

Composition, Engineering and industrial Significance of Soil Deposits along Major Highways in Ondo State, Nigeria

ABSTRACT

Geochemical and geotechnical studies of soil deposits along some highways in Ondo State were investigated. Field mapping revealed an underlying basement rock suite comprising granite, granite gneiss, migmatite, and schist. The geochemical analysis employed X-ray fluorescence and Atomic Absorption Spectrophotometer (AAS) to determine the major and minor oxide geochemistry while particle size analysis test, Atterberg limit test, compaction test, specific gravity, triaxial compression test and California bearing ratio were determined following the British Standards (BS-1337). Abundances of major elements show a predominant SiO_2 (43.4 – 61.30 %), Fe_2O_3 (18.30 – 33.70 %), and Al_2O_3 (14.50 – 23.28 %) constitute over 95 % of the bulk chemical compositions. Other constituents include Na_2O , K_2O and TiO_2 . The Silica:Sesquioxide ratio (S_e) of the soil shows that all sampled soil are true laterite except samples AL-1 and AF-1 (are lateritic) which correspond to samples taken from sites 1 and 3 respectively. However, the soils satisfy Federal Ministry of Works and Housing of Nigeria and AASHTO recommended standard for subgrade and subbase/base foundation construction materials, but samples AL-3, OF-2, and OF-4 need to be graded with sand or gravel to reduce its plasticity, while only sample AL-2 can serve as base course material for highway construction. It's concluded from results that the soil have more engineering applications than industrial uses, since only samples from sites 1 and 3 can serve as ceramic material and brick clay provided the alumina and iron contents are reduced. The soils in their raw state, may not be able to serve as fillers and coating materials in the paint and cosmetic industries generally as coating, and filler due to amount of sand in the samples (above 50%), which makes them unsuitable,

Keywords: AASHTO, soil, Ondo State, sesquioxide, FMWH, subgrade

1. INTRODUCTION

Soil, a valuable natural resource has been fundamental to human existence and can be said to play a part across the range of human activities such as housing, industrialization, economic activities, mining, fishery, and transportation. Plants depend on it for survival, as it provides physical support and nutrients. All activities that constitute the cycle of life including procreation and extinction, and adverse environmental events one way or the other relate to it. Knowledge about soil is fundamental to its utilization and management and therefore to the ecology and economy as a whole [1]. Ondo State, southwestern Nigeria is endowed with abundant soil resources being the product of in-situ weathering of Nigerian Basement Complex. These soil deposits vary from rudaceous (boulders, cobbles, pebbles), arenaceous (sand), argillaceous (silt and clay), kaolin, laterite, limestone, mud stone, shale etc. Many of these geological materials occur as extensive cover of allochthonous units or as beds, lenses or bands at southern parts of Ondo State, notably Okeluse, Arimogija etc.

and within the basement rocks and Cretaceous/Tertiary sedimentary sequences [2].

Clays are, undoubtedly, important in agriculture, ceramics, and engineering and also have other industrial applications. The nature of a clay and its composition determine, not only its quality and commercial value but also, to a large extent, its engineering behaviour. Among the characteristics of clays that influence their engineering performance are clay mineral composition, physical properties such as particle size distribution, non-clay mineral composition, organic matter content and geologic history [3]. The present uses of clay and clay products are too numerous to list completely. In domestic life, clay is used extensively in pottery, earthenware, china, cooking ware, vases, plumbing fixtures, tiles, porcelain wares and ornaments. In building, it is used for building bricks, vitrified and enameled bricks, tiles for floors, roofs, walls and drains, sewer pipes and as an ingredient of cement. In the electrical industry. It is used for conduits,

sockets, insulators and switches. It is used on a large scale in making refractory ware, such as fire bricks, furnace linings, chemical stone ware, crucibles, retorts etc. [4].

Sand and gravel provide most important resources of natural aggregate, limestone forms the basis of cement, clay is the bulk mineral of ceramic ware, silica sand is the substance of glass and gypsum provides the body of plaster. These sediments sustain the building industry with necessary materials for construction. The principal objective of this study is to determine the nature, compositional, and basic geotechnical and physical characteristics of three soil deposits along Akure - Ilesha, Owo - Ifon and Akure – Ondo Highway in Ondo State, Nigeria with a view to predicting their engineering behavior and evaluating their economic potentials or industrial suitability, as a contribution to the nation's industrial raw materials data base.

2. SITE DESCRIPTION AND GEOLOGY

The three studied sites are along three major Highways in Ondo State namely Akure – Ilesha, Akure – Ondo, and Owo – Ifon representing Ifedore, Ondo East, and Owo local government areas of Ondo State and located within Latitudes $07^{\circ} 00'$ and $07^{\circ} 30'N$ and Longitudes $04^{\circ}50'$ and $05^{\circ} 50'E$ (Plate 1; Fig. 1). These sites are designated as 1, 2, and 3 respectively. Vertical electrical sounding conducted at site 1 (Fig. 2) shows that the weathered layer can be as thick as 20 m beneath the ground level. Topographic elevation ranges between 320 m and 435 m above the sea level. The area is characterized by dry (November to March) and wet (April to October) seasons and mean annual rainfall ranging between 1000 mm and 1800 mm. The vegetation is mostly secondary, due to intense cultivation, with pockets of typical tropical rainforest rainfall vegetation occurring in the undeveloped portion along the highways.

Field observations show that the granitic rocks constitute the most extensive units at sites 1 and 2 while schists, quartzite and migmatite gneiss dominated site 3 (Plate 2). At site 3 the rocks are dissected in places by quartzofeldspathic veins and bands, giving them conspicuous foliation characteristics. Quartzite occurs as a low gradient hill. The schist manifests as quartz schist but are more extensively weathered and fractured. The granite is weakly foliated and appears to have resulted from the granitization of biotite gneiss and gneiss members. The major structural elements in the rocks are foliation, fractures, and lineation.

3. METHOD OF STUDY

Altogether, ten (10) disturbed samples representative of the three sites in a ratio 3:3:4 respectively were collected in accordance with BS 1377 [5] from freshly exposed surfaces, and then taken to the laboratory in sealed polythene bags to prevent contamination and loss of moisture. The samples were then prepared for testing by crushing using a jaw crusher, followed by milling which was accomplished by gently grinding the sample carefully, so as not to destroy the structure of the constituent minerals. Prepared samples were air-dried for 24 hours (after removing specimens for moisture content determination) before various tests were conducted on them.

