

AN INVESTIGATION OF PHYSICOCHEMICAL CHARACTRIZATION OF OTUKPO CLAY FOR FIRED BRICK PRODUCTION IN OTUKPO LOCAL GOVERNMENT AREA OF BENUE STATE

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ABSTRACT

The study investigated the prospects of producing burnt bricks in Otukpo. Atterberg limits, Specific gravity, Grain size and Hydrometer analysis were determined. The value of the liquid limit and plastic limit at zero percent stabilization found to be 34% and 24% respectively. The plasticity index found to be 10%. Minimum linear shrinkage and specific gravity determined to be 7.1% and 2.60 respectively. The particle size distribution and hydrolysis test show the description of the soil which is Sandy-Clay Silt. X-ray Florescence analysis performed on raw and burnt bricks showed that the clay soil comprises mainly Silica-SiO₂ (15%), Iron-FeO (17.7%), Alumina-Al₂O₃ (5.9%) and other compounds. The study showed that the soil was mainly metakaolin (Al₂Si₂O₇). Alumina and silica were responsible for the strength and thermal stability while the aesthetic nature is due to Iron II oxide. Water absorption rate of 8.3% observed, with compressive strength of the burnt brick determined. A minimum compressive strength of 0.67N/mm² attained, which is less than the minimum standard. The results suggested that for the soil to produce bricks of highest strength, various admixtures needed to be added. The produced bricks were found to be adequate for utilization as non-load bearing bricks of class II, based on BS 3921 specifications.

Keywords: Clay Soil, Characterization, Atterberg Limit, X-Ray Diffraction, Fired Bricks

Introduction

Provision of shelters to humanity is one of the main features of a rational being. Owing to this statement, they have been an increase or rapid development in every part of the country and beyond in terms of building structures (houses). Among the important materials to be used for the erection of the structures is the “cement blocks or “vibrated blocks”. Going by the common trend and demand of house by everybody in this country, the price of cement which is used in the production of the vibrated blocks had risen simultaneously with other building materials. In spite of the government policy towards the importations of cements and proper founding of the cements industries in the recent years, the production is still at the minimum level compared to the population of her citizenry as well as the current demand of the people these days. Also the sand and gravels are not naturally and equitable distributed in every parts of the country, hence, the cost of transporting them to the site of construction risen which is a function of the increment in the pump price of petrol (Amah et al, 2011, Kalu et al,2019)

Without exaggeration, Nigeria is a kind of irony in many ways, on this particular tone, on the socio economic aspect of living about 140 million people or so, Nigerians in their relationship with government that supposed to provide welfare for the multitudes citizens, they are paradoxically living in abject poverty amidst plenitude of resources, means and wealth but which the government fail to make these good things available, accessible and free for people. In the midst of lack of basic and efficient capital infrastructures to enjoy, Nigerian masses are forced to live under pseudo-capitalist economy, fending everything for themselves (Akankpo, 2016). This particular situation is worse in the rural area and villages’ that constitute more than 80 percent of the country settlements. While some time in the past, the cities and townships were considered more habitable and life there was more feasible in view of the availability of some basic infrastructures which were then intact and functional. Presently however, the story is no longer the same. Apart from the fact that the urban centers are over populated and the basic amenities were stretched for the needs of the ever increasing populace, these infrastructures are barely absent and unavailable. Due to current economic meltdown, the challenges had made it practically impossible for an average working class Nigerian to put up a simple structure called a home (Agbede and joel, 2011)

This research has given the researcher the opportunity to look for alternative measures to put smile on the faces of people. This alternative measure involves the use of “Clay” to produce bricks. It is mostly in abundance in Otukpo Local Government Area of Benue State, North Central of Nigeria, where the price of cement had gone beyond the reach of the people and sand not readily available. It is universally acknowledge that shelter is the basic need for both psychological and physical comfort of mankind. The struggle by man to have shelters fates back to the Stone Age and transcends through all civilizations. Shelter remains inadequate for the worlds growing population, irrespective of the technological advancements of the present’s generation. Severe housing shortages have been experienced by most developing countries in the past decades. Solutions to existing problems have been hindered by the scarcity and high cost of building materials and manpower (technical knowhow). The development and use of low cost, locally available building materials could provide an economic solution due to its high blast resistance, strength, sound insulation and its elegance in representing a home. It is cheaper and can be made locally. It is therefore advisable that they should be employed in use for buildings constructions and engineering works both in Nigeria, developing and under developed nations of the world (Ibanga and Amed, 2007)

