AN EVALUATION FOR STRENGTH PARAMETERS OF STEEL AND GLASS FIBERS CONCRETE USING GGBFS

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Abstract: Today, concrete is the most commonly used material made from cement, water, and fine aggregate and coarse aggregate. As we all know that the production of cement which is the main component of concrete produces the emission of CO_2 gas. Due to the higher emission of CO_2 by cement manufacturing, the need arise to lower down the CO_2 emission by replacing cement with other pozzolanic admixture, which having less cost and produce less CO_2 emission in its manufacturing process. The aim of study is partial replacement of cement with GGBFS. Fiber reinforcement is normally used to improve mechanical properties in brittle cementitious matrices. The use of more than one fiber in concrete is called as hybrid fiber concrete. In this study, the mechanical properties of the hybrid fiber concrete are studied with GGBFS and cement mix. In this study the comparison of mechanical characteristics of 50% GGBFS and 25% GGBFS replacements with cementitious materials based concrete with steel and glass fibers have been studied. In this study to improve overall mechanical properties of concrete specially the flexural and tensile strength, the use of fiber including steel fiber and glass fiber are introduced. The Compressive strength, Split tensile strength and Flexural strength are more in the specimen which contains higher amount of steel fiber. With increase in the Glass fiber in the mix the strength parameters tends to decrease gradually. The compressive strength at 7 days was max. for S5 specimen (0%GF, 1.5%SF, 25%GGBFS). Also, the split tensile strengths of S6 specimen (0 %GF, 1%SF, 25%GGBFS), is higher. The compressive strength at 28 days was max. for S5 specimen (0%GF, 1.5%SF, 50%GGBFS), Also, the split tensile strengths of S5 specimen (0 %GF, 1.5%SF, 50%GGBFS), is higher. This shows that 50% of GGBFS mix develops more strength than the 25% of GGBFS mix with cementitious materials
Key Words: Steel fiber, Glass fiber, Hybrid fiber, GGBFS, Compressive Strength, Split Tensile Strength, Flexural Strength

I. INTRODUCTION

Concrete is mostly wide construction material in the world due its ability it can be mould and shape. However, concrete has some deficiency as listed below, low tensile strength, Low post cracking capacity, brittleness and low ductility, limited fatigue life, not capable of accommodating large deformation, low impact strength. These properties can be improved by the use of fiber reinforced concrete. The fibers are dispersed and distributed randomly in the concrete during mixing and thus improved concrete properties in all directions .The fiber helps to arresting the internal widening cracks and fly ash help as an admixture for improving the properties of concrete. Concrete is strong in compression, but shows lesser strength in tension. Concrete shows brittle behaviour when subjected to normal stresses and impact loads. Due to widening of micro cracks existing in concrete subjected to tensile stress when load is applied, the tensile strength comes lesser with respect to compressive strength. When fibers are added in the concrete the micro cracks are arrested by the fibers, which lead to increase in the tensile and flexural strengths. The addition of fibers to concrete considerably improves its structural characteristics such as static flexural strength, tensile strength, ductility, flexural toughness for long term, strength and toughness and high stress resistance, Steel Fiber reinforced concrete (SFRC) is increasingly being used in structures such as flooring, housing, precast, tunneling, heavy duty pavement and mining. In general the character and performance of fiber reinforced concrete changes with varying concrete formulation as well as the fiber material type, the fiber geometry, fiber distribution, fiber orientation and fiber concentration. A Concrete can be called as hybrid fiber concrete, if two or more types of fibers are rationally combined to produce a composite that derives benefits from each of the individual fibers and exhibits the synergetic response. Reinforcement of concrete by using a single type of fiber may improve the properties of concrete to a limited level. However by using the concept of making hybrid fiber concrete with two or more different types of fibers incorporated in common cement matrix, these type of composite can offer more attractive engineering properties because, the presence of one fiber enables the more efficient utilization of the potential properties of the other fiber. The GGBFS is an industries waste product which can be replace in cementitious material. GGBFS concrete gives lower earlier strength than normal concrete. However, GGBFS concrete gives higher ultimate strength than normal concrete. The main components of ground granulated blast furnace slag are CaO(30-50%) ,SiO_2 (28-38%),AL_2O_3(8-24%)and MgO(1-18%).In general increasing the CaO content of the slag results in raising of slag basicity and after effect is increment in the compressive strength of concrete. It is one of the cheaper material than cement. GGBFS can be replaced up to 90 % of cement as partial replacement of cement

1.1 Objectives of the Work

- To improve the concrete strength characteristics in Tensile Strength, Flexural Strength, etc
- By using GGBFS and fiber in concrete to introduce a durable concrete

- To study the mechanical Properties of hybrid fiber concrete using GGBFS

II. EXPERIMENTAL INVESTIGATION

2.1 Materials

1. Cement

Ordinary Portland Cement of Ultra-tech brand of 53 grade confirming to IS: 12269-1987(9) was used in the present study. Cement used in practical having specific gravity 3.15, initial and final setting time was 47 and 260 minutes respectively.

