The Strength and Durability Characteristics of Concrete by Using Basalt Fiber

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Abstract- **Basalt Fiber Reinforced Polymer (BFRP) materials have been as of late presented as inside support for concrete individuals and in addition outside fortification for retrofitting structures. Not at all like Carbon FRP (CFRP) and Glass FRP (GFRP) materials, BFRP materials have not been broadly utilized. The restricted utilization of BFRP materials can be ascribed to the absence of principal investigates required to set up the proper plan proposals and rules. Basalt fiber is a high performance non-metallic fiber made from basalt rock melted at high temperature. Basalt fiber strengthened solid concrete offers more Characteristics, for example, light weight, great imperviousness to fire and quality. This thesis presents an experimental program investigated the effect of using chopped basalt fibers with an aspect ratio of 600 to 700. The study included testing concrete cylinders and prisms, cubes with basalt fiber as an additive. The main objective of this research was to determine the fundamental characteristics of basalt fiber -reinforced concrete (BFRC). The fundamental characteristics include compressive strength, flexural strength, split tensile strength as well as durability tests such as sorptivity and water absorption test etc. The experimental program included with different basalt fiber percentages were used in concrete as 0.1%, 0.2%, 0.4%, 0.8% as total weight of ingredients. The testing was done on 24 no of cubes (150mmX150mmX150mm) for compressive strength, 12 no of Quantities of cylinders (150mmX300mm) was tried for part split tensile test and 4 quantities of beams (100mmX100mmX500mm) were tried for bending strength. The effect of the basalt fiber was determined by comparing test results to control specimens without fiber.**

Index Terms- **Basalt Fibre, Compressive Strength, Split Tensile Strength, Flexural Strength, Sorptivity**

I. INTRODUCTION

Concrete is a building material made out of cement, fine aggregate, coarse aggregate and water. Each affable building development has its own particular planned purposes. With a specific end goal to meet this reasons numerous alteration has been acquired old bond solid development. It has been discovered that strands included particular rate to concrete enhances the mechanical properties, solidness of the structure. It is presently settled that one of the imperative properties of Fiber Reinforced Concrete (FRC) is its better protection than splitting and break engendering. It contains short discrete filaments that are consistently dispersed and haphazardly situated. There are many sorts' filaments accessible; they incorporate steel strands, glass strands, manufactured filaments and normal filaments – each of which loan differing properties to the solid. The strands are utilized as a part of the solid notwithstanding steel fortification. As concrete is powerless in strain expansion of strands in solid prompts increment in basic trustworthiness. Aside from protecting the uprightness of cement, enhances the heap conveying limit of basic part past splitting .Fibres are typically utilized as a part of cement to control breaking because of plastic shrinkage and to drying shrinkage. They additionally decrease the porousness of cement and in this way lessen seeping of water. The term bond is usually used to allude powdered materials which create solid glue qualities when joined with water. Bond is a fastener, a substance that sets and solidifies freely, and can tie different materials together. These materials are all the more legitimately known as water powered concretes. Gypsum mortar, regular lime, water powered lime, characteristic pozzolana and Portland concretes are the more typical pressure driven bonds, with Portland concrete being the most critical fixing in development. Bond was first created by the Egyptians. Concrete was later re-evaluated by the Greeks and the Babylonians who influenced their mortar to out of lime. Afterward, the Romans delivered bond from pozzolana, fiery debris found in the greater part of the volcanic regions of Italy, by blending the powder with lime. Concrete is a fine greyish powder which, when blended with water Forms a thick glue. When this paste is mixed with sand and gravel and allowed to dry it is called concrete. About ninety-nine percent of all cement used today is Portland cement. The name Portland cement is not a brand name. This name was given to the cement by Joseph Aspdin of Leeds, England who obtained a patent for his product in 1824. The concrete made from the cement resembled the colour of the natural limestone quarried on the Isle of Portland in the English Channel. The balance of cement used today consists of masonry cement, which is fifty percent Portland cement and fifty percent ground lime rock.

