INFLUENCE OF FLAKE THICKNESS ON FLEXURAL AND MOISTURE PROPERTIES OF WOOD CEMENT PANELS FABRICATED FROM MIXED FURNISH OF EIGHT HARDWOOD SPECIES

***Badejo, S. O. and ** Omole, A. O.**
**Timber Engineering Section,*
Forestry Research Institute of Nigeria, Ibadan

***Department of Forest Resources Management,*
University of Ibadan

ABSTRACT

The study was undertaken to investigate the influences of flake thickness on physical and mechanical properties of wood cement panel produce from mixed hardwoods species. The properties investigated are modulus of rupture (MOR), modulus of elasticity (MOE), water absorption (WA), thickness swelling (TS) and linear expansion (LE) of the experimental cement-bonded particleboards. Both the moduli MOR and MOE of specimens were calculated as specified in the ASTM Standard No D-1037 of 1978. MOR and MOE ranged from 6.04N/mm² to 11.96 N/mm² and 3110N/mm² to 5060 N/mm², respectively. Flake thickness had a significant effect on MOR and MOE at the 5% and 1% level of significance, respectively. Both cement/wood ratio and board density had a significant effect on MOR at the 1% level. Flake thickness was negatively and linearly correlated with MOR and MOE. On the other hand, cement/wood mixing ratio and board density were positively and linearly correlated with MOR and MOE.
WA and TS tests for the study ranged from 34.60 to 44.04% and 0.57 to 1.61%, respectively. Analyses show that flake thickness, cement/wood mixing ratio, and board density had significant effects on WA and TS at the 1% level of significance. Results showed that WA and TS of the experimental panels increased as the thickness size of the particles increased from 0.250 to 0500mm. Two-way or three-way significant interactions were not found to be significant between and among the three production variables applied in the experiment.
The thinner the flakes used in board production, the stronger, stiffer and more dimensionally stable the cement-bonded particleboards.

Key words: Flake thickness, flexural properties, cement-bonded particle boards, mixed hardwoods dimensional stability.

INTRODUCTION

Particle geometry is an essential production variable for cement-bonded particleboard manufacturing. Particle geometry as related to length and thickness dimensions is important in the particle production used for particleboard. The effect of 0.2mm, 0.4mm and 0.5mm thick flakes on properties of cement-bonded particleboards from Larch (*Larix occidentalis*) wood Samples were investigated by Yamagishi *et al.* (1981). Results showed that boards made with 0.4mm thick flakes were superior in static bending to those made with 0.2mm and 0.5mm flake thickness. However, use of increasing flake thickness was associated with decreasing values of water absorption and thickness swell, an indication of more dimensional stability. Lida *et al.* (1983) studied the effect of chip lengths of 20mm, 40mm, and 60mm on cement-bonded particleboard manufactured from Larch. Panels made from longer flakes produced higher Modulus Of Rupture (MOR) and Modulus Of Elasticity (MOE) values when tested in static bending.

Badejo (1988) studied the effect of flake geometry on properties of cement-bonded particleboards made from mixed particles of three Nigerian hardwoods for, flakes at lengths of 12.5mm, 25.0mm and 37.5mm, and thicknesses of 0.25mm and 0.50mm. Badejo's (1988) results revealed that longer and thinner flakes resulted in stronger, stiffer and more dimensionally stable cement-bonded particleboards panels. This may be due to the slenderness ratio. At constant flake length, slenderness ratio is expressed as the ratio of length of the flake to its thickness size which increases with thinner flakes. Board properties were reported to improve with an increase in slenderness ratio (Moslemi 1974, Maloney 1977).

One of the most practicable ways to improve most of the mechanical board properties of particleboard is usually through an increase in the board specific gravity. Hse (1975), Rice and Carey (1978), and Namioka *et al.* (1972) reported on the influence of board density within the range of 0.7 to 1.2 gm/cm^3 on properties of cement-bonded particleboard panels made from mixed particles of two temperate wood species. Both MOR and MOE in static bending increased as board density increased. Kavvouras (1987) investigated the effect of board density at levels of 1400, 1600 and 1700 kg/m^3 on properties of cement-bonded particleboards made from Oak (*Quercus conferta*) flakes. MOR improved with increased panel density. However, panels made at increasing density showed a greater increase in water absorption and thickness swelling. It is likely this is due to the "spring-back" effect during demoulding which follows completion of the pressing cycle. Boards made at increased board density level contain more raw material input (essentially cement and wood particles) than those made at lower density levels. Since the pressing pressure is fixed regardless of the density of board, the compaction effect on the panels had reduced considerably thereby creating increased porosity within the boards which consequently allowed for increased moisture uptake when such panels were soaked. Badejo (1988) investigated the effect of board density at levels of 1050, 1125 and 1200 kg/m^3 on properties of cement-bonded particleboards made from mixed particles of three Nigerian hardwood species.(*Terminalia superba, Triplochiton scleroxylon and Terminalia superba*). From his work, board fabrication at increasing density levels resulted in stronger, stiffer and more dimensionally stable cement-bonded particleboard panels. Fuwape and Oyagade (1993) reported on the influence of nominal board densities within the range of 800 to 1400 kg/m^3 on bending strength and dimensional stability of cement-bonded particleboards made from *Terminalia superba* species. Both the static bending strength and stiffness increased linearly with an increase in board density. At a constant level of cement/wood mixing ratio, water absorption, and thickness swell values of the boards decreased with an increase in board density. This study is therefore carried out to assess the influence of different flake thicknesses fabricated from mixed wood species of tropical timber, on the physical and mechanical properties of the boards so produced.

