Analysis of Glass Fibre Composite Laminate For Improved Flexural And Compression Strenghts

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Abstract- *Composite material constitutes variety of compositions having different properties prepared by two or more substance. Compression and Flexural test was conducted for different volume fractions of UD GFRP specimens (45%, 50%, and 55% of epoxy and glass fibre. E-Glass fibre is used reinforced with epoxy L –12 resin and 10% hardener K6 these constitutes were combined to fabricate composite laminates by hand lay-up technique. Further the characterization of the composites was done by conducting Compression and flexural tests as per Astm standards D-3410-03, D- 790. Universal Testing Machine (UTM) of 400KN capacity is used for testing specimen. Validation of experimental results by analysis of UD GFRP composite is carried through Ansys APDL 14.5 software. In compression test the FEM results varied by 25% with respect to experimentally obtained values. The FEM results of flexure test showed related to the experimental values.*

I. INTRODUCTION

Composite material constitutes variety of compositions having different physical and chemical properties made up of two or more substances. There are two type of polymer matrix composite material is Natural and other one is artificially occurring combination materials.

1. Finite Element Analysis of Laminates

To optimize components of different designs applied to enhance the productivity.

The model is created using FEA software –ANSYS 14.5. Analysing mechanical properties of composite laminates based on experimental data's of three point bending, compression test and obtained results are validated for accuracy.

2. Constitutes of Composites

Matrix of Fibre Reinforced Composites

Matrix in composites act as binding agent to strengthen the bond between fibres arranged in different directions and shielding them from damages like environmental, mechanical damage. Matrix phase is classified under two categories one is thermo set and other is thermoplastic.

a) Thermoset
b) Thermo Plastic

Reinforcement

The fibres are embedded into polymer resin matrix to provide strength and stiffness to the composite. Matrix holds firmly fibres to form good binding property so that it is not damaged as the load is distributed evenly over the composite and help to resist cracks and fractures.

a. Fibre Reinforced Polymer (FRP) Composites
b. Glass Fibre Reinforced Polymer [GFRP]

Applications

Glass fibre reinforced polymer composite due to its numerous advantages as light weight ratio, high strength, stiffness, chemical resistant, with stand at high temperature and widely used in furniture, electronics, aerospace applications, marine, boat construction.

II. METHODOLOGY

- Manufacturing glass fibre composites using epoxy resin lapox – L12, by aid of hand lamination technique.
- Volume calculations of fibre and resin using rule of mixture.
- Preparation of wooden moulds of required size as per ASTM to prepare laminates.
- Machining of laminates using laminate cutting machine.
- Testing of prepared laminates for flexural and compression strength using universal testing machine.
- Optimising tested results for higher compression and flexural strength among the varied composite laminates.

- Validation of experimental results using finite elements
- Documents of the above results.

III. MATERIALS AND METHODS

Materials

a. E-Glass Fibre:
b. Epoxy Resin:
c. Hardener K6:

These materials were used for manufacture of laminates. E glass fibre is supplied by Marktech composites Pvt. Ltd. Basavangudi Bangalore. Grade- 220 GSM of 0.25mm thickness. The resinLapox (L12) andhardener k6grade is utilized in this workit is supplied by Yujee Enterprises, Bangalore.

Fig. 1: Unidirectional E Glass fibre, lapox L-12, HardenerK6

Methods

The methods involved in manufacturing of FRP composite, experimental and FEA procedure adopted for the present work is discussed under the following sections

Manufacturing of GFRP composites

To manufacture laminates initially it needs some basic proportional steps like sizing of laminas, mould preparation, coating of mould releasing agent and then actual lamination followed by curing under room temperature, all these steps were discussed under following sections.

