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Evaluation the Effect of Laminated Layer Sequence of Plain-Woven Bamboo on Tensile and Impact Performance of E-glass Woven/ Epoxy Hybrid Composites

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Abstract: Bamboo reinforced hybrid composites are needed in claim to progress use of polymer composite technology. This paper describes a hand lay-up laminate process using plain-woven bamboo/E-glass woven/epoxy hybrid composite with the Design of experiment (DOE) 2 factor with 3- level and analysis of variance (ANOVA) was implemented for an evaluation against how the bamboo and e-glass woven affect the mechanical properties of hybrid composite in various sequence. The present study considers influence of plain-woven bamboo and e-glass woven laminated hybrid composite towards its tensile and charpy impact test performance. The results show that the 2-layer composites withstood better tensile strengths 185.372 MPa for EG/BW/EG while charpy impact 158.224 KJ/m^2 for EG/BW sequence respectively. Experiments results show that concentrate on both lay-up sequence and layers are important effect factors for tensile and charpy performance. It had been proven that both the layers and also the lay-up sequence demonstrated significantly different leads to terms of the mechanical performance.

Keywords: Woven bamboo, e-glass woven, laminate, hybrid composite

1. Introduction

Along with the growing global energy crisis and ecological risks, bamboo fibers reinforced polymer composites are now have attracted more research interests because of their potential characteristic as another for artificial fiber composites [1,2,3]. Accordingly, the wide studies on research of thermosetting and thermoplastic composites stuffed with the bamboo fibers undertaken [4,5,6]. First, because of bamboo fibers have many advantages like high specific mechanical performance, low cost, lightweight, environmental friendly, instead of synthetic fibers like glass fibers or carbon fibers.

Their availability, renewability, tenuity, simple separation, enhanced energy recovery, biodegradability, reduced jeopardy and price make them a sexy ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites and resulting an oversized number of applications to bring it at par and even superior to synthetic fibers [7,8,9]. Additionally, a combining some particular materials in a very certain way, they may produce a brand new material that possessed greatly enhanced material properties than by themselves. Consequently, they developed and perfected fabrication methods and tools to manufacture these materials to be used for building construction, weapons, and clothing.

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Generally, bamboo structure is extremely unique and a smart range of uses from the roots to the branches. Bamboo contains a macroscopically graded structure (i.e. diameter, thickness, internodal length) and exhibits a microscopically graded architecture (i.e. fiber distribution) that cause favorable properties [10,11]. China and India producing a good range of bamboo daily use products and handicrafts; bamboo is employed as an alternate to wood for manufacturing components in-house. Bamboo are molded into the laminate boards. Except for the development components, boards used for the manufacture of laminated bamboo flooring boards trucks, material packaging boxes, wall furniture. Besides that, [12] bamboo can further enhance through innovations which can be option to be used as structural material application. While in [13, 14,15] show the positive impact of using bamboo to be used as construction material. Because on the outstanding mechanical performances of bamboo, structural rationality and obeying principles of saving materials, this paper puts forward a brand new quite bamboo composite products by taking a series of experimental studies on the mechanical properties of the new reasonably hybrid composite to debate the feasibility of its application. The target of this work is to spot the factors that affect laminated plain bamboo woven and e-glass woven hybrid composite using three different sequence layers.

2 Experimental

2.1 Experimental Design

The focus of this work is on two parameters: the sort of layer and its sequence. Because the amount of every factor used were determined bearing on the manufacturing capability and its competency, three levels were chosen for the composition of the layer and its sequence. The factor (2) and levels (3) for the design of experiments (DOE) was then used supported outcomes of the SPSS and Design-Expert software.

2.2 Selection of Materials

EpoxyAmite 100 resin which is a convenient mix ratio, Easy to use, excellent moisture resistance, low viscosity, non-blush formula, easy to combine & apply and exceptional physical & performance properties type was selected. The matrix system consisted of synthetic resin kind of mix ratio by volume 3A:1B, mix ratio by weight 100A: 28B, mixed viscosity 650, relative density 1.10, spec volume 25.2, pot life 55 minutes, cure time 20-24 hours and color mixed clear yellow with 103 slow hardeners was used. The normal roving woven optical fiber type E (600 g/m^2) was used. The bamboo species employed in these tests were Gigantochloa Scortechinii (*Buluh Semantan*) which is impede into lumber strip fiber parts with thickness and width 0.4 to 0.6 mm and four to six mm (Fig.1). All of the specimens were washed with water and so dried in an oven at 60^{0}C for six hours for reduce its moisture. The formulation for epoxy and plain-woven bamboo is split into three main parts of EG/BW, EG/BW/EG and BW/EG sequence can be seen in Fig.2.

