PERFORMANCE OF LOCUST BEAN PODS ASH AND COCONUT HUSK ASH AS PARTIAL REPLACEMENT FOR CEMENT IN CONCRETE

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Abstract
The present high cost of construction materials in the country calls for alternatives which will also be appropriate for construction works and as well achieve the desired strength. This research work investigates the use of locust bean pod ash (LBPA) and coconut husk ash (CHA) as partial replacement for cement in concrete works. Chemical composition of LBPA and CHA as well as the density and compressive strength properties were studied and analyzed. The concrete were prepared using batched by weight of mixing ratio 1 : $1^1/_2$: 3 with water – cement ratio of 0.55. Slump test was carried out to check the effect of combination of LBPA and CHA on the workability of fresh concrete. A total of 60 concrete cubes of size 150mm x 150mm x 150mm with different percentages by weight of combination of LBPA and CHA to ordinary Portland cement in the order of 0%, 5%, 10%, 15% and 20% were cast. The concrete cubes were tested at the ages of 7, 14, 21 and 28 days. The results showed that the combination of LBPA and CHA are not a good pozzolan with combined SiO_2, Al_2O_3 and Fe_2O_3 of 5.32%. The slump value decreased as the percentage combination of LBPA and CHA contents increased indicating that concrete becomes less workable (stiff) as the ashes content increased. The density of concrete cubes decreased with days of curing and decreased with increasing ashes replacement. The compressive strength of the concrete cubes increased as the days of curing increased and decreased with increasing ashes replacement. The highest compressive strength was 18.24N/mm^2 and 15.41N/mm^2 at 28 days for 0% and 10% combination of LBPA and CHA respectively. It was concluded that the use of combination of LBPA and CHA as a partial replacement for cement in concrete works, mostly in plain concrete and non – load bearing structures, will enhance waste to wealth creativity, reduction of cement usage in the concrete, thus reducing the cost of production though only 10% LBPA and CHA replacement is satisfactory to enjoy maximum benefit of strength.

Keywords: Locust bean pod ash (LBPA), Coconut husk ash (CHA), Ordinary Portland cement, Concrete, Compressive strength

Introduction
Concrete is the most widely used man – made construction material in the world, and is second only to water as the most consumed substance in the planet. The other significant characteristics of concrete, in addition to its strength, are its capacity to be effortlessly moulded into any shape, it is an engineered material that can meet virtually any desired design, and it also flexible, fireproof, inexpensive and obtained easily *(Aprianti et al., 2015)*. The great advantage of concrete is its exceptional physical and mechanical properties, if correctly designed and produced. Presently, concrete is widely used with more than 10 billion tons manufactured annually in modern developed society (*Meyer, 2009)*. It has been projected that by 2050, the proportion of the world's population will increase significantly from 1.5 to 9 billion, and, thus, will cause a rise in the demand for food, clothing, housing and energy as well as for concrete, which is estimate to increase to about 18 billion tons annually by 2050 *(Mehta and Monteiro, 2006)*.

Concrete is produced by mixing cementing material, aggregates and water, and occasionally admixtures, in required proportions. The mixture when placed in forms and allowed to cure hardens into a rock – like mass known as concrete. The hardening is caused by chemical reaction between water and cement and it continues for a long time, and consequently the concrete grows stronger with age. Though all materials that go into a concrete mixture are indispensable, cement is by far the utmost significant constituent for the fact that it is generally the delicate connection in the chain. The purpose of cement is, first to bind the fine (sand) and coarse (granite) aggregates together, and second to fill the voids in between the fine and coarse aggregate particles to form a compact mass. Though cement is made up of only about 10 percent of the volume of the concrete mix, it is the active portion of the binding medium and the only scientifically controlled concrete ingredient (*Gambhir, 2013)*.

