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# Geoelectric and Geotechnical Methods of Subsurface Conditions In Lagos State Polytechnic, Ikorodu, Nigeria

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***Abstract*— Geophysical method using 1-D and 2-D resistivity probing techniques and Geotechnical method using Cone Penetrometer Test (CPT) has been integrated to delineate the characteristics of subsurface layers at the School of Management and Library complex areas of Lagos State Polytechnic, Ikorodu. The 1-D vertical electrical resistivity sounding data (VES) and 2-D resistivity data using the Wenner array were acquired with Allied Ohmega Resistivity meter. Two 2.5 tonnes Cone Penetration Test (CPT) was considered for the work.. The VES data obtained were processed and interpreted using partial curve matching technique and 1D computer assisted forward modeling using WinResist software. The 2D data were also processed and interpreted using DiproWin software version 4.0. The interpreted results of the investigations shows that, the main lithological unit of the two areas consists of sandy clay and sand materials. In conclusions, the northern part of School of Management area consist of sandy clay, a mechanically unstable soil formations and the southern part consist of the sand layer which is viewed as the only competent geo-material for the foundation of any engineering works while in general, the Library complex area has competent sand layer that can support medium to giant engineering structures.**

***Keywords*— *DiproWin software; Geophysical method; Geotechnical method; Lithological unit; WinResist software.***

## I. INTRODUCTION

The statistics of failures of structures such as buildings, dam, bridges and roads throughout the country has increased geometrically and posed a threat to life and properties. The need for pre-foundation studies has therefore become very imperative so as to prevent loss accompany such failure [1]. Foundation studies usually provide subsurface information that aid in the design of structures [2]. In recent years, several organization and private individuals have been engaging in infrastructural development but recent studies showed that many of them do not engage the services of professionals in order to maximize profits; the effect being poor building constructions which may ultimately lead to gradual or sudden collapse of such structures [3].

The upgrading of the Lagos State Polythenic, Ikorodu, Lagos, with more buildings call for proper geophysical and geotechnical subsoil investigations for foundation works to avoid building collapse as well as loss of lives and properties. Geophysical surveys have been steadily increasing in importance in the last few decades. Their usefulness in the search for mineral deposits such as water, oil and gas and engineering investigation among others cannot be over emphasized.

Several authors such as [4-8], amongst others have identified various reasons for the failure of buildings in Nigeria. The reasons identified by them include: lack of structural design, faulty design implementation, faulty construction methodology, excess loads on buildings due to abtrarily increase in number of storeys, the host materials that is the soil type and failure to carry out and integrated geophysical and geotechnical methods. A combined geophysical and geotechnical investigations offer very useful approach for characterising near surface earth and thus can help in preparation before engineering structures are found on same [7].

## II. **LOCATION AND GEOLOGICAL SETTING OF THE STUDY AREAS**

Nigeria lies approximately between latitudes 4$^{o}$N and 15$^{o}$N and Longitudes 3$^{o}$E and 14$^{o}$E, within the Pan

African mobile belt in between the West African and Congo cratons. The Geology of Nigeria is dominated by crystalline and sedimentary rocks both occurring approximately in equal proportions [9].

The study areas are Library complex and School of Management, Lagos State Polytechnic, Ikorodu Campus. Ikorodu is a suburb of Lagos which is purely sedimentary and falls in Dahomey Basin (fig.1). It consists of thick shale in its Northern part with Coastal Plain Sand in its Southern end according to [10-13].

