

# Experimental Analysis of Glass Fiber Composite on Low Velocity Impacts

Mahendra M.A.<sup>1,\*</sup>, Riya Singh<sup>2</sup>, Harsh Raj<sup>3</sup> and Pawandeep Singh<sup>4</sup>

## Abstract

*This research specifically deals with determining the retained tensile strength after loading Glass Fiber Reinforced Polymer (GFRP) composites following low-velocity impact. The purpose is to determine the degree to which these impacts affect the structural performance and mechanical integrity of GFRP materials. Experimental tests were conducted on glass fiber composite specimens in order to observe variation in tensile strength upon impact. The results indicated significant tensile strength reduction in impact samples compared to non-impact-exposed samples, which suggested a significant relationship between impact damage. Yet in real-world applications, such materials tend to experience unforeseen impacts, leading to hidden damage that is not apparent from the outside but can have appreciable effects on their structural behavior. Key findings revealed a progressive loss in tensile strength with increasing impact energy, with the highest degradation (over 52%) observed at 50J impact. unidirectional glass fiber composites (~33–57% reduction). Stress-strain behaviour analysis indicated that un-impacted samples possessed greater stiffness and ultimate tensile strength, whereas the impacted samples experienced nonlinear deformation and early failure. These findings underscore the importance of incorporating impact resistance considerations in the design and maintenance of composite structures. The study provides valuable insights for engineers and designers aiming to enhance the damage tolerance and safety of composite materials in critical applications. Future work may explore hybrid composites or modified resin systems to improve impact resistance further.*

**Keywords:** Hybrid Fiber, Residual tensile strength, Low-velocity impacts, Mechanical behavior, Glass Fiber Reinforced Polymer

## INTRODUCTION

Glass fiber-reinforced polymer (GFRP) composites are increasingly well-known in a wide range of engineering fields, including the aerospace, automotive, marine, and defense industries. They have appeal due to superior mechanical properties in a high strength-to-weight ratio, corrosion resistance, and durability over the long term, which is suitable for uses requiring performance along with light construction [1–5]. These benefits tend to make GFRPs superior options compared to traditional metals,

particularly in situations where design flexibility and efficiency are of paramount importance. All the same, GFRPs are highly susceptible to impact-induced damage that can compromise their structural performance and mechanical integrity. Thus, obtaining a realistic picture of their behavior under impact loading is crucial to improve their reliability and design in high-performance applications [6–7]. This work seeks to experimentally evaluate the behavior of glass fiber composites under low-velocity impacts. It investigates parameters like different impact energy levels, damage propagation mechanisms, and residual tensile strength post-impact

### \*Author for Correspondence

Mahendra M.A.

<sup>1</sup>Assistant Professor, Department of Aeronautical engineering, Nitte Meenakshi Institute of Technology (NMIT), Nitte (Deemed to be University), Bengaluru, Karnataka, India

<sup>2,3,4</sup>Student, Department of Aeronautical engineering, Nitte Meenakshi Institute of Technology (NMIT), Nitte (Deemed to be University), Bengaluru, Karnataka, India

Received Date: 21 May 2025

Accepted Date: 24 July 2025

Published Date: 17 January 2026

**Citation:** Mahendra M.A., Riya Singh, Harsh Raj and Pawandeep Singh. Experimental Analysis of Glass Fiber Composite on Low Velocity Impacts. Journal of Polymer & Composites. 2026; 14(Special Issue 1): S789–S796p.

incidents [4]. The results of this study can contribute to the advancement of composite material design, which can enhance damage detection methods. [8–10]

The primary objective of this project is to experimentally investigate the residual tensile strength of a hybrid composite laminate after being subjected to low velocity impact. The aim is to understand how impact energy affects the mechanical integrity of the material and quantify the extent of strength degradation. This investigation involves:

- Fabrication of hybrid composite specimens using different fiber configurations (e.g., glass-fiber).
- Subjecting the specimens to controlled low velocity impact at varying energy levels.
- Performing tensile tests post-impact to evaluate residual strength.
- Analyzing damage patterns and failure modes using visual inspection or non-destructive testing methods.
- Drawing conclusions about the material's impact tolerance and suitability for critical structural applications.

