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An Experimental Study on the Hybrid Basalt Fiber Reinforced Concrete's Strength Characteristics

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Abstract: The use of natural, environmentally friendly fibers as reinforcement in the production of lightweight, low-effort polymer composites is continuously growing on a global scale. One such material of interest presently being broadly utilized is basalt fiber, which is savvy and offers uncommon properties over glass fibers. The conspicuous focal points of these composites incorporate high specific mechanic-physicochemical properties, biodegradability, and non-grating characteristics to give some examples. This study presents a survey of basalt fibers utilized as a reinforcement material for composites names as basalt fibre reinforced concrete (BFRC). The study also discusses the influence of curing on the strength of concrete. Separated from this, an endeavor to grandstand the expanding pattern in research distributions and action in the territory of basalt fibers are also covered. 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 is obtained for a mix made with 1% of chopped basalt fiber 50% 6mm Long BFR and 50% 12mm Long BFRC.

Index Terms **-** HY-BFRC, Compressive Strength, Tensile Strength, Flexural Strength.

I. Introduction

Concrete is made up by mixing all the important and useful materials such as cement, coarse aggregate, fine aggregate and last but not the least water. Water used in concrete batch must be free from all the impurities and other sort of bacteria. The concrete is successful as a building material because it can withstand any environment and any temperature. But, Scientists and researchers are still trying to enhance the limitations of concrete by adding various chemical admixtures and different fibers i.e. natural fibers, steel fibers, synthetic fibers, glass fibers and basalt fiber, termed as fiber reinforced concrete (FRC) (Kene K.S. et al., (2012), Sinha D., et al., 2014, Gadgihalli V et al., 2017, Onal M.M 2009, Suhail M.,Kumar C.A. and Reza M 2018, Pathan M.G. and Swarup A. 2017, Cao H 2017, Kirthika S.K 2018, Inman M et al., 2016, Soares B et al., 2016, Jay Singh G.P. and Joshi D.A et al., 2014). By adopting FRC, the property of concrete like durability is enhanced to a great extent.

In general, basalt is an igneous type of rock made by the quick cooling of molten lava on the surface of earth. It is one of the most familiar rocks found beyond the earth surface. Basalt rocks allocate vary from the origin of lave, its cooling rate and historical exposure to it. High quality fibers are made up from constant chemical makeup of basalt fiber. The method adopted for the production of basalt fibers is a single stage process: melting, homogenization of basalt and extraction of fibers. In this the basalt is only one time. The next step is to transform these basalt continuous fibers into various materials by adopting “cold technology” with lesser energy inputs in terms of money. The operation is practiced on a single stone which is carefully quarried from the source. The chosen stone must have at least 46% of silica content and must have very low iron content and this type of stone is adopted for the production of products. After selecting the stone having both the qualities then it is washed and then melted at a temperature of 1,500 °C. After melting this molten rock is then passed from small nozzles to obtain continuous basalt fibers. These types of continuous fibers have filament diameter of between 10 and 20µm which is good enough to make basalt fiber a satisfactory replacement for other types of fibers. This type of fibers has high specific strength which is thrice to the steel and it has high modulus of elasticity as well (Singha K 2012).

As we all know concrete is very good in compression but can bear only up to 10% in tension as compare to compression. This work attempts to conduct various tests such as compressive strength, split tensile strength and flexural strength on one percentage of basalt fiber was used for different mono and HY-BFRC mix combinations. In this investigation, concrete strength tests were conducted at 7, 14 and 28 days of curing ages.

I. EXPERIMENTAL PROGRAMME

1.1 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 days was obtained for all the concrete specimens. Chemical admixtures such as super plasticizers or high range water reducers are in common use these days. Dosage of the super plasticizer (naphthalene polymer based) used was 0.2% by weight of cement in order to achieve adequate workability of concrete mixes. Then basalt fibers were added by 1% by weight of cement. The attributed illustration of all mixes is given in Table 1.1.

Table 1.1: Concrete Mixes.

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

1.2 Basalt fiber

Basalt fiber used in this study as an additive was golden brown in color as shown in Figure 1. The use of Basalt fiber helps to reduce cracks in concrete during hardening stage reduces leakage and provides resistance to corrosion in reinforced concrete. The average diameter of a filament of fiber was around 13 micron and average length of filament of fiber was 6mm and 12mm. Table 1.2 shows the properties (provided by the manufacturer) of BFRP.

