IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 11, Issue 2 Ser. I (Mar. – Apr. 2023), 32-41
www.iosrjournals.org

Geophysical Evaluation for stability check in Okija bridge site project

Onwuka, O.J[1],Ugochukwu, T. E[2] , Ogundeji, O. V[1],, Okeugo, C.G[3], Amadi, C.S[3]
[1]Department of Geophysics, Federal University Oye-Ekiti, [2]Department of Civil Engineering, Federal University Oye-Ekiti.[3]Department of Geology, University of Nigeria, Nsukka,

Abstract
Search for engineering and other challenges associated with bridge construction require tactfulness and sensitivity to assure overall technical and financial success for the project. This paper focuses on the investigation of the geophysical properties of the soil and the underlying basement rock of the proposed site of a bridge at Umuohi section of Ozubulu-Okija road in Okija, Anambra State. The geophysical investigation involved geological hydrogeological survey of the study area followed by Geo-electrical investigation. Two Coordinates were taken at two stations using Vertical Electrical Sounding (VES) done using Campus Ohmega Resistivity meter model 143 instrument, Point 1 (VES1) and Point 2 (VES 2) to determine the geophysical parameters that can be used to evaluate the structural competence of the subsurface geological characteristics of the study area for the construction development using the Schlumberger configuration data acquisition at a distance of 12m apart, also using Garmin GPS MAP 76C for effective coordinate mapping. Models obtained from each VES were used for construction of geo-electric characteristics of the geological formation in the study area. The results interpretation revealed that the geo-electric sections comprise of four lithology namely: top soil, lateritic clay, weathered basement and basement rock. The resistivity values comprise of 120 – 421Ohm-m, 17.6 – 225Ohm-m, 4.7 – 20.3Ohm-m and 1369 – 1456Ohm-m respectively while the layer thickness ranges from 0.7-1.2m, 1.0-4.4m, 4.6-12.4m and infinite thickness respectively. This investigation showed that the VES1 type 'A' curve implied area not highly fractured and is to be the most competent for the engineering structure while listed recommendation must be taken care of to check subsurface instability, cracks and distress.
Key word: *Foundation, Geophysical, Lithology, Sounding, Subsurface Instability*

Date of Submission: 01-04-2023 Date of Acceptance: 11-04-2023

I. Introduction

Subsurface investigation is an important program in engineering foundation and that calls for this study in structural project such as bridge construction in road building. The term bridge applies to structures over waterways, grade separation structures, road over rail structures and elevated highways above 6meters which convey traffic. This bridge structure supports its own weight, loads due to do natural elements and daily traffic loads (Ede and Nwachukwu, 2019). In Engineering and construction, a bridge is seen as a structure that spans horizontally with supports with the aim to carry vertical loads with the beam resting on it. These supports have to have the required strength to withstand the load it will carry. Several approaches have been used for the success of foundation investigations including electrical resistivity technique (ERT) geophysical methods, extensively used for a wide variety of engineering and environmental problems (Zohdy, 1975; Barker, 1980; Boyce and Kaseoglu, 1996; Mousa, 2003, Olorunfemi, et al., 2004; Hosny et al., 2005; Alotaibi and Al-Amri, 2007; Nigm et al., 2008; Oyedele et al., 2009). Geophysical method of electrical resistivity measurements using the vertical electrical sounding (VES) technique is a well established and widely used approach for solving a variety of geotechnical, geological, hydrological and environmental sub surface detection problems (Ward, 1990; 1998). As a result of the relatively cheap cost that is involve in (ERT) and the fact that it saves time and easy to carry out, and can also be used to geological structures investigation (Al-Sayed and El-Qady, 2007). In this study, a non-destructive geophysical technique involving Vertical Electrical Sounding using Schlumberger array was adopted to investigate the subsurface conditions at the proposed bridge site in Okija - Ozobulu road Ihiala local government area with the aim of investigation and determining the competency condition of the competent rock upon which the structure will be laid. Consequently two vertical electrical soundings (VES) stations were carried out and the data obtained were processed and their output was presented as geoelectric curves. The geophysical information obtained during in-situ observation is an essential part of ensuring safety and cost effectiveness during the bridge design and its construction.

I.II Description of the study area

Okija town in Ihiala local government area is about 30km North of Ozubulu town in Anambra state were the study area is located, approximately bounded in the North by Longitude 5.8994° N - 5.8997° N and in the East by Latitude 6.8354° E - 6.8345° E . The topography of the area is of relatively flat to a gentle slope terrain, and lies in Southeastern Nigeria, which is within the humid tropical region of the equatorial zone and is typified by two main climatic seasons, namely the wet and dry seasons. The area belongs to the tropical rainforest of southern Nigeria and is covered mainly by tall trees typical of savannah vegetation with average temperature of 27°C, Wind S at 6 km/h and 78% Humidity and bordered in the east by Ihembosi and Ukpor cities, within the west by olu or Ogbakubara, within the north by Ozubulu and within the south by Ihiala. In the area, the Ulasi River on its flow to the Atlantic, joins Okposi river one of its tributaries.

