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The Effect OF Internal Structure on Tensile Strength, Flexural Strength and Impact Resistance of Pineapple Leaf Fibre-PLA 3D Printed Composites

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ABSTRACT: The increasing demand for sustainable materials has led to the exploration of natural fibers as alternatives to conventional materials. This study investigates the mechanical properties of composites fabricated from Pineapple Leaf Fiber (PALF) reinforced with Polylactic Acid (PLA) core material. The core material was 3D printed using Fusion Deposition Modeling (FDM) technique in triangular, grid patterns. The PALF mats were layered on the 3D printed core plates and bound together using a resin through a traditional hand-layup method. Luffa biochar was added as a filler material to enhance the mechanical properties of the composites. The fabricated samples were subjected to experimental evaluation, including flexural, impact, and tensile tests. Scanning Electron Microscopy (SEM) analysis was performed on the fractured samples to examine their microstructure. The results of this study demonstrate the potential of 3D printed PALF composites with Luffa biochar fillers for various industrial applications, offering a sustainable and eco-friendly solution.

Keywords: **Natural composite, Pineapple leaf fiber, PLA, 3D Printing, Infill pattern, Mechanical behavior, Scanning electron microscopy analysis.**

1.INTRODUCTION

The quest for sustainable and eco-friendly materials has led to the exploration of natural fibers as alternatives to synthetic materials. Pineapple Leaf Fiber (PALF), also known as pina fiber, is a promising natural fiber extracted from the leaves of pineapple plants. PALF-blended yarns have found applications in various industries, including apparel, textiles, and automotive. Pineapple leaf fibre composites offer several attractive features, including eco-friendliness, biodegradability, low cost, and high cellulose content. The fiber extraction process can be performed manually or mechanically, and the resulting fiber boasts acceptable specific strength properties, high toughness, and thermal properties. The advent of additive manufacturing (AM) techniques, such as Fusion Deposit Modeling (FDM), has enabled the creation of complex internal structures, including honeycomb, grid, and triangular patterns. This study investigates the mechanical properties of PALF-reinforced 3D-printed PLA bio composites with varying internal structures. The composite samples underwent mechanical tests, including tensile, impact, flexural, and hardness tests, to assess the impact of internal structure on the composite's mechanical behavior. This research aims to contribute to the development of sustainable and eco-friendly materials, exploring the potential of PALF-reinforced 3D-printed PLA bio composites for various industrial applications.

2. LITERATURE REVIEW

Asim, M., Abdan, et al., (2015). Examined the natural fibre-based composites are under intensive study due to their eco-friendly nature and peculiar properties. The advantage of natural fibres is their continuous supply, easy and safe handling, and biodegradable nature. Although natural fibres exhibit admirable physical and mechanical properties, it varies with the plant source, species, geography, and so forth. Pineapple leave fibre (PALF) is one of the abundantly available wastes materials of Malaysia and has not been studied yet as it is required. A detailed study of chemical, physical, and mechanical properties will bring out logical and reasonable utilization of PALF for various applications. From the socioeconomic prospective, PALF can be a new source of raw material to the industries and can be potential replacement of the expensive and non-renewable synthetic fibre. However, few studies on PALF have been done describing the interfacial adhesion between fibres and reinforcement compatibility of fibre but a detailed study on PALF properties is not available. In this review, author covered the basic information of PALF and compared the chemical, physical, and mechanical properties with other natural fibres. Furthermore, it summarizes the recent work reported on physical, mechanical, and thermal properties of PALF reinforced polymer composites with its potential applications.

Vigneshwaran, K., & Venkateshwaran, N. (2019). Examined the Additive manufacturing circumscribes numerous technologies that allow for the construction of three-dimensional parts by superimposing layers of material. These technologies have undergone greater development in recent years. In this work, using 3D additive printing technology, the samples are prepared using biodegradable wood-PLA composite by varying the layer height (0.08 mm, 0.16 mm, and 0.24 mm), infill (30%, 60%, and 90%) and three different patterns such as layer, triangle, and hexagon. Using universal testing machines tensile properties, energy absorption, and toughness of samples are evaluated as per ASTM standards. The results show that better values are achieved with increase in the infill percentage and layer pattern provides better strength and stiffness. A statistical linear regression model was successfully developed to predict the mechanical properties with an accuracy of 96% predicted in layer pattern when compared to other. Linear regression method helps to find the relationships between two sub-properties of mechanical property of different types of materials and helps to predict the properties of unknown materials.

Naga Venkata Sai Charan. V Akhil Composites are chosen primarily for their ability to maintain relative stiffness, strength, and component weight. To distinguish the mechanical properties of alkali-treated hybrid composite laminates, this article analyses the two types. Different types of manufacturing processes also affect the properties of composite laminates. The results of several machine test carried out to confirm this.

