Development and Evaluation of Mechanical Properties of 30% Hybrid Fiber- Epoxy Resin Composites

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Abstract: There has been a growing interest in utilizing fibers as reinforcement in polymer composite for making low cost construction materials in recent years. A wider adoption of emerging thermosetting composite materials using bamboo fiber, coir fiber and coconut shell powder will be facilitated by establishing their mechanical properties and production costs. This study aims to characterize these reinforced composites on the basis of performance and economic considerations that can be used by manufacturers and designers. Composites were prepared and tested in tension, bending and impact load. The results are compared with those predicted by several micromechanics models and their limitations have been identified. The developed composites are ranked on a cost-performance basis that can be used for different applications. This work deals with fabrication and investigation of mechanical properties of fiber such as bamboo fiber, coir fiber and coconut shell powder composite. Tensile and impact strength of the composites are investigated in the process of mechanical characterization. This composite material is widely used in industrial application purpose. Tests to be conducted: Impact test, Bending test, Tensile test with the certain experimental composition of composite material.

Key words: Bamboo fiber, Coir fiber and Coconut shell powder, composites, mechanical characterization.

I. INTRODUCTION

India endowed with an abundant availability of natural fiber such as jute, pineapple, bamboo, banana etc. has focused on the development of natural fiber composites primarily to explore value-added application avenues. Such natural fiber composites are well suited as wood substitutes in the housing and construction sector. The development of natural fiber composites in India is based on two pronged strategy of preventing depletion of forest resources as well as ensuring good economic returns for the cultivation of natural fibers. The developments in composite material after meeting the challenges of aerospace sector have cascaded down for catering to domestic and industrial applications. Composites, the wonder material with light-weight; high strength-to-weight ratio and stiffness properties have come a long way in replacing the conventional materials like metals, wood etc. The material scientists all over the world focused their attention on natural composites reinforced with jute, pineapple etc. primarily to cut down the cost of raw materials.

1.1 Definition of Composite

The most widely used meaning is the following one, which has been stated by Jartiz, “Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form”. The weakness of this definition resided in the fact that it allows one to classify among the composites any mixture of materials without indicating either its specificity or the laws which should given it which distinguishes it from other very banal, meaningless mixtures.
1.2 Characteristics of the composites
Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the ‘reinforcement’ or ‘reinforcing material’, whereas the continuous phase is termed as the ‘matrix’. Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergistic way resulting in improved or better properties. Apart from the nature of the constituent materials, the geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent. The concentration distribution and orientation of the reinforcement also affect the properties.

II. AIM AND OBJECTIVES

3.1 Aim of the Project
The present study deals with the mechanical characterization of natural fibers reinforced composites. In this project the bamboo and coir fibers have been made into small fiber size which is used to make the composite materials by using LY-556 resin and HY-951 hardener. To know the influence of mechanical characterization like tensile, bending strength, hardness and impact strength.

3.2 Objectives of the Project
- In this project hand layup technique is used to make the composite laminates of three different compositions.
- The laminates will be having layers of bamboo, coir fibers and coconut shell powder with LY-556 resin and HY-951 hardener.
- In this bamboo, coir fibers and coconut shell powder and paddy husk powder are used as a reinforcement materials and LY-556 resin is used as a matrix material and HY-951 hardener.
- In this project we are determining the mechanical characterization of composite (bamboo, coir fibers and coconut shell powder) by using hand layup method. Mechanical properties to be determined by the tests like tensile test, impact test, bending test.
- All the test specimens are prepared as per the ASTM standards.

III. EXPERIMENTAL PROCEDURE
In this section, the raw material used, the steps followed for carrying out to prepare specimen, test standards and test equipments used for conducting experiments and evaluating various properties are presented under the following headings.
4.1 Selection and Composition of the Raw Material
4.2 Preparation of Specimens
4.3 Tensile strength Evaluation
4.4 Bending strength Evaluation
4.5 Hardness strength Evaluation
4.6 Impact strength Evaluation

4.1 Selection and Composition of the Raw Material
The raw material is selected based on the availability of bamboo and then further peeled and chopped into required dimensions for preparing the specimen. The coir fiber is brought directly from market and then chopped into required dimensions for preparing the specimen. The coconut shell powder is directly available in the market as per as our requirement. The epoxy resin LY-556 and HY-951 hardener is also available in market.
4.2 Preparation of Specimens

