Effect of Angle Ply Orientation On Tensile Properties Of Bi Directional Woven Fabric Glass Epoxy Composite Laminate

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ABSTRACT:
This work investigates that the effects of angle ply orientation on tensile properties of a woven fabric bi-directional composite laminate experimentally. Laminated Composite materials have characteristics of high modulus/weight [1] and strength/weight ratios, excellent fatigue properties, and non-corroding behaviour. These advantages encourage the extensive application of composite materials, for example, in wind turbine blades, boat hulls, automobiles, water tanks, roofing, pipes and cladding. and aerospace. The understanding of the mechanical behaviour of composite materials is essential for their design and application. Although composite materials are often heterogeneous, they are presumed homogeneous from the viewpoint of macro mechanics and only the averaged apparent mechanical properties [2] are considered. For a transversely isotropic composite material, five elastic constants are necessary to describe the linear stress-strain relationship. If the geometry of the material could be considered as two-dimensional, four independent constants are necessary due to the assumption about the out-of-plane shear modulus or Poisson's ratio. The most common method to determine these constants is static testing. For composite materials, ten types of specimens with different stacking sequences, [3] i.e., (±0^0, ±10^0, ±30^0, ±40^0, ±45^0, ±55^0, ±65^0, ± 75^0, and ±90^0) are fabricated.

In this work, specimens are prepared in the laboratory using compression mould technique with bi-woven epoxy glass as fiber & with epoxy resin as an adhesive. The specimens are prepared for testing as per ASTM standards to estimate the tensile properties.

KEYWORDS: *compression moulding, E-glass, Epoxy, Degree of orientation, Resin, stacking sequence, tensile property,*

I. INTRODUCTION

Composite materials are manufactured from two or more materials to take advantage of desirable characteristics of the components. A composite material, in mechanics sense, is a structure with the ingredients as element transferring forces to adjacent members. In almost all engineering applications requiring high stiffness, strength and fatigue resistance, composites are reinforced with continuous fibres rather than small particles or whiskers. Continuous fiber composites are characterized by a two-dimensional (2D) laminated structure in which the fibres are aligned along the plane (x- & y-directions) of the material,. A distinguishing feature of 2D laminates is that no fibres are aligned in the through-thickness (or z-) direction. The lack of through thickness reinforcing fibres can be a disadvantage in terms of cost, ease of processing, mechanical performance and impact damage resistance.FRP composites can be simply described as multi-constituent materials that consist of reinforcing fibres embedded in a rigid polymer matrix. The fibres used in FRP materials [5] can be in the form of small particles, whiskers or continuous filaments. Most composites used in engineering applications contain fibres made of glass, carbon or aramid. Occasionally composites are reinforced with other fibre types, such as boron, and thermoplastics. A diverse range of polymers can be used as the matrix to FRP composites, and these are generally classified as thermoset (eg. epoxy, polyester) or thermoplastic (eg. polyether-ether-ketone, olyamide) resins. Glass-reinforced plastic or GRP is a composite material made of a plastic (resin) matrix reinforced by fine fibers made of glass. GRP is a lightweight, strong material with very many uses, including boats, automobiles, water tanks, roofing, pipes and cladding.

Furthermore, by laying multiple layers of fiber on top of one another, with each layer oriented (stacking) in various preferred directions, the stiffness and strength properties of the overall material can be controlled in an efficient manner. In the case of glass-reinforced plastic, it is the plastic matrix which permanently constrains the structural glass fibers to directions chosen by the designer

II. PREPARATION OF COMPOSITE LAMINATE BY COMPRESSION MOULDING TECHNIQUE:

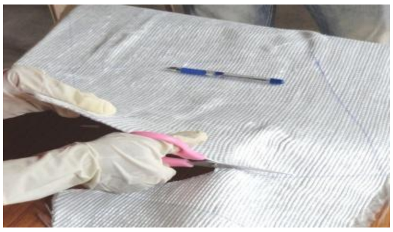
Glass fiber material consisting of extremely thin fibers about 0.005–0.010 mm in diameter. The bi-woven fabrics are available in the standard form 850 GSM. Bi-Woven fabrics are cut to the required size & shape. These are stacked layer [8] by layer of about 4 layers to attain the thickness of 5 mm as per the ASTM D 3039 Standard Specimen. Bonding agent (epoxy resin) is applied to create bonding between 4 layers of sheet. Epoxy is a copolymer; that is, it is formed from two different chemicals. These are referred to as the "resin" and the hardener". The resin consists of monomers or short chain polymers with an epoxide group at either end. The process of polymerization is called "curing", and can be controlled through temperature and choice of resin and hardener compounds; the process can take minutes to hours.

