Mechanical Properties of E-Glass Fiber - Basalt Fiber Reinforced Polymer Matrix Composite

Muhammed Anaz Khan, A Vivek Anand, Lokasani Bhanuprakash, A Ravindra, V Hariprasad

Abstract*: Composite materials have significant role in automobile and aerospace applications because of their attractive mechanical properties compared. This fascinating properties attracted several industries especially automotive sectors. In contrast to metallic alloys, composite materials composed of individual constituent elements with distinguishable interfaces and chemical identities, however, when combined e-glass and basalt fiber, they will produce superior properties. The fundamental advantage of composite materials is their high specific strength and specific stiffness, which emphasis on its weight saving potential in the finished part. Two principal constituent elements of composites are matrix and reinforcement materials. In the present work, an attempt has been made to understand the advancements achieved in the combination of e-glass fiber and basalt fiber composites. Based on the comprehensive literature review, it is observed that broad work was done on the manufacturing techniques and characterization of the composites, however, limited works were carried out in analyzing the tensile, flexural and shear strength properties of differently oriented fibers in the laminated composites. In this paper, focus was given in fabricating and characterizing the glass fiber reinforced epoxy composite laminates with different fiber orientations, thereby, examining the mechanical properties of prepared laminates for tensile and bending strengths.

Keywords*: Basalt fiber, polymer matrix composite, tensile strength, bending strength and flexural rigidity.

I. INTRODUCTION

Composites are well known for its wide range of application in aerospace and automobile sectors. The usage of composite material in the structures of the vehicles was increasing day by day due to its better mechanical property (high strength to weight ratio). To meet the current market needs and to protect the environment, globally researchers working on natural composites to replace the polymer composites. Glass fiber (GF) are the commonly preferred reinforcement in polymer matrix composite due to its easy availability and better mechanical properties. Basalt and glass fibers are suitable candidates to resist alkalis and to withstand high temperature up to certain extent at lower cost, when compare to other aramid and carbon fibers [1]. The manufacturing techniques of both the fibers are moreover same. Basalt is derived from volcanic material and its density is five percentage greater than glass fiber. The mineral deposit of the volcanic substance determines the chemical composition of Basalt. Basalt fiber may stand as a best alternative for glass fiber based composites [2]. Mechanical properties of the basalt fiber is good as glass fiber [3-6] and its temperature withstanding capacity is greater than glass fiber [7][8]. Apart from static behavior, dynamic behavior of the basalt fiber is also observed better when compare to glass fiber [9][10]. The serious disadvantage noted in glass fiber is shrinkage and moisture absorption characteristics. The basalt fiber can be used in the place of glass fiber to overcome the above mentioned disadvantages. Basal fiber electrical insulation is ten times greater than that of glass fiber which makes its suitable in electrical and electronics application. The notable advantage of basalt fiber over glass fiber is in terms of mechanical properties, its Young's modulus is 15% greater than glass fiber and tensile strength is 11% higher than glass fiber [11]. The basalt fiber will stand as a best alternative for glass fiber in all the aspects.

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II. PROPOSED METHODOLOGY

A. Fabrication Process

Hand Laminating Molding is used for fabricate the hybrid (Basalt and E-glass) fiber composites. Epoxy resin (Araldite CY230-1) and hardener (Araldite HY 951) was preferred in our work due to its outstanding bonding efficiency and cost effectiveness. The base plate is fixed inside the frame for fabricate the hybrid fiber composites by resin + hardener mixture are used. In this fabrication process, E glass fiber and basalt fiber are taken as reinforcement and epoxy resin as matrix. The specimen is fabricated into 3 plates with 3 different orientations. The specimen thickness is dependent upon the fiber thickness, the glass fiber thickness is 0.2mm (±0.05mm). So as per the thickness number of plies are used to prepare laminates. In our experiment to obtain 3mm thick specimen we applied 12 layers (four layers of basalt fiber and eight layers of E-glass fiber) of fiber with angle plies as per the orientation of laminate.

B. Layer Orientations

The reinforcement, matrix arrangement and ply orientation dictates the stacking sequence of the composite material. The drastic change in the material properties will be observed without changing the material by doing the minor changes in layer orientation

The following layer orientation standards were chosen for specimen preparation:

ASTM D7264

1. 0|30|45|60|-45|90|90|45|60|-45|30|0 = first angular orientation.
2. 0|45|-45|-60|60|90|90|-60|60|-45|45|0 = second angular orientation.
3. 0|45|-45|45|-45|90|90|-45|45|-45|45|0 = third angular orientation.

