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INVESTIGATION ON THE WATER ABSORPTION CHARACTERISTICS OF PLYWOOD MANUFACTURED USING VENEERS FROM OIL PALM STEM

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Graphical abstract

Abstract

There are four main weaknesses in using Oil Palm Stem (OPS) as a material for plywood manufacturing. High variation in density, moisture contents (MC), high water absorption and surface roughness. This paper report the investigation on the effect of water on physical properties of OPS plywood (PTA) namely water absorption, thickness swelling and delamination. These properties were compared with the properties of another two types of commercial OPS plywood denoted as PTB and PTC which were manufactured using OPS veneer with tropical hardwood veneer for face and back veneer and control plywood denoted as PTD which was manufactured using 100% tropical hardwood veneer. The results showed that PTA has lowest value of water absorption but has highest value of thickness swelling and delaminating.

Keywords: Oil palm stem, water absorption, thickness swelling, delamination

1.0 INTRODUCTION

Plywood can be defined as a wood-based panel. Plywood consists of sheet of wood veneer that has been glued together. Plywood has been manufactured with and odd number of plies, which the plies are cross bonded. Usually the grain of each layer is perpendicular to the plies below and above it. The outer plies usually have the grain direction going parallel to the long dimension of the panel. This type of production will ensure that the stability and also the strength of the plywood. It will give a high resistance to the vibration and shock and also resistance from strain, splitting and warping [1]. Plywood nowadays has been used widely in the construction field because it is flexible, economical, workable, re-usable, and can be locally manufactured.

Plywood is one of the important materials in construction industry. There are different applications or types of plywood namely structural plywood, concrete forming plywood, general use plywood, etc. Plywood mills in Malaysia need a minimum of resources capacity at 7.05 million m^3 to operate. However, current situation is that only 2.75 million m^3 resources accepted from permanent reserved forest subsequently results in declining of supply and productivity [2]. Oil palm stem can be an alternative source for the plywood mill problem.

The attempt to manufacture plywood from oil palm stem started in early 1980s. However, due to the numerous numbers of logs from natural forest, there is no effort to manufacture plywood from oil palm. However, these scenarios changed when the supply of forest wood is limited and it makes the interest on manufacturing of oil palm plywood appear [3]. Currently there are few companies have manufactured plywood by using OPS but with combinations of veneers from solid timber.

Wood structural panels are hygroscopic. It will absorb moisture from surroundings if it is dry and at the same time it will release moisture if it is in a dry surrounding and achieving moisture equilibrium with the vapor pressure around it [4]. Oil palm tree is a monocotyledonous species which consist of vascular bundles and parenchyma cells and does not have cambium, sapwood, heartwood, ray cells, knot, etc.

When wood is used to make the plywood, during production process, the wood veneer is exposed to heat which can make the wood flexible as a result of lignin and hemicelluloses in the cell wall. This may results in the expansion when in contact with water. Similarly for OPS plywood, the heat may have effect on the vascular bundles and parenchyma cells. Currently there is no information on the effects of water on the performance of OPS plywood.

This study reports the investigation made on the water absorption, thickness swelling and delamination of the OPS plywood after exposing to water.

2.0 EXPERIMENTAL

2.1 Materials Preparations

2.1.1 Plywood

Four types of plywood were used in this study namely PTA, PTB, PTC and PTD. PTA is the plywood prepared by the author using 100% oil palm stem veneer. PTB and PTC are commercial OPS plywood from 2 different factories. This plywood used different tropical hardwood veneer for its face and back layer. While, PTD used 100% tropical hardcore veneer.

