An Experimental Study on Self Consolidating Concrete with Silica Fume and Glass Fibre

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***Abstract*— Self-Consolidating Concrete (SCC) is one of "the most revolutionary developments" in construction industry. This concrete is able to flow and fill the most restricted places of the form work without vibration. The Self-Consolidating Concrete is a high performance concrete which is more consistent. To enhance the strength of Self Consolidating Concrete, Silica Fume is added, which is much finer than the cement. Alkali Resistance Glass Fibre is relatively a new construction material, which is used in SCC to increase the tensile strength of concrete. For appropriate workability, Super Plasticizer (SP) and Viscosity Modifying Agent (VMA) are added to reduce segregation of the aggregate.. Self-Consolidating concrete has identical quality, with the use of VMA and Super Plasticizer. The cost of SCC is much higher than the Conventional Concrete. The cost of materials for SCC is greater about 10-15%, when compared to materials for Conventional Concrete. But, It is economical like, savings in rate of labour, rate of pouring and rate of repair work etc., In this study 6%, 12% & 24% of Silica Fume and 0.5% of Glass Fibre by the weight of cement are added in concrete to enhance the possessions of Self Consolidating concrete. Alkali Resistant Glass Fibre with a filament length of 12 mm diameter of 14 microns, and an aspect ratio of 857 is used. In this experimental work, M30 grade of concrete is taken to determine the compressive strength, split tensile strength and flexural strength of Self Consolidating Concrete with the optimum percentage of Silica Fume, Glass Fiber, Super Plasticizer and VMA.**

Keywords— ***Self Consolidating Concrete, Silica Fume, Glass Fiber, Super Plasticizer, Viscosity Modifying Agent, Compressive strength, Split tensile strength, Flexural strength***

I. INTRODUCTION

Self-Consolidating Concrete (SCC) is made from almost the same ingredients as that of Conventionally Vibrated Concrete , except that relative proportions of these ingredients are to be suspiciously chosen to enhance self-leveling and self-consolidating property of fresh concrete without any external compaction. SCC has commonly privileged content of fines (cement, fine aggregate) and chemical admixtures, hence better cohesiveness with zero segregation are achieved.

The availability of improved variety of Super Plasticizers and Viscosity Modifying Agents together with huge quantities of mineral additives like Silica Fume (SF) and Alkali Resistant Glass Fiber (ARGF) contributed to the development of SCC.

Micro silica is a highly reactive puzzolana which is very fine amorphous silica from the Micro Silica family of products. Silica Fume (SF) enriched aggregate-matrix bond resulting from the formation of a less porous transition zone in concrete. When mixed with Portland cement, Micro Silica facilitates high performance concrete by achieving, very low chloride ion diffusion, increased compressive strength, reduced water permeability and improved sulphate resistance.

Several studies in the past have exposed the usefulness of fibers to improve the structural properties of concrete like ductility, post crack resistance, energy absorption capacity etc., Fiber reinforced Self Consolidating Concrete combines the benefits of Self Consolidating Concrete in fresh state and shows an enhanced performance in the hardened state due to the addition of fibers.

Glass Fiber Reinforced Concrete (GFRC) consists of concrete, reinforced with Alkali- Resistant Glass Fibers which produce a thin, lightweight, yet strong material. High compressive and flexural strengths, ability to reproduce fine surface details, low maintenance requirements, low coefficients of thermal expansion, high fire resistance, and environmental friendly made GFRC the ideal choice for civil engineers.

II. INVESTIGATION OF MATERIAL PROPERTIES

A. Cement

Ordinary Portland cement of 53 grade was used in this experimental study, conforming to I.S. – 12269-1987.
The properties of cement are represented in table 1.

TABLE -1: PROPERTIES OF OPC 53 GRADE CEMENT

Property	Values
Specific Gravity	3.15
Initial Setting Time	30 minutes
Final Setting Time	580 minutes
Fineness	8.5%

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B. Fine Aggregate

Locally available sand zone II conforming to I.S. -383-1970 is used in this experimental study.The properties of fine aggregate are represented in table 2.

TABLE -2: PROPERTIES OF FINE AGGREGATE

Property	Values
Specific gravity	2.65
Grading Zone	II
Water Absorption (%)	2.5
Fineness modulus	2.67
Bulk Density (kg/m3)	1668

C. Coarse Aggregate

Coarse aggregate of both size 10 mm and 12 mm confirming to IS 2386-1968 has been selected for this study. The properties of coarse aggregate are represented in table 3.