Fig1(a) showing the Google map showing the digital location of the study area and environs in a larger scale whereas fig1(b) in a smaller scale indicating the vegetation and topography highlighting from North end of Urobo-Okija, Isieke, Akpaka, Osuakwa, Ogboro to down south of Ihite Ihiala. However, fig 2 is the Geological map of Anambra state by local government area indicating the lithology and fig 3 showing the location and various Formation and the energy resources of the study area. Moreover, fig 4 having the drainage pattern and major roads in the study area which aid engineering properties assessment and suitability of the lithology examination for backfill materials which aid in impact assessment and lithology stability and construction sustainability, similarly, fig 5 is the thematic map of Okija with Environmental Impact Assessment and lithology stability for structural construction. Fig 6 showing the entire area structural map indicating various rock units, Gully erosion extent and lake location which revealed the regional structural strength of the research area. All this give insight of the regional and local geology, the area is underlain by three formations, the Eocene Nanka, Oligocene-Miocene Ogwashi, and Oligocene Benin formations as figures indicated. The three formations are characteristically composed of sands interbedded with thin layers of mudrocks and ironstones (Nwajide, 2013). Studies have shown that the formations are generally extensive in the southern Nigeria and inherently weak and collapsible (Chikwelu & Ogbuagu, 2014; Egbueri, Igwe, & Nnamani, 2017; Igwe, 2012; Igwe & Egbueri, 2018; Nwajide, 2013; Obiadi et al., 2014; Okoyeh et al., 2014). Despite their age differences, all the soils underlying the study area are predominantly composed of loose and poorly consolidated fine-grained sand materials with low clay content and little or no coarse-grained aggregates (Egbueri et al., 2017; Igwe & Egbueri, 2018).

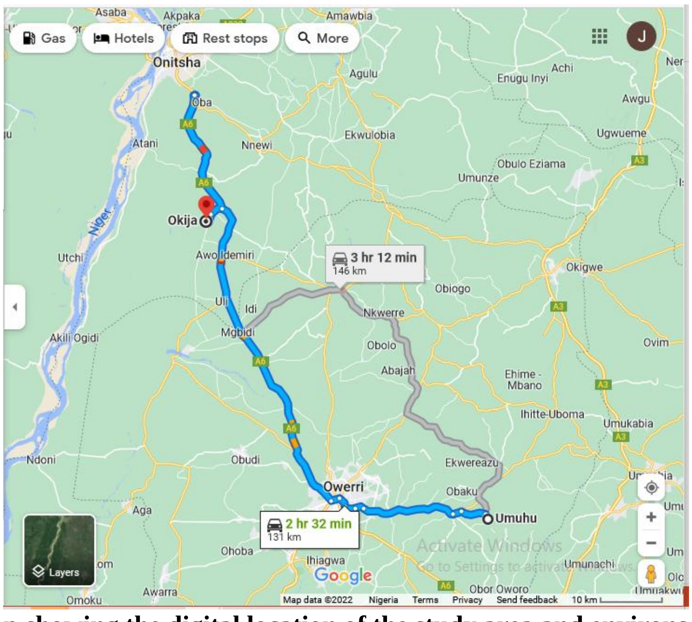

Fig 1(a): Google map showing the digital location of the study area and environs. Larger scale (after google 18/06/2022, Okija town SE Nigeria and its environs)

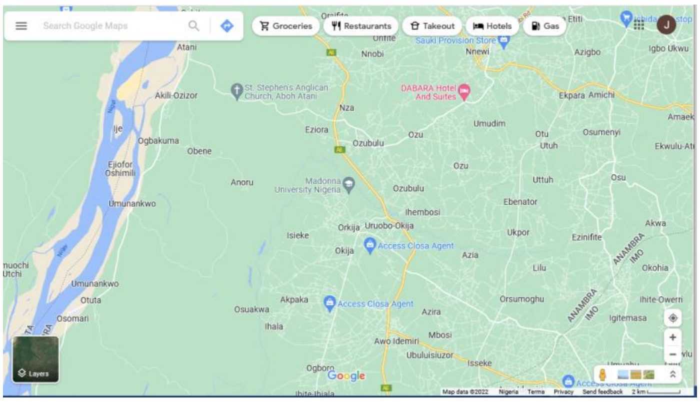

Fig 1(b): Google map showing the digital location of the study area and environs. Smaller scale highlighting Urobo-Okija, Isieke, Akpaka, Osuakwa, Ogboro to Ihite Ihiala (after google 18/06/2022, Ihiala)

