

## **Study on the Mechanical Properties of Glass Fiber Reinforced Polyester Composites**

*A.H.M Fazle Elahi\*<sup>1</sup>, Md. Milon Hossain<sup>2</sup>, Shahida Afrin<sup>3</sup>, Mubarak A. Khan<sup>4</sup>*

<sup>1</sup> Department of Mechanical Engineering,  
Khulna University of Engineering & Technology, Khulna-9203, BANGLADESH

<sup>2</sup> Department of Textile Engineering,  
Khulna University of Engineering & Technology, Khulna-9203, BANGLADESH

<sup>3</sup> Abdur Rab Serniabat Textile Engineering College,  
University of Dhaka, Dhaka-1000, BANGLADESH

<sup>4</sup> Institute of Radiation and Polymer Technology,  
Bangladesh Atomic Energy Commission, Dhaka-1000, BANGLADESH

### **ABSTRACT**

Glass fiber reinforced unsaturated polyester (GFRP) based polymer composite was prepared using hand layup process. Four layers of GF were impregnated by polyester resin and pressed under load of 5kg for a day. Then the fabricated composite were heat treated from 60 degree Celsius to 150 degree for 1 hour and finally taken for mechanical test. Tensile strength, tensile modulus, elongation at break, impact strength, shear strength and hardness of the fabricated composite were measured. The experiment showed wonderful improvement in the mechanical properties of the fabricated composite resulted from the heat treatment. The maximum tensile strength of 200.6 MPa is found for 90°C heat treated sample. Inverse relationship between heat and mechanical properties of the composite was observed above 100°C. Finally, the excellent elevated heat resistant capacity of GFRP composite shows the suitability of its application to heat exposure areas such kitchen furniture materials, marine, electric board etc.

**Keywords:** Glass fiber, Polyester-resin, Composite material, Mechanical Properties test, Tensile test

### **1. Introduction**

Composite materials are one of the most significant inventions of the material sciences. Composite materials are used in furniture, packaging, assembly boards, paneling, fencing, kitchen to civil constructions, automobile and marine industries, military purposes and even space or aircraft manufacturing. So, composites are a versatile and valuable family of materials that can be used in many fields with high quality and low cost applications. Currently, synthetic fiber-reinforced thermoplastic composites are widely used because of their excellent mechanical properties and durability [1]. Composite materials produce a combination property of two or more materials that cannot be achieved by either fiber or matrix when they are acting alone. Fiber-reinforced composites were successfully used for many decades for all engineering applications. Glass fiber-reinforced polymeric (GFRP) composites were most commonly used in the manufacture of composite materials due to their low cost, high tensile strength, high chemical resistance, and insulating properties. The matrix comprised organic, polyester, thermo stable, vinylester, phenolic and epoxy resins. Suitable compositions and orientation of fibers made desired properties and functional characteristics of GFRP composites was equal to steel, had higher stiffness than aluminum and the specific gravity was one-quarter of the steel. The various GF reinforcements like long longitudinal, woven mat, chopped fiber (distinct) and chopped mat in the

composites have been produced to enhance the mechanical and tribological properties of the composites [2-3]. Glass fiber reinforced unsaturated polyester resin (UPR) composite materials have become the alternatives of conventional structural materials, such as wood and steel in some applications, because of its good mechanical properties. Mechanical properties of fiber-reinforced UPR composites depend on the properties of the constituent materials, the nature of the interfacial bonds, the mechanisms of load transfer at the inter-phase and the adhesion strength between the fiber and the matrix [4].

Glass fiber reinforced (GFRP) Composite is the largest segment in the composite industry, worth several billions. Glass fiber is made from extremely fine fibers of glass. It 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. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. The glass fibers are most extensively used as a raw material for composite materials. Glass fiber accounts for about 90% of the reinforcements used in composite consumption, globally. Most of the GFRP Composites are used in construction and transportation sectors. The demand for renewable energy in the form of wind turbines, demand for light-

\* Corresponding author. Tel.: +88-01912-239243; fax: +88-041-774403  
E-mail address: fazle.elahi.ashek@gmail.com

weight fuel efficient aircrafts & cars, and the demand for GFRP pipe, tank and other corrosion resistant equipment are major drivers increasing its demand in the coming years.

