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Performance Evaluation on Hybrid Basalt Fiber Reinforced Concrete

Maninder Pal Singh[1], Franklin F.R. Frederick[2], Hemant[3], Sahil Sharma[4], Vishal Mahajan[5]

[1]Assistant Professor, Department of Civil Engineering, Guru Nanak Dev University, Amritsar
[2]Assistant Professor, Department of Civil Engineering, Guru Nanak Dev University, Amritsar
[3]Assistant Professor, Department of Civil Engineering, Guru Nanak Dev University, Amritsar
[4]Assistant Professor, Department of Civil Engineering, Guru Nanak Dev University, Amritsar
[5]Research Scholar, Department of Civil Engineering, Guru Nanak Dev University, Amritsar

Abstract
Globally, there is a steady increase in the use of natural, eco-friendly fibers as reinforcement in the creation of lightweight, low-effort polymer composites. Basalt fiber (BF), which is clever and has unique qualities over glass fibers, is one such material of interest that is currently being used widely. 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 study of basalt fibers utilized as a reinforcement material for composites termed 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 hybrid basalt fiber reinforced concrete (Hy-BFRC) 3% of chopped basalt fiber 50% 6mm Long BF and 50% 12mm Long BF.

Keywords: BFRC, HY-BFRC, Compressive Strength, Tensile Strength, Flexural Strength.

Introduction

Concrete is shaped by combining all of the necessary and practical ingredients, including cement, fine and coarse aggregate, and water. The water used to make concrete must be free of all contaminants and germs. Because it is resistant to all temperatures and conditions, concrete is a successful building material. The fiber reinforced concrete (FRC) is a product of scientists and researchers who are still working to improve the limitations of concrete by adding different fibers, such as glass, steel, synthetic, natural, and basalt fibers, as well as diverse chemical admixtures. Adopting FRC significantly improves concrete's durability and other qualities. Basalt is generally an igneous rock formed by the rapid cooling of molten lava on the earth's surface. Among the rocks that are most commonly found outside of the earth's surface is this one. The origin of the lake, its rate of cooling, and its historical exposure all affect the distribution of basalt rocks. The consistent chemical composition of basalt fiber is what creates highquality fibers. Melting, homogenizing, and extracting the fibers are the three steps in the single-stage process used to produce basalt fibers. This basalt occurs only once. Adopting cold technology to convert these continuous threads of basalt into different materials with lower energy and financial inputs is the next stage. The procedure is performed on a single stone that has been meticulously extracted from the quarry. The selected stone must contain at least 46% silica and very little iron; this kind of stone is used to make items. The stone that possesses both of these characteristics is chosen, cleaned, and then melted at 1,500 °C. This molten rock is then fed through tiny nozzles to create continuous basalt fibers once it has melted. These continuous fibers have a filament diameter of 10 to 20 µm, which is sufficient to make basalt fiber a good substitute for other fiber types. Concrete is quite good at compression, as we all know, but it can only withstand up to 10% of stress. This study aims to perform a number of tests, including flexural, split tensile, and compressive strengths, on three percent of basalt fiber utilized for various mono and HY-BFRC mix combinations. Concrete strength tests were carried out in this study at 7, 14, and 28 days after curing.

EXPERIMENTAL PROCEDURE

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. Then basalt fibers were added by 3% by weight of cement. The attributed illustration of all mixes is given in Table 1.

Table 1: Description of Concrete Mixes.

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

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 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. Table 2 lists the characteristics of BFRP as supplied by the manufacturer.

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

Table 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/m^3)	2700

CASTING AND TESTING OF SPECIMENS

Specimen Details

Compressive strength experiments were conducted using 150 x 150 x 150 mm cubes, split tensile strength tests were conducted using 100 x 200 mm cylinder specimens, and flexural strength tests were conducted using 100 x 100 x 500 mm beam specimens.

Concrete Batching

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.

TEST CONDUCTED

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 (CTM). 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.

Split Tensile Strength Tests (IS 516-1959)

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

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

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.

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. The modulus of rupture and load-deflection curves was plotted in the computer-controlled apparatus itself.

