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# Characterization of Kenaf Fiber Reinforced Composite with and Without Alkali Treatment

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ABSTRACT

In this study, we investigate the potential of natural fiber-reinforced composites (NFRC) as a sustainable alternative to synthetic fiber composites, leveraging their inherent benefits such as low density, high specific strength, recyclability, cost-effectiveness, and environmental friendliness. Our focus centers on utilizing kenaf plant bast fibers as the primary reinforcement, combined with epoxy resin, while maintaining a consistent weight ratio. The key objectives include fabricating and evaluating the mechanical properties of these composites, with a specific emphasis on the impact of fiber and alkali treatment and fiber orientations. Employing the hand layup technique and adhering to ASTM standards, our results demonstrate significant improvements in mechanical properties, with alkali treatment enhancing performance by approximately 12%. Additionally, a combined fiber orientation strategy leads to substantial advancements, increasing flexural and impact strength by 17% and 8%, respectively, while unidirectional fiber orientation proves optimal for maximizing tensile strength. This research highlights the potential applications of kenaf plant bast fiber-reinforced composites across various industries and offers valuable insights for further development and utilization of these sustainable and cost-effective materials.

Keywords- Natural Fiber Reinforced Composites (NFRC), Synthetic fiber composites, Low density, High specific strength, Recyclability, Cost-effectiveness, Eco-friendliness, Natural fiber, Kenaf plant bast fibers, Epoxy resin,, Fiber orientations, Alkali treatment, Hand layup technique, Mechanical properties, Tensile strength, Flexural strength, Impact strength.

# I. INTRODUCTION

In recent years, there has been a growing interest in the development of sustainable and environmentally friendly materials for various applications. Natural fiber reinforced composites (NFRCs) have emerged as a promising alternative to synthetic fiber reinforced composites due to their unique advantages, including low density, high specific strength, recyclability, cost-effectiveness, and eco-friendliness. Among the various natural fibers, kenaf fiber has garnered significant attention for its potential as a reinforcement material in composites.

However, despite the numerous advantages associated with NFRCs, there remain challenges and gaps in our understanding of their properties and behavior. One key area that warrants thorough investigation is the effect of alkali treatment on kenaf fiber reinforced composites. Alkali treatment, a chemical modification process, has the potential to enhance the fiber's properties and, consequently, the overall performance of the composite material. Yet, the extent of this improvement and the optimal conditions for alkali treatment in the context of kenaf fiber composites remain relatively unexplored.

This paper aims to address this critical gap in knowledge by conducting a comprehensive characterization of kenaf fiber reinforced composites both with and without alkali treatment. The primary motivation behind this research is to unlock the full potential of kenaf fiber as a reinforcement material and to provide valuable insights into the influence of alkali treatment on the mechanical and structural properties of these composites.
Key contributions of this project include:

- Characterization of Kenaf Fiber: A detailed analysis of the inherent properties of kenaf fiber to establish a baseline for comparison.
- Effect of Alkali Treatment: A systematic study to evaluate how alkali treatment impacts the mechanical characteristics and structural integrity of kenaf fiber reinforced composites.
- Optimization: Identification of optimal conditions for alkali treatment to maximize the performance of the composite material.
- Practical Applications: Insights that can inform the development of sustainable materials for a wide range of applications, including aerospace, automotive, medical, sports, defense, and more.

By shedding light on the benefits and challenges associated with kenaf fiber reinforced composites with and without alkali treatment, this research endeavors to contribute to the ongoing efforts to develop eco-friendly and high-performance materials for various industries.

The remainder of this paper is structured as follows: Section 2 delves into the literature review, Section 3 outlines the methodology employed in this study, Section 4 provides a detailed discussion of the results and analysis, and finally, Section 5 presents the concluding remarks of this paper.