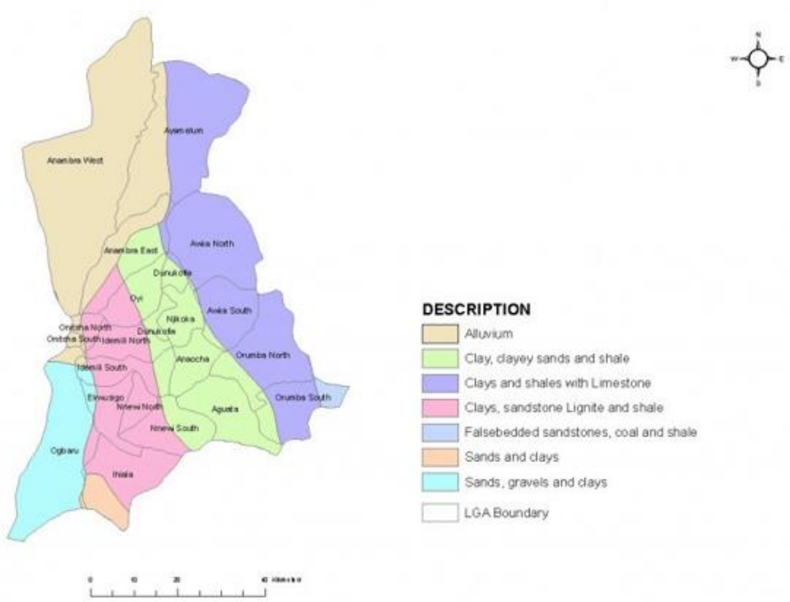

Fig 2: Geological map of Anambra state by local government area indicating the lithology of the study area (after Nigeriandata mall 2016)

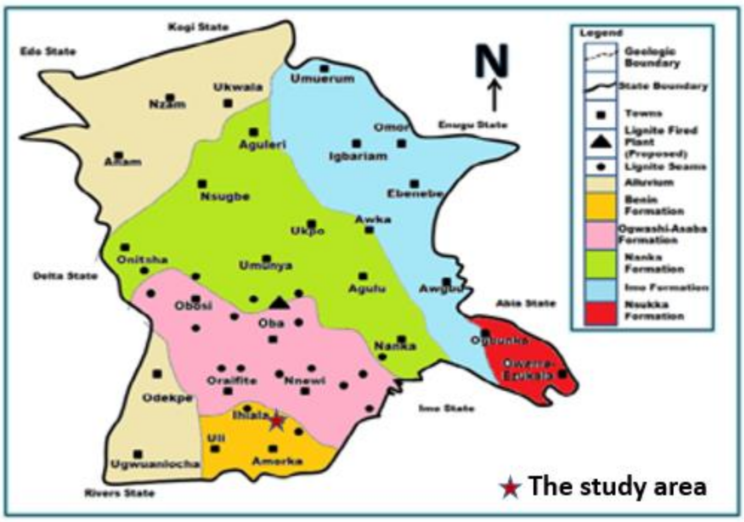

Fig 3: Geologic map of Anambra state indicating the location and Formation of the study area (after Ikechukwu et al.,2019)

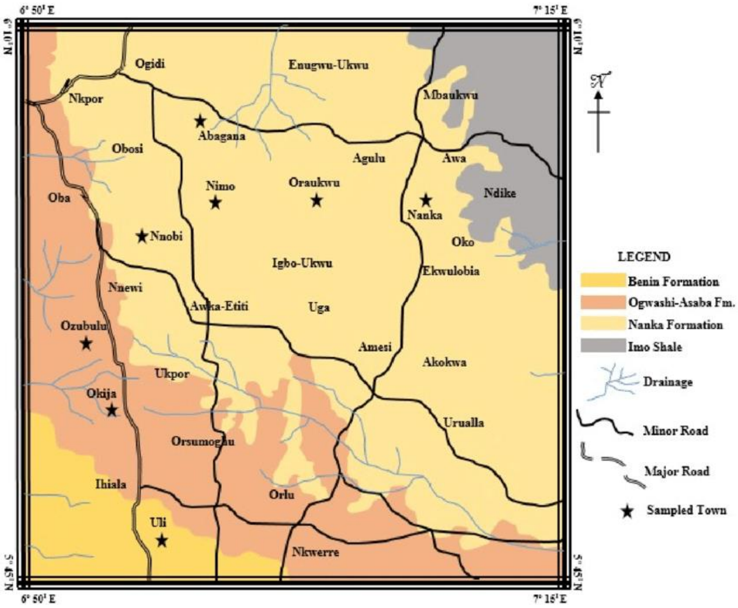

Fig 4: Geologic map showing the drainage and major roads in the study area (after Egbueri et al., 2017)

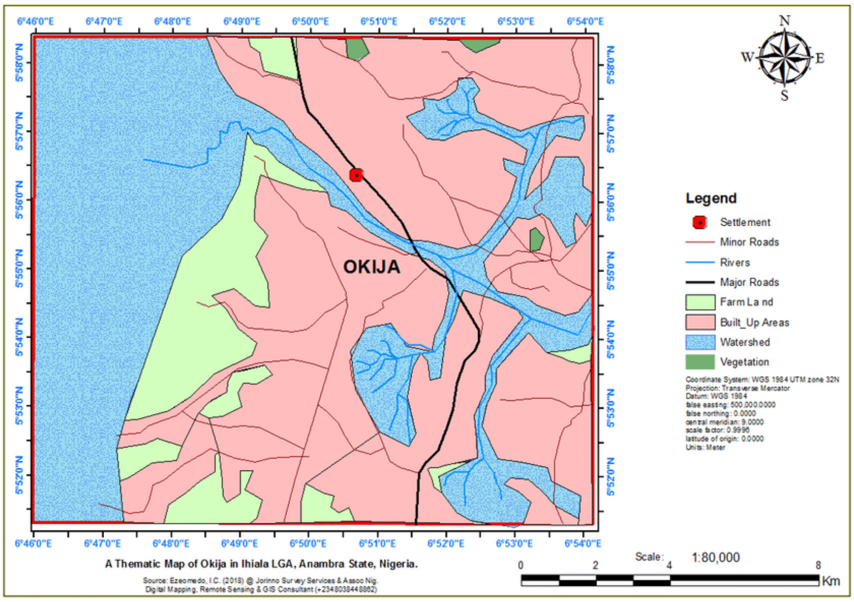

Fig 5: A thematic map of Okija with Environmental Impact Assessment and lithology stability for structural construction (after Anukwonke, C and Muoghalu, L 2019)

