IJETIR

ISSN (Online) 2583-0554

International Journal of Emerging Technologies and Innovative Research (IJETIR)

Impact Factor: 5.731

Volume 4, Issue 10, October 2024

Development and Characterization of Bamboo Mat Composites

Dipanshu Sharma[1], Munna Verma[1], Yadram Singh[2]
Department of Mechanical Engineering, Bhagwant University, Ajmer, India[1]
Department of Mechanical Engineering, Ideal Institute of Technology, Maharashtra, India[2]
syadram1984@gmail.com

Abstract: *The development and characterization of bamboo mat composites are the main topics of this research, which also examines how these materials might be used as sustainable substitutes for traditional ones. Bamboo is a renewable resource that grows quickly, making it a desirable choice for making eco-friendly composites. We assessed the bamboo mat composites' mechanical qualities using tensile, flexural, and impact tests. Furthermore, the material's viability for different applications was evaluated by analyzing its thermal and water absorption properties. In order to improve the performance of the composites and open the door to additional environmentally friendly material options, this research emphasises how crucial it is to optimise the bamboo treatment and resin choice. The composites with a composition of 50% bamboo mat and 50% epoxy showed the maximum tensile strength and tensile modulus, demonstrating the benefits of a well-balanced bamboo mat and epoxy resin combination.*

Keywords: Bamboo Mat, Epoxy Resin, Mechanical Characteristics, Water Absorption

I. INTRODUCTION

Respected for its quick growth and environmentally friendly characteristics, bamboo has become a viable substitute material in a number of industries, including furniture, building, and the automobile industry. Because of its remarkable mechanical qualities and environmental advantages, bamboo mat composites have attracted a lot of interest as the demand for long-lasting, environmentally friendly materials grows worldwide. In order to investigate the production methods, mechanical characteristics, possible uses, and environmental effects of bamboo mat composites, this paper explores their development and characterisation. This study aims to provide important insights into the development of sustainable materials technology and its consequences for contemporary industrial practices by utilising the renewable qualities of bamboo.

The literature has published a number of studies on composites made of polyester, epoxy matrix, and natural fibres such as wood, banana, sisal, coir, cardia dicotama, and wheat straw [1-3]. The tensile properties of polyester composites reinforced with bamboo fibres show that the strength increases with the amount of fibre present, as reported by Wong et al. [4]. Polyester natural fibres show good strength when treated with alkali, according to study by Varadharajulu et al. (quoted in Varadharajulu et al., 2005) [5]. Osorio et al. [6] concluded that the mechanical properties of treated composite samples are superior to those of untreated samples after examining the morphological aspects of both treated and untreated natural fibre hybrid composite samples. Oushabi and associates [7]

Composite materials are created by combining two or more distinct materials. The manner they are combined results in a composite material or composites with superior properties not achievable from the combination of the separate constituent materials. The most popular synthetic composite material is glass fibre reinforced polymers (GRP), which have a high strength, sufficient stiffness, and durability.

Composites are substances that clearly show a microscale interface between two or more chemically different elements. One or more discontinuous phases need to be surrounded by a continuous phase in order to create a composite [8].

Glass fibre reinforced plastics, the most popular category of synthetic composite materials, are created by mixing plastic with glass fibre (GRP). Fibre reinforced polymer composites are used in a wide range of items, such as sporting goods, public works projects, ships, submarines, helicopters, spaceships, and aeroplanes.

When two or more distinct macroscale components with dissimilar properties are combined to generate a new material with a property that is entirely different from the constituent pieces, the resultant material is called a composite material. The basic phase of a composite material is defined as a matrix that is continuous. Stated differently, matrix is a material that transfers the external load to the reinforcement by acting as a binder and holding the fibres in the desired location.

It is believed that these matrixes are less stiff and more ductile. The fibre, the matrix, and some filler make up the composite material. Fibres, either synthetic or natural, can be utilised to strengthen the material. The market is becoming more competitive as a result of the introduction of several natural fibre reinforced polymer composites (NFPCs) in response to the need for greater environmental security. NFPCs are superior to composites comprised of synthetic fibres in a number of ways.

Among these advantages are strong creep resistances, high toughness, high strength to weight ratios, and high strength at high temperatures [9]. Their low weight, high degree of durability, and adaptability in terms of design all contribute to these advantages. Thermoset or thermoplastic matrices can be utilised in NFPC construction.

This is primarily due to the fact that they weigh less and have unique characteristics from metals and ceramics. Polymer matrix composites can also be processed at low temperatures and pressures.

In this study, epoxy functions as the matrix material. Strong adherence to other materials, good mechanical and electrical insulating qualities, and strong chemical and environmental resistances are only a few of the classic advantages of epoxy, which normally has a glassy look [9].

By combining with natural fibre, epoxy forms a contact between the fibre and the matrix, resulting in a fiber-reinforced polymer composite. The qualities of the composites, which determine their eventual application, are controlled by the adhesion between the fibres and the matrix surrounding this junction. Widespread application in medical prostheses and tiny gadgets is possible. When it comes to high strength, durability, stiffness, corrosion resistance, fatigue resistance, and weight, composites perform better than the most popular metallic alloys, such as steel and iron. The constructability, improved mechanical qualities, low coefficients of thermal expansion, and superior dimensional stability of composites are among their advantages.

The usage of composite materials is rapidly increasing despite the fact that they are frequently more expensive than traditional materials. These advantages include increased functionality, durability, light weight, high specific characteristics, flexibility in design and production, and flexibility in manufacturing. The bulk of composites utilised in engineering applications use aramid, carbon, or glass fibers. The fibre used in FRP materials comes in the form of whiskers, small particles, or continuous filament.

Polymers, which include cellulose nitrite, polymides, polyvinyl alcohol, and polyisobutylene, are thermoplastic and thermosetting resins. Polyester, urea-formaldehyde, epoxy, and phenol-furfural are examples of thermosetting polymers.

High strength-to-weight ratios, increased toughness, fatigue resistance, electrical insulation, anti-friction qualities, ease of construction or diversity of fabrication techniques, greater longevity, and reduced maintenance costs are just a few of the many advantages of composite materials. They also have better stiffness, hardness, and toughness, as well as increased resistance to corrosion and fire. Continuous fibre composites have a two-dimensional (2D) laminated structure, with the fibres aligned along the plane of the material (in the x and y dimensions).

As these materials become increasingly common in their current industries and establish themselves in relatively new markets like those for biomedical devices and civil structures, the use of FRP composites is growing at an astonishing rate [10].It is reasonable to say that the most commonly used type of composite in structural applications, such those for cars, boats, aeroplanes, and other vehicles, is polymer matrix reinforced composite with woven textiles. The aircraft industry is a key application area for new types of quickly made composites because they are used to produce composite components using time-consuming high temperature curing techniques, which is acceptable if high performance materials or high utilisation temperatures are required [11].

The physical and mechanical properties of the matrix composite will be further modified by the inclusion of a solid filler phase during preparation. The use of particle filler materials to enhance the performance of polymers and their composites in structural and industrial applications has proven to be incredibly safe, and there is currently a lot of interest in this area. The quality of composite materials is improved and altered by the addition of fillers or additions.

Composite material can be classified into three types: Metal Matrix Composite (MMC), Polymer Matrix Composite (PMC), and Ceramic Matrix Composite (CMC) depending on the matrix that is employed. The kind of application determines which of the aforementioned composite materials should be used. Polymer matrix composites are the most widely utilised composites.

Table 1.1 Comparisons of Natural Fibers

Category	Common Uses	Strength	Elasticity	Moisture Absorption	Insulation
Plant Fibers (Cotton, Flax, Jute)	Clothing, ropes, sacks	Moderate to high	Low to moderate	High	Low
Animal Fibers (Wool, Silk)	Textiles, luxury garments	Moderate to high	High	High	High
Mineral Fibers (Asbestos, Basalt)	Insulation, construction	High	Low	Low	High

Because of their adaptability, sustainability, and advantageous qualities, natural fibres are essential to the textile industry as well as many other industries. All fibres, whether they come from plants, animals, or minerals, have unique qualities that suit them for particular uses.