METHODOLOGY

This study employed a systematic approach to investigate the effects of internal core structure on the mechanical properties of Pineapple Leaf Fiber (PALF) reinforced Polylactic Acid (PLA) composites. The methodology consisted of the following key steps:

3.1 Material Selection and Preparation

The materials used in this study were Pineapple Leaf Fiber (PALF) and Polylactic Acid (PLA). The pineapple leaf fibers were extracted and processed into mats through a series of mechanical and chemical treatments to enhance their structural integrity and adhesion properties..

3.2 Designing the Internal Core Structure

Computer-aided design (CAD) software was utilized to design different internal core structures, including triangular and grid patterns. These designs were optimized to explore their effects on the mechanical properties of the composite.

3.3 Fabricating the Core using 3D Printing Technique

The designed internal core structures were fabricated using additive manufacturing or 3D printing technology, specifically the Fusion Deposition Modeling (FDM) process. This technique enabled the creation of complex internal structures with high precision and accuracy. The FDM printer infused layers of PLA material to create the desired patterns.

3.4 Composite Fabrication

The fabricated internal core structures were integrated with PALF mats and PLA resin to form the composite material. A hand layup method was employed to ensure uniform distribution of the PALF fibers and PLA resin.

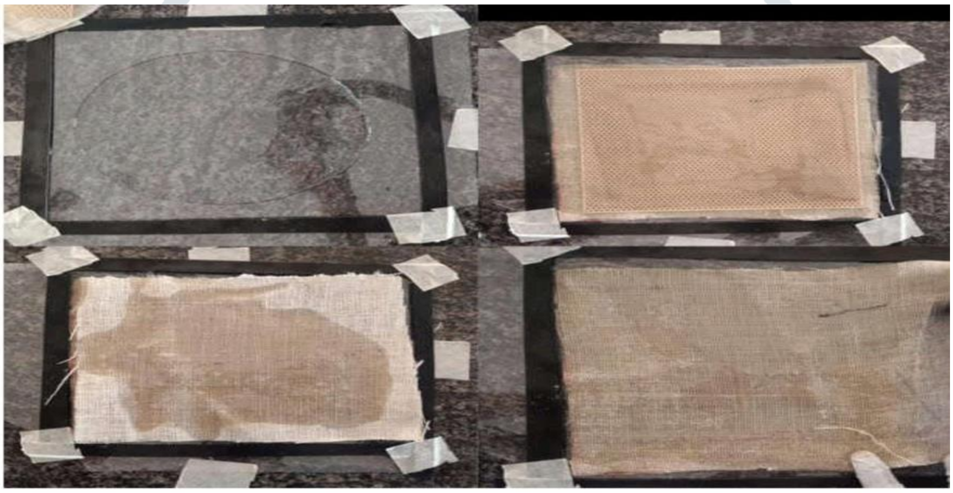


Figure 1: Fabrication of the composite.

3.5 Mechanical Testing

The fabricated composites underwent mechanical testing, including tensile, impact, flexural, and hardness tests, to evaluate the effects of internal core structure on their mechanical properties.

