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An Experimental Study on Strength and Durability Properties of Steel Fibers and Glass Fibers with M_{30} Grade Concrete using GGBS

K.Deepthi[1], P.Prudhvija[2]
M.Tech, Structural Engineering[1], Assistant Professor[2]
Department of Civil Engineering
Usharama College of Engineering and Technology, Telaprolu, Andhra Pradesh, India

Abstract:
The Ground Granulated Blast Furnace Slag (GGBS) is a Waste Product from the Steel Plant, which may be used as Partial Replacement of Cement in Concrete Due to Its Inherent Cementing Properties, Which Improve Mainly the Mechanical Properties of Concrete and Reduce the Cement Consumption by Replacing Part of Cement with These Pozzolanic Materials. When Fibers Are Added in Specific Percentage to Concrete It Improves the Mechanical Properties, Durability and Serviceability of The Structure. It Is Now Established That One of The Important Properties of Fiber Reinforced Concrete Is Superior Resistance to Cracking and Crack Propagation. The Study Has Been Made to Evaluate the Effect on Mechanical and Durability Properties of M_{30} Grade Concrete with Various Proportional of Replacement of Cement with Ground Granulated Blast Furnace Slag (GGBS), (0%,10%,20%,30%&40%) By Weight and the Addition of Steel Fiber in Different Percentages (0%, 1%, 1.5%, 2%&2.5%) and Glass Fiber in Different Percentages (0%, 0.1%, 0.2%, 0.3%&0.4%). For this Purpose, along with a Control Mix, 9 Sets were prepared to Study the Compressive Strength, Tensile Strength, Flexural Strength and Durability Properties were studied. Each Set Comprises of 15 Cubes, 6 Cylinders and 6 Beams.

Keywords: Concrete, Ground Granulated Blast Furnace Slag, Steel Fibers and Glass Fibers.

I. INTRODUCTION

Concrete is probably the most extensively used construction material in the world. The main constituent in the conventional concrete is Portland cement. Cement production is consuming significant amount of natural resources. The incorporation of supplementary cementitious material is GGBS is a mineral admixture, which improves mainly the mechanical properties of concrete and reduces the cement consumption by replacing part of cement with these pozzolanic materials. Moreover, only limited studies have been carried out in India on the use of slag for the development of high strength concrete with addition of steel fibers and glass fibers. Plain concrete possesses a very less tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are present in the concrete and its poor tensile strength is due to the propagation of such micro cracks. It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to concrete would act as crack arrester and uniformly dispersed fibers to concrete would act as crack stop and would substantially improve its static and dynamic properties. In this study the addition of steel and glass fibers are added to concrete, leads to improvement in cracking and tensile strength.

II. MATERIAL PROPERTIES

1.1 Cement: Cement used in this experiment work is ordinary Portland cement of 43- grade available in the local market. The cement should be fresh and of uniform consistency. The specific gravity of the cement is 2.9. All properties of cement are tested by referring IS 12269 – 1987.

Table.1. Properties of cement

properties	Results
Normal consistency of cement	32%
Initial setting time Final setting time	33min 10hrs 35min
Specific gravity of cement	2.9

2.2 Fine aggregate: Fine aggregates conforming to grading zone II with particles greater than 2.36mm and smaller than 150mm removed are suitable. Specific gravity of fine aggregate is 2.6.

Table.2. Properties of fine aggregate

Property	Results
Sieve analysis	Zone II
Specific gravity	2.6
Fineness Modulus	2.65

2.3 Coarse aggregate: locally available crushed stones conforming to graded aggregate of nominal size 20mm as per IS: 383-1970. Specific gravity of coarse aggregate is 2.5.

Table.3. Properties of course aggregate

Property	Results
Specific gravity	2.5
Fineness modulus	2.94

2.4 Water: Water is used in the mixing is to be fresh potable water free from acid and organic substances was used for mixing and curing concrete.

2.5 Ground granulated blast furnace slag: GGBS is obtained by quenching molten iron slag (a product of iron and steel making) from a blast furnace in water or stream, to produce a glassy, granular product that is then dried and ground into a fine powder. GGBS cement can be added to concrete manufacturer's batching plant, along with Portland cement, aggregates and water.

