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Effect of Superplasticizer on Fresh and Hardened Properties of Self-Compacting Concrete Containing Fly Ash

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Abstract: **-** The use of mineral and chemical admixtures in concrete is a common solution to achieve full compaction particularly where reinforcement congestion and shortage of skilled workers. The past researchers have been underscored the use of mineral and chemical admixtures imparts the desirable properties to concrete in both fresh and hardened state. This paper has been made an attempt to study the influence of superplasticizer dose of 0.25, 0.30 and 0.35percentage on performance of Self-Compacting Concrete containing 10% fly ash of cement content. The experimental tests for fresh and hardened properties of Self-Compacting Concrete for three mixes of M_{20} grade are studied and the results are compared with normal vibrated concrete. The tests considered for study are, slump test, compaction factor test, unit weight and compressive strength test The results show that for the constant water cement ratio, increase of superplasticizer dose in Self-Compacting Concrete leads to gain of good self compaction ability in addition to marginal reduction in unit weight. Moreover, there is also slightly increase in compressive strength than that of normal concrete mix.

Keywords: **-** *Compressive strength, Fly ash, Normal concrete, Self-Compacting Concrete, Superplasticizer, Unit weight, Workability*

I. INTRODUCTION

The concrete performance plays a vital role in the development of infrastructures including commercial, industrial, residential, military structures etc. In recent past, there is wide use of reinforced concrete not only for medium structures but also for long span heavy loaded structures. To some circumstances, there is more congestion of reinforcement's which causes in difficulty for its full compaction but there is shortage of skilled workers, resulting to adverse effects on properties and quality of concrete. In order to obtain workable concrete without strength loss, minerals and chemical admixtures are added in fresh mix of normal concrete, known as Self-Compacting Concrete (SCC). During further study, it is noticed that Self-Compacting Concrete is also referred as Self-Consolidating Concrete or High-Performance Concrete. The SCC concept was first introduced into scientific world in Japan in 1980 by Professor Hajime Okamura from Tokyo University. The Self-Compacted Concrete is a kind of concrete with excellent deformability and good segregation resistance which is able to flow under its own weight and self compacted into every corner of a formwork as a results it offers rapid rate of concrete placement [1]. The Self-Compacting Concrete is often produced with lesser water-cement ratio yielding early strength and hence faster use of structures. Moreover, elimination of vibrating equipment improves the environment at site in addition to reducing noise and vibrations. Further, to ensure high filling ability and flow without blockage, Self-Compacting Concrete should have lesser coarse aggregate contents and hence high cement content which can increase the cost and temperature during hydration [2] which leads to possible effect on other properties such as creep and shrinkage. In recent past, to enhance the properties of fresh and harden concrete, an addition like fly-ash is often partially incorporated in place of cement. Further, the use of fly ash in concrete is well established and widely applicable because it is not only economical from cost but it also improves the fresh and hardened properties of concrete [3]. Its typical usage is about 10-25% replacement to the cement which helps to maintain the viscosity of concrete resulting to in blockage risk and decreases the superplasticizer requirements. Therefore, to extend the concept of Self-Compacting Concrete, cement is partially replaced by fly ash due to its sustainability and reduced cost. The exhaustive study [4] have been underscored that initial cost of Self-Compacting Concrete mix get increases due to addition of Polycarboxylic ether based superplasticizer but the same shall be compensated by the production cost efficiency such as reduction in placing time, vibrator use and its maintenance, formwork cost, worker safety in addition to the achievement of filling ability, passing ability and segregation resistance. The optimized composition of SCC was prepared with silica fume (0-20% of cement weight) and superplasticizer (0.20-0.50% of cement weight) then each composition is tested by slump cone, L-box and V-funnel apparatus to meet the requirements of SCC [5]. The performance of Self-Compacting Concrete containing minerals through experimental study illustrated that an addition of mineral and chemical admixtures not only modify the properties of wet concrete in-flow and filling ability but also retain/enhance the properties of harden concrete like strength and durability. It is also observed that when mineral admixtures used in SCC, can reduce the amount of normal range (plasticizer) and high range (superplasticizer) admixtures which are necessary to achieve the fluidity but its requirements is depends on their participle size, shape and surface characteristics [6].