The materials used in the collection of the samples were sample bags, hand-held Garmin geographic positioning system, masking tape for labeling, marker for field indentation and digging tools. Laboratory procedures were followed in the determination of natural moisture content of the samples. Thereafter, several of the required geotechnical analyses were carried out. These include particle size analysis, liquid limit, plastic limit, plasticity index, linear shrinkage, specific gravity, standard compaction test, triaxial compression test and the California Bearing Ratio (CBR) test.

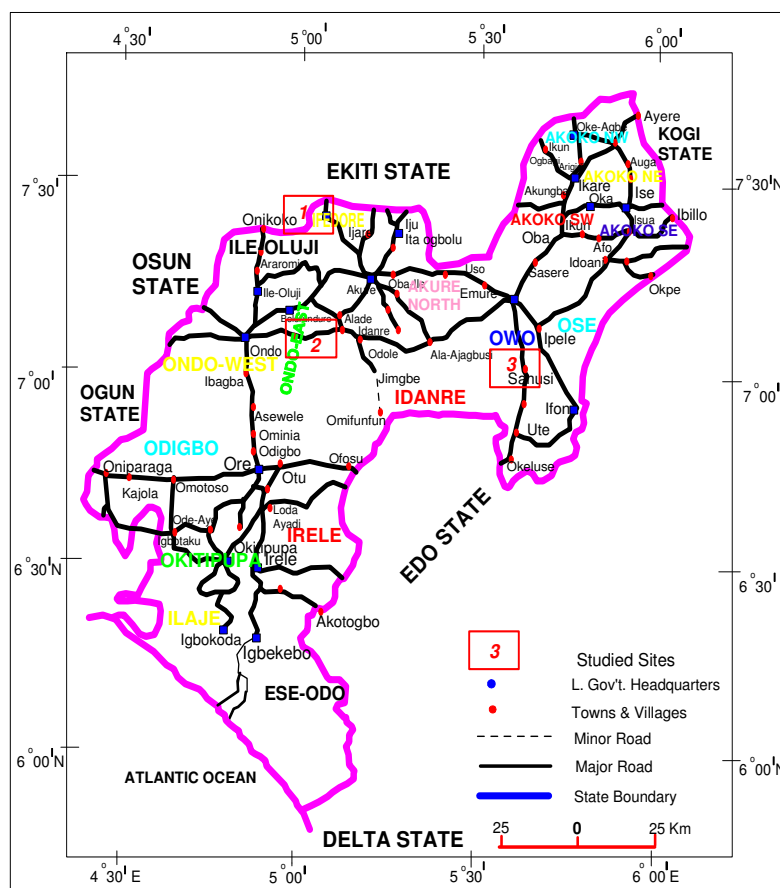


Fig. 1: Map of Ondo State showing the Studied Sites, where representative samples were collected for chemical and geotechnical analyses

Chemical analysis was also carried out on the samples to determine the mineral oxides that were present in each sample. The sample were initially sieved using 2 mm sieve and 2 g of the sieved sample was taken, after which they were put into digesting tube and digested using and HCl, then with $HClO_4$ and H_2O_2 . The samples were heated to dryness and make up with distilled water in a 100 ml volumetric flask. The resultant solution was analyzed using X-ray fluorescence and Atomic Absorption Spectrophotometer (AAS). The silicon oxide and Aluminium oxide were analyzed with nitrous oxide while Iron-oxide with oxyacetylene. P_2O_5 and TiO_2 were determined by a colorimetric method. The steps were repeated for the remaining samples, and the samples were subsequently

allowed to stand for at least 1 hour in the solutions while they were frequently stirred. The extent to which a residual soil has been laterized may be measured by the ratio of silica - SiO_2 , remaining in the soil (except for discrete pebbles of free quartz that may remain) to the amount of Fe_2O_3 and Al_2O_3 that has accumulated. The silica: sesquioxide ratio (S_e) has served as a basis for classification of residual soils. Ratios less than 1.33 have sometimes been considered indicative of true laterites, those between 1.33 and 2.00 of lateritic soils, and those greater than 2.00 of non-lateritic tropically weathered soils [6].

