EFFECT OF PRODUCTION VARIABLES ON THE PROPERTIES OF CEMENT BONDED FLAKE BOARD FROM POLYALTHIA LONGIFOLIA (SONN.)THW. WOOD

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ABSTRACT

The effect of flake size and mixing ratio on the TS, WA, LE and MOR, MOE properties of cement bonded flake boards produced from *Polyalthia longifolia* wood residues were evaluated to examine their propensity on the strength and dimensional movement of the boards. Cement bonded board 6 mm in thickness were produced from Pl, PC and calcium chloride. Boards were made at 3 levels of flake sizes of 18.85 mm, 12 mm and 6.35 mm and wood cement ratios of 1:1, 2:1 and 3:1 were adopted for production. Physical properties test were conducted at 24, 48 and 72 hours intervals. Water absorption, thickness swelling and linear expansion decreased with decrease in flake size and as mixing ratio increased. For the MOR, MOE increased as the FS and MR increased. The highest strength was achieved at the FS of 6.35 mm and MR of 3:1. Flake size and mixing ratio had significant effects on the properties of the boards produced ($P>0.5$). Hence the study affirmed the suitability of spent *P. longifolia* flakes for cement bonded board, which can be used for both interior and exterior applications in building.

KEYWORDS:

Flake size, mixing ratio, physical properties, mechanical properties

INTRODUCTION

Research interests in wood cement bonded boards are on the increase in the developing countries. The interest in wood cement bonded boards can be attributed to the compatibility of wood with cement as well as the simplicity and availability of technology for board production (Owoyemi et al., 2013). With advances in technology and increase in the global population, the demand for wood in the forest product industries has grown over the years. In addition, the application of wood in new areas had also caused a significant pressure on the current standing forest resources. This phenomenon is responsible for the concerted effort made by scientists to find alternative biomass for raw materials for sustainable production and utilization of wood products.

Alternative fibers such as agro fibers will play an important role in the wood fiber supply and demand map of the future (Ibrahim et al., 2005). However, there are little or no information on the use of residue from ornamental trees for other purposes especially particle board production. Particleboard is mainly use in the construction industry, bracing walls and flooring and other structural applications (Erakhrumen et al., 2008). The Wood cement board is a versatile material suitable for interior and exterior use, for core and low-cost housing construction. It can be moulded into any form and shape to meet specific end use and has resistant to fire, water, rot, termites, insects and fungi attack. The production of flake board from *Polyalthia longifolia* using cement as binder may provide an alternative to the use of wood and other agricultural wastes materials. Most *P. longifolia* planted as ornamental trees around houses have grown to large size with the roots causing structural problems on buildings. These trees are harvested and processed into chips and flakes to produce value added materials. One way to explore the economic benefit of wood residues is to incorporate these into cement bonded particle board production, this will however reduce the environmental hazard emanating from wood wastes burning and also contribute to economic growth of the country as well as reduces pressure on trees from forest (Olufemi et al., 2012).

MATERIALS AND METHODS

Materials Procurement and Preparation

Polyalthia longifolia wood flakes were obtained from felled ornamental trees within the campus at the Federal University of Technology, Akure. The flakes were separated into three different flake sizes of (FS1) 18.85 mm, (FS2) 12 mm and (FS3) 6.35 mm and treated with hot water at temperature of 80 °C to remove the extractive capable of inhibiting the setting and curing of the cement, thereafter flakes were air dried in controlled ambient temperature for two weeks to attain moisture content of 12% approximately prior to use. The inorganic binder used (Portland cement) was bought from fresh consignment at a Cement shop and calcium chloride was added as additive.

Mat Formation

The dimension of cement bonded flakeboards (CBFB) produced were 350 x 350 x 8 mm. Portland cement and sawdust were weighed based on the mixing ratio of about 70:30 ratio which was then compounded. The amount of water used was calculated using the formula by Simatupang (1979), which is expressed as:

$$Wt = W\,(0.30 - MC) + 0.60C.$$

Where: Wt = Weight of water (g), W = Wood dry weight (g),
MC = Moisture Content (%) and C = Cement weight (g).