BASALT FIBER

Basalt is a characteristic, hard, thick, dim darker to dark volcanic molten shake starting at a profundity of several kilometres underneath the earth and coming about the surface as liquid magma. Also, it's dim, dim in shading, framed from the liquid magma after hardening. The generation of basalt fiber comprises of liquefy readiness, expulsion, fiber arrangement, use of greases up lastly winding. Strategy is otherwise called turning. A fiber is a material made into a long fiber with thickness for the most part in the request of 300g/cm2 of 50cm. The aspect ratio of length and diameter can be ranging from thousand to infinity in continuous fibers. It is do not undergo any toxic reaction with water and do not pollute air also. The functions of the fibers are to carry the load and provide stiffness, strength, thermal stability and other structural properties in the BFRP.

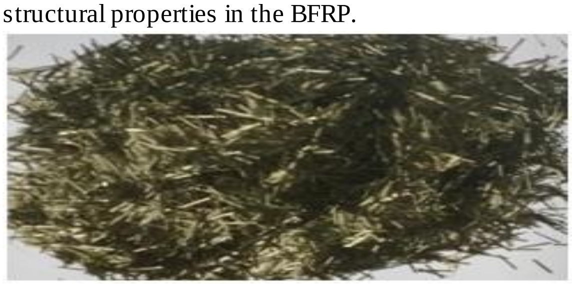


Fig.1.1 Basalt fiber

II LITERATURE SURVEY

Jongsungsim et al (2005) have studied the characteristics of basalt fiber as a strengthening material for concrete structures. The authors have tested and calculated different properties of basalt fiber like mechanical properties (tensile strength, elasticity modulus & elongation at failure), durability of basalt fiber (alkali-resistance test, weathering resistance test, autoclave stability test and thermal stability test). The authors have evaluated the applicability of basalt fiber as a strengthening material for reinforced concrete beams. The authors have bonded the basalt fiber sheets on the surface of beam and this flexure strengthened specimens have tested under bending load. Based on the test result the authors have analyzed that the strength of specimens have increased by increasing number of layer of basalt fiber sheet. Finally the authors have concluded that when compared to other FRP strengthening systems, basalt fiber strengthening system gave more strength with economical manner. Li & Xu (2009) have investigated the mechanical properties of basalt fiber reinforced Geopolymeric concrete under impact loading including dynamic compressive strength, deformation and energy absorption capacity. The authors have used SHPB apparatus and pulse shaping techniques to test BFRGC (Basalt Fiber Reinforced Geopolymeric Concrete). These tests were conducted at seven strain rates, and the stress-strain curves have obtained from the result. It indicated that the impact properties of BFRGC were prominently dependent on strain rate and increase approximately linearly with the increase of average strain rate. Further the authors have analyzed about the fiber effects, which showed that the addition of basalt fiber couldn't significantly improve the dynamic compressive strength of Geopolymeric Concrete (GC) but the failure of concrete was limited effectively and increases the deformation, energy absorption capacities of GC.

Ludovico et al (2010) have investigated about the structural upgrade using basalt fibers for concrete reinforcement. The authors have used basalt fibers bonded with a cement based matrix as a strengthening material for confinement of reinforced concrete members. The effectiveness of the proposed technique was assessed by comparing different confinement schemes on concrete cylinders like uniaxial glass fiber reinforced polymer (FRP) laminates, alkali resistant fiberglass girds bonded with a cement based mortar, bidirectional basalt laminates pre-impregnated with epoxy resin or latex and then bonded with a cement based mortar and a cement based mortar jacket. Finally the authors have concluded that the confinement based on basalt fibers bonded with a cement based mortar could be a promising solution to overcome certain limitations of epoxy based FRP laminates.

Lapko & Urbanski (2014) have studied about the experimental and theoretical analysis of deflections of concrete beams reinforced with basalt rebar. The tested BFRP (Basalt Fibre Reinforced Polymers) model beams have been made of concrete class C30 / 7 and reinforced with flexural basalt bars of 8 mm in diameter. During the investigation of model beams the authors have registered beam deflection, concrete strains, and crack width, as well as critical forces. The examination has demonstrated that substantially lesser cross sectional solidness of BFRP produces higher avoidances and split widths contrasted with the pillars strengthened with steel bars of a similar cross-segment. The results of theoretical analysis of BFRC beam deflections showed that some significant discrepancies compared to experimentally obtained deflections, especially for lower level of loading forces. From the results the authors have concluded that the basalt fibre rebar having full resistance against corrosion may be good alternative for the reinforcement of concrete structures, like RC bridge girders subjected to an environmental attack.

