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ARTICLE

Geotechnical Properties of Some Clay Deposits in Some Parts of Southwestern Nigeria in Relation to Its Engineering Implications on Constructions

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ABSTRACT

Twenty-two clay samples from Oduna, Okada, and Etsako clay deposits in Southwestern Nigeria were subjected to Geotechnical analysis to evaluate their impact on engineering, especially on construction. The results revealed that the clays deposits were majorly fine-grained texture (<60%), with Plasticity ranging from 23% to 121%, Liquid Limit (25%~205%) having plasticity of medium to very high with a specific gravity from 1.93 to 2.58. Using the American association of state highway and transportation office (AASHTO) and Unified system classification scheme (USCS), the samples fell within A-7-6 (clayey soil) indicating a subgrade that is fair to poor and within the CL-CH category of fine-grained soil with medium to very high plasticity. Compaction having maximum dry density (MDD) to optimum moisture content (OMC) ranges from 0.94 g/cm^3~1.68 g/cm^3 to 11.9%~44.5%, Triaxial result with cohesion between 0.33~35 and shear strength from 44~120 and California bearing ratio for unsoaked bottom 7.52~40, top 4.82~39.18 and soaked bottom 2.89~30.41, top 4.21~33.53. The geotechnical properties of the clay deposits do not meet the standard requirement hence the implication in engineering might be susceptibility to construction failures.

1. Introduction

The use of soils for Engineering purposes cannot be overemphasized for soils are part of the essential materials for life. To an Engineering Geologist, the soil is a material that can be built on, as in foundations, tunnels, culverts, roads, runways, as support in retaining walls, and quays [1]. These soils in engineering must have certain properties before they can be considered to be used for construction, such properties include permeability, strength, compaction characteristics, drainage, shrink-swell potential, grain size, plasticity, and reaction. And to understand these

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properties, we must take into account the origin of the soils such as geological factors which include the type of parent material and its mineral composition, the relief of the area, its exposition, and the groundwater regime. Whitens and Brooks, defined soils used by the Engineering Geologist as any soil that is soft, loose, unconsolidated, and deformable and the clays fall within the categories but it's different from other soft soils, in terms of their size and mineralogy [2]. Clays can be defined in different terms because of its diversity in meaning and uses, each having developed over the years. Clays can be defined as rock term (Claystone), particle size term (<2μ), and mineral term (clay mineral) [3]. These Clays are formed by processes of weathering, erosion, and diagenesis. In Engineering, Miblenz and King emphasized that Clays are important to the designer and the construction engineer because their structures frequently rest upon them, such as clayey formations and excavations which are commonly made into clayey materials, and vast quantities of earth materials containing clays are used in embankments and as linings, and clays are commonly used as constituents in engineering materials for aggregate, pozzolans, and grout [4]. Moreover, the presence of clays may cause unique problems to the engineer primarily because their physical and chemical instability renders masses of earth susceptible to collapse due to the repeated change of form and volume in response to loading or unloading, vibration, and change in moisture content. As though these qualities were not sufficiently annoying, the degree to which clays respond to these actions commonly changes with the adsorption of ions or molecules from solutions, precipitation interstitially of granular substances, and alteration of internal texture and structure. This creates different properties and compositions of clays influencing the engineering behavior as well as the quality of its performances [5]. Owing to its diversity of clays in terms of mineral species, mineral properties, and behavior, the industrial applications and their implication and possible treatment are complex and manifolds [6]. Finally, this study is to attempt to examine the different types of clays and their limitations in some parts of Edo because the soils in some areas in Edo are said to be problematic [7] for engineering construction. It is inevitable to avoid construction on clays with the growing development in the state. Rather adaption to it by knowledge and hence improvement in the usability of the clay soils.

2. Geology of Study Area

According to age and mode of Deposition see Table 1, the Mamu formation (Etsako) being the oldest are whitish in colour with intercalation of coal seams, heterolith, sandstone, and siltstone, Imo Formation (Okada) is essentially thick clayey shales, fine textured, dark grey to bluish in colour with an occasional admixture of clay ironstone and thick sandstone beds and youngest Benin formation (Oduna) reddish-brown-yellow, generally white sands often with clayey and pebbly horizons. Find below (Plates 1-4) some pictures of the deposit:

Table 1. General stratigraphic sequence of study locations(bolded). Modified from [8]

AGE	BASIN	STRATIGRAPHIC UNITS						
Oligocene-recent		Ogwashi- Asaba Fm			**Benin Fm**			
Eocene	Niger- Delta Basin	Ameki/ Nanka Fm / Nsugbe Sandston (Ameki Group)			Agbada Fm			
Thanetian		**Imo Fm**			Akata Fm			
Danian			Nsukka Fm					
Maastrichian	Anambra Basin		Ajali Fm					
Campanian			**Mamu Fm**					
Santonian	Southern Benue Trough	Nkporo Fm	Nkporo Shale	Enugu Fm	Owelli Ss	Afikpo Ss	Otobi Ss	Lafia Ss
		Agwu Fm						

Plate 1. Clay deposit (Oduna)

Plate 3. Clay deposit (Okada)

Plate 2. clay deposit (Oduna)

Plate 4. Clay deposit (Imiegba, Etsako)

