

Geotechnical Evaluation of Subgrade Soils and their Implications for Road Construction: A Case Study of the Oru-Ijebu Igbo Road, Southwest, Nigeria

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Abstract

Review Article

This study presents a geotechnical evaluation of subgrade soils along Oru-Ijebu Igbo Road, Southwestern Nigeria, with the aim of determining their suitability for road construction. A total of twenty-six (26) samples, including thirteen (13) disturbed and thirteen (13) undisturbed, were collected at depths between 0.4 to 1.0 meters from both failed and stable sections of the road. The samples underwent various tests following the British Standard code of practice, including natural moisture content, grain size distribution, specific gravity, Atterberg limits, California Bearing Ratio (CBR), compaction, and shear strength (Triaxial). The results revealed moisture content values between 6.6% and 10.5%, indicating that the soils require low moisture for optimal compaction. Grain size analysis showed that fine grains constituted 21.0% to 67.0%, while coarse grains ranged from 1.0% to 27.0%, indicating poor subgrade quality due to the high fine grain composition. Specific gravity values ranged from 2.59 to 2.62, with 8 out of 13 samples meeting the standard, suggesting notable laterization. Atterberg's limits indicated low clay content with liquid limits between 42.0% to 44.0% and plasticity indices between 27.1%, 29.0%, classifying the soils as having intermediate, plasticity. Maximum Dry Density (MDD) ranged from 1770 kg/m³ to 1887 kg/m³, while Optimum Moisture Content (OMC) ranged from 10.0% to 16.0%, suggesting the soils require further compaction. CBR values for unsoaked samples ranged from 43% to 84%, indicating good subgrade quality, except for samples 1, 3, 4, 5, 9, 11, and 12. Cohesive strength values were moderate, ranging from 65.0 kN/m² to 80.0 kN/m², with an internal friction angle of 11° to 15°. Based on the AASHTO classification, 7 samples were rated as fair to poor (A-7-5), and 6 samples were rated as excellent to good (A-2-7). Ultimately, only six (6) samples met the Nigerian Federal Ministry of Works and Housing (FMWH) standards for road construction, emphasizing the importance of thorough geotechnical investigation. Results indicate significant variability in soil properties along the Road align, with some sections exhibiting low bearing capacity, high plasticity and suboptimal compaction behavior-conditions that pose challenges to pavement performance and long term structural stability.

Keywords: Geotechnical evaluation, subgrade soil, road construction, California Bearing Ratio, Atterberg limits.

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1 INTRODUCTION

Road network plays a vital role in the socio-economic development and progress of many nations; this aids the linkage of all enterprises/markets and leads to employment

creation, driving trades and equal wealth distribution. Road transport generally dictates the distribution of economic practices across the world (Ajero, 2009). Foundation soils and highway pavements are inseparable duo toward the



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development of any country (Meshida, 2006). However, a good number of engineering structures are often constructed without preceding knowledge of the geology of the area hence leading to the failure and collapse of the structures constructed. In Nigeria, the paucity of information on the geotechnical properties of soils is the bane of most road failures noting that the integrity of the construction material used is as important as other design factors (Habeeb et al., 2012). Salter (1988) reported that the performance of a highway pavement is influenced to a very considerable extent by the subgrade material.

Major Nigerian highways are known to fall shortly after construction and well before their design age. The poor construction materials, bad design, usage factor, poor drainage network are some of the factors responsible for these road failures. Geological factors are rarely considered as precipitators of road failure even though the pavement is founded on the geology. This is due to non-appreciation of the fact that proper design of roads requires adequate knowledge of subsurface conditions beneath the road route. The non-recognition of this fact has led to loss of integrity of many roads (Olorunfemi et al., 2000).

Roads are constructed on geological materials, such as rocks or soils, and the characteristics of these materials affect how well the roads function as transportation routes (Olabode et al., 2019). The primary components of a typical flexible highway pavements, arranged from the bottom to the top, include the subgrade, subbase, base course, and riding surface (Gupta and Gupta, 2003; Adeyemi, 2013). For a material to be used as either a base course or sub-base course depends on its strength in transmitting the axle-load to the sub-soil and or sub-grade (the mechanical interlock). Sub grade soils are native soils beneath any type of construction which have been compacted before the construction of a road, pavement and other structures to withstand the loads above it, while sub base soil are aggregate of material that lies immediately below the pavement of crushed aggregate of recycled materials (Dawson 1995). The degree of success in each case depends on the genetic characteristic of the soils and the specific purpose for which they have been used.

The term ‘soil’ is referred to as a mixture of organic matter, gases, liquids, and organisms that together

support the life of plant, and soil organism (Voroney et al, 2007). Soils are found to change in terms of texture and composition from the top to the parent material at depth. This variation is known as soil profile. The soil profile typical of basement complex is the top soil underlain by the lateritic zone which is underlain by the mottled zone, which is underlain by the saprolite, which is underlain by the sap rock, which is underlain by the fresh bedrock (parent rock). Soil is formed by breakdown of parent rock which can be one or combination of physical, chemical and biological weathering. Soil is important for engineering purposes as the strength and stability of soil greatly affect the design and construction of roads and other infrastructures. The classification of soil is influenced by the soil moisture content present during testing, whether the soil is on the swelling (wetting) path or the drying (desiccation) path (Goracako, 2017; Onyelowe et al., 2020b). Understanding this behavior in clay within lateritic soil is of great importance for hydraulically bound structures because of the inherent and seasonal interactions with moisture (Bui Van and Onyelowe, 2018). Therefore, it is essential to thoroughly study the durability of an environment before design and construction to ensure a comprehensive understanding of the materials being used (Onyelowe et al., 2020; Antench and Yihus, 2019; Zhang et al., 2005). Strength of soil depends on the California bearing ratio.

