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Experimental Study on The Mechanical Properties of Natural Fibers Reinforced Hybrid Composite

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Abstract

The aim of the present work is to investigate the effect of hybridization of sugarcane bagasse and coir fibers as reinforcements in the polymer matrix. Composites made of natural fibers possess favourable properties like low cost, light weight, high strength and eco-friendly nature compared to synthetic fibers. It can be used for structural applications in aerospace and automobile industries. In this research work, two lightweight composite materials were developed, one with a linear pattern and other with the chopped pattern of sugarcane bagasse and coir fiber reinforcements. The developed composites were subjected to different tests to investigate their mechanical properties. Both the developed specimens were investigated for their tensile strength, hardness, and water absorption capacity to compare their behaviour. It is examined from the test results that the composite with the chopped fiber reinforcement holds better mechanical properties compared to the linear reinforcements.

Keywords: Coir, Mechanical Properties, Reinforced Hybrid Composites, Sugarcane Bagasse.

Introduction

Researchers worldwide are now using locally available natural fibers to make composites considering the cost-effectiveness and ease of manufacturing [1]. A wide variety of natural fibers, individually and in combination with all possible orientations as reinforcements in the polymer matrix are attempted as it offers endless scope for feasibility trials. The composite materials are investigated for their mechanical behaviour and optimized for all the factors involved to suit the intended application [2-4]. Though the behaviour of composite material is complex and direction oriented, they find wide applications in modern industries [5], [6]. As they are used for structural applications, many attempts have been made towards improving their mechanical properties with new bonding techniques [7], [8], [10]. Natural fiber reinforcements have shown improved flexural, and impact strengths, but the improvement in tensile property has only been marginal requiring attention for further investigation [11-13]. Sandhyarani Biswas et al. studied the effect of fiber length on mechanical behavior of these epoxy based polymer composites shows that untreated coconut coir fibers have been used in epoxy resin composites as reinforcement materials. This study has confirmed that coconut coir fiber reinforced epoxy composites have better tensile strength, tensile modulus and flexural strength [9].

Materials and Methods

A. Selection of Materials

The raw materials used in this work are Bagasse, Coir, Epoxy Resin and Hardener.

i. Bagasse Fiber (Saccharum Barberi)

The dry pulpy residue left while extracting the juice from the sugarcane is called as Bagasse. One of the most widely used natural fibers is Sugarcane (Bagasse) fiber that has been successfully incorporated in a variety of applications. Figure 1 shows the Sugarcane plant has a single, straight and branchless stalk and made up of an inner woody core and an outer fibrous bark surrounding the core. Applied first to the debris from the pressing of olives, palm nuts, and grapes, the word was subsequently used to mean residues from other processed plant materials such as sisal, sugarcane, and sugar beets. In modern use, the word is limited to the end product of the sugarcane mill. Bagasse may be used as fuel in the sugarcane mill or as a source of cellulose for manufacturing animal feeds.

Figure 1: Stem of Sugarcane

Bagasse is an essential ingredient for the manufacture of pressed building board, acoustical tile, and other construction materials. In order to produce 3 tons of Bagasse, a quantity of 10 tons of sugarcane to be crushed. Since Bagasse is a by-product of the sugarcane industry, the quantity of production in each country is in formation with the amount of sugarcane produced. Thus, it would reduce the demand for timber that now is facing problem of deforestation.

ii. Coir Fiber (Cocos nucifera Linn)

Figure 2 shows the Coir is a natural fiber produced from the coconut husk. It is a thick and coarse but durable fiber. It is relatively water-proof and has resistant to damage by salt water and microbial degradation. For structural applications, the investigation of the mechanical properties and dynamic characteristics of the coir fiber reinforced composites is vital. Because of having a suitable stiffness and damping coefficients, the composites can be utilized for certain applications that required characteristics such as strength, rigidity, light weight and eco- friendliness.

