IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 12, December 2015.
www.ijiset.com
ISSN 2348 – 7968

Experimental analysis on glass/epoxy composite beams

Y.Karnakar/K.Madh

ABSTRACT

Composite materials have been used in the industry for many years because they perform better than the comparable homogenous isotropic materials. Advanced composites like fiber reinforced composite are widely used in aerospace industry. The advantages of composite such as high specific strength and stiffness, good corrosion resistance, and lower thermal expansion make them a primary preference in aircraft structures and other applications.

A composite beam a one dimensional structure or a rod all of them are sectional dimensions in which width and height are much smaller in comparison to the structure. Generally composite beams are preferred due to high strength and less weight in structural engineering applications. A beam is a member mainly subjected to bending. The terms rod (or bar) and column are for those members that are mainly subjected to axial tension and compression, respectively. Beams are one of the fundamental structural or machine components. Composite beams are lightweight structures that can be found in many diverse applications including aerospace, submarine, medical equipment, automotive and construction industries.

In structural applications longer beams are more frequently used. In this project a composite beam is manufactured with glass and epoxy combination. And stress analysis is carried out using derived analytical expressions. The research carried out in this project will enable to determine the beam strength due to bending loads. The importance of fiber reinforcement in the manufacturing of the beam is studied in terms of bending strength of the beam. Mat lab codes are generated to implement analytical expiations of the composite beam. The analytical results are validated by performing experiments on composite beams. For the investigation, two different composition beams have been tested and compared the experimental results with the analytical results. It is found that the bending stress and deflections evaluated with the mat lab code are almost coincided with the values observed in bending experiment.

ISSN 2348 – 7968

INTRODUCTION

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

Composite materials, with their high strength/weight ratio are becoming popular with their increasing availability due to advancement in their manufacturing processes

Glass Fibers

Glass fibers with polymeric matrices have been widely used in various commercial products such as piping, tanks, boats and sporting goods. Glass is by far the most widely used fiber, because of the combination of low cost, corrosion resistance, and in many cases efficient manufacturing potential. It has relatively low stiffness, high elongation, and moderate strength and weight, and generally lower cost relative to other composites..

Glass fibers are also available in woven form, such as woven roving and woving cloth. Woven roving is coarse, droppable fabric in which continuous roving are woven in two mutually perpendicular directions.

Classification of Composite Materials

There are four commonly accepted types of composite materials. These types are listed as follows;

- Fibrous composite materials that consist of fibers in a matrix

- Laminated composite materials that consist of layers of various materials

- Particulate composite materials that are composed of particles in a matrix

- Combinations of some or all of the first three types fiber orientation of the layers is not symmetric about the middle surface of the laminate. The layers of a laminate are usually bonded together by the same matrix material that is used in the individual lamina. Laminates can be composed of plates of different materials or, in the the present context, layers of fiber-reinforced lamina. A laminated circular cylindrical shell can be constructed by winding resin-coated fibers on a removable core structure called a mandrel first with one orientation to the shell axis, then another, and soon until the desired thickness is achieved.