The general objective of this paper is to evaluate the performance of Self-Compacting Concrete containing 10% percent cement replacement with fly ash in addition to varying dose of superplasticizer. In this study, it is decided not being reduced the percentage of coarse aggregates in mix against the addition of superplasticizer in order to achieve the self compact ability without losing its strength. The specific objectives are (i) effect of superplasticizer on workability and strength of Self-Compacting Concrete containing fly ash through various tests (ii) interpretation of test results obtained from the normal and various SCC mix (iii) based on experimental results, superiority of SCC mix containing fly ash and superplasticizer with respect to normal mix has been established in terms of workability, unit weight and compressive strength.

II. MATERIALS USED AND PROPERTIES

The materials used for study are cement, fly ash, superplasticizer, fine and coarse aggregates. This type of concrete involves many factors that affect the deformability and segregation such as water- cement ratio and numerous properties of aggregates that is, volume, size distribution, void content, fine to coarse aggregate ratio, surface properties and density. Further, few tests of our interest are conducted as per codal provisions on concrete materials to determine their properties and suitability for the tests under consideration.

2.1. Cement

Cement is one of the important concrete components that bind the concrete ingredients all together. In order to achieve more workable mix, an increased paste is required to achieve the required deformability. The various tests are conducted on an Ordinary Portland Cement (OPC) of 43 grade confirming to IS: 8112-1989 [7] to know the physical properties such as fineness= 4%, normal consistency= 28%, initial setting time= 70min, final setting time= 265min, specific gravity= 3.15, compressive strength at 7 days= 22.45 N/mm^2 and compressive strength at 28 days= 48.88 N/mm^2.

2.2. Fly Ash

The most often fillers used to increase the viscosity of Self-Compacting Concrete is the fly ash, obtained from the Eklahare thermal power plant Nashik (Maharashtra, India). This fly ash is used as partial replacement to cement in concrete as mineral admixture for reducing heat of hydration, permeability and bleeding. Further, incorporation of fly ash also eliminates the need of viscosity-enhancing chemical admixtures and may improve the rheological property and reduce thermally-induced cracks in concrete. Further, reducing the cement content is one of the economical benefits besides the use of fly reduces the environmental pollution. However, there are some disadvantages to use the fly ash regarding the reduced air-entraining ability and early strength due to the influence of residual carbon in fly ash. In this work, 10% cement content required for normal mix is replaced by fly ash for all trial mixes of Self-Compacting Concrete. The test results obtained from the laboratory of thermal power plant Nashik are, fineness ROS # 350 (45 MIC) = 16.37%, specific surface by Blaine's permeability method= 371 m^2/kg, moisture content= 0.28%, soundness by autoclave expansion= 0.03% and compressive strength at 28 days= 44.23N/mm^2.

2.3. Fine and Coarse aggregates

The fine aggregates with well-graded, spherical shape and low absorption are advantageous to self-compacting concrete. The fine aggregates are used from locally available river confirming to grading zone II of IS code [8] whereas crushed stones having nominal size 12.5mm as coarse aggregates confirming to IS 383-1970 are used for conducting the various tests. To investigate the properties and suitability of aggregates for its intended application, the tests are conducted as (1) sieve analysis and fineness modulus (2) specific gravity (3) water absorption (4) silt content. The test results obtained in laboratory for fine aggregates are, fineness modulus= 3.20, specific gravity= 2.63, water absorption = 2.23 % and silt content= 2.33 % whereas for coarse aggregates, fineness modulus= 7.12, specific gravity= 2.78, water absorption= 0.37 % and silt content= 0.30 %.

