

# Comparison between Strength and Durability of Glass Fiber Reinforced Self Compacting Concrete with Normal Concrete

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**ABSTRACT:** Self Compacting Concrete (SCC) is a novel invention in concrete and addition of fibers to it shows improved strength and other engineering properties. In the past, several studies have been carried out on the SCC with addition of fibers. In this study, addition of four different volume fractions of glass fibers viz. 0.05%, 0.10%, 0.15% and 0.20% on a M30 grade SCC was investigated. For testing the properties of SCC and Glass Fiber Reinforced SCC (GFRSCC) in fresh state, slump-flow, L-box and V-funnel tests were conducted. Whereas for testing the properties in hardened state, compressive, split tensile, flexural strengths and durability tests were planned to be carried out. In this paper, the results obtained on the fresh and hardened properties of SCC with and without glass fibers are presented.

**KEYWORDS:** Self Compacting Concrete, Glass Fiber Reinforced SCC, Super plasticizer, Strength and durability properties.

## I. INTRODUCTION

In the recent days due to rapid industrialization and urbanization tall, robust and smart structures are quite common. Hence researchers are developing new materials which are durable and strong enough to resist the applied loads. Many structures are being designed with congested reinforcement making the placement of concrete a highly difficult task. In such situation Self Compacting Concrete (SCC) offers a good solution. SCC is relatively a brittle material and addition of fibers improves its ductility and other engineering properties. Fiber Reinforced Concrete (FRC) is relatively a new construction material developed through extensive research and development work during the last two decades. It has already found a wide range of practical applications and proved to be reliable construction material having superior performance characteristics compared to conventional concrete. Incorporation of fibers in concrete has found to improve several properties like tensile strength, cracking resistance, impact & wear resistance and ductility & fatigue resistance. Many fibers like asbestos, steel, nylon, coir, etc. have been used in the past. Out of these, asbestos fiber concrete is successful although its exposure is detrimental to the health of human beings. Steel fibers in concrete improve ductility, flexural strength and toughness. Sometimes corrosion damage and increased density are the drawback of the steel fibers. Further development in the field of FRC was due to the introduction of high strength fibers like glass and carbon fibers. The initial studies showed deterioration of glass fibers due to corrosive alkali environment of the cement paste. The alkali resistant glass fiber, which is developed, recently has overcome this defect and can be effectively used in concrete. In this paper the fresh and hardened properties of SCC with and without glass fibers are investigated, and the results obtained are presented and discussed. Based on the investigations carried out, the conclusions arrived at are given.

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## 1. Super plasticizer

Most admixture manufactures have a range of super plasticizing admixtures tailored to specific user requirements. The admixtures should bring the required water reduction and fluidity at the same time should also maintain its dispersing effect during the time required for transport and application. The required consistence retention will depend on the application. The super plasticizer produces a homogeneous and cohesive concrete generally without any segregation and bleeding. In this study CONPLAST SP 430 with the following properties has been used.

1. Appearance : Brown liquid
2. Shelf life : 12 months
3. Specific gravity : 1.19 (appr.)
4. Chloride content : 0.0 %

## 2. Glass fibers

Both metallic and polymer fibers have been used in the production of SCC, but they may reduce flow ability and passing ability. Trials are therefore needed to establish the optimum length, diameter and quantity of fibers to give all the required properties at both the fresh and hardened stages of concrete. The properties of glass fiber are given in Table 1. Fig. 1 shows the glass fiber used in this study.

**Table 1: Properties of glass fiber**

S. No.	Name of property	Value
1	Fiber length	6 mm
2	Fiber diameter	12 microns
3	Number of fiber	225 million/kg
4	Dosage rate	0.4 kg/m <sup>3</sup> to 0.6 kg/m <sup>3</sup>
5	Specific surface area	110 m <sup>2</sup> /kg
6	Tensile strength	1700 MPa
7	Specific gravity	2.6
8	Density	28 KN/m <sup>3</sup>
9	Aspect ratio	1000 : 1
10	Modulus of elasticity	75 GPa
11	Size content	1.0 %

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**Fig. 1: Glass fiber**

## II. JAPANESE METHOD OF TESTING OF SCC AND GFRSCC

This method was suggested by Okamura in 1993, after extensive trials in laboratory and at sites. It was based on the basis of the result carried out by Ozawa, Okamura and Maekawa at the University of Tokyo and further refined by Ouchi. The research program commenced as early as 1998. The basic principles enunciated by them are described below.