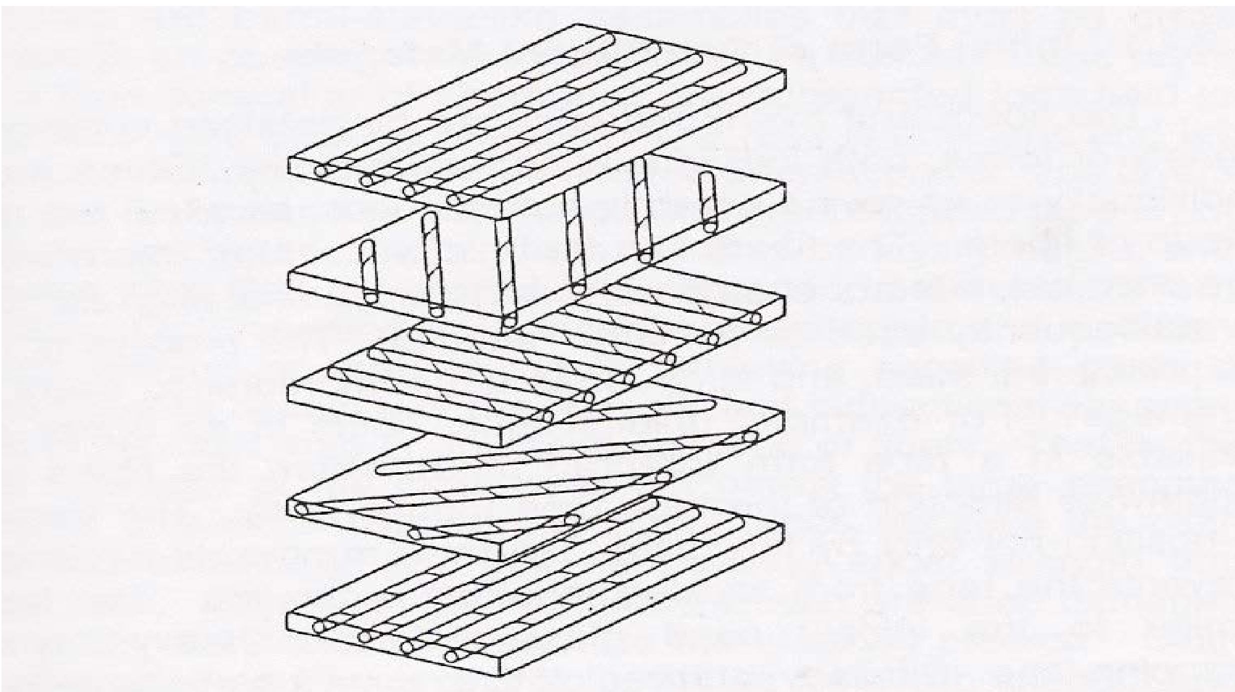
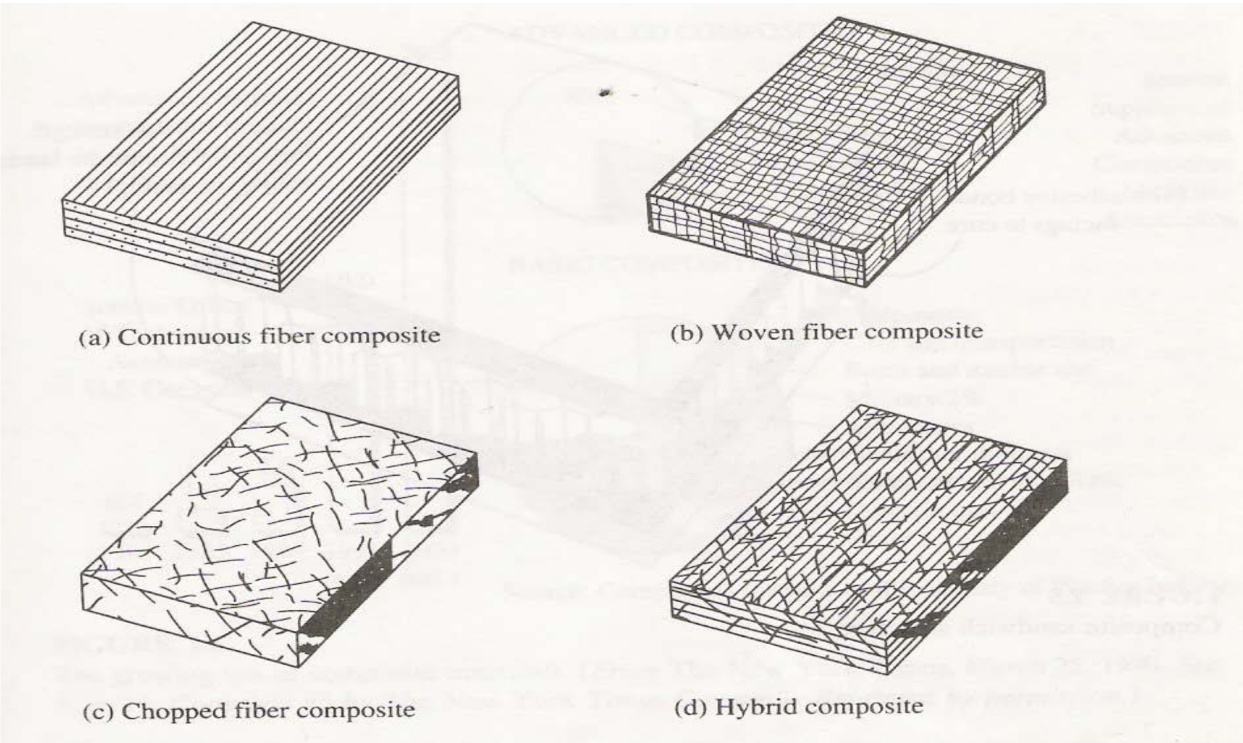


