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Flexural Properties of Laminated Veneer Lumber Manufactured from Oil Palm Veneers

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ABSTRACT

The uniform properties and higher strength of laminated veneer lumber (LVL) makes it a superior structural material than other solid timber or glue-laminated timber. It requires round logs to process into veneer and laminated parallel to each other to form LVL. However, due to shortage of quality timber (round log), efforts have been made to use alternative materials such as oil palm trunk to produce LVL. This study was undertaken to determine the flexural properties of oil palm LVL of different veneer lay-up patterns and glue-spread rates. In this study, nine types of LVL were produced using three different veneer lay-up patterns and three glue spread rates i.e., 250, 300 and 350 g m² for double glueline. The results revealed that LVL with optimum flexural properties (bending properties and shear-strength) was produced using outer-layer veneers bonded by phenol formaldehyde at a glue spread rate of 350 g m². Higher glue spread rate and veneers of the outer-layer of oil palm trunk can produce LVL of better flexural properties.

INTRODUCTION

Laminated Veneer Lumber (LVL) is a structural composite lumber which is produced by many companies around the world. The production technology of LVL has been widely established.

The uniform properties and higher strength of LVL makes it a superior structural material than other solid timber or glue-laminated timber. It requires round logs to process into veneer and laminate parallel to each other to form LVL. However, due to shortage of timber (round log), good quality and larger timber is difficult to find in natural forests of Malaysia. Therefore, efforts have been made to use another alternative material to produce LVL. Many researchers had found that the oil palm trunk can be converted into veneers for producing plywood and converted into sawn timber, particle and fiber for particleboard and medium density fiberboard, respectively (Khozirah *et al.*, 1991; Paridah and Zaidon, 2000). Thus, this provides a potential alternative veneer material for LVL to supplement the depleting supply of timber.

There are extensive oil palm plantations in Malaysia covering a total of 4.2 millions hectares (Bakar *et al.*, 2007). The annual availability of oil palm trunk is estimated to be around 13.6 million logs based on the 100,000 hectares of replanting reach year (Paridah *et al.*, 2007).

However, oil palm which is a monocotyledonous species does not posses any vascular cambium, so it does not increase in diameter with age. All procambial cells in monocotyledons typically differentiate into primary xylem or phloem, leaving no vascular cambium. These plants, therefore, do not produce secondary xylem and phloem that serves to increase stem diameter throughout the life of the tree. The typical feature is the distinct occurrence of the primary vascular bundles that are randomly embedded in parenchyma ground tissues (Tomlinson, 1961). These vascular bundles are concentrated at the outer portion and reducing towards the inner portion of the trunk. This uneven distribution of vascular bundles along the radial direction of trunk corresponds to a great variation of density values at different parts of the oil palm trunk. The veneer ribbon density distribution along the trunk was found to decrease from outer layers towards inner layers and from bottom part towards the top part of the oil palm trunk. The density values of the oil palm trunk ranged from 200 to 600 kg m³ with an average of 370 kg m³ (Lim and Khoo, 1986).

The veneers peeled from oil palm trunk can be segregated into four density groups i.e., high density (600 kg m^{-3}), medium density (400-600 kg m^{-3}), low-medium density (<400 - 550 kg m^{-3}) and low density (< 400 kg m^{-3}) based on the section of the oil palm trunk (Lim and Khoo, 1986). The high density gradients which exist along the radial, as well as, the longitudinal directions of the trunk indica te that the oil palm trunk is unable to produce consistent quality veneer like other forest timber. Therefore, products from oil palm veneers may lack quality in terms of the flexural strength which is important for structural application.

The objective of this study was to determine the flexural properties i.e., bending properties and gluebond shear strength of LVL produced from oil palm veneer by using different veneer lay-up patterns and glue-spread rates.

METHODOLOGY

The veneers used in the production process were rotary peeled from oil palm trunk in a commercial plywood factory. There were two peeling stages. The first peeling stage peeled to about 25 cm (10 in) in diameter after debarking. Veneer peeled from the first peeling stage was identified as outer-layer veneers having an average thickness of 3.5 mm. For the second peeling stage, the billet was transferred onto a small lathe machine where the trunks were peeled until a final diameter of 12 cm was achieved. These veneers were about 4.1 mm thick and were identified as inner-layer veneers. Each veneer density was determined and recorded. All the veneers were dried to 7% moisture content.

