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Functionally Graded Concrete Using Glass Fiber and Flyash

M.P.Sureshkumar[1*], V.Naveenkumar[2], R.Thangaprakash[3], S.Gokul[3], M.A.Gunasekaran[3]

[1]*Assistant Professor, Department Of Civil Engineering, K.S.Rangasamy College of Technology, Tiruchengode – 637215, Tamil Nadu, India.*
[2]*PG Scholar, Department Of Civil Engineering, K.S.Rangasamy College of Technology, Tiruchengode – 637215, Tamil Nadu, India.*
[3]*UG Scholar, Department Of Civil Engineering, K.S.Rangasamy College of Technology, Tiruchengode – 637215, Tamil Nadu, India.*

**Corresponding author E-Mail ID: sureshkumarmp@gmail.com*

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ABSTRACT

It has been found that different type of fibers added in specific percentage to concrete improves the mechanical properties, durability and serviceability of the structure. Fiber-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Different types of Fibre reinforced concrete includes steel fibres, glass fibres, synthetic fibres and natural fibres Basalt fiber is a material made from extremely fine fibers of basalt, which is composed of the minerals plagioclase, pyroxene, and olivine.

Keywords: Graded Concrete, steel fibres, glass fibres

1. INTRODUCTION

The basalt is simply washed and then melted. The manufacture of basalt fiber requires the melting of the quarried basalt rock at about 1400 °C (2550 °F). Basalt fiber is a material made from extremely fine fibers of basalt, which is composed of the minerals plagioclase, pyroxene, and olivine. Basalt fibre have a high elastic modulus, resulting in excellent specifictenacitythree times that of steel. There are three main manufacturing techniques, which are centrifugal-blowing, centrifugal-multirole and die-blowing. The fibers typically have a filament diameter of between 9 and 13 µm which is far enough above the respiratory limit of 5 µm to make basalt fiber a suitable replacement for asbestos.

Jongsungsim et al (2005) 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 bonded the basalt fiber sheets on the surface of beam and this flexure strengthened specimens have tested under bending load. 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 used SHPB apparatus and pulse shaping techniques to test BFRGC (Basalt Fiber Reinforced Geopolymeric Concrete).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 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 uni-axial 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

Lopresto et al (2011) have studied the mechanical characterization of basalt fiber reinforced plastic. The authors were carried out tensile, compression, flexural, shear and low velocity impact tests. Basalt composites showed a 35-42% of higher Young's modulus as well as have a better compressive strength and flexural behaviour. the authors have concluded that the basalt fiber reinforced plastic has good mechanical properties when compared to other fiber reinforced plastic and also it has good fire resistance properties which could be very useful in order to offer new perspectives in the fields of engineering.

Manikandan et al (2012) has authors initially treated the fiber and basalt fiber reinforced polymer matrices were fabricated using hand layup method, and then the authors have evaluated the mechanical properties by conducting tensile test, inter-laminar shear test and impact test. These test showed that base-treated basalt fiber reinforced polymer composites have very good mechanical properties than base-treated glass fiber reinforced concrete the authors have concluded that basaltfiber composite with unsaturated polyester was superior to the glass fiber and these composites have great impact strength.

Quagliarini et al 2012have investigated the tensile characterization of basalt fiber rods and ropes. In general the Basalt Fiber Reinforced Polymer (BFRP) rods and Basalt Fiber (BF) ropes can be used as an alternating materials to glass, carbon or aramidic fibers for strengthening purpose.Then the tensile test has been done and from the test results the authors have concluded that the tested BFRP rods seems to be not so rigid (less than glass FRP rods) but rather deformable with good tensile strength (better than GFRP rods), and also the experimental results confirms that BF ropes have good mechanical performance.

Shi et al (2013) have investigated the bond behaviour between basalt fiber-reinforced polymer sheet and concrete substrate under the coupled effects of freeze-thaw cycling and sustained load. Test variables were freeze-thaw cycles, level of sustained load, and adhesive type. Double-lap shear specimens were used in the tests, and a specially designed reaction-loading system was used to apply the sustained load during freeze-thaw cycles the authors have found that significant decreases were observed in mechanical properties of the concrete material and original epoxy resin when subjected to freeze-thaw cycling. The freeze-thaw environment had almost no effect on the durability of the BFRP composite and the modified epoxy resin.

Yuan et al (2013) have investigated about the flexural behaviour of Engineered Cementations Composite (ECC) and concrete / ECC composites beams reinforced with basalt fiber reinforced polymer. This test results showed that for an FRP-reinforced concrete beam, substitution of conventional concrete with ECC could significantly improve the flexural properties in terms of strength, deformation capacity. the authors have concluded that the application of ECC in FRPreinforced beam members was effective in enhancing load-carrying and deformation capacities, shear resistance, and ductility (in terms of energy dissipation ratio), in comparison to FRP-reinforced concrete members

Ma et al (2013) have studied the seismic behaviour of an earthquake-damaged reinforced concrete frame structure retrofitted with basalt fiber-reinforced polymer From the shake table tests of the FRP-retrofitted structure the authors have concluded that the shear capacity, ductility, and hysteretic energy dissipation capacity of each story were greatly improved and that the beam-column joint failure mode was prevented and the structure experienced much less damage compared with the original structure when subjected to ground motions of the same intensity. No de-bonding between the FRP sheets and the joints was observed after the shake table tests

