The density of the aggregate was computed from the specific gravity and the unit weight. The density refers to the total volume of solids in the mass. The voids in the aggregate is the complement of the density.

Mixing Concrete

The studies of the effect of time of mixing covered periods of ¼ to 10 minutes. The cement, water and aggregate for the batch were all weighed or measured and placed in the mixing drum before the mixer was started. The mixing period was measured from the time the mixer was started to the beginning of discharge.

In series 93 a parallel set of compression cylinders was made, using hand-mixed concrete made in the manner regularly followed in concrete tests made in this laboratory. In these tests a batch of concrete was proportioned of the size required for one cylinder (about 1/5 cu. ft.); each batch was mixed by hand with a trowel in a shallow metal pan. The methods of molding, etc., were the same for all specimens. These tests were carried out for the purpose of securing a direct comparison between the strength of hand-mixed and machine-mixed concrete.

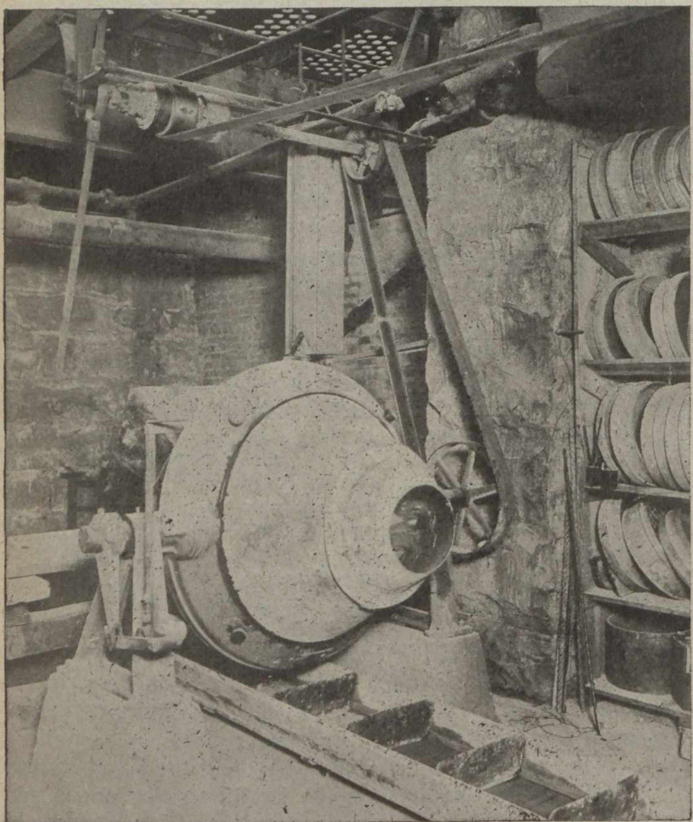

Fig. 3—3½-Cu. Ft. Concrete Mixer Used in Tests
The trough shown in the foreground was used to receive the concrete as the batch was discharged.

The different rates of rotation of the mixer drum used in Series 96 were secured by shifting the driving belt to pulleys of different size or by varying the speed of the motor.

The water tank which supplied the concrete mixer was calibrated in such a way that accurate readings of the quantity of water could be secured. Both hot and cold water were available for mixing purposes. The variations in temperature of mixing water in Series 97 were secured by this means. The extremely low temperatures were reached by placing ice in the water tank. The temperatures near the boiling point were obtained by heating the water tank by means of gas jets.

Fig. 3 shows the mixer used in these tests. The water tank can be seen in the background. In the foreground is shown a trough which was used for receiving the batch as it was discharged from the mixer. The trough is about 5 by 14 ins. in section, 15 ft. long; the bottom is lined with galvanized sheet steel; partitions of ⅛-in. steel plates are provided at intervals of about 15 ins. The sides are sloped slightly to facilitate placing the partitions. It is mounted on castors in such a way that it can be pulled over the floor so as to distribute the concrete throughout its length as the mixer is discharged. The partitions prevent the concrete from flowing from one point to another in the batches mixed to very wet consistencies.

Test Pieces

Most of the tests covered in this report consist of compression tests of 6 by 12-in. concrete cylinders. The wear tests in Series 89 were made on concrete blocks 8 ins. square and 5 ins. in thickness. The hand-mixed specimens in Series 93 were each mixed and proportioned separately. All proportions are expressed in terms of the volume of cement and mixed aggregate. For instance, a 1:4 mix would be made up of 1 cu. ft. of cement (equivalent to 1 sack) and 4 cu. ft. of aggregate, without regard to the size of grading of the aggregate. A 1:4 mix was used in most of the tests; this corresponds to the usual 1:2:3 or 1:1½:3 mix. The exact equivalent of the 1:4 mix expressed in the customary manner would vary with the size and grading of the aggregates.

The consistency of concrete was varied in most of the series. In the tables and diagrams we have used the term "relative consistency." What we have called "100 per cent. consistency" is a plastic mix which when molded in the form of a 6 by 12-in. cylinder will show a shortening of about ¼ to ½ in. if the steel form is slipped off immediately after molding. The quantity of water required to produce this condition varies, of course, with the proportions of the mix, the grading and absorption of the aggregate, etc. Other consistencies for the same mix are expressed in terms of the quantity of water required to produce "normal consistency," *e.g.*, 90% or 150%. It should not be assumed that this "normal consistency" gives concrete of the highest strength. Highest strength has generally been found at consistencies around 90% of normal.

While the method of expressing the consistency by reference to a certain "normal" is most convenient, it should be stated that the method of testing for this consistency described above is not entirely satisfactory. For lean or very rich mixes or for aggregates of unusual or fineness or coarseness, the test does not give concordant results. A penetration test for consistency was used in Series 97. In this test a bar ¾ in. in diameter, 24 ins long, weighing 800 g. was used. The bar was made of thin brass tubing with a pointed steel shoe at one end. The steel point was tapered from 1/16 in. to ¾ in. in a length of 2 ins. It was held in a vertical position over the top of the cylinder with the pointed end in contact with the fresh concrete. Upon being released the bar falling of its own weight penetrated the concrete a certain distance depending on the viscosity of the mass. This test was repeated several times, the depth of penetration in inches measured and the average recorded. If the point struck a large piece of aggregate and did not penetrate, that trial was not considered.

This method gave fair results in Series 97. However, it should be borne in mind that only one mix was used and there was no variation in the character or grading of the aggregate. The method is not satisfactory for wide