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ENGINEERING PROPERTIES AND USES OF SOIL DERIVE FROM MAASTRITCHIAN AJALI FORMATION IN A PART OF SE NIGERIA

Onunkwo – A, A, Uzoije A.P, Onyekuru, S, O
Dept. of Geosciences, Federal University of Technology, Owerri, Nigeria.

ABSTRACT: *The study is necessitated by the recent move by Imo State government of Nigeria to raise Okigwe town to urban status. Ajali Formation being the prominent geological terrain in Okigwe area, most structures would be erected on the soil derived from it. The parameter measured include grain size, atterberg limits, and compaction, shear strength, permeability and porosity as well as bulk density. The result shows that the soil underlain by Ajali Formation within Okigwe area is sandy silt with low clay content and has plasticity index, bulk density, porosity and permeability values of 9.65%, 2.06%,kg/m^3, 0.45 and 0.35cm/s respectively.The value for the optimum moisture content (OMC) maximum dry density(MDD) shear strength, angle of internal friction are 13.5%, 2.06kg/m^3, 106.86KN/M^2 and 28.4^o. These values indicate that the soil derived from Maastrichtian Ajali Formation within Okigwe area of south eastern Nigeria is of high strength, porous and permeable and can be used as a recharge site for regional aquifer, but cannot be used as a waste disposal area or for road construction. The soil due to its low plasticity index with no swelling characteristics and high shear strength is a good site for building foundations, but cannot be used in dam construction. It is ideal for projects requiring good drainage and embankments. However, for the soil to be used in any engineering construction works, it has to be compacted to its maximum dry density value of 2.06kg/m3 within the range of optimum moisture content of 13.5% as to achieve maximum strength.*

KEYWORDS: Soil, Uses, Engineering Properties, Ajali Formation, Okigwe , SE Nigeria.

INTRODUCTION

Since Imo State Government wishes to raise Okigwe town to Urban Status, this study becomes necessary since soil factors affect the designs, construction and stability of engineering structures such as dams, bridges road construction, canals, buildings and water supply structures (Bell 1992). The type and characteristics of soil depends on its origin (Barnes, 2000). The engineering properties namely permeability, consolidation, compaction and shear strength are governed by the mode of formation, stress history, groundwater conditions and physicochemical characteristics of the surficial deposits derived from parent material (Craig, 2004). The work is intended to determine through experimental procedure some of the geotechnical properties and engineering applications of soils derived from maastritchian Ajali Formation within Okigwe in Anambra /Imo sedimentary basin of SE Nigeria. Geotechnical engineers classify soil according to their engineering properties as they relate to use for foundation support or building material Budhu, (2007). According to Joseph, (2008) Structures of all types - buildings, bridges,

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highways, dams and canals rest directly on soil and solid foundation is necessary to ensure that these structure remain safely free of undue settlement and collapse (Att well and Former, 1976). According to Terzaghi and Peck (1995), soil laboratory analysis is an important step in the evaluation of soil engineering properties. Quantitatively, since soil conditions vary from one location to another, no construction site presents soil conditions exactly like any other (Das Braja, (2006). According to Montgomery (2000), Major soil tests commonly carried out for engineering purposes include atterberg limit tests (Liquid limit, plastic limit and plasticity index) porosity and permeability test shear strength, bulk density and compaction. Montgomery, (2000) pointed out the importance of atterberg limits in engineering works. Atterberg limits are used to distinguish between silt and clay. According to the author, the consistency of a given soil depends on its water content as described by atterberg limits.

According to Craig, (2004), Soil permeability/Porosity has many implications in engineering works, for example a pond built in permeable soil will loose water through seepage. The design of earth dams is based upon permeability of the soil used; also, the stability of slopes and retaining structures can be greatly affected by the permeability of the soil involved. Joseph, (2008) pointed out that knowledge of the permeability properties of soil is necessary in the estimation of groundwater seepage and also the stability of slopes and retaining structures can be greatly affected by the permeability of the soil involved. Joseph, (2008) pointed out that knowledge of the permeability properties of soil is necessary in the estimation of ground water seepage and also helps in the stability analysis of earth structure and earth retaining walls subjected to seepage forces. Shear strength of soil is important in engineering works as it signifies its resistance to deformation. According to Burland, (2005) soil derives its strength from two sources namely Cohesion and frictional resistance between particles. In his work, Kaneko et al, (1993) indicated that the safety of any geotechnical structure is dependent on the strength of soil. Understanding the shear strength of a soil is the basis in the analysis of soil stability problems, such as Lateral pressure in earth retaining structures, Slope Stability and bearing capacity.

Bulk density reflects the soils ability to function as structural support Kramer, (2000). According to the author high bulk density is an indicator of low soil porosity and compaction. In his work, Price (2008), indicated that high bulk density of soil reduced vegetative cover, exposes the soil to erosion and leads to water logging in areas of flat surfaces. The importance of soil compaction in engineering work was clearly spelt out by Rober, (2001). He pointed out that soil compaction properties is one of the most common and cost effective means of stabilizing soil. Design specifications state the required density maximum and water content used in increasing the bearing capacity of foundations and reduction in hydraulic conductivities.

In third world countries including Nigeria, little attention is paid to soil analysis prior to construction to ascertain the carry capacity of the soil in question. This is due probably to the activities of quakes and unavailability of soil analysis data bank. This perhaps is a strong factor

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for frequent structure collapse and its attendant loss of human and material resources in Nigeria and other parts of the world (Onunkwo Akunne, et al 2011). To meet up with the standard of soil specifications, the federal government of Nigeria set up a standard as reference point for various soil properties before use as to avoid economic loses. Therefore, this work is intended to determine through experimental procedure some of the geotechnical properties and likely engineering applications of soil derived from Maastrichtian Ajali Formation within Anambra/Imo sedimentary basin of south eastern Nigeria as case study and this also serves as a soil data bank for engineering work.