TABLE -3: PROPERTIES OF COARSE AGGREGATE

Property	Values
Specific gravity	2.74
Water Absorption (%)	1.35
Bulk Density (kg/m^3)	1755
Crushing value (%)	20
Impact value (%)	7.84

D. Silica Fume

Silica Fume also referred to as silica dust, condensed Silica Fume, Micro Silica, and Fumed Silica. Silica fume imparts betterment to rheological, mechanical and chemical properties. It increases the durability of the concrete by reinforcing the microstructure through filler effect and consequently reduces segregation and bleeding. The powdered form of Silica fume with the specific gravity of 2.25 is used in this study as shown in fig-1.

Fig -1:Silica Fume

E. Glass Fibre

Alkali Resistant Glass Fiber with a filament length of 12 mm, diameter of 14 microns with an aspect ratio of 857 is used in this study as shown in fig-2.

Fig -2:Glss Fibre

The properties of Alkali Resistance Glass Fibre are represented in table 4.

TABLE -4: PROPERTIES OF GLASS FIBRE

Property	**Values**
Specific gravity	2.68
Filament diameter (microns)	14
Tensile strength (N per sq. mm.)	80
Strain at breaking (%)	3.6
Length (mm)	12
Number of fibers per Kg weight (millions)	220
Aspect ratio	857

F. Super plasticizer

Conplast SP430 complies with IS 9103:1999 and BS: 5075 Part 3 is used in this experimental study. The Conplast SP430 is based on Sulphonated Naphthalene Polymers and supplied as a brown liquid instantly dispersible in water. Conplast SP430 has been specifically formulated to offer high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability. The Conplast SP430 is shown in fig-3.

Fig -3: Conplast SP430

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The properties of Conplast SP430 are represented in table 5.

TABLE -5: PROPERTIES OF CONPLAST SP430

Property	Values
Specific gravity	2.74
Water Absorption (%)	1.35
Bulk Density (kg/m^3)	1755
Crushing value (%)	20
Impact value (%)	7.84

G. Viscosity Modifying Agent

A Viscosity modifying admixture is colorless free flowing liquid and having Specific of gravity 1.01 ± 0.01 @ 25 º C and pH value < 6 and Chloride Content < 0.2% is used in this study. The Rheodynamic concrete is an ultra-stable form of self consolidating concrete, a very flow able concrete mixture that is able to fill every part and corner of formwork, even in the presence of dense reinforcement, due to its high fluidity and stability. Rheodynamic Concretes is produced using a GLENIUM series, which is a high range water reducing admixture. In this study, GLENIUM STREAM 2 is used as VMA as shown in fig 4.

Fig -4: Glenium Stream 2

III. CONCRETE MIX PROPORTIONS

The M30 grade of proportioning was done according the Indian Standard Recommended Method IS 10262- 2009 and with reference to IS 456-2000 .The total binder content was 350 Kg/m3, fine aggregate was taken 866 Kg/ m3 and coarse aggregate was taken 1153 Kg/m3. Water absorption capacity and moisture content were taken into consideration and the Mix ratio for conventional M30 grade of concrete is 1:2.47: 3.29.

IV. EXPERIMENTAL INVESTIGATION

A. Workability

The following trial mixes are taken to obtain the optimum percentage of Super plasticizer and Viscosity modifying agent can be added into conventional concrete to get self consolidating concrete.

TABLE -6: PROPORTIONS FOR TRIAL MIX

Trial Mix	Cement Kg/m^3	F.A Kg/m^3	C.A Kg/m^3	Water lit/m^3	SP (%)	VMA (%)
T1	350	866	1153	197	0	0
T2	350	866	1153	197	0.5	0.5
T3	350	866	1153	197	0.5	1.0
T4	350	866	1153	197	0.5	1.5
T5	350	866	1153	197	1	0.5
T6	350	866	1153	197	1	1.0
T7	350	866	1153	197	1	1.5

Workability test were conducted to choose the optimum percentage of SP and VMA. 1% of SP and 1 % of VMA by the weight of cement are obtained as optimum percentage from various workability tests.

Self Consolidating Concrete mix proportion is shown in the following table 7. Slump cone test, V funnel test and L box test were carried out to find the fresh concrete properties.

