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PLASTICITY AND COMPACTION CHARACTERISTICS OF LATERITIC SOILS IN TOUNGO AREA, ADAMAWA STATE, NIGERIA

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Abstract:

The plasticity and compaction characteristics of lateritic soils in Toungo area, Adamawa State, Nigeria were investigated to establish their suitability as civil engineering construction materials. Ten disturbed samples were subjected to geochemical and geotechnical analyses. The dominant oxides ranges are: silica (SiO_2) (42.85 % to 45.34 %); aluminum oxide (Al_2O_3) (39.12 % to 39.20%); and iron-III-oxide (Fe_2O_3) (6.73 % to 8.96 %). The percentage fines, specific gravity SG and natural moisture content NMC ranges are (1.23% - 45.36 %), (2.57 - 2.64) and (11.65 % - 29.12 %) respectively. Samples TNG_8 and TNG_{10} recorded more fines and higher NMC due to higher void ratio and clay in their void spaces. The liquid limits LL, plastic limits PL and plasticity index PI ranges are (17.25 % - 48.75 %), (13.15 % - 27.85 %) and (4.10 % - 20.90%) respectively. The ranges of maximum dry density MDD and optimum moisture content OMC are (2.830 g/cm^3 - 4.15 g/cm^3) and (6.15 % - 14.15 %) respectively. The soils are generally poorly graded and sandy clay with plastic fines. All the lateritic soil samples (except TNG_8 and TNG_{10}) are suitable as fill materials; only samples TNG_4, TNG_5 and TNG_9 are suitable as base and sub-base materials; samples TNG_1, TNG_2, TNG_3, TNG_6 and TNG_7 can be regarded as fair; while samples TNG_8 and TNG_{10} can only be used after stabilization.

Keywords: Lateritic soils, Oxides, Geotechnical investigation, Liquid limit, Plasticity index, Compaction characteristics, Civil engineering projects.

Introduction

The rate at which newly constructed civil engineering structures such as roads in southern part of Adamawa State quickly developed cracks and later become damaged is alarming and worrisome. This may be as a result of wrong application of constructional materials especially lateritic soils as fills, base and sub-base material by construction companies (Ogunribido, et al., 2019). It therefore became imperative for engineers and engineering geologists to investigate the geotechnical properties of the lateritic soils in order to reveal the engineering and environmental issues involving swelling soil especially expansive lateritic soils that can cause significant damages in road construction and other engineering applications (Fatoyinbo, et. al., 2024;

Ampadu, et. al., 2022). The suitability of a lateritic soil as fill, base course or sub-base course depends on its strength; and the characteristics and durability of any constructional material depend on its efficiency (Ogunribido, et al., 2019).

Lateritic soils are rich in iron and aluminium, commonly formed in hot and wet tropical areas, and rusty-red in color due to high iron oxide content. They develop by weathering of the underlying parent rock. Tropical weathering (laterization) results to a wide range in the thickness, grade, chemistry and ore mineralogy of the resulting soils (Yunusa, et al., 2024). They are mostly well graded soils covered with rich concretions of sesquioxide, highly weathered and usually more durable than cohesive soils. They consist of non-cohesive (gravels and sands) and cohesive (clay and silt) soils fractions and contain both clay minerals and sesquioxides (Kumar, et. al., 2022). Yunusa, et al., (2024) opined that the mineralogical composition of a lateritic soil has an influence on its geotechnical parameters such as specific gravity, shear strength, swelling potential, atterberg limits and compaction characteristics.

The plasticity of a soil is its quality that allows it to retain its change in shape after being bent, stretched, or squeezed. It is its ability to undergo deformation without cracking or fracturing and is an important index property of fine grained soils due to presence clay minerals (Sivakugan, 2021). Plasticity of lateritic soils are described based on their atterberg limits; which represent the water content where the consistency of a fine-grained soil is transformed from a plastic state (plastic limit PL) to a liquid state (liquid limit LL) and from a semi-solid state (shrinkage limit SL) to a plastic state, as well as the water content at which different fine-grained soils have an approximately equal undrained shear strength, which is 1.7 – 2.7 kPa at the LL (depending on the method of measurement) and about 100 times greater at the PL. The water contents at the atterberg limits and other physical properties depend mostly on compositional factors, such as the type of minerals, the amount of each mineral, the shapes and size distribution of the particles and the pore-water composition (Sivakugan, 2021).

