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STRENGTH CHARACTERISTICS OF CONCRETE HAVING CRUSHED BONE AS PARTIAL REPLACEMENT OF FINE AGGREGATES AT DIFFERENT WATER~CEMENT RATIOS

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Abstract: This paper reports the results of investigation to find the effects of water cement ratio on some properties of concrete containing crushed cow bone (CCB) as partial replacement of fine sand. Concrete samples containing 20% CCB as replacement of sand were used. The properties investigated are: workability, density and the compressive strength. Slump test and compacting factor test were used to determine the workability while 150 x 150 x 150 mm cubes were used for density and the compressive strength. The water~cement ratios were 0.4, 0.5 and 0.6. The density and compressive strength specimens were tested at 7, 14, 28, 60, and 90 and 120 days of moist~curing. The results showed that: (i) workability, measured in terms of slump loss, increased with water~cement ratios, (ii) compacting factor test may be more appropriate as a tool to assess the workability characteristics of the specimens due to the lower value of the factor, (iii) there are possibilities of producing concretes whose densities fall into more than one density ranges as water~cement ratio is increased, (iv) compressive strengths of the specimens decreased with water~cement ratio.
Keywords: Concrete, Fine Aggregate, Crushed Cow Bone, Water~Cement Ratio, Compressive Strength

INTRODUCTION

Concrete has become the most important man~made construction material in the world produced with four basic components of cement, fine aggregates, coarse aggregates and water. Further it is the single most widely used material in the world (Crow, 2008), whose consumption is surpassed only by water (Mehta and Merman 2009, GEAS, 2010, Ferrari et al., 2012 and Arezoumandi, et al., 2014). One of the many reasons for its prominence is the flexibility it allows to vary part of its composition either partially or fully for a concrete that is strong and durable. In some instances cement has either been partially or fully replaced by some materials like slag, silica fume, rice husk ash, etc. In other instances, the aggregates portion (fine or coarse) have been replaced by any of the mentioned materials to produce concrete with acceptable structural characteristics. Aggregates can be described as granular materials such as sand, gravel, crushed stone, and blast furnace slag, etc., embedded in cement~water paste to form concrete. Aggregates usually occupy approximately 60 to 75% of the volume of concrete or about 70 – 85% by weight. (ACI, 1999). As such, the properties of aggregates greatly affect properties of both fresh and hardened concrete. Aggregates reduce the dimensional instability of the concrete due to the drying shrinkage and reduce the cost of making concrete because of its cheapness (Duggal, 2008). Unlike cement, which is factory~made, and which is produced under controlled and standard conditions resulting in uniform properties; aggregates properties vary depend on many factors like size, shape, gradations, unit weight, etc. Some of these properties are transferred into the concrete. The properties of aggregates affect the workability of concrete in plastic state. In the hardened state of concrete properties like strength, thermal conductivity, durability, abrasiveness, and density are influenced by the properties of aggregates. While the coarse aggregate gives the bulk to the concrete, the fine aggregate acts as the filler in form of mortar. The materials mostly used for fine aggregates are river sand and crushed stones. In other to obtain river sand, difficult dredging and transportation over long distances are involved. Producing crushed stones to produced fine aggregates is also costly. These, added to the need for the conservation of natural resources made it incumbent on researchers to find alternatives to fine aggregates in concrete production. Materials that have been found to be suitable alternatives to fine aggregates, usually from agricultural and industrial wastes are: groundnut shell (Sada et al., 2013), iron ore tailings (Kumar et al., 2014, Falade et al., 2013), manufactured fine aggregates (Goncalves et al., 2007), rice husk (Obilade, 2014), stone powder (Mahzuz et al., 2011), waste glass (Malik et al., 2013). All these have been used by these researchers either for normal weight concrete or lightweight concrete in their investigations. Another waste that is yet to be investigated for its suitability as fine aggregates replacement in concrete is the crushed cow bone. In Nigeria, the annual production of cow bone is estimated to be about 5 million tons, which are not properly disposed of, thereby constituting environmental problems (Falade et al., 2011). Using the cow bone as substitute for fine aggregate, if found suitable will help in cleaning the environment and convert waste to wealth. In concrete works, assuming full compaction, and at a given age and normal temperature, the strength of concrete can be taken to be inversely proportional to the water/cement ratio (Neville and Brooks, 2008). But it is to be noted that at the time this Law, attributed to Abram, was discovered, the materials used for fine aggregates in the production of concrete were either sand or crushed stone. Substituting fine aggregates with wastes materials other than sand or crushed stone was not in practice. What is not known is whether the Law could still hold if fine aggregates portion of concrete mix were substituted with any wastes – industrial and agricultural; in this case, crushed cow bone. Thus the aim of this work is to investigate the effect of water-cement ratio on strength properties of concrete with crushed cow bone as partial substitute of fine aggregates. Although Otunyo et al. (2014) had earlier attempted to investigate the possibility of using cow bone as substitute for fine aggregates. Effect of water-cement ratio was not one of the parameters they considered for investigation as in the present work. Also the works of Falade et al (2013a,b) and Falade et al (2014) on cow bones were in relation to foamed aerated concrete in which cement was replaced with pulverized cow bone. In addition, the investigations carried out by Vu et al., 2009, Shamsoo et al., 2012 and Reddy and Rao, 2014 in relation to the effect of water-cement ratios on concrete, were not on CCB but were respectively on extreme loading concrete, nano-silica concrete, and high strength self-compacting concrete. The strength properties investigated in this work, using water cement ratios of 0.4, 0.5, and 0.6 and at 20% replacement of fine aggregates with crushed cow bone (CCB) are: workability, density and the compressive strength.

