“EXPERIMENTAL INVESTIGATION ON BASALT FIBRE-REINFORCED CONCRETE”

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ABSTRACT:

Fibres are used in concrete to improve its structural integrity. Nowadays, among all basalt fibres, an inert mineral fibre is gaining more importance due to its exceptional properties, which include resistance to corrosion and low thermal conductivity. It also improves tensile strength, flexural strength and toughness of concrete. It can be used to extend the life of important concrete structures such as nuclear power plants, highways, bridges and runways. Basalt fibre in concrete is still an exploratory area due to limited studies. Therefore, a systematic study on basalt fibre-reinforced concrete was carried out with percentage volume fraction of fibre 0.50 (13.0 kg/m3), 0.75 (18.36 kg/m3) and 1.00 (24.48 kg/m3). The increase in compressive, splitting tensile and flexural strength is in the order of 26.80, 44.06 and 53.22%, respectively, for 0.50% dosage of basalt fibre as compared to control concrete. In addition, basalt fibre is found to be amorphous and hydrophilic in nature.

Keywords- Basalt fibre, Compressive strength Fibre-reinforced concrete (FRC) ,Basalt fibre-reinforced concrete (BFRC) , Hydrophilic

1) INTRODUCTION

Concrete is a composite material having high compressive strength but low tensile strength. Fibres are used in concrete to improve its tensile strength, flexural strength, toughness, impact, fatigue resistance, abrasion resistance and ductility characteristics. The most commonly used fibres are steel, glass, carbon, aramid, polypropylene, nylon and polyester. The properties of this concrete depend on fibre types, its geometries, orientations and densities. In recent years, basalt fibre in concrete is found to be cost effective having excellent properties than other fibres. Basalt, an igneous, extrusive rock (volcanic magma which solidifies in open air), is generally found near East Asian countries among which Russia has abundant reserves. In India, these rocks are found near Deccan Plateau. Basalt fibres in concrete exhibit higher ultimate strength and Young’s modulus and add stiffness to the concrete. Basalt fibres also have excellent insulating properties, resistance to heat and chemicals as compared to other fibres. Basalt fibre, which is typically a ceramic fibre, is dispersed easily when mixed in concrete or mortar. The cost of basalt fibre is relatively higher than of polypropylene, nylon and other types of fibres, but it is lesser than the carbon and S-glass fibres. It is also more stable than organic and synthetic fibres under a radioactive ambiance. The research on and development of basalt fibre and its composites are started in early 1980s, but, in the last 5 years, there is extensive research on mechanical properties and durability of basalt fibre- reinforced concrete (BFRC), basalt fibre-reinforced plastics (BFRP) and basalt fibre rebars (BR). It is found that basalt fibres possess relatively good resistance to water and salt corrosion, moderate resistance to acid corrosion and severe degradation in an alkaline environment. However, in initial study, Ramachandran et al. opined that it has excellent resistance to alkalinity but it has poor resistance to acids. Sim et al. found that the reduction in compressive strength of BFRC is only 10% at elevated temperature of 600 _C. Addition of basalt fibres in concrete significantly improves tensile strength, flexural strength and toughness of concrete mix. It also improves fracture energy and abrasion resistance. Dias et al. studied the fracture toughness of the geo-polymeric concrete and found that basalt fibre geo-polymeric concrete 4is much better than normal geo-polymeric concrete. Donget al. observed that recycled aggregate concrete embedded with basalt fibres increases deformability of the concrete by better bonding between the cement paste and aggregates. A very few researches have explained the efficiency of basalt fibres in concrete. Therefore, a more systematic study on BFRC is required. This study presents characterization of basalt fibres and mechanical properties of BFRC with different volume fractions. The prediction formulae to calculate flexural strength and elastic modulus of BFRC based on the regression analysis are also given in this study.

i. Objective

- To study the properties of concrete with or without basalt fibre.
- To study the properties of hardened concrete such as compressive strength, splitting tensile strength and flexural strength.
- Experimental study on concrete when basalt fibre added in proportion.

