

# Development and Characterization of Hybrid Fiber Reinforced Polymer Composites

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## Abstract

**Objectives:** To develop hybrid composite material by incorporating jute/bamboo fibers and jute/kneaf fibers in epoxy matrix. To evaluate and compare the mechanical properties of aforesaid hybrid composites using various test. **Methods/Statistical Analysis:** Compression molding machine is used for preparing two hybrid composite laminates, viz, jute/bamboo/epoxy and jute/kneaf/epoxy. The physical and mechanical properties of jute/bamboo/epoxy and jute/kneaf/epoxy hybrid composites are found by conducting various test like tensile, flexural, impact etc. **Findings:** Based on physical and mechanical examination, it is observed that there is no difference in density value and volume fraction of voids. But, there is difference in tensile, flexural, inter laminar shear and impact strengths. The result of this study showed that the jute/bamboo fiber reinforced epoxy composite is successfully developed in terms of strength for the same weight compared to jute/kneaf fiber reinforced epoxy composite. **Application/Improvements:** These hybrid composites are biodegradable and can be utilized to make household articles and mechanical parts like gears.

**Keywords:** Epoxy Resin, Hybrid Composites, Jute Bamboo Fiber, Jute Kneaf Fibers

## 1. Introduction

Composites are made by two or further materials united through different properties. Generally, it consists of reinforcement and matrix. The presence of fibers improves the mechanical properties, viz, tensile strength, flexure strength, impact strength, inter laminar shear strength. The matrix is used to transfer stresses between reinforced fibers and hence it protects the mechanical damage. The reinforcement can be natural fibers or synthetic fibers. Among all reinforcement fibers, natural fibers reinforcement in polymer matrix attracts more because of low cost, low density, availability, biodegradable etc., Extensive work have been carried out to assess the characteristics of natural fiber as reinforcement in polymer namely bamboo, jute, flax, rice husk, coir and wood fiber<sup>1-10</sup>. The tensile strength and flexural strength of tri layer oil palm Empty Fruit Bunches (EFB)/woven jute (Jw) fiber reinforced

epoxy hybrid composites was investigated by author<sup>11</sup> and the results showed that the tensile and flexural strength of hybrid composite is higher than that of EFB composite but less than woven jute composite. In<sup>12</sup> investigated the mechanical and thermal properties of raw jute and banana fiber/epoxy hybrid composites and found that incorporation of banana fiber in jute/epoxy composites of until 50wt% results in increasing the mechanical and thermal properties and decreasing the moisture absorption property. In<sup>13</sup> reinforced the untreated sisal and oil palm fibers with natural rubber and found that there was reduction in tensile strength and tear strength, but the modulus of the composites was increased.

The natural fiber composites of sisal/silk unsaturated polyester based hybrid composites was studied by author<sup>14</sup> reported that there was improvement in tensile, flexural, and compressive strengths of the sisal/silk hybrid composites observed after by NaOH treatments. In<sup>15</sup> iden-

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tified the thermal diffusivity, thermal conductivity and specific heat of jute/cotton, sisal/cotton and ramie/cotton hybrid fabric-reinforced unsaturated polyester composites. The tensile, flexural, impact and water absorption tests were carried out using banana/sisal epoxy composite material by author<sup>16</sup> and concluded that the addition of sisal up to 50% with banana fiber increase the mechanical properties. In<sup>17</sup> studied the fiber composition of jute/coir epoxy novolac composites and reported that there is an increase in mechanical properties for the composite containing the jute/coir of 50:50. In<sup>18</sup> studied the tensile and flexural properties of the snake grass fiber-reinforced composites are compared with the snake grass/banana and snake grass/coir fiber-reinforced hybrid composites and found that the snake grass/banana and snake grass/coir fiber composites have the maximum tensile and flexural properties when compared with the snake grass fiber composites. Luffa fiber and Ground nut reinforced epoxy resin matrix composites have been developed by author<sup>19</sup> and reported that Tensile, Compressive, Flexural, Impact strength were improved. In<sup>20</sup> compared the properties of treated banana/coir epoxy composites with untreated banana/coir epoxy composites and concluded that treated banana-coir epoxy hybrid composites have higher tensile strength and impact strength than untreated composites and also reported that untreated fiber composites have greater flexural strength than the treated fiber composites.

## 2. Experimental

### 2.1 Materials

In the present work, jute/bamboo and jute/kneaf fibers were used to reinforce with epoxy matrix material. The properties of these fibers are presented in Table 1.

