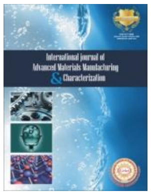

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Mechanical Characterizations of Natural Fiber Reinforced Composite Materials

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ABSTRACT

The present work consists of mechanical characterization of Natural Fiber Reinforced Composites (NFRC) consisting of epoxy resin reinforced with jute fiber and bamboo fiber. Hand lay-up technique was used for fabrication of the composite specimens. The specimens were prepared according to the ASTM D3039 and D3410 standards for tensile and compressive test respectively. Experimentation was carried out using INSTRON 8801. The results were compared with the glass/epoxy composite. The effect of fiber orientation ($0^0/90^0$, $15^0/-75^0$, $30^0/-60^0$, and $45^0/-45^0$) was analyzed and it shows that the fiber orientation of $0^0/90^0$ provides higher strength and stiffness than other fiber orientations used in this work. For compressive test jute composite shows higher strength as compared to bamboo composite but it is not at par with glass composites.

Introduction

Natural fiber reinforced composite materials are considered as the one of the new class of engineering materials. These composites are environmentally friendly and have wide applications in transportation, construction, packaging, consumer products etc. The interest in this area is rapidly growing both in terms of their industrial applications and fundamental research as they are renewable, cheap, completely or partially recyclable, and biodegradable. Many researchers have worked in this area and a considerable amount of literature has been published.

Younjiang et al. [1] carried out an experimental study on glass epoxy and Kevlar epoxy composites. They observed that the presence of micro fibers in the composite system did not have any strong effect on the elastic properties of the composite. Based on an extensive experimental investigation Shaikh et al. [2] found that the modulus of short random fibers composite increases linearly with the volume fraction of fiber under longitudinal loading condition..

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For this work they used jute polyester composite under short random fiber arrangements. Singha et al. [3] suggested that the properties of natural fibres can vary depending on the source, age and separating techniques of the fibres. Long and discontinuous natural fiber (kenaf and jute) reinforced polypropylene composites were fabricated by varying their nominal fiber weight fractions (10 %, 20 %, 30 %, 40 %, 50 %, and 70 %). Compression molding process was used for these purposes. From experimental investigation, Lee et al. [4] concluded that the jute fiber reinforced composites having fiber fraction of 40% seems to be the optimum one in respect to tensile and flexural modulus Satish et al. [5] performed an experimental investigation to study the effect of hybrid composite specimen subjected to in-plane tensile and compressive loading. The laminated specimens in accordance with ASTM standards were fabricated using steel and nylon as reinforcements and polyester as the binder. The various volume fractions and fiber orientations were used in which the percentage of polyester (40%) was maintained constant. The different bidirectional fiber orientations were considered for preparation of specimen. The tensile and compressive strengths are superior in case of $0^0/90^0$oriented specimens as compared to specimens with other orientation. Gohil et. al. [6] fabricated specimens with the help of unidirectional cotton fiber and polyester resin. Testing of these specimens was carried out to study the effect of volume fraction of reinforcement on longitudinal elastic modulus of unidirectional cotton fiber reinforced polyester composites. The experimental investigation indicates that, as the fiber volume fraction increases the strength as well as longitudinal elastic modulus increases linearly.

Experimental details

Reinforcing Material

Bamboo Fiber

Bamboo is a diverse group of plants with over 1,200 varieties of various sizes. Specifically in Arunachal Pradesh (India), fourteen species of bamboos are available. The botanical name of bamboo fiber used for this present work was Bambusa Tulda. These fibers are extracted through mechanical needling and scraping. Fig. 1(a) shows the bamboo fiber in mat form.

Jute Fiber

Jute is a long, soft and shiny plant fiber that can be spun into coarse, strong threads. Jute is one of the cheapest natural fibers, and it is composed of cellulose and lignin. Fig. 1(b) shows the jute fiber (in mat form) used in this work.

Glass Fiber

Glass fiber is a material made from extremely fine fibers of glass. Glass fiber is formed when thin strands of silica based or other formulation glass is extruded into many fibers with small diameters. Cross- plied woven E-glass fibers have been used as the reinforcing phase in the composites used in this work. The fig. 1(c) shows the E-glass fiber in mat form.

