

Development of bamboo – rice husk ash and cement mixture for livestock house roofing sheets

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ABSTRACT

The purpose of this research is to design, fabricate and install locally developed roofing sheets on a king post truss model of a livestock house using rice husk and bamboo fibers which are readily available in most Nigerian farms with some additions of cement to the mixture. The effects of ratios of Rice Husk Ash (RHA) and bamboo fibers on the impact strength, density, thickness swelling and water absorption were also investigated. The average density of the composite roofing sheet produced ranged from 1779 to 2197Kg/m³. The control test specimen density was 2376Kg/m³. The addition of pozollan decreased the density of the composite. Thickness Swelling (TS) values ranged from 0.07 to 5.97% at two hours and from 0.08 to 6.5% at 24 hours for different composition. The percentage water absorption (WA) by the composite was from 0.17 to 1.13% at 2 hrs while it was 0.21 to 1.43% at 24hrs. However further research would be carried out on the structure to determine the thermal comfort of the livestock to be kept in the building.

INTRODUCTION

Livestock are domesticated animals kept under the control of human beings and which depend on human beings solely for protection, food and shelter (Cole and Ronnig, 1974,). Livestock shelter can be defined as the protective physical infrastructure which animals require to survive. (LEGS, 2009). Housing for livestock is an important component of the animal production process because it protects the animal from inclement weather, pilferage and accidents (Y.Mijinyawa, 2010). However the cost of procuring roofing sheets which is the most important part of structure for most livestock rearers in Nigeria are usually high and this fact tend to discourage most of them from putting up livestock structure for their animals but would rather prefer to use open range method for animals and woven baskets for poultries or dilapidated buildings within their surroundings to provide shelter for their animals. Due to limited means within developing countries, it is necessary to seek ways to reduce construction costs especially for low income farmers as well as adopting easy and effective solutions for their repair and maintenance. These objectives can be achieved partially through the production and use of cheap yet durable locally available building materials (Adam and Agib, 2001). Two-third of the expenditure in housing construction goes for building materials. Production of building components using techniques imported from Western world is highly capital and energy intensive. A significant cost cut down can be achieved in building

construction using improved locally available traditional building materials with appropriate technology (Proceedings of Civil Engineers, 1981). In Nigeria, there are various traditional construction materials that are suitable for production of roofing sheets, these include bamboo fibre, coir fiber, bagasse fibre, palm oil fiber and elephant grass fiber. Rice husk is the waste product generated from the accumulation of the outer covering of rice grains during the milling process. Each country is faced with the challenging problem of the disposal of this low valued by-product within the framework of her economy. Use or disposal has frequently proven difficult because of the tough and woody abrasive nature of the husks, their low nutritive properties, resistance to weathering, and great bulk and ash content. Bamboo is a perennial grass found in areas with tropical and sub-tropical climates from sea level to about 4000m above sea level. Extensive uses have been made of bamboo especially in Asia, where it has found use as a major construction material. This research is aimed at developing roofing sheet from bamboo fiber and RHA with some quantities of cement and installed on a model livestock house for poultry keeping with the aim of carrying out further research on the environmental implication of this roofing sheets on the livestock kept in the shelter.

MATERIALS AND METHODS

Materials: Bamboo: The bamboo used was harvested from the Baptist Primary School, University

of Ibadan, Oyo State. The moisture content of the bamboo at harvest was about 40-45%. It was sun-dried for one week, cut into billets thereafter and further sun-dried for three weeks to a moisture content range of 5-8%. The dried billets were then hammer milled into particles and sieved as shown in Figure 1. Particles that passed through 2.4mm but were retained on the 850 μ m were used.

Cement: Ordinary Portland cement was procured at Bodija, Ibadan, Oyo State. It was then stored in an air-tight plastic container to prevent strength losses due to interaction of the cement with moisture present in air.