Before the advent of Portland cement, all forms of houses (shelters) were produced using locally available materials such as Clay Bricks, Kneaded Clay mixed with straw, thatch raffia palms and bamboo for roofing. Nigerian and Canadian researchers evaluated the physical and ceramics properties of clay from three sites in Nigeria, one of these, Ikabigbo-Ugbenor Clay was deemed suitable not only for building brick but to be used in construction of lime kiln due to its fires resistance. The use of port land cement in most construction works as always recommended by the government encouraged the intensive use of imported materials. This is despite the fact that houses in the countries from where the cement is imported were not built intensively with cement. By using clay bricks for housing program, Nigeria and other Africa countries will saved their foreign exchange. It will also provide solution to the housing

challenges and might contribute to employment opportunities in rural areas. According Amah et al (2011), the building industry in Nigeria is greatly expanding and the demand for various types of cement for construction blocks is becoming alarming. The cost of cement is getting out of reach of most Nigerians. Cheaper and locally abundant construction materials offer a potential solution. Bricks are considered as an important substance for cement in Nigeria. The problem with the bricks produced, however, is for them to meet basic standard.

To produce good quality bricks, various admixtures have been used by different researchers such as rice husk (peplink house, 1980, Digyhan, 2014). Okongwu (1988), Negedu and Nwakonobi (2015) showed that relatively small concentrations 2% by weight of saw dust and rice husk admixture greatly enhanced or improved the properties of burnt brick and those admixtures above 3% by weight were found to be deleterious. Ibanga and Ahmed (2007) concluded that the two most important properties of burnt bricks, namely: compressive strength and water absorption capacity can be improved substantially by adding rice husks.

Bricks are the only man made building materials that are evidence of their use since the early human civilization. With their attractive appearances and superior properties or characteristics such good thermal and sound insulations, excellent fire and weather resistance, compressive strength and durability, hence, high load carrying capacity, creation of structures and shelter, cheaper and can be made locally. However, some bricks fall short of these specifications either because of inherent properties or method of production. Burnt brick production is carried out locally in most part of the world and in number of places in Nigeria. However for this research is confined to laboratory tests that described the properties of clay such as: Particle size distribution, Atterberg/Consistency limits, Plastic limit, Linear shrinkage, Specific gravity and Hydrometer analysis as well as composition and compressive strength of bricks.

In view of the above need, this research is aimed at evaluating the performance of locally produced burnt bricks using Otukpo Clay as sample specimen for the laboratory work. The broad objectives of this research were to determine the fired Clay potential and the specific objectives were to determine or identify the chemo physical criterions of clay soil which influence the quality of burnt bricks, to determine strength and properties (compressive strength) of burnt bricks produce and to recommend ways of improving properties of locally burnt clay bricks

Materials and Methods

The chief material (sample) used for the tests consist of Otukpo Clay soil obtained from Clay deposit along Otukpo Adoka Road. LOCATION: Otukpo, as a Local Government is in Benue State bounded by Latitude 7° 13' 57"N and Longitude 8° 05' 26"E with area of 24461km². Others material used for this research include; Digger and Hoe, Weighing balance (mechanical and electrical), Oven, Mortar and Piston, Sieve (different diameters), Mold, Electrical muffle Furnace, Porcelain mixing dish, Water container, Grooving tool, Casagrande Cup, Moisture content cans, Silicon grease, Shrinkage mold, Palette knives, Damp cloth, Measuring rule, Density bottle or flask, Sodium hexa-metaphosphate (NaPO₃), Measuring cylinders, Malt mixer Cup, stop Watch, Hydrometer, Thermometer, Agate mortar, Binder, Mini pal Energy dispersive X-ray Spectrometer, Compression Testing Machine and compression plate.

Methodology

The sample described was obtained at a depth of 2m by the road side and excavation was by means of digger and hoe. The sample was dried in oven at a regulated temperature of 110⁰C for 24 hours. It was then pounded and sieved so as to remove impurities. The sample gave a good molding consistency and thereafter molded into bricks each measuring 5cmx5cm5cm using a wooden mold cavity. The molded bricks were carefully removed from the mold. The bricks were left to dry under room temperature for 10days. This was to ensure uniform drying without cracking. After careful drying, the bricks were subsequently fried in an electric muffle furnace to a temperature of 1000⁰C so as to observe the colour changes. The physical method was used to determine the physical criterions of the clay sample. The tests carried out under this method are Atterbeg limits (consistency limits), specific gravity, grain size analysis and hydrometer analysis.

