IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 7, Issue 6 Ser. III (Nov. – Dec. 2019), PP 37-45
www.iosrjournals.org

Construed Geotechnical Significance of Geoelectric Sounding and Hydrogeological Measurement at the Eastern Border of Federal University of Technology, Akure Campus, Nigeria

Adeyemo, Igbagbo A.
Department of Applied Geophysics, Federal University of Technology, Akure, Nigeria

Abstract:*Geoelectric sounding technique of electrical resistivity method and hydrogeologic measurement involving static water level measurement were utized in predicting the foundation beds competence of the residential area located at eastern border of the Federal University of Technology, Akure campus, Nigeria.. The geoelectric sounding survey delineated eight curve types in the study area namely the A, H, HA, KH, HK, QH, HKH and KHA type. The 3 to 5 geoelectric layers delineated from the study area corresponds to the top soil, weathered layer, weathered basement, fractured basement and the presumed fresh bedrock. The layer resistivity varies respectively from 5 - 213 Ωm, 5 - 593 Ωm, 7 - 1156, 14 - 649 Ωm and 72 - 2968 Ωm in the top soil, weathered layer, weathered basement, fractured basement and the presumed fresh bedrock. The 0.5 m iso-resistivity depth slice map of the study area shows that about 75 % of the area are of low resistivity (60 - 150 Ωm) and are thus classified as low competence area. Similarly the 1.0 m iso-resistivity depth slice map shows that about 65 % of the area (northwestern and southwestern parts) are of very low to low resistivity (0 - 150 Ωm) indicating poor to low competence. The total longitudinal resistivity map revealed that only the western, central and extreme southeastern parts of the study area are of low competence (60 - 150 Ωm)while the rest of the study area are of very low competence (7 - 60 Ωm). The static water level of the area varies from 0.5 - 7.0 m and the static water level map indicates that only the west, central and eastern flanks of the map can be decribed as moderate to high competent based on their static water level of 3.0 - 7.0 m, while the rest of the study area can only be classified as very low to low competent zones (SWl of 0.5 - 2.0 m). There is a trong correlation between the total longitudinal resistivity map and the static water level map. They both indicated that extreme western, central and extreme eastern parts of the area are of low geotechnical competence. The advantage of Dazzarouk (second order geolelctric) parameters in analyzing geoelectric sounding results was hereby highlighted.*

Keywords:*Geoelectric sounding,static water level,depth slice isoresistivity, longitudinal resistivity and geotechnical competence*

Date of Submission: 17-12-2019 Date of Acceptance: 31-12-2019

I. Introduction

The incessant incidence of collapse building is a major concern in Nigeria. This failure is associated with a number of factors; such as inadequate information about the subsurface soil conditions, non-adherance to standard practice, building on incompetent subsurface layer(s), presence of expansive clayey materials in the shallow subsurface layers, the presence of subsurface structures like bedrock depression, rock contact, sheared zones, fractured and faulted zones and shallow static water level (Adeyemo et al, 2014a). Some geologic materials by nature cannot support heavy and rigid structures. Thus there is need to carry out detailed geotechnical investigation in order to determine the geotechnical competence of the topsoil and subsoil before deciding on the appropriate foundation design suitable for the soil condition (Olayanju, et al 2017).

Different geophysical methods consisting electrical, electromagnetic, seismic refraction, ground-penetrating radar, magnetic methods and others have been employed in investigating subsurface competence (Olorunfemi and Meshida, 1987; Olayanju, 2004; Momoh et al, 2008; Akintorinwa, and Adeusi, 2009; Akintorinwaand Abiola, 2011; Adeyemo et al, 2014a and Olayanju, et al 2017). Geotechnical approaches such as cone penetrometer test (CPT), Atterberg limit, grain size analysis, and cone penetrometer test have also been used (Gidigasu, 1983; Graham and Shields, 1984; Mesida 1986 and Mesida, 1987). Integrated geotechnical and geophysical methods in investigating causes of building failure and geotechnical characterization of different study areas have also been done (Olorunfemi and Mesida, 1987; Sabinus et al, 2014 and Olayanju et al 2017). Water table is the surface of the saturated zone, below which all soil or rock pores are filled with water only(Delleur, 1999). Ground water moves through the subsurface much like water on the ground surface, except that it travels a great deal more slowly. If the soil consist of mostly sand and gravel, ground water can move as much as 1.5m per day. But, more often, ground water moves at speeds of a few cm per day or less(Delleur, 1999). Groundwater is the major source of threat to civil engineering structures such as buildings, roads and dams. A major condition necessary for a good foundation is that it must be far from static water level. This implies that static water level measurement should be considered as an important aspect of foundation intergrity tests. This study utilized integeration of geoelectric sounding and hydrogeologic measurement (static water level measurement) in predicting foundation beds competence. The two methods adopted for this investigation are cheap and reliable and can be replicated in any geologic and geographic environments.

