Mechanical Properties Testing of Uni-directional and Bi-directional Glass Fibre Reinforced Epoxy Based Composites

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Abstract- Glass Fiber composites are considered to have potential use as a reinforcing material in epoxy polymer based composites because of their good strength, stiffness etc., in present study, mechanical properties for glass fiber composites were evaluated. Here, Glass fiber is the fiber reinforcement and epoxy polymer resin as a matrix material. Composites were prepared with longitudinal (Unidirectional) and cross (Bidirectional) glass fiber reinforced with epoxy based polymer. Mechanical test i.e. compression and tensile test were performed on UTM and the results are reported. The result showed compressive and tensile strength of unidirectional and bidirectional glass fiber reinforced epoxy polymer composites and presented the conclusion.

Index Terms- Glass Fiber, Epoxy polymer resin, compression, tension, Universal Testing Machine (UTM)

1. INTRODUCTION

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. The two constituents are reinforcement and a matrix. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part. The reinforcing phase provides the strength and stiffness. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. The reinforcement is usually a fibre or a particulate. Particulate composites have dimensions that are approximately equal in all directions. They may be spherical, platelets, or any other regular or irregular geometry. Particulate composites tend to be much weaker and less stiff than continuous fibre composites, but they are usually much less expensive. Particulate reinforced composites usually contain less reinforcement (up to 40 to 50 volume percent) due to processing difficulties and brittleness.

A fibre has a length that is much greater than its diameter. The length-to-diameter (*l*/*d*) ratio is known as the *aspect ratio* and can vary greatly [6]. Continuous fibres have long aspect ratios, while discontinuous fibres have short aspect ratios. Continuous-fibre composites normally have a preferred orientation, while discontinuous fibres generally have a random orientation. Examples of continuous reinforcements include unidirectional, woven cloth, and helical winding, while examples of discontinuous reinforcements are chopped fibres and random mat. Continuous-fibre composites are often made into laminates by stacking single sheets of continuous fibres in different orientations to obtain the desired strength and stiffness properties with fibre volumes as high as 60 to 70 percent. Fibres produce high-strength composites because of their small diameter; they contain far fewer defects (normally surface defects) compared to the material produced in bulk. As a general rule, the smaller the diameter of the fibre, the higher its strength, but often the cost increases as the diameter becomes smaller. In addition, smaller-diameter high-strength fibres have greater flexibility and are more amenable to fabrication processes such as weaving or forming over radii.

Typical fibres include glass, aramid, and carbon, which may be continuous or discontinuous. 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. The matrix (continuous phase) performs several critical functions, including maintaining the fibres in the proper orientation and spacing and protecting them from abrasion and the environment. In polymer and metal matrix composites that form a strong bond between the fibre and the matrix, the matrix transmits loads from the matrix to the fibres through shear loading at the interface. In ceramic matrix composites, the objective is often to increase the toughness rather than the strength therefore; a low interfacial strength bond is desirable. The type and quantity of the reinforcement determine the final properties the highest strength and modulus are obtained with continuous –fibre composites. There is a practical limit of about 70 volume percent reinforcement that can be added to form a composite. At higher percentages, there is too little matrix to support the fibers effectively.

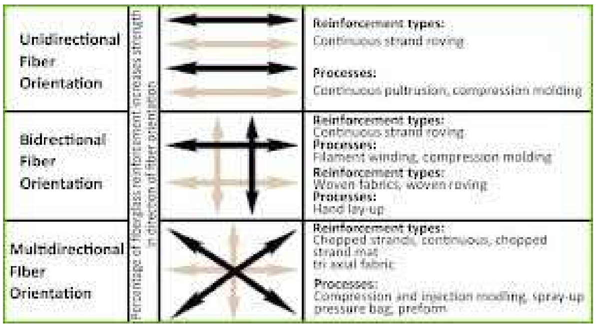
The Theoretical strength of discontinuous-fibre composites can approach that of continuous-fibre composites if their aspect ratios are great enough and they are aligned, but it is difficult in practice to maintain good alignment with discontinuous fibres. Discontinuous-fibre composites are normally somewhat random in alignment, which dramatically reduces their strength and modulus. However, discontinuous-fibre composites are generally much less costly than continuous-fibre composites. Therefore, continuous-fibre composites are used where higher strength and stiffness are required (but at a higher cost), and discontinuous-fibre composites are used where cost is the main driver and strength and stiffness are less important.[6]. Continuous fibres are of three types according to direction of fibres 1. Longitudinal or Uni-directional 2. Transverse or Bi-directional 3. Cross or Multi-directional.

