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# Geoelectric Survey for Post-Foundation Investigation of a Distressed Building at Ade Super Hotel Akure, Southwestern Nigeria

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**ABSTRACT**

*A geophysical investigation involving the combination of two field techniques of Electrical Resistivity method were carried out within the premises of Ade Super Hotel, Akure with the aim of investigating the cause(s) of the foundation failure of a building within the premises and to understand the subsurface structures of the area. Two traverses (1 and 2) were established along S-N and W-E directions, covering a total length of about 50 and 75 m respectively. Two electrical resistivity field techniques were employed which are the Vertical Electrical Sounding and Dipole-Dipole Configurations. Thirteen (13) VES stations were occupied within the study area and the dipole-dipole data were acquired using electrode spacing of 5 m. Four geoelectric layers were delineated within the premises; the topsoil (clay, sandy clay and clayey sand), lateritic weathered layer, weathered layer (clay/sandy clay/clayey sand) and partially weathered/fractured/fresh bedrock and their resistivity values vary respectively as 45-210 Ω-m, 305-5858 Ω-m, 12-142 Ω-m, and 109 -10075 Ω-m. The thickness values also vary respectively as 0.5-2.3 m, 0.2-2.8 m, 6.2-36.8 m and depth to bedrock from 9-40.1 m to an undeterminable depth. The result obtained from the 2-D image correlates with that obtained from the geoelectric sections drawn for the two traverses. They showed that the upper lateritic layer is underlain by a clayey weathered layer, which in turn is underlain by partially weathered/fractured basement bedrock. The similarity in the results obtained therefore showed that the two techniques correlate and reveals the true nature of the subsurface in the study area. It could therefore be concluded that the foundation instability observed in the building was as a result of the clayey nature of the weathered layer on which the building was founded and the presence of linear features such as faults, fractures, fissures and joints within the bedrock.*

***KEYWORDS:*** *Cracks, competent layer, lateritic layer, weathered layer and bedrock.*

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## I. INTRODUCTION

Buildings are important to the people because it provides shelter as its primary function. On the other hand, it is used as places of business transaction, comfort and public utilities. Buildings among other things have capacity to provide socio-economic benefits to the country. The increase in the incessant failure of buildings has been attributed to subsurface problems (geologically) which have not been taken into consideration by the owners and foundation engineers prior to foundation design and construction. Several lives have been lost and lots of properties have been wasted due to incessant collapse of building as a result of foundation problem, poor construction practice and the use of substandard building materials among other things. Building cracks commonly occur due to resultant differential settlement in the subsurface. The size, shape, pattern and location of cracks on a building, when compared with other sites and construction conditions can help to distinguish among probable causes of foundation based failures (Tim, 2002). Seasonal volumetric changes in certain types of soil are the major factors affecting buildings' stability in most parts of the world. Certain clay soils can swell if they get saturated and when there is loss of water in them, they shrink drastically. These expansions and shrinkages of clayey soils can result to cracks on buildings even shortly after they are constructed (Egwuonwu and Sule, 2012). The closeness of static water level to the foundation beds could also precipitates foundation instability (Adeyemo and Omosuyi, 2012). The foundation of any structure is meant to transfer the load of the structure to the ground without causing the ground to respond with uneven and excessive movement. Moreover, building failures can be considered to have occurred in a component when that component can no longer be relied upon to fulfill its principal functions (Egwuonwu, 2012). In view of the above named factors, it is important to carry out pre-construction or post-construction geophysical investigation of a building site using appropriate geophysical field techniques (Akintorinwa and Adeusi, 2009, Ofomola, et al, 2009, Akintorinwa and Abiola, 2011, Bayode, et al., 2012 and Egwuonwu and Sule, 2012) to delineate the underlying geologic conditions.

## II. THE STUDY AREA

The building under study is located within the premises of Ade-Super Hotel, Akure, Ondo State, southwestern, Nigeria (Figure 1). It is located within the geographic grids (Northings) 804580 mN and 804755 mN and (Eastings) 739138 mE and 739407 mE (Zone 31, Minna datum) and accessible through Oyemekun road, Akure (Figure 1). The topographic elevation of the study area varies from 339 to 365 m above sea level and falls within the tropical rain forest climate. The study area lies within the crystalline basement complex of Southwestern, Nigeria and is underlained essentially by Charnockitic rocks (Figure 3).The building under study is a one-storey building in Ade-Super Hotel, Akure (Figures 1and 2). The building shows cracks in various directions and dimensions (Figure 2). The neighbouring buildings around the one under study have shown little or no similar kind of distress. The basal part of the building on the four sides shows wetness and serious cracks, and some of these cracks extend to the first floor of the building.

