ISSN (Print): 2476-8316
ISSN (Online): 2635-3490
Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 6 No. 1 March 2020*

Geoelectrical Investigation on Road Failure of part of London Road Minna, Nigeria

[1]Ndanusa H. H., [2] Rafiu A.A., [3] Salako K. A., [4] Alhassan U. D., [5] Adetona A. A., *[6] Shehu J. and [7] Udensi E. E.

[1,2,3,4,5,6,7]Department of Geophysics,
Federal University of Technology,
Minna, Nigeria

*Email: jameeelshehu@futminna.edu.ng

Abstract
An electrical resistivity method involving Wenner technique was carried out at part of London Road Minna, Niger State. The aim of the study was to investigate the causes of road failure. Two profiles parallel to the road of the study area of 300 m in length were investigated using Wenner array electrical configuration method. The electrode spacing was at equal interval of 7.5 m and current was sent into the ground using both current electrodes while potential electrodes received the signal which is display by the terrameters in resistivity. A total of 42 electrodes were probed. The calculated apparent resistivity pseudo section of profile A shows low resistivity. At the distance between 205 - 250 m the material is of low resistivity which can also lead to failure of the road. Profile B shows some anomalies *between the distances of 45-60 m which is likely to be clay.*

Keywords: Resistivity, Wenner array, Sub-grade, London Street and Road failure.

INTRODUCTION
Improved road transport facilities in any developing nation provides economic and social opportunities and benefits that result in a multiplier effects such as better accessibility to markets, employment and additional investments but if they are deficient in terms of capacity and reliability, they can have an economic cost such as reduced or missed opportunities and lower quality of life (Ibitomi *et al*. 2014)

The use of the geoelectrical method as an effective tool for gaining knowledge into the subsurface structure, in particular, for identifying anomalies and defining the complexity of the subsurface geology is fast gaining grounds (Soupois, 2007; Colangelo, 2008; Lapenna, 2005). In recent times, much attention is being paid to the electrical resistivity imaging (ERI) method which provides a high spatial resolution with a relatively fast field data acquisition time and is low in cost. It is more of a natural counterpart to the near surface seismic reflection method and therefore may play a more significant role in the geophysical exploration of many subsurface investigations (Loke and Barker, 1996).

In the last decade, the involvement of geophysics in civil and environmental engineering has become a promising approach. Geophysical methods are implemented in a wide range of applications ranging from ground investigations in building constructions to the inspection

*Author for Correspondence

of dams and dikes (Klimis *et al*., 1999; Jadi, & Luna (2000), aiming towards the exploration of geological structures and the determination of the physical parameters of the rock formations. In engineering geophysics, the question of the quality of building foundations is frequently addressed in the very late stages, when earthquake damage is either observed or expected (Delgado *et al*., 2000). In the case of building construction, geophysics can be applied for exploration purposes to provide useful information regarding the early detection of potentially dangerous subsurface conditions. The sources of hazards in civil engineering disciplines result essentially from undetected near-surface structures, such as cavities and/or in homogeneities in the foundation geomaterials.

Some of the geophysical methods that can be applied in the direct method for mapping subsurface structures include: ground penetrating radar (GPR), seismic, electromagnetic terrain conductivity (Ward, 1990), electrical resistivity tomography (ERT), 2D and 3D electrical resistivity imaging (ERI).

The 2D and 3D electrical resistivity imaging can be carried out using the electrical resistivity method with the necessary software for processing of the acquired field data. The use of 2D and 3D geoelectrical resistivity imaging to address a wide variety of hydrological, environmental and geotechnical issues is increasingly popular. The subsurface geology in environmental and engineering investigations is often subtly heterogeneous and multi-scale such that both lateral and vertical variations of the subsurface properties can be very rapid and erratic (Aizebeokhai *et al*., 2011). The use of vertical electrical sounding is grossly inadequate to map such complex and multi-scale geology. 2D geoelectrical resistivity imaging, in which the subsurface is assumed to vary vertically down and laterally along the profile but constant in the perpendicular direction, has been used to investigate areas with moderately complex geology (Griffiths and Barker, 1985).

