Physicomechanical Properties of Plywood from *Neolamarckia cadamba* using Different Adhesive Spreads of Phenol Resorcinol Formaldehyde

Kang Chiang Liew#, Yung Kang Fung
Faculty of Science and Natural Resources, Forestry Complex, Universiti Malaysia Sabah, Jalan UMS, 88400, Kota Kinabalu, Sabah, MALAYSIA
#Corresponding author. E-Mail: liewkc@ums.edu.my; Tel: +6012-8890122

ABSTRACT The objectives of this study were to determine the physical and mechanical properties of plywood from veneers of *Neolamarckia cadamba* by using four different adhesive spreads (150, 200, 250 and 300 g/m^2) of phenol resorcinol formaldehyde (PRF). Veneers were assembled perpendicularly to each other's grain direction before being cut and tested for density, bending test (Modulus of Elasticity, MOE and Modulus of Rupture, MOR), shear test and delamination. The results were used to compare with control adhesive spread of 250 g/m^2 which is used by the industry. The physical test based on ASTM D734 showed trend to increase in density with the increment of adhesive spreads. For the mechanical test based on JAS 233:2003, although none of the MOE and MOR values of the four adhesive spreads fulfilled the requirement of JAS standard, their values increased with the increment of adhesive spreads. Shear value increased from 150 to 250 g/m^2 but dropped at 300 g/m^2. The delamination test showed no delamination (0%) to all the four different adhesive spreads which showed the water resistance properties of PRF. Generally, the results of both physical and mechanical test showed no difference for every increment of 50 g/m^2 of adhesive spreads from 200 g/m^2 onwards. Since the result showed that 200 g/m^2 no significant difference using $p < 0.05$ to 250 g/m^2 in all the physical and mechanical test, the adhesive spreads of PRF could be reduced to 200 g/m^2 in plywood manufacturing in order to reduce cost and pollution without affecting the physical and mechanical properties of plywood.

KEYWORDS: Plywood, *Neolamarckia cadamba*, Adhesive spread, Physical properties, Mechanical properties
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Negative Result

INTRODUCTION

Wood can be densified, and its properties modified by not only filling its void volume with polymers, molten sulfur, or molten metals but also by compressing it under conditions such that the wood structure is not fractured.

Plywood is thin strips of wood glued together at uneven number like a sandwich. The adhesive is applied between each layer at 90^0 which is perpendicular. The cross-graining has several benefits for examples, it can reduce the shrinkage of product and provide dimensional stability. The quality of plywood depends in the quality of adhesive. The better quality of adhesive used bring the better quality of plywood. High quality of adhesive has better adhesive bonding performance between wood elements.

According to Resobondò Industrial Adhesives Technical Information Sheet in 2014, Phenol Resorcinol Formaldehyde is categories as Resobond A3 which had 250 g/m^2 of adhesive rate. PRF is a water resistance adhesive that widely use in wood industry. The durability of PRF is longer than UF and offer a better delamination level (Sahri, 1990). Adhesive is an essential material to wood industry. A good quality of adhesive will improve the performance of wood product. Even though adhesives are important materials made up of both natural and synthetic substances for bonding wood components into wood product, they still might have some negative environmental impacts (Yang & Rosentrater, 2015).

METHODOLOGY

In this study, Laran (*Neolamarckia cadamba*) was selected as the raw material for making plywood. Its veneers peeled were air-dried to a moisture content of 8 – 12% which is the range used by plywood industry, before cut into 300 mm × 300 mm based on standard ASTM D-1037-12. Four different adhesive (PRF) spreads (150 g/m^2, 200 g/m^2, 250 g/m^2 and 300 g/m^2) at ratio of PRF (AkzoNobel PRF System 1734) and hardener (AkzoNobel Hardener System 2734) 1:0.25 were used to glue the veneers to become 3-ply plywood as shown in Figure 1. Veneers used were in a range of 1.1 to 1.17 mm in thickness.

Figure 1. Sample of Laran 3-ply plywood.

Density was evaluated according to ASTM D734. Bending and shear properties were evaluated according to JAS 233:2003 using Universal Testing Machine while delamination test (according to JAS 233:2003) were test for adhesive failure of plywood, where values for Modulus of Elasticity and Modulus of Rupture, and shear strength were obtained respectively. The speed for bending and shear was set at 1 mm/min for both tests.

