International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 16 (2018) pp. 12932-12940

Experimental Investigation On Mechanical Properties Of Hybrid Fiber Concrete With GGBS

M.Rajaram[a*], A.Ravichandran[b] and A.Muthadhi[c]

[a]*Research scholar, Dept. of Civil Engineering, Pondicherry Engineering College, Puducherry-605014, India.*

[b]*Director, Christ College of Engineering and Technology, Puducherry-605010, India.*

[c]*Assistant Professor, Dept. of Civil Engineering, Pondicherry Engineering College, Puducherry-605014, India.*

Abstract

In this study, mechanical properties of hybrid fiber concrete with admixture were investigated. The combination of different fiber proportions of steel and glass with the presence of Ground Granulated Blast furnace Slag (GGBS) for a 25MPa grade concrete at a total fiber volume fraction of 0.5%, 1.0%, 1.5% and 2.0% were studied. The cement was replaced by 20% of GGBS in 12 different mixes of hybrid fiber. In hybridization, steel fiber with aspect ratio of 40 and glass fiber with aspect ratio 50 were kept constant. The specimens were cast based on IS 10226:2009 and kept in curing for 28 days. The results were shown that the concrete has reached its maximum compressive and split tensile strength at the volume proportion of 1% of hybrid fibers. There will be a significant increase in flexural strength up to the volume proportion of 1.5% of hybrid fibers.

Keywords: Hybrid fibers, Steel, Glass, GGBS, Mechanical properties.

INTRODUCTION

All over the world, concrete made with Portland cement is one of the most used material among all construction materials. Concrete is relatively brittle material when subjected to normal stresses and impact loads [2]. Investigations on overcoming the brittle response and limiting post-yield energy absorption of concrete led to the development of fiber reinforced concrete using discrete fibers within the concrete mass [9]. The addition of fibers not only enhances the requisite properties of reinforced concrete but also alters the characteristics of the material from brittle to ductile [5]. Hence, in recent years in that respect has been research on hybrid fiber reinforced concrete, which comprises the advantages of both types of fibers in an undivided matrix. One case of hybridization is simply found in the geometry of the fibers. In some other case of hybridization is to mix stiff and flexible fibers to enhance both the first crack strength and the post-crack toughness [9]. Since concrete is fragile steel and glass fibers are supplemented to improve the performance of the concrete. This steel fiber (SF) helps as a bridging element to arrest the propagation of the crack [6,8,10]. To dilute the chemical onslaught and to increase thermal insulation in concrete, glass fibers (GF) were added [1].

Ordinary Portland Cement (OPC) being a significant material in the production of concrete form an indigenous substance to bind aggregates. The manufacturing of OPC necessitates firing a great quantity of fuel for the decomposition of limestone, resulting in the discharge of carbon dioxide [4]. The output of cement causes pollution to the environment and subsequently contributes to the depletion of raw material (limestone) [3].

Ground Granulated Blast furnace Slag (GGBS) is a byproduct from the blast furnaces used to produce iron. The use of GGBS serves as a replacement to already depleting conventional building materials and also as being a byproduct it serves as an Eco Friendly way of utilizing the product without dumping it on the dry land [7]. The major problem is the original conventional materials are consumed and we are in the search for alternate building materials which lands us here for the use of GGBS. Hence, this work explores the possibility of using the steel fiber and glass fiber with GGBS in concrete.

Thus far in the literature, most of the work has done with incorporating, Steel fiber, Polypropylene fiber, Basalt fiber and Synthetic fiber in concrete. And a very few has covered in the Steel fiber and Glass fiber in concrete with admixtures. Hence it is worth the experimenting to use the Steel fiber and Glass Fiber in M25 grade of concrete with GGBS.

The primary aim of this investigation is to examine the mechanical behavior of hybrid fiber concrete (Steel fiber and Glass Fiber) with the presence of GGBS, compared with conventional concrete. The compressive strength, split tensile strength and flexural strength of hybrid fiber concrete with GGBS were tested and analyzed in this study.

a- Steel fiber b- Glass fiber c- GGBS

Figure 1.1 Materials used in the mixtures.

