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[1.] J.O. AKINYELE, [2.] A.A. ADEKUNLE,
[3.] O. OGUNDAINI

THE EFFECT OF PARTIAL REPLACEMENT OF CEMENT WITH BONE ASH AND WOOD ASH IN CONCRETE

[1-3.] Department of Civil Engineering, Federal University of Agriculture, Abeokuta, NIGERIA

ABSTRACT: The indiscriminate dumping of agro waste in the environment has brought about the need for adequate, safe disposal and recycling of such waste. Both animal and vegetative wastes have been found to be very useful especially in the agro industry. But this research has looked into the use of these types of wastes in the construction industry, especially in the partial replacements of cement in concrete. Cement was partially replaced in concrete at 5, 10, 15, 20 and 25% with both bone and wood ashes. Chemical analysis was carried out on both the wood and bane ashes in order to determine their pozzolanic properties. While compressive strength test was conducted on the concrete obtained from both cement replacements. The chemical analysis revealed that the bone ash is a better pozzolana when compared to the wood ash. The compressive strength test showed that wood ash is not a good material for replacing cement in concrete, while 10% of bone ahs can partially replace cement in concrete at 28 days compressive test.
Keywords: bone ash, wood ash, concrete, pozzolana, cement

1. INTRODUCTION

The effect of cement production on the environment has made the research for alternative materials to cement popular in the last decades, various work has been conducted in this area, by looking for materials that will totally or partially replace cements in the construction industry. Most especially industrial and agro-based waste materials like fly ash, coal fired ash, rice husk ash, corncob ash, palm oil fuel ash etc.

Krammart, and Tangtermsirikul (2004) used municipal solid waste incinerator bottom ash (MSWI) and calcium carbide waste (CCW) as a part ofcement raw materials, cement was replaced by 5% and 10% of MSWI and CCW in cement mortar, the chemical and mechanical properties of the samples were determined. It was discovered that the chemical composition of the MSWI and CCW were similar with that of the control sample, but the silicon oxide (SiO_2) content of MSWI cement was higher than that of the control, whereas the calcium oxide (CaO) was lower. Setting times of cement pastes were slightly delayed when MSWI or CCW were used to replace a part of raw meal in cement production, longer setting times of cement mortar was observed due to high C_2S and low C_3S content in the samples when compared with the control. In the mechanical test, the compressive strength of CCW mortars was close to that of the control, while that of the MSWI was lower than the control sample this work showed that cement can by partially replaced by the two materials investigated in cement mortars.

Fly ash is another materials that has been used in partial replacement of cements in concrete and cement mortars, Jo et al. (2007)showed that fly ash based lightweightartificial aggregate is suitable for the production of concrete having a compressive strength of 29 N/mm^2. Cold bonded fly ash was also found to be suitable for the production of concrete with a compressive strength up to 30 N/mm^2 (Joseph and Remamurthy 2008, 2009).

Another test on fly ash was conducted by Gesoglu et al (2012) the result indicated that the specific gravity of fly ash–ground granulated blast furnace slag artificial aggregate increases with an increase in the cement content hence it usefulness as partial replacement of cement was encouraged. Thomas and Harilal (2015), also determined the characterization of cold blended and artificial aggregate made from fly ashand its usefulness in concrete production. The work concluded that the specific gravity of the artificial aggregate containing fly ash and quarry dust is found to be between 1.9 and 2.5. The artificial aggregate prepared in the study belongs to normal weight aggregate. The compressive strength of concrete having a water cement ratio 0.45 and containing artificial aggregate is found to be varying from 20 MPa to 30 MPa.

The use of coal fired ash in concrete has also been investigated by Singh and Siddique (2014), The results from the work indicates that at fixed water cement ratio, workability and loss of water from bleeding decreased with the use of coal fired ash as replacement for fine aggregate in concrete, the compressive strength of the coal ash concrete was not affected at the curing age of 28 days, but at 90 days of curing, compressive strength of the coal fired ash surpassed that of the conventional concrete. The modulus of elasticity decreased with the addition of coal fired ash at all the curing ages.

