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Structural failure investigation using electrical resistivity method: A case study of Amafor Ihuokpala, Enugu, Southeastern Nigeria

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An electrical resistivity investigation was carried out within the vicinity of some failed building structures at Amafor Ihuokpala through Agbani, Enugu, Southeastern Nigeria. The aim of the survey was to determine the causes of the failure of the structures. Resistivity data were acquired by using PASI (16GL) digital earth resistivity meter. Interpretation of the vertical electrical sounding results indicates the occurrence of relatively thin topsoil (<2 m) composed of sandy-clay which is underlain by clay-shale formation to about 40 m depth. The resistivity distribution map of the formation shows significant lateral facie and/or moisture changes within the topsoil. The clay-shale has vertical facies changes without any significant lateral facies changes. Synthesis of the result indicates that, due to hydrological and petrological factors, there is significant variation in the moisture regime of the soils underlying the site. This results in substantial swelling and shrinkage of the foundation soils leading to occurrence of cracks/deformation in the building structures. Improvement of the soil through stabilization and/or reinforcement is required for effective foundation design.

Key words: Electrical resistivity, vertical electrical sounding, lateral facies, and soil stabilization.

INTRODUCTION

Geophysical investigation is one of the methods used in probing the soil/subsoil and subsurface for any engineering construction activities. The deduced soil characteristics are used as preliminary information to determine the suitability of the site for the proposed structure. If this crucial step is omitted, concealed geologic features within the subsurface may precipitate excessive total or differential settlement leading to failure or collapse of civil structures. Geophysical methods that have been found useful in pre and post–construction geotechnical investigations include the gravity, the electrical resistivity and the seismic refraction methods including the Ground penetrating radar (GPR) (Roth et al., 2002; Fatoba and Salami, 2004; Olorunfemi et al. 2005; Akintorinwa et al., 2011; Salami et al., 2012).

Some failed building structures with major cracks and deformation of the walls are noticed at Amafor Ihuokpala via Agbani, Enugu, Southeastern Nigeria. These cracks, which are mainly vertical and diagonal, are common and more pronounced on high buildings with strip footy foundation (Plates 1 and 2). A geophysical investigation involving the electrical resistivity survey and using Schlumberger technique was carried out at the site with the sole objective of delineating the subsurface

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Plates 1 and 2. Typical failed structures at the investigated area.

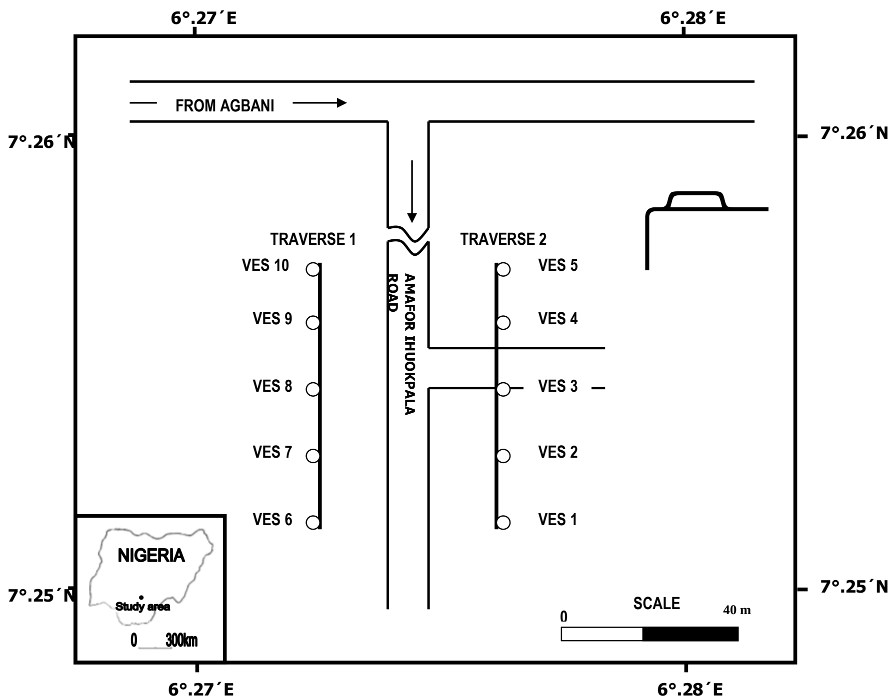


Figure 1. Sketch map of the survey area showing the traverses and the vertical electrical sounding stations.

lithologies and determining the layer geoelectric parameters, determining the nature of the near surface (soils), and deeper materials, and identifying the presence and nature of the geologic features responsible for the failure.

