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Durability Study of Self Compacting Concrete using Hybrid Glass Fibres

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Abstract: This paper reports the results of an experimental study on durability of self compacting concrete with hybrid glass fibres. The durability is studied by addition of glass fibre and polypropylene. In this research work, M50 grade concrete is used and tests were conducted by casting cubes with proportion of GF 0.06% + 0.1% PP and GF 0.06% + 0.2% PP. Tests were conducted for flow properties, mechanical properties and durability. Results show that the PFSSCC mixes compared to normal SCC mixes have shown an improvement in compressive strength by 17%, split tensile strength by 18% and flexural strength by 21% respectively.
Keywords: Polypropylene fibre strands self compacting concrete, Glass fibre reinforced concrete, Fly ash, Flexural strength, Split tensile strength.

1. Introduction:

Self compacting concrete (SCC) is a flowing concrete mixture that is able consolidate under its own weight. The highly fluid nature of SCC makes it suitable for placing in difficult conditions and in sections with congested reinforcement. Use of SCC can also help minimize hearing – related damages on the worksite that are induced by vibration of concrete[1]. Another advantage of SCC is that the time required to place large sections is considerably reduced.

Current studies in SCC, which are being conducted in many countries, can be divided into the following categories, use of rheometers to obtain data about flow behavior of cement paste and concrete, mixture proportioning methods for SCC, characterization of SCC using laboratory test methods, durability and hardened properties of SCC and their comparison with normal concrete, and construction issues related to SCC[2]. These will be relevant to the immediate needs. In addition, the following questions also need a particular attention, from a long-term perspective: (i) development of mixture design guideline tables similar to those for normal concrete, (ii) a shift to more 'normal' powder contents in SCC, from the existing high powder mixtures, (iii) better understanding of the problems of autogenous and plastic shrinkage in SCC,[5] and (iv) development of site quality control parameters such as 'all-in-one', acceptance tests.

Despite having numerous advantages, it does not reach the common man because of the high material cost. SCC is used only in major projects and it does not serve the whole society due to its high cost. To overcome this limitation, SCC should be made as a cost-effective material so that it could reach the common man also and serve the whole society. Replacing the cement (60%) partially by local waste materials like fly ash (40%) would reduce the cost of SCC. Moreover using these materials in construction process will reduce their disposal problems thereby reduce the environmental hazards[6]. So this study includes dual purpose of making SCC a cost effective and proper utilization of waste material that would not affect the environment and also to prepare SCC with addition of PFSSCC for M50 grade concrete

2. Experimental Investigations:

2.1 Materials Used:

Admixture

The modified Polycarboxylated Ether based Super Plasticizer (GLENIUM B233) which is light brown color and free flowing liquid and having Relative density 1.09 +- 0.01 and pH value as >= 6 and chloride content < 0.2% was used as Super Plasticizer. Optimum dosage of GLENIUM B233 should be determined with trial mixes. As a guide, a dosage range of 500 ml to 1500 ml per 100 kg of cementitious material is normally recommended[3]**.** A viscosity modified admixture (GLENIUM Stream 2) for Rheodynamic Concrete which is colorless free flowing liquid and having specific gravity 1.o1+-0.01 @ 25^{o}C and pH value as >= 6 and Chloride content <0.02% was used as Viscosity Modifying Agent. GLENIUM stream 2 is dosed at the rate of 50 to 500 ml/100 kg of cementitous material.

Fly Ash

Fly ash from Tuticorin power station, Tamilnadu was used as cement replacement material. The properties fly ash is confirming to IS 3812 – 1981 of Indian Standard Specification for Fly Ash for use as Pozzolona and admixture. The specific gravity was 2.054.

Table 1: Fineness test of Cement and Fly Ash:

Trial No	Weight of sample	Weight of Residue of Cement	% of Fineness of Cement	Weight of Residue of Fly Ash	% of Fineness of Fly Ash
1	100	0.2	0.2	0.5	0.5
2	100	0.2	0.2	0.5	0.5
3	100	0.2	0.2	0.5	0.5

2.2 Mix design:

Nan-Su method:

Jagadish Vengala & R.V Ranganath., 2004,Mixture proportioning procedures for self-compacting concrete[4]

Table 2 Mix Proportion

Cementitious Material		Fine Aggregate	Coarse Aggregate
0.6 – Cement	0.4 – Fly Ash	1.80	1.49

Dosage of Super plasticizer - 1.4% of Weight of Powder
Dosage of VMA - 0.15% of Weight of Powder
Dosage of FIBRE strands: 0.06% GF + 0.1 PP & 0.06 % GF + 0.2 PP in Volume of Concrete

Slump Flow Test and T_{50cm} Test:

The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. The test method is based on the test method for determining the slump. The diameter of the concrete circle is a measure for the filling ability of the concrete.

