



EFFECT OF CORNCOB POWDER ON THE MECHANICAL BEHAVIOR OF GLASS FIBER/EPOXY HYBRID COMPOSITES

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ABSTRACT

The incorporation of natural fibers into composite materials serves as an environmentally sustainable approach by integrating biodegradable components. By blending natural and synthetic fibers, the utilization of natural fibers in hybrid composites can be expanded, resulting in potential cost reductions in production. This study investigates the mechanical properties of glass fiber/epoxy hybrid composites reinforced with corncob powder. The composite specimens were fabricated using a layering method, incorporating glass fiber, epoxy resin, and corncob powder. Five different ratios of corncob powder to epoxy resin were tested (10:90, 40:60, 50:50, 70:30, and 80:20) to evaluate their tensile, flexural, and impact performance. Statistical analysis using ANOVA was conducted to interpret the results and determine the optimal composition. The composite with 10% corncob powder exhibited superior tensile strength (37.28 MPa) and flexural strength (805.75 MPa), attributed to enhanced resin-particle bonding and load transfer. The impact strength peaked at a 70:30 ratio, indicating improved toughness at moderate filler content. These results highlight the potential of corncob powder as a sustainable, eco-friendly filler that enhances mechanical properties while reducing environmental waste.

Keywords: corn cob powder, epoxy resin, mechanical testing, mechanical properties, natural fiber.

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1. INTRODUCTION

Epoxy resins are extensively used across industries for their excellent mechanical properties, chemical resistance, and versatility under challenging environmental conditions. They serve as essential structural adhesives in aerospace, automotive, and electronics applications, as emphasized by Christiansen *et al.* [1]. However, despite their advantages, synthetic fiber composites like glass fiber-reinforced polymers (GFRP) face challenges related to brittleness, environmental sustainability, and cost. Recent studies have demonstrated that natural fiber-reinforced composites provide sustainable alternatives, combining biodegradability, low cost, and competitive mechanical performance (Sanjay and Yogesha [2]).

Natural fibers, including jute, rice husk, bagasse, coconut shell, and coir, have demonstrated remarkable mechanical properties, making them viable candidates for hybrid composite development. Recent advancements in material science and composite engineering have emphasized their potential in enhancing impact strength, flexibility, and energy absorption while reducing dependency on fully synthetic materials (see Oladele *et al.* [3]). However, the mechanical limitations of standalone natural or synthetic composites necessitate the development of hybrid composite solutions. By strategically combining natural fillers with synthetic reinforcements, hybrid composites can achieve a balanced

synergy between strength, weight reduction, and environmental sustainability.

One such underutilized natural by product is corncob, a waste material from maize cultivation, predominantly discarded or burned, particularly in Sub-Saharan Africa and agricultural markets. This wasteful disposal practice contributes to environmental pollution, despite the potential of corncob for value-added applications through thermochemical conversion technologies. In composite fabrication, corncob-based fillers offer an innovative solution to enhance mechanical strength, rigidity, and energy dissipation, making them a viable reinforcement in hybrid glass fiber-epoxy composites. Glass fibers, known for their high tensile strength, lightweight nature, and corrosion resistance, are widely used in structural composites. These fibers primarily consist of B_2O_3 , SiO_2 , Al_2O_3 , MgO , and CaO , providing excellent durability and moldability (Bhagwat *et al.* [4]). However, they exhibit lower temperature tolerance compared to carbon fibers. The integration of corncob powder as a filler in glass fiber-epoxy composites can address both mechanical performance requirements and sustainability concerns by minimizing reliance on fully synthetic reinforcements.

Epoxy resins play a crucial role as the matrix material, ensuring strong adhesion and load distribution between reinforcement phases (Sathishkumar *et al.* [5]). The addition of natural fillers, such as corncob powder,



glass powder, and fly ash, has been shown to improve the hardness, impact resistance, and bending strength of epoxy composites (Kumar *et al.* [6]). These attributes make epoxy-based hybrid composites particularly valuable for applications in aerospace, automotive, and biomedical engineering, where a balance between performance, weight efficiency, and environmental responsibility is critical.

This study aims to investigate the mechanical performance of corncob-reinforced glass fiber/epoxy hybrid composites, focusing on tensile strength, flexural properties, and impact resistance using statistical data analysis. By incorporating corncob powder as a filler material, this research seeks to provide an eco-friendly, cost-effective composite solution, aligning with global efforts toward waste reduction, resource efficiency, and sustainable material development.

