

# Analysis of Flexural Properties of Carbon Fiber Reinforced / E-Poxy Composite Material



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## ABSTRACT

Many structures used in Automobile, Aerospace, Naval and other Transportation vehicle structural parts are subjected to various kinds of loads. These structures are further subjected to bending loads causing flexural stress in the structures. The structures subjected to bending loads are prone to various failures. Therefore, the structural integrity of structures is a must to overcome bending. Structures subjected to pure bending load often experiences maximum flexural stress of the specimen either at the outer or the inner fiber leading to failure, the stress will be zero at the neutral axis or the middle axis. Fabrication of carbon fiber reinforced laminates is prepared using hand layup method. The present study aims at investigating the flexural parameters of carbon fibre reinforced Epoxy composites when subjected to static flexural loading using ASTM D790. Using load deflection graph the maximum load, maximum deflection and the flexural strength of specimens for different laminated composites is evaluated and appropriate conclusions are drawn.

**Keywords**— Carbon fiber, Epoxy, Flexural strength, Composite materials.

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## I. INTRODUCTION

Rapid technological advances in engineering brought the scientists and engineers to a point, where they became limited by the capabilities of traditional materials. With the limits of the technology pushed, the materials failed to answer the requirements of the designers or manufacturers. Researchers in materials technology are constantly looking for solutions to provide stronger, durable materials which will answer the needs of their fellow engineers. Composite

materials are one of the most favored solutions to this problem in the field. By combining the stronger properties of traditional materials and eliminating the disadvantages they bear, composite materials technology is providing limitations like heavy weight, structural strength, and thermal resistance are being solved by the compromising solutions and alternatives to many engineering fields. Problems born from material composite material alternatives, and many more alternatives are being

introduced to readily use in engineering applications Due to the high specific stiffness and strength, composite materials are being used increasingly in many engineering applications.

Composite materials are produced by combining two dissimilar materials into a new material that may be better suited for a particular application than either of the original material alone. The reinforcing phase provides the strength and stiffness. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. The continuous phase is the matrix, which is a polymer, metal, or ceramic. Polymers have low strength and stiffness, metals have intermediate strength and stiffness but high ductility, and ceramics have high strength and stiffness but are brittle.

Applications include aerospace, transportation, construction, marine goods, Sporting goods, and more recently infrastructure, with construction and transportation being the largest. Materials can be classified as either isotropic or anisotropic. In general high performance but more costly continuous carbon fibre composites are used where high strength and stiffness along with light weight are required, and much lower-cost fiber glass composites are used in less demanding applications where weight is not as critical. So it is important to study beam strength and flexural properties of a composite beam so that we can predict a loading conditions for various application. The stresses induced by the flexural load are a combination of compressive and tensile stresses. Composites are rarely used in the form of unidirectional laminates, since one of their great merits is that the fibers can be arranged.

Davies explained parameters that effects on flexural properties of carbon fiber reinforced composites [3]. Shivanand showed effects of fiber orientation on flexural strength of glass and graphite reinforced polymer [1]. Tomita investigate about stacking sequence of CFRP composite laminates and their fracture behaviour [6]. Sideridis E studied about behaviour of composite material for short beam test and flexural properties of same [8].

Flexural test according to ASTM D790 provides the determination of maximum load bearing capacity of the materials at the one set of plastic deformation of the composites. From this ultimate flexural stress are computed [5].

## II. MATERIALS AND FABRICATION

### A. Laminate Fabrication:

- Selection of Composite material –
- Reinforcement - Carbon (200 GSM).
- Matrix – Epoxy EPOLAM Resin & Hardner 5015.

Properties of materials used are tabulated are as follows:

TABLE 1  
MATERIAL PROPERTIES(SI UNIT)

Material	Properties	Value
Carbon Fiber	$E_f$	242
	$\rho_f$	1.81
	$v_f$	0.25
Epoxy Resin	$E_m$	3.7
	$\rho_m$	1.14
	$v_m$	0.245
Laminate (Orthotropic)	$E_1$	146.68
	$E_2=E_3$	9.04
	$\rho_c$	1.62
	$G_{12}=G_{13}$	3.476
	$G_{23}$	3.630
	$v_{12}$	0.25
	$v_f$	0.60

### B. Fabrication of Carbon Fiber Laminate:

The reinforcing material such as Unidirectional 200 GSM Carbon fibres are cut into required size and are laid on the flat surface of the mould. The fibres of the required size are laid along the required direction as per the design requirements. The resin and hardener of EPOLAM are mixed in the proportions as recommended by the manufacturer in the required proportions that is in the proportions of 70:30 as suggested by the manufacturer is mixed thoroughly and is applied on the laminated surface to be laminated. First put ply of carbon fibre in  $0^\circ$  orientation. The resin is spread evenly on the reinforcing fiber, the resin is squeezed evenly on the surface using a roller and compressed thoroughly with the roller itself. Then put another ply in  $90^\circ$  orientation. The reinforcing fibres are stacked one above the other and the above mentioned procedure is repeated up to 8, 10 and 12 layer of carbon fiber repeatedly.

