IJIRAE:: International Journal of Innovative Research in Advanced Engineering ISSN: 2349-2163
Volume 11, Issue 05, May 2024 https://www.ijirae.com/archives

Study on Structural Behavior of Basalt Fiber Reinforced Concrete

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Publication History
Manuscript Reference No: IJIRAE/RS/Vol.11/Issue05/MYAE10091
Research Article | Open Access | Double-Blind Peer-Reviewed | Article ID: IJIRAE/RS/Vol.11/Issue05/MYAE10091
Received: 15, April 2024 | Revised: 21, April 2024 | Accepted: 28, April 2024 | Published Online: 12, May 2024
https://www.ijirae.com/volumes/Vol11/iss-05/12.MYAE10091.pdf
Article Citation: Rajkumar,Seenirajan(2024). Study on Structural Behavior of Basalt Fiber Reinforced Concrete. IJIRAE:: International Journal of Innovative Research in Advanced Engineering, Volume 11, Issue 05 of 2024 pages 524-530 **Doi:>**https://doi.org/10.26562/ijirae.2024.v1105.12
BibTeX Key Rajkumar@2024Study
Academic Editor-Chief: Dr.A.Arul Lawrence Selvakumar, AM Publications, India

Abstract: Worldwide, a great deal of research is currently being conducted concerning the use of Fibre 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 fibre reinforced concrete to control cracking and crack propagation in plain concrete, and to increase the overall ductility of the material. 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 structural 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 fibre in concrete was found with respect to cube compressive strength at the age of 7 and 28 days. The cube 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 volume of fraction) by the mass of concrete. The optimum level of basalt fibre was determined. By keeping the optimum level of dosage of fiber the structural behavior of the concrete was evaluated by casting a Beam. By the Structural Behaviour Test, the Basalt Fiber Reinforced concrete shows effective properties such as it control cracking and increase the properties like Tensile strength, Energy absorption and Stiffness. So, Basalt Fibre Reinforced Concrete has the potential for large scale use in concrete construction.

INTRODUCTION

Fibre-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented. Fibres include steel fibres, glass fibres, synthetic fibres and natural fibres each of which lend varying properties to the concrete. In addition, the character of fibre-reinforced concrete changes with varying concretes, fibre materials, geometries, distribution, orientation, and densities.

HISTORICAL PERSPECTIVE

The concept of using fibres as reinforcement is not new. Fibres have been used as reinforcement since ancient times. Historically, horsehair was used in mortar and straw in mud bricks. In the early 1900s, asbestos fibres were used in concrete. In the 1950s, the concept of composite materials came into being and fibre-reinforced concrete was one of the 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 fibres such as polypropylene fibres were used in concrete. Research into new fibre-reinforced concretes continues today.

EFFECT OF FIBRES IN CONCRETE

Fibres 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 fibres produce greater impact, abrasion, and shatter resistance in concrete. Generally fibres do not increase the flexural strength of concrete, and so cannot replace moment–resisting or structural steel reinforcement. Indeed, some fibres actually reduce the strength of concrete.
The amount of fibres added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibres), termed "volume fraction" (Vf). Vf typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing fibre length (l) by its diameter (d). Fibres with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the fibre's modulus of elasticity 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 fibre usually segments the flexural strength and toughness of the matrix. However, fibres that are too long tend to "ball" in the mix and create workability problems. Some recent research indicated that using fibres in concrete has limited effect on the impact resistance of the materials. This finding is very important since traditionally, people think that ductility increases when concrete is reinforced with fibres. The results also indicated out that the use of micro fibres offers better impact resistance compared with the longer fibres. BASALT FIBRE 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 fibres 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 fibre is the rock of a volcanic origin. These fibres are created by melting the basalt stones down at temperature of 1400°C.

Basalt continuous fibers offer the prospect of a completely new range of composite materials and products. As it is well known, basalt is the name given to a variety of volcanic rock, known principally for its resistance to high temperatures, strength and durability, widely diffused all around the world, in which SiO_2 accounts for the main part, followed by Al_2O_3, then Fe_2O_3, FeO, CaO and MgO. For this reason, basalt rocks are classified according to the SiO_2 content as alkaline (up to 42% SiO_2), mildly acidic (43 to 46% SiO_2) and acidic basalts (over 46% SiO_2). Only acidic type basalts satisfy the conditions for fiber preparation.