$$S_e = \frac{SiO_2}{Al_2O_3 + Fe_2O_3} \quad (1)$$

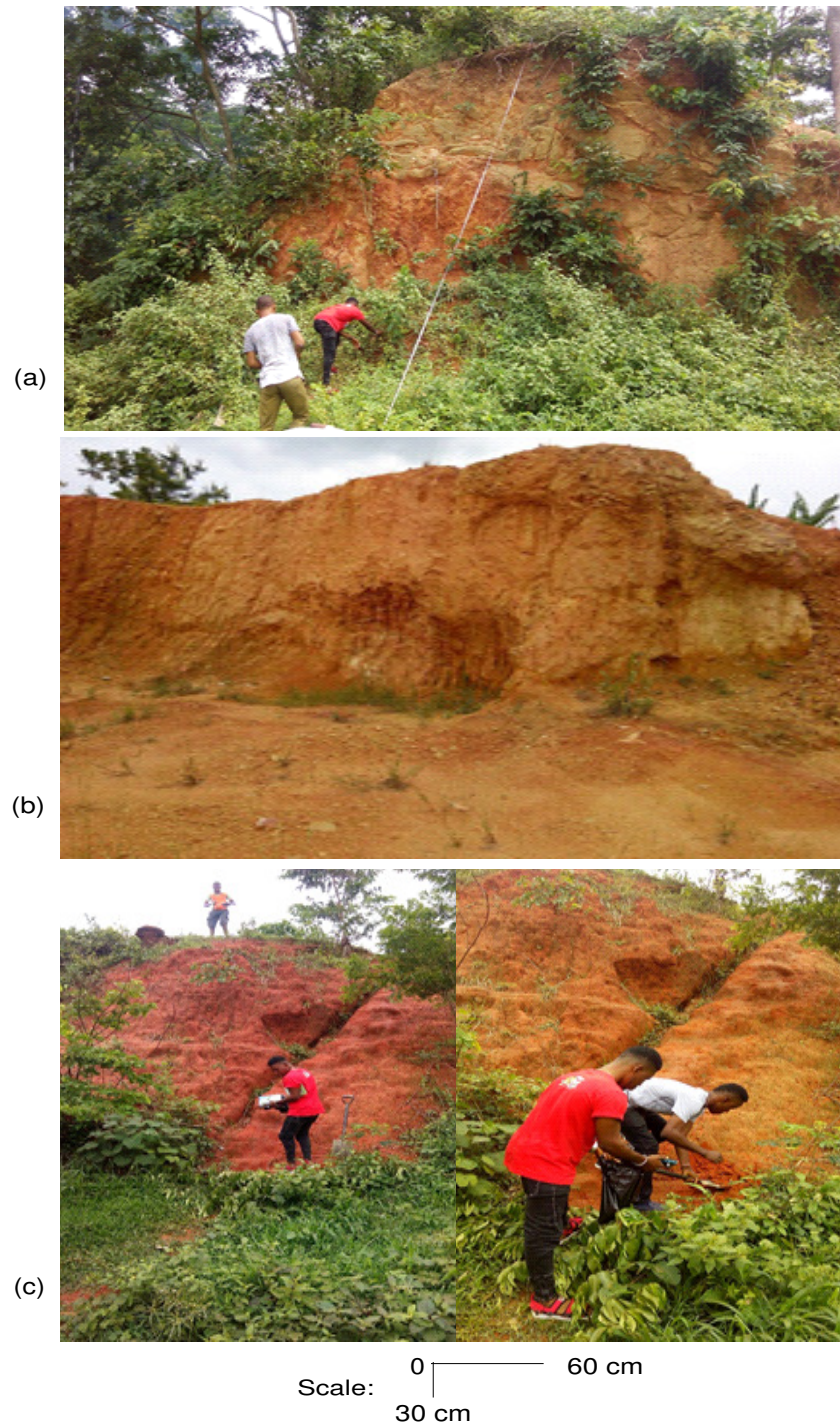


Plate 1: Investigated Soil Deposits at (a) Site 1 (b) Site 2, and (c) Site 3 representing Akure – Ilesha, Akure –Ondo and Owo –Ifon Highways respectively

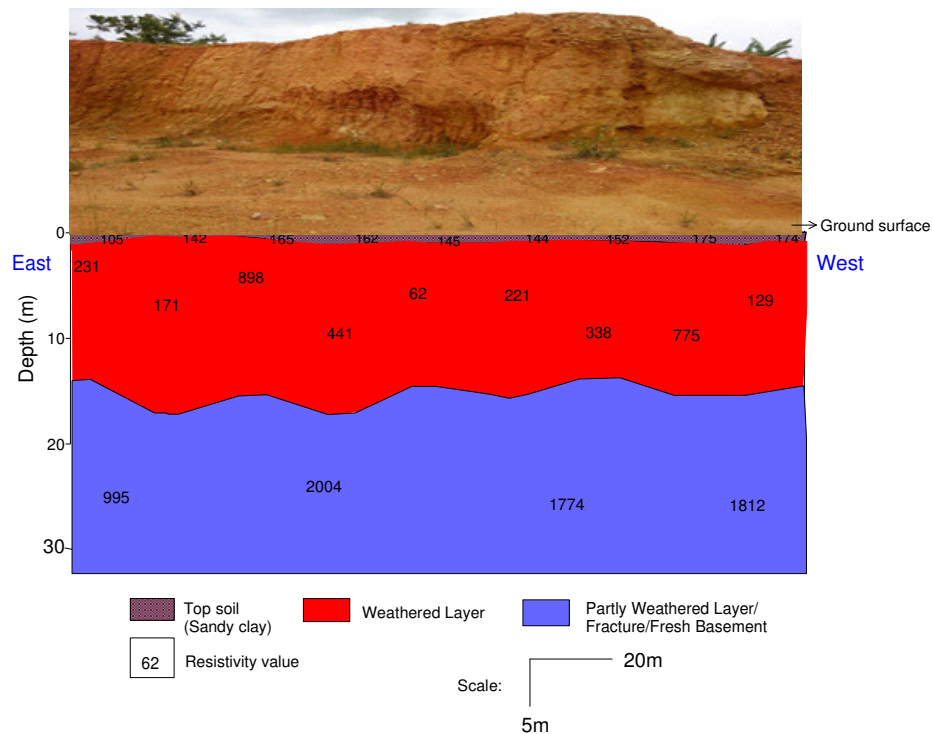


Figure 2: Geologic section conducted along Akure – Ilesha (Site 1) showing the thickness of regolith to be more than 15 m below the ground level

