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RESEARCH ARTICLE

THE SELECTED PROPERTIES OF LAMINATED RATTAN STRIP FROM LARGE DIAMETER *CALAMUS MANAN*-EFFECT OF BONDING DIRECTION

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ABSTRACT

The laminated rattan strip from large diameter rattan (*Calamusmanan*) of more than 50 mm was investigated. The commercial rattan was cut into square shape of 25 mm X 10 mm X 320 mm (*W x T x L*) and glued together with urea formaldehyde resin (UF) either as face to face or edge to edge bonding. Each bonding was fabricated to 2, 3 and 4 layers. The physical and mechanical properties were tested in according to Japanese Agricultural Standard (JAS) and British Standard (BS). Overall, the study found that the water absorption, thickness swelling and delimitation in either cold or hot water were not significantly different with the type on bonding and number of layer. The modulus of elasticity (MoE) and maximum load (ML) were significantly different with type of bonding, but not the modulus of rupture (MoR). The MoR and MoE were not significantly different with number of layer. The ML increased with increasing layers. Large diameter *Calamusmanan* can be laminated with either type of bonding or number of layer.

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INTRODUCTION

Rattans are renowned as the climbing palms that can grow up to hundreds of metre long and was classified in Calameae tribe, consisting of approximately 600 species. The majority of rattans are discrete from other palms as they have a flexible slender and taper stem of 2 to 5 cm diameter, with long internodes between the leaves (Dransfield, 1992). The stem is a valuable material for many products ranging from traditional items such as fish trap, crossbow string and basketry to modern furniture, handbags and sports equipment. About 80 % of rattan resource is consumed by furniture industry. Currently, rattan cut-off waste was used as handles for hammer and hoe, replacing more expensive and scarce tropical timber (Hamid *et al.,* 2014). In industrial practice, rattan was harvested from forest and then transported to primary processing mill, which they were further oil cured in diesel at temperature of 80 to 100 °C for 30 to 40 minutes. This was followed by grading its appearance and diameter into 5 different classes of 18 – 24 mm, 25 – 29 mm, 30 – 34 mm, 35 – 39 mm and more than 40 mm (Mohmod, 1992). These diameter ranged were basically ideal for the structural furniture frame. Many rattans with diameter more than 40 mm were converted into splits for weaving purpose, without considering its advantage such as a high elasticity for a glue laminated product. Glulam has many benefits over sawn timber such as it can produced a larger size, curve into a specific architecture design, cross section can be adjusted to specific strength and stiffness, and mixing grade can be made from a low and a high quality of wood (Walker, 2006).The possibility of using rattan as a glue laminated products could gave an advantage since rattan can easily bend to any curve design compared to common wood. Therefore, the objective of this study was to investigate the physical and mechanical properties of glue laminated rattan.

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MATERIALS AND METHODS

Source of Material

The *Calamusmanan* (local name: manau) with diameter more than 50 mm was obtained from local oil curing rattan mill and used in this study. They were cut and trimmed into strip sized of 25 mm X 10 mm X 320 mm (*W x T x L*) followed by oven dried at 103±2 °C to 12 % moisture content (Figures 1 and 2).

Laminating of rattan strip

The rattan strips were sanded with a sand paper (grit of 120) using a rotary sanding machine and the access sawdust were cleaned with air from compressor. Two different bonding directions were tested: 1) face to face and 2) edge to edge (Figures 3 and 4). The rattan strips were laminated either with two, three or four layers using a urea formaldehyde resin. The strips were then manually clamped for 24 hours to ensure that the resin was spread uniformly along all surfaces. The rattan strips were hot pressedat125°C and pressure of 6.6 MPa was applied for 20 minutes (2 layers), 30 minutes (3 layers) and 40 minutes (4 layers) for each face to face bonding. The pressure was applied for only 10 minutes for edge to edge bonding. The weight and thickness of the laminated rattan board were determined, and they were conditioned in conditioning room at 22°c and 65 % relative humidity (RH) for 2 weeks.

Figure 1. ***Calamusmanan***

Figure 2. Square rattan

Figure 3. Face to face bonding

Figure 4. Edge to edge bonding

Testing of laminated rattan strip

The physical properties were tested according to Japanese Industrial Standard (Anon., 1993) for structural laminated veneer lumber and the mechanical properties were tested according to British Standard BS 373 (Anon., 1957).

