

An Experimental Investigation on Mechanical Properties of BFRC (Basalt Fiber Reinforced Concrete)

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ABSTRACT: Concrete is the most widely used construction material in the world due to its ability to get cast in any form and shape. However, Concrete has some deficiencies i.e. it is very strong in compression but very weak in tension. It has been reported that tensile and bending strength of concrete is 10 to 15% of the compressive strength respectively. The research work was carried out on experimental investigation of properties of basalt reinforced concrete. It was checked by testing cylinder & beams. The specimens were casted using M30 Grade concrete with locally available material. The object of present work was to study effect of different proportion of fibers in the mix design and find out optimum percentage of fibers with maximum strength criteria. The experimental results showed that the addition of basalt fiber in concrete enhance the properties of concrete.

KEYWORDS: Basalt Fibers, Split Tensile Strength, Flexural Strength, Fiber reinforced concrete, M 30 Grade of concrete.

I. INTRODUCTION

Concrete is the most extensively used construction material in the world. It is used as the second source for human needs than water source in the world. It provides good workability and it can be moulded to any shape. Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. The resulting material is a stone like structure which is formed by the chemical reaction of the cement and water. This stone like material is a brittle material which is strong in compression but very weak in tension. This weakness in the concrete makes it to crack under small loads, at the tensile end. These cracks gradually propagate to the compression end of the member and finally, the member breaks.

The formation of cracks is the main reason for the failure of the concrete. The formation of cracks in the concrete may also occur due to the drying shrinkage. These cracks are basically micro cracks. These cracks increase in size and magnitude as the time elapses and the finally makes the concrete to fail. To increase the tensile strength of concrete many investigations have been made. One of the successful and most commonly used methods is providing steel reinforcement. Cracks in reinforced concrete members extend freely up to the bars, which need for multidirectional and closely spaced, steel reinforcement will arise. Hence practically it cannot be possible. To overcome this, Fiber reinforcement is used. It gives the better solution for this problem so as to increase the tensile strength of concrete, under a technique of introduction of fibers in concrete is being used. Fibers are a small piece of reinforcing material possessing certain characteristics properties. These fibers act as crack arrestors and prevent the propagation of the cracks. These fibers are uniformly distributed and randomly arranged. Hence this concrete is named as "Fiber Reinforced Concrete".

Basalt is an igneous rock, which means it began in a molten state. For many years, basalt has been used in casting processes to make tiles and slabs for architectural applications. Additionally, cast basalt liners for steel tubing exhibit very high abrasion resistance in industrial applications. In crushed form, basalt also finds use as an aggregate in

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concrete. More recently, continuous fibers extruded from naturally fire-resistant basalt have been investigated as are placement for asbestos fibers, in almost all its applications. In the last decade, basalt has emerged as a contender in the fiber reinforcement of composites.

A new advancement in the fiber reinforced concrete is the use of "Basalt Fiber", which has shown better results in improving the compressive & flexural strength of concrete composites. Basalt Fiber is a relatively new material aramid for strengthening. It has a similar chemical composition as glass Fiber but has better strength characteristics, and is highly resistant to alkaline, acidic and salt attack making it good for concrete, bridge and shoreline structures. It is easy to disperse when mixed with cement concrete and mortar. Therefore, basalt Fiber reinforced concrete serves the functions of reinforcement, crack resistance and can extend the life of construction in the fields of housing, Highways, railways, urban elevated roads, runways, ports, subway tunnels etc. Basalt Fiber is produced in a continuous process by melting crushed basalt rock at 1500°C temperature and is stretched into the Fibers. The Fiber has high strength of extension and has excellent ductility and its corrosion resistance is far better than other types of Fibers

II. MATERIALS USED

This programme deals with the properties of the materials used, the methodology adopted for mix proportioning of various Basalt Fiber Reinforced concrete mixes and the parametric evaluation of the Basalt Fiber Reinforced concrete mixes.

