Determination of Sub-Soil Surface Layers Suitable for Site Foundation in Bowen University Iwo, Osun State

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Abstract: **Geo-electrical methods offer a fast, cheap and cost effective method of evaluating competency of soils for building foundations. Electrical investigation of sub-surface soils in Bowen University, Iwo, Osun State, Nigeria, was undertaken in order to acquires a VES data of the subsurface soil, construct geological section of the subsurface, delineate the possible geological structural beneath the study area and to categorize the area into different subsoil competence zones which will assist to prevent the structural failure and collapse of building in the future. Seven vertical electrical sounding stations were surveyed for the site investigation. Schlumberger array was used for the VES with maximum current electrode separation (XY/2) of 75m and readings of the resistance observed from the Terrameter were converted to apparent resistivity. The data obtained was presented as geoelectric sounding curve and geoelectric section shows the subsurface layer resistivity and thickness while geoelectric sounding curve were obtained by plotting apparent resistivity value against electrode spacing on a tracing paper superimpose on log graph sheet. All were iterated on the computer with a software program called WinResist version 1.0**

The results revealed three to four geo-electric sections within the study area which comprises topsoil, sandy clays/possibly gravel, lateritic layers and fresh basement which are between the depth of 1.1m to 20.9m below the earth surface. VES 1, 2, 4 and 6 of the study areas shows the lowest resistivity values that suggest high clay content or possible fracture which have impact on the competence and reliability of the soil for construction and building development. Therefore, the topsoil has to be excavated beyond the depth of 4.8m for the choice of shallow foundation that will be suitable for any engineering work and building development in the study area.

Key Words: **Resistivity, Foundation, lateritic, subsurface, Vertical Electrical Sounding**

I.BACKGROUND OF STUDY

Geophysics is the application method of physics to the study of the earth. All structures built on the earth surface have its own substructure that is, foundation that are supported by the soils and rocky materials. Most problems of structural failure can be associated to the failure of the builders to adequately have the knowledge of the physical parameters and geologic features governing competency of the soil material for building development. Therefore the nature of the soil or rock supporting the substructure becomes an extremely important issue for structural safety, integrity and durability. However, since every engineering structure is seated on geological earth materials, it is very essential to carryout pre-construction investigation of the subsurface of the proposed site in order to ascertain the strength and the fitness of the host earth materials as well as the timed post-construction monitoring of such structure to ensure its integrity. . (Lateef and Adegoke 2011) reiterated that in any engineering studies, Geophysical methods offer a fast, cheap and cost effective method of evaluating competency of soils for building foundations. Thus, in engineering and foundation studies Geophysics plays significant roles in the investigation of subsurface materials and structures which are likely to have significant engineering implication.

As alluded by (Poongothai and Sridhar 2017), Geophysical methods can be used to measure the physical properties of the subsurface, specifically related to the position of water and its quality, and the position and properties of geological units. Essentially, the geophysical methods comprise of measurement and interpretation of signals from or induced physical phenomena generated as a result of the spatial changes in one or more physical properties of sub-terrain formation. The various physical properties, currently used in different geophysical techniques for groundwater exploration are electrical conductivity, magnetic susceptibility, density, gravity, elasticity, dielectric constant and radioactivity. In this study, one of the geophysical methods, namely the electrical resistivity technique has been employed to delineate the subsurface lithology and assess the groundwater potential of the watershed.

Therefore a detailed investigation of the subsurface materials of the proposed site is an important task needed to be considered before the erection of any structure to avoid foundation failure and undue loss of lives and properties. Factors responsible for failure of engineering structures include poor construction materials, non-compliance to specifications, inadequate supervision and nature of the subsurface conditions of the ground on which the building is sited. To locate a successful site for construction in the sedimentary environment, a detailed subsurface study should be carried out. Site investigation is therefore required for a long term performance and stability of structures. The extent of such investigation depends on the type of foundation, the complexity of the soil conditions and available information on existing foundations on similar soils in order to ascertain the strength, bearing capacity and factor of safety of such soil. (Oluwafemi and Ogunribido 2014)

It is imperative to conduct pre-construction investigation of the subsurface of the proposed site in order to ascertain the strength and the fitness of the host earth materials as well as the timed post-construction monitoring of such structure to ensure its integrity. The need for pre - foundation studies has therefore become necessary so as to prevent loss of valuable lives and properties that always accompany such failures (Oyedele and Okoh, 2011).

The objective of this study is to integrate the geo-electrical method in order to determine the overburden thickness, delineate the subsurface layer and determine their geo-electric characteristics, determine the nature of the superficial deposits, investigate possible discontinuities and other exiting subsurface structures that may be inimical to the foundation of the any proposed engineering structure. It is also intended to evaluate the competency of the geologic materials underlying the study area to sustain the load of the proposed engineering structures (Mundher Dhahir Nsaif 2016).

The aim of this study is to investigate soil and to provide information on the stratigraphy, thickness, nature, and competence of the subsoil suitable for foundation building construction using geo-electrical methods of investigation.

II. OBJECTIVE OF THE STUDY

The study aims at investigating soil and to provide information of the stratigraphy, thickness, nature and competence of the sub-soil surface for site foundation.

