INFLUENCE OF BAMBOO LEAF ASH BLENDED CEMENT ON THE ENGINEERING PROPERTIES OF LATERITIC BRICKS

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ABSTRACT

Bamboo leaf ash (BLA), which is obtained by the calcination of bamboo leaves, is highly pozzolanic. This study investigates the properties of lateritic soil bricks stabilized with BLA blended cement. The bricks were prepared from a mix ratio of 1: 6 (cement: lateritic soil) as control. The cement constituent in the reference mix was replaced with varying percentages of BLA at 5% interval up to 25% by mass of the cement. Properties of the bricks evaluated were compressive strength, abrasive resistance, and water absorption. The values of the compressive strength range between 4.0 N/mm^2 and 5.3 N/mm^2 for 25% BLA content and 5% BLA content, respectively. The results also indicated that the compressive strength decreases with increase in the content of BLA but increases with curing age up to the 56 days tested. The abrasive resistance was noted to improve with increase in the BLA content, while the water absorption values range between 2.39% and 3.95%. The study concluded that lateritic soil brick when stabilized with BLA blended cement, with up to 25% BLA replacing cement, can be used for the construction of load-bearing walls.

KEYWORDS: *Abrasive strength; bamboo leaf ash; compressive strength; water absorption; stabilized soil bricks*

1.0 INTRODUCTION

Housing is one of the major problems in developing countries like Nigeria where the majority of the population live in sub-standard houses. According to Anthonio (2002), housing can be described as an essential component of human settlement that ranks comparably with the provision of food and clothing in the hierarchy of the basic primary elements required for human existence. At its most elemental level, it addresses the basic human needs by serving as shelter, offering protection against excessive cold, heat, rain, high winds and any other form of inclement weather, and also protection against unwanted aggression.

The housing problem is acute especially in urban areas due to the shortage of affordable houses for low-income earners and the poor, who constitute over 70% of the urban population. The high cost of building materials has been observed to be the greatest problem besetting housing delivery in Nigeria (Okoli, 1998). This is particularly true of cement, which has conventionally been used as a binder in the production of sandcrete

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blocks, concrete and as a stabilizing admixture in soil blocks. In order to ameliorate this problem, alternative materials from a range of widely abundant local materials have been sought to replace the expensive conventional ones, most especially cement. Pozzolans such as fly ash, silica fume, rice husk ash and blast furnace slag have been discovered to be viable alternative binders to cement, especially in the realm of partial replacement (Sai-Prasad & Jha, 2006; Gonzalez-Fonteboa & Martinez-Abella, 2008; Chindaprasirt, Rukzon & Sirivivatnanon, 2008; Khatib & Hibbert, 2005).

Lateritic soil, on the other hand, has been a major traditional building material among rural dwellers in Nigeria; and it has also prominently featured in the construction of wall elements in traditional buildings and in rural roads. However, some lateritic soils are suitable for use in their natural state, while others require additives (or stabilizers) in order to meet the purpose. Kamang (1998) defined lateritic stabilization as any treatment applied to soil in order to render it suitable and strong. Over the years, vegetable straws (like from cereal crops) have been used for the stabilization of lateritic soils for block making in the rural areas. Straw reduces shrinkage of lateritic blocks and improves their quality and strength, which depends upon the quality and quantity of straw added. Other materials that have been used in stabilizing lateritic soil include cement, brick dust, fly ash, coconut fiber and shell, and rice husk.

Recently, bamboo leaf ash, which is obtained by the burning of bamboo leaf at a controlled temperature, has been found to possess high reactive silica, which makes it suitable for use as a supplementary cementitious material (Villar-Cociña, Santos, Savastano & Frías, 2011; Dwivedi, Singh, Das, & Singh, 2006; Arum, Ikumapayi & Aralepo, 2013). The use of bamboo leaf ash in concrete exposed to a sulfate environment has been reported (Ademola & Buari, 2012; Asha, Salman & Kumar, 2014) to enhance the resistance of concrete to sulfate attack. Adewuyi, Olusola and Oladokun (2013) reported its use as a supplementary cementitious material in the production of sandcrete blocks. The availability of bamboo leaf and the low technology required to process it into ash necessitates its usage as a material for the production of some building elements for affordable housing provision, especially in developing countries. Hence, the study seeks to investigate the effect of bamboo leaf ash blended with cement on the properties of lateritic bricks.