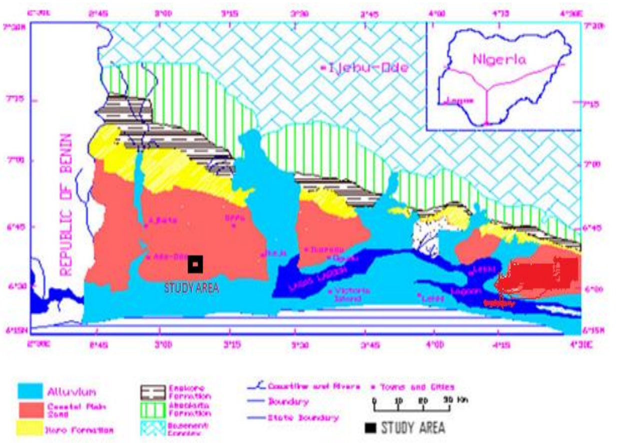


**Fig. 1**: Geologic map of Lagos showing the study area

III. MATERIALS AND METHODS

Figures 2 and 3 shows the location map of the study areas at Library Complex and School of Management respectively. The electrical resistivity data was acquired with the Allied Ohmega Resistivity meter along with its accessories, such as: two metallic current and two potential electrodes, four reels of cables, two reels of tape, hammer for driving the electrodes in the ground, GPS for finding the position and elevation of the survey point, data sheet for recording the field data. Six vertical electrical sounding of Schlumberger array with a total electrode spread (AB) was taken to a maximum of 400m.

One of the newly developments in recent years is the use of 2-D electrical imaging/tomography surveys to map areas with moderately complex geology. The equipment used was the same as that used in vertical electrical sounding (VES). Four electrodes of equal spacing were moved along each profile of the traverses.

The spacing was varied for 10m, 20m, 30m, 40m, 50m and 60m in turns. There are three traverses (profiles) conducted each in Library Complex and School of Management areas. The traverses are in North-South and East-West Directions. Wenner array has a high vertical resolution.

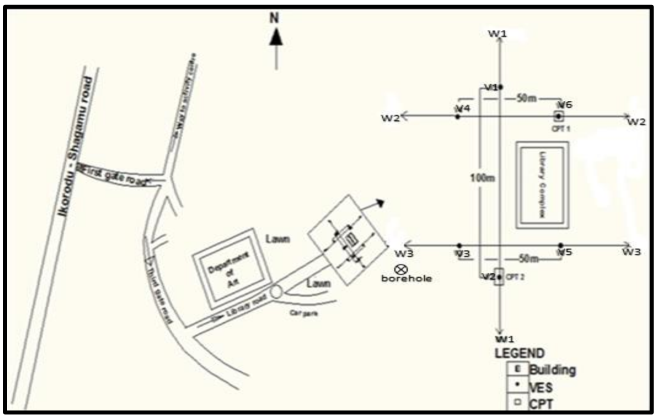


Figure 2: Location map of the Library Complex area showing the data points

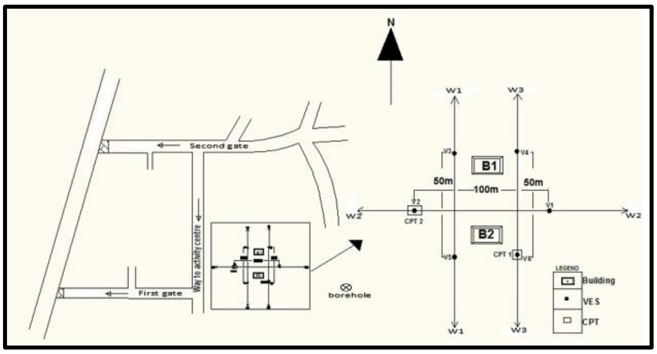


Figure 3: Location map of School of Management showing the data points

IV. THE CONE PENETROMETER TEST (CPT).

This test is a continuous measurement of resistance to penetration of the cone tip $(q_c)$ and frictional resistance$(f_s)$ [14 and 15]. Measurements can also be made of other soil parameters using more specialized cones such as pore water pressure (piezocone), electrical conductivity, shear wave velocity (seismic cone), pressuremeter cone, etc. Equation (1) shows the relationship between cone end resistance and sleeve frictional resistance.

$$R_f = \frac{q_c}{f_s} \qquad (1)$$

Where $R_f$ = frictional ratio

Two CPT tests were conducted on each profile corresponding to a VES points to constrain the geophysical results. $60^0$ cone head was penetrated to the ground through a set of 1m long rods. Measurements were taken at every 0.25m penetration of the rod into the ground. A borehole log was obtained for the borehole earlier drilled at the Library Complex.