Sizing of unidirectional (UD) E-Glass woven fibres Lamina

UD E-Glass fibres are chopped into standard size. Final size of the UD Glass fibre lamina is shown in **Fig 2.**

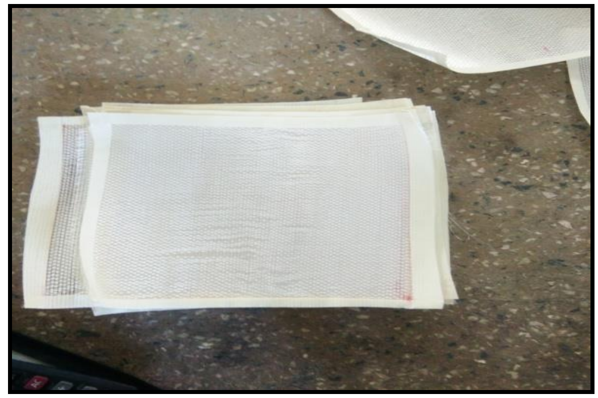


Fig. 2.Sizing ofUDE-Glass fibre Ply's

Fig. 3. Lamination process

Fig. 4. Procedure by hand layup method

In open mould epoxy resin and 10% of hardener to its volume is taken in beaker and mixed and then using roller it is dispersed uniformly on the plane of the fibre layer by layer to reinforce glass fibres and evenly spread and compressed.

The images shown in **Fig.3 and Fig. 4** gives detailed procedure of hand lamination technique.

Fig. 5.Finished composite products.

After curing it for an 24 hours under room temperature. Followed by post curing is done in oven at 70 degrees for 1 hour to remove any left out wetness in resin and then ultimately obtained final product of composite which is shown in **Fig 5.**

Testing Methods:

Experimental procedure of Compression Test

Compression test is conducted by using ASTM standard D-3410-03. The dimensions of laminated glass fibre reinforced plate 140mm X 15mm X 5mm and gauge length is 15mm.The size of the specimen was cut as per ASTM D-3410-03.using laminate cutting machine as shown in **Fig.6.**

Fig. 6.Specimen of standard sizes.

Universal Testing Machine (UTM) of 400KN capacity is used along with fixtures between top and bottom supports which is shown in **Fig 7** and load is applied gradually at strain rate 1mm/minute. In this test a load is applied from the top of the specimen slowly till the fracture of laminated glass fibre reinforced plate.

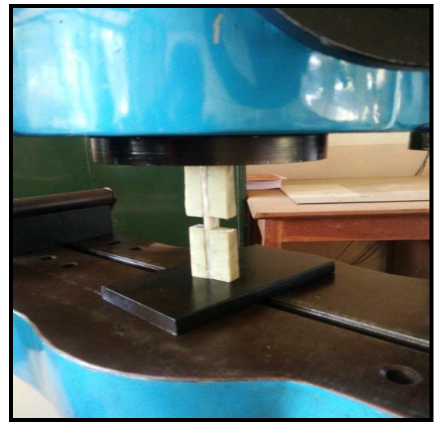


Fig.7. Compression specimen test setup

Experimental procedure of Flexure Test

Flexure test is conducted by using ASTM standard D-790. The dimensions of laminated glass fibre reinforced specimen of size 140mm X 12mm X 3mm.

Universal Testing Machine (UTM) of 400KN capacity is used and specimen is placed over two fixtures under simply supported condition which is shown in **Fig 8** and load is applied at centre of specimen gradually at strain rate 1mm/minute. The load displacement values were recorded until final fracture of composite specimen

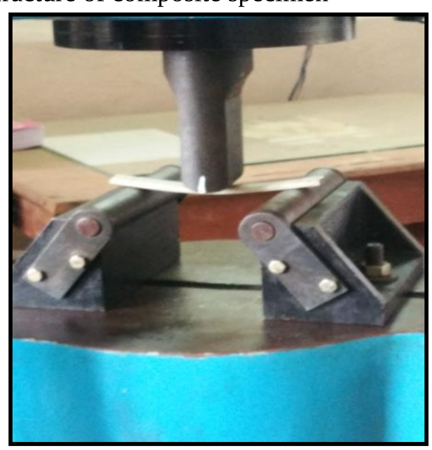


Fig.8. Loading of three point bend (Flexural) specimen in UTM

Finite Element Analysis:

FE Simulation of Compression Test:

Ansys APDL 14.5 is utilized for analysing the composite specimen of specific dimension for compression strength. The dimensions were 140mm x15mm x 5mm. Each layer thickness of lamina is 0.25mm. Totally there are 20 layers and it is modelled and meshed using ANSYS. Material is considered as orthotropic in nature. Element type was chosen as 8 noded shell and all other properties are assigned as listed in **Table 1**. Model is been meshed and which is shown in **Fig 9(a) and (b)**. Boundary conditions were applied based on experimental conditions and compressive load is applied on the model (**Fig. 10).**

Table. 1. Mechanical properties of E-Glass fibre

Young's Modulus (GPa)	E1	E2	E3
	4.81	12.3	4.81
Poisson's Ratio	$\mu 1$	$\mu 2$	$\mu 3$
	0.25	0.25	0.25
Shear Modulus (GPa)	G 1	G 2	G 3
	3.1	3.1	3.1

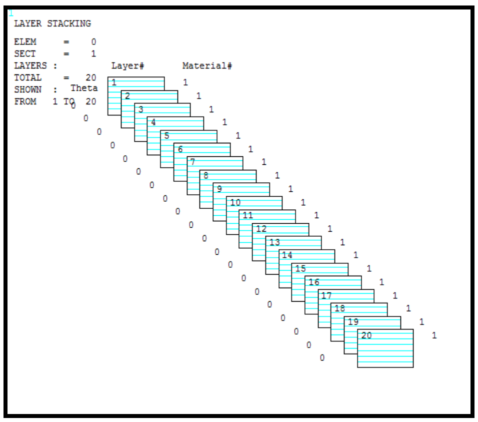
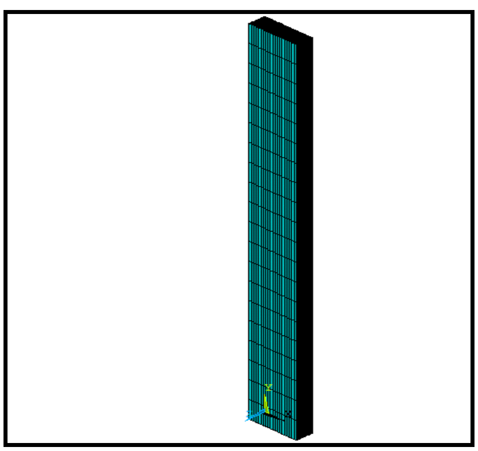


Fig: 9a)



9(b)

Fig 9(a) orientation and number layers in UD E-Glass composite Laminate and

(b) Meshed model of UD E-Glass composite specimen.