# II. LITERATURE REVIEW

The literature review for the Paper encompasses previous research related to kenaf fiber reinforced composites, with a focus on the effects of alkali treatment and the mechanical properties of these composites. The reviewed studies provide insights into the current state of knowledge in this field:

Table 1. Summary of Literature Review

| Author | Year | Fiber type | Characteristic | Result | Remarks |
|---|---|---|---|---|---|
| I.S. Aji et al. | 2009 | Kenaf | Tensile strength | Directly proportional to the volume fraction of fibers | The study also found that the tensile strength of kenaf fiber composites is affected by climatic and growing conditions. |
| Dr. Rajappan et al. | 2015 | Natural fibers | Water absorption behavior | Gained weight and experienced a reduction in compression strength when submerged in water | The extent of strength reduction varied under different immersion conditions, including acidic environments. |
| W. H. Haniffah et al. | 2010 | Kenaf | Effect of immersion in tap water and bleach | Continuous immersion in bleach had a more significant adverse impact on tensile strength compared to cyclic immersion | Immersion in bleach also led to a degradation of tensile strength. |
| +Upendra Sharan Gupta et al. | 2021 | Natural fibers (including kenaf) | Orientation of fibers | Fibers oriented at $0^o$ and $90^o$ exhibited minimum stress in tensile and flexural tests, while $45^o$ orientation produced the best results in Brinell hardness tests | The study also found that the mechanical properties of natural fibers are affected by fiber length and wettability. |
| Reza Mahjoub et al. | 2014 | Unidirectional kenaf fiber epoxy composites | Fiber volume fraction | Increasing the fiber volume fraction led to higher tensile modulus and reduced ultimate tensile strain | The study also noted that the rule of mixture analytical model was effective in predicting physical and tensile properties. |
| M. A. Abu Bakar et al. | 2010 | Kenaf | Mechanical properties of kenaf fiber reinforced epoxy composites through alkali treatment | Significant improvements in flexural modulus and strength, as well as impact strength | The study also found that the alkali treatment process can be optimized to improve the mechanical properties of kenaf fiber composites. |

| | | | | | |
|---|---|---|---|---|---|
| Nurazzi, N.M. et al. | 2021 | Natural fibers | Use of natural fibers as alternatives to synthetic fibers | Layering and sequencing of natural fiber fabric in composites as a replacement for kevlar in defense equipment | The study also found that natural fiber composites can be used in other applications, such as automotive and aerospace. |
| Kin-tak Lau et al. | 2018 | Natural fibers | Stress transferability in composites and analytical models | Insights into the use of natural fibers in engineering applications | The study also provided recommendations for future research on the use of natural fibers in engineering applications. |

While the literature survey covers various aspects of kenaf fiber reinforced composites, there is a research gap related to the comprehensive exploration of the influence of fiber orientation on mechanical properties and the optimization of fiber chemical treatment and loadings to achieve desired composite characteristics. Further research is needed to bridge these gaps and advance our understanding of kenaf fiber composites.

The literature review also identified a number of studies that have investigated the optimization of fiber chemical treatment and loadings to achieve desired composite characteristics. However, these studies have also been limited in scope and have not fully explored the effects of different treatment methods and loadings on the mechanical properties of composites. For example, some studies have focused on the use of alkali treatment, while others have focused on the use of silane treatment. There is a need for more comprehensive studies that investigate the effects of different treatment methods and loadings on all of the mechanical properties of kenaf fiber composites.

Further research is needed to bridge the gaps identified in the literature review and advance our understanding of kenaf fiber composites. This research could focus on the following areas:

- Comprehensive exploration of the influence of fiber orientation on mechanical properties
- Optimization of fiber chemical treatment and loadings to achieve desired composite characteristics
- Development of new and improved kenaf fiber composites for specific applications

This research would help to improve the performance and applications of kenaf fiber composites and make them more competitive with synthetic fiber composites.

## III. Methodology

The methodology section of a research paper describes the methods and procedures used to collect and analyze data. It is important to be clear and concise in the methodology section, and to provide enough detail so that other researchers can replicate the study.

The following methodology was used in this study:

- Sample preparation: The samples were prepared using the hand layup technique. This technique is a manual process that does not require any
- machine technology. The fibers were first aligned in the desired orientation, and then the polymer resin and hardener were applied. The samples were then cured under controlled conditions.
- Testing: The samples were tested using three different tests: tensile, flexural, and Charpy impact test. The tensile test measures the strength

of the material when it is pulled apart. The flexural test measures the strength of the material when it is bent. The Charpy impact test measures the energy absorbed by the material when it is struck by a hammer.

- Data analysis: The data from the tests was analyzed using statistical methods. The results of the analysis were used to determine the effects of fiber pre-chemical treatment and orientation on the mechanical properties of the composites.

