bending of angles if forms are handled roughly. Proper placing of side forms involves a little more expense than the careless placing that is altogether too commonly practised. The improved riding quality of the road and the increased satisfaction resulting therefrom compensate for the slightly added trouble and expense of setting forms properly. When concrete is placed against the forms they tend to bulge outward. Unless properly staked to prevent this bulge, more concrete is placed than is required and the contractor thus furnishes material for which he is not paid. To stake wooden forms, $\frac{3}{4}$ to $\frac{7}{8}$ inch round steel pins have proved more satisfactory than wood stakes. They should be 12 to 18 inches long. In all cases the pins or stakes must be driven below the top of the forms, otherwise the tops will act as obstacles to working the template.

MIXING CONCRETE

No other single operation of concrete pavement work is more often slighted than mixing of the concrete. Attempt to speed up the work often results in shortening the time of mixing. Today the tendency is to increase time of mixing, since it has been proved that up to a certain limit, other things being equal, longer mixing has great influence on the strength, wearing qualities, and other desirable properties of the concrete. Some mixer manufacturers make extravagant claims that owing to the particular construction of their machine its efficiency is greater than others and therefore concrete need be mixed only for a very short time.

The method of measuring materials, including water, must be one which will insure separate and uniform proportions of each material at all times. A bag of Portland cement, ninety-four pounds net, is considered as one cubic foot. Measuring the cement is therefore a simple and economical procedure. Under most conditions the easiest and cheapest method of measuring the sand and stone is by wheelbarrows. Those commonly in use have a definite capacity but require a certain amount of heaping to produce it. If wheelbarrows are used they should be of the type intended for that purpose and have a known, definite capacity when properly struck off level full, as gaging the heaping by the eye often results in variable quantities of material being used in the different batches. Unless wheelbarrows of definite capacity when struck off level are used a bottomless measuring box of the desired capacity should be used by setting into an ordinary wheelbarrow, filling evenly, and then be struck off. When the job is large enough to warrant, industrial railway cars can be loaded with exact amounts at the stock pile or quarry. The carload is dumped directly into the hopper of the mixer. Materials must never be measured by the shovelful. No two men will load a shovel alike. The amount of water required may vary from day to day, depending on the varying moisture content of the aggregates. The amount of water giving the desired consistency should be noted each day when beginning work and this amount be adhered to as long as the aggregates remain in the same condition. The latest improved paving mixers have adjustable tanks for measuring the water, and this is the most satisfactory and economical method.

QUANTITY OF WATER

A certain quantity of water is necessary for the chemical reaction of the cement. A certain additional quantity is generally required to produce a plastic mass which can be molded in the desired form. Tests have shown that the effect of proportional changes in the mixing water is approximately the same for all mixes of concrete. The amount of water which gives the maximum strength in concrete produces a mix which in general is too stiff for most purposes. The exact amount of water corresponding to the maximum strength of concrete will vary with the method of handling and placing the concrete. Any method which involves puddling, tamping, rolling, or vibration, or the exertion of pressure in any manner, will have a tendency to increase the strength of the concrete regardless of the amount of water used. How this influence is displayed in the strength of concrete pavements will be referred to later when describing finishing methods.

In constructing concrete roads it is necessary to mix the concrete a little wetter than that giving the maximum strength. The consistency which should be aimed at in constructing roads corresponds to about 105 to 115 per cent of that giving the maximum strength. In other words, a small portion of the strength must be sacrificed in order to secure a workable concrete. It is evident that there may be a difference of opinion as to what constitutes a workable mix, but the accompanying table will give a close approximation of the quantity of water required under average conditions with average materials.

Mix		Approximate Mix as Usually Expressed			Water Required (Gallons per Sack of Cement)	
Cement	Volume of Aggregate after Mixing	Cement	Aggregate			
			Fine	Coarse	Minimum	Maximum
1	5	1	2	4	6	6½
1	4½	1	2	3	5¾	6¼
1	4	1	1½	3	5½	6
1	3	1	1¼	2½	5	5½

This quantity will vary slightly with the quantity of cement and the size and grading of aggregates, but the table will furnish a dependable approximation of quantities to use under average conditions. To get a proper strength, mixing must continue until all the sand is thoroughly coated with cement and all the stone with mortar. It takes at least a full minute to do this after all materials, including water, have been placed in the drum. Even with one-minute mixing, aggregates will not be thoroughly coated with the sand-cement mortar unless the drum is revolved a sufficient number of times and not at excessive speed. Speed is regulated by the type of machine and the size of the batch. To insure uniformity of mixes each batch must be entirely emptied from the drum before the next batch is put in. The capacity of the mixer is a factor to be considered on every job. This often means money to the contractor and should be given careful consideration. The efficiency of a mixer is considerably lowered if the interior blades, vanes, or other stirring device, are allowed to become coated with hardened concrete. The mixer should be carefully cleaned and washed each time when leaving off work. Even with these precautions some hardened concrete will collect in the drum and it should be removed at frequent and regular intervals.

STRIKING OFF AND FINISHING THE CONCRETE SURFACE

Concrete pavements are finished to the required crown or contour by striking off the surface of the freshly deposited concrete with a template or strikeboard cut to the desired crown. The strikeboard consists of a plain or built-up plank from two to three inches thick. To lengthen its life the cut-out portion should be shod with a strip of steel. Convenient handles should be attached to the end to permit operating it back and forth across the pavement. Some contractors have fitted templates of this kind with handles like plow handles. These make it easy for the men to operate the template while standing and also permit using it, if occasion requires, to tamp the surface. Several combined paving gages and striking and finishing machines are on the market. Each of these has its particular points of merit.

ROLLER AND BELT FINISHING

Late practice in concrete pavement finishing has practically done away with hand floats except for some touching up at joints. One of the latest methods of finishing is to use a light steel roller which was first employed in concrete pavement work in Macon, Georgia. This roller was originated by Capt. J. J. Gaillard while City Engineer of Macon. It has since become known commercially as the Macon Concrete Paving Roller.

Those not familiar with the Macon method of finishing concrete pavements will be interested in knowing its particular advantages. For ease of manipulation it is necessary to use a little more water in the concrete than is required for maximum strength. Until the advent of the Macon roller, the presence of this excess quantity of water in the concrete could not be readily overcome. But with the roller method of finishing, much of the excess water is removed from the concrete, while at the same time the concrete is considerably compacted, which insures a marked increase in strength. It is very necessary that the excess water be removed as soon as possible after concrete has been placed. Laboratory tests on full thickness slabs, the results of which were reported in the 1917 Proceedings of the American Society for Testing Materials, show that rolled slabs are twenty per cent stronger than those finished by the ordinary hand-floating method alone. The facility with which the roller may be used is within the range of unskilled workmen and has resulted in practically every contractor who has tried it becoming loud in its praise. The standard roller, ten inches in diameter and six feet long, weighs approximately one pound per linear foot. These rollers are manufactured by the Ransome-Leach Company. Considerable experience has resulted in formulating the following directions for use of the roller in concrete pavement finishing.

After the concrete has been struck with a template the roller is to be used just as soon as may be without displacing the concrete. In warm weather, especially with rock aggregate if the concrete has not been mixed too wet, the roller may be used immediately. In gravel concrete it may be necessary to wait for ten or fifteen minutes. In cool weather it may be necessary to delay the first use of the roller for thirty to forty minutes.

If the pavement is not over twenty feet wide the roller may be operated from one side of the road to the other by a long handle. If the pavement is much wider than twenty feet it will be found more convenient to attach a rope to the roller and pull it from one side of the pavement to the other, discarding the handle entirely. In this way it is possible to roll with the greatest facility any width pavement. The roller is always to be moved transversely across the road at a small angle so that it will move lengthwise of the road about two feet each trip across.

After the first rolling the same area should be gone over again in about fifteen or twenty minutes. The concrete should receive successive rollings at intervals of fifteen or twenty minutes, until little or no free water is squeezed from the surface. This usually requires not less than three rollings and frequently four or five, depending upon the amount of water with which concrete has been mixed and also on the temperature. The less the amount of water and the warmer the weather, the fewer the number of rollings required.

If integral curbs are being built, the water removed by the roller will find its way to the gutter line, and if not brushed off onto the subgrade will greatly hinder the curb work, as the water contains more or less laitance, which will form a deposit along the gutter. The best method of removing this water is to use an ordinary street broom, brushing the water along the gutter and onto the subgrade.

BELT FINISHING

After the roller has been run over the surface a proper number of times, depending upon the consistency of the concrete and the amount of water necessary to remove it, final finishing is done with a belt. This may be either canvas or rubber, eight to twelve inches wide. It is operated by seesawing back and forth across the concrete surface. For the first belting the stroke should be at least eighteen inches and the forward movement should be very slight. At the time of the first belting the concrete is plastic and the long stroke moves the material from the high into the low spots, thus securing a crown that is a true arc of a circle. For subsequent beltings the strokes should be short, with the forward movement greater than that used the first time. Usually two beltings are given. This will produce a surface that is as near perfect as is possible to get. The belt method secures a uniformity of surface and one free from minor irregularities that cannot be obtained by hand-floating methods. It produces an ideal finish for concrete pavement, that is, the even but gritty texture which makes the nonskid surface characteristic of concrete.

REINFORCEMENT

Common practice has been to omit reinforcing in concrete pavements less than twenty feet wide. Recent practice tends toward specifying reinforcement regardless of width, although it has been common practice always to specify it for pavements twenty feet and wider. The practice of reinforcing concrete pavements has several features to commend it. It has the merit of preventing cracks from opening, thus eliminating much maintenance and keeping water from seeping through to the subgrade. As a rule pavements are reinforced by some type of mesh fabric manufactured particularly for this purpose. It is particularly necessary that slabs which span possibly unstable fills or cross low spots be reinforced. In order to get reinforcing in its proper position concrete has to be placed in two courses. This does not necessarily mean that so-called two-course construction be adopted.

