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Synthesis and Analysis of Eco-Friendly Materials - Banana Fibre and Fly Ash Reinforced Composite

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Abstract: *This research paper presents an experimental study on the fabrication and testing of Banana Fibre/Fly Ash Reinforced Composites. The goal of this study was to explore the mechanical properties and potential applications of these composites in various industries. The fabrication process involved preparing six specimen samples with different compositions of banana fibre and fly ash, following the ASTM D3039/D3039M standard dimensions for tensile testing. The specimens were manufactured using epoxy resin and hardener, with proper vacuum casting to eliminate air bubbles and ensure uniformity. Tensile tests were conducted using a Universal Testing Machine (UTM) according to the ASTM D638 standard. The results indicated that the composite with 6% banana fibre and 10% fly ash exhibited the highest tensile strength of 45.80 MPa. Comparison with other materials/composites revealed that the tensile strength of the Banana Fibre/Fly Ash Reinforced Composite surpassed that of various commonly used materials. The study identified potential applications for these composites in building materials, automotive components, packaging, furniture, textiles, and agricultural/horticultural fields. The research findings highlight the advantages of these composites, including their lightweight, strength, durability, and eco-friendliness. Overall, the study provides valuable insights into the fabrication, mechanical properties, and potential applications of Banana Fibre/Fly Ash Reinforced Composites, making them a promising alternative in diverse industries.*

Keywords: Banana Fibre, Fly ash, Composite materials, Tensile testing, Mechanical Properties, Sustainable materials, Potential applications

I. INTRODUCTION

The increasing demand for eco-friendly materials has led to extensive research in the field of composite materials that offer sustainable alternatives to conventional materials. In this context, the combination of natural fibres and industrial waste materials has gained significant attention. This research focuses on the synthesis and analysis of an eco-friendly composite material consisting of banana fibre and fly ash.

Banana fibre, derived from the stem of banana plants, is a renewable and biodegradable material known for its exceptional mechanical properties. It offers advantages such as high strength, low weight, and good flexibility, making it a promising candidate for various applications. Fly ash, on the other hand, is a by-product of coal combustion in thermal power plants. It is an abundant industrial waste material that poses significant environmental challenges if not properly utilized. By incorporating fly ash into composite materials, its disposal can be addressed while enhancing the performance and sustainability of the resulting composites.

The objective of this research is to explore the synthesis and analysis of Banana Fiber/Fly Ash Reinforced Composites. The research aims to investigate the mechanical properties of the composites, specifically their tensile strength, and analyse their potential applications in different industries. By studying the fabrication process and conducting mechanical tests, valuable insights can be gained regarding the performance and feasibility of these composites.

The fabrication of the composites involves the calculation of composition in weight percentages, where the banana fibre and fly ash are combined with epoxy resin and hardener. The specimens are manufactured following the ASTM D3039/D3039M standard dimensions for tensile testing. The mechanical testing is conducted using a Universal Testing

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Machine (UTM) according to the ASTM D638 standard. Tensile tests provide essential data on the composite's strength, elongation, and other mechanical properties.

The results of this study will contribute to the existing knowledge on eco-friendly composite materials and their potential applications. Furthermore, the comparison of the Banana Fiber/Fly Ash Reinforced Composites with other materials will provide insights into their performance and suitability for specific applications. The findings will help in evaluating the viability of these composites in industries such as construction, automotive, packaging, furniture, textiles, and agriculture.

In conclusion, this research aims to explore the synthesis and analysis of Banana Fiber/Fly Ash Reinforced Composites. The investigation into the mechanical properties and potential applications of these composites will contribute to sustainable material development. The utilization of banana fibre and fly ash offers an eco-friendly and economically viable approach to develop composites with desirable properties. The findings of this research will pave the way for the adoption of these composites in various industries, promoting sustainability and environmental responsibility.

II. LITERATURE REVIEW

In the literature review titled "Investigations on Tensile and Flexural Characteristics of Fly Ash and Banana Fiber-Reinforced Epoxy Matrix Composites" by Venkatachalam G et al., the authors explore the mechanical properties of composites made from fly ash, banana fiber, and an epoxy matrix. The study aims to understand the tensile and flexural characteristics of these composites.

Another review conducted by Upendra S. Gupta and Dr. Sudhir Tiwari focuses on the development of banana fiber-reinforced polymer composites for industrial and tribological applications. The review provides an overview of the research background, experimental methodology, key findings, implications, strengths, limitations, and potential future investigations in this field.

A literature review on the utilization of plant fibers as reinforcements in polymer composites discusses various natural fibers, including wood fiber, sisal, kenaf, pineapple, jute, banana, and straw. This review emphasizes the economic and technical advantages of using natural fibers as mechanical components, particularly in the automotive and construction sectors.