## METHODOLOGY

**Material Selection:** The composite has been reinforced using carbon and glass fibers based on their remarkable strength and pliability. The epoxy resin has been used as matrix material because of its strong adhesiveness and endurance to environmental effects [11]. This matrix-fiber hybrid achieves the maximum compromise among mechanical strength, low weight properties, and durability to environmental exposure [12–14]. Figure 1 shows unidirectional glass fibers cut into 300 x 300 mm. The specific geometric specifications and physical dimensions for the test specimens used in this study are detailed in Table 1.



**Figure 1.** Unidirectional glass fiber

**Specimen Preparation:** Specimens are prepared as per ASTM D3039 standards. Fiber orientations and stacking sequences optimized for testing.[15] The below table 1 represents the dimension. 30\*30 mm. This section details the experimental procedure used to assess the residual tensile strength of unidirectional glass fibers following low-velocity impact. The process begins with cutting and preparing the fiber materials, followed by weighing and mixing a resin system in a 90:10 ratio of epoxy to hardener. The fibers are layered with resin, maintaining proper alignment, and topped with a polymer separator and breather fabric. The assembled layers are then vacuum bagged and cured for a minimum of six hours. Once cured, the composite is trimmed into specific sample sizes for testing. These samples undergo impact and tensile tests to evaluate their damage tolerance and residual strength, allowing for a comparative analysis of the mechanical and thermal performance of glass fiber.

**Table 1.** Representation of the dimensions

Dimension	Size
Tape Size	5 cm each
Sample size	150 mm
thickness	0.8 mm
width	15 mm
Total Length	250 mm

The material preparation can be briefly observed in the below figure 2,3,4,5,6. Dimensions- tape size = 5 cm each, Sample size = 150 mm, thickness = 0.8 mm, width = 15 mm, total length = 250.



**Figure 2.** Unidirectional glass fiber



**Figure 3.** Resin & Hardener



**Figure 4.** Layering



**Figure 5.** Vacuum bag



**Figure 6.** Sample Cutting

**Experimental Setup:** Impact Testing- Drop-weight impact tester used for low-velocity impacts. Impact energy levels: 20J,40J. A drop-weight impact tester was used for low-velocity impacts at energy levels of 20J and 40J. A Universal Testing Machine (UTM) was used for the test of residual tensile strength. The physical condition of the specimens immediately following the impact event is captured in Figure 7, showing the localized damage areas.

**Tensile Testing:** A Universal Testing Machine (UTM) is used for the test of the residual tensile strength of specimens retained. Before testing, the specimens are pre-conditioned and impacted at low velocity to examine their damage resistance and energy absorption performance. After this, similar samples are tested under tensile to find out their residual strength. This methodical procedure is [16–20] used to evaluate the post-impact tensile performance of glass fiber-reinforced composites.

The results thus obtained allow for a comparative assessment of the materials, specifically highlighting differences in their mechanical strength and thermal resistance.[21]

## CALCULATION

This section outlines the mathematical formulas and measurement techniques used to derive the impact energy parameters, specimen area, and the subsequent tensile stress levels following experimental testing.

From the equation of Potential Energy ( $m \times g \times h = 20J$ ), where the drop height (**h**) was determined to be 0.3m. The cross-sectional area was calculated as 12 mm<sup>2</sup> based on a width of 15mm and thickness of 0.8mm. The results of stress and percentage reduction in stress after impact for all test conditions are summarized in table 2 and table 3.

*Experimental Setup:* Sample with impact of 20J, 40J .

From the eq<sup>n</sup> of P.E,  $m \times g \times h = 20J, h = 20 \div \{ 6.7 \times 9.81 \} = 0.3m$

where, m = mass of Impact, g = Acceleration due to gravity, h = Drop height

Area= w\*d =15\* 0.8 =12 mm<sup>2</sup>

Where, t= thickness, W= width, d=depth

**Table 2.** Calculated Tensile Stress and Percentage Reduction for Impacted and Non-Impacted samples subjected to 20J of impact