MATERIALS AND METHOD

Description of the study areas

Okigwe lies within latitude 5^0 46N to 5^0 539 and longitude 7^0 18 E to 7 ^{0} 25'E as shown in topographic map fig1. It is characterized by massive elevated land form that slops from eastern to western axis, and has a gradation as a result of variation in lithology, Reyment, (1965). According to Iloeje (1981), there is non homogeneity in the structural features of the overall topography from escarpment and valleys that run in the same northeastern direction with elevated land form . According to Mananu (1995), the area has a tropical climate and experiences two climatic seasons-the rainy and dry seasons.The rainy season is characterized by rain bearing south west wind from the Atlantic ocean whiledryseason is characterized by dusty northeast harmattan wind from Sahara desert . According to the author, the mean annual rainfall is 1750mm, while the mean temperature is 26.5^0c to 27^0 .Vegetation is of tropical rainforest but as a result of greater demand for agricultural activities like grazing and cultivation, the rain forest has been replaced by economic crops like oil palm tree. The extensive deforestation has changed the area to grass land structure. The drainage pattern is dendritic [see fig 1`] typical of homogeneous geology Mananu, (1995). Geologically the area lies within Imo sedimentary basin of south eastern Nigeria.The geology is made of Nskukka Formation, Ajali Formations and Mamu Formation respectively.Mamu Formation been the oldest of the three is overlain by Ajali sand stone while Ajali sand stone is over lain by the youngest Nsukka Formation and Imo Shale in the study areas. This sequence indicates that the Ajali Aquifer is confined [Reyment,(1965), Nwayide 1979, 1986, Anyanwu and Aura 1990]

The Ajali sandstone is a coarse friable and cross bedded sandstone and consists of 90% sub angular quartz [Hoque and Ezepue 1977]. The Ajali sand stone consists of bands of white mudstone occurring at intervals and increasing in thickness down wards,(Reyment (1965). The stratigraphic succession of the areas is shown in table 1, while the geologic map of the area is shown in fig 2

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Table 1- STRATIGRAPHIC SEQUENCES IN IMO BASIN (AFTER NWAJIDE 2005)

Age	Basin	Sratigraphic Unit						
Thanctian Danian Maastrichtian Campanian	Niger Delta Anambra Basin	Coal Measure	Imo Shale Nsukka Formation Ajali Formation Mamu Formation					
		Nkporo Fm	Nkporo Shale	Enugu Fm	Owelli SSt	Afikpo SSt	Otabi SSt	Lafia SSt
Santonian	Southern Benue Through	AWGU Formation						

