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# GEOELECTRIC SURVEY OF FOUNDATION BEDS OF THE PROPOSED FACULTY OF ENGINEERING BUILDING, OSUSTECH PERMANENT SITE, OKITIPUPA, NIGERIA.

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**Abstract**

*Geoelectric resistivity method was employed to characterize the geo-materials at Ondo State University of Science and Technology (OSUSTECH) Okitipupa,Dahomey Basin, Nigeria, for suitability for foundation purposes.The methods involved Constant Separation Traversing (CST) using Wenner array and Vertical Electrical Sounding (VES) using Schlumberger array. The data obtained were processed with Ipi2win and excel software. The results showed that the subsurface structures were made up of lateritic topsoil with resistivity varying from 85 Ohm-m to 612 Ohm-m and thickness varying from 0.5 to 2.14 m; clayed sand with resistivity varying from 295 to 2,587 ohm-m and thickness vary from 0.67 to 3.4; clay with resistivity varying from 10 to 350 ohm-m and thickness varying from 3.8 to 26 m; and sand with resistivity ranging from 383Ω-m to 59,707Ω-m. The clayed sand would have been the best layer to host the foundation because of its depth to the surface but it is generally less than 1.5 m and underlay by thick column of clay. The only competent layer that can host the foundation of high-rise building is the sand layer, therefore, the building foundation should be piled to the sand layer or pilling should be suspended within the thick column of clay.*

***Keywords:***
Geoelectric Resistivity,
Vertical Electrical Sounding,
Constant Separation Traversing,
Shallow Foundation,
Subsurface Structure

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## 1.0 Introduction

The statistics of failures of structures such as road, buildings, dam and bridges throughout the nation has increased geometrically. The need for pre-foundation studies has therefore become very imperative so as to prevent loss of valuable lives and properties that always accompany such failure. Foundation study usually provides subsurface information that normally assists civil engineers in the design of foundation of civil engineering structures [1].

The properties of soil and rock are the results of the natural processes that formed them, and natural or man-made events following their formation. The replacement of unsuitable foundation materials is often impractical and uneconomical. The large volume of soil and rock needed for construction, as a rule, makes it prohibitive to manufacture and transport pre-engineered material [8].The geotechnical expert in designing and constructing facilities is faced with the challenges of using the foundation and construction materials available on or near the project site. Therefore, the designing and building of such structures requires a thorough understanding of properties of available soils and rocks that will constitute the foundation and other components of the structures. The proper execution of this role requires a thorough understanding of the concepts and practice of subsurface investigation techniques, principles, design procedures, construction methods and planned facility utilization.

Generally, there are two types of subsurface investigation that new construction may require; the first being a conceptual subsurface investigation, or route selection study. It generally does not require a detailed subsurface investigation and is normally limited to general observations such as the depth to rock or competent soils, presence of sinkholes and/or solution cavities, organic deposits in low lying swampy areas, and/or evidence of old fill, debris, or contamination. The second and more common type of subsurface investigation is the detailed investigation to be performed for the purpose of detailed site characterization to be used for the design. The design investigation typically includes a number of geotechnical and geophysical tests sufficient for defining the general stratigraphy, soil and rock characteristics, groundwater conditions, and other existing features of importance to foundation design [4, 3].Several geophysical methods are routinely used to image the subsurface of the earth in support of subsoil investigations. Commonly employed geophysical methods include seismic tomography, electrical resistivity, electromagnetic and gravity methods [11, 12].

However, in terms of spatial resolution, cost effectiveness and target definition, electrical resistivity methods ranked first [5]. In this study, electrical resistivity method was used to investigate the subsurface stratigraphic relationships or variation of subsurface materials in Ondo State University of Science and Technology (OSUSTECH) Okitipupa, Nigerian, as an aid to construction engineer.

The management of the Ondo State University of Technology, Okitipupa, recently allocated a site for a proposed faculty of engineering complex. The site is located within Sedimentary area of Southwestern Nigeria. The need to provide information in the subsurface sequence and structure disposition necessary for foundation design necessitated a geophysical investigations of the site whose results are presented in this paper.