4.2.1 Specimen Dimensions

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Specimens Tested</th>
<th>Length l (mm)</th>
<th>Width w (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tensile</td>
<td>250</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>Impact Izod</td>
<td>75</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Bending</td>
<td>125</td>
<td>12.7</td>
</tr>
</tbody>
</table>

4.2.2 Densities for Bamboo Fiber, Coir fiber, Coconut shell powder and Epoxy Resin.
- Bamboo Fiber = 1.26 gm/cm$^3$
- Coir fiber = 1.2 gm/cm$^3$
- Coconut shell powder = 1.15 gm/cm$^3$
- Epoxy Resin = 1.1 gm/cm$^3$

4.2.3 Determination of Fiber Volume Fraction.
Fiber volume fraction is a percentage of fiber reinforced in the matrix material. The volume of matrix material was obtained by using rule of mixture. It is calculated as follows:
The Specimens are prepared in Volume fraction
30% Volume Fraction [Fibers-25%, Coconut shell powder-5%, Resin-70%]

30% Volume Fraction [Fibers-25%, Coconut shell powder-5%, Resin-70%]
- Bamboo – 15% - 0.15
- Coir – 10% - 0.10
- Coconut shell powder – 5% - 0.05
- Resin – 70% - 0.70

Now,
\[
\frac{1}{\rho(\text{Total})} = \frac{V_{\text{Bamboo}}}{\rho(\text{Bamboo})} + \frac{V_{\text{Coir}}}{\rho(\text{Coir})} + \frac{V_{\text{C.S.Powder}}}{\rho(\text{C.S.Powder})} + \frac{V_{\text{Epoxy}}}{\rho(\text{Epoxy})}
\]
\[
= \frac{0.15}{1.26} + \frac{0.10}{1.20} + \frac{0.05}{1.15} + \frac{0.70}{1.10}
\]
\[
= 0.882222849
\]
\[
\rho(\text{Total}) = 1.133500453 \text{ gm/cm}^3
\]
Preparation of a Tensile Specimen

Volume of the Composite [Tensile Specimen],
\[ V_{\text{Total}} = 1 \times b \times t \]
\[ = 250 \times 25 \times 5 \]
\[ V_{\text{Total}} = 31250 \text{ mm}^3 \]
\[ V_{\text{Total}} = 31.250 \text{ cm}^3 \]

Also,
\[ m_T = \rho(\text{Total}) \times V_T \]
\[ = 1.133500453 \times 31.25 \]
\[ m_T = 35.42358144 \text{ gms} \]

Individual quantities added to prepare a Tensile Specimen
\[ m_{\text{Bamboo}} = 35.42 \times 0.15 = 5.31 \text{ gms} \]
\[ m_{\text{Coir}} = 35.42 \times 0.10 = 3.54 \text{ gms} \]
\[ m_{\text{C.S.Powder}} = 35.42 \times 0.05 = 1.77 \text{ gms} \]
\[ m_{\text{Epoxy}} = 35.42 \times 0.70 = 24.79 \text{ gms} \]

Preparation of a Bending Specimen

Volume of the Composite [Bending Specimen],
\[ V_{\text{Total}} = 1 \times b \times t \]
\[ = 125 \times 12.5 \times 3 \]
\[ V_{\text{Total}} = 4687.5 \text{ mm}^3 \]
\[ V_{\text{Total}} = 4.6875 \text{ cm}^3 \]

Also,
\[ m_T = \rho(\text{Total}) \times V_T \]
\[ = 1.133500453 \times 4.6875 \]
\[ m_T = 5.313987216 \text{ gms} \]

Individual quantities added to prepare a Bending Specimen
\[ m_{\text{Bamboo}} = 5.31 \times 0.15 = 0.79 \text{ gms} \]
\[ m_{\text{Coir}} = 5.31 \times 0.10 = 0.53 \text{ gms} \]
\[ m_{\text{C.S.Powder}} = 5.31 \times 0.05 = 0.26 \text{ gms} \]
\[ m_{\text{Epoxy}} = 5.31 \times 0.70 = 3.71 \text{ gms} \]

