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Suitability of Crushed Cow Bone as Partial Replacement of Fine Aggregates for Concrete Production

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Abstract: *This paper presents an assessment of the strength properties of concrete containing crushed cow bone (CCB) as partial or full replacement of fine aggregates. Fine aggregate was replaced with CCB by weight up to 100 % at intervals of 10%. The properties investigated were: workability, density and the compressive strength. The slump test and the compacting factor test were used to assess the workability of the concrete sample specimens. The density and compressive strength were determined using 150 mm cube specimens. The results showed that: (i) increase in the percent replacement of sand with CCB resulted in less workable concrete, (ii) replacing sand with CCB resulted in different types of concrete, and (iii) a compacting factor test will be appropriate to assess the workability of concrete containing CCB because of the resulting dry mix and (iv) up to 20% of sand replacement with CCB will result in compressive strength that is not significantly different from the control.*

Keywords: *Compressive Strength, Concrete, Crushed cow bone, Density, Workability*

1. Introduction

Concrete is considered to be a universal construction material for many reasons. It is resistant to water when hardened. It is preferred for the ease with which structural concrete elements can be formed into a variety of shapes and sizes, and it is reasonably low cost to produce. However, in comparison to other materials used in construction industry, concrete consumes a high quantity of natural resources. Mehta and Monteiro (2006) reported that about 11.5 billion tons of resources are being used annually for the production of ordinary concrete consisting of 1.5 billion tons cement, 1 billion tons of water, and 9 billion tons of aggregates. Aggregates consist of fine aggregates and coarse aggregates. Generally aggregate less than 4.75 mm is classified as fine aggregate. The popular and most preferred materials used as fine aggregates are river sand and crushed stones. However, river sand and crushed stone are produced at great cost and at the expense of non-replaceable natural resources, and raises serious environmental concern (OSPAR, 2004). Researchers have been investigating possible alternatives. The materials that have been found as possible alternatives are: recycled glass bottles, recycled fine aggregates, polymer waste material, weathered crystalline rocks, crushed clay bricks, bottom ash, laterite, etc. (Falade et al., 2013a, Mathews et al., 2013, Dahiru and Usman, 2013, Ashiquzzaman and Hussein, 2013, Ganiron Jnr, 2013, Raju et al., 2014, and Otoko, 2014). The present study investigated the use crushed cow bone (CCB) as a partial or full replacement of fine aggregates in the production of normal concrete. Cow bones are waste from abattoirs and slaughterslabs. Annual production of cow bones in Nigeria is about 5 million tonnes, and no efficient disposal system is presently available besides burning and indiscriminate dumping (Falade et al., 2011). This is serious environmental issue that will be solved if found suitable for use in concrete production. Recent studies—Falade et al. (2013b), Ikponmwosa et al. (2013), and Falade et al. (2014)—have investigated using pulverised cow bone as a partial substitute for cement in the production of foamed aerated concrete. But foamed aerated concrete presently has limited application, while cow bones continue to be generated, and thus this application is incapable of solving the environmental and solid waste problems emanating from the slaughterslabs and abattoirs. Also Otunyo et al., (2014) tried using cow bone in lightweight concrete, which by definition is the concrete having a density not greater than 1920 kg/m^3 (ACI, 2003, Falade et al., 2011). An attempt was also made by Bhat et al (2012) to use cow bone as a partial replacement of coarse aggregates in concrete. But the aim of this work is to assess the strength potentials of concrete in which the fine aggregates component has been fully or partially replaced with CCB, without any weight limitations. The parameters investigated include workability, density and the compressive strength.

