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Properties of Laminated Veneer Lumbers from Oil Palm Trunks

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Abstract: Oil palm trunks found in abundant and considered as an agriculture waste were investigated as alternative to dimensional wood. The trunks are of no economic importance in their natural form. However, once converted into the form of Laminated Veneer Lumber (LVL) their properties improved tremendously. This study highlighted properties of the LVL made from oil palm trunks at four different positions comprising two portions height and two cross-sectional zones. These LVL have shown to behave differently when tested for their physical, mechanical and glue delaminating properties. Testing on all the LVL specimens were done in accordance with the Japanese Agricultural Standard SE-11, 2003.

Key words: Oil palm trunks, laminated veneer lumber, physical properties, mechanical properties, glue delaminating

INTRODUCTION

Prediction for the future indicates that the demand for timber by various wood-based industries in Asia and elsewhere will exceed the existing supply. Researchers in many parts of the world are focusing their effort in overcoming this anticipated shortage. Various alternative wood and non-wood forest products are being investigated for potential replacement to future timbers. One of these is the oil palm trunks.

Oil palm is one of the main agriculture commodities in Malaysia. Currently, 4.17 million ha of land are being planted with this agriculture trees (Anis *et al*., 2007) and over the years the area seemed to be on the increased. The economic live span of an oil palm tree is between 25 to 30 years. After this period the oil palm trees are no longer considered of having economic value. They need to be replaced with new trees. It is estimated that about 7 million metric ton of oil palm trunks were felled annually for replanting of the new trees. Most of these trunks are left to rot in the field as they are considered to be an agriculture waste.

The trunks possess densities ranging from 170 to 700 kg m^{-3} depending on position along the height and cross-sectional zones (Paridah and Anis, 2007; Khoo *et al*., 1991; Killmann and Lim, 1985). The oil palm trees at the age of 25 to 30 years normally possess diameters from 45 to 65 cm and can reach the height of 7 to 13 m (Khoo *et al*., 1991; Lim and Khoo, 1986). In natural form they are considered to be of no economic important to the wood industry.

However, once peeled for veneers and converted into the form of Laminated Veneer Lumber (LVL) their properties improved tremendously. This study highlighted properties of LVL made of oil palm trunks. Properties such as the physical, mechanical and gluing were investigated.

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MATERIALS AND METHODS

The oil palm trunks used in this investigation were harvested from a plantation in Taiping, Perak. All together, ten oil palm trunks of 30 year-old palms were harvested. Within a week after felling these trunks were transported to a plywood mill in Butterworth, Penang, for peeled veneers production and later conversion into Laminated Veneer Lumber (LVL). Twelve LVL from oil palm trunks were produced with dimension of 610×2440 mm. Three LVL were produced from each of the bottom portions of the trunks at peripheral area, bottom portions at inner cross-sectional zones, top portions at peripheral area and top portions at inner cross-sectional area, respectively. Urea formaldehyde adhesive was used as the binding material to glue the veneers together. Eight oil palm veneers were used to produce LVL of dimension 240 cm length ×120 cm width ×30 mm thickness. The oil palm LVL were prepared based on method outlines by Hashim *et al*. (2004).

The LVL were labeled and later cut into various sizes to accommodate the physical, mechanical and glue delaminating tests. Prior to testing, all samples were conditioned in a condition chamber to attain Moisture Content (MC) of 12%. The samples were placed in the chamber which was set to 20±2°C and 65±5% Relative Humidity (RH) for 2 weeks. Testing of all samples were done in accordance with Japanese Agriculture Standard (JAS) No. 237: SE-11 (Anonymous, 2003). The physical tests focused mainly of the density, thickness swelling and the water absorption of the LVL. The strength tests for static bending parallel and perpendicular to the grain at flatwise, edgewise position and shear were conducted using the Shimadzu Computer Controlled Universal Testing Machine located at the Forest Research Institute Malaysia (FRIM). Ten replicates were used for each test. Rubberwood LVL of the same dimension were used a control specimens.

