tities of mortar or of concrete materials, is a quite different proposition when considered from an economic viewpoint. The results of the tests herein described give ample evidence of the economy of well-graded sands when used as aggregate for mortars and concretes proportioned in accordance with the surface-area method. It will frequently happen that such an investigation will involve only the collecting and testing of sample aggregates secured from commercial companies dealing in these materials. In other cases an investigation might involve a search for satisfactory sand and gravel deposits or for quarry sites.

It is an encouraging fact, and worthy of note in passing, that tests of aggregates are being regarded of much greater importance and are receiving correspondingly greater attention than formerly.

Practical Application of the Method

The adaptation of the surface-area method of proportioning mortars and concretes to both laboratory investigations and to field construction operations presents no serious difficulties. The outstanding feature of this method, in so far as its practical application is concerned, is the importance of knowing the granulometric composition of the aggregates. It must be admitted that the securing of this all-important information involves a comparatively small amount of labor, and by way of equipment the use of only the necessary scales, standard sieves and screens. The time element involved is comparatively negligible, since, as described more fully herein, the computation work of determining areas and quantities of cement can be largely reduced to the most simple mathematical operations by the use of tables and diagrams. For use in the laboratory and in the field, diagrams drawn to a large scale increase accuracy and reduce labor.

Figs. 21 and 22 are designed for use in determining the surface areas of sand aggregate. The former is intended for laboratory use and the latter for both laboratory and field use. These diagrams are derived from information contained in Table III.

Fig. 23 is designed for use in determining the surface area of stone aggregate and is intended for both field and laboratory use.

Fig. 24 shows a conversion diagram for determining the relative quantity of cement in pounds per 100 lb. of sand from the corresponding relation of cement in grams to the surface area of 1,000 g. of sand and vice versâ.

Use of Diagrams.—The following examples explain the method of using the diagrams shown in Figs. 21 to 24, inclusive:

Example No. 1.—Required to find the composition of a batch of mortar using 1000 g. of sand A and a cement content proportioned: 1 g. cement to 15 sq. in. sand area.

Sand Area.

Sieve.	Grading, per cent.	Weight, g.	Area (Fig. 21), sq. in.
P 4 –R 8	15.0	150	142
P 8 –R 10	5.0	50	75
P 10–R 20	25.0	250	694
P 20–R 30	15.0	150	676
P 30–R 40	15.0	150	997
P 40–R 50	10.0	100	992
P 50–R 80	10.0	100	1,348
P 80–R 100	5.0	50	932
Totals	100.0	1,000	5,856

$$\text{Cement (g.)} = \frac{5856}{15} = 390.5.$$

$$\text{Water (cc.)} = 390.5 \times 22.25 \text{ per cent. (normal consistency)} + \frac{5856}{210} = 115.$$

Example No. 2.—Required to find the composition of a batch of concrete using 100 lbs. of sand A, 200 lbs. of broken stone graded as shown below, and a cement content proportioned: 1 g. cement to 15 sq. in. aggregate area.

The area of the sand aggregate is determined as shown in Example No. 1 except that Fig. 22 is used, therefore: Sand area (sq. ft.) = 1,845 sq. ft. per 100 lbs.

Stone Area.

Screen.	Grading, per cent.	Weight, lbs.	Area (Fig. 23), sq. ft.
P 1½ in.–R 1 in.	60.0	120	69.0
P 1 in.–R ¾ in.	25.0	50	41.5
P ¾ in.–R ½ in.	10.0	20	24.5
P ½ in.–R ¼ in.	5.0	10	16.0
Totals	100.0	200	151.0

Total area of aggregates = 1,996 sq. ft.

Cement (lb.) = 19.96 × 2.11 (Fig. 24) = 42.12 lbs.

Practical Limitations

It is especially important to note that in its application the surface-area method of proportioning admits of certain physical limitations. The more important of these are here discussed briefly.

Effect of Dust.—The effect upon the physical properties of mortars and concretes of a sandy "dust" passing a No. 100 sieve is not definitely known. The main feature to be considered in this connection is the relation of the sizes of the "dust" particles to the sizes of the cement particles. A microscopic examination of the cement used in the tests described in this paper showed the sizes of the greater portion of the cement particles to range from 1.5 to 3.3 μ[1] in their largest dimensions with an average dimension of approximately 2.2 μ, that is $\frac{1}{11,540}$ in. Some of the larger particles measured ranged in size up to 6.7 μ.

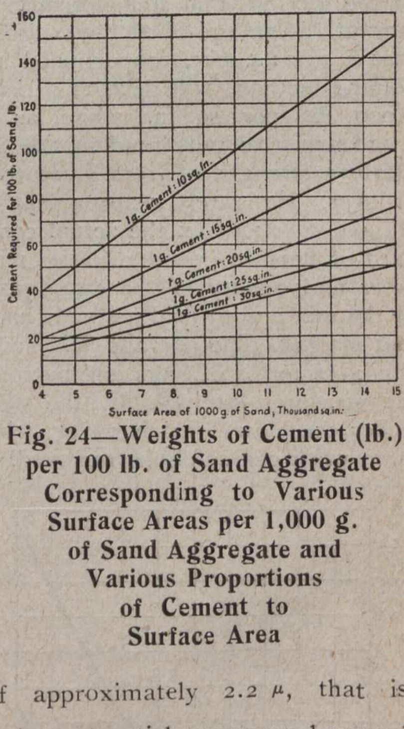

Fig. 24—Weights of Cement (lb.) per 100 lb. of Sand Aggregate Corresponding to Various Surface Areas per 1,000 g. of Sand Aggregate and Various Proportions of Cement to Surface Area

Disregarding entirely the effect of the surface tension of the water used in the mix, it is reasonable to assume that the particles of dust do not become "coated" with cement paste, but that instead they become linked to adjoining particles of aggregate by one or more separate cement bonds. Doubtless the cohesion existing between particles of cement is greater than the adhesion existing between these particles and the particles of dust or other aggregate. It follows, therefore, that the strength of the mass must be somewhat weakened by the inclusion of dust in the aggregate.

Laboratory vs. Field.—The most important difference between the preparation of mortars in the laboratory and the field is found in the methods of mixing. In the laboratory the operator submits the mix to a thorough

[1] One micron (μ) = $\frac{1}{25390}$ in.