

Experimental Testing on Mechanical Properties of Various Natural Fibers Reinforced Epoxy Hybrid Composites

S. Sathish^{1*}, K. Kumaresan², L. Prabhu¹, S. Gokulkumar¹, S. Dinesh³ and N. Karthi¹

¹Department of Mechanical Engineering, KPR Institute of Engineering and Technology, Coimbatore – 641407, Tamil Nadu, India; Sathi175@gmail.com, loguprabhucim@gmail.com, gokulkumarmeprof@gmail.com, karthimli@gmail.com

²Park College of Engineering and Technology, Coimbatore – 641659, Tamil Nadu, India; mech_hod@pcet.edu.in

³SRM University, Chennai – 600089, Tamil Nadu, India; s.dineshmech@gmail.com

Abstract

Objectives: The purpose of this study was to investigate the mechanical and morphological characteristics of various bio fibers reinforced epoxy hybrid composites. Various bio fibers such as snake grass, hemp, banana, bamboo, sansevieria, ramie, sisal, jute, flax, pineapple and kenaf fibers are used as reinforcements in polymer composites and appear more attractive due to their bio degradability, low density, recyclability, easily availability and less CO₂ emission. **Methods:** The hybrid composites reinforced with flax, kenaf, pineapple and sisal fibers were fabricated using a compression molding technique with weight ratio of fiber to resin as 40 : 60 and tested for mechanical properties such as tensile, flexural and impact strength. **Findings:** Among the different hybrid composites, flax/kenaf/epoxy composite produced better tensile, impact and flexural strength. SEM analysis of the fracture surface indicated that flax/kenaf/epoxy was produced without creating porosity which showed homogeneous distribution of fibers and matrix with better bonding which play an important role in improving the mechanical properties of composites.

Keywords: Epoxy, Flax, Kenaf, Pineapple, Sisal

1. Introduction

In recent years, Bio Fiber Reinforced Composites (BFRC) are used in many sectors due to various attractive properties that they offer such as light weight, biodegradability, renewability, low cost and corrosion resistance. BFRC are used in many industries such as automotive, aerospace, sporting equipment, marine, electrical, construction and household appliances¹⁻³. Kenaf, sisal, coir, banana, jute flax, pulp, wood flour, oil palm, pineapple leaf and coir are the main natural fibers used as reinforcements. Kenaf fibers provide high stiffness and strength values. They also have higher aspect ratios making them suitable to be used as reinforcement in polymer matrix

composites. Pineapple Leaf Fiber served as reinforcement in most of the polymer matrix has shown its significant role as it is cheap, exhibiting better properties when compared to other natural fiber. PALF is a lignocellulosic fiber extracted from the leaves of plant *Ananas comosus* belonging to the Bromeliaceae family by retting (separation of fabric bundles from the cortex). PALF has a ribbon-like structure and is cemented together by lignin material, which contributes the strength to the composites. In recent years, there is a growing interest in the use of bio fibers as reinforcing components for thermoplastics and thermoset. Sisal fiber, a member of the Agavaceae family is a natural and biodegradable crop. Moreover, sisal fiber is a stable, strong and versatile material and it

*Author for correspondence

has been recognized as important resources for polymer composites. One of the best-known natural fibers is kenaf fiber, which is used for a variety of applications. Kenaf (*Hibiscus cannabinus* L.) is a high-yielding cordage crop traditionally grown for the production of twine and rope. Newer application for kenaf fibers includes paper products and building materials. The main drawbacks of Bio Fiber Reinforced Composites are their water absorption, poor dimensional stability, poor adhesion with matrix, and poor processability at high fiber contents. Chemical treatment of the natural fiber can help to overcome such drawbacks to improve the interfacial between fiber and the matrices, resulting in improved properties of fiber-reinforced composites. Various chemical treatment methods such as alkaline treatment, silane treatment, benzoylation treatment, permanganate treatment and peroxide treatment have been applied on the various natural fibers to improve their properties and the fiber-matrix interface by converting them from hydrophilic nature into hydrophobic nature⁴. Alkaline treatment is used to improve interfacial strength between fiber and matrix and dynamic flexural modulus of the composites⁵. The scope of this present project work is to investigate the effect of various bio fibers on mechanical and morphological properties of epoxy hybrid composites.

2. Materials and Methods

2.1 Sisal Fiber

Sisal fibers are stiff fibers extracted from an agave plant. These fibers are straight, smooth and yellow in color. Strength, durability and ability to stretch are some important properties of sisal fibers. It was collected from M/s Tokyo Engineering Corporation, Coimbatore.

