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Bamboo Leaf Ash as Supplementary Cementitious Material

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Abstract: *As a result of the rising cost of building materials, it has become necessary to search for the affordable and cheaply obtainable material which might be partially replaced cement in the production of concrete. However, this research work was aimed at determining the chemical and physical properties of BLA, workability properties of fresh concrete, the specific gravity, bulk densities and compressive strength of the hardened concrete under uniaxial compressive load. This project is an experimental study on the use of Bamboo Leaf Ash (BLA) as partial replacement for cement. More so, Bamboo leaves were dried, burnt and heated in a furnace to produce Bamboo Leaf Ash, which was discovered to possess pozolanic properties. Research findings have revealed that this material can be used as partial replacement for cement in concrete due to its chemical and physical properties. The Ordinary Portland cement was replaced by BLA at 10%, 20%, 30% and 40% by weight and the cubes were crushed to get the various compressive strength of the concrete at different curing days. The results revealed that, the workability and strength properties of the resulting concrete was dependent on the water cement ratio, total days of curing, and percentage of replacement of BLA for OPC. It was however noticed that the result of 10% and 20% BLA were closer to the concrete with only OPC at 28 days. It is therefore hope that this research work will provide a quick reference to practicing Engineer, who will find BLA as a good partial replacement for cement in concrete, thus reducing cost of concrete production.*

Keywords: *BLA, OPC, Concrete production, Compressive Strength, Workability.*

I. INTRODUCTION

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. The only way is to use certain low cost materials for partial replacement of Portland cement clinker. The Low cost materials used are industrial and agricultural by-products (wasted), mixture of Portland cement and bamboo leaf ash 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 behavior is quite similar to that of Portland cement since they hardened when mixed with water and form the same hydration products. The most common ingredients for blending with Portland cements clinkers are latent hydraulic components (blast furnace slag or pozzoanic component such as pozzo-lanna, fly ash, rice husk ash, condensed silica fume, burnt clay or filler component such as limestone and other waste materials (Hernandez etal, 1998; Massaza 1999; Massaza, 1994; Mehta, 1994; Navang, 1992).

During hydration of Portland cement, $Ca(OH)_2$ is obtained as one of the hydration products which infact is responsible for deterioration of concrete. But when certain pozzolanic materials containing amorphous silica is added during hydration of Portland cement, it reacts with lime giving additional amount of Calcium Silicate hydrate (C-S-H), the main cement component. Thus pozzolanic material reduces the amount of $Ca(OH)_2$ and increases the amount of calcium silicate hydrate (C-S-H). Thus if a good quality pozzolanic material in suitable amount is added during the hydration of Portland cement, the cementing quality is enhanced (Vatsala, 2003). Concrete is by far the most widely used material because of its low cost, availability of raw materials, strength, durability and most importantly versatility (V.N. Diwivedi et al, 2006). Worldwide, more than one ton of concrete is produced every year for each person on the planet, looking at North America alone, this number jumps to roughly 2.5 tons produced per person per year (V.N. Diwivedi et al, 2006).

The key to concrete success is its versatility and no other sector of the construction industry utilizes this attribute more than the manufactured concrete products industry. Concrete can be designed to withstand the harshest environments while taking on the most inspirational forms. Engineers are continually pushing the limits with the help of innovative chemical admixtures and supplementary cementitious materials. Supplementary cementitious materials are often incorporated in the concrete mix to reduce cement contents, improve workability, increase strength and enhance durability (Navang, 1992). Supplementary cementitious materials date back to the ancient Greeks who incorporated volcanic ash with hydraulic lime to create a cementitious mortar. The Greek passed this knowledge on to the Romans, who constructed such engineering marvels as the Roman aqueducts and the coliseum, which still stand today. Early supplementary cementitious materials consisted of natural, readily available materials such as volcanic ash or diatomaceous eart (Navang, 1992). Supplementary cementitious materials can be divided into two categories based on their type of reaction, and these are hydraulic or pozzolanic. Hydraulic materials react directly with water to form cementitious compounds while pozzolanic materials chemically react with calcium hydroxide $Ca(OH)_2$, a soluble reaction product in the presence of moisture to form compounds possessing cementing properties (Mehta PK, 1987). The word "Pozzolan" was actually derived from a large deposit of material. Vesuvius volcanic ash located near the town of Pozzuoli, Italy. Pozzolanic supplementary cementitious material can be used either as an addition to cement or as a replacement for a portion of the cement. Most often supplementary cementitious material will be used to replace a portion of the cement content for economical or property enhancement reasons (Mehta PK, 1987).

