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Subsurface Integrity Assessments of a Proposed Plaza Building at Oniru Lekki, Lagos, South-western Nigeria, Using Geoelectrical and Geotechnical Methods of Investigations

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Abstract

Subsurface integrity assessment for building foundation using geophysical and geotechnical methods was carried out at Oniru, Eti- Osa, Lagos State. A total of twenty-five Vertical Electrical Sounding (VES), five 2-D Resistivity Imaging Survey traverses and two borings with Standard Penetration Test (SPT) were carried out at the study site. The acquired data were processed quantitatively using partial curve matching and computer iteration technique to generate the geoelectric sections, the 2-D model and the SPT logs. The VES results revealed five to six geologic units corresponding to topsoil, clayey sand, sandy clay, clay/peat, and sand while the 2-D resistivity structure corresponds with the VES result. The borehole log reveals sand layers having an N-value of 22-30 which is indicative of medium-dense, brown (medium to fine) sand with occasional gravels from depth 1.50 - 7.50m. The borehole log information correlates well with the VES/2-D result. For the sand layer which connotes dense, grey (medium to fine) sand with occasional gravels from a depth 7.50 – 15.75m with N-value ranging from 26–30m. The study analysis shows that the proposed building could be placed on the dense sand at depth 7.50 – 15.75m, this, however, should depend on the proposed load, length, and breadth of the proposed building. This study has provided useful information about the subsurface condition for engineering structure and zone suitable for the proposed foundation.

Keywords: Assessment, Building-foundation, Integrity, Geotechnical, Subsurface

1. Introduction

These days, the statistics of engineering structures failures have increased geometrically, several probable reasons speculated to be responsible for this ugly incident highlighted by the engineering community. These include inadequate supervision, poor construction materials, non-compliance to specification and host of others. However, one critical point that has always not been given due attention is the availability of adequate information on the nature of subsurface conditions prior to construction exercise. Foundation design depends on the characteristics of both the structures and the subsurface materials. Therefore, the competence, strength and load capacity of the soil supporting the super structure becomes an extremely important issue for the integrity and durability of the engineering structure (Akintorinwa & Abiola, 2011).

Globally, in many coastline terrains, the near surface soil is composed of expansive clay, a material that behaves differently compared to sandy soil which does not expand when it gets wet. Instead, the pore spaces in between the grains are filled by water. Because of this, the soil volume does not change and there is little movement of structures supported by the soil when the soil moisture conditions alternate between wet and dry. Although, since every engineering structure is seated on geological earth materials, it is imperative to conduct a lithological investigation of the subsurface materials of the proposed site to ascertain the strength and fitness of the host materials (Olorunfemi & Mesida, 1987; Oyedele & Okoh, 2011).

Potential of geophysical prospecting in engineering investigations is yet to be fully maximized; this is because of its merits of enabling information to be obtained for large volumes of ground that cannot be investigated by direct methods because of the costs involved. Several geophysical methods have been deployed for both pre- and post-construction investigation, geophysical investigation including gravity, electrical resistivity, electromagnetic (EM), and seismic refraction methods have been employed in different areas of applied geophysics for about a century, particularly for shallow and near-surface investigations (Aizebeokhai, 2010; Loke, 2001; McDowell et al., 2002; Roth, Mackey, Mackey, & Nyquist, 2002). The use of geoelectrical resistivity for investigating subsurface layered materials has its origin from the work of Conrad Schlumberger who conducted the first geoelectrical resistivity experiment in the fields of Normandy; and similar idea was developed by Frank Wenner in the United State of America. Ever since, geoelectrical resistivity surveying has greatly improved, and has become an important and useful tool in hydrogeological studies, mineral prospecting, and mining, as well as in environmental and engineering applications (Aizebeokhai, Olayinka, & Singh, 2010; Amidu & Olayinka, 2006; Ayolabi, Adeoti, Oshinlaja, Adeosun, & Idowu, 2009; Ayolabi, Enoh, & Folorunso, 2013; Coker, 2015; Ehibor & Akpokodje, 2019; Fajana, Olaseeni, Bamidele, & Olabode, 2016; Kunetz, 1966).

To have adequate knowledge of the subsoil behaviors of the individual materials, geotechnical investigation is necessary to ascertain the engineering properties of the subsoil materials that would have direct interaction with structures in a particular area. Standard penetration tests (SPT) and Cone penetration test (CPT) are some of the commonly applied techniques used for this purpose this is because they are accurate, fast, and economic methods by which foundation soils can be characterized in terms of stratigraphy, associated strength and deformation characteristics (Adebajo, 2005).

The study area, a commercial center primarily an event center, consists of a pre-existing bungalow building with a prospect of having a multi-story structure for events hosting and functions. Therefore, due to the coastal plain sediment deposits in the study area, there is a need to carry-out adequate pre-foundation investigation in which this study was used to address. Combined geophysical and geotechnical investigation methods were used to characterize the subsurface materials.

1.1 Study area and the geology

The study area is the Oniru Beach which lies within latitude N 06º 25' 19.7" to N 06º 25' 22.1’’ and longitude E 003º 26' 33.2" to E 003º 26' 39.1" in Oniru Beach, Ozumba Mbadiwe Avenue, Eti-Osa, Lagos, State South-western Nigeria. It is bounded by the clean sea water and variety of restaurants (Jones & Hockey, 1964). The map of Lagos shows different Local Government Areas (Figure 1).

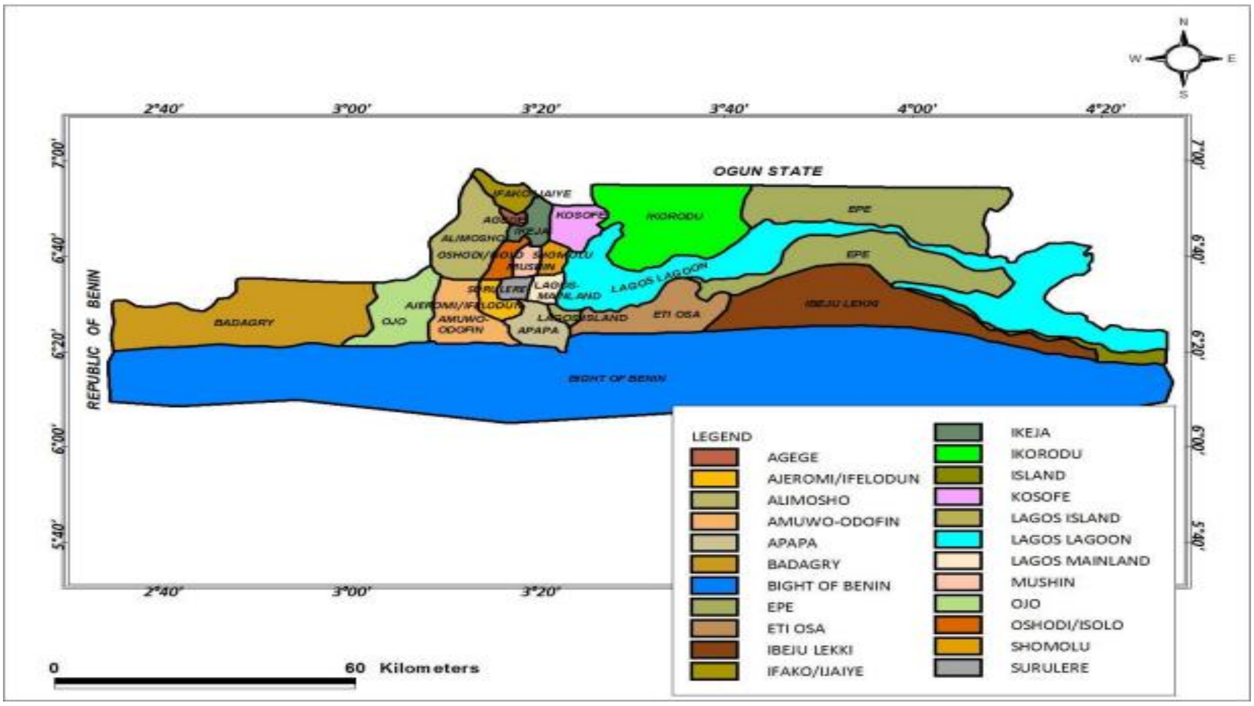

Figure 1. Map of Lagos showing Local Government Area (Afolabi, Oluwaji, & Fashola, 2017).

