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ELECTRICAL CHARACTERIZATION OF THE SUBSURFACE SOIL USING ELECTRICAL RESISTIVITY TOMOGRAPHY FOR FOUNDATION STUDIES AT AHMADU BELLO UNIVERSITY PHASE II, ZARIA, NIGERIA.

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ABSTRACT

Electrical resistivity tomography is a geophysical method that was used to characterize the soil in Ahamdu Bello University Phase II, Zaria. Ahmadu Bello University site II lies between longitudes 7° 37.98' E and 7° 39.07' E and latitudes 11° 7.86' N and 11° 8.50' N. A multi-electrode resistivity meter (ABEM Terrameter SAS 4000) was used for data acquisition on the field using a dipole-dipole array and the data were processed and interpreted using RES2DINV. The results obtained from the resistivity tomograms of the three profiles were used to correlate with the borehole data and the correlation indicates four distinct layers (Topsoil, weathered basement, fractured and fresh basement). The most competent layer for building a foundation in the study area is the fresh basement which is about 15.9m deep from the earth surface. In this study, electrical resistivity tomography has been successfully used to determine the depth to basement and the extent to which the bedrock was delineated. Weak zones that may be prone to subsidence and the competent areas that can support massive engineering were identified.

Keywords: Electrical resistivity tomography, tomograms, borehole data, competent layers, foundation studies

INTRODUCTION

The suitability and stability of the foundation soil is the most crucial factor that civil engineers usually consider for the design and construction of engineering structures. The physical properties of earth materials such as resistivity, soil strength, compressibility, permeability, and porosity, are some of the factors usually considered, in order to characterize the soil for foundation studies.

It is highly desirable to characterize the soil for foundation studies, large or small scale, prior to the commencement of any project work, in order to have a better knowledge of competent areas for the foundation of engineering structures, which will, in turn, prevent loss of life and properties as a result of building collapses. Ahmadu Bello university phase II is a new site that requires a detailed evaluation of the subsurface soil prior to the commencement of construction on the site and the information from this investigation will assist the civil engineers in the setting of foundation structures.

The geophysical method is a non-invasive method that is commonly used for engineering application such as foundation studies, road and bridge constructions, because of its cost-effectiveness and less time consumption as compared to the geotechnical method. One of the most widely used geophysical methods for civil engineering application is electrical resistivity tomography (ERT) (Castiho and Maia, 2008; Arjwech and Everett, 2015). According to Arjwech and Everett (2015), Electrical resistivity tomography (ERT) has been used by many researchers for geotechnical site investigation.

In this present paper, Electrical resistivity tomography (ERT) will be used for soil characterization in Ahmadu Bello university phase II to determine the depth and extent to which the bedrock has been weathered and identify the weak zones that may be prone to subsidence and the competent areas that can support massive engineering structures.

Location and Geology of the Study Area

The study area falls within the area covered by Ahmadu Bello University Samaru, Zaria, which is located in Sabon-gari local government area of Kaduna State, Nigeria (Figure 1).

Ahmadu Bello University site II lies between longitudes 7° 37.98' E and 7° 39.07' E and latitudes 11° 7.86' N and 11° 8.50' N and is positioned on the Northwestern part of the Kubanni River Basin as shown in Figure 2. It falls within the Nigeria Basement Complex which is underlain by Precambrian rocks at the elevation of about 670 m above the mean sea level. They are mainly granites, gneisses, and schists. The gneisses are found as small belts within the granite intrusions and are also found east and west of the batholiths (McCurry, 1970). The biotite gneiss extends westwards to form a gradational boundary with the schist belt. The gneiss continues eastwards to some extent and is occasionally broken up by the Older Granite (Wright and McCurry, 1970).