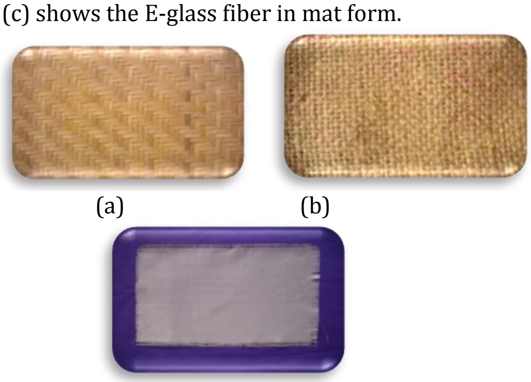


Fig. 1(a), 1(b) and 1(c) shows bamboo, jute, and glass fiber in mat form.

Matrix Materials

The matrix system consists of a medium viscosity epoxy resin (LAPOX L-12) and a room temperature curing hardener with a tetra-amine functional group (K-6).

Composite Fabrication

All laminates used in this study were manufactured by hand lay-up technique. At first the epoxy resin is mixed with the hardener in the ratio 10:1 by weight and mix for 5 minutes or until mixture is thoroughly blended. Before molding the mold release sheet is thoroughly polished to obtain a smooth glossy finish and in-order to ensure that the absence of moisture or any foreign particles. The mold release agent is then generally used as wax-pool or silicon spray on the sheet for ease removal of casted composite laminate from the mold after curing. When the release agent is completely dry, epoxy resin in the form of paste is spread on a sheet by a brush. Reinforcement materials are laid on the resin. The entrapped air must be forced out by rolling over the entire layer of fiber. The layers of fiber reinforcement and resin will continue upto laying of required no of ply. In this work number of layer is kept constant i.e. four layer for each of glass composite, bamboo composite and jute composite. The cast of each composite is cured at room temperature under a load of about 25 kg in order to avoid any distortion during curing. The casted bamboo, jute, and glass laminates are shown in figure 2(a-c).

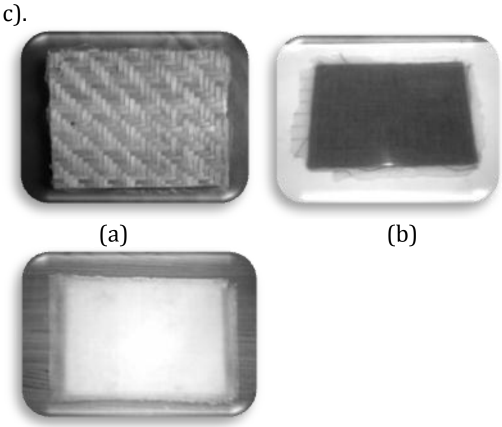


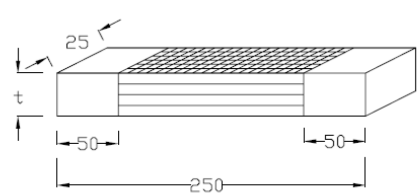
Fig. 2(a-c): Casted bamboo, jute, and glass laminates.

Specimen preparation

Specimen for Tensile Test

The specimens were prepared according to ASTM D3039/D3039M-08 standard. The straight sided specimens with fiber orientations of $0^\circ/90^\circ$, $15^\circ/-75^\circ$, $30^\circ/-60^\circ$, and $45^\circ/-45^\circ$ were used. The jute, bamboo, and glass composite specimen used for tensile test is shown in Fig 3. The geometry of specimens for tensile test of composite laminate is shown in Fig 4.

Fig.3: Composite specimen for tensile test



Where, t= thickness of the specimen
(All the dimensions are in mm)

Fig. 4: Geometry of specimen for tensile test

Specimen for Compressive Test

For compressive test straight sided specimens are prepared according to ASTM D3410/D3410M-03 standard from bamboo fiber, jute fiber, and E-glass fiber and the loading axis is $0^\circ/90^\circ$ of the principal material axis. The bamboo, jute, and glass composite specimen used for compressive test is shown in Fig 5.The geometry of specimens for compressive test is shown in Fig. 6.