## III. MATERIALS AND METHODS

Electrical resistivity method involving the Vertical Electrical Sounding (VES) and 2-dimensional resistivity imaging was carried out using Half-Schlumberger and Dipole-Dipole Configurations respectively along two traverses. Traverse 1 runs in approximately S-N direction while traverse 2 runs in approximately W-E direction (Figure 1). All the resistivity data was acquired using the PASI 16GL resistivity meter and its accessories. The electrode separation (AB/2) for the VES was varied from minimum of 1 m to maximum of 65 to 100 m, while the electrode separation (a) of 5 m, with inter-dipole expansion factor (n) of 1-5 was adopted for the dipole-dipole survey along the two traverses. The first traverse has a total length of 50 m while the second traverse was 75 m long. The obtained data was modeled and inverted using the DIPRO for windows version 4.0 Software (Kigam, 2001). Thirteen (13) VES stations were occupied with the PASI 16GL resistivity meter within the study area using the Half-Schlumberger Array type due to space constraint (Figs. 1 and 4). The co-ordinates of each VES station were determined along with their respective elevation above sea level using the *etrex* Garmin GPS (Global Positioning System) device. The VES curves were interpreted quantitatively by partial curve matching technique (Keller and Frischknecht, 1966) and the obtained results were refined through the computer iteration technique using WinRESIST Version 1.0 Software (Vander Velpen, 2004).

## IV. RESULTS AND DISCUSSION

The results of the data obtained from the study are presented in form of Tables, Depth Sounding Curves, Pseudosections and Geo-electric Sections. The field curves obtained within the study area are the KH, KQ, HKH and KQH types with the KH-type being dominant (Figs. 5 and 6a-d) and the summary of the VES results are presented in Table 1.

**Geo-electric Sections**

The sections revealed approximately four geoelectric layers within the study area which include; the topsoil, lateritic weathered layer, weathered layer and the partially weathered/fractured/fresh basement (Figs. 7a and 8a). The resistivity of the topsoil (clay, sandy clay, clayey sand and sand), lateritic weathered layer, weathered layer (clay, sandy clay and clayey sand) and the partly weathered/fractured/fresh basement varies from 45-210 Ωm, 305-5858 Ωm, 12-142 Ωm and 109 to 10075 Ω-m respectively, with thickness values ranging from 0.5-2.3 m, 0.2-2.8 m, 6.2-36.8 m to an undeterminable depth and depth to bedrock ranging between 9 and 40.1 m to an undeterminable depth respectively. The topsoil is generally thin (less than 1 m) within the study area except beneath VES 4 and 7 where it is thicker than 1 m. The laterite is also thin; with thickness value not more than 2 m and the resistivity shows that it is hard-pan in some areas. The weathered layer generally has great thickness and the total thickness could not be determined in some areas especially beneath VES 11 and 12 (Fig. 8a). The basement bedrock is also fractured beneath some sounding points.

**2-D Dipole-Dipole Image**

The 2-D resistivity structures delineated two major subsurface layers; the topsoil/lateritic layer (in yellow/reddish/purple colour band) and the weathered layer (blue to green colour band). The topsoil is observed to generally subsume into the lateritic weathered layer because of its thinness and therefore could not be identified on the 2-D images (Figs. 5b and 6b). The 2-D resistivity structure beneath traverse 1 reveals a high resistivity lateritic weathered layer along the traverse to a depth of about 8 m. The layer thins to about 3 m between distance 15-25 m (between VES 3 and 4) along the traverse. The resistivity value of the lateritic weathered layer ranges from 100-494 ohm-m. The low resistivity values (20-100 ohm-m) typical of clayey materials observed beneath this layer reaches a depth of about 15 m. The presumed fresh bedrock was not delineated beneath this traverse. The 2-D resistivity structure beneath traverse 2 also shows a high resistivity lateritic layer along the traverse to a depth of about 5-9 m. The layer thins to about 5 m between distance 25-30 m and beyond 55 m (between VES 10 and 11 and VES 7-8) along the traverse. The resistivity value of the

