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LIQUID AND PLASTIC LIMIT STUDY OF MAKURDI AND UJAGBA CLAY DEPOSITS FOR FOUNDRY APPLICATIONS

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ABSTRACT

A study of the primary characteristics of Makurdi and Ujagba clay deposits was carried out with a view of determining their suitability for foundry applications. Sieve/particle size distribution, chemical analysis and liquid and plastic limits investigations were conducted using standard procedures. The results showed that Makurdi clay with 27.70% SiO_2 and Ujagba with 25.30% SiO_2 are really below the standard required for fire clay production, but can be improved by the addition of special additives. Results of liquid, plastic limits and shrinkage analysis gave values within the accepted ranges of 5-40%, 4-35% and 0-10% respectively to suggest that the clays has potential for use for foundry application.

Keywords—Clay, liquid, plastic limits, shrinkage, foundry applications

INTRODUCTION

Clay is a common name for a number of fine-grained earthly materials that becomes permanently hard when baked or fired. According to (Velde, 1995), clay is applied both to materials having a particle size of less than 2 micrometers and to the family of minerals that has similar chemical composition and common crystal structural characteristics.

Clay is formed either as a product of the chemical weathering of pre-existing granitic rocks and feldspar minerals, particularly in warm tropical and sub-tropical regions of the world or as a result of the hydrothermal alteration of granite rocks. Chemically, clays are hydrous aluminium Silicates, ordinarily containing impurities, for example potassium, sodium, Calcium, Magnesium, or iron in small amounts and are characterised by sheet Silicates structures of composite layers stocked along the C-axis (Grim, 1968) clay has a wide variety of physical characteristics such as plasticity, shrinkage under firing and under air-drying, finess, of grain, colour after firing hardness cohesion, and capacity of the surface to take decoration. Clay and clay minerals have been mined since the stone age and has been indispensible in architecture, in industry, and Agriculture. They are natural, earthy fine-grained material which are powdery when dry, plastic when wet and stone –like when baked. Today they are among the most important minerals used by manufacturing and environmental studies. Globally, clay has a wide spread occurrence. In Nigeria, clay is widely distributed though not always found in sufficient quantity or suitable quality for modern industrial purposes. More than 80 clays deposits have been reported from all parts of the country. Akhirevbulu, *et al* (2010). The liquid and plastic limits of soils and clays are two of five “limits” proposed by Atterberg, Joseph, (1986).

Plastic limit is the moisture content below which the soil is non plastic and liquid limit is the moisture content, below which the soil behave as a plastic material. At this moisture content, the soil is on the material. At this moisture content, the soil is on the verge of becoming a viscous fluid. These are used for soil identification and classification as well as for strength correlations.

MATERIALS AND METHOD

Materials

The clay materials were obtained from Abinsi-Makurdi, Benue State and Ujagba Kogi State, Nigeria.

Method

The clay as received was dried, crushed, in a laboratory pulveriser and ground in a ball mill. The material clay was washed with water to remove the organic materials and other impurities.It was sun-dried for two (2) days and again ground to 200 micrometer diameter particle size

Particle Size/Sieve Analysis

The clay was then sieved through a standard 200μm set of sieves to check the particle size distribution/sieve analysis as presented in Tables 1 and 2, and Figures 1 and 2 respectively

Table 1: Particle Size/Sieve Analysis of Makurdi Clay

Diameter (mm)	Mass retained (g)	Retained %	Passing %
20	15	3.75	96.25
14	0	0.00	96.25
10	3	0.75	95.50
6.3	14	3.50	92.00
5	7	1.75	90.25
3.35	20	5.00	85.25
2.36	24	6.00	79.25
1.7	23	5.75	73.50
1.18	33	8.25	65.25
0.85	34	8.50	56.75
0.6	76	19.00	37.75
0.425	83	20.75	17.00
0.3	46	11.50	5.50
0.15	14	3.50	2.00
0.075	7	1.75	0.25
	1	0.25	0.00

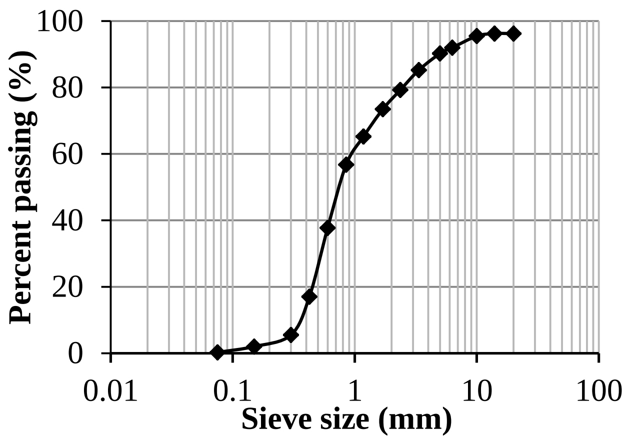

Figure 1: Particle Size Distribution Curve of Makurdi clay

Table 2: Particle Size/Sieve Analysis of Ujagba Clay

Diameter (mm)	Mass retained (g)	Retained %	Passing %
20	122.00	30.50	69.50
14	64.00	16.00	53.50
10	46.00	11.50	42.00
6.3	40.00	10.00	32.00
5	12.00	3.00	29.00
3.35	14.00	3.50	25.00
2.36	10.00	2.50	23.00
1.7	12.00	3.00	20.00
1.18	16.00	4.00	16.00
0.85	9.00	2.25	13.75
0.6	18.00	4.50	9.25
0.425	8.00	2.00	7.25
0.3	8.00	2.00	5.25
0.15	7.00	1.75	3.50
0.075	5.00	1.25	2.25
	9.00	2.25	0.00