## 2.0 Description and Geology of the study area

The study area is part of the permanent site of the Ondo State University of Science and Technology (OSUSTECH), Okitipupa. This area is the proposed Faculty of Engineering Site at OSUSTECH Okitipupa (Figure 1). The study site lies between longitude 4°3' E to 6°00' E and latitude 5°42' N to 8°15' N.Okitipupa is a coastal area and is at the contact between the Niger Delta and the Dahomey Basins in Nigeria, which stretches from this point in Nigeria through republic of Benin, Togo and terminates at Ghana, the second largest bitumen deposit in the world is located at Agbabuarea in Okitipupa area, Ondo State, Nigeria.

The land rises from the coastal part of Ilaje/Ese Odo (less than 15m above sea level) in the South to the rugged hills of northern eastern portion in Akoko area. Sand ridges, lagoon and swampy flats of sedimentary terrain characterize the area. It belongs to the sedimentary terrain of Nigeria. Thelithologywithin the Dahomey (as shown in Figure 2) are described as coastal plain sand of the Benin formation [7, 9]. The sands are relatively well sorted and non-cemented and the sediments were deposited during the late Tertiary-Early Quaternary period [9]. Okitipupa area has three distinct types of soil namely Okitipupa series, Omotosho series and Ode Erinje series. Okitipupa series occupy 52% or 41,623 hectares of the entire land areas. The soils are associated with nearly plains of 0-4 % slopes at elevation of 40-60m above sea level and are developed on recent to tertiary sediments termed coastal plain sands or cretaceous Abeokuta formation [6].The Omotosho soil series constitutes 21.64% or 17, 318 hectares of the land area and are associated with strongly undulating topography of 8-12% slopes at high elevations of 60-105m above the sea level. The soils are derived from basement complex rocks composed mainly of granite-gneiss, mica-schist and feldspathic rocks.

The Ode Erinje Fadama Soil series occupy 26.36% or 21,099 hectares of the land area on nearly level plains of 0-1% at very low elevations of 10-20 m above mean sea level. They are underlain by coastal plain sands and are seasonally waterlogged [2].

