International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 5 Issue 10, October - 2021, Pages: 1-12

Mechanical Properties Of Banana Fibers Reinforced Polyester Composites (Tensile And Flextural Tests)

Omniyat Zain Elabdeen[1], Seedahmed A. I[2], Ramadan Mohmmed[3]

[1]Textile Department, Collage of Engineering and Technology of Industries, SUST, Khartoum, Sudan
omniyat207@gmail.com
[2]Polymer Department, Collage of Engineering and Technology of Industries, SUST, Khartoum, Sudan
Kmmmmahmed@gmail.com
[3]Textile Department, Collage of Engineering and Technology of Industries, SUST, Khartoum, Sudan
drrmadan79@gmail.com

Abstractt*—Natural fibers has been used extensively in various engineering fields, the mechanical properties of banana fibers play a broad role in determining their applicability in various industrial and engineering fields such as household, furniture, paper and automotive. This study presents use of Banana fibers to reinforcing Polyester composite using hand layup technique. Unidirectional and quasi isotropic [0°, 90°, 45°] samples were fabricated, Tensile strength and flexural tests are performed to determine the load-displacement. The result showed that the unidirectional [0°] sample has high tensile and flexural strength comparison with unidirectional [90°] and quasi isotropic [0°, 90°, 45°] samples. From the previous findings it was estimated that the Banana fibers reinforced polyester composite has high mechanical properties, low cost and easy in fabrication. Because of that the use of Banana fibers in polymer matrix composites is recommended.*

Keywords— Natural fibers, banana fibers, unidirectional, quasi isotropic

1. INTRODUCTION

Natural fiber-reinforced polymer composite materials are rapidly growing both in terms of their industrial applications and fundamental research as they are renewable, low, completely or partially recyclable and biodegradable. [1]

In the recent years, the natural fiber reinforced composites created a great interest among researchers towards technological developments. Among different fibers available, the banana fiber (a waste product obtained from the dry stalks of banana trees) offers a wide possibility for engineering applications. In general, the banana fiber reinforced polyester composites are used for structural applications, as they possess a good mechanical property, eco-friendly and are renewable. [2]
Polymeric based composites materials are being used in many application such as automotive, sporting goods, marine, electrical, industrial, construction, household appliances, etc. Polymeric composites have high strength and stiffness, light weight, and high corrosion resistance. [3]
Using agricultural wastes for industrial purposes is much more environmentally friendly practice than many residues available currently in use. Until recently, many farmers disposed of agricultural wastes by burning or land filling them. [4]
A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components.
Typical engineered composite materials include:

- Composite building materials, such as cements, concrete
- Reinforced plastics, such as fiber-reinforced polymer
- Metal composites
- Ceramic composites (composite ceramic and metal matrices).

Composite materials are generally used for buildings, bridges, and structures such as boat hulls, swimming pool panels, race car bodies shower stalls, bathtubs, storage tanks, imitation granite and cultured marble sinks and countertops. The most advanced examples perform routinely on spacecraft and aircraft in demanding environments.

Structure of Composites:
Structure of a composite material determines its properties to a significant extent.
Structure factors affecting properties of composites are as follows:

- Bonding strength on the interface between the dispersed phase and matrix.
- Shape of the dispersed phase inclusions (particles, flakes, fibers, laminates).
- Orientation of the dispersed phase inclusions (random or preferred).

Laminate is a stack of plies of composites. A composite laminate is an assembly of layers of fibrous composite materials which can be joined to provide required engineering properties, including in-plane stiffness, bending stiffness, strength, and coefficient of thermal expansion.

The individual layers consist of high-modulus, high-strength fibers in a polymeric, metallic, or ceramic matrix material.
Layers of different materials may be used, resulting in a hybrid laminate. The individual layers generally are orthotropic (that is, with principal properties in orthogonal directions) or transversely isotropic (with isotropic properties in the transverse plane) with the laminate then exhibiting anisotropic (with variable direction of principal properties). [5]
Composite Manufacturing Processes:
For making a composite part, a manufacturer can combine or alternate several processes, depending on the requirements for quality and cost, as follows:
Hand lay-up.
Prepregs forming.
Pressure molding.
Vacuum bagging.
Filament winding.
Pultrusion.
Spray method.
Resin transfer molding.

For the Hand lay-up technique, Resins are impregnated by hand into fibers which are in the form of woven, knitted, stitched or bonded fabrics. This is usually accomplished by rollers or brushes, with an increasing use of nip-roller type impregnators for forcing resin into the fabrics by means of rotating rollers and a bath of resin. Laminates are left to cure under standard atmospheric conditions.

In this work Banana fibers were used for fabricated the composite specimen. The Banana fibers Fig (1), were obtained from Khartoum, Polyesters resin were obtained from industrial chemicals resins CO.LTD, Saudi Arabia.

Some properties of Banana fibers are illustrated in Table (1).

Table 1: Mechanical and Physical properties of the banana fibers.

property	range
Tensile Strength (N)	17.2
Strain (%)	37.4%
Young’s Modulus (N)	4.7
Average Length (mm)	1500
Diameter (mm)	0.6

International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 5 Issue 10, October - 2021, Pages: 1-12

Figure 1: Banana fibers.

Table 2: Some properties of Polyester resin.

Property	Range
Tensile Strength	60 Mpa
Tensile Modulus	7700 Mpa
Flex Strength	170 Mpa
Flex Modulus	7700 Mpa
Shrinkage	-0.14 %
Specific Gravity	1.96
Moisture Absorption%	0.5

Table 3: Weight of materials used.

