PHYSICO-MECHANICAL PROPERTIES OF CEMENT BONDED BOARD FROM MIXTURE OF AGRO-WASTE.

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ABSTRACT

Physico-mechanical properties of cement bonded board produced from rice chaff and maize stalk at the blending proportions (BP) of 100:0, 75:25, 50:50, 25:75, 0:100; and mixing ratio (MR) of cement to agro-waste at 2:1 and 3:1 were investigated. The influence of BP and MR on the water absorption (WA), thickness swelling (TS), modulus of rupture (MOR) and modulus of elasticity (MOE) were determined. Increase in BP and MR caused decrease in WA and TS and increase in MOR and MOE. Board produced from 100% rice chaff (100:0) has the lowest physico-mechanical properties than that from maize stalk (0:100). Board produced from BP 25:75 and MR 3:1 exhibits highest properties. The WA, TS, MOR and MOE were significantly affected by the MR and BP. The agro-waste residues are suitable raw material for the manufacture of value-added panel products for core and social housing for low income citizens.

KEYWORDS: Blending proportion, Mixing ratio, Physical and Mechanical Properties, Agro-waste and Cement Bonded Board

INTRODUCTION

The advent of technology provides solutions to environmental health and economic implications of bio-residues such as wastes from agriculture and wood processing outfits by the production of value added panel products (Ajayi, 2000 and 2006a) for economic growth and use. These requirements justified a series of research efforts aimed at achieving different objectives in the judicious use of agricultural residues and wastes, In 2006, the annual global production of lignocellulosic fibres from agricultural crops was about 4 billion tons, of which roughly 60% came from agricultural crops and 40% from forests (Justiz-smith *et al*; 2008). There is the growing need therefore to use these non-valuable huge agricultural wastes for the production of value-added boards. The benefits derivable include: increase farmers' income and alleviate poverty, increase raw material supplies for construction, create job opportunities, increase food production and reduce pressure on other forest resources (Ajayi 2006a). Agricultural residues have been steadily gaining popularity as alternative sources of raw materials for the manufacture of cement-bonded boards (Ma *et al*; 2000 Ndazi *et a*l; 2005; and Ajayi, 2011a). These agricultural wastes and residues include bagasse, banana stem, maize stalk, yam stem; coffee chaff and cotton stalk among others (Ajayi 2003, Adewopo, 2007, Ajayi, 2006a and 2006b).

A cement-bonded particleboard is a value-added composite material made from wood/ agriculture particles, inorganic binder and a catalyst. The product can be formed into different shapes to meet specific end uses. The development and manufacture of this product is due to: 1) recognition of the suitability of a wide range of raw materials for board production, 2) desires to increase bio-wastes resources, 3) acceptability of the new products in the market and construction industry, and 4) the desire to protect forest biodiversity (Ajayi, 2006a).

Cement-bonded board is considered to be a suitable raw material for internal and external buildings construction due to its inherent qualities such as resistance to insect, termite and fungal attack; high resistance to moisture, freezing and fire; good insulation properties, durability and nailing ability and because its dust is non-aggressive and non-contagious(Ajayi, 2006a and Olanike *et al*, 2008). The acceptance of cementitious materials is based largely on their reliability against fire and insect attack as well as decay, in addition to their perceived performance during natural disasters such as earthquakes and tropical storms (Ramirez-Coretti *et al*, 1998). Cement bonded board is environmentally friendly as it does not emit harmful chemical substances during and after manufacture or while in service (Ajayi, 2006c).

The study was carried out to evaluate the physical and mechanical properties of cement-bonded particleboard made from mixture of rice chaff and maize stalk.

MATERIALS AND METHOD

Raw Materials Procurement and Preparation

The rice chaff used in this study was collected from a local rice processing mill at Akure, Ondo State. The rice chaff was dried and dirty particles were screened out. The maize stalks were harvested in dry form and cut into billets at each node. The nodes were cut off and the spongy-like substances inside the core of the stalk were also removed. A machete was then used to reduce the stem into flakes and later sun dried.

