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(RESEARCH ARTICLE)

Effect of increased basalt fibre dosage on hybrid basalt fibre reinforced concrete's strength properties

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Abstract

Natural, eco-friendly fibers are increasingly being used as reinforcement in the creation of lightweight, low-effort polymer composites on a global scale. Because it is intelligent and has unique properties above glass fibers (GF), basalt fiber (BF) is one such material of interest that is currently in widespread use. Among these composites' clear advantages are their high specific mechanic properties, biodegradability, and non-grating nature. In this paper, basalt fibers used as reinforcement for composites are surveyed. The study also addresses how concrete's strength is affected by curing. In addition to this, an attempt is made to highlight the growing trend in research dissemination and activity in the area of basalt fibers. Further segments talk about the improvement in mechanical, warm and synthetic safe properties accomplished for applications in specific enterprises. The results of this study reveal that the optimum value of strength at 28th day of curing is obtained for a mix made with 5% of chopped basalt fiber 50% 6mm Long BF and 50% 12mm Long BF.

Keywords: BFRC; HY-BFRC; Compressive Strength; Tensile Strength; Flexural Strength

1. Introduction

Concrete is made by combining all of the necessary and useful components, such as water, cement, and coarse and fine aggregate. All contaminants and other microbes must be removed from the water used to make the concrete mix. Because concrete can tolerate any temperature and any environment, it is a successful building material. However, by adding different fibers, such as steel, glass, synthetic, natural, and basalt fibers, as well as different chemical admixtures, scientists and researchers are still attempting to improve the limitations of concrete. This process is known as fiber reinforced concrete (FRC). In general, molten lava cools rapidly on the earth's surface to create basalt, an igneous rock. It is among the most well-known rocks that can be found outside of the earth. The distribution of basalt rocks varies depending on the lava's origin, pace of cooling, and past exposure. High-quality fibers are composed of basalt fiber's consistent chemical composition. The process used to produce basalt fibers consists of three steps: melting, homogenizing the basalt, and extracting the fibers. There is only one instance of basalt in this. The next stage involves using "cold technology" to convert these continuous threads of basalt into different materials with lower financial and energy inputs. One stone that has been meticulously quarried from the source is used to practice the procedure. The selected stone must contain at least 50% silica and very little iron; this kind of stone is employed in product manufacturing. Once the stone with both characteristics has been chosen, it is cleaned and melted at 1,500 degrees Celsius. To create continuous basalt threads, the molten rock is first fed through tiny nozzles. The filament diameter of these continuous fibers ranges from 10 to 20 μm, which is sufficient to make basalt fiber a suitable substitute for other fiber types. This kind of fiber has a high modulus of elasticity and a high specific strength, which is three times that of steel. Concrete is known to operate rather well under compression, although its tension tolerance is only approximate

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10%. The goal of this work is to test five percent of basalt fiber for various mono and HY-BFRC mix combinations in terms of compressive strength, split tensile strength, and flexural strength. Concrete strength tests were performed at 7, 14, and 28 days of curing ages as part of this inquiry.

2. Experimental programme

2.1. Materials specifications

The materials used for casting the specimens were Portland Pozzolana Cement (PPC) and 12.5 mm graded coarse aggregates were used in concrete preparation. The average cube compressive strength of 24 MPa for 28.18 days was obtained for all the concrete specimens. Then basalt fibers were added by 5% by weight of cement. The attributed illustration of all mixes is given in Table 1.

Table 1 Concrete Mixes

S. No.	% age of Basalt Fiber	Name of Mix
1.	0%	Plain Concrete
2.	5%	100% 6mm Long BF
3.		50% 6mm Long BF + 50% 12mm Long BF
4.		100% 12mm Long BF

2.1.1. Basalt fiber

The golden-brown color of the basalt fiber utilized as an addition in this investigation is depicted in Figure 1. Basalt fiber is used in reinforced concrete referred as basalt fiber reinforced concrete (BFRC) to assist prevent cracks during the hardening process, minimize leaks, and give corrosion resistance. The fiber filaments typically had an average diameter of 13 microns and an average length of 6 to 12 mm.

