Numbers are used to designate the sizes of stone on road construction, and stone bought from a crusher is likely to be sold in this way. In such cases it must be borne in mind that these numbers are of local significance. Some plants call their finest product, including dust, No. 1 stone, while others commence to number from their coarsest size or tailings.

WASHING SAND AND STONE

Gravel frequently requires washing to remove the coating of clay or loam from the pebbles. Crushed stone may require removal of the dust. Sand sometimes has too much silt to produce a strong concrete, or may contain vegetable matter (see p. 154b) which renders it absolutely unfit for concrete. Washing also may be employed to assist in the separation of aggregates into the sizes required for accurate proportioning.

The most satisfactory plan for washing appears to be to wash the material down a trough over screens in the bottom of the trough, or against and through screens inclined in the opposite direction from the trough. Screens with round punched holes are better for this purpose than wire mesh.

Bellows Falls Canal Company's Plant. The method used by the Aberthaw Construction Company for washing both the crushed stone and gravel consisted of shoveling the material from an elevated platform into inclined chutes over the upper end of which were placed eight 1-inch pipes with their lower ends hammered together to form a spray. The water from these pipes washed the gravel and stone down the chute into storage bins below, the dirty water passing through screens near the bottom of the chute into troughs lined with tarred paper which carried it away. For washing stone or gravel, ¼-inch screens were used, and for sand, No. 20 mesh screens, the latter requiring frequent cleats to support the wire cloth.

Rockingham Power Company Washing Plant.* In this plant the gravel was dumped as it came from the pit into hoppers forming the upper end of an inclined sluice carried on a light pole trestle. Enough water was then drawn from an elevated tank to float the gravel down the chute to the lower end which terminated in an inclined screen with ½-inch mesh. The water and sand passed through the screen into hoppers below, while the pebbles rolled along the screen and passed over the end into a gondola car. The water overflowing the sides of the sand hopper carried off the loam and lighter material while the sand settled, and when the hopper was filled it could be drawn off into cars beneath.

* Engineering-Contracting, May, 13, 1908, p. 292.

CHAPTER XVI

MIXING CONCRETE

The method employed for mixing concrete is immaterial, provided the result is a homogeneous mass of the required uniform consistency, containing the various aggregates and cement in proper proportions. If the color of the mass is not absolutely uniform, that is, if uncoated particles of sand or stone are visible, if masses of stones are separate from the mortar, or if some portions of the mortar are dryer than others, the mixing has not been thorough.

Hand vs. Machine Mixing. First-class concrete may be produced, with careful superintendence, by either hand or machine-mixing.

The relative cost of the two methods depends entirely upon circumstances, and must be estimated for each individual case. If the job is a small one, so that the cost of erecting the plant plus the interest and depreciation, divided by the number of cubic yards to be made, is a large item, or if frequent moving is required, concrete may be and often is mixed cheaper by hand than by machinery. The information which follows concerning both methods will serve as a guide for comparison in special cases.

MIXING CONCRETE BY HAND

The methods employed by different engineers and contractors for handling the materials and arranging the men are nearly as varied with hand-mixed as with machine-mixed concrete. Concrete mixing is seemingly so simple an operation that it is often neglected by the inspector, and poor workmanship escapes detection.

The inspector should lay the greatest stress upon (*a*) exact measurement of the gravel or broken stone, (*b*) thorough mixture of the cement and sand, (*c*) thorough mixture of the mass, and (*d*) care in dumping the concrete into place. The quantity of water used in the mixing and the proper ramming or puddling of the concrete in place are equally important but are less likely to be overlooked.

In proportioning the ingredients, it is poor economy to make allowance for insufficient mixing or improper handling of the materials. The additional cement will be much more expensive than the extra time expended by laborers in securing a homogeneous mixture.

In the first place the mixing platform should be located as near the work as possible, and so situated that the coarse materials can be conveniently dumped on one side of it and the sand on the other. It should be not less than 15 to 20 feet square if all the work is to be done upon it, and except for a very small job should be of 2-inch plank, planed one side, spiked to, say, 2 by 4-inch stringers about 5 feet apart, so that it can be moved from place to place as required. A 2 by 3-inch strip around the edge will prevent loss of material. If the sand and cement are made into a mortar before mixing with the stone, the platform may be narrower and a mortar box employed in addition.

