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# **Investigation of Mechanical and Thermal Properties of PLA Matrix Natural Fibre Composites using Biochar as an Additive**

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**ABSTRACT:** The utilization of eco-friendly reinforcing materials and the fabrication of sustainable composites with enhanced mechanical and electrical properties are a subject of great scientific interest. Such research is aiming to be applied in a variety of industrial applications. This study addresses the development of eco-friendly bio composites using polypropylene used as a matrix material and combined with biochar (BC) as a filler at different loadings to produce reinforced composites. Biochar has garnered a lot of attention as a filler material and has the potential to replace properties. The potential of biochar as an additive in composite materials to enhance their mechanical and thermal properties. Biochar, a carbon-rich material derived from biomass, was incorporated into a polymer matrix to create a novel composite material. The effects of biochar content, size, and dispersion on the composite's mechanical properties (tensile strength, flexural strength, and impact resistance) and thermal properties (thermal conductivity, thermal stability, and flame retardancy) were systematically evaluated. The findings of this study contribute to the development of eco-friendly, high-performance composite materials, paving the way for future research and industrial applications. Conventionally used inorganic mineral fillers. Biochar is a carbon rich product obtained from thermochemical conversion of biomass in nitrogen environment. On the effect of addition of biochar on the overall composite properties showed immense promise in improving the overall composite.

**KEYWORDS:** Pla, Banana Fibre, Biochar, Compression Moulding, Thermal Analysis

## **I. INTRODUCTION**

The increasing demand for sustainable and eco-friendly materials has led to significant research interest in polymer matrix natural composites. These composites, comprised of biodegradable polymers and natural fibres, offer a promising alternative to traditional synthetic materials. However, their properties, such as mechanical strength, thermal stability, and durability, often require enhancement to meet specific application requirements.

Biochar, a carbon-rich, porous material derived from biomass pyrolysis, has emerged as a versatile additive for improving the properties of polymer composites. Its unique structure and surface chemistry enable biochar to interact with polymer matrices and natural fibres, potentially enhancing mechanical, thermal, and electrical properties.

This project aims to investigate the effects of biochar addition on the properties of polymer matrix natural composites.

## **II. EXPERIMENTAL**

### **2.1 Materials**

The materials used for the fabrication of the composite material in this study involves Polylactic Acid (PLA), Natural Fibre (Banana Fibre) and Biochar. The PLA used in this study was procured from Herenba Instruments, Chennai. The fibre were purchased from a Local Dealer from Kannur District and the Biochar was purchased from India mart.

### **2.2 Specimen Preparation**

The preparation process is done by applying pressure and temperature using compression moulding. The banana fibre is cut into small pieces to sizes around 1 inches. There is a square type piece which have a 10mm thickness with two sides hollow. The two sides are covered by using Aluminium foil which will hold the materials also the Aluminium foil is

rubbed with wood wax to not to stick by the materials after the moulding process. Totally 4 plates are making 2 pair with different compositions for testing and 2 for college presentation. In this one plate contains 233gms of PLA and 100gms of Natural fibre and the other contains 233gms of PLA ,66gms of Natural Fibre and 33gms of Biochar. Then after placing the Aluminium foil a small amount of PLA is spreaded over the foil and a amount of fibre is placed above it. This process is continued for 5 coatings of PLA and Fibre also for the another plate which having Biochar is also done like this. After this step the plate fixed between the two press of the moulding machine. The specimen is pressed inside the machine with 175°C temperature and 40 kg/cm<sup>2</sup> pressure.

SL NO:	COMPOSITE	PLA (wt %)	Fibre (wt%)	Biochar (wt%)
1.	C1	70	30	-
2.	C2	70	20	10

Table 2.1 weight percentage of matrix and reinforcement

## 2.3 Fabrication Of Composite Material

### Compression Molding

Compression molding is a manufacturing method for fabrication of composite materials. In this method, a preheated material is placed into an open heated mold cavity, the mold is closed with a top plug and compressed under uniform pressure so that the polymer contact all areas of the mold. Then, the molding material is cured under determined temperature and pressure and removed from the system . The final products usually have high mechanical strength with complex geometry. In order to obtain high quality products by compression molding, optimizing the mold design and processing conditions such as flow and cure analysis are crucial.