A. MATERIALS USED

In this study, Numerous materials are used in the preparation of concrete mixes includes cement, fine aggregates, coarse aggregates, Water, Basalt chopped fibers and admixtures. Each material was tested & its physical properties are described below.

1. CEMENT:

Ordinary Portland Cement of 43 grade was used in this work. It was tested as per IS 8112-1989 recommendation. The properties of the cement are given in Table 1.

2. FINE AGGREGATE:

Natural sand confirming to IS 383-1970 of Zone III was used. Specific Gravity, Fineness Modulus and Water absorption of fine aggregate were calculated according to the procedures confirming to IS 383-1970. The Properties of Fine aggregates used in this study are given in Table 2.

3. COARSE AGGREGATE:

A combined grading of Locally Available Crushed angular coarse aggregates was incorporated confirming to IS 383-1970 were used. 60% of the coarse aggregates passing through 20mm and retained on 12.5mm IS sieve and 40% of the coarse aggregates passing through 12.75mm and retained on 4.75mm were used in this study. The Properties of Coarse Aggregates are given in Table 3.

4. WATER

The water to be used for mixing and curing of concrete should be free from deleterious materials as per recommendation of IS 456-2000. Therefore, potable water was used in the present study in all operations demanding control over water quality. Secondly, it serves as a vehicle or lubricant in the mixture of fine aggregates and cement.

5. ADMIXTURES

Locally available Sulphonated naphthalene polymer based superplasticizer – FOSROC CONPLAST SP430 were used in this study. The addition of fibers reduces the workability. Therefore, in order to make it use for practical purposes admixtures in appropriate quantity was added to the mix.

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6. BASALT FIBRE



Basalt chopped fiber golden brown color was used in the concrete mixes. Fibers of length of 25 mm and hairline width obtaining aspect ratio of 80. Density of Basalt fiber was found to be 2.75 kg/m³. The specifications of these fibers are presented in Table 4 and 5.

Figure 1: Basalt Fibres used

Physical properties	Experimental values	Recommended values
Normal consistency (% by weight of cement)	33	30-35
Specific Gravity	3.1	3.15
Setting time (minutes) (i) initial (ii) final	40 460	30(min) 600(max)
Compressive strength (i) 7-days (ii) 28-days	36.3 42.5	33 43

Table 1: Physical properties of ordinary Portland cement

Physical Properties	Observed values		Recommended value
	12.5mm aggregate	20mm aggregate	
Fineness Modulus	7.96	6.96	6.5-8.0
Aggregate crushing value	19.25	24.48	Not more than
Specific Gravity	2.6	2.6	
Aggregate impact value	27.36	23.10	Not more than
Water absorption	0.49	0.45	< 0.5%

Table 3: Physical Properties of Coarse aggregate

Physical Properties	Observed values	Recommended values
Grading Zone	III	-
Fineness modulus	3.0	2.9-3.2
Specific Gravity	2.52	2.6-2.67
Water absorption	0.81	< 0.5%

Table 2: Physical Properties of Fine aggregate

Physical Properties	Recommended values by the supplier
Density (g/cc)	2.75
Tensile Strength (Mpa)	1045
Yield Strength (Mpa)	685
Tensile Elastic Modulus	79
Length (mm)	24

Table 4: Physical Properties of Basalt Fibre

Sl.No.	Chemical Name	Composition Percent (%)
1	SiO ₂	51.6% - 59.3%
2	Al ₂ O ₃	14.6% - 18.3%
3	CaO	5.9% - 9.4%
4	MgO	3.0% - 5.3%
5	Na ₂ O + K ₂ O	3.6% - 5.2%
6	TiO ₂	0.8% - 2.25%
7	Fe ₂ O ₃ +FeO	9.0% - 14.0%
8	Others	0.09% - 0.13%

Table 5: Chemical composition of Basalt Fiber

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III. EXPERIMENTAL PROGRAMME AND METHODOLOGY

A. CONCRETE MIX PROPORTIONS

The mixture proportioning was done according to the IS 10262-2009. The target mean strength was 38.25MPa for the control mixture, the total cement content was 438 kg/m³, fine aggregate is taken 600.56 kg/m³ and coarse aggregate is taken 1126.98kg/m³ i.e. 1:1.37:2.57 respectively. The water to cement ratio was kept as 0.45, the Super plasticizer content was taken as 0.5% of water for all mixtures.