2. Materials and Methods

2.1 Materials and Mix Proportion

For this investigation, the following materials were used: cement; fine aggregate; coarse aggregates; CCB; and water. Ordinary Portland cement (OPC) of Grade 43, whose production was in accordance with BS 12 (BSI, 1996) and NIS 444-1 (NIS, 2014), was used as the main binder. For the fine aggregates, river sand excavated at the river Ogun bed at Ibafo town in the Ogun State of Nigeria were used. Particles passing through sieve size 4.75mm but retained on sieve size with 0.150 mm aperture, in accordance with BS 882:1992, were used. The coarse aggregates used for this research were crushed granite chippings quarried from Abeokuta of the Ogun State, Nigeria. The coarse aggregates ranged in size from 4.75 mm to 20 mm. The CCB was obtained from Oko-Oba abattoir of the Agege Local government, Lagos State, Nigeria. The bones had been crushed after they were dried and burnt; the muscles, flesh, tissues, intestines and fats having been separated and removed prior to drying and burning. The crushed cow bone was later allowed to undergo sieve analysis so that the fraction passing through 4.75mm but retained on the sieve size 0.150 mm, compatible with the sand to be replaced, was separated, packaged in bags and stored in cool dry place. This was subsequently investigated. Figure 1 is the sample of the crushed cow bone.

Figure 1. Sample of the Crushed Cow Bone (CCB)

The water used for in this study was potable tap water. This was well treated for domestic consumption and maintained for the purpose of this research experiment. A mix ratio of 1:2:4 (cement: fine aggregate: coarse aggregate) by weight and water/cement ratio of 0.50 were used. The fine aggregates in the mix were replaced with crushed cow bow up to 100% at intervals of 10%.

2.2 Experimental Investigations

2.2.1 Preliminary Investigations

Some preliminary investigations carried out included determination of the particle size distribution of the fine aggregates, CCB and the coarse aggregates. Also, the bulk density, specific gravity, porosity, void ratio and the 24-hr water absorption capacity were determined for the fine aggregates, CCB and the coarse aggregates. All the investigations were conducted using relevant standards.

2.2.2 Main Investigations

Workability Test

Workability properties of the concrete with CCB as partial or full replacement of fine aggregates were assessed through the slump test and the compacting factor tests. The slump test was carried out in accordance with the provisions of BS EN 12350 Part 2: (BSI, 2000). The compacting factor test was done in accordance with the provisions of BS 1881-103 (BSI, 1993). During the investigation, the fine aggregates portion of the mix was progressively replaced by CCB (by weight) up to 100% at intervals of 10%. The mix without CCB served as the control.

Density and Compressive Strength Test

The density and the compressive strength tests were carried out respectively in accordance with the provisions of BS 12350: Part 6 (BSI, 2000) and BS EN 12390-3 (BSI, 2009) using 150 x 150 x 150 mm concrete cube specimens. Tests on the cube specimens were carried out at 7, 14, 28, 56 and 90 days of moist-curing. The specimens were allowed to dry for about 2 hours after taking out of the curing tank. The compressive strength characteristics of each cube were determined on 600 kN Avery Denison Universal Testing Machine at a loading rate of 120 kN/min. Three (3) specimens for each of the curing ages were tested to failure by crushing, and the failure load was recorded. The average failure load of the three specimens was then divided by the area of the specimens to obtain the compressive strength. In order to determine the density, the weight of each of the cube specimens at the point of testing for compressive strength was taken, and later used for the computation of the density.

Specimen Preparations

Concrete samples with a mix ratio of 1:2:4 and water-cement ratio of 0.50 were prepared. The fine aggregate portion of the mix was progressively replaced with CCB up to 100% by weight at intervals of 10%. The sample without CCB (that is, 0% CCB) served as the control. The 150 x 150 x 150 mm cube specimens cast from the concrete samples were compacted using a poker vibrator. After casting, all test specimens were kept in a dry ventilated space and demoulded after 24 hours. To facilitate the demoulding process, the moulds were oiled. The specimens were then lowered into the curing tank filled with water for curing, until the required test date. A total number of 150 cube specimens were prepared and tested.

