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Investigation of Mechanical Properties of Bagasse Fiber and Human Hair Reinforced Hybrid Composite

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ABSTRACT
Now-a-days various types of mechanical applications require composite of better quality and performance having lower weight to strength ratio. Sometimes natural fibers are treated with different chemicals or combined with other materials to achieve better performance. This work represents the fabrication and evaluation of different mechanical properties of hybrid composite made from alkali-treated (10% NaOH solution) bagasse fiber and human hair reinforced with epoxy resin and compared the properties with the composite that made from untreated natural bagasse fiber and human hair. Hand lay-up technique is used for fabrication process. In both cases, six total layers have been used, four human hair stitched layers in between two bagasse fiber stitched layers. Mechanical tests such as tensile, flexural and impact tests are performed for both hybrid composites and then comparisons are deliberated. The result of this work indicates the hybrid composite made from treated bagasse fiber shows slightly better properties than the composite with untreated bagasse fiber.

Key Words: Hybrid composite, Bagasse fiber, Human Hair, Epoxy resin, Alkali treatment.

1. Introduction

Composite material is made from two or more different types of constituent materials with knowingly dissimilar physical and chemical properties, when combining together yield a material with characteristics different from the individual constituent. Mainly contains two constituents, one is called reinforcing phase and the other one which it is implanted is called the matrix. The reinforcing phase may be in the form of fibers, particles or flakes whereas the Matrix phase materials are continuous.

Surface treatment of natural fibers has been extensively used to increase and modifying the fiber properties. There is possible to increase the properties of bagasse fiber and hair by physical or chemical treatment. These processes help to modify the crystalline structure and removing weak lignin structure.

Cao Y [1] studied Biodegradable composites reinforced with bagasse fiber before and after alkali treatment. Mechanical properties of the composites made from alkali treated bagasse fibers were higher than the untreated fibers. Composites of 1% NaOH solution treated fibers showed maximum improvement.

Daniella Regina Mulinari [2] studied both pre-treated and modified deposits from sugarcane bagasse. Polymer of High-Density Polyethylene (HDPE) was engaged as matrix in to composites, which were formed by mixing high density polyethylene with cellulose (10%) and Cell/$ZrO_2.nH_2O$ (10%), by a hydraulic press. Tensile tests showed that the Cell/$ZrO_2.nH_2O$ (10%) HDPE composites existing better tensile strength than cellulose (10%) HDPE composites.

Varun Mittal, and Shishir Sinha [3] studied on the effect of chemical treatment on thermal properties of bagasse fiber-reinforced epoxy composite. Where it is found that thermal stability of the bagasse composite treated with NaOH and acrylic acid is higher as compared to the untreated bagasse fiber composite. Surface structure of the fiber modified due to the treatment.

Yang Yu, Wen Yang, Bing Wang, Marc Andre Meyers [4] studied mechanical behavior of human hair under various conditions and evaluate the effects of strain rate, relative humidity and also the temperature. Where it shows high tensile strength 150-270MPa, which is dependent on strain rate and relative humidity and strain-rate is nearly 0.06-0.1.

P. Divakara Rao, C. Udayla Kiran, K. Eshwara Prasad [5] prepared composite of human hair permeating in polyester resin and observed maximum tensile strength of the human hair reinforced composite is 31.45MPa using 30mm length of fiber and maximum tensile strength shows at 20% fiber weight ratio.

There is a possibility to increase the properties of bagasse fiber and hair by physical (i.e. plasma treatment) or chemical treatment (i.e. alkali, silane, water repelling etc.). Using plasma treatment form strong covalent bonds with matrix, leading to strong fiber and matrix interface, improves surface roughness thus provide mechanical interlocking [6]. These chemical processes help to modify the crystalline structure and removing weak lignin structure.

Treated bagasse fibers has variety of application as packaging, furniture. As the hybrid composite made from bagasse fiber and human hair is made from waste, low cost, biodegradable, low weight and easily available these can be applied to make hardboard, wall panel, boat manufacturing etc.

2. Experimental Procedure

2.1. Materials

Bagasse Fiber, sugarcane residue was collected from a local sugarcane juice seller after liquor extracted. After separation of cellulose, lignin and moisture, around 7-8% fiber was found from the total weight.

