IIBCC
International Inorganic-Bonded Fiber Composites Conference

STRENGTH PROPERTIES OF OIL PALM FIBRE CEMENT BONDED COMPOSITE

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ABSTRACT

Cement-bonded composites were produced from oil palm fibre (OPF). The manufactured experimental boards were based on different levels of production variables; vis-à-vis board thickness, fibre pre-treatment and mixing ratio translating to 12 treatment combinations with nominal board density of 400kg/$m^3$and chemical additive concentration of 3.5% of cement weight. Thereafter boards were cut into test specimens with which water absorption (WA), thickness swelling (TS), modulus of elasticity (MOE) and modulus of rupture (MOR) were evaluated to determine the effects of the production variables on the properties of the cement-bonded composites. The study reveals that TS and WA increased with increase in the fibre content. Whereas both MOE and MOR reducedas the fibre-cement ratio is increased. The study further revealed that to achieve better dimensional movement and improved strength properties cement content of the mix should be increased.

KEYWORDS:

cement-bonded composite; Oil palm Fibre; Dimensional stability; Strength properties; pre-treatment

INTRODUCTION

The high demand for wood and wood products as well as high percentage of waste generated during the conversion process of log to timber at sawmills are some of the factors responsible for depletion of timber resources (Ajayi 2001). The large quantity of the waste generated during the conversion process of log to timber have been utilized over the years for the production of wood fibre composites; resin fibre board, particle board, flake board, strand board, wood-cement composites and wood plastic composites. Recently there have been a lot of ongoing researches on fibre plastic composite which involve the use of agricultural residue as alternative source of raw material for the production of fibre plastic composites.

Agricultural residues are the parts of the plant that remain in the field after a crop is harvested. Examples of such residues are yam stem, groundnut shell, rice husk, maize cob, maize stalk, coffee waste, bagasse, wheat straw etc. after harvesting; these agricultural residues are usually burned and ploughed in to the ground as compost. These agricultural residues contain cellulosic fibre which has outstanding potential of being used as a fibre source in the production of non-wood fibre composites

METHODOLOGY

The pressed fruit fibre dried in the open under sunlight for 2 weeks, materials such as residual palm kernel shell and other impurities was removed. The residual oil in the PFF was extracted by washing with soapand hot water at 100^0C for one hour until oil is removed, thereafter the fibres was hammer milled into fine particles improve mat formation. The fibre and the cement quantities was measured based on the mixing ratio by weight. The quantity of additives ($Cacl_2$)also was measure at 3% of the weight of cement. The quantity of water was determined by the relationship developed by Simatupang (1979) and was also adopted by Moslemi and Pfister (1987) and Sudin et al. (1995). The additive was dissolved in the appropriate quantity of water

Quantity of water = 0.35C + (0.30 - M)W

Where

C = cement weight (g), M = moisture content of the fibre, W = weight of the fibre.

A wooden mold of dimension 350 by 350 was used to form the mat. The mold is placed on a playwood caul plate and covered with a polythene sheet, the mixtures (cement, water, fibre and additive) were then formed into a mat in the box. The formed mat was also covered with polythene sheet, then another plywood sheet was placed on the mat.

The mat was cold pressed at a pressure of 1.23 Nmm^{-2} for 24 hours.

After 24 hours, the board formed was demolded and stacked at room temperature. The boards were trimmed to avoid edge effects and cut to test specimens for water absorption (WA), thickness swelling (TS), dry Moduli of rupture and elasticity (MOR and MOE) in accordance with ASTM D 1037-96a (1998).

The production variables in the experiment include:

i. Nominal board density at 400kg/m ^{3}
ii. Mixing ratio of fibre to cement at 1:3 and 1.5:3 based on oven dry weight and volume of the board.
iii. Pre-treatment: hot water, soap+hot water
iv. Board thickness: 10mm, 15mm and 20mm
v. Additive concentration at level of 3% of cement weight in each board.
vi. Pressing pressure: 1.23N/mm^2
vii. Board size: 350mm by 350mm by 10mm, 15mm and 20mm (thickness)

The experimental design was 2x2x3 factor factorial experiment in complete randomized design, the combination of which gave 12 treatments.

