International Journal of Agriculture, Environment and Bioresearch

Vol. 3, No. 05; 2018

ISSN: 2456-8643

DURABILITY OF BAMBOO LEAF ASH BLENDED CEMENT CONCRETE

Alake Olaniyi[1], Olusola Kolapo Olubunmi[2] & Ata Olugbenga[2]

[1]Department of Building, School of Environmental Technology
Federal University of Technology Akure, Nigeria
[2]Department of Building, Faculty of Environmental Design and Management, Obafemi Awolowo University, Ile-Ife, Nigeria

ABSTRACT

The performance of bamboo leaf ash (BLA) in sulphate environment has been investigated with a view to enhancing its effective utilization. In an attempt to convert waste product into useful material for the construction industry, this research considered the use of bamboo leaf ash as partial replacement for cement in concrete. The effects of varying percentage replacement on the compressive strength of concrete in sulphate environment were investigated.

Test specimens to determine the sulphate resistance involved concrete having its cement components replaced with bamboo leaf ash (BLA) at five (5) levels (0%, 5%, 10%, 15% and 20%) on the compressive strength of concrete exposed to varying concentration of sulphates of magnesium and calcium at four (3) levels each (1 %, 3 % and 5 %) and for four exposure periods (32, 92, 152 and 182 days) after complete immersion in water for 28 days. Using three (3) replicates in all the test, a total of 480 specimens were cast and tested. The study concluded that Magnesium sulphate solution at 5% concentration at 182 days exposure had greater effect on the compressive strength reduction for both plain and BLA blended cement concrete than the other variables.

Keywords: Aggressive environment, Bamboo leaf ash, Blended cement, Compressive strength, Durability

1. INTRODUCTION

The use of waste materials with pozzolanic properties in concrete production is a worldwide practice. The assessment of the pozzolanic activity of cement replacement materials is becoming increasingly important because of the need for more sustainable cementing products.

Concrete is widely used as construction material for various types of structures due to its durability. For a long time it was considered to be very durable material requiring a little or no maintenance. Many environmental phenomena are known significantly the durability of reinforced concrete structures. We build concrete structures in highly polluted urban and industrial areas, aggressive marine environments and many other hostile conditions where other materials of construction are found to be nondurable

Concrete could be approximately considered as a two-phase material containing a mixture of hydrated cement paste and aggregate. The properties of concrete are governed by the properties of the two phases and also by the presence of interfaces between them (Neville, 2000).

ISSN: 2456-8643

Variation in the behavior of different forms of concrete subjected to similar test conditions could be attributed to these two factors.

For concrete to meet performance requirement when used in structures, it must be satisfactory both in fresh state and hardened state. Satisfactory performance in its fresh state means, the mix is cohesive enough to be transported and placed without segregation, the consistence of the mix ensures that the concrete can be adequately compacted by the available means on the site. Satisfactory performance in the hardened state portrays the concrete as having a satisfactory compressive strength, as an indicator of the quality of the concrete. Thus, as Neville (1987) puts it, compressive strength of concrete is an easy way of ascertaining the compliance with the specification. Other reasons that had been given for the prominence of compressive strength is that many other properties- e.g. density, tensile strength, durability, resilience, e.t.c.-are related to it.

One way is to use certain low cost materials for partial replacement of Portland cement clinker. Low cost materials used are industrial and agricultural by-products (wastes). Mixture of Portland cement and the above by-products are known as 'blended cements' or 'composite cements'. By definition blended cements are hydraulic binders in which a part of Portland cement is replaced by other hydraulic or non-hydraulic materials. Their general behaviour is quite similar to that of Portland cement since they harden when mixed with water and form the same hydration products. The most common ingredients for blending with Portland cement clinkers are latent hydraulic component (blast furnace slag), or a pozzolanic component such as pozzolana, fly ash, rice husk ash, condensed silica fume, burnt clay or filler component such as lime stone and other waste materials.

Durability is the resistance of concrete to deterioration resulting from external and internal causes. (Jackson, 2005) The external causes include the effects of environmental and service conditions to which concrete is subjected such as weathering, chemical actions and wear, while the internal causes are the effects of salts, particularly chlorides and sulphates, in the constituent materials, such as alkali-aggregate reaction, volume changes, absorption and permeability. Two major sources of chemical aggression in concrete have been identified to include the natural sources such as sea-water and soils rich in sulphates, nitrates, chlorides and carbonates; and the artificial sources such as chemical manufacturing industries, salts and usage of industrial chemicals and catchment areas of effluents from rearing units (Baeby, 1978; Sadiq *et al.*, 1996).

Sulphate attack is one of the most important matters concerning the durability of concrete structures. Under the Sulphate environment, cement paste undergoes deterioration resulting from expansion, spalling and stiffening (Chindaprasirt *et al* .2007). Sulphate attack occurs in concrete when concrete is in contact with a source of Sulphate ions, which can be underground, soil or rain water. Sulphate attack usually manifest itself by spalling and cracking of concrete accompanied by expansion or loss of strength. The resistance of concrete to Sulphate attack is determined by several factors such as water/cement, permeability and cement properties which include fineness and cement composition.

