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The geological and geotechnical properties of earth materials of Plateau State University, Nigeria in relation to its suitability for facility layout

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Abstract— This study aims at establishing the sub-soil types and profile to ascertain the geotechnical characteristics of the underlying soils in Plateau State University, Nigeria and recommend appropriate foundation design and construction of projects in the area. Ten (10) trial pits were dugged from where representation samples were taken and subjected to laboratory tests. They are predominantly fines (silt and clay), an indication of its great influence on the engineering properties of the soil as a whole. From the plasticity values, the soils exhibits low to medium swelling potential of 11 – 23.6. The bearing capacity of the soil at 1.5m as compared with the standard values of net bearing capacity of North central zone which is between 250-500 KN/m^2 is within the recommended standard for engineering works as by calculation stands at an average of 1131. 6kN/m^2. Considering the moderate compressibility of the soils, any proposed foundation in the area should be supported on raft foundations founded. However, where the project precludes the use of raft foundation pile foundation should be employed to transmit the load to the underlying soil stratum.

Index Terms— Bearing capacity, construction, earth materials, facility layout, foundation, geotechnical, soils.

1 INTRODUCTION

Appropriate civil engineering studies before any civil works not only save lives, reduce cost but control the direction of economic and social development in the country (Bolaji, 2003)[1]. It also remove fear stigma from investors and international donors, thereby enhancing people's confidence in civil engineering sector.

Several cases of collapsed buildings and other civil engineering structures since pre-independence in Nigeria (Pollit,1950[2];Jegede,1989[3]) are to likely to start with one or all of the deformational failures such as cracking, subsidence, corrugation, collapsing and or sliding/formational failure etc of the sub-surface soils formations on which structures are built.

Occasionally, some of these civil engineering structures such as buildings, dams, roads etc do not stand the taste of time possibly as a result of lack of due consideration of the importance of the study of the sub-surface layers of the soils there by causing collapse. For instance, recent collapse of buildings in Lagos and even Plateau State that led to loss of lives and properties worth millions of naira is a matter of concern.

As a result of these, the problem of bad construction of civil works in Nigeria has become an embarrassing stigma. In many parts of the country, most of the civil works are done by unqualified personnel who are not civil engineers and even when they are, some do not give priority to any consideration of the fact that these heavy structures transmit their weight into the ground and the effect of the weight increase with time. In an attempt to minimize this, many agencies were established by the Federal Government so as to tackle the problems. Prominent amongst them were the Directorate of food, Road and Rural Infrastructure (DFRRI) established in 1986. During the years of Petroleum Trust Fund (PTF), which was responsible for maintaining Federal roads and other civil constructions works. These previous arrangements did not adequately tackle the problems of structural maintenance in the country; therefore, a Presidential Policy Advisory Committee (PPAC) was set up in 1999 to look into the state of the National infrastructure. Thus, in the current democratic dispensation, the Federal Government has established Federal Road Maintenance Agency (FERMA), and other civil engineering works which is saddled with the responsibility of maintaining the application/abiding by the rules/specification of construction works.

The seeming intractable problem of civil construction failures points to the fact that not many of the repairs/ construction works put in place during the aforementioned interventions was mainly addressing the collapsed building, dams and roads without getting to know the actual cause(s) of these failures. It is almost never reasoned out that structural facilities, like other civil engineering structures, are founded on rocks/soils, and that civil engineering failures could be directly related to the inadequate information on engineering properties of those sub-grade geological materials unlike the blame is seemingly to the design and material used. This perhaps explain the reason why Nigerian civil engineers give little or no attention to the inevitable necessity of carrying out pre-construction geological/geophysical and geotechnical site investigations and even when these investigations are carried out, they could or are not factored in to the engineering design schemes before implementation. The objective of this research work cannot be overemphasized hence the need for appropriate geological, geophysical and geotechnical studies as a pre-requisite especially in the case of the study area (Plateau State University Bokkos) where heavy structures are to be built that will carter for thousands of people considering the future /additional load especially during various school activities. However this paper focuses only on the geological/geotechnical aspect of site investigations.

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2 Background of the study area

2.1 Geographical conditions

The study area is in Bokkos Local government area of Plateau State and lies within the Kura N-E sheet 189 on Latitude 9° 20′N and 9° 25′N and Longitude 8° 55′E and 9° 00′E. The study area is part of the distinguished topographical features on the Jos Plateau and the general characteristics of the area can be described as gently undulating surface. The area owes its height preservation largely due to the close concentration of resistant Younger and Older Granites, and indeed almost all of the upland areas coincide with outcrops of one of these two rock groups and some lateritic hills. The basalts of the study area produced some of the most prominent landscape featured on the Plateau, especially the laterite-caped mesas of decomposed Older basalts and the Lateritized Older basalt (fig.1).

