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Strength Aspects of Basalt Fiber Reinforced Concrete

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Abstract* — The objective of this paper is to investigate and compare the compressive, flexural and splitting tensile strength of basalt fiber reinforced concrete with plain M30 grade concrete. Fiber reinforced concrete is a most widely used solution for improving tensile and flexural strength of concrete. Various types of fibers such as steel, polypropylene, glass and polyester are generally used in concrete. In this research, the effect of inclusion of basalt fibers on the compressive, flexural and splitting tensile strength of fiber reinforced concrete was studied. Based on the laboratory experiment on basalt fiber reinforced concrete, cube, beam and cylindrical specimens have been designed with basalt fiber reinforced concrete containing 1kg/m^3, 2kg/m^3 and 4kg/m^3 basalt fibers .The experimental test results demonstrated a considerable increases in compression ,flexural and splitting of specimen at 3, 7 and 28 days with addition of basalt fibers .

***Keywords*— Basalt fiber, Compressive strength, Flexural strength, Split tensile strength, Fiber reinforced concrete**

I. INTRODUCTION

In this modern age, civil engineering constructions have their own structural and durability requirements, every structure has its own intended purpose and hence to meet this purpose, modification in traditional cement concrete has become mandatory. 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 [6]. Fiber-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers – each of which lend varying properties to the concrete. In addition, the character of fiber-reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities.

The weak matrix in concrete, when reinforced with fibers, uniformly distributed across its entire mass, gets strengthened enormously, thereby rendering the matrix to behave as a composite material with properties significantly different from conventional concrete. Because of 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. High percentages of steel fibers are used extensively in pavements and in tunneling. Use of basalt fibers are picking up in western countries [7].

Fibers are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion, and shatter–resistance in concrete.

1.1 Basalt Fiber

Basalt rock is a volcanic rock and can be divided into small particles then formed into continues or chopped fibers. Basalt fiber has a higher working temperature and has a good resistance to chemical attack, impact load, and fire with less poisonous fumes. Some of the potential applications of these basalt composites are: plastic polymer reinforcement, soil strengthening, bridges and highways, industrial floors, heat and sound insulation for residential and industrial buildings, bullet proof vests and retrofitting and rehabilitation of structures.

Basalt is fine-grained, extrusive, igneous rock composed of plagioclase, feldspar, pyroxene and magnetite, with or without olivine and containing not more than 53 wt% SiO2 and less than 5 wt% total alkalis. Many types of basalt contain phenocrysts of olivine, clinopyroxene (augite) and plagioclase feldspar. Basalt is divided into two main types, alkali basalt and tholeiites. They have a similar concentration of SiO_2, but alkali basalts have higher content of NA_2O and K_2O than tholeiites. 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.

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II. EXPERIMENTAL PROGRAM

2.1 Materials Used

In this the various materials used for the study, their properties, test conducted and results are discussed. This section also explains the mix proportions used for the study.

2.1.1 Cement

The cement used was Portland Slag cement. The following table I is the various tests conducted as per Indian Standard to determine the properties of this cement.

TABLE I
PHYSICAL PROPERTIES OF CEMENT

S NO.	PROPERTIES	VALUE
1	Specific gravity	2.91
2	Standard consistency	34%
3	Initial Setting time in minutes	147
4	Final Setting time in minutes	325

2.1.2 Fine Aggregate (Sand)

Manufactured sand was used as fine aggregate for the experiments. Various tests were conducted to determine the properties of sand which are shown in table II. Grading is the particle-size distribution of an aggregate as determined by a sieve analysis. The test was done according to IS: 2386 (Part 1) – 1963.

TABLE II
PROPERTIES OF FINE AGGREGATE

S.NO	PROPERTIES	VALUE
1	Specific gravity	2.54
2	Fineness modulus	2.963
3	Water absorption	11%
4	Zone	II

2.1.3 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 following table III shows the tests conducted in order to determine the properties of this aggregate.

TABLE III
PROPERTIES OF COARSE AGGREGATE

S NO.	PROPERTIES	VALUE
1	Specific gravity (20mm)	2.778
2	Specific gravity (12.5mm)	2.75
3	Fineness modulus(20mm)	2.596
4	Fineness modulus(12.5mm)	2.273
5	Water absorption(20mm)	0.5%
6	Water absorption(12.5mm)	0.9%

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2.1.4 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 Master Glenium SKY 8233.

