Investigation of Mechanical Characteristics of FRP Composite Material Using Natural Fibres

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Abstract- ***Researchers are concentrating more and more on the development of Natural Fibre-Reinforced Polymer Composites (NFRP) as environmentally friendly and sustainable due to its biocompatibility, high specific strength, low heat conductivity, and biodegradability, which make it a potential material for use in engineering and medical devices. These composites can be used to replace conventional metals and non-metals (synthetic) such as glass, aramid and carbon. Composites reinforced with natural fibres can be utilized as an environmentally friendly alternative to synthetic materials since natural fibres are inexpensive in cost, less weight, renewable, need little energy to manufacture and are biodegradable. This study focuses the development of FRP composite by combination of natural fibres. The raw materials of palm fruit fibre and sisal fibre is chosen as reinforcement material and epoxy resin as adhesive. Mechanical characteristics of this proposed FRP material to be experimented for different material combination. These composites may be employed in a variety of practical applications such as carpets, geotextiles, dartboards, baskets, shoes, bags and masquerade dresses. The results found that the composition of specimen 2 exhibited greater flexural strength 89.879 MPa, 1.4% elongation, 1.25 joules of impact strength and hardness 19.29HV respectively.***

Keywords: NFRP Composites, Natural Fibre, Mechanical Characteristics, Experiment Test.

I. INTRODUCTION

A growing number of engineers are looking for less expensive structural materials with low density, high strength, stiffness, resistance to abrasion and impact, low thermal expansion, and corrosion resistance. Natural fibre composite materials, such sisal and palm fruit, are both economical and environmentally beneficial. Both renewable and non-renewable natural fibres may be found in plants and animals. There are several varieties of them, including jute, flax, hemp, sisal, bananas, kenaf, and cellulose fibre from oil palm fruit bunches. Composite materials made on jute fibre have become more popular in recent years. Natural fibres provide several benefits, including low density, machine wear, biodegradability, non-renewable, and non-toxicity. The automobile sector benefits greatly from their low density. Natural fibres are materials that resemble hair that may be found in many places. Paper and composite materials can be created from them by turning them into nonwoven fabrics, filaments, thread or rope. Researchers are looking into how natural fibres may be improved for a variety of uses. Based on their resources, natural fibres may be divided into three categories: mineral fibres, plant cellulose fibres, and animal fibres. The tensile and flexural characteristics of epoxy hybrid composites reinforced with glass, jute, and carbon fibres in an interaction structure were studied by Baky (2017). Test specimens were made using hand lay-up technique in this work, and the effects of fibre content, hybridization, and plies stacking order were examined on the composites. Nadendla et al (2014) introduce the Palmyra Palm petiole fibre, a novel natural fibre with tensile and surface properties. They conduct mechanical and dielectric property tests on composites composed of both treated and untreated fibres. The best tensile, modulus and flexural strength are found in chemically treated fibre reinforced polymer composites; impact strength is noticeably greater. It is recommended that designers use lightweight insulating materials by considering data on fibre content and dielectric strength.

For semi-structural applications, Reda et al. (2022) created aliphatic epoxy composites reinforced with date palm fibre. The best results were achieved by the hybrid composites composed of bamboo and date palm fibre, which decreased water absorption and swelling by 15.37% and 27.66%, respectively. High flexural strength was exhibited by the bamboo composites, which were followed by PDF-A/B, PDF-L/B, and date palm fibre-AA/B. The density, water absorption, and mechanical characteristics of an epoxy composite made of pressed palm oil fruit fibre (PPOFF) were examined by Eze et al (2019). When constructing partition panels, the composite material might be useful. Hongwu et al (2021) investigated the impact of extended sisal fibre (SF)/polylactic acid (PLA) premixes on the mechanical characteristics of composites reinforced with sisal fibres (LSFCs). The study discovered that long sisal fibres greatly increase the tensile strength of LSFC material and that SF/PLA premixes may be produced successfully.

