

Geophysical Investigation for Foundation Studies at Ogudu River Valley Estate, Lagos, Southwestern, Nigeria.

Aderoju B. Ademola M.Sc.¹ and Adebayo O. Ojo, M.Sc.^{2*}

¹Office of the Shell Professor of Geophysics, Department of Geology, Obafemi Awolowo University, Ile-Ife, Nigeria.

²Department of Geosciences, University of Lagos, Akoka-Yaba, Lagos, Nigeria.

E-mail: adembamidele@yahoo.com *
ojo.adebayo.oluwaseun@gmail.com

ABSTRACT

In order to evaluate the competence of subsurface layers, determine optimum depth to competent layers, and provide preliminary recommendations for foundation design, an engineering geophysical investigation involving the 2D Resistivity Imaging (RI) technique was carried out at the Ogudu River Valley Estate in Lagos, Southwestern Nigeria.

2D resistivity measurements involving the Gradient array were carried out along ten traverses using ABEM SAS 4000 Terrameter with 64 electrodes spaced at 3m. The 2D dataset were inverted using the commercially available EarthImager 2D software to provide both lateral and vertical variation of the subsurface resistivity in the study area.

The 2D resistivity structure beneath the different traverses revealed that the lithological units underlying the study area up to a maximum depth of 66 m are composed mainly of decomposed organic matter (peat) with resistivity values ranging from 1 – 10 Ω m and clay layers with resistivity values less than 100 Ω m intercalated with varying degree of sand units (sandy clay/clayey sand/sand) with resistivity values greater than 150 Ω m. The sand unit distribution is inhomogeneous, having different thicknesses and lateral extent at varying depth. The results obtained from previous geotechnical investigations (borehole logging and Dutch Cone Penetrometer Test (DCPT)) carried out in the study area corroborate the results obtained from this study.

It can be therefore concluded that, the subsoil on or within which engineering structures will be founded within the study area are generally

incompetent and future engineering development may have to consider alternative foundation designs such as pilling and chemical injection.

(Keywords: foundation studies, Ogudu River Valley Estate, 2D resistivity imaging, gradient array)

INTRODUCTION

Due to urbanization and the geometrically increasing population in Lagos Metropolis, areas which are normally not considered for development are now been developed. These areas include swamp forest, old river paths, flood zones, and coastline. However, to reduce the menace of building collapse which results in wasted resources and the possible loss of life, pre-foundation studies have been recommended before any structure is laid so that proper foundation design and recommendations can be made for a proposed structure.

Engineering design and construction of foundation, especially of buildings, dams, highway routes, and bridges requires a sound knowledge of the subsurface. Information are needed on the nature/competence of the soil, the configuration of the subsurface layers, the bedrock topography, and its structural disposition to enable structures to be designed and located to suit the variable character of the bedrock. Civil engineers need this information to determine the load bearing capacity of the soil in order to decide on the suitable type of foundation for an engineering structure in these areas.

To gather the information outlined above, it is necessary to conduct subsurface investigations. This information is often obtained from direct mechanical boring and some other geotechnical methods. Although, these techniques are good,

they are expensive and might not give adequate information about the entire area and good depth of investigation may not be achieved. The number of boreholes required for detailed study is usually large resulting in huge financial costs. These methods of investigation, apart from being slow, are seriously handicapped due to its lack of continuity, most especially in fairly complex geologic environments.

Geophysical methods offer the chance to overcome some of the problems inherent in more conventional ground investigation techniques. Therefore, it is imperative to complement these with cost effective geophysical method which are commonly applied in engineering site investigation (Ayolabi et al., 2012; Akintorinwa and Adesoji, 2009; Akintorinwa and Adeusi, 2009; Omoyoloye et al., 2008; Olorunfemi and Mesida, 1987). The application of geophysical methods in environmental and civil engineering investigation has become more important in recent decades. The method has the advantage of continuity in sub-surfaces sampling. It is cheap, fast and accurate and requires only very few boreholes for control purposes.

The electrical resistivity method has been successfully used to solve a wide variety of engineering and environmental problems (Adepelumi and Olorunfemi, 2000; Adeoti et al., 2009; Olorunfemi, et al., 2002; Adeyemo et al., 2012; Salami et al., 2012, Fatoba et al., 2013; Fatoba et al., 2010; Ayolabi et al., 2010). The use of electrical resistivity measurements have also been a favored because of the wide range of resistivity values found in nature. It is also one of the simplest and least costly geophysical surveys employed. The method is best suited to the determination of depths to the bedrock and detecting the presence of structural features in the bedrock, or potentially dangerous subsurface conditions before the erection of any engineering structure (Soupios et al., 2007).

