Experimental Investigation on Basalt Fiber Reinforced Concrete

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Abstract
Basalt fiber reinforced concrete (BFRC) has been widely utilized in various constructions such as buildings, large industrial floors, and highways, due to its excellent physical and mechanical properties, as well as low production cost. In order to address the influence of basic parameters such as fiber volume fraction (0.05~0.2%), fiber length (6~12 mm) of BF, Aspect ratio (600 ~ 1200) and compressive strength of concrete on compressive strength, tensile and flexural strength, a series of standard material tests were conducted. After which a mix design for 25Mpa was found by the help of IS 10262. The proposed fiber length and content are 12, 6, 9mm and 0.10% respectively, the fiber diameter being 10 micro meter (based on availability).
Keywords: Basalt fiber reinforced concrete (BFRC), Basalt fibers (BF), mechanical properties

1. INTRODUCTION

Concrete is known as one of the most conventionally and widely consumed construction materials, which has several advantages such as economic, durability, components availability, good performance in a service environment, and high compressive strength. However, plain concrete (PC) is a brittle material with poor tensile properties and low ductility [13-14]. Consequently, plain concrete is susceptible to cracking under tensile stress. When mixed into concrete, randomly distributed fibers can bridge these cracks and arrest their development; therefore, the addition of fibers can enhance the mechanical behavior of plain concrete, such as rheology, tensile strength, flexural strength, fatigue and abrasion resistance, impact, as well as ductility, energy absorption, toughness, and post cracking capacity

Different types of fibers such as asbestos, cellulose, steel, carbon, basalt, aramid, polypropylene, and glass have been used to reinforce cement products [13-14] and to strengthen concrete and steel structures in civil engineering infrastructures and military applications due to their high strength-to-weight ratio, good fatigue performance, and excellent durability properties. Although a variety of fiber-reinforcing materials exist, steel fiber is one of the most used types in fiber-reinforced concrete (FRC) for structural applications. However, steel fiber-reinforced concrete (SFRC) has a low strength-to-weight ratio, weaker corrosion resistance, and fiber balling at high dosages. Thus, glass fiber is a good alternative. Glass fiber reinforced concrete (GFRC) has been used extensively to produce thin, lightweight structural elements. But GFRC may be easily degraded in the alkaline environment of concrete. Although carbon fiber is chemically inert and stiffer, the cost is too high for common engineering applications. In terms of synthetic fibers like polymeric fiber, their low elastic modulus, low melting point, and poor interfacial bonding with inorganic matrices limited their applications

As for the flexural modulus and strength, the addition of basalt fibers can improve the flexural strength even at low contents, as well as the flexural toughness especially when large fiber volume fractions are used.

The effect of the addition of basalt fibers on the static compressive strength of normal concrete and high-strength concrete, as well as on the dynamic compressive strength of concrete, has been investigated extensively over the past few years. Borhan [10] showed that the compressive strength of concrete is increased with increasing the content of basalt fiber up to 0.3% and this enhancement gradually decreases by the further increase of fiber volume fraction. However, Ma et al. highlighted that the variation in content (0.1~0.3%) and length of pre-soaked basalt fiber do not induce an increase in the compressive strength of concrete. Results of several studies also found that the effect of fiber addition (on the compressive strength and modulus of elasticity of the mixtures is insignificant. In contrast, Hau Zang [7] found that the inclusion of BF (>0.2 ~ 0.3 %) in concrete resulted in a decrease in compressive strength. Therefore, the effect of basalt fiber on compressive strength is still not clear based on the conclusions drawn by several research studies.

Based on the literature review, one can see that there is a limited number of studies that address the influence of basic parameters, such as (i) fiber volume fraction and fiber length, on both physical and mechanical properties of BFRC, (ii) the quantitative relationship between mechanical properties of different basalt fiber lengths and fiber content, and (iii) the early shrinkage cracking resistance of BFRC. Accordingly, the main objective of this investigation is to study the effect of the fundamental parameters, namely, fiber volume fraction and BF length on the mechanical behavior of BFRC as compared with that of plain concrete. The fundamental properties of BFRC such as slump, flexural strength, compressive strength and splitting tensile strength are assessed and analyzed.