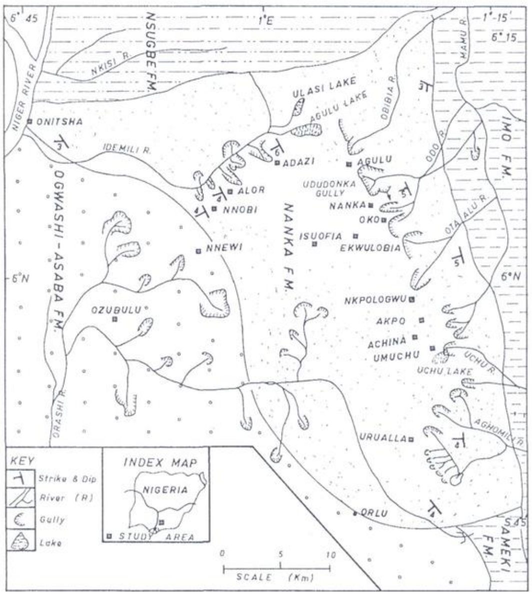

Fig 6: Structural map indicating the Formations, Gully erosion and lake location (after Obiadi et al.,2011)

II. Material and Methods

Electrical resistivity surveying is a procedure that introduces direct current into the ground through surface electrodes, it provides and measures the potential difference which can then determine the subsurface resistivity distribution. Resistivity sounding is the method of survey which is designed to determine resistivity variations with depth beneath some fixed surface location and it is also called electrical drilling. In this survey, electrode spacing varies for each measurement, however, the center of the electrode array, where the electrical potential is measured remains fixed. In this array, electrodes are distributed along a line, centered at a midpoint that is considered the location of the sounding. Therefore, the two current electrodes and the two potential electrodes are placed in line with one another and centered on some observed location. The current electrodes are at equal distances from the center of the sounding (AB/2). The potential electrodes are also at equal distances from the center of the sounding; however, this distance (MN/2) is much less than the distance AB/2.

The number of layers, their thickness and resistivities are derived from VES in favourable conditions. The method centres on the principle of four electrodes, which consist of two current and two potential electrodes. Depth of penetration increased with the increase of distance between current electrodes that is AB spacing. In this way deep seated layer influenced the apparent resistivity values and these apparent resistivity values plotted against the current electrode spacing on log-log scale and interpolated to a continuous curve called sounding curve as an initial stage of data interpretation and the layered earth model thus obtained served as the input model for the inversion algorithm as a final stage in the quantitative data interpretation. The final interpreted results were used for the preparation of geoelectric section and map. The data were analyzed for each VES curve. It was first compiled to describe the apparent resistivity (Ω a) from the different segments on the discontinuous curve, obtained during field measurements. The interpretation of the field data was carried out using the IP12WIN software, which converts the apparent resistivity as a function of electrode spacing to the true resistivity as a function of depth in two dimensions. (Fig 4) Principle of electric sounding (a) For small current electrode separation (b) For larger current electrode separate. (Ibitoye et al., 2013) Vertical Electrical Sounding (VES) using the systematic and practically advantageous Schlumberger array electrode configuration (Fig 5) was carried out at selected points were located and fully occupied within the study area. The VES data obtained were subjected to partial curve matching using two-layer master curves and auxiliary curves as an initial stage of data interpretation (Orellana and Mooney, 1966; 1972). VES using the Schlumberger electrode array was carried out at 2 selected station points within the proposed site axis using the instrument named Campus Ohmega Resistivity terrameter model 143 instrument of 0.001 Ω accuracy.The current electrode separation (AB/2) was varied from a minimum of 1.5 m to a maximum of 100 m, ensuring at least 25 meters of depth of investigation at the VES locations. The potential electrode separation was 0.5, 2 and 6 m.