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

Table 1.2: Specified Properties of Basalt Fiber

S. No.	Property	Value
1.	Tensile Strength (MPa)	3200
2.	Elastic Modulus (GPa)	110
3.	Elongation at break (%)	3.5
4.	Specific gravity(kg/m3)	2700

1.3 CASTING OF SPECIMENS

1.3.1 Specimen details

Cubes of size of 150 x 150 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 x 100 x 500mm for flexural strength tests.

1.3.2 Concrete batch

For each concrete mix, the proportions of various ingredients i.e. cement, fine aggregate, coarse aggregate, water, super-plasticizer and basalt fibers were kept ready. Firstly, the mixture of coarse and fine aggregate was prepared by mixing both in dry state until a uniform mix was achieved and no separate material among these were visible with naked eye. Then the binder which is cement was added and mixed in a tilting drum. Subsequently 50% water mixed with super-plasticizer was added and the ingredients were mixed for about one minute. Finally, the rest of the water was poured into the drum and the mixing was continued for about one minute. The prepared concrete was put into moulds in to different layers, each layer properly vibrated. The casted samples were marked with the help of permanent marker and then after allowed to set for 24 hours. The specimens were de-molded thereafter and immersed in fresh water for curing.

1.4 TEST SETUP AND INSTRUMENTATION

1.4.1 Compressive Strength Tests (IS 516-1959)

Compressive strength tests were conducted on cube specimens of size 150 x150 x 150 mm after 7, 14 and 28days of curing. These tests were carried out in accordance with IS: 516-1959 on a 2000 kN Compression Testing Machine (Fig.2). The load was applied at a rate of 14 N/mm2/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 Set-Up.

1.4.2 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 7, 14 and 28 days of curing.

Figure 3: Split Tensile Strength Test Set-Up

1.4.3 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 (Fig.4). 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.

Figure 4: Flexural Strength Test Set-Up

II. RESULTS AND DISCUSSIONS

2.1 Tests on Fresh Concrete

The very first test on the concrete is called workability test generally, performed to measure its ability to handled, carried, placed, compacted and then finished with less efforts and to avoid segregation. The test is performed to achieve good finishing and to neglect any signs of bleeding in the compacting stage and final stage. 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 temping 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 2.1 shows the workability test results of all mixes.

Table 2.1: Workability of all Mixes

S. No.	Basalt Fiber Percentage	Name of Mix	Slump Value (mm)
1.	0%	Plain Concrete	96
2.	1%	100% 6mm Long BF	82
3.		50% 6mm + 50% 12mm Long BF	78
4.		100% 12mm Long BF	73

2.2 Compressive Strength

Basalt fiber 1% was used for different mono and 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 1% of basalt fiber increase in compressive strength with respect to plain concrete. Table 2.2 shows the compressive strength test results of all mixes at all curing ages.

Table 2.2: 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.	1% BF	100% 6mm Long BF.	15.33	19.31	31.54
3.		100% 12mm Long BF	16.96	20.87	30.85
4.		50% 6mm + 50% 12mm Long BF	17.85	22.41	32.18

*Average of three specimens

The results of the compressive strength test led by adding basalt fiber in plain concrete by weight of cement with 1% have been presented in Fig. 5. It very well may be seen from Fig.5 that the expansion in compressive strength for mono mix in with 1% basalt fiber over the plain concrete (control mix) is 11.92 % expanded at 28 days of curing on adding 6mm Long BF and for 12mm long BF the strength enhanced by 9.47%. 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 1% volume fraction of BF with respect to plain concrete by adding 6mm +12mm long BF where strength was enhanced by 14.19% at same curing age (28 days). 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 1% volume fraction of BF with respect to plain concrete by adding 6mm +12mm long BF where strength was enhanced by 22 % with plane concrete and also 21.2% compressive strength enhanced at an age of 14 days curing. It seems that the gain in early age strength also enhanced by adding HY-BFRC.

