TABLES OF RUBBLE CONCRETE

The tables on pages 236 and 237 give the quantities of materials and the volumes of concrete mixed in different proportions and with different percentages of rubble. The values are made up as described on pages 298 and 299, where illustrations are given of the methods of computing the cost.

The percentages of rubble are based on the ratio of the volume of the concrete after it is laid to the actual volume of the large stone contained in it. In other words, it is the percentage of the finished concrete occupied by the large stone.

CHAPTER XIII

PREPARATION OF MATERIALS FOR CONCRETE

The various operations relating directly to the laying of concrete are discussed in detail in this and several succeeding chapters. While the selection of the special methods and machinery, which are described at length in the succeeding chapters, are determined by local conditions, certain general principles apply to all classes of work. The preparation of the materials relates to the storing of cement, the screening of sand and gravel, and the crushing of stone.

STORING CEMENT

Portland cement is not injured by storing in a dry place for an indefinite length of time; in fact, contrary to former belief, instead of deteriorating, the quality is often improved by storage. Cement manufacturers when rushed with orders sometimes ship material which, not being sufficiently air-slaked, contains free lime that exposure to air may change to a hydrate and thus render harmless.

Recognition of the fact that exposure to dry atmosphere does not injure cement has led to packing it in bags instead of in barrels, thus saving both the cost of the barrel and the extra freight upon it. If, however, the work is in a damp location, as in marine construction, barrel shipments are advisable.

The economy of storing the cement as near as possible to the mixing platform or mixing machine is obvious, but since, on the other hand, it is more easily handled and is always less in volume than sand and stone, these should be given the preference in the matter of location.

SCREENING SAND AND GRAVEL

The three most common methods of screening are (1) by hand, that is, by throwing shovelfuls of the material on to an inclined screen, (2) by dumping or hoisting the material on to a fixed inclined screen, (3) by a revolving screen.

Cost of Hand Screening. The cost of hand screening depends upon the total amount of material handled rather than upon the quantity of sand or gravel produced. A material most of whose particles run through the screen can be most cheaply screened, because the screen can be moved, or arranged over a hole, while if a large proportion of the particles are caught they must be shoveled from the foot of the screen.

An average laborer, properly superintended, will throw about 24 cu. yd. of material against a screen in a ten-hour day, but in estimating the cost, allowance must be made for shoveling the material out of the way, moving screen, and superintendence.

The following are approximate costs of screening sand and gravel by hand under ordinary conditions. The prices are from actual records on a number of jobs and are based on labor at $1.50 for ten hours, with a suitable allowance for superintendence and contractor's profit. The minimum prices apply to first-class men.

	Average cost per cu. yd.	Minimum cost per cu. yd.
Screening sand, coarse stuff wasted	$0.11	$0.08
Screening gravel to remove large stones	0.15	0.10
Screening gravel to remove sand, sand wasted	0.24	0.17
Screening gravel coarse, and fine stuff, both measured	0.18	0.12

If laborers are working alone with no foreman in sight, as is often the case on concrete work, 50% should be added to the average costs.

Inclined Screen fed by Carts, Derrick Buckets, or Endless Chain. The slope of an elevated screen may vary from 35° to 45° from the horizontal, according to the character of the material. Coarser screens are required to pass material of a certain size than for hand screening.

At the new Cambridge Bridge, Boston, the contractors employed a screen about 15 feet long, hinged at the top so that the slope could be varied to suit the material. A hopper located above the screen fed on to a 3-inch bar screen, consisting of parallel iron bars about 3 inches apart, supported by iron cross pieces about 5 inches apart. The stones too large for the concrete ran down this coarse screen, and rolled off one side, while the remainder of the material fell through it on to a screen with 1-inch by ¾-inch mesh, which separated the medium gravel from the sand.

On another large job in Everett, Mass., where an inclined screen was fed by a bucket elevator supplied by carts, 300 to 350 cu. yd. of sand and gravel were screened in ten hours, and an even larger quantity could have been handled had it been supplied with absolute regularity.

The cost of screening by this method depends both upon local conditions and the quantity screened. The average cost may be assumed to be from 4 to 8 cents per cubic yard when large quantities of sand or gravel are handled at once.