Due to rapid development of automobiles in the 20th and 21st centuries and the demand for hard surface roads, concrete roads on uncompacted fills easily break up and that the surface of other types of high-grade pavement tends to become very uneven. This necessitated the development of methods of soil compaction that would be economical and efficient. The level of soil compaction mainly depends on the soil moisture content. The greatest degree of compaction is obtained when the water content is at optimum level. The compaction characteristics of lateritic soils are investigated with the aim of determining the optimum moisture contents (OMC) and maximum dry densities (MDD) at which they can be compacted so as to assess their suitability as fills, sub-base and sub-grade materials.

This study is therefore aimed at investigating the variability of chemical, physico-chemical and geotechnical properties of a lateritic soils derived from Toungo area in southern Adamawa State; with emphasis on their plasticity and compaction characteristic. This is done to establish their relationships and determine the effects of parent rocks on the engineering properties and suitability of the lateritic soils as construction materials in various civil engineering projects.

Materials and Methods

Location and Physiography of the study Area

The area under study covers Toungo town and its environs; in southern Adamawa State, Nigeria; which lies within latitudes 08°05′N - 08°09′N and longitudes 12°03′E - 12°06′E, covering an area of about 57.7 km² (Figure 1). The area is characterized by moderate to high relief; marked by isolated hills and valleys; rising about 1,400 m to 1,750 m above mean sea level; and exhibits a dendritic drainage pattern dominated by the River Kom (Ishaku, et. al., 2015); which flows from northeast to southwest (Figure 1). Rainfall in the study area is seasonal; the rainy season starts from April and ends in October while the dry season starts from November and ends in March. The mean annual rainfall is about 700 to 1,200 mm (Adebayo, et. al., 2020). The mean annual temperature range from 24 to 27°C with an average of 26°C recorded during the dry season; while the humidity is low in December and January; and high between April and October (Adebayo, et. al., 2020).

