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Strength Properties Of Commercially Produced Clay Bricks In Six Different Locations/ States In Nigeria

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Abstracts: - The purpose of this study is to verify whether commercially produced Clay Bricks contribute to collapsing of buildings in Abuja, Oyo, Lagos, Ondo, Edo and River States. **72** different Clay Brick industries were visited in which **six industries** were randomly selected for the study. **Seventy Two Commercially Produced Clay Bricks** including the clay soil **samples** were purchased. They were transported to the department of Civil Engineering Geotechnical Soil and Concrete Laboratory FUTA for analysis. The following Tests were conducted: Sieve Silt Clay, Organic Content, and Compressive Strength. All these tests were performed to ascertain if these commercially purchased clay bricks conform with the **NIS 87: 2000, BS 3921: 1965,** which specifies that the lowest compressive strength for Load bearing units **2.5N/mm^2** while **highest is 5.0N/mm^2**. The results showed that the compressive strength obtained was between 1.509N/mm^2 and 13.43N/mm^2. All Clay bricks purchased are suitable except B samples Akure 1.509N/mm^2.

Keywords: *Clay Brick, Sieve analysis, Organic Content, Load bearing, Compressive Strength*

I. INTRODUCTION

The rapid deterioration of construction materials and collapse of building frequency in Nigeria indicated that there is a need for proper evaluation of construction materials in the building and construction industry in the country. Construction materials include: Timber, cement, concrete, bricks, blocks and others. This study focuses on commercially produced Clay Bricks. Clay Bricks has not gained popularity in Nigeria as compared to Sandcrete or Concrete blocks. Clay Bricks are widely used as walling units or partition, often as a load bearing walls in the developed world. In the past two decades there was a controversy over the use of Clay bricks in Nigeria. Few Contractors argued in favour while other parties critically kicked against it. As a result Building and Construction Industries declined to promote Clay Bricks as cheap, durable engineering material that is locally available and maintenance cost is very low. Construction project original and maintenance costs are always consider together against the useful life expectancy of the materials being selected or used. Also, often a low cost means high maintenance cost while high cost means low maintenance cost. In Nigeria Clay Bricks are commonly used for fences except few government and individual buildings. Building investors in Nigeria are not looking at durability and availability of raw clay materials including low maintenance costs due to the industry ignorance. The earlier controversy surrounding clay bricks in Nigeria can no longer hold especially with modern technology, improvement in construction techniques and the availability of raw materials existing in every state in Nigeria, Clay Bricks may soon replace the popularity of Sandcrete blocks. In line with this development in Building and Construction industry, there is a need for researchers to investigate the quality of commercially manufactured Clay Bricks available in Nigeria construction material market. In an attempt to reflect the importance and durability of Clay Bricks, John Hodge (1993) described bricks surface textures as smooth, fine and combed made of varieties of colours. Similarly, Andam K.A (2004): classified brick into two categories: sizes/shape and usage. He went further to comment on physical properties, appearance, strength, size and visual inspection of Clay bricks manufacturers. According to ASTM Specification C16, three types of bricks are recognized and distinguished (FBS, FBX and FBA). The distinction between them is based on colour range, variation in texture, architectural effect and mechanical perfection. Commonly used dimension or sizes found in Nigeria market ranges from 148mm × 165mm× 315mm, 115mm x 215mm x 2300mm, 65mm x 117mm x 247mm, 132mm x 147mm x 250mm, 120mm x120mm x250mm and 150mm x 200mm x335mm. There may be others beyond the scope of this study. The purpose of this study is to investigate, test and justify the quality and strength properties of clay bricks commercially manufactured in Abuja, Akure, Edo, Lagos, Oyo and Port Harcourt. It is believed that the quality may vary from one industry to another; however, the study is designed to determine the quality of commercially produced Clay bricks in Nigeria.

II. BRICKS AND BRICKWORK

The word Brick is used to describe a small block or burned clay which is small in size, slightly longer in length twice than its width and it can be conveniently held in one hand. There are different types of Bricks such as concrete bricks, glass bricks, Clay bricks and sand- lime bricks. The most common brick today is clay brick. Clay bricks are widely used worldwide. The standard brick sizes available in Nigeria construction material market are not different in sizes from the rest of the world. Brickwork, with 10mm Mortar increases the sizes of the bricks for example 148mm+ 10mm becomes 158mm, 165 +10 =175 and 315 +10 becomes 325mm (158mm X 175mm X 225mm). 125mm x 225mm x 240mm, 75mm x 127mm x 257mm, 142mm x 157mm x 260mm, 130mm x130mm x 260mm and 160mm x 210mm x345mm. These types of clay bricks are produced commercially in different sizes and shapes into Nigerian building and construction material markets.