2. EXPERIMENT

2.1 *Elements and Specifications of Composites*

There are a number of reinforcement materials and the selection is done depending upon the properties to be imparted to the end product. Major fibres are used as reinforcement materials such as Glass Fibre, Carbon

Figure 1. Fiberglas (Left), Kevlar (Middle),



And Carbon fibre (Right)

Figure 2 Different Glass Fiber orientations

or Graphite fiber, Kevlar or Armid fiber etc. Glass for reinforcement is available in several forms like fibers, rovings, chopped strands, yarn and mats. A particular form is chosen depending on the moulding methods and properties to be imparted to end products. Element of Polymer composite are Glass fiber, hardener, Epoxy Resin, Releasing agent.

2.1.1 *Glass Fibre*

Fibre glass has a white colour and is available as a dry fibre fabric as shown in Fig.1. Four major types of Glass Fibre used for composites: **E-glass:** have good strength & electrical resistivity. **S-glass:** have 40% higher strength, better retention of properties at elevated temperatures. **C-glass:** have corrosion resistant. **Quartz:** have low dielectric properties, good for antennae. There are in two different types of form we put glass fibre.

Unidirectional

Unidirectional tapes have been the standard within the aerospace industry for many years, and the fibre is typically impregnated with thermosetting resins. Tape products have high strength in the fibre direction and virtually no strength across the fibres. The fibres are held in place by the resin. Tapes have a higher strength than woven fabrics. As shown in fig.2

Bi-directional

Most fabric constructions offer more flexibility for layup of complex shapes than straight unidirectional tapes offer. Fabrics offer the option for resin impregnation either by solution or the hot melt process. Generally, fabrics used for structural applications use like fibers or strands of the same weight or yield in both the warp (longitudinal) and fill (transverse) directions. For aerospace structures, tightly woven fabrics are usually the choice to save weight, minimizing resin void size, and maintaining Fiber orientation during the fabrication process.

2.1.2 *Thermosetting Resin*

Resin is a generic term used to designate the polymer. The resin, its chemical composition, and physical properties fundamentally affect the processing, fabrication, and ultimate properties of a composite material. Thermosetting resins are the most diverse and widely used of all man-made materials. They are easily poured or formed into any shape, are compatible with most other materials, and cure readily (by heat or catalyst) into an insoluble solid. Thermosetting resins are also excellent adhesives and bonding agents. Epoxy resin is mostly used.

Figure 2. Glass Fiber

Epoxy resin

Epoxy resins are much more expensive than polyester resins because of the high cost of the precursor chemicals most notably epi chloro hydrin. However, the increased complexity of the 'epoxy' polymer chain and the potential for a greater degree of control of the cross linking process gives a much improved matrix in terms of strength and ductility. Most epoxies require the resin and hardener to be mixed in equal proportions and for full strength require heating to complete the curing process. This can be advantageous as the resin can be applied directly to the fibres and curing need only take place at the time of manufacture. And known as pre-preg or pre impregnated fibre.

Epoxy polymers are made by reacting epichlorohydrin with bisphenol-A in an alkaline solution which absorbs the HCl released during the condensation polymerisation reaction. Each chain has a molecular weight between 900 and 3000 with an epoxide grouping at each end of the chain but none within the polymer chain.

The epoxy is cured by adding a hardener in equal amounts and being heated to about 120°C. The hardeners are usually short chain diamines such as ethylene diamine. Heat is usually required since the cross linking involves the condensation of water which must be removed in the vapour phase.

Figure 3. Epoxy Resin

Figure 4. Hardener

2.1.3 *Hardener*

A substance or mixture added to plastic composition to promote or control the curing action by taking part in it. Also, a substance added to control the degree of hardness of the cured film.

2.1.4 *Releasing Agent*

It is oil obtain from the engine after burn which is used for easily Removal of Specimen from the mould.

2.1.5 *Compositions of composite material*

Compositions of composite material for preparation of sample for Testing are purchased from market of Delhi, India and are shown in table No.1

Table 1 Composition of composite material

S.No.	**Material for composition**	**Specification**	**Mix ratio by weight**
1	Epoxy Resin	Araldite-AW-106	1 Liter
2	Hardener	HV-953	0.8 Liter
3	Glass Fiber	E-Glass (E-300) 2.5 gm/cm^3	75 gm per sample

2.2 *Fabrication of composite material*

The fabrication of the polymer matrix composite was done at room temperature. The required ingredients of resin and hardener were mixed thoroughly in beaker as shown fig.5 and the mixture so made was transferred to mould cavity of the mould and the mould tightened with the help of nuts & bolts.

