2D ELECTRICAL RESISTIVITY IMAGING SURVEY FOR FOUNDATION STUDIES AT THE REAR OF FUOYE ADMINISTRATIVE COMPLEX, OYE-EKITI, NIGERIA

Supported by tetfund

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Received: December 14, 2023 Accepted: March 28, 2024

Abstract: 2D Electrical Resistivity Imaging (ERI) was carried out for pre-construction foundation investigation at the rear of the administrative complex of Federal University Oye-Ekiti, Southwestern Nigeria, to delineate the nature of the subsurface geological structures. The ERI technique was employed, using a Wenner array electrode configuration, whereby eight (8) profiles were established across the study area. 2D georesistivity maps were generated to display the resistivity distribution across the various depths of investigation. The RES2DINV results show three (3) subsurface layers with resistivities of 210 Ωm, 420 Ωm and 600 Ωm at depths of 2 m, 7.8 m, and 9.9 m, respectively. The resistivity distribution splits the study area into two zones: zones of high resistivity and zones of low resistivity. Zones of low resistivity suspected in the northwest section of the study area are depicted on the georesistivity maps, while zones of high resistivity (> 250 Ωm) are depicted in the south and northeastern sections. Zones of low resistivity are inimical to engineering structures. Geological structures such as fractures, faults, and shear zones were delineated in the study area, which could affect structures constructed on them. The 2D images and the georesistivity maps gave continuous and precise information about the subsurface in different representative geological situations.
Keywords: Georesistivity, pre-construction, engineering, subsurface, electrical

Introduction

It is important to do a pre-construction study of the subsurface to reduce the risk of structural failure. This is because Nigeria has a lot of failed and flop buildings and other distressed engineering structures, which have caused people to die and property to be destroyed (Ede, 2010; Amosun et al., 2018). The support that the materials used as the structure's foundation provide is one factor in the success of engineering constructions placed directly on the surface of the earth (Terzaghi et al., 1996). Whether or not foundation rocks can provide the support needed for engineering projects depends on how much weight they can hold. Geological and structural factors like the rock's mineralogical composition, rock fabric, rock association, degree of weathering, fluid saturation, rock deformation, and the presence of joints and faults can also change how strong the foundation material is in different places.

In addition to affecting their bearing strength, these things also affect the bearing strength of the foundation rocks (Fishman, 1979).Even though proper engineering design, structural balance, reinforcement, and quality of materials have all gotten a lot of attention, less attention has been paid to making sure the foundation material is strong enough to hold up the structure. Because of this, both public and private engineering projects often have many stress-induced cracks and other foundation-related flaws, some of which are disasters waiting to happen (Matawal, 2012; Osinowo et al., 2011).In order to determine whether the foundation rocks can provide any engineering structure with the support it needs, this study will map the subsurface geological structures as well as measure the depth of the bedrock and the thickness of the overburden.

Description of the Study Area

The study area is located at Federal University Oye-Ekiti (FUOYE) campus. It has geographic coordinates of Eastings 754900 and 756500 mE and Nothings 859700 and 860900 mN of Zone 31N (Minna datum) in the Universal Traverse Mercator (UTM) coordinate system. It is accessible by road from Faculty of law to new Administrative block, within the school campus. (Figure 1). The topography of the study area is gently undulating. Typical of these are the identified series of valleys within the study area. The study area falls within the tropical rain forest of southwestern Nigeria with distinct wet and dry seasons. The dry season comes up between November and April while the wet season prevails between May and October. The mean monthly temperature is about 28^{o}C while the mean humidity is over 70%. The main river in the study area is River Atirin close to the university hostel and River Egburu across the university road that leads to Are town both of which are tributaries to River Awere, close to the University ICT center (http://ekitistate.gov.ng/about-ekiti/overview/).