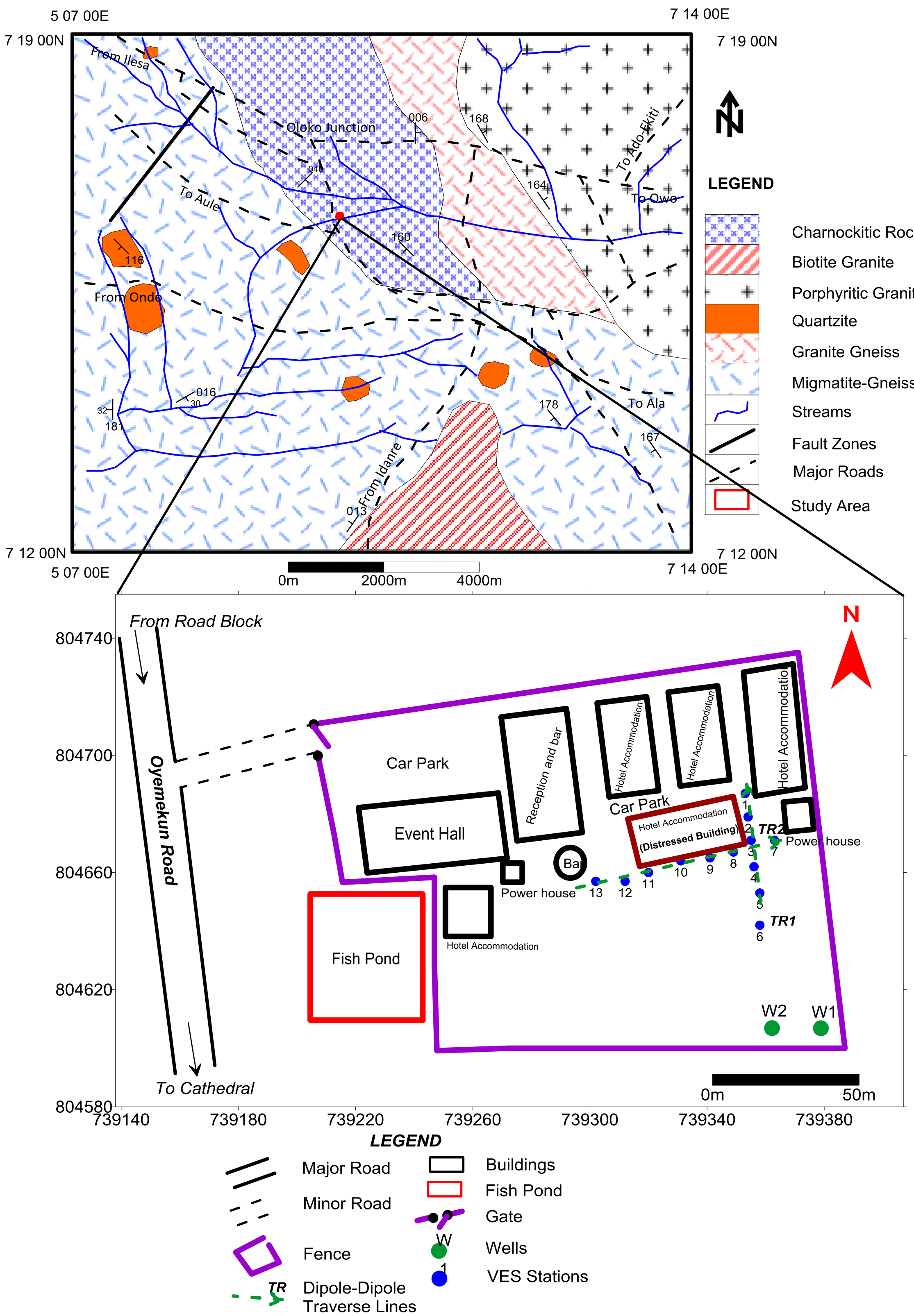


Figure 1: Simplified Geological map of Akure (After Owoyemi, 1996) and base/data acquisition map of the study area


Figure 2: Various parts of the building under study showing some of the cracks observed on it
(a) Right, (b) Front, (c) Left and (d) Back

lateritic weathered layer ranges between 130 and 1598 ohm-m on this traverse. The low resistivity values (15-130 ohm-m) observed beneath this layer to a depth of about 15 m is typical of the weathered (clay/sandy clay) layer resistivity. The weathered layer resistivity reduces towards the western part of the area especially between distance 15 and 35 m. The basement could not be delineated beneath this traverse as well.