2.2.1. *Dough Preparation*

The required mixture of resin & hardener were made by mixing them in (10:8) parts in a beaker by stirring the mixture in a beaker by a rod taking into care that no air should be entrapped inside the solution.

2.2.2 *Mould preparation*

Two wooden moulds of size 310 X 185 X 10 (mm) were used for casting of polymer matrix composite slabs. The moulds made of pressed wood. The mould comprises of two plates one top & other bottom & third rectangular mould cavity inside. After that by placing the three pieces together drill the holes & then it has to be tightened by nuts & bolts as shown in fig.6. Each mould has four samples each sample has size of 300 X40 X10 mm.


Figure 5. Mixing of Resin & Hardener

2.2.3 *Castings of samples*

The dough prepared was transferred to mould cavity by care that the mould cavity should be thoroughly filled. Leveling was done to uniformly fill the cavity.

Figure 6. Mould Assembly

2.2.4 *Curing*

Curing was done at room temperature for approx. 24 hrs. After curing the mould was opened slab taken out of the mould and cleaned.

2.3 *Material Properties testing of composite material*

Compression & Tensile tests were carried out using Universal Tensile testing machine & Tensile testing machine respectively for Samples of Unidirectional and bidirectional oriented glass fiber reinforced epoxy resin based polymer composite. Each test have two sample from Unidirectional and two samples from bidirectional glass fiber composite materials so total four samples are required from unidirectional and four samples from bidirectional composites are required.

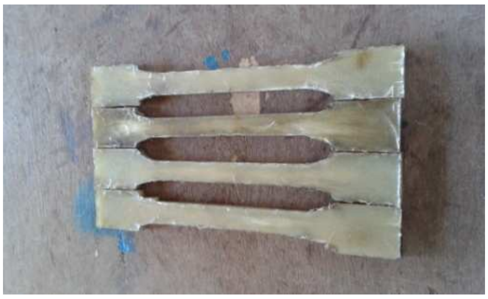


Figure 7. Prepared samples (Uni-directional)

2.3.1 *Compression Test*

The values of Compression strength of specimen Composite material with different Alignment of fiber is given in Table 2. Compression Test was carried out on UTM as shown in fig.8

Table 2 Result from compression test with average of value from two samples

Specimen	**Ultimate force(KN)**	**Compressive strength, (MPa)**
Uni-directional	10.4	52
Bi-directional	2.8	14

Figure 8. Compression test on samples

2.3.2 Tension *Test*

The tensile test on unidirectional and bidirectional glass fiber samples were performed on two specimens of each prepared Composites material as shown in fig.9 and the tensile strength, ultimate force, yield force and elongation were obtained and given in table no.3

Table 3 Result from Tensile test with average of value from two samples

Specimen	**Yield force (KN)**	**Ultimate force (KN)**	**Tensile strength (MPa)**	**Elongation Δ (mm)**
Uni-directional	2.125	3.375	16.87	0.75
Bi-directional	1.425	1.615	8.07	0.25

Figure 9. Tensile test on samples

3. RESULTS AND DISCUSSION

Fabricated materials have been tested on Universal Testing Machine for find out the value of tensile strength, Compressive strength yield force, ultimate force and Elongation with different alignment of fiber.

The tensile test & Compression test in longitudinal direction was performed on four specimens of each prepared composites material and the Yield Force, Ultimate force, Elongation, Tensile strength & Compressive strength and obtained. It may be noted that the test was successful because in the all tested specimens the fracture occurred in the middle of the specimen. The calculated values of the Compressive strength and its corresponding value are given in Table 2. And the values of tensile strength and its corresponding value in table 3.