Fig. 1: Sieving of Bamboo Particles

Rice husk ash used as pozzolan: The rice husk was obtained from Ilesha, Osun State. Ashing of the rice husk was done using the open air burning as shown in Figure 2. The burnt ashes were then sieved with 75 μ m sieve. Particles retained on the sieve were reprocessed by grinding and then sieved again. It was then stored in a plastic.

METHODS

Manufacturing of Bamboo- RHA and Cement Composite Roofing Sheets

Composites were manufactured by manual mix of bamboo fiber, Ordinary Portland cement, sand and potable water in a head pan using pre-determined cement, sand and water ratios as shown in the experimental set up in the appendix. For the control sample, the fiber and pozzolan content were both 0%. The cement-water ratio was 1:0.5 while the cement-sand ratio was 1:3. For other test samples, bamboo fibers were added at the rate of 1%, 2%, 3% and 4%. Rice Hush Ash (RHA) was also added at the rate of 10%, 20%, 30% and 40% as partial replacement for

Water: Portable water was obtained at the Department of Agricultural and Environmental Engineering, University of Ibadan. The adequate water required was calculated using the trial and error method.

Sand: Sharp sand was obtained from River Zik, University of Ibadan. The sand was then washed and dried to eliminate the effect of inhibitory substances that might be present. Sieve analysis was then carried out in agreement with BS 8110 Part 1 (1997).



Fig. 2: Ashing of Rice Husk

cement. The added dosages of the fiber and pozzolan were based on the mass of cement. The mixtures were thoroughly mixed until homogenous slurry was formed. Three replicate samples each of dimension 10x76x152mm were prepared for strength test while 10x152x152mm samples in replicates of three were also prepared for thickness swelling, water absorption test and hydration test. This was done in accordance with the ASTM Standard (1991). The sample with the desirable properties was chosen and used in the production of bamboo- RHA and cement composite roofing sheets. Each mixture was poured on a vibrating machine overlain with polythene sheet. The aggregate was spread uniformly to a thickness of 10mm. It was then vibrated for 60 seconds to reduce and eliminate voids in the composite produced. The slurry was carefully transferred on a corrugated metal mould as shown in Figure 3, the mixture was smoothed with the aid of a hand trowel as seen in Figure 4 and covered with polythene. It was allowed to dry for 24 hours then it was removed from the mould.

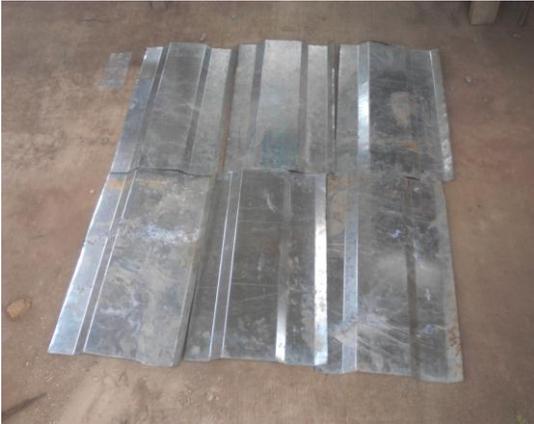


Fig. 3: Corrugated metal mould



Fig. 4: Smoothing with hand trowel

Curing of the composite was done under water in the curing tank for a period of 28 days, it was then drained and properly stored ready for installation.

Tests and Measurements carried out

Hydration test: The hydration text was carried out using the methods described by Hofstrand et al (1984) and Okino et al (2005). This test investigated the compatibility of bamboo fibers in wood cement composite production. Each 15g of bamboo sample was gradually mixed with 200g of cement in polythene bag after which the measured quantity of distilled water was added to the mixture to for a homogenous paste. The mixture was transferred to a thermos flask and a thermocouple was inserted to enable temperature measurement at 10s intervals over a period of 24hrs by a data logger as shown in Figure 5. The time taken to reach maximum temperature was read. The experiment was carried out at room temperature of $25 \pm 2^{\circ}\text{C}$.