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The geology of the area in Lagos is mainly sedimentary, comprising tertiary and quaternary sediments. There is no basement outcrop within the state because its basement is several kilometers beneath the earth surface. Lagos states coastline zones with creeks and lagoons developed by barrier beaches and sand deposition lies on the longitude 3^0E and latitude 6^0N with alternate wet and dry seasons. Tertiary sediments are unconsolidated sandstones, grits with mudstone bands and sand with layers of clay. Quaternary sediments are recent deltaic sands, mangrove swamps and alluvium near the coast (Jones & Hockey, 1964). Figure 2 shows the base map of the survey site.

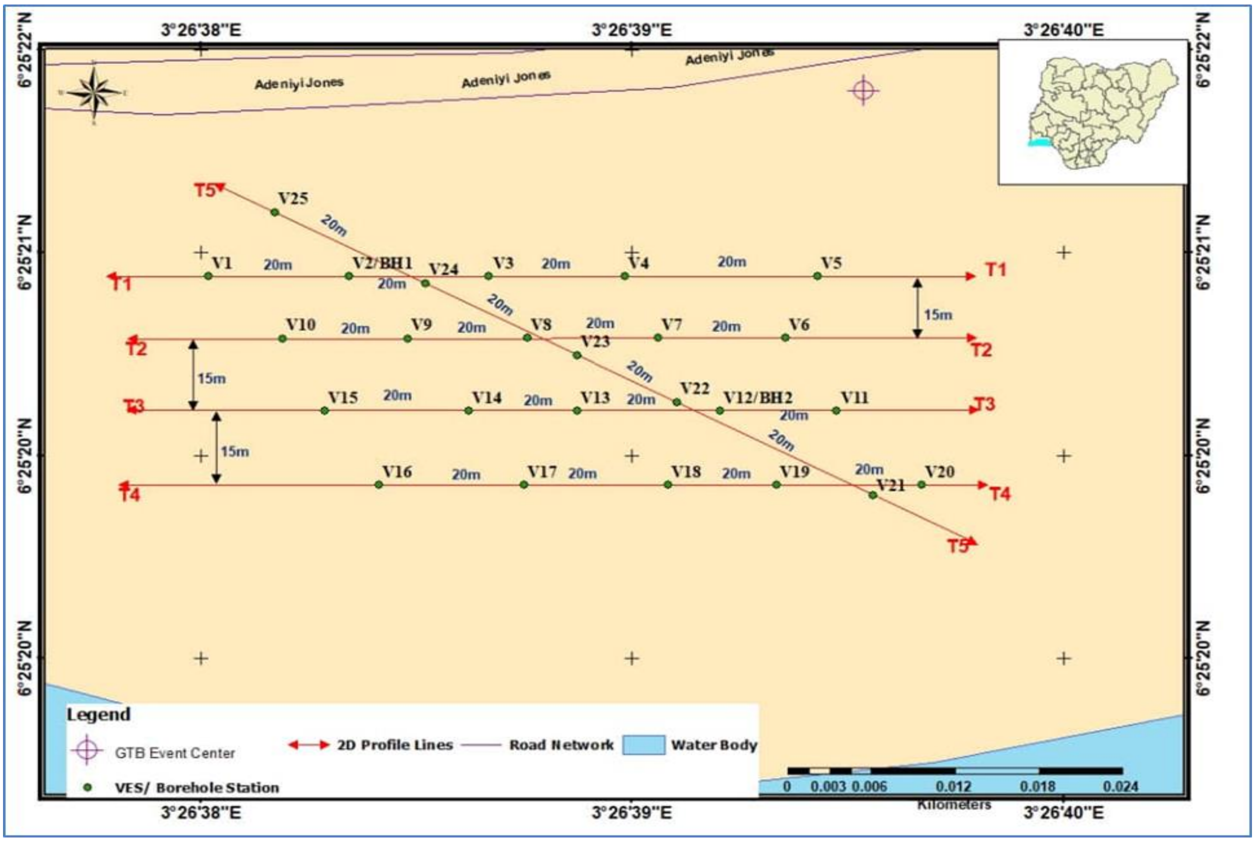

Figure 2. Base map of the survey site.

1.2 Basic theory of electrical resistivity

The basic theory of electrical resistivity for a conductive material described by one-dimensional body the relationship between the current and potential difference is defined by Ohms' law (Kearey, Brook, & Hill, 2002) in equation 1:

$$V = IR \tag{1}$$

Where the constant of proportionality, R, is known as the resistance and is measured in ohms where current **(I)** is in amps and voltage **(V)** is in volts (Kearey et al., 2002).

One of the most common arrays used in resistivity surveying is the Schlumberger array. The Schlumberger array is arranged with two current electrodes on the outside of the array, set apart by a distance at least five times the spacing between the two interior potential electrodes (Figure 3). The potential difference measurement is believed to lie at the mid span of the interior potential electrodes, at a depth approximately one half of the length between the exterior current electrodes.

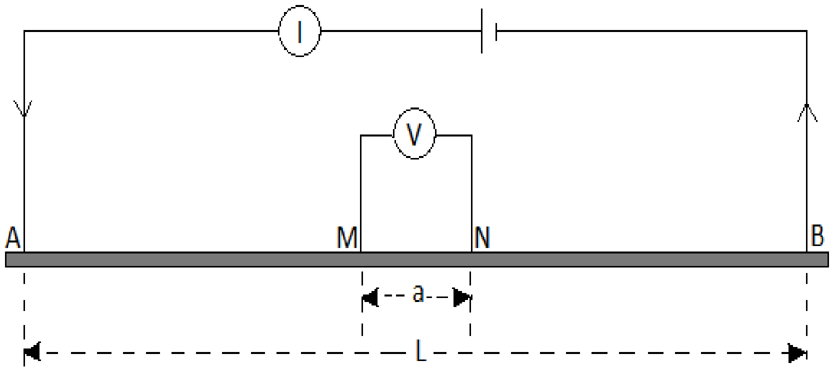

Figure 3. Schlumberger array (Milsom, 2003).

1.3 Basics of geotechnical investigation

The British Standards code of practice for site investigations, B.S 5930:1981 and the Methods of Testing Soils for Civil Engineering Purposes, B.S 1377:1975, have the generally acceptable methods used for boring, sampling, in-situ testing and describing soils. Boring in soil is mainly by the "Shell and Auger" or "Cable Percussion" method. This is based on the use of a variety of tools which, except for the auger, are alternatively raised and dropped to break up and recover the soil. Undisturbed samples of cohesive soils are taken with a 100 mm (approximate) internal diameter open tube sampler fitted with a cutting shoe. This consists of a split barrel thick-walled sampler (split spoon) of about 35mm internal diameter is driven 450mm into the soil by repeated blows from a trip hammer weighing 65Kg and falling through 760mm. The Standard Penetration Test Resistance, or "N_{SPT}"-value gives an empirical measure of the soil consistency and is also used to estimate the bearing capacity and compressibility of granular soils. The cutting shoe is often replaced with a solid cone for use in gravels (Sanchez-Salinero, Roesset, Shao, Stokoe, & Rix, 1987).

2. Materials and Methods

2.1 Data acquisition

A total of five (5) 2D traverses and wenty-five VES stations were acquired at differen points, as shown in Figure 2. The Wenner array electrode was used for the 2D resistivity imaging data acquisition with the length of spread of 200 m and sequences of electrode spacing at 10, 20, 30, 40, 50 m. While for the VES, the Schlumberger array was used, and the current electrode separation (AB) was varied out from a minimum of 2 to 200 m and the ge0detic system of coordinates was obtained using Garmin 12 GPS.

Two (2) boreholes were drilled within the study area as undisturbed samples at every location were taken at appropriate intervals using a specially designed 60.5 mm internal diameter U-Type sampler. The sampler was fitted with a cutter at the open end and a waste barrel at the other end. A round steel ball in the driving head of the sampler permits the escape of air and water as the sampler enters the tube. The diameter of the sample tube is 25 mm and lined with 60.5 mm plastic tube. The samples were trimmed to the desired length and usually 15 cm covered in a plastic tube. An identification label was attached. The number of blows required to drive the sample 15 cm into the ground was recorded. Sometimes, the regular U4 sampler is used to recover the undisturbed sample.