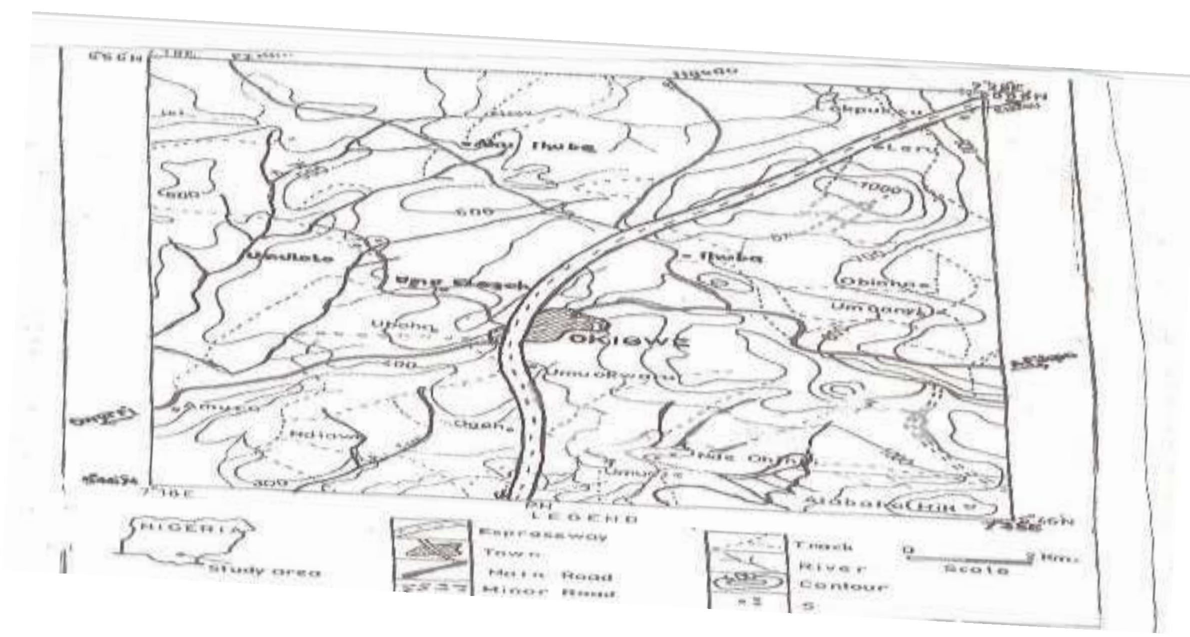

fig1: Topographic map of the study area

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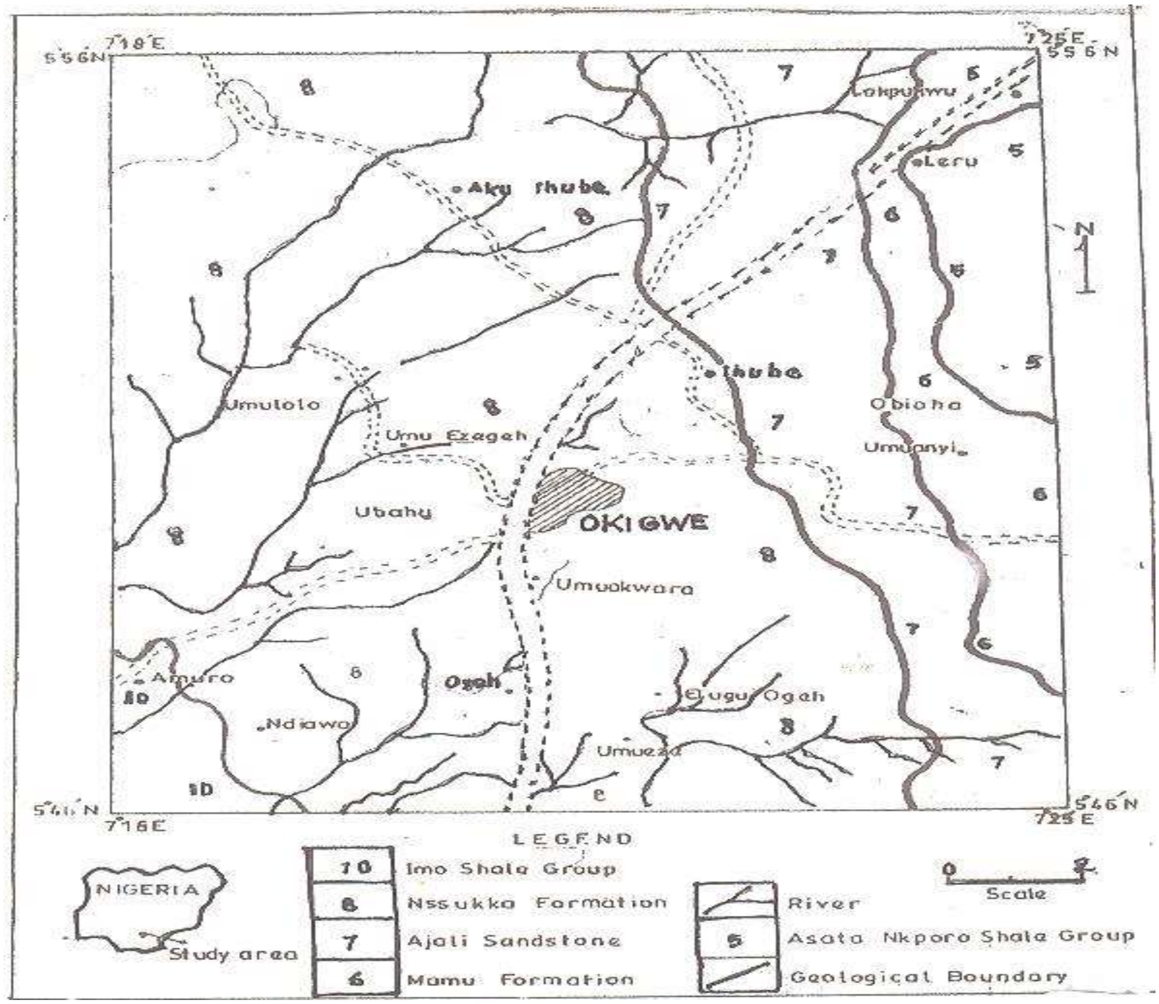

Fig 2: Geological map of map of the study area.

SOIL SAMPLING TECHNIQUES AND ANALYTICAL METHODS

A total of eight (8) soil samples were collected within the area underlain byAjali Formation to represent the areal distribution of the Formation in Okigwe area. Method of stratified random sampling techniques was adopted for the sampling of the soil underlain by the Formation. Soil collection and laboratory analysis were performed in accordance with ASTMD 4318 – 98 (2000) provisions.

Equipment used include soil auger, British electric shaker machine for dry sieving, cassgrande apparatus for atterberg limit, and moisture content tests, proctor compaction apparatus for compaction test, triaxial cylinder test for shear strength, consolidometer for consolidation test, permeameter for porosity and permeability tests. The laboratory investigations carried out on the

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soils include natural moisture content, atterberg limit, sieve analysis (dry sieving) compaction tests, shear strength, porosity and permeability tests. All experimental procedure are as in ASTM, 1988 and ASTMD 4318 – 98 (2000) specifications. All details of analytical procedures are reported in Robert (2001).

RESULT AND DISCUSSION

The average results of laboratory experiment are shown in tables 2, 3, 4, 5, 6… 10 and figures 3, 4, 5 and 6 respectively.

Table 2 SUMMARY OF THE AVERAGE VALUES OF THE MEASURED SOIL SAMPLES.

TEST	AVERAGE	REMARKS
Liquid limit	29.6%	Good for building foundation according to Fed. Nig
Plastic limit	19.9%	
Plasticity index	9.65%	
Bulk density	1.63	Good for building foundation according to Fed. Nig
Permeability	0.35cm/s	
Porosity	0.45	
Optimum moisture Content	13.5%	Good for building foundation according to Fed. Nig
Maximum Dry Density	2.06mg/m^3	
Cohesion (C)	10.5KN/m^2	
Shear Strength	106.86KN/m^2	
Angle of internal friction	28.4^0	
Moisture content	9.35%	Goodfor engineering works
Coefficient of Uniformity	0.003.	Low (Anon 1981)

In terms of federal government of Nigeria specification control N058 Government of East Central State the liquid limit and plasticity index are ideal for sub base course materials and for building foundation.