III. MATERIALS AND METHODS

The cement used was Ordinary Portland Cement of 53-Grade Conforming to IS: 8112-1989.The cement should be fresh and of uniform consistency. Where there is evidence of lumps or any foreign matter in the material, it should not be used. The cement should be stored under dry conditions and for as short duration as possible. Different tests were done on cement to determine its properties. They are

STANDARD CONSISTENCY OF CEMENT:

The standard consistency of a cement paste is defined as which measures the depth of penetration of a 10 mm diameter plunger under its own weight. When the depth reach a certain value, the water content required gives the standard consistency between 26% to 33% (expressed as a percentage by mass of dry cement).

1. Firstly take the vicat mould and collect the same with Plunger G, and later check the gear for any rectification if required by enabling the plunger to lay on the base plate and note the perusing on the scale, on the off chance that it is zero no redress is required any esteem higher than zero ought to be noted as revision.
2. Take 400 g of cement going through 90 micron ÌS sieve and places it in plate.
3. Mix around 25% water by weight of dry cement completely to get cement glue. Add up to time taken to get altogether blended water concrete glue i.e. "Gaging time" ought not be under 3min but rather in the meantime it ought not be over 5 minutes.
4. Fill the vicat shape, resting upon a glass plate, with this cement glue.
5. After filling the form totally, smoothen the surface of the glue, influencing it to level with best of the shape and shake it somewhat to remove air.
6. Place the entire get together (i.e. shape + cement glue + glass plate) under the bar bearing plunger.
7. Lower the plunger delicately in order to touch the surface of the test piece and rapidly discharge the plunger enabling it to sink into the glue.
8. Measure the profundity of entrance and record it.
9. Prepare trial glues with changing rates of water content and take after the means (2 to 7) as depicted above, until the point that the profundity of infiltration moves toward becoming 5 to 7 mm from the base.

$$\text{Standard consistency (\%)} = \frac{\text{Weight of water added}}{\text{Weight of cement}} \times 100$$

FIG VICAT'S APPARATUS

INITIAL AND FINAL SETTING TIME:

This test shall be conducted at a temperature of 27 +2ºC and 65 + 5% of relative humidity of the Laboratory. Prepare a paste of 300 grams of cement with 0.85 times the water required to a give a paste of standard consistency IS: 4031 (Part 4) 1988. The time of gauging in any case shall not be less than 3 minutes not more than 5minutes and the gauging shall be completed before any sign of setting occurs. Count the time of gauging from the time of adding water to the dry cement until commencing to fill the mould. Fill the Vicat's shape with this glue influencing it to level with the highest point of the form. Marginally shake the shape to remove the air. In filling the mould the operator hands and the blade the gauging trowel shall only be used.

Initial Setting Time:

Immediately place the test obstruct with the non-permeable resting plate, under the pole bearing the underlying setting needle. Lower the needle and rapidly discharge enabling it to enter in to the shape.
In the starting the needle will totally penetrate the form.
Repeat this system until the point that the needle neglects to penetrate the form for 5 + 0.5mm. Record the period passed between the seasons of adding water to the concrete to the time when needle neglects to penetrate the form by 5 + 0.5mm as the underlying setting time.

Final Setting Time:

1. Replace the needle of the Vicat's mechanical assembly by the needle with an annular ring
2. Lower the needle and rapidly discharge.
3. Rehash the procedure until the point that the annular ring establishes a connection on the form.
4. Record the period slipped by between the seasons of adding water to the concrete to the time when the annular ring neglects to establish the connection on the shape as the last setting time.