B. CASTING OF SPECIMENS:

In order to prepare the basalt fiber reinforced concrete specimens, Basalt fibers were added in several percentages i.e. 0%, 0.5%, 0.1%, 1.5%, 2.0% and 2.5% of volume of Specimen in separate concrete mixes. For each mix, beam of 500 X 100 X100 mm and cylinders of 150 mm diameter by 300 mm height were prepared. All specimens were fabricated and then cured in water for 7 and 28 days in accordance with Indian Standard 10262.

The details of specimens casted in laboratory for compressive and split tensile tests are as shown Table 6.

Mix	Basalt Fiber (%)	Split Tensile Strength (No of Cylinders)		Flexural Strength (No of Beams)	
		7 days	28 days	7days	28 days
M1	0	3	3	3	3
M2	0.5	3	3	3	3
M3	1	3	3	3	3
M4	1.5	3	3	3	3
M5	2.0	3	3	3	3
M6	2.5	3	3	3	3

Table 6: Casting of number of Concrete specimens

C. MIXING OF CONCRETE, CASTING AND CURING OF TEST SPECIMENS

Mixing was done using machine mixer. Initially the dry mix constituents of the mix namely cement, fine aggregate and coarse aggregate was mixed for two minutes and then the water with chemical admixtures were added and mixing continued for another 2 minutes. The total mixing time was kept at 4 minutes for all the trials until a homogeneous mixture was obtained. Compaction was achieved initially by hand using the standard tamping rod ensuring the filling of the moulds in layers with appropriate blows and then finally compacting by vibrator. All specimens were de moulded after 24 hours and stored in water until the age of testing.

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D. TEST METHODS

1. Fresh concrete properties -slump test:

The slump factor is used to measure the horizontal free flow known as workability of concrete. The test has been carried out for M30 grade concrete. Hence it is preferred to make use of workability with 0.45 water cement ratio.

2. Hardened Concrete Properties

i. Split Tensile Strength:

Split tensile test was carried out on cylindrical specimens of 150mm diameter and 300mm height at the age of 7 and 28 days. The specimens were tested using compression testing machine of 3000 KN capacity. The Split tensile strength = $2P / (\pi \times D \times L)$, Where P = load, D= Diameter, L= Length.

ii. Flexural Strength:

The purpose of Flexural Strength test is to determine the bend strength of hardened concrete. Flexural Strength test was carried out on beam of size 100 x 100 x 500 mm. The strength was recorded at 7 and 28 days. The average reading of 3 specimens was recorded as the strength at respective age of concrete. The ultimate strength is recorded after the specimens fail to resist more loads.

The Flexural strength can be calculated by using formula: Flexural strength = $PL/bd^2 \times 1000$



