# Utilizing Cow Bone Ash (CBA) as Partial Replacement for Cement in Highway Rigid Pavement Construction

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***Abstract***

*Slump, compressive strength and flexural strength tests were conducted on concrete to investigate the possible use of Cow Bone Ash (CBA) as partial replacement for cement in rigid pavement construction. Ordinary Portland cement (OPC) was replaced with CBA in the percentages of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 40% and 50%. The chemical analysis conducted on the cow bone ash, showed that the summation of $SiO_2$, $Al_2O_3$ and $Fe_2O_3$ was less than 70%, thereby making the CBA used non-pozzolanic. However, the high proportion of CaO in its composition makes it an effective additive for concrete construction. A total of 108 cubes and 54 beams were produced using a mix proportion of 1: 0.8: 2.4 with water-cement ratio of 0.35. The cube and beam samples were water-cured and tested to determine their compressive strength at 7, 28, 56 and 90 days; also, their flexural strength at 7 and 28 days were determined. The results obtained showed that workability increased as percentage replacement of cement with CBA increased. The results of the compressive and flexural strength revealed that concrete containing 20% Cow Bone Ash (replacement) content was satisfactorily adequate for rigid pavement construction. There was early gain in strength and gradual increment in strength with time and this was statistically confirmed using ANOVA. The comparative cost analysis showed a cost reduction of about 9.65% when compared to conventional concrete which could result to a potential annual saving of over One Hundred Billion Naira.*

**Keywords —** *Cow Bone Ash, Pozzolans, Compressive Strength, Flexural Strength, Rigid Pavement Construction.*

## I. INTRODUCTION

The cost of construction continues to rise in every nation of the world [1], including Nigeria, where the construction cost is acknowledged to be the highest [2]. The major construction material is concrete, with cement as the main binder. Concrete is one of the most commonly used material in building and rigid pavement construction because of its versatility, durability and compressive strength. In Nigeria, analysis shows that the cost of cement represents a substantial portion of the total construction cost with the annual consumption of cement put at 19.5million tonnes [3]. Nigeria requires N1.092 Trillion at the current rate of 2,800 naira to meet her cement needs alone for concrete production. This is about 14.96% of her annual budget for the 2017 fiscal year, making cost of cement the major contributor to high cost of construction; with the production of cement increasing annually by about 3% [4].

The production of one tonne of cement liberates about one tonne of $CO_2$ to the atmosphere, as the result of de-carbonation of the limestone in the kiln during manufacture of cement and the combustion of fossil fuel [4]. The contribution of Portland cement production worldwide to the greenhouse gas emission is estimated to be about 1.35 billion tonne annually or about 7% of the total greenhouse gas emissions to the earth's atmosphere [5]. This effect of cement production on the environment has made the research for alternative materials to cement popular in the last decades. Various works have 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.

One of such waste, which the production runs to millions of tonnes in Nigeria, is cow bones from which cow bone ash is obtained [6]. The present disposal system of burning in open sites and indiscriminate dumping on any site does not augur well for the health of human beings and it also constitutes environmental hazard.

Application of Cow Bone Ash (CBA) disposal for road construction, such as, rigid pavement construction, is significant and this serves various benefits to the environment. This application 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, CBA production requires less energy demand compared with Portland cement production and saves the needed foreign exchange spent on importation of cement and its components.

The over-dependence on conventional concrete materials raises sustainability concerns, not to mention the ever-increasing cost of production and construction due to these conventional materials (e.g. cement).

## II. MATERIALS AND METHODS

### A. Materials

***1) Ordinary Portland Cement*:** The Dangote 3X Portland cement was used as a binder. This was sourced locally.

***2) Cow Bone Ash:*** Cow Bone Ash (CBA) was obtained from burning cow bones. The cow bones, after careful removal of adhering flesh and tissues, were cleaned, sun-dried, before burning. They were then ground, with hammer mill, to fine powder at Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos state, Nigeria and passed through B. S sieve of 75 microns. The cow bones used for this work was obtained from a local abattoir in Oko-oba, Agege, Lagos State.

