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Dimensional Properties Of Wood Cement Panels Produced From Wood Waste Of Some Municipal Tree Species In University Of Ibadan, Nigeria.

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Abstract
A study was carried out to investigate the dimensional properties of cement bonded particle board from wood waste of 3 urban trees common in University of Ibadan campus. The 3 wood species used for board production are: *Gmelina arborea, Delonix regia,*and *Samanea sena*. The dimensional properties investigated are thickness swelling and water absorption. Data collected were subjected to analysis of variance (ANOVA) at 0.05 probability level. Results showed that the mean values obtained for the thickness swelling (TS) after 24- and 48-hours of water immersion ranged from 0.52% - 7.72% and 0.51% - 7.66%. Cement-bonded particleboard made from *Gmelina arborea* sawdust have the lowest value of thickness swelling of 0,51% followed by *Samanea sena* of 1.79% and least thickness swelling value of 5.96% from *Delonix regia*. The effect of wood species, mixing ratio levels and interaction were significantly different at 5% significance level. The mean values obtained for the water absorption (WA) after 24- and 48-hours of water immersion ranged from 29.60% - 11.47% and 33.34% - 14.20%. All the wood species used in the production of cement-bonded particleboards show decrease in the physical properties assessed as the mixing ratio level of the cement binder increases in the production

Key words: Wood cement panel, wood waste, municipal tree, dimensional properties

Introduction

Production of wood cement composite panels (WCP) from mixed Nigerian hardwoods species has been achieved through the manipulation of the various board process variables such as board density, flake geometry, wood cement ratio among other factors. (Badejo , 1988, Oyagade 1990, Oyagade *et al* 1995, Omole 1994, Omole and Badejo 1999).

Research efforts in Nigeria particularly have focused on evaluating the suitability of different lignocellulosic materials for the manufacture of WCP. The major obstacles to the utilization of these materials for WCP and total acceptability of these products are the inhibitory effects caused by hardwood species on the cure of cement, and the high densities of the final products. Wood component, mainly extractives and polysaccharides, affects reactions between wood and cement resulting in boards of low quality. Jorge *et al*. (2004) argued that the nature of the extractives also has influence on this inhibitory effect. To solve inhibition problems, chemicals additives known as accelerators have been identified and employed to accelerate the setting of cement with wood. In certain instances the use of pretreatments such as aqueous extraction to remove inhibitory substances from wood has also been employed. Cement chemicals accelerators usually improve the properties of WCB (Badejo 1989, Jorge *et al.* 2004).

Although for most structural materials, density is an important physical attribute because it is correlated with most mechanical properties, this is however a limitation to the total acceptability of wood cement panels. Therefore, low density boards is usually desired through the manipulation of the process variables such as altering the type and geometry of the particles and the type of mat forming to increase the mechanical properties of the boards. Satisfactory results have been reported with low-density panels produced with flake-type particles (Semple and Evans, 2004; Teixeira and Pereira,

1987) as well as with excelsior-type particles (Cabangon *et al.*, 2002; Miller *et al.*, 1989).

The manufacture of cement bonded particle board differs from other resin bonded particle board because it is species selective. This is one of the major setbacks to total commercial production of these categories of composite boards. Many wood especially the hardwood species will not bond well with cement to form suitable boards due to the presence of chemical substance in form of extractive present in the wood which inhibit the setting of cement binder with wood (Sandermann 1970, Chittenden *et al*, 1975, Simatupang *et al.*, 1978). Production of wood cement board is therefore generally preferred from softwood than in hardwood.

By products of timber processing such as sawdust and slabs generated after logs are felled and processed have in the past assumed to have no economic value. This waste have not in any way stimulated any form of industrial use either as agro based material or industrial development of any sort. Research to relate properties of the raw materials to the performance of the composite is the first step in developing a new class of materials designed to utilize rather than dispose of wood waste. This study was focused on providing information on the potentials of the wood waste generated from management of three municipal trees and also as a way of making earnings or income from these wastes.

The objective of this study was to determine the suitability of 3 municipal wood species common in the University Campus for wood cement board production using different process variable and determine the physical properties such as water absorption and thickness swelling of the boards so produced.

Materials and Methods

Raw Materials and Preparation

The wood materials used for this study were: *Gmelina arborea* Robx, *Delonix regia* (Hook) Raf, *Samanea saman*(Jacq.) Merr, ordinary portland cement (OPC), water and calcium chloride as the additive which served as a mineralizing agent to quicken the setting of the cement. The wood materials for the study were collected as wood wastes resulting from activities of University of Ibadan Campus Tree Management Committee.