ASTM D3039

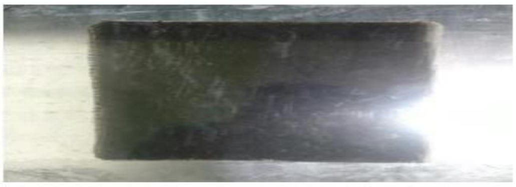
1. 0|30|45|60|-45|90|90|45|60|45|30|0 = first angular orientation.
2. 0|45|-45|-60|60|90|90|-60|60|-45|45|0 = second angular orientation.
3. 0|45|-45|45|-45|90|90|-45|45|-45|45|0 = third angular orientation.

C. Specimen Preparation

A flat surface is required for preparing the laminates. For this flat surface we have used Galvanized Iron (G.I0 sheet is used as a mold plate. The sheet is cleaned thoroughly with acetone to wipe away any grease, oil, and other foreign particles. The overhead projector sheets were placed at the top and bottom surface of the mold for better surface finish. The fiber and matrix both are used for laminate preparation based on 60:40 weight ratio respectively. In this first of all the fiber plies used to prepare the laminate is weighed and noted down. For this fiber weight the matrix is calculated by the ratio fabric: matrix is 60:40 respectively [12]. The matrix is the combination of epoxy resin and hardener. This resin and hardener is taken in 10:1 weight ratio for calculated matrix value. The resin and hardener are mixed thoroughly using mixing sticks until air bubbles are removed from the mixture. The matrix is poured over the sheet and spread over it using the roller or non-sticking glass rods. Then after the first layer of the ply is placed over previously applied matrix and roller is moved over it to remove air gaps in between the layers. The plies are layered based on the orientation, the angles are marked on the mold plate. Layers of composites are placed one over other with reference to standard orientations and dimensions. Specimen should be place separately for curing and to get good characterization and better mechanical properties of specimen, the curing time of specimen is 24h to get better solidification and good strength.

Finally specimen is prepared according to standard values as shown in Fig. 1.

(a)



(b)

Fig. 1. Prepared specimen as per ASTM standards for mechanical testing (a) Bending test - ASTM D7264 and (b) Tensile test - ASTM D3039.

III. RESULTS AND DISCUSSION

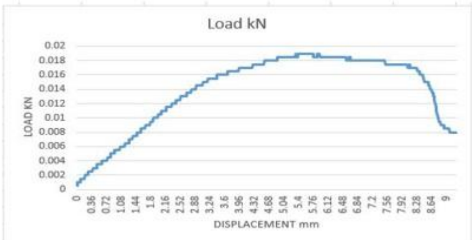
A. Three Point Bending Test

The specimens are prepared according to the ASTM D7264 standard to know standard mechanical properties (bending) using three point bending method to determine bending strength. The testing is carried out in bending test machine with displacement velocity at 2 mm/min. As per ASTM standards the gauge length of the specimen was fixed as 158mm. Initially the width and thickness of the specimen is observed and the cross sectional area is calculated and the test results are listed in table 1. After performing the bending test on different orientation specimens the result values are taken separately as per orientation of the specimens.

Table- I: Test results of three point bend test

Specimen	Load (kN)	Displacement (mm)
S1	0.5	9
S2	0.4	11
S3	0.2	8.5

All specimens exhibited elastic or tensile modulus of fracture along the elongation face. The higher stiffness and Young's modulus of the composite exhibits its resistance to deformation under external loading. The strain rate is kept constant at 2mm/min for all the test specimens. S1 and S2 exhibits comparatively lower modulus of elasticity compared with S3. This variation was attributed through the optimum orientation of fiber layers followed in S3. The variation of displacement with respect to load for different specimens was shown in Fig. 2.



(a)

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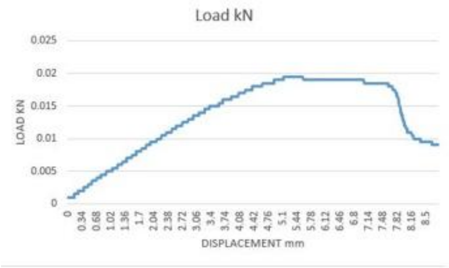

