CHAPTER 3

MEASUREMENT OF WORKABILITY OF CONCRETE

3.1 Introduction

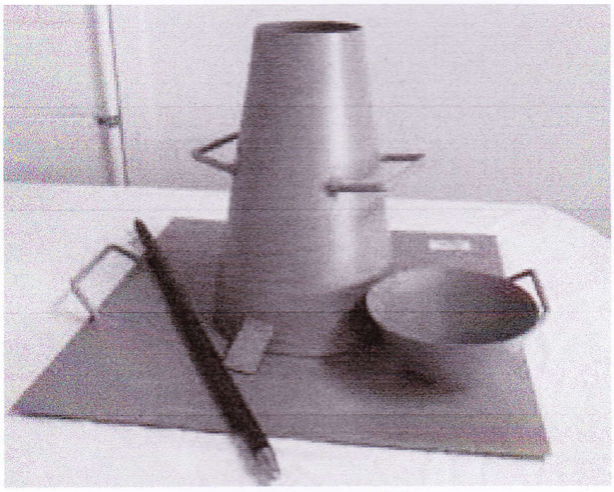
The quantitative assessment describing concrete as being of high or low workability or semi-dry or plastic, etc. may mean different things to different people. The commonly used practice of defining this physical property by a numerical scale based on the empirical tests for its measurement has been found to be unsatisfactory in many situations, thus restricting its applications, in that many builders prefer to rely on subjective assessment rather than on empirical tests.

3.2 Workability tests

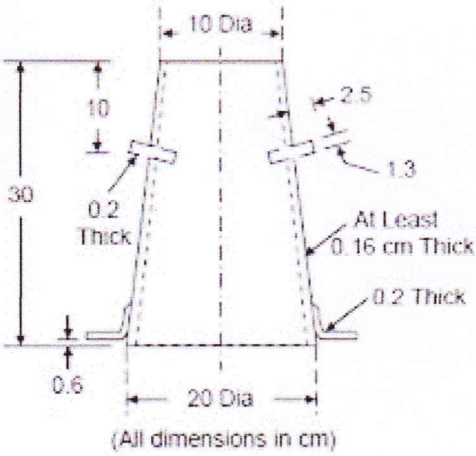
A number of different empirical tests are available for measuring the workability of fresh concrete, but none of them is wholly satisfactory. Each test measures only a particular aspect of it and there is really no unique method which measures the workability of concrete in its totality. However, by checking and controlling the uniformity of the workability, it is easier to ensure a uniform quality of concrete and hence uniform strength for a particular job. The empirical tests widely used are

(i) the slump test,
(ii) the compacting factor test,
(iii) the Vee-Bee consistency test, and
(iv) the flow test.
(v) the Kelley ball test

A typical test apparatus is shown in Fig. 3.1. Of these four tests, the slump test is perhaps the most widely used, primarily because of the simplicity of the apparatus required and the test procedure. The slump test indicates the behavior of a compacted concrete cone under the action of gravitational forces. The test is carried out with a mould called the slump cone. The slump cone is placed on a horizontal and non-absorbent surface and filled in three equal layers of fresh concrete, each layer being tamped 25 times with a standard tamping rod. The top layer is struck off level and the mould is lifted vertically without disturbing the concrete cone. The subsidence of concrete in millimeters is termed the slump. Test procedures are shown in Fig.3.2. After the test when concrete slumps evenly all around is called *true slump*. In the case of very lean concrete, one-half of the cone may slide down the other which is called a *shear slump*,' or it may *collapse* in case of very wet concretes as shown in Fig. 3.3. The slump test is essentially a measure of *consistency* or the *wetness* of the mix. The test is suitable only for concretes of medium to high workabilities (i.e. having slump values of 25 mm to 125mm). For very stiff mixes having zero slump the slump test does not indicate any difference in concretes of different workabilities. It must be appreciated that the different concretes of the same slump may, indeed, have different workabilities under the site conditions. However, the slump test has been found to be useful in ensuring the uniformity among different batches of supposedly similar concrete under field conditions. The slump test is limited to concretes with maximum size of aggregate less than 40mm.