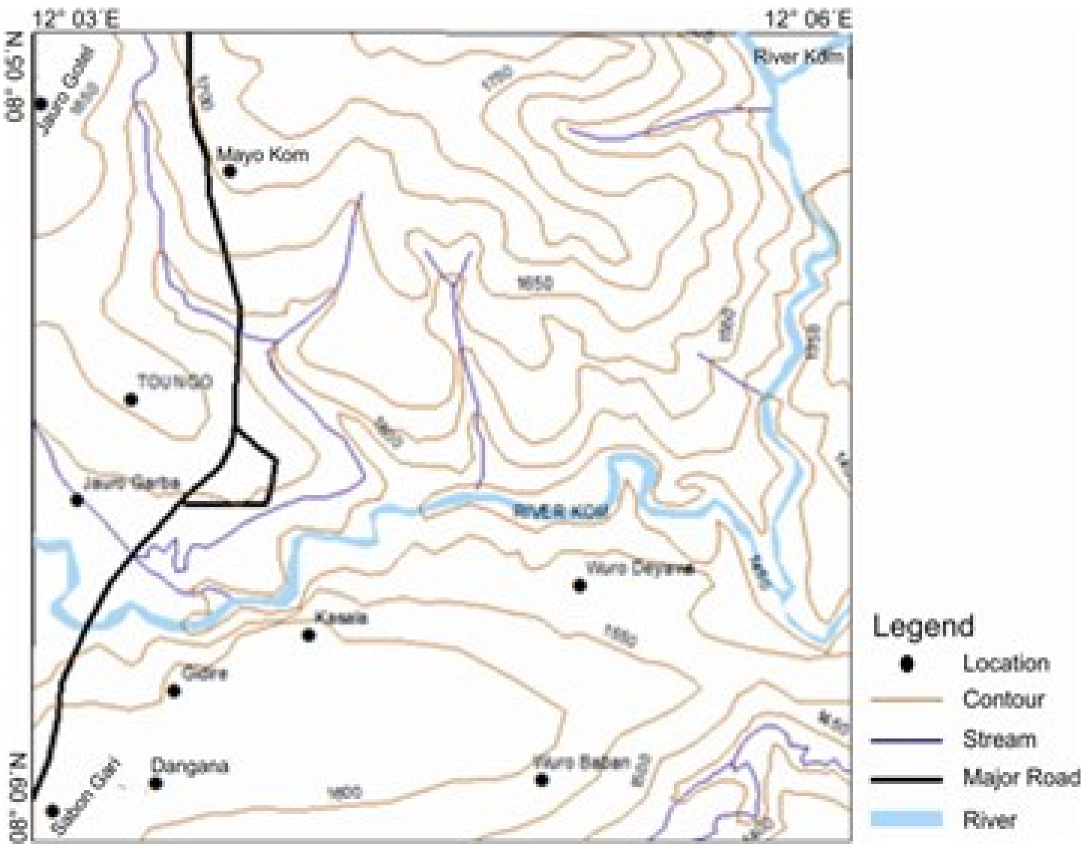

Figure 1: Topographic map of the Toungo area Source: Ishaku, et. al., (2015)

Geology of the Study Area

The study area is underlain by older granites which are enclosed within the migmatite-gneiss-quartzite complexes. The rocks have been identified as biotite-granite, pegmatitic-granites, granite-gneisses and amphibolites; and occupy the east and north-central part of the area. These granites were emplaced during the Pan African thermotectonic event (450 ma) (Ekwok, et. al., 2021). The south-east and western portion of the study area contain the eluvium; which result from weathering of the Precambrian basement complex rocks (Ishaku, et. al., 2015). The floodplains contain the alluvials; characterized by sands, silts, clays and gravels (Figure 2).

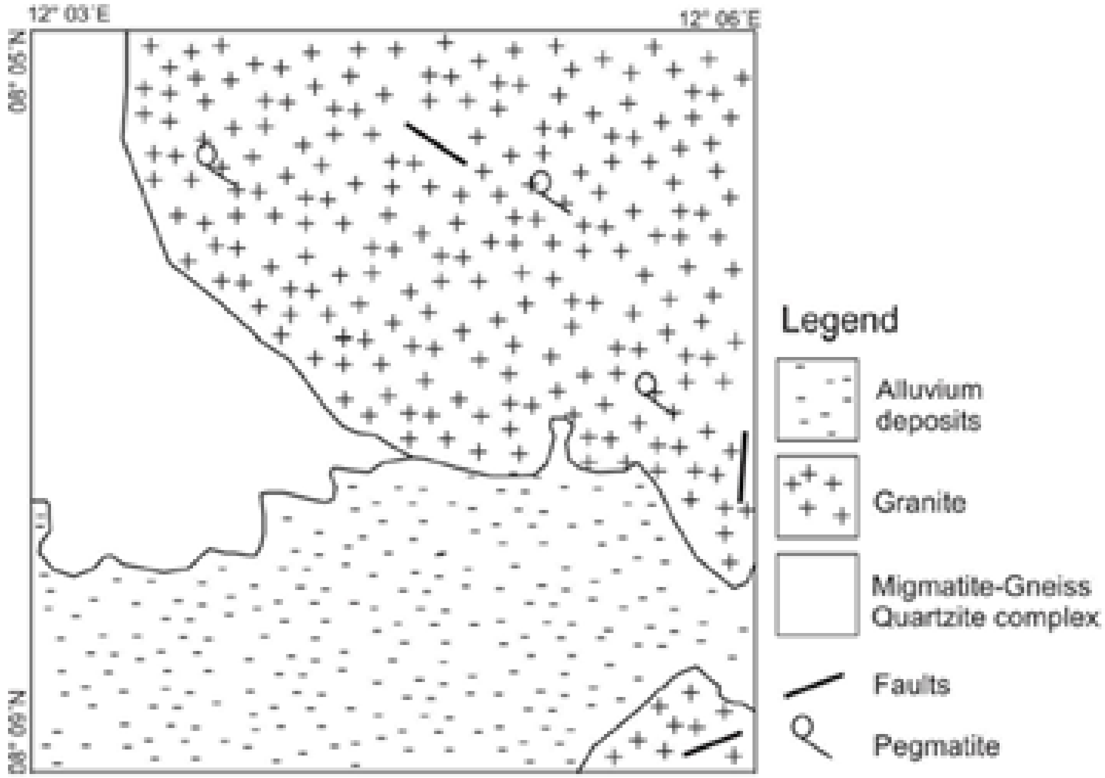

Figure 2: Geological map of the Toungo area Topographic map of the Toungo area
Source: Ishaku, et. al., (2015)