FINE AGGREGATES:

River sand shall be obtained from a reliable supplier and shall comply with IS 383:1970 for fine aggregates. It should be clean, hard, strong and free of organic impurities and delirious substance. It should inert with respect to other materials used and of suitable type with regard to strength, density, shrinkage and durability of mortar made with it. Grading of the sand is to be such that a mortar of specified proportions is produced with a uniform distribution of the aggregate, which will have a high density and good workability and which will work into position without segregation and without use of high water content. The fineness of the sand should be such that 100% of it passes standard sieve No.8. The fine aggregate which is the inert material occupying 60-70% of the volume of mortar must get hard strong non-porous and chemically inert. Fine aggregates conforming to grading zone-II with particles greater than2.36mm and smaller than 150mm removed are suitable. We considered River Sand having density of 1460 kg/m3 and fineness Modulus (FM) of 2.69 was used. The specific gravity was found to be 2.6.

SPECIFIC GRAVITY OF FINE AGGREAGTES:

Specific gravity is the ratio of weight of the dry aggregates to the weight of water. It is determined by using a pycnometer. The empty weight of the pycnometer is taken (W1).It is then filled with aggregates upto 1/4th level and its weight is taken (W21). It is then filled with water upto the tip and then its total weight is taken (W3). It is then made empty and it should be filled with the water upto tip and then its weight is taken (W4).
It is obtained by
Specific Gravity= (W2-W1)/ ((W4-W1) - (W3-W2))
Where,
W1=Weight of the empty pycnometer
W2=Weight of the empty pycnometer + Weight of the aggregates taken
W3=Weight of the empty pycnometer + Weight of the aggregates taken + weight of water
W4=Weight of the pycnometer + water

COARSE AGGREGATE:

Machine crushed hard granite chips of 67% passing through 20mm sieve and retained on 12mm sieve and 33% passing through 12mm and retained on 10mm sieve were used as coarse aggregate throughout the work. The different tests done on coarse aggregates are
a) Specific gravity
b) Particle size analysis
c) Flakiness and elongation
d) Impact value test

e) Abrasion value test
f) Water absorption test

IV MIX DESIGN

Design mix configuration can be characterized as the way toward choosing reasonable elements of concrete and their relative proportions with the object of producing concrete of sure minimum strength and sturdiness as economically as attainable.

Design Specifications: AS PER (IS-10262-2009)

- Grade designation = M30
- Type of cement to be used = OPC 53 grade conforming IS 12269
- Maximum nominal size of coarse aggregates = 20mm
- Minimum & maximum cement content = 320 kg/m^3 & 360 kg/m^3
- Maximum water-cement ratio = 0.5
- Workability = Medium (100 mm TO 120 mm)
- Exposure conditions (As per IS-456-Table-4) = moderate
- Method of transporting & placing = transit mixer & pumping
- Type of aggregate = Crushed Angular Aggregate
- Type of admixture to be used = Super Plasticizer ECMAS HP 890

STEP: 1 Target Strength Calculation:-
Calculate the target compressive strength of concrete using the formula given below.

$f_{ck}' = f_{ck} + 1.65s$
$= 30 + 1.65*5$
$= 38.25\ N/mm^2$

Where,
f_{ck}' = Target compressive strength at 28 days in N/mm^2.
f_{ck} = Characteristic compressive strength at 28 days in N/mm^2. (Same as grade of concrete, see table below)
s = Standard deviation
The value of standard deviation, given in the table below, can be taken for initial calculation.

TABLE 4.1: Suggested values of standard deviation

Grade of concrete	Standard deviation for different degree of control in N/mm^2		
	Very good	Good	Fair
M 10	2	2.3	3.3
M 15	2.5	3.5	4.5
M 20	3.6	4.6	5.6
M 25	4.3	5.3	6.3
M 30	5.0	6.0	7.0
M 35	5.3	6.3	7.3
M 40	5.6	6.6	7.6
M 45	6.0	7.0	8.0
M 50	6.4	7.4	8.4
M 55	6.7	7.7	8.7
M 60	6.8	7.8	8.8

STEP: 2 Selection of Water-Cement Ratio
For preliminary calculation, water cement ratio as given is IS-456-Table 5 (also given below) for different environmental exposure condition, may be used.