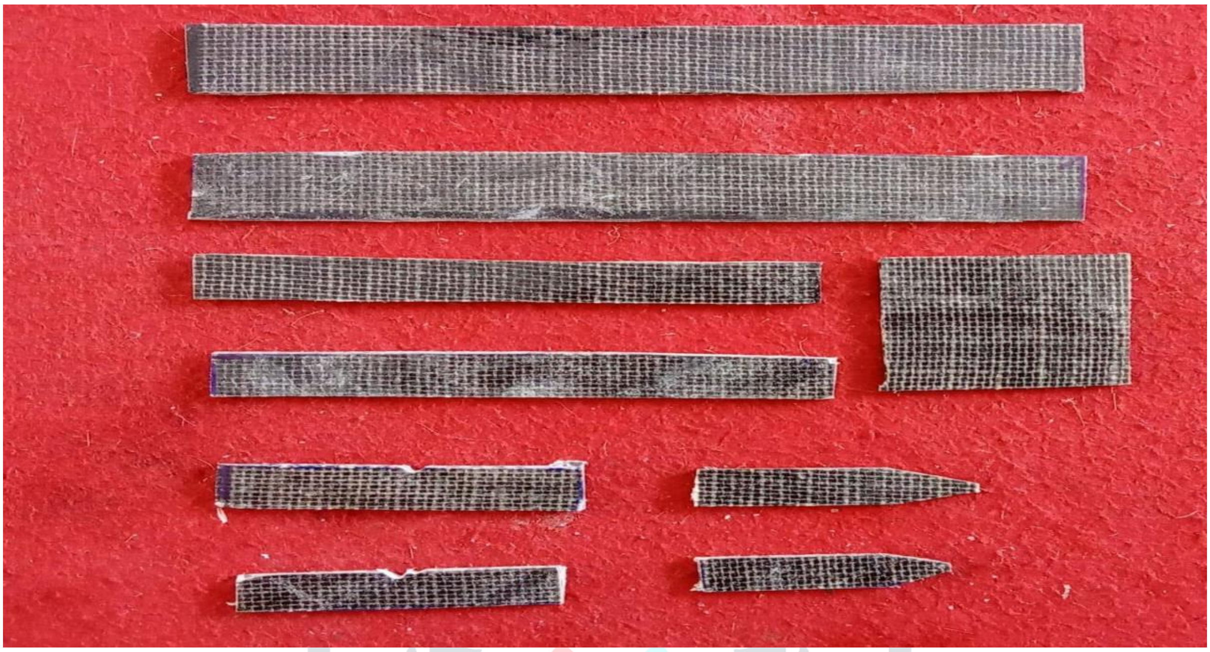


Figure 2: Samples prepared for testing

3.6 Data Analysis

The obtained mechanical test data were analyzed using statistical software to determine the significance of the internal core structure on the mechanical properties of the composite. The results were presented in graphical and tabular formats to facilitate comparison and discussion.

4.EXPERIMENTATION

4.1 Flexural test

The flexural strength of the composite samples was evaluated in accordance with the ASTM D790 standard test method using a universal testing machine (UTM) with servo-control. The UTM was equipped with a deflection measuring device and software for operating the machine and recording data. The test was conducted using a three-point bend fixture, where the composite samples were subjected to a constant crosshead speed, and the load and deflection data were recorded. The flexural strength was subsequently calculated from the load-deflection curve, providing valuable insights into the material's resistance to bending and its mechanical behavior under real-world conditions.

4.2 Tensile Test

Tensile strength testing is a critical engineering evaluation that assesses the strength and elasticity of materials by measuring mechanical properties such as ultimate tensile strength, yield strength, and ductility. This testing methodology plays a vital role in ensuring material safety by evaluating quality and verifying the mechanical properties of materials to guarantee compliance with safety standards. The tensile testing process involves securely clamping a material sample between two grips, followed by the application of a controlled force to one end of the sample, while the other end remains fixed. The resulting deformation is meticulously measured to determine the material's tensile properties. In accordance with ASTM D3039, a standard test method for testing tensile properties of composite materials, this evaluation provides invaluable insights into the material's behavior under various types of loading, enabling informed decisions regarding material selection for specific applications.

4.3 Impact test

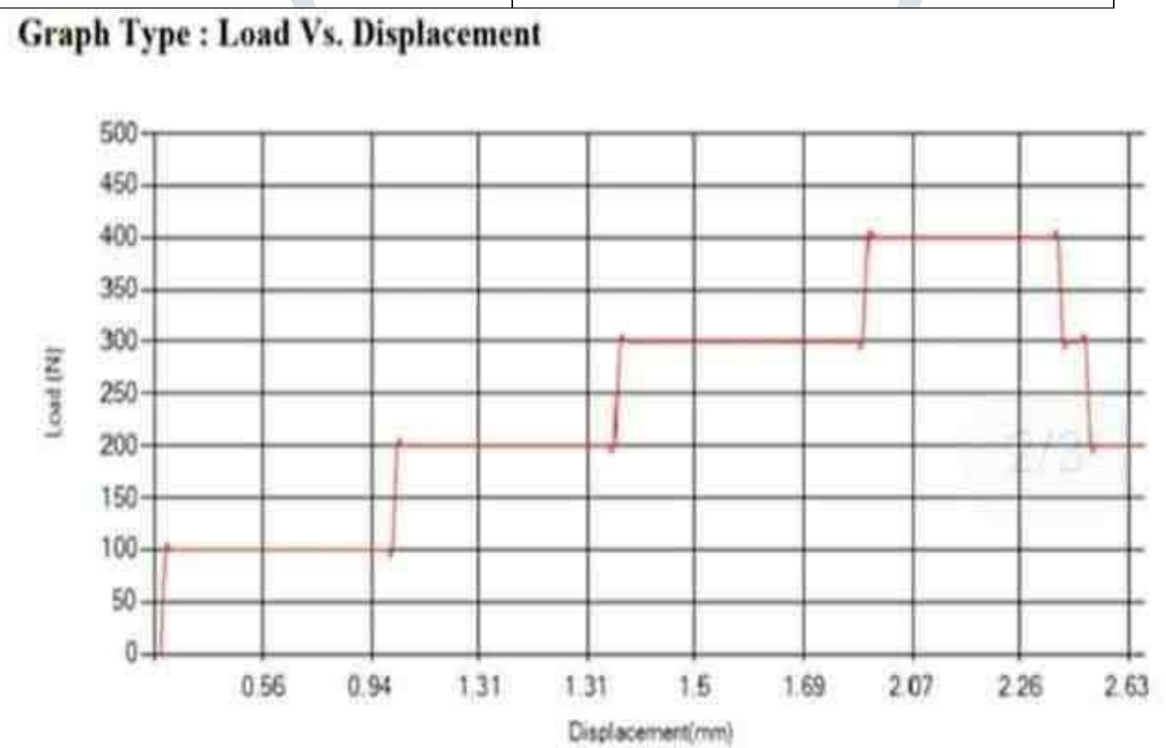
The impact test is a critical evaluation method employed to assess the toughness, resilience, and durability of composite materials. This test determines the energy absorbed by a material during fracturing at high velocities, providing valuable insights into its impact strength and notch toughness. A pendulum-type single-blow impact test, as described in ASTM D256, was conducted to evaluate the impact properties of the composite samples. In this test, a notched specimen is supported as a simple beam and subjected to a high-velocity impact by a falling pendulum. The energy absorbed during this process, as measured by the subsequent rise of the pendulum, serves as a quantitative indicator of the material's impact strength and notch toughness. The Izod impact test, in particular, provides a reliable means of determining a material's impact toughness, which is essential for evaluating its ability to resist high-rate loading.

