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Effect of Open Air Burnt Bamboo Leaf Ash Blended Cement Concrete

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Abstract
The research aimed at assessing the compressive strength of open air burnt bamboo leaf ash blended cement concrete, to determine the effect of curing age on compressive strength of bamboo leaf ash and to determine the effect of percentage replacement of cement with bamboo leaf ash on compressive strength of bamboo leaf ash blended cement concrete. In achieving this aim, dried bamboo leaf was collected and burnt completely to ash in an open air. The required percentages of the Bamboo leaf ash (BLA) of 0%, 10%, 20%, 25%, 50%, 75% and 100% respectively were used to replace Ordinary Portland Cement partially in cement mix ratio 1:2:4. Three specimens were prepared for each curing days for the entire mix ratio. The types of aggregate used are sharp sand and crushed granite of 19mm size. The combination of these materials was used to cast eighty four (84) concrete cubes of size 150mm x 150mm dimension as well with the mix proportion of 1:2:4 and water – cement ratio of 0.60. The six specimens for each ratio mix were tested at ages of 7, 14, 21 and 28days to know both the compressive behaviour under loading. Average compressive strengths were determined via the compressive optimum loads from the results. In the light of this, the three specimens of each mix ratio showed different performance in strength as the ages of 7, 14, 21 and 28day test. It was concluded that whenever bamboo leaf ash (as a pozzolanic material) is to be used for concrete production as between 20% and 25% of 1:2:4 mix must be used. In addition, the workability of the mix ratio must be considered in terms of water cement ratio.

Keyword: Compressive strength, air burnt, bamboo leaf ash, blended cement, curing

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I. Introduction

The practice of building technology, usage of building materials and building production in general has evolved through ages. Housing and building conditions reflect the living standards of a society [1]**.** Stones, mud, thatch/leaves and timber represent the earliest building materials used for the construction of buildings. Burnt bricks, metal products and lime are the manufactured materials commonly used for construction by our ancestors for a very long period.

The hope of new Nigeria is to ensure that every individual can afford a housing unit by the year 20:20, in a way to increase the standard of living of every Nigerian [2]. The current housing deficit is put at about 16million housing units nationwide and this must be brought to acceptable international standard of one housing unit per one household. This requires the professional participation and the use of local materials to subsidize the exorbitant and cost of building materials. The poor state of infrastructure development in Nigeria has been held responsible for slow pace of progress in all areas of human endeavours. Hence, there is a need for the execution of local capable construction materials in order to upgrade the infrastructure development of the country.

Housing for the poor remains a major challenge for most developing nations like Nigeria where majority of the population still live in sub-standard houses. According to [3]**,** 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 as well as protection against unwanted aggression. As observed by Mustapha (2004), homelessness and the incidence of people living in poor housing and unhealthy neighbourhoods are rapidly growing. The housing problem is acute especially in the urban areas due to shortage of affordable housing for low-income earners and the poor who constitute over 70% of the urban population [4].

Concrete is the most versatile heterogenous construction material and the impetus of infrastructural development of any nation [5]. Concrete is a composite material composed of gravels or crushed stones (coarse aggregate), sand (fine aggregate) and hydrated cement (binder). When mixed with small amount of water, the cermet hydrates to form a microscopic opaque crystal lattice structure, encapsulating and locking the aggregate into its rigid structure.The compressive strength of mortar is sometimes used as a principal criterion for selecting mortar type, since compressive strength is relatively easy to measure, and it commonly relates to some other properties, such as tensile strength and absorption of the mortar; it is considered as a basis for assessing the compatibility of mortar ingredients. Compressive strength of mortar increases with an increase in cement content and decreases with an increase in lime, sand, water or air content. Flexural strength is also important because it measures the ability of a mortar to resist cracking.

In cement industries, continuous attempts are being made to reduce the cost of production of Portland cement, to reduce the consumption of the raw materials, to protect the environment and to enhance the quality of cement. Ordinary Portland Cement is discovered and known as vital construction material all over the world. The production rate is approximately 2.1 billion tonnes per year and is expected to grow rapidly to about 3.5 billion tonnes per year by 2015 [6].[7] reported and gave an instance, about 4 billion tonnes of cement was produced globally in the year 2020 [8], which can be said to lead to about 3.5 million tonnes of carbon dioxide [9].

