Geotechnical Assessment of the Residual Soils Beneath the Ile-Ife – Ilesha Bypass Road Pavement, Southwestern Nigeria

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ABSTRACT

Soil samples collected along the Ile-Ife – Ilesha bypass road alignment, southwestern Nigeria, were assessed for use as road pavement construction material. Sixteen soil samples collected at depth ranges of 0.50 m to 3.10 m were subjected to index properties test for grain size distribution and Atterberg consistency limits, compaction test, and California Bearing Ratio (CBR) test in accordance with the British Standards (BS) 1377 methods for soil testing. Grain size distribution of the soils revealed that the fine contents percentage passing sieve No. 200 BS ranged from 23.2% to 54.8%. Atterberg consistency limits of the soil samples indicate that the soils are suitable for use as subgrade materials except for Soil Samples 6 and 14 with liquid limits of 51% and 52%, respectively. Only Soil Samples 5, 13 and 15, which exhibited high plasticity met the requirement for use as subgrade/ fill material.

The results of the compaction tests revealed that Soil Samples 2, 5, 12, 13, and 15 had the highest maximum dry density at the corresponding lowest optimum moisture content, hence are the best soil samples for use as sub-grade materials. The results of the CBR test revealed that all the soil samples are not suitable for use as sub-base material except for Soil Samples 13 and 15 with CBR of 40 % and 38 %, respectively; while Soil Samples 5, 12, 13, and 15 with CBR of 14%, 10%, 40% and 38%, respectively are suitable for use as subgrade material. The study concluded that Soil Samples 13 and 15 are suitable for use as sub-base material, while Soil Samples 5, 12, 13 and 15 are suitable for use as subgrade material. Drainage control was recommended to prevent erosion, landslide and ultimate failure of the road pavement.

(Keywords: geotechnical properties, Atterberg consistency limits, grain size distribution, CBR test, soil classification).

INTRODUCTION

Soil is the most plentiful construction material in the world. In many regions it is essentially the only locally available construction material. Soil materials has been used for construction of monuments, tombs, buildings, transport facilities and water retention structures. Soils are derived from the weathering of different geologic materials. The nature of soil formed from a particular weathering process depends on the parent geologic material. A typical example is the clayey soil derived from feldspar rich rocks unlike sandy and silty soils derived from quartz rich rocks soils (Carlson *et. al.*, 2011).

In the use of soil as a construction material, the proper type of soil and method of placement of the soil is essential. Usually, the soil at a site to be developed may not be ideal from the viewpoint of soil engineering. In some cases, the engineer can avoid potential soil problems by choosing another site. He can also remove the undesirable soil and replace it with desirable soil if choosing another site becomes impossible. In the early days of highway construction, this procedure of soil replacement was widely employed especially in highways routed around swamps.

In more recent times, the decision to avoid bad soils was made less frequently. The increase in speed of vehicles forced stricter alignment standards on tracks, highways and runways. With the growth of cities and industrial areas, the supply of sites with good foundation conditions became depleted. Increasingly, the soil engineer is forced to construct at sites selected for reasons other than soil conditions. The consequence of the use of soils with bad foundation condition in highway construction is the problem of road failures which give rise to increased number of road accidents and deaths in most cases (WHO, 2015; Evurani et al., 2020).

Reports have it that death rates from road accident result in about 34 per 100,000 cases. Most of these deaths and injuries resulting to disabilities affect working age population of between 15 and 64 years (World Bank, 2018). The annual death rate from road accident in Nigeria is estimated at over 39,000 (WHO, 2019). Despite several interventions from the Nigerian government in setting up regulations guiding road use, the number of road accident deaths continue to increase.

The World Bank (2018) report suggested amongst other factors that the integration of road safety in all phases of planning, designing and operation of road infrastructure will go a long way in saving lives and bringing development.

This study therefore aims at assessing the engineering properties of the residual soils derived from basement rocks. The assessment will determine the suitability or otherwise of the soil as sub-base and sub-grade materials, and proffer ways of preventing failure of the road pavement.