***3) Fine Aggregate (River Sand):*** The sand used passed the 4.75mm sieve and was determined to be within the specified requirement for fine aggregates in accordance with ASTM C136. The percentage passing the 600µm sieve indicates that it falls within zone II.

***4) Coarse Aggregate (Granite):*** Coarse aggregate is the crushed stone used for making concrete. The commercial stone is quarried, crushed and graded. Much of the crushed stone used is granite, limestone and trap rock. For this study, 20 mm maximum nominal size granite aggregate was used.

### B. Methods

***1) Chemical Analysis of Cow Bone Ash (CBA):*** The chemical analysis of the Cow Bone Ash (CBA) was carried out at the Lafarge Cement Factory Laboratory, at Ewekoro, Ogun State, Nigeria. X- Ray Fluorescence Spectrometry (XRF Fused Bead Test) was used to determine the chemical composition. The result of the chemical analysis, in comparison to Ordinary Portland Cement (OPC), is presented in Table 1.

**Table 1: Chemical Composition Of Ordinary Portland Cement (Opc) And Cow Bone Ash (Cba)**

| Oxides | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | $SO_3$ | CuO | $P_2O_5$ | MnO | LOI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **OPC (%)** | 21.00 | 5.30 | 3.30 | 65.60 | 1.10 | - | - | 2.70 | - | - | - | 0.90 |
| **CBA (%)** | 2.28 | 2.97 | 0.43 | 76.31 | 1.21 | 0.37 | 0.24 | Traces | 0.28 | 5.57 | 0.086 | 0.37 |

***2) Laboratory Tests on Soils:*** The laboratory tests conducted are presented in Table 2.

**Table 2: Laboratory Tests Conducted**

| Sample ID | Materials / Combination | Laboratory Tests |
|---|---|---|
| | Cement, Sand, CBA and Coarse Aggregate | • Specific Gravity |
| $S_0$ | 0% CBA + 100% Cement (Control Sample) | • Workability (Slump test)<br>• Compressive Strength, cube tests (7days, 28days, 56 days and 90days)<br>• Flexural Strength, cylindrical beam tests (7days and 28days) |
| $S_5$ | 5% CBA + 95% Cement | |
| $S_{10}$ | 10% CBA + 90% Cement | |
| $S_{15}$ | 15% CBA + 85% Cement | |
| $S_{20}$ | 20% CBA +80% Cement | |
| $S_{25}$ | 25% CBA + 75% Cement | |
| $S_{30}$ | 30% CBA + 70% Cement | |
| $S_{40}$ | 40% CBA + 60% Cement | |
| $S_{50}$ | 50% CBA + 50% Cement | |

***3) Mix Proportion*:** In this research, 108 cubes and 54 beams were cast. Concrete was prepared by replacing OPC with CBA in the proportions of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 40% and 50%. A Grade 40 concrete and mix ratio of 1:0.8:2.4 by weight was adopted with water/cement ratio of 0.35. The mix proportions are summarized in Table 3.

**Table 3: Mix Proportions Of M40 Grade With W/C Ratio Of 0.35**

| Mix ID | Water ($Kg/m^3$) | Cement ($Kg/m^3$) | CBA ($Kg/m^3$) | Sand ($Kg/m^3$) | Coarse Aggregate ($Kg/m^3$) |
|---|---|---|---|---|---|
| $S_0$ | 187.97 | 537.06 | 0 | 429.65 | 1288.94 |
| $S_5$ | 187.97 | 510.21 | 26.85 | 429.65 | 1288.94 |
| $S_{10}$ | 187.97 | 483.35 | 53.71 | 429.65 | 1288.94 |
| $S_{15}$ | 187.97 | 456.50 | 80.56 | 429.65 | 1288.94 |
| $S_{20}$ | 187.97 | 429.65 | 107.41 | 429.65 | 1288.94 |
| $S_{25}$ | 187.97 | 402.79 | 134.27 | 429.65 | 1288.94 |
| $S_{30}$ | 187.97 | 375.94 | 161.12 | 429.65 | 1288.94 |
| $S_{40}$ | 187.97 | 322.24 | 214.82 | 429.65 | 1288.94 |
| $S_{50}$ | 187.97 | 268.53 | 268.53 | 429.65 | 1288.94 |