2.1.2 Manufacturing of 100% Oil Palm Plywood (PTA)

The manufacturing of PTA was conducted at Central Kedah Plywood (CKP), Sg. Petani, Kedah. The oil palm stems were debarked and peeled to produce veneers of thickness between 4.5-6.0mm. Then these veneers were cut to dimensions of 4 ft x3 ft. These veneer were then feed into roller pressing machine with three series of roller of different gap; R_1:R_2:R_3=3.5:2.8:2.8 mm at a speed of 8.0 rpm to squeeze out the water. These veneers were moved into continuous roller dryer with temperature at 150°C and speed 450 rpm for 1 hour to obtain moisture content (MC) of 0% MC. Once dried, the veneers were applied with medium molecular weight phenol formaldehyde (MmwPF) with ratio 80:20 for resin to water respectively and solid content of 49.1% for two times through glue spreader during gluing process. Then these veneers undergone plattern press machine for pre-curing process for 9 minutes with the temperature of the plate ranging between 90-140°C. The targeted MC at this stage was between 6-20%. Three layers of veneers were combined together and subjected to heat and pressure in the hot press until the glue was cured to form plywood panels at a temperature 115°C and pressure 120 kg/cm^3 for 15 minutes. After curing the boards are ready to be used. Figure 1 shows the different types of plywood used in this study.

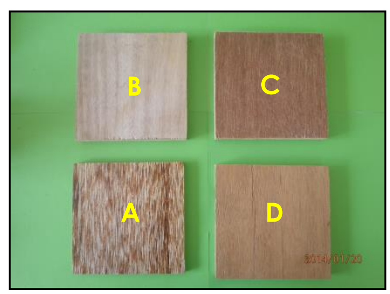

Figure 1 Different types of plywood; A- PTA, B- PTB, C- PTC, D-PTD

2.2 Sample Preparations and Test Methods

The plywood investigated in this study is to be used in the sections where intermittently exposed to wet conditions and this type of exposure is in category ofType I (JAS 1751, 2008).

2.2.1 Thickness Swelling and Water Absorption

The plywood was cut into size 50mm x 50mm for thickness swelling and water absorption samples with 10 replicates per plywood types. Thickness swelling and water absorption was determined based on European Norm standard [5]. The test pieces were immersed with their faces vertical in clean, still water, having a pH of 7 ± 1 and a temperature of (20 ± 1) °C inside water bath. This temperature was maintained for 24 hours throughout the test period. During the test, the test pieces were place in the tub separated from each other and without touching the bottom and the sides of the water bath. The tub was also filled with water to cover the upper edges of the test pieces with at least 25mm of water throughout the test. The water was changed after each test.

The rate of thickness swelling (Gt) of the specimens was determine in term of percentages, using the following equation:

$$G_t = \frac{t_2 - t_1}{t_1} x100 \quad (1)$$

where
t_2: thickness of the test piece after immersion (mm)
t_1: thickness of the test pieces before immersion (mm)

The rate of water absorption (A) of the specimens was calculated as percentages, using the following equation:

$$A\% = \frac{m_1 - m_2}{m_2} x100 \quad (2)$$

where
m_1 : weight of the test pieces after immersion (g)
m_2 : weight of the test pieces before immersion (g)

2.2.2 Delamination

For type I exposure, the produced plywood must satisfied the requirement for cyclic boiled test. For this purpose, the samples and test methods were performed in accordance with JAS 1751 (2008) [6]. The test samples of size 75 mm x 75 mm were cut from the prepared plywood board with 10 replicates per type of board. The test pieces were immersed in boiling water for 4 hours, dried at a temperature of 60 ± 3°C for 20 hours, and then immersed in boiling water for another 4 hours, and then dried at a temperature of 60 ± 3°C for further 3 hours. The perimeters of the samples were measured for failed glue line over the total perimeter of glue line available using equation (3):

$$D = \frac{PglF}{PglxN} x100 \quad (3)$$

where
$PglF$ is the perimeter of failed glue line
Pgl is the perimeter of glue line
N is the number of glue line

3.0 RESULTS AND DISCUSSION

3.1 Thickness Swelling and Water Absorption of Different Types of Plywood

The dimensional stability in terms of thickness swelling and water absorption is of the major problems for plywood as this plywood is for structural application and to be exposed intermittently to wet conditions. Therefore the dimensional stability needs to be satisfactory under wet condition. Table 1 shows the thickness swelling and water absorption properties of all the plywood.

