An Alternative Method for Assessment of Consistency of Cement Paste

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Abstract:

Concrete's versatility, durability, and economy have made it world's most used construction material. The main reason for this status is that this material can be moulded into desired geometrical shape in dense state while it is in its fresh state to impart potential to harden with time to exhibit desired structural strength and stiffness characteristics. The realization of concrete in its dense state is dictated by its workability. Realization of desired workability is not certainly an end by itself, but it is a means to an end in concrete technology.

Workability of Fresh Concrete is its ability to be worked is almost a tautology; nevertheless this statement provides the most general definition and is the one from which it is useful to start. Of course, a little reflection on practical experience soon shows that this term workability must in some way cover the ability of the concrete to flow in a mould or formwork, perhaps through congested reinforcement, the ability to be compacted to a minimum volume, perhaps the ability to perform satisfactorily in transporting operation or forming process , and may be other requirements as well. An alternative method for assessment of consistency of cement paste is studied and presented in this paper

Key words; Workability, Consistency of cement paste , Vicat's test apparatus, Phenomenological Model

1. INTRODUCTION

Though many penetration tests have been developed, only two have gained acceptance, viz., Vicat's apparatus for assessing normal consistency and Kelly ball test for workability of concrete. The analysis of vicat's apparatus is made here Even in this case, the penetration of a standard plunger reflects the consistency of the cement paste. This paper deals with the consistency of the cement paste.

1.1 Objectives

This investigation consists of the following aspects.

- Basic principles with particular emphasis on soil – concrete analogy and their implications
- Experimental Investigation
- Analysis of data and Development of Phenomenological Model
- Validation of Phenomenological Model

1.2 Consistency of cement paste

Consistency is the tendency of the cement to get wetted. This is measured by Vicat's apparatus. The water content, corresponding to a standard penetration using the standard plunger, is referred to as normal consistency. This is an important property as this is a major parameter while determining the setting time and compressive strength of cement.

Though, the method of assessment of normal consistency is same in Indian (BIS), British (BS) and American (ASTM) codes of practice, the normal consistency is defined for different depths of penetration in different codes. IS 4031 - 1988 define normal consistency as the water content corresponding to a penetration of 5 to 7 mm from the bottom of the mould,

Whereas, ASTM C-187 defines it as the water content corresponding to a penetration of 10+1 mm from the original surface of the paste. The regular method of finding normal consistency is a trial and error method. Penetration is found out for different water contents and the water content that gives the standard penetration will be taken as normal consistency. The objective of this investigation is to determine the normal consistency in a single trail.

2.0 An alternative method for assessment of consistency of cement paste : In the first part of the investigation, one brand of cement (brand name' ACC) was used. The cement used was ground to different finenesses. The chemical composition was kept constant. Table 1.1 provides the details of chemical composition of the cement.

Table 1.1 Chemical composition of Cement (percent by weight)

Cao	Sio_2	Al_2o_3	Fe_2o_3	Mgo	So_3	IR	LoI
60.98	20.00	6.79	3.51	1.41	2.20	2.10	3.01

IR: Insoluble residue LOI: Loss on ignition

The finenesses determined using Blaine's air permeability method to verify the validity of this 'One-point method', cements of two more brands

(Vasavadutta and Ultratech) were used.

The normal consistency was determined. The mixing and preparation of test specimens were done as per the guidelines of code IS-5513-1996

The second set of tests was conducted on Vasavadutta cement. The validity of the correlation between the two tests was verified using Ultratech cement

In case of Vicat's test, mixing was done manually; Penetrations (from bottom) were measured for different water contents.

In case of cone penetration test, mixing was done using a motorized mortar mixer (Aimil product specifications).

The paste was placed in two layers; each layer being compacted by giving 25 jolts on a flow table. The penetrations (from top) were measured for different water contents. In this test, at least two separate mixes were tested (which were prepared at a time) for each water content since the test is very sensitive. The results were plotted as shown in figure 1.