Fig. 1 - The schematic extraction of bamboo woven

Fig. 2 - (a) EG/BW sequence; (b) EG/BW/EG sequence; (c) BW/EG sequence

2.3 Laminate Fabrication

Hybrid laminate of bamboo woven layer/ E-glass woven and epoxy were prepared by simple hand lay- up practice in an exceedingly mould 400 mm x 400 mm which represent length and width respectively at laboratory temperature. At first, a scrapper was wont to clean the dirt surface of the mould and a rag was accustomed wipe the mould surface.

Then to facilitate sample easy removal from mould the silicon release agent was applied to the surfaces. EpoxyAmite 100 which was mixed with the 103 slow hardener as weight ratio 100: 28.4 were stirred until its changes its physical colour to clear yellow. The layers of bamboo woven and e-glass roving woven were amassed sequential. A layer of every hybrid composite sequence all oriented at same direction (weft/warp) was cured at temperature for twenty-four hours with a load 15 kg.

2.4 Testing Standards

The tensile tests were performed in step with ASTM D3039 using Instron 5569A (USA) with a capacity of fifty KN, and a cross head speed of two mm/min, and also the specimen positioning and therefore the operating conditions were 25 ± 2 ° C with 50% humidity (Fig. 3). Ten 250 mm x 16 mm samples composed of the BW/EG, EG/BW/EG, and EG/BW hybrid composition sequences were created. Meanwhile charpy accordance with the ASTM: D6110 procedure 120° clockwise to specimen position using the "Pendulum Charpy Tester Model: Eurotech ET-2206" with a 50 J impact force hammer (Fig. 4). Ten 127 mm x 12.7 mm samples composed of the BW/EG, EG/BW/EG, and EG/BW hybrid composition sequences were created.

Fig. 3 - Tensile testing

Fig. 4 - Charpy testing

3 Results and Discussion

Table 1 shows the factor and level of the sequence and layers variables, while Table 2 to Table 4 show the ANOVA results for the tensile and impact strengths.

Table 1 - Factor and level

Factor	Level 1	Level 2	Level 3
Sequence	BW/EG	EG/BW/EG	EG/BW
Layer	2	2	2
	4	4	4
	6	6	6

3.1 Tensile Properties

Fig. 5 and Fig. 7 show the traditional probability plots. The residuals tensile and modulus strength demonstrated a stable variability for the tensile test samples, with R^2 values of 0.9301 and 0.9105. Supported analysis of variance (Table 2 and Table 3), all mean values for every group are significantly different (P-value<0.05). Thus, each variable incorporates a significant effect on the strength performance of the composites. The results of the interaction plot for tensile and modulus strength on the various sequence and layers are presented in Fig. 6 and Fig. 8. As shown in these graphs, sequence with EG/BW/EG 2 layer are outperformed as a layered composite. The tensile strength value of the BW/EG and EG/BW sequence is under that of the EG/BW/EG sequence for every layer. The mean values for tensile and modulus strength are 185.372 MPa and 5.084 GPa, which were found for EG/BW/EG sequence. Jayabal et al. [16] directed that including woven glass in extreme plies of woven coir fiber composites increase the improved mechanical properties of natural fiber composites. While, according to Zhang et al. [17] multilayer plain weft knitted glass fiber/epoxy composite laminates with different stacking configurations shows that with the variation in the layer

stacking structure, a corresponding difference in the composite strength and stiffness can be succeeded. An increase in the tensile strength and tensile modulus of 2.26% & 5.00%, and 7.16% & 17.39% is observed for the EG/BW/EG hybrid laminate sequence when compared to the EG/BW and BW/EG sequence respectively. The results for sequence types during this research show similarities with the tensile strength performance for every layer. Fig. 11 shows the samples that failed within the mechanical testing.