RESULTS AND DISCUSSIONS

Workability

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 specifically, workability is the properties of concrete which can be completely compacted with less energy inputs. The slump cone test employed 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 3 and figure 2 shows the workability test results of all mixes.

Table-3: Workability Test Results

S. No.	Basalt Fiber %	Name of Mix	Slump Value (mm)
1.	0%	Plain Concrete	96
2.	3%	100% 6mm Long BF	78
3.		50% 6mm + 50% 12mm Long BF	71
4.		100% 12mm Long BF	58

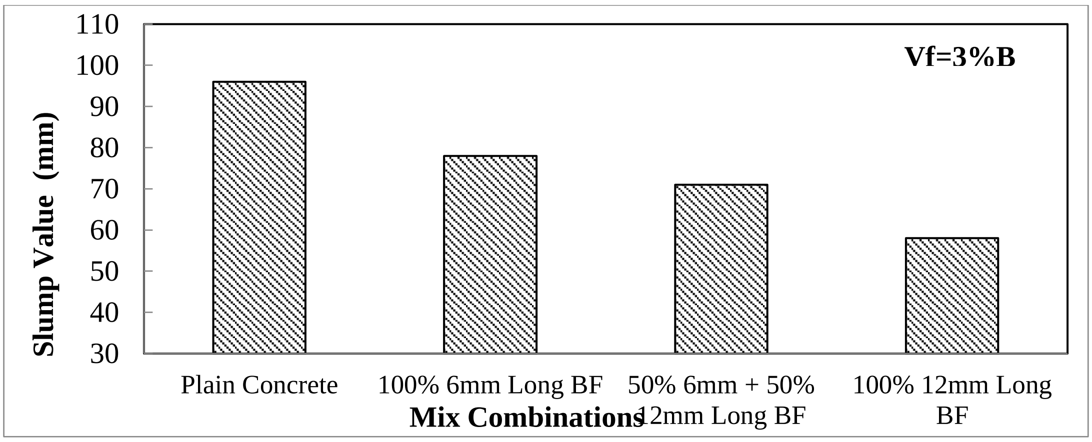

Figure 2: Workability Test Results of mono BF and Hy-BF mixes with plain concrete,(3% BF @100% 6mm, 100%12mm, and 50% 6mm+50% 12mm Long BF)

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Compressive Strength

Basalt fiber 3% 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 3% of basalt fiber increase in compressive strength with respect to plain concrete. Table 4 shows the compressive strength test results of all mixes at all curing ages.

Table 4: 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.	3% BF	100% 6mm Long BF.	17.37	22.18	35.34
3.		100% 12mm Long BF	18.05	21.28	34.54
4.		50% 6mm + 50% 12mm Long BF	19.21	23.18	36.41

The results of the compressive strength test led by adding basalt fiber in plain concrete by weight of cement with 3% have been presented in Fig. 3. It very well may be seen from Fig.3 that the expansion in compressive strength for mono mix in with 3% basalt fiber over the plain concrete (control mix) is 25.4 % expanded at 28 days of curing on adding 6mm Long BF and for 12mm long BF the strength enhanced by 22.5%. Fig. 3 shows practically identical patterns can likewise see from plotted results at other curing dates for basalt fiber mix. It can be observed with 3% volume fraction of BF with respect to plain concrete by adding 6mm +12mm long BF where strength was enhanced by 29.2% 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 3% volume fraction of BF with respect to plain concrete by adding 6mm +12mm long BF where strength was enhanced by 31.21 % with plane concrete and also 25.36% 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.