TABLE -7: SCC TRIALS

SCC Trials	Cement Kg/m^3	F.A Kg/m^3	C.A Kg/m^3	Water lit/m^3	SP (%)	VMA (%)	SF (%)	GF (%)
S	350	866	1153	197	1	1	0	0
S1	350	866	1153	197	1	1	6	0.5
S2	350	866	1153	197	1	1	12	0.5
S3	350	866	1153	197	1	1	24	0.5

1) Slump Test

Mould in the shape of a truncated cone with the internal dimensions 200 mm diameter at base, 100 mm diameter at top and a height of 300 mm, conforming to EN 12350-2 is shown in fig. 5.Base plate of a stiff non-absorbing material, at least 700mm square, with a circle marking the central location for the slump cone, and a additional concentric circle of 500 mm diameter. Roughly 6 litres of concrete is needed to carry out the test. Wet the base plate and inside of slump cone. Place the base plate on level ground and the slump cone on the base plate centrally. Fill the cone with concrete using the scoop. Do not tamp and simply strike off the concrete with the trowel. Take away any surplus concrete from around the base of the cone. Lift the cone vertically and allow the concrete to flow out freely. At the same time, start the stopwatch and record the time taken for the concrete to reach the 500mm spread circle. (This is called T50 time). Calculate the final diameter of the concrete in two perpendicular directions and the average of the two measured diameters. (This is called slump flow in mm). The tests results are represented in table 8.

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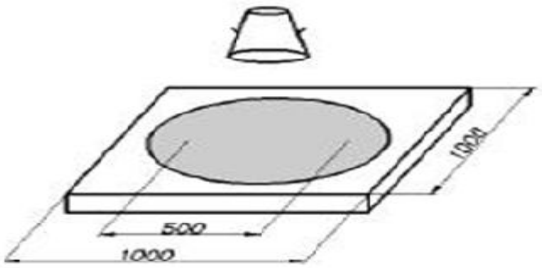

Fig-5: Slump test

2) *V-funnel test*

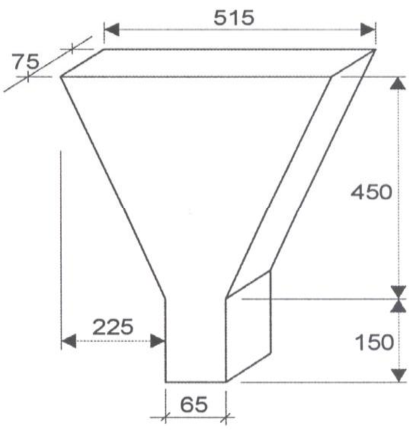

Fig-6: V-funnel test

Approximately 12 liter of concrete is required to perform the test. Set the V-funnel on stiff ground which is shown in fig-6.Wet the inside surfaces of the funnel. Keep the trap door open to allow any leftover water to drain. Lock the trap door and place a bucket beneath. Fill the apparatus completely with concrete without consolidating or tamping, simply strike off the concrete level with the top with the trowel. Open the trap door within 10 sec after filling and allow the concrete to flow out under gravity. Begin the stopwatch when the trap door is opened, and record the time taken for the concrete discharge to complete (the flow time). The entire test has to be performed within 5 minutes. The test results are represented in table 8.

3) *L-Box Test*

Fig-7 shows the experimental setup L-Box test to determine the workability of fresh concrete. Approximately 14 litres of concrete is needed to perform the test. Set the apparatus on stiff ground, and ensure that the sliding gate can open freely and then close it. Wet the inside surfaces of the apparatus and remove any surplus water. Fill the vertical section of the apparatus with the concrete. Make it to stand for 1 minute. Raise the sliding gate and allow the concrete to flow out into the horizontal section. At the same time, start the stopwatch and record the time taken for the concrete to reach 200 and 400 mm marks. When the concrete stops flowing, the distances "H1" and "H2" are measured carefully. Calculate the blocking ratio (H2/H1). The entire test has to be performed within 5 minutes.

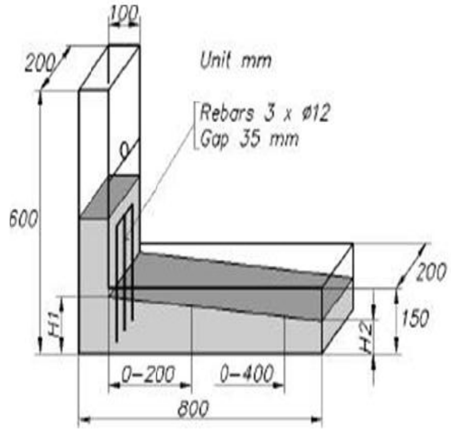

Fig-7: L-Box Test

The results are tabulated in table 8.

