

# Performance Analysis of GLARE Composites in Aerospace Engineering

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## Abstract

*The fuel consumption of an aircraft is largely governed by its payload, which emphasizes the continuous demand for advanced lightweight structural materials to enhance the lift-to-weight ratio and improve overall fuel efficiency. Fiber Metal Laminates (FMLs) have emerged as a novel class of hybrid materials that combine alternating layers of thin metals with fiber-reinforced polymer composites, thereby offering mechanical properties superior to those of the individual constituents. Among the different varieties of FMLs, Glass Laminate Aluminum Reinforced Epoxy (GLARE) has been widely adopted in aerospace applications, particularly in fuselage and wing structures, due to its ability to significantly reduce weight while simultaneously improving fatigue resistance, impact strength, and damage tolerance. The present study aims to investigate the mechanical characteristics of hybrid composites fabricated using epoxy resin, bi-directional E-glass fibers, and aluminum alloy with different lamination sequences. To evaluate the performance of these GLARE composites, tensile and flexural tests were conducted under controlled laboratory conditions using a Hydraulic Universal Testing Machine in accordance with standardized guidelines. The experimental investigation focuses on understanding the influence of varying lay-up sequences on the overall strength and stiffness of the composite. The outcomes of this study are expected to provide valuable insights into the optimization of GLARE laminates for aerospace structural applications where weight reduction and superior mechanical performance are critical.*

**Keywords:** Glass, Aluminum, GLARE, Sandwich, Laminate.

## INTRODUCTION

Since its inception, the aerospace industry and aviation have both placed a significant emphasis on the study and development of a wide range of different kinds of materials. There is not a single

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material that has been created by man that is perfect or without flaws, but as inventive technology advances, newer materials will become available that are safer and more stable for use in structural applications. The most recent development in materials, such as FMLs, will make it possible to employ laminates that mix aluminum and glass or epoxy composites [1]. Aircraft manufacturers from all around the globe are now testing the performance of various materials in order to determine how well they can reduce the weight of their products. GLARE laminate, which is a sandwich material assembled from alternating layers of aluminum and E- Glass fiber material with the bond layer, is the most important method among the materials that are now being evaluated

for use in major and minor aircraft structural components. The literature indicates that the material utilizes aluminum panel sheets characterized by high stiffness, high strength, elevated yield properties, enhanced resistance to thermal transmission, and a low-density structure [1]. Additionally, it benefits from the rupture resistance provided by glass fiber. GLARE exhibits excellent resistance to impacts, effectively slows the progression of cracks due to its glass layers, and maintains its strength even after sustaining damage, which renders it significantly more damage-tolerant than metals, also demonstrates enhanced fatigue properties, ease of use, and machinability, making it straightforward to work. But The GLARE material not only exhibits excellent adhesion with fiber epoxy and superior curing characteristics [2]. Common problems encompass delamination, moisture absorption, intricate manufacturing processes, and challenging repairs. Failure mechanisms consist of fiber breakage, matrix cracking, and interface debonding so Needs include better fiber-metal bonding, new materials, smart damage detection, improved modeling, and understanding long-term durability.

