

Coastal Foundation Investigation Using Geoelectrical and Geotechnical Techniques at Okerenkoko, Delta State, Nigeria

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Abstract

This report presents an Application of Geoelectrical and Geotechnical Investigation of Coastal Foundation at Nigeria Maritime University (NMU) Okerenkoko Campus, Warri South West, Delta State, to determine the subsurface Lithology, depths to bedrock and moist content of the soil. Vertical electrical sounding (VES) survey were conducted using a resistivity meter along, three (3) profiles, at 75 m and 4 stations at 25 m interval from each sounding point; and a total of 12 VES measurement were made. The results of the VES suggest that the entire subsurface of the area, is made up of three (3) distinctive Lithologies, the First layer is Topsoil with resistivity value between 22.38 and 6880 Ωm , the second layer is a Loose Sand with resistivity values variation between 5.393 to 896.5 Ωm and the third layer is consolidated Sandstone with resistivity value of 14.12 to 675.5 Ωm . Geotechnical investigation was carried out to check the soil Moisture content therefore knowing the elevation where the high percentage of mixture is located and water filling the void space. The result of the geophysical investigation of this work shows that the third layer is generally consolidated sandstone and the Geotechnical investigation of this work shows that the Western part of the Site has high percentage of mixture and water while the Eastern part has low percentage of mixture content, it is therefore advisable for engineers to consider this in their design. The heavy foundation should be situated towards the Eastern section of the site, where the bedrocks are consolidated and less mixture content, to avoid any form of future building collapse.

Keywords: Coastal Foundation, Geoelectrical, Moisture Content, Loose Sand

Article History:

Received 06 June 2022

Received in revised form 29 August 2022

Accepted for publication 06 September 2022

Published 23 September 2022

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1. Introduction

Application of Geophysical and Geotechnical Investigation for Coastal Engineering Infrastructure, takes place when you want to erect a building around an area where the soil or ground is not strong. In order to avoid building

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collapse, Geologist conduct geophysical and geotechnical investigation to determine whether the soil or ground can withstand the load of the building planning to be erected. Geologists would then conduct some electrical resistivity survey on the site and collect some soil samples that would be analyzed in a lab.

A site investigation is the overall process for the collection of information, appraisal of data, assessment and reporting. Data must be collected adequately, correctly and in a timely manner at each stages of design development. In this ways risk are minimized, economic and safe design is maximized and this leads to the completion of the project work on time and within budget [1]. Inadequate site investigation may lead to the wrong choice of design, incorrect dimensioning, overhead supply lines, inadequate foundation solution, ill-judged or dangerous execution of ground construction work as well as damage to neighboring buildings or other structures. The economic cost can be enormous.

Some subsurface information that are required before infrastructures design are; Location of groundwater, the presence and magnitude of artesian pressures, engineering properties of the soil and rock in-situ such as permeability, compressibility and shear strength, areal extent, depth and thickness of each identifiable soil stratum within a limited depth dependent on the size and nature of the structure, together with a description of the soil including its degree of stiffness if cohesive, dip and spacing of joints and bedding planes; presence of fault and shear zones and state of weathering or decomposition [2].

According to Akintorinwa and Adesoji [3], an engineering evaluation of the development parts of Ondo State University of Science and Technology, Okitipupa, Nigeria was carried out using engineering geophysical approach with the aim of determine the competency of the subsurface soil within the area and evaluate its engineering implication for infrastructural development. Six geologic/geo-electric sequences delineated across the area are the topsoil, medium sand, coarse grain sand, clayey sand, sandy clay and clay formation. Based on the resistivity value gotten of the topsoil it can withstand loads imposed by of light civil engineering structures using strip foundation; heavy weight engineering structures can be hosted within the second layer on deep foundation.

Akintorinwa and Adesoji [3] conducted geophysical and geotechnical studies at a proposed Switch station facility for telecommunication at a site in the south eastern part of Nigeria. The aim is to evaluate the subsoil conditions and electrical properties of the soil which may have effect on the proposed mast and switch facilities system. The geophysical results shows four layers within the study area, these include the topsoil (mixture of sand, silt and clay), lateritic clayey with coarse sand, lateritic clayey and sand, the second layer is supposed to accommodate the earthing electrodes is resistive; hence, there is a need to enhance the conductivity of this medium may not protect the instrumentation when there is a lighting or thunder-storm.