Basalt fiber (BF) is extruded from melted basalt rock, with an environmentally friendly and non-hazardous nature, and is currently available commercially. The BFs have better tensile strength but are cheaper than the E-glass fibers. In addition, in comparison with carbon fibers, the BFs have good resistance to chemical attack, impact load and fire, and greater failure strain. In comparison with synthetic fibers such as polypropylene fibers and polyvinyl alcohol fibers, the BFs have a higher elastic modulus. In all, BF possesses excellent physical and mechanical properties, including high chemical stability, non-combustible and non explosive nature, resistance to high temperature, and high strength and durability. These favorable characteristics qualify BF to be a good alternative to steel, glass, carbon, or aramid fiber as a reinforcing material for enhancing the mechanical properties of plain concrete. In addition, the availability of surplus raw materials and the low production cost of basalt fiber increase its widespread utilization as a concrete reinforcing material.

For the past decade or so, the majority of published research studies related to the use of basalt fiber-reinforced concrete (BFRC) have focused mainly on identifying the fundamental physical and mechanical properties. The effect of basalt fiber utilization on the workability of concrete has been investigated by Borhan; they concluded that the increase in the percentage of fiber volume leads to a reduction in the slump, resulting in the decrease of the workability, which was the same as other type FRCs.

Considering BFRC tensile strength and crack resistance, the effect of different lengths of BF, inclusion dosage and different types (bundle dispersion fibers and minibars) were investigated. Results of these studies indicated that the increase in the length and fiber dosage of basalt fibers causes a rise in the tensile strength, both types of basalt fibers increase pre-cracking strength, but only minibars enhance the post-cracking behavior.

2. MATERIAL SPECIFICATION SHEET

Basalt is an addition of strength, along with excellent acid, alkali and corrosion resistance characteristics.

Available forms;

• Basalt Additives – For producing high performance engineering thermoplastics. Use as additives in engineering thermoplastics like PTFE (includes Teflon), PEEK, PES and others

• Basalt Roving's – For manufacturing pipes for fertilizer, chemical, oil and gas industries. Also used as a reinforcing material for high pressure applications.

• Basalt Fabrics & Mats – For thermal insulation, fire-proofing and sound-proofing applications.

• Basalt tapes – For inner lining of pipeline used in highly acidic or alkaline environment.

A. Properties

The material specification sheet highlights, properties of material compared to other well-known materials Physical/Mechanical Properties.

Table I - Physical/Mechanical Properties

Properties	UOM	Basalt	E Glass-fibre	Teflon	Steel
Density	g/cc	2.8	2.57	2.16	7.8
Tensile Strength	MPa	4840	3450	31	450
Elastic Modulus	GPa	89	77	0.5	200
Elongation at break	%	3.15	4.7	300	15
Linear Expansion coefficient	x 10K	5.5	5	-	-
Absorption of Humidity	65% RAH	< 0.1	< 0.1	< 0.01	0

B. Thermal Stability

Table II

Properties	UOM	Basalt	E Glass-fibre	Teflon	Steel
Max. application temperature	°C	982	650	-	1095
Max. operating temperature	°C	700	400	260	925
Min. operating temperature	°C	-200	-60	-	-270
Thermal conductivity	W/mK	0.031-0.038	0.029-0.035	0.16-0.24	44
Melting temperature	°C	1450	1120	330	1400
Thermal expansion coefficient	ppm/°C	8	5.4	135	9.5

C. Electrical Properties

Table III

Properties	UOM	Basalt	E Glass-fibre	Teflon	Steel
Specific Volume Resistance	Ω-cm	1012	1011	1018	10 May 2023
Relative Dielectric Permeability	at 1 MHz	2.2	2.3	2.1	-

D. Acoustic Properties

Table IV

Properties	UOM	Basalt	E Glass-fibre	Teflon	Steel
Sound Absorption coefficient	%	0.9 – 0.99	0.8 – 0.93	-	-

E. Chemical Stability

Table V.

Properties	UOM	Basalt	E Glass-fibre
3 Hour boiling in 2N HCl	%	2 – 7	38.5
3 Hour boiling in 2N NaOH	%	6	-
3 Hour in H_2SO_4	%	2 – 6	14 – 22
3 Hour boiling in saturated cement solution (pH 12, 9)	%	0.35	4.5

Figure 1. Basalt fibers

3. LITERATURE REVIEW

The first five literature reviews have been added below to shed some light on the research work carried in the present experimental investigation.

[1] AZZAM et al.

