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Characterization and Fabrication of Particle Board from Banana Fiber and Sawdust as A Hybrid Composite

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Abstract

The current global landscape emphasizes the search for eco-friendly and regenerative materials. Utilizing environmentally available fibers in conjunction with polymeric resins through efficient manufacturing processes offers a cost-effective solution with high-quality standards. Polymer matrix composites with fiber reinforcements possess several advantages, including low production costs, ease of fabrication, and improved material properties, making them applicable in a wide range of industrial contexts. This paper emphasizes the creation of Particle boards using banana fiber flakes and saw dust as reinforcement, with epoxy serving as the matrix. The study examines the mechanical characteristics and micro structural characteristics, specifically at a 40% volume fraction of fiber particles. The principal goal of this research is to create a low-density composite particle board using banana fiber and epoxy as the matrix. The findings reveal enhanced tensile strength and hardness, Ascribed to a robust interfacial bond between the matrix and fibers with low water absorption. The composite's SEM analysis light on agglomerations and structural evaluations in the bonding between the fiber and epoxy resins. This context suggests that banana fiber particle boards could be a suitable replacement for traditional wood boards in domestic household applications.

Keywords: Banana fiber from stem, epoxy, saw dust, hand lay-up process, micro hardness, and tensile strength

INTRODUCTION

The use of composite materials is becoming increasingly prevalent in the field of engineering [1,2]. It is the matrix and the fiber that make up the majority of the composite. Inventions from all over the world have been encouraged to test out locally affordable fiber, examine their patentability, and evaluate how well they fit the requirements of polymer composites built for structural purposes. This is due to the availability of natural fiber and the ease with which it may be assembled [3]. It is common practice to favor composites over ideal polymers due to the fact that composites are easier to create, straighter forward to manage, and feature superior quality [4]. Due to these factors, scientists and technologists are increasingly interested in natural fibers because of the benefits they offer over traditional reinforcement materials. Moreover, the development of composites using bio-fibers has gained significant attention. Temesgen Batu et al. [5] examined the mechanical characteristics of hybrid (false banana and glass fiber) reinforced composite materials at various fiber volume fractions and fiber orientations. Bhoopathi et al. [6] utilized universal testing machine for a study in which, Hybrid epoxy composites comprised of banana hemp and glass fibers performed well in tests and could replace synthetic fiber composites.[7], the morphological, mechanical, and chemical features were investigated using a scanning electron microscope, a computerized tensile machine, and an FTIR instrument. Panel et al. [8] conducted a study on the benefits of natural fibers compared to synthetic

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reinforcement materials. Karthikeyan et al. [9] examined the mechanical properties of epoxy composites reinforced with sisal and banana fibers, specifically focusing on tensile, flexural, impact, and compression behavior. An analysis of variations was performed to identify the relevant factors and determine their respective contributions. The study revealed that the volume proportion of fiber in the polyester matrix has a greater impact than other parameters [10]. Dynamic mechanical analysis on polyester composites reinforced with banana fiber done by. Pothanet al.[11]. The study utilized a banana-coir epoxy composite consisting of five distinct combinations of banana and coir fibers, which were manufactured based on their volume fraction. The BBBB composite, including 0% coir, 40% banana, and 60% epoxy, demonstrates the maximum mechanical strength [12]. Murugan et al. [13] conducted a study on the fabrication and examination of composite materials reinforced with kenaf fiber and banana fiber. Arup Kar et.al.[14]. Demonstrates that adding 10 weight percent Calamus tenuis fibers to reinforcing epoxy composites significantly enhances their mechanical and dynamic qualities, leading to maximal strength and fiber-matrix adhesion.Sivasubramanian Palanisamy et.al. [15] States that adding higher amounts of treated areca nut husk fibers to an epoxy matrix improves the composites' tensile, flexural, impact strength, and wear resistance, although gains in hardness are minimal. A key limitation is the fibers' low elongation, even post-treatment.Rengaiyah Govindarajanet.al.[16]Revels hybrid tubes with epoxy reinforcement and aluminum mesh, especially the Basalt + Bamboo (BBmABmB) specimen, exhibit superior mechanical qualities, such as high load-bearing capacity and energy absorption.Shanmugavelet.al.[17] In axial, flexural, and radial compression testing, the AlBmB hybrid tube which is made up of layers of basalt and bamboo performed exceptionally well, exhibiting exceptional compressive strength, energy absorption, and crashworthiness. The success of material layering and roll-wrapping techniques in creating strong, lightweight composite structures is highlighted in this study