TABLE 3: RESULT OBTAINED FROM GRAIN SIZE TESTS

Initial mass before washing and drying = 60.0g mass after washing and drying = 34.4g mass of fines [mass lost to washing] = 25.6g of fines =42.7%.

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Dry sieving of residue, mass=34.4g.

SIEVE SIZE (MM)	**MASS RETAINED(G)**	**MASS PASSING(G)**	**% PASSING**
2.0	1.1	58.9	98.2
1.18	2.5	56.4	94.0
0.85	2.7	53.7	89.5
0.600	3.0	50.7	84.5
0.425	3.1	47.6	79.3
0.300	5.4	42.2	70.3
0.150	14.6	27.6	46.0
0.075	3.9	23.7	39.5
Pan	0.3	23.4	-------

In the same way as table 3, the average value of 8 samples gave a graph of fig 3, signifying that the soil is better classified as sandy silt.

TABLE 4: RESULT OBTAINED FROM TRIAXIAL SHEAR TEST

Length of sample = 60.0mm
Width of sample=60.0mm
Area of sample = 0.0036m^2

The normal stress computation computed from $\frac{L}{A}$ (where L is load and A is area) is shown as;

Load (Kg)	**Load(KN)**	**Area(m^2)**	**5(normal stress)**$\frac{kn}{m^2}$
24	0.24	0.0036	66.6
44	0.44	0.0036	122.2
64	0.64	0.0036	177.8

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The shear stress computation for the eight samples of the soil is shown below.

(1)sample (1)	**(1)load (kg) (2)**	**(2)MAX HR (3)**	**(3) X.002 (MM) (4)**	**4X0.88 (KN)**	**Area (m^2)**	**(….) KN/M^2**
1	24 44 64	93 151 220	0.186 0.302 0.440	0.164 0.266 0.387	0.0036	45.5 73.8 107.6
2	24 44 64	90 153 218	0.180 0.306 0.436	0.158 0.269 0.384	0.0036	44.0 74.8 106.6
3	24 44 64	98 160 227	0.196 0.320 0.454	0.173 0.282 0.399	0.0036	47.9 78.2 111
4	24 44 64	103 166 235	0.206 0.332 0.470	1.181 0.292 0.414	0.0036	50.4 31.2 114.9
5	24 44 65	100 162 230	0.200 0.324 0.460	0.176 0.285 0.460	0.0036	48.9 79.2 112.4
6	24 44 64	103 164 232	0.206 0.328 0.464	0.181 0.289 0.408	0.0036	50.4 80.2 113.4
7	24 44 64	111 170 240	0.222 0.340 0.480	0.195 0.299 0.422	0.0036	54.3 83.I 1217.3
8	24 44	93 159	0.186 0.318	0.164 0.272	0.0036	45.5 11.7
	64	222	0.444	0.391		108.5

The value of shear strength (τ) obtained from the graph of fig 6 using equation (1): gives C=10.75, Q= 28.4^o, τ =106.86KN.

Shear strength (τ)= C + σ tan Φ ………………(1)

Where τ = shear strength. C =cohesion (kn/m^2) , Q = fractional angle between grain, σ =177.8

TABLE 5: RESULT OF THE COMPUTATION OF COEFFICIENT OF PERMEABILITY USING ALLEN HAZENS METHOD.

Sample	D_{10} (mm)	K=100x D_{10} Cm/s
1	0.0032	0.32
2	0.0025	0.25
3	0.0045	0.45
4	0.0017	0.17
5	0.0045	0.45
6	0.0025	0.25
7	0.0020	0.20
8	0.0075	0.75

Table 5: indicates that the permeability of the soil stand as 0.35 cm/s. This is high (Heyman 1972). Therefore the soil can be used as drainage material (James, 2008).

TABLE 6: RESULT OF COMPUTATION OF POROSITY OF THE SAMPLES

Sample	Sb	W	Sd	Gs	V	Vs	Vv	N (%)
1	1.73	17.2	1.49	2.75	1.0	0.54	0.46	46
2	1.58	3.9	1.49	2.75	1.0	0.54	0.46	46
3.	1.89	8.0	1.74	2.75	1.0	0.63	0.37	37
4.	1.63	5.3	1.55	2.75	1.0	0.57	0.43	43
5.	1.46	12.2	1.30	2.75	1.0	0.47	0.53	53
6.	1.58	7.8	1.47	2.75	1.0	0.54	0.46	46
7.	1.53	10.4	1.39	2.75	1.0	0.51	0.49	49
8.	1.70	10.0	1.55	2.75	1.0	0.57	0.43	43

Where Sb = Bulk weight, density (g/cm^3)
W = Moisture content (%)
Sd = Dry unit weight (g/cm^3)
Gs = Specific gravity
V = Total volume of sample (g/V^3)
Vs = Volume of solids = Sd/Gs (m^3)
Vv = Volume of voids = v – vs (cm^3)
n = Porosity = Vv/V (%)

From table 6 the average porosity of the soil is 0.45. This is also high and indicates that it can't be used as waste disposal site (Joseph, 1985).

