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ASSESSMENT OF CONCRETE PRODUCED BY PARTIAL REPLACEMENT OF CEMENT WITH WASTE CLAY BRICKS POWDER

Assessment of Concrete Produced by Partial Replacement of Cement With Waste Clay Bricks Powder

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ABSTRACT

Cement production emits carbon dioxide (CO_2) gas to the atmosphere, thereby contributing to global greenhouse gas emission. While Waste Clay Bricks are abundant in Minna and it is mostly used in landfills. This study focuses on the pozzolanic properties of the Waste Clay Bricks and their effect on the compressive strength of concrete. X-ray fluorescence (XRF) test was used to examine the oxide composition of Waste Clay Bricks powder. WCB was used as a partial replacement for cement in increasing percentages of 5, 10, 15 and 20% by weight for grade 25. Concrete specimens prepared target mean strength was 33.2N/mm^2 and water/cement ratio of 0.5. Sieve Analysis, Natural Moisture Content, Specific Gravity and Bulk density test were also conducted on the aggregates with all tests done in accordance with relevant British Standards. The oxide composition of Waste Clay Bricks powder obtained for this research meets the ASTM C618 (ASTM, 2015) recommendation that for a suitable pozzolanic materials, the summation of the SiO_2, Al_2O_3 and Fe_2O_3 was 94% which according to ASTM C618 must not be less than 70%. It was observed that waste clay brick increases the workability and consistency of fresh concrete. However, at 5% partial replacement of cement with Waste Clay Bricks powder, the compressive strength at 28 days curing is 25.41 N/mm^2 which is above the targeted value at 28days. The 5% partial replacement of Waste Clay Bricks powder value is close to the compressive strength of the control concrete at 28days which is 26.07 N/mm^2. Hence the use of Waste Clay Bricks powder to replace cement should be limited to 5% for plain concrete of grade 25.

Keywords: Cement, Waste Clay Bricks powder, Compressive strength, Pozzolana.

1 INTRODUCTION

Concrete is the most broadly utilized man-made construction material on the earth's surface and it is second to water as the most used substance on the planet. Concrete is widely used in almost every sphere of construction among others, building, infrastructure and structures which are used for other developments. It consist of Portland cement, water mixed with sand, gravel, crushed stone or other inert material such as vermiculite or expanded slag (Brady 1986).

Cement, a major binding material in making concrete, influences the quality of the concrete so produced with it. Its chemistry dictates the chemistry of concrete (Bhanumathidas and. Kalidas, 2003). According to Imbabi et al., 2012, Portland cement production generates about one tonne of carbon dioxide (CO_2) to the atmosphere and it is of 5% of global CO_2 emission.

ASTM C618 defined pozzolana as "siliceous or siliceous and aluminous material which in themselves have little or no cementitous properties. But in finely divided form and in the presence of moisture, they can react with calcium hydroxide which is liberated during the hydration of Portland cement at ordinary temperatures to form compounds possessing cementitous properties". Pozzolanic materials do not harden in themselves when mixed with water but, when finely ground and in the presence of water, they react at normal ambient temperature with dissolved calcium hydroxide ($Ca(OH)_2$) to form strength-developing calcium silicate and calcium aluminates compounds. (BS EN 97-7:2000,).

Although Waste Clay Bricks has not yet acclaimed supplementary cementitious material status commercially (Rashed, 2014). The usage of the waste bricks in concrete will leads to enabling the construction industries utilize thousands of tons of brick blocks that would have ended up as waste or landfill materials. Waste clay brick (WCB) is silicate solid waste which has great environmental and social significance. (Haili, 2016). According to the research by Ali *et.al* (2014), the assessment of pozzolanic reactivity based on strength activity index specified by ASTM C618 and outlined in ASTM C311 has not been previously reported by other researchers implying that not all burned clay possess pozzolanic reactivity. Ulukaya and Yüzer (2016) examined the pozzolanicity of clay fired bricks using direct and indirect methods. Their investigation revealed that clay treated at 850°C can be regarded as the best pozzolan, and the pozzolanicity of Waste Clay Bricks significantly changes the mechanical properties of crushed brick-lime mortars.

