Full Length Research Paper

2D Electrical Resistivity Imaging for the Investigation of the Subsurface Structures at the Proposed Site for Kauridan Estate at Ibagwa – Nike, Southeastern Nigeria

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Received 26 September 2013; Accepted 03 November 2013

Abstract. Electrical resistivity imaging survey was carried out at the proposed site for Kauridan Estate at Ibagwa – Nike, Southeastern Nigerian, in order to investigate the suitability of the subsurface geological structures for the housing estate. The multielectrode ABEM Lung resistivity meter system, employing the Wenner array, was used to acquire 2D resistivity data sets along six parallel profiles in the survey area. The acquired data was processed and interpreted using Res2DINV software to produce the 2D inverse resistivity models. The subsurface images showed that the near surface materials, up to a depth of about 7m from the surface, have moderately high resistivity range of 728 – 1100Ωm, and were inferred to be coarse sand and gravel. These materials were underlain by other materials of a lower resistivity range of 164-358Ωm at a depth of 26.2m, which vary from shaley sand - shale. The images did not suggest the presence of clay formations or any other building constraints such as fractures, faults or voids.

Key words: 2D resistivity imaging, subsurface structures, pseudosections, inversion, building collapse

1. INTRODUCTION

Subsurface investigations employing geophysical techniques are of paramount importance in assessing the suitability of an area for the construction of buildings, bridges, dams, among others. Nigeria in the past two decades has witnessed the collapse of several buildings under construction or shortly after construction. It is common knowledge that these buildings, among other reasons, collapse because appropriate geophysical investigations were not carried out to determine the nature of the subsurface structures. Most of these buildings were built on soils that have inadequate bearing capacity to support the weight of the building.

The geology of an area is critical in assessing its suitability for the type of building to be erected. Near-surface soil may consist of expansive clay that expands or shrinks as a result of change in moisture content (Sands, 2002). Movement of foundation may occur if the clay moistening and drying is not uniform. Subsurface geological features such as fractures, voids, small depth of bedrock, near – surface depth to water table are among the common constraints to building constructions, especially to their foundations.

The geophysical studies provide the geotechnical information required in the engineering design in order to enhance the strength and stability of buildings or structures. The use of electrical resistivity imaging to address a wide variety of hydrological, environmental and geotechnical problems is increasingly becoming very popular. The 2D electrical resistivity imaging is now being used to detect fractures and cavities in the subsurface, geotechnical investigations for buildings, roads, bridges and dams. The method can also be used for delineating archeological features, locating surface utilities and for monitoring pollution seepage through the earth’s subsurface. The method has been proven to be an effective tool for indentifying anomalies and defining the complexity of the subsurface geology (Griffiths and Barker, 1993; Loke and Barker, 1996a; Giano et al, 2000; Andrews et al, 2013; Ugwu, 2012). The 2D electrical resistivity imaging can be carried out using the electrical resistivity method with the necessary software for processing and interpreting the acquired field data. The 2D electrical resistivity imaging in which the subsurface is assumed to be varying vertically down and laterally along the direction of profile but constant in the perpendicular direction has been used to investigate areas with moderately complex geology (Griffiths and Barker, 1993; Andrews et al, 2013).

This paper reports on the geophysical investigations carried out at the proposed site for Kauridan Estate at Ibagwa – Nike, southeastern Nigeria. So many housing estates are being planned in the area by both the Enugu State Housing Development Authority as well as private estate developers. This research is therefore aimed at providing the geophysical and geological information about the subsurface structures of the area. Detailed
geophysical investigations are required to obtain information on the presence of fractures, faults, voids and clay which are important in assessing the suitability of the area for the various housing estates.

