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Effect of Fiber Orientation on the Mechanical Properties of Fabricated Plate Using Basalt Fiber

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Abstract

Rehabilitation of deteriorated civil engineering infrastructures is mainly due to corrosion, destructive environmental situations, ageing, poor initial design or construction errors, poor maintenance and unintended situation like earthquake and has been a major issue in the last decade. It is necessary to find out the suitable substitute with low weight, high strength and low cost materials. The Aramid, carbon and glass are the most commonly used fibres, whereas basalt fibres are comparatively novel fibre in the civil engineering industry for the strengthening of structures using Basalt fiber which is made from basalt rock. Basalt fiber has high tensile strength, good range of thermal resistance, acid resistance, good range of electro-magnetic properties, inert nature, and high resistance to corrosion, radiation and UV light. This investigation focuses on the effect of fibre content and fiber orientation of basalt fibre on mechanical properties of the fabricated composites. In this investigation different fiber orientations are taken and the fabrication is done by hand lay-up process. The variation of the properties with the increasing number of plies of fiber in the composites is also studied. Specimens are subjected to tensile strength test and the failure of the composite is examined with the help of INSTRON universal testing Machine. The average tensile strength and modulus of elasticity of BFRP plates are determined from the test Program.

Keywords: Basalt fiber, basalt fabric plate, fabrication, fiber reinforced polymer (FRP), strengthening.

Introduction

Generally composite materials constitute of Fibre reinforced polymers (FRPs) which have high strength, high stiffness, high tolerability and matrix which binds the fibres to fabricate the structural material. Fibres in the composites are used for increasing the strength and stiffness to the low strength matrix. Fibers in the composite act as the reinforcement filaments which take most of the external loads when the materials are in service. Basalt fiber is a unique product seeming in current ages. In addition, the manufacture of basalt fibers is a solo process which is not comprise of any other condiments in the production. This marks them to have an extra benefit in cost compared with other commonly used fibers. Basalt fibres are non-toxic, non-combustible and have higher chemical stability, higher tensile strength than the E-glass fibers and as compared with carbon fiber their strain to failure is larger. Due to these advantageous properties the basalt fibers could be extensively useful to many grounds, such as corrosion-resistance material in the chemical trade, wear and friction ingredient in the automobile trade, strengthening material in structure, and high temperature-insulation of automobile catalysts.

Basalt fiber of mineral origin has gained cumulative attention as a reinforcing material compared to traditional glass and carbon fibers (2000)[1]. Several articles dealing with glass and carbon fiber reinforced polymer composites mention the significance of basalt fiber as a promising innovative strengthening material (1999, 2002)[2,3]. With use of such low density and tough composites instead of metal raw materials e.g. in manufacturing of rotating fluid machinery mechanical problems e.g. related to swept rotor blades (1993, 2002)[4, 5] can be surmounted (1994)[6]. There are only a few researchers who managed to create a composite to embed basalt fibers in a polymer matrix (2001, 1999)[7, 8]. The main reason is the problem of fiber-matrix interfacial interaction and the high sensitivity to fracture in basalt fibers. The earlier revisions on the poverty of the strengthening fibers in chemical environments are related to the fabricated materials in which the fibers are shielded by the matrix. The conflict of the fibre to corrosion is primarily based on the resin's corrosion-resistance, and the corrosion crack circulation is also linked to the resin stiffness (2007)[9-11].

From the existing literatures it has been observed that the works on basalt fiber fabricated composites are very scanty. Based on the critical observations made from the existing literatures, the objectives of the present study are defined as follows. i. To study the effect of fiber orientation on the mechanical properties of basalt fiber fabricated composites. ii. To study the effect of number of layers of fiber on the mechanical properties of basalt fiber fabricated composites.

Material and Methods

Experimental program: The parameters selected for the experimental study are as follows: i. Number of BFRP layers (variation of BFRP thickness), ii. Fiber orientation ($0^0/90^0$ fiber direction)

Materials: Basalt fiber: Basalt fibre is an innovative fibre reinforced polymer (FRP) in the construction industry and has an identical chemical composition as glass fibre. It has superior strength, high resistant to alkaline, acidic and salt attack which makes it a good applicant for concrete, bridge and ocean front structures and also it has the higher thermal insulation property, higher radiation resistance, higher compression strength, higher shear strength and higher oxidation resistance as compared to carbon and aramid fibre. Different forms of basalt fiber are available in market. Unidirectional basalt fiber is used throughout the experiment.