SCC can be achieved by limiting coarse aggregate content, by having high powder content and by using a good super plasticizer. In a fresh concrete the energy required for smooth flow is principally consumed by increased internal stresses arising from collisions and blockages caused by coarse aggregate content, to a level lower than in a conventional concrete, reduces this energy loss. A highly viscous paste is also required to avoid blockage of coarse aggregate particles when concrete flows through obstacles. This also prevents localized internal stresses caused by coarse aggregate particles when concrete is deformed. High deformability of fresh concrete can be achieved only by the employment of a super plasticizer, keeping the water-powder ratio by volume to a low value.

In Japanese method, coarse and fine aggregate contents are initially fixed so that the self compatibility is achieved by adjusting water-powder ratio and super plasticizer dosage. Strength requirements are assessed from the field trials of SCC at a later stage. Following steps are involved in this method.

- Decide the air content, this would depend on air entering requirements, if any. If no-air entrainment is specified one may assume about 2 percent of air content.
- The coarse aggregate content in concrete is tentatively fixed at 50 to 60 percent of volume of concrete. This is based on its bulk density.
- The fine aggregate content is also tentatively fixed at 40 to 50 percent of the mortar volume of concrete. Mortar is defined as a mixture consisting of cement paste, filler and fine aggregate. Okamura et al. arrived at this range of fine aggregate content after extensive field trial and also from laboratory trial, in which they employed an instrument called V-funnel and postulated funnel speed index. Funnel speed index, like marsh cone, indicates the flow ability of mortar through a narrow opening and is an empirical test for measuring of mortar.
- The type of filler and its proportion to cement are then decided based on experience. In order to arrive appropriate value of powder ratio, defined as ratio of water to powder consisting of cement and filler, test are conducted on mortar at different water powder ratio using flow cone.
- Super plasticizer is then added to the mortar at different dosages and the flow cone and V-funnel tests are

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performed. The target values are slump flow of 240 mm to 260 mm and V-funnel time of 7 to 11 seconds. If these criteria cannot be fulfilled, then the particular combination of material in the mortar is considered inadequate.

- Once water–powder ratio and super plasticizer dosage have been determined, coarse aggregate is added to mortar and trial mixes of concrete are made. U-box test is carried out to ascertain the self-compatibility of concrete.

### III. MIX PROPORTION

There is no proper procedure available for SCC, hence the final mix proportions were designed based on trial and error method in which various proportion of Water-Cement (W/C) ratio have been tried to arrive at the mix giving the appropriate workability which meets the self compacting standards.

### SPECIMEN PREPARATION AND CASTING

All the ingredients were first mixed in dry condition for 1 minute then 70 % of water was added to dry mix and mixed thoroughly for 1 minute. Remaining 30 % of water is divided into 2 parts i.e. 20 % and 10 %. Now the 20 % of water is mixed with Conplast SP 430 (super plasticizer) and it is poured into already mixed concrete and mixed for four minutes. Then the last 10 % of water mixed for 1 minute. Then required quantities of glass fibers were sprinkled over the concrete mix and mixed for 1 minute to get a uniform mix. Before casting, mould oil of grade 40 was smeared on the inner surface of cube moulds, cylindrical moulds and beam moulds. Then the mix was checked for fresh properties such as passing ability, filling ability by L-box test, V-funnel test and slump cone test. Afterwards the mixed concrete is used for casting cubes, cylinders and beams/prisms. After 24 hours of casting, the specimen were de-moulded and cured for 7 days and 28 days period.

