

Mechanical characteristics of Biomaterial Particles Reinforced Epoxy Resin Composites for Automobile Accessories

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Abstract

In this study, rattan corncob composite materials were developed and their mechanical properties were determined. This was with a view to producing alternative composite materials for automobile applications. Dried corncobs and rattan cane were crushed, treated with caustic alkali NaOH_(aq) and transferred into a water bath machine to reduce the hydrophilic nature of the fibres in the polymer. The shredded corncobs and rattans cane were sun-dried after the treatment to remove the moisture content and were further pulverized and sieved to obtain 400µm particle size. Compositions of the particles were varied for seven samples with the binder kept constant at 80wt% of the whole mixture and forming them into particle panels using a metal mould. The process was repeated in order to obtain three replicates to get the exact mean value. The produced panels were tested for density, water absorption, tensile strength and modulus, flexural strength and modulus, and optical microstructure. The results revealed that the densities ranged between 1.06g/cm³ to 1.30g/cm³, the water absorption properties ranged between 0.87% to 4.55%, tensile strength ranged between 42MPa to 90MPa, tensile modulus ranged between 2.2GPa to 5.9GPa, flexural strength ranged between 50MPa to 70MPa and flexural modulus ranged between 1.5GPa to 2.7GPa. It was concluded that the developed composite materials have good mechanical properties and could serve as alternative materials for making automobile accessories like bumpers and spoilers. It could also help in solving the problem of environmental pollution caused by open burning.

Keywords: agricultural wastes, mechanical strength, mechanical modulus, automobile accessories



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1.0 Introduction

A composite material is a solid structural material that consists of two or more constituents (either in whole or particulate forms) combined together without being soluble in each other. Majorly, a composite material comprises two parts known as the reinforcing phase and the matrix. Flakes, fibres, and particulate materials are examples of the reinforcing phase, while polymers such as epoxy resin, polyvinyl chloride, and local starch slurry are examples of matrix phase materials. Composite materials have the advantage over a pure metallic material in terms of mechanical strength, weight, corrosion resistivity and cost advantage among others (Bledzki et al., 2015). Composite materials became very popular in automotive, aerospace, marine and sporting goods applications because of their appreciable in weight reduction and mechanical strength. An example of a composite system is polyvinyl chloride reinforced with graphite fibres. Composite materials are designed for engineering the properties of combined materials whose constituents possess interesting properties. Properties of these materials depend strongly on the volume fraction and properties of each of its constituent materials. Natural fibres are potential reinforcing materials and they have been used in the past for traditional applications (Oladele and Okoro, 2015). In automobile industries, the composite materials are used in racing cars to reduce weight. Car bonnets and spoilers are among the parts of an automobile made of composite materials. They offer much lighter parts and are cheaper when compared with wood or metallic structures (Terzopoulou et al., 2015); (Adekunle et al., 2018).

Composite panels have now been used in sport applications like badminton and golf games. The lightweight and the strength of the glass fibre are the reasons why it is used in golf application. Badminton racket frames are made from composite materials of good physical and mechanical properties such as strength and flexibility. Traditional fibres like carbon fibre and glass fibre are used as reinforcement in making composite materials. For instance, glass fibre and carbon fibre offer lightweight material substitutions for automotive parts. This enables a car to consume less fuel to overcome drag during motion (Scarponi and Messano, 2015). However, a new issue came up regarding the uncontrolled disposal of artificial fiber composites. These composites are non-biodegradable and can cause environmental pollution during open burning. Disposal of these trashes into the sea can harm sea creatures and some other aquatic plants in the seas. On land, these materials pollute land, clog the drain and create air pollution when burned in the air. Natural fibre composites are gaining popularity in recent years due to these issues. They are biodegradable in nature, which means they are environmentally friendly and are easy to source. They are very cheap when compared to the cost of artificial fiber composite materials. For example, hemp is a natural fiber that is readily available and does not require energy and time to process before being used as a component in composites (Terzopoulou et al., 2015). However, there are limitations in using natural fibre as reinforcement in composite materials. These include incompatibility with the matrix, the risk of degradation due to water absorption properties, and the physical properties which create a weak bond between the filler and matrix (Anbukarasi and Kalaiselvam, 2015).