3. Results and Discussions

3.1 Preliminary Investigations

It can be observed from Table 1 that the weight-related properties of CCB, that is, the bulk density and specific gravity, showed lower values than that of the river sand. What is suggested is that a larger volume of CCB will result for a unit replacement by weight of river sand. The parameters that measure the internal structures like the void ratio, porosity and the water absorption showed higher values than the river sand. This suggests that concrete with CCB may require more water and develop lower compressive strength in relation to concrete with river sand using the same mix ratio. Also it may consume more cement than fine aggregate (ACI, 1999).

Table 1. Some Physical Properties of the Fine Aggregates and Crushed Cow Bone

Properties	CCB Aggregate	River Sand
Bulk Density (Kg/m3)	20.5	58.16
Specific Gravity (SSD)	1.67	2.63
Void Ratio	0.229	0.223
Porosity	0.186	0.182
24-hour Water Absorption (%)	3%	0.15
Aggregate Crushing Value (%)	30%	23.19
Fineness Modulus	2.44	2.88

Further, the water absorption value for CCB, which is a measure of the total pore volume accessible to water (ACI, 1999) is higher than the sand. This means that part of the mixing water may be absorbed by the CCB and thus deprived the concrete mix of the water necessary to maintain the strength-forming hydration process. Figure 1 shows the results of the particle size distribution for both the river sand and the CCB. It can be observed that the grading for both river sand and CCB are similar. Their grading can be described as uniform, and only a few sizes dominate the bulk material. This similarity is further reinforced from the values of their fineness modulli (see Table 2).

Both the river sand and the CCB with the fineness modulus respectively of 2.88 and 2.44 satisfy ASTM C 33 specifications (ASTM, 2003), for fine aggregates which require fineness modulus not to be less than 2.3 or more than 3.1.

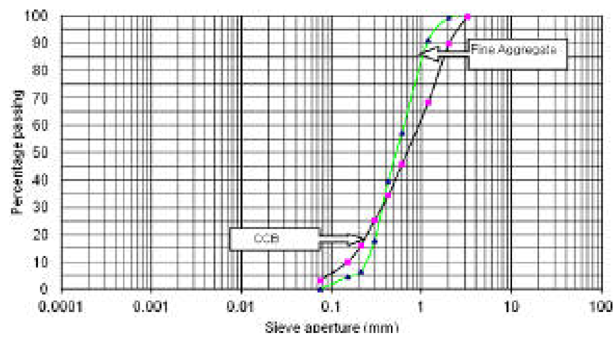

Figure 2. Particle Size Distribution Curve for the Fine Aggregate and CCB

3.2 Workability Test

The results of the slump and the compacting factor tests to assess the workability properties of the concrete mix are presented in Table 2. It can be seen that both the slump and compacting factor values of the concrete samples reduced with an increase in the percent replacement of sand with CCB. For example, the slump decreased by 80% from 25 mm at 0% to 5 mm at 100 % replacement. For compacting factor, there was a reduction of 42.53%. The reduction in slump with increase in quantity of CCB in the mix is due to the cumulative effects of its water-draining characteristics. First a lower specific gravity means more volume for a unit weight replaced (see Table 1), and the resultant larger surface areas means more water will be required to maintain the same workability otherwise there will be reduction in workability.

Moreover, CCB is more porous and had higher water absorption capacity than sand (see Table 1) indicating that part of the mixing water is lost. This results in harsh mixes with an attendant low slump.