Several researchers such as (Soroka and Setter, 1980; Fookes *et al.*, 1991); and Sadiq *et al.*, (1996), have identified that sulphates, nitrates, chlorides and many other salts either in natural

form or artificially introduced could be responsible for the reduction in the compressive strength of concrete or cement products as a result of their adverse effects on the quality of the products.
Bamboo is one of the oldest building materials used by mankind (Abdulatif *et al.,* 1990). The bamboo culm (stem) has been made into different products ranging from domestic household products to industrial applications, examples are found in food containers, skewers, chopsticks, handicrafts, toys, furniture, flooring, pulp and paper, boats, charcoal, musical instruments and weapons. In Asia, bamboo is quite common for bridges, scaffolding and housing, but it is usually a temporary exterior structural material, while in many overpopulated region of the tropics, certain bamboos supply the one suitable material that is sufficiently cheap and plentiful to meet the extensive need for economical housing (McClure, 2007). Bamboo shoots are important sources of food and delicacy in Asia and in addition to its more common applications, bamboo has other uses from skyscraper, scaffolding and phonograph needles to slide rules, skins of airplanes and diesel fuels (Farelly, 1984). Extracts from various parts of the plant have been used for skin ointment, medicine for asthma, eyewash, potions for lovers and poisons for rivals. Bamboo ashes are used to polish jewels and manufacture electrical batteries. (Ernesto *et al.*, 2011). Bamboo has been used in bicycles, dirigibles, windmills, scales, retaining walls, ropes, cables and filament in the first light bulb. Indeed, bamboo has many applications beyond imagination. Its uses are broad and plentiful. (Lee, *et al.,* 1997)
Several studies have been conducted on the use of bamboo leaf ash (BLA) as pozzolanic material in construction. Dwivedi (2006) reported the reaction between calcium hydroxide $Ca(OH)_2$ and bamboo leaf ash for 4h of reaction, using the differential scanning calorimetry (DSC) technique. Ernesto *et al.* (2011) presents a characterization and study of the pozzolanic behavior between calcium hydroxide $Ca(OH)_2$ and bamboo leaf ash (BLA). To evaluate the pozzolanic behavior, conductometric method was used, which was based on the measurement of the electrical conductivity in a BLAsh/CH solution with the reaction time. Later, the kinetic parameters are quantified by applying a kinetic diffusive model. The kinetic parameters that characterize the process (in particular, the reaction rate constant and free energy of activation) were determined with relative accuracy in the fitting process of the model. The pozzolanic activity is quantitatively evaluated according to the values obtained of the kinetic parameters. The correlation between the values of free energy of activation and the reaction rate constants are in correspondence with the theoretical studies about the rate of processes reported in literature.

Massazza (1990) identified the structure complexity and the wide variability of chemical and mineralogical composition of pozzolans justify the difficulties which arise in establishing general validity relation between chemical and physical characteristics and activity of pozzolanas.

Singh *et al.,* (2007) discussed that eco friendly composite cement may be obtained by partial replacement of Portland cement with certain low cost materials. They studied the hydration of bamboo leaf ash in in a blended Portland cement. It was concluded that bamboo leaf ash is an effective pozzolanic material. When 20 % weight of bamboo leaf ash was mixed with OPC the compressive strength values of mortars at 28 days of hydration were found to be quite comparable to those of OPC.

Iorliam *et al.*, (2012), studied the effect of bamboo leaf ash (BLA) on cement stabilization of Makurdi shale for use as flexible pavement construction material. Compaction, Consistency, California Bearing Ratio (CBR) and unconfined compressive strength (UCS) tests, were conducted on Markurdi shale specimen treated with cement and bamboo leaf ash in combined incremental order of 2% to 14% cement, and 4% up to 20% BLA of dry weight of soil sample respectively. The results of test showed that Makurdi shale can be classified as high swell potential soil by AASHO, USCS and NBRRI classification, systems respectively therefore, recommending BLA for use as sub-base materials in flexible pavement..

Umoh, *et al.*, (2013). Investigated the mechanical properties of concrete incorporating periwinkle shell ash (PSA) and bamboo leaf ash (BLA) as partial replacement for cement. Concrete specimens of 100mm cube size were cast from a prescribed mix of 1:2:4. The content of the reference mix was replaced with combined % weight of PSA and BLA. The weight of PSA was increased from 10% to 30%, in 5% step. While the % weight of BLA was fixed at 10% for all the five blended mixes. Water-cement ratio of 0.60 was adopted for the reference and blended mixes. The results indicated that the slump values range between 0 to 25mm; the compressive strength generally increase with curing age and decreases as the % weight of PSA increases.

Umoh and Femi (2013) examined the performance of ternary blended cement concrete incorporating Periwinkle Shell Ash (PSA) and Bamboo leaf Ash (BLA) as cement supplements. PSA and BLA were obtained by burning Periwinkle Shell and Bamboo Leaves in a furnace at a temperature of 600^oC for 20 minutes. The chemical analysis of the ashes revealed that they are amorphous in nature. A nominal mix of 1:2:4 with water cement ratio of 0.65 was used as references. The cement content of the reference mix was replaced with varying combined percentages (by weight) of PSA and BLA up to 40% given 10 mixes. The result revealed that at 28 and 56 days hydration, ternary blended cement concrete containing combined percentage of PSA and BLA of 20% cement replacement attained higher compressive and tensile strength and lower water absorption and porosity values than the reference. It is concluded that blended cement concrete of 20% cement replacement is the optimum combination for ternary blended cement concrete. This paper therefore studies the physical, chemical properties as well as compressive strength of bamboo leaf ash subjected to sulphate environment

Experimental Work

The bamboo leaves were obtained from thick forest at Federal University of Technology, Akure, in Akure South Local Government of Ondo State, Nigeria. The bamboo leaves collected were taken to the Laboratory of Department of Building, Federal University of Technology. Akure. The leaves were spread on the floor so as to be properly dried. The leaves were placed inside open perforated metallic drum and burnt completely in an open air.. The dried leaves were ignited in the open drum at a temperature of 150^0C, without the application of external energy such as charcoal or firewood. The burning was stopped as soon as the ashes turned to black colour. The ash was allowed to cool for 24 hours before removal from the burning drum. The ashes produced was taken to Federal Institute of Research Oshodi and heated in a gas furnace and heated to a temperature of 600^0C for two hours until it becomes grey in color. The ash was allowed to cool for 48 hours and was sieved through 45 µm sieve wire mech. The chemical composition of the ash were determined by an X-ray Fluorescence (XRF) Technique. The following physical properties were conducted on the ash, specific gravity, Fineness, soundness, consistency as well as initial and final setting times of the blended cement concrete as shown in Table 1. The ash satisfied the requirement for class F pozzolans (ASTM C610, 2008).A. Cement Ordinary Portland cement of 53 grade (Elephant brand) with specific gravity 2.65 available in local market was used in this investigation found to be in conformity to various specification of BS EN 197-1 (2009), the properties of cement used are given in Tables 1. and 2. Water is an important ingredients in concrete as it actually participates in chemical reaction with the cement. portable water was used for mixing. The fineness of the ash, expressed as percentage retained on the 45 µm mesh sieve was in accordance with ASTM C311. Fine aggregate used were sharp sand satisfied the requirement of BS EN 12620 (2008) for sand to be used for concrete and granite chipping used of nominal maximum size of 25 mm,