Benefits of Basalt Fibre

1. High chemical resistance, including to concentrated acids.
2. High thermal resistance (thermo stability) and low flammability.
3. Relatively high mechanical strength, abrasion resistance and elasticity.
4. Tensile strength greater than same size steel mesh.
5. High thermal and acoustic insulation properties.
6. High electrical insualting properties.
7. Renewable alternative to metal building materials.
8. Ecologically clean and non-toxic to the end use

EXPERIMENTAL INVESTIGATION GENERAL

This chapter deals with the test results of materials which are used for this project.

MATERIALS USED

The following are the materials and their properties that are used for the specimen casting and curing.

Cement

Ordinary Portland cement (OPC 53) grade conforming to IS 12269-1987. Physical Properties of Cement was listed in Table 3.1

Table 3.1 Physical Properties of Cement

Property	Description
Standard consistency	33 %
Initial setting time	35 min
Final setting time	276 min
Strength test	54.08 N/mm²
Fineness test	6 %
Specific gravity	3.1

The fine aggregate was used clean dry river sand conforming to IS 383:1970.The sand was sieved to remove pebbles. Properties for fine aggregate was listed in Table 3.2.

Table 3.2 Test results of fine aggregate

Property	Description
Specific gravity	2.7
Water absorption	1%
Sieve analysis	Conforming to zone III

Coarse Aggregate

Crushed blue granite broken stones of 20mm size were used as coarse aggeragate conforming to IS 383:1970. Properties of coarse aggregate was listed in Table 3.3

Table 3.3 Test results of coarse aggregate

Property	Description
Specific gravity	2.7
Water absorption	0.5%

Chemical admixtures

Sulphonated naphthalene formaldehyde was used as superplasticizer in concrete mixtures. The dosage of superplasticizer was used as 1% / m3.

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 purposes.

Basalt Fibre

Fine aggregate

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

1. Diameter = 16 micron
2. Cut length = 130 mm
3. Aspect ratio = 812

Reinforcing steel

The high yield strength deformed steel bars of 12mm and 16mm diameters are used for main reinforcement and 8mm diameter bars are used for shear reinforcement.

CONCRETE MIX PROPORTION

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 1m3 of concrete are given in Table 3.4

Table 3.4 Material required for 1m3 of Concrete (Kg/m3)

Grade	Cement	FA	CA	Water
M30	352	718	1276.9	147.75

Different volume fractions of Basalt fibre were adopted in concrete mix as described in Table 3.5

Table 3.5 Different Volume Fractions of Fibres adopted in Concrete mix.

Specimen Identification	Basalt fiber (%)
B0	0
B1	0.05%
B2	0.10%
B3	0.15%
B4	0.20%
B5	0.25%
B6	0.30%
B7	0.35%
B8	0.40%
B9	0.45%
B10	0.50%

B0 - Plain Reinforced Concrete
B1 – Reinforced Concrete with 0.05% of Basalt Fibre
B2 – Reinforced Concrete with 0.10% of Basalt Fibre
B3 – Reinforced Concrete with 0.15% of Basalt Fibre
B4 – Reinforced Concrete with 0.20% of Basalt Fibre
B5 – Reinforced Concrete with 0.25% of Basalt Fibre
B6 – Reinforced Concrete with 0.30% of Basalt Fibre
B7 – Reinforced Concrete with 0.35% of Basalt Fibre
B8 – Reinforced Concrete with 0.40% of Basalt Fibre
B9 – Reinforced Concrete with 0.45% of Basalt Fibre
B10 – Reinforced Concrete with 0.50% of Basalt Fibre