This study was conducted from Jun 2006 to May 2007 using facilities located at Forest Research Institute Malaysia (FRIM) and University Malaysia Sabah (UMS).

RESULTS AND DISCUSSION

Physical Properties

The density of the oil palm LVL varies according to their veneer positions along the height and cross-sectional zone of the oil palm trunks. The LVL at bottom portion and peripheral zone (AX) shows the highest value of 591.77 kg m^{-3} followed by top portion and peripheral zone (BX) at 584.20 kg m^{-3}, bottom portion and inner zone (AY) at 487.62 kg m^{-3} and top portion and inner zone (BY) at 436.67 kg m^{-3} (Table 1). These values were lower between 16 to 37% than the density of the rubberwood LVL that were used as control specimens. The values are higher than the mean density of the oil palm steam which is around 370 kg m^{-3} (Lim and Khoo, 1986). However, according to density category the oil palm LVL of these densities fell under the light hardwood and strength group C (Anonymous, 2001).

The thickness swelling and the water absorptions properties were also observed to behave opposite to the density properties. These properties are greatly influenced by the value of density that each LVL possess as shown in Table 1. The thickness swelling at bottom portion and peripheral zone

Table 1: Density, thickness swelling and water absorption of LVL from oil palm trunks

LVL samples	Density (kg m^{-3})	Percentage lower than RBW LVL	Thickness swelling (%)	Percentage higher than RBW LVL	Water absorption (%)	Percentage higher than RBW LVL
AX	591.77 (35.51)	-15	2.99 (0.26)	+79	63.03 (12.91)	+52
AY	487.62 (31.14)	-30	4.35 (0.32)	+86	87.98 (10.43)	+66
BX	584.20 (25.76)	-16	3.01 (0.20)	+80	66.53 (15.11)	+54
BY	436.67 (28.93)	-37	5.62 (0.31)	+89	94.33 (14.84)	+68
RBW	696.54 (45.56)	-00	0.60 (0.25)	+00	30.28 (00.61)	+00

All value represent mean of ten replicates; value in bracket indicate either % lower or higher than rubberwood LVL

Table 2: Delaminating tests of LVL from oil palm trunks

LVL samples	Total samples tested	Samples passed test	Samples failed tests	Percentage of passed tests
AX	360	358	2	99.44
AY	360	320	40	88.88
BX	360	353	7	98.05
BY	360	312	48	86.67
RBW	360	342	18	95.00

Table 3: Bending parallel to the grain flatwise position

LVL samples (flatwise)	Density (kg m^{-3})	Percentage lower than RBW LVL	MOR (N mm^{-2})	Percentage lower than RBW LVL	MOE (N mm^{-2})	Percentage lower than RBW LVL
AX	555.63 (38.25)	-19	15.43 (2.32)	-73	570.27 (39.31)	-78
AY	481.97 (31.41)	-30	12.10 (1.07)	-79	384.05 (29.67)	-85
BX	519.70 (33.44)	-25	15.07 (2.53)	-73	539.69 (35.82)	-79
BY	414.02 (29.29)	-40	8.84 (0.75)	-84	324.67 (28.68)	-87
RBW	689.15 (44.61)	-00	56.57 (7.76)	-00	2543.34 (507.15)	-00

All value represent mean of ten replicates; value in bracket indicate % lower than rubberwood

Table 4: Bending parallel to the grain edgewise position

LVL samples (edgewise)	Density (kg m^{-3})	Percentage lower than RBW LVL	MOR (N mm^{-2})	Percentage lower than RBW LVL	MOE (N mm^{-2})	Percentage lower than RBW LVL
AX	554.11 (34.25)	-19	19.68 (3.13)	-66	1200.89 (143.51)	-60
AY	470.29 (30.46)	-31	16.82 (2.92)	-71	925.21 (134.74)	-69
BX	525.08 (32.14)	-23	17.58 (2.73)	-70	932.09 (138.26)	-69
BY	404.33 (31.96)	-41	10.43 (1.75)	-82	653.18 (98.73)	-78
RBW	682.23 (42.33)	-00	57.94 (6.98)	-00	2991.41 (585.65)	-00

