Evaluation of Flexural Properties of Jute Natural Fiber Reinforced Polyurethane Polymer Matrix Composite Material

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Abstract: The objective of this Research work is to evaluate & analyze the flexural properties of developed composite specimen with polyurethane foam as matrix material & jute fiber as Reinforcement material. The first research experimentation shall be the flexural test is done as per the ASTM D 7264 standard to investigate the flexural properties of this combination of composite materials The main aim of this experimentation tests done are to investigate mechanical properties & strengths of newly developed jute reinforced composites to resist against the subjected tensile & bending loads under various conditions.

Keywords: Composites, fiber, jute, polyurethane, flexural test.

I. INTRODUCTION

This research work is basically focusing on the development of natural fibers composites using jute fibers [12] reinforcement is to explore in low load condition applications and analyze its mechanical properties. Composites, the wonder material [13] with light weight, high strength to weight ratio and stiffness properties have come a long way in replacing the conventional materials like metals, woods etc. The replacement of steel with composites can save a 60% - 80% of component weight and 20% - 50% weight of aluminum components.

Thus jute fiber reinforced PU foam composites is a latest & new combination of composite materials with its combined properties & characteristics have wide scope and can be introduced for several salient applications such as Railway coach interiors, sleepers for railway girder bridges, modular toilet units in railway, railway coaches main doors for passengers, for automobile seats & accessories, boat hulls, Modular house construction & domestic furniture’s.

II. OBJECTIVE

In this research work proceedings, firstly, the jute fibre reinforced composites were prepared by Resin Transfer Mold (RTM) [11] process using mild steel moulds. The proportions of jute fiber – PU foam [1] are mixed as per the rule of mixture ratio in composites.

The developed composite specimens of:
(a) 50% PU & 50% Jute fibers ratio
(b) 60% PU & 40% Jute fibers ratio

Table I : Matrix & Reinforcement details

| Reinforcing fiber | Bi-directional , woven Jute fiber mat (Stitched into a fabric form) of 500gsm |
|-------------------|----------------------------------------------------------------------------------|
| Matrix system     | Polyurethane foam (140 HRC)                                                     |
| Moulding process  | Resin Transfer Mould (RTM) process followed by room temperature moulding        |
| Reinforcements    | Matrix ratio : (a) 50:50 (b) 40:60                                               |

III. SPECIMEN SIZE FOR FLEXURAL TEST

The most common specimen for ASTM D 7264 is a constant Rectangular cross section, 25 mm (1 in) wide and 250 mm long.

IV. FLEXURAL PROPERTIES OF COMPOSITES BY ASTM D 7264

Fig. (2) Three Point Flexural Test conducted on Tensometer
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ASTM D 7264 outlines testing of flexural properties [3] of polymer matrix composites [4] using a bar of rectangular cross section supported on a beam and deflected at a constant rate to determine the flexural modulus [5]. The tests are done by two methods. Method-1 outlines a three point loading system for center loading. Method-2 outlines a four point loading system for two equal loading points. This test method is designed for polymer matrix composites and uses a standard 32:1 span-to-thickness ratio. Fabric-reinforced composite materials [6] are also referenced within the ASTM D 7264 standard.

A. FLEXURAL TEST PROCEDURE:

1. This experimentation is conducted on a tensometer according to the ASTM D 7264 as per Method-1 which outlines a three point loading system for center loading as shown in Fig. (5). The developed specimen lies on a support span and the load is applied to the center by the loading nose producing three-point bending at a specified rate.

2. The specimen is placed in the machine between the grips and the machine itself can automatically record the displacement between its cross heads on which the specimen is held during the test. This records the change in length of the specimen & its elastic components of the testing machine and its drive systems including any slipping of the specimen in the grips.

3. The machine is started; it begins to apply an increasing load on specimen.

4. During this test, the control system and its associated software record the load and extension or compression of the specimen.

5. Data Recording: The varying load signal is displayed in real time on a computer system screen using an inbuilt software PC2000, which can be taken printout hardcopy for validation.

6. The cross section of the subjected specimen is Rectangular type [6].

7. Finally, end the test after sample break or ruptures and tabulate the results.

8. Records the max load applied and the graph is applied according to the varying load.

B. FLEXURAL TEST SPECIMEN DIMENSIONS:

Fig. (6a & b) : Developed composite test specimen dimensions for flexural test

C. FLEXURAL TEST CONDUCTED ON DEVELOPED SPECIMEN IN CERTIFIED TEST CENTRE:
Fig. (4-a&b) Tensile test conducted on Tensometer

D. EQUIPMENT USED:
1. The testing machine used is Tensometer (With UTM attachment setup) for conducting flexural test.
2. The testing machine equipped with servo controlled for keeping a constant rate of speed.
3. The capacity needs to be enough for the testing materials. Usually a 2,000 Kgs dual column system is very commonly used. A high capacity of 10,000 Kgs model is sometimes needed for larger samples and / or stronger materials such as reinforced composites or plastics [7].
4. The extensometer or strain gauges are interfaced and integrated within the testing equipment.
5. Obtaining Data: The testing software has built-in support for ASTM D 7264 and suitable mechatronics are essential to operate this machine and to carryout the measurements. The basic systems will provide the raw data and Stress-Strain characteristics charts. Using these sources of data, we can determine and all of required calculations & analysis are provided immediately after performing the test.

