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EVALUATION OF PHYSICAL AND MECHANICAL PROPERTIES OF NATURAL FIBER REINFORCED POLYMER COMPOSITES (KENAF FIBER AND POLYESTER RESIN) FOR STRUCTURAL APPLICATIONS

Pyendang. Z. SHENDAM[1]*, Solomon. E. APEH[2], Felix ACHEMA[3] & Olanrewaju. O. OJO[4]

[1,2,3,4]Nigerian Building and Road Research Institute, 10 NBRRI Way/I.T. Igbani Street, off Awolowo Way, Jabi, Abuja, Nigeria

***Corresponding author:** pyendangzach@gmail.com*

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ABSTRACT

Natural fibers such as kenaf (Hibiscus cannabinus) have gained significant attention as reinforcement in polymer composites due to their biodegradability, lightweight nature, low cost, and favorable strength-to-weight ratio. This research investigates the mechanical and physical properties of kenaf fiber reinforced with polyester resin for potential use in structural applications. Composites with varying fiber volume fractions (0%, 10%, 20%, 30% and 40%) were fabricated and subjected to physical and mechanical characterization such as tensile, flexural, impact, compressive strength tests, density and water absorption test in accordance with ASTM standards. The results revealed that at 0%, 10%, 20%, 30% and 40%; the tensile strength are 21.66, 18.89,16.81, 9.65 and 4.39Mpa; the compressive strength are 83.70, 64.16, 60.40, 47.17 and 33.55Mpa; the flexural strength are 13.49, 10.80, 8.64, 5.78 and 2.49Mpa; the impact strength are 12.5, 10.8, 9.2, 7.5 and 6.1J; the density are 1.13, 1.14, 1.24, 1.21 and 1.22g/cm^3 while the water absorption are 1.86, 5.79, 6.78,9.54 and 19.32% respectively. The tests result from some mechanical and physical properties show a decline in strength as volume fractions of kenaf fiber increases. This decline in strength with increasing fiber content suggests that higher kenaf fiber incorporation reduces the matrix–fiber interfacial bonding strength. This implies that as the volume of fiber fractions increases, it should be with proportional increase in the volume of the resin. This study highlights the potential of kenaf fibers as eco-friendly reinforcements in advancing sustainable construction materials.

Keywords: Kenaf fiber, polypropylene resin, FRP composite, physical and mechanical properties, structural applications.

Introduction

The increasing global demand for sustainable and environmentally friendly materials has stimulated significant research interest in natural fiber reinforced polymer (NFRP) composites as alternatives to conventional synthetic fiber composites (Abdollahiparsa et al., 2023). Traditional construction and structural materials such as steel, concrete, and glass fiber reinforced polymers possess excellent mechanical properties; however, their production is associated with high energy consumption, greenhouse gas emissions, and environmental concerns (Mahboubizadeh et al., 2024). Consequently, researchers have focused on the development of bio-based composite materials that combine renewable natural fibers with polymer matrices to produce lightweight, cost-effective, and sustainable structural materials (Kiruthika, 2024).

Natural fiber reinforced polymer composites are engineered materials consisting of natural fibers embedded within a polymer matrix. These composites have attracted considerable attention due to their low density, biodegradability, renewability, availability, and favorable specific strength and stiffness (Arjmandi et al., 2021). Various natural fibers such as kenaf, hemp, sisal, flax, jute, and bamboo have been investigated for use as reinforcement materials in composite structures because of their environmental advantages and acceptable mechanical performance (Kiruthika, 2024). Recent studies have demonstrated that natural fiber composites can be effectively utilized in automotive, aerospace, marine, and civil engineering applications where lightweight and sustainable materials are required (Abdollahiparsa et al., 2023).

Among the numerous natural fibers available, kenaf (Hibiscus cannabinus) has emerged as one of the most promising reinforcement materials for polymer composites due to its excellent mechanical properties, rapid growth rate, low density, and widespread availability (Arjmandi et al., 2021). Kenaf fiber possesses high tensile strength and modulus relative to many other natural fibers, making it suitable for structural and semi-structural applications (Bhambure et al., 2023). Furthermore, kenaf cultivation contributes to environmental sustainability through carbon sequestration and reduced dependence on non-renewable resources (Kiruthika, 2024).

Polyester resin is one of the most widely used thermosetting polymer matrices in composite manufacturing because of its low cost, ease of fabrication, dimensional stability, corrosion resistance, and good mechanical performance (Arjmandi et al., 2021). The resin acts as a binding medium that transfers applied loads to the reinforcing fibers while protecting them from environmental and mechanical damage. When reinforced with kenaf fibers, polyester resin composites exhibit enhanced tensile, flexural, and impact properties compared with unreinforced polyester resin (Bhambure et al., 2023). The overall performance of these composites depends on several factors, including fiber content, fiber orientation, fiber-matrix adhesion, manufacturing process, and environmental conditions (Yusuff et al., 2021).

The physical properties of natural fiber reinforced composites play an important role in determining their suitability for structural applications. Properties such as density, water absorption, porosity, and dimensional stability influence the durability, service life, and performance of composite materials under varying environmental conditions (Yusuff et al., 2021). One of the major challenges associated with natural fibers is their hydrophilic nature, which can lead to increased moisture absorption and subsequent degradation of mechanical properties. However, studies have shown that appropriate fiber treatment methods and optimized composite formulations can significantly reduce moisture uptake and improve composite durability (Yusuff et al., 2021).

Mechanical properties are critical indicators used to evaluate the structural performance of composite materials. These properties include tensile strength, flexural strength, compressive strength, impact strength, hardness, and modulus of elasticity (Bhambure et al., 2023). Tensile strength measures the ability of a material to resist pulling forces, while flexural strength evaluates its resistance to bending loads. Impact strength determines the material's ability to absorb energy during sudden loading conditions, which is particularly important in structural applications exposed to dynamic forces (Sathya et al., 2021). Research findings indicate that kenaf fiber reinforcement significantly improves the mechanical behavior of polyester composites when compared with neat polyester resin (Adole, 2024).