Location and description

The study area is Amafor Ihuokpala through Agbani, Enugu. It lies within longitude 6° 27´ to 6° 28´ E and latitude 7° 25´ to 7° 26´N (Figure 1). The climate of the area is typical of the tropical rain forest with mean annual rainfall range of 1500 to 1800 mm (Inyang, 1975). The residents have reported high amount of surface run-off, which is diagnostic of very low infiltration capacity of the subsoil. The major streams in the area are also reported to be seasonal. The topography of the area is gentle undulating with an average elevation of about 120 m above mean sea level.

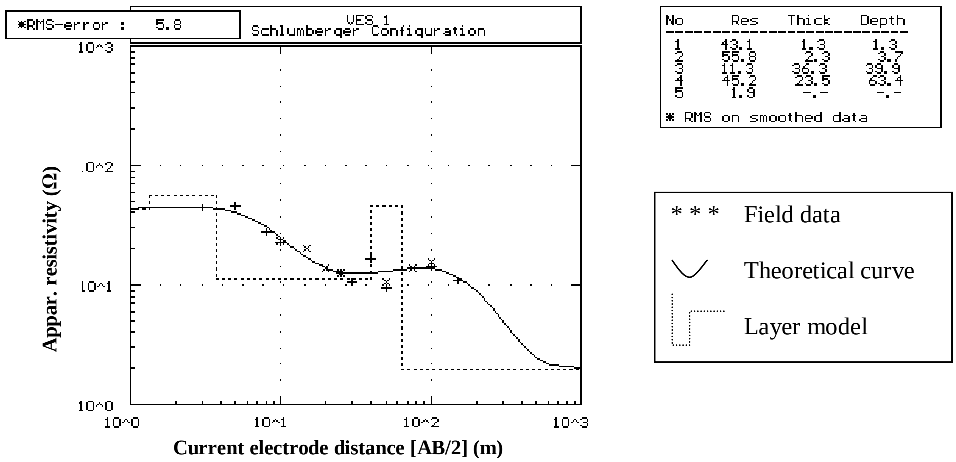


Figure 2. Interpreted schlumberger depth soundingc for VES 1.

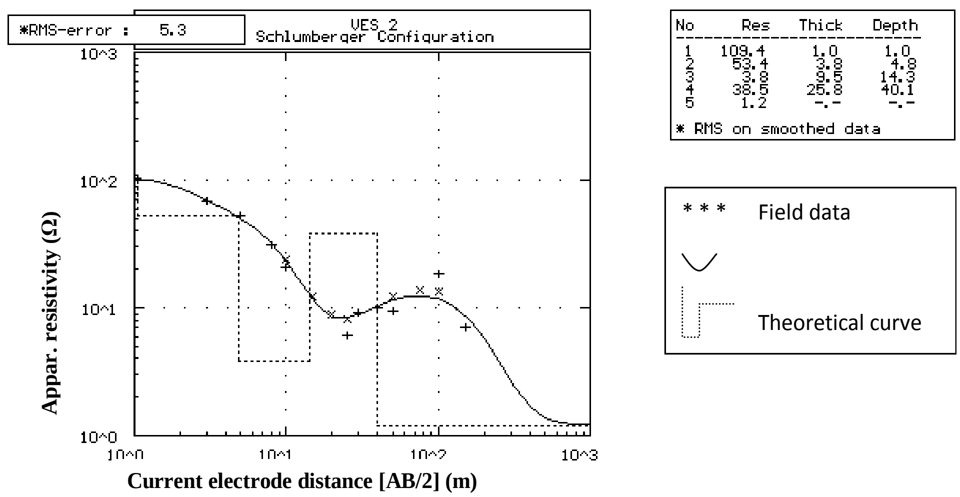


Figure 3. Interpreted schlumberger depth sounding curve for VES 2.