DIMENSIONS OF THE SPECIMEN

Cube - 150mm x150mm x150mm Beam – 1600mm x185mm x110mm

PREPARATION OF BEAM SPECIMEN

The beam specimens may be prepared by steel, wood or plywood sheets. Anyway, the Mould should be in enough stiffness to withstand the stresses which are developed by handling and compacting of concrete while concreting. The compressive strength of various mixes was calculated and then the Optimum Fiber content was identified through that result. The Beam Specimens were prepared in the optimum fiber Content and the above one and also the below one of the fiber content. In this way, three percentages of fiber content and the Conventional concrete (M30) were used for concreting to prepare Beam Specimen. Totally four numbers of beams were casted for different combination of with and without fibre. The beams were casted in our laboratory for a dimension of 1600mmx185mmx110mm. Wooden moulds for casting column were oiled and properly aligned to exact dimension on the concrete platform. Reinforcement cage was placed inside the mould maintaining proper cover. Concrete mix was prepared as explained in 3.3 placed into the mould with reinforcement cage. After filling the mould, the concrete surface was leveled and finished using a trowel. After 24 hours, the formwork was stripped off and specimens were cured for a period of 28 days. Figure 3.5 shows concreting of beam specimen

Fig.3.5 Concreting of Beam specimen

TESTING PROCEDURE OF SPECIMEN

Compressive Strength of FRC

The compressive strength determination was the primary objective. The cube specimens of 150 mm size were tested at the age of 7 and 28 days.

Fig 3.6 Test setup of compressive strength

All the specimens were tested under saturated surface dry condition. Three identical specimens were tested in all the mixtures. The fig 3.6 shows the testing specimen under the compression.

Experimental set up for beam specimen

The experimental sets up for testing of beam specimen are shown in fig.3.7. The beam was supported on the two simply supported knife edges and 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 intensity of load was measured by the load cell having a capacity of 500KN. The load is applied at an increment of 5KN up to the failure of specimen. The beam was loaded as shown in fig 3.7. 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.

Fig 3.7 Test setup for Beam specimen

RESULTS & DISCUSSION

GENERAL

This chapter deals with the test results of plain concrete and fibre reinforced concrete.

TEST RESULTS OF CONTROLLED SPECIMEN

Compressive strength of FRC

All cubes of plain concrete and basalt fibre 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 7 days and 28 days. The values for compressive strength of concrete for all the mixes are listed in table 4.1

Table 4.1 Compressive strength of FRC

S.No	Fibre in %	Compressive strength in N/mm2	
		At the age of 7days	At the age of 28days
1	0	18	30
2	0.05	19.5	32.5
3	0.1	21.37	35.62
4	0.15	22.76	37.94
5	0.2	23.83	39.73
6	0.25	25.68	42.8
7	0.3	20.85	34.76
8	0.35	17.79	29.65
9	0.4	18.42	30.71
10	0.45	13.84	23.08
11	0.5	18.61	31.02

The compressive strength of Conventional and Basalt Fiber Concrete mix with 0.05%,0.1%,0.15%,0.2%,0.25%,0.3%,0.35%,0.4%,0. 45% and 0.5% at the age of 7 days and 28 days are shown in fig 4.1 and fig 4.2.

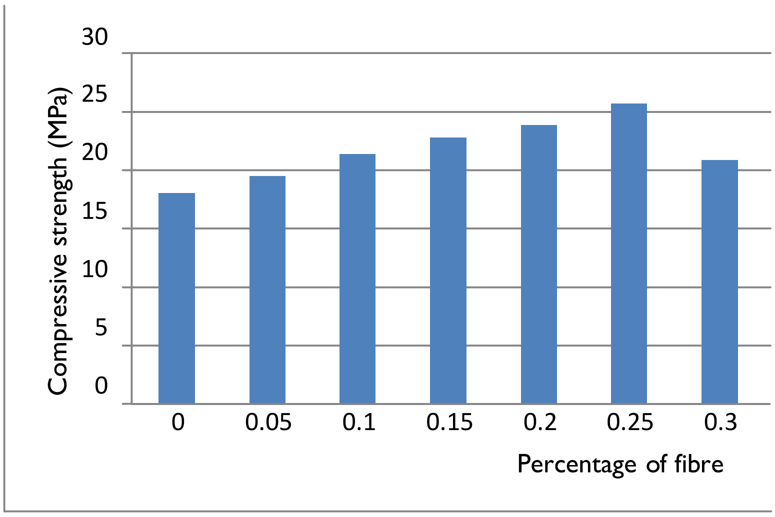

Fig 4.1 Compressive strength of Control and various FRC mix with Basalt fibre at the age of 7 days.