## III. RESULTS AND DISCUSSION

### A. *Effect of Cow Bone Ash (CBA) on Workability (Slump Test)*

From the results obtained, as shown in Fig. 1, workability increased with incremental addition of Cow Bone Ash (CBA). It is observed that samples containing 5 to 20% of CBA have medium degree of workability and beyond that, the degree of workability became high. This steady increment in the workability of the fresh concrete can be attributed to the higher fineness of CBA compared to cement which makes CBA demand more quantity of water.

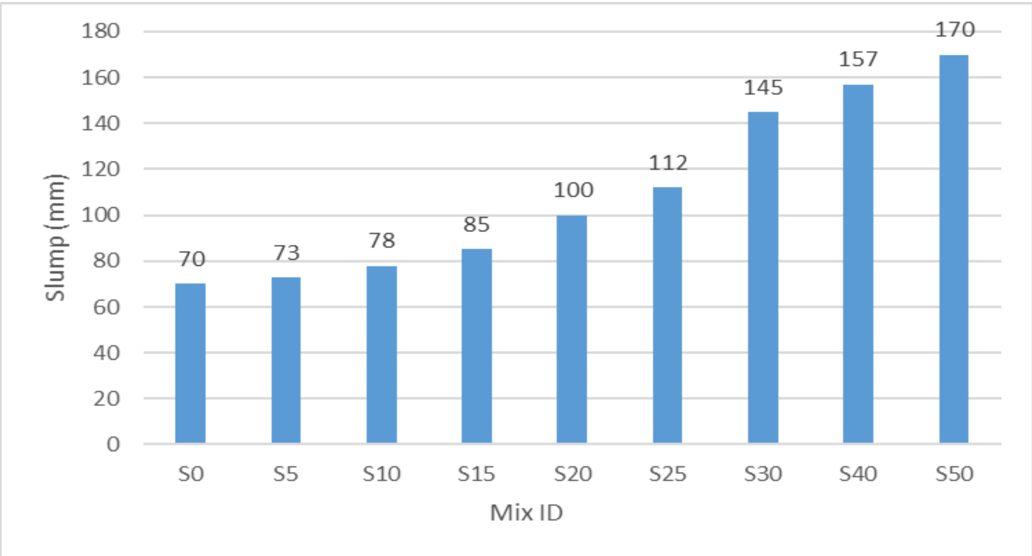


**Fig. 1: Variation of Slump of Concrete for the Different Sample Mixes**

### B. *Effect of Cow Bone Ash (CBA) on Compressive Strength*

The recommended compressive strength for rigid pavement is 35-40N/$mm^2$ at 28 days [7]. The results obtained as shown in Fig. 2 reveal a drop-in strength for samples containing 5 to 15% and 40 to 50% CBA at 28days. This drop-in strength can be attributed to the reduction of Calcium-Silica-Hydrate (CSH) in the matrix due to the reduction in the volume of OPC in the mix. But at 20-30% CBA content, the strength was regained and satisfied recommended strength for rigid pavement construction. This gain and gradual increase in strength at this percentage content may be due to the fact that there is now sufficient amount of CaO in the mix to form Tricalcium Silicate ($C_3S$) which is responsible for strength in the late or early part of the concrete. The results also showed the compressive strength of samples containing 5-20% CBA increased gradually with curing duration, with the most satisfactory result obtained at 20% CBA. Other samples containing 25-50% CBA content showed relative decrease in strength with curing duration.