Table 1 Vicat's penetrations for two cements

Sample	Water content w-%	Penetration (mm) measured from bottom-	Normal consistency w_N as per eqn.4.2
A (Vasavadutta)	24.0	27.5	25.18
	25.0	13.0	25.46
	25.5	5.5	25.58
B (Ultratech)	24.0	23.0	24.95
	25.0	17.0	25.15
	25.5	10.5	25.33

Specific surface area of cements A,B and C are --- cm^2/gm
A : 3080 ACC
B : 4500 ACC
C : 6060 ACC

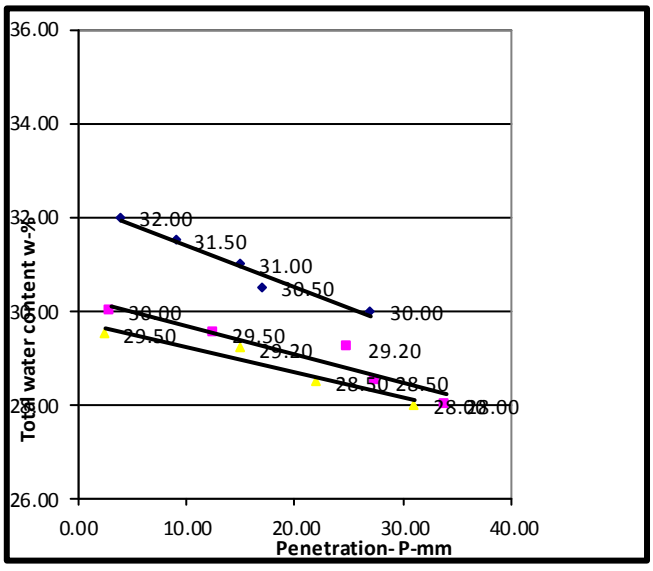
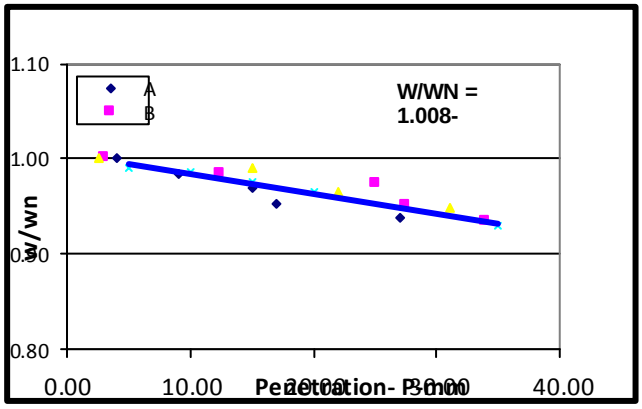


Figure -1



$W/W_N = 1.008- 0.002P$

Figure-2

At first, tests were conducted using ACC cement only. Cements of three different fineness were tested. Penetrations (P) were measured for different water contents (W) for the three cements. A graph of water content versus penetration was plotted Fig.1. From this graph, water contents (w_N,) corresponding to 5 mm penetration from bottom were readout. Then, the water contents at different penetrations were generalized by dividing them by the corresponding w_N (normal consistency) values. Using this data, an equation relating water content, normal consistency and penetration was developed in the form.

$W / W_N = a- bP$

For the data analyzed the value of constants are a=1.008 and b=0.002 and

r= Coefficient of Correlation

It can be seen from the figure 2 that, all the points fall in a narrow band indicating the uniqueness and the equation is

$W/W_N = 1.008- 0.002P$ ----------(1)

Where W_N = Water content for Normal consistency - The more cements of different brands like Vasavadutta and Ultratech and were tested to assess the validity of this equation for other cements. Table 2 gives the details of test data.

