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Engineering Properties of Lateritic Soils in Ado-Ekiti, South Western Nigeria

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ABSTRACT: *The engineering properties of lateritic soils in Ado Ekiti Area of Ekiti State, Nigeria were evaluated. Rapid urbanization in the city area has led to an increased interest in the engineering behavior of the soils which are present within the city area. The study area was divided into Six Zones: A total of 30 samples were collected with five samples per zone. Laboratory tests such as: Natural Moisture Content (NMC) , Specific gravity, Grain size analysis, Consistency tests, Compaction test, California Bearing Ratio (CBR), Triaxial test, Permeability test, Odometer test, were carried out on each of the samples. These tests were carried out in accordance with the British Standard code of practice (BS1377:1990). The visual soil profile description of all trial pits to a depth of 1.3m investigated, reveal little variation within the soil strata. The laboratory results indicated that the particle size gradation for gravel ranged from 1 to 44 %, sand ranged from 26 to 77% and fines ranged from 8 to 46%; natural moisture content ranged from 1.1 to 18.7%; specific gravity ranged from 2.23 to 2.79 ; the liquid limit ranged from 25 to 65%, plastic limit ranged from 17 to 43%, plasticity index ranged from 10 to 30%; linear shrinkage ranged from 3.6 to 15.5%.The soils were classified as clay of low compressibility (CL) for zones 1 and 2, clay of high compressibility (CH) for Zone 3 samples 1,2 and 5 and Zone 4 sample 2,Zone 5 samples 2 and 5 and Zone 6 samples 1and 2 according to the Unified Soil Classification System (USCS) and A-2-4, A-2-6, A-6, and A-7-5 which describe and classified the soil in the area into four as excellent to good, fair to poor and clayey for (AASHTO) classification system. The strength performance test shows that Zones 1 and 2 samples have their MDD and OMC ranging between 2000 Kg/m^3 – 2236Kg/m^3 and 11.1 % – 15.3 % respectively while zones 3,4,5 and 6 varied between 1667 Kg/m^3 – 1869Kg/m^3 for compaction characteristics. Unsoaked CBR values range from 80 % – 95 for Zones 1 and 2 % and 07 – 68 % for Zones 3,4,5 and 6 while soaked (SK) CBR value ranged from 45 % – 70 % for Zones 1 and 2 and 04 % - 36 % for Zones 3, 4, 5 and 6 respectively. The analysis indicate that soil sample from zones 1 and 2 fells within the minimum dry density recommended for base course material while zone 2 soils fell within the minimum recommended for sub base, sub grade and earth fill materials. However, zones 3, 4, and 5 can be recommended for sub grade and fill material, since their MDD is within the minimum recommended for sub grade and earth fill materials The research work will provide information for Engineers and Contractor in this area.*

KEYWORD: consistency limit, plasticity index, subgrade, engineering properties, dry density

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I. INTRODUCTION

The engineering properties of soil play a significant role in civil engineering construction works particularly in road constructions, foundations, embankments and dams to mention a few. This made imperative, the testing of soil, on which a foundation or superstructure is to be laid. This would determine its geotechnical suitability as a construction material (BelayhunYilma, 2013). In recent times, the alarming rate at which lives are being lost due to collapsed buildings and road failures calls for a solution (Omotosho et al, 2012). Soil has been in use for ages Dave, (1981) and is still being used today especially in developing nations. The usefulness of soil generally borders on their strength properties especially their load bearing capacity Amu et al (2005). The concern of geotechnical engineers to the rapid growth in the developmental project across the globe, the challenges in understanding soil conditions and the problem associated with tropical soils and the need to solve these problems in the tropics has led to the increase in research on the tropical soils and their engineering properties. The construction of foundations of most engineering structure requires that adequate information about the engineering properties of the soil and sub-soil condition of the area are known. This is necessary for the engineering planning, design and construction of such foundations to be based on sound geotechnical parameters. This is more important especially in the design and construction of highways, where there is need for a good and sound knowledge of the geotechnical and engineering properties of the sub grade and, more importantly, the construction materials' properties for sound engineering decisions to be taken. Such geotechnical parameters include the shear strength parameters, soil compressibility, maximum dry density (MDD), and the amount of fines (clay and silts). Many attempts have been made of recent to study the geotechnical properties of soils around Ekiti State in Southwestern Nigeria (Bayowa et al., 2014, Okunade, 2007; Oladapo and Ayeni, 2013; Owolabi and Aderinola, 2014; Talabi et al, 2013; etc). However, very few attempt has been made to investigate the engineering properties of soil sequence in Ado Ekiti area of Ekiti State, Nigeria. Therefore, it is the aim of this research to evaluate engineering properties of lateritic soils in Ado Ekiti Area of Ekiti State, Nigeria. This will subsequently consolidate the data requirement for a web-based geotechnical database management system for Nigerian soils as proposed by Okunade(2010