Table 2 - ANOVA for the Tensile strength values of bamboo sequence

Tensile strength		Sum of squares	Degree of freedom (df)	Mean square	F (value)	P (value)
BW/EG	Between Groups	36032.199	2	18016.100	310.148	.000
	Within Groups	1568.395	27	58.089		
	Total	37600.595	29			
EG/BW/EG	Between Groups	28867.746	2	14433.873	166.949	.000
	Within Groups	2334.329	27	86.457		
	Total	31202.075	29			
EG/BW	Between Groups	36624.028	2	18312.014	692.352	.000
	Within Groups	714.123	27	26.449		
	Total	37338.151	29			

Table 3 - ANOVA for Tensile modulus values of bamboo sequence

Tensile modulus		Sum of Squares	Degree of freedom (df)	Mean square	F (value)	P (value)
BW/EG	Between Groups	12.369	2	6.185	142.306	.000
	Within Groups	1.173	27	.043		
	Total	13.543	29			
EG/BW/EG	Between Groups	20.628	2	10.314	134.808	.000
	Within Groups	2.066	27	.077		
	Total	22.693	29			
EG/BW	Between Groups	15.664	2	7.832	187.912	.000
	Within Groups	1.125	27	.042		
	Total	16.790	29			

Table 4 - ANOVA for the Impact strength values of bamboo sequence

Impact strength		Sum of Squares	Degree of freedom (df)	Mean Square	F (value)	P (value)
BW/EG	Between Groups	16412.665	2	8206.333	57.683	.000
	Within Groups	3841.176	27	142.266		
	Total	20253.841	29			
EG/BW/EG	Between Groups	15772.316	2	7886.158	61.978	.000
	Within Groups	3435.501	27	127.241		
	Total	19207.817	29			
EG/BW	Between Groups	18837.412	2	9418.706	60.222	.000
	Within Groups	4222.759	27	156.398		
	Total	23060.171	29			

