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EXPERIMENTAL INVESTIGATION OF CONCRETE WITH BASALT FIBRE

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***Abstract*— This thesis focus on "EXPERIMENTAL INVESTIGATION OF CONCRETE WITH BASALT FIBRE", works were carried out on experimental investigation of basalt fibre concrete. Properties of concrete were checked by testing cubes, cylinders and prisms. The specimens were cast using M_{20} Grade concrete with locally available materials. The object of the present work is to study the effect of different proportions of fibres in the concrete and find out optimum percentage of fibres with maximum strength criteria. The specimens like cubes, cylinders and prisms were cast to test the compression strength, split tensile strength and flexural strength. Concrete specimens with different proportions (0.20%, 0.25%, and 0.30%) of basalt fibres were cast along with control specimens. Based on the literature study, it was found that the basalt fibre concrete have better toughness and impact strengths than the control concrete. It was also found that the addition of basalt fibre 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 fibre ratio and has shown adequate enhancement in flexural behavior such as Load-deflection, Moment-curvature and crack pattern.**

***Key words* - Basalt fibre 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 and life enhancement of structures are very important. Concrete is the 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. fibre reinforced concrete, in which cement based matrix, is reinforced with ordered or random distribution of fibres. Fibre in the cement based matrix acts as cracks arrester which restricts the growth of flaws in the matrix, preventing these from enlarging cracks under load which eventually cause failure. The weakness can be removed by inclusion of fibres in concrete. The fibre helps to transfer loads at the internal microcracks. Fibres like basalt, steel, glass, recron and nylon have been tried.

II. BASALT FIBRE

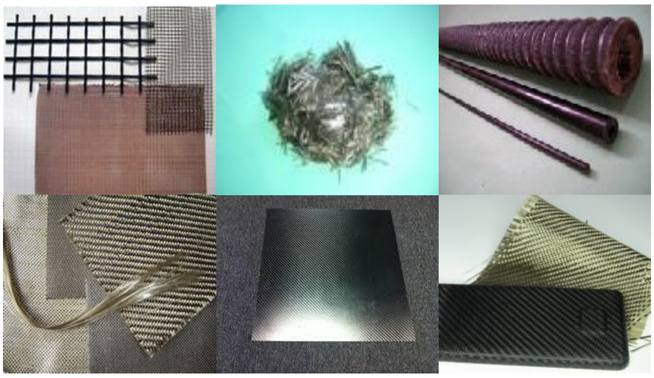


Fig: 1

Basalt fibres 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. It is the most common type in the earth's crust (the outer 10 to 50 km).

Its origins are at a depth of hundreds of kilometers beneath the earth surface and it reaches the surface as molten magma. Basalt density ranges between 2700 to 2800 kg/m^3. The basic characteristics of basalt materials are high-temperature resistance, high corrosion resistance, resistance to acids and alkalis, high strength and thermal stability.

Basalt can be formed into continuous fibres with the same technology utilized for E-Glass and AR-Glass fibres, but the production-process requires less energy and the raw materials are widely diffused all around the world. This justifies the lower cost of basalt fibres compared to glass fibres. Moreover, basalt fibres are environmentally safe, non-toxic, non-corrosive, non-magnetic, possess high thermal stability, have good heat and sound insulation properties, durability and vibration resistance.

Some studies have already investigated on fundamental properties of basalt fibres and its application as strengthening and reinforcing material. It is found that the basalt fibre presents a modulus of elasticity atleast 18% higher than that of E-Glass fibres and beams strengthened with basalt fibres showed a more ductile failure than those strengthened with E-Glass fibres. Strengthened with E-Glass fibres.

CHEMICAL COMPOSITION OF BASALT FIBRE

Oxide	Basalt fibre in %
Sio_2	69.51
Al_2O_3	14.18
Fe_2O_3	3.92
Cao	5.62
Mgo	2.41
K_2o	1.01
Na_2O_3	2.74

III. MIXING PROPORTIONING

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 fibre were 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 fibres with different percentages 0.20%, 0.25%, 0.30% 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 in the mould and allowed to set for 24 hours before the moulds were de-moulded and then they were placed in the curing tank until the day of testing (28 days). The mix proportion obtained is as shown below.

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 BASALT MATERIALS

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

1. High temperature resistance
2. High corrosion resistance
3. Resistance to acids and alkalis.
4. High strength & thermal stability.
5. Environmentally safe.
6. Having good heat and sound insulation properties.
7. Durability and vibration resistance.
8. Non-toxic, Non-corrosive & Non-magnetic.
9. Possess high resistance against low and high temperature & have high thermal stability.