Rotating Screens. Rotating screens, cylindrical or hexagonal in shape, although most frequently employed for separating crushed stone

(see p. 245), are also adapted, if power is available, for separating sand from gravel, or for separating gravel into several sizes to remix in the theoretical proportions required for a dense, impervious concrete.

While the first cost of a rotating screen is more than that of an inclined screen, less elevation is required and it may be fed with a bucket conveyor.

A plant for ordinary concrete made from two aggregates, sand and gravel, requires a screen with only two sizes of mesh, the smaller about ¼-inch and the larger 2, 2½ or 3-inch mesh, as desired. Often no screening is required except to remove the sand, as a few large stones do no harm. The screen may be about 3 feet in diameter by 12 feet in length.

The present tendency, for concrete which is to be subjected to severe stress or to water pressure, is to require more scientific proportioning by separating the aggregate into several sizes and remixing them so as to produce the greatest density. This separation may be accomplished in practice by adding more sections, and thus lengthening the screen, or by employing a double cylinder, which occupies about half the space of a single cylinder.

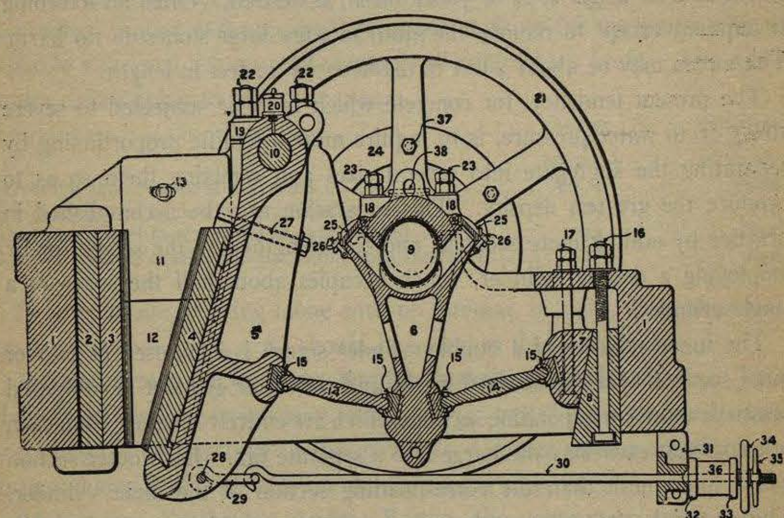
The inner cylinder of a double-cylinder screen is composed of two or more sections of different sized mesh, and the outer cylinder is composed of two or more corresponding sections which are entirely separate from each other so that each may discharge into a separate bin. Each outer section has a finer mesh than the corresponding section of the inner cylinder. The material, after passing through a section of the inner cylinder, falls upon the outer wire and is again separated, the part which is caught rolling out through an annular opening into one bin and the remainder passing through the mesh into another bin.

STONE CRUSHING

The crushing of stone for concrete must be approached from a different standpoint than the preparation of material for macadam paving, although the costs will not vary materially from those of a well-arranged portable crushing plant used on road construction.

For city or town macadam paving, where a suitable ledge is available, it is possible to establish a fixed plant with stationary engine, large stone bins, and economical machinery for handling cars, so that the stone can be hauled over a system of movable tracks directly from the ledge to the crusher, while for country road building the plant is arranged with a view to its portability, sometimes even resting on wheels.

For concrete work a plant intermediate in style between these is usually required. Its design is governed by the local conditions and by the quantity of concrete to be made. In some cases where the concrete is laid in excavation it is possible to locate the crusher on the bank, and allow the stone to pass by gravity on to and through an inclined screen, or, if "crusher run" is used, to fall directly into a pile below. Generally the stone from the crusher must be taken by bucket or belt conveyors to bins, located, if possible, above the concrete mixer, or where the stone can be conveniently conveyed to the mixer without shoveling.