Aggressive Environments

The specimens were subjected to Sulphate environment, the sulphate used were Magnesium sulphate ($MgSO_4$) and calcium sulphate. ($CaSO_4$). The concentration of the aggressive solutions were 1 %, 3 % and 5 %. A volume of 100 L of each solution was prepared and the specimens were immersed until their testing ages was attained. The volume of each solution was prepared with the known concentrations

Test Specimen preparations

The constituents materials were batched by weight and mixing was done manually on a platform using a shovel and hand trowel until a uniform mix was obtained without segregation. This was done on over a large, clean

Curing

The specimens were stored in a place free from vibration and not exposed to direct sunlight or other sources of heat. The curing was carried out in two different media; water and Sulphate environment. The specimens were cured in water for 28 days and then immersed in sulphate solutions of various concentrations of magnesium Sulphate $MgSO_4$ and calcium Sulphate $CaSO_4$ of 0, 1, 3 and 5 % for 32, 92, 152 and 182 days respectively According to BS EN 12390-2: 2009. The percentage replacement of cement with bamboo leaf ash (BLA) at five (5) levels (0%, 5%, 10%, 15% and 20%) The curing was carried out by complete immersion. For the purpose of comparison, before casting it should be noted that the control specimens were cured in water alongside with the specimens in sulphate environment.

Table 1. Physical properties of BLA blended cement

Vol. 3, No. 05; 2018

ISSN: 2456-8643

Properties	BLA content (%)				
	0	5	10	15	20
Fineness (% retained on 45µm sieve)	34.0	31.5	30.0	28.5	27.0
Soundness (mm)	0.90	1.20	1.60	2.00	2.50
Consistency (%)	26.72	28.70	30.72	32.04	37.56
Initial setting time (minutes)	96	92	104	114	152
Final setting time (minutes)	201	152	225	240	320

Table 2. Chemical composition of BLA-blended cements

Elemental oxide (%)	BLA Content (%)				
	0	5	10	15	20
SiO_2	62.03	62.38	63.40	64.07	68.58
Al_2O_3	3.23	3.37	3.40	3.92	3.45
Fe_2O_3	1.00	1.02	1.04	1.06	1.07
CaO	27.41	27.13	26.71	27.01	26.61
MgO	0.54	0.56	0.60	0.81	0.83
SO_3	2.81	2.71	2.74	2.71	1.52
K2O	0.97	0.43	0.60	0.50	0.40
Na_2O	0.21	0.20	0.18	0.19	0.19

Vol. 3, No. 05; 2018

ISSN: 2456-8643

MnO_2	0.20	0.10	0.10	0.05	0.05
P_2O_5	0.16	0.17	0.12	0.10	0.08
TiO_2	0.28	0.19	0.12	0.16	0.14
Cr_2O_3	0.20	0.24	0.25	0.26	0.25
LOI	0.09	0.11	0.14	0.17	0.18

Table 3 Elemental oxide content of BLA sample calcined at different temperatures

Elemental oxide (%)	Calcination Temperature (^{0}C)		
	500	600	700
SiO2	80.25	83.33	83.00
Al2O3	1.08	1.03	1.02
Fe2O3	1.97	1.95	2.01
CaO	4.23	4.44	4.43
MgO	1.01	1.02	1.02
SO3	0.15	0.10	0.10
K2O	3.13	3.09	3.09
Na2O	0.05	0.05	0.06
MnO2	0.22	0.22	0.23
P2O5	0.74	0.72	0.72
TiO2	0.35	0.34	0.36
Cr2O3	0.00	0.00	0.00
LOI	2.93	0.40	0.41
SiO2+Al2O3+Fe2O3	83.30	86.31	86.03

Table Physical properties of the aggregates

Material Characteristics	Fine aggregates	Coarse aggregates
Fineness modulus	2.09	2.13
D60	1.18	0.9

Vol. 3, No. 05; 2018

ISSN: 2456-8643

D10	0.27	0.3
Cu	4.37	3.00
Specific gravity	2.65	2.65
Moisture content	0.74	2.20
.		

Table 5.: Percentage change in compression strength of BLA blended cement concrete exposed to different sulphate types and concentrations at various exposure periods

BLA content(%)	exposure period (Day)	Compressive strength reduction					
		$MgSO_4$(%)			$CaSO_4$ (%)		
		1	3	5	1	3	5
0		8.29	8.75	8.95	-1.90	6.72	3.80
5		-0.55	-0.97	-0.28	-6.53	-6.26	-6.07
10	32	-4.88	-4.50	-3.81	-9.81	-9.16	-9.00
15		-1.36	-1.13	-0.96	-9.52	-9.01	-8.22
20		0.78	1.39	-1.63	-3.27	-2.72	-1.39
0		8.91	9.22	9.34	3.71	3.86	4.89
5		5.62	5.75	5.85	0.46	1.28	1.78
10	92	4.55	3.72	4.80	0.62	1.14	1.55
15		6.22	6.44	6.71	1.07	2.31	3.00
20		4.28	4.57	4.74	0.74	2.06	2.34
0		6.72	7.02	7.14	4.50	5.04	5.31
10	152	3.92	4.66	4.95	1.31	1.64	1.80
15		2.16	2.68	3.06	9.00	0.61	1.08
		6.86	7.06	7.27	1.47	1.98	2.74