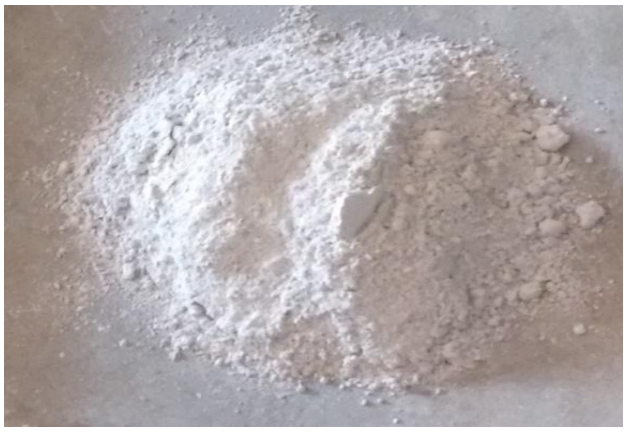


Figure.1. GGBS

2.5.1 Comparison of Chemical composition of GGBS and OPC:

Table.4. Comparison of OPC & GGBS

Chemical constituent	Portland	GGBS
CAO	65%	40%
SiO_2	20%	35%
Al_2O_3	5%	10%
MgO	2%	8%

2.6 Steel fibers: Fiber is small piece of reinforcing material possessing certain characteristics properties. They can be circular or flat. The fiber is often described by a convenient parameter called" aspect Ratio". The aspect ratio of the fiber is the ratio of its length to its diameter. The steel fiber type used here is hooked end with 35mm fiber length and 0.45mm diameter. The aspect ratio of the fiber is the ratio of its length to its diameter and generally the aspect ratio ranges from 30 to 150 and here the aspect ratio of the steel fiber is 80.

Figure.2. Steel fibers

Table.5. Properties of Steel Fiber

properties	Improvement over ordinary concrete
Ductility	5 to 10 times
Impact resistance	100 to 200%
Cracking & flexural strength	80 to 120%
Shear strength	50 to 100%
Bearing strength	50 to 100%
Abrasion resistance	Several times

2.7 Glass fibers: It is material made from extremely fine fibers of glass fiber is a light weight, extremely strong & robust material. The glass fiber type used here is E glass with 50mm fiber length & 0.1 mm diameter. The aspect ratio of the glass fiber is 500.

Figure.3. Glass fiber

And submerged in water for curing. After a curing period of 7&28 days specimens were taken out and tested.

Table.6. Properties of glass fibers

Fiber length	Density, (g/cm^3)	Tensile strength, Mpa	Modulus, Gpa	% Elongation
E-glass	2.54	3400	72	4.7

Figure.4. Specimens

2. EXPERIMENTAL PROGRAMME

Mix design for each set having different combinations are carried out by using IS: 10262 – 2009method. The mix proportion obtained for normal M30 grade concrete is 1:1.35:2.82 with a water-cement ratio of 0.40

Table .7. Mix proportion

Material	Cement	Fine aggregate	Coarse aggregate
Kg/m^3	400	543	1131

The experimental investigation consists of casting and testing of 9sets along with control mix. Each set comprises of 15 cubes, 6 cylinders and 6 beams for determining compressive, tensile and flexural strengths respectively. By taking different percentage of GGBS, along with steel & glass fibers individually as a partial replacement of cement will be replaced accordingly with the different percentages by weight of slag and different percentages by weight of steel fiber and glass fiber. The concrete was filled in layers and compacted. The specimens were removed after 24 hours

3. TESTS AND RESULTS

Several tests were carried out to determine the design mix properties of concrete in the laboratory. The Strength criterion includes measurement of following parameters:

- Compressive Strength Test
- Split Tensile Strength Test
- Flexural Strength Test

3.1 Compressive Strength Test: Compressive Strength of concrete is calculated by casting 150mm × 150mm × 150mm cubes. The test results are presented here for the compressive strength of 7days, 14days&28days of testing