ii. Basalt fibre

Basalt fiber (BF) is a kind of Hi-Tech fibre which is developed by former Soviet Union through more than 30 years' research; it has many unique advantages, such as outstanding mechanics performances, high temperature-resisting, acid and alkali-resisting, etc. Basalt fibre reinforced concrete (BFRC) is a kind of fibre reinforced concretes, it is prepared through utilizing concrete as base body and BF as strengthening material. As one of fibre reinforced composites, it is considered to have favourable development prospect in 21st century. BF's effect on fracture toughness of BF reinforced inorganic polymer cement concrete was studied, and the effect was compared with experiment results of BF reinforced Portland cement concrete. BF has ever been used to reinforce mechanical properties of concrete in experimental studies. The mechanical properties and application of BF and BFRC have ever been investigated. Experiment studies on dynamic properties of BFRC have also been carried out. At present, studies on BFRC's impact- mechanics properties are less, however the studies on impact-mechanics properties of material have important theory significance and application value. In this paper, the impact test on BFRC was carried out using 100mm-diameter split Hopkinson pressure bar (SHPB) device, BFRC's impact- mechanics properties were investigated according to dynamic stress-strain curves and testing data obtained.

iii. Characteristics 0f basalt Fibres

Chemical Properties

1) Basalt are more stable in strong alkalis.
2) Weight loss in boiling water, Alkaline and acid is also significantly lower.
3) Basalt fibers have very good resistance against alkaline environment, with the capability to with stand pH up to 13-14.
4) It also has good acid and salt resistance

Physical properties

1) Colour: It is available in golden brown colour.
2) Diameter: It is available in different diameter like 5.8 micron.
3) Length: Available in 6mm, 8mm, and 12mm.
4) Density: Density of basalt fiber is 2.75g/cm^3.
5) Coefficient of friction: The coefficient of friction may be between 0.42 to 0.50.

Thermal Resistance

1. Basalt fiber has excellent thermal properties to that of glass fibers.
2. It can easily withstand the temperature of 1200°c to 1300°c for hours continuously.
3. Unstressed basalt fibers and fabrics can maintain their integrity even up to 1250°c.

iv. Advantages

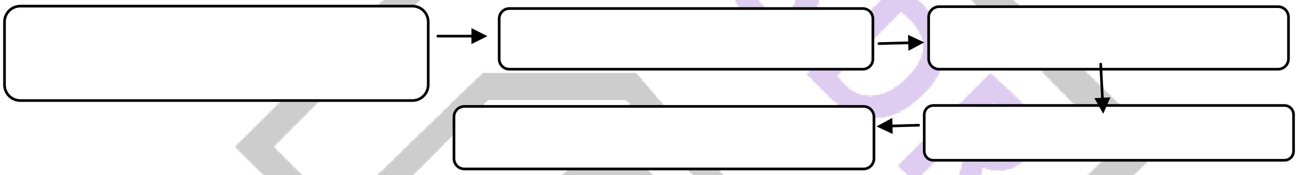
1. Reduces the width of the cracks
2. The total cost of the construction work reduces.
3. The fiber can be easily mixed.
4. The cost of repairs and maintenance greatly reduces due to fiber reinforced concrete.
5. The thickness of the concrete layer can be reduced to half.

v. Application

1. Basalt has good electrical and sound insulating properties and chemical resistance, especially in strong alkalis.
2. Basalt composite pipes can be used to transport corrosive liquids and gases.
3. Field application of basalt fiber reinforcement includes concrete industrial concrete floors, runways in airport, motor way, industrial floors, in shops where heavy equipment is used, internal reinforcement of tunnels and channels, and military installation.