Methods of Measuring Material. Cement should invariably be measured by weight. In practice this is accomplished not by weighing on scales but by counting packages, since bags or barrels of cement have standard weights.*

The volumes of sand and stone or other aggregate should be distinctly stated in the proportions in terms of the number of cubic feet of each material to a barrel of cement, or else by parts, coupled with the explanation that one part, or barrel, represents a definite volume, such as 3.8 cubic feet. In specifications where the proportions are given by parts with no unit of measurement, the contractor undoubtedly has the legal right to base the volumes of aggregate on the loose measurement of cement, hence the necessity of exact statement of units, as prescribed on page 217.

The sand measure preferred by the authors is a bottomless box similar to the gravel box shown in Fig. 5, page 18, having a depth of about 6 inches, and other dimensions determined by the required volume. The filling of cement barrels or half-barrels with sand is a slower and less accurate process. If the sand cannot be conveniently unloaded close to the measuring platform, it may be measured in a barrow or other wheeled vehicle so constructed that it can be accurately leveled off after filling. For rough measurement ordinary contractors' barrows, whose approximate "large" capacities are given on page 9, are suitable. If more exact quantities are required, however, it takes only a few more seconds to dump the sand from the barrows into a bottomless box.

For gravel or broken stone a bottomless box about 8 or 9 inches deep, shown in Fig. 5, page 18, is a convenient measure. Special barrows built to exact dimensions are more exact measures than ordinary contractors' barrows and, in some cases, than the bottomless box, because an unscrupulous contractor can more easily heap the material in the latter when the inspector's back is turned. Cement barrels are accurate measures, but time is wasted in lifting the shovels when filling, and in dumping them.

*See page 2.

A measuring barrow car,* built so that it can be handled with a derrick, is sometimes convenient.

Hand Mixing. A detailed description of one of the best ways to mix concrete by hand is given in Chapter II for the benefit of those not familiar with concreting. It is the general opinion of concrete experts that the particular order adopted for mixing the materials has little effect upon the strength of the concrete, provided the materials are turned a sufficient number of times to incorporate them thoroughly. Some engineers prefer to make the cement and sand into a mortar, while others do not add the water until the final turning. The authors have seen excellent work produced by both methods, but prefer the latter chiefly because shoveling the mortar on to the stone involves more labor than handling the dry mixed cement and sand; in fact, comparative tests show that it costs less to mix the cement and sand dry, shovel the mixture on to the stone and mix three times, than to make a mortar, shovel it on to the stone and mix only twice.

Methods variously employed, the first of which is described in detail on page 21, are outlined as follows:

(1) Cement and sand mixed dry and shoveled on to the stone or gravel leveled off, and wet as the mass is turned.

(2) Cement and sand mixed dry, and the stone or gravel dumped on top of it, leveled off, and wet as the mass is turned.

(3) Cement and sand mixed with water into a mortar which is shoveled on to the gravel or stone, and the mass turned with shovels.

(4) Cement and sand mixed with water into a mortar, the gravel or stone spread on top of it, and the mass turned with shovels.

(5) Gravel or stone, sand, and cement, spread in successive layers, mixed slightly and shoveled into a circle or crater, water poured into the center, and the mass mixed with shovels and hoes.

The last method is applicable only where a small amount of concrete is to be mixed on the ground with no mixing platform or mortar box.

Sand and cement must never be mixed up in advance, as lime and sand are often mixed, because the natural moisture which all sands contain will make the cement set and cake.

The systematic arrangement of the men in pairs, as described on page 21, and insistence upon their shoveling from the bottom of the pile and then turning their shovels completely over, are essentials for thoroughly mixed concrete. In the final wet mixing the materials should be turned in this way two or three times.

For wetting the concrete some engineers specify spraying with the hose,

*See illustration in *Engineering News*, April 23, 1896, p. 268.

but in practice there appears to be no special advantage in this over ordinary galvanized iron buckets, while with the latter the quantity can be gaged more accurately by filling the required number of buckets in advance. Nearly all the water can be poured on the dry materials before commencing to turn, and the remainder used to wet up occasional dry spots.

The quantity of water is regulated according to the appearance of the concrete after placing. In a thin wall the water will rise to the surface through successive layers so that the first batches in a day's work require the most water. Whatever the quantity, it should be thoroughly incorporated with the other ingredients, and the amount which can be thus incorporated may sometimes be taken as the allowable limit in hand-mixing. The best consistency for different classes of concrete is discussed on page 279.