U Box Test:

The apparatus is called a “box-shaped” test. The test is used to measure the filling ability of self-compacting concrete. The apparatus consists of a vessel that is divided by a middle wall into two compartments. An opening with a sliding gate is fitted between the two sections. Reinforcing bars with nominal diameters of 13mm are installed at the gate with centre-to-centre spacings of 50mm. This creates a clear spacing of 35mm between the bars. The left hand section is filled with about 20 liter of concrete then the gate is lifted and concrete flows upward into the other section. The height of the concrete in both the sections is measured.

L Box Test Method:

The apparatus consists of a rectangular section box in the shape of an 'L' with a vertical and horizontal section, seperated by a moveable gate, in front of which vertical lengths of reinforcement bar are fitted. The vertical section is filled with concrete, and then the gate is lifted to let the concrete flow into the horizontal section. When the flow is stopped, the height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section (h2/h1). It indicates the slope of the concrete when at rest. This is an indication passing ability, or the degree to which the passage of concrete through the bars is restricted. The horizontal section of the box can be marked at 200mm and 400mm from the gate and the times taken to reach these points are measured. These are known as the T_{20} and T_{40} times and are an indication for the filling ability.

Table 3: Slump characteristics

S. No	Methods	Unit	SCC	SCC with 0.06% GF + 0.1% PP Glass Strands	SCC with 0.06% GF + 0.2% PP Glass Strands	Min. Value	Max. Value
1	Slump Flow	mm	700	680	650	650	800
2	T_{50cm} Slump Flow	sec	4	5	5	2	5
3	V – funnel	sec	4	5	5	2	5
4	V – funnel at T_{5mins}	sec	10	7	5	8	12
5	U – box	(h2-h1) mm	16	11	9	0	30
6	L – Box	(h2/h1)mm	0.93	0.94	0.75	0.8	1

3. Results and Discussion:

3.1Mechanical Property:

3.1.1Compressive Strength Test:

Compressive strength tests were carried out on cubes of 150mm size using a compression testing machine of 2000 KN capacity as per IS 516:1959

Table 4: Compressive Strength Test

Sl. No	Cube	7 Days (N/mm^2)	28 Days (N/mm^2)
1.	SCC	13.00	47.96
2.	SCC with 0.06% GF + 0.1% PP	17.89	56.24
3.	SCC with 0.06% GF + 0.2% PP	17.88	53.83

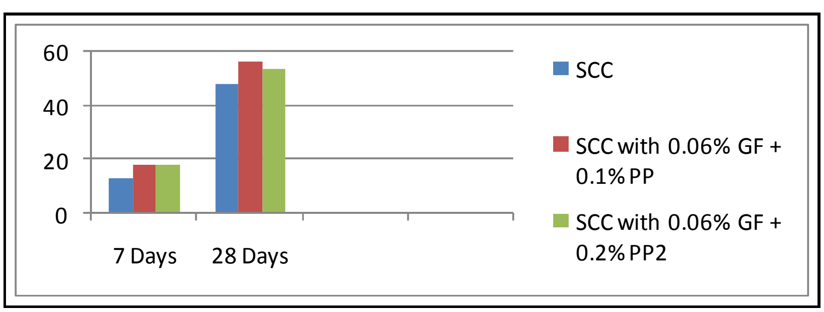

Fig 1: Compressive strength (N/mm^2)

3.1.2 Split Tensile Strength Test:

Split tensile strength tests were carried out on cylinders of 150 mm diameter and 300 mm height using a compression testing machine of 2000 KN capacity as per IS 516:1959.