Fiber orientation and fiber loading are among the most important factors influencing the mechanical performance of kenaf fiber reinforced polymer composites. According to Adole (2024), composites reinforced with aligned or unidirectional kenaf fibers generally exhibit higher tensile and flexural strengths than randomly oriented fiber composites because of improved stress transfer along the fiber direction. Similarly, increasing fiber content within an optimum range has been reported to enhance stiffness and strength, although excessive fiber loading may result in poor fiber dispersion and reduced interfacial bonding (Bhambure et al., 2023).

Recent advancements in composite technology have expanded the potential application of natural fiber reinforced composites in the construction industry. Researchers are increasingly investigating the use of kenaf fiber reinforced polyester composites in roofing panels, wall panels, ceiling boards, partition systems, and other lightweight structural components (Mahboubizadeh et al., 2024). The growing interest in sustainable construction materials has further accelerated the development of natural fiber composites as viable alternatives to conventional synthetic composites and traditional building materials (Abdollahiparsa et al., 2023).

Despite the numerous advantages associated with kenaf fiber reinforced polyester composites, challenges related to moisture sensitivity, variability in fiber properties, interfacial bonding, and long-term durability remain significant concerns (Arjmandi et al., 2021). Therefore, a comprehensive evaluation of the physical and mechanical properties of kenaf fiber reinforced polyester composites is necessary to determine their suitability for structural applications. Such an evaluation will provide valuable information for optimizing composite design, improving performance, and promoting the adoption of sustainable materials in engineering and construction industries.

FRP composites are well suited for structural applications that require rapid installation or must withstand harsh environments. Their chemical and corrosion resistance gives them an advantage over traditional materials in aggressive conditions. Beyond repair uses and as rebar to carry tensile forces in concrete, full FRP profiles serve as primary structural elements in chemical and food processing plants, wastewater treatment facilities, cooling towers, foot- and road-bridges, bridge decks and edge elements, and railway platforms. Based on fiber length, FRP composites are classified as continuous (long-fiber) or discontinuous (short-fiber) composites (M. H. Islam, 2022). In this work, the kenaf fiber used has no specific length because it was pounded into powdered form.

Traditionally, synthetic fibers such as glass and carbon fibers have been used to improve mechanical properties. However, environmental concerns, high production costs, and non-biodegradability associated with synthetic fibers have encouraged the exploration of natural fiber alternatives (Yusuff et al., 2020).

Natural fibers such as kenaf, jute, sisal, and hemp are increasingly being used as reinforcement materials due to their renewability, biodegradability, low density, and environmental friendliness. Among these, kenaf (Hibiscus cannabinus L.) is particularly attractive due to its fast growth rate, availability, and favorable mechanical properties. Kenaf fibers possess relatively high tensile strength and stiffness, making them suitable for reinforcing polymer matrices (Akil et al., 2011).

According to Pyendang et al. (2026), which studied the Microstructural Characterization of Fibre Reinforced Polymer (FRP) Composite (Kenaf Fibre and Polyester Resin) for Structural Applications using TGA, FTIR, XRD, SEM and EDX. The result revealed that as the kenaf fiber content increases, the interfacial bonding between the fiber and the polyester resin become weak due to insufficient distribution of the resin in the fiber.

In addition to mechanical properties, physical characteristics such as density, water absorption, and thermal stability play a crucial role in determining the suitability of these composites for practical applications. The hydrophilic nature of kenaf fibers often leads to increased moisture absorption, which may affect dimensional stability and durability (Yusuff et al., 2020).

Given the increasing demand for sustainable and eco-friendly materials, the study of polypropylene reinforced with kenaf fiber is of significant importance. Understanding the physical and mechanical properties of these composites will help in optimizing their performance and expanding their applications in various industries. Polypropylene composites have not been fully realized due to challenges related to interfacial bonding and moisture absorption.

Therefore, this study seeks to evaluate the physical and mechanical properties of natural fiber reinforced polymer composites produced from kenaf fiber and polyester resin for structural applications. The findings of this research are expected to contribute to the growing body of knowledge on sustainable composite materials and provide useful information for their effective utilization in structural engineering applications.

1.2 Limitations of the study

This research work is limited to the mechanical and physical properties of kenaf fiber reinforced with polyester resin. The kenaf fiber used was pounded in powdered form and no chemical treatment (either NaOH or compatibilizers or coupling agent) were used on the fiber before the composite fabrication.

2.0. MATERIALS AND METHODS

Materials

The materials used in this research are kenaf fiber and polyester as polymer matrix or resin.

Equipments/Reagents/Materials Used

The equipments/ reagents/materials used in the research are polyester resin (Henan Jinhe industry co. Ltd in China), Cobalt Naphthalene Accelerator, Methyl-ethyl-ketone (MEK) Peroxide (at Josh Resins & Chemicals Ltd, India) Catalyst, kenaf fiber, digital weighing balance, plastic container, oven, measuring cylinder, 50mm x 50mm x 50mm metal fabricated mould, wooden mould, digital stop watch and desiccators.

Sample Preparation

1. Kenaf fiber

The dried kenaf fiber was obtained in Zam-Ponzhi Jat village of Bwarat District, Langtang North of Plateau State. The fiber was pounded or crushed into powdered form (i.e discontinuous fiber).

