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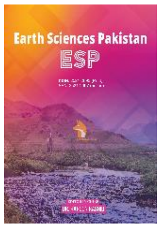

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RESEARCH ARTICLE

INTEGRATED GEOLOGY AND ENGINEERING GEOLOGICAL PROPERTIES OF LATERITIC SOIL AT ITA – ONIYAN AREA, SOUTHWESTERN NIGERIA

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ABSTRACT

This study investigates the geology and the engineering geological properties of lateritic soil of Ita – Oniyan area of Ondo state, Southwestern, Nigeria. Twenty soil samples were collected from twenty test pits at depth of about 1.0m and were air–dried for two weeks and, thereafter were subjected to laboratory analyses which include natural moisture content, particle size analysis, consistency limits, linear shrinkage, specific gravity, standard compaction, shear strength, and unsoaked California Bearing Ratio (CBR) tests. Results showed that the natural moisture content of the soils ranged from 7% to 28%, the liquid limit ranged from 30.2% to 69.1%, the plastic limit ranged from 17.5% to 43.4%, while the plasticity index ranged from 8.6% to 36.9%. The soils were grouped into CL (low plasticity), CI (medium plasticity), and CH (high plasticity). Linear shrinkage ranged from 3.7% to 11.9%. Grain size analysis gave coarse contents varying from 30.4% to 98.1% and fine contents from 27.4% to 86.9%. The unsoaked CBR ranged from 18% to 72%, for compaction, MDD ranged from 1482kg/m^3 to 1981kg/$m^{3,}$ and OMC from 13.7% to 32.5%. Geologic mapping showed that the major rock types in the study area were biotite gneiss, charnockite, quartzite and granite parent rocks from which the soil was formed. The soil samples are made up of lateritic soil with high clay content mainly illite, since the soil samples in the study area have poor engineering properties therefore the soil needed to be stabilized to improve their engineering properties.

KEYWORDS

keCompaction, geology, lateritic soil, rock types, structural failure.

1. INTRODUCTION

Lateritic soils occur as a result of weathering of rock in - situ in tropical climatic regions where there are alternate drying and wetting. Weathering may be in form of physical disintegration or chemical dissolution of rock into their constituent minerals. Disintegrated materials above rock which have not been transported by the agent of denudation are generally classified as lateritic soil. It also may be produced when soil is leached of bases and organic matter. This soil generally has a high content of iron and aluminum oxides, low silica and relatively high clay contentment. Iron oxide is responsible for the red color of the soil. Lateritic soil may also be formed in the tropical region when there are prolonged chemical decomposition processes due to high temperature, high humidity, and high rainfall.

Engineering structures are mostly erected on soil that bears the load of the superstructure which is transmitted to the soil by the substructure. Soil serves as a support for almost all types of engineering structures which includes bridges, houses, aerodromes, roads, and railroads among others. For soil to act as support, it must have high shear strength or high bearing capacity otherwise structural failure will occur. One of the problems associated with soil is differential settlements. The magnitude of the settlement generally depends on the factors such as the nature of the soil, types and the intensity of the load transmitted unto the soil. The main instability problems are the collapse of buildings, dam failure, soil creeps, or landslides.

A foundation must be stable against shear failure of the supporting soil and must not settle beyond a tolerable limit to avoid damage to the structure. Statistically, failures of roads, buildings, dams, and bridges in Nigeria have increased geometrically. The need for engineering geological investigation of the proposed site for engineering structures is pertinent to prevent the loss of lives and properties that always accompany such structural failures. For the engineering geological properties, there is a need for a thorough investigation of the index and strength properties of the soil. Recently, researchers that worked on engineering geological properties of soil include (Adejumo et al., 2015; Adeyemi, 2002; Aghamelu et al., 2011; Coker et al., 2013; Gure et al., 2013; Ogunribido, 2011; Ogunribido, 2020; Ale et al., 2022).

