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Development of Suitablecement Stablized Clay Bricks From Oke-Adu Clay Soil Sample.

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ABSTRACTS:
This study examines the suitability ofthe locally producedcement stabilized clay bricksfor both residential and commercial buildings inAkureOndo State capital. The purpose of the study is to evaluate the suitability of a selected clay sample from Oke-Adu for the production of cement stabilised bricks.Atotal number of 60 Clay bricks stabilized with cement proportion of 5%, 10%, 15%,and 20%were produced in size of (150 x150 x150mm), observed for 7days, 14 days, 21days and 28days andthe compressive strength determined. The results showed that all stabilized brickswere above the minimum compressive strength recommended by NIBBRI and NIS at all mix percentages with varying results between 2.00N/mm^2 and 3.93N/mm^2)greater than the minimum 1.65N/mm^2 recommended. The study recommends that 5% and 10% cement content are suitablefor buildingconstruction purposes and can be affordablesince the clay material is sufficiently available in Akureenvironment/ locality..

Keywords:*Clay Brick, Sieve analysis, Mineralogy Content, Clay mining, Compressive Strength*

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I. INTRODUCTION

Over the years to own a shelter in Nigeria has been a major problem for the middle and lower classes of people due to highcost of building construction materials and maintenance. One way to address this challenge is to encourage investors to use locally available materials such as clay bricks.Clay material is well recognized worldwide. Many developedcountries such asAustralia,reinforced concrete and structural steelare receiving little attention in engineering courses; instead theyconcentrated their attentions on clay brickwork R SRI Ravindrarajah (2007). Clay bricksare used for wallinglow- rise commercial and industrial buildings with large wall panels, such as factories, warehouses, shopping centres, auditoriums including School and hospitals. For high-rise and medium-rise commercial and residential buildings clay bricks are also used for both Load and non-load-bearing walling including fire-rated wallingStephen and Gorse (2005). Clay materialcan be transformed into different construction materials such as bricks, blocks, and tilesof different types including roofing tiles.Transformation of clay soil into different materials was possible because of its composition, mechanical and aesthetic properties. Clay bricks can be used to replace wood, concrete and other construction materialsas it is being used in Scandinavian countries (Sweden, Norway, Denmark etc).Moreover, Clay bricks also can be recycled to attain its original quality. Due to its wide- ranging properties, high resistance to atmospheric condition, low tensile strength, hard high creep resistance, geochemical purity and easy access to its deposit near the Earth Surface and low mining cost such as its existence in Akure makes it suitable and affordable.Commercially produced clay bricks are scarcely found in the construction material market (Aiyewalehinmi and Aderinola, 2005). Reasons areattributed to construction industries and contractor'sinability to promote clay bricks as suitable material for all types of buildings. All commercially produced clay bricks at present in Nigeria are too expensive for both lower and middle class to purchase equally skill artisans are not available in everystates in Nigeria (Aiyewalehinmi and Aderinola (2015). Comparing the cost of commercially produced sandcrete blocks, with cement stabilized Clay bricks produced locally is economically cheaper and affordable than commercially produced blocks because only small quantity of cement is needed for stabilization (Aiyewalehinmi, E.O and Tanimola, M.O (2013). Nigerian Building and Road Research Institute (NBRRI) have been able to establish water absorption rate and compressive stress for both load and unload bearing wall for clay bricks.In addition clay brick is permeable when stabilized with Ordinary Portland Cement (OPC). The purpose of this study is to develop a locally suitable available and sustainable building and construction material that complies with NIS and NIBBRI requirement and is affordable by both middle and lower classes of people in Nigeria.

II. CLASSES OF CLAY MINERALS

There are three main groups of clay minerals, Kaolinite, Illite and Montmorillonite.

i) Kaolinite: Kaolinite is known to be the most dominant of residual clay deposit and made up of large masses of single tetrahedral sheets of silicate and octahedral sheets of aluminium. This type of clay mineral form strong structure, stable, absorbs little water with low swelling and shrinkage characteristics due to water content variations(Ravindrarajah (2007).

ii)Illite: Illitecomprise series of octahedral sheets of aluminium cram between two tetrahedral sheets of silicon. This type of clay mineral tends to absorb more water than Kaolinites, higher swelling and shrinkage characteristics.(Ravindrarajah 2007)

iii) Montmorillonite: It has similar structure with Illite group; demonstrate high water absorption, swelling and shrinkage characteristics. Bentonite belongs to this family or group.(Ravindrarajah 2007)**.**

2.2 Clay Mining

There are different methods used in mining clay, but it depends on the depth, thickness, hardness and physical geology of the clay beds. Surface clay, Shale and some fire clays are mined in an opened pit,manually and with the use of powerful equipment.To transform clay rock into plastic mouldable material it must undergone a process of grinding and mixing with water.

2.3Clay bricks

Clay Bricks are made from ground in mills mixed with water to become plastic and then moulded with either by hand or machine. Clay Bricks are mainly construction materials used only by building and construction industry (Stephen and Christopher, 2005). Clay Bricks processed by machine can be either hydraulically pressed in a steel moulds or extruded as a continuous band of clay. The continuous band of clay is cut into bricks by a wire frame. The moulded brick is baked to dry out the water and burned at higher temperature to blend the whole mass of the brick into hard durable units.