The stock was hand formed in a wooden mould of 350 mm x 350 mm and placed on a metal caul plate that was covered with polythene sheet; plywood plate was used to pre-press the formed mat to reduce the thickness and covered with polythene sheet before the top metal caul plate was placed on it. Three replicates were prepared, thereafter, the boards were removed from the mould, trimmed, cut into specimen sizes and conditioned and subjected to tests in accordance to modified ASTDM 1037 (1995) Standard. Water Absorption (WA), Thickness swelling (TS) and linear Expansion (LE) at 24hr, 48hr and 72 hr were determined manually while 195 x 50 mm specimen size was used for modulus of rupture (MOR) and modulus of elasticity (MOE) test in accordance with ASTM (2005) Standard Method for particle/ board test using specimen size of 195 mm x 50 mm. Physical properties, WA, TS and LE were calculated using equations 1, 2 and 3 while the mechanical properties MOR and MOE were calculated using equations 4 and 5.

$$\mathrm{WA}_{(\mathrm{t})}\ (\%) = \left(\frac{\mathrm{W_t} - \mathrm{W_0}}{\mathrm{W}_o}\right) \times 100 \qquad (1)$$

where: WA (t) is the water absorption at time t, W_0 is the dried weight and W (t) is the weight of specimen at a given immersion time t

$$\mathrm{TS}\ (\%) = \left(\frac{T_w - \mathrm{T_0}}{T_o}\right) \times 100 \qquad (2)$$

where: TS is the thickness swelling, T_w is the thickness of the board after water immersion, T_0 is the thickness of the oven dried board.

$$\mathrm{LE}\ (\%) = \left(\frac{L_w - \mathrm{L_0}}{L_o}\right) \times 100 \qquad (3)$$

where: LE is the linear expansion of the board, L_w is the expansion of the board after water immersion, L_0 is the expansion of the oven dried board.

$$\mathrm{MOE} = \frac{\mathrm{PL^3}}{4\mathrm{ywh^3}} \quad (\mathrm{N/mm^2}) \qquad (4)$$

$$\mathrm{MOR} = \frac{3PL}{2bh^2} \quad (\mathrm{N/mm^2}) \qquad (5)$$

Where: P is the load, L is the length, b is the deflection, w is the width and h is the thickness of the specimen.

Statistical analysis

The experimental design was 3 by 3 factorial in Completely Randomized Design translating to 9 experimental boards each having three replicates. The main factors considered were; flake size (FS1, FS2 and FS3), and mixing ratio (1:1, 2:1, 3:1). Duncan Multiple Range Test was used at 95% probability level to test the significance of treatment means.

RESULTS AND DISCUSSION

Effect of Production Variables on Water Absorption

The mean values for WA (Table 1) ranged from 19.33±1.36% to 34.87± 1.33%, 22.32±1.59 to 40.34± 4.01 and 25.59±5.13 to 42.76± 1.55 for 24 hr, 48 hr and 72 hr respectively. Figure 1 revealed decreased in FS and increase in MS causes decrease in WA. The board produced at FS3 at MR 3:1 was found to be the strongest at 24 hr, 48 hr and 72 hr. The result of analysis of variance (ANOVA) in Table 2 showed that WA is significantly affected by the flake size, mixing ratio, and their interaction. Multiple comparism test Table 3 showed that there was significant difference between FS1and FS2, FS1 and FS3, FS2 and FS3 at 24 and 48 hr while there was no significant difference ($P<0.05$) between FS2 and FS3 at 72 hr. also, there are significant differences in WA for MR between MR1:1 and MR2:1; MR1:1 and MR3:1; MR2:1 and MR3:1 at 24, 48 and 72 hr respectively. The trend of water absorption (WA) in response to water intake at the different flake sizes to mixing ratio is shown in Figure 1. At prolong soaking at 72 hr, (Figure 1) all the boards were found to swell most than that of 24 and 48 hr indicating that the longer the boards stay in water, the more it absorb water and more so weaken the inter-particle bond and create larger void spaces through the wash away of the binder which was observed in the colour changes of the water. These void spaces accommodate more water thereby increasing the weight of the board which is a measure of WA and these observations agree with the findings of (Ajayi, 2006; Oyagade, 1990; Fuwape, 1995; Olufemi et al., 2012) that increase in cement content caused improvement in the physical properties of the board. This result showed a downward trend as the cement/wood ratio increases. The lowest water absorption and thickness swelling was achieved at the highest mixing ratio.