Determination of initial moisture content and density

The specimens sized of 50 mm x 50 mm x thickness were prepared and their mass was weighed and then oven-dried at 103±2°C, until it reached a constant mass. The density was measured by dividing the mass and volume; and the MC was calculated according to the following formula:

Moisture Content (%) = $((W_1 – W_2)/W_2)$ X 100

Where, W_1: Weight before drying (g), W_2: Weight after drying (g)

Density (g/cm³) = (M_1/V)

Where: M_1 is mass (g), V is volume (cm³)

Determination of water absorption and thickness swelling

The water absorption (WA) and thickness swelling (TA) were determined by measured the increased in mass and thickness of specimen after immersion in water. The specimen sized of 25 mm x 75 mm x thickness was submerged in 3 cm below the water surface at 20± 1°C for 24 hours, released, wiped with cloth and then measured its thickness and weight. The thickness swelling and water absorption were calculated as the following formula:

Thickness swelling (%) = $(T_2 – T_1)/ T_1)$ X 100

Where: T_1 is thickness of sample before immersion (mm),T_2 is thickness of sample after immersion (mm).

Water absorption (%) = $((M_1\text{-}M_2)/M_1)$X 100

Where: M_1 is weight of sample before immersion (g), $M_2$is Weight of sample after immersion (g)

Determination of static bending properties

The specimens sized of 300 mm x 300 mm x thickness were prepared and the test was conducted according to British Standard 373 (Anon., 1957) using Instron universal testing machine. The span and speed of the test was set at 280 mm and 15mm/min respectively for both face to face and end to end bonding (Figures 5 and 6).The load at proportional limit, maximum crushing load and deflection at proportional and at maximum crushing was used to calculate the MOR (Modulus of Rupture) and MOE (Modulus of Elasticity).The MoR and MoE were calculated using the following formula:

MOR (N/mm²) = $(3P_mL/2bt^2)$

Where: MoR is modulus of rupture, P_m is maximum load applied on the test specimen (n), L is span between the centers of supports (mm), b is width of the test specimen (mm), t is mean thickness of test specimen (mm).

MOE (Nmm-²) = $(L^3\Delta P/4bt^3\ \Delta S)$

Where: MOE is modulus of elasticity, L is span between the centers of supports (mm), ΔP is the increment in the load on the straight line portion of the load deflection curve (N), b is width of the test specimens (mm), t is mean thickness of the test specimens (mm), ΔS is the increment in deflection corresponding to ΔW increment in load (mm).

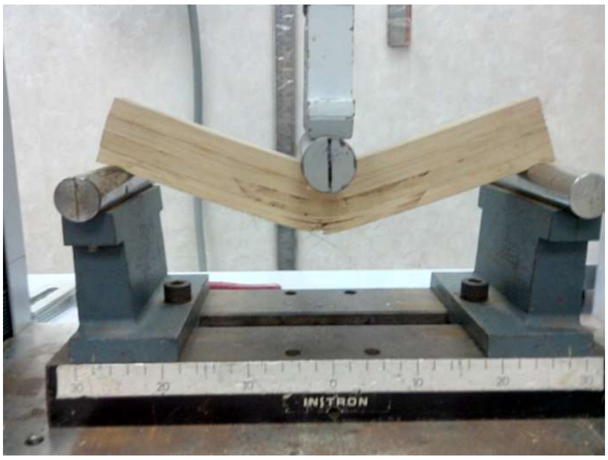

Figure 5. Face to face bonding

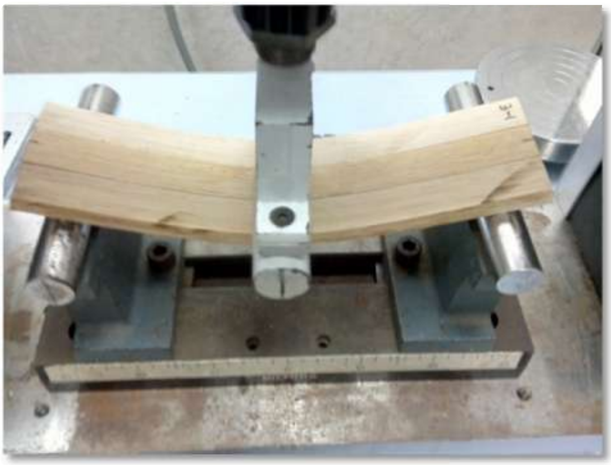

Figure 6. Edge to edge bonding

Determination of immersion delamination test

Three square test specimens of 75 mm were prepared from each sample. The specimens were immersed in water at a room temperature for 24 hours (Figure 15), oven dried at 60±3ºC for 24 hours. The rate of delamination was calculated using the following formula:

Rate of delamination (%) = (LD/LG) X 100

Where: LD is total length of delamination on 4 sides; LG is total length of glue line on 4 sides.

Determination of boiling water delamination test

The specimen size (same as immersion delamination test) was immersed in boiling water at 90˚C for four hours in water bath. This was followed by immersing in water at a room temperature (10˚C to 25˚C) for one hour. Finally, the specimen was weighed and oven dried at 70˚C±3˚C. The rate of delamination was calculated using the following formula:

Rate of delamination (%) = (LD_b/LG_b) X 100

Where: LD_b is total length of delamination on 4 sides; LG_b is total length of glue line on 4 sides.

RESULTS AND DISCUSSION

Physical properties

Overall, the physical properties of laminated rattan strips were not significantly different with types of bonding as shown in Table 1. The cold water absorption was not significantly different by the layers in face to face bonding, ranging from 104.86 to 120.83%. The results was opposite for edge to edge bonding, which 2 layers had the highest absorption (75.67%) compared to the 3 (61.22%) and 4 (64.35%) layers (Figure 7A). The hot water absorption was significantly lowest for 3 layers (104.86%); but the 2 (120.83%) and 4 (119.87%) layers was not significant for face and face bonding. In contrast, the hot water absorption was not significantly different by the layers, ranging from 102.78% to 128.34% for edge to edge bonding (Figure 7B). The thickness swelling (cold) was also not significantly different by layer for both types of bonding. They were ranged from 2.97% to 3.77% and from 3.08% to 3.15% for face to face and edge to edge bondings respectively (Figure 7C).

Table 1. The summary of ANOVA on the physical properties of laminated rattan strips

Properties	Type of bonding		DF	F	Significance
	Face to Face	Edge to edge			
Water absorption (cold, %)	64.33	67.08	1	0.80	0.39^{Ns}
Water absorption (hot, %)	115.19	114.88	1	0.00	0.96^{Ns}
Thickness swelling (Cold, %)	3.32	3.10	1	0.60	0.45^{Ns}
Delamination	3.05	5.78	1	0.76	0.40^{Ns}

F is face, E is Edge, DF is Degree of freedom, F is F-Distribution, Ns is not significant at P>0.1, * is significant at P <0.05