MATERIALS AND METHODS

Wood raw materials composition:

The eight hardwood species used for the study are: *Triplochiton scleroxylon K. Schum* (Obeche), *Terminalia ivorensis A. Chev.* (Idigbo), *Terminalia superba Eng. & Diets* (Afara), *Brachystegia nigerica Hoyle & A.P.D. Jones* (Okwen), *Khaya ivorensis A. Chev.* (Lagos Mahogany), *Nesogordonia papaverifera A. Chev.* (Danta - Oro), *Tectona grandis Linn. F.* (Teak) and *Gmelina arborea Roxb.* (Gmelina)

Coarse sawdust and slab wastes of the above species were collected from sawmills which operate around Ibadan in Oyo State. Both the coarse sawdust (generated from the ripping processes of the circular saws) and slab wastes of each of the desired species were collected and thereafter transported for further processing in the laboratory.

Laboratory processing of the sawdust and Flakes preparation

The pile from each species was sieved through 6mm mesh but retained on a 2mm mesh to remove fine materials that are not suitable for board production. Those less than 2mm were rejected as fines and were not used for board formation. The sizes of some of the accepted particles were measured using a 0-25mm micrometer screw gauge. They ranged between 5-10 mm in length, 1 - 3mm in width and 0.2 - 0.6 mm in thickness for the eight hardwood species. No further hammer milling of the particles was done prior to use.

The coarse sawdust particles were air seasoned for four weeks in order to allow for gradual degradation of starches and sugars present in them that could impede setting of the cement binder. After seasoning, 25 kg by weight from the sawdust pile of each of the eight hardwood species was weighed out.

The flake particles used for the central core layers of the particleboards were prepared from the slab wastes and processed under green condition. Based on previous investigation on cement-bonded particleboard from Nigerian hardwood species (Badejo 1988) a flake length of 37.5mm was selected as a standard for this study. Three flake thicknesses of 0.250mm, 0.375 mm and 0.500mm were produced for board formation. Flakes of similar thickness prepared from the different species were equally mixed together in equal weight proportion and pretreated with hot water at a temperature level of 80°C. The pretreated particles were later air seasoned for two weeks to a moisture content of about 12%, bagged and stored for board production.

Experimental designs and procedures:

The experimental boards were made using three flake thicknesses of 0.250 mm, 0.375 mm and 0.500 mm, two board density levels of 1100 and 1200 kg/m^3 and two cement/wood mixing ratio levels of 2.25: 1.0 and 2.75: 1.0. A combination of these three reduction variables resulted in a 3 x 2 x 2 factorial experiment which manifested in 12 treatment combinations. The model for this type of experimental arrangement according to Hicks (1973) is given as:

$$Y_{ijk} - M + R_i + A_j + RA_{ij} + B_k + RB_{ik} + AB_{jk} + RAB_{ijk} \quad (1)$$

Where:

Yijk = Individual observation.
M = General mean
Hi = Effect of replicates
RAij = Whole plot error
RABijk = Split-plot error
Aj = Effect of factor A.
Bk = Effect of factor B.

Variable terms Ri + Aj + Raij represent the whole plot while variable terms Bk + RBik + ABjk + RABijk represent the split plot

Four replicate panels were made for each treatment combination and all of the fabricated panels were 6 mm thick with each panel having the standard specifications:

(i) Flake length: 3.75 mm.
(ii) Board density: 1200 kg/m^3
(iii) Percent chemical additive content: 3% based on weight of dry cement in board.
(iv) Pressing pressure: 2.23 N/mm^2.

Following trimming four test specimens were obtained from each panel for the static bending tests in accordance with ASTM Standard No D-1037 of 1978. The MOR and MOE values for each replicate panel were taken as the mean for the four test specimens.

The moisture response properties assessment made from the test specimens are Water Absorption (WA), Thickness Swell (TS) and Linear Expansion (LE). These properties were however assessed following prolonged soak in cold water for 144 hours because of the tropical moist weather condition even above the 24 hours soak cycle specified in ASTM Standard. The percent water absorption, thickness swelling and linear expansion of the replicate panels were the mean values which were obtained from the four test specimens.

RESULTS AND DISCUSSIONS

Flexural Properties (MOR and MOE): The compiled averages of the MOR and MOE for the 12 treatment combinations used in the study are listed in Table 1. As shown from Table 1, MOR and MOE ranged from 6.04 to 11.96 N/mm^2 and 3110 to 5060 N/mm^2 respectively. The mean MOR and MOE range values obtained from this experiment are in agreement with other studies (Prestemon 1976, Dinwoodie 1978, Badejo 1988 and 1989, Oyagade 1990, Fuwape and Oyagade 1993, Fuwape 1995).

Factorial analysis of variance results presented in Table 2 showed that flake thickness had significant effect on MOR and MOE at 5% and 1% level of probability respectively. Both cement/wood ratio and board density, which were the other two production variables used along with it, had significant effect on MOR at 1% level. As for MOE however, the mixing ratio, influenced it at 1% while board density had significant effect on it at 5% level of probability. At each of the board density levels of 1100 and 1200 kg/m3, strength (MOR) and stiffness (MOE) of the test panels decreased as flake thickness size was increased from 0.250mm to 0.500mm. Stronger and stiffer panels in static bending were produced as the cement/wood mixing ratio was increased from 2.25:1 to 2.75:1.0; and also as the board density was raised from 1100 to 1200 kg/m^3. The strongest and stiffest cement-bonded particleboards from mixed particles of the eight hardwood species were those fabricated with 0.250mm thick flakes; and which contained the highest cement binder content as indicated by the cement/wood mixing ratio level of 2.75: 1.0; and similarly pressed to board density level of 1200 kg/m^3.

