Investigation on Structural Characteristics of Bamboo-Laminates

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Abstract. Composite materials are structural and functional materials formed artificially or synthetically by combining two or more dissimilar materials having different characteristics (physical or chemical) which are in macroscopic level and are essentially not soluble in each other. Our present venture is focused on polymer composites due to their light weight, high damping factor, high stress concentration factor, anti-corrosiveness and anti-chemical properties. The need for strengthened composites (FRP) for renewable fibers has never been as prominent as it is now. The Natural fiber provides both densities decrease and cost savings in comparison with glass fibers. Nevertheless, natural fiber resistance is not as good as glass, the specific characteristics are similar. In the current work bamboo fiber woven as cloth is used to manufacture a polymer composite through and lay process which includes the application of uniform pressure using rollers to impregnate the fibres with the adhesive resin. The Natural fiber-epoxy composite is then subjected for mechanical properties tests like Brinell’s hardness, flexural, tensile and compression strength tests. Further also observes the laminate orientation and observes the deformation and von-mises stress under the load conditions using ANSYS. The composite shows greater promises to be a better natural fibre composite with strengths comparably better than other natural fibre composites like that of jute, linen, kenaf.

Keywords: Bamboo, Polymer Composite, Mechanical Properties, Hand Layup, fibre orientation.

1. Introduction
Many scientists have researched widely the outstanding efficiency of composite materials relative to monolithic materials[1]. Because of their outstanding mechanical and thermal characteristics, strengthened polymer composites are commonly used in many sectors such as automotive, aviation and submarine among polymer composite materials FIBER. Nevertheless, it is unknown and non-biodegradable to discard synthetic and polymer products at the end of life. The use and manufacturing...
technique of these products will therefore harm nature. Natural fibers, on the other hand, are environmentally friendly and renewable materials; they have reduced prices, densities and mechanical characteristics that are satisfactory. Many scientists and researchers are therefore interested in replacing them with synthetic products for environmental preservation. Natural fibers are split into three distinct classifications based on their sources: crop fibers (hemp, flax, sisal, bamboo, etc.), parts of livestock including protein (hair, silk, wool, etc.) and minerals. Hemicellulose, cellulose, lignin, and pectin are the main components of plant fibres. Cellulose fibers kept together in the framework of plant fibers hemicellulose and lignin matrix. As the amount of cellulose increases, the mechanical characteristics will improve[2, 3]. Cellulose fiber has been used in automotive, building and bridge construction as polymer-reinforced composites. Zakikhani P R. et.al.,[4] described that the bamboo fiber reinforced with epoxy resin has more advantage over the chemical and mechanical properties when compared with glass fibers. In the event of replacing synthetic fibers many researchers [5 -7] have reported that the utilization of natural fibers exhibiting high tensile modulus, high tensile strength, low breakage elongation and in-sensitive to chemicals and appropriate for low load applications.

In the present investigations an attempt was made to manufacture Bamboo woven fabric reinforced with suitable epoxy-based resin was used for the various mechanical tests to characterize the potential applications of semi bio-based bamboo fiber composite system.

2. Materials

The raw materials used are Bamboo Fiber woven fabric, Araldite Epoxy LY556 and Araldite HY951 hardener. The Bamboo fabric was obtained from weavers in Erode, for which the yarn was supplied by Aditya Birla Yarns and knit supplies Pvt.Ltd. and it contains - starch about 2-6%, deoxidized saccharide about 2%, 2-4% fat and protein to an extent of 0.8-6%. The physically the Bamboo fibers appears as shown in Figure 1. Resin and the hardener were obtained from Huntsman Resins.

