Properties of Oriented Strand Board (OSB) from *Acacia mangium* and Rubberwood

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Abstract

This study used *Acacia mangium* and rubberwood species as the raw materials in manufactured of oriented strand board (OSB). The objectives of this study were to determine the physical and mechanical properties of OSB using *Acacia mangium* and rubberwood, and effect of different board densities (600 kg/m^3 and 700 kg/m^3) and layer arrangement (species) on properties. In this study, phenol formaldehyde (PF) was use as a binder and it was fixed at 9%. Oriented strand board was assessed for the mechanical properties (bending and internal bonding) and physical properties (thickness swelling) according to European Standard (EN 300:1993). Mechanical properties revealed the highest MOR (34.18 MPa) and MOE (6 835.78 MPa) with higher board density of 700 kg/m^3 from 100% *Acacia mangium*. However, the highest results for IB value was 1.32 MPa from RRR with lower board density of 600kg/m^3. Furthermore, for the physical properties with density board of 600kg/m^3 with 100% Acacia mangium strands point the lowest TS value with 27.24%. The results revealed that board density show significant effect on mechanical properties except for IB. However, TS values results were no significant.

Keywords : *Oriented strand board, Acacia mangium, rubberwood, board densities, layer arrangement (species), phenol formaldehyde*

1. INTRODUCTION

Oriented strand board (OSB) is the first to be introduced in USA from 1935 and was later for wood panels based on "veneer strips crosswise oriented". In 1963, experiment of production started for the first pilot plant in USA and the first commercial plant in Europe started in 1978. OSB was first produced by MacMillan Bloedel in Saskatchewan, Canada in 1963 and it is a waferboard plant where the raw material were randomly oriented wafers (Rowell, 2005). Oriented strand board is an engineered wood based panel that involve the strands of wood bonded together with adhesive or resin normally synthetic in nature. Besides that, the strands are pressed together in layer range. OSB is a structural panel similar to plywood and is made of wood strands that are arranged in cross-oriented layers. According to Steidl et. al. (2003), OSB is one of the many engineered wood products that can be used increasingly by both residential and commercial construction. There are still many aspects based on the behaviour and the properties of OSB not fully understood despite being used for over 20 years. The two major types of wood structural panels used in North America new homes constructions, OSB and plywood, when surveyed in 2009 showed that these two materials consumptions are approximately at 44.3% and 14.9% respectively.

Oriented strand board is equivalent to other structural panels such as plywood and fiberboard in its' strength and rigidity, panel size and thickness, fastener performance and paint ability (Nadir, 2009). OSB panel increased acceptance in the markets was proven by use of wood-based composite panel products substantially in housing and furniture construction in North America over the past decades (Hartley et. al., 2007). OSB good performance is rated as structural panel as it is engineered for uniformity, strength, versatility, and workability. It is utilized internationally in varied array of applications, including building construction, flooring, partitioning packing as and parts in furniture and automotive products.

2. MATERIALS AND METHODS

2.1 Materials Preparation

In this study, the wood species used were *Acacia mangium* and Rubberwood (*Hevea brasiliensis*). Adhesive applied in this study was phenol formaldehyde (PF) resin with fixed resin content of 9% based on the wood dry weight. The effects of densities and layer arrangement were parameters tested. Wood species of *Acacia mangium* (2 logs) were cut down from UiTM Jengka, Pahang forests. The timber used in the OSB production comes mainly from young growth forests or fresh wood. Rubberwood strands were taken from Mieco Manufacturing Sdn. Bhd., Pahang. The board dimension was produced at 380 mm x 380 mm with thickness of 12 mm. The oriented strand board was made in three layers being the face layer, core layer and back layer.

2.2 Manufacturing Process of OSB

The manufacturing process of OSB starts from forest and go through to log sorting. The *Acacia mangium* and Rubberwood were cut down into small billets. The diameter of timbers was more than 140mm (14.0cm). Diameter at breast height (DBH) was 18.7 ft and 14.2ft for both timbers respectively. The logs were cross cut for half of the original log length (quarter sawn method). It was then further sized down to 6" to 8" (15 cm to 20cm) to accomodate the flaker machine. Debarking was carried out manually using machete. Debarking was carried out in order to decrease organic waste load during flaking process. The freshly debarked logs were then carried to disk wood flakers for flaking. The flakers were produced with many strands of random sizes. The strands were air dried at an open area to until moisture content (MC) of 17 – 20%. Then, the strands or flakes were placed into oven for drying at the temperature of 80°C for 24 hours to remove excess MC and it also to achieve desired MC of below 5%. After that, the strands were blended with 9% phenol formaldehyde (PF) resin. After the strands have been blended with resin, the strands were carrying through to mat forming line where cross-directional layers were formed. The dimension of mould size used is 380mm x 380mm. The moulded strand was then cold pressed to remove excess air followed by hot pressed. Finishing and conditioning was then done prior to board testing.