Sub-grade soil is an integral part of pavement structures by supporting the pavement and hence, must give adequate support and stability under adverse loading condition (Akanbi and Job, 2014). Flexible pavements and the geotechnical properties of laterite subgrade soil can vary depending on factors such as the type of soil, the degree of weathering and the presence of additives or other materials.

Pavements are the actual travel surface specially made durable and serviceable to withstand the traffic load commuting on it. Pavements are the major facilities in road transportation; it presents a platform on which vehicles ply. The Pavement is a fixed facility subjected to impose both momentary and continuous loading. A pavement designed and constructed is required to serve the purpose for which

it was designed throughout its life time with no or little deterioration. That is, it should have adequate surface condition, provide the required service and be efficient in its structural and functional capacity throughout the design life. The overall performance of pavement largely depends on the characteristics of the sub grade soil. Studies have identified that geotechnical pavements are placed in order to meet the highway subgrade or sub base specifications. However, a pavement is said to be defective when it can no longer perform this function during its design life (Ogundipe, 2008).

Frequencies of pavement failures have also been related to the engineering indices of the subgrade materials and the underlying geology. The engineering behavior of the underlying geology has been reported to have been influenced by their mineral compositions (Akpan 2005; Amadi et. al, 2012). Poor geotechnical properties of the soils such as low maximum dry density (MDD), poor bearing capacity, high compressibility, high liquid limit, plasticity index, optimum moisture content (OMC) and California bearing ratio (CBR) are usually responsible for road failures (Akpan 2005; Ademilua 2018). These conditions usually lead to pavement failures in the form of surface deformation and cracked pavements.

However, the suitability of soils as base course or sub-base course and subgrade are in strong relation to the transfer and bearing of axle load which determine the durability, strength and life of roads (Jegede and Olaleye, 2013; Nwankwoala and Amadi 2013). Information about the surface and sub-surface features is essential for the design of structures and for planning construction techniques, and this involve detailed explorations to determine the engineering properties of the soils for different strata (Arora, 2008). Lack of understanding of the soil parameters can lead to the construction errors. The suitability of soil for a particular use should be determined based on its engineering characteristics and not on visual inspection or apparent similarity to other soils (Vincent et al., 2020). Road failure in Nigeria has been recognized by several researchers to be as a result of geotechnical factors, excessive loads, poor construction and inadequate or poor drainage

In most cases, subgrade and sub-base materials on roads and highways are constructed without adequate geotechnical investigation of the soils along highways alignments and borrow pits constructed of several layers of natural granular materials covered with one of more water proofed bituminous surface layer sand as the name implies, is considered to be flexible. The load distribution pattern changes from one layer to another, this in turn provides comfort and easy ride for drivers and passengers.

Different soils have different properties, it then underscores the need to carry out a detailed investigation on the properties of the soil. Geotechnical characteristics and field performance of soil may be interpreted in the light of all or some of the following parameters; the mineralogical composition of the soil which has an influence on the geotechnical parameters such as specific gravity, shear strength, swelling potential, Atterberg limits, bearing capacity and petrographic properties, position in the topographic site, and depth of soil in the profile (Amadi et al., 2012). The characteristics and durability of any construction material especially soil is a function of its efficiency in response to the load applied (Oke et al., 2009b; Nwankwoala and Amadi, 2013). Sherwood and Pike (1984) noted that for proper design of a pavement, geotechnical parameters include the strength, the maximum dry density (MDD), amount of fines (clay and silts) as well as the compaction performance of the proposed highway construction materials must be known.

2 STUDY AREA

2.1 Location and accessibility

The study area is Oru – Ijebu Igbo road in the Southwestern part of Nigeria within the Latitude 06°56'20"N to 06°59'20"N and Longitude 03°56'00"E to 04°00'00"E (Figure 1). The study area is moderately populated, surrounded by settlements such as Awa, Ago-Iwoye, Ilaporu, Imope and Ijebu Igbo and is accessible by network of both major and minor roads as well as footpaths. Oru - Ijebu Igbo road falls within the Pre-Cambrian Basement Complex of Southwestern Nigeria. The relief is moderately low forming ridges in some

places an undulated plain dotted with small isolated hills or hills rocks are noticed generally within Ago Iwoye (Ishola and Olufemi, 2024). The general level of surface rises Northwards from about 0- 500ft above the coast northward to the area of the crystalline rocks (Ishola and Olufemi, 2024). The area has a typical tropical climate with high rainfall of up to 1600 mm, temperature ranges between

21°C–28 °C, and mean monthly relative humidity is less than 70% with thick rain vegetation. It is characterized by two distinct seasons [the rainy season (April–October) and dry season (November–March)]. The average relative humidity is highest in September and lowest in December or January with an average of 8%.