However subsurface features are inherently 3D and the 2D assumption is commonly violated for such heterogeneous subsurface. This violation often leads to out-of plane resistivity anomaly in the 2D inverse models which could be misleading in the interpretation of subsurface features (Bentley and Gharibi, 2004). There are many electrode configurations designed for collection of geoelectrical resistivity data, but the use of a particular configuration depends on the particular geological situation and the research interest.

The most commonly used electrode arrays include wenner, Schlumberger, dipole-dipole, pole-pole and pole-dipole arrays. Traditionally, electrical resistivity surveying was limited to either delineating the variation of apparent resistivity over a surface or compiling quasi-2D sections from a rather limited numbers of vertical electrical soundings (VES). The use of multielectrode systems for data acquisition in geoelectrical resistivity surveys has led to a dramatic increase in field productivity as well as increased quality and reliability of subsurface resistivity information obtained. Initially, multi-electrode systems with manual switching were used before the emergence of computer-controlled multi-electrode systems with automatic measurements and data quality control, which has tremendous impact on the quality of the data and the speed with which they are collected (Baker, 1979). Intelligent multi-electrode with built-in preamplifiers, analogue -to-digital converters, and digital transmission lines can now be effectively used for data acquisition. Multi-channel transmitter and receiver systems are now being used in simultaneously carrying out series of measurements (Stummer and Maurer, 2001; Auken *et al.*, 2006).

LOCATION AND GEOLOGY OF THE STUDY AREA

The study area is low density area and is located at London Street extending to Bosso Low-cost Road, Bosso Local Government Area of Niger State. The people of the area comprises of the students of Federal University of Technology Minna and original settlers of the area, the Nupe's and the Gwari's. The study area is basically a residential area.

Figure 1 shows the digitalized map of the study area, while figure 2 is the Google map of the area. The location lies between latitude 9˚38'907'N and 9˚38'903'N and longitude 006˚30.952'E and 006˚30.946'E. The map has the scale of 1:100,000. (Bosso LGA).

The geology of the area which is also the geology of Minna area which is entirely underlain by rock of the Nigeria basement complex. The three (3) types of rock groups that make up the complex are; Migmatite-gneisse, Low grade schist belt, and the older granites (Razzell, and Trussell, 1963).