Studies on plastics and cements reinforced with natural fibres, such as sisal, straw, banana, bamboo, coir, jute, pineapple leaf, and sun hemp, have been conducted [14–22]. For a number of reasons, short bamboo fibre was selected as the natural fibre for this investigation. The largest members of the grass family are bamboos. It is a tall, fleshy plant that is never quite like grass, even though it is technically a member of the grass family.

Table 1.2 Properties of Natural fibers [13]

Fiber	Tensile Strength (MPa)	Young's Modulus (Gpa)	Elongation at break (%)	Density gm/cc
Abacca	400	12	3-10	1.5
Alfa	350	22	5-8	0.89
Bagasse	290	17	--	1.25
Bamboo	140-230	11-17	--	0.6-1.1
Banana	500	12	5.9	1.35
Coir	175	4-6	30	1.2
Cotton	287-597	5.5-12.6	7-8	1.5-1.6
Curaua	500-1150	11.8	3.7-4.3	1.4
Date palm	97-196	2.5-5.4	2-4.5	1-1.2
Flax	345-1035	27.6	2.7-3.2	1.5
Hemp	690	70	1.6	1.48
Henequen	500±70	13.2±3.1	4.8±1.1	1.2
Isora	500-600	--	5-6	1.2-1.3
Jute	393-773	26.5	1.5-1.8	1.3
Kenaf	930	53	1.6	--
Nettle	650	38	1.7	--
Oil Palm	248	3.2	25	0.7-1.55
Piassava	134-143	1.07-4.59	21.9-7.8	1.4
Pineapple	400-627	1.44	14.5	0.8-1.6
Ramie	560	24.5	2.5	1.5
Sisal	511-635	9.4-22	2-2.5	1.5
E-glass	3400	72	--	2.5

Bamboo is most typically utilised for agroforestry, tools, utensils, houses, weaponry, and agricultural practices. Asia is the primary region for its cultivation, accounting for around 65% of the global bamboo resources [23]. China and India are the world's two largest bamboo producers. The overall area covered by bamboo, if bamboo found outside of forests is taken into account, is estimated to be 36 million hectares, or 3.2% of all the forest area. Bamboo forests cover 24 million of these 36 million hectares, or roughly 4.4 percent of the total forest area; they are all located in Asia [24].

The structural composite utilised in automobile roofs is made of longer bamboo strips; medium-sized bamboo flake can be used to make bamboo flake board; shorter bamboo fibres are used to make medium density fibreboard; and bamboo vaneer is used to make bamboo ply [25].

The possibility of employing bamboo for reinforcing concrete with flat, symmetrical construction decisions and smooth surface is being investigated using a combination of bamboo, bamboo strips, and wood veneer particles that play a vital role as new material and are used for concrete formwork [26]. Bamboo is frequently employed in many different fields, although it is rarely used in polymer matrix composites.

1.1 Objective of the present research work

The knowledge gap in the present literature review has helped us to set the objectives of this research work which are pointy highlighted below:

a. Fabrication of a new class of epoxy based composites reinforced with short bamboo fibres.

b. Evaluation of mechanical properties such as flexural strength, impact strength, tensile strength and hardness etc.

c. To study the influence of fiber lengths and fiber content on mechanical behavior of short bamboo fiber reinforced epoxy based composites.

d. To study of SEM..

II. MATERIAL AND METHODS

2.1 Materials

2.1.1. Matrix Material

Epoxy resin is the most widely used composite material for low-temperature applications, usually below 2000F (93°C), since it has excellent dimensional stability, excellent fibre adherence, and good chemical resistance.

Epoxy formulations can be made with a wide range of viscosities to accommodate different manufacturing processes and cure durations. They are free of volatiles that cause voids, have a long shelf life, and exhibit very little cure shrinkage. Araldite LY556, an epoxy resin, was utilised to create the composite in the presence study. Its density is between 1.15 and 1.20 g/cc and its viscosity is between 10,000 and 20,000 MPa-s at 25°C. The hardener used for the LY556 epoxy was Ardur HY951, which has a density of 1g/cc at 20°C and a boiling point of more than 200°C.

Figure 2.1 Epoxy resin

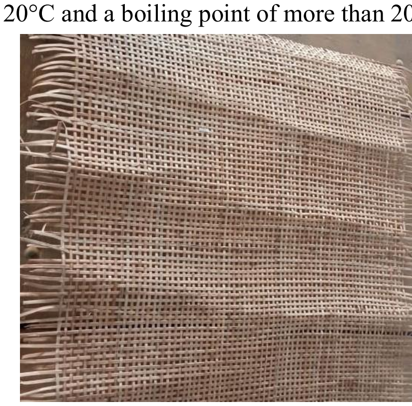

Figure 2.2 Bamboo mat

IJETIR
ISSN (Online) 2583-0554
IJETIR
Impact Factor: 5.731
International Journal of Emerging Technologies and Innovative Research (IJETIR)
Volume 4, Issue 10, October 2024

Table 2.1 Tensile Strength, Tensile Modulus, Density of Materials

S. no	Property	Value
1	Tensile Strength	63.5 - 73.5 MPa
2	Tensile Modulus	2.6 - 3.8 GPa
3	Flexural Modulus	3.35 GPa
4	Density	1.5 g/cm^3
5	Thermal Conductivity	0.19 - 0.25 W/(m·K)

2.2. Composites Fabrication

The composites with different ratios of epoxy and bamboo fibres were made by hand lay-up. Hand layup, rolling, curing, and chemical treatment of the fibre are important stages in the process. To produce the tensile test specimen, the aluminum mould was built in compliance with the ASTM standard. Two mild steel plates, each weighing roughly 10 kg, made up the arrangement; one was used as the foundation plate and the other as a plate to cover the plate. After it dried, it was ready to be used in specimen preparation. During the preparation phase, the aluminium mould was carefully cleaned and wrapped with cellotape to make the specimen removal easier.

Additionally, wilon wax was applied to the mould, which made the specimen removal process easy. The polythene material was also treated in wax and placed both above and below the aluminium mould because it was not intended to stick to the foundation plate (soft steel). Epoxy was measured out in a cup with a 10:1 hardener to epoxy ratio in mind for creating specimens with bamboo fibre composite contents of 50 wt%, 55 wt%, 60 wt%, and 65 wt%. Subsequently, the 50wt%, 45wt%, 40wt%, and 35wt% of epoxy were thoroughly mixed to guarantee that the epoxy coated every fibre in the bamboo. The hardener was added and the mixture was stirred for two to three minutes after the mixing was finished.

Next, the material was put into the aluminium mould; evenly spread using a roller, and the mould was closed and left for a day.

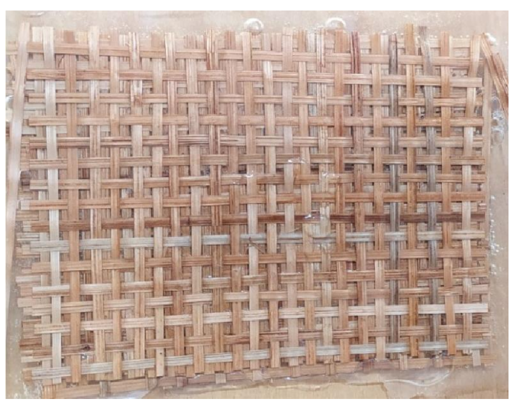

Figure 2.3 fabricated composites

Table 2.2 Designations and detailed compositions of composites

Designation	Composition
A_0	Bamboo Mat (50wt%) +Epoxy (50wt%)
A_1	Bamboo Mat (55wt%) +Epoxy (45wt%)
A_2	Bamboo Mat (60wt%) +Epoxy (40wt%)
A3	Bamboo Mat (65wt%) +Epoxy (35wt%)

