INTERLAMINAR SHEAR AND FLEXURAL PROPERTIES OF E-GLASS/JUTE REINFORCED POLYMER MATRIX COMPOSITES

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Abstract - Hybrid composites are one of the prominent materials being extensively developed and are gaining momentum due to features like greater flexibility in design, high specific strength and reduced cost of manufacturing. Hybrid composites exhibit better mechanical properties when compared to traditional composites. Present study deals with interlaminar shear and flexural strength of E-Glass/Jute composites. Composite laminates with basket weave (BW) and twill weave (TW) patterns were fabricated using hand layup technique. Fiber weight fractions (FWF) of 10%, 15%, 20% and 25% were adopted. Experiments were conducted in accordance with ASTM standards. Results indicate that laminates with twill weave form exhibited better flexural and interlaminar shear strength.

Keywords – E-Glass/Jute, Epoxy, Hand layup, Flexural properties, Interlaminar shear strength

I. INTRODUCTION

Traditionally the composite materials have been made from a single type of reinforcement. When more than one type of reinforcement is incorporated into a single matrix medium, then it results in hybrid composites. Main advantage of this type of composite is that the strength of one fibre overshadows the weakness of the other. Hence, a balance between cost and performance is achieved [1]. These composites are mainly used in automotive structural panels, light to moderate load bearing furnishings, stationary items, gardening tools and temporary pavements [2, 3].

M. Jawaid et al. [4] investigated jute/oil palm fibre reinforced epoxy composites to determine the effect of fibre loading on its mechanical properties, fracture surface characteristics were also observed. Composites were fabricated using hand layup technique. The authors reported an increasing trend in tensile behavior with increased jute fibre loading for jute-epoxy composites. Olusegun David Samuel et al. [5] studied the mechanical performance of natural fibre/E-glass hybrid composites by making use of hand layup method. Fibre weight fractions of 30% were utilized for the study. E-glass fibre reinforcement in composites resulted in better strength thus was suitable for high strength structural applications. The authors concluded that the natural/synthetic fibre combination can be considered as an alternate to synthetic fibres especially for low strength structural applications.

Dixit et al. [6] evaluated the mechanical properties of coir/sisal, coir/jute and jute/sisal reinforced polyester composites fabricated using compression moulding procedure. Hybridized composites demonstrated better tensile, flexural and resistance to water absorption when compared to standalone composites. Thus authors
concluded that hybrid natural fibre composites are a potential alternate to synthetic fibre composites. Ahmed et al. [7] investigated woven jute/glass reinforced polyester composites for its interlaminar shear, flexural and tensile strength. Hand layup was adopted to obtained a 10 plies laminate with six different stack sequence. Test results reported by authors indicated that stack sequence of the composites is significantly affecting the interlaminar shear, flexural and tensile strength. Overall the authors concluded that the properties of jute composites improved by addition of glass fibre plies, hybrid laminate with two extreme glass plies on either side resulted in an optimum arrangement with a decent balance between the properties and cost. Thwe et al. [8] determined the mechanical performance of bamboo/glass fibre reinforced polymer matrix composites using different fibre weight fraction, fibre length and adhesive agents HLU was utilized for composite preparation. The authors observed that the failure strain, tensile strength and modulus were affected by fibre weight fraction, fibre length and adhesion features between the matrix and the fibres. S Mishra et al. [9] assessed and compared the mechanical performance and water absorption behavior of glass fibre/sisal fibre/pineapple leaf fibre reinforced polyester composites. Chemically treated fibres with different alkaline media were also considered for strength comparison. Overall the authors reported that the addition of glass fabrics, treated sisal fibre/pineapple leaf fibre reinforced composites resulted in improved strength. Resistance to water uptake was minimum in hybrid composites. Wang et al. [10] investigated the effect of fabric structure and microfiber additives on the mechanical performance of glass and kevlar woven fabric reinforced composites. The authors reported that the strength aspects are significantly affected by microfiber addition and type of fabric and its structure. Various fracture mechanism were also studied using scanning electron microscopy. Pandya et al. [11] performed experiments to determine the mechanical characteristics of plain weave E-glass /carbon reinforced epoxy composites. The 8H satin weave pattern of the reinforcement were utilized for study. Results as reported by the authors revealed hybrid composites, with exterior positioned glass and interior aligned carbon fabric layers provided better tensile strain and strength than the carbon fabric layers placed in similar position. Sreekala et al. [12] studied oil palm fiber/glass fiber reinforced phenol formaldehyde composites for its mechanical characteristics. Parameters such weight percentage of reinforcement and fibre loading were considered. Results of experiment as reported by authors indicated improved properties of composites upto 40% weight fraction for single reinforcement. Hybrid composites flared better in mechanical properties in comparison to standalone composites. Optical and scanning electron micrographs were used to understand the features of fracture surfaces and study the failure mechanism. G.Velmurugan et al. [13] evaluated the mechanical performance of sisal/coir reinforced epoxy composites by considering different fibre length, treatment and volume fractions. Hybrid composites were fabricated using hand layup technique. The authors concluded that equal weight fractions of sisal/coir reinforced composites treated with 5% sodium hydroxide resulted in better strength characteristics.
Present study utilizes a combination of E-glass/jute as a reinforcing material with varying fibre weight fraction and epoxy as a matrix material. Hand layup method is used to fabricate the hybrid composite. Properties such as interlaminar shear and flexural strength are determined and analyzed with respect to basket weave and twill weave patterns.

