Properties of Hybrid Plywood from Coconut and Rubberwood Veneer using Different Spread Level Adhesives

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Abstract

Plywood is a panel product composed of three or more thin layers of wood that are glued together one or more veneers to perpendicular for both side of a veneer and united under high temperature and pressure. The shortage of wood as a raw material has recently become a great concern. Therefore, wood-based industries must find alternative sources of local raw materials, and coconut tree currently appears to be an alternative source for substitute. The coconut, Cocos nucifera L., has been proven to be a good substitute for many conventional woods. Like conventional wood, the coconut stem is durable, sturdy and versatile and can often be used at a considerably lower cost. The cost of coconut wood is only about half or a little more than half the price of conventional wood traditionally used for structural purposesThis study investigated the effects of plywood (coconut, hybrid and rubberwood) and spread level on the mechanical and water resistant properties of different types of plywood. The measured mechanical properties include tensile strenght (TS), modulus of rupture (MOR) and modulus of elasticity (MOE). Water absorption and thickness swelling were tested to evaluate the water resistance properties. Density and moisture content effect the quality of board. The plywood made from rubberwood give higher quality compare to the plywood made from hybrid coconut with rubberwood and plywood made from coconut. The plywood made from spread level 360 g/m^2 PF resin had lower qualities than the plywood made from spread level 180 g/m^2 PF resin. The quality of plywood were decrease as the spread level of PF increase. The results indicated that the bond between spread level 360 g/m^2 of PF and veneer is over to tight and becomes less bond because too much resin content. The water absorption and thickness swelling presence resulted in higher water resistance related to the mechanical properties. The plywood made from hybrid had potential as an appropriate material for plywood manufacturing.

Keywords : *Cocos nucifera L., Density, Moisture Content, Spread level, water absorption, thickness swelling*

INTRODUCTION

Plywood is a building material consisting of veneers (thin wood layers or plies) bonded with an adhesive. Plywood was originally produced from tropical hardwood as main sources. As the global population increases so does the demand for wood. With the industrial revolution the demand went further up. The indiscriminate deforestation is showing signs of global warming, melting of polar ice, rising of sea water level, draught and consequent destruction. Plywood had major problem in getting raw material at competitive price. Shortage of wood as a raw material has forced wood-based industries to find alternative local raw materials. Coconut wood has been proven to be a good substitute for many conventional woods. Like conventional wood, the coconut stem is durable, sturdy and versatile and can often be used at a considerably lower cost. The cost of coconut wood is only about half or a little more than half. The price of conventional wood traditionally used for structural purposes (APCC 2000). Rubberwood is used in high-end furniture. Rubberwood had many advantages especially in sawing, machining, working and finishing properties. It is valued for its dense grain, minimal shrinkage, attractive color and acceptance of different finishes. In addition it is a byproduct and plentiful, it is cheap, which makes it a very popular material in the countries with plantations. In fact, rubberwood is one of the more durable lumbers used in the manufacturing of today's home furnishings. Rubber wood has a dense grain character that is easily controlled in the kiln drying process. Rubberwood has very little shrinkage making it one of the more stable construction materials available for furniture manufacturing. Phenol Formaldehyde (PF) is widely used to produce softwood plywood for several service çonditions. These resins are dark reddish in color and are available as liquid and powder or in film form. They may be manufactured to cure at a variety of temperature. When compound with filler and accelerate they still produce joints which exhibit high bond strength even under severe condition of exposure. PF properties are high in wet and dry strength, very resistance to moisture and damp conditions, and more resistance that wood at high temperature, often combined with neoprene, polyvinyl butyral, nitrile rubber or epoxy resins for bonding metals. Beside it more resistance to wood chemical aging. The objectives of this study were (1) to study the properties of hybrid from coconut and rubberwood with rubberwood and coconut and (2) to compare the properties of veneer plywood with different spread level.