Tensile Stress value of sample without impact:	Stress = Load (KN)/ Area(mm <sup>2</sup> ) = (4.3*10 <sup>3</sup> ) /12 = 358.33N/mm <sup>2</sup>
Tensile Stress value of sample with impact Sample 1:	Stress=Load (KN)/ Area(mm <sup>2</sup> ) = (2.88*10 <sup>3</sup> ) /12 = 240N/mm <sup>2</sup>
Tensile Stress value of sample with impact Sample 2:	Stress = Load (KN)/ Area(mm <sup>2</sup> ) = (2.84*10 <sup>3</sup> ) /12 = 236.67N/mm <sup>2</sup>
% Reduction of tensile stress (residual stress) Sample 1:	= (358.33-240) /358.33 = 33.02%
% Reduction of tensile stress (residual stress) Sample 2:	= (358.33-236.67) /358.33 = 33.95%

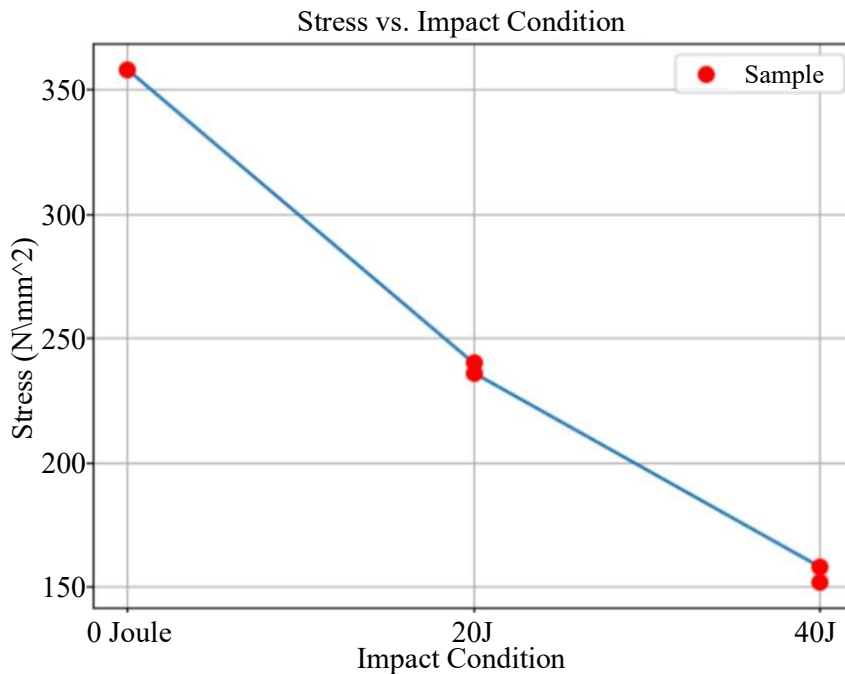
**Table 3.** Calculated Tensile Stress and Percentage Reduction for Impacted and Non-Impacted samples subjected to 40J of impact:

Tensile Stress value of sample without impact:	Stress = Load (KN)/ Area (mm <sup>2</sup> ) = (4.3*10 <sup>3</sup> ) /12 = 358.33N/mm <sup>2</sup>
Tensile Stress value of sample with impact Sample 1:	Stress=Load (KN)/ Area (mm <sup>2</sup> ) = (1.827*10 <sup>3</sup> ) /12 = 152.3N/mm <sup>2</sup>
Tensile Stress value of sample with impact Sample 2:	Stress = Load (KN)/ Area (mm <sup>2</sup> ) = (1.904*10 <sup>3</sup> ) /12 = 158.7N/mm <sup>2</sup>
% Reduction of tensile stress (residual stress) Sample 1:	= (358.33-152.3) /358.33 = 57.49%
% Reduction of tensile stress (residual stress) Sample 2:	= (358.33-158.7) /358.33 = 55.71%

**RESULTS AND DISCUSSION**

This graph illustrates the stress (measured in N/mm<sup>2</sup>) vs strain varying impact conditions. It compares stress vs strain levels under three conditions: with or without impact, impact of 20J, 40J. The trend observed is a consistent decrease in strength as the impact energy increases [22–25].

The following analysis evaluates the correlation between specific impact energy levels and the resulting degradation of the material's mechanical properties and structural integrity. **Figure 8** illustrates stress vs. strain behavior under varying impact conditions (0J, 20J, and 40J), showing a consistent decrease in strength as impact energy increases. At 0J, the sample exhibits the highest residual strength (355 N/mm<sup>2</sup>), whereas at 40J, the strength declines to 160 N/mm<sup>2</sup>.



