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To study the effect of varying proportion of Fly Ash and Silica Fume on Fresh and Mechanical Properties of High Strength Self Compacting Concrete.

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ABSTRCT

The development of high-strength self-compacting concrete is a positive contribution to sustainable concrete technology. If high strength concrete is self compacting, the production of densely reinforced building element from high strength concrete with high homogeneity would be an easy work. Self compacting concretes (SCC), a new kind of high performance concrete with excellent deformability and segregation resistance itself possesses an ability to flow under its own weight. The present study has attempted to present an experimental study of the effect of varying proportion of Fly Ash (FA) and Silica Fume (SF) on fresh and mechanical properties of SCC for M60 grade of concrete keeping content of cement, sand, and aggregate constant. Properties such as slump-flow, L-box, and V-funnel investigated for fresh concrete and mechanical properties such as compressive strength, split tensile strength have been investigated. The result shows that the SCC with 30% SF and 70% FA possess maximum compressive strength and split tensile strength and also satisfy all the tests for self compactibility.

Keywords: Self compacting concrete, Fly ash, Silica fume, Fresh properties, Mechanical properties.

1. INTRODUCTION

The construction of concrete structures needs thorough placement and good compaction of concrete to obtain good fresh and mechanical properties. However, the proper placement and compaction were not always achievable with non vibrating concrete in spite of good mix design and placed by skilled labours [1]. The lack of skilled labours was also a great concern in construction industry. Then, the concept of SCC first came out in Japan to build durable concrete structures and to offset the growing shortage of skilled labours in 1986 by Okamura and Ozawa [2].

It is a special kind concrete that can flow through and fill the gaps of reinforcement and corners of mould without any need for vibration and compaction during the placing process [3]. Use of SCC can help to minimize damages on the worksite that are induced by vibration for compaction. Another advantage of SCC is the time required to place the concrete in large section is considerably reduced. It minimizes the voids in the concrete and also enhances the strength and durability of the concrete [4].

SCC has higher powder content and a lower course aggregate volume ratio as compare to vibrated concrete in order to ensure its fresh properties [1]. In this study for the production of high performance concrete the industrial by products Fly Ash (FA) and Silica Fume (SF) are used.

Fly ash is a divided residue resulting from the combustion of coal. High fineness, low carbon content & good reactivity are the essence of good FA. It improves the flow ability & reduces water demand. And also gives proper slump without segregation & bleeding [2].

Silica fume is the by product of the industries producing silicon alloys. It has very fine particle size. It makes the concrete stickier that it can be placed without segregation & also increases water demand to large extent. It makes the concrete durable & gain more strength than the FA because it is highly reactive [2].

Lot of study has been done on use of FA and SF in concretes till now. The ternary blends containing SF and FA have proved better than binary blend.

It has been observed that the ternary blends with different powders can be used successfully in the SCCs but the optimum proportions satisfying the self compactibility as well as strength criteria are to be investigated for required strength class. An attempt has been made in this investigation to arrive at such proportions of FA and SF which will satisfy both criteria and produce maximum strength as SF is a costlier material than cement and FA.

2. MATERIALS AND THEIR PROPERTIES

2.1 Materials

2.1.1 Cement

In this experimental study, Ordinary Portland Cement 53 grades, conforming to IS: 8112-1989 was used. The different laboratory tests conducted on cement to determine the physical and mechanical properties of the cement used are shown in Table-1

Table 1: Properties of Cement

Physical Property	Result
Normal Consistency	**29%**
Vicat initial setting time (minutes)	**75 min.**
Vicat final setting time (minutes)	**482 min.**
Specific gravity	**3.15**

2.1.2 Aggregates

Locally available natural sand with 4.75 mm maximum size conforming to class II- IS 383 was used as fine aggregate, having specific gravity, fineness modulus and unit weight as given in Table 2 and crushed stone with 16mm maximum size having specific gravity, fineness modulus and unit weight as given in Table-2 was used as coarse aggregate. Table-2 gives the physical properties of the coarse and fine aggregates.

