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The Ransome Book

HOW TO MAKE AND
HOW TO USE
CONCRETE



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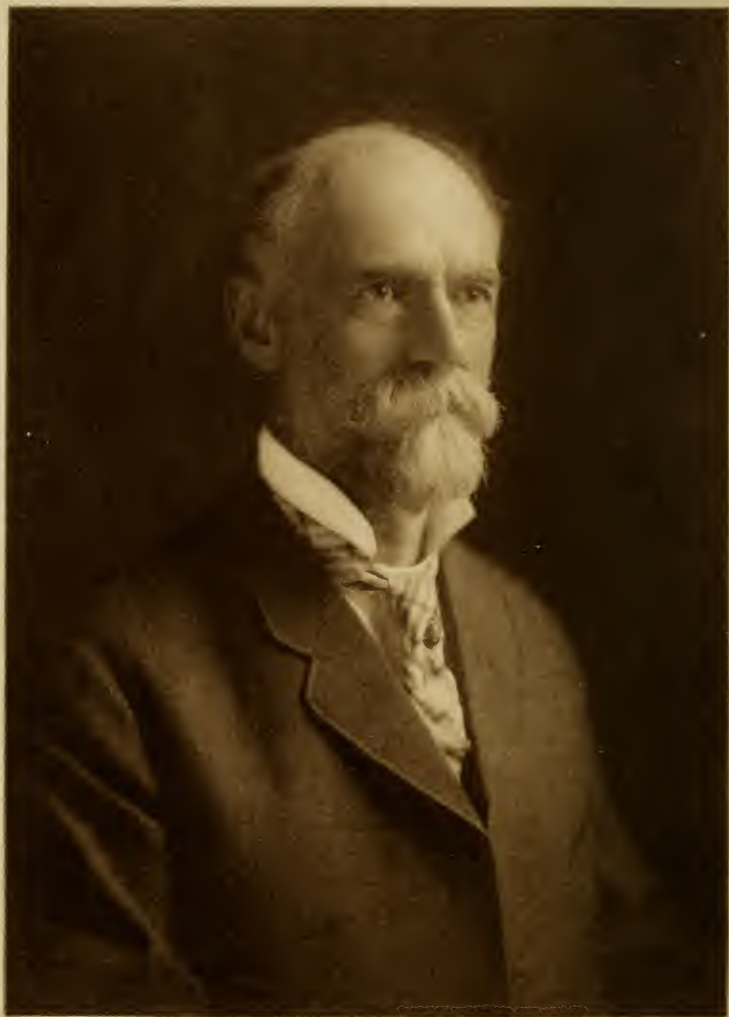


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ERNEST L. RANSOME

FOUNDER

The Ransome Book

HOW TO MAKE AND HOW TO USE CONCRETE

copy Written and Compiled by
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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.

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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.

A T R I B U T E

ON March 5, 1917, Ernest L. Ransome died at his home at Plainfield, New Jersey.

The Ransome Concrete Machinery Co. can conceive of no more fitting place than this to pay its tribute to a man to whom, more than perhaps any other person, we owe the present-day perfection of concrete machinery. More than that, the engineering profession — the whole concrete construction field, the cement industry — is indebted to the pioneering spirit which Mr. Ransome displayed in the early years of his very active life.

Ernest L. Ransome was truly a pioneer in the field of concrete construction. To him belongs the honor of having built the first reinforced concrete building and the first reinforced concrete bridge in the United States. Fate in part marked Mr. Ransome for the career which he chose. His father was a well-known experimenter with cement, since he was among the first, if not the first, to perfect ways and means of making artificial stone.

From 1850 to 1890 Ernest L. Ransome, who was then located in San Francisco, devoted his time to applying the many discoveries he had made in the use of cement, that is in concrete construction, to work of elaborate and expensive character. His fame was not confined to the Pacific Coast, nor even to the United States, for his connection with many

societies and his contributions to the mechanical side of the concrete industry through numerous inventions which he devised, made his name a common one among builders throughout the world.

Numerous patents stand to his credit. He developed the first real machine for mixing concrete. The cold twisted bar, for reinforcing, of which there are so many tons used in concrete construction today, was a patent of his fertile mind. Floor systems, method of reinforcing, types of reinforcing materials, all had his deep attention and profited from his keen insight and extremely practical nature. Perhaps in his time he did more to develop methods of design, workmanship, etc., related to the use of concrete than any one contemporary with him. It can be said, without fear of contradiction, that in the early years of his life he was far in advance of his co-workers. Others who then used concrete, or had their interest drawn to its possibilities, failed to appreciate the true worth of the many discoveries which Mr. Ransome made. The construction world was behind him — not quite ready for his forethought and farsightedness. For example, as early as 1894 he called attention to the marked influence which time of mixing had in increasing the strength of mortar. Likewise he determined with accuracy, that has only recently been confirmed, the fact that there was a limit to the time of mixing which was profitable both from the standpoint of economy and the strength secured in the resulting concrete.

Mr. Ransome designed some of the first collapsible

steel forms for concrete tunnel lining. No man ever contributed more largely or unselfishly to any similar interest than did Mr. Ransome to the advancement of concrete for building purposes; and he contributed with a firm faith in the building material he loved. As is unfortunately too often the case, only when a great man has passed away is the full measure of his worth discovered.

Assisted by his son, A. W. Ransome, he founded the Ransome Concrete Machinery Company, at Dunellen, New Jersey, and at various times helped to organize and managed construction and contracting firms. Until the day of his death he was identified more or less actively with the company which bears his name, although in the last few years in more of an advisory capacity than otherwise.

The Ransome Concrete Machinery Co. feels that its many friends should know that the prestige and success which it has enjoyed is deeply founded in the farsightedness of Ernest L. Ransome. As marvelous as the growth of the concrete industry has been during the last fifty years, we can confidently predict that the ten years ahead of us will witness even greater achievements; but this thought should not in any way dim the honor which is due to Ernest L. Ransome, to whom the engineering and contracting professions will always owe a debt which can never be fully paid.

THE RANSOME CONCRETE MACHINERY
COMPANY.

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 $\frac{1}{4}$ inch upward to particles as large as can conveniently be used on the job in question. The larger sizes will vary from $\frac{3}{4}$ inch for fence posts and other concrete products up to 1, $1\frac{1}{4}$ and $1\frac{1}{2}$, 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 reportion 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 some-

times 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. This trough is set at an angle sufficient to cause the aggregates to be tumbled down the trough in which when the right amount of water is supplied continuously at the upper end through a hose or otherwise, the material will be washed in tumbling about and the foreign matter will be removed and carried away by the water. Just before the contents leave the trough the sand and pebbles are separated by the screen fixed at the lower end of the trough.

More elaborate washing outfits have to be installed at commercial gravel plants sometimes. On large jobs it is necessary to arrange better facilities for washing aggregates than are provided by the simple trough just suggested.

| Symbol | Description |
|--|--|
| A | Use 2 - 5/8" - 11 1/2" bolts with washers |
| B | " 2 - " - 13" " " " |
| C | " 1 - " - 13" " " " |
| D | " 2 - " - 13" " " " |
| E | " 2 - " - 6 1/2" " " " |
| F | " nails " " " |
| G | " 2 - 5/8" - 13 1/2" " " " |
| H | " 2 " " " " " |
| I | " 2 " 15 1/2" " " " |
| J | " 4 " - 13 1/2" " " " |
| K | " 1 3/4" 17 1/2" " " " |
| L | " 2 " - 15 1/2" " " " |
| M | Bin Gates 12" x 16" Opening - Steel |
| N | Steel Chutes |
| R | Wood Hopper - Steel Lined |
| <p>Note:- Obtain standard sprockets etc. near to the following sizes:-</p> | |
| 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'-9 1/2" 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 |
| B.G-1 | Bevel Gear P.D. 31.44 T=79 pitch 1/4" bore 2 7/16" |
| B.G.2 | " " " 7.99 T=20 " " " 1 5/16" |
| Sc-60 | Gilbert Screen 60" Inner wearing skirt |
| Sc-54 | " " 54" No wearing skirt |

**BILL OF MATERIAL
FOR
SEMI-PORTABLE 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 $\frac{1}{16}$ " turned shaft (approx. length)
 6 fixed post bearings
 1 3'-6" x 1 $\frac{1}{8}$ " dia. countershaft (approx. length)
 1 4'-0" x 2 $\frac{1}{16}$ " 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, 1 $\frac{3}{4}$ " \square 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 | $\frac{1}{2}$ " x 6" dowels | Steel | |
| 4 lbs. | 20d. nails | | |
| 12 | $\frac{5}{8}$ " x 13" bolts and washers | | |
| 16 | $\frac{5}{8}$ " x 11 $\frac{1}{2}$ " bolts and washers | | |
| BINS | | | |
| Floor | | | |
| 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 |
| 11 $\frac{1}{2}$ lbs. | 10d. nails | | |

Carried forward 3,628

**BILL OF MATERIAL
FOR
SEMI-PORTABLE GRAVEL PLANT**

| <i>No. Pcs.</i> | <i>Dimensions</i> | <i>GIRTS AND POSTS</i> | <i>Brought forward</i> | <i>3,628</i> |
|-------------------------------|--|------------------------|------------------------|--------------|
| <i>No. Pcs.</i> | <i>Dimensions</i> | <i>Material</i> | <i>Bd. Ft.</i> | |
| 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 | 5/8" x 9 1/2" bolts and washers | | | |
| 68 | 5/8" x 11" bolts and washers | | | |
| 116 | 5/8" x 13 1/2" bolts and washers | | | |
| 48 | 5/8" x 15 1/2" bolts and washers | | | |
| 16 | 3" x 4" x 1/2" 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 | |
| 5/8" BOLTS AND WASHERS | | | | |
| | 12 6 1/2"; 4 11 1/2"; 28 13"; 24 13 1/2"; | | | |
| | 4 15 1/2"; 2 3/4" 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 1/2" x 8"; 6 1/2" x 10"; 8 5/8" x 15 1/2"; | | | |
| | 8 3/4" x 15 1/2"; 4 3/4" x 17 1/2" | | | |
| 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 | |

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 $\frac{1}{4}$ to $\frac{1}{2}$ 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 | | Stone or Pebbles | |
| | | | | | | | cu. ft. | cu. yd. | cu. ft. | 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 | | Minimum | Maximum |
| | | | Fine | Coarse | | |
| 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 posts 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 | <u>9</u> |

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 com-

panies 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 | 14.4 | 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 $3\frac{20}{81}$ 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 con-

crete, 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 resistant 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 above-ground, 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.

