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Experimental Investigation on Mechanical Characteristics of Jute and Bamboo Reinforced Epoxy Hybrid Composite

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ABSTRACT
Experimental investigation on mechanical properties of jute and bamboo reinforced epoxy hybrid composite has been conducted in this study. The objectives of this experiment were to fabricate jute and bamboo based composite and to conduct destructive and non-destructive tests to evaluate mechanical properties. A total of four types of composites has been fabricated with the combination of unidirectional jute mat, twill type jute mat, and unidirectional bamboo mat. Chemically treated bamboo strips has been used to fabricate bamboo mats, and jute yarn has been used to fabricate unidirectional mats using special type of manual handloom [1]. From the experimental result, higher mechanical properties were found where unidirectional jute mats in the center of jute-bamboo hybrid composites.

Keywords: Jute yarn, Bamboo strips, Hand layup with cold press process.

1. Introduction
These days, researcher and designers working in the field of materials are excessively worried about supportability issues and natural security. Hence, ecological beneficent, natural, reusable, or biodegradable materials are pulling in part of interest. The purpose of a composite is to achieve a mix of features that no single fabric can match, as well as to combine the best qualities of each of the component elements [2]. The major advantages of composite materials over bulk materials are their high strength and stiffness combined with low density, allowing for weight reduction in the completed object.

A composite material is a material comprising of at least two constituents with various qualities and exclusive features, bringing about another material having extensive and great properties unlike original constituents. Two essential constituents of a composite material are matrix and reinforcement. The matrix goes about as a binder to the reinforcement that covers the composite material, while the reinforcements give the shape and inner structure [3, 4]. Natural fiber fortification of composites has attracted a lot of attention from the academic community as well as the industry. Compared to artificial strands, common filaments have a number of key advantages. Several different kinds of natural fibers, such as flax, hemp, jute straw, wood, rice husk, wheat, grain, oats, rye, cane (sugar and bamboo), grass, reeds, kenaf, ramie, oil palm purge natural product bunch, sisal, coir, hyacinth, pennywort, kapok, paper mulberry, etc. have been studied for their potential [5]. As of late, modern items made of glass fiber-reinforced plastic have been utilized broadly in light of the fact that this material is light and has a particular rigidity as high as that of steel. Nonetheless, utilization of such materials may negatively affect the climate as manufactured fibers are non-degradable, radiate harmful gases to the air, particularly when consumed, and are costly. Natural fibers picked up consideration as swaps for manufactured fibers in composites as they have genuinely great mechanical properties and a drawn-out constant supply, and they are cheap, and eco-accommodating. Natural composites have potential in the aviation, car, development, transportation, safeguard, bundling, shopper items, sport enterprises and so on [6].

Bamboo is a naturally occurring composite material that may be used to make polymer composites. Bamboo fiber contains structural variation, and has been chemically modified, allowing it to be used in a variety of applications. Bamboo fiber can be used in a variety of ways, such as strips or fibers, as seen by the prior literature [7]. Bamboo fibers have high explicit strength and solidness, at appropriate levels for primary materials. The fibers are adjusted longitudinal to the length of culm, which makes its solidarity similar to mild steel when it is matured. Bamboo is not utilized properly in this sub-continent due to lack of proper data. Jute is a long and delicate fiber, which falls into the bast fiber class (which is collect from skin of plant) that is used widely in manufacturing yarn, clothes etc. This fiber is in extraordinary interest because of its inexpensiveness, non-abrasiveness, shading, high money esteem, adaptable nature, radiance, consistency and length. Favorable circumstances of jute incorporate great insulating and antistatic properties, just as having low thermal conductivity and a moderate dampness recover [8].