**Table 1.** Properties of natural fibers

| Property                     | Jute | Bamboo | Kneaf |
|------------------------------|------|--------|-------|
| Density (g/cm <sup>3</sup> ) | 1.3  | 0.8    | 0.75  |
| Tensile strength (MPa)       | 608  | 192    | 930   |
| Young's modulus              | 26.5 | 15     | 53    |
| Elongation at break (%)      | 1.65 | 11.2   | 1.6   |

### 2.2 Chemical Treatments

The natural fibers were powdered, cleaned with dirt free running water and then dried. In a glass beaker, a solu-

tion was prepared by mixing 5% NaOH and 80% distilled water. The dried fibers were then soaked in the prepared NaOH solution. After soaking, these fibers were washed with distilled water and then dried.

### 2.3 Composites Preparation

The two different natural fiber hybrid composites were fabricated using hand layup method. The first hybrid composite consists of jute and bamboo fibers and the second consists of jute and kneaf fibers. The fiber fillings were set at 40% (weight of jute and bamboo are set as 1:1) and the balance 60% was completed with epoxy resin. First, the mould was polished and the mould releasing agent was applied on the surface of mould to facilitate the removal of composite. The low temperature curing epoxy resin LY556 and hardener HY951 were mixed in the ratio of 10:1. The jute/bamboo and jute/kneaf fibers were reinforced with epoxy matrix of size 290 mm x 290 mm x 3 mm and then pressed in a hydraulic press of 35 kg/cm<sup>2</sup> at a temperature of 130°C for 45 minutes. Then the mould was kept for curing at room temperature. After that, these hybrid composites were cut in to required specimen as per ASTM standards and edges were finished by emery sheets. Table 2 shows the details of hybrid composite by weight percentage.

### 2.4 Characterization Tests

#### 2.4.1 Density

The theoretical density ( $\rho_{ct}$ ) of hybrid composite material can be calculated using the following equation 2.1.

$$\rho_{ct} = \frac{1}{\frac{Wf}{\rho f} + \frac{Wm}{\rho m}} \quad (\text{Eq.2.1})$$

where, W and  $\rho$  denotes the weight proportion and weight density respectively. The suffix f and m stands for fibre and matrix respectively. The actual density ( $\rho_{ce}$ ) can be calculated experimentally by simple water immersion technique. The volume fraction of the voids ( $V_v$ ) in the composite is calculated by following equation 2.2

$$V_v = \frac{\rho_{ct} - \rho_{ce}}{\rho_{ct}} \quad (\text{Eq.2.2})$$

#### 2.4.2 Tensile Test

There are two different specimens prepared for tensile test, viz, jute/bamboo epoxy and jute/kneaf epoxy. These

**Table 2.** Details of hybrid composites (Wt.%, Density and void volume fraction)

| Sl.No | Name of hybrid composite    | Name of fiber and matrix (wt.%) |        |       |       |
|-------|-----------------------------|---------------------------------|--------|-------|-------|
|       |                             | Jute                            | Bamboo | Kneaf | Epoxy |
| 1     | Jute/Bamboo epoxy composite | 20                              | 20     | -     | 60    |
| 2     | Jute/Kneaf epoxy composite  | 20                              | -      | 20    | 60    |

  

| Sl.No | Type of hybrid composites | Theoretical density (g/cm <sup>3</sup> ) | Actual density (g/cm <sup>3</sup> ) | Volume fraction of voids (%) |
|-------|---------------------------|--|-------------------------------------|------------------------------|
| 1     | Jute/bamboo epoxy         | 1.18                                     | 1.11                                | 6.0                          |
| 2     | Jute/kneaf epoxy          | 1.14                                     | 1.07                                | 6.1                          |

specimens were fabricated as per standard ASTM D638. This test was conducted on the universal testing machine. The procedure includes placing the specimen in between the fixture and applying the load till fracture takes place.

### 2.4.3 Three Points Bend Test

The specimen used for this test is prepared as per ASTM D790 standards. Three points bend test was conducted using tensile testing machine. The testing procedure involves engaging the specimen in the machine and applying load till fracture takes place.

### 2.4.4 Impact Test

The impact test specimens are prepared as per ASTM A 370 standard. The testing procedure involves placing the specimen in the fixture and allows the pendulum to strike the specimen.

## 3. Results and Discussions

### 3.1 Density

The presence of void in the composite considerably decreases the properties of the composites. Presents the theoretical density, actual density and the corresponding volume fraction of voids.

The disparity between theoretical density and actual density is since the void exists in the composites. Hence, knowledge about volume proportion of voids is vital. From the table it is detected that there is no substantial variation in density and volume proportion of voids.

### 3.2 Tensile Strength

The Table 3 shows the tensile strength of the fabricated composites and the effect of fibers on the tensile strength.