2.3 Testing Methods

Physical and mechanical tests on the experimental OSB panel were conducted in accordance with European Norm (EN). Mechanical tests were performed on a Universal Instron Testing Machine to determine the values of modulus of elasticity (MOE), modulus of rupture (MOR) and internal bond (IB). The flexural properties for MOR and MOE were determined on specimens of nominal size 290mm x 50mm x 12mm, cut from each experimental panel in accordance with EN 310:1993 standard. Sixth specimens for IB with dimension 50mm x 50mm x 12mm were cut from each panel as per EN 319:1993 standard. IB specimens were bonded together with two wooden blocks by using epoxy-hardener resin mix (1:1 ratio). The average of all measurements were reported for mechanical properties. Measuring and weighing of test specimens were done according to EN 325:1993. Thickness, length and width of specimens were measured using vernier calipers accurate to 0.01mm and weight measurements were made using a balance accurate to 0.01g. Six thickness swelling (TS) and water absoption (WA) specimens of a nominal size 50mm x 50mm x 12mm were cut from each experimental board and used to determine WA and TS after 2 and 24 hours submersions at room temperature (20°C) following EN 317:1993 standard requirements.

OSB panels were produced according to experimental design in Figure 1. This design involves two factors namely boards density and layering arrangement. A total of 16 boards were produced with 2 replicates for each treatment.

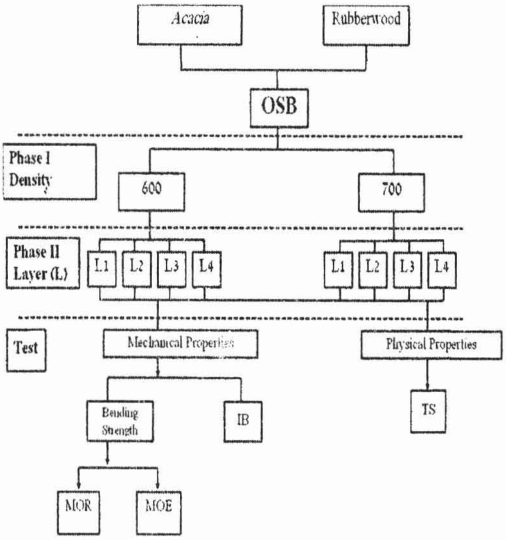

Figure 1: Experimental Design

3. RESULTS AND DISCUSSION

3.1 Mechanical Properties and Physical Properties

Table 1 shows the average values of bending properties; modulus of rupture (MOR) and modulus of elasticity (MOE), internal bond (IB) and thickness swelling (TS). Generally, all treatments for mechanical properties met the requirement of EN 300:1993 standard except for thickness swelling. For treatment with density of 600 kg/m³ the highest value of MOR (25.67 MPa) and IB (1.28 MPa) was seen for 100% rubberwood. Highest value of MOE of 5207 MPa coupled with lowest swelling value of 27.2 % was observed for AAA arrangement. Boards with density 700 kg/m³ register highest value of MOR (34.18 MPa), MOE (6 835 MPa) and IB (1.23 MPa) againt for AAA combination. In term of thickness swelling RRR layering gave lowest swelling value of 28.8%.

Table 1: Properties of OSB from Acacia mangium and Rubberwood

DENSITY (kg/m³)	LAYER	RESIN (%)	MOR (MPa)	MOE (MPa)	IB (MPa)	TS (%)
600	ARA	9	17.07	4,648	0.47	31.94
600	RAR	9	19.43	3,042	0.48	37.69
600	AAA	9	25.59	5,207	0.60	27.24
600	RRR	9	25.67	3,588	1.28	29.81
700	ARA	9	28.43	6,102	0.76	36.73

700	RAR	9	29.07	3,999	0.55	34.49
700	AAA	9	34.18	6,835	1.12	28.92
700	RRR	9	29.48	3,664	1.23	28.79
BS EN 300 : 1993 Type OSB/1: General Purpose EN Standard			> 18 EN 310: 1993	> 2 500 EN 310: 1993	>0.28 EN 319: 1993	< 25 EN 317: 1993

Notes: Modulus of Rupture (MOR), Modulus of Elasticity (MOE), Internal Bonding (IB), Thickness Swelling (TS), ARA : Acacia-Rubberwood-Acacia, RAR : Rubberwood-Acacia-Rubberwood, AAA : Acacia-Acacia-Acacia and RRR : Rubberwood-Rubberwood-Rubberwood.