2.4. Superplasticizer (SP)

When cement mixes with water, cement particles always flocculate and agglomerate then electrostatic attractive forces are generated by the electric charge on particle surface as a results large amount of free water being trapped in flocks, leads to reduce the homogeneity of concrete. The water reducing agents or workability agents such as plasticizer and superplasticizer among which superplasticizer is more consistence and viscous even at low w/c ratio. Further, to achieve high filling ability, it is necessary to reduce inter-particle friction among solid particles in concrete by using superplasticizer and reducing coarse aggregate contents. The incorporation of a superplasticizer not only reduces the inter-particle friction but also maintain the deformation capacity and viscosity. The locally available admixture that is, CONPLAST SP 430 G8 used as a superplasticizer with density 1.2 kg/l, specific gravity= 2.10 at 30^{o}C, air entrainment = 1% (approximately) and blackish in colour. For all the mixes, an addition of superplasticizer about 0.25, 0.30 and 0.35 percent of cement content is used.

III. CONCRETE MIX PROPORTION

For the performance analysis, three design mixes of M_{20} concrete grade with same water cement ratio 0.55 in which 10% replacement of cement with fly ash in addition to varying superplasticizer dose of 0.25, 0.30 and 0.35 percentage of cement content required for mix of normal concrete are prepared. These mixes are casted in standard cement concrete cubes and tested in the Applied Mechanics Department, Government Polytechnic Nashik. These three mixes of SCC are abbreviated as A1, A2, and A3 for further discussion and interpretation with respect to normal concrete (compacted artificially without addition of fly ash and superplasticizer) being designated as A. The design proportion obtained for normal concrete mix using IS code practice for concrete mix design [9] and are re-adjusted the same proportion for various Self-Compacting Concrete mixes corresponding to use of 10% fly ash are mentioned in following table 1.

Table 1 Mix proportion for various trials mixes of M_{20} concrete grade

Trial mix	Water		Cement		Fly ash		Fine aggregate		Coarse aggregate		Superplasticize	
	Proportion	Quantity (Liters)	Proportion	Quantity (Kg)	Proportion	Quantity (Kg)	Proportion	Quantity (Kg)	Proportion	Quantity (Kg)	Proportion	Quantity (Liters)
A	0.55	191.4	1	348	--	--	1.61	558	3.47	1207	--	--
A1	0.55	191.4	1	313.2	0.11	34.80	1.78	558	3.85	1207	0.0027	0.87
A2	0.55	191.4	1	313.2	0.11	34.80	1.78	558	3.85	1207	0.0033	1.04
A3	0.55	191.4	1	313.2	0.11	34.80	1.78	558	3.85	1207	0.0038	1.22

IV. EXPERIMENTAL RESULTS AND DISCUSSION (LITERS)

The proposed study has undertaken the various tests on mix are, slump, compaction factor, unit weight and compressive strength at 7th and 28th days. The complete mixing operation is performed manually using drinkable water and table vibrator is used while casting mix of normal concrete only. After casting the mix in cube mould for 24 hours then the same is cured in normal water of curing tank having room temperature.

4.1. Workability test

The workability test includes slump test as shown in Fig. 1 and compaction factor test are conducted as per special code of practices [10] in order to produce homogeneous and workable mix. From the observations shown in table 2, it is noted that slump value and compaction factor are, 120 mm and 0.92 respectively for normal concrete mix whereas for mix containing 0.35% superplasticizer along with 10% fly ash, the slump value and compaction factor as 285 mm 1.12 which is very high. The results of both tests reflects that fluidity or workability of Self-Compacting Concrete is a function of increase in percentage of superplasticizer with 10% fly ash of cement content for same water-cement ratio of 0.55. Once an acceptable workability achieved then concrete cubes casted and hardened cubes after 28 days of curing is shown in Fig. 2.