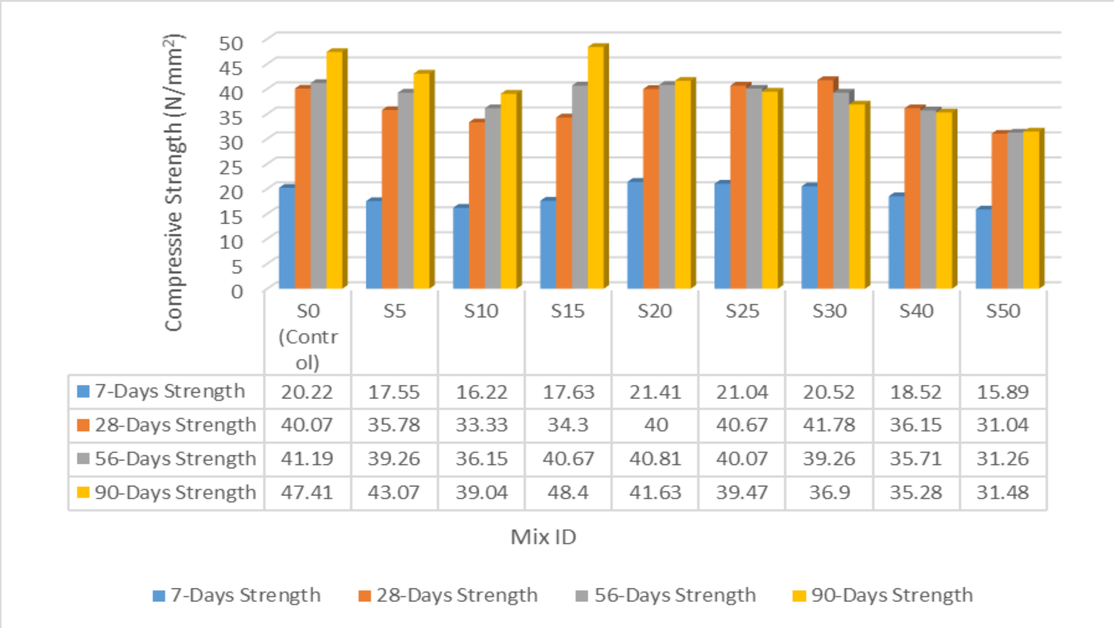


**Fig. 2: Bar Chart Showing Compressive Strength of Samples at Different Curing Days**

### *C. Effect of Cow Bone Ash (CBA) on Flexural Strength*

The recommended flexural strength for rigid pavement is 3.5-4.0N/mm$^2$ at 28 days [7]. The results, as presented in Fig 3, showed that this recommendation was satisfied by all the samples ($S_0$-$S_{50}$), though samples containing CBA have flexural strength less than that of the control sample. Since flexural strength is largely dependent on the bonding ability of the concrete constituent materials, the reduction in flexural strength for samples containing CBA ($S_5$-$S_{50}$) can be attributed to the lack of pozzolanic property of CBA which reduces the volume of OPC and resultantly, the bonding ability of the mix.

