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Density Distribution of Oil Palm Stem Veneer and Its Influence on Plywood Mechanical Properties

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Abstract: Oil Palm Stem (OPS) has been introduced as potential raw material for plywood manufacture in Malaysia. Two 25 years old OPS were selected for the study which aim to establish the veneer density distribution of the stem. The main purpose of this study is to improve the strength and to determine the optimum resin spread rate for oil palm stem plywood manufacture. The study comprised (1) the establishment of veneer density profile and (2) the effects of resin consumption and lay-up pattern on the strength and bond integrity of the plywood. The method used to determine the veneer density was a standard oven-dry method. The OPS veneer were fabricated into 5-ply plywood panels using UF (urea formaldehyde) resin adhesive. Three types of OPT veneer were classified which were 100% from outer veneer, 100% from inner veneer and mix (2-ply of outer veneer as face and Three-ply of inner veneer as core material) with four different glue spread rate (250, 300, 350 and 400 g m^{-2}). The results show the veneer density of the OPS can be categorized into three classes: 400-500, 300-400 and 200- 300 kg m^{-3}. The outer-layer veneers have density between 358 to 442 kg m^{-3}, whilst the densities of the inner-layer veneer were 272 to 446 kg m^{-3}. Segregating the oil palm veneers by density classes prior to plywood manufacture improved the strength and bond integrity of the OPS plywood greatly.

Key words: Plywood, oil palm stem, density, strength, bond integrity

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INTRODUCTION

The past few decades have seen rapid growth of oil palm industry in Malaysia in terms of cultivated area and volume of production. It is reported Malaysia produced about 13.9 million tonnes (dry weight) of oil palm biomass, including trunks, fronds and empty fruit bunches annually (Anis *et al.,* 2007). This figure is expected to increase substantially when the total planted hectare of oil palm in Malaysia reached 5.10 million hectares in 2020 (Hashim *et al.*, 2004). A recent figure indicated that oil palm plantation areas in Malaysia have expanded from 3.37 million hectares in year 2002 to 4.17 million hectares in year 2006. The use of oil palm trunk and oil palm biomass for various products have been extensively explored and some good results have been reported (Anis, 2006; Loh *et al.,* 2010; Ratnasingam *et al.,* 2008; Nasrin *et al.*, 2008). The alternative biomass is comparatively cheaper, sustainable, as well as, environment friendly.

Oil Palm Stem (OPS), one of the potential residues for wood-based industry, has its imperfections. It is very hygroscopic in nature, shrinks and swells at a much higher rate than wood does. Even though it is similar to wood, not all parts of the OPS can be used as solid wood. Economically, only the outer part of the stem is suitable for this purpose, as the centre part of the trunk contains only soft parenchyma tissue. Utilization of OPS as raw material could reduce the environment burden of wood consumption. Since OPS is a potential lignocellulosic material, therefore it is possible to utilize it as an alternative for the declining supply of timber. Measures have to be taken to enhance the low quality of OPS and transform it into useful by-products that meet the demands in the market. There has been a wide range of products made from oil palm waste such as medium density fiberboard (Laemsak and Okuma, 2000), particleboard (Chew, 1987), fiber reinforce cement board (Abraham *et al.*, 1998), fiber plastic composite (Liew *et al.*, 2000), plywood (Ho *et al.*, 1985), blockboard

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(Mohamad *et al.*, 2001), laminated-veneer lumber (Kamarulzaman *et al.*, 2003) and furniture (Ratnasingam *et al.*, 2010). OPS lumber also has shown promising potential, performance in strength properties and machining characteristic (Ratnasingam *et al.*, 2008).

