Application of Electrical Resistivity in Buildings Foundation Investigation in Ibese Southwestern Nigeria

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ABSTRACT

Application of geophysical investigation has been carried out using Vertical Electrical Sounding (VES) at the proposed building site in Ibese Southwest Nigeria to determine the geophysical parameters that can be used to evaluate the structural competence of the subsurface geological characteristics of the site for construction purposes and building development. The Schlumberger configuration was used for the data acquisition. One-dimensional numerical inversion of individual DC resistivity was used to enhance the processing of the results for better achievement of the aim of the study. Models obtained from the 2D inversion of each VES were used for construction of geo-electric sections which exhibit the main geo-electric characteristics of the geological units present in the area. The interpretation results showed that the geo-electric sections consist of three-four layers namely: topsoil, pebble clay, limestone and sand/limestone. The layer resistivities and thicknesses range from 11 - 404 Ohm-m/0.4 - 1.5 m, 2-210 Ohm-m/ 0.8 - 9.2m and 33 - 160Ohm-m respectively. The investigation revealed that the sand/limestone litho unit is to be the most competent for shallow foundation for small to medium engineering structures.

Keywords: Geophysical, building, geo-electric section, shallow foundation

How to Cite:
Omowumi FP. 2014. Application of Electrical Resistivity in Buildings Foundation Investigation in Ibese Southwestern Nigeria *Asia Pacific Journal of Energy and Environment*, 1, 91-102.

Source of Support: Nil
Conflict of Interest: None declared

INTRODUCTION

Foundation investigation is an important program in building and engineering structures. Several approaches have been used for the success of foundation investigations. Geophysical methods, particularly electrical resistivity technique, had been extensively used for a wide variety of engineering and environmental problems (Zohdy, 1975; Barker, 1980; Boyce and Kaseoglu, 1996; Mousa, 2003, Olorunfemi, et al., 2004; Hosny et al., 2005; Alotaibi and Al-Amri, 2007; Nigm et al., 2008; Oyedele et al., 2009). The application of electrical resistivity survey has become a prime choice, as a result of the cheap cost that is involve and the fact that it saves time and easy to carry out, and can also be used to determine geological structures (Al-Sayed and El-Qady 2007). Engineering applications of electrical resistivity include investigation the bridge, dam and building structure foundations using electrical resistivity survey (Omoyoloye et al., 2008; Adeoti et al., 2009; Mahmoud; et al., 2009). Apart from engineering applications, electrical resistivity can also be of great importance in ground water investigation, determination of contamination source and impact of leachate. In this study, a non-destructive geophysical technique involving Vertical Electrical Sounding using Schlumberger array was adopted to investigate the subsurface conditions at the proposed building site in Ibese with the aim of determining the competency of the competent soil upon which the structure will be laid.

DESCRIPTION OF THE STUDY AREA

Ibese town is about 4km North of Ilaro town in Yewa North Local Government Area of Ogun state. The study area approximately bounded in the North by Longitude 07^0 00'14.0''- 7^0 00'03.2'' and in the East by Latitude $003^0$02'58.0'' - $003^0$02'49.1'' The topography of the area is of relatively flat to a gentle slope terrain. The study area lies in Southern Nigeria, which is within the humid tropical region of the equatorial zone and is typified by two main climatic seasons, namely the wet and dry seasons. The area belongs to the tropical rainforest of southern Nigeria and is covered mainly by tall trees typical of savannah vegetation. The coastal swamp is mainly mangrove. The local geology of the study area (Fig.2) is that of Ewekoro formation.