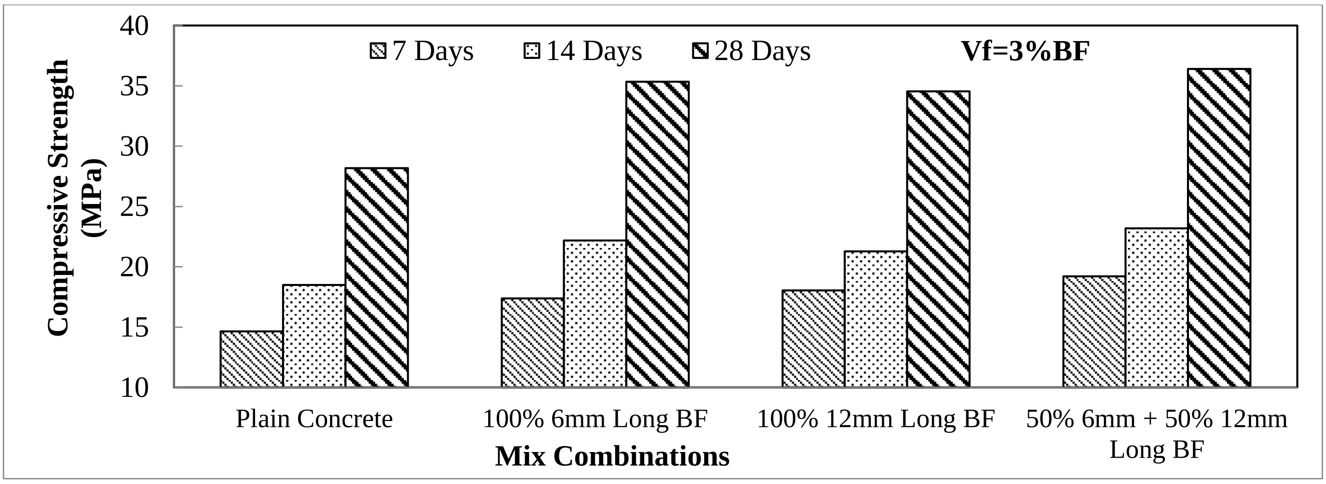

Figure 3: Compressive Strength of mono BF and Hy-BF mixes with plain concrete, (3% BF @100% 6mm, 100%12mm, and 50% 6mm+50% 12mm Long BF)

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SPLIT TENSILE STRENGTH

Basalt fiber 3%, 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 5 and shown in Fig. 3. 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 3% of basalt fiber increase in split tensile strength with respect to plain concrete.

Table 5: 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.	3%	100% 6mm Long BF	1.62	2.22	6.04
3.		100% 12mm Long BF	1.15	2.13	4.59
4.		50% 6mm + 50% 12mm Long BF	1.93	2.32	6.19

The results of the split tensile strength test conducted in plain concrete and mono and HY-BFRC mix made by adding chopped basalt fiber with plain concrete by weight of cement with 3% have been presented in Table 5. It very well may be seen from Fig.4 that the expansion in split tensile strength for mono mix in with 3% basalt fiber over the plain concrete 35.8% expanded at 28 days of curing on adding 6mm Long BF and for 12mm long BF the strength enhanced by 78.7%. Fig. 4 shows practically identical patterns can likewise see from plotted results at other curing ages for basalt fiber mix. It can be observed with 3% volume fraction of BF with respect to plain concrete by adding 6mm +12mm long BF maximum enhancement in splitting tensile strength of 83% 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 concrete with full time water curing only for 7 days with 3% volume fraction of BF with respect to plain concrete by adding 6mm +12mm long BF where strength was enhanced by 89% with plane concrete It seems that the gain in early age strength also enhanced by adding HY-BFRC.