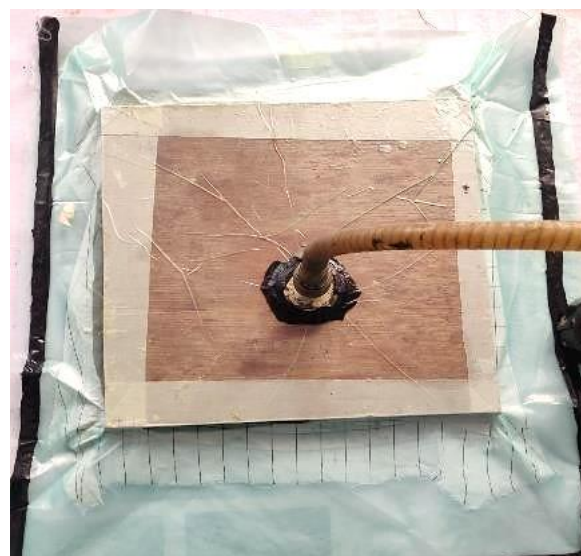
### EXPERIMENTAL PROCEDURE

The hand layup method was used to make the GLARE composite. Each composite layer was hand-layered, and any excess resin was removed with a roller. The aluminium alloy 6061, with a thickness of 0.1 mm, was cut into 300 x 300 mm sheets. The prepreg layer consisted of e-glass fiber and epoxy (Araldite, Hardener). Sandpaper of 80 grit size was used to raise the surface roughness value of the aluminium sheet, which was then washed with acetone to eliminate any foreign particles. Raising the surface roughness value promotes a stronger connection between the laminates [3]. The epoxy and hardener were mixed in a 10:1 ratio to improve molecular bonding inside the epoxy. The orientation of fibers has an impact on strength and stiffness in particular directions, whereas the stacking sequence affects the overall mechanical performance. An appropriate configuration improves load-bearing capacity, fatigue resistance, and impact resistance.

Next an epoxy was spread all over the aluminum sheet to make preprag layer, then placing glass fiber on top of the epoxy, followed by another epoxy layer to end the layering process. The roller was used to remove the excess resin before applying farther coat. Composite material was prepared as shown in Figures 1 and 2, and this was cured for about 24 hours using a vacuum bagging process [4]. The layup series has two separate configurations: 3/4 and 5/4 layup sequences. The 3/4 layup is made up of three layers of aluminum and four layers of glass fiber, organized as Al/G/G/Al/G/G/Al. The 5/4 layup is made up of five layers of aluminum and four layers of glass fiber, ordered in the order Al/G/Al/G/Al/G/Al/G/Al.



**Figure 1.** Hand lay-up process



**Figure 2.** Vacuum bagging process

## MECHANICAL TESTING

### Tensile Testing

The tensile characteristics of the produced GLARE composite were assessed utilizing a Universal Testing Machine (UTM). The evaluation focused on determining the ultimate tensile strength and tensile modulus in accordance with ASTM standard D3039 as shown in Figures 3 and 4. The specimens measured 250mm in length and 25.4 mm in breadth in both layup configurations [5].

### Flexural Testing

To examine the specimen's flexural properties, a three-point bending test was performed in line with ASTM Standard D790 as shown in Figures 5 and 6 [6]. The specimen's thickness after production measured 3.91mm and 5.1mm, provided necessary support of span lengths 59.2mm for the 3/4 layup and 68.8mm for the 5/4 layup. Additionally, the specimen widths were specified as 16.4 mm for the 3/4 layup and 20 mm for the 5/4 layup, corresponding to one-fourth of the support span length.

The impact test measures the energy absorbed during fracture of the sampled material.

ASTM Standard (D7137 M-12). The test specimen's dimensions are 150mm in length, 100mm in breadth, and 4.5mm in thickness mentioned in Figures 7 and 8.

## RESULTS AND DISCUSSIONS

### Flexural Test

Figures 9 and 10 illustrating Stress (MPa) versus Strain% has been presented below. From Table 1 The average flexural strength for the 3/4 specimen is recorded at 94.52 MPa, while the 5/4 specimen exhibits an average flexural strength of 100.48 MPa. The flexural strain for the 3/4 specimen varies between 5% and 5.5%, whereas the flexural strain for the 5/4 specimen ranges from 2% to 3.5%. Notably, the flexural strength of the 5/4 configuration surpasses that of the 3/4 lay-up sequence, although the strain percentage for the 3/4 specimen is greater than that of the 5/4 specimen. Additionally, the average flexural modulus for the 5/4 specimen is 19.66 GPA, compared to 22.39 GPA for the 3/4 specimen.



**Figure 3.** Tensile Test



**Figure 4.** Tensile testing using UTM machine



**Figure 5.** Flexural testing machine



**Figure 6.** Specimen after testing



**Figure 7.** Impact test machine



**Figure 8.** Specimens after testing

The flexural modulus of 3/4 is higher than the 5/4 GLARE lay-up sequence. It is inversely proportional to deflection [7]. The flexural strength is more in 5/4 when compared to the 3/4 GLARE lay-up sequence. 3/4 can take more strain% when compared to 5/4 GLARE lay-up sequence.