**Figure 8.** Comparison of stress level under impact, without impact

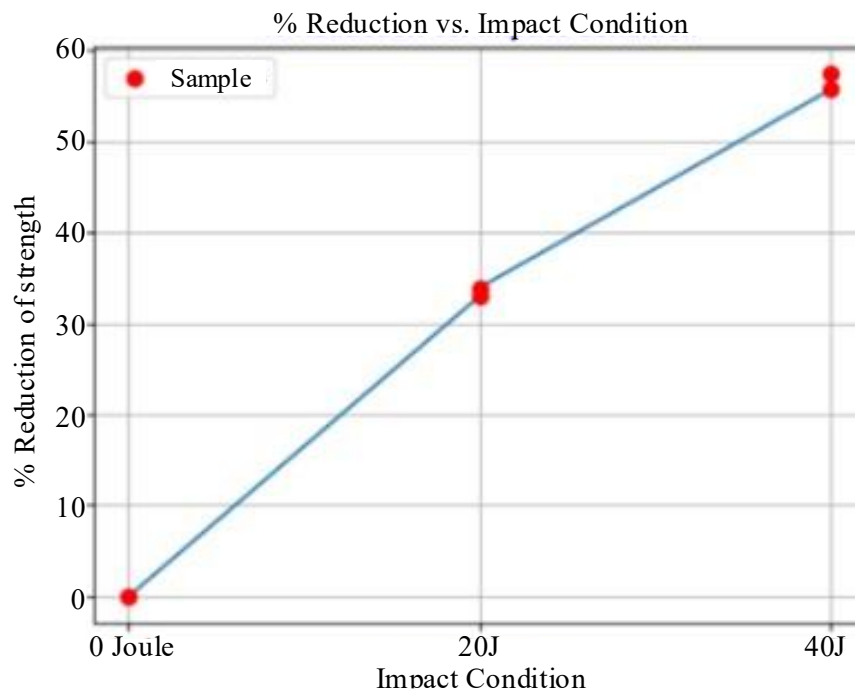
This graph illustrates how the residual tensile strength of the hybrid composite (made of unidirectional glass fibers) declines with increasing impact energy:

- At **0 Joule**, the sample exhibits the highest residual strength (355 N/mm<sup>2</sup>), representing undamaged or pristine material.
- At **20J**, there is a noticeable drop to approximately **240 N/mm<sup>2</sup>**, indicating moderate internal damage.
- At **40J**, the strength further declines to **~160 N/mm<sup>2</sup>**, showing severe structural degradation.
- **Reason for Strength Reduction**
- The steep drop in residual strength at higher impact energies (especially 40J) can be attributed to:
  - **Matrix Cracking:** High impact loads induce micro cracks within the resin matrix, weakening the bonding between fibers.
  - **Delamination:** The layered structure of hybrid composites is prone to separation between plies under impact. This inter laminar failure reduces the ability of the laminate to carry loads.
  - **Fiber Breakage:** At higher energy, both glass and carbon fibers may undergo fracture, leading to significant stiffness and strength loss.
  - **Interfacial De-bonding:** The mismatch in mechanical properties between glass and carbon fibers can lead to stress concentrations, causing fiber-matrix separation.

These mechanisms cumulatively degrade the load-bearing capacity, leading to the observed trend.

As quantitatively depicted in Figure 9, the percentage of strength lost increases dramatically with increasing impact energy. At 20J, the reduction is approximately 33%, while at 40J, it reaches

approximately 56–58%. This reduction is attributed to matrix cracking, delamination, and fiber breakage, which reduce the load-bearing capacity. These findings highlight that non-destructive inspection methods are vital for detecting internal damage.



**Figure 9.** Percentage reduction of strength varying impact condition

This graph quantitatively depicts the percentage of strength lost due to increasing impact energy:

- **0J:** 0% reduction (baseline).
- **20J:** ~33% reduction.
- **40J:** ~56–58% reduction in tensile strength.