2.1 Clay Bricks:

Clay raw materials differ in composition from one part of a field site to another site of the same environment. Clay dug from one part of a field may be differing from the other part of the same field (Stephen and Christopher 2005). Clay is ground in mills, mixed with water to make it plastic and then molded either by hand or machine to shape and size of a brick. Brick that are shaped and pressed by hand in a sanded wood mould and then dried and fired have a sandy texture are irregular in shape and colour, they are used as facing bricks due to the variety of their shapes, colour and texture. (McKay, W.B 1970). Machine made bricks, are either hydraulically pressed in steel moulds or extruded as a continuous band of clay. The continuous band clay, the section of which is the length and width of a brick, is cut into bricks by a wire frame. The molded brick is baked to dry out the water and burned at a high temperature so that part of the clay fuses the whole mass of the brick into a hard durable unit (Stephen and Christopher 2005). Clay is suitable for brick making because of its wide variation in composition and also possible to burn bricks over a wide range of temperature sufficient to fuse the material into a durable mass. Clay Bricks may be classified into common, facing and engineering bricks depending upon what they are intending to use them for (Hodge, J. 1993) Engineering Bricks are made from selected Clay that have been carefully prepared, heavily molded, thoroughly burned and safely capable of carrying much heavier loads than other type of bricks (RSRI Ravinindrarajah 2007). These types of bricks are exceptionally hard, dense, low porosity and absorb very little water. Engineering bricks are commonly used for walls carrying exceptionally heavy loads for brick piers and general engineering works. The compressive strength of brick is found by crushing individual brick until it crumbles or fails. The crushing resistance varies from 3.5N/mm^2 for soft facing brick up to 140N/mm^2. .

2. 2. Water Absorption and Suction

The amount of water a brick can absorb is a guide to its density, thus its strength in resisting crushing. The level of water absorption is critical for bricks to be used below Damp Proof Course (DPC) level or for damp courses. Mostly absorption rates vary between 1% and 35%. Brick with high suction rates absorb water rapidly from the mortar and it is very difficult to reposition them as work proceeds. Normally, bricks manufacturers usually provide information on suction rates. The disadvantage is that, increase in moisture and heat can causes brick to expand (Stephen and Christopher 2005). Generally, when bricks shrink it will not return to its original position and this will eventually cause cracks.

2.3. Efflorescence

Clay Bricks contain soluble salts that migrate in water to the surface of brickwork. The efflorescence of white salts is mostly visible in Parapet walls, Chimneys and below DPCs where brickwork is most liable to saturation (Clay Bricks Industry Brochure). The concentration of salts depends on the soluble content of the brick and the degree and persistence of saturation of brickwork. When brickwork is persistently wet as in foundations, retaining walls, parapets, and chimney, sulphates in bricks and Mortar may crystallize and expand and cause Mortar and rendering to disintegrate, to minimize this effect, Bricks with low sulphate content may be considered.

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2.4. Bonding Bricks

Bricks are usually laid in horizontal courses so that each brick bears on two below. In this way bricks are considered bonded. The advantage of bonding is that the wall acts as a whole so that the load of a beam carried by topmost brick is distributed or spread to the bricks below and transferred to the foundation. In addition the poor quality of one brick will not affect the strength and stability of the whole wall. The load carried by the weak brick is transferred to the foundation immediately. In construction engineering material, the strength of a material must be related to its weight. In Construction design, the ratio of **strength/weight** is the governing factor. The **strength** of Brick is **45 Mpa (Compression**), **Weight is 2200 kg/m^3**, **and Strength MPa/Weight Kg/m^3 is 0.022. Properties of Clay Bricks include: Density 1900kg/m^3, Tensile strength 3Mpa, Elastic Modulus 20 GPa, Toughness low, Hardness Hard and Creep resistance High (BS 3920 and NIS.87; 2004).**

2.4.1 Clay Brick Embodied Energy include:

Extrusion Low, Manufacture high brick 1100^{o} C, Transportation fairly high due to high Density, Cost in use very low (material durable) overall Clay brick is high energy cost, but it is recyclable. Clay brick is an engineering material which is required to meet the appropriate standard engineering material definition. Based on Structural and Geotechnical application plus material components, Clay bricks should be uniform in production to meet construction regulatory and civil engineering standard definition (ASTM, NIS and BS).

