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Comparative Analysis of Flexural Properties of Bamboo-Glass Hybrid FRP Composites: Influence of Water Absorption

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Abstract

Hybrid fibers are crucial in the self-propelled vehicle industry, with bamboo-glass fiber composites playing a significant role. Bamboo fibers, in particular, feature numerous tiny gaps that enhance their properties and performance. Hence there is a possibility for the absorption of moisture content from the atmosphere when compared to the relevant fibers. These setbacks can be rectified in various ways. Apart from that these fibers are very friendly to echo systems, can degrade quickly, and are flexible in their property. The major drawbacks of most of the fibers are, that they get easily affected by bacteria and fungus when they get soaked and wetted. But as far as the bamboo fibers are concerned they have a high resistance to these attacks. Therefore these materials can be preferred for external use such as engine guards of vehicles. The bamboo fiber in the glass hybridized polyethylene composite is alkali-treated to enhance the adherence of these materials. The high interpenetration of the resin into the fiber surface reduces the contact of this fiber especially the bamboo's direct reach to the atmosphere. In this work, this hybrid material is preferred for doing a two-wheeler engine safety guard or a protective cover to protect the engine from the external natural compressive or the tensional forces acting on the engine when moves forward along with the vehicle. So, there is a necessity for measuring the flexural strength of the material, whether it will be suitable for this assigned work and also the stiffness of the material is obtained through the flexural modulus curve. Apart from this though these materials are placed in the outdoor sector, these materials can get in contact with external climatic conditions such as rain, dust, and moisture due to cold climatic conditions. This leads to the

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need for conducting the water absorption test. The test was conducted separately to obtain the water absorption coefficient as well as flexural test before and after water absorption to obtain any deviation if any after water absorption. The test was conducted in the open atmosphere at room temperature for both water absorption and flexural test. The results were tabulated and compared. The comparative study shows that only negligible deviation in property due to water absorption of the hybrid composite is observed.

Keywords:

Flexural, water absorption, engine safety guard, hybrid composite, bamboo fiber, glass fiber, polyethylene.

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Introduction

The bamboo fiber is a natural grass that grows to a very high height. Though it is natural, this can be naturally degraded over a period of years. It also possesses equal strength when compared to artificial fiber made from glass. The fabric made from these fibers is considered to be very soft, and hence their usage is most preferred for clothing purposes (Imadi et al., 2014). In the current era, these plant-based bamboo fibers are mostly preferred as an alternative source in the replacement of glass fiber material (Barabash et al., 2020). Though these materials are hydrophilic, it is desirable to have treatments to increase the sticking properties of this material (Liu et al., 2012). The bamboo fibers are of less weight and strong enough which makes this an effective alternative material for artificial as well as metallic materials (Mohit et al., 2021; Rathi et al., 2024). The experiments conducted on bamboo fiber-based hybrid had excellent mechanical properties in terms of strength as well as modulus (Bino Prince Raja et al., 2018). The increase in content of bamboo in the form of small particles basically increases the tensile property initially up to about ten percent and starts declining after that and also stable at increased water absorption (Li et al., 2021; Laith et al., 2023). The surface of the materials should be modified to improve the adherence of the materials one over the other in order to increase the tensile and thermal properties (Gil, 2009; Godinho et al., 2001). One process that can be done to reduce the amount of water absorption by this bamboo fiber is the heat treatment method (Yağız et al., 2022). When this has been done the water absorption is reduced to about 4.5 percent in the case of treated bamboo (Azadeh & Ghavami, 2018). The water absorption property of bamboo is considerably very lower when compared to all the other fibers (Agarwal et al., 2015). The density of the FRP composites has a major influence on the water absorption property of the materials (Kumar et al., 2016). The water-observing capability of the bamboo has a definite impact on its mechanical behavior (Venkatesha et al., 2021). Therefore, many property-enhancing treatments can be done at the various levels of processing the bamboo fiber (Manickam & Thilagavathi, 2015; Morais et al., 2016; Patel & Tandel, 2005; Yağız et al., 2022; Zhang et al., 2003; Rahman Bhuiyan et al., 2017). The fiber loading should be limited to maintain the water-absorbing capability of the composite (George et al., 1998; Ramachandran & Kalita, 2014). The hybridization of the natural fiber with glass fiber reinforced with polyethylene resign always exhibits a very potential property against water absorption (Robles et al., 2015). hence hybridization process can be considered as a better choice as far as water absorption is concerned (Panthapulakkal & Sain, 2007).