II. The Study Area

The study area lies at the eastern borders of the Federal University of Technology, Akure (FUTA) campus and it is bordered to the north and south by Akure-Ilesa expressway and FUTA south gate road respectively (Figure 1). These composite layouts are very important to the university community since a lot staff and students who lives off-campus resides in these layouts. The area extent of the study area is about 1.12 km^2.The area is moderately undulating with surface elevation ranging from 370 - 403 m above sea level (Figure 2). The climate is within the sub-equatorial climate region, and it is situated in the tropical rain forest of southwestern Nigeria. The area is characterized by ever green plants and scattered trees. The area is noted for uniformly high temperature and well distributed rainfall year round. It has two distinct seasons; wet and dry seasons. The annual rain fall is about 1600 mm, while the average daily temperature is 33 ^{0}C (Iloeje, 1980). The rock types encountered within the study area consist essentially thecharnockites which occurs as low-lying outcrops (Rahaman, 1988) and discrete bodies in the entire study area(Figure 3).

III. Research Methodology

This study compriseof hydrogeologic and geoelectric sounding measurements. The geoelectric sounding (GS) measurement adopts Schlumbergerarray field technique. A total of 48 geoelectric sounding points were occupied across the study area. The current electrode spread (AB/2) was increased to maximum 65 - 100 m. The PASI 16 GL earth resistivity meter was used for this survey, the equipment can automatically calculate the resistance R, such that the three values (Current, I; Potential difference, ΔV and Resistance, R) are displayed after each measurement. The acquired VES data were plotted on a transparent log-log graph as a plot of apparent resistivity values (ρ_a) against the electrode spacing (AB/2). The curves were interpreted both qualitatively and quantitatively. The quantitative interpretation was done using partial curve matching technique (Zohdy, 1965; Keller and Frischnecht, 1966 and Koefoed, 1979) and the resultant geoelectric parameters were further refined using computer iteration algorithm RESIST Version 1.0 (Vander Velpen, 1989). The geoelectric soundings results were presented in tabular form and iso-resistivity depth slice maps of 0.5 and 1.0 m.

Static water level measurements were taken in all the accessible 52 hand dug wells across the study area. A water level indicator was attached to one end of a tape rule and the tape rule was subsequently lowered into wells and when the water indicator makes an audible sound which indicates that the indicator has reached the water surface in the well. The tape rule is pulled out of the well and the depth to the water surface or static water level is read off the tape rule. The coordinates of the well were determined using the hand held GPS. The hydrogeological measurements data was presented as static water level map.