2.2 Data processing

The measured apparent resistivity VES data were processed both quantitatively and qualitatively. The quantitative interpretation of the depth sounding curves was carried out using the partial curve matching technique (Bhattacharya & Patra, 1968). To deduce the true resistivity distribution, a computer inversion software

WINRESIST was used. The result of the computer iteration shows the quantitative analysis to know the resistivity, thickness, and depth. This was presented in the form of a geoelectric section with the aid of AUTOCAD software. The 2D apparent resistivity data inversion was done using the DIPROFWIN program. The field data pseudo section and the 2D resistivity structure were produced after running the inversion of the raw data to filter out noise and the resistivity of each block was then calculated to produce an apparent resistivity pseudo section. The soil samples were taken to the engineering laboratory at the University of Lagos, where the soil analysis was carried out.

3. Results and Discussion

3.1 Geoelectric sections results

Along AA', figure 4 consists of five (5) VES stationed at 70, 90, 110, 130, and 150 m respectively. A total of five to six geoelectric layers which vary from layer one topsoil characterized by resistivity values and layer thickness ranging from (622.1 to 6356.9 Ohm-m; 0.6 to 0.8 m); second layer clay/ sandy clay/sand having resistivity values and thickness ranging from (104.7 to 746.9 Ohm-m; 1.2 to 2.6 m), and along with VES 1 to 3 the resistivity and thickness values ranges from (54.3 to 93.1 Ohm-m; 3.2 to 5.9 m); the third layer in VES 4 and 5, depicts clay with resistivity and thickness values ranging from (33.4 to 44.0 Ohm-m; 3.7 to 5.7 m); the fourth horizon beneath VES 1 is indicative of clay with resistivity value and thickness of (24.7 Ohm-m; 24.4 m), while the fourth geoelectric layer in VES 2 connotes sandy clay having resistivity and layer thickness value of (50.0 Ohm-m; 4.2 m). However, the fourth layer in VES 3 to 5 is diagnostic of sand with resistivity and thickness value ranging from (114.2 to 155.7 Ohm-m; 5.6 to 15.6 m); the fifth substratum layer in VES 1 is representative of sand having a resistivity value of (134.2 Ohm-m), but the layer thickness could not be determined because the current terminated within this zone. While the fifth layer in VES 2 represent clayey sand having resistivity and thickness value of (94.6 Ohm-m; 15.8 m). However, the fifth geoelectric layer in VES 3 to 5 signified clay with resistivity values ranging from (16.8 to 22.9 Ohm-m). The layer thickness in VES 3 is (23.3 m), but the layer thickness in VES 4 and 5 could not be determined due to current terminated within this region. The sixth geoelectric layer beneath VES 2 and 3 is symptomatic of sand having resistivity values ranging from 346.4 to 1007.8 Ohm-m, but their layer thickness could not be determined due to the current terminated within this zone. The sand in this zone represents a competent layer that can withstand engineering structures.

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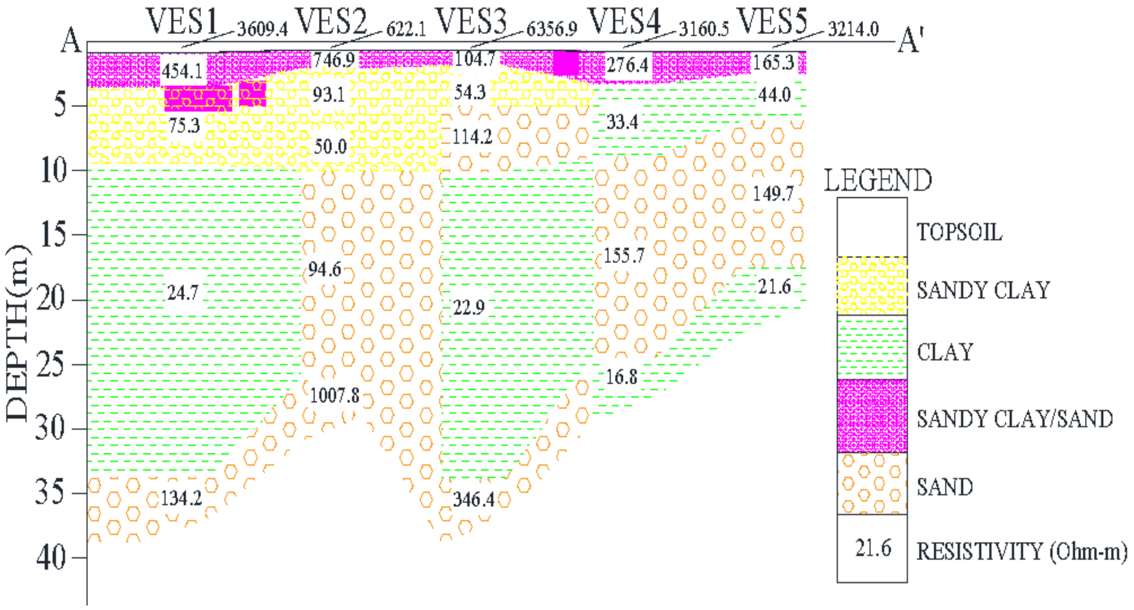

Figure 4. Geoelectric section for VES 1, 2, 3, 4 and 5.

Figure 5 along BB' consists of VES 6 to 10 stationed at 50, 70, 90, 110 and 130 m respectively. The section reveals five geoelectric layers which varied from; The topsoil having resistivity values and thickness ranging from (23.0 to 2971.7 Ohm-m; 0.4 to 0.7 m); The second identified layer in VES (6 and 8) denotes clay having resistivity and thickness values from (18.5 to 21.8 Ohm-m; 2.0 to 2.2 m), while the second layer in VES 7 revealed clay/peat with resistivity and thickness value of (8.3 Ohm-m; 2.3 m). However, the second layer in VES (9 and 10) represents sandy clay/sand with resistivity and layer thickness values of 145.1 to 1157.2 Ohm-m and 1.8 to 2.3 m respectively; The third geoelectric units along VES (6 to 8 and 10) denote sand having resistivity and layer thickness ranging from (120.3 to 284.1 Ohm-m; 4.3 to 5.5 m), while the third layer in VES 9 depicts clay with resistivity value of 43.5 Ohm-m and layer thickness of 3.8 m; The fourth horizon beneath VES 6, 8 and 10 is indicative of clay with resistivity and thickness values ranging from (12.8 to 35.0 Ohm-m; 12.0 to 48.6 m), while the fourth geoelectric layer in VES 7 and 9 connotes sand having resistivity and layer thickness values ranging from (244.2 to 467.4 Ohm-m; 12.0 to 13.0 m); The fifth substratum layer in VES 6, 8 and 10 is symptomatic of sand having resistivity values ranging from 108.8 to 246.8 Ohm-m, but their layer thickness could not be determined because the current terminated within this zone; the fifth layer in VES 7 and 9 is represent clay having resistivity values ranging 20.1 to 21.6 Ohm-m, but their layer thickness could not be determined due to current terminated within this region. The sand zone in the third geoelectric unit represents a competent layer that can withstand engineering structures.