2.2 Pineapple Fiber

Pineapple Leaf Fiber (PALF) is one such fiber source known from a long time obtained from the leaves of pineapple plant from the family of Bromeliaceae. It was obtained from local supplier.

2.3 Flax Fiber

Flax fibers come from the flax plant; one species of *Linum usitatissimum* breed and is widely cultivated in West Europe where the daily temperature is generally below

30°C. The diameter of the flax stem is in the range of 1–2 mm, with a height of about 80 cm. It was obtained from TMG Textiles and Garments, Coimbatore.

2.4 Kenaf Fiber

Kenaf (*Hibiscus cannabinus* L.) is a traditional, third world crop after wood and bamboo that is poised to be introduced as a new annually renewable source of industrial purpose in the so called developed economies. Kenaf is a warm-season annual fiber crop growing in temperate and tropical areas. It is related to cotton, okra and hibiscus due to systematic. It is a fibrous plant, consisting of an inner core fiber (75–60 %), which produces low quality pulp and an outer bast fiber (25–40 %), which produces high quality pulp, in the stem. It was obtained from local dealers.

2.5 Matrix and Hardener

Epoxy resin (LY556) is used as a matrix which was purchased from M/s Covaiseenu and Company, Coimbatore. HY 951 is used as curing agent who was obtained from M/s Covaiseenu and Company, Coimbatore. In the present investigation, 10% by weight has been used in all material developed⁶.

2.6 Chemical Treatment

Interaction between fiber and matrix plays a vital role in finding the mechanical characteristics of the composites. Since applied stress is transferred between matrix and fibers across the interface, good interfacial bonding is required to obtain optimum reinforcement although, it is possible to have an interface that is too strong, enabling crack propagation which can reduce toughness and strength⁷. However, for Bio Fiber Reinforced Composites there is usually limited interaction between the hydrophilic fibres and hydrophobic matrices which leading to poor interfacial bonding limiting mechanical performance as well as low moisture resistance affecting long term properties. For bonding to occur, fiber and matrix must be brought into intimate contact; wettability can be regarded as an essential precursor to bonding. Insufficient fiber wetting results in interfacial defects which can act as stress concentrators. Fiber wettability has been shown to affect the tensile and flexural strength of composites. Chemical treatment can enhance the wettability of the fiber and thus improve the adhe-

sion strength. Interfacial bonding can occur by means of mechanisms of molecular interlocking, electrostatic bonding, chemical bonding and inter-diffusion bonding. Mechanical interlocking occurs to a greater extent when the fiber surface is rough and increases the interfacial shear strength.

For that, alkaline treatment using sodium hydroxide (NaOH) is the most commonly used chemical treatment for bleaching and cleaning the surface of bio fibers to produce high-quality fibers. 5% sodium hydroxide solution was prepared using NaOH pellets and distilled water. Pineapple, sisal, flax and kenaf fibers were then dipped in the solution for 3 hours separately. Solution preparation and fibers immersed in solution are shown in Figures 1-2 respectively. Then it was washed with flow water. Then it was kept in hot air oven for 4 hours at 60°C⁸. Fibers kept in hot air oven are shown in Figure 3.



Figure 1. Chemical preparation.



Figure 2. Fibers immersed in solution.



Figure 3. Fibers placed in hot air oven.

2.7 Preparation of Composites

Fiber orientation and volume fraction are the two important factors that influence the properties of the composite. In this research, all the bio fibers are used in the form of long fibers and epoxy resin used in the form of continuous phase to the weight fraction of 40% and 60% respectively to prepare the composites. The epoxy resin LY556 and the corresponding hardener (HY951) were mixed in a ratio of 10:1 by weight as recommended. The mixing was done thoroughly before the mixture filled into the mould and pressed in a hydraulic press at the temperature of 130°C for 45 minutes and a pressure of 35 kg/cm² for 45 minutes is applied before it is removed from the mould. Then, this sample is post cured at standard atmosphere for some period of time to study the effect of post curing time on mechanical properties⁹. Fibers stacking arrangement is shown in Figure 4.



Figure 4. Fibers stacking.

3. Mechanical Tests

3.1 Tensile Test

The tensile test samples were prepared as per ASTM D3039 standard. The dimensions, gauge length and cross-head speeds were chosen as per ASTM D3039 standard¹⁰. A tensile test involves mounting the sample in a clamp and subjecting it to the tension. The testing process involves placing the test samples in the testing machine and applying tension to until it fractures.

