1st International Civil Engineering Conference (ICEC 2018)
Department of Civil Engineering
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INVESTIGATING SOME GEOTECHNICAL PROPERTIES OF OVERBURDEN SOIL WITHIN ABUJA IN NORTH CENTRAL NIGERIA

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ABSTRACT

Boreholes were drilled to bedrock at ten different locations, along a stretch path, within the study area. Tests including, natural moisture content (NMC), specific gravity (SG), Liquid Limit (LL), Plastic Limit (PL) and sieve analysis were carried out with the aim of classifying the soils according to Unified Soil Classification System (USCS). Result of the study showed that the soil along the studied path is characterized by a cap of silty organic top soil, followed by clayey soil, which in some cases formed lenses along the path. Below the clayey soil layer is stratum of weathered silty soil, which extends to the parent rock.

Keywords: *Geotechnical properties, Overburden soil, Soil classification, Bedrock.*

1 INTRODUCTION

Almost all civil engineering structures are founded on soil. The stability of such structures therefore depends on the stability of the foundation soil. The stability of foundation soils for civil engineering structures depends on the geotechnical properties of the soils. Geotechnical properties of soils are appraised through geotechnical investigation. Investigating geotechnical properties of soils at sites proposed for civil engineering structures is therefore, an important prerequisite to successful design and construction of the structures.

Soil is overburden weathered material on parent rock. Overburden soil consists of loose, silt, sand and clay, which overlies the parent material (bedrock). It is uncemented or weakly cemented accumulation of mineral particles, which are formed by weathering of rocks, and contain void spaces between particles, which are filled by water and air (Craig, 1998). The geological formation of soil is based on rock weathering which occur either chemically, when minerals of rock are altered through a chemical reaction with rain water, or mechanically through climatic effects such as freeze-thaw and erosion (Gidigasu, 1976).

Geotechnical soil investigation is necessary because it provides the needed information on geotechnical characteristics, which help civil engineers to understand the strength and mechanical properties of soil in generating relevant data for design, assessment and construction of foundations for proposed structures (Nwankwoala and Warmate, 2014). It helps in adopting soil with properties that can be safely and economically used to avoid future construction errors. For successful geotechnical investigation of soil, it is necessary to be mindful of composite and complex nature of the weathering material and the variation in the morphological and geotechnical properties, both in depth and horizontal spans. This is most appreciated through knowledge of geology and geomorphology of the area.

2 GEOLOGY AND GEOMORPHOLOGY OF NIGERIA

Nigeria is geologically bounded on the south by the gulf of Guinea and on the north by the southern edge of the Sahara desert. The climate is characterized by hot tropical condition, which is humid in the south and semi-arid in the north. Seasonal rainfall results from the influence of the wet south westerly monsoon winds from the sea and the hot dry dusty north east trade wind from the Sahara, known locally as the hamattan (Alhassan, 2016).

According to Durotoye (1983), Rahman (1983), McCurry (1989), Rahaman (1989), the geology of Nigeria is dominated by sedimentary and crystalline Basement Complexes formations (Figure1), which occur in almost equal proportions all over the country. The sediment is mainly Upper Cretaceous to recent in age while the basement complex rocks are thought to be Precambrian.

According to Malomo (1983), products of weathering in Nigeria are generally grouped into four main basic classes (Figure 2): Ferruginous soils, Ferrallitic soils, weakly developed soils, and Vertisols, which is localized to the North-eastern part of the country. Due to the climatic conditions in the tropical region, soil formation from the parent rocks (igneous, sedimentary or metamorphic), is mainly by process of chemical weathering. Rahaman (1980) however, asserted that, mechanical process of weathering is also encountered within the tropics. The weathered material is usually residue of both chemical and physical process of rock weathering. The most important end products are clays and the resistant minerals, quartz. Other end products depend very much on the type of rock, however, in Nigeria, iron oxides are also common residues. They contain the reddish, brownish and yellowish coloration on the weathering residues, which are generally referred to as laterite (Durotoye, 1983). Most available residual soils in Nigeria are mainly ferruginous and ferrallitic tropical soils (Malomo, 1983).

The existing soil map of Nigeria only depicts soil types in different regions of the country. Many studies have been carried out on the properties of soils in Nigeria (Solanki, 2008; Ola, 1987; Farrington, 1983; Ajayi, 1983; Madedor and Lal, 1985; Adesunloye, 1987; Omange and Aitsebaomo, 1989; Abolarinwa, 2010; Nwaiwu and Nuhu, 2006; Mustapha and Alhassan, 2012; Adebisi and Adeyemi, 2012; Alhaji and Alhassan, 2013). Variations of the geotechnical properties of these soils with depth over a region (location) of the country have not been given much attention in the literature. This study therefore, focused on variation of geotechnical properties of soil with depth within Abuja in North Central Nigeria.