Figure 1. Unbonded view of laminate construction (Jones, R.M; 1998; 17)

A major purpose of lamination is to tailor the directional dependence of strength and stiffness of a composite material to match the loading environment of the structural element. Laminates are uniquely suited to this objective because the principal material directions of each layer can be oriented according to need. For example, six layers of a ten-layer laminate could be oriented in one direction and the other four at 90° to that direction; the resulting laminate then has a strength and extensional stiffness roughly 50% higher in one direction than the other. The ratio of the extensional stiffness in the two directions is approximately 6:4, but the ratio of bending stiffness is unclear because the order of lamination is not specified in the example. Moreover, if the lamina are not arranged symmetrically about the middle surface of the laminate, the result is stiffness that represent coupling between bending and extension. (Jones Robert M; 1998;15).



Types of fiber-reinforced composites (Gibson. R.F; 1994; 5)

Current Applications

Composite structural elements are now used in a variety of components for automotive, aerospace, marine and architectural structures in addition to consumer products such as skies, golf clubs and tennis rackets. (Gibson R.F; 1994; 13) The applications can be considered by as follows.

- Marine field
- Aircraft and space
- Automotive
- Sporting goods

Composite Beam

A structural element having one dimension many times greater than its other dimensions can be a rod, a bar, a column, or a beam. The definition actually depends on the loading conditions beam is a member mainly subjected to bending. The terms rod (or bar) and column are for those members that are mainly subjected to axial tension and compression, respectively.

A composite beam a structure or a rod all of them are sectional dimensions in which width and height are much smaller in comparison to the structure. Generally composite beams are preferred due to high strength and less weight in structural engineering applications composite beams are made of at least three to four laminates .In the composite beam the main analysis carried out are bending stress, bending defections, torsional stress and Eigen values.

MANUFACTURE OF COMPOSITE BEAMS

Composite beams are combined with the matrix and fibre.Manufacture of glass/epoxy composite beams are fiber is the GLASS, matrix is the EPOXY RESIN. In this project the epoxy resin is used in $\boldsymbol{L_2}$ grade and $\boldsymbol{K_6}$ hardner.Material of the composite beam is,

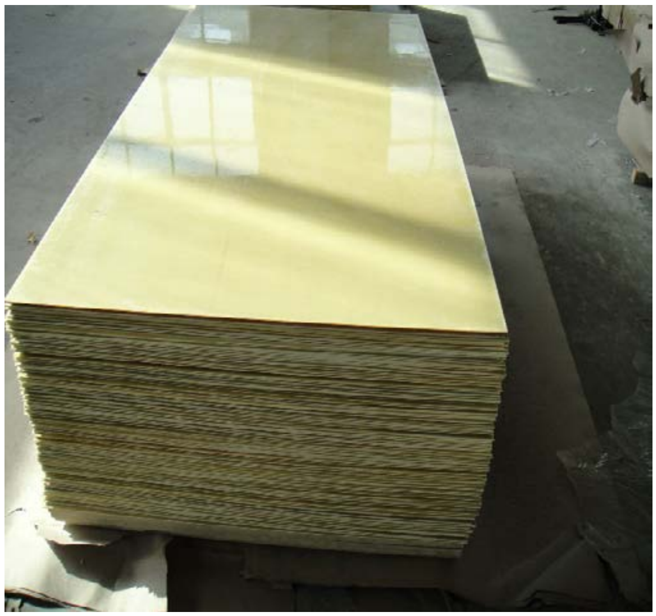
Unidirectional glass cloth-360GSM,Chopped strand mat-300GSM,Wovenroving-400GSM,

Glass cloth-10mil.