## V. CORRELATION OF RESULTS

The geoelectric section beneath traverse 1 (Fig. 5a) shows zones of thick topsoil/laterite and weathered layer. These areas of thick topsoil/laterite and weathered layer correlate with that observed on the 2-D dipole-dipole image, especially the reduction in the lateritic weathered layer from VES 4 to 3 which is also observed between 15-25 m on the 2-D subsurface image (Fig. 5). The 2-D resistivity structure could not image beyond 15 m (due to the 5 m electrode separation used) and the basement could not be delineated at this depth. In corroboration, it was observed that the basement could not be delineated on the geoelectric section at this depth, except beneath VES 3 and it shows an evidence of fracture. The geoelectric section beneath traverse 2 (Fig. 6a) also shows correlation on the zones of thick topsoil/lateritic weathered layer and weathered layer in both techniques. The reduction in the resistivity of the weathered layer towards the western part of the area especially between distance 15 and 35 m on the 2-D subsurface image also corroborates the low resistivity and the undeterminable depth of the weathered layer within this area especially beneath VES 11 and 12 (typical of basement structures such as fault) (Fig. 6).The similarity in the results obtained showed that the two techniques correlate and reveals the true nature of the subsurface condition in the study area. The 2-D resistivity structure beneath traverse 1 reveals a high resistivity lateritic weathered layer along the traverse to a depth of about 8 m. The layer thins to about 3 m between distance 15-25 m (between VES 3 and 4) along the traverse. The resistivity value of the lateritic weathered layer ranges from 100-494 ohm-m. The low resistivity values (20-100 ohm-m) typical of clayey materials observed beneath this layer reaches a depth of about 15 m. The presumed fresh bedrock was not delineated beneath this traverse.

The 2-D resistivity structure beneath traverse 2 also shows a high resistivity lateritic layer along the traverse to a depth of about 5-9 m. The layer thins to about 5 m between distance 25-30 m and beyond 55 m (between VES 10 and 11 and VES 7-8) along the traverse. The resistivity value of the lateritic weathered layer ranges between 130 and 1598 ohm-m on this traverse. The low resistivity values (15-130 ohm-m) observed beneath this layer to a depth of about 15 m is typical of the weathered (clay/sandy clay) layer resistivity. The weathered layer resistivity reduces towards the western part of the area especially between distance 15 and 35 m. The basement could not be delineated beneath this traverse as well.

## VI. CORRELATION OF GEOPHYSICAL RESULTS

The geoelectric section beneath traverse 1 (Fig. 5a) shows zones of thick topsoil/laterite and weathered layer. These areas of thick topsoil/laterite and weathered layer correlate with that observed on the 2-D dipole-dipole image, especially the reduction in the lateritic weathered layer from VES 4 to 3 which is also observed between 15-25 m on the 2-D subsurface image (Figure 5). The 2-D resistivity structure could not image beyond 15 m (due to the 5 m electrode separation used) and the basement could not be delineated at this depth. In corroboration, it was observed that the basement could not be delineated on the geoelectric section at this depth, except beneath VES 3 and it shows an evidence of fracture. The geoelectric section beneath traverse 2 (Fig. 6a) also shows correlation on the zones of thick topsoil/lateritic weathered layer and weathered layer in both techniques. The reduction in the resistivity of the weathered layer towards the western part of the area especially between distance 15 and 35 m on the 2-D subsurface image also corroborates the low resistivity and the undeterminable depth of the weathered layer within this area especially beneath VES 11 and 12 (typical of basement structures such as fault) (Fig. 6).

## VII. CONCLUSIONS

It was observed that across the two traverses the partly clayey and sandy thin topsoil is underlain by lateritic weathered layer (majorly hard-pan) which correlates with field observation. The underlying weathered layer is observed to be thick and clayey while the basement underlying it is also fractured in many places.