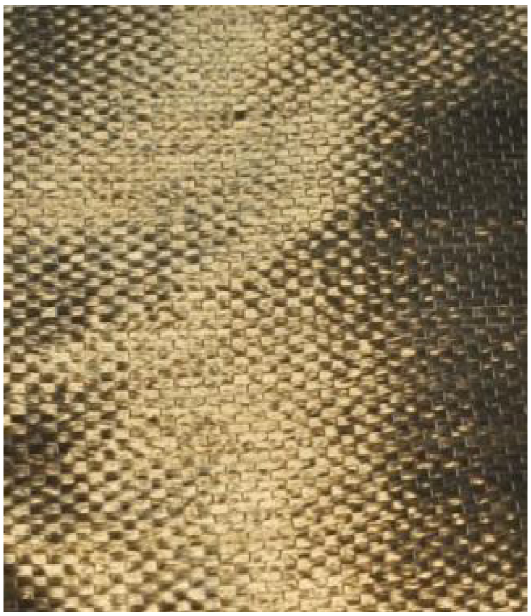

Figure-1
Woven basalt fiber

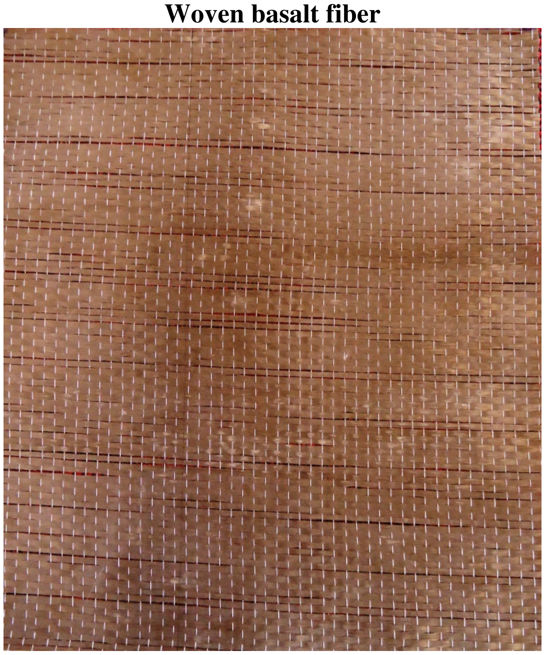

Figure-2
Unidirectional basalt fiber

Epoxy Resin: Fibre composites used in the strengthening technique contain an adhesive of thermosetting resins that can be epoxy, vinyl ester or polyester. Epoxy resin is the widely used and encouraging matrix in the construction industry. Epoxy resin is prepared from two dissimilar chemicals, an epoxide “resin” with polyamine “hardener”. The resin and hardener used in this study are Araldite LY 556 and hardener HY 951 respectively.

Methodology: Fabrication process: There are two basic processes for moulding, that is, hand lay-up and spray-up. The most common method for fabrication process is the hand lay-up process of FRP marine construction. In hand lay-up process liquefied resin is sited along with reinforcement (unidirectional basalt fibre) against the finished surface of an open mould. Resin was used for hardening the material to a durable, lightweight product due to chemical reaction. The resin acts as the matrix for the reinforcing basalt fibres, just like concrete acts as the matrix for steel reinforcing rods. The percentage of fiber and matrix was 45:55 in weight.

The subsequent component materials are used for fabricating the BFRP plate: i. Unidirectional basalt FRP (BFRP), ii. Resin (Epoxy), iii. Catalyst (Hardener), iv. Releasing agent (Polyvinyl alcohol)

A flat plywood rigid platform was used to fabricate the plies of unidirectional basalt fibre in the prescribed sequence using hand lay-up process. On the plywood platform a releasing sheet was placed and polyvinyl alcohol was used as a releasing agent. The fabrication starts by applying the resin (epoxy and hardener) on the mould by brush, which provide an even peripheral surface and protect the fibers from straight contact to the environment. The first layer of reinforcement was placed on the mould over the resin and resin was spread uniformly over the reinforcement by using brush. A steel roller was used to eliminate the entangled air gurgle. The above process of hand lay-up was repeated till all the fibres (reinforcements) were placed. Again, the top of the plate was covered with a releasing sheet which was applied with polyvinyl alcohol. Then, for compressing purpose a heavyweight rigid platform was placed on the uppermost surface of the plate. A curing process for a minimum of 48 hours was maintained before being transported and cut to exact shape for testing.