## 2. Background

Many researchers investigated the mechanical behavior of GFRP in different media. Environmental and moisture content impact of GFRP was investigated previously [5-6]. Thermal behavior of glass fibers were investigated by many researchers with the change of temperatures which is the basis of the experiment presented in this paper. Shokry studied the effect of five temperature levels (25, 50, 100, 150 and 200°C) as well as three times of exposure (60, 120 and 180 minutes). The experiment showed that temperature has considerable effect on different properties of GRP. The results of the investigations show that the tensile strength, compressive strength and hardness for GPR composite decrease proportionally to temperature increase [7]. Properties of E-glass/epoxy composites at 650°C for 1000 hours were studied by Abdel-Magid et al. The values of module of elasticity, stress-strain was examined and compared with the values obtained at room temperature. A decrease in module of elasticity and break of elongation was noticed from the experiment. The authors concluded that longer exposure of the samples to higher temperatures caused ductile breaks on E-glass/epoxy composites [8]. Behavior of E-glass fiber unsaturated polyester composites, subjected to moderate and high temperatures was investigated by Laoubi et al. [9]. The characterization of the resin and the composite, after heating, revealed that at moderate temperatures (lower than 100 °C) an improvement of the properties of materials is observed in the experiment. A thermogravimetric analysis (TGA) revealed that the thermal degradation of the composite occurs in two steps: the first between 130 and 200 °C and the second between 250 and 440 °C. When the temperature reaches the temperature of decomposition ( $T_d$ ), a fall of the mechanical properties was recorded for both resin and composite. Bisht and Chauhan investigated the effect of temperature on the tensile properties of E-glass/unsaturated polyester composite [10]. It was found from the experiment that temperature and tensile strength is inversely proportional.

The main objective of this experiment is to investigate the influence of various temperature levels of glass fiber reinforced unsaturated polyester composite. Four plies of glass fiber were reinforced to polyester resin and its response to different mechanical properties of the fabricated composite by temperature variations were determined and exhibited in this study.

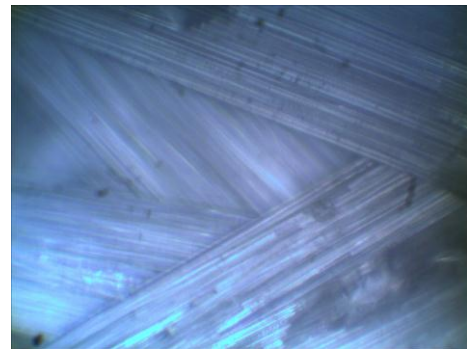
## 3. Experimental

### 3.1 Materials

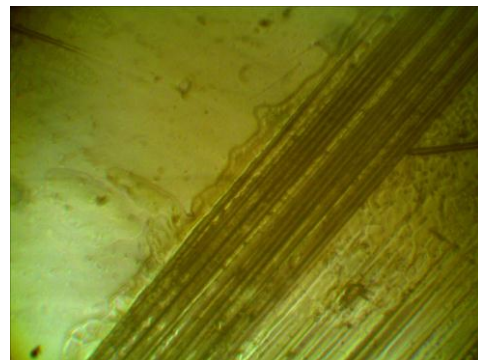
Unsaturated polyester and methyl ethyl ketone peroxide (MEKP) were supplied by Polyolefin Co. Limited; Singapore and E-glass fiber of GSM 300 was purchased from Saint-Gobain Vetrotex, India.

### 3.2 Method of Composite Fabrication

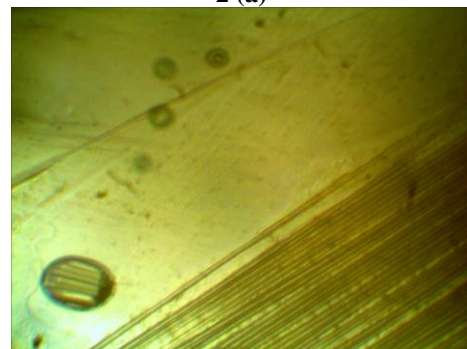
The composite specimens were prepared in open mold cold compression method. Unsaturated polyester resin and MEKP hardener were taken in a beaker. They were then mixed well and made ready for laminating reinforced mats. The composite samples were fabricated by hand lay-up technique. At first, a melot paper was placed on dried bottom part. Then some of the prepared resin mixture was spread evenly on the paper. After that, a piece of non-woven glass was placed on the resin mixture and a part of resin mixture was spread on the mat. Another piece of glass fabric was placed and similarly rest of the resin mixture was spread on the mat and so on. A melot paper was placed on the mat following which top part of the open mold was kept on the paper. The prepared samples were allowed to cure under pressure at room temperature.



**Fig. 1** Microscopic view of glass fiber (1000X)



**2 (a)**



**2(b)**

**Fig. 2** Microscopic view of fabricated composite (1000X)

The above figures are microscopic view at 1000X zoom. Fig. 1 provides information about fiber alignment and shows how the fiber is bonded within different layer. Fig. 2(a) shows the composite surface and the bonding with polyester resin. Fig. 2(b) shows there are some bubbles formed in between the layers during fabrication. The bubble formed part has been omitted from the mechanical test specimen to get precise results.