Table 1: Average values of MOR, MOE, WA, and TS of cement-bonded particleboards produced at different flake thickness levels.

Treatment combinations			MOR of (N/mm^2)	MOE (N/mm^2)	WA (%)	TS (%)
Cement/wood Mixing ratio	Board density (kg/m^3)	Flake Thickness (mm)				
2.25:1.0	1100	0.250	6.04	3110	37.	1.08
2.25:1.0	1200	0.250	6.64	3440	36.42	0.67
2.25:1.0	1100	0.375	5.68	2860	40.38	1.35
2.25:1.0	1200	0.375	6.25	3140	38.16	0.96
125:1.0	1100	0.500	5.14	2530	44.04	1.61
125:1.0	1200	0.500	5.94	2810	40.79	1.16
2.25:10	1100	0.250	10.88	4570	35.49	0.92
1.75:1.0	1200	0.250	11.96	5060	34.60	0.57
1.75:1.0	1100	0.375	10.22	4200	38.36	1.15
1.75:1.0	1200	0.375	11.25	4620	36.25	0.78
175:1.0	1100	0.500	9.25	3700	41.84	1.36
1,75:1.0	1200	0.500	10.69	4130	38.75	0.99

Table 2: Factorial Analysis of Variance of Effect of Flake Thickness on Board Properties

Source of Variation	Df	Mean square Values (MS)			
		MOR	MOE	WA	TS
Mixing Ratio (MR)	1	271.90**	23.52**	0.4641**	0.3745**
Board Density (BD)	1	10.16**	1.67*	0.1617**	0.8840**
Flake Thickness (FT)	2	5.07*	2.29**	0.5125**	1.8252**
MR x BD	1	0.82	0.06	0.0005	0.0085
MR x FT	2	0.42	0.09	0.0006	0.0069
BD x FT	2	0.12	0.005	0.0464	0.0012
MR x BD x FT	2	0.02	0.003	0.0003	0.0009
Error	36	1.22	0.401	0.0632	0.1033

* Significant at $P<0.05$

From the results of the Newman-Keuls test (Hochberg and Tamhame 1987) carried out to determine the significant differences in treatment means obtained at the levels in which the three production variables were applied in the experiment, the mean MOR value of 8.88 N/mm^2 obtained at the flake thickness size of 0.250mm was significantly higher at 5% level of probability than the mean value of 7.76 N/mm^2 obtained at the thickest flake size of 0.500mm. The mean MOR value of 8.88 N/mm^2 obtained at the thinnest flake size of 0.250mm used in the experiment was found however, not to be significantly higher at 5% level than the mean MOR value of 8.35 N/mm^2 recorded at the thicker flake size of 0.375mm. Furthermore, the mean MOR values of 10.71 N/mm^2 and 8.79 N/mm^2 obtained at the higher cement/wood mixing ratio level of 2.75:1.0 and board density of 1200 kg/m^3 were found to be significantly higher in values than the mean figures of 5.95 N/mm^2 and 7.87 N/mm^2 recorded at the lower levels of 2.25:1.0 and 1100 kg/m^3 respectively.

The treatment means of the three production factors for MOE compared similarly to those of MOR. As shown in Table 2, the mean MOE value of 4050 N/mm^2 obtained at the flake thickness size of 0.250mm was significantly different at 5% level of probability from the mean value of 3290 N/mm^2 obtained from the thickest flake size of 0.500 mm; but did not differ significantly however from the mean value of 3710 N/mm^2 obtained at the thicker flake size of 0.375mm. Also, the mean MOE values of 4380 N/mm^2 and 3870 N/mm^2 obtained at the higher cement/wood mixing ratio level of 2.75: 1.0 and board density level of 1200 kg/m^3 were significantly different at 5% level of probability from the mean values of 2980 N/mm^2 and 3500 N/mm^2 obtained at the lower levels of 2.25:1.0 and 1100 kg/mm^3 respectively.