RESULT AND DISCUSSION

PHYSICAL PROPERTIES OF CEMENT BONDED FIBRE BOARD

THICKNESS SWELLING AND WATER ABSORPTION

The result of the physical proper of cement-bonded board produced after 24hours soaking shows that the values of thickness swelling (TS) ranged from 2.46%-12.76%, 2.22%-8.58% for hot water treated fibre and soap+hot water treated fibre respectively. TS increases with increase in the amount of fibre in the mixture, hence a poor resistance to moisture intake. This suggests that an increase in the cement ratio will result in better dimensional stability. Also, TS of boards produced from fibres that were pretreated with hot water only is higher than those pretreated with soap and hot water (Fig 1 and 2). This follows the report of Eusebio *et al.* (2000b) who worked with soaked and unsoaked wood particles found out that untreated, in this case unsoaked, particles exhibit higher values of TS. And concluded that pre-treatment of the wood has an effect on TS. Moslemi and Pfister (1987) reported that a higher cement content of board lowers TS, the embedding of wood inside CBCs restricts expansion. Also Eusebio *et al.* (2000b) confirmed that increasing cement coating on the particles may have a positive effect on TS.

Water absorption (WA) of boards producedranged from 7.96% to 25.78%, 9.92% to 23.06% for hot water and hot water+soap pre-treatment respectively. As expected resistance to moisture intake was less in when the fibre content of the board was increased. This is corroborated by Savastano*et al*., (2000) who reported that when particle content is increased, water absorption increases, whereas density decreases. Water absorption increases in the boards produced from hot water treated fibre when compared with that of hot water+soap pre-treatment.

Hot water pre-treated fibre is believed to still have some residual oil which inhibits proper binding of cement with the fibre, hence there is opportunity for moisture to infiltrate the fibre. However, hot water+soap pre-treatment ensured that the residual oil was removed and hence ensuring proper cement-fibre consolidation, the pre-treatment removed the residual oil, to create more active (sorption) sites and at the same time, it aids hydration of cement and effective bonding between the two materials.

