

Investigation on the Compatibility of Cement Paste with SNF and PCE based Superplasticizers

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Abstract

Background/Objectives: Cement particles disperse due to the flow character of the cement paste which also controls the quality of concrete. Cement particles also disperse due to the addition and action of Super-plasticizers (SPs) and this influences the high fluid paste behaviour. In the development of High Performance Concrete the Super-plasticizers and mineral admixtures such as fly ash plays an important role. SPs are normally adsorbed on the cement particles and sometimes the adsorption will not be even and slightly erratic. This is due to the clinker composition of cement and the type of SP used. Various combinations of materials including mineral admixtures affect the behaviour of the cement-based system and become incompatible like slump loss, delayed setting of concrete etc. **Methods:** In this study an attempt is made to explore maximum benefits of the compatibility between cement, Fly-ash and super-plasticizers (SP). The Flow table and marsh cone tests were conducted to determine the optimum dosage of the mixture. The different combination was tried in the cement mortar and the improvements in compressive strength were studied. **Findings:** Results show that the cement with 20% Fly-ash has the better compatibility with Poly carboxylate ether with optimum dosage of 0.9% by weight of cement. **Improvement:** The investigation shows that the polycarboxylate type superplasticizer has better compatibility with the different types of cement considered in this study.

Keywords: Flyash, Flow Table, Marsh Cone, Poly Carboxylate Ether, Super-Plasticiser

1. Introduction

Nowadays concrete always possesses mineral or chemical admixtures. Particularly chemical admixtures usage has become common place in the production of concrete. The addition of super-plasticizers (SPs) is expected to achieve better fluidity and workability. Due to this, the role of SPs in concrete has become increasingly important. When compared to cement the Super-plasticizer plays a significant role in the development of high strength concrete. The SPs adsorption on the cement particles, in turn gets deflocculated and separated. Because of this action trapped water released from cement flocs. Different types of SPs has been developed based on different basic groups, such as lignosulfonic acid (LS), melamine formaldehyde sulfonic acid (SMF), naphthalene formaldehyde sulfonic acid (SNF) and polycarboxylic acid (PCE)¹. The

performance of an admixture in concrete is dependent on many factors, like the nature and amount of admixture, nature of cement and aggregates, water – cement ratio and environmental conditions. Compatibility issues occur due to the increasing number of types and brands of cement, and also due to the variants of the water reducing chemicals. The incompatibilities arise between the cement and SPs are delay in setting and gaining the sufficient strength, loss of slump etc., Incompatibility may also be due to the cement belonging to a certain batch and a particular chemical. In addition high performance concrete certainly requires mineral admixture in the form of flyash, metakaoline or silica fume. The mineral admixtures play a critical role in determining the hydration reactions and the water availability during early age of concrete in the cement based system².

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The understanding of the effects of super-plasticizers (SP) on the properties of concrete is essential for further improvement of the properties and behaviour of both the super-plasticizers and concrete. Furthermore the flow properties of concrete are related to the rheology of paste, which is generally studied through viscometer tests³. However the results obtained from the paste tests need to be correlated to the behaviour of concrete. Behaviour of fresh cement paste influences the development of mortar and concrete microstructure. The dosages are decided on cement slurry which is prepared using different amount of super-plasticizers for a fixed water cement ratio. It was inferred from experiment that two super-plasticizers used were compatible with the cement used for the project. The super-plasticizers which gave the minimum percentage

of dosage for the cement was selected as it proved more economical⁴.

The research is focussed to study the flow characteristics of Ordinary Portland Cement (OPC), OPC and Fly-ash with sulphonated naphthalene admixture (SNF) and Poly-Carboxylate admixtures (PCE) using Marsh Cone apparatus. It also aims to study the cement mortar flow with cement & Fly-ash against SNF and PCE admixtures and finally to identify the best compatible combination of cement, Fly-ash and SP from the tests.

2. Material Properties

To investigate upon the compatibility of cement/superplasticizers system two brands of Ordinary Portland cement OPC 53 grade named C1 and C2 conforming to IS: 12269:2013⁵ and ASTM Type I specifications are used. The river sand which was locally available was used throughout the investigation in accordance to grading zone II as per IS:383 (1970)⁶ with a specific gravity of 2.65 and fineness modulus of 2.64. To improve fluidity two types of superplasticizers are used at different dosages; SP1 based on sulphonated naphthalene admixture (SNF) with 38% mass content and relative density 1.20; and SP2 based on Poly-Carboxylate admixtures (PCE) with 37.3% mass content and relative density 1.10. In order to examine the compatibility of cement with these super-plasticizers, fly-ash was also used as a mineral admixture with a fineness of 332 m²/kg and 51.72% of SiO₂.