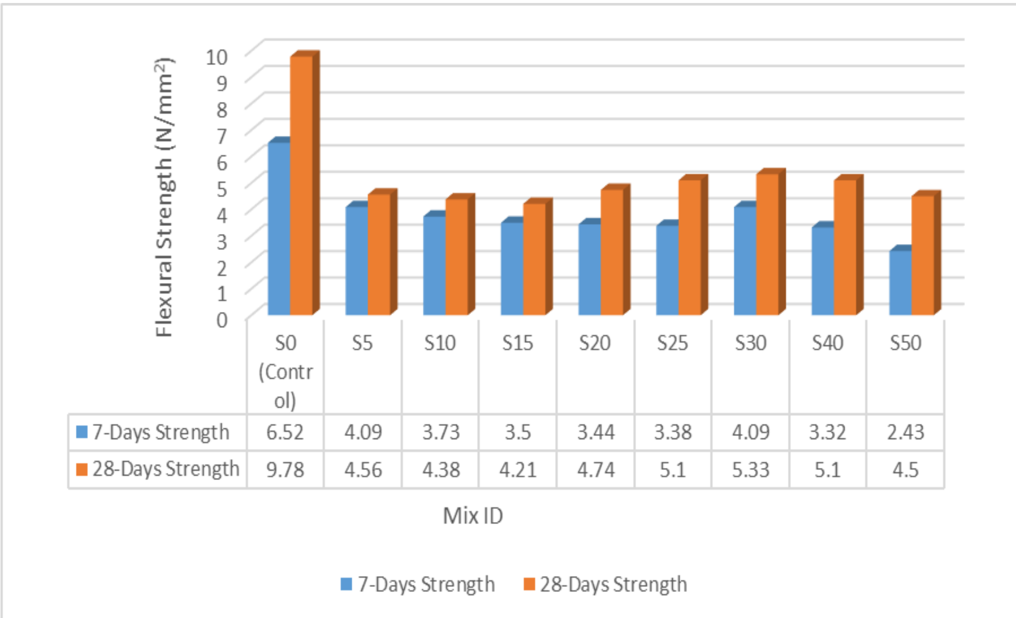


**Fig. 3: Bar Chart Showing Flexural Strength of Samples at Different Curing Days**

### *D. Analysis of Variables (ANOVA)*

One-way ANOVA analysis was used to express the differences between the recommended compressive strength and flexural strength and those obtained from the laboratory tests carried out for the different samples. These analyses were carried out to investigate the structural adequacy of partially replacing cement with Cow Bone Ash (CBA) in rigid pavement construction. Tables 4 to 6 show the results of the statistical analysis for both compressive and flexural strength.

**Table 4: Compressive And Flexural Strengths For The Different Samples**

| COMPRESSIVE STRENGTH | | | FLEXURAL STRENGTH | |
|---|---|---|---|---|
| MIX ID | RECOMMENDED STRENGTH AT 28 DAYS ($N/mm^2$) | VALUE FOR THE DIFFERENT MIXES | RECOMMENDED STRENGTH AT 28 DAYS ($N/mm^2$) | VALUE FOR THE DIFFERENT MIXES |
| $S_0$ | 40 | 40.07 | 4 | 9.78 |
| $S_5$ | 40 | 35.78 | 4 | 4.56 |
| $S_{10}$ | 40 | 33.33 | 4 | 4.38 |
| $S_{15}$ | 40 | 34.3 | 4 | 4.21 |
| $S_{20}$ | 40 | 40 | 4 | 4.74 |
| $S_{25}$ | 40 | 40.67 | 4 | 5.1 |
| $S_{30}$ | 40 | 41.78 | 4 | 5.33 |
| $S_{40}$ | 40 | 36.15 | 4 | 5.1 |
| $S_{50}$ | 40 | 31.04 | 4 | 4.5 |

**Table 5: Summary Output Of Anova For Compressive Strength**

| Groups | Count | Sum | Average | Variance | | |
|---|---|---|---|---|---|---|
| Column 1 | 9 | 360 | 40 | 0 | | |
| Column 2 | 9 | 333.12 | 37.01333 | 14.154 | | |
| ANOVA | | | | | | |
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Between Groups | 40.1408 | 1 | 40.1408 | 5.672008 | 0.029997 | 4.493998 |
| Within Groups | 113.232 | 16 | 7.077 | | | |
| Total | 153.3728 | 17 | | | | |

**Table 6: Summary Output Of Anova For Flexural Strength**

| Groups | Count | Sum | Average | Variance | | |
|---|---|---|---|---|---|---|
| Column 1 | 9 | 36 | 4 | 0 | | |
| Column 2 | 9 | 47.7 | 5.3 | 2.960875 | | |
| **ANOVA** | | | | | | |
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Between Groups | 7.605 | 1 | 7.605 | 5.136995 | 0.03764 | 4.493998 |
| Within Groups | 23.687 | 16 | 1.480438 | | | |
| Total | 31.292 | 17 | | | | |

From the results obtained, it is observed that F is greater than F*crit* in all cases. This shows that the mean of the population is not equal and that there is significant difference between the recommended compressive and flexural strengths and those obtained from the different samples. The result of the analyses therefore proves that Cow Bone Ash (CBA) is structurally adequate for rigid pavement construction.

### *E. Comparative Cost Analysis*

After determining the structural adequacy of using Cow Bone Ash as partial replacement of cement in rigid pavement construction, it is also quite important to determine its economic advantage.

