ABSTRACT - This present work has been under taken to develop a polymer matrix composite (epoxy resin) using sugarcane fiber and to study its mechanical behaviour. Composites having different percentage weight fraction of sugarcane fiber for different laminates were made using hand layup method. The interfacial behavior of these composites was investigated by tensile test, short beam test, and Rockwell hardness test. The fabricated composite samples were cut according to the ASTM standards for different experiments and its mechanical properties like density, hardness, tensile strength and short beam strength are performed.

Keywords: Sugarcane fiber; Epoxy resin; hardner: Interfacial compatibilizers;

INTRODUCTION

The use of natural fibers as additives for composite materials presents a great potential for improving their performance and technological application due to their low cost, abundance, biodegradability and high specific strength [1]. Furthermore, due to their low density, natural fibers reduce the mass of the composite [2]. This is especially important if such fibers are residues of agroindustrial processes and if their raw properties are suitable for composites [3], thereby also satisfying ecological parameters and the demands of society. However, the major limitation of vegetal fibers used as reinforcement is the poor interfacial adhesion between polar-hydrophilic natural fibers and nonpolar-hydrophobic polymers. Coupling agents such as maleate and silane have been used to increase the compatibility between natural fibers and thermoplastic matrices, thereby enhancing the composite’s performance [6,7].

Accordingly extensive studies on preparation and properties of polymer matrix composite (PMC) replacing the synthetic fiber with natural fiber like Jute, Pineapple, Bamboo, Kenaf and Bagasse were carried out [8-11]. Recently, car manufacturers have been interested in incorporating natural fiber composites into both interior and exterior parts. This serves a two-fold goal of the companies; to lower the overall weight of the vehicle thus increasing fuel efficiency and to increase the sustainability of their manufacturing process. Many companies such as Mercedes Benz, Toyota and DaimlerChrysler have already accomplished this and are looking forward to expanding the uses of natural fiber composites [12].

The knowledge gap in the existing literature summarized above has helped to set the objectives of this research work which are outlined as follows:
1) Preparation of raw sugarcane fiber to different sizes.
2) Fabrication of a new class of epoxy based composite reinforced with sugarcane fiber fillers
3) Evaluation of mechanical properties and characteristics of sugarcane fiber reinforced composite with two different laminates.
4) Besides the above all objectives is to develop a new class of composites by incorporating sugarcane fiber reinforcing phases into polymeric resin. Also this work is expected to introduce a new class of polymer composite that might find many engineering applications.

1. PREPARATION OF COMPOSITES.

1.1 Processing of Sugarcane fiber Perticulates:
The sugar cane were crushed manually to remove bagasse. The sugar cane fibers were sun-dried for three days. The fibers on the outer bamboo were also scraped and cleaned. Emery paper was used to clean the outer shells. The cleaned fibers obtained from were cut into pieces of using scissoring. The collected fibers was then scissoring to different sizes. The fibers sizes chosen for the experiment are 150mm, 90 mm and 60mm. The procedure of making raw sugarcane fiber is shown in figure .1.
1.2 Preparation Of Composites Hand Layup Method:

A wooden mould of 150x60x8 mm Figure.3 was used for casting the composite sheet. For quick and easy removal of the specimen a teflon sheet was attached to the inner and outer surfaces the mould. Mould release spray was also applied at the inner surface of the mould wall. The weight percents of sugarcane fiber (ie.10, 20 and 30 wt %), were mixed with the matrix material consisting of epoxy resin and hardener in the ratio of 10:1. Care was taken to avoid formation of air bubbles during pouring. Pressure was then applied from the top and the mould was allowed to cure at room temperature for 24 hrs. During the application of pressure some polymer squeezes out from the mould. For this, care has already been taken during pouring. After one day the samples were taken out of the mould, cut into different sizes for further experimentation. Figure .4 (a) and (b) shows the photograph of the samples cut from the slab.

2. MECHANICAL TESTING.

The characterization of the composites reveals that the volume % of fiber is having significant effect on the mechanical properties of composites. Mechanical testing includes testing of micro-hardness, tensile strength and flexural strength respectively.