5 TEST RESULTS FOR GRID STRUCTURE

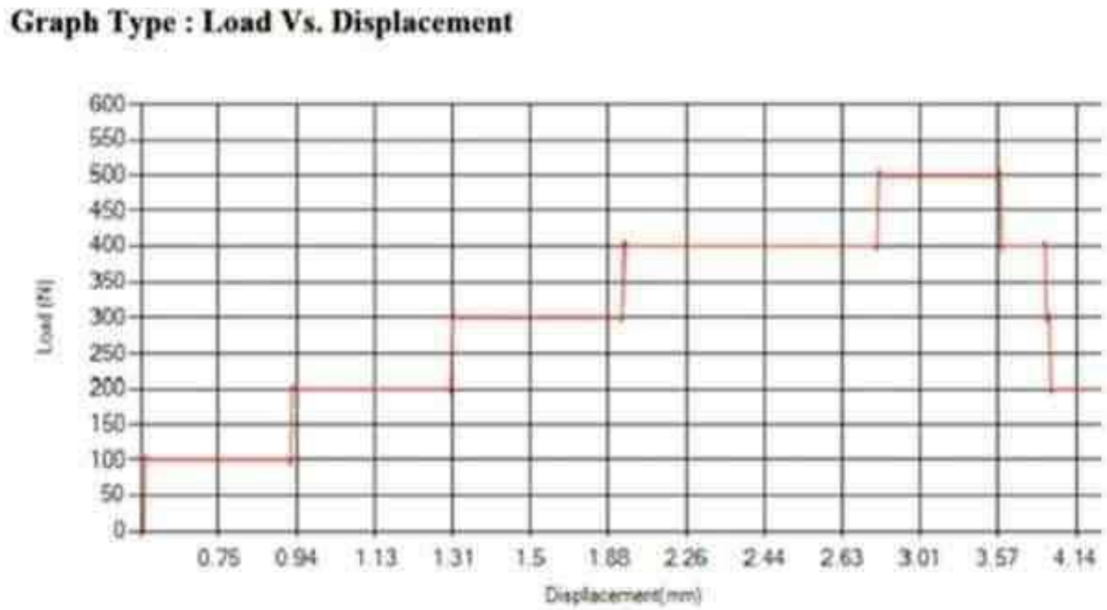
P2-PINEAPPLEFIBRE +VINYLESTER RESIN+3D CORE (GRID)+LUFFA BIOCHAR (5%)

