MORTAR-MAKING QUALITIES OF SAND.

THE importance of careful discrimination in the selection of ingredients of mortar is a consideration to which attention has been called frequently in these columns. The term "mortar," as defined by the American Railway Engineering Association, is a mixture of fine aggregate (sand or crushed stone screenings), cement or lime, and water, used to bind together the materials in concrete, stone, or brick masonry, or to form a covering for the same. Owing to varying geological conditions, sand, for instance, is one ingredient which may be expected to vary widely in character, and in practice it is found to fully comply with such expectations. In concrete construction the cement is nowadays subjected to careful inspection. The specification requires the sand to be "clean and sharp," although such wide latitude as has heretofore been allowed in its inspection is giving way to closer investigation and scrutiny. This is owing to failures that have been caused by deficiency in both durability and strength, that may be laid only to the inferior quality of sand used.

There is a growing demand for more information concerning the general characteristics of sands, as well as for reliable data on the mortar-making qualities of typical sands. The subject has been very fully discussed in a bulletin recently issued by the University of Illinois, containing a complete account of an investigation undertaken by Mr. C. C. Wiley, with the object of determining the relative value of a number of representative sands in common use in the cities of Illinois. It is of special interest to engineers and contractors, as the methods which it describes and the conclusions arrived at will be found distinctly useful for general guidance.

Description of Tests.—Each sand was tested for cleanness, gradation of size of grains (sieve analysis), specific gravity, voids, and weight. The approximate mineralogical composition and comparative sharpness were also determined. Tests for tensile strength were made on mortars made of each of the sands. In making all of these tests especial care was taken to eliminate the personal factor from the results. There were 576 briquettes prepared and tested, 18 for each specimen of sand. The mixture contained Portland cement, and the various sands mixed in the proportions of 1:3 by weight.

The sands were tested for cleanness as follows: 1,000 grams of the sand were thoroughly agitated in about one gallon of water. The mixture was then allowed to settle for about one minute, experience showing that this allowed sufficient time for the finest sand to settle. The dirty water was then siphoned off, care being taken that none of the sand was carried over with the water. This washing process was repeated until the water showed no discoloration. The sand was then transferred to a pan and as much water as possible drawn off by jarring the sand until the water flushed to the surface, and then removing the water with a pipette. The sand was then re-dried over steam coil and weighed. The loss in weight due to the washing was taken as the amount of suspended matter.

The following standard sieves were used: Nos. 5, 8, 10, 16, 20, 30, 40, 60, 74, 100, 150, and 200. The washed sand was then placed on the top sieve and the whole shaken for forty minutes on an agitator driven by power at 100 r.p.m. After shaking, the sand retained on each sieve was weighed and from these weights the percentage passing each sieve was calculated. In making these calculations the amount of suspended matter, as determined by the cleanness test, was included with the material passing the finest sieve.

The specific gravity of the sands was determined by means of a Schumann flask, consisting of a bulb or bottle into the neck of which a graduated stem fits with a ground joint. The bulb was filled with water and the height of the column of water in the stem read from the graduations. Fifty grams of sand were used and results checked by an additional 50 grams.

The large variation in the percentage of voids in sands as determined by different observers is doubtless due to errors of observation, particularly to a failure to compact all sands to the same extent. For the present series of tests some method of operation was desired which would compact all sands alike, and hence yield reliable results; and, further, a method was desired which would be easy to perform and which could make use of a limited quantity of sand. After a number of trials the following method was adopted:—

A graduated cylinder about 2 in. in diameter and of 500 c.c. capacity was used. About 20 c.c. of sand was placed in this cylinder and compacted by striking lightly with the cylinder on a pad composed of eight thicknesses of heavy cotton flannel. Twelve blows were given at the rate of about two per second with a fall of about one inch, care being taken that the blow was not hard enough to cause the sand to bounce, and also that the cylinder struck squarely so that the sand was not thrown from side to side. Successive increments of the sand were added in this way until the cylinder was filled. The difference between the weight of the empty cylinder and the cylinder full of sand gave the weight of 500 c.c. of dry, compacted sand. Then, knowing the specific gravity of the sand, the percentage of voids was computed from the equation

$$V = 100\,\frac{S - W}{S}$$

in which V is the voids expressed in per cents. of the total volume, W is the weight of the sand, and S is the product of the volume of the sand, its specific gravity, and the weight of a unit volume of water; i.e., S is the weight of an equal volume of sand containing no voids. In the present case S equals 500 multiplied by the specific gravity. The results obtained by the above method were quite uniform, the maximum variations from the mean averaging only from about 0.8 to 1.5 per cent.

The weight per cubic foot of each sand was computed from the weight of 500 c.c. The results averaged about 3 per cent. higher than the results obtained by other observers on similar sands, due evidently to a difference in the method of compacting the sands.

Mineralogical compositions and sharpness were determined by microscopical examinations.

Conclusions.—Following is a brief discussion of the series of tests and the conclusions arrived at:—

The mineralogical composition of a sand is the fundamental factor in its mortar-making qualities, since not only its durability, and hence the durability of the mortar, but the size and gradation of the grains, the nature of the grain surfaces, the strength of the grains themselves, and all the other factors which affect the strength of the mortar are more or less directly dependent on the nature of the component materials of the sand.

The specific gravity of a sand affords but little information relative to its mortar-making qualities, its principal value being as a factor in certain computations. Quartz has a specific gravity of about 2.65; and the nearer the specific gravity of a sand approaches this value the greater is the content of silicious material. A higher