The effect of sisal fibre content on the mechanical and thermal characteristics of composites has been studied by Patil et al. (2017). Melt-mixing and compression molding were the methods used to create the composites. The fibre and epoxy percentages were varied from 4% to 10% in 2% steps. In 2016, Akash et al. investigated the water absorption and mechanical characteristics of epoxy resin thermoset hybrid composites reinforced with sisal and coir fibres that had been treated with sodium hydroxide (NaOH). Water absorption increased with increasing fibre volume. Based on the findings, sisal and coir fibres show promise as reinforcement for inexpensive bio composites that have a high strength-to-weight ratio.

II. METHODOLOGY

Due to its many qualities, including low density, strong wear resistance, good tensile strength, and superior surface quality, composite materials are becoming more and more necessary. A new FRP composite is being developed using Palm Fruit and Sisal Fibre as reinforcement and epoxy resin as adhesive. The automotive industry may use the composite for side panel linings, roof linings, dashboards, and rear walls. The material's mechanical properties will be optimized through experimentation.

III. RAW MATERIAL (Natural Fibres)

Fibre reinforced polymer composite offers the higher stiffness and strength making them lighter than conventional steel. This study focuses the FRP composite which has developed using natural fibres such as palm and sisal fibre. Because it is lighter than sisal and hemp, palm fibre is more wettability resistant and appropriate for use in space and automobile applications. Sisal fibre, on the other hand has a higher tensile strength and more commonly used in construction and marine applications due to its durability and resistance to moisture. The combination of these two fibres in a composite material can provide better features for various industries. In this project epoxy is used as an adhesive material. Thermosetting polymers with at least two epoxide groups in their monomers are the basis for epoxy resins. Additionally, a variety of curing agents and modifiers can be used with epoxy resins. The purpose of this is to attain the characteristics needed for a particular use.

(a) (b)

Fig. 1 Selected Raw Materials (a) Palm Fruit Fibre (b) Sisal Fibre

IV. SPECIMEN CASTING

The traditional process for creating woven composites is hand lay-up technique. The specimens are produced by adhering to certain guidelines. Release the antiadhesive chemical first to treat the mold surface and prevent polymer from adhering to it. Next, to give the product a smooth surface, a thin plastic sheet is put to the top and bottom of the mold plate. Hand lay-up is a straightforward molding technique that produces composites with a large variety of part sizes, inexpensive tooling, and easy processing. It works well with several molds and may be produced in small to big numbers. The process involves applying a gel coat to the mould, then manually placing roll stock Fibreglass reinforcement on it. In order to solidify the laminate, moisten the reinforcement and release trapped air, laminating resin is applied using a pouring technique. To increase the thickness of the laminate, additional layers of fiberglass reinforcement are applied. Figure 2 displays the schematic of the hand lay-up. In the fabrication process we should take a fibre into sheet form as shown in figure 1.

Table. 1 Proportions of Composite Material

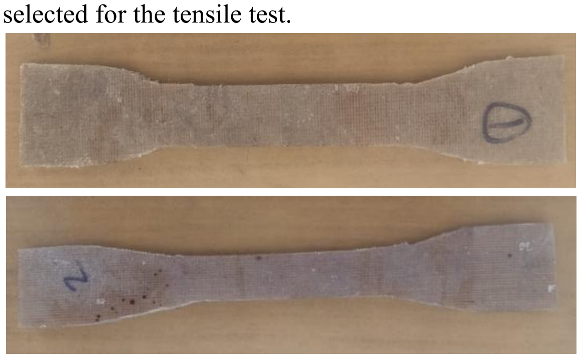
Specimen ID	Palm Fibre	Sisal Fibre	Resin
1	50%	10%	40%
2	30%	30%	40%

Fig. 2 Hand layup method

The two different compositions of composite mixture ratios were prepared by the hand layup process to determine the strength of the composites. The specimen was taken as a sheet with a length of 5mm and a mass of 500g by means of moulding. In the moulding process the wax is applied (here the wax is used for non-sticking purposes; in this project, we use the wax as a transparent sheet), it helps to demolish specimens easily and avoid resin sticking to mould cavities. (50% epoxy and 50% hardener) mixture was applied into the Mould by hand layout as shown in figure 2. The resin matrix phase (gel) was added to the mould surface following mould preparation.