Table 2. Workability Properties of the Concrete Specimens

% CCB iIn the Mix	Slump Type	Slump (mm)	Compacting Factor (mm)	Description of Workability
0	True	25	0.87	Very Low
10	True	17	0.82	Very Low
20	True	15	0.74	Very Low
30	True	12	0.71	Very Low
40	True	10	0.66	Very Low
50	Collapse	7	0.63	Very Low
60	Collapse	5	0.60	Very Low
70	Collapse	5	0.60	Very Low
80	Collapse	5	0.55	Very Low
90	Collapse	5	0.55	Very Low
100	Collapse	5	0.50	Very Low

True slump was observed for the specimens up to 40% sand replacement with CCB. The true slump displayed by the sample up to 40% replacement was an indication of cohesiveness of the mix and absence of segregation characteristics (Shetty, 2009). After 40% sand replacement with CCB, the sample did not tend to zero but true slump.Particularly at 70% and above replacement value of sand with CCB, the mixes became progressively vicious so that it was becoming difficult to achieve adequate compaction without much effort. The fact that the CCB is organic may have accounted for this at higher replacement values. Generally, concrete with CCB, irrespective of the level of replacement with sand, resulted in a dry mix and low workability.

3.3 Density

The results of density measurements at the chosen curing ages and for all the replacement of fine aggregates with crushed cow bone are presented in Table 3 with the standard deviation in parenthesis.

Table 3: Density development in kg/m^3 with Curing Ages at all percentage of fine aggregate replacement with

% CCB in Mix	Curing Age (Days)				
	7	14	28	60	90
0	2364.44 ± 9.78	2494.82 ± 10.11	2592.59 ± 10.22	2640.00 ± 10.11	2672.59 ± 10.14
10	2109.63 ± 9.01	2157.04 ± 10.04	2219.26 ± 10.25	2284.44 ± 10.22	2361.48 ± 10.22
20	1774.82 ± 10.20	1819.26 ± 10.23	1845.93 ± 10.27	1928.89 ± 9.87	2050.37 ± 10.17
30	1736.96 ± 10.10	1771.85 ± 9.56	1831.11 ± 10.00	1869.63 ± 9.99	1961.48 ± 10.56
40	1682.96 ± 9.34	1706.67 ± 1056	1745.19 ± 9.89	1810.37 ± 10.21	1860.74 ± 9.90
50	1605.93 ± 9.78	1668.15 ± 9.98	1694.82 ± 9.78	1777.78 ± 10.11	1828.15 ± 9.97
60	1600.01 ± 9.98	1634.23 ± 9.67	1678.99 ± 9.67	1710.12 ± 10.21	1757.47 ± 9.91
70	1578.78 ± 10.23	1609.21 ± 9.78	1634.56 ± 9.89	1678.23 ± 10.01	1699.86 ± 10.01
80	1570.01 ± 10.32	1598.56 ± 10.23	1610.23 ± 10. 23	1645.23 ± 10.05	1667.56 ± 10.16
90	1566.23 ± 10.56	1571.67 ± 10.21	1588.45 ± 10.19	1610.10 ± 9.78	1625.78 ± 10.17
100	1545.56 ± 9.66	1560.32 ± 10.01	1570.98 ± 10.12	1589.10 ± 9.99	1602.56 ± 10.14

3.4 Crushed Cow Bone (CCB)

It can be observed from Table 3 that densities of the specimens increased with curing age at all the replacement levels of sand with CCB. For example, at 10% replacement of fine aggregates with CCB, an increase of 11.94% between the densities of 7- and 90-day curing was recorded. This pattern was observed for all the curing ages. This increase in the density can be explained as the result of the densification effect that the product hydration has on the internal matrix of the concrete specimens, with curing. It can also be observed that the densities of the specimens decreased with increase in the percent replacement of fine aggregates with crushed cow bone. From 0 to 100% replacement, the decrease was 34.63%, 37.46%, 39.41%, 39.81% and 40.04%, respectively at 7, 14, 28, 60, and 60 days curing. This represents an average decrease of 3.46%, 3.75%, 3.94%, 3.98% and 4.04% per each level of replacement.

This decrease can be expected from the results obtained for weight-related properties of CCB and the river sand used as the fine aggregates. As shown in Table 1, CCB has lower values of bulk density and specific gravity when compared with the river sand. This means that more volume will result for a unit weight replacement of sand with CCB. It then follows from density relations, (that is density which equals mass divided by the volume), that the increase in volume with constant mass will result in lower density. In concrete work, concrete is classified into three (3) categories according to its density.

