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Strength and Durability Properties of Basalt Fiber Reinforced Concrete

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ABSTRACT

This project discusses with Basalt fiber reinforced concrete. And the report present the art of knowledge of basalt fiber, it is relatively new material Basalt is an igneous rock. Basalt fiber reinforced concrete offers more characteristics such as lightweight and good fire resistance and strength. In future it is very beneficial for construction industry. Many applications of basalt fiber are residential industrial, highway and bridges. The information in this report has been compiled from reports of test programs by various researchers and represents current opinion.

Keywords: *FRC, BFRP, Basalt Fiber.*

1. Introduction

The main challenge for civil and structural engineers is to provide sustainable, environmentally friendly and financially feasible structures to the society. FRP's have become increasingly more studied and utilized in the reinforcement and prestressing of structural members. Most of the FRP materials to date have at least some type of major drawback which prevents them from becoming more widely utilized for structural applications.

The relatively new development of an FRP composed of fibers of melted basalt rock (BFRP) is beginning to create excitement within the construction industry as a viable FRP alternative to CFRPs and GFRPs [1-4]. Presence of fiber in concrete improves the physical properties as well as it acts as crack arresters. In attempt is made to predict the impact of basalt fiber in the properties of M30 grade concrete for various proportions of basalt fiber. Basalt fiber is a relative newcomer to fiber reinforced polymers (FRPs) and structural composites.

It has a similar chemical composition as glass fiber but has better strength characteristics, and unlike most glass fibers is highly resistant to alkaline, acidic and salt attack making it a good candidate for concrete, bridge and shoreline structures.

1.1. Advantages of Basalt Fiber Reinforced Polymer

The main advantages of the basalt bar are [5-8],

- Its weight is one-third of the weight of steel and the thermal expansion coefficient is very close to that of concrete.
- They have no toxic action with air and water.
- Water absorption, noise absorption qualities and very high chemical resistance.
- Melting temperature & working temperature up to 600 degrees.
- Basalt bar over steel rebar, they have higher specific strength and no permanent deformation when bent.

1.2. Objectives of the Study

- To study the mechanical properties of concrete with basalt fibers.
- To increase the flexural strength of concrete by replacing the conventional steel with BFRP bars.
- To compare the flexural strength of conventional beam with BFRP reinforced beam.

2. Methods and Material Testing

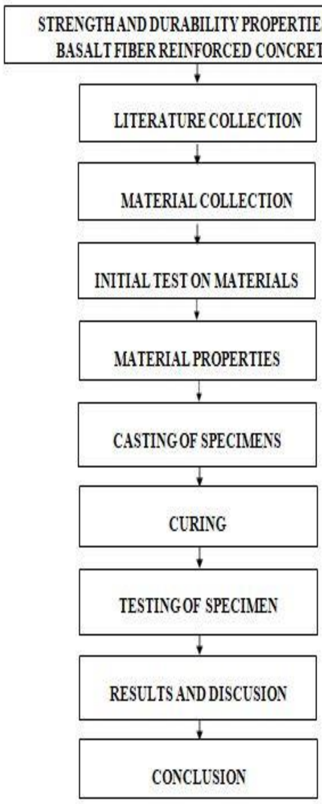

Fig.1. Methodology

3. Basalt Fibers

Basalt is a type of igneous rock formed by the rapid cooling of lava at the surface of a planet. It is the most common rock in the Earth's crust. Basalt rock characteristics vary from the source of lava, cooling rate, and historical exposure to the elements. High quality fibers are made from basalt deposits with uniform chemical makeup. The production of basalt and glass fibers is similar [9-11].

Crushed basalt rock is the only raw material required for manufacturing the fiber. It is a continuous fiber produced through igneous basalt rock melt drawing at about 2,700° F (1,500° C) as already shown in fig 1. Though the temperature required to produce fibers from basalt is higher than glass, it is reported by some researchers that production of fibers made from basalt requires less energy by due to the uniformity of material.

Basalt as a fiber used in FRPs and structural composites has high potential and is getting a lot of attention due to its high temperature and abrasion resistance. Compared to FRPs made from glass, aramid and carbon fiber, its use in the civil infrastructure market is very low.