V. EXPERIMENT

Mechanical testing that measures a material's response to stress by applying tensile force is called tensile testing, or tension testing. It establishes the strength and elongation capabilities of a material. Figure 3 displays the ASTM D 638 specimens that were selected for the tensile test.



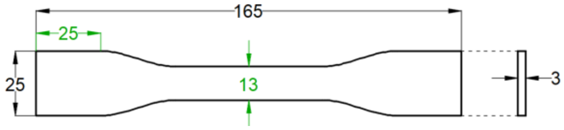


Fig. 3 Tensile Test specimen (ASTM D 638)

Impact tests calculate a material's toughness and temperature-dependent brittle-ductile transition by measuring the energy absorbed by the material during fracture. They entail applying a sudden, dynamic load to components like as dies, shafts, bolts, and anvils. In this instance, we selected a specimen (ASTM D 256) for the tensile test, and figure 4 displays the test specimen.

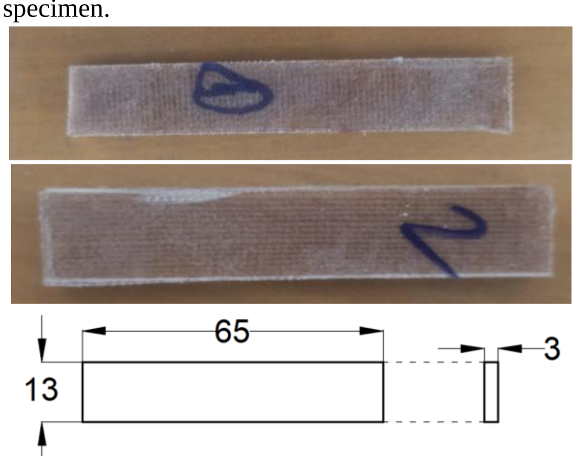


Fig. 4 Izod Test specimen (ASTM D 256)

Flexural testing quantifies the force needed to bend a plastic beam and assesses a material's stiffness or resistance to bending. The amount of flexure a material can withstand before permanent distortion is indicated by its flexural modulus. The specimen that was chosen for this particular flexural test is shown in Figure 5 and is recognized as an ASTM D 790 standard.

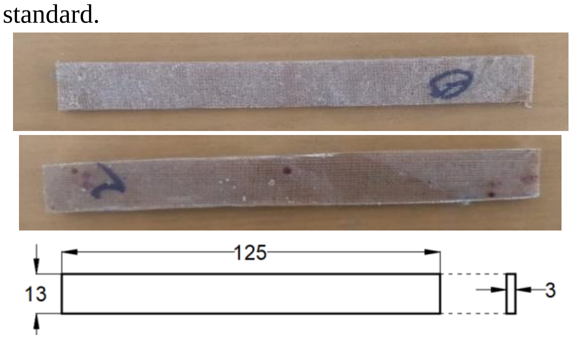


Fig. 5 Flexural Test specimen (ASTM D 790)

Hardness refers to a material's mechanical resistance to indentation by a harder body, with diamond being the hardest natural material used as an indenter. It differs from strength, which measures a material's resistance to deformation and separation.

