EMPIRICAL STUDY ON EFFECT OF BAMBOO LEAF ASH IN CONCRETE

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ABSTRACT

The use of fly ash and other industrial-based wastes as pozzolans in the cement industry is widely acceptable in the production of blended cements. However, to-date, there is limited information about the use of agricultural wastes in the building construction industry is little known in view of their availability. This study focuses on experimental investigation on the use of Bamboo Leaf Ash (BLA) as cement substitute in concrete. Concrete cubes with dimensions of 100 mm x 100 mm were cast from a mix ratio of 1:2:4 by weight as the reference. The cement constitute was replaced with percentages of bamboo leaf ash in the range of 5-20% by weight. All mixtures were maintained at water-cementitious ratio based on slump value of 10-30mm. Properties investigated were compressive strength, tensile splitting strength and water absorption up to 90 days hydration. The results indicated that compressive strength of BLA blended cement concrete ranges from 11.75 N/mm^2 at 7 days for 20% BLA content to 30.12 N/mm^2 at 90 days for 0% BLA content, and that 10% BLA content attained up to 75% of the reference value at the standard age of 28 days. The percentage performance of tensile splitting strength value over the reference for all the blended specimens for all curing ages were over 75%, and had a strong correlation coefficient of 0.790 with the compressive strength; while the water absorption of blended cement specimens generally has less water absorption than the reference. The least water absorption value was recorded with the specimens containing 10% BLA. Therefore 10% BLA content is recommended as the optimal percentage suitable for medium grade concrete.

KEYWORDS*: bamboo leaf ash; compressive strength; tensile splitting strength; water absorption*

1.0 INTRODUCTION

Bamboo leaf is the common term for members of a particular taxonomic group of large woody grasses (subfamily *bambusoideae*, family *Andropogoneae/Poaceae*). Bamboo is one of the most ornamental as well

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as easy to grow garden and potted plants in Akwa Ibom State. It is natively known as '*Akpo Nyanyanga*' in the dialect of the people of the State. Bamboo is particularly adapted to the rainforest belt of Nigeria where it is found in abundance along riverbanks and other relatively marshy areas.

It has been identified that over 1200 bamboo species are available globally (Wang & Shen, 1987), and out of these species, seven are found in Nigeria of which the specie bambusa vulgaris constitutes 80% (Omotoso, 2003) and commonly referred to as the Indian bamboo.

Bamboo is being hailed as a new super material with uses ranging from textile to construction. In construction, it is used for the construction of bridges, water transportation facilities, scaffoldings, construction of wattle and daub walls; and widely used in building applications, such as flooring, roof-trusses, rafters and purlin (Abd Latif et al., 1990). It is also used for home utilities such as containers, chopsticks, and woven mats. Massive plantation of bamboo provides an increasingly important source of raw materials for pulp paper industry in China (Hammett et al., 2001).

In China and India dried mature bamboo leaves are used to deodorize fish oils while, the foliage has long been used as forage. Ashes obtained by the burning of bamboo leaf under control temperature have been reported to show a very high pozzolanic activity (Dwivedi et al., 2006; Singh et al., 2007; Frias et al., 2012).

Several studies have been conducted on the use of bamboo leaf ash (BLA) as pozzolanic material in construction. Asha et al. (2014) investigated the effect of BLA, as cement replacement, on compressive strength and durability characteristics of concrete with mix ratio 1: 1.5: 3, and found out that the compressive strength of the concrete decreases with increase in percentage of bamboo leaf ash but recorded improvement in acid and chloride resistance at 10% replacement of cement with bamboo leaf ash and therefore concluded that concrete with bamboo leaf ash should be used for civil engineering works where durability is a major concern than high strength.

Amu and Adetuberu (2010) and Amu and Babajide (2011) studied the characteristics of BLA stabilization on lateritic soil, and as a complementary material to lime in stabilization on lateritic soil, in highway construction. It was reported that BLA has the potential for stabilizing lateritic soils as well as increasing the strength of lime stabilized lateritic soil for highway construction.

Iorliam et al. (2012) examined the effect of bamboo leaf ash on cement stabilization of Markurdi shale for use as flexible pavement construction material and found that the use of the shale treated with 14 % cement + 20 % BLA is suitable for use as sub-base materials in flexible pavement. The use of only BLA as stabilizing agent was carried out by Iorliam et al. (2013). They investigated the geotechnical properties of makurdi shale treated with bamboo leaf ash and observed that the strength properties of BLA treated shale were below the minimum values specified for road building materials and therefore recommended for use as a modifier, in the stabilization of shale with either cement, lime or other additives for road work.

The mechanical performance of ternary blended cement concrete incorporating periwinkle shell and bamboo leaf ashes have been assessed by Umoh and Femi (2013) and Umoh, et al. (2013) while Ademola and Buari (2014) examined the behaviour of BLA blended cement concrete in sulphates environment and concluded that Portland cement–bamboo leaf ash blended cement concrete could be used in civil engineering and building works in sulphate environment and where early strength is not a major requirement.