Bediako (2018), observed that compressive strength results indicated that the optimum Portland cement replacement with Ground Waste Clay Bricks was at 30%.

Abdelghani *et.al*. (2009), investigated the use of waste brick powder as a partial replacement for cement in the production of cement mortar. A substitution of cement by 10% of waste brick increased mechanical strengths of mortar. The results of the investigation confirmed the potential use of this waste material to produce pozzolanic cement.

Paulo (2009) evaluated the properties of concrete made with crushed bricks replacing natural aggregates. Observed results indicate that ceramic residuals could be used as partial replacement of natural aggregates in concrete without reduction of concrete properties for 15% replacement and with reduction of concrete properties at 20 to 30% replacement.

Ali *et al*. (2014) studied the effect of using crushed clay brick as an alternative aggregate in aerated concrete. A comparatively uniform distribution of pore in case of foamed concrete with natural sand was observed by scanning electron microscope, while the pores were connected mostly and irregularly for mixes containing a percentage higher than 25% clay brick aggregate.

2 MATERIALS AND METHOD

2.1 MATERIALS

The constituent materials used for this research work were sourced locally and they are as follows;

- Cement
- Waste Clay Bricks powder
- Fine Aggregate
- Coarse aggregate
- Potable water

The cement used in this research was Ordinary Portland Cement (OPC) which was bought from a cement depot at Bosso road, Minna, conforming to BS 12: 1996, Specifications for Portland ordinary cement. Samples of the Waste Clay Bricks was collected from Shelter Clay Company and pulverized in Civil Engineering Laboratory, Federal University of Technology Minna, Niger state. The Pulverized Waste Clay Bricks samples was thoroughly sieved (grains passing through BS sieve 0.075mm size) and cleaned before use to ensure that the debris and other forms of impurities that could alter or influence the hydration and bonding of cement water paste are removed. The X-ray fluorescence (XRF) test was used to examine the oxide composition of Waste clay brick powder in Nigeria Geological Survey Centre, Kaduna in accordance to BS ISO 29581-2:2010. The fine aggregates sample used for this work was selected based on availability in Minna. The particles passed through sieve with aperture 5mm and retained on sieve with aperture 0063mm. The sand was collected from a river in Bosso village, Minna. It was well graded in accordance with BS 882: 1992, Aggregates from natural Sources for concrete. Coarse aggregate sample used was mainly gravel from crushed parent rock. Its maximum aggregate size was 20 mm. The smallest sieve size allows all the coarse aggregate to pass through was 20mm sieve size. The physical properties of the aggregates used for the preparation of the test samples was determined in the Civil Engineering Laboratory, Federal University of Technology Minna, in accordance with BS 812: 1989. The potable water used for mixing and curing of the concrete samples was obtained from the tap at Civil Engineering Laboratory, Federal University of Technology Minna, Nigeria as specified in BS 3148: 1980.

Plate 1: Waste Clay Bricks in clay shelter

Plate 2: Waste Clay Bricks as landfill in Minna.

Plate 3: Pulverizing of Waste Clay Bricks

2.2 METHOD

2.2.1 X-ray Fluorescence (XRF)

The chemical composition of the Waste Clay Bricks powder was examined in Nigeria Geological Survey Centre, Kaduna, using X-ray fluorescence (XRF) to meets the standard requirements for pozzolanic material.

2.2.2 Sieve Analysis

Sieve analysis, also called particle size distribution is a process whereby materials are separated into various fractions within specific limits of the opening of standard test sieves in accordance with BS 812 (1975).