PROTECTION OF FINISHED PAVEMENTS

Curing the concrete pavements has much to do with the results that they will give in service. Rapid drying out of the concrete results in a chalky surface and possibly surface checks or cracks. Keeping concrete properly wetted after initial hardening has taken place will not only assist in further hardening but will greatly increase the strength of concrete. A chalky surface will wear rapidly and will dust. Just as soon as the concrete is hard enough to stand it, water should be applied by spraying. If the weather is favorable to rapid evaporation, additional precautions must be taken to prevent the concrete from drying out rapidly. A canvas covering must be spread over the green concrete until it is hard enough to be sprinkled and to receive a covering of moist earth. An earth covering is an economical means of retaining moisture and protecting the concrete while hardening. Water sprinkled on the concrete surface will run off or evaporate quickly and will not fully answer the purpose. If the surface is entirely covered with two inches or more of earth less sprinkling will be required, but nevertheless the earth must be kept constantly moist for at least ten days. Under the most favorable conditions for hardening in hot weather, the pavement should be closed to traffic for at least fourteen days and in cold weather for an additional time, possibly a month or even more. Where possible to do so, an efficient method of curing is the ponding method. This is done by building earth dikes along the edges of the concrete and over the joints, then flooding the space with water to a depth of at least two inches on the crown. This method does not necessitate the handling of so much earth and insures more uniform curing than can be obtained by any other method.

TEMPERATURE BELOW 65°F. DURING DAY BUT NO FROST AT NIGHT

During the fall or spring when damp, cool, or rainy weather prevails, when the maximum temperature is below 65°F. and there is no danger of frost at night, the concrete will cure and harden more rapidly if left unprotected. Therefore it is advisable under these conditions not to cure according to the above methods, but to allow the concrete to get the benefit of the sun during the day. This does not mean that the concrete must be allowed to dry out. To prevent the moisture from evaporating too rapidly the surface must be sprinkled when the temperature is around 60°F. during the middle of the day, for the number of days required for curing in the specifications.

Later in the fall or early in the spring no sprinkling will be required. The concrete must be watched, however, and any sign of dry spots is an indication that sprinkling is necessary.

TEMPERATURE BELOW 65°F. DURING DAY AND FROST AT NIGHT

When there is danger of frost or a light freeze at night, although the day temperature be high, the concrete one and two days old must be sprinkled. That day's work must be covered with canvas, which must not be allowed to touch the concrete. It should be laid over frames and the sides reach the ground. The following day the canvas should be removed to again give the concrete the benefit of the sun. If it is necessary the following night to cover the previous day's concrete again to protect it from freezing, use not less than three inches of straw, marsh hay, or similar material, properly held down to prevent being blown away.

OPENING ROAD TO TRAFFIC

The hardening of concrete is a chemical and physical action requiring heat and moisture. During cool weather it hardens slowly and consequently requires a longer time to get the proper strength to bear traffic without injury. Therefore a longer time than fourteen days must elapse before traffic is permitted. Even twenty-eight days is sometimes not enough.

All road contractors know the difficulty of keeping traffic off a new road. It is cheaper to erect substantial barriers or to have a watchman constantly on guard than to remove concrete damaged by traffic. Detour signs with specific directions will always tend to restrain impatient travelers who may be disposed to break down barriers.

Arrangements should be made to get the weather forecasts every day so as to know what to expect the following twenty-four hours. The forecast is usually posted in the post office.

Concrete road construction is an expensive operation in freezing weather. The thin slabs and the area to be protected soon eats up profits. When the weather reports indicate that the temperature will remain cool during the day and a hard freeze is likely at night, work should be stopped. Only when a short stretch is to be completed to finish a contract should it be continued. It will then be cheaper to go to the extra expense of proper precautions than to find it necessary later to remove defective concrete.

Water and aggregates must be heated to insure proper temperature when deposited. The day's work must be covered with at least three inches of straw, or similar material, and this covered with canvas weighted down so that the wind will not get under it. Work should not continue after 3.30 in the afternoon, and over the afternoon's concrete roofing paper should be placed prior to placing straw and canvas as mentioned for the morning's work. If the temperature is cold enough the next day the canvas may be removed and the straw entirely covered with three inches of earth. This covering may be removed after ten days if the weather proves favorable.

If practicable the straw may be omitted and steam turned under the canvas. The night watchman can keep the steam going in the mixer boiler for this purpose, or salamanders can be placed under the canvas. The next day, if weather permits, the canvas can be used to cover up the new work and that laid the day before can be covered with straw or earth.

ESTIMATING FOR THE CONTRACTOR

GENERAL

For accurate work every one should compile his own estimating data. Figures that have been compiled by others may be of some value in estimating the cost of a particular piece of concrete work, but it is almost always true that there are some details lacking that make the figures of some one else misleading or insufficient. They usually fail to give an idea of all conditions associated with the work, so a contractor who accepts the figures of some one else as the basis of an estimate is likely to find that after receiving a contract some of his figures represent a price below cost. Every contractor should keep data tables of his own with details of the job, which will help to an accurate comparison with other similar jobs. Contractors are frequently asked to give an approximate estimate of the cost of a certain piece of work. This is quite different from an estimate which calls for exact details. Buildings of a certain class average in cost a certain price per cubic foot of volume. Knowing this, approximate figures can be given that will furnish a fair idea of what a finished structure will cost.

Most important among the items that influence the cost of any piece of work are materials, labor, location of the work, transportation conditions, weather, character of the work, rapidity of construction, equipment required, incidentals, and finances.

MATERIALS

Materials used in concrete work will be in general from twenty to seventy per cent of the work's total cost. Forming such a large item, errors in estimating have considerable effect on probable profit. If materials are not up to standard in quality, strength, and durability, all the work will be affected adversely and the contractor may be compelled to remove and rebuild a portion of it, thus involving a loss greater than his figured profit. These conditions have often been responsible for the financial ruin of a contractor.

On concrete work the contractor is the manufacturer. On work where steel and wood figure largely, finished material is supplied to the job and the contractor is merely a builder. In the case of concrete construction he must know the materials he is to use and how to combine them for best results.

He is both a manufacturer and a builder. He must know the suitability of aggregates, must know the principles of good concrete practice, and must see that good materials and good practice are used; otherwise he cannot guarantee the finished work. Often an owner, engineer, or architect compels a contractor to use a material or method which is not perhaps in favor from the standpoint of specifications, yet the contractor may be held responsible for the resulting work. The contractor should safeguard himself against such happenings by seeing that the specifications after which he is working properly relieve him from responsibility when compelled to follow variations from what is in general recognized as better practice.

The item of waste must be considered in estimating. Certain quantities of cement and aggregate will be wasted in spite of the best handling. Economy of use and care in handling will reduce waste to a minimum. Labor varies in cost within wide range; just at present it is particularly variable. Constant supervision must be exercised to keep working forces efficient. Labor cost can be estimated accurately only by knowing from long experience the amount of work which certain classes of laborers can be depended upon to perform within a given time and under various conditions. Each job is a problem in itself from the labor standpoint. The available supply of men, whether they live near or far from the work, the possibility of labor disturbances, all must be discounted in advance.

LOCATION

Progress of the work, time of completion, and cost are influenced by the location of the work with respect to supplies of materials and labor. If the work is in a locality where all labor needed can be obtained readily, there will be one labor situation to figure upon. If labor must be imported, then the supply is likely to be variable and more costly.

TRANSPORTATION

Distance from base of supplies and the condition of roads and availability of teams or motor trucks must be taken into consideration. With good roads there is probably no question but that motor transportation is most dependable. If large quantities of materials are required, speed of construction is limited by transportation facilities. Unless materials can be delivered and stored on the site in large quantities before work commences, then deliveries must be carefully planned so that there will be an uninterrupted supply to keep men and equipment always busy.

A team or motor truck can be depended upon to haul a certain tonnage a given distance per hour on a certain kind of road over certain grades. The net results will vary in accordance with variation of average conditions. If roads that are good in fair weather quickly become bad in bad weather, transportation costs will rise rapidly; in fact, the work may have to be suspended because materials cannot be moved.

WEATHER CONDITIONS

Weather conditions play an important part in the cost of construction. Storms are often more prolonged than expected, especially where the job is one extending over a long period of time, and the average conditions considered when estimating may turn out quite contrary to what will be actually experienced during the work.

CHARACTER OF WORK

In reinforced concrete construction cost of materials is secondary to labor. On mass concrete work, such as foundations, conditions are reversed. Certain kinds of work require complicated and costly form work. In other cases forms are relatively cheap. Variations in methods of placing concrete involve greater or less cost. Labor-saving devices can often be economically adopted, but experience is necessary to enable decision as to whether or not more machinery or devices on the job will pay.

RAPIDITY OF CONSTRUCTION

There is a limit to the speed with which concrete work can be carried on. Speed is considerably limited in cold weather. If work is speeded too much at any time the structure may collapse. Such conditions often compel a larger investment in forms or form material where otherwise it might be possible to make more frequent use of fewer sets of forms.

Machine mixing is always preferable. An approved durable type of batch mixer is an indispensable part of every concrete contracting equipment.

Forms should be considered as part of the equipment. After it is known how long service forms or form lumber will give, the amount of form cost to charge to any particular job can readily be determined.