Figure 1 Chopped Basalt Fibre of 6 mm and 12 mm Length

2.2. Casting and curing of specimens

2.2.1. Specimen Details

Cubes of size of 150 mm X 150 mm X 150 mm were used for compressive strength, cylinder specimens of size 100 x 200 mm were used for split tensile strength tests and beam specimen of 100 mm X 100 mm X 500 mm for flexural strength tests.

2.2.2. Concrete Batch

The ratios of different components, such as cement, fine and coarse aggregate, water, and basalt fibers, were readily available for each concrete mix. Coarse and fine aggregate were first mixed together in a dry state until the combination was homogeneous and no distinct material could be seen. After that, the cement was added and mixed in a tilting drum. A minute or so was then spent mixing the components after 50% water was added along with super-plasticizer. Eventually, the remaining water was added to the drum, and mixing proceeded for approximately one minute. After the concrete was ready, it was placed in moulds in layers, each of which vibrated properly. For identification specimens marking the cast samples with a permanent marker, they were let to set for a full day. After that, the specimens were demoded and cured by submersion in water for 28 days.

3. Test setup and instrumentation

3.1. Compressive Strength Tests (IS 516-1959)

Compressive strength tests were conducted on cube specimens of size 150 mm X 150 mm X 150 mm after 7th, 14th and 28th days of curing. These tests were carried out in accordance with IS: 516-1959 on a 2000 kN Compression Testing Machine (Figure.2). The load was applied at a rate of 14 N/mm^2/minute. The maximum compressive load on the specimen was recorded as the load at which the specimen failed to take any further increase in the load. The average of three samples was taken as the representative value of compressive strength for each batch of concrete.

Figure 2 Compressive Strength Test

3.2. Split Tensile Strength Tests (IS 516-1959)

The split tensile strength was conducted on the compression testing machine by placing the cylinder as shown in fig. 3. The split tensile strength tests were conducted on all the mixes after 7th, 14th and 28th days of curing. The split tensile strength was determined by using the following formula:

$$\sigma\ spt = \frac{2P}{\pi DL}$$

Where:
$\sigma\ spt$ = Split Tensile Strength in MPa
P = Splitting Load in N,
D = Diameter of the Cylinder in mm.
L = Length of the Cylinder in mm.

Figure 3 Split Tensile Strength Test Set-Up

3.3. Flexural Strength Test (IS516-1959)

The tensile testing machine is of reliable type and a maximum capacity of 100 kN for testing the beam specimen. The permissible error is not being more than ± 0.5% on applied load. Two steel rollers are provided on bottom to support the specimen and mounted in such way that centre-centre distance is 460 mm for 100 mm thick sample. Load was dispersed alike between two rollers so that load was axially applied through the third roller with centre to centre spacing 230 mm between the rollers and not subjected to any tensional restraint. The beam specimen was tested immediately after removal from water in wet condition. Samples were analyzed on computer-controlled machine as demonstrated in Figure 4 with rate of loading at 180 kg/min or 0.3 mm/min as specified in the apparatus. The modulus of rupture and load-deflection curves were plotted in the computer-controlled apparatus itself.

Figure 4 Flexural Strength Test

4. Results and discussion

4.1. Tests on Fresh Concrete

In general, the workability test is the first test conducted on concrete to see how easily it can be handled, moved, placed, compacted, and finally finished without separating. The purpose of the test is to ensure proper finishing and to ignore any bleeding during the last and compacting stages. More precisely, workability refers to the concrete's ability to be fully compacted with minimal energy input. The 'Slump Cone Test' was used to measure the workability of the concrete. Slump Cone was placed on the horizontal surface and concrete is added into three different layers of equal height and each layer of the three layers were tamped with the help of tamping road by 25 times. In this investigation, since a large number of basalt fiber concrete mixes were proposed to be tested. The slump cone test shows that the slump value was reduced when the mix with 100% 12mm length basalt fiber used. The results also shows that the concrete mix with basalt fiber reduce the workability than conventional concrete. Table 2 shows the workability test results of all mixes.