Samples	**Unidirectional sample**	**Quasi isotropic [0º,90º,45º]**
Polyester (g)	400	**600**
Banana fiber (g)	20	**65**

2.1 Composites Manufacture Process

Hand Lay-Up Molding

The composite materials used for this work were fabricated by hand layup process. Continues long Banana fiber was used to prepare the specimen. The composite specimen consists of total six layers.
The two samples of Banana/Polyester composite unidirectional and quasi isotropic [0º,90º,45º] were manufactured.

Figure 2: Unidirectional sample.

Figure 3: Quasi isotropic [0º,90º,45º] sample.

2.2 Mechanical testing

2.2.1 Tensile Test

For tensile testing, the ZWICK/ROELL (ZWICK Z010) machine was used as shown in figure (4). Tensile test applied according to ASTM D 638 standards, the applied velocity is 5 mm/min, and the initial load is 0.1 Mpa. The samples have been prepared in the form of the dog bone shape.
For tensile test, specimen was prepared according to the ASTM D638 standard. The dimensions table (4), gauge length and cross-head speeds are chosen according to the ASTM D638 standard.

Figure 4: Tensile test machine

Figure 5: Flexural test machine.

2.2.2 Flexural Test (Three-Point Flexural Testing)

The 3-point Flexural test is the most common Flexural test for composite materials. For Flexural testing, the ZWICK/ROELL (ZWICK Z010) machine were used as shown in figure (5).Flexural test applied according to ASTM D 790 standards, the applied velocity is 1 mm/min, and the initial load is 0.1 Mpa. The samples have been prepared in the form of the rectangle shape.

The Flexural specimens were prepared according to the ASTM D 790 standard. The dimensions of these test specimens are listed in Table (4).Specimen deflection is measured by the cross head position.

2.3 Preparation of Composite Specimen

International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 5 Issue 10, October - 2021, Pages: 1-12

Table 4: Dimensions of tests specimens.

Specimen Types and Specifications				
Unit	**Tensile Test**		**Flexural Test**	
	a	**b**	**a**	**b**
Length (mm)	115	115	95	115
Width(mm)	19	19	13	13
Thickness (mm)	5	6	5	6

a: Unidirectional sample.
b: Quasi isotropic [0º,90º,45º] sample.

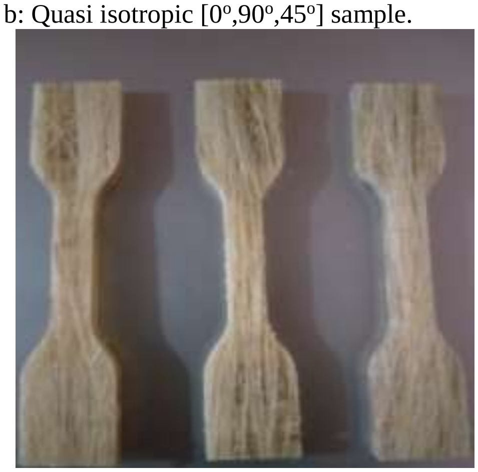

Figure7: Tensile test specimen.

Figure 8: Flexural test specimen.

3. RESULTS AND DISCUSSIONS

Table 5: Results of tensile and flexural tests

Type of tests / Type of specimen	**Tensile strength (N)**	**Displacement (mm)**	**Flexural load (N)**	**Displacement (mm)**
Unidirectional [0º]	2500	3	270	10
Unidirectional [90º]	270	0.9	145	3.75
Quasi isotropic[0 º, 90 º, 45 º]	1000	2	135	9.5

3.1 Tensile Test

3.1.1 Load displacement behavior

The different composite specimen samples were tested in the ZWICK/ROELL (ZWICK Z010) testing machine and the samples were left to break till the ultimate tensile strength occurs. Stress-strain curve is plotted for the determination of ultimate tensile strength and elastic modulus. The sample graph generated directly from the machine for tensile test with respect to load and displacement for unidirectional [0º] is presented in Fig (9), for unidirectional [90 º] is presented in Fig (10), and for quasi isotropic [0º,90 º,45 º] is presented in Fig (11). The curves in this graphs shown a linear behavior at the first stage followed by a complete

International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 5 Issue 10, October - 2021, Pages: 1-12

failure of the composite in unidirectional [0º] unidirectional [90º] samples, but vibration occurs in the quasi isotropic [0 º, 90 º, 45 º] sample after failure due to the structure of the composite. Fibers and matrix behave linearly at low displacement.

The comparative results of the different composites specimens tested are presented in Fig (15) the results indicate that unidirectional [0º] gives better tensile strength than the other two types of composites considered.

The tensile strength of the unidirectional [0º], unidirectional [90º] and quasi isotropic [0 º, 90 º, 45 º] are in the range 0f 2500N, 270N and 1000N respectively. The results indicate that the unidirectional [0º] composite outperformed the other types of composites tested.

Stress-strain curve obtained from the ZWICK/ROELL (ZWICK Z010) testing machine for the unidirectional [0º], unidirectional [90º] and quasi isotropic [0 º, 90 º, 45 º] are shown in Fig (12), Fig (13) and Fig (14) respectively. The results indicated that same trend as that of the load vs. displacement curve.

For the results, it can be asserted that the unidirectional [0º] composite are performing well compared to the other types of composites.