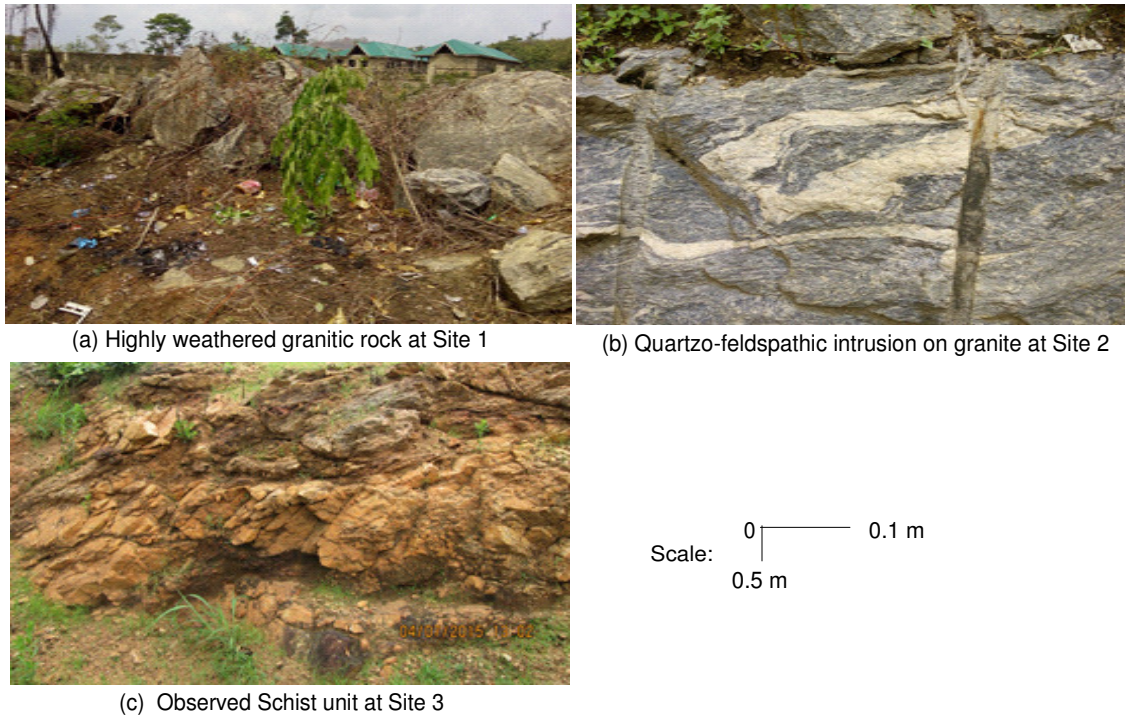


Plate 2: Major rock units observed at the sites investigated

4. RESULTS AND DISCUSSION

The strength of rock, or of less well consolidated sediment, is influenced by the

mineralogy of its particles and by the character of the particle contacts. These properties are inherited from the processes that formed the

rock. Consequently the strength of rocks and sediments will reflect their geological history. The results of chemical analysis and their corresponding silica: sesquioxide ratio (S_e) are presented in Tables 1 and 2 respectively, showing the different oxide forms of the major elements contained in the soil samples. The samples are well dominated (in ascending order of magnitude) by Al_2O_3 , Fe_2O_3 , and SiO_2 with a little over 95 % of the materials being characterized by these three elements oxide. The remaining (less than 5%) of the composition are majorly contributed by Na_2O , K_2O and TiO_2 .

Other oxides tested occur in relatively insignificant proportions, which is indicative of the high degree of weathering under tropical conditions, from which the laterite/lateritic bodies resulted. The % SiO_2 in site 1, site 2 and site 3 varied from 46.70 to 50.80, 43.40 to 51.40, and 50.20 to 61.30 respectively. The % Fe_2O_3 concentrations also range between 20.27 – 22.00, 20.40 – 33.70, 18.3 – 27.20, while Al_2O_3 ranges between 16.60 and 23.28 %, 15.33 and 18.10 % and 14.50 to 17.30 % respectively. Site 1 shows higher degree of SiO_2 derived from weathering of granite. Site 2 is characterized by high Fe_2O_3 content reflecting the higher degree of oxidation. Sesquioxide ratio (S_e) of the soil shows that all the soil sampled soil are true laterite except samples AL-1 and AF-1 which correspond to samples taken from sites 1 and 3.

Engineering properties of soils play a significant role in civil engineering construction works particularly in road constructions, foundations, embankments and dams. 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 and other uses. The satisfactory design and construction of an engineering structure can be accomplished only when the character of the soil or rock, on which or within which it is to be built, is known. Geotechnical characteristics of soils are often associated with their mineralogical composition, especially with clay mineralogy. The results of the geotechnical tests are presented in Tables 4 and 5.

The moisture content of a soil, which can be used to determine the volumetric strain of a saturated soil and varied in relation with depth

[7]. The moisture content of the samples varies from 4.30 % (AF-1) to 25.70 % (AL-1), this range of values shows that the soil have low – moderate high moisture content in their natural states. However samples taken from site 1 recorded very low values. The result of the grain size analysis (Table 4) and grading curves (Fig. 3) show that % fines range between 16.10 % and 45.50 %. All the soil samples from sites 1 and 2 contain % fines less than 35, while site 3 are greater than 35 %. The % sand content of the samples range from 53.20 to 79.40, while gravel in the samples are generally less than 5 % except sample AL-2 which recorded a value of 5.3 %. The result of the grain analysis shows a sand dominated laterite/lateritic soil.

Liquid limits value, ranges between 31.20 to 53.00 % while the plastic limits range between 19.10 and 26.20 %. Plasticity index ranges between 9.60 to 28.80 %. The shrinkage limits of the soil is between 7.7 % - 12.0 % with an average less than 8 %. This implies that all sampled soils will exhibit medium good (5-10%) and poor (10-15%) shrinkage potential, according to [8]. The specific gravity of the soil depends on the amount of sand and also depends on their mineral constituents and mode of formation of the soil. According to specification, a good lateritic material should have specific gravity ranging from 2.5 to 2.75. The specific gravity of the tested samples lies between 2.655 and 2.754 indicating a lateritic material. These values are suitable in accordance with [9] which states that the standard range of values of specific gravity of soils lies between 2.60 and 2.80. Lower specific gravity values indicate a coarse soil, while higher values indicate a fine grained soil [10]. The maximum dry density for the soil samples varied between 1266 Kg/m³ and 1956 Kg/m³ while that of optimum moisture content ranged between 14.5 % and 34.4 %, typical curves are shown in Fig. 4. All the studied samples have MDD at lower OMC. The values of compaction parameters are generally overlapping in all the studied sites. These values show that, the soils respond gradually to compaction. The importance of compaction is to improve the desirable load bearing properties of soil as foundation material. The results of the triaxial compression test is presented in Table 4 and typical curves are shown in Fig.5.

