Development of Roofing Tiles from Bamboo Flakes Treated with Magnesium Chloride

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Abstract

The quest for alternative building materials, easy availability with supply in an economy where the population increases at high rate in a steady flow per year. Bamboo as a renewable, sustainable alternative material is explored for the production of roofing tiles, *Bambusa vulgaris* were chipped into flakes, sieve and further subjected to modified conventional treatment, the flake were oven dry in a control temperature of 170°C to Moisture Content range of 11- 12 %, Portland cement were employed as a binder, using batch method of mixing in the production of the roofing tiles. Moisture content, density of the roofing tiles, thickness swelling and impact test were determined, the average moisture content of the tiles12.7%, average density 0.031g/cm^3, average thickness swelling which showcases the dimensional stability of the tiles is 0.75%. The impact test is 2.6N/mm^2. The various results obtained were favourable suggesting that bamboo most especially of the *Bambusa vulgaris* can be suitable raw material and substitute material to wood for the production of roofing tiles.
Keywords: Bamboo Flakes, cement, roofing tiles, Magnesium Chloride ($Mgcl_2$**).**

INTRODUCTION

Bamboo as a renewable material has similar environmental characteristics to wood, (Lee *et al*, 1993 ; Rittironk and Elnieiri,2007) . Bamboo is one of the oldest building materials used by mankind (Abd.Latif *et al*.1993).It is conceivable that bamboo could become a sustainable alternative to current building materials in Asia and North America; with sufficient and adequate research(Mahdavi *et al.* 2011). On account of the enforcement of our natural forest protection project in Nigeria, wood is becoming increasingly scarce. The realization that bamboo is the most potentially important non- timber resource and fast –growing woody biomass has evoked keen interest in the processing, preservation, utilization and the promotion of bamboo as an alternative to wood (Janssen, 2008). Its use as top grade building material availability makes bamboo material always sought for in the field of construction. Its high valued utilization not only promotes the economic development but also reduces pressure on our forest resource and protects the environment when used as wood substitute. It has tremendous economic potential products. Also, its wide availability offers great opportunities to the micro, small and medium scale enterprises (Markus, 2008). The area of this study Cross River State is home to bamboo species *Bambusa vulgaris* aside the mangrove forest. The state has a rich reserve of commercial tree species in Afi forest reserve, though the forests area is depleting due to growth in population size and exploitation activity of the host communities. Bamboo is one of the major non- wood materials forest resources. Basically, bamboo is used majorly for scaffold and decking. After that, it is refer and regard as waste maerial often used as bio-fuel for cooking, whereby generating carbin monoxide to the environment (Adewole 2013) evaluated selected physical and mechanical properties of furniture produced from bamboo recovered from scaffold . The result showed efficient resistance to bending and deflection. (Ghavami, K. 1995) also investigate on ultimate load behavior of bamboo reinforced lightweight concrete beams and result showed a distinctive property of bamboo with increasing flexural tensile strength and toughness of the composite.

METHODOLOGY

Bamboo culms (*Bambusa vulgaris*) were harvested from the forest, and air seasoning for seven days, the bamboo were split into small pieces with a Rip saw, then further seasoned for one week to obtained equilibrium moisture content of 20 to 18%, so as to ensure the breakdown of extractives which are known to adversely affect bonding of cement. The dried specimens were crosscut using a cross cut machine and mill into flakes, using planning machine. Thereafter, the flakes were sieves with the sieves size of 2mm and 0.05mm respectively.

The sieve flakes were soaked in a treatment vat containing distilled water. After 36mins they were subjected in 2 treatment schedules: +0.5 magnesium chloride, soaked + 1.5 magnesium chloride (Adewole, 2013). The flakes were then, oven dry under a control temperature range of 110^{o}C, for 5hours to 12- 15% moisture content.