The production of cement is an energy intensive process and is a major contributor to carbon (iv) oxide (CO_2) emission into the atmosphere, accounting for about 7% - 10% of global emission annually (*Altwair and Kabir, 2010)*. Thus cement contributes to climate change, which is an environmental problem that disturbs the current and upcoming generations. At the same time, the cost of production of cement is increasing day by day and natural resources used for manufacturing of cement are reducing. Presently, in Nigeria, a 50kg bag of cement is sold for #2,500 compare to #1,500 in 2015 in which the cost has increased by 67%, it is therefore necessary to find alternative means of economizing the use of cement. One of the practical solutions to economize cement in concrete production is to replace cement with waste materials which can be in form of agricultural wastes (rice husk ash, corn cob ash, palm oil fuel ash), industrial wastes (fly ash, silica fume, granulated blast furnace slag) and municipal wastes (glass, plastics, paper) *(Liew et al., 2017)*.

Many industrial by - products such as fly ash, silica fume, granulated blast furnace slag, etc., and some of the agricultural by products like palm oil fuel ash, corn cob, coconut shell ash, rice husk ash, etc have been found useful as additions or substitutions to cement in concrete. *Hawileh et al., (2017)* carried out an investigation on the performance of reinforced concrete beams cast with different percentages of GGBS replacement to cement. They concluded that the performance of RC beams with GGBS replacement up to 70% is the same to that without GGBS. Nevertheless, the strength and stiffness for the beam specimens with 90% of GGBS were lower than that without GGBS by 6% and 16%, respectively. *Ranjbar et al., (2016)* studied the properties of self - compacting concrete containing POFA and inferred that it is possible to replace up to 20% of cement with POFA without any adverse effect on the fresh properties of self - compacting concrete (SCC).

Ikumapayi, (2016) investigated the crystal and microstructure analysis of pozzolanic properties of bamboo leaf ash (BLA) and locust beans pod ash (LBPA) blended cement concrete. He concluded that both BLA and LBPA are pozzolans which when partially substituted with ordinary Portland cement will affect the hydration process as well as the mechanical interlock or microstructure of such concrete. The optimum percentage replacement of BLA and LBPA range between 8% and 16%. *Ndububa and Uloko, (2015)* studied locust bean pod ash (LBPA) as a pozzolanic material in concrete. They concluded that the compressive strength of the cement - LBPA concrete is satisfactory enough for usage as a load bearing building material and the values of water absorption capacity though higher than that of plain concrete is good enough for a durable building material.
Oyedepo et al., (2015) reported that the utilization of CSA and PKSA as a partial replacement for cement in concrete, at lower volume of replacement, will increase the reduction of cement used in concretes, thus lowering the cost of production and the environmental pollution produced by the dumping of the agricultural waste. It was found in the work of *Ettu et al., (2013)* that the strength of OPC - CHA binary blended cement concrete is higher than that of the control at 90 days of curing for 5 - 15% replacement.

Consequently, OPC - CHA binary blended cement concrete can be utilized for high strength requirements at ages of curing above 50 days.

The combination of locust beans pod ash and coconut husk ash which are classified as an agricultural waste are used as a partial replacement for cement in concrete is the focus of this study. More so, the importance of the study is to help reduce the total cost of concrete production arising from the high cost of cement, and reduce the volume of solid waste generated from locust beans and coconut husk. Proper utilization of the combination of these two waste materials as a partial replacement for cement will bring ecological and economic benefits to the country and to the whole world.

Locust bean pod is a waste agricultural product which is obtained from the African locust bean tree (*Parkia Biglobosa*) and it is the material required for the production of locust bean pod ash (LBPA). The tree grows up to 20m in height and grows in much of sub - sahara Africa which commonly found in Nigeria *(Ntui et al., 2012)*. It grows large fruit pods that contain both sweet yellow pulp and valuable black seeds. The harvested fruits are ripped open while the yellowish pulp and seeds are detached from the pods. The seeds are used for food flavour when fermented. Yoruba people called these seeds "Iru" while Ibo people called it "Ogiri" and Hausa people called it "Dadawa" *(Gernah et al., 2007)*. Coconut husk are the rough exterior shells of the coconut and are regarded as agricultural waste products obtained in the processing of coconut oil. Coconut plants are available in large quantities in the tropical regions of the world, most especially in Africa, Asia and America. Coconut husk are not commonly used in the construction industry but are often dumped as agricultural wastes.