STUDY AREA

The study area is the Ile-Ife – Ilesha bypass located in Osun State, Southwestern Nigeria. The study area lies within latitudes 7° 29' N and 7° 38' N and longitudes 4° 26' E and 4° 42' E (Figure 1). The road alignment starts at the Ipetumodu end along Ile-Ife – Ibadan highway and terminates at the Ile-Ife – Ibodi – Akure junction. The road alignment bypass Ile-Ife main town, Opa, Alakowe and Osu towns. The road also intersects the Ile-Ife – Ipetumodu road, OAU – Ita-Elewa road, OAU – Tonkere road and the Osu – Iloba road. The road alignment is 29 km long. Osun State in which the study area falls within is characterized by tropical weather condition.

The weather condition is governed by the moist longer south-westerly and shorter north-easterly monsoons. Four distinct climatic seasons occur in the area. The first is the long wet season that runs from mid-March to July, with heavy rainfall and high humidity. The second is the short dry season around August. The third is the short wet season that follows the August break and usually runs from September to November. The fourth is the long dry season that runs from November to March. The average annual rainfall of Osun State is about 60 in (Ayoade, 1975). The topography of the area is gently undulating with occasional bodies of weathered and fresh rocky hills.

The study area is well drained by three major rivers and numerous tributaries. The major rivers include Rivers Opa, Shasha and Osun. The road alignment crosses these rivers at different locations (Fig. 1). The rivers and their tributaries form a dendritic drainage pattern. The tributaries of River Opa is cut across by the road mainly at Ogangi and Kajola.

Osun State is underlain by Basement Complex rocks of the West African craton, in the region of the late Precambrian to early Palaeozoic orogenesis (Rahaman, 1976; Affaton *et. al.*, 1991). The five major rock groups described by Rahaman (1988) occur within Osun State. They include the migmatite-gneiss rock group, slightly migmatised to non-migmatised metasediment and meta-igneous rock group, chanockitic rock group, Older Granite rock group and the dolerite dyke rock group. Rainwater is the major source of water along the road alignment. However, the water table along the road is inferred to be relatively shallow because there is a seepage of groundwater from the contact between biotite schist and the overlying compacted laterite. This was observed at a depth of 1.7 m at kilometer 11.75.

MATERIALS AND METHODS

Sixteen (16) soil samples were collected along the road alignment using geologic hammer, shovel, measuring tape, sacks, markers and tie strings; and each location noted using the Global Positioning System (GPS). Soil samples were collected from both sides of the road alignment and from each change in lithology observed. Soil samples were also collected from two (2) different borrow pits (Soil Samples 13 and 15).

The borrow pits were located some few meters off the road alignment at kilometers 23.65 and 24.70, respectively. About 40 kg of soil samples were collected from each locality at 0.50 m interval to 3.10 m depth below the topsoil for soil classification tests and for determination of the soil strength.