The objectives are to:

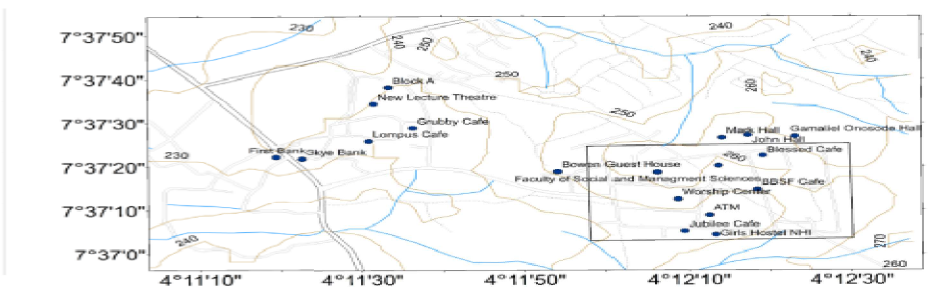
i. Acquire VES data of the subsurface soil in the study area
ii. Delineate possible geo-electric structural features beneath the study area and;
iii. Use (i) to categorize the area into different subsoil competence zones.

Statement Of The Problem

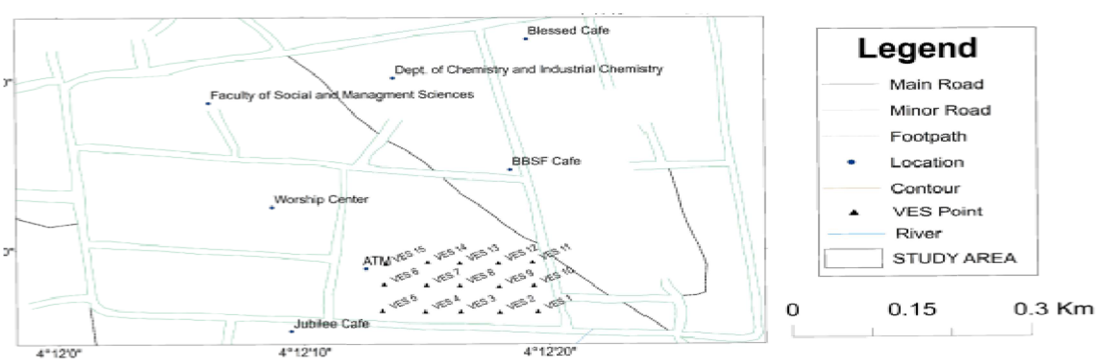
The major problems faced by the Engineers, builders, farmers in the time of past is the disregard of the fact that the use of land for any purposes like construction of roads, building of houses, using of land for farming, boring of holes for water consumption should be proceeded by a careful study of the subsoil surfaces on which the structures will be located as this has resulted to the failure of the many structures on the soil.

Study Area

The study site is located in Iwo Local Government in Osun State Nigeria; it is accessible due to availability of effective road network linking Iwo to Oluponna-Ikire. The area lies between Latitude 7o 37’ 5’’N to Latitude 7o 37’ 11’’N and Longitude 4o 12’ 13’’E to Longitude 4o 12’ 20’’E of the equator. It is located at an elevation of 260 meter above sea level. The study area is located within Bowen University Iwo, Osun State. (Fig 3.1)



Topographical map of Iwo



Topographical map of Bowen University Iwo

III. MATERIALS AND METHODS

Instrumentation and Measurement Procedure

Instruments and Field Equipment

i. RESISTIVITY METER: for this survey, the field data was acquired with the aid of Ohm mega resistivity meter, the meter comprises of the currents source, ammeter and voltmeter. This is a high-quality earth science resistance meter capable of accurate measurement over a wide range of conditions. The meter is powered by a large rechargeable battery. It has a maximum power of 10watts, manual selection of current in steps up to 100mA: Modern resistivity meter employ low frequency alternative current rather than direct current in order to prevent polarization effect at the electrodes and the possible interfering effect of natural current which cause regional potential anomalies
ii. ELECTRODES: These are two pair of electrodes from stainless steel were used. A pair served as current electrodes while the other served as the potential electrode. The electrodes were driven into the earth to ensure good electrical contact, at least two-third the length of the electrodes should be below the ground surface. A controlled amount of electrical current flows from the equipment through the current electrodes into the ground while the potential difference across the potential electrode is measure.
iii. CABLES: Two pair of cables was used to connect the electrode to the resistivity meter: one pair for current electrode and second pair for potential electrode.
iv. MEASURING TAPES: These are used in the graduation of the electrode spacing and to determine length of traverse.
v. HAMMER: This is used in driving the electrodes into the ground to maintain firm physical contact with the soil at their various positions.
vi. GLOBAL POSITIONING SYSTEM (GPS) DEVICE: The GPS is a satellite-base, global radio-navigation and time transfer system. Global Positioning System (GPS) device is used in taking the longitudes, latitudes and elevations of the mid-point between the current electrodes.