Figure 1: Base map of the study area

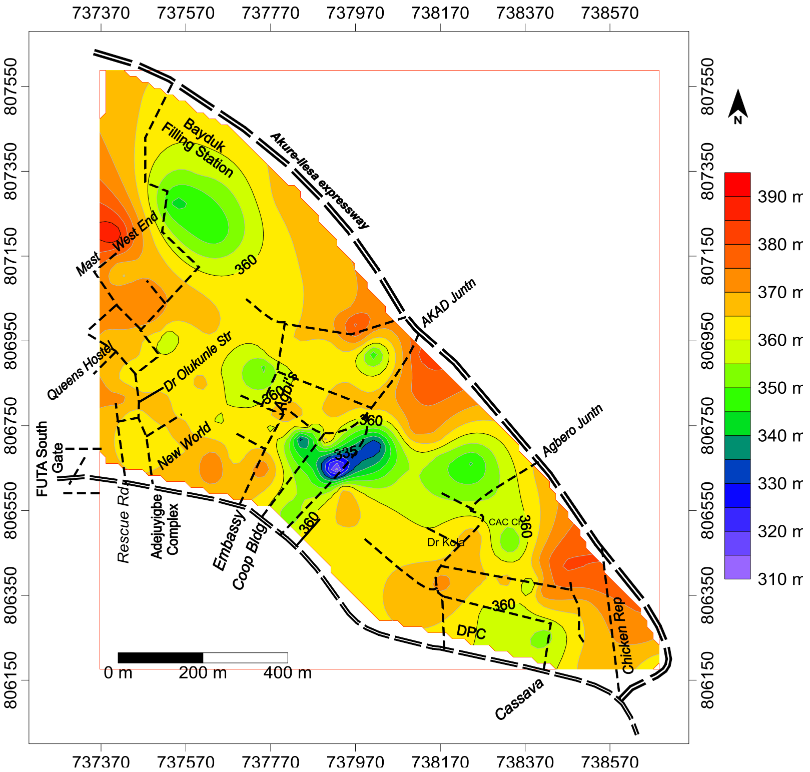


Figure 2: Topographic map of the study area

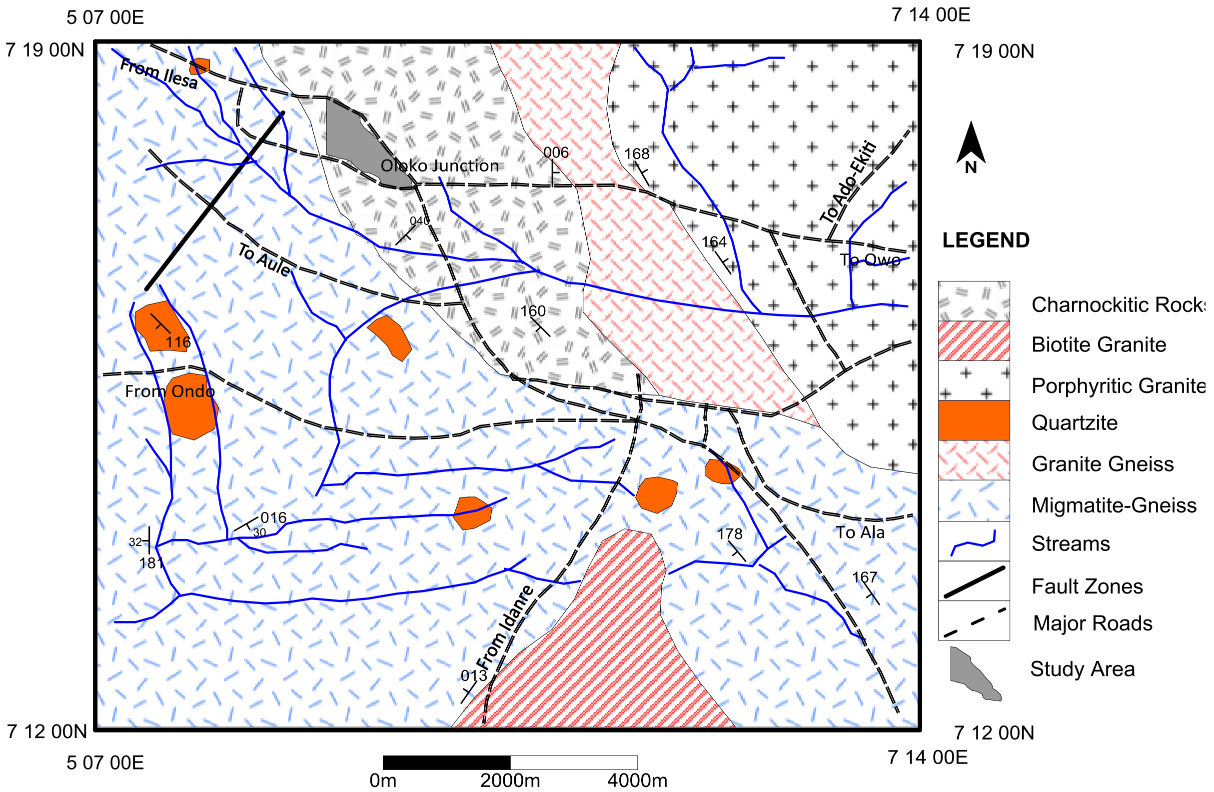


Figure 3: Geologic map of Akure showing the study area (After, Owoyemi, 1996)

IV. Results and Discussion

Geoelectric Sounding Results: Eight different geoelectric curve types were identified in the study area (Table 1), these include the A, H, HA, HK, KH, QH, HKH and KHA type. The delineated geoelectric layers vary from 3 – 5 and they corresponds to the top soil, weathered layer, weathered basement, fractured basement and the presumed fresh bedrock. The layer resistivity varies from 5 - 213 Ωm, 5 -593 Ωm, 7 -1156, 14 - 649 Ωm and 72 - 2968 Ωm in the top soil, weathered layer, weathered basement, fractured basement and the presumed fresh bedrock respectively. The thickness values of the upper four layers vary respectively as 0.2 - 1.4 m, 0.5 - 16.9 m, 2.5 - 43.3 m and 3.1 - 19.4 m in the top soil, weathered layer, weathered basement and fractured basement respectively.

Resistivity values can be utilized in mapping and delineating subsurface competence because resistivity responds to many geologic factors affecting subsurface layers competence. These factors includes; presence of clayey materials, soil moisture content, presence of geologic structures (fracture and faults), porosity and permeability. Generally when subsurface layer resistivity is low it suggest possible presence of the above mentioned factors which are inimical to geotechnical competence of such geologic materials and conversely when resistivity value is high it indicates the absence of the above mentioned factors suggesting a competent subsurface layer. Therefore the geoelectric survey (GS) results were presented as maps of iso-resistivity depth slice atdifferent surfaces (0.5 and 1.0 m) and total longitudinal resistivity to enabled the spatial classification of the area into different geotechnical competence zones.