Table 1. Physical Properties of Basalt Fiber

S.No	Physical Properties	Values
1	Tensile strength (Mpa)	2800-4800
2	Specific gravity	2.7
3	Density (g/m³)	2.67
4	Young's modulus (Mpa)	86-90

3.1. Basalt Fiber Reinforced Polymer Bars

Basalt fiber is a material made from extremely fine fibers of basalt, which is composed of the mineral's plagioclase, pyroxene, and olivine. It is similar to carbon fiber and fibre glass, having better physico mechanical properties than fiberglass, but being significantly cheaper than carbon fiber. It is used as a fireproof textile in. The aerospace and automotive industries and can also be used as a composite to produce products such as camera tripods. Basalt is a natural, hard, dense, dark brown to black volcanic igneous rock originating at a depth of hundreds of kilometers beneath the earth and resulting the surface as molten magma. And it's gray, dark in colour, formed from the molten lava after solidification. The production of basalt fiber consists of melt preparation, extrusion, fiber formation, application of lubricates and finally winding. This method is also known as spinning. It is do not undergo any toxic reaction with water and do not pollute air also. The main functions of the fibers are to carry the load and provide stiffness, strength, thermal stability and other structural properties in the BFRP.

Table 2. Physical Properties of BFRP Bars

S.No	Physical Properties	Values
1	Tensile strength (Gpa)	4.84
2	Elastic modulus (Gpa)	90-110
3	Elongation at break (%)	3.15%
4	Density(g/cm³)	2.7
5	Specific strength	1.57-1.81
6	Specific modulus	37.7-41.5

4. Material Used

In this project, we are using ordinary Portland cement (OPC) grade of 53 confirming to IS 8112 and also the physical properties of cement were tested according to standard procedure conforming to IS:12269:1987. A fine aggregate with locally available river sand conforms to the grading zone II were used and the physical properties of fine aggregates were characterized based on IS 2386-1963 and IS 383-1970. And a crushed granular aggregate of 20mm size conforming to IS 383:1970 is used as coarse aggregate. The physical properties of coarse aggregates were characterized based on IS: 2386-1963.

4.1. Mixing

It is the process of measuring concrete mix ingredients either by volume or mass and introducing them into the mixture. Traditionally batching is done by volume but most of specifications require that batching should be done by mass rather than volume. Percentage of accuracy for measurement of concrete materials is based on the mix proportion. By this we can classify the concrete mixture into two, one is fresh concrete and another is hardened concrete. The potential strength and durability of concrete of a given mix proportion is very dependent on the degree of its compaction. In this project, we have conducted two tests on fresh concrete.

- Slump cone test
- Compaction factor test

Fig.2. Slump Cone Test

Fig.3. Compaction Factor Test

Table 3. Physical Properties of Fresh Concrete

S.No	Tests	Value	As Per Is Standards
1	Slump cone	90mm	Medium
2	Compaction factor	0.93	Medium

4.2. Casting and Curing of Specimens

The cubes size of 150mm × 150 mm × 150 mm was casted to determine the compression Strength of concrete. The cylinders size of 150mm diameter and 300mm height were casted for split tensile strength test. And the prismatic beam of size 100 mm × 100 mm × 500mm was casted for flexural strength test. After demolding the specimens to be kept for curing of 7 days and 28 days.

5. Results and Discussion

In this experimental study specimens were casted based on the mix proportion with five various percentages of basalt fibers and the beams were casted with the combination of basalt fibers, steel rod and basalt fiber polymer bars and tested to determine the strength parameters such as compression strength, split tensile strength and flexural strength and also the durability properties.

Table 4. Results of Compressive Strength

Volume Fraction (V_f)	Basalt Fiber (N/mm^2)		% of Increase with Control Specimen		% of Decrease with Control Specimen	
	7 days	28 days	7 days	28 days	7 days	28 days
0%	28.67	40.18	-	-	-	-
0.2%	25.50	42.92		6.82	11.06	
0.25%	30.22	47.93	5.4	19.29		
0.3%	31.89	46.45	11.23	15.60		
0.35%	29.15	45.11	2.67	12.27		
0.4%	27.45	44.80		11.49	4.26	

