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

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Abstract:
The physico-chemical properties of lateritic soils in Ado Ekiti Area of Ekiti State, Nigeria were evaluated. The study area was divided into Six Zones: A total of 30 samples were collected with five samples per zone. Laboratory tests such as: X-ray fluorescence (X-RF) and X-ray diffraction (X-RD) in other to evaluate their chemical composition. Natural Moisture Content (NMC) , Specific gravity, Grain size analysis, Consistency tests ,were carried out on each of the samples the purpose of which to study their physical properties. These tests were carried out in accordance with (BS1377:1990). The laboratory results indicated that the NMC 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 (USCS,1986) and A-2-4, A-2-6, A-6, and A-7-5. From the foregoing, the soils classified some as low plasticity, sandy gravelly clay, clayey soils and others as medium compressibility soils. Based on Sesquioxide (S-S) ratio the soils grouped into True laterite and lateritics soils which indicate poor laterisation for zones 1 and 2 while other zones have undergone considerable degree of laterisation. Major clay mineral found were: illite, heamatite, and to lesser amount of halloysite. It was concluded that the research work has provided information for all construction personnel within the study area. The soils are not expected to perform very well as concrete aggregates since they contain high amounts of SiO_2 and Fe_2O_3.since the oxides have deleterious effects on construction materials, particularly concrete aggregate.

Keyword: Claymineral, physico-chemical properties, lateritic soil, oxides, Sesquioxide

1.0 Introduction:
Ado-Ekiti, capital of Ekiti State of Nigeria is a rapidly growing urban area with many major construction projects, including the Ekiti State University, Crown Polytechnic, Afe Babalola University, Ultra-modern market and Overhead Bridge were established. The Ado-Ekiti area is expected to be the site of many major construction projects in the years to come. The geochemical 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 success or failure of such projects will require a knowledge of the properties of soils of the area. The principal purpose of this investigation is to obtain the basic properties of the soil of Ado-Ekiti area. A considerable increase

in soil utility for engineering works is expected as any country aspires towards improved infrastructural development. The relationship between all engineering infrastructure and their foundation soils is of paramount importance for designers and contractors (Brice et al, 2015). Incessant occurrence of road pavement deterioration and building collapse, mainly because of their poor geotechnical and mechanical properties has made it imperative for a proper understanding of the geotechnical properties of soils (Garg, 2009). Chemical reactions increase with an increase in rainfall and temperature, and accordingly soils from the tropics exhibit different engineering properties (Millard, 1993). Despite the great effort that has been made by previous works to classify and differentiate tropical soils, a uniform nomenclature /classification system does not exist yet for these soils. Hence, the term “lateritic clays”, “lateritic gravels” and even “laterites” are still used by engineers to describe any reddish tropical soils (North more et al. 1992). Fortunately, for the engineering purposes it does not matter whether the classification is correct, but that the geological and engineering properties as predicted or derived from testing are reliable.

The soils used in road construction in “Sub-Saharan Africa” are mostly lateritic soils including lateritic gravels, lateritic clays and lateritic shales. Lateritic soils contribute to the general economy of the region where they are found (Lemougna et al, 2011). Their scope is very wide and include civil engineering, agronomic, mining research (iron, aluminum and manganese) deposits. In a tropical area such as Ado-Ekiti is in a phase of infrastructural development, lateritic soils has been, and still a topic of interest and discussion. Due to the natural relative abundance of these soils, availability, favorable engineering properties, they have been very useful for construction of foundation, roads, airfields, low-cost housing and compacted fill in earth embankments (Gidigasu 1983; Autret 1983; Ekodeck 1984; Sikali and Mir-Emarati 1986; Bagarre, 1990; Tardy, 1992 Tockol et al, 1994; Ojo and Adeyemi, 2003). Few 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). Therefore, it is the aim of this research to evaluate physico-chemical 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)

1.1 Geology of Ado-Ekiti (The Study Area):

Ado-Ekiti is located on latitude $7^0 36^1$N and longitude $5^0 4^1$E.It is an area located at the South western area of the country. Most part of these area is underlain by the ancient crystalline igneous and metamorphic rocks generally referred to as Pre-Cambrian Basement complex.The area is a low relief with elevation about 185m above the sea level and it is enveloped by rocky and hilly outcrops such as that of Olota, OkeIla etc.