II. JUSTIFICATION OF STUDY

The study is important for the following reasons:

i. The suitability of the use of laterite as sub base or base for pavement construction of roads in South Western part of Nigeria is worthy of challenge because of the prevailing premature failure of their road pavements.. In recent times, the alarming rate at which lives are being lost due to collapsed buildings and road failures calls for a solution. The solution could be brought by critical geotechnical testing of the engineering soil. (Omotosho e tal ,2012)

ii. Ado-Ekiti area is expected to be the site of many major construction project in the year to come. The success or failure of such project will require a knowledge of the properties of soils of the area.

iii. Rapid urbanization in the city area has led to an increased interest in the engineering behavior of the soils which are present within the city area. Geotechnical information of the subsoil in an urban area is important for various civil engineering works.

III. LOCAL GEOLOGY OF THE AREA

The study area is located in Ado-Ekiti, the capital city of Ekiti State, and South Western Nigeria. AdoEkiti is located between latitudes 07^o $31^1$and 07^o 49^1 north of the equator and longitude 05^o 27^1 east of the Greenwich Meridian . The area is readily accessible by a network of roads which also link the area with nearby towns. It has a total land area of about $180km^2$.

SAMPLE LOCATION MAP

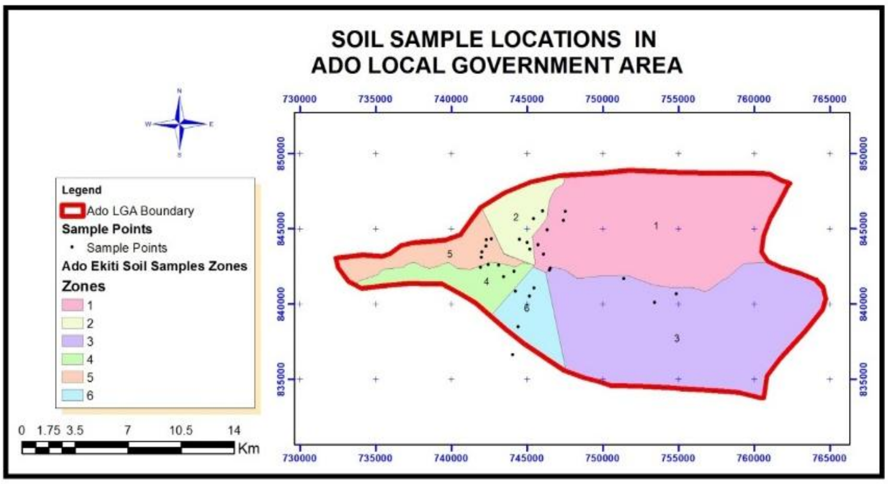


Figure 1.0 sample locational map of the study area

IV. MATERIAL AND METHOD

Sample Collection

Thirty lateritic soils samples were collected at six major zone within the metropolis of Ado-Ekiti. Two major type of soil was collected: (a) disturbed samples and (b) undisturbed samples which shall be used to test for soil index properties and strength properties respectively. Samples specimens shall be prepared in accordance with BS 1377 (1990), AASHTO specification and FMW (1997)

V. METHODS

Laboratory tests such as: Natural Moisture Content (NMC) , Specific gravity, Grain size analysis, Consistency tests, Compaction test, California Bearing Ratio (CBR), Triaxial test, Permeability test, Odometer test,were carried out on each of the samples. All the tests were carried out in accordance with British standard code of practice (BS1377:1990). Methods of test for soils for civil engineering purposes: All the tests were also carried out at Geotechnical Engineering Laboratory in Federal polytechnic Ado-Ekiti, South western Nigeria.

