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Geotechnical Investigation of Clay Soil as Subgrade Material in Road Construction. A Case Study of Itakpe-Lokoja Road, Kogi State, North Central Nigeria.

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Abstract
This paper presents some geotechnical investigation report on subgrade soils. The aim of the study is to carry out investigation on sites being excavated for subgrade soil for road construction with the sole aim of identifying expansive soil. A clear understanding of the expansive sub-grade soils behavior and their geotechnical characteristics has been of more interest of study in order to identify the source of swelling problem in our roads. One case study sites on two different pits along Okene - Lokoja road were carefully selected for geotechnical site investigation. The field exploration consist of excavating trial pits and collecting their soils samples for sub-grade testing. These soils were subjected to laboratory testing for measuring the particle size analysis, Atterberg test, shrinkage test, compaction test, shear strength test, load bearing capacity test, aggregate crushing test, consolidation test and swelling tests. The soils were found to have over 50% clay particles, high plasticity index of more than 30% and high free swell of 160% to 250%. The compacted sample were found to have swell potential of 7% to 15% coupled with high swelling pressure in excess of 90 kpa and low shear strength, California bearing ration (CBR)values of less than 4%.

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Aim and Objective
The aim of the study is to investigate the properties of the sub-grade soil meant for road construction.
The objectives of the study are to evaluate the following index properties in order to determine the mechanical properties of the soil: Liquid limit test, Plasticity limit test, Shrinkage limit test, Compaction test, Wet and Dry density test, Sieve analysis test, Shear strength test, Load bearing capacity, Aggregate crushing values, and Consolidation of the soil

Problems of the Study
Expansive soils are common over a large area of Itakpe and have caused significant damages to irrigation systems, water lines, sewer system, buildings, roads and other structures. These damages have made the government at federal, state and local government including individual to loss enormous amount of money in rehabilitation and reconstructing new structures.

Justification of the Study
The high rate of road failures and the attendant accidents that occurred along the Itakpe – Lokoja road is very Worrisome. As both the old and recent roads shows evidence of failure and this necessitate the study.

Location and Accessibility of the Study Area
The study area is Itakpe which is located in Okehi Local Government Area of Kogi State in North Central Nigeria. It lies within latitudes $7^0$36'N to $7^0$39'N and Longitudes $6^0$17'E to $6^0$22'E. Itakpe is located Northeast of

Okene and is about 10 km along the Okene – Lokoja road. Fig.1.1 shows the location map of Kogi state showing Itakpe, Okene and the other important towns.
The climate of the area is similar to that of other parts of the middle belt of Nigeria with rainfall stretching for about seven (7) months from April to October and dry season lasting for five months from November to March Nigerian Steel Development Authority Report (N.S.D.A. 1976).