This research was carried out to know the suitability, lithologies, of the soils in withstanding and supporting the buildings and other engineering structures, due to so many cases of building collapses and natural hazard affecting builds during the years and recent times, it is very important to embark on this research to avoid more future occurrence. Mapping of the research areas is very important. Geophysical investigation was carried out to give detail information of what the soils look like under the subsurface for example to measure variation of the subsurface materials e.g., electrical resistivity and geotechnical investigation involves soil sampling and laboratory tests of the soil samples retrieved [4].

2. Materials and Method

A total of Three (3) profiles of about 60 *m* long with four (4) VES point along each profile of about 75 *m* long (Figure 2) were conducted. Reading were taken from 12 VES stations 30 *m* for profile and 25 *m* apart for station. The instrument used is an Earth Resistivity Meter; it was stationed at each VES point with a total number of five persons, two with current electrodes, two with potential electrodes and one with the system taken the readings. The study adapted Schlumberger electrode configuration at a maximum of 50 *m* current electrode separation (AB/2) and maximum of 5 *m* potential (MN/2) electrode separation. The reading was taken by increasing the current electrodes from 1 *m* to 50 *m* and potential electrodes spacing from 0.5 *m* to 5 *m*. The electrodes were driven into the Earth with the aid of a hammer. The cables were connected to the Ohm Resistivity meter which was powered by a DC battery. A global positioning system (GPS) was used to take the coordinates as well as the elevation of the area.

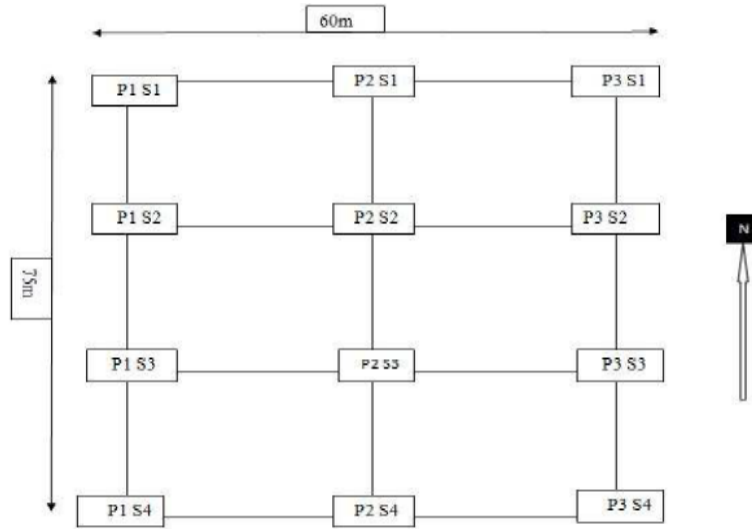


Figure 1. Research Profile

Data gotten from the field were entered into the computer system and computed using Equation 1, to add the geometric factor values for each of the VES point and the resulting curve was plotted and saved. The curves were then inverted using Sufer 11 software to deduce the subsurface Lithologies.

$$\rho = \frac{\left[\frac{AB}{2}\right]^2 + \left[\frac{MN}{2}\right]^2 R}{MN} \quad (1)$$

where, ρ = Apparent Resistivity, AB = Current Electrode Spacing, MN = Potential Electrode Spacing & Resistance.

Soil samples were collected from the research site on each profile with a shovel (0.5 m deep) and packed into a clean leather bag. The samples were taken to the laboratory for moisture content analysis to evaluate the amount of water filling the void space, the mass of the empty cans (m_1 or A) was first weigh with a digital weighing balance. The mass of can and wet soil (m_2 or B) was then weigh according to their profiles and station e.g. P1S1, P1S2, ..., P3S4. The weighed wet soil samples were dry up in the oven and weighed again as mass of can and dry soil sample (m_3 or C). Moisture content were determined using Equation 2 based on British Testing Standard.

$$\text{Moisture Content} = \frac{\text{mass of can and wet soil (B)} - \text{mass of can and dry soil (C)}}{\text{mass of can and dry soil (C)} - \text{mass of empty can}} \times 100 \quad (2)$$

2.1. Research Location

The Okerenkoko community is among the many communities in Gbaramatu kingdom, Warri- Southwest of which other surrounding communities include Kurutie (site for the NMU take off Campus), Oporoza, Benikrukru, Kunukunuma and a whole lot of other communities. Okerenkoko lies between $N5^{\circ}37.251'$ to $N5^{\circ}37.184'$, and $E5^{\circ}23.313'$ to $E5^{\circ}23.439'$, with an average elevation of about 19.6 meters above mean sea level.

