

## Industrial Potential of Some Clay Deposits In Kogi State North Central Nigeria

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**Abstract:** The samples collected from ten sites each from Uhodo, Oguma and Odogi were pulverized, dried, sieved and quantitatively analyzed. Physical, chemical and mechanical properties of the samples were determined. Results of the chemical analysis carried on the raw samples showed that it contained substantial amount of silicon oxides (44-46%) and aluminum oxides (34-35%), which qualifies it as Alumino-silicates. Physical and mechanical properties also determined are particle size distribution, specific gravity, bulk density, solid density, water absorption, apparent porosity, permeability to air, refractoriness, thermal shock resistance, modulus of rupture, linear shrinkage and thermal conductivity. The sieve test showed that most of the clay were retained within 300  $\mu\text{m}$ . The values for specific gravity, bulk density, solid density and apparent porosity averaged 2.82, 2.88  $\text{g/cm}^3$ , 2.88  $\text{g/cm}^3$ , and 12.67% respectively and they were within the internationally accepted range. The values for linear shrinkage, permeability to air and thermal shock averaged 8.75%, 77.3, and 29+ respectively and these also were within the accepted limits. The values for modulus of rupture and thermal conductivity averaged 90.67  $\text{MN/m}^2$  and 0.443  $\text{W/m}^2\text{K}$ . The refractoriness of all the samples were  $>1300^\circ\text{C}$  and this showed that they could be used as insulating materials.

**Keywords:** Industrial, Potential, Clay Deposits, Kogi State Nigeria

### I. INTRODUCTION

Clay is a common name for a number of fine-grained, earthy materials that become plastic when wet. Chemically, clays are hydrous aluminum silicates, ordinarily containing impurities, e.g., potassium, sodium, calcium, magnesium, or iron, in small amounts Grimshaw (1959). They are divided into two classes: residual clay, found in the place of origin, and transported clay, also known as sedimentary clay, removed from the place of origin by an agent of erosion and deposited in a new and possibly distant position. Residual clays are most commonly formed by surface weathering, which gives rise to clay in three ways—by the chemical decomposition of rocks, such as granite, containing silica and alumina; by the solution of rocks, such as limestone, containing clayey impurities, which, being insoluble, are deposited as clay; and by the disintegration and solution of shale Manukaji (2004). One of the commonest processes of clay formation is the chemical decomposition of feldspar. Clay minerals are typically formed over long periods of time by the gradual chemical weathering of rocks, usually silicate-bearing, by low concentrations of carbonic acid and other diluted solvents. These solvents, usually acidic, migrate through the weathering rock after leaching through upper weathered layers. In addition to the weathering process, some clay minerals are formed by hydrothermal activity Guggenheim et al (1995). Clay deposits may be formed in place as residual deposits in soil, but thick deposits usually are formed as the result of a secondary sedimentary deposition process after they have been eroded and transported from their original location of formation. Clay deposits are typically associated with very low energy depositional environments such as large lakes and marine basins. Primary clays, also known as kaolins, are located at the site of formation. Secondary clay deposits have been moved by erosion and water from their primary location. Depending on the academic source, there are three or four main groups of clays: kaolinite, montmorillonite-smectite, illite, and chlorite. Chlorites are not always considered a clay, sometimes being classified as a separate group within the phyllosilicates. There are approximately 30 different types of "pure" clays in these categories, but most "natural" clays are mixtures of these different types, along with other weathered minerals. Ehlers et al(1982)

Clays exhibit plasticity when mixed with water in certain proportions. When dry, clay becomes firm and when fired in a kiln, permanent physical and chemical changes occur. These reactions, among other changes, cause the clay to be converted into a ceramic material. Because of these properties, clay is used for making pottery items, both utilitarian and decorative. Different types of clay, when used with different minerals and firing conditions, are used to produce earthenware, stoneware, and porcelain. Clay, being relatively impermeable to water, is also used where natural seals are needed, such as in the cores of dams, or as a barrier in landfills against toxic seepage (lining the landfill, preferably in combination with geotextiles). Hillier (2003) Clay is one of the oldest building materials on Earth, among other ancient, naturally-occurring geologic materials such as stone and organic materials like wood. Between one-half and two-thirds of the world's population, in traditional societies as well as developed countries, still live or work in a building made with clay as an essential part of its load-bearing structure.