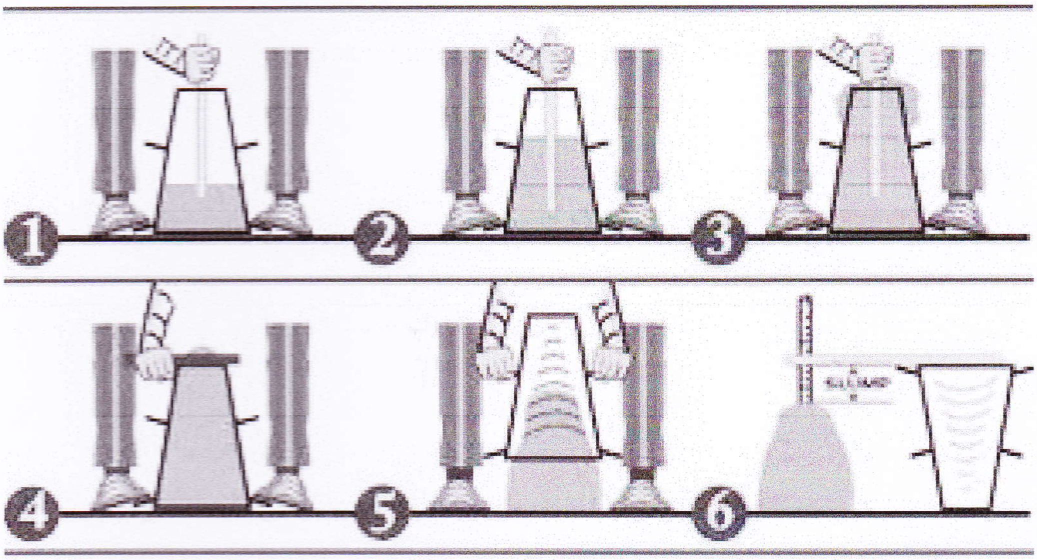


a. contents of the apparatus



c. Slump cone

Fig. 3.1 slump test apparatus



a. Schematic diagram of the test procedures

b. Test procedures

Fig. 3.2 Procedures of slump test

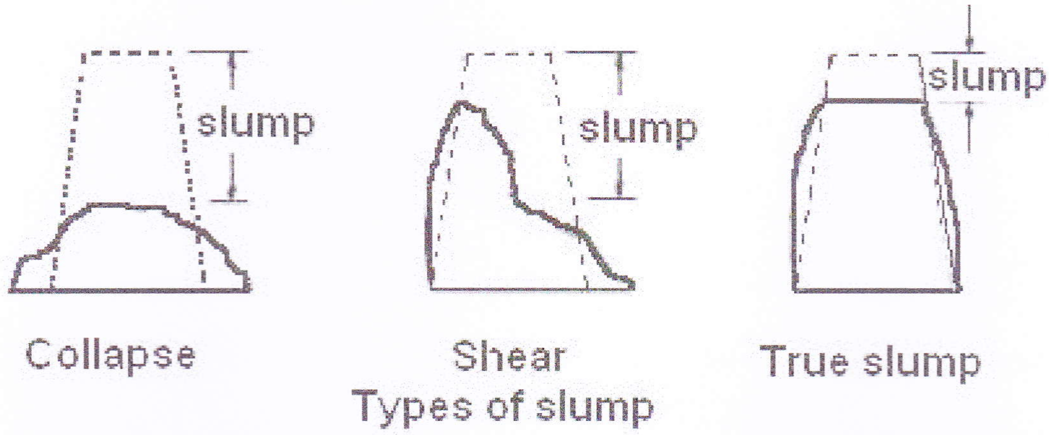


Fig. 3.3 Types of slump

The *compacting factor test* gives the behavior of fresh concrete under the action of external forces, Fig 3.4. It measures the compactability of concrete which is an important aspect of workability, by measuring the amount of compaction achieved for a given amount of work. The compacting factor test has been held to be more accurate than slump test, especially for concrete mixes of *medium* and *low workabilities*, i.e. compacting factor of 0.9 to 0.8, because the test is more sensitive and gives more consistent results. The test has been more popular in laboratory conditions. For concrete of very low workabilities of the order of 0.70 or below, the test is not suitable, because this concrete cannot be fully compacted for comparison in the manner described in the test. The relationship between slump and compacting factor is given in Fig. 3.5.