There have been cases where natural fibres do not form a uniform phases with the matrix; because of the weak bonds between them, composite degradation, and filler geometry. In order to overcome these limitations, the nanoparticle calcium trioxocarbonate can be used to increase the tensile strength and the water resistance of kenaf reinforced polymer composite to about 20% when compared with kenaf reinforced polymer composite without nanoparticle impregnation (Xia et al., 2015). Corncobs are agricultural waste materials of cereal making industries like Unilever Plc, Nestle Nigeria Plc, etc, which are discarded off openly, and they cause environmental pollution. Many researchers have studied the use of many agricultural waste materials such as corncob, rice-husk, sawdust, sugarcane bagasse, bamboo fibre, coconut fibre. The results revealed that these agricultural-wastes can be used in epoxy polymer as fillers for structural purposes. Corncob constitutes larger percentage of corn's waste. It is calculated that the corn cob is about 45-55% of the corn. The size of the corncob is affected by the corn's varieties. Corncob contains a higher percentage of hemicelluloses (11.8%) when compared with the content of other agricultural-products (Richana et al., 2007). Rattan canes are generally hollow-filled usually slender and flexible plants grown mostly in marshy areas. Rattan canes are very important forest products, they are part of the bamboo family and their use in Portland cement has been studied extensively by Clemson Agricultural College (Archila et al., 2018). Rattan cane is the major essential product of rattan because it has appreciable properties such as toughness, flexibility and shiny skin. In the area of furniture making, it is used either in whole form or curve form because of its flexibility. In engineering field, researchers can either use it in particulate form or also in whole form as matrix reinforcement depending whether particulate or fibre composites. It is used as cane in some schools in southwestern part of Nigeria just because it takes time to fail, thereby, it is more economical. Village people in the Western Africa region are also fond of using rattans as hunting tools e.g. fish and rat trap, and also in farms, to tie fire wood and yam. It is calculated that about 25% of the identified rattan families are of some commercial advantages. The other rattan families are not being utilized because of their brittleness and being their proneness to fracture or due to biological rarity (Dransfield et al., 2002).

Rattan canes and Corncobs are very important agricultural waste products. People have used them extensively for various activities like medicine, energy source, furniture making, cooking utensils, roofing, and reinforcements in composite materials. Adekunle et al. (2015) developed a concrete beam by using rattan as reinforcement. It was discovered that the bending strength of rattan reinforced concrete beam is 2.56 N/mm², which shows that the bending strength of rattan reinforced concrete beams is 21% of the traditional steel-reinforced concrete bar when compared with concrete beam without reinforcement. Furthermore, they also concluded that the bending modulus of rattan reinforced concrete beam is 0.83 N/mm². Therefore, the bending modulus of rattan reinforced concrete beams is 14% of the conventional steel-reinforced concrete when compared with concrete beam without steel. Oladele and Okoro (2015) worked on rattan particulate reinforced paper pulp-based composites. Their results revealed that the choice of chemically treated rattan particles and

locally prepared cassava starch paste to reinforced wet paper is extremely good for the material productions used in structural applications. It was discovered that rattan offers more bending strength and bending modulus of 1.97N/mm^2 and 56.21N/mm^2 respectively to the paper pulp. In addition, the bond strength of the treated rattan particulates reinforced paper pulp was also discovered to be much higher than the untreated one. Akinyemi et al. (2015) conducted an investigation on the use of corncob particles and sawdust as reinforcement in a polymer matrix. The study revealed that the modulus of rupture and the tensile modulus increase as the percentage composition of corncob increases up to 75% and decrease afterwards. The study concluded that the mechanical properties of the produced panels were increased with an increase in the percentage composition of corncob. The 75% composition of corncob in the panel had contributed to the increase in value of moduli of rupture and elasticity, but possess poor physical properties. Kiran et al. (2015) investigated the mechanical behaviors of corncob particles and E-glass as reinforcement in a polymer matrix. The results show that 25%CC particles and 4.8% E-glass fibre exhibited good mechanical strength of 18MPa; the flexural load carrying capacity of 22.5% CC and 7.5% E-glass are better and gave the optimum value of 37.14MPa. They concluded that the use of corncob and E-glass as reinforcements provide good material alternatives for artificial filler-reinforced composite panels. The aim of this study was to develop rattan corncob composite materials and to determine the mechanical properties of the produced composite materials. These were with a view to looking for alternative composite materials for automobile applications.



