An Experimental Study of Basalt Chopped Fibers Reinforced Concrete with replacement of GGBS on Compressive, Tensile and Flexural Behaviour

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Abstract - *In this paper an experimental work is carried out to study the behaviour of basalt fibre reinforced concrete with GGBS replacement of fine aggregates by various percentages as 0, 25, 50, 75 and 100% on compressive, flexural and split tensile strength with plain M40 grade concrete. Total 108 No's of specimens are casted for M40 grade concrete (36 cubes, 36 cylinders and 36 prisms). A design mix of M40 is prepared by using the IS 10262:2009. 28 days water curing is adopted for all the testing specimens. From this experimental work, it can be concluded that constant percentage of fibre 1.5% for cubes and cylinders and 2% for prisms the optimum dosage of GGBS for the compressive strength of cubes, split tensile strength and flexural strength is 25%.*

KeyWords: *Basalt fiber, GGBS, Compressive strength, Split tensile strength, Flexural strength, FRP, Plain concrete*

1. INTRODUCTION

As the structural use of concrete developed in the second half of the 1800's, interest was focused on reinforced to enhance its low tensile capacity. The concern with the inferior fracture toughness of concrete are alleviated to a large extent by reinforced it with fibers of various materials. The resulting material with a random distribution of short discontinuous fiber is referred as fiber reinforced concrete (FRC).It has been found that different type of fibers added in specific percentage to concrete improves the mechanical properties, durability and serviceability of the structure. It is now established that one of the important properties of Fiber Reinforced Concrete (FRC) is its superior resistance to cracking and crack propagation. Fiber- reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity .the vast improvements achieved by the addition of fibers to concrete; there are several applications where fibers Reinforced Concrete (FRC) can be intelligently and beneficially used. These fibers have already been used in many large projects involving the construction of industrial floors, pavements, highway-overlays, etc. in India. These fibers are also used in the production of continuous fibers and are used as a replacement to reinforcing steel .

1.1 Basalt Fiber

Basalt rock is a volcanic rock and can be divided into small particles then formed into continues or chopped. Basalt fiber has a higher working temperature and has a good resistance to chemical attack, impact load and fire with less poisonous fumes. It is fine-grained, extrusive, igneous rock composed of plagioclase, feldspar, pyroxene and magnetite, with or without olivine and containing not more than 53 wt% SiO_2 and less than 5 wt% total alkalis.The production of basalt fibers is similar to the production of glass fibers. Basalt is quarried, crushed and washed and then melted at 1500° C. The molten rock is then extruded through small nozzles to produce continuous filaments of basalt fiber .

1.2 GGBS

Ground granulated blast furnace slag (GGBS) is a sustainable material which helps in greener environment by reducing the energy consumption and carbon dioxide (CO2) gas emission. Direct emission of CO2 occurs through the chemical process called "calcinations" whereas burning of fossil fuels to heat the kiln indirectly results in CO2 gas emission.

It has been reported that the manufacture of one tonne of Portland cement would require approximately 1.5 tonnes of mineral extractions together with 5000 MJ of energy, and would generate 0.95 tonne of CO2 equivalent [18]. As GGBS is a by-product of iron manufacturing industry, it is reported that the production of one tonne of GGBS would generate only about 0.07 tonne of CO2 equivalent and consume only about 1300 MJ of energy.
GGBS is obtained from iron manufacturing industries, when Silicate and aluminate impurities from ore and coke are combined with flux lowered the viscosity of slag. Molten iron is then tapped off, the remaining

molten slag, which consists of mainly siliceous and aluminous residue, is then water-quenched rapidly below 800oC in order to prevent the crystallization of merwinite and melilite, resulting in the formation of a glassy granulate. This glassy granulate is then dried and grounded into fine powder, which is known as ground granulated blast furnace slag (GGBS).

Concrete made with GGBS has many advantages, including improved strength, durability, workability, economic and environmental benefits.

The only drawback in the use of GGBS concrete is that its strength development is considerably slower under the standard curing conditions than that of portland cement concrete, although the ultimate strength is higher for the same water– binder ratio.