Rice husk ash is one of the agro-based waste that have been investigated in the past, Akinyele et al (2015) investigated the use of rice husk and rice husk ash as a filler in the production of clay bricks, The chemical composition of the rice husk ash was investigated and the work revealed that the total composition of oxides of iron, silicon and aluminium in the rice husk was below 70%, which is a minimum requirement for a pozzolana, but the ash was classified as a class 'c' pozzolana. Guneyisi et al (2007) concluded that concrete containing 15% of rice husk ash showed an utmost compressive strength and loss at elevated content more than 15%. Also Habeeb and Fayyadh (2009) investigated the effects of concrete incorporating 20% rice husk ash as partial replacements of cements at different particle sizes, the study concluded that tensile strength increases systematically with increased rice husk ash replacements in concrete.

2. MATERIALS AND METHODS

Bone Powder Ash (BPA)

Bone powder ash was obtained from burning cattle bones at a temperature of 900°C. The bones were cleaned and sun-dried and oven dried to reduce its oil content before burning. The burnt bone was allowed to cool before grinding in a hammer mill to fine powder. The bones used for this work was obtained from a local abattoir in Abeokuta, Ogun State. The availability of cattle bone abounds in commercial quantities in various abattoirs that are scattered in cities and villages all over Nigeria.Aribisala et al (2006).

Wood Ash (WA)

The wood ash obtained was powdery, amorphous solid, sourced locally from the bakery of the Federal University of Agriculture, Abeokuta, Nigeria (FUNAAB). The wood ash was passed through a sieve in order to determine the particle size distribution.

Cement and Aggregates

Ordinary Portland cement (OPC) wasused in which thecomposition and properties is in compliance with theNigerian standard organization defined standard ofcement for concrete production. The raw materials from which it is made are silica, lime, alumina and iron oxide. This constituents are crushed and blended in the correct proportion and burnt in rotary kiln. The aggregates used were chemically inert,clean, hard, and durable. Natural aggregates are classified according to the rock type, e.g basalt, granite, flint.

Organic impurities can affect the hydration of cement and the bond between the cement and the aggregates. Some aggregates containing silica may react with akali in the cement causing the concrete to disintegrate. Both the coarse and fine aggregate were sourced locally.

Water

The quality of the water used in the concrete mix was such that the chemical reaction, which take place during the setting of cement, are not imparied. In general, portable water is suitable for concreting. Thus, the water should be free from impurities such as suspended solids, organic matters and salts,e.t.c which may affect the setting of the cement.

Bouge's Model

Bogue's model was used in the calculation of the compound composition of cement and cement replaced with the different agro-wastes, due todifficulty in the direct determination of theprincipal compound. Calculations using Bogue's equations was based on the following assumptions:

(i) Concentration would be based on a function of theweight, volume or percentage of eachmaterial in the combination of cementand any agro waste.
(ii) The oxide composition of the percentageof each material that would be use is equivalent to that of material used multiplied bythe oxide composition of each constituentin the material.
(iii) In a mixture or combination of cementand any agro waste the oxidecomposition of the mixture is equal tosum of the proportion or the percentageof the oxide composition of each materialin the mixture.
(iv) In a mixture or combination of cementand any agro waste the oxidecomposition of the mixture is equal tosum of the proportion or the percentageof the oxide composition of each material in the mixture.
Example: the CaO in acombination of 90% cement +10%AHA,= 57.6+0.084 = 57.684
Compound composition of the different mixture as calculated based on assumption (i)– (iii).
Since test on the suitability of the Agro-wastewould be carried outon concrete cubes,percentage decrease in strength would be used asbasis for evaluating the suitability of anycombination of cement and the differentAgro-wastes considered.Percentage decrease in strength equalstrength achieved using cement replaced withthe different percentages of the agro wastes,less strength achieved using only cementdivided by strength achieved using onlycement. Positive values indicate increase instrength while negative values representdecrease in strength.

Chemical analysis

The bone and wood ashes were taken to a chemical laboratory for chemical analysis, the Atomic absorption photometer and Flame photo spectrometer were used to determine the elemental oxides such as CaO, SiO_2, Al_2O_3, Fe_2O_3 and so on. These equipment uses light beams and high temperature causing emission of lights to excite the ground atoms of each elements in the ashes, since each elements has a characteristic wavelenght and intensity of emission to calculate the concenytration according to their presence in the periodic table.