Recent advancement in electrical resistivity method has allowed the use of two-dimensional (2D) resistivity imaging to map areas with moderately complex geology (Griffiths and Barker 1993). In the 2D model, the subsurface resistivity is considered to vary both laterally and vertically along the survey line but constant in the perpendicular direction. At present, the 2D surveys are the most practically economic, both in terms of achieving accurate results and in limiting the survey cost (Dahlin, 1993; Dahlin and Loke,

1998). Hence, this study proposes to obtain relevant geotechnical information on the *in-situ* nature, thickness and engineering properties of the suspected layers by carrying out 2D electrical resistivity investigation to determine the subsurface layers and their thicknesses; map the distribution and extent of unstable soil that may be inimical to the life span of the proposed engineering structures; correlate the results with available geotechnical data from the area so as to provide relevant information that will assist the civil engineer in the choice of foundation type and design for the study area.

This study will contribute to the decision making process for prescribing appropriate foundation footing in the study area.

SITE DESCRIPTION AND GEOLOGICAL SETTINGS

The study area, Ogudu Garden Valley Residential Scheme, Lagos is located behind Ogudu GRA in Ogudu part of Lagos State, Nigeria. The Global Positioning System (GPS) indicates that the study is bounded between geographic coordinates 06°34.250'N, 03°23.127'E and 06°34.545'N, 03°34.545'E. The area is accessible through a good network of roads.

Geology of the Study Area

The study area is underlain by the sedimentary rocks of the Dahomey basin which includes the coastal and continental shelf sedimentary sequence west of Benin City, and extending westward through Republic of Benin, Togo and slightly into south-eastern Ghana. During deposition, tertiary and cretaceous sedimentation was partially separated from the Niger Delta Basin to the east of the Okitipupa Ridge.

According to the works of Omatsola and Adegoke (1981); Kogbe (1976); Jones and Hockey (1964); Reyment (1965) and Ogbe (1972), the formations recognized in the Nigerian part of the basin according to lithologic unit of formational rank are: the Abeokuta Group (comprising of Ise, Afowo and Araromi Formations); others are the Ewekoro, Akinbo, Oshoshun, Ilaro Formations and the coastal plain sands. The geologic period and age dates back to Quaternary and recent Oligocene to Pleistocene.

Geologically, the study area falls within the loose sediment ranging from silt, clay, and fine to coarse grained sand referred to as the coastal plain sand (Figure 1). The investigated area is an old river channel. It is a swampy environment bordered on the north by an exposed lateritic soil. The exposed surface consists of peat and probably underlain by sand layers at depth. It is likely that as the river dried up (probably due to blockage of its path) plant remains fell directly on the sand, which must have built up in thickness over time. Due to high water content and incomplete aeration of the environment, the partially decomposed plant remains were preserved. Physiochemical and biochemical processes must have caused this organic material to remain in a state of preservation over a long period of time.

RESEARCH METHODOLOGY

The Electrical Resistivity method employs artificial source of current, which is introduced into the

ground through current electrodes. The procedure then is to measure potentials between the potential electrodes in the vicinity of the current flow. From these measurements, the resistance is computed and converted into apparent resistivity, from which the true resistivity of the subsurface is estimated by inversion using a computer program. Several arrangements of the current and potential electrodes are possible but for the purpose of this research the gradient electrode arrangement is employed.

2D Electrical resistivity dataset were acquired along ten traverses (Figure 2) with the Gradient array using a multi electrode system. Electrode spacing of 5 m for 64 electrode systems was utilized which sums the total length each traverse covered to be 315 m. The profiles are parallel to each other except for the last two which intersect the rest diagonally. The traverses were established generally in the North-West direction.