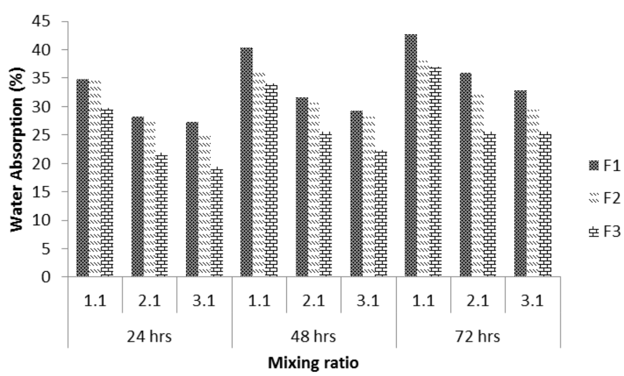

Figure 1 – Effect of Flake size, Duration and Mixing ratio on Water Absorption

Table 1: Mean Values for Water Absorption, Thickness swelling and Linear Expansion of the Cement Bonded Flake Boards.

Flake size	Mixing ratio	WA 24 (%)	WA 48 (%)	WA 72 (%)	TS 24 (%)	TS 48 (%)	TS 72 (%)	L.E 24 (%)	L.E 48 (%)	L.E 72 (%)
FS1	1:1	34.87± 1.33	40.34± 4.01	42.76± 1.55	10.09± 3.58	12.95± 6.68	16.34± 5.61	0.067± 0.08	0.067± 0.08	0.067± 0.08
	1:2	28.18± 1.69	31.51± 0.47	35.92± 0.74	6.06±2.37	8.81± 2.27	12.12± 2.36	0.025± 0.05	0.025± 0.05	0.025± 0.05
	1:3	27.28± 0.58	29.32± 2.32	32.77± 6.01	5.25±2.67	7.54±1.23	9.15±2.06	0.000± 0.00	0.000± 0.00	0.000± 0.00
FS2	1:1	34.56± 5.04	36.49± 1.32	38.01± 0.46	8.77±2.32	12.58± 1.91	15.58± 1.45	0.000± 0.00	0.017± 0.04	0.017± 0.04
	1:2	27.38± 5.13	30.78±2.39	32.01±2.45	6.00±4.12	8.31±1.41	11.49± 2.91	0.033± 0.52	0.033± 0.05	0.033± 0.05
	1:3	25.18± 4.51	28.23±2.00	29.45±7.78	5.20±2.50	6.96±2.15	8.83±3.35	0.016± 0.41	0.017± 0.04	0.017± 0.04
FS3	1:1	29.77± 0.81	34.04±2.12	37.04±4.04	8.19±2.00	10.93± 4.51	13.35± 3.75	0.000± 0.00	0.033± 0.05	0.033± 0.05
	1:2	21.82± 2.42	25.62±1.69	25.63±1.76	5.21±2.93	8.01±3.76	10.73± 4.79	0.067± 0.82	0.083± 0.07	0.083± 0.07
	1:3	19.33± 1.36	22.32±1.59	25.59±5.13	4.96± 2.70	6.62±2.08	8.38±1.43	0.067± 0.10	0.083± 0.07	0.083± 0.09

The values are means from three replicates

Table 2 – Analysis of Variance for the Flake Size and Mixing Ratio on Physical Properties of the Boards