![Figure 1. Physical appearance of Bamboo fibers.](image)

3. Composite manufacturing

Plywood is trimmed to 350mm*350 mm in size. A square of 310* 310 mm was labelled on the plate and wooden beadings were stuck along the labelled rows shown in Figure 2. Based on the resin percentage literature fiber was selected as 55:45. Mold releasing agent was applied by means of thin steel blades throughout the prepared mould box and on the inner sides of the beadings. Using a blow warm air drier, the mould box was subsequently dried and held aside for about 24 hours. The hardener and resin were carefully blended in the 9:1 ratio and slender steel blades were used to apply the standardized blend to the mould box. Alternatively, the resin and fibers are placed one by one,
followed by a prearranged order of stacking. Pressure of approximately 5kg / sq Ft., after full laying of laminates., applied to the laminates and left for 2 days to curing. The laminates were removed from the mould box after appropriate curing by cracking the mould box. Final thickness of Bamboo fiber composite, resin, hardner and its composition are summarized in the Table 1.

![Mould preparation for Bamboo composite laminate](image)

Figure 2. Mould preparation for Bamboo composite laminate

| Bamboo Fibre | Resin withHardener AralditeLY556 |
|--------------|----------------------------------|
| Density      | 1.25 g/cm³                       |
| Thickness    | 0.474 mm                         |
| Poisson’s Ratio | 0.38            |
| Young’s Modulus | 20GPa         |
| Density      | 1.18 g/cm³                       |
| Shear Modulus | 6.21GPa                       |
| Poisson’s Ratio | 0.35           |
| Young’s Modulus | 25.53GPa       |

3.1 Mechanical Testing
To know the physical behavior of the Bamboo fiber reinforced composite laminates various strength tests have been carried out. The detailed methodology followed for the tests as discussed under following sections.

3.1.1 Tensile Test
The thin flat strip of laminates with a steady rectangular cross-section region was installed in the mechanical testing machine grips and exposed to tension loading while noting down the force applied. The material's Ultimate Tensile Strength (UTS) was determined from the material's maximum strength prior to failure. If the coupon strain has been monitored with displacement or strain transducers then the material's stress and strain response can be derived from which the elasticity tensile module, ultimate tensile strain, transition strain, and Poisson's ratio can be derived. Grips at each head of the testing device will carry one grip to hold the test sampling so that the direction of force applied to the specimen coincided with the sampling longitudinal axis. The grips apply enough lateral pressure to prevent slipping between the top of the cover and the coupon. It was extremely desirable to use the grips that are rotational and self-aligning to diminish bending stress in the coupon.

Tensile properties were gotten by conducting uniaxial tensile strength test using Universal Testing Machine (UTM) as per ASTM D3039. The dimensions of the specimen were as shown in Figure 3.
3.1.2 Compression Test
Composite strengths against compression was carried out by conducting uniaxial compression test using UTM as per ASTM D3039. The dimensions of the specimen are as shown in Figure 4.

3.1.3 Flexural Test
The flexural strength determination of the fabricated sample is significant characterization for any structural composites. It gives the information on the ability of material to sustain the bending before attainment of the breaking point. Conservatively a three-point loading test was conducted for the determination of flexural properties of the fabricated composites using computer controlled UTM. A sample length of 80 mm and thickness of 4 mm (Figure 5) under low strain rates of $6 \times 10^6$ were taken and the speed of cross head was continued at 4 mm/min at room temperature. At the immediate failure, the bending resistance of a material was demonstrated as the stress on a bent sample specimen’s outermost or farthest fiber. The test was conducted at room temperature in accordance with ASTM D790.

3.1.4 Hardness test
The measurement of hardness testing was performed using Rockwell hardness testing devices as per ASTM D785-08. The hardness of the specimen tested is indicated directly on the dial gauge of the instrument. Rockwell hardness number was always quoted with a scale symbol in lieu of the indenter size, dial scale used and load. Each Rockwell scale division signifies 0.002-mm [0.00008-in.] vertical movement of the indenter.
3.1.5 Effect on orientation of laminates

The analysis of laminate orientations will result in improving further strength in the laminate composite. The change in orientation of laminates can be analyzed by using the Ansys APDL software[8]. First it starts with selection of element type by selecting shell element of 8 node 281 type. Applied the laminate properties as investigated from the experiments. The layer creation tools will help us to design the layers in different orientations. In this work three orientations are considered to study the laminate behaviour under loads, following table 1 will illustrates the details of layer orientations. The positions and orientations of the laminated layers are showed in the figure 6 below.