V. DATA PROCESSING AND INTERPRETATION

a. Discussion on Vertical Electrical Sounding (VES) Results

Table 1 shows the summary of interpreted VES results with their curve type. The result of the VES at the Library complex has a maximum of four layered type curves. The curve types identified within the study area include HA, HK and AK type with the HA as the predominant curve type which compose of topsoil, sandy clay, sand and coarse sand. The topsoil of the lithology has a relatively low resistivity between the range 68.4 and 420.7 ohm-m and thickness range of 0.5 to 2.4m, the low resistivity values of the topsoil is attributed to the location found in the swampy area.

Table 1: Summary of the VES Results for Library Complex

| VES NO | LAY-ERS | RESISTI-VITY (Ωm) | THICK-NESS (m) | DEP-TH (m) | CUR-VE TYPE | INFER-RED LITHO-LOGY |
|---|---|---|---|---|---|---|
| **1** | 1 | 125.00 | 0.5 | 0.5 | **AK** | Topsoil |
| | 2 | 164.5 | 13.60 | 14.1 | | Sandy clay |
| | 3 | 400.01 | 24.00 | 38.1 | | Coarse sand |
| | 4 | 268.8 | | | | Sand |
| **2** | 1 | 117.5 | 2.4 | 2.4 | **HK** | Topsoil |
| | 2 | 102.6 | 6.0 | 8.4 | | Sandy clay |
| | 3 | 602.7 | 13.4 | 21.8 | | Coarse sand |
| | 4 | 427.5 | | | | Sand |
| **3** | 1 | 215 | 1.5 | 1.5 | **HA** | Topsoil |
| | 2 | 143.7 | 10.3 | 11.8 | | Sandy clay |
| | 3 | 259 | 35.4 | 47.2 | | Sand |
| | 4 | 695.6 | | | | Coarse sand |
| **4** | 1 | 420.7 | 0.5 | 0.5 | **HA** | Topsoil |
| | 2 | 172.7 | 13.7 | 14.2 | | Sandy clay |
| | 3 | 259.2 | 25.8 | 40 | | Sand |
| | 4 | 863.6 | | | | Coarse sand |
| **5** | 1 | 106.1 | 1.0 | 1.0 | **AK** | Topsoil |
| | 2 | 131.2 | 9.1 | 10.1 | | Sandy clay |
| | 3 | 180 | 43.9 | 54.0 | | Sand |
| | 4 | 474 | | | | Coarse sand |
| **6** | 1 | 68.4 | 1.3 | 1.3 | **HA** | Topsoil |
| | 2 | 197.7 | 7.5 | 8.8 | | Sandy clay |
| | 3 | 259.5 | 27.3 | 36.1 | | Sand |
| | 4 | 856.1 | | | | Coarse sand |

The second layer has same lithology for VES 1 to VES 6 which is sandy clay. The resisitivity range and the thickness are 102.6 – 197.7Ωm, and 6.0 - 13.7m. The weathered layer lithology is mainly sand a competent materials with a thick thickness of range 25.8 and 43.9m and low resistivity of values 180 and 259.5 ohm-m respectively for VES 3 to 6. The corresponding last layer is underlain by coarse sand of resistivity 474 - 863.6 ohm-m with a range of depth to basement values between 36.1 and 54.0m.

The computer iterated curves at the School of Management also showed a smooth geometry of four layers, characteristics of a typical sedimentary terrain. The curve types identified within the study area include KQ, QQ, KH and AK type which compose of topsoil, coarse sand, sandy clay and sand (Table 2).

The topsoil of the lithology has a relatively high resistivity than the recorded value at the Library complex between the range 313.1 and 2459.3 ohm-m and thickness range of 0.2 to 2.1m, the high resistivity values of the topsoil is attributed to the hard nature of soil deposits in the study area.

