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STUDY THE EFFECT OF ZRO_2 FILLER ADDITION ON TENSILE AND FLEXURAL PROPERTIES OF BAMBOO-GLASS HYBRID EPOXY COMPOSITE

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ABSTRACT**:** Effect of Zro2 filler addition on the mechanical properties of woven bamboo-glass fabric reinforced polymer hybrid composites has been investigated experimentally. Hybrid composites with and without fillers are fabricated by hand layup technique. All the laminates were made with a total of 4 plies, by varying the number and position of glass layers so as to obtain five different hybrid stacking composites. Specimen preparation and testing was carried out as per ASTM standards. The results indicated that the Zro2 filler addition increases the strength of the hybrid composite. GBBG+6Wt% filler shows better properties among all the fabricated composites.

KEYWORDS**:** bamboo fiber, glass fiber, flexural, ZrO2.

INTRODUCTION

Polymeric composites commonly used consist of wide range of particulate and fibrous materials. The growing demand for new materials with specific properties for aircraft, automobile, leisure, electronics and medical industries has led to develop better and cheaper polymer composites. Compared with synthetic fibres, natural fibres have many advantages like low density, cheaper, high strength, high stiffness and biodegradable properties [1]. Presently bamboo is taken into account vital natural plant fiber and includes a nice potential to be utilized in polymer composite industry. Its structural variation, mechanical properties, extraction of fibers, chemical modification, and thermal properties had created it versatile for the utilization in composite trade [2].

Bamboo or genus Bambusa is profusely obtainable in a geographical area like South America, and also the rest comes from Africa and Oceania. The obtainable literature of bamboo and bamboo-polymer based mostly composites attests to its importance. Based on the literature bamboo can be used in different forms, including water bamboo husk [3], bamboo strip[4] and bamboo fibers [5]etc. Previous analysis has been studied the effects of bamboo fibers reinforced polyester matrix towards varied testing for example tensile and flexural properties[6] and fracture properties[7]. Slawomir Borysiak [8] prepared the wood/polypropylene (PP) composites for structural characterization by using compression moulding method and injection technique. Further, investigated the effect of chemical modifications of wood and also studied the processing parameters on the super molecular structure and morphology of composite by using Wide-angle X-ray scattering (WAXS) and scanning electron microscopy (SEM). It was found that, the amount of hexagonal phase of PP matrix slightly decreases due to modification of wood. Ramesh K. Nayak [9] has modified the epoxy matrix by Al2O3, SiO2 and TiO2 micro particles in glass fiber/epoxy composite to improve the mechanical properties. They were observed that mechanical properties like flexural strength, flexural modulus and ILSS are more in case of SiO2 modified epoxy composite compare to other micro modifiers Based on the literature very few people worked on the bamboo fiber composites and also filler addition of ZrO2 in to hybrid composites to this end, an effort has been made to fabricate bamboo-glass fiber laminate hybrid composite, and added ZrO2 filler in to hybrid composites and study their mechanical behavior of both bamboo and glass fiber reinforced epoxy based hybrid composites.

EXPERIMENTAL DETAILS

Materials and Methods

The ZrO2 is filler material in size range of +20 to 40 microns are added to the matrix in the different weight fraction 3,6 and 9wt%. The bamboo fiber in the shape of mats which are collected from the local sources is shown in Figure 1. E glass fiber is shown in Figure 2, epoxy resin (LY556) and the hardener (HY951) are supplied by Ciba Geigy India Ltd.

Fig.1 Bamboo fiber mat [10]

Fig. 2 E-Glass fiber mat

Laminate Composite Fabrication

Hybrid laminates (4 plies) of bamboo and glass composite were prepared by the hand layup technique with different stacking sequence. A wooden mold of (150x60x5) mm^3 was used for composite fabrication. For quick and easy removal of the composite a mold release sheet is placed on the top and bottom of the wooden mold. The mold release spray is also applied to the inner surface of the mold wall to facilitate easy removal of the composite specimen. A calculated amount of epoxy resin and hardener (ratio of 10:1 by weight) was thoroughly mixed with a mechanical stirrer. The ceramic titania (ZrO_2) (3, 6 and 9 wt%) are mixed indivisibly in the epoxy resin and the hybrid (bamboo/glass fiber) epoxy composites as filler materials. The weight percentages of matrix in all the hybrid composites are nearly 78%. In micro filler addition the matrix weight percentage varies as the filler percentage increases. After 5 min stirring, the mixture was poured into the mould uniformly and bamboo fiber mat and glass fiber mats was placed in the mold. The process was continued for 4 layers of bamboo/glass mat and for each time, a roller was used to roll over the fiber in order to remove the air bubbles from it. Care is taken to ensure that the excess polymer will not squeeze out of the mould. Each composite is cured under a load of about 30 kg for 24 h at room temperature before it is removed from the mold. Then, the laminate was cut into required size of mechanical and tribological tests by the diamond cutter. The densities of epoxy resin, bamboo and glass fiber are 1.2, 0.9 and 2.24g/cm3 respectively.

