INORGANIC-BONDED STRAND BOARD MANUFACTURED FROM YAM (D*ioscorea rotundata)* STRANDS

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ABSTRACT

White yam (*dioscorea rotundata*) strands with ordinary Portland cement (opc) were mixed together to manufacture cement-bonded strandboards of 6 mm in thickness. Board density and additive concentration were factors varied with mixing ratio as a constant factor. Bending strength and dimensional stability were evaluated with the aim of selecting the most suited levels of combinations for board manufacture. As the board density and additive concentration increased, the bending strength increased and dimensional movement decreased. boards produced at the highest levels of board density (1200kg/m^3) and additive concentration (3%) were structurally stronger and dimensionally stable as they were able to resist the springback forces and movement as a result of contact with moisture. Yam strands proved to be suitable for the manufacture of cement-bonded strandboards after hot water pretreatment.

KEYWORDS: inorganic- bonded strand boards; additive concentration; board density

INTRODUCTION

Inorganic – bonded composites are versatile panel products usually used as building materials for interior and exterior works. They are structurally strong and highly durable than resin-bonded boards, as they offer higher resistance against moisture movement, fire, fungus, termite and any other biodegradable agents. They also have resistance to flexural forces in bending and tensile forces in stiffness which causes stress and strain on the bonds

As a result of the releases of formaldehyde and toxic substances in production of resin bonded particleboards and that of harmful hazardous and cancerous materials from asbestos, new products that are free of all these harmful substances have been developed from available local raw materials. These products are produced using locally adaptable production process to manufacture inorganic – bonded value added boards that meet the requirements for various applications. The production process is environmentally friendly and does not emit any form of toxic or poisonous materials. Researchers, Scientists and Technologists have investigated the suitability of Tropical Hardwood and the by-products generated from the industrial processing of the timber for boards production. This research effort was due to the availability of wood raw materials at low cost, inorganic binders, simplicity in the production process, and availability of cheap labour force to produce, process and manufactures the boards. Lots of small and medium scale manufacturing enterprises are springing up and more are being developed at increasing rate using locally available technology. However the problems pose by hardwood in enhancing adequate compatibility with cement has been surmounted through the use of hot water extraction mechanism. Inhibitory water soluble sugars and other extractives can be extracted by this means. Also the addition of curing reagents will improve the bonding of wood with cement (Blackenhorn *et al* 1994, Kossatz *et al* 1994, Miller and Moslemi 1991and Moslemi and Lim 1984). Such processed and treated wood particles are found to be suitable for the production of strong boards (Ajayi, 2000). As a result of over exploitation of commercial timber and lesser known species, research search light is pointing towards the utilization of agricultural by-products for similar use in board production and possibly on commercial basis. Some agricultural by-products such as coffee chaff (Ajayi, 2005), maize stalk (Ajayi, 2006), banana stem with sawdust (Ajayi, 2003) have been investigated and found suitable for boards' manufacture which is capable of meeting the local and international standard specifications for commercial utilization and applications.

Yam stem is being considered as suitable material for inorganic – bonded particleboards. Yam belongs to the family of Dioscorea, for the purpose of this study; white yam (*Dioscorea rotundata)* stem was used. It is intensively and widely cultivated in Nigeria and has its tuber buried inside the ground. The stem is like a rope, which twines around a stick usually of 2.5 – 3 meters high, as it cannot stand upright on its own (Plate 1). Naturally, Spine and Wings are present on the stem, the leaves grow on the nodes and the diameter at the nodes is greater than internodes. The internodes are bigger at the stump and thinner toward the top. Yam is planted twice a year, at water logged area during the dry season (Plate 2) and other land area during the raining season. Yam tubers can be harvested when the stem is green or dried. (Plate 3) The stem is left on ground after harvesting as it is of no economic value to the cultivators. In 2001, 2002, 2003, and 2004, the total yam tubers harvested was put at 26.42 million, 27.59 million, 28.98 million and 32.55 million tones respectively (Central Bank of Nigeria, 2005). The purpose of this study is to investigate the suitability of yam stem for inorganic–bonded boards and to examine the flexural resistance to modulus of rupture, modulus of elasticity and reaction of boards to water immersion.

