Effects of Filler Material on Mechanical Properties of Abaca and Kenaf Fiber Composites

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Abstract
Natural fiber-reinforced polymer composites have gained increasing attention due to their sustainability, lightweight characteristics, and cost-effectiveness. This study investigates the effect of filler materials—fly ash and sawdust—on the mechanical properties of hybrid abaca-kenaf fiber reinforced epoxy composites. Equal weight fractions of epoxy resin and hybrid fibers were used, and the composites were fabricated with and without the inclusion of fillers. Mechanical tests including flexural, tensile, and impact tests were conducted as per ASTM standards. The results showed that the inclusion of sawdust filler improved the flexural modulus and tensile properties compared to other samples, while fly ash significantly enhanced the impact resistance. These findings suggest that appropriate filler selection can tailor composite performance for specific applications.

Keywords: Natural fibers, Abaca, Kenaf, Filler material, Sawdust, Fly ash, Mechanical properties, Composite materials

1. Introduction

Natural fiber composites are increasingly used as an alternative to synthetic composites in automotive, packaging, and construction applications due to their biodegradability, renewability, and good specific mechanical properties. Among natural fibers, abaca and kenaf have shown excellent reinforcing potential. However, limitations such as moisture absorption and lower impact strength can hinder their application. To overcome these challenges and improve mechanical performance, filler materials such as fly ash and sawdust are introduced into the composite matrix. This study explores the influence of these fillers on the mechanical properties of abaca-kenaf fiber reinforced epoxy composites. The objective is to determine the optimum filler for improving mechanical performance and to provide insight into the application of low-cost, sustainable fillers.

Composites are divided into two types. Typically, the matrix state is used to classify the first level of classification. Metal Matrix Composites (MMCs), Ceramic Matrix Composites (CMCs), and Polymer Matrix Composites (PMCs) are the three main types of composites. A polymer matrix is reinforced with a wide range of fiber materials to form PMCs. Polymer matrices are more often utilized than metal and ceramic matrices owing to their cost-effectiveness, simplicity of manufacturing complicated components with inexpensive tooling investments, and good room temperature properties. Polymers have essentially replaced conventional metals and minerals in the range of applications during the last several decades.

Most of this composite is utilized in the widest range of applications because of its benefits, which include low mass and insulators that are both thermally and electrically beneficial. Polymers' characteristics are changed in the majority of these applications by adding fibers that meet high strength/high modulus criteria.

2. Literature Review

Natural fiber-reinforced polymer composites have been extensively explored over the past two decades due to their low cost, renewable nature, and biodegradability. Researchers have shown increasing interest in replacing synthetic fibers like glass or carbon with lignocellulosic fibers such as abaca, kenaf, jute, hemp, and sisal to reduce environmental impact while maintaining competitive mechanical properties. Abaca and Kenaf fibers are among the most promising reinforcements for thermoset composites. Abaca, derived from Musa textilis, offers high tensile strength and flexibility, making it suitable for structural applications. Kenaf (Hibiscus cannabinus) is valued for its high specific strength and ease of cultivation. According to George et al. (2001), natural fibers such as kenaf and abaca have demonstrated improved performance in epoxy composites when treated chemically to enhance fiber-matrix adhesion.

Several studies have investigated the hybridization of natural fibers. Mixing different fiber types often results in synergistic effects where one fiber compensates for the limitations of the other. For instance, Puglia et al. (2008) reported that combining abaca and kenaf in a hybrid configuration improves both tensile and flexural properties due to the fiber distribution and load transfer efficiency. Filler materials are also widely used in composites to modify mechanical, thermal, and barrier properties. Fly ash, a byproduct of coal combustion, contains silica and alumina, which contribute to increased rigidity and thermal stability in polymer composites (Singh et al., 2013). Fly ash particles are known to fill micro-voids within the matrix, thus enhancing stiffness and load transfer.

Sawdust, a lignocellulosic byproduct from wood processing industries, is another low-cost and eco-friendly filler. Sawdust not only reduces the overall weight of composites but also offers reasonable mechanical support. Studies by Shubham et al. (2017) revealed that sawdust-filled composites showed improved impact resistance and a reduction in crack propagation due to the presence of fibrous particles that help in absorbing energy.The choice of filler directly impacts the fiber-matrix interface and overall composite integrity. While inorganic fillers like fly ash enhance strength and modulus, they may adversely affect impact resistance due to brittleness. Conversely, organic fillers like sawdust improve ductility and energy absorption, making the material more resilient under dynamic loading. Despite various investigations, limited research is available on the combined effects of hybrid natural fibers and dual filler systems on the mechanical performance of composites. Most available literature focuses either on fiber-reinforced composites or filler-enhanced systems separately. The current study attempts to bridge this gap by analyzing the impact of two different fillers—fly ash and sawdust—on a hybrid abaca-kenaf reinforced epoxy matrix, providing new insights into performance tuning of sustainable composite materials.

