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## **Fabrication and Evaluation of Properties of Glass Fiber Reinforced Polymer Composites**

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### **ABSTRACT**

*The present work examines the mechanical properties of glass fiber reinforced polymer composites. Fiber-reinforced polymer composites have played a dominant role for a long time in a variety of applications for their high specific strength and modulus. The fiber which serves as a reinforcement in reinforced plastics may be synthetic or natural. Previous studies shows that only synthetic fibers such as glass, carbon etc., have been used in fiber-reinforced plastics. Although glass and other synthetic fiber reinforced plastics possess high specific strength, their fields of application are very limited because of their inherent higher cost of production. This work describes the mechanical properties and development of a new set of synthetic fibers based polymer composites consisting of coir as reinforcement and liquid epoxy resin. Experiments are carried out to study the effect of fiber length on mechanical behavior of these epoxy resin based polymer composites.*

### **KEYWORDS**

*Glass fiber, epoxy, specific strength, modulus.*

### **1.0 INTRODUCTION**

The quest for increased performance and efficiency in the aerospace industry has resulted in the need to utilize composite materials in a greater percentage of structural components. The high strength to weight and stiffness to weight characteristics of fibre reinforced, polymer matrix composites (P.M.C's) has made them desirable for use in aerospace applications, where weight savings are crucial. 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.

Fibre-reinforced polymer (FRP), also Fibre-reinforced plastic, is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass, carbon, or aramid, although other fibres such as paper or wood or asbestos have been sometimes used. The polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic, and phenol formaldehyde resins are still in use. FRPs are commonly used in the aerospace, automotive, marine, and construction industries.

Composite materials are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct within the finished structure. Most composites have strong, stiff fibres in a matrix which is weaker and less stiff. The objective is usually to make a component which is strong and stiff, often with a low density.

Commercial material commonly has glass or carbon fibres in matrices based on thermosetting polymers, such as epoxy or polyester resins. Sometimes, thermoplastic polymers may be preferred, since they are mouldable after initial production. There are further classes of composite in which the matrix is a metal or a ceramic. For the most part, these are still in a developmental stage, with problems of high manufacturing costs yet to be overcome. Furthermore, in these composites the reasons for adding the fibres (or, in some cases, particles) are often rather complex. For example, improvements may be sought in creep, wear, fracture toughness, thermal stability, etc.

Fibre reinforced polymer (FRP) are composites used in almost every type of advanced Engineering structure, with their usage ranging from aircraft, helicopters and spacecraft Through to boats, ships and offshore platforms and to automobiles, sports goods, chemical Processing equipment and civil infrastructure such as bridges and buildings. The usage of FRP composites continues to grow at an impressive rate as these materials are used more in their existing markets and become established in relatively new markets such as biomedical devices and civil structures. The applicability of Fibre Reinforced Polymer (FRP) reinforcements to concrete structures as a substitute for steel bars or pre-stressing tendons has been actively studied in numerous research laboratories and professional organizations around the world. FRP reinforcements offer a number of advantages such as corrosion resistance, nonmagnetic properties, high tensile strength, lightweight and ease of handling. However, they generally have a linear elastic response in tension up to failure (described as a brittle failure) and a relatively poor transverse or shear resistance. They also have poor resistance to fire and when exposed to high temperatures. They lose significant strength upon bending, and they are sensitive to stress-rupture effects. Moreover, their cost, whether considered per unit weight or on the basis of force carrying capacity, is high in comparison to conventional steel reinforcing bars or pre-stressing tendons.

## 2.0 MATERIALS REQUIRED FOR FABRICATION OF COMPOSITE:

### 2.1 GLASS FIBER

Glass fiber is a material consisting of numerous extremely fine fibers of glass. It is marketed under the trade name Fiberglas, which has become a genericized trademark. Glass fiber when used as a thermal insulating material, is specially manufactured with a bonding agent to trap many small air cells, resulting in the characteristically air filled low density "glass wool" family of products.

Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. Although not as strong or as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites. Glass fibers are therefore used as a reinforcing agent for many polymer products. To form a very strong and relatively lightweight fiber reinforced polymer (FRP) composite material called glass reinforced plastic (GRP), also popularly known as "fiberglass". This structural material product contains little or no air or gas, is denser, and is a much poorer thermal insulator than is glass wool.

