Experimental Investigation on Basalt Fiber Reinforced Concrete

[1]Kirankumar, [2]Chethan V R

[1]PG Student, [2]Assistant Professor
Department of Civil engineering, VTU,
Adichunchanagiri Institute of Technology, Chikkamagaluru, India

***Abstract*- this thesis focus on experimental investigation on fiber reinforced concrete, works were carried out on experimental investigation of basalt fiber concrete. Properties of concrete were checked by testing cubes, cylinders and prisms. The specimens were cast usingM20 Grade concrete with locally available materials. The object of the present work is to study the effect of different proportions of fibers in the concrete and find out optimum percentage of fibers with maximum strength criteria. The specimens like cubes, cylindersandprismswerecasttotestthecompressionstrength, split tensile strength and flexural strength. Concrete specimens with different proportions (0.25%, 0.30%, and 0.35%) ofbasalt fibers were cast along with control specimens. Based on the literature study, it was found that the basalt fiber concrete have better toughness and impact strengths than the control concrete. It was also found that the addition of basalt fiber in concrete changes the mode of failure from brittle mode of failure to ductile mode of failure when subjected to compression, bending and impact. Because of its high tensile property it improves tensile strength of concrete when mixed in optimum fiber ratio and has shown adequate enhancement in flexural behaviour such as Load-deflection, Moment-curvature and crack pattern.**

***Key words* - Basalt fiber concrete (BFC), Compressive strength, Flexural strength, Split tensile strength, Chopped basalt fibres.**

I. INTRODUCTION

Construction is a major part of development plan of developing countries including India. To meet the large demand for infrastructure development, maintenance andlife enhancementofstructuresareveryimportant.Concreteisthe most widely used man-made construction material. Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Conventional concrete doesn't meet many functional requirements such as impermeability, resistance to frost adequately. The presence of micro cracks at the mortar–aggregate interface is responsible for the inherent weakness of plain concrete. Because of the poor tensile strength, crack propagates with the application of load leading to brittle fracture of concrete. Micro cracks are formed in concrete during hardening stage. Natural disasters like earthquakes, cyclones, tsunami, etc destroy the high rise buildings, bridges, monumental structures, world wonders, etc. One such development has been two phase composite materials i.e. fiber reinforced concrete, in which cement based matrix, is reinforced with ordered or random distribution of fibers. Fiber in the cement basedmatrixactsascracksarresterwhichrestrictsthegrowth offlawsinthematrix,preventingthesefromenlargingcracks under load which eventually cause failure. The weaknesscan beremovedbyinclusionoffibersinconcrete.Thefiberhelps totransferloadsattheinternalmicro cracks. Fibers like basalt, steel, glass, recron and nylon have beentried.

II. BASALTFIBER

Basalt fibers are manufactured in a single-stage process by melting naturally occurring pure basalt rock. Basalt is a natural, hard, dense, dark brown to black volcanic igneous rock.Itisthemostcommontypeintheearth'scrust (theouter 10 to 50km).

Its origins are at a depth of hundreds of kilometers beneath the earth surface and it reaches the surface asmoltenmagma. Basaltdensityrangesbetween2700to2800kg/m^3.Thebasic characteristics of basalt materials are high-temperature resistance, high corrosion resistance, resistance to acids and alkalis, high strengthand thermal stability.
Basalt can be formed into continuous fibers with the same technology utilized for E-Glass and AR-Glass fibers, but the production-processrequireslessenergyandtherawmaterials are widely diffused all around the world. This justifies the lower cost of basalt fibers compared to glass fibers. Moreover, basalt fibers are environmentally safe, non-toxic, non-corrosive, non-magnetic, possess high thermal stability, have good heat and sound insulation properties, durability and vibration resistance.