METHODOLOGY

Geologic setting

The study area falls within the Anambra basin. It is essentially underlain by Campano-Maastrichtian sediments predominantly consisting of sandstone and shale with minor coals and limestone (Okoro, 1995). The Campano-Maastrichtian deposits constitute the Proto-Niger Delta and represent the third and terminal cretaceous marine depositional phase in the Benue trough. At the base of the Campano- Maastrichtian succession, and uncomfortably on Turonian-Coniacian beds, is the marine Nkporo shale with the Enugu shale as its lateral equivalent in the Anambra basin. (Kogbe, 1976).

Field measurement

The geophysical investigation involved the use of electrical resistivity survey employing the Vertical electrical sounding (VES) technique. The Schlumberger configuration was utilized for the investigation. The PASI (16GL) digital resistivity meter was used for the data collection. A total of 10 depth-sounding stations were occupied along two profiles that from run North-south around the failed structures. The current electrode spacing (AB/2) was varied from 3 to 150 m giving total spread length of 300 m for each sounding location.

Data presentation and interpretation

The VES data were plotted on log-log graph with the apparent resistivity (Pa) values on the ordinate and the electrode separation (AB/2) along the abscissa. The curves were interpreted qualitatively through visual inspection and quantitatively through partial curve matching (Keller and Frischknecht, 1966). The sounding curves are the QH and KH types. The results were further iterated using RESIST computer software (Vander, 1988; Figures 2 and 3). Geoelectric sections and borehole log (Figures 4, 5 and 6) were prepared for the study area. Resistivity distribution maps (Figures 7 to 9) were also prepared for the topsoil and depth levels of 3 and 8 m.

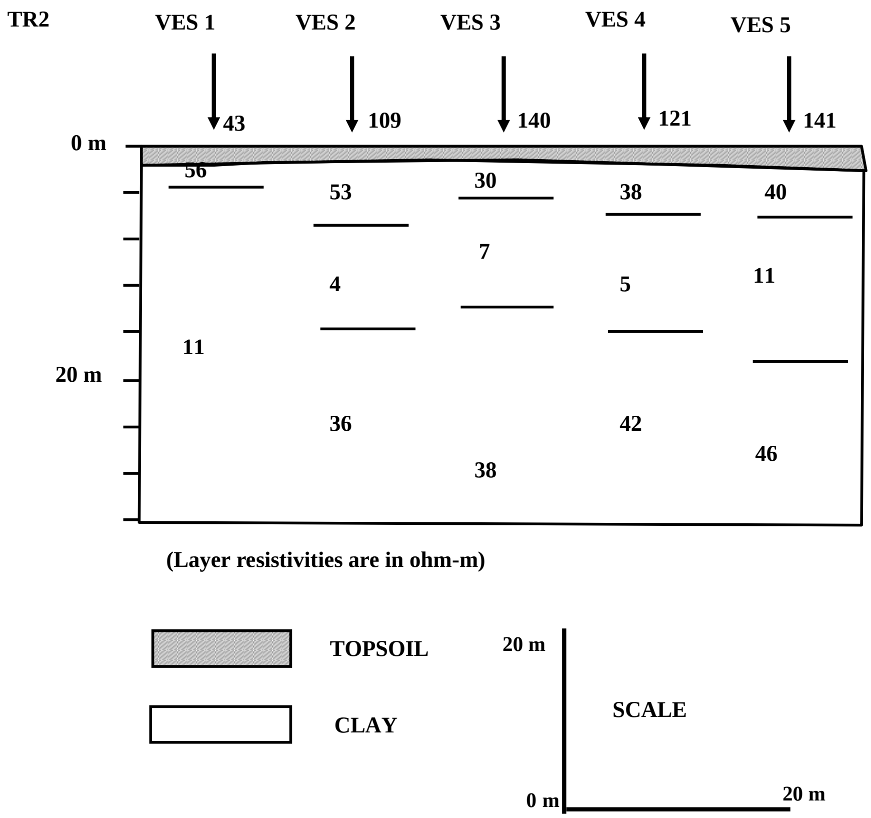


Figure 4. Geoelectric sections relating VES 1, 2, 3, 4, and 5.