2.0 EXPERIMENTAL PROCEDURE

Cement used in this study was CEM II/B-L 32.5R Portland limestone cement produced in conformity with BS EN 197-1: 2007specifications. The chemical composition and physical properties of the cement are presented in Table 1. The lateritic soil used for the production of the bricks was excavated from a burrow pit along Itu-Calabar expressway, Uyo, Nigeria. The lumps of the soil sample were broken into smaller pieces and sieved through a 4.75 mm mesh wire. The physical properties tests carried out on the lateritic soil sample included sedimentation test to determine the quantity of clay, silt and sand content in the soil, and Liquid limit (L.l) and Plastic limit (P.l) tests to determine the plasticity index (P.I.) of the soil sample. Also conducted were the specific gravity and the Proctor compaction test to determine the optimum moisture content of the soil sample. The tests were carried out in accordance with BS EN 1377 – 2: 1990.

Table 1. Chemical and Physical properties of Portland limestone cement

Chemical Composition	
Elemental Oxide	**(%)**
SiO_2	21.90
Al_2O_3	5.05
Fe_2O_3	4.40
CaO	61.14
MgO	1.35
K_2O	0.48
Na_2O	0.24
SO_3	2.53
IR	1.65
LOI	1.29
Physical properties	
Consistency (%)	29.24
Initial setting time (minutes)	104
Final setting time (minutes)	210
Soundness (mm)	1.0
Specific gravity	3.12

Rajput (2006) stated that soil suitable for the production of soil bricks should be easily molded and dried without cracking and warping, and should have a clay content of 20-30 percent by weight, sand content of 35-50 percent by weight, and silt content of 20-25 percent by weight; and that the total content of clay and silt is recommended to preferably be less than 50 percent by weight. The results for the physical properties of the soil as presented in Table 2 show that the soil is good laterite for use in making bricks. The optimum water content for the soil used was 12% which is within the range of 4 - 12% by weight of laterite (Rajput, 2006). Table 2 shows that the liquid limit is 37% and the plastic limit 22.4%, while the plasticity index is 14.6%. These values of the Atterberg limits of the lateritic soil conformed to the range specified by the findings of Abidoye (1977) for soil suitable for earth bricks.

Table 2. Physical properties and particle size distribution of the lateritic soil

Properties	(%)
Specific gravity	2.57
Liquid limit (%)	37
Plastic limit (%)	22.4
Plasticity index (%)	14.6
Optimum moisture content (%)	12
Maximum dry density (kg/m^3)	2.04
Particle size distribution (%)	
Sand	42.50
Silt	21.00
Clay	27.40
Gravel	9.10

The bamboo leaves for the study were obtained from the bamboo forest along Ikot Ekpene road, Uyo, and taken to the Department of Building laboratory at the University of Uyo, where they were dried in an open shed for 5-7 days (Figure 1). The dried leaves were then calcined in a gas furnace (Figure 2) to a temperature of 500^{o}C, at which they become grey in color (Figure 3). When cooled, the ashwas then sieved with a mesh sieve, size 75um. Physical tests on the ash were conducted as per ASTM C311-2007, and the chemical composition of the ash was found using an X-Ray fluorescence analyzer. The results of the physical and chemical properties as presented in Table 3 satisfied the requirements as specified by ASTM C311 (2007) for a class N pozzolanic material.

In this study, the water used for mixing and curing was obtained from the portable tap water provided in the Department of Building laboratory, University of Uyo.

Figure 1. Dried bamboo leaves

Figure 2. Gas furnace for burning of bamboo leaves

Figure 3. Bamboo leaf ash sample

Table 3. Physical and chemical composition of bamboo leaf ash (BLA)

Chemical Composition	
Elemental Oxide	**(%)**
SiO_2	70.15
Al_2O_3	4.10
Fe_2O_3	1.85
CaO	5.51
MgO	1.10
K_2O	3.39
Na_2O	1.69
SO_3	0.15
LOI	3.25
Physical Properties	
Specific gravity	2.68
Strength activity index with Portland cement	
7 days (% of control)	76.10
28 days (% of control)	78.88
Material retained on 45µm sieve (%)	33.10

2.1. Mix Proportion and Casting of Specimens

Amix ratio of 1: 6 (cement: Lateritic soil) was used as the control mixture. The quantity of the cement constituent was replaced with varying percentages of bamboo leaf ash (BLA) ranging from 5% to 25% and at an interval increment of 5% by mass of the cement. The quantity of water added to the mix in order to achieve a workable mix ranged between 12-15% of the quantity of the materials.

The materials were manually mixed until a paste of uniform consistency was attained. The mixture was then cast into a metal mold of size 225mm x 113mm x 75mm and compacted to form a solid mass. The molds were removed and the bricks placed on the ground in the laboratory for proper air circulation and curing process (Figure4). The curing was carried out by sprinkling water on the cast bricks on a daily basis until two days before their testing ages of 7, 14, 28, and 56 days. Three replicates were used for each mix and curing age, thereby giving a total of 72 bricks for each of the required properties to be investigated.