Materials and Methods

To conduct the various tests, the base raw materials are procured from the relevant places. First among them is the bamboo fiber which possesses a dia. of about 80 to 300 micrometers. The preference was given for linear one as unidirectional fiber orientation is taken in account in this work. The other fiber preferred was glass fiber in the form of a mat. These two materials were combined along with the polyethylene matrix to form a complete composite by compression moulding (Shalini & Anitha, 2016). The mould of three numbers in the dimension of about 400 mm^2 was made in the form of plates. The different specimens with their mixing ratios are tabulated in Table 1.

Table 1. The specimen samples with mixing ratios

Specimens	Orientation	Composition	Vol. %
BG1	Unidirectional	Polyethylene	70
		Bamboo	20
		Glass	10
BG2	Unidirectional	Polyethylene	70
		Bamboo	15
		Glass	15
BG3	Unidirectional	Polyethylene	70
		Bamboo	10
		Glass	20

Three specimens were prepared such as BG1, BG2, and BG3 with Polyethylene, bamboo, and glass in the ratio of 70:20:10, 70:10:10, and 70:10:20 respectively. The plates are cut to form specimens as per ASTM standards to conduct water absorption tests.

Result and Discussion

Water Absorption Test

The specimen samples for the water absorption test are cut as per the ASTM D 5229. The three specimens are uniform-sized and are subjected to the above test. The medium used for the purpose is the natural rainwater with a pH value ranging around 5.5 to 5.7. The initial weight of each specimen is calculated using an electronic weighing machine. The test was conducted in an open room maintaining a temperature around 32^{o}C approximately for a period of seven days. Rainwater is preferred as the material is preferred for external usage. For every interval of one day, the specimen was taken out, wiped, and cleaned from external water content and weighed for all seven days and the values were tabulated in Table 2.

The water absorption (Mt) is calculated by taking into consideration of the specimen before W (0) and after W (t) water absorption and calculated using the formula (1).

$$Mt = 100 \text{ X} \frac{\text{W(t)} - \text{W(0)}}{\text{W(0)}} \quad (1)$$

Table 2. % of weight gain in specimens concerning √t sec

Days	√t sec	%Wt.gain in for Specimen BG1	%Wt.gain in for Specimen BG2	%Wt.gain in for Specimen BG3
1	289.83	2.07012	0.808248	0.46132
2	416.12	2.87618	1.301578	0.68473
3	516.11	3.45391	1.587595	0.81924
4	582.67	3.68513	1.820709	0.97375
5	644.33	4.02734	1.994319	1.05046
6	714.21	4.08514	2.052033	0.97261
7	768.72	4.31965	2.109846	0.91262

Figure 1 shows the weight gain of all three specimens concerning the square root of time in seconds. It is absorbed that BG1 due to the presence of cellulose plant fiber bamboo in more volume percent the water absorption is more followed by BG2 and BG3 depending upon the volume availability of bamboo fiber. Therefore the glass fiber is added to compensate for the purpose.