III. RESEARCH APPROACH AND SAMPLING

The samples for the study were collected from six different locations in Nigeria, this include: Abuja, Akure, Benin, Ibadan, Lagos and Port Harcourt. Seventy two Clay bricks were purchased all together, Twelve bricks samples from each manufacturing site including clay soil samples used for molding the Bricks and They were transported to the Federal University of Technology Akure (FUTA), Department of Civil and Environmental Engineering Geotechnical and Concrete laboratory to carry out clay soil tests and compressive strength tests. The purpose of quantities of clay soil samples purchased was basically to ascertain their suitability for the brick and to verify whether these bricks are produced in line with the recommendation of BS3921. There were two types of samples purchased; hollow and solid bricks having dimensions as shown in the Table 1 below. Then three bricks were selected from each manufacturer as labeled on the Table 1 below.

Table 1 Types of Commercially clay bricks.

Manufacturer ID	Location	Types Bricks	Dimension of Samples (H X W X L)MM	Volume (M^3)	Net Area (MM^2)
A	Abuja	Hollow	148X 165X315	7.69X10^{-3}	5.20X10^{-2}
B	Akure	Solid	115X215X230	5.69X10^{-3}	4.95X10^{-2}
C	Benin	Solid	65X117X247	1.88X10^{-3}	2.89X10^{-2}
D	Ibadan	Hollow	132X147X250	4.85X10^{-3}	3.68X10^{-2}
E	Lagos	Hollow	120X120X250	3.66X10^{-3}	3.0X10^{-2}
F	Port Harcourt	Hollow	200X 150X 335	1.01X10^{-3}	5.03X10^{-2}

Three samples were selected from each industry for analysis.
Determination of Volumes, Area and Density
Determination of samples in (mm^3) from Abuja Hollow
Volume= HXWXL = (148X165X315) mm = 7692300mm^3 or 7.69 x10 $^{-3}$m^3
Total volume of big holes: (3 holes)
Volume = (148 x 66 x74)mm^3 =722832mm^3 x3 =2168496mm3 or 2.17x10^{-3}m^3
Volume of small holes (26 holes)
V=148x20x20mm^3=59200mm^3 x26 holes =1539200mm^3 or 1.54 x10^{-3}m^3
The total volume of big and small holes of all Brick samples (A)
Total =2168496mm3 + 1539200mm^3 = 3707696mm^3 or 3.71x10^{-3}m^3

Area determination of samples from Abuja
Area = Length x Width (mm^2)= (165 x 315)mm = 51975mm^2 or 5.20x10^{-2} m^2
Area of big holes = 66x 74 mm =4884mm^2 x 3 holes = 14652mm^2 =1.47x10^{-2} m^2
Area of small holes (26holes)
Area = (20x20)mm = 400mm^2 x 26 holes =10400mm^2 =1.04x10^{-2}m^2
Total (big +small) holes = (14652 +10400)mm^2 = 25052 mm^2
A Net Area =(51975-25052)m m^2 =26923 mm^2 = 2.69x10^{-2}m^2

Density determination of Sample from Abuja (A) Hollow

$$\text{Density } \rho = \frac{\text{Mass of Brick (kg)}}{\text{Dimensional volume of (mm)}^3} \quad (1)$$

Density before immersed ρA1 = 6.4

$3.71x10^{-3}m^3$
$= 1725.07kg/m^3$

ρA2= = 6.7/ $3.71x10^{-3}m^3$ =$1805.93kg/m^3$
ρA3 = 6.4/ $3.71x10^{-3}m^3$ = 1725. $007kg/m^3$
Density after Immersed in water;
ρA1 =7.4/$3.71x10^{-3}$ m^3 = $1994.61kg/m^3$
ρA2 = 8.0/ $3.71x10^{-3}$ m^3 =$2156.33kg/m^3$
ρA3 = 7.6 / $3.71x10^{-3}$ m^3 = $2048.52kg/m^3$
Density Oven Dry
ρA1 =6.4/ / $3.71x10^{-3}$ m^3 = $1725.07kg/m^3$
ρA2 = 7.5 / $3.71x10^{-3}$ m^3 =$2021.56kg/m^3$
ρA3 =7.1 / $3.71x10^{-3}$ m^3 = $1913.75kg/m^3$
The above calculations are repeated for all other samples (B, C, D, E, & F) the summary is show in figures below.