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Only jute fiber or bamboo fiber has been used to fabricate the composites in previous studies. Mostly jute raw fibers have been used to fabricate jute cloth. In this study, jute fiber is used along with bamboo fiber to investigate the feasibility to use this new composites in various industrial and domestic sectors. Bamboo is very common to countries like Bangladesh, Sri Lanka, India, but most of the time its strength is underestimated. Previously bamboo cloth and powder has been used with other reinforcements. Bamboo cloth shows better flexure strength and has similarity to glass fiber. But bamboo strips are strong types of fiber because numerous fiber bundle are tied together in matrix of lignin. It provides great tensile strength as well as impact Unidirectional jute mat woven from jute yarn, results in high tensile strength as well as flexure strength [10]. Previously, this type of jute mat has been used with carbon fiber and found good outcome [11, 12]. But carbon fiber is too costly. So for low budget production it is not feasible.

Observing previous experiments, it has been found that still there is vast scope of improvement in this uprising field. In this study jute yarn is used to fabricate unidirectional jute mat, and bidirectional jute mat and are mixed with bamboo strip mat which is also unidirectional, to fabricate different types of composites along with epoxy-resin with 10:1 ratio.

2. Methodology

2.1 Unidirectional jute mat preparation


(a)


(b)

Fig.1 (a) Unidirectional jute mat, (b) Twill type jute mat

A simple manual handloom was used to fabricate unidirectional jute mat [1]. The handloom was designed with some special arrangements. Then using the handloom jute mats were woven. Each mat was of 381*381 mm in dimension. Total six jute mats were woven using this handy tool. The yarn was arranged unidirectional in the mat. Also, twill type jute mat was used to fabricate hybrid composites in some cases. Figure 1(a) shows the unidirectional jute mat that was weaved by the manual hand loom using jute yarn.

2.2 Bamboo strip mat preparation

At first bamboo strips were prepared from bamboo. Each strip was of 381 mm in length and thickness was about 2.16mm. Then the strips were soaked in 4% NaOH (w/w) solution for 72 hours. This was done to decrease the amount of lignin present in the strips to increase their bonding ability with resin [13]. It helps to attach the strips firmly with resin-hardener solution. After soaking, strips were dried in direct sunlight. Finally, the mats were weaved by manual hand loom.

2.3 Fabrication procedure


(a)


(b)


(c)


(d)

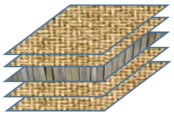
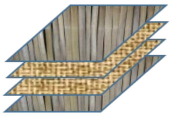
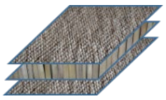
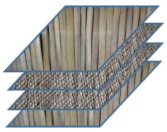
Fig.2 (a) Untreated bamboo strips, (b) Alkaline treatment, (c) Bamboo strips after alkaline treatment, (d) Bamboo mat.

To fabricate composites, hand layup with cold press process were applied. A wooden frame has been made of 381*381-mm^2 inner area. At the beginning, layers of very thin film (polythene sheet) were applied on both the frame and lid. Polythene sheet were used to avoid stickiness of epoxy resin-hardener solution to the surface of wooden frame. Epoxy crystal resin and hardener of ratio 10:1 by weight was used to fabricate these composite materials. The resin-hardener solution was mixed homogeneously for 5 to 8 minutes before the fabrication process. Then some portion of resin and hardener solution was applied to the polyethylene surface. Then a layer of mat were laid down. More resin hardener solution applied and distributed to the whole surface properly. After that another mat was laid down. This process was continued until the specified number of layer or required thickness of the composites were gained. Then a polyethylene sheet was placed on the final layer. Finally, a surface plate of weight about 150 kg was placed on the top to remove excess resin-hardener solution, and void or air bubble. Also to make the proper bonding between fiber and resin more strong.

2.4 Types of composites

Total four types of composites were fabricated using above described method. Combination of unidirectional jute mat, twill type jute mat and unidirectional bamboo mat were used to fabricate these four types of hybrid composites. Table 1 shows the arrangement of different types of fiber mats to fabricate A, B, C and D types of composites.