Figure 1: Corncobs and Rattan canes in the whole form

2. MATERIALS AND METHODS

2.1. Materials

The materials used during the course of this study are; corncobs, rattan canes, epoxy and hardener, water, sodium hydroxide solution, water bath machine, pestle and mortar, detachable metal mould, measuring cylinder, sieve, cutlass, hammer, stirring rod, polythene nylon bags, air cream, and knife. The equipment used are; a digital electronic measuring balance, a computerized universal testing machine (UTM), and milling machine. These agro-waste materials were selected because this in the long-run can reduce the rate at which agro-wastes would be burnt openly or left to decompose, thus causing environmental pollution. Also, agro-waste possesses appreciable strength and flexural properties.

2.2 Methods

The methods used in this present study are as follows;

(a) Production of epoxy

Grade LY 127 ED resin and its hardener were used in mixed ratio 2:1

epoxy to hardener to increase the curing rate, these chemicals are the products of Aditya Birla Chemical Limited Thailand, procured from Tony Nigeria Enterprises Ojota, Lagos, Nigeria.

(b) Chemical treatment

The shredded rattan and corncob fibres were treated with 2 molar caustic soda (prepared by dissolving and proper stirring of sodium hydroxide (160g) in 2dm^3 of water). The fibres being hydrophilic in nature was soaked in the solution separately for 2 hours and then transferred into the water bath machine (MODEL NO.DK-420) at a temperature of 70°C as shown in Plate 1. The fibres were later removed after 4 hours from the machine, washed and sun dried. This process was aimed to prevent the fibres affinity for water when embedded into the resin (Oladele and Okoro, 2015).

(c) Production of rattan particulates

The rattan canes were harvested from a reserved area in Ile Ife, sun dried, milled into shredded forms by a local milling machine and later treated chemically. The treated rattans were sun dried and then later pulverized for further size reduction using a mortar and appropriate sieves. The obtained required sizes of $400\mu\text{m}$ are shown in Plate 2a.

(d) Production of corncob particulates

Locally sourced dried corncob shells were cleaned with pure water to remove dirt and then sun-dried. They were later hammered into shredded forms. The shredded form was chemically treated, to prevent the degradation of the fibre contents, when incorporated into the matrix. The treated corncobs were sun dried again to remove the moisture content and then pulverized by mortar for further size reduction. An appropriate sieve was used to get the required particle sizes $400\mu\text{m}$ as shown in Plate 2b.



(a) Rattan cane

(b) Corn cob

Plate 1: Crushed rattan cane and corn cob in water bath machine



(a) Rattan particles

(b) Corncob particles

Plate 2: Sieved rattan cane and corncob in microns

2.3. Preparation of composite specimen

The specimens were prepared by a process called hand layup. Corncob particulates, rattan particulates and epoxy resin were used for the experiment. Since the specimens are hybrid composites, the rattan particles were varied from 0% to 20% in weight, and corncob particles were also varied from 20% to 0% in weight. 80% in weight of the epoxy resin was constantly used throughout. The composite specimens were varied as A (100% Epoxy, 0% Corncob, 0% Rattan), B (80% Epoxy, 20% Corncob, 0% Rattan), C (80% Epoxy, 0% Corncob, 20% Rattan), D (80% Epoxy, 4% Corncob, 16% Rattan),

E (80% Epoxy, 7% Corncob, 13% Rattan), F (80% Epoxy, 10% Corncob, 10% Rattan), G (80% Epoxy, 13% Corncob, 7% Rattan) and H (80% Epoxy, 16% Corncob, 4% Rattan).

The different compositions of the specimens were batched in a container along with constant epoxy resin and stirred thoroughly to get a homogeneous mixture. These processes were repeated for the batched compositions B, C, D, E, F, G and H to produce the replicates. The obtained mixtures were poured into a mould. These set up were kept for 2 hours to cure, after which the specimens were brought out and allowed to dry, the mechanical properties of the specimens; tensile strength and modulus, flexural strength and modulus were determined, by using the Instron Universal Testing Machine (UTM). Table 2 presents the variations of percentage weight compositions of the specimens.