Experimental Procedure

Preparation and Collection of Materials

The materials that were used include locust bean pod ash (LBPA), coconut husk ash (CHA), Cement, fine aggregates, coarse aggregate and water. The Locust bean pods shown in Figure 1 were obtained from Kisi in Oyo State of Nigeria and the coconut husk shown in Figure 2 were obtained from Kajola, in Osun State of Nigeria. The Locust bean pod and coconut husk were burnt separately by local open air burning after being properly sun dried. The idea of burning them in an incinerator was dropped because it will be time – consuming and uneconomical for most people particularly those at the rural areas. Each burnt locust bean pods and coconut husk was then grounded separately after cooling using mortal and pestle and the burnt ashes were sieved separately through British Standard sieve of 75microns. The resulting locust bean pods ash (LBPA) and coconut husk ash (CHA) which has the required fineness was collected for use.

Fine aggregate was obtained from natural deposit in Ede and coarse aggregate was obtained from Quarry Company at Apomu in Osun state. Ordinary Portland cement (Dangote brand) was purchased from a cement dealer in Ede town and portable water was used for concrete mixing.

Figure 1: Locust Bean Pods

Figure 2: Coconut Husk

Production of Concrete Cubes

The batching of the concrete materials was done by weight. Table 1 showed the batching information for concrete cube cast. The mixing was done on a dry, clean and hard surface free of all harmful materials which could affect the properties of the mix. The required quantity of sand was measured and spread using a shovel to a reasonably large surface area. The quantity of cement in the mix was then replaced by combination of locust bean pod ash and coconut husk ash in proportions of 0%, 5%, 10%, 15% and 20% by mass of cement. The cement, locust bean pod ash and coconut husk ash were manually mixed in dry state and later added to the already measured sand where the mixing continues until the whole mass becomes uniform in colour. Thereafter, a depression was made in the middle of the whole mass while the required quantity of granite was measured and spread evenly on it. The required quantity of water was then added gradually and turned over with shovel until the mix appeared in colour and consistency.

The cube moulds were later cleaned using engine oil to prevent the development of bond between the mould and the concrete and permit easy removing. Each mould was then filled with prepared fresh concrete in three layers and each layer was compacted with tamping rod using twenty five strokes uniformly distributed across the seldom of the concrete in the mould. The top concrete was later smoothened by hand – trowel to level with the edge of the mould and then left in the open air for 24 hours. For each of the cement / ashes proportion, three cubes of concrete were cast and therefore, a total of 60 cubes were produced for testing. The concrete cubes were demoulded after 24 hours of the concrete hardened under air. They were later kept in curing tank measuring 3.0m by 1.5m filled with tap water only for periods of 7, 14, 21 and 28 days respectively.

Table 1: Batching information for concrete cubes cast

% Combination of LBPA and CHA Replacement	Cement (kg)	LBPA (kg) (kg)	CHA	Sand (kg)	Granite (kg)	Water (kg)	Water / Cement Ratio
0	17.75	0.00	0.00	26.63	53.25	9.76	0.55
5	16.86	0.44	0.44	26.63	53.25	9.76	0.55
10	15.97	0.89	0.89	26.63	53.25	9.76	0.55
15	15.09	1.33	1.33	26.63	53.25	9.76	0.55
20	14.20	1.77	1.77	26.63	53.25	9.76	0.55

Testing

Determination of Oxide Composition of Locust Bean Pods Ash and Coconut Husk Ash

Some quantity of locust bean pods ash and coconut husk ash were taken to the centre for energy and research development (CERD) of Obafemi Awolowo University (OAU), Ile - Ife in Osun state of Nigeria and test were performed on each samples to know the oxide composition. The results were shown in Table 2 and compare it with that of ordinary Portland cement (OPC).

Table 2: Chemical composition of locust bean pods ash and coconut husk ash

Oxide	Percentage Composition (%)		
	Locust Bean Pods Ash (LBPA) Average	Coconut Husk Ash (CHA) Average	OPC BS 12 Limits
SiO_2	3.85	5.92	17 – 25
Al_2O_3	0.13	0.09	3 – 8
Fe_2O_3	0.21	0.42	0.5 – 6.0
CaO	3.69	0.71	60 – 67
MgO	6.10	1.08	0.1 – 4.0
K_2O	18.71	22.42	0.4 – 1.3

Slump Test

Slump test was carried out to check the effect of LBPA and CHA on the workability of fresh concrete. The tests were carried out in accordance with the requirements of *BS 1881 (1983)*.