NAME AND NUMBER OF PARTS

1 Main Frame	11 Upper Half Cheek Plate	21 Balance Wheel	30 Spring Rod
2 Round Back	12 Lower Half Cheek Plate	22 Bolt for Swing Jaw Shaft Cover	31 Spring Bar
3 Fixed Jaw Plate	13 Bolt for Cheek Plate	23 Bolt for Main Bearing	32 Washer
4 Swing Jaw Plate	14 Toggle	24 Pulley	33 Washer
5 Swing Jaw	15 Toggle Bearing	25 Grease Box Cover	34 Hand Wheel
6 Pitman	16 Bolt for Wedge	26 Bolt and Thumb Screw	35 Thumb Nut
7 Toggle Block	17 Bolt for Toggle Block	27 Bolt for Swing Jaw Plate	36 Rubber Spring
8 Wedge	18 Cover for Main Bearing	28 Shackle Pin	37 Bolt for Pulley
9 Eccentric Shaft	19 Cover for Swing Jaw Shaft	29 Spring Rod Shackle	38 Grease Box Cover on Main Bearing
10 Swing Jaw Shaft	20 Grease Cup		

FIG. 77.— Jaw Crusher. (*See p. 242.*)

Stone Crushers. Stone crushers are of two general types, jaw crushers and gyratory crushers.

The size of a jaw crusher is designated by the opening into which the stone is introduced. A 16 by 10-inch crusher has jaws 16 inches in width, and the space between the two jaws at the top is 10 inches. A "duplex" crusher has two pairs of jaws operated by the same shaft, but working alternately by means of different eccentrics. Single jaw crushers range in size from 3 by 1½ inches to 36 by 24 inches.

The operation of a typical jaw crusher is shown in Fig. 77. One of the jaws is fixed, and the other is hinged at the top, and swung back and forth

through a very small arc. The motion is imparted by the eccentric shaft, which, in revolving, raises and lowers the "pitman," whose lower end is connected by toggles with the lower end of the movable jaw. The size of the stone passing through the jaws, that is, the size of the largest particles, is regulated by the opening at the bottom of the swing jaw, which is changed by using longer or shorter toggles.

The capacity of any crusher — that is, the quantity of broken stone which it will turn out per hour or per day — is dependent not only upon the size of the crusher, but upon the texture of the stone and the sizes of the largest particles. From the following catalogue capacities for a 16 by 10-inch jaw crusher per day of ten hours, it may be inferred that the quantity turned out is nearly in the ratio of the sizes of the stones.

120	tons	crushed	to	2½	-inch	size
100	"	"	"	2	"	"
80	"	"	"	1½	"	"
60	"	"	"	1	"	"

In estimating the actual daily output of a crusher, — and this is in fact true for most machinery, — all catalogue figures are likely to be misleading because they are based on maximum capacity with continuous feeding, while in practice there are likely to be unavoidable delays. An average day's work of ten hours, — based on actual records obtained by the authors from a number of jobs, — for a 15 by 9-inch crusher set for 2½-inch stone, with a small percentage of tailings, may be taken at 65 cu. yd. or, say, 78 tons, in ten hours. This estimate applies to continuous running of the crusher, allowing only for occasional unavoidable delays.*

A section of a gyratory crusher, which is adapted for more stationary plants, is shown in Fig. 78, page 244. It consists essentially of a cone with a gyratory motion within an inverted conical chamber or shell. The size of the crusher is determined by the width of the opening between the top of the cone and the shell, and the circumference. The gyratory motion of the cone shaft is produced by an eccentric keyed to its lower end. As the shaft revolves, the cone is given a kind of a rocking motion which continually directs it toward, and then away from, different portions of the shell. The size of the broken stone is regulated by raising or lowering the cone on the shaft.

For a concrete plant producing 200 cubic yards per day, manufacturers recommend a No. 4 gyratory crusher with openings 8 x 27 inches.

The horse-power required to drive a crusher and its attendant machinery

*The Annual Report of the Newton, Mass., City Engineer for 1891 gives interesting data on detail costs of stone crushing, a portion of which are here summarized on page 249.

varies largely with the material handled. It is advisable to make ample allowance above the figures given in manufacturers' catalogues. It is, also, economical to use a wider and heavier belt than is generally specified,

