INTEGRATION OF GEOPHYSICAL AND GEOTECHNICAL INVESTIGATION FOR A PROPOSED NEW LECTURE THEATRE AT FEDERAL UNIVERSITY OF AGRICULTURE, ABEOKUTA, SOUTH WESTERN NIGERIA

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Abstract

A combined geophysical and geotechnical method was carried out at Federal University of Agriculture, Abeokuta for a foundation studies of a proposed New Lecture Theatre of 2,500 capacity. The survey is aimed at evaluating the competence of the subsurface formation as foundation materials. To image the subsurface, Electrical Resistivity imaging (ERI) and soil analysis techniques were adopted. Five (5) traverses and five (5) soil samples from different location within the study area were considered for the work. Four geoelectric layers were delineated from the geophysical results: these are the topsoil, sand clay/clayey sand, weathered rock and fractured rock/fresh basement. The result of the geotechnical method shows that the soil has relatively low clay content. It is concluded from the combined results above, that the subsurface on which the building structures will be located within the study area is safe and fairly competent for any engineering work.

KEY WORDS: Depth to bedrock, Foundation, Geophysical method, Geotechnical method, Subsurface formation,

Introduction

In any engineering works such as buildings, dams and bridges, poor soil stability is one of the major factors that cause collapse, subsidence and havocs. On consideration of soil particles, certain clay soils for example, can expand greatly in volume if they are saturated with water during the raining season and also contract in volume when the water are lost especially in the dry season.

Thus, rise and fall in water content of the clay soils even when they are not under a long-term process of compression and stiffening are more susceptible to subsidence (Soupios et al, 2007).

However, citing any engineering works across such low bearing capacity material will result to foundation failure or differential settlement is the soils (Oyedele, 2012).

The understanding of swelling and shrinkage characteristics of soils is very important in solving engineering problems commonly associated with the construction of buildings, dam and high ways (Egwuonwu et al, 2011). Subsidence and heave caused by moisture content variation especially in clay soils is a major problem throughout the world, and may be made worse as global warning increases local climate variability

Burland et al, (1977) says visual appearance, function and stability must be satisfactory when considering the limiting movement of a structure. Excessive tilting may occurred and this could lead to the complete collapse of structure. The degree of damage caused by settlement is to some extent dependent on the sequence and time of construction operations (Tomlingson and Booman, 1999).

An integration of geophysical data and geotechnical measurements may greatly improve the quality of engineering work. Geophysical and geotechnical surveys are often the most cost effective and rapid means of obtaining subsurface information, especially over large study area (Oyedele and Bankole, 2009; Sirles, 2006; Fatoba and Olorunfemi, 2004; Robert et al, 2004 and Adepelumi and Olorunfemi, 2000).

In this work, geophysical and geotechnical techniques were integrated to ascertain the in- situ geo-mechanical properties of the subsoil. A combined geophysical and geotechnical investigations offer very useful approach for characterizing near surface earth and thus can help in preparation before engineering structures are found on same.

Location and Geology of the Study Site

The investigated site (Figure 1) lies between longitudes $3^0$35’02’’ and $3^0$35’06’’ East of the Greenwich meridian and Latitude $7^0$14’03’’ and $7^0$14’07’’ North of the Equator. The topography of the site is low lying.

The study area is located within Federal University of Agriculture, Abeokuta. It is underlain by rocks of the Precambrian Basement Complex of South Western Nigeria (Rahaman, 1989).

The Nigerian Basement Complex, occupying approximately 50% of the surface area of the country is part of the Pan African crystalline shield (Figure 2). The number and size of outcrops vary considerably partly due to their varying resistance to weathering and other physical properties. The oldest rocks comprise a Gneiss Complex series predominantly of sedimentary origin. The second major group is the older Granite emplaced by intrusion and replacement in the Gneiss Complex (Oyawoye, 1970).