Figure 2: Split Tensile Test on Cylinders

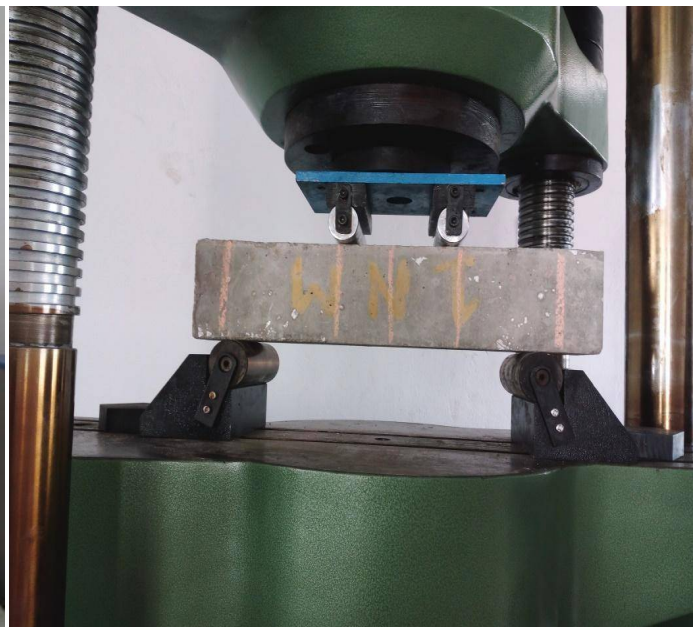


Figure 3: Flexural Strength on Beams

IV. EXPERIMENTAL RESULTS

Result indicates that as the percentage of basalt fibers increases in the mix there is corresponding increase in the strength.

A. SPLIT TENSILE STRENGTH

The split tensile strength values of ordinary concrete and basalt fiber concrete mixes are observed at 7 and 28 days of testing. The test results are presented in the table 7 below.

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Sl.no	Mix No.	% of Basalt Fibers	7 days		28days	
			Mean Split Tensile Strength	Percentage increase of Split Tensile strength w.r.t reference mix (%)	Mean Split Tensile Strength	Percentage increase of Split Tensile strength w.r.t reference mix (%)
1	M1	0	1.35	0	2.26	0
2	M2	0.5	1.65	22.22	2.76	22.12
3	M3	1.0	1.86	37.77	3.11	37.61
4	M4	1.5	2.03	50.37	3.39	50
5	M5	2.0	2.25	66.66	3.75	65.93
6	M6	2.5	1.99	47.4	3.32	46.90

Table 7: Tensile Strength for 7 and 28 days

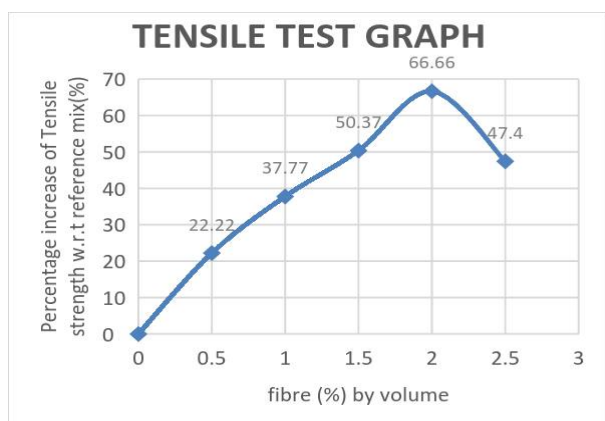


Figure 3: Percentage Variation of Tensile strength for 7 days

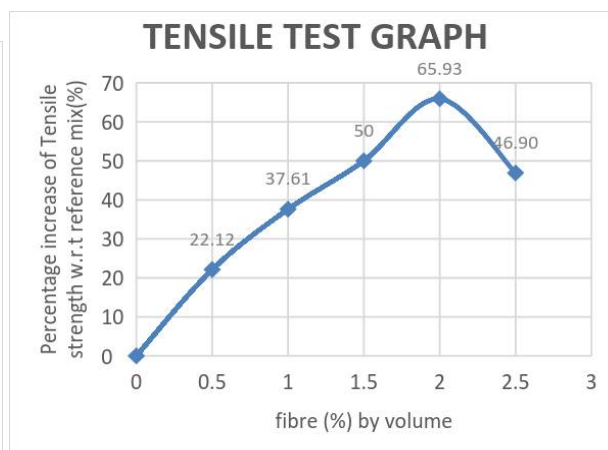


Figure 4: Percentage Variation of Tensile strength for 28days

B. FLEXURAL STRENGTH TEST

The Flexural strength values of ordinary concrete and basalt fiber concrete mixes are observed at 7 and 28 days of testing. The test results are presented in the table 8 below.

