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EFFECT OF PROCESS VARIABLES ON THE STRENGTH PROPERTIES OF VENEER LAMINATED CEMENT BONDED PARTICLE BOARD FROM MIXED TROPICAL HARDWOODS

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ABSTRACT

Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) of veneer laminated wood cement panel were evaluated. The boards were made of 3 layers comprising 1.5 mm thick mixed hardwoods sawdust for the two surfaces, and 9mm thick core layer made of plantation grown *Gmelina arborea* flakes. Three variables were investigated namely: Density at three levels (1000 kg/m^3, 1100kg/m^3 and 1200 kg/m^3), Cement: wood ratios of 2.5:1.0, 2.75:1.0 and 3.0:1.0 and glue spread of 1.02 kg/m^2, 1.43 kg/m^2 and 1.74 kg/m^2 double glue line (DGL) for the boards lamination.For all the treatment combinations, the mean MOR ranged from 26.79 N/mm to 42.59 N/mm^2 while for MOE, the mean value was in the range of 3114N/mm^2 to 5310N/mm^2. At board density level of 1250 kg/m^3 the laminated panels gave value of the highest MOR and MOE. Statistical analysis showed that the three variables considered in this study had significant effect on the board strength.

Key Words: **Process variables; strength properties; cement-bonded and particle board.**

INTRODUCTION

Cement-bonded particle board is a composite panel product produced from wood and other ligno-cellulosic materials, mineral binders, additives and water. The production and utilization of this product in the developing countries became popular from the 70s when prices of petroleum products increased, thereby affecting the activities of the petro-chemical industries which manufacture the organic resin used in the panel product manufacturing industries (Badejo 1983).

Due to the scarcity and expensiveness of petroleum based systematic binder, increasing research interest are being focussed on the development of alternative binders for wood based panel production both in the developed and developing countries. An alternative binder which has generated considerable interest is cement for the manufacture of particle board because

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cement can be sourced locally in many countries. The industrial development of particle board with cement as binder in the tropical countries has been hindered. The major reasons which account for this is non compatibility of most tropical hadwood with cement. This problem is attributed to high content of chemical substances which are inhibitory to the setting of cement paste in hardwood species. These inhibitory substances include tannin,hemi-celluloses, simple sugar and phenolic compounds (Simatupang,1986) . Hot water at varying temperaturre levels and chemical additives like Calcium chloride have however been applied on some tropical timbers found in Nigeria with resultant effect of possible board production from them (Badejo, 1989).

The acceptance of wood cement board can be associated with many of its admirable properties among which is its potential as very good constructional material of repute for building low cost houses. The board is highly resistant to moisture uptake and decay, noise, heat and fire attack. It is highly resistant to termite attack due to high alkalinity of the cement binder and has been adjudged to perform well with respect to long exposure to fluctuations in weather elements. (Badejo, 1988). Over the years, researchers have been able to show the influence of production variables such as wood factor, cement, chemical additive and water in the wood-cement mix on these quality of the boards formed. Badejo (1988) and Oyagade (1990 both observed that wood particle geometry exhibits significant influence on properties of boards produced. Apart from particle geometry, other wood factors that affect board quality include elasticity, moisture content, specific gravity and grain deviation (Simatupang *et al,* 1978). Also the type of cement and wood-cement ratio were reported to have significant effect on the board qualities (Badejo 1987,Oyagade 1988, Moslemi 1986).

In spite of many laudable qualities of wood cement panels, research findings have indicated that the major threat to the total acceptance is the high density. Although wood cement panels have been produced in the past using different board densities, the densities for commercially manufactured panels range from 1100 – 1300 kg/m^3 (Oyagade 1990). These high densities which are approximately twice that of chip board and the abrasive nature of the cement stimulate high wearing of cutting tools. Increasing research efforts have been intensified with the objectives of reducing the panel density and simultaneously improving its strength properties. These objectives have been achieved through manipulation of the board process variables which can influence the density and other relationship that may exist between the density and the strength properties. Oyagade (1990) observed that the board density is linearly and positively correlated to the bending properties of wood cement panels when wood-cement ratio is held constant . As presented out by Oyagade (1990), it is desirable that the density be reduced to allow easier site handling while still retaining the strength qualities.

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The objective of this study therefore, is to assess the effect of three process variables (density, mixing ratio and glue spread) on technically accepted 3-layered, wood cement panel using mixed tropical hardwoods. The flexural characteristics of the board so produced be also assessed on the basis of Modulus of Rupture (MOR) and Modulus of Elasticity (MOE).