The current work aims to create a particle board using banana fiber as the primary material. In this study, hybrid composite board composed of banana fiber, sawdust, and epoxy was fabricated .This resulted in a reduction in the weight of the Board. The banana fiber composite material is renowned for its environmental sustainability and affordability. A result of its abundance in tropical climates, banana fiber serves as a sustainable substitute for fiberglass.

MATERIALS METHODS

The banana fiber was sourced from the “Banana Fiber Plant” in Uttar Pradesh, India, and the sawdust was obtained from teak wood. The epoxy resin (LY-556) used as the matrix binder was supplied by Ciba Geigy India Ltd., along with Araldite HY 951 hardener. Epoxy resin is known for its excellent mechanical and thermal properties. The properties of the fiber presented in Table: 1.

EXPERIMENTATION PROCESS

First, a wooden mold with dimensions of 550 mm x 370 mm x 10 mm is prepared. Banana fiber mats are cut into short fibers (chopped fibers). A mold release agent is applied inside the mold, followed by placing alumina paper coated with wax inside the mold. Next, the predetermined epoxy resin with a hardener ratio of 10:1 is poured into the mold. A thin layer of sawdust is spread on the bottom of the mold, the chopped fibers are placed in the middle, and another thin layer of sawdust is added on top. This creates a sandwich-type composite with 60% of epoxy, 30% of short fibers, and 10% of sawdust. Fig: 1b represents the conventional Hand-layup technique and Figure: 1a shows the sandwich structure of fiber and matrix. Using 300 kg of weights, a hybrid laminate was loaded and allowed to cure for 24 hours. The Sawdust took timber depot shown in Fig: 2a and required banana flakes represented in Fig: 2b then in Figure: 2c showed the fabrication of particle Board in mold, the final board with required dimensions given in Figure: 2d. The experimental samples shown in Figure: 3.

Table1. Properties of Banana Fiber.

Property	Density (kg/m)	Tensile strength (MPa)	Young’s modulus (GPa)	Failure strain (%)	Elongation
Value	750-950	529-914	27-32	1-3	6.54

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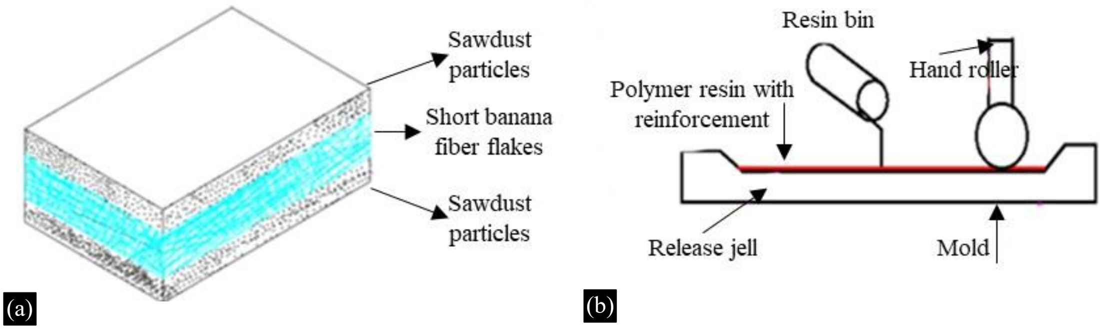

Figure 1. a) Representation sandwich structure b) Schematic representation of hand- layup.

Figure 2. (a) Teak wood saw dust (b) short banana fiber chips (c) Mold (d) Particle board.

