Mechanical Properties of Self-compacting Concrete Made of Glass Fibre

Debarshree, Biswajit Jena, Kaliprasanna Sethy, Asish Kumar Pani, and Kirti Kanta Sahoo

Abstract Self-compacting concrete (SCC) which is an extremely floatable, non-segregated concrete can reach easily at the congested formwork and covers the brace without any vibration. This present research work is focused on comparison of the mechanical properties of glass-fibre-reinforced SCC of grade M30. The mechanical properties of SSC like compressive strength, flexural strength, split tensile strength with different ages at 7 and 28 days are evaluated. During the experimental work, the workability is measured by slump flow test, T50 flow test, L-box test and V-funnel test. In this current experiment, long chopped glass fibres of size 12 mm are used to reinforce SCC. Replacement percentages such as 0.05, 0.10, 0.15, 0.20, 0.25 and 0.30% are adopted throughout the research programme. It is observed that at 0.20% replacement, mechanical properties show the better results than control mix and other replacement percentage. Load deflection curve of SCC beam reinforced with glass fibre shows better ductility.

Keywords Compressive strength · Flexural strength · Split tensile strength · Load deflection curve · Sorptivity

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B. B. Das et al. (eds.), *Recent Developments in Sustainable Infrastructure*, Lecture Notes in Civil Engineering 75, https://doi.org/10.1007/978-981-15-4577-1_40

1 Introduction

Self-compacting concrete (SCC) is a highly fluid and stable concrete that can flow consistently under its own weight, pass between the bars and fill in the formwork without the need of compaction. The self-compact ability is achieved by adding a superplasticizer to the mixture and by increasing the amount of fine materials. From different types of studies, it has been shown that fibre reinforcement materials are proved to be efficient as compared to other materials. These types of fibre component are used to improve cracking and fracture toughness of the structure. The local structure has deboning, pulling out and sliding of the fibres which provide the bridging action. The fibres reduce the starting of macrocracking and avoid opening as well as growth of cracks in the structure. Due to these types of components, high demand of energy is required for remarkable crack propagation. Use of low volumetric fibre demand does not affect the elastic performance of the structure.

The glass fibres are two types: (1) continues, (2) discontinues or chopped fibres. Principal choices are below cost, huge capacity, easy and safely functioning and rapid and orderly diffusion expedite comparable mixes [ShahanaSheril, P.T, 2013].

In the current work, SCC having 12 mm chopped glass fibre added in various proportions like 0.05, 0.1, 0.15, 0.20, 0.25 and 0.39%, respectively, have been used.

2 Experimental Programme

2.1 Materials

In this project, Portland slag cement is used according to IS 455:1989. The physical properties are referred from IS 12089:1987 presented in Table 1. In this experiment, 10 mm size of coarse aggregates are used. The required physical properties are referred from IS: 383-1970 (Table 2). Zone III sand is used according to IS: 383-1970 and the properties are in Table 2. Alkali-resistant glass fibre (ARGF) of Young's modulus of 72 GPA and 12 mm long is utilized and the physical properties are given in Table 3. Advantages of this type of glass fibres are little price, better strength, easy and safe behaviour, and then quick and unchanging dispersion simplifying same mixes which in word produce durable concrete. In this research, the SIKA VISCOCRETE 2004 NS superplasticizer is used.

2.2 Mixture Proportion

The experiment of the ordinary concrete and GFRC mix concrete, M30 grade of concrete mix for SCC using subsequent EFNARC code 2005 is prepared. Table 4 shows the mix proportion for both mix. Sika Viscocrete 2004 NS was used to improve

Table 1 Physical properties of Portland slag cement

Sl. no	Particulars		Test results	Requirement of IS:12089:1987
1	Fineness obtained (in M^2/Kg)		389	225 (min)
2	Setting time (minutes)			
	Initial setting time		98	30 (min)
	Final setting time		198	600 (max)
3	Soundness			
	Lechatilier expansion (mm)	1.00		10 (max)
	Autoclave (%)	0.12		0.8 (max)
4	Compressive strength (MPa)			
	72 + 1 h	27.60		16.00
	168 + 2 h	39.50		22.00
	672 + 4 h	56.7		23.00
5	Consistency	31.5%		
6	Fineness	100%		
7	Specific gravity	3.00		

Table 2 Physical properties of coarse aggregate

Sl. no	Coarse aggregate	Fine aggregate
Specific gravity	2.53	2.67
Fineness modulus	6.2	2.28
Water absorption	0.4 (%)	0.85 (%)

