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To Study the Effect of Varying Proportion of Fly Ash and Silica Fume on Sorptivity of High Strength Self Compacting Concrete

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ABSTRACT- Concrete is an important versatile construction material, used in wide variety of situations. So it is very important to consider its durability and strength as it has indirect effect on economy, serviceability and maintenance. Durability of concrete depends largely on the movement of water and gas enters and moves through it. In the present study durability is measured by sorptivity. Sorptivity is materials ability to absorb and transmit water through it by capillary suction. 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 Sorptivity of High Strength Self Compacting Concrete (SCC) for M60 grade of concrete keeping content of cement, sand, and aggregate constant. The result shows that the SCC with 30% SF and 70% FA possess less sorptivity and maximum strength. Also satisfy all the tests for self compactibility.The utilization of FA and SF in SCC solves the problem of its disposal, thus keeping environment free from pollution.

KEYWORDS- **Self compacting concrete, Sorptivity, Fly Ash, Silica Fume.**

I. INTRODUCTION

The demand of SCC is growing rapidly due to the shortage of skilled labours for which it was originally developed mainly due the work of Okamura; it is also proved to be more economical, durable and termed as high performance concrete [1]. The SCC is now an emerging technique in the field of concrete technology. It is unique, because of its properties, like fill ability, flow ability, pump ability, and make production of concrete more industrialised. [2] It not only increases the reliability of structures but also reduces the number of workers required at the construction site and streamlines the construction [3]. It has capacity to flow and to fill out the most restricted places of the formwork, without losing homogeneity [4]. On the other hand, a self-compacting concrete should have the capacity of self-densification, resulting in a material whose properties in the hardened state are at least the same achieved with concrete compacted by vibration[4]. In general, SCC results in reduced construction times and reduced noise pollution [3]. It not only shows good fresh and hardened properties, it also improves the durability of structure. Durability of concrete has been a major concern of civil engineering professionals [5]. In this paper attempt is made to determine durability by the sorptivity test. Sorptivity, which is an index of moisture transport into unsaturated specimens, has been recognised as an important index of concrete durability, because the test method used for its determination reflects the way that most concretes will be penetrated by water and other injurious agents and it is an especially good measure of the quality of near surface concrete, which governs durability related to reinforcement corrosion [3]. This is a simple parameter to determine and is increasingly being used as a measure of concrete resistance to exposure in aggressive environments [6]. The sorptivity coefficient is essential to predict the service life of concrete as a structural and to improve its performance [3]. In this study for the production of high strength concrete the industrial by products FA and 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 [7]. ***Silica fume*** is the waste 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 [7]. 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 blends.

II. DESIGN MIX MATERIALS

A. Materials

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

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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. *Aggregates*

Locally available natural sand with 4.75 mm maximum size conforming to class II- IS 383 was used as fine aggregate, and crushed stone with 16mm maximum size 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

3. *Water*

Ordinary potable water available in the laboratory was used.

4. *Fly Ash*

FA 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, Nasik. The physical properties of FA 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

5 Silica Fume

SF 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

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.

III. EXPERIMENTAL WORK AND TESTS

A. Mix Design

The mix proportion was done based on the method proposed by [8]. The mix designs were carried out for concrete grade 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.

B. Compressive Strength Test Method

In this investigation for compressive strength test, standard 100mm cube specimens were cast. On the following day of casting, the specimens were de-moulded and located in water curing condition for 3days, 7days, and 28days. After curing on each day the specimens were taken out of the curing tank and compressive strength test was carried out. The concrete cubes were tested by using Compression Testing Machine having capacity of 2000kN. Three standard cubes each for various mixes were tested to determine 3days, 7 days and 28 days compressive strength.

C. Sorptivity Test Method

Standard 100mm cube specimens were cast for this test. On the following day of casting, the specimens were de-moulded and located in water curing condition for the periods of 28 days. After 28 days curing the specimens were taken out of the curing tank and water absorption (sorptivity) tests was carried out to determine the sorptivity

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coefficient of concrete specimens which were preconditioned in oven at 1050C for 24 hr. and then cooled down for 24h to achieve a constant moisture level. Then, four sides of the concrete specimens were sealed by electrical tape to avoid evaporative effect as well as to maintain uniaxial water flow during the test and the opposite faces left open see in figure1. Before locating the specimens on water, their initial weight was recorded. One face of specimen was in contact with water, while the water absorption at predefined intervals was noted by taking weight. The specimen was submerged 5mm in water. Procedure was repeated, consecutively at various time intervals 15 min., 30 min., 1 hr, 2 hr, 4 hr, 6 hr, 24 hr, 48 hr and 72 hr until the last reading. Sorptivity coefficient can be calculated by the following expression.