Table 1: Geoelectric Sounding Results

VES NO	Layer Resistivity (Ωm) $\rho_1/\rho_2/\rho_3......h_n$	Layer Thickness (m) $h_1/h_2/h_3......h_n$	No of Layer	Curve Type
1	136/ 24/ 114	1.1/ 6.6	3	H
2	48/ 10/ 118/ 19/ 578	0.7/ 1.4/ 5.8/ 11.9	5	HKH
3	15/ 5/ 86/ 666	0.9/ 2.3/ 5.6	4	HA
4	50/ 13/ 319/ 1634	1.4/ 10.5/ 16.5	4	HA
5	127/ 41/ 14/ 345	1.0/ 2.1/ 3.3	4	HA
6	77/ 217/ 137/ 615	0.9/ 3.9/ 8.7	4	HK
7	112/ 38/ 91/ 1474	0.5/ 1.2/ 10.5	4	HA
8	109/ 429/ 110/ 1779	0.6/ 2.7/ 6.4	4	KH
9	75/ 134/ 613	0.9/ 7.4	3	A
10	88/ 36/ 83/ 603	0.6/ 0.6/ 8.5	4	HA
11	141/ 47/ 17/ 259	0.9/ 1.8/ 3.6	4	HA
12	14/ 6/ 17/ 559	0.8/ 2.6/ 1.2	4	HA
13	142/ 28/ 1156/ 50	1.1/ 6.6/ 43.3	4	HK
14	94/ 157/ 46/ 374	0.7/ 1.0/ 6.2	4	HA
15	77/ 44/ 18/ 387	0.8/ 1.7/ 6.2	4	HA
16	58/ 42/ 237/ 423	1.0/ 7.6/ 3.5	4	HA
17	81/ 43/ 14/ 335	1.0/ 2.9/ 7.5	4	HA
18	94/ 157/ 46/ 374	0.4/ 3.5/ 4.6	4	KH
19	60/ 39/ 85/ 193	0.9/ 5.3/ 4.5	4	HA
20	51/ 23/ 9/ 110	1.1/ 1.8/ 8.1	4	HA
21	41/ 18/ 12/129	0.9/ 1.7/ 23.5	4	HA
22	213/ 157/ 7/ 146	1.4/ 0.5/ 1.9	4	QH
23	88/ 318/ 50/ 182	0.8/ 7.6/ 28.6	4	KH
24	98/ 311/ 54/ 168	0.5/ 4.9/ 26.9	4	KH
25	38/ 593/ 34/ 547	0.9/ 4.4/ 10.5	4	KH
26	40/ 124/ 84/ 1145	0.6/ 16.9/ 19.1	4	KH
27	27/ 383/ 44/ 1480	0.5/ 4.2/ 12.5	4	KH
28	37/ 340/ 18/ 957	0.6/ 2.4/ 10.6	4	KH
29	61/ 11/ 41/ 150	0.8/ 4.9/ 3.1	4	HA
30	100/ 10/ 174/ 1516	0.7/ 2.3/ 3.5	4	HA
31	38/ 7/ 78/ 4829	0.7/ 1.6/ 2.0	4	HA
32	117/ 279/ 82/ 302/ 2430	0.8/ 1.6/ 4.4/ 3.1	5	KHA
33	39/ 131/ 21/ 153/ 1114	0.3/ 2.4/ 5.9/ 6.9	5	KHA
34	24/ 46/ 2968	1.1/ 4.2	3	A
35	24/ 44/ 33/ 115	0.9/ 5.8/ 5.0	4	KH
36	5/ 10/ 1365	1.4/ 1.5/	3	A
37	15/ 42/ 14/ 608	0.2/ 3.7/ 2.5	4	KH
38	41/ 78/ 450	0.5/ 6.3	3	A
39	16/ 57/ 22/ 649/ 2041	0.7/ 2.6/ 6.2/ 19.4	5	KHA
40	38/ 169/ 63/ 414	0.6/ 5.7/ 22.5	4	KH
41	95/ 57/ 199/ 14/ 244	0.6/ 0.8/ 2.5/ 8.5	5	HKH
42	21/ 48/ 12/ 465	0.9/ 4.3/6.2	4	KH
43	107/ 49/12/ 465	0.9/ 3.3/ 9.9	4	QH
44	10/12/ 2628	1.1/ 1.9	3	A
45	68/ 13/ 152/ 565	0.6/ 2.5/ 3.9	4	HA
46	178/ 46/ 8/ 72	1.0/ 2.1/ 2.7	4	QH
47	34/ 342/ 23/ 1048	0.4/ 2.3/ 6.3	4	KH
48	83/ 7/ 102/ 1125	0.8/ 4.2/ 6.1	4	HA

Depth slice isoresistivity maps: The 0.5 m depth slice iso-resistivity map (Figure 4) of the study area shows that most part of the area is of low resistivity (60 - 150 Ωm) and are thus classified as low competence area, while the central and southwestern parts of the area are characterized by lower resistivity values (0 - 60 Ωm) and are considered as poor competence zones. The north and northeastern parts of the area are characterized by relatively higher resistivity values (150 - 250 Ωm) and thus considerd to be of moderate competence.

The 1.0 m depth slice iso-resistivity map (Figure 5) of the study area shows that northwestern and southwestern parts of the area are of very low to low resistivity (0 - 150 Ωm) and are thus classified as poor to low competence area, while the central part of the area are characterized by relatively higher resistivity values (150 - 600 Ωm) and are considered to be moderate, high and very high competence zones.