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TABLE 7: RESULTS OBTAINED FROM THE BULK DENSITY

Sample	Wi	W2	W3	V	D
1	128.2	60.3	67.9	39.3	1.73
2	121.3	60.3	61.0	39.3	1.55
3.	134.7	60.3	74.4	39.3	1.55
4.	124.2	60.3	63.9	39.3	1.89
5.	117.6	60.3	57.3	39.3	1.46
6.	1.58	7.8	1.47	39.3	1.58
7.	1.53	10.4	1.39	39.3	1.53
8.	1.70	10.0	1.55	39.3	1.70

Where WI is the weight of ring + Sample (g)
W2 = wt of ring (g)
W3 = wt of sample (g)
V = volume of sample (Cm^3)
D = bulk density (mg/m^3)

TABLE 8: RESULT OF OBTAINED FROM MOISTURE CONTENT TEST

Sample	C	Mcws	MCS	Mc	Ms	Mw	W	D
1	25S	44.2	41.2	23.8	17.4	3.0	7.20/3.0	1.49
2	B	52.4	48.5	23.8	19.5	2.47	3.9	1.49
3	35	50.5	48.2	19.5	28.7	2.3	8.0	1.75
4	20	33.5	32.8	19.7	13.1	0.7	5.3	1.55
5	41	41.7	39.1	17.8	21.3	2.6	12.2	1.30
6	M	41.9	40.6	23.9	16.7	1.3	7.8	1.47
7	4	39.6	37.7	19.5	18.2	1.9	10.4	1.39
8	15	48.7	46.0	19.1	26.9	2.7	10.0	1.55

Where C= can identification Mcws = Can + wet Soil
Mcs = Can + dry Soil , Mc= Canlg) Ms = Dry Soil(9) Mw=water
W=water content (%), D= Dry density (Mg/m^2)

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TABLE 9: Result Obtained From Compaction Test (Moisture Content /Dry Unit Weight)

	Sample 1			**Sample 2**			**Sample 3**			**Sample 4**		
Trial no	1	2	3	1	2	3	1	2	3	1	2	3
Can I d no	37	42	17	100	33	77	25	20B	10	35	46	77
Can+wet soil	90.1	76.7	72.2	88.9	77.9	71.1	95.4	76.2	68.7	79.9	57.4	79.0
Can+drysoil	85.9	70.3	63.5	84.3	71.3	62.0	90.6	69.2	60.2	77.5	53.8	71.9
Can (g)	21.3	23.9	19.1	19.5	23.8	17.4	20.0	19.5	19.1	17.5	19.5	23.9
Dry Soil (g)	64.6	46.4	44.4	64.8	47.5	44.6	70.6	49.7	41.1	60.0	34.3	48.0
Water (g)	4.2	6.4	8.7	4.6	6.6	91	4.8	7.0	8.5	2.4	3.6	7.1
Water content (w)%	6.5	13.1	19.6	7.1	17.9	20.4	6.8	14.1	20.7	4.0	10.5	14.8
Dry Density (ing/m^3)	1.81	2.04	2.07	1.81	1.98	2.06	1.81	1.99	2.02	1.91	2.11	2.08

	Sample 5			**Sample 6**			**Sample 7**			**Sample 8**		
Trial no	1	2	3	1	2	3	1	2	3	1	2	3
Can I d no	134	100	44	10	13	21	35	18	13	100	36	37
Can+wet soil	84.0	63.9	80.4	74.4	48.5	65.3	72.7	37.7	66.9	82.2	61.5	59.4
Can+drysoil	81.5	39.8	73.1	71.9	45	585	70.6	34.5	60.0	794	57.6	54.4
Can (g)	21.7	22.5	23.8	17.5	14.8	13.5	23.9	5.4	13.2	18.5	19.0	19.2
Dry Soil (g)	59.5	37.5	49.3	54.4	30.2	45.0	46.7	29	46.8	60.7	38.6	35.2
Water (g)	2.5	4.1	7.3	2.5	3.5	6.8	2.1	3.2	6.9	2.8	3.9	5.0
Water content (w)%	42	11.0	14.8	4.6	11.6	151	4.5	11.0	14.7	4.6	10.1	14.2
Dry Density (ing/m^3)	1.81	2.04	2.07	1.81	1.98	2.06	1.81	1.99	2.02	1.91	2.11	2.08

From table 8 and fig 3; the optimum moisture content (OMC) is 13.5% while the maximum dry density (MDD) is 2.06. This means for any engineering work in the area the soil should be compacted at calculated OMC and MDD for Maximum Strength.

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TABLE 10 SUMMARY OF AVERAGE VALUES FOR THE MEASURED SAMPLES

Test	Average Value
Liquid limit	29.6%
Plastic Limit	19.9%
Plasticity Index	9.65
Bulk density	1.63mg/m^3
Permeability	0.35 cm/s
Porosity	0.45
Optimum Moisture content	13.5
Max dry density	10.5KN/M^2
Shear strength	106.86KN/m^2
Angle of Internal friction	28.4
Moisture content	9.35%
Coefficient of Uniformity	0.003