EXPERIMENTAL STUDY

Material and mixture proportion

Ordinary Portland Cement (OPC) 43 grade conforming to IS 12269-1987 with a specific gravity of 3.08 was used in concrete mixtures. River sand passing through 4.75 mm IS sieve conforming to grading zone II of IS 383:1970 and having a specific gravity of 2.45 was used in this work. Crushed aggregate available from local sources with a maximum size of 20 mm and conforming to IS 2386:1963 was used as coarse aggregate in this study. Steel fiber having length a of 30mm with diameter of 0.75mm and glass fiber having a length of 25mm with diameter of 0.5mm were used. The aspect ratio of 80 for steel fiber and 50 for glass fiber were kept constant. Four different volume fractions (0.5%, 1.0%, 1.5%, and 2%) of hybrid fiber with 20% GGBS (as a replacement of cement) were used in this investigation.

Mixing and curing

Based on trial mixes for different proportions of constituents, the final design mix was prepared for M25 grade of concrete as per IS 10262:2009. The concrete mix proportion and w/c ratio are presented in the table 2.1 and 2.2. The hybrid concrete is manufactured by as similar to the classical concrete. Initially the dry materials, Cement, Aggregates & Sand are mixed. Further, fibres were added into the dry mixture for another 1 min. The fluid part of the mixture was then added to the dry materials and the mixing continued for further about 4 minutes to ensure even distribution of fibers in the fresh concrete. The fresh concrete was cast into the molds immediately after mixing, in three layers for cube specimens. For compaction of the specimens, each layer was given 60 to 80 manual strokes using a rodding bar. A sum of 248 specimens was cast and de-molded after 24 hours. The specimens were tested after 28 days of curing.

Table 2.1 Mix Proportion

Grade	Mix proportion	w/c
M 25	1 : 1.82 : 2.83	0.5

Table 2.2 Mixing proportion for 1m^3

Mix	W/C	Water Kg/m^3	Cement Kg/m^3	Fine Aggregate Kg/m^3	Coarse Aggregate Kg/m^3	Volume Fraction V_f	Steel fiber content Kg/m^3	Glass fiber content Kg/m^3	GGBS (20% Replacement) Kg/m^3
M25 (0%)	0.5	195	390	712.64	1105.68	0	0	0	0
M25 (0.5%)	0.5	195	312	712.64	1105.68	0.5	12.01	0	78
	0.5	195	312	712.64	1105.68	0.5	9.61	2.40	78
	0.5	195	312	712.64	1105.68	0.5	7.20	4.81	78
M25 (1.0%)	0.5	195	312	712.64	1105.68	1.0	24.03	0	78
	0.5	195	312	712.64	1105.68	1.0	19.22	4.81	78
	0.5	195	312	712.64	1105.68	1.0	14.42	9.61	78
M25 (1.5%)	0.5	195	312	712.64	1105.68	1.5	36.05	0	78
	0.5	195	312	712.64	1105.68	1.5	28.84	7.21	78
	0.5	195	312	712.64	1105.68	1.5	21.63	14.42	78
M25 (2.0%)	0.5	195	312	712.64	1105.68	2.0	48.06	0	78
	0.5	195	312	712.64	1105.68	2.0	38.44	9.62	78
	0.5	195	312	712.64	1105.68	2.0	28.83	19.23	78

Compressive Strength

The compressive strength was determined to find out the behavior of normal concrete and hybrid concrete in compression. Preparation of specimens and testing were done as per IS: 516-1959. The specimens of size 100 × 100 ×100 mm were cast with the required mix proportions and were cured for 28 days for 7 days and 28 days compressive strength. The loading was carried on gradually and maximum load applied on the specimen was noted as show in Figure 2.1. Compressive strength was obtained by dividing the maximum load by the area of a cross section of the specimen.

Compressive strength = F/A N/mm^2

Where,

F = Failure load in Newton

A = Area of cross section of specimen in mm^2

Figure 2.1. Compression Test

Split tensile strength

The behaviour of normal concrete and hybrid concrete in direct tension was determined by this test. The split tensile strength test was conducted on cylinders of size 100 x 200mm at the age of 7 days and 28 days confirming to IS: 5816-1970. The specimen was mounted on the testing platform of the compression testing machine. Two packing strips of 3 mm thick metal were set at the top and underside. The load was applied uniformly till breaking and the load was recorded. Figure 2.2 shows the split tensile strength of normal concrete and hybrid concrete.