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Human Hair, collected from nearby parlor.
Epoxy resin and Hardener.

2.2. Fiber Extraction

First bagasse collected after removal of juice from the sugarcane (Figure 1).

Figure.1 Collected Bagasse

Then the extraction process was began with the bagasse soaking in drossy water. There the bagasse was drawn for 4 weeks; this makes the cellulose and lignin bond weak. After the bagasse was been rotten and bonds between the lignin and fibers were weak enough, bagasse from the drossy water had been brought out and carefully separated the lignin and cellulose by hand. After collecting the fibers from the bagasse, they were washed in clear water and dried in sun. Finally, the bagasse fiber was extracted.

Figure.2 Rotten bagasse in drossy water after 4 weeks

Figure.3 Extracted bagasse fiber

2.3. Fiber Treatment

After the extraction of bagasse fiber, a portion of fiber (one third) had been taken for further treatment to observe differences in properties. For alkali treatment, an alkali solution of 10% NaOH was taken and fibers had been soaked in the solution for 10 hours under sunlight with temperature about 40-45°C.
Then after treatment done, fibers had been washed with water and dried in the sun.

Figure.4 Alkali treatment of Bagasse fiber

2.4. Composite Fabrication

For fabrication of both of the composite, Hand Lay-up technique is used. It is an open molding method and less expensive process for composite manufacturing [7-8].
First, all the molding plates had been cleaned with acetone and carefully covered with plastic sheet using tape.
Second, hardener and epoxy resin had been mixed with suitable ratio, here the resin and hardener ratio were 10:1. When the mixing was done, a smooth and thin layer of resin hardener mixer had been formed on the plastic covered mold plate with brush. Then, carefully a bagasse fiber layer had been placed on the plate over mixer layer, and pressurized the layer with roller for obtaining a smooth layer formation. Then again resin mixture had been given over the bagasse fiber layer with brush, after distributing resin mixture properly, carefully put a hair layer over the bagasse layer, and pressurized with roller brush.
When a perfect resin mixture layer had been formed over the hair layer, another hair layer had been placed and pressurized with roller brush. Similarly, another two-hair layer had been placed. And finally, a bagasse fiber layer had been sited over the top (4^{th}) hair layer over which a suitable resin mixture had already been formed, and pressurized carefully with roller brush.
Then finally, a resin mixture sheet had been formed over the top most bagasse fiber layer with brush and enclosed with the second mold plate covered with plastic sheet (a thin distribution of resin mixture may be used on the plastic sheet).

For proper pressure distribution and kept the composite layer under pressure, a certain amount of weight had been placed on the topmost mold plate and kept it for 24 hours. Molding process for both treated and untreated fiber similar as described.

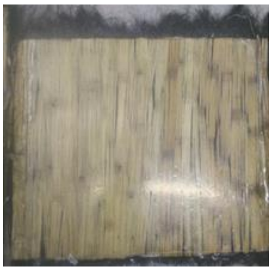
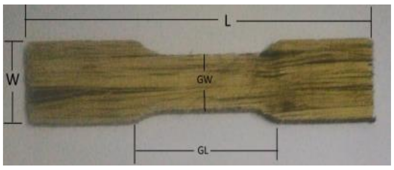


Figure.5 Composites after removing mold plate

2.5. Tensile Test

Tensile test was carried out in Universal Testing Machine (UTM) following ASTM D638 standard [9].
Specimen Preparation-
For the tensile test the composite materials are cut into small specimen by wood cutter machine following the standards-

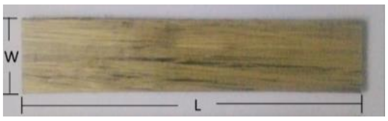


Where,
L= Overall length = 150 mm
W= Width = 30 mm
GL = 60 mm
GW = 20 mm

Figure.6 Cutting of specimen for tensile test

2.5. Flexural Test

Flexural test was carried out in Universal Testing Machine (UTM) following ASTM D7264 standard [10].
Specimen preparation-
For the tensile test the composite materials are cut into small specimen by wood cutter machine following the standards-

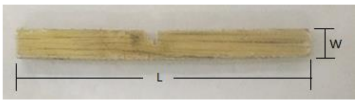


Where,
L= Length = 130 mm
W= Width = 30 mm

Figure.7 Cutting of specimen for flexural test

2.6. Impact Test

Charpy Impact Tester is used to evaluate impact properties following ASTM D256 standard [11].
Specimen preparation-



Where,
L= Length = 10 cm
W= Width = 1 cm
And the notch depth is 1/3rd of its width

Figure.8 Cutting of specimen for impact test

4. Result and Discussion

In this work, five samples were taken for each test for both of the composites.

