International Journal of Advanced Technology in Civil Engineering

Volume 2 | Issue 2 Article 10

April 2013

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DESIGN OF SCC MIXES BASED ON ORDINARY PORTLAND CEMENT – SP COMPATIBILITY STUDIES.

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Abstract- In The present study 4 superplasticizers were used and on the basis of the workability test on cement paste two SP's were selected for further studies and to compare their effects on mortar properties such as workability, compressive strength, water reduction and tensile strength. Two different mortar mixes (1:1.5 & 1:2) were tested for three values of w/c ratio (0.3,0.35,and 0.4) for varying SP dosage i.e. from 0.6 to 2%. Further Design of Self Compacting Concrete by replacing Fly ash is proposed and the studies on fresh and hardened properties were conducted. The results showed that PCE type Superplasticizer is performing better than SNF type in terms of workability.

Keywords*- Cement, Superplasticizers, mortar, SCC, Fly ash, fresh and hardened properties, compressive strength, split tensile strength.*

I. INTRODUCTION

Cement exhibit variable characteristics depending on the location and quality of raw material, manufacturing process-dry/wet, grinding and temperature.Varieties of SP's with different physical and chemical properties are available in the market.As a result there will be variability in interaction with different cement and SP's that can have an adverse effect on flash setting, delayed setting, rapid slump loss, improper strength gain, inordinate cracking etc. collectively called as incompatibility of cement –SP combination.This can be assessed only by an experimental investigation.Therefore for every brand and batch of cement compatible SP combination should be identified based on test.The variation of SP on cement can vary from batch to batch of cement and for different SP's. In the present study there are four types of superplasticizer's are used two of them are Sulphonated naphthalene formaldehyde based i.e. (Rheobuild 1125, Conplast 430) and other two were Polycarboxylate ether type F (Auramix 400, Glenium 6100).on the basis of workability test on cement paste two SP's were selected for further studies as shown in figure 2 and figure 3. In this study three types of Sand were used i.e. Natural sand (N1), Natural sand (N2) and Manufactured sand (M). The texture of sand is shown in figure 6. On the basis of the workability test we shortlisted Manufactured Sand for further studies as shown in table 5.

Modern concretes almost always possess additives, either in the mineral form or chemical form. Particularly, chemical admixtures such as water reducers and set controllers are invariably used to enhance the properties of fresh and hardened concrete.A 'Chemical Admixture' is any chemical additive to the concrete mixture that enhances the properties of concrete in the fresh or hardened state. The term admixture is defined as 'a material other than water, aggregates, hydraulic cement, and fiber reinforcement, used as an ingredient of concrete or mortar, and added to the batch immediately before or during its mixing'.A number of types of chemical admixtures are used for concrete. The general purpose chemicals include those that reduce the water demand for a given workability (called 'water reducers')(1),Common problems that arise as a result of incompatibility between cement and water reducers are: rapid loss of workability, excessive quickening / retardation of setting, and low rates of strength gain. Very often, there even exists incompatibility between a particular chemical and a certain batch of the same otherwise compatible cement, indicating that the nature of the problem is complex, and needs further understanding. Moreover, high performance concretes, which are in wide use today, almost always incorporate a mineral admixture or filler such as silica fume, fly ash and limestone powder. This further complicates the physico-chemical behaviour of the cement-based system since the mineral admixtures play an important role in the evolution of the hydration reactions and the availability of free water during the early ages of concrete. Verities of SP's available in the market the variation of SP on cement can vary from batch to batch of cement and for different SP's. The change in the cement and SP leads to adverse effect on setting time, flowability, and strength etc. Expressed as incompatibility. Self-compacting concrete is a highly flowable, yet stable concrete that can spread readily into place and fill the formwork without any consolidation and without undergoing any significant separation. In general, SCC results in reduced construction times and reduced noise pollution. Self-Compacting Concrete is characterized by filling ability, passing ability and resistance to segregation. Many different methods have been developed to characterize the properties of SCC. No single method has been found until date, which characterizes all the relevant workability aspects.Hence, each mix has been tested by more than one test method for the different workability parameters. EFNARC gives the recommended values for different tests to be characterized as SCC mix.

The study assesses the effect of water reducing admixture on Mortar and concrete. Selection of optimum SP-cement combination based on compatibility studies on cement paste.Assessment of change in SP dosage for cement mortar due to incorporation of sand and the effect of SP on setting time, flowability, segregation and strengthTo Design of high strength SCC mixusing binders for achieving compatibility characteristics.Evaluation of fresh and hardened properties and the Confirmation to specified performance characteristic.

