IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 5 Ver. II (Sep. - Oct. 2016), PP 66-73
www.iosrjournals.org

Study on Correlating Properties of Cement Paste and Concrete

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Abstract: *Concrete is a composite material consisting of aggregates, binding material, water and admixtures. It is the most widely used construction material on earth. This paper is a study on loss of workability, setting time, property correlation between paste and concrete for various admixture and superplasticiser dosages. The mineral admixtures considered are Fly ash and (Ground granulated blast furnace slag) GGBS with superplasticiser Masterglenium SKY 8233. The flow analysis in paste can be used as a guideline for finding saturation superplasticiser dosage. The study on setting time shows than results of paste and concrete are comparable. It is also found that saturated superplasticiser dosage in paste and concrete can be correlated for better compressive strength. By this study, tests on the paste can be used as guide for optimising flow behaviours, setting time, compressive strength in concrete without doing tedious tests in concrete.*

Keywords **-** *Compatibility, Marsh cone Time, Retention time, Saturation dosage.*

I. INTRODUCTION

Concrete is the most widely used construction material on earth. An additive or admixture is a material added into the concrete in small quantities to give desirable properties to the concrete. Admixtures in concrete confer some beneficial effects such as acceleration, retardation, air entrainment, water reduction, plasticity etc. To understand the consequences of admixture- cement interactions, and to optimize the functional properties of admixtures, appropriate descriptions of their mode of action must be developed. This paper is an effort to study paste fluidity, concrete compressive strength, correlation of paste and concrete setting time in the presence of chemical admixture Masterglenium SKY 8233 and mineral admixtures- fly ash and GGBS.

II. EXPERIMENTAL DETAILS

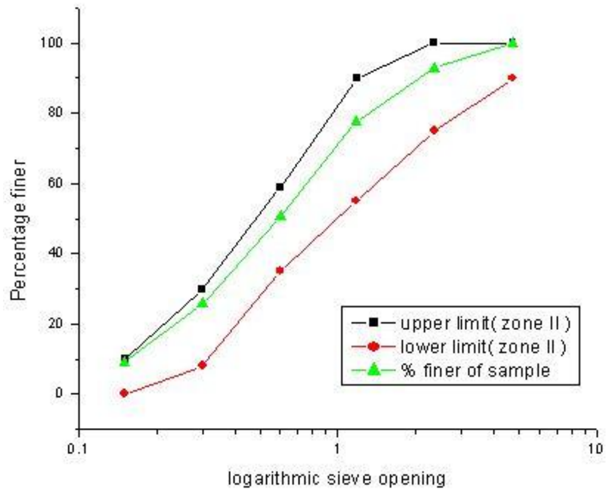
2.1 Cement

The cement used was Deccan Cements. The following are the various test results conducted as per IS:12269-1987 to determine the physical properties of this cement.

Sl.No.	Properties	Values
1.	Specific gravity	3.125
2.	Standard consistency	30%
3.	Initial setting time(in minutes)	75

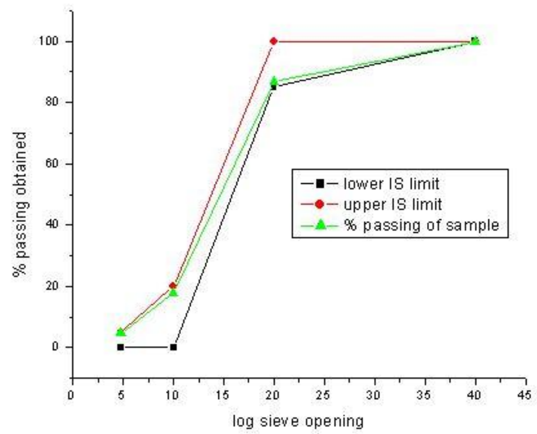
2.2 Fine aggregate

Manufactured sand was used as fine aggregate for the experiments. Various tests were conducted to determine the properties of sand. Grading is the particle size distribution of an aggregate as determined by sieve analysis and the taken fine aggregate belongs to zone II. The sieve analysis was done as per IS:2386 (Part-1)-1963. The sieve analysis and properties are shown in table below.