3.1 *Result of different values of compression test on graph*

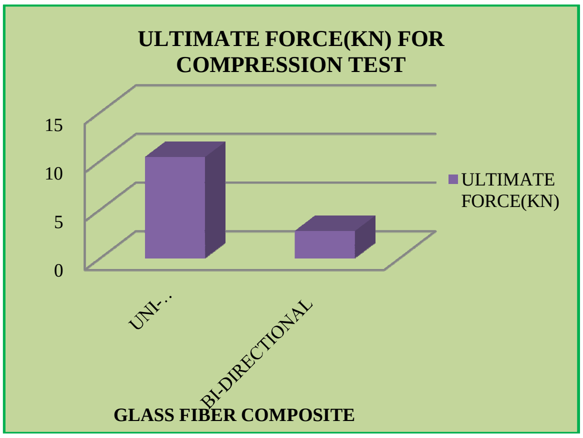


Figure 10. Values of ultimate forces

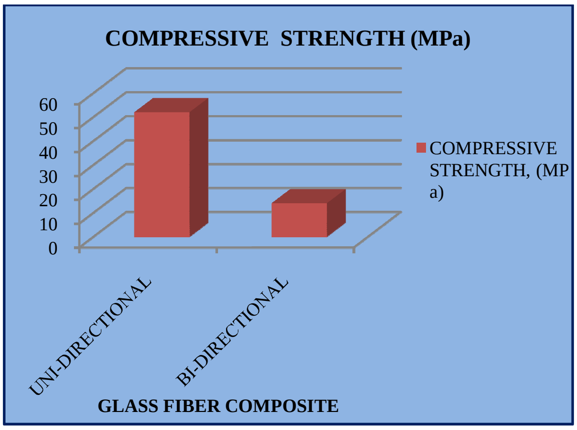


Figure 11. Values of compressive strength

Result shows in fig. 10, the value of ultimate force in case of unidirectional alignment is greater than the ultimate force in bidirectional Alignment and result shows in fig 11, The value of Compressive strength in case of unidirectional alignment is greater than the Compressive strength in bidirectional alignment.

3.2 *Result of different values of tension test on graph*

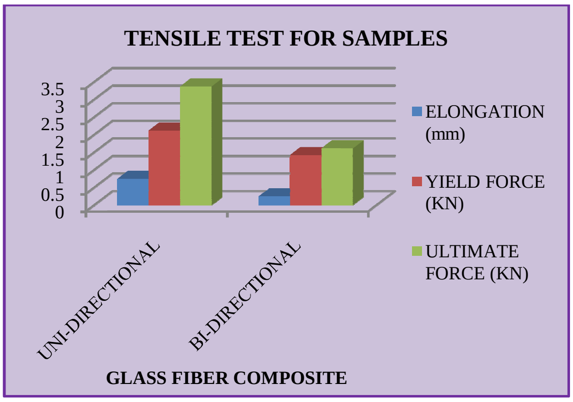


Figure 12. Values of ultimate forces, yield force and elongation

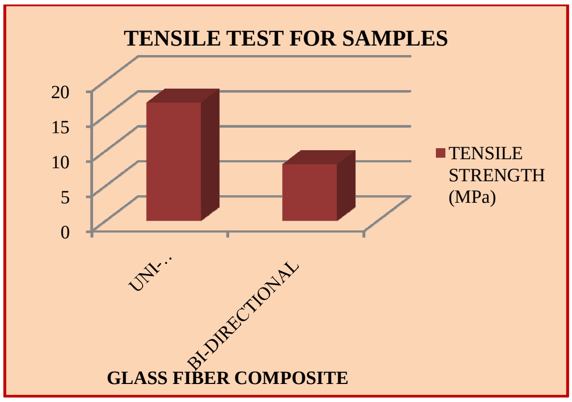


Figure 13. Values of Tensile strength

Result shows in fig. 12, shows that the value of Elongation, yield force and Ultimate force in case of unidirectional alignment is greater than the bidirectional alignment and fig.13 shows that the value of Tensile strength in tensile test greater in unidirectional orientation of glass fiber reinforced epoxy based polymer composites.

4. CONCLUSION

In all the testing of properties of material as compression and tension on samples of uni-directional and bi-directional glass fiber reinforced epoxy resin based polymer composites, following points have been concluded.

- Unidirectional oriented glass fiber reinforced epoxy composites have large value of all the properties such as Ultimate force, yield force, Compressive strength, Tensile strength, elongation etc. in tensile as well as compression test. It means unidirectional oriented glass fiber composites have more strength than Bidirectional.
- The comparison between result of both the fig.10 &12 shows that the value of ultimate force in Compressive test is greater than the value of ultimate force in Tensile test in case of unidirectional alignment & bidirectional

alignment. It means Compressive strength is more in Glass fiber based epoxy composites.

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