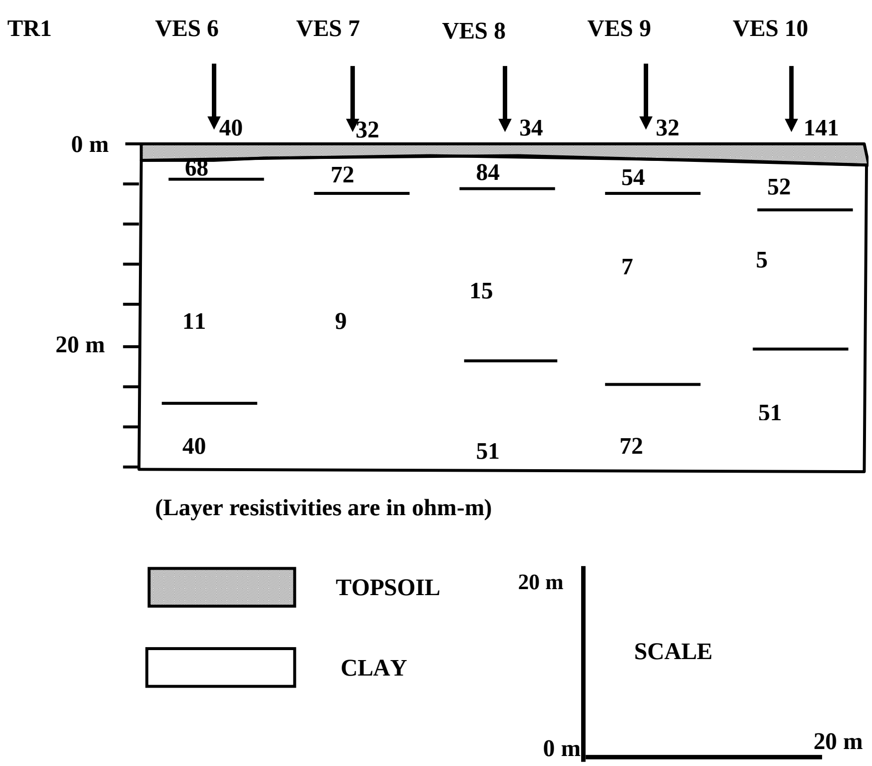


Figure 5. Geoelectric sections relating VES 6, 7, 8, 9, and 10.