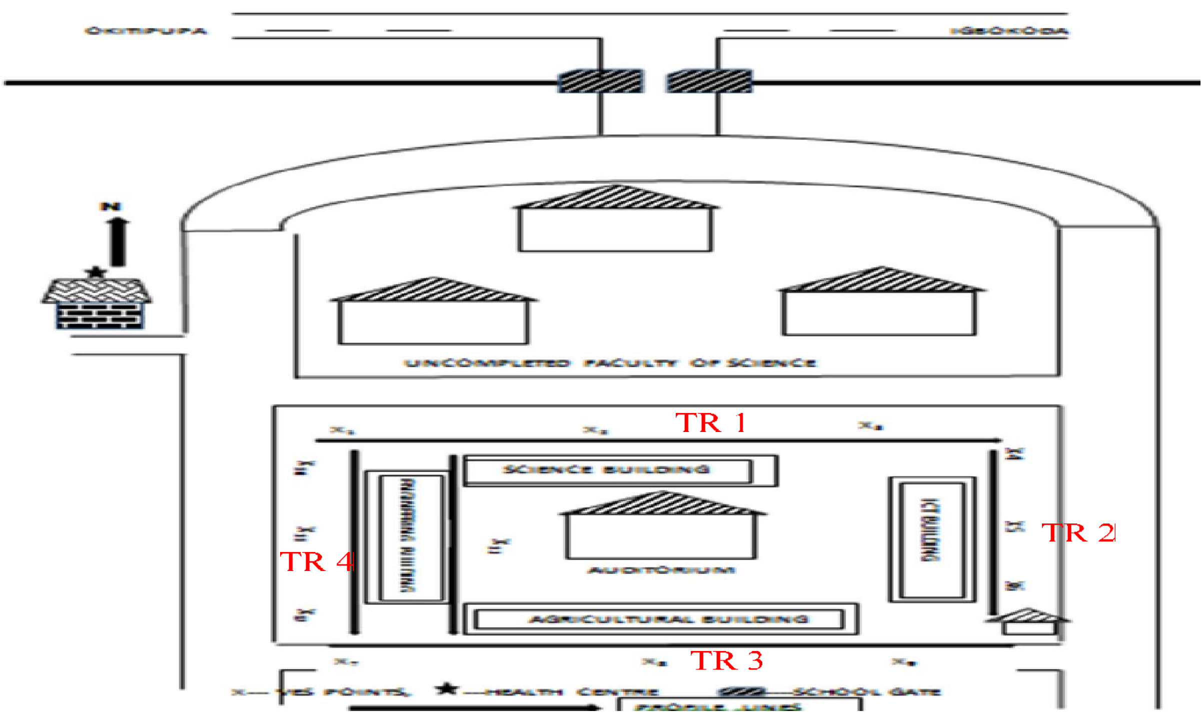


Figure 1: Location map of the study area

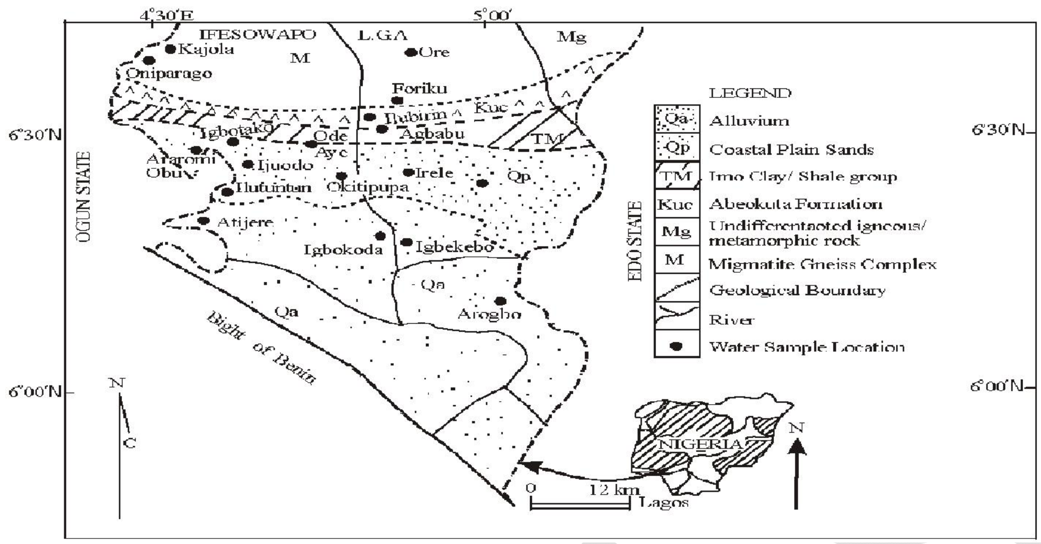


Figure 2: Geology map of study area (Adapted from PTF [10])