Fig 5: Hydration set up with single data logger

Water Absorption and Thickness swelling Tests:

Water absorption and thickness swelling of the composites were determined in accordance with the ASTM D 1037-96 and ASTM D570. Specimens from each sample were submerged horizontally under 50mm of distilled water maintained at a room temperature of $27 \pm 2^{\circ}\text{C}$ for 21 days. The amount of water absorbed after 2 hours, 24 hours, 7 days, 14 days and 21 days were calculated from the increase in weight of the specimen during submersion, while thickness swelling of each board was expressed as a percentage of original thickness. Moisture content was determined in an oven at a temperature of 105°C for varying time until constant mass is obtained.

$$\% \text{Water Absorption} = \left(\frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} \right) \times \frac{100}{1}$$

Density of composite: The volume of $152 \times 152 \text{mm}^2$ composite samples were measured to the nearest 0.01mm and weighed to the nearest 0.1 gram. The density of the composite was calculated with the formula;

$$\text{Density (g/mm}^3\text{)} = \frac{\text{Composite Weight}}{\text{Composite Volume}}$$

Impact Strength Test: The bamboo cement roofing tiles were tested for impact in accordance with ASTM D 1037(1991). The apparatus used for the test was constructed from wooden materials as shown in Figure 6. The impact ball weights 0.153kg with a diameter of 15.5mm. The height of the impact testing apparatus was a 1420mm and the dimension of the base was $90 \text{mm} \times 275 \text{mm} \times 400$. The apparatus was then calibrated in an increment of 25mm. Each test piece was $100 \text{mm} \times 100 \text{mm} \times 10 \text{mm}$ in dimension

and was supported on a rigid support at the base of the apparatus. The metal ball of was then arranged to fall freely on to the center of the test specimen. The ball was allowed to fall from a height of 25mm measured from the top of the test specimen to the table where the ball was released. The height was then increased in an increment of 25mm until failure occurs. The height of the fall at failure was then recorded for each specimen. Impact strength was calculated from the formula:

$$\text{Impact} = Mgh(Nm)$$

Where: M = mass of ball (kg)
 g = acceleration due to gravity (m/s²)
 h = height of fall (m)



Fig. 6: Impact resistance test setup with specimen of roofing sheet

Table 1: Total weight of truss

Member	Notation	Length (m)	Area (mm ²)	Volume (m ³ x10 ⁻³)	Weight (592xV)
Top Chord	A-B	1.67	3750	6.2625	3.7074
	B-C	1.67	3750	6.2625	3.7074
Bottom	A-D	1.33	3750	4.9875	2.9526
Chord	D-C	1.33	3750	4.9875	2.9526
Strut	B-D	1.02	3750	3.8250	2.2644
Total					15.58kg

Pressure coefficient: The wind load normal to the roof slope is given by the equation:
 $N = q(C_{pe} - C_{pi})N/m^2$ (Nigerian Code of Practice, 1973)

Design of the roofing system

Truss Design: The type of truss that was used is the king post truss is shown in Figure 7. The calculated values for the total weight of truss are as shown in Table 1 while the Coefficient of forces in the truss member due to joint loading is shown in Table 2.

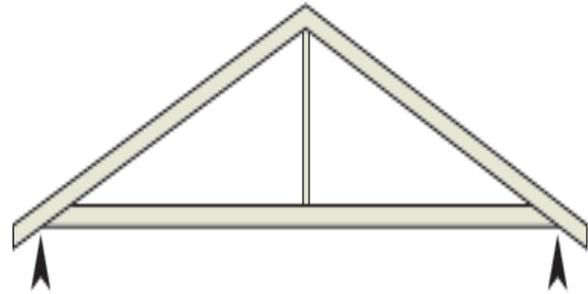


Fig. 7: King post truss used for livestock house roofing system

Where:
 C_{pe} = external pressure coefficient
 C_{pi} = internal pressure coefficient
 The maximum value of C_{pe} , C_{pi} = +0.2

The worst loading condition is obtained:

	C_{pe}	C_{pi}
Windward side	-0.7	+0.2
Leeward side	-0.6	+0.2

Windward

$$N = -0.135(0.7 + 0.2)$$

$$N = -0.135(0.6 + 0.2)$$

Leeward

$$= -0.123\text{kN/m}^2$$

$$= -0.108\text{kN/m}^2$$

Table 2: Coefficient of forces in the truss member due to joint loading (W)

Member	Force Coeff.	Dead load (DL)	Wind load (WL)	WL+DL
1	-0.8W	-0.3048	-0.1664	-0.4712
2	0.64W	0.2438	0.1331	0.3769
3	0.04W	0.0152	0.0083	0.0235
4	-0.8W	-0.3048	-0.1664	-0.4712
5	0.64W	0.2438	0.1331	0.3769

$$DL = 0.381\text{KN}$$

$$WL = 0.208\text{KN}$$

Common wire nails of three inches were used to connect various member of the roofing system together as seen in Figure 8. The points of connections are Truss, Beam, Purlin and Roofing tiles. The truss was secured to the beam with four inches nail to ensure maximum penetration of the nail into the wooden member. For the purlins, three inches nails were also used. Finally, two inches nails were used to nail the roofing tiles to the purlin at the nib. In the assembly, any protruding nail due to toe nailing was adequately clinched.

The roofing tiles were carefully laid on the roofing system of the model livestock house. The nib of the roofing tile was held to the purlin with a two inch nail. Installation was started from the eaves to the ridge of the roof. Sufficient overlapping was obtained between rows and column of the assembly before securing the tile to the purlin and the nails were bent over the nib for tighter grip. The installation is shown in Figures 9 and 10.



Fig 8: Roofing system construction



Fig 9: Installation of roofing tiles



Fig 10: Interior of the roofing

RESULTS AND DISCUSSIONS

Hydration

The highest temperature attained by the neat cement was 49 degrees Celsius. The addition of bamboo fibers lowered the hydration temperature to 42°C. Mixture of cement and water that attained maximum hydration temperature in less than 15 hrs are considered suitable, while those that require more than 20 hrs are considered inhibitory (Papadoulous, 2008). Since the maximum temperature obtained with the bamboo-cement mixture was attained within the first 15 hrs of the hydration, bamboo fibers are compatible with cement.

Water Absorption and Thickness Swelling: The thickness swelling of composite at different ratio of cement and pozollan are shown in Table 3. Composites having the 40% pozollan and 1% Fiber has the highest thickness swelling of 6.5%. The lowest value was obtained at 10 and 30% replacement. The result showed that water absorption increased with an increase in pozollan and fiber substitution.

The water absorption values obtained at two hours and 24 hours were displayed in Table 4. Composites having 20% pozollan and 1% have the highest value of 1.24% at two hours. This is in contrast to the theory that the test samples with higher fiber dosages will absorb more water. After 24hrs of soaking the water, the results showed that the composites containing 20% pozollan and 1% fiber had the highest WA of 1.43%. This agreed with the two hours soaking. Generally, the water absorption was low in the composite. However, the thickness swelling and water absorption test does not totally agree with each other as the sample with the highest thickness swelling does not absorb water correspondingly.

Impact Resistance Test: In the Composite with 10% pozollan replacement, the samples with 1 and 4% fiber content have the lowest impact strength of 0.46Nm while samples with 2 and 3% fiber content have the highest impact strength of 0.5Nm. For 20% pozollan replacement, highest impact strength (0.5Nm) was obtained at fiber levels of 1 and 3%. 2% fiber content sample has a value of 0.46Nm while the 4% has the lowest value of 4.2Nm. In the 30% pozollan replacement shown in Figure 11, 0.5Nm impact value was obtained at fiber content of 1 and 2%. 0.42Nm was obtained for fiber content of 3 and 4%. 0.46Nm was the highest value of impact obtained in the samples with 40% pozollan replacement. Generally, the impact resistance decreased as the pozollan replacement was increased. 30% replacement appears to be suitable. Also, impact strength decreased as the fiber content increased. The maximum value corresponds to an average fiber level of 3%. Therefore, the test sample 30% pozollan replacement and 3% fiber content was used in the production of roofing tiles.