In order to carry out the cost analysis, Sample $S_{20}$ is used, which contains 20% CBA content of compressive strength of 40N/mm$^2$ and 41.63 N/mm$^2$ at 28days and 90 days respectively as against 40.07 N/mm$^2$ and 47.41 N/mm$^2$ at 28days and 90 days respectively for control mix.

The production cost of the concrete used in this work is calculated from the cost of each of the constituents for the concrete, and presented in Tables 7 to 10.

**Table 7: Production Cost For The Control Specimens Per M$^3$**

| S/N | Materials | Quantity (kg) | Unit Cost (N) | Total Cost (N) |
|---|---|---|---|---|
| **1** | Cement | 537.06 | 2800/50kg | 30,075.36 |
| **2** | Sand | 429.65 | 40,000/5000kg | 3437.2 |
| **3** | Granite | 1228.94 | 140,000/30,000kg | 5735 |
| **4.** | Labour | | | 7500 |
| **Total (Production Cost)** | | | | **46,747.56** |

**Table 8: Production Cost For Sample $S_{20}$ Per M$^3$**

| S/N | Materials | Quantity (kg) | Unit Cost (N) | Total Cost (N) |
|---|---|---|---|---|
| **1.** | Cement | 537.06 | 2800/50kg | 24,060.29 |
| **2.** | Sand | 429.65 | 40,000/5000kg | 3437.2 |
| **3.** | Granite | 1228.94 | 140,000/30,000kg | 5735 |
| **4.** | Cow Bone Ash | 107.42 | 15/kg | 1,611.18 |
| **5.** | Labour | | | 7,500 |
| **Total (Production Cost)** | | | | **42,343.67** |

**Table 9: Summary Of Cost Analysis Per M$^3$**

| Specimen | Production Cost (N) |
|---|---|
| $S_0$ (Control Sample) | **46,747.56** |
| $S_{20}$ (20% CBA + 80% Cement) | **42,343.67** |
| **Cost Reduction** | **4,403.89** |
| **% Cost Reduction** | **9.42%** |

From Table 9, it can be seen that there are benefits to be derived by the use of Cow Bone Ash (CBA) at 20% cement substitution. The cost reduction is about 9.42% per m$^3$. In monetary terms, this can be seen in Table 10.

**Table 10: Monetary Benefits From The Use Of Cow Bone Ash**

| S/N | | COST (Billion Naira) |
|---|---|---|
| 1. | National Cement Consumption for 2017 fiscal year (Estimate from Franklin, 2009 [8]) | 1,092.00 |
| 2. | Consumption assuming 20% substitution with CBA = 1092- (9.42% * 1092) | 989.13 |
| | **Potential Annual Saving** | **102.87** |

From Table 10, Nigeria needs N1.092 trillion to satisfy her cement needs. But if 20% of her cement needs is replaced with Cow Bone Ash, the cost will be reduced to N989.13 billion. The cost reduction is N102.87 billion.

It can therefore be seen that the use of Cow Bone Ash (CBA), up to 20% cement replacement in the production of concrete will result in savings in the hundreds of billion naira.

## IV. CONCLUSION

From the observations, critical examinations and analyses carried out in this study, the following conclusions have been drawn:

- Concrete containing Cow Bone Ash (CBA), up to 20% as partial substitution for cement, satisfies the minimum structural requirement for rigid pavement construction.
- From the comparative cost analysis, concrete with 20% CBA content, as partial substitution for cement, is cheaper than conventional concrete of equivalent strength.
- The comparative cost analysis also proved that the nation will save 9.42% of its annual expenses on cement consumption; thereby resulting to potential annual savings of over one hundred billion naira.
- The 20% usage of CBA in partial replacement of cement in concrete production gives additional environmental benefits, as it provides an alternate and effective solution to the disposal of cow bone wastes.

## V. RECOMMENDATION

In view of the results presented in this study, it is recommended that field testing be carried out to evaluate the pavement performance of rigid pavement containing Cow Bone Ash (CBA) when subjected to traffic loading.

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