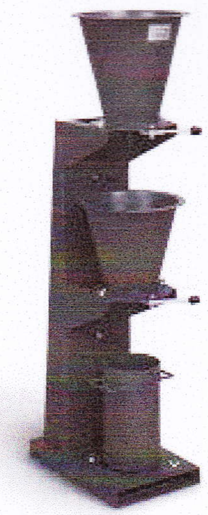


Fig. 3.4 The compacting factor apparatus

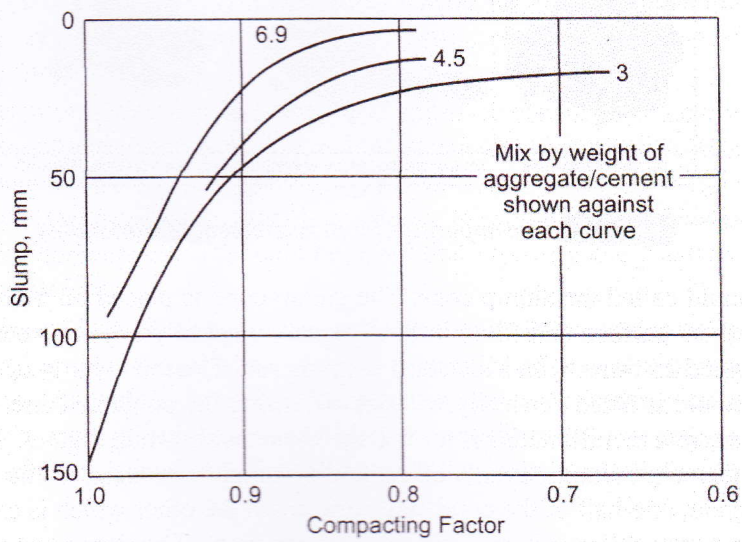


Fig. 3.5 The relationship between slump and compacting factor

The Vee-Bee test is suitable for stiff concrete mixes having *low* and *very low workability*. Compared to the slump test and compacting factor test, the Vee-Bee test has an advantage that the concrete in the test receives a similar treatment as it would in actual practice. The test consists in molding a fresh concrete cone in a cylindrical container mounted on a vibrating table as shown in Fig. 3.6. The concrete cone when subjected to vibration by starting the

vibrator starts to occupy the cylindrical container by the way of getting remolded. The *remolding* is considered complete, when the concrete surface becomes horizontal. The time required for complete remolding in seconds is considered as a measure of workability and is expressed as the number of Vee-Bee seconds. Since the end point of the test when the concrete surface becomes horizontal is to be ascertained visually, it introduces a source of error which is more pronounced for concrete mixes of high workability and consequently records low Vee-Bee time. For concrete of slump in excess of 125 mm, the remolding is so quick that time cannot be measured. The test is therefore, not suitable for concrete of higher workability, i.e. slump of 75 mm or above. An approximate relationship between slump and Vee-Bee time is given in the Fig. 3.7.

