strengths are affected by the moisture contained in the sand aggregate.

No less important than the barrow measurement variations heretofore described are the variations in the strengths of mortars and concretes produced by the moisture contained in the sand aggregate. Unlike the above, however, these variations very commonly tend to decrease the net volume of sand material in the mix. The common effect is, therefore, to increase rather than to decrease the strengths of mortars and concretes. However, there is no evidence that the "bulking" effect of the moisture in the sand has

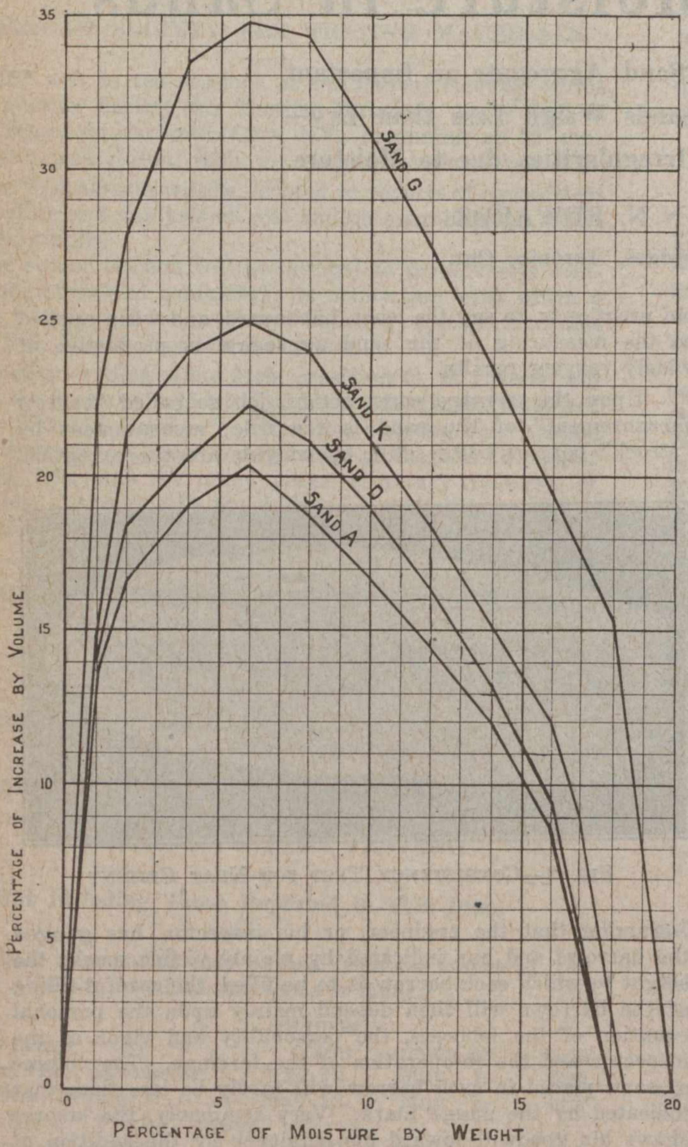

FIG. 3—CURVES SHOWING THE RELATION OF MOISTURE TO VOLUMES OF SAND

been given consideration either in written specifications or in the field operations incident to mortar and concrete making.

Paradoxical as it may seem, the addition of a quantity of water, equal to one per cent. of the weight of a given quantity of dry sand, will serve to throughly coat the surfaces of the sand particles, a uniform distribution of the water being secured by working the sand with a trowel or other tool. This moisture has the rather remarkable effect of increasing the volume of sand by holding the sand particles somewhat rigidly in positions different from those they would readily assume when dry.

A series of tests made for the purpose of securing definite information relative to the "bulking" effect of moisture in sands differing in their granulometric analyses, shows that the surface area of the sand particles is a direct function of the volume increases, produced by varying the quantities of water. In a portion of these tests the water content was varied in relation to the weight of the sand. Fig. 3 shows the volume increase curves derived from tests of three different sands. These curves are typical of those secured from the entire series of tests. In this connection it is of interest to note that when the water content has reached the "flooding" stage, the volume of the sand is the same as that originally occupied by it when thoroughly surface dried. Incidentally, Fig. 3 gives unquestionable proof of the reliability of the common practice of compacting sandy or other earths of rock origin by flooding them with water.

Occasionally, a carload of sand is delivered at the work site in a practically dry—sometimes a thoroughly dry, condition. Doubtless, in such cases the sand was taken from a portion of the pit in which, due to several hot days without rain, a considerable quantity of dry sand had fallen from the pit face and had accumulated at its bottom. This accumulation of dry sand when loaded would, no doubt, contain sufficient heat to render thoroughly dry any moist sand that might be loaded with it. On the contrary, carloads of sand may contain, by reason of continued rainy weather, comparatively large quantities of water. Under such conditions fine sands will retain a larger volume of water per cubic yard than will coarse sands.

Having discussed, at least to a limited degree, the possible range of moisture contained in sands, it will not be amiss to examine its effect mathematically, no allowance being made for the "bulking" effect of moisture contained in the sand.

Assume that a desired strength of concrete can be produced by the use of sand, thoroughly surface dry and mixed with cement and stone aggregate by volume measurement, one part cement, two parts sand, and four parts stone, 100 lbs. of cement being considered as producing 1 cu. ft. of cement paste. Assume now that the sand, as used on the job, contains 6% of moisture, and when shoveled into barrows will bulk up 23%. From simple calculations it is found that the batch as used on the job will contain the following: 100 lbs. cement, 1.54 cu. ft. sand, 4 cu. ft. stone.

Lest the question may arise as to why deficiencies in the quantity of sand are not more commonly noticeable in the field, it may be well to call attention to the fact that a lack of mobility in the mix, due to a lessening of the net volume of sand, is very commonly supplemented by an increase in the volume of water. This increase in the volume of water dilutes the cement paste and ultimately produces a marked change in its physical structure. When examined under the microscope a cement matrix, produced by the use of a quantity of water sufficient for the development of its natural functions in the mix, appears gray in color and adheres closely to the surfaces of the aggregates in amorphous masses containing myriads of minute voids, but nevertheless giving the impression of possessing strength, hardness and rigidity. In comparison, the cement matrix produced by the use of an excessive quantity of water is milky white in color, presenting a loose, skeleton-like, flaky structure lacking cohesiveness and other attributes of physical strength.

Fig. 1 shows photomicrographs (x 60) of "normal" and "wet" specimens. The latter specimen was produced from the concrete of the former by the addition of sufficient water to render it a soft, mushy mixture.

Another condition may be mentioned here which indicates very clearly the "bulking" effect of moisture in sands. While the weights of sands vary with the character of the rock material from which they take their origin and also with their granulometric composition, yet, for any given sand, its weight per cubic foot when dry is greater than its weight when wet, provided, of course, that in each case the sand is shoveled into the measuring receptacle. This condition holds true, even when the wet sand is subjected to a moderate amount of compacting.