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Fig 1: Kenaf fiber

Fig 2: Powdered kenaf fiber

2. Polyester Resin

The polyester resin was obtained at old Bukuru park, terminus market at chemicals and fibers shop. A volume of polyester resin was measured in a measuring cylinder and Cobalt Naphthalene Accelerator of volume 6% (61789-51-3- Otto Chemie pvt Ltd, India) of the volume of the resin to be used was added. The mixture was thoroughly stirred and also 1.25% volume of Methyl-ethyl-ketone (MEK) Peroxide (at Josh Resins & Chemicals Ltd, India) Catalyst was added to the mixture and further stirred for 2 minutes to enhance the drying process of the polymer composite when mixed with the fibers.

3. Composites moulding/fabrication

An iron mould 50mm x 50mm x 50mm was constructed and lightly smeared with petroleum jelly. The kenaf fiber was varied from 0%, 10%, 20%, 30% and 40% respectively, with an interval of 50g. . A volume of polyester resin was measured in a measuring cylinder and Cobalt Naphthalene Accelerator of volume 6% (61789-51-3- Otto Chemie pvt Ltd, India) of the volume of the resin to be used was added. The mixture was thoroughly stirred and also 1.25% volume of Methyl-ethyl-ketone (MEK) Peroxide (at Josh Resins & Chemicals Ltd, India). Catalyst was added to the mixture and further stirred for 2 minutes to enhance the drying process of the polymer composite when mixed with the fibers.

Each was mixed in a random orientation within the polypropylene resin and manual method was used to pour the mixtures into the mould using hand pressing. They are allowed to cure under room temperature. No heating process is carried out throughout the preparation of composites. The cured composite is then subjected to various methods of characterization. While 381mm x 20mm x24mm wooden mould was fabricated for production of fiber reinforced polymer composites at different volume fractions for tensile strength test determination as shown below.

Fig 3; wooden mould

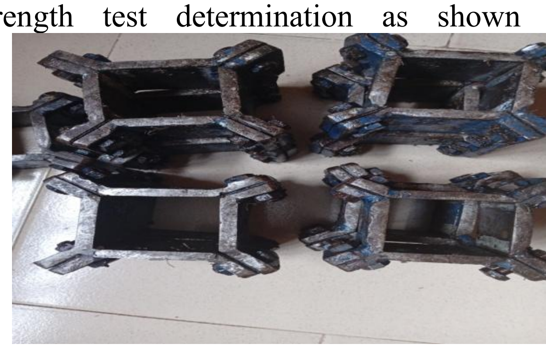

Fig 4; Iron fabricated mould

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Fig 5; Measuring the volume of PP Resin.

Fig 6; Measured fractions of powdered kenaf fiber

Fig 7; FRP composites at different volume factions
For compressive, impact, density and water absorption test

Fig 8; FRP composites at different volume factions
for tensile strength and flexural strength test

Composites Testing and Procedure

1. Tensile Strength Test

The tensile strength of the composite refers to the maximum stress a fiber composite material can withstand while being stretched or pulled before failing breaking. It's a critical property that determines the material's ability to resist deformation and failure under tensile loads. Tensile strength test was conducted using universal testing machine at Nigeria Building and Road Research Institute laboratory & training centre; No 10 Igbani street, off Chief obafemi Awolowo way, Jabi, Abuja, to determine the tensile strength of composite material at different volume fractions. The samples to be tested were fabricated according to ASTM Standard D638M, using 380.1mm x 25mm x 25mm thickness wooden mould was used to produce the sample as shown in fig 5 above. Uniaxial load was applied through the ends until the specimen failed or breaks and the breaking load was recorded in kN and the tensile strength is calculated in Mpa as

$$Tensile\ strenght = \frac{2F}{b\ x\ h} \quad \ldots (1)$$

Where F = Crushing load in N

b = breadth of the sample in mm

h = height of the sample in mm

The result is presented in table 1 of chapter 3.

Fig 9; Sample on universal testing machine for tensile strength test **Fig 10**; Break sample specimen after force applied

2. Compressive strength Test

Compressive strength refers to the ability of a fiber composite material to withstand compressive forces or loads that squeeze or compress the material without failing or deforming excessively. The compressive strength test was carried out according to ARSO 2018 standard and ASTM D695 standard method. The fiber composites was tested using a universal testing machine at the department of building university of Jos, to assess the actual failure rate in kN and the compressive strength is calculated as

$$Compressive\ strength = 10\ x\ \frac{F}{A} \quad \dots (2)$$

Where F = Crushing force in kN

A= Surface Area in cm^2

The result is presented in table 2 of chapter 3.

Fig 11: Universal testing machine testing the Compressive strength of the kenaf FRP composites **Fig 12**: Crushed kenaf FRP composites

3. Flexural strength Test

Flexural strength is a material property characterized as the failure stress in bending of the structure. This is equivalent or slightly greater than the stress at failure during tension. Flexural strength of a construction and manufacturing materials is usually measured so as to understand the bending and load-carrying capacity of the material. As this Kenaf fiber reinforced composite is to be used for such purposes, flexural strength is measured for various weight percentages. The flexural strength was determined at Nigeria building and Road research institute laboratory & training centre; No 10 Igbani Street, off Chief Obafemi Awolowo Way, Jabi, Abuja. The test was carried out in accordance to ASTM D790 Standard in universal testing machine using three points bending approach. The dimensions of the samples were 150mm x 20mm x 24mm. The distance between the spans was 50mm, and the strain rate or speed was 1- 5 mm/min. Three specimens were tested for each volume fraction and the average was reported. The flexural strength and breaking load (F) were recorded in table 8 of chapter 4. The flexural can be determine using the following formula,

$$Tensile\ strength\ (\sigma) = \frac{3FL}{2b\ d2} \qquad ..(3)$$

Where, F is the force applied in N, L is the length between two pivot supports in mm, b is the breadth in mm and d is the depth in mm of the composite material. The result is presented in table 3 of chapter 3.

Fig 13; Sample placed on universal testing machine.