Sl.No.	Properties	Values
1.	Specific gravity	2.66
2.	Fineness modulus	3.442
3.	Water absorption	10%

2.3 Coarse aggregate



Sl.No.	Properties	Values
1.	Specific gravity	2.77
2.	Fineness modulus	2.596
3.	Water absorption	2.3%

III. TESTING PROCEDURE

3.1 Tests on paste

3.1.1 Marsh cone test

The marsh cone test is a workability test used for specification and quality control of cement pastes. The time needed for 1000 ml to 500 ml paste volume to flow out of a standard size cone is recorded which is linked to fluidity. For pastes, a metal cone of 8 mm nozzle diameter was employed. according to European EN 445 standard. The longer the flow time, lower is the fluidity. A graph can be prepared for log time and dosages of super plasticizer. The dose at which the log T vs Superplasticizer dosage curve makes an angle 140±10^{o}C is the saturation point. If we increase the content of Super plasticizer more than saturation point it does not affect much to the time. The dose is the optimum dose for that brand of cement, mineral admixture and super plasticizer for selected w/b ratio.

3.1.2 Mini slump test

The mini-slump test was done to measure the consistency of cement paste. The mini-slump cone has a bottom diameter of 38 mm, a top diameter of 19 mm, and a height of 57 mm. The cone is placed in the center of a square piece of glass on which the diagonals and medians are traced. The cone is lifted and after one minute, the average spread of the paste, as measured along the two diagonals and two medians, is recorded. This test was done to find out the range of superplasticiser dosage having an influence on the fluidity.

3.1.2 Vicat penetration Test

Vicat apparatus consists of plunger of 10mm dia, measuring cylinder, weighing balance, weight box and trowel. In this paper vicats apparatus is used to study the setting nature of cement paste containing various admixtures at optimum superplasticiser dosage. The graph showing penetration reading versus time can be used for predicting the nature of setting in concrete.

3.2 Tests on fresh concrete

3.2.1 Slump Test

Slump is a measure indicating the workability of cement concrete. A slump test apparatus consisting of slump cone which is in the form of a hollow frustum made of thin steel sheet and tamping rod placed over a base plate. Fresh concrete is filled in 4 layers with each layer tamped 25 times. Subsidence of the concrete after removing the cone is measured and should be ensured within the limits as per the mix design.

3.2.2 Penetrometer Test

Penetrometer is an instrument used to find setting time of concrete by measuring the penetration resistance. Needles (of area 645,323, 161, 65, 32 and 16 mm2) penetrating the concrete can be changed as time elapses. In this test initial setting time is the elapsed time after initial contact of cement and water, required for the mortar (sieved from the concrete using IS 4.75 mm sieve) to reach a penetration resistance of 3.43 N/mm2. And final setting time is the elapsed time after initial contact of cement and water, required for the mortar (sieved from the concrete using IS 4.75 mm sieve) to reach a penetration resistance of 26.97 N/ mm2.

3.3 Tests on hardened concrete

3.3.1 Test for compressive strength

The test was conducted as per IS: 516 -1959. At least three specimens, preferably from different batches, shall be made for testing to avoid error in the result. The specimen should be surface dry before testing. The specimens were tested in digital compression testing machine of capacity 5000 kN. The testing results can be used to find the effect of admixture addition in compressive strength of concrete.