Properties of the clays include plasticity, shrinkage under firing and under air drying, fineness of grain, color after firing, hardness, cohesion, and capacity of the surface to take decoration. On the basis of such qualities clays are variously divided into classes or groups; products are generally made from mixtures of clays and other substances. The purest clays are the china clays. A refractory material is one that retains its strength at high temperatures. ASTM C71 defines refractories as "non-metallic materials having those chemical and physical properties that make them applicable for structures, or as components of systems, that are exposed to environments above 1,000 °F (811 K; 538 °C)". Guggenheim et al (1995)

Refractory materials are used in linings for furnaces, kilns, incinerators and reactors. They are also used to make crucibles. Refractory materials must be chemically and physically stable at high temperatures. Depending on the operating environment, they need to be resistant to thermal shock, be chemically inert, and/or have specific ranges of thermal conductivity and of the coefficient of thermal expansion. The oxides of aluminium (alumina), silicon (silica) and magnesium (magnesia) are the most important materials used in the manufacturing of refractories. Another oxide usually found in refractories is the oxide of calcium (lime). Fire clays are also widely used in the manufacture of refractories. Refractories must be chosen according to the conditions they will face. Some applications require special refractory materials. Zirconia is used when the material must withstand extremely high temperatures. Silicon carbide and carbon (graphite) are two other refractory materials used in some very severe temperature conditions, but they cannot be used in contact with oxygen, as they will oxidize and burn.

Binary compounds such as tungsten carbide or boron nitride can be very refractory. Hafnium carbide is the most refractory binary compound known, with a melting point of 3890 °C. Hugh(1992) The ternary compound tantalum hafnium carbide has one of the highest melting points of all known compounds (4215 °C). McGraw-Hill (1977)

## MATERIALS AND METHODS

The clay samples to be used for the manufacturing of the base plates were mined from ten different locations on a particular sight in order to have a good representation of the sight. Three sights were used for the state in order to further give a wider sample spread for the state. The sights are

### KOGI STATE NIGERIA: Uhodo, Oguma, Odogi

The mined clay samples from the ten locations on a sight were mixed properly and a representative specimen for test from that sight was produced using the cone and quartering system as recommended by the American Society of Testing Materials (ASTM). The resultant specimen for each sight were kept in a P.V.C. bags and labeled as follows.

LOCATION	SPECIMEN LABEL
Uhudo	G
Oguma	H
Odogi	I

### COLOUR INSPECTION

The specimen were physically inspected for colour appearance and the following results as shown below were observed.

SPECIMEN	COLOUR
G	Grayish
H	Whitish ash
I	Creamy Yellow

## II. SIEVE TESTING

Each specimen was milled down using a ball or hammer mill. It was soaked in water for 48 hours after which, it was dried by spreading it on a tray and placing it in the sun to dry. It was milled to powdery form using a ball or hammer mill after which 600g of the specimen were sieved using 700 $\mu$ m, 500 $\mu$ m, 300 $\mu$ m, 100 $\mu$ m, 50 $\mu$ m. The sieve were placed on a mechanical vibrator operated for 30 minutes after which the content of each sieve was weighed. The mass of the specimen left at each compartment of the sieve, the percentage retained and the percentage passed were calculated.

TABLE 1: SIEVE ANALYSIS

CLAY SPECIMEN	Sieve no in $\mu$ m	Mo	M1	%R	%P
SPECIMEN G	700	600	27.20	4.53	95.47
	500	600	125.42	20.90	79.10
	300	600	230.07	38.35	61.65
	100	600	140.47	23.41	76.59
	50	600	60.47	10.08	89.92
SPECIMEN H	700	600	32.21	5.37	94.63
	500	600	152.51	25.42	74.58
	300	600	230.17	38.36	61.64
	100	600	112.47	18.75	81.25
	50	600	61.30	10.22	89.78
SPECIMEN I	700	600	38.19	6.37	93.63
	500	600	143.02	23.84	76.16
	300	600	220.09	36.68	63.32
	100	600	128.08	21.35	78.65
	50	600	43.31	7.22	92.78

## CHEMICAL ANALYSIS

In determining the chemical constituents of the specimens, The Atomic Absorption Spectroscopy method was used and the results were as follow

TABLE 2: CHEMICAL ANALYSIS

Oxides in Specimen	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	CaO	MgO	K <sub>2</sub> O	Na <sub>2</sub> O	L.O.I
G in %	44	35	1.3	2.4	0.5	0.6	1.5	0.7	14
H in %	45	34	1.5	1.5	0.4	0.1	1.4	0.1	16
I in %	46	34	0.9	3.0	0.2	0.4	1.2	0.3	14

## FURTHER TESTS

The specimen were subjected to further standard refractory test and the result obtained are tabulated below.