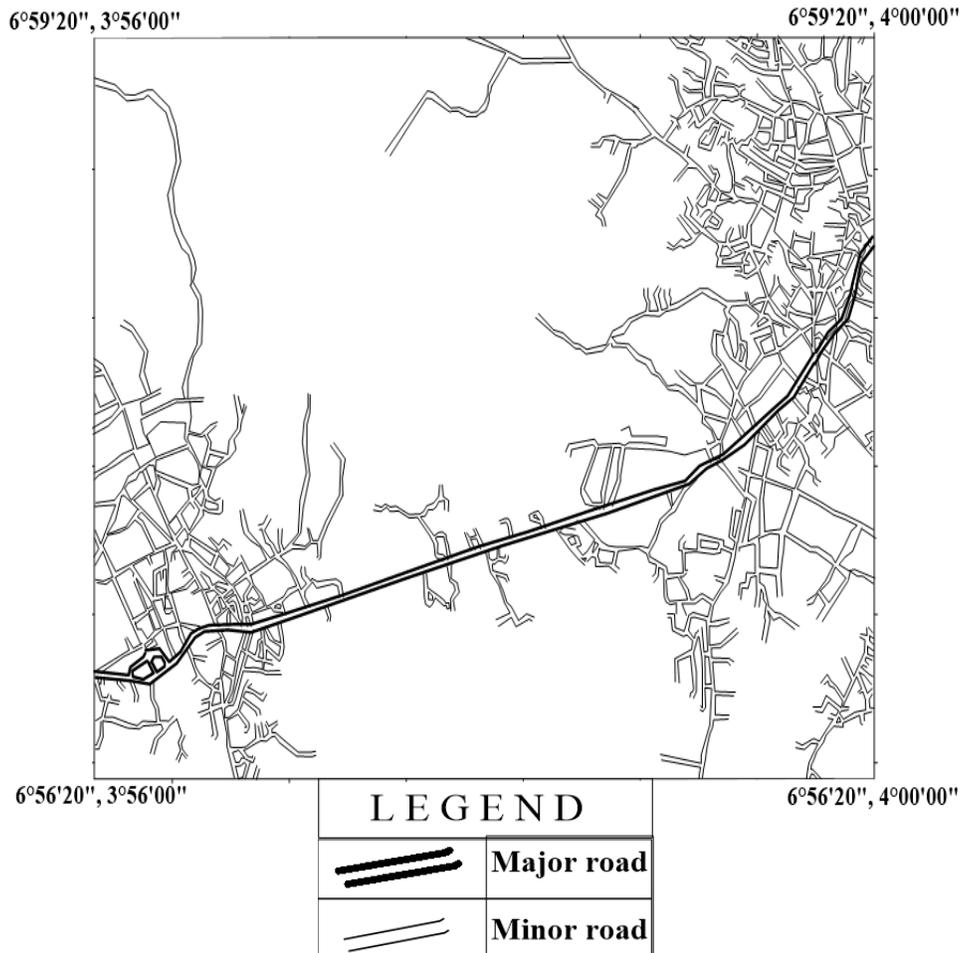


Figure 1.1: A map showing the location and accessibility of the study area.

2.2 Geological Setting

The study area is located within the southwestern part of Nigeria and is underlain predominantly by rocks of the Precambrian basement complex which consists of migmatite, gneisses, schist and quartzite into which has been an emplacement of granitic and,

to a lesser extent, more basic materials (Rahaman, 1988). The predominant rock types in the area of study include granite gneiss, granite, pegmatite and undifferentiated migmatite and these have been intruded by quartz veins and pegmatite veins. (Figure 2).