3.2 Water absorption:

Individual clay brick was weighed and then immersed in water for 24 hours. After the completion of the time, they were removed and weighed again. The difference between the dry and wet clay bricks was then recorded and calculated, expressed using the formula below.

$$A = \frac{\text{Wet weight }(W_w) - \text{Dry weight }(W_D) \times 100}{\text{Volume of Clay Bricks }(V_B)} \quad (2)$$

Each Individual was labeled for-example A = Abuja, B= Akure, C =Benin, D= Ibadan, E =Lagos and F= Port Harcourt

IV. ANALYSIS OF RESULTS

The analysis of results of Clay Bricks samples investigated is shown in figures 1-9 above. As can be seen in the figures below; the results of each purchased clay brick are analyzed. It indicated that the clay soil purchased at individual site was suitable for all the clay bricks that were purchased because grading limit is between 0 -15%. However, the compressive strengths tests obtained from all the clay bricks purchased are found to be suitable load bearing except sample B Akure Zone (1.51), fell below NIS Standard recommendation $5N/mm^2$. As shown in the figure below, the average crushing load ranges from 33.9 to 374.0 (KN/mm^2), the weakness is pointing to B Akure Zone which shows the lowest crashing load. Also, the average compressive strength ranges from sample $1.509N/mm^2$ to 13.430 N/mm^2 sample C Benin zone, attain the highest compressive strength while sample B Akure attain the lowest which is below NIS Standard. The average water absorption capacity was also considered in the analysis; it ranges from 8.89 to 19.67 kg/m^3. Sample B attains the highest $19.67kg/m^3$ while sample F Port Harcourt zone has the lowest.

The analysis of wet density soaked and oven dry for 24hours were considered, the results are shown in the figures. Wet or soaked density ranges from $1599.2Kg/m^3$ sample B to 2227.7 kg/m^3. Sample E Lagos Zone attained the highest density while sample B has the lowest density. The analyses of Oven Dry Density for 24 hours also show variations, the average Oven Dry Density ranges from 1423.6 to 2029.7(kg/m^3). The calculations show that sample B attained the lowest 1423.6 kg/m^3 while the calculation shows that sample E attained to 2029.7 (KN/m3) the highest Oven densities. The average dry weight and wet weight immersed in for 24hours were also considered and the calculations are indicated in the figures below. In line with clay soil BS882:1992) indicates that 150µm size, the overall mass finer grading percentage limit must be between 0 – 15%. The outcome results of sieve analysis shows that sample A – F satisfy the overall grading limit. As it can be seen from the analysis of Sample A –F the percentage passing fall between the limit 0 -15%, shows that the clay is suitable for construction.

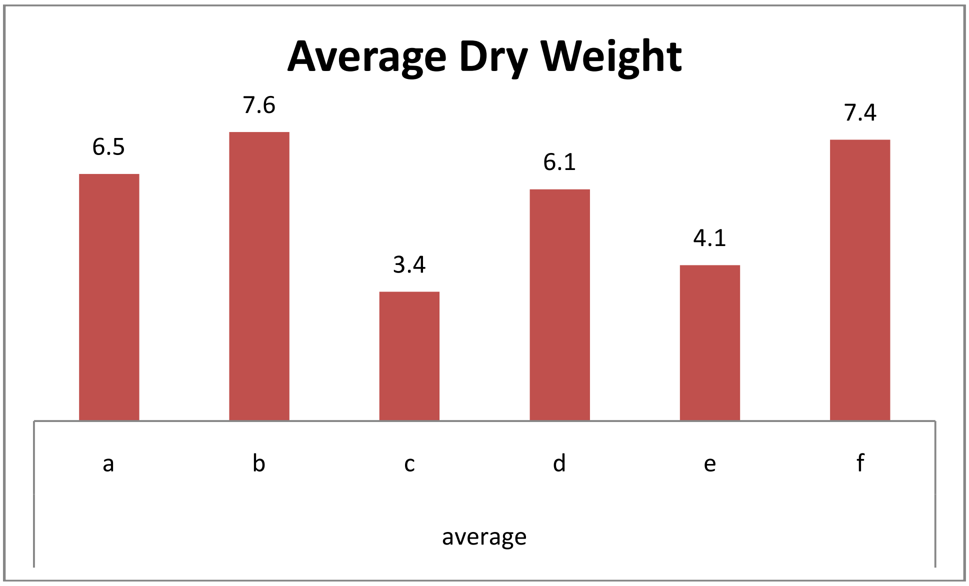

Figure 1. Average dry weight of samples

Figure 1 above shows the dry weight of the 18 purchased clay bricks samples selected for the study. Three samples were from each manufacturer for the study. As indicated in the figure the bricks samples vary in sizes and weights. Sample B appear to be the heaviest followed by F while samples C is seen to be the lightest. This can be noticed in the Figure above.