The main objective of the present work is to develop a high performance concrete (HPC) by the use of GGBS. Therefore, the experimental program has been undertaken with the objectives to check the compressive, tensile and flexural strength of concrete grade M40.

2. OBJECTIVES

The main objective of this experimental work is to investigate the behaviour of basalt fiber (chopped strand) reinforced concrete with replacing GGBS by fine aggregate compressive strength, tensile strength, flexural strength of concrete using basalt fiber and GGBS and identify the use of these two materials in regular construction. To study the strength characteristics of concrete are compared with the reference mix (M40 concrete without fiber and GGBS) and possible use of basalt fiber and GGBS.

3. EXPERIMENTAL PROGRAMME

3.1 Materials

It is obvious that the performance of the basalt fiber and GGBS concrete depends upon the various physical properties of the ingredients, proportion of the mix, water cement ratio, compaction effect type and period of curing.

So in order to know the physical properties of the materials, various testes specified by the Indian Standards were conducted and their suitability for use was checked. The detail of the investigation is presented below.

A. Cement

The cement used in all mixtures was Ordinary Portland cement (43Grade) with a specific gravity of 3.15. Initial and final setting times of the cement were 30 min and 480 min, respectively.

Some of the important required experiments conducted on the cement as specific gravity of cement, normal consistency of cement, initial and final setting time of cement, results are shown below table.

Table No-1 Physical Properties of Cement

Sl. No.	Properties	Values
1	Specific Gravity	3.15
2.	Standard consistency	34%
3.	Initial setting time in min.	30
4.	Final setting time in min	480

B. Fine aggregates (sand)

Manufactured sand was used as fine aggregate for the experiments. Various tests were conducted to determine the properties of sand. Grading is the particle-size distribution of an aggregate as determined by a sieve analysis.

Some of the importance tests will be conducted on fine aggregates which is required in mix design of concrete as shown in below table. The test was done according to IS: 2386 (Part 1) – 1963.

Table-2 Properties of Fine Aggregate

Sl. No.	Properties	Values
1	Specific Gravity	2.56
2.	Fineness modulus	2.96
3.	Water absorption	11%
4.	Zone	II

C. Coarse aggregate

Aggregate is commonly considered inert filler, which accounts for 60 to 80 percent of the volume and 70 to 85 percent of the weight of concrete .Maximum size of aggregate affects the workability and strength of concrete. It also influences the water demand for getting a certain workability and fine aggregate content required for achieving a cohesive mix. In this study the natural coarse aggregates are used, which was bought from the nearby quarry. Aggregates of 20 mm and 12.5 mm size were chosen for the experiment which is clean and free from deleterious materials.

The importance tests are to be conducted on the coarse aggregates as per IS 10262:2009. Which the experimental results are required in mix design as shown in below table.

Table-3 Properties of Coarse Aggregate

Sl. No.	Properties	Values
1	Specific Gravity	2.67
2.	Fineness modulus	2.59
3.	Water absorption	0.5%

D. Super plasticizer

In modern concrete practice, it is essentially impossible to make high performance concrete at adequate workability in the field without the use of super plasticizers. The super plasticizer used in the study was PARPLAST-RC 230.

Benefits:

- Increase the workability.
- Increase the compressive strength by reducing water content.
- Reduces the cement content without altering workability and strength.
- Increases durability of concrete by reducing water permeability.
- Minimize the risk of segregation, cracks and bleeding by forming a dense, close textured surface.
- Chloride free, hence safe for reinforced concrete.

E. Basalt Fiber

The fibers used were chopped basalt fibers which are uniformly and randomly distributed in the concrete matrix. For the experimental work length 12mm and the fiber diameter 13μ basalt chopped fiber were used. Chopped basalt fibers are shown in figure.

