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EVALUATION OF 3-LAYER OIL PALM FROND PARTICLEBOARD

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Abstract- Three-layer or heterogeneous particleboard made of different particles for face and core layer. Fines particles were practically used for face layer and coarse particles used for core layer. This study aim to determine the mechanical and physical behavior of three layers particleboard made from oil palm fronds (OPF) as source of raw material and phenol formaldehyde (PF) used as bonding agent. Two different size were used in this study for face layers which were 0.5 and 1.0 mm while core layer with 2.0 mm particle size. The resin content for face layers were used at 11% throughout study and core layer used at 3 different contents, which were 7, 9 and 11%. The result indicated that increasing in particle size on surface layer insignificantly affected both mechanical and physical properties. However, increasing in resin content on core layer directly improve the physical properties of particleboard.

Keywords- Particleboard, Heterogeneous, Phenol Formaldehyde

I. INTRODUCTION

Particleboard is a wood-based product made from lignocellulosic particles that pressed into a mat with presence of pressure and adhesive. Particleboard used in various productions, mainly in furniture, door core, paneling, flooring and table top. The demand of particleboard massively increased each year contributed by low availability of solid wood, available in various thicknesses, wide, length and easy handling with tools compared to solid wood. Particleboard available in single or multi-layers depends on final use. However, multilayer or 3-layer particleboard is commonly produced than single layer (1). Three-layer board was made by sandwiching a core layer of coarse particles with fines particles of surface layers and higher resin content at both faces than core layer to reduce the total resin used without reduce overall strength (2).

The main idea behind production of particleboard is to reduce and utilize the excessive waste at sawmill into useable product rather than being burn. Currently, agricultural waste shows bright potential as raw material in production of particleboard. Agricultural waste such as oil palm trunk, sugarcane bagasse, oil palm trunk, kenaf, rice husk and fiber coir has been studied by researcher in various researches as alternative raw material to satisfy industries demand especially furniture industries as well reducing dependency on solid wood waste in particleboard production (3-6).

Oil palm frond (OPF) is one of abundant agricultural waste that partially utilized and had potential as new raw material for particleboard. Malaysia, as the second largest in the world behind Indonesia as palm oil exporter, covers 5.2 million hectares plantation areas by end of 2013, produced 10 tonnes OPF per hectare annually (7). The large quantity of OPF mainly left on plantation site for nutrient recycling however, generate uncontrollable quantity as it felled twice in a month and approximately 2-3 fronds felled for a fruit bunch. Several researches utilizing OPF has been studied in production of compressed oil palm frond composite board or COPaF, pulp, and cement bonded board show comparable result to existing products with other lignocellulosic as raw material (8-10). Although particleboard from oil palm biomass especially trunk have been investigated in several research, studies on manufacturing particleboard using OPF especially phenol formaldehyde as resin generally still in limitation. Study on its chemical composition shown it contain comparable hemicelluloses and lignin to other lignocellulosic used in production of particleboard (11).

This study aims to investigate the mechanical and physical properties of 3-layer particleboard made by OPF particles as raw material and Phenol Formaldehyde (PF) as adhesive and evaluate the properties accordance Malaysian Standard for Particleboard (MS1787: 2005).

II. MATERIALS AND METHOD

Oil palm fronds (OPF) were collected from UiTM Pahang's Plantation area during harvesting season. Phenol Formaldehyde (PF) used in this study as adhesive was supply by a local adhesive manufacturer in Shah Alam, Malaysia. The leaflets of collected OPF were cut off before the samples transported to laboratory. The OPF chips produced using rotating chipper was then transfer into Pallman Knives – Ring Flaker to reduce shape into particle form. The particles were then air-dry for at least one week to reduce its moisture content (MC) around 8-10% before feed into Vibrating Screen to obtain particles needed. Screened particles were oven dry for 24 hours or until the MC reduce around 3 – 5 % prior to particleboard production.

Particleboard manufacturing

Particleboards were made at 700 kg/m³ target density, and 3 level of resin content (7, 9, 11%) based on oven dried particles weight at core layer while face and back layer were set at 11% resin content. The particle of face and core layer

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were mix with PF resin separately in the Particleboard Mixer and resin was sprayed at 0.35 MPa for even distribution on particle surface. The resinated particles were manually laid layer by layer into 350 mm x 350 mm wooden mould lining by caul plate. Another caul plate was place on particle mat after cold press and transferred to hot press machine at 175°c for 6 minutes with 12 mm thick stopper. The consolidate mat were condensed in conditioning room for at least 3 days before cut into samples for mechanical and physical testing.