Distribution of Mixing Gang. Whatever the methods of mixing, the chief requisites for economy are such an arrangement of the gang that each man will have definite duties, and that the number of men on one set of operations will perform their work in the same length of time required by another set of men to perform a different operation or set of operations. A gang should be as large as practicable in order to lessen the cost of superintendence and the general expense.

The best plan, where the size of the gang can be regulated to suit, is to give each man a single operation to perform. For example, let one man or set of men wheel and measure all the sand; let another set of men mix the sand and cement; let a third set be continually employed measuring the gravel or stone; a fourth mixing the mass, while one or two of their number supply water; a fifth filling the barrows and wheeling the concrete to place, and still another set leveling the concrete and ramming or puddling.

It is generally economical to have two batches of concrete in preparation at once, although one set of men usually can measure and mix the sand and cement for two mixing gangs. While one batch of concrete is being shoveled to place or wheeled in barrows, the other batch, either in a different location on the same platform or on a separate platform, may be spread and mixed.

The method of handling a small gang is described on page 21. The arrangement of gangs on two well managed actual jobs is illustrated in the following outline:

(1) Gang on a core wall for a dike where the sand and cement were mixed dry and spread on to the stone, then wet as the mass was turned.

The large mixing platform was located 30 to 50 feet distant from the excavation, and the concrete was handled in wheelbarrows.

One foreman.

One man wheeling sand to measuring box.

Two men, working alternately at the two ends of the mixing platform, opening cement, and mixing sand and cement dry.

Three or four men, working alternately at each end of platform, shoveling gravel into bottomless boxes.

Six men working alternately at each end of platform, mixing concrete (turning it three times).

Two men handling water.

Four men wheeling concrete, each filling his own barrow.

Four men leveling and ramming.

The average quantity of concrete in proportions 1 : 2 : 5 laid by this gang per day of ten hours was about 65 batches or 47 cubic yards, with a maximum of about 90 batches or 65 cubic yards.

(2) Gang for a 6-inch foundation for a street pavement, where the sand and cement were made into a mortar and spread on to the stone, and where two mixing platforms were used, one on each side of the street, with a mortar box between them.

One foreman.

Two men mixing mortar in one mortar box.

Four men shoveling stone alternately into two measuring boxes.

Four men working alternately on the two mixing platforms, spreading mortar on stone, mixing concrete, and shoveling to place.

Three men leveling and ramming concrete and also assisting to shovel to place.

One man carrying water and doing other odd work.

The total quantity of concrete in proportions 1 : 2 : 5 laid per day of ten hours averaged from 40 to 46 batches or 29 to 33 cubic yards per day for the gang. The gang was not quite up to the average, for under given conditions they ought to have turned out regularly 34 cubic yards per day of ten hours.

Approximate costs of concrete mixing are discussed on page 25.

MIXING BY MACHINERY

On all large contracts, machinery for mixing concrete is universally replacing hand labor. The economy of this usually is due as much to the appliances introduced for handling the raw materials and the concrete as to the saving in the actual labor of mixing. Any arrangement which requires the measuring and spreading of materials by shovelers before entering the mixer results simply in saving the process of hand turning of the concrete and the labor of shoveling it into the vehicle, and this saving is partly balanced by the cost of maintaining and operating the mixer. On a small job this last item almost invariably exceeds the saving in hand labor and renders the expense with the machine greater than without it.

The design of the appliances or plant for handling the materials, and to some extent the selection of the type of mixer, depends upon local conditions, the quantity to be mixed per day, and the total volume of concrete. For a large mass of concrete masonry it is evident that it pays to invest a considerable sum in machinery to reduce the number of men and horses, but if for any reason only a small quantity, we will say not over 50 cubic yards, can be deposited in a day, the cost of expensive machinery cuts a very large figure and hand labor is generally cheaper. In estimating the interest on the cost of the plant which must be charged against a cubic yard of concrete, instead of dividing the interest per day by the usual daily output, the interest for the year must be divided by the total amount of concrete to be laid in the year. In other words, allowance must be made for the days when inclement weather prevents work. To find the depreciation, the value of the entire plant when new, minus its value after the job is completed, is divided by the total number of yards of concrete. Some of the other running expenses, such as the wages of the engineman, may continue from day to day whether or not any concrete is being laid.

Concrete Mixers. An effective concrete mixer not only stirs the mass, which may tend to separate the light and heavy particles, but cuts it again and again, and repeatedly transfers the materials from one part of the machine to another, so that in whatever order they are introduced, the product will be homogeneous. Continuous turning alone does not accomplish the result so quickly or thoroughly as the more complicated motions. The appearance of the concrete as it falls from the mixer will often distinguish the better of two machines.