Fig 14; Break sample specimen after force applied

4. Impact Strength Test

Impact strength is defined as the ability of a material to absorb and dissipate energy under impact or shock loading (Biswas, 2011). The impact properties depend on the inter-laminar and interfacial bonding, fiber and matrix properties, the construction and geometry of the composite and test conditions (Alavudeen, 2015; Wambua, 2003 & Biswas, 2011). The impact strength of composites is directly related to its overall toughness.

The impact test was carried out at NDA defense industry cooperation of Nigeria (DICON) research center Kaduna state on a Charpy Impact Testing Machine and the samples were cut according to ASTM Standard D256M using 5mm thickness sample. The sample was placed in a Charpy V-notch across parallel jaws in the machine. A pendulum of known weight and height was released to strike the sample on its downward swing fracturing the sample. The energy absorbed by the fractures was taken and recorded. The results are presented in table 4 of chapter 3

Fig 15; Sample specimen on Izod charpy impact testing machine.

5. **Density test**

The densities of the specimens were obtained according to the ASTM Standard D792 – 13.Using this standard a G&G model electronic digital scale weighing balance was used to determine the mass and the volume of the sample was determined by measuring the length, width and height of the sample. The density of the kenaf fiber composite is calculated as

$$Density = \frac{mass}{volume} = \frac{m}{v} \qquad \dots (4)$$

The results are presented in table 5 of chapter 3.

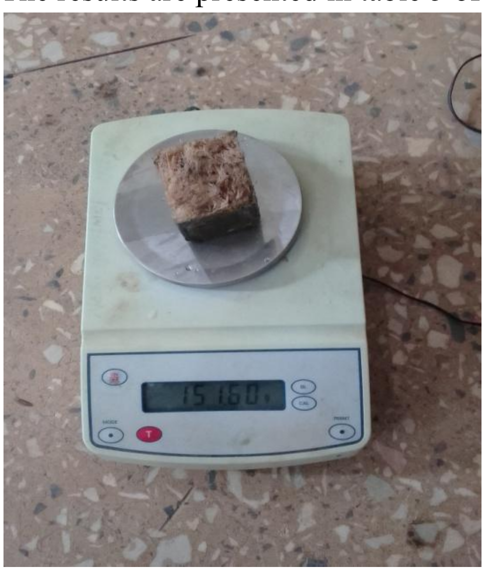

Fig 16; Measurement of kenaf FRP composites for density determination

6. Water Absorption Test

The water absorption is the amount or quantity of water absorbed by a composite material when exposed to water or humid environments. This property is crucial in determining the material's durability and performance in various applications. The water absorption test was carried out according to ASTM C272 test method and ASTM D570-81 test method, at Nigeria building and road research institute Jos laboratory. A regular shape of known dimension of the fiber composite sample was weighed and the sample was placed in the oven for 24hours at 70-105^{0}C and cooled in a desiccator. The cooled sample was soaked in water for another 24hours and reweighed. The initial and final weights of the samples were recorded to determine the water absorption. The percentage change in weight before and after water treatment is calculated as

$$Percentage\ of\ water\ absorption = \frac{W-D}{D}\ X\ 100 \qquad \ldots (5)$$

Where W = Wet weight

D = Dry weight

Fig 17; water absorption test of the kenaf FRP composites

Fig 18; Heating of wet FRP composite at 105°C in oven.

Result

Kenaf Fiber Reinforced Polymer Composites Test Results

Mechanical Properties

1. Tensile strength test

Table 1; Result of tensile strength test

Volume fractions	Sample No	Length (L) in mm	Breadth (b) in mm	Height (h) in mm	Breaking load(F) in kN	Tensile strength= $\frac{2F}{b\ h}$ in Mpa	Average tensile strength in MPa
0%	1	381	20	24	5.05	21.02	21.66
	2	381	20	24	5.20	21.67	
	3	381	20	24	5.35	22.29	
10%	1	381	20	24	4.89	20.38	18.89
	2	381	20	24	4.50	18.75	
	3	381	20	24	4.21	17.54	
20%	1	381	20	24	4.20	17.50	16.81
	2	381	20	24	4.15	17.29	
	3	381	20	24	3.75	15.63	
30%	1	381	20	24	2.25	9.38	9.65
	2	381	20	24	2.65	11.04	
	3	381	20	24	2.05	8.54	
40%	1	381	20	24	1.25	5.21	4.39
	2	381	20	24	0.98	4.08	
	3	381	20	24	0.93	3.88	

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ASTM Standard is 29 – 58Mpa

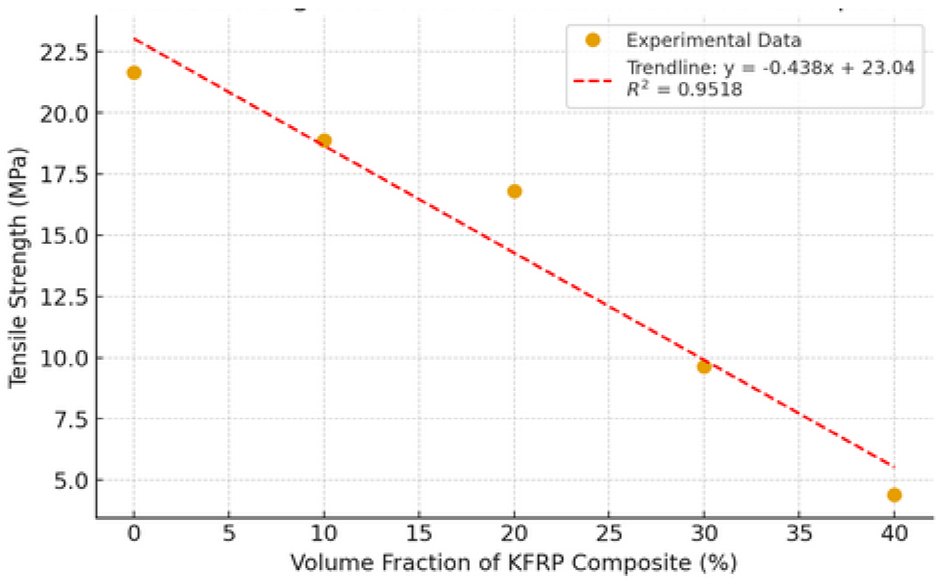

Fig 19; A Plot of tensile strength against volume fractions of KFRP composite

From the graph above, the trend line Equation is

$y=-0.436x+21.16$

Coefficient of Determination (R^2): 0.965

The negative slope (−0.436) confirms a strong inverse linear relationship between tensile strength and fiber volume fraction. The tensile strength decreases as fiber loading increases.

