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Omuh Ignatious1,Amusan Lekan2,Olusola Kolapo 3,Mosaku Timothy5,Fagbenle Olabosipo4,Owolabi Dele6, Tunji-Olayeni Patricia7, Opeyemi Joshua8,

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PROPERTIES OF CONCRETE INCORPORATING CALCINED EARTHWORM CAST AS PARTIAL REPLACEMENT FOR CEMENT

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ABSTRACT

The high cost of cement is a major drawback in concrete usage. This research aimed at determining the strength characteristics of concrete incorporating calcined earthworm cast as partial replacement of cement. The objectives were to obtain the optimum percentage of calcined earthworm cast that can be used to replace cement in a given concrete mix, and to examine the physical / chemical properties of the calcined earthworm cast. Percentage replacement of cement with the earthworm cast was done at 0, 10, 20, 30% respectively and tests were carried out on fresh and hardened concrete. The results showed that while the initial and final setting time of the concrete containing earthworm cast increased with the increase in earthworm cast content, the compressive strength decreased with increase in calcined earthworm cast replacement. It was concluded that a partial replacement of not more than 30% of cement with calcined earthworm cast will suffice.

KEYWORDS: *concrete , compressive strength , calcined earthworm cast, cement*

1.1 INTRODUCTION

Concrete is the most widely used material in the world. It plays an important role in infrastructure and private buildings construction. Its popularity can be attributed to two factors. First, its versatility, concrete is used for many different structures, such as dams, pavements, building frames, or bridges, much more than any other construction material. Second, its production, the amount of concrete used is much more than any other material. Its worldwide production exceeds that of steel by a factor of 10 in tonnage and by more than a factor of 30 in volume (Li, 2011). In a concrete structure, there are two commonly used structural materials: concrete and steel. A structural material is one that carries not only its self-weight, but also the load passing from other members. Concrete production in not an exact science, factors like the type and size of the aggregates, the water cement ratio, transportation, placing and compaction of concrete affect its final strength. Concrete production is not as precise as steel. Steel, on the other hand, is manufactured under carefully controlled conditions, always in a highly sophisticated plant; the properties of every type of steel are determined in a laboratory and described in a manufacturer's certificate. Thus, the designer of a steel structure need only specify the steel complying with a relevant standard, and the builder needs only to ensure that the correct steel is used and that connections between the individual steel members are properly executed (Neville and Brooks, 2010). Aggregates make up about 75% of the volume of concrete, so their properties have a large influence on the properties of the concrete (Alexander and Mindess, 2005). Aggregates are granular materials, most commonly natural gravels and sands or crushed stone, although occasionally synthetic materials such as slags or expanded clays or shale are also used. Most aggregates have specific gravities in the range of 2.6 to 2.7, although both heavyweight and lightweight aggregates are sometimes used for special concretes.

In Nigeria, the cost of cement has been on the increase. Within the period of six months, the cost of cement has increased by about 67%. This has led to the intervention of Federal Government of Nigeria to intervene by giving an ultimatum that the cost should be reduced within a specified period (Sawyerr, 2011). The increase in the price of cement in Nigeria has been attributed to the rising cost of diesel and other factors of production. Another way of reducing the cement cost might be to introduce pozzolanic cements into the market.

A pozzolan is a natural or artificial material containing silica in a reactive form. By themselves, pozzolan have little or no cementitious value. However, in a finely divided form and in the presence of moisture they will chemically react with alkalis to form cementing compounds (Neville, 2000). Pozzolan must be finely divided in order to expose a large surface area to the alkali solutions for the reaction to proceed. Examples of pozzolanic materials are volcanic ash, pumice, opaline shales, burnt clay and fly ash. The silica in a pozzolan has to be amorphous or glassy, to be reactive. Fly ash from a coal-fired power station is a pozzolan that results in low-permeability concrete, which is more durable and able to resist the ingress of deleterious chemicals (Lewis *et al*, 2003).
. At the inception of the use of admixtures in 150 BC, the Romans discovered that finely divided pozzolan had to be amorphous (glassy) to chemically react. This was possible because the pozzolan was heated (calcined) by the volcano (Herring, 2002).

Earthworm cast is the excrements of earthworms; this is a result of ingested soil. Earthworm cast is digested material that is excreted back into the soil. Cast is enriched with nutrients (Nitrogen, Phosporus, Potassium, and Calcium) (Hubbard, 1999).

