Effect of Basalt Rock Fibre on Mechanical Properties of M30 Grade Concrete-An Experimental Study

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Abstract **- Basalt rock fibre (BRF), which is also known as "the green industrial material of the 21st century", combines ecological safety, natural longevity and many other properties. Basalt rock fibre is similar to the glass fibre but is produced by basalt rock having better Physic mechanical properties. The properties mainly include the fire resistance and the high tensile strength of the fibre which makes it special and suitable for adding it in the concrete to gain the increase in compressive stress and split tensile strength. The compressive stress and split tensile strength properties are observed by adding different proportions of basalt fibre to the concrete Basalt is a common extrusive volcanic rock. An inert rock found worldwide; basalt is the generic term for solidified volcanic lava. Safe and abundant, basalt rock has long been known for its thermal properties, strength and durability. It is formed by decompression melting of the earth's mantle. It contains large crystals in a fine matrix of quartz. It is a material made from extremely fine fibres of basalt. Extruded basalt stone is formed into a metal like wool composed of pyroxene, plagioclase and olivine minerals.**

Keywords— **Basalt rock fibre (BRF), Compressive strength, split tensile strength, chopped fibres, maximum load, specimen.**

I. INTRODUCTION

Basalt is well known as rock found in virtually every country around the world. Its main use is as a crushed rock used in construction, industrial and highway engineering. However it is not commonly known that basalt can be used in manufacturing and made into fine, superfine and ultra fine fibres. Comprised of single-ingredient raw material melt, basalt fibres are superior to other fibres in terms of thermal stability, heat and sound insulation properties, vibration resistance and durability. Basalt continuous fibres offer the prospect of a completely new range of composite materials and products.

Basalt products have no toxic reaction with air or water, are non-combustible and explosion proof. When in contact with other chemicals they produce no chemical reactions that may damage health or the environment. Basalt replaces almost all applications of Asbestos and has 3 times its heat insulation properties.

The first attempts to produce Basalt fibre were made in the United States in 1923 by Paul Dhe who was granted US patent. These were further developed after World War II.

Fibres from basalt rock have been produced for about 90 years. In 1923 the first attempts to manufacture basalt fibres were made in the USA by a Frenchman from Paris, Paul Dhe. During World War II and from the 1950s to the 1980s, the research (conducted in the Soviet Union, the USA and Europe) advanced the fibre production technology and the fields of fibre applications for military and aerospace purposes. Since 1995 basalt fibres were used in the civilian field. In the 1960s in the north-western USA, where large basalt formations are concentrated, the investigations on the relation between the chemical composition of basalt and the characteristics of the resulting fibres were carried out. Currently, basalt fibres are industrially produced in Russia, Ukraine, other countries of the former Soviet Union, China and the USA.

II. MANUFACTURING PROCESS OF BASALT ROCK FIBRE

A. *From lava to rock*

Basalt is a type of igneous rock formed by the rapid cooling of lava at the surface of a planet. It is the most common rock in the Earth's crust. Basalt rock characteristics vary from the source of lava, cooling rate, and historical exposure to the elements. High quality fibres are made from basalt deposits with uniform chemical makeup. Millions of years ago, eruptions from the centre of the Earth expelled an enormous quantity of lava in the planet surface. In contact to atmosphere the lava has cooled creating the first continents in the planet, the Pangaea. Later on, new eruptions and still unknown phenomenal had split the first continent in the today's structure. The Earth mantle has a thin layer called sphere, this thin lava when in contact with superficies will create the basalt Rock, in many places in the earth is possible to find great canyons and natural sculptures made in basalt by the nature, as result of long years of earth centre temperature and pressure stabilization.

B. From rock to fibre

The process of producing fibres from basalt is based on selecting the richest chemical proprieties basalt rocks with the use of quality tests, crushing the rocks and melting to high temperatures. The melted basalt falls from a specific calculated hole where its temperature gradually decreased and forms a yarn which thickness reduces over the cooling process where it gets rolled in a roving. Crushed basalt rock is the only raw material required for manufacturing the fibre. It is a continuous fibre produced through igneous basalt rock melt drawing at about 2,700° F (1,500° C). Though the temperature required to produce fibres from basalt is higher than glass, it is reported by some researchers that production of fibres made from basalt requires less energy by due to the uniformity of its heating.

C. From fibre to products

The CBF - Continuous Basalt Filament formed in the melting process of basalt results in our Primary products product line. The filament can be winded in three types of roving's: assembled roving; direct roving and Gun roving. From the chopped filament we produce the chopped strands and from twisted filaments ours twisted yarns.

III. CHEMICAL COMPOSITION

Not all basalt rocks can be good to make continuous filament fibres. The typical chemical constituents are SiO_2, Al_2O_3, CaO, MgO, Na_2O, K_2O, TiO_2, Fe_2O_3, and FeO. For instance, the following form shows the typical range of various constituents in basalt rock that would be suitable to make continuous filament fibers.