Scope of the Study:The main aim of the project is to select the SP type and dosage required from compatibility studies based on the tests.Design of SCC mixes for selected range of control parameters, so as to achieve the target performance characteristics.Study of fresh and hardened properties of concrete.

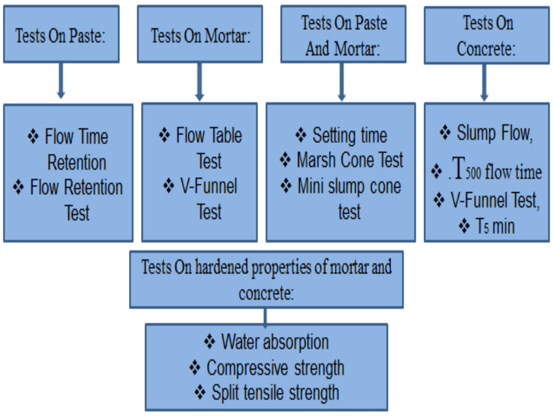


Figure 1: Scope of the study

Sl No	Properties	Results
1	silica	58.58
2	Iron oxude	3.42
3	alumina	28.2
4	CaO	2.23
5	MgO	0.32
6	SO3	0.07
7	Alkalies(K2O)	1.26
8	(Na2O)	0.58

Table 1: physical properties of cement

II. METHODOLOGY AND MATERIALS

The materials used for this study includes:Polycarboxylate ether and sulphonated naphthalene formaldehyde based superplasticizers complying with ASTM C-494 type F, was used.

Materials Used:
Cement:
Ordinary Portland cement (Grade 53) was used. Its physical properties are as given below.

Properties	Results obtained	IS:8112-1989 specification
Fineness	9	10 mm
Consistency	28%	-
Initial setting time	105 min >	30 min
Final setting time	310 <	600 min
Specific gravity	3.15	-

Table 2.Chemical properties of Fly ash

Fly ash:
Class F Fly ash obtained from “Raichur Thermal Power Station, Karnataka state, India. The physical and chemical properties of fly ash are given in the above Table 2 respectively.

Equipment Used:
The equipment utilized in the study included70.5mm*70.5mm*70.5mm mortar moulds and 150mm × 150mm × 150mm moulds (for mouldingthe mortar andconcrete cubes),weighing balance for weighing the concrete materials, shovel for mixing the concrete, hand trowel for designing the concrete surface, tank for curing of the concrete cubes, mini slump cone, marsh Cone, mortar mixer, flow table for mortar. For concrete, slump cone with 300mm height used in carrying out the spread diameter, V-funnel used to check the flow time after keeping the concrete in funnel, base plate, tamping rod, meter ruler for measuring the slump, concrete cylinder used for the compaction test, compression testing machine used to determine concrete compressive strength, scoop used for taking the samples.

Tests on materials:Constituents of the concrete mix namely the coarse aggregate (granite), fine aggregate (sharp sand), and cement (Ordinary Portland cement), water and chemicals. The granite used was well graded, free from unwanted particles and of 12.5mm and 20mm sizes while the sharp sand consisted of 5mm sized particles on average.

The tests carried out include tests on the coarse (granite) aggregates, sieve analysis of the fine (sharp sand) aggregate, workability tests, and crushing test on the concrete cubes.

The sieve analyses of the coarse aggregates and fine aggregates (sand) are given in Table 3. The size of aggregates was between 4.75 to 9.5mm. The water absorption of the aggregate was 18.02%, and the fineness modulus of the sand was 2.76, specific gravity was 2.68, and absorption value was 2.94.

Type II Portland cement was used in all mixes with a specific gravity of 3.15. The 0%, 35% and 50% fly ash by mass of cementitious materials as cement replacement was used. A polycarboxylicether (PCE) and sulphonatednaptheleneformaldhyde (SNF)superplasticizerwas incorporated in all mixture; the PCE used was in the liquid form with a specific gravity of 1.13 and solid content of 38.4%.where as SNF used was with specific gravity 1.22 and solid content of42.8.To enhance the stability of SCC also filler (lime stone powder) with the nominal particle size of 0.15 and 0.3mm was used. sand, lime stone powder, cement, and fly ash were mixed first for 1 min, and then Superplasticizer that was mixed in water was added (due to high value of water observation. several attempts were made to find out the way of adding SP and water content of the mixture, and finally it was found that the SP mixed in total water is a good solution when one is used aggregate in the SCC). Then all the materials were mixed for 2 to 4 minutes. Several design procedure based on scientific theories or (1) empirical experience have been proposed for normal SCC [4]. In general, these procedures fall into the following two categories: (1) combination of super-plasticizer and high content of mineral powders and (2) combination of superplasticizer. Table 3 gives the gradation of sands and Table 4 gives the gradation of coarse aggregate.

