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Strength Performance and Dimensional Stability of Peeled Bamboo - Fiberglass Composite (PBFC) from Buluh Betong

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Abstract

Bamboo is considered as environmentally and eco-friendly material compared to hardwood and nowadays bamboo veneer is getting very popular in the market. Bamboo veneer is suitable for many modern designs. The alternate layers of veneer bamboo (3 and 5 layers) were combined with fiberglass by using Epoxy resin (2% hardener) as bonding agent to produce PBFC at different pressure. Panels produced were assessed for the mechanical and physical properties such as MOE and MOR, thickness swelling (TS), and water absorption (WA) in accordance with the European Standard. Results revealed that strength performance of board improved with increasing pressure. Thickness swelling and water absorption values were much lower for the 5 layer composite Thus such findings revealed that bamboo veneer from *Buluh betong* possess great potential for the manufacture of bio-composite products.

1. Introduction

Nowadays, due to the environmental concern related deforestation and wood supply has become shortage since it is highly sought for the wood-based products. Fortunately, Malaysia has a lot of forest resources such as oil palm and bamboo as alternative raw materials for composite products, and to maintain the production of composite product, alternative raw material is needed to replace or top up wood source.

This fast growing monocotyledon plant can be found in temperate, subtropical and tropical areas. There are 75 genera and 1250 species of bamboo in the world and from out of them, 14 genera and 120 species can be found in Asia (Azmy *et al*., 1997). Its fast growth rate and high strength, light weight, suitable fiber characteristics and better mechanical properties than many other wood species make this resource as an alternative raw material for various types of composite panel production (Fuyuan &

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Jianmin, 1988; Midmore, 1998; Ganapathy *et al*., 1996). Furthermore, bamboo can be harvested in 3 to 5 years while most softwood species used for composite board manufacturing require 10 to 20 years of maturing period (Chen *et al*. 2000). It must be an amazing process to produce bamboo veneer from the round and tall bamboo to be so soft and thin veneer. The worlds want to know how and what technology issued to make it happen. The process to produce bamboo veneer is not a secret, but it is really complicated compare to produce regular wood veneer. It is because different physical properties of wood and bamboo which has hole along the middle of it.

Peeled bamboo–fiberglass composite (PBFC) can be classified as composite product because of the combination of two or more materials. The alternate layers of bamboo veneer with fiberglass to produce PBFC. The primary focus of this study is to examine the use of bamboo as an alternative raw material to produce PBFC from Malaysian bamboo species bonded with epoxy. The number of bamboo veneer layers in the composite system on the strength and dimensional of the structural PBFC will be study. This study will produce the bamboo veneer by peeling the round bamboo directly. The Malaysian bamboo is use as a raw material to determine their suitability as a potential raw material in the manufacture of such composite.

2. Materials and methods

2.1 Raw Material Preparation

In this study, betong bamboo *(Dendrocalamus asaper)* the primary raw material was harvested from Sungkai, Perak and transported to Kin Heng Timber Industries Sdn. Bhd. in Khantan Industrial Area, Chemor, Perak for peeling process. The bamboos were peeled using special peeler machine which is owned by Forest Research Institute Malaysia (FRIM) which is located in Kin Heng primary plant. Before peeling process, bamboo culm was cut to 920 mm in length and removed all knots to eliminate knife blunt and broken. Then the bamboo culm were soaked and boiled 1 to 2 hours in order to softening their fiber. Subsequently, peeling process was done by using bamboo peeler machine to produce veneer with the thickness of 0.6 mm. The required size veneers were dried in dryer for 30 minutes to ensure the veneer moisture content is below 12% and to prevent fungal attack. All the processes to produce 2 ft x 2 ft veneer were carried out at Kin Heng, Timber Industries Sdn. Bhd. in Chemor, Perak.