Calcination is a thermal treatment process applied to ores and other solid materials in order to bring about a thermal decomposition, phase transition, or removal of a volatile fraction. The calcination process normally takes place at temperatures below the melting point of the product materials. Sometimes, calcination can be in natural processes as in the heating of volcanic ash. Calcined Earthworm cast (CEWC) refers to the earthworm cast that has been subjected to heat of up to the temperature of 850^{o}Celsius in a furnace.

If the cement manufacturers utilize the available materials as partial replacement for cements, the overall cost of cement might be reduced. This paper however, studies the suitability of calcined Earthworm cast (CEWC) as a pozzolan, a partial replacement for cement.

1.2 MATERIALS AND METHODS

1.2.1 Materials

Cement has important property that when mixed with water, a chemical reaction (hydration) takes place, which with time produces a very hard and strong binding medium for the aggregate particles (Neville, 2000).

The cement type used in the research was Ashaka brand of ordinary Portland cement (OPC) manufactured by the Ashaka cement Plc Gombe in Nigeria.

The fine aggregate used is natural burrow pit sharp sand. The sand was air dried in the laboratory. The sand was sieved in order to remove both those particles passing a 600 microns sieve and those retained on a 4.75mm sieve. A sieve analysis of the sand sample was undertaken using standard sieves manufactured in conformance with (BS 812:1990).

The coarse aggregates used in the concrete mixes are crushed rock (granite). The grading curve of the aggregates are shown in the figures 1 & 2

The grading for the fine aggregates show that it falls within of zone 1 of the grading limits of the BS 882 according to Neville (2000). The coarse aggregate grading, similar to the fine aggregate was within range of the parameters set out by (BS 882:1992) [10], the rock samples corresponded to requirements of the nominal size of graded aggregate to size 20mm. It is important to note that any aggregate meeting the criteria set by the British standard may be suitable for use in concrete production

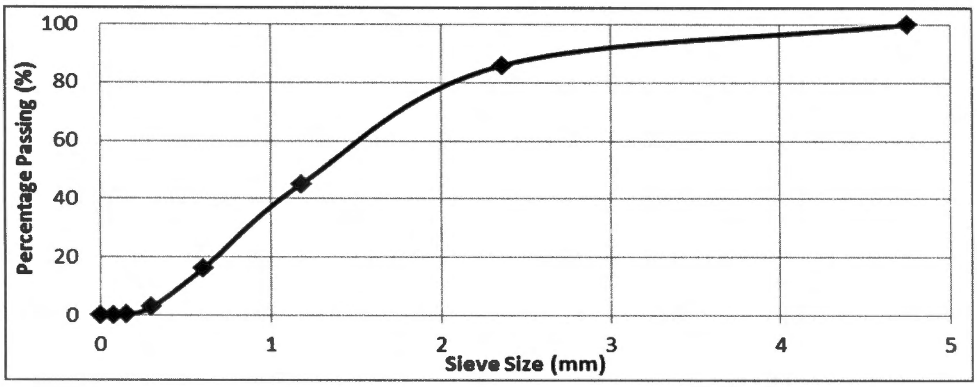

Figure 1. Particle size distribution for the sharp sand

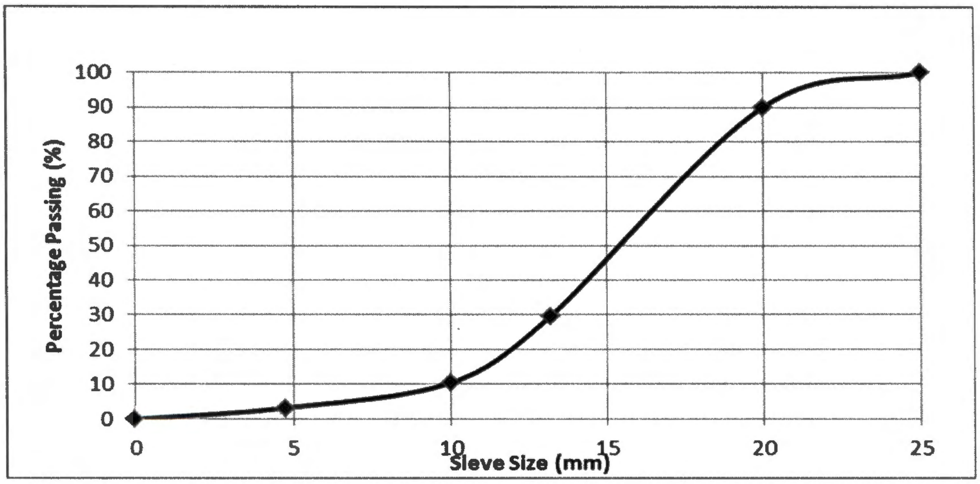

Figure 2. Particle size Distribution Curve for Crushed Stone

Earthworm cast is composed of mainly clay materials and very fine sand as well as little humus. The earthworm cast used for this research work was collected from Giring village, Abattoir, Jos. It was collected in dry lumpy form. The earthworm-cast was first of all grinded. Earthworm casts was sieved through B.S sieve size 45 microns to get the size corresponding to that of cement. The grinded earthworm cast was then subjected to a temperature of 850 degrees Celsius in a furnace at the Nigerian Metallurgical Development Centre in Jos. The resulting product was analysed chemically.

