Asian Journal of Chemistry; *Vol. 31, No. 3 (2019), 687-689*

ASIAN JOURNAL OF CHEMISTRY

https://doi.org/10.14233/ajchem.2019.21790

A Comparative Study on the Effect of Hygrothermal Exposure over the Mechanical Strength of Glass Fiber and Hybrid Fiber Reinforced Polyester Composites

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Received: 1 November 2018; *Accepted*: 5 December 2018; *Published online*: 31 January 2019; AJC-19269

A composite material is a combination of two or more different materials and it plays a vital role in a wide range of applications. In automotive and mechanical industries the demand for lighter weight components is increasing day by day. Glass and flax reinforced composites have superior properties such a high tensile strength at any weather conditions. As the composite materials are used in many applications and exposed to harsh environment, the water molecules from the environment may induced in to the material then reinforcements may be affected and which causes damage to the interface bonding. In this work the effect of hygrothermal environment on hybrid fiber reinforced composites are studied, two types of composite laminates are prepared one is glass fiber reinforced composite (GFRC) and the other is glass and flax fiber reinforced hybrid composite (HFRC). Tensile test samples are cut from the laminates prepared as per ASTM D 638 standard and the tensile strength values before and after hygrothermal exposure are identified and compared from the result it is presumed that hybrid materials are showing better resistance towards hygrothermal behaviour compare to mono glass fiber composites.

Keywords: Fiber reinforced composites, Tensile strength, Polyester resin, Hygrothermal testing.

INTRODUCTION

The natural fiber reinforced composite has a rapid growth in research and innovation. These are low environmental impact and potential across wide range applications. The researchers show much effort to increase these materials mechanical performance and factors that affecting its mechanical performance of natural fiber composites. These are biodegradable and eco-friendly in nature. Asian countries being the large agricultural producers, there are a large number of biomaterials easily available as agricultural residuals [1,2]. The applications of green composites in automobile industries have comparable mechanical properties with the synthetic and it has problems due to their decomposable nature to avoid that the hybrid fiber reinforced composite shows better mechanical properties than natural fiber reinforced composites [3]. Mechanical properties of the composites such as tensile strength, flexural strength, impact strength and water absorption rate are influenced by the type of fiber. Hybrid composite acts as an immediate replacement for glass fiber composites [4]. The tribological properties of natural fiber reinforced polymer composites such as jute, kenaf, sisal, coir, rice husk and bio-waste products play an important role in industrial application and the effect of fiber treatment, fiber orientation, fiber volume fraction can improve the tribological properties of natural fiber reinforced polymer composite [5]. The fiber volume fraction plays a significant role in the determination of mechanical properties and the value of the fiber volume fraction is determined considering fibrous structure consistent, yarns and fabric [6].

The tensile strength is based on the fiber treatment and resin used. If there is any existence of heterogeneity in composite it can observe by using scanning electron microscopy. It can avoid volumetric retraction [7]. To predict the deformation of misaligned short flax fiber reinforced polymer matrix composite and perfect bonding of flax fiber in a linear elastic unit cell to yield an accurate prediction of the stress-strain relations in the tension of flax/propylene composites with different fiber volume fractions [8]. The stress-strain curve of a flax fiber upon tensile loading appears markedly non-linear. It has been explained by a visco-elastic-plastic deformation of amorphous polymer within fiber together with a progressive alignment of its cellulose microfibrils with the tensile axis [9]. If the interfacial bonding between the fiber and matrix not adequate it leads to decrease the fatigue life [10]. The alkali treatment of natural fibers such as areca fibers can improve the mechanical properties and fiber treatment can improve the adhesion properties between fiber and matrix simultaneously reduce water absorption. It is useful for small loading application [11]. The effect of alkali treated jute and banana fiber in hybrid polymer matrix composites are analyzed using ANSYS shows a greater tensile strength while compared with untreated jute and banana fiber [12]. The sisal GFRP composites have better for tensile loading and jute-GFRP composites have greater strength in flexural loading. So, the hybrid fibers show better results than the glass fibers [13]. Jute inforced epoxy composite is exhibited better mechanical properties than jute polyester composite. It better suited for automotive applications [14]. Woven jute has high mechanical properties as compared with nonwoven jute fabric reinforced poly(L-lactic) based composite and tensile strength at warp direction than weft direction [15]. Flax fiber is a suitable structural replacement and comparable mechanical properties of E-Glass [16]. The hybrid fiber composite can be used as an alternative for glass fiber composite depend on the strength required by which the synthetic content in polymeric matrix composite [17]. In this work the effect of hygrothermal environment on hybrid fiber reinforced composites are studied, two types of composite laminates are prepared one is glass fiber reinforced composite (GFRC) and the other is glass and flax fiber reinforced hybrid composite (HFRC). The tensile strength values before and after hygrothermal exposure are identified and compared.

EXPERIMENTAL

The raw materials used in this work are glass fiber, flax fiber, polyester resin, methyl ethyl ketone peroxide as catalyst and cobalt as accelerator.