Based on the obtained results, it could be concluded that the possible causes of the distress on the building include:

(i) Clayey nature of the weathered layer on which the building was founded, Clays have the ability to swell when it absorbs water and collapse under the influence of heavy load, thereby causing distress or failure of engineering structures such as buildings and roads if founded on it.

(ii) Presence of linear features such as faults, fractures, fissures and joints within the bedrock, such as it was observed within distances 15-35 m on the 2-D image of Traverse 2, which correlates with the fault-like structure observed beneath VES 11 and 12 on the geoelectric section. These could create deep structurally weak zones beneath the building foundation.

Table 1: Summary of the Vertical Electrical Sounding Results

| VES No. | Resistivity (ohm-m) | | | | | Thickness (m) | | | | Curve Type |
|---|---|---|---|---|---|---|---|---|---|---|
| | $\rho_1$ | $\rho_2$ | $\rho_3$ | $\rho_4$ | $\rho_5$ | $h_1$ | $h_2$ | $h_3$ | $h_4$ | |
| 1 | 77 | 327 | 52 | 3297 | | 0.7 | 2.8 | 15.3 | | KH |
| 2 | 45 | 699 | 32 | 419 | | 0.5 | 1.2 | 17.4 | | KH |
| 3 | 99 | 305 | 42 | 498 | | 0.9 | 1.8 | 6.2 | | KH |
| 4 | 210 | 185 | 956 | 142 | 1237 | 1.1 | 0.8 | 1.4 | 21.1 | HKH |
| 5 | 146 | 1108 | 91 | 10058 | | 0.7 | 2.6 | 36.8 | | KH |
| 6 | 88 | 4554 | 56 | 3754 | | 0.5 | 0.6 | 23.9 | | KH |
| 7 | 175 | 39 | 325 | 58 | 522 | 0.8 | 1.5 | 1.8 | 25.1 | HKH |
| 8 | 109 | 5538 | 65 | 10075 | | 0.5 | 0.2 | 28.8 | | KH |
| 9 | 171 | 932 | 82 | 28 | 109 | 0.8 | 1.3 | 8.7 | 16 | KQH |
| 10 | 163 | 900 | 137 | 21 | 10041 | 0.7 | 0.8 | 5.7 | 16.2 | KQH |
| 11 | 129 | 5858 | 90 | 35 | | 0.7 | 0.4 | 14.7 | | KQ |
| 12 | 91 | 2128 | 39 | 12 | | 0.5 | 1.5 | 28.6 | | KQ |
| 13 | 95 | 700 | 36 | 840 | | 0.7 | 1.8 | 21.8 | | KH |