2. MATERIALS AND METHODS

2.1 Materials and Composite Fabrication

In the present work, corncob powder and epoxy resin were used for mixing composite fabrication. The epoxy resin LY 556 and the hardener HY 951 are commercially available, and the corncob powder was extracted manually as discussed in this section. Mechanical properties of epoxy resin are shown in Table-1. The grinding process for corncobs involved two primary stages to prepare for composite production. Mechanical grinding was used to reduce dried corncobs into smaller particles or fibres using equipment such as grinders or milling machines. This initial step ensured uniform particle size, a critical factor for consistency in subsequent mixing and layering processes. Following grinding, particle size regulation was performed to ensure the particles achieved the desired size uniformity, enhancing reliability and quality of composite material as cited by Garadimani *et al.* [7].

The sizing process refined the ground corncob particles to meet specific requirements. Sieving the corncob powder, as shown in Figure-1 was employed to separate particles into distinct size fractions based on the composite's specifications. Quality control measures, including meticulous inspection of sieved particles, ensured size consistency and the removal of impurities. This careful sizing process improved the performance and reliability of the final composite material in various applications.

Mixing and layering in Figure-2 played a crucial role in the manufacturing process of corncob-based composites. Corncob particles were thoroughly mixed with epoxy resin to create a uniform blend, ensuring even fiber distribution within the matrix. The layered structure was then reinforced by sequentially adding E-glass fiber sheets. This combination of corncob-epoxy mixture and glass fiber layers provided enhanced strength and stability to the composite referred to by Sanjay and Yogesha [2].

The curing process solidified the composite under specific conditions of heat and pressure, optimizing bonding and enhancing material properties. The resulting composite exhibited superior mechanical strength and durability, making it suitable for diverse applications.



Figure-1. Corn cob powder.



Figure-2. Hand-layup process.

In this study, Corncob waste was collected locally, cleaned, dried, and ground into fine powder using a mechanical grinder. The particle size distribution was controlled by sieving through a 150 μm mesh. Composites were prepared with five different corncob-to-epoxy ratios (10:90, 40:60, 50:50, 70:30, and 80:20) using the hand lay-up method. Epoxy resin and hardener were mixed at a 2:1 ratio and poured uniformly into prepared molds. Specimens were cured at room temperature (25°C) for 24 hours, followed by post-curing at 70°C for 2 hours to achieve complete polymerization.

Table-1. Mechanical properties of epoxy resin.

Density (g/cm ³)	Modulus of elasticity (GPa)	Poisson' ratio
1.2	2.7	0.4



2.2 Mechanical and Physical Test

This study investigates the mechanical characteristics of Corncob Powder Epoxy Resin (CCPER) hybrid composites to evaluate their suitability for diverse engineering applications. Mechanical testing ensures materials' reliability, effectiveness, and safety while promoting innovation in material design and performance. Four essential tests were conducted: tensile, flexural, impact, and water absorption tests. All test specimens were precisely fabricated using a CNC router according to relevant ASTM standards, ensuring accuracy, consistency, and reproducibility.

The tensile test measures the composite's resistance to tensile stress—specifically, its ability to withstand pulling forces without failing. Incorporating reinforcing materials like carbon and glass fibres significantly influences the composite's strength. For instance, previous studies have shown that carbon fiber-reinforced composites exhibit approximately 65.24% greater Ultimate Tensile Strength (UTS) compared to their glass fiber counterparts. Moreover, hybrid composites integrating both carbon and glass fibres have demonstrated notable enhancements in mechanical performance. This test provides insights into the composite's capacity to handle tensile loads, highlighting its potential for structural applications.

The impact test evaluates the composite's capability to absorb sudden energy impacts, a critical attribute for materials used in automotive and construction applications. During testing, notched specimens are impacted by a pendulum to quantify the energy absorbed upon fracture. Two impact testing methods were employed: the Charpy test, involving horizontal placement of the specimen, and the Izod test, where specimens are clamped vertically. Specimens were fabricated in compliance with ASTM D256, featuring accurately positioned notches to guarantee test reliability. Results from these tests offer valuable data on the composite's toughness and resistance to impact loads.