Table 1 Thickness swelling and water absorption for all plywood

Types of Plywood		Thickness Swelling (%)	Water Absorption (%)	Density (Kg/m³)
PTA	Mean	10.6	45.7	685.7
	C.O.V	17.5	15.3	5.8
PTB	Mean	3.8	49.8	792.4
	C.O.V	23.4	16.2	5.3
PTC	Mean	2.1	57.7	551.3
	C.O.V	28.4	7.6	1.8
PTD	Mean	4.1	50.0	524.4
	C.O.V	21.2	6.3	13.6

The thickness swelling values observed ranged from 2.1 to 10.6%. The types of veneers significantly affected the thickness swelling of the plywood. Analysis of variance (ANOVA) was computed to see is there any significant difference in the TS among the 4 types of plywood and it was found that there is significant different (P-value) =.00 < 0.05). From Figure 2 it can be seen that TS for PTA is the highest followed by PTD, PTB and PTC. TS for PTA is (156.4%) higher than PTD, (180.0%) higher than PTB and (404.3%) higher than PTC. The thickness of panels for all types of plywood were not the same. However thickness swelling was independent of panel size and thickness of veneer as stated by Kelly *et al*. [7].

The water resistance of the plywood was evaluating by water absorption after 24 hours of soaking (Table 1). Water absorption values ranged from 45.7 to 57.7%. Based on ANOVA, there is significant different in the WA (P value=.001<0.05). From Duncan Multiple Comparison, it was found that, PTC is significantly different in the WA from PTA, PTB and PTD. PTA exhibited lowest value and this may be due to the veneers with MmwPF which provides resistance to water penetration. This finding was supported by Abdul Khalil *et al*. [8]. They found that Phenol Formaldehyde (PF) gave greater water resistance due to higher methylene content and greater cross-linking density where he investigated the plywood made of OPS and oil palm frond (OPF) using PF and Urea Formaldehyde (UF). There are high variations in WA for PTA and PTB (15.3% and 16.2%) but low variation in WA for PTC and PTD (7.6% and 6.3%) respectively. This suggests that PTA, PTB and PTD panels are less susceptible to WA. The trend in the TS does not in line with the trend in the water absorption (see Figure 2 and 3).