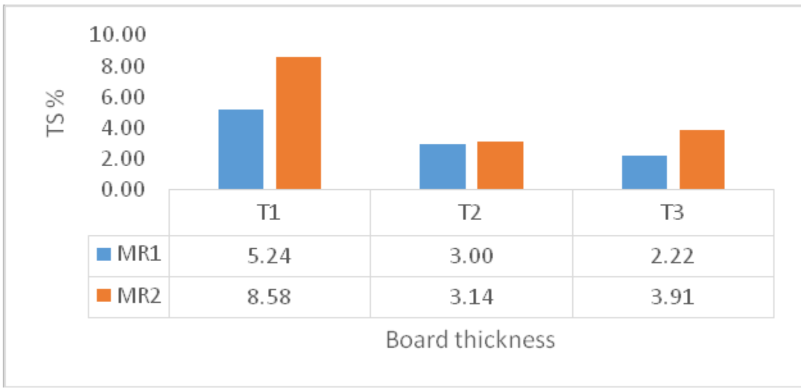

Figure 1: TS of soap+hot treated cement bonded composite

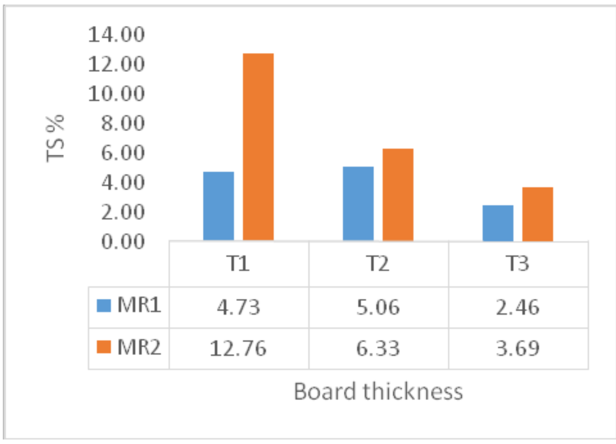

Figure 2: TS of hot water treated cement bonded composite

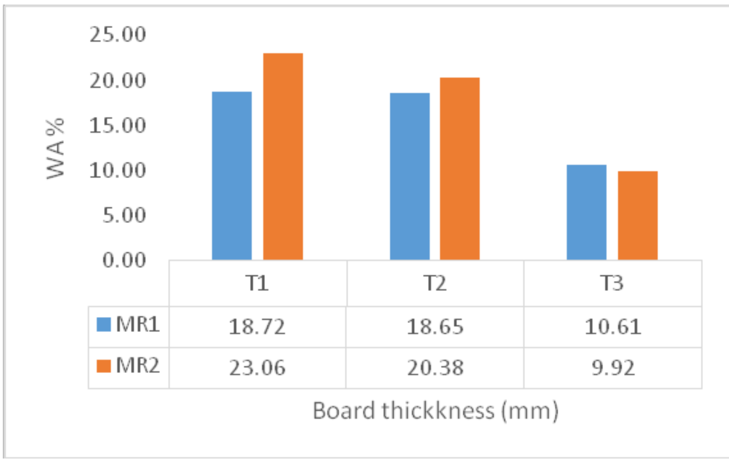

Figure 3: WA of hot water treated cement bonded composite

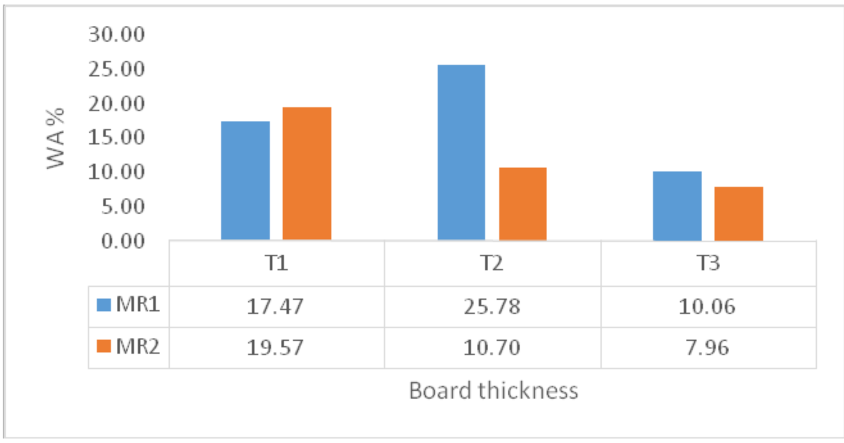

Figure 4: WA of soap+hot water treated cement bonded composite

Table 1: Analysis of variance for TS and WA of cement-bonded board

		Thickness Swelling			Water Absorption		
SV	df	MS	F	sig	MS	F	sig
A	1	0.286	3.234	ns	3.642	7.036	*
B	2	0.109	1.232	ns	4.609	8.904	*
C	1	0.172	1.946	ns	0.279	0.539	ns
AB	2	0.023	0.255	ns	0.191	0.369	ns
AC	1	0.825	9.323	*	1.626	3.141	ns
BC	2	0.192	2.165	ns	0.569	1.099	ns
ABC	2	0.299	3.379	*	0.402	0.776	ns

* = Significant ($p < 0.05$), ns = Not Significant ($p \geq 0.05$)

A= Pre-treatment, B=Thickness, C=Mixing ratio, AB=Interaction of pre-treatment and thickness, AC=Interaction of pre-treatment and mixing ratio, BC=Interaction of thickness and mixing ratio, ABC=interaction of pre-treatment, thickness and mixing ratio.

Table 1 shows the result of Analysis of variance of thickness swelling and water absorption, it is seen that the effect of pre-treatment , thickness and mixing ratio for TS were not significant, the interaction between thickness and mixing ratio was also not significant. However, interaction between pre-treatment and mixing ratio, pre-treatment , mixing ratio and thickness were significantly different. While for water absorption, the pre-treatment , board thickness had significant effects on the physical properties of the boards while the effect of the mixing ratio was not significant. Also the interactions of the factors were not significant.

MECHANICAL PROPERTIES OF CEMENT-BONDED FIBRE BOARD

Modulus of Elasticity (MOE) and Modulus of Rupture (MOR)

The results of Modulus of elasticity of hot water pretreated fibres ranged from 634Nmm^2 to 1210Nmm^2, and soap and hot water treatment ranged from 705Nmm^2 to 2706Nmm^2. While the Modulus of Rupture for hot water pretreated fibre and soap and hot water treated fibre ranged from 0.71Nmm^2 to 2.72Nmm^2, and 1.23Nmm^2 to 5.67Nmm^2 respectively.

The result show that as the fibre proportion in the matrix increases, the Modulus of Elasticity reduces. This trend is observed through the three thickness classes. This indicated that the amount of cement in the matrix provides the stiffness for the matrix, hence any attempt to reduce the cement-fibre ratio results in reduced tensile modulus. Stiffness characteristics depend on cement-wood ratio. This relationship is based on the fact that cement is inherently a more rigid material than wood. Therefore greater cement-wood ratios result in higher MOE values (Moslemi and Pfister 1987), as MOE is dependent on the total amount of the stiff and incompressible cement matrix (Pablo *et al*., 1994).