2. Fine Aggregate

Natural sand as per IS: 383-1987 was used. Locally available River sand was used having specific gravity 2.65, fineness modulus 3.00 and zone of grading II

3. Coarse Aggregate

Crushed aggregate confirming to IS: 383-1987 was used. Aggregates of size 20mm and 12.5 mm of specific gravity 2.73 and Elongation Index and Flakiness Index value in % is 11.96 and 12.74 respectively.

4. GGBFS

Ground-granulated blast-furnace slag (GGBFS or GGBFS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. Tested properties of GGBFS are described in the below table.

Table 2.1 Properties of GGBFS

Chemical Properties of GGBFS	
Chemical Compound	In Percentage
CaO	31.5
SiO_2	32.5
$Al_2 O_3$	12.4
$Fe_2 O_3$	0.8
MgO	5.6
MnO_2	3.5
Physical Properties of GGBFS	
Specific Gravity	2.77
Bulk Density	1.06 g/cc

5. Steel Fiber

Steel fiber is one of the most commonly used fibers. It has high modulus of elasticity. Use of steel fiber makes significant improvements in flexure, impact and fatigue strength of concrete. Hooked ended steel fiber is used in this study.

Table 2.2 Properties of Steel Fiber

Chemical Properties of Steel Fiber	
Chemical Compound	In Percentage
Carbon	0.08
Manganese	0.35
Silicon	0.15
Sulphur	0.05
Phosphorous	0.035
Physical Properties of Steel Fiber	
L	30 mm
Diameter	0.6 mm
Aspect ratio	50
Specific Gravity	7.45
Density	7450 kg/mm^3
UTS	128.2 kg/mm^2

6. Glass Fiber

Glass fiber is also called as fiberglass. It is material made from extremely fine fibers of glass Fiberglass is a lightweight, extremely strong and robust material. Alkali resistant glass fibers is used in this study

Table 2.3 Properties of Glass Fiber

Physical Properties of Glass Fiber	
Length	12 mm
Diameter	14 microns
Specific Gravity	2.68
Density	2680 kg/mm^3
Softening Point	845 ˚C

2.2 Mix proportions

M30 grade of concrete was used for the present investigation. Mix design was done based on I.S 10262-2009

Table 2.4 Mix proportion for 1m^3 Volume of Concrete

Water	Cement	F.A.	C.A.
191.58 lit.	425.73 kg	659.824 kg	1121.196 kg
0.45	1	1.549	2.633

2.3 Experimental Procedure

The specimen of standard cube of (150mm x 150mm x 150mm), standard cylinders of (300mm x150mm) and beam of (700 mm x 150mm x 150mm) were used to determine the compressive strength, split Tensile strength and flexural strength of concrete respectively. Three specimens were tested for 7 & 28 days with each proportion of combination of GGBFS replacement and inclusion of fiber contents.

S1,A1,B1,C1,G1,S3,A3,B3,C3,G3,S5,A5,B5,C5 and G5 code names are used for 50% of GGBFS replacement in the cementitious materials.

S2,A2,B2,C2,G2,S4,A4,B4,C4,G4,S6,A6,B6,C6 and G6 code names are used for 25% of GGBFS replacement in the cementitious materials .

The casting combinations are described in the Table 2.5.

Table 2.5 Combinations detail

Sr No.	Code	Cementitious materials		Fiber in % of Volume of Concrete	
		GGBFS	Cement	Steel Fiber	Glass Fiber
1	S1	50%	50%	1	0
2	A1			0.75	0.25
3	B1			0.5	0.5
4	C1			0.25	0.75
5	G1			0	1
6	S2	25%	75%	1	0
7	A2			0.75	0.25
8	B2			0.5	0.5
9	C2			0.25	0.75
10	G2			0	1