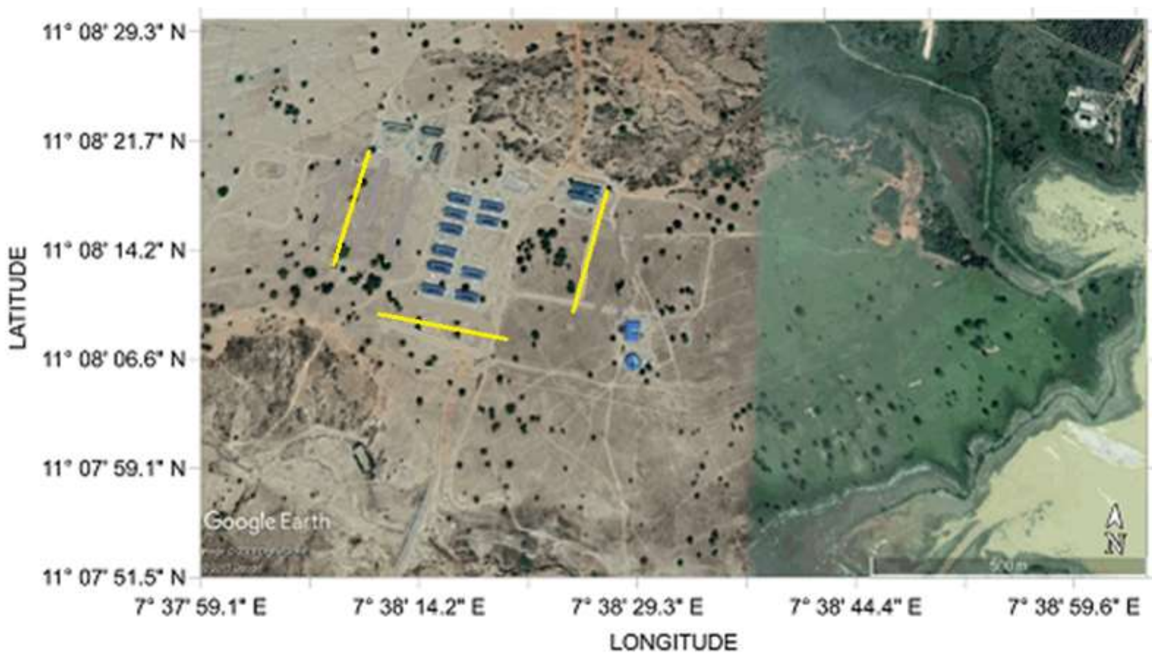

Fig. 1: Google Earth map of the location of the study area.