Composition of few natural fibers

Natural Fiber	Cellulose (%)	Lignin (%)	Pentosans (%)	Ash (%)
Bamboo	26-43	21-31	15-26	1.7-5
Sisal	47-62	7-9	21-24	0.6-1
Jute	41-48	21-24	18-22	0.8
Kenaf	44-57	15-19	22-23	2-5
Cotton	85-90	0.7-1.6	1.3	0.8-2
Wood	40-45	26-34	7-14	<1

2.3 Mechanical Characterization

2.3.1 Density

The theoretical density (ρ_{ct}) of composite materials in terms of weight fractions of different constituents can easily be obtained as for the following equation given

$$\rho_{ct} = \frac{1}{\left(\frac{W_f}{\rho_f}\right) + \left(\frac{W_m}{\rho_m}\right)} \quad \text{.................... .... (1)}$$

Where, W and ρ present the weight fraction and density respectively. The suffixes f and m stand for the fibre and matrix respectively. Since the composites under this investigation consist of the components namely matrix, fibre and particulate filler, the expression for the density has been modified as

$$\rho_{ct} = \frac{1}{\left(\frac{Wf}{\rho f}\right)+\left(\frac{Wm}{\rho m}\right)+\left(\frac{Wp}{\rho p}\right)} \quad \text{........................... (2)}$$

Where, the suffix p stands for particulate fillers. The actual Density (ρ_{ce}) of the composite, However, it can be determined experimentally by simple water immersion method. The volume fraction of voids (V_v) in the composites is calculated using the following equation

$$V_v = \frac{\rho_{ct}-\rho_{ce}}{\rho_{ct}} \quad \text{................................ (3)}$$

2.3.2 Tensile Strength

Generally, flat specimens are used for the tensile test. The specimen has dimensions of 175 x 17 x 3 mm, and both ends are subjected to a uniaxial load. D 3039-76 is the description of the ASTM Standard Test technique for tensile characteristics of fibre resin composites. In the current work, the tensile strength of composite materials is determined using the test, which is carried out in the universal testing machine (UTM) (figure 2.4a) at a crosshead speed of 10 mm/min.

2.4 (a) The Universal Testing Machine

2.3.3 Flexural Strength

The highest tensile stress that a composite can bear during bending before breaking is known as its flexural strength. All of the composite samples in the Universal Testing Machine Instron 1195 undergo the three point bend experiment. Each specimen has the following dimensions: 100x20x3. The cross head speed is 10 mm/min, and the span length is 50 mm. In figure 3.5(b), the loading configuration is displayed. The following formula is used to calculate the composite specimen's flexural strength.

$$\text{Flexural Strength} = \frac{3PL}{2bt^2} \qquad \text{.....................} \ (5)$$

Where, L = span length of the sample (mm)
P = Maximum load (Newton)
b = Width of specimen (mm)
t = thickness of specimen (mm)

figure 3.5(b), the loading configuration

2.3.4 Impact test

An Izod impact tester was used to determine the impact strength. The samples were made in compliance with ASTM 256 specifications. In order to evaluate the Charpy impact properties, sub-size Charpy V-notched specimens that were 2 mm deep, 45 °C, and 5 mm thick were employed. The composites were measured at T26◦, room temperature. The incision on the specimen was 10 mm below the surface. The Charpy impact testing device and the composite specimen, measuring 60 mm by 12 mm by 5 mm, are shown in Figure 8. The Charpy pendulum in use has a 2.7 J capacity. That was the impact speed, 3.46 mm/s. For each case, five samples were tested in order to determine average values.

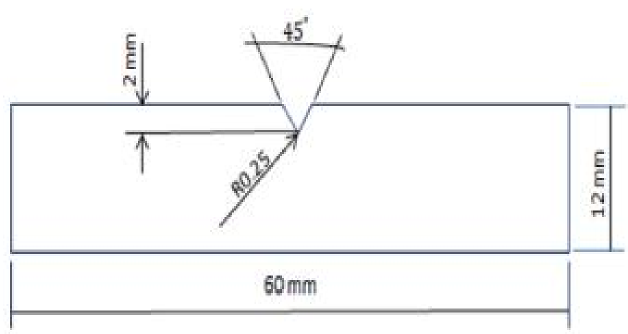

Fig.2.6 specimen dimension for charpy test.

Fig.2.7 Testing machine charpy impact.

2.4 Scanning Electron Microscopy

The Surfaces of the samples are examined directly by Scanning Electron Microscope (figure 3.8). The dimension of the each sample for SEM 25x25x3 mm.The composite samples is mounted on stubs with silver paste. To develop the conductivity of the samples, a thin film of platinum is vacuum-evaporated onto them before the photomicrographs are taken.

Figure 2.8 Scanning Electron Microscope

2.5 Rockwell hardness test

An effective, dependable, and reasonably easy method for determining a material's resistance to persistent deformation is the Rockwell hardness test. Because of its broad range of applications—from metals to polymers—it is indispensable for sectors requiring exact material selection and quality assurance. However, appropriate sample preparation, indenter selection, and testing protocol observance are necessary for its accuracy.

A popular technique for figuring out a material's hardness—a measure of resistance to deformation—is the Rockwell hardness test. It entails applying a certain load while pushing a hard indenter—either a diamond cone or a steel ball—into the material's surface. The hardness value, which appears as the Rockwell hardness number on a dial or digital readout, is determined by the depth of penetration HRB.

Figure 2.9 Rockwell hardness testing machine

III. TESTING AND ANALYSIS PROCEDURE

3.1 Tensile Tests Results

Table 3.1 (a). Results of tensile strength of bamboo mat-epoxy composite

Bamboo fiber	Tensile Strength (MPa)
A_0	22.75
A_1	18.25
A_2	14.5
A3	10.75

Tensile tests for hybrid composites, as well as tests with varying amounts of bamboo mat fibres (50w%, 55w%, 60w%, and 65w%) and epoxy resin (50w%, 45w%, 40w%, and 35w%), were conducted using a universal testing machine. Calculations of Young's modulus were made for strains between 0.05 and 0.25%. The dimensions of the samples utilised in this test were 120 × 10 × 5 mm.

The specimen of A_0 has a maximum tensile strength of (50wt%) + (50wt%) Epoxy, which equals 22.75 MPa, as indicated by the tensile test results displayed in Figure 3.2(f). A_3 is the minimal tensile strength. The maximum Tensile Modulus (MPa) for the A_0 speciman is 2250 MPa, while the minimum is 1025 MPa. Tensile modulus rises as epoxy resin weight percentage increases and falls as resin weight percentage decreases. The minimal tensile modulus is A_3. When compared to A_2, A_1 Bamboo Mat (50wt%) + Epoxy (50wt%) has a higher tensile modulus. The tensile moduli of A_3 to A_2, A_2 to A_1, and A_1 to A_0 increased by 1520 MPa, 1780 MPa, and 2250 MPa, in that order. In terms of tensile strength, A_0 Bamboo Mat (50wt%) + Epoxy (50wt%) provided the greatest value.

Figure 3.2(a)**.** Specimens tension test

IJETIR
ISSN (Online) 2583-0554
International Journal of Emerging Technologies and Innovative Research (IJETIR)
Impact Factor: 5.731
Volume 4, Issue 10, October 2024

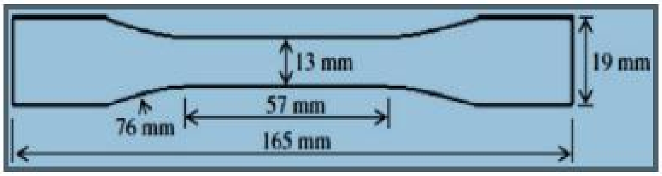

Fig.3.2(b) The dimensions of the tensile test specimen for matrix

Figure 3.2(c) specimens after breaking

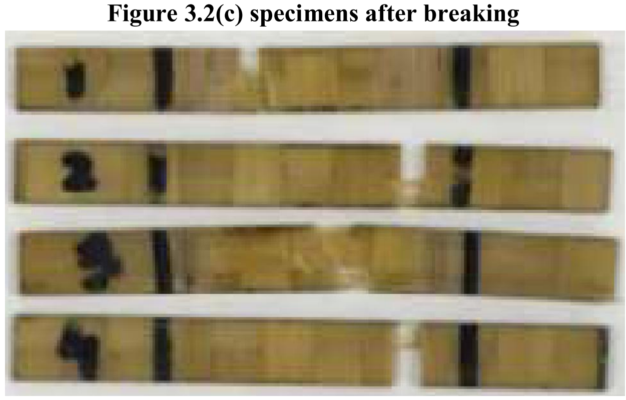

Fig.3.2 (d) specimen after tensile test

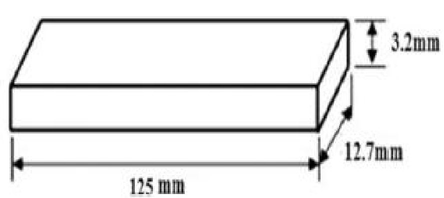

Fig 3.2(e). Dimensions of the flexural test specimen for matrix.