The larger the machine, the more economical it will be, provided the arrangements for supplying it with material and conveying the concrete to the work permit running at full capacity.

Concrete mixers are of two general classes: (1) continuous mixers into which the materials are fed constantly, usually by shovelfuls, and from which the concrete is discharged in a steady stream, and (2) batch mixers, designed to receive at one charge, say, a barrel or a bag of cement with its proportionate volume of sand and stone, and after mixing to discharge it

in one mass. It is impossible to separate these two classes very distinctly because many of the machines are adapted to either continuous or batch mixing.

The authors are opposed, as a rule, to the use of continuous mixers, unless the materials are measured and fed mechanically, because of the difficulty of uniform feeding. When the ingredients are measured out by hand, spread in layers one above another, and then, starting at one edge, are shoveled into the mixer, the proportions of the materials in the resulting concrete are regulated by the thickness of the layers of the different ingredients rather than by the dimensions of the measuring barrels or boxes. If in one portion of the pile the layer of cement is thicker than in another, the resulting concrete will be proportionally richer. With batch mixers all the materials enter the machine at once; the homogeneity of the product depends upon the character and length of time of mixing rather than upon the care exercised by the laborers in feeding, and less inspection is necessary.

The regulation of the water supply in machine-mixing as in hand-mixing is largely a matter of judgment. Even if the materials were all supplied under absolutely uniform conditions, the same volume of water would not produce from each batch a concrete of uniform consistency, because, as the concrete is laid, the water works up through from one layer to the next, so that more water may be necessary early in the morning than later in the day. It is well, nevertheless, to roughly measure the quantity each time, varying the amount from batch to batch as the condition of the materials and the state of the mass require.

The selection of the type of mixer is often governed by local conditions. If, for example, there is to be a large quantity of concrete, and the machinery can be located at one place, a stationary machine, mounted perhaps on timber framework, with derricks, elevators, or belts, to raise the materials, may be economical. On running work, like a conduit or retaining wall, more portable machines are required, while for thin layers, like pavement foundations, if any machine is used it must be very light or easily moved. If stone for the aggregate is to be broken on the spot, a stationary plant may be built, or the stone may be hauled from the crusher bin to the mixer. In some cases the conformation of the ground will permit of dropping the materials into or through the machine by gravity. Frequently the volume of concrete to be laid is limited by the construction of forms, and a machine of small size is sufficient.

Mixers may be classified in three general types:

Rotating mixers

Paddle mixers.
Gravity mixers.

Rotating or rotary mixers, as they are usually termed, sometimes mix the materials by simply tumbling them in an oblong or cubical box, and in other cases by throwing them against the deflectors, blades, or plows.

The cubical box is one of the simplest forms of rotating mixers, and formerly was used largely on extensive concrete construction, but is now giving place to modified forms which permit more thorough mixing and the inspection of the material during mixing. The cubical box is of steel, generally mounted on a timber frame similar to the plan in Fig. 95, page 272. The shaft for revolving it runs through two opposite corners and consists of a perforated hollow tube which supplies the water. The measured materials are dropped in from above through a hinged door in the side of the mixer, and the machine after some twelve or fifteen revolutions is stopped, the door is opened, and the concrete dropped into carts or cars When most of the concrete is out, the box is revolved once again to empty it more completely. The mixer itself is inexpensive, but the cost of erection and of raising the stone and sand often renders it less economical than more expensive machines.

Cube mixers are also made on a frame and geared so that they may rotate while filling and dumping as illustrated in Fig. 85.

The rotating mixers illustrated in Figs. 82 and 83 which contain deflectors, or blades, are usually mounted by the manufacturers upon a suitable frame, although in certain cases it is preferable to construct special timber framework, so that materials may be introduced and the concrete taken away more economically. The larger machines of this type are so constructed that the materials can be introduced from derrick buckets, carts, or barrows. The rotating of the drum tumbles the material and also throws it against the mixing blades which cut and throw it from side to side. Most of these machines can be dumped while running, by tilting either them or their chutes. They are also provided with hoppers as shown in Fig. 83, or with loading skips or trays, operated by the engine that runs the mixer, which lift the materials from the ground up to the charging hopper as in Figs. 82 and 85.

