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CHARACTERIZATION OF REINFORCEMENT BANANA FIBER IN EPOXY COMPOSITES

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Abstract:

The present and future sights of commercial material are focusing on composite material due to its lightweight, low thermal expansion, and versatility. At the same time, the composite must be eco-friendly, so that it degrades easily. Green fibers are emerging as low cost and have a less environmental impact on their production due to its biodegradable characteristics. This thesis aims to produce Green composite material, where both fiber and matrix are from the natural source. Synthetic resin as matrix and banana fibers are used and its characteristics are studied. Also, to evaluate the effect of chemical modification on mechanical properties of banana fiber epoxy composites. Chemically treatment-induced such modification where fibers were immersed in 6% NaOH aqueous solution (w/v) for 2 hours at room temperature (1:15 fiber-to-solution weight ratio). The treated fiber was then washed thoroughly with distilled water to remove excess NaOH from the surface and oven-dried at 110 ^{0}C. To study the mechanical properties of the composite, different volume fractions of fiber have been taken. These fibers were randomly distributed in the matrix. Usually, hand lay-up technique has been adopted for manufacturing the composites.

Keywords: Fiber-reinforced composites, natural fiber, chemical treatments, NaOH, epoxy resin, and hardener.

1. INTRODUCTION

Natural fibers are renewable and obtained from natural resources that present several advantages, including low density, acceptable specific strength properties, good sound abatement capability, low abrasive, low cost, high biodegradability, and the existence of vast resources. Besides, at the end of their life cycle, these can be incinerated for energy recovery because they have a good calorific value. Numerous researchers have exploited the reinforcement potential of kenaf, flax, hemp, and jute for developing thermoplastic and thermoset composites using several different techniques.

1.1 Definition of Composite: The most widely used meaning is the following one, which has been stated by ***Jartiz* [8]** "Composites are multifunctional material systems that provide characteristics not attainable by any discrete material. They are a cohesive structure made up of physically combining two or more conflict materials, different in composition and characteristics and sometimes in the form". The impoverishment of this definition lies in the fact that it allows one to classify among a mixture of any materials without indicating its specificity or laws, which would be given it, which separates it from other very banal, meaningless mixtures.

1.2 Objective: Before starting any work, there is an objective behind that work, and similarly the present work is undertaken with the following objectives,

The following are the main objectives of this research,

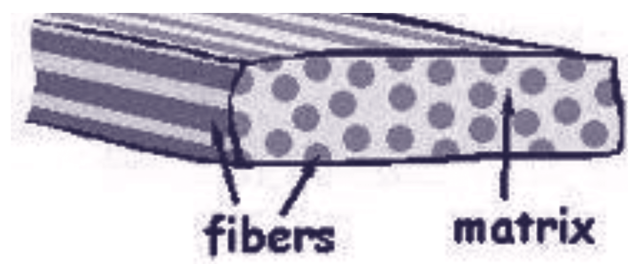


Fig. 1.1 A close up of what composites might look like

1. To develop banana fiber reinforced banana fiber polymer composite.

2. To study the mechanical properties of the developed composite for different volume fractions. The following mechanical properties are evaluated:

- Tensile strength
- Compressive strength
- Bending strength

These properties were evaluated for both untreated and treated fiber composite.

1.3 Methodology: To execute any work properly, it should fallow some order or in simple the work should be planned, then only the success comes, with such an intention the present work is given with a plan, and the steps followed are given in the following lines,

➢ Formulate the problem and defining the objectives of the work.

- ➢ Selection of proper matrix material and reinforcement.
- ➢ Deciding the volume fractions.
- ➢ Procuring the raw materials needed for the fabrication of the composites.
- ➢ Fabricate the composites using a compression molding technique.
- ➢ Specimen preparation: Prepare the tensile test, compression test and bending test specimen according to ASTM (American Society for Testing Material) standard.
- ➢ Testing of prepared specimens.
- ➢ Obtaining results for tested specimens.
- ➢ Analyzing the results and graphs.

1.4 Application of Banana Fiber Composites:

- • Decorative purposes
- • Roofing panels
- • Constructive bridge parts
- • Small boats
- • Automobiles
- • Fluid container

2. LITERATURE SURVEY

This chapter outlines some of the recent reports published in the literature on composite banana fiber reinforced polymer composites.