2. MATERIALS AND METHODOLOGY

To carry out the present work we have used the following work flow:



i. COLLECTION OF MATERIAL

1. **CEMENT :-** ULTRATECH CEMENT OPC 53 GRADE
   Product details: Grade 43 and 53 grade cement in opc and ppc variety Packing Size 50kg/ bag Minimum Order Quantity 100 Bag Product description:
   ULTRATECH CEMENT is available in 43 and 53 Grades as:
   OPC (Ordinary Portland Cement).
2. **SAND :-** Circular Well Graded Sand To Use To Collected The Sand On Pravara River
3. **AGGREGATE** - Obtain aggregate locally available Size 20mm
4. **Basalt fibre -**12mm size

ii. MIX PROPORTIONING

Concrete of M325 grade was used in the present study. It was proportioned in accordance with the Indian standard IS: 10262.Ordinary Portland cement (OPC) of 43 grade confirming to IS: 269 was used. River sand of grading Zone II, specific gravity of 2.69 and fineness modulus of 2.31 confirming to IS: 383 was used. The dosages of basalt fibre were 0.50% (13.00 kg/m3), 0.75% (19.50 kg/m3) and 1.00% (26.00 kg/m3) by volume fraction of the concrete. The mix designations with different fibre dosages are given in Table 2.

CEMENT	FINE AGGREGATE	COARSE AGGREGATE	WATER
394 Kg/m^3	**837.83 Kg/m^3**	**1019.88 Kg/m^3**	**197 lit**

Table 1 Mix proportion of M 25 grade concrete

Concrete mix designation	Control	BFRC1	BFRC2	BFRC3
%Volume fraction of basalt fibre	**0.00**	**0.5**	**0.75**	**1.00**
Basalt fibre (kg/m3)	**0.00**	**13**	**18.36**	**24.48**

Table 2 Mix designations and fibre dosages

3. EXPERIMENTAL INVESTIGATION

Cube of size 150 mm * 150 mm 9*150 mm, cylinder of size 150 mm * 300 mm and beam of size 700 mm * 150 mm * 150 mm were cast to evaluate the properties of control and BFRC. The sequence of adding fibres in the concrete mix was followed as per ACI 544. The cast specimens were demoulded after 24 h and water-cured until testing of the specimens at 7 and 28 days. Fresh and hardened properties of the BFRC were compared with control concrete.

Sr.No.	Basalt Fibre Content	cube	beam	Cylinder
1.	0.00%	6	6	6
2.	0.5%	6	6	6
3.	0.75%	6	6	6
4.	1%	6	6	6

Table 3 Number of Specimen Casted

4. RESULT AND DISCUSSION

5.

Hardened Properties of Concrete Mixes

1. Compressive Strength

Compressive strength tests were carried out as per IS: 516 on concrete cubes in Universal Testing Machine (UTM) of capacity of 1000 KN under 0.5 mm/min loading rate. The average compressive strength of the control specimens and basalt fibre-reinforced concrete is shown in fig. An increase in compressive strength of BFRC was in the order of 20.85% and 26.80% as compared to control concrete at 7 days and 28 days, respectively. Furthermore, compressive strengths of BFRC2 and BFRC3 were found to be comparable probably due to ineffective dispersion of higher dosage fibres in concrete or due to bunching/sticking together.