TABLE 3: SPECIFIC GRAVITY

Clay specimen	G	H	I
Specific Gravity	2.92	2.78	2.77

TABLE 4: BULK DENSITY

Clay specimen	G	H	I
Bulk density g/cm <sup>3</sup>	1.91	2.08	2.01
Solid densityg/cm <sup>3</sup>	2.85	3.01	2.79

TABLE 5: LINEAR SHRINKAGE

Clay specimen	G	H	I
% average drying shrinkage	2.32	2.16	2.27
% average firing shrinkage at 1200°C	9.11	9.13	8.01

TABLE 6: PERCENTAGE WATER ASORPTION

Clay Specimen	G	H	I
% water absorption at 110°C	29.2	28.7	30.1
% water absorption at 1200°C	3.1	3.0	3.1

**TABLE 7: APPARENT POROSITY**

Clay specimen	G	H	I
% apparent porosity at 110°C	23	25	20
% apparent porosity at 1200°C	13	14	11

**TABLE 8: PERMEABILITY**

Clay Specimen	G	H	I
Permeability	78.3	74.5	79.1

### III. REFRACTORINESS

Test cones were prepared from each clay specimen, dried and placed in a furnace along with pyrametric cones designed to deform at 1000, 1300, and 1500°C respectively in accordance with the American society of testing materials (ASTM). The temperatures were then raised at 10°C per min. and was determined by the means of an optical pyrometer. The maximum temperature available in the furnace was 1300°C and the test cones did not show any sign of failure or deformation, meaning that all the clay samples have a > 1300°C refractoriness.

### IV. THERMAL SHOCK RESISTANCE

Test cubes 50mm square were also produced from each clay specimen and put in an electric furnace that already attained a temperature of 900°C. They were soaked there for 20 minutes after which they were brought out and cooled in stream of air. The cubes were tested by using hand to pull them apart. If they do not fracture or crack, they were returned to the furnace for the process to be repeated. This process must continue repeatedly until fracture or crack occurs. The results showed that non of the cubes cracked under 29 cycles.

**TABLE 9: MODULUS OF RUPTURE**

Clay specimen	G	H	I
M.O.R at 110°C KN/m <sup>2</sup>	6283	7172	6983
M.O.R at 1200°C MN/m <sup>2</sup>	88	94	90

**TABLE 10 : THERMAL CONDUCTIVITY**

CLAY SPECIMEN	G	H	I
THERMAL CONDUCT W/mK	0.502	0.427	0.401

### V. RESULTS AND DISCUSSION

#### FIRING COLOUR CHANGE.

The samples showed some darkened colour changes at temperatures of 1200°C from their original colour to ashy black. This was however attributed to the fact that the firewood smoke had serious effect on the colour change.

#### SIEVE ANALYSIS

Tables 1 showed the particle distribution of the clay samples. It was however observed that most of the particles were retained within the sieve mesh of 300µm

#### CHEMICAL ANALYSIS

TABLE 2 showed the chemical analysis of the clay samples. The results showed that most of the clays were siliceous in nature, having the highest number of silica present. Also the presence of Aluminum oxide of the order of between 25—45% makes them to fall under the class of Alumino-Silicate refractories. **Hassan et al (1993)**

#### SPECIFIC GRAVITY

The specific gravity values of the samples in table 3 fell between 2.7 – 3 and this fell within the ranges for Nigerian clays as reported by **Akinbode (1996)**, **Hussaini (1997)**. It is pertinent to note that the values compared favourably with international range of 2.0 and 2.9. Sample **I** had the lowest value of 2.77 while sample **G** had the highest value of 2.92. **Obi(1995)**