#### 2.1.1 Chemical Compositions:

**Table 1: Composition of Selected Glass Fiber**

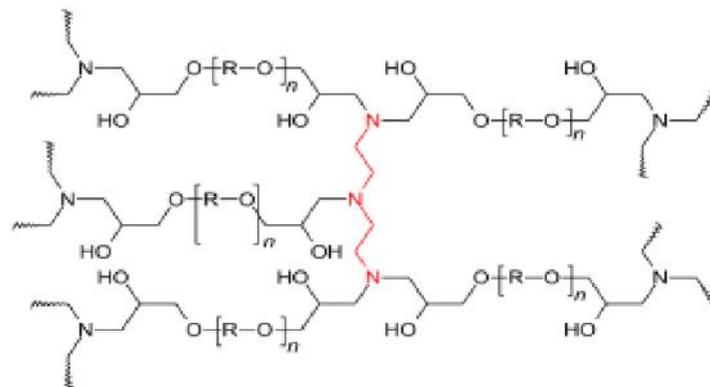
S.No	Element	Percentage (%)
1	SiO <sub>2</sub>	64-66
2	Al <sub>2</sub> O <sub>3</sub>	24-26
3	MgO	8-12
4	Na <sub>2</sub> O	0-0.1
5	Zr <sub>2</sub> O <sub>3</sub>	0-1
6	Fe <sub>2</sub> O <sub>3</sub>	0-0.1

### 2.1.2 Properties of Glass Fiber

Glass fibers are useful because of their high ratio of surface area to weight. However, the increased surface area makes them much more susceptible to chemical attack. By trapping air within them, blocks of glass fiber make good thermal insulation, with a thermal conductivity of the order of 0.05 W/(mK). The strength of glass is usually tested and reported for "virgin" or pristine fibers those which have just been manufactured. The freshest, thinnest fibers are the strongest because the thinner fibers are more ductile. The more the surface is scratched, the less the resulting tenacity. Because glass has an amorphous structure, its properties are the same along the fiber and across the fiber. Humidity is an important factor in the tensile strength. Moisture is easily adsorbed, and can worsen microscopic cracks and surface defects, and lessen tenacity. In contrast to carbon fiber, glass can undergo more elongation before it breaks. There is a correlation between bending diameter of the filament and the filament diameter. The viscosity of the molten glass is very important for manufacturing success. During drawing (pulling of the glass to reduce fiber circumference), the viscosity should be relatively low. If it is too high, the fiber will break during drawing. However, if it is too low, the glass will form droplets rather than drawing out into fiber.

### 2.2 EPOXY RESIN

Epoxy is either any of the basic components or the cured end products of epoxy resins, as well as a colloquial name for the epoxide functional group. Epoxy resins, also known as poly epoxides, are a class of reactive prepolymers and polymers which contain epoxide groups. Epoxy resins may be reacted (cross-linked) either with themselves through catalytic homo polymerisation, or with a wide range of co-reactants including polyfunctional amines, acids (and acid anhydrides), phenols, alcohols and thiols. These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing. Reaction of poly epoxides with themselves or with polyfunctional hardeners forms a thermosetting polymer, often with high mechanical properties, temperature and chemical resistance. Epoxy has a wide range of applications, including metal coatings, use in electronics / electrical components/LED, high tension electrical insulators, paint brushes manufacturing, fibre-reinforced plastic materials and structural adhesives.



**Figure 1: Chemical Structure of Epoxy Resin**

### 2.3 HARDENER

Hardener is a substance mixed with paint or other protective covering to make the finish harder or more durable. It is a curing agent for epoxies or fibreglass. An agent which does not enter into the reaction is known as a catalytic hardener or catalyst. A reactive curing agent or hardener is generally used in much greater amounts than a catalyst, and actually enters into the reaction.

Hardener is usually classed as a corrosive, and as an irritant when in contact with the skin or by inhalation. The used Hardener is Araldite HV 953 U for the Manufacturing process.

