Physicochemical Analysis of a Local Clay and its Utilization in Ceramic Tiles

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ABSTRACT

In this study the clay deposits from Mbaukwu in Awka South Local Government Area, Anambra State, Nigeria, were characterized for their potential utilization as industrial raw material for ceramic tiles. The results of physicochemical analyses of the modified samples were investigated using standard methods and the results compared with that of unmodified samples.

The clay was modified with additives (Silica and Feldspar). Results obtained showed that Mbaukwu clay is kaolinite and chemically composed of mainly silica (42.97%) and alumina (23.34%), respectively. The results of Physicochemical analyses showed water absorption for unmodified and modified samples at various temperatures are 900ºC (19.03% and 20.23%), 1000ºC (19.03% and 10.31%), 1100ºC (18.01% and 11.89%), and 1200ºC (16.93% and 12.28%), respectively. Making moisture showed high value for unmodified sample and average of 20.44% for modified sample. The values of Modulus of rupture for unmodified and average for modified samples at various temperatures are shown, at 900ºC (16.44kg/cm^3 and 30.79kg/cm^3), 1000ºC (21.14 kg/cm^3 and 36.36 kg/cm^3), 1100ºC (24.87 kg/cm^3 and 34.43 kg/cm^3) and 1200ºC (20.01 kg/cm^3 and 38.89 kg/cm^3), respectively. Total shrinkage showed increase in value with increase in temperature with 1200ºC showing the highest value. The physical characteristics examined confirmed that the addition of additives greatly improve the strength of the clay and are useful for ceramic tiles and other ceramic applications.

(Keywords: physicochemical analysis, water absorption, apparent porosity, Mbaukwu clay, ceramic tiles)

INTRODUCTION

Clay is defined as earth or soil that is plastic due to particle size and geometry as well as water content, that becomes permanently hard, brittle and non- plastic upon drying, baked or firing at a higher temperature. Singer and Singer (1963) found that on heating dried clays, water is given off. With time, a hard but porous piece forms. A swollen appearance might occur during the release of some gases, but overall shrinkage must occur when verifications set in leading to a strong dense piece.

Clay is a finely-grained natural rock or soil material that combines one or more clay minerals with possible traces of quartz (SiO_2), metal oxides (Al_2O_3.MgO, etc.) and organic matter. Recently, various studies on solid mineral resources using geoscientific surveys and mineralogical characterization considered that the understanding of the nation's mineral potentials is critical for efficient exploration and exploitation towards promoting sustainable economic development, (Obaje, 2009; Anifowose, et al., 2006).

Results have shown that Nigeria's geosphere is enriched with a wide range of both metallic and non-metallic minerals deposited across many states of the nation which are and could still be beneficiated to provide the raw materials for industrial manufacturing among other useful purposes. Depending on the soils content in which it is found, clay can appear in various colors from white to dull grey or brown to deep orange-red. Different clay is the principal raw material in the traditional –ceramic manufacturing industries. Depending on composition and various other technical characteristics, clay can be processed into different shapes where plasticity, strength and other parameters are varied (Nwoye, 2003).

The features that industries frequently look for in clay are mainly the composition and the particle size, which determines the feasibility of that clay to be processed, (Mousharraf, et al., 2011). Clay minerals have a wide industrial application in the production of ceramic products, bricks, filter candles, porcelain tiles, chalk, paper and agro-allied industries (Ogbebor, et al., 2010). When clay is fired, after processing, the resulting physical properties usually determine their suitability for intended use. Clay swells in water, creating a thixotropic gel (particularly bentonite) as a consequence of interlayer water adsorption. The chemical and mineralogical composition of the samples bears enormous influence on the physical characteristics (Abia-Bassey *et al*., 2006).

MATERIALS AND METHODS

Materials

The materials used for the various mixes are clay from Ovollo-Mbaukwu, Awka South in Anambra State, Nigeria. Silica (course-grained), feldspar as binder, de-ionized water, glaze, lubricant, hydrochloric acid (HCl), nitric acid (HNO_3) and filter paper.