ISSN: 2456-8643

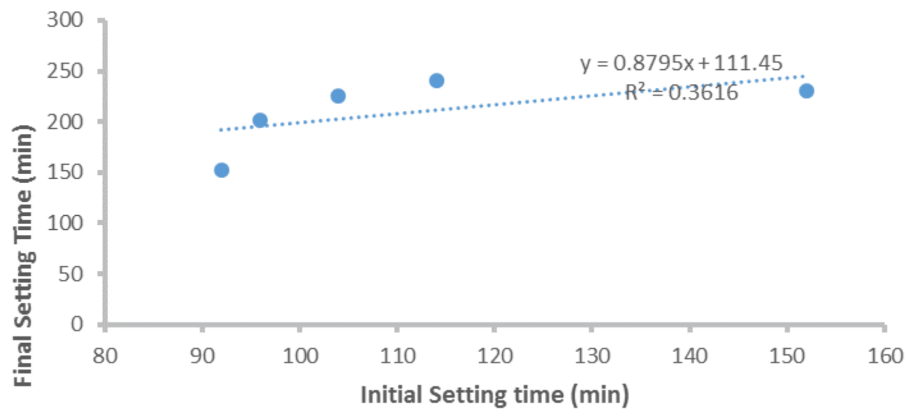
20		4.75	5.35	5.78	11.00	1.03	2.05
0		11.35	11.53	11.86	8.46	9.34	9.48
10		4.76	4.99	6.31	9.90	10.12	10.54
		1.25	1.30	1.75	6.00	0.45	0.58
15	182	2.23	2.33	2.48	4.00	0.29	0.53
20		0.02	2.35	0.26	6.00	0.46	0.56

2. RESULTS AND DISCUSSION

Physical properties of bamboo leaf ash blended cement

The physical properties of the bamboo leaf ash blended cement are presented in Table 1. The result of the fineness test expressed as % retained on sieve 45µm sieve were 34 %, 31.5 %, 30.0 %, 28.5 %, 27.0 % for BLA content of 0 %, 5 %, 10 %, 15 %, and 20 % respectively. Therefore, the parameters decreases from 34.0 % at 0 % to 27.0 % at 20 % BLA replacement. The fineness test shows that the blended cement were finer than the control. This revealed that the higher the BLA content in the blended cement the lower the residue retained on the sieve. All the cement satisfied the BS EN 196:6 (1992).

The Table 1.also revealed that the soundness of the cement ranged between 0.90 and 2.50mm for replacement levels of 0 % to 20 %. These values are lower than the 10mm limiting value recommended by NIS 439; 2000 and BS EN 197-1:2009. Hence blended cement did not show any appreciable change in volume after setting. The consistency increases from 26.72 % to 37.56 % as BLA content increases from 0% to 20 %. The quantity of water required for a standard consistency was noted to increase as the BLA content increased. This can be attributed to the finer particle sizes of blended cement as much water was required for proper lubrication. the results also depicts the various percentage replacement. The setting times increased with increase in the amount of bamboo leaf ash. The initial setting time increased from 1 hour 36 minutes at 0 % replacement to 2 hours 32 minutes at 20 % replacement while the final setting time increased form 3 hours 21 minutes at 0 % replacement to 5 hours 20 minutes at 20 % replacement. All the cement satisfy the NIS 439: 2000 and BS EN 197-1: 2000 requirements of 45 minutes minimum initial setting and maximum of 10 hours final setting as spelt out by NIS 439: 2000 and 375 minutes maximum specified for final setting time by ASTM C150. BS EN 197-1:2000.were equally satisfied by all the cement. The variation of setting times with percentage BLA replacement increased. As a result of measured setting time the hydration process was slowed down in consonance with the views of Hossain (2003). The slow hydration means low rate of heat development which is one of the notable characteristics of pozzolanic cements. This is of great importance in mass concrete construction where low heat development is very essential as it reduces thermal stress.



Fig, 1

A plot of initial setting time against the final setting time as shown in fig, 1 indicate a strong relationship between the parameters as the coefficient of correlation was calculated to be R^2 = 0.3616 with an equation of final setting time being $y = 0.8795x + 111.45$

From where the estimate of the final setting time can be deduced when an initial setting time is known, where y = final setting time, x = initial setting time

This is in accordance with Johnson (1994) who opined that a strong relationship exists between two variables.

Chemical composition of BLA blended cement

Table 2 shows the chemical composition of BLA blended cement. Details of how the average values of the chemical constituents were obtained are shown in Tables A15 to A19 in appendix A. The cement satisfied the chemical composition as spelt out by NIS 441-1:2003 and BS EN 197-1: 2009. From table 5.4. The percentages of the silica content increased from 62.38 % for 5 % BLA replacement to 63.58 for 20 % BLA content representing about 1.89 % increase in the percentage of silica content of BLA blended cement. It was also observed that alumina and ferric oxide increased from 3.23 % to 3.45 % and 1.00 % to 1.07 % for 5 % and 20 % BLA contents respectively. Similar trends were observed with magnesium oxide MgO which increased from 0.56 % at 5 % BLA content to 0.83 % at 20 % BLA content. The calcium oxide CaO content decreases from 27.13 % for 5 % BLA to 26.61 % for 20 % BLA replacement. The minor compounds of Na_2O and K_2O, known as alkalis, ranges from 0.20 % to 0.19 % for Na_2O and 0.43 to 0.40 for K_2O for 5 % and 20 % of BLA content.. These values are lower than those for the control, which are 0.21 for Na_2O and 0.97 for K_2O respectively. However, the limiting value of 0.4 % to 1.3 % of the combined alkalis content was satisfied for both the Portland cement and the blended cements.

ISSN: 2456-8643

The loss on ignition (LOI) of the BLA blended cement was higher than that of the control. There was an increase in the LOI of the blended cement from 0.11 % at 5 % BLA content to 0.18 % at 20 % BLA content as against 0.09 % content for the control. The increase in the LOI depicts the presence of much carbon in the blended cement which could adversely affect the binding properties of the cement. However, the LOI content in all the cements was within the limit of 5 % recommended by BS EN 197-1: 2009.

