

Analysis and Characterization of Clay Soil in Abakaliki, Nigeria

E.S. Nweke, M.Sc. and E.I. Ugwu, Ph.D.*

Department of Industrial Physics, Ebonyi State University, PMB 053, Abakaliki, Nigeria.

*E-mail: ugwuei@yahoo.com

ABSTRACT

A study of the characteristics of clay samples from different locations in Nigeria has been carried out. The specimens were processed and sintered using the normal ceramics techniques and the particles size distribution, sedimentation test, density, porosity, cation exchange capacity, mechanical strength, and electrical characteristic were determined for each specimen. The exchange capacity increased with increasing magnitude of porosity. Similarly, the resistivity increased with decreasing porosity. Samples were then processed individually and blended to the following ratio:10:90, 30:70, 50:50, 70:30, and 90:10. The blends were fired at furnace temperatures of 800 C, 850 C, 900 C, and 950 C, respectively, and then tested for density, porosity, and modulus of rupture. The results obtained showed that the maximum service temperature of the blends was 900 C and that the 90:10 blend presented the best characteristic under the conditions studied, suggesting that the blends can only be used in furnaces where temperature requirements fall below 900 C.

(Keywords: particle size, sediment, density, porosity, soil, ion exchange, building material, sintering, ceramics, bricks)

INTRODUCTION

The oldest clay deposit was found in Africa by archeologists some ten thousand years ago (Norton, 1974, Dinadale, 1986 and Prudence, 1987). This is an abundant fine earthy powder produced by the weathering and disintegration of granite and feldspathic rocks (Idenyi et al. 2003). In the southern part of Nigeria, most regions are richly blessed with natural resources like clay. These clay-based materials occur both in the plain and river rime areas (Amaefule, 1990). In recent times, coconut fibers, laterites, and other useful materials have been mixed in different proportions to produce roofing sheets and bricks as building materials. The rate of development and application of such new materials and the constant demand for high quality

building/agricultural materials necessitated the need for this study. The use of these material resources was made possible by the application of heat in transforming the soft clay deposit into something malleable, hard, and durable (Norton, 1974; Dinadele, 1986; Owate, 1988 and Ogbi, 1984).

It is believed that the history of ceramics really began with recognition of clay as useful raw material. The characteristic features of interest include plasticity, resistance to high temperature, malleability (can be shaped to any form), and complex composite formulations (adding various substances to clay with a view to improving the properties and usefulness).

The various characteristic properties of most clay products are believed to be the consequence of impurity additions, sintering (firing procedure), and manufacturing processes. As it is clear and well known that clay-based materials are especially abundant in high temperature areas like Nigeria, since it possesses the ability to resist compressional forces to a reasonable extent,

Our work is therefore based on finding the fundamental properties of different soil sample of clay from three zones in Abakaliki, (Onnueke, Eda-Achara, and Iboko), Ebonyi state. This is a sequel to the importance of such knowledge as oil prospecting operations and structural applications. Furthermore, any knowledge of clay properties would help in the process modification and development of clay refractory products, especially as it relates to foundry works (Owate et al. 1996 and Whitman, et al. 1979). It also supports understanding of the agricultural viability of these study areas.

EXPERIMENTAL PROCEDURE

Clay samples were collected from three different locations in Abakaliki, Ebonyi State, Nigeria;

Sample A (Onueke), sample B (Ede – Achara), and Sample C (Iboko). These were collected at a depth of 0.5 m and analyzed. The specimens were dried, crushed, and then sieved. The pressed samples were of 26 mm diameter and about 2.5 mm in thickness.

The soil samples were crushed (using mortar and pestle) to their powdery forms. Fine aggregates were graded using sieve sizes between 1.18 and 60 mm. The cumulative mass of dry crushed samples used for the sieve analysis was approximately 200 g. About 20 g of each specimen was weighed and put into a conical flask which contained 20 mm of hydrogen peroxide as a catalyst. The mixture was properly stirred and then placed into a 1000 mm measuring cylinder containing deionized water. The solution was again stirred for 15 minutes and left to stand for another 15 minutes after which the percentage mass of solute was determined after every 10 minutes for a duration of 24 hours.

The densities of the samples were determined using a simple weighing method. The porosity of the materials were obtained using the ASTM C373 (American standard of testing material) test method (Owate, 1996). The porosity σ of the system was calculated using the formula:

$$\sigma = \left[1 - \frac{fd}{td} \right] \times 100$$

where fd = final density and td = theoretical density.

All samples were preserved for three and seven days before the mechanical strength determinations. The specimens were tested in air at room temperature (35 C) by a diameter compression technique using an 1 Å testing machine (ModelT-DML-AO675) at a constant displacement rate of 0.5 mm/mm. The powder was blended to the following ratio by weight: 10:90, 30:70, 50:50, 70:30 and 90:10. The samples were loaded into a Gallenkamp muffle furnace with a maximum temperature of 1200 C. They were then fired at the 800 C, 850 C, 900 C, and 950 C. At each temperature, selected samples from each ratio were withdrawn, allowed to cool normally, and then subjected to test for porosity densities and modulus of rupture according to standard specifications.