11	S3	50%	50%	0.5	0
12	A3			0.375	0.125
13	B3			0.25	0.25
14	C3			0.125	0.375
15	G3			0	0.5
16	S4	25%	75%	0.5	0
17	A4			0.375	0.125
18	B4			0.25	0.25
19	C4			0.125	0.375
20	G4			0	0.5
21	S5	50%	50%	1.5	0
22	A5			1.125	0.375
23	B5			0.75	0.75
24	C5			0.375	1.125
25	G5			0	1.5
26	S6	25%	75%	1.5	0
27	A6			1.125	0.375
28	B6			0.75	0.75
29	C6			0.375	1.125
30	G6			0	1.5

Totally 180 cubes, 180 cylinders and 30 Beams were casted for the determination of strength parameters. W/C ratio is kept constant for all the mix, it was 0.45. The constituents were weighed and the materials were mixed by mixture. The concrete was filled in different layers and each layer was compacted. The specimens were demoulded after 24 hrs, cured in water for 7 & 28 days, and then tested for its compressive, split tensile and flexural strength as per Indian Standards.

III. TEST RESULTS AND DISCUSSIONS

3.1 Fresh Concrete Test Result

Results of fresh concrete of various combinations are discussed in comparison with those of normal concrete. Workability is carried out by conducting the slump test.

3.1.1 Slump Test Results

The results of slump test were presented in table 3.1. Slump test is the most commonly used test for measuring consistency of concrete. The apparatus for slump test consists of a metallic mould in the form of a frustrum of a cone with bottom diameter of 200 mm, top diameter of 100 mm and height of 300 mm. For tamping the concrete, a steel tamping rod of 16 mm diameter, 600 mm length with bullet end was used. The thickness of the metallic sheet for the mould should not be less than 1.6 mm. The mould is provided with suitable guides for lifting vertically up.

Table 3.1 Slump test

Sr No.	Mix	Fiber in % of Volume of Concrete		Slump (mm)
		Steel Fiber	Glass Fiber	
1	Normal	0	0	47
2	S1	1	0	45
3	A1	0.75	0.25	43
4	B1	0.5	0.5	41.5
5	C1	0.25	0.75	40
6	G1	0	1	38.5
7	S2	1	0	43.5
8	A2	0.75	0.25	41.5
9	B2	0.5	0.5	40
10	C2	0.25	0.75	38
11	G2	0	1	37.5
12	S3	0.5	0	45.5
13	A3	0.375	0.125	45.5
14	B3	0.25	0.25	44
15	C3	0.125	0.375	42
16	G3	0	0.5	40
17	S4	0.5	0	45
18	A4	0.375	0.125	45
19	B4	0.25	0.25	43
20	C4	0.125	0.375	40
21	G4	0	0.5	39
22	S5	1.5	0	43
23	A5	1.125	0.375	43
24	B5	0.75	0.75	41
25	C5	0.375	1.125	38
26	G5	0	1.5	38
27	S6	1.5	0	42
28	A6	1.125	0.375	40
29	B6	0.75	0.75	37
30	C6	0.375	1.125	37
31	G6	0	1.5	35

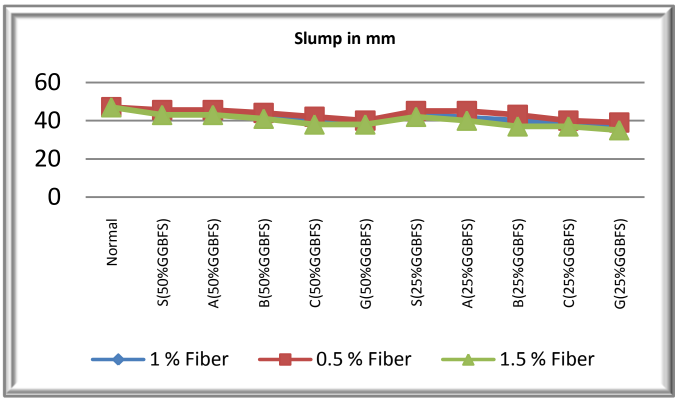

Figure 3.1 Slump comparisons

From the results of the Slump test, it was noticed that the slump values are more for the 50% of GGBFS replacement with cementitious materials with respect to 25% of GGBFS replacement with cementitious materials. It was noticed that the slump value decreases with increment in the glass fiber contents. The minimum slump was observed for G6 combination. From following results, it was noticed that the 50% GGBFS replacement with cementitious materials gives higher workable concrete than the 25% GGBFS replacement with cementitious materials.

3.2 Hardened Concrete Test Results

3.2.1 Compressive Strength

The results of compressive strength were presented in table 3.2. The test was carried out conforming to IS 516-1959 to obtain compressive strength of concrete at the age of 7 and 28 days. The cubes were tested using Compression Testing Machine (CTM) of capacity 2000 kN.