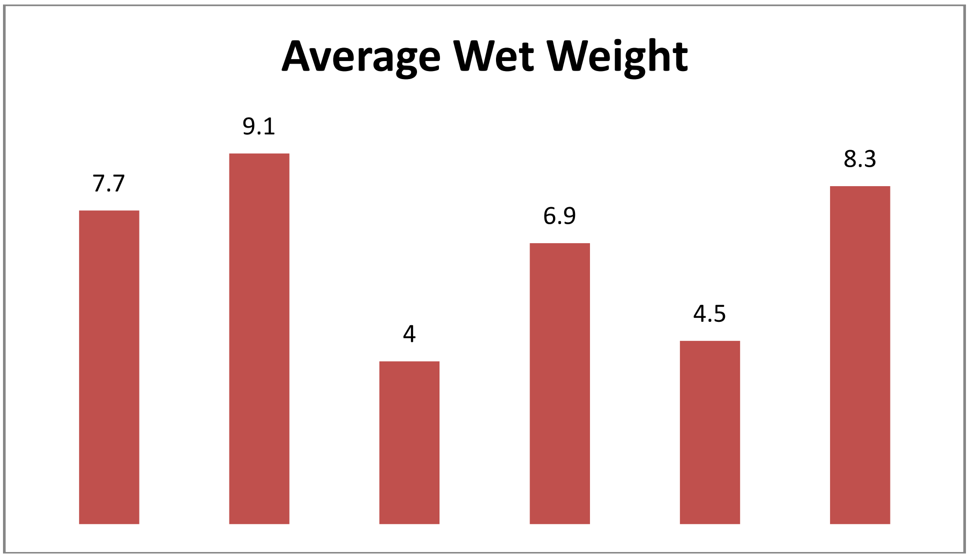

Figure 2 Average wet weight 24hrs

Figure 2 above shows the average weight of the wet clay bricks; they were allowed to wet for 24 hours. As shown in the figure, there is an increase in the weight of individual brick under study. The figure shows that sample B gained more weight 9.1 kg followed by sample F 8.3 kg while Sample C remains smallest weight. The difference between the dry and wet weights gained is indicated in the figure below.

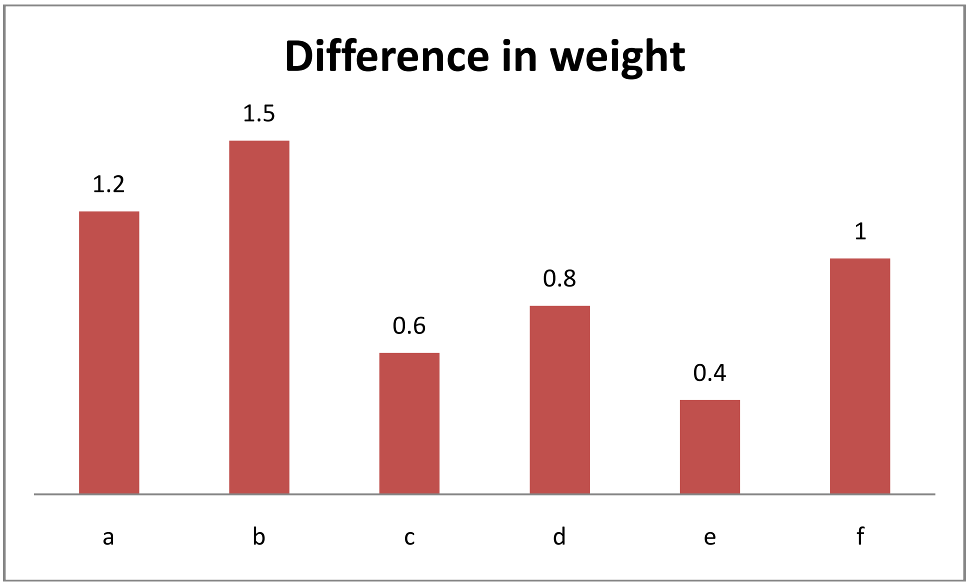

Figure 3 Difference in both Wet and Dry weight.

The figure 3 above shows the weight difference between dry and wet bricks. The average weight ranges from 0.4 samples E to 1.5 samples B. The increase varies from 0.4 samples E to 1.5 samples B. It seems that Samples B absorbed more water than the rest samples. It means that samples B will be drain the water present in mortar faster than others and allow Cracks to occur at earlier age of the structure.