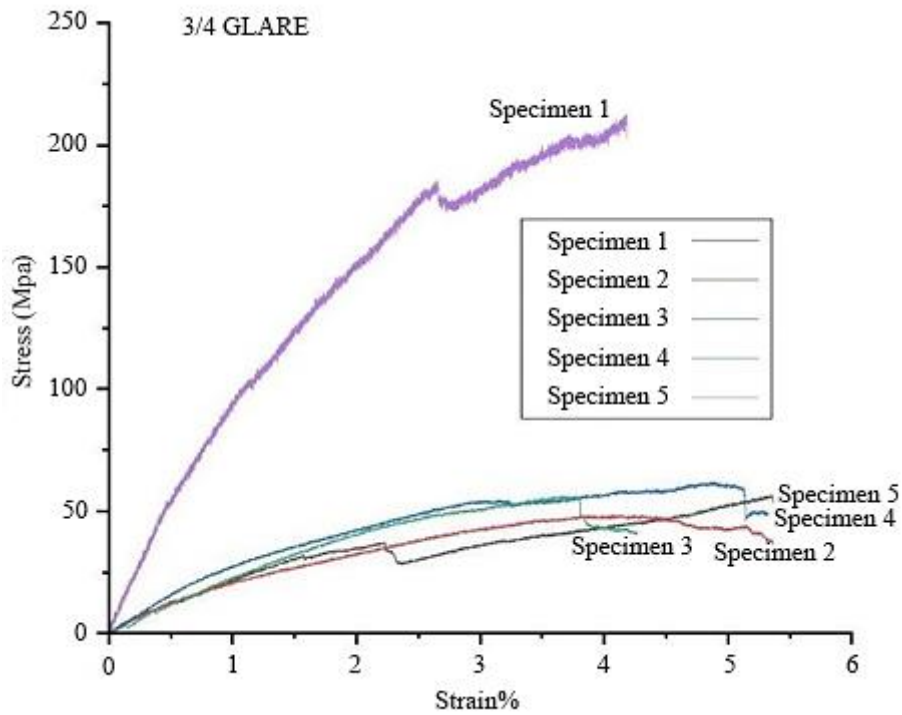


Figure 9. 3/4 GLARE Stress Vs Strain graph

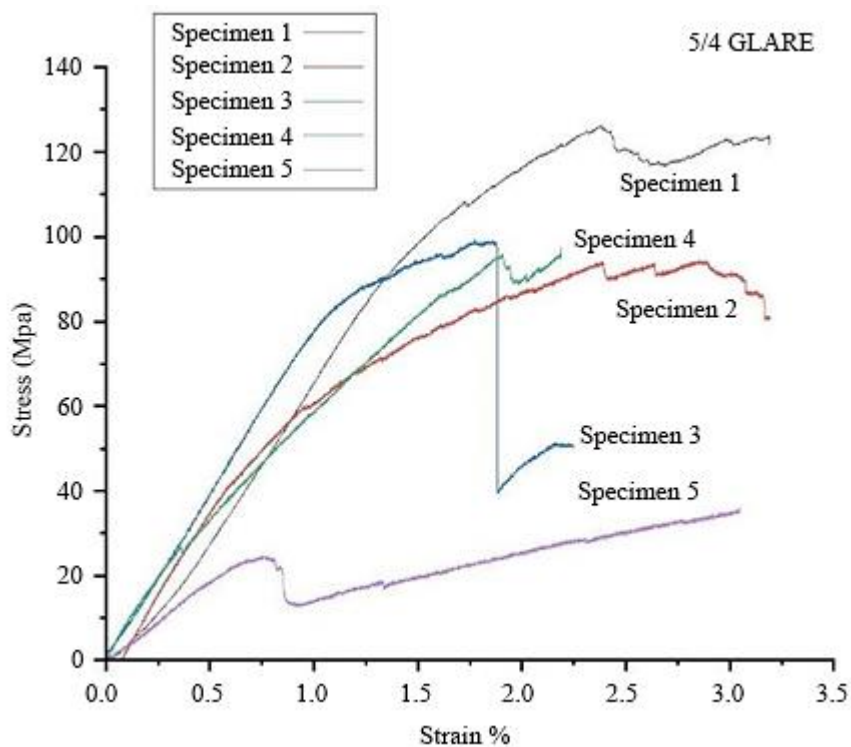


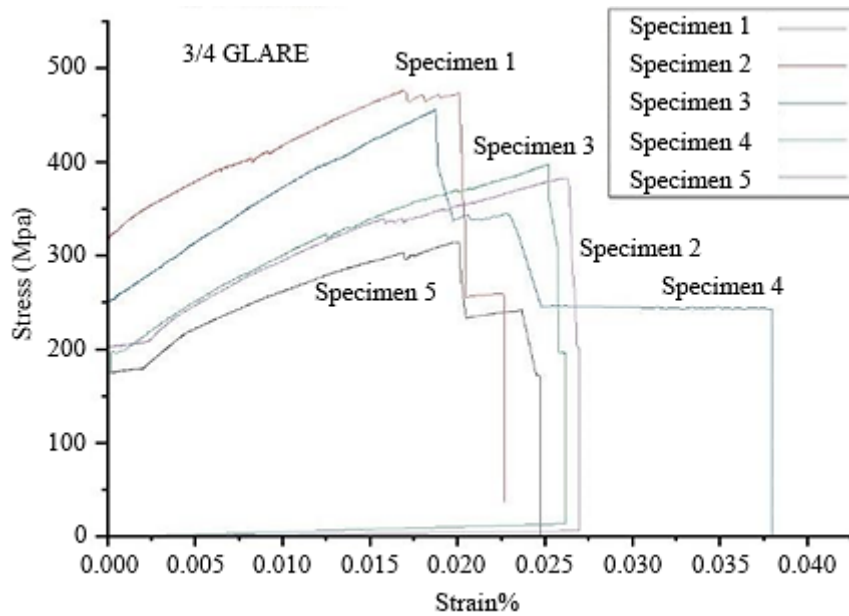