Table 5: Split Tensile Strength Test

Sl. No	Cylinder	7 Days (N/mm^2)	28 Days (N/mm^2)
1.	SCC	2.08	2.71
2.	SCC with 0.06% GF + 0.1% PP PFS	2.50	3.19
3.	SCC with 0.06% GF + 0.2% PP PFS	2.12	2.92

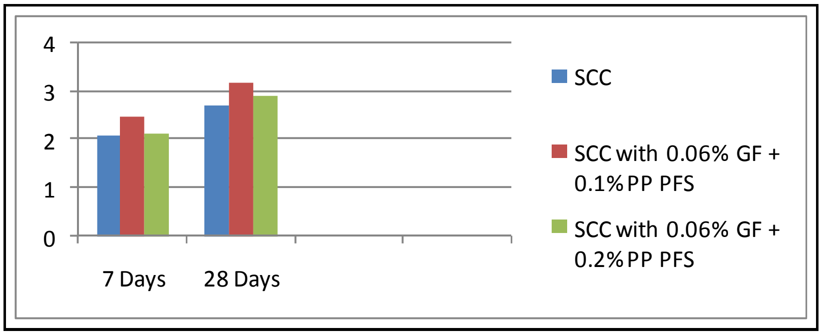

Fig 2: Split Tensile Strength Test (N/mm^2)

3.1.3. Flexural Strength Test:

Flexural strength tests were carried out on prisms of size 100x100x500 mm on flexure testing machine of capacity 100 KN as per IS 516:1959.

Table 6: Flexural Strength Test

Sl. No	Prism	7 Days (N/mm^2)	28 Days (N/mm^2)
1.	SCC	6.25	7.38
2.	SCC with 0.06% GF + 0.1% PP	7.75	7.88
3.	SCC with 0.06% GF + 0.2% PP	8.00	8.78

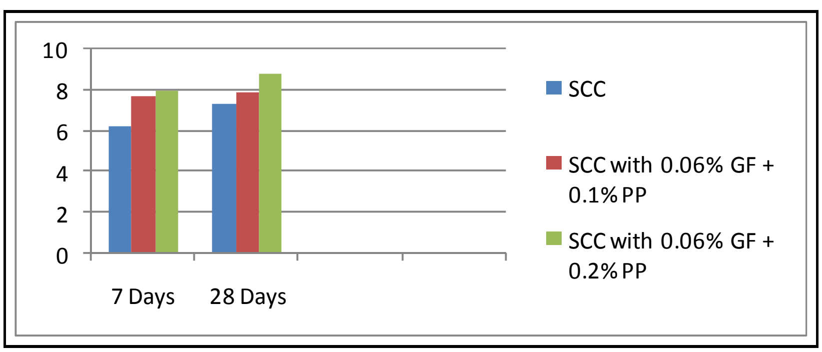

Fig 3: Flexural strength (N/mm^2)

3.2 Durability Studies:

Acid Attack (H_2SO_4 and HCl):

Acid attack was determined by immersing specimens of size 150x150x150 mm test cubes in Sulphuric acid H_2SO_4 (5%) solution and Hydrochloric acid HCl (5%) solutions. The specimen is weighed and immersed immediately after curing in normal water after 28 days. The deterioration concrete specimens were measured as percentage reduction in weight 7, 28, 56 days and compressive strength of concrete at 28, 56 days.

Sulphate Resistance (Na_2SO_4):

Sulphate resistance of concrete was determined by immersing 150x150x150 mm test cubes at 10% sodium sulphate solution (Na_2SO_4). The specimen is weighed and immersed immediately after curing in normal water for 28 days. The deterioration concrete specimens were measured as percentage reduction in weight 7, 28, 56 days and compressive strength of concrete at 28, 56 days.

Marine Environment:

The test was carried to study the effect of sea water on the durability of concrete; the specimen includes the cubes of size 150x150 mm. The specimens immediately after 28 days of curing were weighed and kept in the prepared composition of marine water. The composition of marine water prepared in the laboratory as per ASTM. The percentage of loss in mass determined for 7, 28 and 56 days. The compressive strength of concrete is 28 and 56 days were determined.

Preparation of Solutions:

a) 5% - hydrochloric acid
 140 litres of water, 7 litres of hydrochloric acid (HCl)
b) 5% - sulphuric acid
 130 litres of water, 6.5 litres of H_2SO_4
c) 10% - sodium sulphate
 90 litres of water, 9 kg of Na_2SO_4

Table 7: Weight of Cubes Measured at 7, 28, 56 days after Immersion of HCl, H_2SO_4 , Marine environment and Na_2SO_4.

Weight in Kg for 0.00% fibre				
Solution	**Actual Cube Weight**	**Weight at 7 Days**	**Weight at 28 Days**	**Weight at 56 Days**
HCl	7.922	7.846	7.800	7.628
HCl	7.892	7.742	7.640	7.441
H_2SO_4	7.956	7.639	7.350	7.226
H_2SO_4	7.997	7.619	7.449	7.388
Marine water	7.887	7.883	7.839	7.801
Marine water	8.095	8.093	8.050	7.906
Na_2SO_4	7.745	7.743	7.666	7.567
Na_2SO_4	7.912	7.910	7.908	7.814

Table 8: Percentage of weight loss in cube (0.00% fibre) at 7, 28, 56 days after immersion of HCl, H_2SO_4, Marine environment and Na_2SO_4.