Pozzolans are a broad class of siliceous or siliceous and aluminous materials which, in themselves, possess little or no cementitious value but which will, in finely divided form and in the presence of water, react chemically with calcium hydroxide ($CaOH_2$) at ordinary temperature to form compounds possessing cementitious properties [10]. The quantification of the capacity of a pozzolan to react with calcium hydroxide and water is given by measuring its pozzolanic activity [11]. Pozzolana are naturally occurring pozzolans of volcanic origin.

The general definition of a pozzolan embraces many materials which vary widely in terms of origin, composition and properties. Both natural and artificial (man-made) materials show pozzolanic activity and are used as supplementary cementitious materials. Artificial pozzolans can be produced deliberately, for instance by thermal activation of kaolin-clays to obtain metakaolin, or can be obtained as waste or by-products from high-temperature process such as fly ashes from coal-fired electricity production. The most commonly used pozzolans today are industrial by-products such as fly ash, silica fume from silicon smelting, highly reactive metakaolin, and burned organic matter residues rich in silica such as rice husk ash. Their use has been firmly established and regulated in many countries. However, the supply of high-quality pozzolanic by-products is limited and many local sources are already fully exploited. Alternatives to the established pozzolanic by-products are to be found on the one hand in an expansion of the range of industrial by-products or societal waste considered and on the other hand in an increased usage of naturally occurring pozzolans [12].

Natural pozzolanas are abundant in certain locations and are extensively used as an addition to Portland cement in countries such as Italy, Germany, Greece and China. Volcanic ashes and pumices largely composed of volcanic glass are commonly used, as are deposits in which the volcanic glass has been altered to zeolites by interaction with alkaline waters. Deposits of sedimentary origin are less common. Diatomaceous earths, formed by the accumulation of siliceous diatom microskeletons, are a prominent source material here.

Bamboos are a diverse group of evergreen perennial flowering plants in the subfamily Bambusoideae of the grass family Poaceae. The origin of the word "bamboo" is uncertain, but it probably comes from the Dutch or Portuguese language, which originally borrowed it from Malay or Kannada [12].Bamboo as desirables is group of perennial evergreens (except for certain temperate species) plants in the true grass family poaceae, subfamily Bambusoideae, tribe Bambuseae, Giant bamboos are the largest members of the grass family [13]. It is as well defined as any of the hardy tropical grasses from Malay bamboo. It is a natural fibre which is bacteria and odour resistance as well as absorbent and breathable, Bamboo’s strength tends excellent durability to a fabric.

Figure 1: Picture of fresh Bamboo Leaves

According to American Heritage Dictionary of the English Language, Bamboo is defined as any of Various usually woody, temperate or tropical grasses of the genera Arundinaria, Bambusa, Dendrocal-amus, Phyllostachys or sasa. Certain species of bamboo can reach heights of from 20 to 30 meters (66 to 98ft), the hand or woody jointed often hollow stems of these plants, used in construction, crafts and fishing poles. According to Collins English Dictionary, Bamboo is defined as any tall tree like tropical or semitropical fast-growing grass of the genius bambusa, having hallowed woody–walled stems with ranged joints and edible young shorts.

Figure 2: Picture of dried Bamboo Leaves

In bamboo wheat and other grasses, the intermodal regions of the stem are hollow, but the vascular bundle as seen in cross section, are scattered throughout the stem instead of a cylindrical arrangement. Also, the dicotyledonous woody xylem is absent. The absence of secondary growth, wood, causes the stems of monocots, even of palms and large bamboos to be columnar rather than tampering. They are also the fastest growing woody plants in the world. They can grow up to 60cm (24inches) or more per day due to unique rhizome – dependent system

From the available and previous research in the literature, over 20 million tonnes of bamboo are used annually by individual and various companies such as food, brewing, culinary, paper, fabrics, board, fencing, handicraft, water harvesting, brewing, medicinal, combustion and other bioenergy applications etc.

The cultivation of raw materials (local) is one method of reducing the cost of production (construction). The international symposium for industrial development help in Athens in 1967 recommended that developing countries should where necessarily give higher priority to the development of building materials in order to achieve greater efficiency in their construction activities better ultimate of local materials resources and saving in foreign currency. Therefore, bamboo leaf ash as a local occurring material has attracted interest in many circles as a cheap source of pozzolanic cementic material to produce longer construction that can be used in construction. Hence the use of pozzolan as a cementic material for building processes cannot be over-emphasized.