Many studies have been done to determine the feasibility of using bamboo to reinforce concrete. Feasible uses of bamboo with concrete include making stirrups with nine month old bamboo. Also tanks can be made by applying cement plaster to bamboo baskets. These can be used for toilets, water storage or boats. Waffle slabs of concrete can be formed utilizing bamboo baskets to create the void spaces. Woven bamboo mesh at 6in. on centre can be used to reinforce a 5in. concrete slab (Olugbenga et al, 2010). Bamboo is a well established cultural feature of many regions throughout the world. Its diversity and versatility are well documented; some 1250 species and 1500 traditional applications have been identified. Notably, the main users are the rural poor, and perhaps for this reason it has largely been taken for granted by the wider community. As such, bamboo has not received the mainstream recognition it deserves as a material resource (Farrelly, 1984).

From the economical view point, ordinary Portland cement is known to be more expensive as its production is highly energy intensive. On the other hand, cementitious material processing requires little or no direct energy-related costs, hence cheaper than Portland cement. This illustrates that a significant replacement of Portland cement by cementitious material is a cost-effective means to produce mortar or concrete (Bouzoubaa and Fournier 2009).

Therefore, the objective of this research work was to investigate the potential of Bamboo Leaf Ash (BLA) as a supplementary cementitious material in other to reduce the cost of concrete production using Ordinary Portland Cement only as a bonding agent.

II. MATERIALS AND METHODS

2.1 Sample Materials

During this research the sample materials used are:

A. Bamboo leaf ash (BLA)

The bamboo leaves (Fig. 1) used in the research was gotten from the bush behind new Celestial church of Christ Odo-Arin Oyo. The leaves air dried, properly burnt, then sieved with 212micrometer (No.70) to a require fineness and heated in a furnace in Department of chemistry Laboratory, University of Ibadan. The ash generated then taken to the Department of Agronomy Laboratory, University of Ibadan for chemical analysis. Bamboo leaf ash (Fig. 1) can serves as a cementitious material and at the same time serve as stabilizer in soil stabilization.

Fig 1: Bamboo Leaf Ash and Freshly Harvested Bamboo Leaves

B. Cement

Ordinary Portland cement was used during research. It was the cement in question that was to be replaced partially by bamboo leaf ash. The OPC was bought from the cement vendor or dealer. Each bag of OPC is 50kg in size. Some of the properties required of this cement are as follows:

(i) Initial setting time most not be more than 45minutes.
(ii) Final setting time must not be more than 10hours.
(iii) The strength of concrete cube made from it after 28days must have a value of not less than $25N/mm^2$.

C. Aggregate

The remaining ingredient of concrete, beside the cement and water, that is the sand, broken stone, cenders, slag e.t.c, are chemically inert and are classed as the aggregates. The material less than 6.35mm in diameter is designated as fine aggregates and generally refers to sand. All materials over 6.35mm in diameter is called coarse aggregate and includes the broken stone, cinder e.t.c. Any crushed rock or slag of durable character or any clean, hard, natural gravel may properly be used as coarse aggregate. Granite, traprock or hard limestone are preferred and are prepared at the quarries for such use. They are crushed and screened to adopted sizes, so that the aggregates may be exactly graded by sieve analysis.

D. Water

The water used for this work was from the Soil Laboratory at the Department of Civil Engineering University of Ibadan, Ibadan in Oyo state. The water was free from injurious amount of oil, acid, organic matter, alkali and other deleterious substances.

2.2 Experimental Procedures

The method used in this research was basically experimental. It involved field and laboratory tests. The chemical analysis of the ash was carried out within the University of Ibadan and molding, curing and crushing was done at the Department of Civil Engineering, University of Ibadan.

2.2.1 Number of Specimens for each Mix

In this research, total number of three cubes was cast for each of ordinary Portland cement as a control mix and for each of replacement by BLA. Therefore, for each batch, total numbers of 12 cubes were cast. For compressive strength, 150mm cubes were cast and three specimens were tested for each age in a particular mix (i.e. the cubes were crushed at 7, 14, 21 and 28 days respectively). All freshly cast specimens were left in the molds for 24 hours before being molded and then submerged into water for curing until it is time to be tested. Since the numbers of molds required are many, plank molds of size 150 mm x 150mmx 150mm were made to cast the entire specimen in one day. Table 1 showed the age of the different test conducted in the research, the specimen used and the number of the specimen for each mix.