OPS do not grow in diameter as it gets older, but can normally grow from 35 to 75 cm in height each year. Being a monocotyledon, OPS does not possess any vascular cambium, secondary growth, growth rings, ray cells, sapwood and heartwood, branches and knots (Killmann and Lim, 1985). The growth and increment of diameter in trunk result from cell division and cell enlargement in the parenchyma tissues, along with the enlargement of fibres in vascular bundles. The vascular bundles are made of fibrous sheath, phloem cells, xylem and parenchymatous cells. The amount of vascular bundles per unit area declines gradually towards the inner parts and increases from the butt end to the top of the stem (Lim and Khoo, 1986). Hence, throughout the cross-sectional area, there is an occurrence of primary vascular bundles that are randomly embedded in parenchyma ground tissue. Uneven distribution of vascular bundles along the radial direction of stem causes a variation in density values at different parts of the oil palm stem. The height of oil palm tree can be up to 15 m tall with an estimated volume of one stem stands at about 1.6 m^3. With density range between 200-600 kg m^{-3} and moisture content ranges 100-500%, OPS becomes the biggest challenge in wood-based industries, in particular the saw milling and panel industry.

Both density variation and instability of the OPS are also responsible for the poor performance of products made from it. The OPS generally had large density variation throughout the trunk. The mechanical properties of Oil Palm Wood (OPW) compared with those other species are rather poor. The best strength values are found in the peripheral region of the lower portion of trunk and the weakest part lies in the centre of upper stem. Beside that, research has found that Modulus of Elasticity (MOE) in the OPW is between 740 and 7960 MPa. The Modulus of Rupture (MOR) varying just as the MOE is very low compared with other conventional timber species. Bending strength of OPW is generally poor compared to other species but is comparable to coconut wood. Highest values are obtained from the peripheral lower portion of the stem and the central core of the top portion of the stem gives the lowest strength (Killmann and Lim, 1985).

Currently, the use of OPS as raw material for certain application has been major focus in the plywood industry in Malaysia. Plywood was the first type of engineered wood use as building material. Plywood is a made of veneers (thin wood layers or plies) bonded with an adhesive, where each layer of veneer are arranged perpendicular to one another. Under Eighth Malaysia Plan (2001-2005), about 42, 870 ha can be harvested from Permanent Reserved Forest in Peninsular Malaysia. But the declining of raw material is one of the major problems in wood-based industry. Plywood mills need resource capacity minimum at 7.05 million m^3 to operate. However, the scenario is that only 2.75 million m^3 resources accepted from Permanent Reserved Forests subsequently result in declining of supply and productivity. Therefore, new alternative resources needed to be found. In Malaysia, the attempt to manufacture plywood from OPS was started only in the early 1980s.

Even though commercial production of OPS plywood has started since about 10 years ago, problems in maintaining the quality (i.e., strength and bond integrity) and in reducing the resin consumption still persist. As a result, the OPS veneers are being used as core veneers only. This problem may be associated with density variations inside the stem itself, as well as the cell structure found in OPS fibers. Such variations are not only responsible for the high resin uptake by the OPS veneers, but also cause the instability of the resulting plywood during use. This study was conducted to determine the veneer density distribution along the logs of OPS used in plywood industry and to evaluate the effects of veneer density distribution on the strength and bond integrity of OPS plywood.

MATERIALS AND METHODS

Materials: The study was conducted at Business Espirit Sdn. Bhd, factory located at Penang, Malaysia in year 2008. Two oil palm stem (25 years) were selected randomly and were cut into three logs (top, middle and bottom) of eight feet length. Cross section of each log was marked for outer and inner portion.

Peeling process: In this study, two OPS logs were selected and subjected to two-stage peeling process. Two types of peeling machines were used to produce outer and inner veneers. The andouter veneers are the first 50% veneer ribbons obtained from the rotary lathe and subsequently the OPS was fed into a spindleless rotary lathe to peel the softer inner veneer type of OPS. For instance, during the first stage some remaining barks will be removed prior to peeling the peripheral layer (outer layer). The OPS normally has 39 cm diameter and upon first peeling stage, the diameter was reduced to 25 cm. In the second peeling stage, the peeling continued until the diameter of OPS was reduced to 11 cm. One crucial weakness of spindleless rotary lathe is that the peeling process would stop not only when the diameter of stem