### TESTING PROCEDURE

The specimen were then taken off from water after curing, wiped with clean dry cloth and kept ready for compression test, split tensile test and flexural test. The testing for hardened concrete properties were conducted as per IS: 516 code.

### TESTS ON FRESH PROPERTIES OF SCC

The main characteristics of SCC are the properties in the fresh state. SCC mix design is focused on the ability of flowing under its own weight without vibration, the ability to flow through heavily congested reinforcement under its own weight, and the ability to obtain homogeneity without segregation of aggregate. Several test methods are available to evaluate these main characteristics of SCC. The tests have not been standardized by national or international organizations. The more common test for evaluating the compacting characteristics of fresh SCC in accordance with the draft standards of Japan society of civil engineering are described below.

#### Flow ability

Flow ability is the ease of flow of fresh concrete when unconfined by formwork or reinforcements. SCC flows under its own weight filling formwork and flowing around recesses or embedded without leaving voids. As it is highly fluid, it can flow considerable distances horizontally and upwards to fill vertical elements from the bottoms. SCC can be pumped into the column and wall formwork from the bottom through special valves, eliminating the use of cracked platforms etc.

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### Passing ability

The ability of fresh concrete to flow through dense steel reinforcements bars without segregation and blockage. The passing ability enables SCC, of appropriate aggregate grade, to flow around congested reinforcements without blocking or affecting the homogeneity of concrete.

### Segregation resistance

The ability of concrete to remain homogeneous in composition while in its fresh state segregation is observed as surface bleeding of water and formation of surface mortar laitance. This is undesirable in SCC as in traditional concrete. Most critical problem of segregation is the separation of the mortar from the coarse aggregate fraction even though full compaction is achieved. This can cause settlement of coarse aggregate in deep sections. Together with blocking, it can prevent the free flow of concrete around the reinforcement. As SCC is cohesive in nature and in spite of its high fluidity, there is no internal settlement of coarse aggregate particles.

### Slump flow test

The slump test is used to attain the horizontal free flow of SCC in the absence of obstruction. This method is based on the best method of determining the slump. The diameter of the concrete is a measure of the filling ability of concrete and some indication or resistance towards segregation. Fig.2 shows the slump flow test in progress. The procedure for slump flow test is given below.



Fig. 2: Slump flow test

### Procedure of slump flow test

- About 6 liters of concrete was taken to perform the test.
- The slump cone inside and the base plate top were moistened with water.
- The slump cone was placed centrally over the base plate and firmly held in position.
- The slump cone was filled with the SCC.
- Then cone was raised vertically and concrete was allowed to flow freely.
- Diameter of the slump flow was measured.

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## Acceptance limit for slump flow test

Diameter of the slump flow should be between 600 and 800 mm.

## V-Funnel test

The V-funnel test is used to determine the filling ability of the concrete with a maximum aggregate size of 12 mm. The funnel is filled with about 12 liters of concrete and the time taken for it to flow through the apparatus is measured.

## Procedure of V-funnel test

- About 12 liters of concrete was taken.
- V-funnel was set on firm ground.
- Inside surface of the funnel was moistened.
- The apparatus was completely filled with concrete without compacting or tamping, simply strike off the top surface of concrete.
- The trap door was opened within seconds after filling and the concrete was allowed to flow out under its gravity.
- The time for complete discharge of concrete was noted.

## Acceptance limit for V-funnel test

V-funnel flow time ( $T_f$ ) should be less than 6 seconds.

## V-funnel (at 5 minutes) test

V-funnel test at 5 minutes is used to measure the segregation resistance of the concrete. The funnel is filled with concrete and left for 5 minutes to settle. If it is noticed that if the concrete shows segregation then the flow time will increase significantly.

## Procedure for V-funnel (at 5 minutes) test

- About 12 liter of concrete was taken.
- The V-funnel was set on firm ground.
- The inside surface of the funnel was moistened.
- The apparatus was completely with concrete without compaction or tamping.
- Then it was allowed to settle for 5 minutes.
- The trap door was opened and the concrete was allowed to flow out.