III. MATERIALS AND METHODS.

The Clay materials samples used in this study are raw clay soils dug and collected from Oke- Adu inAkure, North Local Government area of Ondo State Nigeria. The cement content used for stabilization was Ordinary Portland Cement (OPC) bought from Cement Deport at Oba Kekere South Gate, FUTA. The Clay soils samples were stabilized with Ordinary Portland Cement (OPC), using 5%, (3.725Kg) 10%, (7.45Kg) 15% (11.2 Kg) while and 20% (15Kg), while the zero percent control was 74.5Kg.All clay brick samples produced were stabilized andcured for 7 days, 14 days, 21 days and 28 days and then tested for water absorption and compressive strength.

3.1 Sieve Analysis:

The collected Clay samples collected from Oke-Odu, Akure North Local Government area were washed with clean water to get off the impurities and kept in the oven for 24 hours to dry. Sieve analysis was performed to determine the particle size distribution. The total weight of clay soil retained on each sieve was calculated using the following formula.

The percentage loss during the sieve = $\frac{W - W_1}{W} X\,100$ (1)

The sieve analysis is presented in the Table 1.0. The results show that sample is a fine grain soil with more than 90 percent passing through 4mm and about 4% pass through 75 μm. Figure 1.0 shows the gradation chart.

Table 1.0: Particle size distribution of Clay Soil Sample

Particle Size Distribution (PSD) of Clay Soil Sample				
SIEVE Size	Weight Retained (g)	% Weight Retained	Comm. of % Retained	% Passing
3.75 mm	17.4	3.82	3.82	96.18
2.36 mm	81.6	15.9	19.72	80.28
1.70 mm	70.1	12.06	31.78	68.22
1.18 mm	65.4	11.54	43.32	56.68
600μm	115	24.59	67.91	32.08
500 μm	94.5	18.9	86.81	13.19
425 μm	3.1	0.58	87.39	12.61

212 µm	48.8	9.76	97.15	2.85
150 µm	6.2	1.28	98.43	1.58
75 µm	5.0	1.1	99.53	0.40
PAN	2.9	0.47	100	0
	500			

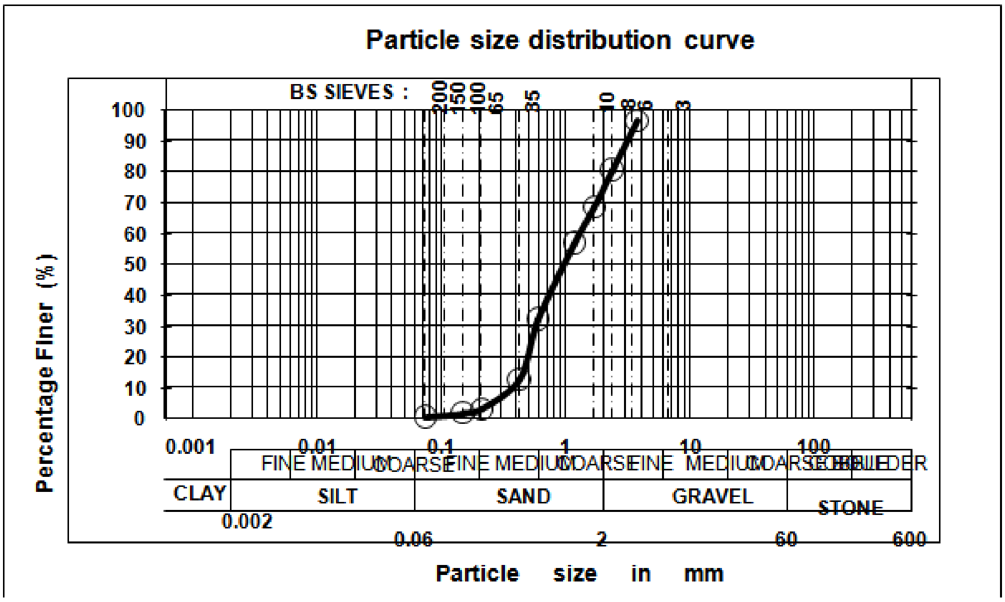

Figure 1.0: Particle size distribution **(**PSD) of Clay Soil Sample used.

3.2 Methods used for the production of brick samples for the study

Locally fabricated steel mould of dimension (150 x 150 x 150) mm was used for the production of clay brick samples. The production process includes: batching, mixing, casting and compaction. The weight of materials used for the production of the sample bricks were measured in accordance with the predetermined percentages of cement content (5%, 10%, 15% and 20%). The optimum moisture content was used for the production.

3.2.1 Batching

The clay soil and cement contents were measured in kilogram (kg)in accordance with determined selected percentages for stabilization. They were mixed thoroughly using locally made shovel to spread and mix comprehensively and adding clean water until optimum moisture content is reached. The optimum content (OMC) was determined by wetting the soil and adding handful of clay soil, compressing and pressing using hand until it becomes hard and flat, the height is approximately 1.10m. There was indication that the mix had already been broken into five parts as recommended by National Building Code 2006. Then the steel mould used was freed of impurities, and sprayed with oil to enhance easy removal from the steel mould. The wet mixture was filled into the mould in three layers; each layer was compacted with a rod of 25 blows. The top was levelled using a straight edge. They were left for two hours before being removed from the mould. They were labelled for referencing and covered with sacks for 24 hours to allow sun to dry them individually.