Table 3 Physical properties of glass fibre

Type of fibres	CT2024
Length of the fibre (mm)	12
Density of fibre (g/cm3)	2.53
Elastic modulus of fibre (GPa)	43–50
Tensile strength of fibre (MPa)	1950–2050
Elongation at break (%)	7–9
Water absorption	<0.1

Table 4 Approve mix proportion of SCC

Cement in (kg/m^3)	Water in (kg/m^3)	Fine aggregate in (kg/m^3)	Coarse aggregate in (kg/m^3)	Superplasticizer in (kg/m^3)
585.42	234.168	910.889	575.424	2.342
1	0.4	1.56	0.98	0.004

Table 5 Result of fresh concrete

Test	Time (SEC)	Measurement
T500 test	3.8	697 mm
V-funnel test	8	8 s
L-box test	6	7.25/7.4 = 0.98

the workability. To satisfy SCC, the workability was measured by T500 test, L-box test and V-funnel test. Glass fibre percentages of 0.05, 0.10, 0.15, 0.20, 0.25 and 0.30% are added to concrete to make composite concrete.

2.3 Testing of Fresh Concrete

T500 and L-box test were conducted to measure the degree of workability. If the concrete can flow above 500 to 700 mm then the slump test value satisfies SCC. Like flow value, in L-box test, concrete can flow in between 8 s. To control the flow ability of self-compacting concrete, V-funnel test is analysed. The test result of workability is shown in Table 5.

2.4 Preparation of Test Specimens

Cube of size 150 × 150 × 150 mm, cylinder of size 150 × 300 mm and prisms of size 100 × 100 × 500 mm were taken for conducting mechanical properties. After demoulding, all the samples are cured for 28 days in normal tap water.

2.5 Sorptivity Test

Sorptivity test measure for capillary force which utilizes the outlet structure produces liquids to be peaked into the body of the structure. Here, the capillary rice is calculated in concrete cube by putting the cube in water to a depth of 2 to 5 mm deep. The relation among absorption and sorptivity is

$$K = \frac{W}{A\sqrt{t}}$$

where K = sorptivity,
W/A = water absorption per unit area cumulatively,
t = time elapsed.

Table 6 Characterization of mixes

Classification	Fibre content (%)	Description
PSC	0.0	Plain SCC
GFC–0.5	0.05	0.05% GFRSCC
GFC–1	0.1	0.1% GFRSCC
GFC–1.5	0.15	0.15% GFRSCC
GFC–2	0.2	0.2% GFRSCC
GFC–2.5	0.25	0.25% GFRSCC
GFC–3	0.3	0.3% GFRSCC

This was accompanied in laboratory. The time interval selected is 30 min, 1, 2, 6, 24 and 48 h and then remove the sample from the water and weigh it. Weigh the cube till the weight increased, when the weight stays constant and the cube is not gaining the weight at that time, then stop the check.

3 Result and Discussion

3.1 Workability

Different mix proportions are made by adding glass fibre at different percentages. The name of the mixes is described in Table 6. All the mixes are tested through slump flow, T_{50} flow, L-box and V-funnel to satisfy the SCC criteria. Respective values are presented in Table 7. Figures 1, 2, 3 and 4 show the graphical presentation of workability in different forms.

4 Mechanical Properties

After successive curing, all the samples at 7 days and 28 days are tested to quantify the difference between SCC and fibre SCC. Table 8 shows all the values at different days, respectively.

In control mix, 7 days value was 34.25 MPa and the FRSCC value was 36.39 MPa. There is an increase in between them around 5.88% which shows no significant improvement. The peak value of FRSCC shows 0.20% of glass fibre. At 28 days, control mix shows 40.78 MPa and the FRSCC shows 48.95 MPa. Here the glass fibre shows 16.69% of increase at 0.20% of glass fibre. Deviation in the compressive strength in both types of SCC is presented in Figs. 5 and 6.