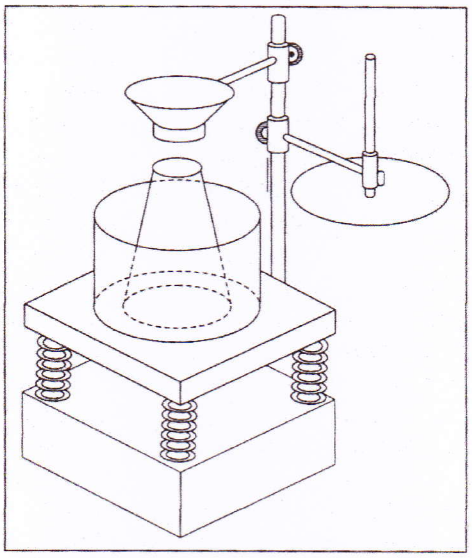


Fig. 3.6 The Vee-Bee Apparatus

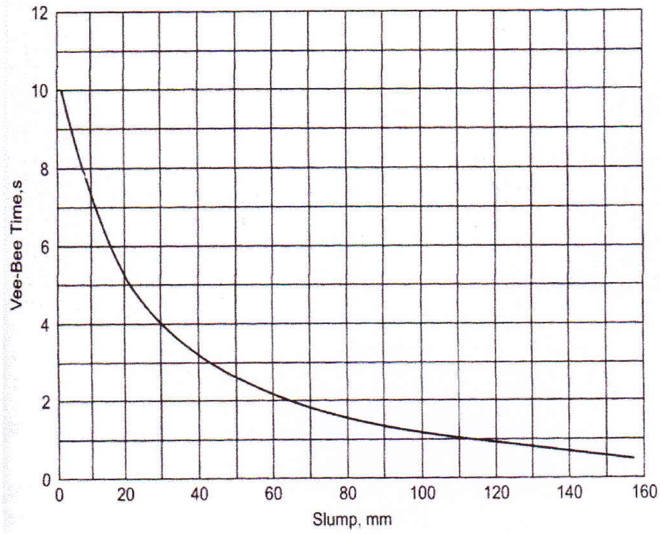


Fig. 3.7 Relationship between slump and Vee-bee time

The flow table test, Fig. 3.8, measures the horizontal spread of a concrete cone specimen after being subjected to jolting. Multiple versions of the test have been proposed since its original introduction in Germany in the 1930s. The test was added to the British Standards in 1983in response to the increase use of highly fluid concretes. The test is sometime referred to as the DIN flow table, in reference to its inclusion in German standard DIN 1048. The test is currently standardized in the Europe as EN 12350-5. The apparatus consists of a 700 mm square wooden top plate lined with a hin metal sheet, as shown in Figure 12. The plate is hinged on one end to a base, while on the ther end, clips allow the plate to be lifted a vertical distance of 40 mm. Etched into the metal sheet are two perpendicular lines that cross in the center of the plate and a 200 mm circle concentric with the center of the plate. The frustum of a cone used to mold the concrete is shorter than the slump cone, with a top diameter of 130 mm and with a bottom diameter and height of 200 mm.

The Kelly ball test, an ASTM method, is a simple field method for measuring the consistency of plastic concrete. The apparatus is a simple portable metal ball that penetrates the surface of concrete. It can be performed on the in-place concrete much faster and accurately. Test results are accurate, reliable and compare favorably with results obtained through the more commonly known and used slump test.

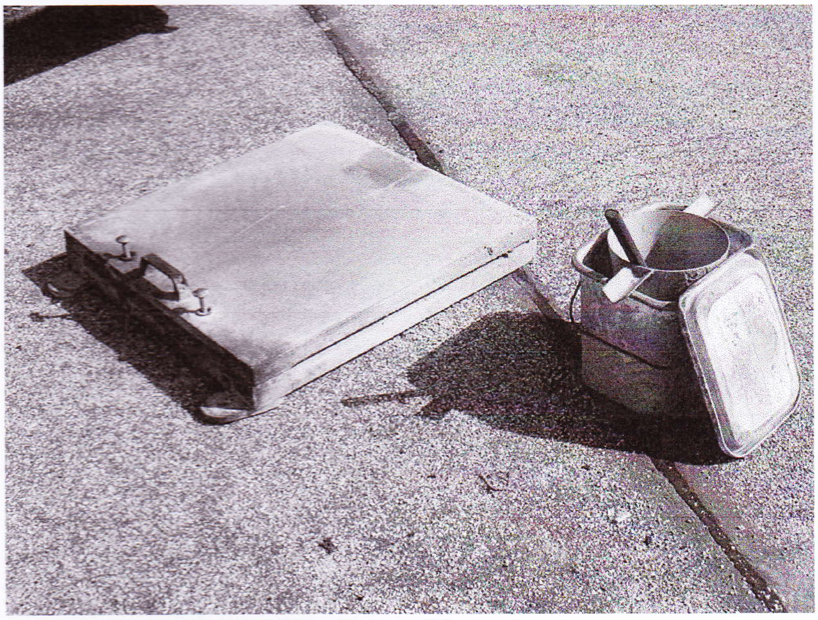
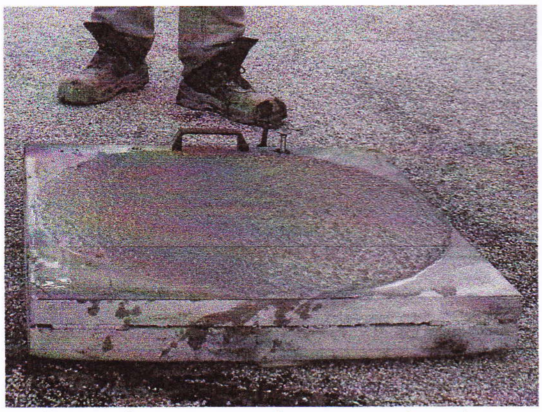