VI. RESULTS AND DISCUSSIO

Natural Moisture Content Test

Table 1 shows the results of natural moisture content of the soils in all the trail pits investigated within the six zones which varied between 1.1 and 19.5%. The values are fairly high considering the time of test, indicating the soil potential for water retention. This is a property of fine grains

. Table 4.1 Summary Result for Natural Moisture Content

SAMPLE	ZONE 1 (%)	ZONE 2 (%)	ZONE 3 (%)	ZONE 4 (%)	ZONE 5 (%)	ZONE 6 (%)
1	12.2	8.2	16	16.9	1.1	13.7
2	7.8	9.6	15	12.5	4.8	11.6
3	9.3	7.5	19	15.8	7.3	19.5
4	9.9	18.7	17	16.7	15.9	17.9
5	11.4	9.6	15	17.3	10.7	18.4

Specific Gravity Test

Table 4.2 shows the results of specific gravity of soils from the study location which varied between 2.29 and 2.70 respectively .Que et al. (2008) have shown that specific gravity is closely linked with the mineralogy and/or the chemical composition of the soil. According to De Graff-Johnson, (1972), the higher the specific gravity, the higher the degree of laterisation. Furthermore, the larger the clay fraction and the alumina concentration, the lower is the specific gravity. Thus, zone 6 samples appear to be the most evolved samples in term of laterization (ferruginization) process

Table .2 Summary Results for Specific Gravity

SAMPLE	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6
1	2.41	2.66	2.2	2.29	2.60	2.7
2	2.50	2.33	2.6	2.44	2.50	2.4
3	2.60	2.36	2.6	2.50	2.54	2.3
4	2.55	2.30	2.5	2.40	2.31	2.4
5	2.60	2.55	2.4	2.45	2.51	2.5

VII. RAIN SIZE ANALYSIS

The graph of grain size analysis performed on the soils samples are shown in Figures 1, 2,3,4 and 5 shows zones 1, 2, 3 and 4, 5, 6 respectively Many of the zones had a very high percentage finer than 0.075 fractions that is > 35% vanried between 13 and 30 % for (Zones 1, 2, and 3) while (4, 5 and 6) gave 35% above respectively. Hence, the soils are describe as silty gravelly soils for (zones 1, 2 and 3) while (Zones 4, 5, and 6) investigated were clay of high compressibility respectively.