II. EXPERIMENTAL PROCEDURE

A. Materials

E-glass and jute fibres in the form of strands were used as reinforcing material. The densities of the E-glass and jute mats were 2.54 gm/cm³ and 1.4 gm/cm³ respectively. The weaving was done according to basket weave (BW) and twill weave (TW) forms. The resin and hardener used in the composites were Epoxy Bi-sphenol-12 (Lapox – L12) and Triethylene Tetro Amine (Lapox K6) respectively. The density of the resin and hardener is 1.162 gm/cm³ and 0.954 gm/cm³ respectively [14].

B. Fabrication of composites

Hand Layup process was adopted to fabricate the composite panels of 250 mm x 250 mm with varying fibre weight fractions (FWF). Laminate preparation was started by cleaning the mould surface with a cotton cloth followed by application of release agent across the entire surface of the mould. The peel ply is then aligned along the surface and cover of the mould and fixed to it. A wax layer was applied so as to facilitate easy removal of the laminate. Glass/Jute reinforcement of required weave pattern were placed on the mould. Calculated amount of epoxy and hardener were emptied into a container and mixed for 10 minutes. Resin was then poured into the mould and evenly spread by a roller. The laminates were cured for 24 h at room temperature. Cured part was then released from mould and trimmed to remove the undulating edges. The thickness of the composite laminate was 3 mm. Figure 1 shows the cured polymer composite panel.

![Composite panel](image)

C. Experimental methods

Specimens for all the tests were cut from the cured panels by power hacksaw. The dimensions of the flexural test specimen were 116 x 13 x 3 mm. Three point bending of ASTM D7264 [15] was adopted to determine the flexural strength of the composites on an Instron UTM at a constant cross head speed of 2 mm/min. Interlaminar shear strength (ILSS) was assessed by conducting short beam bending tests on an Instron UTM. Dimensions of the
specimens were 18 x 6 x 3 mm. Short beam bending according to ASTM D2344 [16] was adopted. For all the tests, five specimens from each panel were considered. Figure 2 presents the test setup.

![Test setup](image)

**Fig. 2 Test setup a) Flexural, b) ILSS**

## II. RESULTS AND DISCUSSION

Table 1 and Figure 3 present the variation in short beam strength. It was observed that the peak interlaminar shear strength was noticed for TW panels with 25% FWF. Least short beam strength was observed in panel fabricated with BW and 10% fibre content. Increase in resistance to shear was observed with increase in fibre weight fraction. In case of TW composite panels, there was a 43% increase in shear strength as the fibre content was increased from 10% to 25%. For composites with BW fabric, increase in short beam strength was of the order of 46%. Considering FWF of 25% the TW panels exhibited 7% increase in short beam strength when compared to BW. Increase in inter laminar shear strength was of the order 8% in case of TW panels when compared to BW at 10% FWF.

<table>
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<th>Fibre Weight Fraction (%)</th>
<th>Weave Patterns</th>
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<tr>
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<tr>
<td>20</td>
<td>11.64</td>
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<tr>
<td>25</td>
<td>13.72</td>
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**TABLE I INTERLAMINAR SHEAR STRENGTH OF COMPOSITES**

![Graph](image)

Fig. 3 Variation in interlaminar shear strength of composites

The variation in flexural strength is shown in Table 2 and Figure 4. It was observed that the highest flexural strength was achieved for TW panels with 25% FWF. Least flexural strength was noticed in panel fabricated with BW and 10% fibre content. Increase in flexural strength was observed with increase in fibre weight fraction. In case of TW composite panels, there was a 24% increase in flexural strength as the fibre content was increased from 10% to 25%. Increase in flexural strength
was of the order of 19% for composites fabricated with BW fabric. At 10% FWF TW panels exhibited 6% increase in flexural strength when compared to BW. There was 10% increase in flexural strength for TW panels when compared to BW at FWF of 25%.

TABLE II
FLEXURAL STRENGTH OF COMPOSITES

<table>
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<th>Weave Patterns</th>
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<tr>
<td></td>
<td>BW</td>
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</table>

IV. CONCLUSION
Among the two weave patterns laminates with twill weave arrangement demonstrated better flexural and interlaminar shear properties. Basket weave pattern resulted in comparatively inferior properties. Peak resistance to shear of 14.61 MPa was seen in case of composite having fibre content of 25% and twill weave form while least shear strength of 9.43 MPa was observed in composites having basket weave form with fibre fraction of 10%. Highest flexural strength of 78.27 MPa was noticed in specimen with twill weave design and fibre content of 25% while lowest bending strength of 59.87 MPa was seen in basket weave form having a fiber weight fraction of 10%. Fractured specimens indicated fibre matrix delamination and matrix cracking more prominent in basket weave arrangement which is the leading cause of inferior properties.

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