In the literature review conducted by P. Gopinath and P. Suresh, the authors investigate the mechanical behavior of hybrid composites filled with fly ash and reinforced with woven banana fibers. The review highlights the potential benefits of using these composites as wood substitutes, focusing on sustainability, durability, and cost-effectiveness.

Overall, these literature reviews collectively delve into various aspects of using banana fiber-reinforced composites, including their mechanical properties, applications in different industries, potential as wood substitutes, fire retardancy, and their advantages over synthetic fiber composites. They provide valuable insights into the characteristics, manufacturing techniques, challenges, and future research directions associated with banana fiber-reinforced polymer composites

III. METHODOLOGY

3.1 Raw Materials:

Banana Fiber:

Commercially available banana fibreswere used as the reinforcing material in the composite preparation. The banana fibreswere obtained from [source/manufacturer] and were in the form of [describe the physical form, such as bundles, mats, or individual fibres]. The fibreswere selected based on their desirable mechanical properties, such as high tensile strength and flexibility.

Fig -1: Banana Fibers

Fly Ash:

Fly ash, a by-product of coal combustion in power plants, was used as the matrix material in the composite formulation. The fly ash was sourced from [source/power plant] and was in the form of [describe the physical form, such as fine powder]. Fly ash was chosen for its pozzolanic properties, which contribute to enhanced binding and densification of the composite matrix.

3.2 Methods:

Composite Fabrication:

Banana fiber preparation: The cleaned and dried banana fibers were further processed to obtain uniform lengths for reinforcement. The fibers were carefully cut into predetermined lengths using a cutting machine or manually.

Composite formulation: Different composite formulations were prepared by varying the ratios of banana fibers and fly ash particles. These ratios were determined through preliminary experiments and literature review to optimize the mechanical properties of the composites.

Composite fabrication: The composite specimens were fabricated using a hand lay-up technique. A mold of the desired shape and dimensions was prepared using a release agent to prevent adhesion. A layer of resin was applied to the mold surface, followed by the placement of banana fibers and fly ash particles according to the predetermined ratios. Additional layers of resin were applied to ensure proper impregnation and consolidation of the reinforcement materials.

Curing: The composite specimens were subjected to a controlled curing process, typically involving temperature and pressure. The curing process followed the recommended guidelines provided by the resin manufacturer.

Specimen Fabrication:

The fabrication of the Banana Fiber/Fly Ash Reinforced Composites involved the following materials and methods. The specimens were designed to represent specific compositions and behaviours of the composite material under study.

Specimen Composition:

A total of six specimen samples were fabricated with varying compositions of banana fibre and fly ash. The compositions were calculated in weight percentages (%w/w). The table below shows the composition of each sample:

Table -1: Specimen Composition

Sample No.	Banana fibre%(w/w)	Fly Ash%(w/w)
1	6	10
2	8	10
3	10	10
4	6	15
5	8	15
6	10	15

Specimen Fabrication Process:

The fabrication process involved the following steps:

1. Cleaning the Mould: The mould used for specimen fabrication was thoroughly cleaned to ensure there were no dirt particles or debris present in the cavity where the solution would be poured.
2. Calculation of Materials: The required amounts of banana fibre and fly ash were calculated using a weigh scale, based on the specified composition for each sample.
3. Mixing Epoxy Resin and Hardener: Epoxy resin and hardener were mixed in a ratio of 10:1 using a mechanical agitator to ensure proper mixing of the components.
4. Pouring the Mixture: The calculated amount of fly ash was mixed with the epoxy resin and hardener solution, and the mixture was poured into the mould.

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5. Vacuum Casting: The mould with the solution was placed in a vacuum casting machine to remove any air bubbles from the solution. This step ensured uniformity in the specimen and prevented the formation of porous structures that could reduce the strength of the specimen.

Fig -2: Vacuum Casting Machine

6. Adding Banana Fiber: After the mould was removed from the vacuum casting, banana fibre strands were added to the solution. The fibres were manually compressed to ensure proper distribution within the specimen.
7. Curing: The specimen was left for curing, allowing the epoxy resin to harden and bond the fibres and fly ash together.
8. Surface Finishing: After curing, the specimens were removed from the mould, and surface finishing was performed to ensure smooth and uniform surfaces for testing.

This specimen fabrication process was repeated for each composition, resulting in a set of specimens representing different combinations of banana fibre and fly ash.

Fig 3: Specimens

Specimen Testing:

The mechanical properties of the Banana Fiber/Fly Ash Reinforced Composites were evaluated through tensile testing. The testing process involved the following materials and methods.