Figure 3. Experimental samples.

MECHANICAL CHARACTERIZATION

Ultimate Tensile Strength

The dog bone-shaped work piece is cut to the required dimensions using a cutter, and the edges are polished with emery paper. The ASTM D638 standard test specimen of 80 mm gauge length and 8.7 mm thinness, Width 23.7,cross section area 205.32 mm^2 specified in Fig:4b is subjected to a tensile test with a 4 KN load on the Universal Testing Machine (UTM), Make: FIE UTES 40 HGFL, (S. No-7/2019-6284) schematic diagram given Figure 4a. The gauge section's elongation is measured concerning the applied force during tension.

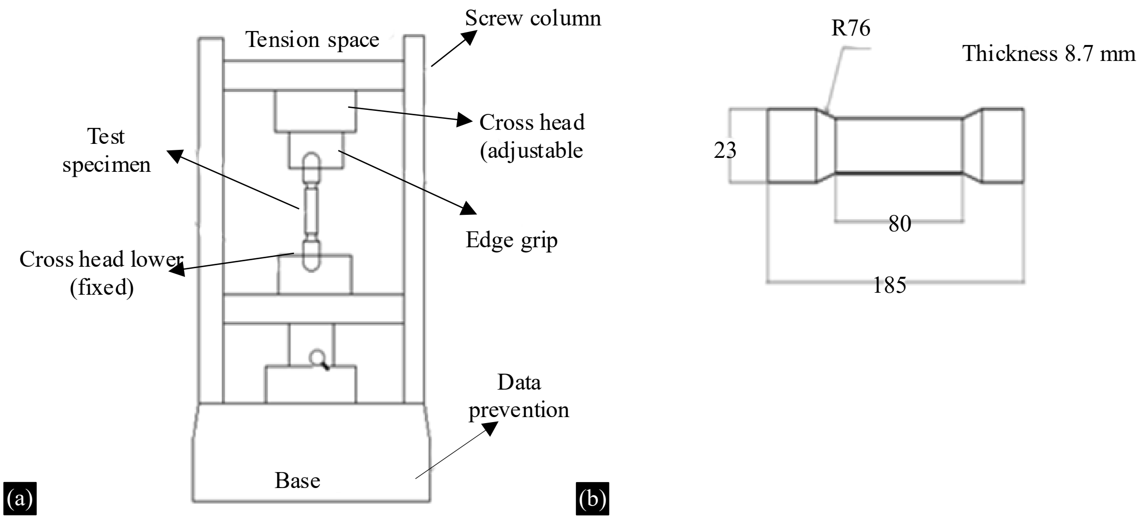

Figure 4. (a) Representation tensile Test machine (b) Specimen for tensile test.

Bending Strength

The material's stress right before yielding is known as it's bending strength .The test was performed using the same UTM, schematic bending given Fig: 5a and the test item was produced by ASTM D790 specifications of 16 mm width, 8 mm thickness and length 75 mm. specified in Figure 5b .In this experiment, a 0.26 KN load, was applied to flexural test to measure the bending strength of the composite materials.

Compression Strength

A UTM machine with a 7.8 KN load was used to perform the compression tests. schematic bending given Figure 6a The test specimen in shape rectangular, according to ASTM D695 was followed, with thickness 12 mm, width of 9 mm. specified in Fig:6b The maximum compression strength obtained is 56 MPa.

Hardness Test

The test specimen, prepared according to ASTM D2240 with a thickness of 10 mm, was tested using a Shore Durometer Type D indenter, schematic bending given Figure 7. The hardness was measured by applying a load of 5 kgf. To get the correct value at multiple points on the work piece tested and found the hardness value as 75.