Table 1 Various types of composites

Type of composite	Arrangement of materials	Arrangement in composite
Type A	J′+J′+B+J′+J′	
Type B	B+J′+J′+B	
Type C	J+B+J	
Type D	B+J+J+B	

J= Unidirectional Jute Mat
J′= Twill type Jute Mat
B= Bamboo Mat

3. Results and Discussion

3.1 Tensile Test

Universal testing machine was used to conduct the tensile test. Three pieces of specimen were used in each cases with ±5% deviation of results. The specimen were prepared according to the ASTM D638. From the experimental result, the maximum stress was found 160.35 MPa, where specimen with four layers (D type) contained unidirectional bamboo mats outside and twill type jute mats inside of the composites. This is because bamboo fiber offers excellent qualities among natural fibers [13] and from the SEM analysis, very few tiny voids were found comparing with other types of composites. The minimum stress was found for specimen A that is 69.17 MPa in which the specimen contained twill type jute mats outside and bamboo mat inside of the composites. The minimum stress was found as in twill type jute mat, there are many void comparing with the unidirectional woven jute mat as shown in figure 1. Figure 3 shows the stress vs. strain diagram, and figure 4 shows the Young's modulus of the fabricated composites.

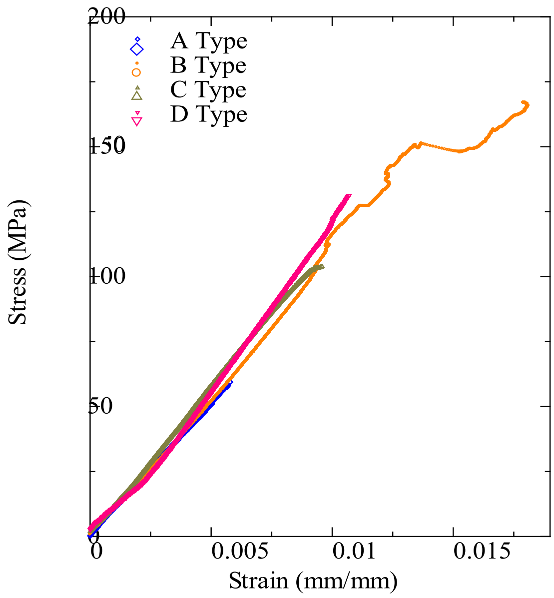


Fig.3 Tensile stress vs. Strain curve of all composites

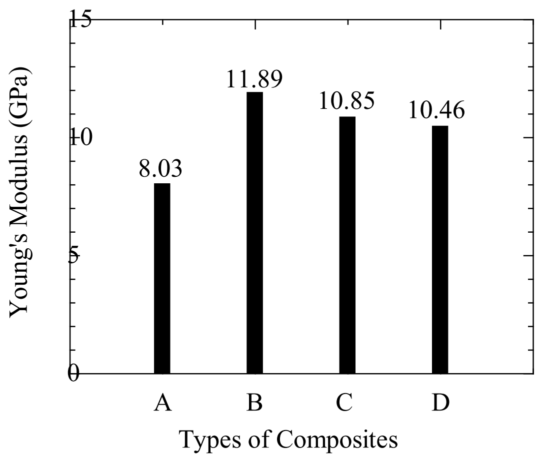


Fig.4 Young's Modulus of hybrid composites

3.2 Flexural Strength Test

Flexural test was carried out to find the flexural strength of the four different types of hybrid composites with the universal testing machine. Three pieces of specimen were used in each cases and the deviation was ±5%. The specimen were prepared according to the ASTM D790. Figure 5-6 show the experimental results of flexural test. It has been found that maximum load has been applied on specimen D that is 1404.01 N and its flexural strength is 151.33 MPa. This type has bamboo mats outside and two twill type mats in middle. It has been found that specimen B can carry a load of 918.72 N, brittle behavior at the center of the sample was observed and resulted in a rough fractured surface. The flexural strength was 169.54 MPa, which is the maximum strength found comparing to others. Specimen A and C has flexural strength about 57.23 MPa and 96.61 MPa, respectively.

Although specimen A shows low flexural strength, it show ductile behavior and failed at a higher strain. This is because the bonding among the layers which was found by the SEM analysis and lower density.