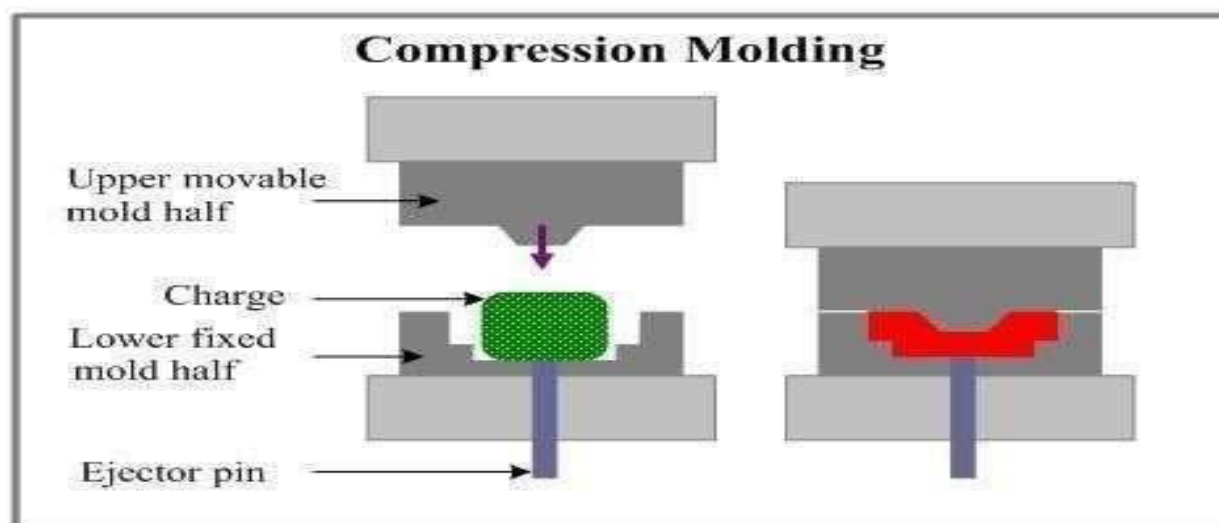


Fig 4.1 Schematic Diagram of compression molding

Compression molding is a versatile and efficient manufacturing technique, offering high accuracy, material efficiency, and cost-effectiveness. Its applications span various industries, and ongoing research aims to address existing limitations. As technology advances, compression molding will continue to play a vital role in shaping the future of manufacturing.



### III. MECHANICAL TESTING

#### 3.1 Tensile test

A tensile test for composite materials is a standard procedure used to determine the mechanical properties of composite materials under uniaxial tensile stress. The test helps in evaluating important parameters such as tensile strength, modulus of elasticity, strain at break, and ultimate tensile strength. Conducted as per ASTM D638 to determine the composite's ultimate tensile strength and elongation..

Table 1.Experimental tensile strength of the composite samples

Property	PLA-70% ,30% banana fibre	PLA-70% , 20%banana Fibre , 10% biochar,
Tensile Strength (N/mm <sup>2</sup> )	0.7730	0.9455
Elongation at Break (%)	0.7198	1.14
Cross-Sectional Area (mm <sup>2</sup> )	187.50	200
Breaking Load (N)	144.94	189.1

#### 3.2 Flexural strength

Flexural testing is used to determine the bending properties of materials, including their ability to resist deformation and fracture under bending stress. Performed according to ASTM D790 to assess bending strength and stiffness.

Table 2.Experimental flexural strength of the composite samples

Property	PLA-70% ,30% banana fibre	PLA-70% , 20%banana Fibre , 10% biochar,
Maximum Flexural Stress (N/mm <sup>2</sup> )	0.0146	0.0695
Maximum Load (N)	5.4782	29.5274
Strain at Maximum Load (%)	1.4498	2.2098

#### 3.3 Impact test

An impact test for composite materials is used to evaluate the material's ability to resist sudden or dynamic loading, which is critical for understanding its durability and performance in real-world applications. These tests help determine how well a composite material can absorb and dissipate energy during impact without catastrophic failure. Measured using Charpy Impact Test (ASTM D256) to evaluate resistance to sudden forces.

Sample Type (Composite Strip )	Impact Strength in Joules			Avg
Banana + PLA	0.01	0.29	0.86	0.386
Banana + Biochar + PLA	1.44	0.93	1.21	1.193

Table 3. Experimental impact strength of the composite samples

#### IV. RESULT AND ANALYSIS

The composite samples were tested using their respective testing machines to evaluate tensile, flexural, and impact properties. Each type of sample underwent two trials, and the average values were recorded.