The authors after literature review have found a problem that the basalt fibers are vulnerable to alkali silica reactions and the degradation of fibers happen. The fibers were subjected to 1N NAOH solution for 7 to 28 days and about 50 to 50 % reduction in tensile strength was observed. The use of basalt fiber pellets were done on concrete (pellets are fibers coated with epoxy or poly amide). In this project 3 mixes of concrete were used one with nominal concrete, other mix had 50% cement and 50% supplementary cementitious material, in another mix there was Nano silica modified binders all 3 mixes had 2.5% and 4.5% by volume so a total of 6 mixes were prepared each mixes cubes were casted, test for hardened properties of concrete were done.

The tests were done for two categories of concrete one which was a good cube (un-cracked) and another that was intentionally cracked (pre-cracked).

[2] QIANG et al.

The flexural behaviour of basalt fiber (BF)/polypropylene fiber (PF)-reinforced concrete (BPRC) was investigated. When the content of BF and PF is 0.1%, the addition of fibers increases the compressive strength of concrete. A BF content of 0.1% has the most obvious effect on improving the compressive strength, but a hybrid fiber content of 0.2% exhibits a negative effect on the compressive strength. The addition of BF and PF can increase the flexural strength and the expansion tortuosity of the fracture cracks, thus enhancing the ductility of concrete. The hybrid fibers with content of 0.1% are most beneficial to increase the flexural strength.

However, the ductility of concrete and the tortuosity of fracture crack decrease with the matrix strength, and the improvement proportion of fibers on the flexural strength also decreases. When the BF and PF are mixed, compared to the case of single fiber added, there is no significant change in the damage of BF, whereas the damage of PF is more severe. The flexural toughness index F Tδ effectively characterizes the change in the flexural toughness of BPRC. The hybrid fiber contents of 0.1% and 0.2% exhibit the most significant improving effect on FT-l/600 and FT-l/150, respectively. Considering the influence of fibers on the compressive strength, flexural strength and flexural toughness of concrete, a hybrid content of 0.1% is the optimal choice of fiber content. A prediction model for flexural strength of BPRC is proposed based on the composite material theory.

[3] YEOU-FONG et al.

In this study, the original basalt fiber (BF), and the sizing-removed BF through the heat treatment were pneumatically dispersed by using an air compressor and then were added into normal strength concrete to produce BF reinforced concrete (BFRC). The compressive test, splitting tensile test, and flexural test of BFRC specimens with two types of BF, three types of BF weight ratios, and three different BF lengths were performed. The test results show that the strength of sizing removed BFRC specimens with 10‰ weight ratio was the highest compared to the other BFRC specimens. The sizing-removed BFRC specimens with 6 mm BF exhibit the maximum compressive strength, and sizing-removed BFRC specimens with 24 mm BF have the maximum splitting tensile strength and flexural strength. The sizing removed BF with 10‰ weight ratio and three different types of fiber lengths were used in the impact test; the BFRC specimens with mixed 12 and 24 mm lengths have the best impact resistance performance compared to the BFRC specimens with fixed BF length. From SEM observation of the BFRC specimens after the impact test, the 24 mm BF in the BFRC specimen tends to breakage in this study the authors have used different ratios of basalt fibers (5%, 10%, 15% of weight%) and varied the different lengths.

[4] VINOTHA et al.

In this study the authors have briefed that the basalt fibers can be used as fire, mini bars etc in the concrete mix to improve its strength, they have also stressed the fact that the used of different volume ratios and different aspect ratios of the basalt fibers can impact the strength characteristics of the concrete

The study was done for static and dynamic loading on concrete various basalt fiber volume ratios were used like 0(nominal mix), 0.1,0.3,0.5,1, 1.2% by volume the 1% had more compressive strength than the other mixes. Basalt fiber reinforced concrete is best when it is used as mini bar, chopped, mesh etc. Even though the increase in volume % of fibers gave increase in strength it was for a particular point after which the increase in volume decreased the strength of the concrete.

[5] HAYDER et al.