RESULTS AND DISCUSSION

Figure 2 showed the density of plywood made using difference adhesive spreads. Overall, the density increased with the increase in the amount of adhesive spreads. Plywood made at adhesive spread 300 g/m^2 had the highest density 438.35 kg/m^3 while 150 g/m^2 had the lowest 404.16 kg/m^3.

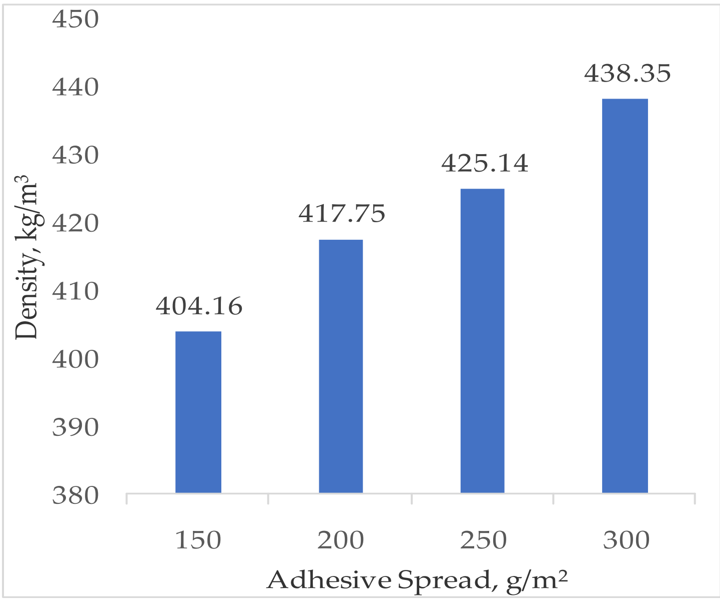

Figure 2. Density of plywoods with different adhesive spreads.

The density of plywood could be affected by the adhesive weight. The more adhesive used, the higher the density of the plywood. The density values varied and influenced by the presence of adhesive spreads (Hatono *et al*., 2019).

Mechanical test was done according to JAS 233:2003. Figure 3 and Figure 4 showed the Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) of plywood with different adhesive spreads. MOE and MOR increased from 3525.95 N/mm² to 6083.89 N/mm² and 15.53 N/mm² to 32.44 N/mm², respectively as adhesive spreads increased from 150 g/m² to 300 g/m² as shown in Figure 3 and Figure 4. JAS 233:2003 standard required a threshold MOE value of 8500 N/mm² and MOR values of 34 N/mm². None of the MOE and MOR values of the four adhesive spreads fulfilled the requirement of JAS standard. The MOE and MOR values were affected by the density of plywood (Hartono *et al*., 2019) and did not fulfil the requirement of JAS standard which might be due to Laran being a low-density hardwood (Jøker, 2000).

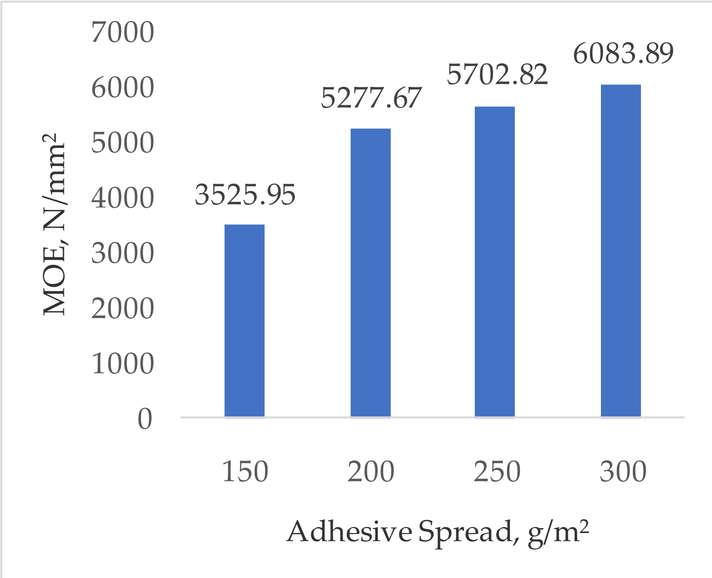

Figure 3. MOE of plywoods with different adhesive spreads.