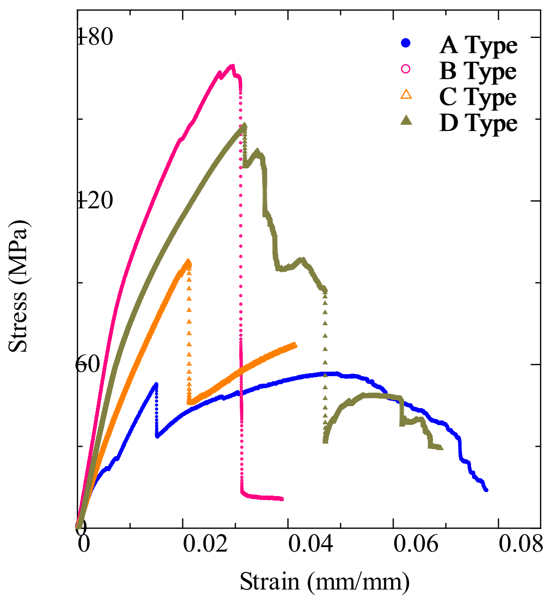


Fig.5 Flexural Stress vs. Strain curve of the fabricated composites

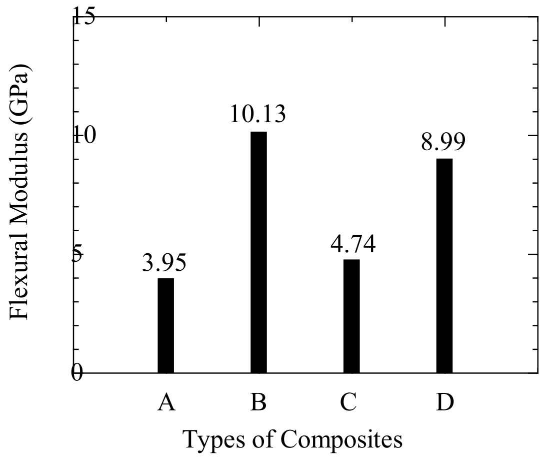


Fig.6 Flexural modulus of fabricated composites

3.3 Impact strength test

Charpy impact test was done by a Pendulum Impact Tester. According to the ASTM D6110 standard samples were used to investigate the impact strength of the fabricated composites. JB-300B impact tester was used to conduct this test. The composite sample is impacted by a pendulum with 20 kg mass when dropped from a testing height for Charpy test. From Figure 7, it can be seen that the maximum impact strength has been found for specimen type C that is 320 KJ/m^2, which contained unidirectional jute layers outside and one bamboo layer inside of the hybrid composites. Minimum strength has been found for specimen A about 201.304 kJ/m^2.