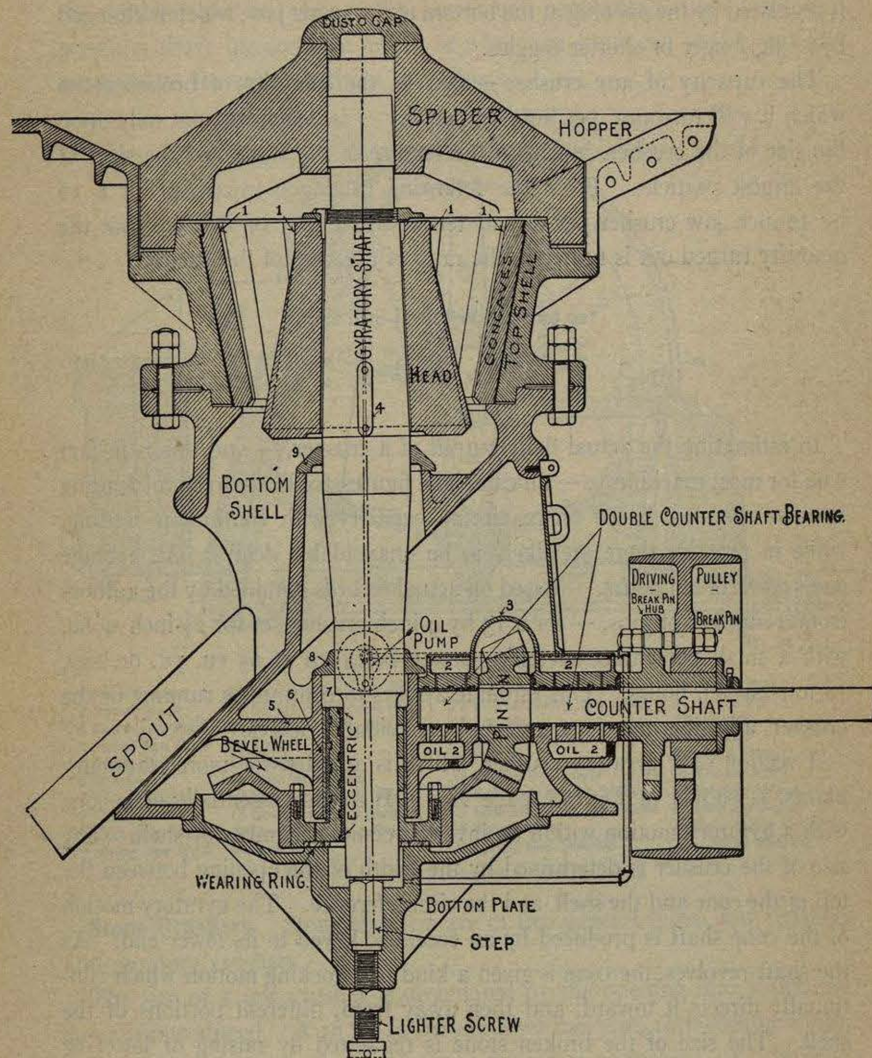


FIG. 78.—Gyratory Crusher. (See p. 243.)

in order to avoid delays and shutdowns. When ordering almost any kind of machinery the authors make it a practice to require a wider and heavier pulley than the standard width. It is wise to make a pulley at least 2 inches wider than the belt which is to be run upon it.

Crusher Screens and Bins. A typical design, by Mr. Earle C. Bacon, for bins suitable for a plant where the concrete mixer or mixing platform is located at a distance from the crusher is shown in Fig. 79. With slight changes they may be arranged to discharge into hoppers over a concrete mixer. The dimensions of timber employed in the construction may be used as a basis for bins of other sizes.