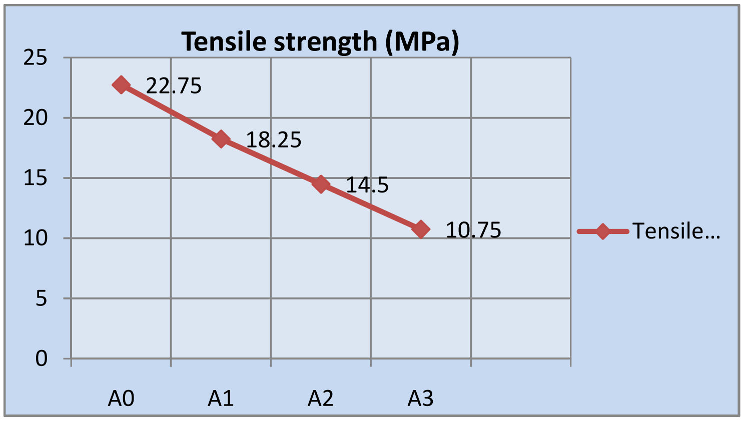

Figure 3.2(f). Comparison of tensile strength of bamboo mat-epoxy composites (w%)

Table 3.2(b) Tensile modulus of bamboo mat-epoxy composite with different compositions

Bamboo fiber	Tensile Modulus (MPa)
A0	2250
A1	1780
A2	1520
A3	1025

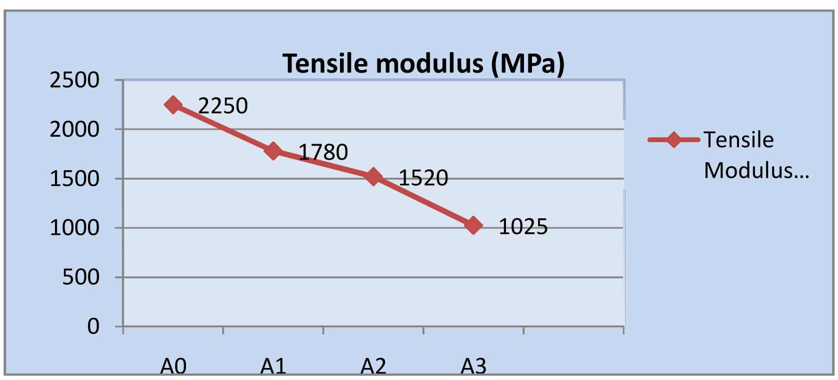

Figure 3.2(g). Comparison of Tensile modulus of bamboo-epoxy composite (w%)

3.3. Flexural Tests Results

The findings of the flexural test show that specimen A_0, [Bamboo Mat (50wt%) + Epoxy (50wt%)], has improved in terms of flexural strength and modulus. Flexural strength and modulus increased as the weight percentage in the composite increased. The flexural modulus and strength maximum values are displayed in Figures 3.3(a) and 3.3 (b). The A_1, [Bamboo Mat (55wt%) + Epoxy (45wt%)] specimen has the highest flexural modulus, at 4450 MPa, with 3500 MPa and 37.8 MPa, respectively. On the other hand, the maximum flexural strength values for the A_1 specimen are 56.5 MPa and A_0 3500 MPa, respectively. The reduction in flexural modulus from A_1 to A_0. Additionally, flexural strength rapidly decreases from A_1 to A_0 as a result of incorrect epoxy and hardner mixing, and there may be additional material-specific reasons.

The flexural modulus (E_f) and flexural strength (σfm) values are displayed in Table 3.3(c). Between A_0 and A_1, the flexural modulus rises by 14.24%. Flexural strength has increased by 24.05% between A_0 and A_1.

IJETIR
ISSN (Online) 2583-0554
International Journal of Emerging Technologies and Innovative Research (IJETIR)
Impact Factor: 5.731
Volume 4, Issue 10, October 2024

Table 3.3 (a) Flexural modulus of composites with different wt%

Bamboo Fiber	Flexural Modulus [MPa]
A0	3500
A1	4450
A2	1550
A3	1200

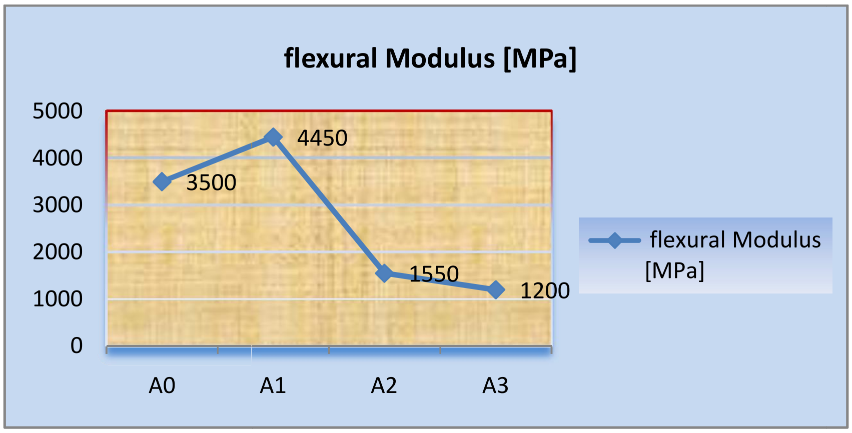

Figure 3.3 (a). Comparison of flexural modulus of bamboo mat-epoxy Composites with different compositions

Table 3.3 (b) maximum flexural strength of composites with different wt%

Bamboo fiber	maximum flexural strength [MPa]
A0	37.8
A1	56.5
A2	30.4
A3	20.45

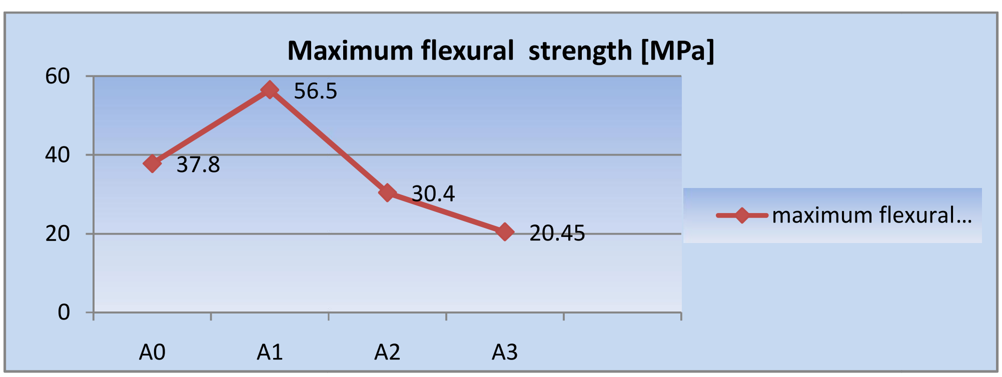

Figure 3.3(b). Comparison of flexural strength of bamboo-epoxy composites with different compositions

IJETIR

ISSN (Online) 2583-0554

International Journal of Emerging Technologies and Innovative Research (IJETIR)

Impact Factor: 5.731

Volume 4, Issue 10, October 2024

Table 3.3 (c) maximum flexural strength of composites with different wt%

Specimen	E_f [MPa]	σ_{fm} [MPa]
A1	3800 ± 320	38.96 ± 2.5
A2	4431 ± 165	51.30 ± 2.0
A3	2000 ± 125	31.08 ± 1.5
A4	1540 ± 50.5	20.24 ± 2.0

3.4. Impact Tests Results

As the fibre loading rises, the impact strength of epoxy resin composites reinforced with bamboo fibre diminishes. This is a result of the fibres' dense packing within the matrix, which raises interfacial friction and limits the composite's capacity to absorb energy and deform when struck. Figure 3.4 displays the impact strength of the specimens. As the filler level dropped, there was a discernible rise in the energy absorption rate. Out of all of them, specimen A_3, [Bamboo Mat (65wt%) + Epoxy (35wt%)], had the highest impact strength A_3 (5.25 kJ/m^2) and the lowest impact strength A_0 (2.57 kJ/m2). It also absorbed an astonishing 5.03 kJ/m^2 of energy, which is 6.63% more than A_2's 4.7 kJ/m^2 of energy.