1.2 Location, physiography and Geology of the Study Area

The study area lies between Latitudes 7^{o} 16^{1} and 7^{o} 18^{1} North of the Equator and Longitudes 5^{o} 9^{1} and 5^{o} 10^{1} East of the Greenwich meridian. The study area is characterized by a humid tropical climate with distinct wet and dry seasons. Annual rainfall means a value of about 1200mm and the highest temperature of 30 ^{o} C. Relative humidity ranged from 70% to 90%. Vegetation in the study area is tropical rainforest type which consists of grasses, shrubs and hardwood but had in many parts been modified by cultivation. The topography is undulating with the presence of depressions at the southern part and a fairly level plain at the northern part of the study area. The stream directions are largely controlled by the trend of the rocks and joints. The study is underlain by the Precambrian basement complex of southwestern Nigeria (Rahaman, 1976; Rahaman, 1988).

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The geologic mapping was carried out to produce the geologic map of the study area on a scale of 1: 20,000 (Figure 1). Four major rocks types identified during the mapping exercise were as stated below:

a) Biotite gneiss: This form is the country rock in the study area, its mineralogical composition was biotite, feldspar and quartz. The dominant mineral was biotite.

b) Charnokite: this is the most extensive rock in the study area, which was emplaced within biotite gneiss. It outcropped in many places while in some places, it has weathered to soil completely. This charnokite is made of pyroxene, amphibole, quartz and plagioclase feldspar, with a texture ranging from fine to medium grain, and occurred at the central portion of the study area.

c) Quartzite: this occurred within the charnokite along the Northeastern part of the study area. It occurred as a local body. It was schistose quartzite.

d) Granite: this rock is made up of biotite, quartz and feldspar minerals. This rock is light-coloured and occurred as a minor rock unit in the study area.

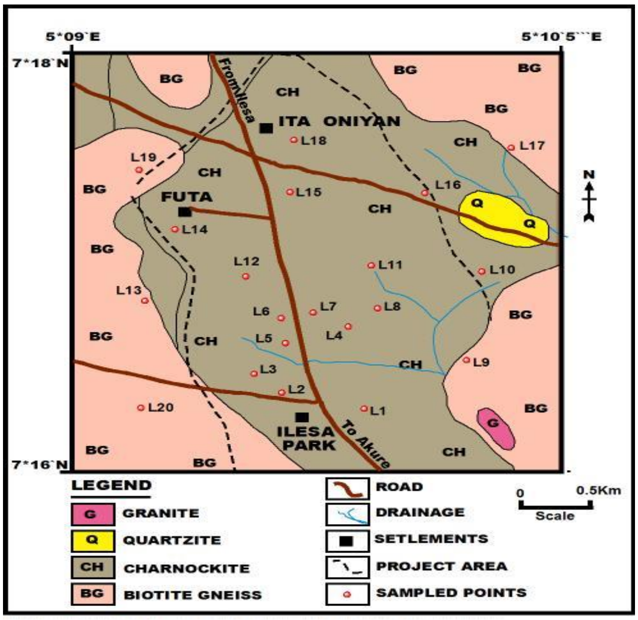

Figure 1: Generalized Geological Map of Ita – oniyan area

2. Materials and Methods

Twenty soil samples were collected at the depth of 1.0m and were air-dried for 2 weeks before laboratory analyses. Engineering properties tested for in the laboratory include; specific gravity, particle size distribution, liquid limit, linear shrinkage, plastic limit, California bearing ratio and compaction. The soil samples were tested according to the standard procedures. (BSI 1377, 1990).

3. Results and Discussion

A summary of the results of different engineering geological tests is presented in Tables 1, 2 and 3.

Table 1: Soil Classifications of Ita - Oniyan Soils.