% of Weight Loss - 0.00% fibre			
Solution	**Day 7**	**Day 28**	**Day 56**
HCl	0.96	1.54	2.21
HCl	1.90	1.90	5.71
H_2SO_4	3.98	7.62	9.16
H_2SO_4	4.73	6.85	7.62
Marine water	0.05	0.61	1.09
Marine water	0.02	0.56	2.33
Na_2SO_4.	0.02	1.02	2.30
Na_2SO_4.	0.02	0.05	1.24

Table 9: Weight of Cubes Measured at 7, 28, 56 days after Immersion of HCl, H_2SO_4 , Marine environment and Na_2SO_4

Weight in Kg for 0.06% GF + 0.1 PP fibre				
Solution	**Actual Cube Weight**	**Weight at 7 Days**	**Weight at 28 Days**	**Weight at 56 Days**
HCl	7.893	7.839	7.820	7.654
HCl	7.840	7.736	7.713	7.524

H_2SO_4	8.056	7.719	7.400	7.199
H_2SO_4	7.689	7.329	7.134	6.990
Marine water	7.700	7.695	7.653	7.649
Marine water	7.972	7.963	7.921	7.879
Na_2SO_4	7.733	7.729	7.726	7.697
Na_2SO_4	7.999	7.992	7.990	7.900

Table 10: Percentage of Weight Loss in Cube (0.06% GF + 0.1 PP Fibre) at 7, 28, 56 days after Immersion of HCl, H_2SO_4, Marine environment and Na_2SO_4

% of Weight Loss - 0.06% GF + 0.1 PP Fibre			
Solution	**Day 7**	**Day 28**	**Day 56**
HCl	0.68	0.92	3.02
HCl	1.33	1.62	4.03
H_2SO_4	4.18	8.14	10.63
H_2SO_4	4.68	7.22	9.09
Marine water	0.06	0.61	0.66
Marine water	0.11	0.64	1.17
Na_2SO_4	0.05	0.09	0.47
Na_2SO_4	0.09	0.11	1.24

Table 11: Weight of Cubes Measured at 7, 28, 56 days after Immersion of HCl, H_2SO_4, Marine environment and Na_2SO_4

Weight in Kg for 0.06% GF + 0.2 PP fibre				
Solution	**Actual Cube Weight**	**Weight at 7 Days**	**Weight at 28 Days**	**Weight at 56 Days**
HCl	7.889	7.848	7.837	7.437
HCl	7.972	7.880	7.694	7.332
H_2SO_4	7.928	7.556	7.264	7.034
H_2SO_4	8.018	7.606	7.335	6.872
Marine water	7.959	7.956	7.926	7.869
Marine water	8.171	8.164	8.136	8.074
Na_2SO_4	8.134	8.121	8.074	7.985
Na_2SO_4	7.932	7.927	7.830	7.730

Table 12: Percentage of Weight Loss in Cube (0.06% GF + 0.2 PP Fibre) at 7, 28, 56 days after Immersion of HCl, H_2SO_4, Marine environment and Na_2SO_4

% of Weight Loss - 0.06% GF + 0.2 PP Fibre			
Solution	**Day 7**	**Day 28**	**Day 56**
HCl	0.52	0.66	5.73
HCl	0.60	2.94	5.03
H_2SO_4	4.69	8.37	11.28
H_2SO_4	5.14	8.52	10.29
Marine water	0.03	0.41	1.13
Marine water	0.09	0.43	1.19
Na_2SO_4	0.16	0.74	1.83
Na_2SO_4	0.06	0.29	1.34