In this work the composite laminate is prepared using compression moulding technique. Here Four plies of E-glass fiber are taken in a symmetric manner i.e. ($+90^0$, - 90^0, -90^0, + 90^0) one over the other and epoxy resin is used as an adhesive. The size of the mould taken is 30 cm × 30 cm.

Type of resin	Epoxy
Type of fiber	E-Glass fiber of Bi-directional type
Hardener used	Lapox K6
No. Plies per laminate	4
Nature of Laminate	Symmetric type (Ex. $+90^0$, - 90^0, -90^0, $+90^0$)
Method of preparation	Compression moulding technique

Table 1: The lists of ingredients to prepare a composite Laminate

Initially the glass fiber is to be cut in required shape of the size 30 × 30 cms of required orientation. Two plies of positive orientation (anti-clockwise) and other two in negative orientation (clockwise) are to be prepared. A thin plastic sheet is used at the top and bottom of the mould in order get good surface finish for the laminate. The mould has to be cleaned well after that PVA (Poly Vinyl Acetate) is applied in order to avoid sticking of the laminate to the mould after curing of the laminate. Then a ply of positive orientation is taken is placed over the sheet. Sufficient amount of resin which is prepared beforehand (hardener of quantity 10% of the resin is to be mixed with the resin and get stirred well) is poured over the ply. The resin poured in to the mould uniformly and it is rolled in order to get the required bonding [4] using a rolling device. Enough care should be taken to avoid the air bubbles formed during rolling. Then on this ply, other ply of negative orientation (clock wise) is placed, after this, other two plies are placed and rolling is done. After the rolling of all plies, the covering sheet (plastic sheet) is placed and the mould is closed with the upper plate. The compression is applied on the fiber- resin mixture by tightening the two mould plates uniformly. Enough care should be taken to provide uniform pressure on the laminate while fixing plates. After enough curing time (7-10 hrs) the laminate is removed from the mould plates carefully.