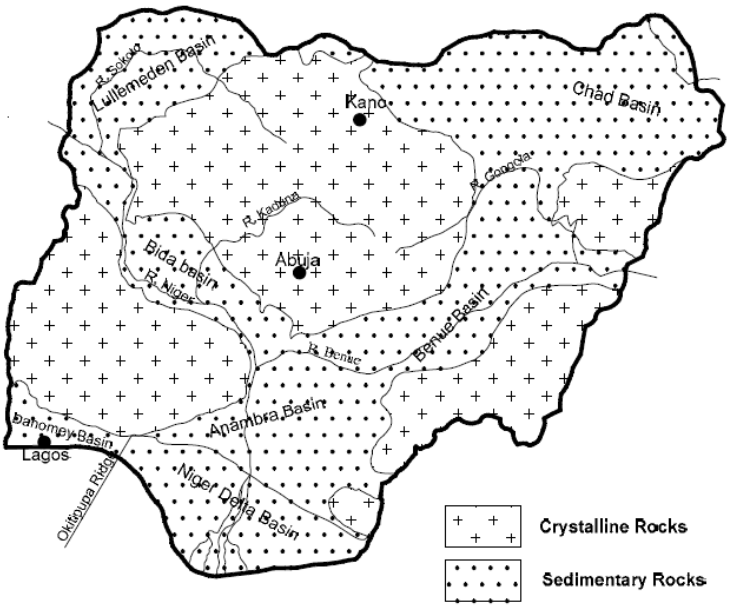

FIGURE 1: GEOLOGICAL FORMATIONS OF NIGERIA (ALHASSAN *ET AL.*, 2012)

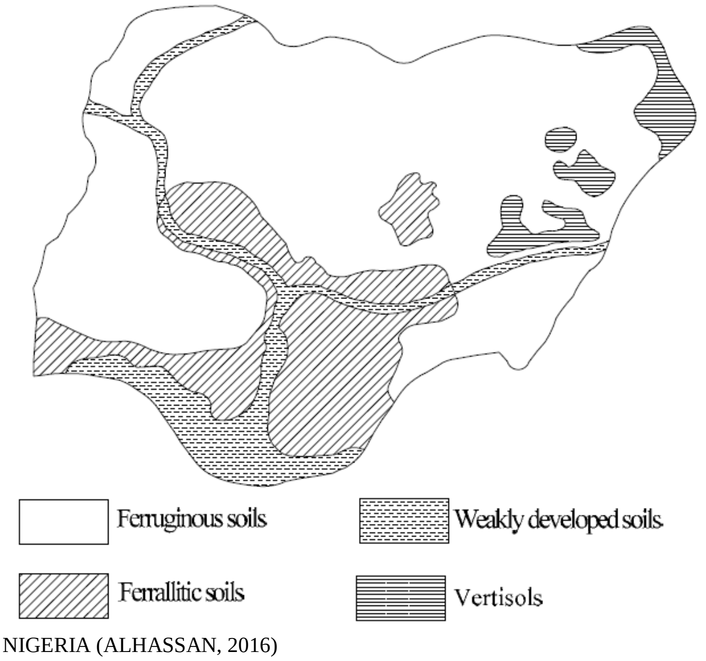

FIGURE 2: SOIL GROUP IN NIGERIA (ALHASSAN, 2016)

3 DESCRIPTION OF THE STUDY AREA

Abuja is Nigeria's capital territory, and is within North Central Nigeria. It lies between latitude 8.25° and

9.20° ***north*** of the equator and longitude 6.45° and 7.39° east of ***Greenwich Meridian***, with 536m as average elevation above sea level. The study line cut through the territories of Kwali and Gwagwalada area councils (Figure 3). Generally, major part of Abuja is geologically located in the basement complex terrain of Northern Nigeria, precisely belonging to the central Northern Block of Nigerian Basement Complex. In terms of rock type, the area is underlain by igneous and metamorphic rocks such as gneisses, Migmatites, Brotites, Granite etc. These rocks are of Precambrian age and are capped by sand and lateritic crust. Laterite is a residual soil found in tropical area with heavy rainfall and high temperatures. Soil map of Nigeria (Figure 2) indicates that the study area is dominantly characterized by ferruginous and partly ferrallitic soils. The study area experiences dry and rainy seasons, with mean annual rainfall of between 2000 to 2500mm. Rainfall in the area reaches its peak in mid-August/September. Temperature ranges between 20°C and less during the harmattan period to about 38°C in the dry season. The wind pattern is strongly from north east/east sector during the harmattan period and at onset/cessation of rainy season.

