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Ductile Response of Basalt Fibre Reinforced Concrete Beams

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Abstract: ***This paper presents the effects of adding basalt fibres on reinforced concrete beams. The fibre volume fraction V_f ranges from 0.0 to 2.0 %. First crack load, service load, yield & ultimate load and their corresponding deflections were noted. The ductility response of BFRC beams were evaluated. The results show that 1.5% by volume of basalt fibre improves the overall performances. The maximum increase in deflection and energy ductility was found to be 34 % and 39% respectively when compared to that of reference beam. The increasing application of basalt is noticed as an insulating material in the construction and automotive industry and less hazardous than asbestos fiber. Basalt fabrics are produce***

d for the structural, electro-technical purposes. Structural applications include electromagnetic shielding structures, various components of automobiles, aircraft, ships and household appliances.

Keywords: Basalt fibre, Deflection, Ductility, Strength and Crack width.

I. INTRODUCTION

Concrete is one of the foremost customarily devoured development material. It has a few preferences but also it has few impediments [1],[2]. Basalt rocks with respect to the geographical site, its chemical composition differs, and however they show good physical stability with both chemical and mechanical properties [3],[4]. Addition of small, randomly distributed fibres will help to improve the ductility and durability of cemented composites [5]-[7]. Basalt fibre has some properties like high tensile strength, good chemical resistance, dimensional stability, high heat resistance, fire resistance, excellent fibre- resin adhesion, good thermal conductivity and nontoxic [8].

In recent times, basalt fibre has attained popularity due to its Pre-eminent mechanical features and eco-friendly manufacturing process [9]. Basalt reinforced composites are one of the recently developed material widely used for reinforced concrete. These materials can be used in lieu of carbon fibres for their low cost and to glass fibre for their strength. Most of the studies has proven that basalt fibre addition results in improved tensile strength and reduces brittleness [10],[11].

This study focusses on adding basalt fibre in RC beams to enhance the ductility response of beams. This experimental study consists of testing five beams, one of which is normal RC beam, which is considered a reference beam, and other beams with basalt fibre in the fraction of the volume 0.5%, 1.0%, 1.5% and 2.0% respectively.

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II. METHODOLOGY

III. EXPERIMENTAL PROGRAM

Material

Basalt is the name given to a wide variety of volcanic rock produced from volcanic lava after solidification, which is grey, brown or dark in colour. There is olivine, salite, plagioclase, and invisible metal oxides in the highly thickene lava. Plagaeocene and pyroxene make up 80 per cent of basalt. Some typical physical properties of basalt fibres are shown in Table I.

Table- I: Physical properties of basalt fibres

Density (g/cm^3)	2.75
Elongation (%)	2.8
Length (mm)	18
Size (mm)	1
Specific Gravity	2.72
Elastic Modulus (GPa)	85
Tensile Strength (GPa)	4.83

Ordinary Portland cement (OPC- 43 grade), which is confirmed from IS: 8112 (2013), was used in the concrete mix. With a specific gravity of 2.54, the sand used was local natural river sand.

The coarse aggregate used has been crushed granite with a maximum size of 20 mm and a specific gravity of 2.67 verified by IS: 382-2016. Concrete grade M20 was utilized in this research. The proportion of the built mix was 1:2.0:2.81:0.50. Different dosage (0.5 – 1.0% by weight of cement) of super plasticizer was used to maintain a slump of 50 – 100 mm for concrete specimens with fibres.

IV. PRELIMINARY TEST RESULTS

A. Compressive Strength

The preliminary results are presented in Table II. Compressive strength is characterized as the materials ability to withstand the load which reduces their size. Concrete is generally strong in compression, and can display high strength. But incorporating different lengths and content of basalt fibre has no effect on significant concrete compressive strength.