V. RESULTS AND DISCUSSIONS

A. Jute Reinforced Composites for 60% PU & 40% Jute after Rupture:
Specimen after fracture on Tensometer subjected to Flexural Test

Fig. (5) Fractured specimens when subjected to Flexural test

TABLE II | TABULATION FOR FLEXURAL TEST CONDUCTED AS PER ASTM D 7264 STANDARDS FOR 60% PU & 40% JUTE:

| Trial No. | Peak Load (N) | Break Load (N) | Break Displacement (mm) | Ultimate Tensile Strength (N/mm²) |
|-----------|---------------|----------------|-------------------------|----------------------------------|
| 1         | 107.90        | 88.26          | 10.964                  | 48.84                            |
| 2         | 156.90        | 156.91         | 4.24                    | 66.40                            |
| 3         | 98.10         | 98.07          | 6.98                    | 69.30                            |
| Average   | 120.97        | 114.41         | 7.395                   | 61.51                            |

B. JUTE REINFORCED COMPOSITES FOR 60% PU & 40% JUTE FOR FLEXURAL TEST

Fig. (6) : Characteristics of Flexural Test for jute Composites of 60%PU & 40% Jute specimens (a,b,c)
C. JUTE REINFORCED COMPOSITES FOR 50% PU & 50% JUTE AFTER RUPTURE:

Fig. (7) Fractured specimens when subjected to Flexural test

TABLE III: TABULATION FOR FLEXURAL TEST CONDUCTED AS PER ASTM D 7264 STANDARDS FOR 50% PU & 50% JUTE:

Specimen cross section: Rectangular type

| Trial No. | Peak Load (N) | Break Load (N) | Break Displacement (mm) | Ultimate Tensile Strength (N/mm²) |
|-----------|---------------|----------------|------------------------|----------------------------------|
| 1         | 166.70        | 166.71         | 7.90                   | 115.44                           |
| 2         | 205.90        | 205.94         | 9.04                   | 96.36                            |
| 3         | 176.50        | 156.91         | 9.25                   | 117.35                           |
| Average   | 183.03        | 176.52         | 8.73                   | 109.71                           |

D. JUTE REINFORCED COMPOSITES FOR 50% PU & 50% JUTE FOR FLEXURAL TEST:

Fig. (8) Characteristics of Flexural Test for jute Composites of 50%PU & 50% Jute specimens (a,b,c)

E. 100% PU SPECIMENS AFTER RUPTURE:

Fig. (9) Fractured specimens when subjected to Flexural test

TABLE IV: TABULATION FOR FLEXURAL TEST CONDUCTED AS PER ASTM D 7264 STANDARDS FOR 100% PU SPECIMEN ONLY:

Specimen cross section: Rectangular type

| Trial No. | Peak Load (N) | Break Load (N) | Break Displacement (mm) | Ultimate Tensile Strength (N/mm²) |
|-----------|---------------|----------------|------------------------|----------------------------------|
| 1         | 78.50         | 68.64          | 7.41                   | 6.94                             |
| 2         | 68.60         | 58.84          | 8.73                   | 12.82                            |
F. FOR 100% PU SUBJECTED TO FLEXURAL TEST

|   | 3   | 58.80 | 49.03 | 9.59 | 17.09 |
|---|-----|-------|-------|------|-------|
| Average | 68.63 | 58.84 | 7.63 | 12.28 |

![Graphs](image_url)

(a)

(b)

(c)

Fig. (10) Characteristics of Flexural Test for 100% PU specimens (a,b,c)

G. DISCUSSIONS - FLEXURAL STRENGTH

From the flexural test, the following are the observations were made:

- The Jute natural fiber reinforcement have effect on the flexural strength of polyurethane foam matrix is as demonstrated in Fig. (6,8,10) respectively.

- As depicted in Fig. (6), the Flexural strength is increased linearly up to certain weight % [7], then after that it tends to decrease despite of the further rise in Wt % of the natural fiber reinforcement. The reason may be the fact that, as the Wt% of the reinforcement fiber increased, the weak interfacial area [8]-[9] and the micro spaces increased between the fibers and matrix, accordingly bringing down the flexural strength.

- It is also fact that at high % reinforcement, is more difficult to completely impregnate the fibers, resulting to poor interfacial bonding and subsequently lower mechanical properties. So as a result, chances are there of decreasing trend in flexural strength with the increasing fiber content in the composites.

- From Fig. (6 & 8) & Table (II &III), It is noticed from the test characteristics that flexural strength for 50% jute & 50% PU mixture has increased than that 40% jute & 60% PU, as the jute fiber density increases. So the breaking load also has increased with this increase in Jute%.

- Also it is seen that the breaking load is higher & have increased for 50% jute & 50% PU with enhanced jute fiber reinforcement comparably with 40% jute & 60% PU mixture ratio.

- From fig. (10), with only PU material which has a lower breaking load signifies that introduction of jute fiber will definitely a suitable reinforcement which will drastically increases the flexural strength [11] of this composite material.

- Hence Jute reinforcement can be increased with PU matrix up to certain mixture ratio beyond which there could arise poor bonding between the two materials.

H. CONCLUSIONS

In this research & experimental investigation, Jute fiber reinforced PU matrix composites were fabricated & developed. The flexural behavior of the developed composites was analyzed. As a result the tensile test of the developed composites substantiates their mechanical behavior. Thus the following conclusions can be drawn.

1. In this investigation it has been found that the reinforcement of jute fibers with PU polymer matrix have drastically increased its respective flexural strength, increasing its sustainability against the subjected loads.

2. Thus the developed composite specimens with mixture ratio of 50% Jute & 50% PU have shown an increased its breaking strength or breaking loads than that of 40% Jute & 60% PU when subjected to flexural test.

3. In the overall study, the strength of 50% Jute & 50% PU foam laminates has higher value than that of 40% Jute & 60% PU foam laminates in Flexural.
4. Hence reinforcement of jute fibers with PU foam matrix [10] is one of the favorable Composite materials which can play a prominent vital role in future for many industrial & other applications.

5. So it is concluded that further investigation on future experimental tests will definitely assure the use of this newer composite materials in coming future for our society.

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