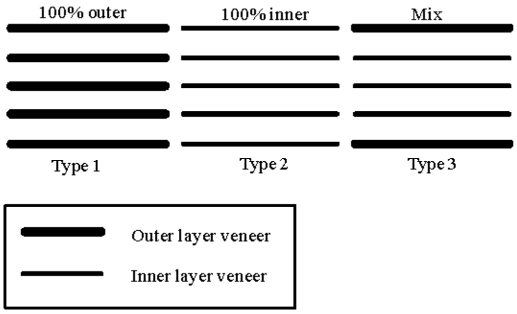

Fig. 1: Lay-up pattern of OPS plywood

becomes smaller but also when it is too soft. All the veneers were numbered according to stem height (top, middle and bottom) and sectional layer (inner and outer). The veneers were clipped into 610×2400 mm (2×8 feet) and dried by passing through a continuous roller dryer until the final moisture content of the veneers were between 7-9%.

Veneer density determination: Samples of 5×5 cm in size were cut from each veneer. The veneer density was determined using oven dry method. The density samples were taken from the edges and middle of the veneer sheet. A total of 18 samples were taken from each veneer sheet. The specimens were oven dried for 24 h. at 103±2°C. The dimension of the veneer samples were measured in order to calculated the volume of the veneer. The densities were calculated using the formula:

$$\text{Density (kg m}^3\text{)} = \frac{\text{Weight at oven-dry}}{\text{Volume at oven dry}}$$

Plywood manufacture: Based on the veneer density distribution determined earlier in 2.3, the veneers for making the plywood were selected randomly from either top, middle or bottom part of the oil palm stem. The veneers were then segregated by outer and inner layers. Adhesive mixtures composed of a commercial grade Urea Formaldehyde (UF) resin (42.5% solids), industrial wheat flour and hardener (ammonium chloride) with and without additional calcium carbonate as a filler were prepared and spread onto the veneers at different spread rates: 250, 300, 350 and 400 g m^{-2} (double glue line). Calcium carbonate as a filler plays an important role in UF resin formulations. Calcium carbonate is a non-adhesive substance added to adhesive formulations. It is added in UF resin formulations to improve its working properties, performance, strength, or other qualities. Other qualities of calcium carbonate could include filling holes and irregularities of OPT veneer surfaces as well as decreasing porosity of the OPS veneer surface. The assembly time was kept in the range of 15-30 min. The assembled veneers were then cold pressed for 5 min and hot pressed at 130°C for 8 min. Three types of 5-ply, 450 x 450 x mm plywood were produced: Type 1 (comprised 100% outer-layer veneers), Type 2 (comprised 100% inner-layer veneers) and Type 3 (comprised outer-layer veneers as face and inner-layer veneers as core). The lay-up patterns of plywood have shown in Fig. 1. The plywood was conditioned at 25°C and 65% relative humidity for a week prior to cutting into test specimens.

Properties assessment: The specimens were tested for static bending according to Anonymous (1993a) to determine the properties of OPS plywood and for shear bonding according to Anonymous (1993b) Plywood-Bonding Quality (Part 1: Test Methods). Analysis of Variance was carried out to determine the effects of stem height and layer on the veneer density and of layer and glue spread rate on the strength (i.e., modulus of rupture), stiffness (i.e., modulus of elasticity) and shear strength of the OPS plywood. Means separation was carried out using Least Significant Difference (LSD) to further analyze the effect of the treatment and veneer type. The apparent cohesive wood failure was visually estimated to the nearest 5%.

RESULTS AND DISCUSSION

Veneer production and density distribution: The average number of 610×2400 mm (2×8) feet veneers that can be obtained from each logs was 84 pieces; 45 from the outer layer and 39 from the inner layer of OPS (Table 1). The top outer layer of the stem produced very low (9 pieces) number of veneers with much greater variation compared to the other parts of the stem. As expected, the bottom part of the stem produced higher number of veneers due to the larger diameter. The veneer density distribution along the stem was found to increase from bottom (outer: 358 and inner: 272 kg m^{-3}) to top (outer: 442 and inner: 446 kg m^{-3}). This result contradicts to that found in solid OPS reported by Lim and Khoo (1986) where the bottom part of the stem has between 500-700 kg m^{-3} at the outer and 250-500 kg m^{-3} at the inner layer and the top part has respectively, 358-558 kg m^{-3} and 200-350 kg m^{-3}.