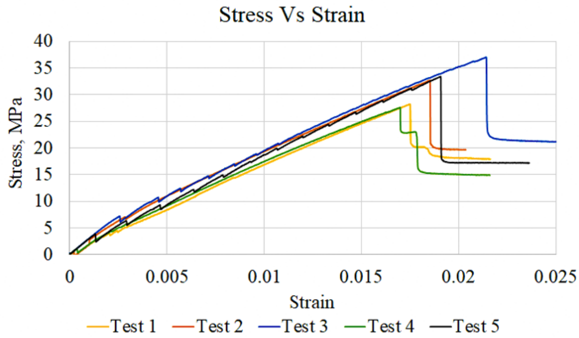


Figure.9 Stress Vs Strain diagram for Tensile test of composite of human hair and untreated bagasse fiber

Figure 9 show the stress-strain graph of tensile test for hybrid composite using untreated bagasse fiber and human hair, where for every sample result were almost same. At starting of the experiment some consecutive compression and tension occurred in the sample due to the starting vibration of machine that is why the starting graph were agitated. According to the Hooks law, both of the graphs show stress-strain proportionality at starting. Due to the alignment and molecular actions of the material, the nature of the curve changed slightly.
From the graph, reaching maximum stress, breakage occurred only in the bagasse fibers but due to the elongation properties of hair in between the bagasse layers, after breakage elongation takes place at a constant stress lower than the maximum stress.
Similarly, figure 10 shows the stress-strain graph of tensile test for hybrid composite using treated-bagasse fiber and human hair.

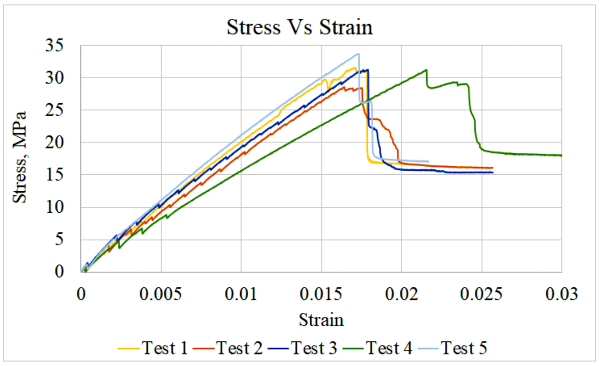


Figure.10 Stress Vs Strain diagram for Tensile test of composite of human hair and treated bagasse fiber

Where,

Maximum Stress, $\frac{F}{A}$ Pa

Maximum Strain = $\frac{\mathit{Max.\ Length\ of\ extension}}{\mathit{Gage\ Length}} \times 100\%$

Young's Modulus= $\frac{\mathit{Change\ in\ stress}}{\mathit{Change\ is\ strain}}$ GPa

Layer thickness, orientation, resin density, difference in volume fraction were found in the samples for experiment due to which the obtained graphs were deviated from each other and not easy to control.

Figure 11 and figure 12 represent the Flexural test of composite made from bagasse fiber and human hair, and composite made from treated bagasse fiber and human hair respectively. In both cases, the ultimate stress was almost similar for all samples but proportional limit range were in a distance due to the elongation properties and very less bending effect of hair. That is why in some of the graph, strain was increasing at a const bending stress lower than the ultimate stress.