1.2 Topography:

Much of the highland in Ado-Ekiti is between 300m-600m, high above sea level. The ruggedness of the topography is characterized by slopes, valleys, and some planes at the suburbs of the town which are used for agricultural purposes. Ado-Ekiti is located along the Western plains and ranges. Due to the folding of rocks, they trend mainly in the North-South direction and the resulting landform are the structural ridges and inselbergs protruding from an almost flat inclined plane consisting of pediments and sloping generally towards the outskirts from which rise some other inselbergs.

1.3 Drainage:

We have some rivers around Ado-Ekiti like River Ureje and River Ogbese which flows into River Ose and Owenaa outside Ekiti state. They empty into the Atlantic Ocean and hence and EXORETIC. The river Ureje has been dammed, and it’s, outflow depends on wash-out from the dam. The river Ogbese flanked AdoEkiti along Ijan-Polytechnic Road. These rivers have eroded some areas in Ado-Ekiti. The major watershed of Ado-Ekiti forms an interesting pattern, because river Ureje has tributaries merged into river Ogbese after the Federal Polytechnic Ado Ekiti premises. The streams and rivers are largely controlled by the trend of foliated rocks.

1.4 Climate and Vegetation:

Ado-Ekiti has tropical climate and vegetation with annual rainfall of nearly 200mm and daily temperature of over 26.7^O C Sun is high throughout the year hence, very high temperature of 26.7^0C. The heavy rainfall favors the climate condition for the growth of thick and luxuriant vegetation having three storeying layer arrangements of trees such as Mahogany, Iroko, Obeche (selvas). Humidity is also high due to the evaporation of the soil and trees. The trees form heavy canopy preventing loss of mixture and hence forests are widespread.

2.0 Materials and Methods:

The following laboratory tests were conducted on the samples: consistency test, specific gravity test, sieve analysis test, moisture content test and: X-ray fluorescence (X-RF) and X-ray diffraction (X-RD) in other to evaluate their chemical composition and their mineralogical properties. Prior to preparing the test specimens, the materials were oven-dried and broken into smaller fragments, care being taken not to reduce the sizes of the individual particles. 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. Nigeria.

2.1 Sample Collection:

Thirty lateritic soils samples were collected at six major zone within the metropolis of Ado-Ekiti. Undisturbed soils samples were collected which shall be used to test for soil index properties and chemical tests. Samples specimens shall be prepared in accordance with (BS 1377, 1990)

2.2 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 $180km^{2}$.