Figure 3.1: A typical Ohmega resistivity meter used

Measuring Procedure

The study area is located in Bowen University Iwo, Osun State, southwestern in Nigeria. The Vertical Electrical Sounding (VES) were conducted using the schlumberger electrode array. The Ohmega resistivity meter Figure (3.1) was used for resistance measurement. The geo-electrical survey comprised of seven (7) VES soundings with maximum current electrode spacing (XY) of 150m (AB/2=75). For the VES operation in the field, the resistivity meter was placed midway between the potential (C and D) electrodes (figures 3.1), while its terminal P1 and P2 were connected to C and D respectively. The current electrodes (A and B) are connected to terminals C1 and C2 respectively, apparent resistivity measurements at each station were plotted against electrode spacing (XY/2) on bi-logarithmic graph sheets. The curves were examined to obtain the number and nature of the layering. Partial curve matching was carried out for the quantitative interpretation of the curves. The results of the curve matching (layer resistivity and thickness) were fed into the computer as a starting model in an iterative forward modeling techniques using Win RESIST Version 1.0 (Vander Velper, 1988). The final layer resistivity and thicknesses were obtained from the modeling Measurement of resistivity, while Global Positioning System (GPS) was used to measure or get the elevation above the sea level, longitude and latitude of the Vertical Electrical Sounding (VES) position. The first step undertaken on the field was the reconnaissance study of the area to know the places to be sounded. Having established these points, they were marked on the base map and Vertical Electrical Sounding (VES) with Schlumberger array was carried out. Fifteen soundings were performed in the study area. The Vertical Electrical Sounding (VES) using Schlumberger configuration in which the potential electrodes remain fixed and the current electrodes were expanded symmetrically about the center of the spread. When the distance between the current electrodes in order to have measurable potential differences. Information related to local soil condition is vital for risk assessment and mitigation. The stage involves in the application of vertical electrical resistivity method of Geophysical survey. The geophysical investigations consist of Fifteen Vertical Electrical Soundings using the Schlumberger array, the electrical resistivity survey was carried out in Fifteen (15) VES. The electric current was introduced into the subsurface by means of two current electrodes, arranged on a straight line with the potential electrodes placed between them and symmetrically moved with respect to the centre.

Data Presentation and Interpretation:

Data generated from the Vertical Electrical Sounding using Schlumberger configuration were presented as geo-electric sounding curve and geo-electric section. Geo-electric section shows the subsurface layer resistivity and thickness while geo-electric sounding curve were obtained by plotting the apparent resistivity value against electrode spacing on a tracing paper superimpose on log-log graph sheet. All of which were iterated thereafter on the computer with the software program called WinResist version 1.0. The interpretation of vertical electrical sounding (VES) data for the survey is quantitative. The method employed is partial curve matching method, each curve generated from the sounding curve was matched segment by segment, while this is in progress, the axes of both the field curves and the model resistivity curve must be in parallel.

The partial curve matching can be regarded as the preliminary interpretation of the field curves which produce the layer resistivity and thickness values for computer iteration. The field data and the obtained parameters were input into the system for computer iteration using Win Resist package (Vander Velper, 1988), which in turn displayed the resultant theoretical curves. Therefore, the parameters were subsequently varied until what was considered the best possible fit between the field curve and the theoretical curve was obtained for each of VES stations. The parameters of the final models give the layer resistivity and thickness for the VES stations.

Qualitative Interpretation

The plots obtained from the resistivity data are examined and their form and character noted in term of the pattern of variation of resistivity with depth for VES, the type of curve obtained are also noted in term of;

Type curve A: $\rho 1 < \rho 2 < \rho 3$

Type curve H: $\rho 1 > \rho 2 < \rho 3$

Type curve K: $\rho 1 < \rho 2 > \rho 3$

Type curve Q: $\rho 1 > \rho 2 > \rho 3$

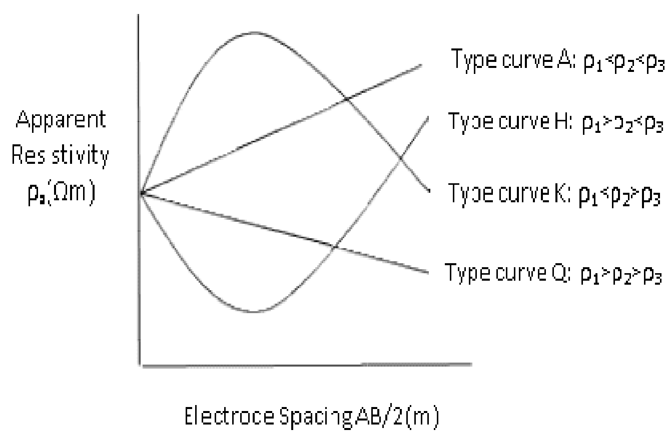


Fig 3.2; Apparent Resistivity curve type

Quantitative Interpretation

Once the observed resistivity curve has been identified as A, Q, H, K the number of layers is estimated (2, 3, 4, etc.). The resistivity and thickness of each layer are obtained by curve matching. This process compares the field curve with a set or sets of theoretical plotted curve using specific values of layer resistivity and thickness. When a match is obtained, the layer parameters of the matched theoretical curve become the Quantitative Interpretation of the field curve, the layer parameters are automatically adjusted by the program if no match (fit) is obtained.

An error tolerance limit is set for the program iteration and when this is achieved the model match become the interpreted layer parameter.