**Raw materials**

The raw materials used to produce natural fiber reinforced polymer (NFRP) are:

- *Natural fiber:* The natural fiber is the main material in NFRP. It should be long and strong, and it should be able to be oriented in the desired direction.
- *Alkali solution*: The alkali solution is used to clean the natural fiber. This helps to remove impurities and improve the bonding between the fiber and the polymer.
- *Polymer resin:* The polymer resin is the matrix material in NFRP. It is responsible for providing strength and stiffness to the composite.
- *Polymer hardener:* The polymer hardener is used to cure the polymer resin. This makes the composite strong and durable.

**Material Preparation**

To create the natural fiber-reinforced polymer samples, we employed kenaf fiber reinforced with epoxy resin. These fibers were of the long strand type. For the epoxy, we used Araldite LY550, along with HY 951 as the hardener. The primary focus of our experiment was on kenaf fiber, specifically the strand structure type.

Before proceeding with composite fabrication, we subjected the fibers to an alkali treatment. The primary goal of this treatment was to eliminate any residue or contaminants adhering to the fibers. We immersed the kenaf fibers in a 5% NaOH solution at room temperature for a duration of 4 hours. Subsequently, we thoroughly rinsed the fibers with water multiple times to remove any remaining alkali residue from the surface. After rinsing, we allowed the fibers to air dry for 24 hours at room temperature.

For the epoxy resin, we followed a mixing ratio of 10 parts resin to 1 part hardener. Initially, we mixed the resin with the hardener, employing a water bath technique during the stirring process to minimize the formation of bubbles.

Considering the weight fraction of the fiber, we maintained a ratio of 60:40 for epoxy to fiber. We oriented the fibers within the mold container before pouring the resin onto the fibers. The entire process of casting composites is visually depicted in Figure 1, employing the Hand Layup Technique.

This meticulous material preparation ensured the quality and effectiveness of our natural fiber-reinforced polymer samples, optimizing their tensile strength, flexural modulus, and flexural strength.

The hand layup technique is a manual process for fabricating composites. It is a relatively simple technique that does not require any machine technology. The technique involves the following steps:

1. The fiber is laid out in the desired orientation.
2. The polymer is applied to the fiber.
3. The sample is cured in a mold.

The mathematical notation for the hand layup technique can be represented as follows:

Let:

* $F = fiber$
* $P = polymer$
* $M = mold$

The hand layup technique can be represented by the following steps:

1. $F$ is laid out in the desired orientation.
2. $P$ is applied to $F$.
3. The sample is cured in $M$.

The hand layup technique can be used to fabricate composites with a variety of fiber and polymer combinations. The technique is relatively inexpensive and easy to learn, making it a popular choice for researchers and hobbyists. The figure1 shows the hand layup technique being used to fabricate a composite panel. The fiber is being laid out in the desired orientation, and the polymer is being applied to the fiber. The panel will then be cured in a mold.

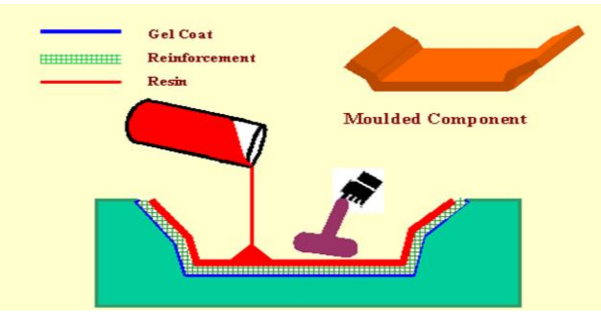


Fig 1. hand layup technique.

## IV. Result and Analysis

The objective of this research study was to investigate the mechanical properties of natural fiber-reinforced composite materials, in pursuit of this goal, a series of comprehensive tests were conducted to assess the tensile, flexural, and impact strengths of the composite specimens. These tests were designed to elucidate the influence of natural fiber reinforcement on the material's performance under different loading conditions. The results of these tests offer critical insights into the feasibility and potential applications of these sustainable and eco-friendly composite materials.

The tensile, flexural, and impact tests are carried out by following the steps:

1. Sample preparations
2. Specimen mounting
3. Zeroing and calibration
4. Gripping the specimen
5. Establish test parameters
6. Apply force
7. Data collection
8. Calculate and plot the graph
9. Analysis and interpretation.

**Tensile test:**

Tensile strength, one of the fundamental mechanical properties, was evaluated to understand how well the composite resists being pulled apart. During this test, specimens were subjected to axial tension until they fractured. The resulting data provides crucial information about the material's ability to withstand stretching forces and deformation under load.