2.2.3 Natural Moisture Content

There is a variation in moisture content from one stock pile to another as a result of weather the moisture content must be determined frequently (Neville 2010). The total water content of the moist aggregate is equal to the moisture content and absorption in the aggregate. Several methods are available but accuracy depends on sampling. BS 812 part 109: 1990 prescribed the best method to be used in the laboratory. Three samples each of Fine was put into a clean tin container respectively with a known weight, then the sample and the weight of the container were determined. The samples were then left in the oven for 24 hours at a temperature of 100℃. It was removed and weighed. The average of the values was used. The moisture content was calculated using:

$$M.C = \frac{Wet\ Weight - Dry\ Weight}{Dry\ Weight} \times 100$$

2.2.4 Specific Gravity

Specific gravity according to ASTM (127 – 93), is the ratio of the mass of a unit volume of material to the mass of the same (absolute) volume of water at the stated temperature. An Empty bottle was cleaned, weighed and designated (m_1). The bottle was filled with one-third of the total volume of the sand sample, weighed and designated (m_2). The bottle was filled with distilled water, weighed and designated (m_3). Then the content of the bottle was discarded and it was rinsed thoroughly. The bottle was then filled with distilled water to the meniscus, weighed and designated (m_4). The Specific gravity (G_s) was calculated using equation:

$$Gs = \frac{(m2 - m1)}{(m4 - m1) - (m3 - m2)}$$

2.2.5 Bulk density test

Bulk density is the mass of material in a given volume. It is used in converting quantities by mass to quantities by volume and it is affected by several factors which include the amount of moisture present plus the amount of effort introduced in filling the measures. Bulk density depends on how densely the aggregate is packed and consequently on the size distribution and the shape of particles. The bulk density of the aggregates was carried out using a cube, the aggregates in the cube was compacted into three layers and 25 blows of tamped using the same procedure as prescribe by BS812 Part 105:1990.

2.2.6 Concrete Mix

The current British method for the design of normal weight concrete made with Portland cement produced by the Department of Environment (DOE), Building Research Establishment (BRE) Laboratory was adopted in designing the concrete mix and the compressive strengths of concrete was determined at 7, 14, 21 and 28 days curing age. The control sample for the normal weight concrete mix design is required to satisfy the following requirements;

- -28 day characteristics concrete cube compressive strength. F_c=25 N/mm^2
- -Assumed Slump 60 mm
- -Crushed aggregate with maximum size of 20 mm
- - Specific gravity of aggregate 2.7
- -The percentage defective permitted below the characteristics strength 1.64
- -Standard deviation 5
- -Type of cement used - OPC (strength class of cement =42.5)

-Target mean strength, $F_m = F_c + M = 25 + (1.64 \times 5) = 33.2$ N/mm^2

2.2.7 Batching and mixing

The batching and mixing of material was performed by weighing the aggregate, cement and water, the percentage of cement replacement by Waste Clay Bricks powder are 0, 5, 10, 15 and 20%. Water cement ratio was 0.5. The 0% replacement is the control sample.

2.2.8 Sample preparation

The constituent materials were batched by weight in accordance to values from concrete mix design and 150mm x 150mm x150mm cube was used to cast all mixed concrete. Concrete was mixed, placed and compacted into three layers and 25 blows tamped for each layers. The sample was removed from the cube after 24 hours and kept in a curing tank for 7, 14, 21 and 28 days respectively. A total number of 100 concrete cubes were cast to determine the compressive strength.

Table 1: Materials Requirements to Produce $1m^3$ of C25 concrete

Materials	Cement	Fine Aggregate	Coarse Aggregate	Water

Quantity (Kg/m^3)	410.0	721.6	1038.4	205.0
Ratio	1.00	1.76	2.54	0.50

Table 2: Constituent Materials of Concrete Samples

Concrete Samples	Constituent Materials(Kg/m^3)				
	Water	Cement	Waste Clay Bricks	Fine Aggregate	Coarse Aggregate
Concrete with 0% WCB	205	410	0	721.6	1038.4
Concrete with 5% WCB	205	389.5	20.5	721.6	1038.4
Concrete with 10% WCB	205	369	41	721.6	1038.4
Concrete with 15% WCB	205	348.5	61.5	721.6	1038.4
Concrete with 20% WCB	205	328	82	721.6	1038.4

3 RESULTS AND DISCUSSION

3.1 Chemical composition of Pulverized Waste Clay Bricks

Table 3 shows the chemical composition of the waste brick clays used in this research. The Waste Clay Bricks powder obtained for this research meets the ASTM C618 (ASTM, 2015) recommendation that for a suitable pozzolanic materials, the summation of the SiO_2, Al_2O_3 and Fe_2O_3 was 94% which according to ASTM C618 must not be less than 70%.