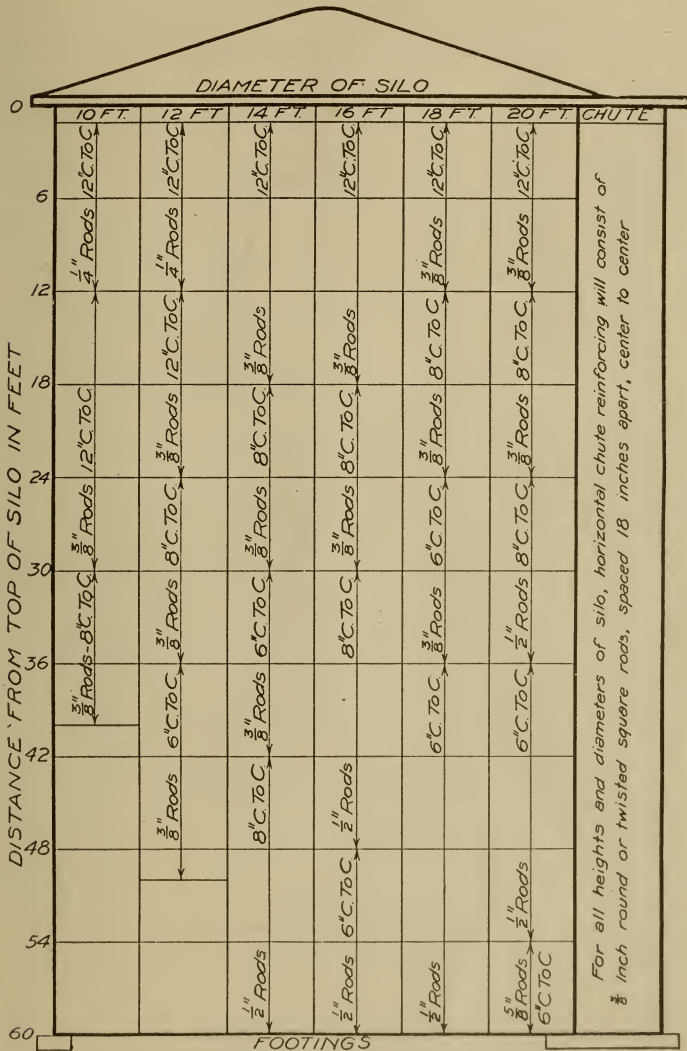
Accompanying tables will be found convenient for estimating quantities of materials, also as a guide for reinforcing silos of various sizes both with mesh reinforcing and with rods.

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 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 | 6 | 1 | 6 |
| 15 to 18 | 1 | 6 | 1 | 6 | 1 | 6 | 1 | 6 | 1 | 6 | 1 | 6 | 1 | 6 |
| 18 to 21 | 1 | 6 | 1 | 6 | 1 | 4 | 4 | 4 | 1 | 4 | 1 | 4 | 1 | 4 |
| 21 to 24 | 1 | 6 | 1 | 4 | 1 | 4 | 4 | 4 | 1 | 4 | 1 | 4 | 1 | 4 |
| 24 to 27 | 1 | 4 | 1 | 4 | 1 | 4 | 4 | 4 | 1 | 4 & 6 | 1 | 4 & 6 | 2 | 4 |
| 27 to 30 | 1 | 4 | 1 | 4 | 1 | 4 | 1 | 4 | 1 | 4 & 6 | 1 | 4 & 6 | 2 | 4 |
| 30 to 33 | 1 | 4 | 1 | 4 | 1 | 4 & 6 | 1 | 4 & 6 | 1 | 4 & 6 | 1 | 4 & 6 | 2 | 4 |
| 33 to 36 | 1 | 4 | 1 | 4 | 1 | 4 & 6 | 1 | 4 & 6 | 1 | 4 & 6 | 1 | 4 & 6 | 2 | 4 |
| 36 to 39 | 1 | 4 | 1 | 4 & 6 | 1 | 4 & 6 | 1 | 4 & 6 | 1 | 4 & 6 | 2 | 4 | 2 | 4 |
| 39 to 42 | 1 | 4 | 1 | 4 & 6 | 1 | 4 & 6 | 1 | 4 | 2 | 4 | 2 | 4 | 2 | 4 |
| 42 to 45 | 1 | 4 & 6 | 1 | 4 & 6 | 1 | 4 & 6 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 23 |
| 45 to 48 | 1 | 4 & 6 | 1 | 4 & 6 | 2 | 4 | 2 | 4 | 1 | 4 & 23 | 2 | 23 | 2 | 23 |
| 48 to 51 | 1 | 4 & 6 | 1 | 4 & 6 | 2 | 4 | 2 | 4 | 1 | 4 & 23 | 2 | 23 | 2 | 23 |
| 51 to 54 | 1 | 4 & 6 | 2 | 4 | 2 | 4 | 2 | 4 | 1 | 4 & 23 | 2 | 23 | 2 | 23 |
| 54 to 57 | 1 | 4 & 6 | 2 | 4 | 2 | 4 | 2 | 4 | 1 | 4 & 23 | 2 | 23 | 2 | 23 |
| 57 to 60 | 1 | 4 & 6 | 2 | 4 | 2 | 4 | 2 | 4 | 1 | 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 |



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 | |
|----------------------------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|
| | Whole | Half | Whole | Half | Whole | Half | Whole | Half | Whole | Half | Whole | Half | Whole | Half |
| Height | | | | | | | | | | | | | | |
| 26 | 897 | 39 | 1155 | 42 | 1463 | 44 | 1776 | 48 | | | | | | |
| 28 | 966 | 42 | 1238 | 44 | 1560 | 48 | | | | | | | | |
| 30 | 1035 | 45 | 1320 | 48 | | | | | | | | | | |
| 32 | 1104 | 48 | | | | | | | | | | | | |
| 34 | 1173 | 51 | 1423 | 50 | 1658 | 50 | 1887 | 51 | 2117 | 50 | 2511 | 54 | 2907 | 57 |
| 36 | 1242 | 54 | 1485 | 54 | 1755 | 54 | 1998 | 54 | 2241 | 54 | 2651 | 56 | 3160 | 60 |
| 38 | 1311 | 57 | 1568 | 56 | 1853 | 56 | 2109 | 57 | 2369 | 56 | 2790 | 60 | | |
| 40 | 1380 | 60 | 1650 | 60 | 1950 | 60 | 2220 | 60 | 2490 | 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 | $\frac{1}{4}$ " | $\frac{1}{4}$ " | $\frac{1}{4}$ " | $\frac{1}{4}$ " | $\frac{1}{4}$ " |
| 4-8 | No. 6 | No. 6 | No. 6 | $\frac{1}{4}$ " | $\frac{1}{4}$ " | $\frac{1}{4}$ " | $\frac{3}{8}$ " | $\frac{1}{4}$ " |
| 8-12 | No. 6 | $\frac{1}{4}$ " | $\frac{1}{4}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " |
| 12-16 | No. 6 | $\frac{1}{4}$ " | $\frac{1}{4}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " |
| 16-20 | $\frac{1}{4}$ " | $\frac{1}{4}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " |
| 20-24 | $\frac{1}{4}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " |
| 24-28 | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " |
| 28-32 | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " |
| 32-36 | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " |
| 36-40 | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{5}{8}$ " |
| 40-44 | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{5}{8}$ " | $\frac{5}{8}$ " |
| 44-48 | $\frac{3}{8}$ " | $\frac{3}{8}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{5}{8}$ " | $\frac{5}{8}$ " | $\frac{5}{8}$ " |
| 48-52 | $\frac{3}{8}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{5}{8}$ " | $\frac{5}{8}$ " | $\frac{5}{8}$ " |
| 52-56 | $\frac{3}{8}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{5}{8}$ " | $\frac{5}{8}$ " | $\frac{5}{8}$ " | $\frac{5}{8}$ " |
| 56-60 | $\frac{3}{8}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{1}{2}$ " | $\frac{5}{8}$ " | $\frac{5}{8}$ " | $\frac{5}{8}$ " | $\frac{5}{8}$ " |

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 | | | | | | | Size Steel |
|--|--|---|-------------------------------|--|-------------------------------|--|--|---------------------------------|
| | 4 ft. | 6 ft. | 8 ft. | 10 ft. | 12 ft. | 14 ft. | 16 ft. | |
| 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. | } $\frac{1}{4}$ 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. | |
| 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. | } $\frac{3}{8}$ 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. | |
| 12 feet... | | NOTE—Upper figures are for cross reinforcement; lower figures for long reinforcement | | | | 6 $\frac{1}{2}$ in. 6 $\frac{1}{2}$ in. | 5 $\frac{3}{4}$ in. 12 in. | 5 $\frac{1}{4}$ in. 16 in. |
| 14 feet... | | | | | | 5 $\frac{1}{4}$ in. 5 $\frac{1}{4}$ in. | 4 $\frac{1}{2}$ in. 8 $\frac{3}{4}$ in. | |
| 16 feet... | | | | | | | 4 in. 4 in. | |

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 $4\frac{1}{2}$ 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 $5\frac{3}{4}$ 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 ROAD, STREET, AND ALLEY CONSTRUCTION

SPECIFICATIONS

Concrete pavements in the United States date from 1894; yet only within the past three or four years has the yardage of them assumed any considerable proportions. On the first of January, 1917, there were approximately 75,000,000 square yards of concrete roads, streets, and alleys in the United States.