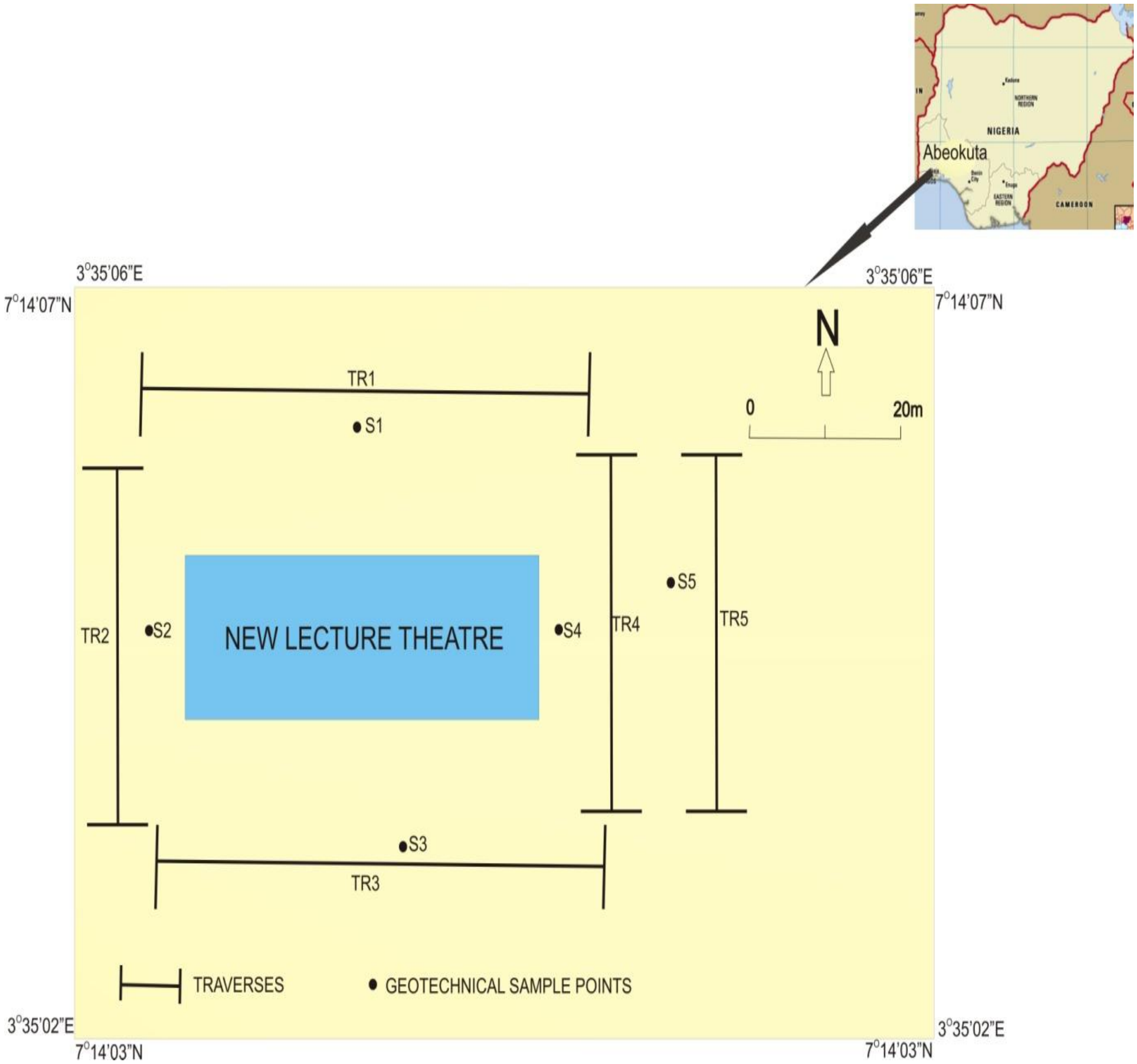

Figure 1: Data Acquisition Map of the Study Area Showing Traverses and Geotechnical Sample Points.

