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Evaluation of Mechanical characteristics and Structural Behavior of Basalt Fiber Reinforced Concrete

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Abstract--- Worldwide, a great deal of research is currently being conducted concerning the use of fiber Reinforced Concrete. Laminates and Sheets in the strengthening and repairing of reinforced concrete members. There have also been several advances made in the development of fiber reinforced concrete to control cracking and crack propagation in plain concrete, and to increase the overall ductility of the material. However, there are now many types of fibers with different materials and geometric properties, but the exact fracture behaviour of fiber reinforced concrete materials is not clearly understood. Majorly, Synthetic fiber has played a dominant role for a long time in a variety of applications for their high specific strength and modulus. In this project the overall aim is to utilize and evaluate the performance of natural based Basalt fiber in the concrete which it has as an properties which it is similar to synthetic fibers.The optimum percentage of Basalt fiber in concrete was found with respect to cube compressive strength, split tensile strength and flexural strength at the age of 28 days. The specimen was casted for different percentages such as 0.05%, 0.10%, 0.15%, 0.20%, 0.25%, 0.30%, 0.35%, 0.40%, 0.45% and 0.50% by the volume of concrete. By keeping the optimum level of dosage of fiber the structural behaviour of reinforced concrete column was evaluated.

Keywords – Concrete, Basalt fibers Fiber reinforced Concrete, Fracture

I. INTRODUCTION

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 fiber 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. Concept of using fibers as reinforcement is not new. Fibers have been used as reinforcement since ancient times. Historically, horsehair was used in mortar and straw in mud bricks. In the early 1900s, asbestos fibers were used in concrete. In the 1950s, the concept of composite materials came into being and fiber reinforced concrete was one of topics of interest. Once the health risks associated with asbestos were discovered, there was a need to find a replacement for the substance in concrete and other building materials. By the 1960s, steel, glass (GFRC), and synthetic fibers such as polypropylene fibers were used in concrete. Research into new fiber-reinforced concretes continues today.

1.1 Effect of fibers in concrete

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. Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment–resisting or steel reinforcement. Indeed, some fibers actually reduce the strength of concrete. The amount of fibers added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibers), termed "volume fraction" (V_f). V_f typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the fiber's modulus is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increasing the aspect ratio of the fiber usually segments the flexural strength and toughness of the matrix.

1.2 Basalt fiber.

Basalt is a common extrusive volcanic rock formed by decompression melting of the earth's mantle. It contains large crystals in a fine matrix of quartz. Basalt rock fibers have no toxic reaction with the air or water, are non combustible and explosion proof. Extruded basalt stone is formed into a metal like wool composed of pyroxene, plagioclase and olivine minerals. Basalt is well known as rock found in virtually every country around the world. Raw material for producing basalt fiber is the rock of a volcanic origin. These fibers are created by melting the basalt stones down at temperature of 1400ºC. The first attempts to produce basalt fiber were made in the United States in 1923.these further developed after

World War II by researchers in the USA, Europe and the Soviet Union especially for military and aerospace application. Since declassification in 1995 basalt fiber have been used in a wider range of civilian application. The Basalt fiber (BF), known as “the green industrial material of the XXI-century”, combines ecological safety, natural longevity and many other properties. It is not a new material, but its applications are surely innovative in many industrial and economic fields, from building and construction to energy efficiency, from automotive to aeronautic, thanks to its good mechanical and chemical performances. Hence basalt fiber has gained increasing attention as a reinforcing material especially compared to traditional glass and carbon fibers.

II. LITERATURE REVIEW

Extensive literature study has been carried out from national and international journals. These literatures are classified as journals, documents collected from web etc.

Ramakrishnan et al (1998) did his research to evaluate the performance of basalt fiber reinforced concrete. There was a noticeable increase in the post crack energy absorption capacity and ductility due to the addition of basalt fibers and also impact resistance increased as the fiber content increased. Report shows that the basalt fiber can be easily mixed in the concrete without any balling, bridging or segregation. In their report they concluded that the satisfactory workability can be maintained, with the addition of basalt fibers, up to 0.5% by volume. Compared to the control (plain) concrete, there was considerable increase in the toughness and impact strengths.