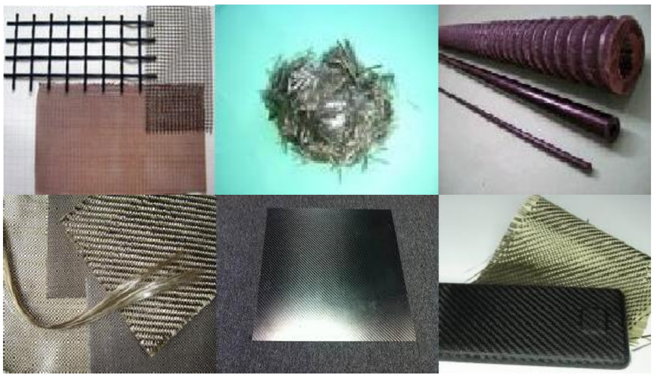


Fig. 1 Basalt fiber

Some studies have already investigated on fundamental propertiesofbasaltfibersanditsapplicationasstrengthening and reinforcing material. It is found that the basalt fiber presents a modulus of elasticity at least 18% higher than that of E-Glass fibers and beams strengthened with basalt fibers showed a more ductile failure than those strengthened with E-Glass fibers. Strengthened with E-Glass fibers.

CHEMICAL COMPOSITION OF BASALT FIBRE

Oxide	Basalt fiber in %
Sio_2	69.55
Al_2O_3	14.19
	3.96
Cao	5.66
Mgo	2.45
K_2o	1.31
Na_2O_3	2.79

III. MIXINGPROPORTIONING

The mixture proportioning was done according to the Indian Standard Recommendation method IS 10262-2009. The ordinary Portland cement (opc) of Grade 43 is used. Cement, fine aggregate, coarse aggregate & basalt fiberwere properly mixed together in accordance with IS code in the ratio 1:1.52:2.78 by weight before water was added and was properly mixed together to achieve homogenous material. Water absorption capacity and moisture content were taken into consideration and appropriately subtracted from the water/cement ratio used for mixing. Basalt fibers with different percentages 0.25%, 0.30%, 0.35% are being replaced for the total volume of concrete. Cubes, cylinders and prism moulds were used for casting; compaction of concrete in three layers with 25 strokes of 16mm rod was carried out for each layer. The concrete was left inthe mould and allowed to set for 24 hours before the moulds were de-mouldedandthentheywereplacedinthecuringtankuntil thedayoftesting(28days).Themixproportionobtainedisas shownbelow.

Table: Mix proportion

Water	Cement	Fine aggregate	Coarse aggregate
192 lit	427 kg/m³	648 kg/m³	1179 kg/m³
0.45	1	1.52	2.78

IV. BASIC CHARACTERISTICS OF BASALTMATERIALS

The use of Basalt fibers has captured the interest of structural engineering community due to its favorable properties such as;

1. High temperatureresistance

2. High corrosionresistance
3. Resistance to acids andalkalis.
4. High strength & thermalstability.
5. Environmentallysafe.
6. Having good heat and sound insulationproperties.
7. Durability and vibrationresistance.
8. Non-toxic, Non-corrosive &Non-magnetic.
9. Possess high resistance against low and high temperature & have high thermalstability.

V. PROPERTIES OF USEDMATERIALS

- Chopped Basalt fiber with aspect ratio50.
- Cement: Ordinary Portland cement of 43 grade having specific gravity of3.14
- Fine aggregate: Natural river sand conforming to IS-383, Zone-II having specific gravity2.60
- Coarse aggregate: Crushed granite angular aggregate of size 20mm confirming to IS-383 having specific gravity 2.78.
- Water: Ordinary potable water conforming to IS456.

VI. STRENGTHPROPERTIES

The program was conducted for understanding the effectiveness of adding basalt fibers in concrete, the testing was carried out on 12 concrete cubes (150mm x 150mm x 150mm) for compressive strength, 12 concrete cylinders (150mm x 300mm) for Elasticity modulus and 12 concrete prisms (100mm x 100mm x 500mm) for flexural strength.
CastingwasmadeinM20Gradeandthespecimensweremade to cure for 28 days in potablewater.

Table: Details of specimens

Specimens	Cubes	Cylinders	Prisms
Control concrete	3	3	3
Concrete with basalt fiber at 0.20%	3	3	3
Concrete with basalt fiber at 0.25%	3	3	3
Concrete with basalt fiber at 0.30%	3	3	3

VII. COMPRESSION STRENGTHTEST

The Compressive strength is the capacity of a material or structuretowithstandcompressiveloadwithoutfailure.Itcan be measured by plotting applied force against deformation noted from the universal testing machine. Some materials fracture at their compressive strength limit, others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strengthisthekeyvaluefordesignofconcretestructures.
Compressivestrengthoftheconcreteisobtainedbytesting the cubes of size 150mmx150mmx150mm at 28th day. The concretecubesdesignedforM20gradewerecastandcuredfor 28 days. After 28 days of continuous curing the specimens were taken out and they were exposed to atmosphere for few hours. Surface water and grit shall be wiped off and any projecting fins are removed. In the case of cubes, the specimen is placed in the machine in such a manner that the load is applied to opposite sides of the cubes.