Table 3.2 Compressive strength

Sr No.	Mix	Fiber in % of Volume of concrete		Compressive Strength (N/mm2)	
		Steel Fiber	Glass Fiber	7 Days	28 Days
1	Normal	0	0	27.68	36.66
2	S1	1	0	29.33	42.22
3	A1	0.75	0.25	29.78	37.78
4	B1	0.5	0.5	28.33	37
5	C1	0.25	0.75	26.11	32
6	G1	0	1	23.99	30.67
7	S2	1	0	30.55	41.33
8	A2	0.75	0.25	31.77	37.56
9	B2	0.5	0.5	29	35.33
10	C2	0.25	0.75	27.56	31.11
11	G2	0	1	26	30.44
12	S3	0.5	0	28.50	40.67
13	A3	0.375	0.125	27.69	37.66
14	B3	0.25	0.25	27.50	37.55
15	C3	0.125	0.375	26.25	36.55
16	G3	0	0.5	25.6	32
17	S4	0.5	0	29.33	39.70
18	A4	0.375	0.125	28.30	36.44
19	B4	0.25	0.25	27.40	35.70
20	C4	0.125	0.375	27.68	33.55
21	G4	0	0.5	27.62	31.50
22	S5	1.5	0	29.57	46.44
23	A5	1.125	0.375	30.485	40.07
24	B5	0.75	0.75	26.67	31.56
25	C5	0.375	1.125	18.50	22.66
26	G5	0	1.5	17.283	21.33
27	S6	1.5	0	32.11	42.22
28	A6	1.125	0.375	31.89	38.37
29	B6	0.75	0.75	29.80	38.15
30	C6	0.375	1.125	21	27.11
31	G6	0	1.5	18.05	24.89

From the above table, it was seen that maximum compressive was observed for S6 and S5 combinations for 7 days and 28 days testing respectively

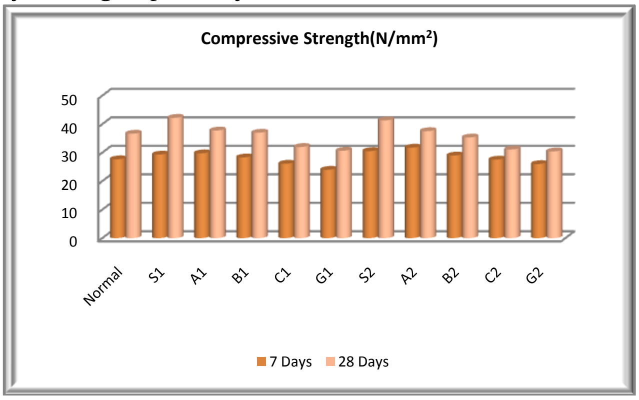

Figure 3.2 Compressive strength results for 1 % fiber addition

From figure 3.2, the maximum compressive strength was observed for 7 days and 28days are respectively 31.77 N/mm^2 and 42.22 N/mm^2.The maximum compressive strength was observed for A2 combination for 7 days and for S1 combination at 28 days. The Earlier strength was more observed in the 25% GGBFS replacement with cementitious materials. However, the 28 days strength was more in the 50% GGBFS replacement with cementitious materials.

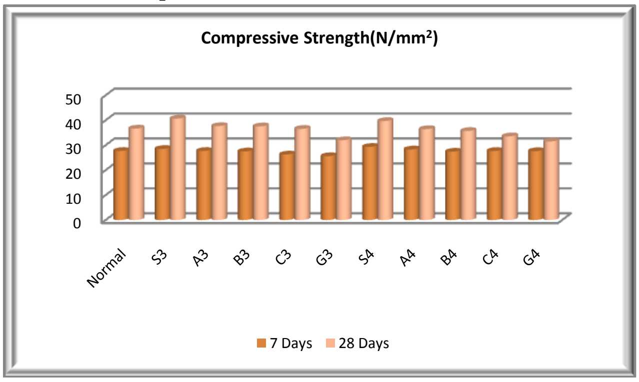

Figure 3.3 Compressive strength results for 0.5 % fiber addition

From figure 3.3, the maximum compressive strength was observed for 7 days and 28days are respectively 29.33 N/mm^2 and 40.67 N/mm^2.The maximum compressive strength was observed for S4 combination for 7 days and for S3 combination at 28 days. The Earlier strength was more observed in the 25% GGBFS replacement with cementitious materials. However, the 28 days strength was more in the 50%GGBFS replacement with cementitious materials. The combinations with 0.375% Glass Fiber + 0.125% Steel Fiber + 25%GGBFS, 0.5% Glass Fiber + 50% GGBFS and 0.5% Glass Fiber + 25% GGBFS show lesser strength than the compressive strength developed by the Normal Control mix at 28 days. The steel fiber addition in the concrete mix develops higher strength when it was compared with the compressive strength gained by addition of 0.5% Glass fiber in the concrete mix.