All equipment must be kept in serviceable condition. In spite of best care, however, there is constant depreciation, and eventually equipment must be replaced. Several methods are used for charging off the cost of equipment and setting aside a certain sum weekly or monthly for replacement. Most contractors agree that if 0.17 per cent of the total cost of equipment is charged to each day's work, sufficient funds will be accumulated to cover maintenance and replacement.

It costs money to move equipment about the job or from one job to another. Cost of erecting and dismantling the plant must also be determined and included in the estimate.

EMPLOYERS' LIABILITY

In some States the laws hold employers liable for accidents incurred by their employees. Liability insurance should be carried for the contractor's protection in this way. Its cost varies for different classes of work, but should be determined, so that the proper charge can be made for it in estimates.

Contractors often have to accept as payments various kinds of commercial paper, such as bonds, warrants, notes, etc., instead of cash. Frequently such securities have a variable market value. An understanding should be reached before bidding as to how payments are to be made, and if securities instead of currency are to be accepted the contractor should make arrangements for disposing of them as necessary. A contractor might estimate a job at $5,000, including a profit of $500. If compelled to take bonds that can be sold for only 90 cents on the dollar he therefore would receive only $4,500 actual cash, so would have no profit.

He should know exactly what capital he needs to finance the job with respect to the credit he can secure on materials, equipment, or other supplies, and time payments for purchases, so that he will at no time use up, even temporarily, his working capital.

ESTIMATING

Cement can be estimated accurately, therefore it is not necessary to increase the quantity estimated for. There should, however, be added something to the actual cost per barrel to cover the handling of sacks. The percentage of sacks lost is largely dependent upon how they are handled on the job. It is safe to say that the average loss amounts to about 10 cents per barrel in sacks, labor of handling them, and accounting for them. This includes return freight, etc.

AGGREGATES

Aggregates are sold by weight or by the cubic yard. A unit weight is adopted and orders received in cubic yards are converted into equivalent weight. The unit weight is often adopted by agreement, so the volume may be only approximately correct. If aggregates are hauled a considerable distance and transferred from railroad cars to wagons there will be some loss in weight and some actual loss on the job because of materials getting mixed with or tramped into the dirt. Losses can generally be figured as not to exceed ten per cent for each class of aggregate.

WATER

Often contractors fail to include cost of water in estimating. Sometimes it costs comparatively nothing, but frequently its cost is considerable. Quantity of water required can be figured at from 40 to 50 gallons per cubic yard for concrete only. In addition, however, water required for operating mixers, engines, wetting forms, sprinkling concrete, sprinkling subgrade in pavement work, etc., will increase the quantity required to 100 gallons per cubic yard. For mass concrete 60 to 75 gallons per cubic yard is a safe estimate. For slab floors, sidewalks, pavements, from 125 to 165 gallons per cubic yard may be required, depending upon the season of the year. Water may have to be hauled or piped a considerable distance. Often water can be contracted for from city water mains. In such case, charges are frequently based on a rate of from ½ to 1½ cents per square yard of concrete pavement.

FORMS

As mentioned elsewhere, forms may cost to erect from $15 to $35 per thousand feet board measure of lumber used. The contractor should keep accurate cost of forms for many classes of jobs, so that eventually approximate cost can be determined for any job.

REINFORCING STEEL

At present steel is much more expensive than ever before. Estimates should be increased ten per cent over actual requirements, to cover wastage from cutting, shaping, etc. Cost of steel is generally figured in place, and this cost is made up of the actual cost of the material plus hauling, loading, bending, where necessary, placing, etc.

HAULING CHARGES

Hauling charges include cost of loading and unloading, both working and waiting time of team and driver, and team time in travel. The less lost motion there is, by just so much can hauling charges be reduced. Rate of team travel is based usually on from twenty to twenty-two miles actual distance in ten hours on average roads and grades with occasional bad spots. If there are difficult places en route two or more teams should be run together so that one can be used as a "snatch" team if the other gets stalled.

A laborer will load loose material by shoveling from ground of car into a wagon about as follows:

Materials Shoveled, Working Continuously	Good Working Conditions and without Delays		Inexperienced Workmen and Delays. Conservative Estimating	
	Cu. Yd. per hr.	Tons per hr.	Cu. Yd. per hr.	Tons per hr.
From car to wagons — Crushed Stone . . .	2.2	3.3	2.0	3.0
From car to wagons — Gravel	2.7	4.0	2.0	3.0
From car to wagons — Sand	3.5	5.0	2.5	3.75
From ground to wagons—Plowed Clay, some Chunks and Stones	2.0	2.5	1.5	1.9
From ground to wagons — Plowed Loam .	2.5	3.0	2.0	2.5
From ground to wagons — Crushed Stone .	3.0	4.5	2.0	3.0
From ground to wagons — Sand	4.0	6.0	3.0	4.5

A team will haul about two cubic yards on a good road, and about half that amount over excavated or soft ground. Sometimes it is necessary to use a "snatch" team to haul material economically under some conditions.

A yard of material can be loaded by shovel gangs in about six minutes. As team time runs high it is often profitable to employ a loading device or extra wagons which can be run in place by a "snatch" team or laboring gang.

The following is based on six-minute loading time and volume loaded of 1 yard:

Slat wagons:

1. Load and dump (1 cubic yard), eight minutes.

2. Hitch, dump, and unhitch (1 cubic yard), four minutes.

Contractor's dump wagon:

1. Load and dump (1 cubic yard), six minutes.

2. Hitch, dump, and unhitch (1 cubic yard), two minutes.

A team will haul on	Pounds	Aggregate cu. yds.	Sacks Cement	Excavation cu. yds.
Very poor earth road	2,000	0.67	20	.8
Poor earth road	2,500	0.835	25	1.0
Good hard road	4,000	1.33	40	1.6
Good macadam or paved road .	6,000	2.00	60	2.4

2,000 feet of travel will take ten minutes, giving a haul length of 1,000 feet. For each 1,000 additional feet of loaded haul ten minutes should be added to time en route.

HAULING CEMENT

A team will haul loads itemized in the foregoing table at ten minutes per 1,000 feet of loaded haul.

Loading near stock pile takes about three quarters of a minute of labor per sack of cement or three minutes per barrel. Unloading under similar conditions takes the same amount of time. The time which a team is delayed while doing this is dependent on the number of laborers employed. It may therefore be profitable to have additional wagons at one or both ends of the haul, so that the teams will not be delayed. Time consumed in changing wagons twice may be taken as five minutes. To the net cost of cement when handled in sacks there should be added a charge of ten cents per barrel to cover handling empty sacks, shipping them back, and the loss of sacks which cannot be redeemed.

SUMMARY HAULING CHARGE

Labor time in loading__________yards__________ hours at $__________per hour__________

Loss of team time waiting or changing wagons __________minutes at $__________per minute______

Team time consumed in unloading__________ minutes at $__________per minute__________

Labor time consumed in assisting unloading______ minutes at $__________per minute__________

Team time__________hours en route at $__________ per hour__________ Total expense for hauling __________yards to job__________

Cost per cubic yard for hauling to job__________

(Superintendence and overhead to be added to total estimate.)

EXCAVATING AND GRADING

Dirt or clay when loosened will increase in volume from twenty to thirty-five per cent and go back in fill to its original volume if compacted to the same degree as in its natural condition. Earth will shrink as much as ten per cent of its original volume if when transferred to another location it is compacted with roller.

Loosening Material

1. With Plow:

(*a*) One plow, team and driver, and one helper will loosen 35 cubic yards ordinary earth per hour.

(*b*) One plow, team and driver, and one helper will loosen 15 to 20 cubic yards of dirt or clay road surface per hour.

(*c*) A pick-pointed plow, four horses, two drivers, one helper will loosen 19 yards of extra tough surface per hour.

2. Picks.

(*a*) One man will loosen as follows per hour:

3½ yards of average earth.

2 yards of tough clay.

¾ yard of hardpan.

3. Moving Material.

Scrapers limit haul "Drag" 200 feet. "Wheel" 500 feet

Drag	25 ft. haul, 1 scraper, 1 team and driver, 1 helper move	60 yd. per day
Drag	50 ft. haul, 3 scraper, 3 team and driver, 1 helper move	150 yd. per day
Drag	100 ft. haul, 3 scraper, 3 team and driver, 1 helper move	120 yd. per day
Drag	200 ft. haul, 3 scraper, 3 team and driver, 1 helper move	105 yd. per day
Wheel	200 ft. haul, 3 scraper, 3 team and driver, 1 helper move	120 yd. per day
Wheel	300 ft. haul, 3 scraper, 3 team and driver, 1 helper move	100 yd. per day
Wheel	400 ft. haul, 3 scraper, 3 team and driver, 1 helper move	80 yd. per day
Wheel	500 ft. haul, 3 scraper, 3 team and driver, 1 helper move	65 yd. per day

MIXING, PLACING, AND HANDLING CONCRETE WITH NOT LESS THAN MINIMUM NOR MORE THAN MAXIMUM SIZED GANGS

1. Mixing by hand 0.2 yards per man per hour__________

2. Stationary mixer with elevated loading platform, wheeling short distance to mixer, $\frac{2}{3}$ cubic yard per man supplying material to mixer and operating mixer.

3. Movable mixer with mechanically hoisted

loading skip, 1 to 1¼ cubic yards per hour per man supplying materials to mixer and operating mixer.

Following is shown the amount of "quaky" consistency concrete which has a tendency to slop over from wheelbarrows on level or average grades from mixer to place of depositing, and also includes labor cost of extra men necessary to place and spread or spade the concrete.