In this journal the authors have focused on implementing the use of basalt fiber, basalt mini bars etc., in the construction field. The authors have used different volume ratios, of basalt fibers were used

Basalt fibers can be used as fibers, mini bars, rebar's and meshes due to dominant property of increased toughness index, energy absorption capacity

BFRC with minibars of 0.6, 0.9, 1.2, 1.5, 1.8% are used to cast cubes

- Minibars BF fraction improves the ffby 21.8%, 16.4%, and 21.3% but it decreases the fcmby 10.8%, 11.8%, and 9% for HPC12, HPC15, and HPC18, respectively, compared with regular HPC.
- The Minibars BF can provide extra safety measures to the concrete as it delays and prevents sudden failure.
- The ff reached 91–95% of the concrete strength after the 14-day test in comparison to the 28-day test.

The Minibars BF has an insignificant effect on the workability of the concrete.

Summary of literature review

• BFRC with varying volumes were used (0.05 to 0.3%) in the concrete to find its compressive strength the tests showed that the increase in volume % of the fibers decreased the compressive strength of the concrete after a certain volume i.e., (0.15% - 0.2%), hence we are incorporating a volume% of 0.1% [2] which is the optimum amount to get high compressive strength.

• The tests conducted on various aspect ratios were found to affect the mechanical properties of the concrete. The available lengths of the fibers are 6 mm and 12 mm and hence 9 mm has to be cut from the 12 mm for experimental purpose. The fiber diameter to be used is 10 micro meter as per the availability i.e., (9 to 11 micro meter)

A. Objectives of the Investigation

1. In this research an experimental study on strength properties of basalt fibers with varying aspect ratios is conducted.
2. The changes in the strength properties of the concrete according to the change in aspect ratio of the fibers are analyzed.

4. BASIC MATERIAL TESTS

A. Tests on Coarse Aggregates

1. Sieve Analysis

Table VI

Sieve	weight retained	% retained	Cumulative % retained	% passing
25mm	0	0	0	100
20mm	580	11.60%	11.6	88.2
16mm	2060	41.20%	52.8	47.2
12.5mm	1640	32.80%	85.6	14.4
10mm	440	8.80%	94.4	5.6
7.6mm	220	4.40%	98.8	1.2
4.56mm	40	0.80%	99.6	0.4
Pan	20	0.40%	100	0
			∑C=542.8	

2. Bulk Density of coarse aggregate
   - Empty weight of cylinder = 10002 g (w1)
   - Weight of Cylinder with coarse aggregates = 42160 g (w2)
   - Weight of CA (w2 – w1) = 32158 g
   - Height of cylinder = 21cm = 0.21 m
   - Diameter of cylinder = 35cm = 0.35 m
   - Volume of cylinder = $v=\pi r^2 h = 0.02\ m^3$
   - Density of CA = mass/volume = 32.158/0.02 = 1607.9 kg/m^3

3. Water absorption of CA

Table VII

	Trial 1	Trial 2	AVG
Basket + CA in water (A1)	1970 g	1920 g	
Empty basket in water (A2)	660 g	655 g	
CA in water (A=A1-A2)	1310 g	1265 g	
Cloth dried aggregates (B)	1999 g	1999 g	
Oven dried aggregates (C)	1996 g	1996 g	
Bulk S.G = $\frac{C}{B-A}$	2.89	2.71	2.8
Apparent S.G = $\frac{C}{C-A}$	2.9	2.73	2.815
% water absorption= $\frac{100(B-C)}{C}$	0.15%	0.15%	0.15%

4. Angularity number

Table VIII

	Trial 1	**Trial 2**
Weight of empty cylinder (w1)	3680 g	3600g
Cylinder+ aggregate (w2)	8620 g	8760g
Cylinder + water (w3)	6680 g	6600g
Aggregate weight (w=w2-w1)	4940 g	5160 g
Water weight (C = w3 – w1)	3000 g	3000g

Angularity number = 67-$\frac{100\ X\ w}{C\ .G}$

= 67 - $\frac{100\ X\ 4940}{3000X2.8}$ = 8.19 = 8 approx.

= 67 - $\frac{100\ X\ 5160}{3000X2.8}$ = 5.57 = 6 approx.