Atterbeg Limits Test: These tests are usually carried out on soil such as clay and silt containing an appreciable quantity (about 20% or more by weight) of material finer than 63µm size where

description based on particles size distribution alone is not sufficient. For mixing and pulverization, it should be approximately at its limit. The procedure is given below:

Liquid limit test: the liquid limit of a soil is the minimum moisture content at which the soil will flow under its own weight. Liquid limit is defined as a percentage of the weight of the oven dried soil at the boundary between liquid and plastic state. The liquid is the water content at which 25 blows of the liquid device just closes the groove made in the soil. To determine the test, 1kg of the soil sample was obtained and quartered to obtain a representative sample. The natural moisture content of the soil sample was obtained and the sample was air dried. The sample was pounded and sieved through a 425µm BS test sieve and sample was placed in a porcelain mixing dish. Small amount of water was added and the soil sample was carefully mixed to a uniform color. Some quantity of the sample was placed in the Casagrande cup and the surface was leveled. A groove was made through the sample along the symmetrical axis of the cup. The Crank was rotated at the rate of about two revolutions per second and the number of blows at which the groove closes was recorded. Small quantity of the sample was then collected for the moisture content determination. The sample was remixed and water content of the soil was increased after repeating the stated steps. The steps were repeated until five different values which ranges from 10-15, 15-20, 20-30, 30-40, and 40-50 blows were obtained.

Plastic limit: this is described as the moisture content at which the soil passes from plastic state to liquid state and expressed as percentage of the oven dried soil. It is the point at which the soil becomes too dry to be in plastic state, as it crumbles when worked. The water content is described arbitrarily as the lowest water content at which the soil can be rolled a thread of 3mm diameter without breaking up into pieces. To determine the plastic limit, the remains of the soil sample paste used for liquid limit determination were used for this test. The sample paste was taken and formed into a ball, placed on the glass plate and rolled into a thread between the fingers and the glass plate by applying a slight but sufficient pressure until it was 3mm in diameter. The moisture content of the soil paste was varied by either adding water or the dried soil sample, and 3mm threads made, until the threads showed signs of cracks. Four threads for each moisture content variation were placed in moisture content cans, which had been weighed. The cans with the samples where then weighed and put in the oven at 100°C for 24hours, for moisture content determination after which the plastic limit was determined.

Shrinkage limit: is the minimum moisture content at which further loss of moisture does not cause a decrease in volume of the soil sample. The remaining homogenously mixed sample paste from the liquid limit test was remixed with water to moisture of content approximating to the liquid of the soil. Then, the mold was cleaned thoroughly and a thin film of silicon grease was applied to its inner walls to prevent the soil from adhering to the mold. The mold was gently jarred to remove any air pockets in the mixture. The soil was then leveled off along the top of the mold with the palette knives. And soil adhering to the rim of the mold was removed by whipping with a damp cloth. The mold and soil was placed in the oven first a temperature of 60%-65% until shrinkage largely ceased and then at 105°C to 110°C to complete drying for 18hours. The mold and soil was cooled and the length of the soil bar measured. When the sample had curved during drying, it was carefully removed from the mould and the length of the top and bottom surfaces measured. The mean of two lengths was taken as the length of oven dry specimen.

The linear shrinkage of the soil was calculated as a percentage of the original length of the sample from the equation given below;

$$\%(SL) = Lf(x) = L_0 - L_1 \times \frac{100}{1} \tag{1}$$

Where

%(SL) is the percentage of linear shrinkage

L₀ is the original length of the sample

L₁ is the final length of the sample

These are express as Atterbeg index as follows;

$$PI = LL - PL \tag{2}$$

Where;

PI is the plasticity index

LL is the liquid limit

PL is the plastic limit

$$LI = \frac{(W_n - W_p)}{(W_1 - W_p)} = \frac{W_n - PI}{LL - PI} \quad (3)$$

Where;

W_n = Natural water content

W_1 = LL = Liquid limit

W_p = PL = Plastic limit

Specific gravity test: Specific gravity (Gs) of soil is defined as the ratio of the weight of a given volume of the soil to the weight of an equal volume of water. This is used to determine how clean the soil is. Clean sand has a specific gravity close to 2.65 and clay a somewhat higher value around 2.72 or more. The reading of lower values of the specific gravity tests suggests the presence of organic matter.