Table1 Flexural strength test

SAMPLE NAME	FLEXURAL RIGIDITY (N/mm^2)
P2-1	242.41
P2-2	263.20



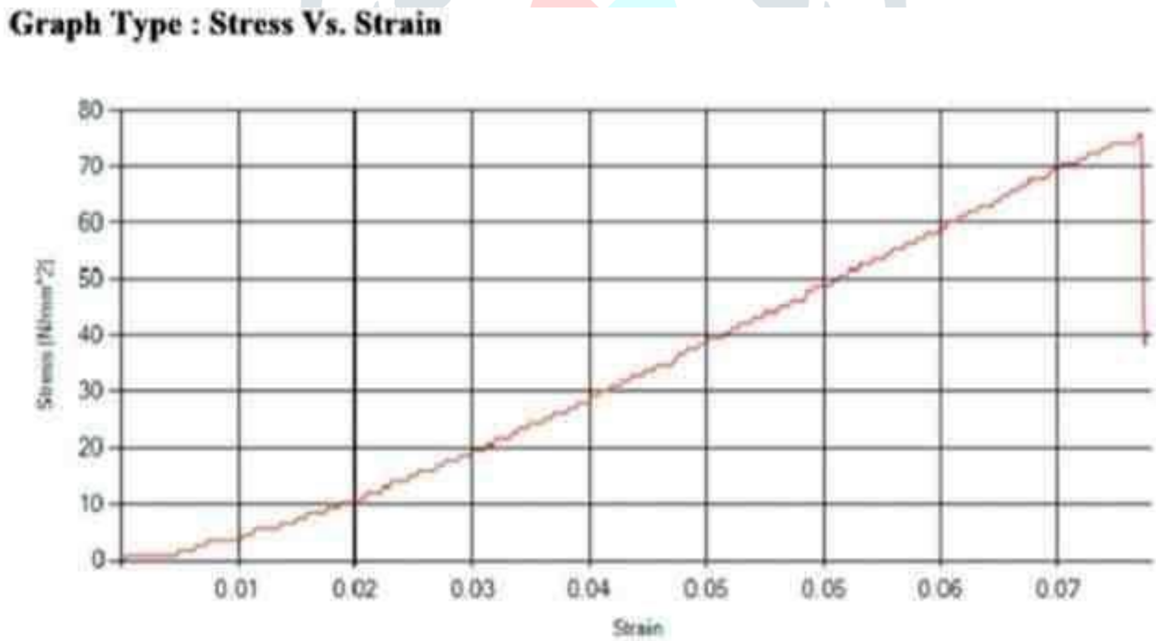
Graph 1: P2-1 flexural strength



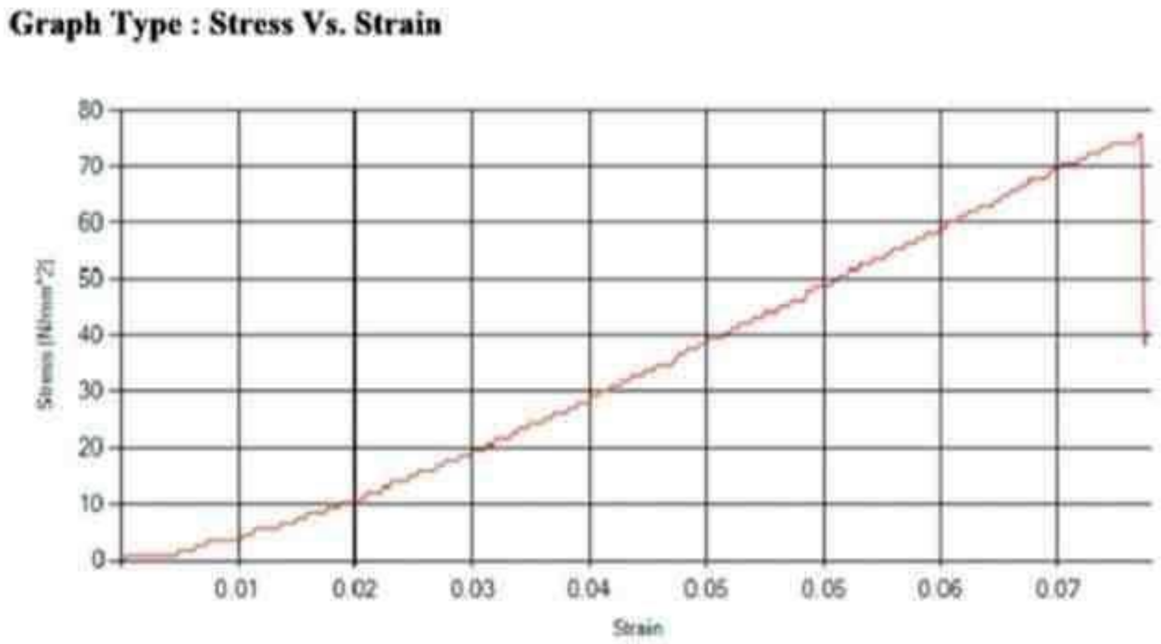
Graph 2: P2-2 flexural strength

Table2: TENSILE STRENGTH TEST

SAMPLE NAME	**TENSILE STRENGTH (N/mm²)**
P2-1	77.88
P2-2	75.02



Graph 3: P2-1Tensile strength



Graph 4: P2-2 Tensile strength

Table3: IMPACT TEST

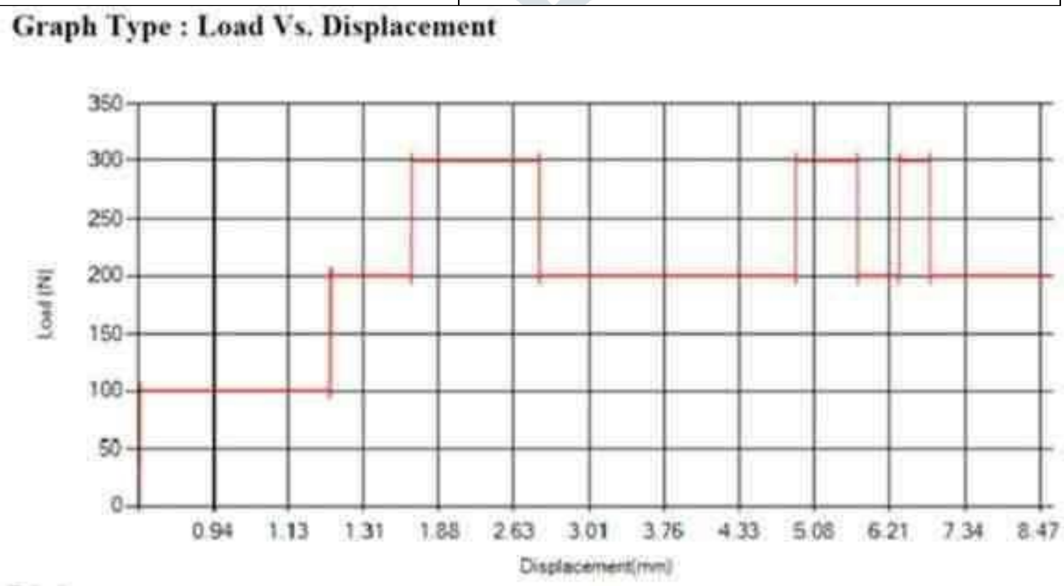
SAMPLE NAME	IMPACT ENERGY (J)
P2-1	4.2
P2-2	3.9