Average= 7

B. Tests on Fine Aggregates (M Sand)

1. Specific Gravity

Table IX

Empty weight of pycnometer (w1)	642 g
Pycnometer + sand (w2)	940 g
Pycnometer + and + water (w3)	1723 g
Pycnometer + water (w4)	1535 g

Specific Gravity= $\frac{w2-w1}{(w4-w1)-(w3-w2)}$

Specific Gravity = 2.7

2. Bulk Density

Table X

	With compaction	**Without compaction**
Empty weight of cylinder	3600 g	3600 g
Cylinder + sand	9320 g	8880 g
Height	0.17 m	0.17 m
diameter	0.15 m	0.15 m
Volume	3x $10^{-3}m^3$	3x $10^{-3}m^3$

Bulk density with compaction $= \frac{9.32-3.6}{3X10^{-3}}$ = 1906.6 kg/m^3

Bulk density without compaction $= \frac{8.88-3.6}{3X10^{-3}}$ = 1760 kg/m^3

3. Water Absorption

Table XI.

	Trial 1	Trial 2
Saturated weight of sand	100	110
Oven dry weight of sand	90	100
Water Absorption	10%	9.09%

Average = 9.54%

4. Sieve Analysis

Table XII.

Sieve	weight retained	% retained	Cumulative % retained	% passing
4.75mm	2 g	0.20%	0.2	99.8
2.36mm	79 g	7.90%	8.1	91.9
1.1mm	248 g	24.80%	32.9	67.1
600mm	142 g	14.20%	47.1	52.9
300mm	297 g	29.70%	76.8	23.2
150mm	164 g	16.40%	93.2	6.8
pan	64 g	6.40%	99.6	0.4
			∑C=357.9	

From IS 383 table 9, it is in zone II

Table 9 Fine Aggregates
(*Clause* 6.3)

Sl No.	IS Sieve Designation	Percentage Passing			
		Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
(1)	(2)	(3)	(4)	(5)	(6)
i)	10 mm	100	100	100	100
ii)	4.75 mm	90-100	90-100	90-100	95-100
iii)	2.36 mm	60-95	75-100	85-100	95-100
iv)	1.18 mm	30-70	55-90	75-100	90-100
v)	600 µm	15-34	35-59	60-79	80-100
vi)	300 µm	5-20	8-30	12-40	15-50
vii)	150 µm	0-10	0-10	0-10	0-15

C. Tests on cement

1. Standard consistency

Table XIII.

% of water added	Reading in mm
25	30
26	25
27	14
28	10
29	8
30	6

2. Specific gravity

Table XIV.

	Weight in g
Empty weight of density bottle(w1)	41 g
Bottle + cement(w2)	90 g
Bottle + cement + kerosene(w3)	159 g
Bottle + kerosene(w4)	130 g
Bottle + water(w5)	150 g

Kerosene S.G = $\frac{w4-w1}{w5-w1} = \frac{130-49}{150-49} = 0.8$

Cement S.G = $\frac{\mathrm{w2-w1}}{(\mathrm{w4-w1})-(\mathrm{w3-w2})}$ X 0.8

= $\frac{130-49}{(130-49)-(159-90)}$ X0.8 = 2.73

3. Setting time of cement

Table XV

Time	Reading
10	0
20	0
30	0
35	0
40	0
45	0
50	0
55	1
60	1
65	1
70	2
75	2
80	2
85	3
90	3
95	3
100	3
105	4
110	4
115	4
120	4
125	5

Initial setting time = 125 minutes
Final setting time = 475 minutes

5. CONCRETE MIX DESIGN

1. Given
M25 grade concrete
Cement 43 grade
Specific Gravity of FA = 2.7
Specific Gravity of CA = 2.8
Specific Gravity of cement = 2.73
Pumpable concrete
Water absorption (Coarse Aggregates= 0.15%; Fine Aggregates= 9.54%)
Fine aggregate is zone II quality
2. Target strength
(f'ck = fck + 1.65S) (or) (f'ck = fck + X)= 25 + (1.65x4) = 25+5.5= 31.6 N/mm2 = 30.5N/mm2, Max = 31.6N/mm2
Air content = 1% for 20 mm nominal aggregate
Water to cement ratio