Table 1: Number of specimens and Age for each Test

Tests		AGE(Days)			
		7	14	21	28
Number of Specimen	BLA 0%	3	3	3	3
	BLA 10%	3	3	3	3
	BLA 20%	3	3	3	3
	BLA 30%	3	3	3	3
	BLA 40%	3	3	3	3

2.2.2 Mix Proportions of Concrete Specimens

Proportioning by weight method was used to determine the physical properties of density and strength of concretebecause it was found to be more accurate than proportioning by volume. The ratio of cement to dried total aggregates used in this work was 1:2:4. Bamboo leaf ash was used to replace OPC at dosage of 10%, 20%, 30% and 40% by weight of binder. The mix proportions were calculated as follows:

No. of Cubes per Batch = 12
Size of each cube = 150 x 150 x150mm
Vol. of cube = $150^3 = 3.375x10^{-3}m^3$
Vol. of 12 cube= $12x3.375x10^{-3}= 0.0405m^3$
To cater for wastage, it was factored by 1.2
Vol. of the Batch = $0.0405x1.2= 0.0486m^3$
The ratio used in this research is 1:2:4= cement: sand: coarse aggregate.

For Cement.
Cement= 1/7
Vol. of cement needed $=\frac{1}{7}$ x $0.0486m^3$= $0.00694286m^3$
Standard weight of concrete = $2400kg/m^3$
Therefore:
Weight of Cement in one Batch = 2400x$0.00694286m^3$ = 16.66kg
= 17kg

For Sand
Vol. of Sand = $\frac{2}{7}$x$0.0486m^3$= $0.01388571m^3$
Weight of Sand = 2400x0.01388571 = 33.326kg
=34kg

For Coarse Aggregate
Vol. of Coarse Aggregate = $\frac{4}{7}$x$0.0486m^3$ = $0.02777143m^3$
Weight of coarse Aggregate = 2400x$0.02777143m^3$= 66.65kg
= 67kg.
The water to cement ratio adopted in this research is 0.5 and this was used to calculate the amount of weight of water required per batch.
Weight of Water = 0.5 x Weight of Cement
= 0.5x17kg= 8.5kg
= 9kg
Base on the calculations above, the Mix Design of concrete in Table 2 was generated.

Table 2: Mix Design of Concrete

Ingredient Materials	Mix Proportion(Kg)				
	Control 0%	BLA10%	BLA20%	BLA30%	BLA40%
Cement	17.00	15.30	13.60	11.90	10.20
BLA(kg)	0	1.70	3.40	5.10	6.80
Total water(kg)	9	9	9	9	9
Fine Aggregates(Kg)	34	34	34	34	34
Coarse Aggregates(Kg)	68	68	68	68	68
Water/binder ratio	0.5	0.5	0.5	0.5	0.5

2.2.3 Workability of Concrete (Slump Test)

The degree of workability or consistency of the concrete was measured by slump test (Fig. 2). The equipment used to make the slump test consist of a piece of sheet metal having the shape of a truncated cone 300mm in height, with a base diameter of 200mm and a top diameter of 100mm. Both top and bottom left open and handles are attached to the outside of the mold. Freshly mixed concrete was placed in the mold in three layers, each layer being prodded separately twenty-five times with 6mm diameter rod. When the mold was filled and prodded, the top was level off and the mold was lifted at once. Immediately the slumping action of the concrete was measured by the taken the difference in height between the top of the mold and the top of the slumped mass of the concrete.

Fig. 2: Slump Test

2.2.4 Curing

Quality concrete can be obtained only when due consideration and provision are made for curing. Because,hardening of concrete is caused by the chemical reaction between water and cement. This hardening continues indefinitely as long as moisture is present and the temperatures are favorable. The initial setting does not begin until two or three hours after the concrete has been mixed. During this interval, moisture evaporates, particularly on the exposed surfaces and this may cause the concrete to craze unless provision is made to prevent the loss of moisture. During this research all the cubes cast were cured inside awater tank for a minimum of seven days and maximum of twenty eight days.