Fabrication of composites [4]**:** Two different types of composite laminates are prepared with different glass and natural fiber. The laminates are prepared by using the hand lay-up method as it is simpler and less costly. Initially, E-glass and flax fiber mats are cut into 300 mm × 300 mm sizes, polyester resin and hardener are mixed in the ratio of 10:1. The laminates prepared three layers of fibers filled in between polyester resin. The voids produce while preparing the laminates are squeezed out using a roller. Three types of composite laminates prepared as shown in Table-1. The highest care has been given to produce a uniform and homogeneous composite laminate of 300 mm × 300 mm × 3 mm.

Testing procedure: Composite laminates prepared are cut into smaller samples of ASTM standards for tensile test procedure. For each type approximately, we have created 12 samples as per ASTM D638 out of that half of the samples we tested the tensile strength directly and remaining we exposed to hygrothermal environment

Hygrothermal test: Samples are cut into the size of (165 mm × 19 mm × 3 mm) in according with ASTM standards D-638. The specimens were tested by using hygrothermal testing equipment, it consist of the container filled with demineralized water of pH value is 7 and TDS value is less than 300. Considering the weather conditions in India, the test temperature for hygrothermal test was fixed as 60 ºC. The specimens were weighed separately by using an electronic balance to avoid sudden impact on specimens we place specimens at 44 ºC and when the temperature reached 60 ºC the specimens were screened to the hygrothermal conditioning for 72 h. After the hygrothermal exposure, the specimens were removed from the container and the excess moisture on the surface were removed after that weighed again and the amount of moisture absorbed are calculated. The specimens were enclosed in aluminium foil to avoid moisture loss (or) moisture gain. The moisture uptake is given by the expression below:

$$W_e(t) = \frac{W_t - W_o}{W_o} \times 100$$

where, W_e is the water absorption percentage, W_t is the weight after time t, and W_o is the initial weight of sample at t = 0.

Tensile test: The tensile test is done using UTM (Universal Testing Machine) with maximum capacity 600KN of FIE Pvt. Ltd. at room temperature. The test was carried out in such a way to find out the ultimate tensile strength and elongation at the peak. The results are analyzed and tensile strength is calculated.

RESULTS AND DISCUSSION

Hygrothermal behaviour of GFRC and HFRC: The temperature and humidity maintained for the hygrothermal test were 60 ºC and 100 %, respectively and time duration was 72 h. After conducting the test, it is found that the percentage of moisture uptake in GFRC-1 is 2.75 %, GFRC-2 is 1.71 % and GFRC-3 is 1.71%. While in case of HFRC, it is less as compare to GFRC where the average of HFRC is 1.11 %. Hence, by comparing the average values of GFRC and HFRC, it is observed that moisture uptake is less in HFRC than GFRC (Table-2).

Comparison of tensile behaviour before and after hygrothermal treatment of GFRC and HFRC: The tensile test was conducted before and after hygrothermal treatment. By comparing both values, we observed that the tensile strength decreases slightly after hygrothermal treatment as compare to before hygrothermal treatment in both GFRC and HFRC. The results are shown in Table-3.

Conclusion

The GFRC and HFRC specimens are subjected to tensile loading before and after hygrothermal exposure and the following conclusions are achieved:

TABLE-1
TYPES OF COMPOSITES USED

Composite name	Composite type	Layer 1	Layer 2	Layer 3
C1	Glass fiber reinforced polyester (GFRP)	Glass fiber mat	Glass fiber mat	Glass fiber mat
C2	Glass and natural fiber reinforced polyester (HFRP)	Glass fiber mat	Natural fiber mat	Glass fiber mat

TABLE-2
PERCENTAGE OF MOISTURE ABSORPTION

Composite type	Weight of the sample (ASTM-D638) before treatment (g)	Weight of the sample (ASTM-D638) after treatment (g)	Moisture absorption (%)
GFRC-1	09.45	09.71	02.75
GFRC-2	09.40	09.48	00.85
GFRC-2	11.10	11.29	01.71
Average	09.98	10.16	01.80
HFRC-1	11.75	11.86	00.93
HFRC-2	10.20	10.38	01.76
HFRC-3	10.49	10.56	00.66
Average	10.81	10.93	01.11

TABLE-3
PERCENTAGE OF VARIATION IN TENSILE STRENGTH

Composite type	Tensile strength before hygrothermal treatment (N/mm²)	Tensile strength after hygrothermal treatment (N/mm²)	Variation (%)
GFRC-1	80.93	77.16	04.65
GFRC-2	95.61	81.99	14.24
GFRC-3	101.17	67.72	33.06
Average	92.57	75.62	18.31
HFRC-1	57.83	49.12	15.06
HFRC-2	72.23	69.59	03.65
HFRC-3	70.21	50.99	27.37
Average	66.75	56.56	15.30

• For GFRC the average percentage of water absorption is 1.8 and average percentage of variation in ultimate tensile strength is 18.31.

• For HFRC the average percentage of moisture absorption is 1.11 and percentage of variation in ultimate tensile strength is 15.30.

• From the above conclusion we could understood that inclusion of natural fibers in fiber reinforced composites will not affects its performance in severe working conditions. This work could extend further by studying other mechanical strengths like compression, impact *etc.*, before and after hygrothermal exposure from which we could understand the complete real capability of HFRC for severe environment.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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