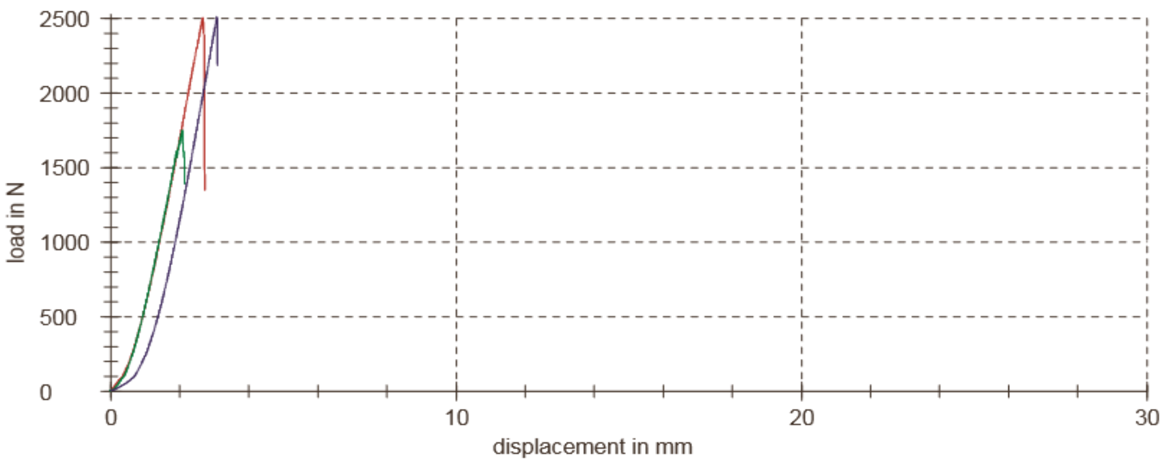

Figure (9): Load-displacement curve for tensile strength test of the unidirectional [0º] specimen.

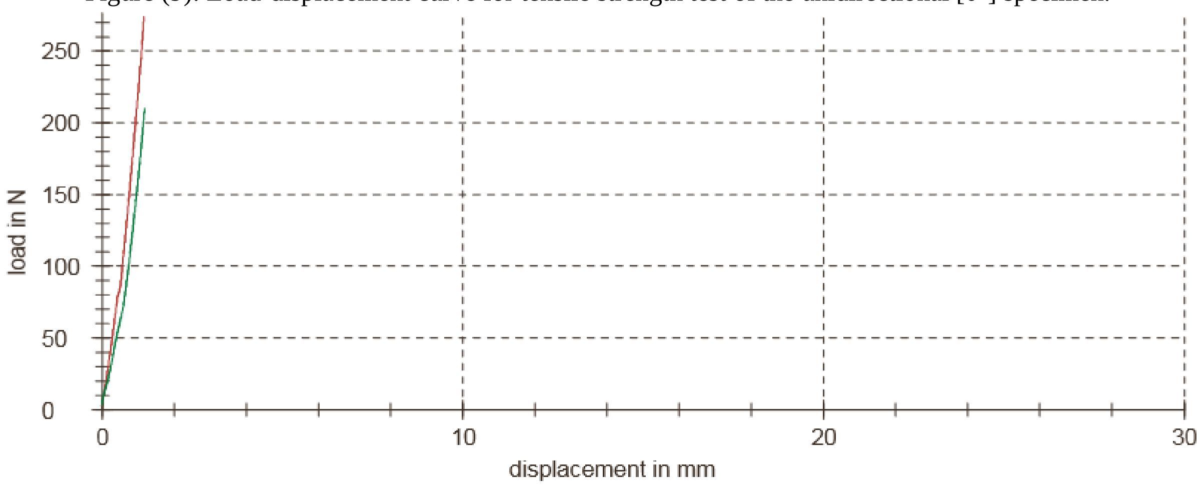

Figure (10): Load-displacement curve for tensile strength test of the unidirectional [90º] specimen.

International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 5 Issue 10, October - 2021, Pages: 1-12

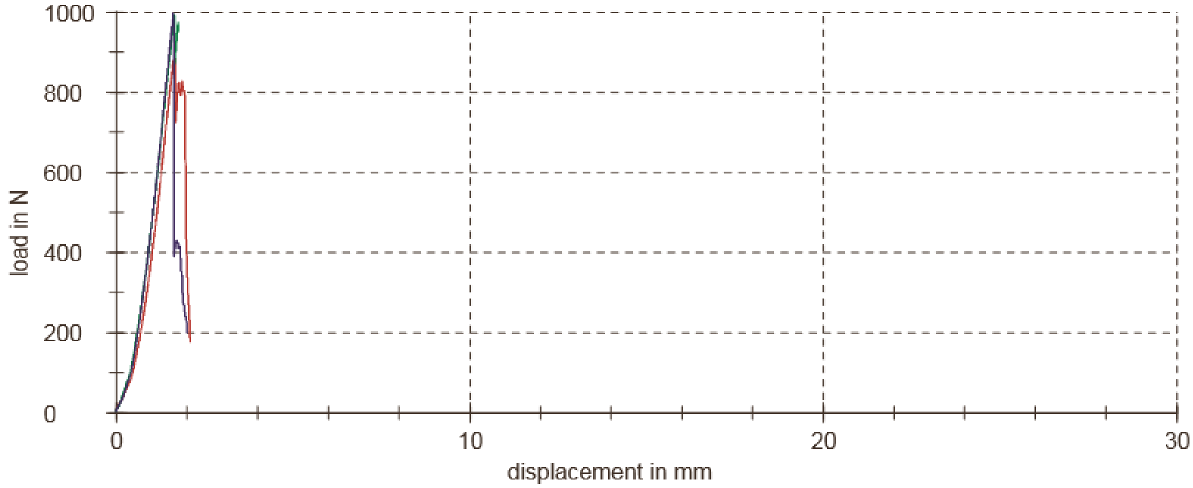

Figure (11): Load-displacement curve for tensile strength test of the quasi isotropic [0 º, 90 º, 45 º] specimen.