Field Work

During reconnaissance survey the study area was traversed and lateritic soil samples were collected for geotechnical and geochemical analysis. Field instruments used include location map for access to the exact location, a Global Positioning System (GPS) device for obtaining the exact co-ordinates of the study area and a field notebook for recording field observations. Ten (10) fresh different representative disturbed samples were collected with the aid of a spade, stored in polythene bags and taken to soil mechanics laboratory for geochemical and geotechnical analyses.

Laboratory Analysis

Geochemical and geotechnical tests were conducted on the sampled lateritic soils in the laboratory.

Geochemical Analysis

About 1.5g of each lateritic soil sample was used for the geochemical analysis using gravimetric and Atomic Absorption Spectrometry (A.A.S) technique. Samples were prepared individually by sun drying and grinding them in a mortar into a fine powder. Physico-chemical property tests were conducted each lateritic soil sample to determine the presence and amount of silicon oxide (SiO_2), aluminum oxide (Al_2O_3), iron oxide (Fe_2O_3), potassium oxide (K_2O), sodium oxide (Na_2O), magnesium oxide (MgO) and tin oxide (TiO_2).

Geotechnical Analysis

Each lateritic soil sample was subjected to geotechnical analysis to determine its index and engineering properties in the laboratory. The laboratory analysis was performed in accordance with the British standard methods of test for soil for civil engineering purposes (BS 1377: Part 2-7, 2021). The laboratory test were carried out to determine the suitability of the lateritic soils for use as fills, bases and sub-base materials using the AASHTO standard method in relation to the general specifications for roads and bridges.

Particle Size Analysis

Particle Size analysis was carried out on each lateritic soil sample to determine the soil particle size distribution. Representative sample of approximately 500 g was used for the test after being washed and oven-dried. The sample was washed using the BS 200 sieve and the fraction retained on the sieve was air dried and used for the sieve analysis. The sieving was done by mechanical method using an automatic shaker and a set of sieves.

Atterberg Limits (Liquid Limit and Plastic Limit)

The atterberg test was done to determine the clay contents in the lateritic soil samples in terms of liquid limit, plastic limit, plasticity index and shrinkage potential in order to estimate plasticity, strength and settlement characteristics of the soil sample. For the determination of liquid limit, the soil sample passing through 425 μm sieve, weighing 200 g was mixed with water to form a thick homogeneous paste. The paste was collected inside the Casangrade's apparatus cup with a grove created and the number of blows to close it was recorded. Similarly, for plastic limit determination, the soil sample weighing 200 g was taken from the material passing the 425 μm test sieve and then mixed with water till it became homogenous and plastic to be shaped to ball. The ball of soil was rolled on a glass plate until the thread cracks at approximately 3 mm diameter. The 3 mm diameter sample was placed in the oven at 105°C to determine the plastic limit (Sivakugan, 2021).

Natural Moisture Content (NMC)

The natural moisture content is the ratio of the mass of the water in a soil specimen to the dry mass of the specimen. The moisture content of lateritic soil can be influenced by the mineralogy and formation environment. The moisture content of the soil is the characteristics which are most frequently determined and it applies to various kinds of soils. It is the amount of water within the pore space between the soil grains which is removable by oven drying at 105^0C – 107^0C and expressed as a percentage of the mass of dry soil. Usually, moisture content test is necessary to determine the plasticity and shrinkage limit of fine-grained soils, for which moisture content is used as an index, determining the NMC for the various soil samples and measurement of the moisture content of samples used for laboratory testing, usually both before and after the test (Sivakugan, 2021). This is normally done on all test samples as a routine procedure.