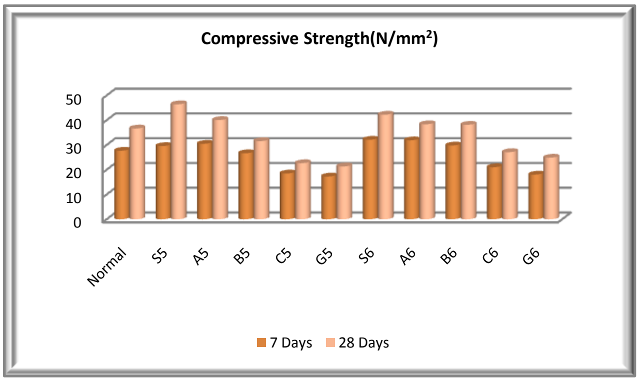

Figure 3.4 Compressive strength results for 1.5 % fiber addition

From figure 3.4, the maximum compressive strength was observed for 7 days and 28days are 32.11 N/mm^2 and 46.44 N/mm^2 respectively. The maximum compressive strength was observed for S6 combination for 7 days and for S5 combination at 28 days. With the increment in the glass fiber contents beyond 0.75%, the concrete start to shows lesser strength generation. The minimum compressive strength was found for G5, possibly the reason is the concentration of higher Silica contents. As the Glass Fiber is a siliceous material, and GGBFS's chemical properties shows 32.5 % SiO_2.

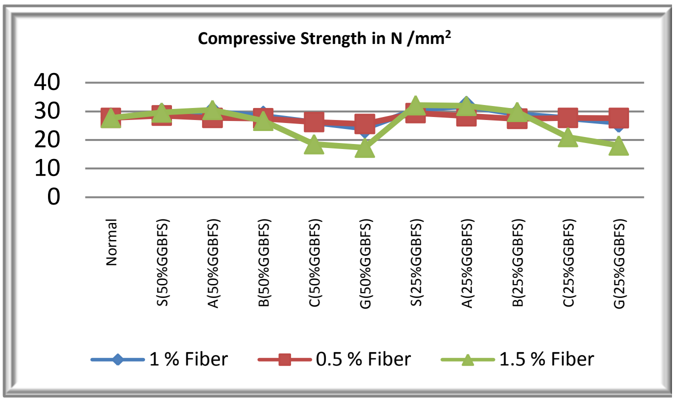

Figure 3.5 Comparison of Compressive strength at 7 days

From figure 3.5, the maximum compressive strength was observed for S6 was 32.11 N/mm^2.

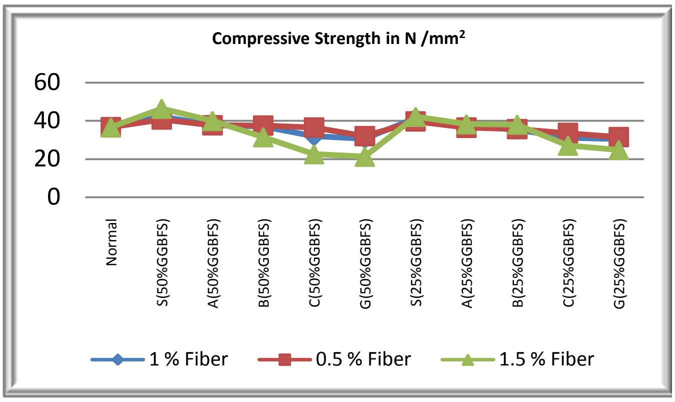

Figure 3.6 Comparison of Compressive strength at 28 days

From figure 3.6, the maximum compressive strength was observed for S5 was 46.44 N/mm^2.The addition of glass fiber in the concrete reduced the compressive strength for concrete. Figure show that the glass fiber increment in the concrete results in the decreased compressive strength.

3.2.2 Split Tensile Strength

The results of Split Tensile strength are presented in table 3.3. The test was carried out conforming to IS 516-1959 to obtain Split tensile strength of concrete at the age of 7 and 28 days. The cylinders were tested using Compression Testing Machine (CTM) of capacity 2000 kN.