Table 3.4 Impact Strength, Kj/m^{2}of composites with different wt%

Bamboo Fiber	Impact Strength ,Kj/m^2
A0	2.57
A1	3.62
A2	4.75
A3	5.25

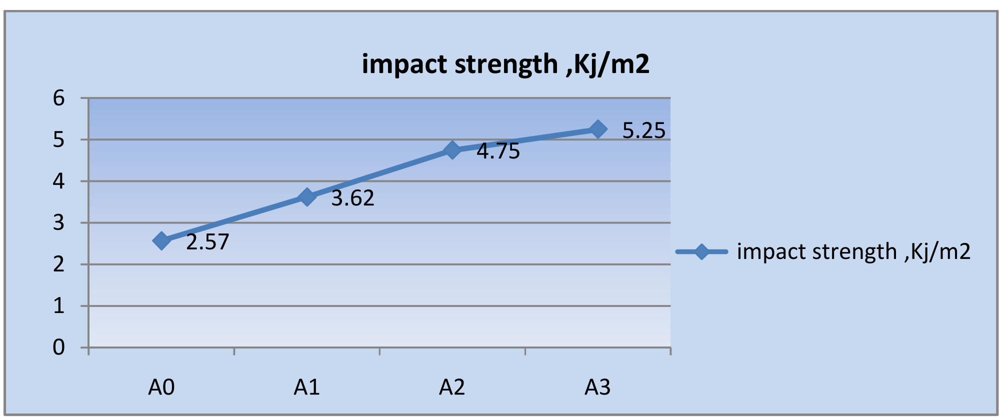

Figure.3.4. Comparison of Impact Strength of bamboo-epoxy composite with different compositions

3.5. Water Absorption Test

Using the following formula, the weight difference between the samples that were submerged in water and the samples that were dry was used to determine the percentage of water absorption in the composites.

$$M_t = ((W_t - W_o)) / W_o \times 100\% \qquad (1)$$

Where W_o is the specimen's weight prior to the water absorption test, W_t is the specimen's weight during the immersion period, and M_t is the specimen's moisture content.

The variation in the rate of water absorption is seen in Figure 3.5. A_0 [Bamboo Mat (50wt%) + Epoxy (50wt%)] has the least amount of water absorption, whereas A_3 [Bamboo Mat (65wt%) + Epoxy (35wt%)] has the most.Compared to A_1 [Bamboo Mat (55wt%) + Epoxy (45wt%)], A_2 [Bamboo Mat (60wt%) + Epoxy (40wt%)] has greater significance. According to the statistics, there was a notable absorption over the initial four days, followed by a notable drop. 20% suggests that there is considerable water absorption in the first four days and minimal absorption in the days that follow. It is evident that A_3 of them absorbs water more quickly than A_0 [50wt% Bamboo Mat + 50wt% Epoxy] of them. A_3[Bamboo Mat (65wt%) + Epoxy (35wt%)] water absorption was high during the first four days of the hybrid; there was thereafter a minor rise in absorption until the four day.

Based on the findings, A_3 [Bamboo Mat (50wt%) + Epoxy (50wt%)] absorbs water more quickly than A_0, with a notable absorption taking place in the first four days. Following this time, every sample experiences a sharp slowdown in the rate of absorption. This indicates that A_0 [Bamboo Mat (50wt%) + Epoxy (50wt%)] would be the best option in situations where water resistance is crucial, but A_3 [Bamboo Mat (65wt%) + Epoxy (35wt%)] could not work well in environments that are prone to moisture due to its greater water absorption rate.

Table 3.5 Water Absorption (%) composites with different wt% Bamboo Fiber

No. of Days	Bamboo Fiber	Water Absorption (%)
1	A_0	1
2	A_1	1.25
3	A_2	1.32
4	A3	1.36

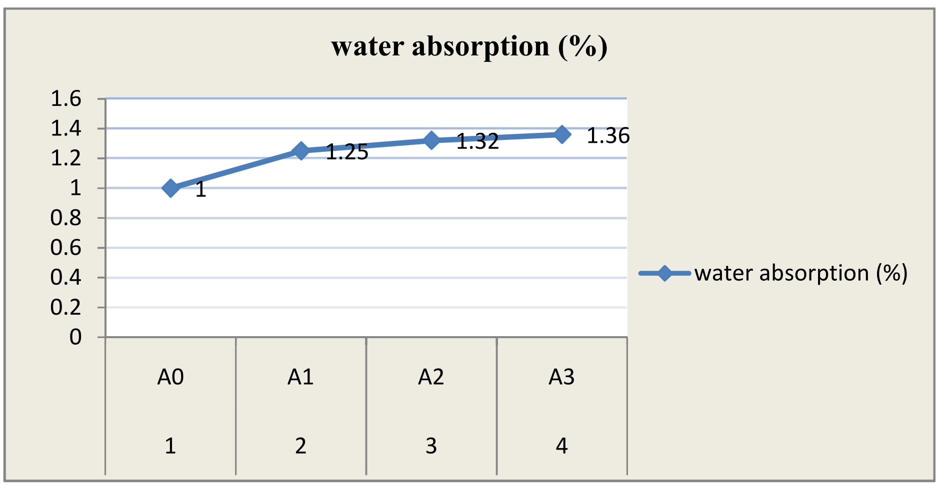

Figure 3.5. Comparison of water absorption of different composites

3.6. Hardness Test (Rockwell)

Because bamboo fibres are naturally rigid and robust, a higher fibre content often results in a harder composite. On the other hand, voids or weak interfaces may cause the hardness to drop if the fiber-matrix bonding is inadequate.

The combination of epoxy and hardener was found to be the hardest after several examples were tested. The hardness of composites made of bamboo fibre increases with the amount of fibre; A_3[Bamboo Mat (65wt%) + Epoxy (35wt%)] has a hardness of 28 HRB.

The resulting composites' hardness values are presented in Figure 3.6. The A_3 [Bamboo Mat (65wt%) + Epoxy (35wt%)] composite is more durable than the other composites that were made (A_0, A_1, and A_2), as shown in Figure 3.6. It should be mentioned that the produced composites' hardness value rises. * A_3 [Epoxy (35wt%) + Bamboo Mat

(65wt%)] weight percentage (wt%) of fibre rises. The highest hardness value for A_3[Bamboo Mat (65wt%) + Epoxy (35wt%)] is 28 HRB, while the lowest hardness number for A_0[Bamboo Mat (50wt%) + Epoxy (50wt%)] is 7. In contrast to A_1 and $A_{0,}$ A2[Bamboo Mat (60wt%) + Epoxy (40wt%)] has greater hardness. epoxy weight percentage declines along with it. The highest hardness number is observed in A3[Bamboo Mat (65wt%) + Epoxy (35wt%)].