Density Test

For the above test samples according to ASTM D792-91 by using Archimedes principle method,

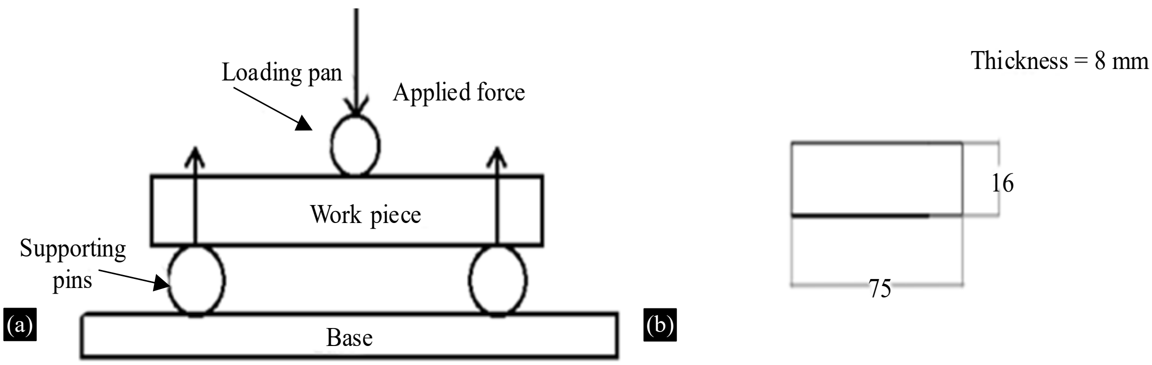

Figure 5. (a) Representation 3-axis Flexural Test (b) Specimen for bending test

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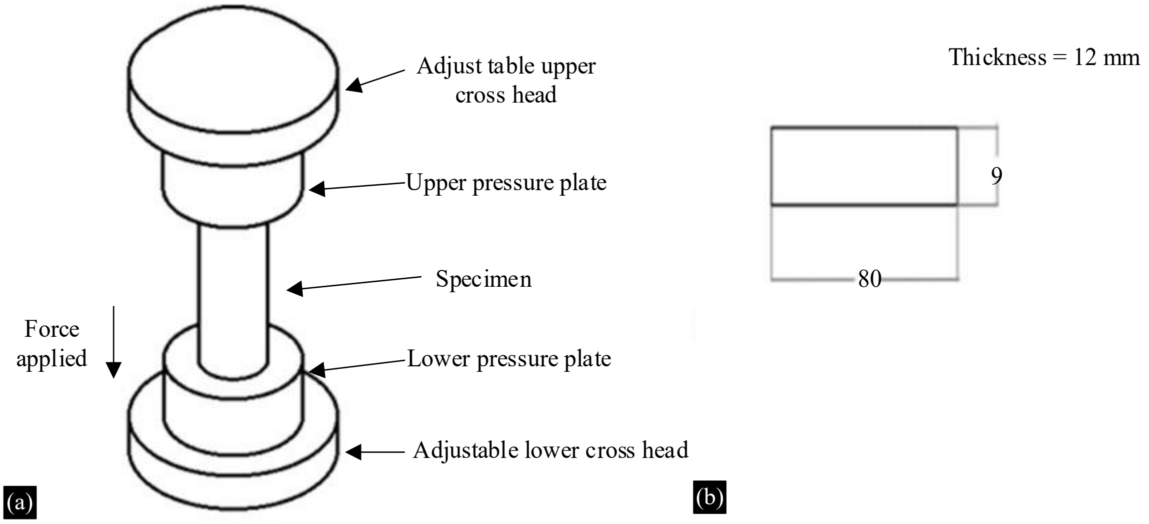


Figure 6. (a) Schematic representation compression test (b) Specimen for compression test