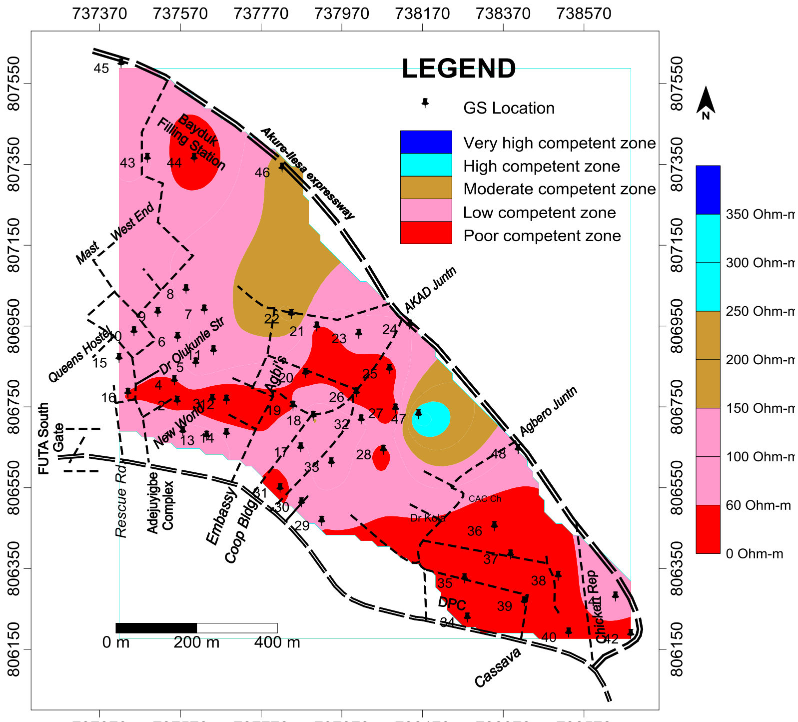


Figure 4: The 0.5 m iso-resistivity depth slice map of the study area

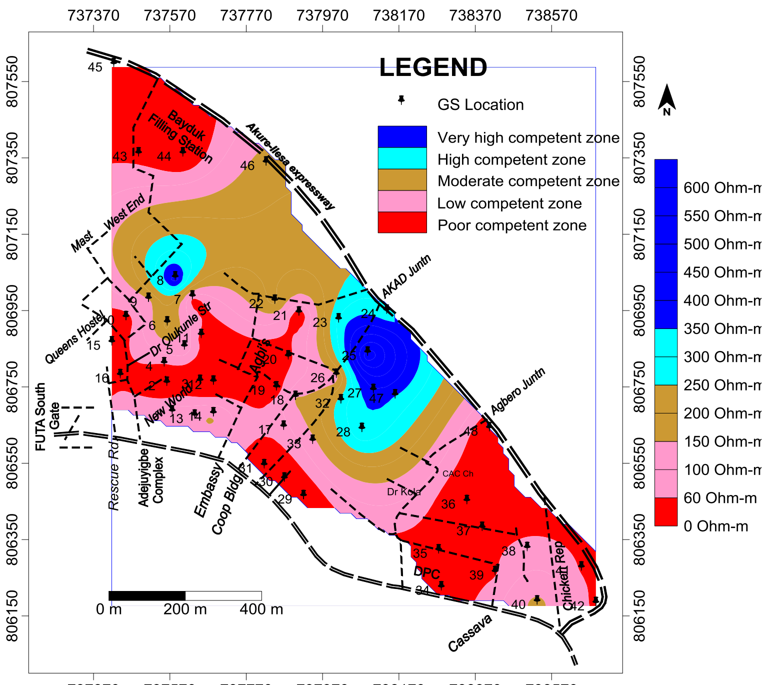


Figure 5: The 1.0 m iso-resistivity depth slice map of the study area

Second order geoelectric parameters: Total longitudinal resistivity, a second order geoelectric parameter was also calculated using the layer resistivity and thickness values. The total longitudinal resistivity values were derived using the following relationship;

$\rho_L = {}^{T}/_{S}$ (After Kosinski and Kelly, 1981 and Adeyemo et al, 2014b) (1)

Where,

$S = \frac{t_i}{\rho_i}$ (2)

t_i = Layer thickness

ρ_i = Layer resistivity

T = Total layer thickness

S= Total longitudinal conductance

The derived total longitudinal resistivity (ρ_L) values across the study area were presented as map (Figure 6). This map gives average resistivity values of all the weathered materials in the study area (top soil, weathered layer, weathered basement and fracturedbasement) and consequently the map is expected to be more reliable than the depth slice isoresistivity maps. The total longitudinal resistivity map revealed that only the western, central and extreme southeastern parts of the study area can be categorized as low competence areas (60 - 150 Ωm) while the rest of the study area can only be classified as very low competence area (7 - 60 Ωm).