Figure 1 Slump cone test

Figure 2 Cement concrete cubes in wet and dry state

From the Fig. 3 as shown below, it is observed that workability in terms of slump and compaction factor of SCC mix increases corresponding to increase in superplasticizer dose along with constant 10% fly ash.

Table 2 Workability test results for various concrete mixes

Concrete mix	% age Fly ash	% age Superplasticizer	Workability test	
			Slump (mm)	Compaction factor
A	0	0	120	0.92
A_1	10	0.25	150	0.99
A_2	10	0.30	200	1.03
A_3	10	0.35	285	1.12

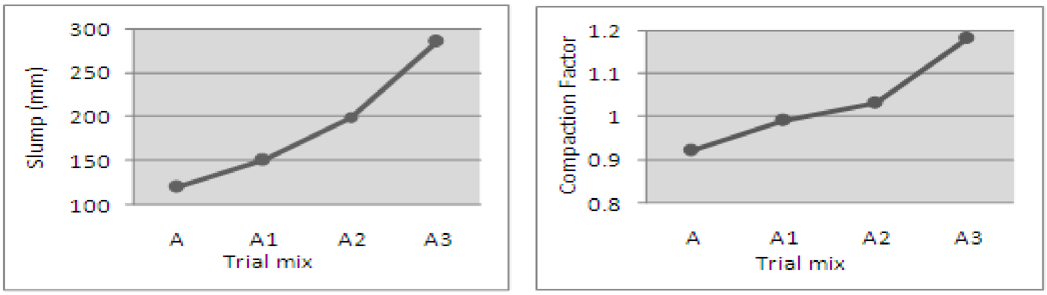


Figure 3 Comparison of compressive strength of various mixes at 7th and 28th days

4.2. Unit weight

The quantities of concrete ingredients required for one meter cubic of normal concrete are estimated to a proportion of 1: 1.61: 3.47 that is, Cement= 348 kg, F.A. = 558 kg, C.A = 1200 kg and Water= 191.6 liters with water cement ratio 0.55 then quantities of concrete ingredients required for three cubes of concrete are, Cement= 4.77 Kg, F.A= 7.67 Kg, C.A. = 16.55 Kg and Water= 2.2 liters respectively. After confirming workability to the normal mix then convert the normal mix to Self-Compacting Concrete mix in which 10% cement content is replaced by fly ash in addition to some varying percentage of superplasticizer. The properties of normal concrete mix of ingredients are re-adjusted to fulfill the required quantities of ingredients as per original proportion. Three mixes are prepared corresponding to additions of superplasticizer dose to 0.25, 0.30 and 0.35 percentage of cement content required for normal mix and are casted in laboratory. Further, weight of each concrete cubes are taken after 7 and 28 days of curing are noted in table 3 as below

Table 3 Unit weight of normal concrete and various SCC mixes

Specimen	% age Fly ash	% age Superplasticizer in %age	Av. unit Wt. (Kg)		Percentage reduction	
			7 days	28 days	7 days	28 days
A	0	0	8.341	8.441	---	---
A_1	10	0.25	8.145	8.245	2.350	2.322
A_2	10	0.30	7.879	7.879	5.538	6.658
A_3	10	0.35	7.717	7.617	7.481	9.761

From the Fig. 4, one can conclude that increase in superplasticizer with 10% fly ash in the SSC mix leads to reduce in weight of mix, resulting to reduction in total dead weight of structures. Hence, using concrete with lower density can result in significant benefit to light weight structures and better thermal insulation than ordinary concrete but use of lower density concrete permits the construction with low load-bearing structures.