Table 3.Fine aggregate gradation.

sieve size in mm	Percentage of passing				
	Upper limit	Lower limit	N1 sand	N2 sand	M-sand
0.15	10	0	2.8	1.4	2.2
0.3	30	8	10	2.8	26.6
0.6	59	35	37	39.4	55.8
1.18	90	55	73.8	89	67.8
2.36	100	75	85	100	80
4.75	100	90	100	100	100

Table 4.coarse aggregate gradation.

sieve size	% passing 20mm	%passing 12.5mm	60% 20mm & 40% 12.5mm	is 383-1970 grading limits for CA
20	91.84	100	95.09	95-100
10	2.62	88.19	36.84	25-55
4.75	0	3.81	1.83	0-10

- Marsh cone test on cement paste:

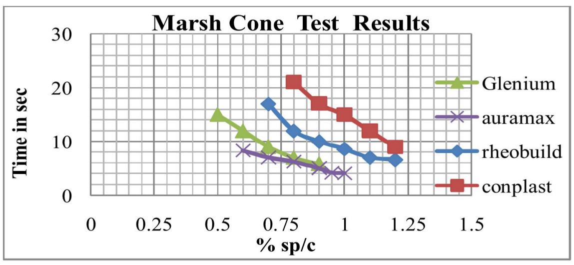


Figure 2: Marsh Cone Test for different SP's.

- **Mini slump cone test on cement paste:**

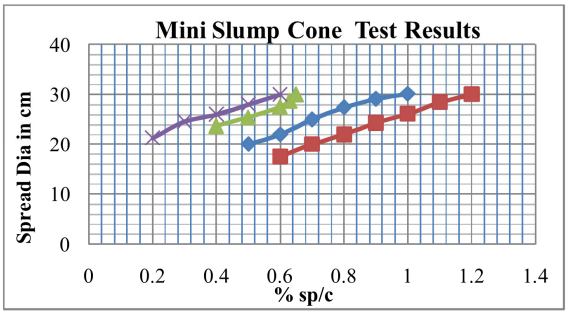


Figure 3:.Mini Slump Cone Test for different SP's.

Table 5:**Mini slump cone test on different sands:4.75mm - 0.075mm**

		Spread in cm		
W/c	Sp/C	N1 sand	N2 sand	M sand
0.4	1%	18	8	9
0.4	1.20%	19	8.8	10.1
0.4	1.40%	20.2	9.4	10.9
0.4	1.60%	21.4	10.1	12.6
0.4	1.80%	22.1	12.1	13.9
0.4	2%	23.5	14	15.2

Table 6: Flow table test on M-sand

w/c	s/c	% SP (SNF)	Spread in cm	s/c	% SP(PCE)	Spread in cm
0.3	1.5	1.9	19.5	1.5	1.4	21.5
0.35	1.5	1.7	23	1.5	1.1	24
0.4	1.5	1.4	25.5	1.5	0.8	26
0.3	2	2	18	2	1.6	18
0.35	2	1.8	22	2	1.3	22.5
0.4	2	1.6	24	2	0.9	25.5

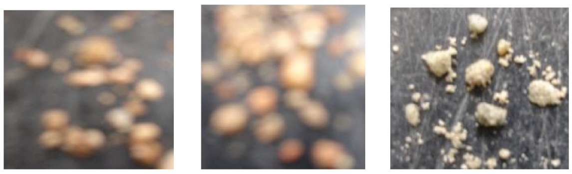
Table 7: V-funnel test on M-sand

w/c	s/c	% SP(SNF)	Flowin sec	s/c	% SP(PCE)	Flowin sec
0.3	1.5	1.9%	34	1.5	1.4%	24
0.35	1.5	1.7%	20	1.5	1.1%	14
0.4	1.5	1.4%	15	1.5	0.8	9
0.3	2	2%	52	2	1.6%	36
0.35	2	1.8%	26	2	1.3%	17
0.4	2	1.6%	18	2	0.9%	11

Figure4:Flow table

figure 5:V-funnel

Texture of Sand:



N1- sand **N2-sand** **M-sand**

Figure 6: Texture for Different Sands.