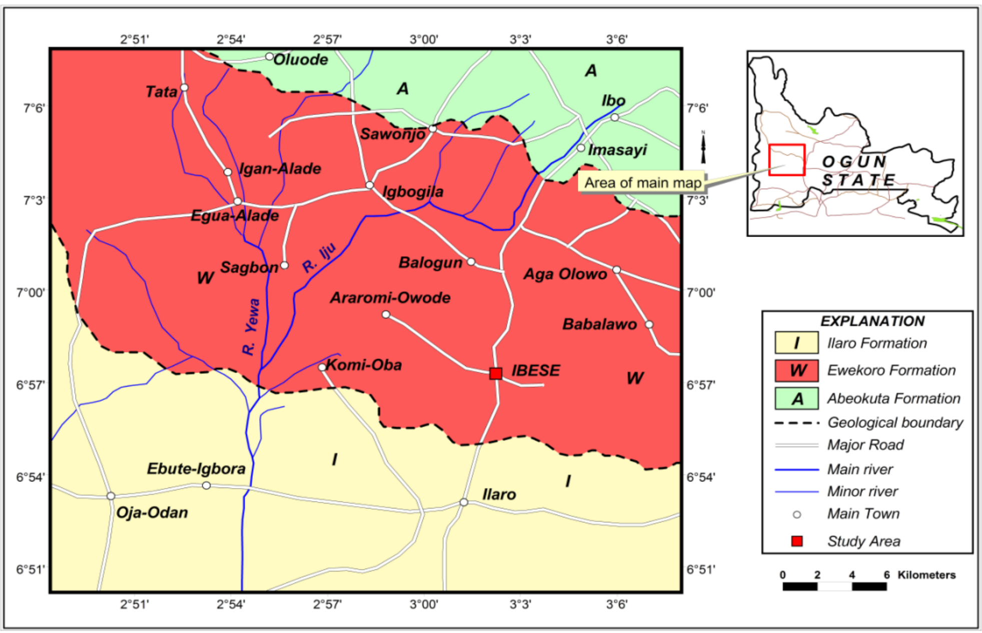

Figure 1, Geological map around Ibese showing the study area

MATERIALS AND METHODS

Vertical Electrical Sounding (VES) using the Schlumberger electrode configuration (Fig 2) was carried out at fifteen (15) selected points within the study area (Fig.3). In all, fifteen VES points were located and fully occupied within the study area. The VES data obtained were subjected to partial curve matching using two-layer master curves and auxiliary curves as an initial stage of data interpretation (Orellana and Mooney, 1966; 1972). The layered earth model thus obtained served as the input model for the inversion algorithm as a final stage in the quantitative data interpretation (Zohdy, 1973; 1975 and 1989). The final interpreted results were used for the preparation of geo-electric sections and maps.

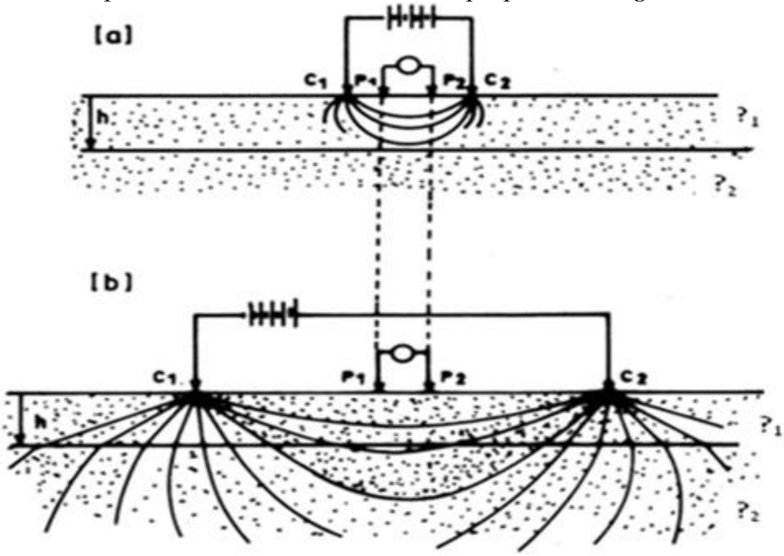

Figure 2, Principle of electric sounding (a) For small current electrode separation (b) For larger current electrode separation