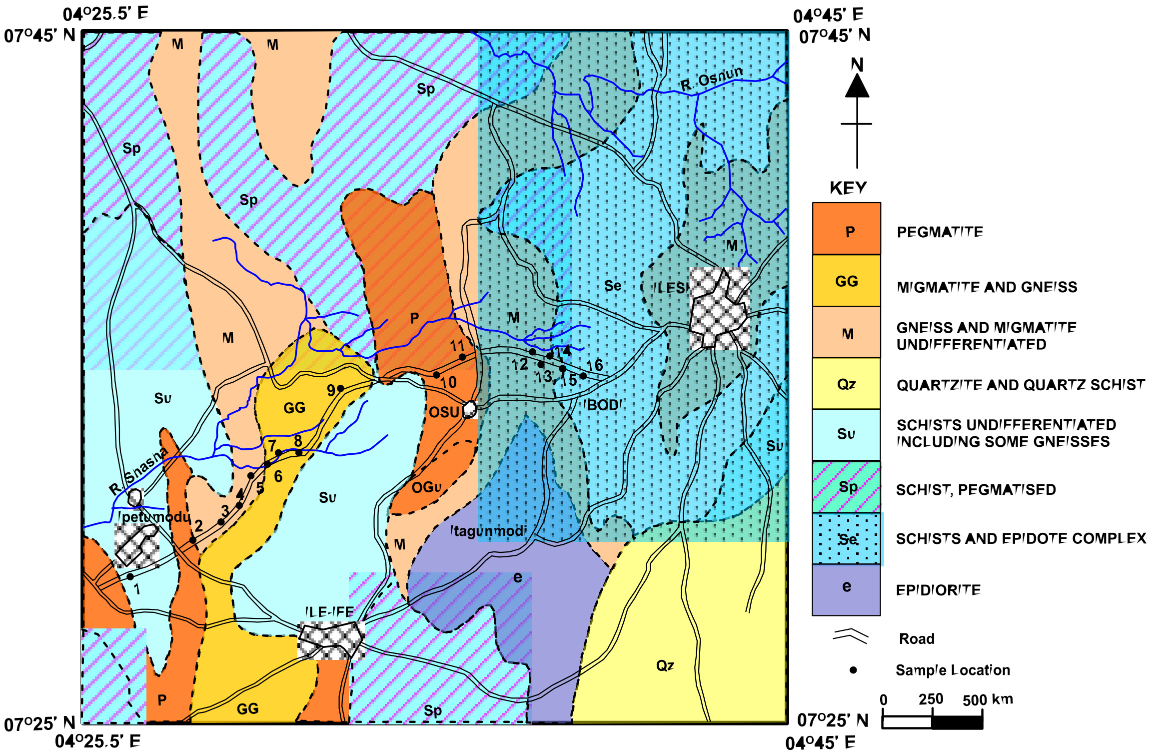

Figure 1: Geologic Map of Ile-Ife and Environs showing Road Networks (Ogunjobi, 2002)

The samples were stored in a sack, labelled and sealed using tie strings. The soil samples and specimens were prepared in accordance with BS 1377 of 1990. Prior to preparing the test specimens, soil samples were tested for moisture content using the moisture content containers, an oven and a weighing balance. The soil samples were thereafter air-dried for two weeks and broken into smaller fragments, with care being taken not to reduce the size of individual particles.

The soil samples were then tested for grain size distribution, Atterberg limits, compaction and California bearing ratio. Both the mechanical sieve analysis and the hydrometer analysis were utilized to determine the distribution of particle sizes for the soil samples. The coefficient of permeability of each of the soil samples was estimated using the Hazen's equation (Equation 1).

$$k = Cd_{10}^2 \quad (1)$$

where, k = Coefficient of permeability (cm. s^{-1})
d_{10} = Effective size (cm)
C = Constant, which may be taken as 100 $cm^{-1}s^{-1}$.

Laboratory Tests

Wet Sieving Grain Size Analysis: 700 g of each air-dried soil was soaked in distilled water for 24 hours. The soil samples were thoroughly washed under running tap water, a little at a time through a 0.075 mm sieve until the water passing through the sieves was nearly clear. The soil material passing through the sieves was collected in a container and left undisturbed for 20 minutes for the silt and clay particles to settle down. The clear water was drained. Finally, fractions coarser than 0.075 mm were oven dried at 105.0°C for 24 hours and then subjected to mechanical analysis.

Mechanical Analysis: The set of sieves were carefully cleaned, and their corresponding weights noted. The oven dried sample with particles coarser than 0.075 mm was sieved through the stack of sieves, with the largest aperture sieve at the top and the smallest aperture sieve at the bottom; having a receiver at the bottom. Ten (10) minutes of shaking was carried out and the amount of soil retained on each sieve was weighed to the nearest 0.01 g.

The percentage of total weight of soil passing through each sieve was calculated using the expression:

% retained on a particular sieve = (weight of soil retained on that sieve/ total weight of soil taken) x 100.

Tests for Atterberg Limits and Indices

Liquid Limit Determination: The liquid limit of each soil sample was determined with the standard Casagrande liquid limit apparatus. About 20 g of air-dried soil passing through a BS sieve 0.425 mm (No. 40) was mixed with water to form a thick homogeneous paste. The paste was placed in the brass cup of the liquid limit device and levelled so as to have a maximum depth of about 10 mm.

The soil in the cup was then cut through the symmetrical axis with a grooving tool. The soil is then subjected to a total of 2 revolutions per second until the groove closes. About 10 g of soil near the closed groove was collected and its water content determined. By altering the water content of the soil and repeating the operations, four readings of water content in the range of 10 to 40 blows were obtained. A graph was then plotted between number of blows, N on logarithmic scale and the water content, w, on the arithmetic scale.