The split tensile strength was calculated as:

Split tensile strength = 2P/ (πDL)

Where,

P = Load at failure

D = Diameter of the cylinder

L = Length of the cylinder

Figure 2.2. Split Tensile Test

Flexural strength

The flexural strength was conducted on prisms of size 100 × 100 × 500 mm at the age of 7 days and 28 days and confirming to IS 516-1959 to find out the behaviour of beams and other flexural members when cast with normal concrete and hybrid concrete. The specimen was mounted on the universal testing machine and two point loading was applied, hydraulically which was increased to failure. Figure 2.3 shows the flexural strength of normal concrete and hybrid concrete. The flexural strength of prisms was calculated as follows:

Flexural strength = 3PL/2bd^2

Where

P = Maximum load applied to the specimen

b = Measured width of the specimen

d = Measured depth of the specimen

L = Length of the span.

Figure 2.3. Flexural Test

TEST RESULT AND DISCUSSION

Density of Hybrid Concrete

The density of the concrete containing various fiber volume fractions (0%, 0.5%, 1%, 1.5% and 2%) with the constant GGBS content (20% replacement) was noted. There is a gradual increase in the density of concrete as the volume fraction of the hybrid fiber increases as is shown in Figure 3.1. The density reaches its maximum value of 2451kg/m^3 at 2% of volume fraction. The average density of the hybrid fibers for various volume fractions has given in the Table 3.1.

Table 3.1 Density of Hybrid Fibers

Volume Fraction (VF)	Density of Concrete (containing hybrid fibers and GGBS) Kg/m^3
0%	2405
0.5%	2411
1%	2427
1.5%	2441
2%	2451

It is observed that the density of hybridfiberss with GGBS is higher than the control mixture. The density of the concrete increases with increase in fiber volume fractions was shown in the figure 3.1. A numerical equation was built up to predict the density of the hybrid fiber concrete. The numerical equation to predict the density of hybrid concrete with GGBS for M25 grade of concrete is y = 24.4x + 2402.6 (where x is the value of volume fraction of hybrid fibers in percentage and y is the value of density in Kg/m^3).

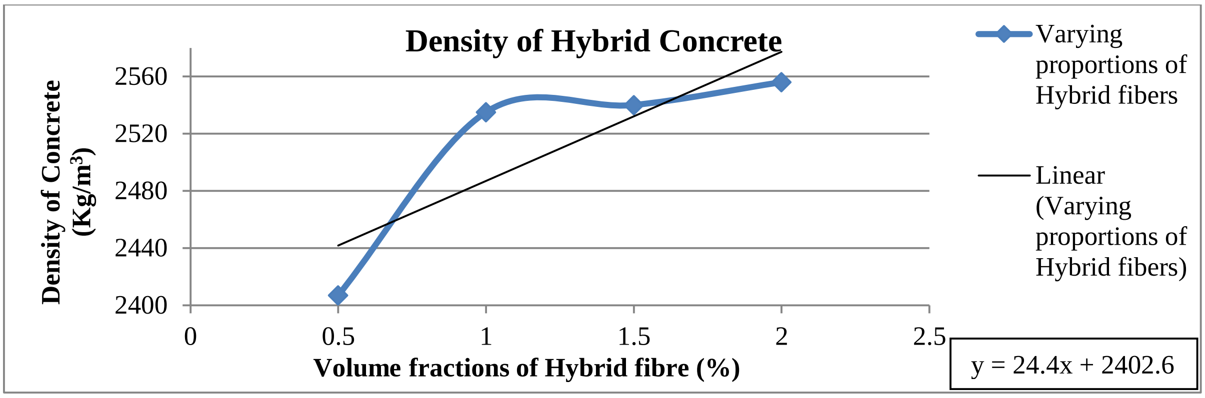

Figure 3.1 Density of Hybrid Fiber

Compressive Strength

A total of 104 cube specimens was cast to find out the compressive strength of the hybrid fiber concrete and steel fiber concrete with GGBS and an average of three cubes for each mix were tested. The compressive strength of hybrid fiber concrete with GGBS is shown in table 3.2. The results indicate that with increase in hybrid fiber content the compressive strength of concrete is increased. This relationship is similar at both ages (7 days and 28 days) of concrete. There will be an increase in compressive strength up to 1.5% of steel fiber concrete than the control mix and falling by 2%. The maximum compressive strength of steel fiber concrete at the age of 7 days and 28 days is 29.94 N/mm^2 and 39.54 N/mm^2 which is 39.12% and 22% higher than the control mix. The maximum compressive strength of steel fiber concrete at the age of 7 days is 29.94 N/mm^2 which is 39.12% higher than the control mix.