Lina et al. **[1]** fiber surface chemical treatment ware studied along with processing conditions for epoxy resin and hardener banana fiber composites. Different kinds of environmental tests were conducted and the compressive properties of the composites evaluated before and after moisture absorption. The resulting banana fiber/epoxy composites were found to have a flexural strength of 34.99 MPa and compressive strength of 122.11 MPa when alkaline pretreated, improved environmental exposure resistance. While the non-alkaline pretreated banana fiber/polyester composites were found to yield a compressive strength of 123.28 MPa flexural strength of 40.16 MPa.

Nilza et al. **[2]** used three Jamaican natural cellulosic fibers for the design and manufacture of composite material. They took bagasse from sugar cane, the banana trunk from banana plant and coconut coir from the coconut husk. Ash and carbon content, water absorption, moisture content, tensile strength, elemental analysis, and chemical analysis are a standardized tests performed.

Bilba et al. **[3]** examined four fibers from the banana tree-like leaf, trunk and coconut tree-like husk, fabric before their appropriation in cementitious matrices, to prepare insulating material for construction. The thermal degradation of these fibers under nitrogen gas flow was studied between 200 and 700 °C. The temperature of pyrolysis was the experimental parameter investigated. The solid residues obtained were analyzed by classical elemental analysis, Fourier Transform Infra-Red (FTIR) spectroscopy and were observed by Scanning Electron Microscopy (SEM).

This study has shown

- • The relation between botanical, chemical composition with both localization of fiber in the tree and type of tree.
- • The rapid and preferential decomposition of banana fibers with increasing temperature of pyrolysis

Rao et al. **[4]** the main aim at introducing new natural fibers used as a filler in a polymeric matrix enabling the production of economical and lightweight composites for load-carrying construction. An investigation of the extraction procedure of vakka, date and bamboo fibers has been undertaken.

The cross-sectional geometry, the density and tensile properties of these fibers, along with established fibers like sisal, banana, coconut, and palm, are determined experimentally under a similar condition and compare. The fiber introduces in the present study could be used as an effective reinforcement for making composites, which gives the advantage of being lightweight.

A lot of research has been done on natural fiber reinforced polymer composites but research on banana-based polymer composites is very rare. Against this background, current research work has been done, to explore the ability of banana fiber polymer composites and to study the mechanical characterization of composites.

3. MATERIALS USED

Banana fibers obtained from the stem of the banana plant (*Musa sapientum*) are bast fiber with relatively good. Bast fibers, like banana, are complex in structure. They are generally lignocellulosic, consisting of helically wound cellulose microfibrils in an amorphous matrix of lignin and hemicellulose.

3.1 Resin and Hardener: The resin used in this project work is epoxy L-12 which is a thermoset polymer and the hardener k-6 in the ratio of 1:10. There are two types of polymer matrix thermosets and thermoplastics.

Sl. No	Constitutents	Percentage
.1	Cellulose	3.61 ± 31.27
.2	Hemicellulose	±2.03 14.98
.3	Lignin	15.07±0.66
.4	Extractives	4.46±0.11
.5	Moisture	9.74±1.42
.6	Ashes	8.65±0.10

Table No. 3.1 Botanical composition of studied pseudostemfibers

Fig. 3.1 Banana stock from which the fibers are extracted

3.2 Fly-ash: Fly ash, a residue of burning of pulverized coal and lignite in thermal power stations, is now being accepted as resource material. Indian coals, though low in sulfur, contain a higher amount of ash (about 35-45%), hence the generation of huge quantities of fly ash in India. The annual generation of fly ash has increased from about 1 million tons in 1947 to about 40 million tonnes during 1994 and to about 112 million tons at present.

Table No. 3.2 Properties of cured resin without reinforcement.

Tensile strength	N/mm^2 50-60
Compressive strength	N/mm^2 110-120
Impact strength	N/mm^2 17-20
Flexural strength	N/mm^2 130-150
Martens value	^{0}c 75-80
Thermal conductivity	Kcal/mh^{0}c 0.211

Fig. 3.2 Banana fibers

3.3 Composite Combinations: In the proposed work specimens were prepared for four different compositions, one at a time. Table 2.3 gives detailed information on all combinations of composites prepared and used.