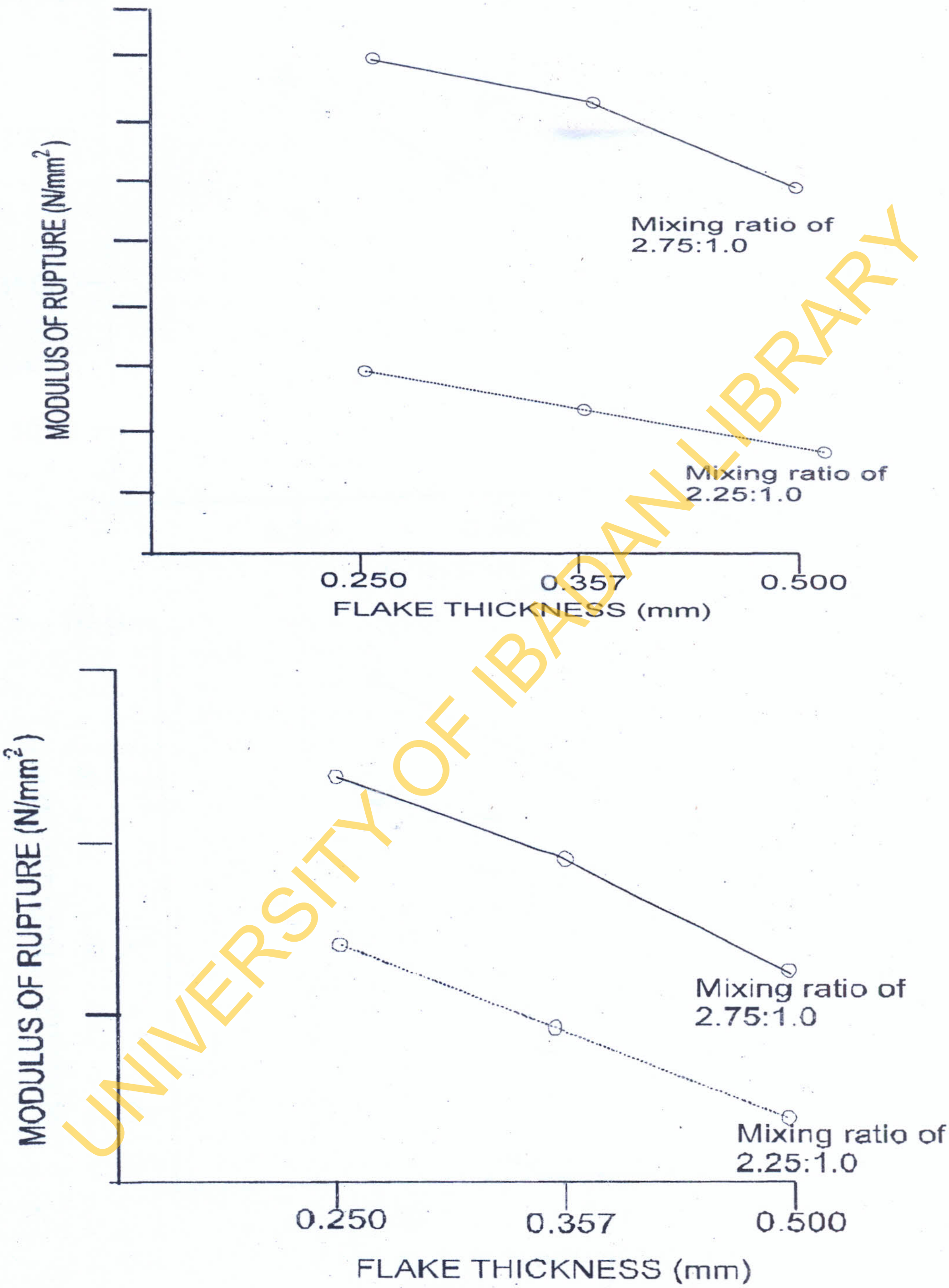

Figure 1 : Influence of flake thickness and cement/wood mixing ratio on Moduli of Rupture and Elasticity of cement bonded particleboards made from mixed particles of the eight Nigerian hardwood species