A spherically seated block is brought to bear on theSpecimen; the movable portion is rotated gently by handso that uniform seating may be obtained. The load isappliedWithout shock and increased continuously untiltheresistance of the specimen to the increasing load breaks down andnoGreater load can besustained.
The compressive test on hardened control&B a s a l t concrete were performed on a 2000kN capacityhydraulic testing machine in accordance to the relevant Indianstandards. A typical setup is shown in fig 2. Three concrete cubes were tested for every compressive strength test.

$$\text{Compressive strength} = \frac{\text{Ultimate load}}{\text{Area of specimen}}$$

Fig: 2 Compressive strength test set up

Table: Compressive strength results

Sl. no	Type of specimen	Ultimate load in	Compressive strength at 28 days	Average compressive
1	Conventional	755	33.56	31.34 N/mm²
		706	31.38	
		653	29.10	
` 2	0.25% of basalt fiber	727	32.42	32.97 N/mm²
		786	34.65	
		719	31.86	
3	0.30 % of basalt fiber	956	42.39	38.43 N/mm²
		815	36.46	
		819	36.45	
4	0.35% of basalt fiber	736	32.54	33.98 N/mm²
		759	33.66	
		806	35.75	

The Experimental test results shows that the compressive strength of Basalt fiber concrete is higher than thatof control concreteanditisalsonotedthat,with0.25%fibercontentthe compressive strength is increased up to 25% that of control concrete and gradually decreased at 0.30% fibercontent.

VIII. FLEXURALSTRENGTHTEST

Concrete as we know is relatively strongincompressionand weak in tension. In reinforced concretemembers,littledependenceisplacedonthetensilestrengthofconcretesincesteel reinforcing bars are provided to resist alltensileforces.TheFlexuralstrengthoftheconcreteisobtainedbytestingthePrismspecimensofsize100mmx100mmx500mmat28thday. The concrete Prism specimens designed forM20gradewere cast and cured for 28 days. After 28 daysofcontinuouscuringthespecimensweretakenoutandtheywereexposedtoatmosphere for few hours. The bearing surfacesofthesupportingandloadingrollersarewipedclean,andanyloosesand or other material removed from the surface of the specimen where they are to make contact with the rollers.

The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 13.3 cm apart. The axis of the specimen is carefully aligned with the axis of the loading device. No packing is used between the bearing surfaces of the specimen and the rollers. The load is applied without shock and increasing continuously at a rate such that the extreme fiber stress increases approximately 0.7 kg/sq cm/minthatis,atarateofloadingof180kg/min.Theloadis being increased until the specimen fails, and the maximum load applied to the specimen during the test is recorded. The appearanceofthefracturedfacesofconcreteandanyunusual features in the type of failure is noted. A typical setup is shown in fig 3. The flexural strengthof the specimen is expressed as the modulus of ruptureF_b