Glass Cloth:

Fiberglass is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Common uses of fiberglass include high performance aircraft (gliders), boats, automobiles, baths, hot tubs, water tanks, roofing, pipes, cladding, casts, surfboards and external door skins.

There are two main types of glass fibers: E-glass and S-glass. The first type is the most used, and takes its name from its good electrical properties. The second type is very strong(S-Glass),stiff, and temperature resistant. Used as reinforcing materials in many sectors, e.g. automotive and naval industries, sports equipment etc. applications used in boats, surfboards, panels, tanks and various other applications.



Glass cloth

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Manufacture of the glass /epoxy composite beams

The each layer has thickness 0.42mm,

Length of the beam is 700mm,

Height of the beam is 16mm,

Breadth of the beam is 24mm,

Weight of the beam is 600grms.

Glass/ epoxy composite beams

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 12, December 2015.
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Properties of Composite Beam

The elastic properties of glass/epoxy composite beam are shown in the table1:

PROPERTY	GLASS	EPOXY
Young's modulus	70GPa($\boldsymbol{E_g}$)	10GPa($\boldsymbol{E_e}$)
Poisson's ratio	0.20($\boldsymbol{\vartheta_g}$)	0.34($\boldsymbol{\vartheta_e}$)
Shear modulus	4GPa($\boldsymbol{G_g}$)	1.2GPa($\boldsymbol{G_e}$)
Tensile strength	3445MPa(σ_g)	85 N/$\boldsymbol{mm^2}$(σ_e)

Properties of glass and epoxy composite beam

To findout the manufacture of glass/epoxy composite beam in the Density, Volumefraction, Young's modulus, Poisson's ratio and Shear modulus.

Determination of the exact volume fraction glass fiber:

Length of the beam = 70cm

Breadth of the beam = 2.4cm

Height of the beam = 1.6cm

Weight(measured)of the beam = 600gr

$$\boldsymbol{\rho_c} = \text{Weight } (\boldsymbol{W_c}) \,/\, \text{Volume } (\boldsymbol{V_c}) \quad (\therefore \boldsymbol{V_c} = \text{lbh})$$

$$\text{Density } (\boldsymbol{\rho_c}) = 2.2321 \; \boldsymbol{g/cm^3}$$

$$\text{Density } (\boldsymbol{\rho_c}) = \boldsymbol{\rho_g V_f} + \boldsymbol{\rho_e V_m} \quad (\therefore \boldsymbol{V_m = 1 - V_f})$$

$$\text{Volume fraction } (\boldsymbol{V_f}) = 0.7282$$

Determination of the exact elastic constants of the glass fiber

$$\text{Young's modulus } (\boldsymbol{E_1}) = \boldsymbol{E_g V_f + E_e V_m}$$

$$\text{Young's modulus } (\boldsymbol{E_1}) = 53.692\text{GPa}$$

$$\text{Transverse stiffness } (\boldsymbol{E_2}) = 8\text{GPa}$$

Poisson's ratio $(\boldsymbol{\vartheta_{12}}) = \boldsymbol{\vartheta_g V_f + \vartheta_e V_m}$

Poisson's ratio ($\boldsymbol{\vartheta_{12}}$) = 0.23

Shear modulus $(\frac{\mathbf{1}}{\boldsymbol{G_{12}}}) = \frac{\boldsymbol{V_f}}{\boldsymbol{G_g}} + \frac{\boldsymbol{V_m}}{\boldsymbol{G_e}}$

Shear modulus ($\boldsymbol{G_{12}}$) = 2.44GP

Tensile strength$(\boldsymbol{\sigma_s}) = \boldsymbol{\sigma_g V_f + \sigma_e V_m}$

Tensile strength$(\boldsymbol{\sigma_s})$ =2531.752MP

A ply is a thin orthotropic material that can be fully characterized by 4 elastic constants,

$\boldsymbol{E_1}$, $\boldsymbol{E_2}$, $\boldsymbol{G_{12}}$, and $\boldsymbol{\vartheta_{12}}$