Because of the fact that methods of constructing concrete pavements have been developed during a relatively short period, there are many contractors and engineers who lack experience in this field of concrete construction. However, two National Conferences on Concrete Road Building, and concerted work on the part of the American Concrete

Institute, American Society for Testing Materials, the Portland Cement Association, and similar bodies, have resulted in specifications which, if followed, insure that concrete pavement will have no superior, if equal. The latest specifications for concrete roads, streets, and alleys are those adopted by the American Concrete Institute in 1917. These can be obtained from the Portland Cement Association, 111 West Washington Street, Chicago, and should serve as a guide or basis for any other specifications covering the class of concrete work to which they apply.

GRADING

For concrete pavements there must be a properly prepared roadbed or subgrade. Experience has proved that many of the cracks which develop in concrete pavements are due to settlement, poor drainage, or other unstable conditions of the foundation on which the concrete is placed. If a concrete pavement is to be laid directly upon an old road surface, this surface should be broken up several inches deep, so that it can be leveled and given uniform compactness before any fresh material for filling or grading is placed. Where fills are to be placed, material for this purpose should be deposited in layers eight to twelve inches thick and rolled to uniform density with an eight or ten ton roller.

FILLS

Concrete must not be laid on fills that have not finished settlement. Regardless of the amount of

rolling given fills, they will not be compacted as solidly as will result from allowing them to stand a proper length of time. Material for fills should be placed in layers of uniform thickness and dampened or sprinkled preparatory to rolling.

DISPOSING OF EXCESS MATERIALS

In highway pavement work it will usually be found good practice to leave enough of any surplus material along the roadside to use later as a protective covering for the concrete to prevent rapid drying out.

DRAINAGE

Proper drainage of the subgrade is of great importance. Faulty drainage will result in cracked slabs, due either to settlement or to the heaving from freezing and expansion of water retained beneath the concrete. A poorly drained subgrade is more likely to heave under frost action than one well drained. This heaving may cause cracking of the slabs, and frequently slabs will fail to return to proper level, thus causing unequal levels at joints of abutting slabs.

Drainage of the surface of concrete roads and streets is provided for by crowning the surface by striking off the concrete with a strikeboard cut to the required contour. Alley pavements are usually dished, that is, are lower in the center than at the sides, thus accomplishing the purpose of a gutter also.

Side ditches on concrete roads frequently must be deep to insure free drainage from beneath the slabs,

but deep ditches are sometimes dangerous to traffic. It is therefore the practice to lay tile drains in these trenches and to then back fill them. Tile lines for subgrade drainage should be laid from one to two feet beyond the edge of the concrete, on both sides of the road or street. Such lines should not be placed directly under the slab, because filtration of water through tile joints will carry away finer particles from the subgrade, thus causing partial undermining at the edges of the slab. Before digging a trench to lay tile, grade stakes should be located with a level every one hundred feet, the amount of cut being marked properly on the stakes. There should be no sags in the tile line, as these will quickly fill with silt and render the drain ineffective.

AGGREGATES

As in all concrete work, the selection of aggregates is important in concrete pavement construction — more important in some respects than in other classes of concrete work, because traffic subjects the concrete to severe impact and abrasion. It is highly important that the sand used be composed of hard grains. It must be tough and durable to withstand the wear of traffic and the weathering action of moisture and frost. Cleanliness of aggregates is also important. If they contain more than three per cent of loam, silt, clay, or other foreign material, they should be washed before used. Elsewhere there have been given details and descriptions of a suitable washing plant for concrete aggregates. This is a

very adaptable plant on woodwork, because semi-portable and can be moved from one job to another. In many natural deposits of so-called gravel there are large boulders. Sometimes these form a large portion of the pit's output. Economy in obtaining material often comes from operating a suitable crusher to make use of all material that must be handled in excavating.

COARSE AGGREGATE

Concrete pavements are either one or two course. In one-course pavements the coarse aggregate should be hard, tough material that will neither weather nor wear rapidly and hence will stand up well under abrasion and impact of traffic. Well-graded, hard particles, free from flat or elongated pieces, should be used. There should be no soft particles nor lumps of clay, as these are certain to weaken the concrete and later develop small pit-holes or pockets on the surface of the pavement. Crushed stone should be free from coating of crusher dust. This has the same injurious effect as clay, silt, or other foreign material. Where two-course construction is used the coarse aggregate for the base need not be so hard and tough, but should be clean and well graded. In two-course work the aggregates of the wearing course should meet with all requirements as to toughness and hardness.

MIXED AGGREGATE

Successful concrete pavement work, among other things, requires accurately proportioned concrete

mixtures, proper consistency of mixture, proper placing and proper protection. Bank-run material will not insure correct proportions of ingredients. The same is true of crusher-run stone. The product of stone crushers varies considerably as to volumes of the different sized particles, just as such variations occur in natural deposits of gravel. Artificially mixed or mixed-at-the-plant aggregates, even though they may have been properly proportioned at the plant, should not be used for concrete pavements, because in transporting and otherwise handling from plant to job the sizes will become unmixed, so to speak; that is, one batch is certain to have too much fine aggregate while another will contain too much coarse aggregate.

AGGREGATES FOR WEARING COURSE OF TWO-COURSE PAVEMENT

The aggregates most commonly used for the wearing course of two-course concrete pavements are obtained from crushed granite or trap rock. There are two sizes of such material suitable for use. Where the best quality of material is available, either $\frac{1}{4}$ to $\frac{1}{2}$ inch or $\frac{1}{4}$ to 1 inch grading may be used, depending upon which proves the more economical. If the available material is not of first-class quality, the $\frac{1}{4}$ to 1 inch grading is preferable. No intermediate sizes in this material should be removed.

HANDLING MATERIALS ON THE JOB

CEMENT

Cement must be so stored as to prevent injury from dampness. A tight building, with tight floor raised aboveground so that free circulation of air will prevail around piles, is necessary. Out on the job, cement should never be piled on the ground even for a short time. Board platforms should be improvised. Covering should be available to protect the piles against sudden showers. Waterproof tarpaulins or canvas are satisfactory for this purpose. On many concrete jobs, and particularly on concrete pavement work, no end of carelessness prevails in the handling of sacks. They cost money, are charged to the contractor, and unless he is able to return all charged to him, he is out at least ten cents for every sack which cannot be accounted for. A wet sack is worthless, and if a sudden shower comes up hundreds of dollars' worth of sacks may be damaged in a minute.

AGGREGATES

Usually out on the job aggregates are dumped in piles along the subgrade, — fine aggregate on one side, crushed stone or pebbles on the other. The following table shows the quantities of materials required for concrete pavement of the width and thicknesses indicated, and will be found convenient when estimating the quantities of aggregates that are to be distributed along the work.

There is always possibility of considerable dirt or refuse becoming mixed with the aggregates when

**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 (cu. yards) | | ROCK OR PEBBLES (cu. 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.

they are dumped in piles along the work as above mentioned. Ballast forks are commonly used for handling broken stone and thus prevent admixture of dirt with coarse aggregate. In shoveling sand from piles there is some waste if the piles are not cleaned up, while if they are cleaned up there is certain to be some dirt mixed with the sand. Some contractors lay planks across the subgrade to dump materials on to prevent loss and also prevent the materials from becoming mixed with dirt.

WATER

Elsewhere, under the subject of "Estimating for the Contractor," the quantity of water likely to be required in concrete pavement construction has been stated, as well as its probable cost. Sometimes on concrete road work the only source of water supply may be several miles distant from the job. In such

case a pumping plant is necessary and usually proves the most economical way of securing a dependable water supply. A pump capable of delivering from 1,500 to 2,000 gallons per hour is necessary. If the source of supply is a stream or pond, the intake pipe of the pump must be protected by a cage or similar device that will prevent weeds, sticks, and other foreign material being drawn into the pipe line and clogging it.

JOINTS

Joints are placed in concrete pavement 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, depending on the concrete to crack at certain intervals, as it surely will. However, these cracks are not straight across the pavement and therefore are unsightly and more difficult to keep in good repair. For this reason the 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 filling material between, or whether the metal plate should be omitted and merely the prepared joint filler used. In general, joints should be not more than $\frac{1}{4}$ inch wide. Greater width is likely to cause increased wear due to impact of steel-tired wheels crossing the joints.

Steel protection plates are set in place by means of an installing device. With some types of plate this device may be used also as a template to test the correctness of its curvature. Where plates are used it is very necessary that they be carefully set and that the pairs be of the same curvature. Otherwise joints will be low or high or otherwise uneven owing to the difference in curvature of the protection plates. Where protection plates are not used, common practice is to allow the felt joint filler to extend slightly above the surface of the pavement. This projecting portion is then soon beaten down or "ironed out" by traffic. To provide for this, the strips of filler used should be one half inch wider than the greatest thickness of the slabs.

FINISHING PAVEMENT SLABS AT JOINTS

The surface of the pavement at joints should be exactly the same level on both sides of a joint and should also be flush with the protection plate, if plates are used. Otherwise there will be impact and consequent wear caused by traffic when crossing the joint. When finishing the concrete at joints where steel protection plates are used, the surface as left by the strikeboard should first be tested by the finisher with a light straightedge about four feet long, placed longitudinally with the road, to see whether the concrete is flush with the top of the plate on both sides of the joint, also to see whether there is enough concrete on both sides. If the plates are slightly

higher than they should be, a little extra concrete should be spread along the joints and struck off with the straightedge until the surface is correct. At unprotected joints where the filler is allowed to project above the surface a split float is used to finish on opposite sides of the filler. This is simply a double wood float so made that the felt filler may project into the space between the two halves or pieces of the float, thus allowing the surface on each side of the joint filler to be finished to exactly the same level.