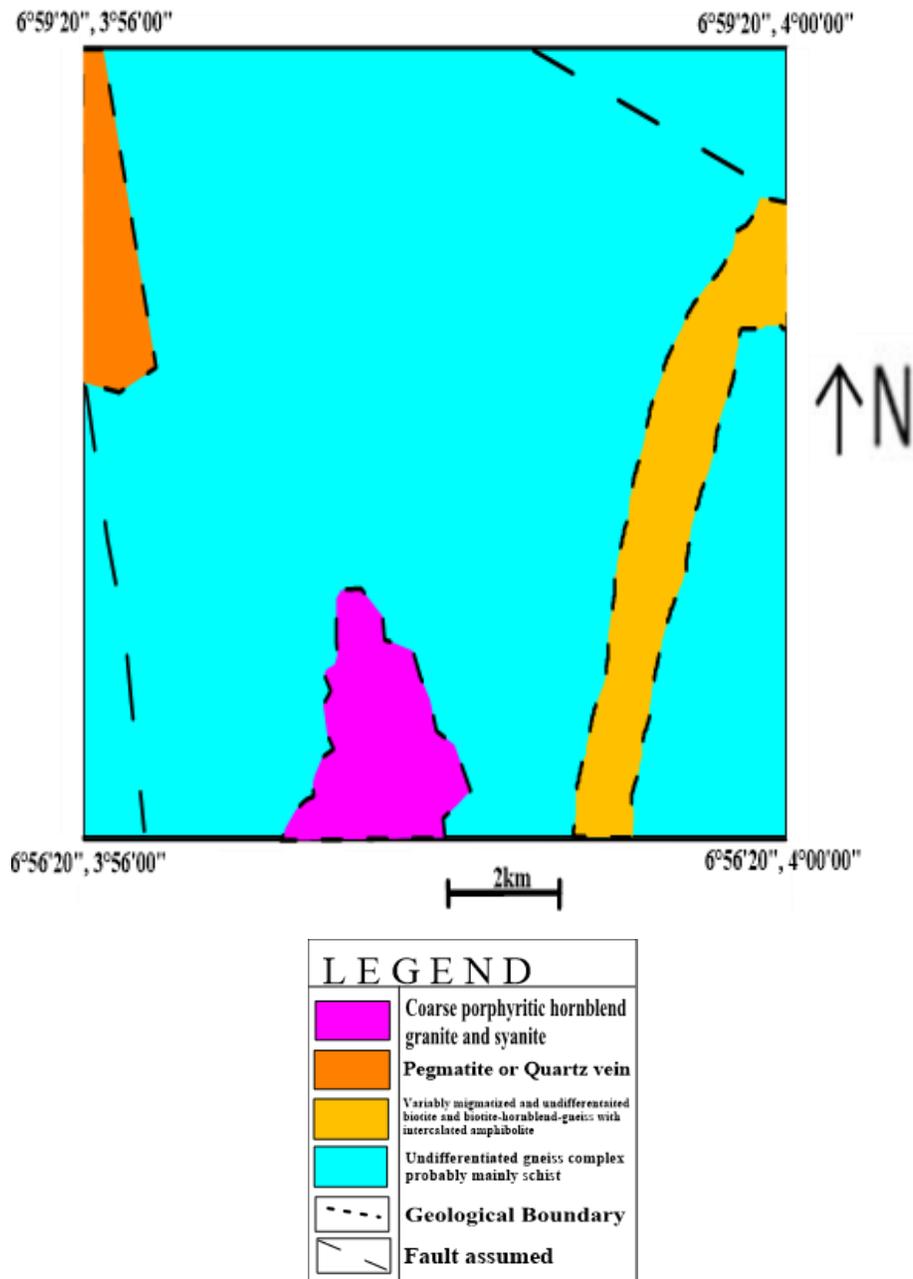


Figure 2: Geological map of the study area (Modified from Adekoya et al., 2017).

3 MATERIALS AND METHODS

The approach utilized in this study includes reconnaissance survey, field sampling, laboratory testing and interpretation of results; all conducted sequentially. The reconnaissance survey was carried out to identify and map out failed sections of the road and also, to determine where samples will be taken. A total of twenty-six samples were gathered, comprising thirteen disturbed soil samples and

thirteen undisturbed soil samples. The undisturbed samples, obtained using 3.5cm in diameter core cutters, were collected first, and followed by the disturbed soil samples, which underwent structural changes, gathered using hand augers. Sampling depths ranged from 0.4m to 1.0m, with 200m to 900m intervals between trial pits, and coordinates were recorded for each sampling point (figure 3). Samples were carefully sealed to prevent moisture

loss and labeled for easy identification. Subsequently, the soil samples underwent the following geotechnical laboratory testing natural moisture content, grain size distribution, specific gravity, Atterberg limits (liquid limit and plastic

limit), California Bearing Ratio (CBR), compaction and shear strength (Triaxial). All the tests were carried out in accordance with British standard code of practice (BS1377:1990) (British Standard, 1990). The samples are represented with L1 to L13.

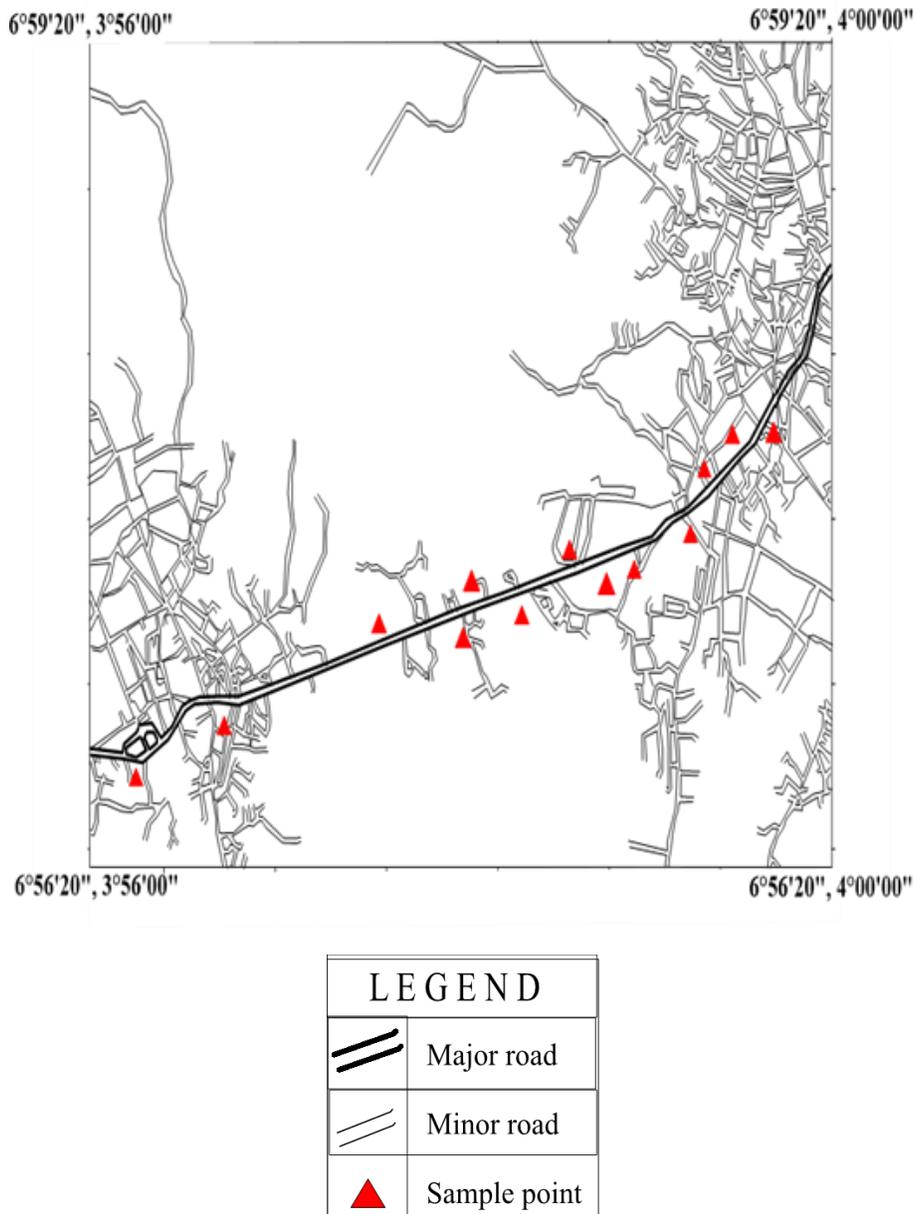


Figure 3: A map of the study area showing sample points.