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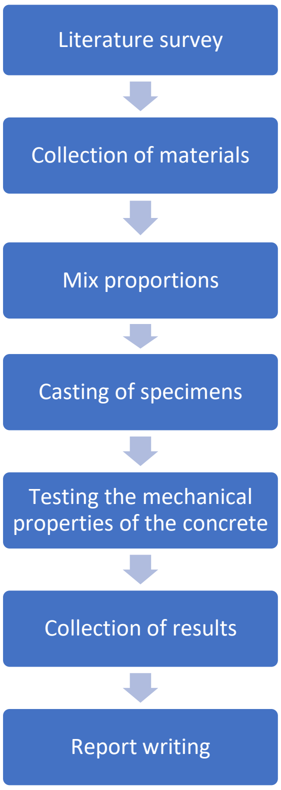
Maleque M. A. et.al (2007) said Natural fibers are available in abundance in nature and can be used to reinforce polymers to obtain light and strong materials. The objective of this paper was to study the tensile, flexural, and impact properties of pseudo stem banana fiber reinforced epoxy composites. By the experimental result tensile strength on the pseudo-stem banana woven fabric reinforced epoxy composite is increased by 90% compared to virgin epoxy and also the flexural strength also increased. Pseudo-stem banana fiber improved the impact strength properties of the virgin epoxy material by approximately 40%.

SalvotareCarmisciano, et al.(2011), have found out the comparative study of basalt and E-glass woven fabric reinforced composites was performed. The fabrics were characterized by the same weave pattern and the laminates tested by the same fiber volume fraction. Results of the flexural and interlinear characterization are reported. Basalt fiber composites showed higher flexural modulus and apparent interlinear shear strength (ILSS) in comparison with E-glass ones but also a lower flexural strength and similar electrical properties. With this fiber volume fraction, scanning electron microscopy (SEM) analysis of the fractured surfaces enabled a better understanding both of the failure modes involved and of points of concern. Nevertheless, the results of this study seem promising in view of a full exploitation of basalt fibers as reinforcement in polymer matrix composites (PMCs)

III. DESIGN METHODOLOGY



3.1 Properties of Cement

Table 3.1 Physical Properties of Cement

Name of the tests	Tested value
Standard consistency test	33 %
Initial setting time	34 min
Final setting time	276 min
Strength test	54.08 N/mm²
Fineness test	6 %
Specific gravity	3.1

3.2 Fine Aggregates

Table 3.2 Sieve Analysis of Fine Aggregate

IS sieve designation	Mass retained	Percentage retained	Percentage passing	Cumulative percentage retained	Remarks
4.75 mm	4	0.2	99.8	0.2	As per IS383-1970 conformed to zone III
1.18 mm	249	9.8	89.6	10.4	
600 µm	555	24.9	64.7	35.3	
300 µm	81	55.5	9.2	90.8	
150 µm	5	8.1	1.1	98.9	
75 µm	5	0.5	0.6	99.4	

Table 3.3 Specific Gravity of Fine Aggregate

S.No	Description	Weight of sample
1	Weight of empty pycnometer (w1)	625gm
2	Weight of pycnometer + Fine Aggerate (w2)	825gm
3	Weight of pycnomete r+ Fine Aggerate + Water(W3)	1620gm
4	Weight of pycnometer + Water(w4)	1492gm

$$\text{Specific Gravity of Fine Aggregate} = \frac{\text{Dry weight of fine aggregate}}{\text{Weight of equal volume of water}}$$

$$= \frac{W2-W1}{(W4-W1)-(W3-W2)}$$

$$= \frac{200}{72}$$

The value obtained for specific gravity of fine aggregate is 2.7.

3.3 Coarse Aggregate

Table 3.4 Sieve Analysis of Coarse Aggregate

IS sieve designation	Mass retained	Percentage retained	Percentage passing	Cumulative percentage retained	Remarks
80 mm	0	0	100	0	As per IS 383-1970 it is conformed to 20 mm size
40 mm	0	0	100	0	
20 mm	466	46.6	53.4	46.6	
10 mm	534	53.4	0	100	
4.75 mm	0	0	0	100	

