Evaluation of Industrial Potentials of Clay Deposits in Akwa Ibom State,SE Nigeria

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Abstract— Clay is one of the natural resources that is present in Akwa Ibom State alongside hydrocarbons, limestone, gravel, etc. If the clay deposit is exploited by the government, it will generate foreign exchange for the country and also create employment opportunities for the teeming unemployed youths, from the establishment of its associated industries. This study which was limited to clay deposits in Itu, Ibiono, Ikot Abasi, Oruk Anam, Uyo, Ikono, and Ini local government areas was aimed at determining the suitability in terms of their physical properties for industrial applications. Results from various tests suggest that clays from all the locations are suitable for paper production except that of Eka Nnung Ikot (OrukAnam) because its colour does not meet this requirement. .From the grit result, clays from Uniuyo ravine, Nkwot Ikot Umo and Eka Nnung Ikot falls within the range of 5 – 8% meaning it can be processed dry,whereas that of Ette, Ikot Obong, Ntiat Itam and Asantim can only undergo wet processing. Based on the properties obtained from other tests including viscosity, hydrometer, firing and specific gravity tests, it can be said that the clays from Nkwot Ikot Umo in Ikono, Asantim in Ini, Ikot Obong in Ibiono Ibom, and those of Uniuyo ravine in Uyo are excellent raw materials for the production of paper, coating, filling and ceramics production with little or no additive.

Key words: Clay, industrial potential, physical properties, natural resources, specific gravity, production, ceramics

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1 Introduction

THE term clay has a double meaning, it can be defined as a rock or as a particle size. Clay as a rock is defined as a natural, earthy, fine grained material composed largely of limited group of crystalline minerals (Ullmann's Encyclopedia of Industrial Chemistry,1986). As a particle size, clay is used for the category that includes the smallest particles that is from 0.0039 microns down in the Udden-Wentworth scale. Clay generally refers to fine- grained materials , less than 2microns, or groups of hydrous aluminum silicate minerals which are characterized by sheet structures composite layers stacked along the C- axis (Grims, 1968). For the purpose of this work, clay is a rock that is earthy with fine grained material.

Clay is one of the natural resources that is present in Akwa Ibom State alongside hydrocarbons, limestone, gravel, etc. If the clay deposit is exploited by the government, it will generate foreign exchange for the State as well create employment opportunities for the teeming unemployed youths arising from the establishment of its associated industries. Clays in Akwa Ibom State have been studied by different scholars especially that of Uruan Local Government Area. From the studies carried out so far on Uruan clay, it is evident that brick's building can be produced using local clay from Ifiayong and the sand from its shores will be a perfect source of quartz, (Akaninyene et al 2016), but the author recommends more research to be carried out on ways of producing high strength bricks that will impact on the structural /technological advancements of the present society as well as the thermal and chemical properties for better utilization. Clay minerals have lots of industrial applications like paper production, bricks production, ceramic production, pottery production, tiles etc , USGS (2001); Righi and Menrier (1995); Guggenheim et al (1995) just to mention but a few. The industrial potential of clay minerals is a function of their physical and chemical properties but this project focuses on the physical properties of clay minerals that can quantify its usage for industrial application. The process by which clay is turn into products for industrial applications is extensive, requiring large capital investments in equipment and technology. The journey from the mines of clay to the paper, rubber, ceramic, paint or other industrial consumers involves many phases. The mining and processing of clay begin with exploration. Geologists study the earth's surface, research literature and other data to identify land with potential clay deposits. (Ehlers et al, 1982; Hillier (2003)

1.1 Location of the Study Area

Akwa Ibom State is one of the states in Nigeria located in the south-south region which is also called the Niger Delta region. It lies between latitudes 40 321 N - 50 331 N and longitudes 70251 E - 80 251 E. The state has lots of natural resources like petroleum and is rated as the highest oil and gas producing state in Nigeria (Nicholas 2013.)],sandstones, clay, gravel, limestone etc. Out of the thirty one (31) local governments areas in the state only few of the local government areas have massive clay deposits while others have different economic material. This study is limited to clay deposits in Akwa Ibom State especially the ones in Itu, Ibiono, Ikot Abasi, Oruk Anam, Uyo, Ikono, and Ini local government areas. The research work is to determine the physical properties of clays in Akwa Ibom State and their industrial application needed for particular production by carrying out scientific tests such as particle size distribution, specific gravity, liquid limit test, plastic limit test and viscosity test.