$$= \frac{PL}{bd^2} \qquad F_b$$

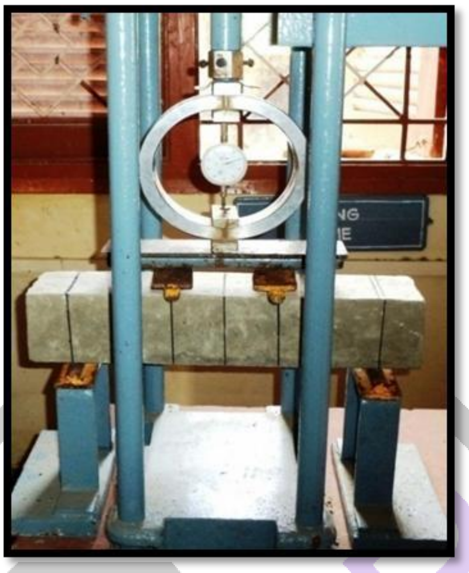
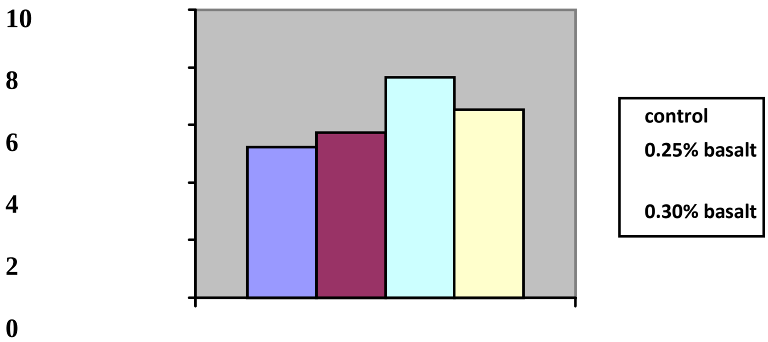


Fig: 3 Flexural strength test set up

Table: Flexural strength for prism

Sl. no	Type of specimen	Load in div	Flexural strength at 28 days	Average flexural strength
1	Conventiona	29	5.8	5.25 N/mm²
		24	4.8	
		26	5.2	
` 2	0.25% of basalt fiber	29	5.9	5.83 N/mm²
		25	5.1	
		32	6.5	
3	0.30 % of basalt fiber	36	7.3	7.76 N/mm²
		41	8.3	
		38	7.7	
4	0.35% of basalt fiber	35	7	6.6 N/mm²
		26	5.3	
		37	7.5	



Flexural strength

TheFlexuraltestresultsshowsthattheFlexuralstrengthof Basalt fiber concrete gives more strength than that of the controlconcreteandwith0.25%offibercontent,thestrength is increased up to 40% at its optimum level and decreased gradually at 0.30% fibercontent.

IX. MODULUS OF ELASTICITY INCONCRETE

ModulusofElasticityisthemeasureoftheratioofstressto the corresponding strain. The modulus of elasticity can be determined by testing the cylinder specimens of size 150mmx300mmbymeansofuniaxialcompression.

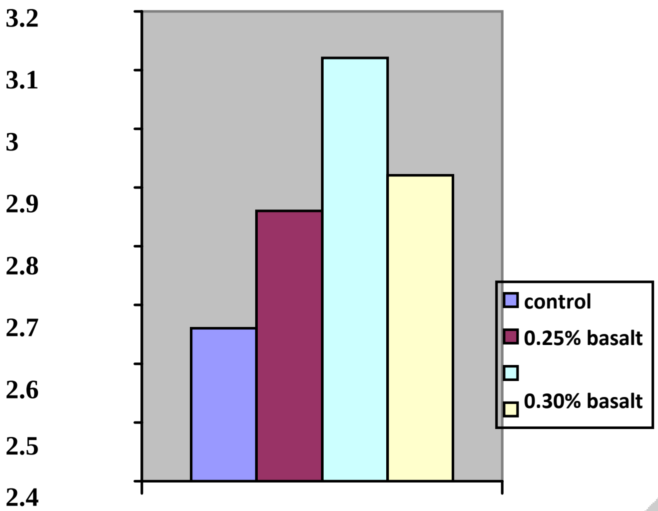
The concrete cylinders designed for M20 grade were cast and cured for 28 days. After 28 days of continuous curing the Specimens were taken out and they were exposed to atmosphere for few hours. Surface water and grit shall be wipedoffandanyprojectingfinsareremoved.Thespecimen isthenplacedinthemachineinsuchamannerthattheaxisof the specimen is carefully aligned with the axis of the loading device. The stress and corresponding strain values can be obtained by subjecting the cylinder specimen to uniaxial compression through an universal testing machine as shown in the fig below, and measuring the deformation by meansof dial gauges fixed between certain gauge length. Dial gauge reading divided by gauge length will give the strain and load applied divided by area of cross-section will give stress. The E value can be finally predicted by drawing initial, secant & chord modulus on the stress-strain graph plotted for tested values.Atypicalexperimentalsetupisshowninfig4.