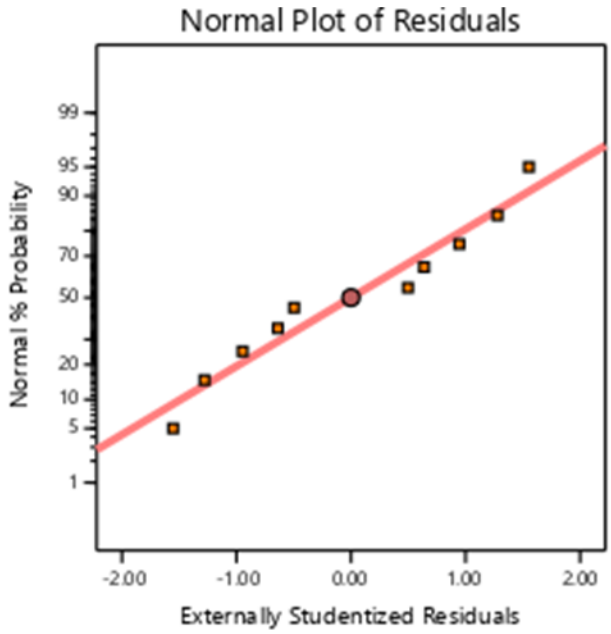

Fig. 5 - Normal plot for tensile strength

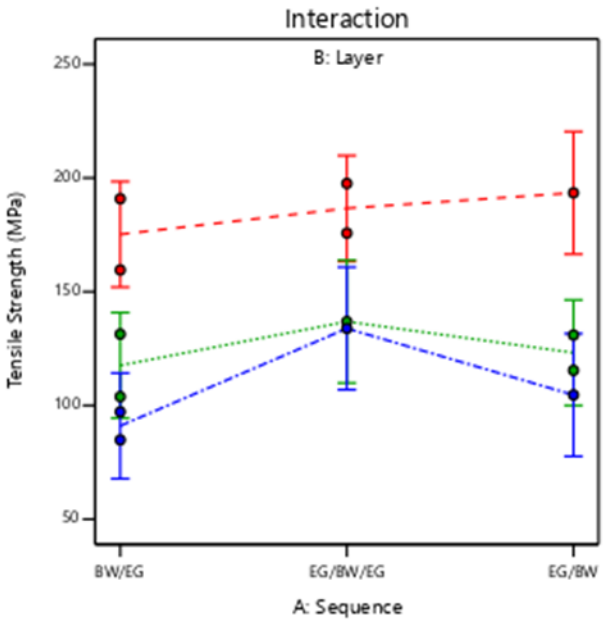

Fig. 6 - Interaction plot for tensile strength

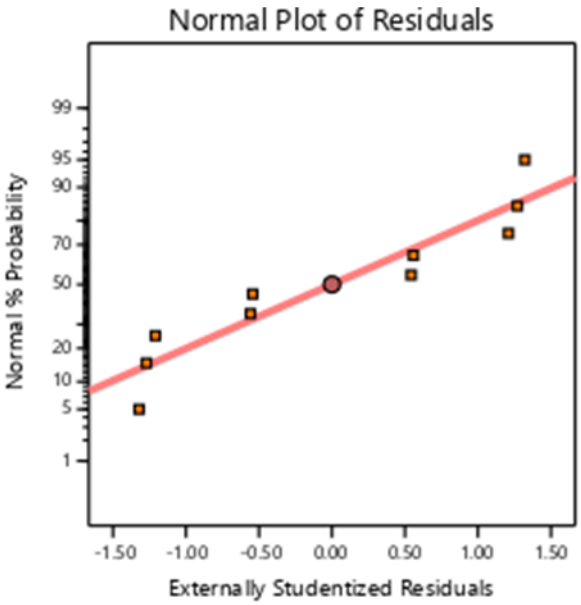

Fig. 7 - Normal plot for tensile modulus

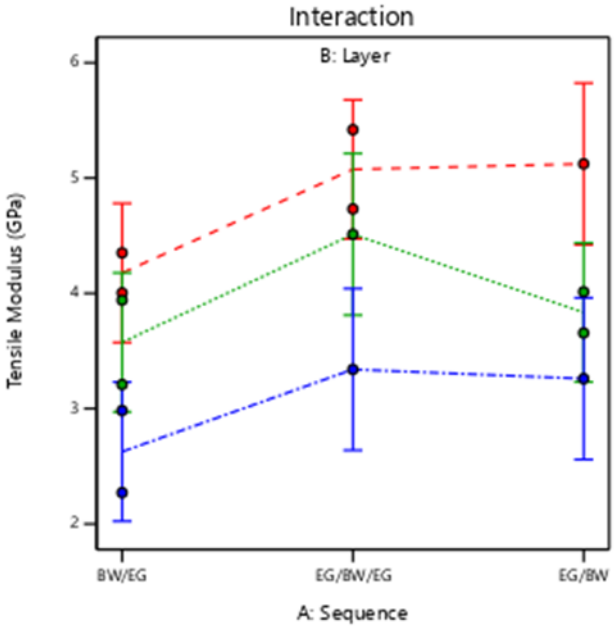

Fig. 8 - Interaction plot for tensile modulus

3.2. Charpy Properties

Fig. 9 show the traditional probability plots. The residual Impact demonstrated a stable variability for Impact test samples, with R^2 values of 0.6932. Supported analysis of variance (Table 4), all mean values for every group are significantly different (P-value<0.05). Thus, each variable sequence and layer, and contains a significant effect on the impact strength performance of the hybrid composites.

Meanwhile, Fig. 10 show the interaction plots for impact strength of sequence with different layer. During this graph, the two layer EG/BW sequence hybrid composites are outperformed as a layered hybrid composite. The impact value of the BW/EG and EG/BW/EG sequence is under that of the EG/BW sequence. The mean values of the Impact strength 158.224 KJ/m^2 occurred within the 2 layer EG/BW sequence. An increase in the impact strength of 10.50%, and 5.47% is observed for the EG/BW hybrid laminate sequence when compared to the EG/BW/EG and BW/EG sequence respectively. There is a similar observation found in Sneha Latha et al. [18] and Jayabal et al. [19] that the

properties of bamboo fiber reinforced composites were significantly improved by incorporation of glass fibers in polymer matrix composite. The many differences in these values indicate that the thinner of the woven bamboo will increase the impact strength when laminated with e-glass/epoxy hybrid composite. Additionally, smaller thicknesses withstand impact force, for every sequence. Fig. 11 shows the samples that failed within the impact testing.