Sl.no	Mix No.	% of Basalt Fibers	7 days		28days	
			Mean Flexural Strength	Percentage increase of flexural strength w.r.t reference mix (%)	Mean Flexural Strength	Percentage increase of flexural strength w.r.t reference mix (%)
1	M1	0	2.85	0	3.8	0
2	M2	0.5	3.45	21.05	4.6	21.05
3	M3	1.0	4.27	49.82	5.7	50
4	M4	1.5	4.8	68.42	6.4	68.42
5	M5	2.0	5.1	78.94	6.8	78.94
6	M6	2.5	4.85	70.17	6.5	71.05

Table 8: Flexural Strength Results for 7 and 28 days

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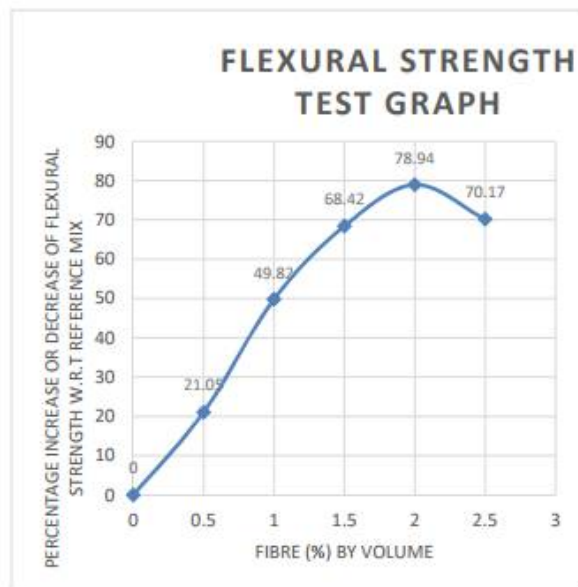


Figure 5: Percentage Variation of Flexural strength for 7 days

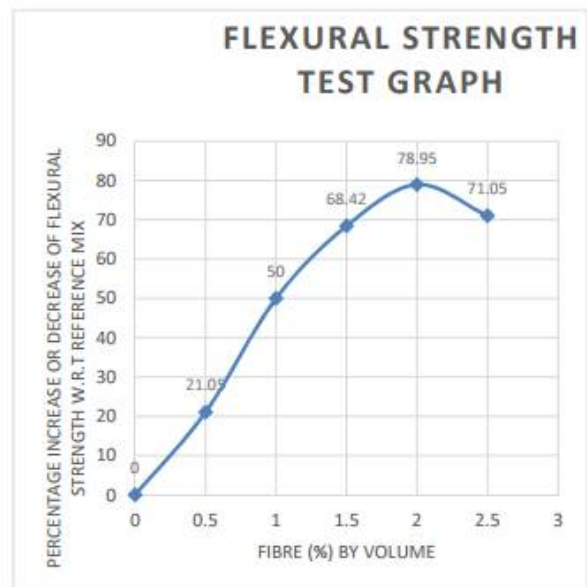


Figure 6: Percentage Variation of Flexural strength for 28 days

V. CONCLUSION

Based upon the results of experimental study with different percentage of basalt Fiber in the concrete mix (M-30) carried out the following conclusions can be drawn:

- It has been observed that the workability of concrete decreases with the addition of Basalt Fibers. But this difficulty can be overcome by using plasticizers or super-plasticizers.
- It was observed that, the percentage increase in the strength of basalt reinforced concrete increases with the age of concrete.
- The tensile strength of concrete produced by adding of basalt fibers shows an increasing trend up to 2% additional level. The percentage increase of tensile strength is found to be more as compared to the reference mix.
- The flexural strength of concrete produced by adding of basalt fibers shows an increasing trend up to 2% additional level. The percentage increase of flexural strength is found to be more as compared to the reference mix.
- In general, it is recommended that 2% of basalt fiber chopped strands can be added to the concrete for effective strength.
- It was found from the failure pattern of the specimens, that the formation of cracks is more in the case of concrete without fibers than the basalt fiber reinforced concrete.
- It shows that the presence of fibers in the concrete acts as the crack arrestors.

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