An inverse relationship was observed in the MOR of the cement-bonded boards produced. MOR increases with increase in fibre-cement ratio. Although elasticity decreases as the fibre aggregate content rises, the zone of plasticity increases. Therefore, material with a high fibre aggregate content is weaker but less brittle, which means its capacity in terms of deformation increases. The increase in deformability with rising fibre content can be explained by the findings of Rim *et al*.,(1999) who stated that the fibrous nature of wood allows it to accommodate deformations and provide good adherence to the matrix.

The effect of board thickness on the mechanical properties was determined. It was observed that the modulus of elasticity of boards reduces with increase in the board thickness. Figure 5 and 7 shows that MOE of boards in the 10mm thickness has the highest values both for hot water and hot water and soap treated fibre. Increase in the thickness results in decreasing MOE. The modulus of rupture had slight changes in values as the board thickness increases.

Also the effect of fibre pre-treatment on board properties was investigated. Results shows that boards produced from hot water+soap has higher mean values both for MOE and MOR. This could be due to the fact that more of the inhibiting factors such as the residual oil have been removed to allow for fibre to fibre bonding and also compatibility between cement and fibre.

Table 2 shows the Analysis of variance for modulus of elasticity, the result shows that the effect of fibre pre-treatment has no significant effect on the modulus of elasticity ($p<0.05$). Board thickness has significant effect on the modulus of elasticity of the boards produced. This is evident in the values of MOE that decreases with increase in the board thickness. However, the higher MOE values were obtained in the 10mm thickness. The mixing ratio, interaction between pre-treatment and board thickness, mixing ratio and pre-treatment , board thickness and mixing ratio and the interaction between pre-treatment , mixing ratio and board thickness all does not have significant effect on the modulus of elasticity of boards at 0.05 probability level.

Table 2 shows the result of analysis of variance of MOR of cement-bonded boards produced. Result shows that Fibre pre-treatment , board thickness, mixing ratio and interaction between mixing ratio, board thickness and fibre pre-treatment was found to have significant effect on the MOR.

Table 2: ANOVA for MOE and MOR of cement-bonded composite

		MOE			MOR		
SV	df	MS	f	Sig.	MS	f	Sig.
A	1	883502.869	3.316	ns	17.008	19.452	.*
B	2	11677600.4	43.822	*	1.914	2.189	ns
C	1	2574896.27	9.663	*	9.682	11.074	.*
AB	2	1413354.25	5.304	*	3.46	3.957	ns
AC	1	1421845.58	5.336	*	4.447	5.086	*
BC	2	4883169.29	18.325	*	1.895	2.168	ns
ABC	2	2264455.13	8.498	*	5.837	6.675	*

* = Significant ($p < 0.05$), ns = Not Significant ($p \geq 0.05$)

A= Pre-treatment , B=Thickness, C=Mixing ratio, AB=Interaction of pre-treatment and thickness, AC=Interaction of pre-treatment and mixing ratio, BC=Interaction of thickness and mixing ratio, ABC=interaction of pre-treatment , thickness and mixing ratio