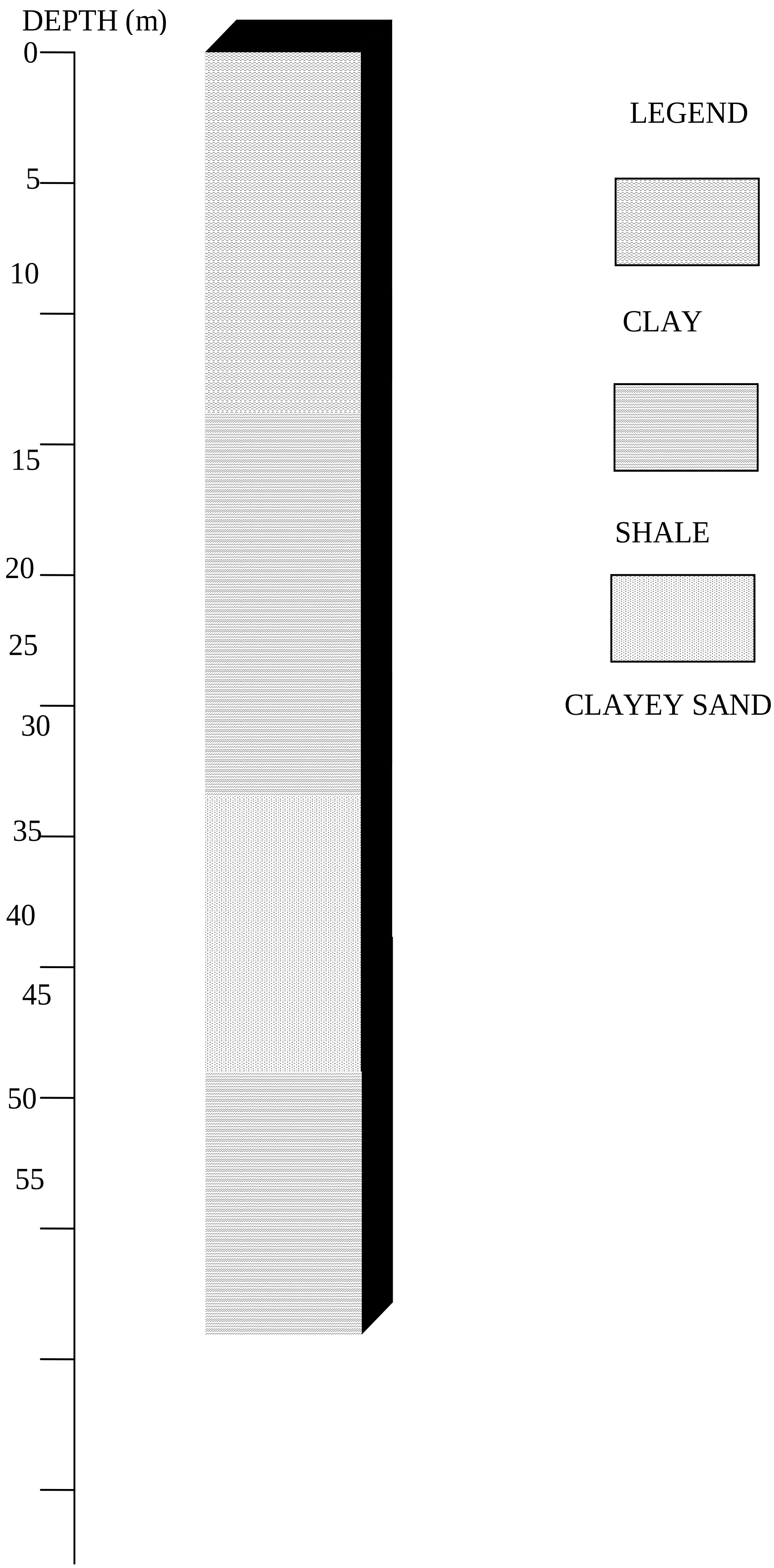
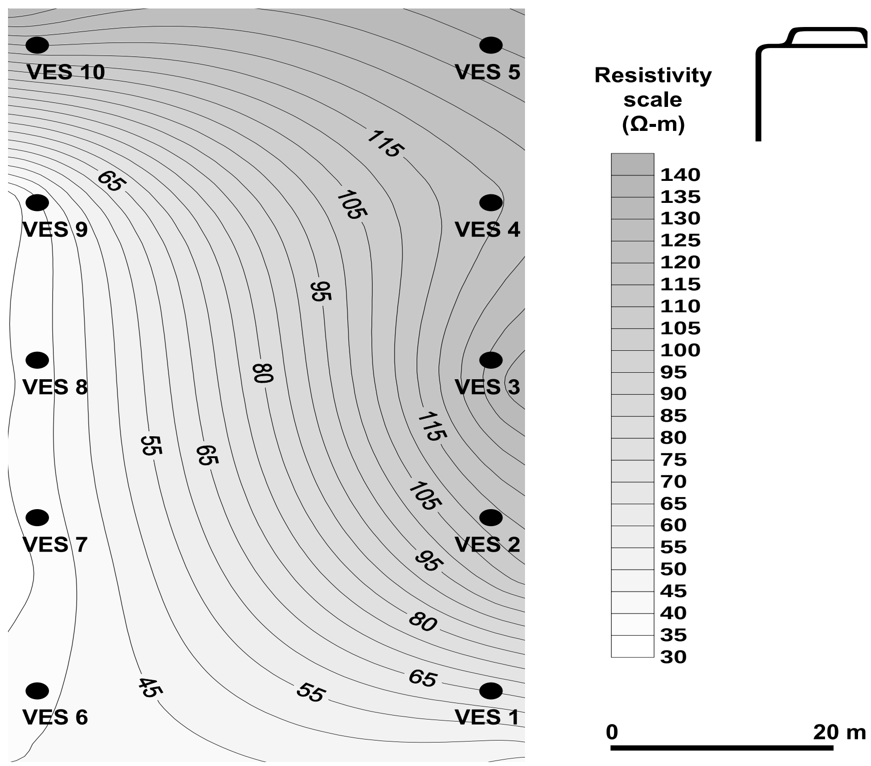
