



# **Impact of Fibre Treatment on Mechanical Properties of Jute Fibre Reinforced Epoxy Matrix Composites**

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**ABSTRACT** Natural composites have gained significant attention as sustainable and eco-friendly alternatives to conventional synthetic fibre composites due to their biodegradability, low cost, and acceptable mechanical performance. However, the inherent hydrophilic nature of natural fibres leads to poor interfacial bonding with hydrophobic polymer matrices, which adversely affects the overall mechanical properties of the composite. Fibre treatment methods, such as alkali treatment, silane treatment, and acetylation, are widely used to improve fibre-matrix adhesion by modifying the surface characteristics of the fibres.

**KEYWORDS:** Natural fibre composites, fibre treatment, Mechanical properties

## **I. INTRODUCTION**

In recent years, the growing demand for sustainable and environmentally friendly materials has led to increased interest in natural fibre composites as alternatives to conventional synthetic fibre-reinforced materials. Natural fibres such as jute, hemp, sisal, and coir are renewable, biodegradable, lightweight, and cost-effective, making them attractive for applications in automotive, construction, and consumer goods industries. Despite these advantages, natural fibre composites face significant challenges, particularly related to their mechanical performance and durability.

One of the major limitations of natural fibres is their hydrophilic nature, which results in poor compatibility with hydrophobic polymer matrices such as epoxy, polyester, and polypropylene. This incompatibility leads to weak interfacial bonding between the fibre and matrix, causing inefficient stress transfer and reduced mechanical properties, including tensile strength, flexural strength, and impact resistance. Additionally, natural fibres tend to absorb moisture, which further degrades the composite's performance over time.

To overcome these issues, various fibre treatment methods have been developed to modify the surface properties of natural fibres and enhance fibre-matrix interaction. Chemical treatments such as alkali (NaOH) treatment, silane coupling, and acetylation are commonly used to remove impurities like lignin, hemicellulose, and waxes from the fibre surface. These treatments increase surface roughness, improve wettability, and reduce moisture absorption, thereby strengthening the interfacial adhesion between fibre and matrix.

The impact of fibre treatment on the mechanical properties of natural fibre composites has become an important area of research. Improved interfacial bonding leads to better load transfer efficiency, resulting in enhanced strength, stiffness, and impact resistance. Understanding the relationship between different treatment methods and composite performance is essential for optimizing material design and expanding the use of natural fibre composites in engineering applications.

This study focuses on analyzing how different fibre treatment techniques influence the mechanical behaviour of natural fibre composites and aims to identify the most effective methods for improving their performance and reliability.

## II. TREATMENT PROCEDURE FOR JUTE FIBRE

Jute fibre requires surface treatment to improve its compatibility with polymer matrices and enhance the mechanical properties of the resulting composite. The most commonly used method is alkali (NaOH) treatment, also known as mercerization. Other treatments such as silane and acetylation may also be applied.

### 1. Alkali (NaOH) Treatment Procedure

Materials Required:

- Raw jute fibres
- Sodium hydroxide (NaOH)
- Distilled water
- Dilute acid (e.g., acetic acid) for neutralization

Steps:

#### 1. Cleaning of Fibre

The raw jute fibres are first cleaned to remove dust, dirt, and impurities using distilled water.

#### 2. Preparation of NaOH Solution

A sodium hydroxide solution (typically 5% concentration) is prepared.

#### 3. Soaking Process

The cleaned jute fibres are immersed in the NaOH solution for about 2–6 hours at room temperature.

#### 4. Chemical Reaction

The alkali treatment removes lignin, hemicellulose, wax, and oils from the fibre surface, increasing surface roughness and exposing cellulose.

#### 5. Washing

After soaking, fibres are thoroughly washed with distilled water to remove excess NaOH.

#### 6. Neutralization

Fibres are treated with dilute acetic acid to neutralize any remaining alkali.

#### 7. Drying

The fibres are dried at room temperature or in an oven (60–80°C) until moisture are completely removed.