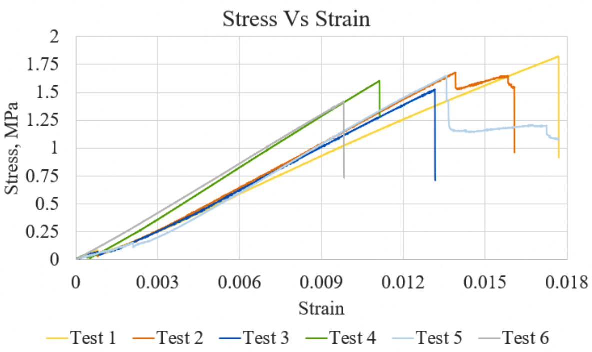


Figure.11 Stress Vs Strain diagram for Flexural test of composite of human hair and untreated bagasse fiber

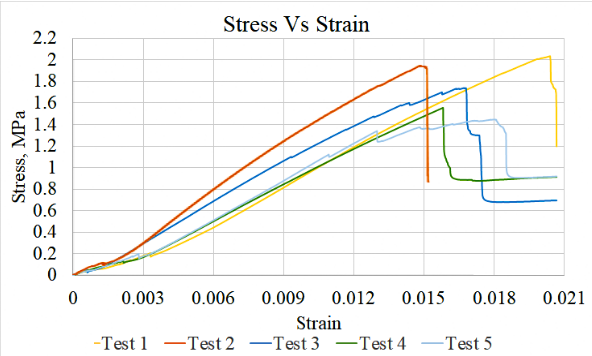


Figure.12 Stress Vs Strain diagram for Flexural test of composite of human hair and treated bagasse fiber

Where, Maximum Flexural Stress, $\frac{F}{A}$

Maximum Flexural Strain = $\frac{6Dd}{L^2}\times 100\%$

D= maximum deflection at center

d= thickness of specimen

L= distance between span

Flexural Modulus= $\frac{Change\ in\ stress}{Change\ is\ strain}$ GPa

Impact test carried out in Charpy Tester, and the obtained results are shown in Table 6.

Table 1 Calculation of average value of impact testing for both composite

Composite	Impact Energy, (kJ/m^2)
Untreated bagasse fiber and human hair	1564.14$\pm$98.26
Treated bagasse fiber and human hair	1585.98$\pm$163.33

After obtaining all the data comparing has been done between the composites. Figure.13 shows the comparison of ultimate tensile strength between the two composites. From the bar chart it seems similar ultimate tensile stress for both of the composites, and which is 31.84 ± 1.07 MPa for composite using untreated bagasse fiber, and 31.87 ± 3.42 MPa for composite using treated bagasse fiber. Though composite using treated bagasse fiber shows slightly higher value.

Figur.14 shows bar chart comparison of tensile module between composites but in the both cases obtained results were almost same, but composite with treated bagasse shows less variation 2 ± 0.286 GPa.

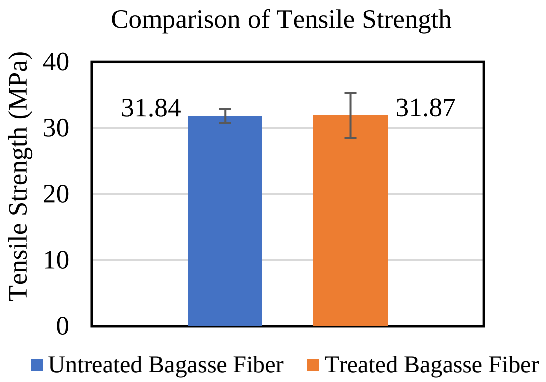


Figure.13 Bar chart presenting comparison of ultimate tensile strength of composites

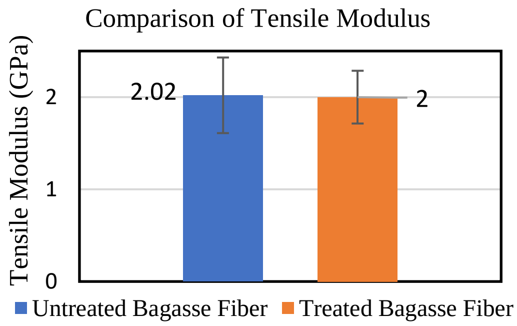


Figure.14 Bar chart presenting comparison of Tensile Modulus of composites

Figure 15 and figure 16 shows comparison of Flexural test for both of the composites. From the bar chart

(Figure 15) it clearly shows that composite with treated bagasse fiber shows higher ultimate flexural stress.

