GEOTECHNICAL INVESTIGATION OF RED TROPICAL SUBGRADES IN SOME FAILED ROAD SECTIONS ON BENIN TECHNICAL COLLEGE AND TEXTILE MILL ROADS IN PARTS OF EDO STATE IN SOUTHWESTERN NIGERIA

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Abstract: Incessant occurrence of road pavement deterioration and building collapse, mainly because of their poor geotechnical and mechanical properties has made it imperative for a proper understanding of the geotechnical properties of soils. Six (6) soil samples were collected along the Benin Technical College road and Textile mill road and were subjected to various Geotechnical tests to ascertain the reasons for failures. The tests conducted are Moisture Content, Particle size distribution Specific Gravity, Atterberg Limits, Compaction, California Bearing ratio (CBR) as specified by the British Standard BS1990 and Federal Ministry of Works. The results showed that the soils were ML/ CL according to the Unified Classification System. The Compaction of the soil between 1.58g/cm3 to 1.72g/cm3, Maximum Dry Density (MDD) 15.9 to 17.1%and Optimum Moisture Content (OMC) 15.1 to18% while the California Bearing Ratio (CBR) for unsoaked 5.9 to 23 and soaked is 2.5 to 16.7. These result shows how unsuitable the soil is for subgrade and one of the causes of the detoriation and failing of the road in these locations but if they are to be used as subgrade and subbase material, the soils should be stabilized chemically, mechanically or reworked.

Keywords: Red tropical, subgrade

Introduction

In a tropical area such as Nigeria, that is in a phase of infrastructural development, red tropical soils have been, and are still a topic of interest and discussion. Due to the natural relative abundance of these soil type, availability, and favorable engineering properties, they have been very useful for road construction. Red tropical soils are formed insitu by chemical weathering and may be found on rock level surfaces where action of elements has produced a soil with little tendency to move i.e. it holds the position of their formation without transporting, just above the parent rock. They can also occur whenever the rate of breakup of rock exceeds the rate of removal of soil. Tropical soils can also be said to be given the characteristic red to brown colour form by chemical weathering under warm, humid tropical conditions when rain water leaches out the soluble rock material leaving behind the insoluble hydroxides of iron and aluminium. This prolonged weathering process produces a wide variety of tropical soils in thickness, grade, chemistry and mineralogy. They also vary significantly according to their depth and host rock. Red tropical soil formation is favoured in low topographical reliefs of gentle crests and plateaux which prevent erosion of surface cover.

Red tropical soil is a residual ferruginous clay-like deposit which generally occurs below a hardened ferruginous crust or hardpan. In Benin-city, most of these red tropical soils are used as subgrades and we know that subgrades serve as the foundation for the highway pavement in providing a platform for the construction of subsequent layers and to provide adequate support for the pavement over its design life. Hence longevity of the road is dependent on the strength and durability of the road makeup. It is confirmed that most road failures can be ascertained to poor soil properties as well as negligence of road maintenance, inadequate design and bad workmanship. This research is intended to determine the likely cause of poor road performance of study areas.

Study Area

The Study areas falls in Benin city, Edo State which is in the Egor Local Government area with Longitude 6° 22'30'' N to 6° 23'50'' N and Latitude 5°36'40'' E to 5° 37'55''.

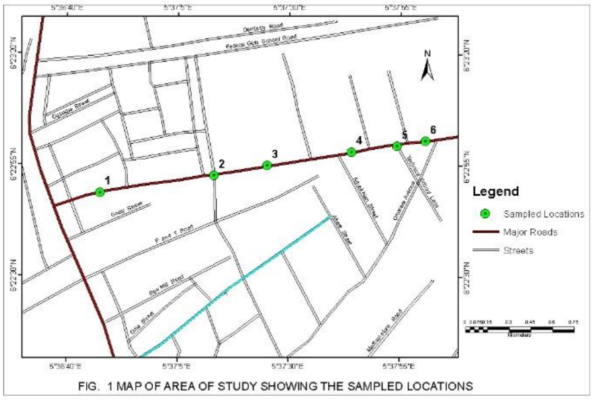

FIG. 1 MAP OF AREA OF STUDY SHOWING THE SAMPLED LOCATIONS

Figure 1: Geology of Study Area

Table 1: Typical Stratigraphic sequence of the Benin region after (2).