### 3.3 Mechanical Testing of Composite

Tensile, impact, shear and hardness (BHN) tests were conducted. For each test and type of composites, five specimens were tested and the average values were reported.

#### 3.3.1 Tensile Test:

Tensile tests were conducted according to ASTM D 638-01 [11] using a Universal Testing Machine (Hounsfield series, model: INSTRON 1011, UK) with a cross-head speed of 10 mm/min. The dimensions of the test specimen were (ISO 14125): 60 mm × 15 mm × 2 mm.

#### 3.3.2 Impact Test:

Impact test for different fabricated composites were carried out according to ASTM D-256. The length and width of the samples used in impact test were 61.5 mm and 12.7 mm respectively. Impact strength was calculated using the following formula-

$$\text{Impact strength} = \frac{\text{Impact Energy}}{\text{Area}} = \frac{J}{A}$$

The unit of impact strength is Joule per square meter.

#### 3.3.3 Shear Strength:

The shearing modulus of elasticity is called modulus of rigidity. Shear strength was measured using punch diameter 3.15 mm. The shear strength was calculated according to ASTM D5868 by using the following equation.

$$\text{Shear Strength, } S = \frac{P}{\pi Dt}$$

Where, P = Applied load

D = Diameter of punch

t = Thickness of the composite

#### 3.3.4 Determination of Hardness:

The test was carried out using 305.92 Kg(f) and the diameter of ball indenter was 5 mm. The diameter of the impression produced is measure by means of a microscope containing an ocular, usually graduate in tenths of a millimeter, permitting estimates to the nearest 0.05mm. Hardness is obtained by dividing the applied load by the area of the surface of the indentation, which is assumed to be spherical. If P is the applied load (in kg), D is the diameter of the steel ball indenter (in

mm) and d is the diameter of the indentation (in mm), then Brinell number (BHN) of the composite-

$$\text{BHN} = \frac{P}{\frac{\pi D}{2}(D - \sqrt{D^2 - d^2})}$$

BHN = Brinell hardness number

P = load on the indenting tool (kg)

D = diameter of steel ball (mm)

d = measure diameter at the rim of the impression (mm)

It is desirable that the test load are limited to an impression diameter in the range of 2.5 to 4.75 mm.

## 4. Results and Discussion

Non-woven glass mat was reinforced in thermoset polyester matrix by hand layup process with the fabric content 40%. The mechanical properties such as tensile strength, tensile modulus, elongation at break, were evaluated. Shear strength and hardness of the fabricated composite were also reported in this experiment. Five samples of which four designated as HT 60, HT 90, HT 120 and HT 150 were heat treated from 600C to 1500C for one hour and last one was untreated. The impact of heat on different samples was compared to the untreated sample.

### 4.1 Tensile Strength:

Fig. 3 demonstrates the tensile strength of GFRP before and after exposure to heat. Effects of heat on the composite were recorded and found that sample expose to temperature 900C shows highest tensile strength while sample exposed to heat 1500C shows lowest strength. Tensile strength increases gradually from untreated sample to temperature 900C and then start decreasing with the increase of temperature. This may be due to the internal phase change during heat treatment.

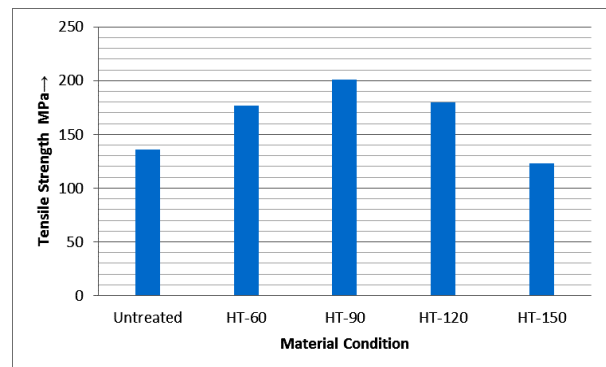


Fig. 3 Tensile strength of GFRP

#### 4.2 Tensile Modulus:

Tensile modulus of GFRP is presented in the Fig. 4. Same pattern of the tensile strength test after the heat treatment is visible here. With the increase of temperature tensile modulus also increased and reaches to the maximum value at 900C compared to untreated sample. Further increase of temperature reduces the tensile modulus of the GFRP and lowest modulus is found at 1500C by value 1.072 GPa. Highest increase of the modulus was found 77.82% at 900C compared to untreated sample. Decreases in strength can be attributed to the hydrolysis of the, disruption of the matrix/fiber interface, and/or degradation of the fibers themselves.