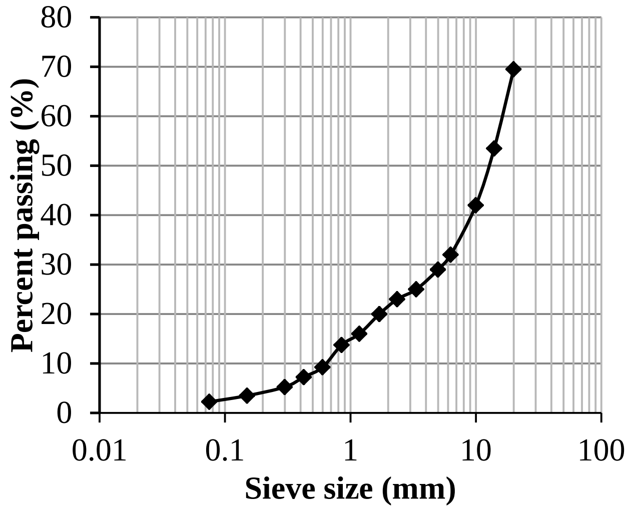

Figure 2: Particle Size Distribution Curve of Ujagba clay

Chemical analysis

The chemical analysis of the clays was done using Atomic absorption spectrometer (ASS).

Liquid Plastic Limits and Shrinkage Test

Water was added and mixed to the clay samples until the clays were plastic mouldable. Each clay sample was load filled in the cone cup of the liquid limit machine, a groove was cut on a straight line on each plastic mould using a standard grooving tool. The number of blows was counted as the cone cup was rotated to fall against a flat surface to seal up the groove (Tables 4 and 5) which defined the liquid limit. The plastic mass from the clay samples were rolled between fingers on a glass plate to form a uniform thread of 3 mm diameter from 80 strokes of forward and backward, the threads were further broken rerolled into threads until the threads crumbled under the rolling pressure as the thread crumbles at a diameter greater than 3 mm which defined the plastic limit. These samples were then weighed on the weigh balance and dried to 80 ^{0}C with the cans in the oven and reweighed again on cooling. The samples were again loaded in a standard metallic shrinkage mould and dried in the electric oven for 24 hours. The lengths before and after drying were measured using venier calliper to check the linear Shrinkage of the samples.

RESULTS AND DISCUSSION

Results

a) The results of the particle size/sieve analysis are presented in Tables 1 and 2 and Figures 1 and 2 respectively.

b) The result of chemical analysis of the clay materials are presented in Table 3

c) The result of liquid limit, plastic limit and linear Shrinkage of Makurdi clay are presented in Table 4 and Figure 3.

d) The result of liquid limit, plastic limit and linear Shrinkage of Ujagba clay are presented in Table 5 and Figures 4.

Particle size/ Sieve Analysis

Results of particle size/ Sieve Analysis (Tables 1 and 2) indicate that about 96% of Makurdi clay and only about 69% of Ujagba clay aggregates passed through the 20 mm sieve diameter. This places Makurdi clay as having fine aggregates while Ujagba is coarse, making the Makurdi clay more suitable for fire clay production, Borode, (2000).

Chemical Analysis

Results of chemical analysis (Table 3), show that Makurdi clay has 27.70% SiO_2 and Ujagba clay has it as 25.30%. These clays are not suitable for fire clays production, as their SiO_2 are below the minimum standard. These can however be improved by blending with more suitable additives, such as Silica sand. Bam, (2006).

Liquid and plastic limit/shrinkage

Results of liquid, plastic limit and Shrinkage (Tables 4 and 5), show that Makurdi clay has liquid limit of 5.30%, plastic limit of 4.20% and linear Shrinkage of 0%. Ujagba clay has liquid limit as 34.0% plastic limit as 33.3% and linear Shrinkage is 9.30%. It is observed that the liquid limit is defined by that water content which produced a standard groove closure of 12.7mm at 25 blows, (Figures 3 and 4) inline with recommendations of Joseph (1986). Since the liquid, and plastic limits and linear Shrinkage fall within required values [(5-40%), (35%), (0-10%)] both Clays are considered suitable for fire clay brick production, based on liquid, plastic Shrinkage requirement.