Tensile Test:

Tensile testing is a destructive test process that provides valuable information about the strength, ductility, and other mechanical properties of materials. The tensile test measures the force required to break a specimen and the extent of elongation before failure.

The ASTM D638 standard test method for tensile properties of plastics was followed for conducting the tensile tests. This method specifies the procedures for testing the tensile strength of plastics and calculating their mechanical properties.

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Universal Testing Machine (UTM):

A Universal Testing Machine (UTM) was used to conduct the tensile tests on the fabricated specimens. The UTM is a versatile testing instrument capable of performing standard tensile and compression tests on materials.

Fig -3: Universal Testing Machine

The test procedure for the tensile test involved the following steps:

1. Loading the Specimen: The specimen was loaded into the tensile grips of the UTM.
2. Attaching the Extensometer: An extensometer was attached to the specimen to measure the elongation during the test accurately.
3. Test Parameters: The UTM was set to the appropriate test parameters, including the test speed, gauge length, and load range, as per the ASTM D638 standard.
4. Test Execution: The UTM was activated to apply a steadily increasing tensile force to the specimen until it reached failure. During the test, the load and elongation values were continuously recorded.
5. Data Analysis: The load-elongation curve obtained from the test was analysed to determine various mechanical properties, such as tensile strength, elongation at break, and modulus of elasticity.

The tensile tests were performed on all the fabricated specimens to evaluate their mechanical behaviour and compare the performance of different compositions.

Data Analysis:

The data collected from the tensile tests, including load-elongation curves and mechanical properties, were analysed using statistical methods. The analysis involved calculations of mean values, standard deviations, and comparisons between different compositions.

Additionally, the mechanical properties of the Banana Fiber/Fly Ash Reinforced Composites were compared with those of other conventional materials to assess their potential applications in various industries.

The materials and methods described above provide a systematic approach for the fabrication of Banana Fiber/Fly Ash Reinforced Composites and the evaluation of their mechanical properties. The data obtained from this study will contribute to the understanding of these composites' performance and their suitability for specific applications in industries such as construction, automotive, packaging, furniture, textiles, and agriculture.

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IV. RESULTS AND DISCUSSIONS

After conducting tensile test on all the 6 specimens, the results are tabulated as follows:

Table 2: Tensile Strength Results

Sample Description	Fiber %	Ash %	Tensile Strength (MPa)	Elongation%
1	6	10	45.80	2.380
2	10	10	33.61	1.072
3	6	15	34.83	2.315
4	8	15	41.14	1.648
5	10	15	43.74	1.767

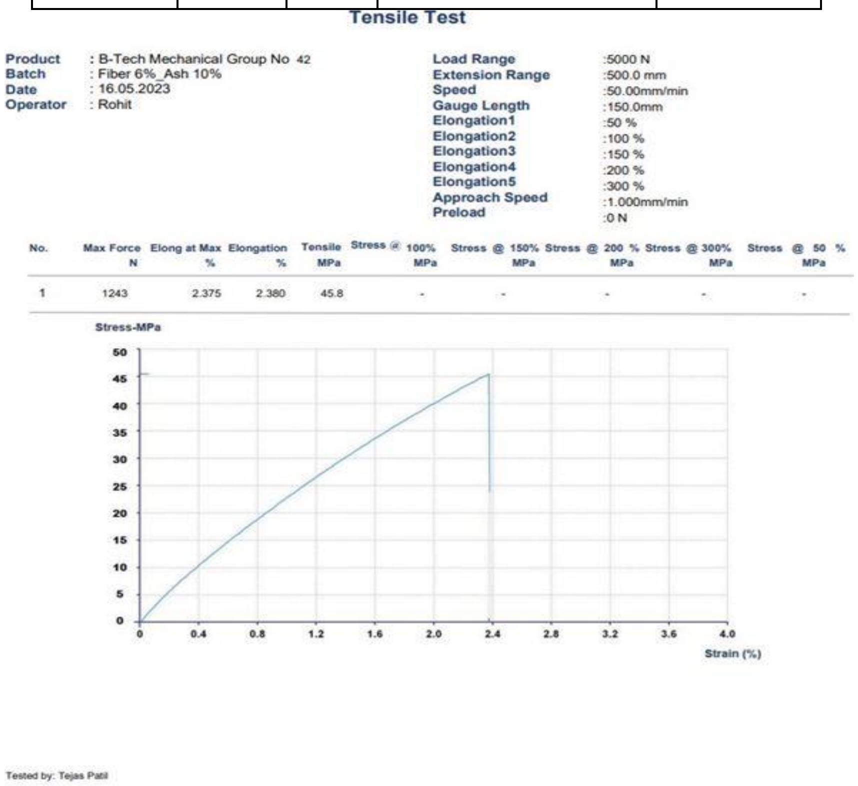

Fig -4:Stress v/s Strain Graph of Optimum Specimen

It is inferred from the table that the sample with the combination of 6% fiber and 10% fly ash provides maximum Tensile strength.