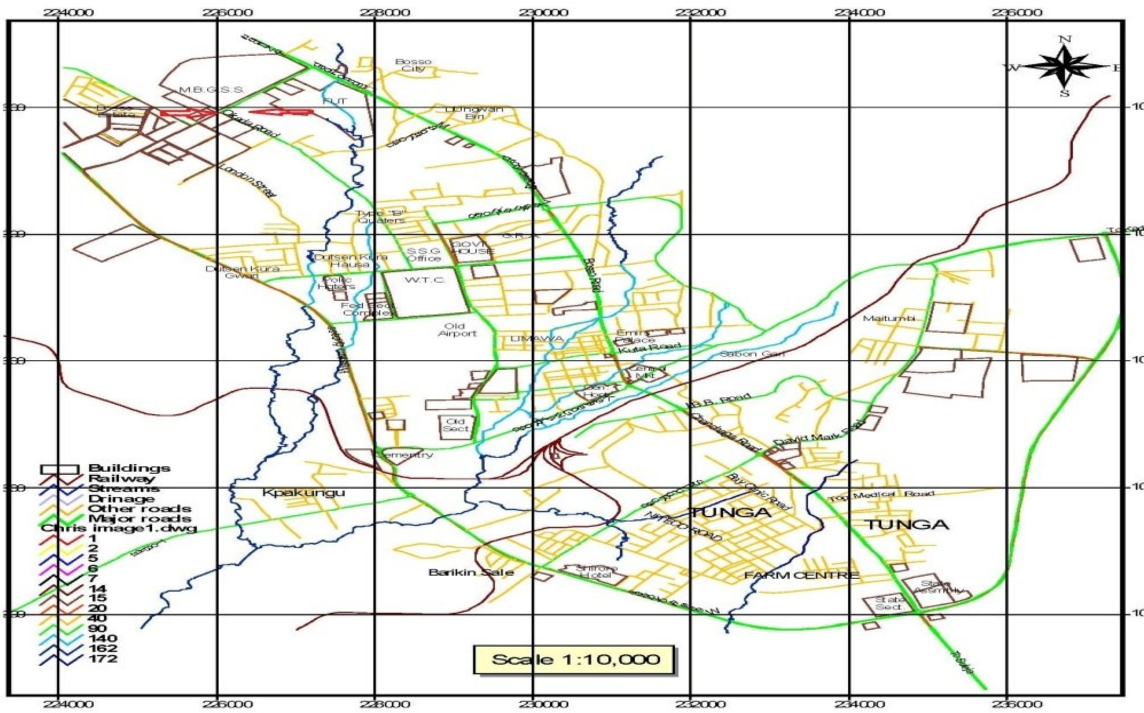


Figure 1: Minna Township Map showing the location of the study area (Bosso LGA)

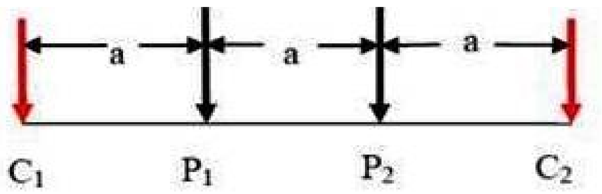
Figure 2: Google image showing the study area (Google, 2016)

METHODOLOGY

Wenner (Horizontal profiling method 2-D) was employed for the survey. The Horizontal profiling method was used to study the lateral variation in resistivity of an area.

Constant separation traversing (CST).

The principle of horizontal profiling is based on the fact that the subsurface is inhomogeneous and that electrical properties vary from one place to another over an area. The resistivity measurement is carried out by the use of collinear four electrode array configuration in which the entire electrode array is moved after taking measurement to successive stations. The depth of investigation in resistivity surveying is proportional to electrode spacing. The choice of electrode array and spacing is often based on consideration of the ease of measurement and time, depth of investigation and the sensitivity to lateral variations and anomaly resolution (Baker, 1979). Four electrodes are generally placed at arbitrary locations, however, a number of electrode configuration shave been used in recording resistivity field data, each suitable for a particular geological situation. The conventional arrays most commonly used include Wenner (alpha), Schlumberger, dipole-dipole, pole-pole and pole-dipole arrays. For the purpose of this survey Wenner array will be implored. This array with its corresponding geometric factor is illustrated in Figure 7. The choice of Wenner array depends on the geological structures to be delineated, heterogeneities of the subsurface, sensitivity of the resistivity meter, the background noise level and electromagnetic coupling. Other factors to be considered are the sensitivity of the array to vertical and lateral variations in the resistivity of the subsurface, its depth of investigation, and the horizontal data coverage and signal strength of the array. The conventional wenner (alpha) is relatively sensitive to vertical variations in the subsurface resistivity below the centre of the array but less sensitive to horizontal variations in the subsurface.