Table 2 Workability Results

S. No.	% age of Basalt Fiber	Name of Mix	Slump Value (mm)
1.	0%	Plain Concrete	96
2.	5%	100% 6 mm Long BF	54
3.		50% 6 mm Long BF + 50% 12 mm Long BF	59
4.		100% 12 mm Long BF	42

4.2. Compressive Strength

Basalt fiber 5% was used for different mono and Hybrid basalt fibre reinforced concrete (HY-BFRC) mix combinations in this investigation and compressive strength tests were conducted at 7, 14 and 28 days of curing. It is evident from the observations that the compressive strength gradually builds up with an age of 7, 14, and 28 days full time water curing. The test results show that 5% of basalt fiber not much increase in compressive strength with respect to plain concrete. Table 3 shows the compressive strength test results of all mixes at all curing ages.

The results of the compressive strength test led by adding basalt fiber in plain concrete by weight of cement with 5% have been presented in Fig. 5. Figure 5 clearly shows that the addition of 6mm long BF causes a 1.1% decrease in compressive strength for monomix concrete with 5% basalt fiber over plain concrete (control mix) after 28 days of curing, and a 3.7% decrease for 12mm long BF. Fig. 5 shows practically identical patterns can likewise see from plotted results at other curing dates for basalt fiber mix. It can be observed with 5% volume fraction of BF with respect to plain concrete by adding 50% 6mm + 50% 12mm Long BF long BF where strength was enhanced by 0.53% at same curing age (28 days).

Table 3 Compressive Strength Test Results

S. No		Mix Combination	Compressive Strength (MPa)		
			7 Days	14 Days	28 Days
1.	Plain Concrete		14.64	18.49	28.18
2.	5% BF	100% 6 mm Long BF	12.82	14.33	27.13
3.		100% 12 mm Long BF	11.86	14.04	27.86
4.		50% 6 mm Long BF + 50% 12 mm Long BF	13.23	14.93	28.33

*Average of three specimens

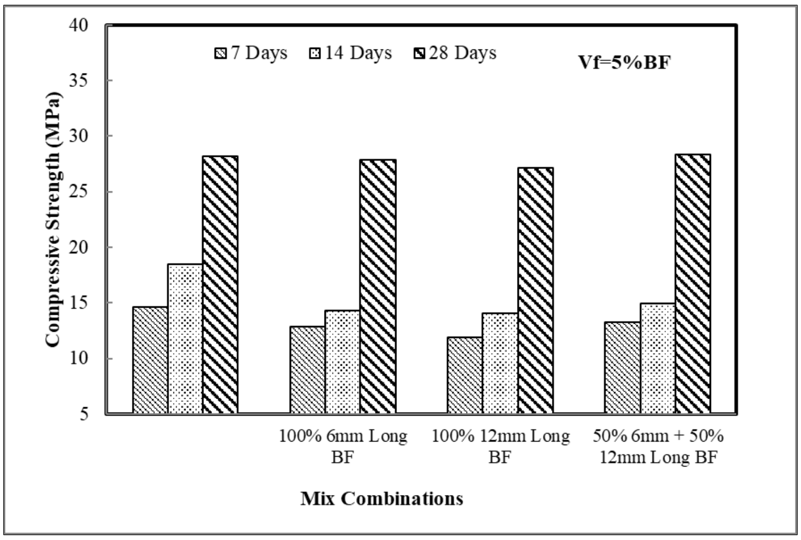

Figure 5 Compressive Strength of mono, binary mixes with plain concrete, (5% B.F. @100% 6mm, 100%12mm, and 50% 6mm+50% 12mm Long BF)

Furthermore, compressive strengths of 12mm long BF used mix concrete strength found to be comparable probably due to ineffective dispersion of higher dosage fibres in concrete or due to bunching/sticking together. It is evident from the test result observations indicate that the strength of the concretes with full time water curing only for 7 days with 5% volume fraction of BF with respect to plain concrete by adding 50% 6mm + 50% 12mm long BF where strength was decrease by 9.63 % with plane concrete and also 19% compressive strength decrease at an age of 14 days curing. It seems that adding HY-BFRC also ineffective in early age strength.