6 TEST RESULTS FOR TRIANGULAR STRUCTURE

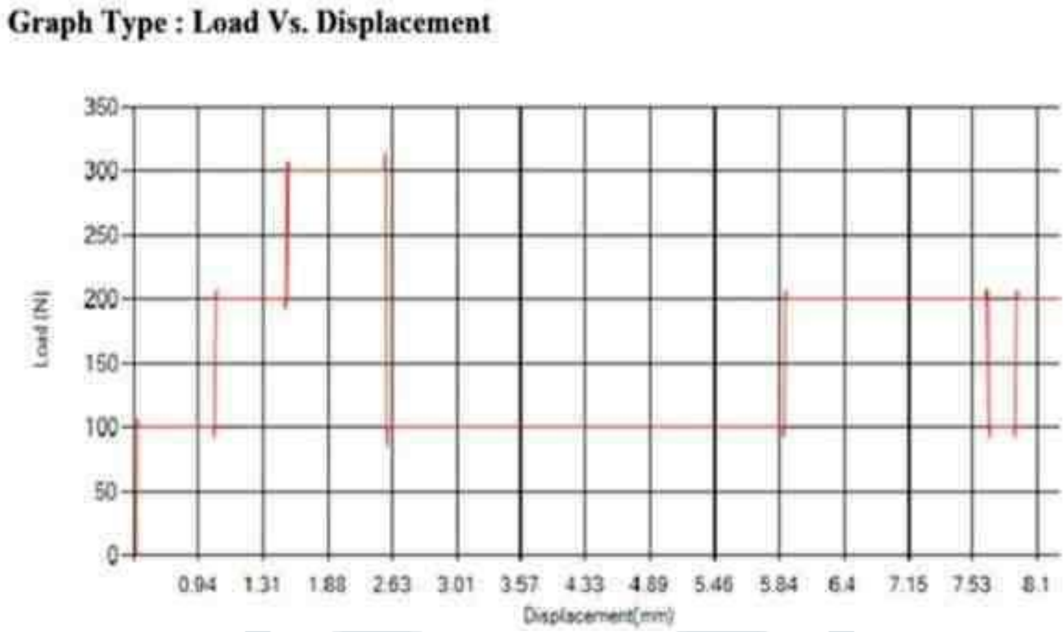
NOTE: P3-PINEAPPLEFIBRE +VINYLESTER RESIN+3D CORE (TRIANGLE)+LUFFA BIOCHAR (5%) FLEXURAL STRENGTH TEST