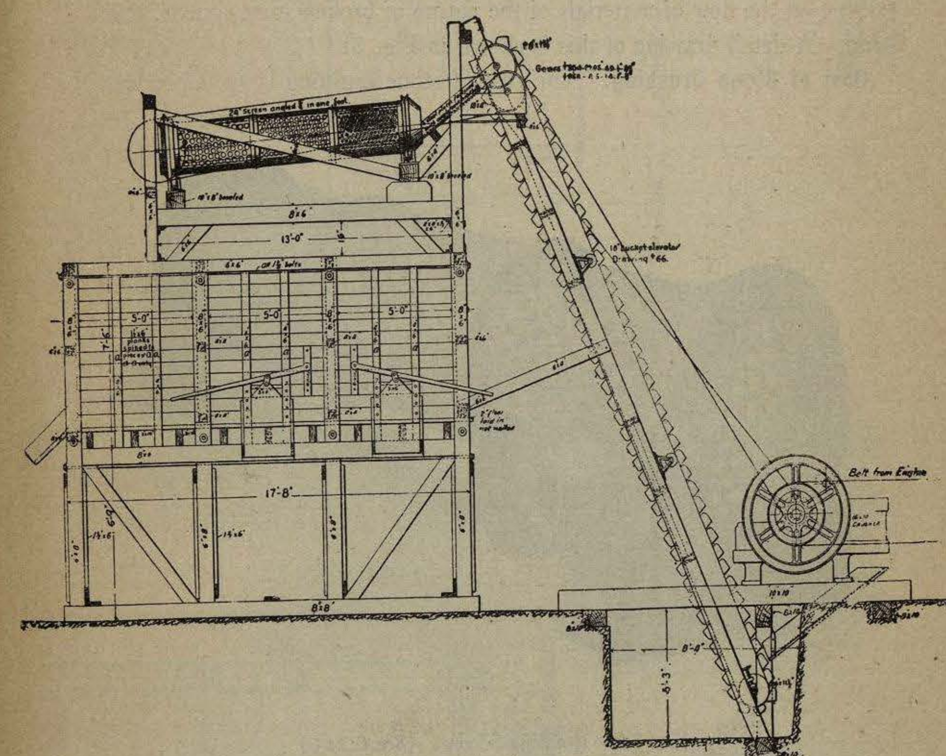


FIG. 79.—Small Crushing Plant with Elevator, Screen, and Portable Bins. (See p. 245.)

A safe slope for the bottom of stone bins is 45°, although if lined with sheet iron this may be decreased to 35° or 40°.

Screens for broken stone as shown in Fig. 80, page 246, are usually made in sections varying in length from 3 to 5 feet, so that they can be bolted together and give as many divisions of sizes as are required. The diameters vary from 24 to 48 inches. The mesh of a rotating screen should be about 20% smaller in diameter than the required size for the stone, as there is more or less wear on the screen, which enlarges the holes, and this allowance will also assist in excluding the oblong pieces whose longest dimension is above the limit. For concrete, unless two or more sizes of stone are mixed, no more than two sizes of mesh are required, one, ¼-inch to remove the dust, and the other, 2, 2½, or 3-inch to remove the coarse stuff. Often it is necessary only to remove the dust which may then be used as sand.

Stone Bin Gates. A gate designed by Mr. C. S. MacHenry, of the Greene Consolidated Copper Co., has proved extremely satisfactory for cutting off the flow of materials of the nature of broken stone, gravel, and sand. A detail drawing of this is shown in Fig. 81.

Cost of Stone Crushing. The cost of stone crushing is so dependent

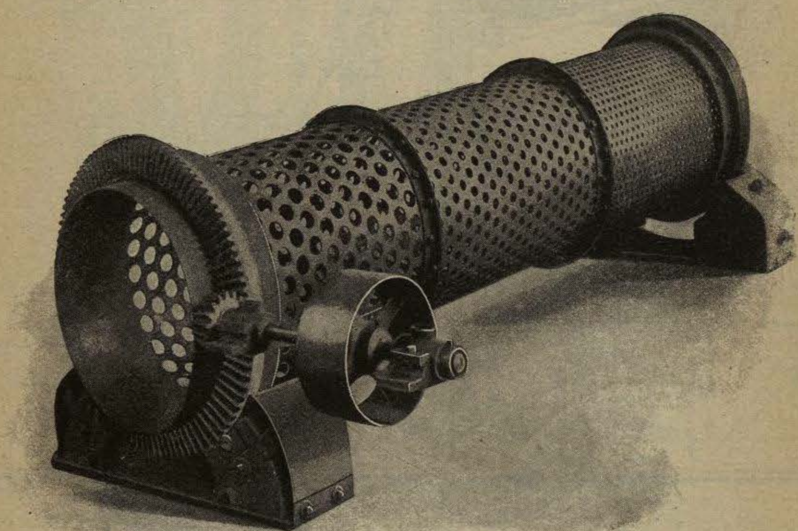


FIG. 80—Rotating Screen. (*See p.* 245)

upon local conditions and upon the character of the rock, that only approximate estimates based upon actual experience can be given. There are, in general, two classes of work,—one where the rock is blasted from a ledge near at hand, and the other where the crushers are supplied with boulders or other loose rock. The gang at the crusher is similar in both cases, and the chief difference in operation is the extra gang for drilling and breaking up the stone in the ledge. On the other hand, usually more permanent, and therefore more economical, arrangements for hauling the stone can be made in ledge excavation than when the stone is obtained from various sources.