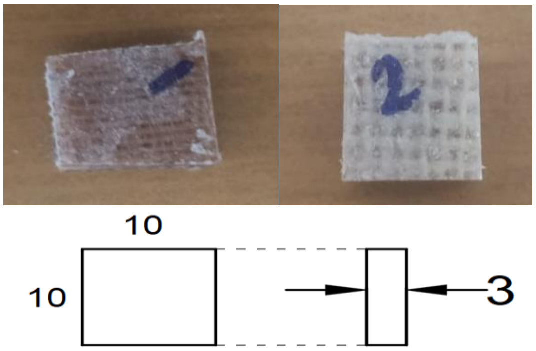


Fig. 6 Hardness Test specimen

VI. RESULT & DISCUSSION

This investigation involved evaluating two different material compositions for a variety of composites in terms of tensile, impact, flexural, and hardness. The outcomes of these experiments have given important new information on the mechanical characteristics of the composites and how composition affects those characteristics. By comparing the performance of the composites in each test, we can determine which material composition offers the best overall mechanical properties.

The experiment test results for the flexural test on the ASTM D 790 specimen (as shown in Figure 5) were conducted on a 52 mm^2 specimen. Table 2 shows specimen 2 has significantly higher flexural strength and modulus, capable of withstanding 89.879 MPa and 1118.668 GPa at a peak load of 560.848 N, demonstrating superior deformation resistance. The inherent qualities of sisal and palm fibres made it possible to mix a composite of (palm 30%, sisal 30%, and epoxy 40%). Thus, the flexural results shows that specimen 2 has 3 times more strengthen than the specimen 1 and it was also represented as a graphical method, as shown in figure 7. This suggests that the composition of palm, sisal, and epoxy in the composite material is well-suited for applications requiring high resistance to flexural loading conditions.

Table. 2 Results of Flexural Test

Specimen No.	Area (mm^2)	Peak Load (N)	Flexural Strength (MPa)
1	52	194.395	70.094
2	52	560.848	89.879

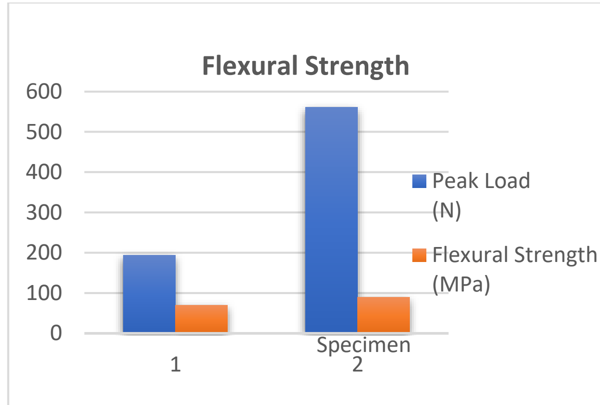


Fig. 7 Comparison of Flexural Strength

Table. 3 Results of Tensile Test

Specimen	Area (mm^2)	Peak Load (KN)	% Elongation	UTS (N/mm^2)
1	78	26.3431	2.790	33.776
2	78	18.1391	1.460	23.260

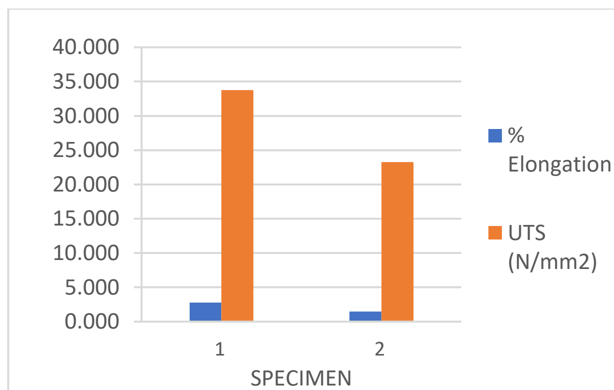


Fig. 8 Comparison of Ultimate Tensile Strength

Tensile strength tests were performed on the ASTM D 638 specimens. The results of the experiment are displayed in Figure 8 and Table 3 respectively where specimen 1 exhibited a notably greater strength than specimen 2. At a peak load of 26.343 N, the specimen 1 showed 33.776 N/mm^2 which showing a tensile strength. However, specimen 2 had a lower percentage of elongation at a peak load of 18.1391 kN. The results suggest that specimen 1 may be more suitable for applications requiring high tensile strength, while specimen 2 may be more suitable for applications where elongation is a critical factor.