The percentage improvement of flexural strength for glass fibre over control mix is 5.91% when 0.20% of glass fibre is added in concrete. In control mix, it shows

Table 7 Test result of workability

Sample	Slump flow test (600–750) mm	T_{50} flow test (2–5) sec	L-box test (H_2/H_1) 0.8–1.0	V-funnel test (6–12) sec	Remarks
PSC	697	3.8	0.98	7	Result fulfilled
GFC–0.5	690	6.0	0.96	6	High viscosity
GFC–1	680	4.2	0.92	7.2	Result fulfilled
GFC–1.5	655	5.0	0.88	7.9	Result fulfilled
GFC–2	640	3.9	0.85	8.3	Result fulfilled
GFC–2.5	625	4.3	0.82	8.5	Result fulfilled
GFC–3	520	6.4	0.65	12	High viscosity blockage

Fig. 1 Slump test

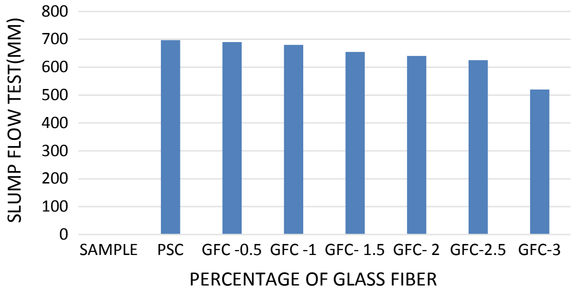


Fig. 2 T_{50} flow test

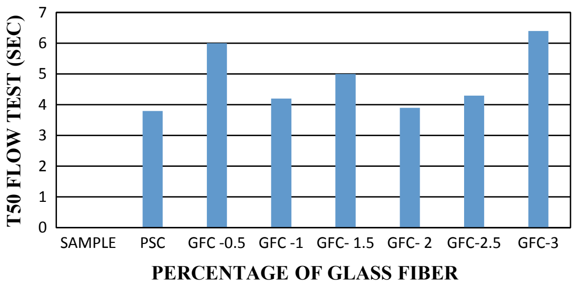


Fig. 3 L-box test

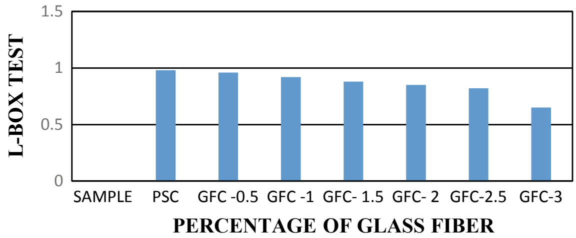


Fig. 4 V-funnel test

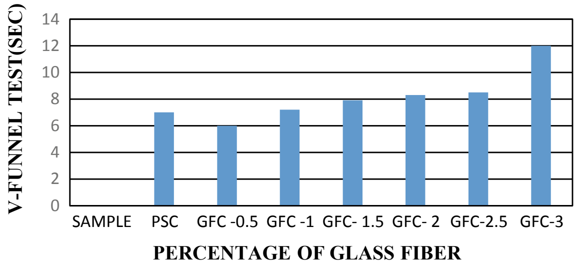
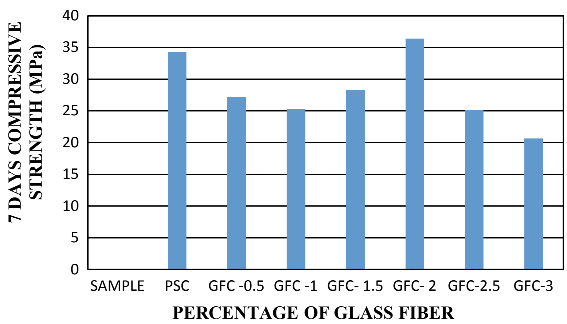


Table 8 Test results at 7 and 28 days

Mixes	Compressive strength test at 7 days in (MPa)	Compressive strength test at 28 days in (MPa)	Flexural strength test at 28 days in (MPa)	Split tensile strength test at 28 days in (MPa)
PSC	34.25	40.78	9.06	4.15
GFC–0.5	27.18	36.67	7.6	3.9
GFC–1	25.27	35.29	7.46	3.72
GFC–1.5	28.33	44.96	8.33	4.26
GFC–2	36.39	48.95	9.63	4.35
GFC–2.5	25.17	36.41	8.27	3.57
GFC–3	20.67	32.21	7.8	3.2

Fig. 5 Deviation of 7 days compressive strength



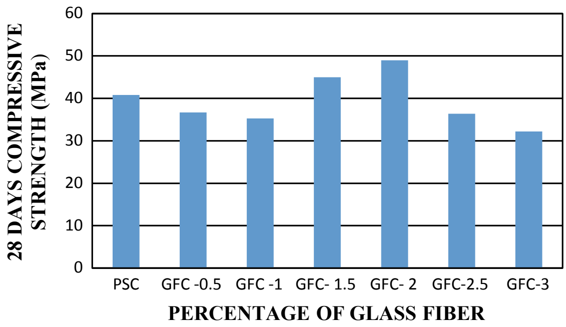


Fig. 6 Deviation of 28 days compressive strength

9.06 MPa and in 0.20% of glass fibre, it shows 9.63 MPa. Figure 7 shows the deviation in the flexural strength for PSC and different fibre SCCs.