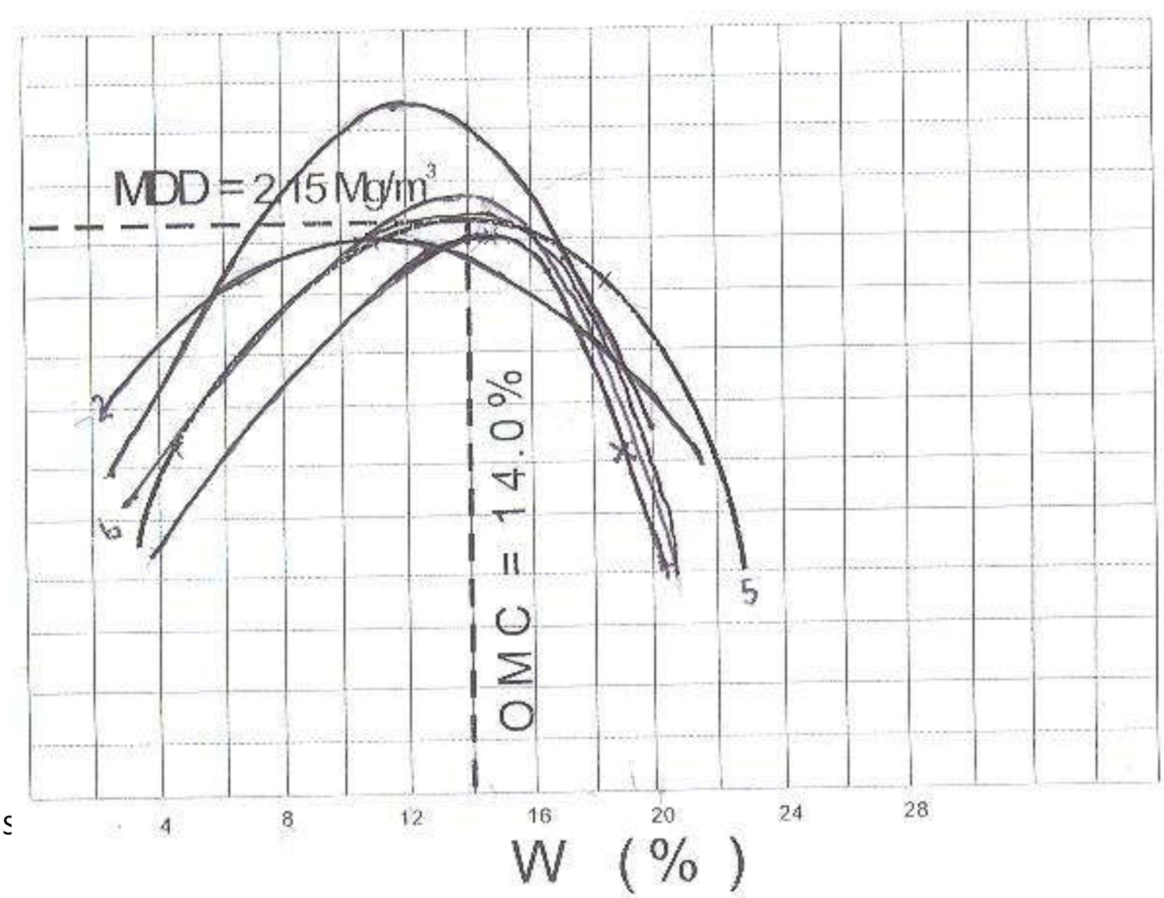

Fig 3:

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Compaction test (Moisture content dry density graph)

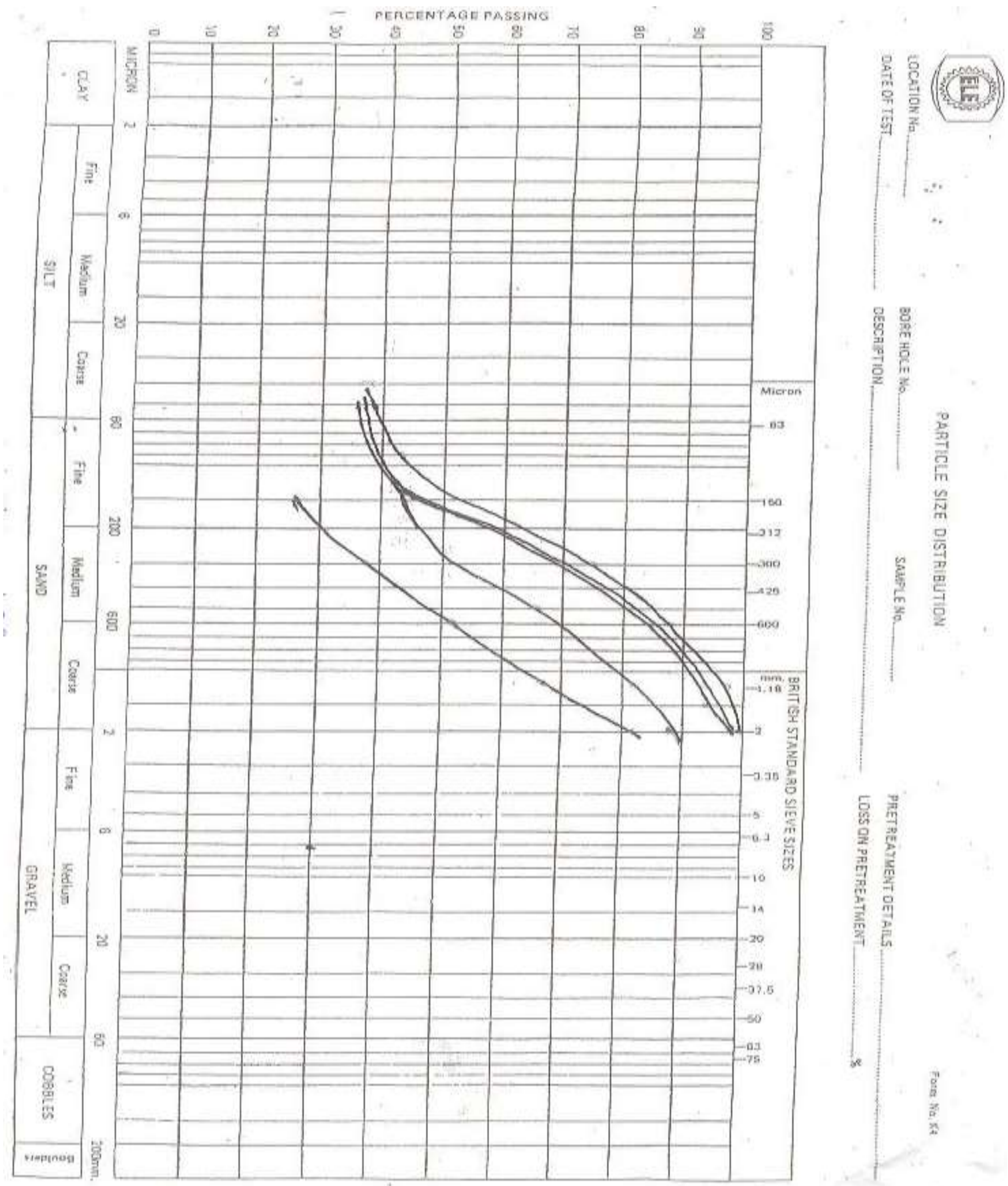

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Fig 4: Sieve Analysis Result

