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Investigation Into The Possibility of Partial Replacement of Cement with Bone Powder in Concrete Production

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Abstract: The compressive strength of concrete using Bone powder(BP) as a partial replacement of cement was investigated. Ordinary Portland cement (OPC) was replace with BP in the ratios of 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% respectively. Workability, setting time and compressive strength were determined. Mineralogical analysis of BP was first carried out to determine its chemical composition. The result showed that almost all the compounds of metals contained in cement are also present in BP but in different proportions. In the absence of BP the crushing strength was 25.95N/mm^2. The strength of cement/BP concrete increased with curing period but decreased with increased BP replacement. Two days after immersion in water, the specimens with 80-100% replacement crumbled in water, hence no strength was recorded. The reason may be attributed to the fact Bone Powder is not a pozzolanic material therefore do not have binding ability unlike OPC. Workability decreased as percentage replacement of cement with BP increased. The initial and final setting times increased with increased proportion of BP. It was discovered that substitution of cement with BP in concrete production was relatively possible but not exceeding 10% by weight for structural works and 20% for rendering purposes. The compressive strength of concrete at 0% Bone Powder was used as control.

Keywords: Bone powder; Setting time; Workability; Compressive, flexural, tensile strengths

I. INTRODUCTION

Necessity is the mother of invention. The need for shelter by man has continued to increase at an alarming rate. In Nigeria as well as in other developing countries, this has led to high cost of building materials which made it virtually difficult for average citizen to own house [Alabadan et al, 2005]. Moreover, production of cement for concrete construction has attracted a lot of criticisms due inherent danger associated with its production. For every ton of cement produced, one ton of CO2 is emitted in the atmosphere, causing green house gases and ozone layer depletion[Mahasenan et al 2003, WBCSD 2005, Gartner 2004, Aggarwal et al 2012]. The two major construction materials, sand and aggregates (fine and coarse aggregates) which are supposed to be cheap because of their availability, are capital intensive both on purchase and transportation [Metha, 2004]. This present situation has necessitated the search for alternative building materials to bring down their prices and to save our environment. Moreover, a lot of research has been done on the use of pozzolanic materials to replace cement in concrete production[Okoye et al 2016, Shao et al 2000, Shi et al 2013, Shao et al 2005, Genasan et al 2008, Okpala et al, 1987]. Despite the wide scale research on the use of pozzolanic materials in concrete, not much has been done on the utilization of Bone powder as cement substitute. These materials are regarded as waste in landfills which can successfully be as cement replacement in concrete. In view of the present scenarios, a preliminary investigation into the possibility of partial replacement of Cement with Bone powder in Concrete production was carried out.

Bone powder is an inorganic material derived from animal bones, dried and heated in a furnace at a very high temperature or burning in the air and grounded to fine powder using milling machine. Animal bones are found in large quantities in abattoirs in almost every town in Nigeria. Some of these bones are disposed in landfills with inherent danger of pollution and other nuisance value. Therefore utilizing these BP as a partial replacement of cement in concrete production will enhance national development. The cost of Bone Powder when compared with Ordinary Portland Cement is lower due to availability of animal bones in large quantities as waste products in many abattoirs in Nigeria.

The utilization of animal bones will reduce landfills, promote waste management at little cost, reduce pollution by these wastes and increase economic base of butchers when such wastes are sold thereby encouraging more production. Also BP production requires less energy demand compared with Portland cement production and saves the needed foreign exchange spent on importation of cement and its components. Hence, the aim of this research is to study the possibility of using BP as a partial replacement of cement in concrete production. The effect of BP on setting time, workability and compressive strength of concrete.

II. EXPERIMENTAL PROGRAM

2.1. Materials

Bone Powder was obtained by filling three empty sacks of 50Kg each with animal bones collected from abattoirs at Ekwulobia and Uga markets both in Aguata L.G.A of Anambra state of Nigeria. The bones were dried in the sun after careful removal of adhering flesh and tissues and then burnt to ash in open air. They were then grounded with hammer mill to fine powder at Project Development Agency (PRODA) Enugu in Enugu state of Nigeria and passed through B. S sieve of 75 microns [Gartner 2004].The particle size distribution is shown in fig 1. Grade 43 OPC corresponding to BS 12, 1996, was used. The Chemical compositions of OPC and Bone powder are given in Table 1.