Therefore, the use of BLA as cement supplement can contribute greatly to economic development as cement can be partly replaced by bamboo leaf ash to bring down the high cost of producing concrete since bamboo leaf ash contains amorphous silica. The few studies on the use of BLA in concrete have only centred on compressive strength and durability performance of sulphate, chloride and acidic attack and up to 28 days hydration therefore, there is the need to investigate into other properties based on different mix ratio hence this study examine the effect on the compressive, tensile splitting strength and water permeability performance when used to partially replace cement in concrete.

2.0 MATERIALS AND METHOD

2.1 Materials

The bamboo leaves were obtained from bamboo forest in Mkpat Enin Local Government Area of Akwa Ibom State, Nigeria. The leaves were taken to the Department of Building Laboratory, University of Uyo and spread on the floor for it to be properly dried. The dried leaves were then placed inside a perforated metallic drum and fired in open air until they were completely burnt. The ash produced from the burning process was allowed to cool for 24 hours before removal from the drum. The colour of the ash so produced was on the main black, suggesting incomplete combustion. The ash was then conditioned using a gas furnace at a temperature of 500°C for 2 hours. Thereafter, the ash was then grind into a powder form and sieved through 45 um sieve wire mesh. The results of the physical and chemical analyses conducted on the ash are presented in Table 1. The ash satisfied the requirements for class F pozzolan (ASTM C610, 2008).

The cement used was Portland cement (Dangote brand) produced to conformity of BS EN 197-1 (2009), the properties of the cement are as presented in Tables 1 and 2. Aggregates were sharp sand and granite chippings used as fine and coarse aggregate, respectively. The sharp sand fall within zone two fine aggregate (Table 3), thereby satisfying the requirement of BS EN 12620 (2008) for sand to be used for concrete; while the coarse aggregate (granite chipping) were of nominal maximum size of 25 mm; the sieve analysis is as shown in Table 4. Tap water, which is equally suitable for human consumption, was obtained from the Building Laboratory, University of Uyo, and used for mixing and curing of specimens.

Table 1. Chemical and Physical Properties of Cementitious Binders

Elemental Oxide (%)	BLA	Portland Cement
CaO	4.23	62.44
SiO_2	72.25	20.06
$A1_2O_3$	4.08	5.85
MgO	1.01	1.93
Fe_2O_3	1.97	3.05
K_2O	3.15	0.97
MnO_2	0.22	0.20
P_2O_5	0.74	0.17
SO_3	0.15	2.71
TiO_2	0.35	0.28
LOI	2.93	1.09

Table 2. Physical Properties of Cementitious Binders.

Properties	BLA	Portland cement
Specific gravity	2.64	3.10
Soundness (mm)	-	0.1
Consistency (%)	-	29.01
Initial setting time (minutes)	-	101
Final setting time (minutes)	-	204
Strength activity index with Portland cement:		
7 days (% of control)	75.47	-
28 days (% of control)	79.45	-
Fineness (material retained on 45µm sieve (%)	32.85	-

Table 3. Sieve Analysis of sharp sand for Concrete.

Sieve sizes (mm)	Material Retained		Total Percentage retained	Percentage Passing
	(g)	(%)		
2.36	90.4	18.1	18.1	81.9
1.18	124.3	24.9	43.0	57.0
0.600	95.4	19.1	62.1	37.9
0.300	106.5	21.3	83.4	16.6
0.150	53.3	10.7	94.1	5.9
0.075	28.2	5.6	99.7	3.0
Pan	1.5	0.3	100	0.0

Table 4. Sieve Analysis of granite chipping used for concrete.

Sieve sizes (mm)	Material Retained		Total percentage retained	Percentage passing
	(g)	(%)		
37.5	–	–	–	100
20	630	15.8	15.8	84.2
14	2150	53.8	69.6	30.4
10	876.7	21.9	91.5	8.5
4.5	310	7.8	99.2	0.8
Pan	33.3	0.8	100	0.0

2.2 Method

The concrete cube specimens with dimensions of 100 mm x 100 mm were made from mix proportion of 1: 2: 4 (cement: sharp sand: granite chipping) by weight with water-cementitious ratio determined based on slump value of 10-30 mm, and used as reference. Portland cement was subsequently replaced by varied percentages of BLA in values of 0%, 5%, 10%, 15% and 20% by weight of cement. The constituent materials were manually mixed until a uniform mixture was obtained. The wet mixtures were cast in hardwood moulds and manually compacted in accordance to BS EN 12390-2 (2009), and covered with polyethylene sheets for one day. The cast specimens were then removed from the mould after 24 hours (Figure 1) and aged in water for 7, 14, 28, and 90 days.