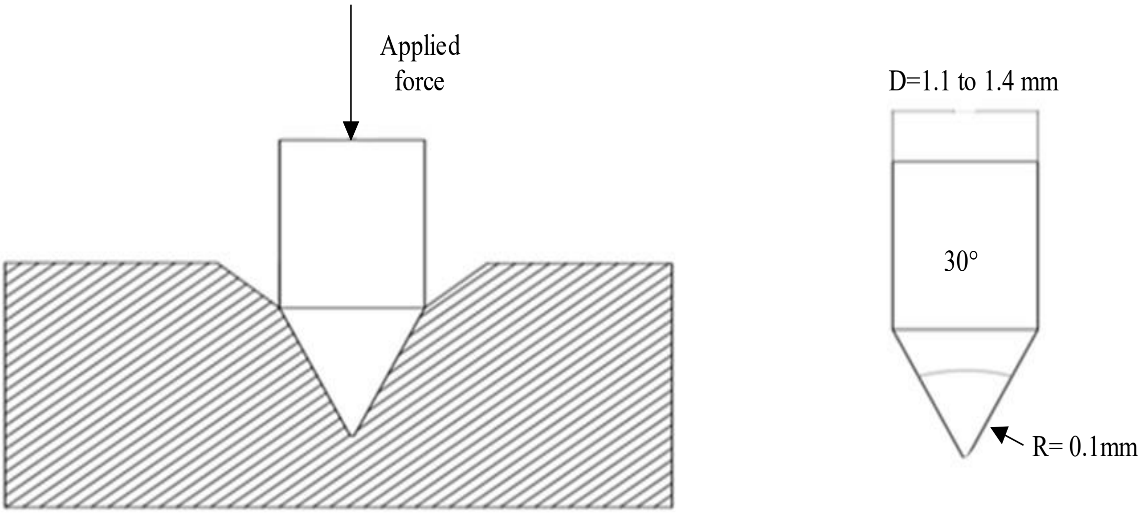


Figure 7. Schematic representation hardness test with tool.

Kept the sample in distilled water for period of 4 hours
From Archimedes Principle $=\rho_{c=}\ \rho_w.w_a/w_a\text{-}w_w$

Where $\rho_{w=}$Density of water=0.9975 gm/cm^3
$w_{a=}$ Weight of sample in air at room temp= 42 grams
$w_{w=}$ Weight of sample in water at room temp= 19 grams

Therefore
ρ_c= 0.8241 gm/cc.

Micro Structural Analysis

Morphology analysis was conducted to examine hybrid composite samples. The images revealed the fiber and epoxy is well-distributed. The void percentage and distribution of the fiber and sawdust also evaluated.

Average composite grain size find from Image J software as 80 and 40 Microns at 100 µm 500µm distances respectively shown in Figure 8&09.

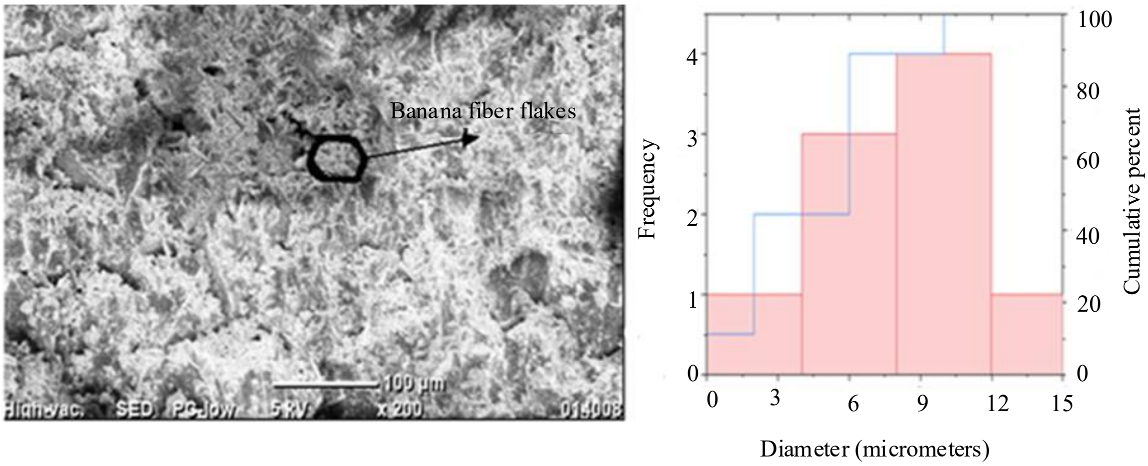


Figure 8. SEM image of composite at 5KV and histogram graph for 100 micrometer distance.