Plates of 2 layers, 4 layers, 6 layers and 8 layers of 0^0 and 90^0 fiber direction were cast and three specimens from each thickness were tested.

Determination of Ultimate Stress, Ultimate Load and Young’s Modulus of FRP: The unidirectional tensile test has been done to determine the ultimate stress, ultimate load and young’s modulus for the specimens cut in longitudinal and transverse directions. By using diamond cutter or hex saw the specimens were cut from the plates and was polished with the help of polishing machine. The mean values of the three replicate tested sample specimens adopted.Table-1 shows the dimensions of the tested specimens.

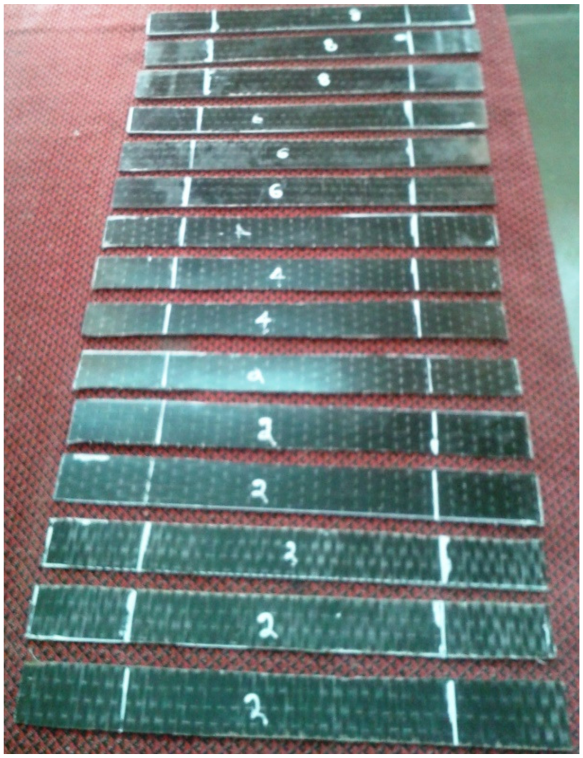

Figure-3
Specimens for tensile testing of Unidirectional Basalt fiber epoxy composite

Figure-4
Experimental setup of INSTRON universal testing Machine (SATEC) of 100 kN capacity

Figure-5
Specimen during testing

Table-1
Size of the Specimens for tensile test

Orientation	No. of layers	Length of sample(cm)	Width of sample(cm)	Thickness of sample(cm)
0^0 orientation	2 Layers	25	2.5	0.51
	4 Layers	25	2.5	1.03
	6 Layers	25	2.5	1.51
	8 Layers	25	2.5	1.99
90^0 orientation	2 Layers	25	2.5	0.56
	4 Layers	25	2.5	1.07
	6 Layers	25	2.5	1.53
	8 Layers	25	2.5	2.03

The tensile strength and young's modulus of the specimens were determinedin Production Engineering Lab, NIT, Rourkela using INSTRON 100 kN. First Specimens were gripped in the fixed upper jaw and then gripped in the movable lower jaw. To prevent the slippage gripping of the specimen should be proper. Here, it is taken as 50 mm from the each side. Initially, the strain is kept zero. The load, as well as the extension, was recorded digitally with the help of a load cell and an extensometer respectively. From these data, stress versus strain graph was plotted, the initial slope of which gives the young's modulus. The ultimate stress and ultimate load were obtained at the failure of the specimen.