3. Materials and Methods

3.1 Materials

The materials used in this work include epoxy as the matrix material, and kenaf and abaca fibers as the reinforcing materials. An equal weight percentage of hybrid Abaca-Kenaf fiber and epoxy resin was used. Two types of fillers—sawdust powder and fly ash—were incorporated into separate composite samples.

Fig.3.1.1 Abaca and kenaf fibre picture

Fig.3.1.2 Epoxy resin

Fig.3.1.3 Fly ash and Saw dust powder

3.2 Fabrication Process

Using an electronic weighing machine, the calculated amount of fibers, filler, and resin was measured. The mixture was stirred thoroughly and poured into a moulding box pre-coated with a releasing agent. A hot press machine applied a 5-tonne load at approximately 120°C for 20 minutes. The cured composite was then removed and cut to ASTM standard dimensions for testing.

Fig.3.2.1 Tensile Test

Fig.3.2.2 Impact Test

Fig.3.2.3 Bending Test

4. Mechanical Testing

Mechanical tests were performed in accordance with ASTM standards to evaluate the flexural, tensile, and impact properties of the composite samples.

4.1 Flexural Test Results

Table 4.1 Flexural test results

Filler Type	Flexural Modulus (MPa)	Flexural Strength (MPa)
Without Filler	750	32
Fly Ash Filler	780	29
Sawdust Filler	901	25

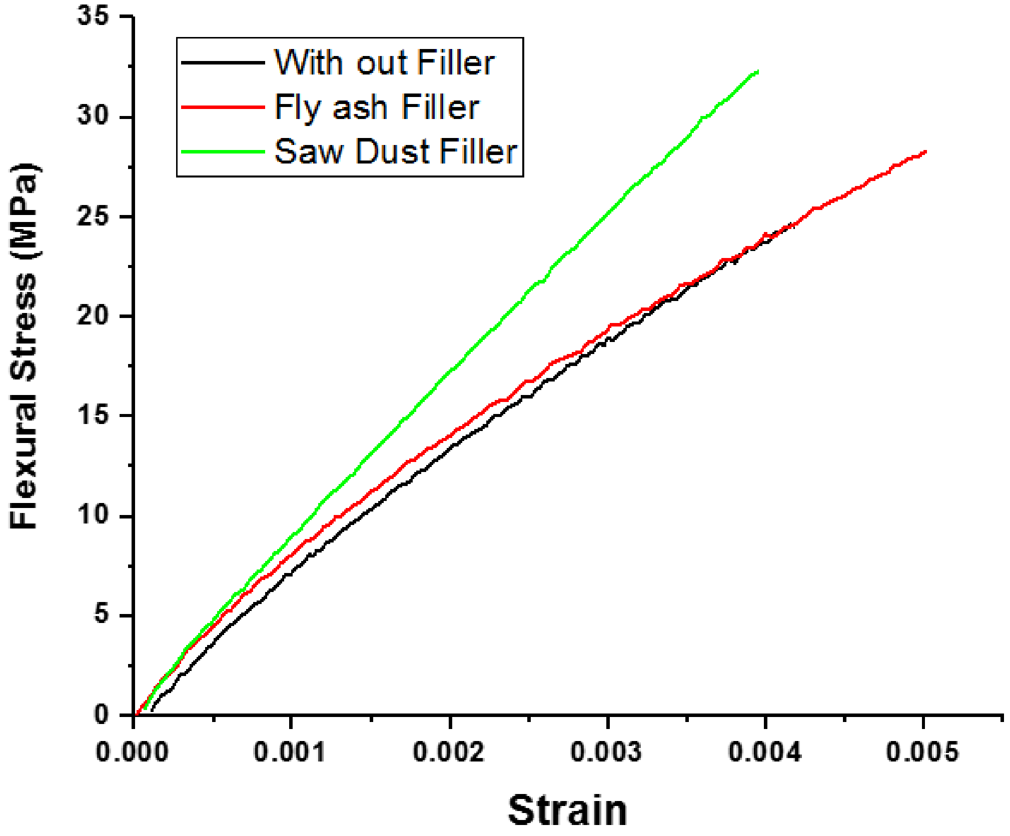

Fig.4.1.1 Flexural stress versus strain

4.2 Tensile Test Results

Table 4.2 Tensile test results

Filler Type	Tensile Modulus (MPa)	Tensile Strength (MPa)
Without Filler	283	19
Fly Ash Filler	393	21
Sawdust Filler	440	24