## Acceptance limit for v-funnel (at 5 minutes) test

Flow time should be less than 6 seconds (or some times less than  $T_f+3$  seconds).

## IV. TEST RESULTS ON FRESH PROPERTIES OF SCC

The various trial mixes tried so as to achieve SCC and fresh properties tests conducted on trial mixes are given in Table 2. From the results obtained for various trial mixes, it is found that trial mix 5 alone satisfies the

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characteristics of SCC.

**Table 2: SCC fresh properties on trial mixes**

Description	Conventional mix (M30)	SCC 1 (Trial 1)	SCC 2 (Trial 2)	SCC 3 (Trial 3)	SCC 4 (Trial 4)	SCC 5 (Trial 5)
Cement (kg/m <sup>3</sup> )	587	495	480	470	450	440
FA (kg/m <sup>3</sup> )	623	862	862	862	862	862
CA (kg/m <sup>3</sup> )	967	660	660	660	660	660
Marble dust (kg/m <sup>3</sup> )	-	85	90	95	95	100
Super Plasticizer (l/m <sup>3</sup> )	-	5	5	5.2	5.2	5.5
Water (l/m <sup>3</sup> )	222	240	320	340	350	360
Slump cone value (mm)	-	450	523	668	745	793
V-funnel value (sec)	-	12	10	8	6	4

## HARDENED PROPERTIES OF SCC & GFRSCC

The 7 days compressive, split tensile and flexural strengths of the SCC on standard specimens were found. The results obtained for SCC are given in the Table 3. Likewise the 7 days compressive, split tensile and flexural strengths of the GFRSCC on standard specimens along with fresh properties were found. The results obtained for GFRSCC are given in Table 3. The standard specimens used were: 150 mm x 150 mm x 150 mm cubes for compression test, 150 mm diameter x 300 mm long cylinders for split tension and 150 mm x 150 mm x 700 mm prisms for flexural strengths.

**Table 3: Test results of SCC**

Description	Conventional mix (M30)	SCC 1 (Trial 1)	SCC 2 (Trial 2)	SCC 3 (Trial 3)	SCC 4 (Trial 4)	SCC 5 (Trial 5)
7 days compressive strength of SCC (N/mm <sup>2</sup> )	-	18.2	20.4	22.5	26.2	18.8
7 days split tensile strength of SCC (N/mm <sup>2</sup> )	-	1.41	1.62	1.63	2.52	1.85
7 days flexural strength of SCC (N/mm <sup>2</sup> )	-	1.6	2.1	2.4	3.2	2.2
28 days compressive strength of SCC (N/mm <sup>2</sup> )	-	27.1	29.3	30.8	31.7	30.5
28 days split tensile strength of SCC (N/mm <sup>2</sup> )	-	2.0	2.7	2.9	3.6	3.2
28 days flexural strength of SCC (N/mm <sup>2</sup> )	-	2.2	2.6	3.1	3.7	2.8

From the compressive strength variation between 7 days and 28 days in Self Compacted Concrete(SCC) in Trial 4 having high compressive strength value among all trial mixes which are used for the test. It will be noted from the following chart 1.

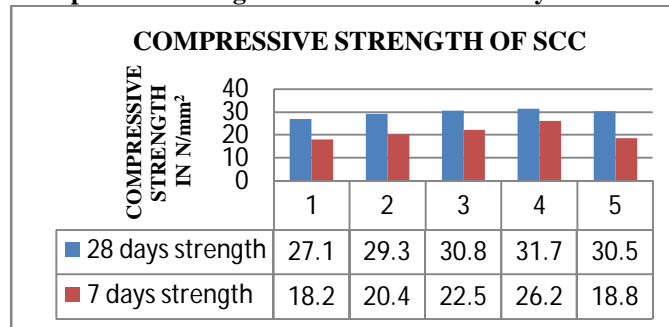
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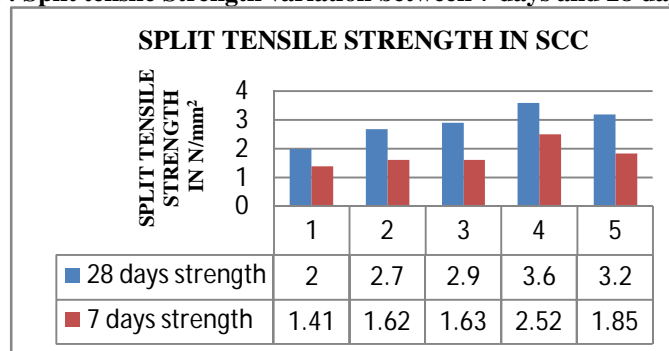
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**Chart 1 : Compressive Strength variation between 7 days and 28 days in SCC**