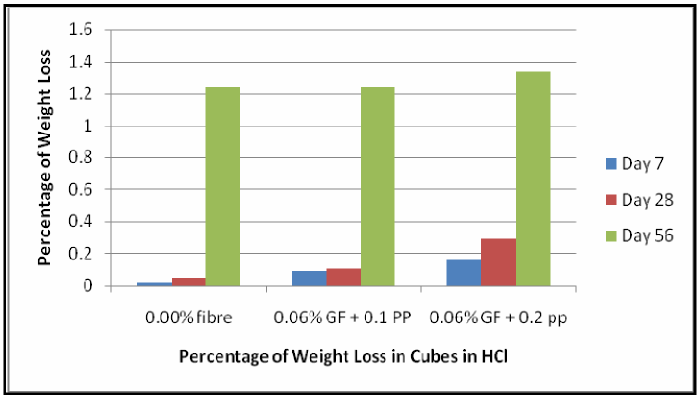

Figure 4: Percentage of Weight Loss in Cubes – HCl

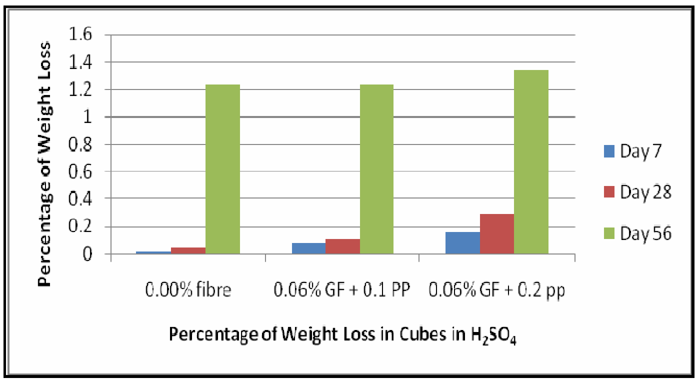

Figure 5: Percentage of Weight Loss in Cubes In H_2SO_4

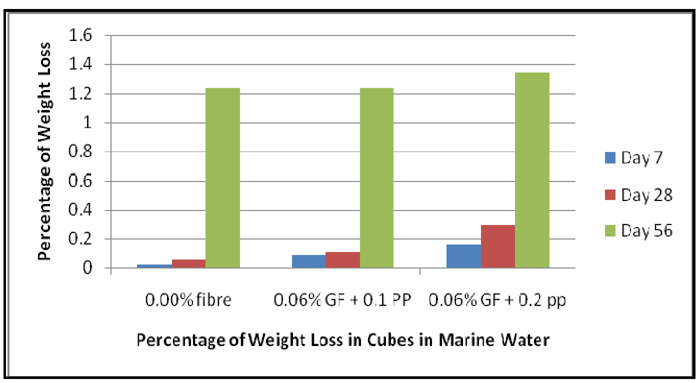

Figure 6: Percentage of Weight Loss in Cubes in Marine Water

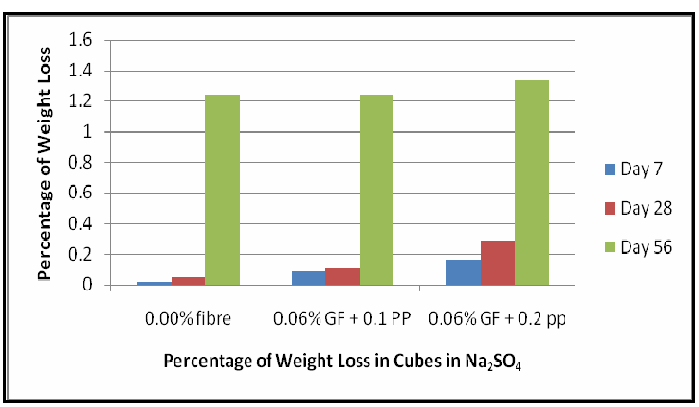

Figure 7: Percentage of Weight Loss In Cubes – Na_2SO_4

Compressive Strength of Cubes after Immersing in Respective Solutions:

Table 13: Compressive Strength of Cubes after Immersing in Respective Solutions at 28 days and 56 days

Sl No.	SCC	HCl		H_2SO_4		Marine Water		Na_2SO_4	
		28 days	56 days	28 days	56 days	28 days	56 days	28 days	56 days
1	0%	42.79	37.50	25.29	13.10	35.80	25.72	40.55	24.90
2	0.06% GF + 0.1 PP	21.80	32.30	27.47	7.90	21.80	34.00	35.75	41.91
3	0.06% GF + 0.2 PP	27.47	28.80	24.85	12.21	43.16	45.00	43.60	47.50