3.2.2Unfired Clay Bricks

Unfired clay masonry construction can be used for load bearing and non- load bearing walls. In the United Kingdom, traditional unfired clay block (clay lump) buildings are common in some areas of East Anglia. The modern use of unfired clay bricks offer opportunities for much thinner clay block wall construction (appropriate 105mm) than practice (150mm -300mm). It has been observed that thin walls of unfired clay bricks are best suited to non-load bearing partition walls within weather proof building envelope (Stephen and Gorse 2005). According to these authors unfired clay bricks are durable cheaper and can be affordable by all classes in the society.

IV. ANALYSIS OF RESULTS

Figure 2.0 below shows the variations in percentage cement for the stabilization of Clay with the control percentage. The control percentage value is 0% while the percentages of cement used for stabilisation are 5%, 10%, 15% and 20%.(3.75kg, 7.45kg, 11.2kg and 15kg respectively) Ordinary Portland Cement (OPC) were used to replace clay soil as a stabiliser.:

4.1Determination of the volume of mould:

Volume = $0.15m^*0.15m^*0.15m = 0.0034m^3$ (2)

12 bricks were used and total weight is 1826kg

The volume of 12 bricks = $0.0034^*12 = 0.0408m^3$ (3)

4.1.1For the determination of the mass of clay for the bricks are $0.0408m^3$ hence the wet density of the 12 bricks is $1826kg/m^3$

Mass of clay = (wet density*volume) is 74.5kg (4)

4.1.2 For 5% cement admixture:(3.725kg of cement) was used to replace 3.725 kg clay soil.

The same calculation method is used for all the admixtures

Percentage of Cement Admixture	Total net clay
5%	3.725kg
10%	7.63kg
15%	11.175kg
20%	15kg

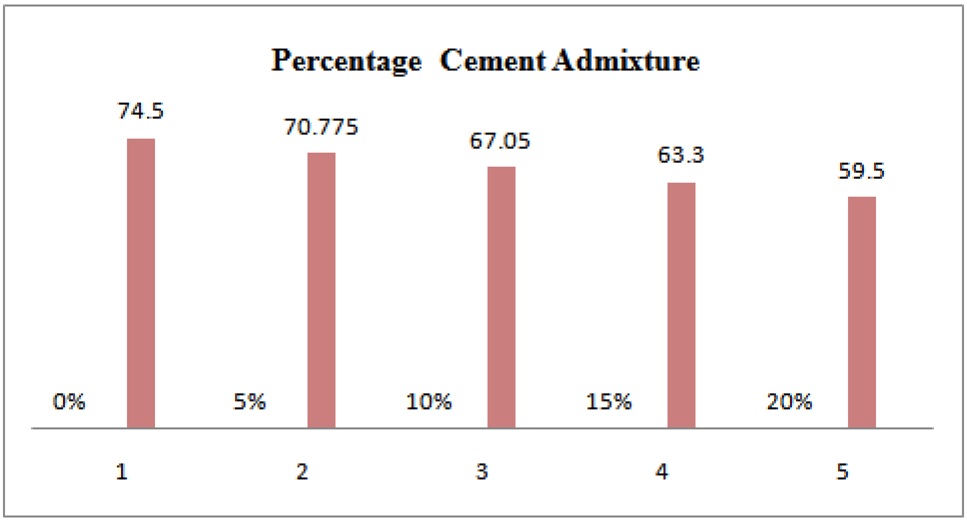

Figure 4.1 Clay Cement mass percentage obtained

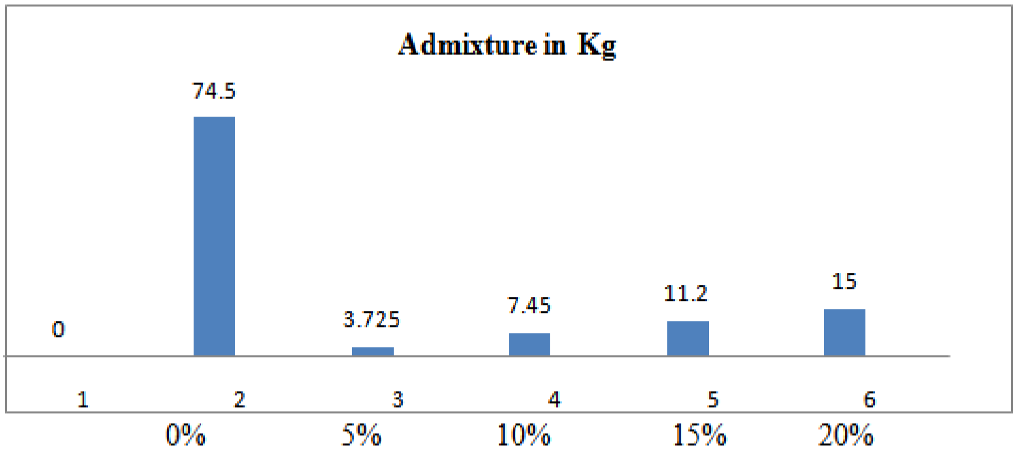

Figure 3 variations of cement in clay kilogram (kg)

4.2Hydrometer Test

Hydrometer Test was conducted by adding the dispersing agent to the distilled water in the proportion of 40gram of sodiumMetaphosphate to 1000ml room temperature distilled water. The temperature of the solution was taken to the nearest 0.1°C. The thermometer was extended to approximately half depth of the solution and the value was recorded. The Standard elapsed time of reading schedule was considered to 2, 5, 15, 30, 60, 250 and 1440 minutes. The following methods were used for the calculation.

a) Corrected reading = hydrometer reading + 3
b) K was obtained from table using specific gravity of 2.56
c) L was obtained from the table using H125h hydrometer used for the study
d) D = diameter, can be obtained using the this formula $D=K\sqrt{L}/T$ (5)

where T = time lapse in the Table

e) a = correction factor. The value of a for the material used is 1.01
f) Ws = weight of sample used for the test

g Partial % passing=$\frac{(RxaX\ 100)}{Ws}$ (6)

a) % passing = $\frac{Y \text{ x partial \% passing}}{100}$ (7)
b) Y is =% passing through 75µm sieve

Hydrometer carried out on the soil samples passing through 75µm sieve. The test shows that the soil consists about11% of clay. According to NBBRI 15% or less is suitable for bricks. The results are indicated on the Table 4.2 and replicated in figure 4.0 and 5.0.