Other rocks in the Basement complex include: Migmatites and Granites; Schists Phyllites and Quartzites which occur chiefly in the western half of the country; Amphibolites, Diorites, Gabbro, Marble are present in some areas and Pegmatites are widely distributed (Oyawoye 1970)

There are two groups of granites present and these are known as the older granites and the younger granites. The Older granites are widespread and often give rise to smoothly domed hills (Inselbergs). The Younger granites suites which include granites, syenites, and rhyolites cover extensive area in Plateau province and also occur as small masses (Kogbe 1976).

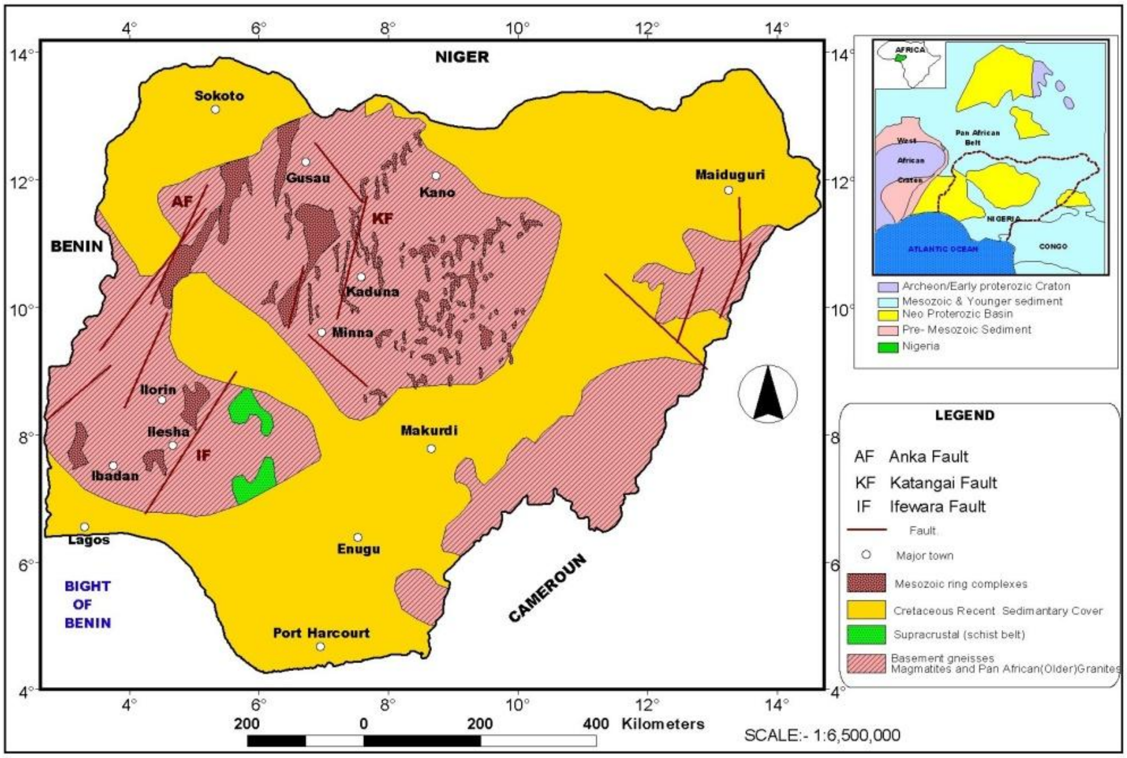

Figure 2: Regional Geology of the Pan-African Shield of Nigeria, Inset Geological Map of Africa (Modified after 1994 edition of the Geological Survey of Nigeria Map).

Methodology

Electrical resistivity imaging was carried out along five (5) profiles laid around the proposed lecture theatre location (figure 1) in order to delineate the resistivity of the subsurface materials. The resistivity data were recorded using PASI-Earth (16GL-N) Terrameter, 220m long, at inter-electronic spacing ranging from 10m to 50m.

The Wenner array was chosen because, of all common arrays, it has the strongest signal strength which is a significant factor in the study site with high background noise. Wenner array is good in resolving vertical changes (i. e. horizontal structures) in subsurface resistivity below the centre of the array Oyedele et al, 2012.