2.4. Mass composition of fibre particles and epoxy resin

In the particulate reinforced polymer, the fibres were perfectly distributed uniformly throughout the matrix in a pattern that could be describe as periodic, and there is a need to determine the mass composition of the particles and matrix in a specimen since the mechanical properties of the subsequent composite depend on it. The mass of the rattan, corncob and epoxy resin is calculated as follows:

- Particulate volume fraction (PVF) was 0.2,
- Matrix volume fraction (MVF) was 0.8,
- Tensile mould (100mm×6mm×3mm); and
- Flexural mould (150mm×50mm×4mm).

The mass of the control samples (specimen A) produced by tensile and flexural mould was 10.30g and 30.60g respectively, and the remaining samples (specimen B-H) mass composition based on their various percentage compositions are shown in Table 1.

Table 1: Percentage mass composition of various samples

Sample	Epoxy (wt%)	Corncob (wt%)	Rattan (wt%)	replicate
A	100	0	0	3
B	80	20	0	3
C	80	0	20	3
D	80	4	16	3
E	80	7	13	3
F	80	10	10	3
G	80	13	7	3
H	80	16	4	3

Table 2: Mass composition of various samples (A-H)

	Tensile			Flexural		
	Epoxy(gm)	Corncob (gm)	Rattan(gm)	Epoxy(gm)	Corncob (gm)	Rattan(gm)
A	10.30	0.00	0.00	30.60	0.00	0.00
B	8.24	2.06	0.00	24.48	6.12	0.00
C	8.24	0.00	2.06	24.48	0.00	6.12
D	8.24	0.41	1.65	24.48	1.22	4.90
E	8.24	0.72	1.34	24.48	2.14	3.98
F	8.24	1.03	1.03	24.48	3.06	3.06
G	8.24	1.34	0.72	24.48	3.98	2.14
H	8.24	1.65	0.41	24.48	4.90	1.22

2.5 Testing method

The produced composite materials were tested for density, water absorptive, tensile strength and modulus, flexural strength and modulus, bulk modulus, and shear modulus.

2.5.1 Density test

The densities of the samples were obtained by measuring the sample's weight on an electrical weighing machine (MODEL FA2204B) and then by dividing by their volumes. Densities of the specimens were determined by using Equation (1):

$$\text{Density} = m/(V) \quad (1)$$

where,

m = sample mass (g)

V = sample volume (cm³)

2.5.2 Water absorption test

The materials are likely to be exposed to water during the rainy season, so, a water absorptive test is necessary to determine the extent to which the samples can absorb water. In order to do this, the weights of the composites were measured in the air when dried by an electrical weighing machine and then soaked in water. The weights after 24 hours at room temperature were taken when removed from the water and dried in accordance with ISO 3087. The percentages of absorption were determined as shown in equation (2), (Onuoha et al., 2017).

$$\text{Thickness swell} = (M_b - M_a)/M_a \times 100 \quad (2)$$

where,

M_a= sample mass in air (g)

M_b= sample mass after absorbing

water (g)

2.5.3 Tensile test

The tensile strength and modulus of the developed specimens were determined based on the ASTM D 790 test procedure. The test specimens of 80mm gauge length, 5.2mm width, and 2.5mm thickness were used as shown in Plate 3a. The test was performed on the specimens by a computerized Instron Universal Testing Machine (UTM) at a speed rate of 5mm/min. Tensile stress, tensile strain, and modulus of elasticity were determined using Equations (3) to (5), (Onuoha et al., 2017).

$$\text{Tensile stress } \sigma = F/\alpha\beta \text{ (MPa)} \quad (3)$$

where,

F= Force applied (N)

α= Tested specimen width (m)

β= Tested specimen thickness (m)

$$\text{Tensile strain } \epsilon = \Delta l/l \quad (4)$$

where

Δl= change in length (m)

l= Initial length (m)

$$\text{Elastic modulus } E = \sigma/\epsilon \text{ (MPa)} \quad (5)$$

where

σ = stress (N/m²)

ϵ = strain

2.5.4. Flexural test

The flexural strength and modulus of the developed specimens were determined based on ASTM D790 with the aid of an Instron Testing Machine set at speed rate of 5mm/min. The samples were sized to 150mm gauge length, 50mm width and 4mm thickness as shown in plate 3b. The specimen span for loading was 65mm. Flexural strength was calculated because the spoiler made from this material would be exposed to vibration load caused by potholes. Flexural strength and modulus were determined using Equations (6) and (7), (Kiran et al., 2015).