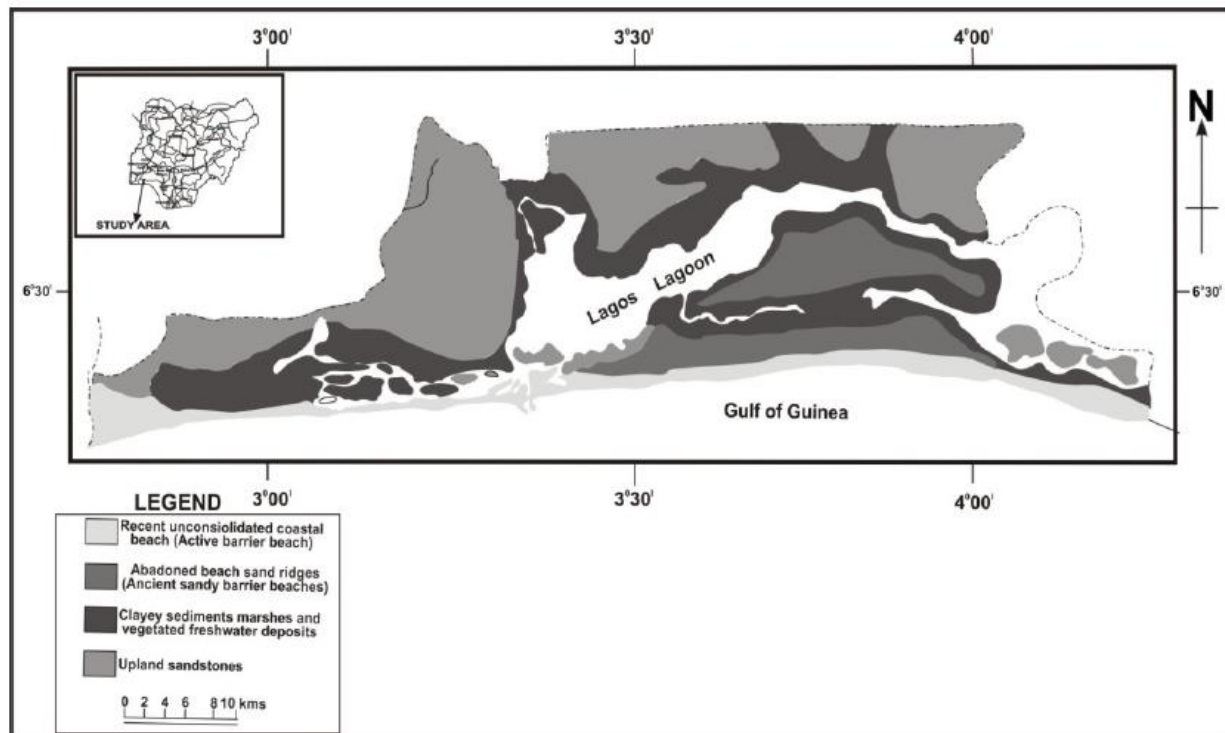


Figure 1: Map of Surface Geology and Morphology of Lagos State (After Fatoba et al., 2013).

