Influence of Particle Sizes on Homogenous and Heterogeneous Wood Cement Board Properties Made from *Acacia mangium*

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Abstract

Wood-cement board (WCB) is a panel product that has the advantages of inorganic and organic materials. However, the main problems affecting the manufacture and use of WCB are the inhibitory effects of wood on the setting of cement and the high specific gravity of the final product. This paper examines the potential and the use of particle sizes and board layer to facilitate the production of a WCB from *Acacia mangium*. WCB were manufactured with wood/cement (w/w) ratio of 1:3, target density of 1300kg m^{-3} and $Al_2(SO_4)_3$ and Na_2SiO_3 content as chemical additives of 3.0%. Besides that, WCB also manufactured with the layer (homogenous and heterogeneous). The WCB were tested for static bending (MOR and MOE) properties in parallel (//) and perpendicular (⊥) directions; internal bond (IB), thickness swelling (TS) and water absorption (WA).

Keywords: *Acacia mangium*; Homogenous and heterogeneous; Particle size; Malaysia industry standards.

1. INTRODUCTION

Wood cement board (WCB) is a panel product that combined wood particles, additives, cement and water. WCBs are used thoroughly in Europe, United States, Russia and South East Asia, mainly for roofs, floors and walls. They possess countless advantages compared to panels produced with organic resins which include high durability, good dimensional stability, acoustic and thermal insulation properties and low production cost. In recent years, several research groups have been evaluating the suitability of different lignocellulosic materials for the manufacture of WCB including among others rubberwood (Okino *et al.*, 2004), eucalyptus (Okino *et al*,. 2004; Menezzi, Castro and Souza, 2007) (Ashori and Azizi, 2011), sesenduk (Jamaludin et al., 2010) and agricultural residues (Soroushian et al. (2004), Almeida *et al.*, 2002).

This panel product also has excellent workability as it can be sawn, drilled, sanded, glued and screwed with normal working tools. In Malaysia, WCB are commonly used in building structure as seen in the manufactured roof sarking of Kuala Lumpur LRT station, Kuala Lumpur International Airport and Sunway Pyramid.

2. MATERIALS AND METHODS

2.1 Field Procedure

Start with particle preparation. After felling, the logs were moved to sawmill and cut into 1 feet length billet using a chain saw. The next process is debarking using cleaver to remove the barks that are useless. The billets are further to smaller size (chip) using wood chipper machine to obtain the desirable thickness and length. The particle were dried and then screened to remove fine and dust like particle. In screening process a vibrator screening machine was used. For homogenous board, sizes 0.5mm, 1.0mm and 2.0mm were used. Heterogeneous board combinations are the face and back using 0.5mm and 1.0mm mixture while core used 2.0mm particle size only.

2.2 Board Manufacture

Wood cement board was fabricated at the density of 1300 kgm^{-3}. The dry particles with moisture content between the range of 15 % - 18 % were ready for manufacturing board process. The process was undergoes steps which were weighing, mixing, mat forming, pressing, hardening in chamber, curing, and trimming into required sizes.

2.3 Sample Cutting

For sample testing, the panel boards are check for bonding conformance and thickness tolerance before the side trimmed and cut accurate to dimension. The board was cut into the required sizes for testing process using the table saw machine. Figure 1 shows the wood cement board sampling sizes and location.

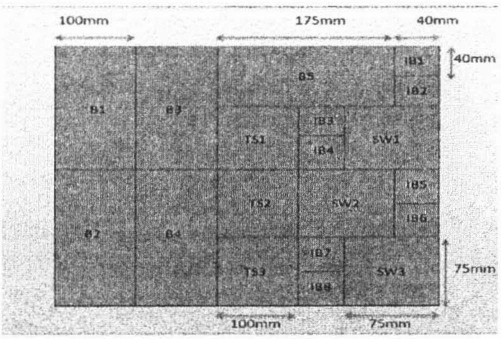

Figure 1: Wood cement board sampling

3. TESTING METHODS

3.1 Bending Strength

Bending test is important to know Modulus of Elasticity (MOE) and Modulus of Rapture (MOR) values. Cut samples were clearly labelled, measured dimensions (length, width and weight) and marked for test positions. Bending machine (Instron) with the load support span of >240mm was used. The force was put onto the board until it broke and the results are determined in MPa. The bending test can be calculated by the following formula:

$$\text{Bending strength}\left(\frac{N}{mm^2}\right) = \frac{3PL}{2bt^2}$$

Where, P: maximum load (N)