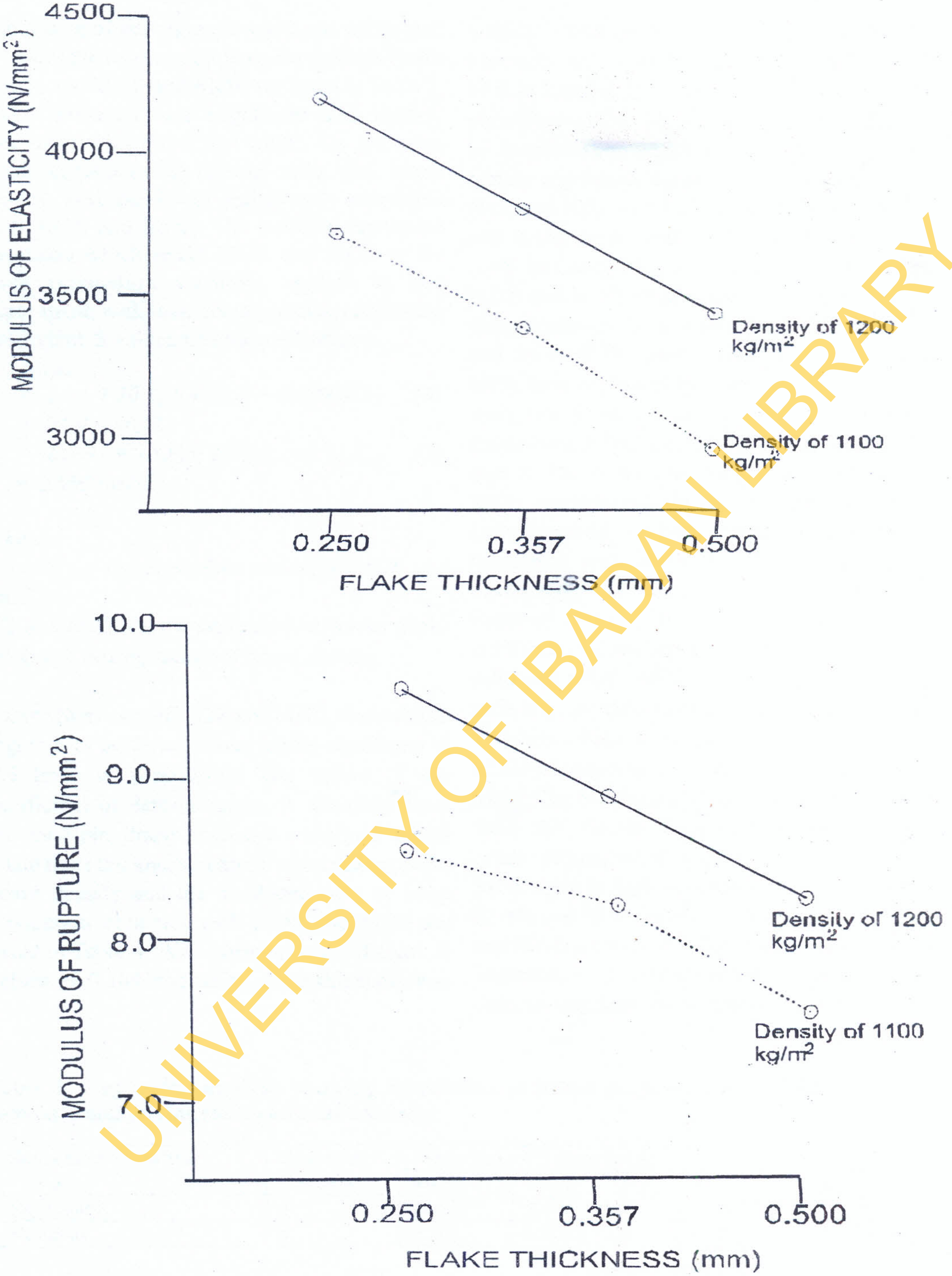

Figure 2 : Influences of flake thickness and board density of MOR and MOE of cement bonded particleboards made from mixed particles of the eight Nigerian hardwood species

The results of the regression analysis performed to model the relationship between the significant factors and MOR and MOE are listed in Table 3. Flake thickness was negatively and linearly correlated with MOR and MOE. On the other hand, cement/wood mixing ratio and board density were positively and linearly correlated with MOR and MOE. The multiple regression equations which relate MOR and MOE to the three production variables applied in this experiment, with their corresponding correlation coefficient, R values are indicated below:

$$Y_1 = -24.4 - 4.50X_1 + 9.52X_2 + 0.00920X_3 \quad (2)$$
$$R = 0.996\ (MOR).$$
$$Y_2 = -6469 - 3015X_1 + 2798X_2 + 3.72X_3 \quad (3)$$
$$R = 0.995\ (MOE).$$

Where
Y_1 *and* Y_2 *= the dependent variables (MOR and MOE)*
X_1, X_2 *and* X_3 *= the independent variables (flake thickness, mixing ratio and board density).*

For the two cases of MOR and MOE, the multiple regressions performed were highly significant at 1% level of probability. The values of the coefficient of determination, R^2 obtained from the multiple linear regression analysis which relate flake thickness, cement/wood mixing ratio, board density and the combined pain of these production variables with MOR and MOE are listed in Table 4. With correlation coefficient, R values of 0.184 and 0390, flake thickness was weakly correlated with MOR and MOE. Similarly, with correlation coefficient, R values of 0.187 and 0.237, board density was weakly correlated with MOR and MOE. The coefficient of determination which were obtained from the simple regression equations which relate flake thickness only with MOR and MOE were 0.034 and 0.152 respectively. This implies that just 3.4% and only 15.2% of the total variations of MOR and MOE respectively were explained by flake thickness. In a similar manner, just 3.5% and 5.6% of the total variations of MOR and MOE were explained by board density. In view of these low R^2 values, the combined pair of flake thickness and board density only explained 6.9% and 20.7% of the total variations of MOR and MOE, respectively. On the other hand however, cement/wood mixing ratio was strongly correlated with MOR and MOE (correlation coefficient, R values of 0.961 and 0.917 respectively). These strong correlation coefficient values between cement/wood mixing ratio and MOR, MOE indicate that the mixing ratio is a very dominating variable, and that other variables - flake thickness and board density are of minor importance with regard to MOR and MOE. The coefficient of determination, R^2 values from the simple regression equations which relate cement/wood ratio alone to MOR and MOE were as high as 0.924 and 0.784 implying 92.4% and 78.4% of observed variations of MOR and MOE respectively. These further indicate the importance of cement/wood mixing ratio in determining these static bending properties.

Table 3: Regression analysis showing correlation of board properties with flake thickness, cement/wood mixing ratio and board density

Sources of variation	Degree of freedom	Mean Square Values (MS)			
		MOR	MOE	WA	TS
Regression	3	24.25**	2.48E + 06**	27.60**	0.331
Residual	8	0.061	0.008E + 06	0.372	0.0009

Table 4: Coefficient of multiple determinations R2 values which relates FT, MR and BD and combination between and among these variables to MOR, MOE, WA and TS

Factors of Production	Coefficient of determination, R^2			
	MOR	MOE	WA	TS
Flake thickness	0.034	0.152	0.677	0.442
Board density	0.035	0.056	0.152	0.457
Cement/wood mixing ratio (MR)	0.924	0.784	0.137	0.094
FT and BD	0.069	0.207	0.829	0.899
FT and MR	0.959	0.936	0.814	0.536
BD and MR	0.959	0.840	0.288	0.550
FT and BD and MR	0.993	0.991	0.965	0.993

Consequently, the combined pair of cement/wood mixing ratio with flake thickness and cement/wood mixing ratio with board density each gave R^2 value of 0.959 on MOR, while they gave R^2 value of 0.939 and 0.840 respectively on MOE. For these high values, the mixing ratio contributed significantly. One other important observation noted in Table 4 is that MOR can be predicted more accurately than MOE in static bending using cement/wood mixing ratio alone or its combined pair with board density as functions of these bending properties. With R^2 values of 0.993 and 0.991, meaning 99.3% and 99.1% of observed variations, MOR and MOE can accurately be predicted from all the three production variables combined.