MATERIAL, AND METHODS

Mixed coarse saw dust of some Nigerian hardwoods was collected from saw mills located at Ibadan, Nigeria, while the flakes were obtained from plantation grown *Gmelina arborea* **bolts.** The collected saw dust was spread in the sun to prevent fungi attack and was later sieved using 2mm and 6mm mesh sieve in order to remove fines, and to screen bark and oversized particles which are not suitable for panel fabrication. On the other hand the plantation grown *Gmelina arborea* bolts were seasoned in the log yard of forestry Research Institute of Nigeria (FRIN) for 8 weeks after debarking. The seasoned bolts were chipped into flakes of about 2.5mm in length and 0.25mm in thickness. Both the saw dust and flakes were pre-treated with hot water at a temperature of 75°c and later air-dried to moisture content of about 12% prior to panel fabrication.

Mineral binder and additive

The mineral binder used for the study is Portland cement purchased in standard bags of 50kg and having a class strength of p350Z. Calcium chloride ($CaCl_2$) at concentration of 3% of cement weight in the standard board was used as the additive.

Experimental design

Three variables were investigated in the study:

(1) Cement/wood ratio: 2.5:1.0, 2.75:1.0 and 3.0:1.0 (based on oven dry weight of the board.

(2) Board density: 1000kg/m³, 1100g/m³ and 1200kg/m³

(3) Glue spread for lamination 1.02kg/m² 1.43kg/m² and 1.74 kg/m² (double glue line DGL) of the board surfaces).

A combination of the above variables gives a 3x3x3 factorial layout resulting in 27 experimental treatment combinations.

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Panel Fabrication Lamination and Testing

For panel fabrication, the required quantity of wood, cement, water and additive were separately weighed into plastic containers. The Additive was dissolved in water and the solution added to the wood. The amount of water applied for mixing was based on the formular developed by Simatupang (1979). The measured cement was then slowly added and mixing was done until a homogenous cement-wood mix was formed. This mixing procedure was separately carried out for the saw dust and the flake core layers of the fabricated panels. The mats were then hand - formed on metal plates inside wooden boxes before being tamped to the required thickness of 12mm on a manually operated hydraulic press with a pressure of 1.25 N/mm^2 for a period of 48 hours. Following the 48 hours press cycle, the boards were stripped from the caul plate and kept inside a polythene bag for 28 days for optimum strength. They were later stacked in the conditioning room at temperature of 21 ± 2^0C and relative humidity of $60 \pm 2\%$ for another 35 days to attain a moisture content of about 12%.

At the attainment of the desired moisture content (12%) the boards were veneer laminated. The required quantity of glue and hardener were measured and little amount of cement was added as an extender. The materials were thoroughly mixed together before addition of water. Using an open assembly time of 15 minutes (after coating the veneer with glue) the boards were later cold pressed for 8 hours using $1.23N/mm^2$ pressure. The laminated boards were allowed to stay for 3 days before being cut and tested in accordance with German Standard DIN 52364 and DIN 52365 of 1965 on the Hunsfield Tensometer Machine type W.

RESULTS AND DISCUSSION

The mean Modulus of Rupture (MOR) and mean Modulus of Elasticity (MOE) obtained from the experimental panels for the various treatment combinations are listed in Table 1. The analysis of variance (ANOVA) of the observed values is presented in Table 2.

Mean MOR values ranged from $26.79N/mm^2$ to $34.62N/mm^2$ for DGL $1.02kg/m^2$ and $27.20N/mm^2$ to $39.01N/mm^2$ for DGL $1.43kg.m^3$ and $28.31N/mm^2$ to $42.59N/mm^2$ for DGL $1.74k/m^2$ for the three mixing ratios and the 3 densities. The MOE values on the other hand ranged from 3114 N/mm^2 to 4234 N/mm^3 for DGL 1.02 $kg.m^2$, 3336 N/mm^2 to 52 09 N/mm^2 for DGL 1.43 kg/m^2 and 3500 N/mm^2 to 5310 N/mm^2 for DGL $1.74kg.m^2$ for the three mixing ratios. The results obtained in this study conform with the average MOR of 42.55 N/mm^2 reported by Oyagade *et al* (1995) for standard panel thickness (12mm) and 1.43 kg/m^2 DGL.