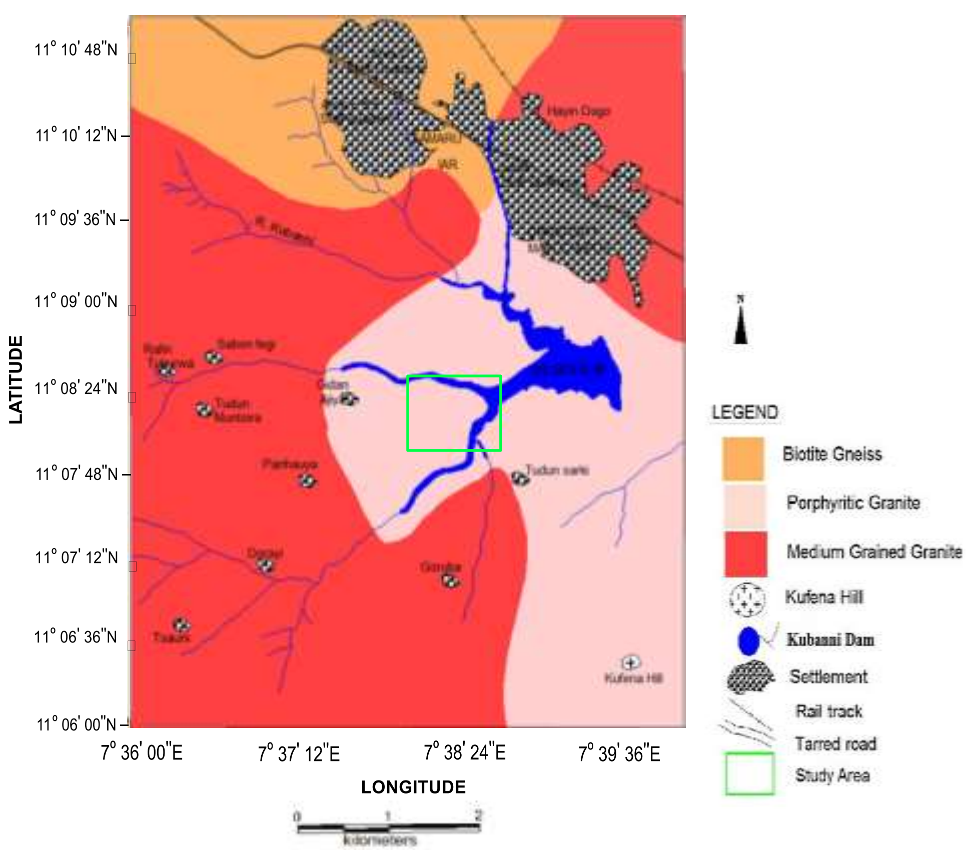

Fig. 2: Geological map of the study area (Modified after Garba *et. al.*, 2014).

MATERIALS AND METHOD

Electrical resistivity tomography (ERT) survey was carried out with a multi-electrode resistivity meter system (ABEM Terrameter SAS 4000). The data were automatically recorded using a dipole-dipole array with 41 electrodes spread along the profile line at an inter-electrode spacing of 5m. Resistivity data were acquired along three (3) profile lengths as shown in Figure 1.

Profile 1 was oriented in the West-East direction while profile 2 and 3 were laid in the direction of North-South. The total profile length of each spread was 200m. The choice of laying the profiles in that direction is as a result of the high numbers of building to be erected in that particular location.

The arrangement of the electrodes set up as described by Loke *et al*. (2013) for the two-dimensional (2D) electrical survey is shown in Figure 3. The raw resistivity data acquired from the field were processed and interpreted using RES2DINV (Loke, 2000) software. The raw data were filtered in order to remove bad datum points and an inversion was carried out on the corrected data. The software then generates the inverted resistivity depth image for each profile line.

Resistivity depth image surfers from non-uniqueness and can be reduced by using additional data usually borehole data, to constrain the resistivity values from the image obtained to an acceptable range for different lithological formation

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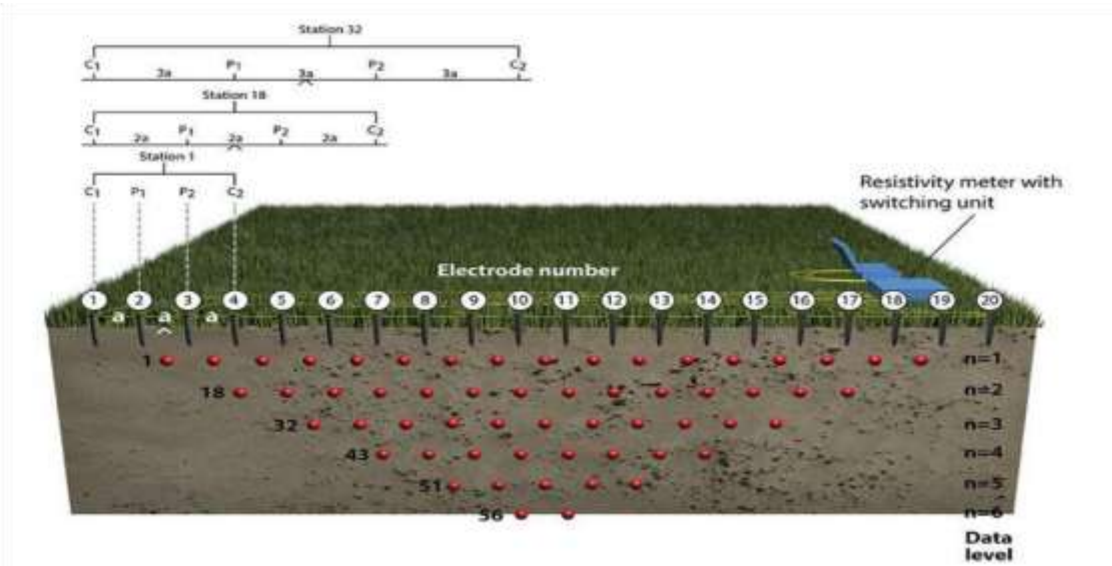

Fig. 3: 2D data collection using multi-electrode resistivity system (Loke *et al.,* 2013).