Table 3.3 Split tensile strength results

Sr No.	Mix	Fiber in % of Volume of Concrete		Split tensile Strength (N/mm2)	
		Steel Fiber	Glass Fiber	7 Days	28 Days
1	Normal	0	0	2.35	2.90
2	S1	1	0	2.9	3.96
3	A1	0.75	0.25	2.71	3.55
4	B1	0.5	0.5	2.76	3.112
5	C1	0.25	0.75	2.28	2.687
6	G1	0	1	2.21	2.61
7	S2	1	0	3.18	3.687
8	A2	0.75	0.25	3.18	3.254
9	B2	0.5	0.5	3.14	3.395
10	C2	0.25	0.75	2.40	2.75
11	G2	0	1	2.25	2.687
12	S3	0.5	0	2.43	3.041
13	A3	0.375	0.125	2.30	2.97
14	B3	0.25	0.25	2.49	2.93
15	C3	0.125	0.375	2.30	2.935
16	G3	0	0.5	2.27	2.687
17	S4	0.5	0	2.56	2.97
18	A4	0.375	0.125	2.756	2.8
19	B4	0.25	0.25	2.52	2.76
20	C4	0.125	0.375	2.378	2.76
21	G4	0	0.5	2.30	2.725
22	S5	1.5	0	3.167	4.17
23	A5	1.125	0.375	2.71	3.537
24	B5	0.75	0.75	2.32	2.62
25	C5	0.375	1.125	1.80	2.12
26	G5	0	1.5	1.73	2.051
27	S6	1.5	0	3.363	3.89
28	A6	1.125	0.375	3.033	3.11
29	B6	0.75	0.75	2.58	2.795
30	C6	0.375	1.125	2.10	2.55
31	G6	0	1.5	2.05	2.405

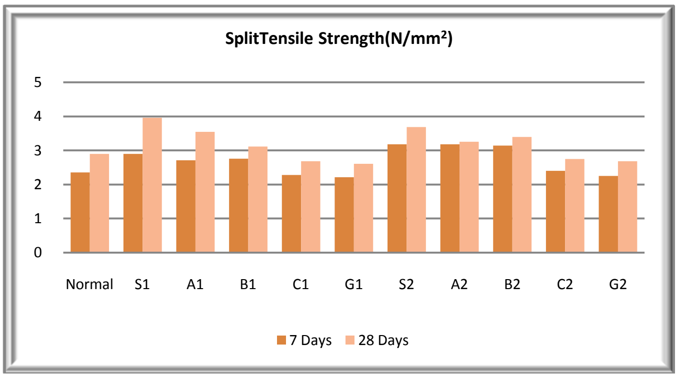

Figure 3.7 Split tensile strength for 1% fiber addition

From figure 3.7, the maximum split tensile strength was 3.18 N/mm^2 and 3.96 N/mm^2 at 7 and 28 days. The maximum increase in split tensile strength is observed for S1 at 28 days. Figure also shows that the split tensile strength of concrete containing glass fiber decreased as the increase in the glass fiber contents.

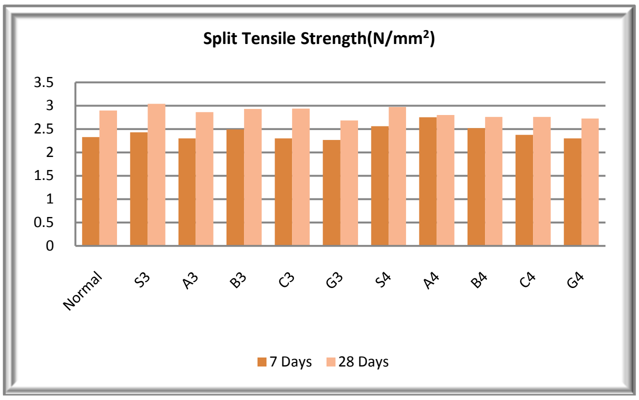

Figure 3.8 Split tensile strength for 0.5% fiber addition

From figure 3.8, the maximum split tensile strength was 2.756 N/mm^2 and 3.041 N/mm^2 at 7 and 28 days. The maximum increase in split tensile strength was observed for S3 at 28 days. Figure also shows that the split tensile strength of concrete at 28 days lies near around the split tensile strength of normal concrete.

