World Journal of Advanced Engineering Technology and Sciences
eISSN: 2582-8266
Cross Ref DOI: 10.30574/wjaets
Journal homepage: https://wjaets.com/

(RESEARCH ARTICLE)

Check for updates

INVESTIGATION OF TENSILE BEHAVIOUR OF GLASS FIBRE REINFORCED POLYMER (GFRP)/COIR RECTANGULAR LAMINATE AFTER HIGH IMPACT PRONE APPLICATION

Ifeanyi Goodluck Ajie *, Daerefa-a Mitsheal Amafia and Ikegwuru Ibezimakor Okachi

Department of Mechanical Engineering, Rivers State University, Rivers State, Nigeria.
* Corresponding Author

World Journal of Advanced Engineering Technology and Sciences, 2026, 21(02), 275–280

Publication history: Received on 04 October 2026; revised on 10 November 2026; accepted on 12 November 2026

Article DOI: https://doi.org/10.30574/wjaets.2026.21.2.0496

Copyright © 2026 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution License 4.0

ABSTRACT

The increasing demand for lightweight, sustainable, and impact-resistant materials has promoted the use of GFRP/coir hybrid composites. However, their post-high-velocity impact tensile behaviour and residual load-bearing capacity remain poorly understood due to complex damage mechanisms. This study investigated the tensile behaviour of Glass Fibre Reinforced Polymer (GFRP)/coir rectangular laminates after high-velocity impact to assess their viability as sustainable, impact-resistant materials. GFRP/coir laminates were prepared and subjected to high-velocity impact, followed by tensile testing (ASTM D638), Charpy impact testing (ASTM E23) and microstructural analysis (ASTM E562). Tensile tests on four samples yielded ultimate strengths ranging from 9 MPa (Sample 3) to 30 MPa (Sample 1), reflecting significant post-impact degradation. Charpy impact tests showed average energy absorption between 1.27 J and 2.77 J, highlighting coir's role in toughness. Microstructural analysis revealed extensive matrix cracking, fibre fractures, and debonding. The results indicate a trade-off between coir's energy absorption and the compromised tensile strength due to glass fibre brittleness and poor interfacial bonding. The study concludes that while GFRP/coir laminates offer sustainability and improved impact resistance, their tensile performance post-high-velocity impact is limited, necessitating optimisation of fibre ratios, matrix adhesion, and laminate thickness.

Keywords: GFRP, Coir, Hybrid composite, Tensile behaviour, High-velocity impact, Microstructure, Residual strength

1 INTRODUCTION

Fibre-reinforced polymer composites have become increasingly important in weight-sensitive engineering applications. Glass fibre reinforced polymer (GFRP) systems, in particular, are widely used because of their high tensile strength, stiffness, corrosion resistance, and relatively low cost [1]. These materials are common in automotive panels, secondary aerospace structures, marine components, and protective elements. Despite these advantages, pure GFRP remains brittle under dynamic loading. High-velocity impact produces matrix cracking, fibre fracture, and delamination that can reduce residual tensile strength by substantial margins [2].

Natural fibres such as coir, obtained from coconut husks, have been examined as partial replacements or hybrid reinforcements for synthetic fibres [3]. Coir is inexpensive, renewable, and biodegradable. Its fibrous and porous structure allows energy absorption through fibre pull-out and matrix micro-cracking. When combined with glass fibres

in a polymer matrix, the hybrid system seeks to retain the structural strength of GFRP while improving toughness and reducing environmental impact. Earlier work on coir/glass hybrids has shown that increasing coir content can raise impact resistance, although overall tensile strength and stiffness usually decline because the modulus of coir is much lower than that of glass [4].

High-velocity impact events, such as those produced by debris or ballistic fragments, create complex damage states that are not fully captured by low-velocity drop-weight tests [5]. In pure GFRP laminates, residual tensile strength after such impacts commonly falls by 30–60 percent [6]. The introduction of coir adds further heterogeneity. Differences in fibre diameter, surface chemistry, and interfacial adhesion between coir and the epoxy matrix can accelerate crack growth and debonding once the laminate is loaded in tension after impact [7]. Consequently, the residual tensile capacity of GFRP/coir rectangular laminates after high-velocity impact is not yet well characterised.

