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Chemophysical characterization of clay soil used for locally manufactured burnt bricks in Makurdi, Benue state, Nigeria

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Abstract

This study characterized raw samples of clay soil used for local production of burnt bricks in Makurdi. The samples were collected from three well known sites where burnt bricks are produced in Makurdi, Benue State. Chemical analysis showed that the clay is highly rich in Silica-SiO_2 (67.9%), Alumina-Al_2O_3 (17.7%), Potassium oxide-K_2O (4.2%) and Iron II oxide-FeO (4.2%). The percentages of fifteen other elements identified are not significant. This shows that Kaolinite ($Al_2Si_2O_7$) must be responsible for the strength of the burnt clay. The physical analysis showed that the sample(s) has on average, 69.8% clay fraction, 20.7% silt fraction and 8.9% sand fraction. The particle size is <425µm. Average plasticity index is 11.4%, Linear shrinkage is 11.0% while Specific gravity is 2.56%. These values are comparable to specifications of Association of American state Highway and Transportation officials, AASHTO H_2O guideline.

Keywords: Raw clay; chemophysical properties; burnt bricks

1. Introduction

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 an important substitute for cement in Nigeria. The problem with the Bricks produced, however, is for them to meet basic standards for proper performance.

Bricks are classified by both the average or minimum compressive strength and the percentage water absorption (Indian standard, 1992 and Ibanga, 2007). According to this classification, minimum compressive strength of bricks should be 3.5 MN/m^2 and the water absorption should not exceed 20%. Some bricks manufactured locally (open kilns), however, fall short of this specification. Additional ingredients (additives) are required to bring the specimen to specification.

The suitability of any clay for structural development and other areas of engineering have been linked to its chemical content, plasticity (particle size and porosity), and the effect of temperature on these parameters (Guggenheim and Martin, 1995; Hillier, 2003; Nelson, 1971; Geiger, 2005). Consequently, clay minerals exhibit wide variations in chemical compositions, physical and thermal properties.

Burnt clay bricks has been locally produced and used for structural development in Makurdi, Benue State of Nigeria since 1950s till date. The beauty of this clay is that houses constructed with its local burnt bricks since 1950s still stand the test of the time. It is a well known fact that the houses built with this bricks deflects bullets fired at a very close range and is also not affected if gutted by fire.

The aesthetic nature of buildings constructed with this local burnt bricks is admirable and has not found rivalry. It is therefore incisive to characterize this clay in raw state in other to form a baseline for identification of quality clay elsewhere. Makurdi is located at latitude $7^o44'$N and longitude $3^o32'$E.

2. Materials and method

The clay samples were collected from three different well known sites for local production of burnt bricks in Makurdi. These samples were dug up 1m deep using a hoe. Sample 1 was collected from Wadata site, sample II from km 6, Gboko road site, and sample III from North bank site. The bricks were molded using cast iron mold of 150mm x 90mm x 80mm dimensions and compressed locally using wooden plank. The molded bricks were extruded by loosening the mold and carefully removing the bricks. The bricks were left to dry for 14 days before analysis. Physical characterization involved determination of particle fractions and particle size, plasticity index, linear shrinkage and specific gravity for clay while chemical characterization involved determination of the elemental contents of the clay.

2.1. Physical Characterization

The particle size analysis was done using standard sieve analysis. Ten standard sieves with varying apertures were arranged in order of increasing sizes. 500g sample was introduced into the topmost sieve and three particle sizes were obtained for each sample and the fraction was obtained using the Eq. 1.

$$\text{Particle fraction} = \frac{\text{Retained weight}}{\text{Total weight analyzed}} \times 100\% \quad (1)$$

The plasticity index of the samples was done using the soil's Atterberg limits with the aid of Cassagranda apparatus to obtain the liquid limits and the plastic limits and the three are related by Eq. 2.

$$\textit{Placticity index} = \text{liquid limit (\%) - plastic limit (\%)} \quad (2)$$

Linear shrinkage test was done by compacting the past clay moisture into a rectangular mould of known length. After the mass had dried up, its new length was noted.

$$\text{Linear Shrinkage} = \frac{\text{Change in length}}{\text{Initial length}} \times 100\% \quad (3)$$

The specific gravity of the samples were also determined using the specific gravity bottle method define by Eq. 4.

$$\text{Specific Gravity} = \frac{(W_2 - W_1)}{(W_4 - W_1)(W_3 - W_2)} \quad (4)$$

Where W_1 = weight of gravity bottle, W_2 = weight of clay and the gravity bottle, W_3 = weight of gravity bottle, clay and water, W_4 = weight of gravity bottle and water.
Table 1 shows the physical properties of raw clay samples.