A different style of rotary machine is shown in Fig. 84. It consists of an open revolving pan in which are stationary plows which mix the concrete. The outlet is through trap doors in the bottom.

Of the paddle mixers, those adapted to mix a batch at a time can be more surely depended upon to produce good concrete than the continous machines. Fig. 86 shows a duplex paddle mixer to be placed upon a

raised platform and fed by hand wheelbarrows or derrick buckets. The mixing paddles, on two shafts, revolve in opposite directions, and the concrete falls through a trap door in the bottom of the machine into carts, cars, or wheelbarrows, or upon a platform whence it is shoveled to place.

The continuous paddle mixer with a single shaft and an open end is sometimes used for a volume of concrete ranging from 75 to 150 cubic yards per day. Care should be taken that the materials are thrown in near enough the upper end to be thoroughly mixed. The water is usually fed near the middle of the machine so that the materials are first partially mixed dry. They may be measured by shovelfuls, or by spreading in layers before shoveling into the mixer, or by automatic machinery which feeds the cement and each aggregate in the proper proportions.

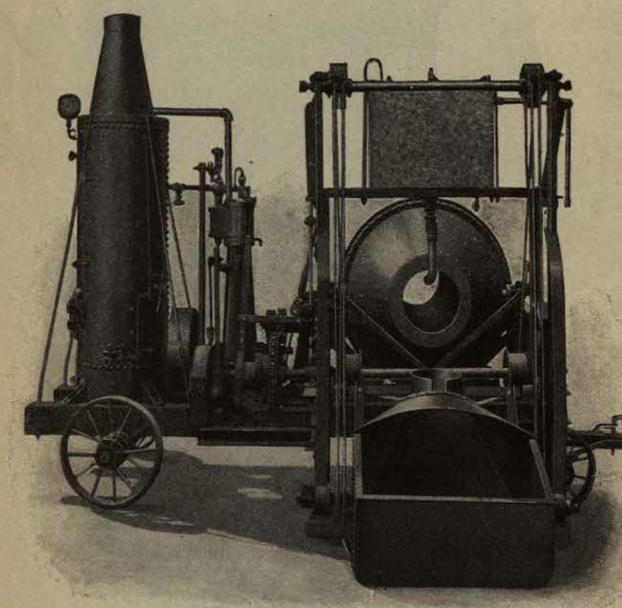

Fig. 82.—Rotary Mixer. *(See p. 258.)*

Measuring the materials by shovelfuls would seem at first thought likely to give a poorer quality of concrete than measuring in boxes or barrels, but with a properly trained gang and periodic checking of the number of barrels of cement to a given volume of concrete, fair results may be obtained. At the Charlestown Bridge piers in Boston (see Fig. 92, p.270), the contractors, by changing off the men who shoveled into the mixer so as to give them light work half the time, turned out (by steady work) concrete at the rate of about 17 cubic yards per hour. Each feeding gang consisted of five men, three shoveling gravel, one shoveling sand,

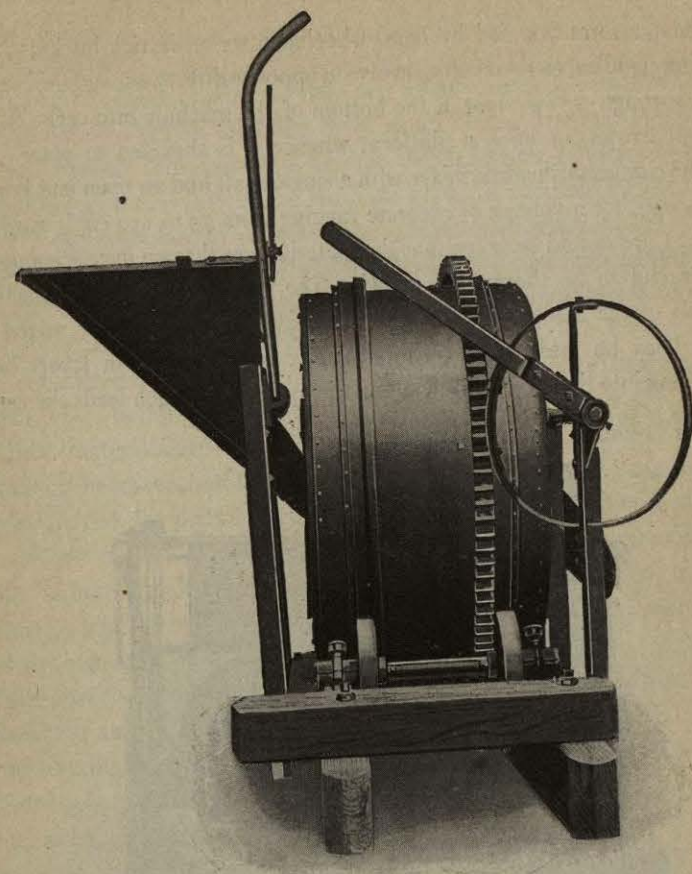

FIG. 83.—Rotary Mixer. (*See p.* 258.)