TABLE -8: WORKABILITY TEST RESULTS FOR SCC

Trials	Slump flow (mm)	T50 cm Slump flow (sec)	V-Funnel (Sec)	L-Box (h_2/h_1)
S	700	2	7	1
S1	695	3	9	0.95
S2	675	4	10	0.9
S3	665	6	11	0.85

B. *Hardened concrete test*

1) *Preparation of Specimens*

Cement, Sand and Coarse aggregate were suitably mixed together in the ratio of 1:2.47: 3.29.With the dry mix suitable percentages of silica fume and glass fibre is added. After that selected percentage of SP and VMA along with mixing water is added and mixed properly to get uniform quality of self consolidating concrete. Mould is first coated with oil and then uniformly mixed concrete is poured in it and allowed to hard for a period of 24 hours. After that specimens were demolded and poured in water for curing.

2) *Compressive Strength Test*

The cube specimens were tested on compression testing machine of capacity 1000KN.The bearing surface of machine should be free from sand or other material. The specimen was placed in such a manner, that the load was applied on the opposite sides of the cubes as casted. The axis of the specimen was cautiously aligned at the center of loading frame. The load applied was increased at a constant rate until the load breaks the specimen. The maximum load sustained by the specimen was recorded carefully. The compressive strength was calculated by using the formula,

$$fck = P/A \quad (N/mm^2)$$

Where, P= Failure load (kN)
A= Surface area of the specimen (mm^2)

The experimental setup is shown in Fig 8.

Fig-8: Compressive Strength Test

The test results are listed in table 9.

TABLE -9: COMPRESSIVE STRENGTH TEST RESULTS

Description	Compressive strength (N/mm^2)		
	7 days	*14 days*	*28 days*
CC	19.4	28.4	31.26
S	33.1	37	38.5
S1	33.43	37.33	38.9
S2	33.7	37.9	39.33
S3	31.5	34.98	37.6

From the table 9, the compressive strength test results for conventional concrete and various self consolidating concrete specimens at 7 days, 14 days and 28 days have been observed and represented in chart 1.

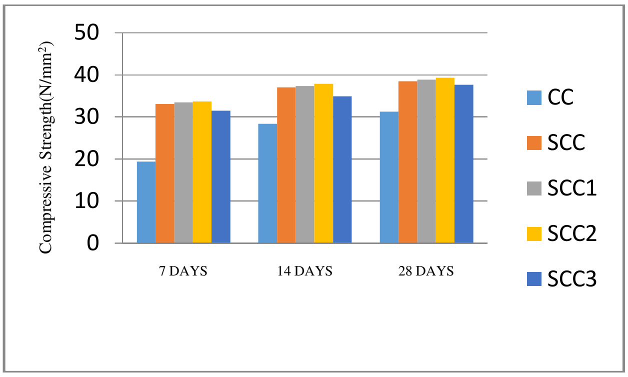

Chart -1: Comparison of Compressive strength test results

By observing the above test results, it is concluded that the S2 specimen (12 % of Silica Fume and 0.5 % of Glass Fibre) gains more Compressive strength compared to other mixes taken.

3) Split Tensile Strength Test

The cylinder specimens were tested on compression testing machine of capacity 1000KN.The bearing surface of machine should be free from sand or other material. The load applied was increased at a constant rate until the resistance of the specimen to the increasing load breaks down and no longer can be sustained. The maximum load sustained by the specimen was recorded carefully. The Split tensile strength was calculated by using the formula,

$$f_{split} = 2\,P/\pi DL \qquad (N/mm^2)$$

Where, P=load (kN)
D= diameter of cylinder. (mm^2)

The experimental setup is shown in fig-9.

Fig-9: Split tensile Strength Test

The test results are listed in table 10.

TABLE -10: SPLIT TENSILE STRENGTH TEST RESULTS

Description	Split tensile strength (N/mm^2)		
	7 days	*14 days*	*28 days*
CC	1.9	1.9	2
S	2.4	2.4	2.5
S1	2.6	2.6	2.8
S2	2.8	2.8	2.9
S3	2.8	2.8	2.8

From the table 10, the Split tensile strength test results for conventional concrete and various self consolidating concrete specimens at 7 days, 14 days and 28 days have been observed and represented in chart 2.