2.2 PBFC preparation

The veneers with 12% and below of moisture content (MC) with sizes of 2 ft x 2 ft was prepare to alternate laminated with fiberglass by applying adhesive (Epoxy) onto the surface of veneer and fiberglass. The manually glue spreading was done by using roller brush. The process was very important to ensure the epoxy was spread uniformly onto the surface of veneer. The raw panels were then placed in the hot press. The temperature of the hot press was set at 120°C for 12 minutes. The panels were then left to cool down to the environment temperature for 4 to 6 minutes before placing them in the conditioning room. The strength performance and dimensional stability of the panels such as MOR and MOE, TS, and WA was evaluated based on European Standard (BS EN 310: 1993).

3. Results and discussion

3.1 Bending Properties

The discussion involves the mechanical properties analysis and the comparison on bending strength between two different veneer layer and pressure as well as which one of the specimens had high strength and durability. Table 1 shows the bending strength results after the testing process.

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Table 1: Bending strength values based on bamboo veneer layer and press pressure

Veneer Layer	Pressure (kg/cm^2)	MOE (MPa)	MOR (MPa)
3	75	17198.33	33.35
	130	22384.83	35.90
5	75	17223.50	72.78
	130	16338.00	102.99

Note: MOR = Modulus of Rupture, MOE = Modulus of Elasticity

3.1.1 Statistical Significance

Data from the study was analyzed using the Statistical Package for the Social Sciences (SPSS) to analyze the effect of bamboo veneer layer and pressure on bending strength properties. The result for the strength properties as represented by MOR and MOE is presented as Analysis of Variance (ANOVA) in Table 2. ANOVA shows that MOR and MOE of PBFC between different veneer layers and different pressures were significantly different (p-value = 0.000).

Table 2: The Analysis of Variance of MOR and MOE of peeled bamboo fibreglass composite at 3 & 5 layer of bamboo veneer and 75 kg/cm^2 & 130 kg/cm^2 of pressure.

Source	Dependent Variable	f-value	p-value	Significance (Yes/No)
Veneer Layer (3, 5)	MOR	150.776	0.000*	Yes
	MOE	30.918	0.000*	Yes
Pressure (75, 130) Kg/cm^2	MOR	14.258	0.001*	Yes
	MOE	15.774	0.001*	Yes

Note: MOR = Modulus of Rupture, MOE = Modulus of Elasticity, * = significant at p-value < 0.05

A) Effect of Veneer Layer on MOE and MOR

The Figure below shows the effect of veneer layer on Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) values of the composite.

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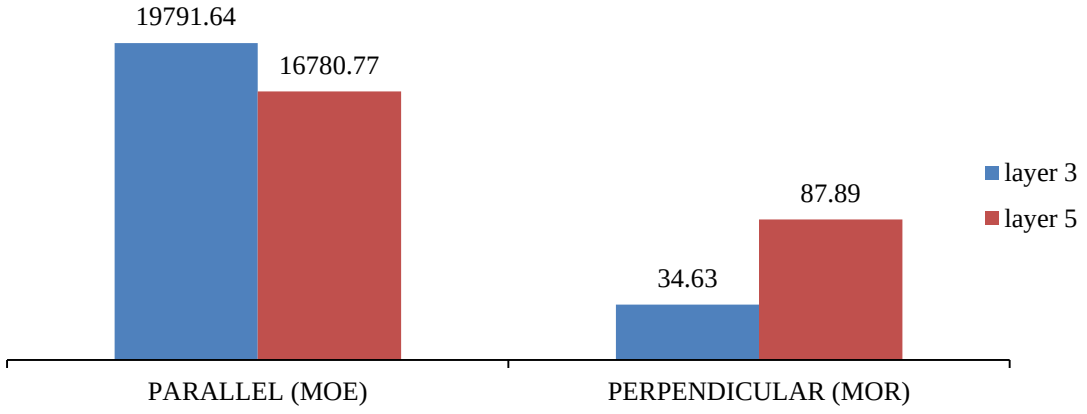

Figure 1: Effect of different layers of composite on MOE and MOR values

From the above Figure, based on mean of Modulus of Elasticity (MOE) value it shows that panel with 3 layer of bamboo veneer was higher than 5 layer of bamboo veneer which were 19791.64 MPa and 16780.77 MPa respectively. While, the 5 layer bamboo veneer showed a high mean of Modulus of Rupture (MOR) value which was 87.89 MPa compared to 3 layer of bamboo veneer was 34.63 MPa. According to the requirements for specified mechanical properties, based on the mean values, for MOR were 15 MPa and 1950 MPa for MOE. The results obtained satisfied the requirements of BS EN 312-4:1996.