In retrospect, it can be said that, the equation based on generalization leads to a simple and rapid way of determining normal consistency, since the penetration resistance of cement paste is a measure of shear strength which in turn depends on physico-chemical interactions between cement and water expressed in terms of generalized water-cement ratios. This method avoids repetitions. The equation is found to be valid for some other cements whose chemical compositions and finesses are not known as shown in table 2

Table 2

Sample	Water content w-%	Penetration (mm) measured from bottom-	Normal consistency w_N as per eqn. (1)
A (Vasavadutta)	24.0	27.5	25.18
	25.0	13.0	25.46
	25.5	5.5	25.58
B (Ultratech)	24.0	23.0	24.95
	25.0	17.0	25.15
	25.5	10.5	25.33

3.0 An Alternative Method for Assessment of Consistency of Cement Paste.

The only method that is used for the assessment of consistency of cement paste is the use of Vicat's apparatus .Various standards have advocated different methods of mixing, placing and assessment of normal consistency of cement pastes. The Indian (IS-4031) and British (BS-4550) standards have specified hand mixing, whereas, The paste is filled into the mould as it is, in case of Indian and British Standards and in the American Standard Method, the paste is made into a ball and tossed between the hands 6 times, holding the hands 6 inches apart; before it is pressed into the mould from the larger end. The normal consistency is also

defined in different fashions in different codes. Thus, the existing methods of assessing consistency of cement paste merit reexamination.

It is quite possible that considerable human errors do creep in while conducting this experiment. The test is fully operator dependent. Hence, an attempt is made here, to substitute the existing method of assessment of normal consistency by a more accurate method.

3.1 The alternate method

The cone penetrometer method is a well-established method for the determination of liquid limit of soils. Since the method of assessment of liquid limit of soil is analogous to that of consistency of cement paste, the same cone penetrometer is made use of in the assessment of consistency of the cement paste.

The details of Vicat's apparatus are given in the above codes. The standard weight of the plunger is 300 grams and diameter is 10 mm. It is only the diameter of the mould that varies from one code to other. Indian and British standards have specified a diameter of 80 mm. whereas, American code specifies a top diameter of 60+3 mm and bottom diameter of 70+3 mm. The height of the mould in all the cases is 40mm. the time allowed for penetration is 30 seconds.

4.0 Details of cone pentrometer

This has got a cone of height 35 mm and apex angle 30^0. The total weight of the cone and the sliding shaft is 80 grams. The mould is 40mm in height and 55 mm in diameter. The apparatus is fitted with an automatic release and locking device which allows the cone to penetrate into the specimen for 5 seconds. The dial gauge can measure the depth of penetration (from top) to an accuracy of 0.1 mm as shown in fig 3

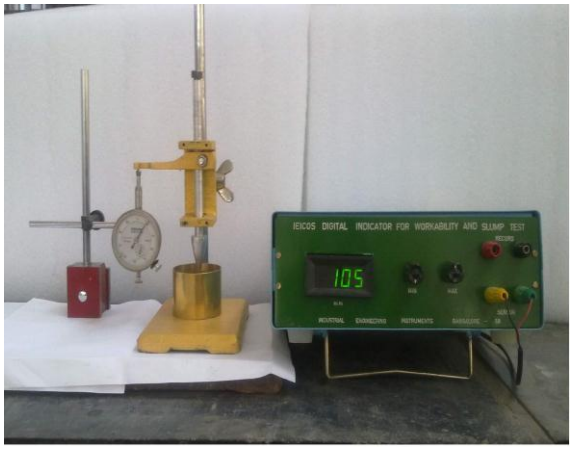


Fig 3

The first set of tests were conducted on ACC cement .The validity of the correlation between the two tests was verified using Birla super cement and results are presented in table 3 and table 4.

In case of Vicat's test, mixing was done manually. Penetrations (from bottom) were measured for different water contents.

In case of cone penetration test, mixing was done using a motorized mortar mixer. The paste was placed in two layers in the mould, each layer being compacted by giving 25 jolts on a flow table. The penetrations (from top) were measured for different water contents. In this test, at least two separate mixes were tested (which were prepared at a time) for each water content since the test is very sensitive. The results were plotted as shown in figure below.