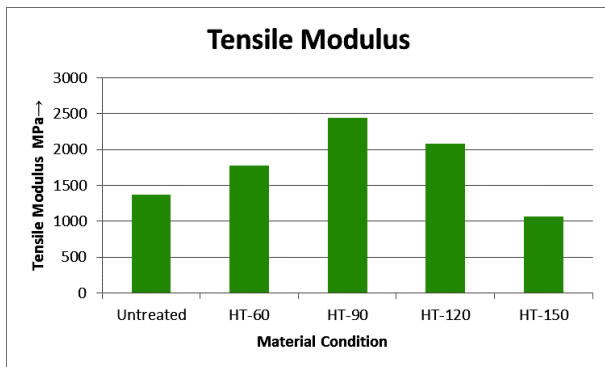


Fig. 4 Tensile modulus of GFRP

#### 4.3 Impact Strength:

Fig. 5 depicts the impact properties of GFRP. Some fluctuation is observed in impact strength with different temperature ranges. Sample treated with 900C shows the highest impact strength of 155.178 KJ/m<sup>2</sup> controversially sample treated with 1500C shows dramatic fall in impact strength by 43.83% compared to untreated sample. Almost zero change is found in the sample treated in initial temperature.

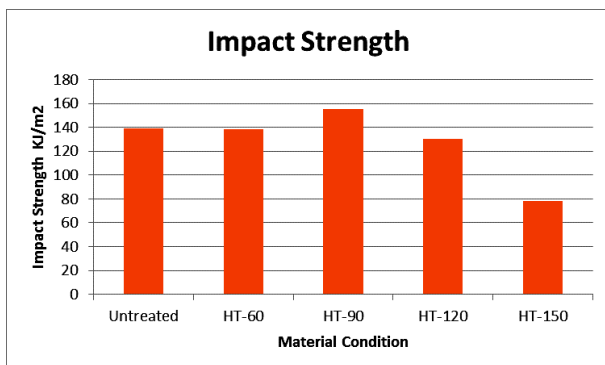


Fig. 5 Impact strength of GFRP

#### 4.4 Elongation at Break:

Elongation at break percentage of GFRP is shown in Fig. 6. Highest elongation is observed in untreated sample by value 21.88%. After heat treatment slight decrease is found in elongation percentages. Negligible effect of

temperature variation is found on elongation at break percentage.

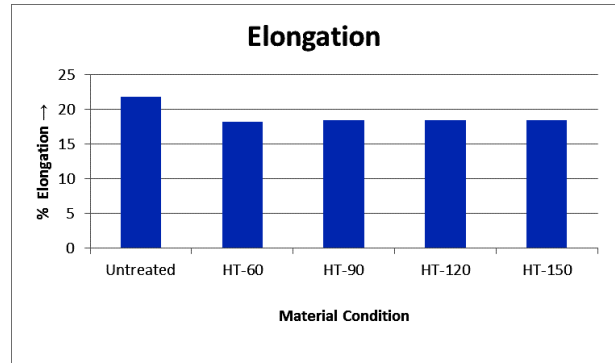


Fig. 6 Elongation at break % of GFRP

#### 4.5 Shear Strength:

Shear strength of GFRP is presented in Fig. 7. An increasing trend in shear strength is observed of GFRP. Temperature is directly proportional to shear strength i.e. with the increase of heat shear strength also increases and reaches to its maximum value 112.742 MPa at 1500C. While all samples shows shear strength greater than 100 MPa untreated sample shows only 96.04 MPa.

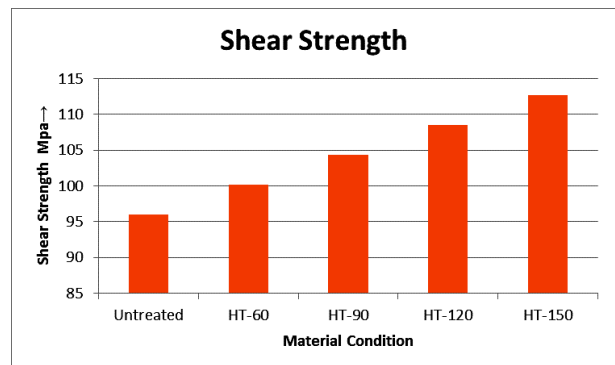


Fig. 7 Shear strength of GFRP

#### 4.6 Hardness:

Fig. 8 depicts the hardness of GFRP. Likewise most of the other properties of GFRP, BHN value of fabricated composite is highest for sample treated at 900C.

