Experimental Investigation on Mechanical Properties of Jute and Hemp fibre based Epoxy Composites

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Abstract. The conventional materials are replacing via composite materials due to their special properties like high specific strength, high elastic constants, and relatively low expansion in the thermal environment. Usage of fibre reinforced composites based on natural fibres has increasingly started as viable material in low load carrying applications. In the current study, hemp and jute fibre based epoxy composites were developed and tested for assessing their suitability for possible applications in automobile and aerospace interiors. Composites were undergone tensile tests, compression tests, and flexural tests to understand their behavior under various loading conditions. The results revealed that the usage of hemp and jute fibre reinforced composites can improve mechanical properties and have shown a viable alternative to replace synthetic fibres such as glass fibres for specific applications. Hemp reinforced natural fibre composites have shown better mechanical properties as compared to jute fibre based composites.

1. Introduction

Over the years composites have been fulfilling the needs of special materials for various structural and domestic applications [1]. Today a huge awareness is being created for the usage of renewable products around the globe. The social influence, demand from consumers and various other aspects is forcing researchers and industrialists to move towards eco-friendly products. The usage of natural fibre composites would be a good solution to this issue as it has displayed a viable replacement to synthetic fibres especially glass fibre based composites in specific applications [2,3]. The various characteristics of natural fibres like biodegradability, less density, lower manufacturing costs, renewable resource, and good mechanical properties in comparison to glass fibres have shown a huge application potential in automotive, construction, aerospace, and various other applications [4–6]. The light weight of components, less fuel consumption, good recycling possibilities act as main drivers for its usage in the interior of automotive and aerospace industries.

Bharath et al. [7] classified the various types of natural fibres and explored the applications of various natural fibres with a view of the various strength parameters. They also addressed the need for emphasis on other criteria such as environmental durability, embedded energy, fire resistance.
Vaisanen et al. [8] studied the effectiveness of the hemp-epoxy composites using various modifications to the hemp fibers by treating with alkali, enzymatic, steam, and wood distillate techniques. The mechanical properties of prepared composites were observed to be reduced after modifications but it lowered significantly the water absorption characteristics. Gopinath et al. [9] reported an experimental study on the mechanical response of jute fiber-epoxy composite and illustrated a detailed testing procedure to understand the behavior of composites under mechanical loadings. In another study, Biswas et al. examined thermal and physical behavior of unidirectional jute-bamboo-epoxy composites and have shown that jute reinforced composites show enhanced physical and thermal stability over banana fibre composites [10]. Rajesh et al. [11] studied the effect of fibre loading and alkali treatments on the tensile properties of short jute fibre reinforced composite. Alves et al. [5] reported a study on the usage of natural fibre composites in ecodesign of automotive components and addressed the effects of factors affecting the performance of the composite components. Ravi Kumar et al. [12] experimentally investigated the mechanical and surface morphological properties of natural fibre based composites and observed that natural fibre composites have the comparable specific tensile strength to that of glass fibre composites.

In the current study natural fibre based composites are fabricated using the hand lay-up technique and the properties like tensile, flexural, and compressive stability are assessed to look for possible applications of these bio-composites in Industrial sectors.

2. Material and Experimental Methods

2.1. Material

Fibres selected for composites fabrication are plant based fibres, i.e., jute and hemp due to their cheap price and rapid growth over a wide range of climatic conditions. Polymer used as matrix material is epoxy (LY556) and Araldite hardner (HY 951). Figure 1 shows the chemically treated hemp and jute fibre Mats supplied by Go green composites Chennai.

![Hemp and Jute Fibre Mats](image)

**Figure 1.** (a) Hemp fibre Mat (b) Jute Fibre Mat

2.2. Composite Fabrication

The hand layup technique is the most economical method and is used for the fabrication of hemp/epoxy and jute/epoxy composite plates. Epoxy and a suitable hardener were mixed in the weight ratio of 10:1. The layup was loaded inside a square mould box of inner dimensions 300 mm x 300 mm. Four layers of
fibres mat in the laminate sequence of [45/0]s are placed inside the mould box and plates of 4 mm thickness with fibre weight fraction of 45% were fabricated. Curing was carried out under a load of 50kg at atmospheric temperature. Figure 2 shows the fabrication process and fabricated composite plates.

Figure 2. (i) Hemp fibre reinforced composite (HFRC), (ii) Loaded mould box, (iii) Jute fibre reinforced composite (JFRC)

2.3. Samples Preparation

Samples were prepared for different testing as per ASTM standards as follows:

2.3.1 Individual fibre Tensile Testing:

Individual fibres were tested to assess their tensile strengths before reinforcing them into the polymer matrix. Twenty single fibres of the uniform length of 30 cm were selected and tested on a 10 kN universal tensile testing machine. As fibres are having different diameters along the lengths so the average linear density was measured in Tex and fed into the UTM machine for measuring fibre breaking force and corresponding elongation as per ATMD 3822.