V. PROPERTIES OF USED MATERIALS

- Chopped Basalt fibre with aspect ratio 50.
- Cement: Ordinary Portland cement of 43 grade having specific gravity of 3.14
- Fine aggregate: Natural river sand conforming to IS-383, Zone-II having specific gravity 2.60
- Coarse aggregate: Crushed granite angular aggregate of size 20mm confirming to IS-383 having specific gravity 2.78.
- Water: Ordinary potable water conforming to IS 456.

VI. STRENGTH PROPERTIES

GENERAL

The program was conducted for understanding the effectiveness of adding basalt fibres 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.
Casting was made in M_{20} Grade and the specimens were made to cure for 28 days in potable water.

Table: Details of specimens

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

VII. COMPRESSION STRENGTH TEST

The Compressive strength is the capacity of a material or structure to withstand compressive load without failure. It can 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 strength is the key value for design of concrete structures.

Compressive strength of the concrete is obtained by testing the cubes of size 150mmx150mmx150mm at 28th day. The concrete cubes designed for M_{20} 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 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. The axis of the specimen is carefully aligned with the centre of thrust of the spherically seated plate. No packaging is used between the faces of the test specimen and the steel plate of the testing machine.

A spherically seated block is brought to bear on the specimen; the movable portion is rotated gently by hand so that uniform seating may be obtained. The load is applied without shock and increased continuously until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained.

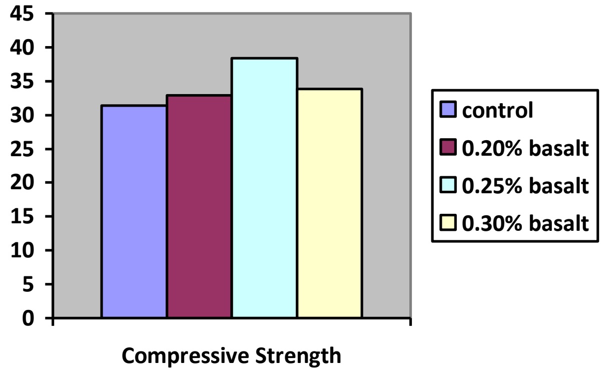
The compressive test on hardened control & Basalt concrete were performed on a 2000kN capacity hydraulic testing machine in accordance to the relevant Indian standards. A typical setup is shown in fig 2. Three concrete cubes were tested for every compressive strength test.

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

Fig: 2 Compressive strength test set up

Table: Compressive strength results

Sl. no	Type of specimen	Ultimate load in Nx10³	Compressive strength at 28 days	Average compressive strength
1	Conventional	755	33.56	31.34 N/mm²
		706	31.38	
		653	29.10	
` 2	0.20% of basalt fibre	726	32.27	32.93 N/mm²
		785	34.89	
		712	31.65	
3	0.25 % of basalt fibre	953	42.35	38.34 N/mm²
		818	36.36	
		817	36.32	
4	0.30% of basalt fibre	730	32.44	33.84 N/mm²
		750	33.44	
		804	35.74	



The Experimental test results shows that the compressive strength of Basalt fibre concrete is higher than that of control concrete and it is also noted that, with 0.25% fibre content the compressive strength is increased up to 25% that of control concrete and gradually decreased at 0.30% fibre content.

VIII. FLEXURAL STRENGTH TEST

Concrete as we know is relatively strong in compression and weak in tension. In reinforced concrete members, little dependence is placed on the tensile strength of concrete since steel reinforcing bars are provided to resist all tensile forces.

The Flexural strength of the concrete is obtained by testing the Prism specimens of size 100mmx100mmx500mm at 28th day. The concrete Prism specimens designed for M_{20} 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. The bearing surfaces of the supporting and loading rollers are wiped clean, and any loose sand or other material removed from the surface of the specimen where they are to make contact with the rollers.

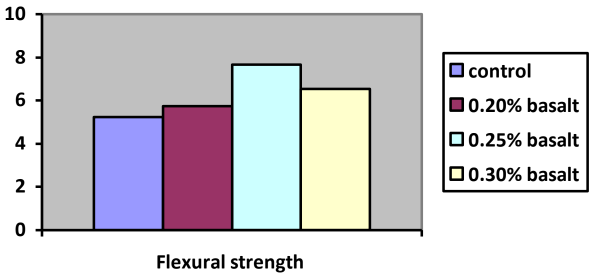
The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 13.3 cm apart. The axis of the specimen is carefully aligned with the axis of the loading device. No packing is used between the bearing surfaces of the specimen and the rollers. The load is applied without shock and increasing continuously at a rate such that the extreme fibre stress increases approximately 0.7 kg/sq cm/min that is, at a rate of loading of 180 kg/min. The load is being increased until the specimen fails, and the maximum load applied to the specimen during the test is recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure is noted. A typical setup is shown in fig 3. The flexural strength of the specimen is expressed as the modulus of rupture F_b