The high R^2 value (0.965) indicates that 96.5% of the variation in tensile strength can be explained by changes in the fiber volume fraction, implying an excellent linear correlation.

This reinforces that as more kenaf fibers are added, poor interfacial adhesion, void formation, and fiber agglomeration reduce load transfer efficiency (Saba et al., 2015; Asumani et al., 2012). The composite thus becomes weaker in tension with higher fiber content unless surface treatments or compatibilizers are applied. From the graph, the tensile strength decreases progressively as the fiber volume fraction increases from 0% to 40%.

2. Compressive strength test

Table 2; Result of compressive strength test

Volume fractions of fibers	Sample No	Length (L) in cm	Breadth (b) in cm	Surface Area (L x b) in cm^2	Crushing time in seconds	Breaking load(F) in kN	Compressive strength= $10\ x\ \frac{F}{A}$ in Mpa	Average compressive strength in MPa
0%	1	5.0	4.8	24.00	35	206	85.83	83.70
	2	5.0	5.0	25.00	35	204	81.60	
	3	5.0	4.9	24.50	34	205	83.67	
10%	1	5.0	4.9	24.50	33	155	63.27	64.16
	2	5.0	4.9	24.50	33	153	62.45	
	3	4.9	4.8	23.52	32	157	66.75	
20%	1	4.9	4.8	23.52	31	143	60.80	60.40
	2	4.9	4.9	24.01	30	145	60.39	
	3	5.0	4.9	24.50	29	147	60.00	
30%	1	5.0	4.9	24.50	22	102	41.63	43.17
	2	5.1	4.8	24.48	25	108	44.12	
	3	5.0	4.8	24.00	24	105	43.75	
40%	1	4.9	4.9	24.01	20	79	32.90	33.55
	2	5.0	4.8	24.00	21	81	33.75	
	3	4.9	4.8	23.52	20	80	34.01	

ASTM/BSEN Standard compressive strength of FRP Composite is 20 -200Mpa

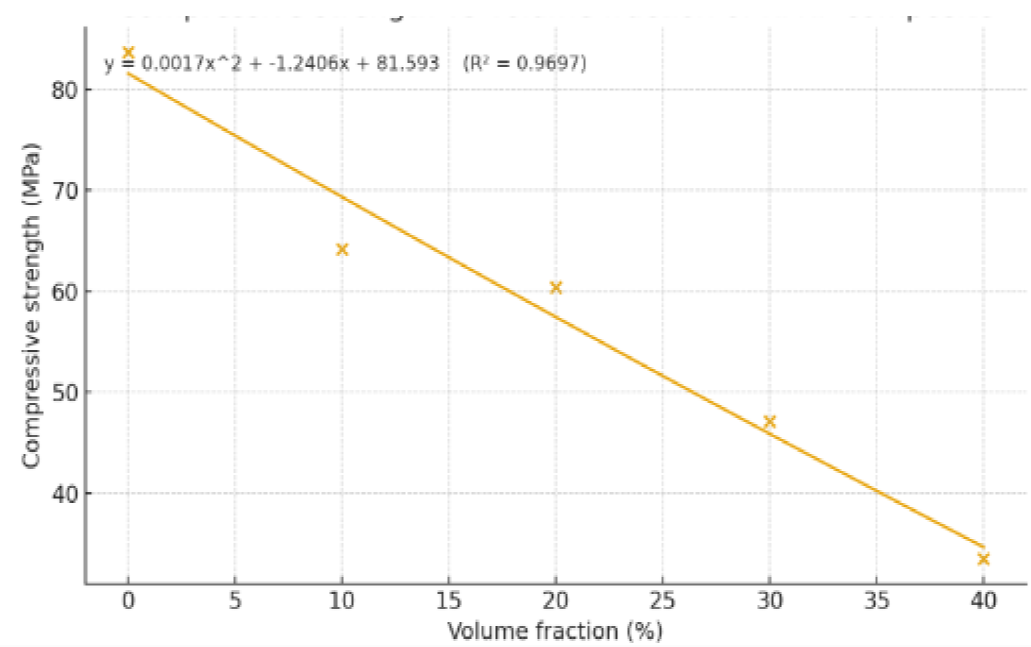

Fig 20; A Graph of compressive strength against volume fractions of fibers composites

The Trend line equation is

$y = 0.0017\,x^2 - 1.2406\,x + 81.593$

$R^2 = 0.9697$

Where

x = volume fraction in %.

y = compressive strength in MPa.

The plot shows a clear decreasing trend of compressive strength as kenaf fiber volume fraction increases from 0% → 40%.

At 0% (pure matrix): The composite shows the highest compressive strength (83.7 MPa).

At 10–20% fibers: Strength decreases (64.16 → 60.40 MPa). This suggests the fibers are not carrying compressive loads effectively. At 30–40% fibers: The compressive strength drops significantly (47.17 → 33.55 MPa). This is due to Load transfer inefficiency. When too many fibers are added, the matrix (which resists compressive forces well) becomes insufficient to distribute stress. As the volume of fibers increases, it should be with proportional increase with the volume of the polypropylene resin for optimal performance.