Figure.5. Cubes in Compressive Testing Machine

Table.8. Compressive Strength of Trail Mix

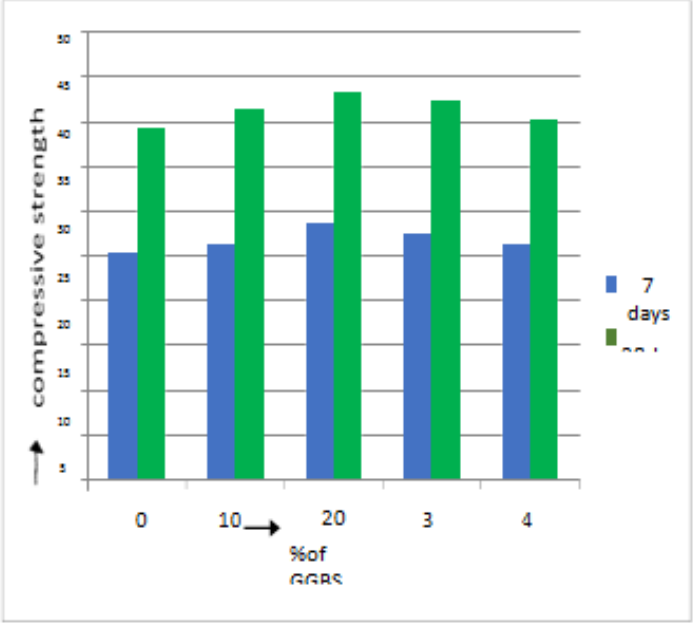
MIX DETAILS	Compressive strength(Mpa)	
	7 days	28 days
Conventional Concrete	25.30	38.40

3.1.1 GGBS Optimum:

The mix proportions with partial replacement of OPC with (0%, 10%, 20%, 30%&40%) of GGBS are calculated.

Table.9. Compressive strength for GGBS

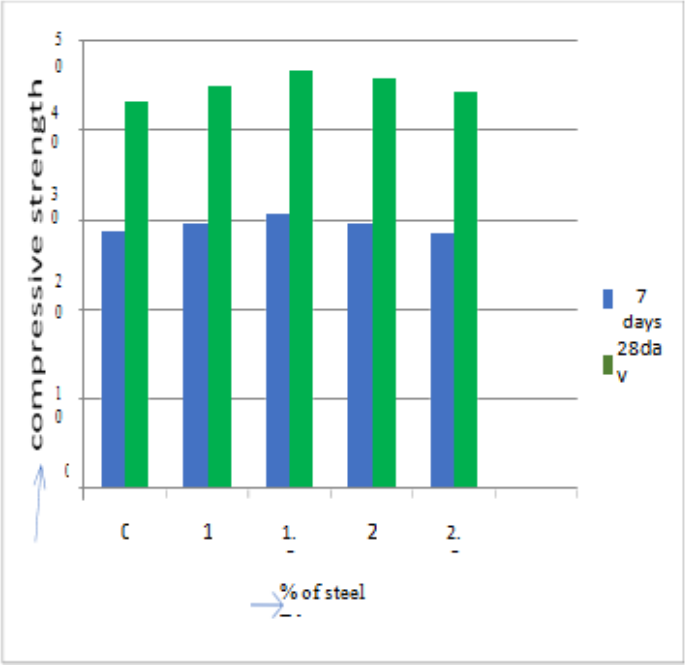
S.No	% of GGBS	Compressive Strength (Mpa)	
		7days	28days
1	0	25.30	38.40
2	10	26.37	41.50
3	**20**	**28.64**	**43.25**
4	30	27.61	42.31
5	40	26.40	40.15



Graph.1. compressive strength of GGBS for 7&28 days

Table.10. Compressive Strength for Steel Fibers

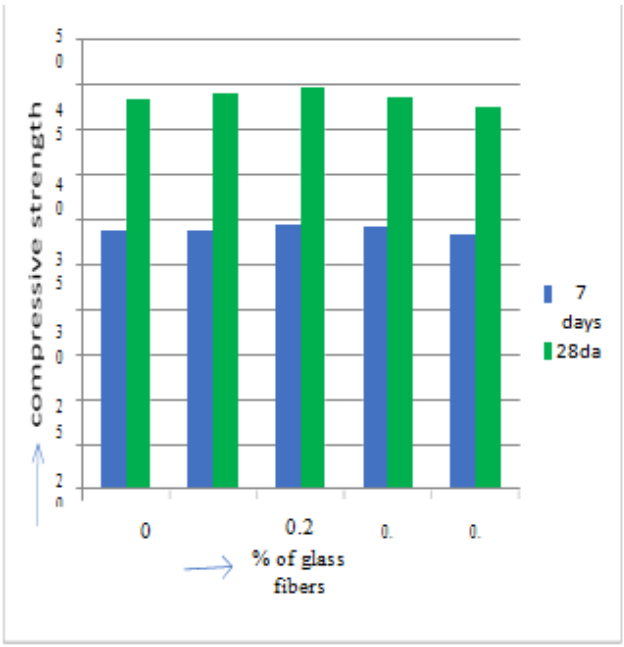
S.No	% of GGBS	% of steel fibers	7days (N/mm^2)	28days (N/mm^2)
1	20	0	28.64	43.25
2	20	1	29.47	44.85
3	**20**	**1.5**	**30.67**	**46.75**
4	20	2	29.61	45.68
5	20	2.5	28.46	44.27