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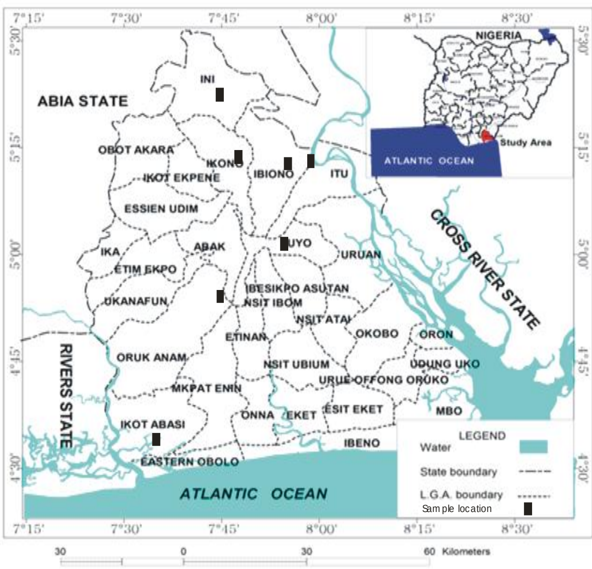

Fig.1 Sample Location Map

2 MATERIAL AND METHODS

The samples were collected with the aid of the following tools; hammer, sample bags, masking tape, measuring tapes, maker pen and global positioning system (G.P.S) and field notebook. Representative samples were collected from outcrops in seven Local Government Areas of Akwa Ibom State. The Local Government areas include; Ini, Ikono, Ibiono, Itu, Oruk Anam, Uyo and Ikot Abasi local government. Each was dried under the sun to remove the moisture. Thereafter, the clays were pulverized using mortar and pestle after which the samples were put in a zip lock and labelled to avoid confusion. The laboratory tests carried out to determine the industrial potential of these clays include: Atterberg test (liquid limit and plastic limit, plasticity index), particle size distribution by Hydrometer method, firing colour, specific gravity and viscosity.


Fig.2 Outcrop of Clay at Ibiono LGA


Fig.3 Outcrop of Clay at Ikot Abasi LGA

3 THEORY/CALCULATION

3.1 Liquid Limit Test

This is to determine the moisture content at which the material passes from a plastic to a liquid state.

Apparatus: Casagrande machine, sieve size of 425um, air tight container, glass plate spatula, moisture content can, straight edge, evaporation dish.

Procedure: 200g of sample were measured for all the clays from different locations, (these samples passed through 425 sieves). Some quantity of water was added to the samples and mixed to form a paste. This paste was then stored for 24hours in an air tight container to enable the water to penetrate through the soil. The soil was then removed and kept for about 10minutes. The standard grooving tool was drawn through the paste along the diameter through the pallet so that the section of the cup is seen. Then the hadles of the Cassagrande apparatus were turned and the number of blows was counted till part of the soil closed the cup to a distance of 2mm. The number of blows was recorded (fig.1-fig.8) and at the end, the sample was collected for moisture content determination. More paste was added and the test was repeated for four times. A graph of moisture content versus number of blows was plotted to determine the liquid limit

3.2 Plastic Limit

Plastic limit is the moisture content at which the material passes from a semi solid to a plastic state. Tables 2-8 shows platic limits and liquid limits for all the studied locations.

Equipment: Cassagrande machine, sieve size of 425um, air tight container, glass plate, spatula, moisture content can, straight edge, evaporation dish .

3.3 Viscocity Test

The viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress or tensile stress. Viscosity of these clays were determined by mixing 100g of dried samples with distilled water, the mixture was poured into a 1000ml measur-

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ing cylinder and a sphere was dropped into the fluid. The time taken for the bulb to reach the bottom of the cylinder was noted. The weight and volume of the sphere were recorded respectively.

$$\text{Viscosity } (V) = \{2(Ps-Pl)ga^2\}/gv \quad (1)$$

Ps = density of sphere =2.024g/cm^3, Pl=density of liquid.
g = acceleration due to gravity(9.81m/s), v=velocity =distance/time
a=radius of sphere(1.44cm) determined by using $V=4/3\times\pi r^3$