3. Flexural strength test

Table 3; Result of flexural strength test

Volume fractions	Sample No	Length (L) in mm	Breadth (b) in mm	Depth (d) in mm	Breaking load(F) in kN	Flexural strength $(\sigma) = \frac{3FL}{2\,b\,d2}$ in Mpa	Average tensile strength in MPa
0%	1	50	20	24	2.07360	13.50	13.49
	2	50	20	24	1.98298	12.91	
	3	50	20	24	2.15808	14.05	
10%	1	50	20	24	1.56241	10.38	10.80
	2	50	20	24	1.68490	10.97	
	3	50	20	24	1.69728	11.05	
20%	1	50	20	24	1.27380	8.46	8.64
	2	50	20	24	1.27012	8.43	
	3	50	20	24	1.38547	9.02	
30%	1	50	20	24	0.87622	5.83	5.78
	2	50	20	24	0.77909	5.17	
	3	50	20	24	0.95615	6.35	
40%	1	50	20	24	0.42923	2.85	2.49
	2	50	20	24	0.41011	2.67	
	3	50	20	24	0.30106	1.96	

ASTM Standard is 45 – 200Mpa

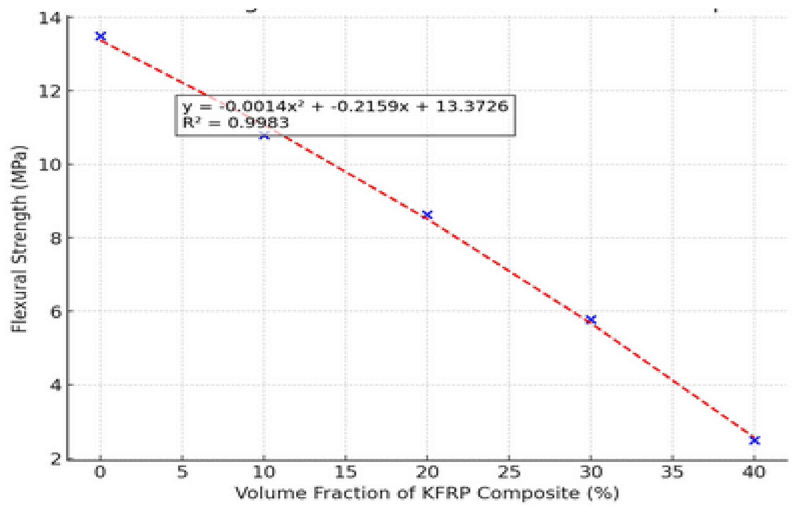

Fig 21; A plot of flexural strength against volume fractions of KFRP composite

The Trendline Equation from the graph above is

y= −0.00136x2−0.2159x+13.3726

Where y = Flexural strength (MPa)

x = Volume fraction of KFRP composite (%)

R^2 = 0.9983, indicating a very strong correlation between experimental data and the polynomial fit. The graph shows a progressive decline in flexural strength as the volume fraction of kenaf fiber increases from 0% to 40%. This behavior suggests that at higher fiber contents, the fiber–matrix interfacial bonding becomes less effective, leading to stress transfer inefficiency and premature failure under flexural loading. At 0% fiber (pure resin), the composite exhibits the highest flexural strength (13.49 MPa), attributed to the homogeneous and defect-free polymer matrix. As the kenaf fiber content rises, void formation, fiber agglomeration, and poor fiber wetting can occur, which introduce stress concentration zones that reduce flexural strength (Saba et al., 2015; Jawaid & Khalil, 2011). The polynomial decay pattern (high R^2 = 0.9983) suggests that the degradation of flexural performance with fiber loading is non-linear, which aligns with observations from natural fiber composites where optimal mechanical performance often occurs at moderate fiber loadings (10–20%) before decreasing sharply (Nourbakhsh & Ashori, 2009).

4. Impact strength test

Table 4; Result of impact strength test

Volume fractions of the fiber composite (%)	Sample number	Energy absorbed(J)	Average energy absorbed (J)
0	1	11.6	12.5
	2	13.3	
	3	12.7	
10	1	10.8	10.8
	2	11.0	
	3	9.16	
20	1	9.0	9.2
	2	8.4	
	3	10.2	
30	1	8.2	7.5
	2	7.9	
	3	6.4	
40	1	5.0	6.1
	2	7.1	
	3	6.2	