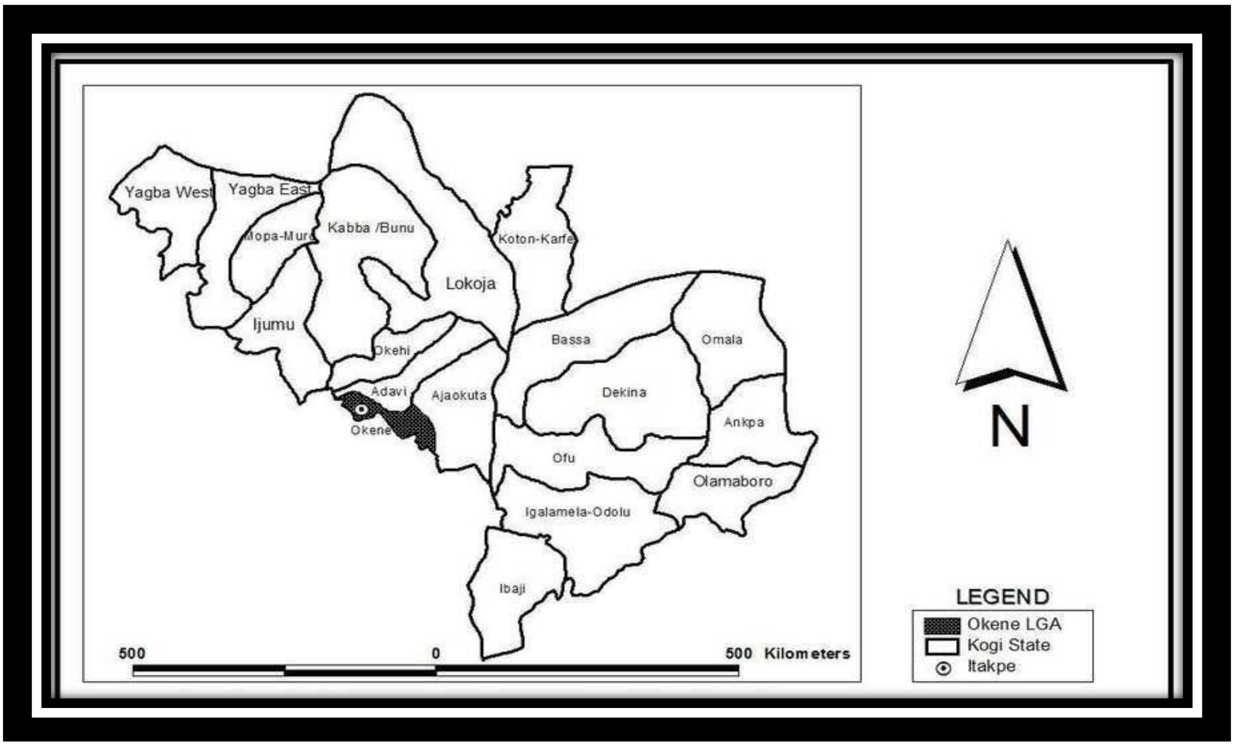


Fig1: Map of the Study area.

I. Introduction

Clay minerals are phyllosilicate (sheet – like) or layer lattice minerals which commonly occur as minute, platy crystals. They may also be fibrous. They can primarily be group into two, according to their lattice structures. These group are the kaolinites with a lattice of two (1:1 layer) and montmorillonite group with a three layer lattice (2:1) layer.

Clays are spread throughout the world. Clays have the potential to swell and to shrink; these two problems are associated with it. Okogbue (1984) describe heaving and settlement of structures as a physical expression resulting from swelling or shrinking respectively of the foundation soil. Cracking of structure is the result of heaving and settlement of the areas underlain by expansive clays.

Damages caused by expansive clays are enormous and can be recognized in all kinds of structures including buildings, high ways, hydraulic conduits, aerial surveillance equipment, underground utilities, slopes, and embankment (Jones & Holtz, 1973), Clay can be inform of rocks, mineral species or soils. Legget (1962) is of the views that a soil mixture containing clay sized particles (silts & sand) mixtures of up to 70 % by weight of the entire soil mixture. Pettijohn (1975) on the other hand thinks that a definition based on particle sizes is inadequate since most commercial clay will be excluded. He suggested that for a naturally Plastic earth material to be called clay, it should be composed of hydrous aluminium silicates (clay mineral) even if it is less than one – third of the entire rock mass

The existence of problem clays is commonly recognized by surfacial expressions such as cracking and uplifting of structures, dislocation, disruption of fences and high Ways and other underground utilities.

These expressions may be due to heaving when the clay absorbs moistures and swells or due to settlement when the clay losses water and shrinks. The potential to swell or shrink is closely associated with montmorillonites minerals and other indices which indicate swelling or shrinkage.

Geology of Itakpe

The Nigerian Basement Complex forms a part of the Pan – African mobile belt and lies between the West African and Congo Cratons and lies within south of the Tuareg (Black, 1980). The geologic setting of the study area is made up of two distinct complexes of rocks (Wright, 1976); (a) Pre - Cambrian rocks which have undergone intensive tectonic and metamorphic changes and are commonly referred to as the Basement Complex and (b) Mesocenozoic deposits which are only slightly affected by the same processes. The Basement Complex of Nigeria includes those of the North Central Nigeria, the Southwestern Nigeria and the Eastern province. The three broad lithological groups within the Nigerian Basement Complex are the Migmatite Gneiss Complex made up largely of Migmatite and Gneisses of various compositions, the low grade sediment dominated Schist belt and the Granitic rocks which cut both the Migmatite Gneiss Complex and the Schists belt (Ajibade and Woakes, in Kogbe 1980).