Table 1: Result of the Chemical analysis of the lateritic soil samples

Element	Oxide Percent (%)									
	Site 1			Site 2			Site 3			
	AL-1	AL-2	AL-3	AD-1	AD-2	AD-3	OF-1	OF-2	OF-3	OF-4
<i>MgO</i>	0.30	0.20	0.17	0.11	0.04	0.24	0.03	0.04	0.14	0.41
<i>Al₂O₃</i>	16.60	18.30	23.28	18.10	16.33	15.33	14.50	17.30	16.20	16.90
<i>SiO₂</i>	50.80	48.20	46.70	51.40	43.40	50.20	61.30	50.30	51.20	51.20
<i>P₂O₅</i>	0.00	0.00	0.00	0.00	0.11	0.01	0.02	0.11	0.08	0.00
<i>Na₂O</i>	2.60	2.17	1.18	2.02	1.05	0.81	1.10	0.61	0.56	1.20
<i>K₂O</i>	3.18	4.15	1.88	2.30	0.41	0.47	0.32	0.41	0.34	2.67
<i>CaO</i>	0.10	0.27	0.25	0.71	0.22	0.22	0.22	0.22	0.08	0.10
<i>TiO₂</i>	1.50	1.50	1.19	2.08	1.13	0.43	0.33	0.88	1.10	1.72
<i>V₂O₅</i>	0.81	0.81	0.07	0.09	0.13	0.11	0.11	0.13	0.51	0.67
<i>Cr₂O₃</i>	0.03	0.03	0.05	0.02	0.05	0.04	0.04	0.05	0.03	0.03
<i>MnO</i>	0.03	0.03	0.05	0.01	0.15	0.15	0.15	0.15	0.13	0.03
<i>Co₃O₄</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>Fe₂O₃</i>	20.27	21.70	22.00	20.40	33.7	28.32	18.30	27.20	26.80	22.80
<i>NiO</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>CuO</i>	0.02	0.02	0.02	0.00	0.36	0.00	0.00	0.25	0.11	0.02
<i>ZnO</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>As₂O₃</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>PbO</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>WO₃</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>BeO</i>	0.00	0.00	0.00	0.00	0.03	0.03	0.03	0.02	0.00	0.00
<i>Ag₂O</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>Rb₂O</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>ZrO₂</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>Nb₂O₅</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>MoO₃</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>CdO</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>SnO₂</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>Sb₂O₃</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2: Silica: Sesquioxide Ratio (S_e) of the Sampled Soils

Location	Sample No.	Sesquioxide Ratio	Soil Classification
Site 1	AL-1	1.38	Lateritic soil
	AL-2	1.21	True laterite
	AL-3	1.03	True laterite
Site 2	AD-1	1.34	True laterite
	AD-1	0.87	True laterite
	AD-1	1.15	True laterite
Site 3	OF-1	1.87	Lateritic soil
	OF-2	1.13	True laterite
	OF-3	1.19	True laterite
	OF-4	1.29	True laterite

Table 3: Results of the Grain size Analysis, Consistency limits, Natural Moisture Content and Compaction

Location	Sample No.	N.M.C (%)	% Fines	% Sand	% Gravel	S.G	L.L (%)	P.L. (%)	P.I (%)	L.S (%)	OMC (%)	MDD (Kg/m ³)
Site 1	AL-1	25.7	18.2	79.4	2.4	2.647	32.2	19.1	13.1	10.6	16.4	1890
	AL-2	14.9	16.1	78.6	5.3	2.655	37.6	26.2	11.4	9.6	14.5	1956
	AL-3	21.1	32.9	67.1	-	2.754	53.0	24.2	28.8	7.7	34.4	1266
Site 2	AD-1	8.3	21.2	77.5	1.3	2.742	31.2	19.1	12.1	12.0	15.7	1914
	AD-1	8.2	33.1	66.9	-	2.736	35.2	19.5	15.7	12.0	20.2	1756
	AD-1	6.5	33.3	65.4	1.2	2.731	38.7	21.7	17.0	10.6	18.2	1826
Site 3	OF-1	4.3	45.5	53.2	1.3	2.731	29.0	19.4	9.6	12.0	14.7	1949
	OF-2	11.5	43.7	55.1	1.3	2.739	44.7	20.4	24.3	9.1	22.3	1686
	OF-3	11.1	43.6	55.1	1.3	2.747	39.3	21.1	18.2	9.6	23.3	1651
	OF-4	12.8	45.0	53.8	1.2	2.745	45.4	21.3	24.1	9.1	24.3	1616

Table 4: Results of the Shear strength and California Bearing Capacity (CBR)

Sample Location	Sample No.	Shear Strength (Kpa)	CBR (%)
Site 1	AL-1	338	67
	AL-2	368	82
	AL-3	176	41
Site 2	AD-1	414	69
	AD-2	114	53
	AD-3	339	61
Site 3	OF-1	409	78
	OF-2	304	50
	OF-3	309	48
	OF-4	296	51

The shear strength of the soil varies between 114 Kpa and 409 Kpa. Therefore soil showing higher shear strength would be less susceptible to rupture or failure along any plane inside it. The results of the California bearing ratio and typical curves of the studied soil samples are presented in Table 4 and Fig. 6. The unsoaked California bearing ratio (CBR) value for the lateritic soil samples range from 41 % to 82 %. All CBR values of all the samples recorded from the three sites show no distinctive differences, except sample AL-2 which exhibits high CBR value. However there is a direct positive correlation between compaction attributes and CBR characteristics of the soil samples. Typical CBR obtained are shown in Figure 6.

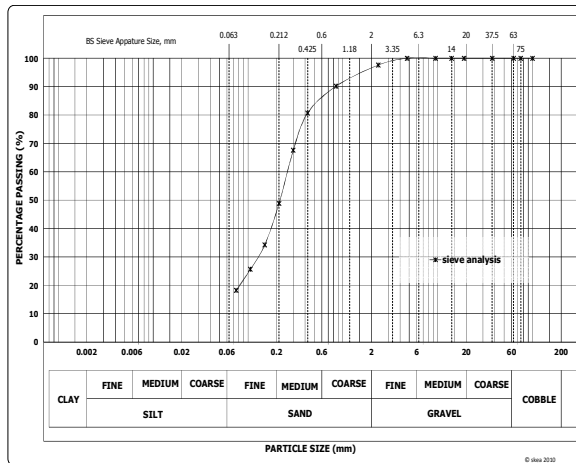
Industrial and Engineering Potential

The chemical composition, mineralogical composition, and physical characteristics constitute crucial parameters in the assessment of the suitability of clays as industrial raw materials. A comparison of the