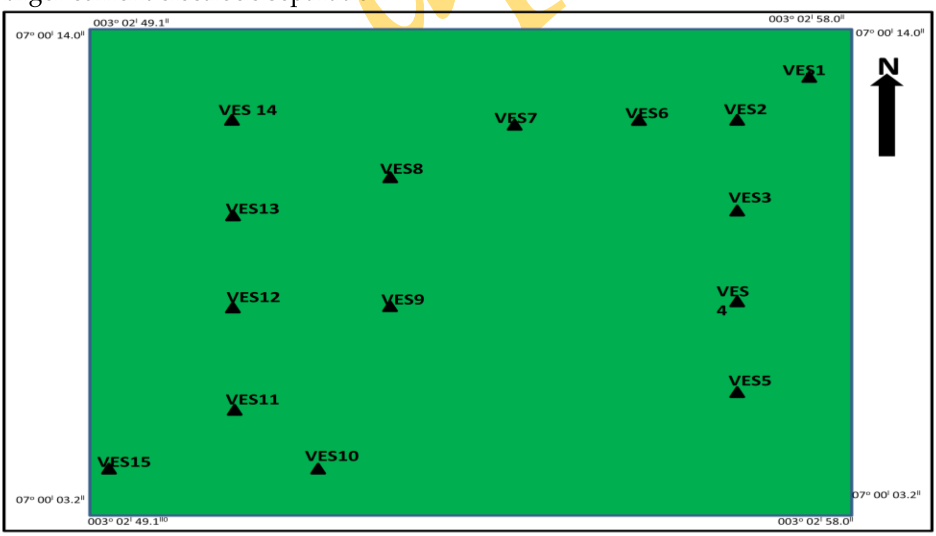

Figure 3: Spatial distribution of the VES point

RESULTS AND DISCUSSION

The result of the geophysical survey is presented in Sounding Curves, Geo-electric sections and Maps. The layer model interpretations of all the VES points are presented in the figure 4a-4o. The results of the interpretation show a system of three geo-electric layers for VES1-14 while VES15 shows a system of four geo-electric layers. All the curves show an H curve pattern. A summary of the VES interpretation is presented on Table 5.1. From the Table, it is quite evident that the resistivity of the first layer is very low indicating a high degree of saturation. The resistivity values range from 1.7 – 21 Ohm-m suggesting saturated clay/limestone unit. The thickness of this layer ranges from 6 – 9.2 m. The second-layer shows a fairly saturated sandy/limestone unit with resistivity value ranging from 33-269.3 Ohm-m.