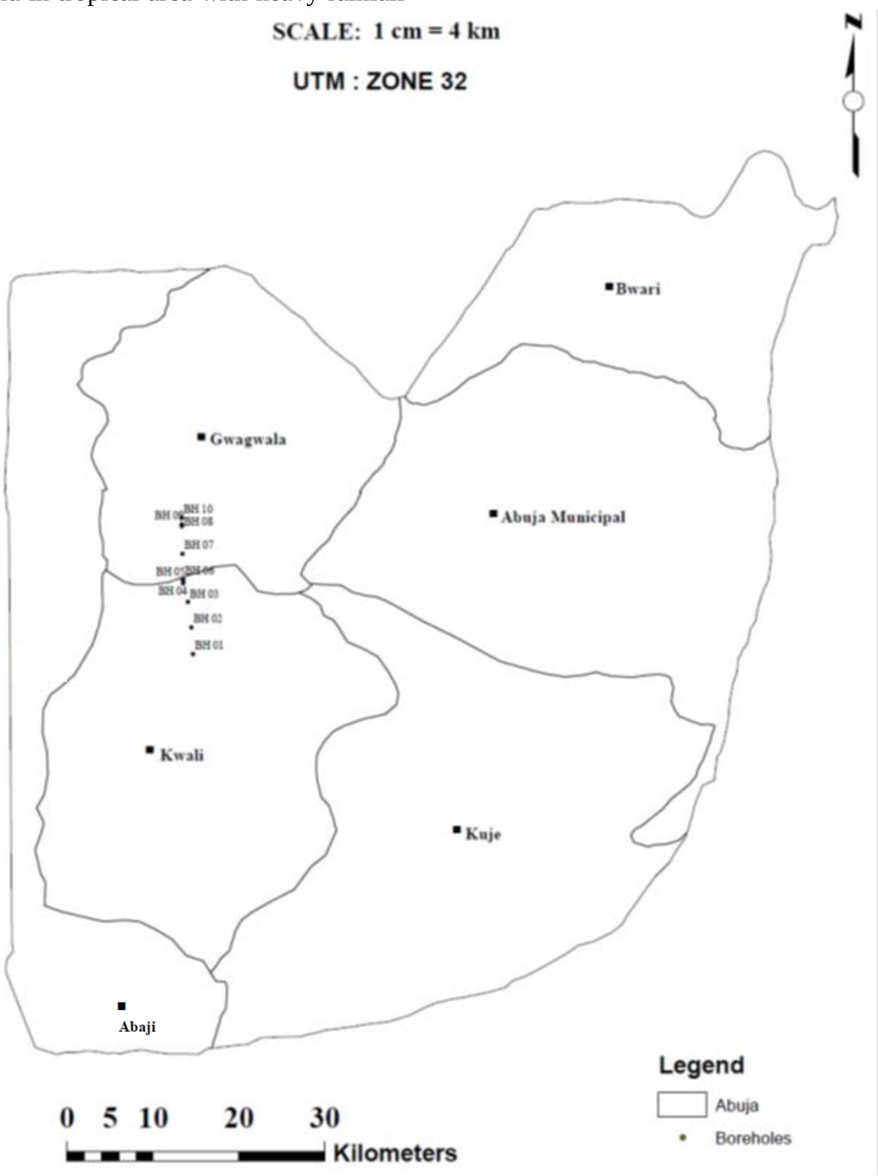

FIGURE 3: MAP OF ABUJA SHOWING BOREHOLES LOCATIONS

4 METHODOLOGY

Ten Boreholes (BH) were drilled to bedrock, at different locations, but along a stretched path, within the study area. Global Positioning System (GPS) was used to define the coordinates (Table I) and height above sea level for each location. Soil Samples were collected at 0.25 to 10m for the locations: BH 01, BH 02, BH 03, BH 04, BH 05, BH 06, BH 07, BH 08, BH 09, and BH 10. Tests including, Natural Moisture Content (NMC), Liquid Limit (LL), Plastic Limit (PL), mechanical and hydrometer sieve analysis, Specific Gravity (Gs) were carried out in Civil Engineering laboratory, Federal University of Technology, Minna in accordance with BS 1377 (1990). These tests were conducted with the aim of classifying the soils.