Table-II: Preliminary test result of specimens

Beam ID	B 0	B 0.5	B 1.0	B 1.5	B 2.0
Fibre volume fraction, vf (%)	0	0.5	1.0	1.5	2.0
Compressive strength, MPa	27.20	27.72	28.78	31.48	29.16
Modulus of rupture, MPa	4.52	4.68	4.84	5.38	5.16

B. Modulus of Rupture

The modulus of rupture is important in the construction and engineering sector to ensure that the material is strong enough to be used in structures. The flexural resistance is known as the capacity of the material to withstand deformation under load. The finding of the flexural concrete strength test using prism for various samples showed that the flexural strength of concrete increases with age for all the concrete. This suggest that the impact made by mixing basalt fibre with concrete increase its flexural strength. The modulus of rupture increases 19 % with 1.5 % fibre content, after that the strength gets reduced.

V. EXPERIMENTAL INVESTIGATION ON BEAMS

A. Beam Details

There were a total of five beams cast and examined in this analysis. The research program was designed to study with and without fibres, the ductile response of reinforced concrete beams. The beams in cross-section were 150 mm × 250 mm, and 3000 mm wide. A reinforced concrete beam B 0 was used as reference beam. B 0.5 was cast with a fraction of the total fibre volume of 0.5 per cent. B 1.0 was casted with a minimum 1.0 percent fiber volume fraction. B 1.5 was casted with a fraction of the total fibre volume of 1.5 percent and B 2.0 was casted with a minimum 2.0 percent fibre volume fraction. The details of test beams are presented in Table III.

Table- III: Details of test beams

Sl. No.	Fibre volume fraction, V_f (%)	Beam dimension (mm)	Tensile steel ratio (%)
1	0	150 × 250 ×3000	0.60
2	0.5		
3	1.0		
4	1.5		
5	2.0		

B. Preparation of Test Beams

Cement, sand, coarse aggregate and fibres were placed and then dry mixed. To this dry mixture, 80% of the water and 60% of the Superplastizer were added slowly and mixed thoroughly. The remaining water and superplastizer were finally added slowly to the mixture and mixed. Steel moulds were used for casting beam specimens. Care was taken to see that the concrete was properly placed, evenly compacted and properly cured.

C. Testing Procedure

All the beams were tested under a four-point bending until failure. The test set-up details are shown in Fig.1. The deflections were assessed using 0.01 mm mid-span and at load point's precision mechanical dial gauges. On the compression side of the specimen, dial gauges were placed over supports to measure slope at both ends. A specially designed mechanical dial scale was also used to measure deflection at ultimate load level and a crack deduction microscope was used to measure the cracks at various stages of loading.

All Dimensions in mm

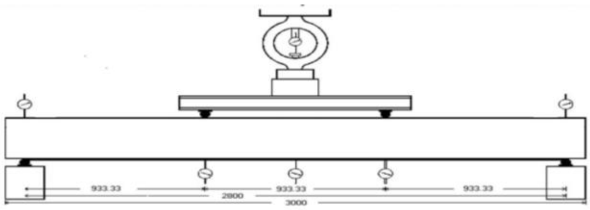

Fig. 1. Test setup

VI. RESULTS AND DISCUSSION

The results of beams are presented in Table IV. On addition of basalt fibres the characteristic of the reinforced concrete beam improves which is reflected by the increase in strength and deformation. The BFRC beams show an increase in deflection relative to the reference beam with fibre content rising at all load levels. The first crack load and their subsequent deflection was observed up to 60% and 118%; the maximum yield and ultimate load rise was 31% and 36% respectively, with 1.5 percent fibre content compared to the beam efficiency of comparison. The maximum service, yield and ultimate deflection were found to be 81%, 26% and 68.7% relative to the reference beam. The comparison of the load at different stages as shown in Fig.2.