3.2 Statistical Significance

Table 2 shows the summary of analysis of variance (ANOVA) and Duncan's multiple range test for the various properties in this study. The results indicate that there is a significant effect between density and layer arrangement of wood species on mechanical and physical properties. The values of OSB panels on properties were obtained from testing their strength of boards on the value of MOR, MOE and IB values.

Table 2: Summary of ANOVA on OSB Properties

Sources	df	MOR	MOE	IB	TS
DENSITY	1	19.579**	21.811**	1.125ns	2.315ns
LAYER	3	3.082*	35.599**	4.284*	8.470**
DEN X LAYER	3	0.689ns	2.603ns	1.914ns	3.415*

Notes : Degree of freedom (df), Modulus of Rupture (MOR), Modulus of Elasticity (MOE), Internal Bonding (IB), Thickness Swelling (TS), ** = highly significant, * = significant at $P < 0.05$ and ns = not significant at $P > 0.05$.

Density of boards were shown to have highly significant difference in MOR and MOE values, whereas IB and TS values were not significantly effected. In addition, two values were highly significant difference for layers that are MOE (35.599) and TS (8.47). Furthermore, the interaction between density and layer arrangement shows no significant for MOR, MOE and IB. TS is an exception with significant at $p<0.05$ for density and layer interaction.

3.3 Effects of Density

Table 3 shows that the board density influences the strength properties of OSB panel produced from *Acacia mangium* and rubberwood. The effects of board density on bending strength properties, MOR and MOE values show significant difference because higher density board was associated with increasing the bending strength. Board density is one of the most important factors affecting board strength and stifness. According to Ibrahim & Fauzi. (2013), where higher density board is related to higher strengths. Sumardi et. al., (2007) stated that MOR of OSB panel increased almost linearly with increasing board density.

Table 3 shows IB values were not significantly difference with board density changes. This might be due to board density having no influenced on board's integrity. That defines how well the core material is bonded together with 9% PF resin. Besides that, IB was influenced by the geometry of flakes. Lehmann & Boone (1974) reported that IB strength generally increased with increase in board density but it is closely related to flake types with a percentage of small particles. In addition, bonding properties depends on many process related factors such as pressure, temperature, raw material, adhesive content and adhesive type rather than material density alone. According to Rathke et. al. (2012), failure of internal bonding specimens is due to adhesion and wood failure in the specimen.

Table 3: Effects of Density on OSB Properties

DENSITY (kg/m^3)	MOR (MPa)	MOE (MPa)	IB (MPa)	TS (%)
600	22.83a	4,183a	0.72a	31.56 a
700	30.52 b	5,309b	0.92 a	32.04 a

Notes: Modulus of Rupture (MOR), Modulus of Elasticity (MOE), Internal Bonding (IB), Thickness Swelling (TS), a = not significant, b = significant.

Based on the results, OSB panels produced at $600kg/m^3$ and $700kg/m^3$ were not significantly differences despite of increased board density. Swelling in thickness of OSB panels indicated that 700 kg/m^3 show higher TS value as compared to $600kg/m^3$. This might be occurring due to excessive amount of raw materials with increase board density which could influence spring-back. Meanwhile, the difference of the density distribution in the thickness direction affected the amount of TS of the boards according to Ruhendi (2007). In addition, increases in mechanical with increases in density can be sufficient to offset increased swelling tendency and high density can increase efficiency of resin usage (Ibrahim & Fauzi, 2013).

3.4 Effects of Layer Arrangement (species)

The results show that MOR for values of OSB from 100% *Acacia mangium* (29.89 MPa) perform better than ARA (24.17 MPa) and RAR (24.79 MPa) board layers. According to the analysis results for layer arrangement factor, MOR values showed no significant differences for each strand combination. Heterogenous boards have no influenced on bending strength. This might be closely related to density of the raw materials from *Acacia mangium* and rubberwood in three-layers of board. According to Ibrahim & Fauzi (2013), MOR value of the board with the highest result increased the strand mixed with the lower density to the higher density of wood species.