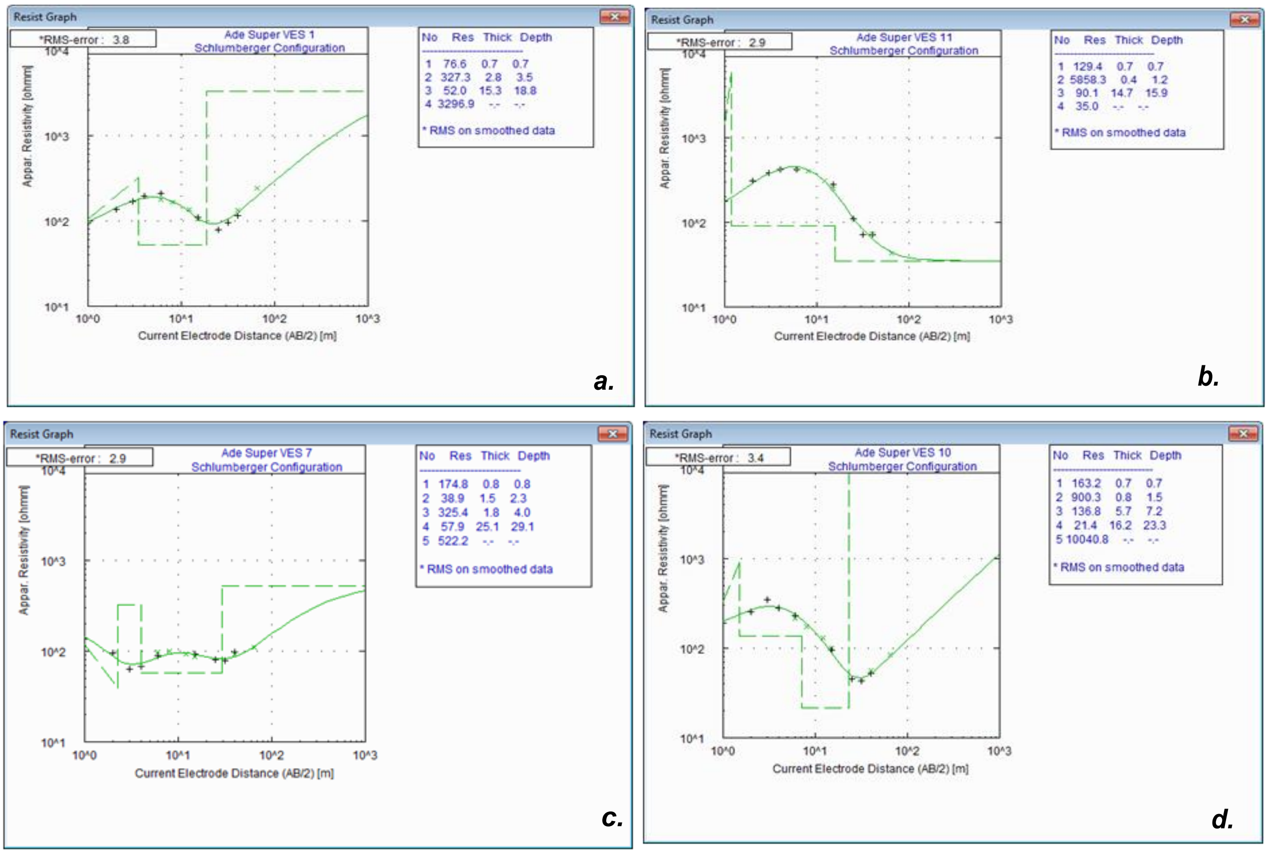


Figure 3: Curve types obtained in the study area

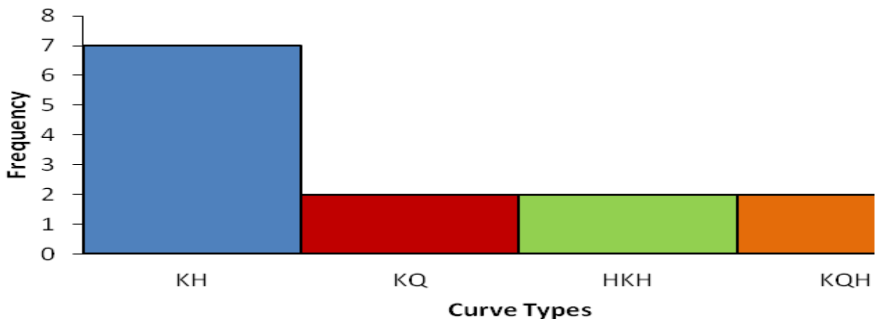


Figure 4: Histogram of curve types