Table 4: FLEXURAL STRENGTH TEST

SAMPLE NAME	FLEXURAL RIGIDITY (N/mm^2)
P3-1	190.83
P3-2	179.64



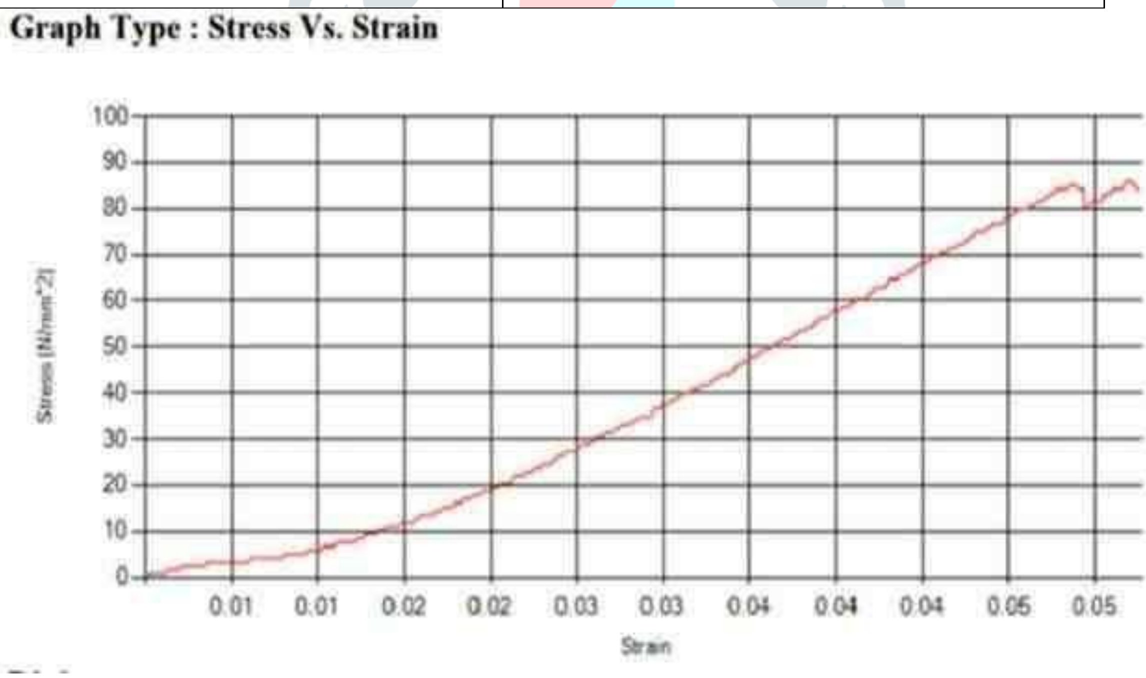
Graph: P3-1 Flexural strength



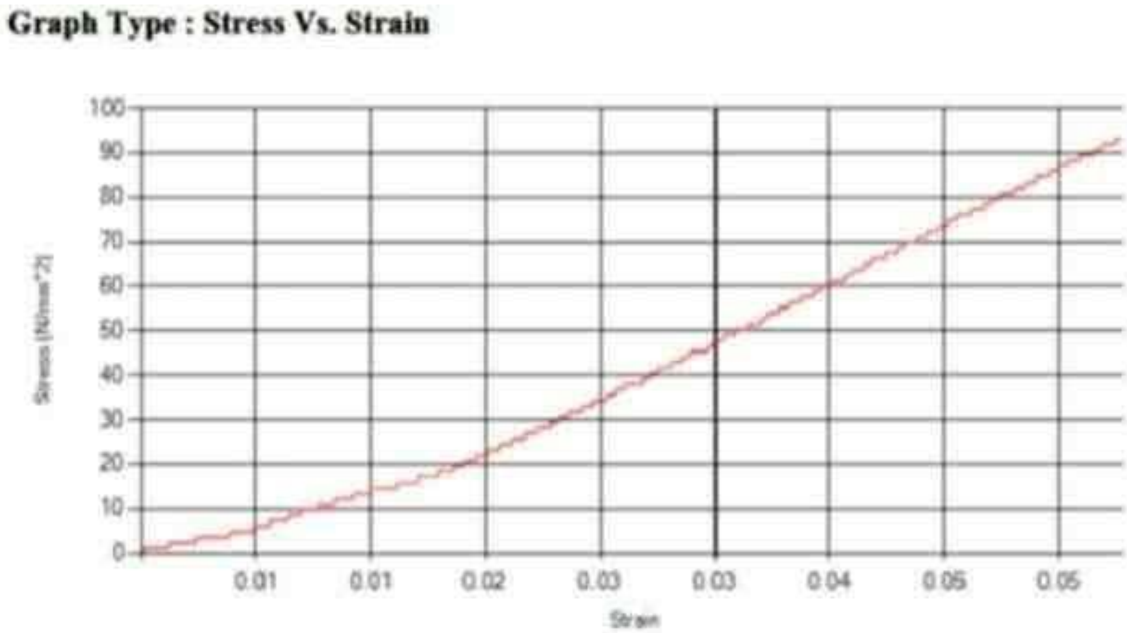
Graph 6: P3-2 Flexural strength

Table5: TENSILE STRENGTH TEST

SAMPLE NAME	**TENSILE STRENGTH (N/mm^2)**
P3-1	85.81
P3-2	93.51



Graph 7: P3-1 Tensile strength



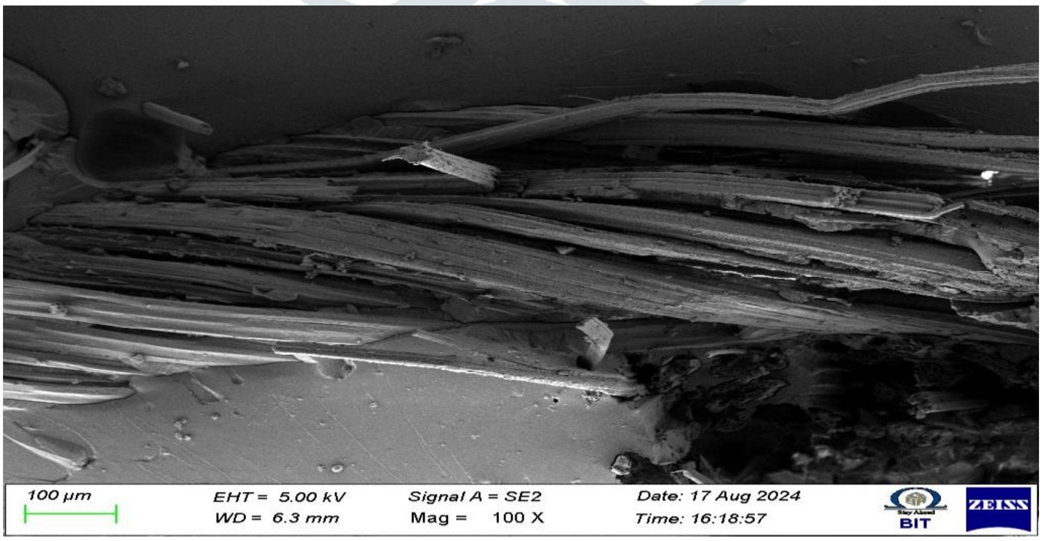
Graph 8: P3-2 Tensile strength

Table 6: IMPACT TEST

SAMPLE NAME	IMPACT ENERGY (J)
P3-1	4.0
P3-2	4.4

7 SEM ANALYSIS:

The scanning electron microscopy analysis of pineapple leaf fiber reinforced 3D printed composites reveals significant insights into the interfacial bonding and structural integrity of the materials. The microscopy images demonstrate the uniform dispersion of fibers within the polymer matrix, enhancing mechanical properties. The images demonstrate the scanning electron microscopy session focused on pineapple leaf fibre reinforced 3D printed PLA