Source	Df	W.A 24 (%)	W.A 48 ((%)	W.A 72 (%)	T.S 24 (%)	T.S 48 (%)	T.S72 (%)	L.E24 (%)	L.E48 (%)	L.E72 (%)
FS	2	71.07*	92.10*	27.87*	3.89*	5.26*	8.12*	1.00*	2.66*	2.66*
MR	2	74.39*	94.66*	31.04*	2.10*	2.93*	4.55*	0.47^{ns}	0.22^{ns}	0.22^{ns}
MR*FS	4	0.78*	1.45*	1.68*	1.02*	1.72*	2.02*	2.19*	1.51*	1.51*
Error	43									
Total	51									

* significant (p 0.05) ns – not significant

Table 3 – Duncan Multiple Range Test of Flake Size an Mixing Ratio for Physical Properties

Flake Size	WA 24	WA 48	WA72	T.S 24	T.S 48	T.S 72	L.E24	L.E 48	L.E72
1	34.56^{a}	36.16^{a}	37.844^{a}	6.20^{a}	8.36^{a}	10.19^{b}	0.02^{a}	0.04^{a}	0.04^{a}
2	27.39^{b}	29.17^{b}	29.71^{b}	7.84^{a}	10.61^{a}	13.45^{a}	0.44^{a}	0.05^{a}	0.05^{a}
3	25.18^{c}	26.71^{c}	29.57^{b}	5.77^{a}	8.38^{a}	11.45^{ab}	0.03^{a}	0.03^{a}	0.03^{a}
Mixing Ratio									
1:1	30.35^{b}	31.88^{b}	32.42^{b}	6.40^{ab}	9.28^{ab}	11.52^{b}	0.31^{a}	0..31^{a}	0.31^{a}
2:1	23.64^{c}	25.36^{c}	28.00^{c}	8.11^{a}	10.73^{a}	13.93^{a}	0.17^{a}	0.02^{a}	0.02^{a}
3:1	33.46^{a}	35.05^{a}	37.01^{a}	7.20^{b}	7.20^{b}	9.42^{b}	0.44^{a}	0.67^{a}	0.07^{a}

Alphabets with the same letter along the column shows that there is no significant difference

Effect of Production Variables on the Thickness Swelling on Properties of the Cement Bonded Flake Boards

TS mean values presented in Table 1ranged from 4.96 ± 2.70 to 10.09 ± 3.58; 22.32 ± 1.59 to 40.34 ± 4.01 and 25.59 ± 5.13 to 42.76 ± 1.55 for 24 hr, 48 hr and 72 hr respectively. Figure 2 revealed decreased in FS and increased in MS causes decrease in TS. The board produced at FS3 at MR 3:1 was found to be the strongest at 24 hr, 48 hr and 72 hr. The trend of thickness swelling response of board to water intake at the different flake sizes and mixing ratio is shown in Figure 2. The result of analysis of variance (ANOVA) in Table 2 shows that Thickness Swelling is significantly ($P>0.05$) affected by flake size, mixing ratio, and their interaction. DMRT (Table 3) revealed that there was no significant difference ($P<0.05$) on board production between FS1 and FS2, except for the soaking at 72 hr which showed a significant difference between FS2 and FS3 ($P>0.05$). The result also showed that mixing ratio has significant difference on board and it ranked the board produced at MR3:1 as the best and MR 1:1 as the weakest. The result also showed that there is significant difference between mixing ratio MR 2:1 to mixing ratio MR 3:1. There was decrease in Thickness swelling as the mixing ratio increase and flake size decrease which could be due to less irregular void spaces in the board and the wood particles from lower wood-cement ratio are not encapsulated by cement which resulted in higher thickness swelling. This also conforms with the findings of (Olufemi et al., 2012). While reduction in thickness swelling arises because of sufficient encapsulation of the wood particles at high cement-wood ratios and the minimal swelling of the small particles. This is in consonant with Ajayi (2008) that the lower the thickness swelling means more cement coating on the fibres may have restrained the boards from swelling. (Moslemi et al., 1986; Ajayi et al, 2008; Meneeis et al., 2001; Sadiku, 2012; Karade et al., 2003).