Figure 1. Demoulding of cast concrete cube specimens.

The hardened specimens were tested for compressive strength (Figure 2) as specified in BS EN 12390-3 (2009), tensile splitting strength as described in BS EN 12390-6 (2009), and water absorption.

The water absorption was performed on samples removed from the curing tank at 7, 14, 28 and 90 days and allowed to dry properly for 21 days in open space. The cubes were weighed using digital weighing balance (Figure 3) and then soaked in water for 24 hours (Figure 4), after which they were removed, mopped and re-weighed. The difference in weight represents the water absorbed. The water absorption, expressed in percentage, was then computed using Equation (1).

$$Water \quad absorption(\%) = \frac{M_w - M_d}{M_d} \quad x100 \qquad (1)$$

where M_w is mass of wet specimen after immersion in water for 24 hours, and Md is the mass of dry specimen before immersion in water.

A total of 180 specimens were cast for all the properties investigated. Three specimens were tested for each curing age and replacement level and the mean value computed.

Figure 2. Testing of concrete cubes for compressive strength.

Figure 3. Weighing of specimen before being soaked in water.

Figure 4. Specimens soaked in water for 24 hours.

3.0 RESULTS AND DISCUSSION

3.1 Compressive Strength

The compressive strength results as presented in Table 5 indicated that the strength of the concrete within the curing period of 7-90 days ranged from 11.75 N/mm2 to 30.12 N/mm2. The least value of 11.75 N/mm2 occurred with blended cement concrete containing 20% BLA at 7 days hydration period while the highest value was attained with the reference concrete at 90 days curing period.

The percentage performance of the various contents of BLA (5-20%) over the reference were 81.22%, 59.76%, 58.54% and 57.07% for 5%, 10%, 15% and 20% BLA content, respectively at 7 days period. These percentage values were increased to 95.47%, 77.71%, 67.75% and 56.07% at 14 days. At the standard age of 28 days, the strength achievement over the reference range between 90.06% and 64.96% while at 90 days curing period it ranges from 94.29% to 57.27% with 10% BLA content having 75% and above of the reference value. It was equally observed that beyond 10% BLA content the compressive strength values were less than 75% of the reference mix beyond 7 days curing age. Based on this observation it can be deduced that 10% BLA content in the mix could be considered the optimal value. This also confirmed the assertion of ASTMC 618 (2008) that a good pozzolan should be able to attain up to 75% of the value of the reference mix in order to be considered suitable for use in concrete.

Table 5. Compressive strength of BLA blended cement concrete at various curing ages.

BLA Content (%)	Curing Ages (Days) [N/mm^2]			
	7 days	14 days	28 days	90 days
0	20.50	21.40	25.40	30.12
5	16.65	20.43	23.13	28.40
10	12.25	16.63	19.00	25.80
15	12.00	14.50	17.00	19.58
20	11.75	12.00	16.50	17.25

3.2 Tensile Splitting Strength

The results of the tensile splitting strength of BLA blended cement concrete cubes as presented in Tables 6 increases with curing age but decreases with increased in BLA content. The results at 7 and 14 days show that in all the replacement levels the strength attainment with respect to the reference were 87.60%, 88.47%, 74.38% and 68.83% for BLA content of 5%, 10%, 15%, and 20%, respectively for 7 days, and 90.00%, 94.29%, 78.57%, and 77.14% for BLA content of 5%, 10%, 15%, and 20%, respectively for 14 days. These indicate that mixtures with BLA contents up to 10% and 20% met over 75% tensile splitting strength of the reference at 7 and 14 days, respectively.

At 28 and 90 days hydration period, the reference strength equivalent were 83.33%, 91.95%, 78.73% , and 75.29% for BLA content of 5%, 10%, 15%, and 20%, respectively for 28 days hydration period. At 90 days hydration period the strengths were 84.88%, 85.37%, 76.59%, and 75.61% for BLA content of 5%, 10%, 15%, and 20%, respectively. These indicate that all the blended cement specimens met up to 75% of the reference concrete.

Table 6. Splitting Tensile strength of BLA blended cement Concrete at various curing ages.

BLA Content (%)	Curing Ages (Days) [N/mm^2]			
	7 days	14 days	28 days	90 days
0	2.42	2.80	3.48	4.10
5	2.12	2.52	2.90	3.48
10	2.14	2.64	3.20	3.50
15	1.80	2.20	2.74	3.14
20	1.69	2.16	2.62	3.10

The compressive strength plotted against tensile splitting strength as shown in Figure 5 indicates a very strong linear relationship between the parameters as the coefficient of correlation, R2 = 0.790, indicating that tensile splitting strength can be effectively estimated from the experimental compressive strength value using the expression of Equation (2).

$$Y = 0.102X + 0.783 \tag{2}$$

Where Y is the tensile splitting strength and X the compressive strength.