Table 3.6. Hardness test of Bamboo epoxy resin composite

specimen lavel	rockwell hardness number(HRB)
A0	18
A1	20
A2	24
A3	28

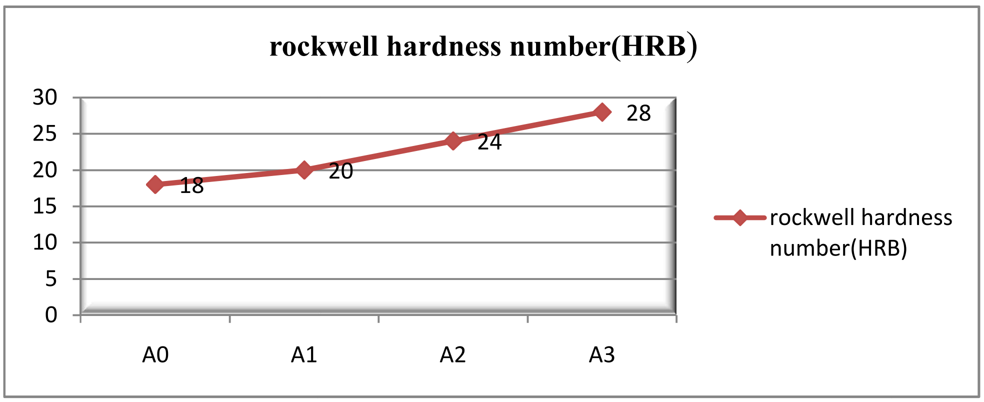

Figure 3.6. Comparison of hardness with different composite specimen

IV.0. SCANNING ELECTRON MICROSCOPY

A scanning electron microscope (SEM, NOVA NANOSEM 450) operated in high vacuum mode at an accelerating voltage of 20 kV was used to examine the tensile fracture morphology of the composite. One useful method to verify that the fibre and matrix are attached to each other is to use SEM pictures. Whether or not the fibre bundles are actually impregnated by the matrix may be seen in images of the fracture surfaces. Fig. 4.7(a) shows the fibre fracture surface with matrix trace, emphasising the superior interface quality. Furthermore, these micrographs show that, in the case of bamboo fibre composites, the fibres were separated rather than removed from the matrix [12].

SEM images of the tensile fracture samples of the natural bamboo fiber/epoxy composites are shown in Figs. 4.7 (a) and (b). These images demonstrate a few fractures on the matrix surface, which is another sign of a strong adhesion between the fibre and matrix. A fracture on the matrix's surface is the result of force being passed from the matrix to the fibre during the tensile test; similar results are shown in Fig. 4.7(c), where fibre breaking is observed at the fiber-matrix contact. The size 0.52 µm (9, 13, 18 wt%) is shown in Figs. 4.7 (d), (e), and (f). There was less void development and filler clumping aggregation in bamboo fiber/epoxy composites.

The strong link between the fibre and matrix is evident as the epoxy resin has completely penetrated the fiber's surface. Figs. 4.7(g) and (h) show the fibre breakage and voids of the 1.5 µm bamboo fiber/epoxy composites. The void discovered on the 18 weight percent bamboo composites is shown in Figure 4.7(a) and (b). Low mechanical characteristics resulted from insufficient interface bonding between the fibre and matrix due to a lower concentration of vacancies on the composite surface.

IJETIR

ISSN (Online) 2583-0554

International Journal of Emerging Technologies and Innovative Research (IJETIR)

Impact Factor: 5.731

Volume 4, Issue 10, October 2024

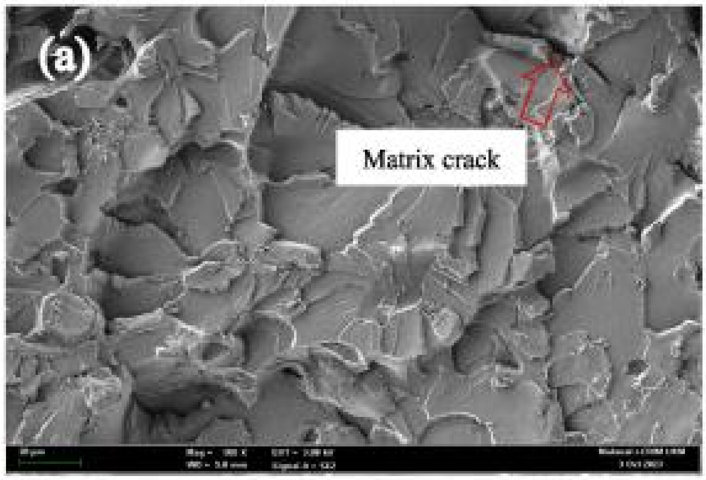

Fig.4.1 (a). SEM micrograph of tensile section failure for bamboo fiber/epoxy composites Matrix crack.

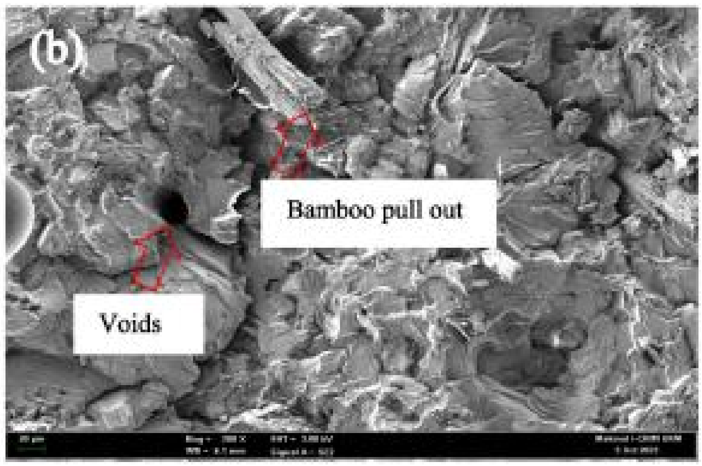

Fig. 4.2(b). SEM micrograph of tensile section failure for bamboo fiber/epoxy composites Bamboo pull out

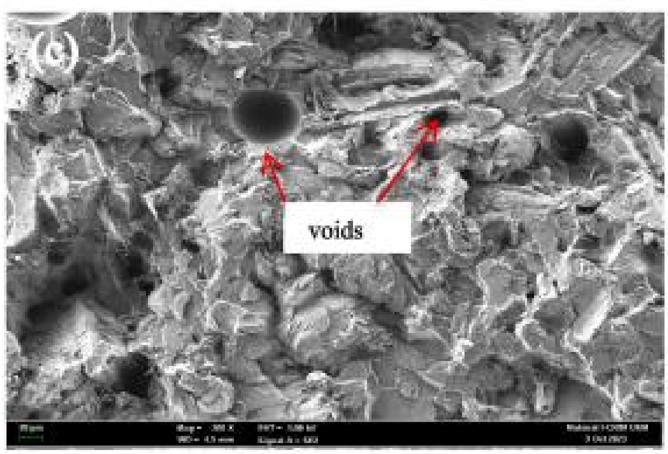

Fig.4.3 (c). SEM micrograph of tensile section failure for bamboo fiber/epoxy composites Voids.