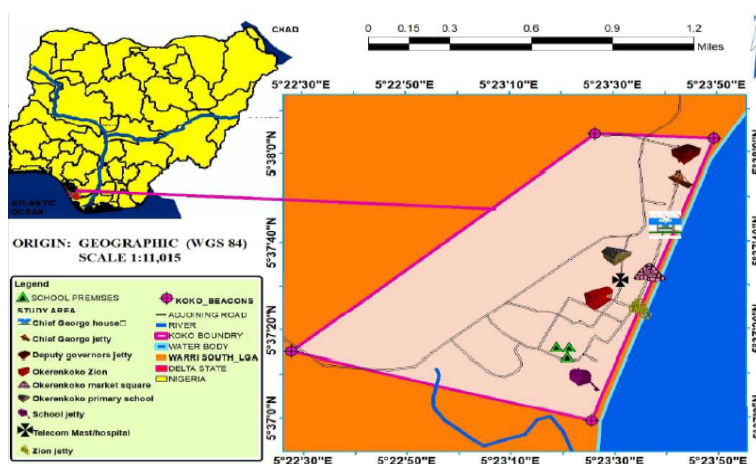


Figure 2. Map of the research Location

Geologically, Okerenkoko belongs to Mangrove formation; one of the recently deposited suit of sediments overlying the Warri Sombrero (Deltaic plain sands) formation in the Niger Delta sedimentary Basin [5]. The Warri Sombrero formation is underlain by the Benin formation, the youngest of the Niger Delta sedimentary Basin [6]. The sediments of the mangrove formation are Quaternary to Recent and have not been properly assigned.

3. Results and Discussion

The data used for this research was acquired with a resistivity meter; it was in current (*Ampere*) and voltage (*Volt*) mode, the voltage was divided by the current to obtain the resistance (Ω) (Equation 2), in accordance to Ohm's law. The resistance (Ω) was then multiplied with the pre-calculated geometric factor (Equation 1) which gave us apparent resistivity (ohm-meter). Apparent resistivity values for each Vertical Electrical Sounding (VES) points were plotted against current electrode separation ($AB/2\ m$) using IP12WIN inversion software [7]. After inserting the values and a number of iteration, the software produced, the Geologic sections (delineating the different rock type with various distinctive color), curves (Figures 8 and 9), with their corresponding number of layers, resistivity values, depth (m) and equivalent thickness (m) as well as percentage errors.

3.1. Profile 1

Table 1, Figure 3a and b display the VES interpretation for profile 1. All VES point has three layer models. The profile shows 50% of A, 25% of K, and 25% of H curves type. Figure 8 shows how A curve looks like. The following were deduced: The first layer has resistivity values ranging from 22.98 to 548.1 Ωm . The highest resistivity value of 548.1 Ωm was obtained on VES S4, and the least resistivity value of 22.98 Ωm was found on VES S1. The profile is thickest at VES S4 (about 3.113 m) and thinnest at VES S1 (about 2.343 m). The second layer's resistivity values ranges between 24.45 and 370.2 Ωm . Highest resistivity value is found at VES S3 (370.2 Ωm) smallest resistivity value of about 24.45 Ωm was found at VES S4. The layer is thickest at VES S4 (about 22.74 m) and thinnest at VES S2 (about 7.131 m). The third layer has resistivity values ranging between 98.7 Ωm and 675.5 Ωm . The highest resistivity value of 675.5 Ωm is found at VES S2 and lowest resistivity value of 98.7 Ωm is found at VES S3. The layer is deepest at VES S4 and shallowest at VES S2.

Table 1. Interpreted result of Profile 1.

VES Point Profile 1	Number of Layers	Curve Type	Resistivity of Layers (Ωm)	Layer Thickness(m)	Depth of Layers(m)
Station 1	1	A	22.98	2.343	0.00
	2		83.27	11.49	2.343
	3		608.7		13.84
Station 2	1	A	127.7	2.66	0.00
	2		349.6	7.131	2.66
	3		675.5		9.791
Station 3	1	K	86.83	2.275	0.00
	2		370.2	11.81	2.275
	3		98.75		14.09
Station 4	1	H	548.1	3.113	0.00
	2		24.45	22.74	3.113
	3		209.4		25.86

