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A Review on Geotechnical Properties of Soil Profile

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Abstract: ***The geotechnical properties and litho-stratigraphic soil profile of soils in Ikole area of Ekiti State were investigated from the analysis of results of laboratory tests on disturbed and undisturbed soil and water samples obtained from 3 borings. The investigation revealed a subsurface stratification made up of reddish brown granitic clayey sand from existing ground level to a depth of 9m to 12.0m. This is underlain by a layer of mottled, brown, decomposed micaceous sand to a depth of 16.5m - 18m immediately after which are layers of mottled grey, decomposing quartzite sand to about 18.0m to 19.0m depth. This is further underlain by fragments of freshly weathered granitic rock to the termination depth of 19.5m. The consistency limits indicate LL of 44 – 58% and PL of 18 – 26% while the quick undrained triaxial tests indicate undrained cohesion within the range (128.4 - 157) kN/m2 and undrained angle of internal friction (15.0 - 20.0)0. Groundwater was encountered between 6.5m to 7.5m below the existing ground level during the course of soil exploration. The water in the area has pH values of 5.79 to 7.05, the chloride content values range between 12.0mg/l and 16.0mg/l while sulphate content varies from 6.12mg/l to 7.10mg/l.***

Keywords: Geotechnical Properties, Classification Characteristics, Strength Characteristics, Soil Profile, Southwestern Nigeria**.**

1. Introduction

A good knowledge about a site including its subsurface conditions is very important in its safe and economic development. It is therefore an essential preliminary to the construction of any civil engineering work such as roads, buildings, dams, bridges, foundations, etc, Adeyeri (2015). Unfortunately in developing countries like Nigeria only few investors in the construction industry take time to execute subsoil investigation prior to commencement of construction activities on their projects. The result is the disastrous consequences such as failure or collapse of buildings and other massive engineering structures which often cause untold hardship and damage and sometimes even loss of lives and properties. Many attempts have been made of recent to study the geotechnical properties of soils around Ekiti State in Southwestern Nigeria (Bayowa et al., 2014, Okunade, 2007; Oladapo and Ayeni, 2013; Owolabi and Aderinola, 2014; Talabi et al, 2013; etc). However, no previous attempt has been made to investigate the soil geotechnical properties and soil litho- stratigraphic sequence in Ikole Ekiti area of Ekiti State, Nigeria. Therefore, it is the aim of this research to evaluate the profile and geotechnical properties of soils in Ikole Ekiti Area of Ekiti State, Nigeria. (This will subsequently consolidate the data requirement for a web-based geotechnical database management system for Nigerian soils as proposed by Okunade (2010).)

2. Study Area and Its Geology

The study area is situated at Holy Apostolic Nursery/Primary School, Ootunja, Ikole Local Government Area (L.G.A.) of Ekiti State in Southwestern Nigeria. It can be accessed through a network of roads most especially Oye-Ilupeju-Itapa-Osi-Ikole, Ado-Ijan-Iluomoba-IjeshaIsu-Ikole and Omuo-Ikole roads. Ootunja is one of the twenty four towns and villages constituting Ikole L.G.A., (www.ekitistate.gov.ng). Ikole is located between latitude 7.47’0^0N 5.31’0^0E and 7.78333^{0}N 5.51667^{0}E. The general geology of Ekiti State is well researched e.g. (Rahaman,1989; Ademilua, 1997; Ayodele, 2011, 2013; Bayowa et al, 2014; Okunlola et al., 2011; Oyinloye, 2011; Okwoli et al, 2014; Talabi et al., 2013; etc.). The state is underlain by the Precambrian rocks of the Basement Complex of Southwestern Nigeria which covers about 50% of the land surface of Nigeria. The general geological map of Ekiti State digitized after Ademilua (1997) is shown in Figure 1. The major lithological units include the granite gneiss, migmatites gneiss and charnockite, (Oladapo and Ayeni, 2013). The Basement rocks show great variations in grain size and in mineral composition. The rocks are predominantly quartz gneisses and schists consisting essentially of quartz with small amounts of white micaceous minerals. In grain size and structure, they vary from very coarse grained pegmatite to medium grained gneisses. The site layout showing all the test points and features is shown in Figure 2 while Table 1 shows the positions of the borings.