Itakpe (fig.1) is endowed with Iron Ore deposit, and the deposit is localized within the Gneiss – Migmatite – Quartzite unit of Nigerian Basement Complex. Annor and Freeth (1985). Olade (1979) describe the geology of Okene as Granodiorite – tonalite – gneiss lithologic unit, overlain by sequences of low grade Metasediments and intruded by Granodioritic and Granite rocks. The major rock types that occurred in the area includes Granite Gneiss, Granites, Quartzites, Schists,, Amphibolites and Pegmatites but in this particular area, Amphibolites was not visible. Olade (1979) gave a vivid description of the geology of the ore deposit to be made up of two types of Quartzites: the ferruginous quartzite and non ferruginous quartzite. The ferruginous quartzites occur as Magnetites – rich and Hematite – rich bands and lenses in alternation with gneiss. The non ferruginous quartzites are rear in Itakpe hill but are localized at the southern fridges.

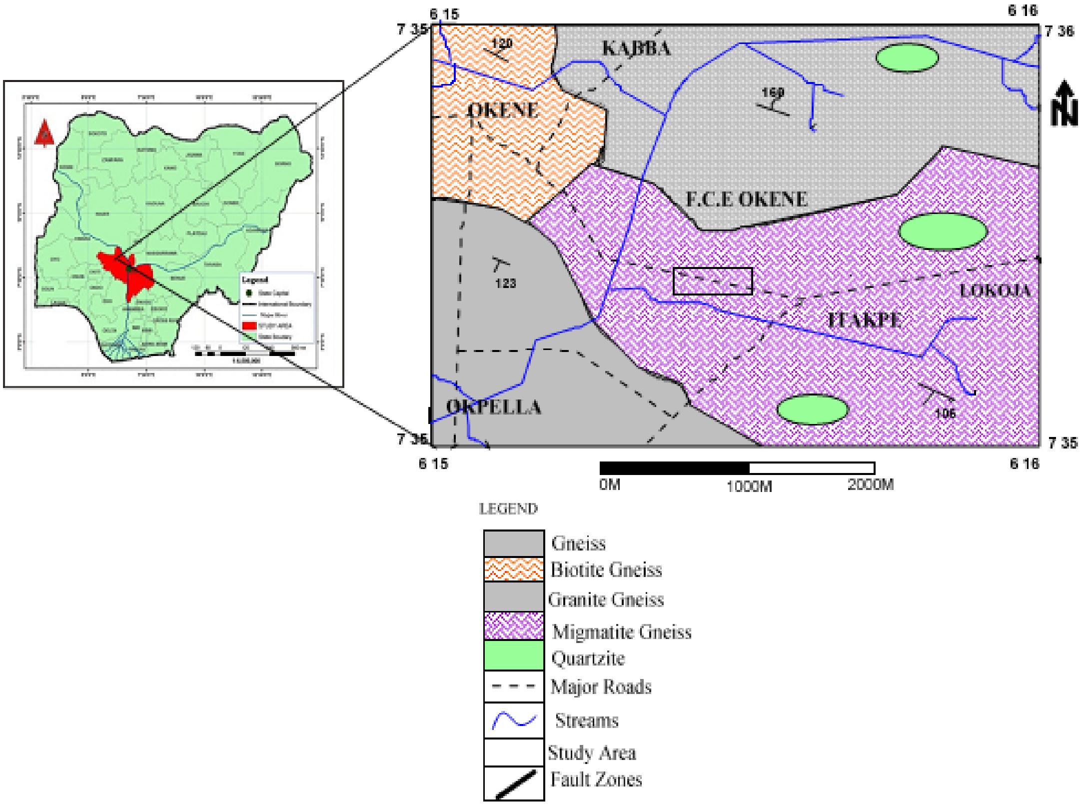


Figure 1: Geology Map of the Study Area.

Method of Study

Two (2) different sites were investigated by taking soil samples from excavated pits into sampling bags for analysis in the laboratory.