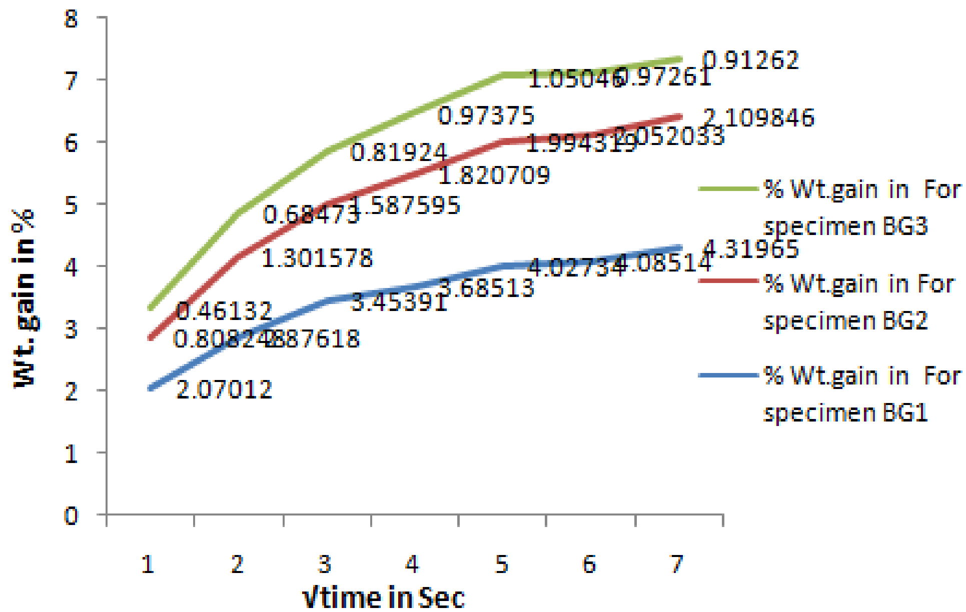

Figure 1. % of weight gain Vs √time in seconds for water absorption specimens

Flexural Test

Similarly, the specimen for the flexural test was cut as per ASTM D 790. The specimens are tested for flexural strength and modulus until 5 percent deflection. This is conducted before and after water absorption to ensure the loss in strength and modulus as the fiber will not be back to equilibrium once the water is absorbed. These flexural specimens were compared among themselves using a bar chart.

Flexural Strength Before and After Water Absorption

Table 3 represents the values obtained after conducting the flexural test three-point bending test. The values obtained were compared with each other and represented in Figure 2. as a bar chart.

Table 3. Flexural strength before and after water absorption

Sl. No.	Specimens	Flexural Strength Before Water Absorption in MPa	Flexural Strength after Water Absorption in MPa
1	BG4	10.26.	9.21
2	BG5	11.02	10.87
3	BG6	11.68	11.59

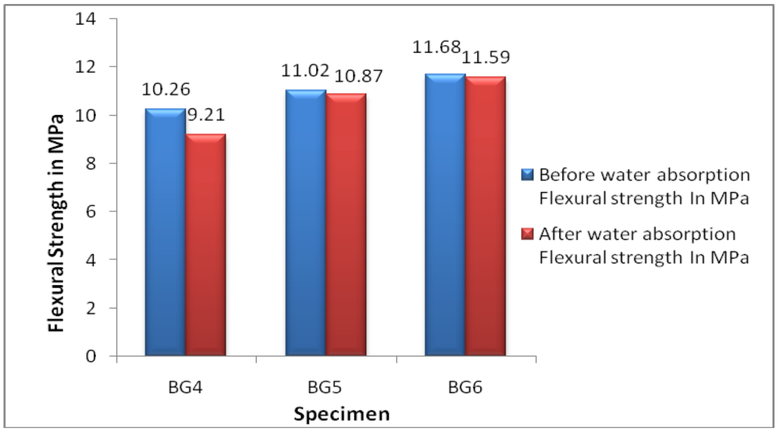

Figure 2. Specimen Vs flexural strength before and after water absorption

This is the property of the material to withstand the force applied on a material to bend. The load is applied on the material to obtain the flexural strength. This is conducted first in the usual manner followed by dipping the specimen combination in rain water similar to water absorption test and testing. The results show that a very minimum difference is absorbed between the two specimens in the case of BG4-BG6. This is done by minimizing the bamboo and introducing glass despite that.