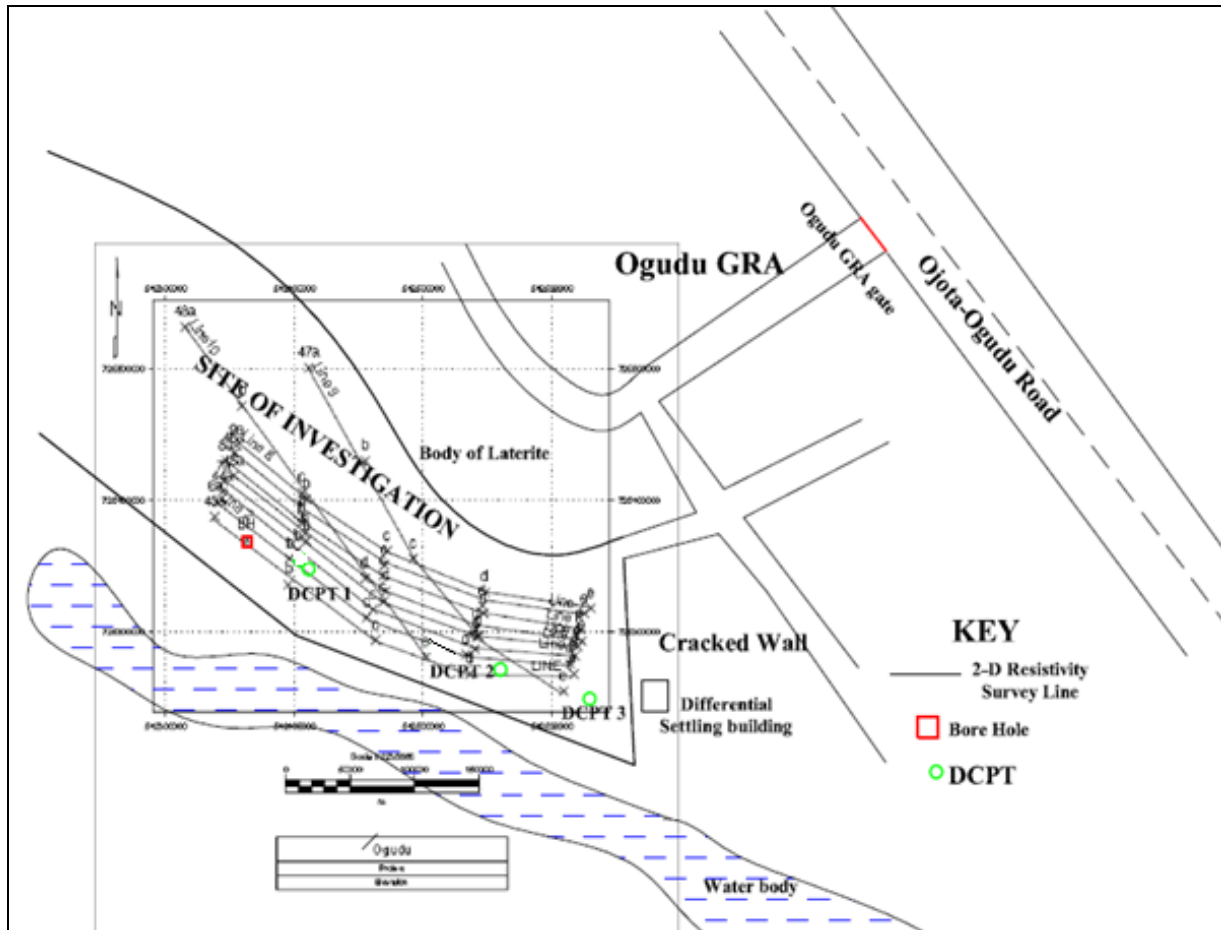


Figure 2: Base Map of the Study Area Showing the 2D ERT Profiles, Borehole and DCT Points.

A multi-electrode system developed at Lund University (Dahlin, 1993) was used for data acquisition in this study. The system consists of a standard resistivity meter (ABEM Terrameter SAS4000), a 4 X 64 channel relay-matrix switching unit, four rims of electrode cables, 64 steel electrodes and various connectors. The data acquisition process is completely automated.

Figure 3 shows a typical set up for a 2-D survey with a number of electrodes along a straight line attached to a multi-core cable. Normally, a constant spacing between adjacent electrodes is used. The multi-core cable is attached to an electronic switching unit which is connected to a laptop computer. The sequence of measurement to take, the type of array to use and other survey parameters (such as the current to use) is normally entered into a command file which can be read by a computer program in a laptop computer.

After reading the control file, the computer program then automatically selects the appropriate electrodes for each measurement. In a typical survey, most of the fieldwork is in laying out the cable and electrodes. After that, the measurements are taken automatically and stored in the computer. Most of the survey time is spent waiting for the resistivity meter to complete the set of measurements. The data is then inverted using a numerical inversion routine to obtain a geologic model whose theoretical response fits the field data within a limit of acceptable error (Loke, 2004). The commercially available EarthImager 2D software developed by Advance Geosciences Incorporated (AGI) was used to invert the 2D dataset.

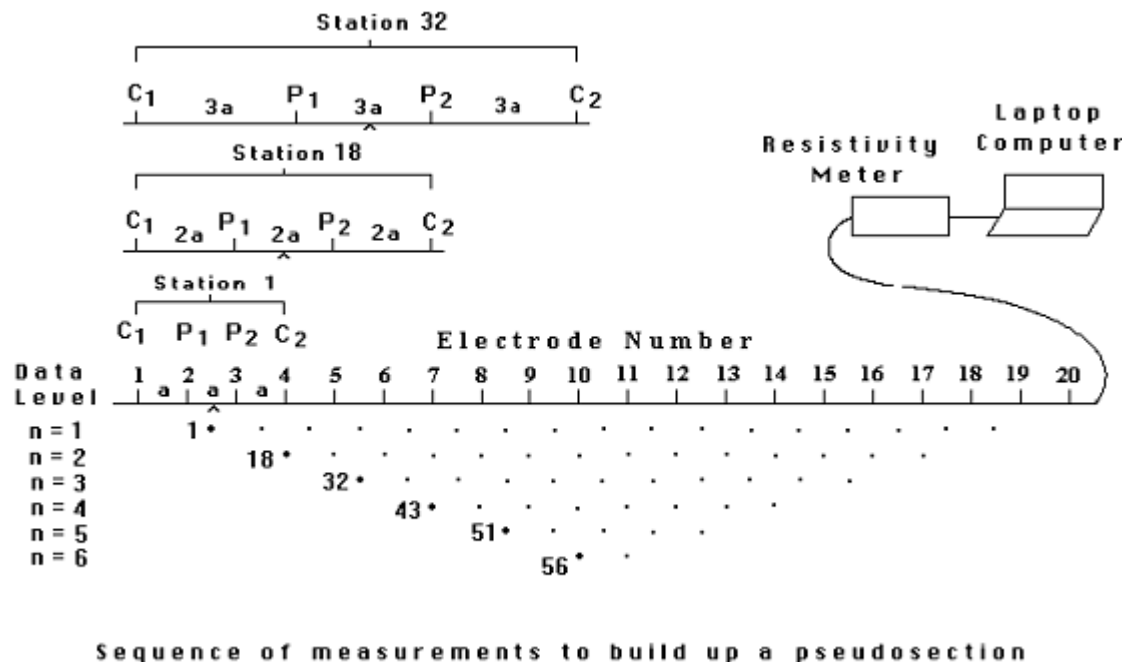


Figure 3: Typical Setup for a 2D survey (After Loke, 2004).

RESULTS AND DISCUSSION

The inverted 2-D resistivity structure along each of the ten traverses is presented in Figures 4 and Figure 5 below.