Preparation of test specimen

Cement was replaced by bone powder ash and wood ash in the ratios: 0%, 5%, 10%, 15%, 20%, 25%. Where the 0% represents the control sample which consists of only cement, fine aggregate and coarse aggregate in the ratio 1:2:4, The batching of concrete tests samples was by weight in order to eliminate errors due to variation in the proportion of voids contained in a specified weight, in conformity with BS 8110, the water cement ratio was 0.6, aggregrate size of 12 mm was mixed with sand and cement mixture. The cube size used was 150 mm x 150 mm x 150 mm. With each percentage sample having a replicate of three. Table 1 showed the proportion of mixes for cement (Bone ash or wood ash), sand and granite.

Table 1: Quantity of materials used in production of concrete

Bone Powder Replacement (%)	Mass of Concrete (Kg)			Granite
	Cement	BPA/WA	Sand	
0	12.73	0	25.46	50.91
5	12.09	0.64	25.46	50.91
10	11.46	1.27	25.46	50.91
15	10.82	1.91	25.46	50.91
20	10.18	2.55	25.46	50.91
25	9.55	3.18	25.46	50.91

According to BS 1881; PART 108 (1983), each of the constituent was weighed and mixed until a uniform mixture was achieved, the the mould were oiled properly to prevent the concrete from sticking to the mould and for easy removal of cubes. The concrete mixes were left inside the mould for a bout 24 hours before removing from the moulds, this is to allow proper setting of concrete.
The curing of concrete was done according to BS 1881:part3 (1983) , the cubes were immersed inside water trough such that the cubes were completely covered with water. On each testing day the samples was brought out of the trough and allowed to dry before the weight was determined.

3. RESULTS AND DISCUSSION

Chemical Analysis

Chemical analysis was conducted on the replacement materials to determine their chemical constituents. The result of the analysis are shown in the Table 2. It can be observed that bone powder ash and have a high calcium oxide more than cement , while that of wood ash is lower than that of cement, the silica oxide of bone powder ash is very low when compare to that of wood ash and cement. Looking at the aluminium and iron oxide, it was observed that they both vary in composition.
The loss on ignition, a measure of the extent of carbonation and hydration of free lime and free magnesia due to atmospheric exposure, of bonepowder ash is 0.37%. This value is within the

limits of 3.0% set by BS 12 (1996), while that of wood ash is far above the recommended value at 8.75%. The total percentage composition of Iron oxide (Fe_2O_3) at 0.6%, aluminium oxide (Al_2O_3) at 11.24% and silicon dioxide (SiO_2) at 48.96% was found to be 60.8% for wood ash. While the total percentage composition of Iron oxide (Fe_2O_3) at 2.28%, aluminium oxide (Al_2O_3) at 2.97 % and silicon dioxide (SiO_2) at 0.43% was found to be 5.68% for bone powder ash both ash can be classified as class C pozzolans. Both percentages arefar less than 70% minimum required for pozzolana (ASTM C 618-94).According to the code, when the sum percentage of SiO_2, Al_2O_3 and Fe_2O_3 exceed 70%, and loss of ignition (LOI) less than 10%, then the ash belongs to a class "F" pozolans, and hence the ash exhibit pozolanic properties. The alkali content (Na_2O) for wood ash was found to be 8.76%. This value is higher than the maximum alkali content of 1.5% required for pozzolana. The alkali content is important were the wood ash is to be used with reactive aggregate, Neville (1995). While the alkali content (Na_2O) for bone powder ash was found to be 0.37% this value is lower than the maximum alkali content of 1.5% required for pozzolana.