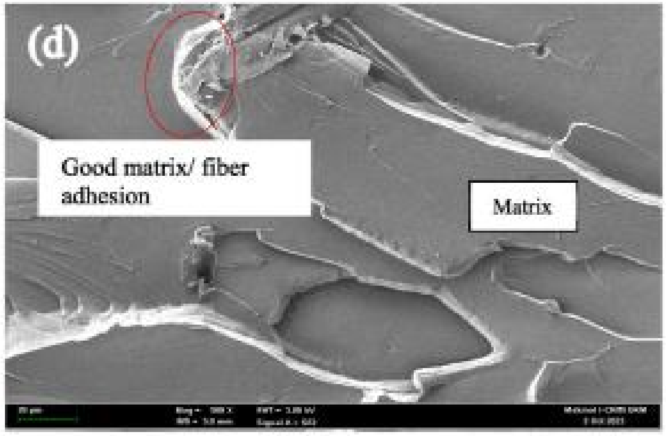

Fig.4.4 (d). SEM micrograph of tensile section failure for bamboo fiber/epoxy composites good matrix/fiber adhesion

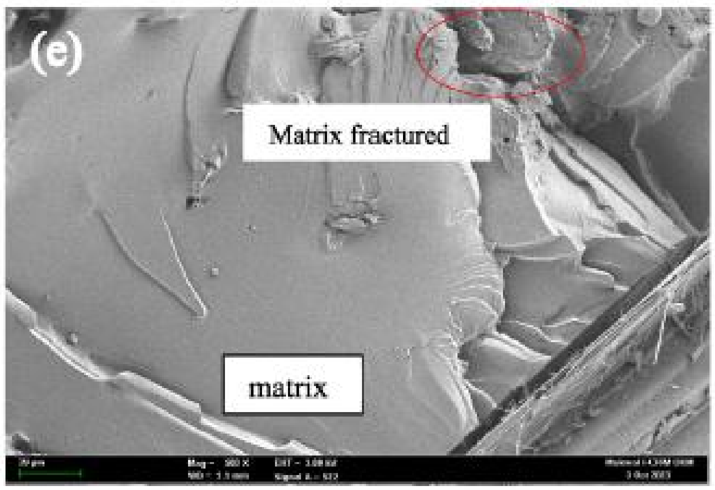

Fig.4.5 (e). SEM micrograph of tensile section failure for bamboo fiber/epoxy composites Matrix fractured

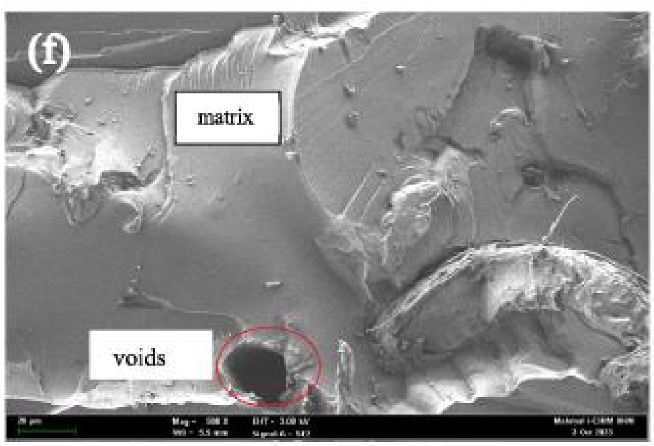

Fig. 4.6(f). SEM micrograph of tensile section failure for bamboo fiber/epoxy composites Fiber voids

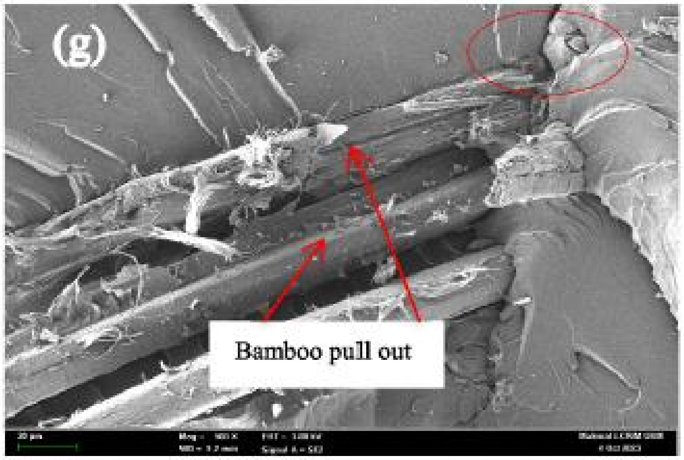

Fig.4.7 (g). SEM micrograph of tensile section failure for bamboo fiber/epoxy composites
Bamboo pull out

Fig. 4.8 (h). SEM micrograph of tensile section failure for bamboo fiber/epoxy composites
Fiber fractured and pull out

V. CONCLUSION

The specimen with A_0 has a maximum tensile strength of 22.75 MPa, calculated as 50wt% + 50wt% Epoxy. A_3 is the minimal tensile strength. The maximum Tensile Modulus (MPa) for the A0 speciman is 2250 MPa, while the minimum is 1025 MPa. Tensile modulus rises as epoxy resin weight percentage increases and falls as resin weight percentage decreases. The minimal tensile modulus is A_3. When compared to A_2, A1 Bamboo Mat (50wt%) + Epoxy (50wt%) has a higher tensile modulus. The tensile moduli of A_3 to A_2, A_2 to A1, and A_1 to A_0 increased by 1520 MPa, 1780 MPa, and 2250 MPa, in that order. In terms of tensile strength, A_0 Bamboo Mat (50wt%) + Epoxy (50wt%) provided the greatest value.

In contrast, the tensile strengths of A_3 to A_2, A_2 to A_1, and A_1 to A_0 increased by 28.36%, 19.31%, and 18.20%, respectively. The findings of the flexural test show that specimen A_0, [Bamboo Mat (50wt%) + Epoxy (50wt%)], has improved in terms of flexural strength and modulus. Flexural strength and modulus increased as the weight percentage in the composite increased. The A_1, [Bamboo Mat (55wt%) + Epoxy (45wt%)] specimen has the highest flexural modulus, at 4450 MPa, with 3500 MPa and 37.8 MPa, respectively. On the other hand, the maximum flexural strength values for the A_1 specimen are 56.5 MPa and A_0 3500 MPa, respectively.

The reduction in flexural modulus from A_1 to $A_{0.}$ Additionally, flexural strength rapidly decreases from A_1 to A_0 as a result of incorrect epoxy and hardner mixing, and there may be additional specific material-related reasons.The flexural modulus (E_f) and flexural strength (σ_{fm}) values are displayed in Table 4.3(c). Between A_0 and A_1, the flexural modulus rises by 14.24%. Flexural strength has increased by 24.05% between A0 and A1.

As the filler level dropped, there was a discernible rise in the energy absorption rate. Out of all of them, specimen A_3, [Bamboo Mat (65wt%) + Epoxy (35wt%)], had the highest impact strength A_3 (5.25 kJ/m^2) and the lowest impact strength A0 (2.57 kJ/m^2). It also absorbed an astonishing 5.03 kJ/m^2 of energy, which is 6.63% more than A_2's 4.7 kJ/m^2 of energy. Conversely, the impact strengths of specimens A_1 [Epoxy (45wt%) + Bamboo Mat (55wt%)] and A_2 were 4.75 kJ/m^2 and 3.62 kJ/m^2, respectively. There was a 0.63% difference in impact strength between A_0 and A_1.

A_0 [Bamboo Mat (50wt%) + Epoxy (50wt%)] has the least amount of water absorption, whereas A_3 [Bamboo Mat (65wt%) + Epoxy (35wt%)] has the most.Compared to A_1 [Bamboo Mat (55wt%) + Epoxy (45wt%)], A_2 [Bamboo Mat (60wt%) + Epoxy (40wt%)] has greater significance. According to the statistics, there was a notable absorption over the initial four days, followed by a notable drop. 20% suggests that there is considerable water absorption in the first four days and minimal absorption in the days that follow. It is evident that A_3 of them absorbs water more quickly than A_0 [50wt% Bamboo Mat + 50wt% Epoxy] of them. A_3[Bamboo Mat (65wt%) + Epoxy (35wt%)] water absorption was high during the first four days of the hybrid; there was thereafter a minor rise in absorption until the four day.

Based on the findings, A_3 [Bamboo Mat (50wt%) + Epoxy (50wt%)] absorbs water more quickly than $A_{0,}$ with a notable absorption taking place in the first four days. Following this time, every sample experiences a sharp slowdown in the rate of absorption. This indicates that A_0[Bamboo Mat (50wt%) + Epoxy (50wt%)] would be the best option in situations where water resistance is crucial, but A3[Bamboo Mat (65wt%) + Epoxy (35wt%)] could not work well in environments that are prone to moisture due to its greater water absorption rate.