25 foot haul 0.75	cubic yards per man per hour
100 foot haul 0.50	cubic yards per man per hour
150 foot haul 0.40	cubic yards per man per hour
200 foot haul 0.33⅓	cubic yards per man per hour
225 foot haul 0.30	cubic yards per man per hour

The above are safe estimates where the crew is balanced so that no portion is materially delayed.

When the mixer can be kept close to the place where concrete is being deposited the only labor required is that to spread the concrete. One man can handle up to 2.5 cubic yards per hour; two men can generally do more than twice that done by one man, and four men can handle from 12 to 16 cubic yards per hour, depending on the nature of the work.

When concrete must be hoisted above the level of the mixer the problem is simple to solve; but it is difficult to give any general cost data because of the variation in character of plants and the many different heights to which the concrete is raised. The plant, however, when once chosen remains constant in daily operating cost, while its output is dependent upon time of operation.

For example: A one-horse operated winch is used to hoist concrete in silo work. The quantity of concrete deposited each day must be the same, as the forms must be filled once each day. As the height of hoist increases, the time consumed in raising the bucket of concrete increases; the horse must work more hours to raise the same amount of concrete and the time of the gang is lengthened accordingly. Even with engine hoist the same results follow.

When the quantity of concrete to be deposited in a given period is variable, the cost will vary unless the size of the gang is kept adjusted to working conditions.

Several types of ordinary elevator hoists are available. Their output may be estimated by dividing one fourth the loaded speed in feet per minute into the height to which operating. There is also an endless chain hoist with lugs which catch the barrow or wheel carts, carry them to the required height, automatically set them off, and return the empties in the same manner. With this equipment the output may be maintained constant by adjusting the number of carts or barrows; then the cost of raising concrete would be the cost of operating the hoist together with accessories.

Concrete is sometimes delivered by gravity spout or chute, but here the hoist problem is the same, and the spout substitutes the conveying of concrete by barrows or carts from the elevator to place where deposited.

For general estimating the following cost of concrete work complete may be used in normal times. These figures include forms, profit, and all other necessary items.

Concrete in large masses $4 to $6 per cubic yard where few forms enclose a large quantity of concrete. For example: Engine foundations, pavement foundations, building foundations, bridge abutments, and walls two feet or more thick, of medium height.

Plain concrete walls from eight to sixteen inches thick, and other plain concrete construction requiring simple form work and some steel reinforcement for temperature stresses, $6 to $8 per cubic yard.

The same class of work, but more complicated, up to $12.

Reinforced concrete work, including bridge floors, building construction, etc., $12 to $20, with a general average figure of $15.

*Concrete sidewalks, $7 to $9 per cubic yard.

*Concrete street pavements, $7.50 to $9.50 per cubic yard.

SURFACE TREATMENT OF CONCRETE

There being practically no limit to the variation possible in the treatment of concrete surfaces, naturally the cost must often resolve itself into the known items, such as materials required, scaffolding, and the unknown quantity of labor, which must be

*Note: For his own information the contractor must figure the *volume* of concrete. As pavement specifications may vary in stating the thickness required, the contractor will then reduce his cubic-yard cost to a square-yard basis, as paving costs are usually expressed in this way.

conservatively estimated from the contractor's knowledge of the surface area that can be treated in a given time by the men available. Hence the contractor must have personal knowledge of the ability of the men who will actually do the work or feel certain that he can teach men to do it for the cost estimated.

The following table gives the quantities of materials required for Portland cement exterior plastering of varying thicknesses:

NUMBER OF SQUARE FEET OF WALL SURFACE COVERED PER SACK OF CEMENT, FOR DIFFERENT PROPORTIONS AND VARYING THICKNESS OF PLASTERING

Proportions of Mixture	MATERIALS			TOTAL THICKNESS OF PLASTER				
	Sacks Cement	Cu. Ft. Sand	Bushels Hair*	½ in. Sq. Ft. Covered	¾ in. Sq. Ft. Covered	1 in. Sq. Ft. Covered	1¼ in. Sq. Ft. Covered	1½ in. Sq. Ft. Covered
1:1	1	1	⅛	33.0	22.0	16.5	13.2	11.0
1:1½	1	1½	⅛	42.0	28.0	21.0	16.0	14.0
1:2	1	2	⅛	50.4	33.6	25.2	20.1	16.8
1:2½	1	2½	⅛	59.4	39.6	29.7	23.7	19.8
1:3	1	3	⅛	67.8	45.2	33.9	27.1	21.6

*Used in scratch coat only.

NOTE. These figures are based on average conditions and may vary 10 per cent either way, according to the quality of the sand used. No allowance is made for waste.

After having decided upon the thickness of the wall plaster and the mixture to be used, it is easy to determine the total materials required for covering a given wall surface, since the table shows the number of square feet of surface covered by the mortar resulting from one sack of cement. Waste can be reduced by placing a plank on the ground at the base of the wall to catch plaster that falls. Such plaster should never be used after it has once begun to harden, and therefore should not be allowed to accumulate but should be gathered up promptly and remixed with the mortar already prepared. Cement plaster should not be mixed in batches larger than are needed for immediate use, otherwise some of the mortar may begin to harden before it can be used and must be thrown away.

Cement stucco work generally costs from $1.50 to $1.75 per square yard, including building paper and wood or metal lath, the metal lath costing a little more than the wood. The two-coat smooth work often costs less than $1.50. When granite or marble chips are used in the rough exposed dry or other dash, the extra cost of such materials may raise the price to $1.75 or slightly more.

When the form face is plastered with chips or colored pebbles backed by the regular wall concrete, and after the forms are removed, the surface film of cement is brushed or washed with a weak solution of acid, the extra cost generally runs from five to ten cents per square foot of surface.

Concrete wall surfaces are treated by one coat of cement mortar, smooth or dash finish, at a cost of approximately five cents per square foot. Concrete surfaces are frequently tooled to reveal the aggregate.

The tooth-axed surface is probably the most widely known. This work is done by lightly chipping with a tooth-ax and thus breaking away the surface skin of the concrete. The work is generally done in panels or to produce designs with borders or certain areas left smooth. The smooth surfaces are rubbed with cement grout and a carborundum stone and pointed up. The work generally is contracted for at from six to seven cents per square foot of exposed area of the building with the addition of all areas to be treated at angles to the surface. Stone cutters are preferable for this work and one man will cut from 80 to 100 square feet per day of eight hours or over, approximately 150 square feet of surface in like time.

BRICKWORK—WALLS

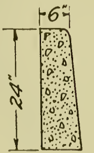
8⅜ in. by 2⅜ in. by 4 in. brick $\frac{5}{16}$ in. joints requires 12 cu. ft. of mortar per 1,000 brick. With a 1 *cement* 3 *sand* mix, 1 barrel cement per 1,000 brick. Allowing for waste 1.25 *barrels cement per* 1,000 *brick.* 1,000 *brick* will lay 475 *square feet* of 12 in. wall.

CONCRETE FOUNDATIONS—WALLS, ETC.

1 cu. ft. Concrete	Sacks of Cement	1 cu. yd. Concrete	Bbls. of Cement
1:1:1	.5404	1:1:1	3.375
1:1½:3	.2808	1:1½:3	1.895
1:2:4	.2220	1:2:4	1.498
1:2½:5	.1848	1:2½:5	1.247
1:3:6	.1570	1:3:6	1.060

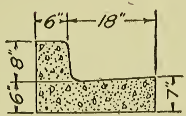
ESTIMATES ON SPECIFIC CONTRACTS

FLOOR WALKS ROADS AND STREETS								
Sacks of cement required for 1000 sq. ft. of surface for varying thickness of course								
PROPORTIONS	1"	2"	4"	5"	6"	7"	8"	9"
1-2	3.9	7.88						
1-1-1	4.2	8.34						
1-1-1½	3.7	7.30						
1-1½-2½	2.6	5.14						
1-1½-3			9.36	11.70	14.04	16.38	18.72	21.06
1-2-3			8.60	10.75	12.90	15.05	17.20	19.35
1-2-4			7.40	9.25	11.10	12.95	14.80	16.65
1-2½-4			6.88	8.60	10.32	12.04	13.76	15.48
1-2½-5			6.16	7.70	9.24	10.78	12.32	13.86
1-3-6			5.22	6.52	7.86	9.16	10.44	11.79



CURB

1:2 Face
1:2½:5 Base
.28 Sacks per foot
14.2 Feet per barrel cement



CURB & GUTTER

1:2 Face
1:2½:5 Base
.26 Sacks per foot
15 Feet per barrel cement

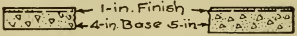
Grouting - one barrel of cement for 30 square yards of brick pavement - 1 cement - 1 sand mix.

AMOUNT OF CEMENT REQUIRED FOR CERTAIN TYPICAL STREET IMPROVEMENTS

— Portland Cement Association.- K.C. Office — 5-28-17

MIX	BBLS. CEMENT PER SQ.YD. PAVING OR BASE			
	4 in. Thick	5 in. Thick	6 in. Thick	7 in. Thick
1 – 1½ – 3	0.212	0.266	0.318	0.371
1 – 2 – 3	0.193	0.242	0.290	0.338
1 – 2 – 4	0.168	0.210	0.252	0.294
1 – 2½ – 5	0.138	0.172	0.207	0.241
1 – 3 – 6	0.118	0.147	0.177	0.206
* 1 – 4	0.211	0.264	0.317	0.370
* 1 – 5	0.175	0.219	0.263	0.307
* 1 – 6	0.150	0.188	0.225	0.262

GARAGE FLOORS & SIDEWALKS



For 4 in. or 5 in. Base, use quantity as indicated for pavement and add for each 1-in. of top per sq.yd.