**Table 3.** Tensile strength of hybrid composites

| Sl.No | Name of the composite       | Tensile strength (MPa) |
|-------|-----------------------------|------------------------|
| 1     | Jute/Bamboo epoxy composite | 25.5                   |
| 2     | Jute/Kneaf epoxy composite  | 21.5                   |

From the Figure1, it was observed that the tensile strength of jute/bamboo epoxy hybrid composite having higher values when compared with jute/kneaf epoxy hybrid composite. The jute/bamboo epoxy hybrid composite demonstrated the extreme tensile strength and it may be due to proper adhesion between fibers and matrix which in turn restrict the mobility and deformability of the matrix.

### 3.3 Flexural Strength

The flexural strength was calculated by using the equation 2.3 given below.

$$FS = \frac{3PL}{2bh^2} \quad \text{Eq.2.3}$$

where, FS = flexural strength, P is the maximum load (in newtons); L is the distance between the supports (in mm); b is the width of the specimen (in mm) and h is the height (in mm).

The flexural strength of hybrid composites was presented in Table 4 and the effect of these fibers on flexural strength.

**Table 4.** Flexural strength of hybrid composites

| Sl. No | Name of the composite       | Flexural strength (MPa) |
|--------|-----------------------------|-------------------------|
| 1      | Jute/Bamboo epoxy composite | 63.5                    |
| 2      | Jute/Kneaf epoxy composite  | 38.5                    |

**Table 5.** ILSS of hybrid composites

| Sl. No | Name of the composite       | ILSS (MPa) |
|--------|-----------------------------|------------|
| 1      | Jute/Bamboo epoxy composite | 2.69       |
| 2      | Jute/Kneaf epoxy composite  | 1.5        |

**Table 6.** Impact strength of hybrid composites

| Sl. No | Name of the composite       | Impact strength (J) |
|--------|-----------------------------|---------------------|
| 1      | Jute/Bamboo epoxy composite | 1.2                 |
| 2      | Jute/Kneaf epoxy composite  | 1.6                 |

**Table 7.** Results comparison

| Sl.No | Composite                   | Volume fraction (%) | Tensile strength (MPa) | Flexural strength (MPa) | ILSS (MPa) | Impact strength (J) |
|-------|-----------------------------|---------------------|------------------------|-------------------------|------------|---------------------|
| 1     | Jute/Bamboo epoxy composite | 6.0                 | 25.5                   | 63.5                    | 2.69       | 1.2                 |
| 2     | Jute/Kneaf epoxy composite  | 6.1                 | 21.5                   | 38.5                    | 1.5        | 1.6                 |

### 3.4 Inter Laminar Shear Strength

The flexural strength was calculated by using the equation 2.4 given below.

$$ILSS = \frac{3F}{4bt} \quad \text{Eq.2.4}$$

where, ILSS - Inter-laminar shear strength (in MPa), F - Maximum load (in N), b - Width of specimen (in mm), t - Thickness of specimen (in mm)

The inter laminar shear strength of hybrid composites was presented in Table 5 and the effect of these fibers on ILSS.

From, Jute/Bamboo epoxy hybrid composite exhibit inter laminar shear stress value of 2.69 MPa. Inter laminar shear strength depends primarily on the matrix properties and fiber matrix interfacial strength rather than the fiber properties. ILSS can be improved by increasing the matrix tensile strength<sup>21</sup>.

### 3.5 Impact Strength

The impact strength of hybrid composites was presented in Table 6 and the effect of these fibers on impact strength.

The jute/bamboo epoxy hybrid composite shows the impact strength in decrease in trend. This variation of impact strength may be due to presence of small spaces between the fiber and matrix polymer, which in turn

stimulate the crack propagation easily and decrease the impact strength of the composites<sup>22</sup>.

**Comparison:** The results of the jute/bamboo epoxy composite are compared with the results of the jute/kneaf epoxy composite and are shown in Table 7.

## 4. Conclusions

The present works make known that both jute/bamboo and jute/kneaf were successfully used as reinforcement fiber in epoxy resin for making hybrid composites. Based on the experiment conducted on these fibers, it is concluding that

- There is no significance change in densities and volume fraction of voids for both hybrid composites.
- Jute/Bamboo epoxy hybrid composite provides better tensile strength which is 15.7% higher than the Jute/Kneaf epoxy hybrid composite.
- Similarly, Jute/Bamboo epoxy increases the flexural strength by 39.4% and inter-laminar shear strength by 44% than the Jute/Kneaf epoxy composite.
- But, the impact strength of Jute/Kneaf epoxy composite provides good impact strength which is 25% higher than the Jute/Bamboo epoxy composite.

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