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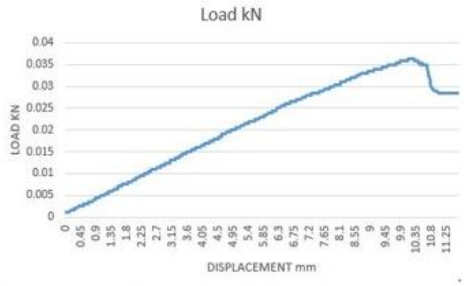
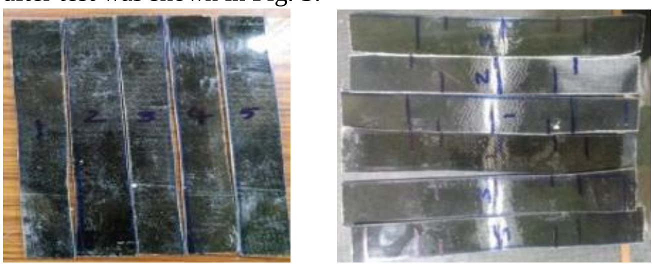


(c)

Fig. 2. Variation of displacement as a function of load (a) S1 (b) S2 and (S3).

Tensile modulus of the composite is depending upon the tensile stress and strain of the composite. The increment in tensile stress and decrement in tensile strain increases the tensile modulus of the material. The test specimens before and after test was shown in Fig. 3.



(a) **(b)**

Fig. 3. Three point bending test specimens (a) before test and (b) after test

B. Tensile Test

The testing is carried out using Universal Testing Machine (UTM) with displacement velocity at 2 mm/min. the gauge length for testing specimen is 250 mm as per ASTM standards. Initially the thickness and width of the specimen is observed and the cross sectional area is calculated. The output results are tabulated in below tabular column accordingly. After performing the tensile test on different orientation specimens the result values are taken separately as per orientation of the specimens and listed in table 2.

Table- II: Test results of tensile test

Specimens (S)	Peak Load (kN)	Tensile Strength (N/mm^2)
S1	16	315
S2	13	286
S3	12	270

The tensile test is conducted on the polymer matrix composite of different orientation. Tensile strength ie., the maximum stress withstanding capacity of the material while stretched, was determined under the constant strain rate of 2 mm/min. Tensile strength of S1 is found to be 315 N/mm^2. The necking of the specimen starts from this point onwards. However, the tensile strength decreases with the other two orientation. The fiber orientation in S1 provide perfect bonding between the reinforcement and matrix. The ductile-brittle transition behavior of the material is found high for the specimen having higher percentage of glass fiber.

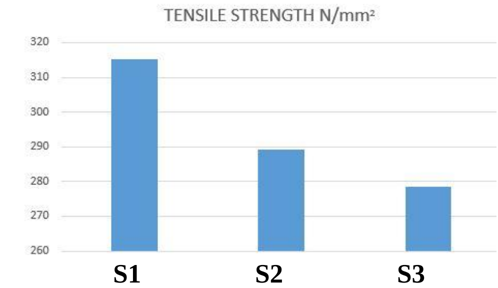
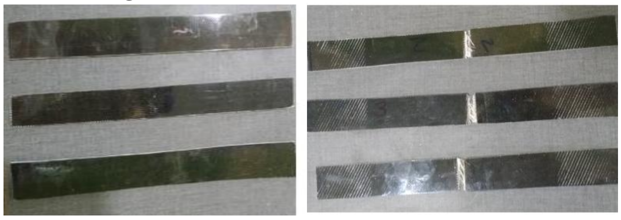


Fig. 4. Tensile Strength for prepared composites

Tensile test on different orientation exhibits noticeable variation. The tensile strength specimens having S1 orientation (0|30|45|60|-45|90|90|45|60|45|30|0) exhibited a tensile strength of 315 N/mm^2 at a peak load of 16 kN, S2 orientation (0|45|-45|-60|60|90|90|-60|60|-45|45|0) exhibited a tensile strength of 286 N/mm^2 at a peak load of 13kN and S3 orientation (0|45|-45|45|-45|90|90|-45|45|-45|45|0) exhibited a tensile strength of 270 N/mm^2 at 12kN peak load. From observing the tensile test results 1st and 2nd orientations samples have a better strength, compared to 3rd orientation specimen. The test specimens before and after tensile test is shown in Fig. 5.



(a) **(b)**

Fig. 5. Tensile test specimens (a) before test and (b) after test

IV. CONCLUSION

Basalt and E-glass fiber hybrid composite specimens are prepared with 3 different orientations to study the mechanical properties and following conclusions were drawn:

- S3 hybrid (Basalt + E-glass) fiber composite possess good bending strength compared to S1 and S2 orientations. Fiber orientation of S3 attributed to this better property.
- S1 composite possess good tensile strength compared with S2 and S3, it exhibited a higher tensile strength of 315 N/mm^2.
- Optimum fiber orientation provides superior bonding between reinforcement and matrix.

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