All value represent mean of ten replicates; value in bracket indicate % lower than rubberwood

(AX) shows the lowest value of 2.99% followed by top portion and peripheral zone (BX) at 3.01%, bottom portion and inner zone (AY) at 4.35% and top portion and inner zone (BY) at 5.62%. The water absorption properties were found to be 63.03% at bottom portion and peripheral zone (AX), followed by top portion and peripheral zone (BX) at 66.53%, bottom portion and peripheral zone (AY) at 87.98% and top portion and inner zone (BY) at 94.33%.

In the delaminating test of the LVL, surprisingly the specimens from bottom portion and peripheral zone (AX) and top portion and peripheral zone (BX) showed higher passing percentage compared to the rubberwood LVL (Table 2). LVL made from oil palm trunks taken from bottom portion at peripheral zone and top portion at peripheral zone passed delamination tests.

Strength Properties

In this part of the investigation, the bending and the shear tests were conducted on the LVL in determining their strength properties. Testings on static bending were carried out both in parallel and perpendicular to the grain in flatwise and edgewise positions. The rubberwood LVL were used as standard and control specimen for comparison. The results on LVL bending for the flatwise and edge position are shown as in Table 3 and 4, respectively.

For static bending in parallel to the grain, the MOR values for the LVL ranged from 8.84 to 15.43 N mm^{-2} and MOE from 324.67 to 570.27 N mm^{-2} for LVL specimen AX, AY, BX and BY, respectively for flatwise position. The values increases for the edgewise position where the MOR values for the LVL ranged from 10.43 to 17.58 N mm^{-2} and MOE from 653.18 to 1200.89 N mm^{-2} for LVL specimen AX, AY, BX and BY, respectively

Table 5 and 6 shows the results for static bending in perpendicular to the grain, the MOR values for the LVL ranged from 1.06 to 1.56 N mm^{-2} and MOE from 85.34 to 93.91 N mm^{-2} for LVL specimen AX, AY, BX and BY, respectively for flatwise position. The values increases for the

Table 5: Bending perpendicular to the grain flatwise position

LVL samples (flatwise)	Density (kg m^{-3})	Percentage lower than RBW LVL	MOR (N mm^{-2})	Percentage lower than RBW LVL	MOE (N mm^{-2})	Percentage lower than RBW LVL
AX	577.15 (35.52)	-17	1.56 (3.13)	-58	93.91 (13.71)	-69
AY	478.14 (31.42)	-31	1.08 (2.92)	-71	87.75 (10.83)	-71
BX	504.35 (36.23)	-27	1.22 (2.73)	-67	91.34 (12.81)	-63
BY	419.23 (29.56)	-40	1.06 (1.75)	-71	85.34 (9.34)	-72
RBW	695.51 (42.54)	-00	3.71 (6.98)	-00	304.73 (19.65)	-00

All value represent mean of ten replicates; value in bracket indicate % lower than rubberwood

Table 6: Bending perpendicular to the grain edgewise position

LVL samples (edgewise)	Density (kg m^{-3})	Percentage lower than RBW LVL	MOR (N mm^{-2})	Percentage lower than RBW LVL	MOE (N mm^{-2})	Percentage lower than RBW LVL
AX	560.72 (34.28)	-19	1.67 (3.82)	-61	164.22 (14.15)	-62
AY	483.29 (30.42)	-30	1.33 (3.02)	-69	141.67 (13.22)	-67
BX	508.14 (35.96)	-27	1.39 (2.99)	-68	144.46 (14.03)	-67
BY	401.03 (27.88)	-42	1.14 (1.59)	-74	123.77 (12.76)	-71
RBW	692.12 (44.54)	-00	4.33 (4.92)	-00	432.63 (34.53)	-00

All value represent mean of ten replicates; value in bracket indicate % lower than rubberwood