According to Falade et al. (2011), concrete having densities in the range of 300 – 1,950 kg/m3 are classified as lightweight concrete; when the densities are in the range of 2,200 – 2,400 kg/m3, they are classified as normal weight concrete; and concrete with densities greater than 2,500 kg/m3 are classified as heavyweight concrete. As shown in Table 1, replacement of sand by CCB up to 10% resulted in the densities in the range of normal weight concrete. From 20% and above, the resulting concrete specimens had densities in the range for lightweight concrete. Thus, it can thus be concluded that differential densities range or different type of concrete can result from the usage of CCB as partial replacement of sand, depending on the CCB replacement values.

3.5 Compressive Strength

The results of the compressive strength development for all the percent replacements of sand with CCB are presented in Figures 3 and 4, and Table 4. It can be observed from Figure 3 that the compressive strength of the mix decreased with an increase in crushed cow bone. At 28-day curing, the compressive strength decreased from 24,62 N/mm2 for the control specimens to 12.45 N/mm2 at 100 % replacement of sand with CCB (see Table 4). This represents a decrease of 49.43% or an average of 4.94 decreases, for each level of replacement. This pattern was observed at other curing ages.

The results as presented in Table 1 shed some light on this pattern of behaviour. It was found that the weight-related properties of CCB are lower than that of the sand used for this investigation. The immediate effect of this is that for unit weight of sand replaced, more volume than replaced resulted. This inevitably lead to reduced density. In concrete, low density always results in low compressive strength (Sin, 2007). Also, as from Table 1, CCB was found to be more porous than the sand used.

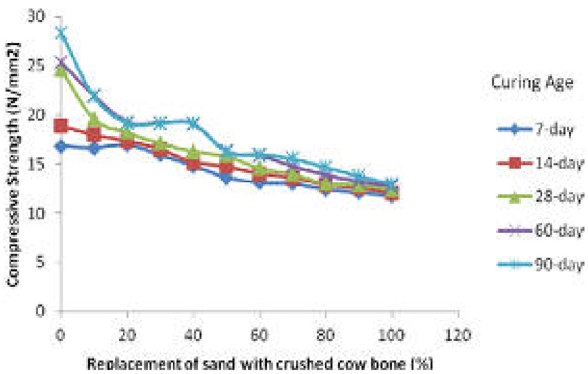

Figure 3. Effect of replacement of sand with Cow Bone on the Compressive Strength

Moreover, this CCB higher porosity when combined with higher water absorption led to the total volume of pores in CCB being more than that of the sand. Neville (2003) reported a direct relationship between the total volume and the compressive strength. With the same water/ cement ratio, the effective water that is available for the strength-forming hydration process in the sample with more CCB is reduced (Neville, 2003). Insufficient water will slow down the formation of the C-S-H gel known to be responsible for the strength development in concrete, and will thus result in reduced strength as the quantity of the CCB in the mix increases.

It can however be observed from Figure 4 that the compressive strength increased with curing age with all the replacements of sand with CCB. This is due to the fact that the longer a concrete is allowed to cure, the more the products of hydration that will be generated. Table 4 shows the statistical analysis of the results of compressive strengths for the concrete specimens at all replacement values of sand with CCB, for curing ages of 28, 60 and 90 days. The figures following "±" represent the standard deviation of the data samples.