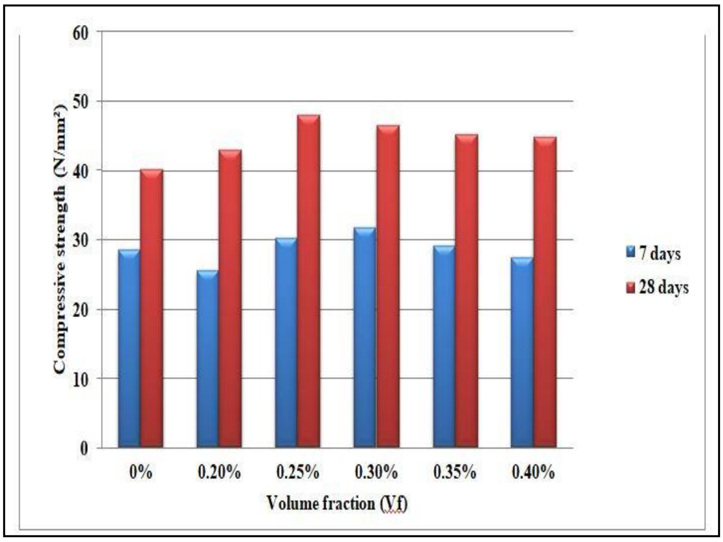

Fig.4. Compressive Strength Test on Cube at 7 & 28 Days

Table 5. Results of Flexural Strength

Volume Fraction(V_f)	Basalt Fiber (N/mm^2)		% of Increase with Control Specimen		% of Decrease with Control Specimen	
	7 days	28 days	7 days	28 days	7 days	28 days
0%	4.43	5.63	-	-	-	-
0.2%	4.65	6.11	5	8.53		
0.25%	4.87	6.38	10.1	13.32		
0.3%	5.02	6.24	13.32	10.83		
0.35%	5.14	6.73	16.02	19.54		
0.4%	4.41	6.49		15.28	0.45	

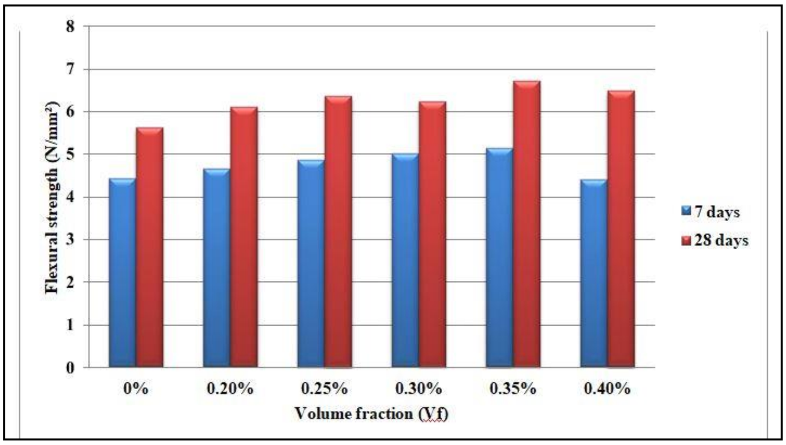

Fig.5. Flexural Strength Test on Prismatic Beam at 7 days & 28 days

Table 6. Sorptivity test results

S.No	Mix designation	Sorptivity at 28 days ($mm/min^{0.5}$)
1	CC	0.049
2	BF 0.2%	0.022
3	BF 0.25%	0.022
4	BF 0.3%	0.020
5	BF 0.35%	0.026
6	BF 0.4%	0.029

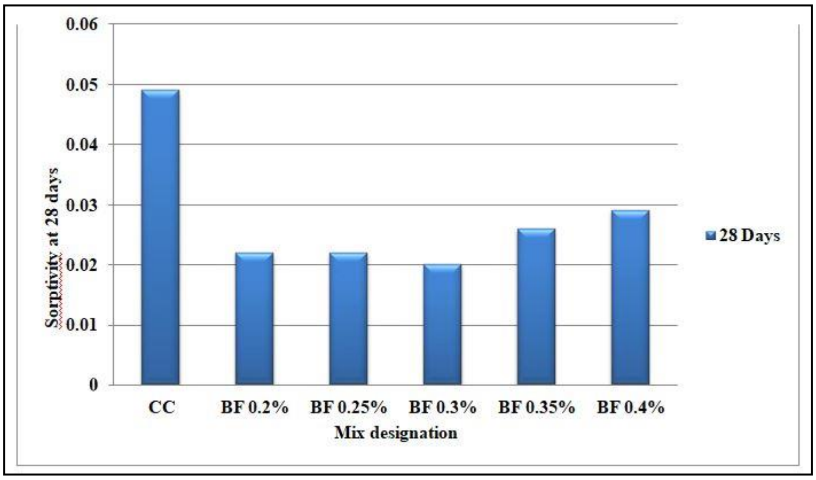

Fig.6. Sorptivity of various concrete mix

Fig.7. Cubes after exposure to H_2SO_4

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The concrete cube specimens exposed to H_2SO_4 environment result in leaching of maximum parts of the outer surface of concrete. It is also observed that H_2SO_4 environment fully erodes the mortar exposing the coarse aggregate.