This gap limits the confident use of the hybrid material in applications where both impact tolerance and post-damage load-bearing capacity are required. Without quantitative data on residual strength, energy absorption, and the associated microstructural damage, designers cannot reliably judge whether the sustainability benefit of coir justifies the reduction in tensile performance [8]. The present study therefore focuses on the tensile behaviour of GFRP/coir rectangular laminates after high-velocity impact.

The aim of the work is to investigate the residual tensile properties of the hybrid laminates. The objectives are to measure the tensile response of impact-damaged specimens, quantify impact energy absorption by Charpy testing, and document the microstructural damage mechanisms that govern the observed loss of strength.

2 MATERIALS AND METHODS

2.1 Materials

Hybrid laminates were fabricated from cleaned and dried coir fibres, matted E-glass chopped strand mat, epoxy resin, accelerator, and catalyst. A rectangular steel or aluminium mould was coated with mould-releasing wax. Hand lay-up was used to build laminates of nominal thickness 3–5 mm. Specimens were cured at ambient temperature for 24-48 hours before trimming.

2.2 Methods

2.2.1 Mechanical Testing

Tensile tests followed ASTM D638 on a universal testing machine. Specimens that had previously been subjected to high-velocity impact were loaded at constant crosshead speed until failure. Charpy impact tests were performed according to ASTM E23 at a constant temperature of 25 °C. Microstructural examination of polished sections was carried out with an optical microscope at 100× and 200× in accordance with ASTM E562.

2.2.2 Theoretical Relations

Tensile stress in a rectangular cross-section is

$$\sigma = F / (w \times t) \quad (1)$$

where F is the applied force, w is the specimen width and t is the thickness. Strain is

$$\varepsilon = \Delta L / L_0 \quad (2)$$

Young's modulus is obtained from

$$E = \sigma / \varepsilon \quad (3)$$

Ultimate tensile strength corresponds to the maximum recorded force. For three-point bending, the maximum flexural stress is

$$\sigma_f = (3FL) /(2wt^2) \quad (4)$$

Impact energy delivered by a drop weight of mass m falling through height h is

$$E_{imp} = mgh \quad (5)$$

The critical fibre length required for efficient load transfer is

$$l_c = (\sigma_f \times d) / (2\tau) \quad (6)$$

where σ_f is the fibre tensile strength, d is the fibre diameter and τ is the interfacial shear strength. Charpy energy absorption is read directly from the testing machine.

3 RESULTS AND DISCUSSION

3.1 Tensile Test Results

Four GFRP/coir specimens were tested in tension after high-velocity impact. Sample 1 reached an ultimate tensile strength of 30 MPa and a yield strength of 19 MPa. The stress–time curve showed a linear elastic region, limited plasticity, and abrupt failure after approximately 62 seconds. Sample 2 recorded 20 MPa ultimate strength and 9 MPa yield strength. Sample 3, the most heavily damaged, attained only 9 MPa ultimate strength and 7 MPa yield strength. Sample 4 gave 15 MPa ultimate strength and 8 MPa yield strength. Elongation at break remained near 1.50 % for all specimens, confirming predominantly brittle failure after impact.

3.2 Comparison of Ultimate Tensile Strength of GFRP/Coir Samples

Residual ultimate tensile strengths ranked as Sample 1 (30 MPa) > Sample 2 (20 MPa) > Sample 4 (15 MPa) > Sample 3 (9 MPa). The spread is attributed to differences in local fibre packing, specimen thickness, and the severity of impact damage. All values lie well below the strengths expected for undamaged GFRP of similar construction, confirming substantial loss of load-bearing capacity.