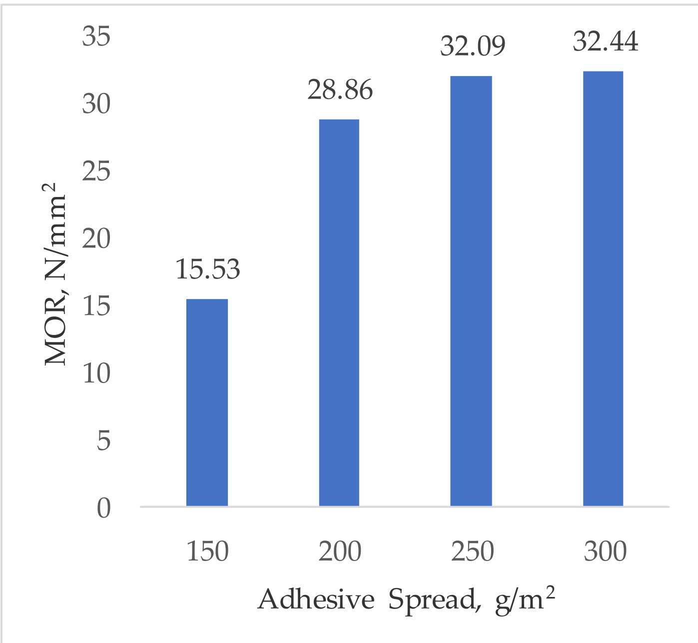

Figure 4. MOR of plywoods with different adhesive spreads.

Meanwhile, JAS 233:2003 indicated that the minimum requirement of shear strength was 0.7 N/mm^2 where all the four adhesive spreads had fulfilled. As shown in the Figure 5, the shear strength increased drastically from 150 g/m^2 (2.10 N/mm^2) to 200 g/m^2 (3.50 N/mm^2) and dropped at 300 g/m^2 (3.87 N/mm^2). The higher the adhesive spread the higher the shear strength according to Correal *et al.* (2010). However, the shear strength starts to lose after achieving an optimum adhesive thickness (Naito *et al.*, 2012). The adhesive thickness of 300 g/m^2 was around 0.5 mm.

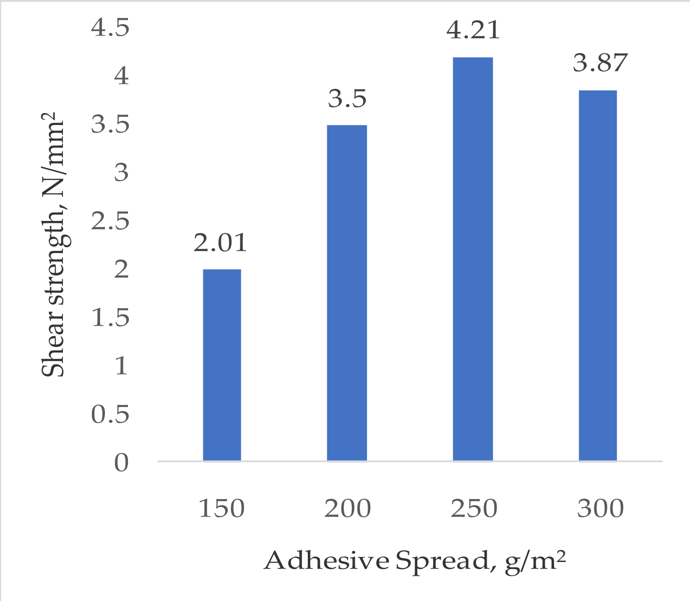

Figure 5. Shear strength of plywoods with different adhesive spreads.

Type II delamination test was conducted in this study. The requirement of JAS 233:2003 standard for delamination test was less than 10%. However, all the plywood at four different adhesive spreads did not suffer any delamination or 0%. According to Sahri (1990), the PRF adhesive had less than 1% of delamination level to the plywood made from Malaysia's hardwood as refers to the water resistance properties of PRF adhesive. The plywoods were further tested at the extended time of soaking (24 hours at 70^{o}C) and oven dried (24 hours at 61^{o}C) to investigate whether the plywoods will delaminate or not. A set of 10 replicates were used in this investigation. 3 out of 10 replicates of 150 g/m^2 adhesive spread had 22 to 94% delamination level while there was no delamination for 200, 250 and 300 g/m^2 of adhesive spreads thus showing PRF adhesive proved its excellent water resistance properties.

CONCLUSION

This study was set out to determine the properties of plywood with different adhesive spreads. In general, physical and mechanical properties of plywood showed no significant differences between 200 and 250 g/m^2 of adhesive spreads. However, the properties change with the increasing of adhesive spread amounts.

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