Longitudinal stiffness ($\boldsymbol{E_1}$) = 53.692GPa

Transverse stiffness ($\boldsymbol{E_2}$) = 8GPa

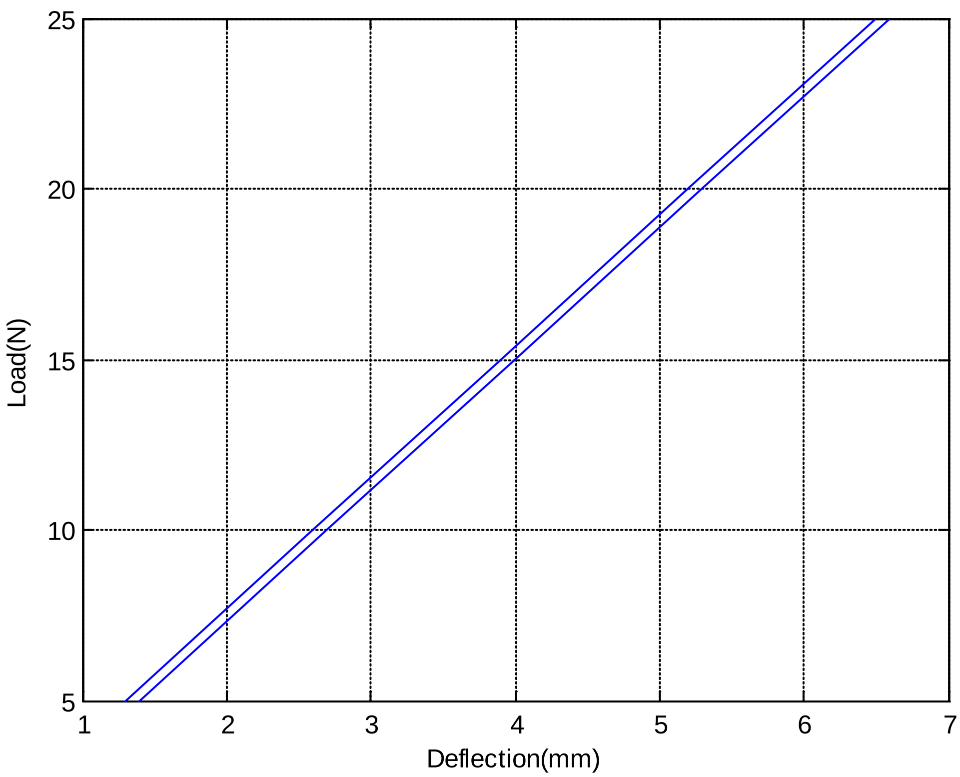
Shear modulus ($\boldsymbol{G_{12}}$) = 2.44GPa

Poisson's ratio ($\boldsymbol{\vartheta_{12}}$) = 0.2380

Analytical Results with MAT lab Code

Numerical values			
S.NO	LOADS(P) (N)	DEFLECCTION($\boldsymbol{\delta}$)	STRESS ($\boldsymbol{\sigma}$)($\frac{N}{mm^2}$)
1	5	1.2997	3.4525
2	10	2.5994	6.9050
3	15	3.8991	10.3575
4	20	5.1988	13.8100
5	25	6.4985	17.2625

Numerical values of the Deflection and Stress with respect to Loads



comparision of the unidirectional and different orientation of the composite beam.

EXPERIMENTAL SETUP

A composite beam a one dimensional structure or a rod all of them are sectional dimensions in which width and height are much smaller in comparison to the structure. Generally composite beams are preferred due to high strength and less weight in structural engineering applications .composite beams are made of at least three to four laminates. In the composite beam the main analysis carried out are bending stress, bending deflections,torsional stress and Eigen values. In this project glass/epoxy composite beam is evaluated for experimental and analytical.