Graph.2. compressive strength of steel fibers for 7&28 days

Table.11. compressive strength for glass fibers

S.NO	% of GGBS	% of glass fibers	7days (N/mm^2)	28days (N/mm^2)
1	20	0	28.64	43.25
2	20	0.1	28.85	43.93
3	**20**	**0.2**	**29.37**	**44.70**
4	20	0.3	29.07	43.54
5	20	0.4	28.25	42.38



Graph.3. compressive strength of glass fibers for 7&28 days

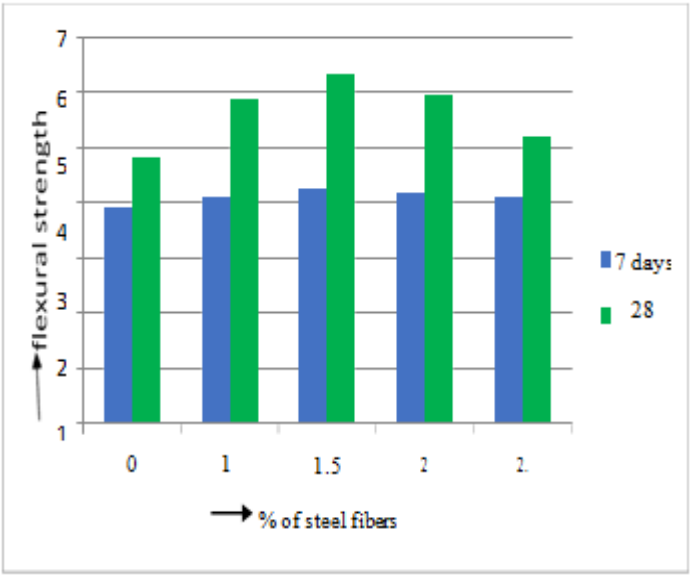
Flexural Test:

Flexural test was performed on beams by placing them on universal find out the flexural strength. After testing the concrete (flexural strength) for M30 grade concrete separately for replacement of GGBS, Glass & Steel fiber by cement respectively. Finally, combined percentage of GGBS & steel fiber mix, GGBS & glass fiber mix in which maximum strength is obtained was used to get optimized strength

Figure.6. flexural test

Table.11. flexural strength for steel fibers

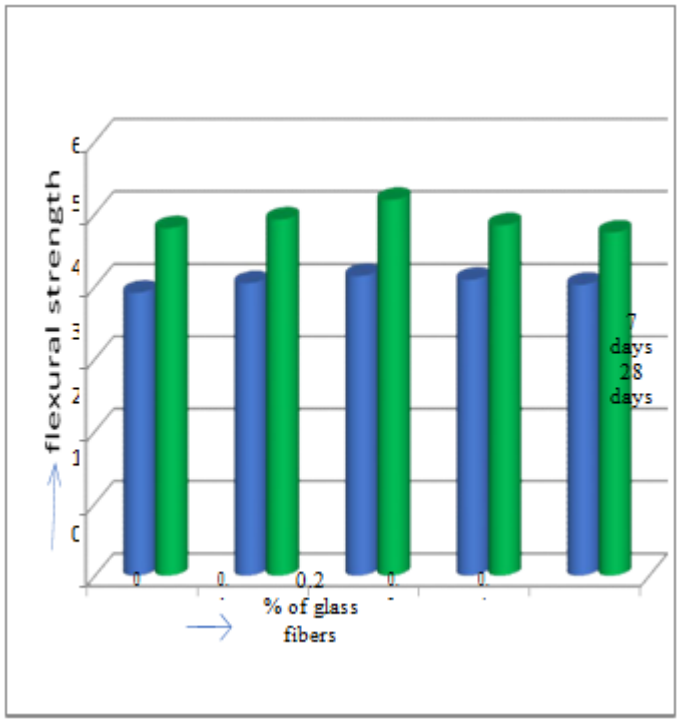
S.NO	% of GGBS	% of glass fibers	7days (N/mm^2)	28days (N/mm^2)
1	20	0	28.64	43.25
2	20	0.1	28.85	43.93
3	**20**	**0.2**	**29.37**	**44.70**
4	20	0.3	29.07	43.54
5	20	0.4	28.25	42.38



