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Structural stability of basalt fibers with varying biochemical conditions- A invitro and invivo study

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ABSTRACT

Basalt rocks are formed in nature due to the rapid cooling of lava carbonatite and are available in plenty. They are used as reinforcement fibers worldwide, but their chemical properties were found to vary with geographical region. In the study, the degradative properties of basalt fibers with altered chemical and biological conditions were found to deplete the strength of the basalt fiber reinforced concrete and polymer modified basalt fiber reinforced concrete. Further investigations on the degradative and degenerative properties of the fibers with various chemical and biological stress explained the structural instability of the basalt fibers. SEM and optical micrographs has clearly shown the spalling and exfoliation of the basalt fibers by leaching out the mafic minerals on biochemical degradation. EDX and FT-IR data has also revealed the utilization of mafic minerals by the microorganisms as their carbon and nitrogen source explaining the rapid degradation of basalt fibers.

1. Introduction

Basalt is a hardest and the denser volcanic igneous rock that contributes to the major part of the earth's crust. It comprises of a wide variety of rocks that may generally have gray, brown or dark color [1]. Typically lava of volcanic eruption contain olivine, clinopyroxene (salite), plagioclase and opaque metal oxides as their major constituents. Plageocene and pyroxene contribute to about 80% of almost all types of basaltic rocks [2]. Basalt has been extensively used in construction, industrial and highway engineering sectors due to its good hardness and thermal stability [3]. It is used to layer the surface, as road fills, as ceramic tiles, linings of pipes and reinforcement. Also as major alternate to the asbestos reducing the health hazards. Based on these applications basalt has been transformed to fibers of fine, superfine and ultrafine sizes replacing other fibers due its chemical structure, purity and easy to handle procedures [4]. Immediately after which, it became a new range of concrete composite and has acquired status in thermal and sound insulators, bars, fittings, fabrics, structural plastics, automotive parts and also as concrete reinforcement [5].

The pressure on the development and the usage of an environmental friendly material in the industrial and construction sector as reinforcement and the abundance of basalt in the earth crust has directed the researchers to use basalt fibers as reinforcement materials [6]. Even though, researchers like Wu et al. [7], Ramachandran et al. [8], Wang et al. [9] and Scheffler et al. [10] have already discussed about the stability of basalt fibers in the altered chemical condition. Studies related to the biochemical stability of the basalt fibers are scanty. Biochemical factors influence each and every material as they are mainly dependent on the environmental aspect to which the fibers are exposed. The study elaborates the fibers liability to degradation with the biochemical variation that generally occur in concrete. Two types of concretes were used in the study namely; basalt fiber reinforced concrete (BRC) and polymer modified basalt fiber reinforced concrete (PBRC). To know the optimum concentration of fibers and the adverse effect caused by aggregation of high concentrations of basalt fibers, the relation of high concentration of fibers in altering the biochemical environment and the effect of chemical admixtures like superplasticizer and SBR on the fibers. So, the present study deals with the experimental investigation and characterization on the degradative and degenerative effects caused by the biological and chemical stress that exists in nature on the basalt fibers in in-vitro condition explaining the stress at in-vivo condition.

2. Experimental program

2.1. Preparation of basalt fiber reinforced and polymer modified basalt fibers reinforced concrete

A concrete mix of 1:1.67:1.86 with w/c ratio 0.45 was used for

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Table 1
Mix proportions for BRC.

Water (kg/m^3)	Fiber (%)	Cement (kg//m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Fiber (kg/m^3)
216	Nil	480	801	891	Nil
216	0.5	480	801	891	13.15
216	1	480	801	891	26.3
216	1.5	480	801	891	39.45
216	2	480	801	891	52.6

the investigations. Styrene butadiene rubber (SBR) of 5% of the cement content in concrete mix was used as the polymer for PBRC. Basalt fibers in various percentages of 0.5%, 1%, 1.5%, 2% were used in different mixes. In all the mixes, Superplasticizer (SP) was added to get the required workability. The quantity of materials used in BRC for different mixes are given in Table 1. In the case of PBRC, 5% of SBR is added to the mixes given in Table 1. Cubes of 100 × 100 × 100 mm and cylinders of 150 mm diameter and 300 mm height were cast for BRC and PBRC with different mixes to determine the compressive strength and split tensile strength. All the BRC specimens were cured in water for 28 days, whereas for PBRC the curing cycle adopted was 2 days air curing followed by 5 days water curing and subsequent air curing till the test date.