$$\text{MOR (Flexural strength)} = \frac{3F_{\text{max}}L}{2bg^2} \text{ (MPa)} \quad (6)$$

where

F_{max} = Maximum load (N)

L = The support length (m)

α = Tested specimen width (m)

β = Tested specimen thickness (m)

$$\text{MOE (Flexural modulus)} = \frac{L^3(F_2 - F_1)}{4bg^3(\epsilon_2 - \epsilon_1)} \text{ (MPa)} \quad (7)$$

where

L = The support length (m)

α = Tested specimen width (m)

β = Tested specimen thickness (m)

$F_2 - F_1$ = Load increment along a

straight line portion (N).

$\epsilon_2 - \epsilon_1$ = Deformation (m).



(a) Tensile (b) Flexural
Plate 3: Tensile and Flexural samples

2.5.5 Theoretical Approach for Particulate Composite materials

• Density of the produced composite specimens

The total volume of the developed composite material is expressed as;

$$V = V_r + V_c + V_e \quad (8)$$

where

V_r , V_c , and V_e are volume compositions of rattan, corncob and resin respectively.

Let the volume fraction of rattan, corncob and epoxy resin be a , b , and $(1 - (a+b))$ respectively, the equation (8) becomes;

$$V = aV + bV + (1 - (a+b))V \quad (9)$$

The total mass of the developed composite material is expressed as:

$$M = m_r + m_c + m_e \quad (10)$$

where

m_r = Mass ratio of rattan (g)

m_c = Mass ratio of corncobs (g)

m_e = Mass ratio of epoxy resin (g)

From Equation (1)

$$\text{Density} = \frac{m_r + m_c + m_e}{V} \quad (11)$$

$$\rho = \frac{aV\rho_r + bV\rho_c + (1-(a+b))V\rho_e}{V} \quad (12)$$

$$\rho = \frac{aV\rho_r + bV\rho_c + (1-(a+b))V\rho_e}{V} \quad (13)$$

Hence, Equation (10), (11), (12), and (13) becomes;

$$\rho_{\text{composite}} = a\rho_r + b\rho_c + (1 - (a+b))\rho_e \quad (14)$$

This is the basic density of the produced composite material.

• Tensile strength and modulus of the produced composite specimens

The elastic modulus E in Nmm⁻² is defined as;

$$E = \frac{Fl}{A\Delta l} \quad (15)$$

where,

F = Load applied (N)

l = Sample Length (m)

A = Cross sectional Area (m²)

Δl = Deformation in length (m)

If the applied loads on rattan, corn cobs and epoxy resin are F_r , F_c , F_e respectively, the load becomes;

$$F = F_r + F_c + F_e \quad (16)$$

Incorporate equation (15) into (16), the load becomes;

$$F = \frac{E_r A_r \Delta l}{l} + \frac{E_c A_c \Delta l}{l} + \frac{E_e A_e \Delta l}{l} \quad (17)$$

On dividing both sides by cross-sectional area, applied load

$$\frac{F}{A} = \frac{\Delta l}{l} \left(\frac{E_r A_r + E_c A_c + E_e A_e}{A} \right) \quad (18)$$

Equation (17) becomes (18) after dividing through by strain,

$$E_{\text{composite}} = \left(\frac{E_r A_r + E_c A_c + E_e A_e}{A} \right) \quad (19)$$

Since,

$$A_r = \frac{aV}{L} \quad (20)$$

$$A_c = \frac{bV}{L} \quad (21)$$

$$A_e = \frac{(1-(a+b))V}{L} \quad (22)$$

Length of the composite is constant throughout, $L = L_r = L_c = L_e$

Incorporate (20), (21), and (22) into (19), then, it becomes;

$$E_{\text{composite}} = \frac{E_r aV + E_c bV + E_e (1-(a+b))V}{A} \quad (23)$$

$$E_{\text{composite}} = V \left(\frac{E_r a + E_c b + E_e (1-(a+b))}{A} \right) \quad (24)$$