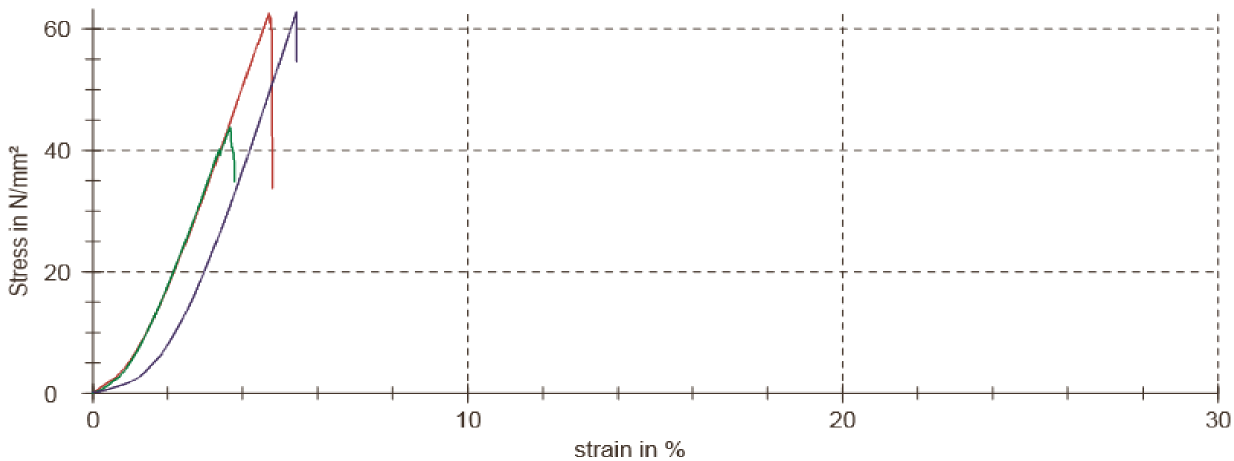

Figure (12): Stress-strain curve for tensile strength test of the unidirectional [0º] specimen.

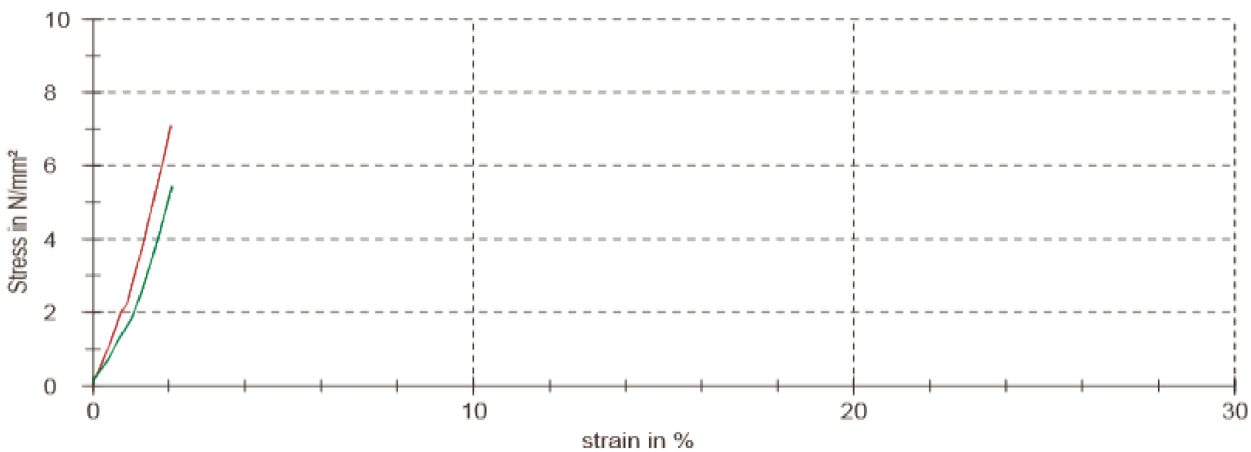

Figure (13): Stress-strain curve for tensile strength test of the unidirectional [90º] specimen.