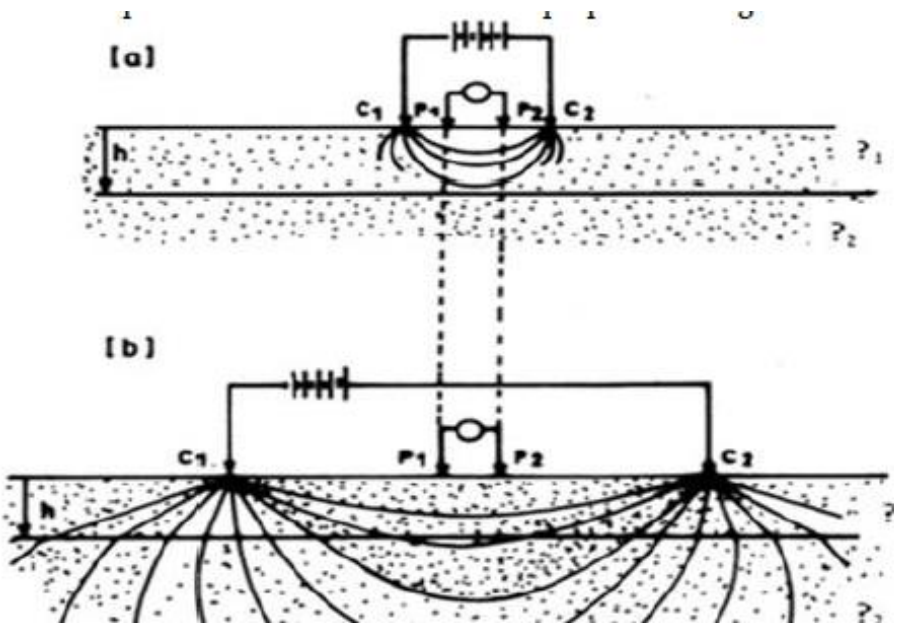

Fig 7: Principle of electric sounding (a) For small current electrode separation (b) For larger current electrode separate

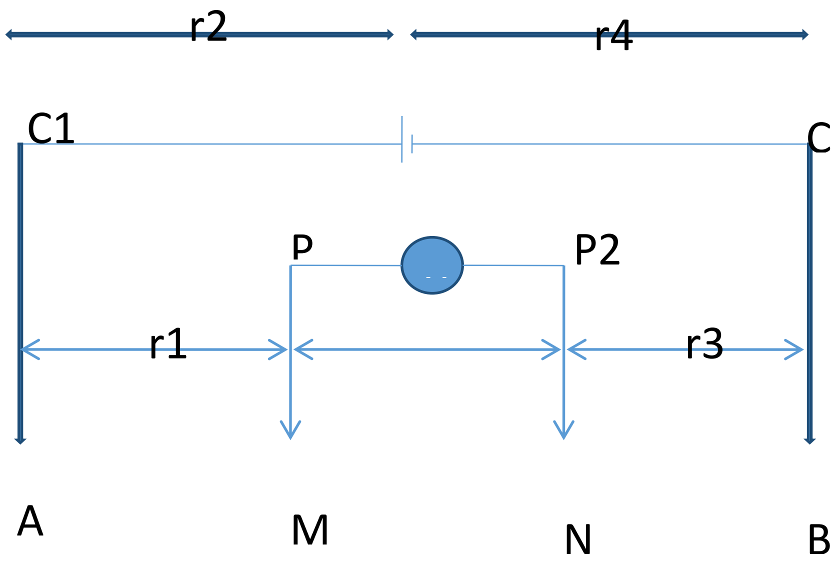

Fig 8: Field electrode layout for schlumberger array

III. Result

The geo-electric layers pictorially revealed from the results of the geophysical survey is presented in geophysical profile in Fig 9 from top soil at the top to lateritic clay, weathered basement and basement rock at the base, and sounding curves interpretations (layer model) of VES1 and VES2 in Fig10 (a) and (b) respectively while the resistivity results as shown in Table 1.

Fig 9: Geophysical profile of the study area

Unified Rock Classification for the profile

TS: top soil
LC: lateritic clay
WB: weathered basement
R: rock (basement)

Table1: VES 1 and 2 Resistivity results in the study area

AB2	Restivity result (VES1)	Restivity result (VES2)
1.0000	368.9000	243.9600
2.0000	321.1600	299.4800
3.0000	212.6900	244.0000
3.0000	231.5700	221.0000
5.0000	135.1500	152.9600
7.0000	128.8100	89.6200
10.0000	162.7600	69.4500
10.0000	174.0300	67.4400
15.0000	227.3300	97.6600
20.0000	264.5900	133.2400
20.0000	255.2500	133.8800
25.0000	302.4400	166.1100
25.0000	290.2100	170.0100
30.0000	332.0600	204.2300
35.0000	373.3200	236.2700
40.0000	425.7000	262.4700
45.0000	477.2200	289.5300
50.0000	544.2300	342.5800
60.0000	647.8000	NIL