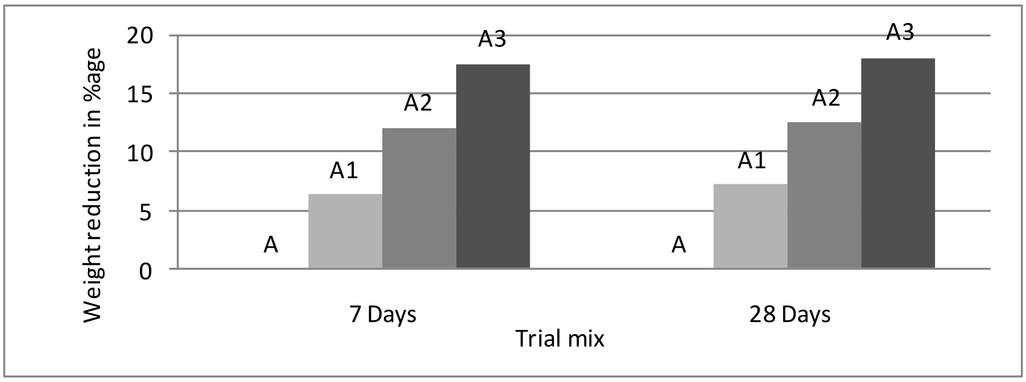


Figure 4 Variation of reduction in unit weight with various concrete mixes

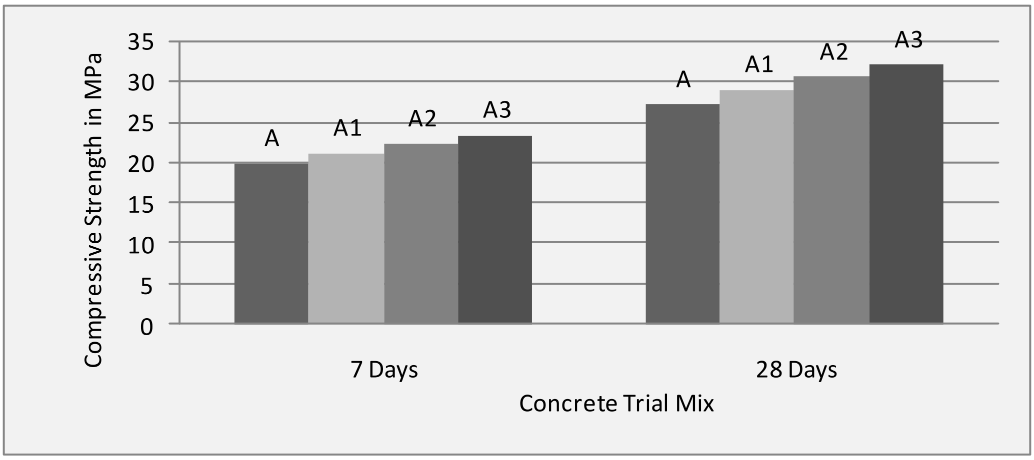
4.3. Compressive strength

For each trial mix, three concrete cubes are casted for both normal as well as three trial mixes of Self-Compacting Concrete are tested to know the average compressive strength at 7 and 28 days of standard curing in the Laboratory of Government Polytechnic Nashik and results are mentioned in table 4.

Table 4 Compressive strength of various concrete mixes at 7 and 28 days

Specimen	% age Fly ash	% age Superplasticizer	Actual Comp. Strength (MPa)		Av. Compressive Strength (MPa)		% age Strength Gain	
			7 days	28 days	7 days	28 days	7 days	28 days
A	--	0	19.00	27.11	19.90	27.11	----	----
			22.00	27.32				
			18.60	26.89				
A_1	10	0.25	22.00	29.11	21.95	28.96	06.28	07.12
			22.44	29.32				
			21.55	28.42				
A_2	10	0.30	22.36	31.56	22.29	30.48	12.01	12.43
			22.25	29.11				
			22.29	30.21				
A_3	10	0.35	23.12	32.00	23.37	31.98	17.43	18.01
			22.98	31.52				
			24.45	32.67				

The observations from table 4 show that compressive strength of Self-Compacting Concrete contains fly ash and superplasticizer is increases relatively faster upto 7 days thereafter its rate becomes slower for same water-cement ratio. Overall, on can conclude that superplasticizer dose increases the compressive strength of concrete mix at both 7th and 28th days of curing.