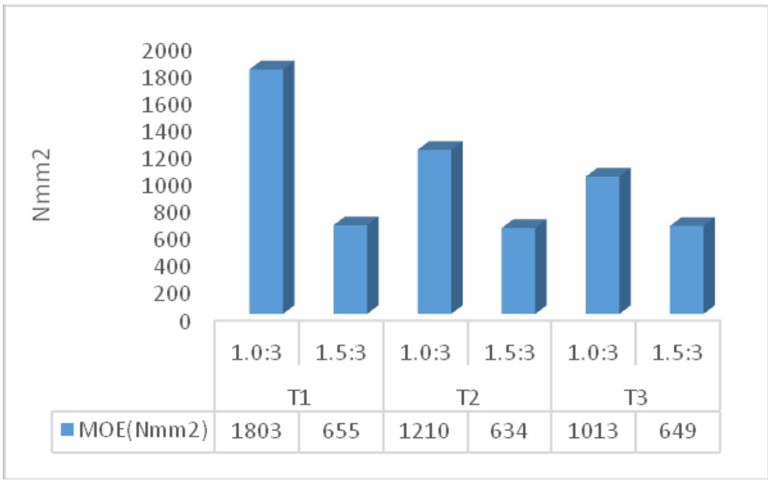

Figure 5: MOR of hot water pretreated cement-bonded composite

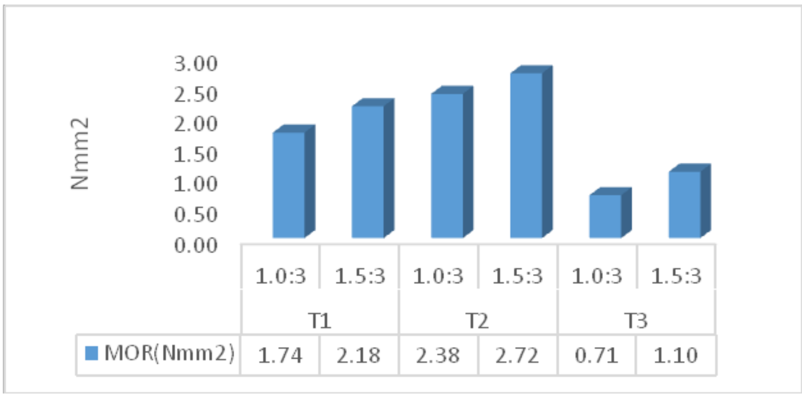

Figure 6: MOE of hot water pretreated cement-bonded composite

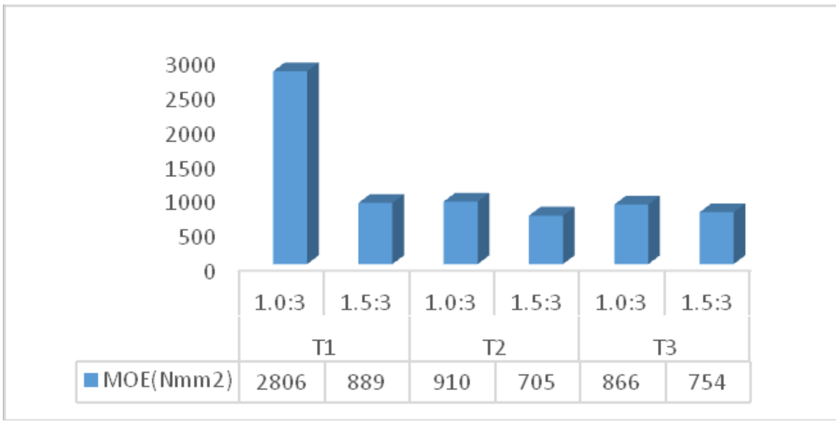

Figure 7: MOE of hot water+soap pretreated cement-bonded composite

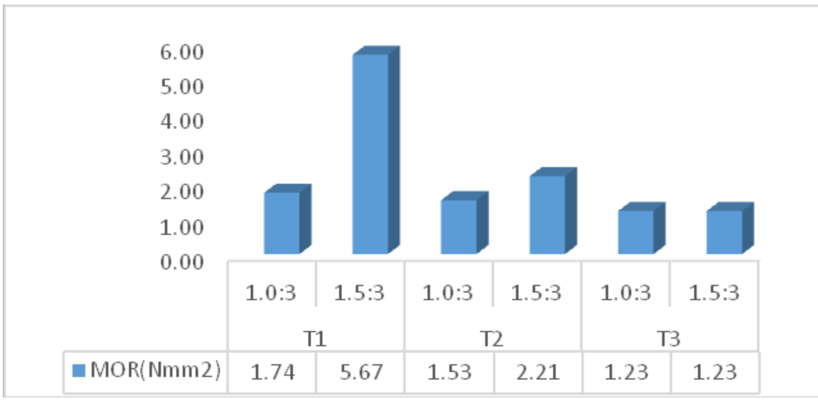

Figure 8: MOR of hot water+soap pretreated cement-bonded composite

CONCLUSION

The strength properties of cement and fibre-plastic composites have been evaluated and the effects of production variables on board properties was determined. Strength properties was found to be improved when a higher proportion of fibre is utilized in the boards both for cement and plastic board.

Increasing the amount of fibre in the composites produced resulted in higher value of water absorption and a higher percentage in thickness swelling (Fig 1, 2, 3 and 4). Since the fibre content is increased the consolidating ability of the cement and is reduced because the available cement spread round the fibre which might be inadequate to provide a strong interfacial boning thereby resulting to an increase instance of dimensional instability. Also, it has been established that hot water+soap for fibre pre-treatment produced boards with higher dimensional stability and higher mean values both for MOE and MOR

The study also show that higher cement-fibre proportion could help to attain higher mechanical properties in terms of MOE while higher values of MOR is achievable with higher fibre-cement proportion.

The study also reveal that Increase in the board thickness has direct relationship with MOE while the modulus of rupture had slight changes in values as the board thickness increases. Further studies on the effect of board thickness on mechanical properties of cement-bonded composite is recommended.

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