Physicochemical Analysis of the Samples at Various Temperatures

Various formulations of modified samples were characterized to investigate the water absorption, apparent porosity, total shrinkage test, apparent porosity, bulk density, and modulus of rupture and compared with the results of unmodified samples.

Test Sample Preparation

The unprocessed clay sample brought into the laboratory was soaked in water and was stirred vigorously, they were allowed to stand for 20 mins then the suspended particles were decanted. The processed clay sample were poured into a Plaster of Paris (POP) bath and were allowed to stand for 4 days to dewater. The dried processed sample was also oven dried at a temperature of 109ºC for 3 hrs. and was pulverized for the physicochemical analysis. The processed sample were modified with the additives silica and feldspar and the physical parameters were carried out.

Testing of Samples

Water Absorption: Water absorption (WA) measures the maturity of a fired clay body. The rectangular bars test pieces of dimension 8cm x 4.1cm x 2.1cm were used for this study according to British standard EN (1991). The test pieces fired to the various temperature were measured to the nearest cm. The fired test pieces were then boiled for 2hrs and then allowed to cool. The surface of the bar (test pieces) were dried with a dry towel and then weighed again. The percentage water absorption was then calculated using the equation:

percentage water absorption =

$$\frac{Saturated\ weigth - Dried\ weigth}{Dried\ weigth} \times 100$$

Apparent Porosity: The weight of each fired sample was taken and recorded as M1. Each sample was immersed in water for 1hr to soak and weighed while been suspended in air. The weight was recorded as M2. Finally, the specimen was weighed when immersed in water. This was recorded as M3. The apparent porosity was then calculated from the expression:

$$\text{Apparent porosity}(\%) = \frac{M2 - M1}{M2 - M3} \times 100$$

Shrinkage Test: Shrinkage test was done to determine the volumetric firing shrinkage of the fired samples. The procedure involved taking the dimensions of the sample before and after firing. The difference in the dimension was calculated from the expression:

Dry shrinkage (%) =

$$\frac{Plastic\ length - Fired\ length}{Plastic\ length} \times 100$$

Modulus of Rupture (MOR): MOR is the measure of the specimen's strength before rupture. Modulus of rupture of unmodified samples were tested at various temperatures and results were compared with that of modified samples at varying temperature and percentage of additives (silica and felspar). The results of MOR were calculated using:

Modulus of Rupture (kg/cm²) = $\frac{3PL}{2BH^2}$

Where,
P = breaking load (kg)
L = distance between support of the transversal machine (cm)
H = height of the broken pieces (cm)
B = width of the broken pieces (cm) (Abuh *et al.*, 2014).

RESULTS AND DISCUSSION

Effect of Feldspar and Silica on the Tile Properties

The results of the various tests carried out to determine the characteristics of the test specimens are presented in Figures 1 to 4 The effect of silica and feldspar on the water absorption behavior is given in Figure 1.

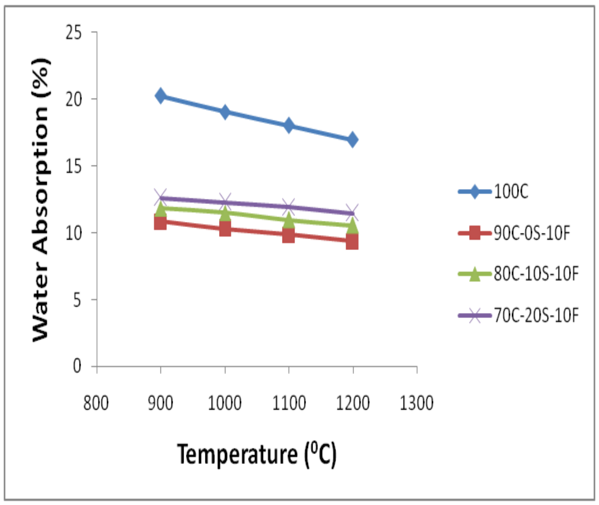

Figure 1: The Effect of Temperature on the Water of Absorption of the Clay and Tiles.