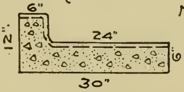
TOP

Mix	Bbls. per sq.yd.
1 – 2	0.089
1 – 2½	0.076
1 – 3	0.066

MATERIALS REQUIRED FOR ONE CU.YD. OF CONCRETE

MIX	Cement Bbls.	Sand Cu.Yd.	Stone Cu.Yd.
1 – 1½ – 3	1.91	0.42	0.85
1 – 2 – 3	1.74	0.52	0.77
1 – 2 – 4	1.51	0.45	0.89
1 – 2½ – 5	1.24	0.46	0.92
1 – 3 – 6	1.06	0.47	0.94

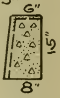
Curb & Gutter



NOTE
If mortar surface is specified add 0.01 Bbl. per lineal foot.

Straight Curb

NOTE
If mortar surface is specified add 0.005 Bbls. per lineal foot.



CURB & GUTTER	MIX	STRAIGHT CURB
0.084 Bbls. per lin. ft.	1 – 2 – 4	0.039 Bbls. per lin. ft.
0.069 " " " "	1 – 2½ – 5	0.034 " " " "
0.059 " " " "	1 – 3 – 6	0.029 " " " "
0.105 " " " "	* 1 – 4	0.051 " " " "
0.088 " " " "	* 1 – 5	0.043 " " " "
0.075 " " " "	* 1 – 6	0.036 " " " "

NOTE * If gravel contains three-quarter inch pebbles and below in size reduce the quantity of cement about ten per cent.

MATERIALS REQUIRED FOR 100 SQ. FT. OF SIDEWALKS AND FLOORS FOR VARYING THICKNESS OF COURSE

CONCRETE BASE

Proportions	1:1½:3			1:2:3			1:2:4			1:2½:4			1:2½:5		
Thickness	C.	Sd.	St.	C.	Sd.	St.	C.	Sd.	St.	C.	Sd.	St.	C.	Sd.	St.
2½ in.	5.9	0.33	0.65	5.4	0.40	0.60	4.6	0.34	0.68	4.3	0.40	0.63	3.9	0.36	0.72
3	7.0	0.39	0.78	6.5	0.48	0.72	5.6	0.41	0.82	5.2	0.48	0.77	4.6	0.43	0.86
3½	8.2	0.46	0.91	7.5	0.56	0.84	6.5	0.48	0.96	6.0	0.56	0.89	5.4	0.50	1.00
4	9.4	0.52	1.04	8.6	0.64	0.95	7.4	0.55	1.10	6.9	0.64	1.02	6.2	0.57	1.14
4½	10.5	0.59	1.17	9.7	0.72	1.07	8.3	0.62	1.23	7.7	0.72	1.14	6.9	0.64	1.28
5	11.7	0.65	1.30	10.8	0.80	1.19	9.3	0.69	1.37	8.6	0.80	1.27	7.7	0.71	1.43
5½	12.9	0.72	1.43	11.8	0.88	1.31	10.2	0.76	1.50	9.5	0.87	1.40	8.5	0.78	1.57
6	14.0	0.78	1.56	12.9	0.96	1.43	11.1	0.82	1.64	10.3	0.95	1.53	9.2	0.86	1.72

WEARING COURSE

Thickness	1:1		1:1½		1 : 2		1:1:1			1 : 1 : 1½		
inches	C.	Sd.	C.	Sd.	C.	Sd.	C.	Sd.	St.	C.	Sd.	St.
½	3.0	0.11	2.4	0.13	2.0	0.15	2.1	0.08	0.08	1.8	0.07	0.10
¾	4.5	0.16	3.6	0.19	2.9	0.22	3.1	0.11	0.11	2.7	0.10	0.15
1	6.0	0.22	4.8	0.26	3.9	0.29	4.2	0.15	0.15	3.7	0.14	9.20
1¼	7.5	0.27	6.0	0.33	4.9	0.36	5.2	0.19	0.19	4.6	0.17	0.25
1½	9.0	0.33	7.2	0.40	5.9	0.43	6.3	0.23	0.23	5.5	0.20	0.30
1¾	10.5	0.39	8.4	0.46	6.9	0.50	7.3	0.27	0.27	6.4	0.24	0.36
2	12.0	0.45	9.6	0.53	7.9	0.58	8.3	0.31	0.31	7.3	0.27	0.41

NOTE. Quantities expressed in the following units:

Cement . . . sacks Sand . . . cubic yards Pebbles or Broken Stone . . cubic yards

MATERIALS REQUIRED FOR 100 SQ. FT. OF SURFACE FOR VARYING THICKNESS OF COURSE

Thickness	1 in.			2 in.			4 in.			5 in.		
Mix	C.	Sd.	St.	C.	Sd.	St.	C.	Sd.	St.	C.	Sd.	St.
1:2	3.9	0.29	....	7.9	0.58	....	....	....	....	....	....	....
1:1:1	4.2	0.15	0.15	8.3	0.31	0.31	....	....	....	....	....	....
1:1:1½	3.7	0.14	0.20	7.3	0.27	0.41	....	....	....	....	....	....
1:1½:2½	2.6	0.14	0.24	5.1	0.28	0.47	....	....	....	....	....	....
1:1½:3	....	....	....	....	....	....	9.4	0.52	1.04	11.7	0.65	1.30
1:2:3	....	....	....	....	....	....	8.6	0.64	0.95	10.8	0.80	1.19
1:2:4	....	....	....	....	....	....	7.4	0.55	1.10	9.3	0.69	1.37
1:2½:4	....	....	....	....	....	....	6.9	0.64	1.02	8.6	0.80	1.27
1:2½:5	....	....	....	....	....	....	6.2	0.57	1.14	7.7	0.72	1.43
1:3:6	....	....	....	....	....	....	5.2	0.58	1.16	6.5	0.73	1.45

Thickness	6 in.			7 in.			8 in.			9 in.		
Mix	C.	Sd.	St.	C.	Sd.	St.	C.	Sd.	St.	C.	Sd.	St.
1:1½:3	14.0	0.78	1.56	16.4	0.91	1.82	18.7	1.04	2.08	21.1	1.17	2.34
1:2:3	12.9	0.95	1.43	15.0	1.11	1.67	17.2	1.27	1.90	19.3	1.43	2.14
1:2:4	11.1	0.82	1.64	12.9	0.96	1.92	14.8	1.10	2.19	16.7	1.23	2.47
1:2½:4	10.3	0.95	1.53	12.0	1.11	1.78	13.8	1.27	2.03	15.5	1.43	2.29
1:2½:5	9.2	0.86	1.72	10.8	1.00	2.00	12.3	1.14	2.29	13.9	1.29	2.57
1:3:6	7.9	0.87	1.74	9.2	1.02	2.03	10.5	1.16	2.32	11.8	1.31	2.61

NOTE. Quantities expressed in the following units:

Cement . . sacks Sand . . . cubic yards Pebbles or Broken Stone . . cubic yards

MATERIALS REQUIRED FOR 100 SQ. FT. OF SURFACE FOR VARYING THICKNESS OF PLASTER

Proportions	1:1		1:1½		1:2		1:2½		1:3	
Thickness (in.)	C. (sacks)	Sd. (cu. yds.)	C. (Sacks)	Sd. (cu. yds.)	C. (Sacks)	Sd. (cu. yds.)	C. (Sacks)	Sd. (cu. yds.	C. (Sacks)	Sd. (cu. yds.)
⅜	2.2	0.08	1.8	0.10	1.5	0.11	1.3	0.12	1.1	0.13
½	3.0	0.11	2.4	0.13	2.0	0.15	1.7	0.16	1.5	0.17
¾	4.5	0.16	3.6	0.19	2.9	0.22	2.5	0.23	2.2	0.25
1	6.0	0.22	4.8	0.26	3.9	0.29	3.3	0.31	3.0	0.33
1¼	7.5	0.27	6.0	0.33	4.9	0.36	4.2	0.39	3.7	0.41
1½	9.0	0.33	7.2	0.40	5.9	0.43	5.1	0.47	4.5	0.50
1¾	10.5	0.39	8.4	0.46	6.9	0.50	6.0	0.56	5.4	0.60
2	12.0	0.45	9.6	0.53	7.9	0.58	6.9	0.64	6.2	0.69

If hydrated lime is used it should be added in amounts of from 5 to 10% by weight of the cement.
Hair is used in the scratch coat only in amounts of ⅛ bushel to 1 sack of cement.
These figures may vary 10% in either direction due to the character of the sand.
No allowance is made for waste.

QUANTITIES OF PORTLAND CEMENT, SAND, AND PEBBLES OR CRUSHED STONE FOR 100 SQUARE FEET OF CONCRETE 10 INCHES THICK, EQUAL TO 3.08 CUBIC YARDS

Proportions			Quantities		
Sacks of Cement	Cu. Ft. of Sand	Cu. Ft. Pebbles or Stone	Sacks of Cement	Cu. Yd. of Sand	Cu. Yd. Pebbles or Stone
1	1	......	60.2	2.23	......
1	1½	......	47.7	2.65	......
1	2	......	39.4	2.92	......
1	2½	......	33.8	3.13	......
1	3	......	29.5	3.29	......
1	1	1	41.7	1.54	1.54
1	1½	3	23.4	1.30	2.60
1	2	3	21.5	1.59	2.38
1	2	4	18.5	1.37	2.74
1	2½	4	17.2	1.59	2.54
1	2½	5	15.4	1.43	2.86
1	3	5	14.2	1.58	2.64

Note. These quantities can be safely used for estimating, ordering materials, and, after the work is done, as a check to prove that the required quantity of cement has been used. Actual quantity of materials used in the concrete should not vary more than ten per cent above or below the quantities given in the table.