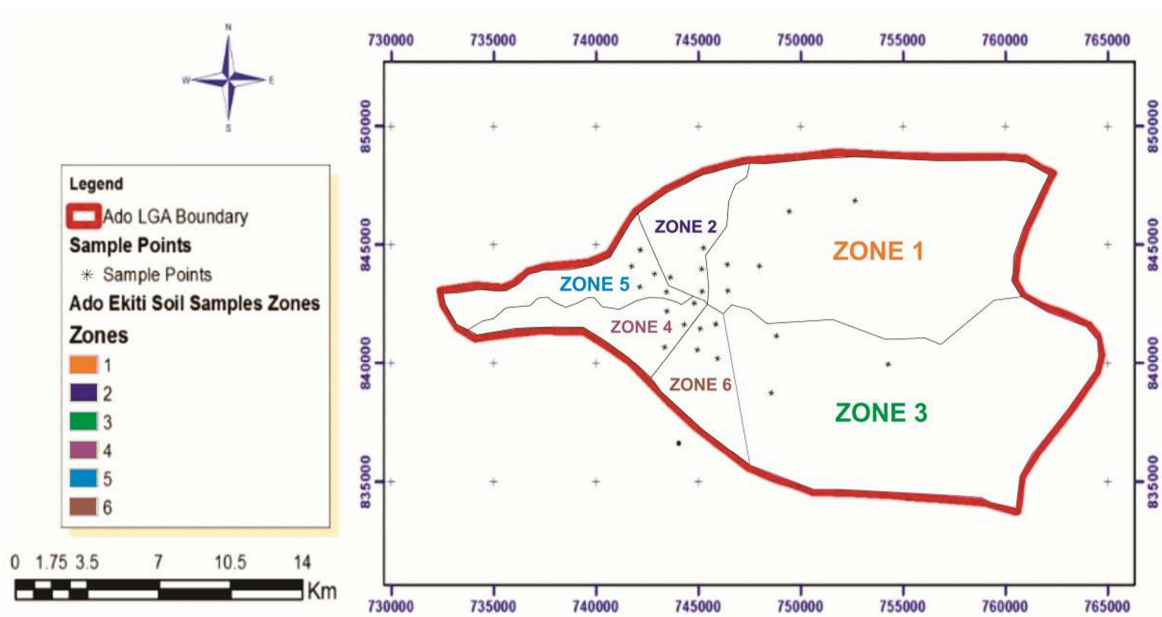
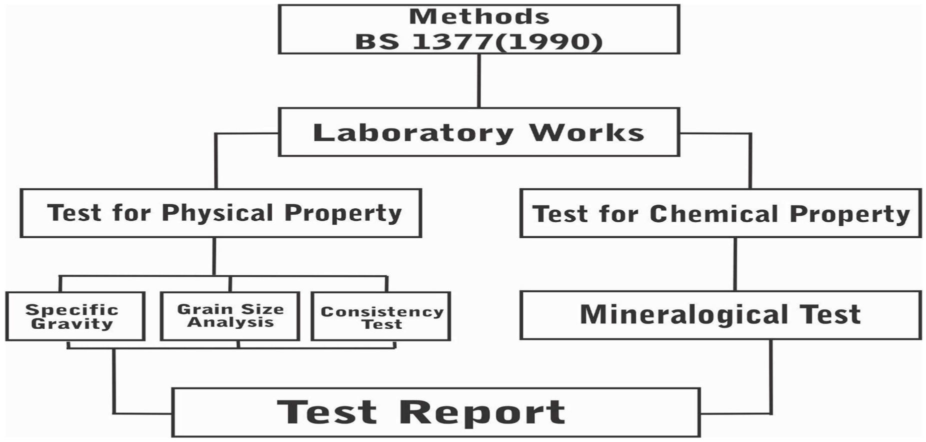


Fig 1: Sample Locational Map of the Study Area



The flow chart of the laboratory approach is hereby shown

3.0 Results and Discussion:

3.1 Specific Gravity Test:

The results of specific gravity of soils from the study location which varied between 2.29 and 2.70 respectively as shown in Table 1. (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.

3.2 Soil Classification:

The laboratory results as shown in Table 1.0 , indicated that the 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,1986) and A-2-4, A-2-6, A6, and A-7-5. From the foregoing, the soils classified some as low plasticity, sandy gravelly clay, clayey soils and others as medium compressibility soils

3.3 Mineralogical and Chemical Characteristics:

Mineralogical Characteristics:

Figure 2 Shows the distribution of minerals discovered from the regroup samples taken from the six zones within the study locations. The X-ray patterns showed that the soils under investigation consists illite, Chrysotile, Halloysite and Muscovite as major mineral while sanidine and chrytobalite are the minor minerals found in the study area. The above analysis showed that the absence of swelling clays suchs as montmorillonite hence undesirable swelling characteristics seems not expected in these soils. The mineralogical investigation also reveal the soils in the area is rich in illite and Heamatite with lesser amorphous material. Nevertheless, the presence of other iron oxides existing in these residual soils may act as cementing agents, which as a consequence may contribute to tensile cracking by making the compacted structure relatively brittle.