2.1.5 Basalt Fiber

The fibers used were chopped basalt fibers which are uniformly and randomly distributed in the concrete matrix. Three different fiber content were chosen 1kg/m^3, 2kg/m^3, 4kg/m^3 for each mix. Chopped basalt fibers are shown in figure 1.

Fig: 1 Basalt fiber

2.2 Concrete mix proportions

The mixture proportioning was done according the Indian Standard Recommended Method IS 10262-2009.The target mean strength was 30 MPa for the control mixture, the total cement content was 420 kg/m^3, fine aggregate is taken 828 kg/m^3 and coarse aggregate is taken 1123kg/m^3, the water to cement ratio was kept as 0.45, the Super plasticizer content was taken as 0.3% for all mixtures. The total mixing time was 5 minutes, the samples were then casted and left for 24 hrs before demoulding .They were then placed in the curing tank until the day of testing Cement, sand, Basalt fiber and fine and coarse aggregate 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^3 cubes, 500mm × 100 × 100mm^3 Beam and 150 mm diameter and 300 mm height Cylinder moulds were used for casting. The concrete specimens were cured in the tank for 3, 7, 28 days.

III. EXPERIMENTAL TEST RESULTS AND DISCUSSIONS

3.1 Workability

Slump test was carried out on each mix to ascertain workability of BFRC as well as control mixtures. The results of slump tests for M-30 grade concrete with and without Basalt Fibers are shown in table IV.

TABLE IV
SLUMP TEST

FIBER CONTENT (KG/M^3)	SLUMP (MM)
0	120
1	108
2	103
4	97

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From the experimental results it was observed that there is gradual decrease in the slump values with an increase in basalt fiber dose, which indicates that addition of BF content is associated with an increase in water demand. Thus some water reducing admixtures may be used to get required workability of concrete.

3.2 Compressive Strength Test

The compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine. Compressive strength were measured at 3, 7, 28 day of testing. The test results are shown in the following table V.

TABLE V
COMPRESSIVE STRENGTH OF BASALT FIBER SPECIMENS

BASALT FIBER (kg/m^3)	Compressive Strength (N/mm^2)		
	3 days	7days	28 days
0	19.3	25.1	35.4
1	20.37	25.67	36.5
2	21.6	27.75	38.4
4	22.2	28.89	40.2

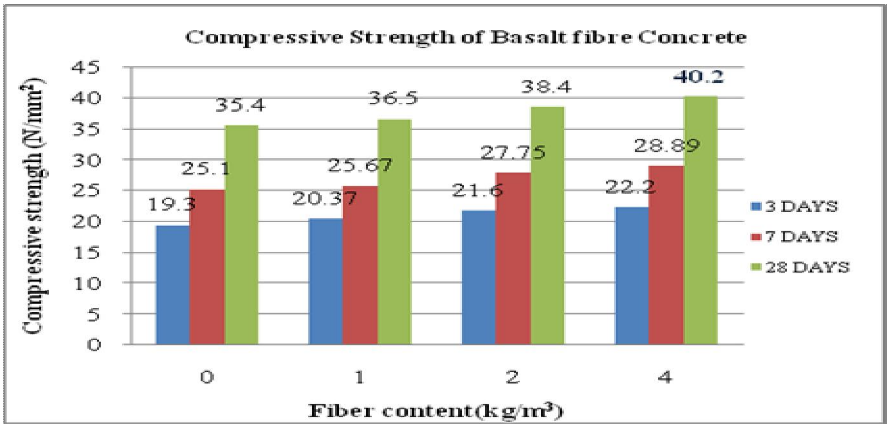

Fig: 2 Compressive strength of basalt fiber specimens

The figure 2 indicates the comparison of result of compressive strength using cube specimen of M30 grade concrete. It is observed that for addition of $4kg/m^3$ fiber gives more compressive strength than other volume fraction. Figure 3 shows the test setup for compressive strength.