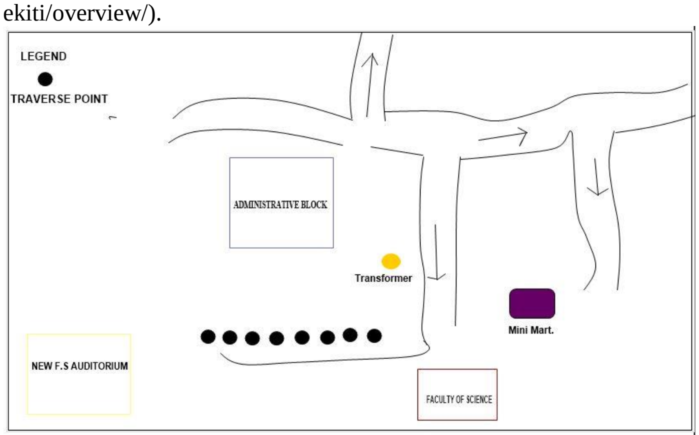

Figure 1: Base Map of the Study Area (not drawn to scale)

Materials and Methods

The acquisition of data was carried out using the electrical resistivity method, adopting a Wenner array configuration.

The current electrode and potential electrodes are equally spaced, and all the electrodes are moved at the same time. In order to measure both vertical and horizontal resistivity, the space between the electrodes is made larger, and the survey is moved along a profile. The obtained data was then used to generate an image of the subsurface by creating a pseudosection (Loke et al., 2013).

Each profile was 100 m long, and there was 10 m of space between each profile. The apparent resistivity generated from the subsurface was measured using an SAS 300 terrameter. Electrode stations of 2 m, 5 m, 10 m, 15 m, and 20 m were sounded on each profile to acquire 2D information (Figure 2). Results were inverted using non-linear least squares optimization. The two-dimensional (2D) resistivity distribution model of the subsurface in the study area was shown. It is made up of noise-free (very little noise) and depth-matched resistivity data from Loke et al. (2013). The forward modelling subroutine of RES2DINV figures out the theoretical apparent ground resistivity (DeGroot-Hedlin and Constable, 1990; Auken and Christiansen, 2004; El Hameedy et al., 2023).

The subsurface resistivity delineation produced 2D resistivity models and depth maps that show how the resistivity is spread out. The resistivity data from each profile was turned around to make the 2D resistivity distribution models. These models show changes in ground resistivity along the electrode stations used in each profile. They also show variation in ground resistivity across the established profile stations and with depth (Osinowo and Falufosi, 2018). Surfer 12 software was used to create the images of the resistivity distribution. The processed data were interpreted both qualitatively and quantitatively.

Results and Discussion

2D Electrical Resistivity Imaging Interpretation

The eight (8) profiles run along the South - North direction on the horizontal axis of the RES2DINV images (Figures 2a-h).

Profile 1 tend from S to N and has a length of 100 m in the high resistivity zone, which is between stations 24 to 36 and 49 to 96, respectively. The first (upper) layer has a depth range of 0–2 m, with resistivity values ranging from 28 Ωm –210 Ωm across all the profiles. This layer is characterized by a moderately low resistivity range of 28 Ωm - 150 Ωm with the exception of profile 4, which shows moderately high resistivity at the upper layer with a resistivity of 210 Ωm, at the lateral extent of 20 to 30 m. This layer covers the entire lateral extent of the profile, from 3 m to 97 m. The characteristics and features of this layer are similar and consistent throughout all the profiles.

The second (middle) layer has a depth range of 3m to approximately 7.8m which exhibits variation of resistivity values ranging from (20 to 680Ωm). The lateral extent of this layer is 12.5 m to 92.5 m. This layer has a relatively high resistivity value in the southern part of all profiles, with a lateral extent ranging from 10 to 56 m. Profiles 1, 2, 3, 4, 5, 6, and 8 show relatively high resistivity values (300 to 680 Ωm), except profile 7 which didn't depict the common feature in the second layer with a resistivity (< 150Ωm). While at the northern part, it shows a low – moderate resistivity value throughout the whole profile (20.9 to 259Ωm) much less than the northern region, except for Profile 1 which shows a relatively high resistivity value of 265Ωm.