L: span (mm)

b: width of test piece (mm)

t: thickness of test piece (mm)

3.2 Internal Bonding

The purpose of internal bonding (IB) is to determine the tensile strength of the board panels. For IB, the samples sized to 50mm x 50mm were recorded all of its data and marked. Samples' surface was sanded to avoid pre-mature failure during the test. It was glued to the steel block using two-component glue mixed with ratio 1:1. The test block was allowed to cure for 2 hours. Instron machine will pull the two sides of block until it break at the middle of sample. The IB can be calculated from the formula below:

$$\text{Internal bond } (N/mm^2) = \frac{P'}{2bL}$$

Where: P' = Maximum load (N) at the time of failing force

b = Width (mm) of sample

L = Length (mm) of sample

3.3 Thickness Swelling

To testing the thickness swelling (TS), all of the samples must be precisely soaked into the water to make sure that the overall of the samples were properly soaked. The formula that use in TS is as given below. The sample size was 50 mm X 50 mm, marked and all the data was record. The test samples were soaked in the water until all part of the samples sink for 24 hours.

$$\text{Thickness swelling: } \frac{\text{Final dimension} - \text{Initial dimension}}{\text{Initial dimension}} \times 100$$

3.4 Water Absorption

The purpose of water absorption testing is basically to determine how much the particles absorbs water. This thickness swelling testing also indicates how durable the particleboard to water. The formula used in calculation for the percentage of water absorption is as shown below:

$$\text{Water absorption: } \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial weight}}$$

4. RESULTS AND DISCUSSIONS

4.1 Mechanical and physical properties of particleboard from *Kelempayan* sp

Table 1: Mechanical and physical properties of boards

Table 4.1 Properties of wood cement board according to particle size

Particle size	Layer	MOR (MPa)	MOE (MPa)	IB (MPa)	TS (%)	WA (%)
0.5	Homogenous	12.23	4752.89	0.23	1.29	30.32
1.0		10.74	4810.03	0.12	1.62	34.12
2.0		10.62	4121.98	0.12	2.49	34.49
0.5/2.0/0.5	Heterogeneous	10.51	6335.34	0.15	2.81	34.62
1.0/2.0/1.0		9.74	4579.18	0.13	2.92	35.79
MS544-200		≥9	≥3000	≥0.5	≤2	≤30

Notes: MOR: Modulus of Rupture, MOE: Modulus of Elasticity, IB: Internal Bonding

TS: Thickness Swelling, WA: Water Absorption

Table 1 shows the properties of WCB according to particle sizes and layer. The highest mechanical properties (MOR, and IB) belonged to particle size of 0.5mm in homogenous layer which MOR, 12.23MPa and IB, 0.23MPa. The highest MOE was for heterogeneous layer combination of Face/Core/Back with (0.5/2.0/0.5)mm and the value is 6335.34MPa. The lowest physical properties for TS and WA also belonged to particle size of 0.5 mm homogenous layer which is TS at 1.29% and WA at 30.32%.

4.2 Statistical significant for Particleboard

Table 2 showed mechanical properties, MOR and IB to have a significance value while MOE was not significance. Meanwhile for physical properties, TS is highly significance and WA is only significance at $P<0.01$.