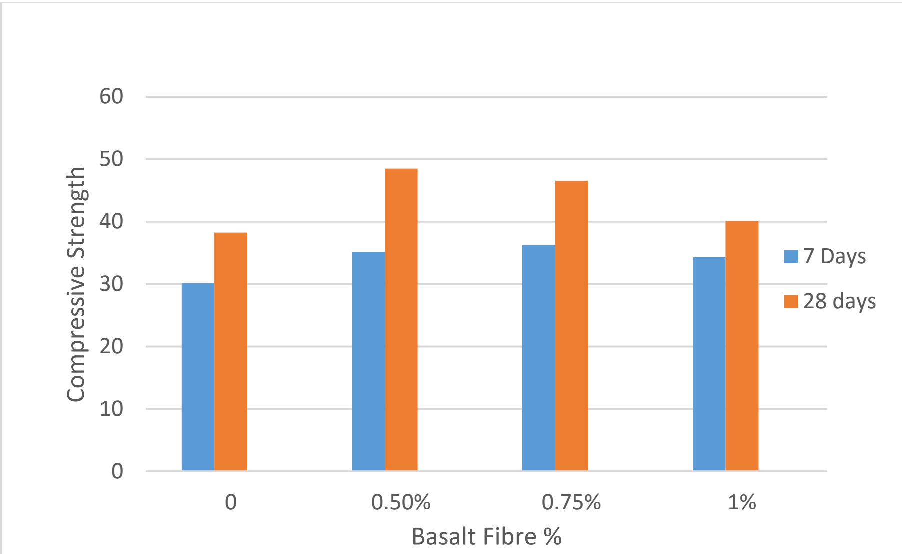


Fig 2 Compressive strength of BFRC

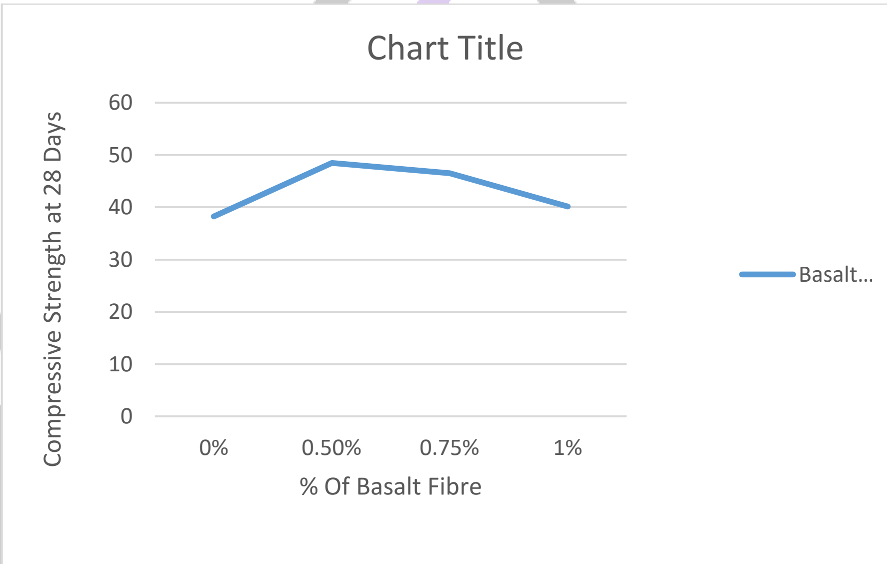


Fig 3 Comparison between compressive strength

2. Flexural Strength

Flexural strength or modulus of rupture of concrete was determined by applying the failure load on prismatic specimen after 28 days of curing in UTM under four-point loading. The location of the crack was also observed. The average flexural strength of different concrete mixes is shown table. An increase in flexural strength of BFRC was in the order of 59.20% and 44.06% as compared to control concrete at 7 days and 28 days, respectively. This is due to arresting of micro-cracks by basalt fibre. It was also found that first crack in the BFRC appeared almost near the maximum value and its location was found around the midspan of the prism. Appearance of crack at mid-span shows that bending of the prism takes place in the middle. Different countries have established their design codes which include empirical relationship between the flexural strength and compressive strength of the plain concrete at 28 days. The Indian code, IS: 456, gives the empirical relation between the static modulus of rupture and characteristic cube compressive strength (fck) of concrete as: $f_r = 0.7\ (f_{ck})^{1/2}$

The ACI code (ACI-318) defines the modulus of rupture with cylindrical compressive strength (fc) as: $fr = 0.62\ (fc)^{1/2}$
Similarly, European code suggests an empirical relation between flexural and cube compressive strength as: $f_r = 0.3(fck^{2/3})$
All above empirical relations were only for plain concrete. Hence, it was necessary to establish an empirical relationship between flexural and compressive strength of the concrete containing basalt fibres. Flexural strengths of BFRC are more than the values obtained from the codal provisions. The empirical relation for flexural strength of BFRC obtained by linear regression analysis is given below having less than 7% error in deviation:
$F_{cr} = 0.95\ (f_{ck,bfrc,})^{1/2}$
Where fcr is the flexural strength in MPa; $f_{ck};_{bfrc}$, cube compressive strength of BFRC in MPa