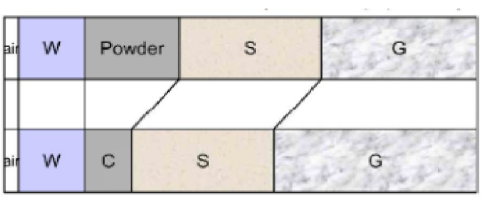
Test Methods:

Self Compacting Concrete is characterized by filling ability, passing ability and resistance to segregation. Many different methods have been developed to characterize the properties of SCC. Each mix has been tested by more than one test method for the different workability parameters. Table 8 gives the recommended values for different tests given by different researchers for mix to be characterized as SCC mix.

Table8: Recommended Limits for Different Properties.

Sl.No	Property	Range
1	Slump flow diameter	600-800mm
2	T500mm	2-5 sec
3	V-funnel	6-12 sec
4	T5min	Vf + 3

(2) The slump flow test is used to assess the horizontal free flow of SCC in the absence of obstructions. On lifting the slump cone, filled with concrete, the concrete flows. The average diameter of the concrete circle is a measure for the filling ability of the concrete. The time T_{500mm} is a secondary indication of flow. It measures the time taken in seconds from the instant the cone is lifted to the instant when horizontal flow reaches diameter of 500mm as shown in fig 4.



Conventional Concrete

Figure 7: comparision of mix proportion between SCC and conventional concrete

Slump flow testV-funnel test

Figure 8: Workability test on concrete.

The flowability of the fresh concrete can be tested with the V-funnel test, whereby the flow time is measured, figure 8.The funnel is filled with about 12 litres of concrete and the time taken for it to flow through the apparatus is measured. Further, T5minis also measured with V-funnel, which indicates the tendency for segregation, wherein the funnel can be refilled with concrete and left for 5 minutes to settle. If the concrete shows segregation, the flow time will increase significantly. According to Khayat and Manai, a funnel test flow time less than 6s is recommended for a concrete to qualify for an SCC [9].

Workability Test on the Mortar and Concrete:

A total of 108 cubes were cast comprising of control cubes and cubes containing 0.9% to 1.2% SP by weight of cement. A mix ratio of 1:1.5:2.4 (that is 1.65kg of cement, 2.47kg of sand and 3.96kg of granite) was used to produce the self-compacting concrete. For mortar, total of 144 cubes were cast comprising of control of cubes and cubes containing 0.3% to2% SP by weight of cement. This was batched by weight. After the mixing of the batched material, water was added and mixed thoroughly with shovel to achieve a homogenous mix and then the cubes were moulded (figure 9) and cured in a curing tank for the durations as shown in Table 1.

Experimental Procedure:

The procedure adopted in the study is as follows

1) Using Japanese method of mix design, initial mix design was carried out at coarse aggregate content of 50 percent by volume of concrete and fine aggregate content of 40 percent by volume of mortar in concrete, the water/powder ratio was kept at 0.90. These Trial mixes were designed withsuperplasticizer content of 0% and 0.76% for mixes TR1, TR2, TR3 respectively.
2) To proceed towards achieving SCC, the coarse aggregate content was reduced to 45% by volume of concrete and thereby kept constant. Fine aggregate content was kept constant at 40% by volume of mortar in concrete, until a slump flow of 500-700 mm is achieved by slump flow test. For each trial, tests are carried out in order that the mix satisfies slump flow test and V-funnel test. AndSP content at 1.14 percent of powder content i.e. Cement and Fly ash. The water-powder ratio was varied from 0.80 to 1.17 for trial mixes., required results in all the tests i.e., slump flow, V-funnel

Table 9: Results of Fresh properties of SCC

Sl No	Cement replaced	Slump flow mm	T_{500mm} sec	V-funnel sec	T_{5min} sec
1	0% FA	680	2	6	8.5
2	35% FA	630	4	10	13
3	50% FA	610	5	12	15

T_{500mm}: time taken for concrete to reach the 500 mm spread circle.
T_f: V-funnel flow time after keeping the concrete in funnel for 10 sec.
T_{5min}: V-funnel flow time after keeping the concrete in funnel for 5 min.