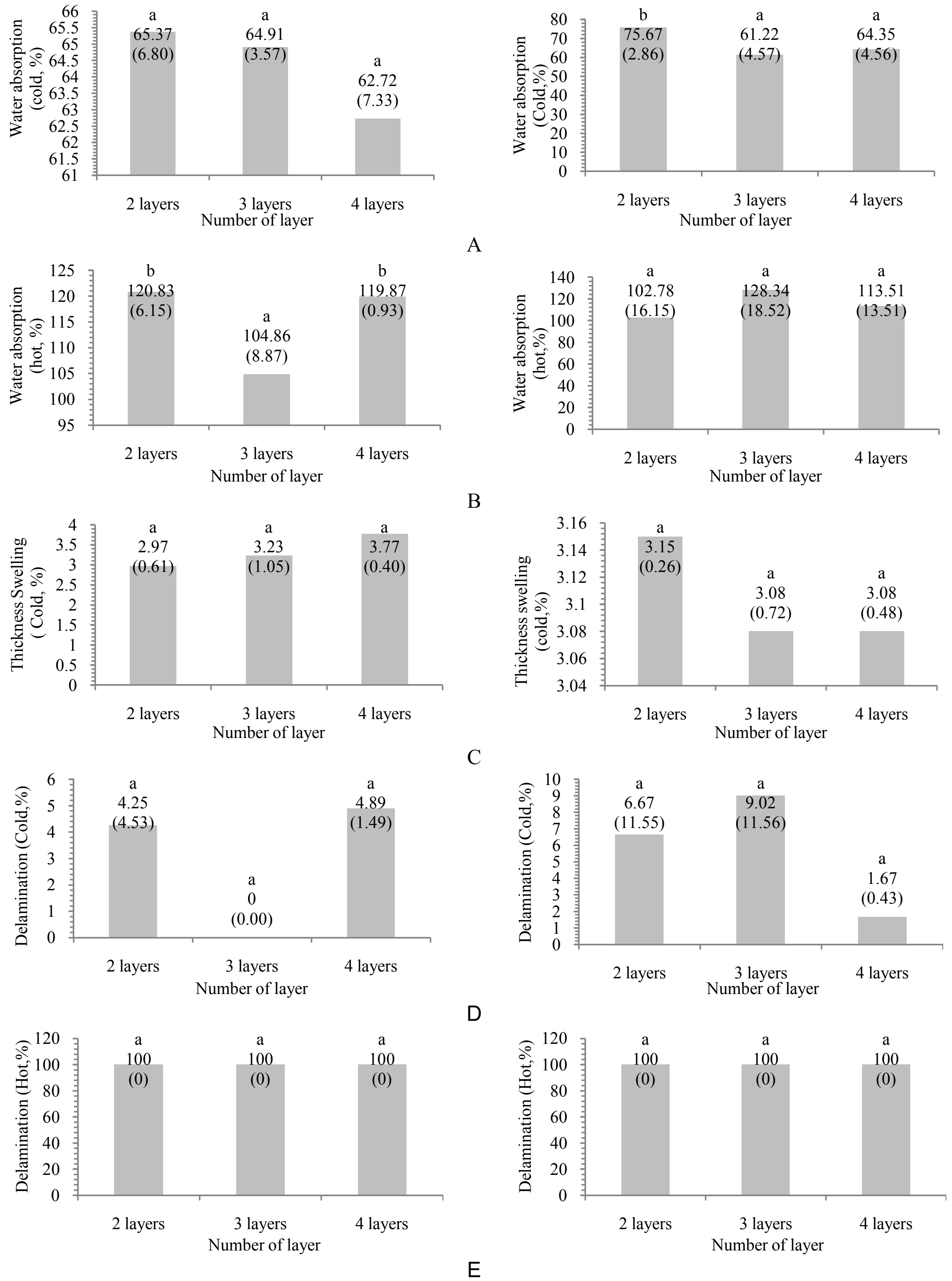

Figure 7. The physical properties of laminated rattan strips: A. Water absorption, (cold), B. Water absorption (hot), C: Thickness swelling, D: Delamination, E: Delamination (hot). Left side: face to face bonding, right side: edge to edge bonding.

Table 2. The summary of ANOVA on the physical properties of laminated rattan strips

Properties	Type of bonding		DF	F	Significance
	Face to Face	Edge to edge			
Modulus of Rupture (MoR, MPa)	50.41	52.21	1	0.31	0.58^{Ns}
Modulus of Elasticity (MOE, MPa)	1942.97	2342.52	1	5.59	0.03*
Maximum Load (ML, MPa)	3.57	1.41	1	8.46	0.01*