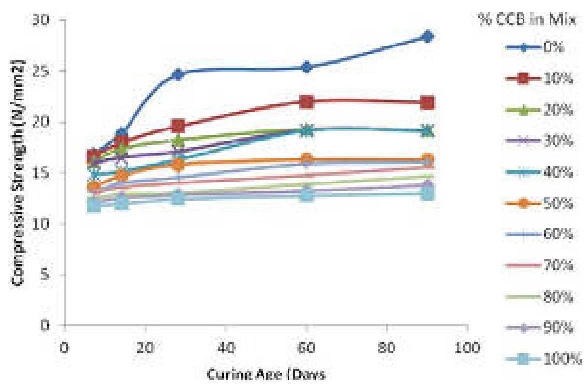

Figure 4. Effect of curing age on the Compressive strength of the Concrete Specimens

Table 4. Compressive strength development in N/mm2 of the concrete Specimens

% CCB in Mix	Curing Age (Days)		
	28	60	90
0	24.62 ± 1.23	25.38 ± 2.23	28.37 ± 2.11
10	22.58 ±1.30 (2.721)	23.98 ± 2.45 (0.989)	25.88 ± 2.14 (2.013)
20	20.22 ± 2. 95 (2.588)	22.28 ± 2.99 (1.794)	24.19 ± 2.99 (2.419)
30	18.11 ± 2.37 (4.751)	20.20 ± 2.78 (3.223)	23.68 ± 2.68 (3.028)
40	16.28 ± 2.34 (6.177)	**19.11** ± 2.56 (4.237)	**21.12** ± 2.10 (6.239)
50	15.83 ± 2.85 (5.337)	16.29 ± 2.78 (5.657)	19.28 ± 2.01 (7.823)
60	14.56 ± 2.71 (6.765)	15.89 ± 2.23 (7.362)	16.01 ± 2.11 (10.131)
70	13.99 ± 2.90 (6.342)	14.78 ± 2.01 (9.122)	15.56 ± 1.99 (11.139)
80	13.01 ± 2.93 (6.851)	13.89 ± 2.23 (8.914)	14.67 ± 1.89 (12.534)
90	12.87 ± 2.83 (7.182)	13.23 ± 2.11 (9.960)	13.78 ± 1.89 (12.349)
100	12.45 ± 2.95 (7.138)	12.78 ± 2.39 (9.117)	12.99 ± 178 (14.947)

As shown in Table 4, the figures in the parenthesis are the computed t-values at 10% confidence interval using a two-tailed test to determine at what percent of sand replacement with CCB is the difference between the compressive strength of the control specimens and specimens with CCB are to be considered significant. At 10% confidence interval, the statistical table t-value is ±2.920 (Kothari and Garg, 2014). Hence, the computed t values for sand replacement with CCB up to 20% for the curing ages of 28 days and above were below the statistical t value, and thus fall within the acceptance region of the normal distribution curve. What this means is that the compressive strengths of the concrete specimens up to 20% sand replacement with CCB are comparable with the compressive strength of the control specimens.

4. Conclusions and Recommendations

Based on the results of this investigation, the following conclusion can be made:

1) There was a reduction in concrete workability with an increase in the percent replacement of sand with CCB. The use of CCB also resulted in harsh mixes with attendant low slump.
2) The density of the concrete specimens reduced as the percent increase in sand replacement with CCB increased.
3) Using CCB as partial replacement of sand can result in different types of concrete based on the density attainable.
4) The compressive strength of the specimens decreased with an increase in the percent replacement of sand with crushed cow bone.
5) The compressive strength of the specimens increased with curing ages.
6) Replacement of sand with CCB up to 20% by weight will result in compressive strength development that is not significantly different from those of the control samples.
7) The use of CCB in the replacement of cement up to 20% by weigh in the production of concrete will have a positive impact on the environment, and encourage the use of bio-concrete in structural engineering.

This paper describes an investigation into the potential use of crushed cow bone as a partial replacement of fine aggregate in concrete, with particular focus the compressive strength and related properties. Evidence shows that compressive strength is the sole measure of concrete quality (Wright and McGregor, 2009). However, durability properties are also important if its usage is to gain wide acceptance. This should be investigated. Usage of CCB as partial replacement of fine aggregates in concrete will help in no small measure to bring about efficient solid waste management systems. This in turn results in a clean environment and promotes sustainable construction by reducing the use of non-renewable natural resources.

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