The combination of epoxy and hardener was found to be the hardest after several examples were tested. The hardness of composites made of bamboo fibre increases with the amount of fibre; A_3[Bamboo Mat (65wt%) + Epoxy (35wt%)] has a hardness of 28 HRB.

Compared to the other composites (A_0, A_1, and A_2), the composite A_3 [Bamboo Mat (65wt%) + Epoxy (35wt%)] is harder. It should be mentioned that the produced composites' hardness value rises. * A_3 [Epoxy (35wt%) + Bamboo Mat (65wt%)] weight percentage (wt%) of fibre rises. The highest hardness value for A_3[Bamboo Mat (65wt%) + Epoxy (35wt%)] is 28 HRB, while the lowest hardness number for A0[Bamboo Mat (50wt%) + Epoxy (50wt%)] is 7. In contrast to A_1 and A_0, A_2[Bamboo Mat (60wt%) + Epoxy (40wt%)] has greater hardness. epoxy weight percentage declines along with it. The highest hardness number is observed in A_3[Bamboo Mat (65wt%) + Epoxy (35wt%)].

A few fractures on the matrix surface can be seen in the SEM pictures of the tensile fracture samples of the natural bamboo fiber/epoxy composites. An additional sign of a strong adhesion between the fibre and matrix is the surface fracture. A surface fracture in the matrix occurs when force is applied from the matrix to the fibre during the tensile test. Similar results are shown, showing that fibre breakage occurs at the fiber-matrix interface.

5.1 Scope for Future Work

By using these concepts, stakeholders can successfully harness the potential of bamboo mat composites to transform the field of sustainable materials technology. This would not only help protect the environment but also boost economic growth by taking the lead in the global composite materials market and fostering innovation.Because of their eco-friendliness, affordability, and mechanical properties, bamboo mat composites (BMCs) present a sustainable option for traditional materials. Many research and development subjects can still be explored to improve their application and performance.

REFERENCES

[1]. Rao, K. M., Rao, K. M., & Prasad, A. R. (2010). Fabrication and testing of natural fibre composites: Vakka, sisal, bamboo and banana. Materials & Design, 31(1), 508-513. doi:10.1016/j.matdes.2009.06.023

[2]. Sathishkumar, T., Navaneethakrishnan, P., & Shankar, S. (2012). Tensile and flexural properties of snake grass natural fiber reinforced isophthallic polyester composites. Composites Science and Technology, 72(10), 1183-1190. doi:10.1016/j.compscitech.2012.04.00

[3]. Rao, K. M., Prasad, A. V., Babu, M. N., Rao, K. M., & A. V. S. S. K. S. Gupta. (2007). Tensile properties of elephant grass fiber reinforced polyester composites. Journal of Materials Science, 42(9), 3266-3272. doi:10.1007/s10853-006-0657-8

[4]. Wong, K., Zahi, S., Low, K., & Lim, C. (2010). Fracture characterisation of short bamboo fibre reinforced polyester composites. Materials & Design, 31(9), 4147-4154. doi:10.1016/j.matdes.2010.04.029

[5]. Reddy, E. V., Rajulu, A. V., Reddy, K. H., & Reddy, G. R. (2010). Chemical Resistance and Tensile Properties of Glass and Bamboo Fibers Reinforced Polyester Hybrid Composites. Journal of Reinforced Plastics and Composites, 29(14), 2119-2123. doi:10.1177/0731684409349520

[6]. Al-Bayati, R. I., Nief, O. A., & Hameed, A. N. Synthesis Of 2, 5-Disubstituted-1, 3, 4-Thiadiazole Derivatives And Evaluation of Their Antibacterial Activity.

[7]. Osorio, L., Trujillo, E., Vuure, A. V., & Verpoest, I. (2011). Morphological aspects and mechanical properties of single bamboo fibers and flexural characterization of bamboo/ epoxy composites. Journal of Reinforced Plastics and Composites, 30(5), 396-408. doi:10.1177/0731684410397683.

[8]. Agarwal,B.D and Broutman L.J.(1990),“Analysis and Performance of fiber Composites”, Second edition, John wiley & Sons, Inc, pp.2-16.

[9]. Sethy S.R, “A study on mechanical behaviour of surface modified natural fiber based polymer composites” Thesis, NIT Rourkela, (2011).

[10]. Tong L,Mouritz A.P and Bannister M.K,(2002).“3D Fiber Reinforced polymer Composites”, Elsevier Science Ltd, The Boulevard, Langford Lane, Kindlington, Oxford OX5IDB,UK,1-2.

[11]. Suhreta Husic,Ivan Javni, Zoran S, Petrovic,(2005),“Thermal and mechanical properties of glass reinforced soy - based polyurethane composites”,composites science and Technology 65(2005),pp. 19-25.

[12]. Sastra H Y, Siregar J P, Sapuan S M, Leman Z & Hamdan M M, Polym-Plast Technol Eng, 45 (2006) I-8.

[13]. John M. J and Anandjiwala R. D, (2008). Recent Developments in Chemical Modification and Characterization of Natural Fiber-Reinforced Composites, Polymer Composites, 29(2), pp.187-207.

[14]. Handbook of Engineering Polymeric Materials,” edited by N. P. Cheremisinoff (Marcel Dekker, New York, 1997).

[15]. Collier J. R., Fahrurrozi M., Lu M. and CollierB. J. “cellulosic reinforcement in reactive composite systems” Journal of Applied Polymer Science vol 61(1996) pp-1423-1430.

[16]. Karmaker A. C., “Effect of water absorption on dimensional and impact energy of jute fiber reinforced polypropylene” Journal of Material Science Letters vol 16 (1997) pp 462-464.

[17]. Chanda N. and Hashmi S.A.R., “Mechanical properties of sisal fibre at elevated temperatures” Journal of Material Science ,vol 28 (1993) pp 6724.

[18]. Mahato D.N., Mathur B.K. and Bhatacherjee S ., “Radial distribution function analysis of coir fibre” vol 28 (1993) pp 2315-2320. Devi L. Uma , Bhagawan S S and Thomas S, “Mechanical properties of Pineapple leaf fiber-reinforced polyster composite” Journal of Applied Polymer Science 64 (1997) pp 1739-1748.

[19]. White N. M. and Ansell M. P, “Straw reinforced polymer composites” Journal of Material Science 18 (1983) pp- 1549 -1556.

[20]. Shin F G , Xian x j , Zheng W P , Yipp M W “Analyses of the mechanical properties and microstructure of bamboo-epoxy composites” journal of material science ,vol 24 , pp- 3483-3490.

[21]. Lobovikov M, Paudel S, Piazza M, Ren H, Wu J, Non-wood Forest products (18), World Bamboo Resources, A thematic study prepared in the framework of the Global Forest Resources Assessment, Rome, 2007.

[22]. Suhaily S.S, Khalil H.P.S.A, Nadirah W.O.W & Jawaid M, "Bamboo Based Biocomposites Material, Design and Applications"; pp. 492.

[23]. Xiao, Y, & Ma, J. Fire Simulation Test and Analysis of Laminated Bamboo Frame Building. Construction and Building Materials. (2012). , 34(0), 257-66.

[24]. Oushabi, A., Sair, S., Hassani, F. O., Abboud, Y., Tanane, O., & Bouari, A. E. (2017). The effect of alkali treatment on mechanical, morphological and thermal properties of date palm fibers (DPFs): Study of the interface of DPF–Polyurethane composite. South African Journal of Chemical Engineering, 23, 116-123. doi:10.1016/j.sajce.2017.04.005.

[25]. Oushabi, A., Sair, S., Hassani, F. O., Abboud, Y., Tanane, O., & Bouari, A. E. (2017). The effect of alkali treatment on mechanical, morphological and thermal properties of date palm fibers (DPFs): Study of the interface of DPF–Polyurethane composite. South African Journal of Chemical Engineering, 23, 116-123. doi:10.1016/j.sajce.2017.04.005.

[26]. Wambua P, Ivens J, Verpoest I. Natural fibres: can they replace glass in fibre reinforced plastics? Compos Sci Technol 2003;63:1259–64