2.2. Experimental methods

Basalt fibers of 24 mm in length and 13 μm in diameter were exposed to various extreme chemical environments like water, SBR and SP that prevails in any cementitious or plastic material that needs a fiber as reinforcement. The whole test was maintained at pH 12 to know the effect of alkalinity in addition to the chemicals on the fibers. The reported results were noted everyday up to 28 days and the spalling or degradative effect of these elements on the mafic minerals were observed using light microscopy initially. When the degradation and degeneration was visible the fibers were examined using optical microscopy.

Similarly, the basalt fibers were tested for their degradative ability with the bacterial strains like *Bacillus cereus*, *Bacillus subtilis* and *Pseudomonas aeruginosa* that were isolated from the specimens collected form BRC and PBRC. About 500 mg of the fibers were added to a sterile test tube containing 10 ml of minimal medium (K_2HPO_4 - 1.8 g/l, Glucose - 0.5 g/l, NaCl - 0.5 g/l at pH - 7.00) and were inoculated with 500 μl of overnight culture grown in Luria Bertani broth (HiMedia, India). Then the tubes were incubated at 37 °C for 7 days. These tubes were monitored regularly to note the visible surface structural change in the fibers at every 24 h interval.

2.3. Characterization methods

Chemically, biologically treated and untreated fibers were characterized using the optical microscopy, SEM, FTIR, XRD and EDAX to know the morphological and structural changes caused by the chemical and biological conditions to which the fibers were exposed.

2.3.1. XRD analysis

Phase identification was carried with a Bruker D2-Phaser XRD-diffractometer, Germany that used monochromatic Cu-Kα1 radiation at 30 kV and 10 mA over the specimens. The samples were scanned in the range of 10–80° 2θ at the rate of 1.5°/min. Crystalline phases were identified by comprising the intensities and positions of Bragg peak with those listed in the JCPDS-ICDD data files.

2.3.2. FTIR analysis

The surface chemical bonding and the functional groups were determined by the spectra obtained from Fourier transform infrared spectroscopy (Nicolet 6700, Thermo Scientifics, USA). The spectral resolution was 4 cm^{-1}, and 256 scans were coded into the mid infrared region (4000–400 cm^{-1}).

2.3.3. SEM and EDAX analysis

The micrographs were obtained from the Scanning Electron Microscope, ZEISS EVO18 to know the surface structure, morphology and size of the ash and silica in the sample. EDAX, ZEISS EVO18 was used to determine the components and their percentage in the ash samples.

3. Results and discussion

3.1. Mechanical characterization of concretes with basalt fiber

Mechanical properties were evaluated for two types of concretes namely, basalt fiber reinforced concrete (BRC) and polymer modified basalt fiber reinforced concrete (PBRC) to know the influence of the basalt fibers concentration over the chemical and biological factors in the environment that depletes the strength of the concrete. Fig. 1 discusses the average compressive strength variation of BRC and PBRC with different volume fraction at 14th and 28th day. Aggregation of fibers caused great difficulty to cast BRC specimens with 2% fibers due to its reduced workability; hence the results were not reported. The specimens were tested using 100 tones UTM. It was observed that the average compressive strength of 0.5%, 1%, 1.5% and 2.0% PBRC was 22.63 N/mm^2, 21.94 N/mm^2, 24.75 N/mm^2, 23.8 N/mm^2 respectively and that of BRC was 38.34 N/mm^2, 38.64 N/mm^2, and 21.4 N/mm^2.

When the compressive strength of PBRC was compared with BRC cast with 0.5% of basalt fibers, it was observed that 14th day compressive strength of BRC was approximately twice the value obtained for PBRC and the 28th day strength of BRC was 40% higher than PBRC. Similarly, on 28th day 1% basalt fibers incorporated BRC demonstrated 76% strength improvement when compared to PBRC and 1.5% basalt fibers incorporated BRC attained only 15% improvement in strength compared to PBRC. This may be due to the degradation of basalt fibers with structural deformation

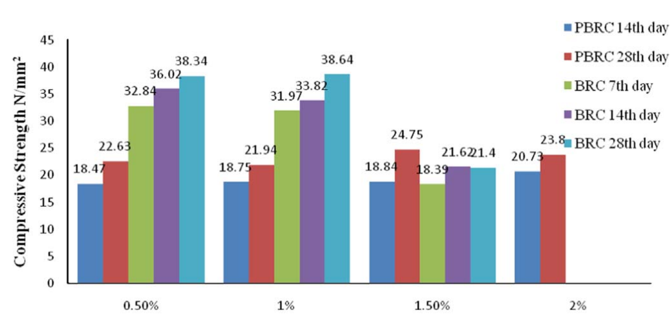

Fig. 1. Compressive strength of BRC and PBRC.