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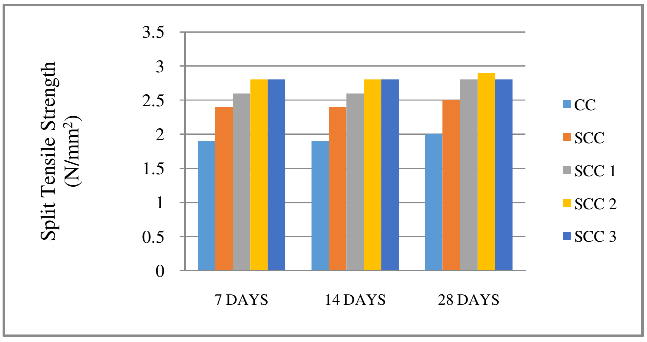

Chart -2: Comparison of Split tensile strength

By observing the above test results, it is concluded that that the S2 specimen (12 % of Silica Fume and 0.5 % of Glass Fibre) gains more Split tensile strength compared to other mixes taken.

4) Flexural Strength Test

The beam specimens were tested on a universal testing machine for two-point loading to create pure bending. The bearing surface of machine should be free from sand or other material. The two point bending load applied was increased at a constant rate until the specimen breaks down and no longer can be sustained. The maximum load sustained by the specimen was recorded carefully. The modulus of rupture depends on the place where the specimen breaks along the span. If the specimen breaks at the middle third of the span then the modulus of rupture is given by frup = (WL) / (bd2) If the specimen breaks at a distance of 'a' from any of the supports then the modulus of rupture is given by

F_{rup} = (WL) / (bd2) (N/mm^2)

where , W = load at failure, (kN)
L = length of specimen (500mm)
b = width of specimen (100mm)
d=depth of specimen (100mm)

The experimental setup for flexural strength test is shown in fig-10

Fig-10: Flexural Strength Test

The test results are listed in table 11.

TABLE -11: FLEXURAL STRENGTH TEST RESULTS

Description	Flexural strength (N/mm^2)		
	7 days	*14 days*	*28 days*
CC	2.85	3.43	3.82
S	3.5	3.82	4.23
S1	3.55	3.87	4.27
S2	3.59	3.91	4.32
S3	3.43	3.75	4.13

From the table 11, the Flexural strength test results for conventional concrete and various self consolidating concrete specimens at 7 days, 14 days and 28 days have been observed and represented in chart 3

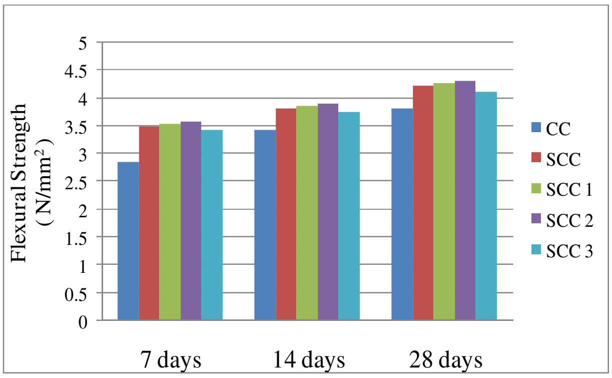

Chart -3: Comparison of flexural strength

By observing the above test results, it is concluded that the S2 specimen (12 % of Silica Fume and 0.5 % of Glass Fibre) gains more Flexural strength compared to other mixes taken.

V. CONCLUSIONS

- Based on the above experimental investigation, the following conclusions are drawn.
- The test results of fresh concrete are within the limits of SCC i.e., flow ability, passing ability and resistance against segregation.
- The compressive strength, split strength and flexure strength of Self-Consolidating Concrete is more than the Conventional Concrete.
- It is found that the ratio of gain in strength is almost same or even better than that of Conventionally Vibrated Concrete.
- The compressive strength of self consolidating concrete which has 12% of Silica Fume and 0.5 % of Glass fibre is 2.15 % greater than the conventional self consolidating concrete and 25.81% greater than the conventionally vibrated concrete.
- The split tensile strength of self consolidating concrete which has 12% of Silica Fume and 0.5 % of Glass fibre is 16 % greater than the conventional self consolidating concrete and 45 % greater than the conventionally vibrated concrete.

- The Flexure strength of self consolidating concrete which has 12% of Silica Fume and 0.5 % of Glass fibre is 2.13 % greater than the conventional self consolidating concrete and 13 % greater than the conventionally vibrated concrete.

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