The empty density bottle was weighed to the nearest 0.001g and recorded as W_1 . 10g of fined grained soil, ground to pass 2mm BS test sieve, was transferred to the density bottle and weighed to the nearest 0.0001g and recorded as W_2 . Sufficient free distilled water was added to the soil in the bottle and shaken vigorously to expel air, the bottled filled with more air-free liquid and the stopper replaced. It was ensured that the stopped bottle was completely filled and whipped dry and the whole was weighed to the nearest 0.001g and recorded as W_3 . The density bottle was empty of its content and filled completely with air free water, with stopper inserted and was weighed to the nearest 0.001g and recoded as W_4 . The steps were repeated for two more soil samples and the results tabulated on test forms and specific gravity was calculated using the expression given below;

$$\text{Specific gravity (Gs)} = \frac{\text{weight of soil}}{\text{weight of equal volume of water}} \quad (4)$$

$$Gs = \frac{(W_2 - W_1)}{(W_4 - W_1)} - (W_4 - W_1) - (W_3 - W_2) \quad (5)$$

Where;

W_1 = Mass of the empty density bottle (g)

W_2 = Mass of the dry bottle and dry soil (g)

W_3 = Mass of the bottle, soil and water (g)

W_4 = Mass of the bottle when filled with water only (g)

Grain size distribution analysis: the grain size of soil refers to the diameter of the soil mass. Grain analysis expresses quantitatively the proportion by weight of the various sizes of the particles present in the soil. It is determine by measuring 500g of the dried clay soil using the weighing balance. Pour the sample in the weighing pan in a labeled container. Filled the container and its contents with water and allowed the sample to dissolve for sometimes (3 hrs.). Washed the sample with water using sieve of dimension 75 μ m. continued the washing until the drained water through the sieve become clean (i.e. no more clay content in the sieve). Transferred the retained contents into another stainless container and labeled it. Put the container in the oven for 24 hrs. Sieve the particles to determine its sizes using sieve of dimension 3.53mm, 2.36mm, 1.70mm, 1.18mm, 850 μ m, 600 μ m, 425 μ m, 300 μ m, 150 μ m and 75 μ m. record the retained weight of the content of each sieve.

$$\text{Percentage retained on each sieve} = \frac{\text{Weight of soil retained}}{\text{Total soil weight}} \times 100\% \quad (6)$$

Percentage passing (pp.) = Cumulative percentage retained on each sieve – Sum of percentage retained on all coarse sieve.

Percentage finer than any size = 100% - Cumulative %

Hydrometer analysis: this was carried out mainly to determine the approximated grain size of sample soil, as well as to obtain the proportion of sand, silt, and clay in the sample. 50g of the oven dried sample that was passed through 150 μ m, were taken and mixed with 125ml of sodium hexa-metaphosphate (NaPO_3) solution. Enough water was then added to make 1000ml. the soil mixture was allowed to stand for one hour and was transferred to a malt mixer cup ad tap (distilled) water added until the cup was two third full. The mixture was allowed to stand for five minutes. The mixture was then transferred to 1000 cm^3 sedimentation cylinder. This was done carefully to avoid any material loss.

Distilled water then added to fill the sedimentation cylinder 1000cm³. The top of the hydrometer jar was covered with hand and the soil suspension was carefully agitated for about one minute. The jar was set down on flat surface and hydrometer was immediately inserted at the interval of 0.15min., 0.30min., 1.00min., 2.00min., 5.00min., 180.00min., 260.00min., and 1440.00min. Also the temperature readings at these intervals were taken using thermometer.

The formula used for obtaining percentage proportion of clay, silt and sand is given as thus;

$$\% \text{ Sand} = 100 - \{H_1 - 0,2(T_1 - 68) - 2.0\}2 \quad (7)$$

$$\% \text{ Clay} = \{H_2 - 0,2(T_2 - 68) - 2.0\}2 \quad (8)$$

$$\% \text{ Silt} = 100 - (\% \text{ sand} + \% \text{ clay}) \quad (9)$$

Were;

H₁ = Initial hydrometer reading

H₂ = Final hydrometer reading

T₁ = Initial temperature reading

T₂ = Final temperature reading

Compressive strength test on bricks: to determine the compressive strength, the numbers of whole bricks from sample collected should be taken and dimensions should be measured to the nearest 1mm. placed the specimen with flat faces horizontal between plates of the testing machine, applying load axially at a uniform rate of 14N/mm² (140kg/cm²) per minute till failure occurs and note maximum load at failure. The load at failure is maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine.

$$\text{Compressive strength} = \frac{\text{Maximum load at failure (N)}}{\text{Average Area (mm}^2\text{)}} \quad (10)$$

$$\text{Crushing strength} = \frac{\text{crushing load (N)}}{\text{Area (mm}^2\text{)}} \quad (11)$$

Chemical/Composition test: it was used for the chemical analysis of the sample. The composition test determined the elemental constituent of the bricks using X-ray Florescence (XRF) Method.