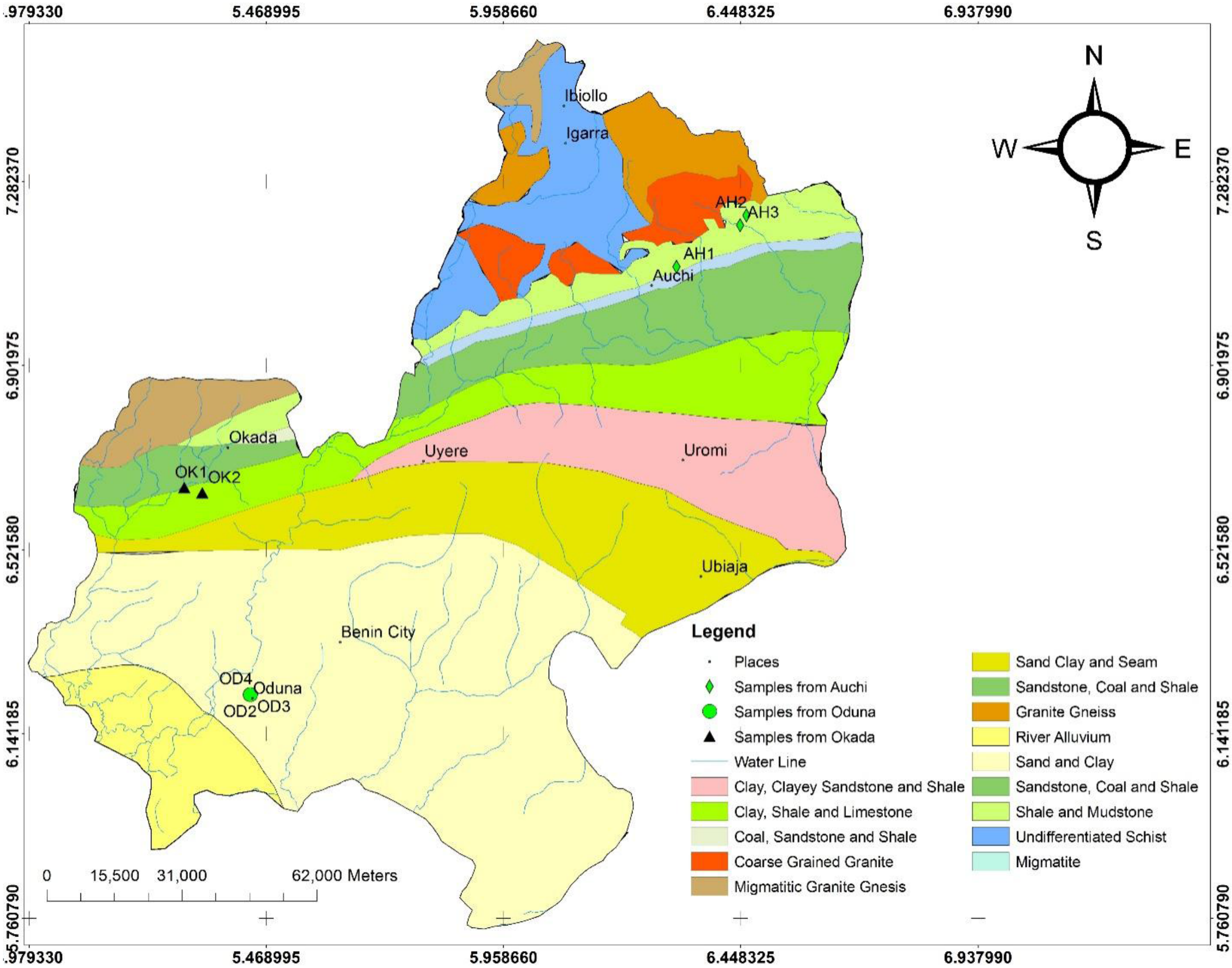

Figure 1. Map of Study area

3. Methodology

Three locations were sampled by carrying out three (3) processes of analyses to achieve the methodology:

1) Field Study and Sample collection;

2) Laboratory Analysis;

3) Data Collection and Data Analysis.

Fieldwork was conducted using the traverse method to access the sample locations (see Table 2) and a total of twenty-two (22) samples were collected (eight (8) samples from Oduna, seven (7) samples from Okada (A & B samples were from a pit and 1-5 were from a ridge) and seven (7) from Etsako. The soils were gotten from pits dug between 0-1 m and 1-2 m in depth, some were gotten from the ridge and each soil sample collected was observed in hand specimen to determine if the clay deposit using the following basic techniques Dry strength test, Dilatancy, Toughness test, and Dispersion test, after which the samples were stored in a separate polythene bag and labeled for easy identification. It is pertinent to note that topsoil/ cover soil was first removed before fresh samples were collected.

Table 2. Location points of deposit

LOCATIONS / GPS POINTS SAMPLE ID	LONGITUDE	LATITUDE
Oduna (upper Ekenwan)	N 06°13'19.3"	E 005°26 '09.3"
	N 06°13'18.5"	E 005°26 '08.3"
	N 06°13'17.9"	E 005°26 '08.8"
	N 06°13'17.9"	E 005°26 '08.9"
Okada (ridge)	N 06° 38' 59.1"	E 005° 17' 59.4"
(1-2 m Dug Deep)	N 07° 38' 21.2"	E 005° 19' 71.5"
Etsako Afowa (Quarry)	N 07° 06' 19.9"	E 006° 18' 56.5"
Auchi	N 07° 11' 13.0"	E 006° 21' 11.6"
Imiegba (River Akowe	N 07° 12' 40.4"	E 006° 27' 36.1"
Imiegba	N 07° 11' 27.8"	E 006° 26' 50.3"

The samples collected were sent to the Laboratory for the following analyses.

1) Sieve analysis (particle size),

2) Atterberg limits test,

3) Bulk and dry density,

4) Soil compaction test,
5) Specific gravity test and,
6) Triaxial Test,
7) California Bearing Ratio.