Fig: 5. Glass epoxy composite beam

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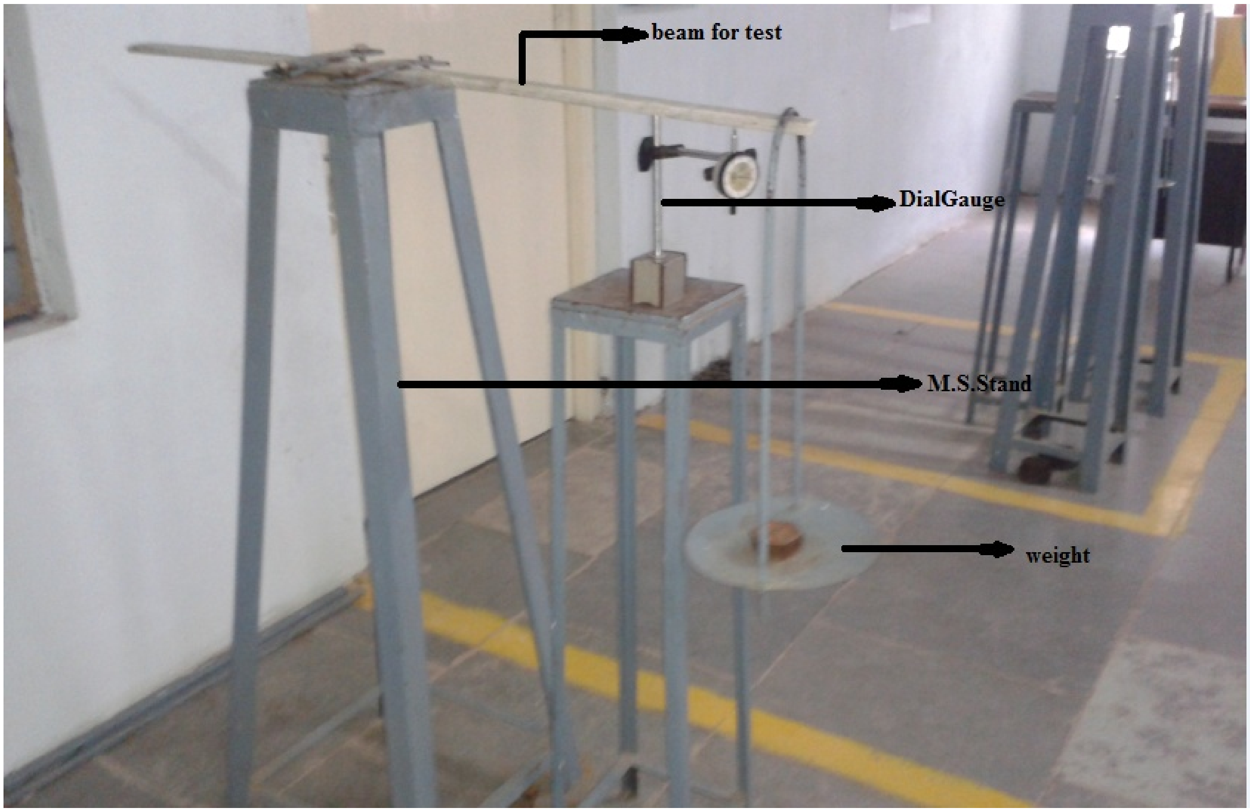

Experimental setup of cantilever in the glass epoxy composite beam

Experiment Method

The set up contains the following:

- One rigid clamping support for fixing one end of the beam.
- Loading arrangement along with different weights.
- Dial gauge with magnetic stand.
- Measuring tape or steel scale.

The experimental method of the composite beam procedure to find the deflections. Clamp the beam horizontally on the clamping support at one end, Measure the length of cantilever L distance from clamp end to loading point, Fix the dial gauge under the beam at the loading point to read downward moment and set to zero, Hang the loading pan at the free end of the cantilever, Load the cantilever with different loads and note the dial gauge readings. And next find moment of inertia I to calculate of the different weights to the different stress values.

The cantilever beam of the formula as follow:

$$\text{DEFLECTION} \quad \boldsymbol{\delta} = \frac{\mathbf{WL^3}}{\mathbf{3EI}}$$

$$\text{MOMENT OF INERTIA I} = \frac{\mathbf{bh^3}}{\mathbf{12}}$$

$$\text{STRESS} \quad \boldsymbol{\sigma} = \frac{\mathbf{MY}}{\mathbf{I}}$$

Where M is the bending moment Y is distance from the reference line to the last layer, I is the moment of inertia.