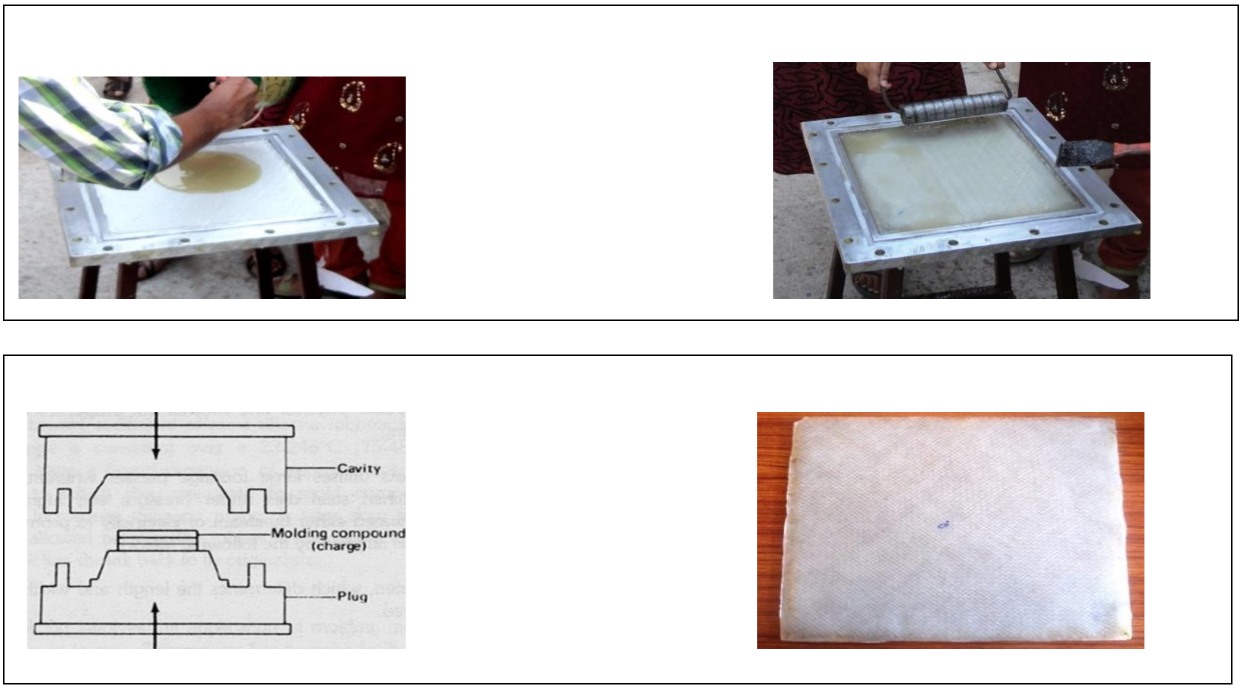


Fig 1: Various steps for preparing a composite laminate

III. PREPARATION OF SPECIMEN FOR THE TENSILE TEST:

After preparing the laminate, in order to find the ultimate tensile strength of the composite laminate[8] conduct the tensile test with UTM, and the specimen is prepared using ASTM standards D3039 The specimen is prepared in dog-bone shape which has a gauge length of 150 mm. The specimens prepared are now tested on the UTM machine and the ultimate tensile strength of the each specimen is determined. As there is a difference in their orientation, each specimen exhibits a definite behaviour during failure

Fig 2: The specimens with different orientations are prepared for tensile test

IV. TENSILE TESTING:

Mechanical characterization of composite materials is a complex scenario to deal with, either because of the infinite number of combinations of fiber and matrix that can be used, or because of the enormous variety of spatial arrangements of the fibers and their volume content. The foundation of the testing methods for the measurement of mechanical properties is the classical lamination theory [6]; this theory was developed during the nineteenth century for homogeneous isotropic materials and only later extended to accommodate features enhanced by fiber-reinforced material, such as in homogeneity, anisotropy, and elasticity. Two basic approaches are proposed to determine the mechanical properties of composite materials: constituent testing and composite sample testing The mechanical tests were carried out in an Universal testing machine. The Universal testing machine is a highly accurate instrument.