ASTM standard is 5 – 50J

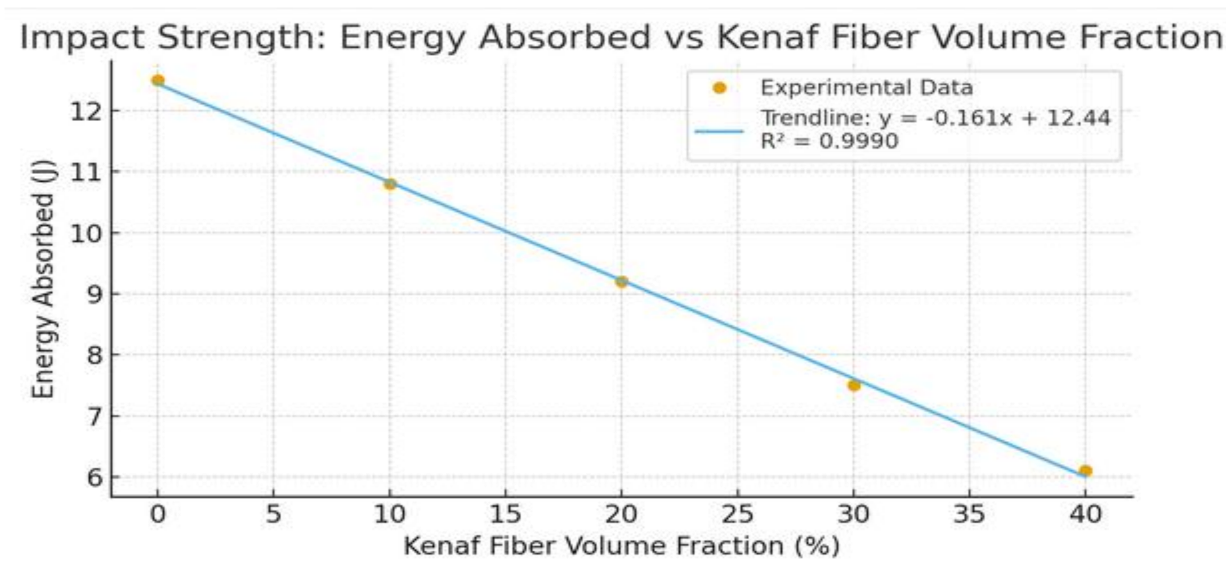

Fig 22; A graph of impact strength against volume fractions of composite

Trend line Equation

$y=-0.161x+12.44$

Where:

y = Energy absorbed (J)

x = Kenaf fiber volume fraction (%)

This extremely high R^2 indicates a very strong linear relationship between fiber volume fraction and impact strength reduction.

The negative slope (−0.161) confirms that impact strength decreases as kenaf fiber content increases. The high R^2 suggests that fiber loading is the dominant factor influencing energy absorption, with minimal unexplained variability in the data set. This aligns with findings in literature, where natural fiber addition tends to lower toughness due to brittle fiber behavior and weak fiber–matrix bonding (Fiore et al., 2015). The plot shows a progressive decline in impact strength (energy absorbed) as kenaf fiber volume fraction increases:

This behavior is typical in natural fiber composites: while fibers increase stiffness and tensile/flexural strength, they often reduce impact resistance because natural fibers are more brittle compared to the polymer matrix.

Physical Properties

1. Density test

Table 5; Result of Density test

Volume fractions	Sample No	Length (L) in cm	Breadth (b) in cm	Height (h) in cm^2	Volume (Lx b x h) in cm^3	Mass of the dry sample in g	Density in g/cm^3	Average density (g/cm3)	Standard Deviation
0%	1	5.0	4.8	4.7	112.80	132.97	1.17	1.13	0.0287
	2	5.0	5.0	4.7	117.50	132.77	1.13		
	3	5.0	4.9	4.9	120.05	132.61	1.10		
10%	1	5.0	4.9	5.2	127.40	142.65	1.12	1.14	0.0208
	2	5.1	4.9	5.0	124.95	141.22	1.13		
	3	5.1	4.8	4.9	119.95	140.31	1.16		
20%	1	5.2	4.8	4.9	122.30	150.67	1.23	1.24	0.0265
	2	5.1	4.9	4.9	122.45	149.96	1.22		
	3	5.0	4.9	4.8	117.60	149.38	1.27		
30%	1	5.0	4.9	5.0	122.50	152.98	1.25	1.21	0.0306
	2	5.1	4.8	5.2	127.30	151.51	1.19		
	3	5.0	4.8	5.2	124.80	150.24	1.20		
40%	1	4.9	4.9	4.9	117.65	146.51	1.25	1.22	0.0306
	2	5.0	4.8	4.9	117.60	144.78	1.23		
	3	4.9	4.8	5.1	119.95	143.27	1.19		

ASTM/BSEN standard density of NFRP Composite is 1-1.5g/cm^3

According to *Ramnath e..tal*, (2014) is 0.6 -1.5g/cm^3

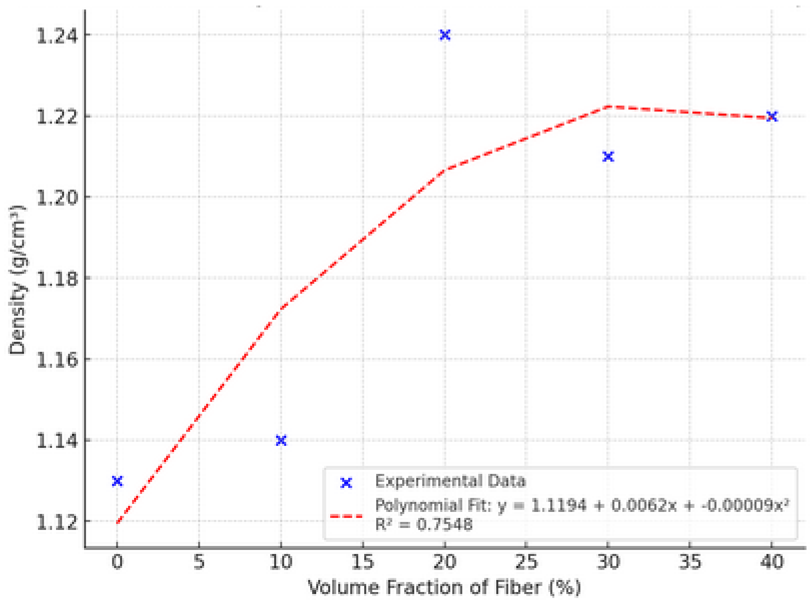

Fig 23: Graph of density against volume fractions of fibers composites

The Trend line Equation from the graph above is

y=1.1194+0.0062x−0.00009x2

Where

y = density (g/cm³),

x = fiber volume fraction (%).

Coefficient of Determination (R^2) = 0.7548, indicating a moderately strong correlation.

The plot shows that the density of the KFRP composite increases gradually from 1.13 g/cm³ at 0% fiber to a peak around 1.24 g/cm³ at 20% fiber, followed by a slight decline at higher fiber contents (30–40%). At 0% fiber content (pure matrix), the density is 1.13 g/cm³.