RESULTS

The results obtained from the inverted resistivity models; Figure 4, 5, 6, showed cross-sections of the true resistivity depth image of the subsurface soil within the area of study. Each of the profile lengths is 200m long and the resistivity distribution of all the profiles are almost similar at the horizontal distance of 95-170m.

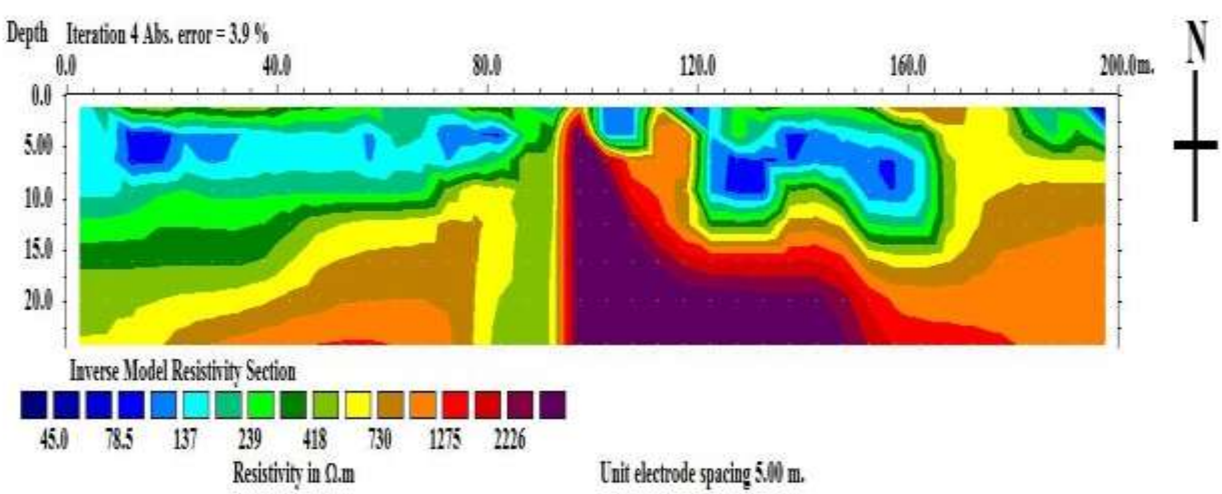

Fig. 4: 2D resistivity inversion model section for profile 1

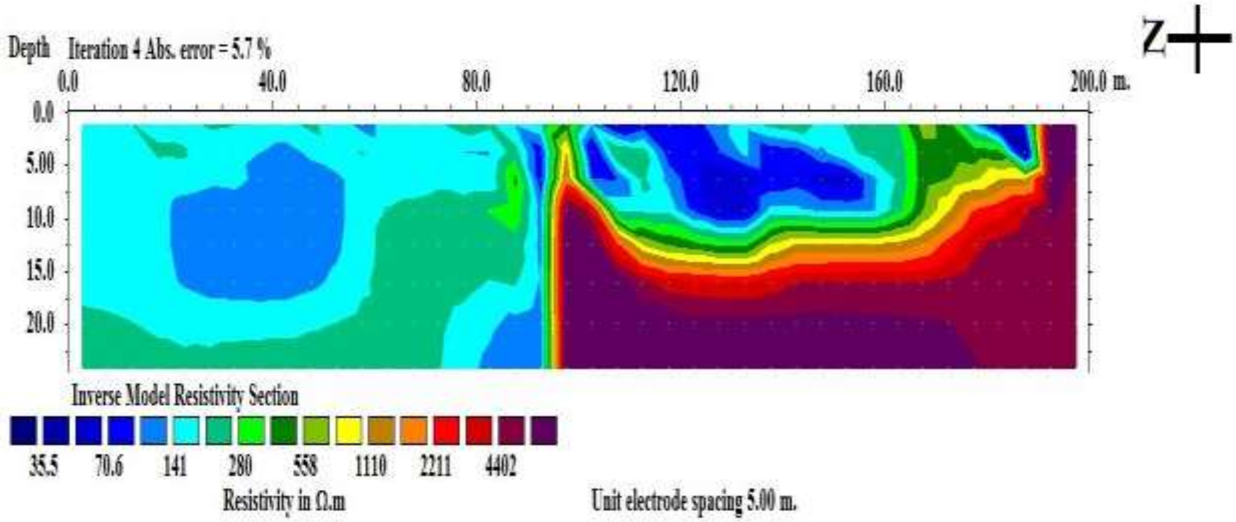

Fig. 5: 2D resistivity inversion model section for profile 2

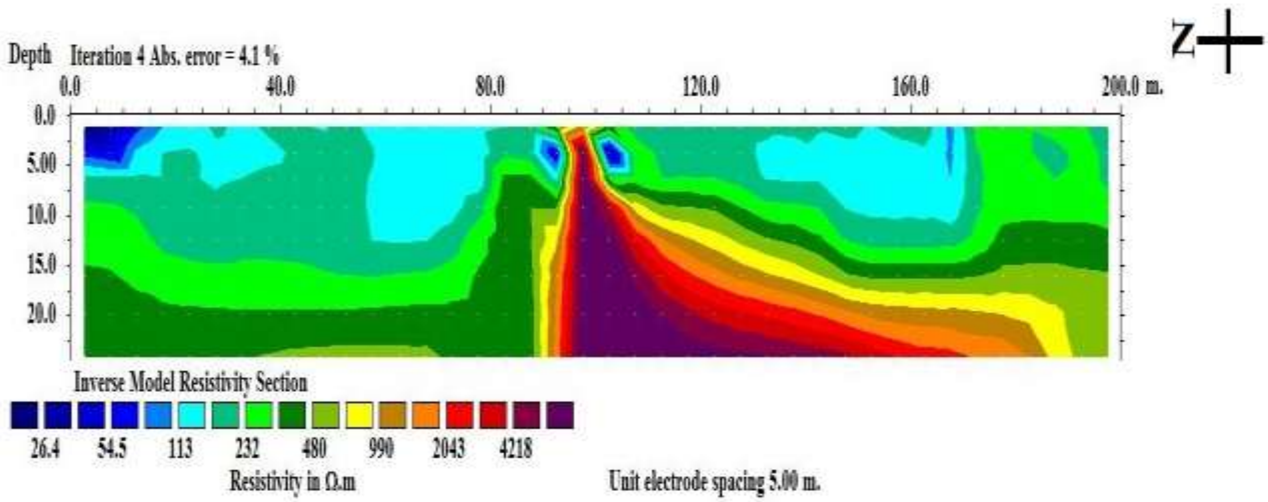