The resulting sawdust was air dried in the open for 2 weeks before it was treated with hot water at a temperature of 85^{0}C. The pretreated materials were then air dried to moisture content (M.C) of 12% before further use. Calcium chloride ($CaCl_2$) was used as the additive which acted as an accelerator by speeding up the reaction process.

The study was then laid out using 3 by 3 factorial experiment in a complete randomized design which gave nine, treatment combinations. The quantity of each material required for board fabrication were calculated and measured out according to the level of combination in the experiment. The quantity of cement and hardwood species sawdust were measured out and poured inside an aluminum bowl. Quantity of additive required was dissolved in a quantity of water needed, then mixed together thoroughly. The water containing chemical additive i.e. ($CaCl_2$) was added and mixed together thoroughly until well blended, lump-free finish is obtained.

Mat Formation and Processing

The blend was hand formed into a uniform mat inside a wooden box of 350 mm x 350 mm that was placed on a caul plate made of iron. The mat formed was pre-pressed using wooden caul plate. Prepress was done in order to reduce the thickness of the mat formed, for free loading unto the cold press. The steel caul plate was covered with polythene sheet before board formation to prevent the sticking of the board on the plate. After board formation, the wooden plate was removed; another polythene sheet was placed on the mat before placing the metal caul plate. The board was loaded into the hydraulic press and pressure was applied at 1.23 Nmm-2 for 24 hours, before the demoulding. The fabricated boards were allowed to cure in the laboratory for 28 days. Possible loss of water from the board was prevented through proper wrapping of the sheet so as to maintain constant ambient condition. Thereafter, the board was stacked for 21 days inside a conditioning room at relative humidity of 65 ± 2% before testing.

Testing of the Board Properties

Each board was cut into test specimens of 152 mm x152 mm x 6 mm to investigate the thickness swelling, water absorption and linear expansion. For water absorption rate, test specimens of the boards were soaked in cold water for moisture uptake for 24 and 48 hours. Later the new weight was measured using a sensitive weighing balance. Water absorption was then expressed as the percentage of increase in weight of the board over the original or initial weight. The same procedure was used to determine the thickness swelling, using the same specimens at the same period of time for soaking. The thickness of the boards was measured using electronic veneer caliper before soaking and after soaking for 24 and 48 hours. The thickness swelling was expressed as the percentage of increase in thickness of the board over the original thickness.

Moisture Response Tests

The water absorption, thickness swelling and linear expansion specimens were cut into sizes of 152 mm×152 mm. The water absorption test specimen or samples were first weighed before soaking; the initial weight was then recorded. The test specimen was then placed horizontally in a large container containing distilled cold water at a temperature of 20^{0}C. The test specimens were left in the water for 24hours, after which they were dried to remove excess water from the soaked specimens before they were finally weighed on a weighing balance.

The water absorption reading was expressed as the percentage of increase in the weight of the board after 24 hours soaking over the original dry weight. As for the thickness swelling specimen, their initial thicknesses were taken with the aid of micrometer screw gauge. The boards were soaked in water for 24 hours as that of the water absorption test. After 24 hours, the specimens were removed from water and dried with a piece of cloth before the final thickness was observed. The rate of thickness swelling was expressed as a percentage of the increase in thickness of board over the original dried thickness. The same process was repeated for 48hours and the values were derived.

Results and Discussion

The mean values of the dimensional properties of cement-bonded particleboard made from municipal wood species are presented in Table 1.

Thickness swelling

The results obtained after 24 and 48-hours of water-soak test conducted on the experimental boards are presented in Table 1. The mean values obtained for the thickness swelling (TS) of the experimental boards after 24- and 48-hours of water immersion ranged from 0.52% - 7.72% and 0.51% - 7.66%. The values observed are low in physical properties after 24 and 48-hours. Cement-bonded particleboards samples produced from municipal wood species sawdusts are dimensionally stable. Cement-bonded particleboard made from *Gmelina arborea* sawdust have the lowest value of thickness swelling of 0.51% followed by *Samanea saman* of 1.79% and least thickness swelling value of 5.96% from *Delonix regia*. The ranged of thickness swelling (TS) values obtained in this study are within the values reported for cement-bonded particleboards in previous studies of Prestemon 1976, Dinwoodie 1978, Bison-Worke 1981, Dennisov *et al.*, 1985, Badejo 1986 and 1988, Oyagade 1988, Fuwape 1992, Fuwape and Oyagade 1993.