4.0 RESULTS AND DISCUSSIONS

Table 1: Summary of Laboratory test results of studied soil samples.

Sample No.	Sieve Analysis Test	Compaction	Test	Atterberg	Limit	test	CBR (%)	values
	(% passing)	MDD (kg/m^3)	OMC (%)	Liquid limit (%)	Plastic Limit (%)	Plasticity Index (%)	Soaked	Unsoaked
1	49.0	1782	15.30	43.80	15.0	28.8	24.00	48.00
2	32.0	1873	14.10	43.3	15.0	28.3	34.00	66.00
3	47.0	1789	15.00	43.4	15.0	28.4	27.00	52.00
4	53.0	1776	15.80	44.0	15.0	29.0	22.00	46.00
5	48.0	1785	15.20	43.5	15.0	28.5	28.00	49.00
6	27.0	1881	10.20	42.8	15.0	27.8	42.00	83.00
7	22.0	1884	10.10	42.4	15.0	27.4	45.00	84.00
8	28.0	1887	10.20	42.9	15.0	27.9	43.00	82.00
9	51.0	1781	15.50	44.0	15.0	29.0	21.00	43.00
10	21.0	1886	10.00	42.0	14.9	27.1	47.00	86.00
11	67.0	1770	16.20	46.0	16.0	30.0	21.00	43.00
12	56.0	1773	16.00	44.0	15.0	29.0	26.00	49.00
13	30.0	1875	10.30	43.0	15.0	28.0	44.00	81.00

Table 2: Summary of Laboratory test results of studied soil samples.

Sample No.	Triaxial	shear test	Natural moisture content (%)	Specific gravity
	Angle of internal friction ($^\circ$)	Undrained cohesion (KN/m ²)		
1	12.0	70.0	9.1	2.59
2	13.0	70.0	8.1	2.62
3	12.0	70.0	8.2	2.62
4	12.0	75.0	7.2	2.59
5	12.0	70.0	7.5	2.62
6	14.0	78.0	6.6	2.62
7	14.0	80.0	7.9	2.62
8	14.0	75.0	7.6	2.62
9	12.0	70.0	7.5	2.59
10	15.0	80.0	8.0	2.62
11	11.0	65.0	10.2	2.59
12	12.0	70.0	10.5	2.59
13	14.0	73.0	8.3	2.62

4.1 Grain Size Distribution

Bowles (2012) found that grain-size is one of the suitable criteria of soils for roads, airfield, levee, building, dam and other embankment construction. The grain size distribution is an important evaluation

and classification parameter for highway subgrade and sub-base materials because most road failures due to geotechnical factors result from the shrinking of clay as a result of withdrawal of water and expansion of clay when there is ingress of water. As a result, with other factors being constant, a soil

largely made up of fines (clay and silt size particles) is likely to have worse geotechnical properties as highway subgrade or subbase than a soil largely made up of coarse particles (particles greater than 63 μm). The percentage passing through BS 200 sieve ranges from 21% to 67% with sample from location 10 having the lowest percentage and sample from location 11 having the highest percentage (Table 1). As stated by the Federal Ministry of Works and Housing (2010), for a sample to be used for road construction, the percentage by weight passing of BS 200 sieve must not be greater than 35%. Following this requirement, Samples 2,6,7,8,10 and 13 all pass as good sub grade material for road construction while samples 1,3,4,5,9,11 and 12 does not pass this

requirement. This suggest that the soils are prone to repeated shrinkage and swelling abilities during alternate dry and wet seasons typified of the climatic conditions of the study area. From the grain size distribution curve of samples 2,6,7,8,10 and 13 (Figure 4) are well graded and poorly sorted while having a high fraction of large sized particles while high amount of fines were contained in soil of samples 1,3,4,5,9,11 and 12 (Figure 5) but are poorly graded and well sorted. High amount of the fine grains had been related to abundance of clay content which makes them mechanically unstable. Therefore, they are unsuitable for subgrade and sub-base and base road construction materials.

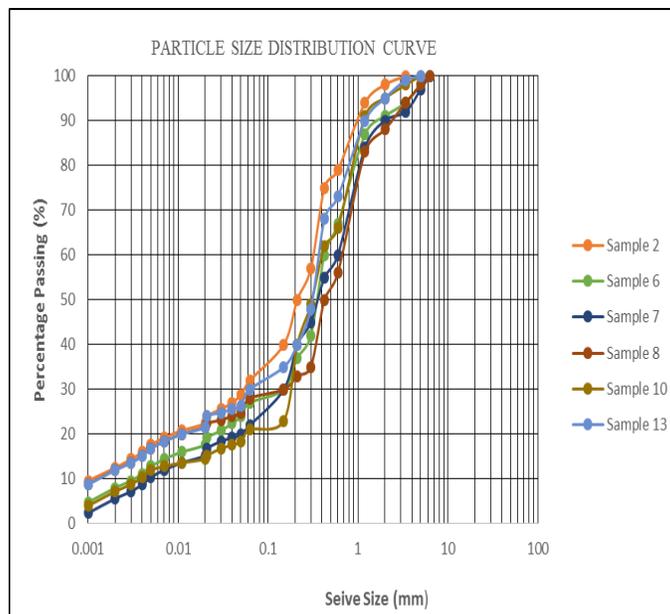


Figure 4: Grain size distribution curve A.