Problem of expansive soils results from a wide range of factors such as swelling and shrinkage of clay soil which resulted from moisture change, type of clay minerals, rise in groundwater level or poor surface drainage and compression of the soil strata resulting from applied load.

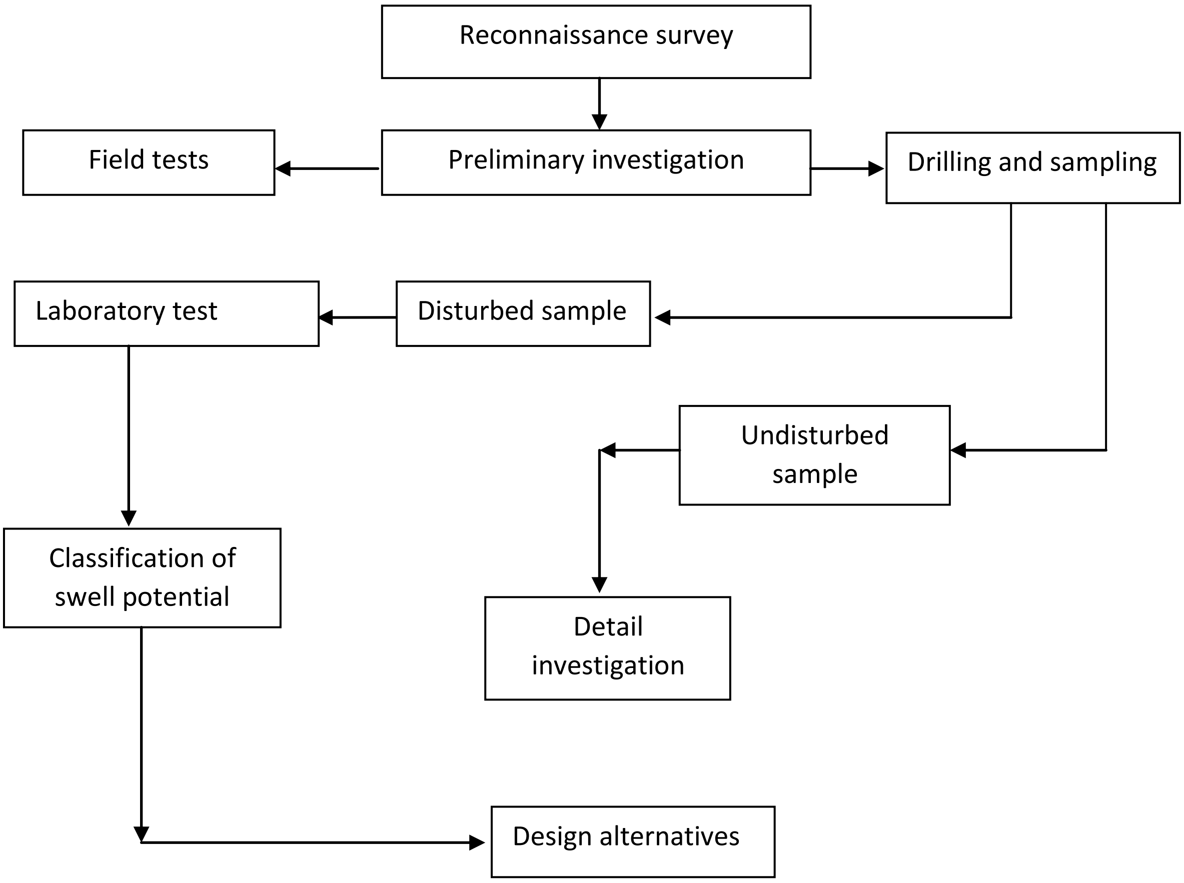
Geotechnical site investigation:

Geotechnical investigation practice varies from places to places but the three major procedures are :

- Reconnaissance survey
- Preliminary investigative
- and detailed investigation

The reconnaissance stage is mainly to review available information and perform a surface reconnaissance survey.

