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Mechanical Properties of Banana Fiber Reinforced Polymer Composites

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Abstract—*Natural fibers have been widely used in different engineering fields. Mechanical properties of banana fibers play a wide range in deciding their applicability in various industrial and engineering fields like furniture, papers and automobile. This work are fabricating the banana fiber reinforced epoxy composite. In order to evaluate the external damage resulting under static loading (three point bending - tensile) tests using product computerized Universal Testing Machine, Model (WDW-100).The load-displacement curves were obtained to characterize the failure mechanisms of the specimens. The failure modes were studied, it was observed that the specimens beard high load in tensile test more than 3-point bending, the sudden crack due to brittleness of the specimens and air bubbles between fiber and matrix that due to faults in manufacture process.*

Keywords— *Banana fiber, flexural test, strength, durability.*

I. INTRODUCTION

Common fiber reinforced composites are composed of fibers and a matrix. Fibers are the reinforcement and the main source of strength while matrix glues all the fibers together in shape and transfers stresses between the reinforcing fibers.Natural fiber composites include coir, jute, cotton, bamboo, Banana, hemp. Natural fibers come from plants. These fibers contain lingo cellulose in nature.Natural fibers are eco-friendly; lightweight, strong, renewable, cheap, and biodegradable. The natural fibers can be used to reinforce both thermosetting and thermoplastic matrices. Thermosetting resins such as epoxy, polyester, polyurethane, phenolic are commonly used composites requiring higher performance application [1].

They provide sufficient mechanical properties in particular stiffness and strength at acceptably low price levels. Recent advances in natural fiber development are genetic engineering. The composites science offer significant opportunities for improved materials from renewable resources with enhanced support for global sustainability. Natural fiber composites are attractive to industry because of their low density and ecological advantages over conventional composites. These composites are gaining importance due to their non-carcinogenic and bio-degradable nature. Natural fiber composites are very cost effective material especially in building and construction, packaging, automobile and railway coach interiors and storage devices [1].

These composites are potential candidates for replacement of high cost glass fiber for low load bearing applications [2].

Natural fibers have the advantages of low density, low cost and biodegradability [3_7]. However, the main disadvantages of natural fiber composite are the relative high moisture absorption. Therefore, chemical treatments are done so as to modify the fiber surface properties. Physical and mechanical properties of composites depend on the single fiber chemical composition (Cellulose, hemicelluloses, lignin, pectin, waxes, water content and other minors) according to grooving (soil features, climate, aging conditions) and extraction/ processing methods conditions. Grooving conditions is recognized as the most influent parameter for the variability of mechanical properties of the fibers. [8]

In the last few years, there has been intense research on natural fiber composites. These researches show that natural fiber composite exhibits superior properties compared to conventional composites. Numerous studies have shown that the addition of natural fiber reinforcement can lead to a significant enhancement of many properties, such as stiffness and strength.1–5 the key to obtaining significant property enhancements is by homogenous dispersing of fiber, i.e. the individual banana fiber within the polymer matrix to take advantage of their high aspect ratio and surface area. The affinity between the polymer matrix and banana fiber is determined, to some extent, by the polarity of the functional groups. The affinity of the polymer with the surface of the banana fiber is essential to promote favorable interactions to obtain high-level mechanical properties.

All these properties make the materials suitable for a wide variety of applications such as construction, automotive, electronics, packaging, etc. [9]

The development and application of lightweight sandwich structural elements is a growing trend in the construction industry all over the world due to their high strength-to-weight ratio, reduced weight, and good thermal insulation characteristics. In general, utilization of biomass in lignocellulosic composites brings several advantages such as low density, greater deformability, less abrasiveness to equipment, biodegradability, and low cost. [10]

II. MATERIALS AND METHOD

Banana Fibers

Stems were brought from Omdurman and garri. The fibers were obtained from outer layers from the stalks of the plant and extracted traditionally. After extraction and dry, it provides a white lustrous color fiber.

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Epoxy

Epoxy used in this article was Sikadur 31 CF Component-A, 100% solids, solvent-free, moisture-tolerant, high-modulus, high strength, and structural epoxy paste adhesive. It conforms to the current ASTM C-881, Types I and IV, Grade-3, Class-B/C and AASHTO M-235 specifications.