Table 1: Boring Coordinates and Elevation

Borehole No.	Coordinates (Northings & Eastings)	Elevation (m)
BH01	0862222N; 0774975E	559.0
BH02	0862245N; 0774967E	559.5
BH03	0862174N; 0775010E	572.5

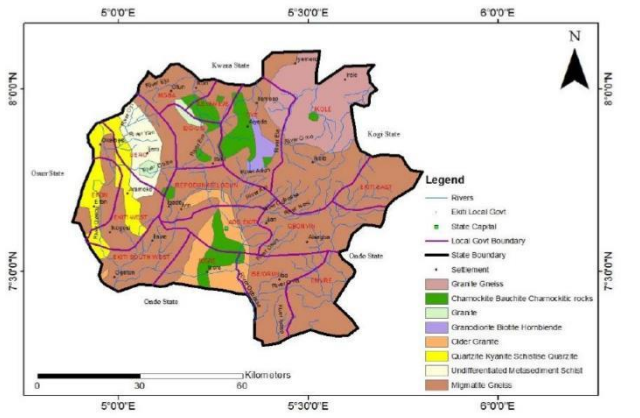

Figure 1: The Geological Map of Ekiti State (digitized form Ademilua, 1997.)

3. Materials and Methods

Field Work: Basically, the field work involves; exploration of three (3) geotechnical boreholes to refusal depth (bedrock) by using the shell and auger boring technique. A mobile Dando 150ton mobile rig complete with tools was mobilized for the exercise. Although, sampling procedure was dictated by the nature and thickness of subsoil encountered in the course of the investigation, a summary of sampling and field testing procedure followed in the course of drilling is as follows:

(i) Ordinary disturbed samples were collected within the first 1m of drilling and at every change of strata. Samples from the cutting shoe in the case of undisturbed sampling and from the split spoon barrel in respect of SPT were also collected as disturbed samples and placed in sealed polythene nylons.
(ii) Undisturbed samples were collected at relevant intervals in cohesive soils. This sampling is designated with a 'U' on borehole logs.
(iii) In some cases, taking of undisturbed samples was attempted but futile as some of the clays were too sandy to stay in the 100mmdiameter sampling tubes.
(iv) Standard Penetration Tests (SPT) were carried out at 1.5m depth intervals particularly in cohesionless materials on the site. This test involves obtaining the number of blows [N-values] required to produce the last 300mm of penetration of the 50mm Split Spoon sampler in connection with an overall 450mm penetration test by 63.4kghammer free falling through 760mm.

The site investigation program was carried out in agreement with the procedure set out in British Standards 1377 (1990). All the tests were carried out in the "Geotechnical Engineering Laboratory" at Trevi Foundations Nigeria Ltd., Lagos, Nigeria.

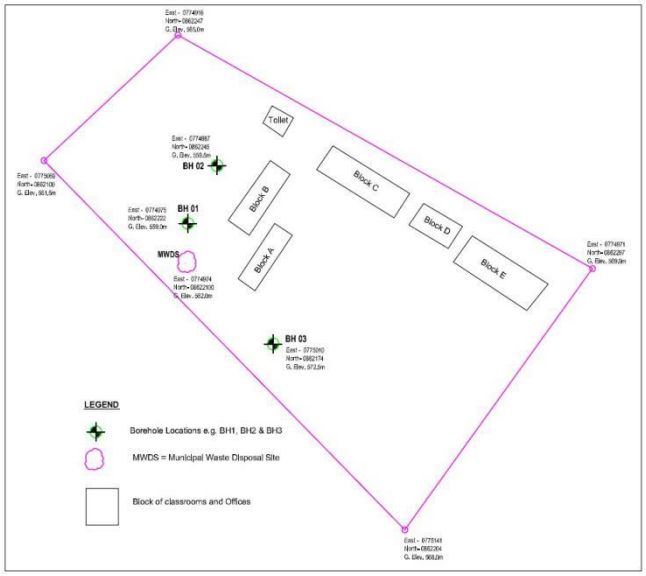

Figure 2: Site Layout of the Study Area

Laboratory Testing: Following the procedure spelt out in B. S. 1377: 1999 – Testing Soils for Civil Engineering Purposes, the following laboratory tests were carried out on the soil samples:

(a) Physical Properties of Soil {Classification}: (i) Moisture content determination; (ii) Consistency limit tests [Atterberg]; (iii) Particle size analysis
(b) Mechanical Properties of Soils: The following test was undertaken: Quick Undrained Triaxial Test.
(c) Chemical properties of groundwater: (i) PH-level;(ii) Chlorides; and (iii) Sulphatescontent tests were carried out.

4. Results and Discussion

Particle Size Analysis

The percentage range of the soils passing through No. 200BS sieve is between 15.4 and 74.2%, Figure 3. According to the Nigeria Federal Ministry of Works general specifications requirements for roads and bridges (1994), samples BH2S19, BH2S25, BH3S15, BH3S25, and BH3S27 can be recommended for use as sub-grade, sub-base and base course materials as the percentage by weight finer than No.200BS test sieve is less than 35%. The percentage range of the grain sizes of the soils are as follows: gravel; 0.00 – 20.72%, coarse grained sand; 0.00 – 7.19%, medium grained sand; 5.53 – 33.53%, fine grained sand; 7.02 – 45.51% and fines; 30.7 – 74.25%. These values indicate that most of the soils are fine-grained (clayey sands and silts). There are essentially four distinct groups which according to the Unified Soil Classification System (USCS) can be classified as follows: CL, CL/ML, SM/ML and CL/ML. Table 2 shows some observed physical properties of the soil samples.

Table 2: Physical Properties

Physical Property	BH01	BH02	BH03
Specific Gravity	2.70-2.80	2.75-2.86	2.78-2.88
Natural Moisture Content (%)	13-20	13-18	14-20
Permeability (cm/s)	$1.12*10^{-4}$	$1.35*10^{-4}$	$2.06*10^{-4}$
Liquid Limit (%)	48-54	44-58	53-58
Plastic Limit (%)	18-20	24-30	24-26
Plasticity Index (%)	30-34	26-31	29-34
USCS Classification	CL or CL/ML or SM/ML	CL/ML or SM/ML	CL or CL/ML or SM/ML

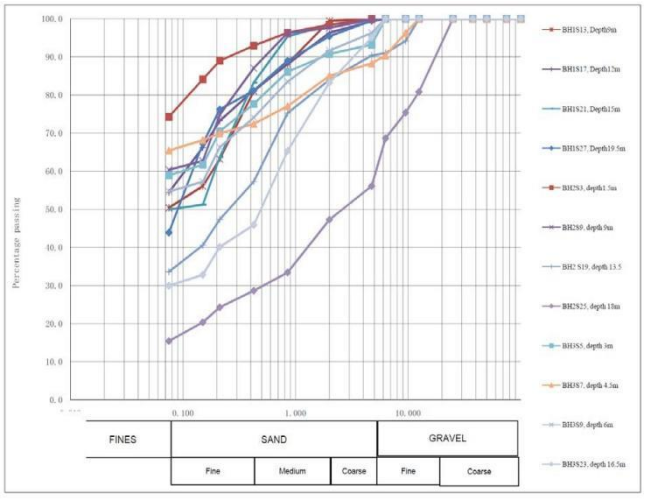

Figure 3: Particle Size Distribution of Samples (selected)

Consistency and Other Physical Properties

The Atterberg limit tests on soil samples from the site revealed that the following variations: liquid limits; 44 – 58, plastic limits; 18 – 26 and plasticity indices; 29 – 34. Federal Ministry of Works (FMW) general specification requirements for roads and bridges (1994) recommend liquid limit not

greater than 80% for sub-grade and not greater than 35% for sub-base and base course. Also, plasticity index not greater than 55% for sub-grade and not greater than 12% for both sub-base and base. From the examined soil samples, the soils fall within these specifications, thus making them suitable for sub-grade, sub-base and base course materials. The natural moisture content for all soil samples ranges between 13 and 20%. Specific gravity ranges from 2.70 to 2.88. Results of permeability test indicate low coefficients of permeability of the soils in the range of $1.12*10^{-4}$ to $2.06*10^{-4}$ cm/sec: this is due to the high fines content in the studied soil samples. The soils can therefore be classified to be of low permeability with relatively poor to fair drainage characteristics.