4.3. Split tensile strength

Basalt fiber 5%, was used for different mono and hybrid Basalt (Hy-BFRC) fiber mix combinations in this investigation to find split tensile strength. The tests were conducted at 7, 14 and 28 days of curing. The average splitting tensile strength of the control specimens and basalt fibre-reinforced concrete with different length of fibres is given in Table 4 and shown in Fig. 6. It is evident from the observations that the split tensile strength gradually builds up with an age of 7, 14, and 28 days full time water curing. According to the test results, adding 5% basalt fiber to normal concrete did not significantly boost its split tensile strength.

Table 4 Split Tensile Strength Test Results

		Mix Combination	Split Tensile Strength (MPa)		
S. No			7 Days	14 Days	28 Days
1.	Plain Concrete		1.02	2.03	3.38
2.	5% BF	100% 6 mm Long BF	0.9	1.43	3.34
3.		100% 12mm Long BF	0.95	1.4	2.85
4.		50% 6 mm Long BF + 50% 12 mm Long BF	0.99	1.49	3.4

*Average of three specimens

The results of the split tensile strength test conducted in mono and HY-BFRC mix made by adding chopped basalt fiber with plain concrete by weight of cement with 5% have been presented in Table 5. It very well may be seen from Fig.6 that the expansion in split tensile strength for mono mix in with 5% basalt fiber over the plain concrete (control mix) is 1.1% reduction at 28 days of curing on adding 6mm Long BF and for 12mm long BF the strength decrease by 15.6%. Fig. 5 shows practically identical patterns can likewise see from plotted results at other curing ages for basalt fiber mix. It can be observed with 5% volume fraction of BF with respect to plain concrete by adding 50% 6mm + 50% 12mm long BF maximum enhancement in splitting tensile strength of only 0.6 % than control concrete at same curing age (28 days).

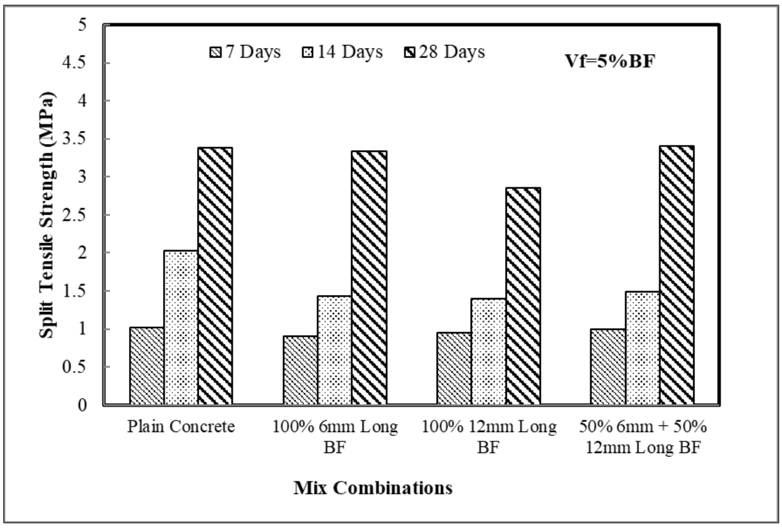

Figure 6 Split Tensile Strength of mono, binary mixes with plain concrete, (5% B.F. @100% 6mm, 100%12mm, and 50% 6mm+50% 12mm Long BF)

This shows that the addition of basalt fibres in concrete not significantly increases its splitting tensile strength. This is due to the high volume of basalt fibres. It is evident from the test result observations indicate that the strength of the concrete with full time water curing only for 7 days with 5% volume fraction of BF with respect to plain concrete by adding 50% 6mm + 50% 12mm BF where strength was reduced by 2.9% with plane concrete in terms of early age strength, it appears that adding a large volume of HY-BFRC is equally unsuccessful.