Preparation of a Hardness Specimen

Volume of the Composite [Hardness Specimen],
\[ V_{\text{Total}} = 1 \times b \times t \]
\[ = 50 \times 50 \times 10 \]
\[ V_{\text{Total}} = 25000 \text{ mm}^3 \]
\[ V_{\text{Total}} = 25 \text{ cm}^3 \]

Also,
\[ m_T = \rho(\text{Total}) \times V_T \]
\[ = 1.133500453 \times 25 \]
\[ m_T = 28.32526515 \text{ gms} \]

Individual quantities added to prepare a Hardness Specimen
\[ m_{\text{Bamboo}} = 28.32 \times 0.15 = 4.25 \text{ gms} \]
\[ m_{\text{Coir}} = 28.32 \times 0.10 = 2.83 \text{ gms} \]
\[ m_{\text{C.S.Powder}} = 28.32 \times 0.05 = 1.41 \text{ gms} \]
\[ m_{\text{Epoxy}} = 28.32 \times 0.70 = 19.82 \text{ gms} \]
Preparation of Impact Specimen Izod Test
Volume of the Composite [Impact Specimen],
\[ V_{\text{Total}} = l \times b \times t \]
\[ = 75 \times 10 \times 10 \]
\[ V_{\text{Total}} = 7500 \text{ mm}^3 \]
\[ V_{\text{Total}} = 7.5 \text{ cm}^3 \]
Also, \( m_T = \rho(\text{Total}) \times V_T \)
\[ = 1.133500453 \times 7.5 \]
\[ m_T = 8.497579545 \text{ gms} \]

Individual quantities added to prepare a Impact Specimen
- \( m_{\text{Bamboo}} = 8.49 \times 0.15 = 1.27 \text{ gms} \)
- \( m_{\text{Coir}} = 8.49 \times 0.10 = 0.84 \text{ gms} \)
- \( m_{\text{C.S.Powder}} = 8.49 \times 0.05 = 0.42 \text{ gms} \)
- \( m_{\text{Epoxy}} = 8.49 \times 0.70 = 5.94 \text{ gms} \)

4.3 Tensile strength Evaluation
Tensile testing utilizes the classical coupon test geometry as shown below and consists of two regions: a central region called the gauge length, within which failure is expected to occur, and the two end regions which are clamped into a grip mechanism connected to a test machine. These ends are usually tabbed with a material such as aluminum, to protect the specimen from being crushed by the grips. This test specimen can be used for longitudinal, transverse, cross-ply and angle-ply testing. It is a good idea to polish the specimen sides to remove surface flaws, especially for transverse tests.

4.4 Bending strength Evaluation

![Bending Testing specimen.](image)

The three-point bending tests were conducted with an electronic universal tester (Type: WDW-20) machine. The applied velocity of the bending load was 2 mm/min. Fig 4.7 shows the load configuration for a beam in three-point bending test. Different stacking sequence laminate types were tested, firstly quasi-isotropic and secondly unbalance stacking sequence. Load–displacement plots were obtained for each test specimen, and three specimens of each type of composite laminate were tested.
In Fig 4.7, F = applied force, R1 = indenter radius, R2 = fixed support radius, h = specimen thickness, L = support span and M = specimen length.

4.5 Hardness strength Evaluation
Hardness testing is usually performed using test machines equipped with an indenter that is forced into the test material over a certain amount of time. The shape of the indenter varies by type of hardness test and includes cone, ball and pyramid shapes. Each test machine also uses a different force or load application system and records an indentation hardness value in kilograms-force according to their individual hardness scales. Rockwell Hardness Test, there is a Superficial Rockwell. For each test, a minor load is applied to either a diamond cone or a steel ball indenter positioned on the test material’s surface to establish a zero reference position. A major load is applied for a specified amount of time, leaving the minor load applied upon release. The Rockwell hardness number will be the difference in depth between the zero reference position and the indent due to the major load. The choice of indenter is dependent upon the characteristics of the test material. The Rockwell Hardness Test applies larger minor and major load values than the Superficial Rockwell, yet both tests offer three different major load options.