Density

Before the compressive strength test was carried out, the mass of the concrete cube specimens were taken to determine the density of the concrete cubes. The density of the concrete cubes were later obtained from the mass and volume of the concrete cube which is calculated as :

$$Density = \frac{M}{V} \quad ---------- \quad (i)$$

Where:

M = Mass of the Concrete Cube and V = Volume of the Concrete Cube

Compressive Strength Test

Before crushing, the cubes were brought out of the storage curing tank and weighed on a weighing balance. They were later taken to the digital compression machine with maximum capacity of 1000kN in accordance with *BS 1881 (1983)* to determine the compressive strength. The load on the cube was applied at a constant rate of stress equal to 0.01N/mm^2 per second. The concrete cubes experienced cracks due to failure in their strength as a result of the load applied by the compression machine. The compressive strength was recorded to the nearest 0.01N/mm^2 and the value was the average of three concrete cubes.

Test Results and Discussions

Chemical Composition

Table 2 shows the oxide composition of locust bean pods ash and coconut husk ash samples. The result showed that LBPA and CHA has combined percentages (SiO_2 + Al_2O_3 + Fe_2O_3) of 5.32% which is far less than 70%, indicating that the two samples is not a good pozzolanic materials in accordance with the requirements in *ASTM C 618 (2005)*. The percentage composition for silicon (iv) oxide (SiO_2) in the combination of LBPA and CHA was below the minimum value specified by *BS 12 (1978)* for ordinary Portland cement and also the oxide composition for potassium oxide (K_2O) in the combination of LBPA and CHA has a high percentage of 20.57%. This may be a source of disruption on the compressive strength of concrete cubes.

Workability

The results of the slump test carried out are shown in Table 3, indicating the workability of the LBPA – CHA concrete. The table indicates that the slump value decreases as the percentage of LBPA and CHA increases. This implies that the concrete became less workable (stiff) as the LBPA and CHA content increased.

Table 3: Slump Value of LBPA – CHA Concrete

% Combination of LBPA and CHA Replacement	0	5	10	15	20
Slump (mm)	80	65	50	35	25

Density

The relationship of the density with days of curing for different percentages of the combination of LBPA and CHA is expressed graphically in Figure 3. From the result, it can be revealed that for the control (0% ash content) and for each cement: combination ash ratio, the density reduced with days of curing. This is predictable as a result of concrete hardens and water is used up in hydration process while the products of hydration occupied less space than the original water and cement *(Neville, 1995)*. The results also revealed that for the same days of curing, the density decreases as the proportion of combination of LBPA and CHA increases. This is predictable because ordinary Portland cement has a higher specific gravity of 3.04 than the combination of ashes which is 2.55. The 0% ash had the highest density followed by the 95 : 5% cement : ashes combination. This implies that the concrete cubes produced with 0% ash are densely packed and there are fewer voids to be filled by sand and cement as compared with the other cement : ashes combination.

The mathematical equations for predicting density of LBPA and CHA concrete obtained from the results of linear regression analysis are also shown in Figure 3. For instance, for 0% percentage combination of LBPA and CHA, the equation of density at 7 days of curing is

$$y_7 = -20.4x + 2696 \quad --------- \quad (i)$$

Where y_7 is the 7 days density in kg/m^3 of LBPA and CHA concrete and x is the days of curing. Similarly, for 5% percentage combination of LBPA and CHA, the equation of density at 14 days of curing is $y_{14} = -23.4x + 2607 \quad ----------- \quad (ii)$

For 10% percentage combination of LBPA and CHA, the equation of density at 21 days of curing is $y_{21} = -25x + 2493 \quad ----------- \quad (iii)$
For 15%, the equation of density at 28 days of curing is
$$y_{28} = -12.1x + 2409 \quad ----------- \quad (iv)$$
For 20%, the equation of density at 56 days of curing is
$$y_{56} = -15.3x + 2366.5 \quad ----------- \quad (v)$$

From equations (i) – (v), it shows that there is linear relationship between density of concrete cubes and percentage combination of LBPA and CHA. This indicating that the density of concrete cubes decreases as both the days of curing and percentage combination of LBPA and CHA increased. In addition, the R – square value of each chart in the Figure 3 is closer to 1, this means that the linear relationship between density and the days of curing is more accurate.