The third (and final) layer spans all profiles and has a depth range of 8-9.9 m and a lateral extent coverage of 22-54 m. At profiles 2 and 7, the fresh basement was reached with a resistivity (> 600Ωm), the basement was not reached at profiles 1, 3, 4, 5, 6, and 8 with moderate resistivity values ranging from (63 to 300Ωm).

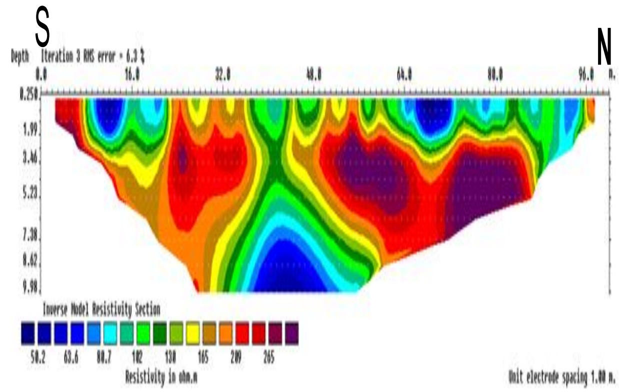

Figure 2a: 2D Image Showing Profile 1.

Based on soil classification of resistivity values, the upper layer is the topsoil which is clayey in nature; the middle layer is the weathered layer which is lateritic in nature, while the third layer is the weathered basement.

Geological structures such as fracture zones, shear zones and fault zones were discovered from the RES2DINV results. The following pseudo-sections show the nature of the fracture (130Ωm) delineated in the individual profiles. Figure 2b with resistivity of 160Ωm at the lateral extent of 48- 53m, figure 2c with resistivity of 70Ωm at the lateral extent of 66- 74m, having a depth extent of 2.5-8m, Figure 2d with resistivity of 280Ωm at the lateral extent of 36-46m, having a depth extent of 7-9m, Figure 2e with resistivity of 142Ωm at the lateral extent of 21-27m, having a depth extent of 0.25-7.5m. It is to be noted that Figure 2e, has two fracture zones, at lateral extent of 22-24m with resistivity of 85Ωm with resistivity value of 50Ωm at the lateral extent of 42-44m which could affect any structure constructed across this zone.

Figure 2f, gives a shear zone, showing rock intrusion running throughout the established subsurface layers. This would affect any structure constructed on this point, being a zone of weakness. These geological structures are prominent in the second layers of all the 8 profiles.