MATERIALS AND METHODS

» Materials

The materials used for this investigation are: Portland cement, fine aggregates, coarse aggregates, crushed cow bone and water.

- **Cement:** The cement used was Ordinary Portland Cement which conformed to BS 12 (1996) and NIS 444-1 (2014) was used for this investigation.
- **Coarse Aggregates:** Crushed granite of maximum nominal size 20mm was used to produce the concrete used for this work.
- **Fine Aggregates:** River sand obtained in Ibadan was used as fine aggregates during the execution of this project.
- **Crushed Cow Bone (CCB):** the cow bones were obtained from the slaughter slab in Ibadan. 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 4.75 mm 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, which was subsequently used for this investigation.
- **Water:** The water used in mixing is clean potable water, without any visible impurities.

» Mix Proportions & Specimens Preparation

This investigation is to determine the effects of water-cement ratios on concrete containing crushed cow bone (CCB) as partial replacement of fine aggregates. But preliminary investigation on strength developments of concrete 150 mm cube specimens containing CCB as partial replacement of fine aggregates from 0% up to 100% at interval of 10% were first carried out using the mix in Table 1 for each batch of concrete produced. The concrete mix without CCB served as the control. Strengths were measured at 7, 14, 28, 60, 90, and 120 days of moist curing.

In other to investigate the effects of water-cement ratios on the concrete samples containing the pre-determined content of CCB, water-cement ratios of 0.4, 0.5 and 0.6 were used. The mixing of all the concrete batches was done through concrete mixer from which 150 x 150 x 150 mm cube specimens were cast. The cube moulds were greased to make demoulding easier. Compaction was done using poker vibrator, after which the specimens were kept in a dry ventilated space and demoulded after 24hours. The specimens were then moist-cured in curing tank, filled with water until the day of testing. Prior to casting of the cube specimens, slump tests were carried out on the concrete specimens. A total number of 594 cube specimens were prepared and tested.

Table 1: Concrete mix for Preliminary Strength Development Potential

% CCB in Mix	Mix	W/C Ratio	Cement (kg)	Sand (kg)	CCB (kg)	Granite (kg)	Water (kg)
0	1:2:4	0.5	21	41.66	0.00	83.31	8.4
10	1:2:4	0.5	21	37.49	4.17	83.31	8.4
20	1:2:4	0.5	21	33.33	8.33	83.31	8.4
30	1:2:4	0.5	21	29.16	12.50	83.31	8.4
40	1:2:4	0.5	21	25.00	16.66	83.31	8.4
50	1:2:4	0.5	21	20.83	20.83	83.31	8.4
60	1:2:4	0.5	21	16.66	25.00	83.31	8.4
70	1:2:4	0.5	21	12.50	29.16	83.31	8.4
80	1:2:4	0.5	21	8.33	33.33	83.31	8.4
90	1:2:4	0.5	21	4.17	37.49	83.31	8.4
100	1:2:4	0.5	21	0.00	41.66	83.31	8.4

EXPERIMENTATION

» Characterization of the Aggregates

Preliminary investigations were carried out on the aggregates to determine their properties for the purpose of characterization. These properties are: the bulk density, the specific gravity, water absorption capacity, and the mechanical analysis of the aggregates through sieve analysis.