Particle-size analysis was done with a combination of wet sieving and hydrometer method. The sieves were arranged in order of reducing the aperture on the mechanical shaker. (100 g each of the soil samples was used throughout the analysis) by a jarring action for 5 minutes. The mass of the soil sample retained on each sieve was recorded against the sieve aperture size on a semi-log graph together with percentage fines (known as particle size distribution curve). The general slope has the shape of the distribution and it is described by means of some constants such as effective sizes D_{10}, coefficient of uniformity (*Cu*), and coefficient of curvature (*Cc*) which was calculated to determine the grading of soil.

The moisture content test was used to determine the water content of the soil. It is expressed as a percentage of the weight of water to the dry weight of the soil. A known weight of sample about 50 grams was taken out of the preserved samples from the field and weighed. The sample was oven dried at a temperature of about 110 °C for about 24 hours.

Specific gravity is the ratio of the weight of a substance to that of an equal volume of water at some known temperature (usually 40 °C) and it is dimensionless. Soil sample which was air-dry weighed 150 g after which it was filled with distilled water. The pycnometer with the water was weighed and the bottle was then emptied and dried. The oven dry samples were introduced into the bottle. The soil was stirred with a glass rod in order to allow trapped air to be released. Sufficient air-free distilled water was added so that the soil in the bottle is just covered and then weighed.

The Atterberg Limit test, also known as the Consistency Limit Test is used to determine the effect of moisture content on fine-grained soil. It defines the boundaries of several states of consistency of plastic soil. It is used to determine the plasticity of the soil. Liquid limit, plastic limit, plasticity index, liquidity index, and relative consistency are some parameters determined. These parameters help to determine the plasticity and clay content of a soil sample. The Casagrande method was used.

Compaction tests are carried out with the aim of determining the moisture density relationships and changes in soils, increasing unit weight, and shear strength, and reducing permeability. This makes the soil less susceptible to settlement under load, especially repeated loading. This is usually done by mechanical means, a 2.5 kg method of compaction was used for this test, a known volume of mould with a removable base and a detachable collar. Three kilograms of air-dried soil were used for the test and the test was repeated five times for each sample. The moisture content used was between 4% and 20% of the weight of the sample, and samples were mixed thoroughly before compaction. Three layers of compaction were done for each trial and 25 blows were used to compact each layer. Graphs of dry density, ρd against moisture content were plotted to determine the optimum moisture content.

California Bearing Ratio

This was carried out using air-dried sample mixed with about 5% of its weight of water (determined from optimum moisture content). This was in C.B.R mould with a diameter of 150 mm and 175 mm in height in 3 layers with each layer compacted with 25 blows using 2.5 kg hammer at drop of 450 mm (standard proctor test) and the mould was weighed and placed under C.B.R machine. Soaked condition is simulated for the worst conditions in the field and to achieve this condition the soil samples were submerged in water for 4 days. Unsoaked conditions are the normal field condition, and as such the moulding water content is equal to the equilibrium water content.

The method adopted for this work is the West African standard method recommended by the Federal Ministry of Works and Housing FMWH due to its availability (note it is between the BS light standard proctor and heavily modified proctor) and others in accordance with British Standard BS [9-11].

4. Results and Discussion

In determining the suitability of samples for engineering construction, we need to determine and compare the geotechnical results individually and collectively. The results are as follows below:

4.1 Particle Size Analysis

The particle size curve (Figures 2, 3, 4) is extremely useful in soil classification in terms of understanding compressibility because uniform soils are more compressible than well-graded [12]. Also, useful in soil stabilization and pavement design. The particle curve of the study shows the soils are uniformly graded with some gap graded in some points in Oduna. Indicative of origin from weathered rocks and compressible soils, also mode of geologic deposition succession. According to the British standard BC1377 (1990), if the percentage fines are less than 35%, its adjudged as a good subgrade material [11]. But only the soils from Oduna fit into this category. According to the American association of state highway and transportation office (AASHTO), they fall within the A-7-5 to A-7-6 (clayey soil) hence as a subgrade it's fair to poor The soils above curves show the soils are uniformly graded with some gap graded in some points in Oduna. This distribution can be an attribute of the mode of deposition. According to the British standard [10,11], if the Percentage Fines is less than 35%, its adjudged as good subgrade material. But these soils only from Oduna fitted slightly into this category. According to AASHTO, the soil samples are A-7-5 to A-7-6 indicating poor subgrades.

4.2 Specific Gravity

Specific gravity, which is directly proportional to soil strength, the higher the specific gravity, the higher will be the load carrying capacity, and the higher the strength, the higher the California bearing ratio of soils [13]. It is stated [14] that a soil is a good subgrade if its specific gravity (Gs) ranges between 2.50-4.60. The Oduna samples are between 2.32-2.58, Okada 1.93-2.57, and Auchi 2.26-2.55 respectively. With the except of Okada samples which were<2.00 which indicates that it is a fine-grained soil (good subgrade) with fairly high specific gravity mineral and also correlates with the mechanical strength of subgrade [15]. The other two fell within the range of 2.26-2.58, Hence better for road construction and foundation. (Tables 3, 4, 5)

4.3 Atterberg and Plasticity Chart

From the result in Tables 3, 4, 5, the liquid limit values of the samples indicate that they are clays of high compressibility which corresponds with the particle size analysis [16]. The Shrinkage limits reveal that the soils are fine because the greater the fines the greater the shrinkage. The Federal Ministry of Works and Housing FMWH (1997) [8] standard for Liquid Limit (LL) is 50% max, Plastic Limit (PL) is 30% max, and Plasticity Index (PI) is 20% maximum for subgrade. All the tested soil samples in tables except those in the Etsako fall out of the stipulated specification. Hence the Etsako soils are suitable as subgrade materials.