Figure 10. 5/4 GLARE Stress Vs Strain graph

Table 1. Flexural test results

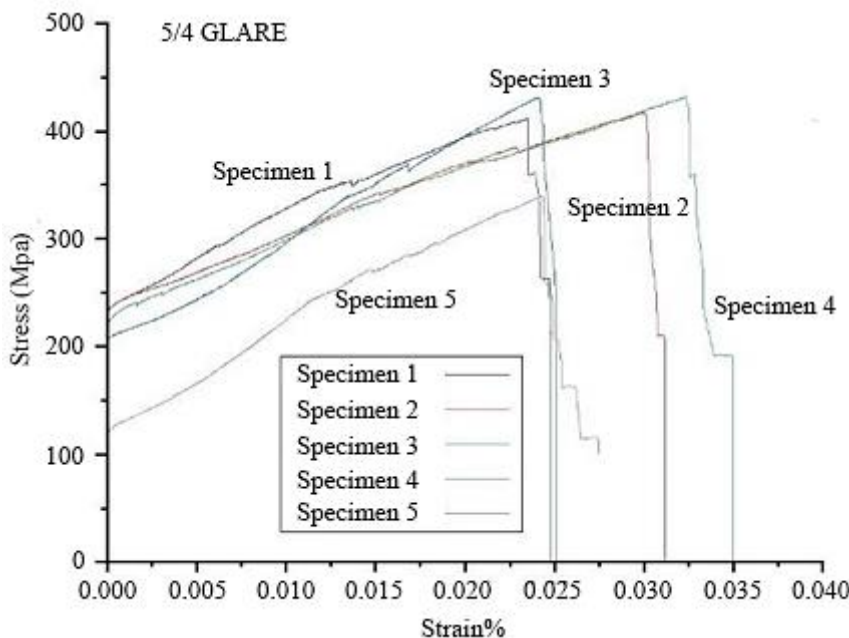
Specimen	Average flexural peak stress (MPa)
3/4 Specimen	94.52
5/4 Specimen	100.48