2.1 Density

Density is one of the most important mechanical properties of the particle board material. The density of sugarcane fiber reinforced composite for different mesh sizes for various wt% of fibers are calculated. The most commonly used method for calculating the density is to divide its weight by volume of the specimen. Mass of the sample is calculated by using pocket weighing scale.

\[
\text{Density} = \frac{\text{mass of sample}}{\text{volume of sample}}
\]  

(1)

2.2 Micro-Hardness

Micro-hardness measurement is done using a Lecco Vickers Hardness (LV 700) tester. A diamond indenter, in the form of a right pyramid with a square base and an angle 136° between opposite faces, is forced into the material under a load F. The two diagonals X and Y of the indentation left on the surface of the material after removal of the load are measured and their arithmetic mean L is calculated. In the present study, the load considered F = 10 N and Vickers hardness number is calculated using the following equation:
Where, 
F is the applied load (N),
L is the diagonal of square impression (mm),
X is the horizontal length (mm) and
Y is the vertical length (mm).

\[ H_v = \frac{\frac{1.854F}{L^2}}{E} \quad \text{and} \quad L = \frac{X+Y}{2} \quad (2) \]

2.3 Tensile Strength
The tensile test is generally performed on flat specimens. The most commonly used specimen geometries are the dog-bone specimen (figure 6). The standard test method as per ASTM D 3039-76 [33] has been used; The value of gauge length (L), width (d) and thickness (t) of the test specimen used in the experimentation as 125 mm, 10 mm and 5 mm. The tensile test is performed in universal testing machine. The tests were performed with a cross head speed of 10mm/min. Figure 6 (a, b) shows the machine used for the test and the sample in loading condition.

Tensile strength was calculated by the formula:

\[ S = \frac{F}{A} \quad (3) \]

Where,
F is the maximum load (in newtons);
A is the area of the specimen (in mm\(^2\)).
S is the tensile strength (MPa)
2.4 Short Beam Test

This test method determines the short-beam strength of high-modulus fiber reinforced composite materials. The specimen is a short beam machined from a curved or a flat surface up to 6.00 mm thick. Figure 8 describes the specimen configuration and Figure 8 describes loading for the short beam shear test. Based on ASTM standards, the specimen length is 6 times the specimen thickness and the span length is 4 times the specimen thickness. The width of the specimen is 2 times the specimen thickness. [13]

As per the loading configuration the fixture for this test should be designed as it won’t be available with this particular configuration. Figure 10 shows the fixture for the short beam strength test.
Test procedure: Test specimens were placed on the two 3.0 mm diameter supports, with care taken to align the center of the specimen in the center of the span. Loading supports were free to rotate, allowing free lateral motion of the specimen. Load was applied in the center of the specimen at the rate described above through the use of a 6.0 mm diameter steel dowel. The beam was loaded until fracture, and the fracture load was taken as a measure of the apparent shear strength of the material. The test set-up can be seen in Figure.11 below.

Short beam shear strength was calculated for each specimen based on the formula [14]:

\[ F_{sbs} = 0.75 \times \frac{P_m}{b \times h} \]  

Where:  
\( F_{sbs} = \) short-beam strength, MPa  
\( P_m = \) maximum load observed during the test, N  
\( b = \) measured specimen width, mm  
\( h = \) measured specimen thickness, mm

**3. RESULTS AND DISCUSSIONS.**

### 3.1. Density Measurement

From the table.1 it is observed that as the density decreases as the weight percentage of fiber increases and with the decrease of size. The decrease in density can be related to the fact that the sugarcane fiber are light in weight but occupy substantial amount of space. Figure.11 is the graph drawn between the measured densities of the composites and weight fraction of fiber for different meshes.

**TABLE.1**  
Density of different samples

<table>
<thead>
<tr>
<th>Laminates</th>
<th>Fiber volume</th>
<th>Density [gm/cm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossed laminates(40°/0°/40°)</td>
<td>10</td>
<td>2.424</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>2.304</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>2.193</td>
</tr>
<tr>
<td>Uni directional laminate(0°/0°/0°)</td>
<td>10</td>
<td>2.251</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>2.182</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>2.009</td>
</tr>
</tbody>
</table>

![Density Vs %Fiber volume](image)

Figure.11 Variation of density with different fiber contents
3.2 Hardness Measurement
Vickers hardness number is measured by Leitz Micro hardness tester. The results are tabulated in the table.2. Figure.12 drawn between the hardness values of composite and the weight percentage of composite for different fiber laminates. It is observed that as the reinforcement increases the hardness increases the maximum value is obtained for composite prepared with the 30% composite of 90mm length of fiber.