According to the USCS, all the soil samples excluding one from Oduna fall above the A-line indicating an inorganic clayey material. Using, the USCS, all the soil samples excluding Oduna (Figure 5) fall above the A-line indicating an inorganic clayey material [17]. They ranged from medium CI (Etsako), high CH (Oduna) to very high (Okada) CVH in plasticity. The soils of Okada revealed that they are active (Table 6) and the other two i.e., Oduna and Etsako areas are Inactive to Normal. This also corroborates with the very high plasticity from the Plasticity chart (Figure 5) and particle size telling the use of the percentages of fines and type of clay, retaining power as well as weathering.

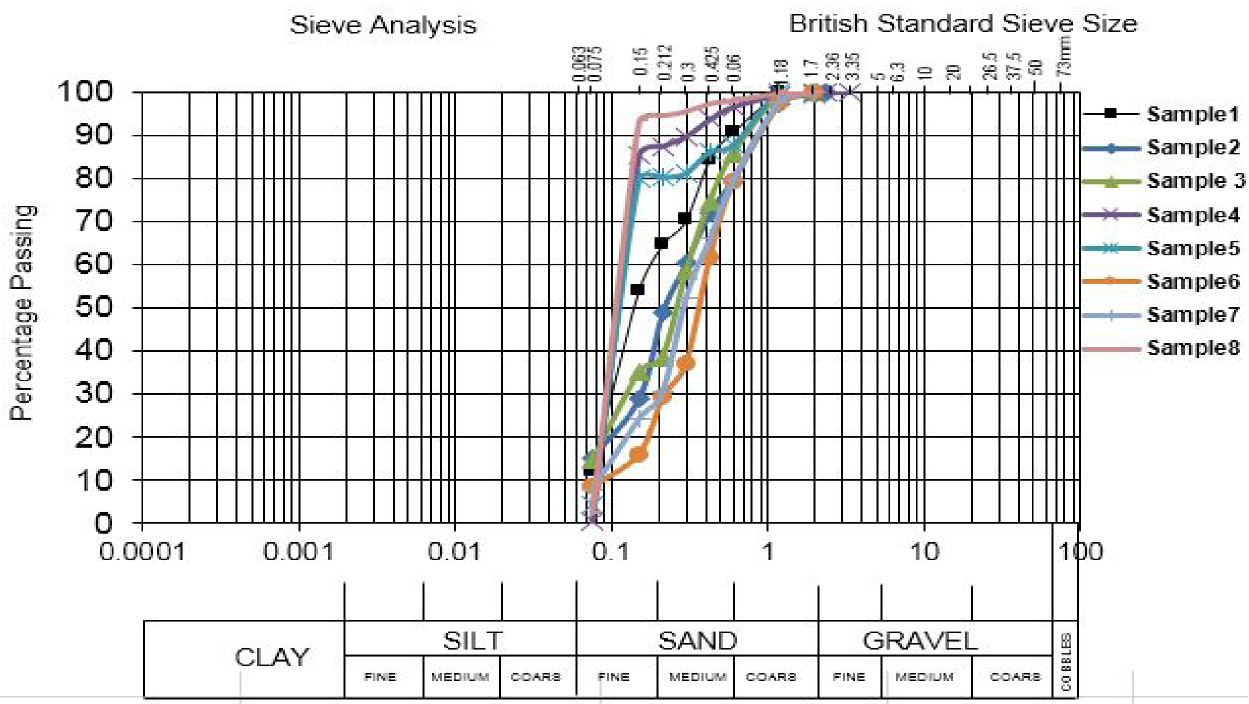

Figure 2. Particle size curve for Oduna

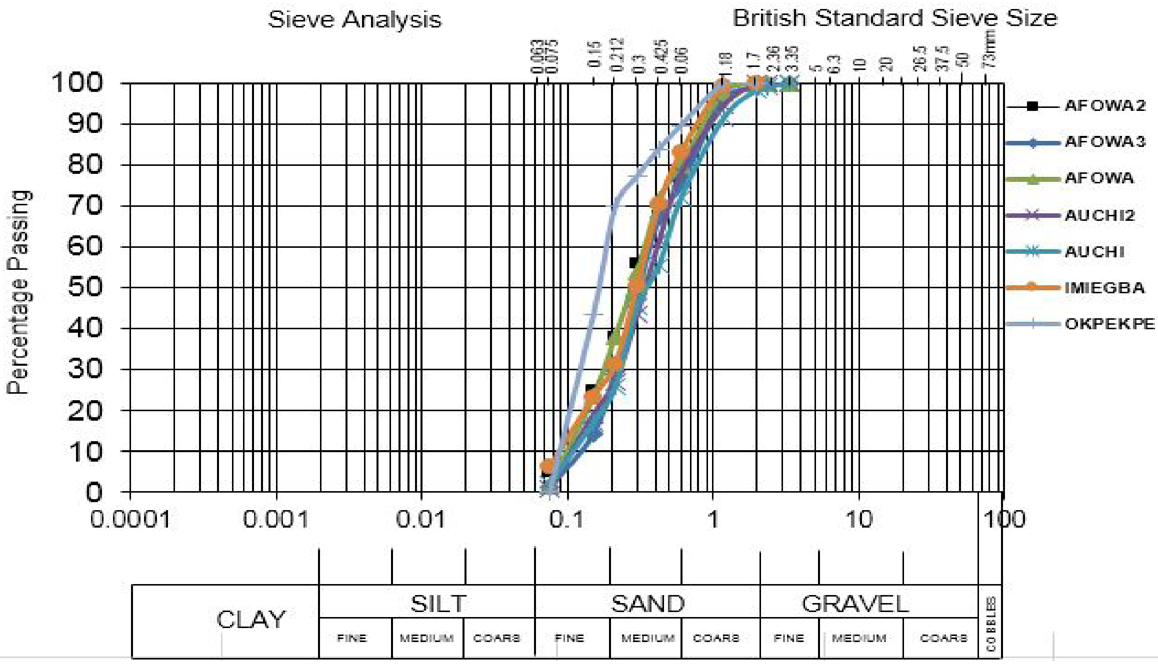

Figure 3. Particle size curve for Etsako

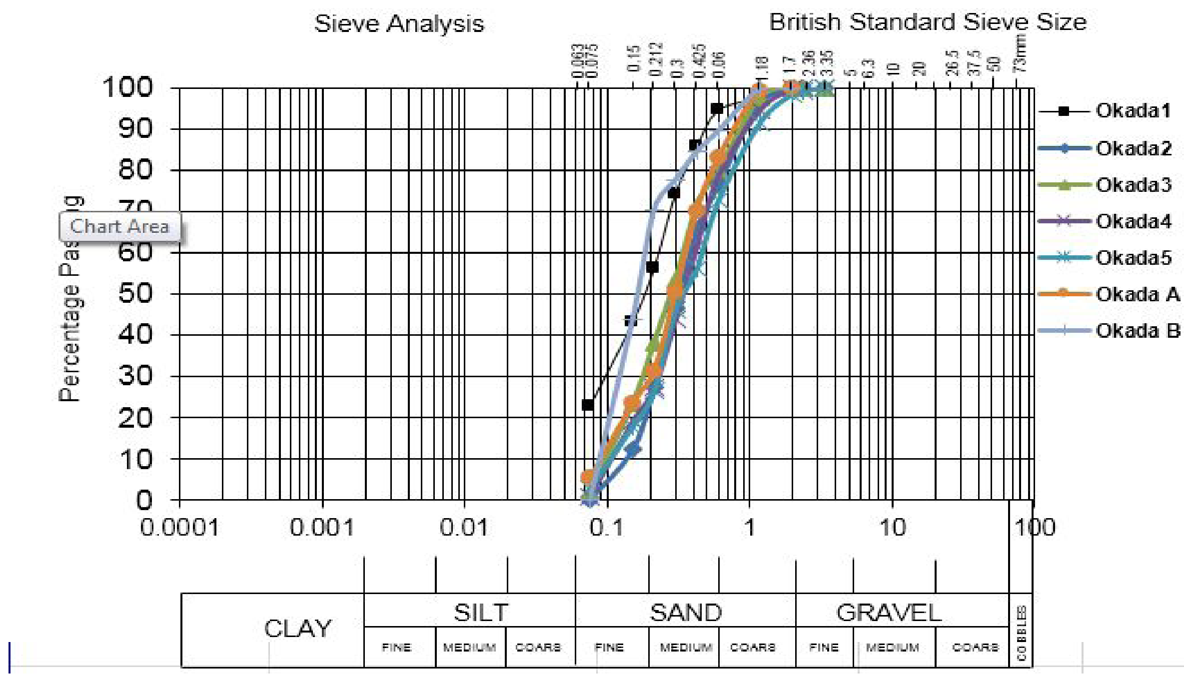

Figure 4. Particle size curve for Okada

4.4 Moisture Content

The moisture content helps us to understand the behavior of soils in terms of the porosity which tells us the retaining or holding capacity of a soil and how susceptible to compaction especially in cohesive soils i.e., fine-grained in nature. Fine-grained