Table 3.5 Specific Gravity ofCoarse Aggregate

S.No	Description	Weight of sample
1	Weight of empty pycnometer (W1)	625 gm
2	Weight of pycnometer + Coarse Aggregate (W2)	825 gm
3	Weight of pycnometer + Coarse Aggregate + Water(W3)	1620 gm
4	Weight of pycnometer + Water (W4)	1492 gm

$$\text{Specific Gravity of Coarse Aggregate} = \frac{\text{Dry weight of coarse aggregate}}{\text{Weight of equal volume of water}}$$

$$= \frac{W2-W1}{(W4-W1)-(W3-W2)}$$

$$= \frac{200}{72}$$

The value obtained for specific gravity of Coarse aggregate is 2.7

3.4 Water

According to IS 3025, water to be used for mixing and curing should be free from injurious or deleterious materials. Potable water is generally considered satisfactory. In the present investigation, available water within the campus is used for both mixing and curing.

3.5 Basalt Fiber

Basalt fiber which is purchased from Russia is used for this study. The specification given by the company is listed below

Diameter = 16 micron
Cut length =130 mm
Aspect ratio =812

3.6 Concrete Mix proportions

The mixes were designated in accordance with IS 10262-2009 mix design method. Based on the results, the mix proportions M_{30} was designed. Concrete mix with w/c ratio of 0.42 was prepared.The details of mix proportions for $1m^3$of concrete are given in Table 3.6

Table 3.6 Material required for $1m^3$ of Concrete(Kg/m^3)

Grade	Cement	FA	CA	Water
M_{30}	352	718	1276.5	147.75

Table 3.7 Different Volume Fractions of Fibers adopted in Concrete mix

Specimen identification	Basalt fiber(%)
BFO	0%
BF1	0.05%
BF2	0.10%
BF3	0.15%
BF4	0.20%
BF5	0.25%
BF6	0.30%
BF7	0.35%
BF8	0.40%
BF9	0.45%
BF10	0.50%

3.7 Colum design

Grade of Concrete	M30
Grade of steel	Fe 415
Length of column	0.9m
Effective span Length	0.8m
Breath of column	200mm
Depth of column	125mm
Loading Method	Axially Loaded column
End Condition	Fixed end condition

Provide maximum spacing of shear resistance, IS 456:2000, Clause 26.5.1.5
1. Shall not exceed 0.75d for vertical stirrups (135mm)
2. Spacing should not exceed 300mm
Hence 6mm φ 2 legged vertical stirrups at a 125mm c/c are provided.

3.8 Mould Preparations
The column specimen were made by the play wood sheets by column size of 900mmx200mmx125mm is shown in Figure.3.2

Figure. 3.1 Column Mould

3.9 Experimental set up for column specimen
The experimental sets up for testing of column specimens are shown in fig. The column was hinged supported. Tested in 100 T of loading frame in Structural Engineering Laboratory. The load was gradually applied to the specimen by using

hand operated hydraulic jack. The load is applied at an increment of 50KN up to the failure of specimen. The column was loaded as shown in fig. The dial gauge was used to measure the deflection at mid-span.
At each increment of loads, deflection and crack pattern were recorded. The failure mode of the specimen also observed.

Figure 3.2 Testing of column specimen

IV. RESULTS AND DISCUSSIONS

All cubes of plain concrete and basalt fiber reinforced concrete were tested in a compression testing machine with the references of IS516-1959 to determine compressive strength of concrete at the age of 28 days

Table 4.1 Compressive strength of control and Basalt fiber reinforced concrete

Identification	Compressive Strength (MPa)
BF0	30.162
BF1	20.265
BF2	31.190
BF3	31.913
BF4	32.651
BF5	32.743
BF6	32.170
BF7	31.921
BF8	31.300
BF9	30.363
BF10	29.746

4.2 Split tensile strength.

Table 4.2 Flexural Strength of control and Basalt fiber reinforced concrete

Identification	Flexural Strength (MPa)
BF0	7.145
BF1	7.305
BF2	7.588
BF3	8.348
BF4	9.496
BF5	9.869
BF6	9.236
BF7	9.031
BF8	8.571
BF9	8.210
BF10	8.161