MATERIALS AND METHOD

White yam (*Dioscorea rotundata)* stem was harvested in dried form at the author's farm at Akure and that of Federal College of Agriculture in Akure, Ondo State, Nigeria. The stem was removed from the yam stakes twined together and loaded inside collection bags for easy transportation to the laboratory environment. The yam stem was further dried for 14days with constant agitation during which the spines and the bark were removed naturally.

The nodes were cut off by the use of pen knife, this was done to prevent the formation of weak points in the boards produced as its function is similar and like that of knot in wood. The internodes were sliced into two, the fluffy materials in the core were scraped and the spines at the bark dropped naturally. Each strand is equivalent to the length of the internodes, but they are not of the same length. They were then processed into homogenous strands by Hammer mill and received hot water treatment inside aluminium pot at temperature of 80^0C for one hour to remove the available water soluble inhibitory substances which may inhibit the setting of the cement when the boards are manufactured. They were later washed in cold water for 10 minutes; the leachate was separately removed and exposed to atmospheric air condition for 14 days. The strands were transferred to controlled laboratory room at 12% approximately where the quantity required for each board was measured out into a mixer. This was then treated with calcium chloride ($CaCl_2$) solution and mixed with ordinary Portland cement in a ratio of 2:1 based on oven dry weight, the mixture was manually spread out evenly inside a wooden mould of 350 mm x 350 mm that was placed on metal caul plate already wrapped with polythene sheet. The mat formed was pressed down using plywood sheet, and then replaced with polythene sheet, before it was transferred to the cold press under pressing pressure of 1.23 N/mm^2 for 24 hours, thereafter board was removed from the mould. Similarly several mats were formed, pressed, stacked and stored inside sealed polythene bags to further cure for 14 days. Thereafter boards were trimmed to avoid edge effect on the test specimens, while the rest were cut into standardize test specimens of 194mm x 50mm and 152mm x 152mm by circular saw and to determine the board bending strength and dimensional stability respectively. Subsequently, all tests were carried out by applying the test procedures stated in ASTM D (1978). Bending strength specimens were supported equally on each side at the points measuring 17 mm to both edges. Loads were centrally applied at uniform rate until deflection seizes, Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) was determined. Dimensional stability test was done by arranging the specimens vertically inside the trough and cold water was poured until they were submerged completely. After 48 hours, boards were removed and the thickness swelling, water absorption and linear expansion were determined. Data were analysed to determine the effect of production variables and their interaction on board properties. Multiple comparison tests was carried out using Least Significant Difference (LSD) to examine which of the three levels of each production variables has significant effect on the board properties.

RESULTS AND DISCUSSION

MODULUS OF RUPTURE AND MODULUS OF ELASTICITY

The flexural behaviour and good reaction to static bending was associated with cumulative effect of levels of board density and curing agents used in board manufacture. Table 1 summarizes the results of MOR and MOE as determined at 3 – point flexural resistance points. The mean values range between 6.99 N/mm^2 and 13.99 N/mm^2 for MOR and 6052.50 N/mm^2 and 7724.80 N/mm^2 for MOE. Figures 1 and 2 show the effects of board density and additive concentration on MOR and MOE. Increase in board density and curing reagent (calcium chloride) was responsible for the increase in mean values of MOR and MOE. This implies that more mass of yam stem and calcium chloride were available at increasing rate up to maximum levels of 1200kg/m^3 and 3% respectively. Therefore the effective performance of boards under applied load was the result of the effective bonding created by board density and calcium chloride in producing sound boards of high compatibility and good strength. This therefore suggests that boards produced at these levels were structurally stronger than other boards and those boards made under similar production variables but with different raw materials, such as wood and other agricultural by-products. For example the MOR values recorded for board made from *Gmelina arborea* ranged from 7.68 N/mm^2 to 9.75 N/mm^2 and *Gmelina arborea* + *Leucaena .luecocephala* from 5.49 N/mm^2 to 8.93 N/mm^2 (Ajayi 2000), mixed hardwood from 4.94 N/mm^2 to 9.16 N/mm^{2,} and MOE values ranged from 2340 N/mm^2 to 3840 N/mm^2 (Badejo 1999). While the MOR values for maize stalk-based boards ranged from 1.17 N/mm^2 to 5.35 N/mm^2 and the MOE values ranged from 1033.07 N/mm^2 to 6409 N/mm^2 (Ajayi 2006).