Sample Testing

All boards produced were cut according cutting plan to obtain a random selection of samples throughout the board size of 300mm x 300mm x 12mm. Sample test was kept under air dried condition under 20±2°C and relative humidity at 65±5% for 24 hours until the constant weight reached. The purpose of conditioning is to produce uniform board moisture content. Table 1 show the experimental design of study with 2 particle size were used at both surface layers while 2.0mm was used at core layer throughout the study. Surface layer constantly applied with 11% resin content and different resin content were used at core layer. Four boards replication were produced for each parameter with 24 boards produced.

Samples were tested for modulus of elasticity (MOE), and modulus of rupture (MOR), internal bonding (IB), and thickness swelling (TS). Mechanical test of board was conducted using Instron Universal Testing Machine model 5569 and the testing was carried out accordance to Malaysian Standard (MS) for particleboard (MS1787)., MS1787: PART 11:2005 for MOE and MOR, MS1787: PART 10: 2005 for IB and, MS1787: PART 6: 2005 for TS (12-14). The properties of 3-layer was compared to properties of single layer board (control) made with 0.5 mm particle size, target density of 700 kg/m³, and 11% resin content.

Table 1. Experimental Design

Type	Particle Size (mm)		Resin Content (%)	
	Face	Core	Face	Core
A	0.5	0.5	11	11
1	0.5	2.0	11	7
2	0.5	2.0	11	9
3	0.5	2.0	11	11
4	1.0	2.0	11	7
5	1.0	2.0	11	9
6	1.0	2.0	11	11

Type A – control board
1-6 – sample

Statistical Analysis

The significance difference in density and resin content were statistically analyzed using analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) was used to indicate the significant of the mean at $p< 0.05$.

III. RESULT AND DISCUSSION

Table 2 shows the mechanical and physical properties of control and 3-layer OPF particleboard. Board type 3 exhibit highest MOR (25.99 MPa) and MOE (3407 MPa) while lowest MOR (22.78 MPa) and MOE (3138 MPa) display by board type 4. Highest (0.53 MPa) and lowest (0.25MPa) internal bonding strength were show by board 6 and board 1 respectively. Thickness swelling of board negatively affected with increasing of resin content on core layer from 7% to 11%. The best dimensional stability strength was shown by board type 6. In general, according to the MS requirement, all bending properties board sample exceeded the minimum requirement while only board type 6 pass the requirement appointed for IB and non of samples were meet the minimum requirement needed. The bending properties of 3-layer board comparable to MOR and MOE strength of control board. However, IB strength and TS properties shown control board had better result.

Table 2 Mean value of Mechanical and Physical Properties of Control and 3-layer Particleboard

Type	MOR (MPa)	MOE (MPa)	IB (MPa)	TS (MPa)
A	**25.19 (3.58)**	**3483 (459)**	**0.70 (0.05)**	**8.77 (0.81)**
1	25.03 (3.57)	3387 (255)	0.25 (0.03)	28.13 (1.30)
2	25.62 (2.69)	3395 (250)	0.37 (0.04)	24.16 (0.73)
3	25.99 (2.72)	3407 (344)	0.44 (0.06)	22.19 (1.12)
4	22.78 (3.21)	3138 (289)	0.25 (0.04)	26.82 (1.61)
5	24.97 (3.60)	3141 (474)	0.31 (0.04)	23.30 (1.39)
6	25.37 (1.78)	3185 (288)	0.53 (0.09)	20.73 (1.48)
MS requirement	**14**	**2000**	**0.45**	**15**

Numbers in parenthesis represent standard deviation

Effect of resin content

Figure 1 and 2 show the mechanical properties of boards affected by resin content. Boards with 11% resin content at core layer had highest value for both MOR (25.68 MPa) and MOE (3296 MPa). Increasing in bending properties with increasing of resin content at core layer however display insignificant result to one another and further reveal by ANOVA (Table 3) and correlation coefficient (Table 4). Increasing resin content statistically insignificant affecting both MOR and MOE values with ($r = 0.171$) and ($r = 0.044$) respectively. The result obtained meets the well-known fact that bending properties of particleboard depends on strength of surface layer. As the experiment continuously used 11% resin content on surface layer throughout study, the MOE and MOR showed insignificance in strength between boards.

Highest internal bonding (Fig. 2) value (0.45 MPa) was obtained by boards made with 11% resin content for all layers while lowest value obtained by board 11/7/11 % resin content with difference of 80%. The internal bonding (IB) however, show contradict result to bending properties when DMRT indicated apparent difference in strength between resin level used. The significant result further reveal by ANOVA (Table 3) and correlation coefficient (Table 4) that

IB strength statistically significant and affected with increasing resin content with (r=0.786) at p<0.05.