<table>
<thead>
<tr>
<th>Fiber volume</th>
<th>HV</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>183</td>
</tr>
<tr>
<td>20</td>
<td>198</td>
</tr>
<tr>
<td>30</td>
<td>190</td>
</tr>
<tr>
<td>10</td>
<td>205</td>
</tr>
<tr>
<td>20</td>
<td>223</td>
</tr>
<tr>
<td>30</td>
<td>279</td>
</tr>
</tbody>
</table>

Figure.12 variation of hardness value with different laminates

3.3 Tensile Test and Short-beam Test
The results of tensile test and short beam test are conducted on universal testing machine are tabulated below:

<table>
<thead>
<tr>
<th>Fiber volume</th>
<th>Tensile strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>38.79</td>
</tr>
<tr>
<td>20</td>
<td>42.52</td>
</tr>
<tr>
<td>30</td>
<td>47.17</td>
</tr>
<tr>
<td>10</td>
<td>39.12</td>
</tr>
<tr>
<td>20</td>
<td>47.89</td>
</tr>
<tr>
<td>30</td>
<td>45.82</td>
</tr>
<tr>
<td>10</td>
<td>14.99</td>
</tr>
<tr>
<td>20</td>
<td>16.15</td>
</tr>
<tr>
<td>30</td>
<td>17.38</td>
</tr>
<tr>
<td>10</td>
<td>18.22</td>
</tr>
<tr>
<td>20</td>
<td>20.34</td>
</tr>
<tr>
<td>30</td>
<td>20.07</td>
</tr>
</tbody>
</table>
Figure 13. Variation of tensile strength values with different laminates.

The tensile strength results for various specimens which were prepared with raw sugarcane fiber particles with different weight fraction for different grains sizes were plotted in Figure 13. The plot shows that, the maximum tensile strength is obtained for the composite prepared with the 20wt % of Crossed sugarcane fiber laminate filled epoxy composite.

Figure 14. Variation of short-beam strength values with different fiber contents.

Figure 14 shows the variation in flexural strength for different volume fraction of Fiber composites with different laminates. The plot shows that, the maximum flexural strength is obtained for the composite prepared with the 20wt % of Crossed laminate sugarcane fiber particulate filled epoxy composite.

3.4 Comparison of sugarcane fiber reinforced composite with other natural fiber reinforced composite

A.S. Ferreira et al. conducted the experiments on natural fiber reinforced composites like sisal, ramie, curaua, jute, bamboo and coir and their mechanical properties like tensile strength are obtained as in shown in figure 15 [15].

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Sisal</th>
<th>Ramie</th>
<th>Curaua</th>
<th>Jute</th>
<th>Bambo</th>
<th>Coir</th>
</tr>
</thead>
<tbody>
<tr>
<td>A(Mpa)</td>
<td>39</td>
<td>21</td>
<td>17</td>
<td>19</td>
<td>54</td>
<td>13</td>
</tr>
</tbody>
</table>
From the above results it is analysed that the maximum sugarcane fiber reinforced composite is 47.89 MPa. It is high when compared to other natural fiber composites made up of Kenaf, acacia, water hyacinth banana, EFB, ramie, curaua, coir and jute. And it is having near strength compared to bamboo strength which exhibits naturally. As the sugarcane fiber composite exhibits good mechanical properties when compared to other natural composites researchers are showing interest and developing its for future use.

4. CONCLUSIONS

The present work deals with the preparation of characterization of sugarcane fiber reinforced epoxy composite. The mechanical behaviour of the composite lead to the following conclusions.

- This work shows that successful fabrication of a sugarcane fiber reinforced epoxy composites by simple hand lay-up technique.
- The density of the composite gradually decreases with the increase of weight percentage of fiber content.
- The hardness value of the composite increases with increasing of the fiber content. The highest hardness value observed is 279Hv for crossed laminated composite and content of sugarcane fiber found to be maximum i.e. 30 %
- Maximum tensile strength value is observed for the composite prepared with sugarcane fiber of crossed laminate and the weight percentage of the fiber is 20%.
- Maximum short-beam strength value is observed for the composite prepared with sugarcane fiber of crossed laminate and the weight percentage of the fiber is 20%.

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