B) Effect of Pressure on MOE and MOR

Figure 2 below shows the effect of pressure on Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) of the composite board PBFC.

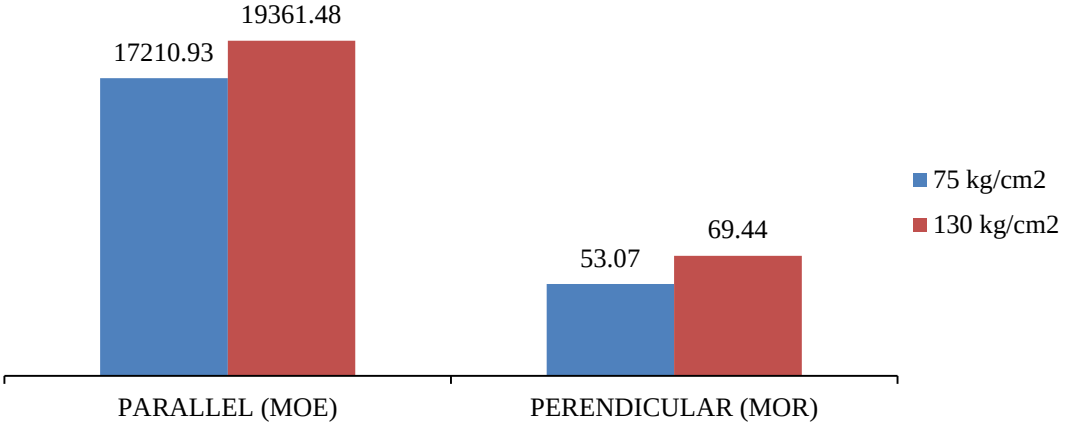

Figure 2: Effect of different press pressure on MOE and MOR values

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The graph shows the Modulus of Elasticity (MOE) mean value of 130 kg/cm2 had a high value were 19361.48MPa compared to 75 kg/cm2 with the mean value were 17210.93 MPa. The pressure at 130 kg/cm2 (69.44MPa) shows the higher mean Modulus of Rupture (MOR) values compare to pressure at 75 kg/cm2 (53.07MPa).

3.2 Thickness Swelling (TS) and Water Absorption (WA)

The discussion involves the physical properties analysis and the comparison on TS and WA between two different veneer layer and pressure as well as which one of the specimens had high stability and durability. Table 3 shows the results after the testing process.

Table 3: TS and WA values based on bamboo veneer layer and pressure

Veneer Layer	Press Pressure (kg/cm^2)	TS (%)	WA (%)
3	75	7.96	12.86
	130	5.24	11.51
5	75	2.72	6.97
	130	2.76	7.55

Note: TS = Thickness Swelling, WA = Water Absorption

3.2.1 Statistical Significance

Data from the study was analyzed using the Statistical Package for the Social Sciences (SPSS) to analyze the effect of bamboo veneer layer and pressure on physical properties. The result for the dimensional stability as represented by TS and WA is presented as Analysis of Variance (ANOVA) in Table 4. ANOVA shows that veneer layer p-value of TS was 0.000, and WA was 0.000 which all variables was significantly different between the means value. Pressure shows that p-value of TS was 0.026 was significantly different, and WA was 0.426 which was not significant.

Table 4: The Analysis of Variance of TS and WA of peeled bamboo fibreglass composite at 3 & 5 layer of bamboo veneer and 75 kg/cm^2 & 130 kg/cm^2 of pressure.