Sedimentary Unit	Lithologic description
Drift/Top soil	Loose Light Gray-Dirty white Sands, Silts, and Mudflows.
Alluvium(Only at River Banks)	Light Gray-Brown-Dirty White Sands, silts, clays gravel and pebble.
Benin Formation	Top reddish brown clays sands, crapping thick sequences of poorly bedded friable-loose sands gravelly-pebble sands and pinkish- white clay stingers.
Asaba-Ogwashi(Azagba-Ogwashi Formation)	Dark gray-woody clays, alternating with dark clay and lignite

The lithostratigraphy of the Benin Formation (Miocene-Recent) is characterized by 90% sand, conglomeratic gravels (pebbles and cobbles), clays, peat and lignite (infrequent;, occurring as beds or dispersed fragments) deposited in a continental coastal plain (fluvial) depositional setting (3). The sands of the Benin Formation are dominantly coarse grained; poorly to moderately sorted, sub angular – to well rounded, generally loose (although weakly to moderately cemented in some areas) becoming progressively finer with abundant clay, some peat/ lignite and ferruginous bands towards the top, which is commonly reddish due to Fe-oxide coating. From the aforementioned, the textural properties of the Benin sands resulted in good petrophysical/ aquifer characteristics (porosity and permeability). The sands of the Benin Formation is the most productive aquifer in the Niger- Delta Basin (2)

Methodology

Field work was conducted using traverse method to access sample locations and they were collected 400m interval and 4m deep. The Instruments used were the Global positioning system (GPS), hand auger, shovel, measuring tape and sample bags. A total of six (6) samples were collected and subjected to Geotechnical analyses. The samples were put in sample bags to keep the moisture intact.

Laboratory Analyses

The samples collected were sent to the Laboratory for the following analyses.

1. sieve analysis(particle size)
2. Atterberg limits test (Liquid Limit, Plastic limit and Shrinkage Limit),
3. Bulk and dry density,
4. soil compaction test,
5. specific gravity test and ,
6. California bearing ratio.

These analyses were carried out at the Civil Engineering Department Laboratory of University of Benin, Benin-City in accordance with B.S. 1377(4). Compaction was done with the West African standard.

1. Particle-size analysis was done with a combination of wet sieving and hydrometer method. The sieves were arranged in order of reducing aperture. (100g each of the soil samples was used throughout the analysis). The set of sieves were placed on the mechanical shaker accompanied by a jarring action for 5 minutes for proper sieving of the soil sample. The mass of soil sample retained on each sieve was recorded against the sieve aperture size on a semi-log graph together with percentage fines (known as particle size distribution curve). The general slope has the shape of the distribution and it is described by means of some constants such as effective sizes D_{10}, coefficient of uniformity (*Cu*) and coefficient of curvature (*Cc*) which was calculated to determine the grading of soil. For a material to be well graded it must fulfill one or all of the following: the *Cc* is between 1.0 and 3.0; and or *Cu* must be greater than 5.0. Otherwise it is poorly graded.

2. The moisture content test was used to determine the water content of the soil. It is expressed as a percentage of the weight of water to the dry weight of the soil. A known weight of sample about 50grams was taken out of the preserved samples from the field and weighed. The sample was oven dried at a temperature of about 110^0C for about 24 hours

3. Specific gravity is the ratio of the weight of a substance to that of an equal volume of water. The specific gravity is dimensionless. The specific gravity for water is 1. Apparatus used are conical flask, distilled water and measuring scale Soil sample which was air-dry weighed 150g after which it was filled with distilled water. The pycnometer with the water was weighed and then bottle was then emptied and dried. The oven dry samples were introduced into the bottle, the soil was stirred with a glass rod in order to allow trapped air to be released. Sufficient air-free distilled water was added so that the soil in the bottle is just covered then weighed. The specific gravity is the ratio of the unit weight of soil particles to the unit weight of water at some known temperature (usually 400C). The specific gravity of soil is generally between 2.50 and 2.90 for sand is 2.63; silt is 2.70 and 2.90.