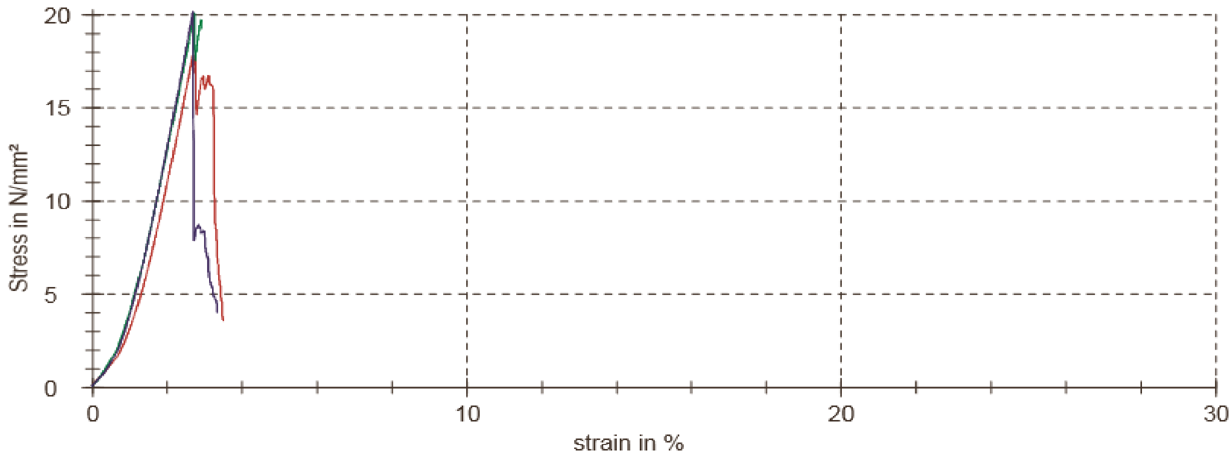

Figure (14): Stress-strain curve for tensile strength test of the quasi isotropic [0 º, 90 º, 45 º] specimen.

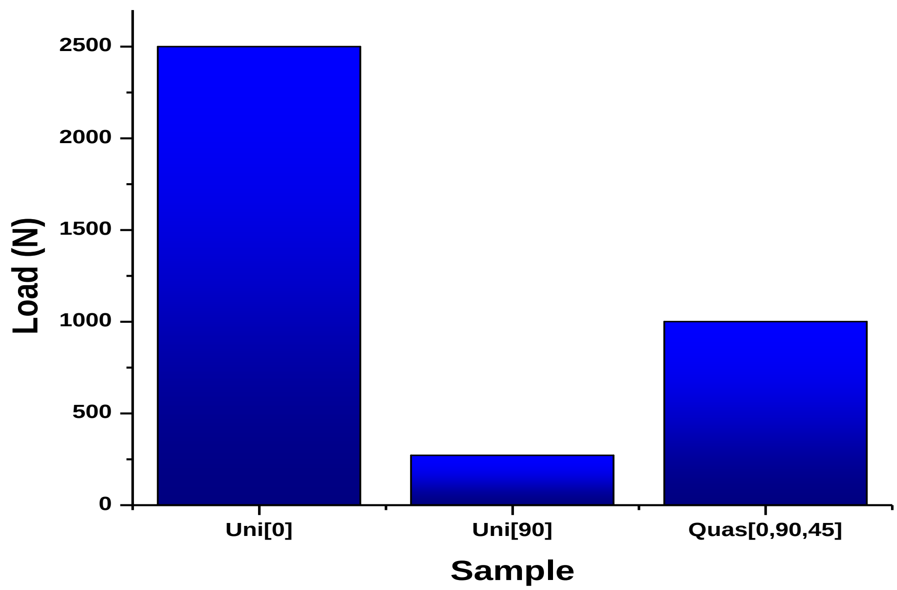

Figure (15): Tensile load comparison of different samples.

3.1.2 Failure Mode

The failure observed in Fig (16) for the unidirectional [0º], unidirectional [90º] and quasi isotropic [0 º, 90 º, 45 º] specimens. The behavior was almost similar in the failure mode for the unidirectional [0º] quasi isotropic [0 º, 90 º, 45 º], but for unidirectional [90º] was different.

Specimen of the unidirectional [0º] and quasi isotropic [0 º, 90 º, 45 º] shows crake matrix and exhibit small fiber pull-out and breakage but no complete breakage for the composite. Unidirectional [0º] Specimen has high tensile strength and shows sudden break for the composite, Due to the composite brittleness.

International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 5 Issue 10, October - 2021, Pages: 1-12

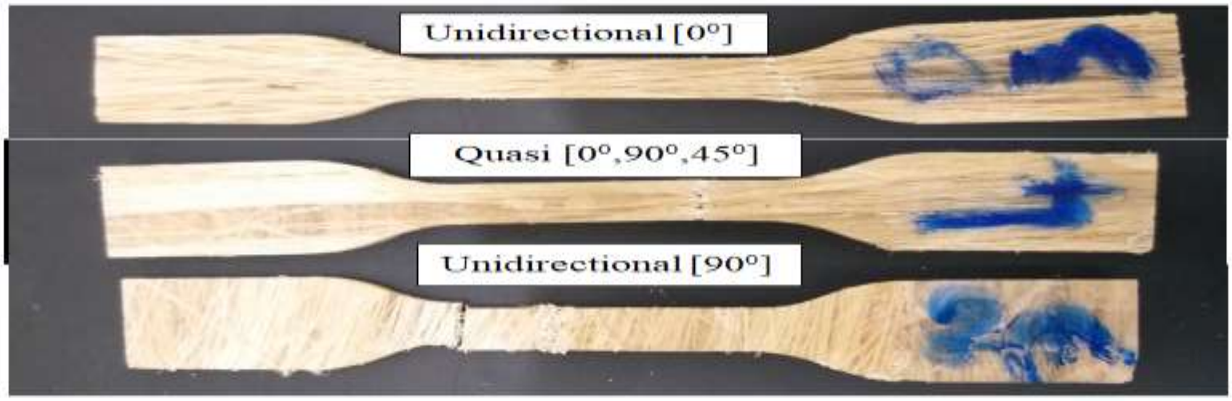

Figure (16): Tensile specimens after failure.

