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PROPERTIES OF ENGINEERED OIL PALM COMPOSITE BOARDS FROM 32 YEAR-OLD TREE STEMS

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ABSTRACT

The unutilized stems of oil palm trees found in abundant in Malaysia and considered as an agriculture waste were investigated as a possible alternative to future wood. The stems are of no economic importance in their natural form, but once converted into the form of engineered composite boards their properties improved tremendously. This paper highlighted properties of the engineered composite boards made from oil palm stems at four different height positions comprising two portions height and two cross-sectional zones. The engineered boards have shown to have variation in properties when tested for their physical, mechanical and glue delaminating studies. Testing on all the composite boards specimens were done in accordance with the Japanese Agricultural Standard, JAS No. 237: 2003.

Keywords: oil palm stems, engineered composite boards, physical properties, mechanical properties, glue delaminating.

INTRODUCTION

The demands for timber by various wood-based industries all over the world are expected to exceed the existing supply in the future. Researchers all over the globe are currently studying various materials to replace wood in anticipating shortage of timbers. Various types of alternative material which are organic in nature such as lesser known wood and non-wood forest products are being investigated. One of these materials is the oil palm stems. 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 increasing. The economic live span of an oil palm tree is between 25 to 32 years. After this period the oil palm trees are no longer considered to have an economic value. They need to be replaced with new trees. It is estimated that about 7,000,000 metric ton of an oil palm trunks were felled annually in Malaysia for replanting of the new trees. Most of these oil palm stems 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 locations along the height and cross-sectional zones (Khoo *et al.*, 1991; Killmann and Lim, 1985). The oil palm stems at the age of 25 to 32 normally possess diameters from 45 to 65 cm, and can reach the height of 7 to 13 m (Khoo *et al.*, 1991). In natural form they are considered to be of no economic important to the wood industry. However, once they are process into engineered products such as composite boards their properties improved tremendously. This paper highlighted properties of the engineered composite boards from oil palm stems. Properties such as the physical, mechanical and gluing were investigated.

MATERIALS AND METHODS

The oil palm trunks used in this investigation were harvested from a plantation in Taiping, Perak. Ten (10) oil palm trees of 32 year-old were harvested. Within a week after felling the trunks from the oil palm stems were transported to a plywood mill in Tanah Merah, Kelantan, for subsequent process, peeled veneers production and later converted into engineered composite boards. Twelve (12) composite boards from oil palm trunks were produced with dimension of 610 x 2440 mm. Three (3) composite boards were produced from 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 (8) oil palm veneers were used to produce composite boards of dimension 240 cm length x 120 cm width x 25 mm thickness. The oil palm composite boards were prepared based on method outlines by Hashim *et al*. (2004). The composite boards 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. All testing were done in accordance with Japanese Agriculture Standard (JAS) No. 237: 2003. The physical tests focused mainly of the density, thickness swelling and the water absorption of the composite boards. The strength tests for static bending parallel and perpendicular to the grain at flat wise, edgewise positions and shear were conducted using Universal Testing Machine located at the Forest Research Institute Malaysia (FRIM). Ten (10) replicates were used for each test. Rubber wood composite boards of the same dimension were used as controls.

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RESULTS AND DISCUSSIONS

The results on the physical, mechanical and glue delaminating properties of composite boards from oil palm trunks are tabulated in Tables 1 to 7, respectively.

Physical properties

The density of the oil palm composite boards varies according to their veneer locations along the height and cross-sectional zone of the oil palm trunks. The composite boards at bottom portion and peripheral zone (AX) shows the highest value of 596.77 kg/m^3 followed by top portion and peripheral zone (BX) at 589.20 kg/m^3, bottom portion and peripheral zone (AY) at 492.62 kg/m^3 and top portion and inner zone (BY) at 441.67 kg/m^3. These values were lower between 14 to 36% than the density of the rubberwood that were used as controls. 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 composite boards of these densities fell under the light hardwood and strength group 5 and 6. 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 composite boards possess as shown in Table-1. The thickness swelling at bottom portion and peripheral zone (AX) shows the lowest highest value of 2.99% followed by top portion and peripheral zone (BX) at 3.01%, bottom portion and peripheral 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 composite boards, surprisingly the specimens from at bottom portion and peripheral zone (AX) and top portion and peripheral zone (BX) showed higher passing percentage compared to the rubberwood composite boards (see Table-2). Composite boards made from oil palm trunks taken from bottom portion at peripheral zone, and top portion at peripheral zone passed delamination tests.