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Table-IV: Test result of beams

Sl. No.	Beam ID	First crack		Service		Yield		Ultimate		Maximum crack width (mm)
		Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	
1	B 0	12.26	1.58	28.32	4.90	39.24	12.10	42.48	32.00	0.64
2	B 0.5	14.71	2.18	32.36	8.20	41.70	12.78	48.54	39.60	0.60
3	B 1.0	17.16	3.05	35.37	7.76	48.60	13.48	53.60	47.00	0.56
4	B 1.5	19.62	3.45	38.57	8.89	51.50	15.26	57.85	54.00	0.48
5	B 2.0	17.16	3.20	37.15	9.76	49.10	13.98	55.72	49.00	0.50

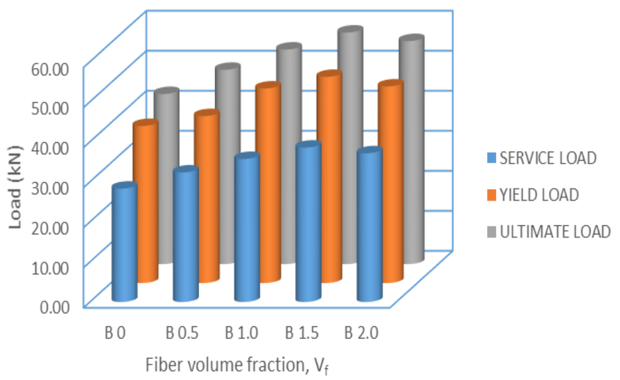

Fig. 2. Load comparisons of beams

C. Load Deflection Response

All the beams were tested in the loading frame under four point bending to observe beam behaviour in detail, and load was noted after each 2.5 kN interval. A significant difference in the behaviour of RC beams with plain and basalt was noticed in flexural research. From the graph it was observed these curves show a linear variation in the initial stages of loading and then the curves are significantly non-linear and reach its peak at the ultimate load (Fig.3).

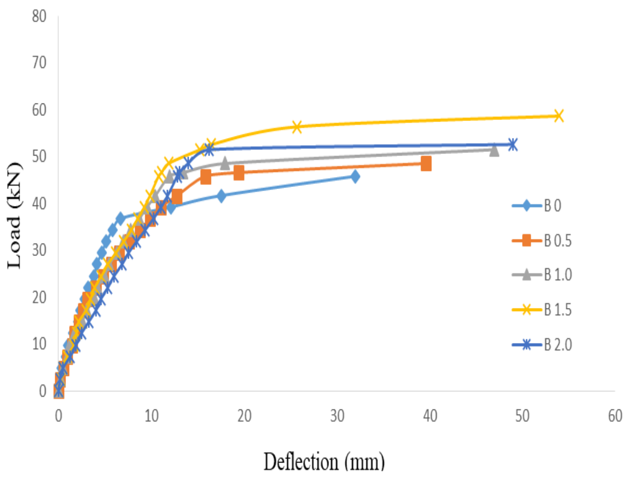

Fig. 3. Load deflection behavior of beams

D. Effect on Ductility

Ductility is the relative ability of material to stretch plastically without fracturing at room temperature. By injecting isolated fibers into concrete matrix at random, concrete can be changed to function in more ductile way [12].The ductility of beams are presented in Table V. It may be concluded that the RC beam with basalt fibres display greater deflection and energy ductility 34% and 39% respectively. The ductility enhancements are shown in Fig.4.

Table-V: Ductility ratio of tested beams

Sl.No.	Beam Id	Deflection ductility	Energy ductility	Deflection ductility ratio	Energy ductility ratio
1	B0	2.64	2.86	1.00	1.00
2	B0.5	3.10	3.61	1.17	1.26
3	B1.0	3.49	3.85	1.32	1.34
4	B1.5	3.54	3.97	1.34	1.39
5	B2.0	3.51	3.98	1.33	1.39