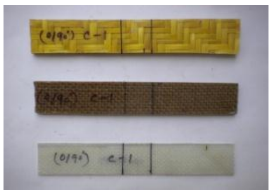
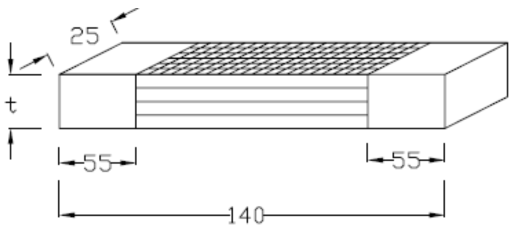


Fig.5: Composite specimen for compressive test



Where, t= thickness of the specimen
(All the dimensions are in mm)

Fig. 6: Geometry of specimen for compression test

Experimental Set-up

A suitable experimental set-up is required for testing selected properties. The tensile test and compressive test of composites were carried out on a computer controlled Universal Testing Machine (servo hydraulic INSTRON 8801 testing machine, equipped with hydraulic clamps, a Fast Track 8800 digital controller and a load cell of $\pm$ 100 KN). A uniaxial load is applied at both the ends of the sample for tensile and compressive test having cross-head speed of 2 mm/min, 1.5 mm/min respectively. For tensile and compressive test the wedge shape grippers are used whose gripping length was 55 mm and width was 50 mm. The experimental set up for tensile and compressive test is shows in Fig. 7.

Fig. 7: INSTRON 8801

Result and discussion

Composite specimens are tested and the results obtained from the experiments are discussed, including

(1) Ultimate tensile strength (σ_t), and
(2) Ultimate compressive strength (σ_c) test.

Tensile Test

Tensile strength is one of the important properties of composite materials. Generally, composite materials are designed to transfer load in the direction of the reinforcements are embedded. However, in some cases where the applied load direction is off-axis and not parallel to the fibers, it becomes important to investigate mechanical properties of composites. Hence, to investigate the effect of fiber orientation, three bi-directional fibers having four different orientation angles $0^\circ/90^\circ$, $15^\circ/-75^\circ, 30^\circ/-60^\circ$, $45^\circ/-45^\circ$ were selected in this study. Each sample was tested for three time and average result have been reported.

The effect of fiber orientation on tensile strength of bamboo fiber reinforced epoxy composites is shown in Fig. 8. It is clear from the Fig. 8 that the tensile strength of bamboo composite is increases by increasing the orientation angles from $45^\circ/-45^\circ$ to $0^\circ/90^\circ$. The increase in tensile strength from $45^\circ/-45^\circ$ to $30^\circ/-60^\circ$, $45^\circ/-45^\circ$ to $15^\circ/-75^\circ$, and $45^\circ/-45^\circ$ to $0^\circ/90^\circ$ is 3.19%, 11.41%, and 21.73% respectively.

The tensile responses of jute composite with change in fiber orientation angle is shown in Fig. 9. The figure 9. indicates that tensile strength of jute composite with fiber orientation $0^\circ/90^\circ$ gives the superior value than other direction of orientation. The percentage increase in tensile strength from $45^\circ/-45^\circ$ to $30^\circ/-60^\circ$, $45^\circ/-45^\circ$ to $15^\circ/-75^\circ$, and $45^\circ/-45^\circ$ to $0^\circ/90^\circ$ is 5.66 %, 8.15 %, and 9.49 % respectively.

The effect of fiber orientation angle on tensile strength of glass composite is shown in Fig. 10. It shows that tensile strength of glass composite for fiber orientation $0^\circ/90^\circ$ is superior to the $15^\circ/-75^\circ, 30^\circ/-60^\circ$, $45^\circ/-45^\circ$ of fiber orientations.