Trial concrete mix
Figure 5 Compressive strength of various trials concrete mixes at 7th and 28th days

From the Fig. 5, it has been observed that consistent increase in compressive strength could attributed due to addition of superplasticizer in concrete containing 10% fly ash with constant water-cement ratio. Further, one can say that compressive strength increases rather than decreases though there is increase in workability of mix. Similarly, from the scenario of graph shown in figure 6, one can comment that rapid in strength gain takes place up to its 7 days of curing later on its gaining rate getting flatter with increase in curing period of various Self-Compacting Concrete mixes.

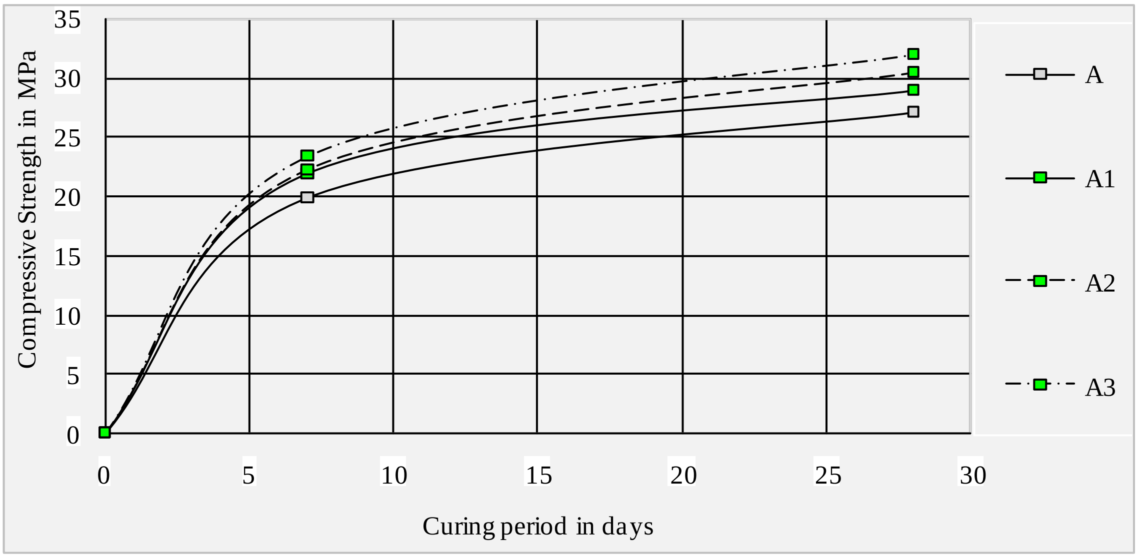


Figure 6 variation of compressive strength of concrete mix

V. CONCLUSION

The general objective is to evaluate the workability, unit weight and compressive strength of concrete mix with 10% replacement of cement content by fly ash in addition to varying doses of superplasticizer. From the test results, following conclusions are

1. Use of supplementary cementious materials that is, fly ash with an aim to achieve better workability with the saving in cementious material.
2. From the slump and compaction factor tests, it is observed that concrete containing fly ash and superplasticizer yields good workable mix in addition to increase in compressive strength marginally.
3. Addition of superplasticizer along with 10% fly ash of cement content accelerates the compressive strength of Self-Compacting.
4. Self-Compacting Concrete not only establishes the uniform and homogenous mix but also gives marginal reduction in weight of hardened mix of concrete.

5. From the present study, one can support to the comments made by previous researchers about saving of time in construction and also environment friendly user because of no compaction and vibrations resulting to no noise creation.
6. The scope of study in future is to assess the workability of mix using L-box test for the requirement of properties like passing, filling and flow ability whereas V-funnel test employed to know the property of viscosity. Further, hardened properties of SCC could be assessed for other test like flexural strength, split tensile strength and water absorption test as per Indian standards.

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