Bamboo fire is a regenerated cellulose fibre produced from bamboo. Starchy pulp is produced from bamboo stems and leaves through a process of alkaline hydrolysis and multi-phase bleaching. Further chemical process bamboo fibre. Repeated technological analysis has proved that these kinds of fibre have a thinness degree and whiteness degree close to normal finely bleached viscose and has a strong durability, stability and tenacity[14].

There are limited literatures or papers published on the use of bamboo leaf as pozzolan in concrete production. From the few that were reviewed, it was discovered that the rate at which bamboo leaf ash react with calcium hydroxide (from cement and water) increases with time and temperature [15]. Calcium hydroxide, Ca $(OH)_2$ increasingly dissociates in solution to give more ca+ and OH+ which quickly react with silica at a faster rate and the compressive strength develops gradually until 28 days of hydration when its value becomes comparable with its control values.The results suggest that bamboo leaf ash is a pozzolanic material and its pozzolanic activity increases with the increase in temperature. The pozzolanic reaction can be expressed as:

$$\mathrm{Ca(OH)_2 + SiO_2\ (bamboo\ leaf\ ash) \rightarrow C - S - H\ (calcium\ silicate\ hydrate)}$$

The Bamboo leaf Ash (BLA) is obtained by first, open air burning and then further heating in a muffle furnace at 600c for 2hours. Upon testing with Vicat apparatus, 20% by weight of BLA blended cement was found to be more consistent and of the optimum replacement in terms of its initial and final settings times. Most bamboos are erect, but some are vine, producing impenetrable thinks in some areas.

Figure 3: Picture of burning of Bamboo leaves into ashes

1.1 Physical properties of the OPC and BLA

The physical properties of the bamboo leaf ash are silver and powdered in nature having its fineness 30 percent residue on 45 µm sieve. The specific gravity of bamboo leaf ash 2.00.

Table 1: Physical properties of the OPC and BLA

Parameter	OPC	BLA
Fineness (% residue on 45 µm sieve)	29	30
Fineness (% residue on 90 µm sieve)	4	3.66
Standard consistency (%)	28	100
Initial setting time (min)	110	-
Final setting time (min)	210	-
Soundness (mm)	0.00	0.00
Specific gravity	3.14	2.00
Bulk density (g/cm3) (Uncompacted)	1.04	0.40
Bulk density (g/cm3) (Compacted)	1.30	0.60

1.2 Chemical properties of bamboo leaf ash (BLA)

Bamboo leaf ash (BLA) is primarily composed of silica, alumina and potassium with small amounts of calcium and magnesium. Bamboo leaf contains hydrocyanic and benzoic acids, silica, potash, lime, ferrite, alumina, some vegetable substances like colin and carbohydrates which affect concrete behaviour. It also contains some trace elements which include Na_2O, MgO, and TiO_2. The source of the bamboo controls the chemical composition of bamboo leaf ash. The previous researchers on bamboo leaf ash [15, 16, 17, 18, 19]shown that BLA has a high silica content (SiO_2 of about 76 – 81%) and low alumina content (Al_2O_3 of about 1 – 4%) cited by [7].Table 1 shows the comparative study among chemical composition of bamboo leaf ash obtained from different burning of bamboo leaves.

Table 2: Chemical compositions of OPC and BLA

System	SiO_2	Al_2O_3	Fe_2O_3	CaO	Mgo	K_20	N_20	TiO_2	$S0_3$	IR	LOI
OPC	21.40	5.03	4.40	61.14	1.35	0.48	0.24	-	2.53	1.65	1.29
BLA	75.90	4.13	1.22	7.47	1.85	5.62	0.21	0.20	1.06	-	-

LOI – Loss on ignition, IR – Insoluble residue
Oxide Composition[20]

II. Experimental Program

2.1. Materials

The major materials and equipment employed in this research includeBamboo leaves, crushed stone (granite – 19mm), sand, cement, tamping rod, BS sieves, hand trowel, hand scoop, spade, water, Curing tanks, steel and concrete cube mould, mould oil, brush, compressive machine (ELE 2000KN compressive machine).