3.2 Flexural Test

3.2.1 Load Displacement Behavior

The three point Flexural tests were being performed in order to obtain the load-displacement curves for all specimens as shown in Fig (17), Fig (18) and Fig (19), for the unidirectional [0°], unidirectional [90°] and quasi isotropic [0 °, 90 °, 45 °] respectively. These curves were used to determine the behavior of the failure modes of banana Fiber Reinforced Composite.
Results of the three specimens from unidirectional [0°] and quasi isotropic [0 °, 90 °, 45 °] have similar behavior, and that behavior indicated that displacement increases with the load increasing, after that, it is tends to decrease, breaking takes place. The results indicate that the unidirectional [0°] shows better results than the other type of composites tested.
The curves can be divided into three regions, the first region, linear in appearance can explain the elastic deformation of the banana/polyester composite due to the composite sample carrying the load exerted, and the bonding was proper between the fiber and the matrix. The second region observes the oscillation form can explain the plastic deformation, due to the fibers only carry the load, In Third region the specimen failed.
Stress-strain curve obtained from the ZWICK/ROELL (ZWICK Z010) testing machine for the unidirectional [0°], unidirectional [90°] and quasi isotropic [0 °, 90 °, 45 °] are shown in Fig (20), Fig (21) and Fig (22) respectively. The results indicated that same trend as that of the load vs displacement curve, the results indicate that the unidirectional [0°] composite are performing well compared to the other types of composites.
The average values observed for different composites specimen is presented in Fig (23).for the unidirectional [0°], unidirectional [90°] and quasi isotropic [0 °, 90 °, 45 °] are in the range 0f 270N, 145N and 135N respectively. The results indicate that the unidirectional [0°] composite outperformed the other types of composites tested.

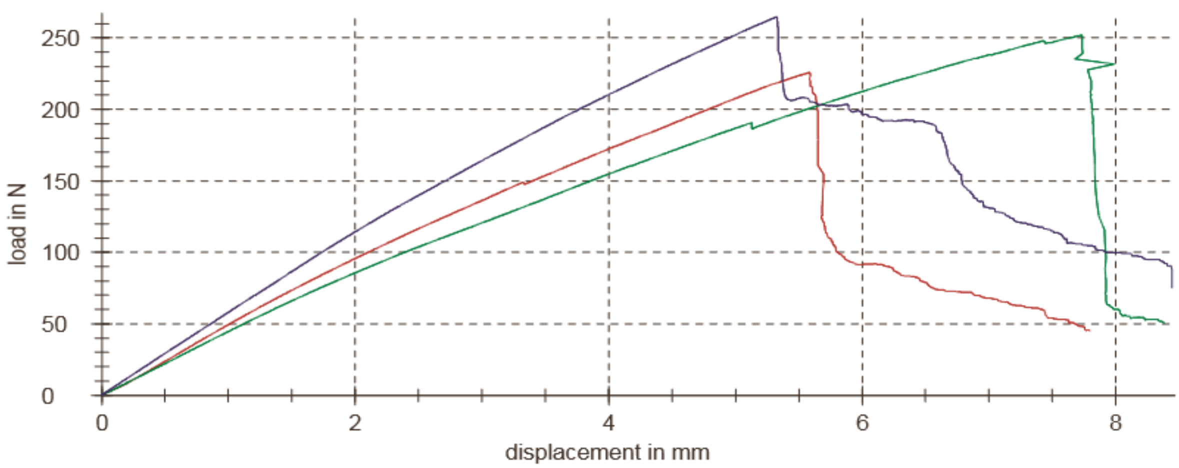

Figure (17): Load-displacement curve for flexural test of the unidirectional [0°] specimen.

International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 5 Issue 10, October - 2021, Pages: 1-12

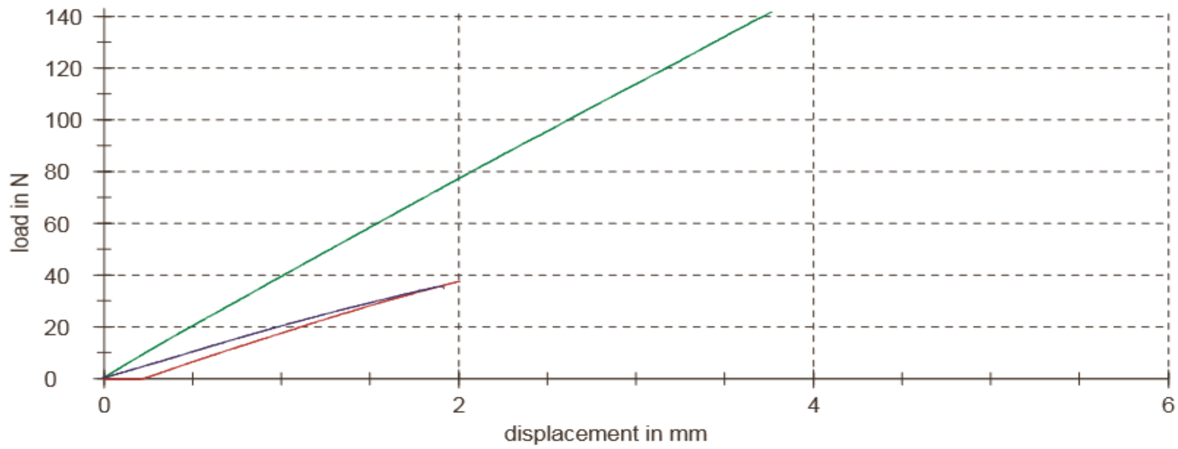

Figure (18): Load-displacement curve for flexural test of the unidirectional [90º] specimen.