This table can readily be used for any concrete structures which can be measured in area and which are of uniform thickness over any considerable area, such as walls, floors, and walks.

The following examples illustrate the use of the table:

Example 1. Required the quantity of materials for a 12 inch thick basement wall, 6 feet 5 inches high above footing, for a house 25 feet by 40 feet outside dimensions. The footing 1 foot 6 inches wide and 6 inches thick. Concrete proportioned 1: 3: 5.

WALL:

Length of wall 25+25+39+39=128 ft.

Height of wall 6 ft. 5 in. $=6\frac{5}{12}=6.417$ ft.

Area of wall $=128\times6.417=821.4$ sq. ft.

Thickness of wall =12 in.

Quantities of materials for wall concrete:

Factor for multiplying units in

$$\text{table} = \frac{821.4}{100}\times\frac{12}{10}=8.214\times1.2=9.8568;$$

Take 9.86

Sacks of cement $=14.2\times9.86=140.0$

Cu. yd. of sand $=1.58\times9.86=15.6$

Cu. yd. of pebbles or crushed stone $=2.64\times9.86=26.0$

FOOTING:

Length of footing =25.5+25.5+37.5+37.5=126 ft.

Width of footing =1 ft. 6 in. $=1\frac{6}{12}=1.5$ ft.

Area of footing $=126\times1.5=189$ ft.

Thickness of footing =6 in.

Quantities of materials for footing:

Factor for multiplying units in the

$$\text{table} =\frac{189}{100}\times\frac{6}{10}=1.89\times.6=1.134=1.13$$

Sacks of cement $=14.2\times1.13=16.0$

Cu. yd. of sand $=1.58\times1.13=1.8$

Cu. yd. of pebbles or stone $=2.64\times1.13=3.0$

Total quantities of materials:

Sacks of cement =140+16=156.0

Cu. yd. of sand =15.6+1.8=17.4 or 17.5

Cu. yd. of pebbles =26.0+3=29.0

EXAMPLE 2. Required the quantities for a concrete floor for a basement. Interior dimensions of the basement 23 feet by 38 feet. Floor 5 inches thick over all, with 4 inch base of concrete proportioned 1:2½:5, and 1 inch wearing course composed of cement mortar proportioned 1:2.

Area of floor $=23\times38=874$ sq. ft.

Factor for multiplying quantities in table for

$$\text{base} =\frac{874}{100}\times\frac{4}{10}=8.74\times.4=3.5$$

Quantities of materials for base concrete:
Sacks of cement = 15.4 × 3.5 = 54.0
Cu. yd. of sand = 1.43 × 3.5 = 5.0
Cu. yd. of pebbles or stone = 2.86 × 3.5 = 10.0
Factor for multiplying quantities in table for wearing surface $= \frac{874}{100} \times \frac{1}{10} = 8.74 \times .1 = .9$

Quantities of materials for wearing surface mortar:
Sacks of cement = 39.4 × .9 = 35.5
Cu. yd. of sand = 2.92 × .9 = 2.6 cu. yd.

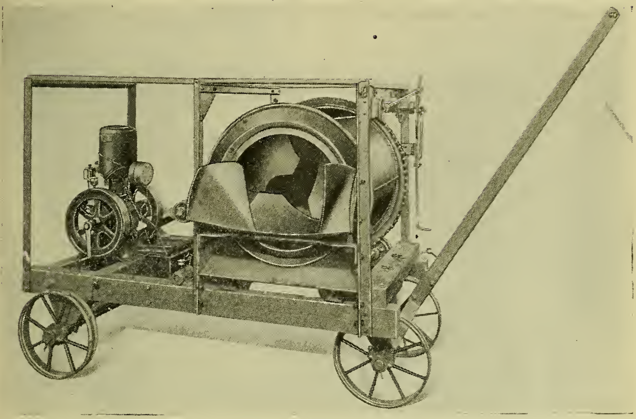
Total quantities of materials for floor:
Sacks of cement = 54.0 + 35.4 = 89.5
Cu. yd. of sand = 5.0 + 2.6 = 7.6 or 7.5
Cu. yd. of pebbles or stone = 10.0

SURFACE AREA (IN SQUARE FEET) OF CONCRETE SLABS OR WALLS OF VARIOUS THICKNESSES AND PROPORTIONS THAT CAN BE MADE WITH ONE SACK OF CEMENT

Thickness of Slab or Wall in inches	Concrete Mixture				
	1:2:3	1:2:4	1:2½:4	1:2½:5	1:3:5
3	15.52	17.88	19.42	21.77	23.2
3½	13.31	15.33	16.65	18.67	19.9
4	11.64	13.41	14.56	16.33	17.4
4½	10.36	11.93	12.96	14.53	15.5
5	9.31	10.73	11.65	13.06	13.9
5½	8.46	9.74	10.58	11.86	12.6
6	7.76	8.94	9.71	10.88	11.6
6½	7.18	8.27	8.98	10.07	10.7
7	6.65	7.66	8.33	9.33	9.9
8	5.82	6.70	7.28	8.16	8.7
10	4.66	5.36	5.83	6.53	6.9
12	3.88	4.47	4.85	5.44	5.8
14	3.32	3.83	4.16	4.66	4.7
16	2.91	3.35	3.64	4.08	4.3

WEIGHTS AND VOLUMES

Portland cement weighs per barrel, net	376 lb.
Portland cement weighs per bag, net	94 lb.
Natural cement weighs per barrel, net	282 lb.
Natural cement weighs per bag, net	94 lb.
Loose Portland cement averages per cubic foot about	92 lb.
Weight of paste of neat Portland cement averages per cubic foot about	137 lb.
Volume of paste made from 100 lb. of neat Portland cement averages about	0.86 cu. ft.
Weight of Portland cement mortar in proportions 1:2½ averages per cubic foot	135 lb.
Weight of Portland cement concrete averages per cubic foot about	130 lb.
Cinder concrete averages	112 lb.
Conglomerate concrete averages	150 lb.
Gravel concrete averages	150 lb.
Limestone concrete averages	148 lb.
Sandstone concrete averages	143 lb.
Trap concrete averages	155 lb.



RANSOME BANTAM MIXER

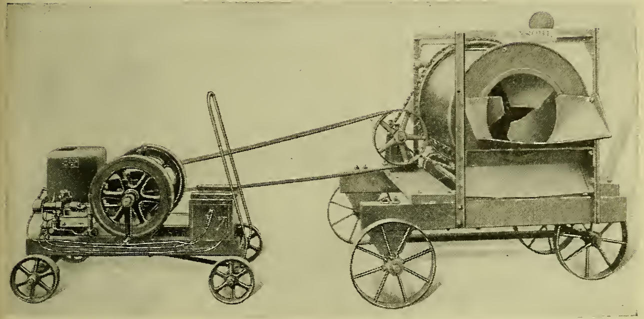
The Ransome Bantam Mixer is of the low charging type and is regularly equipped with platform and runways. The drum has a capacity of 10 cu. ft. of loose material and will produce approximately 6 cu. yd. of concrete per hour. A gasoline engine of 3 H.P. is furnished, amply protected from the weather by a steel roof and side curtains.

WRITE FOR RANSOME BANTAM BOOKLET

RANSOME BANTAM SENIOR

The Ransome Bantam Senior Mixer is built along the same general lines as the Bantam, except that it is regularly furnished with a side loader, automatic water tank, and 4 H.P. gasoline engine. The output is therefore increased to 7½ cu. yds. of concrete per hour.

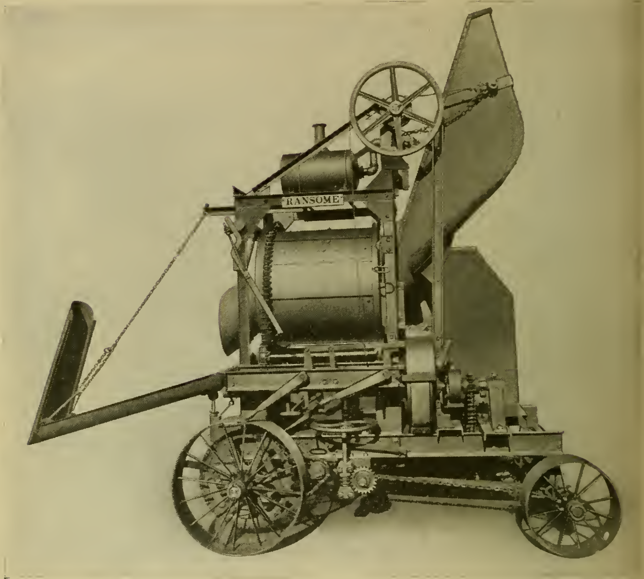
WRITE FOR RANSOME BANTAM BOOKLET



RANSOME BANTAM JUNIOR

FARMERS' TYPE

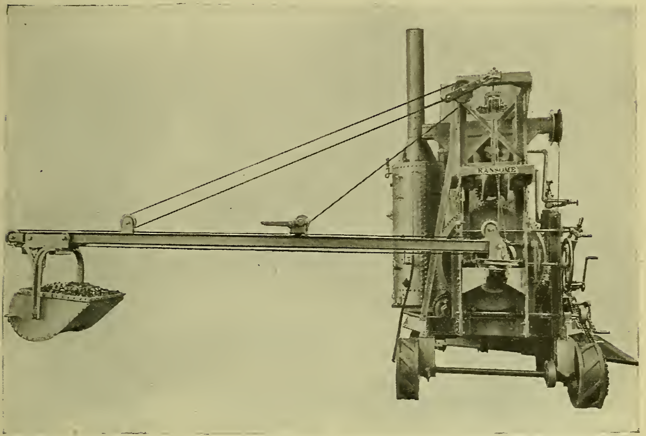
The Ransome Bantam Junior Mixer of the Farmers is furnished with 2½ H.P. gasoline engine on a separate frame and trucks, so that the engine may be used for miscellaneous purposes about the farm or estate. The Contractors' Type of this machine has the engine mounted on mixer frame. Capacity of this mixer is 5 cu. ft. loose material per batch or 3 cu. yd. of concrete per hour.