## III. FABRICATION OF JUTE FIBRE COMPOSITE

### 3.1 HAND LAY-UP METHOD

The hand lay-up method is the simplest and most commonly used technique for manufacturing fibre-reinforced composites. In this process, fibres such as jute are manually placed in a mould, and liquid resin is applied layer by layer using a brush or roller. ( $V_{\text{fibre}} = 20\%$ ,  $V_{\text{epoxy}} = 80\%$ ) A release agent is first applied to the mould surface to prevent sticking. Then, a layer of fibre is placed, followed by the application of resin to ensure proper wetting. This process is repeated to build multiple layers until the desired thickness is achieved. Rollers are used to remove air bubbles and ensure uniform distribution of resin. After lay-up, the composite is allowed to cure at room temperature or under controlled heating. Once hardened, the final product is removed from the mould and finished as required. This method is widely used due to its low cost, simplicity, and suitability for large components, although it may have limitations such as uneven resin distribution and lower production speed.

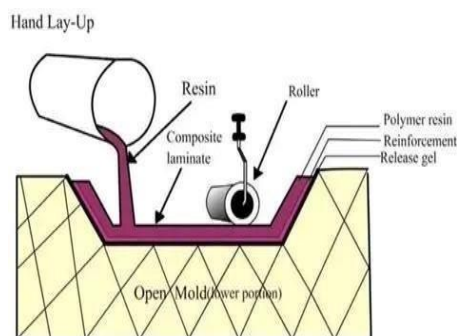


Figure 1 Hand Lay-up.



Figure 2 Fabrication using Hand Lay-up .

### 3.2 MECHANICAL TESTING

#### 3.2.1 Tensile testing

Tensile testing is a mechanical test used to determine the behaviour of a material when subjected to a uniaxial pulling force. In this test, a specimen is placed in a Universal Testing Machine (UTM) and pulled from both ends until it breaks.

The test measures important mechanical properties such as tensile strength, yield strength, elongation, and Young's modulus. As the load increases, the material undergoes deformation, and the corresponding stress-strain relationship is recorded. Tensile testing helps in evaluating the strength and ductility of materials, making it essential for analyzing the performance of composites like jute fibre-reinforced materials.



**Figure 3 Tensile testing**

#### 3.2.2 Flexural testing

Flexural testing is a mechanical test used to evaluate a material's ability to resist bending under load. It is commonly performed using a three-point or four-point bending setup in a Universal Testing Machine (UTM).

In this test, a specimen is placed on two supports and a load is applied at the centre (in three-point bending) until it bends or fractures. The test measures properties such as flexural strength, flexural modulus, and stiffness.

Flexural testing is especially important for composite materials like jute fibre composites, as it helps assess their performance under bending conditions commonly encountered in real-life applications.



**Fig.4 Flexural testing**

### 3.2.3 Water absorption test

The water absorption test is used to determine the amount of moisture a material can absorb when immersed in water over a specific period. This test is particularly important for natural fibre composites, as fibres like jute are hydrophilic in nature. In this test, a dry specimen is first weighed (initial weight), then immersed in water for a defined time (usually 24 hours or more). After removal, the specimen is wiped to remove surface water and weighed again (final weight). The increase in weight indicates the amount of water absorbed.

Water absorption is usually expressed as a percentage increase in weight, which helps evaluate the material's moisture resistance and durability.

## IV. RESULT AND DISCUSSION

### 4.1 TENSILE TEST ANALYSIS

Tensile test analysis of a jute fibre composite is carried out to determine its behaviour under axial pulling forces and to evaluate properties such as tensile strength, modulus, and elongation. The test is commonly performed according to **ASTM D3039**, where a prepared specimen is subjected to a uniaxial load until failure. Initially, the composite exhibits linear elastic behaviour, where stress increases proportionally with strain. As the load continues, the matrix begins to develop micro-cracks, and the load is effectively transferred to the jute fibres, which bear most of the stress. Failure occurs due to fibre breakage, matrix cracking, and fibre–matrix debonding. Jute fibre composites typically show moderate tensile strength and stiffness, with limited elongation compared to synthetic fibre composites. The tensile properties are significantly influenced by factors such as fibre alignment, fibre volume fraction, interfacial bonding, and moisture absorption. Overall, the tensile test analysis indicates that jute fibre composites are suitable for lightweight, eco-friendly applications where moderate strength and acceptable mechanical performance are required.