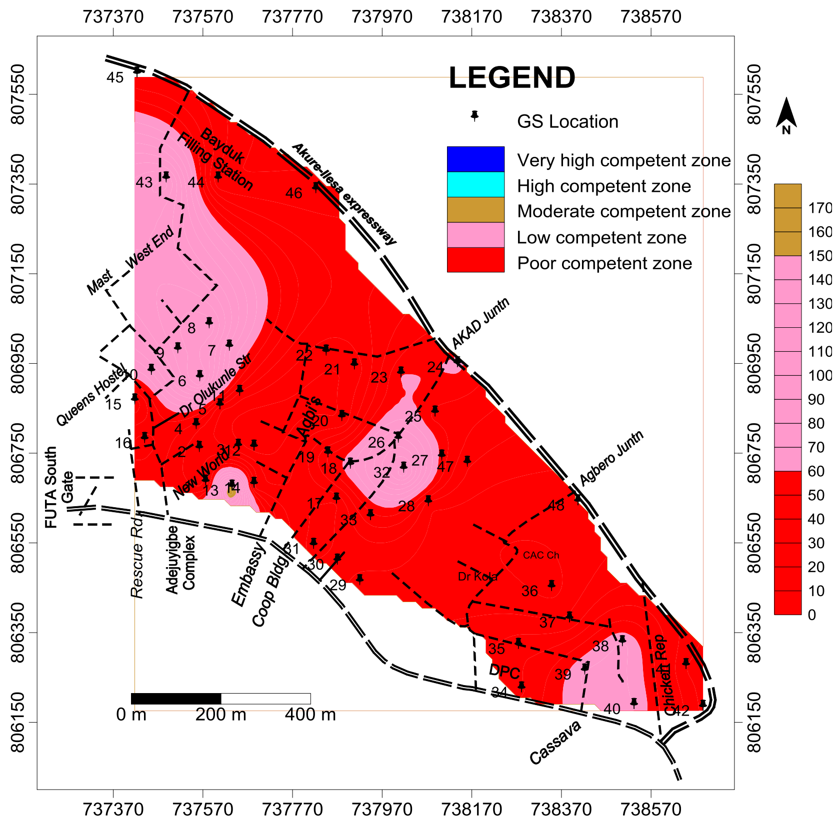


Figure 6: Longitudinal resistivity map of the study area

Hydrogelogic Measurements: The static water level, which is equivalent to the water table was presented as map (Figure 7). The static water level measurement was determined directly from the accessible 52 hand dug wells across the study area. The water table values or the static water levels were subsequently contoured to generate the static water level map. The static water level map of the study area (Figure 4) shows that the static water level (SWL) varies from 0.5 - 7.0 m. The depth to water table can also be employed to estimate subsurface competence, when the SWL value is small suggesting shallow water table; this indicates a very low to low geotechnical competence since presence of water is inimical to foundation intergrity and conversely when the SWL is much suggestsing a deep water table; this indicates a geotechnically competent layer. The study area can therefore be zone into different geotechnically competent zones using the SWL map.

The west and the eastern flanks of the map can be decribed to be of moderate to high competence based on their static water level of 3.0 - 5.0 m, the western part of the area can be classified as poor to low competent zones (SWl of 0.5 - 2.0 m), the central part of the area however can be considered to be of high to very high competent zones (SWL of 4.0 - 7.0 m) and similarly the eastern part of the area can be described as low to moderate competent zones (SWL of 1.5 - 3.0 m). The moderate, high and very high competent zones are places where civil engineering structures should be situated. This conclusion is logical since the water lodged nature of these parts of the study area can lead to structural failure and complete destruction of buildings situated at very low and low competent zones.

Correlation of Results: Out of the three geoelectrically derived maps, the total longitudinal resistivity map (Figure 6) agree most with the static water level map (Figure 7) which is regarded as a direct approach of determine foundation beds competence in any geologic terrain. This is can be seen in the correlation maps (Figure 8). The total longitudinal resistivity map is also useful in resolving the descripancy observed from the use of depth slice isoresistivity maps (0.5 and 1.0 m). This again shows the advantage of Dazzarouk (second order geoelectric) parameters in analyzing geoelectric sounding results.