4.4. Flexural strength

The flexural strength results were conducted on mono and binary mixes at 28days of curing only. Plain concrete was also tested for flexural strength for comparison purpose. The flexural strength test results for various mixes tested in the investigation are presented in the table 5. Figure 7 presents the results of flexural strength test conducted on mono and HY- BFRC mixes made of different aspect ratios for 5% volume fraction at 28 days of curing. For comparison the result of plain concrete also plotted in the same. It can be clearly observed from the test results that the HY-BFRC mix containing 50% 6mm Long BF. + 50% 12mm Long BF at 28days water curing specimens showed maximum enhancement in flexural strength of 3% over plain concrete.

Table 5 Flexural Strength Tests Results for various Fiber Mix Combinations at 28 days water Curing.

S. No		Mix Combination	Flexural Strength (MPa)
			28 Days
1.	Plain Concrete		3.143
2.	5% BF	100% 6 mm Long BF	3.05
3.		100% 12 mm Long BF	2.64
4.		50% 6 mm Long BF + 50% 12 mm Long BF	3.24

*Average of three specimens

This is because basalt fiber stops microcracks. Figure 7 shows that the addition of 6mm long BF reduced the flexural strength expansion by 2.9% after 28 days of curing for monomix concrete with 5% basalt fiber above plain concrete (control mix), while the strength decreased by 16% for 12mm long BF. It seems that a high volume of BFRC is equally ineffective.

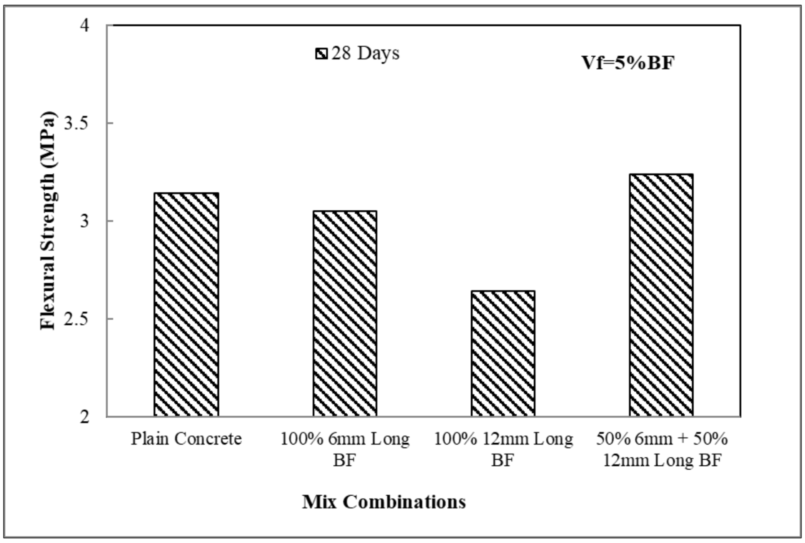

Figure 7 Flexural Strength of mono, binary mixes with plain concrete at 28th day, (5% B.F. @100% 6mm,100 %12mm, and 50% 6mm+50% 12mm Long BF)

5. Conclusion

- Within limited scope of the present investigation, following conclusions have been drawn:
- The concrete mix with the highest compressive strength among those based on basalt fibers evaluated in this study is the one that contains 5% chopped basalt fiber (50% 6mm Long BF + 50% 12mm Long BF). This is just 0.53% more than that of control concrete. In comparison to plain concrete, the test findings indicate that adding 5% of basalt fiber does not significantly boost compressive strength.
- The split tensile strength is achieved with 5% of chopped basalt fiber (50% 6mm Long BF + 50% 12mm Long BF), which is 0.6% higher than that of plain concrete. According to the test results, adding 5% basalt fiber to normal concrete did not significantly boost its split tensile strength.
- The measured flexural strength is observed maximum with HY-BFRC with 5% fiber and the peak value comes out to be 3% higher than that of plain concrete.
- The results of this study reveal that the optimum value of strength is obtained for a mix made with 5% of chopped basalt fiber 50% 6mm Long BF and 50% 12mm Long BF.

The test results indicate that adding a big volume of HY-BFRC seems to be equally ineffective in terms of early age strength also.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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