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

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 N/mm²	Average flexural strength
1	Conventional	29	5.8	5.25 N/mm²
		24	4.8	
		26	5.2	
` 2	0.20% of basalt fibre	29	5.8	5.75 N/mm²
		25	5	
		32	6.4	
3	0.25 % of basalt fibre	36	7.2	7.66 N/mm²
		41	8.2	
		38	7.6	
4	0.30% of basalt fibre	35	7	6.54 N/mm²
		26	5.2	
		37	7.4	



The Flexural test results shows that the Flexural strength of Basalt fibre concrete gives more strength than that of the control concrete and with 0.25% of fibre content, the strength is increased up to 40% at its optimum level and decreased gradually at 0.30% fibre content.

IX. MODULUS OF ELASTICITY IN CONCRETE

Modulus of Elasticity is the measure of the ratio of stress to the corresponding strain. The modulus of elasticity can be determined by testing the cylinder specimens of size 150mmx300mm by means of uniaxial compression.

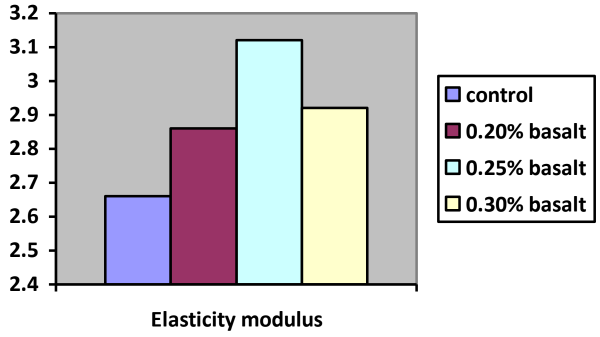
The concrete cylinders designed for M_{20} grade were cast and cured for 28 days. After 28 days of continuous curing the specimens were taken out and they were exposed to atmosphere for few hours. Surface water and grit shall be wiped off and any projecting fins are removed. The specimen is then placed in the machine in such a manner that the axis of 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 means of 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. A typical experimental setup is shown in fig 4.

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

Fig: 4 Test on Concrete Cylinders for E for concrete

Table: Elasticity modulus

Sl.no	Type of specimen	Modulus of Elasticity $(N/mm^2) \times 10^4$	Average
1	Conventional	2.56	2.66 N/mm²
		2.68	
		2.74	
` 2	0.20% of basalt fibre	2.82	2.86 N/mm²
		2.94	
		2.80	
3	0.25 % of basalt fibre	3.04	3.12 N/mm²
		3.21	
		3.11	
4	0.30% of basalt fibre	2.84	2.92 N/mm²
		2.95	
		2.97	



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

X. ADVANTAGES OF BASALT FIBRES

1. Basalt fibre materials does not undergo any toxic reaction with water and air, also do not have any side effects on human health.
2. Basalt fibres have major qualities like acid resistance, alkali resistance. It is thermally, electrically and sound insulated.
3. Basalt can replace almost all the applications of asbestos, which poses health hazards by damaging respiratory system, and has three times its heat insulating property.
4. Basalt is more available than any other raw material. Also the melting temperature is lower during the manufacturing process and the energy consumptions is relatively low. This makes the cost of basalt fibres considerably lower than that of other fibres.
5. Basalt base composites can replace steel (1 kg of basalt reinforces equals 9.8 kg of steel) as light weight concrete can be get from basalt fibre.
6. Basalt has several excellent properties like high Elasticity modulus and excellent heat resistance. These fibres have significant capability of heat & acoustic damping and are outstanding vibration isolators.
7. The basalt fibre 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 fibres, though cheaper than carbon fibre and high strength than glass fibre. Hence basalt is suitable as low weight cheaper tough composite material.
8. They possess a modulus of Elasticity at least 18% higher than that of E-Glass fibres.

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 fibres with the concrete and also imparts the use of super plasticizers to improve the workability but the addition of Basalt fibres with the concrete shows the same workability as the normal concrete and there is no need for any kind of super plasticizers to improve the workability. So in workability point of view addition of basalt fibre is not a defective one.
2. As we know, concrete is strong in compression. The addition of basalt fibre with normal concrete further improves the compressive strength of concrete. The experimental results shows that the compressive strength of Basalt fibre concrete is 38.34 N/mm^2 which is 22% higher than control concrete 31.34 N/mm^2
3. Concrete is very weak in tension, to overcome this defect we are adding high tensile fibre material (i.e. Basalt fibre) into the concrete. It is noted from the experimental results that the Basalt fibre concrete exhibits higher tensile strength than the normal concrete. The tensile strength of basalt fibre concrete 7.66 N/mm^2 is found to be 45% higher than the tensile strength of normal concrete 5.26 N/mm^2

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