Figure 1: Particle size distribution graph for zone 1 sample 1-5

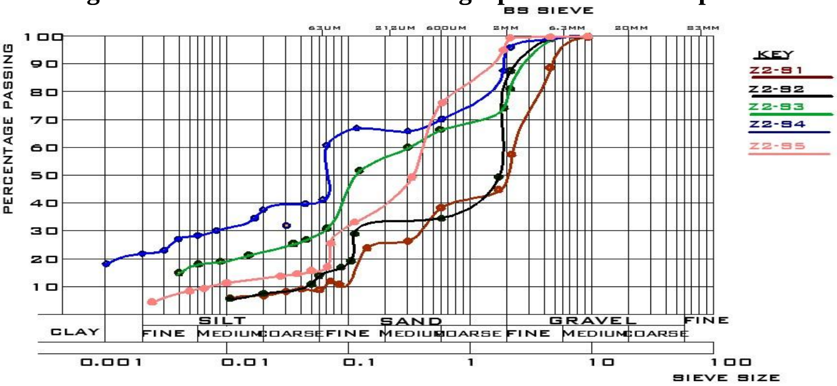


Figure 2: Particle size distribution graph for zone 2 sample 1-5

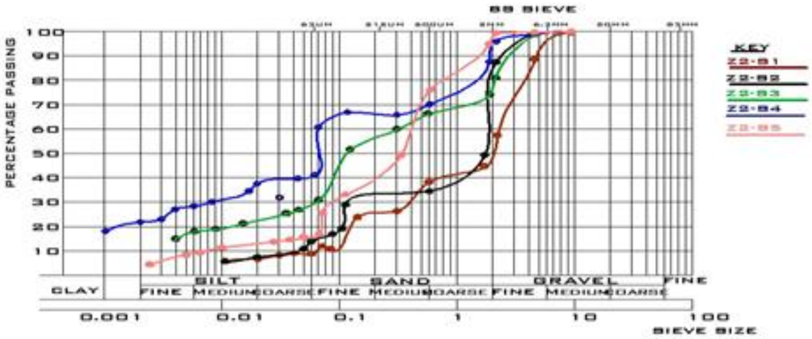


Figure 3: Particle size distribution graph for zone 3 sample 1-5

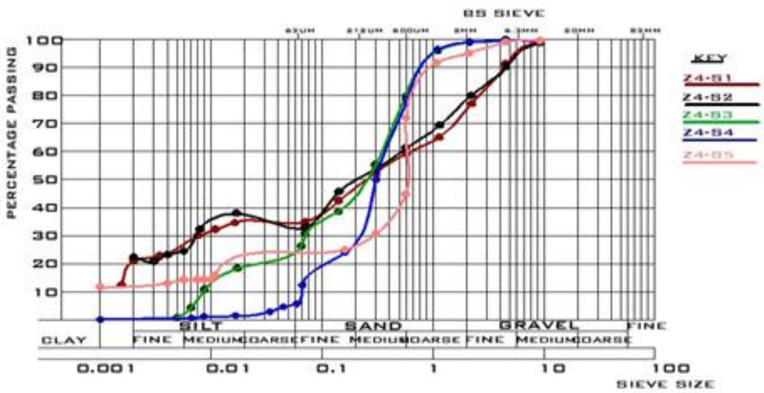


Figure 4: Particle size distribution graph for zone 4 sample 1-5

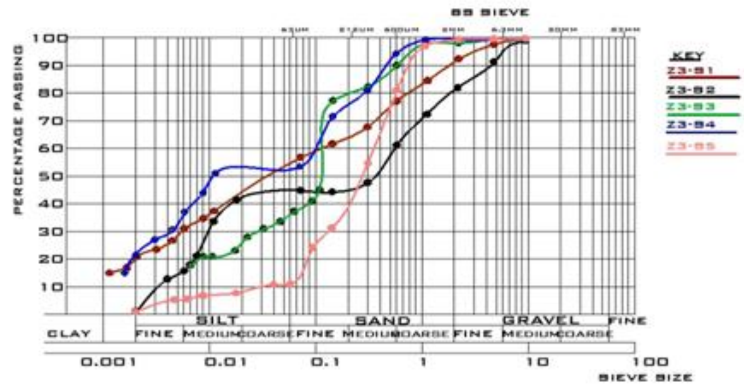


Figure 5: Particle size distribution graph for zone 5 sample 1-5

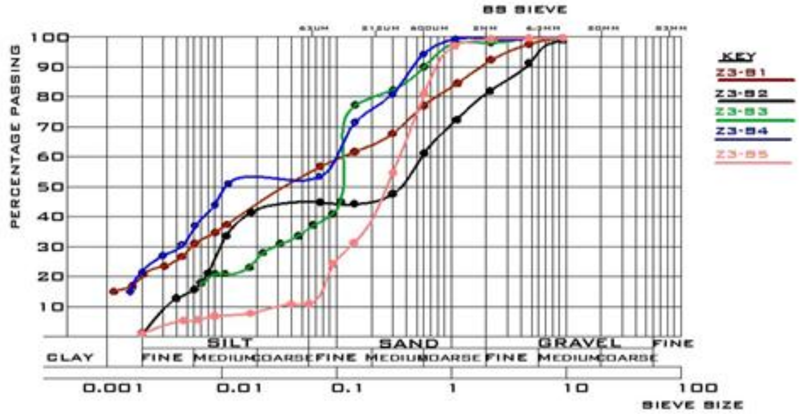
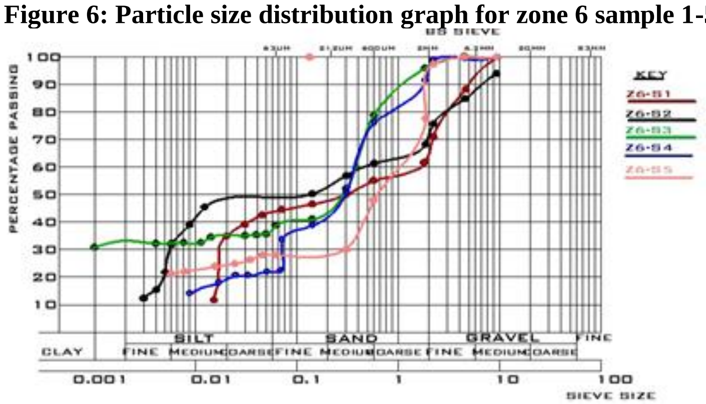


Figure 6: Particle size distribution graph for zone 6 sample 1-5



Consistency Limit Test.