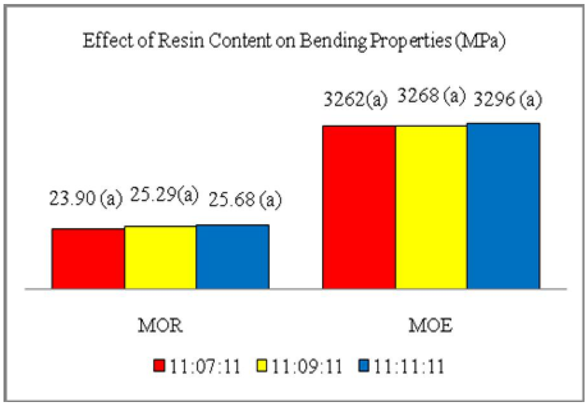

Fig. 1 Effect of resin content on bending properties (MPa)

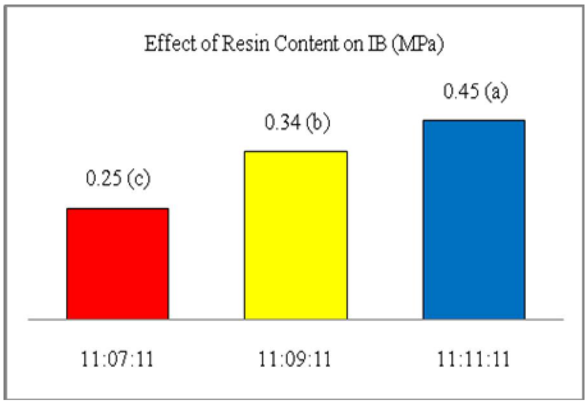

Fig. 2 Effect of resin content on IB (MPa)

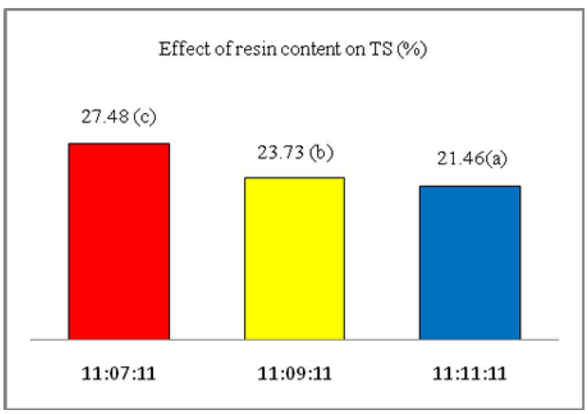

Fig. 3 Effect of resin content on TS (%)

Significant in result affected by variable resin content used at core layer could be explain by face that core layer of a particleboard is responsible for internal bonding strength (15). Increasing in resin content directly increase the ability of particle coating and provide better bonding site for stronger internal bond.

Figure 3 display the thickness swelling (TS) behavior of tested sample. The result indicated, thickness swelling had negative effect in value with increasing of resin content, which means lower thickness swelling exhibit at higher resin content. Boards made with 11/7/11 % resin content display worst (27.48 %) thickness swelling while better swelling was obtain by boards made with 11/11/11 % resin content (21.46 %). After 24 hours water immersion, sample observed to absorb water and increase the thickness especially at core layer. Middle layer of boards experiencing poor swelling compared to face and back layer because particles of core layer had lower bulk density than particles at surface layers. Low bulk density of particle lessens the ability of resin to cover particle surface as high amount of particle available at given density. Different resin content used at core layer resulted distinct value in swelling for all boards. Low amount of resin at core layer leads to lack bonding site for particles to bind together and resulted to form weaker bond between particles thus allow water molecule to penetrate from surface to middle layer and breaks the weak bond. The ANOVA (Table 3) and correlation coefficient (Table 4) further reveals (r = -0.691**) increasing in resin content at core layer negatively correlated to thickness swelling.

Effect of Particle Size

Figure 4-6 show the mechanical and physical properties of 3-layer particleboard affected by different particle size used on surface layer. Particle size is one of important factor affecting wood-based panel's properties. Studies on particle size or particle geometry affecting board properties reported that smaller particle size will produce stronger properties because of its ability to fill the gap and bigger surface area to provide better bonding site between particles (16). Bending properties of boards display both MOR and MOE show decreasing trends with increasing particle size that means smaller (0.5 mm) particle size exhibit stronger bending strength than board made with 1.0 mm. The result of DMRT however display MOR and MOE values fall in same group, indicated that difference in strength did not vary to each other and further reveals by ANOVA (Table 3) and correlation coefficient (Table 4). The result statistically insignificance with increasing particle size on surface layer with (r= -0.196, r = -0.369) at p<0.05 for MOR and MOE respectively. This could be related to insignificant slenderness ratio of both particle sizes.