Resistance of BLA blended cement concrete in sulphate environment

The summary of the effect of different sulphate types and concentrations on the compressive strength of BLA blended cement concrete at various exposure periods are shown in Table 5., Figures 1 to 6 expressed the strength change in percentage BLA content for different calcium and magnesium sulphates

The figure indicated that there was a strength reduction of 8.29% and 0.78 % with 0 % and 20 % BLA content when exposed to 1 % $MgSO_4$ solution for 32 days; whereas there was gain in strength of 0.55 %, 4.88 %, and 1.36 %, at 5 %, 10 % and 15 %, BLA content respectively. When the specimens were in 1 % $CaSO_4$ solution up to 32 days, 0 %, 5 %, 10 %, 15 % and 20 % BLA concrete gain strength by 1.90 %, 6.53 %, 9.81 %, 9.52 % and 3.27 % respectively .In the $CaSO_4$ medium (1 % solution), all the specimens had improvement in their compressive strength. The highest strength loss of 8.91 % and 3.71 % were recorded by 0 % BLA content in $MgSO_4$ and $CaSO_4$ solutions at 92 days of exposure. The loss in strength of 5% to 20% BLA contents were between 4.28% and 6% for that of $MgSO_4$ and between from 0.46% to 1.07% for $CaSO_4$ solution.

At 152 days the control BLA had strength loss of 6.72% and 4.50% in $MgSO_4$ and $CaSO_4$ solutions respectively. Values of 3.92%, 2.16%, 6.86% and 4.75 % loss in strength were recorded in $MgSO_4$, while 1.31 %, 9.00 %, 1.47 %, and 11.00 % in $CaSO_4$ solution for 5 %, 10 %, 15 % and 20 % BLA content respectively. Also, at 182 days 0 % BLA had strength loss of 11.35 % and 8.46 % in $MgSO_4$ and $CaSO_4$ solution while the values of 4.76 %, 1,25 %, 2.23 % and 0.02 % were recorded in 1 % $MgSO_4$.

For $MgSO_4$ and $CaSO_4$ 3 % sulphate concentration as shown in the Figure 0 % and 20 % BLA content had loss in strength of 8.75 % and 1.39 % while 5 % BLA, 10 % BLA and 15 % BLA had improvement in strength of 0.97 %, 4.50 % and 1.13 % in $MgSO_4$ solution at 32 days. In $CaSO_4$ solution, only 0 % BLA loss strength by 6.72 % while the other concrete specimens gained strength by 6.26 %, 9.16 %, 9.01 % and 2.72 % at 5 %, 10 %, 15 % and 20 % $CaSO_4$ solution. At 92 days exposure, loss in strength were recorded by specimen in $MgSO_4$ and $CaSO_4$ solution for all the replacement level of 0 % to 20 % BLA, 0 % had the highest strength reduction of 9.22 %. A gain in strength was recorded with 15 % and 20 % BLA whereas 0 % BLA had strength loss of 3.86 % when the specimens were exposed to $CaSO_4$ solution.

At 152 days exposure, 0 % had the highest loss in strength of 7.02 % and 5.04 % when exposed to $MgSO_4$ and $CaSO_4$ solution. The least strength loss was 2.68 % in $MgSO_4$ at 10 % replacement level of BLA and 0.61 % in $CaSO_4$ at 10 % replacement level of BLA. At 182 days

Vol. 3, No. 05; 2018

ISSN: 2456-8643

the loss in strength recorded by the specimens in $MgSO_4$ and $CaSO_4$ for all the replacement levels of 0 % to 20 % BLA. 0 % BLA had the highest reduction of 11.53 % and 9.34 % respectively. The strength loss of 4.99 %, 1.30 %, 2.33 % and 2.35 % was obtained for $MgSO_4$ and 10.12 %, 0.45 %, 0.29 %, and 0.46 % at 5 %, 10 %, 15 % and 20 % respectively.

In 5 % concentration of sulphate solution at 32 days, 0 % and 5 % BLA recorded a strength reduction of 8.95 % and 3.80 % in $MgSO_4$ and $CaSO_4$ solution as shown in Table 5 strength gained of 0.28 %, 3.81 %, 0.96 % and 1.63 % were recorded with 5 %, 10 %, 15 % and 20 % BLA content respectively. While in $CaSO_4$ solution at 0 % BLA had a strength loss of 3.80 %.while 5 %, 10 %, 15 % and 20 % BLA improved their strength by 6.07 %, 9.00 %, 8.22 % and 1.39 %, respectively.

At 92 days exposure all the specimens recorded reduction in their strength for both $MgSO_4$ and $CaSO_4$ solution, reduction in compressive strength of the specimen in $MgSO_4$ were 9.34 %, 5.85 %, 4.80 %, 6.71 % and 4.74 % for 0, 5, 10, 15 and 20 % BLA content respectively. While values of 4.89 %, 1.78 %, 1.55 %, 3.00 % and 2.34 % were obtained for 0, 5, 10, 15 and 20 % BLA of $CaSO_4$ solution.

Similar strength was observed at 152 days of exposure at 5 % sulphate concentration all the specimen recorded reduction in their strength irrespective of the type of sulphate. In $MgSO_4$ solution. Reduction in compressive strength were 7.14 %, 4.95 %, 3.06 %, 7.27 % and 5.78 % at 0, 5, 10, 15 and 20 % BLA content respectively. Values of 5.31 %, 1.80 %, 1.08 %, 2.74 % and 2.05 % were obtained for 0, 5, 10, 15 and 20 % BLA content respectively in $CaSO_4$ solution.

Sulphate concentration of 5 % at 182 days exposure exhibited the most severe effect on the concrete compressive strength with loss in strength of 11.86 %, 6.31 %, 1.75 %, 2.48 % and 0.26 %. Followed by calcium sulphate with vales of 9.48 %, 10.54 %, 0.58 %, 0.53 % and 0.56 %.