$$G = 2\pi a$$

Figure 3: Conventional Wenner (Wenner-alpha) array

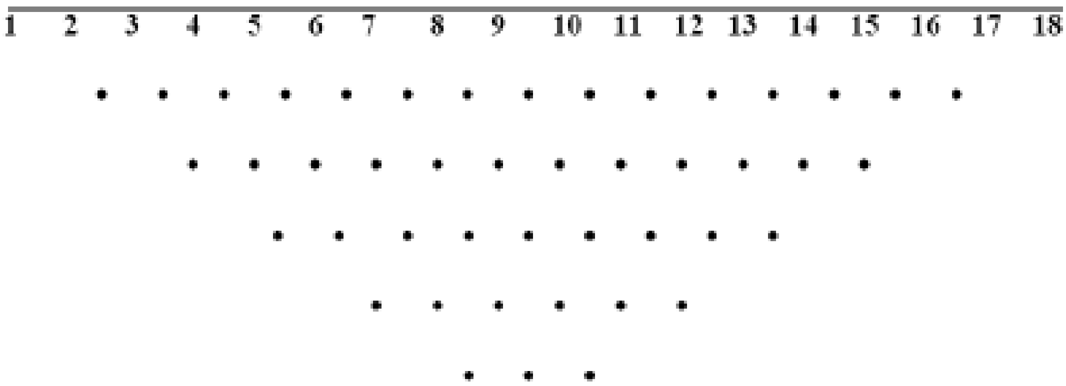


Figure 4: Wenner Configuration Spread and Depth

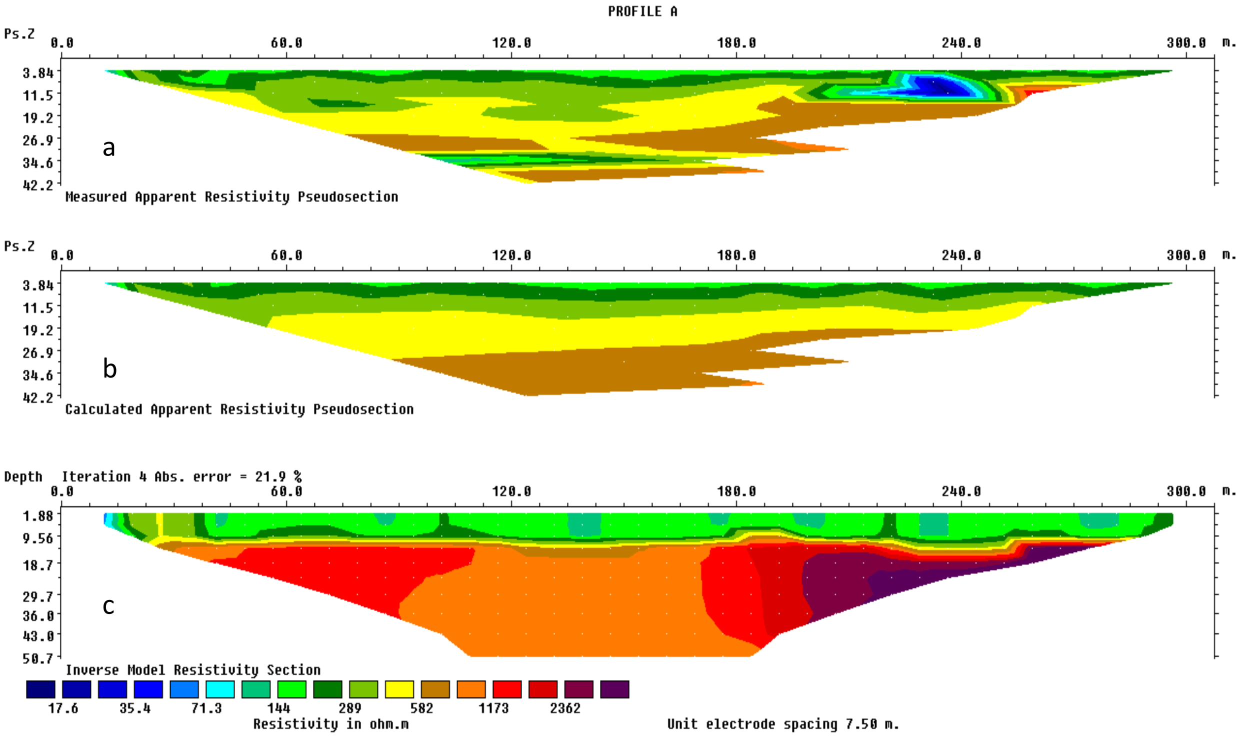
A transverse of two profile parallel to the road of the study area of 300m in length was be investigated using 2D Wenner array electrical configuration method. Figure 8 shows the spread of electrodes at interval of **a = 7.5.** The current are sent into the ground using both current electrode C_1 and C_2 and potential electrode P_1 and P_2 receives the signal which is displayed by the Terra metre in resistivity. A total of 42 electrodes would be investigated at equally interval of electrodes, the first sequence of measurement will be obtained from electrode 1,2,3,4 at C_1, P_1, P_2, C_2 position respectively. The next reading will be obtained by maintaining the current and potential position but the electrode position will be shifted to the right by 1 electrode making the next measurement to begin at 2,3,4,5 with C_1 P_1, P_2, C_2 in place. These progressive pattern and sequence of obtaining such reading will be maintained up to electrode 39,40,41,42. Furthermore, similar routine was done at different interval of **a,** that is **2a, 3a, 4a, 5a, 6a, 7a, 8a, 9a, 10a.** These procedures was conducted along both profiles to obtain resistivity values that was employed for the interpretation.