By following all the steps mentioned above. the data was collected and calculated the tensile strength and modulus of elasticity of the specimen by using the following mathematical relations

Max. Tensile strength = $W \div A$

Where, W – Maximum tensile load at peak in N

A – Cross section Area in mm^2 = 20×8 =160 mm^2

Elastic modulus E= stress ÷ strain in (N/mm^2)

Stress= Maximum tensile load at peak ÷ Cross section Area (N/mm^2)

Strain= elongation in length at peak ÷ original length.

By Using these relations, we got the objected results and observed that the composite structure made of kenaf fibers which chemically treated in aqueous solution of 5% NaOH concentrations offering better tensile properties compared to composite structures made of untreated kenaf fibers.

The Tensile strength is calculated and mentioned in the below table 2.

Table no: 2 Tensile strength of the specimen

| Sample no: | Orientation (in degrees) | Tensile strength N/mm^2 (untreated) | Tensile strength N/mm^2 (5% NaOH treated) |
|---|---|---|---|
| 1 | 0° | 11.02 | 12.26 |
| 2 | 45° | 25.08 | 25.47 |
| 3 | 90° | 18.22 | 20.41 |
| 4 | 0°-90°-0° | 16.36 | 18.47 |
| 5 | 0°-45°-0° | 14.12 | 15.77 |
| 6 | 0°-45°-90° | 15.76 | 17.69 |

The results indicate that the 5% NaOH treatment positively influenced tensile properties, and the 45° fiber orientation demonstrated the highest tensile strength and stiffness. The elastic modulus of the specimen was calculated and the results are plotted on the graph mentioned below which notifying that this specimen have slightly higher elastic modulus than the composites which generally has in the range of 2.1 to 2.4 GPa.

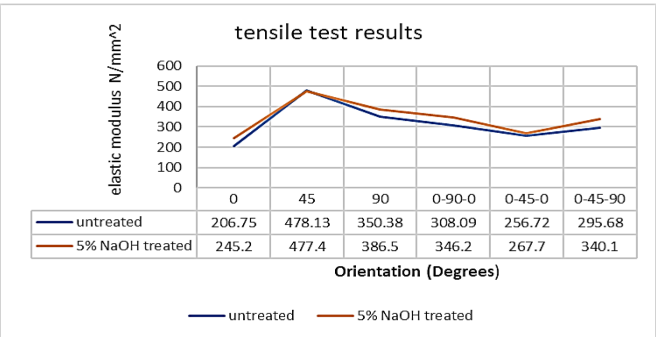


Fig 2. Tensile test result for elastic modulus.

**Flexural test results**

The flexural strength of the composite material was assessed using a three-point bend test. This test measures the material's resistance to bending or flexing under a load applied perpendicular to its longitudinal axis. It is essential for understanding how the material behaves when subjected to bending forces, making it particularly relevant for applications where the composite material is used as a structural component. Flexural strength was calculated from the below relations:

$$\text{Max Flexural strength} = \frac{3PL}{2bd^2} \text{ (N/mm^2)}$$

Where, P - Maximum load in N

L - Span of the specimen in mm

b-Width of specimen in mm

d-Thickness of the specimen in mm

the observations taken while testing flexural strength

Span length of the specimen L = 200 mm

Width of the specimen b= 20 mm

Thickness of the specimen d = 8 mm

The results obtained from the flexural test plotted on the graph:

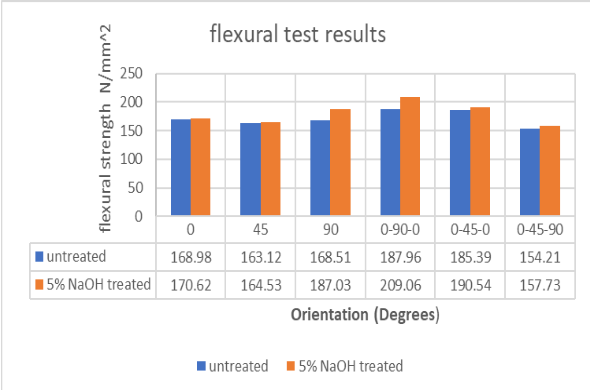


Fig 3. Flexural test results

The flexural strength of the 5% NaOH treated kenaf fiber composite samples is slightly higher than that of the untreated kenaf fiber composite samples. The orientation of the fibers seems to have an impact on flexural strength. For both untreated and treated composites, the highest flexural strength is observed in samples with the orientation of 0°-90°-0° degrees. The chemical treatment of kenaf fibers have a positive effect on flexural strength. This suggests that the chemical treatment might improve the bonding between the fibers and the epoxy matrix, leading to enhanced mechanical properties. Depending on the specific application.