cohesive soils are practically impermeable that, change in volume would have poor drainage qualities and strength with variations in moisture conditions. The moisture content of Okada (48%-60%) was the highest in comparison to Oduna and Auchi (Tables 3, 4, 5), telling us that the soils of the Okada have the greatest holding capacity.

Table 3. Summary of results for Oduna

Sample	P.S (% Fines)	S.G	Atterberg limits				Compaction		Triaxial Test			California Bearing Ratio (CBR)			
			LL	PL	PI	SL	(MDD) g/cm^3	(OMC) %	Cohesion (C)	Angle of friction (Θ)	Shear Strength				
1	54.00	2.41	65.65	34.61	34.04	12.86	1.32	30.2	3.92	45.14	45.21	**2.5M**	**5.0M**	**2.5M**	**5.0M**
2	71.00	2.40	60.39	29.98	30.41	10.70	1.39	26.4	6.62	65.00	65.12	Unsoaked		Soaked	
3	64.80	2.49	68.72	31.09	37.63	8.57	1.38	28.2	5.00	61.25	61.34	Bottom			
4	14.45	2.43	70.54	45.28	25.26	11.40	1.40	27.6	0.33	64.43	64.44	9.74	8.77	2.89	3.18
5	20.01	2.41	65.63	29.48	36.15	12.80	1.27	31.2	0.52	120.00	120.01				
6	83.90	2.58	65.18	35.91	29.27	15.00	1.37	28.4	24.95	95.00	95.27	Top			
7	75.60	2.52	59.01	34.71	24.30	12.10	1.35	29.0	14.80	44.00	44.26	12.72	12.66	4.21	4.88
8	97.53	2.32	72.96	29.50	43.47	13.57	1.39	26.4	7.80	58.00	58.14				