MATERIALS AND METHODS

Field procedure

The samples of veneer were supplied by the Malaysian Timber Industrial Board (MTIB) and Forest Research Institute Malaysia (FRIM). Phenol formaldehyde (PF) resin (PL-60m, 41.17% solid content) was used as the adhesive for making plywood; PF was obtained from Malayan Adhesive Company at Shah Alam, Selangor. All the veneers were dried less than 8% moisture content in an oven dryer upon arrival at the University Teknologi Mara (UiTM) Jengka, Pahang one day before further processing. In other hands, PF resins were placed in cold condition temperatures upon arrival at the University Teknologi Mara (UiTM) Jengka, Pahang.

Plywood were fabricated at three thickness is 3.5mm for coconut and 2.5mm. Phenol formaldehyde (PF) resin was used at 180 g/m^2 spread level and 360 g/m^2 spread level. PF resin (PL-60m, 41.17% solid content) and flour were combined using right amount by using calculation formula. Flour using as substitute for kaolin for make PF content become sticky. The PF resin and flour were mixed in the 100ml of beaker using glass rod. For making one board of plywood, it needs two preparation of glue spread. After finish preparing the glue spread, it spread for one single layer using scraper. Scraper uses as substitute the glue spreader. In plywood making the veneer were perpendicular to the grain. Plate is using on the face and back for cover and protection before transfer to hot press. In hot pressing machine, the temperature of the hot press was 140°C and it's to 3 minutes for rubberwood and hybrid and 6 minutes for coconut to press. The pressure were using is 203 psi with one stages of pressures for all types of plywood. This purpose of the process is to make resin and wood particles are really cure and increasing the board strength. After all process particleboard making were finished. The board is separated from metal plate after several minutes. Then, let to the environment temperature about 4 to 6 minutes to air conditioning to be cold. After it already cold condition, the board must be edge trimming to avoid edge effects and then cut into various sizes for property evaluation. The board also cut to required size based on the testing method.

Density and Moisture Content

The density of plywood was determined by measuring the mass and volume of each sample. Each sample was weighed to an accuracy of 0.01 g by using an analytical balance. The mass of each board was obtained by calculating the arithmetic mean of the mass of all test samples taken from the same board. The dimensions of each test sample were measured using a sliding calliper, in accordance with BS EN 325:1993. The volume of the samples was obtained by multiplying the length, width and thickness of the samples. Determination of density was done in accordance with BS EN 323:1993, using the following formula:

$$D = \frac{m}{v}\left(\frac{g}{cm^3}\right)$$

The moisture content of plywood was determined by measuring the mass of each sample. Each sample was weighed to an accuracy of 0.01 g by using an analytical balance. Determination of moisture content was done with using the following formula:

$$MC = \frac{AD - OV}{OV} \times 100\%$$

Water Absorption and Thickness Swelling

The purpose of this testing is basically to determine how much the strand absorbs the water. This testing is determined by measuring the increase in mass and thickness of the material after complete immersion in water. Firstly all the data will be recorded, and then all samples are soaked into water for each 2 hours until reach constant data for at least 10 hour until 24 hours. All of the sample must be precisely soaked into the water to make sure that the overall of the samples are properly soaked. The size of the sample is 25 mm × 25 mm (width x length).

$$\text{Water absorption (\%)} = \frac{\text{Weight after} - \text{Weight Before}}{\text{Weight Before}} \times 100$$

$$\text{Thickness swelling (\%)} = \frac{\text{Thickness after} - \text{Thickness Before}}{\text{Thickness Before}} \times 100$$

Bending testing (MOE and MOR)

The main principal is the specimen supported as beam, is deflected at constant rate at midspan until the specimen fracture or until the deformation reaches some predetermined value. For this testing, the sample will be tested using Instron machine until the sample is broken, then break and all of data has been take for MOE and MOR value.

The bending test was performed according to BS EN 310:1993 using an Instron Model 4204 Testing Machine. The bending test was carried out using rectangular strips with dimensions of 240 mm × 50 mm × 12 mm. The lengths, widths and thicknesses of the samples were measured and recorded. Samples were tested at a crosshead speed of 10 mm/min and span of 240 mm.