Hence,

$$E_{\text{composite}} = aE_r + bE_c + (1 - (a+b))E_e \quad (25)$$

$$\sigma_{\text{composite}} = a\sigma_r + b\sigma_c + (1 - (a+b))\sigma_e \quad (26)$$

These are the basic tensile properties of the developed composite material. Thus, the shear modulus and bulk modulus both in (GPa) of the specimens were calculated respectively as:

$$G_{\text{composite}} = aG_r + bG_c + (1 - (a+b))G_e \quad (27)$$

$$K_{\text{composite}} = aK_r + bK_c + (1 - (a+b))K_e \quad (28)$$

3. RESULTS AND DISCUSSION

3.1. Density

The produced composite specimen's density was calculated by using Equation (1). Each specimen was weighed using a digital electronic weighing machine (MODEL FA2204B) and the mean values are shown in Figure 2. From the results obtained, the densities of the specimens range from 1.06g/cm³ to 1.30g/cm³, which shows similarity with the values reported by Elakhame et al. (2014) for automobile applications. It can be

observed from Figure 2 that the mean density of specimen C ($1.30\text{g}/\text{cm}^3$) was highest when compared with A ($1.11\text{g}/\text{cm}^3$) and B ($1.15\text{g}/\text{cm}^3$). The mean densities of the hybrid specimens D, E, F, G, and H ranged between $1.06\text{g}/\text{cm}^3$ to $1.27\text{g}/\text{cm}^3$, indicating the maximum for specimen G ($1.27\text{g}/\text{cm}^3$). The results show that there was generally a steady increase in densities as the percentage composition of the corncob increased; but a drop in density was noticed for specimen H. Specimen D ($1.06\text{g}/\text{cm}^3$) had the lowest density of all the specimens. The minimum density requirement prescribed by IS 3087 grade-2 standards for general purpose boards is $0.90\text{g}/\text{cm}^3$. It is apparent that all the specimens meet this specification.

3.2. Water absorption test

The water absorption test for each specimen was carried out after 24hours in accordance with the IS 3087 standards using Equation (2). The initial and final weights of the specimens were measured by a digital electronic weighing machine (MODEL FA2204B) and the mean values are shown in Figure 3. From the results obtained, it was noticed that the plane rattan, plane corncob and the combined rattan-corn-cob particles reduced the rate of absorption of water of the produced panels. The maximum water absorption requirement after 24hours prescribed as per IS 3087 grade-2 for general purpose boards is 40%. All the specimens meet the IS 3087 standard. This could be as a result of strong interfacial bonding between the particles and the epoxy.

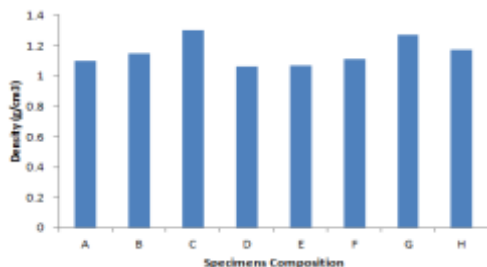


Figure 2: Density of composite specimens

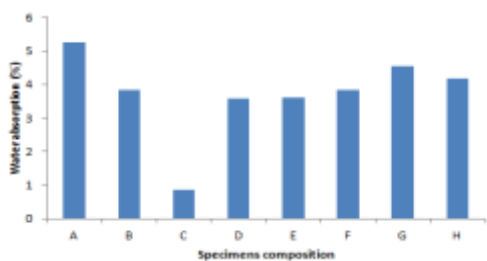


Figure 3: Water absorption of composite Specimens

3.3. Tensile strength and modulus

The produced composite specimens were tested using an Instron Universal Testing Machine (UTM) and the stress against strain curve

generated directly during tensile loading for the composites is shown on the appendix. The mean values of tensile strength and tensile modulus for various composite specimens are presented in Figure 4a and Figure 4b respectively. Figure 4a shows that the mean tensile strength of specimen B (55.3MPa) gives a higher value when compared

with A (41.8MPa) and C (47.4MPa). The tensile strength of the hybrid specimens D, E, F, G, and H is in the range of 55MPa to 90MPa, indicating maximum for specimen F (90MPa). The results showed that there was a progressive increment in tensile strength as the percentage composition of corncob increases in the epoxy resin. It was observed also from Figure 4b that the mean tensile modulus of specimen B (4.0GPa), gives a higher value when compared with A (3.60GPa) and C (2.3GPa). The tensile modulus of the hybrid specimens D, E, F, G, and H is in the range of 2.2GPa to 5.9GPa, indicating maximum for specimen H (5.9GPa).