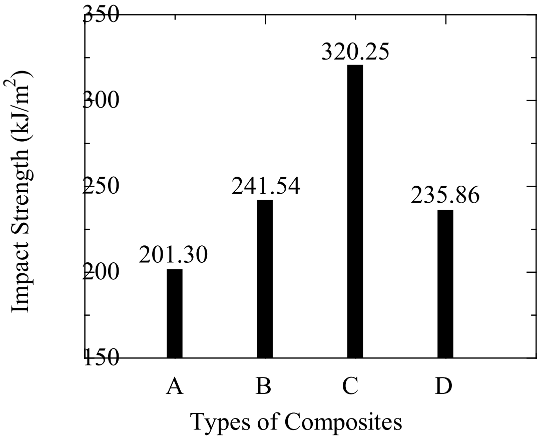


Fig.7 Charpy impact strength

3.4 Water Absorption Test

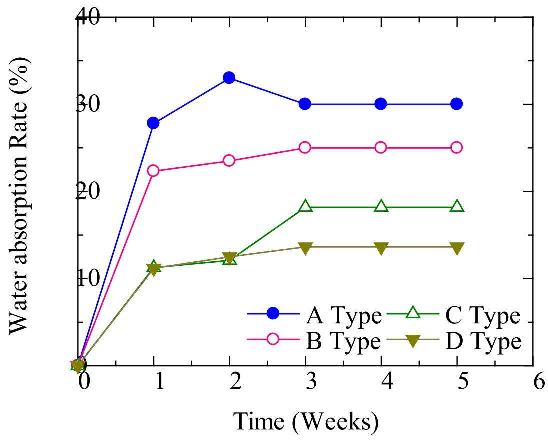


Fig.8 Water absorption rate of specimen

Water absorption test was done on the specimens to find out its water absorption rate, as the natural fibers that is used in this experiment is hydrophilic. Due to the hydrophilic property cellulosic fiber, once this characteristic affects the mechanical properties can lead to poor process ability and porous products during processing of composites [14, 15]. Therefore, water absorption test was also carried out to check the impact of moisture in the fabricated composites. Figure 8 shows the water absorption rate of various types of fabricated composites. It was observed for 5 weeks. The four types of composites were submerged in water. From the figure 8, it has been found that Specimen D has the least absorption rate over the weeks. Specimen A has the maximum absorption rate at second weeks and then absorption rate became constant for the following weeks. Specimen C showed similar rate to D, and suddenly increased after third weeks. Point to be noted, both C and D specimens contained unidirectional jute mats. Specimen A and B has twill type jute mats which is the reason of high absorption rate.

3.5 Swelling Thickness

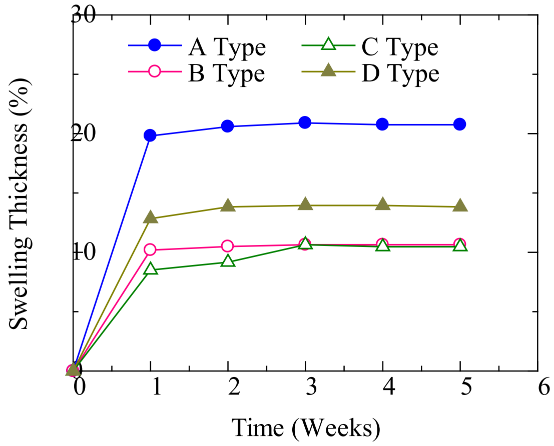


Fig.9 Percentage of swelling thickness

This test has been done to evaluate the increase or decrease in thickness of the specimen after it was submerged in water. After 5 weeks of observation, it has been found that different thickness were found in different types of hybrid composites. From Figure 9, specimen A has shown highest thickness in first week. Its thickness started increasing rapidly after first week and after second week rate of swelling thickness became stable. Specimen B showed gradually increase in thickness. Specimen C showed decrease in swelling rate in second week and then increased in third week and became stable. Specimen B and D shows minimum increase rate as their outside layers are of bamboo. Bamboo is less hydrophilic than jute.