IV. METHODOLOGY

- Preliminary material testing study such as standard consistency, initial setting time, final setting time, specific gravity are done in cement paste.
- Finding the optimum dosage of superplasticiser in control mix using mini slump and marsh cone tests. Both tests are done combinely in same sample to validate each others results and to eliminate insignificant dosages of superplasticiser for testing under various percentages of admixture mixes lately.
- Finding the marsh flow curve for various significant dosages of superplasticiser in cement paste mixes with Fly ash 25%, 30%, 35% and GGBS 35%, 40%, 45%, 50%. Test is conducted at 5 minute and 60 minute for checking loss of fluidity of paste.
- Finding concrete slump and cube compresive strength for M30 mix with various admixture and superplasticiser dosage.
- Effect of admixture and superplasticiser dosages on setting time of cement paste can be done using Vicats penetration instrument and that of concrete can be studied using Penetrometer.
- Effect of admixture and superplasticiser dosages on cube compressive strength also studied.

V. RESULTS AND DISCUSSIONS

5.1 Saturation dosage and loss of fluidity of cement paste mixes

Marsh cone and mini slump tests were carried out on the cement for different admixture dosages at w/c ratio of 0.45. The saturation dosage of superplasticizer for the control mix is obtained as 0.2% at 5 min and 0.25% at 60 min from both the tests which validates the result. The plot of flow time/spread versus superplasticiser dosage shows a distinct change of slope at superplasticiser dosage beyond which there is no distinct difference in flow time or spread. This is recognised as saturation dosage.

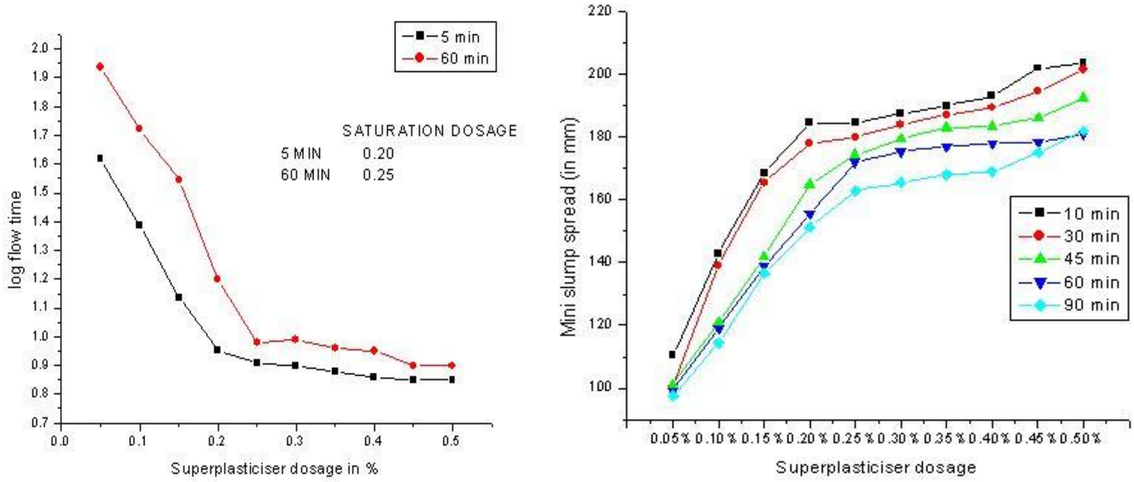


Fig 1 (a) Marsh flow curve from 1000 to 500 ml for control mix (b) Mini slump spread plot for control mix