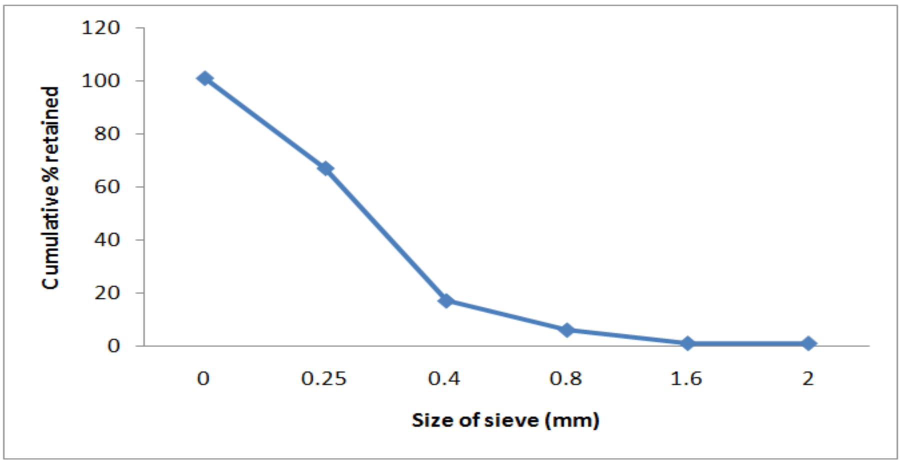

Fig 1. Particle size distribution of Bone powder.

Table 1. Chemical composition of Cement and Bone Powder.

S/N	Percentage Composition	Portland Cement	Bone Powder
1	Loss of ignition	0.98	3.29
2	Silica Oxide(SiO2)	6.0	0.24
3	Calcium Oxide(CaO)	68.7	53.2
4	Magnesium Oxide(MgO)	2.8	0.21
5	Phosphate(P2O5)	-	14.06
6	Sodium Oxide(Na2O)	1.36	1.36
7	Potassium Oxide(K2O)	0.5	0.2
8	Manganese Oxide(MnO)	0.02	8.52
9	Aluminum Oxide(Al2O3)	0.29	Trace
10	Iron Oxide(Fe2O3)	0.03	0.008

A 20mm coarse aggregate was collected from Isiagu in Ivo local government area of Ebonyi state of Nigeria. The aggregate was sieved to BS 2028. Fine aggregate used was river sand collected from Otalu stream at Aguluezechukwu town in Aguata LGA of Anambra State of Nigeria. The sand was prepared to BS 1017 Part 1 and 2 and BS 3406 Part 1. The particle size distribution of both aggregates was determined as shown in fig 2.

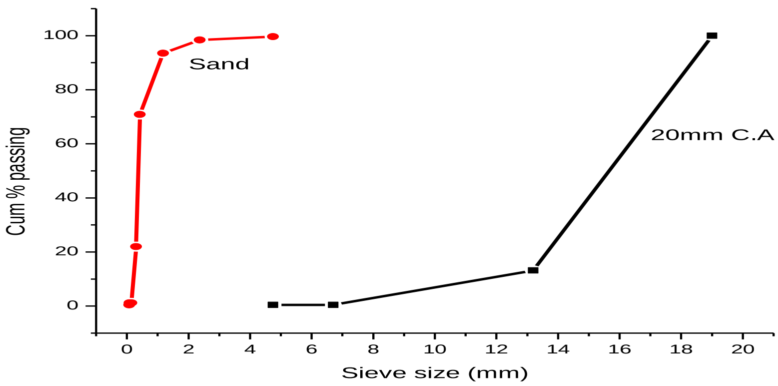

Fig 2. Particle size distribution of coarse aggregates.

III. TRIAL TEST

3.1. Determination of water/cement ratio (w/c ratio)

A trial test was performed to determine the w/c ratio that would give the highest compressive strength. The w/c ratios 0.45 to 0.65 was tested. From the result of the trial tests, it was discovered that 0.55w/c ratio gave the highest average compressive strength which was adopted in this experiment.

III. MIX PROPORTION

In this research, eighty concrete mixtures were designed including trial experiment. Concrete was prepared by replacing OPC with BP in the proportion of 0%,10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100% respectively. A medium concrete workability and mix ratio of 1:2:4 by weight was adopted with water/cement ratio of 0.55. A control mix was cast as MCC with 100% OPC to compare. The detailed mix design is given in table 2.