Figure-6
Failure specimens for 90^0 orientation

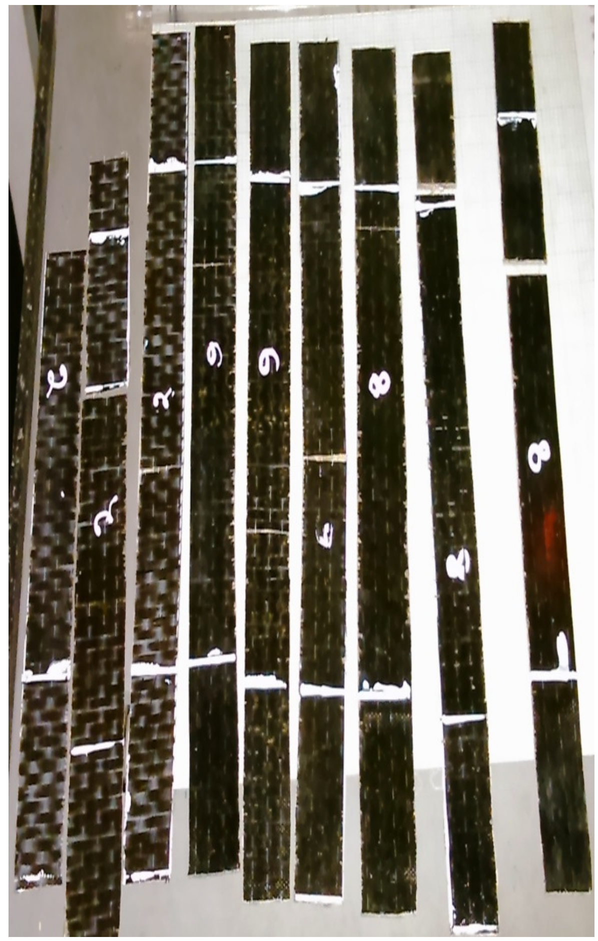

Figure-7
Failure specimens for 0^0 orientation

Results and Discussion

The average value of Ultimate Stress, Ultimate Load and Young's Modulus foreach layer of the specimens of $0^0$and 90^0orientations is given in the table 2. From table-2, it is observed that the specimens for 90^0orientation give conservative result as compared to the specimens for 0^0 orientation for each layer. The ultimate stresses for 0^0 orientation with different layers of BFRP are depicted in figure-8.

Table-2
Result of the Specimens from Tensile test

Orientation	No. of layers	Ultimate Stress (MPa)	Ultimate Load kN)	Young's Modulus (MPa)
0^0orientation	2 Layers	13.86	0.202	4588
	4 Layers	14.07	0.577	5561
	6 Layers	19.53	0.883	5607
	8 Layers	23.57	1.01	6395
90^0orientation	2 Layers	328	5.808	11920
	4 Layers	391	11.87	12870
	6 Layers	421	22.11	13130
	8 Layers	469	25.48	13920

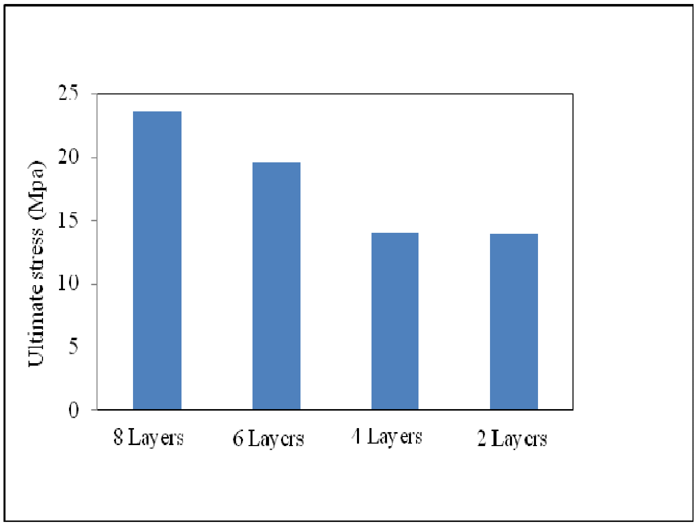

Figure-8
Ultimate stresses for 0^0 orientation

The ultimate stresses for **90^0** orientation with different layers of BFRP are depicted in figure-9.