Compaction Test

Compaction is the compression of soils leading to its densification and particle packing due to the forceful withdrawal of air from the pore spaces. Surface tension in the soils is usually reduced by the addition of water. However, the voids (pore spaces) will tend to increase when the optimum moisture content is exceeded during the addition of water. This state of compaction is usually measured by the dry density. Compaction test usually provides the relationship between moisture content and dry density for a given degree of compaction effort and the values of the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) for soils. The compaction laboratory procedure employed for this research on the soil samples was the Modified AASHTO Test (T- 180) (Sivakugan, 2021).

Results

Geochemistry of Major Elements

Generally, like typical residual soils, lateritic soils are composed of silica (SiO_2), aluminium oxide (Al_2O_3), iron-III-oxide (Fe_2O_3), tin oxide (TiO_2), Magnesium oxide (MgO), calcium oxide (CaO), sodium oxide (Na_2O), potassium oxide (K_2O), and copper (Cu). Others are feldspar, quartz, kaolinite, muscovite, goethite, montmorillonite and traces of other clay minerals as may be found in the parent rock underlining the laterite soil formation. However, the proportions of these elements vary vertically and horizontally in any given formation, as well as, from region to region. An example of the influence of weathering on the chemical composition is the iron-oxide content, which is low in the lateritic shale (skeletal arrangement) but comparatively high in the sandstone (matrix arrangement) laterites (Ajayi, et. al., 2024 and Otieno, et. al., 2023).

Laboratory geochemical analysis of the studied lateritic soils revealed the distribution of the major oxides as shown in table 1. Three main oxides consisting of silica, alumina and iron show high contents. Evaluation of the content of oxides show that silica (SiO_2) is the most abundant oxide ranging between 42.85 % and 45.34 % with an average of 44.033%; followed by aluminum oxide (Al_2O_3) which range from 39.12 % to 39.20% with an average value of 39.19 %; while iron-III-oxide (Fe_2O_3) range between 6.73 % and 8.96 % with an average value of 7.621 %. The iron-III-oxide (Fe_2O_3) exist as inert as well as cementing materials; they bind individual soil particles into coarser aggregates and contribute to the development of random soil structure.

Table 1 Distribution of Major Oxide in the Studied Lateritic Soils

Elemental oxides (%)	TNG1	TNG2	TNG_1	TNG_2	TN_3	TNG_4	TNG_5	TNG_6	TNG_7	TNG_8	TNG_9	TNG10
SiO_2	45.12	43.19	44.78	43.22	45.09	43.10	44.65	43.24	45.34	42.85	44.85	43.21
$A1_2O_3$	39.12	39.14	39.13	39.15	39.12	39.16	39.14	39.17	39.13	39.20	39.18	39.12
Fe_2O_3	6.75	8.91	6.76	8.86	7.23	6.73	8.96	7.55	6.84	7.97	8.45	6.86
Na_2O	1.77	1.67	1.78	1.74	1.68	1.72	1.75	1.73	1.68	1.69	1.65	1.71
MgO	1.81	1.72	1.79	1.81	1.73	1.71	1.75	1.80	1.77	1.76	1.72	1.74
K_2O	1.06	1.03	1.08	1.02	1.04	1.05	1.03	1.06	1.05	1.03	1.03	1.06
TiO_2	0.60	0.52	0.62	0.55	0.61	0.68	0.51	0.63	0.58	0.66	0.72	0.69
Total	96.23	96.18	95.94	96.35	96.50	94.15	97.79	95.18	96.39	95.16	93.60	94.39

Results of Geotechnical Analyses

The results of laboratory geotechnical analyses conducted on the studied lateritic soils are shown in Table 2 while the description of the lateritic soils based on their plasticity and compaction characteristics is contained in Table 3. The general specification for fills, bases and sub-base materials as outlined by the Federal Ministry of Works and Housing FMWH (2022) is shown in Table 4.