The compressive strength of steel fiber concrete is more than the control concrete, but less than the hybrid fiber concrete. The high compressive strength was achieved at 1% volume fraction of hybrid fiber than the control mix and steel fiber concrete at both ages. At the age of 7 days, maximum 70.35% and 22.44% increase occurred in the hybrid fiber concrete than the control mix and steel fiber concrete. At 7 days, the compressive strength of hybrid fiber concrete at 1% volume fraction is 36.66 N/mm^2 which is 13.67% greater than the 28 days strength of the reference concrete. At the age of 28 days, maximum 55.8% and 27.13 % increase occurred in the hybrid fiber concrete than the control mix and steel fiber concrete. However the compressive strength increased for all specimens compared to reference mixture. The graphical relationship from the results in Table 3.2 is shown in Figure3.2 and 3.3 for 7 days and 28 days strength.

Table 3.2: Compressive strength of Hybrid fibers with GGBS

Mix	Volume Fraction V_f	Steel fiber content Kg/m^3	Glass fiber content Kg/m^3	GGBS (20% Replacement) Kg/m^3	Average Compressive Strength (N/mm^2)	
					7 days	28 days
M25 (0%)	0	0	0	0	21.52	32.25
M25 (0.5%)	0.5	11.6	0	88.6	23.22	36.26
	0.5	9.28	2.32	88.6	31.42	35.78
	0.5	6.96	4.64	88.6	32.82	37.53
M25 (1.0%)	1.0	23.23	0	88.6	24.70	37.16
	1.0	18.58	4.64	88.6	28.20	39.23
	1.0	13.93	9.29	88.6	36.66	50.27
M25 (1.5%)	1.5	34.84	0	88.6	29.94	38.05
	1.5	27.87	6.96	886	28.80	38.41
	1.5	20.90	13.93	88.6	23.83	37.81
M25 (2.0%)	2.0	46.46	0	88.6	24.44	36.39
	2.0	37.17	9.29	88.6	35.78	39.48
	2.0	27.87	18.58	88.6	24.44	36.54