» Investigation of Strength development of Concrete sample with CCB

The strength development of concrete samples containing crushed cow bone (CCB) as partial replacement of sand was investigated to determine the % replacement at which the strength developed was not significantly different from the concrete samples without CCB at moist-curing period of 7,14, 28, 60, 90, and 120. The mix ratio used was 1:2:4 with water cement ratio of 0.4. The sand in the concrete samples was replaced with CCB from 0 to 100 % at interval of 10%. The concrete samples without CCB served as the control.

» Investigation of Effect of Water-cement Ratios Concrete Specimens Properties

The concrete properties tested, using samples containing the CCB content for the development of compressive strength that is comparable with the control samples, were: workability, density and the compressive strength

= The Slump Test

Two methods were used to assess the workability characteristic of the concrete specimens. These are the slump test and the compacting factor test. While the slump test was carried out in accordance with the provisions of BS EN 12350 Part 2: (2000), the Compacting factor test was done in accordance with the provision of BS 1881-103 (1993), also taking into consideration inputs from Bartos et al. (2002).

= Density and Compressive Strength Tests

Compressive strengths were of concrete specimens measured at 7, 14, 28, 60, 90 and 120 days of curing in accordance with BS EN 12390-3 (2009) using a 1,500kN ELE International compression testing machine (Figure 1).

Figure 1: ELE Compression Testing Machine

The specimens used were 150 x 150 x 150 mm cubes. The average failure load of the three specimens was then divided by the area of the specimens to obtain the compressive strength. It is to be noted here that the weight of each cube was measured on a digitally displayed ELE International weighing machine before the compressive strength testing process to determine the density of the concrete, which was done in accordance to BS 12350: Part 6 (2009).

RESULTS AND DISCUSSIONS

» Preliminary Investigation

The results of the preliminary investigation on some physical properties of the fine aggregates used, conducted to characterize the aggregates are presented in Table 2. From Table 2, it can be observed that the values of bulk density and the specific gravity, the properties that reflect the weight features of a material, for CCB were lower than that of the fine sand.

Table 2: Physical Properties of Fine Aggregates

Properties	CCB	River Sand
Maximum Aggregate Size (mm)	4.75	4.75
Bulk Density (Kg/m3)	20.5	58.16
Specific Gravity (SSD)	1.67	2.63
Aggregate Crushing Value (%)	30%	23.19
24-hour Water Absorption (%)	3%	0.15
Fineness Modulus	2.44	2.88

The practical implication of this is that a larger volume of CCB will result for every unit weight of sand replaced, thereby increasing the water demand because of increased surface area. Also, the water absorption capacity of the CCB can be seen to be higher than that of the sand. Thus for the same water-cement ratio, a harsh mix may result from replacing sand with CCB. This may affect the workability. In the same vein, a higher aggregate crushing value obtained for CCB is an indication that CCB may not develop adequate crushing resistance in concrete requiring it, for example, bridge deck and runway. Using the sieve analysis results (Figure 2), the fineness modulus, which is the sum of the total percentages retained on each of a specified series of sieves, divided by 100 was computed to be 2.44 and 2.88 respectively for CCB and sand.

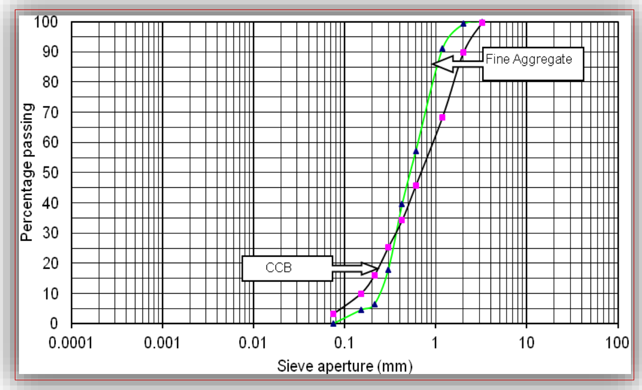

Figure 2: Particle Size Distribution of River Sand and CCB

These values met the requirements of ASTM C 33 specifications for fine aggregates which require fineness modulus not to be less than 2.3 or more than 3.1. Also from Figure 2, it can be observed that the grading for both river sand and CCB is similar. Both can be described as uniform in grading, in which only a few sizes dominate the bulk material. This similarity is further reinforced from the closeness of values of their fineness moduli (Table 2).