3.3 Specific Gravity

Specific gravity is the ratio of the density of a substance to the density of reference substances; equivalently, it is the ratio of the mass of a substance to the mass of a reference substance for the same given volume

$$\text{Specific gravity (G)} = \frac{(m2-m1)}{(m2-m1)-(m3-m4)} \quad (2)$$

m1= mass of empty container
m2= mass of container + sample + water
m3= mass of container + dry sample
m4= mass of container + water

4 RESULTS

4.1 Firing Colour

The clay samples were put into a furnace for about 20 minutes. This process is referred to as firing and their different firing colours were observed at 230º. Different locations exhibited unique colours including white, light brown, grey, milky etc. (Appedix 1)

4.2 Particle Size Distribution

This test is very useful because it differentiates silt from clay fractions. Distilled water was added to 100g of sample and stirred to completely disintegrate the sample using hexametaphosphate. This mixture was kept for 24hours after which it was sieved through a 0.75um mesh opening. The samples were poured into 1000ml cylinder and water as well as the dispersant was added. A hydrometer was inserted to take readings at 0.5, 1, 2, 4, 8, 15, 30, 60, 120, 240, 1440 all in minutes, after which computation of results. Details are as displayed in Appendix 2.

TABLE 1
DESCRIPTION OF CLAY DEPOSITS

S/N	Sample location	Coordinate	Elevatio (m)	Outcrop Description
1	Nkwot Ikot Umo	N 5°14'43.8"	80	The sample occurs in a spring commonly known as "Awong Ayaya Stream" and this spring serves as a source of drinking water to the community. The outcrop is about
2	Ette (Ikot Abasi)	N 4°34'46" E 7°37'45"	7.7	The clay is buried and covered with loose ferruginous sandstone.
3	Eka Nnung Ikot	N 4°56'19" E 7°45'16"	40	The clay is embedded in a stream
4	Asantim (Ini)	N 5°20'0.8"	71.1	The clay is embedded in the stream of Esa AkpaIko flowing to Akon.
5	Ikpa Road	N 5°02'37.5"	45.2	Occurs along a ravine in Uniuyo town campus with laterite overburden.
6	Ikot Obong	N 5°11'15" E 7°55'49"	46.9	The clay occurs in strata with a total thickness of about 3m. It occurs along a road cut and has an overburden of laterite and sandstone separated by a thin band of ferruginous sandstone.
7	Ntiat Itam (Itu)	N 5°11'17"	46.2	The outcrop is exposed some distance away from the major road. It is covered with thick vegetation and occurs in strata with the thickness of about 4.5m.

4.3 Grit test

The grit test gives the percentage of particles that are retained on a 425-mesh screen (45-um). This was obtained by dispersing 50g of sample into about 100cl of water blunging of sample for about two minutes after which the samples were screened, dried and weighed to determine the percentage that retained on 45um. The amount of screen residue is important in estimating the recovery of the minus 325 mesh material since this is the fraction that is usable for industrial purpose. Quartz and mica, along with hard agglomerates of kaolin, were the most common mineral retained on the screen. (Appendix 4)

TABLE 2
PLASTIC AND LIQUID LIMIT DATA FOR IKONO LGA

	Liquid limit				Plastic limit	
No. of blows	11	19	37	47	PL	PL
Can no.	1	2	3	4	5	6
Mass of weight soil container (w_2)	32.21	21.3	25.11	29.31	20.46	19.91
Mass of dry soil container (w_3)	25.2	19.1	22.01	25.85	20	19.41
Mass of container (w_1)	16.1	15.75	18.6	20.31	18.82	18.24
Mass of moisture (w_2 -w (a)	7.01	2.2	3.1	3.46	0.46	0.5
Mass of dry soil (w_3 -w (b)	9.1	3.35	3.41	5.54	1.18	1.17
% moisture content	77.03	65.67	90.9	62.45	38.98	42.74

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PLOT 1. GRAPH OF MOISTURE CONTENT (%) AGAINST NUMBER OF BLOWS (IKONO)

LIQUID LIMIT = 71, PLASTIC LIMIT = 40.86, PLASTICITY INDEX = 30.