RANSOME BANTAM PAVER

THE RANSOME BANTAM PAVER is of the end load, end discharge type, having a capacity of 10 cu. ft. loose material per batch. It is equipped with open-end pivot hopper, 10 ft. distributing chute, and 6 H.P. gasoline engine, chain drive. The self-propelling traction as well as the portability and light weight are attractive features of this machine.

WRITE FOR "RANSOME ROADS" BOOKLET

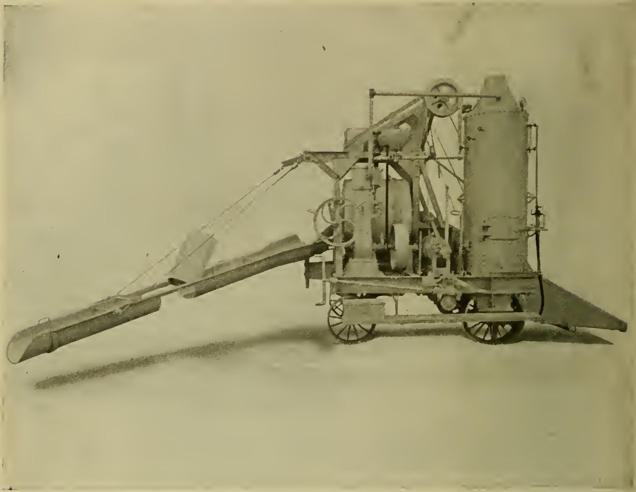


RANSOME STREET PAVER — MODEL 10-E

BUCKET AND BOOM TYPE

The Ransome Road Paver, Bucket and Boom Type, is a distinctly high grade machine for heavy work. It is equipped with a 20 ft. distributing boom, on which runs an automatic dumping bucket. This mixer is equipped with steam power and has self-propelling traction. It is made in one size only, capacity 14 cu. ft. loose material per batch.

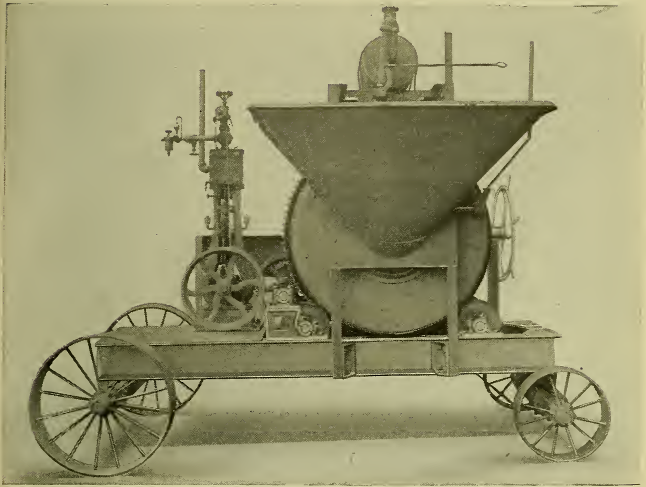
WRITE FOR "RANSOME ROADS" BOOKLET



RANSOME SPOUT STREET PAVER

The Ransome Road Paver, Spout Type, is made along the same lines as the Bucket and Boom Type, except that it is equipped with a distributing chute 15 ft. long. It is made in two sizes only, namely 14 and 30 cu. ft. of loose material per batch, with steam power.

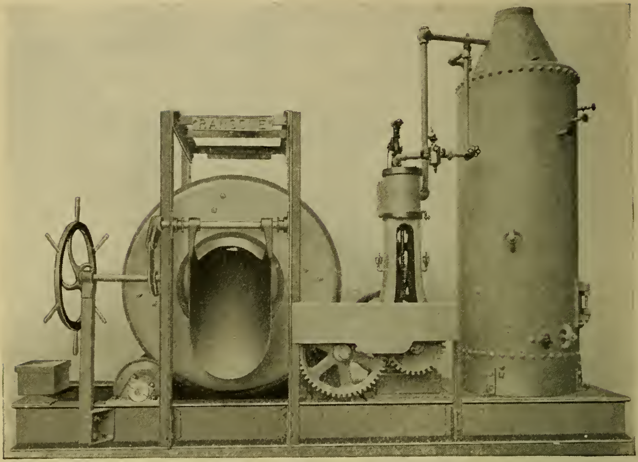
WRITE FOR "RANSOME ROADS" BOOKLET



RANSOME MIXER WITH DIRECT-GEARED ENGINE

WITH FIXED BATCH HOPPER

The above illustration shows the Standard Type of Ransome Mixers equipped with Fixed Batch Hopper. These machines are made in sizes ranging from a batch capacity of 10 to 80 cu. ft. of loose material. Electric, steam, and gasoline power is furnished as desired.

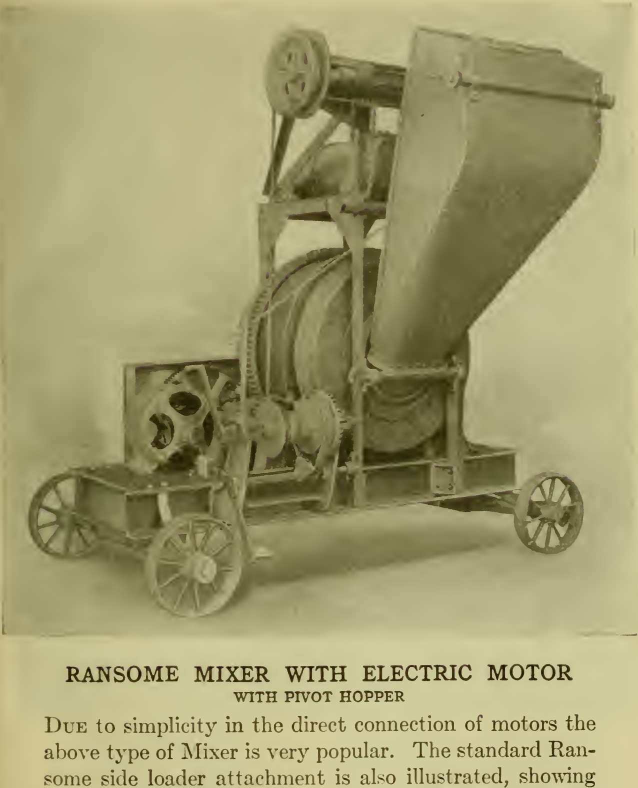


RANSOME MIXER WITH COMPLETE STEAM PLANT

DISCHARGE SIDE

The above illustration shows the discharge side of the Ransome Mixer, Standard Type, on steel frame, with complete steam-power plant. These Mixers are equipped with cut steel gears and split adjustable bearings. Traction rings have heavy steel bands welded and shrunk on.

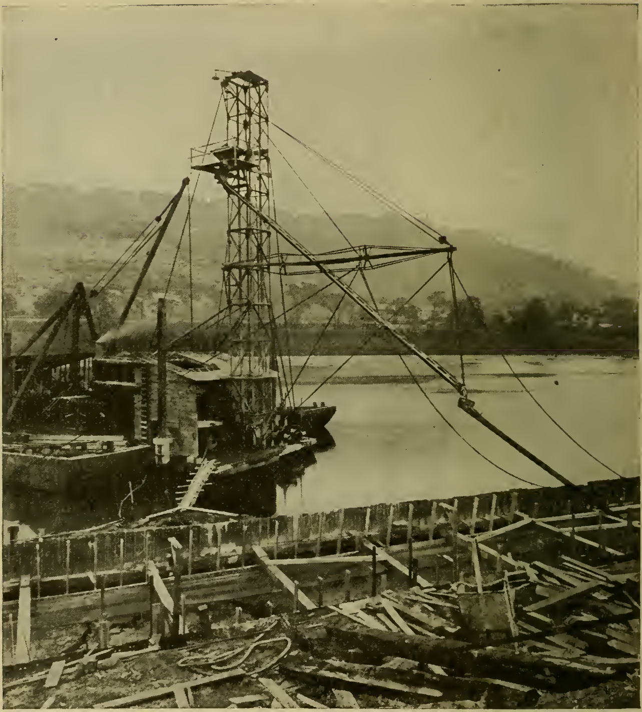
WRITE FOR "RANSOME MIXERS" BOOKLET



RANSOME MIXER WITH ELECTRIC MOTOR
WITH PIVOT HOPPER

DUE to simplicity in the direct connection of motors the above type of Mixer is very popular. The standard Ransome side loader attachment is also illustrated, showing the cone friction hoist and oversize pivot hopper bucket. All motors are furnished with steel housings.