Table 3: Chemical composition of Pulverized Waste Clay Bricks

Major oxides composition	**Pulverized Waste Clay Bricks sample (%)**
SiO_2	58.40
Al_2O_3	16.30
P_2O_5	0.01
SO_3	0.30
CaO	2.00
MgO	Nd
TiO_2	1.04

Na_2O	0.12
K_2O	0.40
MnO	0.04
Fe_2O_3	19.30
L.O.I	2.02

Nd: Not detected.

3.2 Particles Size Distribution

Figure 1 shows the result for the particle size distribution of coarse aggregate. The result revealed that the coarse aggregate is singled size aggregate of 20mm nominal size confirming the aggregate suitable for construction work (BS 882, 1992). The result show in figure 2 revealed that the sand is fine grading aggregate size confirming the aggregate suitable for construction work (BS 882, 1992).

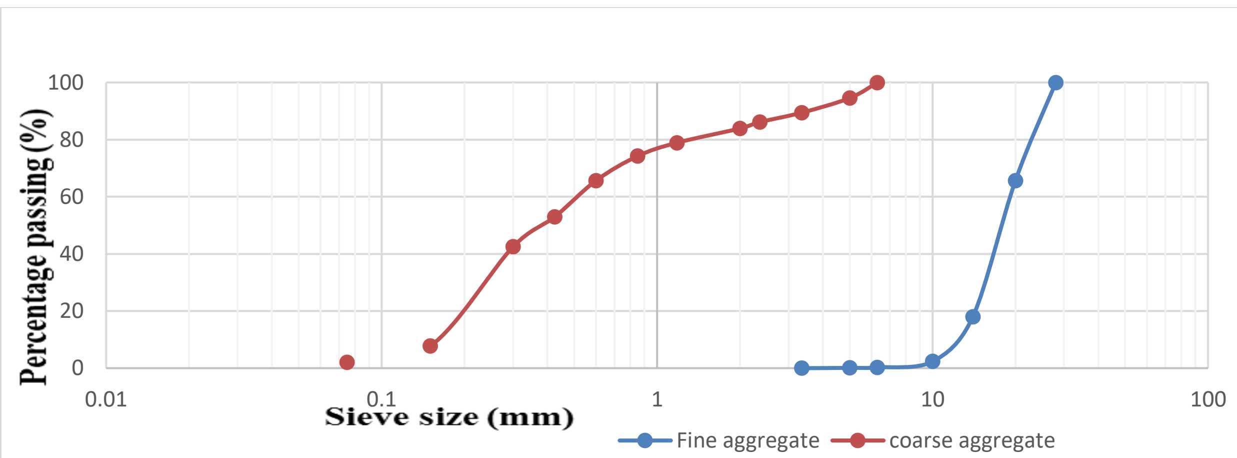

Figure 1: Sieve Analysis for Fine Aggregate and Coarse Aggregate

3.3 Natural Moisture Content

The average moisture content of sand obtained from table 4 is 7% which falls between the ranges of 5 to 15% (BS 812: Part 109, 1990). The moisture content of a soil depends on the void ratio of the soil, thus this value is indicative of the void spaces present in the soil and also the specific gravity. It should be noted that the natural moisture content of soils is also dependent on the prevailing climatic conditions such as temperature, rainfall quantity and the water table level at the study area where the samples have been retrieved.