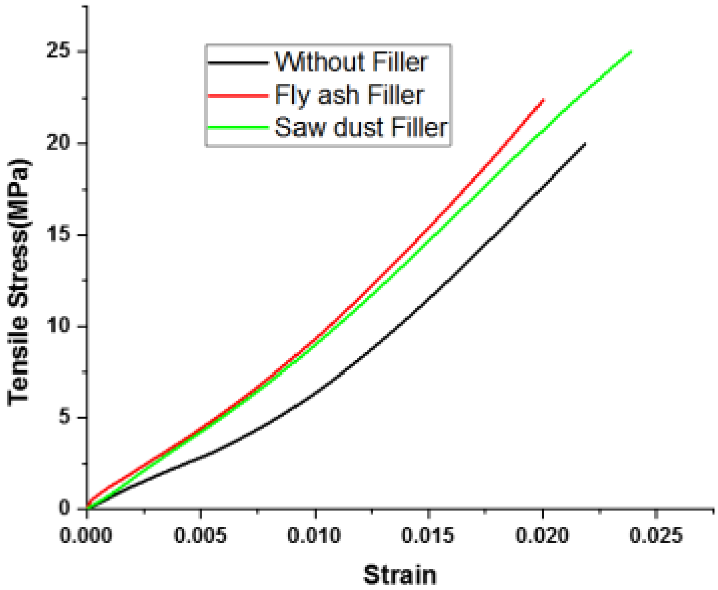

Fig.4.2.1 Tensile stress versus strain

4.3 Impact Test Results

Table 4.3 Impact test results

Filler Type	Absorbed Impact Energy (J)	Impact Strength (J/m)
Without Filler	0.361	99.03
Fly Ash Filler	1.120	145.13
Sawdust Filler	0.639	254.59

Series graph:

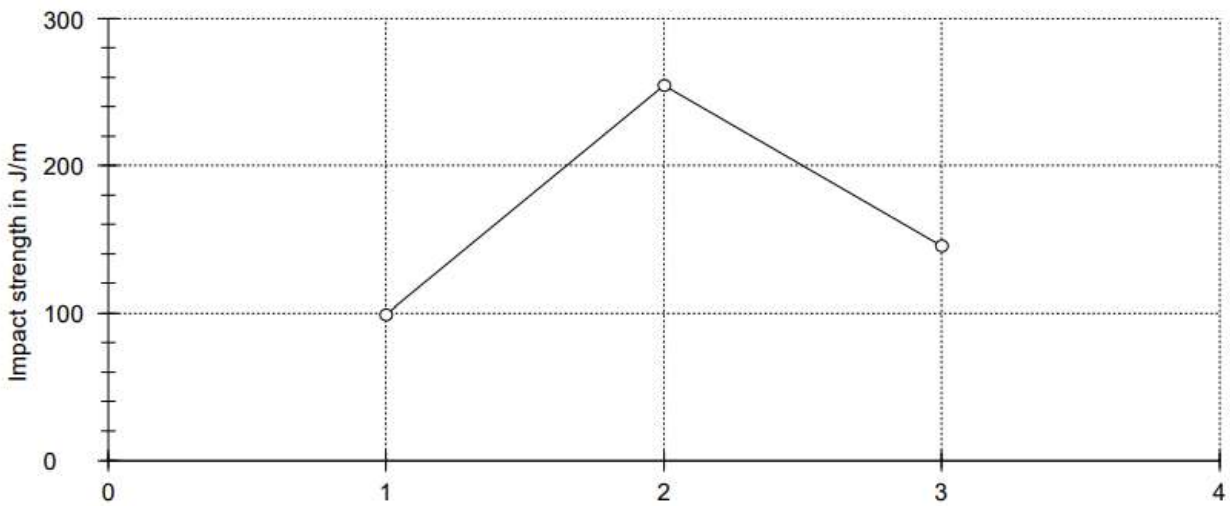

Fig.4.3.1 Impact strength vs specimen number (index)