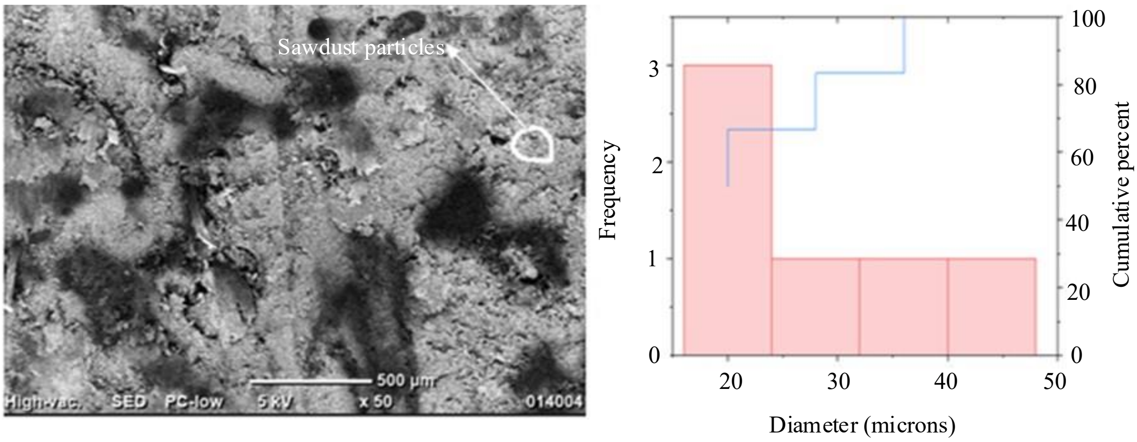


Figure 9. SEM Image of composite at 5 KV and histogram graph for 500µm distance.

RESULTS AND DISCUSSIONS

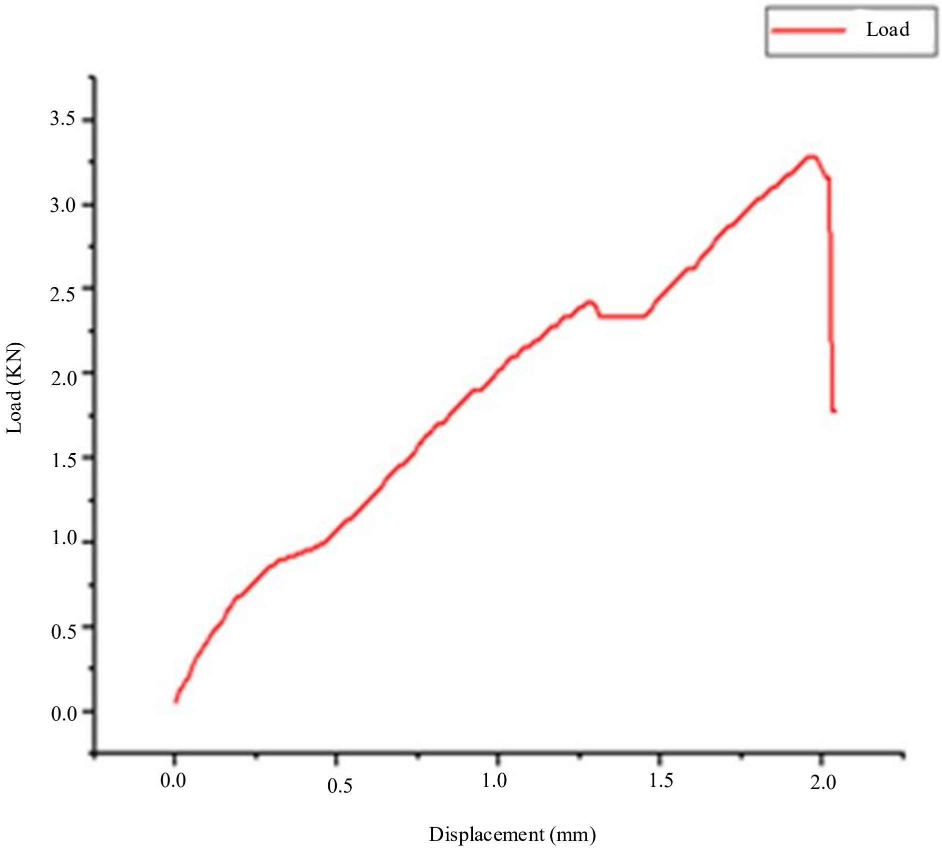
Three samples were taken from the center and two edges of the Fabricated Particle Board to test various properties and evaluate the uniformity of strength. The properties if three samples shown in Table: 2