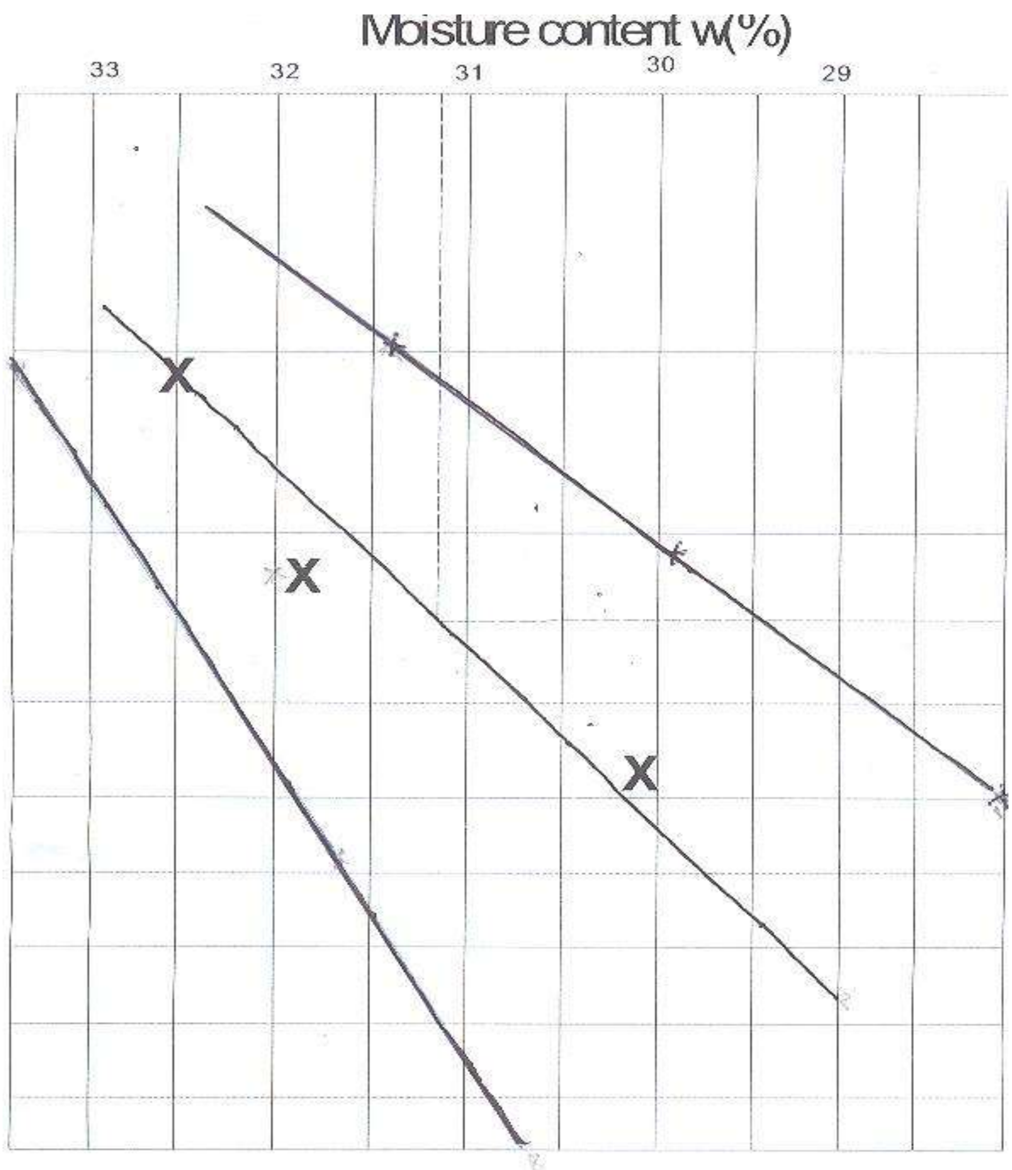

Fig 5: Atterberg Limit Test graph.