It was observed that at all the exposure periods of BLA blended cement concrete specimen in magnesium and calcium sulphate solution, the strength reduction became much manifested with increase in exposure period particularly at 182 days. Magnesium sulphate had the most deleterious effect on the compressive strength of the concrete specimens at 0 % BLA content (i.e. the control) than the other concrete specimen with various percentages of BLA replacement levels with cement. Calcium sulphate solution had the least effect.

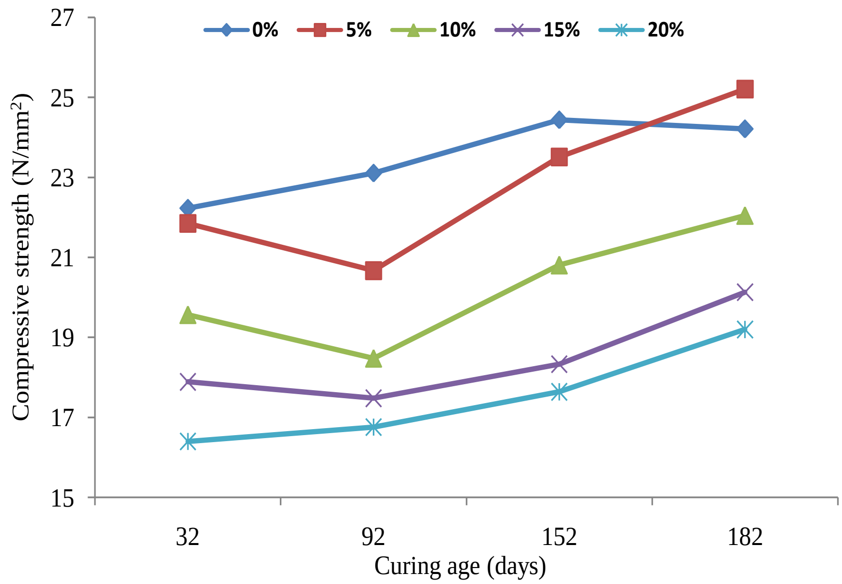
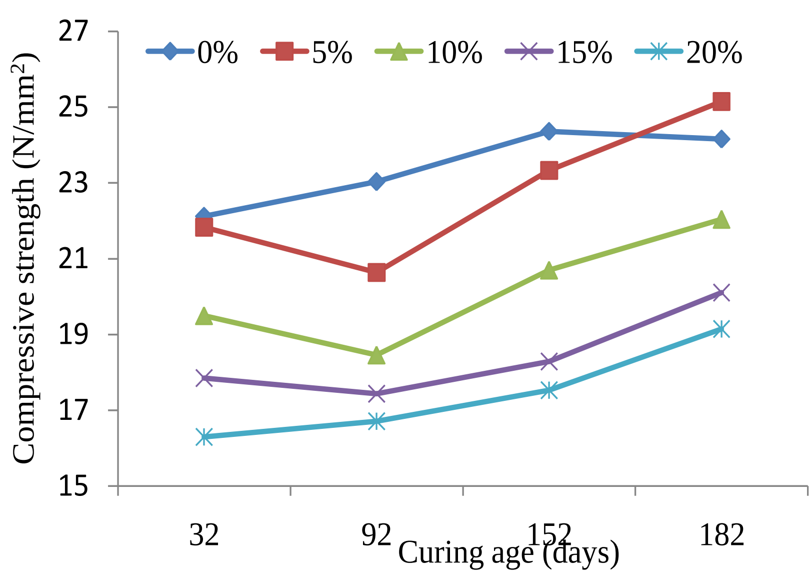