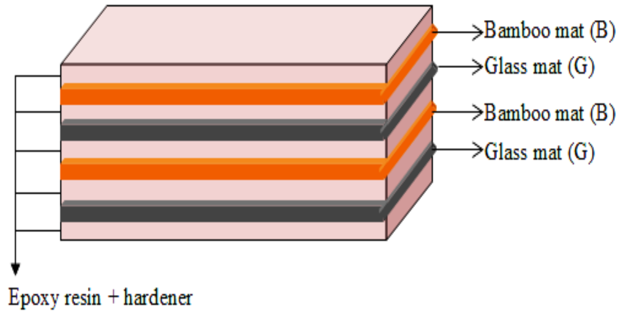

Fig. 3 Schematic View of the composites [10]

Table 1 Laminate stacking sequence [10] (Latha, P. S 2015)

Symbol	Stacking sequence	Wt.% of fibers		Volume fraction (%)
		Bamboo	Glass	
L1	GGGG	0	100	20
L2	BBBB	100	0	24
L3	BGBG	50	50	22
L4	BGGB	50	50	22
L5	GBBG	50	50	22

DENSITY

In terms of weight fraction the theoretical density of the composite materials can be calculated using Agarwal and Broutman equation 1.

$$\rho_{ct} = \frac{1}{\left(W_f / \rho_f\right) + \left(W_m / \rho_m\right)} \qquad (1)$$

where' ' and ' ' represent the weight fraction and density respectively. The suffix 'f ', ' m' and ' ct' stand for the fiber, matrix and theoretical density of composite materials, respectively.

However the actual density of the composite materials in terms of weight fraction is determined experimentally by following equation 2 and 3 using archemidus principle.

$$S_{ct} = \frac{W_0}{(W_0) + (W_a - W_b)} \qquad (2)$$

Where 'S' indicates the specific gravity of the composite. 'W_0', 'W_a' and 'W_b'represents the weight of the sample, the weight of the bottle + kerosene and weight of the bottle + kerosene + sample. Hence the actual density of the composite materials can be obtained using following equation 4. The actual and the theoretical density are given in Table 4.

$$\rho_{ca} = S_{ct} \times \rho_k \qquad (3)$$

The volume fraction of voids (V_v) in the composite is calculated by the following equation 4:

$$V_v = \frac{\rho_{ct} - \rho_{ca}}{\rho_{ct}} \qquad (4)$$

Where'ρ' represents the density of the composite the suffix 'ct' and 'ca' stand for the theoretical and the actual density of the composite materials The volume fraction of voids present in the composite is shown in Table 2.

Table 2 Density and void contain of different stacking sequence[10]

Stacking sequence	Measured density (gm/cm^3)	Theoretical density (gm/cm^3)	Volume fraction of voids (%)
Epoxy	1.200	1.193	0.550
GGGG (L1)	1.324	1.311	0.947
BBBB (L2)	1.111	1.087	2.169
GBGB (L3)	1.208	1.192	1.383
BGGB (L4)	1.208	1.190	1.470
GBBG (L5)	1.208	1.191	1.345

Table 3 Density and void contain of ZrO2 filler added hybrid composites

Stacking sequence	Measured density (gm/cm^3)	Theoretical density (gm/cm^3)	Volume fraction of voids (%)
GBGB+3% ZrO2 (L6)	1.289	1.273	1.239
GBGB+6% ZrO2 (L7)	1.322	1.306	1.212
GBGB+9% ZrO2 (L8)	1.358	1.340	1.318
BGGB +3% ZrO2 (L9)	1.289	1.272	1.323
BGGB +6% ZrO2 (L10)	1.322	1.306	1.269
BGGB +9% ZrO2 (L11)	1.358	1.339	1.352
GBBG +3% ZrO2 (L12)	1.289	1.271	1.372
GBBG +6% ZrO2 (L13)	1.322	1.305	1.326
GBBG +9% ZrO2 (L14)	1.358	1.339	1.359
BBBB +3% ZrO2 (L15)	1.229	1.206	1.862
BBBB +6% ZrO2 (L16)	1.259	1.237	1.762
BBBB +9% ZrO2 (L17)	1.291	1.267	1.899

TENSILE TESTING

Specimens for tension test were carefully cut from the laminate using diamond wheel saw and finished to the accurate size using emery paper. The standard test method as per ASTM D 3039-76 has been used; length of the test specimen is 125 mm. The tensile test is performed in universal testing machine INSTRON H10KS.The tension test is generally performed on flat specimens. The most commonly used specimen geometries are the dog-bone specimen and straight-sided specimen with end tabs. At the rate of loading, 0.5mm/min was used for testing. For each stacking sequence, five identical specimens were tested and the average result is obtained.