IV. RESULTS AND DISCUSSION

The electrical resistivity method of geophysical prospecting using Vertical Electrical Sounding (VES) technique was utilized to map the subsurface layers to a maximum depth of about 20.9m with minimum depth of 0.4m. The VES curves generated are shown in Figure (4.4.1–4.4.15). From the geo-electric section, the results of the interpretation show a system of three to geo-electric layers for VES 2-5 while VES 1 and 6 shows a system of four geo-electric layers. The curves show H, and KH curve pattern, the four geo-electric layers were topsoil, laterite, clayey sand (weathered) and basement (bedrock) formation, as obtained from the result of the partial curve matching which was refined by computer iteration. And the three geo-electrical layers were topsoil, laterite, clayey sand (weathered) or basement. These are tabulated in the Table (4.2) below. The Table 4.1 below shows the few standard resistivity values of rock materials

TABLE 4.1: Typical Resistivity values of Rock Materials

Rock type	**Resistivity (Ωm)**
Topsoil (Clay / Silt)	65 – 200
Laterite / indurated laterite	45 – 800
Weathered basement	2 – 220
Fractured basement	218 – 520
Fresh basement	> 1000

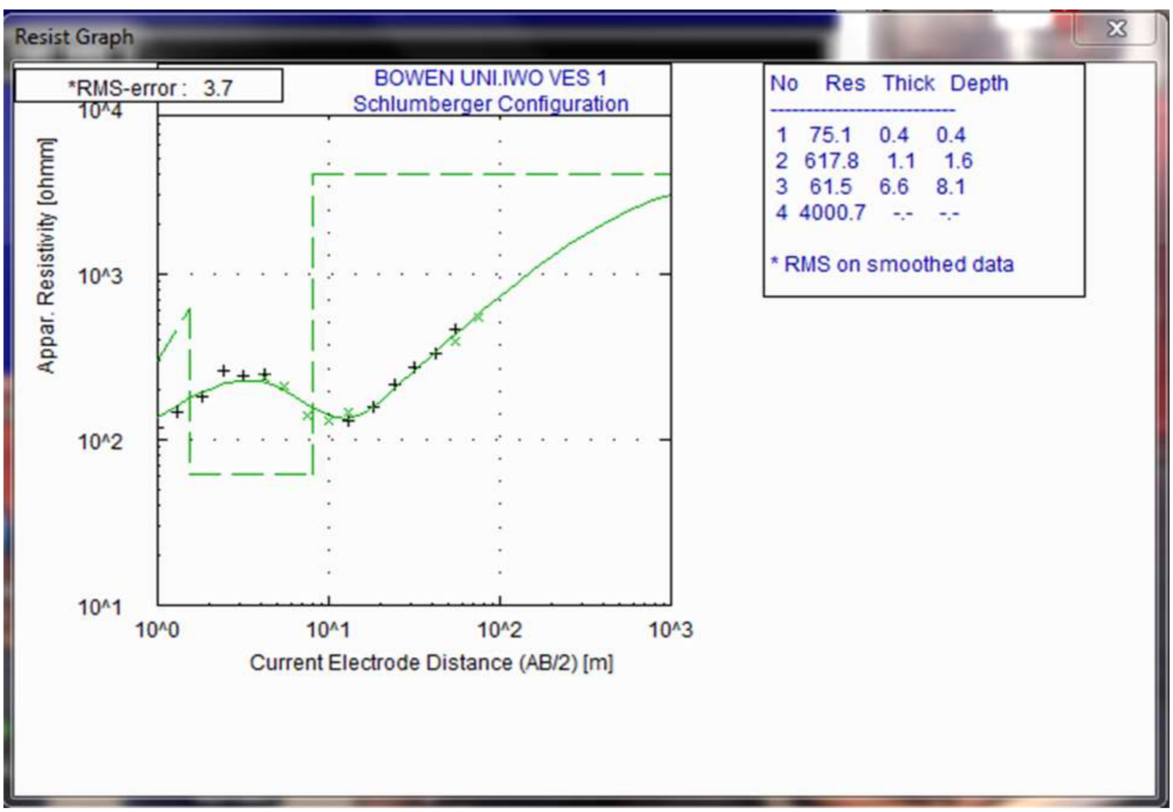
TABLE 4.2:SUMMARY OF VERTICAL ELECTRICAL SOUNDING (VES) INTERPRETATION

VES station	Location	Layer	Apparent Resistivity (Ωm)	Thickness (m)	Depth (m)	Probable Lithology
1	7.61818ºN 4.20549ºE	1	75	0.4	0.4	Topsoil
		2	618	1.1	1.5	Laterite
		3	62	6.6	8.1	Clay
		4	4001	-	-	Fresh Basement
2	7.61825ºN 4.20506ºE	1	247	1.2	1.2	Top soil
		2	63	3.0	4.2	Clay
		3	2196	-	-	Fresh Basement
3	7.61828ºN 4.20467ºE	1	292	1.7	1.7	Topsoil
		2	66	19.2	20.9	Clay
		3	1311	-	-	Fresh Basement
4	7.61829ºN 4.20420ºE	1	153	1.1	1.1	Top soil
		2	94	3.6	4.7	Clay
		3	1015	-	-	Fresh Basement
5	7.61835ºN 4.20385ºE	1	124	1.0	1.0	Topsoil
		2	88	5.5	6.5	Clay
		3	1997	-	-	Fresh Basement
6	7.61840ºN 4.20381ºE	1	44	0.4	0.4	Topsoil
		2	283	1.2	1.6	Laterite
		3	30	3.2	4.8	Clay
		4	621	-	-	Weathered Basement
7	7.61897ºN 4.20418ºE	1	220	0.8	0.8	Topsoil
		2	78	4.6	5.4	Laterite
		3	227	-	-	Weathered Basement