The results show that there was steady increment in tensile modulus as the percentage composition of corncob increases up to F. However, a sharp drop which was noticed in G (5.0MPa) may be due to the increased fiber to fiber interaction leading to the difficulties in achieving a uniform dispersion of the rattan-corn-cob in the epoxy matrix. Onuoha et al. (2017) reported a similar observation. The observed increments in the tensile strength and modulus may be appertaining to the strengthening effect of the chemically treated rattan-corn-cob particles incorporated into the epoxy resin. These results indicate that the combined rattan-corn-cob particulates improved the tensile strength and modulus of the epoxy resin.

3.4. Flexural strength and modulus

The flexural stress against flexural strain curve generated during flexural loading for the composites is shown in the appendix. While the mean values of flexural strength and modulus of rattan-corn-cob specimens are shown in Figure 5a and 5b, respectively. From the experiment, Figure 5a shows that the mean flexural strength of C (61.3MPa) gives higher value when compared with A (53.2MPa) and B (52.2MPa). The mean flexural strength of the hybrid specimens D, E, F, G, and H is in the range of 50MPa to 70 MPa, indicating maximum for specimen D. It can be viewed from the graph that the mean flexural strength of the hybrid composites decreases with decrease in percentage composition of rattan particles. The decrease in flexural strength of the produced specimens could be attributed to the decrease in percentage composition of rattan particulates being more ductile than the corncob. Figure 5b shows that the mean flexural modulus of A (1.7GPa) gives higher value when compared with B (1.5GPa) and C (1.5GPa). The values of the remaining hybrid specimens ranged from 2GPa to 2.7 GPa, indicating maximum for F(2.7GPa). It was noticed from the graph that the mean flexural modulus of the hybrid specimens decreases as the percentage composition of rattan particles decreases. The decrease in flexural modulus of the hybrid specimens could be attributed to the decrease in percentage composition of rattan particulates being more ductile than the corncob.

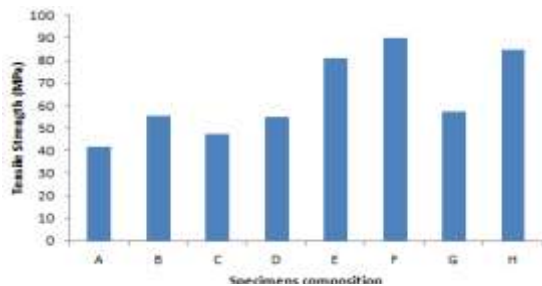


Figure 4 (a): Tensile strength

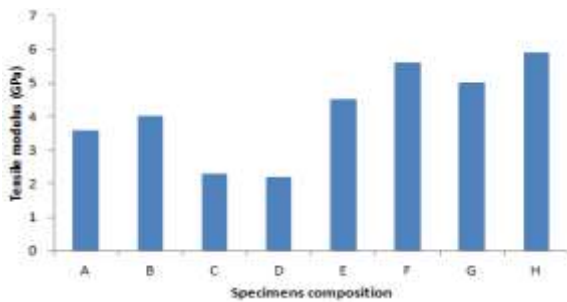


Figure 4(b): Tensile modulus

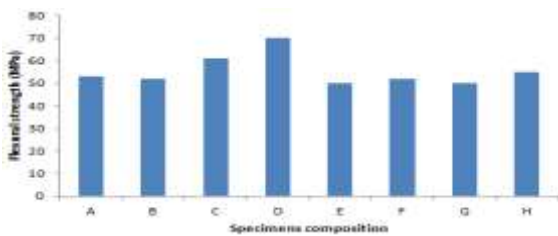


Figure 5(a): Flexural strength

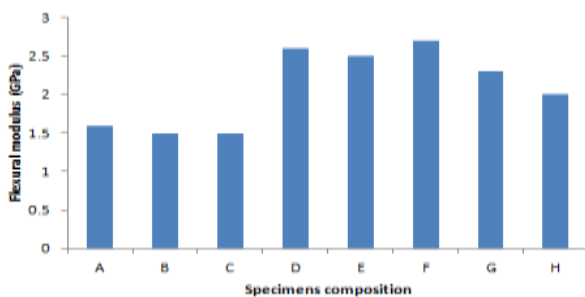


Figure 5(b): Flexural modulus

The minimum static bending requirement for general purpose panels prescribed by IS 3087 grade-2 standards is 11N/m² for modulus of rupture and 2000N/m² for elasticity modulus, It is apparent that all the specimens met this specification. Tables (3a and 3b) show the summary of the physical and mechanical properties of the produced composites.