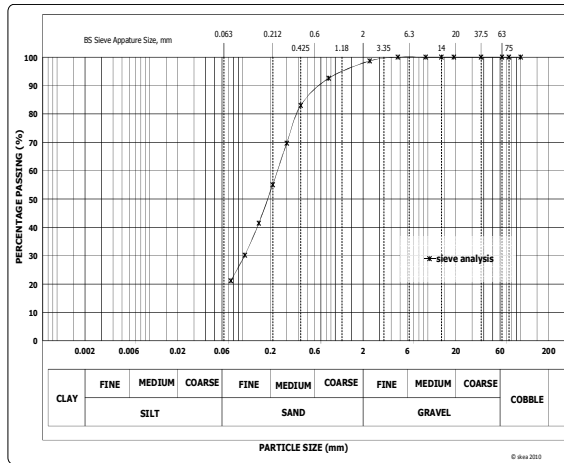
chemical composition of the soil studied with the chemical specification of some industrial clays (Table 5) compared with average values of the results of the tested samples (Table 6), shows quite clearly that samples from site 1 can be improved to serve as ceramic material due to satisfactory SiO_2/Al_2O_3 and Al_2O_3/SiO_2 ratios, while samples from site 3 can also serve as ceramic material and brick clay provided the alumina and iron contents are reduced. The soils generally may not be able to serve as rubber, coating, and filler, this could be attributed to amount of sand in the samples (above 50%), which makes them unsuitable, in their raw state, for use as fillers and coating materials in the paint and cosmetic industries. The Federal Ministry of Works and Housing [10] of Nigeria recommend less than 35% fines, liquid limits of 50% maximum, plastic limits of 30 %, plasticity index of 20 % for subgrade and subbase/base foundation materials, therefore only samples taken from sites 1 and 2 are less than 35 % of fines. All the samples satisfy the

specifications of Liquid limit and plastic limit. All the soil samples recorded low plasticity except AL-3, OF-2, and OF-4 which are a bit higher than recommended 20 %. Subsequently the soils are suitable for subgrade, subbase, and base materials, while samples AL-3, OF-2, and OF-4 can be graded with sand or gravel to reduce its plasticity. This conclusion also corroborates AASHTO classification [11] in Fig. 4 where all the samples fall within A-2-4, A-2-6, and A-2-7 classification signifying good subgrade

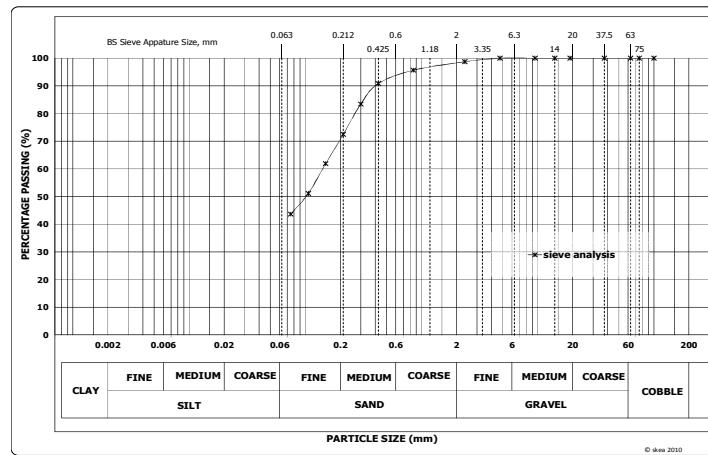
material. However, for highway construction the standard specification of CBR recommended by the Federal Ministry of Works and Housing [10] is 10 % minimum for subgrade, 30 % minimum for subbase materials, and 80 % for base soils . Thus all the sampled soils satisfy the condition of subgrade and subbase materials, while AI-2 can also serve as base course with high shear strength.



(a)

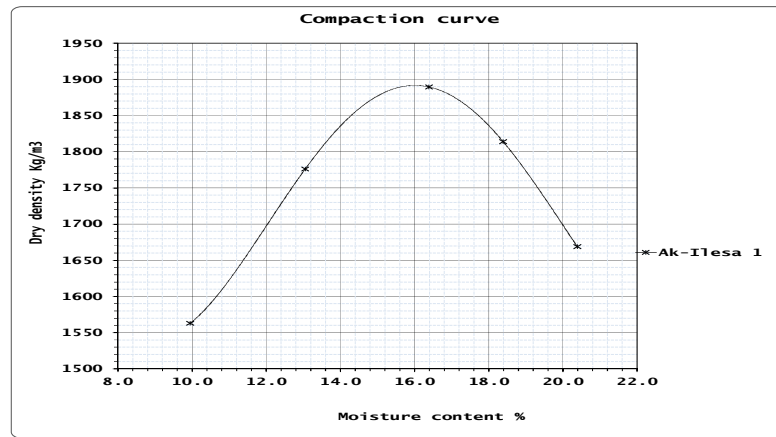


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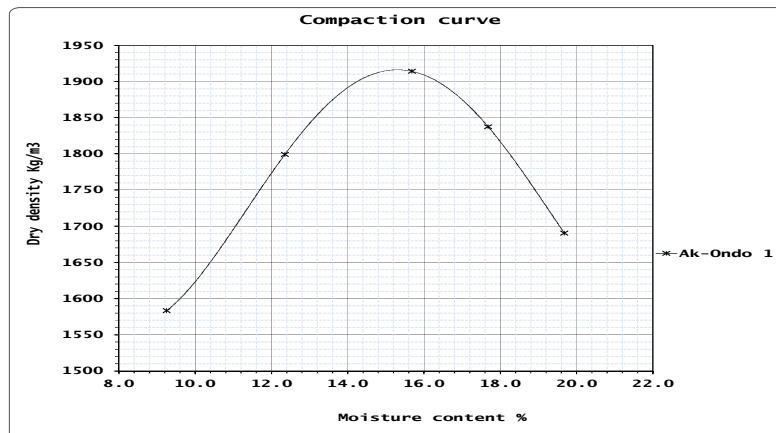


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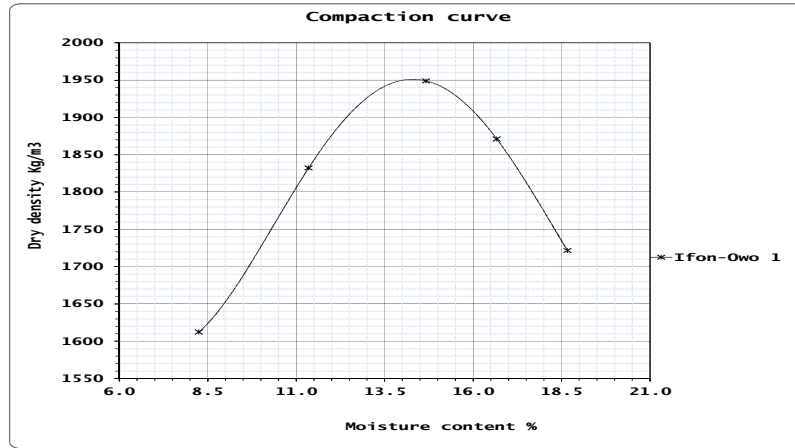
Fig. 3: Typical Grading Curves obtained in (a) LC 1; (b) LC 2; and (c) LC 3