### 3.0 PROCEDURE OF FABRICATION OF COMPOSITE:

There are different types of fabrication methods/process to form a fiber composite. But here we are using vacuum bagging process for fabrication of fibers. The fabrication process of fiber composites are as follows:

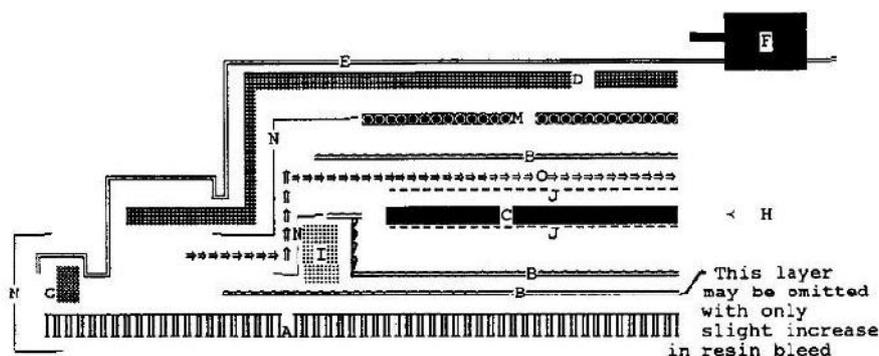
First of all we have to form a fiber composite by using hand layup method. Hand Lay-up process was the method employed for the hybrid composite formation. It is the simplest method for the preparation of composites. The infrastructural requirement is also minimal for this method. The processing steps are quite simple and are follows.

- ) Initially, put thin plastic sheets as the base to get good surface finish of the product.
- ) Reinforcement in the woven mats or chopped strand mats form is cut as per the required size of 250 x 250 mm.
- ) Prepare the matrix by mixing resin and hardener in a proper ratio and spread it over plastic sheets provided as base by means of a brush.
- ) Now place the reinforcement above resin applied at the plastic sheet. The resin should spread properly by means of rollers to get a good base and also excess resin can be removed by the usage of rollers.
- ) Apply resin over the base layer and place layers in alternate order by placing resin in between them and roll it effectively.

After the completion of the above step then follow the vacuum bagging process. It was as follows:

- ) Then place the peel ply on the top most layers by adding mixed resin and hardener in between the layers.
- ) Then place the breather on the component.
- ) Then the top portion of the base plate is covered by means of a plastic sheet/bagging cover by using sealant tape.
- ) Then put the vacuum pump suction pipe in between the breather and bagging cover and seal it with sealant tape to act as a air leakage resistance as shown in figuer.3.11.
- ) The prepared specimen is kept at room temperature is provided.
- ) Then run the vacuum pump up to desired time.
- ) The running time mainly depends upon the type of polymer used for composite formation.
- ) After the desired time of running of vacuum pump, then remove the vacuum bagging cover and the developed composite part is taken out.
- ) Then the prepared stacked composite specimen is cut into ASTM standard specimens by means of a cutter.

The area being used for the layup on the base plate should be bordered with the damming material. The caul plate should be the exact size of the layup area so it can be used as a guide to attach the cork tape around. Adding the rest of the layers as depicted in figure.3 building from the bottom up. Ensuring that the caul plate fits securely after adding each layer of material can help to compress the stack up and ensure everything is in properly.



**Figure 2: Vacuum Bagging Process**

**Key**

A	Base Plate	J	Peel Ply (used on panels that undergo secondary bonding)
B	TFE Film	K	Bleeder cloth (may be several plies)
C	Laminate	L	Release Fabric
D	Air Breather	M	Caul Plate
E	Vacuum Bag	N	High Temperature Tape
F	Vacuum Coupling	O	Breather string (optional along non 0° edges of laminate to provide a path for volatile escape. String must contact air breather).
G	Sealant	P	25 mm (1 in.) wide bleeder cloth
H	Thermocouple		
I	Dam		

When pulling a vacuum on the layup, a venturi will often pull enough pressure but a vacuum pump can be used to get higher pressure if desirable. Always be sure to test the vacuum to make sure that there are no leaks as these can lead to poor result during the layup. This mold should then be placed into an electronically controlled oven programmed to the desired curing temperature. In order to prevent damage from thermal strains, the temperature ramp up and down rates should be set to 3 degrees F per minute.