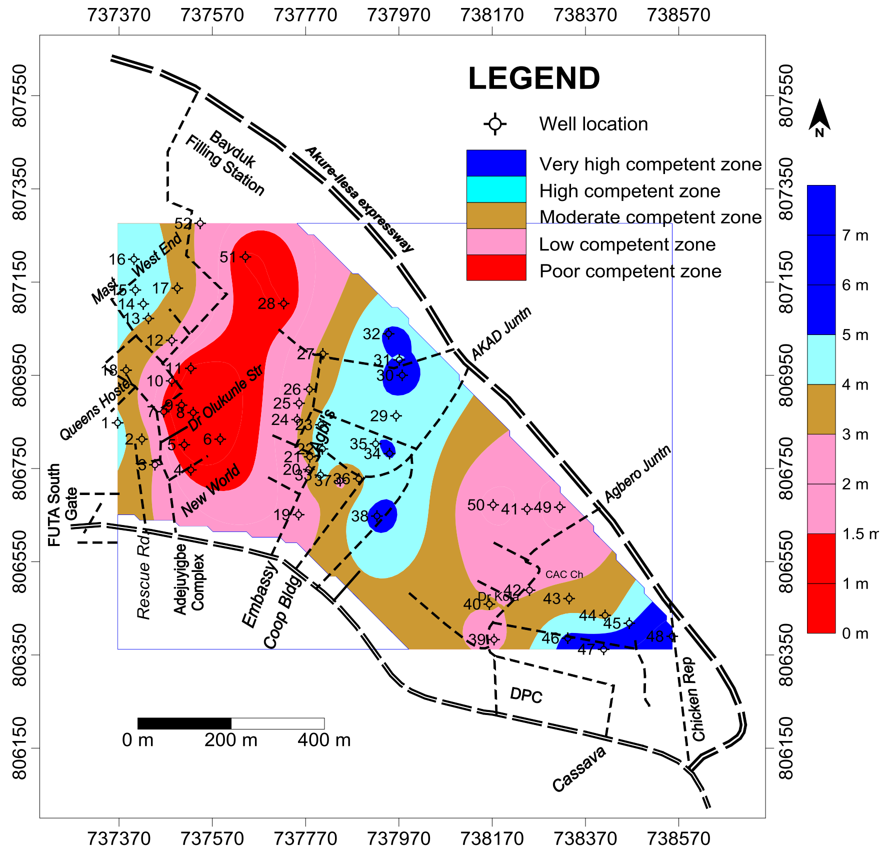
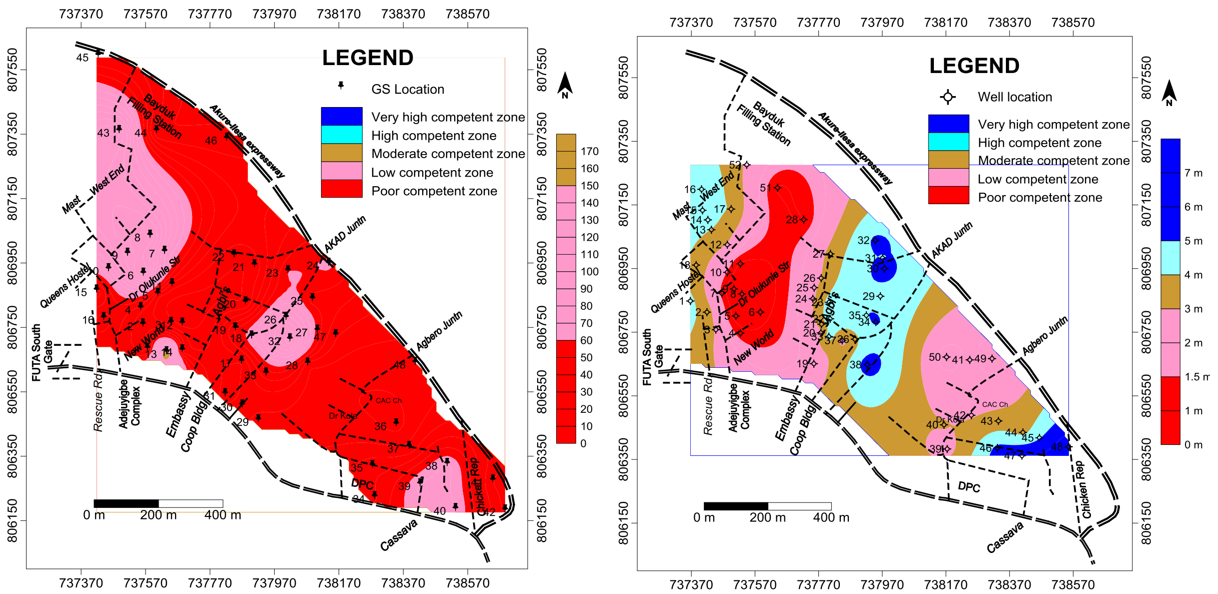


Figure 7: Static water level map of the study area



(a) (b)

Figure 8$_{(a-b)}$: The correlation of the longitudinal resistivity and static water level maps of the study area

V. Conclusion

This study was aimed at predicting the foundation beds competence of the residential area located at eastern border of the Federal University of Technology, Akure campus, Nigeria. Geoelectric sounding technique of electrical resistivity method and hydrogeologic measurement (static water level) were utized in this study. The eight curve types were delineated in the study area consists of the A, H, HA, KH, HK, QH, HKH and KHA type. The 3 to 5 geoelectric layers from the study area corresponds to the top soil, weathered layer, weathered basement, fractured basement and the presumed fresh bedrock. The layer resistivity varies from 5 - 213 Ωm, 5 - 593 Ωm, 7 - 1156, 14 - 649 Ωm and 72 - 2968 Ωm in the top soil, weathered layer, weathered basement, fractured basement and the presumed fresh bedrock respectively. The 0.5 m depth slice iso-resistivity map of the study area shows that about 70 % part of the area are characterized with low resistivity (60 - 150 Ωm) and are thus classified as low competence area. Likewise the 1.0 m depth slice iso-resistivity map shows that about 65 % of the area (northwestern and southwestern parts) are of very low to low resistivity (0 - 150 Ωm) and can be classified as poor to low competence area. The total longitudinal resistivity map revealed that only the western, central and extreme southeastern parts of the study area can be categorized as low competence areas (60 - 150 Ωm), while the rest of the study area can only be classified as very low competence area (7 - 60 Ωm). The static water level of the area varies from 0.5 - 7.0 m. The static water level map indicates that only the west, central and eastern flanks of the map can be decribed as moderate to high competent based on their static water level of 3.0 - 7.0 m, while the rest of the study area can only be classified as poor to low competent zones (SWl of 0.5 - 2.0 m). There is a trong correlation the total longitudinal resistivity map (Figure 6) and the static water level map (Figure 7). They both indicated that extreme western, central and extreme eastern part of the area are of low geotechnical competence. The advantage of Dazzarouk parameters in analyzing geoelectric sounding results was also highlighted.

Acknowledgments

The author acknowledge Adesanya Michael and Olumideboth are students of the Applied Geophysics Department who assisted in acquiring geoelectric sounding and hydrogeologic measurement data.

References.