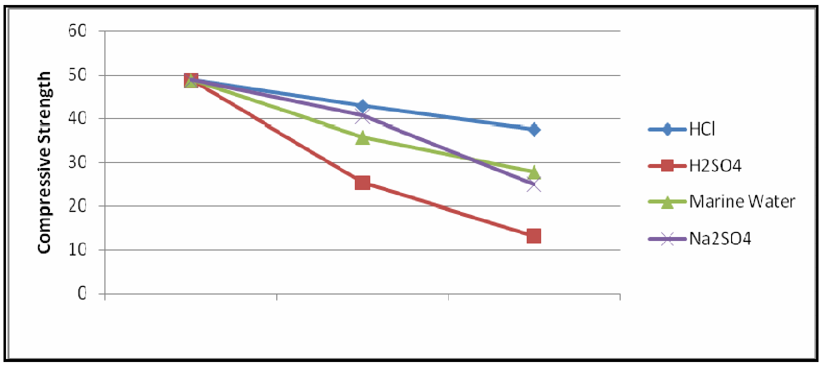

Figure8: Compressive Strength Comparison for 0.00% PFSSCC after Immersion of Test Solutions

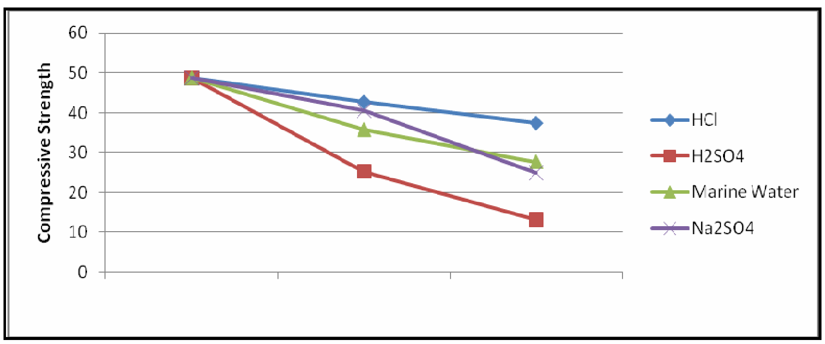

Figure 9: Compressive Strength Comparison for 0.06% GF + 0.1 PP of PFSCC after Immersion of Test Solutions

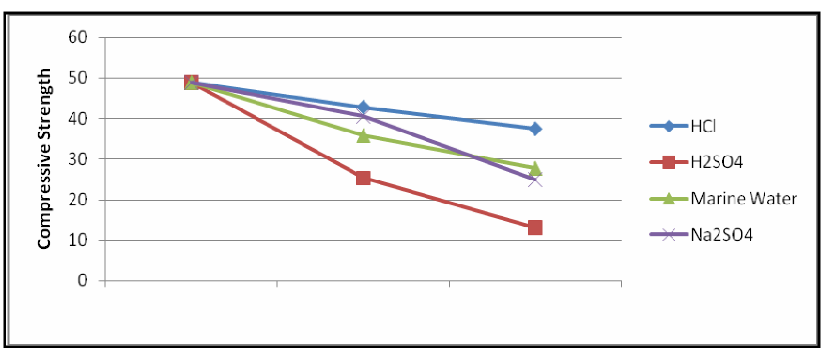

Figure 10: Compressive Strength Comparison for 0.06% GF + 0.2 PP of PFSSCC After Immersion of Test Solutions

4. Summary and Conclusions:

In fresh state the filling ability, passing ability and segregation resistance values of PFSSCC mixes compared to normal SCC mixes indicate that the presence of chopped fibre strands did not have any pronounced effect on 0.06% GF + 0.1% PP and 0.06% GF + 0.2% PP. This may due to the high dispersing nature of the fibre strands.

The compressive strength values obtained by testing standard cubes made with different SCC and PFSSCC mixes have shown strength above 50 MPa, which is the required strength. The mix, without chopped fibre strands, containing the mineral admixture of Fly Ash (40%) shows almost similar value of compressive strength. Further, the PFSSCC mixes compared to normal SCC mixes have shown an improvement in compressive strength by 17 %.

The tensile strength of mixes is obtained by conducting split tensile test on standard cylindrical specimens and flexural strength by conducting two points bend test on standard prisms. The results indicated that the incorporation of PFS into the SCC mixes increased the split tensile strength amd flexural strengths by 18% and 21% respectively. The increase is significant and it may be due to high tensile strength of PFS.

From above discussion of test results, it can be observed that addition of the PFS tested improves the compressive strength, tensile strength and durability tests even with small dosage levels of 0.06% GF + 0.01 PP & 0.06% GF + 0.2 PP. From the above results it is found that the cubes with 0.06% GF + 0.1 PP fibre strands are better durable as that are compared with the other specimens. Hence it is found to be optimum.

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