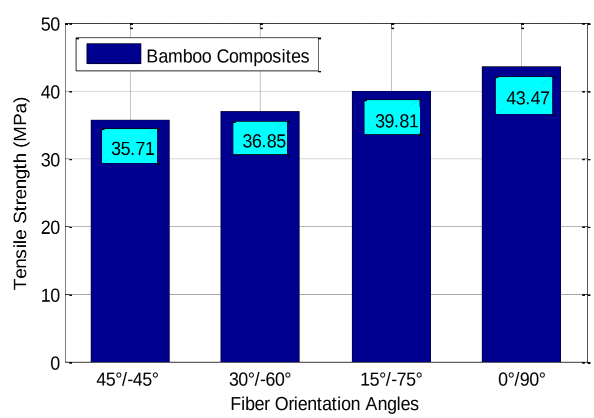


Fig. 8: Effect of Fiber Orientation on Tensile Strength of Bamboo Composites.

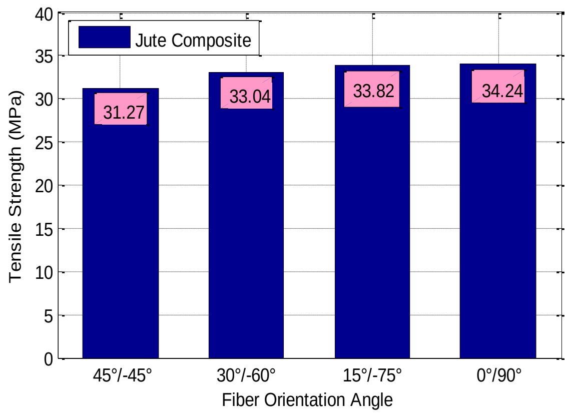


Fig. 9: Effect of Fiber Orientation on Tensile Strength of Jute Composites.

The percentages of increase of tensile strength on glass composite from $45°/-45°$ to $30°/-60°$, $45°/-45°$ to $15°/-75°$, and $45°/-45°$ to $0°/90°$ is 12.66 %, 38.75 %, and 216.83 % respectively.

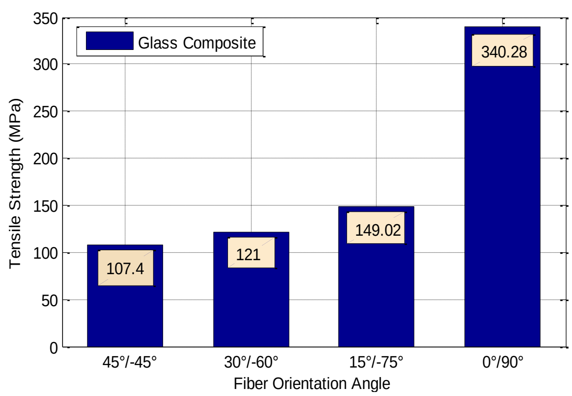


Fig. 10: Effect of Fiber Orientation on Tensile Strength of Glass Composites.

From the above discussion it is clear that the tensile property of bamboo, jute, and glass composite is high in the cases of $0°/90°$ of fiber orientation. The comparison of tensile strength of bamboo, jute, and glass composites for fiber orientation of $0°/90°$ is shown in Fig. 11. It indicates that the tensile strength of glass composite is superior to bamboo composite and followed by jute composite for fiber orientation of $0°/90°$.

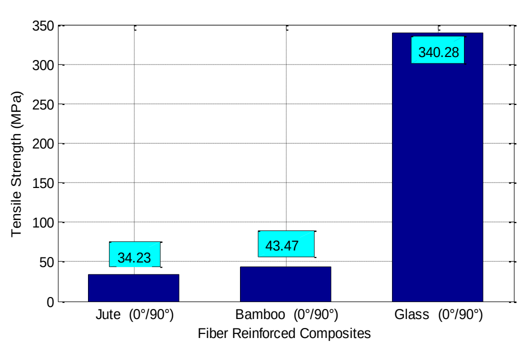


Fig. 11: Comparison of Tensile Strength of Jute, Bamboo, and Glass Composites.