Table 2: ANOVA test results

SOV	df	MOR	MOE	IB	TS	WA
Significance	-	0.015	0.104	0.00	0.00	0.035
Particle size	4	3.805*	2.152ns	19.601**	8.764**	3.064*

Note: ns-not significance at $P>0.05$, *-significance at $P>0.05$, **-highly significance at $P<0.01$

4.3 Effect of Particle Sizes on Modulus of Rupture (MOR)

Figure 2 gave MOR of different particle sizes. In homogenous layer, the value for size particle 0.5mm is 12.23MPa followed by 1.0mm at 10.74MPa and 2.0mm at 10.62MPa. Meanwhile for heterogeneous layer, the value for size particle (0.5/2.0/0.5) mm is 10.51MPa and (1.0/2.0/1.0) mm is 9.74MPa. The particle size at homogenous layer which is 0.5 mm has greater value than the other particle sizes.

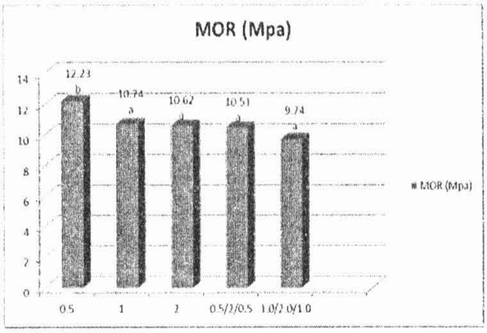

Figure 2 Effect of particle sizes on MOR

There is highly significant difference between the particle sizes for Figure 2. The particle size 0.5 mm is highly significantly different compared to the other particle sizes.. According to Semple and Evans (2004), the smaller sized particle will give more strength and dimensionally stability of the WCB board.

4.4 Effect of Particle sizes on Modulus of Elasticity (MOE)

Figure 3 shows the MOE at different particle sizes. The value for particle size 0.5mm is 4752.89MPa, followed by 1.0mm at 4610.03MPa and 2.0mm of 4121.98MPa. Value for (0.5/2.0/0.5)mm is 6335.34MPa and (1.0/2.0/1.0)mm is 4579.18MPa. The highest value is from heterogeneous layer for particle size arrangemant (0.5/2.0/0.5)mm.

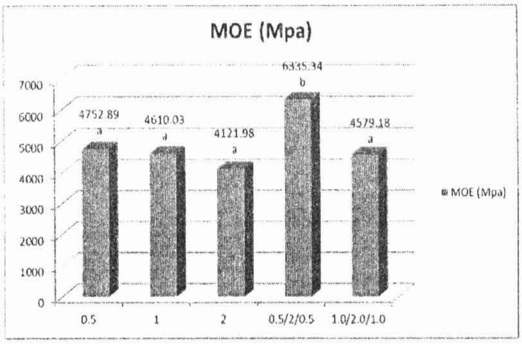

Figure 3 Effect of particle size on MOE

There is a highly significant difference between particle size in heterogeneous which is (0.5/2.0/0.5)mm compared to the other particles sizes from homogenous and heterogeneous. Meanwhile particles sizes from homogenous layer which is 0.5mm, 1.0mm, 2.0mm and from heterogeneous layer which is (1.0/2.0/1.0)mm is not significantly different from each other. According to Olorunnisola (2009), the smaller size of particles was likely to be easily blended with cement in the matrix than the bigger particles thus yielding composites with higher MOE.

4.5 Effect of Particle sizes on Internal Bonding (IB)

Figure 4 shows IB of different particle sizes. The value for particle size in homogenous layer which is 0.5mm is 0.23MPa, 1.0mm is 0.12MPa and 2.0mm is 0.12MPa. Meanwhile for heterogeneous, particle size (0.5/2.0/0.5)mm is 0.15MPa and (1.0/2.0/1.0)mm is 0.13MPa. The particle size 0.5mm in homogenous layer has the highest value.

