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# Mechanical Properties and Micro Structure of Kenaf-Hair Hybrid/Epoxy Composites.

**Siva R*[1], Gokul K[2], Vigneshwaran K[3], Mahamed Naveed Khan Patan[1] , and Purusothaman M[1].**

[1]Department of Mechanical Engineering, Sathyabama University
[2]Department of Mechanical Engineering, SRM University, Tamil Nadu, India.
[3]Department of Mechanical Engineering, Rajalakshmi Engineering College, Tamil Nadu, India.

**ABSTRACT**

Composite material plays an important role to replace the traditional material usages. Most of the current researchers moves towards green environment by focusing the natural materials as their base for research. In this experimental work, hybrid composite plate has been made by Kenaf and Human hair with proportions 5%, 10%, 15% and 20% Kenaf and 5%, 10%, 15% and 20% human hair in the 10%, 20%, 30% and 40% of volume fiber by hand layup method. Mechanical properties such as tensile strength, flexural test and impact strength were tested and analyzed for 10%, 20%, 30% and 40% volume fiber with 90%, 80%, 70% and 60% volume resin. The effect of varying the volume fraction of fiber in was studied and analyzed with scanning electron microscopy (SEM). The free vibration test has performed in this composited plate to find natural frequency. Theoretical natural frequency of composites plates are calculated and compared with experimental value.

**Keywords:** Hybrid composites, Hand layup method, scanning electron microscopy and Mechanical properties

***Corresponding author***

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## INTRODUCTION

Natural fiber is most commonly used fiber to fabricate composite. The natural fibers are very economic, easily available and biodegradable in nature. Kenaf fiber is one which made out from plant hibiscus cannabinus which is abundantly growing in Asian countries. Generally kenaf fibers found in the bast and core of the plant. Normally individual fiber cells are 2 to 6 mm long and 6.3 µm thick. In previous literatures the kenaf fiber has been investigated the mechanical properties and morphological characteristics were analyzed. The mechanical properties for the Jute and Kenaf fiber reinforced epoxy composites [3] had been fabricated by hand layup method and the results revealed the Kenaf fiber reinforced epoxy composite mechanical properties are higher than the Jute fiber reinforced epoxy composite [1]. The Woven Kenaf/Polymer composites [6] using Vacuum Infusion Technique with epoxy, unsaturated polyester and vinyl ester were investigated. The mechanical characteristics of the woven Kenaf/epoxy composite give better mechanical characteristics over others. The morphology Fractography studies of the fracture behavior of the epoxy composite resulted fiber - matrix adhesion were better in Woven Kenaf/Epoxy Composites. Banana/Kenaf Polyester Composites [7] were investigated by the fibers are treated with chemicals such as 10% of sodium hydroxide (NaOH) and 10% Sodium Lauryl Sulfate (SLS) for 30 minutes. The variation in the mechanical properties and morphological changes are studied and concluded that SLS treatment has provided better mechanical properties. Banana and Kenaf fiber reinforced hybrid composites [5] were analyzed and shown that banana and Kenaf fiber hybrid composites give better Mechanical properties value than the un-hybrid composites. Moreover hybrid composites gives better resistance to water absorption when compared to un-hybrid composites. Treated and untreated sugarcane fiber polyester composites were evaluated [4].Interfacial bonding between sugarcane fiber and polyester matrix enhanced by chemical treatments. Improvement in mechanical properties was found in NaOH treated sugarcane fiber composites than Hydrochloric acid (HCL) treated sugarcane fiber composites. Coir/epoxy composites [2] in which the coir used as a reinforcement material has been analyzed. The values for the tensile strength, flexural strength and impact strength values are comparatively lower than those for glass fiber epoxy laminate specimens. Scanning electron microscope is analyzed from the fractured surface of coir/epoxy and compared with glass fiber/epoxy. The different extraction methods such as mechanical, chemical, steam explosion and combination of both mechanical and chemical are discussed to extract the bamboo fiber [8] from the bamboo clum. The study showed that mechanical extraction is ecofriendly method whereas chemical extraction and steam explosion significantly affects the microstructures of fibers. The interfacial properties and tensile properties of flax/glass fiber reinforced hybrid polymer composite are evaluated [9]. The study show that improvement in tensile strength was achieved by the increase in glass fiber content. Kenaf fiber gives more advantages in mechanical properties when it make as a hybrid composite.Hybrid composite application are Automotive components like door panel and accessories like laptop case, cell phone case etc. These natural fibers are used for decking.