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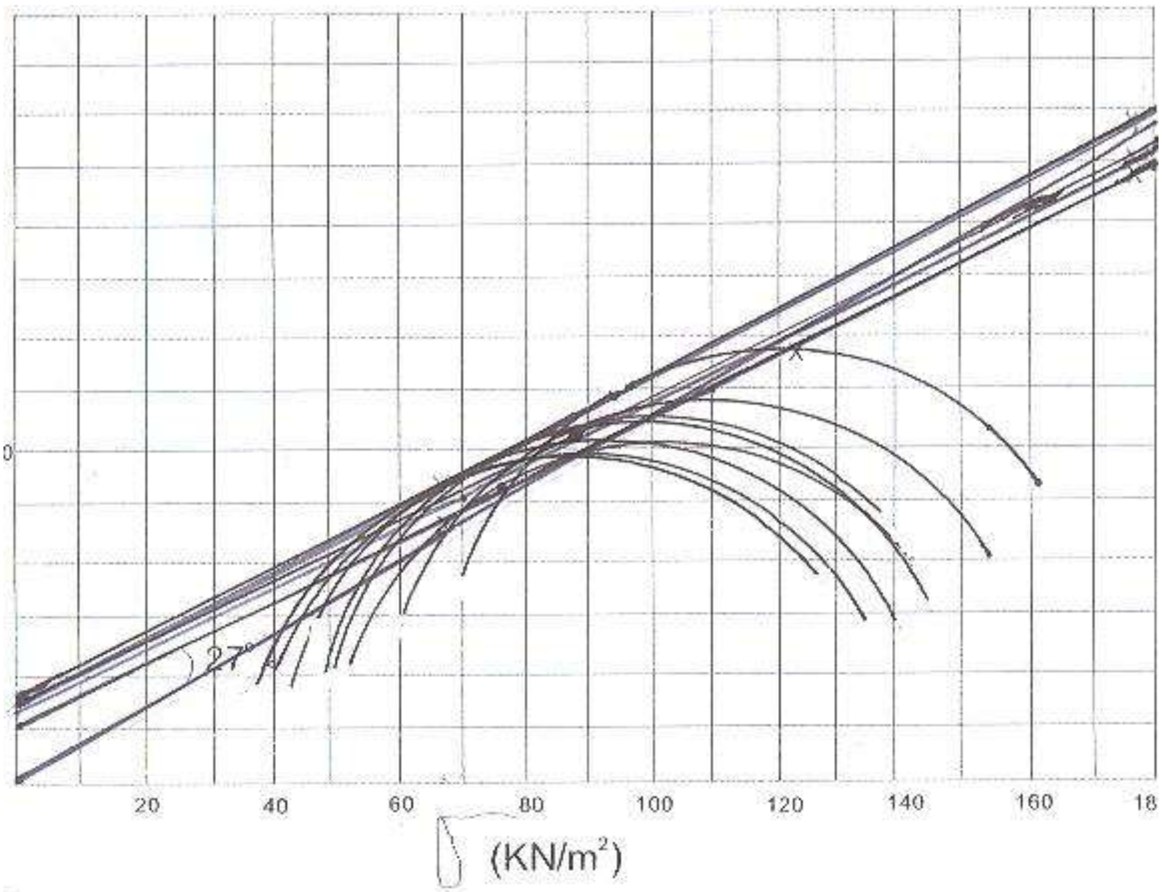

Fig 6: Triaxial Shear Test graph.

RESULT AND DISCUSSION

From laboratory analysis carried out, the soil derived from maastrichtian Ajali Formation within Okigwe area of south-eastern Nigeria sandy silt with insignificant amount of clay. The soil is therefore ideal in embankment performance (Robert, 2001). The average result of liquid limit, plasticity index, Bulk density, permeability and porosity stood at 29.6%, 19.9%, 1.63g/m3, 0.35cm/s and 0.45. Other values such as optimum moisture content, maximum dry density, cohesion, shear strength and coefficient of uniformity gave 13.5%, 2.06kg/m^3, 10.5KN/M^2, 106.86KN/m^2 22.84^o and 0.003 respectively.

From density classification after Anon (1981), the calculated maximum dry density of 2.06kg/m^3 is low and bulk density is also low (1.63kg/m^3) (Navfac, 2008). This confirms the porous and

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permeable nature of the soil (Roscoe, 1985). The federal government of Nigeria specifies that values of plasticity index of the soil should be less than 20% and liquid limit should be less than 30% for the soil to be used in building foundation. The liquid limit value of 29.6% and plasticity index value of 9.65% calculated for the soil of Ajali Formation within Okigwe area is an indication that the soil is ideal for building construction since it confound with the federal government of Nigeria specification for building purposes. According to Ola, (1981), Seed et al (1962), the plasticity index value of 9.65% shows that the soil has low swelling capacity and buildings set up in this environment is not likely to develop kracks. This fact was confirmed by Welthman and Head (1983) who classified the dry density favourable for engineering as 1.78 to 2,58kg/m^3 and moisture content of 5 to 15%. The cohesive value of the soil is low, this shows low clay content and binding force (Burland, 2005) an indication that the soil is vulnerable to erosion. Shear strength of the soil is 106.86/m^2, while angle of internal friction is 28.4%. The high angle of internal fraction and the resulting shear strength is an indication that the soil can withstand stress resulting from heavy structure (Fang and Daniels, 2005). From the compaction test result, the optimum moisture content (OMC) is 13.5% while the maximum dry density is (2.06kg/m^3), therefore, it should be noted that for any engineering construction within the area, the soil should be compacted to an OMC of 13.5% and MDD of 2.06kg/m3 as to achieve maximum strength (Evethand Chengliu, 2007). The permeability value of 3.35×10^{-2}cm/sec shows that the soil is permeable and cannot be used as a site for waste disposal or dam construction, but it is ideal where the project is of the type that requires good drainage (Uduji et al 2005). The soil is therefore ideal as an effective site for artificial recharge of the aquifer.

CONCLUSION

The soil derived from Maastrichtian Ajali Formation within Okigwe area of Anambra/Imo drainage basin of south eastern Nigeria is sandy silt with traces of clay. The soil in ideal for heavy building foundations, but cannot be used for dam site or waste disposal site. It is also ideal for projects requiring good drainage system such as regional aquifer recharge. It may not be good for road construction. However, for any engineering project within the area, the soil has to be compacted to an optimum moisture content of 13.5% and maximum dry density of 2.06kg/m^3% as this is the range within which the soil has maximum strength.

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