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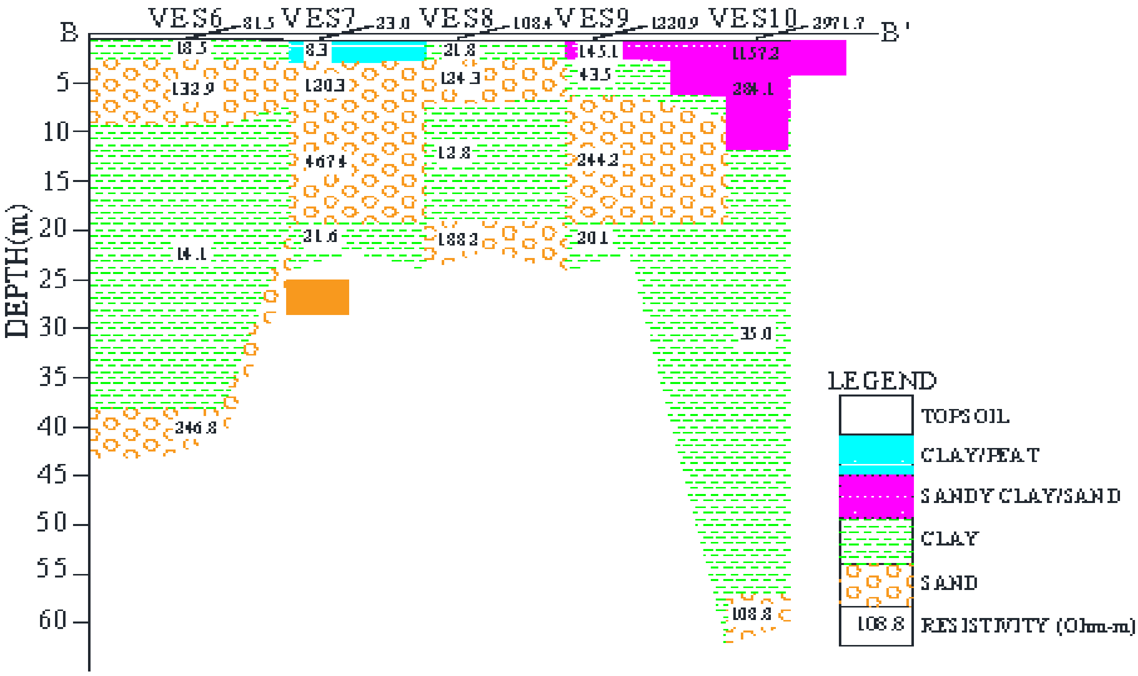

Figure 5. Geoelectric section for VES 6, 7, 8, 9 and 10.

Along section CC', in figure 6 consists of VES 11 to 15 stationed at 60, 80, 100, 120 and 140 m respectively along the 2-D traverse. The geoelectric section reveals four to six layers. The topsoil has resistivity and thickness values ranging from (37.7 to 2658.0 Ohm-m; 0.6 to 0.8 m); The second identified layer in VES 11, 12, 13, 14 and 15 represent sandy clay/sand, clay, and sand with resistivity and thickness values of (188.6 Ohm-m, 90.5 Ohm-m, 19.7 to 45.3 Ohm-m, 119.9 Ohm-m; 3.6 m, 1.4 m, 1.6 to 2.6 m, 3.5 m) respectively. The third geoelectric units denote clay, sandy clay, clayey sand and sand with resistivity and layer thickness values ranging from (13.1 to 46.3 Ohm-m, 60.3 Ohm-m, 83.7 Ohm-m, 200.3 to 251.3 Ohm-m; 2.6 to 26.5 m, 1.3 m, 5.1 m) respectively, except at VES 11, 14 and 15, where the layer thickness could not be determined because the current terminated within this zone. While the fifth layer in VES 13 is symptomatic of sand having a resistivity value of 410.0 Ohm-m but the layer thickness could not be determined due to current terminated within this region. The sixth geoelectric layer beneath VES 12 was diagnostic of sand having a resistivity value of 293.6 Ohm-m but the layer thickness could not be determined due to current terminated within this zone. The sand zones represent a competent layer that can withstand engineering structures while the clay, clayey sand and sandy clay signify an incompetent zone for mega engineering structures.

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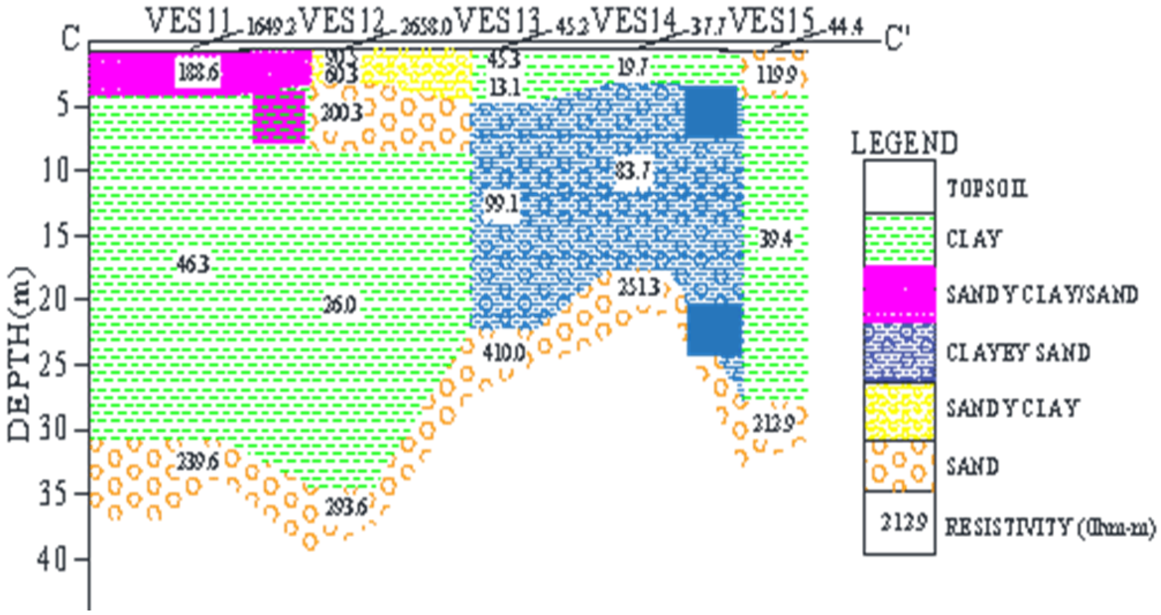

Figure 6. Geoelectric section for VES 11, 12, 13, 14 and 1

The geoelectric Section along DD' in Figure 7 consists of VES 16 to 20 stationed at 60, 80, 100, 120 and 140 m respectively. The section reveals four to five geoelectric layers which vary from topsoil, clay/peat, clay, clayey sand, sandy clay/sand, and sand. The topsoil is characterized by resistivity values and thickness ranging from (30.9 to 1661.7 Ohm-m; 0.6 to 0.8 m); The second identified layer represent sandy clay/sand having resistivity and thickness values ranging from (14.2 to 336.1 Ohm-m and layer thickness of 2.1 to 3.9 m); The third geoelectric units denote sandy clay, sand having resistivity and layer thickness values ranging from (59.9 to 82.5 Ohm-m, 187.8 Ohm-m; 3.1 to 7.7 m, 7.0 m) respectively. However, the third layer in VES 19 and 20 connotes clay/peat and sand with resistivity and thickness values of (9.8 Ohm-m, 84.3 Ohm-m; 5.7 m, 4.3 m) respectively; The fourth horizon layer is an indicative of clay with resistivity and thickness values ranging from (10.3 to 44.6 Ohm-m; 16.3 to 19.7 m), but the layer thickness in VES 18 could not be determined because the current terminated within this zone. While the fourth geoelectric layer in VES 17 and 19 connotes sand having resistivity and thickness values ranging from (113.6 to 473.3 Ohm-m; 8.0 m), but the layer thickness in VES 19 could not be determined because the current terminated within this region. The fifth substratum layer is a symptomatic of sand having resistivity values ranging from 158.4 to 188.4 Ohm-m, but their layer thickness could not be determined because the current terminated within this horizon. The sand zone represents a competent layer that can withstand engineering structures while the clay, clay/peat, clayey sand, and sandy clay connotes an incompetent zone because of the magnitude of the engineering structure that would be erected on the site.