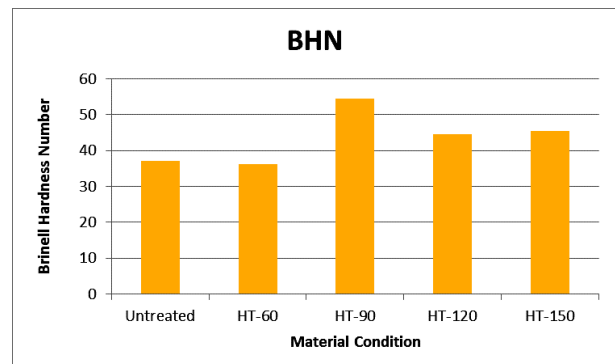


Fig. 8 Hardnes of GFRP

Apparently no change in hardness was visible for the initially heat treated sample. Further increase of temperature increase the hardness of the composite while more temperature reduces the hardness and negligible change is found in the final temperature.

## 5. Conclusion:

The effect of different temperature on GFRP was experimentally investigated. The GFRP were found to be temperature sensitive. Treatment of the composite below 1000C shows highest increase in their different mechanical properties whereas above the boiling temperature there is a huge loss of their mechanical properties. This vivid impact of temperature can be attributed to internal change of fiber matrix adhesion of the composite and evolution of the linkage of resin due to heat.

## References:

- [1] Haydar U. Zaman, Mubarak A. Khan and Ruhul A. Khan, "Physico-Mechanical and Degradation Properties of Banana Fiber/LDPE Composites: Effect of Acrylic Monomer and Starch", *Composite Interfaces* 18 (2011) 685–700.
- [2] TP Sathishkumar, S Satheeshkumar and J Naveen, "Glass fiber-reinforced polymer composites – a review", *Journal of Reinforced Plastics and Composites* 2014, Vol. 33(13) 1258–1275.
- [3] Mariana Etcheverry and Silvia E. Barbosa, "Glass Fiber Reinforced Polypropylene Mechanical Properties Enhancement by Adhesion Improvement", *Materials* 2012,5, 1084-1113
- [4] LUO Weicai, WANG Xiao, HUANG Ronghua, FANG Pengfei, "Interface Enhancement of Glass Fiber/Unsaturated Polyester Resin Composites with Nano-Silica Treated Using Silane Coupling Agent", *Wuhan University Journal of Natural Sciences* 2014, Vol.19 No.1, 34-40
- [5] H. Abdullah, S. Al Araithi and R. A. Siddiqui, "THE EFFECTS OF WEATHERING ON MECHANICAL PROPERTIES OF GLASS FIBER REINFORCED PLASTICS (GRP) MATERIALS", *IIUM Engineering Journal*, Vol. 1, No. 2, 2000.
- [6] P. Sampath Rao, M. Manzoor Hus ain, D. V. Rav i Shankar, "An Investigation on Strength Degradation of Gfrp Laminates Under Environmental Impact", *International Journal of Composite Materials* 2012, 2(4): 48-52.
- [7] Khaled M. Shokry, "Effect of Temperature on Mechanical Properties of Glass Reinforced Plastic GRP", *World Applied Sciences Journal* 31 (7): 1341-1344, 2014
- [8] Beckry Abdel-Magida, Saeed Ziaeea, Katrina Gassb, Marcus Schneiderc, "The combined effects of load, moisture and temperature on the properties of E-glass/epoxy composites", *Composite Structures*, Volume 71, Issues 3–4, December 2005, Pages 320–326.
- [9] K. Laoubia, Z. Hamadia, A. Ahmed Benyahia, A. Seriera, Z. Azari, "Thermal behavior of E-glass fiber-reinforced unsaturated polyester composites" *Composites Part B: Engineering*, Volume 56, January 2014, Pages 520–526
- [10] Devnidhi Bisht, Hemant Chauhan, "Estimating Effects of Temperature on Tensile Strength of Eglass Composite with Unsaturated Orthophthalic Polyester", *International Journal of Emerging Technology and Advanced Engineering*, Volume 4, Special Issue 1, February 2014.
- [11] A. A. Kafi, M. Z. Abedin, M. D. H. Beg, K. L. Pickering and M. A. Khan, "Study on the Mechanical Properties of Jute/Glass Fiber-Reinforced Unsaturated Polyester Hybrid Composite: Effect of Surface Modification by Ultraviolet Radiation," *Journal of Reinforced Plastics and Composites*, Vol. 25, No. 6, 2006, pp. 575-588.