Production of Bamboo Cement Composite

The treated flake was use in the production, with the following mixed ratio. Flakes, cement and preservative chemical thoroughly mixed before the addition of distill water, until slurry was formed, the cement water ratio was [1:0:55]. Flake and cement ratio was [1:2] for all the five specimens. The slurry was then cast on a locally fabricated vibrating machine with a corrugation mould. The vibrated composite was carefully protected for curing, for a day, the dry composite were then de-moulded and submerged in distill water at a room temperature (25^{o}C ± 2) for 27days, after which they are left in a room for another 24hours. Density of the roofing tiles, moisture content, water absorption and thickness swelling test and impact test were carried out on the composite produce.

Density of the roofing tile was determined using the relation shown in equation (i). The specimens were of uniform shape. The length, width and thickness were measured to estimate the volume of the specimens. The dimension of the test specimen was 500×500×200mm.

Density = Eqn (i) (Khurmi and Gupta 2005.)

Where M = masss in (g)

V = Volume (cm^3)

Moisture content of the roofing tile was determined using oven dry method in accordance with ASTM D1037, using the formula in equation (ii) shown below.

M .C (%) = $\times 100$ Eqn (ii)

Where M. C = moisture Content (%)

W_w = Initial weight (g)

W_d = Sun dried weight (g)

Water absorption and thickness swelling of roofing tiles were determined. Two specimens from each of the sample were being submerged horizontally under 800mm of distilled water maintained at a room temperature range of 27oC ± 2 ^{o}C for 24hours. The absorption after 5 hour and 24 hours were calculated from the increase in weight of the specimen after submission in water. The thickness swelling of each sample was expressed as a percentage of the original thickness. The water absorption test was estimate using the formula shown below in equation (iii).

Water Absorption = Eqn (iii)

Where W_1 = Initial weight of the specimen

W_2 = Final weight of the specimen

Thickness swelling test = Eqn (iv)

Where

T_1 = original thickness (Dry)

T_2 = final thickness (wet)

Impact test of the roofing tile was carried out. The falling ball impact test was used to measure the impact resistance of the roofing tiles. These tests were conducted in accordance to ASTM D1037 (1993). The falling ball impact test was carried out on all specimens after curing. This involved dropping a known weight from a height of 2m on the specimens. The resistant of roof tiles was estimated using the formula shown in eqn (v) below.

Velocity of the free V = Eqn (iv)

V =final velocity

momentum (Impulse of force) was calculated

momentum = mass(m) × Velocity (v)

Plate 1: Slurry on corrugated mould Plate 2: Roofing tiles produced Covered with polythene ready for drying.

Result and Discussion

Bamboo roofing tile board with dimension 500mm×500mm×10mm were produced from *Bambus vulgaris* flake bonded with Portland cement. The flake for the formula of the roofing tiles, were treated with magnesium chloride ($MgCl_2$)

Table 1: Results for density of the roofing tiles

Sample	Dimension(cm)	Mass(g)	Volume (cm^3)	Density(g/cm^3)
A	50×50×1.0	60.0	2500.0	0.024
B	50×50×1.0	65.5	2500.0	0.026
C	50×50×1.0	71.2	2500.0	0.028
D	50×50×1.0	63.2	2500.0	0.025
E	50×50×1.0	63.3	2500.0	0.025
			MEAN	0.031

The density of the roofing tiles was between 0.024 g/cm^3 - 0.028g/cm^3 with mean density of 0.031g/cm^3. *Bambusa vulgaris* has a relatively lower density when compared to other engineering construction materials but with a significant increased in mechanical property of the roofing tiles, as shown in table 1 above.

Table 2: Results for moisture content of roofing tiles.

Sample	Initial weight (kg)	Dry weight(kg) after 2hours to 24hours		Moisture content (%)
		After 2hrs	After 24hrs	
A	53.8	53.85	54.7	13.6
B	41.1	41.15	42.2	12.0
C	47.8	48.07	48.8	15.0
D	73. 4	74.00	75.1	11.5
E	61.3	62.00	62.8	11. 4
			MEAN M.C (%)	12.70

The result from the moisture content test on the five samples produced give an average moisture content 12.7% which is satisfactory for material that will be subjected to environmental condition, the bonding agent Portland cement has no significant effect on the moisture content. As shown in figure 1 below.