Table 5. Experimental results

Experimental values			
S.NO	LOADS(P) (N)	DEFLECTION($\boldsymbol{\delta}$)	STRESS($\boldsymbol{\sigma}$) ($\frac{N}{mm^2}$)
1	5	1.3166	3.4179
2	10	2.6333	6.8359
3	15	3.9500	10.2539
4	20	5.2666	13.6718
5	25	6.5833	17.0898

5.2 Tensile Test

Fig:5.2 show the tensile test in the x-axis is displacement and y-axis is load carring,the tensile test in ultimate tensile load is 24.640KN,ultimate tensile strength is 260.520MPa.

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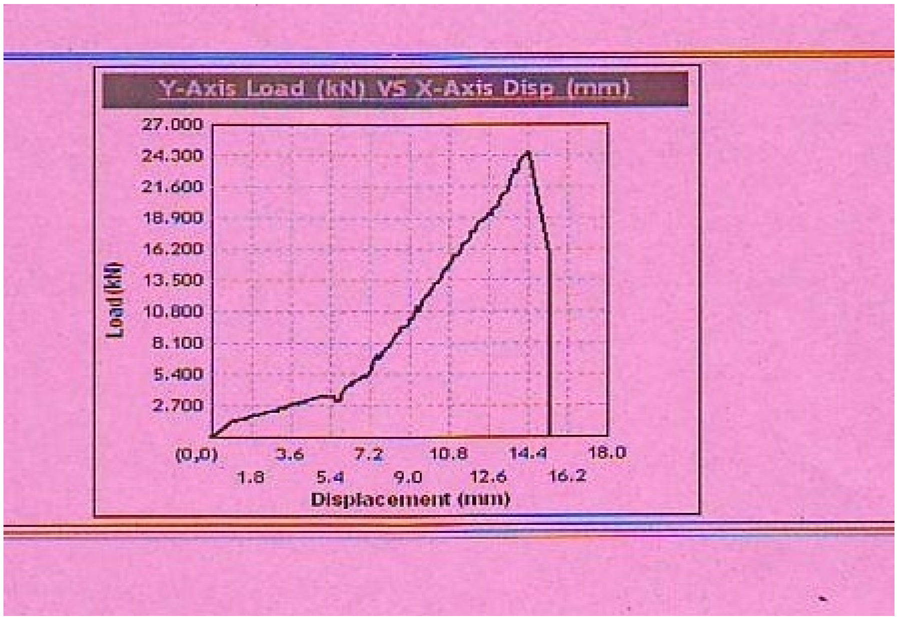


Displacement vs Load

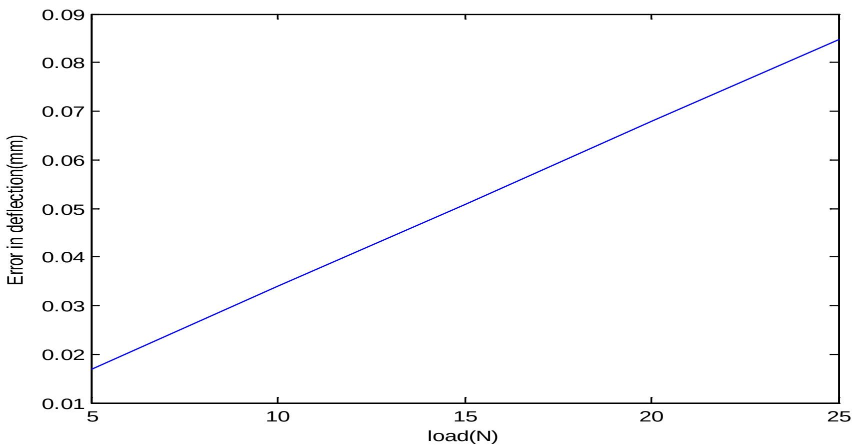
RESULTS AND DISCUSSION

Experimental Stress in Composite Beam in Comparison of Results with Analytical Solutions

Comparison of Expermental and Numerical Results					
S.NO	Different loads	Deflection of Expermental	Deflection of Numerical	Stresses of Expermental	Stresses of Numerical
1	5	1.3166	1.2997	3.4179	3.4525
2	10	2.6333	2.5994	6.8359	6.9050
3	15	3.9500	3.8991	10.2539	10.3575
4	20	5.2666	5.1988	13.6718	13.8100
5	25	6.5833	6.4985	17.0898	17.2625

The errors in deflections and bending stress are evaluated as the different between experimental value and numerical value.