(a)

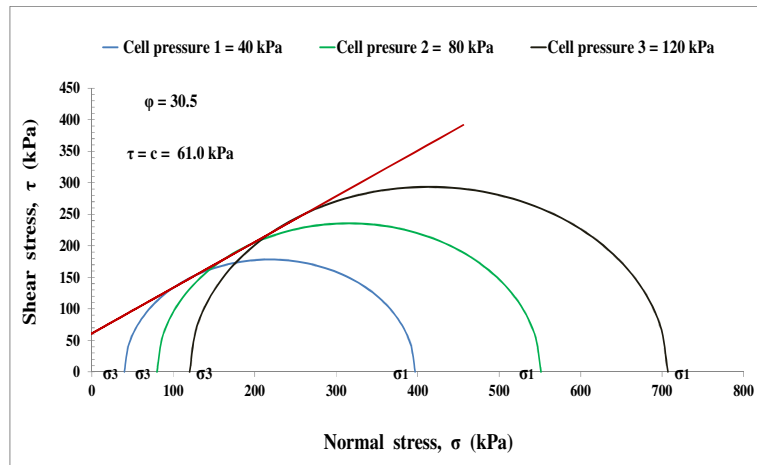


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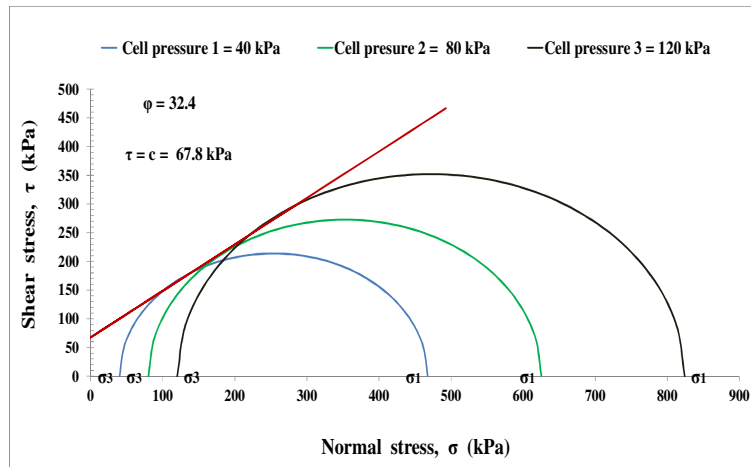


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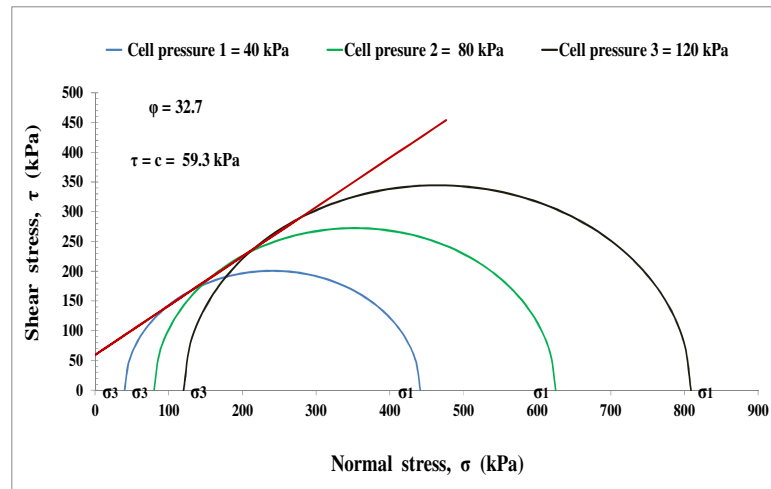
Fig. 4: Compaction Curves of Sampled soils (a) AL-1 (b) AD-1 (c) OF-1



(a)

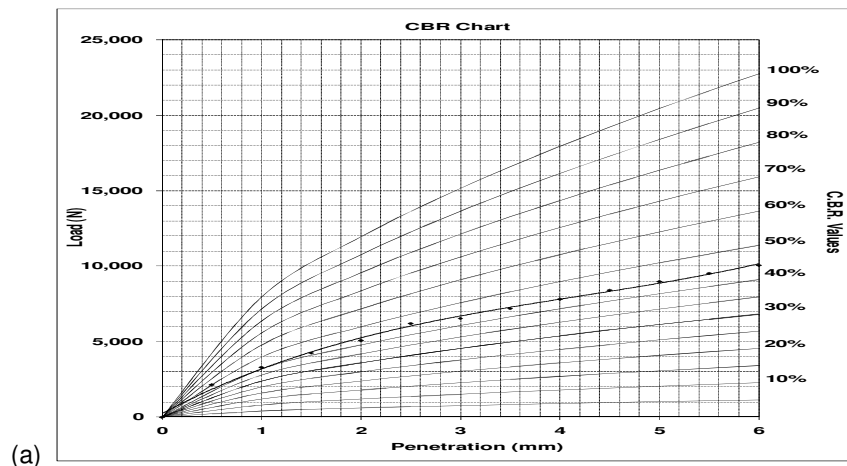


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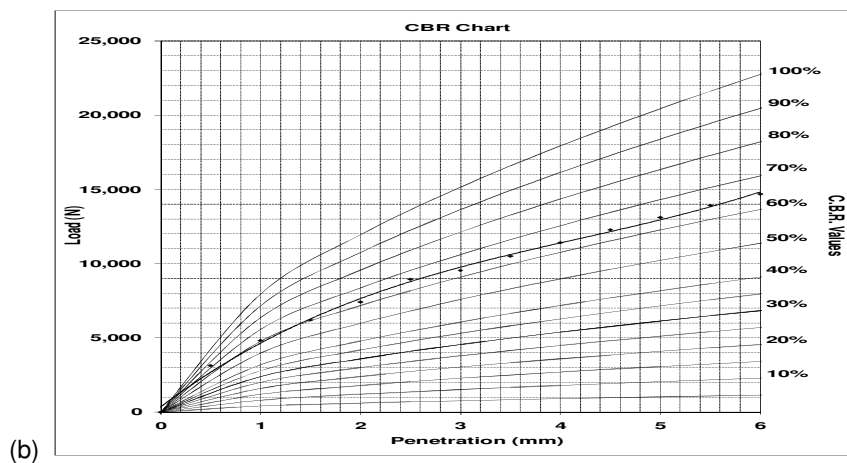