Table 4. Summary of results for Okada

Sample	P.S (% Fines)	S.G	Atterberg limits				Compaction		Triaxial			California Bearing Ratio (CBR)			
			LL	PL	PI	SL	(MDD) g/cm^3	(OMC) %	Cohesion (C)	Angle of friction (Θ)	Shear Strength				
1	56.69	1.97	205.37	72.58	132.79	25.70	1.07	30.8	26.00	7.89	26.14	**2.5M**	**5.0M**	**2.5M**	**5.0M**
2	85.73	2.57	180.71	77.20	103.51	25.00	1.13	16.2	8.00	9.37	8.17	Unsoaked		Soaked	
3	74.41	2.05	194.66	78.64	116.02	27.86	0.99	44.0	35.00	9.35	35.16	Bottom			
4	90.77	1.95	181.29	77.20	104.09	25.00	0.94	38.6	30.00	7.50	30.13	7.52	7.45	3.63	3.01
5	72.09	1.98	206.02	85.61	120.41	26.43	0.94	42.2	12.00	4.66	4.66				
A	53.94	2.00	157.46	57.12	100.34	23.57	1.06	44.5	9.50	6.51	9.61	Top			
B	76.51	1.93	162.43	73.56	88.87	25.00	1.00	38.8	28.00	8.35	28.15	6.11	4.82	4.21	5.91

Table 5. Summary report for Etsako

Sample	P.S (% Fines)	S.G	Atterberg limits				Compaction		Triaxial				California Bearing Ratio (CBR)			
			LL	PL	PI	SL	(MDD) g/cm^3	(OMC) %	Cohesion (C)	Angle of friction (Θ)	Shear Strength		**2.5M**	**0.5M**	**2.5M**	**5.0M**
													Unsoaked		Soaked	
AF 1	76.57	2.51	60.05	31.69	28.37	16.40	1.70	16.6	7.55	45.00	45.13	B	29.73	39.35	15.77	30.41
AF2	75.16	2.45	25.22	19.37	5.85	15.00	1.68	13.1	10.20	89.00	89.18					
AF3	85.71	2.47	36.20	20.71	15.49	15.00	1.76	11.9	9.41	71.00	71.17	T	21.88	39.18	14.29	33.53
AUCHI 1	81.89	2.26	60.05	31.69	28.37	10.00	1.47	22.8	7.78	60.00	60.14	B	22.30	29.76	11.97	15.29
AUCHI 2	80.83	2.55	27.30	19.31	7.99	10.70	1.70	15.5	9.41	71.00	71.17	T	22.29	32.77	16.60	31.46
IMIEGBA	76.64	2.53	35.51	21.79	13.72	12.85	1.65	17.6	10.31	69.00	69.18	B	19.57	19.23	12.55	21.26
												T	23.70	25.21	15.03	21.21
OKPEKPE	56.56	2.43	29.05	7.87	21.18	11.40	1.63	15.6	4.26	40.00	40.07	B	20.15	17.37	24.78	27.13
												T	16.10	17.43	16.52	16.22

4.5 Compaction Result

The importance of the compaction test is to improve the desirable load Bearing Capacity and strength of the soil by increasing soil density, and removing air thereby stiffing the soil, increases strength lowers compressibility and reduces the rate of flow of water through soils. The higher the Maximum Dry Density (MDD), the lower the Optimum Moisture Content (OMC) and the more suitable. The compaction curves (Figures 6 & 7) give an indication of a cohesive soil because cohesive soils have high air voids and the soil attains a relatively low MDD. Using the standard proctor test, the clays MDD values were between 1.44-1.685 mg/m^3 and OMC between 20%-30% with the Etsako samples were within the stipulated limit and suitable for engineering purposes (Tables 3, 4, 5) [18].