Table 1: Summary of VES results on the OSUSTECH main campus

| VES station /curve types | Layers | Resistivity (Ωm) | Thickness(m) | Depth(m) | Curve characteristics | Inferred lithology |
|---|---|---|---|---|---|---|
| 1/KH | 1 | 96 | 0.894 | 0.894 | $\rho_1 < \rho_2 > \rho_3 < \rho_4$ | Top soil |
| | 2 | 1111 | 1.95 | 2.84 | | Clayed Sand |
| | 3 | 52.4 | 11.4 | 14.3 | | Clay |
| | 4 | 9273 | | | | Sand |
| 2/KH | 1 | 304.2 | 0.9744 | 0.9744 | $\rho_1 < \rho_2 > \rho_3 < \rho_4$ | Top soil |
| | 2 | 2587 | 1.607 | 2.59 | | Clayed Sand |
| | 3 | 124 | 13.49 | 16.98z | | Clay |
| | 4 | 31920 | | | | Sand |
| 3/KH | 1 | 210.7 | 1.148 | 1.148 | $\rho_1 < \rho_2 > \rho_3 < \rho_4$ | Top soil |
| | 2 | 968.7 | 3.406 | 4.55 | | Clayed Sand |
| | 3 | 78.2 | 4.495 | 9.05 | | Clay |
| | 4 | 20524 | | | | Sand |
| 4/KH | 1 | 120.8 | 0.8832 | 0.8832 | $\rho_1 < \rho_2 > \rho_3 < \rho_4$ | Top soil |
| | 2 | 1308 | 2.114 | 2.99 | | Clayed Sand |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 3 | 75.5 | 4.55 | 7.55 | | Clay |
| | 4 | 59707 | | | | Sand |
| 5/KH | 1 | 85.69 | 1.713 | 1.713 | $\rho_1 < \rho_2 > \rho_3 < \rho_4$ | Top soil |
| | 2 | 295.9 | 1.882 | 3.59 | | Clayed Sand |
| | 3 | 15 | 12.09 | 15.68 | | Clay |
| | 4 | 3812 | | | | Sand |
| 6/KH | 1 | 177.6 | 1.025 | 1.025 | $\rho_1 < \rho_2 > \rho_3 < \rho_4$ | Top soil |
| | 2 | 1476 | 2.006 | 3.02 | | Clayed Sand |
| | 3 | 38.24 | 3.827 | 6.85 | | Clay |
| | 4 | 35248 | | | | Sand |
| 7/KH | 1 | 207.6 | 0.5 | 0.5 | $\rho_1 < \rho_2 > \rho_3 < \rho_4$ | Top soil |
| | 2 | 1179 | 1.591 | 2.09 | | Clayed Sand |
| | 3 | 174.8 | 25.74 | 27.8 | | Clay |
| | 4 | 29175 | | | | Sand |
| 8/KH | 1 | 424.8 | 2.142 | 2.142 | $\rho_1 < \rho_2 > \rho_3 < \rho_4$ | Top soil |
| | 2 | 1065 | 2.924 | 5.06 | | Clayed Sand |
| | 3 | 11.98 | 6.149 | 11.15 | | Clay |
| | 4 | 2116 | | | | Sand |
| 9/KH | 1 | 520.9 | 1.768 | 1.768 | $\rho_1 < \rho_2 > \rho_3 < \rho_4$ | Top soil |
| | 2 | 1168 | 2.575 | 4.34 | | Clayed Sand |
| | 3 | 106.1 | 11.5 | 15.8 | | Clay |
| | 4 | 10666 | | | | Sand |
| 10/KH | 1 | 438.9 | 0.5 | 0.5 | $\rho_1 < \rho_2 > \rho_3 < \rho_4$ | Top soil |
| | 2 | 1112 | 0.8249 | 1.32 | | Clayed Sand |
| | 3 | 350.8 | 8.758 | 10.07 | | Clay |
| | 4 | 21356 | | | | Sand |
| 11/KH | 1 | 612 | 1.26 | 1.26 | $\rho_1 < \rho_2 > \rho_3 < \rho_4$ | Top soil |
| | 2 | 821 | 0.677 | 1.94 | | Clayed Sand |
| | 3 | 10.3 | 22.4 | 24.3 | | Clay |
| | 4 | 383 | | | | Sand |
| 12/KH | 1 | 244.7 | 0.5301 | 0.5301 | $\rho_1 < \rho_2 > \rho_3 < \rho_4$ | Top soil |
| | 2 | 1865 | 1.287 | 1.81 | | Clayed Sand |
| | 3 | 76.83 | 4.581 | 6.39 | | Clay |
| | 4 | 35368 | | | | Sand |

## 3.0 Methodology

The geophysical investigation involved the electrical resistivity method adopting the Horizontal Resistivity Profiling (HRP) using Wenner array and the Vertical Electrical Sounding (VES) with Schlumberger electrode array. The data was acquired using R50 resistivity meter. The HRP adopted inter electrode spacing of 10 m and was carried out along four traverses (two west to east and two north to south) in order to locate appropriate positions for VES points (Figure 1). The HRP data were presented as profiles and interpreted qualitatively by visual inspection for locations with relatively low apparent resistivity values that are inimical to stability of foundation structures. In Vertical Electrical Sounding (VES), the vertical variation in ground apparent resistivity values were measured with respect to a fixed centre of array. The survey was carried out by gradual increase in the electrode spacing (AB) with respect to the centre of the electrode array. Twelve (12) locations were occupied. The Schlumberger array was adopted with half current electrode spacing (AB/2) varying from 1 to 225 m. The apparent resistivity values ($\rho_a$) at each station were plotted against half current electrode spacing (AB/2) on a bi-logarithmic graph to generate sounding curves. Partial curve matching was carried out for the quantitative interpretation of the curves. The results of the curve matching (layer thickness and resistivity) were fed into the computer as starting model parameters in a 1D forward modelling using the Ipi2win software. From the interpreted results, geoelectric sections were generated to determine the topography and thickness of the underlying strata.