Table 1: Ultimate and yield strengths of GFRP/coir samples after impact

Sample	Ultimate Tensile Strength (MPa)	Yield Strength (MPa)	Failure Time (s)
1	30	19	62
2	20	9	60
3	9	7	45
4	15	8	56

3.3 Charpy Impact Results

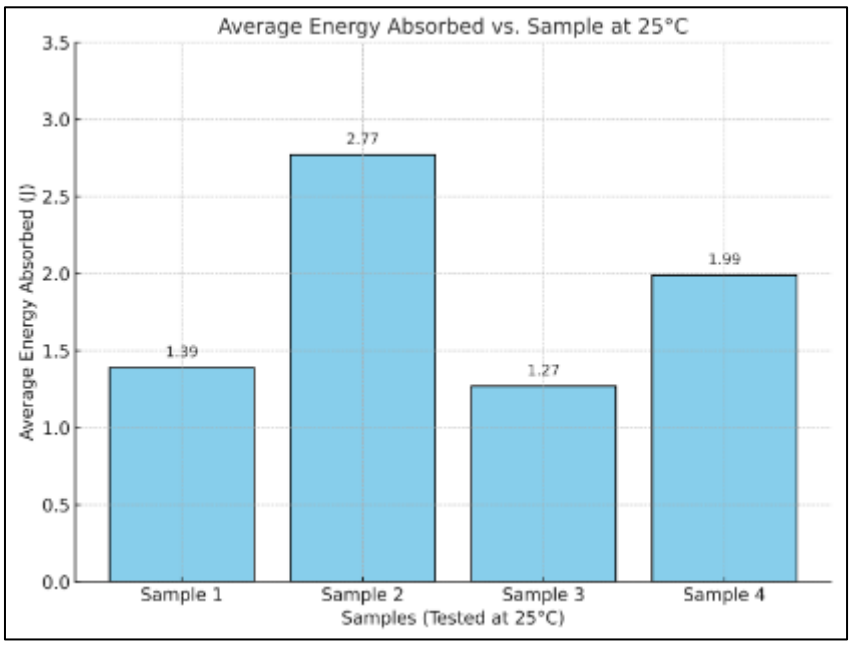


Figure 1: Average Charpy energy absorption of GFRP/coir samples at 25 °C

Charpy tests performed at 25 °C gave average energy absorption values of 1.39 J (Sample 1), 2.77 J (Sample 2), 1.27 J (Sample 3) and 1.99 J (Sample 4). Sample 2 absorbed the highest energy, consistent with better retention of toughness, while Sample 3 absorbed the least. The results indicate that coir contributes to energy dissipation through fibre pull-out and matrix cracking, yet absolute energy absorption remains modest once high-velocity damage has been introduced.

3.4 Microstructural Analysis

Only the 200× micrographs are presented here, as they provide clearer resolution of fibre fracture, matrix cracking and interfacial debonding. Post-impact sections of all four samples show extensive damage. Glass fibres are broken, coir strands are split or pulled out, and the epoxy matrix contains numerous microcracks and voids. Interfacial separation is widespread. The severity of these features correlates with the measured residual tensile strengths: Sample 3, which recorded the lowest strength, displays the most severe fibre breakage and matrix disruption, while Sample 1 retains comparatively better cohesion.