The cement, fine sand, granite and water were sourced locally from stores and dealers in Ado Ekiti, Ekiti State and dry bamboo leaves were collected within Igbara-Odo Ekiti locality, the leaves were opening burnt at Department of Building Technology Concrete Workshop of the Federal Polytechnic, Ado Ekiti, Ekiti State. Also, the equipment and other tools are readily available at the Department. The Bamboo leaves were burnt and grinded into fine ash particles (BLA). The Bamboo leaves ash wash sieved through 45 μm sieve in order to remove any unwanted material and clot size ash particles; and only the ashes which was passed through 45 μm sieve were collected. The chemical analysis was carried out in the chemistry laboratory to give the chemical compositions and some trace elements of SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, K_2O, N_2O, TiO_2, SO_3 etc.

2.2. Experimental procedure

The proportioning by weight was used in this research work. The BLA/OPC-Aggregates ratio in this work was 1:2:4. BLA were partially used to replace OPC at dosage levels of BLA of 0%, 10%, 20%, 25%, 50%, 75%, 100% to OPC of 100%, 90%, 80%, 75%, 50%, 25%, 0% replacementrespectively [21].

Table 3: Number of cubes for the study

Curing age (days)	BLA	0%	10%	20%	25%	50%	75%	100%
	OPC	100%	90%	80%	75%	50%	25%	0%
7	1:2:4	3	3	3	3	3	3	3
14	1:2:4	3	3	3	3	3	3	3
21	1:2:4	3	3	3	3	3	3	3
28	1:2:4	3	3	3	3	3	3	3
Total	1:2:4	12	12	12	12	12	12	12

2.3 The breaking down of materials used for this research work

For mix ratio 1:2:4 at 0% of BLA and 100% of OPC
Weight of cubes = 8.2kg
Total weight of cubes = 8.2 x $12 = 98.4$kg
Cement = $\frac{1}{7}$ x $98.4 = 14.06$kg
Sand = $\frac{2}{7}$ x $98.4 = 28.11$kg
Granite = $\frac{4}{7}$ x $98.4 = 56.23$kg
For mix ratio 1:2:4 at 25% of BLA and 75% of OPC
Weight of cubes = 8.2kg
Total weight of cubes =8.2 x $12 = 98.4$kg
Cement ash = $\frac{1}{7}$ x $98.4 = 14.06$kg
Ash = 25% x $14.06 = 3.52$kg
Cement = $14.06 - 3.52 = 10.54$kg
For mix ratio 1:2:4 at 50% of BLA and 50% of OPC
Weight of cubes = 8.2kg
Total weight of cubes = 8.2 x $12 = 98.4$kg
Cement ash = $\frac{1}{7}$ x $98.4 = 14.06$kg

Ash $= 50\% \text{ x } 14.06 = 7.03\text{kg}$
Cement $= 14.06 - 7.03 = 7.03\text{kg}$
For mix ratio 1:2:4 at 75% of BLA and 25% of OPC
Weight of cubes = 8.2kg
Total weight of cubes = $8.2 \text{ x } 12 = 98.4\text{kg}$
Cement ash = $\frac{1}{7} \text{ x } 98.4 = 14.06\text{kg}$
Ash $= 75\% \text{ x } 14.06 = 10.55\text{kg}$
Cement $= 14.06 - 10.55 = 3.51\text{kg}$

2.4 TEST PROCEDURE

Twelve cubes (12) cubes each were cast for 0% BLA and 100% OPC as a control mix, OPC replaced with 10%, 20%, 25%, 50%, 75%, 100% of BLA 45μm, making a total of Eighty-four(84) cubes. All freshly cast specimens were left in the moulds for 24 hours before being demoulded and then cured in water until it was time to be tested as shown figures 1 and 2. Hitherto, the number of moulds required were many, stell moulds of size 150 x 150 x 150 mm were used to cast the entire specimen in one day. The weights of the cubes were examined prior to crushing to determine their densities as in figure 3. The compressive strength of concrete is given in terms of the characteristic compressive strength of 150 x 150 x 150 mm size cubes tested at 7, 14, 21 and 28 days respectively as shown in figure 4.

Figure 4: BLA/OPC Concrete Casting Section

WORKABILITY OF CONCRETE

Concrete workability basically refers to how easily freshly mixed concrete can be placed, consolidated and finished with minimal loss of homogeneity.The concrete slump test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows. It can also be used as an indicator of an improperly mixed batch. The test is popular due to the simplicity of apparatus used and simple procedure. The slump test is used to ensure uniformity for different loads of concrete under field conditions.