Table. 4 Impact Test

Specimen	CS Area (mm^2)	Izod Impact Value (J)
1	52	0.4
2	52	1.25

The ASTM D 256 specimen, as seen in Fig. 4, was used for the impact test. It has obtained about 1.25 J impact load for the cross section of 52 mm^2. It was achieved by the presence of sisal fibre in specimen 2, which significantly improved its performance in impact testing (table-4). This indicates that specimen 2 is more resistant to impact forces compared to specimen 1, making it a potentially better choice for applications requiring high impact strength. For further investigation, a hardness test was conducted to determine the difference in performance between the two specimens.

The specimens were successfully tested using Vickers hardness testers, with results shown in Table 5 and Figure 10. The average value indicates that specimen 2 has a higher VH number than specimen 1, with each specimen tested at three different locations. The results indicate that specimen 2 consistently displayed higher hardness values across all three locations tested, suggesting a more uniform hardness distribution compared to specimen 1, based on analysis.

Table. 5 Hardness Test

Specimen	Micro Hardness (HV)	Average(HV)
1	11.319	13.52
	15.9	
	13.341	
2	11.98	19.29
	22.94	
	22.94	

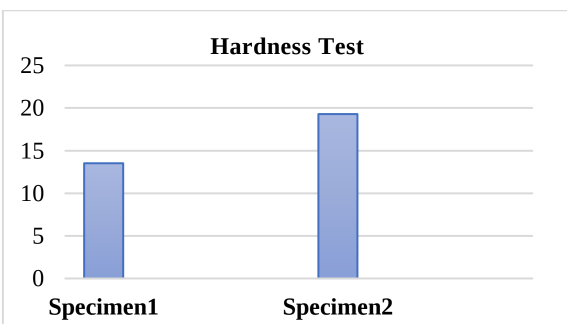


Fig. 10 Comparison of Material Hardness

VII. CONCLUSION

This study presents a hybrid composite made from natural fabric as Palm fruit & Sisal fibre and epoxy resins. The mechanical properties of Flexural, tensile, Impact Test and hardness test have investigated experimentally for proposed composite under two different material composition. From the analysis of the system, it concludes that, the flexural results shows that specimen 2 has 3 times more strengthen than the specimen 1. The specimen 1 demonstrated significantly greater strength than the second at a peak load of 26.343 N, demonstrating a tensile strength of 33.776 N/mm^2. The specimen 2 is more resistant to impact forces compared to specimen 1, approximately 75% better than specimen 1. It is suggestion that making it a potentially better choice for applications requiring high impact strength. The average value (19.29) indicates that specimen 2 has a higher VH number than specimen 1. By observing the experimental results of proposed Fibre metal laminate Concluded that the specimen 2 has a better composite strength over the specimen-1.

REFERENCE

[1] Abd El-baky MA "Evaluation of Mechanical Properties of Jute/Glass/Carbon Fibres Reinforced Hybrid Composites", Fibres and Polymers (2017), Vol 18, pp: 2417- 2432.

[2] Nadendla Srinivasababu, Suresh Kumar J & Vijaya Kumar Reddy K "Manufacturing and Characterization of Long Palmyra Palm/ Borassus Flabellifer Petiole Fibre Reinforced Polyester Composites", Procedia Technology (2014), Vol 14, pp: 252-259.

[3] Mohamad Reda A, Meenakshi Reddy R, Indra Reddy M, Shahul Hamid Khan B, Nagaraju V and Praveen Kumar S "Investigation on Physical and Mechanical Characteristics of Date Palm Fibre Reinforced Aliphatic Epoxy Hybrid Composites", Advances in Polymer Technology (2022).