RESULTS AND DISCUSSION

The results of the geo-electrical investigation from the two profiles, consisting of different location of the failed sections along London road are presented in figure 5. The data were collected in order to automatically generate a two dimensional (2-D) resistivity model for the subsurface which can be referred to as electrical Image.

Profile A

Figure 5: The pseudo sections coloured layering of(a) Measured apparent resistivity of pseudo section values of



profile A.(b) Calculated apparent resistivity pseudo section values of layers of profile A.(c) Computer interpreted iterated inverse model resistivity section of the profile A.

The blue portion in the pseudo section of Profile A shows failed segment of the road as seen in the resistivity key in figure 6. Areas with red and purple colures indicate portions with high resistivity and as such are referred to as stable zone. Areas with green colour are characterized as the intermediate zone.

This profile shows relatively high resistivity which can be compared to stable rock. However, between the distance of 205 m to 250 m the pressure is of relatively low resistivity material, these can lead to failure of road as the material is not consistent and thereby lack the ability to withstand the pressure of the material above it since the surrounding parent material are stable, there is possibilities of weathering of such present rock with result to lower resistivity at this point. This could be as a result of structures like fracture which accumulate ground water thereby leading to chemical alteration of the parent rock. The calculated apparent resistivity pseudo section shows a systematic arrangement of lithologies from that of relatively low resistivity

The measure modes resistivity section shows the lateral succession of various lithology with respect to their resistivity towards the surface, there exist series of low resistance materials and their resistivity series between 7.3 Ωm to 144 Ωm, 12-14 m, 43-45 m, 82-89 m, 135-145 m, 175-180 m, 195-205 m, 230-235 m, and lastly 270-280 m, of these points the road are likely to fail since the insitu material has relatively low resistivity to the depth of 7 m or there about. These material are likely to be sand and since there is ability for water to transmit from one point to the other these affect the asphalt and leads to contraction and expansion during the rainy season and dry season systematically.