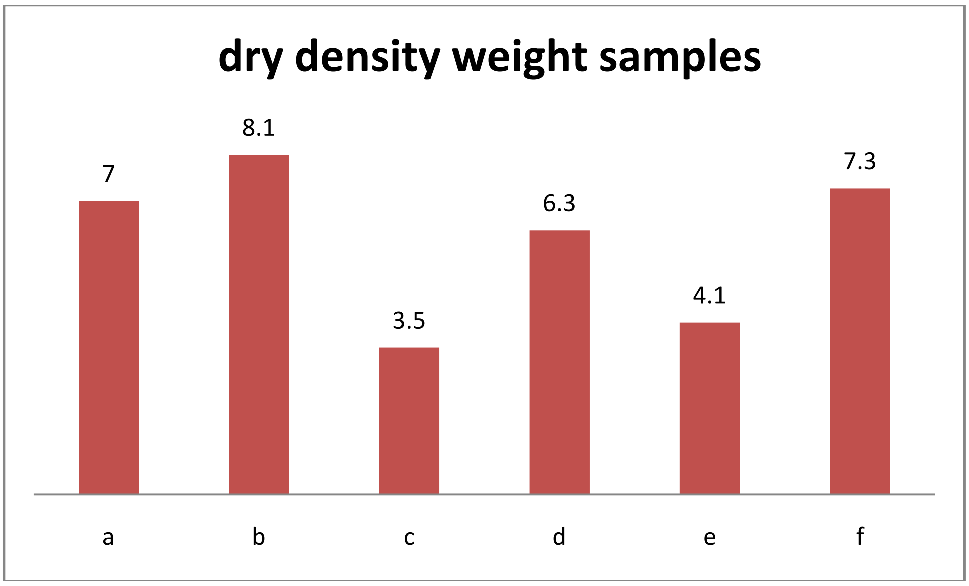

Figure 4 Average samples Dry Density

Figure 4 above shows the average weight of dry density of samples A, B, C, D, E and F. The average weight density varies from one sample to another. The figure shows that samples C attain the lowest density weight 3.5kg/m^3 while sample B attains the highest density weight 8.1kg/m^3. The total analysis is indicated in the figure above.

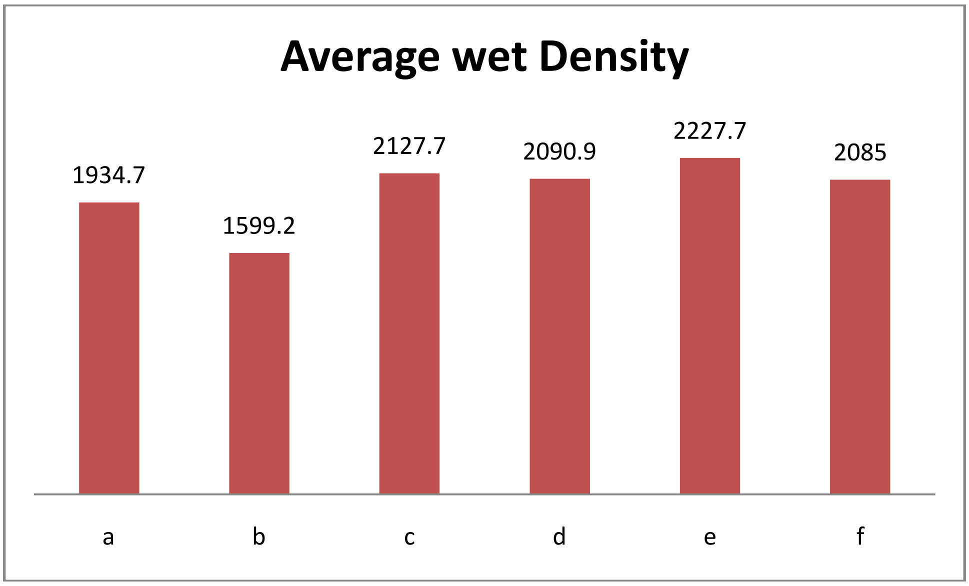

Figure 5: Average weight wet density 24 hrs

Figure 5 above shows the average of the sample bricks when they suppressed under wet condition for 24 hours. As indicate in the figure the average weights vary from samples B 1599.2 kg/m^3 the lowest to samples E (2227.7kg/m^3) the highest. After the results of these tests were established, we decided to dry them in the oven for another 24 hours the results obtained are indicated in the figure 6 below.