Water absorption and Thickness swelling;

As summarized in Table 1, the compiled averages for the WA and TS tests for the study ranged from 34.60 to 44.04% and 0.57 to 1.61% respectively. These range values compare favorably with WA range values of 24.66 to 46.37%, 24.75 to 40.58% and 36.27 to 48.82%, as well as TS range values of 0.98 to 3.62%, 0.41 to 4.01% and 0.49 to 2.30% reported in literature (Prestemon 1976, Badejo 1986 and 1988); and also the mean TS range values (Prestemon 1976, Dinwoodie 1978, Bison-Werke 1981, Dennlsov *et al* 1985, Badejo 1986 and 1988, Oyagade 1988, Fuwape 1992, Fuwape and Oyagade 1993).

The results of the factorial analysis of variance are presented in Table 2 showed that flake thickness, cement/wood mixing ratio and board density had significant effects on WA and TS at 1% level of probability. No two-way or three-way significant interactions were found between and among the three production variables applied in the experiment. Results showed that WA and TS of the experimental panels increased as the thickness size of the particles increased from 0.250 to 0500mm. This means in effect that cement-bonded particleboards made with thicker flakes swell more and absorb more moisture under prolonged soak of 144 hours in water. Invariably therefore, it shows that the thinner the flakes used for board production, the lower the WA and TS values, the more dimensionally stable the experimental panels. This trend of behaviour was consistent at each of the two cement/wood mixing ratio levels applied for board production. Also observed is that, increase in cement binder content of board, as manifested in increased cement/wood mixing ratio from 2.25 : 1.0 to 2.75 : 1.0, resulted in production of more dimensionally stable boards. Board density influenced the experimental cement-bonded particleboard in a similar manner to that of cement/wood mixing ratio. At each of the flake thickness of 0.250 mm, 0.375mm and 0.500 mm, water absorption (W A) and thickness swelling (TS)of the test boards decreased as board density increased from 1100 kg/m^3 to 1200 kg/m^3. The most dimensionally stable cement-bonded experimental panels were those made with 0.250 mm thick flakes, cement/wood mixing ratio of 2.75:1.0 and board density of 1200 kg/m^3.

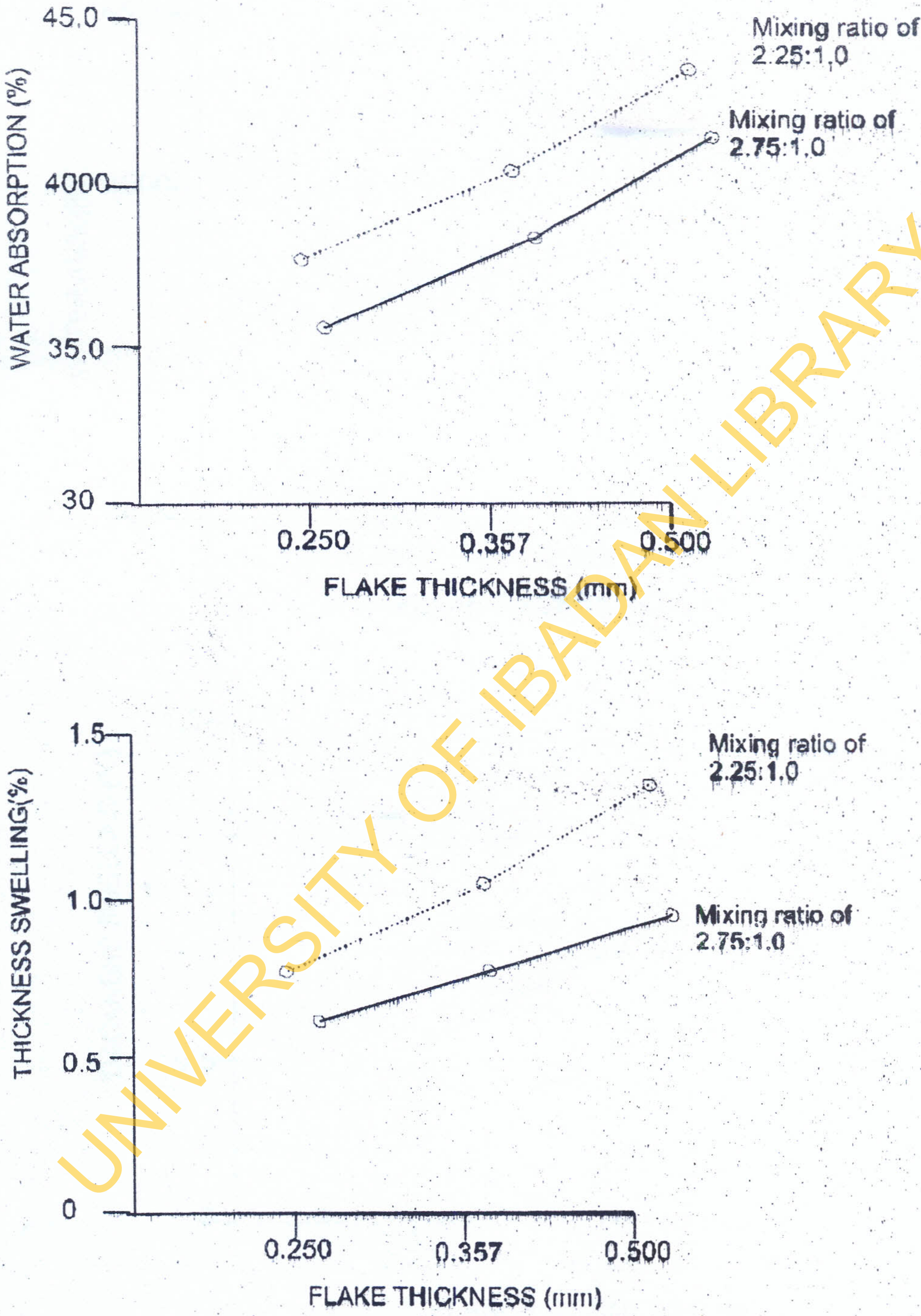

Figure 3 : Influences of flake Thickness and Cement/wood mixing ratio on Water Absorption and Thickness Swelling of Cement bonded particleboards made from mixed particles of the eight Nigerian hardwood species