» Strength Development of Concrete Specimens with CCB

The results of preliminary investigation to determine the strength development potential of concrete samples containing CCB as partial replacement of sand are shown in Table 3. In Table 3, the figures after the "±" represent the standard deviation and the numbers in the parenthesis represent the statistical t-values to determine how significant is the difference in the compressive strength between the samples with CCB and the control samples. Using a confidence interval of 10%, the statistical table t-value is ±2.920 (Kothari and Garg, 2014). From the Table 3, up to 20% sand replacement with CCB have lower calculated t-values. This suggest that there is no significant difference between the compressive strength of the samples containing up to 20% CCB as a replacement of fine aggregates and the control samples.

Table 3: Strength Development of Concrete Samples with CCB as Replacement of Sand

% 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)

Concrete samples containing 20% sand replacement with CCB were produced to evaluate the effects of water-cement ratios on some properties of concrete containing CCB.

» Workability

The results of the workability characteristics of the concrete samples containing CCB as partial replacement of sand with different water-cement ratios are presented Figure 3.

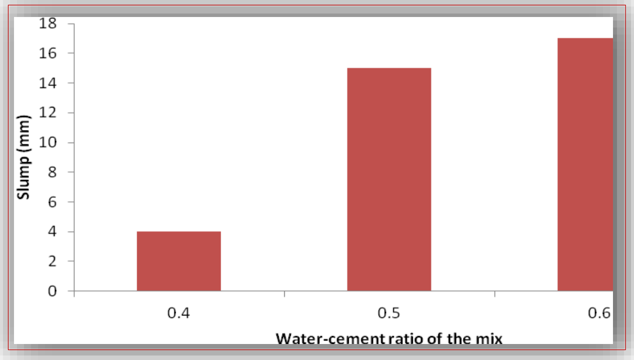

Figure 3: Effect of Water-cement ratio on the slump value of the Concrete Samples

It is obvious in Figure 3 that the workability of the concrete specimens measured in term of slump increased with water-cement ratio. The increase was however at a decreasing rate. For example, between the water-cement ratios of 0.4 and 0.5, the increase was 200%. But between 0.5 and 0.6, the increase was just 13.33%. In addition to seeming improvement in workability with water-cement ratios, the specimens also exhibited true slump. This means that the concrete is cohesive and showed no evidence of segregation within the ranges of water-cement ratios used for this investigation. The results of the compacting factor test which measures the workability by the way of degree of compaction is presented in Table 4 along with the slump values. Despite increasing slump values with water-cement ratios, the values still fall within the range of concrete with very low workability and this makes the compacting factor test the more appropriate (Neville, 2003).

Table 4: The Slump and Compacting Factor (CF) Values for the Specimens

W/C Ratio	Slump (mm)	CF
0.4	5	0.75
0.5	15	0.76
0.6	17	0.77

Though the lower values of compacting factor, increased with water-cement ratios, as can be observed in Table 4, they nonetheless fell within the ranges (0.75 to 0.80) for which compacting factor is suggested as a more appropriate means for assessing workability (Shetty, 2009).

» Density

The results of the density at all the water-cement ratios are presented in Figure 4 and Table 5.

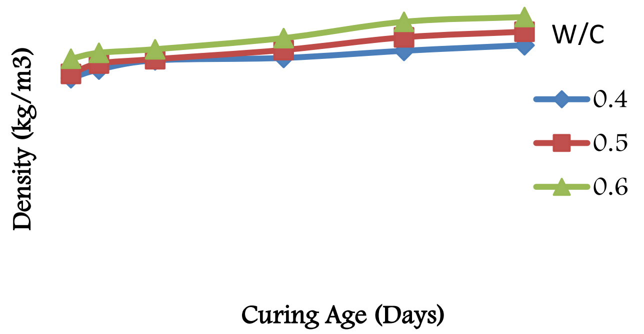

Figure 4: Effects of Water-cement Ratios on the Density of the Specimens

From Figure 4, density of the specimens increased with water-cement ratios. This trend can be explained by the fact that water has been known to aid a more closely-packed internal arrangement of granular materials (Terzaghi et al. 1996). The CCB constituent of the mix has the tendency to absorb water, result in loose internal structure and produce dry mix because the cumulative effect of larger surface area and high water absorption than the sand it replaced (Table 2). Thus the effect of higher water content is to make more water available to the mix, thereby aiding efficient internal arrangement of grains of sand and CCB leading to the densification of the matrix.