The test is carried out using a metal mould in the shape of a conical frustum known as a slump cone, that is open at both ends and has attached handles. The tool typically has an internal diameter of 100 millimetres (3.9 in) at the top and of 200 millimetres (7.9 in) at the bottom with a height of 305 millimetres (12.0 in). The cone is placed on a hard non-absorbent surface. This cone is filled with fresh concrete in three stages. At the end of the third stage, the concrete is struck off flush with the top of the mould. The mould is carefully lifted vertically upwards, so as not to disturb the concrete cone. The concrete then slumps (subsides). The slump of the concrete is measured by measuring the distance from the top of the slumped concrete to the level of the top of the slump cone.

The slumped concrete takes various shapes and according to the profile of slumped concrete, the slump is termed as true slump, shear slump or collapse slump. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. Only a true slump is of any use in the test. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which the slump test is not appropriate

Table 4: Summary of Workability Test on the Various Mix Ratios

% BLA to OPC	0%	10%	20%	25%	50%	75%	100%
W/C Ratio	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Slump (mm)	15	23	31	35	40	50	0

Table 4 shown the summary of workability test on the various mix ratios of 1:2:4

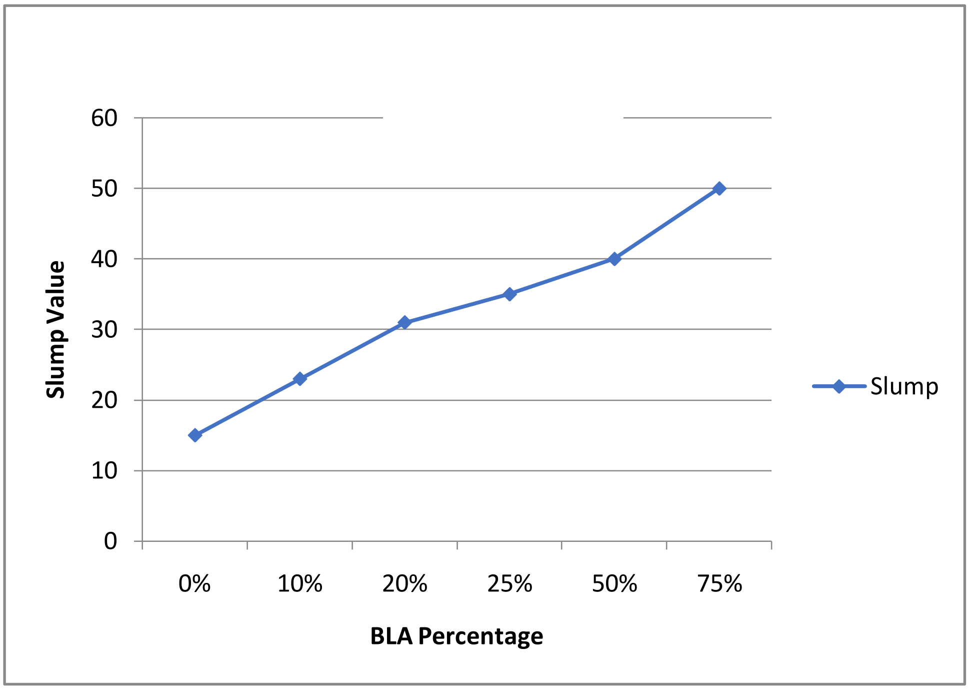

Figure 5: Graph showing Slump test of Cubes

Above graph shows the progression of 0% BLA with 100% OPC having the values of 15mm followed by 23, 31, 35, 40 and 50 mm for 75% BLA with 25% OPC.

Table 5: Compressive Strength of BLA Blended Cement at Various Curing Ages for Concrete Work

BLA Content (%)	**Mix Ratio**	**Compressive strength (N/mm^2)**			
		7 days	**14 days**	**21 days**	**28 days**
0%: 100%	1:2:4	13.78	13.92	17.30	19.33
10%: 90%	1:2:4	12.15	12.28	14.47	16.25
20%: 80%	1:2:4	10.52	10.71	11.69	13.17
25%: 75%	1:2:4	9.70	10.01	10.30	11.63
50%: 50%	1:2:4	5.41	6.15	7.48	8.10
75%: 25%	1:2:4	1.71	1.95	2.44	2.98
100%: 0%	1:2:4	-	-	-	-