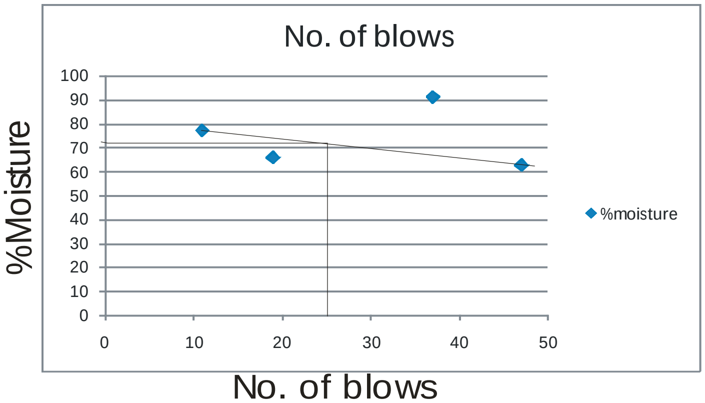

TABLE 3
PLASTIC AND LIQUID LIMIT DATA FOR ORUK ANAM LGA

	Liquid limit				Plastic limit	
No. of blows	12	25	35	40	PL	PL
Can no.	1	2	3	4	5	6
Mass of weight soil container (w_2)	27.37	24.05	27.24	23.56	20.02	24.29
Mass of dry soil container (w_3)	24.07	22.24	24.52	20.79	19.1	23.32
Mass of container (w_1)	18.95	15.88	18.71	16.04	15.87	20.1
Mass of moisture (w_2-w_3) (a)	3.3	1.81	2.72	2.77	0.92	0.97
Mass of dry soil (w_3-w_1) (b)	5.12	6.36	5.81	4.75	3.23	3.22
% moisture content	64.45	28.46	46.82	58.31	28.48	30.12

PLOT 2. GRAPH OF MOISTURE CONTENT (%) AGAINST NUMBER OF BLOWS (ORUK ANAM)

LIQUID LIMIT = 54, PLASTIC LIMIT = 29.3, PLASTICITY INDEX = 25.

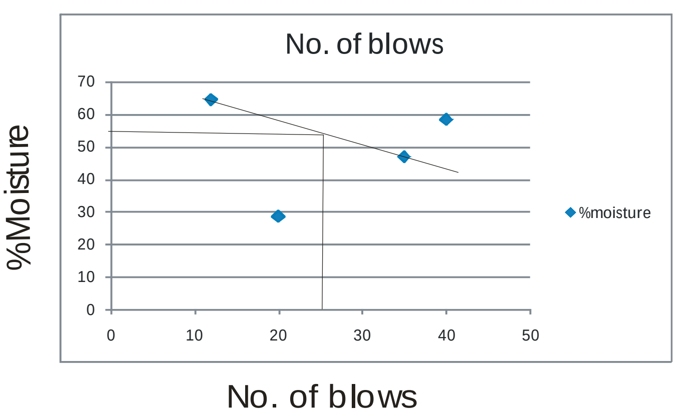

TABLE 4
PLASTIC AND LIQUID LIMIT DATA FOR UYO LGA

	Liquid limit				Plastic limit	
No. of blows	14	20	34	46	PL	PL
Can no.	1	2	3	4	5	6
Mass of weight soil container (W2)	32.21	25.13	36.14	32.21	22.16	22.1
Mass of dry soil container (w_3)	25.2	21.08	30.21	28.24	21.11	21.13
Mass of container (w_1)	16.1	16.01	20.2	20.3	19.31	19.1
Mass of moisture (w_2-w_3) (a)	7.01	4.05	5.93	3.97	1.05	0.97
Mass of dry soil (w_3-w_1) (b)	9.1	5.07	10.01	7.94	1.8	2.03
% moisture content	77.03	79.88	59.24	50	58.33	47.78

PLOT 3. GRAPH OF MOISTURE CONTENT (%) AGAINST NUMBER OF BLOWS (UYO LGA)

LIQUID LIMIT = 68, PLASTIC LIMIT = 53.02, PLASTICITY INDEX = 15.