Curve 1 = 33
Curve 2 = 43
Curve 3 = 53
w/c = 0.48 (according to curve)
3. Water content
20mm – 186kg for 50mm slump
Increase water content by 3% for every increase in 25 mm slump.
Slump of 100 mm is required as FRC fibers decrease workability.
For 100 mm slump 186 + $\frac{6X186}{100}$ = 197.16 kg = 198kg approx.
4. Cement content = 198/0.5 = 396 Kg/m^3
5. Coarse Aggregate
For zone II Fine Aggregates of 0.5 w/c ratio volume of Coarse Aggregates is 0.62
Increase or decrease of 0.05 in water/cement ratio
Increase or decrease 0.01 in Coarse Aggregate volume 0.62.
If it is pumpable concrete, then volume decreases by 10%
0.62 X 0.9 = 0.558 (Coarse Aggregate volume)
1-0.55 = 0.442 (Fine Aggregate volume)
a) 1m3 – vol. of concrete
b) Vol. of air = 0.01
c) Vol. of cement = $\frac{396}{2.73X1000}$ = 0.145/m^3
d) Water = $\frac{198}{1X1000}$ = 0.198/m^3
(a-b) + (c + d + e)
(1-0.01) + (0.145 + 0.198 + 0) = 0.647/m^3
6. Mass of Coarse Aggregates
e X Vol. X S.G X 1000
0.647 X 0.558 X 2.8 X 1000
1011 kg/m^3
7. Mass of Fine Aggregates
773 kg/m^3
Ratio = 1: 1.95: 2.55
The amount of super plasticizer to be used is 2% of the weight of cement. The IS code 10262: 2019 is followed for mix design when super plasticizer is to be used however slump was not appropriate. Hence the mix proportion for M25 was added with 2% of super plasticizer without reduction of water.

6. EXPERIMENTAL PROGRAMME

A. Materials

Cement of 43 grade with Specific Gravity of 2.73 is used. Along with M sand with Specific Gravity 2.7, water absorption is 9.54%, belongs to the zone II category (IS 383 and Coarse aggregates with Specific Gravity of 2.8 and a nominal size of 20 mm. Fosroc conplast SP 430DIS as a super plasticizer. Chopped Basalt fibers of 6 mm, 9 mm, 12 mm in length and 0.1 micrometer diameter have been utilized. The concrete mix design is done for M25-grade concrete.

B. Trials

To obtain the desired concrete mix proportion the mix design is made referring IS code book IS 10262 and it is checked for slump. Where it failed to obtain 100mm slump, hence the use of super plasticizer is incorporated with different trials in different % of super plasticizers to obtain desired slump. The desired slump is obtained by using 2% of super plasticizer (Fosroc Conplast SP430DIS). The optimum slump of 100 mm is chosen as the use of fibers can decrease workability.

C. Mix Design and proportioning

The mix design is done for M25 grade concrete according to IS 10262, the ratio obtained was 1: 1.95: 2.55, 0.5 w/c ratio and an addition of super plasticizer is done to get the required slump 100 mm. During our trials for slump, it is observed that 2% of weight of cement gave good slump value of 110 mm hence it is incorporated. For basalt fibers the optimum amount of fibers that is 0.1% of volume of mould is used. The amount of basalt fibers having variable aspect ratios is taken into consideration.

D. Casting of cubes, cylinders, beams

The concrete is mixed according to the mix design ratio in the pan mixture. First the cement was added then the M sand and later the coarse aggregate, the mixture was first dry mixed and then half quantity of water was added to the remaining quantity super plasticizer was mixed and then added the mixture was mixed thoroughly. The moulds are oiled and kept ready for the casting; we added 3 to 4 layers of mixed concrete and were tamped well. For fibre reinforced concrete, some amount of the fibers for each layer is added and tamped thoroughly. After tamping and evenly leveling, the moulds are kept on the vibrator. The quantity of fibers used for each mould is 0.1% of the volume of the mould. It varied for cubes, beams and cylinder.

Curing (traditional water bath) is done for 28 days and then the tests are conducted. The moulds are demoulded the next day and they were dried a day prior before testing.

7. TESTING

A. Compressive strength test

The compression test for all the cubes casted is done using the compression testing machine. The specimen is of the size 150mmX150mmX150mm loading is set at rate of 5MPa. A total of 3 specimens were tested for each concrete i.e. NC (normal concrete), 6 mm BFRC, 9 mm BFRC, 12 mm BFRC. The average value of all the 3 is taken into consideration.