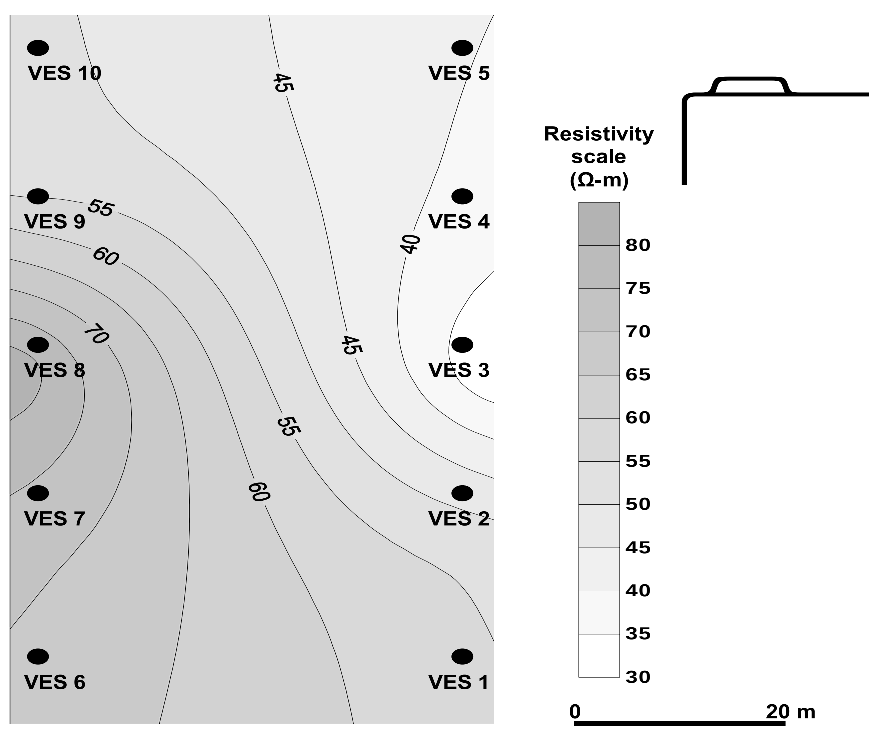