3.2 Impact Test

Impact property of a composite is the measure of the total energy dissipated in the material before its final failure occurs under shock loading. The impact test samples are cut from respective composites according to the ASTM A370 standard and the test carried out in the izod impact testing machine.

3.3 Flexural Test

The flexural samples were prepared according to the ASTM D790 standard. The 3-point flexure test is the most common flexural test for composite materials. Specimen deflection is measured by the crosshead position. The testing process involves placing the sample in the Universal Testing Machine (UTM) and applying force to it until it fractures.

4. Results and Discussion

The hybrid composite samples are tested in their corresponding digitalized machines and the tensile, flexural and impact properties are determined. The strength of composite samples generated with respect to various natural fibers to be reinforced in present below. The results indicated that flax/kenaf/epoxy hybrid composite exhibited better mechanical properties and maximum values observed are 28.36 MPa as tensile strength, 94.42 MPa as flexural strength and 3.15 joules as impact strength. It was clear that tensile strength of the hybrid composite increased with 20% v_f of flax combined with 20% v_f of kenaf fiber. Tensile modulus also enhanced with increasing flax fiber in the composites. This is because the tensile strength and young's modulus of flax and kenaf are much higher than the other fibers.

Table 1 shows the value of tensile strength of pineapple/sisal/epoxy, kenaf/sisal/epoxy, pineapple/kenaf/epoxy, flax/pineapple/epoxy and flax/kenaf/epoxy hybrid com-

posites. From the obtained results, the flax/kenaf/epoxy composite exhibits maximum tensile strength compared to other hybrid composites due to presence of other natural fibers which having poor adhesive strength and high formation of void content during compression. However, to obtain the polymer composites with better mechanical properties, the interaction between fiber and matrix need to be improved. The flax/kenaf/epoxy composite showed an increase in the tensile modulus and strength with addition of 20% v_f of kenaf fiber with flax fibers and there was a decrease in the tensile properties with addition of other fibers like sisal and pineapple to flax fibers.

Table 1. Tensile test values

S.No	Types of Hybrid Composite	Ultimate Tensile Load (N)	Tensile Strength (MPa)	Elongation at Break (%)
1	Pineapple/sisal/epoxy	2356.42	18.84	2.54
2	Kenaf/sisal/epoxy	3104.75	20.64	1.44
3	Pineapple/kenaf/epoxy	2444.65	19.53	1.20
4	Flax/pineapple/epoxy	3188.25	24.82	2.57
5	Flax/kenaf/epoxy	3547.45	28.36	1.42

Table 2 shows the comparison of impact strength of pineapple/sisal/epoxy, kenaf/sisal/epoxy, pineapple/kenaf/epoxyflax/pineapple/epoxy and flax/kenaf/epoxy hybrid composites. From the result, it can be observed that flax/kenaf/epoxy composite exhibits maximum impact strength compared to other hybrid composite which can hold impact load of 3.15 joules. It is clearly observed that when the kenaf fiber was added to the flax fiber, impact strength significantly increased comparing to other combinations.

Table 2. Impact test values

S.No	Types of Hybrid Composite	Impact strength (J)
1	Pineapple/sisal/epoxy	1.85
2	Kenaf/sisal/epoxy	1.90
3	Pineapple/kenaf/epoxy	2.15
4	Flax/pineapple/epoxy	2.75
5	Flax/kenaf/epoxy	3.15

Table 3 shows the value of flexural strength of various hybrid composites. From the obtained result, flax/kenaf/epoxy hybrid composite gives maximum flexural strength (94.42 MPa) compared to other two hybrid composites. It has been noted that, the flexural strength increases with the increase of flexural load then it tends to break. With the high flexural strength and flexural modulus for the flax composite with 20% volume fraction of kenaf fiber and the reduction in the flexural properties with the pineapple and sisal fibers. From the experimentation, it could be concluded that combinations of 20% volume fraction of flax and 20% volume fraction of kenaf is the higher limit for fiber load for the flax composites when considering the flexural properties.

Table 3. Flexural test values

S.No	Types of Hybrid Composite	Flexural Load (N)	Flexural Strength (MPa)
1	Pineapple/sisal/epoxy	184.57	59.60
2	Kenaf/sisal/epoxy	249.83	90.09
3	Pineapple/kenaf/epoxy	238.38	88.05
4	Flax/pineapple/epoxy	140.13	36.77
5	Flax/kenaf/epoxy	272.62	94.42

The five different hybrid composites of samples are tested their tensile, impact and flexural strength from respective machines. Impact test carried out in izod impact testing machine and both tensile and flexural testing were carried out in Universal Testing Machine (UTM). Figure 5 shows tested specimens of five different hybrid composites.