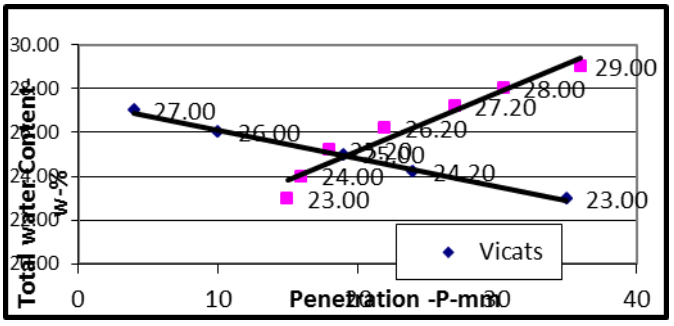


Fig 4

4.1 Results and discussions

The data of Vicat's and cone penetration tests are shown in figure 4. They are plotted as they are obtained. That is, the Vicat's penetration was measured from bottom and cone penetration was measured from top. The equations of the two lines were obtained as follows:

For Vicat's test,

$W_V = 27.3896 - 0.1299\ P_V$ -------(2)

And for cone penetration test,

$W_c = 0.2527\ P_c - 20.0842$ ----------(3)

Where, P_v and P_c are the Vicat's and cone penetrations and w_v and w_c are the respective water contents.

When water contents used for the two tests are same, equations (2) and (3 can be equated. i.e.,

At $w_v = w_c$,

$P_v = 56.24 - 1.95\ P_c$ -------(4)

This equation was used in calculating the values of P_c for various values of Pv obtained. The results are shown in table 4.

It can be seen from tables that, the calculated values are in good agreement with the experimental ones.

Of course, in case of Vicat's test, the results are purely operator dependent. Based on the mode of mixing, the value of penetration also varies. The variations in the results of cone penetrometer may be to difference in compaction.

Table 3 . Penetration from Vicat's apparatus.

(Birla super cement)

Water content %	Trial No.	Vicat's penetration mm P_V	Calculated cone penetration from the eq 4.5 Pc (cal) -mm	Average Pc (cal) mm
25	1 2	30 31	13.46 12.94	13.20
27	1 2	23 24	17.05 16.55	16.79
29	1 2	14 16	21.66 20.44	21.05

Table 4 Actual and calculated cone penetration.

(Birla super cement)

Water content %	Trail No.	Pc (actual)	Average Pc (Actual) mm	Average Pc (cal) mm	Percentage difference over pc (Act)
25	1 2 3	13 12.3 12.0	12.43	13.20	-6.19
27	1 2 3	16.8 15.8 17.3	16.63	16.79	-0.96
29	1 2 3 4	22.3 22.0 21.1 22.0	21.85	21.05	+3.66

But, when the two tests are compared, cone penetrometer test is definitely better. In this case, the cone is allowed to penetrate for only 5 seconds after which it gets locked. Whereas, in case of Vicat' s apparatus, the penetration is read after 30 seconds. The plunger moves faster for the first ten seconds and then it slows down and a major portion of the penetration might have been over in the

first ten seconds only. Hence measurements of penetration before this time seems to be quite sufficient

Another factor that needs to be mentioned regarding operator dependence of Vicat's test is the validity of equation 4. Though, the results obtained in case of consistency tests match well with the calculated values, In retrospect, it can be said that the cone penetrometer seems to be a viable replacement for Vicat's apparatus. .

In retrospect, it can be said that cone penetrometer can be used as one of the workability tests. The purpose of this investigation was neither to assess the precision of the proposed method, nor to compare it with any of the existing methods. The data presented here indicates that the method works.

At the same time, a single cone penetrometer could be used for different purposes, like, for the measurement of consistency and setting time of cement and the workability of concrete.

5.0 Conclusion:

Based on the experimental investigations the following conclusions were arrived at:

1. It is possible to have a single point method of finding the normal consistency of cement paste using Vicat's apparatus.
2. The cone penetrometer method with a modified cone has the potential of being an alternative to the existing workability tests.

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