1.1. Geology of the Area

The study area lies within latitude 6°32'N and 6°33'N and longitude 7°31'E and 7°32'E in Enugu East Local Government Area of Enugu State, Nigeria (Figure 1). This area is within the southern portion of the Benue Trough of Nigeria and is underlain by four main geologic formations: The Asu River Group, the Eze-Aku Shale, the Agwu – Ndeaboh Shale and the Enugu Shale (Reyment, 1965; Murat, 1972; Nwachukwu, 1972; Hoque, 1977). The shale and limestone of the Albian Asu River Group (Lower Cretaceous) are the oldest sediments in the area (Figure 2). Overlying the Asu River Group sediments are the Eze-Aku Shales (Upper Cretaceous) which consist of nearly 1000m of calcareous flaggy shales and siltstones, thin sandy and shaley limestone and calcareous sandstones (Reyment, 1965). They are of Turonian age and are overlain by younger sediments of Agwu – Ndeaboh Shale. The Conanian Agwu – Ndeaboh Shale consists mainly of fossiliferous bluish grey well bedded shale with intercalations of yellow sandstones. The sandstone bodies are consolidated due to long lasting overburden pressure exerted by the younger overlying Enugu Shale. The Enugu Shale is the lateral equivalence of Nkporo Shale (Campanian). It consists predominantly of soft, greyish-blue or dark mudstone and shale, with occasional beds of white sandstone and striped sandy shale.

Fig. 1: Sketch map of the study area

2. MATERIALS AND METHODS

2.1. Basic Theory of 2D Electrical Resistivity Imaging

The earth subsurface layer resistivity is related to various geological parameters of the subsurface formation such as the mineral and fluid content, porosity and degree of water saturation, as well as the salinity of the water in the rocks (Grant and West, 1965). The earth resistivity can be used to predict the lithology of the subsurface earth. Useful relations for describing and characterising resistivity of rocks have been well documented in relevant literatures (Domenico, 1977; Griffiths and King, 1981; Dobrin and Savit, 1988; Kear and Brooks, 1991).

The electrical resistivity method in general involves passing current I into the ground through a
pair of current electrodes and measuring the potential drop $\Delta V$ through a pair of potential electrodes. The apparent resistivity of the model earth formation is related to the potential difference and the current by the equation.

$$\rho_a = k \frac{\Delta V}{I}$$

Where $k$ is the geometric factor for the electrode array in use.

The electrical resistivity imaging is a geoelectrical method of obtaining high-resolution 2D or 3D image of the complex geology of the subsurface (Griffiths and Barker, 1993). The technique employs continuous vertical electrical sounding (CVES) which is a data acquisition process that combines lateral coverage with vertical sounding using a multielectrode resistivity meter system. Loke (2001) describes the arrangement of electrodes for 2D electrical survey and the sequence of measurements for building the pseudosections. Transformation of the apparent resistivity pseudosections into 2D models of the subsurface resistivity distribution is achieved using the method proposed by Loke and Barker (1996a). Res2DINV software is used to generate the 2D resistivity model by inverting the resistivity data set. The inversion routine uses a non-linear least-squares optimization technique (Loke and Barker, 1996b). The optimization technique tries to minimize the difference between the calculated and measured apparent resistivity values by adjusting the resistivity of the model earth subsurface blocks. A measure of this difference is often given after 3-5 iterations by the root-mean-square (RMS) error.

2.2. Data Acquisition and Processing

The multielectrode ABEM Lung resistivity meter system, aided with the electrode selector ES464, was used for the resistivity measurement. A total of 43 electrodes were used, employing the Wenner array. The electrodes were arranged along a line with a constant spacing between adjacent electrodes. The electrodes were connected to the multicore cable which was connected to the selector and then to the resistivity meter. Figure 3 shows the electrode arrangement and the sequence of measurements for building the pseudosections in the 2D electrical
resistivity imaging survey carried out at the study area. The minimum electrode spacing used was 5m (for data level n=1) while the maximum electrode spacing used was 40m (for data level n=6). Six parallel profiles separated 6m apart were carried out in the East-West direction in the survey area. Each profile was 210m long, covering an area of 210 x 230m².