After demolding the films, tapes, and peel ply should all be discarded. Assuming no resin cured in the breather, that can be reused and if there is no visible damage to the resin dams they are okay to be reused.

Machining the composite specimens from the flat composite plate produced needs to be done carefully. Using a water jet, you can cut out the profiles of the specimens, with about 0.040 in of excess material on each side to be machined off later. Additionally ensure that a 2 inch radius around the location of piercing is discarded in a later operation because the piercing operation tends to cause delamination in the specimen. ASTM recommendations for other machining operations can be seen in table 1. Use of abrasive diamond grit cutting wheels is highly recommended as these tend to be very clean cuts without damaging the material. Using a CNCmill for the final cutting of the material will provide clean cuts and a precise geometry to the final specimen. Ensure that the CNC is using a sharp bit, and that you are cutting with a 0.020 in depth of cut and a maximum chip size of 0.006 in.

#### 4.0 MECHANICAL CHARACTERIZATION:

**4.1 TENSILE STRENGTH:** The tensile test was performed in accordance with ASTM D3039. The test specimen size was 250 mm × 25 mm × 4 mm. The test was performed on a universal testing machine (UTM) of 10-tonne capacity. The flat specimens of required size were fixed between the grips of each head of the testing machine in a way that the direction of force applied to the specimen is coincident with the longitudinal axis of the specimen. The strain rate was so selected so as to produce the failure from 1 to 10 min:

$$\text{Tensile Strength} = \frac{W}{BD}$$

W = Load in Kgs, B = Breadth in cm, and D = thickness in cm.

**Table 2: Tensile Strength of test specimen**

S.No	Ultimate strength, MPa	Ultimate Load, KN
01	455.760	54.600
02	451.842	53.340
03	518.377	59.520

#### 4.2 FLEXURAL STRENGTH:

The flexural test was performed in accordance with ASTM D 790-2003. The test specimen size was 125 mm × 13 mm × 4 mm. The test was performed on a universal testing machine (UTM) of 60-tonne capacity.

$$\text{Flexural Strength} = \frac{3pl}{2bd^2} \text{ N/mm}^2$$

The transverse bending test is most frequently employed, in which a rod specimen having either a circular or rectangular cross-section is bent until fracture using a three point flexural test technique.

The three points bending flexural test provides values for the bending modulus  $E_f$ , flexural strength  $f$ , flexural strain  $f$  and the flexural (bending) stress-strain response of the material. The ease of the specimen preparation and testing is main advantage of a three-point flexural test. However, the results of the testing method are sensitive to specimen and loading geometry along with strain rate which are certain disadvantages of this method.

The method for conducting the test usually involves a specified test fixture on a universal testing machine. The sample is placed at a set distance apart on two supporting pins and a third pin is provided for loading purpose lowered from above at a constant rate until failure of sample.

**Table 3: Flexural Strength of test specimen**

Sl. No	Material	Load, P (N)	L (mm)	3PL	d (mm)	d (mm)	d x d	2bd <sup>2</sup>	Flexural Strength (3pl/2bd <sup>2</sup> ) (N/mm <sup>2</sup> )
1	GFRP	1920	60	345600	13.07	4.52	20.4304	534.05	647.13
2		1980	60	356400	13.04	4.74	22.4676	585.96	608.24
3		2040	60	367200	13.08	4.62	21.3444	558.37	657.63

#### 4.3 HARDNESS TEST

The hardness test was performed in accordance with ASTM D2240. The test specimen size was 50 mm × 4 mm. The test was performed on a Duro meter for shore 'D'.

**Table 4: Hardness Test of test specimen**

Sl.No	Location	Observed Values in SHORE D			
		Impression 1	Impression 2	Impression 3	Average
1	ON SURFACE	84	84	85	84.33

#### 5.0 CONCLUSIONS

The effect of chemical treatment of glass epoxy composite in altering the mechanical properties such as tensile, flexural and hardness has been studied. In this work, an efficient and standard methodology has been established to increase the strength of composite. The process of these experiments increases the mechanical properties of materials under the tensile, compression and flexural Loads. As per the results achieved, there is a improvement in mechanical properties such as in ultimate tensile strength, flexural strength and hardness of the composite. Cost of Glass Fiber Material per meter length is very less as compared to Carbon Fiber Composites.

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