Graph.4. flexural strength for steel fibers 7&28 days

Table.12. flexural strength for glass fibers

S.No	% of GGBS	% of glass fibers	7days (N/mm2)	28days (N/mm2)
1	20	0	3.92	4.81
2	20	0.1	4.05	4.93
3	**20**	**0.2**	**4.15**	**5.20**
4	20	0.3	4.10	4.85
5	20	0.4	4.03	4.75



Graph.5. flexural strength for glass fibers for 7&28 days

Split Tensile Strength Test:

The failure load was recorded to find out spit tensile strength. After testing the concrete (split tensile strength) for M30 grade concrete separately for replacement of GGBS, Glass & Steel fiber by cement respectively. Finally, combined percentage of GGBS & steel fiber mix, GGBS & glass fiber mix in which maximum strength is obtained was used to get optimized strength.

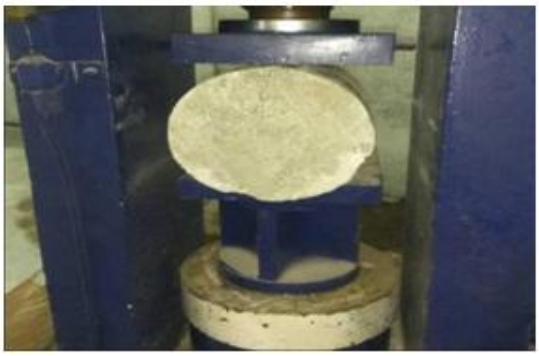
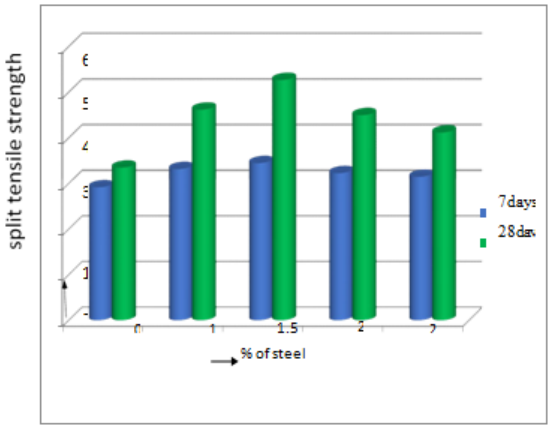


Figure.8. split tensile test for fibers

Table.13. split tensile test for steel fibers

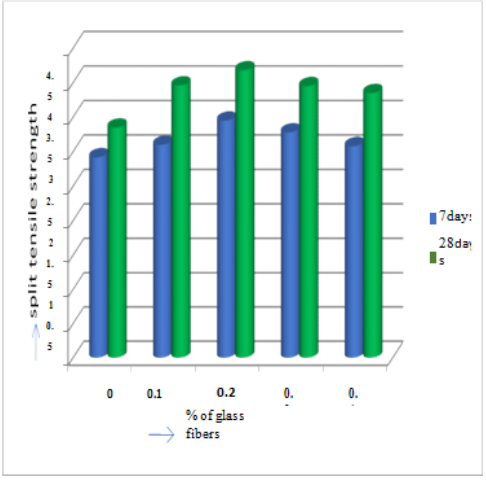
S.No	% of GGBS	% of steel	7days (N/mm	28days (N/mm2)
1	20	0	2.92	3.35
2	20	1	3.32	4.62
3	**20**	**1.5**	**3.45**	**5.27**
4	20	2	3.23	4.50
5	20	2.5	3.15	4.12