Such deviations may occur since the densities determined in this study were those of thin veneers (3.5 and 4.1 mm for outer and inner veneers, respectively). During density sampling, it was observed that a

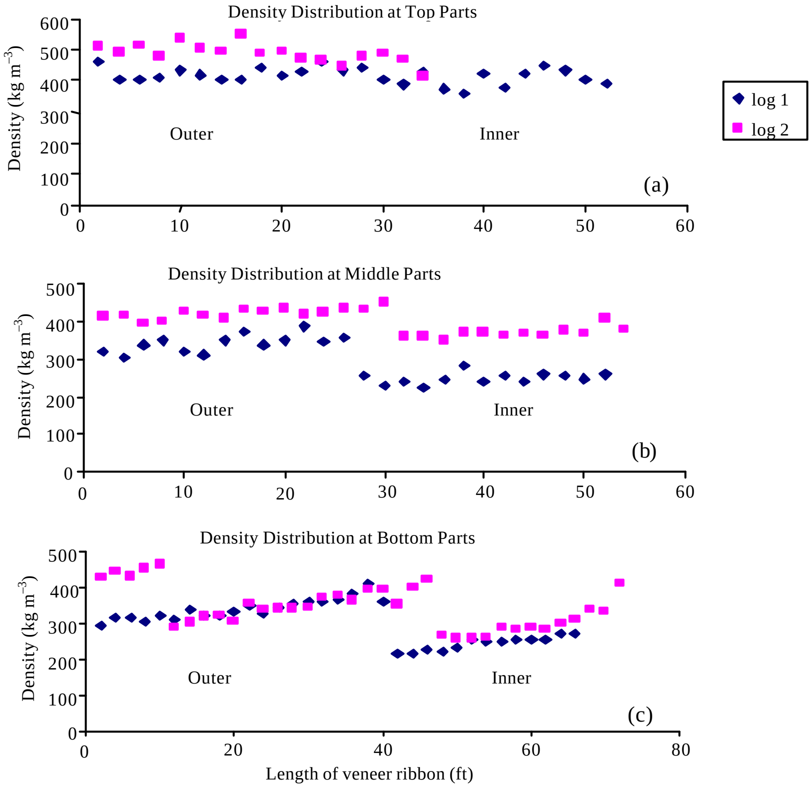

Fig. 2: The relationship between tree height- (a) Top, (b) Middle, (c) Bottom and radial layer or length of veneer ribbon (ft)

Table 1: Veneer Production and density distribution of veneers in oil palm stem (OPS)

Part:Layer	Number of veneers	Veneer density[1] (kg m^{-3})	Stem density[2] (kg m^{-3})
Top:Outer	9 (6)	442 (37)	350-550
Top:Inner	13 (0)	446 (50)	200-350
Middle:Outer	14 (1)	385 (45)	400-600
Middle:Inner	13 (0)	307 (64)	200-400
Bottom:Outer	22 (2)	358 (45)	500-700
Bottom:Inner	13 (0)	272 (43)	250-500
Total	84 (2)	-	-

[1] Values are average of two logs. Values in parentheses are standard deviation, [2] Values published by Lim and Khoo, (1986)

Table 2: Summary of ANOVA for the effects of adhesive spread rate and lay up pattern on the strength and bonding shear of OPS Plywood

	Significance level			
Source	MOR	MOE	Shear without filler	Shear with filler
Adhesive spread rate (A)	***	***	**	NS
Lay-up pattern (L)	***	***	***	***
A X L	***	***	*	**

NS: Not Significant, ***$p \leq 0.01$, **$p \leq 0.05$ and *$p \leq 0.1$

substantial amount of parenchymatous tissues came out of the dried veneers leaving a hollow space between the vascular bundles. The extent of this parenchyma loss was more severe if the veneers came from the bottom part of the stem (as in bottom: outer). Since the inner veneers were relatively thicker, the amount of parenchyma loss per unit volume during drying and handling is lower. Thus, the average veneer density for this section falls within those reported by Lim and Khoo (1986) except for top-inner section. The variations of density are because of number of vascular bundles per square unit which decreasing towards the center.