The maize stalk flakes were hammer milled and the particles were sieved with a 2 mm wire mesh in order to obtain homogenous particles. The rice chaff was separated from the residual rice by air classifier. Both materials were pre-treated with hot water at 80°C for 1 h in different aluminium containers to remove the chemical substances present that may possibly inhibit cement setting. The water soluble extractives were drained and the particles were washed with cold water. The particles were then air dried to about 12% moisture content under a controlled environment for 2 weeks prior to board production.

Experimental Design

The experimental design was based on the blending proportion of agro by-products (rice chaff and maize stalk) at 0:100, 25:75, 50:50, 75:25 and 100:0 levels with mixing ratio (2:1 and 3:1). Board density (1200 kg/m^3), $CaCl_2$ (3%), pressing pressure (1.23 N/mm^2) was applied and the Water requirement was calculated as follows; (litre) = 0.60C + (0.3 – MC) W. Where C = Weight of cement (kg), MC = Moisture content (%), W = Weight of agro waste (rice chaff and maize stalk) particles.

The experimental design was 2 × 5 factorial experiments in complete randomized design (CRD). All combinations gave 10 treatments.

Board Production

The quantities of cement and agro by-products were weighed and poured into a plastic bowl, added to it was Calcium Chloride-Water mix. The material was thoroughly mixed to avoid formation of lumps. A wooden mould (350 mm x 350 mm) was placed on a metal caul plate covered with polythene sheets to enhance easy de-moulding and prevent the sticking of the board on the plate. The mixture was spread out on the plate and thereafter a wooden press was used to press down the mattress within the mould to allow uniform mat formation. It was later covered with another polythene sheet after which a top plate was placed on it and transferred to the cold press for a period of 24 hours. Thereafter the board was removed from the press for further curing. All the boards were produced following the same method. The boards were kept inside a polythene bag for 28 days to enhance further curing of the cement paste.

Testing

The board edges were trimmed with circular saw to avoid edge effect and each test specimen was cut into the required sizes according to the American Society for Testing and Materials (ASTM) 1978. The following tests were carried out on all the samples; Bending strength test and dimensional stability.

Mechanical Properties Test

The test was carried out using the universal testing machine. The test specimens of size 195 mm × 50 mm × 6 mm were cut out of the boards and tested. Load was applied at the centre of the specimen until failure occurred and thereafter, the properties were assessed.

Physical Properties Test

Sample size 152 mm × 152 mm × 6 mm were cut out of each board and each was weighed. Readings were recorded. The test specimens were soaked in water for 24 hours and properties were evaluated.

Statistical Analysis

Analysis of variance was used to test the effect of production variables on board properties while Duncan Multiple Range Test (DMRT) was used in examine the effect of each level of the factor of production on board properties investigated.

RESULTS AND DISCUSSION

Table 1 - Summary of the Mean Values for MOR, MOE, WA and TS

Mixing Ratio (MR)	Blending Proportion (BP)	Modulus of Rupture (MOR) N/mm^2	Modulus of Elasticity (MOE) N/mm^2	Water Absorption (WA) %	Thickness Swelling (TS) %
2:1	BP_1 100:0	0.707±0.03	1512.86±11.21	34.400±0.62	19.533±0.08
	BP_2 75:25	2.273±0.08	2891.20±27.56	27.843±0.21	16.673±.0.68
	BP_3 50:50	5.140±0.15	3946.81±50.32	27.020±0.10	8.643±0.52
	BP_4 25:75	5.430±0.08	5326.79±32.95	25.067±0.55	5.367±0.41
	BP_5 0:100	5.500±0.15	5525.64±23.17	20.570±0.71	3.417±0.18
3:1	BP_1 100:0	0.820±0.04	1724.51±9.97	22.693±0.16	12.763±0.68
	BP_2 75:25	4.370±0.06	3708.30±9.13	22.210±028	10.330±0.29
	BP_3 50:50	4.750±0.02	4571.13±8.21	15.700±0.20	5.817±0.14
	BP_4 25:75	6.650±0.06	5303.03±16.75	14.137±0.24	4.140±0.13
	BP_5 0:100	7.353±0.07	6415.59±26.07	12.980±0.45	1.930±0.16

Table 2 - Analysis of variance for modulus of rupture (MOR), modulus of elasticity (MOE), thickness swelling (TS) and water absorption (WA).