Table 4.2 Hydrometer Test Results

HYDROMETER TEST RESULTS								
Time	Temp.	Hydro. Reading	Adjusted Reading	K	L	D (mm)	% Pass Partial	% Pass Total
0.5	24	35	38	0.01321	10.1	0.059	63.97	54.628
1	24	22	25	0.01321	12.2	0.046	42.08	35.939
2	24	20	23	0.01321	12.5	0.033	38.72	33.064
5	24	14	17	0.01321	13.5	0.022	28.62	24.439
10	24	12	15	0.01321	13.8	0.016	25.25	21. 564
15	24	11	14	0.01321	14.0	0.013	23.57	20.126
30	24	10	13	0.01321	14.2	0.009	21.88	18.688
60	24	7	10	0.01321	14.7	0.007	16.83	14.378
120	24	6	9	0.01321	14.8	0.005	15.15	12.938
240	24	5	8	0.01321	15	0.003	13.47	11.501
1440	24	4	7	0.01321	15.2	0.001	11.78	10.063

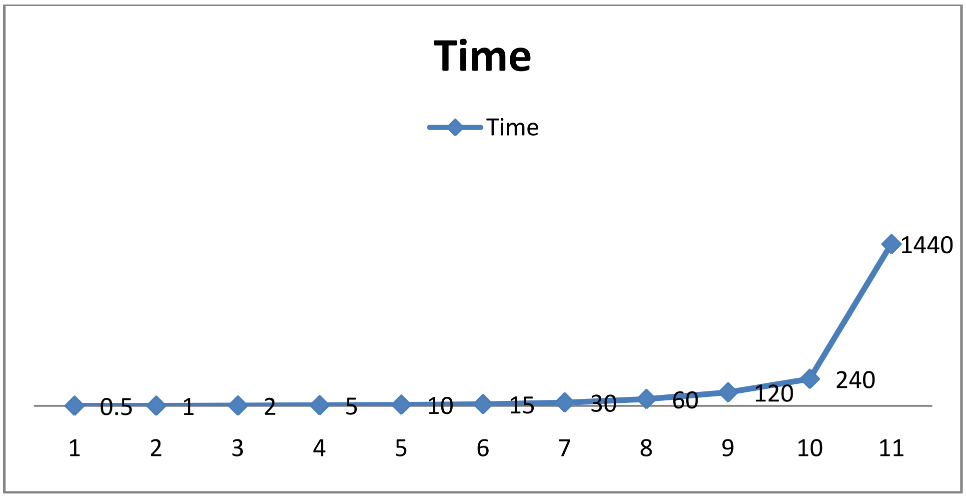

Figure 4.0: Time elapse for Hydrometer Analysis

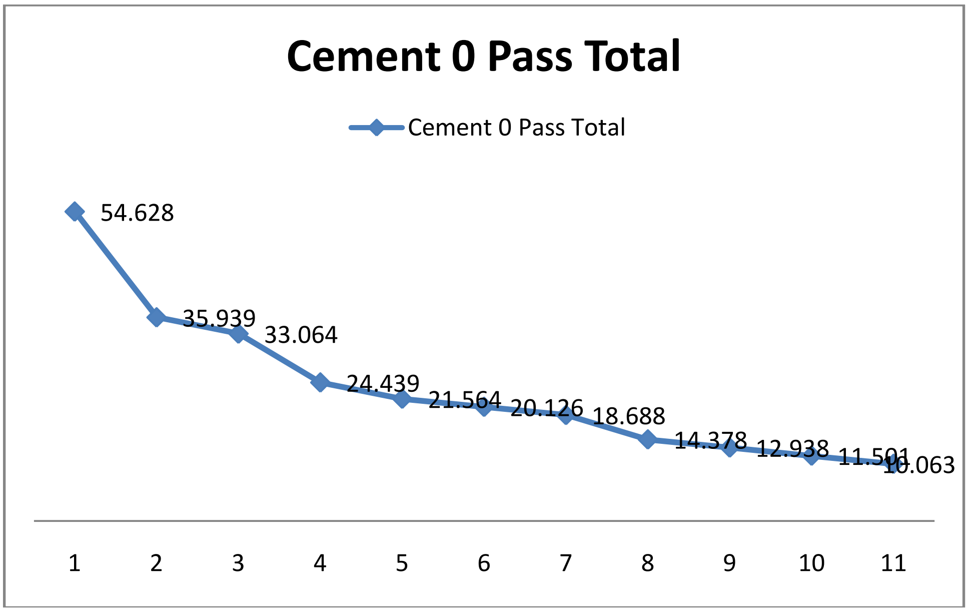

Figure5.0 CementHydrometer Analysis

4.3.0Atterberglimit test

Atterberg limit test was also conducted to determine the general relationship between moisture content and boundary limit. The limits are referred to as liquid and plastic. The results are shown in Table 3.0 while the figure is shown in Figure 6.0. The sample had a liquid limit of 32%, plastic limit of 23.5%, Plasticity index 8.5% and shrinkage limit of 6.82%. It can be regarded as soil of low plasticity.