The readings were stacked three times for each point along the probe so as to enhance data quality. The collected resistivity data were processed by means of Earthimager modeling software in order to give 2D geo-electrical data inversion. The starting mode was constructed directly from the field measurements and data were processed to produce colour cross-sections which indicate variation of earth resistivity values with depth.

The geotechnical method on the other hand employed the use of Auger to collect five disturbed soil samples shown in figure 1. Those samples were preserved in a labeled polythene bags and transported and kept at the Department of Civil Engineering soil laboratories, at Federal University of Agriculture, Abeokuta.

The fist state was the determination of the natural moisture content of the samples collected from the field within a period of 24 hours after collection. This was followed by air drying of the samples by reading them out on plastic trays .Large soil particles, (clods) in the samples were broken with a wooden mallet. Care was taken not to crush individual particles.

For all the soil samples collected, methods of testing soils for engineering parameters were conducted in accordance with B. S. 1377. In this study, the tests conducted include natural moisture content, liquid limit, plastic limit, plastic index, swelling potential,

Interpretation of Results

Geophysical Results

Figures 3 to 7 shows the inverted resistivity sections of the electrical resistivity imaging. All the profiles presented have relatively high resistivity value greater than 450 ohm-m as the topsoil inferred as laterite/sandy material with a thin thickness of value less than 2m.

In profile 1, the traverse is sand witched by clayey sand with resistivity value greater than 200 ohm-m. A fracture/fault zone is noticed at a distance of 90m from the origin.

Profile 2 has same structure as profile 1 except that; high resistivity value is noticed at the topsoil at a distance between 190-200m. At a distance greater or equal to 120m, relatively low resistivity value between 650-950 ohm-m is identified while other distance from origin to 120m gives resistivity value of the basement greater than 1500 ohm-m.

There are splashes of sandy clay materials with resistivity value greater than 120 ohm-m underlain the topsoil in profile 3.

Profiles 4 and 5 are similar in traverse and lithology. There are pockets of clayey materials identified in profile 4 with a significant fracture/fault occurrence at a distance greater or equal to 170m. In profile 5, the fracture/fault zone was equally identified but shifted from a distance of 170m to 130m and towards the last part of the traverse.