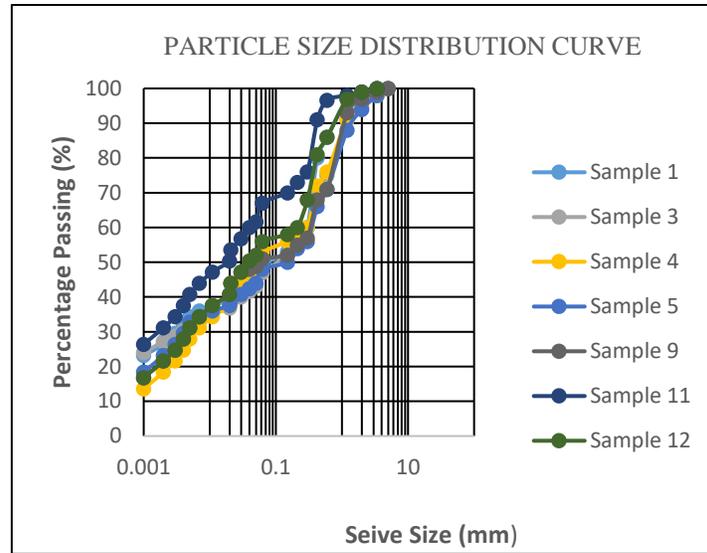


Figure 5: Grain size distribution curve B.

4.2 Specific Gravity

According to Oyelami, (2017), soils with specific gravity between 2.60 and 3.40 have been classified by as laterite soils. In addition to the use of specific gravity on the basis for identification of laterite soils, it has also been found as a useful identification and evaluation index of laterite aggregates for pavements construction, since it correlates well with mechanical strength of soil. An increase in specific gravity has been found to be associated with a decrease in void ratio (Daramola et. al, 2015). These findings have made specific gravity an important parameter in evaluation of soils as subgrade materials, most especially in determining the degree of laterization. The specific gravity values of the studied soils range from 2.59 to 2.62 (Table 2). Soils at locations 2,3,5,6,7,8,10 and 13 all meets the standard minimum value thus implying that they are of lateritic horizon while soils at locations 1,4,9,11 and 12 do not meet the standard and as such are not of lateritic horizon.

4.3 Natural Moisture Content

The natural moisture content of the soil samples range between 6.6% to 10.5% and this can be seen in

Table 1. Samples with high moisture content might not be suitable as subgrade materials for road construction because it's an indication of high affinity for water. Because these values are within the normal range (5-15%) given by FMWH (2010) for engineering construction, all of the soils had significantly low natural moisture contents. This suggests that the soil materials do not have a significant capacity to adsorb water. They are therefore suitable as base, sub-base, and subgrade materials. The sample taken at location 12 has the highest moisture content of 10.5% because the soil particles consist of the higher fine grains (56.0%) than sand (43.0%) and it is very silty therefore it has the greatest affinity of water retention while sample taken at location 6 has the lowest moisture content because it consists more of loosely packed soil particles which has low retention water capability and a lower fine grain percentage of 27.0% and a very high sand particles percentage (64.0%).

The natural moisture content when compared to the optimum moisture content derived from the compaction test using West African Standard, it was observed that all the optimum moisture content values are less than the maximum value (21.0%) and this implies that little moisture will be required to

obtain the OMC. Other factors should also be considered to determine the suitability of the subgrade soil samples.

4.4 Atterberg's Limits

Atterberg's limits estimates the strength and settlement characteristics of soils for road construction. The consistency limits of the soils which relates to the relative ease to which a soil can be deformed based on the relationship or interaction with water are presented in Table 4.4. Soil with high liquid limit could encourage high linear shrinkage (Adeyemi, 2000). The liquid limit value ranged from 42.0% to 46.0% (Table 1). The lowest liquid limit occurred at location 10 and can be considered good for use as sub-grade soil while the highest liquid limit occurred at location 11 and can be considered poor for use as sub-grade soil. For heavy traffic road, for sub base course liquid limit shall not be more than 35% and plasticity index not more than 12% and for light traffic roads, materials for sub base liquid limit shall not be more than 35% and plasticity index shall not be more than 12% (FMWH, 2010). The liquid limits and the plasticity indices of the soil samples in the study area are higher than the Nigerian Federal Ministry of Works and Housing (2010) specifications, therefore soils samples here have poor engineering geological properties and are not suitable as base or sub base materials.

Soils with high plastic limit could lead to road failure when used for road construction. For a light traffic road, soil less than or equal to 50% plastic limit is suitable for use as subgrade. The plastic limit value ranges from 14.9% - 16.0%. The lowest plastic limit occurred in location 10 while the highest in location

11. Soil samples in the study area can be considered good subgrade material for road construction since they fall below the specified limit of 50%.

The plasticity index of the studied soils ranged from 27.1% - 30.0% (Table 1). Soil sample in location 10 has the lowest plasticity index of 27.1% and location 11 has the highest plasticity of 30.0%. Hence, they fall within the range of soil with low cohesion, which will reduce compaction, since the specification for plasticity index for subgrade soil is less than or equal to 12%. The higher the value of the plasticity index, the poorer the value of the soil. The failure of this highway can be inferred from the plasticity index values greater than 12%, which is an indicator of the instability of the pavement. It is advisable to excavate the less stable materials and replace with stable ones.