The result of analysis of variance conducted on thickness swelling of the cement-bonded particleboards produced from municipal wood species sawdust is presented in Table 1 above. The effect of wood species, mixing ratio levels and interaction were significantly different at 5% significance level. This implies that the effect of this factor significantly influence the thickness swelling of the particleboard produced after immersion in water for the period of 24 and 48-hours. The effects of the interaction on the samples are dependent, each factor must be considered in the production of the cement-bonded particleboard samples.

Water absorption

The results obtained after 24 and 48-hours of water-soak test conducted on the experimental boards are presented in Table 1. The mean values obtained for the water absorption (WA) of the experimental boards after 24- and 48-hours of water immersion ranged from 29.60% - 11.47% and 33.34% - 14.20%. The values observed are low in physical properties after 24 and 48-hours. Cement-bonded particleboards samples produced from municipal wood species sawdusts are dimensionally stable. Cement-bonded particleboard made from *Gmelina arborea* sawdust have the lowest value of water absorption of 11.47% followed by *Delonix regia* of 12.43% and least thickness swelling value of 14.00% from *Samanea saman* after 24-hours of water immersion.

Table 1: Mean values of Thickness Swelling (TS), Water Absorption (WA), of Fabricated boards

Wood Species	Sawdust/cement ratio	TS 24hr (%)	TS 48 (%)	WA24hr (%)	WA48hr (%)
Samena Sena	1.0 : 1.0	3.45	2.95	29.60	33.34
	1.0 : 1.5	2.71	2.67	24.20	26.75
	1.0 : 2.0	1.84	1.79	14.00	17.14
Delonix regia	1.0 : 1.0	4.35	4.41	15.47	17.30
	1.0 : 1.5	5.83	5.95	12.73	14.02
	1.0 : 2.0	5.95	5.96	12.43	14.14
Gmelina arborea	1.0 : 1.0	7.72	7.66	16.47	18.18
	1.0 : 1.5	4.18	4.09	13.03	15.62
	1.0 : 2.0	0.52	0.51	11.47	14.20

Table 2: Results of analysis of variance (ANOVA) conducted on thickness swelling of cement-bonded particleboard made from municipal wood species sawdust

Source of Variation	d.f	TS – 24hours F	TS – 24hours Sig	TS- 48 hours F	TS- 48 hours Sig
Species (S)	2	11.20	0.001*	14.29	0.000*
Mixing ratio (MR)	2	8.93	0.002*	8.49	0.003*
S x MR	4	10.13	0.000*	10.75	0.000*
Error	18				
Total	26				

The result of analysis of variance conducted on water absorption of the cement-bonded particleboards produced from municipal wood species sawdust is presented in Table 2 above. The effect of wood species, mixing ratio levels and interaction were significantly different at 5% significance level. This implies that the effect of this factor significantly influence the water absorption of the particleboard produced after immersion in water for the period of 24 and

48-hours. The effects of the interaction on the samples are dependent, each factor must be considered in the production of the cement-bonded particleboard samples. The analyses conducted on the physical properties assessment of the samples are presented in table 1. The values recorded for dimensional stability of the experimental boards observed that the boards followed the same trend with the previous studies of other reports of the following researchers (Prestemon, 1976, Badejo, 1986, 1988, 1999). All the wood species used in the production of cement-bonded particleboards shows a decrease in the physical properties assessed as the mixing ratio level of the cement binder increases in the production.

The results of the Duncan Multiple Range Test (DMRT) carried out to determine the significant difference in treatment means obtained at the levels in which the two process variables of different municipals tree sawdust and mixing ratios applied in the experiment were listed in Tables 4 and 5. The mean WA value of 13.54% and 13.66% obtained by *Delonix regia,* and *Gmelina arborea* was lower in mean values than the mean value of 22.60% *Samanea saman*. The mean value of WA 12.63% obtained at mixing ratio levels of sawdust/cement at 1:2 was lower than the values obtained from other mixing ratios. As indicated in Tables 4 and 5, the mean value of TS of 2.66% obtained from *Samanea saman* was lower than the mean values of 4.14% and 5.38% of *Gmelina arborea* and *Delonix regia*. The mean value of TS obtained from sawdust/cement ratios of 1:2 was lower than the other mixing ratios also.