TABLE I: LOCATIONS OF THE BOREHOLES

Coordinates for boreholes (N$^{\circ}$ and E$^{\circ}$)				
S/N	Depths (m)	Boreholes	N$^{\circ}$	E$^{\circ}$
1	10.00	BH01	274206	976278
2	5.25	BH02	274013	979375
3	5.25	BH03	273611	982304
4	10.00	BH04	273063	984553
5	6.75	BH05	27339.999	984899
6	8.25	BH06	273039	984987
7	5.00	BH07	272969	987977
8	5.00	BH08	272909	991128
9	3.00	BH09	272895	991469
10	5.00	BH10	272855	992114

5 RESULTS AND DISCUSSION

Results of the geotechnical properties tests, conducted on the collected soil samples are presented on Figures 4 to 7 and Table II.

From Figure 4, it is observed that the specific gravity of the soil within the studied area varies with depth at a particular borehole point, and also along the horizontal stretch of the studied path. The observed trend is as a result of geological processes of soil formation, which could have resulted to heterogeneity of the soil. Similar pattern of variation is also observed with Atterberg limits (Figure 5 to 7) of the soil in the suited area.

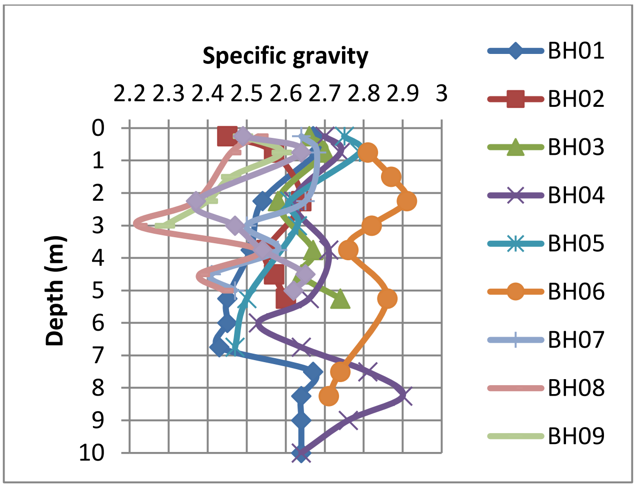

FIGURE 4: VARIATION OF SPECIFIC GRAVITY WITH DEPTH

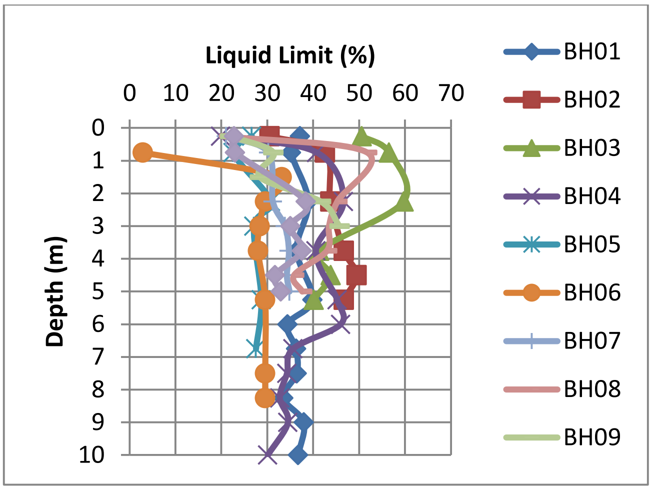

FIGURE 5: VARIATION OF LIQUID LIMIT WITH DEPTH

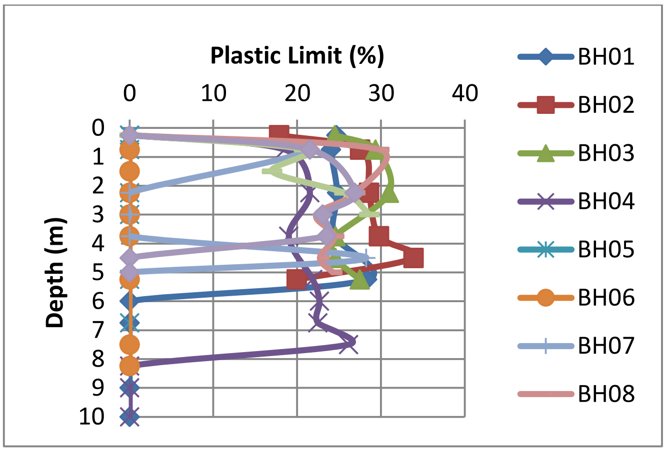

FIGURE 6: VARIATION OF PLASTIC LIMIT WITH DEPTH

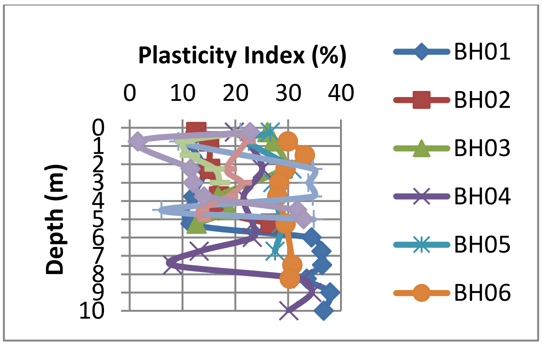

FIGURE 7: VARIATION OF PLASTICITY INDEX WITH DEPTH

From Figure 8, it is observed that the percentage of fines in soils within the studied area also varies with depth at a particular borehole location, and also along the horizontal stretch of the studied path. General observation of the variations showed fine content to be more within 2 to 5m depth, after which the percentage fine content gradually reduces down. This trend is as a result of soil typical formation process in the tropics, which have highly weathered rock, at the top, down through partially weathered to unweathered parent rock.

TABLE II: VARIATION OF SOIL CLASSIFICATION WITH DEPTH OF BOREHOLES

BH01		BH02		BH03		BH04		BH05		BH06		BH07		BH08		BH09		BH10	