Tensile shear strength

The shear test was performed according to BS EN 314-1:2004 using an Instron Model 4204 Testing Machine. The shear test was carried out using rectangular strips with dimensions of 135 mm × 25 mm × 12 mm. The lengths, widths and thicknesses of the samples were measured and recorded. Samples were tested at a crosshead speed of 1.5 mm/min. The testing machine shall be such that at least one grip is free floating to allow alignment of the specimen. The distance between clamps shall be 55mm with the specimen mounted centrally. In testing machine provided with a means of controlling the rate of increase the load, the rate of increase the load shall be 2.0 Kn/min.

RESULTS AND DISCUSSIONS

The results from Table 1 showed that density of coconut plywood was higher density for both 180 g/m^2 and 360 g/m^2 spread level compare with rubberwood plywood and hybrid plywood. This effect can be due to the raw material density, which affects the plywood density. The density of rubberwood veneer is less than coconut veneer because of thickness. It obvious that the plywood manufactured from different layered of rubberwood has lower density than the plywood from the hybrid veneers of rubberwood and coconut.

In addition to the raw materials density, the amount of adhesive also contributes to the density of plywood. The plywood using glue spread 360 g/m^2 showed higher density than the plywood using glue spread of 180 g/m^2 because the amount of the glue.

Table 1 also showed that percentage of moisture content with different plywood and spread levels.The results showed that the coconut plywood either using spread level 180 g/m^2 or 360 g/m^2 higher moisture content than the other plywood. Moisture content is significant with types of plywood. The decreasing moisture content will be increasing the mechanical properties of plywood. In addition, effect moisture content with lower spread level is significant. Lower moisture content also increasing the mechanical properties and make it higher mechanical properties.

Table 1: Result density and Moisture Content of Plywood

Spread Level	Sample	Density	Moisture Content
180 g/m^2	Rubberwood	0.63 (0.03) [a]	9.23 (0.41)
	Hybrid	0.67 (0.05)	9.94 (0.22)
	Coconut	0.70 (0.04)	10.06 (0.27)
360 g/m^2	Rubberwood	0.69 (0.03)	9.94 (0.53)
	Hybrid	071 (0.02)	10.17 (0.04)
	Coconut	0.75 (0.03)	10.40 (0.25)

[a] Value in parenthesis are standard deviation

Water Absorption and Thickness Swelling

Figure 1 showed significant of water absorption percentages on plywood and different spread levels. Coconut plywood is higher water absorption capacity than other plywood. Coconut is non wooden trees and thier anatomy contain high parenchyma tissue. Based on fact that coconut is high parenchyma tissue tend to absorb water is proved. It also can be seen that the panels using higher adhesive spread level (360 g/m^2) have higher water absorption than panel panels using a lower adhesive spread level (180 g/m^2). This may due to the lower compatibility between the hydrophilic fiber and adhesives for panel when using higher adhesive spread level because of the veneers fibers cannot keep bonded because of flooded of glue spread. Study carried out by Sreekala et al., (2002) showed that the weak compatibility between the fibre surface and the adhesive could lead to the formation of void structures within the composites, which facilitates water absorption.