Mini Pal is a compact energy dispersive X-ray spectrometer designed for the elemental analysis of wide range samples. The system is controlled by a PC running the dedicated Mini Pal analytical software. The Mini Pal 4 version used was PW 4030 X-ray Spectrometer, which is an energy dispersive micro-processor controlled analytical instrument designed for the detection and measurement of elements in a sample (solids, powders and liquids), from sodium to uranium.

The sample for analysis is weighed and grounded in an agate mortar and a binder (PVC dissolved in Toluene) is added to the sample, carefully mixed and pressed in hydraulic press into a pellet. The pellet is loaded in the sample chamber of the spectrometer and voltage (30Kv maximum) and a current (1mA maximum) is applied to produce the X-rays to excite the sample for a preset time (10mins in this case). The spectrum from the sample is now analyzed to determine the concentration of the elements in the sample.

Results and Discussion

The results obtained from the test carried out were recorded in table 1-10 and graph 1 and 2 as shown below,

Table 1: Plastic limit

Teat	Plastic Limit	
Container/No. of Blows	7.90	31.50
Weight of Container + Wet Soil (g)	7.60	27.50
Weight of Container + Dry Soil (g)	0.30	4.00
Weight of Moisture (g)	6.40	10.50
Weight of Container (g)	1.200	17.00
Weight of Dry Soil (g)	24.00	23.50
Moisture Content (%)	24.30	24.30

Plastic limit = Moisture content = 24.30%

Table 2: Liquid limit

Test	Liquid Limit			
Container/No. of Blows	10.00	20.00	25.00	40.00
Weight of Container + Wet Soil (g)	27.600	26.900	15.00	17.500
Weight of Container + Dry Soil (g)	22.100	22.600	13.00	15.500
Weight of Moisture (g)	5.50	4.30	2.00	2.00
Weight of Container (g)	9.90	9.90	7.10	6.90
Weight of Dry Soil (g)	12.20	12.40	5.90	8.60
Moisture Content (%)	45.10	37.70	33.90	23.30