## MATERIAL AND METHODOLOGY

### Material

The raw materials Human Hair and Kenaf fiber, Epoxy LY556 and Hardener HY951 for this experimental work has been purchased from Indian Institute of Technology Madras. The Epoxy LY556 is mixed with Hardener HY951 is mixed in the ratio of 10:1. Kenaf is the most affordable natural fibers. They are primarily composed of plant materials, cellulose, lignin, ands pectin. It exhibit low density, better mechanical properties and biodegradable in nature. Kenaf fiber in yarn types, quantity of1Kg, Diameter 71.84 micrometer analyzed using SEM testare purchased from Chittoor, Andhra Pradesh, India are shown in figure1.

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**Figure 1: Kenaf fiber**

Human hair is used as a reinforcing material in fabricating composites plates. It has a high tensile strength equal to the strength of copper of similar diameter. The human hair purchased from parry's corner, Chennai, India in the size of 100 to 150 mm by length. Quantity – 1.5 Kg is shown in figure 2.

**Figure 2: Human Hair**

Epoxy is used as resin which forms a long chain molecular structure with reactive sites at either end. In the epoxy resin, the epoxy groups themselves form reactive sites. This gives epoxy a better water resistant property and low shrinkage during the curing process. Epoxy resins are specially manufactured by reacting Epichlorohydrin with Bisphenol. Different type of resins is formed by varying proportions. As the proportion of Epichlorohydrin is reduced the molecular weight of the resin is increased. The epoxy matrix and hardener are shown in figure 3 and figure 4.


**Figure 3: Epoxy LY556**

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**Figure 4: Hardener HY951**

The physical properties of epoxy matrix are tabulated in table 1.

**Table 1: Physical properties**

| Epoxy resin property | Value |
|---|---|
| Density g/cm$^3$ | 1.1-1.4 |
| Tensile strength Mpa | 35-100 |
| Compressive strength Mpa | 100-200 |
| Impact strength J/cm | 0.3 |

**Methodology**

Kenaf and human hair materials are used as a reinforcement material and Epoxy LY556 as a resin. The preparation of hybrid composites has been done by hand layup method. Different volume percentages of hybrid composite are fabricated. The mechanical properties like flexural, tensile and impact strength were calculated. Free vibration test is carried out on all samples and results were compared with theoretical natural frequency. A scanning electron microscope is a type of electron microscope that prepare images of a sample by scanning it with a focused beam of electrons. The main aim of the fractography examination is to determine the cause of failure by studying the characteristics of a fractured surface. SEM analysis has been carried on the fractured specimen to know the matrix and fiber interaction within the material. Kenaf fiber and human hair are incorporated with matrix Epoxy LY556 resin to fabricate composites plates of dimensions

**Figure 5: Resin in mould**

300mm*300mm*3mm by hand layup method which is shown in figure 5. Different composition of plates has been made which shown in table 2.

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**Table 2: Composition of composite plates**

| Composite Plate | Volume percentage | Composition of fiber |
|---|---|---|
| A | 10% volume fiber + 90% volume resin | 5% Kenaf + 5% human hair |
| B | 20% volume fiber + 80% volume resin | 10% Kenaf + 10% human hair |
| C | 30% volume fiber + 70% volume resin | 15% Kenaf + 15% human hair |
| D | 40% volume fiber + 60% volume resin | 20% Kenaf + 20% human hair |

Hand lay method is oldest method used for fabrication of composite materials. In this method resins and reinforcement are deposited in a mould by hand or hand tools. This is also referred as contact moulding as the resin is contact with air. Kenaf and human hair are chopped 30mm length and mixed up as shown in figure 6. The low temperature curing epoxy and

**Figure 6: Fiber mixing**

corresponding hardener are mixed in ratio of 10: 1 to make the resin. The fibre and resin were mixed in the proportions as mentioned in the table 2. Each composite is cured under a load of about 25 kg for 24 hours before it removed from mould. The mould preparation is shown in figure 7.