Table 4: Natural Moisture Content of fine aggregate

Test	1	2
Weight of can W_1 (g)	24.7	24.8
Weight of can + wet sample w_2 (g)	148.3	119.7
Weight of can + dry sample w_3 (g)	141.2	112.6
Moisture content $(w_2-w_3)/(w_3-w_1)$	0.06	0.08
Mean moisture content (%)	7	

3.4 Specific Gravity

The specific gravity of the sand and gravel were found to be 2.62 and 2.66. The value obtained falls within the limit for natural aggregates with value of specific gravity between 2.6 and 2.7 as prescribed by BS 812 part 109: 1990.

Table 5: Specific Gravity

Data	**Sand**		**Granite**	
	Test 1	**Test 2**	**Test 1**	**Test 2**
Mass of cylinder+ sample + water (m_3) [g]	1685	1678	1732.90	1730.9
Mass of cylinder + dry sample (m_2) [g]	424.5	420	481	480
Mass of cylinder + water (m_4) [g]	1495.9	1493.5	1507.1	1506.9
Mass of cylinder (m_1) [g]	120.1	120.1	120.1	120.1
$(m_2 – m_1)$ [g]	304.4	299.9	360.9	359.9
$(m_4 – m_1)$ [g]	980.3	977.9	991.5	991.3
$(m_3 – m_2)$ [g]	865.0	862.5	856.4	855.4
$(m_4 – m_1) - (m_3 – m_2)$ [g]	115.3	115.4	135.1	135.9
Specific gravity of the particles	2.64	2.60	2.67	2.65

$$G_s = \frac{(m2 - m1)}{(m4 - m1) - (m3 - m2)}$$

Mean of specific gravity	2.62	2.66

3.5 Bulk density test

The average bulk density of fine aggregate was found to be 1620.59kg/m^3 which fall within the standard range of 1300-1800kg in accordance to (BS 812: Part 109, 1990). This implies that the aggregate is well-parked and densely composed.

Table 6: Bulk density test

Data	Sand		Gravel	
	Test 1	Test 2	Test 1	Test 2
Weight of empty cylinder (w_1) [kg]	1.09	1.09	1.09	1.09
Weight of empty cylinder + weight of compacted materials (w_2) [kg]	3.84	3.86	3.77	3.52
Weight of compacted materials (w_3) [kg]	2.75	2.76	2.68	2.43
Volume of Cylinder (v) [m^3]	0.0017	0.0017	0.0017	0.0017
Compacted Bulk density (w_3/v) [Kg/m^3]	1617.64	1623.53	1576.47	1429.41
Mean Bulk density [Kg/m^3]	1620.59		1502.94	

3.6 Fresh and Hardened Concrete Result

The compressive strength result presented in figure 3, shows clearly that the mix with 5% of Waste Clay Bricks powder (25.41N/mm^2) attains design target compressive strength value at 28days (25N/mm^2) which is closer to the compressive strength of the control mix concrete (26.07N/mm^2) for all curing ages. The compressive strength decreased gradually at 10, 15 and 20% partial replacement Waste Clay Bricks powder.