The results of the tensile test for the tested specimen are shown in Graph: 1. the highest ultimate tensile strength recorded is 16 MPa, with an elongation of 2.55%. It is noted that as the load increases, displacement also increases up to a certain point before decreasing. The maximum displacement of 1.95 mm occurs at a load of 3.28 KN.

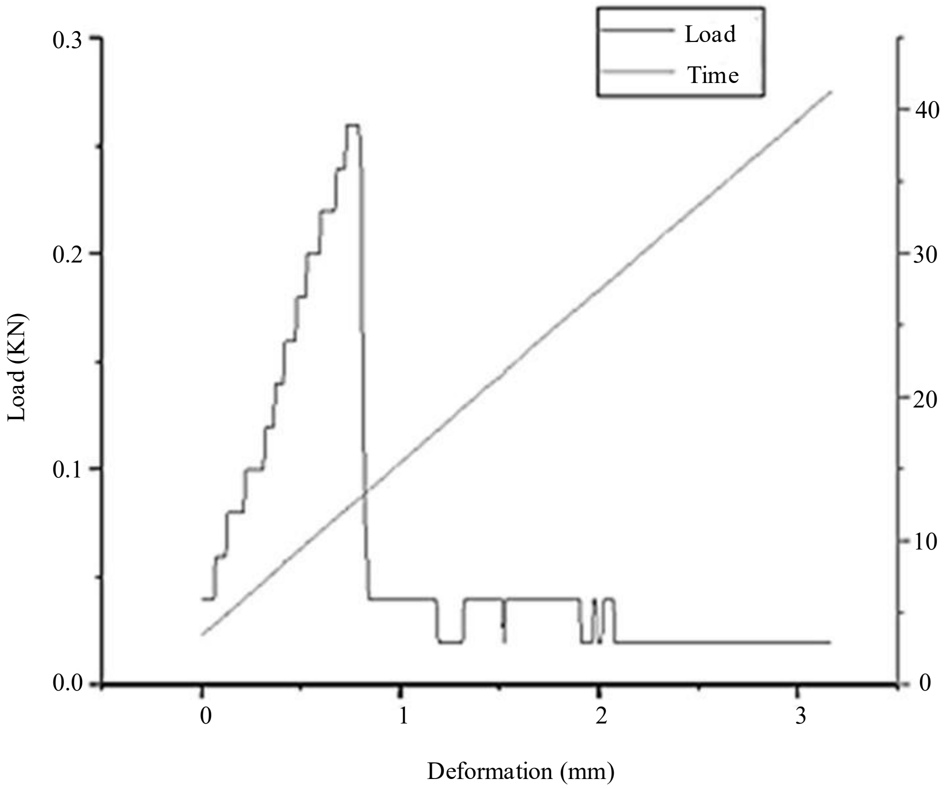
Graph: 2 presents the graph generated directly from the UTM during flexural testing. It shows that deformation increases with the load up to 0.26 KN, after which it begins to decrease, indicating the occurrence of bending. The maximum deformation observed is 3.17 mm, while the deformation at the maximum load is 0.73 mm. The maximum flexural stress for the specimen obtained is 24 MPa.

Table 2. Mechanical Properties Tested for Three samples of Particle Board.