[1]. Adeyemo, I. A., Bamidele O. E. and Obatayo, O. B. (2014a): Geoelectric Survey for Post-Foundation Investigation of a Distressed Building at Ade Super Hotel Akure, Southwestern Nigeria. International Journal of Engineering and Sciences (IJES), Vol. 3, Issue 2, pp. 35 - 42

[2]. Adeyemo, I. A., Omosuyi, G. O., Olayanju, G. M. and Omoniyi, G. K. (2014b): Hydrogeologic and Geoelectric Determination of Groundwater Flow Pattern in Alaba-Apatapiti Layouts, Akure, Nigeria. International Journal of Engineering and Sciences (IJES), Vol. 3, Issue 2, pp. 43 - 52.

[3]. Akintorinwa, O. J. and Adeusi F. A. (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), pp 241 - 254.

[4]. Akintorinwa, O. J. and Abiola, O. (2011): Subsoil Evaluation for Pre-foundation Study Using Geophysical and Geotechnical Approach, Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 2(5):858 - 863.

[5]. Delleur, J.W. (1999): Elementary Groundwater Flow and Transport Processes, In Handbook of Groundwater Engineering, Edited by J.W. Delleur, 41p.

[6]. Gidigasu, M. D. (1983): Development of Acceptance Specifications for Tropical Gravel Paving Materials. Engineering Geology. 19, 213 - 240.

[7]. Graham, J. and Shields, D. H. (1984): Influence of Geology and Geological Processes on the Geotechnical Properties of Ofa Plastic Clay. Journal of Engineering GeologyVolume 22, Issue 2, pp109-126. (http://www.sciencedirect.com/science/journal/00137952).

[8]. Iloeje, N.P. (1980):A New Geography of Nigeria (New Revised Edition). Longman Group: London, UK. 32 - 45.

[9]. Kosinski, W.K. and Kelly, W. E. (1981): Geoelectric Sounding for Predicting Aquifer Properties, Groundwater, Vol. 9, No. 2, pp163-171.

[10]. Keller, G. V., Frischnecht, F. C. (1966): Electrical Methods in Geophysical Prospecting. Pergamon Press, Oxford, United Kingdom.

[11]. Koefoed, O. (1979): Geosounding Principles 1. Resistivity Sounding Measurements. Elsevier Scientific Publishing Comp., Amsterdam, Netherlands, p. 275.

[12]. Mesida, E. A. (1986): Some Geotechnical Properties of Residual Mica Schist Derived Subgrade and Fill Materials in the Ilesha Area, Nigeria, No. 33, pp. 14 - 17.

[13]. Mesida, E. A. (1987): The Relationship between the Geology and the Lateritic Engineering Soils in the Northern Environs of Akure, Nigeria. Bull. Int. Assoc. Eng. Geol. 35, 65 - 69.

[14]. Momoh, L. O., Akintorinwa, O. J. and Olorunfemi, M. O. (2008): Geophysical Investigation of Highway Failure - A Case Study from the Basement complex terrain of Southwestern Nigeria. J. Appl. Sci. Res. 4 (6), 637 - 648.

[15]. Nelson, R. G. and Haigh, J. H. (1990): Geophysical Investigation of Lateritic Terrain. In Ward, S.H. (Ed.), Geotechnical and Environmental Geophysics, Geotechnical. Vol. 2. SEG, Tulsa, pp. 133 - 154.

[16]. Olayanju, G. M. (2004): Geophysical Investigation for Groundwater around Obanla-Obakekere in Federal University of Technology, Akure, Southwestern Nigeria. Journal of Mining and Geosciences. Vol. 4(1): pp.17.

[17]. Olayanju, G. M., Mogaji, K. A., Lim, H. S. and Ojo, T. S. (2017): Foundation Integrity Assessment Using Integrated Geophysical and Geotechnical Techniques: Case Study in Crystalline Basement Complex, Southwestern Nigeria. Journal of Geophysics and Engineering. 14 (2017) 675 - 690. https://doi.org/10.1088/1742-2140/aa64f7

[18]. Olorunfemi, M. O. and Mesida, E. A. (1987): Engineering Geophysics and its Application in Engineering Site Investigation- Case Study from Ile-Ife area. The Nigerian Engineer, 22(2): 57 - 66.

[19]. Owoyemi, F.B. (1996): A Geological-Geophysical Investigation of Rain-Induced Erosional Features in Akure Metropolis. Unpublished. M.Tech Thesis, Federal University of Technology: Akure, Nigeria, pp. 11-18.

[20]. Rahaman M.A. (1988): Recent Advances in the Study of the Basement Complex of Nigeria in Precambrian Geology of Nigeria. Geological Survey. Nig. 11 - 43.

[21]. Sabinus, I. I., Kalu, K. I. and Nwankwo, I. S. (2014): Geoelectrical and Geotechnical Evaluation of Foundation Beds of Naze, Owerri Southeastern Nigeria. Journal of Earth Sciences and Geotechnical Engineering, Vol. 1, No. 3, 77 - 94.

[22]. Vander-Velpen, B. P. A. (1989): RESIST Version 1.0. M.Sc. Research Project. ITC, Delft Netherlands.

[23]. Zohdy, A. A. R. 1965. The Auxiliary Point Method of Electrical Sounding Interpretation and Its Relationship to Dar-Zorrouk Parameters. Geophysics 30, 644 - 650.