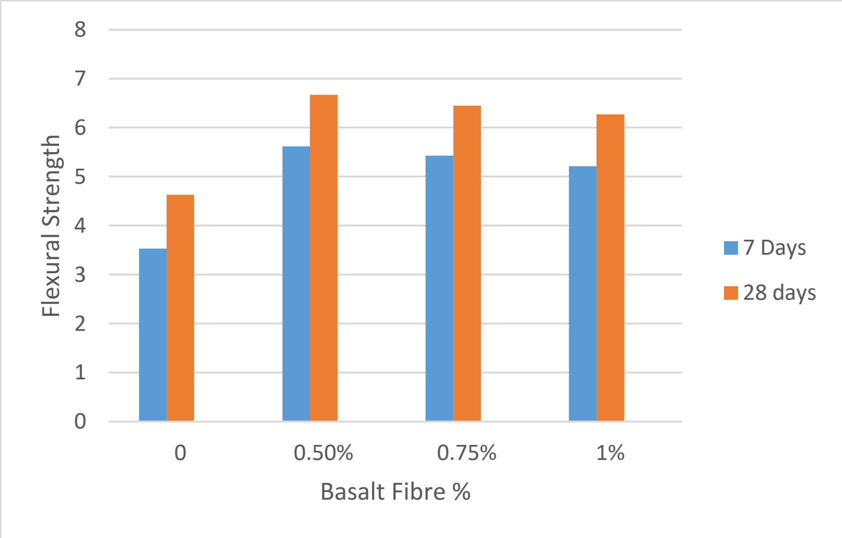


Fig 4 Flexural strength of BFRC

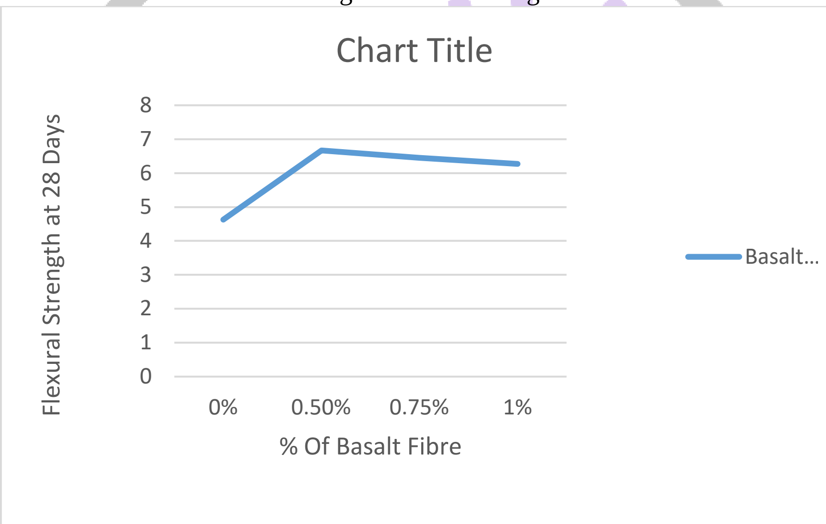


Fig 5 Comparison between Flexural Strength

3. Splitting Tensile Strength

Splitting tensile strength of all mixes was carried out in UTM using the concrete cylinders, loaded in compression side along a diameter plane. The average splitting tensile strength of the control specimens and basalt fibre-reinforced concrete with different volume fractions of fibres. An increase in Tensile strength of BFRC was in the order of 44.44% and 53.22% as compared to control concrete at 7 days and 28 days, respectively. 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. A decrease in splitting tensile strength of BFRC3 is probably due to improper dispersion of fibres in the mix, and yet it was 34.92% more than the control concrete.