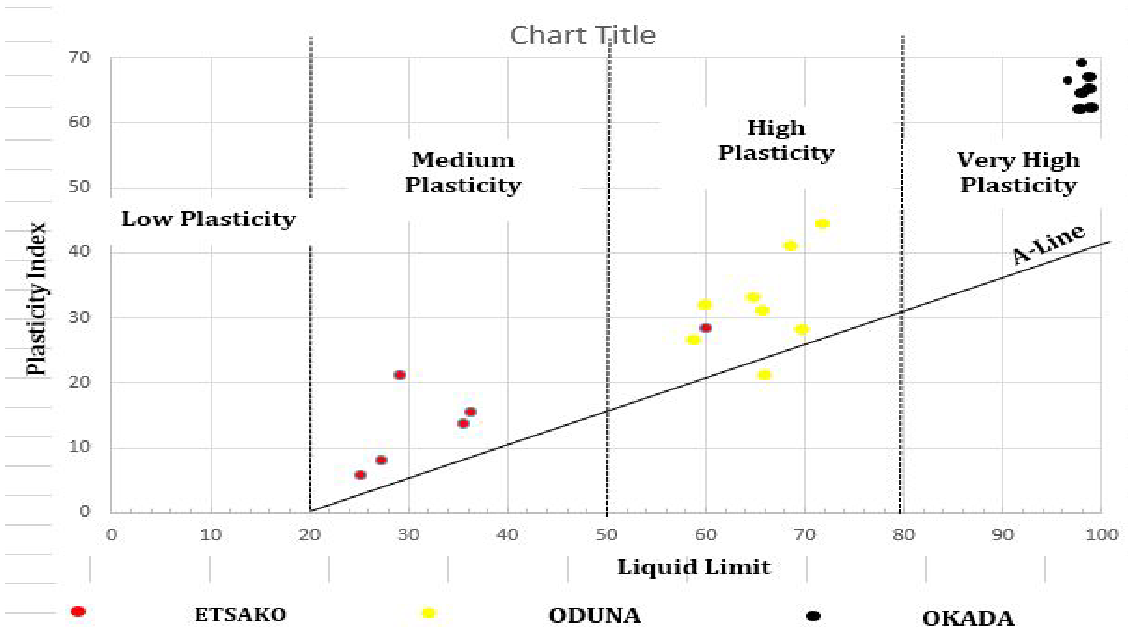

Figure 5. Cassangrande's Plasticity chart

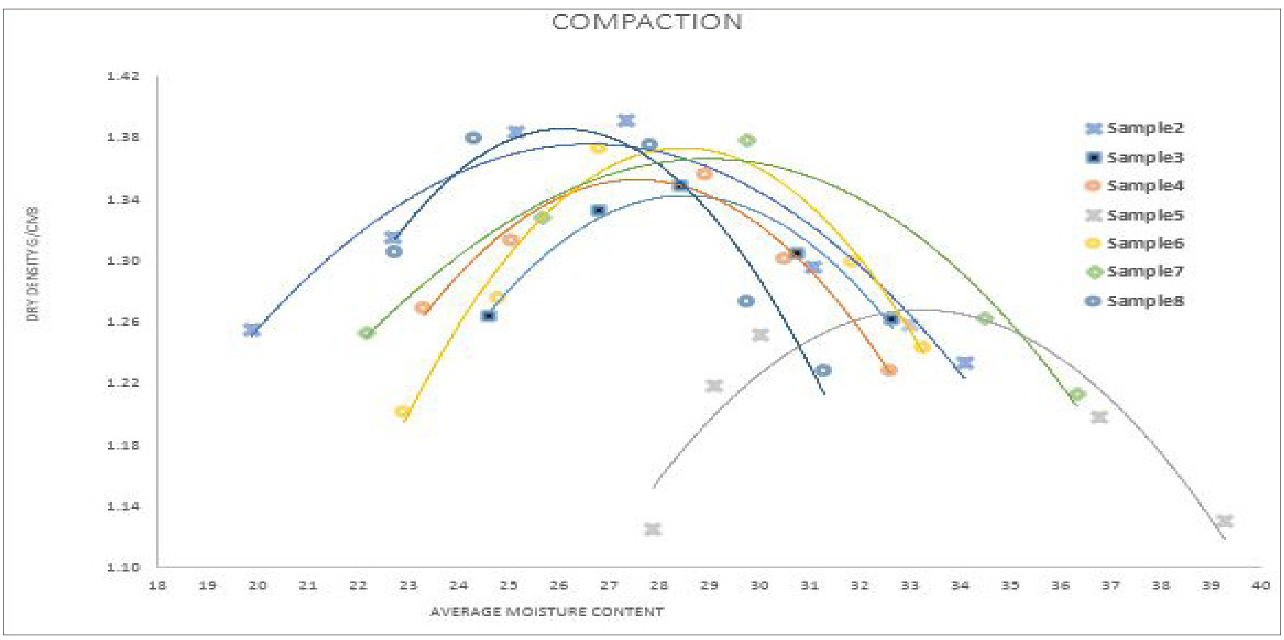

Figure 6. Compaction Graph for Oduna

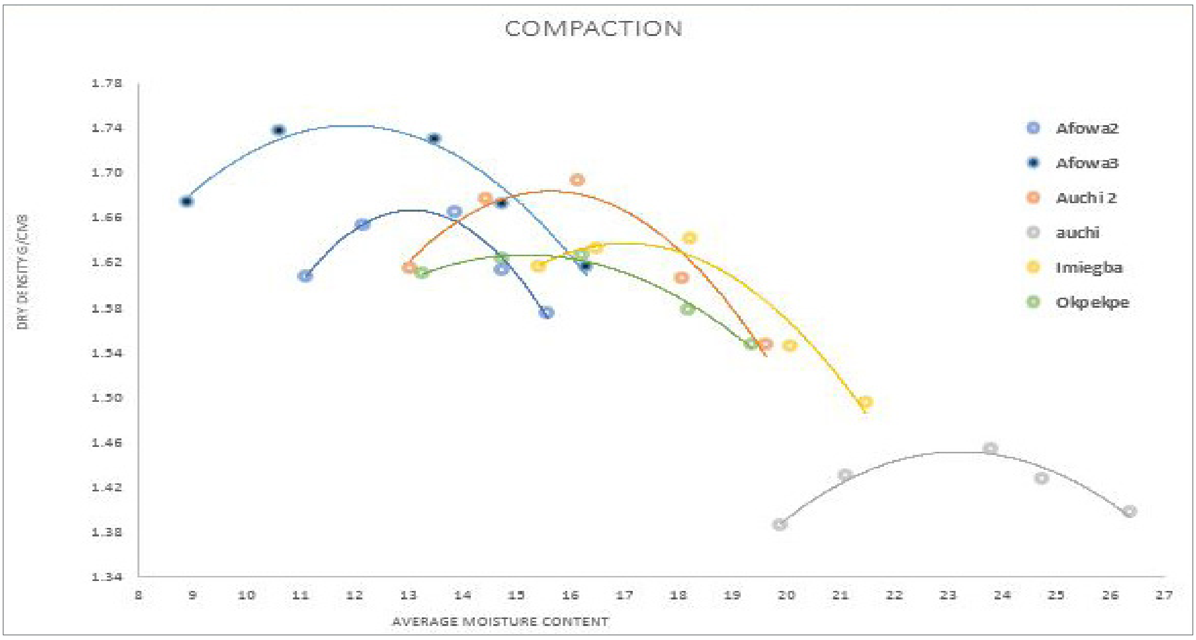

Figure 7. Compaction Graph for Etsako

4.6 Shear Strength

This analysis was mainly done to ascertain its durability for road construction. Shear strength it is needed to estimate the load bearing Capacity of soil and stabilization which is determined by the Internal friction to shearing forces and it is defined by the cohesion and angle of friction. From the result, the clays of the Okada show low shearing as compared to the other two locations. But in general (see Tables 3, 4, 5), the shear strength of the soil samples of Etsako and Oduna would be suitable because of their high shearing Strength. It is noted that the angle of friction is low for clayey soils because of saturation of the soil, mineralogy which affects clays because the cementation causes the chemical bond between the particles to cause shear strength to be low especially in expanded soils because of an increase in its clay content and their activity (Table 6). Also, soils with High plasticity tend to have high cohesion and low angle of friction, and low shear strength causing susceptible to construction failure [19-21].