Depth	USCS	Depth	USCS	Depth	USCS	Depth	USCS	Depth	USCS	Depth	USCS	Depth	USCS	Depth	USCS	Depth	USCS	Depth	USCS
0,25	SC	0,25	ML	0,25	MH	0,25	SM	0,25	SM	0,75	SM	0,25	SM	0,25	SM	0,25	SM	0,25	SM
0,75	GC	0,75	CL	0,75	ML	0,75	SC	0,75	SM	1,5	SM	0,75	GC	0,75	MH	0,75	SC	0,75	SC
2,25	CL	2,25	CL	2,25	MH	2,25	SC	2,25	SM	2,25	SM	2,25	SM	2,25	CL	1,5	CL	2,25	CL
3,75	CL	3,75	GC	3,75	ML	3,75	ML	3	SM	3	SM	3	SM	3	CL	2,25	SC	3	SC
5,25	CL	4,5	CL	4,5	SC	5,25	SC	5,25	SM	3,75	SM	3,75	SM	3,75	CL	3	CL	3,75	ML
6	GM	5,25	CL	5,25	SC	6	GC	6,75	SM	5,25	SM	4,5	CL	4,5	CL			4,5	SM
6,75	ML					6,75	SC			7,5	SM	5	SM	5	CL			5	SM
7,5	SM					7,5	SM			8,25	SM								
8,25	SM					8,25	SM			9	SM								
9	GM					9	GM			10	SM								
10	GM					10	GM												

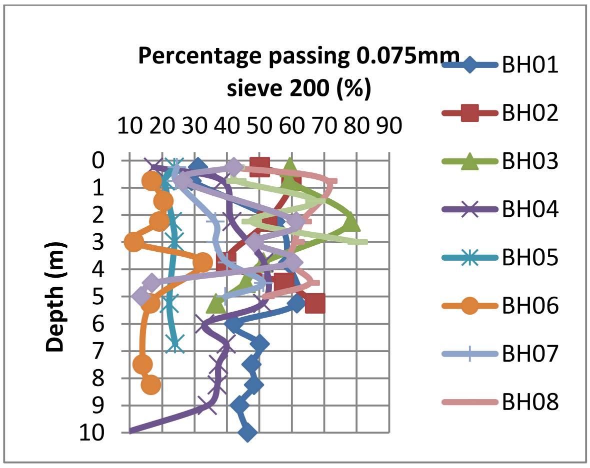

FIGURE 8: VARIATION WITH DEPTH OF PERCENTAGE PASSING 0.075MM SIEVE

Table II presents classifications of the soils according to Unified Soil classification System (USCS). From the table, with exception to BH01, which showed clayey sand, it is observed that, at 0.25m, the soil along the studied path is generally silty. Between 0.75 to 6.0m, soil at BH01, BH02, BH04, BH08 and BH09 ranges from clayey gravel, clayey sand and clay of low plasticity, while soils at BH05, BH06 and BH07 are generally silty sand. In most of the boreholes, from 6.75m downward, the soil was generally silty.

From the foregoing, it was observed that the soil along the studied path is characterized by a cap of silty organic top soil, followed by clayey soil, which in some cases formed lenses along the path. Below the clayey soil layer is stratum of weathered silty soil, which extends to the parent material.

6 CONCLUSION

The study revealed that the soil along the studied path is characterized by a cap of silty organic top soil, followed by clayey soil, which in some cases, formed lenses along the path. Below the clayey soil layer is stratum of weathered silty soil, which extends to the parent rock.

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