Compressive Strength
The effect of different percentages combination of LBPA and CHA on the compressive strength of concrete cubes is shown in Figure 4. The figure show that compressive strength generally increases with days of curing and decreases as the percentage of LBPA and CHA increases. This is due to hydration of cement and ashes possess little cementing properties compared to a Portland cement. The concrete cubes with 0% combination of LBPA and CHA had the highest rate of early strength development. At 7 days, the result showed a decrease in strength from 13.43N/mm^2 for 0% to 7.11N/mm^2 for 20% LBPA and CHA replacement. Similar trend was observed at 14 days as shown in Figure 2. These results indicate that concrete containing LBPA and CHA gain strength slowly at early curing age. At 28 days, there was continuous increase in compressive strength for all the percentages of ashes with values ranging from 18.24N/mm^2 for the 0% to 9.87N/mm^2 for 20% LBPA and CHA replacement. The 0% which serves as control still has the highest compressive strength at this age. As could be seen from the Figure 2, there is a general decrease in compressive strength as the percentage of LBPA and CHA content increases. Since all the concrete cubes meet the minimum strength of 6N/mm^2 after 28 days of curing recommended by *BS 5224 (1976)* for masonry cement, LBPA - CHA concrete could be used for general concrete works such as in masonry construction, floor screed, rendering and plastering.

The mathematical equations for predicting compressive strength of LBPA and CHA concrete obtained from the results of linear regression analysis are also shown in Figure 4. For instance, at 7 days, the equation of compressive strength is $y_7 = -1.569x + 15.107 \quad ---===- \quad (vi)$

Where y_7 is the 7 days compressive strength in N/mm^2 of LBPA and CHA concrete and x is the percentage combination of LBPA and CHA. Similarly, for 14 days, the equation of compressive strength is $y_{14} = -1.572x + 16.384 \quad ------- \quad (vii)$
For 21 days, the equation of compressive strength is $y_{21} = -1.948x + 19.168 \quad - \quad (viii)$
For 28 days, the equation of compressive strength is $y_{28} = -2.101x + 20.909 \quad -- \quad (ix)$

From equations (vi) – (ix), it shows that the compressive strength of concrete cubes increases as the days of curing increases and decreases as the percentage combination of LBPA and CHA increased. In addition, the R – square value of each chart in the Figure 4 is almost closer to 1, this means that the linear relationship between compressive strength and percentage combination of LBPA and CHA is more accurate.