The results of the Duncan Multiple Range Test (DMRT) carried out to determine the significant difference in treatment means obtained at the levels in which the two process variables used in the production of particleboard from different municipal trees sawdust and cement mixing ratios applied in the experiment were listed in Tables 4 and 5. The mean WA value of 13.54% and 13.66% obtained by *Delonix* and *Gmelina* was lower to the mean value of 22.60% *Samanea* after 24 hours. The mean value of WA 12.63% obtained at mixing ratio levels of sawdust/cement at 1:2 was the lowest values obtained. As indicated in Table 1, the mean value of TS of 2.66% obtained from *Samanea* species was lower than the mean values of 4.14% and 5.38% of *Gmelina arborea* and *Delonix* after 24 hours. The mean value of TS obtained from sawdust/cement ratios of 1:2 was lower than the other mixing ratios also at 2.77% after 24 hours.

Table 3: The result of analysis of variance (ANOVA) conducted on water absorption of cement-bonded particleboard made from municipal wood species sawdust

Source of Variance	d.f	WA – 24hours F	Sig	WA- 48 hours F	Sig
Species (S)	2	29.90	0.00	32.48	0.00
Mixing ratio (MR)	2	17.18	0.00	14.14	0.00
S x MR	4	4.71	0.01	4.50	0.00
Error	18				
Total	26				

Table 4: The result of DMRT conducted on the effect of wood species on properties of cement-bonded particleboard assessed

Wood Species	WA-24hrs	WA-48hours	TS-24hours	TS-24hours
Delonix regia	13.53[a]	15.15[a]	5.38[c]	5.44[c]
Gmelina arborea	13.66[a]	15.99[a]	4.14[b]	4.09[b]
Samena sena	22.60[b]	25.74[b]	2.66[a]	2.47[a]

Means on the same column with the same superscripts are not significantly different (P<0.05)

Table 5: The result of DMRT conducted on the effect of mixing ratio levels on Water absorptions and Thickness swelling properties of the fabricated boards.

Mixing Ratio	WA-24hrs	WA-48hours	TS-24hours	TS-24hours
1.0 : 1.0	20.51[c]	22.93[a]	5.17[c]	5.01[c]
1.0 : 1.5	16.66[b]	18.80[a]	4.24[b]	4.24[b]
1.0 : 2.0	12.63[a]	15.16[b]	2.77[a]	2.75[a]

Means on the same column with the same superscripts are not significantly different (P<0.05)