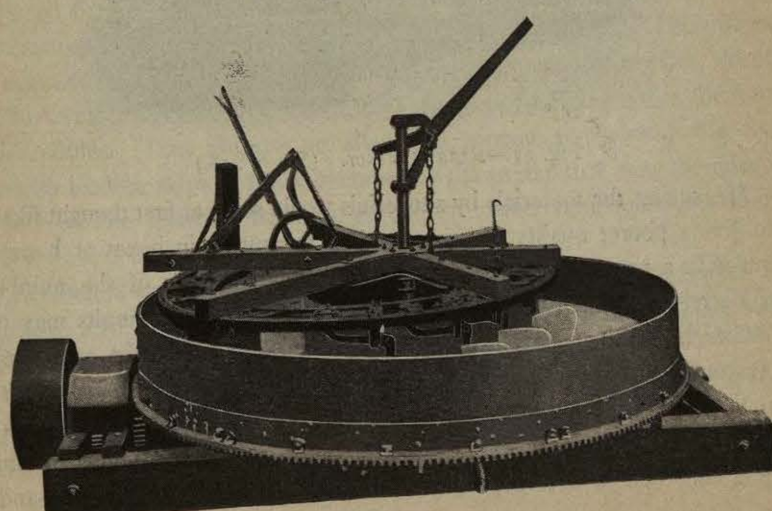

FIG. 84.—Revolving Pan Mixer. (*See p.* 258.)

and one shoveling cement, the size of shovels being so arranged that when all worked together the proper proportions were introduced. The two gangs changed off every half-hour.

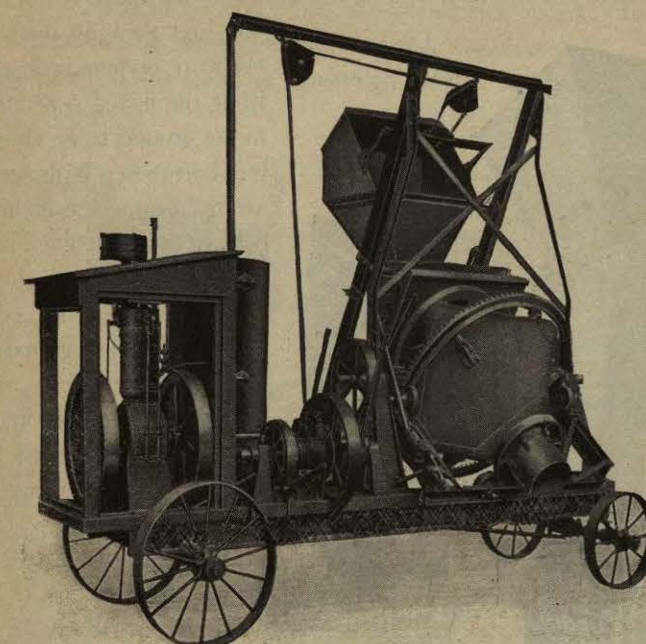

FIG. 85.—Rotary Cube Mixer. (*See p.* 258.)

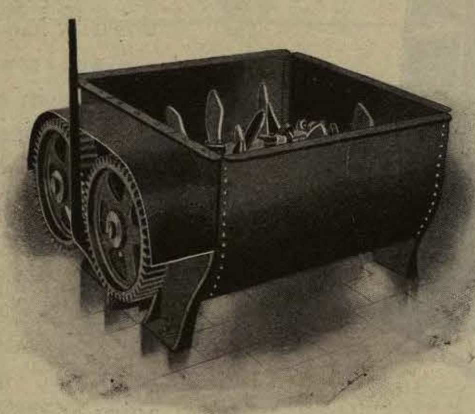

FIG. 86.—Duplex Paddle Mixer. (*See p.* 259.)

When the materials are measured and spread in layers before shoveling into the mixer, the machine should be below the measuring platform, and two gangs of men employed, one on each side of the machine, so that one