The analysis of variance for the Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) data as presented in Table 2 revealed that the three main effects used for the study (density, mixing ratio and glue spread) were highly significant at 0.05 level of probability. Similarly, the interactions between the process variables were significant at 0.05 level of probability. The results were graphically depicted in Figure 1 & 2 showing the influence of the panel density, mixing ratio and glue spread on the strength properties of the fabricated panels.

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Table 1: **Mean Values for Modulus of Rapture (MOR) and Modulus of Elasticity (MOE) for the Veneer Laminated Wood Cement Board**

S/N	Cement/Wood	Glue spread (kg/m²)	Nominal Density (kg/m³)	Actual Density (kg/m³)	MOR (N/mm²)	MOE (N/mm²)
1	2.5:10	1.02	1000	989	26.79	3114
2	"	"	1100	1090	29.79	3586
3	"	"	1200	1230	33.28	4021
4	"	1.43	1000	988	27.20	3356
5	"	"	1100	1087	30.21	3623
6	"	"	1200	1231	35.56	4498
7	"	1.74	1000	989	28.31	3500
8	"	"	1100	2090	32.53	3797
9	"	"	1200	1229	37.13	4610
10	2.75.10	1.02	1000	991	27.24	3297
11	"	"	1100	1115	29.08	3651
12	"	"	1200	1247	33.85	4135
13	"	1.43	1000	989	28.23	3450
14	"	"	1100	1114	32.57	3923
15	"	"	1200	1247	38.44	4800
16	"	1.74	1000	991	29.31	3588
17	"	"	1100	1115	33.53	4089
18	"	"	1200	1249	40.22	3213
19	3.0:1.0	1.02	1200	993	27.71	3280
20	"	"	1100	1122	29.74	3669
21	"	"	1200	1248	34.62	4234
22	"	1.43	1000	993	28.88	3375
23	"	"	1100	1121	33.91	4237
24	"	"	1200	1251	39.01	5209
25	"	1.74	1000	993	29.14	3599
26	"	"	1100	1122	35.98	4279
27	"	"	1200	1250	42.59	5310

*Each value is the mean of 4 samples per treatment combination.

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Table 2: **ANOVA Of the effect of board density Modules of rupture (MOR) and Modulus of elasticity (MOE) of the fabricated panel**

Source of Variation	DF	Modulus of Rapture SS	Modulus of Rapture MS	Modulus of Elasticity SS	Modulus of Elasticity MS
Density(D)	2	1489.3948	739.9674**	24.3923	12.1962**
Ratio (R)	2	117.8681	58.9341**	1.4416	0.7208**
Spread(S)	2	276.6557	138.3278*	3.9760	1.9880**
DR	4	18.3839	4.5960*	0.2017	0.0504*
DS	4	69.4443	17.3611*	0.9537	0.2384*
RS	4	12.2625	3.0656*	0.0839	0.0210*
DRS	8	13.1692	1.6462*	0.2839	0.0355*
Error	81	38.9245	0.4712	1.2751	0.0157
TOTAL	107	2028.0030		32.6082	

** Highly significant at 0.05 level of probabilty
* Significant at 0.05 level of probability

There were variation between the fabricated panel nominal density and the actual density. This could be ascribed lto spring back effect, the degree of which is influenced by the cement-wood ratio in the fabricated panels. The MOR of the fabricated panels increased with increase in density, cement content and glue spread. It could then be submitted that the most favourable panels in terms of strength are those fabricated with density 1200 kg/m³ cement, wood ratio 3:0:1 and glue spread 1.74kg/m² DGL.

CONCLUSIONS

Within the range of the data collected in this study and subsequent factorial statistical analysis the following conclusiion are drawn

(i) On a laboratory scale, it is technical possible to produce wood-cement-panel from mixed tropical hardwood saw dust (for face layer) and *Gmelina arborea* flake (for core layer)

(ii) Modulus of rupture and modulus of elasticity of the fabricated panels increase with increase in broad density.

(iii) It is technically feasible on a laboratory scale, to veneer-laminate wood cement panel using appropriate adhesives and formation

(iv) The board strength increases with increase in the glue spread.