Then prepared laminate is placed under heavy load for 24 hours in room temperature. From this plate of 3, 3.85, 4.5mm thickness is obtained. The laminate is ready and this laminate is cut into required size as per ASTM D790 standard i.e. span to thickness ratio is 16:1. Details of the composite specimens fabricated are as shown in Fig 2 below.

The 3-point bending tests were performed in a servo controlled UTM machine according to the procedure outlined in ASTM D790. Number of specimens was tested for each thickness of laminate. The tested specimens were examined through visual inspection for failure of fibers and matrix.



Fig.1. Preparation of specimen using Hand Lay-up.



Fig.2. Flexural Specimen.

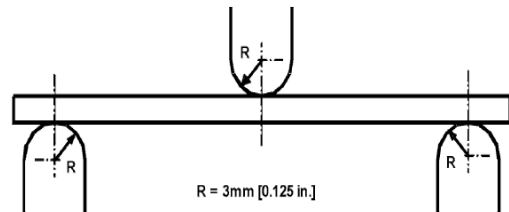
**C. Definition: Flexural Strength:**

The maximum stress at the outer surface of a flexure test specimen corresponding to the peak applied force prior to flexural failure. The flexural strength is the ability to resist deformation under load for a material. The material deforms significantly but does not break, the load at yield is typically measured at 5% deformation/strain of the outer surface, is reported as the flexural strength or flexural yield strength. The test beam specimen is under compressive stress at the concave (inner) surface and tensile stress (Outer) at the convex surface. ASTM D790 test gives the procedure to measure a material's flexural modulus. The flexural test measures the force required to bend a beam under three point loading conditions. The data is often used to select materials for parts that will support loads without flexing. Flexural modulus is used as an indication of a material's stiffness when flexed.

**III. TEST PROCEDURE**

The specimen with the given span is supported between two supports as a simply supported beam and the load is applied at the centre by the loading nose producing three point bending at a specified rate by using UTM. The parameters for this test are the support span, the speed of the loading, and the maximum deflection for the test. These parameters are based on the test specimen thickness and are defined differently by ASTM. The composite laminates were subjected to various loads and computer controlled UTM. The specimens were clamped and tests were performed. The tests were closely monitored and conducted at room temperature. The load at which the complete fracture of the specimen occurred has been accepted as

breakage load. Fig.3 shows loading diagram of three point bending test.



Three-Point Loading Configuration with Fixed Supports and Loading Nose  
Fig.3. Three point Bending test

After taking the values of max.load which is applied in process of loading of beam we can calculate flexural strength and flexural Modulus of beam with help of following formulae.

1. Max. Flexural Stress (3 Point Bending)

$$= \sigma = \frac{3PL}{2bh^2}$$

2. Flexural Modulus of Elasticity (3 Point Bending)

$$= E_f = \frac{L^3 m}{4bh^3}$$

**IV. RESULTS AND DISCUSSION**

**A. Experimental Results:**

We have done testing i.e. experiment on UTM machine for Three Point Bending. From this we get results of max.load that we have applied on specimen at which rupture occurs or fails. Also we get deformation of beam after loading. All these results are tabulated as follows:

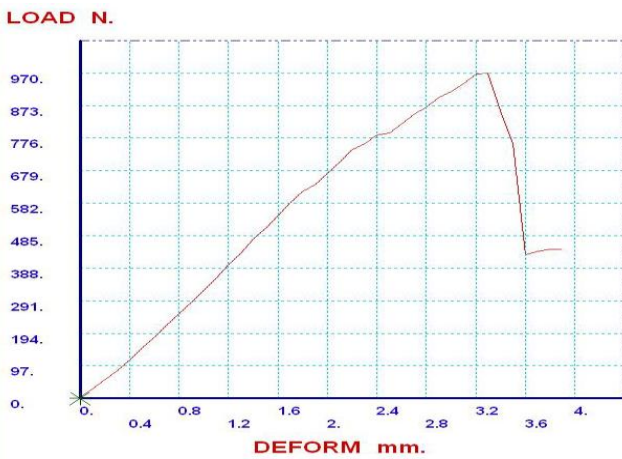
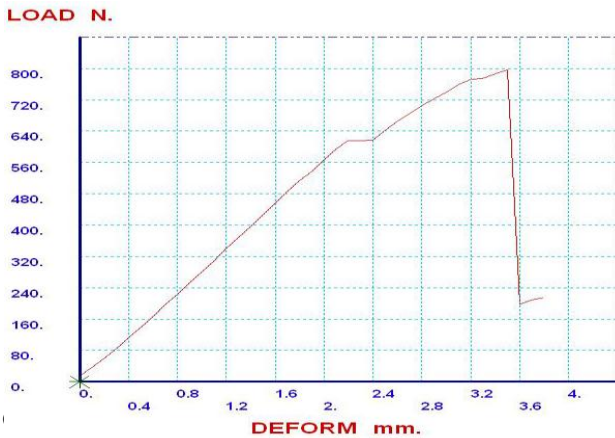
TABLE II (SI UNIT)  
Results of Flexural Testing

La	C.	T	Wi	Loa	Stren	Modu
8 Layer	C.	2.	13.	692	473.3	23756
	C.	3.	12.	743	495.6	25459
	C.	2.	12.	707	484.0	27077
	C.	2.	12.	658	447.0	24703
	C.	3.	13.	795	510.0	25389
Average					482.0	25277
10 Layer	C.	3.	13.	970	453.1	26393
	C.	3.	13.	107	497.7	27854
	C.	3.	13.	976	482.4	30439
	C.	3.	13.	115	554.4	28932
	C.	3.	12.	101	478.3	26508
Average					493.2	28025

12 Layer	C.	4.	12.	127	510.5	33608
	C.	4.	12.	118	498.2	32239
	C.	4.	13.	115	496.9	29879
	C.	4.	13.	113	498.9	25559
	C.	4.	12.	129	515.9	33507
Average					503.4	30958

From the graph 1, 2 and 3 Curves for three specimens show linear behavior until failure. It is observed that as thickness is increased the load carrying capacity is also increased. At the peak load deformation is also increased with respect to thickness 3mm, 3.85mm and 4.5mm. As the result, the flexural strength is also increased as thickness increases, and the deformation is increased as the load increases with respect to thickness.

**B. Graphical Results:**



Graph 2: Load Vs. Deformation (3.85mm thick beam)



Graph 3: Load Vs Deformation (4.5mm thick beam)

**V. CONCLUSIONS**

Three point bending tests were performed on 0<sup>0</sup>/90<sup>0</sup> lay-up composite specimens. The load-deflection curve was evaluated. Three types of laminates were tested with three different thicknesses. The main findings of the present investigation are as follows:

- Effect of thickness on flexural strength to play a vital role in assessing material behavior under flexural loading conditions.
- Because 50% of the fibers are oriented at 0<sup>0</sup> direction for 0/90<sup>0</sup> laminate, and thus appropriate for bending (Flexural Modes). This can be explained by the fact that the fibers oriented at 0<sup>0</sup> are more appropriate to flexural loads.
- To improve flexural properties of fiber composite laminate a slight increase in the thickness without sacrificing much on the weight can be recommended which significantly increases flexural properties.
- There is a significant improvement in strength of carbon laminates as thicknesses under test. This may be due to good adhesion between carbon fiber and matrix.
- The results of this work, is recommended for designers of composites community for better improvement of strength for FRP composites.

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*Nomenclature:*

- $E_1$  = Longitudinal Young's modulus in direction of fibers
- $E_2, E_3$  = Transverse Young's modulus normal to fibers.
- $E_f, E_m$  = Young's modulus for fibers and matrix resp.
- $V_f, V_m$  = volume fractions for fibers and matrix resp.
- $\nu_f, \nu_m$  = Poisson's ratios for fibers and matrix resp.
- $\nu_{12}$  = Poisson's ratio for composite beam.
- $G_f, G_m$  = shear modulus of fibers and matrix resp.
- $G_{12}$  = Shear modulus of composite beam.
- $\rho_f, \rho_m, \rho_c$  = Density of Fiber, matrix and composite.
- $C.F.$  = Carbon fiber.
- $Thk$  = Thickness of Beam.
- $m$  = slope of load Vs deformation.
- $I$  = Moment of inertia

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