Figure 2: Coconut Husk

The example of the application of coir fiber reinforced composites is in automotive industries where it used to make seat cushions for automobiles. Even though it possesses advantageous properties, the coir fiber composites still have some undesirable properties such as dimensional instability, flammability that make it unsuitable for high-temperature applications. Degradability of coir because of humidity, ultraviolet lights, acids with bases create more problem. Therefore, a lot of struggle needed to be put into improving performance of coir fiber reinforced composites.

iii. Fiber Treatment

For getting maximum strength, the bond between matrix and fibers needs to be improved by alkali treatment. This improves the interfacial bonding by giving rise to additional sites for mechanical interlocking, hence promoting more matrix/fiber interpenetration at the interface. The bagasse and coir fibers were dipped in NaOH solution for 24 hours at room temperature for alkali treatment. The fibers were further washed with distilled water including a few drops of acetic acid. Then the fibers were washed with fresh distilled water again until NaOH was removed. During the alkaline treatment, the OH groups present in the fibers react with sodium hydroxide according to the equation:

(Fiber) - (OH) + (NaOH) (Fiber) -O-Na + H_2O

Matrix material selected is Epoxy resin AW-106 and HV-953 as a binder for the resin.

B. Preparation of the Specimen

In the present work the fiber orientations have chosen, were chopped fiber (random discontinuous fibers) reinforcements and unidirectional continuous fiber reinforcements in the polymer matrix. The composites were prepared by hand- layup method in figure 3.

Figure 3: Mold for Making Composite

i. Chopped Fiber Reinforced Composite

Fibers were chopped to a length ranging from 0.5mm to 0.8mm. Initially epoxy and hardener were mixed together based on the weight percentage to form a matrix, and then the matrix was poured over the fiber and compressed and distributed evenly until it achieved a thickness between 4.5mm-5.0mm. The best way to prepare a standard quality test specimen is by mixing the epoxy and hardener for approximately 10 minutes and allowing curing time of around 20-24 hours until the composite plate is dried evenly.

Figure 4: Bagasse and Coir Fibers Composite Samples

ii. Continuous Fiber Reinforced Composite

In this orientation, the fibers of Bagasse and Coir are arranged in the composite plate. The fibers of both Bagasse and coir of 500mm length each are taken. Initially epoxy and hardener were mixed together for required weight percentage to form a matrix and then the matrix is poured over the continuously arranged fiber and compressed and distributed evenly until it achieved a thickness between 4.5mm-5.0mm. A standard quality test specimen is also prepared by mixing the epoxy and hardener for approximately 10 minutes and allowing curing time of around 20-24 hours until the composite plate is dried evenly. Figure 4 shows Bagasse and Coir Fibers Composite Samples.

Mechanical Testing

Each composite board was cut into test sample. The cutting processes were using handsaw and other equipments. After fabrication, the test specimens were subjected to mechanical tests such as tensile test, hardness test, and water absorption test. The sizes of the specimens for different tests have been given in Table 1.

Table 1: Dimension for Test Specimen Preparation

S. no	Test	Specimen Size (mm)
1	Tensile Test	300X 50 X 5
2	Hardness Test	75 X 75 X 5
3	Bending Test	300X 50 X 5
4	Moisture Absorption	75 X 75 X 5

A. Tensile Test

After the fibers had reinforced composite was dried, it was cut using a saw cutter to get the dimension of the specimen for mechanical testing. The tensile test specimen was prepared as per required size in accordance with ASTM D 638. The most common specimen has a constant rectangular cross section, 50 mm wide x 5mm thick and 300 mm long. In Figure.5 the specimen was mounted in the grips of the Instron universal tester with 10 mm gauge length.

To determine the ultimate tensile strength and elastic modulus the stress-strain curve was plotted during the test. All the test results were taken from the average of samples.

Figure 5: Universal Testing Machine (UTM)

B. Hardness Test

To get good measurement accuracy and repetitiveness hardness test done with operation stand of optional accessories. Constant measurement force, to eliminate the errors caused by artificially applied forces. The operation handle evenly applies the force to the sample adjusts the testing height in order to meet the measurement of different sample thickness. In this hardness test, the composite specimens were subjected to the calculation of hardness of each specimen. The specimen size for hardness test is taken as 75mm x 75mm x 5mm as per ASTM D 256.

C. Bending Test

The three point bending tests were performed using a bending testing machine as per ASTM D 790 standards. For the bending test, samples with dimensions of 300 mm × 50 mm × 5 mm were used. The bending strength test was carried out on the tensometer, and the strength was evaluated.