Fig. 3: Electrode arrangement and the sequence of measurements for building the pseudosections in 2D electrical resistivity imaging survey (Loke, 2001).

The acquired electrical resistivity data was processed using the Res2DINV Software (Geotomo, 2008). Elevation corrections were not carried out because the survey area was fairly flat. The data was first filtered to remove the bad data points whose resistivity values were clearly wrong compared to the neighbouring data points. Least-squares inversion was then carried out on the resistivity data using the Res2DINV software in order to generate the 2D inverse resistivity models.

Fig. 4: 2D inverse resistivity model for profile 1 taken at the proposed site for Kauridan Estate
Fig. 5: 2D inverse resistivity model for profile 2 taken at the proposed site for Kauridan Estate.

Fig. 6: 2D inverse resistivity model for profile 3 taken at the proposed site for Kauridan Estate.

Fig. 7: 2D inverse resistivity model for profile 4 taken at the proposed site for Kauridan Estate.

Fig. 8: 2D inverse resistivity model for profile 5 taken at the proposed site for Kauridan Estate.

Fig. 9: 2D inverse resistivity model for profile 6 taken at the proposed site for Kauridan Estate.
3. RESULTS AND DISCUSSIONS

The electrical resistivity images of the earth subsurface obtained at the proposed site for Kauridan Estate is presented as inverse resistivity models in Figures 4-9. The inverse resistivity models shown were obtained by the optimization technique of Res2DINV by minimizing the difference between the calculated and measured pseudosections of the apparent resistivity data sets. The root mean square error (RMS) obtained for the inverse models ranges from 5.0-6.6%. This high range of RMS value is attributable to the small number of data points taken in the sequence of measurement in the field for building the pseudosections. There is a good correlation between the subsurface images depicted by the models. All the modes showed a gradual decrease in resistivity with depth from the surface and covering a horizontal extent of 210m. The near surface materials, up to a depth of about 7m, have moderately high resistivity range of 728-1100Ωm while the underlying materials at a depth of 26.2m have a lower resistivity range of 164-358Ωm. These resistivity ranges in conjunction with the local geology of the study area suggest that the near-surface materials comprise coarse sand and gravel, while the underlying deeper materials vary from shaley sand - shale. Weathering probably accounts for the gradual change from moderately high resistivity zone to a lower resistivity zone. The degree of weathering increases southwards and westwards, resulting in decrease in resistivity and consolidation of the subsurface materials in these directions. Thus making the materials at the eastern part of the survey area more resistive and more consolidated than those at the western part.

The resistivity values of the models do not suggest the presence of clay formations at the survey area, considering the range of 1-120Ωm usually associated with clay (Parasnis, 1972). Fractures, faults and voids were also not depicted by any of the models.

4. CONCLUSION

2D electrical resistivity imaging (ERI) techniques have been successfully used to investigate the suitability of the subsurface structures at the proposed site for Kauridan Estate at Ibagwa – Nike. This was with a view to detecting any geological features that may pose a serious problem to the buildings. The 2D electrical resistivity data were acquired from the area using the ABEM Lung multielectrode resistivity meter system. The acquired apparent resistivity data was interpreted using the Res2DINV software. Results of the interpretation of the inverse resistivity models in conjunction with the known geology of the area showed that the near-surface materials comprise mostly of coarse sand and gravel while the underlying materials vary from shaley sand - shale. The models did not suggest the presence of clay formations that may pose any problem to the building foundations. Other building constraints such as fractures, faults and voids were also not depicted by any of the models.

The overall results showed that the site is suitable for the proposed housing estate. The resistivity values of the subsurface formations indicate that the materials at the eastern part of the survey area are more resistive and more consolidated than those at the western part. Therefore the eastern part of the survey area would be more suitable for the construction of heavy buildings at the area.

REFERENCES


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