4.3.1Plastic Limit

Approximately 20g of dry sample passing through the No 40 sieve into a dish, water was added and mixed thoroughly. From this plastic test the mass of the moisture content was determined (W_1). This test was repeated again two times to determine the average plastic limit of the soil.

4.3.2Liquid Limit:

Liquid Limit test was conducted to determine the water content. The experiment steps were repeated at higher water content rate due to number of drops. As the water content increases, the number of blows tend to decrease. The number of blows was recorded. The relationship between the water content and number of blows is shown in the Figure 4.4. As can be seen in the Figure N is plotted against semi-logarithmic graph with water contents as the ordinates and arithmetic scale and number of blows on the abscissa including the best fit line. Then the Plasticity Index was calculated using the following formula:
PI = LL – PL, LL= Liquid Limit while PL = Plastic limit.

Table .3.0 Liquid and Plastic Limit

LIQUID AND PLASTIC LIMIT RESULT						
		LIQUID LIMIT			PLASTIC LIMIT	
Container no	**A**	**B**	**C**	**D**	**A**	**B**
No of blows	**34**	**26**	**20**	**14**		
Wt container (g)	42.9	49.5	44.2	43.3	28.9	29.70
Wtcont + wet soil (g)	49.2	54.5	50.0	46.8	34.0	34.60
Wtcont + dry soil (g)	47.8	53.2	48.5	45.9	32.9	33.80
Wt moisture (g)	1.4	1.2	1.5	1.0	1.1	0.8
Wt dry soil (g)	4.9	3.7	4.3	2.6	4.0	4.1
Moisture content (%)	27.8	32.5	35.0	37.7	27.5	19.5
LL (%) = 32				PL(%) =23.5		
Plastic index = 8.5						

The Table 4.3 above shows the Liquid and Plastic Limit results including number of containers and the number of blows. The Weight of container are in grams, the container + wet soil, the weight of + dry soil, including the weight of wet soil and dry soil and the percentage of Moisture content are indicated on the Table. The Liquid Limit is shown in A –D while plastic Limit is labelled A and B. All the readingsare indicated on the table. The calculation shows that Liquid limit to be 32% while Plastic is 23.5% and Plastic index is 8.5%. This shows that the soil of low plasticity. These results are also shown in the figure 6.0..

4.4 Specific Gravity

The sample was kept in the oven for 24 hours to dry. The weight of the glass jar and the lid were taken and recorded. The formula given below was used to calculate the specific gravity of the sample soil.

$$Gs = \frac{(W2 - W1)g}{[(W2 - W1) - (W3 - W4)]g} \quad (8)$$

While

W1 = weight of empty glass jar + lid

W2 = weight of sample + jar + lid

W3 = weight of sample + jar + water + lid

W4 = weight of jar + water + lid

Results are indicated as follows:

W4 = 548.1g

W3 = 578.6g

W2 =258.6g

W1 =208.6g, and

$$Gs = (W_2-W_1) = \frac{(W2-W1)g}{[(W2-W1)-(W3-W4)\}^g} \quad (9)$$

Gs = 2.56.

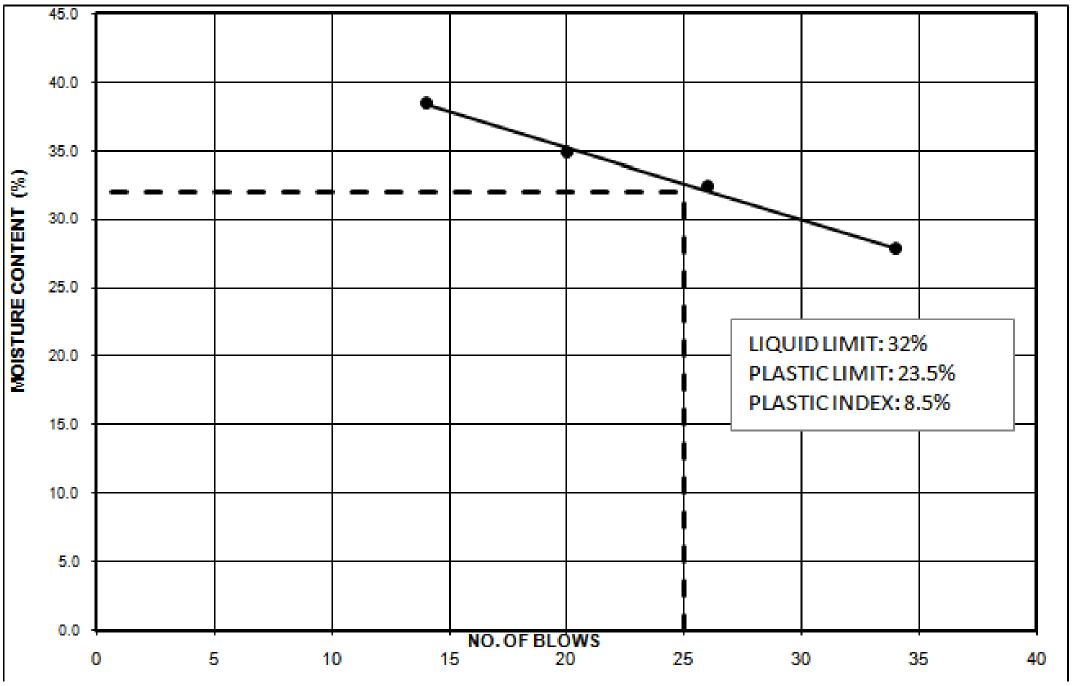

Figure 6.0 Graph of moisture content against no. of blow

The result obtained falls within clay soil range of NIS Recommendation.