The Casagrande chart also called the plasticity chart is used to indicate the level of plasticity of the soil with relation to liquid limit. Liquid limit less than 30% indicates low plasticity, between 35% and 50% indicates intermediate plasticity, between 50% and 70% high plasticity, between 70% and 90% indicates very high plasticity and greater than 90% indicates extremely high plasticity (Whitlow, 1995). The Casagrande plot of the studied soil (Figure 6) reveals that all the soils have Liquid Limit (LL), which ranges from 42% to 46%. This implies that the investigated soils fall in the medium plasticity class. The result from the chart also reveals that the soil samples fall above A line meaning that they are clay and simultaneously below U line and thus are residual soils i.e. soils that are found above the parent rock which they were formed and also retain the characteristics of their parent rocks.

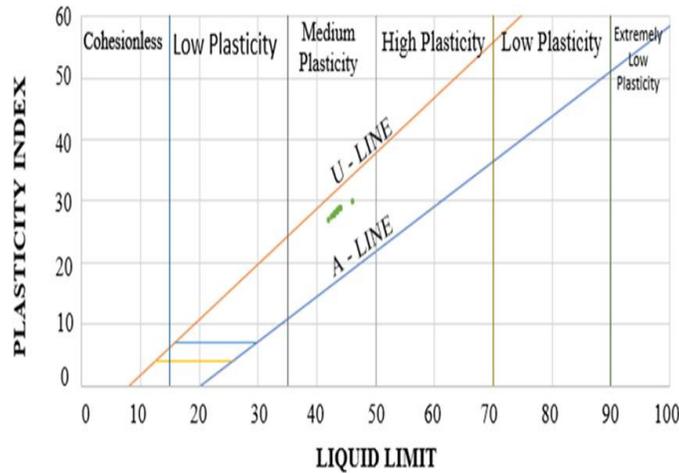


Figure 6: Casagrande chart for studied soil samples

4.5 Compaction

Compaction is used to establish a dry density/moisture content relationship of a soil under controlled condition which can form a standard for comparison with field specifications. According to Bello (2013) soils which are characterized by high maximum dry density and low optimum moisture content are suitable as excellent subgrade soils.

The results for the maximum dry density (MDD) and the optimum moisture content (OMC) for the subgrade samples are shown in table 1. The optimum moisture content for the samples ranges between 10.00% to 16.20% with location 10 having the lowest OMC value of 10.0% and location 11 having the highest OMC value of 16.29%. The maximum dry density ranges from 1770kg/m³ to 1887 kg/m³ using the West African Standard with location 11 have the lowest maximum dry density value of 1770kg/m³ and location 13 have the highest maximum dry density value of 1887kg/m³.

FMWH (2010) standard in Nigeria demands that the dry density of soils in road construction must be greater than 1800kg/m³ while the optimum moisture content must not exceed 15%. From the results,

samples 2,6,7,8,10 and 13 maximum dry density are greater than 1800kg/m³ and the optimum soil content are less than 15% and thus are good soils for road construction. While samples 1,3,4,5,9,11 and 12 have maximum dry density and optimum moisture content less than 1800kg/m³ and greater than 15% respectively and therefore are not suitable for road construction. These values show that, the soils respond gradually to compaction. Therefore, the compaction suggests that the foundation of pavement structures must always be compacted above the MDD and OMC values to yield the maximum strength, prevent ingress of water and distribute wheel loads uniformly into the pavement structures. Compaction increases the shear strength, reduces compressibility and permeability of the soil (Kaniraj, 1988; Apparao and Rao, 1995).

According to O’Flaherty (2001) the ranges of values that may be anticipated when using the standard proctor test methods are: for clay, maximum dry density fall between 1440kg/m³ and 1685kg/m³ and optimum moisture content may fall between 20-30%. For silty clay maximum dry density is between 1600kg/m³ and 1845kg/m³ and optimum moisture content ranges between 15- 25%. For sandy clay

maximum dry density usually ranges between 1750kg/m³ and 2165Mg/m³ and optimum moisture content between 8 and 15%. Looking at the results of soil samples 1,3,4,5,9,11 and 12 it could be deduced that they are silty clay while the results of 2,6,7,8,10 and 13 shows that they are sandy clay.

4.6 California Bearing Ratio (CBR)

The California bearing ratio results obtained in the study area ranged from 21% to 47% for the soaked and 43% to 86% for the unsoaked (Table 1). The lowest CBR value for the soaked which was 21% occurred at location 9 and 11, while the highest value which was 47% occurred at location 10. For the unsoaked, the lowest CBR value occurred at location 9 and 11 which was 43%, while the highest value occurred at location 10 which was 86%.

For the base course, unsoaked CBR must be up to 80% using modified AASHTO or minimum of 30% soaked CBR when using West African Standard Compaction. For sub – base, unsoaked CBR must be up to 80% using modified AASHTO or minimum of 20% soaked CBR when using West African Standard Compaction.

The unsoaked CBR values obtained for samples 6, 7,8,10 and 13 were all above 80% and therefore are good sub grade and sub base materials. The soaked CBR values obtained for samples 2, 6, 7,8,10 and 13 are all above 30% and therefore are good base materials. Sample 1,3,4,5,9,11 and 12 does not meet the required values and as such are not good base materials. Following the West African Standard Compaction, all the samples are good sub base materials.