The linearity in reduction percentage reflects consistent damage progression with increasing energy input. These graphs clearly show that **hybrid composites are sensitive to low-velocity impacts**, especially as energy increases beyond 20J. The dominant damage mechanisms — **matrix cracking, delamination, fiber breakage, and interfacial debonding** — reduce load transmission efficiency across the laminate.

For real-world applications, these findings:

- Stress the importance of **impact protection mechanisms** in structural design.
- Highlight that **non-destructive inspection methods** are vital for detecting internal damage that may not be visible externally.

## CONCLUSION

This research examines the effect of different impact severity levels for the tensile strength of GFRP. It provides a systematic method for assessment of the performance of these materials following exposure to low-velocity impacts. The experimental results clearly showed that: Tensile strength decreases significantly as the impact energy increases—from 20J to 50J. Glass fiber composites exhibited up to 57.5% strength degradation at 40J, with a maximum 52.1% loss at 50J. This study demonstrates the residual tensile strength of Glass fiber composites after low-velocity impact. The samples demonstrated the highest stress values, reflecting the intact internal structure. With increasing

impact energy (from 20J to 50J), the composites showed evident signs of damage (e.g., matrix cracking, fiber breakage), reducing their load-bearing capacity significantly. At 50J, more than 50% reduction in tensile strength was recorded, indicating the critical threshold beyond which structural integrity becomes compromised. GFRP composites lose up to 57% tensile strength at 40J impact—this finding suggests a need for conservative design margins or real-time impact monitoring in structural applications. The **progressive increase in strength reduction** is typical for fiber-reinforced composites under low-velocity impact, as reported in studies by Zhang *et al.* (2021) and Alam *et al.* (2019). Similar patterns were observed in hybrid laminates, where **glass fibers offer impact resistance**. However, **post-impact tensile strength primarily depends on the integrity of the fiber-matrix interface**, which becomes severely compromised beyond 20J. Prior studies also noted that **residual strength loss of over 50% indicates structural damage that could be critical in aerospace applications**, which aligns with 40J result.

#### ACKNOWLEDGMENTS

My sincere gratitude is due towards Management of my institution, **Nitte Meenakshi Institute of Technology, Bangalore**. I am grateful of all the teaching and non-teaching staff of the **Department of Aeronautical Engineering, NMIT, Bangalore**, for providing me support and required facilities.

#### REFERENCES

1. Velmurugan G, Natrayan L. Experimental investigations of moisture diffusion and mechanical properties of interply rearrangement of glass/Kevlar-based hybrid composites under cryogenic environment. **J Mater Res Technol.** 2023 Mar–Apr;22:4513–26.
2. Zhang Y, Chai H, Liu X, Wang Y, Guo L. Temperature and humidity effects on impact damage in hybrid composites. **Constr Build Mater.** 2021 May 17;284:122786.
3. Syed Abdullah SIB, Iannucci L, Greenhalgh ES, Ahmad Z. The impact performance of Vectran/epoxy composite laminates with a novel non-crimp fabric architecture. **Compos Struct.** 2021 Jun 1;265:113784.
4. Katunin A, Danek W, Wronkiewicz A, Dragan K. Methodology of residual strength prediction of composite structures with low-velocity impact damage based on NDT inspections and numerical-experimental CAI testing. **Int J Impact Eng.** 2023 Nov;181:104762.
5. Salahshoor M, Guo YB. Finite element simulation and experimental validation of residual stresses in high-speed dry milling of biodegradable Mg–Ca alloys. **Int J Mech Sci.** 2014 Mar;80:181–91. doi:10.1016/j.ijmecsci.2014.01.010.
6. Gunoz A, Kur M, Kara M. Impact response of hybrid composites under varying environmental conditions: a comparative study. **Polym Compos.** 2024 Jun;45(13):1117–28. doi:10.1002/pc.28650.
7. Velmurugan G, Natrayan L. Experimental investigations of moisture diffusion and mechanical properties of interply rearrangement of glass/Kevlar-based hybrid composites under cryogenic environment. **J Mater Res Technol.** 2023 Mar–Apr;23:4513–26.
8. Damghani M, Atkinson GA, Thapa P, Joy J, Monaghan M, Maleki P, Ward C. An experimental investigation of tensile residual strength of repaired composite laminates after low-velocity impact. **Thin-Walled Struct.** 2024 Jul;200:111896.
9. Vescovini A, Cruz J, Ma D, Colombo C. Experimental investigation on low-velocity impact behavior of glass, Kevlar, and hybrid composites with an elastomeric polyurethane matrix. **Compos Part C Open Access.** 2023 Dec;13(3):100426. doi:10.1016/j.jcomc.2023.100426.
10. Karakuzu R, Algan B, Deniz ME. Effects of specimen dimensions and impact energy on energy absorption and damage of glass/epoxy composite plates. **Mater Test.** 2019 Mar;61(3):231–8. doi:10.3139/120.111309.
11. Yalkın HE, Karakuzu R, Alpyıldız T. Experimental and numerical behaviors of GFRP laminates under low-velocity impact. **J Compos Mater.** 2020;54(21):2855–68. doi:10.1177/0021998320906871.
12. Papa I, Boccarusso L, Langella A, Lopresto V. Carbon/glass hybrid composite laminates in vinylester resin: bending and low-velocity impact tests. **Compos Struct.** 2020 Jan 15;232:111571.