This area belongs to the Guinea-savannah climatic zone characterized by seasonal moisture variations which is marked by two main seasons: dry season (November to March) with an average monthly temperature of 18°C to 22°C, and rainy season (April to October) with average annual rainfall of 1270mm to 1524mm.

2.2 Geology of the study area

The study area comprises of four major types of rocks sequence (MacLeod et al, 1971)[4] (Fig.1)

a) The basaltic rocks consisting of Older basalts (OB) and Lateritized basalt (lB) which occupy mostly the eastern part of the area under investigation and stretches to the west.

b) The granite gneiss (GG) as it forms part of the rocks including Ruku reibeckite biotite granite porphyry (r10) and Yelwa pyrozenes granite (r11) which are small patches of intrusions

c) Porphyitic biotite and biotite hornblende granite (OGp) that forms the central part of the study area

d) Even grained hornblende biotite granite (OGh)

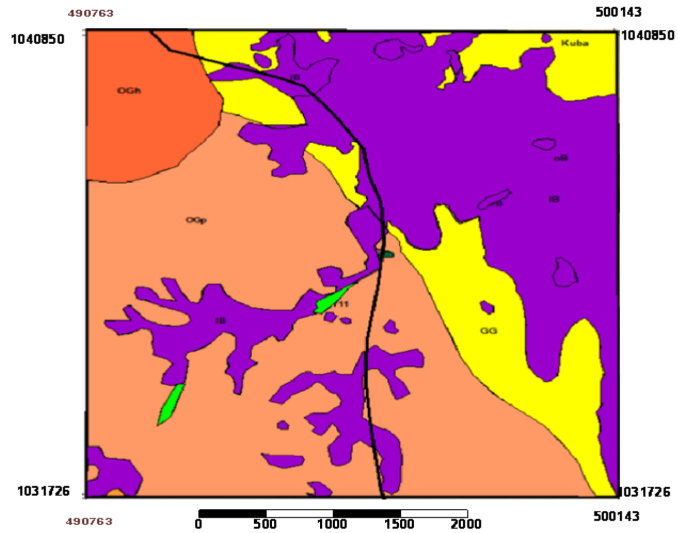

Figure 1: Generalized Geology of study area showing the rock types, OB and LB =Older and Lateritized Basalt; GG=Ggranite Gneiss; r10=Ruku reibeckite biotite granite porphyry; r11=Yelwa Pyrozenes Granite; OGp=Porphyitic Biotite and Biotite Hornblende Granite; Ogh=Even grained Hornblende Biotite Granite

3 Materials and Methods

Ten (10) Representative insitu /undisturbed samples of the soils were collected (Fig.2) and analyzed for atterberg limits, linear shrinkage, sieve analysis, moisture content and shear strength (Triaxial test). The soil tests were conducted in accordance with the British standard in the Ministry of Works,Plateau State.

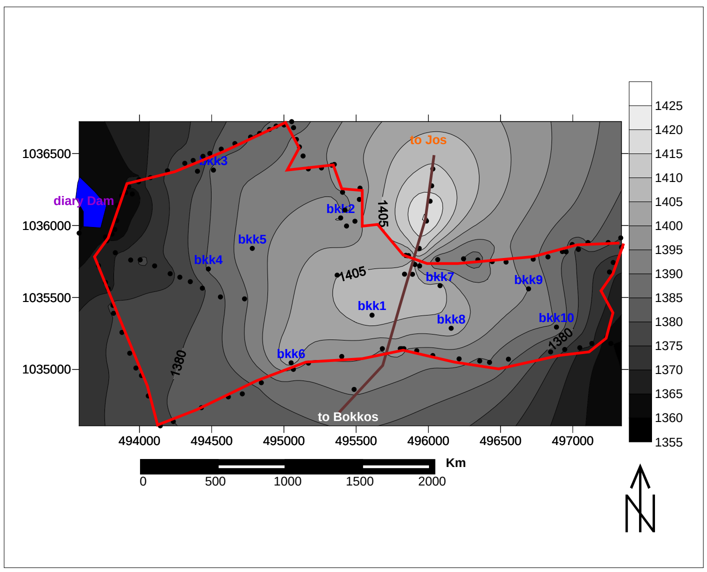

Figure 2: Sample location points of the study area

4 Presentation of Results

The results are presented in form of tables and plots below:

Table 1: Summary of laboratory test

BH. NO	Depth (m)	Natural Moisture	Bulk Density (g/cm^3)	Dry density (g/cm^3)	Mechanical Analysis			LL (%)	PL (%)	Plasticity index (PI)	LS	Shear strength	
					Gravel	Sand	Silt/clay					Cohesion (KN/m^{-2})	Angle of Friction (degrees)
bkk1	1.5	18.9	1.857	1.562	16	27	57	49	33	16	11.4	69	16
bkk2	1.5	20.5	1.892	1.571	5	23	72	52	38.4	13.6	11.4	41.34	22
bkk3	1.5	17.7	1.893	1.594	25	24	51	42	20.9	21.1	8.6	41.34	23
bkk4	1.5	21.6	1.852	1.523	18	16	66	46.8	23.2	23.6	8.6	48.23	15
bkk5	1.5	17.7	1.915	1.627	64	12	24	32.8	20.9	11.9	6.4	55.12	24
bkk6	1.5	16.7	1.826	1.564	35	11	46	37	26	11	7.9	41.34	25
bkk7	1.5	22.8	1.627	1.325	12	27	61	50	38.5	11.5	12.1	28	31
bkk8	1.5	26.8	1.732	1.369	2	24	74	55.5	34.9	20.6	12.1	69	21
bkk9	1.5	21.1	1.738	1.435	28	23	49	36	24.3	11.7	6.4	28	29
bkk10	1.5	11.4	2.22	1.992	43	31	26	31	17.2	13.8	5.7	41.34	32

Table 2: Values of the net bearing capacity and safe bearing capacity

Eastings	Northings	Altitude	Sample points	Net bearing capacity (KN/m^2)	Safe bearing capacity (kN/m^2) not backfilled	Safe bearing capacity (KN/m^2) backfilled
495610	1035377	1409	bkk1	1055.885	263.97	263.99
495393	1036053	1402	bkk2	885.01	221.25	221.277
494512	1036385	1388	bkk3	885.029	221.25	221.277
494477	1035698	1386	bkk4	622.287	155.57	155.597
494781	1035841	1393	bkk5	1179.906	1179.91	1179.93
495050	1035046	1405	bkk6	1038.049	221.26	221.277
496081	1035582	1407	bkk7	1331.04	332.76	332.784
496158	1035286	1403	bkk8	1481.24	370.31	370.335

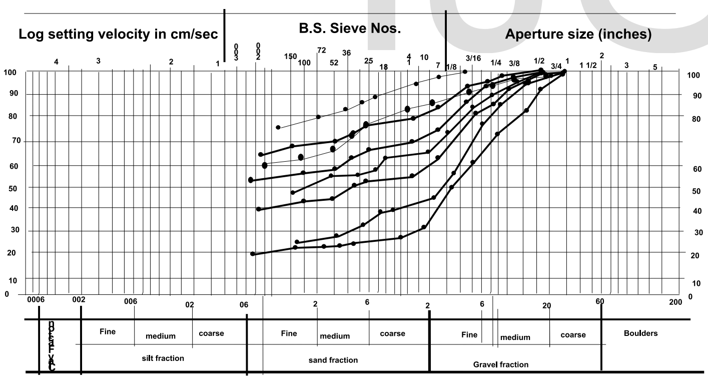

Figure 3: Summary of Particle size distribution curves

5 Discussion of Results

5.1 Grain size distribution of samples

From the result of the sieve analysis, the soil samples were described into three fractions namely; silt fraction, sand fraction and gravel fraction. According to Table 2. Gravel composition is in the range of 2-64%, sand between 11-31% and fines 24-74%. They are predominantly fines (silt and clay), an indication of its great influence on the engineering properties of the soil as a whole.

5.2 Atterberg limit

Atterberg limits are particularly useful indices often used directly in specifications for controlling soils for use in engineered fills. While the liquid limit (LL) is a measure of the water content at which the soil behaves practically like a liquid, but has a small shear strength, the plasticity index (PI) indicates the magnitude of water content range over which the soil remains plastic. In general terms, the higher the plasticity index, the higher the potential to shrink as the soil undergoes moisture content fluctuations.

The liquid limit range from 31 - 55.5 and plastic limit 17.2 - 38.5 According to the plasticity chart, (Cassagrande, 1932)[5] most of the soils have low LL indicating low to medium compressibility, except for three (3) of the samples that have LL of greater than 50% indicating high compressibility. For a liquid limit of >50%, it implies that the foundation material is subjected to continuous wetting especially during wet season as a result, the foundation materials increase in water content thereby change the soil behaviour by making it plastic, making failure eminent. From the plasticity values, the soils exhibits low to medium swelling potential of 11 – 23.6

5.3 Linear Shrinkage (LS)

The linear shrinkage index can aid in recognizing and estimating the degree of expansion of soils. From the results, the soils indicate low to medium swelling potential of 5.7- 12.1 (Attimeyer, 1954)[6] consequently, are indicators of expansiveness, thus can pose field compaction problems.