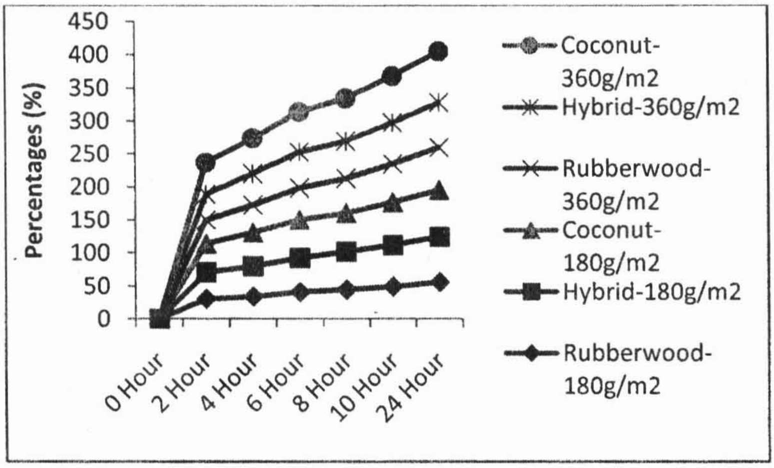

Figure 1: Water absorption of various plywood

Many physical properties of plywood are affected by the amount of moisture present in the plywood. Plywood exhibits greater dimensional stability than most other wood-based building products. Thickness swelling is independent of panel size and thickness of veneer by as stated by (Kelly, 1994). Figure 2 showed that the thickness swelling values of composites increased with lengthier periods of exposure to water. By increasing the exposure time of plywood in water, a significant amount of water was absorbed, resulting in the swelling of the fibres. This incompatibility leads to low fibre–matrix interfacial bond strength, poor wetting of the fibres by the matrix resin, and a reduction of mechanical performance when exposed to moisture. Thus plywood with higher glue spread absorb more water and thereby showed an increase in thickness swelling while plywood with lower glues spread having high bonded fibers, showed a decrease in thickness swelling since it cannot absorp excess water.

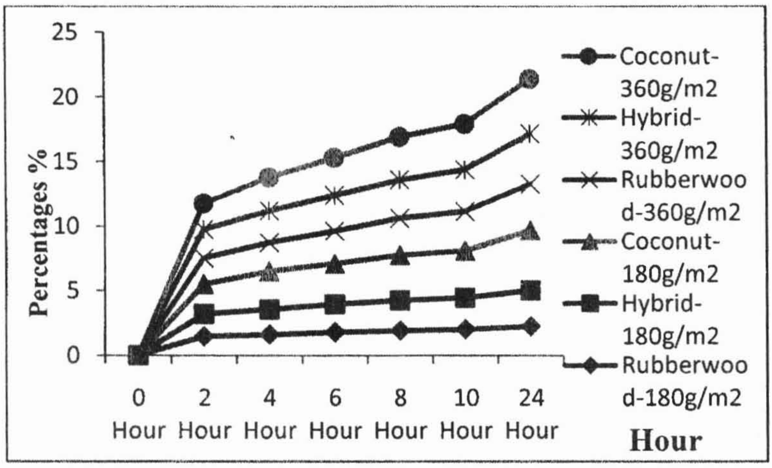

Figure 2: Thickness Swelling of the Plywood

Bending properties

Tests were performed to investigate the effects of different types of plywood using different glue spread on the mechanical properties of the plywood (Figure 3). Clearly, the bending strength of rubberwood plywood is higher. Overall, the results showed that rubberwood plywood using different glue spreads exhibited higher bending strength than hybrid plywood and coconut plywood using different glue spreads. Rubberwood reserve metabolites in the form of soluble sugars, starch etc. are abundant in the storage (parenchymatous) tissues that make it high strength resistance to load when right amount of adhesive were absorb on the rubberwood cells. Hybrid result showed moderate strength when coconut plywood that was lower strength was combining with higher strength of rubberwood plywood. Coconut contain the gross structure comprises of extremely soft tissues (parenchyma) alternating with extremely dense (vascular bundles) tissue that producing lower strength.

Figure 4 shows that plywood made using lower glue spread the bending strength were higher than those of the plywood that using a higher adhesive spread level (360 g/m^2). The lower spread level caused an adhesive that was spread on the surface of veneer to enter the pores where it solidified and anchored. This result an inadequate amount of adhesive being used to form adhesion between the surfaces for plywood over 360 g/m^2.