Fig. 1. Compressive strength of BLA-blended cement in 1 % $MgSO_4$



ISSN: 2456-8643

Fig. 2: Compressive strength of BLA-blended cement in 3 % $MgSO_4$

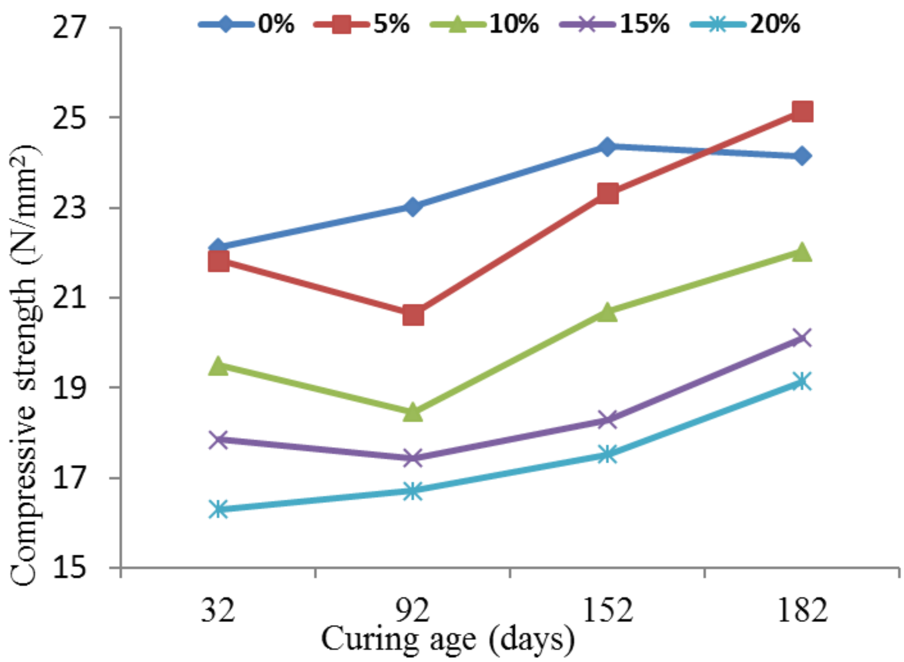


Fig. 3: Compressive strength of BLA-blended cement in 5 % $MgSO_4$

Vol. 3, No. 05; 2018

ISSN: 2456-8643

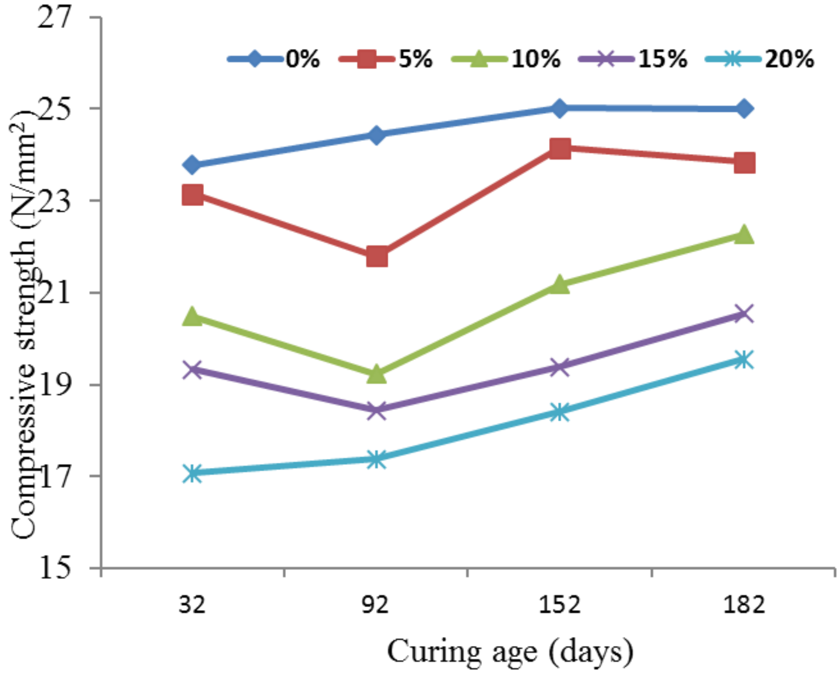


Fig. 4: Compressive strength of BLA-blended cement in 1 % $CaSO_4$

Vol. 3, No. 05; 2018

ISSN: 2456-8643

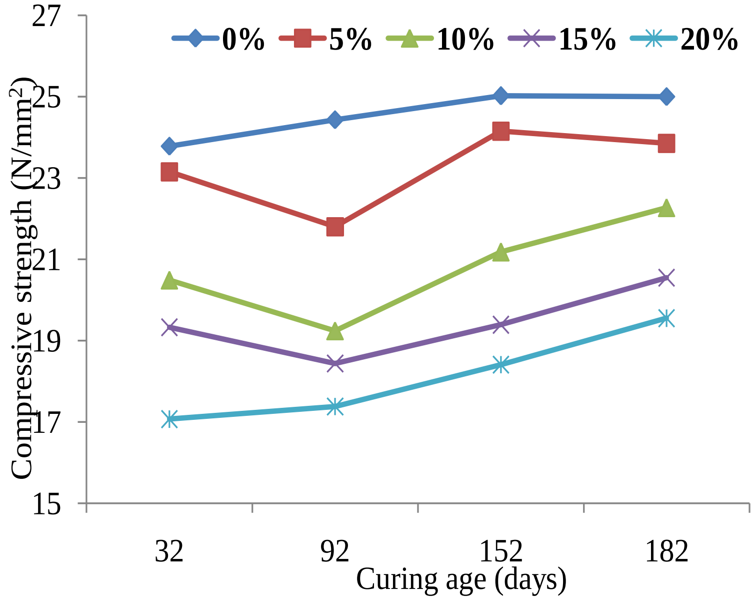
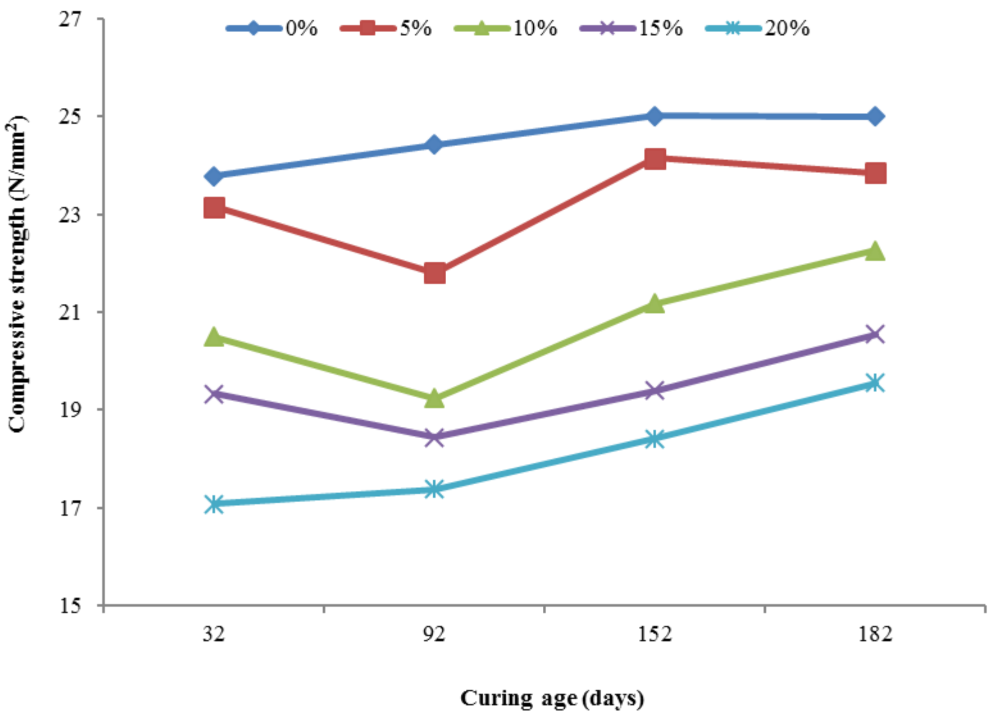


Fig. 5 Compressive strength of BLA-blended cement in 3 % $CaSO_4$



ISSN: 2456-8643

Fig. 6: Compressive strength of BLA-blended cement in 5 % $CaSO_4$

3. CONCLUSIONS

Based on the experimental results, the following conclusions were drawn on the durability of Bamboo leaf ash blended cement concrete in line with the results of this study:

(1) Chemical composition by XRF shows that bamboo leaf ash basically is formed by silica in concentration of about 80 %. The rest oxides are present in low concentrations.