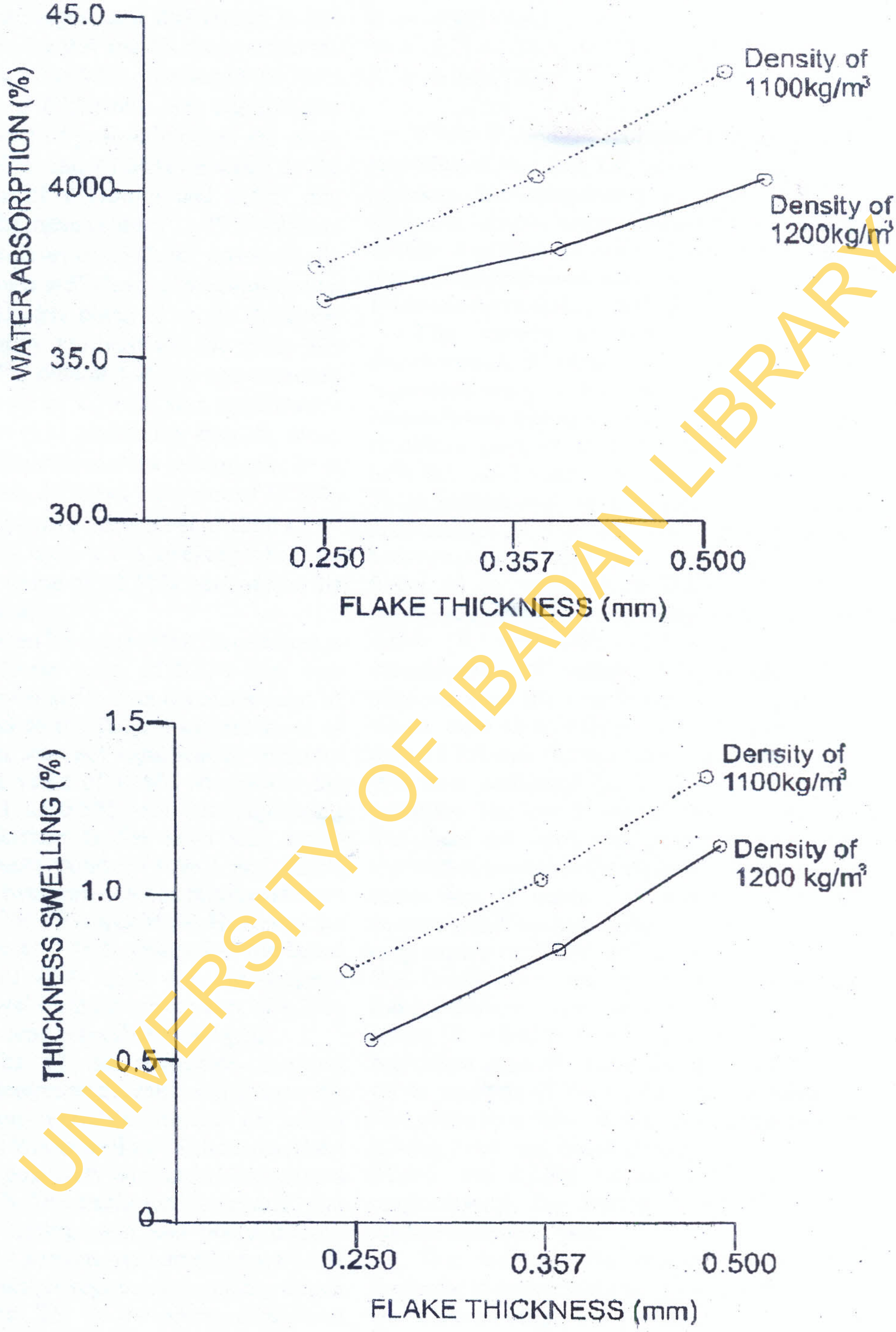

Figure 4: Influences of flake Thickness and Board Density on WA and TS of Cement-Bonded particleboards made from mixed particles of the eight Nigerian hardwood species

The results of the Newman-Keuls test carried out to determine the significant differences in the treatment means for WA and TS showed that the mean WA value of 35.97% obtained at the flake thickness size of 0.250 mm was significantly lower at 5% level of probability than the mean values of 38.29% and 41.36% obtained at the thickness sizes of 0.375mm and 0.500 mm respectively. The mean value of 38.29% obtained at the thickness level of 0375mm was similarly significantly lower at 5% level of probability than the value of 41.36% obtained at the thickness level of 0.500mm. Furthermore, the mean WA value of 37.55% obtained at the cement/wood mixing ratio level of 2.75:1.0 was significantly lower at 5% level of probability than the mean value of 39.53% obtained at the mixing ratio level of 2.25: 1.0. Also, the mean WA value of 37.50% obtained at the board density level of 1200 kg/m^3 was significantly lower at 5% level of probability than the mean value of 39.58% obtained at the level of 1100 kg/m^3.