Determination of Plastic Limit: Plastic limit is used to determine the water content at which a soil sample crumbles when rolled into a thread of 3 mm diameter. About 20 g of air-dried soil passing through BS sieve 0.425 mm (No. 40) was used for plastic limit determination. The soil was mixed with sufficient amount of water until it became moldable. A portion of the soil was rolled on a glass plate with the palm of the hand into a thread of uniform diameter throughout its length. Threading and remolding of the soil mixture was repeated until the thread at a diameter of 3 mm began to crumble. Moisture content was carried out on some of the crumbled portion of the threaded soil. The test was done in triplicate with fresh samples and the average moisture content was taken as the plastic limit.

Compaction Test: Compaction is a mechanical means of increasing the density of soil sample. The empty mold was weighed, and a 5.0 kg representative specimen of the soil sample was obtained; crushed into fine particles and then sieved through a No. 4 sieve (4.750 mm sieve). Finally, the compaction test was carried out using the standard procedure.

California Bearing Ratio (CBR) Test: CBR is used to determine the extent to which ingress of water would reduce the strength and increase the volume of subgrade soils. The strength of the subgrade is the main factor in determining the thickness of road pavement. Subgrade strength is expressed in terms of its CBR value. Standard procedure was used to determine the CBR values after soaking the soil sample for 48 hrs to simulate worse field condition. The cylindrical plunger was subjected to a force of 250 N at a uniform rate of 1 mm/min with the dial gauge being in place. The force gauge was recorded at intervals of 0.25 mm penetration up to 3.0 mm. Test results were plotted as graph of the force of the load on plunger against the penetration rate.

RESULTS AND DISCUSSIONS

Grain Size Analysis

The results of the grain size distribution analyses are presented in Table 1, while a typical grading curve is presented in Figure 2. The result shows that the percentage of fines in the subgrade soil range between 23.2 % and 54.8 %. Soils with high clay and silt contents are reported to be susceptible to expansion while soils with low clay and silt contents are not susceptible to expansion. Low clay and silt contents in soils implies that the influx of moisture into the subgrade would not bring about volume changes in the subgrade. Volume changes in the subgrade could reduce the load bearing capacity of the soil, thereby causing unsatisfactory behavior.

Table 1: Results of Grain Size Analysis.

Sample No	Sampled Depth (m)	d_{10} (mm)	d_{30} (mm)	d_{60} (mm)	$C_u = \frac{d_{60}}{d_{10}}$	$C_c = \frac{d_{30}^2}{d_{10}d_{60}}$	K $(\times 10^{-3} cm.s^{-1})$
1	1.5	0.0055	0.0150	0.1800	32.7	0.23	3.03
2	2.0	0.0100	0.0550	0.8000	80.0	0.38	10.00
3	0.5	0.0010	0.0150	0.6000	600.0	0.38	0.10
4	2.1	0.0035	0.0150	0.3500	100.0	0.18	1.23
5	1.8	0.0060	0.1200	3.0000	500.0	0.80	3.60
6	1.9	0.0013	0.0090	0.1900	146.2	0.33	0.17
7	2.2	0.0090	0.0270	0.2300	25.6	0.35	8.10
8	1.6	0.0170	0.1400	0.7000	41.2	1.65	28.9
9	1.6	0.0090	0.0230	0.1800	20.0	0.33	8.10
10	3.0	0.0140	0.0400	0.2000	14.3	0.57	19.6
11	2.0	0.0025	0.017	0.3000	120.0	0.39	0.63
12	1.8	0.0120	0.0150	0.6000	50.0	0.03	14.40
13	2.6	0.0130	0.1500	2.5000	192.3	0.69	16.90
14	1.8	0.0060	0.0220	0.1400	23.3	0.58	3.60
15	3.1	0.0170	0.1200	1.7000	100.0	0.50	28.90
16	1.8	0.0065	0.0200	0.1400	21.5	0.44	4.23