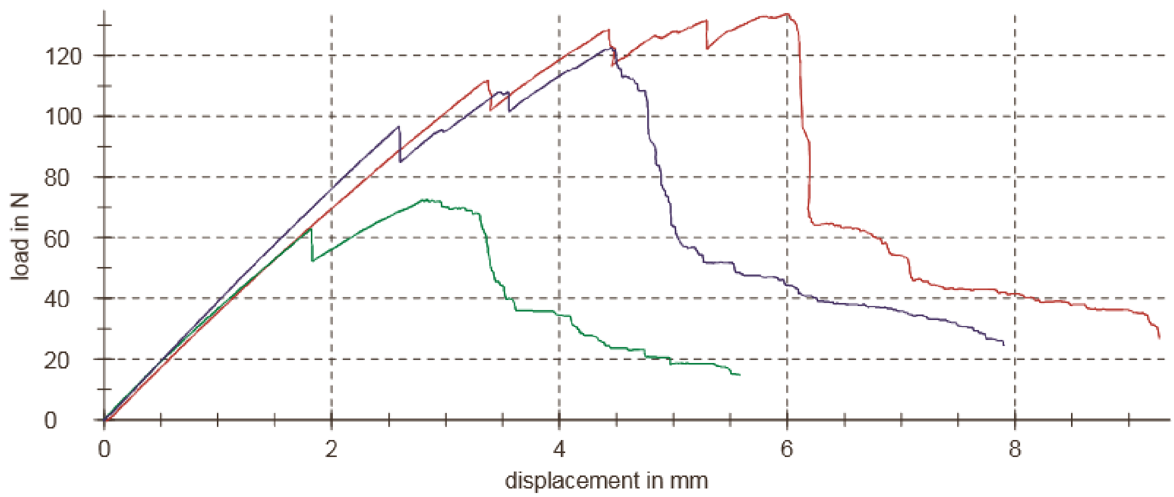

Figure (19): Load-displacement curve for flexural test of the quasi isotropic [0 º, 90 º, 45 º] specimen.

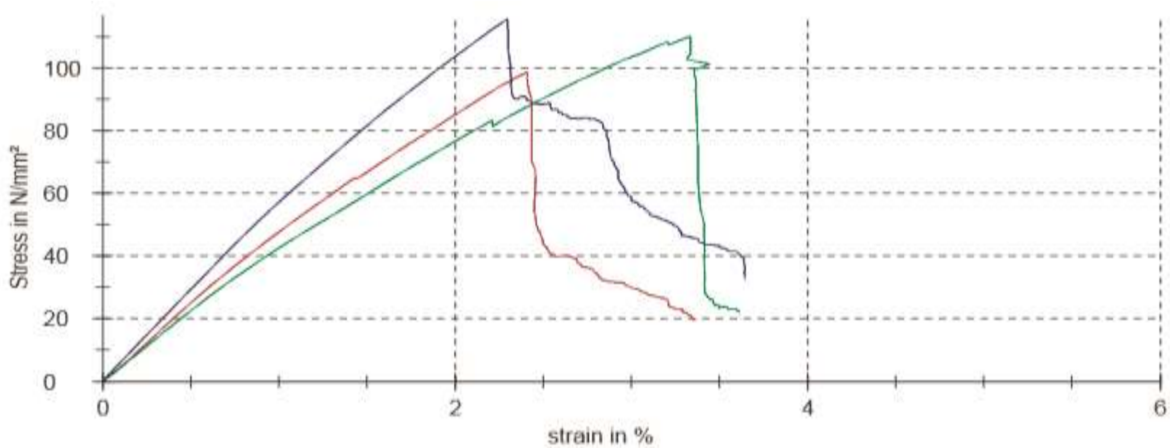

Figure (20): stress-strain curve for flexural test of the unidirectional [0º] specimen.

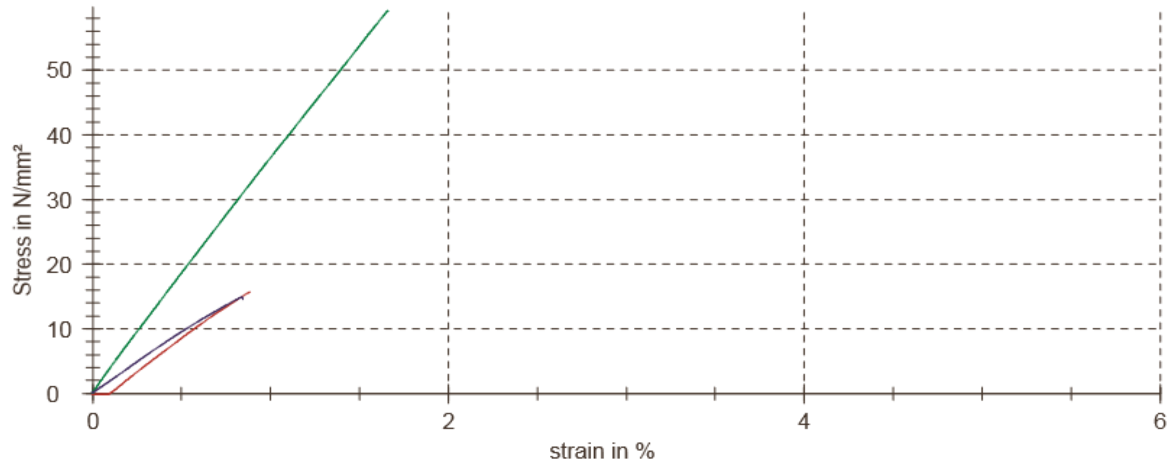

Figure (21): stress-strain curve for flexural test of the unidirectional [90°] specimen.