Fig. 3.8 The flow table test apparatus

a. Filling the cone



b. flow of concrete after removing the cone

Fig. 3.9 Procedures of Flow table test

The Kelly ball test device consists of a cylindrical metal plunger with a hemi-spherically shaped metal ball of 150-mm diameter and 115-mm height at the bottom and a handle at the top as shown in Fig. 3.10. The total assembly weighs 15 kg. A stirrup frame guides the plunger and acts as reference for measuring the depth of penetration. The plunger is graduated for noting the penetration. The semicircular bearing plates at each foot of the frame serve to prevent the frame from tilting. There is a movable pinch clamp which makes it easier to measure the depth of penetration. This clamp is attached to the top of the plunger where it remains until the ball has penetrated the concrete. Then the clamp is lowered until it comes in contact with the frame. When the entire apparatus is removed from the concrete, the position of the clamp on the handle gives the depth of penetration of the ball. The apparatus can be mounted on a simple wooden base with a tin can for holding rags for wiping the ball clean after each test. In addition to carrying the apparatus, it acts as a footboard for the person testing the wet concrete.

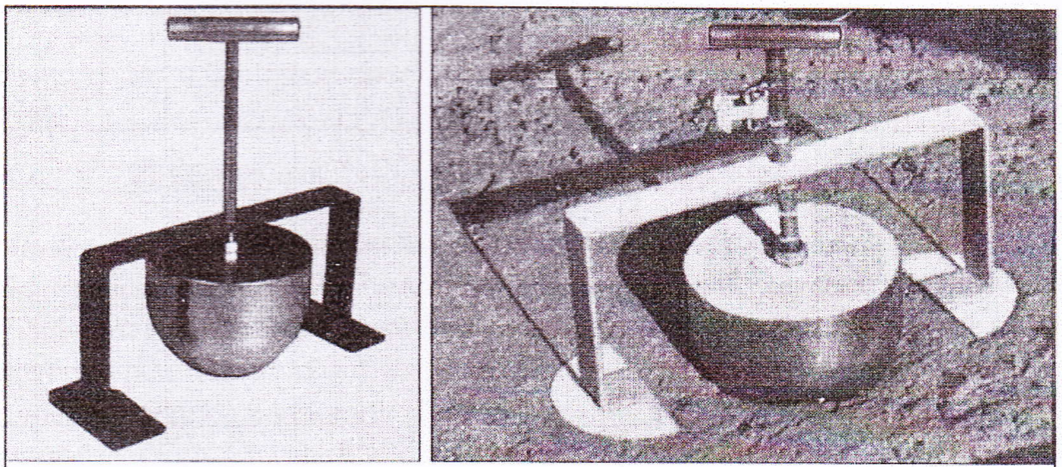


Fig. 3.10 The Kelley Ball apparatuse

The test can be performed quickly and easily at job site directly in the fresh concrete or in a separate container.

1. The ball is held vertically by the handle and brought in light contact with the concrete surface. The zero mark on the rod should appear at the revel of the frame.

2. The handle is released and the ball is allowed to sink freely into the concrete. The depth of the penetration is indicated by the reading on the plunger which has slipped up through the frame from the zero mark. It is not necessary to make any adjustment for the slight sinking of the bearing plates into the concrete.

3. At least three separate measurements of penetration are carried out for each batch-each test is performed with the foot of the frame at least 150 mm away from the place where it rested in the previous test. The consistency is based on an average of first three penetration readings. A penetration of 25mm measured by the Kelly ball method approximately corresponds to about 50mm of slump. The following precautions should be taken:

(i) If the test is performed at the site, the penetration should be measured at distance at least 225 mm away from the nearest face of any forms or walls. In case of pavement concrete test, the horizontal distance of 225 mm between the penetration point on the sub-grade and the form edge of the finished level section of concrete.

(ii) The minimum depth of concrete to be tested for consistency should be more than the larger of 150 mm or three times the maximum size of the aggregates used.