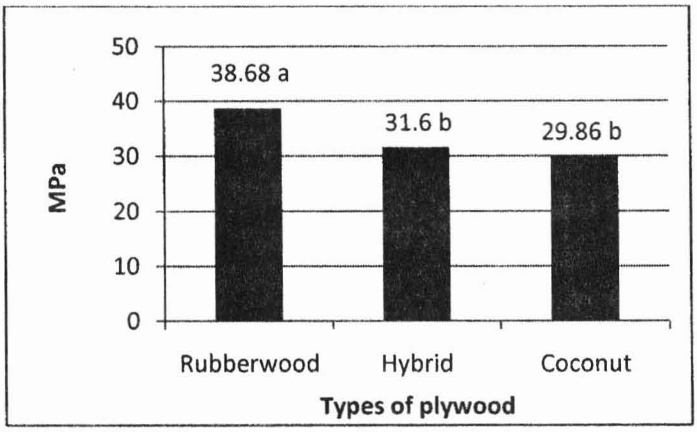

Figure 3: Effect of types of plywood on MOR values

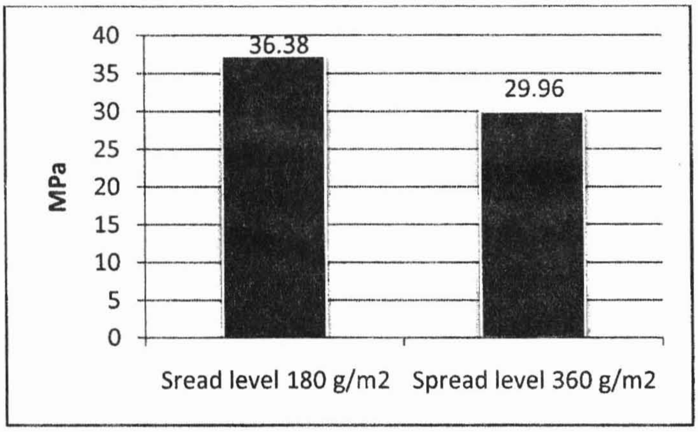

Figure 4: MOR values at different spread level

Higher values of bending stiffness (Figure 5) were found for panels made of rubberwood compared to panels made from hybrid and coconut. Structural anatomy species were impact the strength and stiffness of board quality. In addition right amount of resin content also affected the stiffness of board quality. Rubberwood is composed of fibres (58%), vessel elements (8.5%), axial parenchyma (11.5%), and rays (22%) and is distributed in different patterns and proportions as in other typical hard wood species. Coconut contain large amount of parenchyma that were lower stiffness. Reducing using rubberwood was become moderate in stiffness.

In general higher resin contain also higher in mechanical properties. This resulted show that increase resin contain will resulted decrease mechanical properties. It was because total of spread level are over for each layer. The veneers fibers cannot keep bonded because of excessive of resin contents and make it lower mechanical properties.