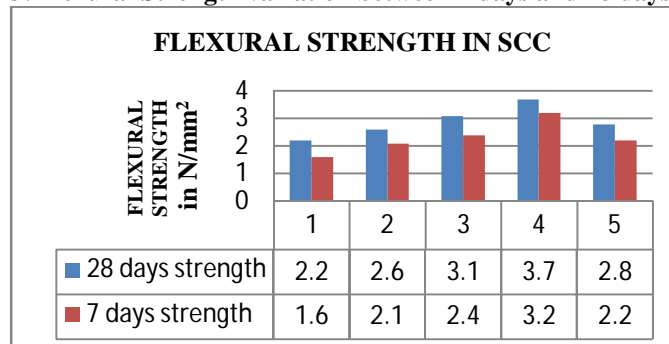
From the split tensile strength variation between 7 days and 28 days in Self Compacted Concrete(SCC) in Trial 4 having high split tensile strength value among all trial mixes which are used for the test. It will be noted from the following chart 2.

**Chart 2 : Split tensile Strength variation between 7 days and 28 days in SCC**



From the Flexural strength variation between 7 days and 28 days in Self Compacted Concrete(SCC) in Trial 4 having high Flexural strength value among all trial mixes which are used for the test. It will be noted from the following chart 3.

**Chart 3: Flexural Strength variation between 7 days and 28 days in SCC**



From the Glass fiber Reinforced Self Compacted Concrete(GFRSCC) Test results, Slump cone test and V-funnel test value are noted and also Compressive strength, Split tensile strength, Flexural strength of GFRSCC values are



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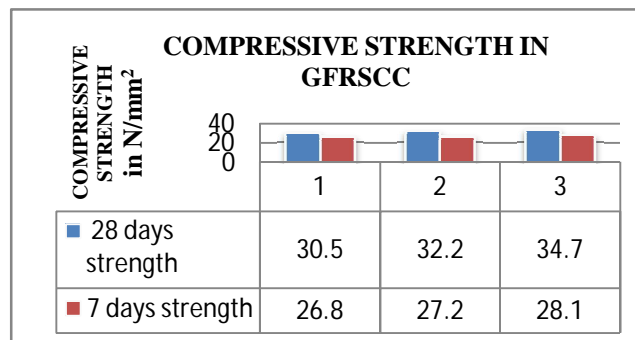
tabulated in Table 4.

**Table 4: Test results of GFRSCC**

Description	GFRSCC 1 (Trial 1)	GFRSCC 2 (Trial 2)	GFRSCC 3 (Trial 3)
Slump cone value (mm)	760	782	785
V-funnel value (sec)	9	10	12
7 days compressive strength (N/mm <sup>2</sup> )	26.8	27.2	28.1
7 days split tensile strength (N/mm <sup>2</sup> )	2.55	2.62	2.80
7 days flexural strength (N/mm <sup>2</sup> )	3.25	3.36	3.41
28 days compressive strength (N/mm <sup>2</sup> )	30.5	32.2	34.7
28 days split tensile strength (N/mm <sup>2</sup> )	2.87	3.03	3.21
28 days flexural strength (N/mm <sup>2</sup> )	3.57	3.89	3.93