Also the mean TS value of 0.81% obtained at the flake thickness level of 0.250 mm was significantly lower at 5% than the mean value of 1.28% obtained at the flake thickness level of 0.500 mm; but was not significantly different from the mean value of 1.06% obtained at the thickness level of 0.375 mm. No significant statistical difference at 5% level was found between the mean values of 0.96% and 1.14% obtained at the two cement/wood mixing ratios of 2.7: 1.0 and 2.25: 1.0 respectively. However, the mean TS value of 0.86% obtained at the board density level of 1200 kg/m^3 was significantly lower at 5% level from the mean value of 1.25% obtained at the density level of 1100 kg/m^3.

The results of the regression analysis performed to determine the relationship between the significant variable inputs in board production and WA as well as TS show that flake thickness was positively and linearly correlated with WA and TS. The results further revealed that cement/wood mixing ratio and board density were negatively and linearly correlated with WA and TS. The multiple regression equations which relate WA and TS to the three production variables applied in this experiment, with their corresponding correlation coefficient, R values, are indicated below:

$$Y_1 = 64.3 + 21.6X_1 - 3.95X_2 - 0.0208X_3 \quad (4)$$

$$R = 0.982\,(WA)$$

$$Y_2 = 5.71 + 1.88X_1 - 0.353X_2 - 0.00390X_3 \quad (5)$$

$$R = 0.996\,(TS)$$

Where Y_1 and Y_2 represent the dependent variables of WA and TS; while X_1, X_2 and X_3 represent the independent variables of flake thickness, cement/wood mixing ratio and board density. For the two cases of WA and TS, the regressions performed were highly significant at 1% level of probability (Table 3).

The values of the coefficient of determination, R^2 obtained from the step-wise regression analysis that relate flake thickness, cement/wood mixing ratio, board density and the combined pairs of these production variables with WA and TS are as summarised in Table 4. These independent variable inputs had varying relationships on WA and TS. The correlation between cement/wood mixing ratio and WA was found to be weak ($R = 0.370$). Also, the correlation between board density and WA was weak ($R = 0.390$). The coefficient of determination, R^2 values of 0.137 and 0.152 obtained from the simple regression equations which relate each of them with WA implies that only 13.7% and 15.2% of the total variations of WA were accounted for by these independent variables. The low R^2 values obtained signifies that there are other vital sources of variable inputs that needed to be explored. Owing to the above low R^2 values, the combined pair of cement/wood mixing ratio and board density only explained 28.8% of the total variations of WA. On the other hand, the correlation between flake thickness and water absorption was fairly strong ($R = 0.823$). From the computed simple regression analysis, flake thickness accounted for as much as 67.7% of the total variations of WA while its combined pair with cement/wood mixing ratio and board density accounted for 81.4% and 82.9% of the total variations respectively for which flake thickness contributed significantly.

This indicates the importance of flake thickness in determining WA property. Similar to its relationship with water absorption, cement/wood mixing ratio was also weakly correlated with TS. This variable explained just 9.4% of the total variations of TS. Flake thickness and board density respectively provided 44.2% and 45.7% explanations for total variations of TS; while their combined pair accounted for 89.9% of the total variations of TS. For this high value, flake thickness and board density contributed almost equally. This indicates the importance of these two production Variables in determining TS property of the experimental boards. One other important observation noted in Table 4 is that WA can be more accurately predicted than TS using flake thickness alone; while thickness swelling can be more accurately predicted than water absorption using board density alone. Both WA and TS can however be equally well predicted from the combined pair of flake thickness and board density as variable inputs in board production. With coefficient of determination, R^2 values of 0.965 and 0.993 respectively, WA and TS can accurately be predicted from all the three production variables combined.

It was observed from the findings of the study that cement-bonded particleboards made with thicker flakes were inferior to those made from thinner flakes. This invariably means that the thinner the flakes used the stronger, stiffer and more dimensionally stable the experimental cement-bonded particleboards. This observation is expected as all the test panels made from the eight hardwood species were fabricated at constant flake lengths of 37.5mm. Slenderness ratio, which is an important factor in particleboard production, is expressed as the ratio of length to thickness of the flake particles used for board production (Moslemi 1974, Maloney 1977). Strength of particleboard increases with increase in the slenderness ratio of the flake particles. At constant flake length, slenderness ratio increases with thinner flakes. Stronger boards will therefore be expected to be made at the flake thickness of 0.250mm than at the level of 0.375mm or 0.500mm. Similarly, boards made with 0.375mm thick flakes will be expected to be stronger than those made with 0.500mm thick flakes. Furthermore, when boards are made to a constant board density level and also from same raw materials, boards made with thinner flakes will be expected to comprise more wood flake materials by volume than those made from thicker flakes. There is therefore sufficient consolidation of the experimental panels made with thinner flakes during pressing. Such boards will be expected to perform better in static bending and moisture response properties than those made from thicker flakes. Available void spaces for water occupation in thicker-flake boards are therefore considerably more than those in thinner-flake boards. This, along with the sorption properties of wood, possibly explained the observed increase in WA and TS values of the test panels with increase in flake thickness. Similarly, the observed decrease in water absorption and thickness swelling with thinner flakes conforms to reported studies on cement-bonded particleboards (Badejo 1988, Oyagade 1988) and resin-bonded types (Vital 1980, Vital et al. 1980).

CONCLUSION AND RECOMMENDATION

The set objectives in this study were achieved in the course of laboratory investigations carried out. The study has contributed to the existing knowledge on cement-bonded particleboard production from Tropical hardwood species. The thinner the flakes used as core materials in board production, the stronger, stiffer and more dimensionally stable the cement-bonded particleboards. It is therefore recommended that thinner and longer flakes are the best particles for wood cement production.

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