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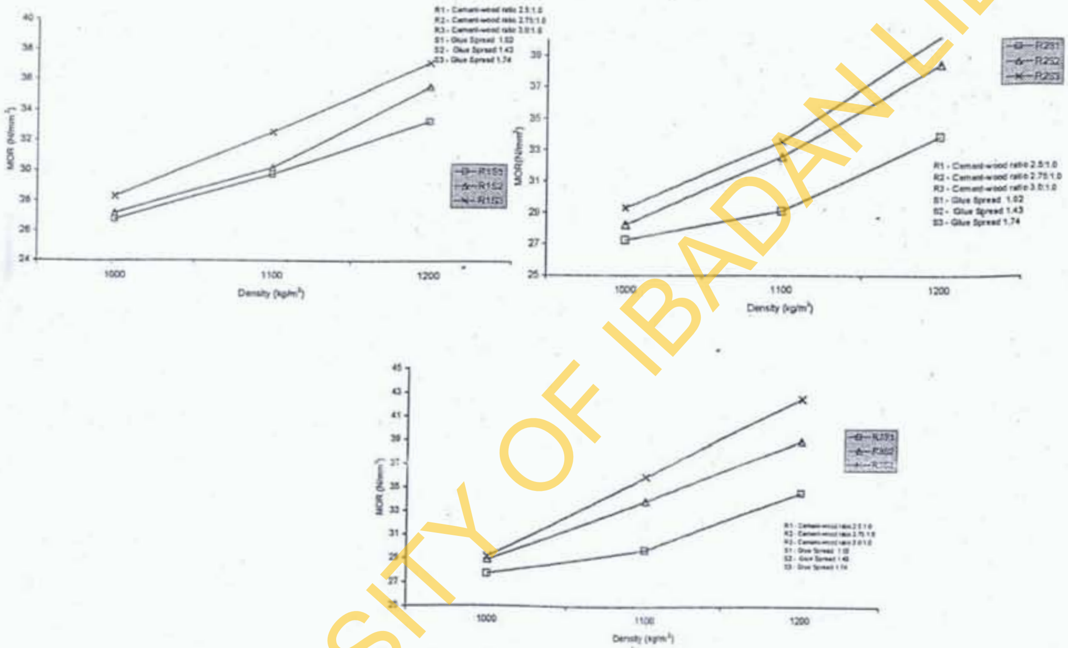

Fig. 1: Influence of panel density, glue spread and wood cement ration on MOR of veneer laminated wood-cement panel from mixed hardwoods.

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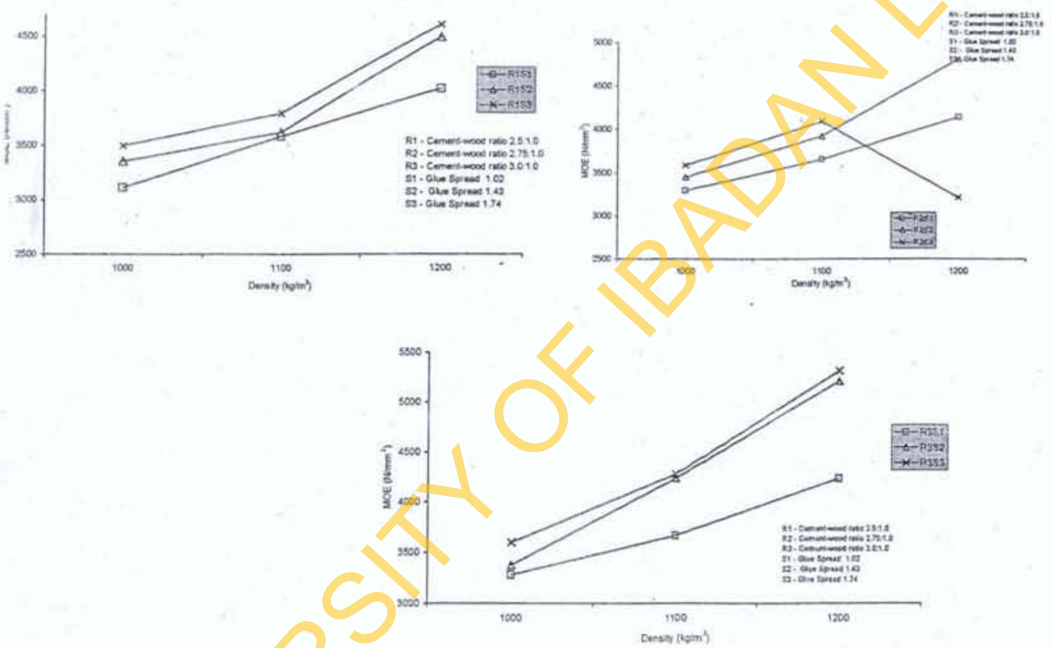

Fig. 2: Influence of panel density, glue spread and wood cement ration on MOE of veneer laminated wood-cement panel from mixed hardwoods.

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