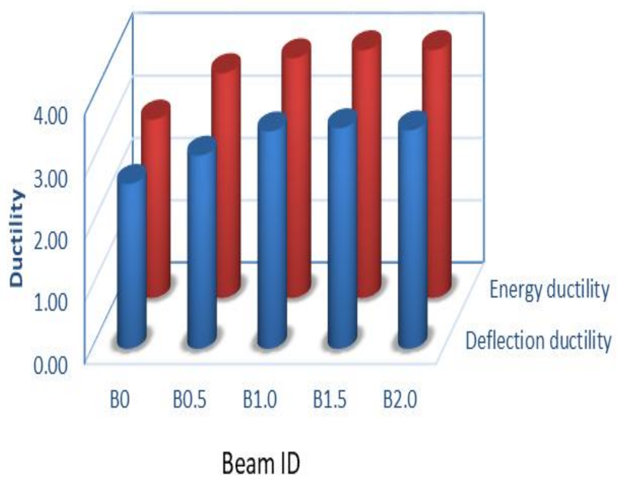

Fig. 4. Ductility of beams with and without fibre

E. Response on Crack width

From Table IV, it was seen that the BFRC beam illustrates decrease in crack width with increase of fibres up to 1.5% beyond that the crack width increases. Fig.5 shows the crack width behaviour of the beam with and without fibres.

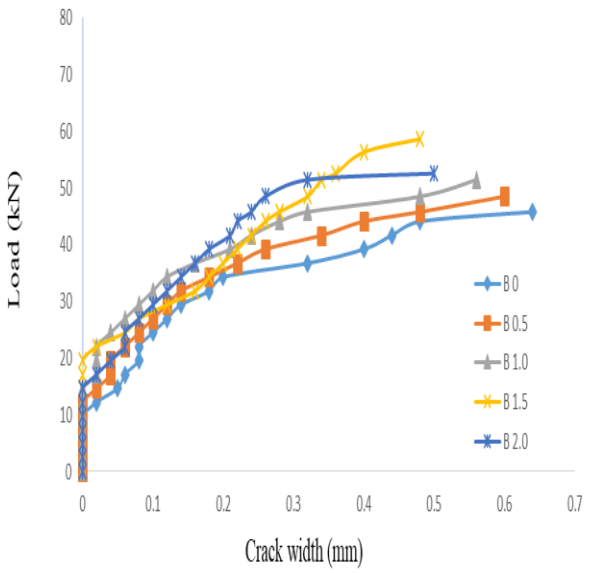

Fig. 5. Crack width behaviour of beams

F. First crack load

The Behaviour of first crack loads at various stages of beams was noted and results are graphically presented in Fig.6. Crack propagation and section separation were resisted by the randomly controlled fibres traversing the cracked section. [13],[14]. The addition of basalt fibre the crack are arrested in the first crack load, and it was gained B1.5 beam was up to 60% when compared to reference beam. So there is a good bond between concrete and fibre helps to resist the crack.

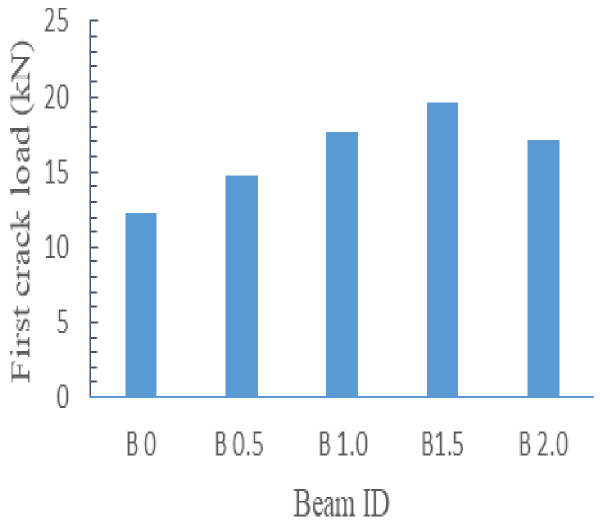

Fig. 6. Behaviour of first crack loads at various stages of beams

G. Ultimate crack load

Naturally, micro cracks appear in concrete due to shrinkage and as they continue to grow, they may intertwine with each other and become larger, creating visible cracking in the concrete. By intersecting and stopping their growth, basalt fibre counteracts this by reducing cracking and creating a more aesthetically pleasing in beams. From Table IV & Fig.7. It is observed that the ultimate crack formation was delayed 36% than that of the reference beam.