Density of Composite: The density on the composite produced ranged from 1779 to 2376Kg/m³. 2197Kg/m³ was the highest average density obtained in the test samples with 10% pozollan replacement and this corresponds with a fiber content of 3% while the lowest value for the same pozollan replacement was 2062Kg/m³. It occurred in sample with 2% fiber content. 2066 and 2114Kg/m³ was obtained for fiber levels 1 and 4% respectively. In the 30% replacement, 2150Kg/m³ was the highest density obtained and it occurred in the 2% fiber content while the lowest average occurred in the test samples with 4% fiber level and the value was 1888Kg/m³. Relatively, average densities values obtained for the 40% pozollan replacement are low. 1908Kg/m³ was the highest. The lowest value obtained for 10 and 20% pozollan replacement was higher than the maximum value obtained in this class of variation. Generally, the average densities decreased as the pozollan replacement increased and as the fiber content increased. It was deduced that the pozollan replacement reduced the density of the composite which is an advantage in its application as roofing tile. However, density is inversely proportional to strength. Therefore average density obtained for 30% replacement is suitable.

Table 3: Thickness Swelling (TS)

Samples	Initial Weight	After 2 hours	After 24 hours	%TS after 2 hrs	%Ts after 24 hrs
A1	11.67	11.68	11.70	0.09	0.26
	12.47	12.65	12.69	1.44	1.76
	12.87	12.87	12.88	0.00	0.08
A2	12.98	13.17	13.17	1.46	1.46
	13.46	13.58	13.58	0.89	0.89
	13.75	13.86	13.86	0.80	0.80
A3	12.28	12.46	12.46	1.47	1.47
	12.32	12.44	12.45	0.97	1.06
	12.03	12.20	12.22	1.41	1.58
A4	12.22	12.22	12.22	0.00	0.00
	12.12	12.17	12.17	0.41	0.41
	10.66	10.90	10.91	2.25	2.35
B1	12.73	12.79	12.84	0.47	0.86
	13.04	13.17	13.35	1.00	2.38
	12.85	12.85	12.90	0.00	0.39
B2	13.36	13.41	13.42	0.37	0.45
	13.55	13.55	13.59	0.00	0.30
	12.92	13.13	13.13	1.63	1.63
B3	13.00	13.06	13.06	0.46	0.46
	12.87	13.02	13.02	1.17	1.17
	13.24	13.41	13.42	1.28	1.36
B4	11.18	11.30	11.30	1.07	1.07
	11.49	11.50	11.59	0.09	0.87
	11.33	11.43	11.65	0.88	2.82
C1	12.54	12.54	12.59	0.00	0.40
	13.94	13.94	13.94	0.00	0.00
	13.81	13.93	13.93	0.87	0.87
C2	13.23	13.23	13.23	0.00	0.00
	13.77	13.85	13.87	0.58	0.73
	12.75	12.81	12.81	0.47	0.47
C3	11.79	11.79	11.83	0.00	0.34
	12.26	12.29	12.35	0.24	0.73
	13.17	13.19	13.19	0.15	0.15
C4	11.97	12.25	12.27	2.34	2.51
	11.09	11.12	11.12	0.27	0.27
	11.44	11.44	11.44	0.00	0.00
D1	12.48	12.51	12.52	0.24	0.32
	12.61	13.41	13.43	6.34	6.50
	13.54	13.55	13.56	0.07	0.15
D2	13.20	13.23	13.24	0.23	0.30
	12.79	12.81	12.85	0.16	0.47
	13.00	13.04	13.07	0.31	0.54
D3	10.80	10.84	10.89	0.37	0.83
	10.69	10.69	10.87	0.00	1.68
	11.30	11.32	11.33	0.18	0.27
D4	12.42	12.45	12.48	0.24	0.48
	11.81	11.85	11.86	0.34	0.42
	12.45	12.50	12.55	0.40	0.80
CONTROL	10.79	11.24	11.24	4.17	4.17
	10.8	10.82	10.88	0.19	0.74
	10.82	11.07	11.07	2.31	2.31