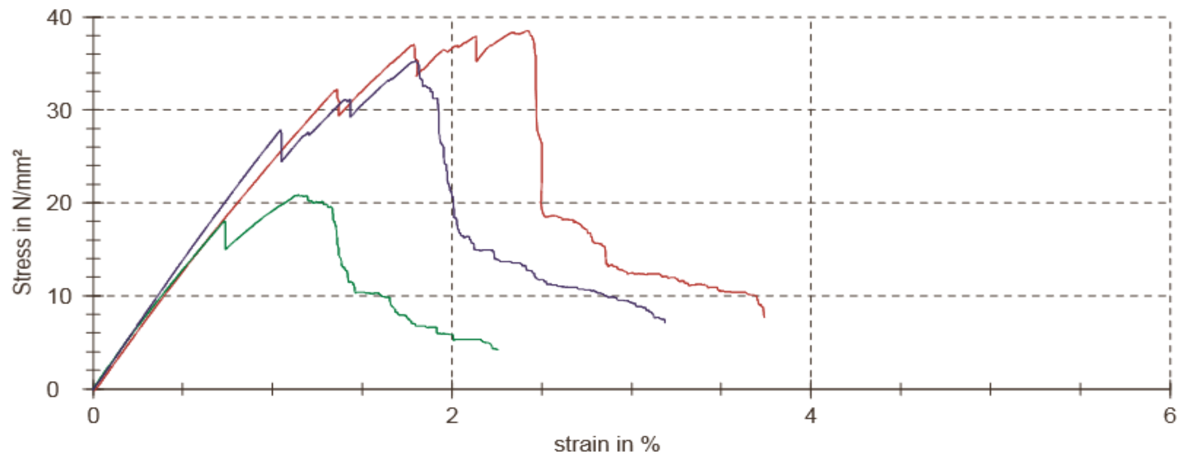

Figure (22): stress-strain curve for flexural test of the quasi isotropic [0 °, 90 °, 45 °] specimen.

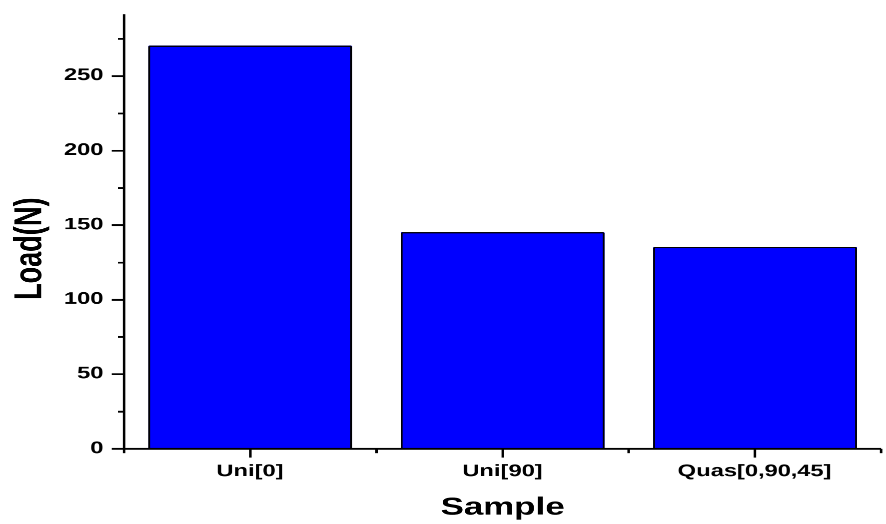

Figure (23): flexural load comparison of different samples.

3.2.2 Failure mode

The Failure mode of banana/polyester composite illustrated in Fig (24).The damage in specimens after flexural event was evaluated by visual inspection. The failure modes involved in flexural damage of the composite were characterized as combinations of matrix cracking, fiber fracture, buckling, and delamination.

Figure (24): flexural specimens after failure.

4. CONCLUSIONS & RECOMMENDATIONS

The banana fiber reinforced polyester composite unidirectional and quasi isotropic [0 º, 90 º, 45 º] samples were fabricated by hand layup process. The composites samples were subjected to mechanical testing such as tensile, flexural and compression tests. Based on the results, the following conclusions are drawn:

- The tensile strength of the unidirectional [0º], unidirectional [90º] and quasi isotropic [0 º, 90 º, 45 º] specimens results indicate that the unidirectional [0º] composite outperformed the other types of composites tested.
- The flexural strength results for different composites specimens indicate that the unidirectional [0º] composite outperformed the other types of composites tested.

5. REFERENCES

[1] ROHIT, K. & DIXIT, S. 2016. A review-future aspect of natural fiber reinforced composite Polymers from Renewable Resources, 7, 43-59.

[2] PRABU, V. A., KUMARAN, S. T. & UTHAYAKUMAR, M. Performance evaluation of abrasive water jet machining on banana fiber reinforced polyester composite. Journal of natural fibers, 2017. 14, 450-457.

[3] SAPUAN, S. & MALEQUE, M. Design and fabrication of natural woven fabric reinforced epoxy composite for household telephone stand .Materials & design, 2005. 26, 65-71

[4] HAYES, M. Agricultural residues: A promising alternative to virgin wood fiber. Issues in Resource Conservation, Briefing Series, 1998.

[5] TALREJA, R. & SINGH, C. V. Damage and failure of composite materials, Cambridge University Pres, 2012.