Table- 4.3 (IS 10262:2009 - Table 2)

Maximum water content per cubic meter of concrete for nominal maximum size of aggregate		
Sl.No.	Nominal maximum size of aggregate	Maximum water content
1	10	208
2	20	186
3	40	165

Adopted maximum water-cement ratio = 0.44. From the above table for moderate
Exposure maximum Water Cement Ratio is = 0.5
0.44 < 0.5 Hence ok.

STEP: 3 MIX PROPORTIONS

Cement = 359 kg/m^3
Water = 158 l/m^3
Fine aggregate = 798 kg/m^3
Coarse aggregate 20mm = 890 kg/m^3
Coarse aggregate 10mm = 223 kg/m^3 (20% By Total weight of Coarse Aggregate)
Chemical admixture = 1.34 kg/m^3 (0.4% by the weight of cement)
Density of concrete = 2430 kg/m^3
Water-cement ratio = 0.44
Mix Proportion By weight = 1:2.2:3.1

V. EXPERIMENTAL INVESTIGATION

Specific gravity and water absorption of fine aggregate:- IS 2386-part 3

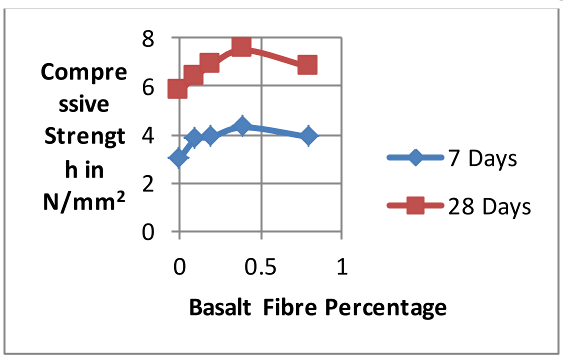
Description	Sample
Weight in gm of saturated surface dry sample taken (A)	500
Weight in gm of pycnometer with sample + filled with distilled Water (B)	1823
Weight in gm of pycnometer filled with distilled water (C)	1514
Weight in gm of oven-dry sample (D)	496
Specific gravity = $\frac{D}{A-(B-C)}$	2.60
Water absorption = $\frac{100(A-D)}{D}$	0.81%

Cube Compressive Strength: - *IS 516-1959*

The cube compressive strength test results at the various ages such as 7 days and 28 days were carried out. Compressive strengths of various mixes B0, B0.1, B0.2, B0.4 and B0.8 are given in below Table 6.14 and Figure.

Table 6.14 Compressive strength test results

MIX ID	Compressive Strength, MPa	
	7 Days	28 Days
B0	29.5	37.7
B0.1	30	38.1
B0.2	30.6	38.8
B0.4	31.6	41
B0.8	31	38.6

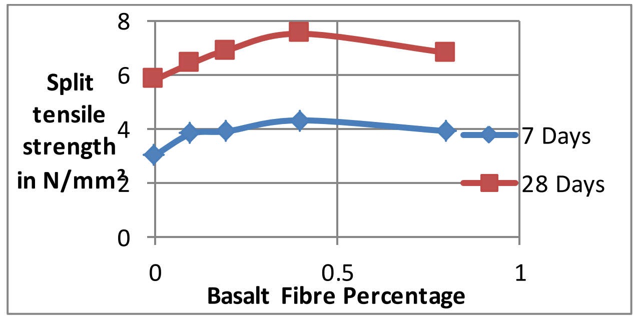


Split Tensile Strength: - *IS 516-1959*

The split tensile strength test results at the various ages such as 7 days and 28 days were carried out. Split tensile strengths of various mixes B0, B0.1, B0.2, B0.4 and B0.8 are given in below Table 6.15 and Figure 6.2.