Table 2: Physical Properties of Coarse and Fine Aggregates

Property	Fine Aggregate	Coarse Aggregate
Specific Gravity	2.5	2.85
Fineness Modulus	2.8	7.44
Particle shape	Rounded	Angular

2.1.3 Water

Ordinary potable water available in the laboratory was used.

2.1.4 Fly Ash:

Fly ash is a by-product obtained by burning coal at thermal power plants. For this study FA was obtained from Dirk India Company pvt. Ltd. Eklehra, Nashik. The physical properties of fly ash have been shown in Table-3 and chemical properties have been shown in Table-4.

Table 3: Physical Properties of Fly Ash:

Sr. No.	Physical Properties	Test Results
1	Colour	Grey
2	Specific Gravity	2.13

Table 4: Chemical Properties of Fly ash:

Sr. No.	Chemical Properties	Test Results
1	Loss on ignition	4.17
2	Silica(SiO_2)	58.55
3	Iron Oxide(FE_2O_3)	3.44
4	Alumina (AL_2O_3)	28.20
5	Calcium Oxide (Cao)	2.23
6	Magnesium Oxide (Mgo)	0.32
7	Total Sulphur (SO3)	0.07

2.1.5 Silica Fume:

Silica fume is obtained from Elkem Ind. Pvt. Ltd. Vashi Navi Mumbai. SF having specific gravity 2.2 as a filler material has been used. Chemical composition of SF is given in table-5.

Table 5: Chemical composition of Silica Fume:

Sr. No	Constituents	Quantity (%)
1	SiO_2	91.03
2	Al_2O_3	0.39
3	Fe_2O_3	2.11
4	CaO	1.5

2.1.6 Super plasticizers

Super plasticizers or high range water reducing admixture is an essential component of SCC. It is used to provide necessary workability. Glenium B233 (modified P.C. based) was obtained from BASF India Limited, Nagpur.

3. EXPERIMENTAL WORK AND TESTS

3.1. Mix Design:

The mix proportion was done based on the method proposed by Nan Su et al.[3]. The mix designs were carried out for concrete grades 60. This method was preferred as it has the advantage of considering the strengths of the SCC mix. The final mixes were arrived after making some changes to meet the strength and self-compacting ability criteria. The details of mixes are given in table-6. All the ingredients were first mixed in dry condition. Then 70% of calculated amount of water was added to the dry mix and mixed thoroughly. Then 30% of water was mixed with the super plasticizer and added in the mix. Then the mix was checked for self compacting ability by slump flow test, v-funnel test and L-box test.

Table 6: Mixture proportion for 1m^3 of SCC

Specimen	Cement (kg/m^3)	Sand (kg/m^3)	Course aggregate (kg/m^3)	Fly ash (kg/m^3)	Silica fume (kg/m^3)	Water (kg.)	Super plasticizer (kg.)
S_0	437	1048	927.4	150	0	176	5.283
S_{10}	437	1048	927.4	135	15	176	5.413
S_{20}	437	1048	927.4	120	30	176	5.625
S_{30}	437	1048	927.4	105	45	176	5.895
S_{40}	437	1048	927.4	90	60	176	6.025
S_{50}	437	1048	927.4	75	75	176	6.231
S_{60}	437	1048	927.4	60	90	176	6.416
S_{70}	437	1048	927.4	45	105	176	6.538
S_{80}	437	1048	927.4	30	120	176	6.687
S_{90}	437	1048	927.4	15	135	176	6.819
S_{100}	437	1048	927.4	0	150	176	7.044

3.2 Slump Flow Test:

Slum flow &T500 time is a test to assess the flow ability & the flow rate of SCC in the absence of obstructions. It is based on the slump test described in EN 1235-2. The result is an indication of the filling ability of SCC, & the T500 time is a measure of the speed of flow &hence the viscosity.
In this experimental work, the slump value of fresh concrete was obtained in the range of 680mm to 730mm. The result shows in Table-8.