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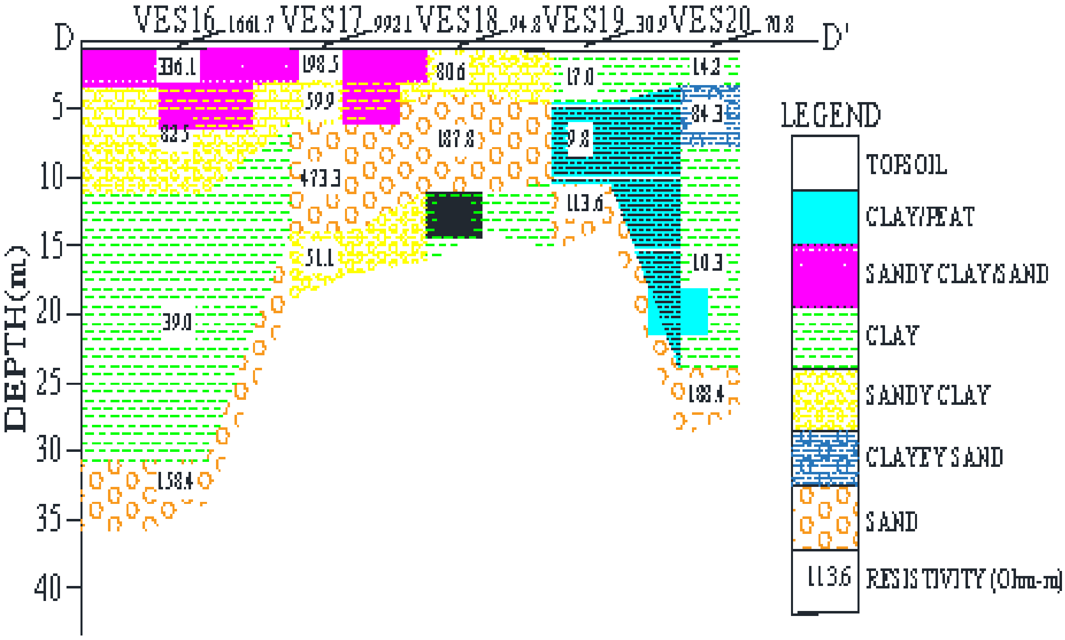

Figure 7. Geoelectric section for VES 16, 17, 18, 19 and 20.

The geoelectric section along EE' in figure 8 consists of VES 21 to 25 stationed at 60, 80, 100, 120 and 140 m respectively. The section reveals four geoelectric layers which varied from topsoil, clay, sandy clay, clayey sand, sandy clay/sand, and sand. The topsoil is characterized by resistivity values ranging from 37.9 to 2444.3 Ohm-m and layer thickness of 0.6 to 0.8 m; The second identified layer denote sandy clay/sand having resistivity values ranging from 108.8 to 339.9 Ohm-m and layer thickness of 1.7 to 4.4 m; The third geoelectric units represent sandy clay having resistivity and layer thickness values ranging from 52.6 to 58.7 Ohm-m and 7.0 to 12.5 m respectively. However, the third geoelectric layer in VES 25 is representative of clay with a resistivity value of 42.2 Ohm-m and layer thickness of 35.5m. The fourth stratum is symptomatic of sand having resistivity values ranging from 139.6 to 379.1 Ohm-m, but their layer thickness could not be determined because the current terminated within this zone. The zone with dense and medium dense sand represents a competent layer that can withstand mega engineering structures.

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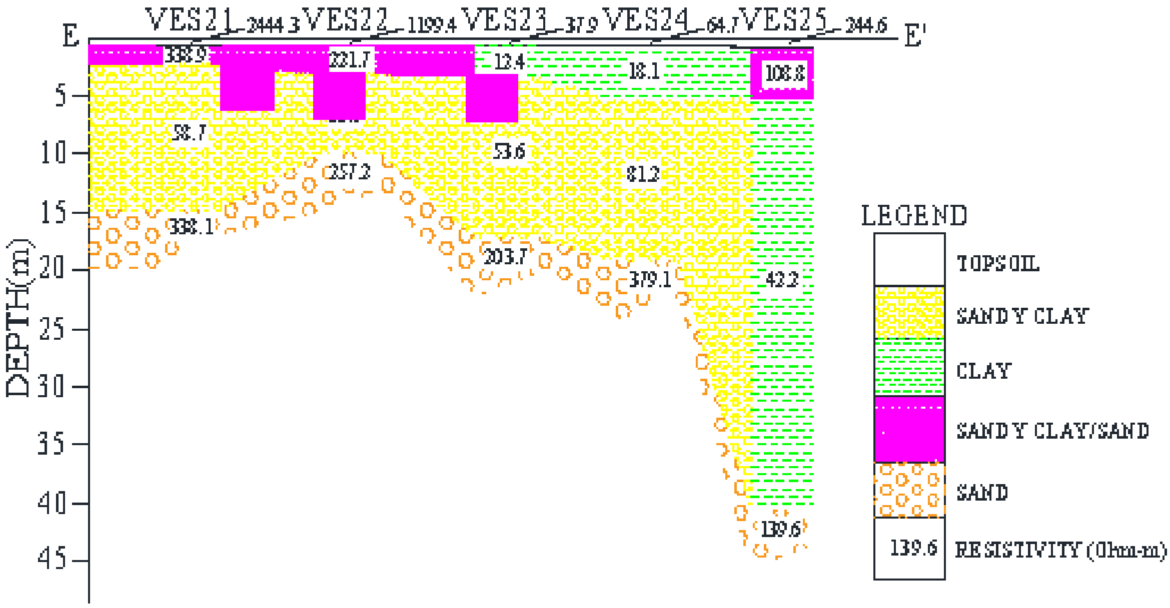

Figure 8. Geoelectric section for VES 21, 22, 23, 24 and 25.

3.2 2-D imaging results:

3.2.1 Traverse one

The total spread of 200 m with a depth of 50 m was probed with resistivity values ranging from 15 to 329 Ωm as shown in Figure 9. The borehole log one was along with a 2-D profile at a lateral distance of 90 m. At depth below 20 m is diagnostic of clay, clayey sand/sandy clay, and sand having a resistivity value ranging from 15 to 178 Ωm across the profile. The depth above 20 m to the subsurface depicts clay, clayey sand/sandy clay, and sand with resistivity in the range of 28 to 329 Ωm across the profile. The sand is distinctive at the depth of 25 to 50 m with a lateral distance of 95 to 170 m across the profile with resistivity values ranging from 178 to 329 Ωm. The sand zone represents a competent layer that can withstand engineering structures while the clay and clayey sand/sandy clay signified an incompetent layer for engineering structures.

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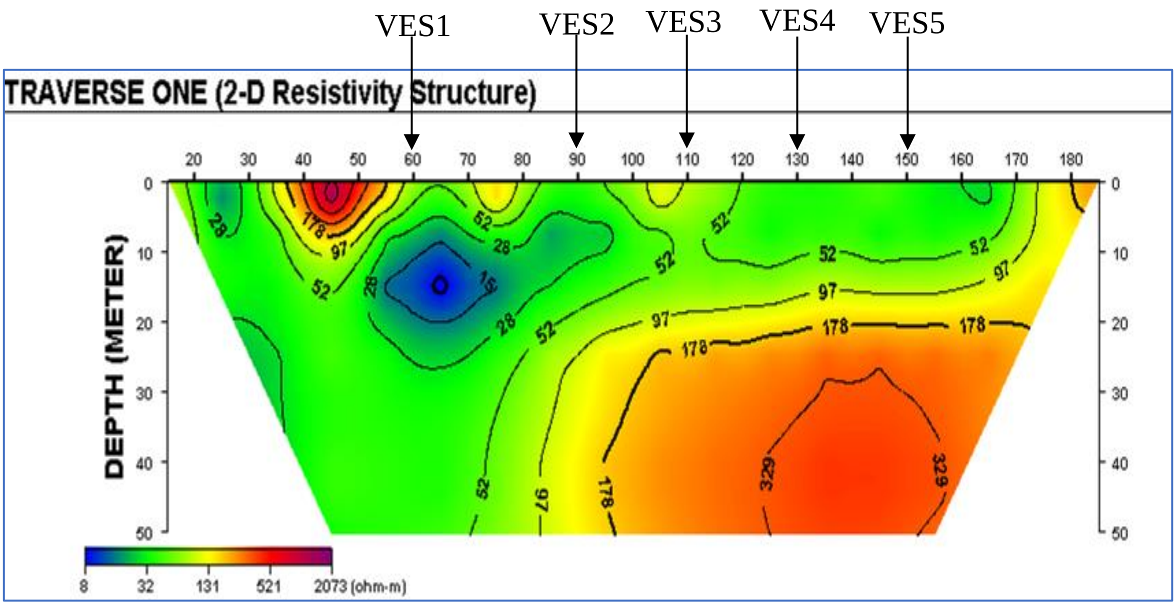

Figure 9. 2-D resistivity structure of traverse one

3.2.2 Traverse two

Traverse two has a profile length of 200 m and depth coverage of 50 m, with resistivity values ranging from 12 to 92 Ωm as shown in Figure 10. At depth below 20 m, clayey sand/sandy clay having resistivity values ranging from 29 to 92 Ωm across the spread was suspected. The depth above 20 m to the subsurface is an indicative of clay with resistivity in the range of 12 to 37 Ωm across the profile. The clay and clayey sand/sandy clay represent an incompetent layer for engineering structures.