2.2.5 Bulk Density

Density of samples specimen were determined using equation (1).

$$\text{Density} = \frac{Mass}{Volume} \quad \dots (1)$$

2.3 Compressive Strength of Concrete

The compressive strength was measured by breaking concrete cube specimen in a compression testing machine. The compressive strength was calculated from the failure load divided by the cross sectional area resisting the load and reported in MPa. During this research, total number of 60 cubes concrete, of size 150 ×150 ×150mm was cured after 24hours of casting. Three specimens were cured and crushed in the testing machine for each replacement at each interval of ages of 7, 14, 21 and 28days. The specimens were tested for compressive strength by applying increasing compressive load until failure occurs. Therefore, the maximum load causing failure was recorded and the load was divided by the cross sectional area which gave us the compressive strength of each sample as calculated from equation (2).

$$CS = \frac{P}{A} \quad \dots (2)$$

Where:

CS = Compressive Strength, N/mm^2

P = Ultimate compressive load of concrete, N

A = Surface area in contact with the plate, mm^2

III. RESULTS AND DISCUSSIONS

3.1 Chemical and Physical Properties of Bamboo Leaf Ash

The results of chemical analysis obtained for BLA were as showed inTable 3.

Table 3: Result of Chemical and Physical Properties of OPC and BLA

Chemical Composition (%)	OPC	BLA
SiO_2	22.13	75.90
Al_2O_3	3.74	4.13
F_2O_3	2.97	1.22
CaO	63.36	7.47
MgO	2.58	1.85
K_2O	0.52	5.62
MnO_2	0.00	0.016
P_2O_5	0.00	3.22
True Density (g/cm^3)	2.97	2.25

The Bamboo Leaf Ash used was heated in a furnace to remove the carbon content in it. The main constituents of BLA are Silicon (as SiO_2), Aluminum (as Al_2O_3) and Iron oxide (Fe_2O_3). The total amount of SiO2, Al_2O_3, and Fe_2O_3 was 81.25% which was more than the minimum requirement (50% Min.) specified by ASTM C618, for type C ash. The calcium oxide content was about 7.47% for BLA.

3.2 Specific Gravity

The various sample weight obtained during this research were as showed in Table 4 and they were used in the determination of specific gravity from Test A and B respectively.

Table 4: Determination of Specific Gravity

Sample Weight (g)	Test A (g)	Test B (g)
W1	5.70	5.70
W2	10.60	10.70
W3	65.00	65.00
W4	62.28	62.23
GS	2.25	2.24

Average GS = $\frac{2.25+2.24}{2}$ = 2.245 ≈ 2.25
Where GS = Specific Gravity

3.3 Slump comparison between Fresh BLA Concrete and OPC Concrete.

The concrete with 100% cement exhibits higher slump compared to the one with BLA replacement. It was observed that the higher the amount of percentage BLA replaced, the lower the slump. At a given cement to water ratio, the small addition of BLA (10 - 20%) improved the workability of the concrete by reducing tendency towards bleeding and segregation. This was due to large surface area of BLA. The larger amount of percentage BLA to replace cement (30 – 40%) produced unworkable mixtures. It was also observed that both initial and final setting time of the concrete with percentage BLA were higher than that of concrete with only OPC.It means that inclusion of BLA increases the setting time, therefore the higher the percentage BLA replacement the higher the setting time.

3.4 Effect of Curing Days on the Bulk Density BLA Concrete

The cubes were weighed for each batch and percentage BLA replacement with respect to curing days. The densities were calculated and the averages of each three cubes were found, and then tabulated in Table 5.

Table 5: The Density of Concrete with and without BLA for each Interval of Curing Days

% BLA Replacement	Density (g/cm^3)			
	7 days	14days	21 days	28 days
0	2.50	2.53	2.56	2.64
10	2.47	2.49	2.52	2.58
20	2.44	2.47	2.51	2.55
30	2.40	2.42	2.45	2.47
40	2.32	2.34	2.35	2.38

The density of the concrete increased with days of curing and decreased with increase in percentage BLA replacement as showed in Figure 3.

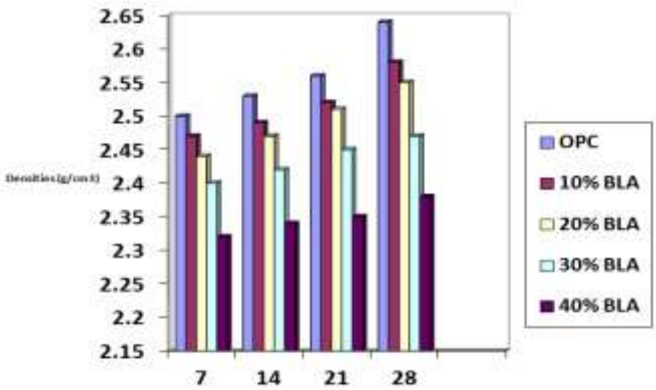

Figure 3: Densities Curing Days with Respect to Percentage BLA Replacement

3.5 Compressive Strength of BLA Concrete

The results of the compressive strength of concrete produced during this research at various percentages of BLA at 7, 14, 21 and 28days were as showed in Table 6.