Source	Dependent Variable	f-value	p-value	Significance (Yes/No)
Veneer Layer (3,5)	TS	44.694	0.000*	Yes
	WA	104.976	0.000*	Yes
Pressure (75,130) Kg/cm^2	TS	5.378	0.026*	Yes
	WA	0.648	0.426^{ns}	No

Note: TS = Thickness Swelling, WA = Water Absorption, * = significant at p-value < 0.05, ns = not significant at p-value >0.10

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A) Effect of Veneer Layer on TS and WA

The Figure below shows the effect of veneer layer (3 layers and 5 layers) on the thickness swelling (TS) and water absorption (WA) of the composite. The graph shows, based on mean of thickness swelling (TS) value it shows that panel with 3 layer of bamboo veneer was higher than 5 layer of bamboo veneer which were 6.60 % and 2.74 % respectively. Same as on mean of water absorption (WA) value, the 3 layer bamboo veneer was higher than 5 layer of bamboo veneer which was 12.18 % and 7.26 % respectively. According to the requirements for specified swelling properties, based on the mean values, for TS and WA were 23 %. The finding indicated that the composite satisfied the requirements of BS EN 312-4:1996.

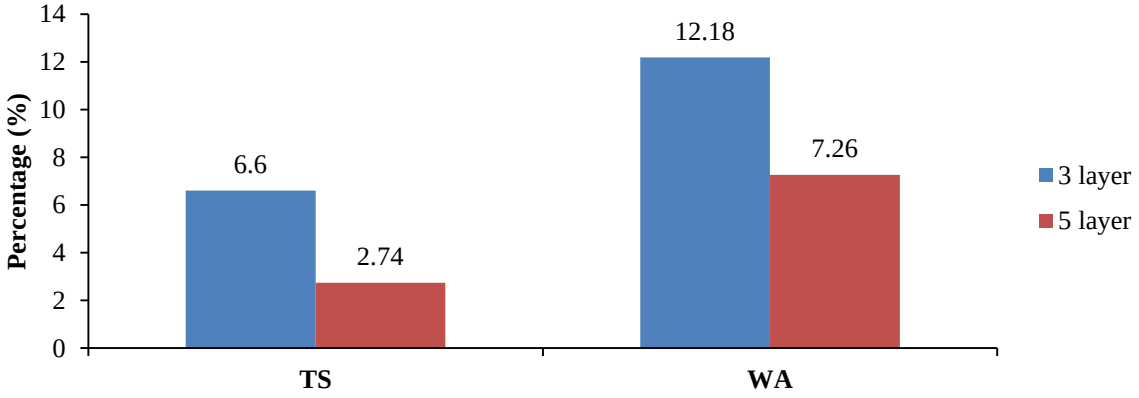

Figure 3: Effect of different layers of composite on TS and WA values

B) Effect of Pressure on TS and WA

Figure 4 below shows the effect of pressure on Thickness Swelling (TS) and Water Absorption (WA) of the composite board PBFC. From the figure the thickness swelling mean value of pressure at 75 kg/cm^2 had a high value were 5.34 % compared to pressure at 130 kg/cm^2 with the mean value were 4 %. Same as to the water absorption mean value of pressure at 75 kg/cm^2 had a high value were 9.92 % compared to pressure at 130 kg/cm^2 with the mean value were 9.53 %. The results were achieved the requirement for swelling properties.

Figure 4: Effect of different press pressure on thickness swelling and water absorption

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4. Conclusion

It can be concluded from the findings that the peeled bamboo-fibreglass composite (PBFC) from *Buluh betong* demonstrated better mechanical and physical properties with 5 layered bamboo veneer at press pressure of 130 kg/cm^2. The panels with the 3 layered bamboo veneer showed better on elastic ability when compared to the 5 layered boards because in 3 layered boards had less sheet of fiberglass. Thus the potential usage of local bamboo species such as *Buluh betong* for the manufacture of PBFC is worth acknowledged.

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