Location	% of Soil Passing 2.36mm sieve	% of Soil Passing 425µm sieve	% of Soil Passing 75µm sieve	Group index, GI	AASHTO classification	USCS Classification Code
1	60.6	44.2	37.0	2.2	A-2-7	CI
2	79.6	57.5	50.4	6.0	A-7-5	CI
3	79.2	57.7	44.4	5.0	A-7-5	CI
4	63.5	36.1	24.3	0.0	A-2-6	CL
5	93.6	75.5	64.5	17.8	A-7-6	CH
6	63.5	38.0	31.6	3.5	A-2-7	CH
7	97.0	68.4	45.5	2.7	A-2-6	CL
8	54.9	31.0	26.3	0.0	A-2-7	CH
9	76.8	60.8	53.6	11.2	A-7-6	CH
10	98.1	91.0	86.9	20.0	A-7-5	CH
11	73.5	51.5	41.4	0.4	A-7-6	CI
12	61.1	39.9	30.8	0.2	A-2-6	CI
13	57.8	37.7	31.7	2.2	A-2-7	CH
14	42.3	30.4	27.4	0.0	A-2-7	CH
15	96.2	78.6	66.1	13.6	A-7-6	CI
16	98.1	91.0	86.3	20.0	A-7-5	CH
17	61.1	39.9	30.8	0.2	A-2-6	CI
18	63.5	38.0	31.6	3.5	A-2-7	CH
19	79.6	57.5	50.4	6.0	A-7-5	CI
20	42.3	30.4	27.4	0.0	A-2-7	CH

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Table 2: Summary of the results from index and strength tests.

L	NMC (%)	LL (%)	PL (%)	PI (%)	L/S (%)	MDD (Kg/m³)	OMC (%)	CBR (%)	Shear Strength (Kpa)
1	17.5	45	23.1	21.9	7.3	1770	20.1	44	38.5
2	19.5	49.5	37.3	12.2	10.1	1690	22.7	18	123.5
3	16	38.8	22.2	16.6	11.9	1542	27.5	22	29.6
4	8	35.2	19.5	15.7	10.8	1963	15.6	72	81.3
5	22.5	53.8	26.1	27.7	9.7	1843	18.5	28	35.0
6	11	59.2	22.3	36.9	7.6	1851	17.9	25	103.5
7	13.5	30.2	17.5	12.7	10.5	1605	24.8	36	36.2
8	17.5	48.6	27.2	21.4	9.3	1970	13.7	65	73.5
9	18.5	57.8	29.7	28.1	5.4	1557	25.4	24	199.6
10	28	69.1	43.4	25.7	6.9	1482	28.3	32	88.6
11	12	48.2	39.6	8.6	7.4	1860	17.8	31	144.5
12	12.5	39.8	23.4	16.4	4.9	1535	28.2	38	95.0
13	18	40.5	24.5	16.0	7.6	1965	16.5	52	162.0
14	14	49.2	34.4	14.8	3.7	1527	27.0	43	157.3
15	7	33.2	21.5	11.7	10.8	1953	15.6	70	85.3
16	21.5	55.8	26.1	29.7	8.7	1843	18.7	21	45.0
17	13	61.2	25.4	35.8	6.6	1858	17.1	28	113.5
18	12.5	37.2	19.3	17.9	12.5	1599	25.8	36	40.2
19	18.5	51.5	28.2	23.3	8.3	1981	16.1	62	83.2
20	19.5	47.4	27.2	20.2	6.4	1498	32.5	31	21.7

Table 3: Summary of Unsoaked California Bearing Ratio results.

Location	Unsoaked CBR	General Rating	Use
1	44%	Good	sub-base
2	18%	Good	subgrade
3	22%	Excellent	subgrade
4	72%	Good	base
5	28%	Good	subgrade
6	25%	Excellent	subgrade
7	36%	Excellent	subgrade
8	65%	Good	base
9	24%	Good	subgrade
10	32%	Excellent	subgrade
11	31%	Good	sub-base
12	38%	Good	sub-base
13	52%	Good	sub-base
14	43%	Good	sub-base
15	70%	Excellent	subgrade
16	21%	Excellent	subgrade
17	28%	Good	base
18	36%	Good	subgrade
19	62%	Excellent	subgrade
20	31%	Excellent	subgrade

3.1 Grain Size Analysis

The result of the grain size distribution of the soil samples in the study area is shown in Table 1. From the graphs plotted, the finer portion of these samples ranged from 24.3% to 86.9% with location 4 having the lowest percentage of finer particles and location 10 having the highest percentage of finer particles. The soil in this location is not good for road construction because it contains a high percentage of fines. According to the Federal Government of Nigeria (FGN) specification for pavement design, the percentage for a good sub-base and base materials should not be greater than 15% (Arumala, and Akpokodje, 1987). The grain size of soil is very important in making a number of important engineering property judgments. According to the Federal Government of Nigeria Specification for road construction (1970), soil that should be used in road construction must not contain less than 12% fines. None of the values falls within that range, so the failed portions of the road may be due to poor drainage.