Figure 6. Typical section of borehole log at Amafor Ihuokpala (Hydrofad, 2002).



Contour interval = 5 Ω-m

Figure 7. Resistivity distribution map of the topsoil of the study area.



Contour interval = 5 Ω-m

Figure 8. Resistivity distribution map of the study area at depth level of 3 m.

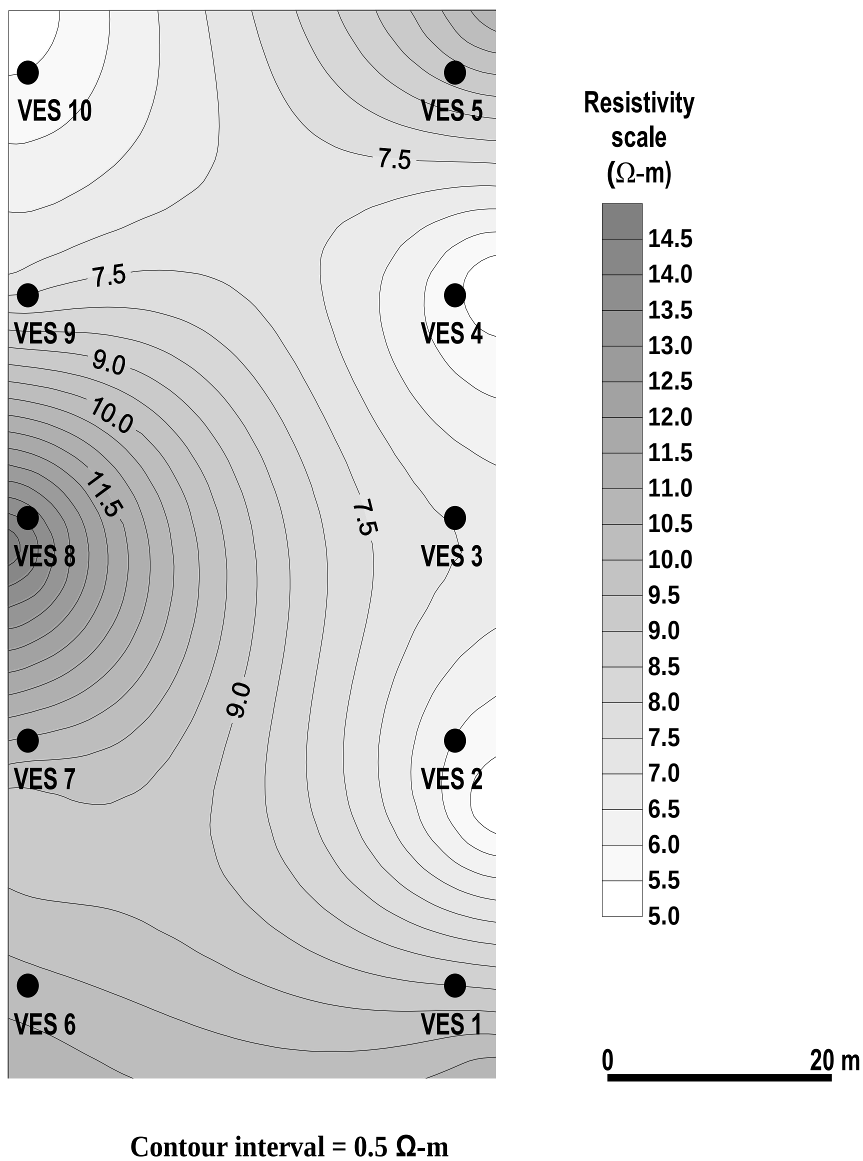


Figure 9. Resistivity distribution map of the study area at depth level of 8 m.

RESULTS AND DISCUSSION

Geoelectric sections

The geoelectric sections (Figures 4 and 5) delineate two major geologic units that comprise the topsoil and the underlying the clay-shale formation. The topsoil is relatively thin. Its thickness varies from 1.0 to 2.0 m and its resistivity varies from 32 to 141 Ω-m. This indicates that, it is partly composed of clay and sandy clay. The topsoil has lateral variation in layer resistivity. This variation may be attributed to facies changes.

The underlying layer is mainly clay-shale formation as depicted by its low resistivity value that varies from 4 to 84 Ω-m. Lithologic log of an existing water borehole in the area (Hydrofad, 2002) confirms occurrence of clay-shale formation to depth of about 60 m with minor sand intercalation at depth below 30 m. In Figure 6, the borehole log shows that, this layer has pronounced vertical facies changes.

Based on the high annual rainfall of the region, the clay-shale formation underlying the area is expected to have significant porosity resulting into high natural moisture content through high groundwater saturation. Evaporation of large volume of water from the soil pores during the dry season will result in substantial shrinkage leading to appreciable volumetric change within the soil.

Moreover, the occurrence of the site within the region is classified as having expansive clay-shale through the effect of the presence of illite and montmorillonite clay minerals (Adesunloye, 1987) further suggests occurrence of swelling and shrinkage within the soil formation. This phenomenal effect of shrinkage and expansion within the soils underlying the site is considered as the major factor responsible for the failure of the building structures. This is manifested as vertical and diagonal cracks/deformation and is more pronounced on light building structures.

Resistivity maps

The resistivity distribution map of topsoil (Figure 7) shows significant variation in the resistivity values. The resistivity of topsoil increases to the West. This indicates that, the topsoil may have lateral facies change and/or variation in water saturation or moisture content. However, the resistivity distribution maps of 3 and 8 m depths (Figures 8 and 9) do not show significant aerial variation in resistivity. This shows that, there is no significant lateral change in resistivity at these depths. This further suggests that, the failures experienced in the study area in forms of cracks/deformation arise from the shrinkage/expansion properties of the underlying clayey topsoil and clay-shale formation.

Conclusion

The electrical resistivity survey for the structures failure investigation at Amafor Ihuokpala area indicates occurrence of two major geologic units made of clay/sandy clay, and clay-shale formation from ground surface to about 40 m depth.

The relatively thin topsoil (<2 m) and the underlying clay-shale formation are considered to be subject to significant variation in moisture regime with the rainy and the dry season leading to substantial volumetric changes. The resultant swelling and shrinkage is believed to be responsible for the various cracks/deformation noticed on the building structures in the area. Moreover, the soils might have appreciable expansive clay minerals in the form of montmorillonite and illite.

The foundation soil may require significant improvement through mechanical and chemical stabilization and/or engineering reinforcement in the form of raft/pile foundation to enhance their bearing capacities.

Result of the study confirms the usefulness of the electrical resistivity method as a valuable tool for the investigation of structure failure and in the determination of the competence of subsurface materials. However, it is recommended that, the method be used vis-à-vis engineering soil testing methods to achieve suitable foundation design for structures.

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