Liquid limit = Average moisture content = 34.2%

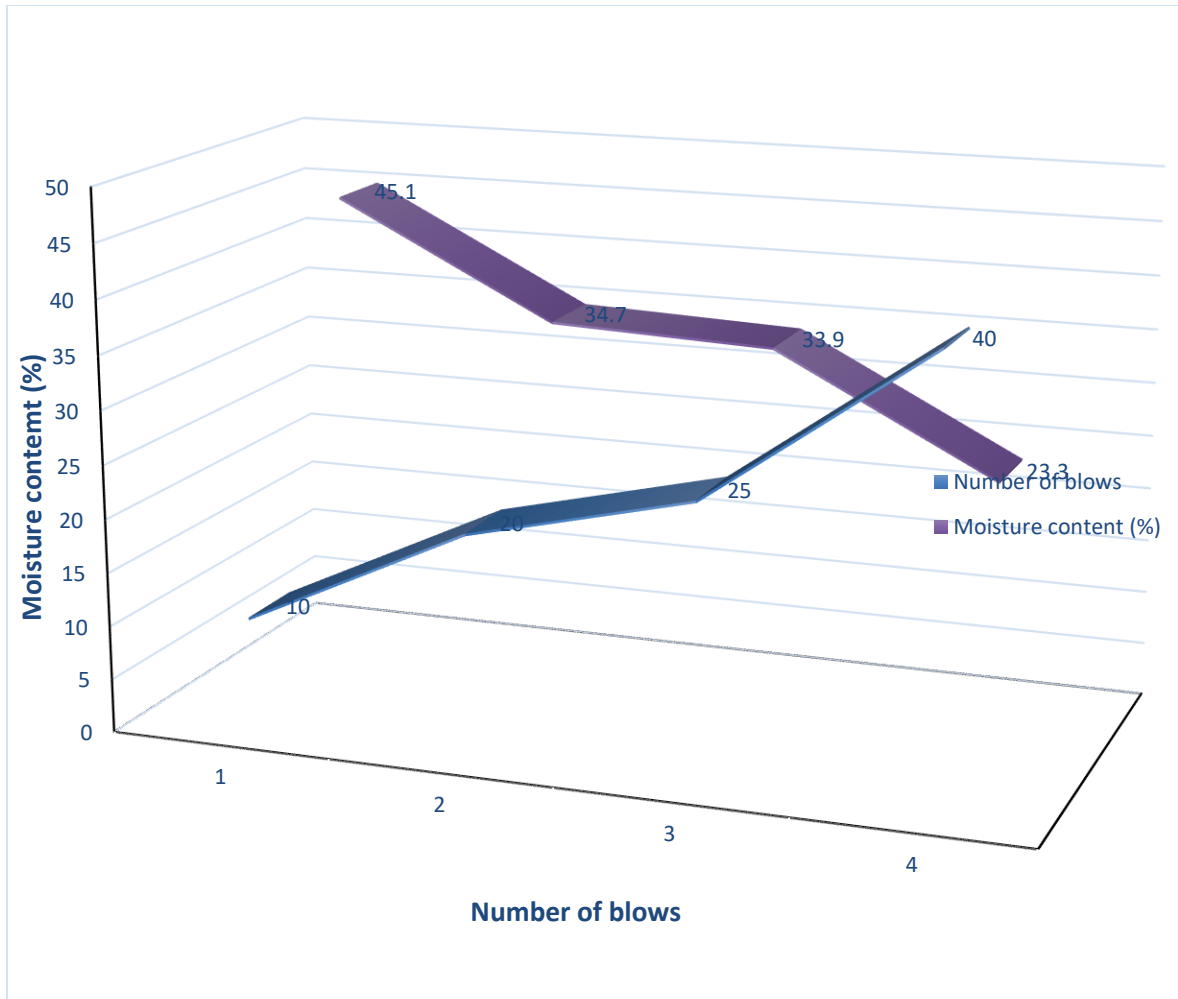


Figure 1: Moisture content against Number of blows

Table 3 Liquid Plastic limits and linear shrinkage test

Liquid limit (LL)	34.3%	Linear shrinkage (LS) = $(1-L_2)/L_1 \times 100\%$	
Plastic limit (PL)	24.3%	L_1 = Initial length of specimen (mm)	140
Plastic index (PI)	10%	L_2 = Length of dried specimen (mm)	130
Linear shrinkage	7.1%		

Table: 4 Specific gravity determination results

Soil specimen number	1	2
Mass of gas jar, plate, soil and water (M ₃) (g)	122	121
Mass of gas jar, plate and soil (M ₂) (g)	55.3	55.9
Mass of gas jar, plate and water (M ₄) (g)	108	108
Mass of gas jar and plate (M ₁) (g)	33.3	33.3
M ₂ – M ₁ (g)	22.0	22.6
M ₄ – M ₁ (g)	74.7	74.7
M ₃ – M ₂ (g)	66.7	65.1
(M ₄ – M ₁) – (M ₃ – M ₂)	8.0	9.6
Specific gravity (GS) = (M ₂ – M ₁) / { (M ₄ – M ₁) – (M ₃ – M ₂) }	2.75	2.40
Average specific gravity	2.60	

Table 5: Grain size analysis- mechanical

Sieve number	Diameter (mm)	Mass retained (g)	% retained	% passing
1.0	3.35	--	--	100
2.0	2.36	3.2	0.6	99.4
3.0	1.70	3.0	0.6	98.8
4.0	1.18	3.2	0.6	98.2
5.0	0.85	3.2	0.6	97.5
6.0	0.60	3.1	0.6	97.0
7.0	0.425	3.4	0.6	96.4
9.0	0.300	3.8	0.8	95.6
10.0	0.150	6.0	1.2	94.4
11.0	0.075	22	4.4	90.0
	PASSING	450	90.0	--