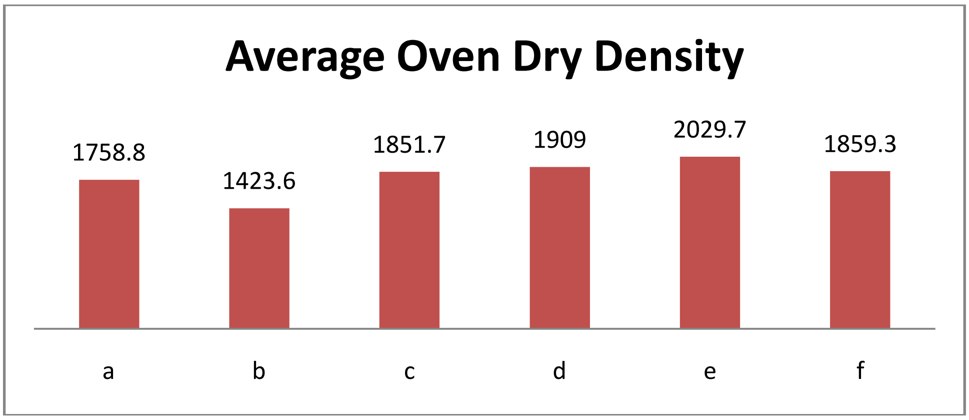

Figure 6: Average oven dry density 24hrs

All the samples were soaked in the water tank for another 24 hours to find out if individual manufacturer takes into the consideration CAN/CSA Standard Recommendations, the minimum standard absorption is 10% while the maximum must not exceed 13.26%. The test results are indicated in the figure 7 below.

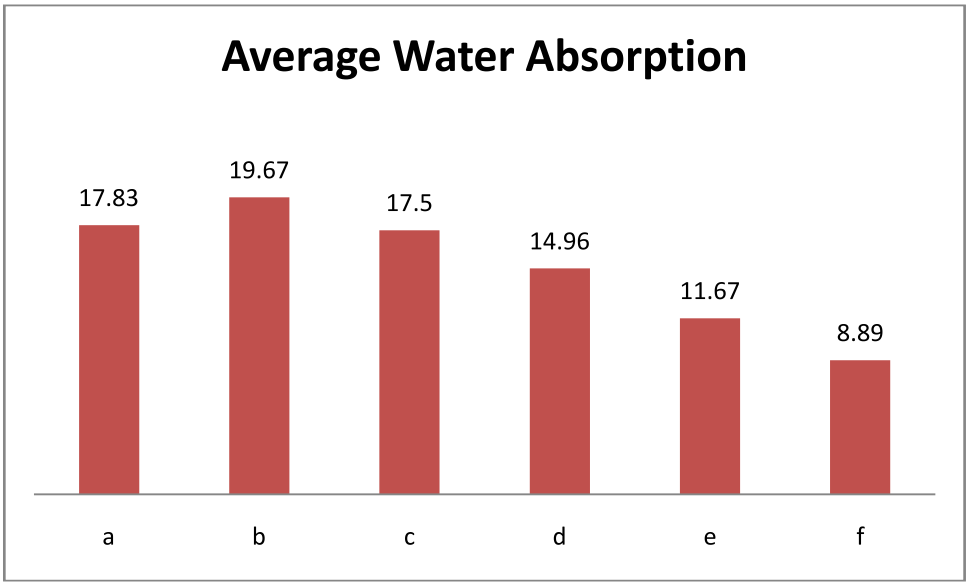

Figure 7: Average water absorption 24hrs results.

As indicated in the figure 7 above shows that absorptions rates are not within the limit, except sample E. Water absorption ranges from 8.89kg/m^3 samples F to 19.67kg/m^3 samples B. The average difference may be associated with types of bricks (solid and hollow).

3.2.1 Compressive Strength

Each of the eighteen block samples was crushed to determine individual compressive strengths. Compression testing machine was utilized; each block was weighed and carefully set between the centres of the plates of the compression testing machine before crushing. The crushing /failure load of each block was recorded and the compressive strength was determined. The formula below was used to determine the Crushing Strength.

$$\text{Crushing Strength} = \frac{\text{Maximum Load at Failure}}{\text{Cross Sectional Area of the block}} \quad (3)$$