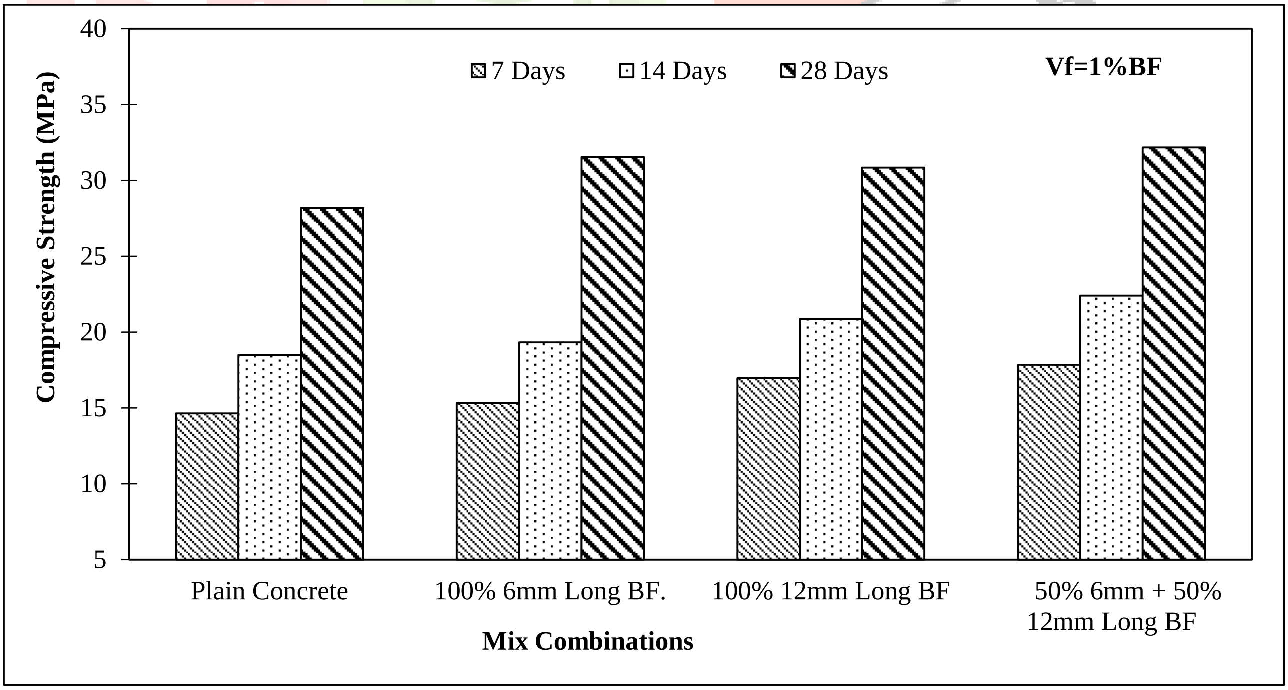

Figure 5 Compressive Strength of mono, binary mixes with plain concrete, (1% BF @100% 6mm, 100%12mm, and 50% 6mm+50% 12mm Long BF)

2.3 SPLIT TENSILE STRENGTH

Basalt fiber's 1% volume fraction was used for different mono and hybrid Basalt 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 2.3 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. The test result shows that 1% of basalt fiber increase in split tensile strength with respect to plain concrete.

Table 2.3: Split Tensile Strength Test Results

S. No	Mix Combination		Split Tensile Strength (MPa)		
			7 Days	14 Days	28 Days
1.	Plain Concrete		1.02	2.03	3.38
2.	1%	100% 6mm Long BF	1.23	1.93	4.10
3.		100% 12mm Long BF	1.19	2.09	4.63
4.		50% 6mm + 50% 12mm Long BF	1.25	2.24	4.83

*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 1% have been presented in Table 2.3. It very well may be seen from Fig.6 that the expansion in split tensile strength for mono mix in with 1% basalt fiber over the plain concrete (control mix) is 21% expanded at 28 days of curing on adding 6mm Long BF and for 12mm long BF the strength enhanced by 37%. 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 1% volume fraction of BF with respect to plain concrete by adding 6mm +12mm long BF maximum enhancement in splitting tensile strength of 43% than control concrete at same curing age (28 days). This shows that the addition of basalt fibres in concrete significantly increases its splitting tensile strength. This is due to the high tensile strength and ductility of basalt fibres. 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 1% volume fraction of BF with respect to plain concrete by adding 6mm +12mm long BF where strength was enhanced by 21% with plane concrete. It seems that the gain in early age strength also enhanced by adding HY-BFRC.