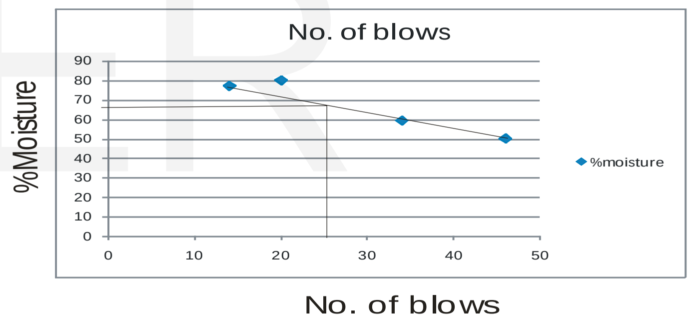

TABLE 5
PLASTIC AND LIQUID LIMIT DATA FOR INI LGA

	Liquid limit				Plastic limit	
No. of blows	13	21	28	49	PL	PL
Can no.	1	2	3	4	5	6
Mass of weight soil container (w2)	28.03	23.22	26.54	25.11	20.35	24.41
Mass of dry soil container (w3)	23.86	19.83	22.98	20.95	19.08	23.35
Mass of container (w_1)	18.93	15.86	18.66	15.98	15.88	20.11
Mass of moisture (w_2-w_3) (a)	4.17	3.39	3.56	4.16	1.27	1.06
Mass of dry soil (w_3-w_1) (b)	4.93	3.97	4.32	4.97	3.2	3.24
% moisture content	84.58	85.39	82.41	83.7	39.69	32.72

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PLOT 4. GRAPH OF MOISTURE CONTENT (%) AGAINST NUMBER OF BLOWS (INI LGA)

LIQUID LIMIT = 84.1, PLASTIC LIMIT = 36.21, PLASTICITY INDEX = 48.

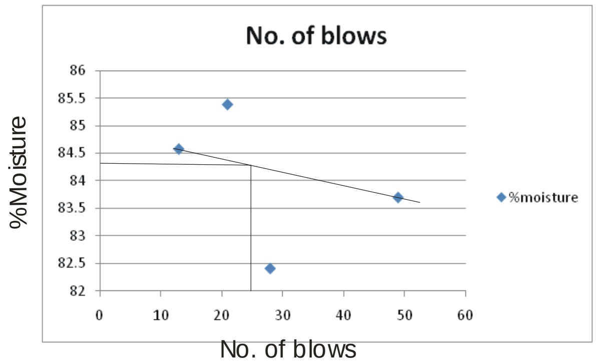

TABLE 6
PLASTIC AND LIQUID LIMIT DATA FOR IBIONO LGA

	Liquid limit				Plastic limit	
No. of blows	14	22	35	49	PL	PL
Can no.	1	2	3	4	5	6
Mass of weight soil container (w_2)	33.1	33.14	32.07	29.31	19.1	18.21
Mass of dry soil container (w3)	28.61	28.25	28.51	25.85	18.6	17.9
Mass of container (w_1)	20.41	18.33	20.21	20.31	16.15	16.12
Mass of moisture (w_2-w_3) (a)	4.49	4.89	3.56	3.46	0.5	0.31
Mass of dry soil (w_3-w_1) (b)	8.2	9.92	8.3	5.54	2.45	1.78
% moisture content a	54.76	49.29	42.89	62.45	20.41	17.42

PLOT 5. GRAPH OF MOISTURE CONTENT (%) AGAINST NUMBER OF BLOWS (IBIONO)

LIQUID LIMIT = 48, PLASTIC LIMIT = 18.92, PLASTICITY INDEX = 29.