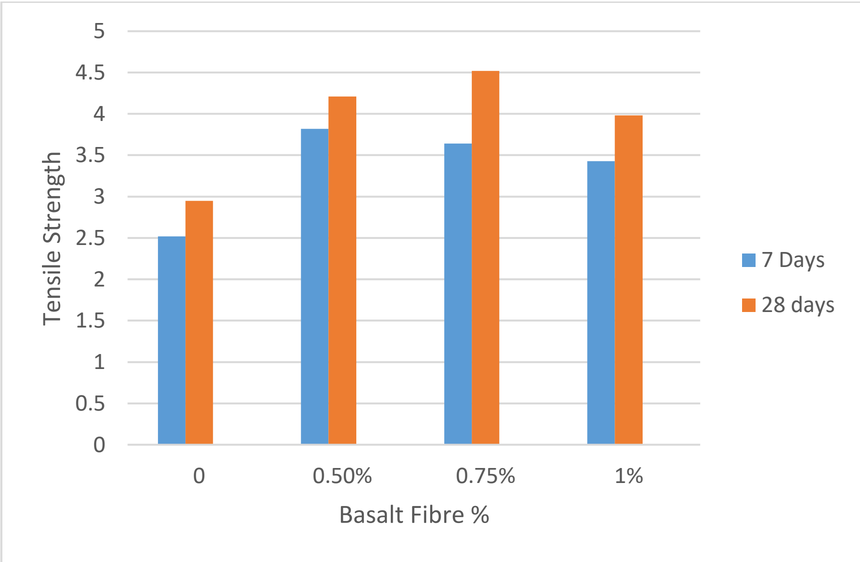


Fig 6 Tensile Strength of BFRC

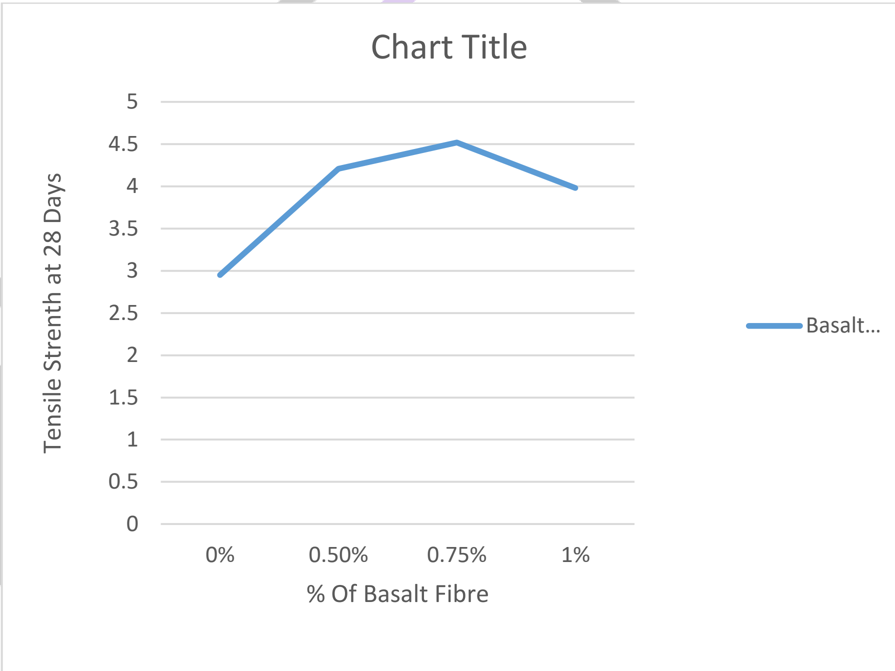


Fig 7 Comparison between Tensile Strength

Specimen	Compressive Strength (mean) (mpa)	Flexural Strength (mean) (mpa)	Tensile Strength (mean) (mpa)

Control (0.00)	38.25	4.63	2.95
BFRC 1 (0.5%)	48.50	6.67	4.21
BFRC 2 (0.75%)	46.54	6.45	4.52
BFRC 3 (1.00%)	40.16	6.27	3.98

Table 4 Average mean strength

5. CONCLUSION

The properties of basalt fibre and BFRC were studied in which it was observed that basalt fibres are definitely a potential building material having higher thermal stability and higher mechanical properties. The following conclusions from the present study are given as follows:

1. Basalt fibre was found to be amorphous in nature.
2. An increase in compressive strength of BFRC was in the order of 20.85% and 26.80% as compared to control concrete at 7 days and 28 days respectively.
3. An increase in flexural strength of BFRC was in the order of 59.20% and 44.06% as compared to control concrete at 7 days and 28 days respectively..
4. An increase in Tensile strength of BFRC was in the order of 44.44% and 53.22% as compared to control concrete at 7 days and 28 days respectively.

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