The preliminary investigation is to conduct detailed surface mapping, preliminary borings, and initial laboratory testing and analysis for soil identification and classification.
The detailed investigation is essentially to conduct soil borings for recovery of specialized samples for test, and partial excavation



Flow chart for site characterization

Laboratory Investigation:
The laboratory investigation program for identification of swelling soil and their geotechnical characteristics has been performed to address the research objectives.
The expansive soil is identified by their mineralogical composition and index properties. The tests were conducted to measure the soil analysis, hydrometer; Atterberg limits (Liquid and Plastic Limit) were carried out for soil classification in accordance with (BS) British standard (1377) and unified soil.

Materials and Methods
- As it varies so its method of determining the stability on road constructions varies:
- California Bearing Ratio Test on Sub-grade soil method.
- Determine liquid limit of soil specimen by casagrande method.
- Dry density of soil by core cutter method for soil compaction
- Sieving methods of sieve analysis.

The following are the various materials used:
Geographical position system (GPS), Sampling bag, Marker, Spatula, Masking tape, Measuring tape, Proctor rammer, Scoopels, Sieve, Mortal, Pestle, Density bottle, Measuring cylinder, Weighing balance, Oven.
The material used were taken from road site borrow pits which are distinctly different in their geotechnical characteristics, were selected for this study. All these soil samples are taken from Okene - Lokoja road at Itakpe.
The soil at the road construction site must be stable enough to carry the loads from the structure through footings without undergoing undesirable settlement during the construction process and during the service period.

II. Result and Discussion

Preliminary Test

The tests results for the soil sample obtained from the subgrade soil of Lokoja -Okene road at Itakpe is presented in table 1 below.

Sieve Analysis:

Different methods can be used, with their standards and these standards are; (a) British Standard (BS) (b) West African Standard compaction method (WASC), but in this research work; British standard will be used and table 1 shows particle sizes distribution of the soil samples; while the cummulative graph is presented in Fig. 2

Table 1: Particle Size Distribution

Sieve NO	Sieve opening in mm	Wt of sieve	Wt. sieve + soil in g	Wt. soil retained	Percent retained (%)	Cumulative percent retained (%)	Percent finer (%)
¾	19.0	423.1	423.1	___	___	___	100
3/8	9.5	386.2	392.8	6.6	1.46	1.46	98.54
3/16	5.0	421.1	426.4	5.3	1.17	2.63	97.37
7	2.36	443.7	453.3	9.6	1.12	4.75	95.25
14	1.18	355.4	372.1	16.7	3.68	8.43	91.57
25	0.600	379.1	411.5	22.4	4.94	13.37	86.63
36	0.425	208.9	230.2	22.2	4.90	18.27	81.73
52	0.300	350.2	426.8	76.6	16.90	35.17	64.83
100	0.150	211.6	361.2	149.6	33.00	68.17	31.83
200	0.075	321.4	412.4	53.3	11.76	17.93	20.07
PAN	PAN			91.0	20.07	100	____