3.5. The microstructure of the composite

Plate 4. reveal s the optical micrographs analysis of the developed composite sample A to H. The particles were dispersed randomly within the epoxy resin. The microstructure of the composite materials shows the grain size in the materials and the formation. The results reveal that the particles are uniformly distributed with good bonding of the epoxy resin and the treated agricultural wastes (combined rattan-corn cob) particles in specimen C, F, and H, except in specimen B, D, E and G where the particles are not well distributed, resulted to increase in the number of spherulites. The optical micrograph results show that specimens C, F, and H interfaces are better when compared with specimens B, D, E, and G. The observed increase in the number of spherulites in the produced composite specimens B, D, E, and G may be attributed to poor dispersion of the combined rattan-corn cob particulates in the resin due to the low curing rate of the epoxy resin.

Table 3a: Physical properties of the developed specimens

Specimen	Properties	
	Densities (g/cm ³)	water absorption (%)
A	1.11	5.26
B	1.15	3.85
C	1.30	0.87
D	1.06	3.57
E	1.07	3.61
F	1.11	3.85
G	1.27	4.55
H	1.17	4.17

Table 3b: Mechanical properties of the developed specimens

Specimen	properties					
	T.S	T.M	F.S	F.M	S.M	B.M
	(MPa)	(MPa)	(MPa)	(MPa)	(GPa)	(GPa)
A	41.7	3.6	53.2	1.7	1.4	3.0
B	55.3	4.0	52.2	1.5	1.6	3.4
C	47.4	2.3	61.3	1.5	0.9	1.9
D	54.9	2.2	69.8	2.6	0.8	1.8
E	81.2	4.5	50.4	2.5	1.7	3.8
F	90.2	5.6	52.5	2.7	2.2	4.7
G	57.4	5.0	50.3	2.3	1.9	4.2
H	84.9	5.9	55.3	2.0	2.3	4.9

T.S is tensile strength, T.M is tensile modulus, F.S is flexural strength, F.M is flexural modulus, S.M is shear modulus, and B.M is bulk modulus.

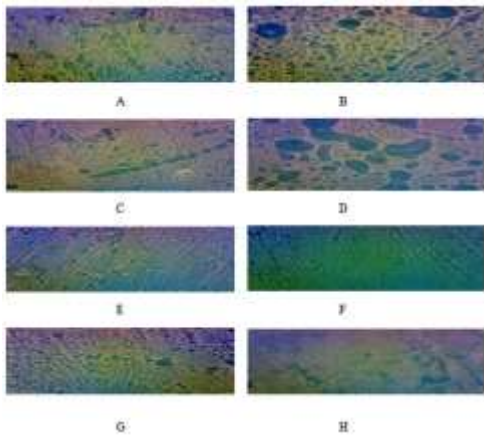


Plate 4: Optical micrographs of the developed composite materials

4. CONCLUSION

In this study, composite materials were developed as alternative materials for automotive applications, by using treated rattan-corn cob composite materials. The use of these agricultural waste materials is due to their abundant availability in many parts of the world. The study shows that all the materials used in the experiments are potential materials for the production of composites that could be used as alternative materials for automobile applications. It is evident from the results obtained that all the specimens meet the minimum required values prescribed by the British and Indian standards for particulates composite materials. The results of the optical microstructure analysis revealed that the particles are uniformly distributed with good bonding of the epoxy resin and the treated agricultural wastes particles. The use of these agricultural wastes (combined rattan-corn cob contents) could provide competitive hybrid composites for lightweight automobile spoilers compared, with synthetic fibers that consume significant amount of energy and time to produce.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors Contribution

GAT design the research
GAT and OAO experimental analysis
GAT and OKA theoretical analysis
GAT and OAO discussion of result

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