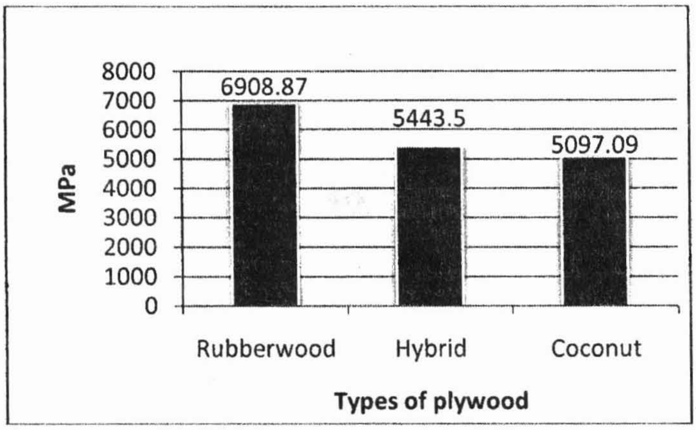

Figure 5: Stiffness values from different types of plywood

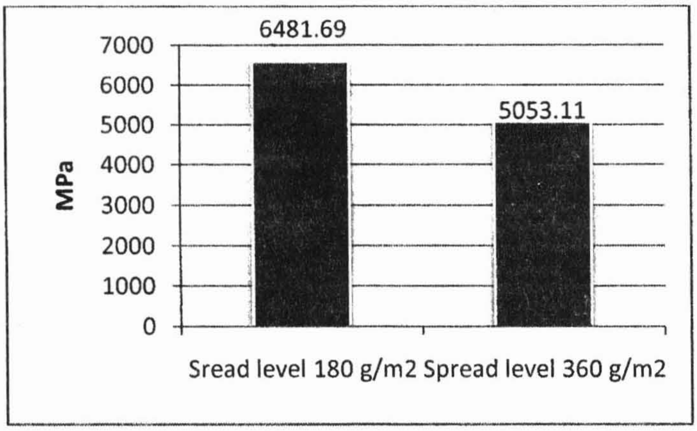

Figure 6: Effect of stiffness by different spread level

Tensile shear properties

The effects of board based on properties of glue bonded were significant between rubberwood, hybrid and plywood. Figure 7 show that rubberwood is high stronger than hybrid and coconut bonded with PF resin. Related to the bending MOR and MOE show that increasing the bonding of cell structure with the resin content will be impact the mechanical properties.

The tensile shear properties of hybrid plywood were also studied as shown in Figure 8. It can clearly be seen that the bond strength of plywood panels decreased by increasing spread level; the highest mean bond strengths were found in the rubberwood plywood using spread level 180 g/m^2.In this case, using spread level 180 g/m^2will be save the money and avoid wastage because PF were expensive.

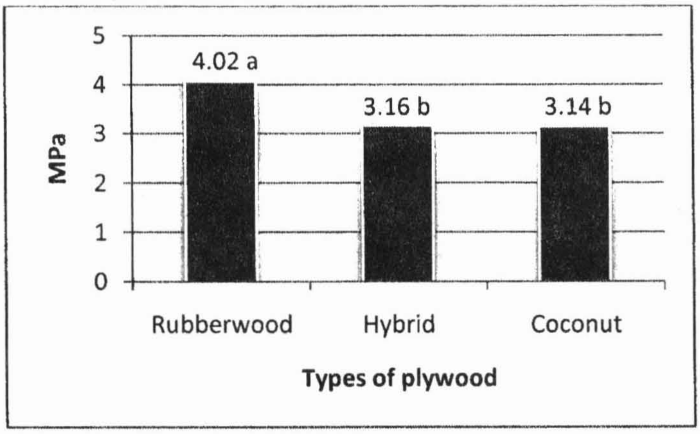

Figure 7: Effect of tensile on types of plywood

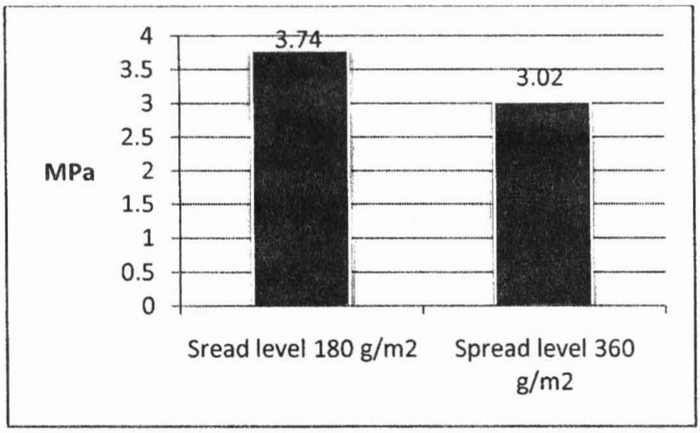

Figure 8: Effect of tensile strength by different spread level

CONCLUSIONS

Physical and mechanical properties of board show significants on types of plywood and different glue spread. Density were affect the strength properties of board especially of the raw material. Moisture content also important in board making to improve strength properties of board. Comparing with minimum standard requirement to pass the standard of Oriented Srand Board (OSB) showed that MOR and MOE were pass the requirement standard for three types of plywood. Choosing right amount of resin is important because this study showed that higher glue spread were decreasing mechanical properties of board. The suitable amount of glue spread basically were in range of 180 g/m^2-250 g/m^2. In this situation reducing using a lot amount of glue spread will be reducing cost in board making especially in plywood industry.

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