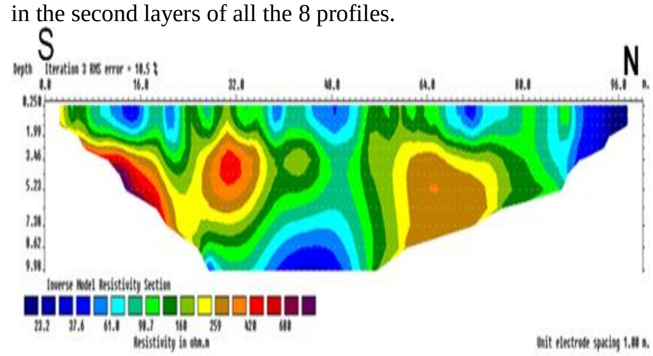

Figure 2b: 2D Image Showing Profile 2

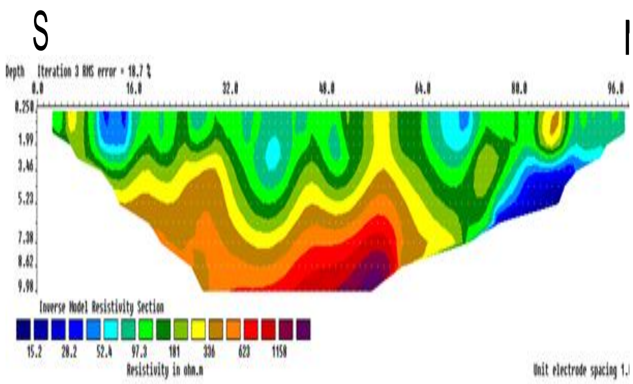

Figure 2c: 2D Image Showing Profile 3

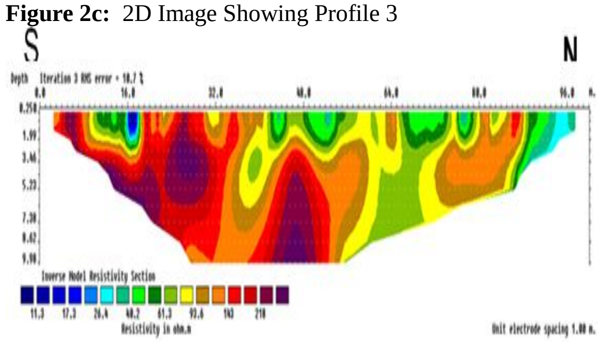

Figure 2d: 2D Image Showing Profile 4

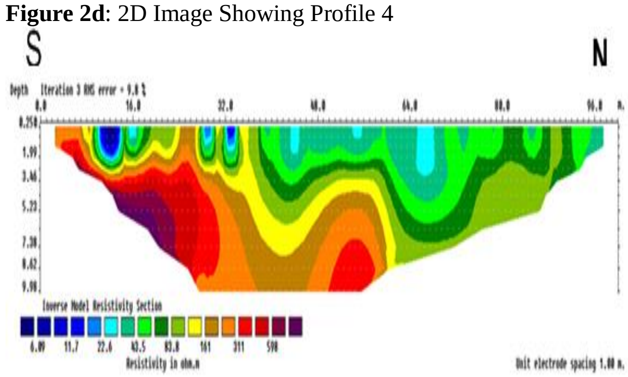

Figure 2e: 2D Image Showing Profile 5

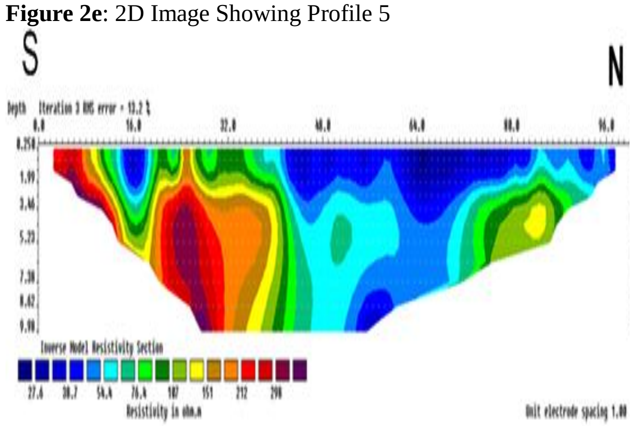

Figure 2f: 2D Image Showing Profile 6

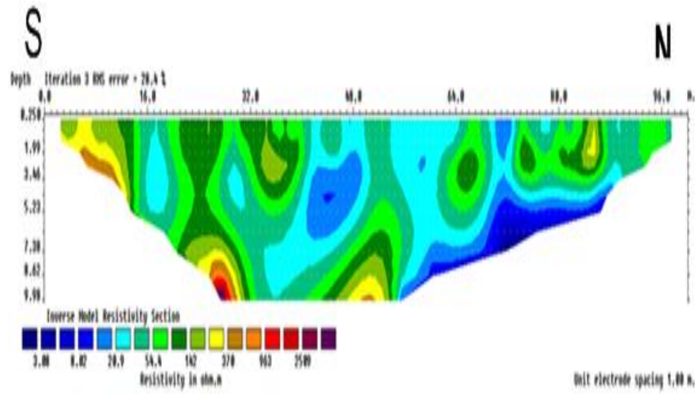

Figure 2g: 2D Image Showing Profile 7

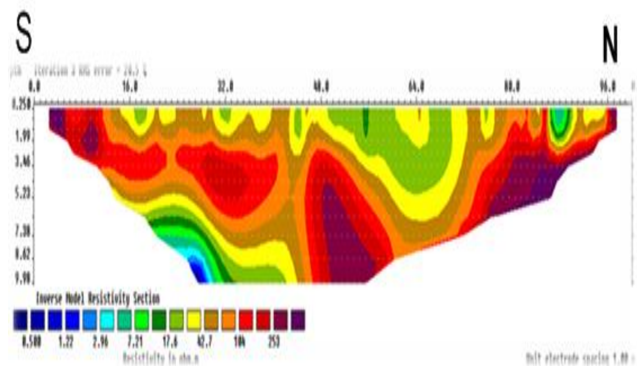

Figure 2h: 2D Image Showing Profile 8

Geo-resistivity Maps

The 2D geo-resistivity maps (Figure 3a – 3e) of the study area indicates the resistivity distribution pattern across the field at different depths. These enabled the evaluation of the resistivity distribution pattern of the entire field at different depths. Same electrode intervals for all the investigated profiles where combined to generate the map i.e. the depth slice. This was generated to classify the resistivity distribution across the study area with respect to various depths.

Figure 3a, presents the field resistivity distribution at a depth (< 2m) very close to the surface with a resistivity range of (<100Ωm), the northern zone with resistivity values less than 60Ωm and the southern part (>200Ωm). This depth correlates and confirms the assertion of the resistivity classification in the RES2DINV images of the profiles.