Profile B

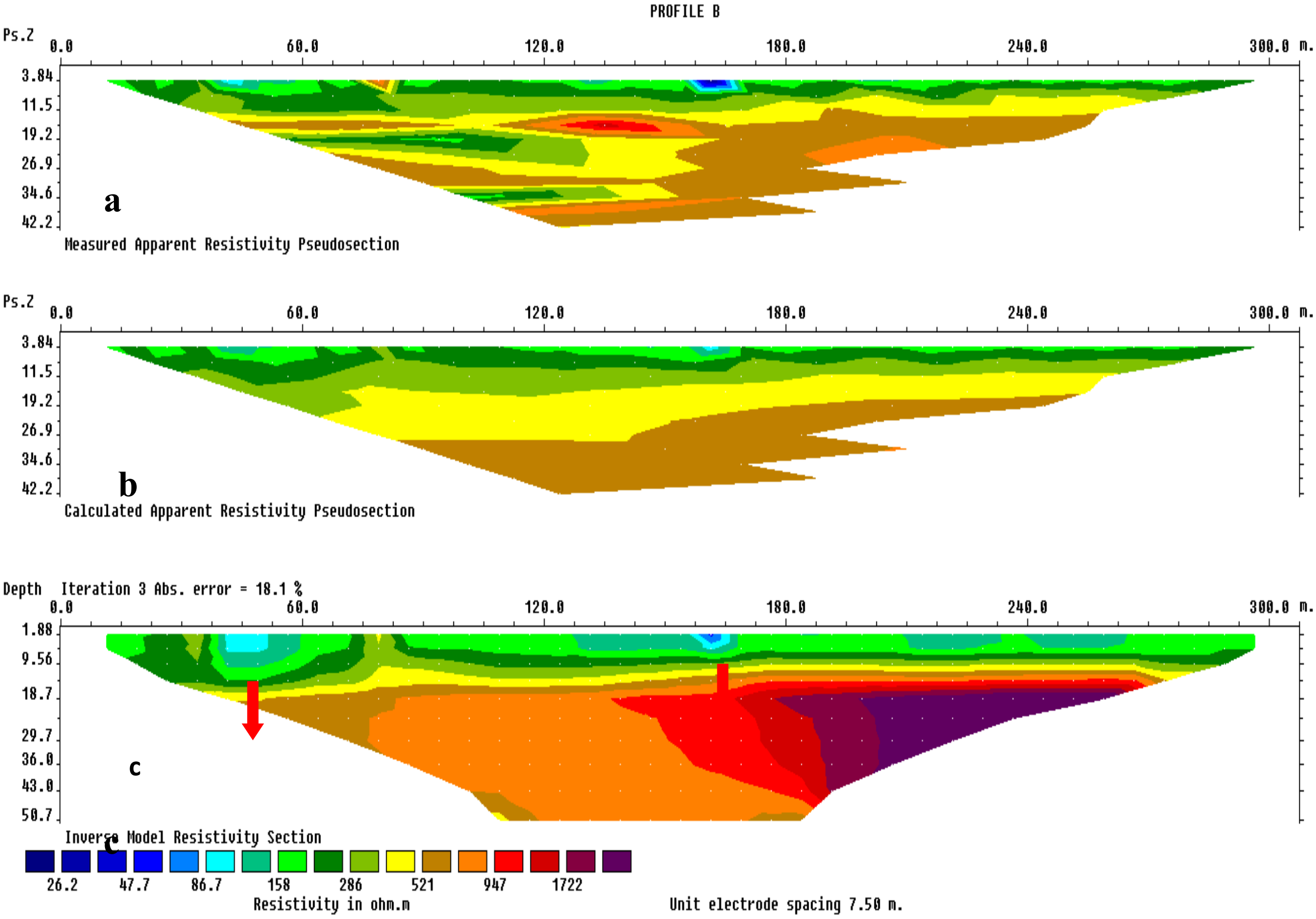


Figure 6: The pseudo sections show coloured layering of (a) Shows measured apparent resistivity of pseudo section values of profile B. (b) Shows calculated apparent resistivity pseudo section values of layers of profile B.(c) Computer interpreted iterated inverse model resistivity section of the profile B

The blue portion in the pseudo section of profile B shows failed segment of the road whereas the blue colour indicates low resistivity.

Areas with red and purple colures indicate portions with high resistivity and as such are referred to as stable zone. Areas with green color are characterized as the intermediate zone.

This profile shows some anomalies toward the surface in some area, mostly between the distances of 45 m to 60 m, 155 m -162 m, these material has very low resistivity which is likely to be clay. These maintain a shallow depth that is less than 5m, therefore it is possible that the infill material for the road was not competent (clay most likely).
Calculated apparent resistivity pseudo section also shows some arrangement of lithologies from strong at the base to weak at the surface (succession) the low resistance lithologies that is found at the surface are the major cause of the road failure.

From the inverse model resistivity section, the surface is dominated by low resistance material amidst the stable rocks and outcrops as seen in distance 35m and 78m respectively. The low resistance material found at distance 30 Ωm to 52.5 Ωm and 125 Ωm, 147.5 Ωm, 155 Ωm to 170 Ωm, 210 Ωm to 232.5 Ωm, 240 Ωm to 262.5 Ωm to 282.5 Ωm. These materials can lead to gross failure of the road. Those material are not the institu material but was brought in during the process of construction. The cause of these failures is due to inconsistency of the material that was use for the construction of the road as some contain clay material which does not transmit fluid instead it increases in volume leading to expansion and with lesser fluid it breaks up leading to crack and holes within the asphalt.