The second layer has same lithology for VES 2 to VES 6 which is coarse sand except VES 1. The resisitivity range and the thickness are 320.5 – 1313.4 Ωm, and 6.6 - 17.2m respectively. The weathered layer lithology for VES 2, 3 and 5 is mainly sandy clay a non - competent materials with thickness values ranging from 19.3m and 34.5m and a close resistivity values between 442.1 and 598.9 ohm

Table 2: Summary of the VES Results for School of Management

| VES NO | LAY ERS | RESISTIVITY (Ωm) | THICKNESS (m) | DEPTH (m) | CURVE TYPE | INFERRED LITHOLOGY |
|---|---|---|---|---|---|---|
| 1 | 1 | 49.5 | 0.2 | 0.2 | | Topsoil |
| | 2 | 320.5 | 6.6 | 6.8 | AK | Sand |
| | 3 | 652.6 | 23.6 | 30.4 | | Coarse sand |
| | 4 | 290.3 | | | | Sandy clay |
| 2 | 1 | 729.1 | 0.6 | 0.6 | | Topsoil |
| | 2 | 1094.6 | 6.0 | 6.6 | KH | Coarse sand |
| | 3 | 598.9 | 19.3 | 25.9 | | Sandy clay |
| | 4 | 621.2 | | | | Sand |
| 3 | 1 | 705.0 | 0.6 | 0.6 | | Topsoil |
| | 2 | 871.2 | 6.0 | 6.6 | KH | Coarse sand |
| | 3 | 483.0 | 19.3 | 25.9 | | Sandy clay |
| | 4 | 491.7 | | | | Sand |
| 4 | 1 | 2459.3 | 2.1 | 2.1 | | Topsoil |
| | 2 | 695.1 | 15.1 | 17.2 | QQ | Coarse sand |
| | 3 | 567.4 | 33.4 | 50.7 | | Sand |
| | 4 | 255.9 | | | | Sandy clay |
| 5 | 1 | 313.1 | 0.9 | 0.9 | | Topsoil |
| | 2 | 1243.1 | 5.8 | 6.7 | KH | Coarse sand |
| | 3 | 442.1 | 34.5 | 41.2 | | Sandy clay |
| | 4 | 682.8 | | | | Sand |
| 6 | 1 | 514.1 | 0.4 | 0.4 | | Topsoil |
| | 2 | 1313.4 | 6.6 | 7.0 | KQ | Coarse sand |
| | 3 | 652.1 | 37.9 | 45.0 | | Sand |
| | 4 | 340.3 | | | | Sandy clay |

The corresponding last layer is underlain by sand of resistivity 491.7 - 682.8 ohm-m with a range of depth to basement values between 25.9 and 41.2m. Similarly, the weathered layer lithology beneath VES 1, 4 and 6 is sand material with thickness of the sand layer vary from 23.6 to 37.9m with a corresponding resistivity values between 567.4 and 652.6 ohm-m.

b. Discussion on 2D Electrical Imaging of Traverse One

At the Library complex, total spread of 220m was surveyed in profile $W_1W_1$ as shown by the 2D resistivity structure in Figure 4 and a depth of 50m was probed from the North – South direction. The 2D resistivity structure has resistivity values ranging from 41 -1193Ωm, the first zone has a resistivity range of 41 – 150Ωm which is indicative of sandy clay as the topsoil along the profile which is along lateral distance of 0 – 25m and 90-100m at depth 0 - 6m and 0 - 4m respectively. The sandy clay is also shown to exist within a depth range of 25m – 50m along a lateral extend of 0 – 170m. Other geoelectric units are made up of resistivity range of 160 – 700Ωm and 800 - 1193Ωm which stretches along the section from about a lateral distance of 20 – 110m and 150 – 220m, which indicates regions of sand and coarse sand to a depth range of about 0 – 20m and 0 – 50m.