.Sl. No	Combination or volume fractions
1	(Short banana fiber 50% + epoxy 50% (untreated
2	(Short banana fiber 50% + epoxy 50% (treated
3	(Short banana fiber 40% + epoxy 60% (untreated
4	(Short banana fiber 40% + epoxy 60% (treated
5	Short banana fiber (untreated) 25% + fly ash 25% + epoxy 50%

Table No. 3.3 Composite combinations

4. FABRICATION

In the proposed work banana fiber is used as reinforcement. The banana fiber chopped by using a grinder and then sleeves the chopped banana fibers by manually. After sleeve different length fibers are obtained and select the suitable fiber length. In the proposed work 2-4 mm fiber length is used. Because the strength of fibers increases with an increase in the fiber length.

4.1 Fiber Chemical Treatment: Banana fibers were immersed in a 6% NaOH solution for 2 hours at room temperature. After the alkaline treatment, the fibers were thoroughly washed by running water. The material was then filtered and dried in sunlight. After drying it the fibers where cut into 4-5 mm length.

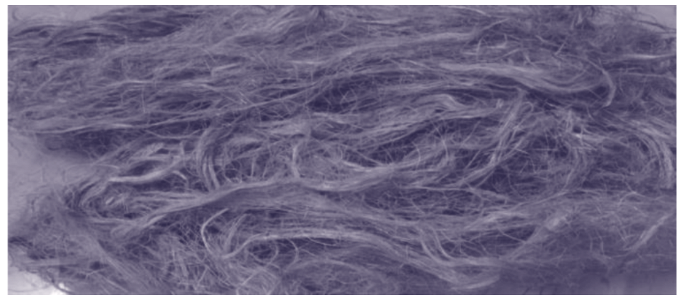


Fig. 4.1 Chemically treated fiber.

4.2 Mould Preparation: In the proposed work the acrylic sheet mould is used and the size of the mould is prepared as for our requirement. In the proposed work three different sized moulds are prepared. They are:

1) 250 mm × 25 mm × 6 mm (Tensile)

2) 25.4 mm × 12.7 mm × 12.7 mm (Compression)

3) 250 mm × 25 mm × 7 mm (Bending)

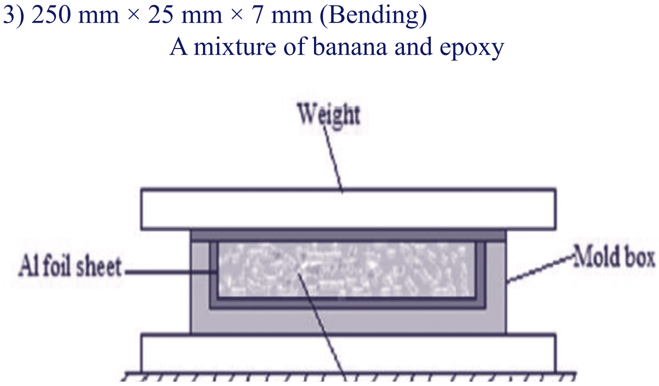


Fig. 4.2 Method of fabrication

4.3 Method of Fabrication: A compression moulding of acrylic sheet was used to prepare the banana fiber reinforced epoxy composites as shown in the figure. Measured quantities of epoxy resin (L-12) were mixed with the hardener (K-6), respectively. The mould was sprayed with vegetable oil as a releasing agent. A pre-weighed quantity of short non-woven banana fiber (50%, 60% by weight) was placed and the measured quantity of resin along with the hardener was poured on the fiber network. All this was mixed properly, placed in the mold, rammed, and was kept for 24hr to dry at the normal room temperature.

Fig. 4.3 Prepared specimens for the tensile test.

5. TESTING

After the fabrication process, the composites will be cut in the standard size for a various tests such as tension, compression, bending.

5.1 Tensile test (ASTM 3039): This test method is designed to produce tensile properties such as tensile strength, modulus of elasticity (Young`s modulus), % of elongation for control and specification of composite material. These data are useful for qualitative characterization engineering design and research and development purposes, testing was carried out on a universal Instron testing machine with standard specimens prepared according to ASTM (D3039).