Table 10: Mix Proportion of SCC for 1m^3

Cement	450	kg/m^3
Water	180	kg/m^3
Fine Aggregate	883.6	kg/m^3
Coarse Aggregate	903.9	kg/m^3
Chemical Admixture	3.05	kg/m^3
Water Cement Ratio	0.4	
Fly Ash	0%	kg/m^3
Mortar		
vol of Sand	518.1	m^3
Vm	0.861	m^3
Vs/Vm	0.4	
Vm	1	m^3
Vw	0.407	m^3
Vp	0.568	m^3
Vs/Vm	0.4	
Vm	0.546	m^3
Vs	0.218	m^3
Vp	0.223	m^3
Vw/Vp	0.805	m^3

Testing of Samples:
To study the effect of addition of the superplasticizers on the workability, compressive strength, water absorption andtensile strength the following tests procedures used.Crushing tests were performed on the mortar, concrete cubes to determine their compressive strengths. After curing for 3, 7, and 28 days and Split cylinders tests were used to check the tensile strength of mortar and concrete mixes at 28 days of age.The load was applied to the cubes through hydraulic operation of the machine until failure occurred. The corresponding peak load and stresses at this point were recorded and used to determine the average compressive strength.

Figure 9: Moulding of concrete cubes

Figure 10: Curing of Mortar moulds and cylinder

Figure 11: Testing of specimen in CTM

Compressive Strength Of Mortarand concrete:

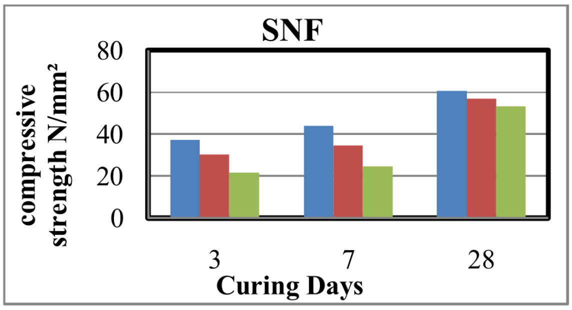


Figure 12: Compressive strength Vs curing days for mortar mix of 1:1.5 cement sand ratio using (SNF)SP

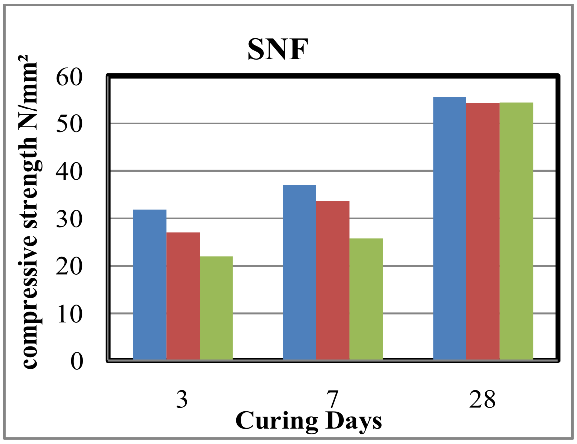


Figure 13: Compressive strength Vs curing days for mortar mix of 1:2 cement sand ratio using (SNF) SP

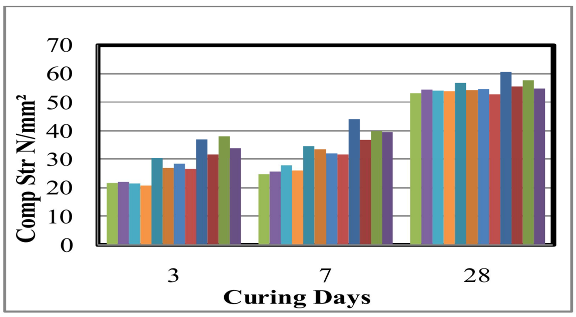


Figure 14:Comparison Of Compressive Strength Vs Curing Time For Different Cement : Sand Ratio And Different Sp's:

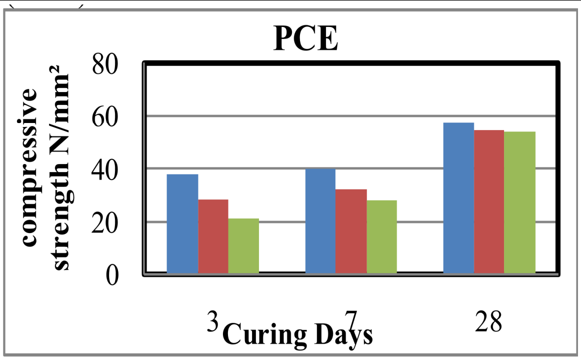


Figure 15: Compressive strength Vs curing days for mortar mix of 1:1.5 cement sand ratio using (PCE) SP