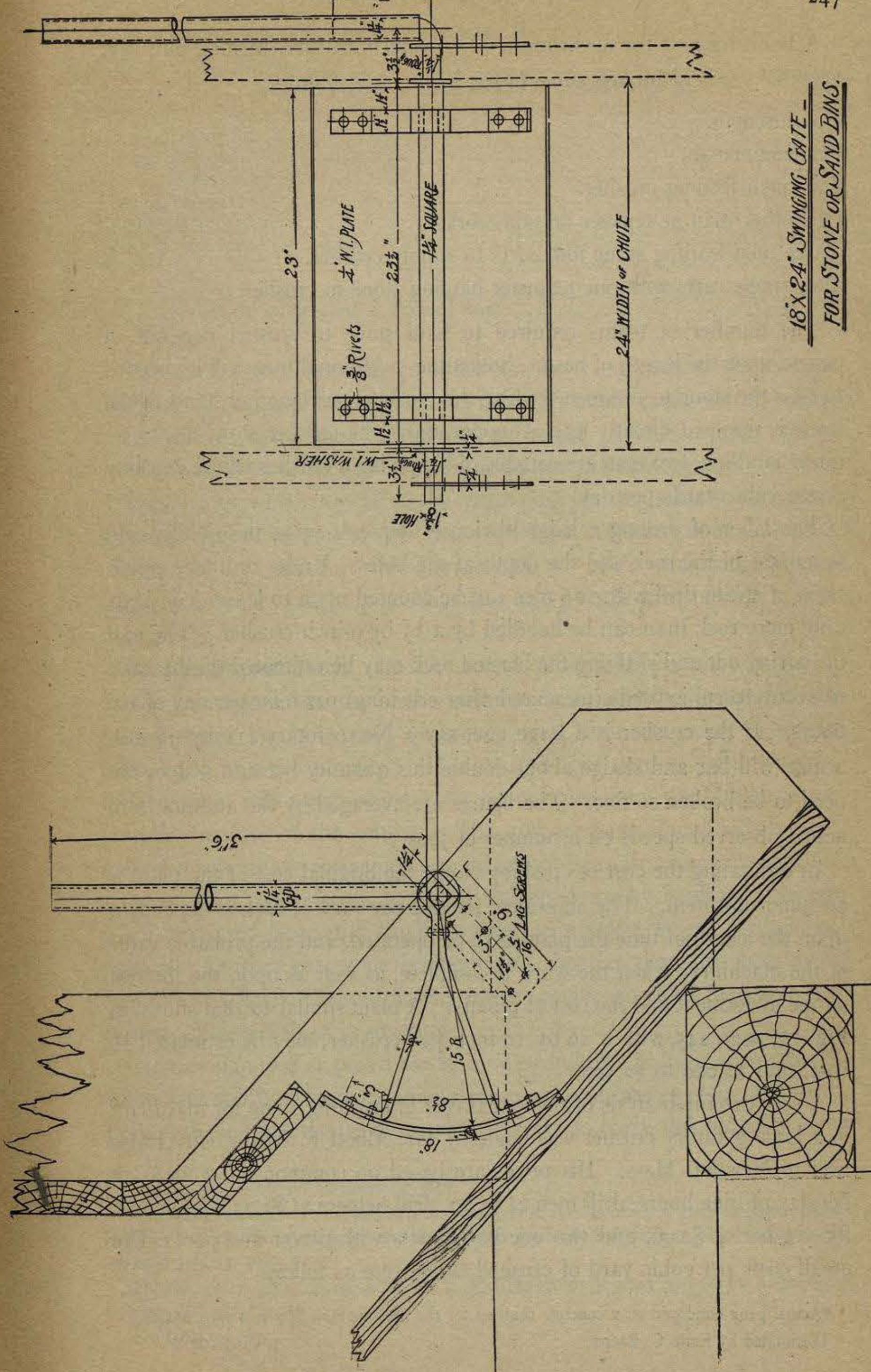


FIG. 81.—Gate for Stone or Sand Bins. (*See p.* 246.)

A typical gang* for operating a 15 by 9-inch crusher, turning out, say, 65 cubic yards of broken stone in ten hours, is as follows:

One foreman.
One engineman.
Two men feeding crusher.
One other man at crusher on odd work.
Three men loading stone into carts to supply crusher.
Two single carts with one teamster hauling stone to crusher.