The glue used to laminate the veneer was phenol-formaldehyde adhesive, which gives a bond of exterior grade. The LVL was manufactured with dimensions of 45 mm x 45 mm and a final thickness of 12 mm using 5 plies of veneer at the Faculty of Forestry, Universiti Putra Malaysia.

Nine types of LVL with five replicates each were produced for this study using three different veneer lay-up patterns; a) homogenous pattern of outer-layer veneers, b) homogenous of inner-layer veneers and c) mixture of outer-layer and inner-layer veneers (surfaces using outer-layer and core using inner-layer veneers). Three glue spread rates, 250, 300 and 350 g m^{-2} were used in the manufacture of the LVL.

The assembled veneers were then cold pressed for 5 minutes and hot pressed at 130°C for 15 minutes. The LVLs were conditioned in a conditioning room maintained at a relative humidity of 65 ± 5% and 20 ± 20C for 7 to 10 days prior to evaluating the properties.

A total of 180 bending and gluebond shear samples were cut from the LVL boards with 10 replicates for each type of LVL. The bending properties of the LVL specimens were tested according to BS/EN 310: 1993 (BSI, 1993a). The glue bond shear test was determined according to BS/EN 314-1: 1993 (BSI, 1993b). In addition, dimensional stability tests were also carried out by soaking the test samples in cold water for 24 hours.

All the flexural data collected were analysed using analysis of co-variance (ANOCOV) to determine the interaction between the variables and effect of the variables used in this study on the bending properties and gluebond shear strength of oil palm LVL at 12% moisture content. The means of the bending strength, stiffness and gluebond shear strength were further analysed by the Least Square Means method to determine the oil palm LVL with optimum bending and gluebond shear performances.

RESULTS AND DISCUSSION

Density of Oil Palm Veneers

The total length of the veneer ribbon that can be peeled from the oil palm trunk was about 15 meter. The length of veneer ribbon which can differentiate the outer- and inner-layer is approximately 4 meter. The density of the outer-layer veneers ranged from 358 to 442 kg m^{-3} whereas density of inner-layer veneers ranged from 272-446 kg m^{-3}.

Physical Properties

The average moisture content of the veneers and densities of the LVL boards are shown in Table 1. LVL produced using homogenous outer veneers had the highest density whereas boards produced using inner veneers had the lowest density.

As shown in Table 1, the average thickness swelling of the oil palm trunk ranged from 23.4 to 30.1% while the water absorption ranged from 49.7 to 62.5%. The highest thickness swelling and water absorption percentage was found in LVL manufactured from inner layer

TABLE 1
Moisture content and density of oil palm LVL

Gluespread rate g m-2	Layup Pattern	Moisture content %	Board Density kg m-3	Thickness swelling %	Water Absorption %
250	Outer	11.16	529	24.4	54.3
250	Inner	10.84	520	28.5	62.5
250	Mix	10.86	528	27.1	58.9
300	Outer	11.41	555	23.4	53.1
300	Inner	11.17	505	30.1	57.0
300	Mix	11.16	539	27.3	56.5
350	Outer	10.13	573	28.3	49.7
350	Inner	11.45	511	30.1	54.6
350	Mix	11.75	549	30.0	53.7

veneers using glue spread rate of 350 and 200 g m^{-2} respectively. The low density of the inner layer veneers may be attributed to the poor performance of the dimensional stability. Vick (1999) stated that high density timbers normally had thicker cell wall and smaller lumen which associate with smaller volume for water absorption compared to lighter density timbers.

Bending Properties

Bending stiffness of the LVL produced from oil palm was lower than for LVLs produced from tropical hardwood species as reported by H'ng *et al.* (2002). He reported that LVL produced from *kedondong*, *bintangor* and white *meranti* respectively had Modulus of Elasticity (MOE) values ranging from 12,000 to 18,000 N mm^{-2} and Modulus of Rupture (MOR) values ranging from 34 to 40 N mm^{-2}. The maximum MOE values found in oil palm LVL manufactured from outer veneer layer with a glue spread rate of 350 g mm^{-2} is far below the minimum requirement for that used in structural applications. According the PRL 501: Performance standard for laminated veneer lumber (APA, 2000), the minimum MOE for LVL to be used in structural applications is 10392 N mm^{-2}.