13. Da Silva AA, Scazzosi R, Manes A, Amico SC. High-velocity impact behavior of aramid/S2-glass interply hybrid laminates. **Appl Compos Mater.** 2021 Dec;28(6):1057–71. doi:10.1007/s10443-021-09946-3.
14. Rezasefat M, Gonzalez-Jimenez A, Ma D, Vescovini A. Experimental study on the low-velocity impact response of inter-ply S2-glass/aramid woven fabric hybrid laminates. **Thin-Walled Struct.** 2022 Aug;177:109458. doi:10.1016/j.tws.2022.109458.
15. Cruz J, Kerche EF, Bianchi O, Manes A. Castor oil-based polyurethane/S2 glass/aramid hybrid composites manufactured by vacuum infusion. **Polymers.** 2022 Nov;14(23):5150. doi:10.3390/polym14235150.
16. Nicholas J, Mohamed M, Dhaliwal GS, Anandan S, Chandrashekhara K. Effects of accelerated environmental aging on glass fiber reinforced thermoset polyurethane composites. **Compos Part B Eng.** 2016 Jun 1;94:370–8.
17. Kabir RB, Ferdous N. Kevlar – the super tough fiber. **Int J Textile Sci.** 2012;1(6):78–83. doi:10.5923/j.textile.20120106.04.
18. Heydari Astarace A, Salerno A, Bagherifard S, Carlone P. Thermographic analysis of composite metallization through cold spray. **Metals.** 2021 Nov;11(11):1860. doi:10.3390/met11111860.
19. Olsson R. Analytical prediction of large mass impact damage in composite laminates. **Compos Part A Appl Sci Manuf.** 2001 Sep;32(9):1207–15.
20. Bandaru AK, Patel S, Ahmad S, Bhatnagar N. An experimental and numerical investigation on the low-velocity impact response of thermoplastic hybrid composites. **J Compos Mater.** 2018;52(7):931–46. doi:10.1177/0021998317714043.
21. Salvetti M, Gilioli A, Sbarufatti C, Manes A, Giglio M. Analytical model of the dynamic behaviour of CFRP plates subjected to low-velocity impacts. **Compos Part B Eng.** 2018 Jun 1;142:47–55.
22. Wagih A, Sebaey TA, Yudhanto A, Lubineau G. Post-impact flexural behavior of carbon-aramid/epoxy hybrid composites. **Compos Struct.** 2020 May 1;239:112022.
23. Termaath S, Ingling B, Noland J, Hart D. Evaluation of low-velocity impact damage in metal/composite layered structure. In: Frangopol DM, editor. **Life-Cycle of Structures and Infrastructure Systems.** London: CRC Press; 2023. p. 3316–23. doi:10.1201/9781003323020-405.
24. Bruno M, Carrino L, Donadio F, Esposito L. Damage analysis of hybrid composites under multi-impact loads: an experimental and numerical study. **Key Eng Mater.** 2022 Jul;926:1939–48. doi:10.4028/p-51evn4.
25. ASTM International. ASTM D7136/D7136M-15: Standard test method for measuring the damage resistance of a fiber-reinforced polymer matrix composite to a drop-weight impact event. West Conshohocken (PA): ASTM International; 2015.