At the ages of 7days the addition of 0.05%, 0.1%, 0.15%, 0.2% and 0.25% basalt fibre in concrete showed 7.69%,15.76%,20.9%,24.65% and 29.9% increase in compressive strength. Increased, Hairline cracks were developed in the few portions of the Specimens. The crack development was lesser that the Conventional concrete beam.

Table 4.2 Load carrying capacity of beam

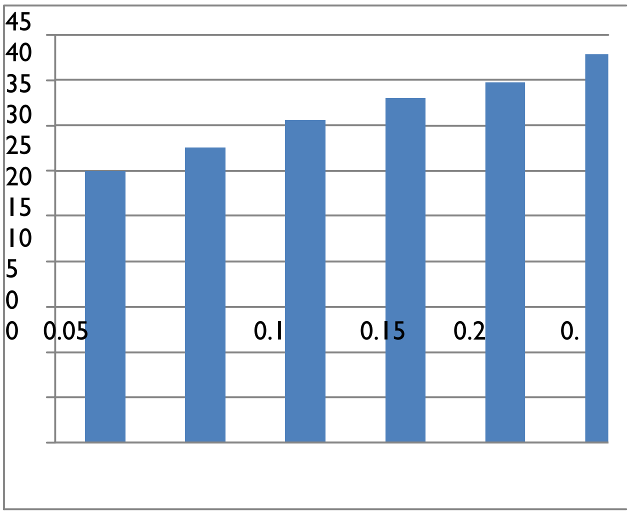

Fig 4.2 Compressive strength of control and various FRC mix of basalt fibre at the age of 28 days.

At the ages of 28days the addition of 0.05%, 0.1%, 0.15%, 0.2% and 0.25% basalt fibre in concrete showed 7.69%,15.76%,20.9%,24.65% and 29.9% increase in compressive strength. A marginal strength reduction was observed in 0.3% and 0.35% of basalt fibre at the age of 28 days. The optimum dosage of basalt fibre at the age of 28 days was obtained as 0.25% with respect to compressive strength.

TEST RESULTS OF BEAMS

Load carrying capacity and first crack load the first crack was witnessed at bottom portion mid-span of the beam. The corresponding load level was measured as 15 KN and load carrying capacity at 20 KN. By the addition of 0.25% of basalt fibre in concrete beam the first crack occurs at 25KN at the load level of 40KN. The Ultimate Load Carrying Capacity of B5 beam was increases about 1.63 times more than B0 due to presence of the Basalt fibre in concrete.

S.No	Specimen	First crack load in KN	Ultimate load in KN
1	B0	25	55
2	B4	25	85
3	B5	30	90
4	B6	25	75

CONCLUSION

Based on the experimental study carried out on the beams the following conclusions are drawn. The first crack load and load carrying capacity of Plain and Basalt fiber reinforced concrete beams are shown in Table 4.2. The first crack was initiated in 25 KN at the Beam for B0 Specimen and in 30 KN for B5 and 25 KN for B4 and B6 specimens respectively. As the load level was The Energy index of B5 beam increases by 63.36 % than that of the conventional concrete. So, addition of Basalt fiber up to 0.25% in reinforced concrete significantly increases the structural behavior of the member.

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[2]. The load carrying capacity of Basalt Fiber Reinforced Concrete B5 beam was increased by than that 1.63times of Conventional beam BO
[3]. The ductility of beam specimen B5 was increased by 22.7% than that of the conventional beam specimen due to presence of Basalt Fiber in concrete.
[4]. The stiffness value of all beams increases compared to conventional concrete.
[5]. The Basalt Fiber Reinforced Concrete B5 beam has a maximum total energy when compared to all other beams. Compared with other beam specimen B5 increases 3.36 times of B0 beam.
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