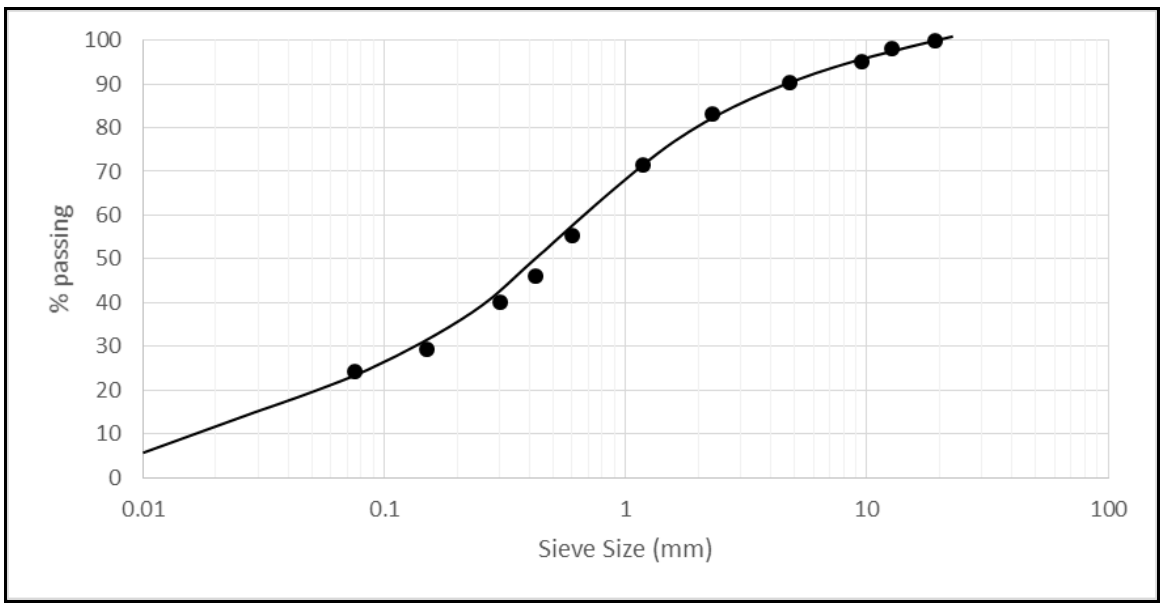

Figure 2: Grain Size Distribution Curve of Soil Sample 8.

Volume change is expected for Soil Samples 1, 6, 10 and 16 with percentage fines 53.7 %, 54.8 %, 50.7 % and 53.3 %, respectively. The permeability characteristics of the soil samples based on the particle size analysis using the Hazen's formula at a constant of 100 $cm^{-1}s^{-1}$ were obtained, although the formula is most appropriate for sandy material where d_{10} is between approximately 0.1 and 3.0 mm (Fetter, 2001). The d_{10} obtained for the soil samples are between 0.0010 mm and 0.0170 mm (Table 1). The results showed that the soil samples have coefficient of permeability between 1.00 x 10^{-4} $cm.s^{-1}$ and 28.90 x 10^{-3} $cm.s^{-1}$ (Table 1), hence are slightly pervious (Bear, 1972). The poor permeability characteristics of the soil samples is attributed to the high clay content of the soil samples with high plasticity index.

Soil Classification

Using the AASTHO classification system, Soil Samples 1, 2, 4, 6, 7, 9, 10, 11, 12, 14 and 16 are classified as clayey or silty clay soils and rated as having fair to poor sub-grade quality. Soil Samples 3, 5, 8, 13 and 15 are silty or clayey gravel and sand and are rated as having excellent to good sub-grade quality. Using the Unified Soil Classification System (USCS), the soils generally classify as either silty or clayey gravel with sand except for Soil Sample 1 which classify as sandy lean clay. The effective grain sizes (d_{10}) ranged from 0.0010 mm to 0.0170 mm (Table 1).

The uniformity coefficient (C_u) obtained for the various soil samples showed exceptionally large values ranging from 14.3 to 500.0 (Table 1). The large C_u reflect the very flat grain size distribution, indicating that the soil samples are all well graded. Well graded soils are usually suitable for construction purposes, but drainage might be problematic.

The coefficient of curvature (C_c) obtained for the soil samples ranged from 0.03 to 1.65 (Table 1). Soils with smooth curves have C_c between 1 and 3, while irregular curves have higher or lower values (Das, 2010). The C_c for the different soil samples indicate that only Soil Sample 8 has smooth curve while the remaining soil samples have irregular curves.