### **BULK DENSITY AND SOLID DENSITY**

The bulk densities of the samples were shown in table 4 and the values fell within the internationally accepted range of 1.7—2.1g/cm<sup>3</sup> for fire clays .Thring (1962)

The solid density of the samples also fell within the internationally accepted range of 2.3—3.5g/cm<sup>3</sup>. Ryan (1978). The highest solid density value was recorded by sample H while the least was by sample I

### **LINEAR SHRINKAGE**

Table 5 showed the linear shrinkage of the samples at 110°C and 1200°C. The linear shrinkage values obtained at 1200°C varied from 8.01 in sample I, 9.11 in sample G to 9.13 in sample H. Although this gives an indication of the efficiency of firing, it fell within the internationally accepted value of 7—10% value for Alumino-silicates, Kaolin and fireclays.Zubeiru(1997)

### **WATER ABSORPTION**

Table 6 showed the percentage water absorption at 110°C and 1200°C. From the table, sample I showed the highest percentage of water absorbed while sample H showed the least at 110°C. At 1200°C, sample G and I showed the highest value while sample H showed the least Hassan(1990).

### **APPARENT POROSITY.**

Table 7 showed the apparent porosity of the samples at 110°C and 1200°C respectively. Sample I had the least value while samples H had the highest at 110°C. Meanwhile all the samples fell within the internationally accepted value of 20% and 80% Thring (1962) for fired bricks. At 1200°C, samples I had the least value of 11% while samples H had the highest of 14%. This shows that as the temperature increases, the percentage apparent porosity decreases, indicating more closure of the pores. This can be increased for insulation purposes by adding saw dust, corn or rice husks. Olusola(1998)

### **PERMEABILITY TO AIR**

The permeability of the samples were presented in table 8. It is important however to state that all the samples had their permeability to air within the internationally accepted value of 25—90, following the observations of Hassan (1990). Sample I recorded the highest permeability to air while sample H recorded the least. High permeability is highly recommended for insulating refractories. The permeability can also be improved by incorporating saw dust and rice husks in the clay, while molding. Manukaji(2004)

### **REFRACTORINESS**

For the fact that all the samples did not show any sign of failure at temperatures of 1200°C and above, it means that their sintering level is very high and will fall within the internationally accepted range of 1580°C – 1750°C. This eventually showed that the samples have high and good refractoriness qualities and can withstand the high temperatures the clay will be subjected to in operation. Abifarin(1999)

### **THERMAL SHOCK RESISTANCE**

All the samples showed a thermal shock resistance of 29+ cycle. The thermal shock resistance values for the samples are acceptable for siliceous fire clays. This property is vital for materials used in places where heating and cooling operation is carried out repetitively Agha(1998)

### **MODULUS OF RUPTURE.**

Table 9 showed the values of modulus of rupture for all the samples. At 110°C sample G showed the least value while sample H showed the highest value. At 1200°C, all the samples showed an improvement in their modulus of rupture but sample G still recorded the least while sample H recorded the highest values Ijagbemi(2002).

### **THERMAL CONDUCTIVITY**

Table 10 showed the values of the thermal conductivity test for all the samples. The values showed that specimen I had the least thermal conductivity value, while the highest value was specimen G. Ijagbemi(2002)

## **VI. CONCLUSION**

With a critical look on the properties of the clay samples surveyed, tested and analyzed during this investigation, the following conclusions can be deduced.

- (1) From the chemical analysis, all the clay samples had silica and alumina as the predominant substances and it could be concluded that they are siliceous in nature and are of the Alumino-Silicate refractories.

- (2) The water content of the clay samples made handling of the clay (mouldability) very possible. The fire shrinkage values which hovered between 8 and 10% were found to be within the internationally accepted range for clays. The clays from sites showed a permeability range of 68-82% which also falls within the range of 24-92% for typical fire clays bricks. The apparent porosity of the clays, compared favourably with the normal acceptable standards as they fell between 20 to 25%. The samples had a thermal shock range of 29 cycles, which closely coincided with the acceptable values internationally. The internationally acceptable range for bulk density is between 1.7 to 2.2 g/cm<sup>3</sup> and the samples fell within the range thereby conforming to the approved values. The refractoriness of the clays showed that the clays could withstand temperatures between 1200 to 1600°C which is good for industrial use.

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