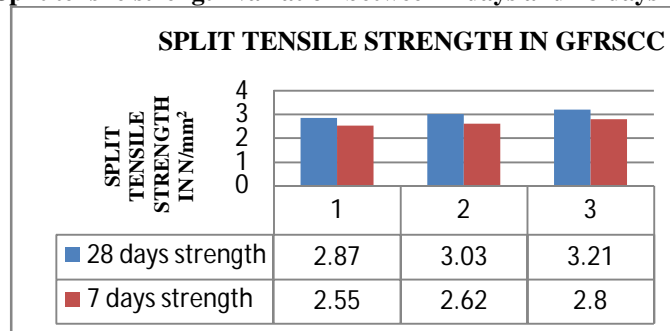
From the Compressive strength variation between 7 days and 28 days in Glass Fiber Reinforced Self Compacted Concrete(GFRSCC) in Trial 3 having high Compressive strength value among all trial mixes which are used for the test. It will be noted from the following chart 4.

**Chart 4: Compressive strength variation between 7 days and 28 days in GFRSCC**



From the Split tensile strength variation between 7 days and 28 days in Glass Fiber Reinforced Self Compacted Concrete(GFRSCC) in Trial 3 having high split tensile strength value among all trial mixes which are used for the test. It will be noted from the following chart 5.

**Chart 5: Split tensile strength variation between 7 days and 28 days in GFRSCC**



From the Flexural strength variation between 7 days and 28 days in Glass Fiber Reinforced Self Compacted Concrete(GFRSCC) in Trial 3 having high Flexural strength value among all trial mixes which are used for the test. It

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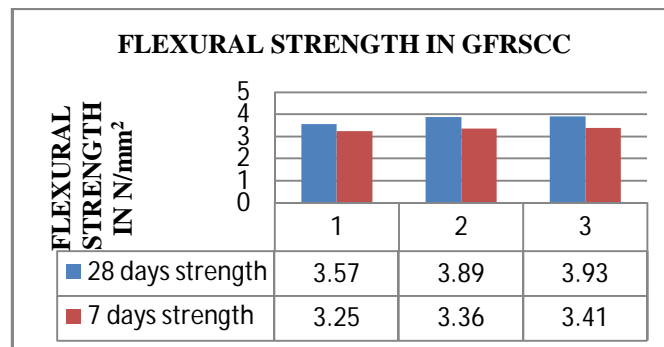
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will be noted from the following chart 6.

**Chart 6: Flexural Strength variation between 7 days and 28 days in GFRSCC**



## V. CONCLUSIONS

The conclusions drawn are presented.

- Fresh properties of SCC & GFRSCC mixes are shown. Fresh properties tests were conducted on all the SCCs.
- The paper highlighted the various tests used to assess the self compacting property of SCC with and without fibers.
- The fresh property results, such as slump cone test value and V-funnel test value, obtained for SCC with and without glass fibers for various trial cases are presented. The flowing ability & passing ability of GFRSCC mixes compared to normal SCC mixes indicates the presence of glass fibers showed very less changes. This may be due to low dosage of fiber addition, and also due to high dispersing nature of glass fibers.
- The average 7 days compressive, split tensile and flexural strengths of SCC are 21.22 N/mm<sup>2</sup>, 1.81 N/mm<sup>2</sup> and 2.3 N/mm<sup>2</sup>. The corresponding strength values at 7 days for GFRSCC are 27.37N/mm<sup>2</sup>, 2.66 N/mm<sup>2</sup> and 3.34 N/mm<sup>2</sup>. Similarly 28 days Average compressive, split tensile, and flexural strength of SCC are 29.88 N/mm<sup>2</sup>, 2.88 N/mm<sup>2</sup> and 2.88 N/mm<sup>2</sup>. The corresponding average strength values at 28 days for GFRSCC are 32.47 N/mm<sup>2</sup>, 3.04 N/mm<sup>2</sup> and 3.80 N/mm<sup>2</sup>.
- From the result, GFRSCC will give the more compressive, split tensile and flexural strength when compared with SCC. Glass Fiber Reinforced Self Compacted Concrete will give more durability when it will be compared with normal SCC.

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