Atterberg Limits

The results obtained for the Atterberg limits tests are presented in Table 2. The results include liquid limits (LL), plastic limits (PL) and plasticity index (PI) of the soil samples. Atterberg limits are used to correlate several engineering properties of soils and make deductions on the suitability of the soils for various purposes. Subgrade materials should have LL ≤ 50 % and PI ≤ 30% while for sub-base, LL should be ≤ 30 % and PI ≤ 12% (Ige, 2010; FMWH, 1992). According to Wright (1986) materials with LL values of 40 % and above and PI value of 10 % and above are considered not suitable for use in pavement design. The LL of the soil samples ranged from 23 % to 52 %, while the PL for the soil samples ranged from 16 % to 35 %. All the soil samples are suitable for use as subgrade materials except for soil samples 6 and 14 with LL of 51 % and 52 %, respectively. Only Soil Samples 5, 13 and 15 meet the requirement for use as sub-base material.

All the soil samples had high LL indicating that the soils are silty or clayey (Table 2). The results of the PL indicate that all the soil samples are plastic. PI ranged from 7 % to 17 % (Table 2). The classification of soils on the basis of PI, Burmister (1949), indicates that all the soil samples are silt or silty clay materials with low to medium plasticity. The soil samples are therefore partly to fairly cohesive (Table 3).

Using the soil classification scheme of Sowers (1979), Soil Samples 1, 6, 10 and 14 have medium plasticity, medium dry strength and exhibit the characteristics of being difficult to crush with the fingers; while Soil Samples 2, 3, 4, 5, 7, 8, 9, 11, 12, 13, 15, and 16 are slightly plastic, slight dry strength and are easily crushed with the fingers (Table 4). The plasticity chart of Cassagrande (1948) shows that Soil Samples 1, 2, 3, 4, 6, 7, 9, 10, 11, 12, 14, and 16 all plot below the A-line and are thus, predominantly silt; while Soil Samples 5, 8, 13 and 15 plot above the A-line and are thus, predominantly clayey soils (Figure 3). The plasticity chart also shows that Soil Samples 1, 2, 3, 4, 7, 9, 10, 11 and 12 classify as ML, which is predominantly silt, medium plasticity soil. Soil Samples 6 and 14 classify as MH, which is predominantly silt, high plasticity soil. Soil Samples 5, 8 and 15 classify as CL, which is predominantly clay, low plasticity soil. Soil Sample 13 classifies as CL-ML, which is clayey silt, low plasticity soil.

Using Sower (1979) assessment of soil properties based on group symbols, Soil Samples 2, 3, 4, 7, 9, 10, 11, 12 and 16, which are ML soils, have good compaction, low compressibility and expansion, poor drainage, fair stability and would require good compression for use as fill material.

Table 2: Soil Characterization.

Sample Location	N7°29.93' E4°26.96'	N7°30.91' E4°28.15'	N7°31.21' E4°28.51'	N7°31.67' E4°29.03'	N7°32.02' E4°29.33'	N7°32.63' E4°30.09'	N7°32.98' E4°30.63'	N7°33.93' E4°31.97'	N7°34.83' E4°32.93'	N7°35.86' E4°34.99'	N7°36.22' E4°36.53'	N7°36.63' E4°37.89'	N7°36.06' E4°38.01'	N7°36.63' E4°38.20'	N7°35.83' E4°48.56'	N7°35.29' E4°39.16'
Sample No.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
Parent Rock	Schist	Pegmatite	Banded Gneiss	Banded Gneiss	Banded Gneiss	Granite Gneiss	Granite Gneiss	Granite Gneiss	Granite Gneiss	Pegmatite	Pegmatite	Banded Gneiss	Banded Gneiss	Banded Gneiss	Banded Gneiss	Schist
% Passing 0.075µm	53.7	39.9	42.8	45.6	28.7	54.8	48.2	24.4	47.2	50.7	49.5	39.7	23.2	49.9	24.9	53.3
Liquid Limit (%)	49	37	40	45	30	51	39	31	38	48	47	37	23	52	28	48
Plastic Limit (%)	33	25	27	30	20	34	26	21	25	32	32	25	16	35	18	35
Plastic Index (%)	16	12	13	15	10	17	13	10	13	16	15	12	7	17	10	13
MDD (mg/m^3)	1.69	1.75	ND	ND	1.90	1.62	1.63	ND	1.69	1.56	1.67	1.78	2.03	1.46	1.99	1.70
OMC (%)	16.4	12.0	ND	ND	11.3	18.2	19.7	ND	12.8	18.0	15.7	11.5	8.4	26.4	10.3	14.5
CBR (soaked %)	1	9	ND	ND	14	4	4	ND	4	4	4	10	40	3	38	7
AASHTO Classification	A-7-5	A-6	A-2-6	A-7-5	A-2-4	A-7-5	A-6	A-2-4	A-6	A-7-5	A-7-5	A-6	A-2-4	A-7-5	A-2-4	A-7-5
USCS Classification	CL	ML-GM	ML-GM	ML-GM	CL-GC	MH	ML-GM	CL-GC	ML-GM	ML	ML-GM	ML-GM	CL-ML	MH-GM	CL-GC	ML
Description of material	Greyish sand	Brown sand	Reddish brown sand	Whitish sand	Reddish brown sand	Reddish brown sand	Reddish brown sand	Reddish brown sand	Reddish brown sand	Reddish brown sand	Yellowish brown sand	Reddish yellow sand	Reddish brown sand	Reddish brown sand	Reddish brown sand	Reddish brown sand