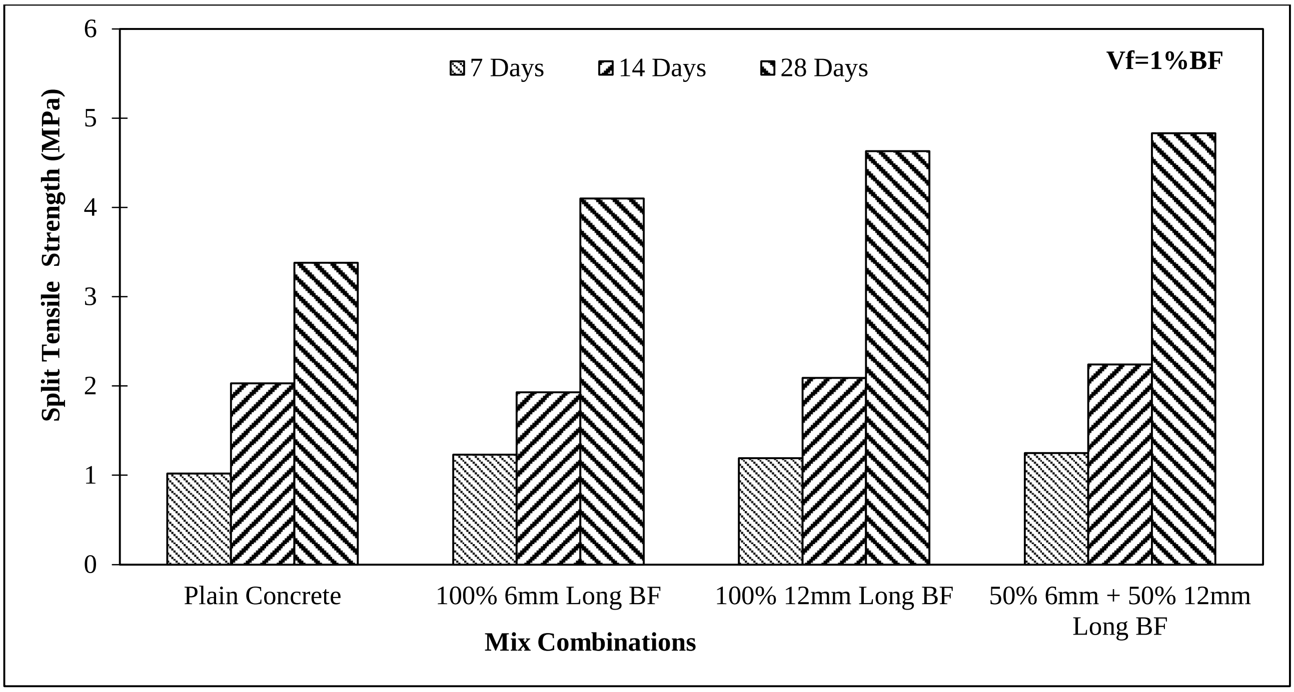

Figure 6: Split Tensile Strength of mono, binary mixes with plain concrete, (1% BF @100% 6mm, 100%12mm, and 50% 6mm+50% 12mm Long BF)

2.4 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 2.4.

Table 2.4: 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		3.14
2.	1%	100% 6mm Long BF	3.834
3.		100% 12mm Long BF	3.66
4.		50% 6mm + 50% 12mm Long BF	4.09

*Average of three specimens

Figure 7 presents the results of flexural strength test conducted on mono and HY- BFRC mixes made of different aspect ratios for 1% 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 flexural strength of 30.25% over plain concrete. This is due to arresting of micro-cracks by basalt fibre. It very well may be seen from Fig.7 that the expansion in flexural strength for mono mix in with 1% basalt fiber over the plain concrete (control mix) is 22% expanded at 28 days of curing on adding 6mm Long BF and for 12mm long BF the strength enhanced by 16%. The flexural strength reduction in 12mm long BF used mix of higher dosage fibres in concrete or due to bunching/sticking together.