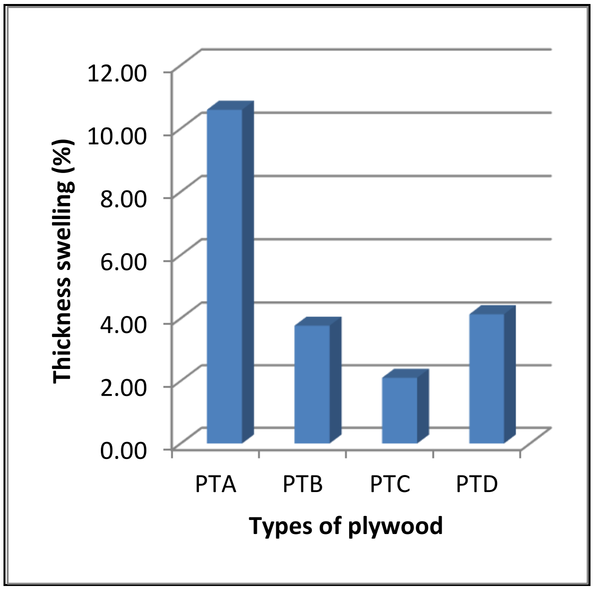

Figure 2 Thickness swellings of all types of plywood

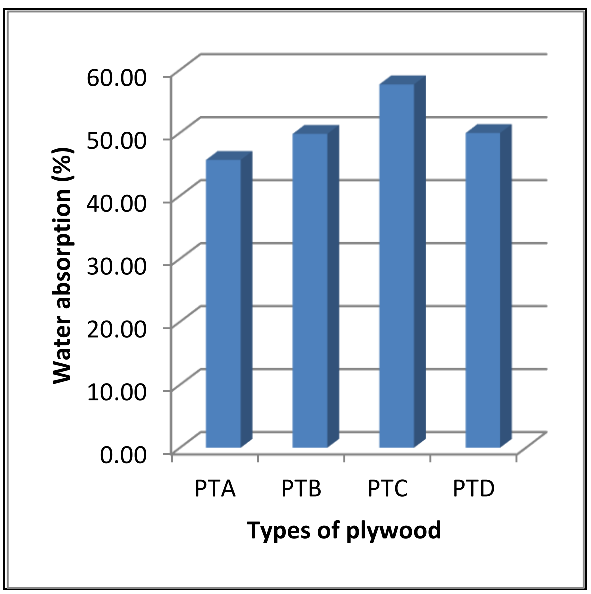

Figure 3 Water absorption of all types of plywood

From Figure 2 and Figure 3, PTA has the lowest WA but highest TS. This may be due to the pre-pressed of the veneer during manufacturing. When PTA is soaked in water, it tends to exhibit spring back which is due to swelling and moisture plasticization. This spring back allows the internal stresses to be relieved from the absorption of water in the cell wall [9].

3.2 Delamination Properties of All Plywood

The bondability of the plywood was excess through delamination test. Table 2 shows the delamination percentage of all the plywood.

Table 2 Delamination percentage of all plywood

Types of plywood	Delamination Test (%)	
PTA	Mean	99.8
	C.O.V	0.5
PTB	Mean	99.2
	C.O.V	1.3
PTC	Mean	99.2
	C.O.V	1.0
PTD	Mean	96.4
	C.O.V	4.7

There is significant difference in the value of delamination test found between PTD and the other groups of plywood but there is no significant different in delamination test for PTA, PTB and PTC. PTA has the highest delamination value which is 0.57% higher than PTB, 0.59% higher than PTC and 3.44% higher than PTD (Figure 4). It can be concluded that oil palm veneers treated with MmwPF have good bonding compared to hardwood veneers or combination of OPS and tropical hardwood veneers.

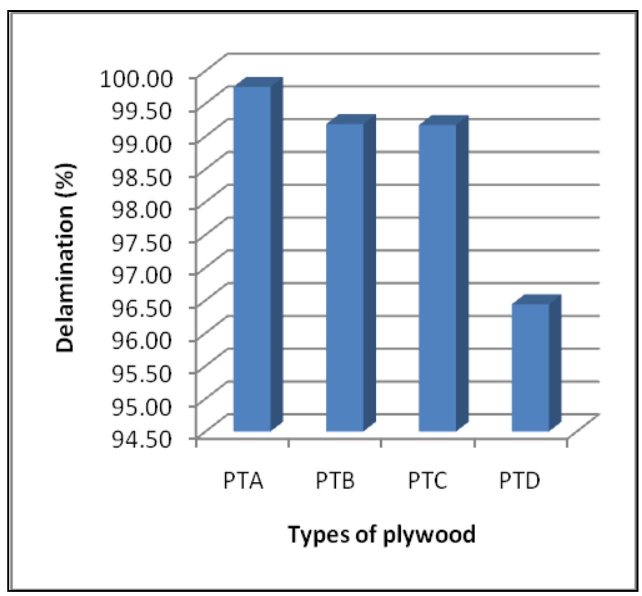

Figure 4 Delamination of all types of plywood

Based on JAS 1751:2008, if the delamination value is not less than 90%, the plywood pass the standard requirement but if less than 90% it is considered fail. This means that all the plywood tested in this study passed the delamination test. The performance of plywood panels depends on the bonding strength between the resin and the substrate. Any failure in the glue bond weakens the mechanical strength. Irshad-Ul-Haq Bhat *et al*. [10] stated that mechanical strength of plywood depends on glue bond between the veneers, whereas, good durability is associated with the absence of delamination in the plywood samples. There are low variations in the delamination test as can be seen in the COV values for all plywoods.

4.0 CONCLUSION

The TS, WA and delamination characteristics of all plywood were investigated in this study. The outcomes of the study are concluded as follows:

a) PTB and PTD were not significantly different but they were significantly different from PTA and PTC for TS. As water enters the cell wall structure, the panels swell but the rate of swelling varies.

b) PTA exhibited lowest WA but highest TS. The MmwPF impregnation provides better resistance to water penetration compared to other plywood. However with the present of water causes the veneer to springback.

c) All plywood shows good bonding and passed the delamination test.

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