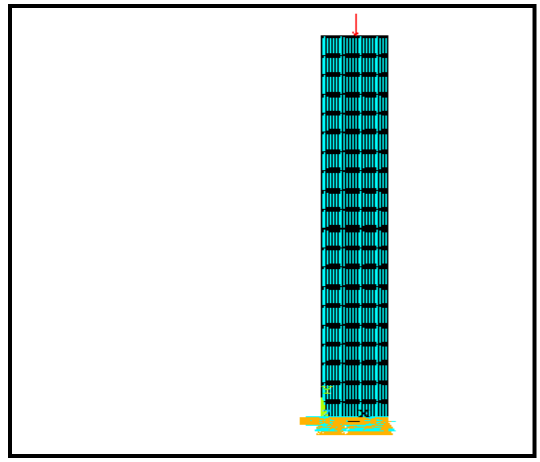


Fig.10. Boundary conditions applied

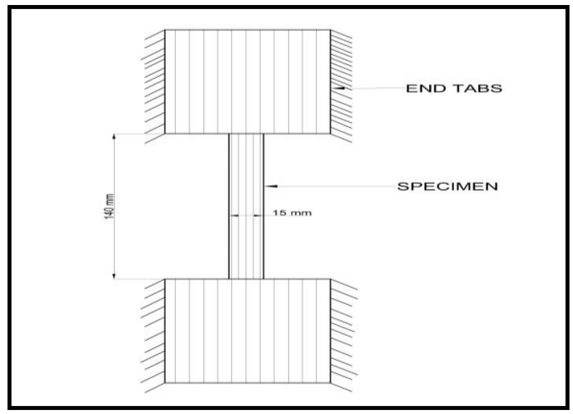


Fig.11. Compression test configuration

FE Simulation of Flexure Test :

Analysis of UD GFRP composite is carried through Ansys APDL 14.5 software. Element type Solid 185and all orthotropic properties are listed in **Table.1**. The dimensions were 140mm x15mm x 3mm. Each lamina thickness is 0.25mm. Totally there are twelve layers which is shown

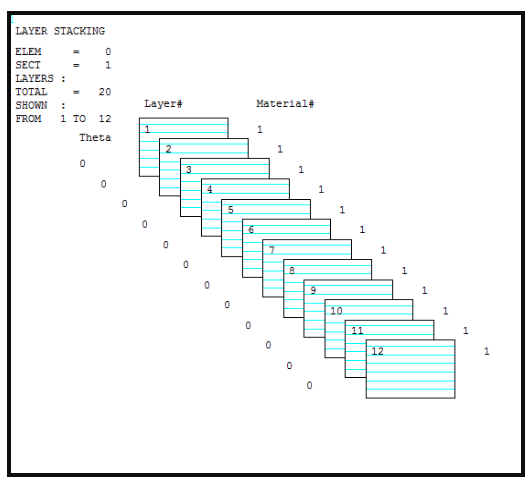


Fig.12. Oreintation of fibre and number of layers

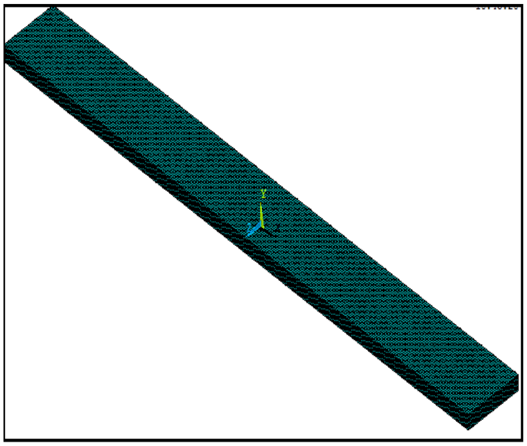


Fig. 13. Flexure Meshed Model.

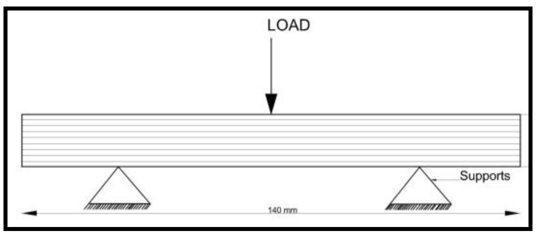


Fig. 14. Schematic showing boundary condtions applied on Flexural sepcimen

IV. RESULTS AND DISCUSSIONS

Compression Test

Compression test results are listed in **Table2**

Compression strength values for different composition of GFRP specimens

Sl. No	Volume fractions (%)	Compression Strength (MPa)	Displacement (mm)
1	45% - 55%	26	2.5
2	50% - 50%	34	2.8
3	55% - 45%	30	2.6

The instantaneous load and displacement values were plotted in **Fig. 15**. As we can see that the slope of all the specimens are similar but the composite with 50% -50% glass and epoxy has highest peak which indicates it can withstand higher compressive loads as compared to other composition composite laminates.