Effect of Fiber Orientation on Tensile Strength:

The effect of fiber orientation on tensile strength is analyzed for bamboo, jute, and glass composites. From the experimental result it is clear that tensile strengths are significantly affected by fiber orientation. Tensile strength of bamboo, jute, and glass composite laminates are superior for fiber orientation with $0°/90°$ as compare to the other direction of fiber orientation of $15°/-75°$, $30°/-60°$, and $45°/-45°$. This is attributed to the reason that, in case of $0°/90°$ of fiber orientation fibers are parallel to the applied load and the applied load is equally distributed on all the fibers and transmitted along the axis of fiber. Whereas in case of other fiber orientations, fiber axis is nonparallel to the load axis. When the tensile load is applied on the oriented specimens other than $0°/90°$, both in-plane shear and tensile forces are act on the specimens. The coupling between in-plane shear and tension resulting off-axis pulling of fiber and causing earlier failure of specimen before ultimate strength reached.

Compressive Test

The bi-directional fiber orientation of $0°/90°$ composite laminate was considered for compressive test specimen preparation. Each sample was tested for three time and average result have been reported.

The comparison of compressive strength of bamboo, jute, and glass composite is shown in Fig. 12. From the figure it is clear that glass composite have higher compressive strength than jute composite and followed by bamboo composites. The compressive strength increase from bamboo composite to jute composite is 14.91% and from bamboo composite to glass composite is 36.98%.

It has been observed that glass and jute laminated plates buckled globally until the failure occurred where as the bamboo composite fails before buckling. The reason is that when the compressive load is applied to the glass, jute, and bamboo specimen the longitudinal fiber directly absorb, transfer and distributed load uniformly throughout the cross-section. Further loading shear stresses are generated near the fiber ends as a result of the difference in elastic properties between the fiber and the matrix. In case of bamboo composite shear stress causes shear failure of composite specimen due to the interface shear stress concentration. But in case of jute and glass composites shear buckling takes place before failure because matrix material is not sufficiently strong to prevent fiber from buckling.

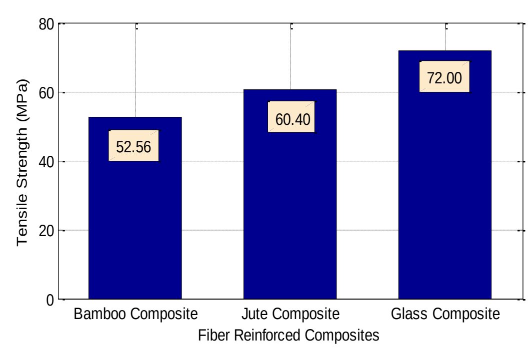


Fig. 12: Compressive Strength of Bamboo, Jute, and Glass Fiber Reinforced Composites.

Conclusions

- The present investigations of mechanical characterization of natural fiber as well as glass fiber reinforced composites leads to the following conclusions:
- Mechanical properties of composites such as tensile strength and compressive strength of natural fiber composite was reported and compare with the data for glass/epoxy composites.
- It has been seen form tensile test that bamboo composite laminates having higher tensile strength and stiffness than jute composite laminates, but not at par the glass fiber reinforced composite.
- Compressive test shows that compressive strength and modulus of jute composite is higher than bamboo composite, but less than glass composite.
- The fiber orientation angle of $0^\circ/90^\circ$, $15^\circ/-75^\circ$, $30^\circ/-60^\circ$, and $45^\circ/-45^\circ$ on tensile behavior were analyzed and showed that the fiber orientation of $0^\circ/90^\circ$ provides higher strength and modulus than $15^\circ/-75^\circ$, $30^\circ/-60^\circ$, $45^\circ/-45^\circ$ direction of fiber orientation.

The mechanical property also depends upon individual material property. The glass fiber was manufactured artificially in an industrial plant with special tool while the bamboo and jute fiber was available from nature & manufactured by simple tool and/or manually that may result inconsistency during manufacturing of product. Due to this reason the strength of natural fibers does not come up to the level of traditional E-glass fiber. But the natural fiber reinforced composite can be used in places where light load application is important and the economics of natural fiber composite materials is more beneficial as compared to E-glass fiber composites.

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