Figure 5. Tested specimens.

4.1 SEM Analysis

For morphological study, the scanning electron microscope was used to reveal fractured surface of composites which together bonded between the fiber and matrix. In this work, scanning electron microscope was used to study the measure of adhesiveness and interaction between natural fibers and epoxy resin. For pineapple/sisal composites, there was hindrance of fibers which tried to hold up uniform resin by applied load and which shows less surface roughness of fiber tends to weaken the bonding strength and fiber pull out. This was identified by air bubbles formation over the sample surface. For kenaf/sisal, the reinforcement was not distributed evenly over the matrix due to bunch of sisal fiber can be observed. This micrograph has highest percentage of void content by fiber pull out. As for flax/kenaf, both alkali treated fibers were aligned perfectly with epoxy resin. Due to poor surface roughness of fibers, aspect ratio were increased which causes better adhesion between fiber and resin. Figures 6(a) and 6(b) shows scanning electron micrograph of flexural fractured.

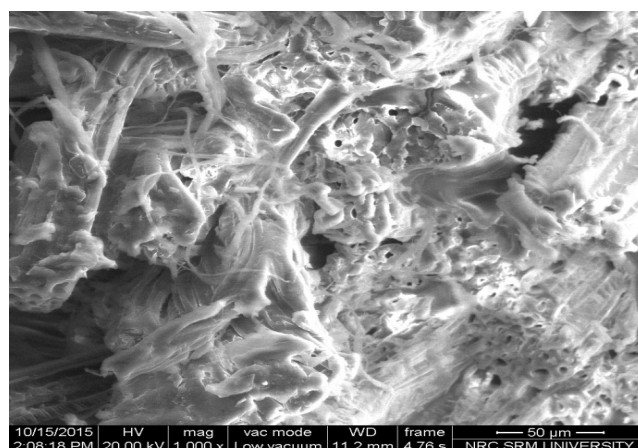


Figure 6 (a). SEM micrograph of flax/kenaf/epoxy hybrid composite.

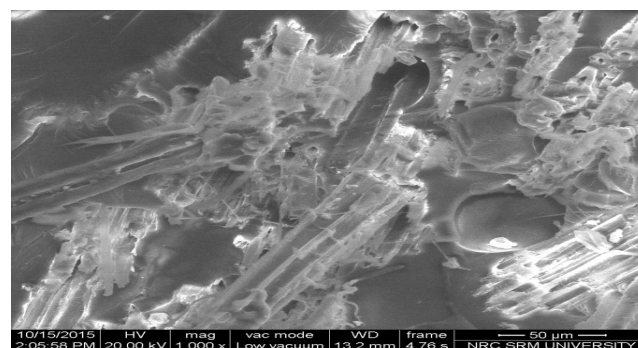


Figure 6 (b). SEM micrograph of pineapple/sisal/epoxy hybrid composite.

5. Conclusion

Based on the study of mechanical properties of five different natural Fiber Reinforced Hybrid Composites, the following conclusions can be drawn:

- In this work, the mechanical properties such as tensile strength, impact strength and flexural strength were analyzed and compared.
- The tensile strength of the flax/kenaf/epoxy hybrid composite is increased by 50.53%, 37.40%, 45.21% and 14.26% compared to pineapple/sisal/epoxy, kenaf/sisal/epoxy and pineapple/kenaf/epoxy and flax/pineapple/epoxy hybrid composites respectively.
- The impact strength of the flax/kenaf/epoxy hybrid composite is increased by 70.27%, 65.78%, 46.51% and 14.54% compared to pineapple/sisal/epoxy, kenaf/sisal/epoxy and pineapple/kenaf/epoxy and flax/pineapple/epoxy hybrid composites respectively.
- The flexural strength of the flax/kenaf/epoxy hybrid composite is increased by 58.42%, 4.80%, 7.23% and 156.7% compared to pineapple/sisal/epoxy, kenaf/sisal/epoxy and pineapple/kenaf/epoxy and flax/pineapple/epoxy hybrid composites respectively.
- From the SEM micrograph of flexural fracture surface samples, flax/kenaf/epoxy hybrid composite excellent bonding to epoxy resin than other hybrid composites.

6. References

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