Table 6.15 Split tensile strength test results

MIX ID	Split Tensile Strength, N/mm2	
	7 Days	28 Days
B0	2.3	3.19
B0.1	2.4	3.38
B0.2	2.45	3.39
B0.4	2.6	3.6
B0.8	2.3	3.35

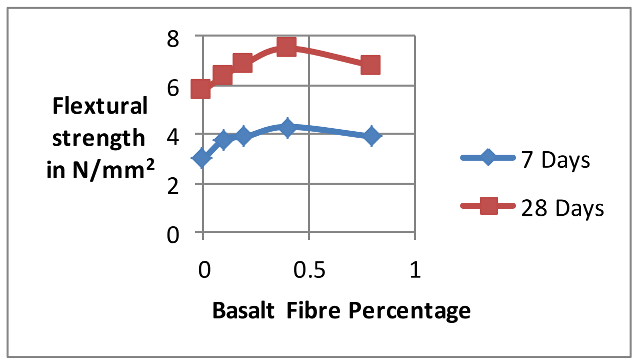


Flexural Strength: - IS 516-1959

The flexural strength test results at the various ages such as 3 days, 7 days and 28 days were carried out. The flexural strengths of various mixes B0, B0.1, B0.2, B0.4 and B0.8 are given in below Table 6.16 and Figure 6.3

Table 6.16 Flexural strength test results

MIX ID	Flexural strength, Mpa	
	7 Days	28 Days
B0	3	5.8
B0.1	3.8	6.4
B0.2	3.9	6.9
B0.4	4.3	7.5
B0.8	3.9	6.8



DURABILITY TEST RESULTS

The Water absorption test, Acid resistance test, pH test and sorptivity test were conducted in geo polymer concrete with fibres and without fibres to find out the durability properties.

Acid Resistance Test Results

The result of the acid resistance tests have shown that when compared to the mix without fibre, the percentage of weight loss for the optimum mix with 0.4% fibre as shown in the table 6.18. From the results it can be seen that the loss in weight is found to be decrease by about 23 % for the concrete with 0.4% fibre.

Table 6.18 Acid Resistance test results

MIX ID	Acid Resistance
B0	2.1
B0.1	1.8
B0.2	1.5
B0.4	1.7
B0.8	1.64

Sorptivity Test Results

The sorptivity test results are shown in table 6.20. The result of sorptivity shows that when compared to the mix without fibre, the percentage decreases for the optimum mix with 0.4% fibre is 23%

Table 6.20

MIX ID	Dry Weight, W1, gm	Wet Weight, W2, gm	Change in Wt, (W2-W1), gm	Sorptivity in mm/t$^{0.5}$
B0	775.2	779.0	3.8	0.09
B0.1	759.0	763.0	4.0	0.09
B0.2	789.5	793.2	3.7	0.08
B0.4	787.7	790.9	3.2	0.07
B0.8	746.2	749.7	3.5	0.08

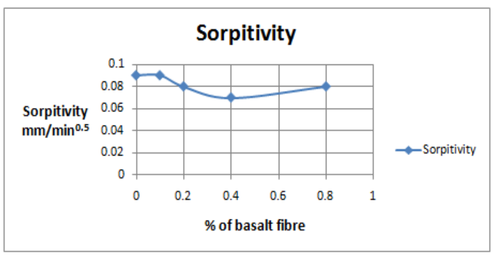


Fig. 6.4 Effect of % of fibres on Sorptivity of concrete

VI. CONCLUSION

From the results obtained it can be concluded the follows:

The slump of concrete decreases with increasing the volume fraction of basalt fibre and the unit weight is not sensitive to it as the fibre content was low in all mixes. Adding basalt fibre to concrete decrease the amount of heat conducted through the thickness. Water absorption of concrete is decreases 5% with increase fibre content at 0.4% It can be seen that the % increase of split flexural strength as compared to the mix without fibres is 29.3% for 0.4 % addition of fibres in volume fraction. It can be seen that the % increase of split tensile strength as compared to the mix without fibres is 12.85% for 0.4 % addition of fibres in volume fraction. It can be seen that the % increase of compressive strength as compared to the mix without fibres is 8.75% for 0.4 % addition of fibres in volume fraction. Sorptivity decreases with increasing fibre content at 0.4%, when compare to mix without fibres pH value is slightly changed.

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