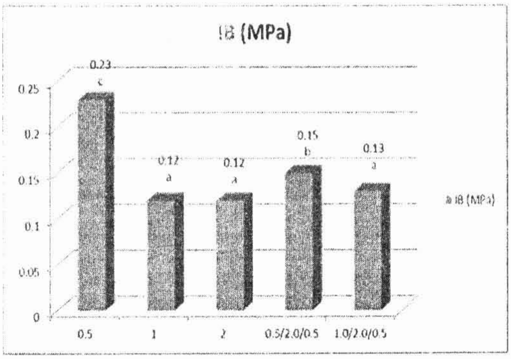

Figure 4 Effect of particle size on IB

There is highly significant difference between particle sizes 0.5mm with other particle sizes in homogenous layer. In heterogeneous layer, there is significant difference between (0.5/2.0/0.5)mm and (1.0/2.0/1.0)mm.

4.6 Effect of Particle Sizes on Thickness Swelling (TS)

The effect of particle sizes on TS is seen in Figure 5. The value of particles sizes from homogenous board is 0.5mm is 1.29%, followed by 1.0mm which is 1.62% and 2.0mm is 2.49%. Meanwhile for heterogeneous layer, particle size (0.5/2.0/0.5)mm is 2.81% and (1.0/2.0/1.0)mm is 2.92%. The TS is from heterogeneous layer (1.0/2.00/1.0)mm particle size.

There is significance difference between 2.0mm particle size compare to the 0.5mm and 1.0mm in homogenous layer. For the heterogeneous layer, there is no impact of particle sizes. Study done by Frybor, (2008) showed TS increase with increasing particle size.

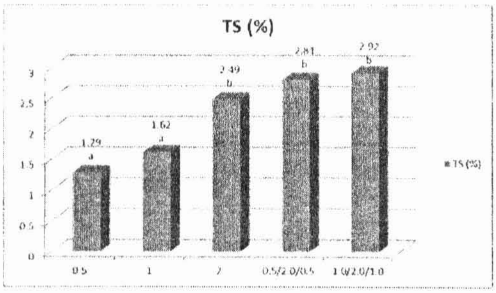

Figure 5 Effect of Particle sizes on thickness swelling

4.7 Effect of Particle Size on Water Absorption (WA)

WA effect due to particle sizes is shown in Figure 6. The WA value of various particle sizes from homogenous layer is 0.5mm is 30.33%, followed by 1.0mm is 34.12% and 34.49% for 2.0mm. Meanwhile for heterogeneous layer, particle size (0.5/2.0/0.5)mm is 34.62 % and (1.0/2.0/1.0)mm is 35.79%. The highest water absorption percentage is seen for heterogeneous layer (1.0/2.0/1.0)mm particle size.

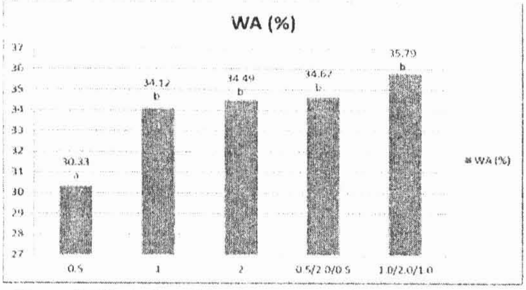

Figure 6 Effect of particle size on water absorption.

There is significance difference between 0.5mm particle sizes compared to the other particle size. This is because, a smaller particle size produced board that more compact and thus have less water absorption.

5. CONCLUSIONS

For conclusion, the finding showed that the particle sizes that used in homogenous and heterogeneous wood cement board is influencing all the wood cement board mechanical properties except for internal bonding. The values of MOR and MOE met the standards of MS544:2001 for all particle sizes effect. Meanwhile in IB, all the particle sizes effect was not met the standards of MS544:2001.

For physical properties in WA, only particle sizes 0.5mm and 1.0mm in homogenous layer are met the standards requirements of MS544:2001. Other particles sizes combination fails. For TS, the value for particle sizes effect are failed to meet the standards of MS544:2001.

Effect of particle sizes on mechanical properties indicating that, smaller particle size (0.5mm) have better mechanical properties for WCB. Besides that homogenous layer are have a better physical and mechanical properties compared to the heterogeneous.

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