3.3 L-Box

L- Box test is used to assess the passing ability of SCC to flow through tight openings including spaces between reinforcing bars & other obstructions without segregation of blocking. The passing ability is calculated from the following equation: PA=H2/H1. In this experimental work, the. L-Box value of fresh concrete was obtained in the range of 0.8cm to 0.94cm.The result shows in Table-8.

3.4 V- Funnel Test

The V-funnel test is used to assess the viscosity & filling ability of SCC. T_v is the V-funnel flow time. In this experimental work , the. V- Funnel value of fresh concrete was obtained in the range of 8.65 to 11.35 sec.The result shows in Table-8.

3.5 Compressive strength test: In this investigation for compressive strength test, Cube specimen of size 100 x 100 x 100 mm. was used. The concrete cubes were tested by using Compression Testing Machine having capacity of 2000kN.The results are as shown in table-9, figure 1.

3.6 Split tensile strength test: In this investigation for split tensile strength test, Cylinder specimen of diameter 150 and height 300 mm. were used. The results have been shown in table-10, figure 2.

4. TEST RESULTS

4.1 Fresh Properties of SCC Mixes

Various tests were conducted on the trial mixes to check for their acceptance and self compacting properties. The tests included slum flow test and V-funnel tests for checking the filling ability and L-box test for passing ability. The mixes were checked for the SCC acceptance criteria suggested by EFNARC (2002) given in table-7.

Table 7: SCC Acceptance Criteria

Method	Properties	Range of values
Slum flow	Filling ability	650-800mm
V- funnel	Viscosity	6-12 sec.
L- box	Passing ability	0.8-1.0

Table 8: SCC Test Results of SCC Mixes

Specimen	Slum flow (mm)	V-funnel (sec.)	L-box (cm)	Segregation	Remark
S_0	700	9.76	0.91	No	SCC
S_{10}	710	11.35	0.91	No	SCC
S_{20}	700	10.43	0.85	No	SCC
S_{30}	720	11.1	0.86	No	SCC
S_{40}	730	10.5	0.92	No	SCC
S_{50}	680	11.6	0.88	No	SCC
S_{60}	730	9.36	0.87	No	SCC
S_{70}	685	10.11	0.92	No	SCC
S_{80}	700	9.74	0.89	No	SCC
S_{90}	730	11.1	0.87	No	SCC
S_{100}	700	8.65	0.94	No	SCC

The result of the self compact ability tests are tabulated in table-8. All the mixes satisfied the acceptance criteria for self compacting concrete. Hence these mixes were chosen as the successful mixes. The cube specimens of size 100 x 100 x 100 mm were cast for the successful mixes and were tested for the 3-days, 7-days and 28-days compressive strengths. Also cylindrical specimens of size 300mm height and 150mm diameter were cast and tested for 28-days split tensile strength.

4.2 Mechanical Properties of SCC Mixes

4.2.1 Compressive Strength of SCC Mixes

Table 9 and figure 1.Gives the cube compressive strength of the mixes. It can be seen that SCC with 30% SF and 70% FA gives maximum compressive strength. Three standard cubes each for various mixes were tested to determine 3days, 7 days and 28 days compressive strength. From these results it can be observed that the HSSCC with combination of 30% SF and 70% FA, exhibiting best performance. The use of SF above 30% decreases the strength. The SF present in this mix is 7.6% of the total powder. SF and FA both are the pozzolanic materials. SF reacts faster than the FA because of its finest particle size which is 100 to 150 times finer than cement. The pozzolanic material hydrates in presence of lime and water. The di-calcium silicates and tri-calcium silicates in cement produce $Ca(OH)_2$ upon hydration. This is made available for the hydration of pozzolanic material. All the FA and SF cannot get hydrated at the age of 28 days. Some amount of these pozzolans remain unhydrated even after months or years as there is limitation on the availability of the $Ca(OH)_2$. That is the reason why strength cannot be enhanced by addition of SF beyond certain limit. The remaining SF and FA provide particle packing effect which also contributes to strength and durability.