Flexural Test

The bending specimens are prepared as per the ASTM D 1037-06 standards the dimensions of these test specimens are 200 x 30 x 6.5 mm and the distance between the two supports is 150 mm. The applied velocity is V=2 mm/min and the maximum applied load is 100 kN .The tests are carried out at a condition of 26 ± 2 0 C and an average relative humidity of 43%.

Fig. 1. The three point bend machine.

Tensile Test

A universal testing machine (Hegewald & Peschke) the most common testing machine used in tensile testing is the universal testing machine. This type of machine has two crossheads; one is adjusted for the length of the specimen and the other is driven to apply tension to the test specimen. The Universal Testing Machine showing in the fig. 2.

Fig. 2. Tensile testing machine.

Fabrication Process

Hand Lay-Up Molding with vacuum:-

The composite are fabricated by hand lay-up technique. The mold used for fabricating the composite is made up of aluminum with a debonding agent applied on the inner side. The inner cavity dimension of the mold is 250mm x 250mm x 10mm. The fiber is dipped in the resin randomly where the resin is also poured. The upper side is pressed using a roller under room temperature until the matrix is set properly as shown in fig. 3.

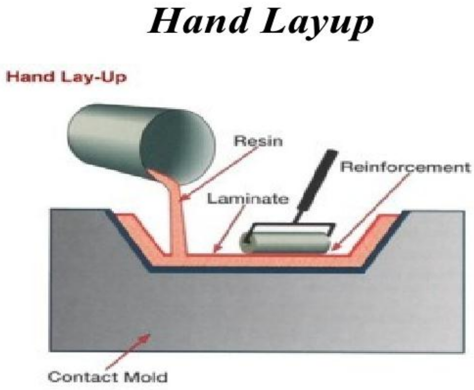

Fig. 3. Hand lay-up molding.

Fig. 4. Hand lay-up random.

Vacuum bag:-

The main purpose of vacuum process is it removes the air which was trapped inside the laminate thus reducing the defect and improving the strength of the laminate. The setup was left to cure for 6 hours at room temperature as shown in fig.5.The prepared composite were cut for testing conform to the dimensions of the specimen as per at ASTM standards as shown in table I and fig. 5 and 6.

Fig. 5. Vacuum bag.

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Fig. 6. Specimen after fabrication.

Specimen Preparation:-

TABLE I. Dimensions tests specimens.

Specimens Types and Specifications		
	3 point-Bending Test	Tensile test
Length(mm)	200	200
Width(mm)	30	15
Thickness(mm)	6.5	6.5

Fig. 7. Tensile strength specimens.

Fig. 8. 3-point bending specimens.

III. Results and Discussion

Tensile Test:

Load displacement behavior:-

The tests were conducted in the same order as the specimens were prepared so that the time between preparation and testing was the same for all bars. A universal testing machine was used for the tests. The top end of the specimen was fixed by the grips on the top cross-head of the machine while the bottom end was not fixed before applying the load. A slotted steel plate was placed between the top of the bottom anchor and the bottom of the middle cross-head. When the specimen was loaded, this plate engaged the bottom anchor. The load was applied at a constant speed until the failure of the specimen.

The tensile test was being performed in order to obtain load-displacement curve, for all specimens as shown in fig. 10. The load-displacement curves were showing same tendency, exhibiting a meander increase, with small deformation. This behavior was attributed to the condition when applied the load initiating some crack in the matrix. As the load reached the peak load value (1.512KN), there is a sudden drop in force after its peak value because of the additional tensile stress induced damage.

Failure modes: -

The result shows the failure as shown in fig. 9.This might be related to the type of manufacturing process. Meanders in the curve because of air existence, mean values of maximum force were determined as given in table II, the results of the individual tests are reported in table II.

TABLE II. Mean value of maximum force.

Type of specimen	Maximum Force (KN)	Tensile force Average (KN)
T1	0.990	1.251
T2	1.512	

Fig. 9. Failure of tensile test.

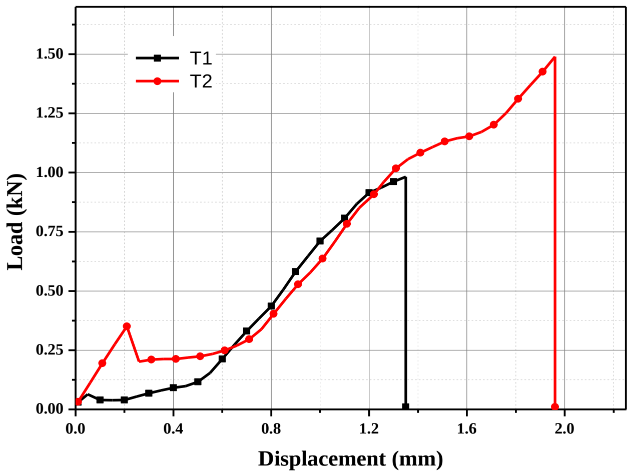

Fig. 10. Load- displacement curve of tensile test for banana fiber reinforced composite.