##### 4.1 Tensile strength analysis

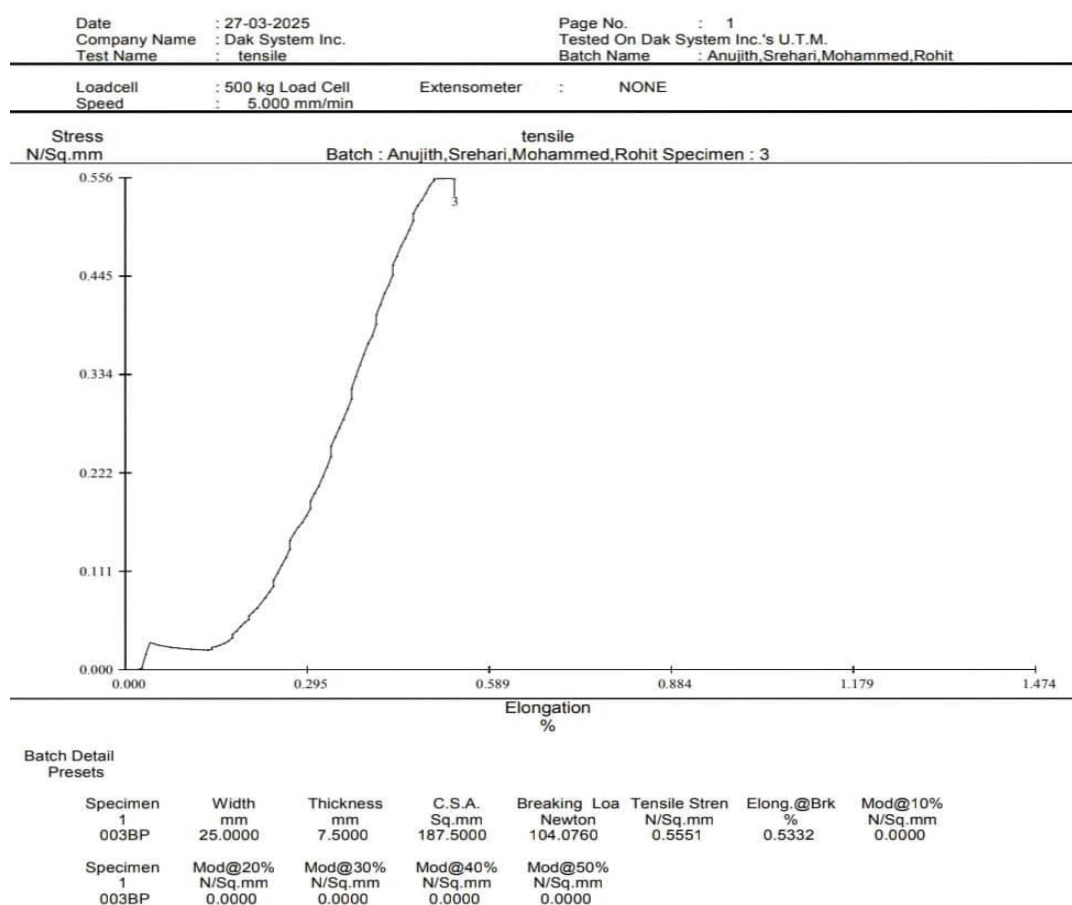


Fig 1.Pla 70% , banana fibre 30%

This is the tensile test result of the composite material with PLA as matrix and Natural Fibre as reinforcement this sample exhibits tensile strength of 0.7730N/mm<sup>2</sup> and a Elongation break at .7198% Cross sectional area was measured at 187.50 mm<sup>2</sup> and breaking load was recorded at 144.94 N .

From this we studied that the tensile strength of this material is quite low , suggesting that the material is relatively weak under tensile loading and also this material appears to be brittle with low tensile strength and minimal elongation