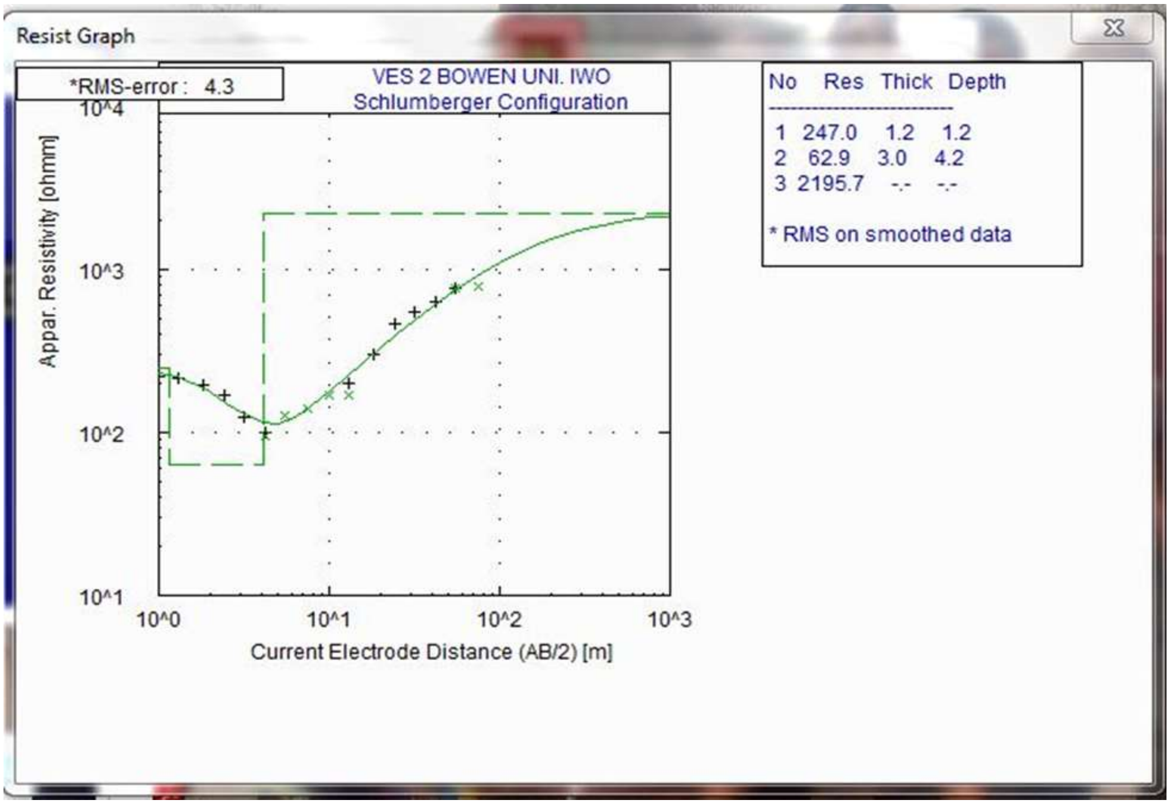
TABLE 4.3: SUMMARY OF VERTICAL ELECTRICAL SOUNDING (VES) CURVE TYPE

VES STATION	CURVE TYPE	CURVE RESISTIVITY
1	KH	$\rho_1<\rho_2>\rho_3<\rho_4$
2	H	$\rho_1<\rho_2<\rho_3$
3	H	$\rho_1<\rho_2<\rho_3$
4	H	$\rho_1<\rho_2<\rho_3$
5	H	$\rho_1<\rho_2<\rho_3$
6	KH	$\rho_1<\rho_2>\rho_3<\rho_4$
7	H	$\rho_1<\rho_2<\rho_3$