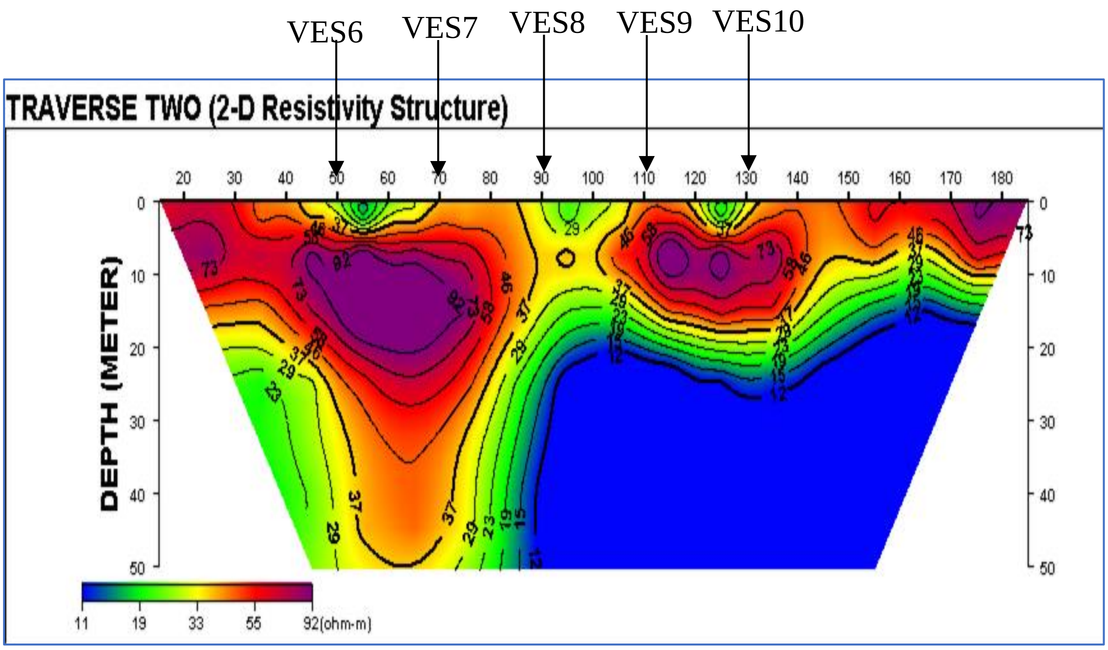

Figure 10. 2-D resistivity structure of traverse two.

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3.2.3 Traverse three

This location has a total electrode spread of 200 m with 50 m depth of penetration. The resistivity values range from 8.5 to 238 Ωm as shown in Figure 11. The borehole log two was along with a 2-D profile at a lateral distance of 80 m. At depth below 20 m, clay/peat, clay, clayey sand/sandy clay, and sand having a resistivity value ranging from 8.5 to 148 Ωm across the profile was suspected. The depth above 20 m to the subsurface depicts clay, clay/peat, clayey sand/sandy clay, and sand with resistivity in the range of 8.5 to 238 Ωm across the profile. The sand is distinctive at the depth of 15 to 50 m with a lateral distance of 40 to 75 m across the profile with resistivity values ranging from 148 to 238 Ωm. The sand zone represents a competent layer that can withstand engineering structures while the clay, clay/peat, and clayey sand/sandy clay signified an incompetent layer for engineering structures.

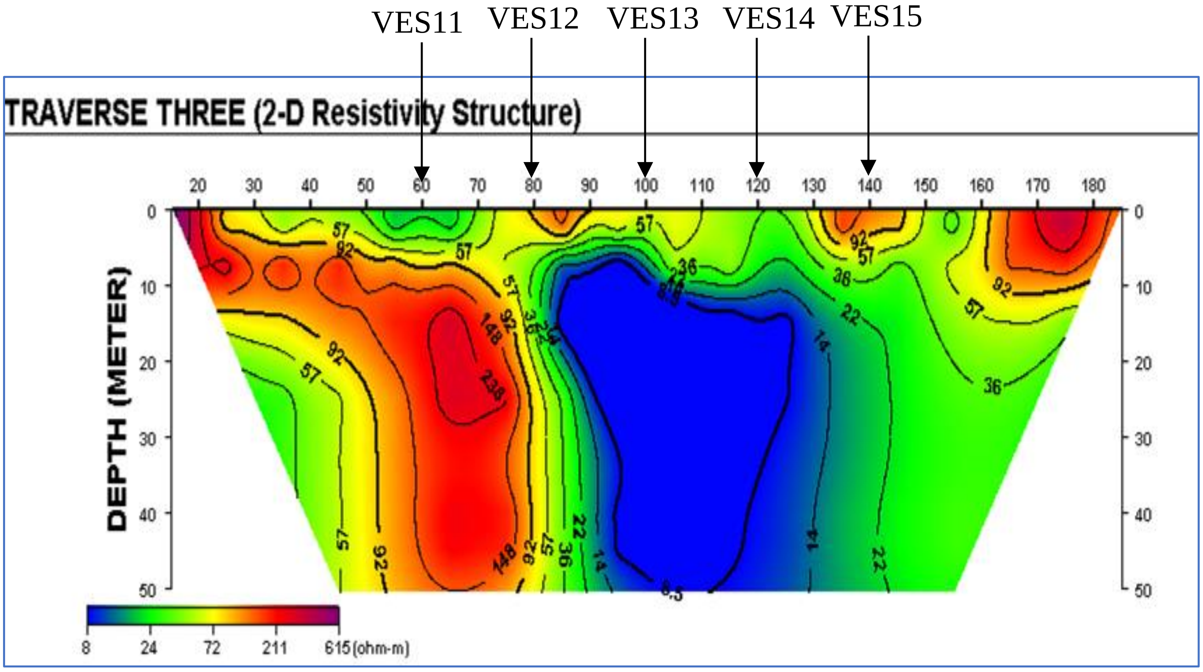

Figure 11. 2-D resistivity structure of traverse three.

3.2.4 Traverse four

The profile length of 200 m was occupied in this location with a 50 m depth of investigation. As shown in Figure 12, the resistivity values range from 3 to 72 Ωm, and at depth below 20 m is diagnostic of clay and clayey sand/sandy clay having a resistivity value ranging from 12 to 72 Ωm across the profile. The depth above 20 m to the subsurface connotes clay and clay/peat with resistivity in the range of 3 to 36 Ωm across the profile. The clay, clay/peat, and clayey sand/sandy clay are indicative of an incompetent layer for engineering structures.