FLEXURAL TESTING

Flexural test was conducted as per ASTM D790.Specimens were loaded in three point bending with a recommended span to depth ratio of 16:1. The span of 70mm and a cross-head speed used for the flexural tests (three point bending) was 5mm/min. The flexural stress in a three point bending test is found out by using an equation 2.

$$\sigma_{max} = \left(\frac{3P_{max} L}{bh^2} \right) \qquad (2)$$

Where P_{max} is the maximum load at failure (N), 'L' is the span (mm), 'b' and 'h' is the width and thickness of the specimen (mm), respectively.

The flexural modulus is calculated from the slope of the initial portion of the load-deflection curve, which is found out by using equation 3.

$$E = \frac{(mL^3)}{(4bh^3)} \quad (3)$$

Where '*m*' is the initial slope of the load deflection curve, for each stacking sequence, five specimens are tested and the average result is obtained.

RESULTS AND DISCUSSION

The density of the various stacking sequence composite is shown in Table 2 and 3. It has been observed that the density of bamboo stacking sequence (L2) composite gives lower value as compared to other composites this is due to the lower density of bamboo fibers. On the other hand the void content of the composites is also more in bamboo fiber this is due to hydrophilic nature of bamboo fiber. The lease void content is shown in glass fiber composites followed to epoxy when compared to other composites.

From the table 3 it is observed that the void content of the filler composites are less when compared to pure hybrid composites. it is also observed that as the Zro2 filler percentage increases the void content decreases in all the composites this may be due to the filling of air gaps by the micro fillers.

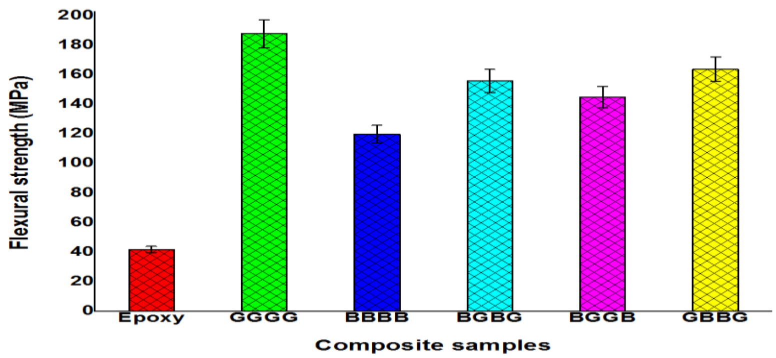

Fig.4 flexural strength of hybrid composites

Flexural strength of various hybrid laminates composites are shown in Figure 4. the glass and bamboo fibers incorporation into the epoxy resin leads to the increase in the strength of the composites. Flexural strength of laminate-only bamboo and glass fiber-reinforced composites are found to be 285% and 447% [10], which is greater than that strength of the neat epoxy composite. However only bamboo fiber and L3 Hybrid composite gives 63% and 83% strength of the glass fiber composites. The same type of behavior is also observed by Gowda et al.[11].

From the Figure 5 it is clearly revealed that the tensile strength of the neat epoxy composite is found to be 22MPa but the strength variation is shown in case of bamboo fiber and glass fiber composite which is almost 386% and 550% greater than the strength of neat epoxy composite.

The strength of three hybrid composites (L3, L4 and L5)[10] increases almost 111%,108%and 117% as compared to bamboo laminate composite (L2). This similar trend is also observed by Raghavendra et al. [15] in their research of jute-glass laminate hybrid epoxy composite.

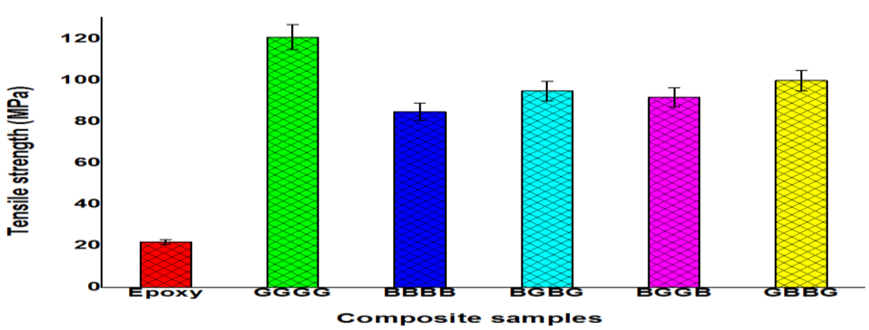

Fig.5 tensile strength of hybrid composites

The tensile strength of hybrid composites with and without filler composites along with neat epoxy is shown in figure 6. it is clearly observed that due to the filler addition the strength increases in all the hybrid composites. The strength of the bamboo fiber composites continuously increases up to the 9wt% filler addition. Where as in the other hybrid composites such as GBGB and BGGB the strength of the composites increases up to 6wt% filler addition after that the strength started degradation. In GBBG hybrid composites the trend is similar to BBBB hybrid composites. The maximum tensile strength is observed in GBBG+9wt%ZrO2 filler composites. The strength is almost 95% of the strength of pure glass fiber. Due to filler addition in to the bamboo the strength increases to 15% when compared to BBBB composites.