4. The Atterberg Limit test, also known as the Consistency Limit Test is used to determine the effect of moisture content on fine grained soil. It defines the boundaries of several state of consistency of plastic soil. It is used to determine the plasticity of soil. Liquid limit, plastic limit, plasticity index, liquidity index, shrinkage limit and relative consistency are some parameters determined through Atterberg limit. These parameters help to determine the plasticity and clay content of a soil sample. The liquid limit test was carried out using the Cassagrande method.

5. Compaction tests are carried out with the aim of determining the moisture density relationships and change in soils, increase unit weight, shear strength, reducing permeability. This makes the soil less susceptible to settlement under load, especially repeated loading. A number of methods have been developed for this purpose. These include the standard compaction method (also called proctor method), the modified (The American Association of State Highway and Transportation Officials) AASHTO method and the vibrating hammer methods. This is usually done by mechanical means. 2.5kg method of compaction was used for this test. The apparatus consists of 2.5kg rammer, a known volume of mould with removable base and a detachable collar. Three kilograms of air-dried soil was used for the test and the test was repeated five times for each sample. The moisture content used was between 4% - 20% of the weight of the sample, and samples were mixed thoroughly before compaction. Three layers of compaction were done for each trial and 25 blows were used to compact each layer. Graphs of dry density, ρ_d against moisture content were plotted to determine the optimum moisture content.

6. The California Bearing Ratio is used for evaluating the suitability of subgrade and materials used in subbase and base course for road construction. The sample was air-dried soil and mixed with about 5% of its weight of water (determined from optimum moisture content). This was put in C.B.R mould with a diameter of 150mm and 175mm in height in 3 layers with each layer compacted with 25 blows using 2.5kg hammer at drop of 450mm (standard proctor test). The compacted soil and the mould was weighed and placed under C.B.R machine and a seating load of approximately 4.5kg was applied. Load was recorded at penetration of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, and 7.0 mm. The values of load on the plunger multiplied by the proving ring constant were plotted along the vertical axis (ordinate) and their corresponding value of penetration of the plunger in millimeter along the horizontal axis. Values were plotted for the test on both top and bottom of soil samples for unsoaked and soaked soil sample. Soaked condition is to try to simulate

the worst conditions in the field and to achieve this condition the soil samples were submerged in water for 4days. Unsoaked conditions are the normal field condition, and as such the moulding water content is equal to the equilibrium water content which the soil is likely to attain after construction of pavementRESULTS AND DISCUSIONS

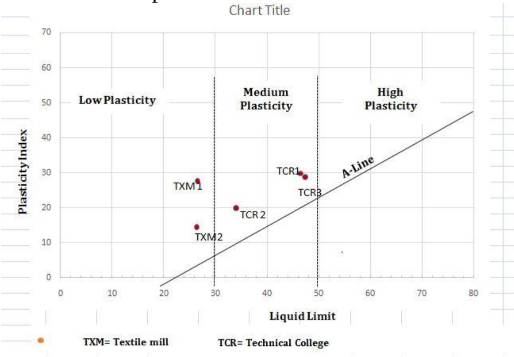

Figure1: The Cassagrande Plasticity chart for sampled areas

Table 2: showing plasticity Index

Soil Properties /soil samples	**TXM1**	**TXM2**	**TCR3**	**TCR 4**	**TCR5**
LL	50.40	32.70	46.93	36.25	47.13
PL	22.92	18.31	18.23	16.51	17.22
PI= LL-PL	27.48	14.39	28.70	19.74	29.91

From figure 1 we can see that the soils fell above the A-line indicating that it's an inorganic clayey material (5). Also, they fall within the low plasticity for textile mill and Technical junction was within medium / intermediate plasticity indicative of slight swelling.