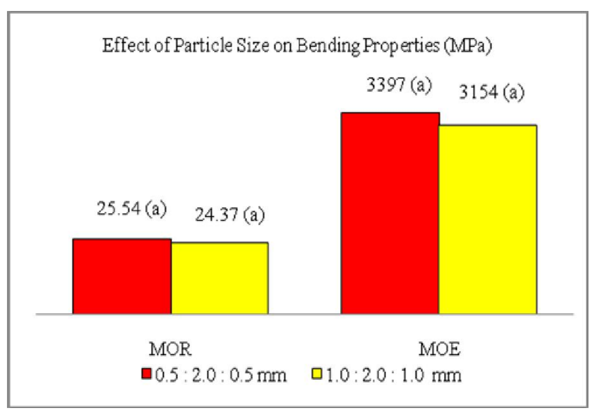

Fig. 4 Effect of particle size on bending properties (MPa)

The insignificant result also shown by IB (Fig 5) and TS (Fig 6) strength where the correlation coefficient (Table 4) show (r= 0.055 and r=-0.214) respectively. The insignificant difference in particle size for both IB and TS however predicted because both testing depending on strength of core layer boards. Thus, at constant particle size used at core layer, the behavior of board insignificantly affected to one another.

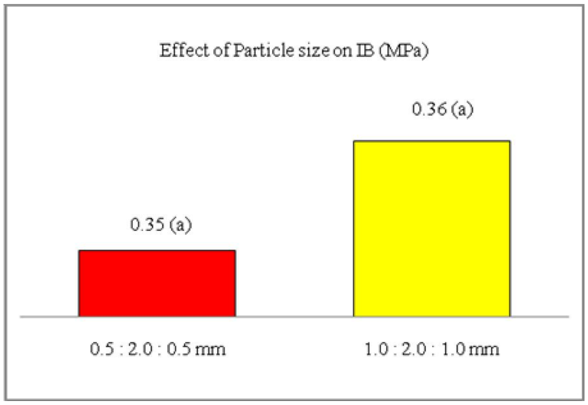

Fig. 5 Effect of particle size on IB (MPa)

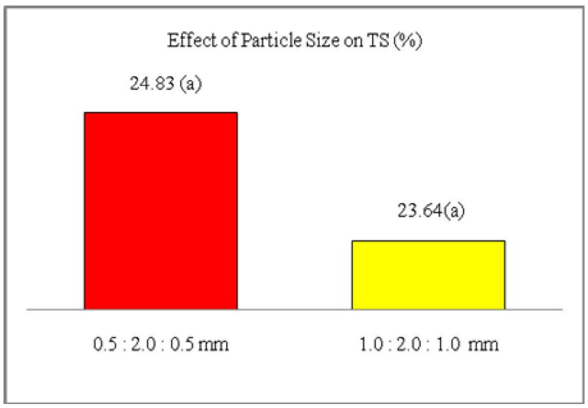

Fig. 6 Effect of resin content on TS (%)

Table 3 ANOVA of resin content and particle size on particleboard properties

Properties	MOR	MOE	IB	TS
Resin Content	ns	ns	*	*
Particle Size	ns	*	ns	*
RC x PS	ns	ns	*	ns

* Indicate significance difference at $p < 0.05$
ns not significant

Table 4 Correlation analysis of resin content and particle size on particleboard properties

Properties	MOR	MOE	IB	TS
Resin Content	0.171^{ns}	0.044^{ns}	0.786**	-0.691**
Particle Size	-0.196^{ns}	-0.369**	0.055^{ns}	-0.214^{ns}

* Indicate significancr difference at $p < 0.05$
ns not significant

V. CONCLUSION

This study aim to determine the mechanical and physical properties of 3-layer particleboard made from OPF. The highest mechanical properties owned by board type 6 with 11% for all layers and 0.5mm at surface layer. The bending properties of particleboard for all board types indicated comparable result to control board and pass the minimum requirement of appointed standard. However, the IB and TS properties display poor characteristic due to low strength of centre layer. Further study on improving IB and reducing thickness swelling in particleboard could be conducted by modified particle surface by alkali treatment and reduce the density on core layer to lower the springback effect of board.

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