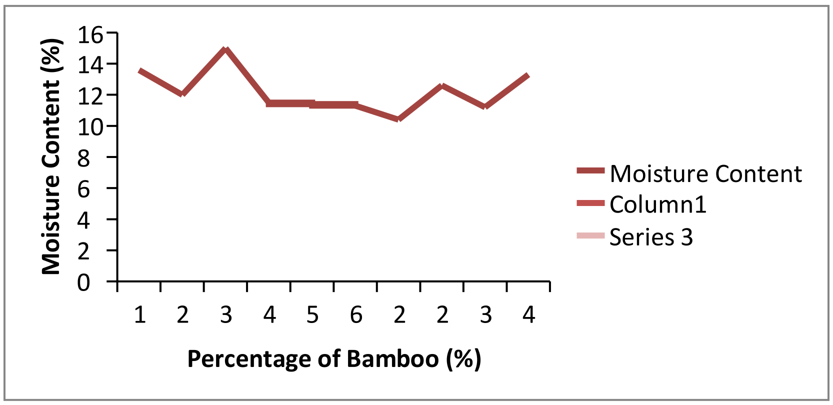

Fig 1: moisture content the roofing tiles samples (%)

Thickness swelling of the roofing tiles produced was equally tested to determine the suitability and dimensional stability in service, since bamboo as the raw materials is hydroscopic in nature. Five difference samples of the roofing tiles with difference percentage of mass of Portland cement (1%,2% 3% 2% 5%) were examined and the results obtained shows in table 3 below.

Table 3: Result of thickness swelling test of the roofing tiles

Specimen	Composition	Initial thickness (mm) T_1	Thickness swelling (mm) T_2 after 24hrs	Thickness swelling (%)
A	Bamboo- 1% mass of cement. $MgCl_2$	10.50	10.54	0.38
B	Bamboo- 2% mass of cement. $MgCl_2$	9.18	9.22	0. 44
C	Bamboo- 3% mass of cement. $MgCl_2$	8.53	8.60	0.82
D	Bamboo- 2% mass of cement. $MgCl_2$	9. 40	9.50	1.06
E	Bamboo- 5% mass of cement. $MgCl_2$	9.33	9. 47	1.50
		Mean thickness swelling		0.75

Impact test conducted on the roofing tiles is in accordance to ASTM D1037 (1998), this involved dropping a known weight from a height of 2m on the specimen and the result obtained is shown in table 4

Table4: Result of Impact test.

Sample	Dimension	Weight (N)	Height (m)	Observation
A	50×50×1.0	4	2	No crack observed
B	50×50×1.0	6	2	0.02mm wide crack
C	50×50×1.0	8	2	The roofing tiles had a wider crack on the surface, but the bamboo particles in the composite hold the tiles from breaking completely.
D	50×50×1.0	10	2	The roofing tiles were shattered.

The velocity and momentum at the instance of initial crack were determined.
The velocity of free fall

V = = =.

Conclusions and Recommendations

The study show that roofing tiles can be produced from *Bambusa vulgaris (*bamboo) grown from the area of study, Cross River State, by partially replacing bamboo and cement and introducing additive with the aim of reducing the inhibitory effect on wood on the setting of Portland cement. The cost of producing a bamboo- cement roofing tiles is of a lower rate, when compared to the cost of producing asbestos. Hence with the necessary infrastructure for the entire conversion process of bamboo flake in place it can serve as a viable alternative to asbestos in construction of roofing tiles. Bamboo when converted to flake increases it cohesive property, resistance to cracking and the ability of the composite not to disintegrate immediately even when there's a crack, shows how bamboo in the composite is able to hold the composite together. From the result obtained the density, Moisture Content (M.C), Thickness Swelling and Impact test have shown that, bamboo –cement composite have very desirable dimensional stability, when compared to asbestos. Also there is a need for appropriate equipment to be designed for it efficient conversion and sufficient laboratory test on it density, moisture content, water absorption, thickness swelling and impact test should be carried out on more sample to populate the body of knowledge of the usage of *Bambusa vulgris* for the production of roofing tiles.

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