REINFORCEMENT FOR CONCRETE PAVEMENTS

Common practice is to omit reinforcement in pavements under twenty feet wide. Over that width, however, reinforcement should be specified, and it would be desirable to use it even in the narrower widths. Mesh reinforcement is the material commonly used. The heavy wires should run perpendicular to the center line of the pavement. Each strip should be carefully lapped so as to develop the full strength of the metal. Specifications require that reinforcement shall come to within two inches of joints and shall not be less than two inches from the surface of the pavement. In placing the mesh in the concrete, strips should be rolled out across the base concrete and then turned over to prevent them from curling up at the ends. To prevent any tendency to bulge upward after the mesh has been laid, it should be struck at various points with the corner

of a shovel. This will put small kinks in the wires, tending to cause the mesh to lie flat and also embed it slightly in the base course, thus making it easier to place the top concrete. Before placing the top, the work should be examined to make certain there are no pockets or footprints beneath the reinforcement, as sometimes the mesh will prevent these from being filled when the top course concrete is placed. These spots then become a source of weakness.

FORMS

Forms for concrete pavement work may be of wood or steel. There are various types of commercial metal forms, all having certain points in common. When wood forms are used they should be made of at least two-inch stock, free from large knots and of straight-grained lumber, which will not tend to warp in use. The top edge of wood forms should be protected with metal plates to prevent rapid wear, also to preserve regularity of top line, as the top edge of side forms serve as a guide for the strikeboard and any irregularities in it will be imparted to the pavement surface. Metal protection for wood side forms may best be of light steel angles. These tend to stiffen the planks and hence make them easier to keep in line. Iron stakes or pins will be found better and more economical in the long run than wood stakes for holding forms in line. Steel stakes should be $\frac{3}{4}$ or $\frac{7}{8}$ inch stock. Lighter ones tend to bend under repeated driving.

MEASURING MATERIALS

Materials must be carefully measured so that correct proportions will always be used. Careful measuring also results in economy of materials. If wheelbarrows are used for measuring materials they should be of a type intended for that purpose and of a known definite capacity when properly struck off level full.

MIXING

No other single operation of concrete pavement work is more often slighted than mixing of the concrete. Attempt to speed up the work 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. Statements of this kind are likely to be misinterpreted. Definite time of mixing or number of revolutions known to be the equivalent of a certain time should govern. The efficiency of a mixer is considerably lowered if the interior blades, vanes, or other stirring devices are allowed to become coated with hardened concrete. This means that a mixer should be carefully cleaned and washed each time when leaving off

work. Even with such precautions taken some hardened concrete will collect in the drum, but it should be removed at frequent and regular intervals.

Of late years the tendency has been to mix all concrete too wet. This is objectionable on any work, but particularly so on concrete pavement construction, where highest resistance to abrasion is required. Concrete should be mixed to a consistency which is difficult to work under the strikeboard. Such a mixture can be properly consolidated on the roadbed and can be struck off and finished to better advantage than wetter mixtures. The concrete should be stiff enough to hold its shape when struck off.

PLACING CONCRETE

The subgrade or sub-base should be sprinkled before concrete is placed, to prevent it from absorbing from the concrete water necessary to its proper hardening. Concrete paving mixers are equipped either with chute or with boom and bucket for depositing the concrete in place. Either type will give satisfactory results. Where a mixer with chute is used, however, the chute must not be placed at so flat an angle that it is necessary to use too wet a concrete to cause the mixture to flow down the chute and into place. This objection is overcome by mounting the drum so high that the chute need not lie at an angle too flat to carry concrete of correct consistency.

In planning work involving paving, the greatest progress will be made if the work is arranged so that

the mixer will travel up grade. This allows laborers to wheel materials down hill to the mixer, and also helps the finishers, as any excess of water from the concrete will run away from them onto the portions of the pavement which have hardened. If the mixer is working down grade the materials must be wheeled up hill to it. This makes more work, not to mention unsatisfactory conditions for finishing.

STRIKING OFF AND FINISHING PAVEMENT SURFACE

A template or strikeboard cut to the desired crown of the finished pavement is the most satisfactory device for obtaining the required preliminary surface contour. The strikeboard consists simply of a plain or built-up plank from two to three inches thick. On the bottom it is cut to the proper crown of the pavement and usually has a strip of iron fastened to the striking face to prevent rapid wear. Strikeboards should be heavy enough to prevent them from riding up over the concrete. Where the ends slide on the side forms or curbs, they should be provided with a bearing piece about eight inches wide to prevent them from tipping and moving forward and so causing irregularities in the surface.

Several combined paving gages and striking and finishing machines are on the market. Each of these has its particular points of merit.

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 first a light steel roller

of a type which was first used in finishing concrete street pavement in Macon, Georgia. This roller has become commercially known as the Macon Concrete Paving Roller.

Those unfamiliar with the Macon method of finishing concrete pavements will be interested in knowing its particular advantages. Any one who has had any experience with concrete street or road construction knows that for ease of manipulation it is necessary to use a little more water in the concrete mixture than is required for the greatest strength of concrete. Until the advent of the Macon roller, the objections to this excess quantity of water in the concrete could not be readily overcome, but with the roller method of finishing developed by Captain Gaillard much of the excess water is removed from the concrete in the process of rolling, while at the same time the concrete is considerably compacted.

The result of using the roller was described in an article by A. N. Johnson, Consulting Highway Engineer of the Portland Cement Association, in the "Concrete Highway Magazine" for April. Mr. Johnson says: "The effect of the roller is that of a rolling squeegee. It consolidates the top layer of the concrete and removes practically all of the surplus water. At the same time it takes out the slight uneven places in the surfaces which may occur, particularly if the pavement has not been struck by a template. The rolling should be continued until free water ceases to come to the surface."

Mr. Johnson also described "Tests of Concrete

Slabs to Determine the Effect of Removing Excess Water Used in Mixing," in a paper presented at the twentieth annual meeting of the American Society for Testing Materials. This paper was based on experiments made by finishing concrete slabs by a wood float and by the roller method. Tests were conducted at the Structural Materials Research Laboratory, Lewis Institute, Chicago, under the supervision of Mr. Johnson and D. A. Abrams, Professor in Charge at the laboratory, who collaborated in this work. The results of tests brought out the fact that slabs finished with the roller developed twenty per cent increase in strength over slabs merely hand finished. The appearance of broken slabs disclosed a marked difference between those finished with the roller and those finished with the hand float. The former had a distinctly denser appearance, which extended for at least half the depth of the slab. Highway engineers should not fail to take advantage of the disclosures made by these recent tests.

Since field operations in concrete highway work do not permit the use of a concrete of the most desirable consistency with particular reference to the strength of the concrete, the roller method of finishing, which removes much of the excess water, is especially desirable.

The Macon roller is not an experiment, as the nearly 300,000 square yards of superior concrete pavement in Macon, Georgia, show. Engineers elsewhere have recognized that there is something

in the Macon finishing methods and have not been slow to follow the practice originated by Captain Gaillard.

The Ransome Concrete Machinery Co. manufactures the Macon Concrete Paving Roller.

After the roller has been run over the surface two or three times, depending upon the consistency of the concrete, final finishing is then done with a belt, either canvas or rubber, eight to twelve inches wide, and operated by seesawing it back and forth across the concrete surface. The belt method secures a uniformity of surface and one free from minor irregularities that cannot be obtained by hand-floating methods. The belt used is a little longer than the width of the pavement, so that workmen have six inches or more play in length to pull it backward and forward across the concrete by handles attached to the belt. Use of the belt produces an ideal finish for concrete pavement, namely, the even but gritty texture which makes the characteristic non-skid concrete surface.

PROTECTION OF FINISHED PAVEMENTS

Curing of concrete pavements has much to do with their success. If the concrete is allowed to dry out the resulting surface will not be highly resistant to wear. As soon as the concrete can be covered with earth without marring its surface, this should be applied to a depth of two inches or more and should be kept wet by frequent sprinkling for a week or ten days. Another and still better method, where avail-

able, is the ponding method. This consists of flooding the finished pavement by building dikes or dams on the slabs so that water will stand at least two inches deep over the crown of the pavement. Concrete pavement construction should not be carried on during weather when freezing temperatures are likely to prevail. Concrete pavements should not be opened to traffic until they are at least three weeks old and preferably a month old. During cold weather concrete hardens slowly, and only experience can determine how long traffic should be kept off the pavement after finished.

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 ap-

proved 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 $\frac{1}{2}$ to $1\frac{1}{2}$ 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:

$3\frac{1}{2}$ yards of average earth.

2 yards of tough clay.

$\frac{3}{4}$ 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 $1\frac{1}{4}$ 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 | $0.33\frac{1}{2}$ | 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 con-

crete 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. | ¾ in. | 1 in. | 1¼ in. | 1½ in. |
| | | | | Sq. Ft. Covered | Sq. Ft. Covered | Sq. Ft. Covered | Sq. Ft. Covered | 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 re-

sulting 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

$8\frac{3}{8}$ in. by $2\frac{3}{8}$ 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.