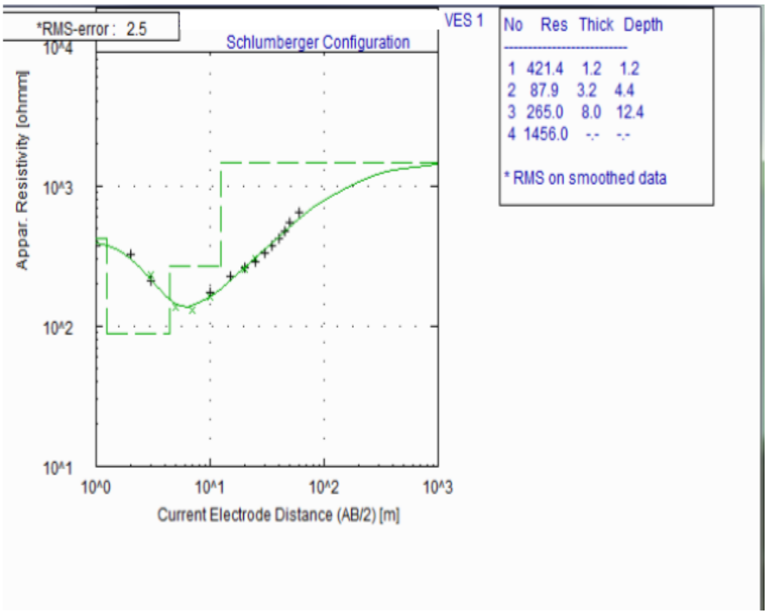

Fig 10(a): Interpretation of VES 1 data

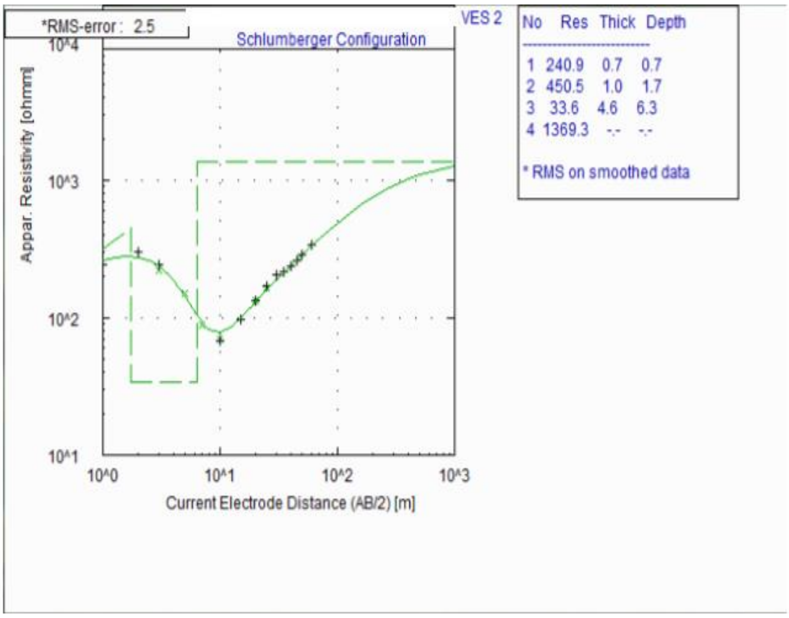

Fig 10(b): Interpretation of VES 2 data

The results of the interpretation show a system of four geo-electric layers for VES1 while VES2 shows a system of four geo-electric layers. VES1 showed presence of the curve type 'A' which may implied that the site is not highly fractured and very competent speculatively as good one for bridge and other engineering construction and VES2 showed an H curve pattern which is satisfactory yet suggest more examination. It is quite evident that the resistivity of the first layer is very low indicating a high degree of saturation. The resistivity values range from 120 – 421 Ohm-m suggesting top soil unit. The thickness of this layer ranges from 0.7 – 1.2 m. The second-layer shows a lateritic clay unit with resistivity value ranging from 17.6 - 225 Ohm-m with the layer thickness ranges from 1.0 – 4.4 m. The third-layer shows a weathered basement unit with resistivity value ranging from 4.7-20.3 Ohm-m with the layer thickness ranges from 4.6 – 12.4 m. The fourth layer is likely basement rock with resistivity value ranging from 1369 – 1456 Ohm-m and the thickness is infinite.

IV. Discussion

Fracture and other structural weakness play an important role in determination of construction development strategy of a bridge project. The standard of work to solve this geo anomaly have to be factored especially in sedimentary terrain like our study area. Despite the proven benefits expected, cost and funding issues go a long way to defeat this goal, the most likely reasons why this study was designed and the chosen method applied for to lower the risk and optimise the resources available.The present study was carried out in a time interval of June 2020 to July 2020. The results revealed that the southern part of the study area (≤100 Ohm-m); the high resistivity depicts competent geologic materials, such as sand or clayey sand formation. Very low resistivity suggests clay or sandy clay materials, or water saturated materials, often less competent to support the stability of heavy engineering structures like such as bridge. The depth of the aquifer unit of 12.4 m as shown in VES 1 indicates a very thicker overburden favouring groundwater potential provided more investigation indicate clay absence in the area. Soils below the groundwater tables generally saturated (Coduto, D.P, 1998). An important factor often considered in structural design is the water table and water table fluctuation (Bowles, J.E, 1984; Coduto, D.P, 1998), as the VES1 interpretation (fig 10 (a)) and its effect was factored in the study for structural check. In addition, raised water table may create a wet basement of foundation, and consequently engenders instability of the overlying structure (Bowles, J.E, 1982; 1984) like the proposed bridge project.In the present study, not all of the concerns were found in comparative with previous studies yet it would help to address foundation issues in bridge construction.