3.6 The effect of curing days and BLA variationson the Compressive strength of BLA Concrete

It was observed that the compressive strength values increase with increase in curing days but the values decrease with the percentage BLA replacement. The initial strength values of the BLA concrete are very low compare with the concrete of only OPC but the strength of 10% and 20% BLA are closer to that of concrete with only OPC at 28days. It was observed that an increase in the level of percentage BLA replacement lead to the reduction of compressive strength in hardened concrete as shown in the Fig. 4a and 4b. Omoniyi and Akinyemi (2012) also reported that compressive strength decreased with the increase in the fiber contents.

Table 6 Compressive Strength Performance of Hardened Concrete without and with various level BLA Replacement

% BLA Replacement	Concrete Strength(MPa)			
	7days	14days	21days	28days
0	16.44	20.67	24.44	30.22
10	10.22	15.78	22.22	28.56
20	8.44	13.78	18.67	25.89
30	6.22	10.67	14.43	19.45
40	4.89	7.33	10.44	12.67

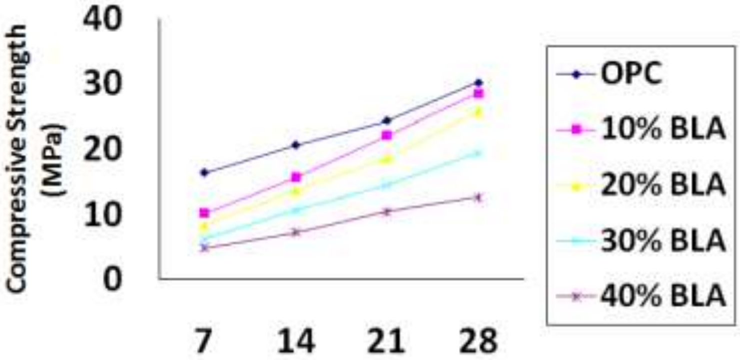

Figure 4a: Graph Showing Relationship between Compressive Strength Results

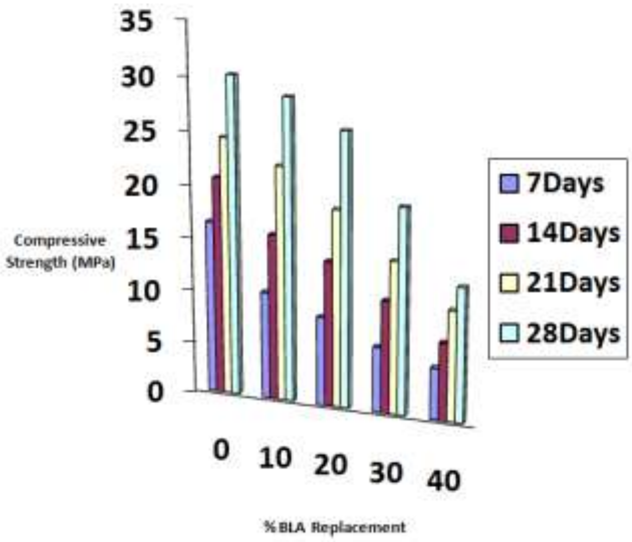

Figure 4b: Relationship between Compressive Strength Results

IV. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

Due to this research work the followings were concluded:

(1) It was discovered that BLA contains all the main chemical constituents of cement though in different quantities compared to that of OPC and that made BLA a good replacement of OPCat an appropriate percentage.

(2) The specific gravity of BLA gotten was less compared to that of OPC it replaced, which means greater volume of BLA will result from mass replacement.

(3) It was observed that about 10 to 20% BLA replacement of OPC enhance the workability of the concrete.

(4) The setting time of concrete increased with increase in the percentages of BLA as partial replacement for OPC.

(5) The use of BLA will reduce cost of concrete, environmental problems and land fill area for the dispose of bamboo leaves.

4.2 Recommendations

The following recommendations were made:

(1) Efforts should be made to keep BLA sealed after burning and heating and should be kept in a dry place to avoid weather attack which may reduce it strength.

(2) When mixing the constituent materials of concrete, care must be taken so that all the materials will be properly mixed.
(3) Super plasticizer should be introduced so that early strength could be generated.
(4) Other tests such as corrosion resistance, shrinkage properties and absorption ratio should be carried out on the BLA concrete.

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