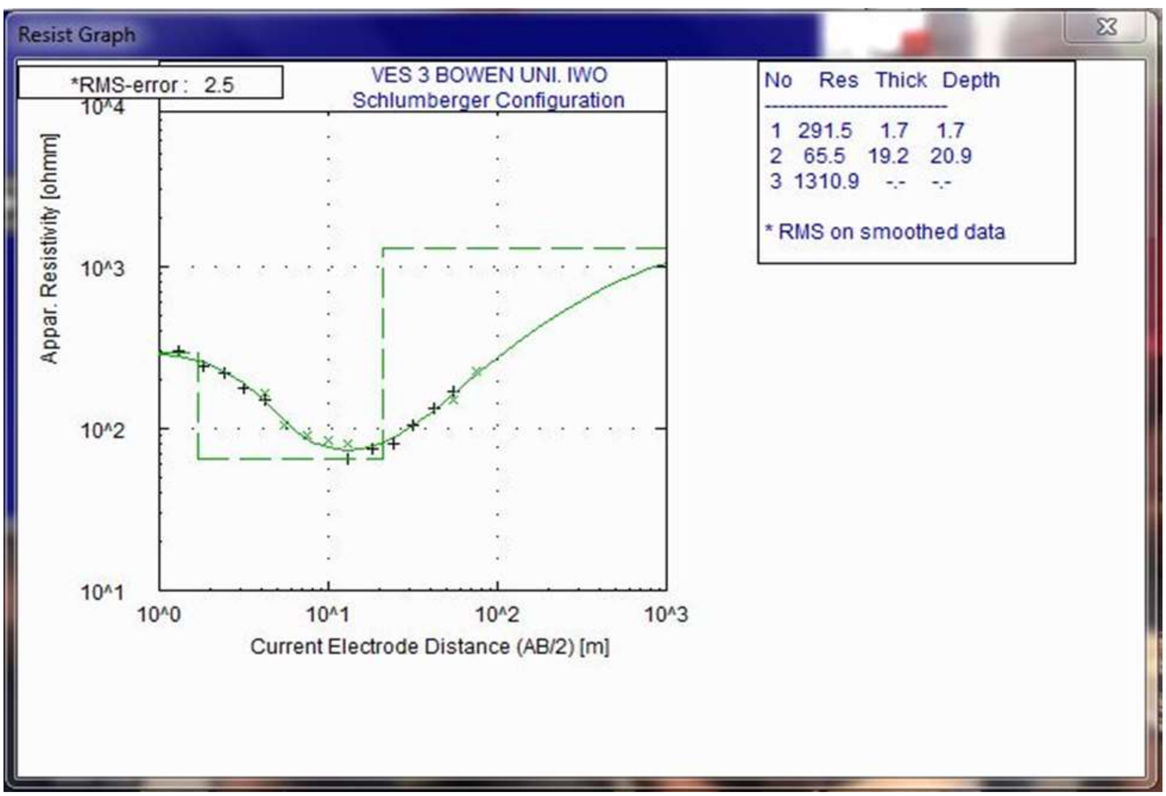
The major geo-electric sequences that were delineated were: topsoil (mostly clay and sandy clay), laterite, weathered basement formation. The first layer is made up of topsoil (clayey sand and sandy clay) which has resistivity values ranging from 44 to 2047 ohm meter. The thickness of the layer is between 0.4 and 1.7m. Beneath the topsoil are the laterite which are mainly wet lateritic of highest thickness with resistivity values vary from 88.1 to 980 Ohm-meter. The thickness ranges from 1.5 to 21m. The second layer of the study area is predominantly lateritic in nature which has the highest thickness of about 20.9m. It has a very low thickness at eastern part of the study area which is about 1.1m. The third layer is made up of the weathered formation that has resistivity values ranging from 62 to 574 Ohm-meter and has a depth range from 4.7 to 9.1m. The forth layer is made up of fresh basement that has the resistivity values ranging from 621 to 31616 Ohm-meters. The depth to the bedrock beyond 20.9m. Table (4.1) shows the summary of the results. The topsoil consists mainly of clay, laterite and sandy clay. The northern part of the study area has the lowest resistivity value (47 Ohm-meter) which is an indicative of a clay environment. But the thickness is about 2.5m. The VES point 8 of the study area; we have a closure of very high resistivity value reaching about 31616 Ohm-meter.