Difference in density of outer-layer and inner-layer was not clear for top part of OPS as shown in Fig. 2. So, veneer obtained from top part did not need to segregate into outer- and inner-layer due to the homogenous in density and can mixed up during veneer processing. Whenever, for middle and bottom part of OPS the length of veneer ribbon which can differential the outer- and inner-layer at approximately 30 feet in middle part and 40 feet in the bottom part of the stem.

The veneer density distributions obtained at Fig. 2 were formed into density groups and positions in Table 1. The highest veneer density groups recorded at outer layer for middle and bottom parts. From the Table 1, it shows that the top outer and inner always exhibit the highest values compared with others. Choo *et al.* (2010) found that the density of veneers taken from the top part of OPS was significantly higher (318 kg m^{-3}) than that taken from the bottom part (290 kg m^{-3}). The outer section consistently gave higher density than the inner layers, irrespective of the height of the tree. Between the two factors, section (outer or inner) has a more apparent effect on the density (Choo *et al.*, 2010). In this study, the top outer and inner having same density groups is because of the younger structure of the cells and not well developed and also the high amount of pectin material in the parenchyma cells of veneer that was not loss during the veneer processing and drying.

Strength of OPS plywood: Assessment on the failure pattern of the static bending specimens found that almost 80% samples failed in the compression area. Normally, compression failure is related to early failure before the material can sustain maximum load. Thus, lower MOR and MOE should be obtained from this kind of sample. In this study, such phenomena was observed on the OPS plywood. The compression failure in oil palm plywood may be due to the presence of higher amount of parenchyma cell in the inner layer (less vascular bundle) that does not provide any strength.

The Analysis of Variance (ANOVA) of the effects of glue spread rate and lay up pattern revealed that there were significant interactions between both variables on the Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) of the OPS plywood. The shear strength, however, was more affected by the lay up pattern than did the glue spread rate (Table 2).

Table 3 gives the interaction effects between lay up pattern and adhesive spread rate on MOR values. Generally, the MOR obtained for OPS reflects the variations in density distribution with highest values from plywood that were assembled from outer-layer veneers and lowest from that of inner-layer veneers. Arranging the outer layer veneers on the surfaces and inner veneers in the core significantly improved the strength of the plywood as high as 65%. Generally, increasing the adhesive spread rate from 250 to 400 g m^{-2} had some marked effects on the strength and this effect is more obvious for plywood produced from inner veneers.

The result in Table 4 indicates that mixing the two types veneers had improved the MOE nearly 100%. In some cases, for instance in the mix lay-up and 400 g m^{-2} spread rate, the MOE value obtained is not significantly different than that obtained from plywood that comprised 100% outer-layer veneers.

Table 3: Effects of adhesive spread rate and lay-up pattern on MOR of OPS plywood

	Modulus of Rupture (MOR) Mpa			
	250	300	350	400
Lay-up pattern	(g m^{-2})			
100% Outer-layer veneers	33.3^{a}	31.6^{b}	32.4^{b}	35.9^{a}
100% Inner-layer veneers	19.1^{d}	16.4^{e}	22.0^{c}	21.4^{c}
Mix (Face: Outer-layer veneers Core: Inner-layer veneers)	31.5^{b}	22.4^{c}	22.7^{c}	34.0^{b}

Means followed by the same letters in the same column are not significantly different at $p<0.05$

Table 4: Effects of adhesive spread rate and lay-up pattern on MOE of OPS plywood

	Modulus of Elasticity (MOE) MPa			
	250	300	350	400
Lay-up pattern	(g m^{-2})			
100% Outer-layer veneers	4728^{a}	3855^{c}	4020^{cb}	4907^{a}
100% Inner-layer veneers	2079^{f}	1688^{g}	2377^{ef}	2503^{ed}
Mix (Face: Outer-layer veneers Core: Inner-layer veneers)	4264^{b}	2750^{ed}	2879^{d}	4684^{a}