Assessment of the failure pattern of the static bending specimens revealed that almost 80% of the samples failed the compression area as shown in *Fig. 1.* Curry and Fewell (1977) stated that material which failed at the compression area during static bending always associates with lower MOR and MOE because compression failure is an early failure that is found in the bending test before the material can sustain the maximum breaking force.

Analysis of co-variance (ANOCOV) revealed highly significant interactions of glue spread rate and lay-up pattern on the MOR and MOE of oil palm LVL as shown in Table 2.

As shown in Table 2, the highest MOR and MOE were achieved for the LVL produced using outer-layer veneers with glue spread rate of 350 g/m^2. This may be due to the higher density of LVL produced from the outer-layer. Density is an indicator and predictor for bending strength, stiffness, and various mechanical properties (Panshin and de Zeeuw, 1980). As the board's density increased, the strength properties of the

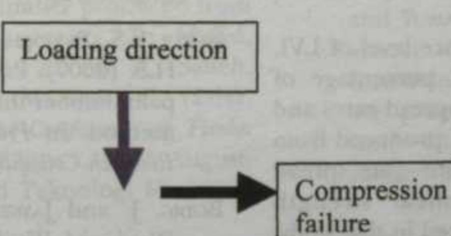

Fig. 1: Compression failure of the oil palm LVL

TABLE 2
Influence of Glue spread rate and lay-up pattern on MOR and MOE

Glue spread rate	Lay-up pattern	MOR N mm-2	MOE N mm-2
250	Outer	30.96[bc] (7.7)	3972[c] (1028)
250	Inner	25.00[de] (2.4)	2758[d] (214)
250	Mix	30.39[c] (3.4)	-3762[c] (688)
300	Outer	34.01[b] (3.3)	5012[ab] (277)
300	Inner	18.60[e] (2.5)	1907[e] (256)
300	Mix	25.96[d] (2.2)	3723[cd] (484)
350	Outer	39.85[a] (5.2)	5399a (881)
350	Inner	21.89[e] (2.9)	2469[d] (405)
350	Mix	30.64[bc] (3.7)	4815[b] (479)

Note: Means with the same letter in the same column are not significantly different. ($P< 0.05$)
The values in brackets are standard deviations

board also increased (Bodig and Jayne, 1982). All the LVL manufactured with glue spread rate of 350 g m^{-2} was higher in MOR and MOE than the LVL using the glue spread rate of 250 g/m^{-2} and 250g/m^{-2}. Youngquist (1999) stated that adhesive played an important role on the bending strength of LVL. By having an optimum adhesive on laminating the veneers, maximum strength can be obtained from the LVL.

Gluebond Shear Strength

ANOCOV results revealed that the effect of glue spread rate and lay-up pattern on the glue bond shear strength was highly significant. Interaction between the glue spread rate and lay-up pattern was also observed, which means that the shear strength was affected by both glue spread rate and lay-up pattern together.

Table 3 shows the significance level of LVL glue bond shear strength and percentage of wood failure for different glue spread rates and lay-up pattern in this study. LVL produced from outer-layer veneer with 350 g m^{-2} glue spread rate had the highest LVL shear strength compared to other LVLs produced in this study. The gluebond shear strength result is consistent with the findings for the bending properties. By improving the density of the oil palm's LVL using outer-layer veneer and higher glue spread, the glue bond shear strength will increased.

CONCLUSION

LVL with optimum flexural properties (bending properties and shear strength) can be produced using outer-layer veneers which were obtained by peeling the trunk to about 25 cm (10 in) in diameter and bonded by using phenol formaldehyde at glue spread rate of 350 g m^{-2}.

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TABLE 3
Influence of the glue spread rate and lay-up pattern on glue bond strength and wood failure

Glue spread rate	Lay-up pattern	Glue bond strength $N\ mm^{-2}$	Wood Failure %
250	Outer	2.05^{b} (0.51)	80
250	Inner	1.64^{bc} (0.13)	100
250	Mix	1.54^{c} (0.26)	100
300	Outer	2.19^{a} (0.15)	90
300	Inner	1.41^{c} (0.11)	80
300	Mix	1.61^{bc} (0.21)	80
350	Outer	2.56^{a} (0.39)	90
350	Inner	1.68^{bc} (0.25)	80
350	Mix	1.83bc (0.31)	80

Note: Means with the same letter in the same column are not significantly different at ($P < 0.05$)
The values in brackets are standard deviations

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