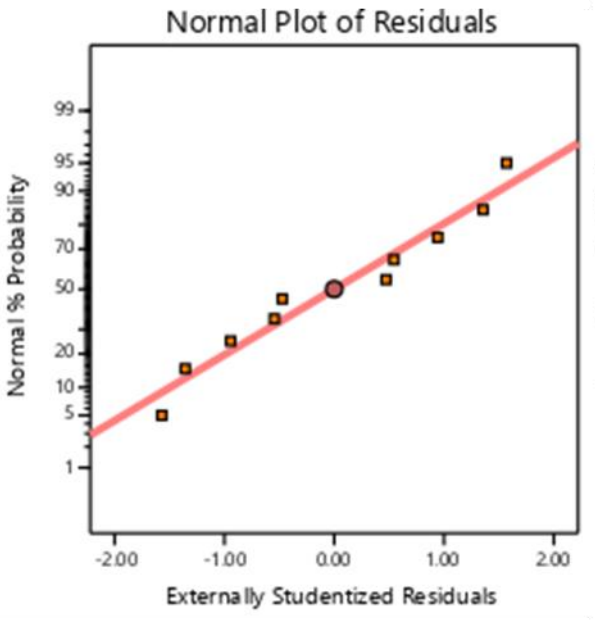

Fig. 9 - Normal plot for charpy impact

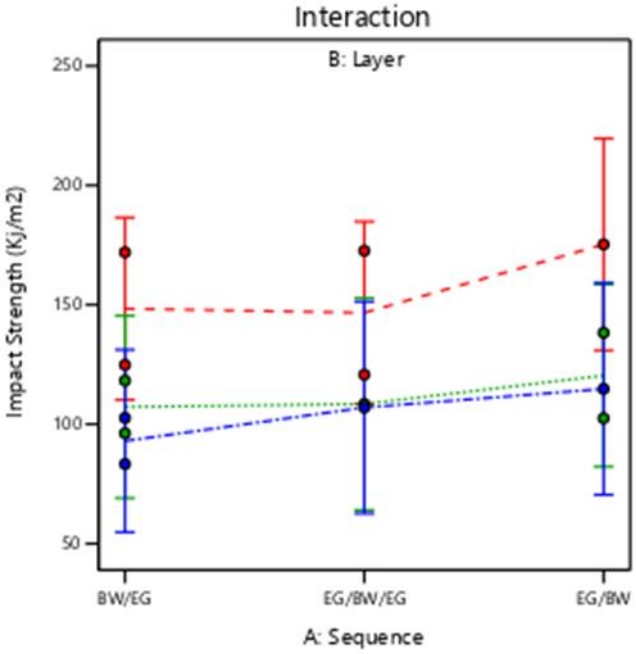

Fig. 10 - Interaction plot for charpy impact

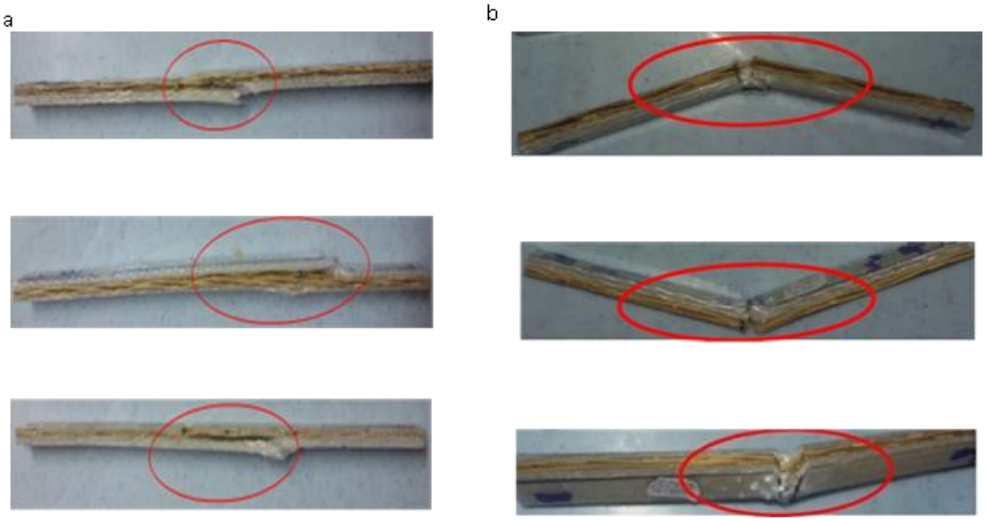

Fig. 11 - (a) tensile failure; (b) charpy failure

4. Conclusions

In these studies, the sequence and layer are identified because the factors that are important within the development of recent woven bamboo composites. Thus, the ANOVA analysis outcome had established correctly that the sequence and layer used have significant effects on the tensile and charpy impact properties. The EG/BW/EG sequence with 2-layer laminate was shown to possess better strengths for tensile while EG/BW sequence for impact. The measurement of composite characteristics indicated that thin layers of laminated woven bamboo displayed greater strength performance compared to a thicker layer.

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