Components	Percentage (%)
SiO_2	50-60
Al_2O_3	14-19
CaO	5-10
MgO	3-5
$Na_2O + K_2O$	3-5
TiO_2	0.5-3
$Fe_2O_3 + FeO$	9-14

Table 1: Components of good basalt rock

Al_2O_3 increases the viscosity of the melt and chemical stability effects of the constituents on the properties of the fibre have been studied in the past, based on existing literature survey that can be generally summarized as below although there might be some different views amongst researchers:

- SiO_2 and Al_2O_3 affect tensile properties.
- Fe_2O_3 and FeO alter the melting parameters by increasing the homogenization period, crystallization temperature and thermal conductivity, high-temp performance of the final products.
- CaO, TiO_2, MgO increase water resistance and resistance to aggressive media.
- Na_2O and K_2O mainly increase the corrosion resistance in alkali.
- Ballast rock fibre proves to be an excellent material in construction due to its extraordinary properties.

IV. LITERATURE REVIEW

Jongsungsim et al (2005) have studied the characteristics of basalt fibre as a strengthening material for concrete structures. The authors have tested and calculated different properties of basalt fibre like mechanical properties (tensile strength, elastic modulus & elongation at failure), durability of basalt fibre (alkali –resistance test, weathering resistance test, autoclave stability test and thermal stability test). The authors have evaluated the applicability of basalt fibre as a strengthening material for reinforced concrete beams. The authors have bonded the basalt fibre sheets on the surface of beam and these flexure strengthened specimens have tested under bending load. Based on the test result the authors have analysed that the strength of specimens had increased by increasing number of layers of basalt fibre sheet. Finally, the authors have concluded that when compared to other FRP strengthening systems, basalt fibre strengthening system gave more strength with economical manner.

Jiang et al (2014) have studied experimentally on the mechanical properties and microstructure of chopped basalt fibre reinforced concrete. The compressive strength test, splitting tension test, the flexural strength test was carried according to Australian standard. Finally, the microstructure test on cement paste was carried out. These test results have shown that the addition of basalt fibre to the concrete leads to decrease in the workability of concrete and the mechanical performances of basalt FRC were better than the polypropylene FRC. Compared with the plain strength of plain concrete, the compressive, splitting tensile and flexural strength of basalt fibre reinforced concrete were increased furthermore SEM images of microstructure show that a good bond between BF surface and hydrated cement matrix is obtained.

V. TESTS CONDUCTED ON CONCRETE

A. *Compression stress test*

Compression strength of concrete with and without basalt was conducted. The compression test was conducted as per IS 516 -1959. The specimens were kept in water for curing for 7 days, 14 days and 28 days and on removal were tested in dry condition and grit present on the surface. The load was applied without shock and increased continuously at a rate of approximately 140 KG/Sq cm/min until the resistance of the specimen to the increasing load breaks down and no great load can be sustained. The maximum load applied to the specimen was then recorded and appearance of the concrete for any unusual features in the type of failure was noted. Average of 3 values was taken as the representatives of the compressive strength of the sample as noted.

B. *Split tensile strength test*

The split tensile test was conducted as per IS 5816-1999. The size of the cylinder is 200mm length with 100mm diameter. The specimens are kept in the water for 7 days, 14 days and 28 days and on removal were tested in wet condition by wiping water and grit present on the surface. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of the compression testing machine and the load is applied until failure of the cylinder along the vertical diameter. The maximum load applied to the specimen was that recorded and the appearance of the concrete for any unusual features in the type of failure was noted.

Average of 3 values was taken as the representative of batch. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until the failure of the cylinder along the vertical diameter.

To find split tensile stress following equation is being used;

Tensile Strength= $2P/\prod DL$

Where, P=Maximum compressive load

D=Diameter of the cylinder

L=Length of the cylinder

VI. EXPERIMENTAL RESULTS

A. *Results of cubes tested*

	Nominal	Nominal	Nominal	1%	1%	1%	2%	2%	2%	3%	3%	3%
	7 DAYS	14 DAYS	28 DAYS	7 DAYS	14 DAYS	28 DAYS	7 DAYS	14 DAYS	28 DAYS	7 DAYS	14 DAYS	28 DAYS
Maximum Load(kN)	495.29	635.78	739.68	620.55	730.7	907.2	778.5	902.25	1085.63	498.3	573.8	686.25
Maximum compressive stress(MPa)	22.01	28.25	37.88	27.58	32.47	40.32	34.6	40.1	48.25	22.14	25.5	30.5