$\% \text{passing} = 100 - \sum \% \text{retained}$

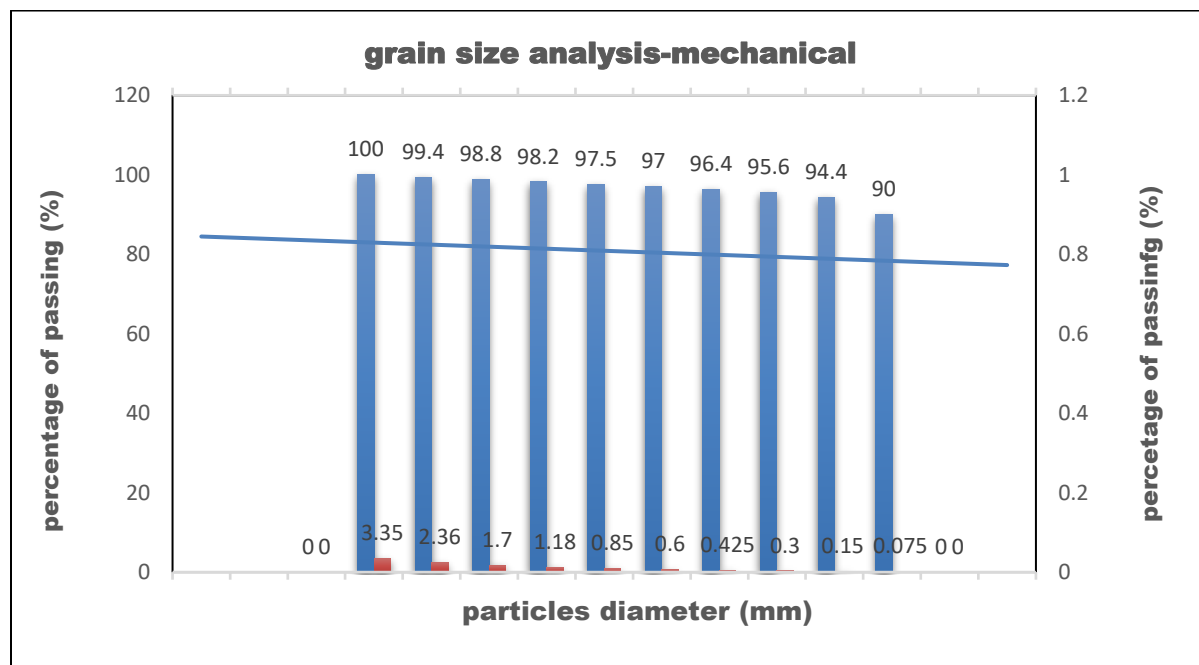


Figure 2: grain size analysis-mechanical / particles size distribution

Table 6: Hydrometer analysis

Elapsed Time Mins	Temp. °C	Actual Hyd Reading R _a	Corr. Hyd. Reading R _c	%finer	Hyd. Corr. Only for meniscus R	L From Table 6-5	L/T	K from table 6-4	D. mm
0	24.0	00	00	0.00	00				
2		16	19	38.4	17	13.5	6.75	0.0128	0.03
5		13	16	32.2	14	14.0	2.8		0.02
8		13	16	32.2	14	14.0	1.75		0.02
15		09	12	24.0	10	14.3	0.98		0.01
30		09	12	24.0	10	14.3	0.49		0.01
60		03	06	12.1	04	15.6	0.0167		0.01
1440		00	03	6.00	01	16.61	0.011		0.001

$$R_c = R_{\text{actual}} + \text{zero correction} + C_r \quad \% \text{finer} = R_c (a)/W_s \quad K = \sqrt{L/T}$$

Gs of solid ...2.60... a...1.01...

Dispersing agent... Calgon... Amount... 4% in 125ml... W_t of soil. W_s... 50g...

Zero correction... 2... Meniscus correction...+1...

Table 7: Soil texture

Cobbles	Gravel		Sand			Silt	Clay
	Coarse	Fine	Coarse	Medium	Fine		

$$C_u = D_{60}/D_{10} \dots 6.8 \dots \quad C_c = (D_{30})^2 / (D_{10} \times D_{60}) = \dots 1.91 \dots \quad \text{Description of soil: Sandy-Clay Silt}$$

Table 8: Compressive Strength Test

Length L (cm)		Width W (cm)		Height H (cm)			
4.70		4.20		4.30			
Cube No.	Age for testing	Structure	Weight of cube (g)	Density of cube (kg/m ³)	Crushing load (KN)	Area (mm) ²	Crushing strength (N/mm ²)
02	3days	Cube	146	1713.4	7.8448	11616	0.67

Table 9: Elemental content of the clay at raw state

Initial weight													0.503			Unburnt Brick		
Final weight													0.422					
compou nd	Al ₂ O ₃	Si ₂ O	Ca O	Ti O ₂	V ₂ O ₅	Cr ₂ O ₃	Mn O	Fe ₂ O ₃	Ni O	Cu O	Ga ₂ O ₃	Rb ₂ O	K ₂ O	Mo O ₃	Rh ₂ O ₃			
Concent ration (%)	11	35	0.37	3.04	0.16	0.21	0.04	24.7	0.14	0.16	0.1	15	4.3	1.7	3.7			

Table 10: Elemental of clay at the baked state

Initial weight													0.503			Fire d Bric k		
Final weight													0.422					
Compound	Al ₂ O ₃	Si ₂ O	Cl	TiO ₂	V ₂ O ₅	Cr ₂ O ₃	Fe ₂ O ₃	Ni O	Cu O	Rb ₂ O	Rh ₂ O	Cd O	BaO					
Concentratio n (%)	5.9	15	0.38	2.3	0.1	0.26	17.7	0.27	0.16	19	3.1	34	0.84					

Table 11: Absorption test

Initial weight (W ₁)	Final weight (W ₂)	Percentage (%) of absorption
109g	118g	8.3

Percentage (%) of absorption = {Final weight (W₂) - Initial weight (W₁)} / Initial weight (W₁)