3.1.1 Properties of Basalt Fibers

Capability	Basalt fiber
Tensile strength, M Pa	3000~4840
Tensile strength, M Pa	79.3~93.1
Elastic modulus, G Pa	3.1~6
Elongation at break, %	2.65-2.8
Specific gravity	6~21
Diameter of filament, mμ	-260~+500
Temperature of application, °C	1450
Price, Rs./kg	150

3.1.2 Chemical Composition of Basalt Rock

Chemical Composition of Basalt rocks	%
SiO2	52.8
Al_2O_3	17.5
Fe^2O_3	10.3
MgO	4.63
CaO	8.59
Na_2O	3.34
K_2O	1.46
TiO_2	1.38
P2O5	0.28
MnO	0.16
Cr_2O_3	0.06

F. GGBS

The physical & mechanical properties of cement and GGBS are given in table 4.

Table-4: Physical & mechanical properties of cement& GGBS

Test	Cement	GGBS
Color	Gray	Off white
Consistency	25%	33%
Soundness	4 mm	--
Initial setting time	110 minutes	--
Final setting time	290 minutes	--
Specific gravity	3.13	2.95
Fineness (sieving on 90μm)	8.5 %	0%
Fineness (Blain's air permeability)	302 m2/kg	320 m^2/kg
Bulk density	1.48 gm/cm3	1.29 gm/cm^3
Compressive strength 3days 7days 28 days	N/mm^2 23.33 34.33 46.18	 -- -- --

Chemical Properties

The test for Chemical Properties of Cement & GGBS has been performed using X-Ray Fluorescence Machine at ACC Plant Sindri. The result of which are given in table 5.

Table-5: Chemical Properties of Cement & GGBS

Chemical Composition	Cement	GGBS
CaO	63.20	35.27
SiO2	21.06	34.72
Al2O3	5.72	19.11
MgO	1.90	8.46
Fe2O3	4.38	0.5
SO3	2.04	0.18
Na2O	0.25	0.16
K2O	0.87	0.58
Cl	0.01	0.01
TiO2	0.40	0.65
P2O5	0.09	0.01
Mn2O3	0.07	0.14 (MnO)
Glass Content	--	95

3.2 Methodology

The mixture proportioning was done according the Indian Standard Recommended Method IS 10262-2009.The target mean strength was 40 MPa for the control mixture, the total cement content was 350 kg/m3, fine aggregate is taken 682.99 kg/m3 and coarse aggregate is taken 1356.5kg/m3, the water to cement ratio was kept as 0.40, the Super plasticizer content was taken as 7kg/m^3 for all mixtures.

The Cement, sand, coarse aggregate, basalt fiber and GGBS were properly mixed together in accordance with IS code before water was added and was properly mixed together to achieve homogenous material. Water absorption capacity and moisture content were taken into consideration and appropriately subtracted from the water/cement ratio used for mixing.150 × 150 × 150mm cubes, 500mm × 100 mm× 100mm Beam and 150 mm diameter and 300 mm height Cylinder moulds were used for casting. The concrete specimens were cured in the tank for 7, and 28 days.

Table No-6: For Cubes

Sl No	Percent age of basalt fiber	Percentage of GGBS	Numbers	
			7days	28days
1	-	-	3	3
2	1.5	0	3	3
3		25	3	3
4		50	3	3
5		75	3	3
6		100	3	3
	Total		**18**	**18**

Table No-7: For Cylinders

Sl No	Percent age of basalt fiber	Percentage of GGBS	Numbers	
			7days	28days
1	-	-	3	3
2	1.5	0	3	3
3		25	3	3
4		50	3	3
5		75	3	3
6		100	3	3
	Total		**18**	**18**

Table No-8: For Prisms

Sl No	Percentage of basalt fiber	Percentage of GGBS	Numbers	
			7days	28days
1	-	-	3	3
2	2.0	0	3	3
3		25	3	3
4		50	3	3
5		75	3	3
6		100	3	3
	Total		**18**	**18**

Fig -1 Moulds After Filling of Concrete

Fig -2 Specimens are kept for Curing in Curing Pond

Fig -3 Testing of prism in flexural Testing Machine

Sl. No	Percentge of basalt chopped fiber (%)	Percentge of GGBS (%)	Compressive strength of concrete in N/mm²	strength over controlled concrete cube (%)
1	-	-	46.75	-
2	1.5	0	47.51	1.62
3	1.5	25	48.57	3.89
4	1.5	50	46.53	-0.47
5	1.5	75	44.31	-5.22
6	1.5	100	40.75	-12.83

4. RESULTS AND DISCUSSION

Test results conducted of m40 mix concrete. all plain concrete mix with different proportion of basalt chopped fiber were cast and tested under suitable testing apparatus. the tests like compressive strength, spite tensile strength and flexural strength were studied. their test results and related discussions are given in tables in detail.