The results of liquid limit (LL %) , (PL%) and plasticity index (PI %) evaluated on all the trial pits within the six zones which varied between 17 – 69% and 10 – 33% respectively are shown in the representative figures 3 and 4 for both the worst condition and good condition of the study area. It was observed that soil from Zone 1 and 2 samples has their liquid limit (LL%) and Plasticity Index (PI %) ranging between 21 – 38% and 04 – 13% respectively while (zone 3, 4, 5 and 6) varied between 26-69 % and 12 – 38 % FMW (1997) recommend liquid limits not greater than 80% for sub- grade and and not greater than 35 for sub base and base course materials. Also plasticity index not greater than 55% for sub-grade and not greater than 12% for both sub-base and base course from the examined soil samples the soil fall within these specifications, except for Zone 3 sample 1 and 2 and Zone 4 sample 2 respectively that fell out of the maximum specification. The implication of this research shows zones 1 and 2 are suitable for sub-base and base course while other location are suitable for sub-grade, and earth fill materials.

Compaction Test

The results of maximum dry density (MDD kg/m3), and the optimum moisture content (OMC %) evaluated on the trial pits within the zones range from 1367 – 2236 Kg/m^3 respectively are shown in the Table 3 at both good and worst condition. It was observed that soils from (zone 1 and 2) samples has their (MDD Kg/m^3) and OMC% ranging between 1690 – 2236Kg/m^3 and 11.1 – 15.3% respectively while (one 3,4,5 and 6) varied between 1367 – 1869Kg/m^3. The above analysis indicate that soil sample from Zones 1 and 2 falls within the minimum dry density recommended for base course material while Zone 2 soils fell within the minimum recommendation for sub base, sub grade and earth fill materials. However, Zones 3, 4, 5 and 6 can be recommended for sub grade and fill material, respectively since their MDD is within the minimum specification for sub grade and earth fill materials.

Table 3: Summary Result for Compaction Test

SAMPLE NO	ZONE 1		ZONE 2		ZONE 3		ZONE 4		ZONE 5		ZONE 6	
	OMC %	MDD (km/m^3)	OMC %	MDD Kg/m^3	OMC %	MDD kg/m^3	OMC %	MDD kg/m^3	OMC %	MDD km/m^3	OMC %	MDD kg/m^3
1	13.3	1776	15.3	1994	16.0	1724	13	1550	15.9	1775	11.1	1860
2	17.7	1935	11.8	2236	14.9	1630	15.9	1639	16.9	1767	12.3	1950
3	17.0	1867	15.5	1906	21.8	1683	16.1	1636	19.8	1753	13.4	1790
4	13.9	1887	16	1784	17.7	1869	15.6	1557	16.0	1787	12.6	1780
5	11.8	1798	13.5	1850	17.7	1699	14.4	1661	15.1	1743	13.5	1860

California Bearing Ratio (CBR)

Table 4 shows the results of the California bearing ratio performed on all the trial pits investigated, which varied between 04 – 53% and 07 – 95% for soak (SK) and unsoaked (UNSK) CBR values for soils within the zone. The above analysis shows that materials within Zone 1 are quite suitable materials for base course, sub base, sub grade and earth fill materials. Soils from others location can be used as sub base, subgrade and earth fill material during construction work.

Table 4. Summary result for Califonia Bearing Ratio (CBR)

SAMPLE NO	ZONE 1		ZONE 2		ZONE 3		ZONE 4		ZONE 5		ZONE 6	
	SK	UNSK	SK	UNSK	SK	UNSK	SK	UNSK	SK	UNSK	SK	UNSK
1	12	22	40	80	10	32	04	13	10	30	31	50
2	35	45	53	95	04	07	05	17	08	25	36	68
3	4.8	35	30	75	05	09	06	15	07	48	06	33
4	9.5	17	30	55	15	43	04	12	10	35	30	45
5	10	18	35	60	4.5	10	05	16	13	40	35	65

Triaxial Compression Test (UU)

Table 5 shows the results of Triaxial test perform on all the trial pits investigated. The results obtained from mohr curves varied between 5 – 87 KN/m² and 16 – 35^0 for cohesion and frictional angle respectively. The above results shows that soils in zone 2 possess lesser fine grains which is an implication of its higher frictional angle and lesser cohesion values compared to other zone investigated.