The number of teams required to haul stone to crusher depends, of course, upon the length of haul. Sometimes additional men will be needed to pass the stone to the men feeding the crusher; on the other hand, if the stone is dumped directly into a hopper above the crusher so as not to require handling, two men are capable of supplying a crusher whose capacity is 200 cubic yards per day.

The labor of drilling a ledge obviously depends upon the quality and seaminess of the rock and the depth of the holes. Under ordinary conditions, a steam drill with two men can be counted upon to loosen considerably more rock than can be handled by a 15 by 9-inch crusher. The cost of barring out and sledging the blasted rock may be estimated on the basis of about 10 cubic yards (measured after crushing) per man per day of ten hours. If the crusher is a large one, say a No. 6 rotary (11 by 36 in.), a man will bar and sledge about double this quantity because it does not need to be broken so fine. The figures are averaged by the authors from actual observed speeds on a number of jobs.

In estimating the cost of crushing stone, the original cost of the plant is an important item. The allowance for this per yard of rock is dependent upon the length of time the plant is to be operated, and the probable value of the machinery when the work is complete, as well as upon the interest on the investment and the cost of repairs. A plant similar to that shown in Fig. 79, page 245, with a 16 by 10-inch jaw crusher, may be estimated to cost from $2,000 to $2,500.†

A very careful analysis of the actual cost of crushing stone for macadam in a large gyratory crusher was made by Mr. Albert F. Noyes, City Engineer of Newton, Mass. His prices are based on common labor at $1.75 per day of nine hours, drill men at $3.00, drill helpers at $1.75, engineman for crusher at $2.00, and two one-horse carts with driver at $5.00. The detail costs per cubic yard of crushed stone were as follows:

*Actual gang employed on a concrete contract for the Metropolitan Water Works, Mass.

†Estimated by Earle C. Bacon.

*Cost per cubic yard of Quarrying and Crushing Hard Green Trap at Newton, Mass.**

Labor of steam drilling	$0.092
Coal, oil, waste, powder, drilling and repairs for drilling and blasting	0.084
Sharpening drills and tools	0.069
Breaking stone for crusher	0.279
Filling carts with rough stone	0.098
Carting stone to crusher	0.072
Feeding crusher	0.053
Engineman of crusher	0.031
Coal, oil, and waste for crusher	0.079
Repairs	0.041
Total cost per cubic yard of crushed stone	$0.898

The total cost of crushing in a jaw crusher conglomerate ledge stone drilled by hand, Mr. Noyes gives as $1.113 per cubic yard; of trap cobble stone wheeled to crusher in barrows, as $0.445 per cubic yard; and of granite cobble stone hauled in carts, as $0.372 per cubic yard.

These costs, which, as well as the wages paid per day, must be taken into account when estimating under other conditions, are based upon an output per hour of 7.7 cubic yards hard green trap, 8.9 cubic yards conglomerate ledge, 11.8 cubic yards trap cobble stone, and 9 cubic yards granite cobble stone.†

Data on Broken Stone. Broken stone is often sold by weight instead of by the cubic yard, because of the variation in volume due to handling or transporting. A cubic yard of broken trap stone may vary in weight from 2 400 to 2 700 pounds.‡ If measured after carting some distance, broken stone will weigh about 10% heavier per cubic yard than at the crusher, because of the settling. The authors have found by repeated measurements that 100 pounds per cubic foot is a fair average weight for screened trap rock after it has been shaken down by hauling, although when measured loose in a small measure an average weight is about 90 pounds. Crusher run stone is about 10% heavier than this because it contains less voids. Stones having lower specific gravities than trap are correspondingly lighter in weight.§

On macadamized or paved roads, if no steep hills are to be encountered, two horses will haul from 6 000 to 7 000 pounds of broken stone to a load. Very high side boards are of course necessary to carry this quantity.

*Annual Report of City Engineer for 1891.

†Cost per cubic yard of stone crushing for pavement in various towns is given in Report Mass. Highway Commission, 1895, p. 38, and further data in *Engineering News*, March 27, 1902, p. 258, and Jan. 15, 1903, p. 55.

‡For data on weights, see article by W. E. McClintock in Journal Association Engineering Societies, Vol. XI., p. 424.

§See table, p. 163.

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