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Categorisation Of Clay Deposits In The Federal Capital Territory Of Abuja

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ABSTRACT

Clay deposits in the Federal Capital Territory of Abuja were investigated with a view to categorizing them in order to determine their suitability as insulating refractory material. The samples were collected from three different locations in the territory, namely Sheda, Abaji and Karimu, and labeled A, B, and C. In order to project a better representation of the territory, the samples were mined from ten cites each. The mined clay samples from the ten cites were mixed properly and a representative specimen for test from that location was produced using the cone and quartering system as recommended by the American Society of Testing Materials (ASTM). Atomic Absorption Spectrometer(AAS) was used to determine the chemical composition, while other established processes were used to determine other insulating properties like 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 chemical analysis showed that all the samples had high percentages of silica and alumina, thereby classifying them as Alumino-silicates.

The values for specific gravity, bulk density, solid density and apparent porosity averaged 2.75, 2.04 g/cm^3, 3.18 g/cm^3 , and 13% respectively and they were within the internationally accepted range. The values for linear shrinkage, permeability to air and thermal shock averaged 8.57% 69.4, and 29+ respectively and these also were within the accepted limits. The values for modulus of rupture and thermal conductivity averaged 81 MN/m^2 and 0.494 W/m^{o}K. The refractoriness of all the samples were >1300^{o}C and this showed that they could be used as insulating materials.

INTRODUCTION

Clay minerals are fine- particle-size hydrous alumino-silicates which develop plasticity when mixed with water. They vary over quite wide limits in chemical mineralogical and physical characteristics. A common characteristics is their layer structure. They are all composed of electrical neutral alumino-silicate layers which move readily over each other, giving rise to such physical property as softness, soapy feel and easy cleavage. **Manukaji (2004)** All clay minerals are of secondary geologic origin i.e. they were formed as alteration products of alumino-silicate rocks in an environment in which water is present. **Ijagbemi (2002)**

Clay minerals are produced mainly from the weathering of feldspars and micas. They form part of a group of complex alumino-silicates of potassium, magnessium and iron, known as layer-lattice minerals.**Abifarin(1999)** They are very small in size and very flaky in shape, and so have considerable surface area **Thring (1962)**. Further more, these surfaces carry a negative electrical charge, a phenomenon that has great significance in the understanding of the engineering properties of clay soils. **Agha(1998)**

To gain an understanding of the properties of clay minerals, it is necessary to examine the essential features of their layer-lattice structure. These comprise of the tetrahedral unit, which comprise of a central silicon ion with four surrounding oxygen ions and the octahedral unit comprising a central ion of either aluminium or magnessium, surrounded by six hydroxyl ions. In both, the metal (with positive valency) is on the inside and the negative non-metallic ions form the outside.**Akinbode(1996)**

The layer structure is formed when the oxygen ions covalently link between units. Thus, a silica layer is formed of linked tetrahedral, having a general formula of nSi_40_{10} $(0H)_2$. The octahedral units also link together at their apices to form a layer, which may be either a gibbsite layer $(Al_4\,(0H)_6)$, in which only two thirds of the central positions are occupied by Al^{3+} ions, giving a dioctahedral structure or a brucite layer $(Mg_6(0H)_6)$, in which all the central positions are occupied by Mg^{2+} ions giving a triotahedral structure.**Li Zaigeng et al(2001)**

The spacing between the outer ions in the tetrahedral and octahedral layers is sufficiently similar for them to link together via mutual oxygen or hydroxyl ions. Two stacking arrangements are possible, giving either a two-layer or a three-layer structure.**Mahmoud et al(2003)**

In a two-layer lattice, tetrahedral and octahedral layers alternate, while a three-layer arrangement consists of an octahedral layer sandwiched between two tetrahedral layers. Mineral particles are built up when the layers are linked together to form stacks.**Chesti (1986)**

Depending on the stacking arrangements and type of ions providing linkage between layers, their mineralogical and chemical composition, particularly the clay mineral constituents, six main groups of clay minerals may be identified: kaolinite, montmorillonite, illite, chlorite, attapulgite and vermiculite **Thring (1962)**. The presence of minor amounts of mineral or soluble salt impurities in clays can restrict their use. The more common mineral impurities are quartz, mica, carbonates, iron oxides and sulfides, and feldspar. In addition, many clays contain some organic materials.**Clews (1969)**

Clay is an abundant raw material. However, certain high grade types of clay deposits are limited in geographic occurrence and extent. Examples are the white kaolin clays found in abundance only in Georgia and South Carolina; the high quality bentonites found in Wyoming, South Dakota, California, Texas, and Mississippi; and the attapulgite clays found in Georgia and Florida. **Theraja et al (1999)**.

METHODOLOGY

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

FEDERAL CAPITAL TERRITORY:
Sheda, Abaji, Karimu

The mined clay samples from the ten locations on a cite were mixed properly and a representative specimen for test from that cite was produced using the cone and quartering system as recommended by the American Society of Testing Materials (ASTM).**IEE(1992)** The process involves mixing the samples and spreading them uniformly and equally into a rectangle. The rectangle is divided into four equal parts and two alternate portions were taken, mixed properly and formed into a cone. The cone was also divided into four equal parts while the alternate portions were further taken. This process of mixing properly, spreading into rectangular shapes and cones and taking the alternate portions continued until a sizable quantity sufficient for the tests to be carried out were produced.

The resultant specimen for each sight were kept in P.V.C. bags and labeled as follows.

LOCATION	SPECIMEN LABEL
Abaji	A
Sheda	B
Karimu	C

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

SPECIMEN	COLOUR
A	Grayish
B	Whitish ash
C	Ashy brown

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 700µm, 500µm, 300µm, 100µm, 50µm. The sieve were placed on a mechanical vibrator operated for 30 minutes after which the content of each sieve was weighed.