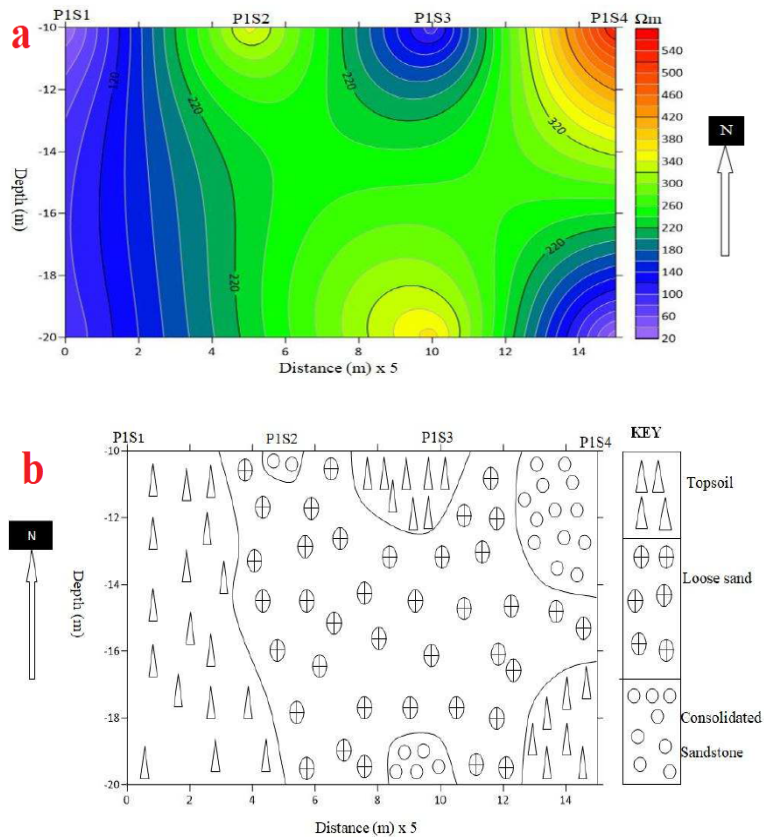


Figure 3. (a) Vertical Geoelectrical section of Profile 1; (b) Geological section of Profile 1 of the study area.

3.2. Profile 2

Table 2, Figure 4a and b display the VES interpretation for profile 2, VES S1 to S4 has three layer models. The profile shows 50% of H, 25% of Q, and 25% of A curves type. Figure 9 shows how Q curve looks like. The following were deduced: The first layer has resistivity values ranging from 191.4 to 6880 Ωm . The highest resistivity value of 6880 Ωm was obtained on VES S4, and the least resistivity value of 191.4 Ωm was found on VES S2. The profile is thickest at VES S2 (about 3.344 m) and thinnest at VES S1 (about 1.963 m). The second layer's resistivity values ranges between 194 and 51.72 Ωm . Highest resistivity value is found at VES S3 (51.72 Ωm) smallest resistivity value of about 194 Ωm was found at VES S1. The layer is thickest at VES S3 (about 50.88 m) and thinnest at VES S1 (about 22.07 m). The third layer has resistivity values ranging between 14.12 Ωm and 308.3 Ωm . The highest resistivity value of 308.3 Ωm is found at VES S2 and lowest resistivity value of 14.12 Ωm is found at VES S3. The layer is deepest at VES S3, S 2 and shallowest at VES S1.

Table 2. Interpreted result of Profile 2.

VES Point Profile 2	Number of Layers	Curve Type	Resistivity of Layers (Ωm)	Layer Thickness(m)	Depth of Layers(m)
Station 1	1	Q	505.6	1.963	0.00
	2		194	22.07	1.963
	3		110.1		24.04
Station 2	1	H	191.4	3.344	0.00
	2		20.36	42.13	3.344
	3		308.3		45.47
Station 3	1	A	594.1	2.442	0.00
	2		51.72	50.88	2.442
	3		14.12		53.32
Station 4	1	H	6880	2.773	0.00
	2		31.22	32.69	2.773
	3		1356		35.47