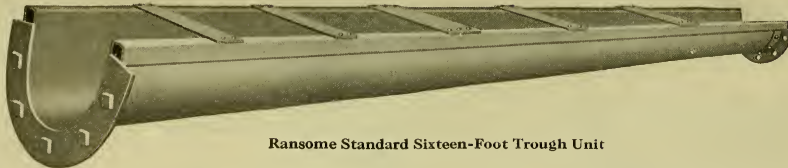
WRITE FOR "RANSOME MIXERS" BOOKLET



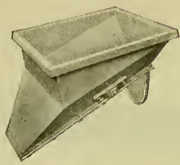
A COMPLETE barge plant is shown above, on which was used the following Ransome equipment: Mixer, Steel Tower, Hoist Bucket, Tower Bin, Spouting and Boom Irons. This type of spouting layout is known as a "Boom Plant."

WRITE FOR RANSOME SPOUTING CATALOG

RANSOME SPOUTING

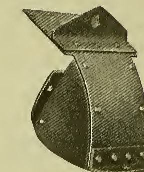


Ransome Standard Sixteen-Foot Trough Unit



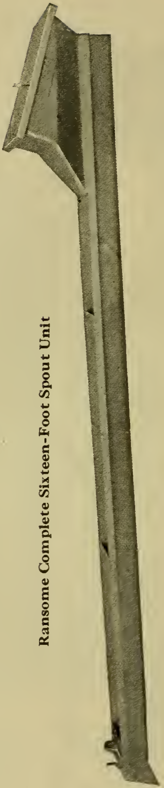
Ransome Standard Hopper Head

Swivel Hook

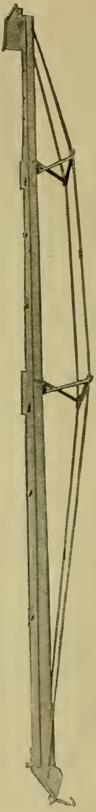


Ransome Standard Splash Hood

The above illustrations show the most important parts of Ransome Spouting, from which any length of section or any type of spouting plant may be assembled. Ransome spouts are made of high carbon steel, insuring long life.

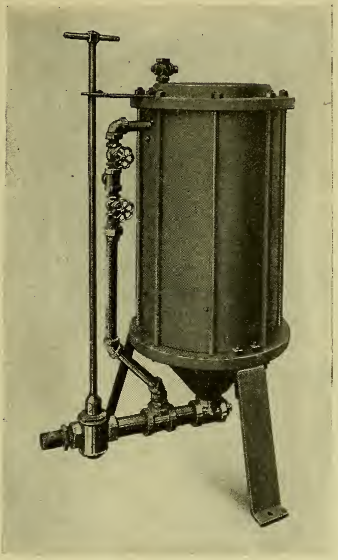


Ransome Complete Sixteen-Foot Spout Unit



Ransome Forty-eight Foot Chute with Truss Members and Tension Rods in Position

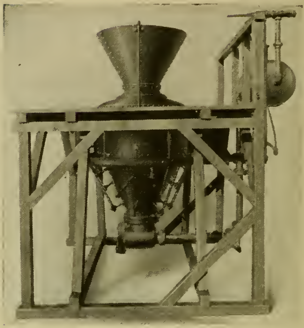
The above show assembled sections of Ransome Spouting. All parts are interchangeable, so that the parts may be dismantled and put in stock or reassembled to suit the next job.



RANSOME-CANNIFF GROUT INJECTORS

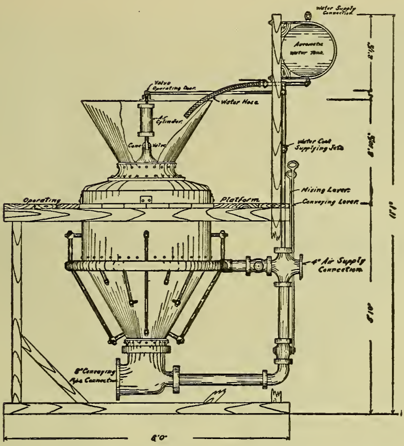
Ransome-Canniff Grout Injectors are designed for mixing and placing grout by compressed air. Cement and sand are delivered to the grout tank through the charging door, the proper proportion of water being added. The grout is mixed by allowing the compressed air to blow in at the bottom, which keeps the mixture "boiling" and prevents sand and cement settling into and choking the outlet pipe. During this operation the blow-off valve is open.

WRITE FOR RANSOME PNEUMATIC BOOKLET



RANSOME-CANNIFF PNEUMATIC MACHINE

The advantages of pneumatic machinery are many and far reaching. The mixer is located at a point where the aggregates can be handled most conveniently and economically. The transportation of the mixed concrete to the forms is accomplished with the least possible expenditure of power and of material. The conveying pipe can be laid in almost any direction required. It takes up but little room — a highly essential feature in tunnel and subway work — and needs no heavy foundation supports or prepared runways of any sort. The concrete can be elevated to any required height or conveyed any reasonable distance in a minimum of time. The concrete is placed through a short length of rubber hose of the same inside



RANSOME-CANNIFF PLACER ASSEMBLY

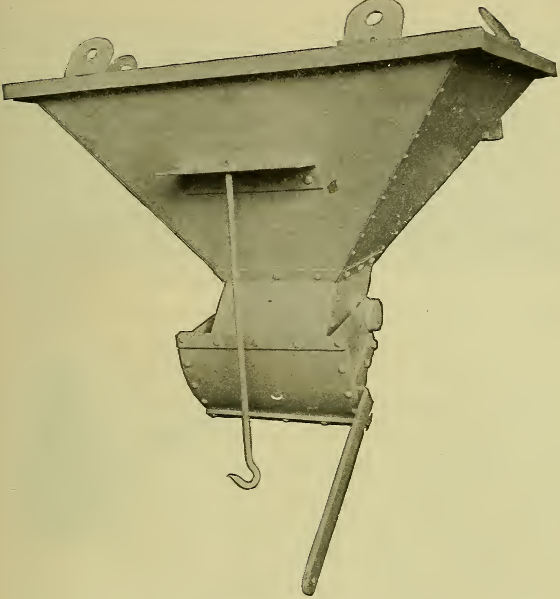
diameter as the pipe. No hand spreading or tamping is necessary, as the concrete can be directed to the exact spot where it is needed. All labor between the mixer and the forms is eliminated except the two men handling the hose.

Not only is the work accomplished more rapidly, but the cost is found in most cases to be considerably under that for any other method. The savings effected depend, of course, upon the particular type of work. In tunnel and subway construction it has amounted to over $2.50 per cubic yard of concrete placed.

RANSOME HOIST BUCKETS

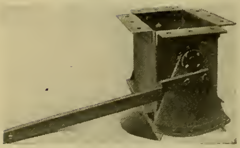
RANSOME HOIST BUCKETS are designed for use in towers where the work is too high to be reached by easy wheeling.

The bucket is constructed along the most simple lines, catches and trips having been eliminated. A substantial bail, built up of angle irons, operates between two 5¾ in. wooden guides, and is furnished at the lower end with journals, in which rests the trunnion of the bucket proper. By removing a front guide at any point, automatic discharge of the bucket will take place through the space so left.



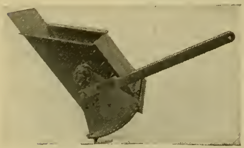
RANSOME CONCRETE BINS

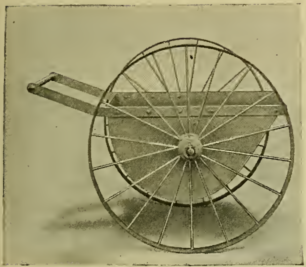
RANSOME BIN GATES

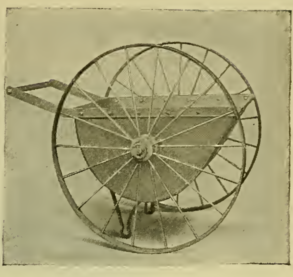

Vertical Bin Gate

Of the three different styles of Ransome Bin Gates some one will always be found suitable for any position on the aggregate storage bins. The upper view shows the gate used for discharging stone and sand through the bottom of the bin; the center, gate for discharging through the bottom and delivering on one side or the other; and the lower illustration shows the gate for attaching to the vertical side instead of the bottom of the bin. Not only the quality of material used in Ransome Bin Gates, but the care in workmanship, insures easy operation and perfect closure, even under the severe conditions of this work.


Bottom Bin Gate


Front Bin Gate

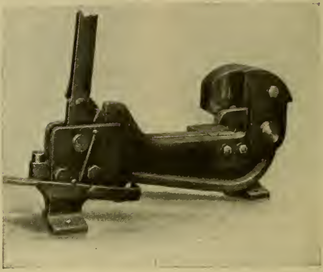




RANSOME CONCRETE CARTS

RANSOME CONCRETE CARTS, when used in place of wheelbarrows for the distribution of concrete, cut down the number of wheelers to about one half, sometimes to one third of the original force. These carts hold 6 cu. ft., water measure. A special Ransome feature is the reversibility of the handles. These may be quickly changed end for end. The round contour of the cart bodies facilitates quick, clean dumping. Ransome Carts are furnished with or without legs. The legs are necessary for elevator work.

Capacity	Weight	Diameter of Wheels	Diameter of Axle
6 cu. ft.	255 lb.	42 x 2 in.	1¼ in.



RANSOME BAR CUTTERS

Ransome Bar Cutters are made from solid steel forgings — no cast iron whatever being used. They may cost a bit more at the start, but they are by all odds the most economical in the end. The lightweight cutter will handle square and round stock up to ¾ in., and flat iron 3⅜ by 2 in. The heavier cutter will cut 1¼ in. round or square stock, and flat iron up to ¾ by 3½ in. For heavier stocks a power cutter is advisable.

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RANSOME

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AMERICA'S FIRST MIXER