A Priori Information

The results of previous geotechnical works such as Dutch Cone Penetrometer Test (DCPT) and borehole logging (Ayolabi et al., 2010) carried out along traverse one in the study area as denoted in Figure 1 corroborated the results obtained from this study. In their investigation, the cone probed a depth of 8.2 m at three points with little resistance (< 2kg/cm²).

This indicates that the soil layer has very low shear strength up to the depth of 8.2m that was probed. This little resistance to cone penetration is associated to peat material or soft clay as identified by the 2D resistivity images. Likewise, ordinary disturbed samples were collected along traverse one (Figure 1) at changes of strata and as deemed fit for strata identification purposes, through visual inspection and classification tests revealed lithology ranging from peat to sandy clay to silty sand up to a depth of 30 m (Ayolabi et al., 2010).

Geophysical Investigation

The available geotechnical data and borehole information in the study serves as a priori information that guided our understanding of the relationship between resistivity values and the lithology in the study area and forms the basis for interpreting the 2D resistivity images. The inverted 2D Resistivity Structure beneath Traverses one (1) to ten (10) is shown in Figure 4 (a – e) and Figure 5 (f – j), respectively.

The 2-D subsurface images obtained from the inversion of the resistivity data revealed both the lateral and vertical variations in subsurface resistivity across the different traverses in the study area. Four different lithology have been identified based on their resistivity values and they are Peat (with resistivity values less than 10 Ω-m), Clay (with resistivity values less than 100 Ω-m), Sandy Clay/Clayey Sand (with resistivity values ranging from 101 – 199 Ω-m for Sandy Clay and 200 – 299 Ω-m for Clayey Sand) and Sand (with resistivity values greater than 300 Ω-m). A description of the lithology has been denoted on the subsurface image obtained across each traverses as presented in Figures 4 and 5.