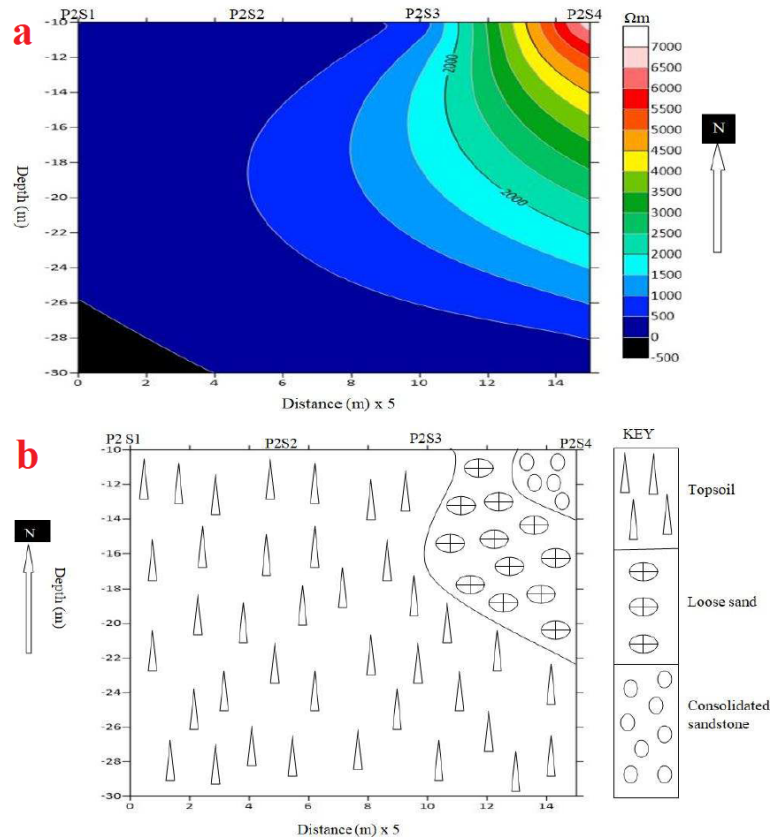


Figure 4. (a) Vertical Geoelectrical section of Profile 2; (b) Geological section of Profile 2 of the study area.

3.3. Profile 3

Table 3, Figure 5a and b display the VES interpretation for profile 3; VES S1 to S4 has three layer models. The profile shows 95% of H and 5% of Q curves type. The following were deduced: The first layer has resistivity values ranging from 351 to 5387 Ωm . The highest resistivity value of 5387 Ωm was obtained on VES S4, and the least resistivity value of 351 Ωm was found on VES S2. The profile is thickest at VES S4 (about 2.899 m) and thinnest at VES S2 (about 2.016 m). The second layer's resistivity values ranges between 5.393 and 896.5 Ωm . Highest resistivity value is found at VES S4 (896.5 Ωm) smallest resistivity value of about 5.393 Ωm was found at VES S2. The layer is thickest at VES S1 (about 27.56 m) and thinnest at VES S3 (about 15.77 m). The third layer has resistivity values ranging between 99.01 Ωm and 483.1 Ωm . The highest resistivity value of 483.1 Ωm is found at VES S3 and lowest resistivity value of 99.01 Ωm is found at VES S2. The layer is deepest at VES S1, S4, S2 and shallowest at VES S3. Figure 5a, 6a and 7a show the VES of each profile. It shows how the subsurface react to electrical current on each station and figure 5b, 6b, 7b show the lithology of the subsurface.

Table 3. Interpreted result of Profile 3.

VES Point Profile 2	Number of Layers	Curve Type	Resistivity of Layers (Ωm)	Layer Thickness(m)	Depth of Layers(m)
Station 1	1	H	3129	2.177	0.00
	2		33.01	27.56	2.177
	3		1813		29.74
Station 2	1	H	351	2.016	0.00
	2		5.393	24.37	2.016
	3		99.01		26.39
Station 3	1	H	277.6	2.897	0.00
	2		19.45	15.77	2.897
	3		483.1		18.67
Station 4	1	Q	5387	2.899	0.00
	2		896.5	23.87	2.899
	3		287.8		26.77