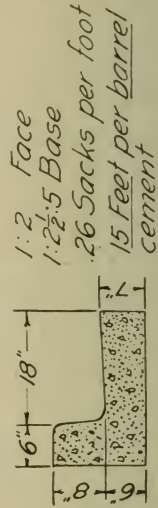
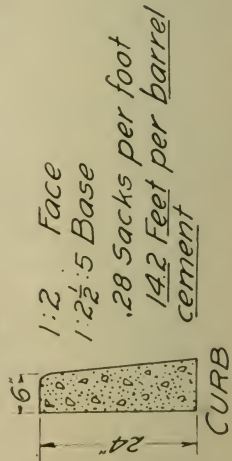
| 1 cu. ft. Concrete | Sacks of Cement | 1 cu. yd. Concrete | Bbls. of Cement |
|-----------------------|--------------------|-----------------------|--------------------|
| 1:1:1 | .5404 | 1:1:1 | 3.375 |
| 1:1½:3 | .2808 | 1:1½:3 | 1.895 |
| 1:2:4 | .2220 | 1:2:4 | 1.498 |
| 1:2½:5 | .1848 | 1:2½:5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



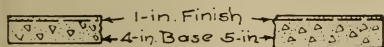
Grouting - one barrel of cement for 30 square yards of brick pavement - 1 cement - 1 sand mix.

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 - 1/2 - 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 - 2 1/2 - 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 - 2 1/2 | 0.076 |
| 1 - 3 | 0.066 |

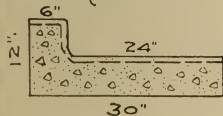
MATERIALS REQUIRED

FOR ONE CU. YD. OF CONCRETE

| MIX | Cement Bbls. | Sand Cu. Yd. | Stone Cu. Yd. |
|---------------|--------------|--------------|---------------|
| 1 - 1/2 - 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 - 2 1/2 - 5 | 1.24 | 0.46 | 0.92 |
| 1 - 3 - 6 | 1.06 | 0.47 | 0.94 |

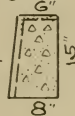


Curb & Gutter



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 - 2 1/2 - 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 Thickness | 1:1½:3 | | | 1:2:3 | | | 1:2:4 | | | 1:2½:4 | | | 1:2½:5 | | |
|--------------------------|--------|------|------|-------|------|------|-------|------|------|--------|------|------|--------|------|------|
| | 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 | 0.77 | 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 inches | 1:1 | | | 1:1½ | | | 1:2 | | | 1:1:1 | | | 1:1:1½ | | |
|---------------------|------|------|-----|------|------|-----|-----|------|-----|-------|------|-----|--------|------|------|
| | C. | Sd. | St. | C. | Sd. | St. | C. | Sd. | St. | C. | Sd. | St. | C. | Sd. | St. |
| ½ | 3.0 | 0.11 | 2.4 | 2.4 | 0.13 | 2.0 | 2.0 | 0.15 | 2.1 | 0.08 | 0.08 | 1.8 | 0.07 | 0.10 | 0.10 |
| ¾ | 4.5 | 0.16 | 3.6 | 3.6 | 0.19 | 2.9 | 2.9 | 0.22 | 3.1 | 0.11 | 0.11 | 2.7 | 0.10 | 0.15 | 0.15 |
| 1 | 6.0 | 0.22 | 4.8 | 4.8 | 0.26 | 3.9 | 3.9 | 0.29 | 4.2 | 0.15 | 0.15 | 3.7 | 0.14 | 0.20 | 0.20 |
| 1¼ | 7.5 | 0.27 | 6.0 | 6.0 | 0.33 | 4.9 | 4.9 | 0.36 | 5.2 | 0.19 | 0.19 | 4.6 | 0.17 | 0.25 | 0.25 |
| 1½ | 9.0 | 0.33 | 7.2 | 7.2 | 0.40 | 5.9 | 5.9 | 0.43 | 6.3 | 0.23 | 0.23 | 5.5 | 0.20 | 0.30 | 0.30 |
| 1¾ | 10.5 | 0.39 | 8.4 | 8.4 | 0.46 | 6.9 | 6.9 | 0.50 | 7.3 | 0.27 | 0.27 | 6.4 | 0.24 | 0.36 | 0.36 |
| 2 | 12.0 | 0.45 | 9.6 | 9.6 | 0.53 | 7.9 | 7.9 | 0.58 | 8.3 | 0.31 | 0.31 | 7.3 | 0.27 | 0.41 | 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 Mix | 1 in. | | 2 in. | | 4 in. | | 5 in. | |
|------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| | C. | St. | C. | St. | C. | St. | C. | St. |
| 1:2 | 3.9 | 0.29 | 7.9 | 0.58 | ..... | ..... | ..... | ..... |
| 1:1:1 | 4.2 | 0.15 | 8.3 | 0.31 | ..... | 0.31 | ..... | ..... |
| 1:1:1½ | 3.7 | 0.14 | 7.3 | 0.27 | ..... | 0.41 | ..... | ..... |
| 1:1½:2½ | 2.6 | 0.14 | 5.1 | 0.28 | ..... | 0.47 | ..... | ..... |
| 1:1½:3 | ..... | ..... | ..... | ..... | 9.4 | 0.52 | 11.7 | 0.65 |
| 1:2:3 | ..... | ..... | ..... | ..... | 8.6 | 0.64 | 10.8 | 0.80 |
| 1:2:4 | ..... | ..... | ..... | ..... | 7.4 | 0.55 | 9.3 | 0.69 |
| 1:2½:4 | ..... | ..... | ..... | ..... | 6.9 | 0.64 | 8.6 | 0.80 |
| 1:2½:5 | ..... | ..... | ..... | ..... | 6.2 | 0.57 | 7.7 | 0.72 |
| 1:3:6 | ..... | ..... | ..... | ..... | 5.2 | 0.58 | 6.5 | 0.73 |

| Thickness Mix | 6 in. | | 7 in. | | 8 in. | | 9 in. | |
|------------------|-------|------|-------|------|-------|------|-------|------|
| | C. | St. | C. | St. | C. | St. | C. | St. |
| 1:1½:3 | 14.0 | 0.78 | 16.4 | 0.91 | 18.7 | 1.04 | 21.1 | 1.17 |
| 1:2:3 | 12.9 | 0.95 | 15.0 | 1.11 | 17.2 | 1.27 | 19.3 | 1.43 |
| 1:2:4 | 11.1 | 0.82 | 12.9 | 0.96 | 14.8 | 1.10 | 16.7 | 1.23 |
| 1:2½:4 | 10.3 | 0.95 | 12.0 | 1.11 | 13.8 | 1.27 | 15.5 | 1.43 |
| 1:2½:5 | 9.2 | 0.86 | 10.8 | 1.00 | 12.3 | 1.14 | 13.9 | 1.29 |
| 1:3:6 | 7.9 | 0.87 | 9.2 | 1.02 | 10.5 | 1.16 | 11.8 | 1.31 |

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**

| Thickness (in.) | Proportions 1:1 | | 1:1½ | | 1:2 | | 1:2½ | | 1:3 | |
|--------------------|-----------------|-------------------|--------------|-------------------|--------------|-------------------|--------------|-------------------|--------------|-------------------|
| | 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.) |
| ¾ | 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 $= 128 \times 6.417 = 821.4$ sq. ft.

Thickness of wall $= 12$ in.

Quantities of materials for wall concrete:

Factor for multiplying units in

$$\text{table} = \frac{821.4}{100} \times \frac{12}{10} = 8.214 \times 1.2 = 9.8568;$$

Take 9.86

Sacks of cement $= 14.2 \times 9.86 = 140.0$

Cu. yd. of sand $= 1.58 \times 9.86 = 15.6$

Cu. yd. of pebbles or crushed stone $= 2.64 \times 9.86 = 26.0$

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 $= 126 \times 1.5 = 189$ 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 $= 14.2 \times 1.13 = 16.0$

Cu. yd. of sand $= 1.58 \times 1.13 = 1.8$

Cu. yd. of pebbles or stone $= 2.64 \times 1.13 = 3.0$

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 $= 23 \times 38 = 874$ 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 = $15.4 \times 3.5 = 54.0$

Cu. yd. of sand = $1.43 \times 3.5 = 5.0$

Cu. yd. of pebbles or stone = $2.86 \times 3.5 = 10.0$

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 = $39.4 \times .9 = 35.5$

Cu. yd. of sand = $2.92 \times .9 = 2.6$ 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