4.7 Triaxial Shear Strength

The cohesive strength values ranged from 65.0 kN/m² to 80.0 kN/m² and the angle of internal

friction ranged from 11° to 15°. According to Schemartman (1969), 40kN/m² to 75 kN/m² are regarded as firm clay while 75kN/m²to 100kN/m² are considered stiff clay. Soil samples 1, 2,3,4,5,8,9,11,12 and 13 are firm clays and as such, they can be used in construction Soil samples 6,7 and 10 are classified as stiff clay thus implying that they pass as good subgrade material. The higher the angle of internal friction, the better the soil for engineering practices. All soil samples have relatively low angle of internal friction and therefore cannot pass as good subgrade soils.

4.8 Soil Classification

The classification American Association of State Highway and Transportation Officials (AASHTO) is the widely used systems for highway purposes. AASHTO classifies soil samples based on grain size distribution, liquid limit, and plasticity index value. The comparison of these values with the standardized values in table 3 shows that samples 1,3,4,5,9,11 and 12 are categorized as A-7-5 and soil samples 2, 6, 7,8,10 and 13 are categorized as A-2-7. Soil samples under A-7-5 contains clayey soils and the general rating as subgrade is fair to poor and soil samples under A-2-7 contains silty or clayey gravel sand and the general rating as subgrade is excellent to good. Thus, soil samples 1,3,4,5,9,11 and 12 are categorized as good subgrade soils.

According to the USCS classification table (Table 4), soil samples 1 and 8 are well graded sand (SW), soil samples 5 and 3 are silty gravel (GM), soil samples 2,6,7,10 and 13 are silty sand (SM) and soil samples 4,9,12 and 11 are silt (ML); this classification is based on the grain size distribution of each soil sample. Subgrade samples 2,3,5,6,7,10 and 13 are the best due to the high content of sand and gravel.

Table 3: AASHTO (1986) soil classification

General classification	Granular materials (35% or less passing No 200 sieve)											Silt-clay materials (more than 35% passing No 200 sieve)
Group classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7	
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7					A-7-5
Sieve analysis, percentage passing:												
No 10 sieve	50max											
No 40 sieve	30max	50max	51max									
No 200 sieve	15max	25max	10max	35max	35max	35max	35max	36min	36min	36min	36min	36min
Characteristic of fraction passing No 40 sieve												
Liquid limit (%)				40max	41min	40max	41min	40max	41min	40max	41min	41min
Plasticity index (%)		6max	NP	10max	10max	11min	11min	10max	10max	11min	11min	11min
Group index	0		0	0			4max	8max	12max	16max	20max	
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand					Silty soils		Clayey soils	
General rating as subgrade	Excellent to good						Fair to poor					

Table 4: Unified Soil Classification System (USCS)

Major Divisions			Group symbol	Group name
Coarse grained soils More than 50% retained on No. 200 (0.075 mm) sieve	Gravel >50% of coarse fraction retained on No. 4 (4.75mm) sieve	Clean gravel <5% smaller than No. 200 sieve	GW	Well-graded gravel, fine to coarse gravel
			GP	Poorly graded gravel
		Gravel with >12% fines	GM	Silty gravel
			GC	Clayey gravel
	Sand	Clean sand	SW	Well graded sand, fine to coarse sand
			SP	Poorly graded sand

	≤50% of coarse fraction passes No. 4 sieve	Sand with >12% fines	SM SC	Silty sand Clayey sand
Fine grained soils more than 50% passes No. 200	Silt and Clay Liquid limit <50%	Inorganic	ML	Silt

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The results revealed that the gravel range from 1.0 to 12.0%, sands range from 1.0 to 22.7% and fines range from 21% to 67%. Eight out of the samples which are samples 2,3,5,6,7,8,10 and 13 met the requirement of less than 35% passing of 0.075mm which implies that the remaining 5 samples; 1,4,9,11 and 12 do not meet the requirement as suitable sub grade soil for road construction according to the FMWH.

According to Oyelami (2017), a good subgrade soil has specific gravity within the range of 2.60 to 4.60. Results from the specific gravity test shows that the specific gravity of the soil ranges from 2.59 to 2.62. Only samples 2, 3,5,6,7,8,10 and 13 met the specification. According to FMWH, the maximum standard for liquid limit is 35% and 12% for plasticity. The liquid limit, plastic limit and plasticity index all range from 42% to 46%, 14.9 to 16.0% and 2.71% to 30% respectfully. None of the samples met the specification as sub grade soil

Using the (Unified Soil Classification System) USCS, the MDD and OMC ranges from 1770kg/m³ to 1886kg/m³ and 10% to 16.2% According to FMWH, MDD must be greater 1800kg/m³ and OMC must be less 15%. Samples 2,6,7,8,10 and 13 all met this requirement.

Using the AASHTO classification system, samples 1,3,4,5,9,11 and 12 are categorized as A-7-5 and soil samples 2,6,7,8,10 and 13 are categorized as A-2-7. Soil samples under A-7-5 contains clayey soils and the general rating as subgrade is fair to poor and soil

samples under A-2-7 contains silty or clayey gravel sand and the general rating as subgrade is excellent to good. Soil samples classified as A-7-5 might be the cause of the incessant failure along the Oru-Ijebu Igbo road.

5.2 Recommendations

It is recommended that the portions with high percentage of fines should be further compacted, stabilized or stripped and back filled with more competent materials(sand or gravel or both) so as to prevent swelling which occurs when these portions get wet and ultimately damages the road

Adequate geotechnical investigations should be carried out before the construction of roads or highways. Proper drainage systems should be put in place so as to enable the long-term functionality of the road and high-quality materials should always be used in the construction of highways.

Appropriate soil improvement techniques and design considerations to enhance the reliability and durability of future roadworks in the area should be employed.

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