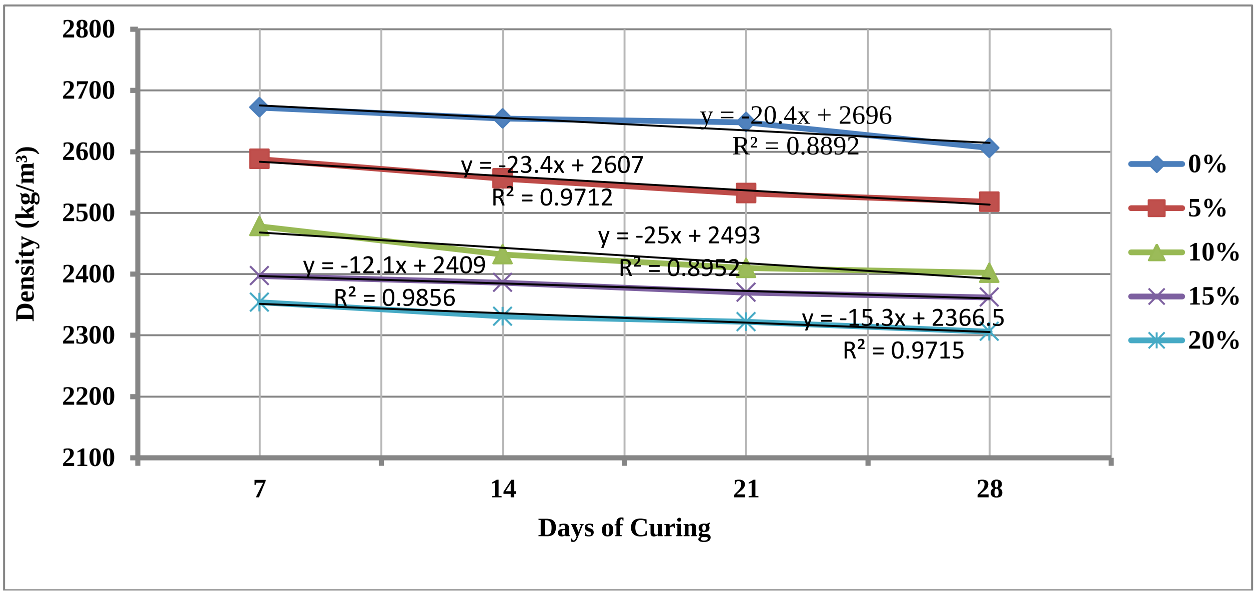

Figure 3: Density – Time characteristics of concrete cubes

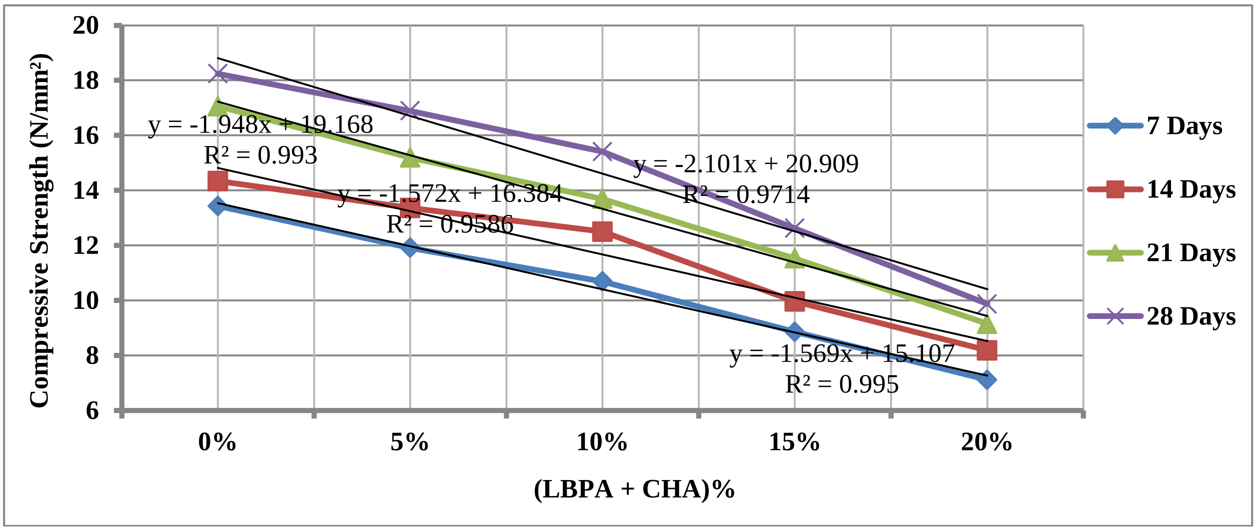

Figure 4: Effect of different percentages combination of LBPA and CHA on the compressive strength of concrete cubes

Conclusion

From the results of the various tests carried out, the following conclusions can be arrived at:

(i) The combination of LBPA and CHA are not suitable materials for use as a pozzolan, since it does not satisfy the requirement for such a material by having a combined (SiO_2 + Al_2O_3 + Fe_2O_3) of 5.32% which is far less than 70%.

(ii) The slump value decreases with increasing percentage combination of LBPA and CHA. This implies that the concrete became less workable (stiff) as the LBPA and CHA content increased.

(iii) The density and compressive strength of concrete cubes decreases with increased amount of the percentage combination of LBPA and CHA.

(iv) The density of concrete cubes decreases with days of curing whereas compressive strength of concrete cubes increases with days of curing. Only the percentage combination of LBPA and CHA up to 10% replacement of Ordinary Portland cement in concrete would be suitable to enjoy maximum advantage of strength gain.

(v) There exists a potential cost reductions in concrete production using combination of LBPA and CHA as partial replacement for cement.

(vi) Though the strength of OPC/ (LBPA + CHA) concrete was lower than that of control, it can still be used for general concrete works such as in masonry construction, floor screed, rendering and plastering.

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