The flexural test examines the composite's behaviour under bending stresses, making it especially relevant for structural components such as beams and aircraft parts. During the test, specimens supported at both ends are subjected to a central loading force, measuring deflection and load until fracture occurs. Testing was performed according to ASTM D790 at a controlled crosshead speed of 0.25 mm/min. The obtained data indicate the composite's bending strength and stiffness, helping determine its suitability for load-bearing scenarios.

3. RESULTS AND DISCUSSIONS

3.1 Tensile Test

The tensile and elasticity properties of CCPER composites were evaluated across five ratios of corn cob powder to epoxy resin—10:90, 40:60, 50:50, 70:30, and 80:20—providing insights into how composition influences mechanical performance. Among these, the 10:90 ratio exhibited the highest performance, achieving a tensile strength of 37.28 MPa and an elasticity modulus of 1.01 GPa. This superior performance was attributed to the high resin content, which enhanced particle bonding, facilitated efficient load transfer, and improved structural cohesion. These properties enabled the composite to withstand applied forces while maintaining flexibility and durability. However, as the corn cob content increased, mechanical performance deteriorated significantly. At the 70:30 and 80:20 ratios, tensile strength declined sharply to 4.74 MPa and 0.48 MPa, respectively, while elasticity became negligible, indicating a loss of structural integrity. The reduced resin content at higher corn cob ratios led to inadequate bonding between particles, resulting in brittle composites prone to failure under stress.

These findings align with the observations of Liu *et al.* [8], who noted that while an optimal balance of filler and resin can maximize flexibility, higher resin content significantly enhances tensile strength by improving cohesion within the composite. The ANOVA analysis, presented in Tables 1 and 2, further confirmed the critical role of material composition. For tensile strength, the F-value of 106.92 and the P-value of 0.000 indicated statistically significant differences among the ratios, with 96.80% of the variation explained by material composition. Similarly, for elasticity, the F-value of 35.89 and the P-value of 0.000 demonstrated a highly significant impact, with 90.88% of the variance attributed to composition. These statistical results underscore the dominant influence of resin content in determining the mechanical properties of CCPER composites. A higher resin proportion in lower corn cob ratios not only improved stress distribution but also minimized void formation and structural weaknesses, leading to superior tensile and elastic performance. Conversely, insufficient resin at higher corn cob concentrations compromised the composite's load-bearing capacity, making it more fragile and susceptible to mechanical failure. This analysis highlights the importance of optimizing the filler-to-resin ratio to achieve a balance between sustainability and mechanical strength, ensuring the development of structurally robust hybrid composites.

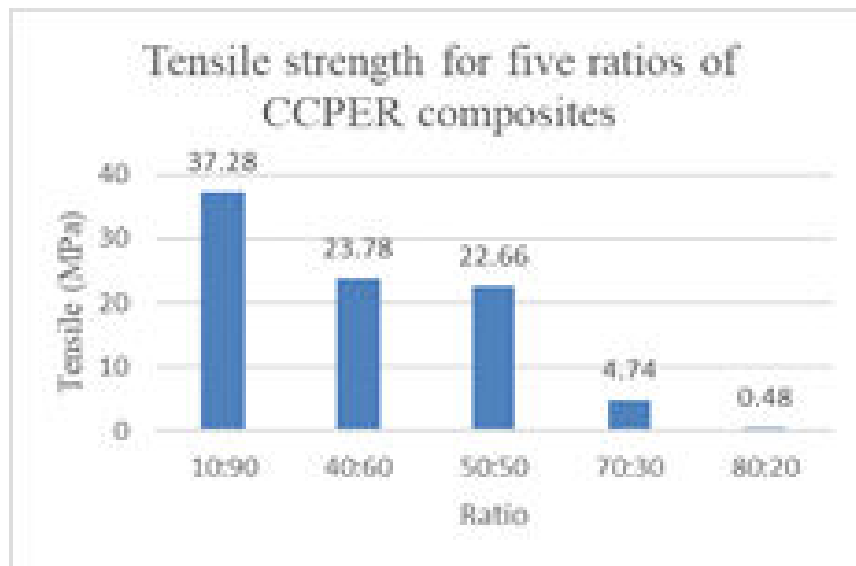


Figure-3. Tensile strength for five ratios of CCPER composites.