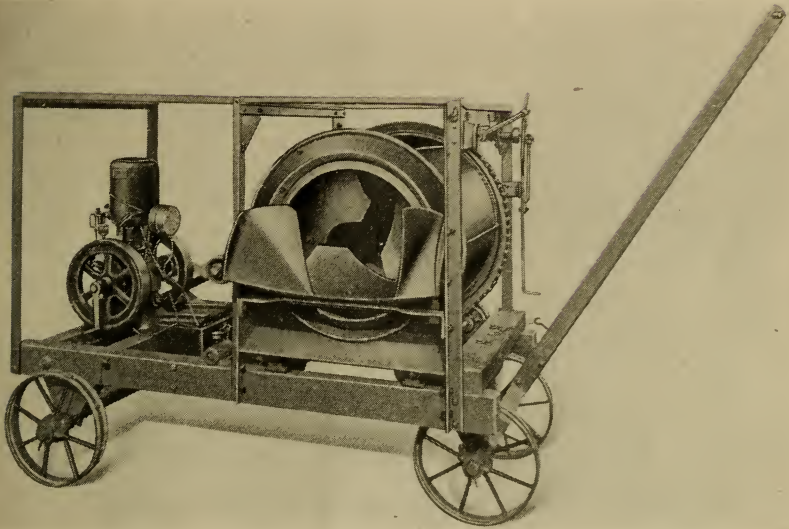
Cu. yd. of pebbles or stone = 10.0

**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

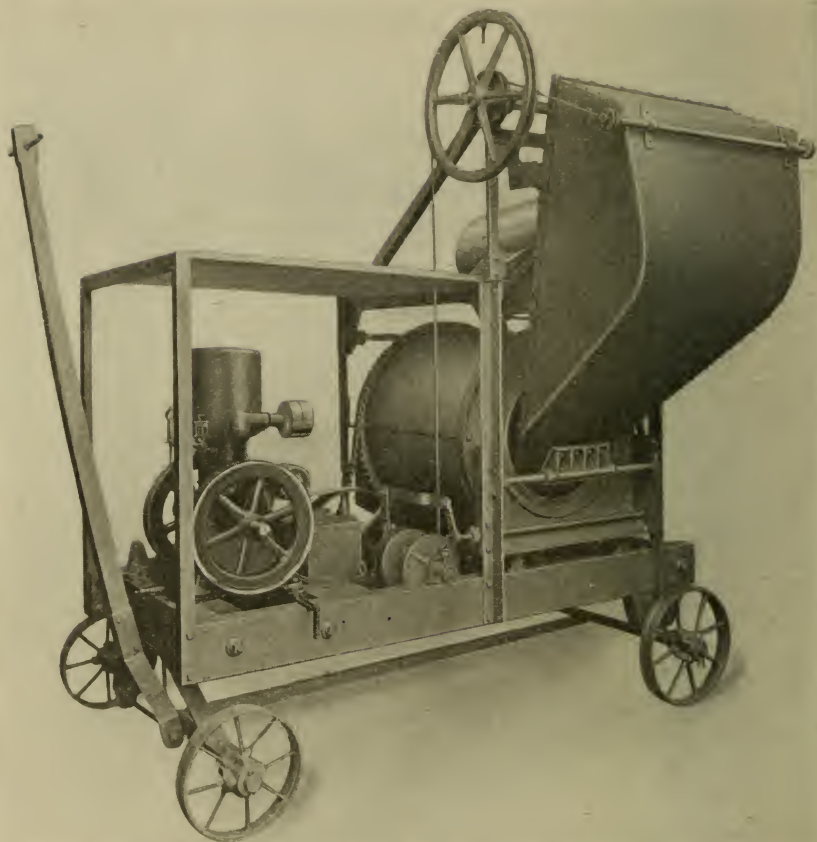
| | |
|---|--------------|
| Portland cement weighs per barrel, net | 376 lb. |
| Portland cement weighs per bag, net | 94 lb. |
| Natural cement weighs per barrel, net | 282 lb. |
| Natural cement weighs per bag, net | 94 lb. |
| Loose Portland cement averages per cubic foot about | 92 lb. |
| Weight 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.

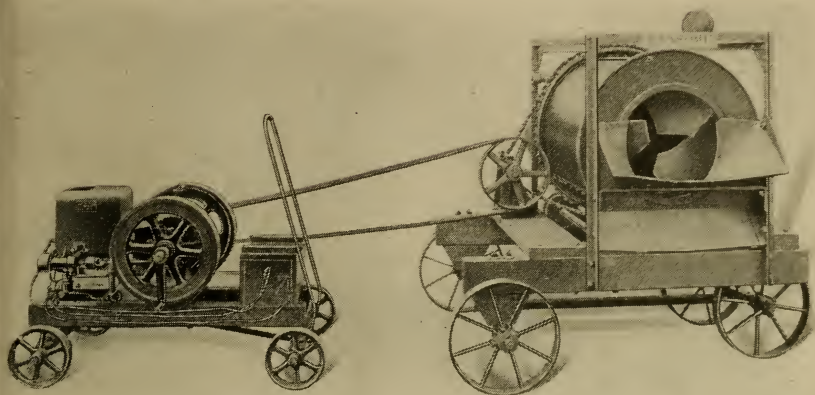
WRITE FOR RANSOME BANTAM BOOKLET



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 $7\frac{1}{2}$ cu. yds. of concrete per hour.

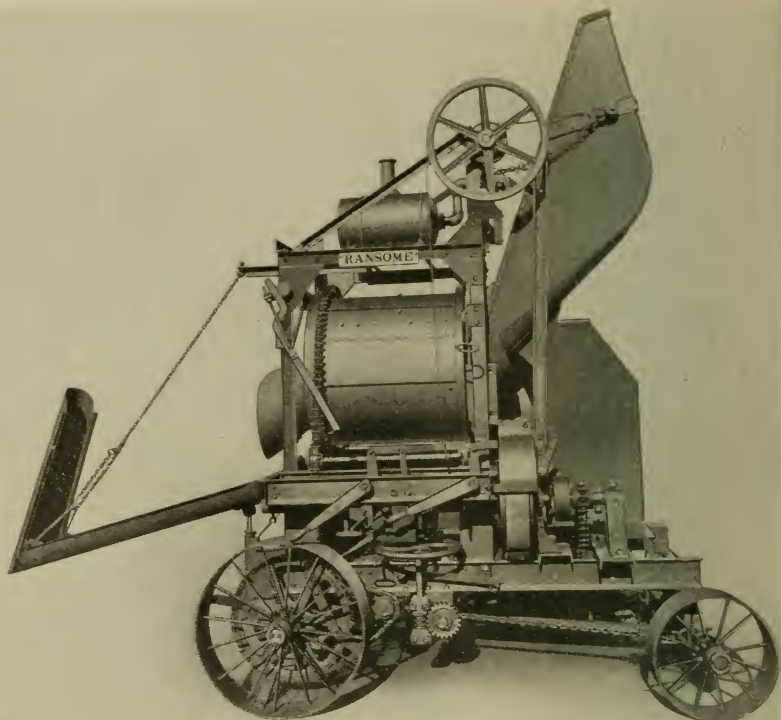
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RANSOME BANTAM JUNIOR
FARMERS' TYPE

THE RANSOME BANTAM JUNIOR MIXER of the Farmers is furnished with $2\frac{1}{2}$ 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.

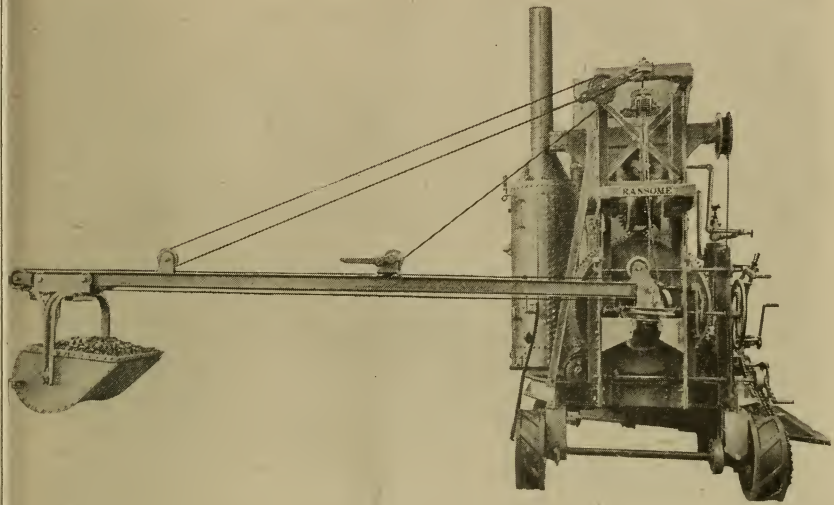
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RANSOME BANTAM PAVER

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.

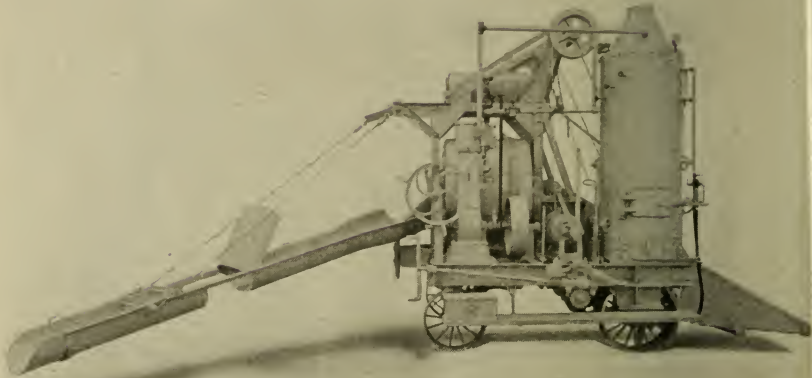
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RANSOME STREET PAVER — MODEL 10-E
BUCKET AND BOOM TYPE

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.

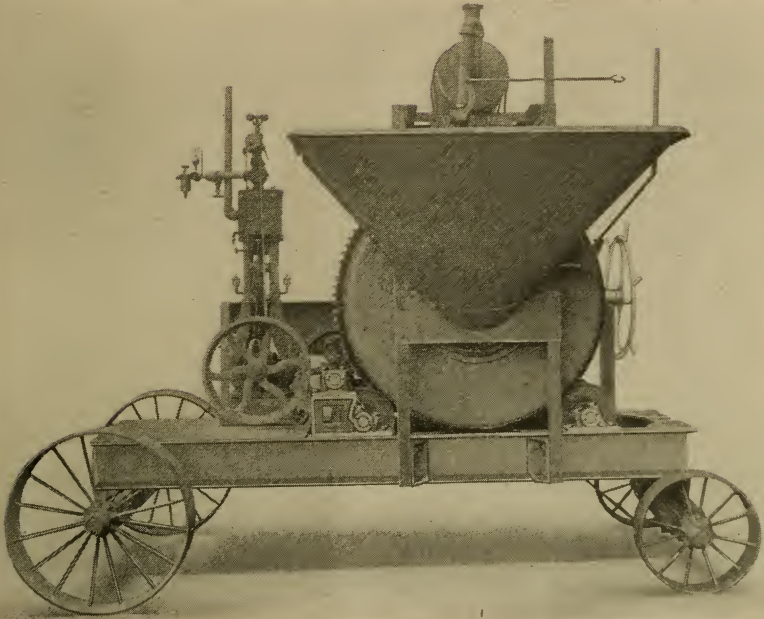
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RANSOME SPOUT STREET PAVER

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.