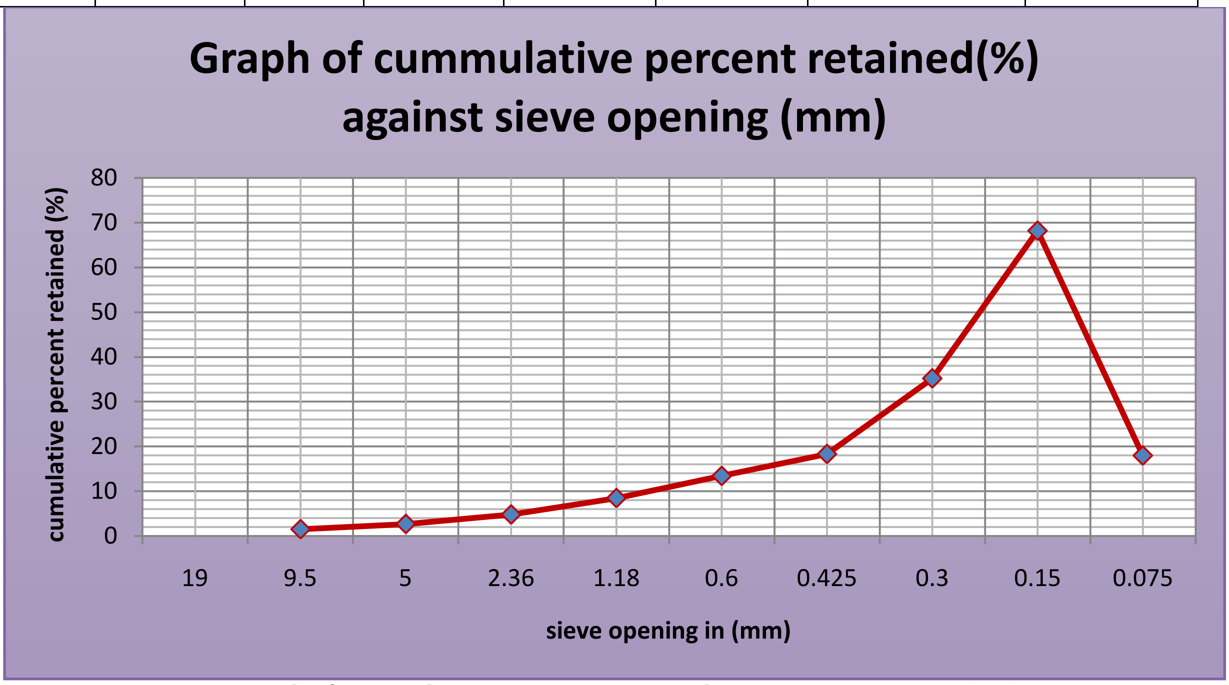


Fig. 2: Graph of Cummulative Percentage Retained against Sieve Opening (mm).

Atterberg Limit Test

The Atterberg limit conducted were liquid limit (LL) and plastic limit (PL), table 2 -5 shows the results of the Atterberg limit test conducted on the soil samples.

Table 2: Atterberg Limit (Liquid and Plastic Limit) LI

	Liquid limit				Plastic limit	
Sample No	1	2	3	4	1	2
Moisture can and lid number	142	157	112	132	142	151
Mass of empty can m_1 (g)	17.0	17.1	16.9	16.4	16.8	16.7

Mass of can + moist soil m_2 (g)	27.4	30.8	28.3	27.5	19.4	19.1
Mass of can + dry soil m3 (g)	22.9	25.0	23.6	23.0	18.6	18.6
Mass of soil (g)	5.9	7.9	6.7	6.6	2.1	1.9
Mass of water (g)	4.5	5.8	4.7	4.5	0.5	0.5
Water content (%)	76.3	73.4	70.1	68.2	23.8	26.3
No. of Blows (N)	13	24	35	46		

Table 3: Atteberg Limit (Liquid and Plastic) L2

Liquid limit					Plastic limit		
Sample No	1	2	3	4	1	2	3
Moisture can and lid number	16.5	16.9	16.5	16.7	144	100	156
Mass of empty can m_1 (g)	42.2	39.1	52.0	47.9	16.7	16.4	16.5
Mass of can + moist soil m_2 (g)	27.4	30.8	28.3	27.5	19.5	19.9	20.1
Mass of can + dry soil m_3 (g)	32.9	30.7	39.2	37.3	18.5	19.2	19.5
Mass of soil (g)	16.4	13.8	22.7	20.6	1.8	2.8	3.0
Mass of water (g)	9.3	8.4	12.8	10.6	1.0	0.7	0.6
Water content (%)	56.7	55.1	53.3	51.5	55.6	25.0	20.0
No. of Blows (N)	19	28	39	48			

Table 4: Atteberg limit (liquid and plastic) L3

Liquid limit					Plastic limit		
Sample No	1	2	3	4	1	2	3
Moisture can and lid number	116	162	161	142	159	156	167
Mass of empty can m_1 (g)	17.0	17.3	16.1	16.5	17.2	16.8	16.1
Mass of can + moist soil m_2 (g)	37.8	36.4	35.9	39.9	20.9	21.1	20.4
Mass of can + dry soil m_3 (g)	31.4	30.7	29.6	32.2	20.3	20.4	19.8
Mass of soil (g)	14.4	13.4	13.0	15.7	3.1	3.6	3.7
Mass of water (g)	6.4	5.7	6.3	7.7	0.6	0.7	0.6
Water content (%)	44.4	42.5	48.5	49.0	19.4	19.4	16.2
No. of Blows (N)	47	38	25	15			