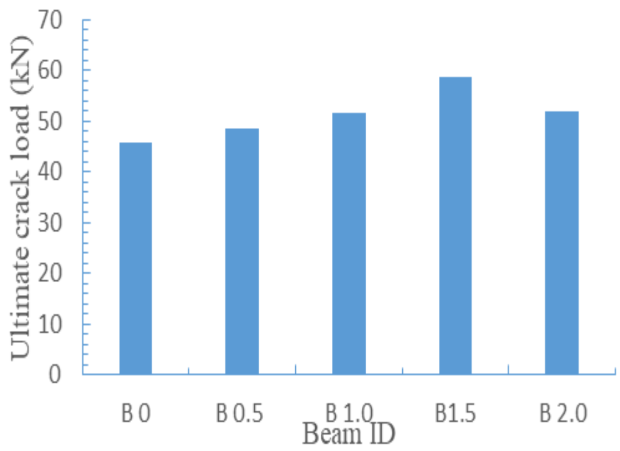

Fig.7. Ultimate crack Load of beams with and without fibres

H. Effect on crack width

Fibres can be effective in arresting cracks at various levels and at various stages of loading [15],[16]. It is evident from Table IV & Fig.8 that the BFRC beam with fibres exhibit lesser crack widths upto 25% with 1.5% relative to the reference beam. Cracks in the BFRC beams become smaller, narrow and closer due to inclusion of fibres.

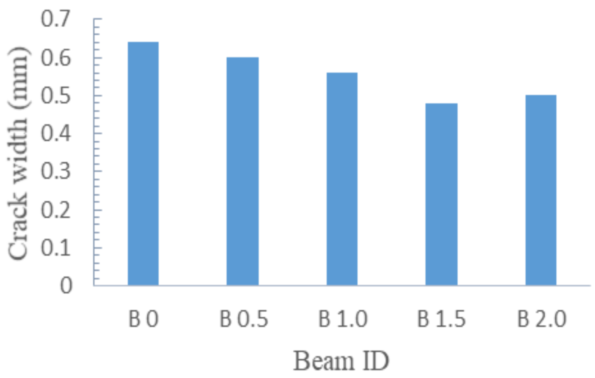

Fig. 8. Maximum crack width of beams with and without fibres

I. Failure modes

The beam compressive flange softens and the section's centre of rotation goes down, rising the inner level limb. Ductile flexural failure occurs when the ultimate capacity of the compressive zone in concrete is reached. Table VI shows the failure modes of all the tested beams. The mode of failure for the reference beam was crushing and at the basalt fibre reinforced beam, it was modified from brittle to ductile manner. Also it was found the failure was not sudden for beams with fibres. The randomly oriented fibres traversing the cracked section resisted crack propagation and section separation. The typical failure mode of tested beams is shown in Figs. 9 (a) & (b)

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Table-VI: Failure modes of tested beam

SI. No.	Beam ID	Mode of failure
1	B 0	Crushing
2	B 0.5	Flexural
3	B 1.0	Flexural
4	B 1.5	Flexural
5	B 2.0	Flexural

(a) Failure mode of reference beam (without fibre)

(b) Failure mode of RC beam with fibre (1.0%)

Fig. 9. Typical failure of RC beams with and without fibre

VII. CONCLUSIONS

1) Strength and ductility of basalt fibre reinforcement beams increased with increasing fibre volume fraction up to 1.5%.
2) The basalt fibre reinforced concrete beams exhibit increase in yield and ultimate load was up to 31% and 36% respectively and their corresponding deflection was found up to 26% and 68.7% compared to that of reference beam.
3) The maximum reduction in crack width was observed 25% than that of reference beam.
4) The maximum deflection and energy ductility increase was found to be 34 % and 39 % respectively relative to the reference beam.

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