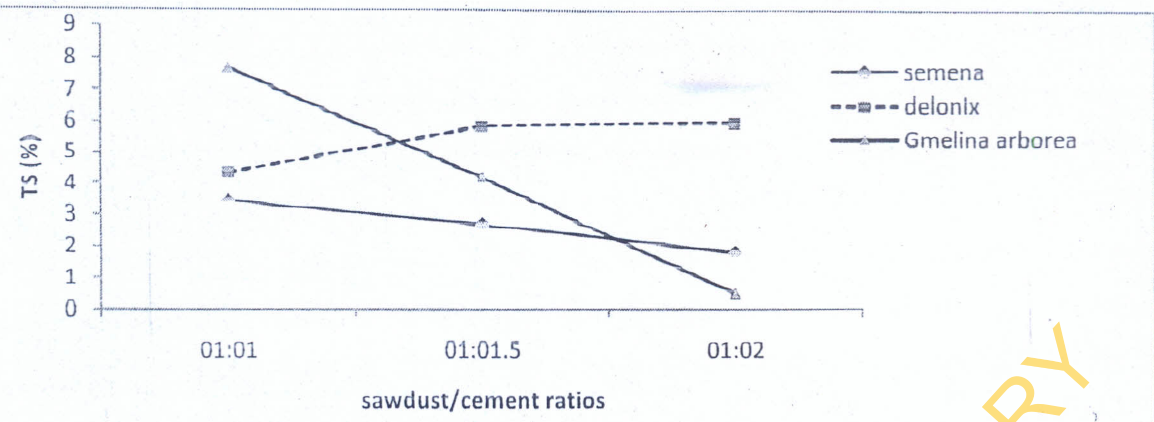

Figure 1: Effect of sawdust/cement ratios on TS-24h of panel boards produced

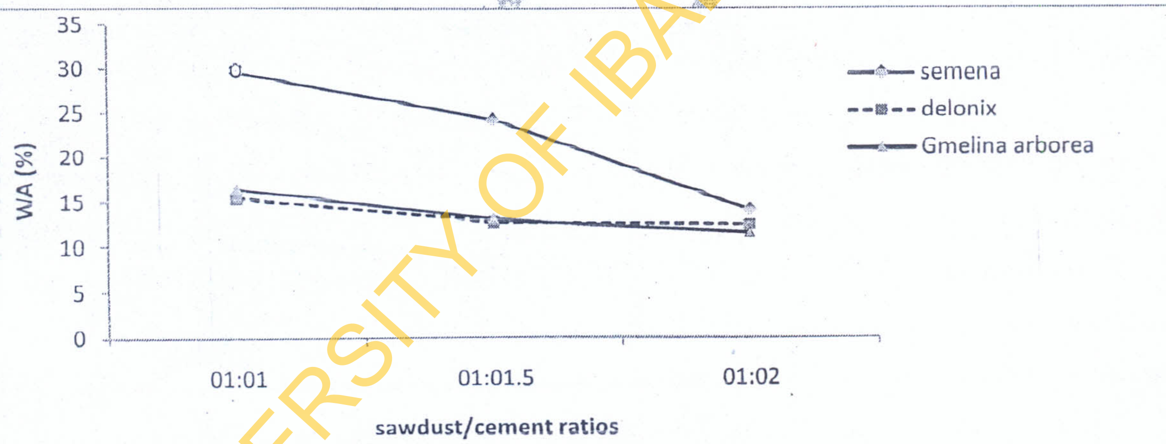

Figure 2: Effect of process variables on WA-24h of panel boards produced

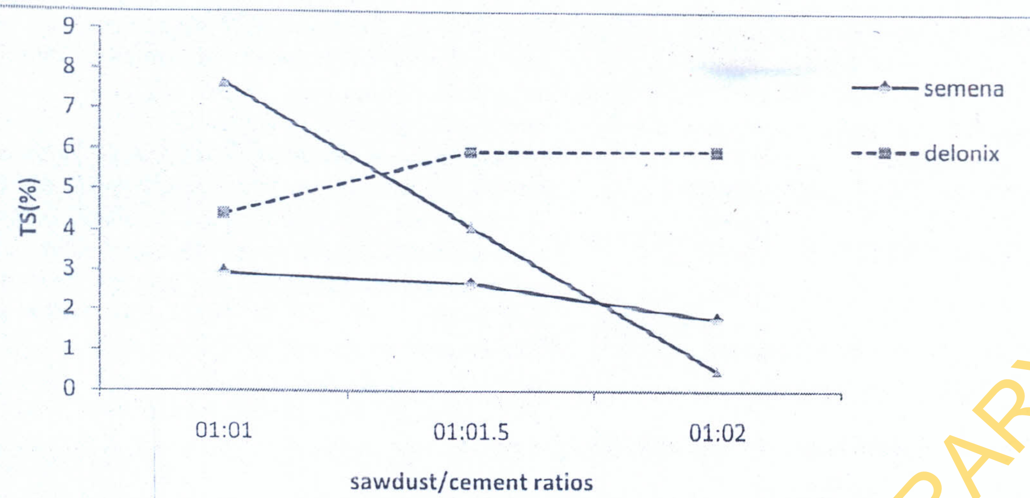

Figure 3: Effect of process variables on TS-48h of panel boards produced

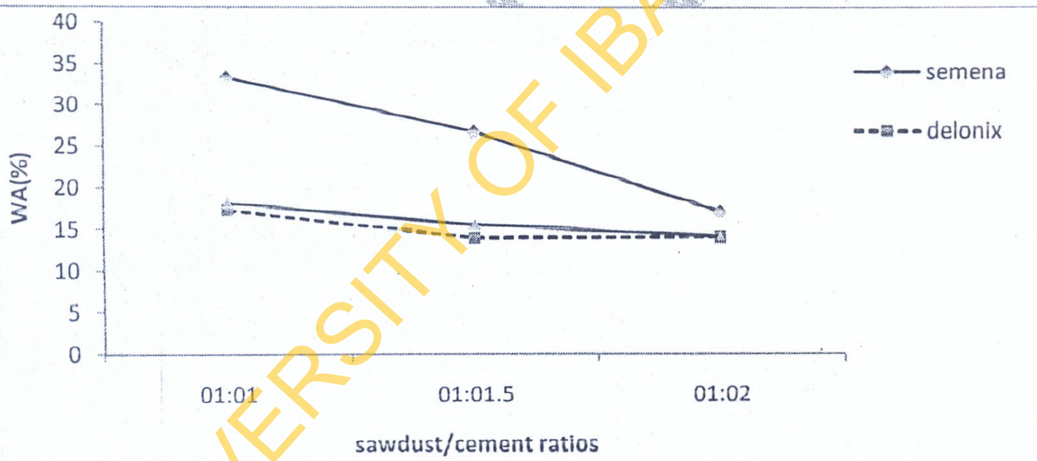

Figure 4: Effect of process variables on WA-48h of panel boards produced

The mean WA value of 15.15% and 15.99% obtained by *Delonix* and *Gmelina* was lower than the mean value of 25.74% for *Samanea* after 48 hours of soaking. The mean value of WA 15.16% obtained at mixing ratio levels of sawdust/cement at 1:2 was the lowest values obtained. As indicated in Tables 4 and 5, the mean value of TS of 2.47% obtained from *Samanea* species was lower than the mean values of 4.09% and 5.44% of *Gmelina arborea* and *Delonix* after 48 hours. The mean value of TS obtained from sawdust/cement ratios of 1:2 was lower than the other mixing ratios also at 2.75% after 48 hours.

Conclusion

Cement-bonded particleboards were successful produced from municipal wood species in mixing ratios from 1:1, 1:1.5 and 1:2. The particleboard produced shows *Samanea* with the best thickness reduction in both 24 and 48hours but poor performance in water retention. The best performance boards were recorded at 1: 2 sawdust to cement ratio.

References

Ajayi, B 2003. Assessment of the dimensional stability of cement-bonded particle board from post harvest banana stem residues and sawdust in proc. World forestry congress 21st -28th sept.2003 at Quebec City, Canada vol.4 pg 157.

Badejo, S.O.O.(1985): Suitability of some tropical hard wood for wood-cement board manufacture. The Nigeria journal of forestry Vol.15.Nos.1 and 2 pg 53-57.

Badejo, S.O.O.(1987): An investigation on the influences of cement binder content on properties of cement-binder content on properties of cement bonded particle board from four tropical hard wood. The Malaysian Forester. Vol. 50, No.1.Jan.107-134