As fiber is introduced (10–20%), density increases to 1.24 g/cm³, indicating that fibers are denser than the matrix and contribute to the composite's higher bulk density. At 30% fiber fraction, the density slightly drops to 1.21 g/cm³, which may be due to void formation or poor fiber dispersion during fabrication. At 40% fiber content, density increases again to 1.22 g/cm³, showing partial recovery of the densification trend.

2. Water Absorption test

Table 6; Result of water absorption test

Volume fractions	Sample No	Wet mass of sample (W) in gram	Dry mass of sample (D) in grams	Water absorption = $\frac{W-D}{D}$ X 100	Average water absorption (%)	Standard Deviation
0%	1	133.56	132.69	0.66	1.86	1.32
	2	135.00	130.56	3.40		
	3	134.12	132.13	1.51		
10%	1	148.67	140.77	5.61	5.79	0.18
	2	149.33	141.24	5.73		
	3	147.94	139.53	6.03		
20%	1	160.84	151.34	6.28	6.78	0.77
	2	158.24	147.34	7.40		
	3	159.64	149.67	6.66		
30%	1	158.14	144.03	9.80	9.54	1.47
	2	156.12	145.05	7.63		
	3	159.02	143.01	11.20		
40%	1	168.14	140.88	19.35	19.32	1.23
	2	167.02	141.78	17.80		
	3	169.12	139.98	20.82		

ASTM/BSEN standard water absorption of NFRP Composite is 2 -10%

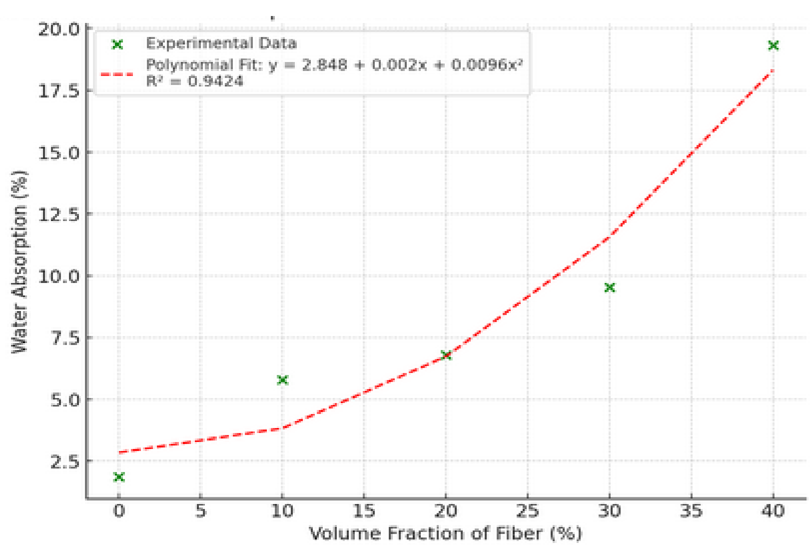

Fig 24: Graph of water absorption against volume fractions of fibers composites

The Trendline equation:

y=2.848+0.0018x+0.0096x2

Coefficient of determination (R^2): 0.9424

The plot shows that water absorption increases sharply with increasing fiber volume fraction. This is due to the hydrophilic nature of kenaf fibers, which contain hydroxyl groups (–OH) in cellulose and hemicellulose that attract moisture (Khalil et al., 2012; Jawaid & Abdul Khalil, 2011). As fiber content rises, more voids and interfacial gaps between fiber and polymer matrix form, allowing water to penetrate more easily (Kumar et al., 2020). The high R^2 value (0.9424) indicates an excellent polynomial fit, capturing the nonlinear relationship between fiber content and moisture uptake.

Conclusions

The mechanical and physical testing of kenaf fiber reinforced polymer composites demonstrated that increase in volume of fiber incorporation without proportional increase in the volume of resin reduces the mechanical properties of the composite, making the composite not suitable for load-bearing applications within a safe range of fiber volume fraction. The safe range according to ASTM Standard for NFRP Composite parameters are; 35-900MPa for Tensile strength, 45 -200MPa for flexural strength, 20 -200MPa for compressive strength, 5 – 50J for impact strength, 1 -1.5g/cm3 or 0.6 -1.5g/cm3 for density and 2 – 10% for water absorption respectively. For conventional building materials such as concrete, 2.9 – 40N/mm2 for compressive strength of solid block and 2.9 – 22.5N/mm2 for cellular & hallow blocks, 0.65 – 2.4g/cm3 for density, 2 -5MPa for flexural strength. For CSEBs, 2 -15MPa for compressive strength and 2 -3MPa for manual pressing, Impact strength values were lower than those of synthetic composites, but still adequate for non-structural applications in buildings. Excessive fiber loading beyond the optimum level resulted in reduced strength due to poor interfacial adhesion and void formation. Overall, kenaf fibers offer a sustainable and cost-effective reinforcement alternative, aligning with the current global shift toward green and renewable construction materials. The study validates that KFRP composites can be recommended for use in lightweight building applications, though further modification of fiber–matrix interfaces may be needed to improve toughness.

Recommendations

Based on this research finding, the following are recommended;

1. Future research should incorporate chemical treatments (e.g., alkali or silane treatment or at least 5-15wt% compatibilizer) to improve fiber–matrix adhesion, mechanical properties and reduce moisture absorption.
2. Combining kenaf fibers with synthetic fibers (e.g., glass or carbon) may help balance strength and toughness, making composites suitable for both structural and non-structural building components.
3. Since structural applications require fire safety, studies should include flame-retardant additives to enhance the fire resistance of KFRP composites.
4. Further studies should assess durability under environmental conditions (humidity, UV exposure, and thermal cycling) to validate the reliability of KFRP composites in real-world construction.
5. Development of standardized processing methods and pilot-scale production should be encouraged to facilitate industrial adoption of kenaf fiber composites in the construction sector.

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