composite. It indicates an EHT of 5.00 kV and a magnification of 32X. The observation was made with a working distance of 6.3 mm. The details also reference ZEISS equipment and the specific signal being observed is labelled as SE2.



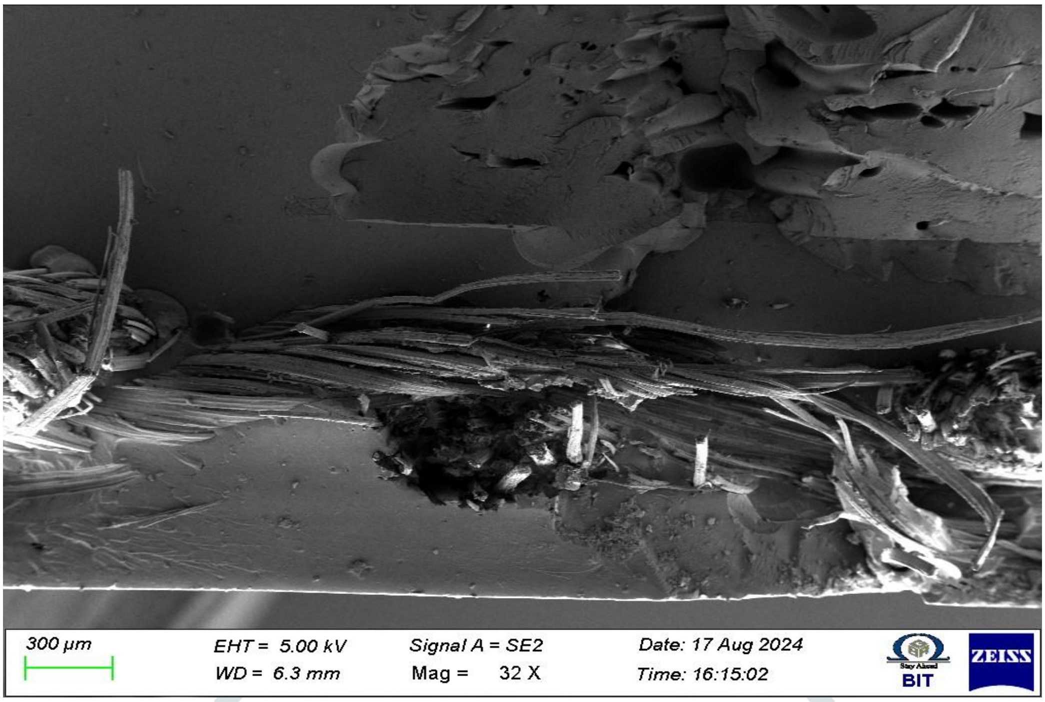


Figure 3: SEM Analysis images

CONCLUSION

In conclusion, the test results for the three different sheet structures are crucial for evaluation. The flexural strength tests show that the grid structure (P2) is the most rigid, surpassing the triangular structure (P3). Similarly, the tensile strength tests demonstrate the superiority of the grid structure (P2) over triangular structure (P3). Moreover, the hardness tests consistently depict the grid structure (P2) as the hardest material among the two. Overall, the test results suggest that the grid structure (P2) outperforms the other structures, making it a promising candidate for further research and application.

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