2.2. Chemical Characterization

Chemical characterization of clay samples involved XRF analysis of the raw samples. The elemental contents are shown in table 2 with the percentage oxide composition (POC) of the elements (in parenthesis) evaluated using Eq.5.

$$\text{POC} = \frac{\text{Molecular weight of oxide}}{\text{Molecular weight of element in the oxide}} \times \frac{\text{Amount of element}}{100} \quad (5)$$

3. Result and discussion

Table 1
Physical properties of raw clay samples

Element	Sample I	Sample II	Sample III
Clay particle size (μm)	<425	<425	<425
Clay fraction (%)	71.1	70.0	68.3
Silt fraction (%)	20.6	21.8	19.7
Sand fraction (%)	8.2	8.2	10.2
Liquid limit (%)	33.1	29.0	34.0
Plastic limit (%)	21.1	20.9	20.7
Plasticity index (%)	12.0	9.1	13.3
Linear shrinkage (%)	9.3	12.9	10.7
Specific gravity	2.58	2.60	2.51

Table 2
Elemental contents of raw clay samples with equivalent oxides in parenthesis

Element	Sample I (%)	Sample II (%)	Sample III (%)
Al (Al_2O_3)	9.52 (17.980)	9.23(17.435)	9.40 (17.756)
Si (SiO_2)	31.79 (68.120)	31.57 (67.651)	31.70 (67.929)
K (K_2O)	3.63 (4.370)	3.50(4.218)	3.38(4.073)
Ca (CaO)	0.01(0.014)	0.02(0.028)	0.02(0.028)
Sc (ScO_3)	0.005(0.008)	0.005(0.008)	0.003(0.005)
Ti (TiO_2)	1.30(2.167)	1.31(2.183)	1.27(2.117)
Cr (CrO)	0.01(0.013)	0.01(0.013)	0.02(0.026)
Mn (MnO)	0.05(0.065)	0.04(0.054)	0.04(0.669)

Fe (FeO)	3.29(4.230)	3.27(4.204)	3.27(4.204)
Ni (NiO)	0.007(0.009)	0.007(0.009)	0.008(0.010)
Cu (CuO)	0.03(0.038)	0.04(0.050)	0.03(0.038)
Zn (ZnO)	0.005(0.006)	0.005(0.006)	0.007(0.009)
Rb (Rb_2O)	0.03(0.033)	0.03(0.033)	0.02(0.022)
Sr (SrO)	0.03(0.035)	0.03(0.036)	0.04(0.047)
Zr (ZrO_2)	0.02(0.027)	0.01(0.014)	0.02(0.027)
Nb (NbO_2)	0.007(0.009)	0.005(0.007)	0.005(0.007)
Au (Au_2O_3)	Nd (-)	Nd (-)	Nd (-)
Pb (PbO)	0.03(0.032)	0.03(0.032)	0.02(0.022)
Mg (MgO)	0.21(0.350)	0.22(0.367)	0.20(0.333)
Na (Na_2O)	0.04(0.054)	0.02(0.027)	0.03(0.040)

Key: % percentage Nd=Not detected

Soil sample is said to be clay provided that at least 50% of the sample is clay (Hurlbut; Klein, 1985). From the physical characterization of Makurdi clay, table 1 shows that Makurdi clay soil contains at least 69.8% clay fraction, 20.7% silt fraction and 8.9% sand fraction.

Therefore Makurdi soil is predominately clay. The particle size of the clay is less than 425µm. Recent analysis (Nwoye, 2008; Viewey and Larry, 1978) has shown that fine particles are more dense (bulk density) and exhibit excellent Engineering properties. This explains why the clay material showed low plasticity index (PI) value of 11.4% compared to 20.3% value for Ibaji clay (Agbede, 2011). Further, the linear shrinkage (LS) from this work is 11%, liquid limit (LL) is 32%, plastic limit (PL) is 20.9% and specific gravity (SG) is 2.56 while for Ibaji clay, the values are 10%, 38.3%, 18.0% and 2.42 respectively. The smaller the value of PI and LS, the bigger is the SG value and better the quality of the clay. The idea behind mixing clay with additives is to increase SG or decrease PI and LS. Makurdi clay therefore does not require any additive to meet up with required specification (IS 1077, 1992).

The result of the chemical analysis shows that each sample contain nineteen elements (the same but slightly different in percentages) as shown on table 2. The percentage oxide compositions of each element are written in parenthesis. The clay is highly rich in Silica (SiO_2), Alumina (Al_2O_3), Potassium oxide (K_2O) and Iron II oxide (FeO) with average percentage contents of 67.9%, 17.7%, 4.2% and 4.2% respectively. When clay is fired, structural transformation takes place. The clay mineral $Al_2O_3SiO_2.2H_2O$ undergoes dehydration to metakaolin, $Al_2Si_2O_7$. Metakaolin (Kaolinite) is a cementitious material that helps in strengthening bricks (Hlavac, 1983). This is an indication that Alumina and silica are responsible for the strength of the locally burnt bricks.

4. Conclusion

Essentially, the need to characterize the raw clay is to form a baseline upon which people can always make reference to while searching for quality clay elsewhere since Makurdi bricks had been identified as second to non at present. Aesthetically, houses constructed using Makurdi burnt brisk are colourful (red) caused by the oxidation of Iron II oxide to Iron III oxide when fired. The physical and chemical properties of this raw clay identified in this research should be seen as synonymous with the brick strength.

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