In **Fig 16.** was observed that the compressive strength is significantly large (34 MPa) in case of equal volume fraction of UD E -Glass fiber and epoxy. This increased compressive strength is due to complete wetness of fibers in epoxy resin, hence fibers are well bonded in matrix material with minimum flaws and porosity.

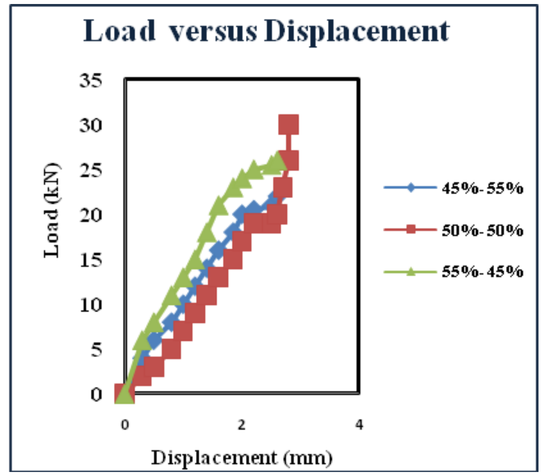


Fig. 15. Plot showing load versus displacement curve for Compression test

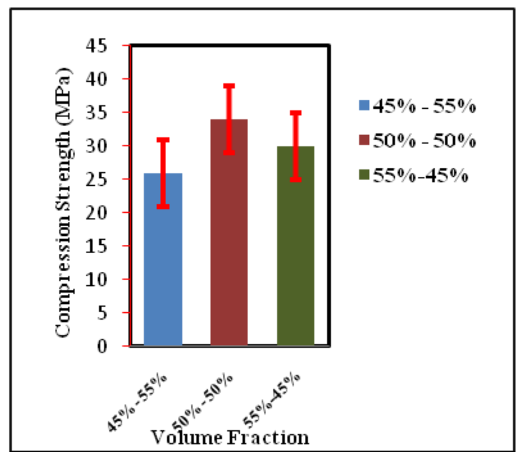
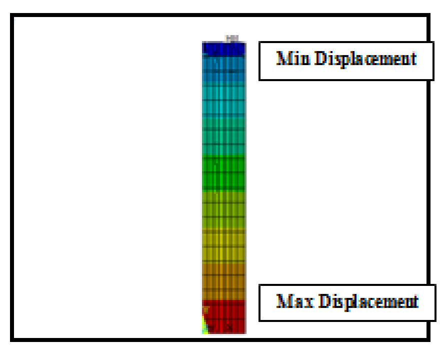


Fig 16. Bar chart showing Compression strength values for different composition composite laminates



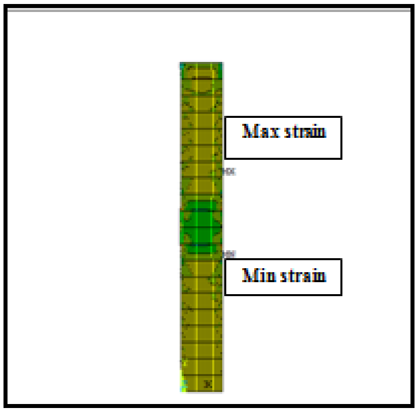


Fig. 17 b. Plots of FE analysis showing distribution stresses and displacement

FE simulation was done using ANSYS 14 for the compression test. The boundary condition which was used in experimental test is applied and results are shown in **Fig. 17.** The trend was almost similar to experimental observation but the results varying by 25% with respect to experimentally obtained values.

Flexural Test:

Table 3. Flexural strength values for different composition of GFRP specimens

Sl. No	Volume fractions (%)	Flexural Strength MPa	Displacement (mm)
1	45% - 55%	6.52×10^3	5
2	50% - 50%	7.33×10^3	6
3	55% - 45%	8.13×10^3	8

in **Fig 18.** From load displacement curves it was seen thatthe flexural load was very dominant for fiber volumer fraction 55% and 45% of epoxy matrix. Further, for 50% fiber volume fraction composite specimens performed relatively low flexural resistence as compared to 55% fiber volume fraction. But both 55% and 50% fiber vloume fraction composite exhibhits higher loads with respect to 45% fiber volume fraction specimens.