Experimental investigation shows control mix having 4.15 MPa and 0.20% of glass fibre shows 4.35 MPa. The glass fibre mixed SCC shows 4.59% of increase at 0.20% of glass fibre. Figure 8 describes about the deviation of split tensile strength.

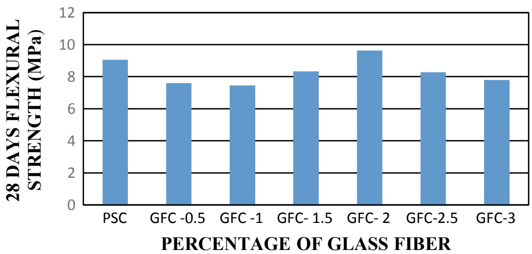


Fig. 7 Deviation of 28 days flexural strength

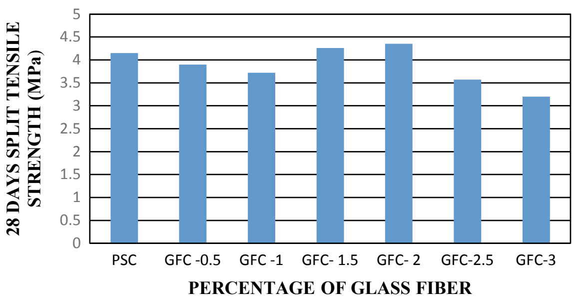


Fig. 8 Deviation of 28 days split tensile strength

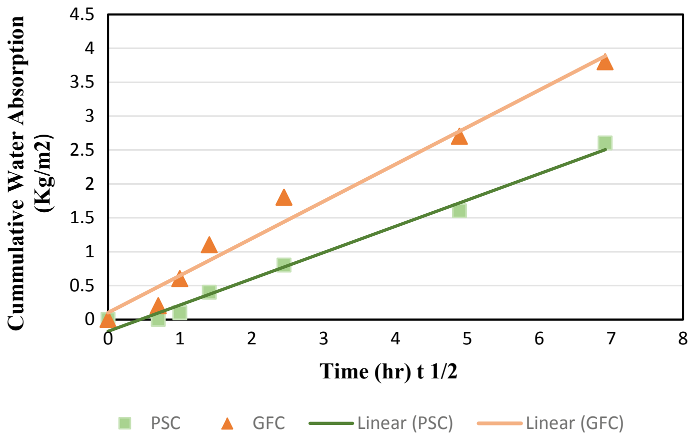


Fig. 9 Sorptivity at different time intervals

Table 9 Sorptivity test results

Sample	Initial dry weight in (gm)	Weight in (gm)					
		At 30 min	At 1 h	At 2 h	At 6 h	At 24 h	At 48 h
PSC	2685	2685	2686	2688	2689	2693	2695
GFC	2450	2452	2454	2455	2457	2459	2461

5 Sorptivity

Figure 9 shows the capillary absorption of water at different time intervals. Here the water absorption through capillary in GFC sample is higher than PSC samples, which indicates the fibres absorbed the water for which the weight of the sample is higher than PSC sample. Figure 9 and Table 9 shows the trend of capillary action for both concretes.

6 Conclusion

1. As glass fibre absorbed more water, it shows the value of slump.
2. Addition of glass fibre in self-compacted concrete enhances the mechanical properties.
3. 0.20% of glass fibre was recognized as optimum doses to increase all the mechanical properties of SSC.
4. At 0.20% of glass fibre, it was observed that compressive strength increased by 5.88% (7 days), and 16.69% (28 days), flexure strength increased by 5.91% (28 days), split tensile strength increased by 4.59% (days), respectively.

5. The GFR concrete is in the state of increased mechanical properties with higher quantity fraction. In fresh state, it showed good performance.
6. In case of sorptivity test, the capillary water absorption of GFC is more than PSC because GFC observed more water due to the glass fibre.

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