(2) The chemical and physical properties of bamboo leaf ash varies with calcinations temperatures of 500^0C, 600^0C and 700^0C had higher silica content greater than 25.00 % (BS EN 197-1-2009) while the ash calcined at 600^0C had the highest combined acidic content of 86.31 % and met the requirements for class C pozzolans as stipulated by (ASTMC618:2008) and therefore taken as the most suitable ash.

(3) Conventional concrete had a better resistance to sulphate attack in terms of compressive and tensile strength than bamboo leaf ash blended cement concrete.

(4) The BLA blended cements have higher setting times than the control; hence, they are most applicable where low heat development is required such as in mass concreting. This shows that BLA blended cement is good as low heat cement.

(5) The value of the strength loss increases as the concentration of the sulphate increases from 1 % to 5 % concentration, and exposure period from 32 days to 182 days. Magnesium sulphate solution at 5 % concentration and 182 days exposure had greater effect on the compressive and tensile strength reduction of both plain and BLA blended cement concrete. Statistically it was observed that the sulphate type, sulphate concentration, BLA content and exposure period, each and collectively had effect on the concrete compressive and tensile strength.

(6) The results also revealed that the higher the concentration of the curing media, the higher its impacts on the mass loss and the compressive strength of the specimens.

REFERENCES

Abdulatif, M.; Wan Tarmeze, and Fauzidah, A. (1990). 'Anatomical features and mechanical properties of three Malaysian Bamboos'. *Journal of Tropical Forest Science,* Vol. 2, No.3, pp. 227-234.

ASTM C311. Standard Test Method for Sampling and Testing Fly Ash or Natural Pozzolans For Use in Portland Cement Concrete, American Society for Testing and Materials 2007.

ASTM C618 (2008), Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolans for Use as Minerals Admixture in Portland Cement Concrete West Conshohoken, PA: ASTM.

BS EN 12390 -2 – (2009). ''Testing hardened concrete. Making and curing specimens for strength tests, London, British Standard Institution

Chinderprasirt, P., Kanchanda, P., Santhonsaowaphak and Cao, H.T. (2007). ‘’Sulphate Resistance of Blended Cement Containing Fly Ash and Rice Husk ash Construction and Building Materials Vol. 21. no. 6 pp. 1356-1361.

Ernesto, V.C.; Eduardo, V.M.; Sergio, F.S.; Holmer, S. and Moises, F. (2011). ‘’Pozzolanic Behaviour of Bamboo Leaf Ash: Characterization and Determination of the Kinetic Parameters” *Journal of Cement and Concrete Composites*, vol. 33 pp. 68-73.

Farelly, D. (1984). The Book of Bamboo. Sierra Club Books, San Francisco, California

Iorliam, A.Y.; Agbede, I.O. and Joel, M. (2012). Effect of bamboo leaf ash on cement stabilization of Markurdi shale for use as flexible pavement construction material. *American Journal of Scientific and Industrial Research*, Vol.3, No.3, pp.166-174.

Jackson, N. and Dhir, R.K. (2005). Civil Engineering materials., Macmillan Press Limited,

London.

Lee, A.W.C., B. Xuesong, and P.B. Audiman. 1997. Flexural properties of bamboo reinforced

Southern pipe OSB beams. Forest Prod. J. Vol. 47 No.6, pp 74-78.

Massaza, F. and Costa, U. (1990). Aspects of the pozzolanic activity and properties of pozzolanic cements II. Cemento. 76: 318.

McClure, F.A. (2007). ‘’The Bamboos, A fresh perspective. Harvard University press. Cambridge, Massachusetts.

Neville, A.M, and Brooks, J.J. (1987). Properties of Concrete, Longman Scientific and Technical, England

Neville, A.M. (2000). Properties of Concrete. Addison Wesley, Longman Limited, England.

Sadiq, O.M.; Akpan, A.J. and Musa, A.O. (1996). Strength Evaluation of Concrete in Chemically Aggressive Environment”. *Nigerian Society of Engineers Technical Transaction*, Vol. 31, No. 2, pp. 80-86.

Singh, N.B.; Das, S.S., Singh, N.P. and Dwivedi (2007). Hydration of bamboo leaf ash blended Portland cement. *Indian Journal of Engineering and Materials Sciences.* Vol.14, pp. 69-76.

Soroka, I. and Setter, N. (1980). ‘’Effect of Mineral Fillers on Sulphate Resistance of Portland ash in cement and concrete” *Building and Environment* 43, pp.991-998. Cement Mortars. *‘’Durability of Building Materials and Components”* ASTM ATP 691, pp .326-335.

Shanaham, N. and Zayed, A. (2007) ‘’Cement Composition and Sulphate Attack’’ Part ‘’ Cement and Concrete Research. Vol. 37, no 4. pp. 618-623.Umoh, A.A. and Femi, O.O. (2013). Comparative Evaluation of Concrete Properties with Varying proportions of Periwinkle Shell and Bamboo Leaf Ashes Replacing Cement. Ethiopia Journal of Environmental Studies and Management. Vol. 6, No. 5.

Umoh, O.O.; Alake, O.; Babafemi, A.J. and Olasunkanmi, O.F. (2013). Assessing the mechanical performance of ternary blended cement incorporating periwinkle shell and bamboo leaf ashes. *Journal of Civil and Environmental research*. Vol.3. No.1, pp. 26-35.