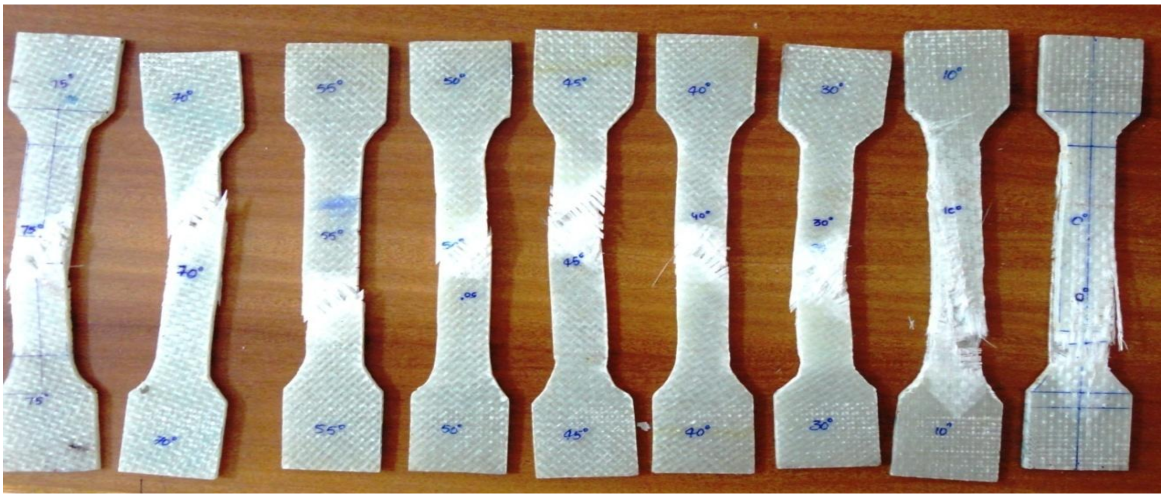


Fig 3: Failure of the Specimens after tensile test

V. RESULTS:

5.1 **X - Axis Displacement (mm) Vs Y- Axis Load in KN (Tensile Test)**

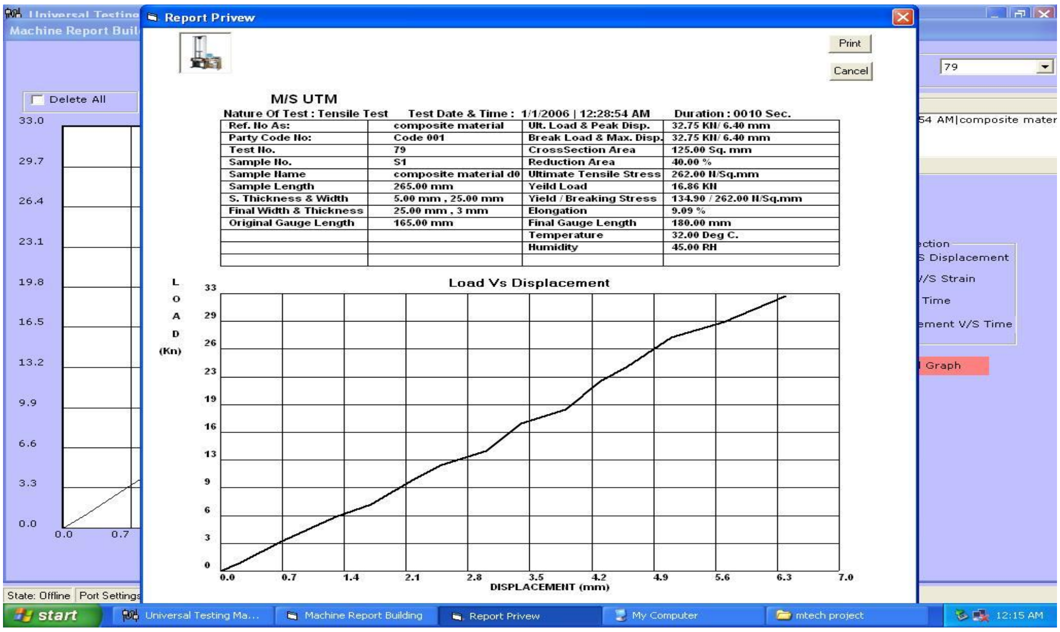


Fig 4: Tensile properties of Bi Directional Woven Fabric Glass fiber with 0^0 orientations

5.2 X- Axis Displacement (mm) Vs Y- Axis Load in KN (Tensile Test)

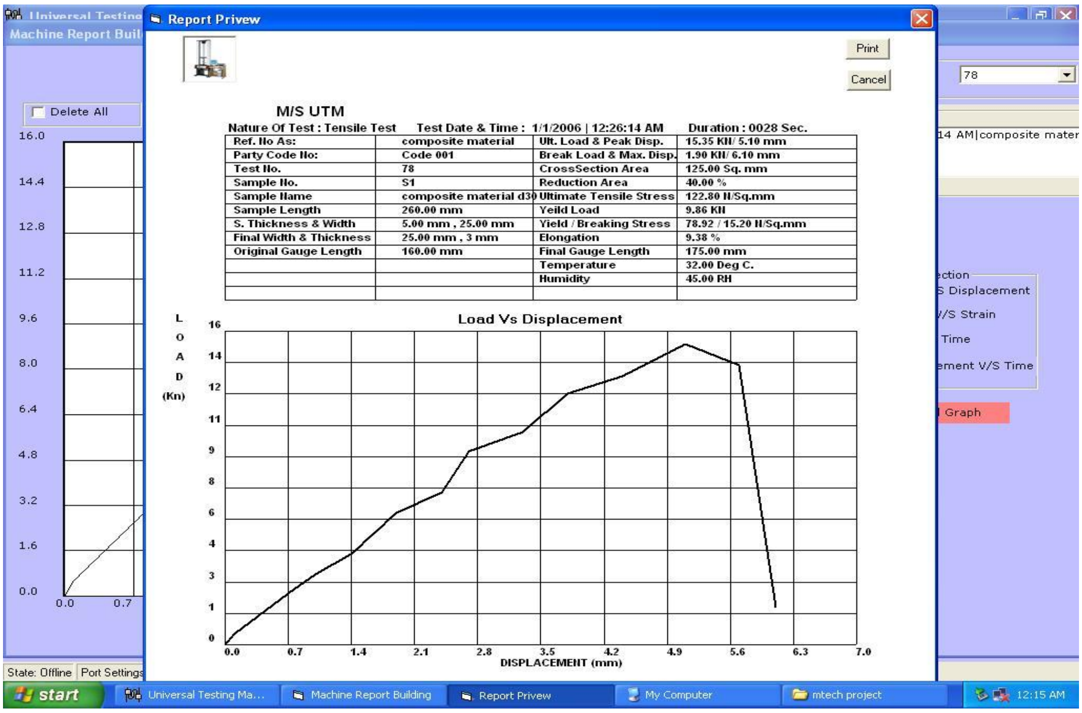


Fig 5: Tensile properties of Bi Directional Woven Fabric Glass fiber with 30^0 Orientation