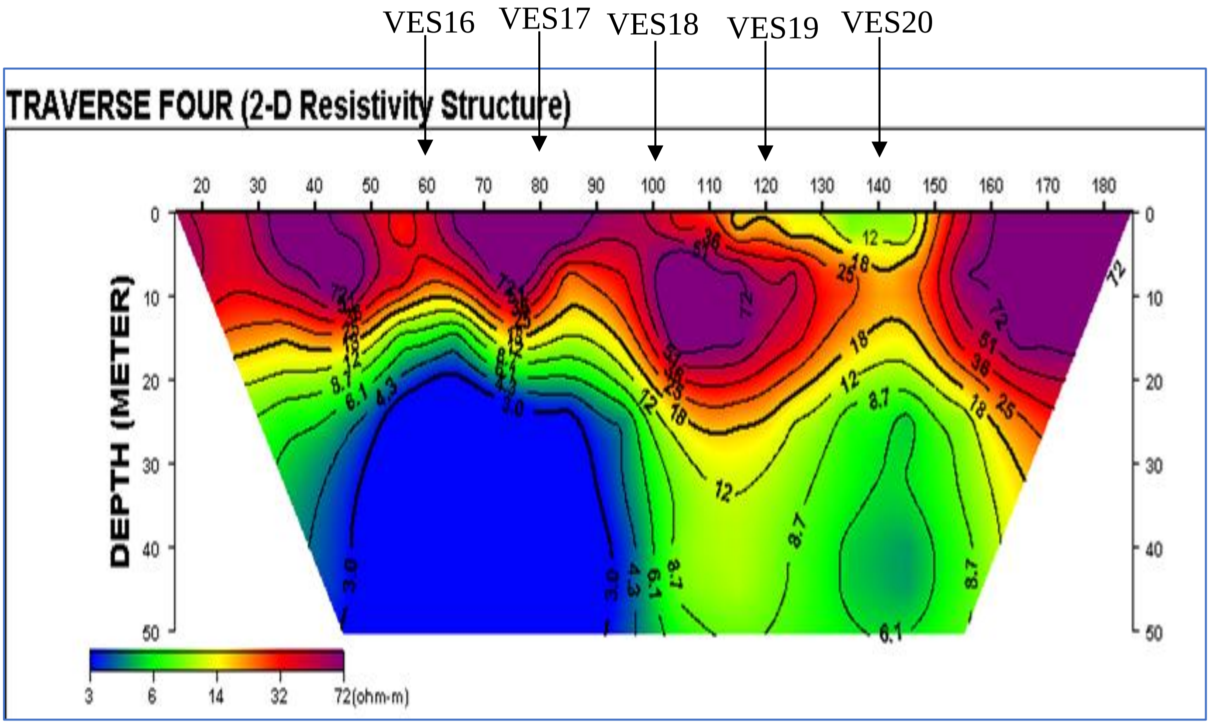

Figure 12. 2-D resistivity structure of traverse four.

1.6.5 Traverse five

The total spread of 200 m and a depth of 50 m was probed with resistivity values ranging from 20 to 985 Ωm as shown in Figure 13. At depth below 20 m revealed clay, clayey sand/sandy clay, and sand having a resistivity value ranging from 20 to 985 Ωm across the profile. The depth above 20 m to the subsurface is representative of clay and clayey sand/sandy clay with resistivity in the range of 20 to 61 Ωm across the profile. The sand is distinctive at the depth of 0 to 10 and 10 to 15 m with a lateral distance of 40 to 80 m and 130 to 160 m respectively across the profile with resistivity values ranging from 107 to 985 Ωm. The sand zone represents a competent layer that can withstand engineering structures while the clay and clayey sand/sandy clay signified an incompetent layer for engineering structure

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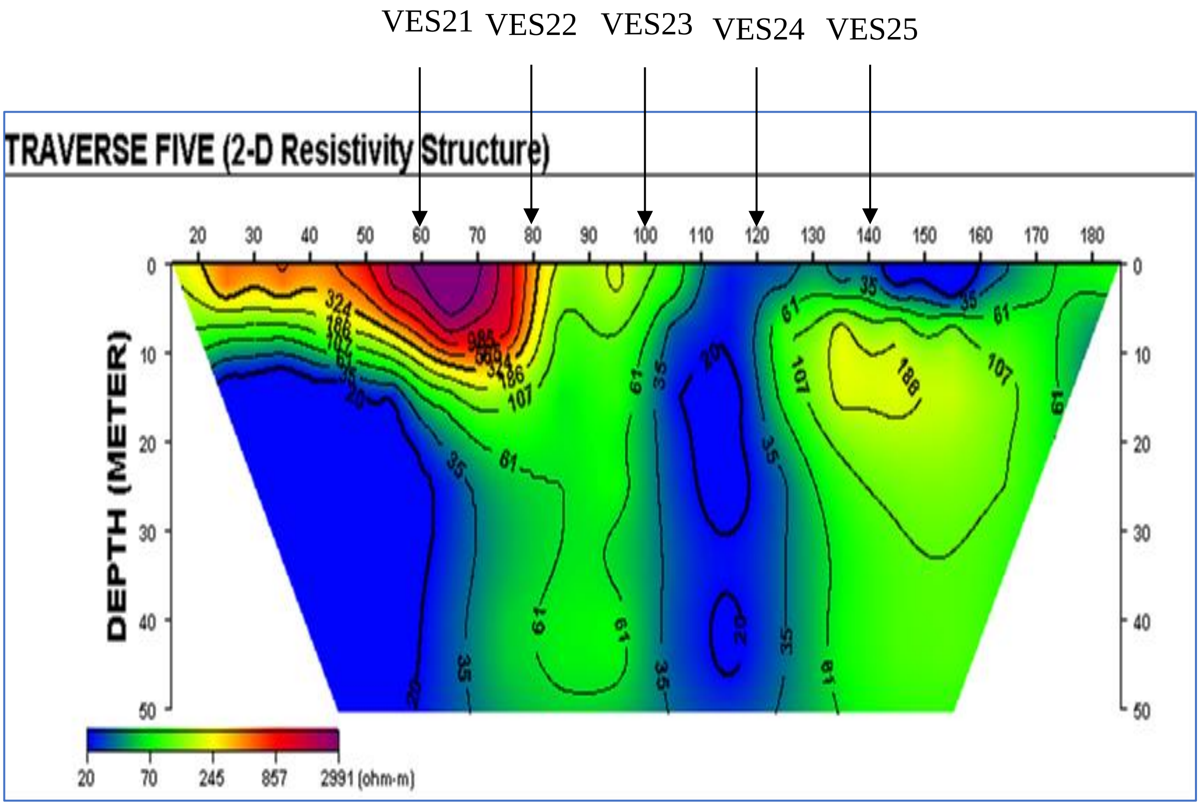

Figure 13. 2-D resistivity structure of traverse five.

3.3 Geotechnical results

The borehole logs obtained from the geotechnical analysis are displayed in Figures 14 (a and b) The first layer of the borehole strata which has no N-Value, revealed brown/grey medium to fine sand with occasional gravels from the ground level to a depth of 1.5 m in borehole (1 and 2). The second zone of the borehole logs has N-Value of 22 to 30 which is indicative of medium-dense, brown medium to fine sand with occasional gravels in the vicinity of the borehole (1 and 2) from a depth of 1.50 - 7.50 m. The third zone of the borehole logs revealed dense, grey medium to fine sand with occasional gravels from a depth of 7.50 – 15.75 m with N-Value ranging from 26 to 30.

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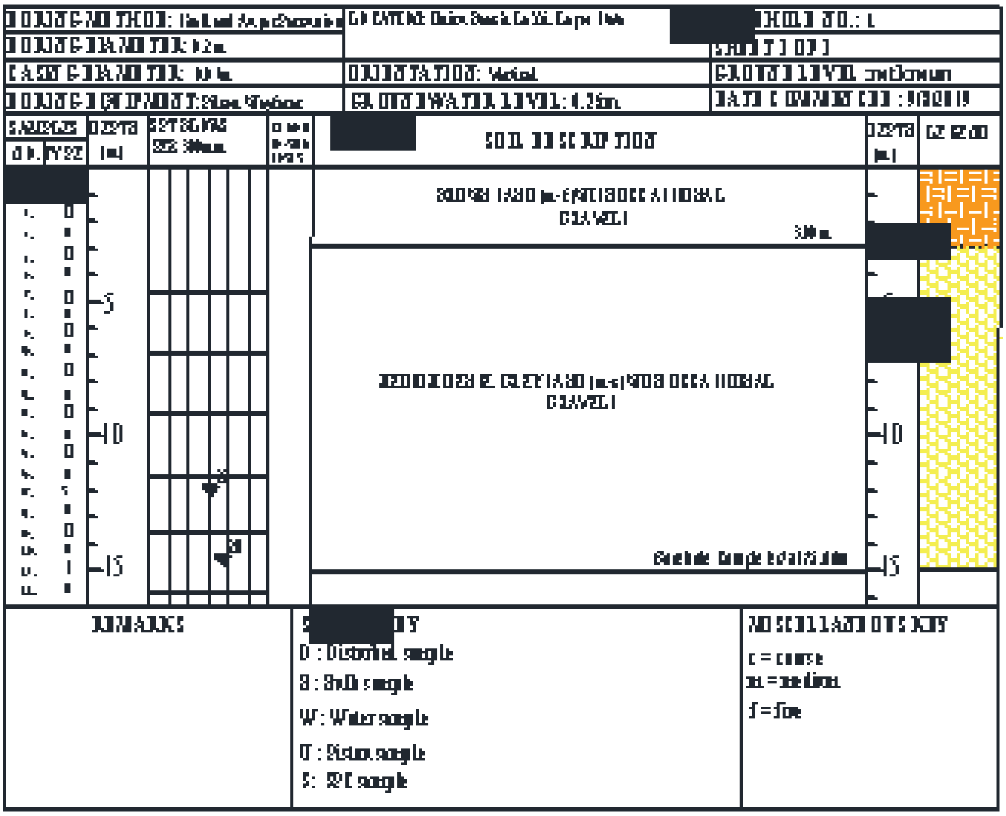

Figure 14a. Borehole log 1.