Table 2. Mix proportion

MIX NO	Coarse aggregate	Sand	Cement	Bone powder	w/c ratio
MCC	1200	600	300	0	0.55
MX1	1200	600	270	30	0.55
MX2	1200	600	240	60	0.55
MX3	1200	600	210	90	0.55
MX4	1200	600	180	120	0.55
MX5	1200	600	150	150	0.55
MX6	1200	600	120	180	0.55
MX7	1200	600	90	210	0.55
MX8	1200	600	60	240	0.55
MX9	1200	600	30	270	0.55
MX10	1200	600	0	100	0.55

4.1. Determination of setting times

The initial and final setting times were determined using vicat apparatus in conformity with BS EN 196-3: 1995 standard.

4.2. Workability Test

Workability of the concrete was determined using slump cone test in compliance with BS EN 12350-2 : 2000 standard.

4.3. Determination of compressive strength

The compressive strength test was determined using 100mm x 100mm x 100mm wooden mould and proportions given in Table 2. The specimens were cast in the mould and left for 24 hours before demoulding. After which they were then immersed in a curing tank containing clean water at room temperature. The compressive strengths were determined at 3, 7, 14, 21and 28respectively with a compression testing machine of capacity 2000KN at a loading rate of 140KN/min.

V. RESULTS AND DISCUSSION

5.1. Water/cement ratio

The fig 3 shows the result of trial experiment on w/c ratio used in this experiment.

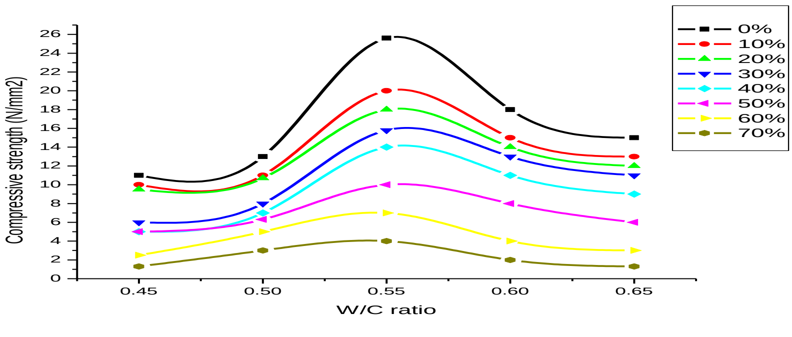

Fig 3. Effect of w/c ratio on compressive strength

It was noticed that the strength increased as the w/c ratio increased up to a certain limit. The increase in strength occurred at 0.45-0.55 w/c ratio and later decreased as the w/c ratio increased to 0.6-0.65. The reason is because at 0.45- 0.5 w/c ratio, the concrete was cohesive which increased bonding between the aggregate and binder in the matrix. Moreover, as the w/c increased to 0.55, the fresh concrete became workable and increased the homogeneity of the concrete specimens, making the hardened concrete more compact, hence, increased the strength. With further increase in w/c ratio to 0.6-0.65, the fluidity of concrete increased tremendously resulting in leaching of binder, thereby creating void spaces in the hardened concrete and reduction in strength. Generally air voids disrupts the packing of binder, consequently reducing the density and increase the heterogeneity in the micro structure, thereby resulting in the reduction of compressive strength. The maximum compressive strength occurred at 0.55w/c ratio.

5.2. Workability

Table 3. shows the result of workability of various replacements of cement with bone ash.

Table 3. Workability of OPC concrete with different proportions of Bone ash

Mix No	Slump(Mm)
MCC	100
MX1	87
MX2	75
MX3	30
MX4	30
MX5	15
MX6	8
MX7	3
MX8	0
MX9	0
MX10	0

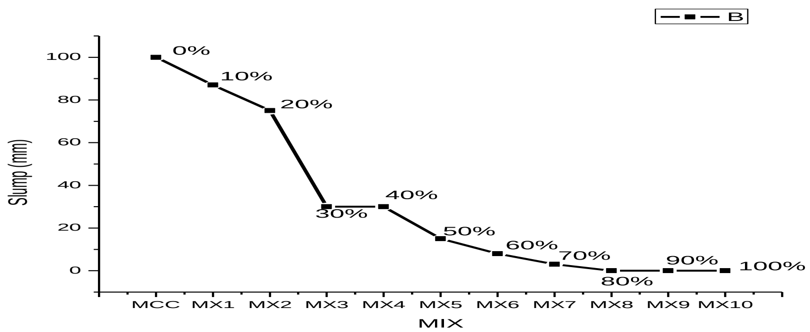

Fig 4. Slump of OPC concrete with various proportions of Bone ash

From the result, it was discovered that the slump decreased as the percentage replacement increased. At 0% replacement(100% OPC), the slump was maximum. There were no slump at 80%-100% replacement. The reason is because the fresh concrete was inconsistent and stiff which made compaction difficult.