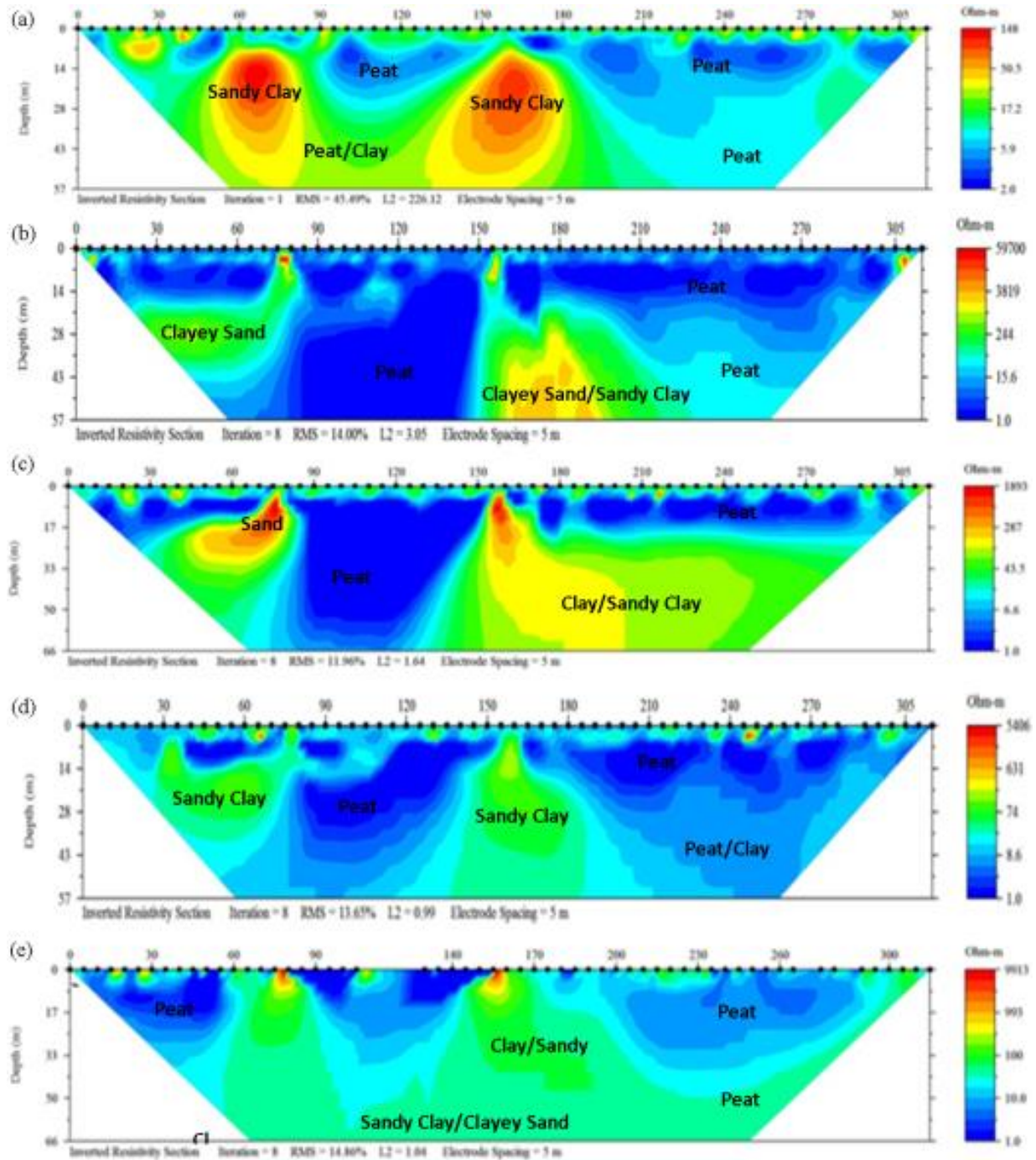


Figure 4: Inverted 2-D Resistivity Section Along (a) Traverse 1, (b) Traverse 2, (c) Traverse 3, (d) Traverse 4, and (e) Traverse 5.

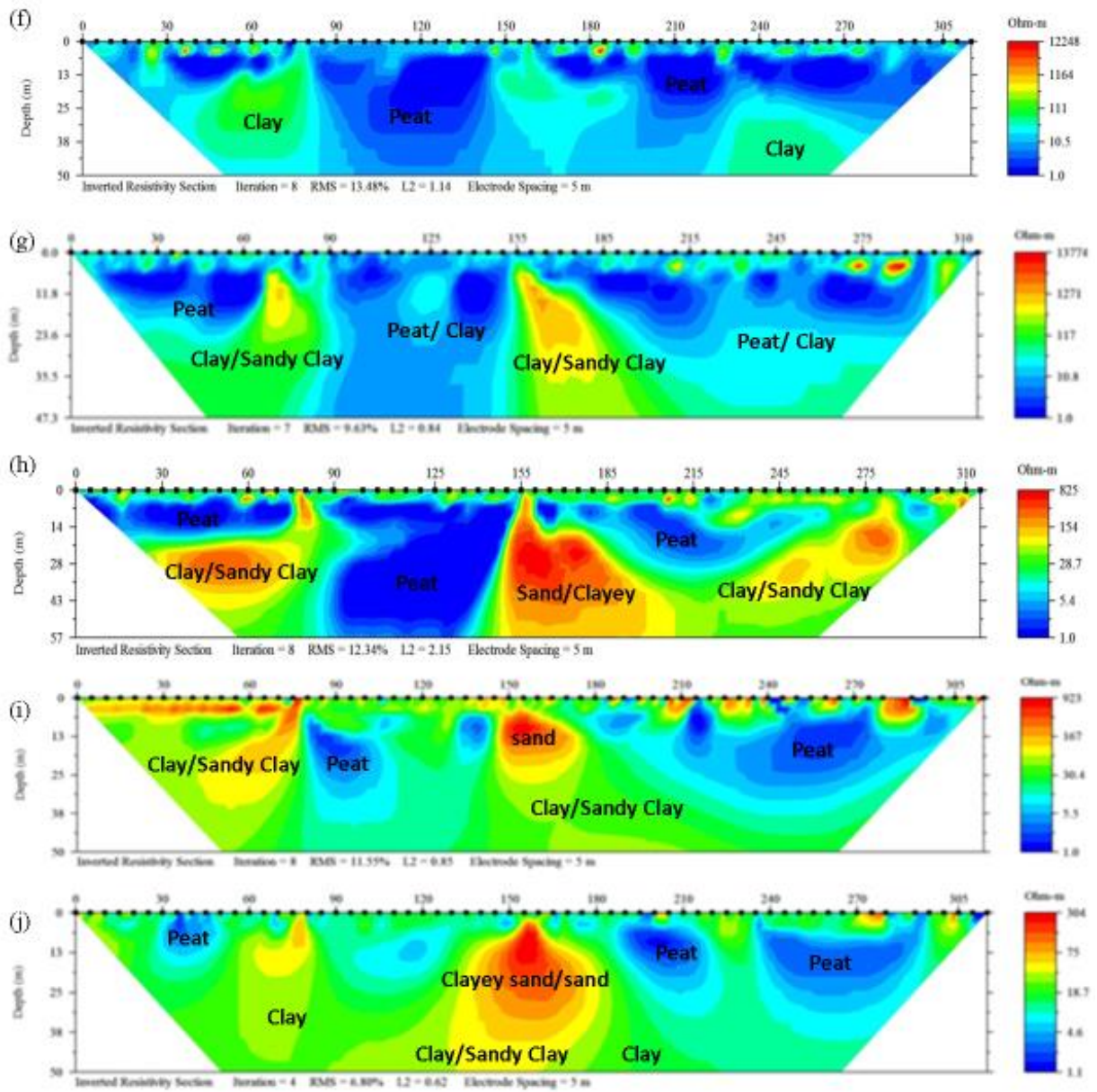


Figure 5: Inverted 2-D Resistivity Section Along (f) Traverse 6, (g) Traverse 7, (h) Traverse 8, (i) Traverse 9, and (j) Traverse 10.