Table 6. Clay Activity

ACTIVITY	CLASSIFICATION
Less than 0.75	Inactive
0.75 -1.25	Normal
Greater 1.25	Active

Based on this classification after [22] above,

Location	% clay	Plasticity Index	Activity (A)
ODUNA			
ODUNA 1	42.10	31.04	0.73
2	55.90	30.41	0.54
3	50.1	37.63	0.75
4	14.06	25.26	1.80
5	15.52	36.15	2.33
6	75.4	29.27	0.39
7	67.7	24.30	0.36
8	95.06	43.47	0.46
OKADA			
OKADA 1	33.69	132.79	3.94
2	80.30	103.51	1.28
3	66.42	116.02	1.75
4	89.6	104.09	1.16
5	70.18	120.41	1.72
A	52.88	100.34	1.90
B	71.02	88.87	1.25
ETSAKO			
AFOWA 1	74.75	28.37	0.38
2	70.44	5.85	0.08
3	80.3	15.49	0.19
AUCHI 1	78.77	28.37	0.36
AUCHI 2	79.17	7.99	0.10
IMIEGBA	76.64	13.72	0.18
OKPEKPE	56.27	21.18	0.38

From Table 6 above, the soils of Okada are active and the other two are Inactive to Normal. This also corroborates the very high plasticity from the Plasticity chart and the shear strength. In the case of road especially those with heavy traffic movement, soil that are active especially when water is encountered would cause a reduction in soil strength causing it to stiffen, and create problems such as undulation in the road (Plate 5), cracks in building, and even lead to collapsibility.

4.7 California Bearing Ratio

The California bearing ratio is used in estimating the bearing capacity of subgrade, sub-base, and base materials [23-25]. There soaked and unsoaked ratio was carried out. Unsoaked conditions are the normal field condition likely to attained after construction of pavements while soaked condition is needed being in a Tropical zone, simulation of the worst conditions is required. Soaked CBR was between 16.10%-39.35%, and unsoaked CBR 12.55%-31.46% using the Federal Ministry of Works and Housing [9] and [26] standard, with the exception of Okada and Oduna, the Etsako samples are suitable for road construction as subgrade and sub base. In comparison with clays of other authors within the Southwestern region (Table 7), they exhibit similar geotechnical properties owing to similar geology. This means this can be used as a knowledge example of clays within this region. For these clays to be used they would be enhanced or used as a binding material in construction

Plate 5. Road Undulation

Table 7. Comparison with some Clays in Southwestern Nigeria

Parameters	Samples		i. [27]	ii. [28]	iii. [5]
Moisture content	Oduna	22.76-30.39	-	23.40- 30.60	4.6-10.5
	Okada	48.10-60.61			
	Etsako	7.31-11.97			
Specific gravity	Oduna	2.41-2.58	2.66-2.68	2.6-2.71	2.60-2.70
	Okada	1.93-2.57			
	Etsako	2.26-2.55			
% fines	Oduna	14.45-97.53	55-74	24.29-32.42	26-62
	Okada	56.69-90.77			
	Etsako	56.56-85.71			
LL	Oduna	59.01-72.96	42.2-50.5	63.0-77.4	27.9-72.0
	Okada	157-46-206.02			
	Etsako	25.22-60.05			

Table 7 continued

Parameters		Samples		i. [27]	ii. [28]	iii. [5]
PL		Oduna	29.43-35.91	21-3-25.8	29.3-37.65	17.9-24.0
		Okada	57.12-85.61			
		Etsako	7.87-31.69			
PI		Oduna	25.26-43.47	20.8-24.7	33.80-46.45	10.0-48.5
		Okada	88.87-132.79			
		Etsako	5.85-28.37			
SL		Oduna	8.57-15.00	-	10.70-17.90	-
		Okada	23.57-27.86			
		Etsako	10.00-16.40			
MDD		Oduna	1.27-1.40	-	1.40-1.75	15.6-19.1
		Okada	0.94-1.13			
		Etsako	1.47-1.76			
OMC		Oduna	26.4-30.2	-	17.70-24.00	18.0-29.0
		Okada	16.2-44.5			
		Etsako	11.9-17.6			
CBR	Unsoaked	Oduna	4.82-7.52	-	10-18	-
		Okada	3.63-5.91			
		Etsako	16.10-39.35			
	Soaked	Oduna	8.77-12.72	-	1-3	-
		Okada	2.89-4.88			
		Etsako	12.55-31.46			

5. Conclusions

The Okada clays has a high moisture content with very high plasticity indicating a high retaining capacity (repeated swelling and contraction during the dry and wet season) which is a characteristic of clays. Furthermore, the Shearing Strength of the soil sample was low for Okada clays than those of the Oduna and Etsako, which collaborates with having percentage fines of less than 35%, with low to medium Plasticity (low swelling potential). This makes the Okada clays active soil which causes instability in engineering construction observed in the undulation of the roads and cracks in some buildings within the area but the clays of Okada and Oduna can be used as materials for stabilization. The Etsako area exhibited the most suitable for construction purposes, with better specific gravity performance which influences the strength and adsorption, CBR, and compaction with good shearing strength, which is the basic requirement for construction, especially for roads.

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Conflict of Interest

There is no conflict of interest.

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