Figure 4. Lateritic bricks under curing

The brick specimens were tested for compressive strength, water absorption, and abrasion. The compressive strengths were tested at ages of 7, 14, 28 and 56 days for 0, 5, 10, 15, 20 and 25% BLA content replacing cement. The compressive strength was tested in accordance to BS EN 12390–3 (2000) and involved subjecting a total of 72 bricks to crushing on a compression testing machine of capacity 2000KN. The crushing force was noted and the average of the compressive strength calculated for three specimens, giving the compressive strength value of the brick sample.

Durability tests were carried out on the brick samples in order to further determine their suitability as construction material. An abrasive strength test was conducted by placing the brick on a horizontal surface for brushing with the use of wire brush; the wire brush used was laid on the brick so that its mass was vertically applied to the brick. The surface of the brick was brushed using the wire brush for 40 strokes. Brushing took place along the whole length of the brick. After brushing, the lost mass was removed from the lateritic brick and the brick was re-weighed.

The abrasion coefficient (C_a) expresses the ratio of the brushed surface S (in cm^2) to the mass of the material detached by the brushing ($M_1 - M_2$, in grams) and as expressed in Equation 1.

$$C_a\ (cm^2/g) = S/(M_1 - M_2) \qquad (1)$$

where M_1 = mass of the brick before brushing, M_2 = the mass of the block after brushing and S = the brushed surface area.

The water absorption was conducted in accordance to BS 1881–122 (1983) after 28 days' curing period. The brick specimens were first weighed dry (W_1), and then immersed in water for a period of sixteen hours (16 hrs) and weighed again (W_2); the difference in mass indicated the water absorbed by the brick. The average of three replicates for each sample type gave the water absorption value of the brick.

3.0 RESULTS AND DISCUSSION

The results of the strength and durability performance of the BLA blended cement lateritic bricks are hereby presented and discussed.

3.1 Compressive Strength

The compressive strengths for both the reference and blended specimens are presented in Table 4. The results show that the compressive strength reduces with increased quantity of BLA blended with the cement but increases with increase in curing age. The compressive strength reduction of the blended specimen when compared with the control specimen (that is, the specimen with 0% BLA content) at 7 days' curing period was 5.36%, 7.44%, 23.21%, 25% and 30.36%, for BLA content of 5%, 10%, 15%, 20% and 25%, respectively.

At 14 days' hydration, the compressive strength reduction was observed to increase, when compared with the control specimen value at the stated age, and ranged from 16.18% for 5% BLA content to 41.18% for 25% BLA content. At 28 days' hydration, there was a drastic decrease in the compressive strength vis-a-vis the reference. The values obtained ranged from 3.45% for 5% BLA content to 29.89% for 25% BLA content. It was also noticed that the compressive strength of the blended specimens with 15-20% BLA content at the standard age of 28 days' hydration attained up to 75% of the compressive strength of the reference specimen, thereby satisfying the requirements of ASTM C618 (2008) for natural pozzolan suitable for use as a cement substitute in mortar and concrete. These strength gains at later hydration periods could be attributed to pozzolanic reaction as a result of release of calcium hydroxide from cement hydration, and highlight the fact that bamboo leaf ash is a highly pozzolanic material.

At 56 days, although there is significant difference in the compressive strength between the blended cement specimens and the reference, however, 5-10% bamboo leaf ash content with a compressive strength of 10.2N/mm^2 and 9.6N/mm^2 can favorably compare with 11.2N/mm^2, as they attained up to 91% and 86%, respectively, of the control. The compressive strength of blended specimens with 15-20% BLA content also attained up to 75% of the compressive strength of the control specimen, thereby satisfying the requirement of ASTM C618 (2008). Therefore, it can be said that, where early strength requirement is not paramount, the blending of cement with up to 20% BLA content could be used in the production of lateritic bricks for housing construction.