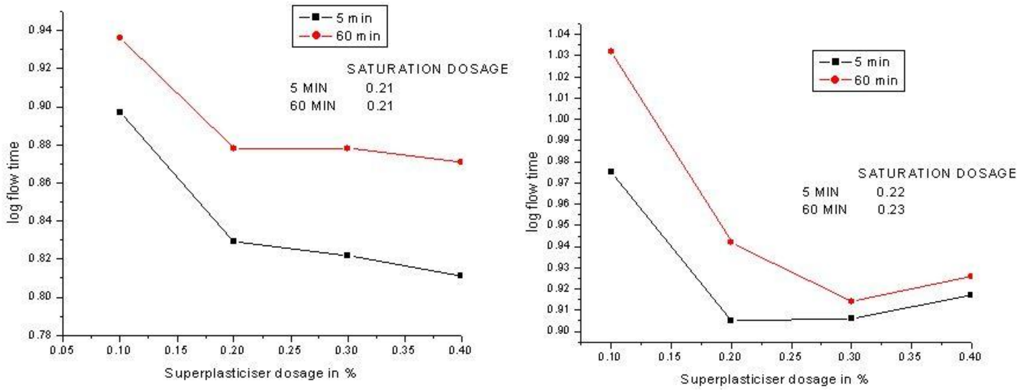


Fig 2 (a) Marsh flow curve of GGBS 35% paste mix (b) Marsh flow curve of GGBS 40% paste mix

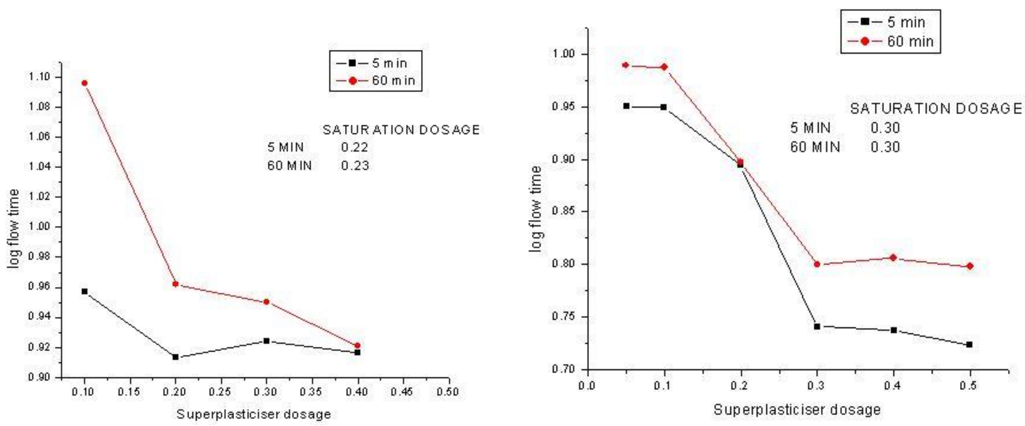


Fig 3 (a) Marsh flow curve of GGBS 45% paste mix (b) Marsh flow curve of GGBS 50% paste mix

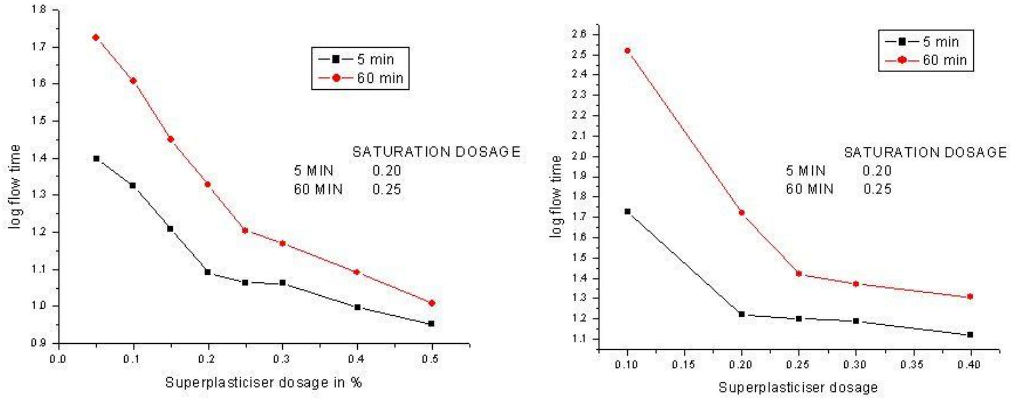


Fig 4 (a) Marsh flow curve of flyash 25% paste mix (b) Marsh flow curve of flyash 30% paste mix