## 4.0 Results and discussion

The VES curves obtained from the study area are four (4) layers KH curve. In order to evolve a geological model of the subsurface layers, the VES interpretation results were used to generate 2-D geoelectric sections. Figures 3,4,5,6 show 2-D geoelectric sections in the study area. Traverse 1 (TR1) relates VES 1,2 and 3 (Figure 3); Traverse 2 (TR2) relates VES 4,5, and 6 (Figure 4); Traverse 3 (TR3) relates VES 7,8 and 9 (Figure 5); and Traverse 4 (TR4) relates 10,11, and 12 (Figure 6). The sections identified four geoelectric layers comprising the topsoil, clayed sand, clay and sand. These sections give respective layer resistivity values and thickness as shown in Table 1. The geoelectric characteristics are as following:

(i) Topsoil: The topsoil varies in composition from clay to sand with resistivity values varying from 85 to 612Ω-m. The thickness of the topsoil varies from 0.5 to 2.14 m.

(ii) Clayed Sand: The resistivity value varying from 295 to 2,587Ω-m. The thickness of the clayed sand varies from 0.67 to 3.41m.

(iii) Clay: The resistivity values varying from 10 Ω-m to 350 Ω-m. The thickness of the clay layer varies from 3.2 m to 26 m. It has thickest column at the middle of TR 1 and TR 3

(iv) Sand: The resistivity of the sand layer varies from 383 to 59707Ω-m

The theoretical depth of penetration of horizontal profiling using Wenner array is approximately 0.115AB, i.e. 3.45 m for AB of 30 m shown as dotted red lines in horizontal profiling curves along TR1 to TR4 (Figure 3). The results of horizontal profiling along TR1 to TR4 correlated well with the geoelectric section along TR1 to TR4 (Figure 7).

The generated geoelectric sections revealed the presence of competent clayed sand immediately below the topsoil of thickness varying from 0.67m to 3.41m but generally less than 1.5 m which make it unsuitable to host the foundation of high-rise structures. beneath this layer is the thick column clay of thickness ranging from 3.8 m to 26 m which is inimical to the competence of the foundation.The only competent layer is the sand layer.