From the knowledge that concrete having densities in the range of 300 – 1950 kg/m³ are classified lightweight concrete; those in the range of 2200 – 2400 kg/m³ as normal weight concrete, and concrete with densities greater than 2500 kg/m3 are regarded as heavyweight concrete (Falade et al., 2011), the following can be observed from Table 5.

Table 5: Effect of Water-Cement ratio on the Density of the Concrete Samples

Curing Age (days)	0.4	0.5	0.6
7	1629.63 ± 7.86	1662.22 ± 7.21	1774.82 ± 7.89
14	1694.05 ± 7.01	1739.26 ± 7.45	1819.26 ± 7.99
28	1762.85 ± 8.10	1771.85 ± 7.89	1845.93 ± 8.10
60	1780.74 ± 6.99	1840.00 ± 8.21	1928.89 ± 8.11
90	1834.07 ± 6.78	1934.80 ± 8.00	2050.37 ± 8.15
120	1875.56 ± 7.78	1976.30 ± 8.02	2085.93 ± 8.22

All concrete with water-cement ratios of 0.4, at all the curing ages considered, are lightweight concrete. At higher curing days however, specimens have water-cement ratios of 0.5 and 0.6 crossed to normal weight concrete. Thus from this results, there seem to be possibilities for differential densities of concrete specimens into more than one classification as the water-cement ratio is increased.

» Compressive Strength

The results of the effects of water-cement ratios on the strength development of concrete mix containing CCB as partial replacement of sand are shown in Figure 5.

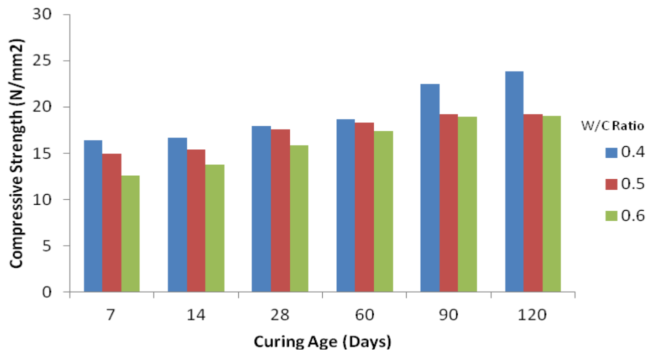

Figure 5: Effect of water-cement ratio on the Compressive Strength of the Specimens

From Figure 5, it can be observed that the compressive strengths of all the specimens decreased with increasing water-cement ratio at all the curing ages considered. Although one may have expected a situation where the compressive strengths would be higher with increasing water-cement ratio, considering that the density increased with water-cement ratio for this particular mix (Figure 4). It is apparent then that unlike in the density where closeness and efficient arrangement of the grains of the particles are the governing factors, compressive strength development is aggregation of strength from three sources, namely (i) strength of the mortar, (ii) strength of the aggregates particles, and (iii) the bond between the mortar and the aggregates (Neville, 2003). Neville (2003) has shown that at higher water-cement ratios, there is the development of interconnected system of randomly distributed capillary pores throughout the matrix of the mortar. He further stated that these capillary pores made the mortar porous and reduces its capacity to develop higher strength. Furthermore, Shetty (2009) concluded that at higher water-cement ratios, the capacity of the mortar to develop cohesion and internal friction is weakened.

CONCLUSIONS

From the results of this investigation, the authors conclude that:

i) Workability of the concrete samples, measured in terms of slump loss, increased with water-cement ratios.
ii) The use of CCB resulted in a dry mix, as such, compacting factor test may be more appropriate as a tool to assess the workability characteristics of the specimens due to the lower value of the factor,
iii) The use of CCB in concrete will results in concrete with densities falling into more than one density ranges – in terms of classification - as water-cement ratio is increased
iv) The compressive strengths of the concrete specimens with CCB decreased with water-cement ratio.
v) Water-cement ratios seem to be the only determinant factor that governs the strength development of concrete samples containing CCB.

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