4.5 Water Absorption

Three bricks were selected from the group of the specified age, and weighed on a scale balance. These bricks were completely immersed in water for 24 hours;thereafter they were removed and weighed again. The water absorption capacity of the bricks can be expressed in percentage using the formula below.

$$Wa = \frac{(Ww - Wdx\ 100)}{wd} \quad (10)$$

Wa =Percentage moisture absorption

Ww = weight of wet bricks

Wd = weight of dry brick

The results of the absorption tests are presented in the Table 4.0 The results show that water absorption rate in 5% to be 8.54% and 3.66% in 10%, these fall below maximum range recommended by NIS of 12%. Therefore 5% and 10% cement stabilization satisfy NIS recommendation. While 15% and 20% cement stabilization, water absorptionratewere 13.88% and 15.61 % respectively which were higher than the maximum

12% recommended by NIS. Alsowith 0% stabilization (control), the result did not support NIS recommendation.Most of the bricks dissolved in the water and they were unable to be measured. The results are also indicated in the figure 7.0

Table 4.0 Results of Water Absorption Rate

Cement % Stabilization	Dry Mass (kg)	Wet Mass (kg)	Average Dry Mass (kg)	Average Wet Mass (kg)	Average Mass Water Absorbed (kg)	Average Water Absorbed (%)
0	4.95	0.00				
0	4.85	0.00				
0	4.90	0.00	4.90	0.00	0.00	0.00
5	5.65	6.70				
5	6.60	6.30				
5	5.90	6.70	6.05	6.57	0.52	8.54
10	6.40	6.40				
10	6.25	6.60				
10	6.45	6.80	6.37	6.60	0.23	3.66
15	6.15	7.00				
15	5.75	6.50				
15	5.75	6.60	5.88	6.70	0.82	13.88
20	5.60	6.00				
20	5.70	7.00				
20	6.00	7.00	5.77	6.67	0.90	15.61

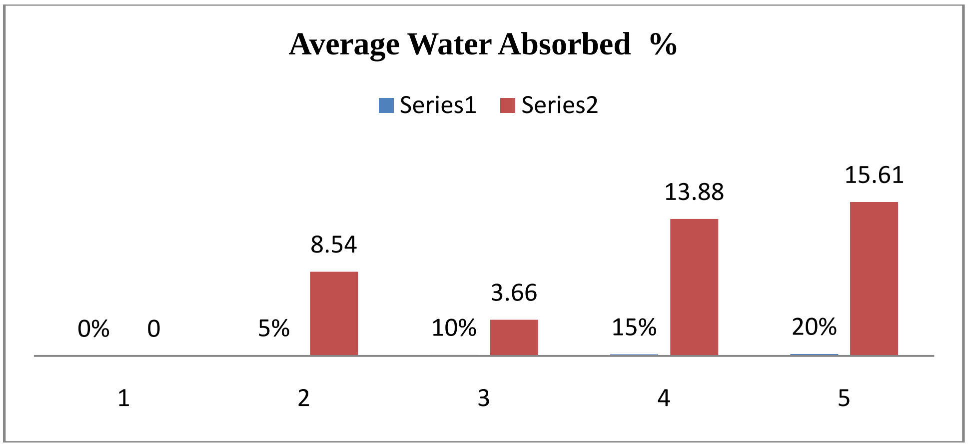

Figure 7.0: Brick water absorption rate % (28 days)

Table 5.0 shows the average dry density test results obtained for 7, 14, 21, and 28 days. As can be seen on the table, the control which is the 0% is indicated in the first column followed by 5%, 10%, 15% and 20%. The results are shown on the Table 5.0 and figures 8.0 (0%, 5%, 10% 15% and 20%) combined results (7, 14, 21 and 28 days) shown in the figure 8.0 represents 28 days.

Table 5.0 Average Dry Density(kg/m^3), (7, 14, 21 and 28) days

Average Dry Density(kg/m^3), (7, 14, 21 and 28) days				
7 days		14 Days	21 Days	28 Days
0%	1456.79	1456.79	1456.79	1456.79
5%	1807.41	1762.96	1792.59	1827.16
10%	1817.28	1861.73	1886.42	1906.17
15%	1733.33	1758.02	1743.21	1846.91
20%	1728.40	1777.78	1708.64	1748.15