**Tensile Test**

The below two graphs Figures 11 and 12 shown stress Vs strain for GLARE 3/4 and 5/4. The ultimate tensile stress of 5/4 is more than 3/4. Table 2 shows that 5/4 has more stress compared to 3/4. The failure strain% for 5/4 ranges from 0.025-0.035% and for 3/4 it ranges from 0.020-0.037%. The average young’s modulus for 3/4 is 18 GPA and for 5/4 is 21 GPA. The GLARE 5/4 has 4% more Young’s modulus compared to 3/4.



**Figure 11.** 3/4 GLARE Stress Vs Strain graph.



**Figure 12.** 5/4 GLARE Stress Vs Strain graph

**Table 2.** Tensile test results.

Specimen	Average tensile strength (MPa)
3/4 Specimen	412
5/4 Specimen	450.2

The data suggests that GLARE 5/4 has excellent mechanical characteristics. Under tensile stress, several damage processes emerge, including plastic deformation of the outer aluminum layer and delamination between the prepreg layer and the aluminum sheet [8]. The specimen's premature failure is ultimately attributed to delamination caused by inadequate bonding between the glass fiber and the aluminum sheet composite with Epoxy. FML failure mechanisms included a brittle fracture caused by fiber fracture [9].

### Impact Test

A drop impact test was performed to assess the energy absorbed or necessary to fracture the item under test, the test results are shown in Figures 13 and 14 [10]. From Table 3, we can see that absorbed energy is more for 5/4 GLARE lay-up sequence at 1m falling height compared to 3/4 and absorbed energy is more for 3/4 at 0.5m falling height compared to 5/4.

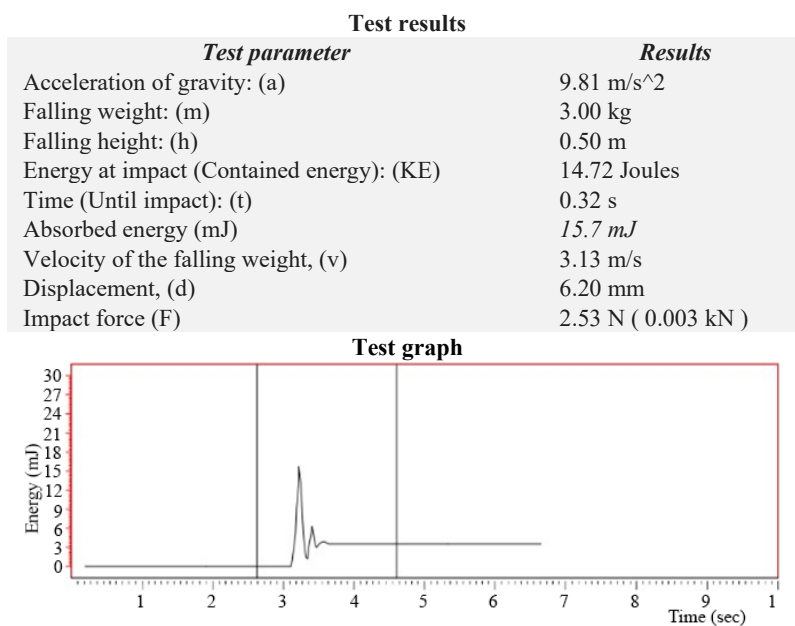


Figure 13. 3/4 Impact test results and test graph.