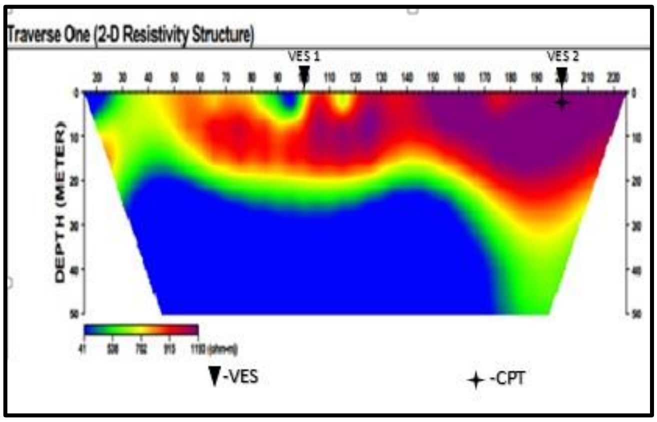


**Figure 4:** 2D Resistivity pseudo-section for traverse one at the Library Complex

A total spread of 220m was also surveyed in profile $W_1W1$ at the School of Management as shown in Figure 5 and a depth of 50m was probed from the North – South direction. The section has resistivity values ranging from 41.0-1193Ωm, the first zone has a resistivity range of 41 – 150Ωm which is indicative of dry clay as the topsoil along the profile which is along lateral distance of 0 – 25m and 90-100m at depth 0 - 6m and 0 - 4m respectively. The clay is also shown to exist within a depth range of 25m – 50m along a lateral extend of 0 – 170m.

Other geoelectric units are made up of resistivity range of 160 – 700Ωm and 800 -1193Ωm which stretches along the section from a lateral distance of 20 – 110m and 150 – 220m, which indicates regions of sand and coarse sand to a depth range of about 0 – 20m and 0 – 50m. From the trend of the inferred lithology, it is obvious that the area is essentially made up of sandy clay materials at high depth of 25 – 50m which VES was unable to reveal.

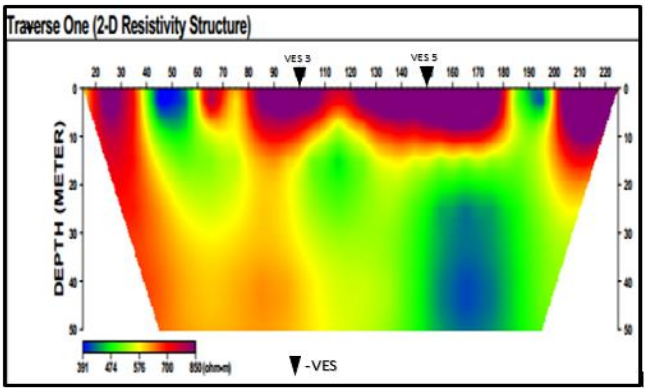


**Figure 5:** 2D Resistivity pseudo-section for traverse one at the School of Management

VI. DISCUSSION ON CONE PENETRATION TEST

A linear graph of cone resistance against depth of penetration was done by Excel software. The maximum cone resistance $(q_c)$ value at refusal was determined. The CPT tests were conducted at same locations as the VES points to constrain the geophysical results.

The cone resistance reading for CPT 2 was recorded to a depth of 4.8m as shown in Figure 6, before the 2.5 tons Dutch Cone Penetrometer anchor pulled, from the surface to a depth of about 3m a cone resistance about 40kg/cm$^2$ which is indicative of loose to medium dense granular soil and this value remained unchanged from the surface to this depth. While from a depth of 3m – 4m, the cone resistance value changed increased sharply to 72kg/cm$^2$ indicating medium dense granular soil, while from a depth of 4m – 4.2m, the cone resistance readings increases to 120kg/cm$^2$ indicating dense sand. . The graph of depth against the cone resistance is used to estimate the bearing capacity of the cone penetration test. Presence of strange debris in the subsurface might prevent the cone penetrometer from penetrating the soil as it is a point source.