1.2.2 Methods

Laboratory Tests

The laboratory tests on the fine and coarse aggregates that were necessary for the purpose of characterization, which include particle size distribution, compaction, and specific gravity were carried out in accordance with (BS 812:1990).

Mixing and Moulding

The mix was designed and the batching was done by weight. Percentage replacements of 0,10,20,30, and 40% of cement with CEWC respectively by weight of cement were prepared and 15 blocks of size 150mm × 150mm × 150mm were moulded for each mix. A total of 75 cubes were cast, vibrated and cured under laboratory conditions for 7, 14, and 28 days. The quantity of materials used in each mix is shown in Table 1. A water-cement ratio of 0.6 was maintained.

Table 1 Summary of the Quantity of Materials Used By Weight

S.No.	Percentage Replacement (%)	Cement (Kg)	CEWC (Kg)	Fine Aggregates(Kg)	Coarse Aggregates(Kg)	Water (Kg)
1	0	11.34	0.00	22.48	57.92	6.89
2	10	10.21	1.13	22.48	57.92	6.89
3	20	9.07	2.27	22.48	57.92	6.89
4	30	7.94	3.40	22.48	57.92	6.89
5	40	6.80	4.54	22.48	57.92	6.89

Workability Tests

Slump test is very useful in detecting variations in the uniformity of a mix of a given nominal proportions. Slump test was carried out for the various percentage replacement levels of cement with CEWC. That is at 0%, 10%, 20%, 30%, and 40% respectively. The test was carried out in accordance to the stipulations of the (BS 1881:1983) and (ASTM C 143: 1990).

Compressive Strength Test

An automatic compression machine was used for the compressive strength test on the cubes in accordance with (BS 1881:1983), at the curing ages of 7, 14, and 28 days.

Five cube were crushed at each respective hydration period of 7, 14, 28 days for each percentage replacement of cement and the average compressive strength was measured.

1.3 RESULTS AND DISCUSSIONS

1.3.1 Chemical Analysis

Before any material can be regarded as a pozzolan, it is required that the chemical composition meets up with the standard requirement from the code (Mindess and Young, 1981).

Table 2 Chemical analysis of CEWC

TYPICAL OXIDE COMPOSITION	CEWC
CaO	1.60
SiO_2	58.86
Al_2O_3	18.98
Fe_2O_3	8.82
MgO	0.17
SO_3	-
K_2O	5.10
Na_2O	0.10
MnO	0.16
ZnO	0.05
BaO	0.10
CuO	-
Loss of Ignition	6.06

Source* Authors research

From the table, it can be seen that the combined $SiO_2 + Al_2O_3 + Fe_2O_3$ (silicon dioxide, aluminum oxide, and iron oxide content) is 86.66 %. This meets the specifications for pozzolan as provided in (Mindess and Young, 1981) (70% minimum requirement). The absence of SO_3 indicated that there will be no sulphate attack on reinforcements. The Sodium oxide (Na_2O) content in CEWC was 0.10%. The low value was indicative of a very low salt content in the concrete. The oxide, Potassium oxide (K_2O), was present in a very high percentage, 5.10%. This increased the risk of failure in concrete elements due to alkali-aggregate activity. According to (Li, 2011), the degree of Alkali Silica Reactivity is affected by;

1. presence of water—if there is no water, there is no expansion;
2. alkali content—if the alkali content (Na_2O and K_2O) is less than 0.6%, there is no reaction, and concrete containing more than 3 kg/m3 of alkali can be considered to have a high alkali content; and
3. concrete porosity—the internal stress may be relieved in concrete with high porosity . Since the potassium oxide alone is 5.10% and the combined Na_2O and K_2O content was 5.20%, the risk was high. The use of lithium nitrate ($LiNO_3$), calcium nitrate, or other types of nitrate, as well as other lithium compounds can control AAR-induced damage. The work of (Li *et al* 1999) has demonstrated that calcium nitrate can effectively reduce ASR.