Table 4. Compressive strength of lateritic blocks containing 0-25% BLA

Curing age (days)	BLA (%)	Weight of block (kg)	Density (kg/m^3)	Compressive strength (N/mm^2)
7	0	4.287	2256.3	5.6
	5	4.457	2345.8	5.3
	10	4.341	2284.7	5.2
	15	4.350	2289.5	4.3
	20	4.223	2222.6	4.2
	25	4.182	2201.1	3.9
14	0	4.366	2297.9	6.8
	5	4.441	2337.4	5.7
	10	4.341	2332.1	5.5
	15	4.357	2293.2	4.7
	20	4.214	2217.9	4.3
	25	4.101	2158.4	4.0
28	0	4.346	2287.4	8.7
	5	4.441	2337.4	8.4
	10	4.393	2364.7	8.0
	15	4.307	2266.8	7.5
	20	4.233	2227.9	6.6
	25	4.195	2207.9	6.1
56	0	4.306	2266.3	11.2
	5	4.350	2289.5	10.5
	10	4.269	2246.8	9.6
	15	4.198	2209.5	9.0
	20	4.165	2192.1	8.4
	25	4.087	2151.1	7.4

3.2 Abrasive Strength

The abrasive coefficients of the lateritic bricks are presented in Table 5. From the results, it can be seen that the lateritic bricks showed a steady improvement in their resistance to abrasion (wear), as the content of the BLA replacing cement increased. It was observed that the brick specimens without BLA content (that is, 0% BLA) had the least resistance to abrasion with a coefficient of 1.695cm^2/g, and the highest resistance with a coefficient of 2.648cm^2/g occurred with brick specimens having 25% BLA content.

Comparatively, the abrasion resistance of lateritic bricks with 5% BLA content was 20.94% better than lateritic brick specimens with 0% BLA. Increasing the BLA content to 10% led to further improvement in its resistance as it was 36.34% better than the control specimens. Lateritic bricks containing 15, 20, and 25% BLA contents had abrasion resistance of 54.04, 44.25, and 56.22% respectively better than the control brick specimens. The increase in abrasion coefficients of the soil blocks as the BLA content increases could be attributed to the improved pozzolanic/cementitious actions among the BLA, calcium hydroxide released by cement hydration, and the lateritic soil, resulting in an enhanced bond strength which holds the particles in the matrix. This also supports the finding by Eko, Mpele, Doumstop, Minisili and Wouatang (2006) that the stabilization of a compressed earth block using cement increases the abrasive strength of the block.

Table 5. Abrasive resistance of BLA blended cement lateritic brick

BLA Content (%)	M_1 (g)	M_2 (g)	M_1-M_2 (g)	S (cm^2)	Abrasive Coefficient, Ca (cm^2/g)
0	4400	4250	150		1.625
5	4400	4276	124		2.050
10	4380	4270	110		2.311
15	4310	4212	98	254.25	2.594
20	4280	4176	104		2.444
25	4270	4174	96		2.648

3.3 Water Absorption

Table 6 presents the results of the water absorption test conducted on lateritic bricks ternary stabilized with cement and BLA at 28 days hydration. The results reveal a water absorption value ranging between 2.39% and 3.95%. The lowest value was recorded with lateritic brick containing 15% BLA replacing cement, while the highest was attained with 25% BLA content.

This improvement in water absorption with increase in BLA content up to 15% could be attributed to complete consumption of calcium hydroxide, Ca(OH), released through cement hydration by the pozzolanic reaction of the silica in BLA and thereby filling up the pores in the bricks, which led to reduction in the amount of water being absorbed by the bricks; and beyond 15% BLA content the excess Ca(OH) which is not consumed by the pozzolanic reaction constitutes weak spots in the bricks for water penetration, hence the higher percentage of water absorption.

It was noted that, in all the replacement levels, the water absorption values were far below the maximum allowable limit of 20% (BS 1377, 1990) for building bricks, and equally less than the 12% specified by NIS 587 (2007) for sandcrete blocks. This strengthens the assertion that pozzolan can be used to reduce moisture absorption of masonry units (ACI 232.1R, 2000).

Table 6. Water absorption of lateritic bricks at 28 days' hydration

BLA content (%)	**W_2 (g)**	**W_1 (g)**	**W_2-W_1 (g)**	**Water absorption (%)**
0	4.465	4.330	0.135	3.12
5	4.460	4.345	0.115	2.65
10	4.455	4.350	0.105	2.41
15	4.452	4.348	0.104	2.39
20	4.462	4.320	0.142	3.29
25	4.470	4.300	0.170	3.95

4.0 CONCLUSION

The compressive strength of stabilized lateritic bricks with up to 25% BLA blended cement attained a value above the minimum strength requirement of 2.8 N/mm^2 for a load-bearing wall at 28 days' hydration. It was equally observed that the compressive strength increases as the curing age increases. The abrasive resistance of the brick increases with increase in BLA content, while the water absorption falls within the allowable limit for bricks to be used as walling elements. It is therefore recommended that lateritic bricks stabilized with 25% BLA blended cement are suitable for load-bearing walls. However, further research needs to be conducted on the stabilization of the brick with higher BLA content replacing up to 40% of the cement and evaluation of other mechanical properties of the stabilized bricks.

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