3.2 AASHTO Classification

The results of AASHTO classification show that four soil samples are classified as A- 2 – 6, seven as A- 2 – 7, five as A – 7 – 5 and four as A – 7- 6. The A- 2 – 6 and A – 2 – 7 are granular soil and A – 7 – 5 and A – 7 – 6 are clayey soils. The granular soils are good for road construction while the clayey soil is a poor material for road construction because of swelling when wet or contraction when dry.

3.3 Natural moisture content

The moisture content of lateritic soil can be influenced by the mineralogy and formation environment (Gana and Mba – Okorie, 2018). Moisture content values ranged from 7% to 28%. The natural moisture content is low to medium, this may be due to the fact that the sampling was carried out during the dry season.

3.4 Liquid limits

The values obtained for liquid limits ranged from 30. 2% to 69.1%. The standard set by the Federal government for pavement design is that the liquid limit must not be greater than 35%. But all the samples except in location 7 are greater than 35% as prescribed by the (Federal Ministry of Works and Housing, 1975).

3.5 Plastic limits

The values of plastic limits ranged from 17.5% to 43.4%. The lowest plastic limit occurred in location 7 and the highest in location 10, all plastic limits are below 50% of specified limits.

3.6 Plasticity index

These ranged from 8.6% to 36.9%**,** since the specification for plasticity index for subgrade soil is less than or equal to 12%, (Ramamurthy M and Sitharam, 2005**,** Ogunribido et al., 2020). The higher the value of the plasticity index, the poorer the value of the soil. Most of the plasticity indexes are higher than 12% which is an indication of the instability of the pavement

3.7 Linear shrinkage

Linear shrinkage should be less or equal to 10% for sub-base and subgrade materials (Gidigasu, 1976). Linear shrinkage values ranged from 3.7% to 11.9% indicating good sub grade material with exception of locations (2, 3, 4, 7, 15 and 18) that are higher than 10% Failed portions are associated with locations which linear shrinkage values are greater than 10%

3.8 Compaction

The proctor compaction test conforms to the requirement of (BS 1377, 1990). The aim of the test was to ascertain the maximum dry density (MDD) and optimum moisture content (OMC) of the soil samples**.** The soil samples were compacted to determine the compaction level for the road subgrade material. From the compaction results, the maximum density (MDD) ranged from 1482kg/m^3 to 1981kg/m^3 and the optimum moisture content (OMC) ranged from 13.7% to 32.5%, the MDD of all the samples have a value less than the recommended value of 2160kg/m^3 for Nigeria soil, therefore, the soil samples in the study area were poor subgrade materials

3.9 Plasticity chart

The plasticity chart (Figure 2) comprises two important lines, A-line and U-line. The A-line is an empirically chosen line that separates the chart between clays and silts; soils that fall above A-line are classified as clays and those falling below as silts. From the study area, most of the soil falls above, this showed that most of the soil has high clay content and only four silty soil. The soil samples ranged from medium to high plasticity.