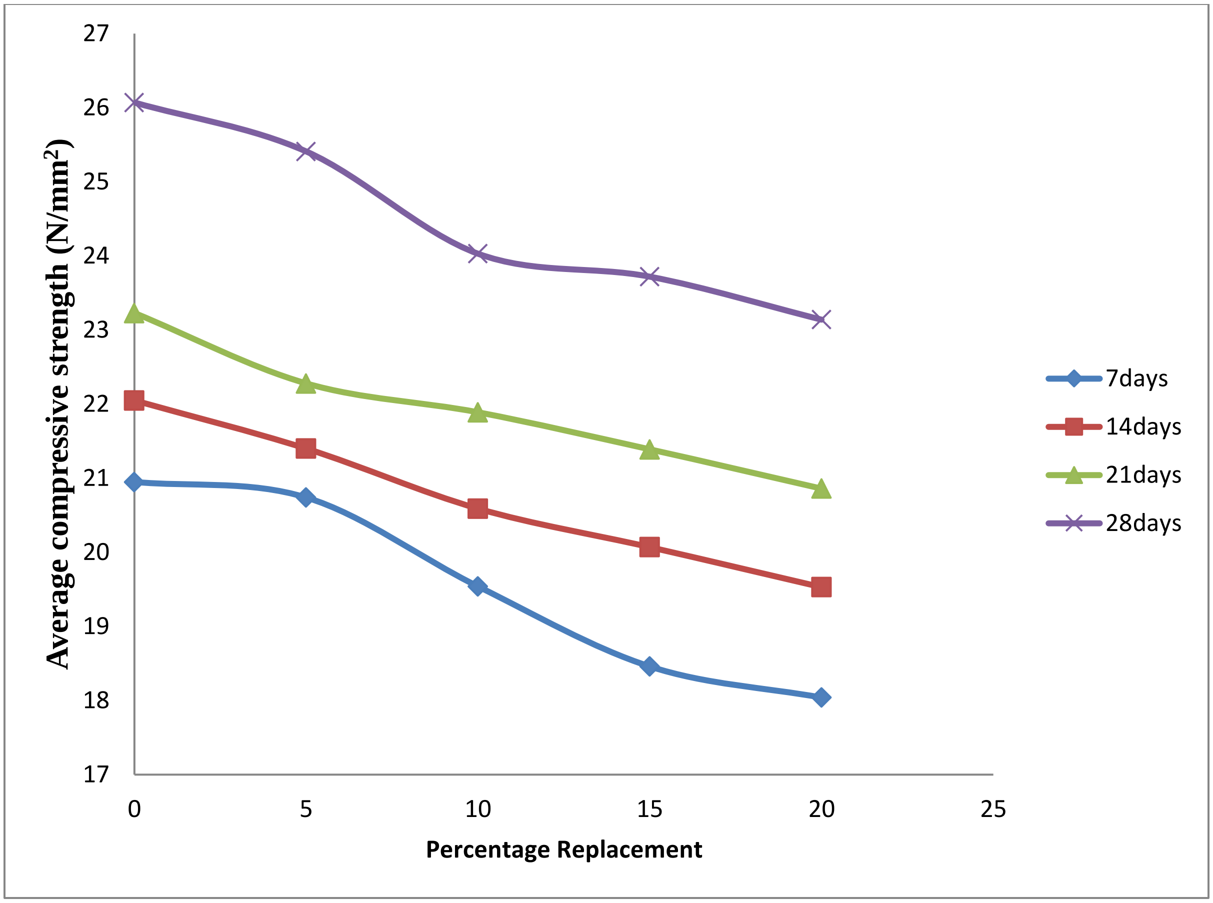

Figure 2: Compressive strength of Concrete

4 CONCLUSION

From the outcome of this study, the following conclusions were drawn:

1. The chemical composition of Waste Clay Bricks powder obtained for this research meets the ASTM C618 (ASTM, 2015) recommendation that for a suitable pozzolanic materials, the summation of the SiO_2, Al_2O_3 and Fe_2O_3 was 94% which according to ASTM C618 must not be less than 70%.
2. The fine aggregates samples were characterised to be medium grading using the tabular data in BS 882:1990 and also satisfy the overall grading limits for natural fine aggregates.
3. The compressive strength of concrete for the control specimen was higher than that of the mix with various percentages of Waste Clay Bricks powder replacement. However, with 5% of Waste Clay Bricks powder attains design compressive strength value which is closer to the compressive strength of the control mix concrete for all curing ages. Hence the use of Waste Clay Bricks powder to replace cement should be limited to 5%. Concrete

produced shows an increase in slump with an increasing cement replacement with Waste Clay Bricks powder. As much as of the total cost of cement in conventional method can be saved by this procedure.

5 RECOMMEDATION

Based on the outcome of the research, it is recommended that further research on flexural and splitting tensile strength should be carried out on the concrete with partial replacement of cement with clay bricks powder.

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