4.3 Test Results on Columns

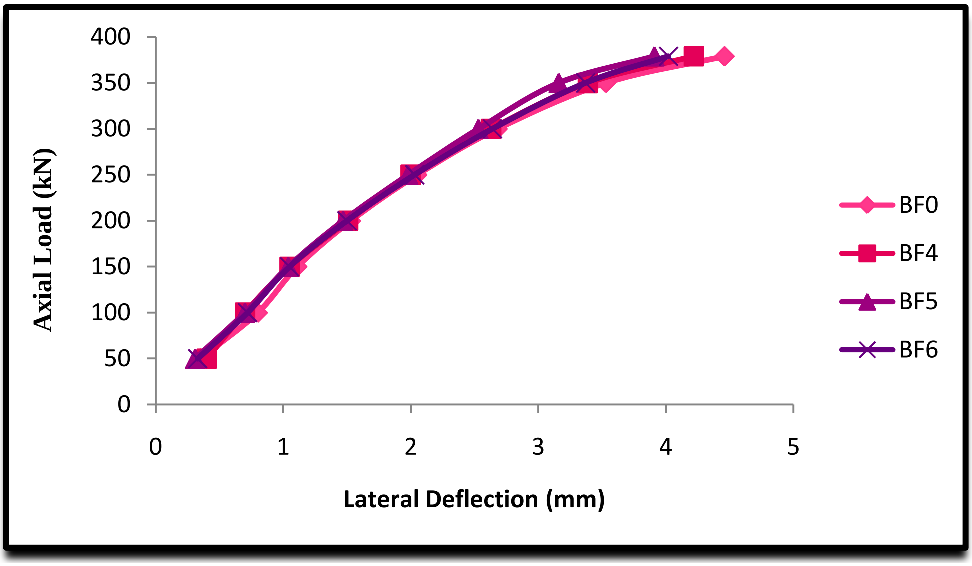


Figure 4.1 Comparison of Load Deflection Curve of BF0, BF4, BF5 and BF6

4.4 Comparison between first crack and ultimate load

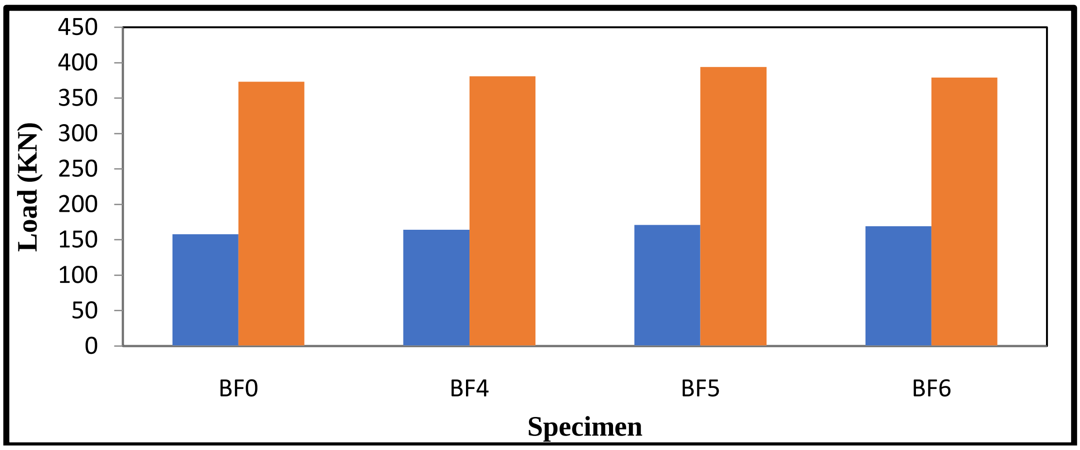


Figure 4.2 Comparison between first crack and ultimate load

V. CONCLUSIONS

- The addition of optimum dosage level of basalt fiber was found as 0.25% by the volume of concrete.
- The compressive, split and flexural strength with 0.25% of basalt fiber in concrete increased by 10.2%, 68.8% and 38.12% when compared to control concrete.
- The load carrying capacity of 0.25% addition of Basalt Fiber in Reinforced Concrete columns was increased by 5.63% when compared Control Concrete column.
- The ductility of column was increased by 9.6% than that of the control column when compared to 0.25% of basalt fiber in concrete.
- The stiffness degradation was found out in all specimens.
- So, addition of Basalt fiber up to 0.25% in reinforced concrete significantly increases the structural behavior of the member, due to the better cracking mechanism.

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