**Figure 7: Preparation of Mold**

## RESULTS AND DISCUSSION

### Tensile Strength

The tensile tests specimen were prepared according to ASTM D638 standard and tested in Universal Testing Machine. The dimensions of specimens are of length 165mm, width 13mm and 3mm thickness for composite plates A, B, C and D are shown in figure 8. The results shows that Composite plate specimens A, B, C, D has tensile strength of 7, 9.6, 12.6, 16.3 MPa. The tensile strength comparison has been shown in figure 9.The tensile strength of composite plate specimen D (which contains Kenaf 20% volume +Hair 20% volume) has better tensile value compare to other plates.

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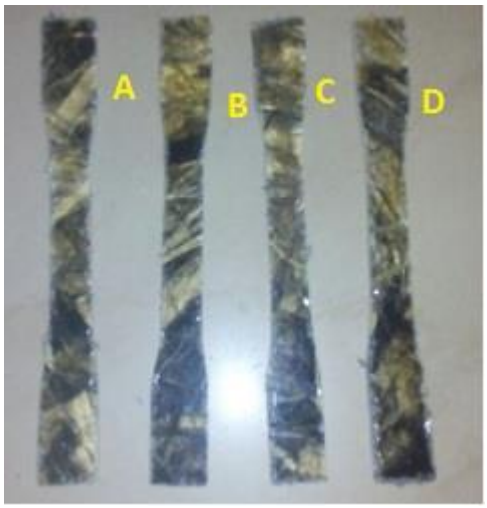


**Figure 8: Tensile specimen for Composite plates**

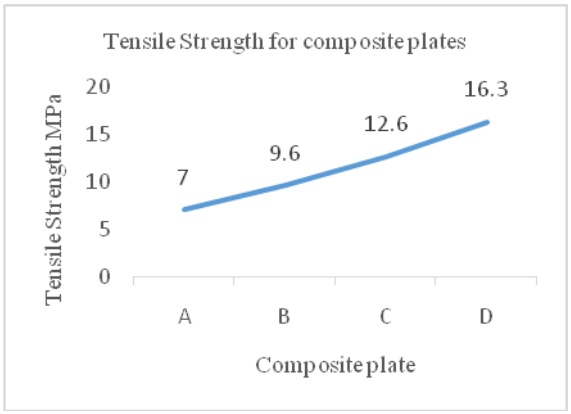


**Figure 9: Tensile strength for composite plate specimens**

**Flexural Strength**

The flexural test specimen were prepared according to ASTM D790 and tested in Universal Testing Machine using three point bending test. The specimens were prepared with dimensions of length 100mm, width 12.3mm and 3mm thickness for composite plate A, B, C and D are shown in figure 10.The results shows that Composite plate specimens A, B, C, D has flexural strength of 98.06, 123.6, 268.38, 291.62 N/mm$^2$. The tensile strength comparison has been shown in figure 11. The flexural strength of composite plate specimen D (which contains Kenaf 20% volume +Hair 20% volume) has better strength compare to other plates.

**Figure 10: Flexural specimen for composite plate specimens**

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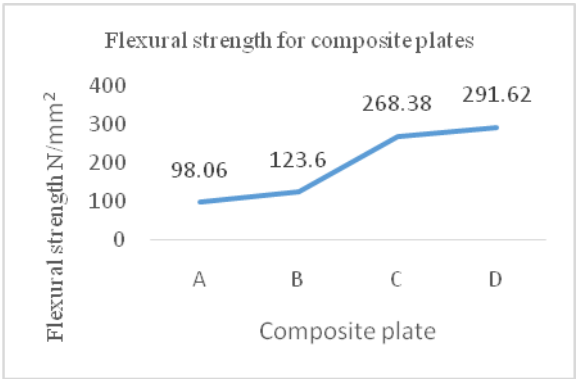