Table 3: Chemical composition of clays

Oxides	Makurdi (%)	Ujagba (%)
SiO_2	27,7	25,3
Fe_2O_3	10,11	4,13
Al_2O_3	13,6	12,5
MgO	3,15	0,32
CaO	16,6	15,7
Na_2O	1,55	1,62
K_2O	1,4	4,48
MnO	0,72	6,48
P_2O_3	2,71	7,92
TiO	1,38	4,43
LOI/Residue	21,08	16,73

Table 4: Liquid limit, Plastic limit and Linear Shrinkage of Makurdi

Test	Plastic limit	Liquid limit			
Container/no of blows	42	35 / 10	26 / 20	83 / 30	50 / 40
Weight of container + wet soil (g)	18.60	31.20	41.00	35.90	42.80
Weight of container + dry soil (g)	18.50	30.20	39.50	34.80	41.90
Weight of moisture (g)	0.08	1.00	1.50	1.10	0.90
Weight of container (g)	16.90	15.00	14.90	14.30	14.90
Weight of dry soil (g)	1.90	15.20	24.60	20.80	27.00
Moisture content %	4.20	6.60	6.00	5.30	3.30
Liquid limit (LL)	5.30	Linear shrinkage $LS = \left(\frac{l_1 - l_2}{l_1}\right) \times 100$			
Plastic limit (PL)	4.20	l_1 = initial length of specimen (mm)			140
Plastic index (PI)	1.10	l_2 = length of dried specimen (mm)			140
Liquid index (LI)	—				
Linear shrinkage (LS)	—				

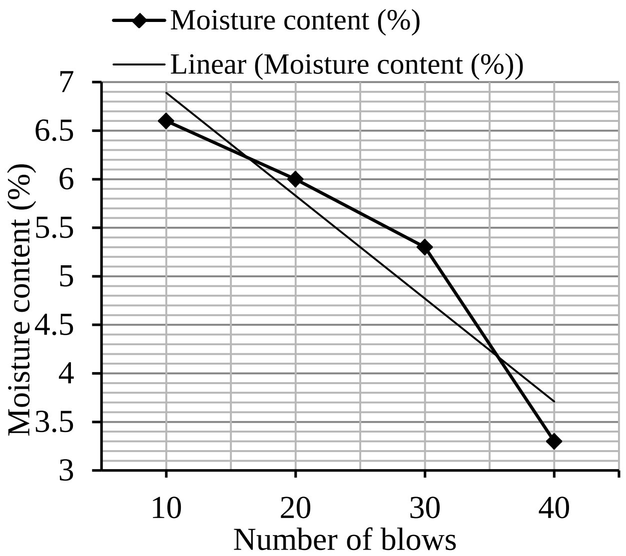

Figure 3: Liquid and plastic limits curve for Makurdi clay

Table 5: Liquid limit, Plastic limit and Linear Shrinkage of Ujagba

Test	Plastic limit	Liquid limit			
Container/no of blows	42	24 / 10	55 / 20	58 / 30	98 / 40
Weight of container + wet soil (g)	17.9	50.8	61.0	59.5	46.7
Weight of container + dry soil (g)	17.8	41.6	49.9	48.6	39.7
Weight of moisture (g)	0.10	9.20	11.1	10.1	7.00
Weight of container (g)	17.5	16.2	17.5	18.2	17.9
Weight of dry soil (g)	0.30	25.4	32.4	30.4	21.8
Moisture content %	33.3	36.2	34.5	33.2	32.1
Liquid limit (LL)	34.0	Linear shrinkage $LS = \left(\frac{l_1 - l_2}{l_1}\right) \times 100$			
Plastic limit (PL)	33.3	l_1 = initial length of specimen (mm)			140
Plastic index (PI)	0.70	l_2 = length of dried specimen (mm)			127
Liquid index (LI)	—				
Linear shrinkage (LS)	9.30				

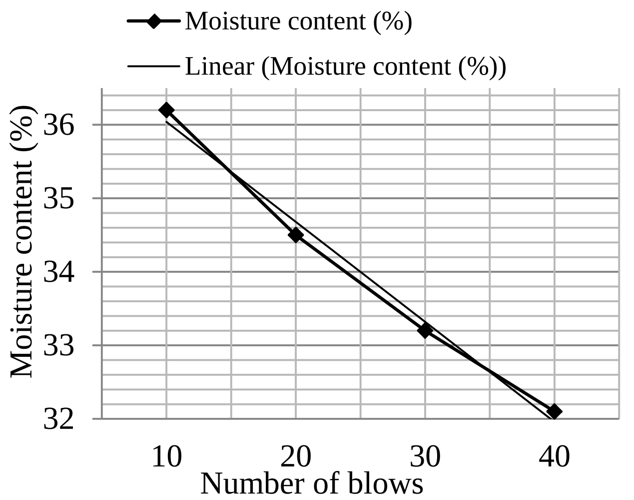

Figure 4: Liquid and plastic limits curve for Ujagba clay

CONCLUSION

It is concluded that Makurdi and Ujagba clays contain very low SiO_2, but can be improved by the addition of Silica rich additives such as Silica sand. Results of liquid and plastic limits and Shrinkage analysis suggest however that the clays can be used for fire clay bricks production.

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