Flexural Modulus Before and After Water Absorption

Table 4 represents the flexural modulus of the specimens. The flexural modulus specimens are named BG7, BG8, and BG9. The comparative chart is drawn to compare the modulus before and after water absorption and is represented in Figure 3.

Table 4. Flexural strength before and after water absorption

Sl. No.	Specimens	Flexural Modulus before Water Absorption in MPa	Flexural Modulus after Water Absorption in MPa
1	BG7	298.35	282.25
2	BG8	537.43	528.33
3	BG9	690.41	686.78

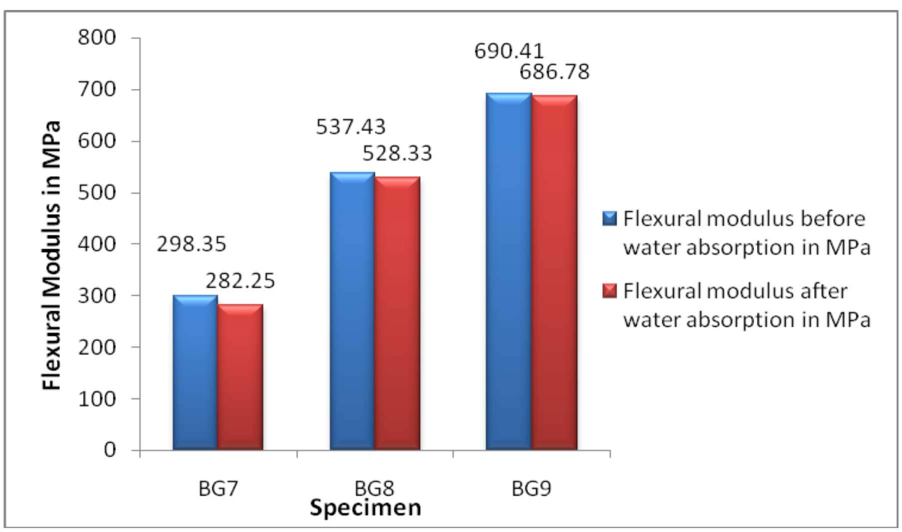

Figure 3. Specimen Vs flexural modulus before and after water absorption

The flexural modulus of the specimen concerning the water absorption property too has a similar impact as that of the flexural strength. The stiffness of all the specimens with and without water absorption shows only a very negligible deviation and also with a decrease in the volume percentage of bamboo the water absorption was found to be in increasing angle from specimen BG7 to BG9.

Conclusion

The prepared specimen has an added advantage that during the preparation of the composite plate, the natural fiber has been completely soaked in alkaline solution so that the bonding is made completely perfect. This leads to very low absorption of water by bamboo fiber. The results obtained in the water absorption and flexural tests before and after water absorption are summarized as follows.

1. The water absorption test conducted in the specimen recorded an increase in water content for about 2.24953 percentage weight gain for specimen BG1. This has been reduced to about 1.301598 weight gain for BG2 and very much reduced to about 0.4513 for specimen BG3. This proves that the reduction in organic fiber has an impact in the reduction of water absorption.
2. The flexural strength deviation for all the specimens before and after water absorption reduced from 1.05 MPa for BG4 followed by 0.15 for BG5 and 0.09 for BG6. This proves that a reduction in water absorption has increased the flexural strength.
3. As far as the flexural modulus is concerned difference in before in after water absorption is observed as 16.1 MPa, 9.1 MPa, and 3.63 MPa for specimens BG8, BG8, and BG9 respectively. This also tends to prove that a reduction in bamboo leads to reduce the deviation between the specimens.

Thus the result shows the reduction in natural fiber increases the water absorption property intern increases the strength and modulus of the specimen. However, the presence of natural bamboo fiber enhances the recyclability of the material to a certain extend.

Author Contributions

All Authors contributed equally.

Conflict of Interest

The authors declared that no conflict of interest.

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