Table 2: Percentage composition elements in test samples

Elements Oxides	BPA	WA	C
CuO	0.28	-	-
SiO_2	2.28	48.96	20.7
Al_2O_3	2.97	11.24	5.75
Fe_2O_3	0.43	0.6	2.5
CaO	76.31	11.59	64
MgO	1.21	5.05	1.94
P_2O_5	5.57	-	-
Na_2O	0.37	8.76	-
K_2O	0.24	5.42	-
MnO_2	0.086	-	-
P_4O_{10}		-	-
SO_3	-	-	2.75
CO_3		-	-
LOI	0.37	8.75	1.3
Ashing (g)	0.32	-	-
Ash	13.2		

Bogue's equations for the percentages chemical content in BPA and WA

Bogue's equations for the percentages of main compounds in binders are given below. The terms in brackets represent the percentage of the given oxide in the total mass of binder.

$$C_3S = 4.07(CaO) - 7.60(SiO_2) - 6.72(Al_2O_3) - 1.43(Fe_2O_3) - 2.85(SO_3)$$
$$C_2S = 2.87(SiO_2) - 0.754\ (C_3S)$$
$$C_3A = 2.65(Al_2O_3) - 1.69(Fe_2O_3)$$
$$C_4AF = 3.04(Fe_2O_3$$

Using the formula on the components of the various binder materials as tabulated in elemental oxide table above another table indicating the percentage components of the main compounds will be generated as shown in the table below.

- C_3S – Tri-Calcium Silicate
- C_2S – Di-Calcium Silicate
- C_3A –Tri -Calcium Aluminate
- C_4AF – Calcium Ferro Aluminate

C_3S and C_2S are the most important components of a binder material because they are the strength indicator of the binder material in concrete and other allied cement products. Their hydration reaction gives the same products but only differ in the quantity produced. The approximate equations showing their reactions in water is as shown below.

$$2(3CaO.\ SiO_2) + 6H_2O \rightarrow 3\ CaO.2\ SiO_2.\ 3H_2O + 3Ca(OH)_2$$

This can be written as $2C_3S + 6H \rightarrow C_3S_2H_3 + 3Ca(OH)_2$

Similarly, $2(2CaO.\ SiO_2) + 4H_2O \rightarrow 3\ CaO.2\ SiO_2.\ 3H_2O + Ca(OH)_2$

or $2C_2S + 4H \rightarrow C_3S_2H_3 + Ca(OH)_2$

It has been observed that C_3S produces a comparatively lesser quantity of calcium silicate hydrates and more of $Ca(OH)_2$ than that formed in the hydration of C_2S. $Ca(OH)_2$ is not a desirable product in the concrete mass because it is porous and gets leached out making the concrete porous. C_3S is responsible for the early strength of cement/binder paste.

The greatest 28 days compressive strength of 10% BPA as seen above should owe its reason to the fact that it has the great amount of C_3S content which is responsible for the early strength of cement products.

Compressive strenght test of samples

The compressive strength of concrete cubes were determined after 7,14,21 and 28 days of normal curing, the results are summarised in Figures 1 and 2. It can be observe that the strength of control cubes mixes is generally higher, but the compressive strength of 10% partial replacement using bone powder ash is higher than that of the control for all the test days, but for wood ash there is reduction in strength of concrete cubes, this reduction increases with increased in replacement. The reason for this properties can be linked to the percentage proportion of the oxides of carbon, aluminium, magnesium and silicon present in each sample. Calcium oxide (CaO), which is the main compound in cement and pozolanas was found to be more in the bone ash at 76.31% when compared to cement 64% and wood ash 11.59%. Calcium is the main costituents of bones hence it aboundance in the bone ash, and this gave it the required advantage as a pozolana. The gradual reduction in strength after the 10% replacement can be attributed to the ecesssive presence of the oxide of calcium in the mixture, while other costituent elements of pozolanas was reducing as more replacement was carried out. The 10% replacement can ce called the threshold mix.The wood ash performed very badly because of the very low CaO in it and the excessive pressence of Silicon oxide at 48.96% instead of the 20.7% for cements which serves as standard control. The other very importanat oxide of aluminium 5.75% and 2.97% in both cement and bone ash respectively and magnesium at 1.94% and 1.21% in cement and bone ash respectively are very close when compared to wood ash with 11.24% of aluminium and 5.05% magnesium, this reaveled why the compressive strenght of the wood ash was very poor