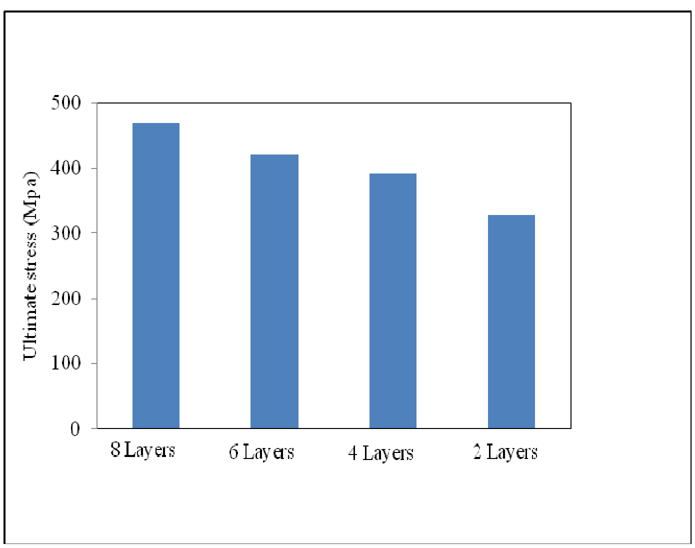

Figure-9
Ultimate stresses for 90^0 orientation

From figures-8 and 9, it is observed that there is marginal increase in the ultimate stress at failure with the increase of number of layers of BFRP.

The ultimate loads for 0^0 orientation with different layers of BFRP are depicted in figure-10.

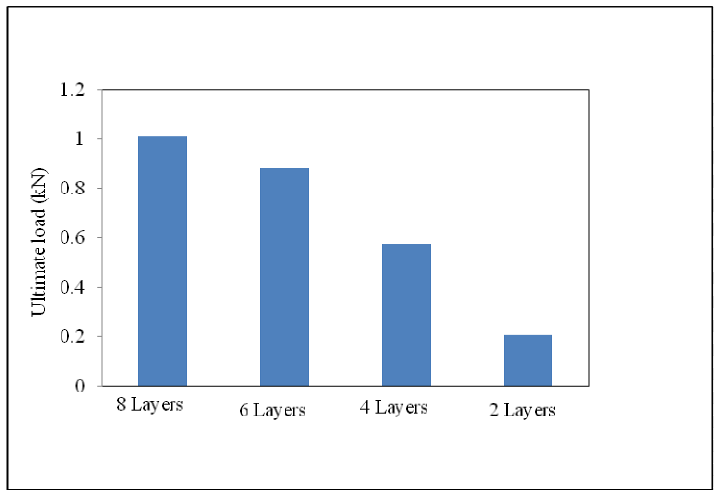

Figure-10
Ultimate loads for 0^0 orientation

The ultimate loads for 90^0 orientation with different layers of BFRP are depicted in Figure-11.

From Figures-10 and 11, it is observed that there is significant increase in the ultimate loads at failure with the increasing layers of BFRP.

The ultimate stresses for 0^0 and 90^0 orientations with different layers of BFRP are depicted in Figure-12.

From Figures-12 and 13, it is noticed that there is substantial increase in the ultimate stress and ultimate load for 90^0orientation as compared to 0^0 orientation.

The young's moduli for 0^0 and 90^0 orientations with different layers of BFRP are depicted in Figure-14.