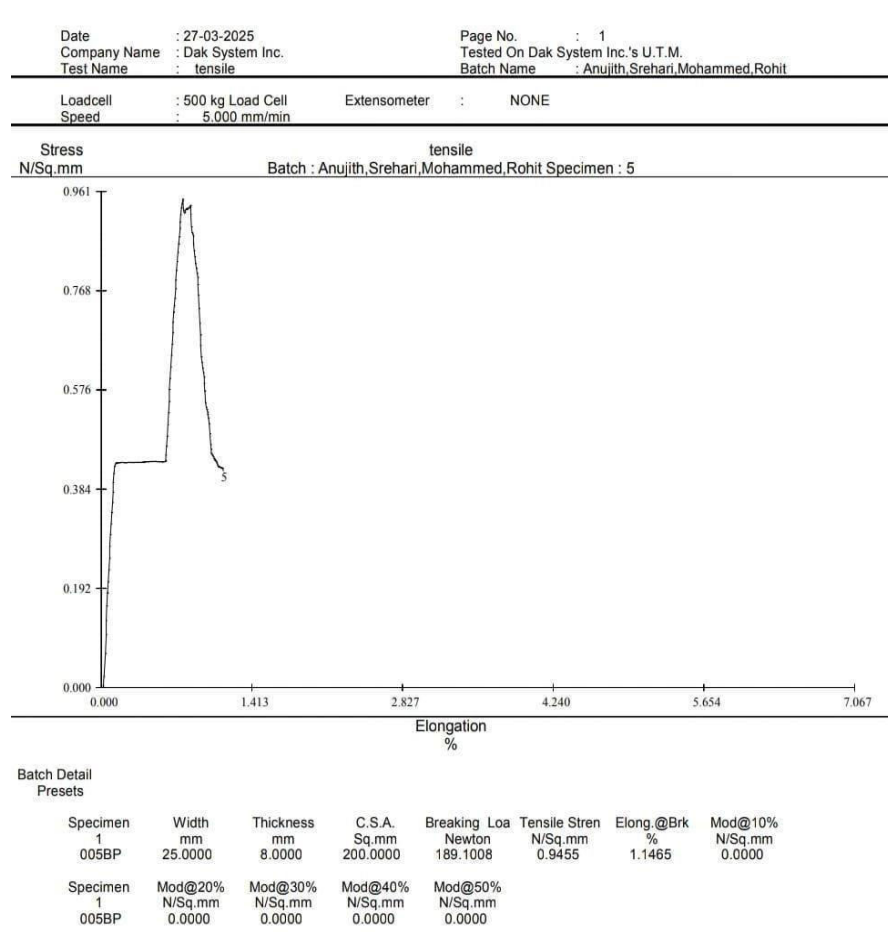


Fig 2.Pla 70% , banana fibre 20%,10%biochar

This is the tensile test result of the composite material with PLA as matrix ,Natural Fibre as reinforcement and biochar as an additive .This sample exhibits tensile strength of 0.9455N/mm<sup>2</sup> and a Elongation break at 1.14%Cross sectional area was measured at 200.0 mm<sup>2</sup> and breaking load was recorded at 189.100 .

From this we studied that C2 have more tensile strength and elongation at break compared to C1 C2 outperforms C1 in terms of tensile strength, elongation at break, and breaking load, making it more suitable for applications requiring better resistance to tensile forces.

## 4.2 Flexural strength analysis

The mechanical properties of two composite materials pla matrix natural fibre reinforced and pla matrix natural fibre reinforced with Biochar. Key findings include: The Biochar-reinforced composite shows significantly higher mechanical performance than the non-reinforced one. Maximum load capacity is 5.4 times higher in the biochar-reinforced composite. Flexural strength is 4.76 times greater, enhancing resistance to bending. Strain at maximum load and deflection are both 52% higher in the biochar composite .The inclusion of biochar improves load-bearing capacity

and toughness, making the composite more resilient to deformation .Overall, adding biochar significantly enhances the mechanical properties of the pla matrix natural fibre reinforced composite, making it stronger and tougher.