5.3 X- Axis Displacement (mm) Vs Y- Axis Load in KN (Tensile Test)

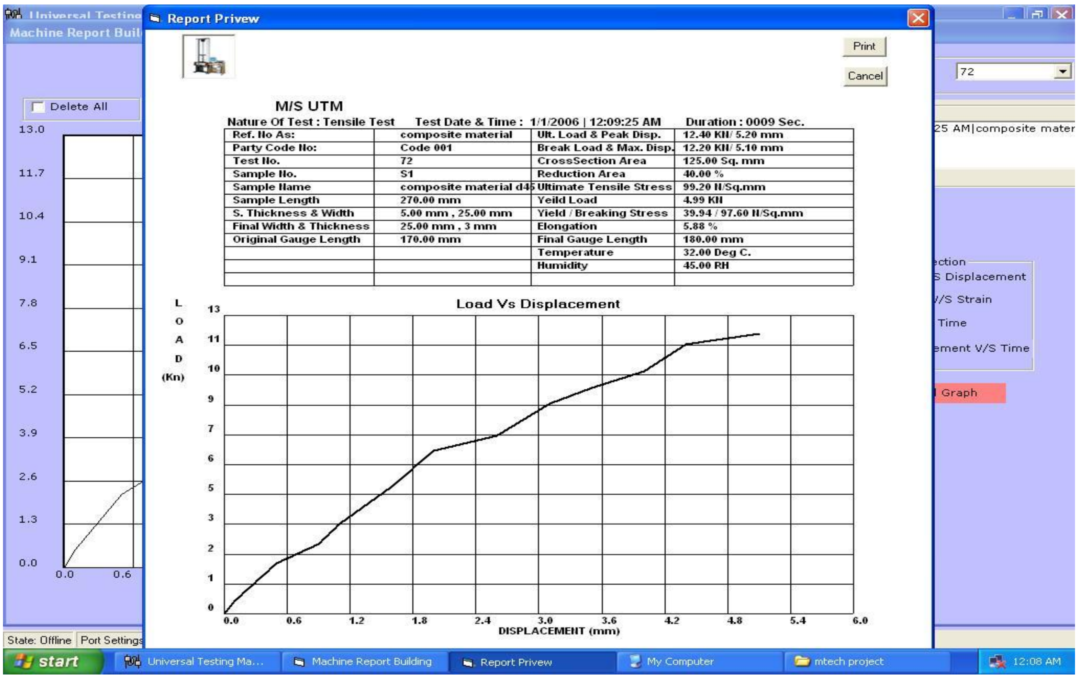


Fig 6: Tensile properties of Bi Directional Woven Fabric Glass fiber with 45^0 Orientation