1. With no filler material
2. Sawdust as filler material
3. Fly ash as filler material

5. Results and Discussion

The flexural modulus was highest for sawdust-filled composites (901 MPa), indicating enhanced stiffness, while the unfilled composite had the highest strength (32 MPa). Tensile tests revealed that sawdust filler led to the best modulus and strength. Fly ash filler showed the highest energy absorption in the impact test, while sawdust filler achieved the highest impact strength. These trends suggest that sawdust improves stiffness and toughness, while fly ash enhances energy absorption under impact.

The mechanical performance of natural fiber composites is significantly influenced by the choice and nature of filler materials. In this study, three different composite configurations were analyzed: a control composite without filler, a composite with fly ash filler, and a composite with sawdust filler. Mechanical tests including flexural, tensile, and impact evaluations were performed to understand the reinforcing efficiency of each filler.

Flexural Properties

The flexural test results indicate that the incorporation of filler materials affected both the stiffness and strength of the composites. The highest flexural modulus was observed in the composite reinforced with sawdust filler (901 MPa), followed by fly ash (780 MPa), and the unfilled composite (750 MPa). This enhancement in modulus suggests that the sawdust particles provided improved rigidity due to better stress transfer between the fiber and matrix phases. However, the flexural strength decreased in the filler-added samples. The unfilled composite exhibited the highest flexural strength (32 MPa), while fly ash and sawdust-filled composites recorded values of 29 MPa and 25 MPa, respectively. This drop in strength might be attributed to stress concentration points or poor dispersion of filler particles, which can initiate micro-cracks under bending loads.

Tensile Properties

In tensile testing, both fly ash and sawdust fillers improved the modulus and strength of the composites compared to the unfilled control. The tensile modulus increased from 283 MPa (control) to 393 MPa and 440 MPa for fly ash and sawdust fillers, respectively. This suggests that the fillers contributed to a stiffer matrix structure capable of resisting axial deformation. The tensile strength also followed a similar trend, increasing from 19 MPa (control) to 21 MPa (fly ash) and 24 MPa (sawdust). The sawdust filler outperformed fly ash in both tensile modulus and strength, indicating a better interfacial adhesion between sawdust particles and the epoxy matrix, potentially due to their similar organic nature and surface roughness aiding mechanical interlocking.

Impact Properties

The most notable difference among the composites was observed in impact testing. Fly ash filler significantly enhanced the absorbed impact energy to 1.120 J, compared to 0.361 J for the unfilled composite and 0.639 J for the sawdust-filled one. The improvement in energy absorption with fly ash may be due to its ceramic-like microstructure, which dissipates energy effectively during fracture. However, when considering impact strength (energy per unit area), the sawdust-filled composite showed superior performance at 254.59 J/m, compared to 145.13 J/m (fly ash) and 99.03 J/m (control). This suggests that while fly ash absorbs more energy overall, sawdust filler enhances the material's ability to resist sudden breakage on a per-area basis.

Overall Observations

The results clearly indicate that filler addition can be used to tailor the mechanical performance of natural fiber composites. Sawdust filler significantly improves stiffness and impact strength, making it suitable for structural applications requiring rigidity and dynamic load resistance. Fly ash filler, on the other hand, is effective in enhancing energy absorption, which may be useful in applications demanding higher toughness. The selection of filler material should thus align with the intended application requirements. Proper dispersion, filler-matrix compatibility, and interfacial bonding remain critical factors in achieving optimal performance.

6. Conclusion

The study demonstrated that filler addition significantly influences the mechanical behavior of hybrid abaca-kenaf fiber composites. Sawdust improved tensile and flexural moduli and impact strength, while fly ash improved impact energy absorption. Thus, filler selection allows tailoring composite properties for specific applications.

The development and examination of the tensile, flexural, and impact properties of the hybrid kenaf-abaca reinforced composite with fly ash addition, the composite without filler, and the composite with sawdust filler led to the following conclusion.

1. The addition of filler such as saw dust and fly ash in hybrid kenaf-abaca reinforced composite increases the mechanical properties
2. The addition of saw dust powder rises the tensile. Flexural and impact properties of hybrid kenaf-abaca reinforced composite increases due rich cellulous content in saw duct powder increases the bonding strength between fibre and matrix

7. References

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