[4] Ezema Ike-Eze IC, Obiegbusi NC, Aigbodion VS, Omah AD, Ude SN, Mgbemene CA "Physical and Mechanical Properties of Pressed Palm Oil Fruit Fibre Reinforced Epoxy Composite for Building Partition Panels", Journal of Recent Trends in Mechanics (2019), Vol 04, pp: 31-40.

[5] Praswasti Pembangun Dyah Kencanca Wulan & Yogi Yolanda "Mechanical property improvement of oil palm empty fruit bunch composites by hybridization using ramie fibres on epoxy–CNT matrices", Science and Engineering of Composite Materials (2023), Vol 30.

[6] Sherwani SFK, Zainudin ES, Sapuan SM, Leman Z & Abdan K "Mechanical Properties of Sugar Palm (Arenga pinnata Wurmb. Merr)/Glass Fibre-

Reinforced Poly (lactic acid) Hybrid Composites for Potential Use in Motorcycle Components", Polymers (2021), Vol 13.

[7] Ayodeji Nathaniel Oyedeji, Ibrahim Iliyasu, James Bitrus Bello, Kazeem Adeniyi Salami, Musa Nicholas Dibal & Danjuma Yawas S "Effect of Fibre Parameters on the Physical and Mechanical Properties of Epoxy-Based Reinforced Deleb Palm Fibre Composite; Using Taguchi Grey Relational Optimization", Journal of Applied Research on Industrial Engineering (2023), Vol 10, pp: 350-363.

[8] Abdul Khalil HPS & Kang CW "Agro-hybrid Composite: The Effects on Mechanical and Physical Properties of Oil Palm Fibre (EFB)/Glass Hybrid Reinforced Polyester Composites", Journal of Reinforced Plastics and Composites (2007), Vol 26, pp: 203- 218.

[9] Venkateswarlu M, Ashok Kumar M & Nagakiran M "Development and Mechanical Characterization of Palmyra Fruit Fibre Reinforced Epoxy Composites", IJSRSET (2016), Vol 02, pp: 40-44

[10] Madhukiran J, Venkateswara Rao T, Madhusudan S & Umamaheswara Rao R "Evaluation of The Mechanical Properties on Sisal-Coir Hybrid Natural Fibre Composites", International Journal of Engineering Research and Development (2017), Vol 13, pp: 43-49.

[11] Adane Dagnaw Gudayu, Leif Steuernagel, Dieter Meiners and Rotich Gideon "Characterization of the dynamic mechanical properties of sisal fibre reinforced PET composites; Effect of fibre loading and fibre surface modification", Polymers and Polymer Composites (2021), Vol 29, pp: 719-728.

[12] Akash, Sreenivasa Rao KV, Venkatesha Gupta NS & Arun kumar DS "Mechanical Properties of Sisal/Coir Fibre Reinforced Hybrid Composites Fabricated by Cold Pressing Method", Materials Science and Engineering (2016), Vol 149.

[13] Manjunath Prasad G, Girimath AG, Sharath Rao, Vinekar AJ, Patil DC, Timmanagoudar SN & Mathad SN "Investigation of Mechanical Properties of Sisal Fibre Reinforced Polymer Composites", Advanced Journal of Graduate Research (2017), Vol 01, pp: 40-48.

[14] Araya Abera Betelie, Anthony Nicholas Sinclair, Mark Kortschot, Yanxi Li and Daniel Tilahun Redda "Mechanical properties of sisal-epoxy composites as functions of fibre-to-epoxy ratio", Material Science (2019), Vol 06, pp: 985-996.

[15] Zhifang Liang, Hongwu Wu, Ruipu Liu and Caiquan Wu "Preparation of Long Sisal Fibre-Reinforced Polylactic Acid Biocomposites with Highly Improved Mechanical Performance", Polymers (2021), Vol 13.