The fig shows the variation in the deflection error as load increases on the beam. The error is increases in gradually from 0.015mm to 0.085mm as load changes 5N to 25N.



The variation of error in deflection with respect to load

ISSN 2348 – 7968

Fig 6.2 show the error is decrease as load increasing on the beam. The developed analytical model can de utilizes bending stress and deflections instead of checking beam for higher loads. The braking loads in the evaluated easily by considering the composite beam strength and moment of inertia of cross section of the beam. The braking of load is 3703N in cantilever beam.

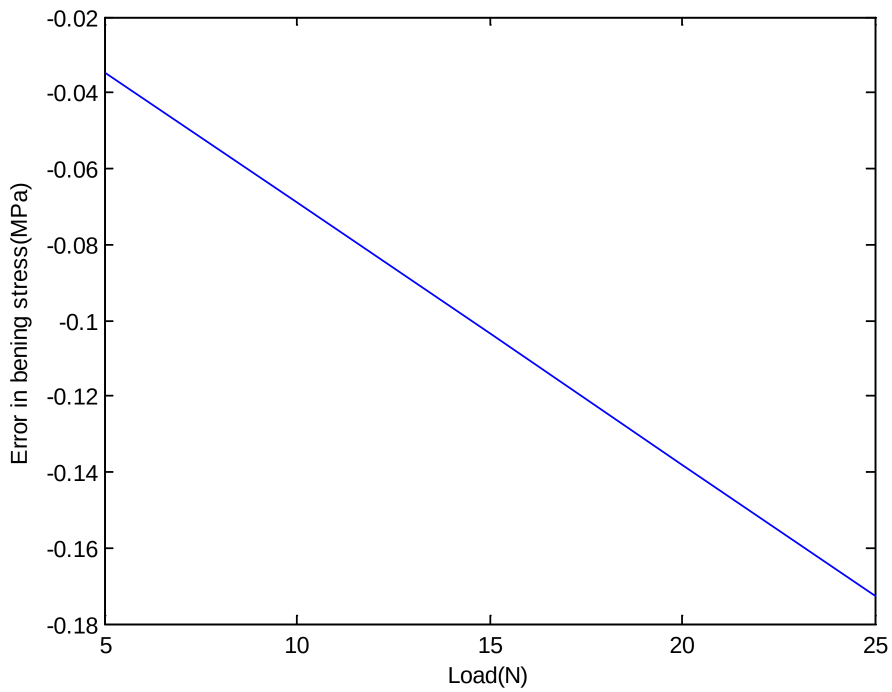


Fig 2 the variation of error in stress with respect to load

CONCLUSIONS

In this project the composite beams are manufactured with hand layup process. A glass CSM, roving fibers are reinforced into the epoxy resin.The deflection and bending stress in composite beam with different loads are investigated experimentally and Numerically.

In this project the density, weight, volumefraction, longitudinal young's modulus, transverse young's modulus, shear modulus, and Poisson's ratio are calculated for the beams by considering elastic and mass properties of glass fiber and epoxy resin .Analytical method is purposed to evaluate stress and deflections of composite beam with cantilever arrangement.MATLAB CODES are used to implement the analytical expressions that are derived.

Bending tests are conducted with a load range from 5-25N .The experimental values of deflection and bending stress are compared with the numerical values obtained by mat lab codes.The tensile strength of beam also tested with standard UTM test procedure.

Simulation studies also carried out on beams having different orientations like ($0^0, 30^0, 45^0$).It is found that unidirectional fibers ($\theta = 0^0$) contributing less deflections and less bending stresses in the glass/epoxy composite beam.It is found that increasing number of layers in beam with overall same cross-section dimensions ,same increases bending stresses and decreases deflections.

ISSN 2348 – 7968

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