At the highest board density (1200kg/m^3) and additive concentration (3.0%), bundles of strands were compactly packed and bonded together to form strong, dense and stone-like panels. This was achievable due to long interfacial contact areas between the adjoining strands lengthwise with increased number of bonds. The inclusion of the calcium chloride was to accelerate the cement hydration and setting process. Production of stronger and heavier boards was attributed to consistent increase of all the production variables involved in boards manufacture (Ajayi 2006) .The result of the analysis of variance in Table 2 shows that significant differences exist in the MOR with board density, additive concentration and the interaction of the two factors of production. In the case of MOE, significant differences do not exist with board density and the interactions of the two factors. Multiple comparison tests (LSD) in Table 3 shows significant differences in MOR with board densities between 1000 kg/m^3 and 1100 kg/m$^{3;}$ 1100 kg/m^3 and 1200 kg/m$^{3;}$ and 1200 kg/m^3 and1000 kg/m^3. For additive concentration, the differences that exist between 1% and 2%; 2% and 3%; 3% and 1% are significant at 0.05 level of significance. For MOE, the significant difference is between 1200 kg/m^3 and 1000 kg/m^3, but the differences between 1000kg/m^3 and 1100 kg/m^3; 1100 kg/m^3 and 1200 kg/m^3 are not significant. For additive concentration, the differences which exist between 1% and 2%; 2% and 3%; 3% and 1% are significant at 0.05 level of significance.

THICKNESS SWELLING; WATER ABSORPTION AND LINEAR EXPANSION.

The summaries of the mean values for thickness swelling, water absorption and linear expansion following 48hours soak in cold water ranged between 1.96% and 3.28%; 14.01% and 18.05%; 0.29% and 0.17% respectively (Table 1). Better boards stability was achieved as the board density and calcium chloride content increased (figures 3,4 and 5) thereby making it possible to have the lowest values for TS, WA, and LE at the highest board density(1200kg/m^3) and additive concentration (3.0%). Suffice to say therefore that the two production variables affected the dimensional movement of boards when immersed in water. The compression stress releases and spring back of boards occurred when in contact with water but the degree of this reaction brought about the highest property values at the lowest levels of board density and additive concentration (Ajayi, 2006). The concrete nature of boards produced at the highest levels of the two variables was attributed to the increase in boards compatibility due to highest mass of yam strands involved in boards manufacture.

This may also be responsible for the increase in the hardness of boards as they showed highest resistance to TS, WA and LE (Ajayi 2000; Ajayi 2006; Ajayi 2005). Boards from yam stem are more dimensionally stable than those made under similar production variables but with different raw materials. For example, the mean values for TS and WA ranged from 2.15% to 6.69% and 27.33% to 32.14% for *Gmelina aborea*- based board; 1.80% to 7.25% and 27.71% to 32.55% for *Leucenea leucocephala*- based board (Ajayi 2000) and 2.25% to 2.94% and 30.13% to 36.51% for maize stalk – based board (Ajayi 2006).

Yam strands appeared to be more suitable for board production than those materials experimented upon as they remain more stable dimensionally. Boards produced at the highest combination of the two variables stand out to be stronger, heavier, compact and concrete–like in nature. This was as a result of high compression ratio and compatibility of the boards, which reduced the quantity and the number of void spaces when compared with other boards. This again justified the reduction in swelling, spring back forces, absorption of water and linear movement.

The analysis of variance in Table 2 shows significant differences in the TS, WA and LE with board density and additive concentration at 0.05% level of significance. The interaction of the two factors of production had significant effect on TS only and not on WA and LE. The result of multiple comparison tests investigated by least significant difference in Table 3 shows that for board densities between 1000 kg/m^3 and 1100 kg/m^3; 1100 kg/m^3 and 2000 kg/m^3; 1200 kg/m^3 and 1000 kg/m^3 significant differences occurred in the TS, For additive concentrations between 1% and 2%; 2% and 3%, 3% and 1% significant differences also exist in TS. Similarly, significant differences exist in the WA of boards between boards' densities of 1000 kg/m^3 and

1100 kg/m^3; 1100 kg/m^3 and 1200 kg/m^3; 1200 kg/m^3 and 1000 kg/m^3. Also for additive concentration between 2% and 3%; 3% and 1% but the difference between 1% and 2% is not significant. Significant differences occurred in LE of boards between boards' densities of 1000 kg/m^3 and 1100 kg/m^3; 1100 kg/m^3 and 1200 kg/m^3; 1200 kg/m^3 and 1000 kg/m^3 and for additive concentrations between 1 % and 2%, 2% and 3%; 3% and 1% significant differences exist.