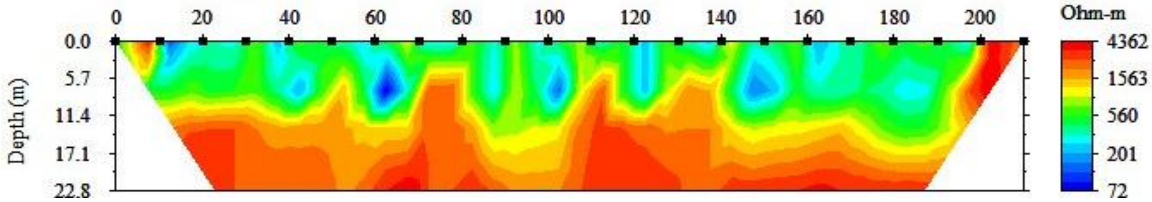

Figure 3: Inverted Resistivity Sections along Traverse 1

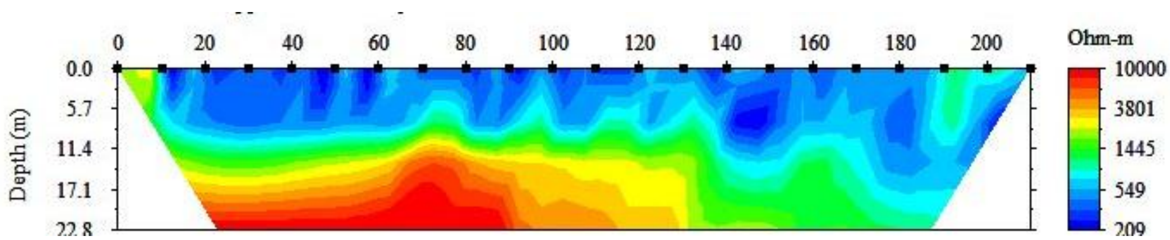

Figure 4: Inverted Resistivity Sections along Traverse 2

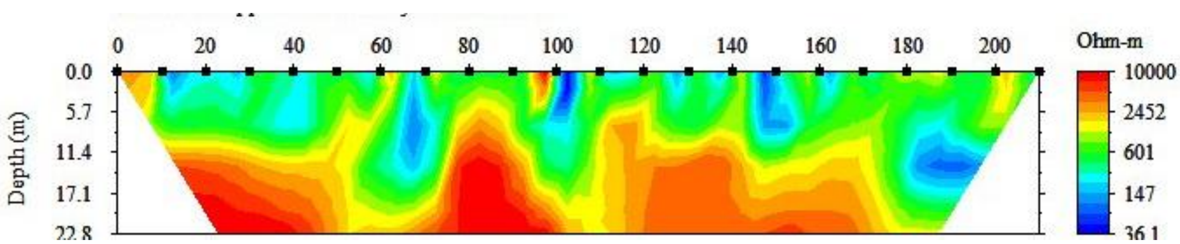

Figure 5: Inverted Resistivity Sections along Traverse 3

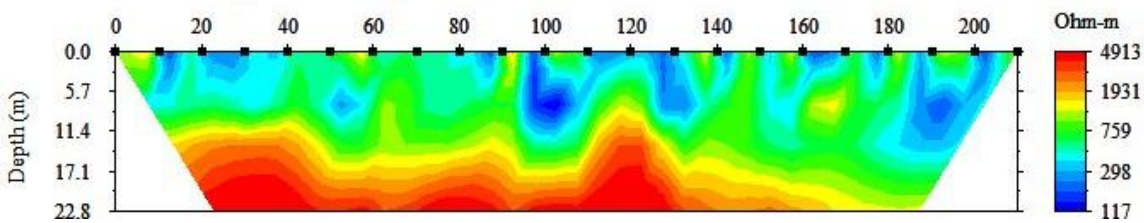

Figure 6: Inverted Resistivity Sections along Traverse 4

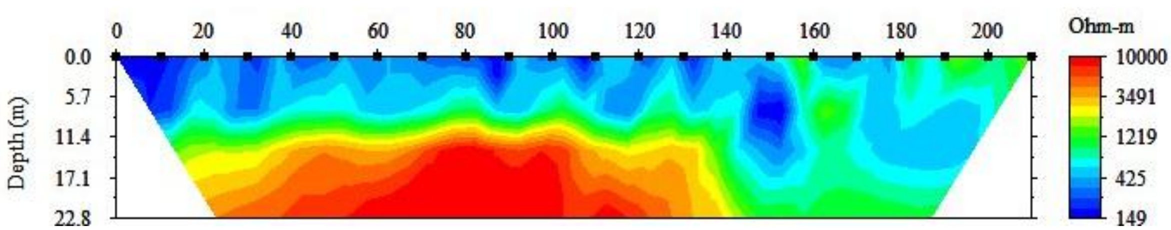

Figure 7: Inverted Resistivity Sections along Traverse 5

Geotechnical Results

The summary of the geotechnical results is showing in Table 1. The natural moisture content of the tested soil samples give a range of values from 10.40 – 15.89%. The result shows that at its natural state, the natural moisture content of the soil in the area is relatively low. Jegede 2000 says moisture variation is generally determined by intensity of rain, depth of collection of sample and texture of the soil.