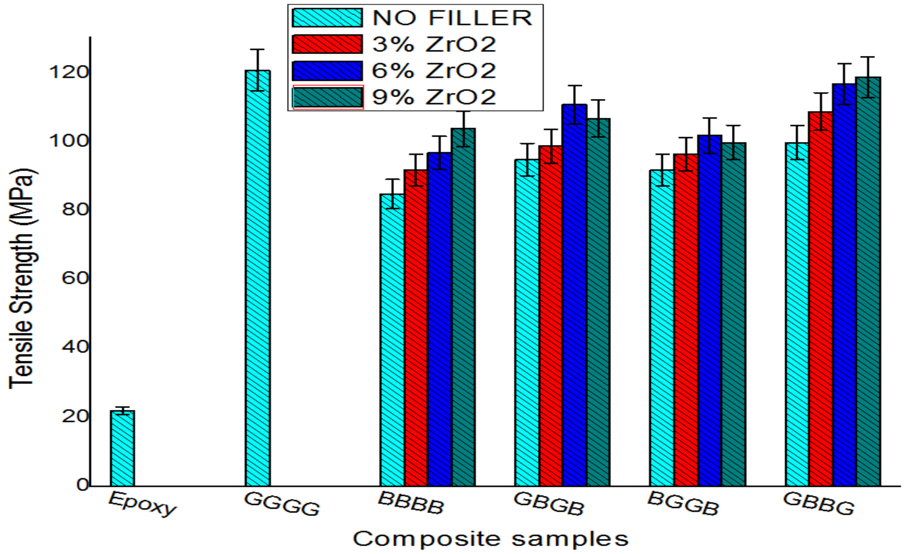

Fig.6 tensile strength of ZrO2 filler hybrid composites

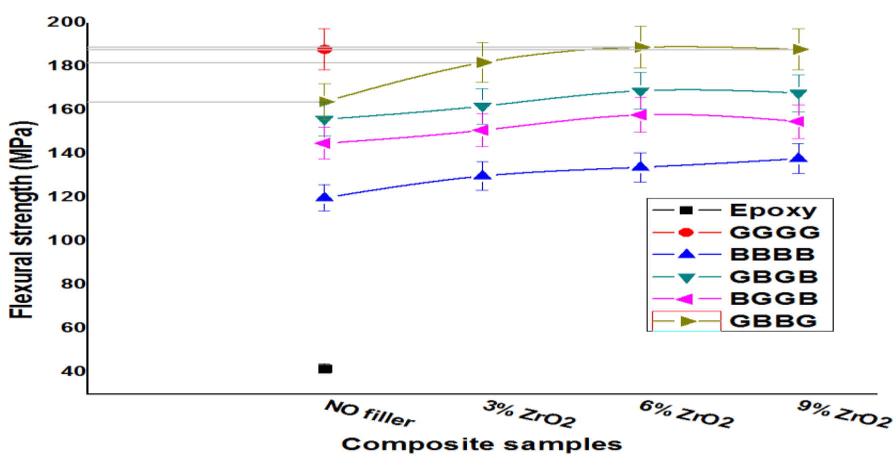

Fig.6 flexural strength of ZrO2 filler hybrid composites

The flexural strength of hybrid composites with and without filler composites along with neat epoxy is shown in figure 7. The strength of the composites increases as the filler percentage increases. The maximum strength is observed in GBBG+6wt% filler addition. the strength is almost more and equal to the strength of GGGG composites in GBBG+6wt% and GBBG+9wt%. GBBG+6wt% and GBBG+9wt% can be an alternate to the pure glass fiber in commercial application.

CONCLUSIONS

The hybrid composites of glass/bamboo fiber reinforced epoxy with and worth out ZrO2 filler addition were made in order to evaluate the effect of filler addition on tensile and flexural properties of hybrid polymer composites, have been experimentally evaluated. From the results of this study, the following conclusions are drawn.

1. Incorporation of Zro2 filler in to the bamboo fiber composites enhances the properties of composites.
2. Two extreme glass plies on either side of the bamboo fiber gives significantly affects on the tensile, flexural strength.
3. Among all the composites GBBG+6wt% and GBBG+9wt% shows the better flexural strength when compared to pure glass fibers.
4. GBBG+9wt%ZrO2 filler composites shows the better tensile strength among all the composites

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