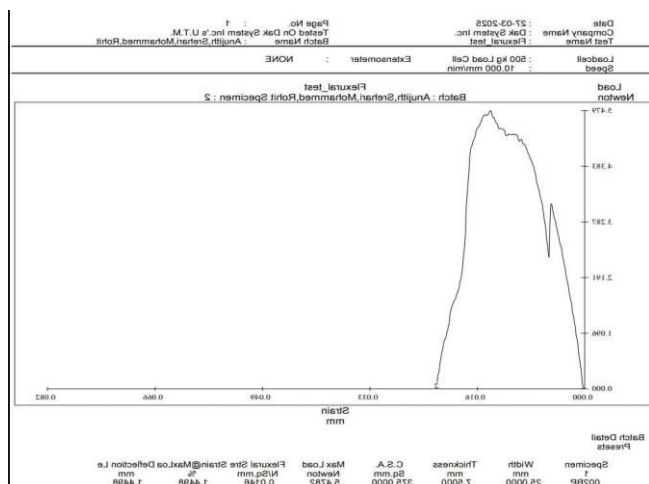


Fig 1.Pla 70% , banana fibre 30%

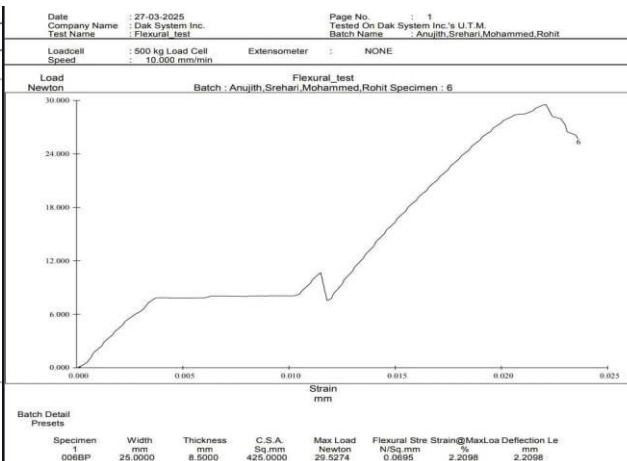


Fig 2.Pla 70% , banana fibre 20%,10%biochar

### 4.3 Impact strength analysis

The impact strength values for PLA matrix natural fibre reinforced sample vary significantly, ranging from 0.01 J to 0.86 J, with an average impact strength of 0.386 J the low impact strength indicates that the banana fibre and PLA combination provides limited resistance to sudden impacts. This is expected as PLA alone has relatively low toughness The impact strength values of PLA matrix natural fibre reinforced range from 0.93 J to 1.44 J, with an average impact strength of 1.193 J. The addition of biochar significantly improves the impact strength, making the material nearly 3 times stronger compared to the sample without biochar. Biochar, acting as a reinforcing filler, enhances the composite's toughness by preventing crack propagation and absorbing more energy during the impact.

## V. THERMAL ANALYSIS

Thermogravimetric analysis (TGA) is a thermal analysis technique that measures the mass change of a sample as a function of temperature or time in a controlled atmosphere, providing information about a material's thermal stability, decomposition, and composition.

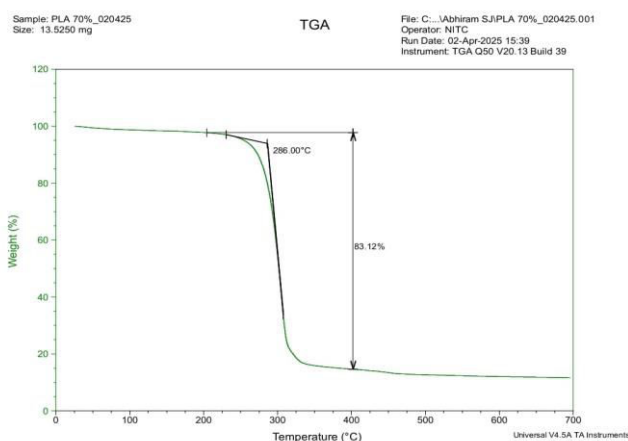


FIG 5.1 Result Of Without Biochar

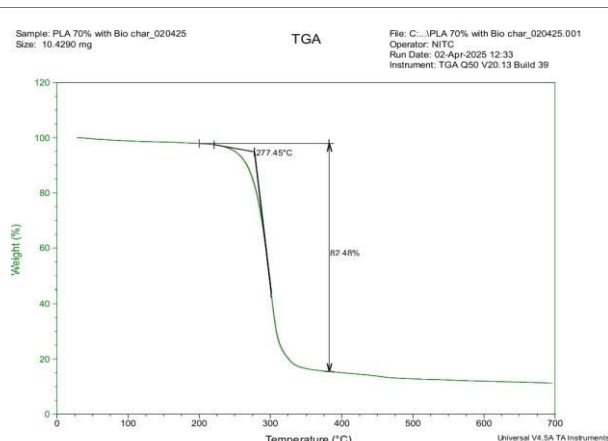


FIG 5.2 Result of With Biochar

The PLA 70% , natural fibre 30% sample decomposes at a slightly higher temperature (286.00°C) compared to PLA 70% , natural fibre 20%with Biochar 10% (277.45°C).This suggests that the addition of biochar slightly reduces the thermal stability of the PLA matrix .PLA 70% without biochar has better thermal stability, as it decomposes at a higher temperature .PLA 70%,natural fibre 20% with biochar 10% decomposes earlier but retains a similar mass, suggesting a slight reduction in thermal stability.

## **VI. CONCLUSION**

From this we understood that the inclusion of biochar in the PLA matrix natural fibre reinforced significantly enhanced the mechanical properties. The tensile strength and flexural strength exhibited noticeable improvements due to the rigid biochar particles acting as secondary reinforcement. The PLA matrix natural fibre reinforced composite, although strong, had relatively lower mechanical performance compared to the biochar-reinforced counterpart, indicating that the natural fibres alone were less effective in strengthening the matrix. The addition of biochar does not significantly improve the thermal ability of PLA but might have other benefits such as mechanical reinforcement or improved biodegradability.

This suggests that adding biochar as a filler in bio-composites can be an effective way to improve toughness and durability, which could be beneficial for applications requiring higher impact resistance , superior tensile performance and preventing crack propagation, enhancing the material's overall toughness and stiffness.

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