V. Conclusion

The application of Electrical resistivity method has been employed in delineating the various litho units at a proposed bridge construction site in Okija, Ihiala local government area in Southeastern Nigeria. Based on the VES measurements taken, four major layers were delineated from the study area which comprise topsoil (sometimes undulate), weathered layer (sand and clay), fractured partly weathered layer and fresh basement rocks. The weathered layer constitutes of aquifer zones in all the points investigated and the depth of the topsoil range from 1.2m at the Southeastern part of the study area to 4.4 m towards the Western part of the area. The depth of the partially competent bed ranged from 3.4 – 13.0 m. The first and second layers are highly saturated, and it is rated incompetent. Weathered rock is the geoelectric layer. The thickness of the layer is about 12.4meters. The fresh basement is the last; geoelectric layer the thickness is infinite. The results of this research has shown that the areas of weakness and distress on the rocks within the study area and the need for additional geophysical study and fortification templates to positively check the differential settlement resulting from the incompetent subsoil materials and the fractured bedrock on which the proposed bridge structure which its foundation be hanged on. Also, the investigation speculatively revealed that the rocks is suitable for shallow foundation for proposed structure, and based on the conclusion stated above, the following recommendations are made:

(i) Ground treatment such as dewatering and in-situ compaction should precede use of reinforced concrete during the construction of shallow foundation.

(ii) The use of piling may be necessary for the structures to rest directly on the competent lithology with regards to the proposed bridge structure

(iii) It is very key to take into cognizance all other engineering construction criteria that may be relevant considering water challenges as may arise in the site.

(iv) Further geological and geotechnical analysis should be carried out on the soil sample of the study area. Further studies in this respect, could adopt integrated geophysical methods and increase in area of coverage in other to enhance accurate delineation of the stratigraphic layers of the subsurface in the study area.

References

[1]. Alotaibi, A.M. and AlAmri, A.M. Ground Water Potentialities of Wadi Malakan- Southern Makkah Al Mokadash City, Saudi Arabia, Geophysical Society Journal, 2007 5(1): 101-116.

[2]. Al-Sayed, E. A. and El-Qady, G. Evaluation of Sea Water Intrusion using the Electrical Resistivity and Transient Electromagnetic Survey: Case Study at Fan of Wadi Feiran, Sinai, Egypt, EGM 2007 International Workshop Innovation in EM, Grav and Mag Methods: a new Perspective for Exploration Capri, Italy, April 15 – 18, 2007.

[3]. Barker, R.D. Application of geophysics in groundwater investigations, Water Surv., 1980; 84: 489-492.

[4]. Bowles, J.E. Foundation Analysis and Design, 3rd Edition, McGraw-Hill Book Company, New York. 1982.

[5]. Bowles, J.E, Physical and geotechnical properties of soils, 2nd Edition, McGraw-Hill Book Company, New York, 1984.

[6]. Boyce, J.I. and Kaseoglu, B.B. Shallow seismic reflection profiling of waste disposal sites. Geoscience Canada, 1996; 23(1): 9-21.

[7]. Anukwonke, C and Muoghalu, L.The Effectiveness and Relevance of Environmental Impact Assessment in the Sustainability of the Built Environment in Nigeria: Perceptions of Three Communities, November 2019; SSRN Electronic Journal 2(1):1-16.

[8]. Ikechukwu, C. V, Okpoko, E. I, Nfor, B.N, Egbunike, M.E, Mgbenu, C.N and Blessing, C.O. The Tertiary Blessing and the Recent Neglects: A Case Study of the Anambra Lignite Energy Resource of Southeastern Nigeria. 2019; Innov Ener Res, Vol 8(2): 227.

[9]. Chikwelu, E. E., and Ogbuagu, F. U. Geotechnical Investigation of Soil around Mbaukwu Gully Erosion Sites, South-Eastern Part of Nigeria. JAGG.2014; 2(4), 6–17.

[10]. Coduto, D. P. Geotechnical Engineering: Principles and Practices, ISBN 10: 0135763800, ISBN 13: 9780135763803, Prentice Hall, Indiana, USA; 1998.

[11]. Ede. A, and Nwankwo. C. Failure Trend of Transport Infrastructure in Developing Nations: Cases of Bridge Collapse in Nigeria. IOP conference Series: Materials Science and Engineering 2019.

[12]. Egbueri, J. C., Igwe, O., and Nnamani, C. H. Assessment of the engineering properties and suitability of some tropical soils as backfill materials. International Journal of Trends in Scientific Research and Development, 2017; 2(1), 590–605.

[13]. Hosny, M.M., EZZ El-Deen, Abdallah, A.A., Abdel Rahman and Barseim, M.S.M. Geoelectrical Study on the Groundwater Occurrence in the Area Southwest of Sidi Barrani, Northwestern Coast, Egypt, Geophysical Society Journal 2005; 3(1): 109- 118.

[14]. Ibitoye, F.E, Ipinmoroti, F.V, Salami, M, Akinluwade, K.J, Taiwo, A.T and Adetunji, A.R. Application of Geophysical methods to building foundation studies, International Journal of Geoscience, 2013; Vol 4 No.9.

[15]. Igwe, C. A. (2012). Gully erosion in southeastern Nigeria: Role of soil properties and environmental factors. InTech. Research on Soil Erosion, G. Danilo, Ed; 2012, doi: 10.5772/51020.

[16]. Igwe, O., & Egbueri, J. C. The characteristics and the erodibility potentials of soils from different geologic formations in Anambra State, Southeastern Nigeria. Journal of the Geological Society of India, 2018; 92(4), 471–478.