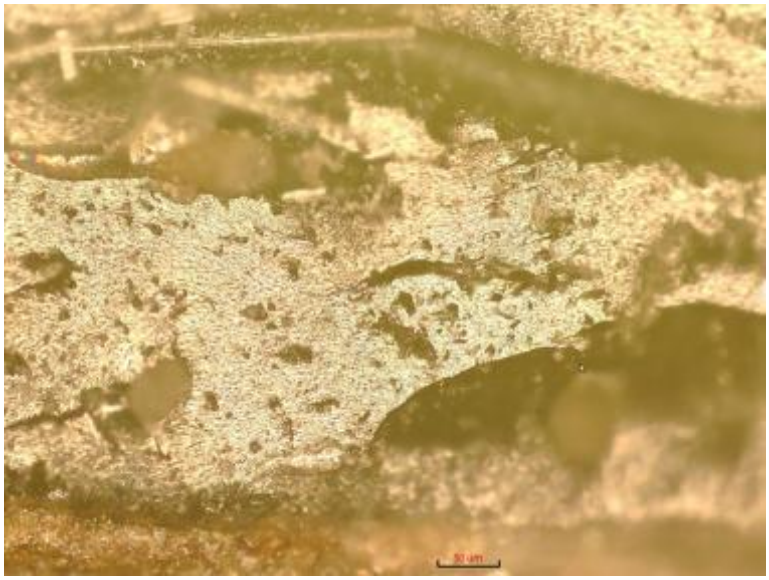


Figure 2: Sample 1 - post-impact micrograph at 200×

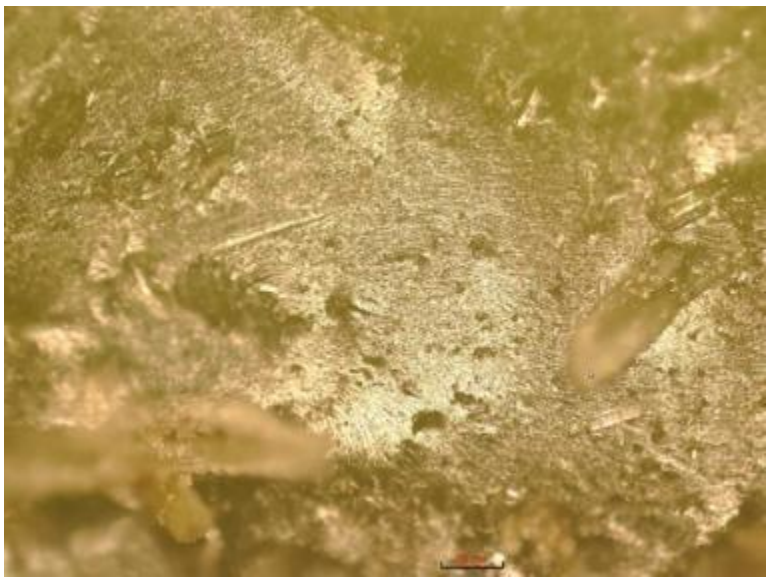


Figure 3: Sample 2 - post-impact micrograph at 200×

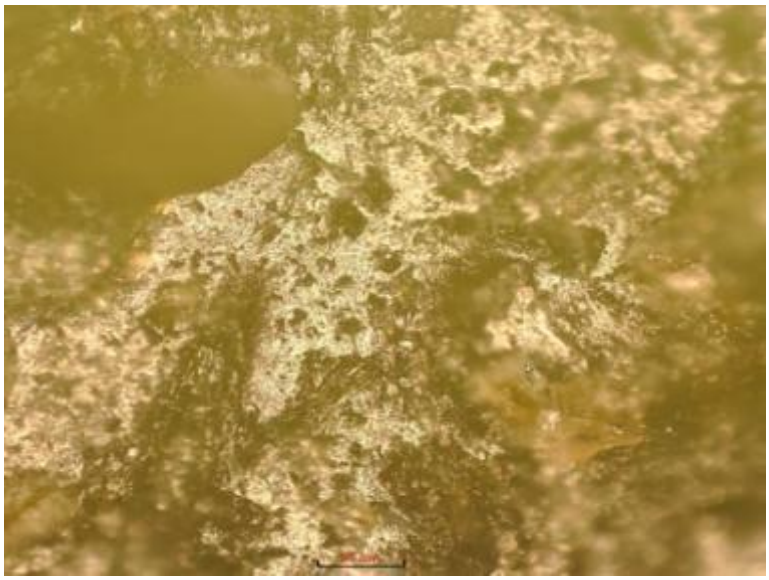


Figure 4: Sample 3 - post-impact micrograph at 200×

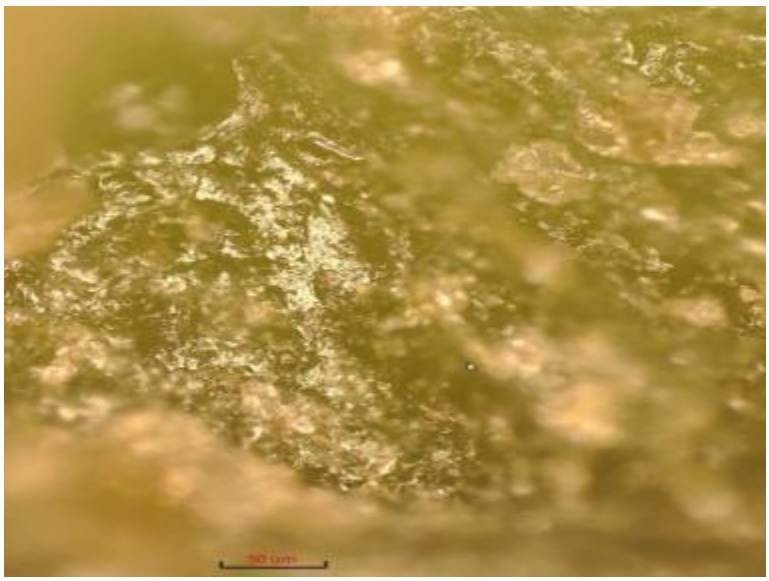


Figure 5: Sample 4 - post-impact micrograph at 200×

The 200× images confirm that the hybrid system experiences a clear trade-off. Coir can assist local energy absorption and crack bridging, yet the stiffness mismatch and weaker interfacial bonding relative to glass fibres promote extensive damage that lowers residual tensile strength.

4 CONCLUSION

The residual tensile behaviour of GFRP/coir rectangular laminates after high-velocity impact has been quantified. Ultimate tensile strengths ranged from 9 MPa to 30 MPa, demonstrating substantial degradation. Charpy energy absorption varied between 1.27 J and 2.77 J. Micrographs at 200× revealed matrix cracking, fibre fracture and interfacial debonding as the dominant damage modes. The hybrid offers improved sustainability and modest toughness gains, but residual tensile performance remains limited. Surface treatment of coir, optimisation of fibre volume fraction and improved matrix adhesion are required before the material can be considered for primary structural use.

Recommendations

Future work should examine alkali or silane treatment of coir, systematic variation of glass-to-coir ratios, and residual flexural strength after impact.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Acknowledgments

The authors appreciate the support of Engr. Dr. Orokor Allwell Chiyonu received during the experimental work.

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

Author Contribution

Ajie Goodluck Ifeanyi: conceptualisation, methodology, investigation, writing, original draft. Amafia Daerefa-a Mitsheal and Okachi Ikegwuru Ibezimakor: supervision, review and editing.

Statement of Ethical Approval

This study involved only laboratory fabrication and mechanical testing of composite laminates. No human participants or animal subjects were involved; therefore, ethical approval was not required.