B. Results of cylinders tested

	Nominal	Nominal	Nominal	1%	1%	1%	2%	2%	2%	3%	3%	3%
	7 DAYS	14 DAYS	28 DAYS	7 DAYS	14 DAYS	28 DAYS	7 DAYS	14 DAYS	28 DAYS	7 DAYS	14 DAYS	28 DAYS
Maximum Load(kN)	80.4	83.0	88.4	81.4	100.8	110.7	115.3	125.1	140.8	69.2	80.2	85.4
Maximum tensile stress(MPa)	2.55	2.64	2.81	2.59	3.21	3.52	3.67	3.98	4.48	2.2	2.55	2.71

C. Variation in values of compressive stress

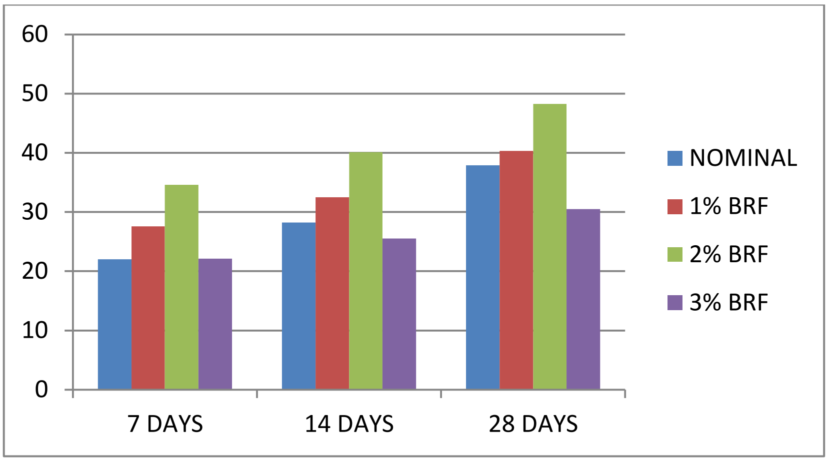

Figure 1: Compressive stress test results

D. Variation in values of Split Tensile strength

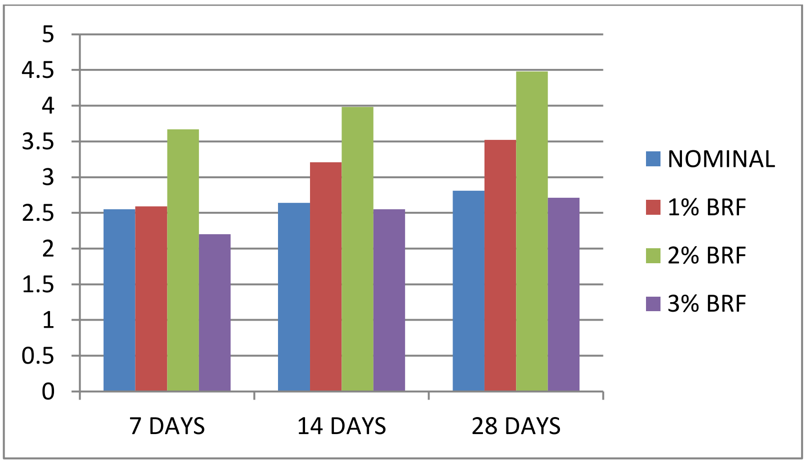

Figure 2: Split Tensile Strength test results

VII. CONCLUSION

- As the result of adding BRF to the concrete, the compressive and split tensile strength test result values are more than the nominal cubes and cylinders. The different percentages of BRF added gives different values for the compressive and split tensile strength. The values for the 1% BRF added was less than the 2% BRF added to the cubes and the cylinders. Whereas, for 3% of BRF added concrete the values of compressive strength and split tensile strength were decreasing rapidly. This shows that the permissible amount of BRF that can be added is less than 3% for obtaining increase in the strength.
- In this study it is observed that compressive stress values for 7, 14 & 28 days are 22.01, 28.25 & 37.88 MPa

respectively.

- For the 1% of BRF the 7, 14 &28 days compressive stress values are increased to 27.58, 32.47 & 40.32 MPa respectively.
- For 2% of BRF added the values 7, 14& 28 days are further increased to 34.6, 40.1 & 48.25 MPa respectively.
- For the 3% BRF added the values for 7, 14& 28 days are decreased to 22.14, 25.5 & 30.5 MPa respectively.
- The Split Tensile Strength values are obtained for 7, 14& 28 days are 2.55, 2.64& 2.81 MPa respectively.
- For the 1% of BRF the split tensile strength value for 7, 14 & 28 days are increased to 2.59, 3.21 & 3.52 MPa respectively.
- For 2% of BRF the split tensile strength value for 7, 14 & 28 days are further increased to 3.67, 3.98 & 4.48 MPa respectively.
- For the 3% BRF the values for 7, 14 & 28 days are decreased to 2.2 ,2.55 & 2.71 MPa respectively.
- Further increase in the amount of BRF added results in less bonding strength between the materials of concrete.

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