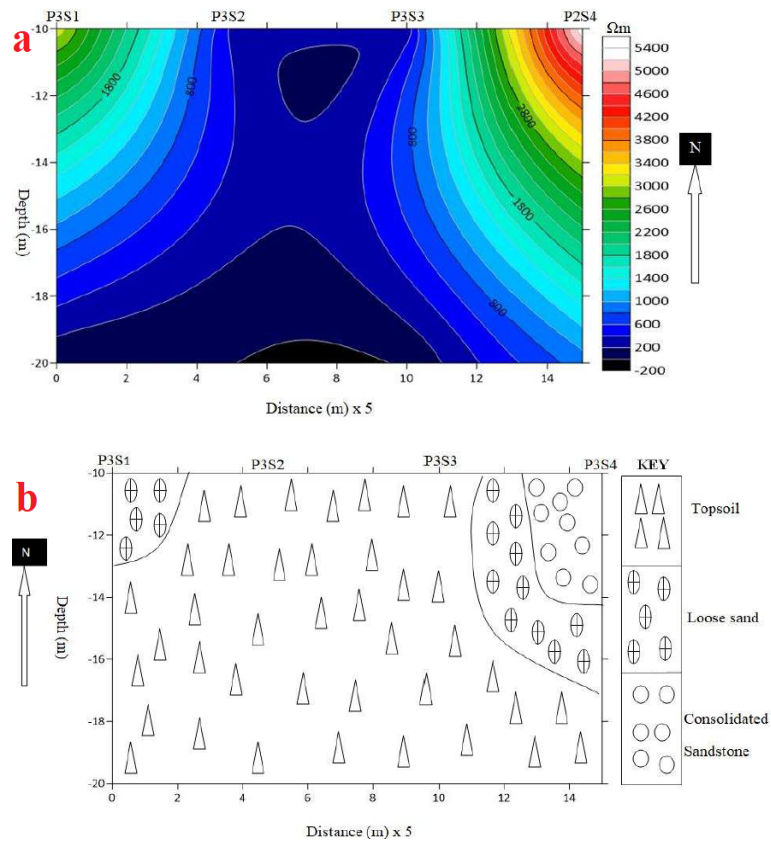


Figure 5. (a) Vertical Geoelectrical section of Profile 3; (b) Geological section of Profile 3 of the study area.

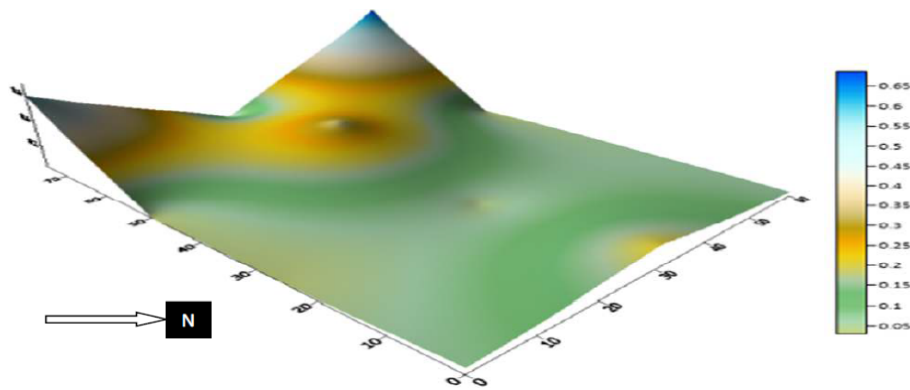


Figure 6. Moisture Content Distribution.

Figure 6 shows the moisture content distribution in the area survey, the yellow and hilly part towards the western part shows high percentage of mixture content and the green leveled part towards the eastern part shows low percentage of mixture. The high moisture content tells that there is too much water in the western part therefore the materials are not consolidated than the eastern part of the area.

4. Conclusion

From this research it has been observed that the entire subsurface of the coastal investigation on the school premises, is made up of three (3) distinctive layers; the Topsoil particles with resistivity value of 22.38 and 6880 Ωm its thickness ranges between 3.113 to 2.343 m, the Loose sand particles with resistivity value of 5.393 to 896.5 Ωm , its thickness 50.88 to 22.07 m and the consolidated sandstone with resistivity value of 14.12 to 675.5 Ωm , it is deepest at the following VES point P1(S4,S3), P2(S3,S2,S4), P3(S1,S4,S2). It is also very shallow at the following VES points: P1 (S2, S1), P2 (S1), P3 (S3).

The Geotechnical investigation shows the moisture content in the area survey, the yellow and hilly part towards the western part shows high percentage of mixture content and the green leveled part towards the eastern part shows low percentage of mixture. The high mixture content tells that there is too much water in the western part therefore the materials are not consolidated than the eastern part of the area.

According to the Geophysical and Geotechnical technique for investigation of coastal engineering carried out for future construction of heavy building in the Nigeria Maritime University Campus, it is advisable to build around the Eastern part of the campus because it consists of consolidated sandstone and low water content which can withstand heavy construction. Geophysical investigation can help determine the depth to bedrocks in any construction site, with this, the cost that supposed to be required could be drastically reduced. It will thereby, save time and many other resources.

Aknowledgement

The Authors are grateful to Peninsular Resources Nig. Ltd for providing the necessary equipment for data acquisition during field work and to the Management of Nigeria Maritime University Okerenkoko for providing enabling research environment.

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