Table 3: Calculations of bone powder ash chemical component

Elemental Oxides	100%C 0%BPA	95%C 5%BPA	90%C 10%BPA	85%C 15%BPA	80%C 20%BPA	75%C 25%BPA
SiO_2	20.70	19.78	18.86	17.94	17.02	16.10
Al_2O_3	4.48	4.40	4.33	4.25	4.18	4.10
Fe_2O_3	2.50	2.20	2.29	2.19	2.09	1.98
CaO	64	64.62	65.23	65.85	66.46	67.08
SO_3	2.75	2.61	2.48	2.34	2.2	2.06
Compound Composition						
C_3S	50.7	72.57	82.71	93.3	103.79	114.39
C_2S	22.5	2.05	-8.24	-18.86	-29.41	-40.04
C_3A	8.6	7.6	7.6	7.56	7.54	7.52
C_4AF	9.4	7.3	6.96	6.66	6.35	6.02

Table 4: Calculations of wood ash chemical component

Elemental Oxides	100%C 0%WA	95%C 5%WA	90%C 10%WA	85%C 15%WA	80%C 20%WA	75%C 25%WA
SiO_2	20.70	22.11	23.53	24.94	26.35	27.77
Al_2O_3	4.48	4.82	5.16	5.49	5.83	6.17
Fe_2O_3	2.50	2.14	2.31	2.22	2.12	2.03
CaO	64	61.38	58.76	56.14	53.52	50.90
SO_3	2.75	2.61	2.48	2.34	2.2	2.06
Compound Composition						
C_3S	50.7	38.50	15.2	-7.79	-30.91	-54.12
C_2S	22.5	34.42	56.01	77.45	98.93	120.51
C_3A	8.6	8.70	9.77	10.80	11.87	12.92
C_4AF	9.4	7.33	7.02	6.75	6.44	6.17

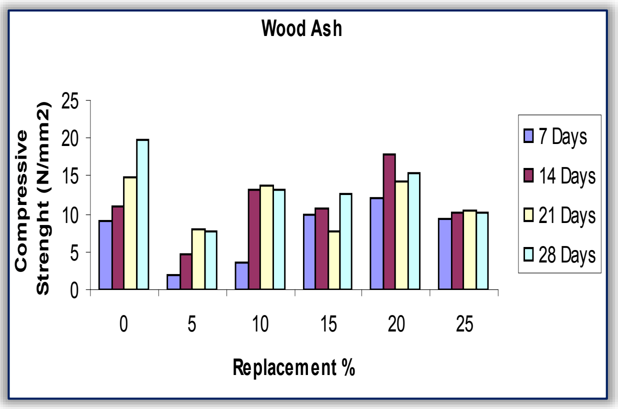

Figure 1: Compressive strenght for wood ash mix

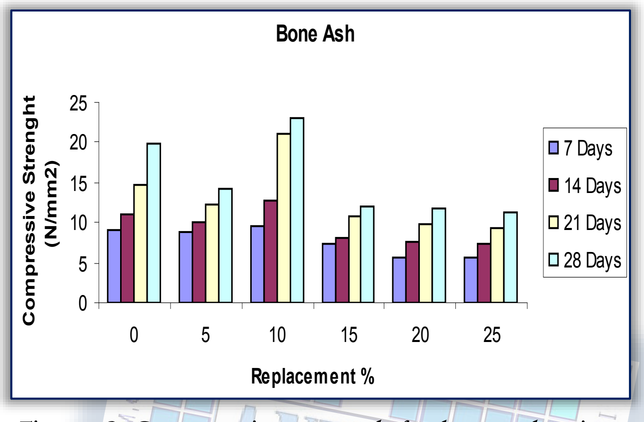

Figure 2: Compressive strength for bone ash mix

4. CONCLUSIONS

This work has looked into the use of both wood ash and bone ash as partial replacements for cement in concrete, it revealed the importance of the use of pozzolanas as partial replacements of cements in concrete, the bone ash contains a lot of calcium oxide (CaO) which gave it the required advantage over wood ash, and a very good performance when compared with cement as showed in figure 2. It can be safely concluded that bone ash can be a very good subatitute for cement in concrete works, but the percentage replacements should not exceed the 10% threshold.

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