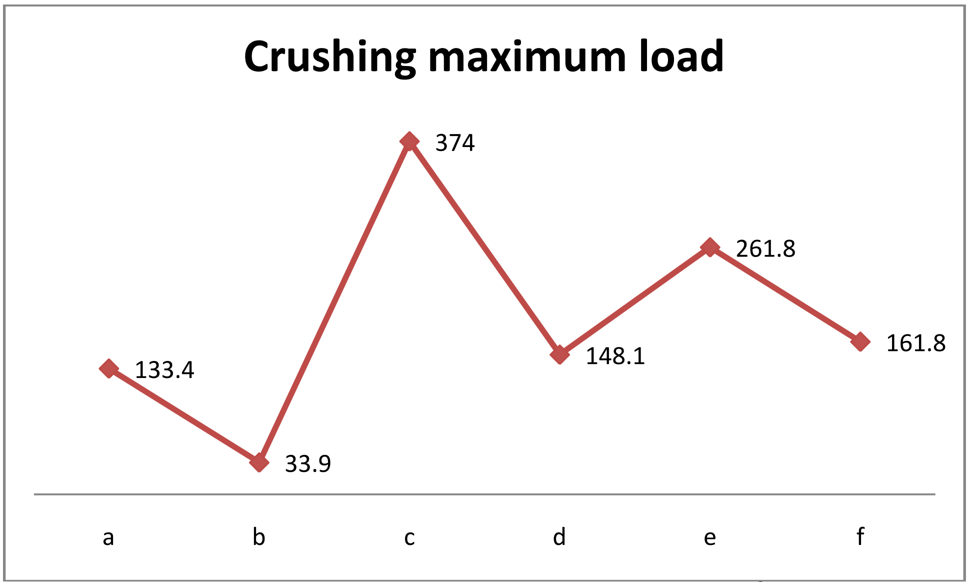

Figure 8: Average crushing maximum load KN/mm^2

Figure 8 above shows the maximum crushing loads of bricks under investigation for quality improvement. The crushing tests were performed relating to bricks types. There were two types of bricks, solid and hollow under the investigation. The maximum crushing loads range from 33.9KN/mm^2 solid to 374KN/mm^2 the rest samples are hollow bricks the average maximum of these are within of the two samples. Figure 9 below shows the compressive strength of the samples.

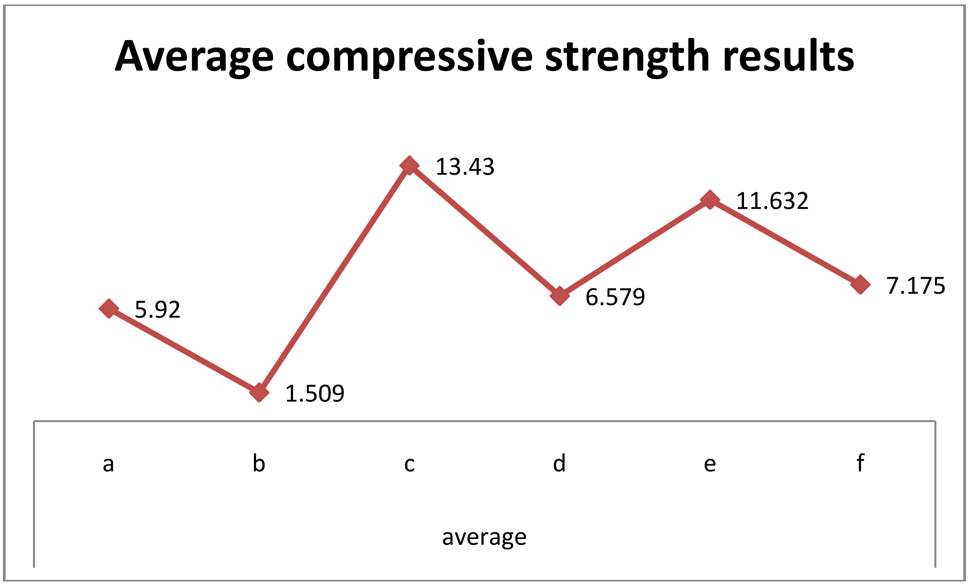

Figure 9: Average compressive strength results.

The figure 9 shows the compressive strength tests results obtained from the clay bricks samples. It shows that samples A, C, D, E and F satisfy NIS and BS3921 recommendation except sample B which fell below the standard. As observed from the figure, the compressive strength varies from 1.509 to 13.43; the weak compressive strength attained by samples B may be associated with manufacturer production method. These clay bricks samples can be recommended as load bearing bricks and sample B can be used as non loading bearing bricks. Sample B will not cause any damage if used with others because they will quickly transfer the load quickly to the foundation.

V. CONCLUSION AND RECOMMENDATION

The test results from obtained from the analysis showed that clay soil components are suitable for the production of clay bricks and also good for construction according to (NIS & BS 3920) recommendation. The findings show that the compressive strength of clay bricks collected from six manufacturing sites is very high with the degree of variability except samples B which appear to be below the NIS BS 3920 standard. From the observation the failure of samples B to satisfy the requirement may be associated with manufacturer control or production system. There may be other reasons which were not considered in this study. All clay bricks samples purchased from the manufacturer have attained or reached 28 days, at this stage these bricks should have attained highest compressive strength.

VI. RECOMMENDATION

It may be necessary to take laboratory sample tests in advance before purchasing Clay Bricks for building construction. Construction Industry should encourage investors to use clay brick because of their durability and low cost of maintenance. Government should encourage small scale clay bricks industry to bring the price down. COREN, NSE, Federal and State governments should assign professional Construction Engineers on an impromptu visitation to all the brick factories to give room for effective compliance with the instruction.

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