6. Conclusion

The following conclusions are obtained from this present study of basalt fiber reinforced concrete are:

- The compressive strength of basalt fiber reinforced concrete with addition of 0.3% of fiber volume fraction is increased by 11.23% (31.89MPa) than control specimen (28.67MPa) at 7days and 0.25% of fiber volume fraction is increased by 19.29% (47.93MPa) than control specimen (40.18MPa) at 28days. Compressive strength has significance effect on basalt fiber addition to M30 grade concrete.
- The split tensile strength of basalt fiber reinforced concrete with addition of 0.25% of fiber volume fraction is increased by 24.58% (3.7MPa) than control specimen (2.97MPa) at 7days and 0.3% of fiber volume fraction is increased by 42.08% (4.23MPa) than control specimen (37.5MPa) at 28days.
- The flexural strength of basalt fiber reinforced concrete prismatic beam with addition of 0.35% of fiber volume fraction is increased by 16.02% (5.14MPa) than control specimen (4.43MPa) at 7days and increased by 19.54% (6.73MPa) than control specimen (5.63MPa).
- The flexural strength of basalt fiber reinforced concrete beam with combination of steel rods and BFRP rods. And it is found that the flexural strength with 0.30% BF with steel rod and basalt rod attains the maximum percentage of strength as 59.21% and 73.49% compared to control concrete at 28days. From this, the test results show the effectiveness of basalt fiber with basalt rod when it used in varying percentage in concrete. It shows that flexural strength of concrete was higher at 0.30% of BF with steel rod and basalt rod at 28 days and after it gets decreased.
- The water absorption percentage varied between 2.47 % and 2.92 % at 28 days. This indicates that BF acts as a filler material which fills the pores and thereby reduces water absorption.
- The comparison of sorptivity values of CC, BF 0.2%, BF 0.25%, BF 0.3%, BF 0.35% and BF 0.4% at 28 days is observed that in general, there is a decrease in sorptivity value for all the mixtures with BF when compared to CC at the initial stage.
- From the results of voids permeability, it is found that ratio of (BF 0.20%, BF 0.25%, BF 0.3%, BF 0.35% and BF 0.4%) concrete is found to have lesser permeable voids when compared to control concrete. This may due to low fineness modulus of BF that filling up the micro pores in concrete. Similarly, it is already stated that, the percentage of permeable voids decreased with increased in BF is constant for all mixes.
- From H_2SO_4 environment, the maximum percentage of weight loss is observed for CC at 28 and 56days as 6.15% and 13.27% respectively. Similarly, the percentage weight loss for various percentages is calculated. From the test results that the percentage weight loss is higher in CC compared to concrete with other concrete mix. The minimum percentage of weight loss for BF 0.3% is 5.10% and 11.78% at 28 and

56 days respectively.

- The concrete cube specimens exposed to H_2SO_4 environment result in leaching of maximum parts of the outer surface of concrete. It is also observed that H_2SO_4 environment fully erodes the mortar exposing the coarse aggregate.
- From the test results of sulphate resistance that the percentage weight loss is higher in CC compared to concrete with other concrete mix. The minimum percentage of weight loss for BF 0.3% mix is 0.88% and 1.38% at 28 and 56 days respectively.
- The percentage strength loss in Na_2SO_4 solution is also found out. In Na_2SO_4 solution, the strength loss percentage and compressive strength percentage was higher. The BF 0.3% mix showed the minimum strength loss percentage compared to remaining mix proportion.
- The durability properties of concrete with basalt fibers in varying percentages have showed that it is a potential building material having higher thermal and chemical stability.

Declarations

Source of Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The authors declare no competing financial, professional and personal interests.

Ethical Approval

Not Applicable.

Consent for publication

Authors declare that they consented for the publication of this research work.

Availability of data and material

Authors are willing to share data and material according to the relevant needs.

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