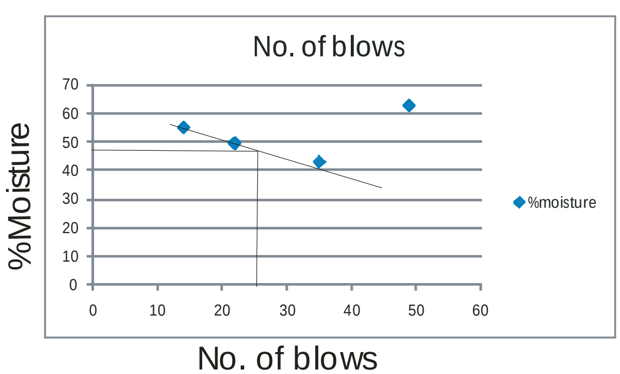

TABLE 7
PLASTIC AND LIQUID LIMIT DATA FOR ITU LGA

	Liquid limit				Plastic limit	
No. of blows	10	21	35	37	PL	PL
Can no.	1	2	3	4	5	6
Mass of weight soil container (w_2)	29.59	25.13	29.46	28.48	21.07	23.81
Mass of dry soil container (w3)	25.01	20.99	25.34	25	20.57	23.22
Mass of container (w_1)	19.75	15.79	20.38	19.67	18.38	20.72
Mass of moisture (w_2-w_3) (a)	4.58	4.14	4.12	3.48	0.5	0.59
Mass of dry soil (w_3-w_1) (b)	5.26	5.2	4.96	5.33	2.19	2.5
% moisture content a	87.07	79.62	83.06	65.29	22.53	23.6

PLOT 6. GRAPH OF MOISTURE CONTENT (%) AGAINST NUMBER OF BLOWS (ITU)

Liquid limit = 77, Plastic limit = 23.07, Plasticity index =54

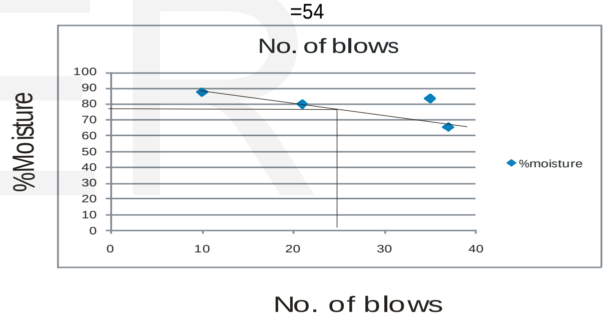

TABLE 8
PLASTIC AND LIQUID LIMIT DATA FOR IKOT ABASI LGA

	Liquid limit				Plastic limit	
No. of blows	13	16	32	37	PL	PL
Can no.	1	2	3	4	5	6
Mass of weight soil container (w2)	30.3	26.35	31.37	31.55	20.58	22.92
Mass of dry soil container (w3)	27.2	23.01	28.42	29.29	20.22	22.57
Mass of container (w_1)	19.74	15.74	19.66	20.37	18.35	20.71
Mass of moisture (w_2-w_3) (a)	3.1	3.34	2.95	2.26	0.36	0.35
Mass of dry soil (w_3-w_1) (b)	7.46	7.27	8.76	8.92	1.87	1.86
% moisture content	41.55	45.94	33.68	25.34	19.25	18.82

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PLOT 7. GRAPH OF MOISTURE CONTENT (%) AGAINST NUMBER OF BLOWS (IKOT ABASI)

Liquid limit = 35, Plastic limit = 19.04, Plasticity index =16

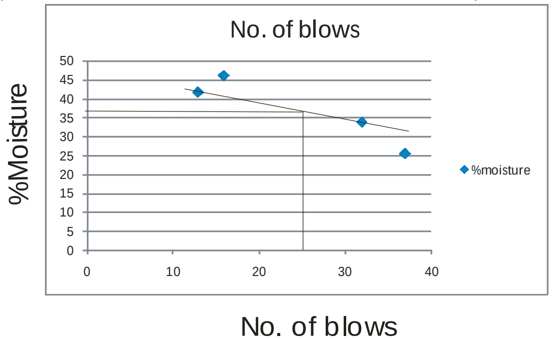

TABLE 8
PLASTIC AND LIQUID LIMIT DATA FOR IKOT ABASI LGA

	Liquid limit				Plastic limit	
No. of blows	13	16	32	37	PL	PL
Can no.	1	2	3	4	5	6
Mass of weight soil container (w2)	30.3	26.35	31.37	31.55	20.58	22.92
Mass of dry soil container (w3)	27.2	23.01	28.42	29.29	20.22	22.57
Mass of container (w_1)	19.74	15.74	19.66	20.37	18.35	20.71
Mass of moisture (w_2-w_3) (a)	3.1	3.34	2.95	2.26	0.36	0.35
Mass of dry soil (w_3-w_1) (b)	7.46	7.27	8.76	8.92	1.87	1.86
% moisture content	41.55	45.94	33.68	25.34	19.25	18.82

5 DISCUSSION

The aim of plastic and liquid limit is to determine the plasticity index of the clay which is derived by subtracting liquid limit from plastic limit.. Using Burmister's classification (Appendix 5), Itu and Ini clays have very high plasticity, Ikono, Ibiono and Orukanam have high plasticity while that of IkotAbasi and Uyo have medium. The knowledge of the plasticity index can lead to tentative conclusions drawn about strength, compressibility and plasticity of clays.