Magnesium oxide was present at 0.17 %. Although high MgO content can lead to unsoundness in concrete, that risk is minimized because of the small quantity. The loss on ignition was 6.06%. According to (BS EN196: 1978), it is specified that the loss of ignition should not exceed 7%. This means that the Loss on ignition in the CEWC was sufficient.

The properties of the materials used are presented in Table 3. The fineness moduli of sand was 3.03, while the specific gravities are 2.68 and 2.66. The CEWC had a specific gravity of 2.38 and bulk density of 1147 kg/m^3. According to Neville and Brooks (2010) the fineness modulus should fall between 2.3 – 3.0, the result obtained indicates that the fineness modulus of the sand is within range. A higher value for the fineness modulus will affect the workability and invariably the final strength of the concrete. The result obtained for the specific gravity shows that the specific gravities of both the coarse and fine aggregates fall within the range as stated in (Mindess and Young, 1981), this range from 2.2 - 3.0.

Table 3 of Properties of Cement, CEWC, Fine and Coarse Aggregates

Property	Cement	CEWC	Sand	Crushed Rock
Bulk Density		1147	1470	1346
Specific Gravity	3.15	2.38	2.68	2.66
Fineness Modulus			3.03	

1.3.2 Workability Test

From the Table 4, it can be seen that at a constant water cement ratio, the slump increases from 25mm to 40 mm as the partial replacement increases from 0% to 40%. The compacting factor also increases from 0.83 to 0.89 as the percentage replacement increases from 0% to 40%. The results show that the workability increases with increase in cement replacement. The presence of the CEWC reduced the rate of hydration of the cement. The table indicates that the concrete slump increases with the incorporation of CEWC. While the control mix had a slump of 25mm, concrete with 10, 20, 30, and 40% earthworm cast replacement had slumps of 28mm, 30mm, 35mm, and 40mm respectively. These results indicated that the CEWC generally improved the workability of Portland cement concrete.

This finding is in agreement with the report of (Kosmatka *et al*, 2003) which stated that adding an admixture to concrete without reducing the water content (i.e. with constant w/c ratio) can produce a mixture with a higher slump. The consistency on the other hand reduces with increase of CEWC percentage replacement.

Table 4 Results of the workability test

Serial no.	Percentage replacement	Cement	CEWC	Water/cement ratio	Slump (mm)	Compacting Factor
1	0	11.34	0.00	0.6	25	0.83
2	10	10.21	1.13	0.6	28	0.87
3	20	9.07	2.27	0.6	30	0.88
4	30	7.94	3.40	0.6	35	0.88

5	40	6.80	4.54	0.6	40	0.89

1.3.3 Initial and Final Setting Time

The initial and final setting time were affected by the cement replacement. The setting time increased directly proportionally to the percentage replacement with CEWC. From the table 5, it can be observed that the increase in the percentage of CEWC increased both the initial and final setting time. This may be due to the very high silicate and low calcium oxide that were present in the earthworm cast. This would reduce the heat of hydration that is responsible for the cement to set fast. The setting time (initial and final) of all the percentage replacements fall within the provisions of (BS 12:1979) and (ASTM 191: 1992),which state that the initial setting time must not be less than 45mins and the final setting time must not be more than 10 hours.

Table 5: Setting time and Consistency test results

Partial Replacement %	**0**	**10**	**20**	**30**	**40**
Consistency (%)	33	33	32	31	31
Initial Setting Time (min)	98	120	150	172	205
Final Setting Time (min)	200	235	270	297	336