3. Results and Discussion

3.1 Marsh Cone Test

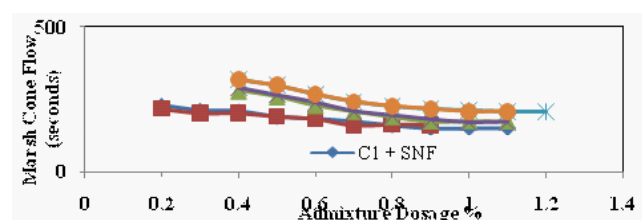
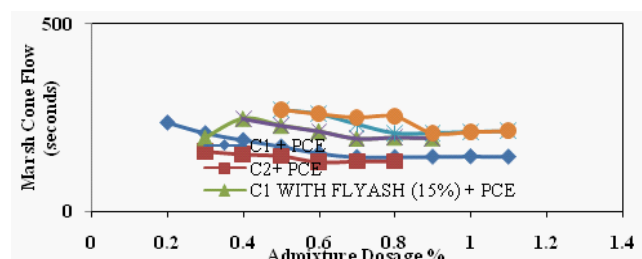
The optimum dosage of super-plasticizer were determined for water to cement binder ratio of 0.33 using a paste of 1.2 litres were prepared in a mortar mixer and poured into the Marsh cone apparatus having a nozzle of opening 10 mm in diameter and 60 mm in length. The details of the mix are shown in Table 2. Time taken for the first 200 ml of paste to flow through cone was measured. This is called as flow time. The dosage at which the Flow Time is lowest is called the saturation point (i.e. super-plasticizer has no further plasticizing effect)^{7,8}. The optimum dosages of super-plasticizer SNF and PCE for cement blended with and without flyash are presented in Figure 1 and 2 respectively. The results show that the optimum dosage of SNF and PCE based super-plasticizer for the combination of cement C1 is 0.9%, 0.7% by weight of cement respectively.

Table 1. Physical and Chemical of Ordinary Portland cement Used

Characteristics	Cement 1 (C1)	Cement 2 (C2)	Requirements of IS:12269-1987
Physical			
Specific Gravity (g/cm ³)	3.15	3.15	-
Consistency (%)	25.5	26.9	-
Initial setting time, (minutes)	260	130	Not Less than 30
Final setting time, (minutes)	345	335	Not more than 600
Fineness(m ² /Kg)	280	330	Not Less than 225
Compressive strength (MPa)			
3 days	36	38.5	Min 27
7 days	43.5	46.5	Min 37
28 days	56	58	Min 53
Chemical			
Lime Saturation Factor	0.86	0.96	Not Less than 0.8 and not more than 1.02
Insoluble Residue	1.08	1.51	Not more than 4
Alumina Iron Ratio	1.40	1.13	Not Less than 0.66
MgO (%)	1.08	1.62	Not more than 6
SO ₃ (%)	1.98	2.27	Not more than 3
LOI (%)	1.40	2.28	Not more than 4

Table 2. Marsh Cone Tests Mix Proportions

Mix Designation	W / C Ratio	Superplasticizer Dosage (%)
C1	0.33	0.2-1.2
C2	0.33	0.2-1.2
C3 (C1+15%Fly-ash)	0.33	0.2-1.2
C4 (C2+15%Fly-ash)	0.33	0.2-1.2
C5 (C1+20%Fly-ash)	0.33	0.2-1.2
C6 (C2+ 20%Fly-ash)	0.33	0.2-1.2

**Figure 1.** Marsh Cone Flow Graph Showing Optimum Dosage for Various Cement Combinations with SNF Superplasticizer.**Figure 2.** Marsh Cone Flow Graph Showing Optimum Dosage for Various Cement Combinations with PCE Superplasticizer.