3.6 Density Evaluation

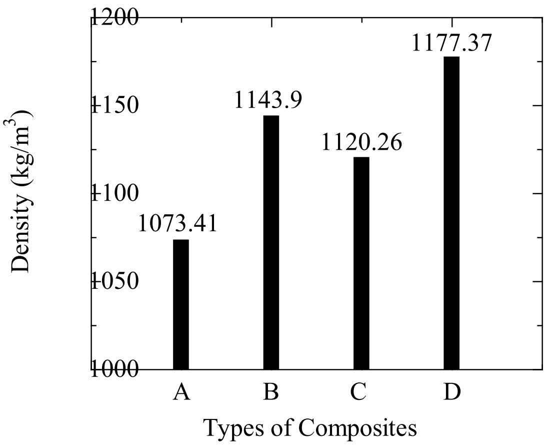
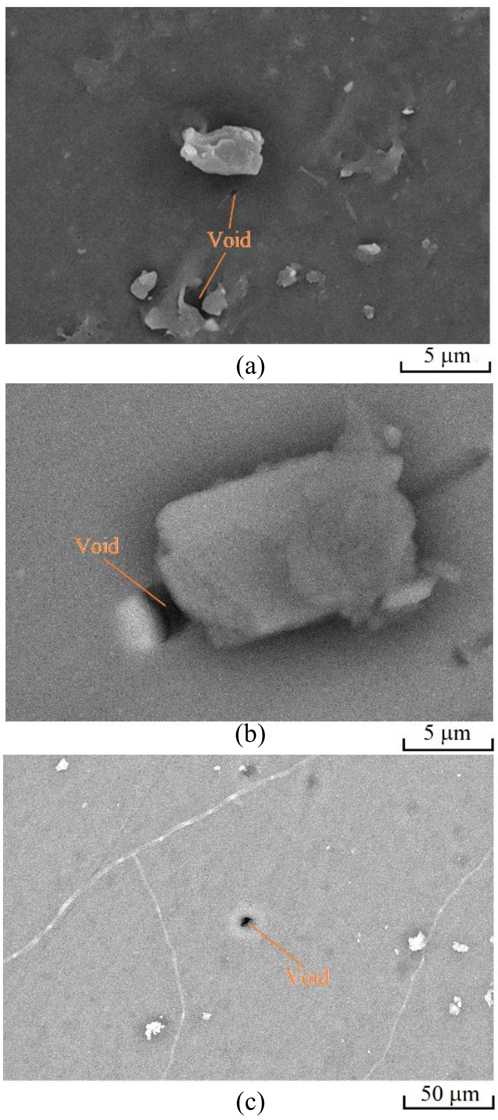


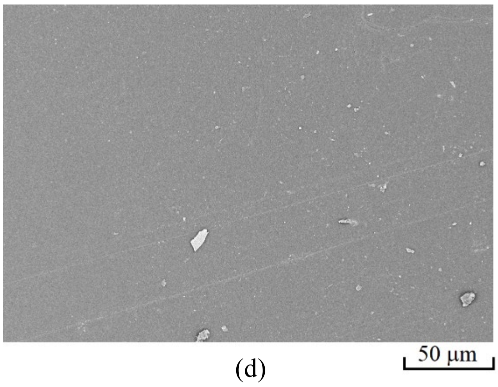
Fig.10 Density of different composites

This test was carried out by measuring the mass of the specimen and the volume of the specimen. Then by dividing the mass of the specimen with respect to volume of the specimen. Figure 10 shows the density of different composites. The maximum density was found in D type hybrid composites where unidirectional bamboo mats cover the unidirectional jute mats, and the lowest density was found in A type where twill type jute mat was used. The reason is that there is no gaps among the fibers in unidirectional mats comparing with that of twill type mat.

3.7 SEM Analysis

The SEM analysis shows an insight into their morphological characteristics. The interfacial bonding among the fibers, and the bonding between the matrix-fibers are comparatively better due to the chemical treatment of the bamboo fibers [10-12]. Figure 11 shows jute and bamboo fibers are homogeneously distributed in the matrix without any overlapping or agglomeration. The figure 11(a) shows presence of few voids, which could be eliminated by improving hand lay-up method or by, fabricated the composites by VaRTM method [9, 13]. Also, fiber imprints are visible in specimen type B, C and D that indicates clearly the bonding between fibers and matrix.





(d)

Fig.11 Scanning Electron Micrograph of (a) Type A, (b) Type B, (c) Type C, (d) Type D specimen

4. Conclusion

Following conclusions can be drawn from this research:

- These hybrid natural fiber composites are prepared with extra techniques using various weight or volume fraction of fibers and epoxy. Hand lay-up and compression molding techniques are very popular among those techniques.
- Reinforced process can increase the mechanical properties of hybrid composites and reduced its confines. Mechanical properties of hybrid composite are found to rise due to least void of hybrid natural fiber having comparably high elongation.
- Natural fibers have many benefits for instance low cost, low density, eco-friendly, easily recyclable and availability in affluence. Natural fibers can be used instead of synthetic fiber due to its satisfactory mechanical properties.

5. Acknowledgement

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