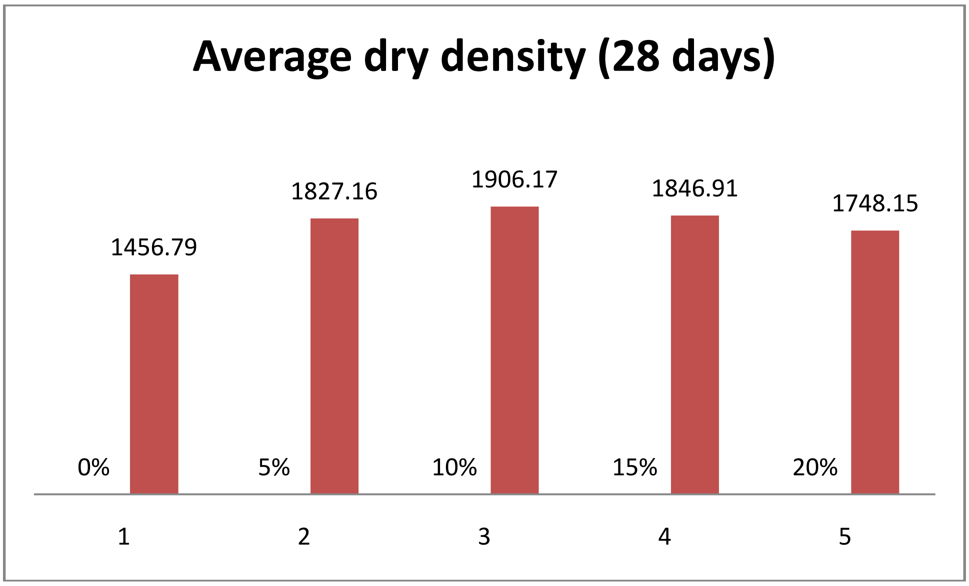

Figure 8.0: Average percentage of Dry Density 28 days

4.6Compressive Strength

Each of the brick samples produced was crushed to determine individual compressive strengths. Each brick was weighed and carefully set at the centre of the plates of the compression testing machine before crushing. The crushing /failure load of each brick was recorded and the compressive strength was determined. The results are shown on Table6.0.

Table 6.0 Average Compressive Strength for 21 and 28 days.

Average Compressive Strength N/mm^2 21 & 28 (days)				
21 days			28 Days	
Cement %	Average crushing (kg)	Average Compressive Strength N/mm^2	Average crushing (kg)	Average Compressive Strength N/mm^2
0%	11.67	0.52	13.33	0.59
5%	43.33	1.93	45.00	2.00
10%	58.33	2.59	66.67	2.96
15%	65.00	2.89	73.33	3.26
20%	86.67	3.85	88.33	3.93

From the tests' results shown on figure 9.0, all additives' percentages (5%, 10%, 15% and 20%) satisfy mixture NIS and BS3921 recommendation of 1.56N/mm^2 minimum except the control (0%) value of 0.59N/mm^2 which was below NIS and BS3921 recommendation of 1.56N/mm^2 minimum standard. As observed from the figure, the compressive strength varies for 0%controls to 20%.Cement stabilizedof (0. 59 to 3.93) the weak compressive strength attained by control samples may be associated with natural condition of clay soil because there is no binding agent and incubation circulation period.Thecement stabilized clay bricks samples 15% and 20% can be recommended as load bearing walling bricks while5% and 10% samples are used as non-loading bearing bricks.