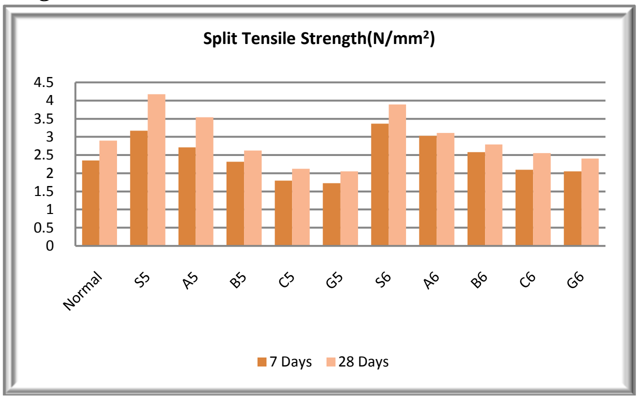

Figure 3.9 Split tensile strength results for 1.5 % fiber addition

From figure 3.9, the maximum split tensile strength was 3.363 N/mm^2 and 4.17 N/mm^2 at 7 and 28 days. The maximum increase in split tensile strength was observed for S5 at 28 days. Figure also shows that the split tensile strength of concrete for glass fiber concrete with 50% GGBFS found minimum.

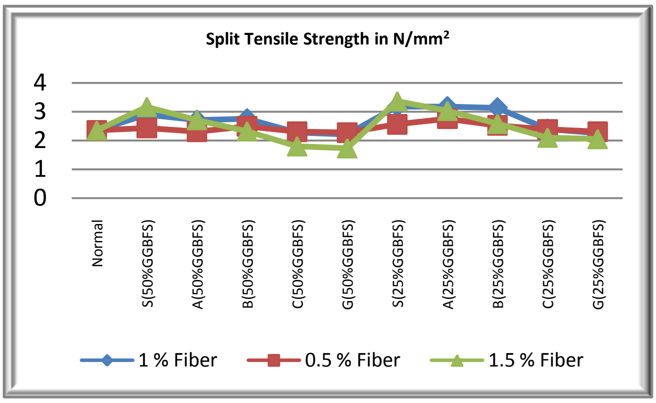

Figure 3.10 Comparison of Split tensile strength at 7 days

From figure 3.10, the maximum Split tensile strength was 3.363 N/mm^2 at 7 for S6. Figure represent that the higher amount of steel fiber result in higher split tensile strength, it also shows that the split tensile strength of concrete containing glass fiber decreased as the increase in the glass fiber contents.

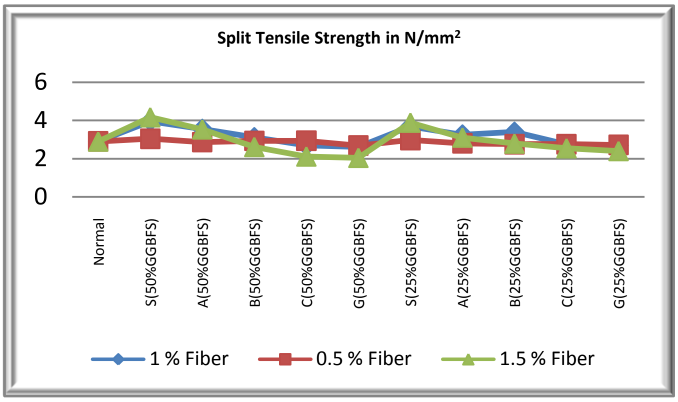

Figure 3.11 Comparison of Split tensile strength at 28 days

From figure 3.11, the maximum split tensile strength was 4.17 N/mm^2 at 28 days. The maximum increase in split tensile strength is observed for S5. Figure also shows that the split tensile strength of concrete containing glass fiber decreased as the increase in the glass fiber contents.

3.2.3 Flexural Strength

The results of flexural strength of concrete were presented in table 3.4. The test was carried out conforming to IS 516-1959 to obtain Flexural strength of concrete at the age of 28 days for fiber addition up to 1% by the volume of concrete. The beams were tested using Flexure Testing Machine (FTM).