4.1 Compressive Strength Test

Tests results of compressive test and its comparison with controlled concrete cube are as shown in the below table.

Table No- 9: 28 Days Compressive Strength

Sl. no	Shape of concrete (controlled specimen)	Compressive strength of concrete for 28 days curing period in n/mm²
1	CUBE	46.75
2	CYLINDER	2.97
3	PRISM	7.4

Table-10: Compressive Strength Of 28 Days Curing (Cube)

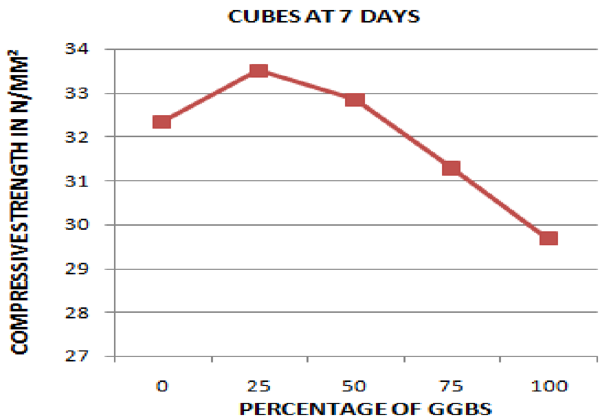

Chart -1: Compressive Strength of 7 Days Curing (Cube)

Table-11: Compress strength of 7 days curing (Cube)

Sl. No	Percentage of basalt chopped fiber (%)	Percentage of GGBS (%C)	Compressive strength of concrete in N/mm²	strength over controlled concrete cube (%)
1	0	-	31.9	-
2	1.5	0	32.35	1.41
3	1.5	25	33.51	5.04
4	1.5	50	32.84	2.94
5	1.5	75	31.28	-1.94
6	1.5	100	29.68	-6.95

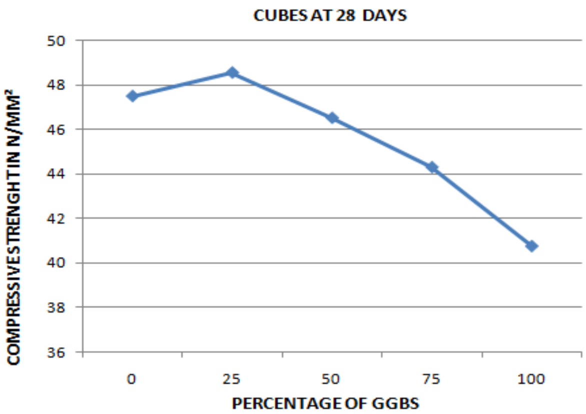

Chart-2: Compress Strength for 28 days (cube)

4.3 Tensile Strength Test:

Tests results of tensile strength test and its comparison with controlled concrete cube are as shown in the below table.

Table-12: Split Tensile Strength of 28 Days Curing (Cylinders)

sl. no	Percentage of basalt chopped fiber (%)	Percentage of GGBS (%)	Split tensile strength of concrete in n/mm²	strength over controlled concrete cube (%)
1	0	-	2.97	-
2	1.5	0	3.02	1.68
3	1.5	25	3.09	4.04
4	1.5	50	2.98	0.33
5	1.5	75	2.84	-4.37
6	1.5	100	2.67	-10.1