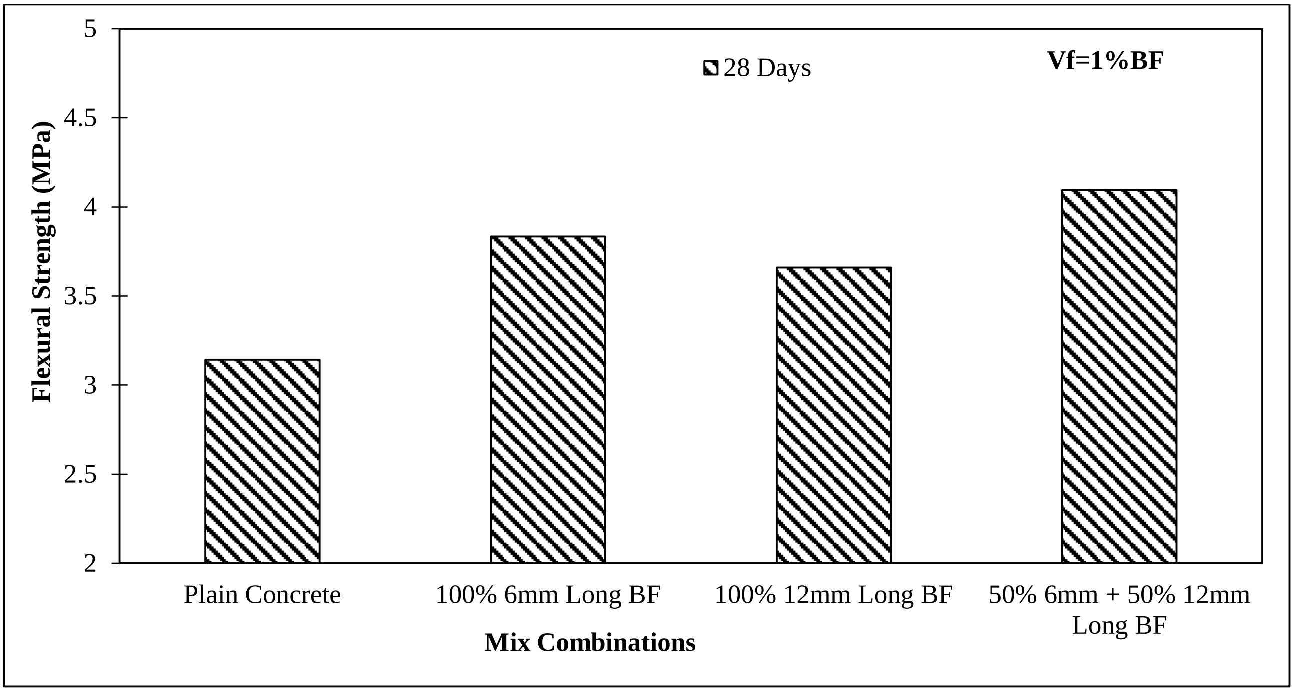

Figure 7 Flexural Strength of mono, binary mixes with plain concrete at 28th day, (1% BF @100% 6mm,100 %12mm, and 50% 6mm+50% 12mm Long BF)

III. CONCLUSION

Within limited scope of the present investigation, following conclusions have been drawn:

1. Amongst the basalt fiber based concrete mix tested in this investigation, the optimum value of compressive strength is obtained for a mix made with 1% of chopped basalt fiber (50% 6mm Long BF + 50% 12mm Long BF) Which is 14.19% higher than that of plain concrete, whereas, the lowest compressive strength is attained by adding basalt fiber 100% 12mm long BF which is 9.45%.
2. The split tensile strength is achieved with 1% of chopped basalt fiber (50% 6mm Long BF+ 50% 12mm Long BF) which is 43% higher than that of plain concrete and in this case lower enhance in split tensile strength is observed with 1% of basalt fiber 100% 12mm Long BF.
3. The measured flexural strength is observed maximum with HY-BFRC with 1% fiber and the peak value comes out to be 4.094 MPa which is 30.25% higher than that of plain concrete.
4. The results of this study reveal that the optimum value of strength is obtained for a mix made with 1% of chopped basalt fiber 50% 6mm Long BF reinforced concrete and 50% 12mm Long BF reinforced concrete.

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