Characterized by two resistivity zones, this classification divides the field into two zones. The maps give similar resistivity distribution throughout the entire depth slice. The identified high resistivity zone is at the south and north - eastern part while the low resistivity is at the north - western part on the geo-resistivity map, showing the various resistivity values across the field.

Figure 3b – e, presents the 2D resistivity distribution across the field at 5m, 10m, 15m and 20m respectively. The 2D resistivity distribution maps corroborates and correlate with the earlier mentioned higher resistivity distribution pattern in the southern part of the field relative to the north as presented by the RES2DINV images. The various depth resistivity distribution maps indicate increase in ground resistivity value with depth at the south and north - eastern part of the field as the resistivity value increases from 120Ωm at near the ground surface to greater than 700Ωm at 20m depth.

Across all the depths, the low resistivity zones are restricted to the north – west of the field, which presents a very low resistivity value (< 55Ω m). The high resistivity zone runs from profile 1 – 6, making profile 7 and 8 at the extreme north - western part, the low resistivity zone.

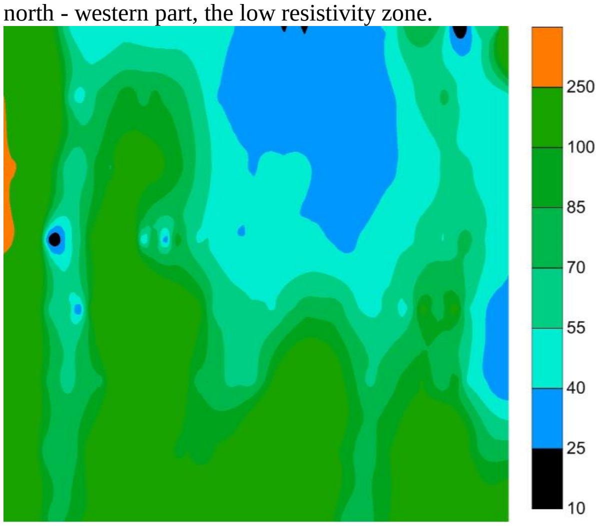

Figure 3a: 2D Georesistivity Map at 2m.

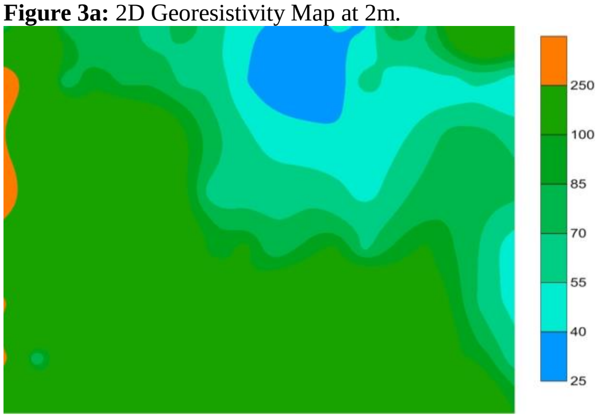

Figure 3b: 2D Georesistivity Map at 5m.