In order to determine the cation exchange capacity of the clay samples, each specimen was dipped into acetone and then crushed to pass through 250 μ m sieve using an ATM sonic method. The

sieved samples were rinsed with toluene and finally acetone. This reduces the effect of any ionic impurity from the system. Rinsed samples were later dried over night and then 8 g of each specimen were weighed out and put into a round-bottom flask containing 150 ml of HCl plus 200 ml of deionized water. This solution was boiled for four hours and then left to cool. The cool solution was later filtered several times and then re-filtered, and the residue obtained were rinsed properly in methanol and washed in distilled water. This was then transferred into a conical flask containing 1 g of MgO , 10 ml of HCl, and 1 ml of 0.2% methyl red. The entire contents were distilled to near dryness and the excess acid was titrated with 0.1 M NaOH to its end point.

The cation exchange capacity (CEC) was then calculated using the expression.

$$CEC = \frac{100}{1} * \left(\frac{M_{HCl} * V_{HCl} - M_{NaOH} * V_{NaOH}}{W_S} \right)$$

where,

M_{HCl} = Moles of HCl;

V_{HCl} = Volume of HCl;

M_{NaOH} = Moles of NaOH;

V_{NaOH} = Volume of HCl; and

W_S = Weight of sample.

The current-voltage characteristic of the sample was determined using the Tektronic-V Curve Tracer (Type 576) and a simple electrical circuit. The resistivity of the specimen was later obtained through simple resistance measurement and calculations. The chemical composition of the clay was also determined.

RESULTS AND DISCUSSIONS

From the chemical analysis (Table 1) the clay sample collected from the three locations consists of kaolinite, smectites and illites as major minerals. The result obtained indicated that sample C, settled very slowly in water, unlike sample B that settles faster than samples A and C.

The density as recorded in Table 1 appears to be relatively the same for the samples, though sample C is slightly higher than the rest of the samples. From Table 2, one observes that sample C has the least porosity followed by sample B. The CEC of the

sample which has the highest porosity is best when compared to the rest.

Table 1: Chemical Analysis of Abakaliki Clay.

Abakaliki Clay	Si O ₂	Al ₂ O ₃	Fe ₂ O ₃	C _a O	M _g O
	54.25	22.83	0.12	2.03	1.44

Table 2: Density and Porosities of Different Clay Samples.

SAMPLES	DENSITY (g/m ³)	POROSITY (%)	CEC Milli equic.
Sample A	2.29	10.60	9.26
Sample B	2.28	10.99	8.89
Sample C	2.33	9.03	9.51

The resistivity of the samples was computed as shown in Figure 3 from the values of resistance obtained from each sample. From the result, it is clear that sample B has the highest resistivity.

Table 3: Resistivity of the Clay Samples.

SAMPLES	RESISTIVITY (Ohm-cm)
Sample A	303.7
Sample B	434.5
Sample C	190.7

From Table 4, it is observed that the modulus of rupture of the samples varied at various temperatures with all the samples showing maximum at 900 C which made it clear that 900 C is the maximum service temperature of the blend. One also observes that the 90:10 and 10:90 blends presented the highest value of modulus of rupture at the maximum service temperature.

From the result obtained, sample B appears to possess the most desired properties for use as a building material. Other properties such as density, porosity, cation exchange capacity, and sedimentation suggest that sample B is a good refractory material.

The block has a high tensile strength compared to cement and other building materials especially when it is molded in a small dimension and well fired grade. The merit of clay blocks is low cost of production, artistic design of the framework, coupled with abundance of the clay materials

available locally. Also as was observed that sample B settles faster in water when compared to other samples of local clay. This indicates its potential application in agricultural uses.

Table 4: Modulus of Rupture Values for Clay and Clay Blends.

SAMPLES	Modulus of rupture (kg f/cm ²)			
	800 C	850 C	900 C	950 C
Sample A	25.15	27.37	45.34	43.11
Sample B	22.71	23.03	36.34	31.11
Sample C	20.90	21.01	25.23	20.10
Clay Blends				
90:10	19.86	23.26	42.99	34.97
70:30	18.87	19.91	28.88	19.48
50:50	23.18	26.66	32.78	31.72
30:70	25.16	28.27	39.38	37.79
10:90	34.74	35.57	40.25	37.76

These properties are indicators of a material that can reduce leaching. Crops such as yam, cassava, cocoyam, and rice grow well in this type of soil and it is why Abakaliki is one of the largest producers of some of these crops in Nigeria today.

CONCLUSION

From this work, we discovered that sample B, from the Ede – Achara area, consists mainly of silt and little sandy clay particles and settles faster in water than samples from the other two study locations. The sample has a low porosity though with reasonable density and high resistivity. As it was discovered in some of the characterization parameters, the sample can be considered a good material for agriculture and in building applications.

From the result of the characterization of blended clay from Nkalaha also in Northern part of Ebonyi State and Nsu in Imo State carried out by Idenyi [Idenyi, 2005], the modulus of rupture after the maximum service temperature started to decrease as a result of spacing since the material becomes weaker.

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ABOUT THE AUTHORS

E.S. Nweke is a researcher in the Department of Industrial Physics at Ebonyi State University with research interests in soil composition and clay characterization.

E.I. Ugwu, Ph.D. is a faculty member of the Department of Industrial Physics; Ebonyi State University, Nigeria. Dr. Ugwu's research interests are in the areas of thin films, solution growth techniques, and chemical analysis.

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