Table 7: Shear of the oil palm LVL

LVL samples	Density (kg m^{-3})	Percentage lower than RBW LVL	Shear (N mm^{-2})	Percentage lower than RBW LVL
AX	581.24 (28.01)	-15	1.36 (0.11)	-68
AY	472.25 (20.19)	-30	0.96 (0.07)	-78
BX	571.42 (27.92)	-16	1.12 (0.09)	-74
BY	442.33 (24.13)	-37	0.62 (0.06)	-85
RBW	682.45 (31.26)	-00	4.27 (0.33)	-00

All value represent mean of ten replicates; value in bracket indicate standard deviation

edgewise position where the MOR values for the LVL ranged from 1.14 to 1.67 N mm^{-2} and MOE from 123.77 to 164.22 N mm^{-2} for LVL specimen AX, AY, BX and BY, respectively

Table 7 shows the shear values of the oil palm LVL and their comparison to the shear of the rubberwood LVL. The MOR of the oil palm LVL ranged from 1.14 to 1.67 N mm^{-2} and the MOE ranged from 123.77 to 164.22 N mm^{-2}. The overall value was lower than the MOR and MOE for rubberwood by 61 to 74% and 62 to 71%, respectively.

The overall results in the strength on the oil palm LVL tests for both the static bending either in parallel or perpendicular (flatwise and edgewise) and shear seem to be greatly influenced by the combined densities of the laminated veneers and the position of the veneers taken along the trunks height and cross-sectional zones. These values increase with the increases in density of the LVL. The highest values obtained in term of the physical, mechanical and glue delaminating tests however fell short of those found in the rubberwood LVL.

The oil palm LVL which possess densities and strengths mentioned earlier can be categorized as light hardwood and strength group C. Rubberwood also fall into light hardwood category and strength group C but they are in the upper category list (Anonymous, 2001). The most suitable uses of the oil palm LVL is as material for LVL paneling and furniture where strength is not the critical element required. The strength of these LVL can however be improved further by increasing the density of the veneers through compression process (Edi *et al*., 2007). Injecting stabilizer or polymer into the veneers or oil palm LVL can also improve the strength but the processes involved are expensive.

CONCLUSIONS

The densities of the oil palm LVL ranged from 436.67 to 591.77 kg m^{-3}. These values lower between 15 to 37% compared to that of the rubberwood LVL.

The thickness swelling and the water absorption of the oil palm LVL were 79 to 89% and 52 to 68% higher than the rubberwood LVL, respectively.

LVL made from oil palm trunks taken from bottom portion at peripheral zone and top portion at peripheral zone passed delamination tests according to JAS: SE-11.

The bending parallel to the grain of the oil palm LVL has values lower between 73 to 84% and 78 to 87%, respectively for MOR and MOE at flatwise position to that of the rubberwood. The specimen placed at edgewise has values 66 to 82% for MOR and 60 to 78% for MOE, respectively to that of rubberwood. They ranged from 8.84 to 15.43 N mm^{-2} for MOR and 324.67 to 570.27 N mm^{-2} for MOE at flatwise position and 10.43 to 19.68 N mm^{-2} for MOR, 653.18 to 1200.89 N mm^{-2} for edgewise position.

The bending perpendicular to the grain of the oil palm LVL has values lower between 58 to 71% and 69 to 72%, respectively for MOR and MOE at flatwise position to that of the rubberwood. The specimen placed at edgewise has values 61 to 74% for MOR and 62 to 71% for MOE, respectively to that of rubberwood. They ranged from 1.06 to 1.56 N mm^{-2} for MOR and 85.34 to 93.91 N mm^{-2} for MOE at flatwise position and 1.14 to 1.67 N mm^{-2} for MOR, 123.77 to 164.22 N mm^{-2} for edgewise position.

The shear values of the oil palm LVL were lower between 68 to 85% to that of the rubberwood LVL. They ranged between 0.62 to 1.36 N mm^{-2}.

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