Table-1. Thickness swelling and water absorption of composite boards from oil palm trunks.

Engineered composite boards	**Density** (kg/m^3)	**Thickness swelling** (%)	**Water absorption** (%)
AX	596.77 (-14%)	2.99 (+79%)	63.03 (+52%)
AY	492.62 (-29%)	4.35 (+86%)	87.98 (+66%)
BX	589.20 (-15%)	3.01 (+80%)	66.53 (+54%)
BY	441.67 (-36%)	5.62 (+89%)	94.33 (+68%)
Rubberwood	696.54 (-00%)	0.60 (+00%)	30.28 (+00%)

(All value represent mean of 10 replicates; value in bracket indicate either % lower or higher than rubberwood)

Table-2. Delaminating tests of engineered composite boards from oil palm stems.

Engineered composite boards	**Total samples tested**	**Samples passed test**	**Samples failed tests**	**% 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
Rubberwood	360	342	18	95.00

(All value represent mean of 10 replicates)

Strength properties

In this part of the investigation, the bending and the shear tests were conducted on the composite boards 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 composite boards were used as standard and control specimen for comparison. The results on composite boards bending for the flatwise and edge position are shown as in Tables 3 and 4, respectively. For static bending in parallel to the grain, the MOR values for the composite boards ranged from 11.05 to 19.29 N/mm^2 and MOE from 405.83 to 712.84 N/mm^2 for composite boards specimen AX, AY, BX and BY respectively for flatwise position. The values increases for the edgewise position where the MOR values for the composite boards ranged from 13.04 to 24.63 N/mm^2 and MOE from 816.47 to 1501.11 N/mm^2 for composite boards specimen AX, AY, BX and BY, respectively.

Table-3. Bending parallel to the grain flat-wise position.

Engineered composite boards (flatwise)	**Density** (kg/m^3)	**MOR** (N/mm^2)	**MOE** (N/mm^2)
AX	560.63 (-18%)	19.29 (-65%)	712.84 (-71%)
AY	486.97 (-29%)	15.13 (-73%)	480.06 (-81%)
BX	524.70 (-24%)	18.84 (-66%)	674.61 (-73%)
BY	419.02 (-39%)	11.05 (-80%)	405.83 (-84%)
Rubberwood	689.15 (-00%)	56.57 (-00%)	2543.34 (-00%)

(All value represent mean of 10 replicates; value in bracket indicate % lower than rubberwood)

Table-4. Bending parallel to the grain edge-wise position.

Engineered composite boards (edgewise)	**Density** (kg/m^3)	**MOR** (N/mm^2)	**MOE** (N/mm^2)
AX	559.11 (-19%)	24.63 (-57%)	1501.11 (-50%)
AY	475.29 (-31%)	21.02 (-63%)	1156.51 (-61%)
BX	530.08 (-23%)	21.97 (-62%)	1165.11 (-61%)
BY	409.33 (-41%)	13.04 (-77%)	816.47 (-73%)
Rubberwood	682.23 (-00%)	57.94 (-00%)	2991.41 (-00%)

(All value represent mean of 10 replicates; value in bracket indicate % lower than rubberwood)