Table 1: The Summary of the Geotechnical Results

Sample No	Natural Moisture Content %	Percentage Passing (0.075mm)	Liquid Limit %	Plastic Limit %	Plastic Index %	Swelling Potential
1	15.89	43.27	15.4	0 NP	15.4	4.28
2	14.69	31.61	20.9	13.3	7.6	1.32
3	10.40	39.59	9.99	0 NP	9.99	2.26
4	12.75	35.75	17.2	9.3	7.9	3.82
5	11.92	41.16	11.3	0NP	11.3	2.75

The percentage finer (percentage passing 0.075 mm) of tested soil ranges from 31.61 to 43.27 %. Thus the average value is 37% which is closer to the maximum value of 35% recommended by Federal Ministry of Works and Housing (FMWH, 1972) for a foundation material, hence the soil samples for the study is rated as fair to good sub-grade foundation material. Akintorinwa and Adeusi, 2009 says that soils that are largely made up of fine particle are likely to have poor geotechnical properties as foundation materials than soils that are largely made up of coarse particle.

The liquid limit of the soil samples, the plastic limit of soils and the plastic index (Liquid Limit-Plastic Limit) of the soils ranges from 9.99 – 20.9%, ONP – 13.3% and 7.6 -15.4% respectively.

The recommended value by the Federal Ministry of Works and Housing (FMWH, 1972) for liquid limit, plastic limit and plastic index are 50%, 30% and 20% respectively.

In the study area, it is shown that the maximum value of the liquid limit is 20.9% less than 50%. Adesodun and Kolade, 2000 says that liquid limit value greater than 50% is interpreted as poor foundation materials but if less than 50%, it gives clay type called kaolinitic in nature which is not a big threat to foundation.

The plastic limit value is range between ONP-13.3% thus the location with non-plastic (NP) has very low clay content and the maximum value is less than 30% thus the location is safe for foundation structures.

The maximum plastic index value of 15.4% recorded in the study area is less than 20% thus, the tested soil samples are of low consistency limits indicating low percentage of clay content in the soil hence, it shows a good engineering property since the higher the plastic index of a soil, the less the competency of the soil as a foundation material.

The swelling potential was calculated using Non-linear relationship between plastic index (PI) and swelling potential (S) giving by Gromka 1974 with equation: $S = (2.16 \times 10^{-3})\ PI^{2.44}$. The value is range between 1.32 – 4.28 interpreted as low to medium using the categorization proposed by Ranaganatham (1965) and Adesodun and Kolade (2000).

Integration of Geophysical and Geotechnical Results

All the five traverses of electrical resistivity images highlight a sub-surface of sandy materials sand witched by pockets of clay. The presence of non-plastic in the plastic limit parameter in the study area depicts a very low clay content which is safe for foundation works/structures.

The topsoil constitutes the layer within which normal Civil Engineering foundation is founded. The layer is composed of laterite and sandy materials.

Foundation competence of the topsoil can be qualitatively evaluated from layer resistivity and geotechnical parameter. According to Akintorinwa and Adeusi, 2009, the higher the layer resistivity value, the higher the competence of the delineated topsoil units, followed by clayed sand and sandy clay being the least competence.

The Federal Ministry of Works and Housing (FMWH 1972) says the higher the geotechnical parameters of a soil, the lesser the competence of the soil as a foundation material hence, the recommended value for liquid limit, plastic limit, and plastic index are 50%, 30% and 20% respectively.

In the study area, the values recorded are lower and falls within recommended value and thus the higher the competence of the soil as a good foundation material.

Conclusions

Geophysical and geotechnical investigations of a proposed New Lecture Theatre at Federal University of Agriculture, Abeokuta have been carried out.

The geophysical electrical resistivity imaging revealed maximum of four geoelectric layers within the study area which comprises of topsoil, sand clay/clayey sand, weathered rock and fractured rock/fresh basement. The topsoil's are generally and majorly composed of laterite and sandy materials.

The geotechnical results show that the soil samples are gradually of low material moisture content and relatively low clay material as revealed by the plastic index of the soils within the area and less than 20% and interpreted as low consistency limits and the soils exhibited low to medium swelling potential indicating low percentage of clay content in the soil.

Hence, an integrated geophysical and geotechnical investigations offer very useful approach for characterizing subsoil and thus can provided information in early preparation before foundation structures are found on the land.

It is concluded from the integrated results that the subsoil on which the lecture theatre structures will be sited within the study area is safe and fairly competent for any engineering work.

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