obtained in the Study Area

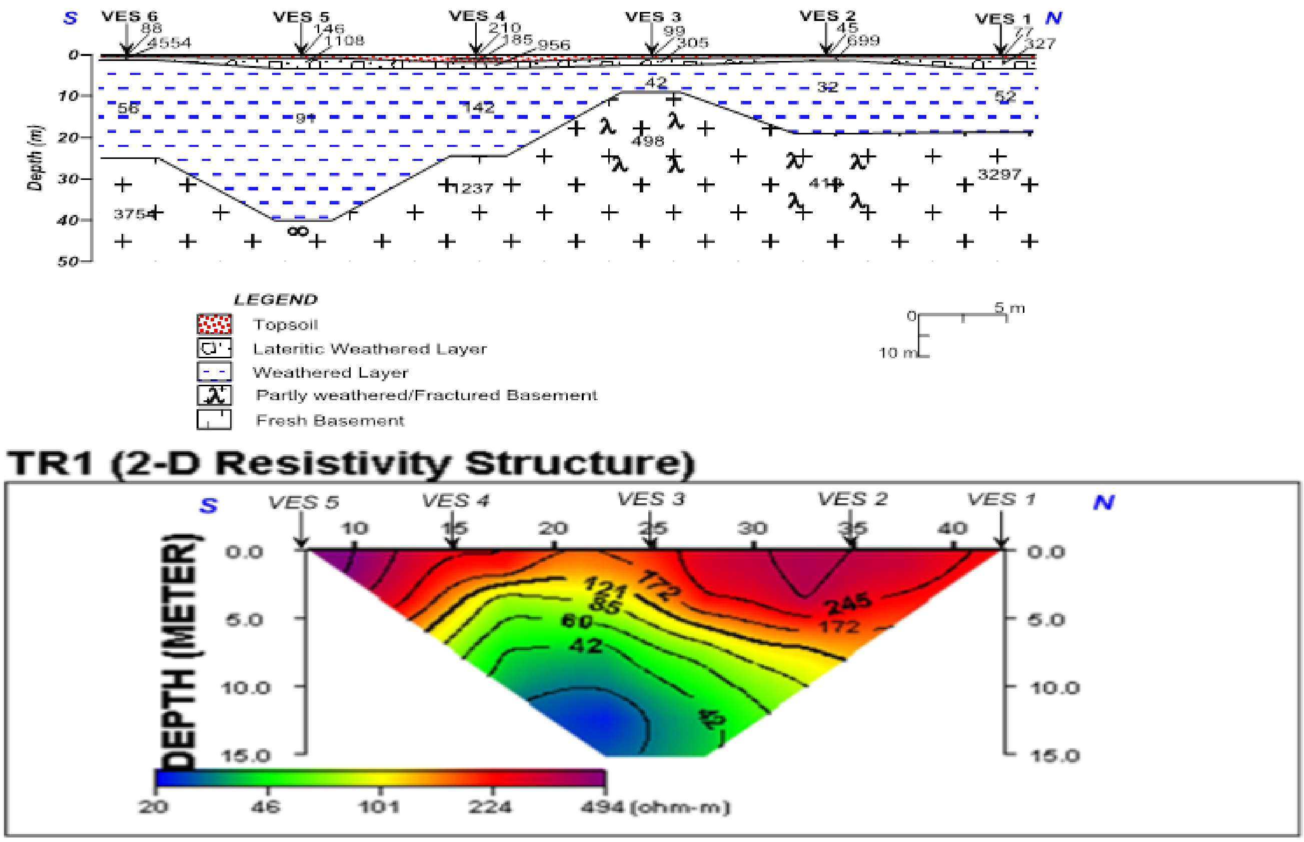


Figure 5: Correlation of (a) Geoelectric Section and (b) Dipole-Dipole Pseudosection along Traverse 1