D. Water Absorption Test

In this water absorption test, the composite specimen is subjected to the calculation of how much water absorbs the specimen. The specimen size for water absorption test is taken as 75mm x 75mm x 5mm as per ASTM D 570.

Table 2: Tensile Properties of Chopped and Continuous Fiber of Bagasse / Coir Composites

Samples	Ultimate Load of Chopped Fiber (KN)	Ultimate Load of Continuous Fiber (KN)	Ultimate Stress of Chopped Fiber (N/mm^2)	Ultimate Stress of Continuous Fiber (N/mm^2)
1	3.2	2.1	9.14	7.12
2	3.4	2.4	9.71	7.43
3	3.8	2.7	10.86	8.43
4	3.9	3.2	11.14	8.47
5	4.4	2.9	12.57	11.23

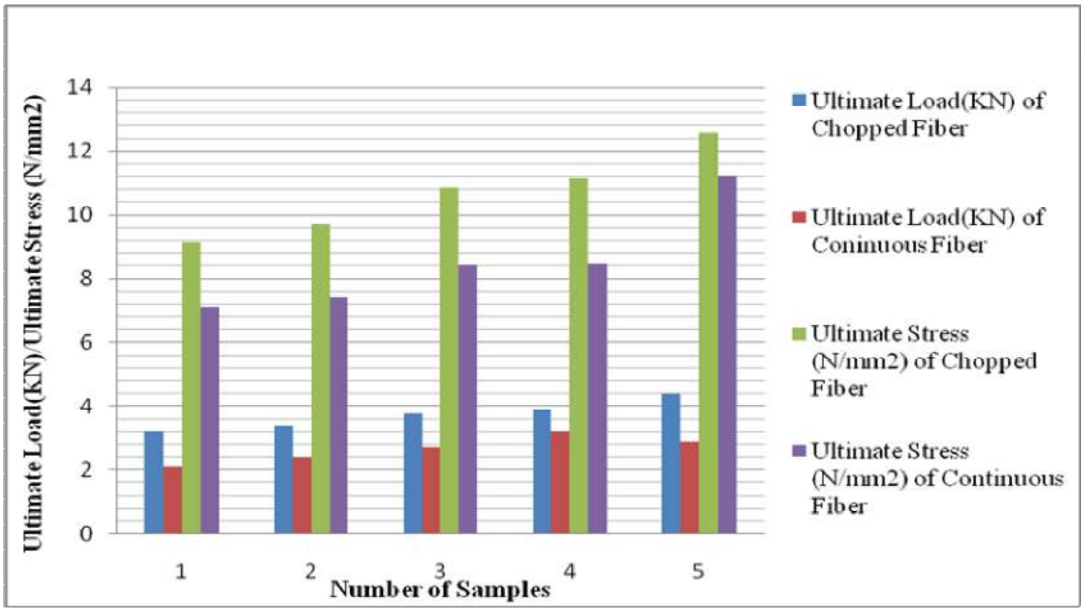

Figure 6: Tensile Properties chart of Chopped and Continuous Fiber of Bagasse / Coir Composites

Table 3: Hardness of Chopped and Continuous Fiber of Bagasse / Coir Composites

S. No	Specimens Orientation	Load (kg)	Perimeter (Inch)	Rockwell Scale	Rockwell Hardness	Mean Value
1	Chopped Fiber	100	1/16	C	46	49
					51	
					50	
2	Continuous Fiber	100	1/16	C	37	37.3
					33	
					42	

Table 4: Bending Strength of Chopped and Continuous Fiber of Bagasse / Coir Composites

Samples	Bending Strength in Chopped Fiber (MPa)	Bending Strength in Continuous Fiber (MPa)
1	2.064	3.021
2	2.242	3.179
3	2.387	3.378
4	2.325	3.687
5	2.357	3.720

Table 5: Water Absorption Weight Percentage of Chopped and Continuous Fiber of Bagasse/Coir Composites