Properties	Specimen 1(Treated jute fibre)	Specimen 2 (Untreated jute fibre)
Ultimate tensile strength	50.52 N/mm <sup>2</sup>	20.41 N/mm <sup>2</sup>
Breaking load	3283.97 N	1735.35 N
Elongation at Break	3.75 %	2.40 %
Stiffness	8.6×10 <sup>4</sup> N/mm	7.5×10 <sup>4</sup> N/mm
Toughness	62.4 N mm	20.01 N mm

**Table.1 Tensile test**

### 4.2 FLEXURAL TEST ANALYSIS

Flexural test analysis of a jute fibre composite is performed to evaluate its behaviour under bending loads and to determine properties such as flexural strength and stiffness. In this test, a specimen is subjected to a three-point or four-point bending setup, typically following the standard **ASTM D7264**. Initially, the composite exhibits linear elastic behavior where stress increases proportionally with strain. As the load increases, micro-cracks begin to form in the matrix, and the load is transferred between the jute fibres and the surrounding resin. The final failure occurs due to a combination of fibre breakage, matrix cracking, and fibre–matrix debonding

Properties	Specimen 1(Treated jute fibre)	Specimen 2 (Untreated jute fibre)
Flexural strength	43.70 N/mm <sup>2</sup>	40.28 N/mm <sup>2</sup>

Breaking load	42.62 N	53.46 N
Flexural modulus	58.87 GPa	26.64 GPa
Stiffness	330.76 N/mm	237.7 N/mm
Toughness	2.77 N mm	5.98 N mm

**Table.2 Flexural test**

### 4.3 WATER ABSORPTION TEST

Water absorption test analysis of a jute fibre composite is conducted to evaluate its ability to absorb moisture and the effect of water on its properties. The test is commonly performed according to **ASTM D570**, where dry specimens are weighed and then immersed in water for a specified period. After immersion, the specimens are removed, surface-dried, and reweighed to calculate the percentage of water absorbed. Jute fibre composites typically show higher water absorption due to the hydrophilic nature of natural fibres, which contain cellulose that attracts moisture. The absorption process usually follows a gradual increase until it reaches saturation. As water enters the composite, it can cause swelling of fibres, weakening of the fibre–matrix interface, and micro-crack formation in the matrix. This results in a reduction in mechanical properties such as strength and stiffness. Factors like fibre content, surface treatment, matrix type, and fabrication method significantly influence the absorption behaviour. Overall, the analysis indicates that while jute fibre composites are eco-friendly and lightweight, their moisture sensitivity must be considered for applications exposed to humid or wet environments.

#### 4.3.1 Treated jute fibre result

$$W\% = \frac{W_2 - W_1}{W_1} \times 100$$

W1 = Initial weight before immersing in water = 6.0g

W2 = Final weight after immersing in water for 24 hours = 6.2g

$$W\% = \frac{6.2 - 6.0}{6.0} \times 100 = 3.33\%$$

#### 4.3.2 Untreated jute fibre result

$$W\% = \frac{W_2 - W_1}{W_1} \times 100$$

W1 = Initial weight before immersing in water = 5.8g

W2 = Final weight after immersing in water for 24 hours = 5.9g

$$W\% = \frac{5.9 - 5.8}{5.8} \times 100 = 1.72\%$$

Alkali treatment successfully removed hemicellulose, the water absorption of the treated composite 3.33 % was higher than the untreated baseline. This behaviour is consistent with the removal of the fibre's natural protective waxy layer and the fibrillation process. The increased surface area and microscopic surface roughness of the treated fibres, while optimal for mechanical interlocking with the epoxy matrix (evidenced by the significant strength gains), likely created microcapillary pathways that facilitated higher moisture uptake.

### V. CONCLUSION

The study on the impact of fibre treatment on the mechanical properties of natural fibre composites clearly demonstrates that fibre surface modification plays a crucial role in enhancing composite performance. Untreated natural fibres, due to their hydrophilic nature and presence of impurities such as lignin and hemicellulose, exhibit poor interfacial bonding with polymer matrices, resulting in lower mechanical strength.

With the application of treatments such as alkali (NaOH) significant improvements are observed in fibre-matrix adhesion. These treatments remove surface impurities, increase surface roughness, and reduce moisture absorption, leading to better stress transfer between fibre and matrix.

Experimental results from tensile and flexural tests indicate that treated fibre composites show higher tensile strength, improved flexural strength, and better stiffness compared to untreated composites. Additionally, treated fibres exhibit reduced water absorption, which enhances the durability and long-term performance of the material.

Overall, fibre treatment significantly improves the mechanical and physical properties of natural fibre composites, making them more suitable for engineering applications such as automotive components, construction materials, and lightweight structures. Therefore, proper selection and optimization of fibre treatment methods are essential for achieving high-performance and reliable composite materials.

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