$$\text{Elasticity modulus (E)} = \frac{\text{Stress}}{\text{Strain}}$$

Fig: 4 Test on Concrete Cylinders for E for concrete

Table: Elasticity modulus

Sl.n o	Type of specimen	Modulus of Elasticity (N/mm^2) x 10^4	Averag e
1	Conventional	2.56	2.66 N/mm²
		2.68	
		2.74	
` 2	0.25% of basalt fiber	2.83	2.863 N/mm²
		2.95	
		2.81	
3	0.30 % of basalt fiber	3.06	3.14 N/mm²
		3.23	
		3.13	
4	0.35% of basalt fiber	2.86	2.94 N/mm²
		2.97	
		2.99	



Elasticity modulus

The Experimental test results shows that the cylinders made with basalt fiber concrete exhibits better Elasticity than the cylinders made with normal concrete

X. ADVANTAGES OF BASALTFIBRES

1. Basalt fiber materials does not undergo any toxic reaction with water and air, also do not have any side effects on humanhealth.

2. Basalt fibers have major qualities like acid resistance, alkali resistance. It is thermally, electrically and sound insulated.

3. Basalt base composites can replace steel (1 kg of basalt reinforcesequals9.8kgofsteel)aslightweightconcretecan be get from basaltfiber.

4. Basalt has several excellent properties like high Elasticitymodulusandexcellentheatresistance.Thesefibers havesignificantcapabilityofheat&acousticdampingandare outstanding vibrationisolators.

5. The basalt fiber has low density as 2.8 g/cc to 2.9 g/cc, which is much lower than other metals and closer to carbon and glass fibers, though cheaper than carbon fiber and high strength than glass fiber. Hence basalt is suitable as low weight cheaper tough compositematerial.

6. TheypossessamodulusofElasticityatleast18%higher than that of E-Glassfibers.

XI. CONCLUSION

The following conclusions were derived from this experimental work:
1. Generally the workability of the concrete is greatly affected by the addition of fibers with the concrete and also imparts the use of super plasticizers to improve the workabilitybuttheadditionofBasaltfiberswiththeconcrete shows the same workability as the normal concrete and there is no need for any kind of super plasticizers to improve the workability.Soinworkabilitypointofviewadditionofbasalt fiber is not a defectiveone.

2. As we know, concrete is strong in compression. The additionofbasaltfiberwithnormalconcretefurtherimprovesThe compressive strength of concrete. The experimental results shows that the compressive strength of Basalt fiber concrete is 38.43 N/mm^2 which is 23% higher than control concrete 31.34 N/mm^2

3.Concreteisveryweakintension,toovercomethisdefect weareaddinghightensilefibermaterial(i.e.Basaltfiber)into theconcrete.Itisnotedfromtheexperimentalresultsthatthe Basalt fiber concrete exhibits higher tensile strength than the normal concrete. The tensile strength of basalt fiberconcrete 7.76N/mm^{2}is found to be 55% higher than the tensile strength of normal concrete 5.26 N/mm^2

REFERENCES

1. Rashid Hameed, Alain Sellier, AncletTuratsinze, Frederic Duprat(2013)"Flexural Behaviour of Reinforced Fibrous Concrete Beams Experiments andAnalyticalModelling" Engineering and application science – vol 13 pp 19-28

2. Singaravadivelan, N Sakthieswaren and K.L Muthuramu(2012) "Experimental Investigation on the Behaviour of Flexural StrengtheningofBeamUsingBasaltFiber"-MechanicalandMaterials Engineeringpp19-20,2012.

3.Singaravadivelan, P.Chinnadurai,,.KL.Muthuramu and .P.Vincent(2013) " Flexural Behaviour of Basalt Chopped Strands Fiber Reinforced Concrete Beams'' - International Conference on Chemical, Ecology and Environmental Sciences pp 17-18. 2013

4.TumadhirMerawiBorhan, Colin G. Bailey (2013) "Structural behaviourof basalt fibre reinforced glass concrete slabs" - Materials and Structures.

5. Tumadhir M., Borhan (2013) "Thermal and Mechanical Properties of Basalt Fibre Reinforced Concrete" - Engineering and Technology vol762013

6.IS 10262: 2009 "Recommended Guidelines for concrete mixdesign"

7. IS 456: 2000 "Plain and reinforced concrete code ofpractice"

8. IS 383: 1970 " Specification for coarse and fine aggregate fromnatural sources forconcrete"