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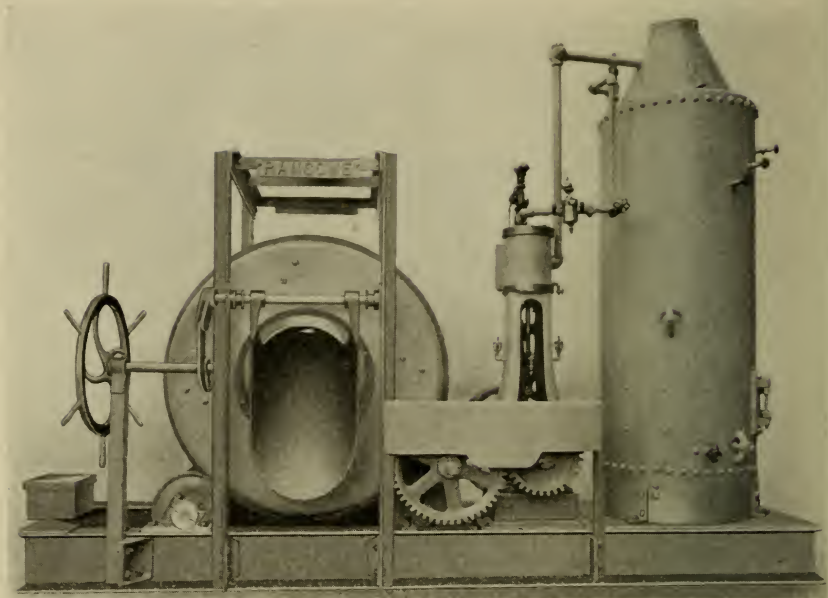


**RANSOME MIXER WITH DIRECT-GEARED
ENGINE**

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.

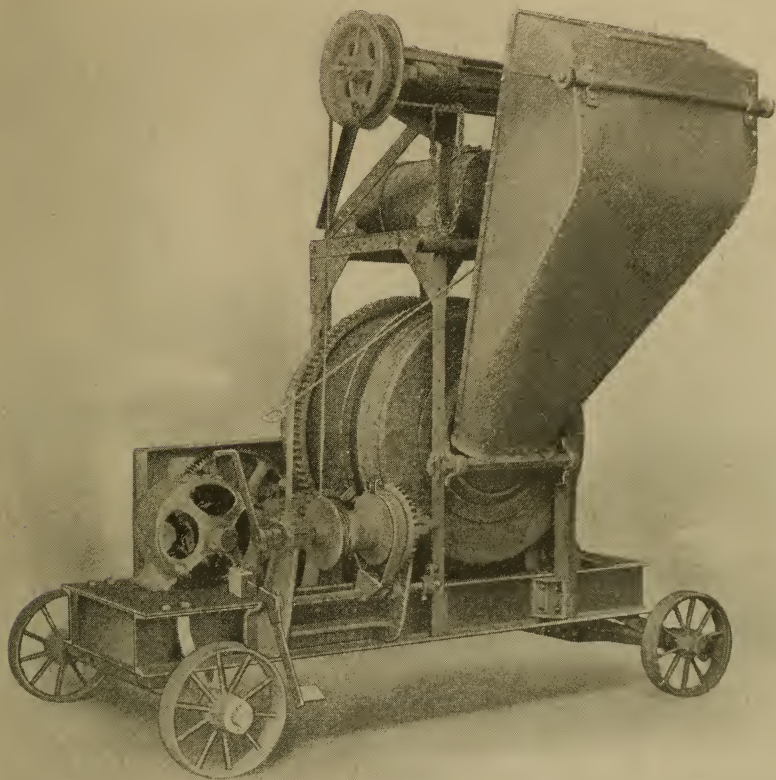
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**RANSOME MIXER WITH COMPLETE STEAM
PLANT**
DISCHARGE SIDE

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.

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**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.

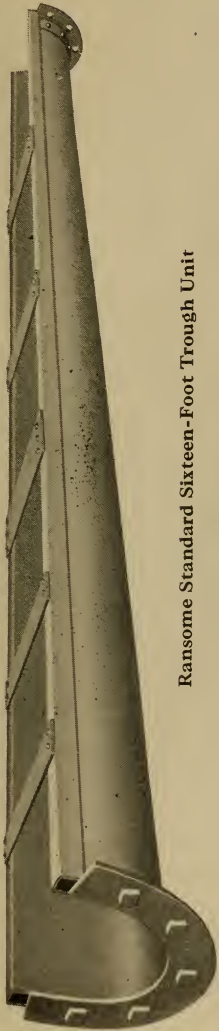
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A COMPLETE barge plant is shown above, on which was used the following Ransome equipment: Mixer, Steel Tower, Hoist Bucket, Tower Bin, Spouting and Boom Irons. This type of spouting layout is known as a "Boom Plant."

WRITE FOR RANSOME SPOUTING CATALOG

RANSOME SPOUTING



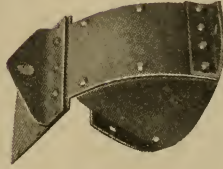
Ransome Standard Sixteen-Foot Trough Unit



Ransome Standard Hopper Head



Swivel Hook

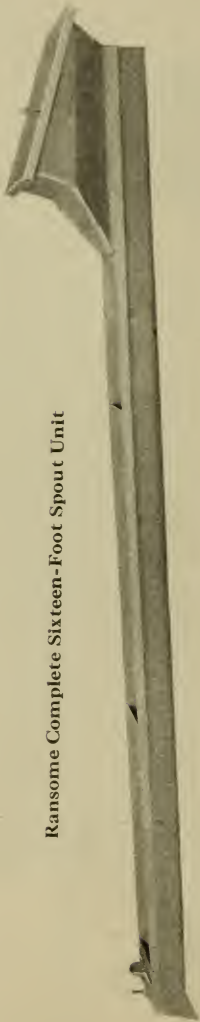


Ransome Standard Splash Hood

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.

WRITE FOR RANSOME SPOUTING CATALOG

Ransome Complete Sixteen-Foot Spout Unit

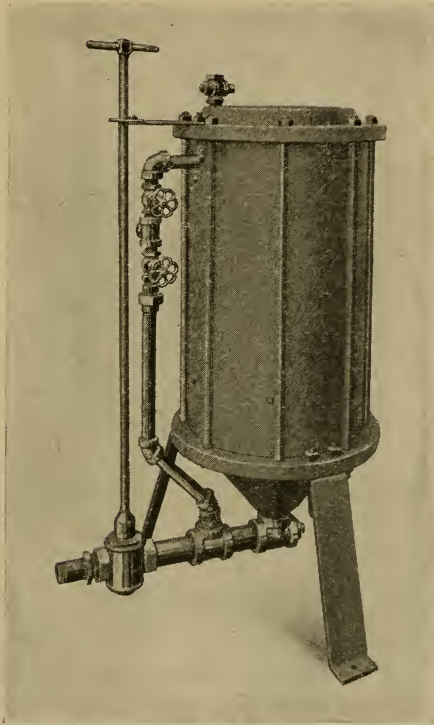


Ransome Forty-eight Foot Chute with Truss Members and
Tension Rods in Position



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.

WRITE FOR RANSOME SPOUTING CATALOG



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.

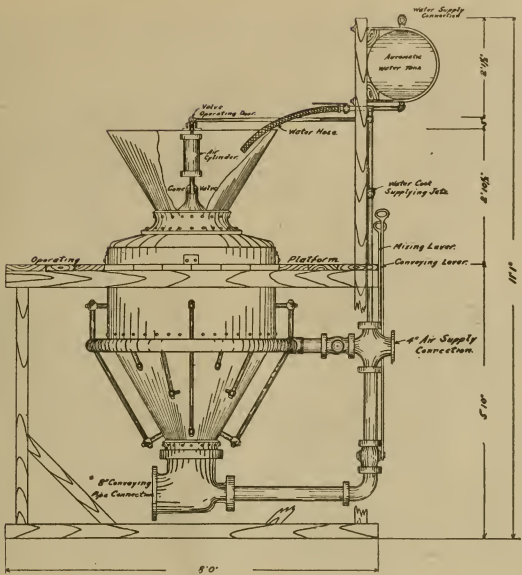
WRITE FOR RANSOME PNEUMATIC BOOKLET



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

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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.

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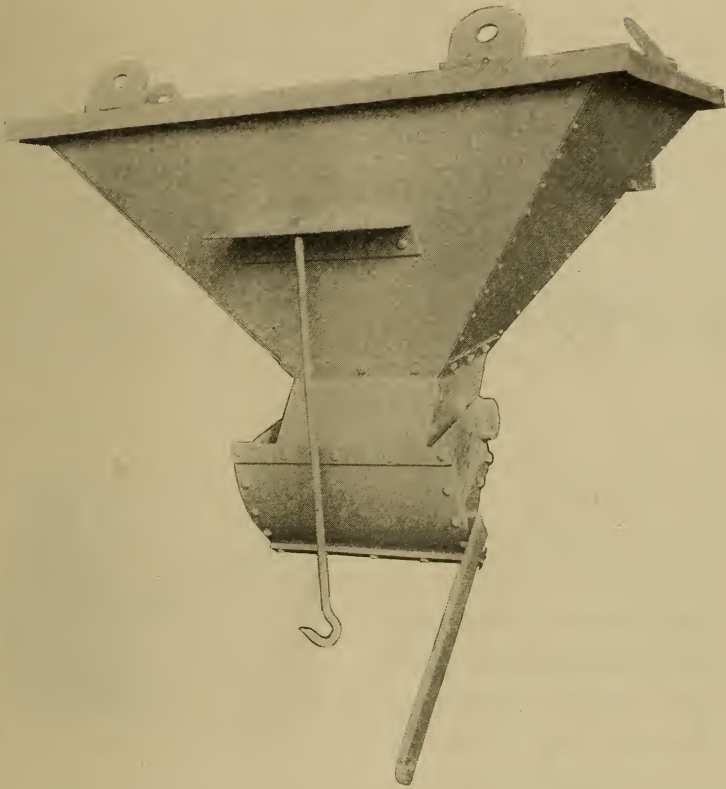


RANSOME HOIST BUCKETS

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 $5\frac{3}{4}$ 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.