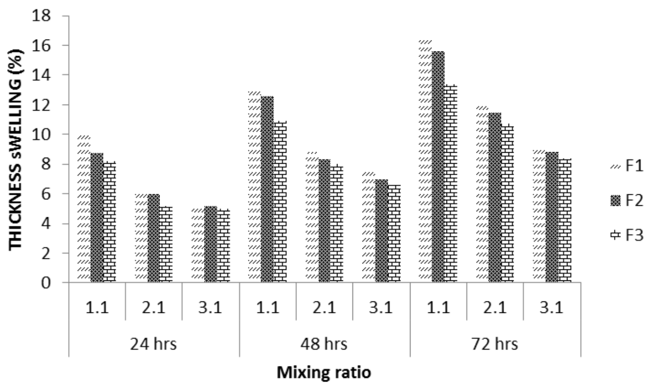

Figure 2 – Effect of Flake size and Mixing ratio on Thickness Swelling

Effect of Production Variables on the Linear Expansion of the Cement Bonded Flake Boards Produced

Table 1 showed the mean values of the LE of the boards ranged from 0.000±0.00 to 0.067±0.08 for 24 hr, 48 hr and 72 hr respectively. Figure 3 revealed decreased in FS and increased in MS causes decrease in LE. Linear expansion was not affected by the flake size of the board. This trend was the same for Linear Expansion at 24, 48 and 72 hr. The result of analysis of variance (ANOVA) in Table 2 shows that LE is not significantly affected by the flake sizes but significantly ($P<0.05$) affected by mixing ratio, and their interaction. DMRT (Table 3) showed that there was no significant difference on board between FS 1 to FS 3. The result also showed that mixing ratio had no significant difference ($P<0.05$) on the board (Table 3). Wood is an anisotropic material. It shrinks most in the tangential direction, about half as much across the rings (radially), and only slightly along the grain (longitudinally). Longitudinal shrinkage of wood (shrinkage parallel to the grain) is generally quite small. This study showed that the expansion was small and this could be due to high resistance of board to movement in a linear direction (Ajayi et al., 2008; Karade et al., 2003).

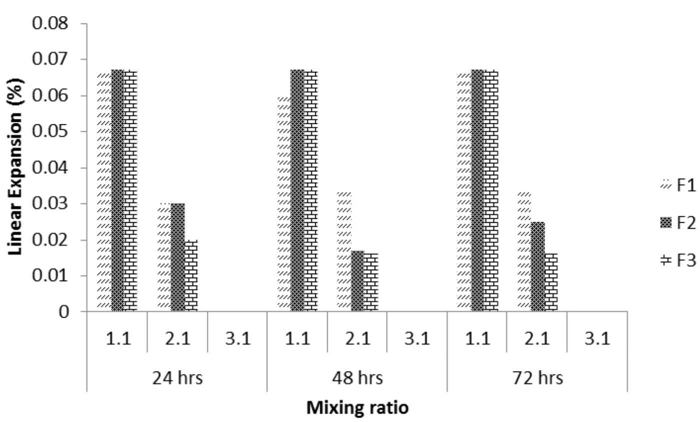

Figure 3 – Effect of Flake size and Mixing ratio on Linear Expansion

Effect of Production Variables on Strength properties

The mean values of MOR and MOE of cement bonded board produced are presented in Table 4 ranged from 0.195 $\pm$ 0.380 to 2.667$\pm$0.44 N/mm^2 and 900.84$\pm$9.67 to 1950.37$\pm$16.30 for FS1 to FS3. Board produced from FS3 had highest strength property, while the lowest board in strength was produced at FS1 with MR of 1:1. The response of the boards to rupture showed that increase in the mixing ratio of cement to flakes showed increase in the modulus of rupture (Figure 4). FS2 had the highest modulus of rupture at the highest MR of 3:1 The results of Analysis of Variance Table 5 showed that the strength properties (MOR and MOE) of the board is significantly affected by mixing ratio, flake size and the interaction between flake size and mixing ratio at 5% probability level. The DMRT analysis Table 6 revealed significant different in boards between FS 1 and FS2, FS2 and FS3 but there was no significant difference between FS 1 and FS 3. This could implied that there is absence of void space in the board gives random distribution of the particles and this gave a well compact mat structure which enhanced the strength of the board (Oyagade, 1990; Ajayi, 2004; Frybort et al., 2008).