The effect of silica and feldspar on the shrinkage behavior is given in Figure 2. It was observed that the Mbaukwu clay mixed with some quantity of water cracked during the drying process and firing operations at a temperature of 105ºC and 1200ºC respectively. This is due to the volumetric shrinkage, which followed the drying and firing operations. Therefore, to reduce the shrinkage and void cracks, free silica was added.

It was observed that compositions with 10% silica and above showed no crack. This was due to the low volumetric shrinkage after firing. The shrinkage was reduced from 15.4% in 100% Mbaukwu clay to 8.8% in 80% clay for 10% silica mix at 1200ºC and 5.6% in 80% clay for 10% silica mix at 900ºC. Since the 5.6% value was acceptable for ceramic purposes (Olasupo and Borode, 2009).

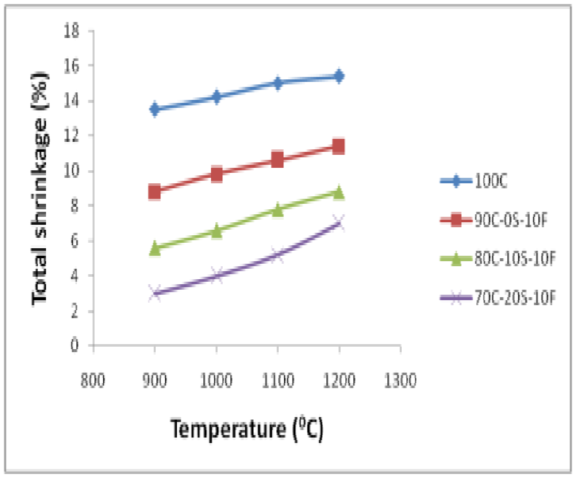

Figure 2: The Effect of Temperature on the Total Shrinkage of the Clay and Tiles.

The effect of feldspar and silica addition and the porosity behavior is given in Figure 2. Porosity was higher in unmodified samples than modified samples. It was observed that the addition of feldspar greatly reduced the porosity as the temperature rose from 900ºC to 1200ºC and a slight in porosity was observed with addition of silica.

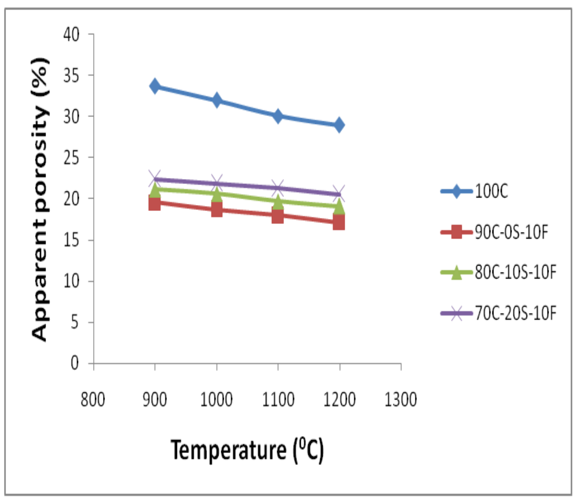

Figure 3: The Effect of Temperature on the Apparent Porosity of the Clay and Tiles.

Also, the porosity values for the sample B, C, and D were within the internationally permissible limits 10% to 28% and 20% for SON (Standard Organization of Nigeria), thus tiles produced with B,C and D were within these standards in terms of porosity.

The effect of feldspar and silica addition and the bulk density behavior is given in Figure 4.It was observed that all the samples gave a good bulk density suitable for the tiles production and other ceramic applications it was within the range 1.7gcm^{-3} to 1.8gcm^{-3} which was within the internationally accepted range for building and fireclays, (Abuh *et al.,*2014).