5.3. Setting time

Table 4. below shows the results of initial and final setting times of various replacements of OPC with Bone ash.

Table 4. Setting times(mins) of various proportions of cement and Bone ash

Mix no	w/c ratio	Initial setting time	Final setting time
MCC	0.55	49	428
MX1	0.55	58	578
MX2	0.55	65	630
MX3	0.55	78	663
MX4	0.55	89	698
MX5	0.55	108	739
MX6	0.55	125	785
MX7	0.55	162	830
MX8	0.55	180	872
MX9	0.55	210	920
MX10	0.55	266	988

The result shows that initial and final setting times increased as the percentage replacement of cement with Bone ash increased. The initial and final setting times of 100% OPC and Bone ash were found to be 49 and 428 minutes and 266 and 988 minutes respectively. According to BS EN 196-3:1995, the initial setting time of cement should not be less than 30mins while final setting time not more than 600mins. From the results, the initial and final setting times of OPC were in conformity with the standard while that of Bone ash was out of range. However, the longer setting time of Bone ash has some merits in practical application. It is observed that quick setting time of OPC causes cracks on the walls of buildings after rendering especially during summer periods. Hence, replacing OPC with Bone ash up to 20% results in delayed setting up to acceptable limit, thereby preventing cracks .

5.4. Compressive strength

Fig 5 shows the compressive strength of concrete with various proportions of BP with age. From the results of the experiment, it was noted that compressive strength decreased with the increasing Bone ash percentage.

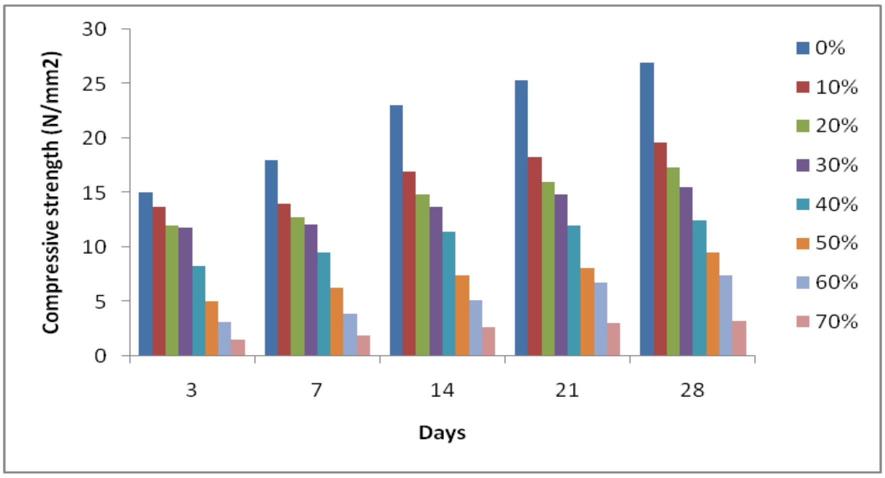

Fig. 5. Compressive strength of concrete with various proportions of Bone powder

This is in conformity with the report obtained by [Javed et al 2012, Falade et al, 2012] The decrease was as a result of reduction of C-S-H in the matrix due to reduction in the volume of OPC. The maximum compressive strength recorded was 25.95 N/mm^2 with 0% replacement at 28 days. At 10% and 20% cement replacements the compressive strengths were 20.3 N/mm^2 and 18.7N/mm^2 respectively. There were no strength recorded at 80-100% replacement. The reason is because, during curing, these concrete specimens crumbled in water two hours after they were immersed. This shows that BP is not a pozzolanic material, hence no binding properties. This also accounts for the reduction of strength of concrete blended with BP. Sensale, (2006), noted that the mechanical properties of concrete and its long-term durability were enhanced when pozzolanic materials are added because of reaction between the material present in pozzolans and free calcium hydroxide during the hydration of cement which produces extra C-S-H which is similar to C-H-S formed by Portland cement. This extra binder gives pozzolan its additional properties.

VI. CONCLUSION

Bone powder has prove to be a good concrete material when mixed in the right proportion. The optimum quantity of Bone ash for which crushing strength is maximum is 10%.The final setting time of Bone powder is very high; hence, the possibility of cracks on application is eliminated. Bone ash cannot adequately substitute cement in concrete because of its lack of binding properties, but can replaced cement with up to 10% for maximum strength. For rendering purposes, it is recommended that 20% should be used for maximum efficiency.. The strength of BP concrete can be improved if other additives that contain aluminium silicate as binding agents are added.

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