4.6 Impact strength Evaluation
Impact tests are used in studying the toughness of material. A material's toughness is a factor of its ability to absorb energy during plastic deformation. Brittle materials have low toughness as a result of the small amount of plastic deformation that they can endure. The impact value of a material can also change with temperature. Generally, at lower temperatures, the impact energy of a material is decreased. The difference between Izod and Charpy is as shown in fig 4.10. The size of the specimen may also affect the value of the Izod impact test because it may allow a different number of imperfections in the material, which can act as stress risers and lower the impact energy.
IV. RESULTS AND DISCUSSION

Table 2: Tensile Load v/s Length Results for 30% Fiber Fraction

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>CS Area (mm²)</th>
<th>Peak Load (N)</th>
<th>%Elongation</th>
<th>Break Load (N)</th>
<th>UTS (N/mm²)</th>
<th>Youngs Modulus (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>000001</td>
<td>125.00</td>
<td>2,281.0</td>
<td>0.79</td>
<td>2,269.45</td>
<td>18.25</td>
<td>2324.20</td>
</tr>
</tbody>
</table>

Summary Report:

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<td>0.00</td>
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<tr>
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### Table 4: Bending Load v/s Length Results for 30% Fiber Fraction

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<th>Sample No.</th>
<th>CS Area (mm²)</th>
<th>Peak Load (N)</th>
<th>%Elongation</th>
<th>Break Load (N)</th>
<th>3Pt Bend Flexural Strength (MPa)</th>
<th>3Pt Bend Flexural Moduli (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>000003</td>
<td>43.75</td>
<td>25.00</td>
<td>1.30</td>
<td>9.23</td>
<td>19.37</td>
<td>-2985.42</td>
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III. **SAMPLE DETAILS:**

Test Name : 3PT BEND FLEXURAL  
Test Type : Normal  
Test Mode : Compression  
Elongation Device :  
Test Parameter : Peak Load  
Test Speed [mm/min]: 3.00
### Table 5: Bending Stress v/s Strain Results for 30% Fiber Fraction

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Based on the results obtained by carrying out mechanical characterization on hybrid composite (bamboo, coir, coconut shell powder and resin) experimentation and observations the following conclusions are shown in the present study.

**Tensile Test**
When a specimen of 30% Fiber Fraction having 125 mm$^2$ is subjected to a peak tensile load of 2281 N, the % of elongation is 0.79 and young’s modulus obtained is 2200.14 N/mm$^2$.

**Bending Test**
When a specimen of 30% Fiber Fraction having 43.75 mm$^2$ area is subjected to a peak bending load of 25 N, the % of elongation is 1.3 and 3 point bending flexural strength obtained is 19.37 MPa.

**Hardness Test**
When a specimen of 30% Fiber Fraction is subjected to a peak load of 60 N with ball indenter, Rockwell hardness number obtained is 84.

When a specimen of 30% Fiber Fraction is subjected to a peak load of 100 N with ball indenter, Rockwell hardness number obtained is 73.

**Impact Test**
When a specimen of 30% Fiber Fraction having 100 mm$^2$ is subjected to impact load in izod testing equipment, the impact energy obtained is 3 J, and the impact strength obtained is 30 KJ/mm$^2$.

**Table 6: Hardness**

<table>
<thead>
<tr>
<th>Sl. no.</th>
<th>Fiber fraction</th>
<th>Indenter</th>
<th>Total load [F] in [Kg-F]</th>
<th>Rockwell hardness number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30%</td>
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<td>100</td>
<td>73</td>
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</tbody>
</table>

**Table 7: Impact strength**

<table>
<thead>
<tr>
<th>Sl. no.</th>
<th>Fiber Fraction</th>
<th>Type of impact test</th>
<th>Area mm$^2$</th>
<th>Impact energy</th>
<th>Impact strength [U/A] in KJ/m$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30%</td>
<td>Izod</td>
<td>10×10</td>
<td>3</td>
<td>30</td>
</tr>
</tbody>
</table>

**V. CONCLUSION**

1. The main emphasis of the present work was on the development and testing of hybrid bamboo, coir fibers and coconut shell powder reinforced with epoxy resin composite to know their suitability and adaptability for various structural applications.
2. The hybrid bamboo, coir and coconut shell powder reinforced with epoxy resin composite possess high tensile strength, impact strength, and bending strength, these are the properties needed for the aerospace doors, helmets, boat steam, furniture, and decorative items.
3. The preparation of composite slabs was carried out by chopping the fibers. Further study need to be done without chopping and carry the further test to find out the strength.
4. The further researches on the bamboo, coir and coconut shell powder helps in the determination of mechanical properties and dynamic properties which helps to determine more applications in various fields economically.
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