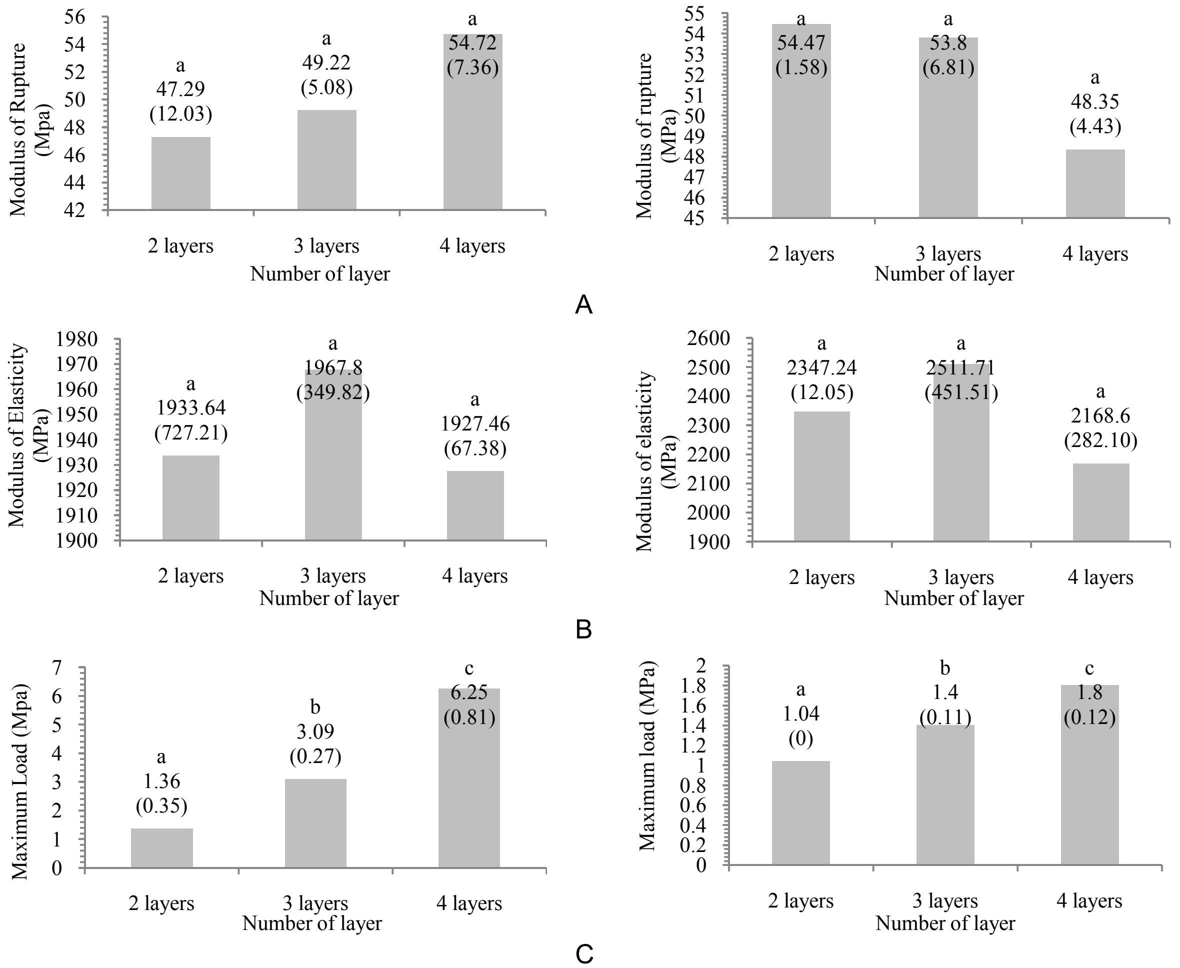

Figure 8. The static bending of laminated rattan: A) Modulus of rupture, B) Modulus of elasticity, C) Maximum load. Left side: face to face bonding, right side: edge to edge bonding

The delamination in cold water was also not significantly different by layer ranging from 0% to 4.89% and from 1.67% to 9.02% for both face to face and edge to edge bondings. The delamination was not significantly different by layer; 100% for both types of bonding (Figure 7D).

Static bending properties

The MoE and ML were significantly different by types of bonding, but not in the case of MoR (Table 2). The edge to edge (2342.52 MPa) bonding had a significantly higher MoE than those of face to face bonding (1942.97 MPa). On contrary, the ML was significantly higher in face to face bonding compared (3.57 MPa) to edge to edge bonding (1.41 MPa). The MoR was not significantly different with layers, ranging from 47.29 MPa to 54.72 MPa and from 48.35 MPa to 54.47 MPa (Figure 8A).

Akin to MOR, the MoE was not significantly different with layers, ranging from 1927.46MPato 1967.8 MPa and from 2168.6 MPa to 2511.71 MPa (Figure 8B). The ML was increased with increasing layers for both types of bonding. The ML increased from 1.36 MPa (2 layers), 3.09 MPa (3 layers) and 6.25 MPa (4 layers) in face to face bonding; 1.04 (2 layers), 1.4 MPa (3 layers) and 1.8 MPa (4 layers) in edge to edge bonding (Figure 8C).

Conclusion: Overall, the type of bonding and number of layer were not influenced the physical and mechanical properties of laminated rattan strips. Large diameter rattan can be laminated with either type of bonding and layer.

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