This is in accordance with Johnson (1994) who opined that a strong relationship exists between two variables when 0.5 </r/<1.

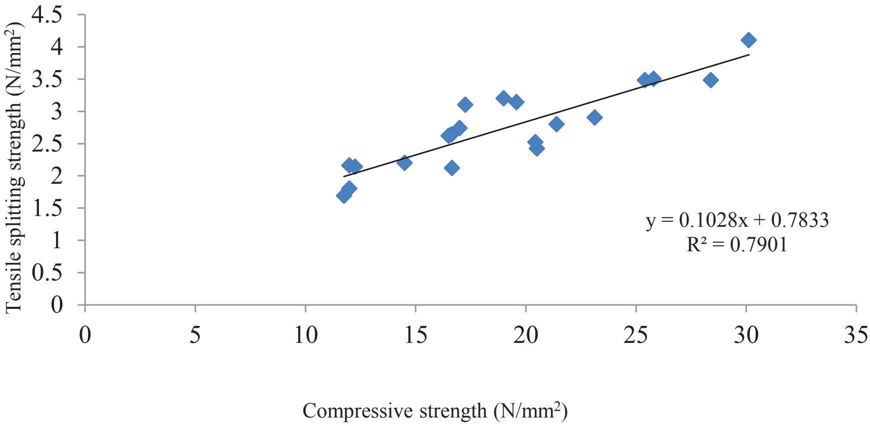

Figure 5. Relationship between compressive and tensile splitting strength of BLA blended cement concrete.

3.3 Water absorption

The results of the water absorption of BLA blended cement concrete cubes is presented in Figure 6. A general decrease in the weight of water absorbed was observed as the percentage BLA substitution increases from 0% to 10% and start increasing from 15% to 20%. The percentage water absorption range between 1.02% and 2.84% with least value attained at 90 days with 10% BLA content, and the greatest value of 2.84% attained by the reference concrete at 90 days. Generally, the water absorption of the blended cement concrete specimens has less water absorption than the reference; an indication that the incorporation of BLA causes reduction in the voids thereby causing impermeability. The decrease in water absorbed at lower BLA replacement may be attributed to the initial filling of the voids by the BLA incorporated. This finding agrees with previous observations by Khatri and Sirivivathnanon (1997) and Adesanya (2001). However, at higher levels of BLA substitution, there was insufficient quantity of calcium hydroxide to react with the excess BLA thus creating pores in the mixture and thereby increasing the water absorption. It is clearly evident from Figure 2 that optimal BLA substitution with respect to water absorption is 10%. The water absorption of all the mixes however, were less than 10% value stipulated for most good concrete (Neville, 2000).

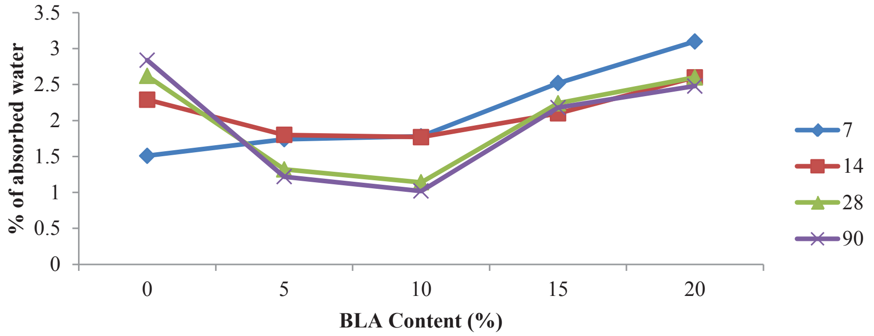

Figure 6. Relationship between BLA content and % water absorption of concrete specimens.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The use of BLA in concrete had enhanced the mechanical properties of concrete. At the standard age of 28 days, the compressive strength attainment of the blended cement concrete over the reference range from 64.96% for 20% BLA content to 90.06% for 5% BLA content; and that beyond 10% BLA content, the percentage performance over reference were less than 75%, an indication that 10% BLA content is the optimal replacement level for the production of medium grade concrete. The tensile splitting strength of BLA blended cement concrete, especially at 14 days hydration and above, all the mixtures met over 75% of the reference tensile splitting strength, an indication that BLA replacing cement up to 20% can improve the serviceability requirement of concrete structures than that of reference structures. There is a strong linear relationship between compressive strength and tensile splitting strength with a correlation equation of $Y = 0.102x + 0.783$ and a correlation coefficient R^2 of 0.790.

The BLA blended cement concrete recorded less water absorption particularly with 10% BLA content than the reference, revealing that an incorporation of BLA causes reduction in the voids thereby leading to impermeable pores formation. Based on these conclusions, it is therefore recommended that 10% BLA content is suitable for the production of medium grade concrete.

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