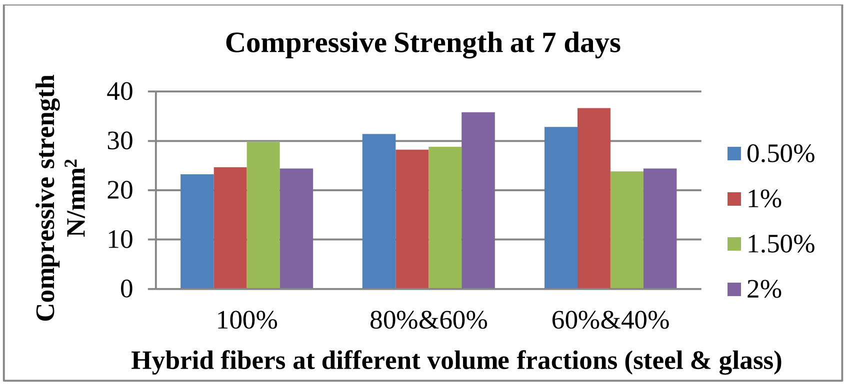

Figure 3.2: Compressive strength at 7 days

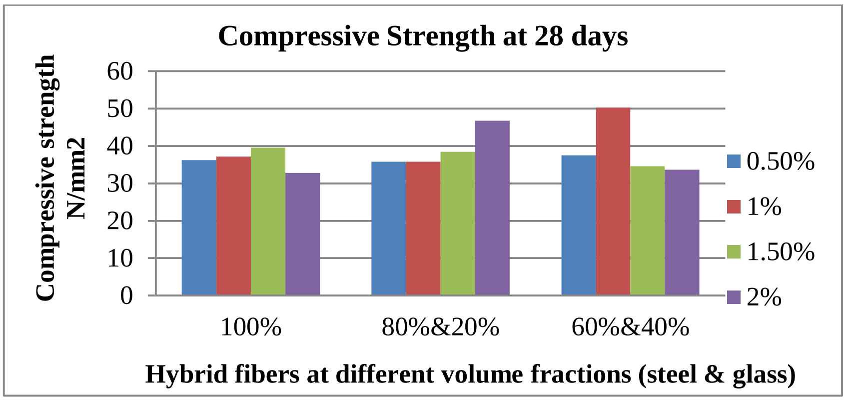

Figure 3.3: Compressive strength at 28 days

Split Tensile Strength

Split tensile strength was carried out on 72 cylindrical specimens and average of three cylinders for each mix was tested to determine the tensile strength of concrete. The split tensile strength of hybrid fiber concrete with GGBS is shown in table 3.3. The results indicate that with increase in hybrid fiber content the split tensile strength of concrete is increased at both ages (7 days and 28 days) of concrete. The split tensile strength of steel fiber concrete is more than the control concrete, but nearly less than the hybrid fiber concrete. The split tensile strength of steel fiber concrete has achieved its maximum at 2% and 1.5 % for 7 days and 28 days strength which is more eminent than the control mix. The maximum split tensile strength of steel fiber concrete at the age of 7 days and 28 days is 3.04 N/mm^2 and 3.52 N/mm^2 which is 11.35% and 16.55% higher than the control mix. The higher split tensile strength of hybrid fiber concrete was attained at 2% volume fraction for 7 days and at 1% for 28 days strength which is greater than the control concrete and steel fiber concrete. At 7 days, the split tensile strength of hybrid fiber concrete at 2% volume fraction is 3.34 N/mm^2 which is 22.34% and 9.86% greater than the reference concrete and steel fiber concrete. At the age of 28 days, maximum 33.8% and 27.13 % increase occurred in the hybrid fiber concrete than the control mix and steel fiber concrete. However split tensile strength increased for all specimens compared to reference mixture. The graphical relationship from the results in Table 3.3 is shown in Figure3.4 and 3.5 for 7 days and 28 days strength.

Table 3.3: Split tensile strength

Mix	Volume Fraction V_f	Steel fiber content Kg/m^3	Glass fiber content Kg/m^3	GGBS (20% Replacement) Kg/m^3	Average Split Tensile Strength (N/mm^2)	
					7 days	**28 days**
M25 (0%)	0	0	0	0	2.73	3.02
M25 (0.5%)	0.5	11.6	0	88.6	2.93	3.34
	0.5	9.28	2.32	88.6	3.12	3.34
	0.5	6.96	4.64	88.6	2.95	3.52
M25 (1.0%)	1.0	23.23	0	88.6	2.85	3.43
	1.0	18.58	4.64	88.6	2.83	3.62
	1.0	13.93	9.29	88.6	3.08	4.32
M25 (1.5%)	1.5	34.84	0	88.6	2.95	3.52
	1.5	27.87	6.96	886	2.85	3.53
	1.5	20.90	13.93	88.6	2.95	3.53
M25 (2.0%)	2.0	46.46	0	88.6	3.04	3.14
	2.0	37.17	9.29	88.6	3.21	3.36
	2.0	27.87	18.58	88.6	2.74	3.25