Fig. 6: 2D resistivity inversion model section for profile 3

The values of the resistivity within the study area range from <26.4 to >4418 Ωm, which indicates a wide difference in the soil type, water content, clay content of the soil, permeability, and porosity. The closest borehole log in 3D (Figure 7) for the area which is interpreted by Hydro Skill and Engineering Services, Kaduna (2005) served as a calibration tool for the resistivity models of all the profiles.

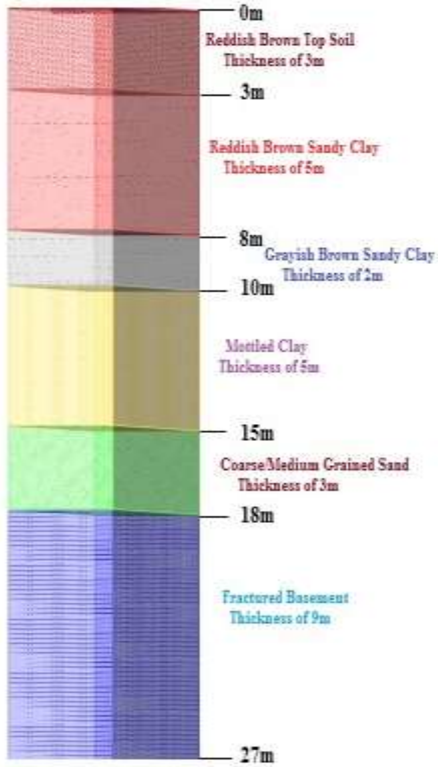

Fig. 7: 3D Geological borehole log used for calibration of the resistivity models