Graph.6. split tensile test for steel fibers 7&28 days

Table.14. split tensile test for glass fibers

S.No	% of GGBS	% of glass fibers	7days (N/mm2)	28days (N/mm2)
1	20	0	2.92	3.35
2	20	0.1	3.10	3.96
3	**20**	**0.2**	**3.45**	**4.18**
4	20	0.3	3.28	3.95
5	20	0.4	3.08	3.85



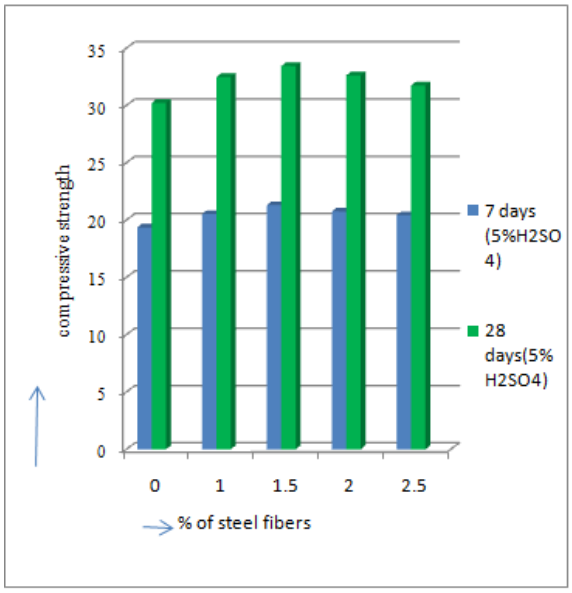
Graph.7. Split Tensile Test for Glass Fibers for 7&28 Days

4. DURABILITY

Durability studies of compressive strength of concrete effected with 5% of HCL & H_2SO_4 acid is studied at 20% replacement of GGBS along with different percentages of steel and glass fibers.

Table. 15. Compressive Strength of Steel Fiber Reinforced GGBS Concrete after H_2so_4 Curing

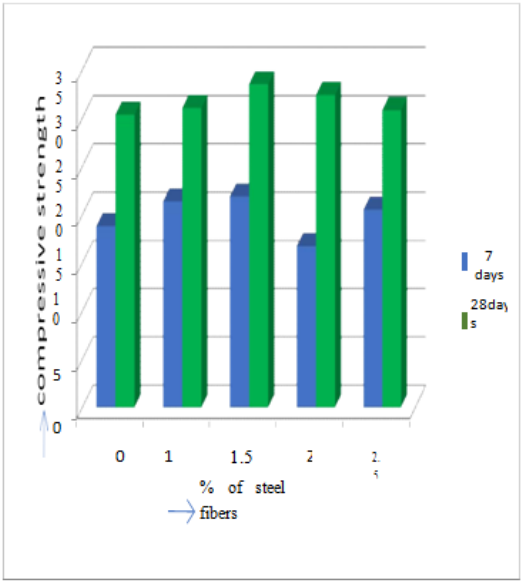
S.No	% of GGBS	% of steel fibers	7days (5% H_2SO_4)	28days (5% H_2SO_4)
1	20	0	19.36	30.21
2	20	1	20.52	32.48
3	**20**	**1.5**	**21.30**	**33.44**
4	20	2	20.75	32.62
5	20	2.5	20.42	31.74



Graph.8. Compressive Strength Of 5% H_2so_4 Cured Steel Fiber Cubes after 7&28 Days

Table.16. Compressive Strength of Steel Fiber Reinforced GGBS Concrete after HCL Curing