Table 1: Summary of Soils Index Properties

SAMPLES ZONE	NMC (%)	GS	CONSISTENCY TEST				SOIL CLASSIFICATION	
			LL (%)	PL (%)	PI (%)	LS (%)	AASHTO	USCS
ZONE1								
Z1S1	12.2	2.41	33	20.9	12.3	5.0	A-2-6	CL
Z1S2	7.8	2.50	28.5	15.1	13.4	3.6	A-2-6	CL
Z1S3	9.3	2.60	37.5	24.3	13.2	5.0	A-2-6	CL
Z1S4	9.9	2.55	32.2	19.7	12.5	3.6	A-2-6	CL
Z1S5	11.4	2.60	21.1	9.0	12.1	2.1	A-2-6	CL
ZONE 2								
Z2S1	8.2	2.66	22	17	5	5	A-2-4	CL
Z2S2	9.6	2.33	30	18	12	5	A-2-6	CL
Z2S3	7.5	2.36	35	27	8	8	A-2-4	ML
Z2S4	18.7	2.30	28	20	10	7	A-2-7	CL
Z2S5	9.6	2.55	21	13	4	8	A-2-4	ML
ZONE 3								
Z3S1	16	2.2	61	36	24.5	10	A-7-5	MH
Z3S2	15	2.6	60	27	32.6	6.0	A-2-7	CH
Z3S3	19	2.6	31.5	16	15.4	7.8	A-2-6	CL
Z3S4	17	2.5	30	18	11.9	6.0	A-2-6	CL
Z3S5	15	2.4	41	24	16.9	6.8	A-7-5	CH
ZONE 4								
Z4S1	16.9	2.29	41.01	32	9.5	9.3	A-2-5	ML
Z4S2	12.5	2.44	69	31	38.3	10	A-7-5	CH
Z4S3	15.8	2.50	41.9	23	19.1	6.4	A-2-7	CI
Z4S4	16.7	2.40	26.5	14	12.5	2.0	A-2-6	CL
Z4S5	17.3	2.45	28.1	15	12.9	2.5	A-2-6	CL
ZONE 5								
Z5S1	1.1	2.60	47	25.9	10.9	1.0	A-2-7	ML
Z5S2	4.8	2.50	40	20.9	19.2	9	A-6	CL
Z5S3	7.3	2.54	46	27.0	18.5	11	A-2-7	ML
Z5S4	15.9	2.31	44	33.2	10.4	10	A-2-4	ML
Z5S5	10.7	2.57	51	20.2	26.7	5	A-7-5	CL
ZONE 6								
Z6S1	13.7	2.7	53	33	20	10	A-7-5	CL
Z6S2	11.6	2.4	52	30	22	10	A-7-5	MH
Z6S3	19.5	2.3	36	21	15	6.4	A-2-6	CL
Z6S4	17.9	2.4	33	21	12	5.1	A-2-6	CL
Z6S5	18.4	2.5	32	20	12	1.4	A-2-6	CL