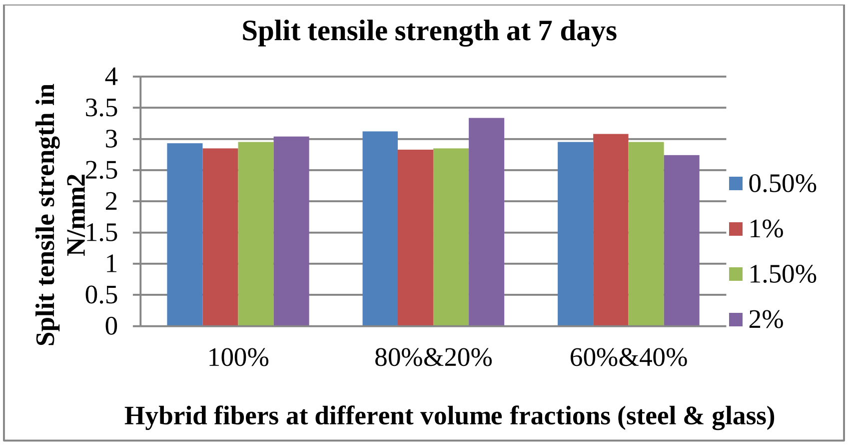

Figure 3.4: Split tensile Strength at 7 days

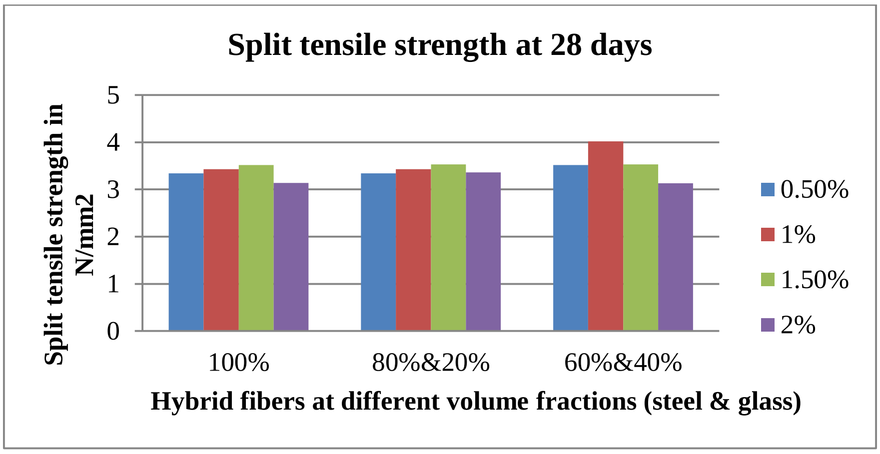

Figure 3.5: Split tensile Strength at 28 days

Flexural Strength

Flexural strength was carried out on 72 prism specimens and average of three prisms for each mix was tested to determine the flexural strength of concrete. The flexural strength of hybrid fiber concrete with GGBS is shown in table 3.4. The results indicate that with increase in hybrid fiber content the flexural strength of concrete is increased. This relationship is similar at both ages (7 days and 28 days) of concrete. In the steel fiber concrete the flexural strength increases as the steel fiber content increases (up to 2%). The maximum flexural strength of steel fiber concrete at the age of 7days and 28 days is 6.61 N/mm^2 and 8.14 N/mm^2 which is 33.81% and 43.81% higher than the control mix. The flexural strength of steel fiber concrete is more than the control concrete, but less than the hybrid fiber concrete. The higher flexural strength was reached by the hybrid fiber concrete than the control mix and steel fiber concrete at 1.5% volume fraction (at both ages). At 7 days, the flexural strength of hybrid fiber concrete at 1.5% volume fraction is 7.79 N/mm^2 which is 57.69% and 17.85% greater than the reference concrete and steel fiber concrete. At the age of 28 days, maximum 65.9% and 15.35 % increase occurred in the hybrid fiber concrete than the control mix and steel fiber concrete. However flexural strength increased for all specimens compared to reference mixture. The graphical relationship from the results in Table 3.4 is shown in Figure3.6 and 3.7 for 7 days and 28 days strength.

Table 3.4: Flexural strength of concrete

Mix	Volume Fraction V_f	Steel fiber content Kg/m^3	Glass fiber content Kg/m^3	GGBS (20% Replacement) Kg/m^3	Average Flexural Strength (N/mm^2)	
					7 days	**28 days**
M25 (0%)	0	0	0	0	4.94	5.66
M25 (0.5%)	0.5	11.6	0	88.6	4.87	7.13
	0.5	9.28	2.32	88.6	6.17	7.83
	0.5	6.96	4.64	88.6	6.61	8.00
M25 (1.0%)	1.0	23.23	0	88.6	5.57	7.58
	1.0	18.58	4.64	88.6	6.26	8.35
	1.0	13.93	9.29	88.6	5.57	7.31
M25 (1.5%)	1.5	34.84	0	88.6	5.71	8.00
	1.5	27.87	6.96	886	7.79	9.39
	1.5	20.90	13.93	88.6	6.61	9.04
M25 (2.0%)	2.0	46.46	0	88.6	6.61	7.68
	2.0	37.17	9.29	88.6	6.09	8.96
	2.0	27.87	18.58	88.6	6.61	8.48