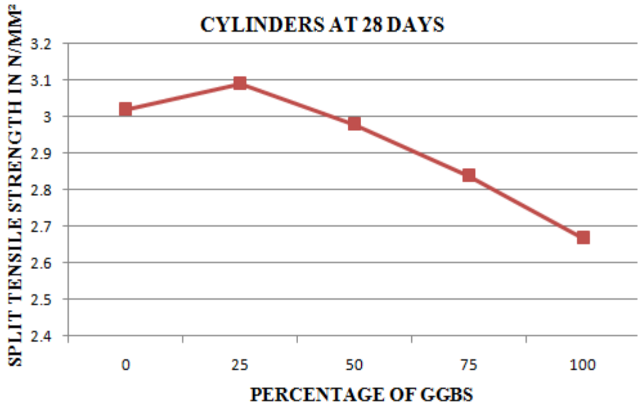

Chart-3: Split tensile strength of concrete

4.4 Flexural Strength:

Tests results of tensile strength test and its comparison with controlled concrete cube are as shown in the below table.

Table-13: Flexure strength of concrete (prism)

sl. no	Percentage of basalt chopped fiber (%)	Percentage of GGBS (%)	Flexure strength of concrete in n/mm²	strength over controlled concrete cube (%)
1	0	-	7.4	-
2	2	0	7.55	2.02
3	2	25	7.85	6.08
4	2	50	7.5	1.35
5	2	75	7.3	-1.35
6	2	100	7.05	-4.73

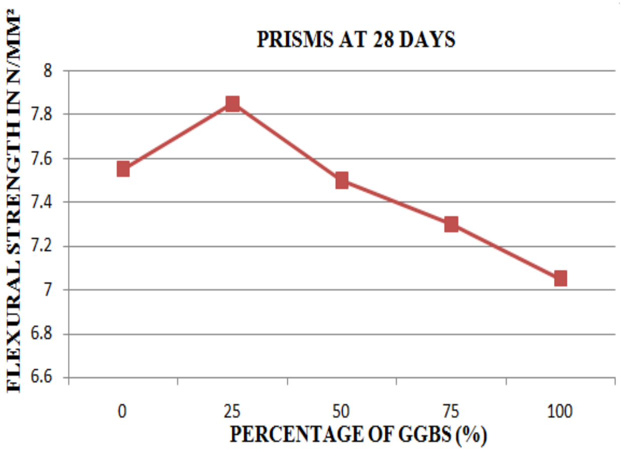

Chart-4: Flexure strength of concrete

5. CONCLUSION

1. The compressive strength at 25 percentages GGBS was 33.51 N/mm2. The increase percentage of strength at 25 percentage GGBS with 1.5% of basalt chopped fiber was 5.04 % over controlled concrete cube strength 31.9 N/mm2, which was an optimum percentage of GGBS content (25 %) for 7 days curing period.
2. The compressive strength at 25 percentages GGBS was 48.57 N/mm2. The increase percentage of strength at 25 percentage GGBS with 1.5% basalt chopped fiber was 3.89% over controlled concrete cube strength 46.75 N/mm2, which was an optimum percentage GGBS content (25 %) for 28 days curing period.
3. The split tensile strength at 25 percentages was 3.09 N/mm2. The increase percentage of strength at 25 percentage GGBS with 1.5% of basalt chopped fibers was 4.04 % over controlled concrete cylinder strength 2.97 N/mm2, which was an optimum percentage of GGBS content (25%) for 28 days curing period.
4. The flexural strength at 25 percentages was 7.85 N/mm2. The increase percentage of strength at 25 percentage GGBS with 1.5% of basalt chopped fibers was 6.08 % over controlled concrete prism strength 7.4 N/mm2, which was an optimum percentage of GGBS content (2.0 %) for 28 days curing period.
5. These strength values were increased in percentage of GGBS up to 25% with basalt chopped fiber at 1.5 % for cubes and cylinders, 2 % for prisms. There was optimum percentage of GGBS in concrete to increase in strength.
6. The achievable strength can be obtained by adding GGBS up to 25%, further increase GGBS in concrete decrease in strength. The desired percentage of GGBS content in concrete would be 0 to 25%.

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