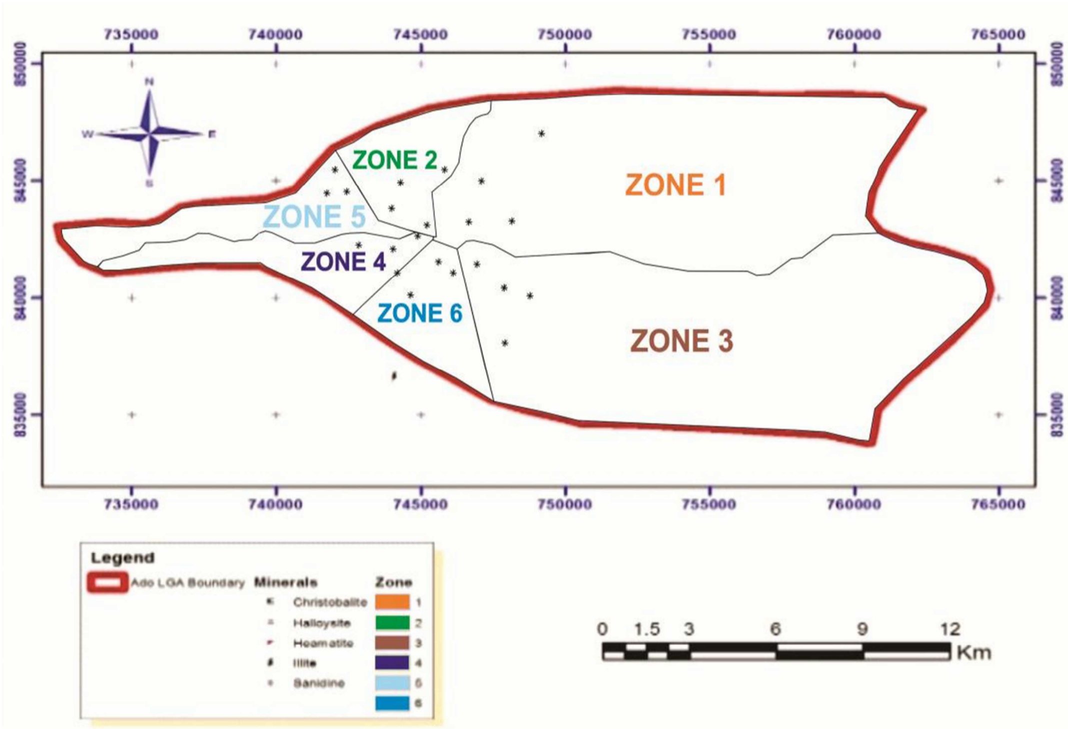


Fig 2: Distribution of minerals in the study area

Chemical Analysis

The thirty soil samples were regrouped based on their degree of laterisation according to (De Graff Johnson, 1972).

The soil samples were regrouped as follows:

1. Zone 1 as sample A
2. Zone 2 as sample B
3. Zone 3 and 4 as sample C

A field examination and visual observation shows that the soils range from light yellow to greyish brown to reddish brown clayey-silty-sandy earth materials and the major oxide composition of the samples given in Table 2.0 and figure 3.0 shows the presence of 7.95-13 wt. % of Fe_2O_3 followed by 39.1-47.3 wt. % of SiO_2 and19.4-23.4 wt. % of Al_2O_3 and feeble content of 0.08-0.11wt.% of K_2O and 0.03-0.12 wt.% of CaO %. For Zone 1, Zone 3 and Zone 4 respectively. The analysis shows that , the silica sesquioxide (S-S) ratio [Si_2O/ (Fe_2O_3+AL_2O_3)] Values are 1.31, 1.42, 1.23, and 1.43 which group the soils in the study areas as true laterite and lateritic soils since the range is between 1.33 and 2 for lateritic and ≤ 1.33 for true lateritic according to (Bell, 1993). Zone 2 and Zone 1 and has not undergone a considerable degree of laterisation based on Specification (Rossiter, 2004) while (Zone 3, 4, 5, 6) has undergo a considerable degree of laterization