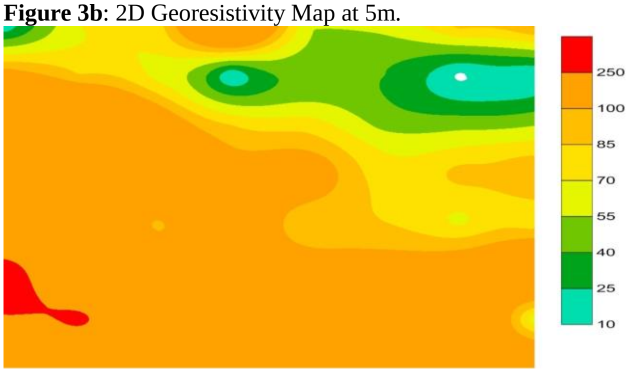

Figure 3c: 2D Georesistivity Map at 10m.

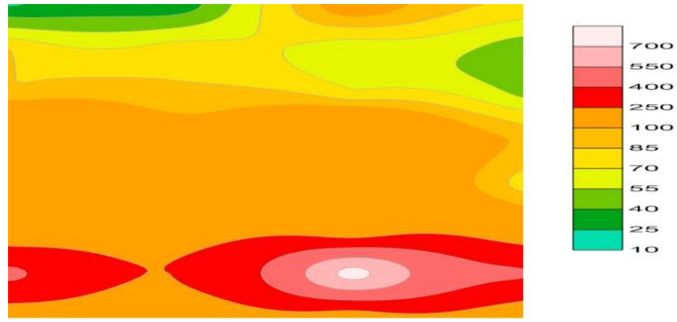

Figure 3d: 2D Georesistivity Map at 15m.

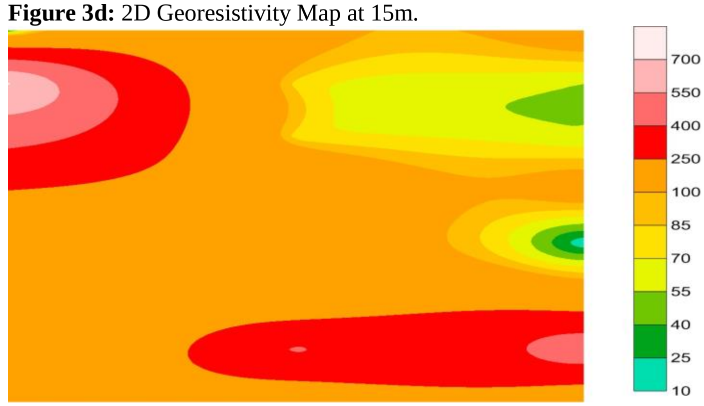

Figure 3e: 2D Georesistivity Map at 20m.

Conclusion

The Electrical Resistivity Imaging (ERI) technique has been very effective in illuminating the subsurface and apt at providing information about the rock's physical properties for economic, environmental, and engineering purposes. The 2D imaging results and the georesistivity maps give almost similar, continuous, and precise information about the subsurface in different representative geological situations. The results generated from the RES2DINV show zones of high and low resistivity; the low resistivity zone is at the northern part of all the profiles, while the zone with high resistivity is at the southern part of the images.

Profiles 1, 3, and 6 show some zones of weakness, which include fractures and shear zones. These geological structures could be a source of failure and collapse for the structures in the future, especially those constructed across the geological structures. The segregated resistivity distribution maps across the area show a zone of low resistivity, which may likely cause stress to engineering structures, while the high resistivity zone supports engineering structures. This supports the spatial variability of ground physical parameters observed throughout the study area. From the results obtained, the construction of the foundation in this study area is recommended at about 2 to 5 m deep.

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