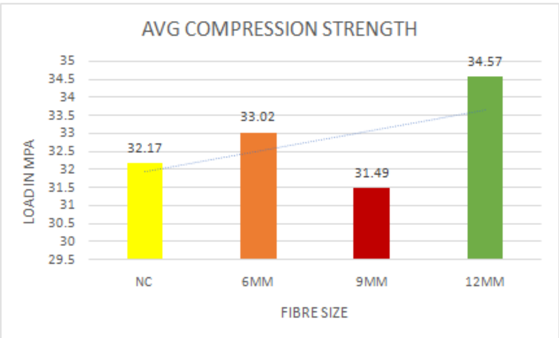

Figure 2

Table XVI

COMPRESSION STRENGTH IN MPa

NC	6MM	9MM	12MM	
31.11	34.8	28.68	33.43	
32.61	32.44	33.32	32.81	
32.78	31.82	32.46	37.47	
32.17	33.02	31.49	34.57	Average

B. Flexural Strength Test

The flexural property of the casted beams is tested using flexural testing machine. The beams used are of the size 500mmX100mmX100mm, the amount of fibers used is 0.1% of the volume of the mould. The formulae for finding the flexural strength is $\frac{3Pa}{BXD^2}$where 'a' is the distance from the crack to the edge of the line leaving 5cm from the corner. If 'a' is b/w 170 to 210 mm, the reading is accepted. If a>210 then $\frac{3PL}{BXD^2}$ where L is 400, discard the reading. The beams are cured for a period of 28 days too. The addition of fibers is done by layer wise while pouring concrete in the moulds. Same as the cubes, then the concrete moulds are placed on vibrators to remove air bubbles.

Figure 3

Table XVII

FLEXURAL STRENGTH IN Mpa

NC	6MM FIBRES	9MM FIBRES	12MM FIBRES	
4	4	6.38	7.02	
4.01	4.05	4	5.4	
4.05	4.23	5	6.01	
4.02	4.1	5.13	6.15	Average

C. Split Tensile Strength

The split tensile strength of the cylinders is found by using the digital compression testing machine. Here the dimension of the cylinder is entered and the cylinders are placed between the two plates, then the machine is turned on, the digital tab provides the load and strength of the cylinder. The maximum load P is taken and inserted in the formula $\frac{2P}{\pi DL}$. Then the split tensile strength is calculated in MPa.

Figure 4

Table XVIII

SPLIT TENSILE STRENGTH IN Mpa 0.1% OF FIBRES

NC	6MM FIBRES	9MM FIBRES	12MM FIBRES	
2.65	2.57	2.42	2.59	
2.25	2.75	2.47	2.66	
2.4	2.51	2.45	2.61	
2.44	2.61	2.45	2.62	Average

8. CONCLUSION

• Concrete is known as one of the most conventionally and widely consumed construction materials, which has several advantages such as economic, durability, components availability, good performance in service environment, and high compressive strength. However, plain concrete (PC) is a brittle material with poor tensile properties and low ductility.

• Consequently, plain concrete is susceptible to cracking under tensile stress. When mixed into concrete, randomly distributed fibres are able to bridge these cracks and arrest their development; therefore, the addition of fibres can enhance the mechanical behaviour of plain concrete, such as rheology, tensile strength, flexural strength, fatigue and abrasion resistance, impact, as well as ductility, energy absorption, toughness, and post cracking capacity

• The addition of basalt fibres enhanced the compressive strength of the concrete. The average compressive strength of NC, 6mm BFRC, 9mm BFRC, 12mm BFRC are 32.17Mpa, 33.02Mpa, 31.49Mpa, 34.57Mpa respectively. There is an increase in 2.6% in 6mm BFRC, 7.46% in 12mm BFRC and we saw a decrease in 2.11% of strength in the 9mm BFRC. (NOTE: All the strengths are average strengths)

• The addition of basalt fibres increased the flexural strength in the concrete, the average flexural strength of NC, 6mm, 9mm, 12mm BFRC are 4.02, 4.1, 5.13, 6.15Mpa respectively. Thus showing an increase in flexural strength of 1.99% in 6mm, 27.61% in 9mm, 52.98% in 12mm BFRC respectively.

• The average split tensile strength of NC, 6mm, 9mm, 12mm BFRC are 2.44,2.61,2.45,2.62Mpa respectively. Hence the increase in split tensile strength are 6.96% for 6mm, 0.41% for 9mm, 7.37% for 12mm BFRC.

• Hence from our study we come to know that the use of fibres did increase the performance of concrete but the 12mm and 10 micro meter diameter fibre was the best at all the 3 test hence the usage of 12mm basalt fibre would be great for any kind of BFRC construction.

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