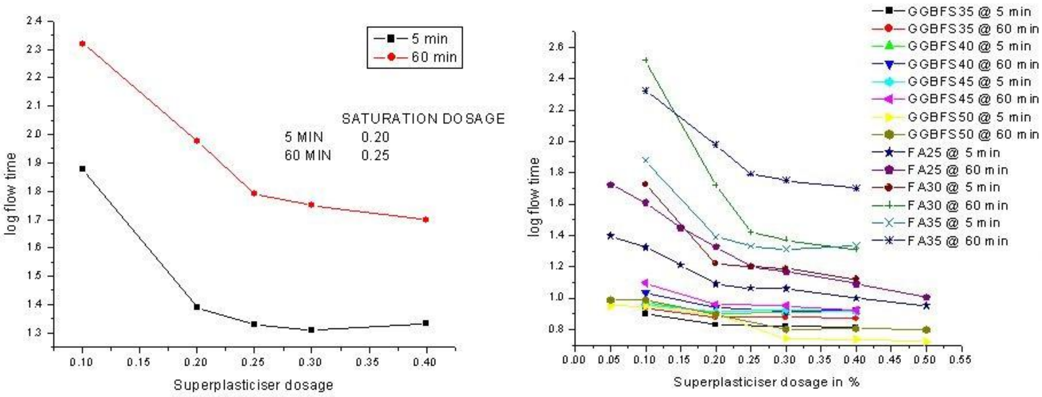


Fig 5 (a) Marsh flow curve of flyash 35% paste mix (b) Loss of fluidity

The change in the flow behaviour of fresh paste was measured at 5 min and 60 min after mixing. Before testing, the paste was kept in an airtight container at 27^0C. For testing, it was taken out of the container and mixed for 15 seconds.

Fig 5(b) gives the Marsh cone flow-time curves at 5 min and at 60 min after mixing. It can be seen that both the 60 minute line and the 5 minute line show decrease in flow times with increasing superplasticiser dosage upto saturation dosage. Beyond saturation dosage the flow time do not change much because of settling of cement particles in the paste.

With reference to 5 minute line, a shift to the right in 60 minute line shows loss of fluidity. The saturation dosage of superplasticiser increases with time. The saturation dosages are higher at 60 min than those at 5 min. This can be attributed to the increase in surface area of the hydrated cement particles with the newly formed hydrates encapsulate the superplasticiser.

Fig 5(b) shows the difference in flow time between 5 and 60 min curves is higher at lower superplasticiser dosage, with comparable levels of fluidity being achieved at 60 minutes only for various dosages of fly ash. By overdosage of plasticiser beyond the 5 minute saturation point can reduce the loss of fluidity in fly ash mix . But for GGBS comparable levels of fluidity is achieved at 5 and 60 minutes before and after saturation dosage of 5 minutes. The high fluidity loss at low dosages can be attributed to rapid flocculation and inadequate dispersion of cement particles at less than saturation dosage. In ready-mixed concrete, the fluidity of the paste after 60 minutes is more significant than immediate fluidity (5 min). The saturation dosage corresponding to 60 min should be used in mix design rather than arbitrarily dosing the superplasticiser to maintain workability.

The following conclusions can be derived from the graphs:

- Marsh flow time decreases with increase in superplasticiser dosage due to increased flow of paste showing increase in workability.
- Beyond saturation dosage (data point at which 140±10° is obtained in marsh flow curve) no significant change in fluidity is observed.
- Fly ash does not affect the fluidity of the paste because saturation dosage at 5 min is 0.2% and at 60 min 0.25% is maintained for all the three fly ash dosages like 25%, 30%,35% and control mix.
- The fluidity of fly ash mixes decreases after 1 hour. This is indicated by the significant shift of the 60 min flow curve to the right of 5 min flow curve of the same mix .
- The fluidity of GGBS mix do not change significantly for 35- 45% after 1 hour.
- Fluidity of various GGBS mixes have similar saturation dosages.
- The difference of fluidity is large at lower superplasticiser dosage and the difference narrows down with the increase in superplasticiser dosage.
- The loss of fluidity after 60 min is highest for fly ash 35% mix and all GGBS mixes 35-45% have significantly less loss of fluidity.