The dosage of SNF has increased nearly by 30% compared to PCE respectively. Due to this fact the addition of PCE always shows better flow compared to SNF which is also observed by Luigi Coppola⁹. When compared to C1 the dosages of SPs both SNF and PCE is low in C2 nearly 25% in case of SNF whereas 13% low in case of PCE. But the optimum dosage of SNF and PCE based super-plasticizer for the combination of cement C2 is 0.7%, 0.6% by weight of cement respectively. The dosage of SNF has increased by 17% compared to PCE. Compared to C1 the dosages of SPs both SNF and PCE is low in C2 nearly 25% in case of SNF whereas 13% low in case of PCE. This is due to

the fineness of C2 cement is less than C1 which is in line with Jayasree³. If the fly ash is employed is finer than the cement the water demand increases with an increase in fly ash replacement level due to the augmentation of surface area of fly ash particles¹⁰. The optimum dosage of SNF and PCE based super-plasticizer for the combination of cement C3 (C1+15% Fly-ash), increases with an increase in fly ash level and the ball bearing effect is not effective in case of cement blended fly ash paste system and the same trend is observed in all other cases C4 (C2+15% Fly-ash), C5 (C1+20% Fly-ash), C6 (C2+20% Fly-ash). The results were also in line with Kondraivendhan⁸ where they have used a single type of cement with flyash with various water binder ratios.

3.2 Flow Table Test

To study the compatibility and the optimum dosage of superplasticizer for the two types of cement used the flow table is performed. The mix details for the flow table test are shown in Table 3. Initially the flow table top was cleaned and dried. Mould was placed at the centre of table and filled with cement mortar. The spilled out excess mortar was removed from the table top to obtain a smooth surface flush with the top of mould. The mould is then lifted and the flow is due to the result of the increase in average base diameter of the mortar mass, at approximately equally spaced intervals¹¹. The results show that there is an increase in percentage flow when optimum dosage decreases with an increase in fly ash content. The flow results and compressive strength test performed with two types of cement in combinations with SNF and PCE super plasticizer are expressed in Table 4. The flow of PCE with all the cement combinations is found to be higher than the SNF which in line with the agreement of researchers the compressive strength of C1 mortar is more in the case

Table 3. Mix Proportions for Cement Mortar Flow Test

CODE	CEMENT (g)	FLY-ASH (g)	SAND (g)	WATER	ADMIXTURE (%)	
					SNF	PCE
C1	885	-	1505	392	0.9	0.7
C2	859	-	1505	392	0.7	0.6
C3	752	133	1505	392	0.9	0.7
C4	752	133	1505	392	1	0.7
C5	708	177	1505	392	1	0.8
C6	708	177	1505	392	1	0.9

Table 4. Flow and Cement Mortar Compressive Strength Test Results

Code	NO SP			SNF			PCE		
	Flow (mm) @ Optimum Dosage	Compressive Strength (N/ mm ²)		Flow (mm) @ Optimum Dosage	Compressive Strength (N/ mm ²)		Flow (mm) @ Optimum Dosage	Compressive Strength (N/ mm ²)	
		7 days	28 days		7 days	28 days		7 days	28 days
C1	120	43	55	370	36.7	48	380	39.8	53
C2	100	49	62	280	42.9	54	370	40.8	52
C3	130	45	63	330	38.8	52.1	390	43	61.2
C4	100	43	62	340	36.7	49	400	41.5	59.2
C5	120	44	55	350	38.8	49	400	42.9	51
C6	100	40.5	59	350	30.6	46.9	370	38.8	49

of the combination of C1 with PCE (cement 1 with PCE) compared to other combinations. The flow of SNF with all the cement combinations is determined to be less than the PCE which in line with the agreement of researchers the compressive strength of C1 mortar is more in the case of the combination of C1 with PCE (cement 1 with PCE) compared to other combinations. Similar results were also obtained for other combinations. The increase in the compressive strength with age was achieved in all the mixes by adding flyash to the system at all replacement levels. The reduction of strength was also observed with respect an increase in fly ash replacement as compared to the controlled specimens. This reduction in compressive strength may be due to the effective water to cement ratio increased with an increase in fly ash replacement level. The pozzolanic reaction tends to react slowly. As a result of this it normally requires more time to react completely to attain higher compressive strength than the controlled specimens and this trend was observed by Kondraivendhan⁸.

4. Conclusions

The dosage of PCE is increased by 17% with cement 1 compared to the dosage of PCE with cement 2 which is observed due to the fineness of cement.

The dosage of super-plasticizer increases with an increase in fly ash content in cement mortar mix due to the greater fineness compared to that of Portland cement.

Based on the flow results and compressive strength results of mortar the best compatible combination found to be C2+SNF, C3+PCE, C4+PCE, C5+PCE

The dosage required to achieve the fluidity with SNF is higher than the PCE's in all the combinations.

In all the cases PCE has yielded better results in terms of compatibility compressive strength compared to other cement combinations.

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