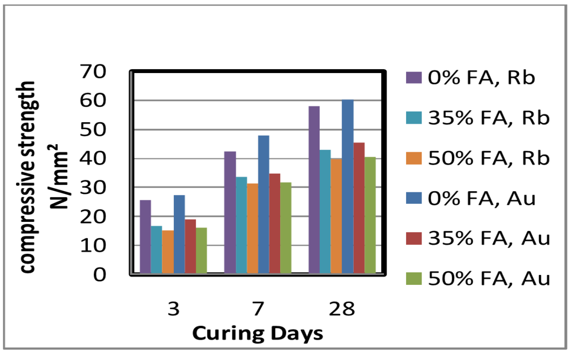


Figure 15: comparision of compressive strength of concrete Vs curing days

Split tensile strength of mortar and concrete:

Table 12: Tensile strength of mortar

Cure days	C:S Ratio	Split tensile strength N/mm²					
		SNF			PCE		
		w/c			w/c		
		0.3	0.35	0.4	0.3	0.35	0.4
28 days	1:1.5	4.4	4.05	4.3	4.8	3.8	3.7
28 days	1:2	3.7	3.6	3.5	4.6	3.6	3.6

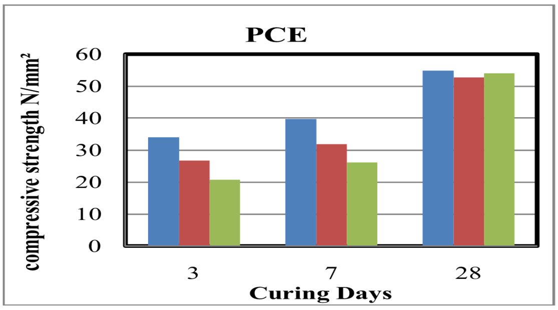


Figure 16: Compressive strength Vs curing days for mortar mix of 1:2 cement sand ratio using (PCE) SP

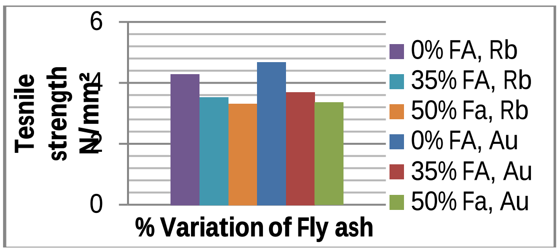


Figure 16: Tensile strength of Concrete

Discussion:

The results of workability tests, conducted to achieve self-compacting concrete.The trials were started at 50 percent volume of total concrete as content of coarse aggregates.40 percent by volume of mortar in concrete as contents of fine aggregates and variation in w/p ratio and super plasticizer was carried out to achieve SCC mixes.In case of further trials, the coarse aggregate content and fine aggregate content were varied with further variation in water/cement ratio.Similarly, different trials were carried out until mix characterizing all the properties of SCC was obtained.

CONCLUSION:

Effect of Mix parameters on fresh and hardened concrete proportion:-
From the above studies it can be seen that PCE type SP is performing better than SNF type in terms of workability.

The observations and test results have revealed that the properties of Concrete in fresh andhardened stages have been improved with the addition of both types of Superplaticisers for allnominal mixes of self compacting concretes. The contribution of Polymer based SP is however morepronounced in terms of increase in the compressive strength, workability and reduction in thewater requirements of concretes. Furthermore new generations of Superplasticisers are beingexplored and more experimental research is required to study the effects of these new SP on theproperties both in short term and long term. SCC could be developed without using VMA as was done in this study.

At the water/powder ratio of 1.180 to 1.215, slump flow test and V-funnel test results were found to be satisfactory, i.e. passing ability, filling ability and segregation resistance are well within the limits.Slump flow shows slight variation from mix to mix (range 600-680) indicating that the mixes have nearly same yielding strength due to nearly constant free water content (Lyse's rule).The V-funnel time and T500 flow time shows significant increase with the increase in binder content (upto 80%).Almost all the mixes produce belonged to class 2 as per Walraven's classification, which is adopted by EFNARC indicating that they are ideally suited for walls and piers.The mix had 7 days compressive strength in the range 47, 35 and 30 MPa, the variation principally arise by replacing cement with Fly ash content.

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