4.1 Comparison with other natural fiber composite

So now we have fabricated our Banana fibre Composite and we have performed the tensile test on our specimens. But results are not just to justify if a material is good or not, for that we have to compare it with existing standards or with material which we are trying to replace it with a material of the same category having similar properties.

Table -3: Tensile strength of different Materials/composites

Sr No.	Materials	Ultimate Tensile Strength (MPa)
1	High-density polyethylene (HDPE)	37
2	Wood,pine(paralleltograin)	40
3	Rubber	16
4	Carbonized palm shell kernel	7.37

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5	Rice Rusk ash	25.8
6	Vinylestersheet	30-993
7	Plywood	27-34
8	Polystyrene	28

So, as we can see tensile strength of different materials and composites. And tensile strength of our Banana Fiber Composite is greater than all these above materials i.e., 45.80 MPa.

The mechanical properties of the Banana Fiber/Fly Ash Reinforced Composites were evaluated through tensile testing, and the results obtained for each sample are presented below:

The obtained results reveal important insights into the mechanical behaviour of the Banana Fiber/Fly Ash Reinforced Composites. The tensile strength values varied across the different compositions, with Sample 1 exhibiting the highest tensile strength of 45.80 MPa. It is noteworthy that Sample 1 had a lower fibre composition compared to Sample 2, but still displayed a superior tensile strength. This suggests that factors other than fibre content, such as the bonding between the fibres and the matrix, play a significant role in determining the overall strength of the composite.

Furthermore, the elongation values indicate the ability of the composites to deform under tensile stress before reaching failure. Sample 1 exhibited the highest elongation of 2.380%, followed closely by Sample 3 with an elongation of 2.315%. These results suggest that increasing the fibre composition may enhance the composite's ability to undergo deformation before fracture.

Comparing Samples 2, 4, and 5, it is evident that an increase in ash composition did not lead to a significant improvement in tensile strength. However, the elongation values decreased as the ash composition increased, indicating a reduced capacity for deformation before failure. This suggests that the ash content may have a negative influence on the composite's ductility.

Overall, the results demonstrate that the mechanical properties of the Banana Fiber/Fly Ash Reinforced Composites are influenced by the fibre and ash compositions. Achieving an optimal balance between the two components is crucial to enhance the composite's tensile strength and elongation properties. The data obtained from this study provides valuable insights for further optimization of the composite composition and processing parameters.

These Banana Fiber/Fly Ash Reinforced Composites show promising potential for various applications in industries such as construction, automotive, packaging, furniture, textiles, and agriculture, where the combination of strength and ductility is essential. Further research and development can focus on optimizing the composite's composition and processing techniques to enhance its mechanical properties and expand its range of applications.

V. CONCLUSION

In this study, banana fibre and fly ash were successfully incorporated into a composite material through a combination of hand lay-up and compression moulding techniques. The composite formulations were prepared by varying the weight percentages of banana fibre and fly ash, ranging from 6% to 10% and 10% to 15%, respectively.

The tensile strength and elongation at break of the Banana Fiber/Fly Ash Reinforced Composites were evaluated through experimental testing. The results showed that the addition of banana fibre and fly ash improved the mechanical properties of the composites compared to the pure fly ash matrix. The composites exhibited enhanced tensile strength and elongation at break, indicating improved resistance to deformation and higher structural integrity.

Statistical analysis of the data revealed significant differences between the composite samples, highlighting the influence of varying weight percentages of banana fibre and fly ash on the mechanical properties of the composites. The optimization of weight percentages can further enhance the performance of the composites for specific applications.

The successful fabrication of the Banana Fiber/Fly Ash Reinforced Composites opens up new possibilities for sustainable materials with improved mechanical properties. The utilization of banana fibre as a reinforcing material and fly ash as a matrix material not only enhances the mechanical performance but also promotes the utilization of agricultural waste and industrial by-products, contributing to environmental sustainability.

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Future studies can focus on further optimizing the composite formulation, exploring the effects of different processing parameters, and investigating the composite's performance under different environmental conditions. Additionally, the potential applications of these composites in various industries, such as automotive, construction, and packaging, can be explored to harness their unique properties.

Overall, the results obtained from this study demonstrate the potential of banana fibre and fly ash composites as sustainable and high-performance materials, offering a promising avenue for the development of eco-friendly and cost-effective solutions in various fields.

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