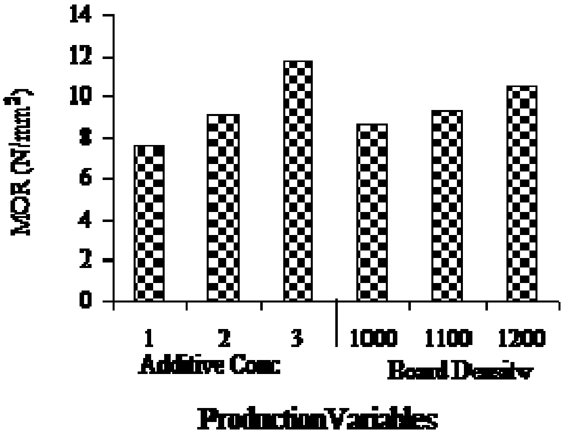

Figure 1: Effect of Production Variables on MOR

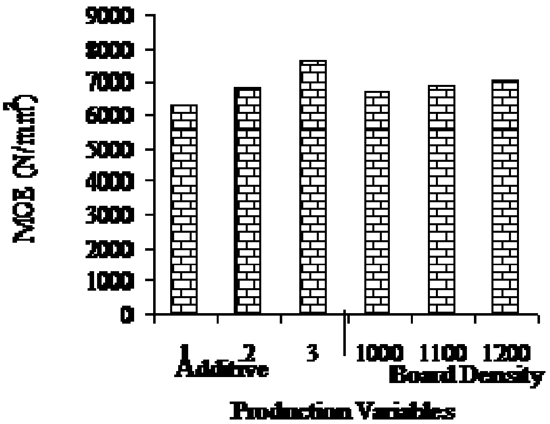

Figure 2: Effects of Poduction Variables on MOE

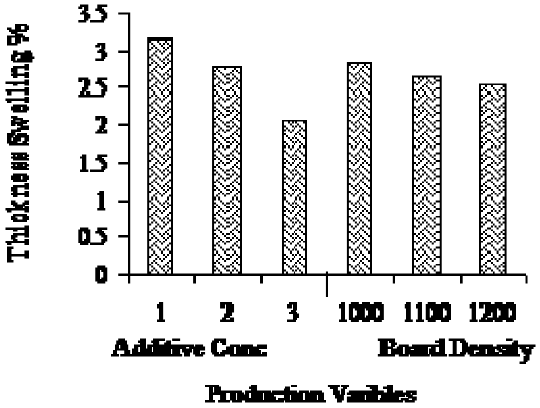

Figure 3: Effects of Production Variables on TS

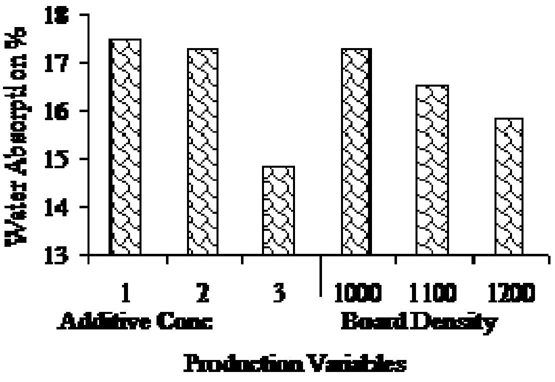

Figure 4: Effects of Production Variables on WA

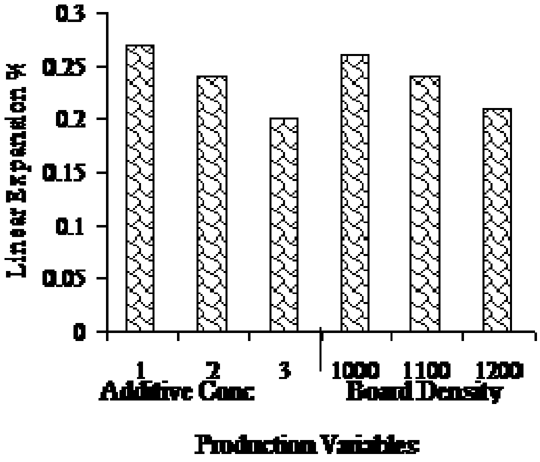

Figure 5: Effects of Production Variables on LE

Table 1 Mean Values of all the Properties Examined.

Additive conc%	Board Density kg/m^3	TS	WA	LE	MOR	MOE
1.0	1000	3.28 ± 0.02	18.05 ± 0.80	0.29 ± 0.01	6.99 ± 0.86	6052.50 ± 815.01
1.0	1100	3.19 ± 0.01	17.59 ± 0.81	0.27 ± 0.14	7.90 ± 1.38	6249.70 ± 695.12
1.0	1200	3.02 ± 0.02	16.89 ± 0.85	0.24 ± 0.02	8.01 ± 0.81	6525.20 ± 102.14
2.0	1000	2.98 ± 0.01	17.88 ± 0.75	0.26 ± 0.02	8.72 ± 0.72	6648.10 ± 101.21
2.0	1100	2.75 ± 0.02	17.48 ± 1.48	0.25 ± 0.02	9.02 ± 1.39	6782.50 ± 129 01
2.0	1200	2.63 ± 0.01	16.58 ± 0.75	0.22 ± 0.01	9.62 ± 0.82	7025.40 ± 37.72
3.0	1000	2.21 ± 0.11	15.98 ± 0.79	0.23 ± 0.02	10.15 ± 0.04	7525.50 ± 164.11
3.0	1100	2.00 ± 0.03	14.57 ± 0.35	0.19 ± 0.01	11.02 ± 0.03	7628.30 ± 155.78
3.0	1200	1.96 ± 0.02	14.01 ± 0.02	0.17 ± 0.01	13.99 ± 0.01	7724.80 ± 7523

Table 2 Analysis of Variance for all the Properties Examined.

Source of Variation	Degree of freedom	TS	WA	LE	MOR	MOE
Additive con (AC)	2	11171.89*	39.03*	57.01*	71.97*	40.12*
Board density (BD)	2	724.56*	9.70*	25.57*	15.89*	2.68^{ns}
AC X BD	4	25.43*	0.536^{ns}	0.94^{ns}	4.89*	0.15^{ns}
Error	27	-				