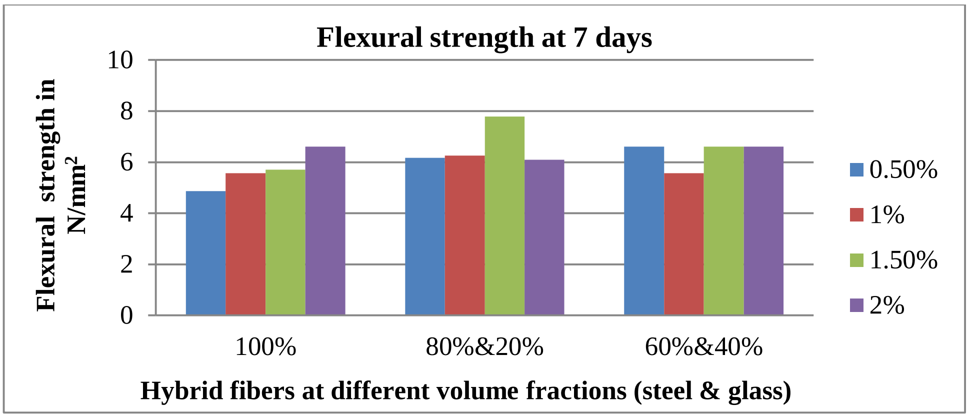

Figure 3.6: Flexural Strength at 7 days

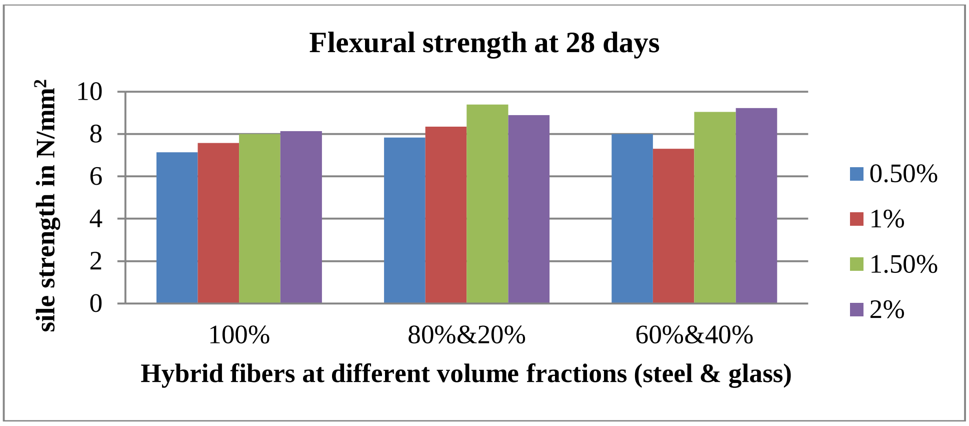

Figure 3.7: Flexural Strength at 28 days

CONCLUSION

In this study, mechanical properties of steel fiber concrete and hybrid fiber concrete with the presence of GGBS were determined, in order to compare the values with control concrete. Based on the results of this investigation, the following conclusions can be made:

- The density of the hybrid concrete having different volume fractions was obtained. The maximum density of hybrid fiber concrete is 2556 kg/m^3, occurred at 2% volume fraction of hybrid fibers and the density of the hybrid concrete is 6.5% higher than the control concrete.
- The density of the concrete increases with increase in hybrid fiber content. The linear equation has been set up to predict the density of this hybrid concrete for M25 grade of concrete.
- The compressive strength of the concrete is increased with increase in hybrid fiber concrete. At both ages the compressive strength of the concrete increases with increase in hybrid fiber content.
- The compressive strength of the steel fiber concrete is higher than the control concrete at both ages. The compressive strength of the steel fiber concrete is more than the control concrete, but less than the hybrid fiber.
- The high compressive strength was achieved at 1% volume fraction of hybrid fiber in both ages than the reference concrete and steel fiber concrete, which is 70.35% and 22.44% higher than the control concrete and steel fiber concrete in 7 days strength of concrete.
- In 28 days, a 55.8 % increase is occurring in hybrid fiber concrete compared to reference concrete and 7 days strength of hybrid concrete is higher than the 28 days strength of control concrete.
- With the increase in hybrid fiber content the split tensile strength of concrete is increased at both ages of concrete. The split tensile strength of steel fiber concrete is more than the control concrete, but less than the hybrid fiber concrete up to 1.5% of volume fraction.
- At both ages the split tensile strength of steel fiber concrete is 11.35% and 16.55% higher than the control concrete. The highest value of split tensile strength was achieved at 1% volume fraction of hybrid characters.
- At 28 days maximum 33.8% and 27.13% increase in split tensile strength was occurred in the hybrid fiber concrete than the control concrete and steel fiber concrete.
- Increase in hybrid fiber content increases the flexural strength of the concrete at both ages. Maximum flexural strength of steel fiber concrete at 7 days and 28 days is 33.18% and 43.81% higher than the control concrete.
- The flexural strength of steel fiber concrete is more than the reference concrete, but less than the hybrid

fiber concrete. At 1.5% volume fraction of hybrid fiber concrete reaches its maximum flexural strength in both ages.

- At 28 days 65.9% and 15.35% increase in flexural strength was occurred than the control concrete and steel fiber concrete.
- Overall strength of the concrete is enhanced by the inclusion of hybrid fiber than the control concrete. Inclusion of hybrid fiber does not affect the workability of the concrete.
- Hence, hybrid fibers can be used with GGBS in concrete to enhance the strength of the concrete without affecting the workability.

REFERENCES

[1] Bhalachandra, S.A., Bhosle, A.Y. (2013). “Properties of Glass fiber reinforced Geopolymer Concrete.” International Journal of Modern Engineering Research, 2007-2010.

[2] Hamdy K, Shehab El-Din., Ahmed S, Eisa., Baligh H, Abdel Aziz., and Ahmed Ibrahim. (2017). “Mechanical performance of high strength concrete made from high volume of Metakaolin and hybrid fibers.” Construction and Building Materials, Science Direct, Construction and Building Materials, Vol. 140, pp. 203–209, DOI: 10.1016/j.conbuildmat.2017.02.118.

[3] Joshua Daniel, A., Sivakamasundari, S., Abhilash, D. (2017). “Comparative Study on the Behaviour of Geopolymer Concrete with Hybrid Fibers under Static Cyclic Loading.” Proc., 11th Int. Symposium on Plasticity., and Impact Mechanics. Symp. Implast 2016, Procedia Engineering, Vol. 173, pp. 417 – 423.

[4] Kong, D.L.Y., and Sanjayan, J.G. (2008). “Damage behavior of geopolymer composites exposed to elevated temperature.” Cement Concrete Composites, pp. 986-991.

[5] Mohammad Adnan Farooq., and Mohammad Shafi Mir. (2013). “Laboratory Characterisation of Steel Fiber Reinforced Concrete for varying Fiber Proportion and Aspect Ratio.” International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Vol. 3, No.2, pp. 75-80.

[6] Perry Adebar., Sidney Mindess., Daniel St.-Pierre., and Brent Olund. (1997). “Shear tests of fiber concrete beams without stirrups.” ACI Structural Journal, Vol. 219, No.1, pp. 68–76.

[7] Rajaram, M., Ravichandran, A., and Muthadhi, A. (2017). “Studies on Optimum Usage of GGBS in Concrete.” International Journal of Innovative Science and Research Technology, ISSN No:2456-2165, Vol. 2, No.5, pp. 773-778.

[8] Swamy, R.N., and Bahia, H.M. (1985). “The effectiveness of steel fibers as shear reinforcement.” Concrete Institute, pp. 35–40.

[9] Thirumurugan, A., and Sivaraja, M.(2015). “Strength And Fracture Properties Of Hybrid Fiber Reinforced Concrete.” IJST, Transactions of Civil Engineering, Vol. 39, No.C1, pp. 93-102.

[10] Yoon-Keun Kwak., Marc O, Eberhard., Woo Suk Kim., and Jubum Kim. (2002). “Shear strength of steel fiber-reinforced concrete beams without stirrups.” ACI Structural Journal, pp. 530–538.