Figure 2 shows MOE value in relation between ARA and RAR, and also 100% *Acacia mangium* and 100% rubberwood. Based on the results, the highest of MOE value for all combinations was 6021 MPa (AAA) as compared to 3574 MPa (RAR). The results revealed that mixed-species and single-species boards showed significant effect on elastic properties. The reason is wood species influence to strength and stiffness of board. According to Steidl et. al. (2010), effects of strand alignment on the mechanical properties of OSB as a mathematical model was constructed to describe the relationship between orientations of individual surface layer and the unidirectional MOR and MOE of OSB panels. Besides that, the models confirmed the positive influence of strand alignment on MOE value. Lehmann & Boone (1974) stated the strength properties from determining MOE were directly related to species density whether of a single species or a mixture of species at each compression ratio.

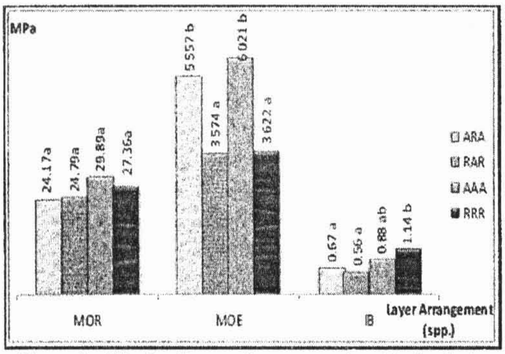

Figure 2: Effects of Layer Arrangement on Mechanical Properties

The values of IB strength were shown in Figure 2. The results for OSB made from 100% *Acacia mangium* show significant differences between ARA, RAR and RRR boards. The IB strength increased when the strand mixed from single-species. This might be due to adhesive bonded together with mixed-species not closely influence by tensile strength. Bonding properties with mixtures cannot be predicted from the weighted means of the results with the single species (Lehmann & Boone, 1974). According to Ruhendi (2007), excessive moisture content on the board can inhibit the adhesive bond.

Figure 3 shows the effects of layer arrangement on physical properties. Thickness swelling (TS) is a factor when considering the moisture effect which is the dimensional change of the board caused by increase in thickness. All of OSB panels were show significant effect on TS values. The OSB panel made from strand orientation of ARA and RRR revealed a significant effect in the dimension change with excessive water content in board. The reason is closely related to different of wood species influence to change in dimension of specimens with absorb minimum of water content. According to Ibrahim & Fauzi (2013), thickness swelling of composite board can be increased by particle geometry, board density, adhesive level, blending efficiency and pressing conditions. Sumardi et al. (2007) stated that strands of the random board had been more damaged than the aligned board which is more uniformly compressed during the mat consolidation process. In addition, the water absorbed causes wood strands in OSB to swell and permanently recover from strains imposed when the composite was pressed (Evans et. al. (2013).

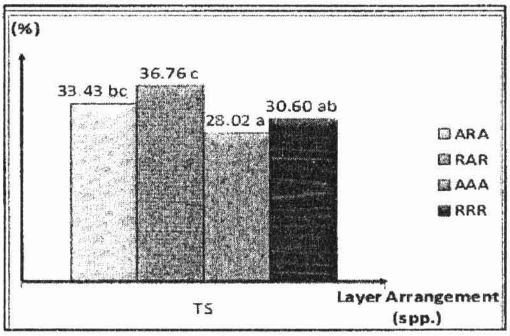

Figure 3: Effects of Layer Arrangement on Physical Properties

4. CONCLUSIONS

Oriented strandboard (OSB) is a structural wood products that cross-oriented for the faces and core layers made by compressing and bonding together the strands with 9% of phenol formaldehyde (PF) adhesive. Densities selected in this study that are 600 kg/m^3 and 700 kg/m^3. The strand alignment were evaluated by measuring the accumulated percentages of strands on the three layers of OSB (face, core and bottom layers).

The main objective of this study was to determine the physical and mechanical properties of OSB using *Acacia mangium* and rubberwood (*Hevea brasiliensis*). The mechanical properties of OSB panel from 700 kg/m^3 was higher strength than 600 kg/m^3. However, the physical properties from 600 kg/m^3 indicated the lower value of TS as compared to 700 kg/m^3 although not meet EN 317:1993 standard requirements. The properties of OSB panels were greatly influenced by wood ratio for layer arrangement. Meanwhile, wood ratio from 100% Acacia mangium and 100% rubberwood gave the best properties as compared to mixed-species (50:50).

On effect board density and wood species ratio on board properties, density results showed significant effect on board MOR and MOE values, whereas IB and TS values were not significantly differences for each density. The effects of wood species ratio for layer arrangement showed significant effect on the properties of OSB panels except for MOR. Therefore, the interaction between density and layer arrangement have no significant effect on the mechanical properties. In conclusion, OSB panels from density of 600 kg/m³ at 100% *Acacia mangium* is suitable to produce as composite product.

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