The percentage by weight finer than No. 200 BS test sieve recorded in the lateritic soil samples range between 1.23 % and 45.36 % with an average of 16.434 %; the specific gravity range from 2.57 to 2.64 with an average of 2.609; while the natural moisture content (**NMC**) values range between 11.65 % and 29.12 % with an average of 16.352 % (Table 2). These results showed that samples **TNG**$_8$ and **TNG**$_{10}$ having higher percentages of fines recorded higher **NMC**. High void ratio and appreciable amount of absorptive materials (clay) in the void space would likely be the cause of high **NMC** recorded in these samples; since values of **NMC** are functions of the void ratios (Sivakugan, 2021), climatic conditions and the degree of weathering (Das, 2023). Hence, soils with appreciable amount of fines tend to have higher void ratio and higher moisture holding capacity. The remaining lateritic soil samples with anticipated low void ratios recorded low **NMC** could be a good evidence to support the fact that void and moisture absorption and retention capacity of the fines play prominent roles in **NMC** results (Das, 2023).

The liquid limits values range from 17.25 % to 48.75 % with an average of 33.405 %; the plastic limits range between 13.15 % and 27.85 % with an average of 20.286 %; while the plasticity index range is from 4.10 % to 20.90 with an average of 13.119 % (Table 2). All the lateritic soil samples (except **TNG**$_8$ and **TNG**$_{10}$) recorded low to medium values of **LL** and **PI**. These may be due to depletion or low content of clayey materials resulting from low amount of convertible feldspathic and ferromagnesium minerals. Samples **TNG**$_8$ and **TNG**$_{10}$ with appreciable **LL** and **PI** may have contained feldspathic mineral(s) whose chemical weathering yielded the most expansive clay type (montmorillonite) (Das, 2023).

The maximum dry density (**MDD**) for the soil samples varied between 2.830 g/cm^3 and 4.15 g/cm^3 with an average of 3.12 % while the optimum moisture content (**OMC)** range between 6.15 % and 14.15 % with an average of 10.085 % (Table 2). The **MDD** and **OMC** values indicated that the lateritic soils are generally poorly graded and sandy clay with plastic fines. High amount of iron oxides fines, with relatively low moisture absorptive capacity, in the void spaces of all the lateritic soil samples (except **TNG**$_8$ and **TNG**$_{10}$) would have resulted in the high **MDD** and low **OMC** recorded; iron oxide is a common binding agent in most residual soils (Das, 2023).

Table 2: Summary of Laboratory Geotechnical Analyses Results

Sample	Sampling Depth (m)	Percentage Passing Sieve No. 200 (%)	Specific Gravity	Natural Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Maximum Dry Density (g/cm3)	Optimum Moisture Content (%)
TNG$_1$	1.5	2.38	2.60	13.25	33.15	18.86	14.29	2.35	11.95
TNG$_2$	1.5	28.42	2.57	13.75	35.30	23.75	11.55	2.85	12.50
TNG$_3$	1.5	1.65	2.62	13.38	34.65	22.50	12.15	3.15	7.35
TNG$_4$	1.5	3.22	2.58	12.77	24.85	14.20	10.65	3.75	6.15
TNG$_5$	1.5	3.86	2.60	12.25	23.40	14.00	9.40	3.93	6.35
TNG$_6$	1.5	1.23	2.63	14.15	36.15	22.95	13.20	4.15	8.75
TNG$_7$	1.5	30.15	2.61	15.55	38.00	23.75	14.25	3.08	10.45
TNG$_8$	1.5	45.36	2.64	29.12	48.75	27.85	20.90	2.44	13.95
TNG$_9$	1.5	3.75	2.61	11.65	17.25	13.15	4.10	3.20	9.25
TNG$_{10}$	1.5	44.32	2.63	27.65	42.55	21.85	20.70	2.30	14.15

Ameratunga and Sivakugan (2021) opined that lateritic soil with liquid limit less than 35% indicates low plasticity, between 35% and 50% indicates intermediate plasticity, between 50%

and 70% high plasticity and between 70% and 90% very high plasticity and greater than 90% extremely high plasticity. Also, Findley, et. al., (2022) outlined the range of values that may be anticipated when using the standard proctor test methods of compaction. For clay, maximum dry density (MDD) may fall before 1.44 mg/m^3 and 1.685 mg/m^3 and optimum moisture content (OMC) may fall between 20-30%. For silty clay MDD is usually between 1.6 mg/m^3 and 1.845 mg/m^3 and OMC ranged between 15-25%. For sandy clay, MDD usually ranged between 1.76 mg/m^3 and 2.165 mg/m_3 and OMC between 8 and 15%. Thus, looking at the results of the lateritic soil samples, it could be noticed that they are all described as sandy clay.