Source of Variation	Degree of freedom	MOR	MOE	WA	TS
Mixing Ratio (MR)	1	589.29*	3046.28*	4069.00*	676.44*
Blending Proportion (BP)	4	2637.00*	2831.00*	778.17*	1288.00*
MR*BP	4	144.44*	375.24*	65.82*	68.510*
Error	20				
Total	29				

"*" denotes significant ($p<0.05$), "ns" denotes not significant ($p>0.05$) and MR*BP denotes interaction between mixing ratio and blending proportion

Table 3 - Duncan multiple range test (DMRT) for blending proportion

Blending proportion	Modulus of rupture MOR	Modulus of elasticity MOE	Water absorption WA	Thickness swelling TS
100:0	0.763[d]	1618.68[e]	28.546[a]	16.148[a]
75:25	3.321[c]	3299.75[d]	25.026[b]	13.501[b]
50:50	4.945[b]	4258.97[c]	21.360[c]	7.230[c]
25:75	6.040[a]	5314.91[b]	19.601[d]	4.753[d]
0:100	6.427[a]	5970.61[a]	16.775[e]	2.673[e]

Data followed by the same letters are not significantly difference from each other

Physical Properties

Water Absorption and Thickness Swelling

Table 1 shows the mean values for water absorption (WA) and Thickness Swelling (TS) after 24 hours immersion in cold water. The mean values for WA and TS ranged from 12.98% to 34.40% and 1.93% to 19.53% respectively. The WA and TS values show decrease with the increase in mixing ratio and blending proportion. The board with the lowest water absorption and thickness swelling rate was obtained from the highest mixing ratio 3:1 (cement/agrowaste) and blending proportion of 25:75 (rice chaff/maize stalk). This therefore suggests that increase in mixing ratio and blending proportion caused decrease in water absorption and thickness swelling (Figures 1 and 2). This can be attributed to the increase in cement content in the boards which lead to complete coating of the particles as obtained in boards produced from mixing ratio 3:1and blending proportion of 25:75. As a result, a low spring back characteristic exhibited was due to the reduction in the release of compression stress after demoulding and when in contact with water. The stone-like nature of the boards may be attributed to the cement content increase which is responsible for increase in hardness of boards. The highly densified boards produced was due to greater cement/wood compaction, better inter-particle contact and improvement in quality and quantity of bonds in boards, elimination or reduction of void spaces in the panel by the cement paste to resist the spring back of boards. Increased number of void spaces may cause board's spring back, thickness and increase in water intake. Similar results were obtained by (Yarbrough, *et al*., 2005 and Ajayi, 2011b).

The analysis of variance result in Table 2 shows that water absorption; thickness swelling and the interaction of the two factors were significantly affected by the mixing ratio and blending proportion. The Duncan Multiple Range Test (DMRT) shows that there is significant difference in water absorption and thickness swelling between individual blending proportions (Table 3). Boards produced at each level of the blending proportion were significantly different from each other.