2.3.2 Composites Tensile Testing:

The test specimens were cut according to ASTM D3039; the most common specimen for ASTM D3039 has a constant rectangular cross-section of 250 mm long and width of 25 mm. Thickness may vary as per the fibres used.

2.3.3 Composites Flexural Testing:

Flexural test was carried out by employing the three-point bending method according to ASTM D790. Sample dimensions for the flexural test were 120mm x 12mm.
2.3.4 Composites Compression Testing:
The compression specimens were cut as per the ASTM D695 standard. In this test, samples were mounted on a test plate and were subjected to the compressive loadings until its fracture. Sample dimensions are a square prism of 12.7 mm × 12.7 mm.

3. Results and Discussion

3.1 Individual fibre Testing

Twenty fibres of uniform length and diameters were selected and tested for tensile strength. Individual fibres were subjected to tensile loading as per ASTM D 3822 in 10 kN Universal tensile testing machine with grip to grip separation at the start position as 65 mm. Cross head travel was at a speed of 10 mm/min.

Figure 3. Force vs strain (%) for Hemp fibres

Figure 4. Force vs strain (%) for Jute fibres

Figure 3 shows the tensile results for hemp fibres, the maximum elongation of individual hemp fiber is observed at about 1.3% and the average elongation of the individual fibers is found out to be 0.7 %. The maximum and average tensile force that a single hemp fiber could withstand is 6.5 N and 4.43 N respectively.

It is observed from figure 4 that the maximum elongation of individual jute fiber is about 0.85% and the average elongation of the individual fibers is found out to be 0.52%. The maximum tensile force that the single jute fiber can withstand is 2.2 N and the average tensile force that the single jute fiber could withstand is 0.75 N.

Results revealed that in raw form hemp fibres can withstand higher tensile force as compared to jute fibres when subjected to the same tensile force environment.

3.2 Composite Tensile Test

Both the composite's cut samples were tested for finding out their tensile strengths using a 100 kN universal tensile testing machine as per ASTM D3039. Four samples for both jute fibre composite (JFRC) and hemp fibre composite (HFRC) were tested as per ASTM standards.
Figure 5(a) shows the variation of tensile stress of hemp fibre composite (HFRC) with fiber weight fraction of 45%, it is clear that the average tensile strength of the composite is 28.41 MPa with an extension of 10.3 %. Figure 5(b) presents the stress variation with strain for jute fibre composite (JFRC). Average tensile strength is observed to be 19.9 MPa with an extension of 8.29%.

From results, it is clear that jute fibre reinforced composites have shown an improved tensile strength over flax reinforced composites.

3.3 Composite Flexural Testing

The test was conducted on both the composites specimens as per ASTM D790 standard. The test specimen was placed horizontally onto the three points of contact and then a force was applied on the top of the specimen through one point until the specimen fails.

Figure 6(a) shows the variation of flexural stress with strain for hemp reinforced bio-composite (HFRC). Three samples were tested and it is observed that maximum bending stress was found to be 53 MPa, with a maximum radius of curvature at 4.8%. The average bending stress is found to be 30.2 MPa and the average radius of curvature is 4.2%. Figure 6(b) presents the bending stress variation with strain for jute
fibre reinforced bio-composite (JFRC). It is observed that maximum bending strength is at 45.5 MPa with a strain % of 5.2. The average bending strength observed is 42.9 MPa and the average radius of curvature is found to be 4.9 %. From results, it is evident that jute fibre reinforced composites have shown better bending strength over hemp reinforced composites.

3.4 Composite Compression Test

Figure 7(a) shows the variation of compressive stress with strain for hemp reinforced bio-composite (HFRC). It is observed that the maximum compressive force was found to be 42.5 kN, with a crush percentage of 18. The average compressive strength is observed as 40 kN and the average percentage crushing strain of 17.7%. Figure 7(b) represents the variation of compressive stress with strain for jute reinforced bio-composite (JFRC). It is observed that the maximum compressive force was found to be 3.4 kN, with a crush percentage of 9.9%. The average compressive strength is observed as 2.6 kN and the average percentage crushing strain of 9.2%.

From results, it is evident that hemp fibre reinforced composites have shown better compressive strength over jute reinforced composites.

4. Conclusion

In this study, the natural fibre reinforced Bio-composites were tested to assess their suitability for possible applications for interior in aircraft and Automobiles. The composites were subjected to testings such as individual fibre tensile tests, composite tensile testing, flexural, and compression test. The following conclusions are drawn:

- Individual hemp fibre in raw form can sustain higher tensile force compared to jute fibre under the same operating force range.
- Hemp fibre composites have shown better tensile properties over jute fibre composites.
- The average flexural strength in hemp fibre-based bio-composites is found to be 30.2 MPa and the average radius of curvature is 4.2% as compared to the average bending strength as 42.9 MPa and the average radius of curvature to be 4.9 % in the case of jute fibre-based composites.
Hemp fibre composites have displayed higher compressive strength as compared to jute fibre composites.

The analysis presented in this research work would be helpful in further exploring the applicability of natural fibre composites with improved mechanical properties for possible use in Industrial, domestic and structural applications.

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