Unconsolidated Undrained Triaxial Compression Test

The UU test was carried out on some soil samples obtained from the superficial layer (i.e. 1.5m to 3.0m). The tests produced undrained cohesion (128.4-157)kN/m^2 and undrained angle of internal friction $(15.0\text{-}20.0)^0$. This shows that soils in the area have cohesive and frictional properties, an indication of their residual origin. Table 3 gives a summary of the triaxial test results while the Mohr circle stress plots are shown in Figures 4 –6. The bearing capacity for shallow foundations can be estimated from these given parameters. The use of shallow spread footings (pad, strip, and or raft foundation) is quite feasible for loads of the order of 50kN/m^2 – 200kN/m^2. Deep foundations like piles are recommended for projects with higher structural loads. In any case proper subsurface investigation should be carried out before the commencement of the project.

Table 3: Summary of Strength Characteristics

BH No.	Sample Depth (m)	Undrained Cohesion cu (kN/m^2)	Undrained Angle of Friction (ϕ)
1	3.0	153.6	15.0
2	1.5	157.7	20.0
3	1.5	128.4	15.1

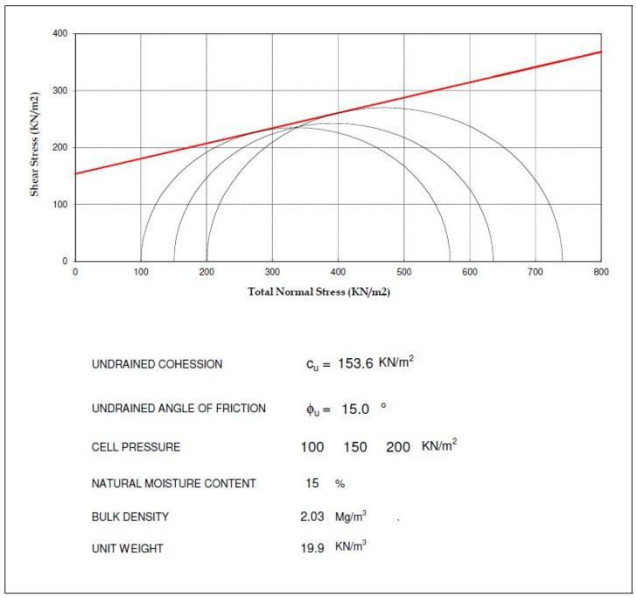

Figure 4: Stress Envelope for Test on BH 1.

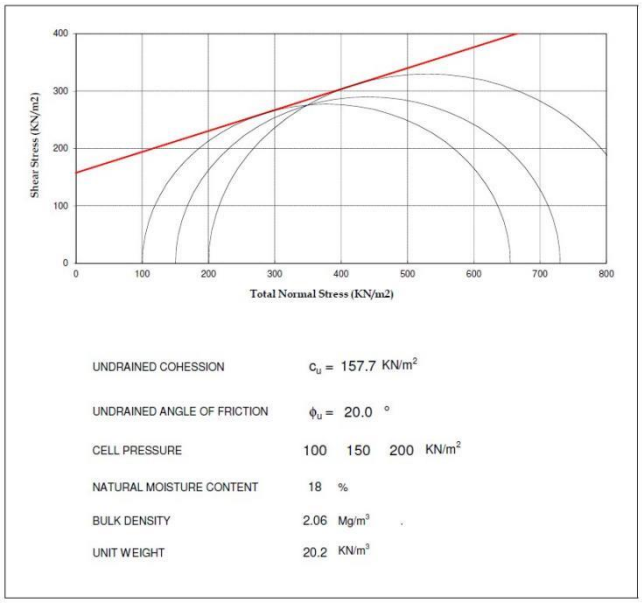

Figure 5: Stress Envelope for Test on BH 2.