5.4 Shear Strength

The knowledge of shear strength of sub-surface soil is very important in all engineering construction works which involve stability analysis that can be used in the design, construction of foundations of structures, retaining walls, and stability of earth slopes. Practically, two different loads are imposing on the soil vertically downward and horizontally transmitting load stresses to the foundation soil. The soil if not in equilibrium with these loads (forces/stresses) may lead to failure. From the tests the strength parameters such as cohesion c and angle of internal friction $ø$ of the soils are known from the plots of the Mohr's diagram with consideration of the overburden weight γz and whether the foundation is going to be backfilled or not backfilled. *Where* γ is the bulk densities of the soils multiplied by the acceleration due to gravity and z is the depth of the foundation. Using a safety factor of 4 on the ultimate bearing capacity, the values for the net bearing capacity and the safe bearing capacity back filled and not back filled for foundation width of 1.2 m, of raft footing at 1.5 m foundation depth, is as presented in table 2, while table 3 shows the design parameters for rocks and soils and the safe bearing capacity.

Considering the moderate compressibility of the soils, it is suggested that any proposed foundation in the area be supported on raft foundations founded. However, where the project precludes the use of raft foundation pile foundation should be employed to transmit the load to the underlying soil stratum.

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Table 3: standard values of safe bearing capacity according to national Building code 1983

Rocks and Cohesionless soils		Cohesive soils	
Description	Safe Bearing capacity (knm^{-2})	Description	Safe Bearing capacity (knm^{-2})
(a) Rocks		c) Cohesive soils	
1 Rocks hard without lamination and defects, for example granite, traps, diorite	3240	1. Soft shale, hard or stiff clay in deep bed, dry.	440
2 Laminated rocks for examples sandstone and limestone in sound conditions	1620	2. Meduim clay readily indented with a thumb nail.	245
3 Residual deposits of shattered and broken bedrocks and hard shale cemented materials	880	3. Moist clay and sand clay mixture which can be indented with strong thumb pressure.	150
4 Soft rock	440	4. Soft clay indented with moderate thumb pressure.	100
(a) Cohesionless soils		5. Very soft clay which can be penetrated several centimeter with thumb.	50
5 Gravels,sand and gravel, compact and offering resistance to penetration when excavated by tools: bkk10	440	6. Black cotton soil or other shrinkable or expansive clay in dry condition (50 percent saturation).	130-160
6 coarse sand, compact and dry	440		
7 medium sand ,compact and dry	245		
8 fine sand silt(dry lump easily pulverized by fingers)	150		
9 loosed gravel or sand gravel mixture: loosed coarse to medium sand, dry	245		
10 fine sand ,loosed and dry	100		

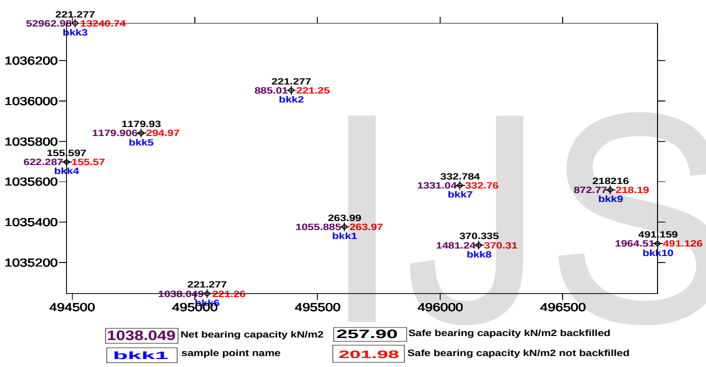

Figure 4: Values of Net bearing capacity and Safe bearing capacities of backfilled and not backfilled foundation

6 Conclusion

The importance of the study of the subsurface properties of the soil structure on which engineering structures are footed cannot be overemphasized. If the sub-surface properties of the soil structure on which engineering structural facilities such as building, roads, bridges, dams, is not properly studied and analyzed and proper construction methods are not adopted, it may lead to their collapse leading to loss of lives. For a better understanding of soils in the Plateau state University layout, Bokkos, a methodological approach was used to study the geotechnical properties of these soils for the proposed structural facility layout of the University regarding foundation properties and strength stability. The geotechnical characteristics of the underlying soils are predominantly fines (silt and clay), an indication of its great influence on the engineering properties of the soil as a whole. The soils exhibits low to medium swelling potential and the bearing capacity of the soil at 1.5m is within the recommended standard for engineering works. It is suggested that any proposed foundation in the area should be supported on raft foundations. But, where the project precludes the use of raft foundation pile foundation should be employed to transmit the load to the underlying soil stratum

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