In determining the chemical constituents of the specimens, The Atomic Absorption Spectroscopy method was used. In this process, the instrument was calibrated while solutions of the specimens were prepared.

The clay samples were also analysed for other properties like Specific gravity, Bulk and Solid Density, linear Shrinkage, Percentage water absorption, apparent Porosity, Permeability to air, Refractoriness, Thermal Shock Resistance, Modulus of Rupture and Thermal conductivity, using standard test procedures in BS 1902 Part 1 A

RESULTS.

TABLE 1: SIEVE ANALYSIS

CLAY SPECIMEN	Sieve no in µm	Mo	M1	%R	%P
SPECIMEN A	700	600	22.10	3.68	96.32
	500	600	150.01	25.00	75.00
	300	600	210.02	35.00	65.00
	100	600	129.03	21.51	78.49
	50	600	66.08	11.01	88.99
SPECIMEN B	700	600	16.10	2.68	97.32
	500	600	100.25	16.71	83.29
	300	600	201.07	33.51	66.49
	100	600	168.74	28.12	71.88
	50	600	85.01	14.17	85.83
SPECIMEN C	700	600	30.18	5.03	94.97
	500	600	96.68	16.11	83.89
	300	600	282.39	47.07	52.93
	100	600	96.38	16.06	83.94
	50	600	66.71	11.12	88.88

M_o = mass of each sample of clay used
M_1 = mass of each sample of clay retained in the sieve
%R = Percentage retained
%P = Percentage passed

TABLE 2: CHEMICAL ANALYSIS

Oxides in specimen	A	B	C
SiO_2	40	43	40
Al_2O_3	41	37	41
Fe_2O_3	1.0	1.0	1.4
TiO_2	2.2	2.2	2.0
CaO	0.3	0.1	0.6
MgO	0.2	0.4	0.1
K_2O	1.7	2.1	2.3
Na_2O	0.6	0.2	0.6
L.O.I	13	14	12

TABLE 3: SPECIFIC GRAVITY

Clay specimen	**A**	**B**	**C**
Specific Gravity	2.69	2.58	2.98

TABLE 4: BULK DENSITY AND SOLID DENSITY

Clay specimen	**A**	**B**	**C**
Bulk density g/cm^3	1.99	2.01	2.11
Solid densityg/cm^3	2.84	3.24	3.46

TABLE 5: LINEAR SHRINKAGE

Clay specimen	**A**	**B**	**C**
% average drying shrinkage	2.38	2.32	2.08
% average firing shrinkage at 1200°C	8.22	8.36	9.12

TABLE 6: PERCENTAGE WATER ASORPTION

Clay Specimen	**A**	**B**	**C**
% water absorption at 110°C	30.3	29.5	28.9
% water absorption at 1200°C	3.2	3.0	2.9

TABLE 7: APPARENT POROSITY

Clay specimen	**A**	**B**	**C**
% apparent porosity at 110°C	22	23	24
% apparent porosity at 1200°C	12	13	14

TABLE 8: PERMEABILITY

Clay Specimen	**A**	**B**	**C**
Permeability	68.7	69.3	70.1

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).**IEE(1992)** 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.

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	**A**	**B**	**C**
M.O.R at 110°C KN/m²	8123	5329	5687
M.O.R at 1200°C MN/m²	98	80	83

TABLE 10 : THERMAL CONDUCTIVITY

CLAY SPECIMEN	A	B	C
THERMAL CONDUCT W/m°K	0.472	0.542	0.468

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 presents 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)** The high Potassium oxide of samples B and C shows that there is high Mica content and this according to **Phelps (1958)** is good for casting.

SPECIFIC GRAVITY

The specific gravity values of the samples in table 3 fell between 2.5 – 3 and this fell within the ranges for Nigerian clays as reported by **Akinbode (1996), Oaikhinan (1988)**. It is pertinent to note that the values compared favourably with international range of 2.0 and 2.9. Sample B had the lowest value of 2.58 while sample C had the highest value of 2.98.**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/cm³ for fire clays .**Thring (1962)**

The solid density of the samples also fell within the internationally accepted range of 2.3—3.5g/cm³.**Ryan (1978)** The highest solid density value was recorded by sample C while the least was by sample A

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 8.22 in sample A to 9.12 in sample C. 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 analyzed the percentage water absorption at 110°C and 1200°C. From the table, sample A showed the highest percentage of water absorbed while samples C showed the least at 110°C. At 1200°C, sample A also showed the highest value while sample C showed the least. **Hassan(1990)**

APPARENT POROSITY.

Table 7 showed the apparent porosity of the samples at 110°C and 1200°C respectively. Sample A had the least value while samples C 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 A had the least value of 12%

while samples C 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 C recorded the highest permeability to air while sample A 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^{o}C and above, it means that their sintering level is very high and will fall within the internationally accepted range of 1580^{o}C – 1750^{o}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 for all 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 presents the values of modulus of rupture for all the samples. At 110^{o}C sample B showed the least value while sample A showed the highest value. At 1200^{o}C, all the samples showed an improvement in their modulus of rupture but sample B still recorded the least while sample A still recorded the highest value.**Ijagbemi(2002)**

THERMAL CONDUCTIVITY

Table 10 showed the values of the thermal conductivity test for all the samples. The values showed that specimen C had the least thermal conductivity value, while the highest value was specimen B. The values are within acceptable range for refractories. **Ijagbemi(2002)**

CONCLUSION

The investigation revealed that the samples are predominantly of the Alumino-silicate. The physical properties also showed that the clay samples could serve as good refractory materials for local industries particularly those involved in the manufacturing of spare parts.

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