Fig: 3 Test for Compressive Strength

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3.3 Splitting Tensile Strength Test

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

TABLE VI
SPLIT TENSILE STRENGTH OF BASALT FIBER SPECIMENS

BASALT FIBER (kg/m^3)	Split tensile strength (N/mm^2)	
	7days	28 days
0	1.65	2.25
1	2.3	3.02
2	2.64	3.33
4	2.87	3.64

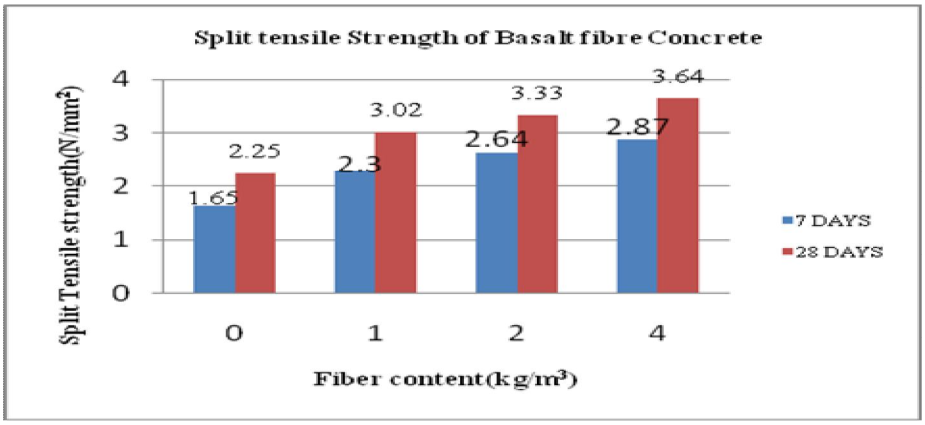

Fig: 4 Split Tensile strength of basalt fiber specimens

The figure 4 indicates the result of split tensile strength for M30 grade basalt fiber reinforced concrete. It is observed that for the addition of 4kg/m^3 gives maximum tensile strength at 28 days. Figure 5 shows the test setup for splitting tensile strength.

Fig: 5 Test for Splitting Tensile Strength

3.4 Flexural Strength Test

The flexural Strength were tested at 7 and 28 day of testing for control mix and basalt fiber concrete mixes. The test results are presented in the table 7 below.

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TABLE VII
FLEXURAL STRENGTH OF BASALT FIBER SPECIMENS

BASALT FIBER (kg/m^3)	Flexural strength (N/mm^2)	
	7days	28 days
0	3.3	5.2
1	4.2	5.8
2	4.8	6.6
4	6.2	8

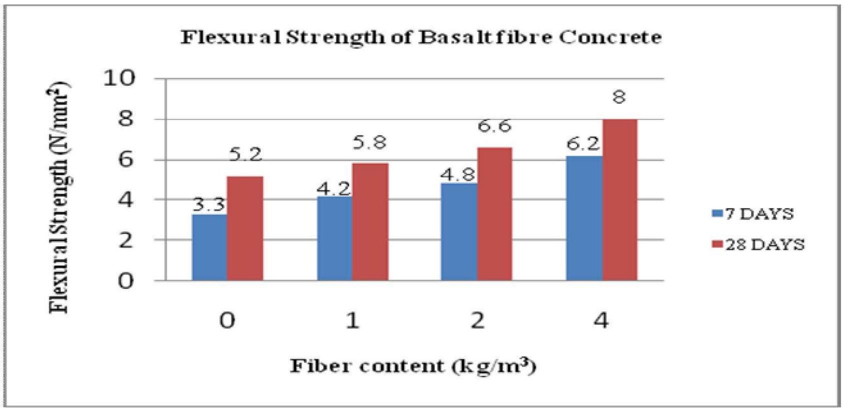

Fig: 6 Flexural strength of basalt fiber specimens

The figure 6 indicates the results of flexural strength of M30 grade concrete. It is observed that for the addition of 4kg/m^3 gives maximum flexural strength at 28 days.

IV. CONCLUSION

Based on the research studies the following conclusions can be made:

- 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.
- The percentage increase of compressive strength of basalt fiber concrete mix compared with 28 days compressive strength of Plain Concrete is observed as 14% .
- The percentage increase of split tensile strength of basalt fiber concrete mix compared with 28 days compressive strength of Plain Concrete is observed as 62% .
- The flexural strength of basalt fiber concrete is also found have a maximum increase of 54% at 4kg/m^3 of fiber content.
- It was observed that, the percentage increase in the strength of basalt reinforced concrete increases with the age of concrete.
- Also 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.

The ductility characteristics have improved with the addition of basalt fibers. The failure of fiber concrete is gradual as compared to that of brittle failure of plain concrete.

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