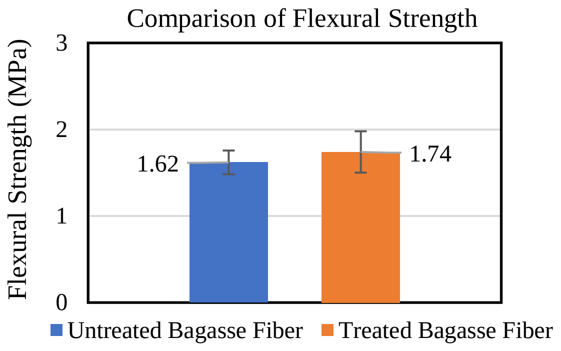


Figure.15 Bar chart presenting comparison of Flexural strength of composites

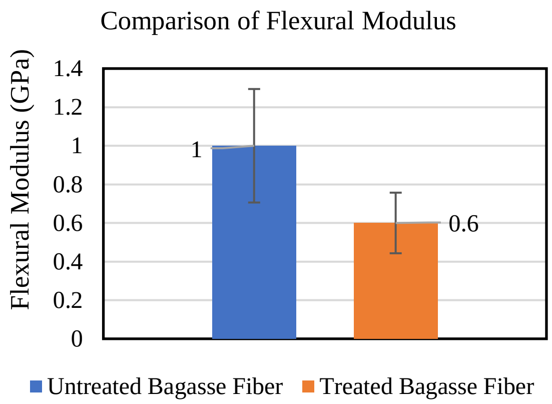


Figure.16 Bar chart presenting comparison of Flexural Modulus of composites

Similarly, from bar chart (Figure 16) composite using untreated bagasse fiber shows greater value of flexural modulus around 1 ± 0.294 GPa.

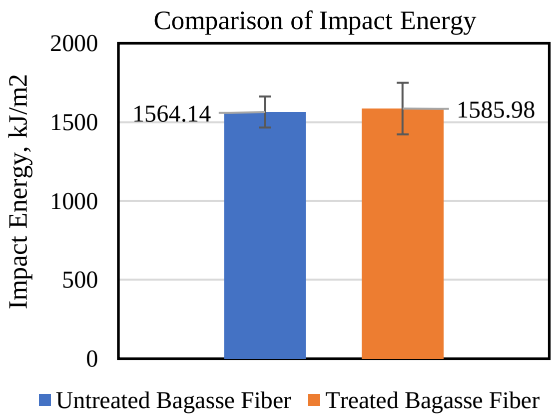


Figure.17 Bar chart presenting comparison of impact energy between composites

Figure 17 represents comparison of impact energy between the composites where it is clear that composite with treated bagasse fiber shows higher impact energy about $1585.98 \pm 163.3\ kJ/m^2$.

Table 2 Result summery comparing the composites 1 (Human hair and untreated bagasse fiber) and 2 (Human hair and untreated bagasse fiber)

Composite using-	Ult. Tensile Stress (MPa)	Tensile Modulus (GPa)	Ult. Flexural Stress, (MPa)	Flexural Modulus (GPa)	Impact Energy $(\frac{kJ}{m^2})$
Untreated bagasse fiber	31.84 ± 1.07	2.02 ± 0.41	1.62 ± 0.137	1 ± 0.294	1564.14 ± 98.26
Treated bagasse fiber	31.87 ± 3.42	2 ± 0.286	1.74 ± 0.239	0.6 ± 0.157	1585.98 ± 163.3

Observing the table 2, using of treated fiber along with human hair is advantageous as it has higher ultimate tensile and flexural stress, higher tensile modulus with good impact energy.

5. Conclusion

The present work has been undertaken, with an objective to discover the potential of the hybrid composite that is manufactured from bagasse fiber and human hair, reinforced with epoxy resin and to study the mechanical properties of composites. A natural fiber, if used as a reinforcement, offers good results compared to technical fibers. The manufactured composites were subjected to various mechanical test to evaluate mechanical properties as tensile, flexural and impact properties. In terms of tensile strength, the specimen is exposed to force axially and started to elongate while force is applied. Then to a maximum value of force the specimen breaks down and a maximum stress obtained. Thus, the tensile properties had been evaluated by UTM (Universal testing machine), and compared between composites made from treated and untreated bagasse fiber along with human hair.

6. References

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