Table 5: Atteberg Limit (Liquid and Plastic) L4

Liquid limit					Plastic limit		
Sample No	1	2	3	4	1	2	3
Moisture can and lid number	131	122	120	116	141	142	144
Mass of empty can m_1 (g)	16.2	16.4	16.4	16.9	16.6	16.5	16.5
Mass of can + moist soil m_2 (g)	37.1	38.9	39.6	40.6	20.4	22.5	21.0
Mass of can + dry soil m_3 (g)	30.2	31.7	32.5	33.6	19.7	21.5	20.2
Mass of soil (g)	14.0	15.3	16.1	16.7	3.2	5.0	3.7
Mass of water (g)	6.9	7.2	7.1	7.0	0.6	1.0	0.8
Water content (%)	49.3	47.1	44.1	41.9	18.8	20.0	21.6
PI = 25,5	LI = 45.6				PL = 20.1		

Table 6: Moisture content

Moisture content container no		156	136	170	132	161	149	159	141
Mass of wet sample + container	(g)	23.5	22.8	21.9	21.8	21.8	22.7	21.5	20.5
Mass of dry sample + container	(g)	23.2	22.5	21.5	21.5	21.5	22.1	21.1	20.1
Mass of container	(g)	16.8	16.3	16.1	16.1	17.4	16.1	17.3	16.4
Mass of water	(g)	0.3	0.3	0.4	0.3	0.3	0.6	0.4	0.4
Mass of dry soil	(g)	6.4	6.2	5.4	5.4	4.1	6.0	3.8	3.7
moisture content	(%)	4.7	4.8	7.4	5.6	7.3	10.0	10.5	10.8
Average moisture content	(%)	4.7		6.5		8.7		10.7	
Dry density (g/cm^3)	(g/cm^3)	2.21		2.25		2.31		2.24	

Maximum dry density = 2.305
Optimum moisture content = 9.1

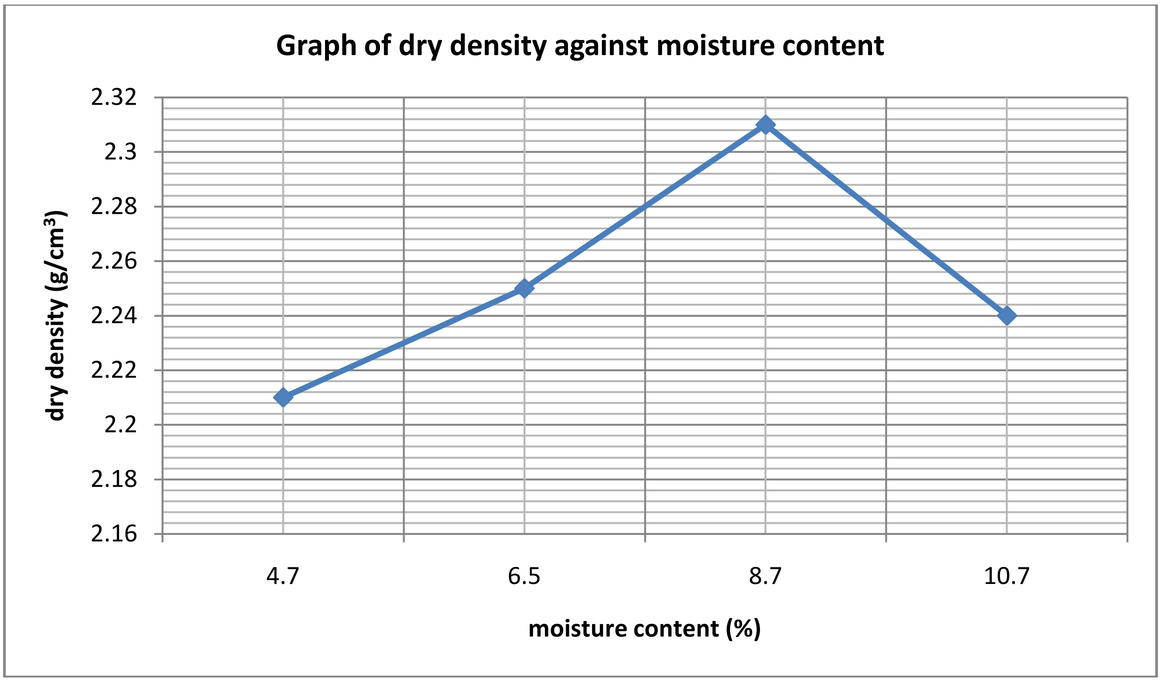


Fig.3 : Graph of Density against Moisture content.