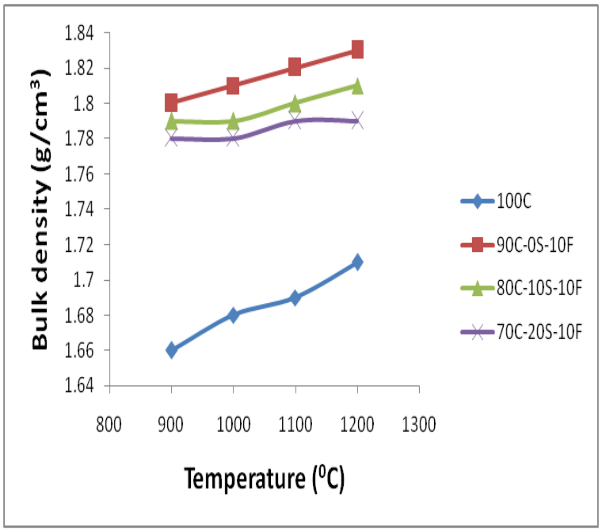

Figure 4: The Effect of Temperature on the Bulk Density of the Clay and Tiles.

The effect of feldspar and silica on addition and the cold compression strength is given in Figure 5. Tiles that contains 100% clay (control sample) was the weakest of all the variations, while tiles that contains only feldspar was relatively the strongest. On addition of silica to the tiles, the strength reduced slightly.

This observed behavior was as a result of the inert surface of silica, silica moderate the alteration to the properties of the body as enhanced by the addition of feldspar. The bisque fired test pieces and the glazed ceramic tiles produced are shown in Plates I and II, respectively.

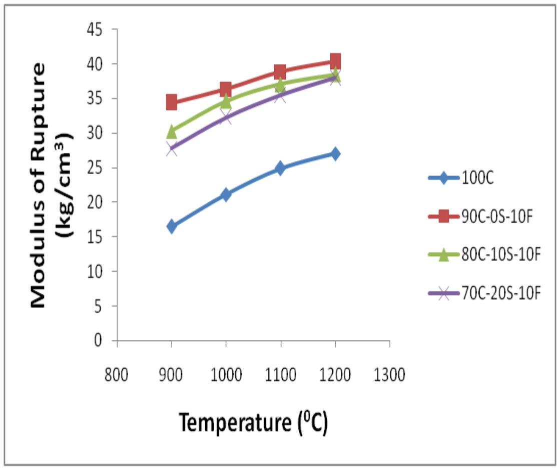

Figure 5: The Effect of Modulus of Rupture of the Clay and Tiles.

Plate I: Bisque Firing Test Pieces at Different Temperatures.

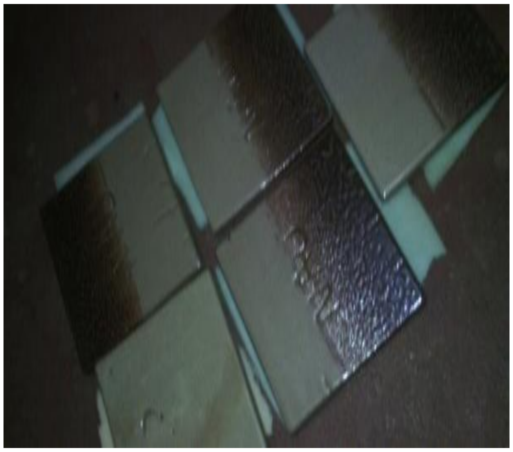

Plate II: The Glazed Tiles Produced.

CONCLUSION

From the tests conducted, the results of physical analysis shows a remarkable improvement in the quality of the tiles produced when additives (silica and feldspar) were added. Addition of feldspar ($K_2O.Al_2O_3.6SiO_2$), greatly reduced the water absorption and porosity of the sample to achieve a reduced penetration of molten materials into wares (tiles). We observed that only tiles (A), the control sample could not be used to compare reasonable with the imported clay tiles. We can produce or own local ceramic tiles using the abundant of clay we have in Mbaukwu, Awka South Local Government Area of Anambra State, this was confirmed by the results from the tests conducted.

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