| S.no | Specimen Name       | Angles orientation from 1 to 8 layers |
|------|---------------------|--------------------------------------|
| 1    | Symmetry Sample-1   | 0,30,45,-45,45,30,0                   |
| 2    | Symmetry Sample-2   | 0,30,-45,45,45,-45,30,0               |
| 3    | Symmetry Sample-3   | 0,3,45,-45,45,-45,-30,0               |

Table 2 List of experiments and details

Figure 6 (a, b and c). Shows the three types of orientations that are considered.
The laminate composite is created in a form of plate 2m x 2m and global sets are created. An uniform mesh is generated. The below figure 7 shows the meshed plate. Boundary conditions are applied as all the sides of the plate are fixed by making the degree of freedom is zero. And a load of 1000N is applied at the centre of the plate in order to estimate the load carrying capacity. The below figure 8 shows the applied boundary conditions.

All the three different oriented laminate plates are designed as per above procedure and applied boundary conditions. Form the results minimum and maximum deformations of the plate will be recorded and minimum and maximum von-mises stresses are recorded for all the three laminated plates.

4. Results and discussion

To characterize the candidate Bamboo composite laminates, experiments have been carried out as per the ASTM standards. Physical behaviours under tensile, compression, flexural and hardness using various specimen configurations has been done by conducting mechanical tests. In the following parts, the examination of the outcomes and the inspiration of different parameters on the different characteristics were summarized.

| Composite                        | Tensile Strength (MPa) | Flexural strength (MPa) | Compressive Strength (MPa) | Hardness |
|----------------------------------|------------------------|-------------------------|---------------------------|----------|
| Bamboo composite laminate        | 27.59                  | 2.45                    | 10.30                     | 87       |
Figure 9. Load versus displacement plots for (a) tensile, (b) compression and (c) flexural tests

From the results, the laminated properties are obtained and applied to the laminated plate which is created in ANSYS. The deformation of the plates and the von-Mises stresses distribution on the three plates are showed in the figure 10, 11 and the results are plotted in the figures 12 and 13.
Figure 10 Shows the plotted results for deformation in the plate in sample 1 (a), sample 2 (b), sample 3 (c).

The results show the change in orientation of each layer effects the behavior of the plate for the boundary conditions applied. The sample 3 (c) in the figure 10, with the oriented angles of 0,-30,45,-45,-45,45,-30,0 is an symmetry orientation which shows the better results in all the three conditions. The sample three (c) is less deformed than sample 1(a) and 2(b).

Figure 11 Shows the plotted results for von-mises stress in the plate in sample 1 (a), sample 2 (b), sample 3 (c).

The graphs are plotted below (figure 12,13) for the both deformation and von-mises stress in all the plates. The von-mises stress is also low in sample 3 (c) when compared with other two conditions.
Figure 12 Shows the maximum (max) and minimum (min) deformation in the 3 samples

Figure 13 Shows the maximum (max) and minimum (min) stress values in the 3 samples.

The results show that bamboo laminate composites are comparatively better than other composites [9]. The study of laminate orientation in this work figured out some potential results and this study also improves the better understanding of the laminates.

5. Conclusion

- Laminates with a greater volume proportion of fiber have found their ultimate tensile strength to have a greater tensile strength. Consequently, the conclusion of the findings is that the Fiber provides more support for greater tensile strength. By also moving the weave pattern and pattern setup, tensile strengths can be further improved.
- In comparison with many other natural fiber composites, the compressive strength of laminates is improved. By giving extra filler or reinforcement content, the compressive resistance can be enhanced.
- Laminate flexural strength with a lower resin proportion showed an improvement in flexural strength.
The results show that layer orientations in the laminated composite plays an important role in improving the load bearing capacity. Sample 3 orientation can make the composite bit high strength and can be suggestible while applying.

Bamboo laminates are showing better results when compared with others.

All characteristics can be further enhanced if it is possible to add additional reinforcements such as E-glass or S-glass alongside natural fiber.

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