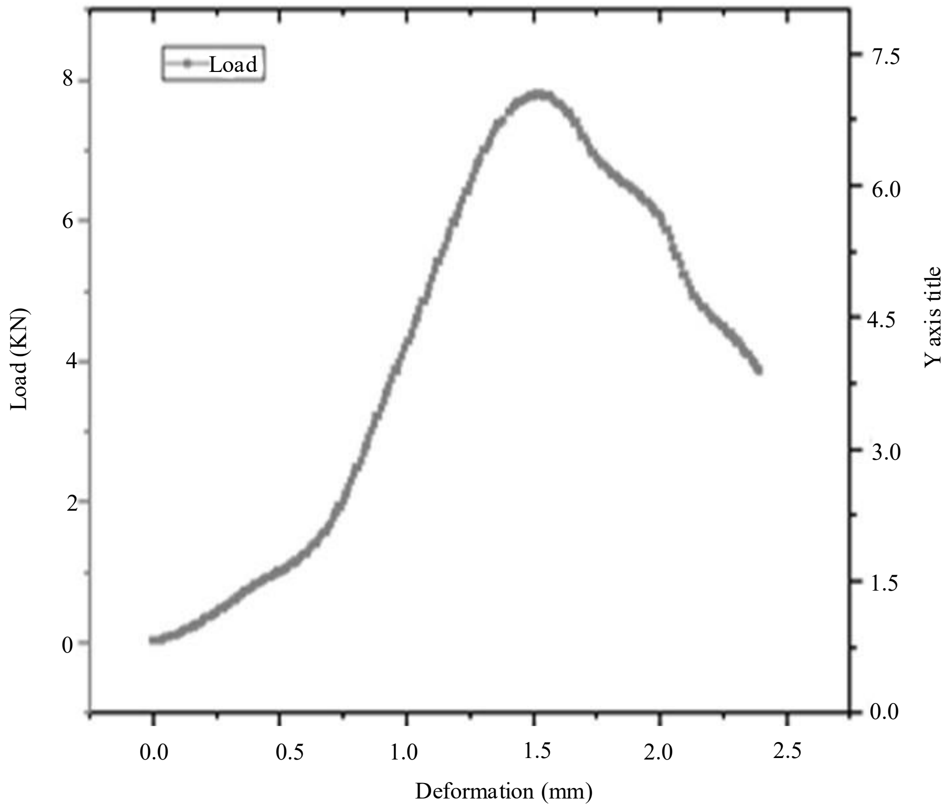
S.N.	Ultimate tensile strength (MPa)	Compression strength (MPa)	Flexural strength (MPa)	Hardness	Density (g/cm^3)	Grain size (u m)
1	15.96	54	25	76	0.902	9.517
2	15.84	53	23	74	0.814	7.619
3	16.02	56	24	75	0.821	8.57



Graph 1. Load Vs Displacement Graph for tensile strength.



Graph 2. Load Vs Deformation graph for flexural strength.



Graph 3. Load Vs Deformation graph for compression strength.

At the maximum load of 7.8 kN, the deformation is 1.51 mm, as shown in Graph:3. The compression deformation increases with the load until it reaches its maximum value, after which it decreases. The final deformation is measured at 2.39 mm. The maximum compression strength recorded is 56 MPa.

CONCLUSION

The hybrid composite was created using short banana fiber flakes, sawdust fillers, and an epoxy polymer matrix. The mechanical properties were assessed, and grain size was analyzed using scanning electron microscopy. The key findings of this research are as follows:The maximum tensile strength observed is 16 MPa, which is higher compared to the other two samples. Additionally, the tensile strength increases with the percentage of banana fiber.The hybrid composite has a maximum flexural strength of 24 MPa. It is observed that as the volume fractions of reinforcements decrease, the bending strength also decreases.The hardness of the banana fiber composite reaches its maximum when the amount of sawdust filler material is increased. This is due to the high interlaminar bonding capacity between the materials.For this work the maximum harness obseved as 76 D.SEM analysis revealed that increasing the load for curing results in a more uniform distribution of the reinforcing elements throughout the epoxy matrix and a reduction in grain size.

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