Specific gravity.—The specific gravity of a sand or gravel may be considered in two different ways. The *apparent* specific gravity of a sand or gravel is the weight of a certain volume of the material, divided by the weight of an equal volume of water. The *real* specific gravity is, on the other hand, the average specific gravity of the fragments composing the material. The real specific gravity is always higher than the apparent specific gravity.

The apparent specific gravity is easily obtained by weighing a known volume of the sand or gravel and dividing the weight of the material by the weight of an equal volume of water. The material should be shaken down as much as possible in order to reduce the volume of voids to the minimum.

Determination of specific gravity.—The real specific gravity of sand may be determined with a glass vessel having a narrow neck with a reference mark. This is filled to the reference mark with water at a standard temperature. A weighed quantity of the sand under examination is poured into the vessel. The pouring should be very slow in order to prevent air bubbles being carried down with the sand. The displaced water is poured from the vessel until the level is the same as before, viz., at the reference mark. This water has been displaced by the sand, and its weight divided into the weight of the sand gives the real specific gravity of the sand. In order to eliminate the air bubbles, the flask containing the sample and water may be placed in an iron cylinder and connected with an air pump to produce a vacuum.

For very coarse gravels a similar method should be applied, the sample having a weight of at least 1,000 grams. The apparatus should be of metal and of a corresponding size.

Weight per cubic foot.—This value is easily obtained from the apparent specific gravity, D_a, and is equal to $62.484 \times D_a$ lbs.

In referring to the weight per cubic foot, the physical condition of the material should be referred to as loose or compact, and the degree of moisture should be stated as wet, moist or dry. Compact sand or gravel may be described as material that has been deposited in a bin from a height or has been shaken down in a vessel.

Percentage of voids.—If D_r is the real specific gravity, and D_a, be apparent specific gravity the percentages of voids (v) may be calculated from the following formula:—

$$v = 100(D_r - D_a) \div D_r.$$

It has been found that in the case of a uniform sand made of equal spherical grains the voids vary between

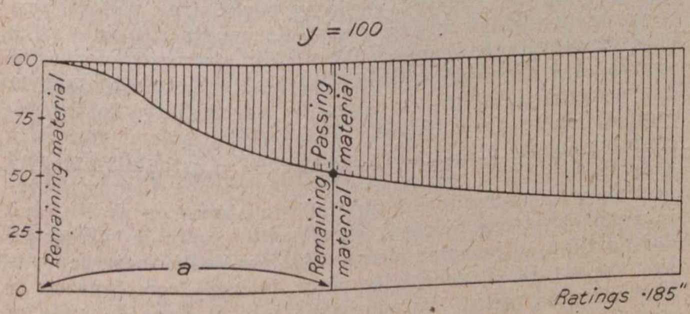

Fig. 1.—Granular Metric Analysis—Shaded Area is Proportional to Fineness of Material

25.95% and 47.64%, depending upon the arrangement of the grains. In the measurement of sands containing grains of different size and of angular shape, the percentage of voids was very often nearly 37%, the average of the two extreme theoretical values. The voids are lower in sands made of grains varying in size than in uniform material; they are also lower in coarse sands than in fine-grained ones.

Diagrams of percentage of voids in functions of the apparent specific gravity, for given values of real specific gravity are straight lines. If the apparent specific gravities are taken as abscissae, and the percentage of voids as ordinates, all the diagrams corresponding to different values of D_r converge at the point $v = 100$ on the axis of the ordinates. The diagram for which $D_r = A$ cuts the axis of the abscissae at a point for which $D_a = A$ (Fig. 3).

The percentage of voids may be directly measured by using a beaker perforated on the side to admit a siphon.

The beaker is filled with water, and the glass tubing acting as a siphon brings the water in the beaker to a constant level. A volume V' of the material to be tested in then poured into the beaker driving a volume V of water out of the beaker through the siphon.

The percentage of voids (v) is given by the following equation:—

$$v = 100(V - V') \div V.$$

Permeability.—While the porosity of a sand or gravel is expressed by the amount of pore space or the percentage

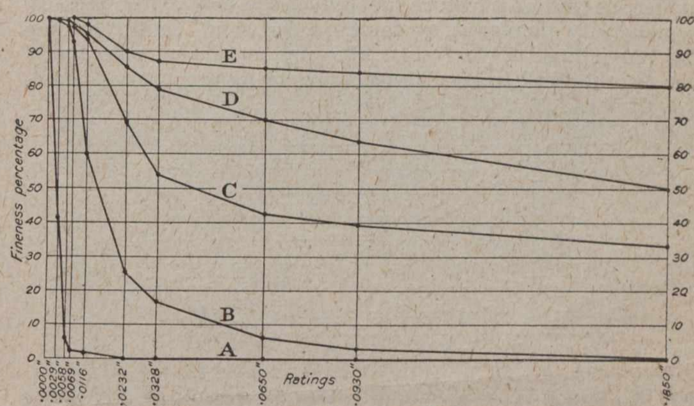

Fig. 2—Granular Metric Analysis of Five Different Sands and Gravels of Various Percentages of Fineness

of voids, the permeability is the quality possessed by certain of these materials to permit an easy passage of liquids or gases. This quality depends partly upon the percentage of voids, but also upon the size of the voids. It is a very important factor in moulding sands and filtering sands. If the pores are small, capillarity and friction prevent or lessen the passage of liquids and gases. Coarse material is therefore more permeable than fine grained. Sands uniform in size are also more permeable than sands of a similar grade, made up of various sizes.

Permeability may be directly measured by filling a tube with a given volume of the material to be tested, and measuring the time necessary for a given quantity of water or air to pass through the material.

Absorption.—On putting a sample of dry gravel or sand into water, a certain amount of water is absorbed by the fragments. The amount depends principally upon the nature of the fragments. The absorption for quartz grains is negligible, but for cleavable minerals such as calcite and feldspar it is larger, and for fragments of porous rocks, such as sandstone, still greater. To measure the percentage of absorption, a sample of the material is placed in water for about one hour; it is then removed and spread on blotting paper and when surface dry, weighed in this state. The sample is then dried over a hot plate to a constant weight. The difference in weight between the surface-dry material and the dried material, multiplied by 100 and divided by the weight of the dried material, gives the percentage of absorption.

Moisture.—The percentage of moisture is obtained by weighing a sample of the material in its natural state—as it comes out of the pit or ready for use—and the sample thoroughly dried. The difference of the two weighings, multiplied by 100, and divided by the weight of the dried sample, represents the percentage of moisture.

Percentage of silt.—This is measured as follows: A weighed sample of the dry material, about 200 grams, is