Formulas: Stress = Force/Area

Strain = Elongation/original length

Tensile Modulus = Stress/Strain in elastic region of graph

Specimen specification: Gauge Length (B) = 100 mm

Overall length (A) = 250 mm

Thickness (D) = 6 mm

Width (C) = 25 mm

Specimen calculation: Area = 150 mm^2

Stress = force/ area

= 700/150 = 4.67 N/mm^2

Strain =Elongation/ original length

= 0.99/100 = 0.0099

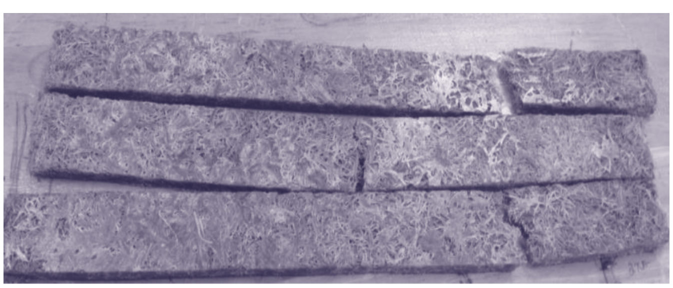


Fig. 5.1 Tensile specimen after testing

Result – The tensile strength for the different volume fraction of banana fiber and epoxy resin followed by 25% fly ash and 25% untreated fiber composites are shown in table 5.1.

Specification	60% treated	60% untreated	50% treated	un- 50% treated	fly 25% ash 25% fiber
Tensile strength MPa	11.56	12.32	11.78	15.34	11.67

Table No. 5.1 Tensile strength

5.2 Compression test (ASTM D695): This test method is designed to produce compression properties such as compression strength for the control and specification of composite material. These data are useful for qualitative characterization engineering design and research and development purposes. Testing was carried out on a triaxial testing machine with standard specimens prepared according to ASTM (D695).

Formulas: Crossectional area = b×h

Stress = Force/Area

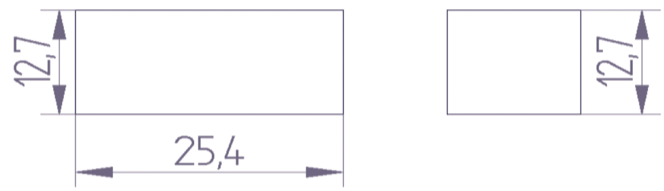


Fig. 5.2 Compression test specimen specification

Specimen specification: Length (l) = 25.4 mm

Width (b) = 12.7 mm

Thickness (t) = 12.7 mm

Calculation: Cross sectional area = b×h = 12.7×12.7 = 161.3 mm^2

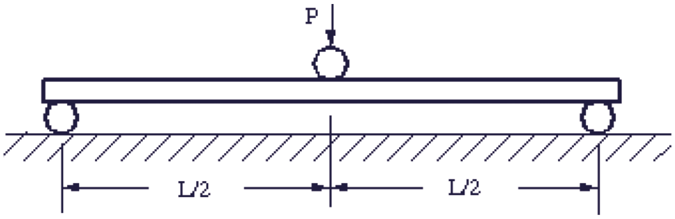
Compressive strength = Load÷area = 8061.85÷161.3 = 49.98 N/mm^2

Result – The compressive strength for different volume fraction of banana fiber and epoxy resin followed by 25% fly ash and 25% untreated fiber composites are shown in the table 5.2.

Specification	60% treated	60% untreated	50% treated	un- 50% treated	fly 25% ash 25% fiber
Compressive strength MPa	24.35	48.79	56.74	67.51	35.7

Table No. 5.2 Compressive strength

5.3 Bending Testing (ASTM D790): If the force act on a piece of a material in such a way that they tend to introduce compressive stresses over one part of a cross-section of the piece and tensile stresses over the remaining part, the piece is said to be bending.