(c)

Fig. 5: Triaxial Compression Curves (a) AL-1 (b) AD-1 (c) OF-1



(a)



(b)

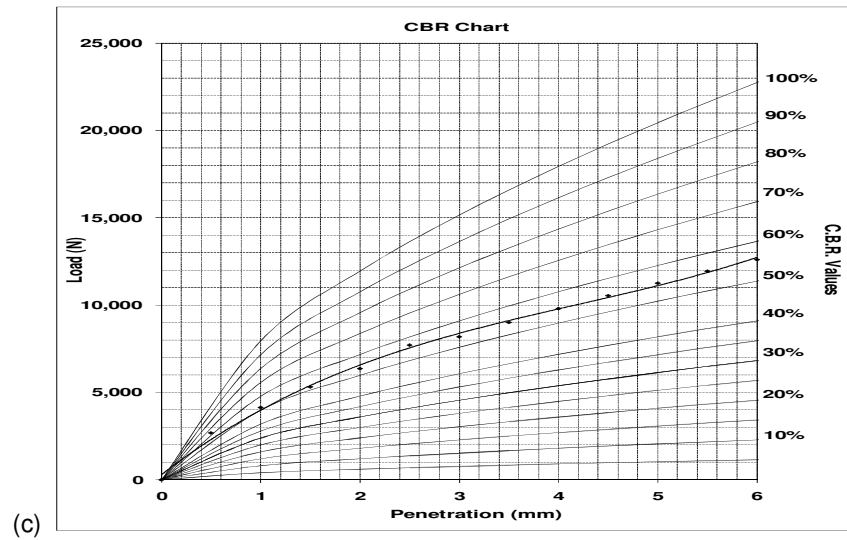


Fig. 6: Typical CBR Curve obtained (a) AL-1 (b) AD-1 (c) OF-1

Table 5: Major elemental oxides of the tested samples compared with chemical industrial specification

Oxides %	Refractory bricks [12]	Rubber [13]	Ceramics [14]	As Coating [15]	As Filler [15]	Brick Clay [16]
MgO	0.2-0.7	Tr	0.10-0.19	0.16	0.25	8.50
Al_2O_3	25-44	32.35	26.50	37.0	36.0	9.45
SiO_2	51 -70	44.90	67.50	47.80	48.70	38.67
Na_2O	0.8-3.50	0.14	0.20-1.50	0.10	0.10	2.76
k_2O	-	0.28	1.10-3.10	1.10	2.12	2.76
CaO	0.1-0.2	Tr	0.18-0.30	0.04	0.06	15.84
TiO_2	1.0-2.80	1.80	0.10-1.0	0.03	0.05	-
MnO	-	-	-	-	-	-
Fe_2O_3	0.5-2.40	0.43	0.5-1.20	0.58	0.82	2.70
SiO_2/Al_2O_3	-	1.39	2.55	1.29	1.35	4.09
Al_2O_3/SiO_2	-	0.72	0.39	0.77	0.74	0.24

Table 6: Average Values of the Tested Samples

Oxides %	Site 1 (Average value)	Site 2 (Average value)	Site 3 (Average value)
MgO	0.22	0.13	0.16
Al_2O_3	19.39	16.59	16.25
SiO_2	48.57	48.33	53.50
Na_2O	1.98	1.29	0.87
k_2O	3.07	1.06	0.94
CaO	0.21	0.38	0.16
TiO_2	1.39	1.21	1.01
Fe_2O_3	21.32	27.47	23.78
SiO_2/Al_2O_3	2.5	2.91	3.29
Al_2O_3/SiO_2	0.39	0.34	0.30

Table 7: AASHTO 1982, Soil Classification System

	Granulary Materials (35 % or less passing No. 200)						Silt-Clay Materials (More 35 % or less passing No. 200)					
General Classification	A-1			A-2			A-7					
Group Classification	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	A-7-5 A-7-6	
Sieve analysis, percentage passing:												
No. 10 (2.00 mm)	50max	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
No. 40 (0.425 mm)	30max	50max	51max	.....	.....	.....	.....	.....	.....	.....	.....	
No. 200 (0.075 mm)	15max	25max	10max	35max	35max	35max	35max	35max	36min	36min	36min	
Characteristics of fraction passing No. 40 (0.425 mm)												
Liquid Limit	.....	.....	.....	40max	40min	40max	41min	40max	41min	40max	41min	
Plasticity Index	6max		N.P	10max	10max	11min	11min	10max	10max	11min	11min	
Usual types of significant Materials	Stone fragments Gravel and Sand		Fine Sand	Silty -	Clayey	Gravel and	Sand	Silty Soils		Clayey Soils		
General Rating as subgrade	Excellent to Good						Fair to Poor					

CONCLUSION

The results of the chemical analysis show that tested soil vary from predominant laterite to lateritic soil. The results of the investigated soil show that the soil have more engineering application than industrial, since only samples from sites 1 and 3 can serve as ceramic material and brick clay provided the alumina and iron contents are reduced. The soils generally may not be able to serve as rubber, coating, and filler due to amount of sand in the samples (above 50%). However, the soils satisfy Federal Ministry of Works and Housing [10] of Nigeria recommend less than 35% fines (except site 3), liquid limits of 50% maximum, plastic limits of 30 %, plasticity index of 20 % for subgrade and subbase/base foundation construction materials, but samples AL-3, OF-2, and OF-4 need to be graded with sand or gravel to reduce its plasticity.

According to AASHTO classification [11] the soil samples fall within A-2-4, A-2-6, and A-2-7 signifying good subgrade material. However, for highway construction the standard specification of CBR recommended by the Federal Ministry of Works and Housing [10] is 10 % minimum for subgrade, 30 % minimum for subbase materials, and 80 % for base soils . Thus all the sampled soils satisfy the condition of subgrade and subbase materials, while only AL-2 also serves as base course material with high CBR and shear strength.

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