Table 3: Description of the lateritic soils based on their plasticity and compaction characteristics

Sample	TNG_1	TNG_2	TNG_3	TNG_4	TNG_5	TNG_6	TNG_7	TNG_8	TNG_9	TNG_{10}
Liquid Limit (%)	33.15	35.30	34.65	24.85	23.40	36.15	38.00	48.75	17.25	42.55
Plastic Limit (%)	18.86	23.75	22.50	14.20	14.00	22.95	23.75	27.85	13.15	21.85
Plasticity Index (%)	14.29	11.55	12.15	10.65	9.40	13.20	14.25	20.90	4.10	20.70
Maximum Dry Density (g/cm3)	2.35	2.85	3.15	3.75	3.93	4.25	3.08	2.44	3.20	2.30
Optimum Moisture Content (%)	11.95	12.50	7.35	6.15	6.35	8.75	10.45	13.95	9.25	14.15
Plasticity	LP	IP	LP	LP	LP	IP	IP	IP	LP	IP
Description	Sandy-Clay	Sandy-Clay	Sandy-Clay	Sandy-Clay	Sandy-Clay	Sandy-Clay	Sandy-Clay	Sandy-Clay	Sandy-Clay	Sandy-Clay

LP = low plasticity; IP = intermediate plasticity

Suitability of the Lateritic Soils in Civil Engineering

For lateritic soils to be used as fills, bases or sub-bases in civil engineering, they must conform to Nigerian specifications complemented by Road Note No. 29 & 31. Generally, lateritic soils having high values of liquid and plastic limits are considered as poor foundation materials. The following are specifications of the Federal Ministry of Works and Housing FMWH (2022).

Table 4: Suitability of the Lateritic Soils as Civil Engineering Construction Materials (FMWH, 2022)

Materials	Liquid Limit	Plasticity Index
Fill	0 - 45%	0 – 20%
Sub- Base	0 – 35%	0 – 12%
Base	0 - 30%	0 – 12 %

In the light of the above specifications, all the lateritic soils (except TNG_8 and TNG_{10}) are suitable as fill materials; only samples TNG_4, TNG_5 and TNG_9 are suitable as base and sub-base materials; samples TNG_1, TNG_2, TNG_3, TNG_6 and TNG_7 can be regarded as fair; which samples TNG_8 and TNG_{10} can only be used after stabilization (Table 4). However, the Atterberg values showed that all the

lateritic soil samples (**TNG_8** and **TNG_{10}**) have low plasticity; suggesting very little potential to swell or shrink.
From the compaction characteristics, it can be observed that the values of **MDD** exceed 1.700g/cm^3 in all the soil samples (Table 4); indicating that the lateritic soils are suitable for general filling and construction of sub grade and sub base courses of roads. **OMC** and **LL** increase with the increase in percentage of fines. Generally, **MDD** and **OMC** of the lateritic soils are influenced by their grading and plasticity.

Table 4: Nigerian Standard of soil classification for fills bases and sub-bases

Sample	TNG_1	TNG_2	TNG_3	TNG_4	TNG_5	TNG_6	TNG_7	TNG_8	TNG_9	TNG_{10}
Liquid Limit (%) (≤ 35%)	33.15 **Pass**	35.30 **Fail**	34.65 **Pass**	24.85 **Pass**	23.40 **Pass**	36.15 **Fail**	38.00 **Fail**	48.75 **Fail**	17.25 **Pass**	42.55 **Fail**
Plasticity Index (%)(≤ 12%)	14.29 **Fail**	11.55 **Pass**	12.15 **Fail**	10.65 **Pass**	9.40 **Pass**	13.20 **Fail**	14.25 **Fail**	20.90 **Fail**	4.10 **Pass**	20.70 **Fail**
Maximum Dry Density (g/cm3)	2.35	2.85	3.15	3.75	3.93	4.25	3.08	2.44	3.20	2.30
Optimum Moisture Content (%)	11.95	12.50	7.35	6.15	6.35	8.75	10.45	13.95	9.25	14.15
Overall Rating	**Fair**	**Fair**	**Fair**	**Good**	**Good**	**Fair**	**Fair**	**Poor**	**Good**	**Poor**