Means followed by the same letters in the same column are not significantly different at $p<0.05$

As shown in Table 3 and 4, the highest MOR and MOE of oil palm plywood was found in plywood produced using glue spread rate 400 g m^{-2} and outer veneers. The lay-up pattern showed that the consistently outer layer giving better result compare to inner layer. The reason is because the density for plywood produced from outer layer is higher than that of inner that of inner layer. Density played an important in strength properties determination. As the board density being increased, the strength properties of the board will certainly increase. Beside, the inner layer gives a weak result for plywood maybe caused by the presence of vascular bundles less and the parenchyma cell was more in the inner layer. Youngquist (1999) stated that adhesive played an important role on the bending strength of plywood. By having optimum adhesive for veneers lamination during plywood production, higher bending strength can be obtained from that plywood.

In summary, there were three apparent observations made in this study: (1) that both MOR and MOE values are less affected by the amount of adhesive applied, (2) all the plywood made from inner layer veneers are consistently more inferior and (3) the interaction effects between lay-up pattern and glue spread rate are more prominent in plywood made from the combination of inner layer veneers and higher (>400 g m^{-2}) adhesive spread.

Bond integrity of OPS plywood: The performance of bonded joint depends on how well the development between the surfaces. In evaluating the glue bond quality

Table 5: Effects of lay-up pattern on bond integrity of OPS plywood

	Adhesive Mix A*		Adhesive Mix B**	
Lay-up pattern	Shear strength (MPa)	Wood failure (%)	Shear strength (MPa)	Wood failure (%)
100% Outer-layer veneers	0.76^a	89	0.87^a	98
100% Inner-layer veneers	0.58^b	95	0.56^c	92
Mix	0.51^c	94	0.71^b	98

*Without calcium carbonate as filler. **With calcium carbonate as filler. Means followed by the same letters in the same column are not significantly different at $p<0.05$

of the bonded product, both information on the glue bond shear and wood failure percentage value are important. Theoretically, when both shear strength and wood failure percentage value are high, good bonding has been achieved and occurred. Wood failure percentage in glue bond test would significantly affect the shear strength of laminated products. Relatively high percentage in the wood failure may contribute to higher shear strength in the shear specimens. However, if the plywood glue bond shear strength is low but the wood percentage is high, it indicates that the glue bond may not necessarily be good but the wood is week. If the plywood glue bond shear strength is high but the wood percentage is low, it indicates that the glue failure is high because of the glue inferior or the wood itself is very strong (Rammer, 1996).

Furthermore, Paridah *et al.* (2002) stated that assumption that higher density is always associated with higher strength properties is only true for solid but not always true for other composite materials. This is due to wood composites consist of two components (i.e. wood material and adhesive). The effective transfer of stress from one member to another depends on the strength of link in an imaginary chain of an adhesive-bonded joint. The individual link of wood, adhesive and the interphasing region will determine the strength of chain.

All the bond quality of the OPS plywood produced in this study satisfies the minimum requirements stated in Anonymous (1993c). Plywood-Bonding Quality Part 2. As indicated in Table 5, the lay up pattern is still the main factor affecting the shear strength of the plywood. Plywood comprising 100% outer-layer veneers (Type 1) exhibited a much superior bonding quality (shear strength of >0.75 MPa with apparent cohesive wood failure of at least 89%).

It is interesting to note that even though the incorporation of higher density veneers as face layers (i.e., in Type 3 plywood) gave higher strength and stiffness than those recorded for plywood composed of 100% inner-layer veneers (Type 2 plywood), it apparently gave an adverse effect to the glue bond quality. The mean shear strength obtained for Type 3 plywood was only 0.51 MPa compare to 0.58 MPa for Type 2 plywood. The lower shear strength in the former can be attributed to the faster rate of resin penetration into the outer veneers which deprived the inner veneers from getting sufficient amount of adhesive to enhance the low density veneers. When tested for shear strength, the already weak inner veneers would easily shear. Examination on the tested specimens confirmed that most of the failures occurred at the inner veneers. On the other hand, the veneers in Type 2 plywood would be penetrated by the adhesive evenly. Since these veneers are relatively low in density (mainly between 250-400 kg m^{-3}), the adhesive can penetrate deep into the fibre. Upon curing, it would reinforce the fibres and provide better resistance during shear test (Sulaiman *et al*., 2009). This explains why the shear strength values of Type 2 plywood are higher than that of Type 3.