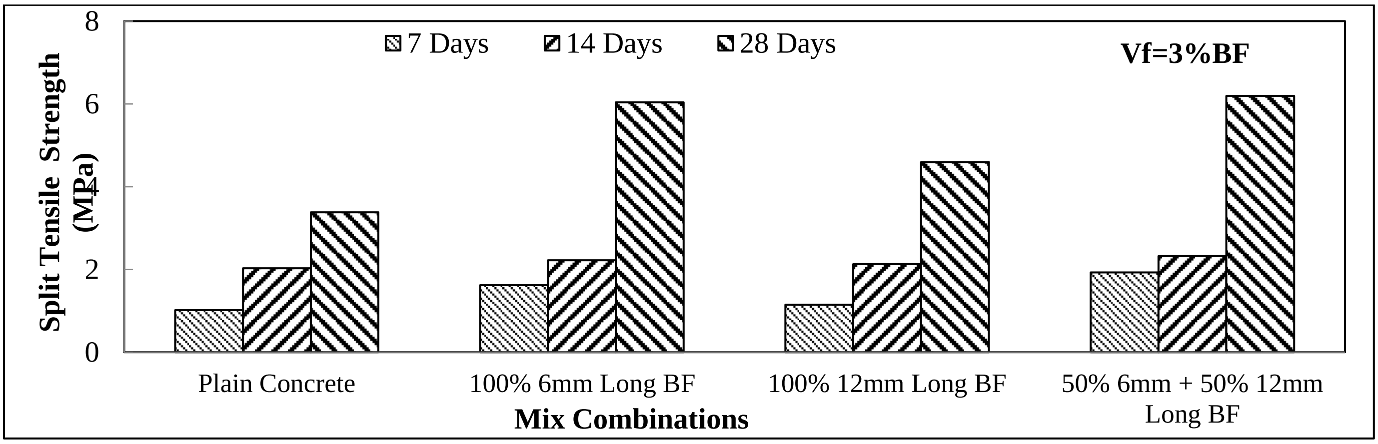

Figure 4: Split Tensile Strength of mono BF and Hy-BF mixes with plain concrete, (3% BF @100% 6mm, 100%12mm, and 50% 6mm+50% 12mm Long BF)

FLEXURAL STRENGTH

The flexural strength results were conducted on mono BF and hybrid BF mixes at 28 days 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 6.

Table 6 Flexural Strength Tests Results at 28 days water Curing.

S. No	Mix Combination		Flexural Strength (MPa) 28 Days
1.	Plain Concrete		3.14
2.	3%	100% 6mm Long BF.	4.65
3.		100% 12mm Long BF.	5.23
4.		50% 6mm + 50% 12mm Long BF	5.66

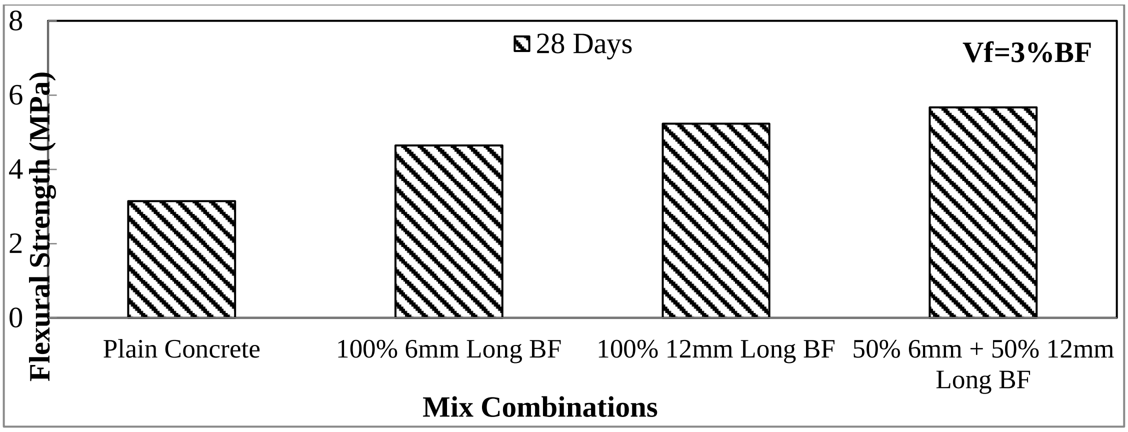

Figure 5 Flexural Strength of mono BF and Hy-BF mixes with plain concrete at 28th day, (3% B.F. @100% 6mm,100 %12mm, and 50% 6mm+50% 12mm Long BF)

Figure 5 presents the results of flexural strength test conducted on plain concrete and mono and HY-BFRC mixes made of different aspect ratios for 3% 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 80% over plain concrete. This is due to arresting of micro-cracks by basalt fibre. It very well may be seen from Fig.5 that the expansion in flexural strength for mono mix in with 3% basalt fiber over the plain concrete (control mix) is 32% expanded at 28 days of curing on adding 6mm long BF and for 12mm long BF the strength enhanced by 66%.