$S = (Q/A)/\sqrt{t}$

Where,
S = Sorptivity ($cm/s^{1/2}$)
Q = Vol. of water absorbed in cm^3
A = Surface area in contact with water in cm^2
t = the time (s)

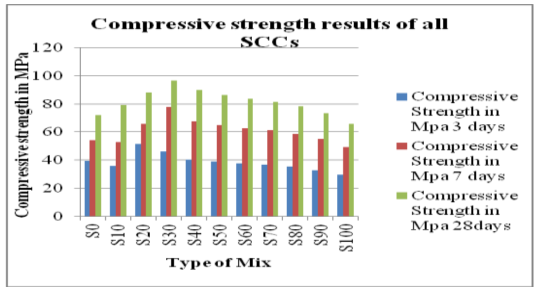
Fig 1: Sorptivity Test

IV. TEST RESULT

A. Hardened Properties of SCC Mixes

1. Compressive Strength of SCC 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. The 28 days compressive strength increases from 71.943 to 96.503 MPa in S_0 to S_{30} mixes and again reduces to 65.883MPa from S_{30} to S_{100} mixes.



Graph 1: Compressive strength results of all SCCs

2 Sorptivity Test

Three specimen of each mix were tested to determine 28-days' sorptivity. The result shows that, 30% of SF and 70% of FA gives lowest value i.e. 0.00113, which specifies that the specimen S_{30} is more durable than other specimens, which are ranges from 0.00168 to 0.00198. 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 as long as hydration of cement takes place. 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 $Ca(OH)_2$. This is made available for the hydration of pozzolanic material as long as hydration of cement takes place. 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. Particularly the finest size of SF particles enhances the impermeability by particle packing effect. That is why the sorptivity reduces by addition of SF. The combination of 30% SF and 70% FA proved to be optimum in increasing strength as well as imparting maximum durability. Sorptivity of SCCs mixes has been shown in table 8, graph2.

Table 8. Sorptivity test

Specimens	Sorptivity coefficient in $cm/s^{1/2}$
S_0	0.00168

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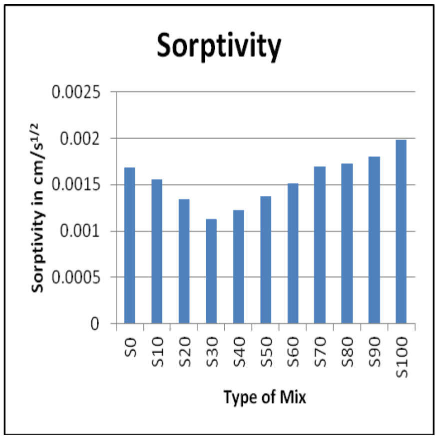
S_{10}	0.00156
S_{20}	0.00134
S_{30}	0.00113
S_{40}	0.00122
S_{50}	0.00137
S_{60}	0.00151
S_{70}	0.00169
S_{80}	0.00173
S_{90}	0.00180
S_{100}	0.00198



Graph 2: Sorptivity of all SCC

V. CONCLUSION

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

- The SCC with 30% SF and 70% FA gives maximum compressive strength and lowest sorptivity.
- The SCC with different combinations of SF and FA, exhibited satisfactory fresh properties.
- As the percentage of SF and FA is varying in each mix the variation in strength was observed.
- All the combinations of SF and FA produced required strength.
- The use of SF above 30% decreased the strength.
- The high strength self compacting concrete with combination of 30% SF and 70% FA, exhibiting best performance.
  - The use of SF above 30% and 70% of FA decreasing the strength and increasing sorptivity.
  - The utilization of FA and SF in SCC solves the problem of its disposal, thus keeping environment free from pollution.

VI. FUTURE SCOPE

The suggestion for future scope from this study is as follows:

This progration has been obtained for High Strength SCC with FA and SF. Different mineral admixture qualititably and quantitably can be varied to determine the strength and sorptivity. The correlation between strength and sorptivity can then be determined for different mineral admixture.

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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

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

Table7, graph1. Gives the cube compressive strength of the mixes