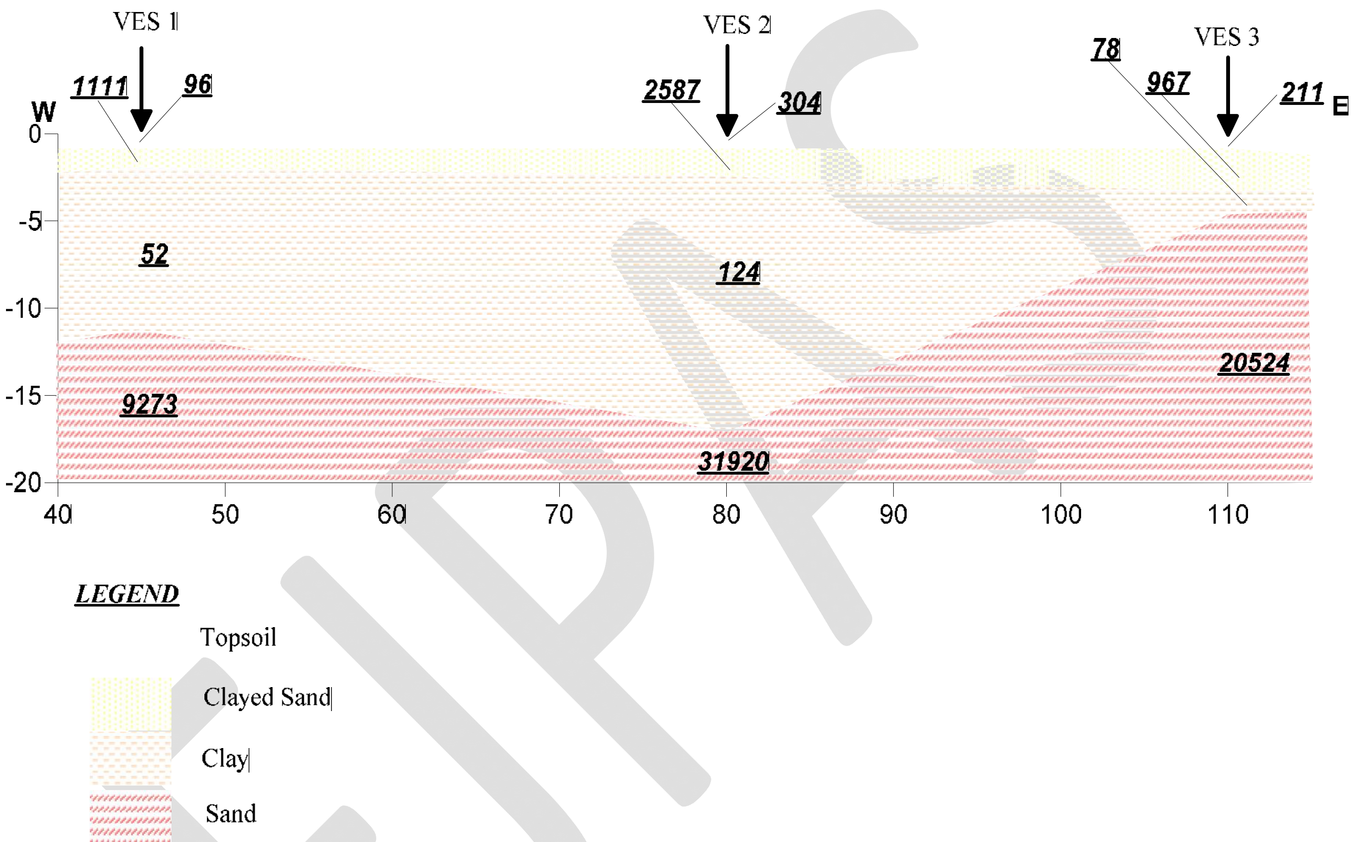


Figure 3: Geoelectric Section along Traverse TR 1

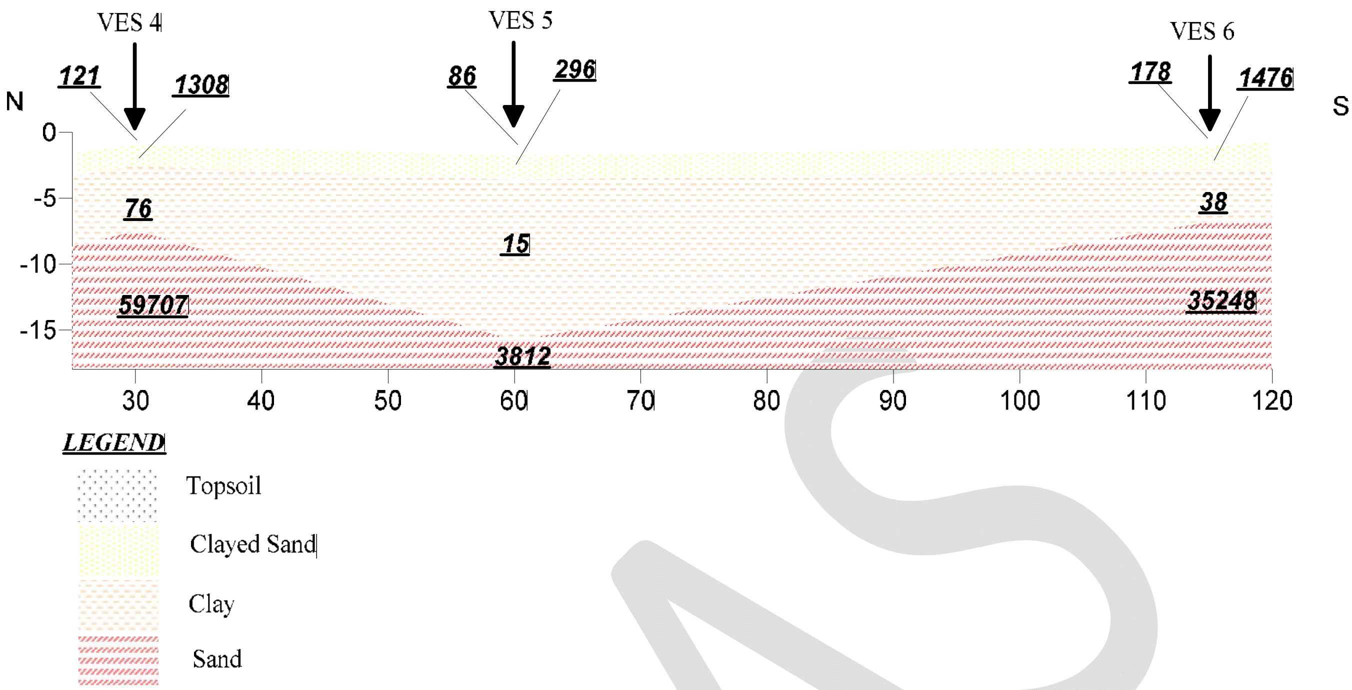


Figure 4: Geoelectric Section along Traverse TR 2

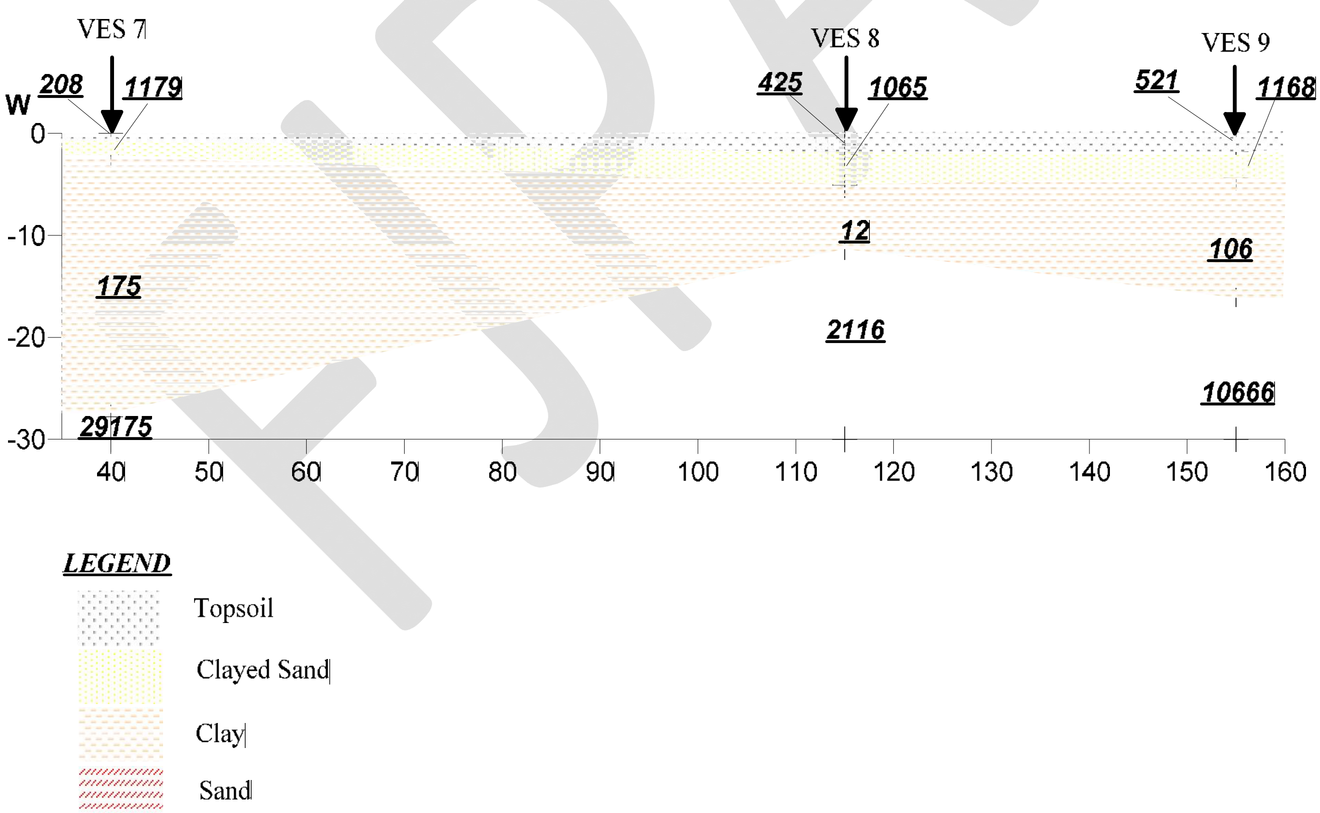


Figure 5: Geoelectric Section along Traverse TR 3

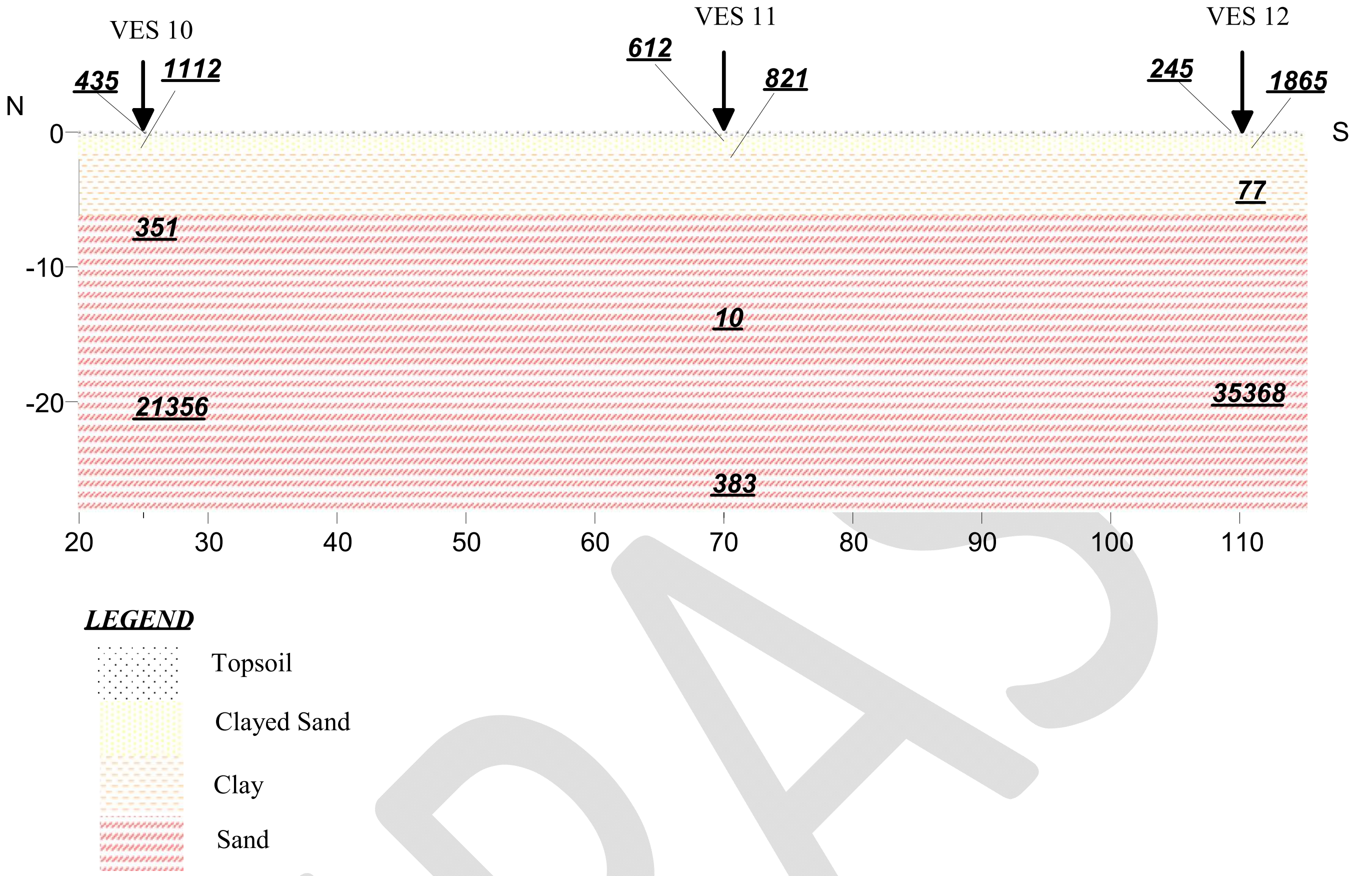


Figure 6: Geoelectric Section along Traverse TR 4


Figure 7: Comparison of Geoelectric Section and Horizontal Profiling along Traverses 1 to 4

## 5.0 Conclusion

Pre foundation study of Faculty of engineering, Ondo State University, Okitipupa, Southwestern Nigeria was carried out using geophysical approach. The geophysical method employed was electrical resistivity method adopting horizontal profiling technique using Wenner array and Vertical Electrical Sounding techniques using Schlumberger array. The geophysical data were processed and interpreted qualitatively and quantitatively to image the subsurface beneath the investigated area. The results show four (4) subsurface layers that is topsoil, clayed sand, clay and sand. The clayed sand would have been the best layer to host the foundation because of its depth to the surface but it is generally less than 1.5 m and underlay by thick column of clay. The only competent layer that can host the foundation of high-rise building is the sand layer, therefore, the building foundation should be piled to the sand layer or pilling should be suspended within the thick column of clay.

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