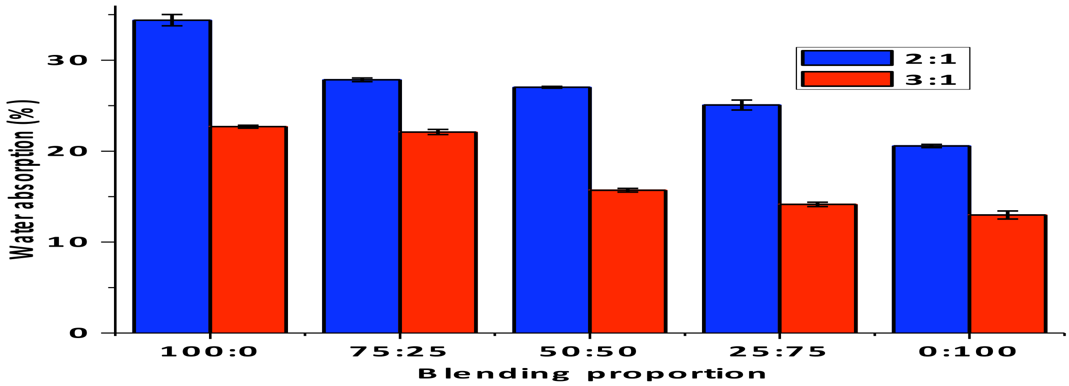

Figure 1 - Effect of mixing ratio and blending proportion on water absorption of the board produced.

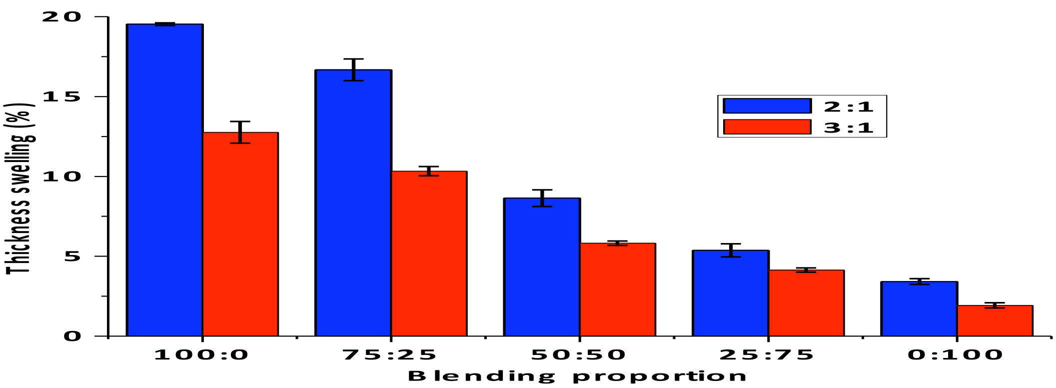

Figure 2 - Effect of mixing ratio and blending proportion on thickness swelling of the board produced.

Mechanical Properties

Modulus of Rupture and Modulus of Elasticity

Table 1 shows the mean values of modulus of rupture (MOR) and modulus of elasticity (MOE) as they ranged from 0.71 N/mm^2 to 7.35 N/mm^2 and 1512.86 to 6415.59 N/mm^2 respectively. The MOR and MOE of boards were affected by the mixing ratio and blending proportion as it shows progressive increase in the values of the strength properties under investigation (Figures 3 and 4). The influence of blending proportion becomes increasingly significant as the proportion of agrowaste and that of cement in the matrix increased (Oyagade 1990, Giemer *et al* 1993, Ajayi, 2006a,). Result further revealed that strongest and stiffest experimental boards were produced at the highest levels of blending proportion (rice chaff/agrowaste 25:75 and cement/agrowaste ratio 3:1. The increase was due to the amount and increased quantity of maize stalk particles in the blended materials. This shows that board with the highest strength capacity to withstand bending force was produced at optimum mixture of rice chaff (25%) to maize stalk (75%) with the highest cement content. this phenomena gave rise to greater compaction of boards due to increased number of bonds, inter particles contact areas and adequate encasing of the particles with cement. The greater bonding quality and cohesive strength inherent in the boards manufactured from high cement/wood ratio and high blending proportion must probably accounts for their glaring flexural strength (Ajayi, 2006a, Ajayi, 2011).