Table 6 Summary Result for Cohesion(c) and Angle of internal Friction (ϕ)

SAMPLE NO	ZONE 1		ZONE 2		ZONE 3		ZONE 4		ZONE 5		ZONE 6	
	c	ϕ	c	ϕ	c	ϕ	c	ϕ	c	ϕ	c	ϕ
1	51.27	21	12.08	31	46.1	29	59	22	12.3	32	60.8	22
2	31.96	32	5.35	32	54.1	20	21	34	61	21	53.8	23
3	61.93	22	14.22	34	55.7	21	30	29	38.5	23	63	21
4	87.22	27	52	22	14.4	32	44.8	22	15.7	35	67	21

5	59.76	16	49.24	22	50.9	22	59.6	21	57.4	21	64	22

Consolidation Test

Table 7 Shows the results of consolidation parameters which varies between Zones Laboratory tests conducted on soil of Ado- Ekiti in this research work have shown that the value of the consolidation parameters of the soil in Zone 3, 4, 5 and 6 is slightly high. The settlement of the soils may be slightly high since the soil in the area contains a considerable percentage of clay

Table 7 Summary Result for Consolidation Parameters

SAMPLE NO	Summa Resultfor\ConsolidationParameters																	
	ZONE 1			ZONE 2			ZONE 3			ZONE 4			ZONE 5			ZONE 6		
	CV	e	Tqo	CV	e	Tqo	CV	e	Tqo	CV	e	tqo	CV	e	tqo	CV	E	Tqo
1	2.58	0.14	17.6	12.16	0.17	8.93	2.64	0.27	18.38	8.35	0.15	6.10	12.90	0.11	8.93	9.12	0.12	5.91
2	6.24	0.12	6.09	2.88	0.11	6.99	13.6	0.25	7.35	3.2	0.14	8.24	2.21	0.17	6.99	3.26	0.27	12.34
3	5.47	0.08	8.86	10.47	0.15	6.42	10.6	0.15	9.76	4.3	0.12	4.36	4.00	0.11	6.42	8.82	0.25	7.63
4	2.39	0.06	16.85	14.2	0.20	7.08	17.1	0.13	2.75	12.2	0.08	12.74	17.50	0.15	7.08	4.53	0.15	11.28
5	4.49	0.09	8.39	7.9	0.09	7.54	14.6	0.10	6.15	6.4	0.06	4.47	7.91	0.20	7.54	7.91	0.13	6.03

Permeability

Table 8 shows the results of permeability coefficient K (cm/s) performed on all the trial pit within the six Zones, which varied between 1.4 x 10^{-2} and 1.94 x 10^{2} cm/s respectively. The above results can be classified as sand mixture soils accordingtoPumia (2007) with soils in Zone 2 showing a higher value of K.

Table 8 Summary result for Permeability test

SAMPLE	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6
1	0.0181	0.0152	0.0179	0.0180	0.0278	0.0256
2	0.0175	0.0148	0.0182	0.0180	0.0256	0.0231
3	0.0194	0.0172	0.0144	0.0243	0.0243	0.0221
4	0.0214	0.0173	0.0159	0.0231	0.0226	0.0211
5	0.0149	0.0174	0.0128	0.0216	0.0216	0.0203

VIII. CONCLUSIONS

Engineering investigation was carried out in Ado-Ekiti, environment of Ekiti State. The results of the tests reveal the following

i. The soils were classified as clay of low compressibility (CL), clay of high compressibility (CH) and silty gravelly sandy soils for unfined soil classification system (USCS) and A-2-4, A-26, A-6, and A-7-5 which describe the soil as excellent to good, fair to poor and clayey for (AASHTO) classification system.

ii. The maximum dry density ranging between 1550kg/m^3 and 2236 kg/m^3For zones 1, 2, 3, 4, 5,and 6 respectively.

iii. The CBR values ranging between 4 % and 53 % for soaked CBR and 7 %- 95 % for unsoaked CBR. It is noteworthy that only zone two samples had CBR values meeting with the minimum requirement i.e 80 % unsoaked CBR for base course and 30 % soaked CBR for sub-base.

iv. The cohesion and angle of friction (Φ) values varies between 5-87 KN/m² and 16-34^0 for all the zones. The results shows that zones 3, 4, 5 and 6 have fairly high cohesion values compared to zones 1 and 2.

v. The coefficient of permeability varies between 1.4 x 10^{-2} and 1.94 x 10^{2} cm/s. The above results can be described as sand mixture soils with soils in zone 2 showing a higher value of K.

This research work has contributed in the following areas;

It provided data for engineers, planners, designers and contractors application, it aids in preventing possible difficulties, delays and additional expenses during construction due to inadequate geotechnical information; and provides geochemical details of soils behavior in the study location in solving engineering and environmental issues.

IX. RECONCONMENDATION

It is recommended that all contractors should ensure that the testing and quality control of pavement materials is done before the commencement of earthworks on site and the adequate quality of construction as the construction project is being executed.

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