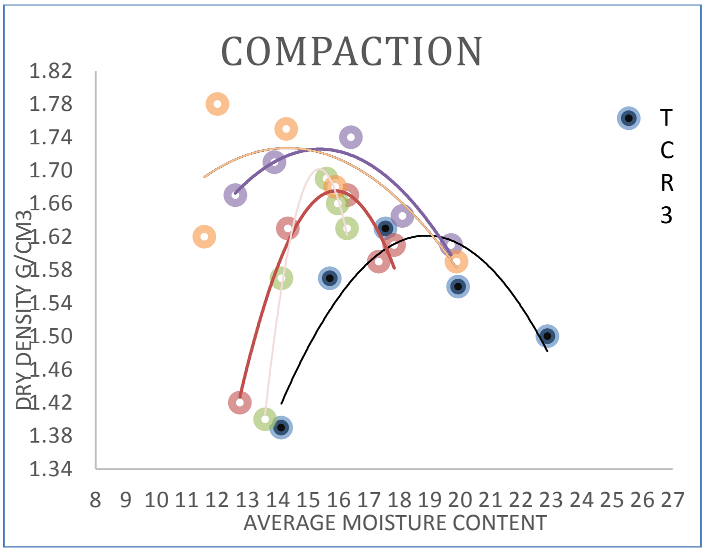

Figure 2: Compaction Analysis

Table : Compaction Results

Properties /soil samples	**TXM1**	**TXM2**	**TCR3**	**TCR 4**	**TCR5**
MDD(mg/m^3)	1.48	1.81	1.71	1.71	1.63
OMC(%)	12.33	15.47	15.1	15.4	17.4

The optimum moisture contents (OMC) of the test samples ranged between 12.33% and 17.6%, while the maximum dry density (MDD) was between 1.48kg/dm3 and 1.74kg/dm3 respectively. The samples all had low OMCs and high MDDs and this meets the criteria for the Federal Ministry of Works. The importance of compaction test is to determine how to improve the desirable load Bearing Capacity of the soil.

California Bearing ratio

According to Federal Ministry of Works and Housing FMWH (6) CBR should be 80% (unsoaked) for base, 30%(unsoaked) for subbase and 10% (unsoaked) subgrade respectively. The soils for unsoaked were between7-26% and 4-17% . these shows mostly the textile mill is better subgrade than Technical college road but are not suitable for subbase.

Table3: Summary of Results for Geotechnical properties of sampled soils

Properties /soil samples		**TXM1**	**TXM2**	**TCR3**	**TCR 4**	**TCR5**
G_s		**2.36**	**2.43**	**2.19**	**2.17**	**2.22**
ATTERBERG LIMITS	**LL**	**50.40**	**32.70**	**46.93**	**36.25**	**47.14**
	PL	**22.92**	**18.31**	**18.23**	**16.52**	**17.22**
	PI	**27.48**	**14.39**	**28.70**	**19.74**	**29.91**
MDD(mg/m^3)		**1.48**	**1.81**	**1.71**	**1.71**	**1.63**

OMC(%)		**12.33**	**15.47**	**15.1**	**15.4**	**17.4**
CALIFORNIA BEARING RATIO	**unsoaked top (2.5mm)**	**12.222**	**16.351**	**13.461**	**14.865**	**13.626**
	unsoaked bottom (2.5mm)	**8.92**	**15.61**	**17.76**	**25.19**	**8.26**
	unsoaked Top(5mm)	**10.412**	**17.646**	**14.632**	**15.947**	**13.755**
	Unsoaked Bottom(5mm)	**7.179**	**15.180**	**20.112**	**23.564**	**7.398**
	soaked Top(5.0mm)	**10.325**	**4.707**	**7.598**	**7.598**	**10.818**
	soaked Bottom(5.0mm	**4.129**	**15.856**	**14.617**	**14.617**	**6.524**
	soaked top(2.5mm)	**9.864**	**4.822**	**8.713**	**8.713**	**9.754**
	soaked Bottom(2.5mm	**5.699**	**15.234**	**16.714**	**16.714**	**6.905**
%<200 Sieve size		**35.10**	**26.03**	**36.09**	**41.11**	**48.78**
AMC		**12.39**	**12.54**	**10.86**	**16.38**	**15.23**

According to American Association of State Highway Officials (AASHTO) soil classification systems, the soil samples fall under A-7-6.

Plate 1: Failed road portion Technical college road   plate2: Failed road portion Textile mill road

Conclusion

The soils from the sampled area the textile mill road shows that

1. it was suitable for subgrade but for longevity, they needed to be enhanced
2. Also, the materials probably used as subbase may likely be of low quality

while the Technical college road showed

1. it wasn't suitable for subgrade having a medium plasticity with an average of 50% clay. This is evident in the failed road portion (Plate1)
2. Increase the subgrade strength by introducing with a known subgrade soil or Enhancing the sub base by adding a base
3. Creation of Drainage (gutters) to support the longevity of the road

There should be a maintenance of the road yearly.

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