Statement of Informed Consent

Not applicable. The research did not involve human participants.

REFERENCES

[1] Morampudi, P., Namala, K. K., Gajjela, Y. K., Barath, M., & Prudhvi, G. (2021). Review on glass fiber reinforced polymer composites. *ScienceDirect*.

[2] Naik, N. K., Shrirao, P., & Reddy, B. C. K. (2021). Ballistic impact behaviour of woven fabric composites: Parametric studies. *Materials Science and Engineering: A*, 412(1-2), 104–116.

[3] Sanjay, M. R., Siengchin, S., Parameswaranpillai, J., Jawaid, M., Pruncu, C. I., & Khan, A. (2018). A comprehensive review of techniques for natural fibers as reinforcement in composites: Preparation, processing and characterization. *Carbohydrate Polymers*, 207, 108–121.

[4] Jayabal, S., Natarajan, U., & Sekar, U. (2011). Mechanical properties of coir/glass fiber reinforced polyester hybrid composites. *Journal of Reinforced Plastics and Composites*, 30(12), 1053–1060.

[5] Hosur, M. V., Abdullah, M., & Jeelani, S. (2015). Studies on the low-velocity impact response of woven hybrid composites. *Composite Structures*, 67(3), 253–262.

[6] Caprino, G., Langella, A., & Lopresto, V. (2003). Impact damage and residual tensile strength of a glass fiber reinforced polymer composite. *Composites Part A: Applied Science and Manufacturing*, 34(8), 727–735.

[7] Harish, S., Michael, D. P., Bensely, A., Lal, D. M., & Rajadurai, A. (2009). Mechanical property evaluation of natural fiber coir composite. *Materials Characterization*, 60(1), 44–49.

[8] Madueke, C. I., Mbah, O. M., & Umunakwe, R. (2023). A review on the limitations of natural fibres and natural fibre composites with emphasis on tensile strength using coir as a case study. *Polymer Bulletin*, 80(4), 3489–3506.

[9] ASTM D638. Standard Test Method for Tensile Properties of Plastics.

[10] ASTM E23. Standard Test Methods for Notched Bar Impact Testing of Metallic Materials.

[11] ASTM E562. Standard Test Method for Determining Volume Fraction by Systematic Manual Point Count.