The thicknesses of the different layers vary across the traverses and are observed to be intercalated with each other in most places while some occur as isolated layers. The regions composed of decomposed organic matters (peat) and clayey materials which are subject to differential settlement and possible flow under load as they exhibit poor geotechnical properties, low shear strength and high compressibility potential (Bowles, 1984). Thus these regions may be inimical to the foundation of engineering structure unless adequate engineering precautions are taken before the foundation.

Other segments of the study area are composed of sandy clay/clayey sand units which are known to exhibit moderate to good geotechnical properties, moderate to high shear strength and low compressibility potentials, while some pockets of sand units which exhibits good geotechnical properties, high shear strength and low compressibility potential which represents a competent layer for the foundation of engineering structure according to Bowles (1984) are also observed on the 2D resistivity sections. However, the sandy layers are generally non-continuous (isolated) and without appreciable thicknesses capable of supporting engineering structures.

Generally, the study area is composed of incompetent subsurface material up to an appreciable depth of 66 m. Hence, alternative foundation design such as pilling or chemical treatment of the incompetent soil is recommended.

CONCLUSIONS AND RECOMMENDATION

Subsoil evaluation within Ogudu Garden Valley Residential Scheme, behind Ogudu G.R.A, Lagos for civil engineering structure using 2-D Electrical Resistivity geophysical method of investigation was carried out in this research. The investigation was to provide information on the nature and competence of the subsoil for foundation development.

The 2-D Resistivity sections revealed very low resistivity regions on major part of the subsurface images indicating that the study area is largely composed of peat/clay from the surface up to a depth of 66 m. Although, some relatively competent materials (sandy clay/clayey sand/sand) exist in the study area, the units are discontinuous and are located at varying depth

across the study area. The uneven nature of these layers has to be considered in the design of the foundation. From engineering point of view, highly organic soils like peat have poor geotechnical properties. It is often unstable to support any kind of structure and considered as the worst kind of materials that may be encountered in the substrata. Hence, the subsoil at the study area can be generally said to be incompetent. The observation from the 2-D electrical resistivity survey is in agreement with the results of prior geotechnical investigations.

Based on the results of this study, shallow foundation should be precluded for use in the study area for proposed development and alternative foundation design such as pilling or soil treatment should be considered. The results have helped in providing a two dimensional variation of the subsoil condition and will serves as a precautionary tools to the engineers.

REFERENCES

1. Adeoti, L., I. Kehinde, R.B. Adegbola, and S.T. Sovi. 2009. "Foundation Investigation using Electrical Resistivity Method: A Case Study of Iponri, Lagos State, Nigeria". *Journal of Engineering Research (JER)*. 14(1):50-57.
2. Adepelumi, A.A. and M.O. Olorunfemi. 2000. "Engineering Geological and Geophysical Investigation of the Reclaimed Lekki Peninsula, Lagos, South West Nigeria". *Bulletin of Engineering Geology and the Environmental*. 125-132.
3. Akintomiwa, O.J. and J.I. Adesoji. 2009. "Application of Geophysical and Geotechnical Investigations in Engineering Site Evaluation". *International Journal of Physical Sciences*. 4(8):443-454.
4. Akintomiwa, O.J. and F.A. Adeusi. 2009. "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):241-254.
5. Adeyemo, I.A. and O.G. Omosuyi. 2012. "Hydrogeologic, Electrical and Electromagnetic Measurements for Geotechnical Characterization of Foundation Beds at Afunbiowo, near Akure, Southwestern Nigeria". *Indian Journal of Science and Technology*. 5(2) ISSN: 0974- 6846.