Badejo, S.O.O.(1988): Effect of flake geometry on properties of cement-bonded particle board from mixed tropical hard woods. Wood science Technology 22:357-370

Badejo, S.O.O.(1989). Influence of pre-treatment temperature and additive concentration on the properties of cement-bonded particle board from plantation grown tropical hard wood. Trop. Sci., 29, 235-296.

Chittenden ,A.E. Hawkes, A.J,; Harmitton, H.R., (1975): Wood-cement systems. Background paper, world consultation on wood based panels. FAO/UNDP/FO/WC.WBP/75, New Delhi, India.178pp.

Dinwoodie, J.M, and Paxton B.H. (1983). Wood-cement particle board- a technical assessment. Build. Res. Estab. Inf. NO 4/83.

Fuwape, J.A. and Oyagade,A.O. (1993). Bending strength and tropical wood. Bioresources technology 4377-79.

Omole, A.O and S.O. Badejo(1999). Effect of process variables on the strength properties of veneer laminated cement bonded particle board from mixed tropical hardwood. Journal of tropical forest resources.16(1):66-71.

Omole, A.O. (1994). Technical assessment of veneer laminated cement bonded particleboard produced from mixed Nigerian hardwoods. B.Tech. project report. Department of forestry and wood technology. Federal university of technology, Akure, Nigeria pg 67.

Omoluabi, A.B. (1982): Demand prospects for particle-wood in Nigeria. M.sc. thesis, Department of Forest Resources Mgt. University of Ibadan. 97pp

Oyagade, A.O. (1988): Thickness swelling and water absorption of cement-bonded particle as influenced by three variable. The Nig.Jour.of For. Vol.18.Nos.1 and 2: 20-27

Oyagade, A.O. (1990). Effect of cement/wood ratio on the relationship between cement-bonded particle board density and bending properties. Journal of Tropical For.Sci. 7:211-219.

Oyagade, A.O (1992): Compatibility of some tropical hardwood species with Portland cement. Journ. Of tropical For. Science 6 (4): 387 – 396.

Oyagade, A.O.,S.O. Badejo and A.O.Omole (1995). A preliminary evaluation of the flexural properties of wood veneer laminated cement bonded particleboard from tropical hardwood species. Journal of Timber Development Association, India.XLI(3):25-29.