Tables 5 and 6 shows the results for static bending in perpendicular to the grain, the MOR values for the composite boards ranged from 1.33 to 1.95 N/mm^2 and MOE from 106.68 to 117.39 N/mm^2 for composite boards specimen AX, AY, BX and BY, respectively for flatwise position. The values increases for the edgewise position where the MOR values for the composite boards ranged from 1.43 to 2.09 N/mm^2 and MOE from 154.71 to 205.27 N/mm^2 for composite boards specimen AX, AY, BX and BY, respectively. Table-7 shows the shear values of the oil palm composite boards and their comparison to the shear of the rubberwood composite boards. The shear values of the composite boards ranged from 0.76 to 1.71 N/mm^2. The overall values are lower than the shear of the rubberwood by 59 to 82%. The overall results in the strength on the oil palm composite boards 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 composite boards. The highest values obtained in term of the physical, mechanical and glue delaminating tests however fell short of those found in the rubberwood composite boards.

Table-5. Bending perpendicular to the grain flat-wise position.

Engineered composite boards (flatwise)	**Density** (kg/m^3)	**MOR** (N/mm^2)	**MOE** (N/mm^2)
AX	582.15 (-17%)	1.95 (-47%)	117.39 (-61%)
AY	483.14 (-31%)	1.35 (-64%)	109.69 (-64%)
BX	509.35 (-27%)	1.53 (-59%)	114.18 (-62%)
BY	424.23 (-40%)	1.33 (-64%)	106.68 (-65%)
Rubberwood	695.51 (-00%)	3.71 (-00%)	304.73 (-00%)

(All value represent mean of 10 replicates; value in bracket indicate % lower than rubberwood)

Table-6. Bending perpendicular to the grain edgewise position.

Engineered composite boards (edgewise)	**Density** (kg/m^3)	**MOR** (N/mm^2)	**MOE** (N/mm^2)
AX	565.72 (-19%)	2.09 (-51%)	205.27 (-53%)
AY	488.29 (-30%)	1.66 (-61%)	177.08 (-59%)
BX	513.14 (-27%)	1.74 (-59%)	180.58 (-58%)
BY	406.03 (-42%)	1.43 (-67%)	154.71 (-64%)
Rubberwood	692.12 (-00%)	4.33 (-00%)	432.63 (-00%)

(All value represent mean of 10 replicates; value in bracket indicate % lower than rubberwood)

Table-7. Shear of the oil palm composite boards.

Engineered composite boards	**Density** (kg/m^3)	**Shear** (N/mm^2)
AX	596.77 (-15%)	1.71 (-59%)
AY	492.62 (-30%)	1.23 (-71%)
BX	589.20 (-16%)	1.41 (-67%)
BY	441.67 (-37%)	0.76 (-82%)
Rubberwood	696.54 (-00%)	4.27 (-00%)

(All value represent mean of 10 replicates; value in bracket indicate % lower than rubberwood)

The oil palm composite boards 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 upper category list (reference for strength group MTC). The most suitable uses of the oil palm composite boards is as material for composite boards paneling and furniture where strength is not the critical element required. The strength of these composite boards 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 engineered oil palm composite boards can also improve the strength but the processes involved are expensive.

CONCLUSIONS

The densities of the engineered oil palm composite boards ranged from 441.67 to 596.77 kg/m^3. The thickness swelling and the water absorption of the oil palm composite boards were 79 to 89% and 52 to 68% higher than the rubberwood composite boards, respectively. The composite boards made from oil palm stems 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 engineered oil palm composite boards has values ranged from 11.05 to 19.29 N/mm^2 for MOR and 405.83 to 712.84 N/mm^2 for MOE at flatwise position, and 13.04 to 24.63 N/mm^2 for MOR, 816.47 to 1501.11 N/mm^2 for edgewise position. The bending perpendicular to the grain of the engineered oil palm composite boards has values ranged from 1.33 to 1.95 N/mm^2 for MOR and 106.68 to 117.39 N/mm^2 for MOE at flatwise position, and 1.43 to 2.09 N/mm^2 for MOR, 154.71 to 205.27 N/mm^2 for edgewise position. The shear values of the engineered oil palm composite boards ranged between 0.76 to 1.71 N/mm^2.

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