Table 4: Results of Mean Values for Modulus of Rupture and Modulus of Elasticity

FLAKE SIZE	MIXING RATIO	MOR (N/mm^2)	MOE (N/mm^2)
FS 1	1:1	0.195$\pm$0.19	900.84$\pm$9.67
	2:1	1.498$\pm$0.38	959.43$\pm$11.10
	3:1	1.662$\pm$0.42	1007.65$\pm$23.32
FS 2	1:1	1.118$\pm$0.283	1100.21$\pm$10.13
	2:1	1.390$\pm$0.456	1325.93$\pm$21.47
	3:1	1.640$\pm$0.267	1395.16$\pm$16.10
FS 3	1:1	1.638$\pm$0.35	1427.52$\pm$22.75
	2:1	1.868$\pm$0.95	1676.12$\pm$54.39
	3:1	2.667$\pm$0.44	1950.37$\pm$16.30

The values are means from three replicates

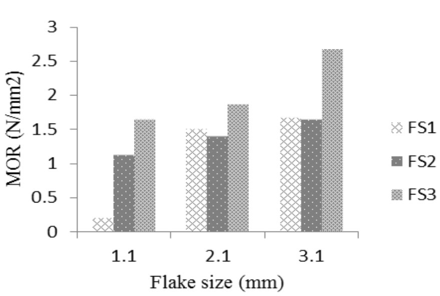

Figure 4 – Effect of Flake Size and Mixing ratio on Modulus of Rupture

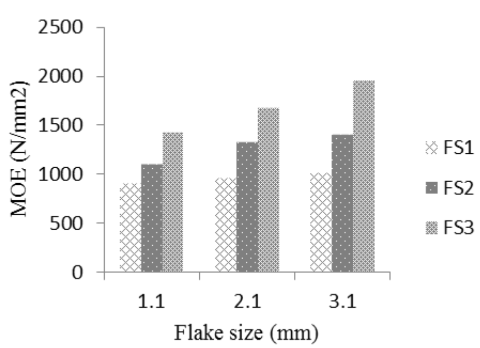

Figure 5 – Effect of Flake Size and Mixing on Modulus of Elasticity

Table 5 – Duncan Multiple Range Test of Flake Size and Mixing Ratio for Mechanical Properties

Flake Size	MOE	MOR	Mixing Ratio	MOE	MOR
FS1	955.97^{b}	1.23^{b}	1:1	1142.86^{b}	1.18^{b}
FS2	1273.77^{ab}	1.61^{ab}	2:1	1320.49^{a}	1.35^{b}
FS3	1684.67^{a}	1.72^{a}	3:1	1451.06^{b}	2.03^{a}

Alphabets with the same letter shows that there is no significant difference
Alphabets with different letter shows that there is significant difference

Table 6 – Analysis of Variance for the Flake Size and Mixing Ratio on Mechanical Properties of the Boards

Source	**Df**	**MOR**	**MOE**
FS	2	29.62*	18.04*
MR	2	6.78*	7.69*
MR*FS	4	5.40*	8.47*
Error	43		
Total	51		

* significant (p 0.05) ns – not significant

CONCLUSION

This study affirmed the suitability of using ornamental tree like *P. longifolia* to produce board. Cement bonded boards can serve as an alternative material to timber from forest trees as this could cause reduction in exploitation pressure on forest biodiversity. The board produced from *P. longifolia* had excellent physical and mechanical properties. Increase in materials and decrease in the size of particles produced a dimensional stable board as well as high bending strength but board produced at the highest FS 3 (6.35 mm) produced board of highest bending and tensile strength. The results of the study showed that increase in cement content lowers the physical properties of the boards. It was observed that the medium size flake exhibited the best effects in strength. From the quality point of view, FS2 ranked best followed by FS3 and FS1 respectively. These results indicated that increase in mixing ratio of cement to flakes resulted in the dimensional stability of the board.

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