

FLOWABILITY OF CONCRETE AND ITS MEASUREMENT BY MEANS OF THE "FLOW TABLE"

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FLOWABILITY is one of the several expressions sometimes used to describe the consistency or placeability of concrete. The quality of a concrete or mortar mixture which has to do with ease of placing may be referred to as "consistency," "mobility," "plasticity," "workability," or "flowability," and these words, although having, perhaps, slightly different meanings to many people, are generally synonymous as used.

The consistency or flowability which must be used in any case is dependent upon the nature of the work, type and arrangement of forms and reinforcing steel. For any given condition there is some minimum flowability which must be attained to result in good workmanship, and in economy and proper progress in the process of concreting. With given materials and proportions, flowability may be increased only by the use of more mixing water, which in turn will lower compressive strength. It is generally agreed that concretes must have the same consistency or flowability to be comparable, yet we have had no satisfactory method for measuring and controlling consistency. Consistency has usually been crudely estimated by eye or the judgment or feel of the operator, and, as a result, test data obtained even in the same laboratory, must in many cases remain as small and isolated groups of tests, none of which bears any definite and known relation to the others. Studies made of the results of such tests are likely to lead to faulty conclusions since such concretes are not comparable.

Slump Test Unsatisfactory

The cylinder slump test and its modification, the cone slump, have been proposed and used for this purpose, and while they are far superior to the old method of "eye" and "feel," they fail to fully meet the requirements of such a test. One criticism of both is that the concrete seldom really slumps when the form is withdrawn, but the mass merely collapses into an unsymmetrical pile. In this respect the cone slump is less satisfactory than the cylinder, since when the former is employed the mass loses all lateral support as soon as the upward movement of the form is started and the tendency of the top to fall over is unresisted. A further criticism of both slump tests is that with different gradations of aggregates, or with different proportions of cement to aggregate, equal slumps do not result in concretes of equal flowabilities, so that the resulting concretes are not comparable.

Investigations in the concrete laboratory of the Bureau of Standards have emphasized that the control and the measurement of flowability is of fundamental importance, not only in laboratory testing of concrete but in the practical application of the results of such investigations to concreting practice in the field.

Nature and Use of Flow-Table

During the past year and a half a new form of consistency measuring apparatus, designated as the "flow-table," has been used in the concrete laboratory of the Bureau. The type first employed consisted of a piece of sheet steel about 30 ins. square, supported at its centre in a horizontal position. A mass of concrete was molded at the centre, the mold withdrawn, and the edge of the plate struck

a given number of weighted, downward blows with a suitable hammer arrangement. The amount of spread of the results, but further experiment resulted in a table of the mass was a measure of the flowability of the concrete.

The preceding type of apparatus gave very satisfactory type shown in Fig. 1. This consists of a metal covered table top which can be raised vertically by means of a cam working at the end of a vertical post to which the top is attached. The height of drop can be adjusted by means of a bolt at the lower end of the shaft. A mass of concrete or mortar is molded at the centre of the table in a sheet metal mold which has the shape of a hollow frustrum of a cone. For aggregates up to 2-in. maximum size this cone has a height of 6 ins. and upper and lower diameters of 8 ins. and 12 ins. For smaller aggregates, when made up in small quantities, a cone having a height of 3 ins. and upper and lower diameters of 4 ins. and 6 ins. is used. The mass of concrete is tamped just sufficiently to completely fill the form, the form is withdrawn, and the table top is dropped 15 times through a distance of $\frac{1}{2}$ in. The mass flattens and usually spreads concentrically. Two diameters at right

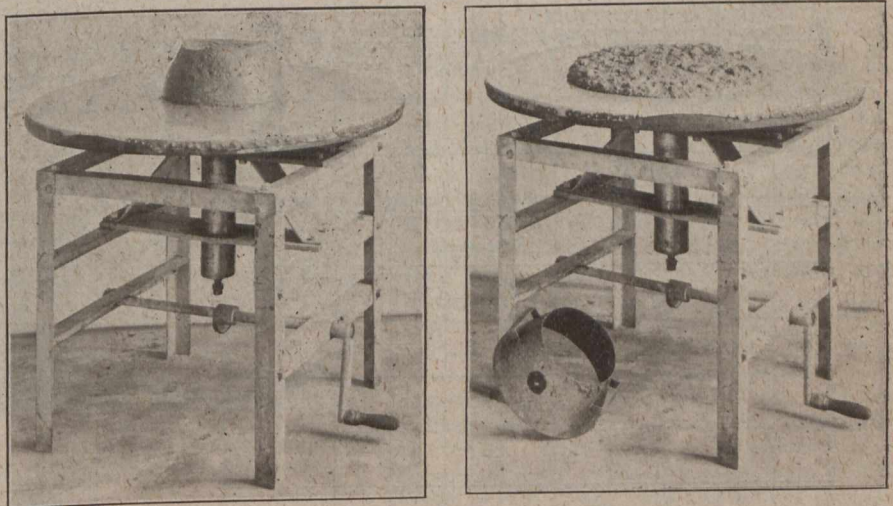


FIG. 1—FLOW-TABLE USED IN LABORATORY OF BUREAU OF STANDARDS FOR MEASURING CONSISTENCY OF CONCRETE. CONCRETE SHOWN IS 1:1½:3 OF STIFF CONSISTENCY

angles to each other are measured, the long and the short if difference is apparent, by means of a self-reading caliper which is so graduated that the sum of the two readings is the value for "flowability," which may also be calculated by dividing the new diameter by the old and multiplying by 100.

Relation Between Flowability and Quantity of Mixing Water

A typical curve showing the relation between the flowability of concrete as measured by the "flow-table," and the quantity of mixing water used is shown in Fig. 2. Five separate batches of 1:2½:3½ volume proportion concrete were prepared with percentages of mixing water ranging from 7 to 11. 7% resulted in a concrete too dry for ordinary construction work. 9% of mixing water resulted in a concrete which flowed sluggishly in a steel chute which had an angle of 21 degs. 10% furnished as wet and fluid a concrete as is ever needed in practice. With 11% a sloppy, segregating concrete difficult to properly sample was obtained. The added water in excess of 10% resulted in practically no increase in flowability as measured by both the flow-table and the steel chute. This straight line relation between mixing water and flow as measured by the flow-table is characteristic of results obtained with other concretes, mortars, neat cement and lime pastes.

Comparison of Flow-Table and Slump Methods

Fig. 3 shows graphically some results of tests in which the "flow-table" and the "cone slump" were used. A single batch of concrete was employed in this case for all determina-

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