Table 7: Aggregate Crushing Test

Test no	Wt. of sample (g)	Wt. of fine passing not sieve after applying 40 ton load	Aggregate crush value (A.C.V)
SAMPLE 1	1000	40	40%
SAMPLE 2	1000	43	40%
SAMPLE 3	1000	41	40%
SAMPLE 4	1000	40	40%
SAMPLE 5	1000	41	40%

Table 8: Strength and Swelling test Result

Sample	CBR (%)	FSI (%)	S (%)	SP (Kpa)
K42+700 pit (1)	1.5	180	10.1	105
(2)	2.5	160	9.5	93
(3)	1.2	250	15.0	130
K52+350 pit (1)	3.2	172	8.7	95
(2)	4.0	165	7.0	90

Table 9: Load Bearing Capacity Test

$Ø^0$	N_c	N_q	N_y
0	5.7	1.0	0.0
5	7.3	1.6	0.14
10	9.6	2.7	1.2

15	12.9	4.4	1.8
20	17.7	7.4	5.0
25	25.1	12.7	9.7
30	37.2	22.5	19.7
35	57.8	41.4	42.4
40	95.7	81.3	100.4
45	172.3	173.3	360.0
50	347.5	415.1	1072.8

Table 10: Shrinkage Test

Even though codes of practice specify shrinkage dish of standard dimensions (i.e. 44mm internal diameter and 12 mm inner height); shrinkage dishes of different sizes were also used in this work.

Soil No	Batch	SL wax
1	A	29
2	B	26
3	C	29
4	C	31
5	C	15

III. Conclusions

In this paper, different geotechnical properties of soils such as particle size distribution, consistency limits, compaction, consolidation, shear and swell strength and their interactions and applications for the purpose of civil engineering structures have been discussed.

The soils were found to have over 50% clay particles, high plasticity index of more than 30% and high free swell of 160% to 250%. The compacted samples were found to have swell potential of 7% to 15% coupled with high swelling pressure in excess of 90 kpa and low shear strength, California bearing ration (CBR)values of less than 4%.

This research was conducted for soil engineering properties and strength test for various inclusions of ashes into the clay soil. The percentage of additives is 5%, 10% and 15% of each ash. Improvement levels were evaluated from the results of unconfined compression test (UCT) carried out at different curing times.

Based on the study results, the following general conclusions can be drawn:

➢ The study showed that it is necessary to carry out geotechnical site investigation on the expansive soils in order to have sufficient knowledge about the geotechnical characteristics, behavior and treatment of expansive soils as roads sub-grade.

➢ Many of the structural problems and premature failures of roads built on expansive soils originate mainly from inadequate or insufficient site investigation; among many other factors which include poor drainage, age, climatic conditions and neglected maintenance on the road.

➢ Effort to maintain roads on expansive soil have not yielded any result, because the maintenance were carried out wrongly and it did not reach the subgrade. It is evidently clear from the findings that the presence of expansive soils as road sub-grade have contributed to road failure.

➢ From the experimental results, it can be concluded that the soils are cohesive and are of high plasticity with high to very high expansive potential and of very active clay due to the presence of montmorillonite minerals. The soils showed high to very high free swell and swell potential coupled with high exerted swelling pressure and low strength.

IV. Recommendations

Based on these, it is therefore recommended that:

1. A more detail geotechnical and geophysical invetigation should be carried out on the study area for further studies.

2. Proper monitoring and maintenance of the road should be ensured in order to reduce the threats of road failure, accident and damages.

3 Since one third of Okene's area may have potentially expansive soils and it is equally recommended that all potential construction sites in the area be evacuated for expansive soils and refill with competent and stable soil.

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