S.NO	Time (hours)	Weight Percentage of Chopped Fiber Reinforced Composite	Weight Percentage of Continuous Fiber Reinforced Composite
1	3	74.0	76.0
2	6	74.5	77.0
3	9	75.0	77.5
4	12	75.5	78.5
5	15	76.0	79.5
6	18	77.0	80.0
7	21	77.5	81.0
8	24	78.5	82.0
9	27	78.7	82.5
10	30	78.7	83.0
11	33	79.0	83.5
12	36	79.0	83.5
13	39	79.0	83.5
14	42	79.0	84.0

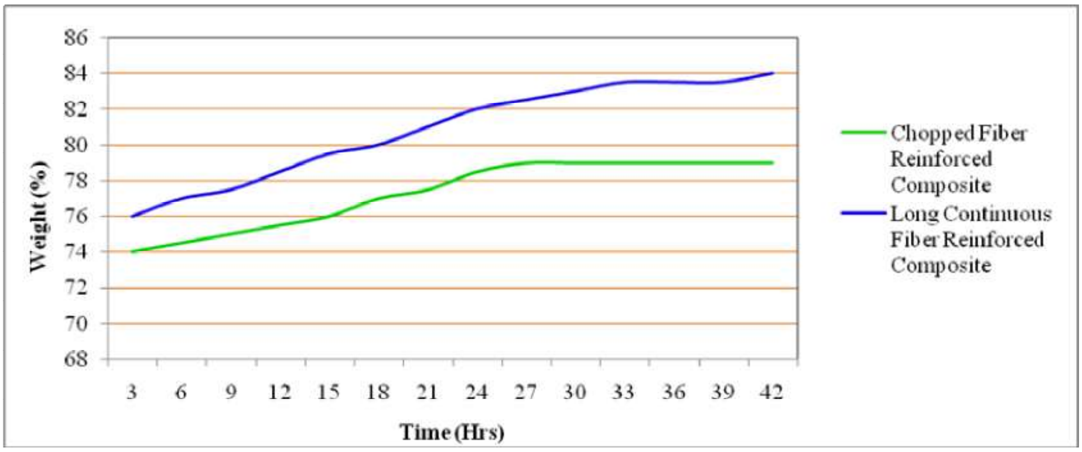

Figure 7: Water Absorption of Chopped and Continuous Fiber of Bagasse/Coir Composites

Results and Discussion

A. Tensile Strength

The tensile strength of the composite is based on the strength of the fiber, length of fiber and the fiber matrix interaction. The samples were tested in the Universal Testing Machine (UTM) and the ultimate load and ultimate stress of chopped and continuous fiber of Bagasse / Coir Composites was plotted. The Ultimate Tensile Strength (UTS) values of the five samples of each type of composite were tested and presented in Table 2 and Figure 6. The results indicate that the ultimate stress of the chopped fiber composite is higher than the continuous fiber composite.

B. Hardness

The hardness of the composite samples was tested in the Rockwell Hardness method. The typical hardness values for chopped and continuous fiber of Bagasse / Coir Composite Samples are presented in Table 3. The results show that chopped fiber composite possesses more hardness when compared to continuous fiber composite.

C. Bending Strength

Table 4 shows the bending strength of chopped and continuous fiber of Bagasse / Coir composite. Bending Strength in continuous fiber displayed highest (3.397 MPa) while Bending Strength in chopped fiber showed the least (2.275 MPa).

Water Absorption of test specimens obtained by 42 hrs immersion in water at 73.4 °F. After the removal from the water, the specimens were dried and weighed immediately. The water absorption percentage values of the samples of composite were tested and presented in Table 5 and Figure 7. The results indicate that the water absorption percentage of the chopped fiber composite is lower than the continuous fiber composite.

Conclusion

This experimental investigation of mechanical properties if Bagasse/coir reinforced polymer composites leads to the following conclusions:

- This work shows that successful fabrication of a Bagasse/coir fiber reinforced epoxy composites with Simple hand lay-up technique and different fiber orientation.
- It has been noticed that the mechanical properties of the composites Tensile Test, Rockwell Hardness Test Bending Test and Water Absorption were greatly influenced by the fiber orientation and its lengths.
- Chopped Arrangements are better Mechanical Property than Continuous Arrangements. Because the interfacial Bonding is Good enough in Chopped Fiber Reinforcement than the Continuous Fiber Reinforcement.

It has been concluded that the poor interfacial bonding is responsible for low mechanical properties.

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