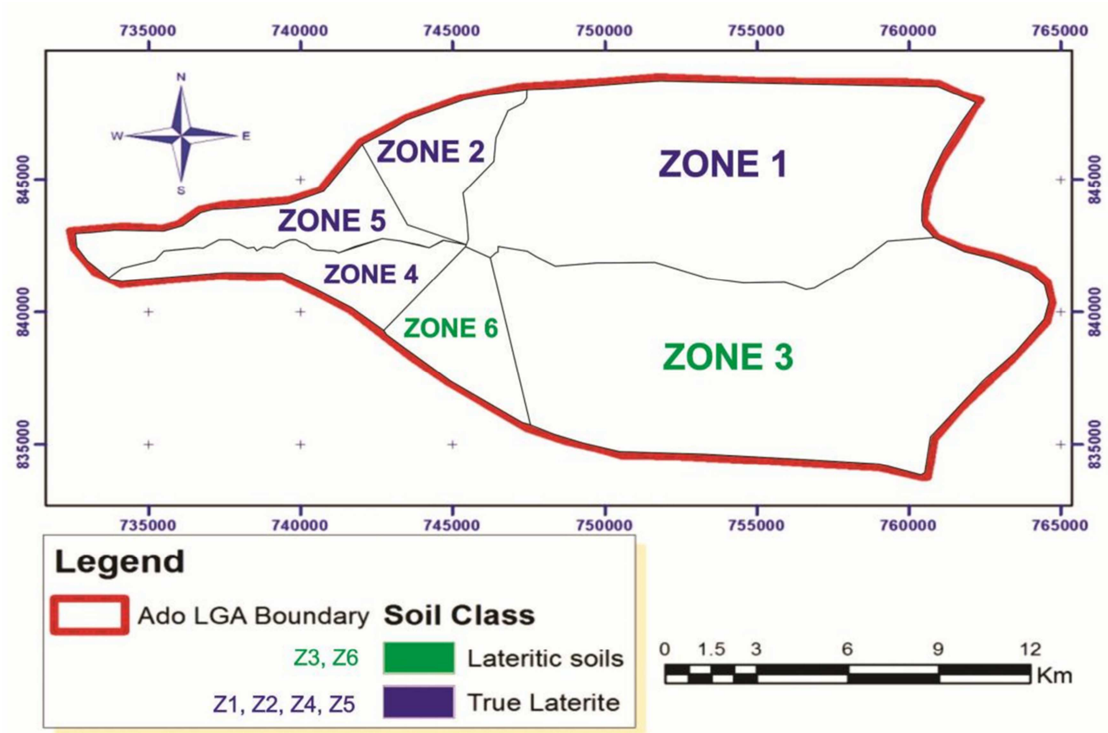


Fig 3: Classification of laterite in the study area

Table 2: Summary Results of Chemical Properties of Regroup Soil Samples

ZONES	OXIDES INVESTIGATED														
	SiO2 (%)	Al_2O_3	Ti_2O	Fe2O3	K_2O	MgO	Na_2O	MnO	CaO	CuO	S	NiO	Y_2O3	V_2O5	LOI	CLASS
A	47.3	23.2	2.6	13.0	0.11	0.19	0.01	0.01	0.12	ND	0.03	0.03	0.01	0.01	8.07	True Laterite
B	45.1	20.1	2.3	11.6	0.21	0.10	0.01	0.01	0.08	ND	0.01	0.01	ND	0.01	9.90	Lateritic soil
C	40.1	21.3	2.11	11.4	0.19	0.15	0.01	0.01	0.10	ND	ND	0.03	ND	ND	8.12	True Laterite
D	39.1	19.4	1.3	7.95	0.08	0.18	ND	ND	0.03	1.02	ND	0.02	0.01	0.01	7.01	Lateritic soil

4.0 Conclusions:

Geochemical investigation was carried out in Ado-Ekiti, lateritic soils. The results of the tests reveal the following

1) The soils index properties classified the soils of the area 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,1986) and A-2-4, A-2-6, A-6, and A-7-5. From the foregoing, the soils classified some as low plasticity, sandy gravelly clay, clayey soils and others as medium compressibility soils.

2) The chemical properties analysis shows that, the silica sesquioxide (S-S) ratio [$Si_2O/(Fe_2O_3+AL_2O_3)$] Values are 1.31, 1.42, 1.23, and 1.43 which group the soils in the study areas as true laterite and lateritic soils since the range is between 1.33 and 2 for lateritic and ≤ 1.33 for true lateritic according to (Bell, 1993). Zone 2 and Zone 1 and has not undergone a considerable degree of laterisation based on Specification (Rossiter, 2004) while (Zone 3, 4, 5, 6) has undergo a considerable degree of laterization

3) The mineralogical properties reveal the X-ray patterns of the soils under investigation as consisting: illite, Chrysotile, Halloysite and Muscovite as major mineral while sanidine and chrytobalite are the minor minerals found in the study area

Recommendation

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.

5.0 Acknowledgement:

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