Table 9: Compressive Strength of all SCCs

Specimen	Compressive Strength (Mpa)		
	3 days	7 days	28days
S_0	39.475	53.96	71.943
S_{10}	35.975	52.75	79.143
S_{20}	51.40	65.925	87.9
S_{30}	46.136	77.715	96.503
S_{40}	40.473	67.455	89.94
S_{50}	38.808	64.68	86.24
S_{60}	37.687	62.812	83.75
S_{70}	36.661	61.102	81.47
S_{80}	35.26	58.762	78.35
S_{90}	32.922	54.87	73.16
S_{100}	29.647	49.412	65.883

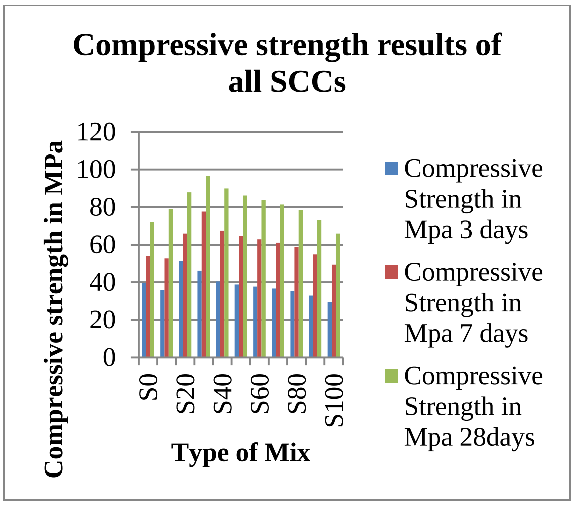

Fig.1: Compressive strength results of all SCCs

4.2.2 Split Tensile Strength

The split tensile strength result shown in table 10 and figure 2. Three standard cylinder specimens each for various mixes were tested to determine 28-days split tensile strength. Results of split tensile strength shows that 30% of SF and 70% of FA gives maximum value and gets decreased as the percentage of SF increases beyond this limit .

Table 10: Split Tensile Strength of all SCCs

Specimen	Split Tensile Strength (Mpa)
S_0	4.30
S_{10}	5.34
S_{20}	6.13
S_{30}	6.96
S_{40}	6.03
S_{50}	6.02
S_{60}	5.91
S_{70}	5.43
S_{80}	4.98
S_{90}	4.65
S_{100}	4.2

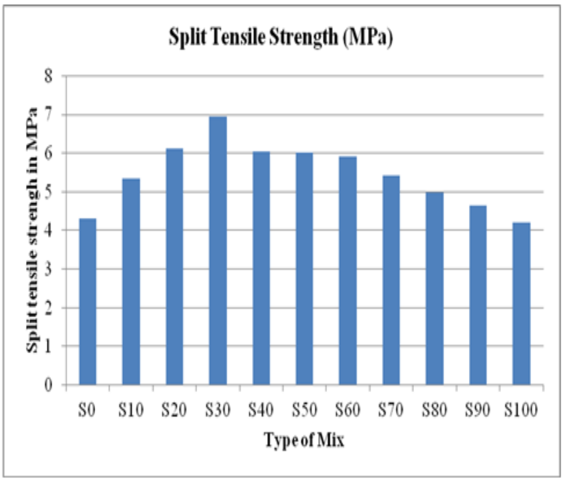

Fig.2: Split tensile strength results of all SCCs

5. Conclusion

From the results obtained in the present study it can be concluded that:

- The SCC with 30% SF and 70% FA gives maximum compressive strength.
- The SCC with different combinations of SF and FA, exhibited satisfactory fresh properties.
- All the combinations of SF and FA produced required strength.
- The use of SF above 30% decreased the strength.
- Split tensile strength for 30% of SF and 70% of FA has maximum value, and gets decreased as the percentage of SF increases.

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