Total	36	-				

TABLE 3 Least Significant Difference for all the properties examined

FACTOR	LEVEL	TS	WA	LE	MOR	MOE
Additive concentration	1	0.38a	0.19a	0.02a	1.49a	542.87a
	2	0.73b	2.46b	0.05b	2.60b	807.53b
	3	1.11c	2.66c	0.07c	4.09c	1350.40c
Board density	1000	0.17a	0.76a	0.02a	0.69a	144.80a
	1100	0.11b	0.72b	0.03b	1.23ab	204.97b
	1200	0.29c	1.48c	0.05c	1.92c	349.77c

Plate 1: Yam Stem Twinned Around the Stakes

Plate 2: Yam stem with Tuber Buried inside the ground

Plate 3: Yam Tuber Harvested at Collection Point

CONCLUSION

Yam stem, a by-product of agriculture was found to be suitable raw material for the manufacture of stranboards with cement as the binder. Boards made at the highest levels of the two factors of production were more stable dimensionally and with greater flexural strength than other boards. Increase in board density and additive concentration gave rise to increase in modulus of rupture and modulus of elasticity, and decrease in thickness swelling, water absorption and linear expansion. They were significantly affected by those factors of production. The study revealed improvement in strength, springback and movement when compared with previous studies using similar parameters, and after hot water extraction of the fibrous materials used before reinforcement with inorganic binder. It is recommended that further research activities could be put in place to investigate the suitability of other agricultural by-products for composites manufactured.

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