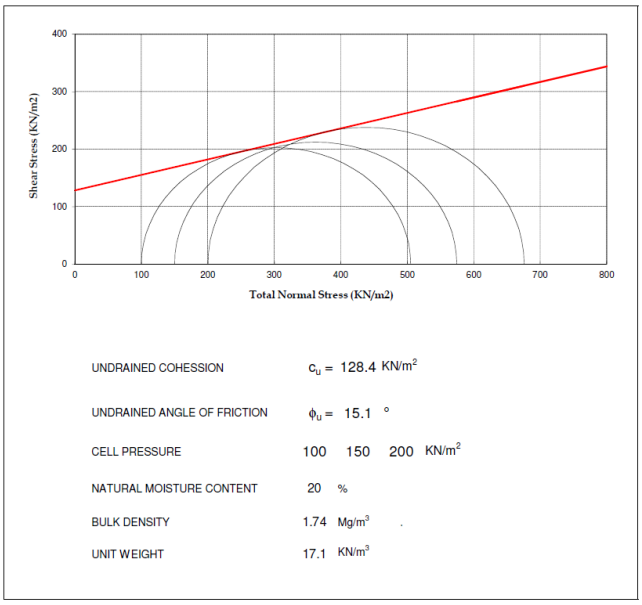

Figure 6: Stress Envelope for Test on BH 3.

Groundwater Conditions: Groundwater was encountered between 6.5m to 7.5m below the existing ground level during the course of soil exploration. pH values range from 5.79 to 7.05, chloride content values were between 12.0mg/l and 16.0mg/l while sulphates content values varied from 6.12mg/l to 7.10mg/l. These values indicate that the water is suitable for construction works because they all fall within the permissible range in the relevant codes (i.e. BS5930 and BS1377).

Soil Profile: The site investigation revealed a subsoil stratification consisting of reddish brown granitic clayey sand (Laterite) top layer from existing ground level to about 12.0m depth. This is then underlain by a layer of mottled, brown, decomposed micaceous sand to a depth of 16.5m to 18m. Immediately after this is the layer of mottled grey, decomposing quartzite sand to 19.0m and this is further underlain by fragments of granitic rock (freshly weathered) to the exploratory termination depth of 19.5m. It is summarized in Table 4 while the stratigraphic soil profile is shown in Figure 7.

Table 4: Soil Profile and Stratigraphic Description

From (m)	To (m)	Thickness (m)	Description
0.00	12.0	12.0	Reddish brown, granitic clayey SAND (Laterite)
12.00	18.00	6.0	Mottled brown, decomposed micaceous SAND
18.0	19.0	1.0	Mottled grey, decomposing quartzite SAND
19.0	19.5	0.5	Fragments of quartzitic ROCK (freshly weathered)

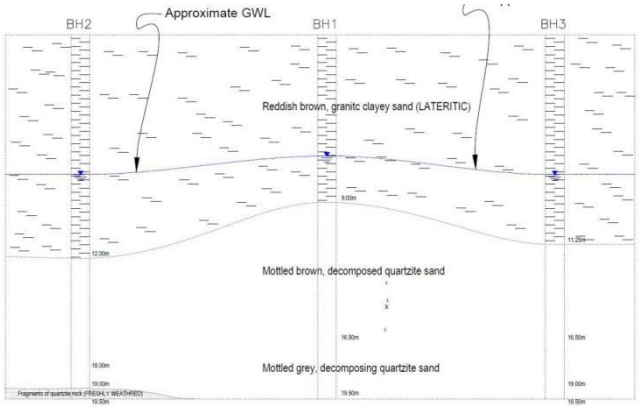

Figure 7: Stratigraphic Description of the Soil Profile.

5. Conclusions

The stratigraphic profile and geotechnical properties of soils in Ikole area of Ekiti State have been investigated. The soils are mostly lateritic and are suitable as subgrade, subbase and base course materials in highway construction. The lateritic soils encountered at the site can comfortably support shallow foundations for loads of the order of 50kN/m^2 – 200kN/m^2.

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