Table-2. ANOVA for tensile strength.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
C1	4	2727.49	681.872	106.92	0.000
Error	10	63.77	6.377		
Total	14	2791.26			

Table-3. ANOVA for elasticity.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
C1	4	3.5812	0.89532	35.89	0.000
Error	10	0.2495	0.02495		
Total	14	3.8308			

3.2 Flexural Test

The bar chart in Figure 4 shows the flexural strength of CCPER composites across five corncob powder-to-epoxy resin ratios: 10:90, 40:60, 50:50, 70:30, and 80:20. The 10:90 ratio exhibited the highest flexural strength at 805.75 MPa, showcasing exceptional resistance to bending forces due to the high resin content, which enables effective stress distribution and prevents failure. The 40:60 and 50:50 ratios followed with flexural strengths of 449.53 MPa and 433.53 MPa, respectively, demonstrating moderate performance. However, as the corncob content increased, there was a sharp decline in flexural strength, with the 70:30 ratio showing just 4.5 MPa and the 80:20 ratio performing the weakest at 0.32 MPa. This decrease aligns with findings by Sanjay and

Yogesha [2], indicating that higher fiber content can reduce bonding efficiency and structural integrity.

The ANOVA results in Table 4 further validate these findings, showing a highly significant F-value of 62.79 and a P-value of 0.000. The analysis revealed that 94.64% of the variation in flexural strength was due to material composition, highlighting the importance of the corncob-to-resin ratio in determining performance. In contrast, only 5.36% of the variation was attributed to errors or inconsistencies. Overall, the 10:90 ratio proved to be the most effective for structural applications requiring high strength, while excessive corncob content severely weakened the composite. These results emphasize the need for a balanced composition to achieve optimal performance in practical applications.

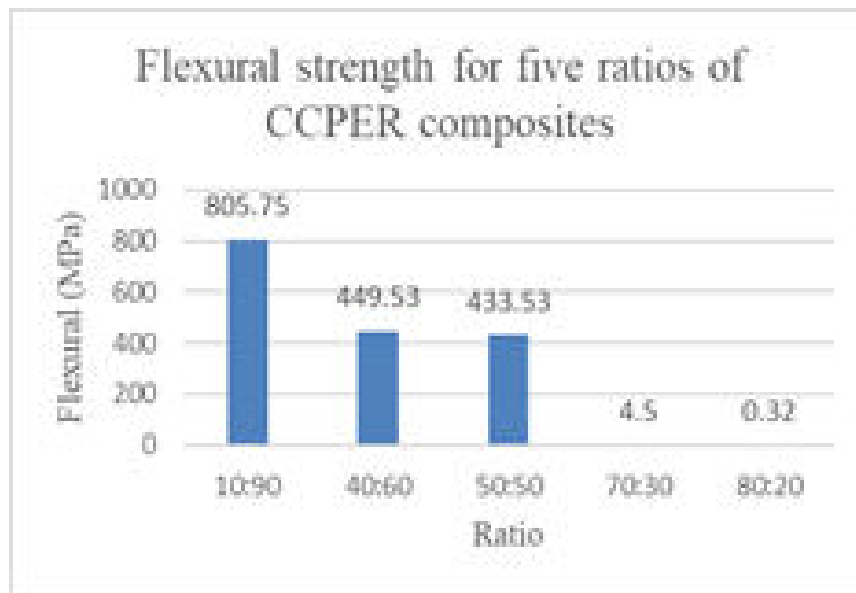


Figure-4. Flexural strength for five ratios of CCPER composites.

Table-4. ANOVA for flexural strength.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
C1	4	13396553	349138	62.79	0.000
Error	10	55607	5561		
Total	14	1452160			

3.3 Impact Test

The bar chart in Figure-10 illustrates the impact energy of CCPER composites for five ratios of corncob powder to resin: 10:90, 40:60, 50:50, 70:30, and 80:20. Among these, the 70:30 ratio demonstrated the highest impact energy at 1.81 J, highlighting its exceptional ability to absorb energy and resist sudden forces. This superior performance is attributed to sufficient fiber content, which facilitates efficient stress transfer between the fibers and epoxy, as noted by Garadimani *et al* [8]. Additionally, this formulation exhibited excellent fiber dispersion, optimizing the composite's structural integrity. However, beyond a certain fiber concentration (around 7.5%), the impact strength declined due to issues like poor bonding and increased voids. The 50:50 ratio followed with an impact energy of 0.84 J, while the 40:60 ratio achieved 0.58 J. On the other hand, the 10:90 and 80:20 ratios exhibited significantly lower impact energies of 0.31 J and 0.14 J, respectively, indicating reduced capacity to absorb and dissipate sudden forces effectively.