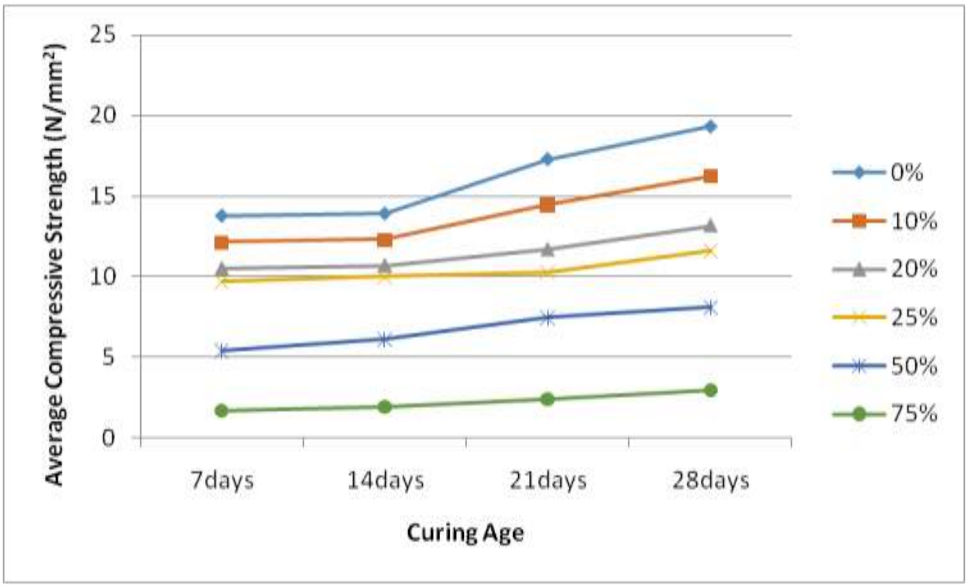

Figure 6: Graph showing Average Compressive Strength of Cubes

III. Discussion Of Result

It can be deduced from the above results that the graphs for the compressive strengths of bamboo leaf ash concrete were very weak as compared with that of control (0% Bamboo Leaves Ash with 100% OPC); and as the curing age increasing the strengths were also increasing until they reached the optimum above of the control and have been to fall again.

It is also discovered that the excess of bamboo leaf ash as partial replacement of cement in concrete production may not be able to give the adequate strength, as the case of 75% and 50% bamboo leaf ash as replacement for cement.

Tables and Figures above made us to understand that the compressive strength of an open air burnt bamboo leaf ash blended cement concrete can be mainly for light weight design as its limit state can be easily reached due to its reduction strength as compared to ordinary concrete (0.5 of pozzolan) as the building life span moves by. In addition, and at 100% of pozzolan which is bamboo leaf ash, and the compressive strength is very low and began to fall, the slump for mix ratio of each percentage tends to increase as the percentage replacement of the cement with bamboo leave ash is increasing.

IV. Conclusions and Recommendation

Bamboo leaf ash is a good pozzolanic material which reacts with calcium hydroxide forming calcium silicate hydrate and its activity as pozzolanic materials increases with increase of time and temperature. Therefore, the following conclusion can be drawn from the results of this research work:

i. The compressive strengths of the cubes specimens containing partial replacements (0%, 10%, 20%, 25%, 50% and 75%) of cement with bamboo leaf ash were lower than the specimen containing 100% replacement (control specimen) at the initial curing days but increased in strengths as the curing age increases, especially between 14 and 21 days respectively, which also reduced as the curing age grew older (toward 28 days).

ii. The workability of the concrete increased as the percentage replacement increased which made the concrete more workable during production and its degree of fineness increased as well as the percentage increased.

iii. At 25% replacement of bamboo leaf ash in the concrete got to its optimum for mix ratio 1:2:4

iv. The bamboo leaf ash had a combined silica, alumina and ferric oxides content of 78.30%, thereby satisfying the requirement of Class N Pozzolan suitable for mortar and concrete production [22].

v. The BLA, which is lighter than cement, and which occupies a greater volume for the same mass of cement, therefore requires additional water in the mix as the amount of BLA content increases in order to attain to a paste of standard consistency.

V. Recommendation

It can be recommended from the results of this research that whenever bamboo leaf ash is to be used for concrete production 25% of 1:2:4 mix must be used. In addition, the workability of the mix ratio must be considered in terms of water cement ratio. Before bamboo leaf ash can be recommended as a blending component, further experiment under different conditions is needed.

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