M_b=PL/4

Fig. 5.3 Point bending test

Specimen specification: Span length = 150 mm

Overall length = 250 mm

Width = 25 mm

Depth = 7 mm

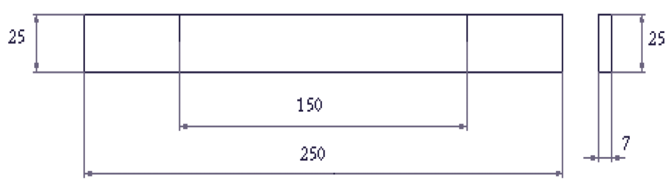


Fig.5.4 Bending test specimen specification

Formulas:

1. Bending equation is

$$M_b/I = \sigma/c = E/R$$

Where $M_{b= \text{bending moment in N-mm, I= moment of inertia of the cross-section in mm}}{}^4$, σ= bending stress in N/mm^2, R= radius of curvature in mm, E= modulus of elasticity in N $/mm^2$ and C= center distance from the neutral axis to the outermost fiber in mm.

2. Moment of inertia of the cross-section is

$$I = BH^3/12$$

Where B is the breadth and H is the depth of the span in mm.

3. Center distance from the neutral axis to the outermost fiber is

$$C = H/2$$

4. Bending stress is

$$\sigma = M_b \times C/I$$

5. Bending moment is

$$M_b = PL/4$$

Where, L is the length of the span in mm.

Specimen calculation: (for 50% chemically untreated composite at break)**:**

Moment of inertia = $BH^3/12$

$= 25\times7^3/12$

$= 714.58\ mm^4$

Bending moment = FL/4

$= 102.269\times150/4$

$= 3835.08$ N-mm

Bending stress = $M_b C/I$

= ٧١٤,٥٨/٣,٥×٣٨٣٥,٠٨

$= 18.78\ N/mm^2$

Result – The compressive strength for the different volume fraction of banana fiber and epoxy resin followed by 25% fly ash and 25% untreated fiber composites are shown in table 5.3.

Specification	60% treated	60% untreated	50% treated	un- 50% treated	fly ash 25% 25% fiber
Bending Strength MPa	4.96	11.86	15.46	19.67	4.96

Table No. 5.3 Bending strength

6. RESULT & DISCUSSION

To analyse the mechanical behaviour of polymer composites is one of the most important techniques. Mechanical properties of fiber and filler reinforced composites depend on the nature of matrix material, the distribution and orientation of the reinforcing fibers, the nature of the fiber-matrix interfaces.

6.1 Mechanical Properties of Composites: In the present work, the mechanical behavior of the composite is tested by tensile test, compressive test and bending test. The polymer composite specimens were prepared according to the ASTM standards for each test. Two different fillers contents by weight were used namely 50% and 60% with epoxy resin to prepare the specimen for tests. Each of these properties was evaluated for three specimens and the average value of these properties was tabulated as shown in table 6.1.

Specification	60% treated	60% untreated	50% treated	50% untreated	25% fly ash 25% fiber
Tensile strength MPa	11.56	12.32	11.78	15.34	11.67
Compressive strength MPa	24.35	48.79	56.74	67.51	35.7
Bending strength MPa	4.96	11.86	15.46	19.67	4.96

Table No. 6.1

From the table, it can be seen that untreated fiber composites have higher strength than the treated fiber composites. The 50% untreated fiber composites are the best composites among all. The reason is simple the treatment of the fiber with 6% sodium hydroxide has reduced the fiber length due to the removable of part of lignin from the banana fiber. Moreover the sodium present in the sodium hydroxide solution leads to the removable of hydrogen from the hydroxide bond and occupying the hydrogen place. Thus this is the same reason why % absorption of water by the chemically treated fiber composites is less.

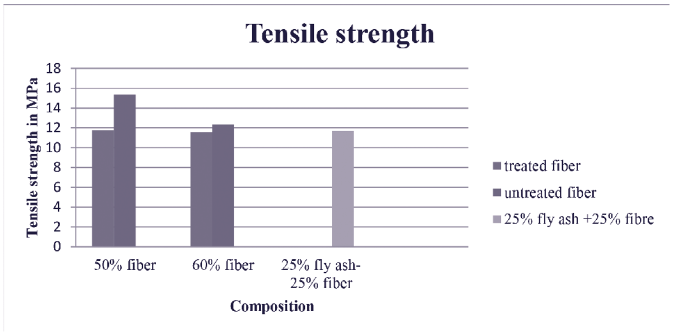


Fig. 6.1 Comparison of the tensile strength of the composite

From the graph, it has seen that the tensile strength of untreated fiber composite is more than treated fiber composite.