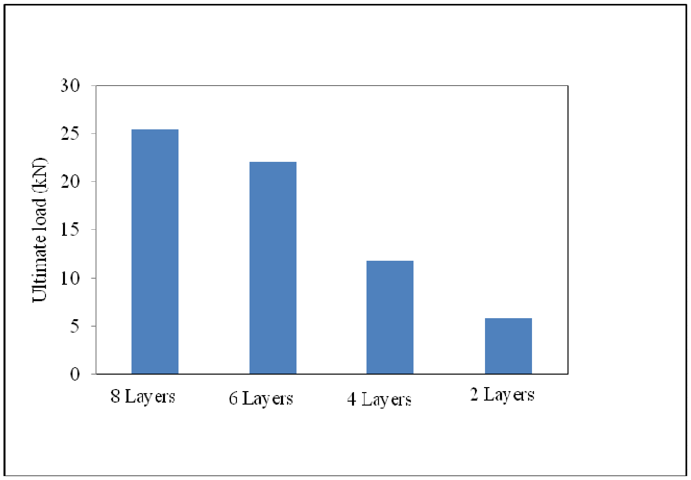

Figure-11
Ultimate loads for 90^0 orientation

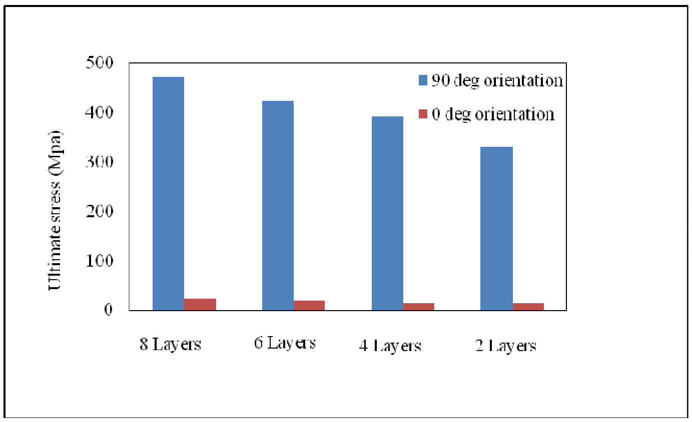

Figure-12
Ultimate stresses for 0^0 and 90^0 orientations

The ultimate loads for 0^0 and 90^0 orientations with different layersof BFRP are depicted in Figure-13

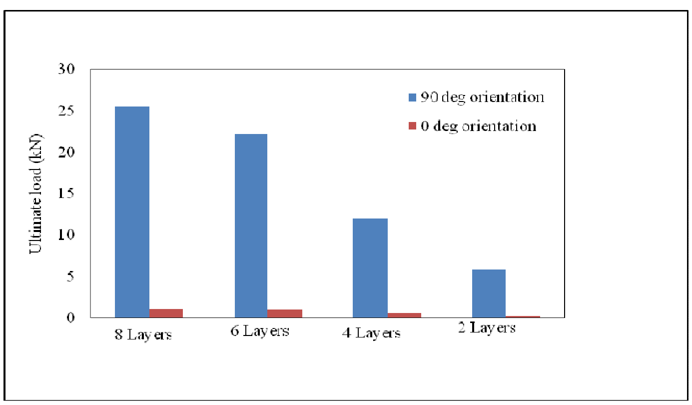

Figure-13
Ultimate loads for 0^0 and 90^0 orientations

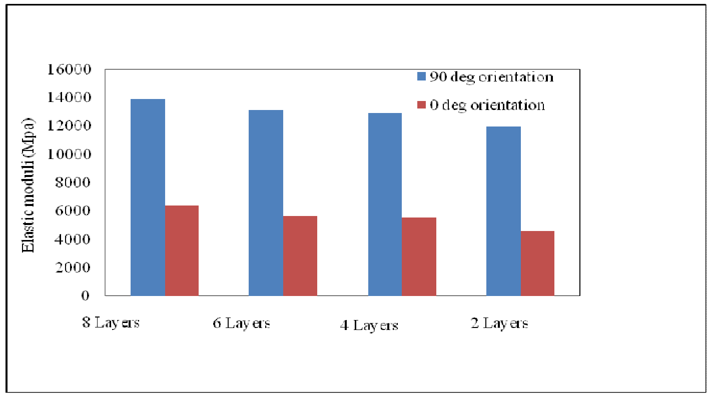

Figure-14
Young's moduli for 0^0 and 90^0 orientations

From Figure-14, it is revealed that there is considerable increase in the elastic moduli for 90^{0}orientation as compared to 0^{0}orientation.

Conclusion

In this study the tensile strength of basalt fiber fabricated plates with different orientations and different thickness were investigated. The following observations emerge out from this investigation: i. The specimens for 90^0 orientation give conservative results as compared to the 0^0 orientation for Ultimate Stress, Ultimate Load and Young's Modulus. ii. Unidirectional basalt fiber can be used in longitudinal direction to get better tensile strength. iii. The tensile strength of the fabricated plate increases with the increasing number of layers of BFRP (i.e. increasing thickness of fabricated plate).

Basalt fiber can be an alternative for fiberglass since their average density and average tensileelastic moduli are almost the same, and the production cost of basalt fibers is onlyone half of that of the fiberglass due to the simplicity of the Junkers productiontechnology.

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