**Impact test results**

Impact strength was evaluated using charpy impact test. This test assess the materials ability to absorb energy and resist fracture when subjected to a sudden impact. Understanding the impact resistance of the composite is vital for applications where it may be exposed to dynamic loads or potential impact events. Impact strength of the specimen is calculated by the formula

Impact Strength $= \frac{\text{Work done}}{(\text{Thickness} \times \text{Depth under notch})} * 1000$ (KJ/m2)

Impact Resistance $= \frac{\text{Work done}}{\text{Thickness}} * 1000$ (J/m)

Values taken from the observations while impact test

Specimen thickness = 8 mm

Specimen width = 10 mm

Depth under notch = 8 mm

Specimen length = 50 mm

The obtained results were plotted on the graph:

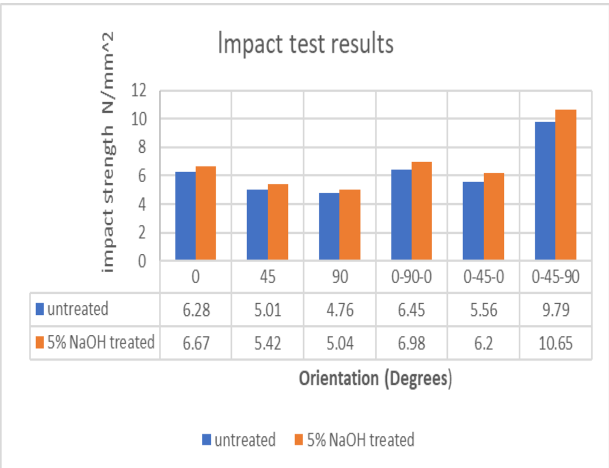


Fig 4. Impact test results

From the results it is observed that 5% NaOH treated samples generally show improved impact resistance compared to untreated samples. And combined fiber orientation laminates, such as 0°-45°-90° tend to exhibit the highest impact strength.

## V. CONCLUSION AND FUTURE SCOPE

In this study, the evaluation of kenaf fiber reinforced composite took into account the pre-chemical treatment of fibers and fiber orientation as key parameters affecting the mechanical properties of the composite. The following conclusions have been drawn:

Improved Mechanical Properties with Pre-Chemical Treatment: Kenaf fiber reinforced composite with pre-chemical treatment exhibited enhanced mechanical properties when compared to untreated fiber composite. This treatment has a positive impact on the composite's performance. The orientation of fibers in the composite plays a significant role. Combined orientations of fibers improved flexural and impact strengths, while unidirectional orientation yielded better tensile strength. The weight of the composite made with 5% NaOH solution treatment decreased compared to untreated fiber-reinforced composite. Treated samples showed higher tensile strength, with the maximum strength of 25.47 N/mm^2 observed at a 45° orientation. And Elastic modulus values got improved above the typical range of 2.1 to 2.4 GPa for general composites. The combined fiber orientation (0°-90°-0°) yielded the highest flexural strength for both untreated and treated composites due to the enhance bonding between fibers and the epoxy matrix. Similarly, Combined fiber orientation at (0°- 45°-90°) demonstrated the highest impact strength in both treated and untreated composites. Overall Chemical treatment not only enhances tensile, flexural, and impact properties but also improves toughness, making kenaf fiber composites more robust in applications involving sudden loads and impacts. The choice of fiber orientation allows customization for specific application requirements.

## VI. Future Scope

Looking ahead, there are several promising avenues for future research. Firstly, exploring various concentrations of pre-chemical treatments and investigating smaller angles of fiber orientation will help optimize load-bearing capacity in specific applications. Additionally, the incorporation of different types of fibers to create hybrid composites holds potential for further enhancing mechanical properties. Hybrid fillers can also be explored to tailor materials for specific applications. Quality optimization efforts, including refining fabrication processes, reducing void content, ensuring strong fiber-epoxy binding, and optimizing weight and volume percentages, will be crucial in achieving desired mechanical properties. Continued research and development in these areas will undoubtedly advance and expand the utilization of kenaf fiber-reinforced composites across various industries.

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