Final weight (W₂) = Wet weight

Initial weight (W₁) = Dry weight

Discussion

Table 1 shows the plastic limit and table 2 shows liquid limit test. The plastic limit valued 24.3%. From figure 1, the liquid limit (LL) was determined to be 34% which agrees with the values in table 2. From table 3, the plastic index (PI) was found to be 10% compared to 11.4% value for Makurdi clay (Amah et al, 2012). This implies that the soil has low plasticity, since the plastic index value fall within the range of 10%. The linear shrinkage (LS) was deduced to be 7.1% compared to 11% and 10% for Makurdi and Ibaji clay respectively. The smaller the value of PI and LS, the bigger the SG and the better the quality of the clay. Table 4 shows the specific gravity determination which value was determined to be 2.6. This value is in accordance with Bowels (1979) which concluded that the specific gravity normally ranges from 2.55 to 2.80. Table 5, 6 and figure 2 shows the particle size distribution of the soil/the grain size distribution. The graph shows a linear trend line based on series with percentage of passing above 80. From the hydrometer analysis that was carried out, it shows the sample contains the following percentage; clay 45%, sand 7%, and silt 48% which put the description as “Sandy-Clay Silt” this agrees with the United Nation Centre for Human Settlement which also gave the following as the best composition of soil for clay bricks; clay (20-30) %, clay and silt (40-65) %, sand stand for the remainder. Table 8 shows the compressive strength of the burnt brick and the value was deduce to be 0.67N/mm². Table 9 and 10 shows the X-ray florescence test of raw and fired bricks. Table 11 shows the water absorption test which value was determine to be 8.3% implying the durability of the burnt bricks. From the X-ray florescence test, the chemical composition of the Otukpo clay showed it contain mainly Silica (15%) which is below the range of 55-75 % for fired clays. Alumina content is 5.9% which is below the range of 25-45% for fired clays. The Iron oxide (17.7%) which has iron content of 12.37% is above the range of 0.5-2.0% for fired clay. The chemical composition of the raw brick also showed mainly silica (35%), Iron oxide (24.7) and alumina (11%). The variation of oxides of silica, iron and alumina is due to a chemical reaction that took place at high temperature. At high temperature, the reactions between Al₂O₃ and SiO₂ Produces metakaolin which is a cementitious mineral responsible for the strength and hardness of the burnt bricks. Oxidation of iron ii to iron iii gives the burnt brick its reddish color. The X-ray florescence test also shows negligible quantity of other oxides.

Conclusion

The test results showed that more than 90% of the particles of Otukpo clay passed through the BS sieve number 200. The values of liquid limit and plastic limit at zero percent stabilization were found to be 34% and 24% respectively. The plasticity index was found to be 10%. Minimum linear shrinkage was found to be 7.1%. Particles size distribution and hydrolysis test shows the description of the soil which is “sandy-clay silt”. X-ray florescence test showed the Otukpo clay soil to be mainly metakaolin, since the soil composition were mainly silica, alumina and iron oxide. The silica and alumina oxide undergoes chemical reactions at high temperature to produce metakaolin which is responsible for the strength and hardness. This is because the bonding combination of hydrogen and van der Waal forces results in considerable strength and stability with little tendency for the inter layer to take in water and swell. The color changes red due to Iron iii oxide present in the brick. Iron iii oxide is the product of the oxidation of Iron ii oxide. The compressive strength or the crushing strength was determined to be 0.67N/mm². The compressive strength of the brick is less than the minimum requirement of 2.5N/mm² specified.

From the study, the following conclusions were drawn;

- a. According to the classification of bricks based on average or minimum compressive strength, minimum compressive strength of bricks should be 2.5N/mm². (Nigeria specification of burnt

bricks, 1976). The results obtained do not meet the specification. The building regulations require only 2.74Nmm^2 for two storey buildings or storey buildings divided into flats. Whereas, construction by laws of 1976 are satisfied with a minimum of $0.6 - 1.3\text{Nmm}^2$ for non-load bearing walls.

- b. The bricks produces can be classified as “Non-load bearing Bricks”, according to BS3921 and can be used in construction for non-load bearing walls.
- c. To produce bricks with high strength using Otukpo clay soil, the soil therefore requires an additive so as to improve its properties. According to Agbede and joel (2011), the properties of clay soil can be improved using various admixtures.

Recommendations

The following recommendation were also drawn from the research,

1. The production of burnt bricks using Otukpo soil required additive because the properties examined meet most of the requirements for non-load bearing walls, implying reduce cost of production
2. It is recommended that more researches be carried out on the structural/technological advancements of the present society from local raw material to cobb the current housing deficits in the country
3. The soil techniques used in the research was manual and all others techniques not carried out should be investigated.

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