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The Three-Point Bending test:

Load displacement behavior:-

The three bending tests were being performed in order to obtain the load-displacement curves for all specimens. These curves were used to determine the behavior of the failure modes of Banana Fiber Reinforcing Composites. The curve obtained in the three bending test as shown in fig.12. The result indicated that the displacement increases with the increase of applied load up to around 0.288 KN, after that, it tends to decrease, i.e., breaking takes place. The maximum displacement observed is 8.75 mm. These curves were used to determine the behavior of the failure modes of banana fiber reinforced epoxy composite. The curves obtained in the bending are shown in fig. 12; all of these curves were not similar in nature, but specimen B_3 which beard a little load due to a manufactured fault. The curves linear in appearance; can explain the elastic deformation of the banana fiber reinforced epoxy composite.

Failure modes:-

All Specimens failed suddenly because they are brittle as shown in the curves. All cracks propagate to the compressive side of the specimen. However, the final failure occurs when the matrix crack but the fiber still caring the load. The three point bend test usually yields good results for material characterization of composites (such as lamination module of elasticity, laminate stresses, etc.) [11].

Fig. 11. Failure in bending test.

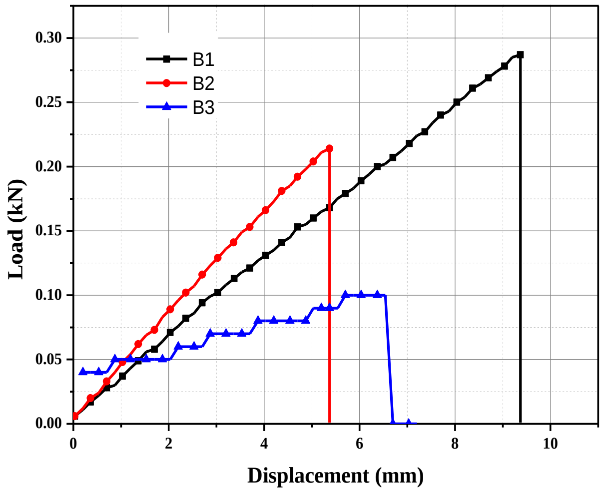

Fig. 12. Load-displacement curve of three point bending test.

Calculation the stress and strain

Confirming the maximum flexural stress was calculated and recorded using Equation 1, shown below

$$\sigma = \frac{3PL}{2bh^2} \quad (1)$$

Where

σ- Stress at the outer surface at mid-span of the specimen, P- Applied force, L- Span length, b- Specimen width, h- Specimen thickness

The distribution of shear stress is parabolic, with a maximum at the neutral axis and zero at the outer surfaces of the beam; the maximum value is given by Equation (2)

$$\tau = \frac{3F_z}{2bh} \quad (2)$$

Where F_z is the force on the specimen.

The result of the calculation as shown in table III.

TABLE III. Calculation of the stress and strain for bending test.

Specimen	Length (mm)	Width (mm)	Thickness (mm)	Span length (mm)	Applied Force (KN)	Stress (σ) MPa	Strain (τ) MPa
B1	200	2985.	4.49	150	0.11	41.07	0.46
B2	200	30.72	6.76	150	0.288	46.16	0.33
B3	200	33.44	7.96	150	0.215	22.83	0.13

IV. Conclusions

Static tests were carried out for banana fiber reinforcement epoxy composite to know the mechanical properties. Three samples of each set were tested under tensile strength and three point bending test. The major conclusions are the following:

- Tensile test, the fiber pull out this due to fiber orientation, the failure in tensile specimens was crack suddenly, due to the brittleness of the materials.
- Three point bending; the failure mode of BFREC tested under bending conditions can be summarized as tensile failure and compressive failure followed by the cracking of the matrixes material. It has low bending resistance because it's brittle and has an air bubbles.
- The tensile had the highest peak load in banana fiber reinforced epoxy composite; the bending test had the lower peak load

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