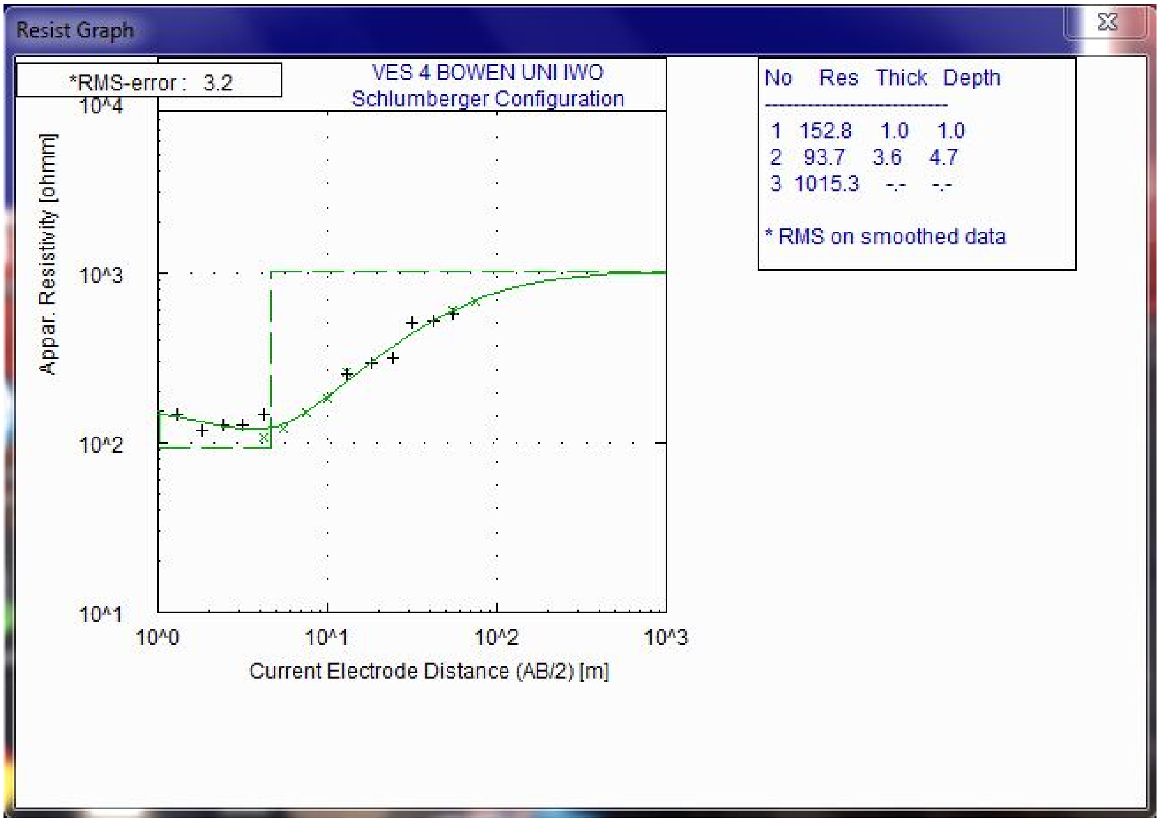
COMPUTER ITERATED GRAPH FOR VES 1



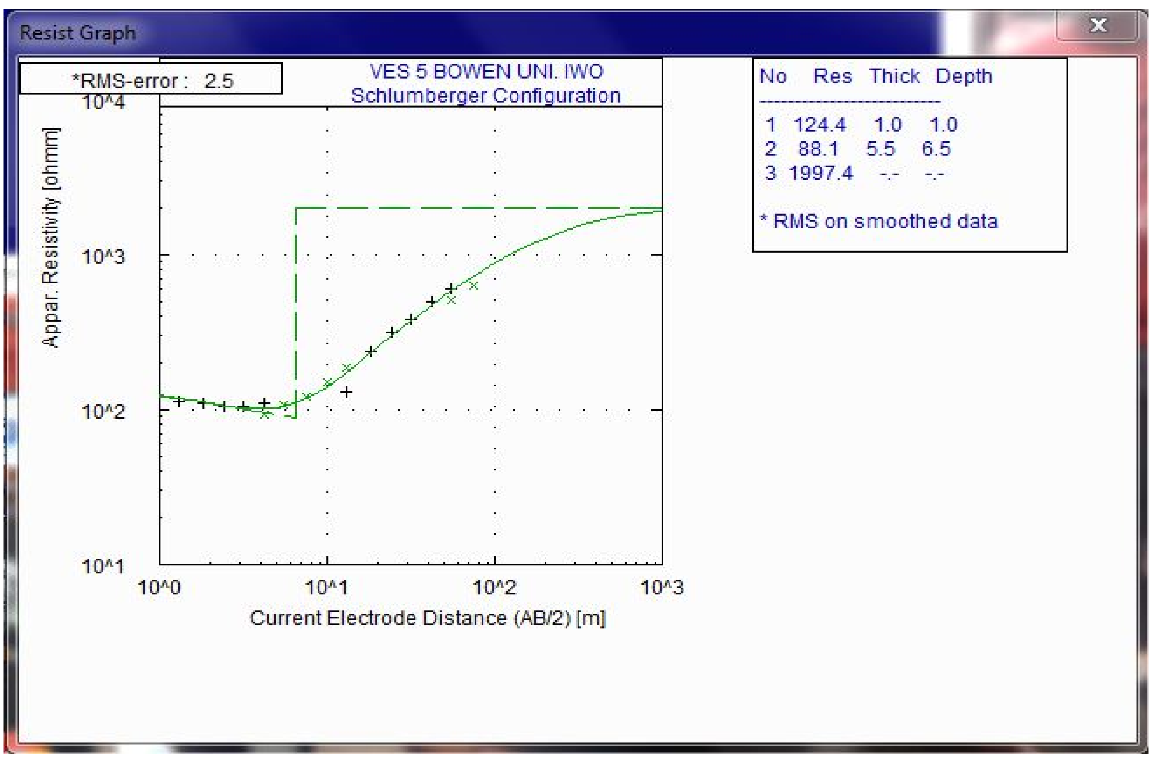
COMPUTER ITERATED GRAPH FOR VES 2



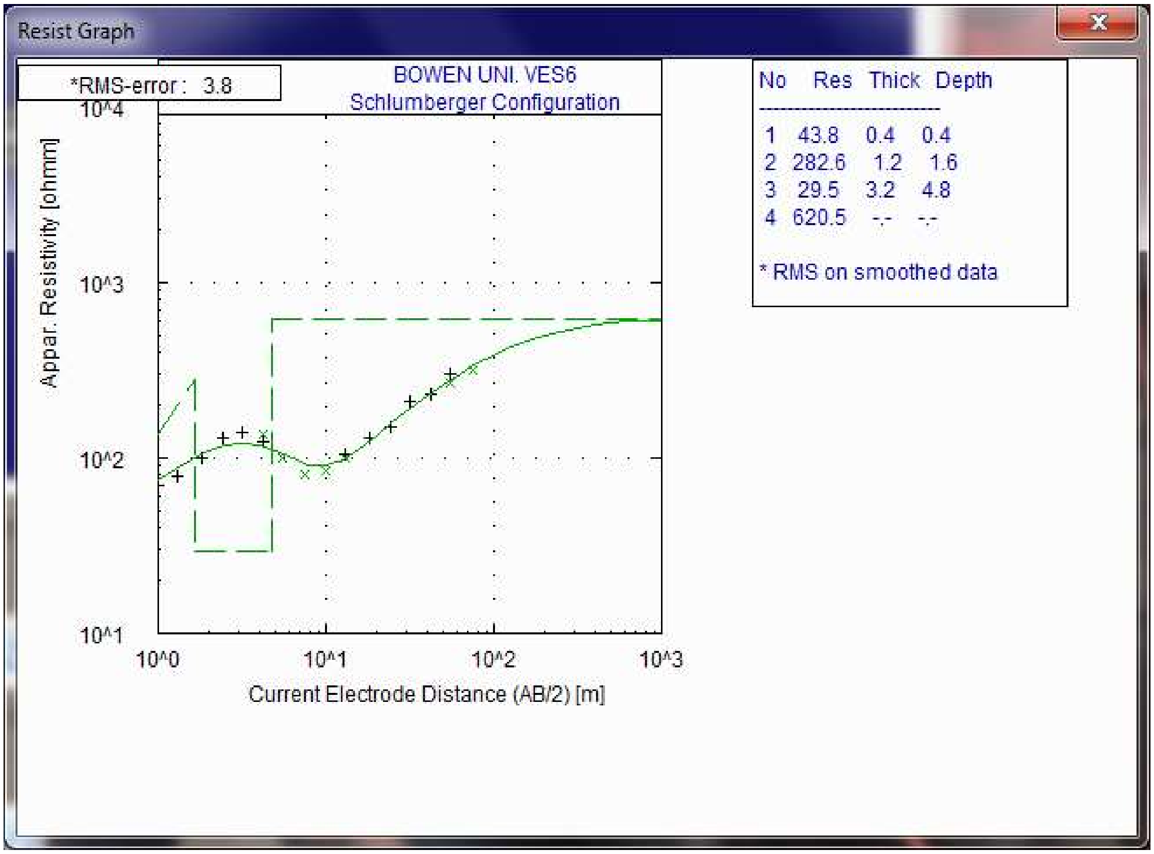
COMPUTER ITERATED GRAPH FOR VES 3



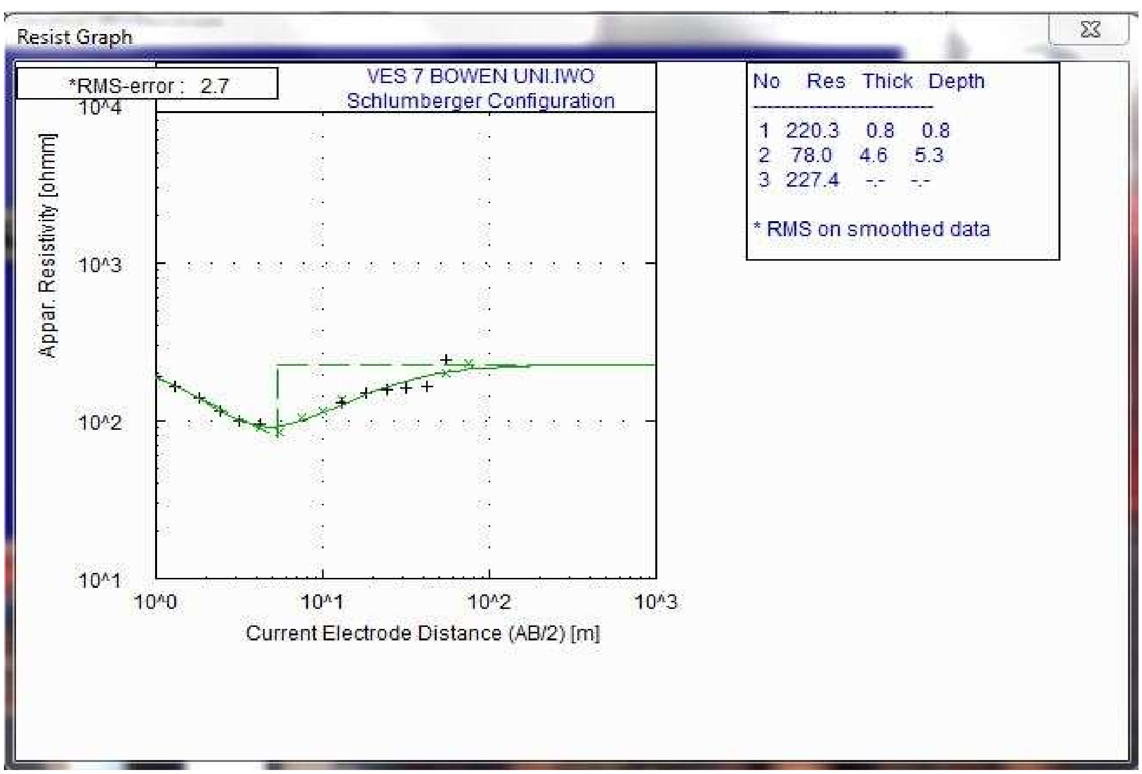
COMPUTER ITERATED GRAPH FOR VES 4



COMPUTER ITERATED GRAPH FOR VES 5



COMPUTER ITERATED GRAPH FOR VES 6



COMPUTER ITERATED GRAPH FOR VES 7

V. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Surface geo-electrical investigation methods involving electrical resistivity method had been used essentially in this study to delineate subsoil surface in Bowen University Iwo, Oyo-Ikire road, Iwo, Osun State Nigeria. The results revealed three to four geo-electric sequences within the study area which comprises topsoil, sandy clay and laterite and weathered basement, which means that the topsoil has to be excavated beyond the depth of 4.8m for the choice of shallow foundation for study area and lateritic layers are between the depth of 1.1 to 20.9m below the earth surface which means that for building development in the study area must be excavated to a reasonable depth in between the lateritic layer at which the soil is adequate competence to bear the load because lateritic soil has a greater load bearing capacity. The thicknesses of the topsoil's range from about 0.4m to 19.2m; but most are less than 2m. VES 1 and 6 exhibit KH curve type, while the remaining VES(s)exhibit H curve type as shown in Table (4.2).

Recommendation

From the survey results, VES 1,2,4 and 6, have a very low resistivity's, which show that the points are conductive due to clayey sand, which may bring about future collapse of structure erection on it therefore these VES points are not recommended for construction due to low resistivity. But VES points 3 & 5 is recommended for construction of building, due to it basement. It is necessary to excavate the soil to some depth so that the structure to be erected will directly rest on the competent bed depending on the structure of the building. Further and geotechnical analysis should be carried out on the soil sample of the study area

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