5.2 Effect of superplasticiser dosage on setting of cement paste and concrete

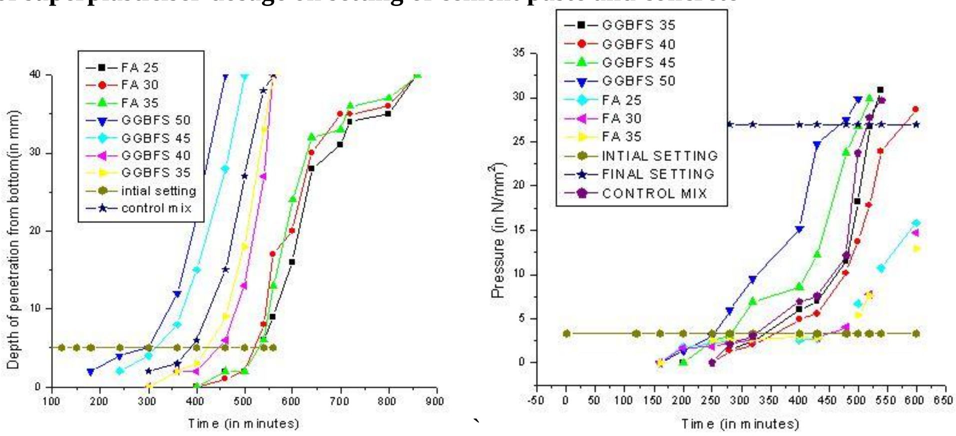


Fig 6 (a) Vicat penetration measurements of cement paste for various mixes at superplasticiser saturation dosage (b) Penetrometer measurements of concrete for various mixes at superplasticiser saturation dosage

The cement paste setting is retarded because the presence of superplasticizer slows down the rate of hydrating and dissolving ions. The Vicats apparatus was used to determine the setting time of superplasticised cement paste. The paste was prepared using a mortar mixer, with a w/c of 0.45 at the saturation dosage of superplasticiser. Fig 6(a) shows the beginning(5-7 mm Vicat penetration) and end of setting (40 mm Vicat penetration) for each superplasticiser at saturation dosage.

Following are the conclusions obtained from the graph:

- Setting time of Fly ash based mix is significantly higher than GGBS based mix.
- GGBS 35 and 40 mixes have prolonged setting duration than control mix while GGBS 45 and 50 sets faster than control mix.
- GGBS 50 is found to have the lowest setting time comparitievely.

The time between beginning and end of setting is 3 to 4 hours. This shows that the superplasticiser delays the setting and alite hydration. However, the effect diminishes when alite hydration sets in.The setting time of concrete was determined following IS 8142-1976. The concrete was sieved through a 4.75 mm IS sieve. The sieved material (mortar) was tested, and the results obtained are as shown in Fig 6(b). The time to penetrate resisting 3.43 N/mm^2 and 26.97 N/mm^2 were taken as the initial and final setting times respectively. The initial and final setting time for GGBS based concrete were 4 hours and 8 hours respectively and initial setting time for Fly Ash based concrete was 7 hours. The final setting time for Fly Ash based concrete was beyond 10 hours because the formation of C_3S responsible for early strength takes time. At GGBS 35 and 40% the setting occurs in a similar manner but a bit prolonged with same initial and final setting times. As the dosage of GGBS increases beyond 40% the setting time reduces significantly beyond control mix for 45% and 50%. However, the difference between initial and final setting times was about 4 hours in both paste and concrete. Both the vicat penetration test on the paste and the penetration resistance test on mortar measure setting by determining the degree of stiffness.