6. Ayolabi, E.A., A.F. Folorunso, and O.E. Jegede. 2012. "An Application of 2D Electrical Resistivity Tomography in Geotechnical Investigations of Foundation Defects: A Case Study". *Journal of Geology and Mining Research*. 3(12):142-151.
7. Ayolabi, E.A., A.F. Folorunso, and M.O. Oloruntola. 2010. "Constraining Causes of Structural Failure using Electrical Resistivity Tomography (ERT): A Case Study of Lagos, Southernwestern, Nigeria". *Journal of Geophysics/Mineral Wealth*. 156/210:7-18.
8. Bowles, J.E. 1984. *Physical and Geotechnical Properties of Soils*. McGraw-Hill Intl. Edi., Civil Eng. Series: London, UK. 1004.
9. Dahlin, T. 1993. "On the Automation of 2D Resistivity Surveying for Engineering and Environmental Applications". Doctoral Thesis. Lund University: Lund, Sweden.
10. Dahlin T. and M.H. Loke. 1998. "Resolution of 2D Wenner Resistivity Imaging Assessed by Numerical Modeling". *Journal of Applied Geophysics*. 38(4):237-249.
11. Fatoba J.O., B.M. Salami, and A. Adesida. 2013. "Structural Failure Investigation using Electrical Resistivity Method: A Case Study of Amafor Ihuokpala, Enugu, Southeastern Nigeria". *Journal of Geology and Mining Research*. 5(8):208-215.
12. Fatoba, J.O., J.O. Alo, and A.A. Fakeye. 2010. "Geoelectric Imaging for Foundation Failure Investigation at Olabisi Onabanjo University Minicampus, Ago-Iwoye, Southwestern Nigeria". *Journal of Applied Sciences Research*. 6(12):2192-2198.
13. Griffiths, D.H. and R.D. Barker. 1993. "Two Dimensional Resistivity Imaging and Modelling in Areas of Complex Geology". *Journal of Applied Geophysics*. 29:211-226.
14. Jones, H.A. and R.D. Hockey. 1964. "The Geology of Parts of Southwestern Nigeria. Lagos". *Geological Survey of Nigeria Bulletin*. 31:101.
15. Kogbe, C.A. 1976. "Paleogeographic History of Nigeria from Albian Time". In: *Geology of Nigeria*. C.A. Kogbe (ed.). University of Ife: Nigeria. 237-252.
16. Loke, M.H. 2004. *Tutorial: 2-D and 3-D Electrical Imaging Surveys*. 2004 revised Edition. www.geometrics.com . 136.
17. Ogbe, F.G.A. 1972. "Stratigraphy of Strata Exposed in the Ewekoro Quarry, Western Nigeria". *Cont. on African Geology*. Ibadan, Nigeria.
18. Omatsola, M.E. and O.S. Adegoke. 1981. "Tectonic Evolution and Cretaceous Stratigraphy of the Dahomey". *Basin. Jour. Min. Geol*. 18(1):130 – 137.
19. Olorunfemi, M.O., J.S. Ojo, and E.A. Ojelabi. 2002. "Geophysical Site Investigation of the premises of Idu Flow Station". Nigerian Agip Company (NAOC) Limited. (For multipurpose Oil Services Company Limited, Port Harcourt). Technical Report.
20. Olorunfemi, M.O. and E.A. Meshida. 1987. "Engineering Geophysics and Its Application in Engineering Site Investigation (Case Study of Ile-Ife Area)". *The Nigeria Engineer*. 22(2):57-66.
21. Omoyoloye, N.A., M.I. Oladapo, and O.O. Adeoye. 2008. "Engineering Geophysical Study of Adagbakuja Newtown Development, Southwestern Nigeria". *Medwell Online Journal of Earth Science*. 2(2):55-63.
22. Reyment, R.A. 1965. "Quantitative Paleocologic Analysis of Ewekoro and Oshosun Formations of Western Nigeria". *Geoll Foren. Stockh. Forhandl*. 86:248–256.
23. Salami B.M, D.E. Falebita, J.O. Fatoba, and M.O. Ajala. 2012. "Integrated Geophysical and Geotechnical Investigation of a Bridge Site: A Case Study of a Swamp/Creek Environment in South East Lagos, Nigeria". *Ife Journal of Science*. 14(1):75- 81.
24. Soupios, P.M., P. Georgakopoulos, N. Papadopoulos, V. Saltas, A. Andreadakis, F. Vallianatos, A. Sarris, and J.P. Makris. 2007. "Use of Engineering Geophysics to Investigate a Site for a Building Foundation". *J. Geophy. & Eng*. 4: 94-103.

ABOUT THE AUTHORS

Ademola Aderoju received his B.Sc. and M.Sc. degree in Applied Geophysics from the Obafemi Awolowo University, Ile-Ife, Nigeria. He is currently preparing for a Ph.D. degree program in Applied Geophysics.

Adebayo Oluwaseun Ojo received his B.Sc. degree in Engineering Physics and M.Sc. degree in Applied Geophysics, from the Obafemi Awolowo University, Ile-Ife, Nigeria. He is currently a Ph.D. student in Solid Geophysics at the School of Earth and Space Sciences, University of Science and Technology of China, Hefei, China.

SUGGESTED CITATION

Aderoju, A.B. and A.O. Ojo. 2015. "Geophysical Investigation for Foundation Studies at Ogudu River Valley Estate, Lagos, Southwestern, Nigeria". *Pacific Journal of Science and Technology*. 16(1):295-304.