**Figure 11: Flexural strength for composite plate specimens**

**Impact Strength**

The impact test specimen were prepared according to ASTM D256 standard and tested in izod impact machine. Izod Impact machine has Arm length 150 mm, Dead weight 5 Kg and Range 0-14 joules.The specimens were prepared with dimensions of length 65.5mm, width 12.7mm and 3mm thickness for composite plate A, B, C and D are shown in figure 12. The results shows that Composite plate specimens A, B, C, D has impact strength of 2.56, 6.41, 14.1 and 17.94 J/mm$^2$. The impact strength comparison has been shown in figure 13. The impact energy of composite plate D (which contains Kenaf 20% volume +Hair 20% volume) has maximum strength compare to other plates.

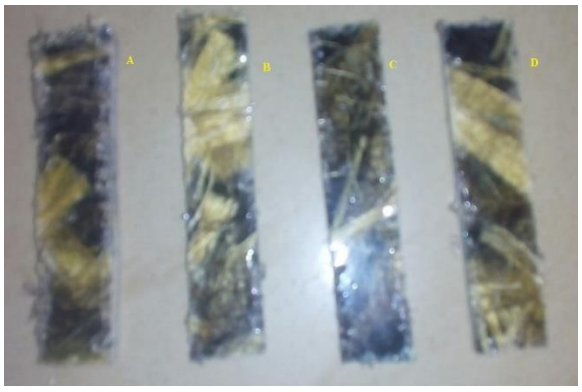

**Figure 12: Impact specimen for composite plate specimens**

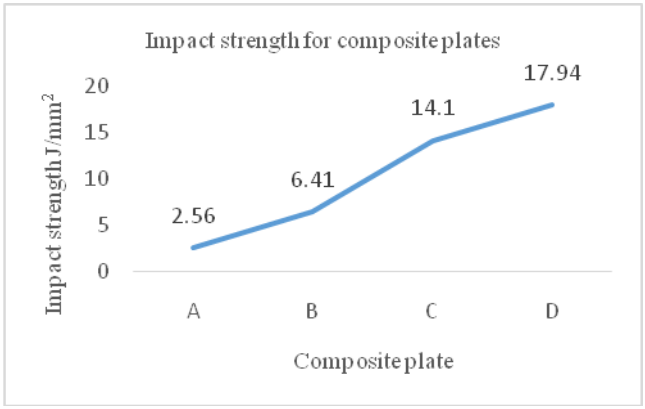


**Figure 13: Impact strength for composite plate specimens**

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**Free Vibration Analysis**

Free vibration analysis used to determine the natural frequency of various beams (with distinct material, mass and length) that are freely vibrated. Using accelerometer and data acquisition software the experimental frequency are calculated and compare with theoretical values, the damping coefficient on the beam under cantilever support condition is determine using logarithmic decrement method. The experimental set up used for free vibration test as shown in figure 14.The composite plate specimens A, B, C and D are tested using free vibration testing machine. The theoretical values are obtained using Euler-Bernoulli beam theory. The theoretical frequency for composite plate specimens A, B, C and D are 36.84, 51.15, 56.06 and 72.98 Hz. The Experimental frequency for composite plate specimens A, B, C and D are 34.18, 48.83, 54 and 69 Hz. The Logarithmic decrement for composite plate specimens A, B, C and D are 0.0961, 0.1059, 0.196 and 0.321. The Damping ratio for composite plate specimens A, B, C and D are 0.0152, 0.0167, 0.0311 and 0.0510. The comparison of theoretical and experimental frequencies are shown in figure 15.