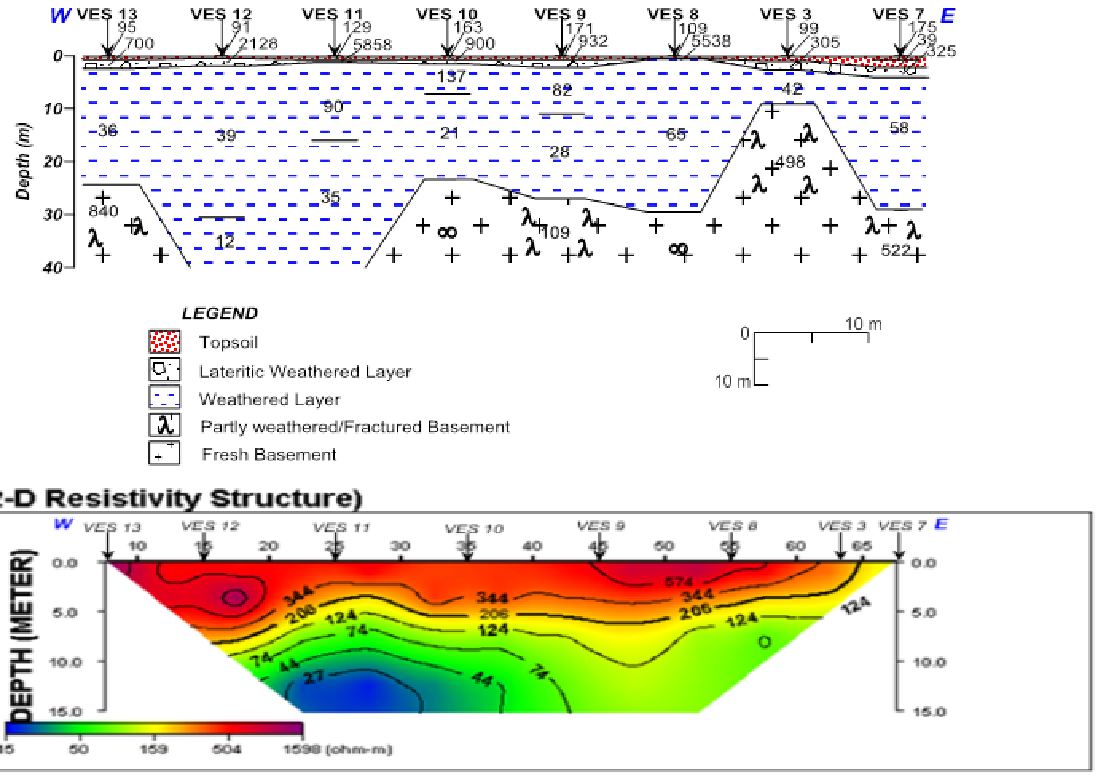


Figure 6: Correlation of (a) Geoelectric Section and (b) Dipole-Dipole Pseudosection along Traverse 2


## VIII. ACKNOWLEDGEMENTS

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## REFERENCES


[1] B.P.A. Vander Velpen, WinRESIST Software Version 1.0'. ITC, IT-RSG/GSD, Delft, Netherlands, 2004.

[2] C. Tim, House Foundation. Ask the Builder, Nationality Syndicated Newspaper Columnists. *www.askthebuilder.com, Free Weekly News and Tips, Column and Special Offers on Tim Cater's ebooks and Checklists, 2002.*

[3] F.G.H. Blyth and M.D. De Freitas, *Geology for Engineers*. Butler and Tannar, Ltd. Frome and London: London, UK. (1988), pp. 292-293.

[4] G.N. Egwuonwu, Application of Geophysical Imaging in Investigation of Structural Failure of Buildings: Case Study of Three Building Sites in Zaria Area, Northwestern Nigeria, *Pacific Journal of Science and Technology*, *13*(1), (2012), pp. 580-589.

[5] G.N. Egwuonwu and P.O. Sule, Geophysical Investigation of Foundation Failure of a Leaning Superstructure in Zaria Area, Northern Nigeria. *Research Journal in Engineering and Applied Sciences*, *1*(2) (2012), 110-116

[6] I.A. Adeyemo and G.O. Omosuyi, Hydrogeologic, Electrical and Electromagnetic Measurements for Geotechnical Characterization of Foundation Beds at Afunbiowo, near Akure, Southwestern Nigeria. *Indian Journal of Science and Technology*, *Vol. 5*, No. 2, (2012), pp. 2017-2022.

[7] Kigam, J. K. "DIPRO for Windows Version 4.01". Copyright 1996-2001. Hee Song Geotek. 2001.

[8] M.O. Ofomola, K.A.N. Adiat, G.M. Olayanju, B.D. Ako, Integrated Geophysical Methods for Post Foundation Studies, Obanla Staff Quarters of the Federal University of Technology, Akure, Nigeria. *Pacific Journal of Science and Technology. 10*(2) (2009), pp. 93-111.

[9] O.J. Akintorinwa and F.A. Adeusi, Integration of Geophysical and Geotechnical Investigations for a Proposed Lecture Room Complex at the Federal University of Technology, Akure, SW, Nigeria, *Ozean Journal of Applied Sciences 2*(3), (2009), pp. 241-254.

[10] O.J. Akintorinwa and O. Abiola, Subsoil Evaluation for Pre-foundation Study using Geophysical and Geotechnical Approach, *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 2* (5), (2011), pp. 858-863.

[11] S. Bayode, G.O. Omosuyi and H.I. Abdullai, Post-Foundation Engineering Geophysical Investigation in Part of the Federal University of Technology, Akure, Southwestern Nigeria, *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS)*, *3* (1), (2012), pp. 91-97.