ND: Not Determined

Table 3: Classification of Soil Based on Plasticity Index (Burmister, 1949).

Plasticity Index (%)	Soil Property	Soil Type	Cohesiveness
0	Non-plastic	Sand	Non-cohesive
1 – 5	Slightly plastic	Silt	Partly cohesive
5 – 10	Low plasticity	Silt	Partly cohesive
10 – 20	Medium plasticity	Silty clay	Fairly cohesive
20 – 40	High plasticity	Clay	Cohesive
>40	Very high plasticity	Clay	Very cohesive

Table 4: Characteristics of Soils with Different Plasticity Index (Sowers, 1979).

Plasticity Index (%)	Classification	Dry Strength	Visual-Manual Identification of Dry Sample
0 - 3	Non-plastic	Very Low	Falls apart easily
3 - 15	Slightly plastic	Slight	Easily crushed with fingers
15 – 30	Medium plastic	Medium	Difficult to crush with fingers
>30	Highly plastic	High	Impossible to crush with fingers

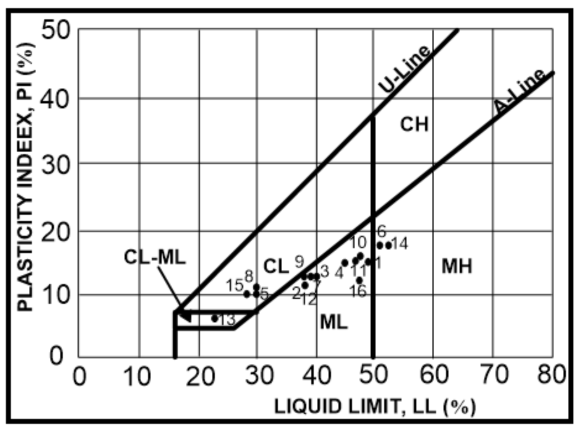

Figure 3: Plasticity Chart of Soil Samples.

Soil Samples 6 and 14, which are MH soils, have fair to poor compaction characteristics, high compressibility and expansion, poor drainage, fair stability and would require good compaction for use as fill material. Soil Sample 4 which is classified as CH has fair to poor compaction, very high compressibility and expansion, no drainage and it is unstable, thus, not suitable as a fill material. Soil Samples 5, 8, and 15, classified as CL and Soil Sample 13, classified as CL-ML have good compaction, slight to medium compressibility and expansion, no drainage and has good stability, thus it is suitable for use as fill material.

Compaction

Thirteen of the soil samples were subjected to compaction test. The results of the compaction tests (West African Level) show that the soil samples all have generally high values of maximum dry densities (MDD) ranging from 1.46 mg/m^3 to 2.03 mg/m^3 at corresponding optimum moisture contents (OMC) ranging from 8.4 % to 26.4 %, Table 2.

Figure 4 is a typical compaction curve for Soil Sample 9. Compaction increases the density and shear strength of soil and decreases the compressibility and permeability of the soil. There is a variation in the OMC and MDD values in the soil samples (Table 2), reflecting the influence of compaction on the soil sample before moisture – density relationships of the soils were determined. The results show that Soil Samples 2, 5, 12, 13, and 15 have the highest MDD at the corresponding lowest OMC, hence they are the best soil samples for use as sub-grade materials.