5.3 Effect of superplasticiser dosage on compressive strength of concrete

Table 1 shows concrete compressive strength with different admixture mixes. The strength of superplasticised concrete at 28 days is more than that of the reference concrete. The design strength of 38.25 N/mm^2 is attained in the reference concrete and lower dosages 35% and 40% of GGBS. Beyond 40 percentage addition of GGBS, strength reduces but stays within the the target mean strength, the highest strength being achieved at GGBS 40 mix. The compressive strength of Fly ash based concrete is less than target mean strength because it can be said that fly ash concrete has less initial strength and attains strength in a later stage. It can be observed that the strength of concrete depends upon admixture and superplasticiser dosage based on the combination compatability. However, superplasticiser dosages above saturation causes bleeding, stiffening and reduced strength.

Table 1 Compressive strength of concrete for different mixes

Admixture dosage (in %)	Saturation dosage of superplasticiser in cement paste at 60 min	Saturation dosage of superplasticiser in cement concrete	Slump (in mm)	28 day Compressive strength in MPa	Correlation number for SP dosage
M30 control mix	0.25	0.38	78	39.28	1.52
GGBS 35	0.21	0.42	82	41.73	2
GGBS 40	0.23	0.44	95	42.61	1.91
GGBS 45	0.23	0.47	90	41.58	2.04
GGBS 50	0.3	0.55	85	39.88	1.83
FA 25	0.25	0.41	80	34.26	1.64
FA 30	0.25	0.40	86	34.1	1.6
FA 35	0.25	0.41	92	33.82	1.55

VI. CONCLUSIONS

The investigation here is only a basic study on the loss of workability, setting time, property correlation between paste and concrete. An extensive literature survey was conducted on the topics related to correlation of properties of paste and concrete. The objectives, scope of this study and tests are finalised.

The first stage dealt with the determination of optimum dosage of superplasticiser in various admixture dosage mixes by analysing the results of marsh cone test. The second stage is to find the effect of admixture dosage in setting time of cement paste and concrete. The third stage is to find the effect of admixture dosage on slump and cube compressive strength of concrete. The study led to the following conclusions:

1. The marsh cone test provides the comparative flow behaviour of superplasticised pastes and allows defining a saturation dosage. Therefore, it can be used in selecting superplasticiser type and dosage.
2. The saturation dosage obtained for concrete is slightly higher than that for cement paste due to superplasticiser adsorption by the fines present in the aggregate.
3. The flow behaviour of pastes at 60 minutes after mixing shows significant fluidity loss in mixes with various dosages of Flay Ash while GGBS show comparitievely less loss of fluidity. If the fluidity of superplasticised paste at 60 minutes or at other duration is to be targeted rather than the immediate fluidity, the corresponding saturation dosage should be used in the mix design rather than arbitrarily overdosing the superplasticiser.
4. The Vicat test results show that the setting behaviour depends on the dosage of admixture and the setting time is higher for Fly ash based concrete than GGBS based concrete. The setting of Fly ash based concrete is far greater than the control mix. GGBS 35% and 40% have delayed the setting time than control mix whereas GGBS 45% and 50% have significantly reduced setting time with GGBS 50% sets at a faster rate. A comparison of the Penetrometer and Vicat test results on concrete and paste respectively indicates that the trend in setting with respect to different admixture dosages is practically the same in both cases. Hence the tests done in paste can be taken as a reference in selecting admixture dosage for concrete. The study confirms that GGBS admixture dosage have an effect on the time difference between initial and final setting times based on the superplasticiser considered here.
5. Desired compressive strength of mixes can be achieved by using saturated superplasticiser dosage in concrete equivalent to saturation dosage of superplasticiser in cement paste at 60 min multiplied by Correlation number. Correlation number for GGBS can be in range 1.83-2.04 and for Fly ash in range 1.55-1.64 for the admixture dosages considered.

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