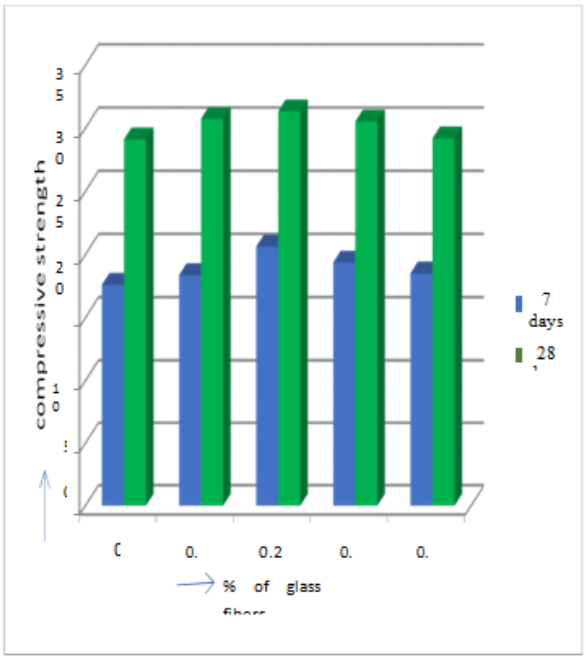
S.No	% of GGBS	% of steel fibers	7days (5% HCL)	28days (5% HCL)
1	20	0	18.95	30.50
2	20	1	21.52	31.16
3	**20**	**1.5**	**22.04**	**33.65**
4	20	2	21.89	32.52
5	20	2.5	20.65	30.94



Graph.9. compressive strength of 5% hcl cured steel fiber cubes after 7&28 days

Table.17. compressive strength of glass fiber reinforced ggbs concrete after h_2so_4 curing

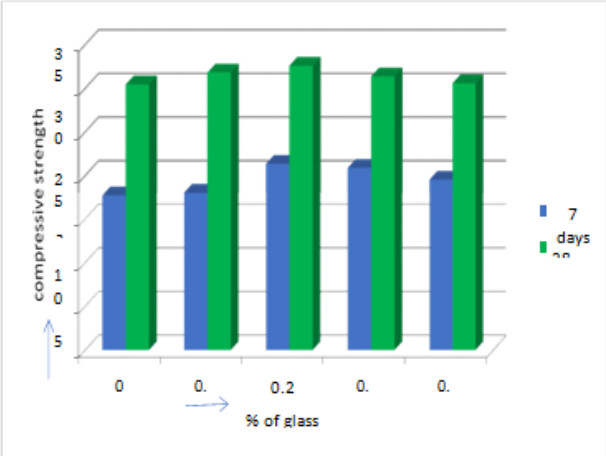
S.No	% of GGBS	% of glass fibers	7days (5% H_2SO_4)	28days (5% H_2SO_4)
1	20	0	17.62	29.12
2	20	0.1	18.38	30.75
3	**20**	**0.2**	**20.64**	**31.34**
4	20	0.3	19.39	30.54
5	20	0.4	18.52	29.20



Graph.10. compressive strength of 5% h_2so_4 cured glass fiber cubes after 7&28 days

Table.18. compressive strength of glass fiber reinforced GGBS concrete after HCL curing

S.No	% of GGBS	% of glass fibers	7days (5% HCL)	28days (5% HCL)
1	20	0	17.79	30.50
2	20	0.1	18.10	31.87
3	**20**	**0.2**	**21.40**	**32.65**
4	20	0.3	20.95	31.43
5	20	0.4	19.59	30.64



Graph.11. Compressive Strength Of 5% Hcl Cured Glass Fiber Cubes after 7&28 Days

5. CONCLUSION

Based on the analysis of experimental results and discussion there upon the following conclusions can be drawn:

- ❖ The optimum quantity for partial replacement of cement by GGBS is obtained at 20%.
- ❖ The concrete mixture with 20% of GGBS and 1.5% of steel fiber has the highest compressive strength, flexural strength, split tensile strength performance at all ages.
- ❖ The concrete mixture with 20% of GGBS and 0.2% of glass fiber has the highest compressive strength, flexural strength, split tensile strength performance at all ages.
- ❖ The effect of acid on concrete decreases with the increase of percentage of GGBS.
- ❖ The results show that steel fiber is more effective than glass fiber.
- ❖ GGBS, glass and steel fiber can be used in concrete as a suitable replacement of cement to make the concrete stronger in compression and tension, to make concrete more economical.
- ❖ The addition of fibers & increases the compressive, split tensile and impact strength at lower percentages of fibers but at large percentages at fibers due to balling effect or due to non homogeneity at the mix, the decrease in strengths are observed

Scope for Future Work:

1. Non-Destructive can also be useful for on-site testing.
2. Some tests relating to durability aspects such as water permeability, resistance to penetration of chloride ions, corrosion of steel reinforcement etc. need investigation.

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