The result of analysis of variance presented in Table 2 shows that MOE and MOR are significantly affected by mixing ratio, blending proportion and the interaction between mixing ratio and blending proportion. The follow up test in Table 3 shows that there is no significant difference between the boards produced at the blending proportion of rice chaff to maize stalk of 0:100 and blending proportion of 25:75.

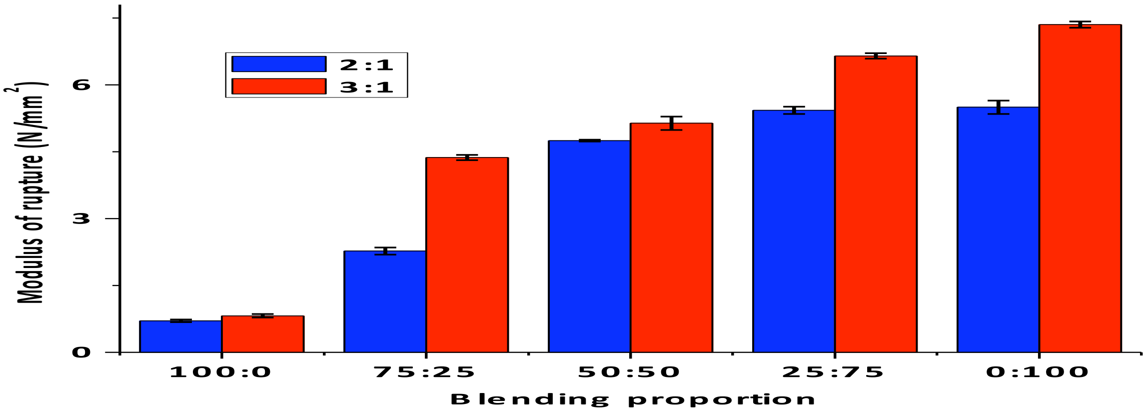

Figure 3 - Effect of mixing ratio and blending proportion on modulus of rupture on the board produced.

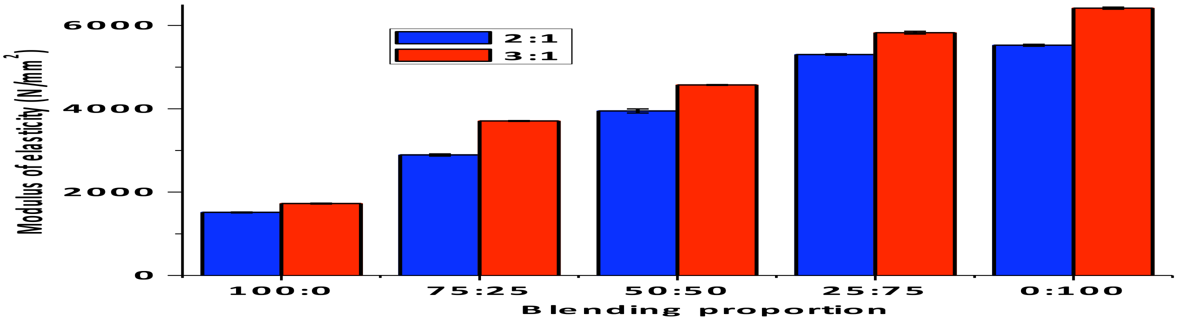

Figure 4 - Effect of mixing ratio and blending proportion on modulus of elasticity on the board produced.

CONCLUSION

The study has indicated that cement-bonded boards could be produced from agro wastes at different mixture and blending proportion. The TS and WA assert the behaviours of boards under moisture fluctuations whereas MOR and MOE present board's reactions to loading. Board produced at the highest level of blending proportion and mixing ratio was most stable, strongest, stiffest and showed highest resistance to stress posed by both test treatments. The production variables and their interactions showed significant differences on both the physical and mechanical properties examined. The study has set standard for commercial production of value added panel products needs for low cost housing and construction works.

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