Table 3.4 Flexural strength results

Sr No.	Mix	Fiber in % of Volume of concrete		Flexural Strength (N/mm2)
		Steel fiber	Glass fiber	28 Days
1	Normal	0	0	4.35
2	S1	1	0	8.91
3	A1	0.75	0.25	7.259
4	B1	0.5	0.5	6.84
5	C1	0.25	0.75	6.43
6	G1	0	1	5.8
7	S2	1	0	8.29
8	A2	0.75	0.25	7.259
9	B2	0.5	0.5	6.22
10	C2	0.25	0.75	5.8
11	G2	0	1	5.39

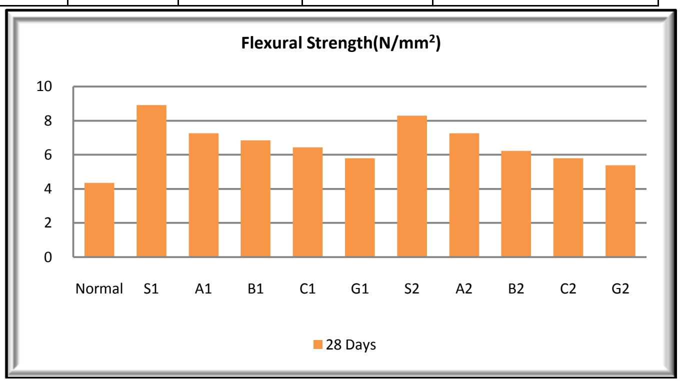

Figure 3.12 Flexural strength results

From figure 3.12, the maximum increase in flexural strength was observed for S1 combination, which is 204.82% of the flexural strength of the control mix at 28 days when GGBFS is replaced by 50% with the cementitious material and Steel fiber was added 1% by the volume of the concrete.

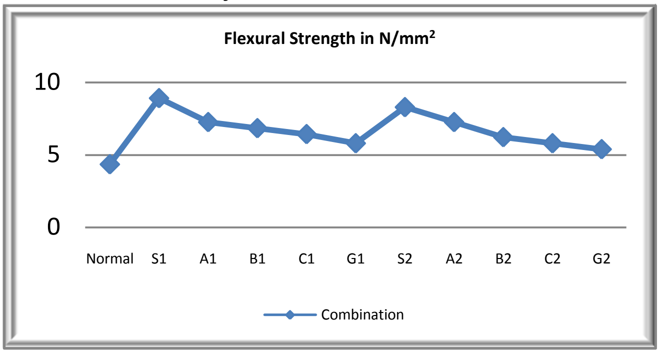

Figure 3.13 Comparison of Flexural strength results

From figure 3.13, the flexure strength of all the combinations was observed higher than the flexural strength of the control mix. However, the 50% of GGBFS replacement gives quite higher flexural strength with respect to 25% of GGBFS replacement with the cementitious materials.

IV. CONCLUSIONS

- Workability of concrete is increased with the increase in the GGBFS contents in the cementitious materials. Maximum workable concrete is found for 0.5% of fiber addition with 50% GGBFS replacement with cementitious materials. With increase in the fiber percentage gives lower slump values, which means it was reducing the workability of concrete.
- Maximum compressive strength is obtained with 1.5% Steel fiber and 50% GGBFS replacement with the cementitious materials, which is 26.67 % more than the control mix, whereas for 1% Steel fiber with 50% GGBFS and 0.5% Steel fiber with 50% GGBFS, it was 15.16% and 10.93% more than the control mix. Also, the compressive strength was found decreasing with increment in glass fiber contents.
- Maximum split tensile strength is obtained with 1.5% Steel fiber and 50% GGBFS replacement with the cementitious materials, which is 43.79 % more than the control mix, whereas for 1% Steel fiber with 50% GGBFS and 0.5% Steel fiber with 50% GGBFS, it was 36.55% and 4.86% more than the control mix. Also, the split tensile strength was found decreasing with increment in glass fiber contents. . The split tensile strength was minimum found for 1.5% Glass fiber and 50% of GGBFS replacement with cementitious material, which is 2.051 N/mm2. It was found 29.27% less than the split tensile strength of Control mix.
- Flexural strength of concrete is respectively increased by 104.48%, 66.87%, 57.24%, 47.81% and 90.57%, 66.87%, 42.98%, 33.33% for S1, A1, B1, C1 andS2, A2, B2, C2 combinations respectively than the flexural strength of Control mix. It shows that 1% of steel fiber with 50% of GGBFS replacement with cementitious materials gives maximum flexural strength of 8.91 N/mm2. From the results; it is clearly visible that steel fiber mix gives higher flexural strength than the glass fiber mix.
- The use of 50% GGBFS replacement with cementitious materials enhance strength properties of concrete more than the strength properties of the 25% GGBFS replacement with cementitious materials with respect to higher amount of steel fiber dosage in the total fiber contents.
- It is recommended to use of 1% of steel fiber with 50% of GGBFS replacement with cementitious materials, with a view of achieving higher strength and to maintain sufficient workability in the placing of concrete in its position.

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