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RANSOME CONCRETE BINS

RANSOME CONCRETE BINS are used in connection with Ransome Hoist Towers, either in conjunction with Ransome Spouting or where the concrete is discharged directly into concrete carts. The sizes match up with the capacities of Ransome Mixers.

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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



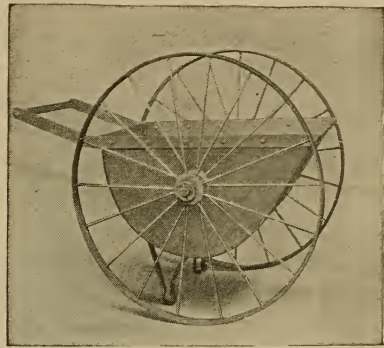
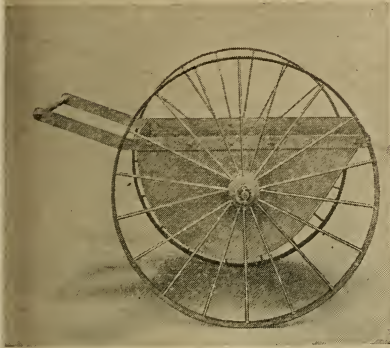
Bottom Bin Gate



Front Bin Gate

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.

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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. |

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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 $\frac{3}{4}$ in., and flat iron $3\frac{3}{8}$ by 2 in. The heavier cutter will cut $1\frac{1}{4}$ in. round or square stock, and flat iron up to $\frac{3}{4}$ by $3\frac{1}{2}$ in. For heavier stocks a power cutter is advisable.

WRITE FOR RANSOME EQUIPMENT BOOKLET

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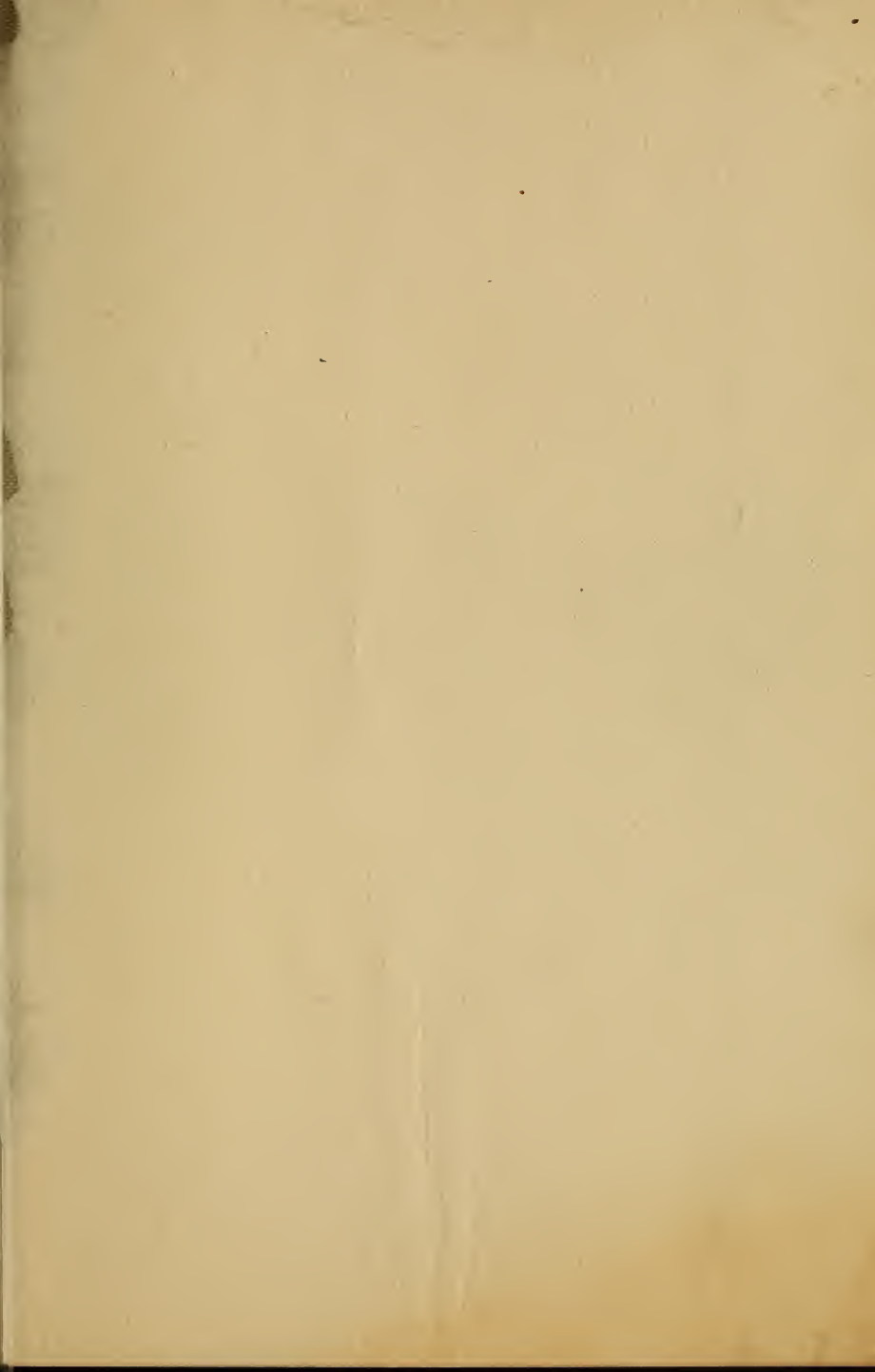
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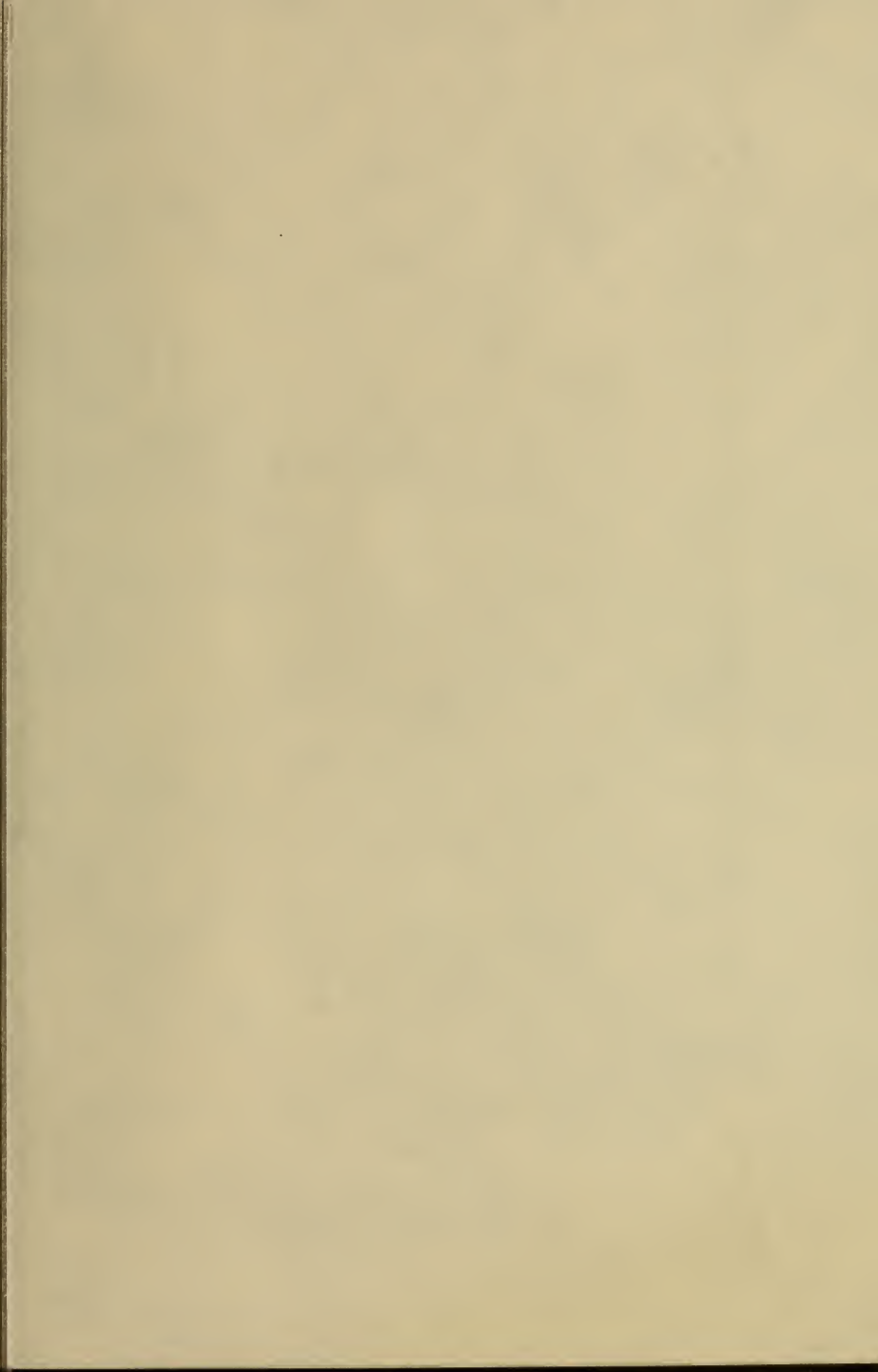
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