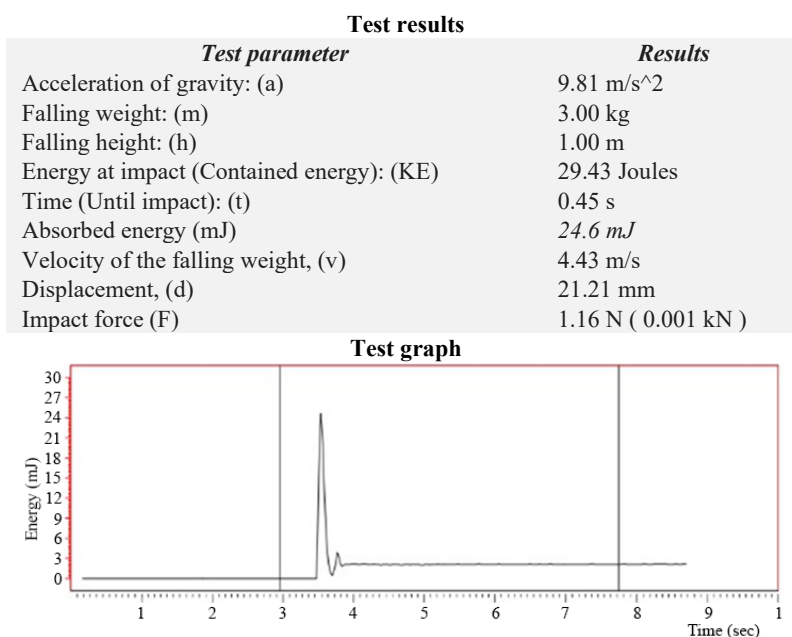


Figure 14. 3/4 impact test results and test graph

**Table 3.** Impact test results

Impact test data				
Specimen	Absorbed energy (mJ)	Displacement (d) (mm)	Impact Force (N)	Impact Force (kN)
<i>3/4 (0.5 m falling height)</i>				
Specimen 1	15.7	6.20	2.53	0.003
Specimen 2	12.5	7.57	1.65	0.002
Specimen 3	11.7	7.08	1.65	0.002
Average	13.3	6.95	1.94	0.0023
<i>3/4 (1 m falling height)</i>				
Specimen 1	22.7	17.14	1.28	0.001
Specimen 2	22.8	10.91	2.09	0.002
Specimen 3	19.8	9.21	2.17	0.002
Average	21.7	12.43	1.84	0.0016
<i>5/4 (1m falling height)</i>				
Specimen 1	24.6	21.21	1.61	0.001
Specimen 2	23.8	16.93	1.41	0.001
Specimen 3	20.5	24.31	0.84	0.001
Average	23	20.81	1.28	0.001
<i>5/4 (0.5m falling height)</i>				
Specimen 1	12.1	6.94	1.74	0.002
Specimen 2	11.4	9.82	1.16	0.001
Specimen 3	11.9	17.19	0.69	0.001
Average	11.8	11.31	1.19	0.0013

## CONCLUSION

In this experiment, we developed GLARE composites with few hands' layup sequences and investigated their mechanical properties. Compared to GLARE 3/4 the GLARE 5/4 has a greater tensile strength, Young's modulus, and failure strain. When compared to the GLARE 3/4 layup sequence, the results show that the tensile property of the material generated with the GLARE 5/4 layup sequence is superior. When compared to GLARE 3/4, GLARE 5/4 has a 20% higher flexural strength. In addition, GLARE 3/4 has a 13.18% higher flexural modulus than GLARE 5/4. The findings from the drop weight impact test indicate that the absorbed energy is higher for the 5/4 GLARE lay-up sequence at a height of 1 meter when compared to the 3/4 configuration. Conversely, at a falling height of 0.5 meters, the absorbed energy is greater for the 3/4 lay-up than for the 5/4 GLARE.

The bonding improves between the aluminum and the prepreg layer with increasing the surface roughness. Over the last few years, significant progress has been made in understanding the behavior of fiber metal laminates, namely glare. The skin material that will be used in the fuselage parts of the Airbus A380 will be made out of this material. Despite this, there is still a very difficult duty that has to be completed. In order to fulfill the demanding criteria established by customers, airworthiness authorities, and Airbus quality standards, all of the information that is now accessible as well as the results of any research that has been conducted must be converted into quality standards and processes, design, and sizing methodologies. As a result, significant efforts are being put out to transform Glare from an idea into a genuine innovation that can be used in the aerospace sector.

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