The bond quality of Types 1 and 3 plywood, however, improved about 14 and 40%, respectively by the addition of calcium carbonate as filler (Adhesive mix B). Calcium carbonate helps to control the flow of the adhesive on the veneer surfaces and into the fibre, resulting in a more uniform adhesive penetration within the veneers. Once cured, the adhesive provides some strength to the fibre which is reflected by the higher shear values obtained for this plywood. Therefore, adhesive mixture should be added with filler in order to maintain the OPS bond integrity in the production of plywood. Calcium carbonate is a type of filler where it can help to control the adhesive penetration on the veneers. Robertson and Robertson (1997) reported that fillers also control the application rate, uniformity of speed and improve the viscosity stability of the glue mix. It also facilitates to close the cells or tiny scratch marks in open-grained OPS. It is mainly useful in filling crevices between joints and repairing minor blemishes on the surface of the substrate. There was no significant difference in shear strength among the adhesive spread rates used for both adhesive formulations. This implies that the spread rate (250 to 400 g m^{-2}) used in this study is sufficient to achieve good bonding quality (Table 6).

In term of adhesive application, smooth veneer can have a relatively uniform rate of spread. But with rough veneer, the spreads are varying substantially. Therefore, roughness of OPS veneer need to apply higher panel pressure during hot pressing for better contact. The adhesive has been pushed to the deep valleys of the rough veneer in a crosshatch pattern like a Scotch tartan. Little adhesive is left on the ridge surfaces and the

Table 6: Effects of adhesive spread rate on bond integrity of OPS plywood

	Adhesive Mix A*		Adhesive Mix B**	
Adhesive spread rate g m^{-2}	Bonding shear (MPa)	Wood failure (%)	Bonding shear (MPa)	Wood failure (%)
250	0.61^{ab}	91	0.69^{a}	97
300	0.56^{b}	95	0.70^{a}	98
350	0.61^{ab}	90	0.74^{a}	94
400	0.69^{a}	94	-	-

*Without calcium carbonate. **With calcium carbonate. Means followed by the same letters in the same column are not significantly different at $p<0.05$

contact of wood to wood is substantially reduced. Plywood adhesive bond quality decreases as the quantity of uneven veneer increases and as the degree of unevenness increases. A smooth and uniform surface can be obtained for subsequent finishing through proper filling. If fillers are not used, finishing materials such as varnish, shellac, paints or lacquer will sink in and produce a rippled effect.

Therefore, the ability of bonding is not only affected by its surface properties but also by its physical properties, particularly the density porosity, moisture content and dimensional movement. In OPS veneer, the roughness of the surface are very uneven and for low density veneer (inner) which are greatly smooth and uniform surface compare to the high density veneer (outer). Because of this, higher penetration of resin in the high density veneer (rough surface) will occur. Meanwhile, the amount of glue spread rate for common practice requirement in OPS plywood are 269 to 376 g m^{-2} (Anis *et al*., 2004).

CONCLUSION

The density pattern of OPS had been established where the veneer density was increased from bottom the bottom to top parts and inner layer to outer layer. The outer layer veneers have densities between 358 to 442 kg m^{-3}, whilst the densities of the inner layer veneers were 272 to 446 kg m^{-3}. In the variables studies, lay-up pattern has more dominant influence on the bending strength and bond integrity compared to adhesive spread rate. The OPS plywood made from outer layer veneers gave a marked influence on the properties of plywood. Arranging veneers of low density in the core and those of higher density at the surfaces significantly increased the strength and stiffness. Generally, the incorporation of calcium carbonate as filler improved bond quality of the plywood.

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