Clays have several industrial uses, which include the manufacture of refractory, pottery/ceramic wares and structural units (Akpokodjeet al, 1991). Each industrial process requires certain property specifications that must be met by either the raw or beneficiated clay. According to Ullmann's Encyclopedia of Industrial Chemistry 1984, clays with high plasticity, light colour when fired are used for ceramics production. From the analysis all the clays are suitable for ceramic production. Also, the coarse fraction can be used as filler in paper, plastics, paint, adhesives, and as casting clays for ceramics. The fine particle sized fraction is used in paper coatings and for special ceramics. Their viscosity is very important for paper coating; low viscosity clays are required for paper coating because the clay coating colour must flow easily as it is applied to the paper surface, not leaving streaks or blotches, which can be caused by high-viscosity clays (Ullmann's Encyclopedia of Industrial Chemistry 1984). From the result of viscosity the clays from various locations have good viscosity for these.

For paper production, the physical properties of clays that are advantageous to the paper maker include; its whiteness, fineness, softness, its non-abrasiveness, and it relatively inert nature (Ullmann's Encyclopedia of industrial chemistry 1984). From the result of analysis, all clays from various locations are suitable for paper production except that of Eka Nnung Ikot (OrukAnam) because it colour does not meet this requirement. Generally, if the clay contains more than 5 – 8% grit, it cannot be dry processed (Ullmann's Encyclopedia of Industrial Chemistry 1984). From the grit result, clays from Uniuyo ravine, Nkwot Ikot Umo and Eka Nnung Ikot falls within the range of 5 – 8% therefore it can be dry processed whereas that of Ette, Ikot Obong, Ntiat Itam and Asantim can only undergo wet processing.

5 CONCLUSION

Clays from various locations can be used for making of native pots and plates because they are plastic in nature. Also, these clays can be used as local bricks for building of mud houses in the village as well as applying it on the body where it acts as a coolant. Based on the properties obtained from various test such as grit, viscosity, hydrometer, firing, and specific gravity tests, it can be said that the clays from Nkwot Ikot Umo in Ikono, Asantim in Ini, Ikot Obong in Ibiono Ibom, and those of Uniuyo ravine in Uyo are excellent raw materials for the production of paper, for coating, filling and for ceramics production with little or no additive while that of Ette in IkotAbasi and Ntiat Itam in Itu, if beneficiated, can also be used. Nevertheless, the clay from Eka Nnung Ikot in UrukAnam LGA cannot be used for production that requires brightness because of its natural colour but it can be used for other industrial purposes which do not require brightness.

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APPENDIX 1: CLAY FIRING FOR LOCATIONS

Location	Initial colours	Observed colours
Uyo	Ash	Ash
Ikotabasi	Brown	Light brown
Itu	Brown	Light brown
Ini	White	White
Ikono	White	White
Ibiono	Light brown	Milky
OrukAnam	Dark grey	Light grey

APPENDIX 2: PARTICLE SIZE DISTRIBUTION

S/N	Sample location	%Clay	%Silt	%Sand
1	Nwot Iko-tUmo (Ikono)	11	32	57
2	Ette (IkotAbasi)	3	13	84
3	Eka Nnung Ikot (OrukAnam)	17	83	0
4	Asantim (Ini)	0	27	73
5	Ikpa Road (Uyo)	9	29	52
6	IkotObong (Ibiono)	8	33	59
7	NtiatItam (Itu)	10	28	62

APPENDIX 3: LABOURATORY ANALYSIS

APPENDIX 4: GRIT TEST (%)

Location	Grit %
Uyo	4.8
Ikotabasi	46.2
Itu	13.6
Ini	10
Ikono	7.8
Ibiono	12.8
OrukAnam	8.2

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APPENDIX 5: **BURMISTER (1994) CLASSIFICATION OF PLASTICITY INDEXES**

Plasticity Index (PI)	Description
0	Non plastic
5-Jan	Slightly plastic
10-May	Low plastic
20-Oct	Medium plastic
20-40	High plastic
>40	Very high plasticity