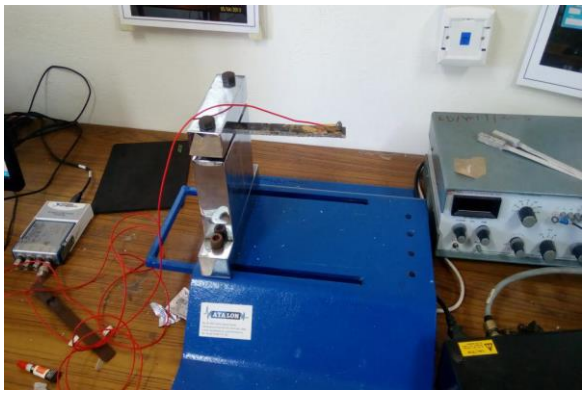

**Figure 14: Free vibration testing machine**

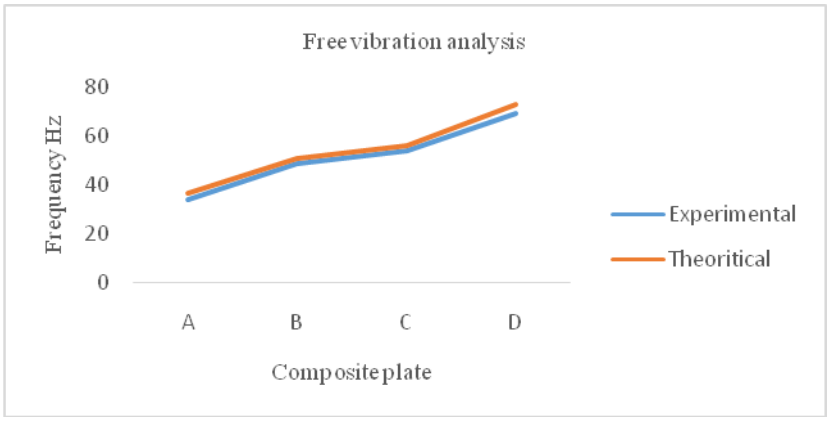


**Figure 15: Free vibration analysis for composite plates**

**SEM Analysis**

Mechanical properties were calculated for all composites A, B, C and D. There is a difference in volume percentage of fiber. The result shows that increase in fiber content increases the mechanical properties. The value of mechanical properties such as (tensile strength, flexural strength and impact strength) is very higher in composites plate D and lower value in composites plate A. So, SEM analysis is carried out on tensile specimen on fractured surface of specimen A and D and not for B and C. The SEM images of the composite plate A and D after fracture are shown in figure 16 and figure17. The composite specimens A has more fiber pull out and matrix crack. Composite specimens D has better fiber matrix addiction and evenly distributed compare to composite plate A.

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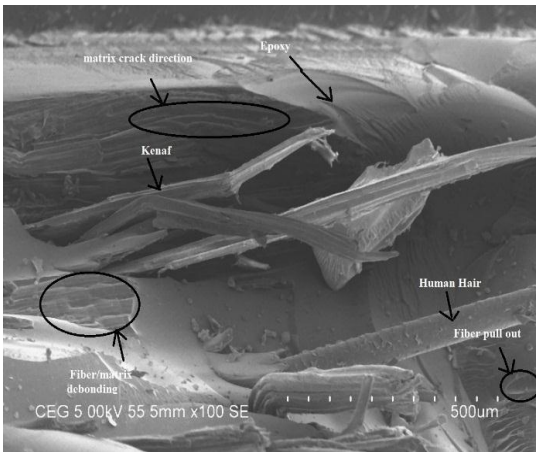


**Figure 16: SEM image of composite plate A**


**Figure 17: SEM image of composite plate D**

## CONCLUSION

Mechanical properties such as tensile, strength, flexural test, impact strength, free vibration test and SEM analysis for Composite plate specimens A, B, C and D were tested and analyzed. The result shows

1. Increase in fiber content percentage
2. improving the values of mechanical properties.
3. The maximum value of tensile strength, flexural strength and impact strength are 16.3 MPa, 291.62 $N/mm^2$and 17.94 $J/mm^2$, which is identified in Composite plate D (20% Kenaf; 20% Human Hair).
4. Theoretical natural frequency of composite plates are calculated and compared with experimental value. The percentage of variation between experimental and theoretical frequency was less than 8%.
5. Theoretical vibration result shows that the increase in tensile modulus increases the natural frequency of the composite plate.
6. The maximum value of natural frequency are 72.98 Hz which is identified in plate D (20% Kenaf, 20% Human Hair).

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