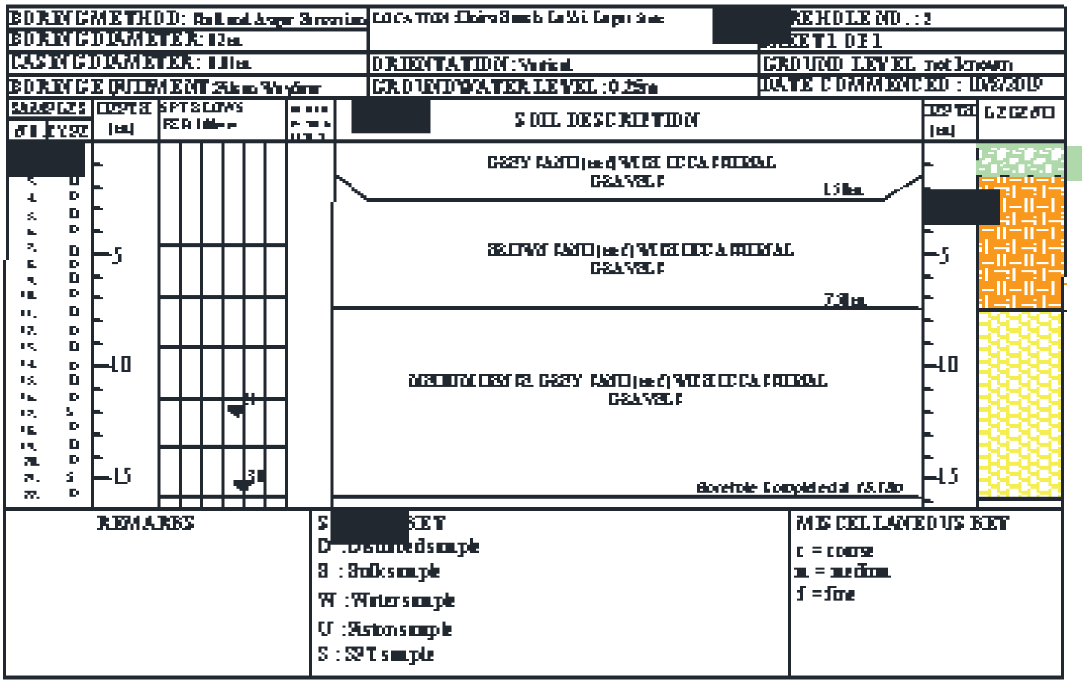

Figure 14b. Borehole log 2.

3.4 Correlation of geophysical and geotechnical methods

The results of the geoelectric section AA[1], BB[1], CC[1], DD[1] and EE[1] signified topsoil with resistivity values ranging from 23.0 to 6356.9 Ωm within the depth range of 0.4 to 0.8 m, while the 2D result indicates topsoil with resistivity values ranging from 28 to 985 Ωm within the depth range of 0 to 5 m. Both results show that the topsoil is composed of clay, clayey sand/sandy clay, and sand brown/gray medium to fine sand with occasional gravels from the ground level to a depth of 1.5 m.

The second layer on all the geoelectric sections depict clay/peat, clay, sandy clay, sandy clay/sand, and sand having resistivity values ranging from 8.3 to 1157.2 Ωm and depth range of 1.8 to 5.4 m which corresponds to the 2D results signifying clay/peat, clay, clayey sand/sandy clay, and sand having resistivity values ranging from 8.5 to 985 Ωm to a depth of 10.0 m. While the second layer borehole log is an indicative of medium-dense, brown medium to fine sand with occasional gravels from depth of 1.50 - 7.50 m.

The third geoelectric layer denotes clay/peat, clay, clayey sand, sandy clay, and sand with resistivity values in the range of 9.8 to 284.1 Ωm within the depth range of 3.2 to 40.6 m which also corresponds with the 2D result indicating clay/peat, clay, clayey sand/sandy clay, and sand having resistivity values ranging from 8.5 to 148 Ωm to a depth of 20.0 m. Also, the third zone of the borehole logs revealed dense, gray medium to fine sand with occasional gravels from the depth of 7.50 – 15.75 m.

The fourth horizon on all the geoelectric sections represents the clay, sandy clay, clayey sand, and sand with resistivity values ranging from 10.3 to 473.3 Ωm within a depth of 8.4 to 57.1 m which also correspond with the 2D result indicating clay/peat, clay, clayey sand/sandy clay, and sand having resistivity values ranging from 8.5 to 329 Ωm to a depth of 40.0 m. The borehole logs could not go further due to the collapse of the sand

The fifth layer on all the geoelectric sections connote clay, sandy clay, sandy clay, and sand having resistivity values ranging from 16.8 to 401.0 Ωm and depth range of 25.9 to 34.4 m which corresponds to the 2D results signifying clay/peat, clay, clayey sand/sandy clay, and sand having resistivity values ranging from 3.0 to 329 Ωm to a depth of 50.0 m.

The sixth identify layer is symptomatic of sand having resistivity values ranging from 293.6 to 1007.8 Ωm. The depth range could not be determined due to the current termination within this zone. This shows that there are some degrees of correlation between the geophysical and geotechnical methods.

4. Conclusion

The electrical resistivity and geotechnical methods were deployed to characterize the subsurface geological parameters for pre-foundation building assessment at Oniru, Eti - Osa, Lagos State.

The integrated analysis of results from the VES and 2D imaging data reveal the soil to have similar layers namely topsoil, clayey sand, sandy clay, clay/peat, sandy clay/sand, and sand. The topsoil thickness values range from 0.4 to 0.8 m with its resistivity values ranging from 23.0 to 6356.9 Ωm, which corresponds with the first layer delineated on the borehole logs which is representative of clay, clayey sand/sandy clay, and sand brown/grey medium to fine sand with occasional gravels from the ground level to a depth of 1.5 m. The clayey sand layer has resistivity values ranging from 53.6 to 99.1 Ωm and layer thickness of 7.6 to 25.9 m. The resistivity values of the sandy clay layer range from 51.1 to 93.1 Ωm, having thickness values from 1.9 to 14.8 m. The sandy clay/sand has resistivity values ranging from 104.7 to 1157.2 Ωm and layer thickness of 1.8 to 5.2 m. The borehole logs correspond to this layer having an N-Value of 22 to 30 which is indicative of medium-dense, brown medium to fine sand with occasional gravels from the depth of 1.50 - 7.50 m. The clay layer has resistivity values ranging from 10.3 to 46.3 Ωm and thickness ranging from 2.2 to 57 m. The clay/peat has resistivity values ranging from 8.3 to 9.8 Ωm and layer thickness of 2.9 to 11.0 m. The sand in VES (3 to 15, 17, and 19) possesses resistivity values ranging from 108.8 to 1007.8 Ωm and layer thickness of 4.3 to 24.4 m. The thickness in VES (1 to 3, 6, 8, 10, 16 and 19 to 25) could not be determined due to current termination. The information obtained from the two borehole logs in the area correlates significantly with the geophysical results for the layers which connotes dense, grey medium to fine sand with occasional gravels at the

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depth range of 7.50 – 15.75. The analysis of the geophysical and geotechnical study shows that the soil in the study area is made up of sand and clay, but the sand is more pronounced at depth intervals of 1.5 to 20 m.

In addition, the sand zones from the study represent a competent layer that can withstand engineering structures. This is because of the thickness of the sand layers and the ability of sand as an engineering material to absorb water without expansion or contraction during the dry period, unlike clay and peat that has high ability to expand and contrast during wet and dry periods.

Lastly, the differences in the electrical properties of the different soil samples available in this location occurred because of the difference in material and mineral compositions of the particles that made up these soil materials. Moreover, some of those soil layers are the same kind but they are found at different depths in this location, this is because of the differences in moisture and salinity content. The area under investigation is located along the coastline part of Nigeria with high levels of saline water intrusion from the coast into the surroundings.

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Conflict of Interest

The authors do not report any financial or personal connections with other persons or organizations, which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

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