(iii) The surface of concrete to be tested for consistency should be smooth and level. The disturbance of the concrete caused by the ball should be limited to as small an area as possible.

The major advantage of the Kelly ball test is that it can be performed at the job site, thus eliminating the time and effort required to prepare samples to be sent to the laboratory. Three or more Kelly ball tests can be made in a time less than it takes to make one slump test, thus eliminating any delay in finishing operations. The Kelly ball test device is easy to carry to the

job site and can be used for further tests simply by cleaning the ball with an oily rag. The Kelly ball device can be used for measuring the consistency of stiff mixture of concrete with large size coarse aggregates, as long as adequate depth is available for penetration.

As each of the above tests measures only a particular aspect of workability, there is no rigid correlation between the workabilities of concrete as measured by different test methods. In the absence of definite correlations between different measures of workability under different conditions, it has been recommended that, for a given concrete, the appropriate test method be decided beforehand and workability be expressed in terms of such a test only, rather than be interpreted from the results of other tests. Table 3.1 gives the range of the expected values of workability measured by different test methods for comparable concretes.

Table 3.1 Range of the expected values of workability measured by different test methods for comparable concretes

		Values of workability			
Placing condition	*Degree of workability*	*Compacting factor, maximum size of aggregate*			*Vee-Bee time, slump for 20 mm aggregate*
		10 mm	*20 mm*	*40 mm*	
(i) Hand compaction of heavily reinforced sections.	High (flowing)	0.95	0.95	0.95	125–150 mm slump
(ii) Concreting of lightly reinforced section by hand or vibration of heavily reinforced sections.	Medium (plastic)	0.88	0.90	0.92	5–2 s Vee-Bee time, 25–75 mm slump
(iii) Concreting of lightly reinforced sections with vibration; road pavements and slabs with hand-operated vibrators; and vibration of mass concrete.	Low (stiff plastic)	0.82	0.84	0.85	10–5 s Vee-Bee time, 5–50 mm slump
(iv) Concreting of shallow sections with vibrations.	Very low (stiff)	0.75	0.78	0.80	20–10 s Vee-Bee time, 0–25 mm slump
(v) Concreting by intensive vibrations with vibro-pressing, centrifugation, etc.	Extremely low (very stiff)	0.65	0.68	Not used	30–20 s Vee-Bee time

In addition to the specific faults inherent to each test, the major drawbacks are summarized below.

(i) The tests are quite arbitrary and empirical as far as the measurement of workability is concerned because each of these tests is a single-point test measuring a single quantity which at times may classify two such concretes 'identical', which may behave quite differently on the job.

(ii) The results from these tests are influenced by minor variations in techniques of carrying out the test, i.e. they are operator sensitive.

(iii) None of the tests is capable of dealing with concrete of whole range of workabilities, e.g. the slump test is quite incapable of differentiating between two concretes of very low workability (zero slump) or two concretes of very high workability (collapse slump). Moreover, the test results could be used as a simple statement of qualitative behavior of concrete under particular circumstances.

However, with all their faults, the empirical tests have facilitated progress in concrete mix design. There is a strong need for the development of a new rational test based on rheological techniques. The recent attempts to rigorously define the workability in terms of one or more physical constants by an idealized model is a distinct possibility.

3.3 References

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3. PROPERTIES OF FLOWING CONCRETE AND SELF-COMPACTING CONCRETE WITH HIGH-PERFROMACE SUPERPLASTICIER - Properties of Flowing and Self Compacting concretes.pdf

4. ACI Concrete Certification Test Preparation (Includes Videos)

5. download test video - Web - WebCrawler

6. http://en.wikipedia.org/wiki/File:Flow_Test_Equipment.JPG

3.4 Problems

1. Draw the following with net sketches:
a. Relationship between slump and the compacting factor values.
b. Relationship between slump values and Vee-bee results.
c. The method of measuring the slump value
d. The three types of slump
e. Details of the slump cone

2. Differentiate between the following test:
a. slump test and the compacting factor test
b. slump test and Kelly ball test
c. compacting factor test and Vee-Bee test

3. State the advantages and disadvantages of the following tersts:
a. Kelley ball test
b. slump test
c. Vee-Bee test

4. What is the performance parameter that the following test measure?
a. the slump test b. the compacting factor test c. the Vee-Bee test