[17]. Mousa, D.A. The role of 1-D sounding and 2-D resistivity inversions in delineating the near-surface lithologic variations in Tushka area, south of Egypt, Geophysical Society Journal, 2003; 1: 57-64.

[18]. Nigm, A.A., Elterb, R. A., Nasr, F.E. and Thobaity, H.M. Contribution of Ground Magnetic and Resistivity Methods in Groundwater Assessment in Wadi Bany Omair. Holy Makkah Area, Saudi Arabia, Egyptian, Geophysical Society Journal; 2008, 6(1): 67-79.

[19]. Nwajide, C. S. Geology of Nigeria's Sedimentary Basins. Lagos Nigeria: CSS Bookshops Limited; 2013.

[20]. Olorunfemi, M.O, Idornigie, A.I, Coker, A.T and Babadiya, G.E. On the application of the electrical resistivity method in foundation failure investigation – A case study, African Journal; 2004, Vol. 2 No. 1.

[21]. Oyedele, K.F., Ayolabi, E.A., Adeoti, L. and Adegbola, R.B. Geophysical and Hydrogeological Evaluation of Rising Groundwater level in the Coastal Areas of Lagos, Nigeria, Bull Eng Geol Environ; 2009, 68: 137-143.

[22]. Obiadi, I. I., Nwosu, C. M., Ajaegwu, N. E., Anakwuba, E. K., Onuigbo, N. E., Akpunonu, E. O., & Ezim, O. E. Gully Erosion in Anambra State, South East Nigeria: Issues and solution. IJES, 2014; 2(2), 796–804.

[23]. Okoyeh, E. I., Akpan, A. E., Egboka, B. C. E., & Okeke, H. I. An assessment of the influences of surface and subsurface water level dynamics in the development of Gullies in Anambra State, Southeastern Nigeria. Earth Interactions; 2014, 18, 1–24.

[24]. Orellana, E. and Mooney, H.M. Master Tables and Curves for Vertical Electrical Sounding over Layered Structures. Interciencia, Madrid; 1966, pp 150–166.

[25]. Orellana E, Mooney H.M. Two and three layer master curves and auxiliary point diagrams for vertical electrical soundings using Wenner arrangement: Madrid; 1972, Interciencia 43 sheets.

[26]. Ward, S.H. Resistivity and Induced Polarization Methods in Geotechnical and Environmental Geophysics. Society of Exploration Geophysicists, Tulsa; 1990, 147-189.

[27]. Ward, S.H. Restivity and Induced Polarization Methods. In Geotechnical and Environmental Geophysics; 1998, V.11, e.d.s.h, Ward, 147-190. Tulsa Oklahoma Society of Exploration Geophysics.

[28]. Zohdy, A.A.R. Automatic interpretation of Schlumberger sounding curves using modified Dar Zarrouk functions, U.S. Geological Survey Bull; 1975, 13 B-E.

[29]. Google map showing the digital location of the study area and environs and Okija town SE Nigeria and its environs and Urobo-Okija, Isieke, Akpaka, Osuakwa, Ogboro to Ihite Ihiala on 18/06/2022; https://www.google.com/maps/@ 5.9274849, 6.8364168, 12z

[30]. Anambra state geologic map; https://www.google.com/search?q=geological+map+of+anambra+state&client=firefox-b-d&tbm=isch&source=iu&ictx=1&vet=1&fir=2BElcJV9AOdp-M%252CxAlIRJDgIb48EM%252C_%253BxKSoGMXZfnXWEM%252C0rfUUOwAPEjXrM%252C_%253Bz5byl-cmMZ_quM%252C9IkXQ9I0TA988M%252C_%253B6ymblFlS_UvVpM%252C-xHKBhtSBFwvGM%252C_%253BpdWe6jDqO9QxAM%252CBz56TUP_-kjFxM%252C_%253BLRL0z23RQdn01M%252CfIAqm6y9scdKYM%252C_%253BjlH2ZsTlbzLS4M%252CUN1sszjyzpvLBM%252C_%253BjR6T_3yAh7zk3M%252CIplcE0P2p4Gb_M%252C_%253BkFoqPZewjduhDM%252CevFZ4OJx0cMRoM%252C_%253BsEPWhIg0Pq7RXM%252CpA7UvTM6AaxDJM%252C_%253Bfpj2oy__p7kBfM%252C7vSSAHAXUllfuM%252C_%253BTgEGwkODEQgbSM%252CxYXFEMm5wl4KcM%252C_%253BU-_aHXUMysI3PM%252C-xHKBhtSBFwvGM%252C_%253BQl_3gT3wRlbPeM%252CVjTVvs0Psw_8iM%252C_&usg=AI4_-kSU32ACeECyeKbM1tBvALlYMtiB1g&sa=X&ved=2ahUKEwiKkvP815v4AhU07rsIHcp_DFEQ9QF6BAgPEAE#imgrc=z5byl-cmMZ_quM

[31]. Geological map of Anambra state by local government area indicating the lithology; https://twitter.com/nigeriandatamal/status/724549576322125824 , 11:44 AM • Apr 25, 2016•NigerianDataMall

Onwuka, O.J, et. al. "Geophysical Evaluation for stability check in Okija bridge site project." *IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)*, 11(2), 2023, pp. 32-41.