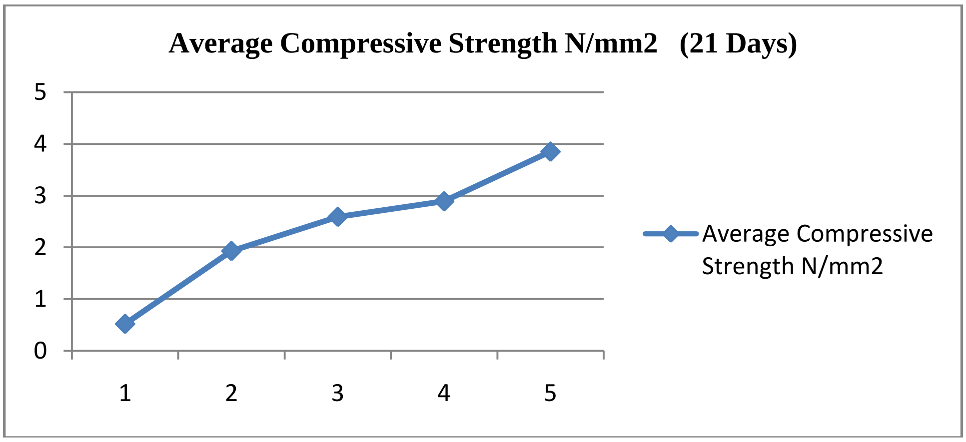

Figure.9.0a: Compressive Strength at 21days

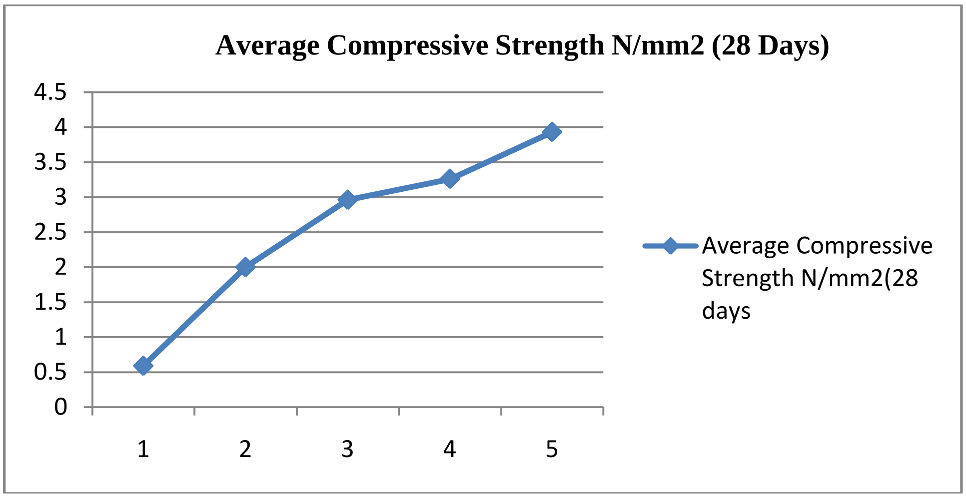

Figure.9.0b:Compressive Strength at 28day

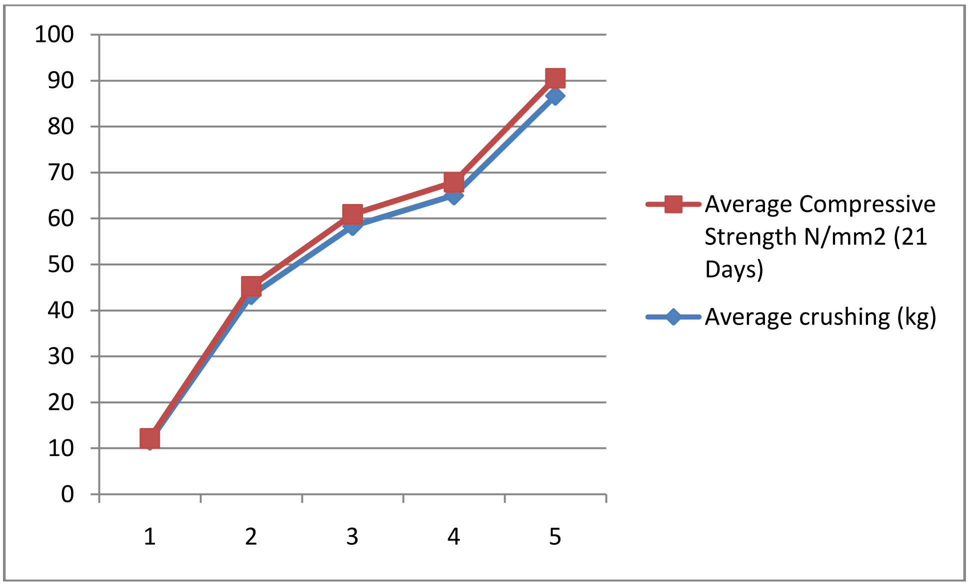

Figure.9 .0c: Average Compressive Strength and crushingload (kg) at 21 days

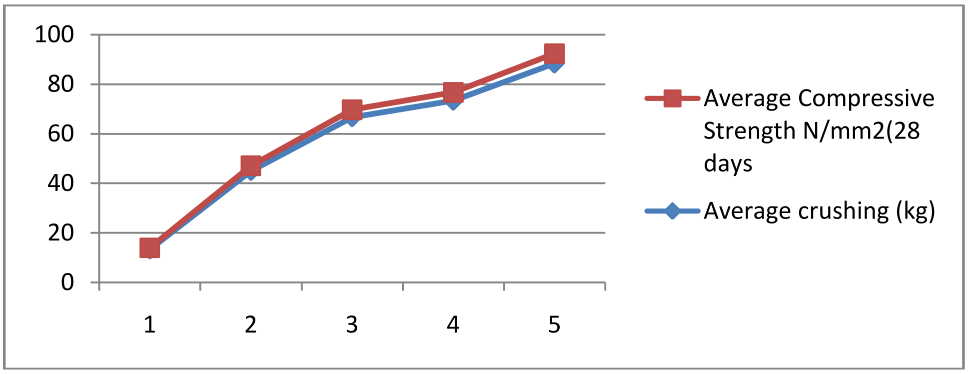

Figure.9.0d: Average Compressive Strength and crushing load(kg) at 28 days

V. CONCLUSION AND RECOMMENDATION

The test results obtained from the analysis of this study showed that clay soil components obtained from Oke- Adustabilized with cement are suitable for the production of clay bricks and also good for both load and non-load bearing walling construction according to (NIS & BS 3920) recommendation/requirement.The findings show that the compressive strength of clay bricks stabilized with 5%, 10%, 15% and 20% of Ordinary Portland Cement (OPC) content, produced at the Federal University of Technology, Akure, Department of Civil and Environmental Engineeringsatisfies the requirement of NIS 2004, NIBRI 2006 and BS: 3920 except the controlsample with 0% cement. From thisstudy, it was identified at both 5%and 10% cement admixture or stabilized is virtually suitable and durable as construction materials compare to commercially produced sandcrete blocks. The study recommends that at both 5% and 10% cement stabilised clay bricks is suitable,affordable, and highly functional, and durable.In this context the study shows that Cement stabilized clay bricksatisfies both loading and non-loading walling structures. All 60 clay bricks samples produced have attained or reached 28 days and have attained highest compressive strength required by (NIS 2004, NIBRI 2006 and BS: 3920).

VI. RECOMMENDATION

Construction Industry should encourage investors to use clay brick treated with cement because of theirstrength durability and low maintenance requirement. 5% and 10% of Cement stabilized clay brick is identified for construction of any building structures except very high load bearing engineering structures. Even at 5% cementstabilized it is highly recommended for load and non-load bearing structures. Cement stabilized clay bricks is highly recommended in Nigeria because it is durable, safer, and also satisfies both NIBRRI and NIS: 87 2004 recommendation or requirement. All Sandcrete blocks commercially manufactured in Nigeria fall below both NIBRRI and NIS: 87 2004 recommendation except International Construction Companiessuch as Julius Berger and RCC.

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