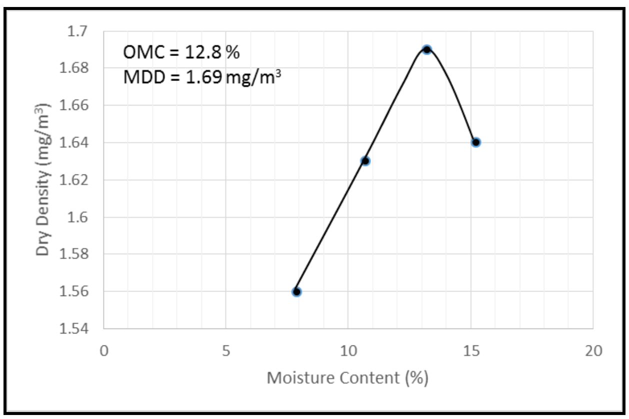

Figure 4: Compaction Curve for Soil Sample 9.

California Bearing Ratio (CBR)

The results of the CBR test are presented in Table 2. The CBR (soaked) for the subgrade soil samples range from 1% to 40%. The minimum CBR requirements for materials to be used for sub-base and subgrade in the construction of highway pavement are 30% (soaked) and 10% (soaked), respectively (FMWH 1992). All the soil samples are not suitable for use as sub-base material except for Soil Samples 13 and 15 with CBR of 40% and 38%, respectively. Again, all the soil samples are not suitable for use as subgrade material except for Soil Samples 5, 12, 13, and 15 with CBR of 14%, 10%, 40%, and 38%, respectively.

CONCLUSIONS

Soil samples collected along the Ile-Ife – Ilesha bypass road alignment were assessed for use as road pavement construction material. Grain size distribution of the soils revealed that the fine contents percentage passing sieve No. 200 BS ranged from 23.2 % to 54.8 %. On the basis of the Atterberg consistency limits, all the soil samples were suitable for use as subgrade materials except for Soil Samples 6 and 14 with LL of 51% and 52%, respectively.

Only Soil Samples 5, 13 and 15, which exhibited high plasticity met the requirement for use as subgrade/ fill material. The results of the compaction tests revealed that Soil Samples 2, 5, 12, 13 and 15 had the highest MDD at the corresponding lowest OMC, hence they are the best soil samples for use as sub-grade materials. The results of the CBR test revealed that all the soil samples are not suitable for use as sub-base material except for Soil Samples 13 and 15 with CBR of 40 % and 38 %, respectively; while Soil Samples 5, 12, 13, and 15 with CBR of 14%, 10%, 40% and 38%, respectively are suitable for use as subgrade material. The study concluded from the results of grain size distribution, Atterberg consistency limits, compaction and CBR tests that Soil Samples 13 and 15 are suitable for use as sub-base material, while Soil Samples 5, 12, 13 and 15 are suitable for use as subgrade material.

RECOMMENDATIONS

The following recommendations will improve the performance of the road alignment:

1. Compaction should be carried out at OMC and MDD. In a situation where execution of the project spans through wet and dry seasons, care should be taken to ensure that moisture variation is controlled;

2. Adequate drainage should be provided. The high rates of runoff due to slope effect should be taken into consideration by making provision for the construction of bridges,

gutters, culverts and discharge systems as appropriate;

3. Slopes in areas of deep road cuts should be stabilized to avoid possibilities of erosion and landslides. These could be avoided by planting of grasses on the slopes and the construction of concrete walls against slopes;

4. Geophysical investigation of the area should be carried out for a more accurate depth to bedrock and water table of the area;

5. Stone aggregates for use in the construction should be subjected to a compressive chemical analysis. This is to ensure that it does not contain organic/ unsuitable mineral materials which will enhance crystalline deformation. Washing of stone is a cheap way of getting rid of unsuitable organic matter. Hence, strict quality control is recommended in quarrying and processing of stone aggregates; and

6. It is also recommended that the weathered derivatives of the pegmatitic intrusions should be subjected to X-ray diffraction. This will enable a classification of the clay types and abundance to be determined.

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