Table 1:Range of apparent resistivity values and lithologic variation

PROFILE	LEAST VALUE	MAX VALUE	RESISTIVITY (OHM.M)	INFERED LITHOLOGY	LAYERS
A	14.763	1624.1	22.57	Clay/laterite	2
B			1407.5	Clay/laterite	2

CONCLUSION

Based on the results of the geoelectrical investigation of road failure along London Street extending to Bosso Low-cost Road, the following conclusions are drawn. Clayey nature of the topsoil and sub-grade soil on which the road is constructed. have tendency of absorbing water which makes them swell and collapse under imposed wheel load stress which subsequently lead to road failure, as observed at failed segment along profiles A and B alsothe resistivity series of Profile A ranges between 205 m to 250 m. At this point the road is likely to fail. Also Profile B possesses low resistivity which maybe clay and the road is likely to fail at 45 m to 60 m, 155 m -162 m.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

ACKNOWLEDGEMENT

The authors wish to acknowledged the effort and contribution of all the staff of geophysics Department, Federal University of Technology, Minna

REFERENCES

Aizebeokhai, A. P., Olayinka, A. I., Singh, V. S., & Uhuegbu, C. C. (2011). Effectiveness of 3D geoelectrical resistivity imaging using parallel 2D profiles. *International Journal of Physical Sciences*6(24), 5623-5647.

Auken, E., Louise P., Niels, B. C., & Kurt, S. (2006). A survey of current trends in near-surface electrical and electromagnetic methods. *Geophysicsjournal,* 71(5), 249-260.

Baker, David S. (1979). Charging current data for guesswork-free design of high-resistance grounded systems. *International Electrical and Electronic Engineering Transactions on Industry Applications*2, 136-140.

Bentley, L. R., & Gharibi. M. (2004). Two-and three-dimensional electrical resistivity imaging at a heterogeneous remediation site. *Geophysics*69(3),674-680.

Colangelo, G. (2008). 2D electrical resistivity tomographies for investigating recent activation landslides in Basilicata Region (Southern Italy). *Annuals of Geophysics.*

Delgado, J., Lopez C.C, Giner J., Estevez A., Cuenca A., & Molina S. (2000). Microtremors as a geophysical exploration tool: applications and limitations. *Pure and applied geophysics* 157(9),1445-1462.

Griffiths, D. H., & Turnbull, J. (1985). A multi-electrode array for resistivity surveying.*FirstBreakJournal* 3(7), 16-20.

Ibitomi, M. A., Fatoye F. B., & Onsachi J. M. (2014). Geophysical Investigation of Pavement Failure on a portion of Okene-Lokoja Highway, North Central Nigeria. *Journal of Environment and Earth Science*4(13), 44-50.

Klimis, N. S., Margaris B. N., & Koliopoulos P. K. (1996) Site-dependent amplification functions and response spectra in Greece. *Journal of Earthquake Engineering*3(2), 237-270.

Lapenna, V. (2005). 2D electrical resistivity imaging of some complex landslides in Lucanian Apennine chain, southern Italy.*Geophysics*7(3),11-18.

Loke, M. H., & Barker, R. D. (1996). Practical techniques for 3D resistivity surveys and data inversion. *Geophysical prospecting* 44(3), 499-523.

Jadi, H. & Luna, R., (2000). Determination of dynamic soil properties using geophysical methods. Proceedings of the first international conference on the application of geophysical and methodologies to transportation facilities and infrastructure geophysics.

Razzell, W. E., & Trussell P. C. (1963). Isolation and properties of an iron-oxidizing Thiobacillus. *Journal of bacteriology*, 85(3), 595-603.

Soupios, P.M. (2007). Estimation of aquifer hydraulic parameters from surficial geophysical methods: A case study of Keritis Basin in Chania (Crete-Greece). *Journal of Hydrology* 338(1), 122-131.

Stummer, P. & Hansruedi M. (2001). Real-time experimental design applied to high-resolution direct-current resistivity surveys. *In International Symposium on Optical Science and Technology,* pp. 143-150. International Society for Optics and Photonics.

Ward, S. H. (ed.) (1990). Geotechnical and environmental geophysics. S*ociety of exploration geophysicists*, 1, pp.147-189, Tulsa, Oklahoma.