Conclusion

This study investigated and analyzed the variability of chemical, physico-chemical and geotechnical properties of a lateritic soils derived from Toungo area in southern Adamawa State; with emphasis on their plasticity and compaction characteristic. This is done to establish their suitability as construction materials in various civil engineering projects. From the results of the geochemical and geotechnical investigations, the following conclusions were deduced:

1. Ten disturbed samples were collected and subjected to geochemical and geotechnical analyses.
2. Three main oxides: silica, alumina and iron are dominant in the studied lateritic soils.
3. Silica (SiO_2) is the most abundant oxide ranging between 42.85 % and 45.34 % with an average of 44.033%; followed by aluminum oxide (Al_2O_3) which range from 39.12 % to 39.20% with an average value of 39.19 %; while iron-III-oxide (Fe_2O_3) range between 6.73 % and 8.96 % with an average value of 7.621 %.
4. The iron-III-oxide (Fe_2O_3) acts as cementing materials; binding individual soil particles into coarser aggregates and contribute to the development of random soil structure.
5. The percentage by weight finer than No. 200 BS test sieve range between 1.23 % and 45.36 % with an average of 16.434 %; the specific gravity **(SG)** range from 2.57 to 2.64 with an average of 2.609; while the natural moisture content (**NMC**) values range between 11.65 % and 29.12 % with an average of 16.352 %.
6. Lateritic soil samples **TNG_8** and **TNG_{10}** having higher percentages of fines recorded higher **NMC**; due to higher void ratio and appreciable amount of absorptive materials (clay) in the void space.
7. The liquid limits **LL** values range from 17.25 % to 48.75 % with an average of 33.405 %; the plastic limits **PL** range between 13.15 % and 27.85 % with an average of 20.286 %; while the plasticity index **PI** range is from 4.10 % to 20.90 with an average of 13.119 %.

8. All the samples (except **TNG_8** and **TNG_{10}**) recorded low to medium values of **LL** and **PI**; due to depletion or low content of clayey materials resulting from low amount of convertible feldspathic and ferromagnesium minerals.
9. The maximum dry density (**MDD**) for the soil samples varied between 2.830 g/cm^3 and 4.15 g/cm^3 with an average of 3.12 % while the optimum moisture content (**OMC)** range between 6.15 % and 14.15 % with an average of 10.085 %.
10. The **MDD** and **OMC** values indicated that the lateritic soils are generally poorly graded and sandy clay with plastic fines. High amount of iron oxides fines, with relatively low moisture absorptive capacity, in the void spaces of all the lateritic soil samples (except **TNG_8** and **TNG_{10}**) would have resulted in the high **MDD** and low **OMC**.
11. All the studied lateritic soils (except **TNG_8** and **TNG_{10}**) are suitable as fill materials; only samples **TNG_4**, **TNG_5** and **TNG_9** are suitable as base and sub-base materials; samples **TNG_1**, **TNG_2**, **TNG_3**, **TNG_6** and **TNG_7** can be regarded as fair; while samples **TNG_8** and **TNG_{10}** can only be used after stabilization .
12. The Atterberg values showed that all the lateritic soil samples (**TNG_8** and **TNG_{10}**) have low plasticity; suggesting very little potential to swell or shrink.
13. The values of **MDD** exceed 1.700g/cm^3 in all the lateritic soil samples; indicating that they are suitable for general filling and construction of sub grade and sub base courses of roads.
14. **OMC** and **LL** increase with the increase in percentage of fines. Generally, **MDD** and **OMC** of the lateritic soils are influenced by their grading and plasticity.

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