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 3% of chopped basalt fiber (50% 6mm Long BF + 50% 12mm Long BF) Which is 29.2% higher than that of plain concrete, whereas, the lowest enhance in compressive strength is attained by adding basalt fiber 100% 12mm long BF which is 22.5%.

2. The split tensile strength is achieved with 3% of chopped basalt fiber (50% 6mm Long BF + 50% 12mm Long BF) which is 83% higher than that of plain concrete and in this case lower enhance in split tensile strength is observed with 3% of basalt fiber 100% 12mm Long BF.
3. The measured flexural strength is observed maximum with HY-BFRC with 3% fiber and the peak value comes out to be 5.668 MPa which is 80.33% 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 3% of chopped basalt fiber 50% 6mm Long BF and 50% 12mm Long BF.
5. The test results show that the addition of HY-BFRC also increased strength of the early- age concrete.

REFRENCES

1. Kene K.S., Vairagade V.S. and Sathwane S. “Experimental Study on Behavior of Steel and Glass Fiber Reinforced Concrete Composites” Bonfring International Journal of Industrial Engineering and Mangement Science, Vol.2, No.4, (2012): pp 125-130.
2. Sinha D., Mishra C.B. and Solanki R.V. “Comparison of Normal Concrete Pavement with steel Fiber Reinforced Concrete Pavement” Indian Journal of Applied Research, Vol.4, Issue 8, (2014): pp 233-235.
3. Gadgihalli V.,Meena Y.R., Sindu and Dinakar R.P.H. “Analysis of Properties of Concrete Using Steel Fibers as Fiber Reinforcement Admixture” International Journal of Research Granthalayah, Vol.5, Issue 4, (2017): pp 59-62.
4. Pathan M.G. and Swarup A. “A Review on Steel Fiber Reinforced Concrete” Inter. J. of Adv. Res. In Science and Engg., Vol. 06, Issue 01, (2017): pp 819-824.
5. Suhail M.,Kumar C.A. and Reza M. “Structural Health Monitoring Using Carbon Fiber Reinforced Concrete” Journal Emerging Technology and Innovative Research,Vol.5, Issue 7, (2018): pp 523-529.
6. Onal M.M. “Reinforcement of beams by using carbon fiber reinforced polymer in concrete buildings” Scientific Research and Essay, Vol. 4 (10), (2009): pp 1136-1145.
7. Singha K. “A short review on basalt fiber.” International Journal of Textile Science, (2012): pp 166-180.
8. Cao H. “Experimental Investigation on the Static and Impact Behaviors of Basalt Fiber-Reinforced Concrete” The open civil engineering general, (2017): pp 14-21.
9. Kirthika S.K. and Singh S.K. “Experimental Investigations on Basalt Fiber-Reinforced concrete” J.Inst. Eng. India Ser. (2018): pp 661-670.
10. Inman M., Thorhallsson E.R. and Azrague K. “A mechanical and environmental assessment and comparison pf basalt fibre reinforced polymer (BFRP) rebar and steel rebar in concrete beams” Energy Procedia 111, (2016): pp31-40.
11. Soares B., Preto R., Sousa L. and Reis L. “Mechanical behavior of basalt fibers in a basalt-UP composite” Procedia Structural Integrity, (2016): pp 082-089.
12. Jaysingh G.P. and Joshi D.A. “Performance of Basalt Fiber in Concrete” International Journal of Science and Research (IJSR), (2014): pp 1372-1373.
13. I.S. 516-1959, “Indian standard code of practice methods of test for strength of concrete”, Bureau of Indian standards, New Delhi, 1959.
14. I.S. 5816-1999, “Methods of test for splitting tensile strength of concrete”, Bureau of Indian

standard, New Delhi 1999.
15. I.S. 10262-1982, “Recommended guidelines for concrete mix design”, Bureau of Indian standards, New Delhi, 1982.
16. I.S. 1199-1959, "Indian standard code of Methods of sampling and analysis of concrete", Bureau of Indian standard, New Delhi, 1982.