Table 4: Water absorption (gm)

Initial Weight	After 2 hrs	After 24 hrs	%WA at 2 hrs	%WA at 24 hrs
247.60	249.00	249.00	0.57	0.57
223.40	225.50	225.50	0.94	0.94
205.20	206.40	206.40	0.58	0.58
269.40	270.40	270.40	0.37	0.37
260.10	261.80	261.90	0.65	0.69
265.50	268.50	268.50	1.13	1.13
248.80	249.80	249.80	0.40	0.40
237.40	238.20	238.40	0.34	0.42
261.20	263.30	263.30	0.80	0.80
237.30	239.00	239.10	0.72	0.76
224.30	226.00	226.00	0.76	0.76
253.00	255.50	255.50	0.99	0.99
258.20	259.60	259.60	0.54	0.54
245.90	247.70	247.80	0.73	0.77
266.20	269.50	270.00	1.24	1.43
267.10	268.80	268.90	0.64	0.67
224.30	226.00	226.20	0.76	0.85
223.10	225.00	225.10	0.85	0.90
256.00	257.00	257.00	0.39	0.39
251.90	252.80	252.80	0.36	0.36
273.40	274.40	274.40	0.37	0.37
214.70	215.60	215.70	0.42	0.47
253.30	254.20	254.20	0.36	0.36
232.10	233.30	233.40	0.52	0.56
242.20	243.80	243.80	0.66	0.66
240.90	241.70	241.70	0.33	0.33
220.80	221.90	222.00	0.50	0.54
262.90	264.10	264.10	0.46	0.46
268.00	269.60	269.60	0.60	0.60
263.50	266.00	266.00	0.95	0.95
228.80	229.80	229.80	0.44	0.44
262.60	263.50	263.80	0.34	0.46
262.00	263.20	263.40	0.46	0.53
222.90	223.80	223.80	0.40	0.40

243.40	244.50	244.60	0.45	0.49
223.80	224.90	224.90	0.49	0.49
237.30	238.40	239.00	0.46	0.72
197.40	198.90	199.60	0.76	1.11
232.80	233.90	234.70	0.47	0.82
238.80	239.40	239.90	0.25	0.46
241.60	242.00	242.10	0.17	0.21
228.20	229.40	230.00	0.53	0.79
203.40	204.90	205.00	0.74	0.79
239.00	240.80	241.10	0.75	0.88
244.50	245.60	246.40	0.45	0.78
230.30	232.10	232.40	0.78	0.91
194.60	195.70	196.10	0.57	0.77
229.10	230.00	230.40	0.39	0.57

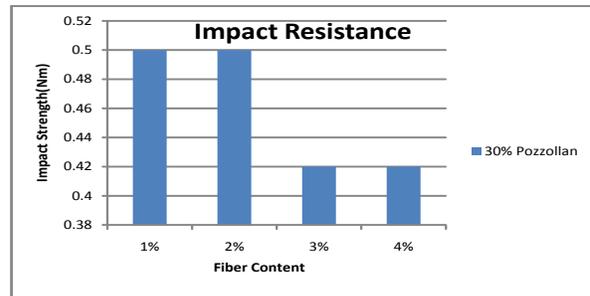


Fig 11: Impact test result at 30% pozzollan.

CONCLUSION

Principle of engineering design was applied in the design and fabrication of the roofing sheet and the installation on the model livestock house roofing system using a kingpost truss with a pitch of 37.2° at line spacing of 1.01m. The roofing tiles can be adapted particularly for hot climate due to its high insulation properties and therefore suitable to provide shelter for livestock by using the locally available agricultural waste materials for its production.

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