The tomograms of the three profiles depicts a thick layer of the topsoil which has a low resistivity values ranging from (0 to < 200 Ωm) and these indicate the presences of saturated water and clay materials in the layer and it almost spread across all the section in profile 2 and was absent in all the profiles at a lateral distance of 95-105m. This layer is made up of reddish-brown topsoil (laterite) and sandy clay. The thickness of this layer is about 8.0 m thick in all the profiles except profile 2 which extends downward in the southern side of the profile. Beneath this top layer is a weathered basement rock which intrudes the first layer at a horizontal distance of 95-105 m and its resistivity ranges from (200 - <2000 Ωm) and these layers may consist greyish brown sandy clay, mottled clay, and coarse/medium-grained sand, having a thickness of 10 m. Underneath this layer is a fractured basement rock having a resistivity value of the range (2000 - <3000 Ωm) and was encountered at the depth of 7.5- 19.8 m in profile 2, while in profile 1 and 3 it intrudes the first and second layer up to the vertical distance of 5 m. Fresh basement rock which is the last layer of the profiles, occurred at the depth of 19.8 m-24 m, although in profile 3 it intrudes the other layers from beneath to the topmost layer and it has a resistivity value above 4000 Ωm. The three electrical tomograms of the study area correlated well with the nearest borehole logs from the area.

DISCUSSION

The 2D electrical resistivity model was used to depict the distribution image of subsurface resistivity. The results of the three profiles from these images were characterized by low and high resistivity values ranging from <26.4 to >2500 Ωm. Generally, for foundation studies, the highly resistive material is usually considered and mostly fresh basement rock is the most suitable materials for the foundation.

The topsoil of the profiles is the overburden that consists of laterite, reddish-brown sandy clay and is about 8m thick. It is characterized by low resistivity values which are less than 200 Ωm, except at the horizontal distance of 95-105m where it is intruded by high resistive material. It dominates the northern part of profile 2. This low resistive material is not competent enough for the foundation structure to be laid on it.

The second lithological layer which is the weathered basement, also has a low resistivity value, though higher than the first layer, it ranges from (200-1953 Ωm). According to Sani, (2018), the weathered basement is a component of the aquifer in the basement complex area. Its implication on foundation structures, geo-technically, is that most times it contains clay materials and this material is inimical to foundation structures due to its ability to shrink and expand during dry and rainy season respectively.

The layer beneath the weathered basement is a fractured basement. It is more pronounced at the lateral distance of 80-95m and at the depths of 17.5m in profile 1 and the resistivity values (1275 -3969 Ωm). This layer is an important factor in terms of groundwater prospect. Similarly, to the first and second layer, it also poses a threat to the foundation and building structures.

The last lithological layer is the fresh basement, whose resistivity values is 4000 Ωm and above. The depth also ranges from 15.9m to infinity.

From this investigation, it can be deduced that the most suitable and competent layer for the foundation of the last building structure is the fresh basement layer and this is due to its high resistivity value which is a characteristic of a competent layer. Hence, for a high rising building, it is suggested that the foundation should be laid on the fourth layer.

CONCLUSION

Two-dimensional electrical resistivity has been carried out in Ahamdu Bello University phase II, Zaria, Nigeria, to characterize the subsurface materials for foundation studies. Three (3) profiles were carried out within the study area, in order to identify and determine the depth to competent layer for building foundation prior to the commencement of any structure in the area.

The results obtained from the resistivity tomograms of the three profiles indicates four distinct layers; Overburden (laterite and reddish-brown sandy-clay), weathered basement (greyish brown sandy clay, mottled clay, and coarse/medium-grained sand), fracture and fresh basement layers, the closest borehole log to the study area was used for calibration. The study shows that the fresh basement is the most competent layer to lay the foundation upon.

This investigation has been used to provide good information on the lateral and vertical variation of the most competent layer for building foundation structures and in identifying the weak zones that may be prone to subsidence.

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