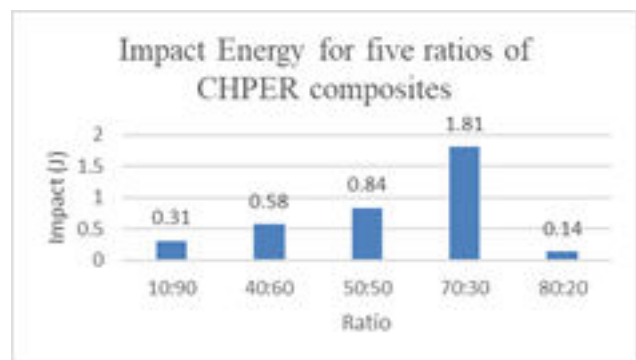


Figure-5. Impact energy for five ratios of CCPER composite.

The ANOVA analysis in Table-5 reinforced the critical role of material composition in determining impact energy, with an F-value of 5.66 and a P-value of 0.012, showing statistically significant differences among the ratios. Material composition accounted for 57.11% of the variation in impact energy, emphasizing its importance in optimizing the toughness and energy absorption capabilities of the composites. The results demonstrate that the balance between corncob powder and resin is a key factor in enhancing the composite's ability to withstand and dissipate impact forces. The findings emphasize the importance of fine-tuning material ratios to achieve the best impact resistance. The 70:30 ratio stands



out as the most effective composition, with its ability to absorb energy and resist sudden impacts making it ideal for applications where durability and toughness are essential. These results provide valuable insights into optimizing composite materials for real-world scenarios requiring superior impact performance.

Table-5. ANOVA for impact energy.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
C1	4	5.154	1.2886	5.66	0.012
Error	10	2.277	2.277		
Total	14	7.431			

4. CONCLUSIONS

This study investigated the mechanical properties of glass fiber epoxy hybrid composites reinforced with corncob powder, focusing on the effects of varying filler content on tensile, flexural, and impact strength. The findings demonstrated that the 10:90 (corncob powder to epoxy) ratio exhibited the highest mechanical performance, achieving a tensile strength of 37.28 MPa and an elasticity modulus of 1.01 GPa. The superior performance at this ratio was attributed to the high resin content, which improved particle bonding, facilitated effective load transfer, and enhanced structural cohesion. In contrast, as the corncob powder content increased beyond 40%, mechanical performance declined significantly. The 70:30 and 80:20 ratios exhibited the lowest tensile strengths of 4.74 MPa and 0.48 MPa, respectively, indicating poor bonding and reduced structural integrity due to excessive fiber content and insufficient resin.

The flexural strength results also followed a similar trend, with the 10:90 ratio achieving the highest value of 805.75 MPa, demonstrating excellent resistance to bending forces. However, higher corncob content led to a sharp decrease in flexural strength, confirming that excessive natural filler reduces the composite's load-bearing capacity. Interestingly, the 70:30 ratio exhibited the highest impact energy at 1.81 J, suggesting improved toughness and energy absorption at moderate fiber content. Statistical analysis using ANOVA confirmed that material composition had a highly significant effect on tensile, flexural, and impact properties, with P-values of 0.000, indicating strong correlations between mechanical performance and corncob-to-resin ratios.

Beyond mechanical performance, this research contributes to global sustainability initiatives by demonstrating the potential of corncob powder as an eco-friendly reinforcement material. The repurposing of agricultural waste into hybrid composites reduces dependence on synthetic materials, mitigates environmental impact, and promotes cost-effective material solutions. The use of the hand lay-up method provided a simple and economical fabrication approach,

though further refinement is required to improve the uniform dispersion of corncob particles within the matrix. Overall, this study underscores the viability of corncob powder as a sustainable reinforcement for hybrid composites, particularly when optimized at lower filler content. Future research should focus on enhancing dispersion techniques, exploring alternative fabrication methods, and evaluating long-term durability under real-world conditions to further advance the application of bio-based hybrid composites in industrial sectors.

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