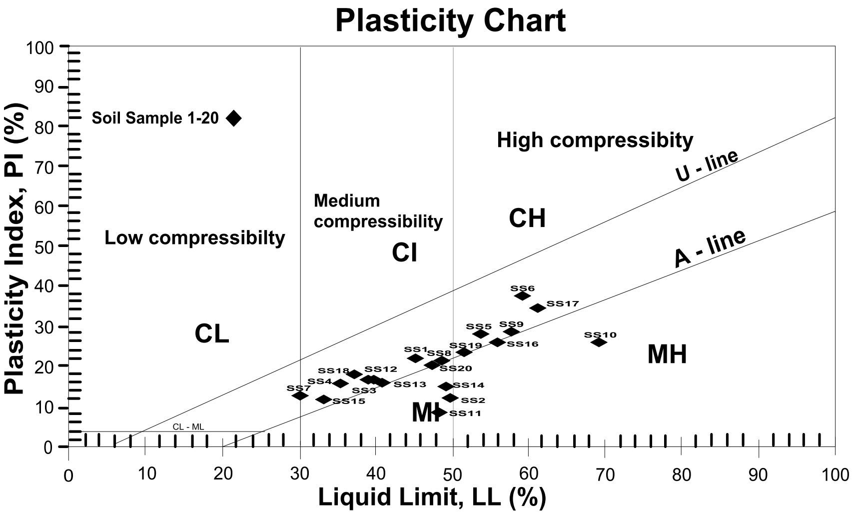

Figure 2: Plasticity chart of the soil samples.

From figure 3 the type of clay present in the soil sample is predominantly illite and minor clay content include chlorite and kaolinite. It follows that the suitability of the soils as road construction materials is low, due to high clay content. They can only be successfully used for base and sub-base courses after stabilization.

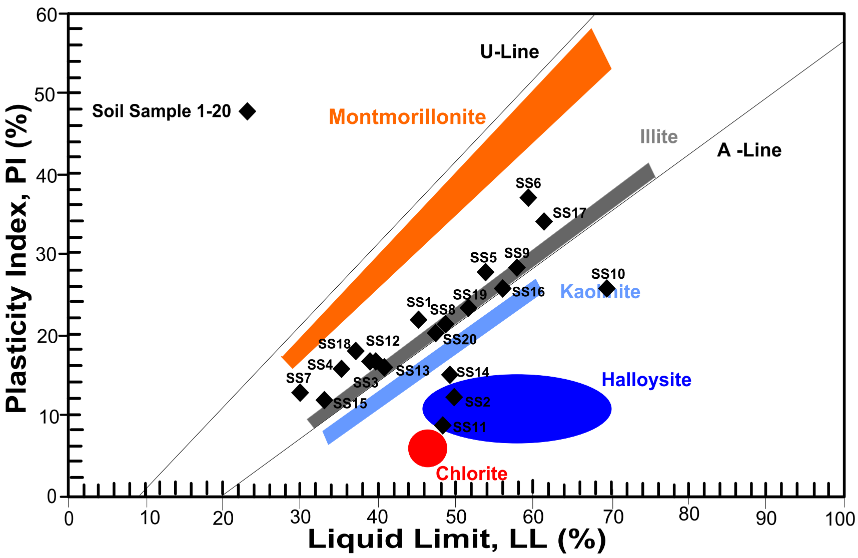

Figure 3: Soil classification chart of the soil samples.

3.10 California Bearing Ratio (CBR)

California Bearing Ratios which has been adjudged as an indication of soil strength for the proper evaluation of highway, road, and footpath subgrade and sub-base materials..Both soaked and unsoaked CBR tests are used in the assessment of granular materials used in bases, sub-bases, and subgrades. The unsoaked CBR ranged from 18% to 72% in the study area. The subgrade must be between 15 and 35%, sub base between 80 and 100% and the base course not less than 10%. Based on the results of the CBR, none of the soil samples is good as sub-base material, ten soil samples are good as subgrade material and four are also good as the base course material.

3.11 Shear strength

Shear strength of soil is indicative of its resistance to erosion. Specifically, it is defined as the resistance to deformation by the action of tangential (shear) stress. Soil shear strength is made up of cohesion between particles and resistance of particles sliding over each other due to friction or interlocking the shear strength of soil samples in the study ranged from 21.7Kpa to 199.6Kpa.

4. Conclusion

Results of compaction, California bearing ratio, consistency limits, shear strength and grain size analyses showed that the soil samples in the study area have a large quantity of clay soil, making the soil have low bearing capacity, therefore, the soil samples are not good material for road construction. Therefore, for the soil to be used as fill materials, the engineering properties of the soil samples needed to be improved by stabilization.

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