5.4 X- Axis Displacement (mm) Vs Y- Axis Load in KN (Tensile Test)

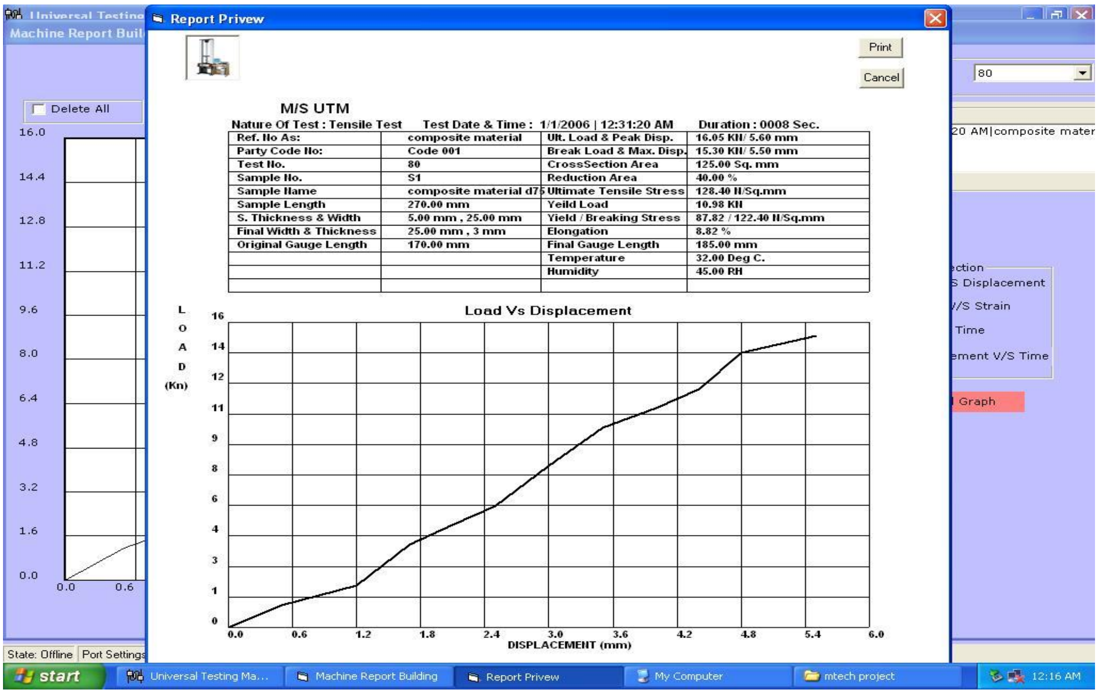


Fig7: Tensile properties of Bi Directional Woven Fabric Glass fiber with 75^0 Orientation

Table 2: Indicates the details of Max Load load, Maximum displacement and Tensile strength

S.No	Bi Directional Woven Fabric with degree of Orientation	Max Load in KN	Max Displacement in mm	Tensile strength in MPA
1	$\pm 0^0$	32.75	15	262.00
2	$\pm 10^0$	24.60	10	196.80
3	$\pm 30^0$	15.35	15	122.80
4	$\pm 40^0$	11.10	15	88.80
5	$\pm 45^0$	12.40	10	92.43
6	$\pm 50^0$	11.85	15	95.60
7	$\pm 55^0$	13.00	10	104.00
9	$\pm 70^0$	18.80	10	118.28
10	$\pm 75^0$	16.05	15	128.40

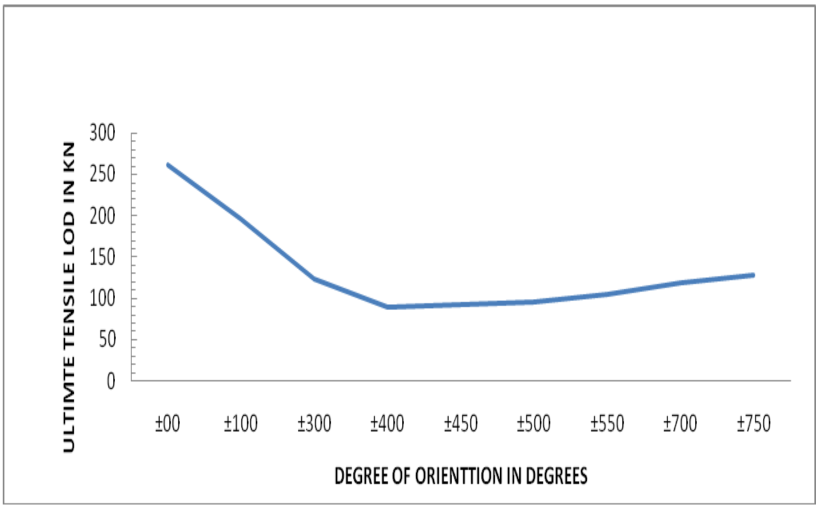


Fig 8: Ultimate Tensile Strength Vs Degree of Orientation

VI. CONCLUSIONS:

Experiments were conducted on bi directional woven fabric Glass/Epoxy laminate composite specimens with varying fiber orientation to evaluate the tensile properties. It is observed from the result that glass/Epoxy with 0^0fiber orientation Yields' high strength when compare to other degree of orientations for the same load, size & shape In addition, we have conducted failure analysis for glass/Epoxy to evaluate different failure modes and recorded. Finally we observe, though glass/epoxy with 00orientation have higher strength, stiffness and load carrying capacity than any other orientation. Hence, it is suggested that fiber orientation with 0^0 is preferred for designing of structures like which is more beneficial for sectors like, wind turbine blades, Aerospace, automotives, marine, space and boat hull etc.

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