Yeboah et al (2013) have investigated the pull-out behaviour of axially loaded Basalt Fiber Reinforced Polymer (BFRP) rods bonded perpendicular to the grain of glulam elements. It was observed that the pull-out load increased approximately linearly with the bonded lengths up to maximum which occurred at a bonded length of 250 mm (15 times the hole diameter) and not increase beyond this bonded length. the authors have concluded the bond stress of the theoretical model (at the ascending and descending branches) of the stress-slip curve was approximately 5-10% of that of the experiment

Wu et al (2013) have studied the flexural behaviour of RC beams strengthened with steel-wire continuous basalt fiber composites plates (SBFCP)**.**The authors have observed that SBFCP strengthened beams have competitive advantages, particularly with respect to their durability and performance-cost ratio, in comparison with specimen strengthened with carbon fiber reinforced polymer (CFRP) materials. From this study the authors have concluded that the volumetric ratio of steel wires in the SBFCPs affects the load capacity and ductility of strengthened specimens

Wang et al (2013) have investigated the effect of basalt fiber on the asphalt binder and mastic at low temperature. The fiber reinforced specimens was tested using the direct specimen test and a newly developed fatigue test procedure. The reinforcement effects of basalt fiber to the fatigue resistance of asphalt binding materials were evaluated**.** From the analysis the authors have concluded that the basalt fiber have increased the mechanical properties of asphalt binder and mastic

Pearson et al (2013) have reported about the long term behaviour of pre-stressed basalt fiber reinforced polymer bars. Testing of the FRP samples was carried out in three stages (initial loading, keeping the desired load level and monitoring of sample). the authors have concluded that pre-stress loses of BFRP bars were seen to be equal or less with steel. The creep coefficient of BFRP and steel were close to each other

Urbanski et al (2013) have investigated on the concrete beams reinforced with basalt rebars as an effective alternative of conventional RC structures. Initially the authors have studied about the tensile strength of basalt bars The authors have tested the beams of size 80 x 140 x 1200 mm. During the tests, the beams were simply supported on two supports with a span of 1000 mm the failure of beams with BFRP reinforcement did not occur suddenly and this effect was a result of transformation of the beam into a tie system because of flexural basalt reinforcement remained unbroken.

Wang et al (2014) have investigated the creep behaviour of basalt fiber reinforced polymer tendons for pre-stressing application. From the conducted test the authors have calculated creep property of BFRP using stress-strain curve, creep rate, residual tensile strength and prediction of creep rupture stress. The authors have also done statistical analysis of creep rupture stress for BFRP tendons at five stress levels. From the conducted test the authors have concluded that Creep rate of BFRP tendons maintained relatively low and stable values of 3.58% and 3.70% under low stress levels of 50% and 60%fu. Finally the authors have founded that these BFRP has better creep properties than the other FRP tendons.

Banibabayat&Pantnaik (2014) have studied creep rupture performance of basalt fiberreinforced polymer bars.The test in this study was performed in accordance with test methods recommended by ACI 440.3R (ACI 2004). As per the ACI recommendation fifteen accelerated creep rupture test were conducted on BFRP bars. Here the authors have used epoxy filled steel tubes, a flexible plastic clear tube, strain gauge, rubber plug and strain gauge to conduct the test. From the test result the authors have concluded that the million hour (114 year) creep coefficient of BFRP bars was estimated to be 13%, which is marginally smaller than that for other AFRP materials.

Greco et al (2014) have studied mechanical properties of basalt fiber and their adhesion to polypropylene matrices. The test result indicated that the tensile strength of fibers was not significantly affected by origin or surface treatment and it was severely dependent on the filament length, and also the authors have calculated adhesion properties of basalt fibers. the authors have concluded that the basalt fiber has good adhesion property with the polypropylene matrices.

Wang et al (2014) have investigated the shear behaviour of basalt fiber reinforced polymer (FRP) and hybrid FRP rods as shear resistance members. From the test results the authors have concluded that the BFRP, CFRP and hybrid FRP rods had similar shear strengths comparable to those of steel rods and constant shear deformation ratios, and the shear strength of the FRP rods was contributed mainly by their internal fibers, whereas the resin contributed only approximate 8% of the total strength. The results show that the shear strength and shear deformation ratio of different FRP rods was maintained almost constantly regardless of the variation in diameters, resin types and fiber types

Lapko&Urbanski (2014) have studied about the experimental and theoretical analysis of deflections of concrete beams reinforced with basalt rebar. The tested BFRP (Basalt Fiber Reinforced Polymers) model beams have been made of concrete class C30 / 7 and reinforced with flexural basalt bars of 8 mm in diameter. The investigation has shown that much lesser cross sectional stiffness of BFRP produces higher deflections and crack widths compared to the beams reinforced with steel bars of the same cross-section.the authors have concluded that the basalt fiber 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

Kabay (2014) has investigated the abrasion resistance and fracture energy of concretes with basalt fiber. In this study the author has researched about the effect of basalt fiber on physical and mechanical properties of concrete. Concrete specimens were tested by three points loading to determine the flexural strength, fracture energy and Bohme test was used to determine the abrasion resistance of concrete. The specimens were tested for 16 cycles and the test results showed that an improved flexural strength, fracture energy and abrasion resistance can be obtained by using basalt fiber even at low contents, and also the relationship between abrasion and other parameters such as void content, compressive e strength, flexural strength were established.

CONCLUSION

The basalt fiber 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. From this study we founded that the basalt fiber composite has low thermal conductivity, high oxidation resistance, high softening and melting temperatures, higher young's modulus and tensile strength properties than that of glass fiber and also it has better fire resisting property compared to glass fiber.

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Conflict of Interest

None of the authors have any conflicts of interest to declare.

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