Similary, the bending strength values with respect to fiber and matrix volume fraction is shown in **Fig 19**. Wrt strength values the compsoite with 50% and 55% fiber volume fraction exhibits higher strength as compared to 45% fiber volume fraction.

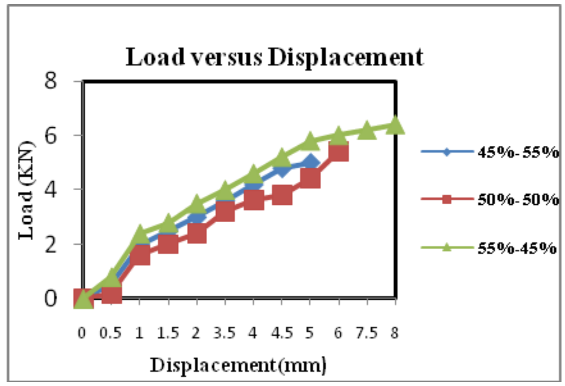


Fig. 18. Plot showingload versus displacement curve for Flexural test

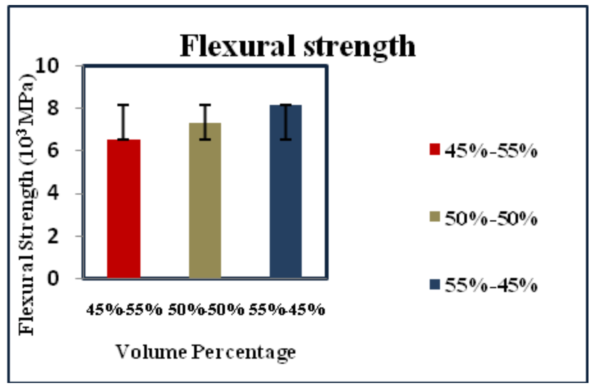


Fig. 19. Bar chart showing Flexural strength values for different composition composite laminates

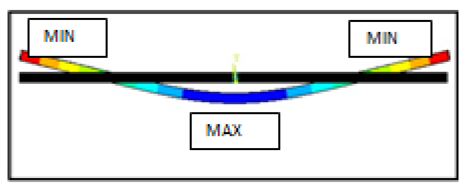


Fig.20.FE analysis plot showing deflection/flexural stress behaviour of UD E Glass epoxy composite specimen under 3 point loading.

According to observation of experimental results, the strength of flexure increases with increase in reinforcement of composite.

The obtained results are plotted in **Fig 20.** The FEM results were almost similar to experimental observed result the maximum deflection is found at mid span of composite specimen.

V. CONCLUSIONS

The summary of conclusions based on experimental and FE analysis results for UD E-Glass epoxy composite are as follows.

- Successfully manufactured UD E –Glass fiber reinforced epoxy composite laminates under room temperature curing hardener by the hand lamination technique.
- Compression and Flexural test specimens were successfully prepared as per the ASTM standards for experimental tests
- It was noticed that the maximum compression strength of 34MPa for the specimens with 50% fiber volume fraction in epoxy matrix.
- Similarly, the maximum flexural strength of 8.13 x 10^3 MPa for 55% fiber volume fraction in epoxy matrix.
- Attempt was made to validate experimental results by simulating Compression and Flexural tests using FE analysis. The results were compared and discussed in chapter

VI. SCOPE FOR FUTURE WORK

The same work can be done by collecting waste residue of E Glass epoxy composite from composite industries.

A suitable method of chemical or thermal recycling can be developed for recycling glass epoxy composite residue for civil engineering and other structural applications.

The varieties of products can be made by using glass epoxy waste residue for domestic applications.

For the prepared composites a proper tests like tensile, compression, durability, weathering and fracture tests can be conducted and which will help us in deciding good quality composite.

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