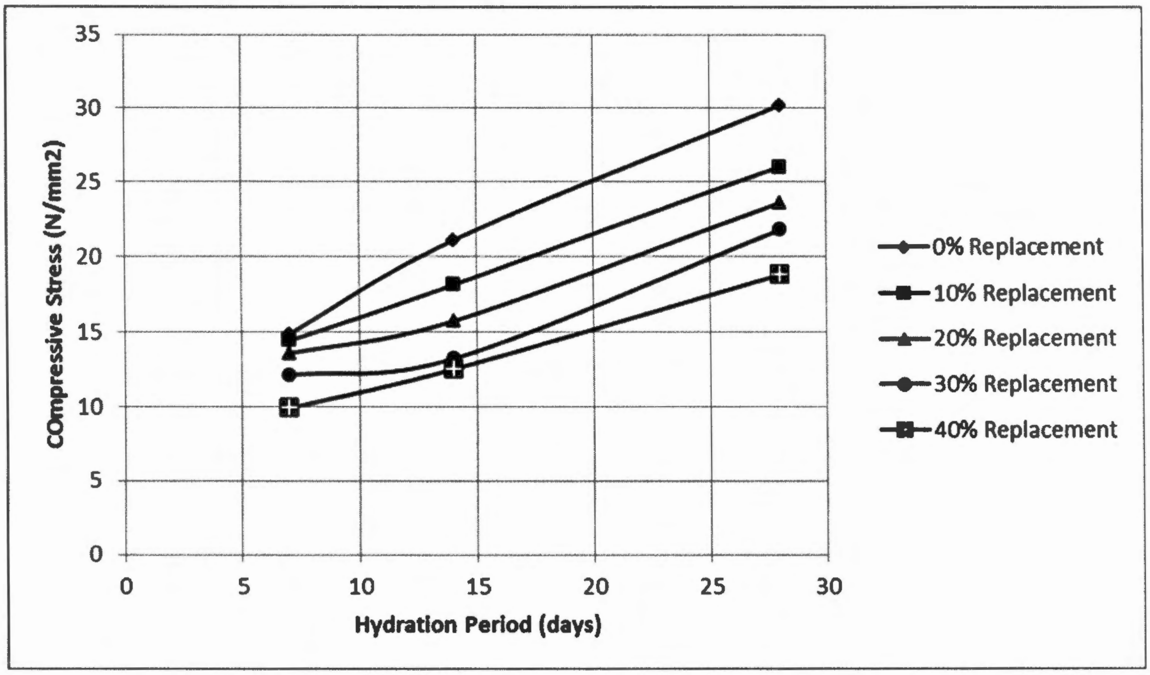

Figure 3. Compressive Strength of Concrete at Different Hydration Periods.

Table 6: Cube density at 28 days

Percentage Replacement (%)	0	10	20	30	40
Cube density at 28 days (Kg/m^3)	2439	2421	2384	2375	2352

Figure 3 presents the following results:

1. At 7, 14 and 28 days hydration period, the compressive strength attained by the replacement of 0, 10, 20, 30, and 40 per cent CEWC decreased with increase in CEWC. This decrease in strength was attributed to the low calcium oxide (CaO) content.
2. It can be further observed that the compressive strength generally increased as the curing period increased, independent of the percentage replacement
3. The rate of strength gain decreased with increase in CEWC present in the concrete. This is indicated in the steep nature of the curve for the control mix and the gentler slopes of the concrete with CEWC.
4. The density of the cube reduced with increase in CEWC as indicated in Table 6. This can be attributed to fact that CEWC has a lower specific gravity in

comparison to cement. Neville (2000) pointed out that concrete strength increased with density.

5. All but one of the mixes failed to reach the average compressive strength value of 20N/mm2 for mix 1:2:4 (Umenwaliri and Ezenwamma, 2008). However the strength of the concrete was inversely proportional to the percentage replacement of cement with CEWC.
6. At the end of 28 days, the concrete cubes with 40% replacement of cement failed to reach 70% of the 28 day strength of the control mix. This could be attributed to the high replacement of cement and the lowered binding and hydrating abilities of the concrete.

1.4 CONCLUSIONS

From the laboratory study carried out on the properties of concrete incorporating CEWC, as a partial replacement for cement, the following conclusions were drawn:

1. Adequate compressive strength of 21.76 N/mm^2 was achieved at 28 days for a mix of 1:2:4 that had 30% replacement of cement with CEWC
2. The concrete with 40% replacement was below the expected strength of $20KN/mm^2$.
3. The chemical analysis of CEWC showed that it met some of the major requirements for pozzolans according to (ASTM C618). However, there was a relatively high presence of K_2O which exposed the concrete to the risk of alkali-silica reaction that weakens the concrete over time. There was no presence of sulphates, so there was no risk of sulphate attack.
4. The slump value of the concrete increased with increase in the percentage of CEWC. This indicates that the workability of the concrete was improved with the addition of CEWC.
5. The density of the concrete cubes reduced with the increased percentage of CEWC. This was due to the lower specific gravity of the CEWC with respect to the cement.
6. On the basis of this study, it is apparent that the use of CEWC should be encouraged because it meets the requirement of (ASTM C618) for pozzolans. However, because of the high risk of alkali silica reactivity, methods must be adopted to reduce this risk. One method of reducing the risk of alkali aggregate reaction is by introducing nitrates that can prevent or even reduce this reaction from taking place.

Further research could be done on the response of concrete incorporating CEWC in fire and increased heat. Other research areas can be in strength improvement of CEWC incorporated concrete by the addition of super plasticizers the effect of CEWC on alkali silica reaction in concrete.

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