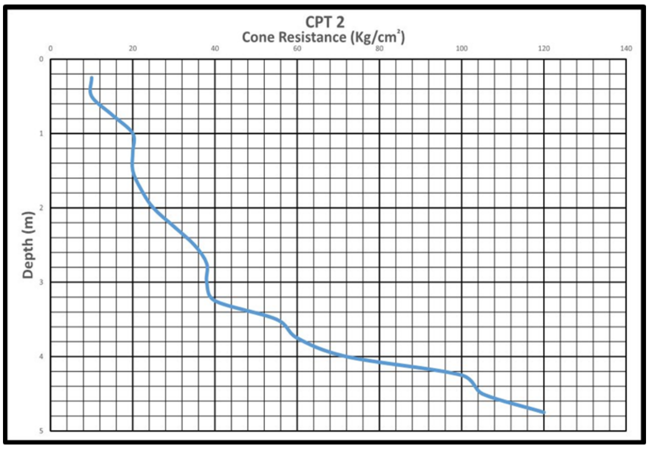


**Figure 6:** A Graph of Depth (m) against Cone Resistance (kg/cm$^2$) for CPT 2 at the Library Complex

The cone resistance reading for CPT 1 was recorded to a depth of 4.2m as shown in Figure 7, at the School of Management before the 2.5 tons Dutch Cone Penetrometer anchor pulled from the surface to a depth of about 2m with a cone resistance of about 20kg/cm$^2$ which is indicative of loose to medium dense granular soil and this value remained unchanged from the surface to this depth.

While from a depth of 2m – 2.8m, the cone resistance value changed and increased sharply to 70kg/cm$^2$ indicating medium dense granular soil, with this value maintain to a depth range of 2.8m – 4m while from a depth of 4m – 4.2m, the cone resistance readings increases to 180kg/cm$^2$ indicating dense sand. Presence of strange debris in the subsurface might prevent the cone penetrometer from penetrating the soil as it is a point source.

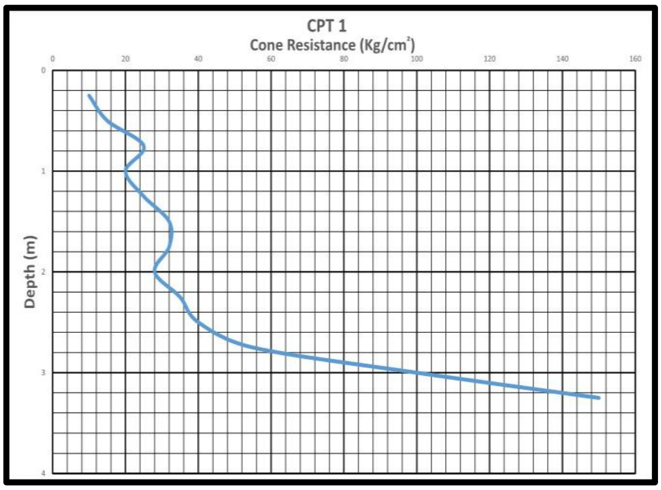


**Figure 7:** A Graph of Depth (m) against Cone Resistance (kg/cm2) for CPT 1 at the School of Management

VII. CONCLUSION

Geophysical investigation involving Vertical Electrical Sounding (VES) and 2D resistivity imaging methods was carried out along with geotechnical method in the Library complex and School of Management areas of Lagos State polytechnic to assess the subsurface layer for any engineering work.

In the study, six Vertical Electrical Sounding, three 2D resistivity imaging, two cone penetration Test data were obtained at the study area in order to characte-rize the subsurface, which is situated at Ikorodu, Lagos State. The integration of the VES results and 2D resistivity imaging data reveal four geoelectric layers which composed of topsoil, clayey sand, sand and coarse sand. A good correlation was found between the geoelectric sections inferred from the resistivity sounding data and the CPT test conducted. The presence of swampy area at the northern direc-tion of the study area at shallow depth is due to the soft nature of soil deposits in the study area and must be taken into consideration before any construction work is erected. On the whole, it is concluded that the area investigated has competent sand layer that can support medium to giant engineering structures.

Based on the results of the investigations at the School of Management area, the main lithological unit consists of sandy clay and sand materials. It is concluded that the northern part of the study area consist of sandy clay, a mechanically unstable soil formations which is capable of being inimical to building structures and the southern part consist of the sand layer which is viewed as the only competent geo-material for the foundation of any engineering structures within the study area.

This work has showed the importance of combination of geophysical and geotechnical techniques in engineering site characterization.

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