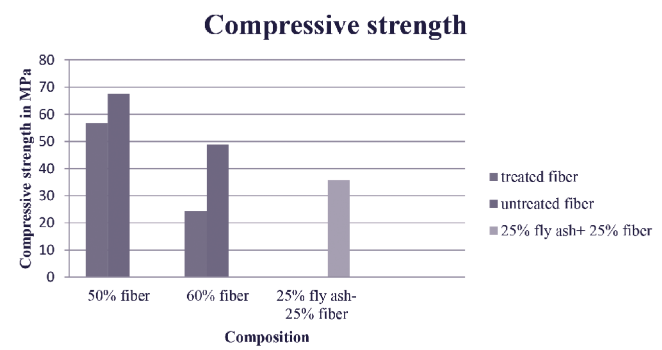


Fig. 6.2 Comparison of compressive strength of the composite

From the graph, it has seen that the compressive strength of untreated fiber composite is higher than treated fiber composite.

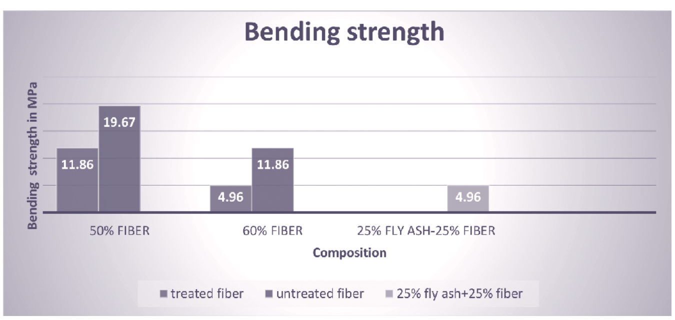


Fig. 6.3 Comparison of bending strength of the composite

From the graph, it has seen that the bending strength of untreated fiber composite is more than treated fiber composite.

The use of 25% fly ash in the composites has not improved the strength of the composites, because the fly-ash was in particle form but the fiber was not in particle form as a result of which there was not proper bonding with the resin.

7. CONCLUSIONS AND SCOPE FOR FUTURE WORK

This case study aims to develop banana fiber- reinforced composite materials with a thermoset epoxy resin (L-12) and hardener K-6, suitable for engineering applications including automobile. Banana fibers are obtained from a banana tree, which is the waste product of banana cultivation. It is seen that banana fiber-reinforced composites have a good future. We have also tried to utilize fly ash, the waste product of industry in making composites with banana fiber, Known as hybrid composites.

From the experiments carried out and results obtained, the following conclusions can be drawn

- The fabrication of banana fiber-based epoxy composites with different loading of fiber and different lengths of fiber are possible by hand lay-up process.
- The tensile strength of the untreated banana fiber is more as compared to treated banana fiber composites. The reason may be that the treatment of fiber with 6% NaOH has re duced the fiber strength due to the removal of part of lignin from the banana fiber. Moreover, the sodium present in sodium hydroxide solution leads to the removal of hydrogen from the hydroxide bond and occupying the hydrogen place. This improved fiber/matrix interaction.
- The compressive strength of the untreated banana fiber is more as compared to treated banana fiber composites.
- The bending strength of the untreated banana fiber is more as compared to treated banana fiber composites.
- The surface modification of fiber significantly improves the fiber-matrix adhesion which in turn enhances the mechanical properties of the composite? The alkali treatment provides the highest improvement in strength in-comparison to acetone treatment.
- There is a good dispensability of bagasse fiber in the matrix, which improves the hardness, strength, and works fracture of the composite. Twenty percent of volume reinforcement fiber gives the best combination among these tested composites.

1.1 **Scope for future work:** Tests can be conducted for different fillers with banana fiber and chopped glass fibers.

- The other mechanical properties of the banana fiber-rein forced composite can be evaluated.
- The thermoplastic polymer can be used with banana fiber.

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