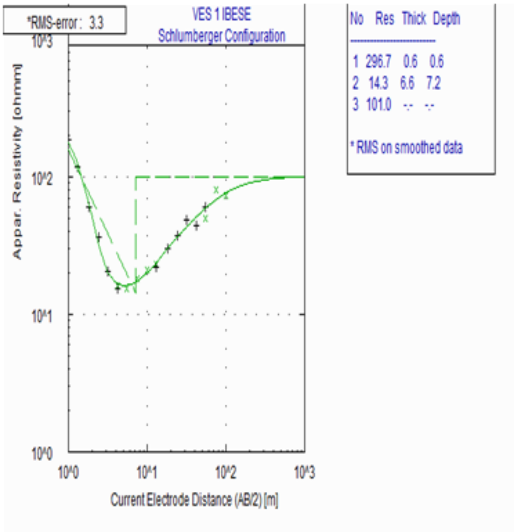

Fig. 4a, Computed iterated graph for VES1

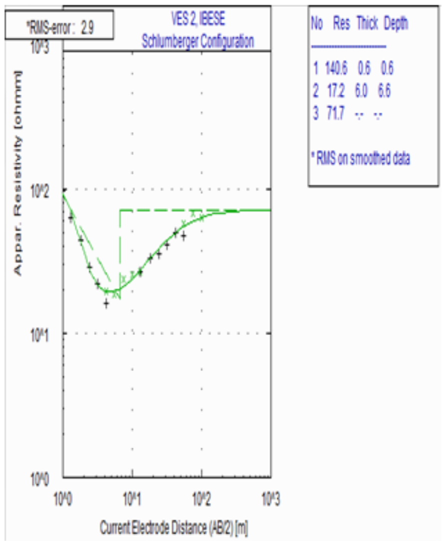

Fig. 4b, Computed iterated graph for VES2

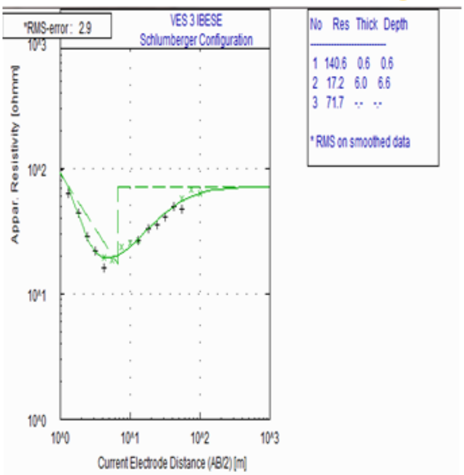

Fig. 4c, Computed iterated graph for VES3

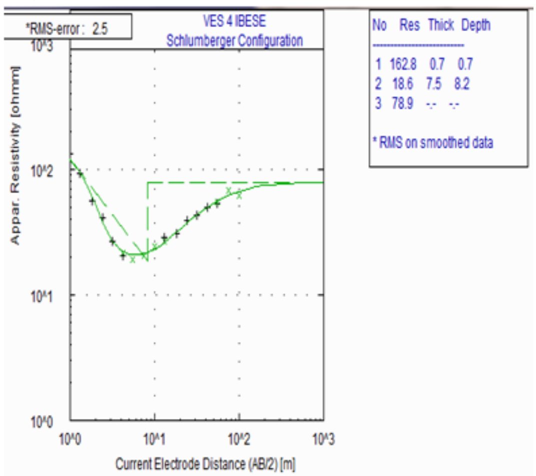

Fig. 4d, Computed iterated graph for VES4

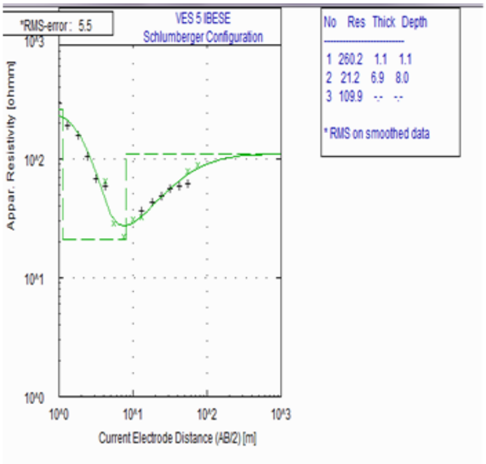

Fig. 4e, Computed iterated graph for VES5

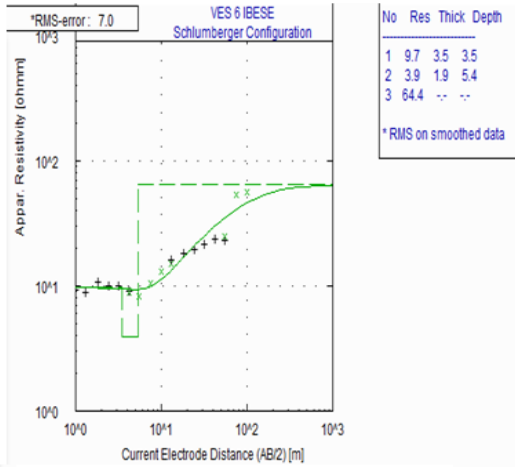

Fig. 4f, Computed iterated graph for VES6

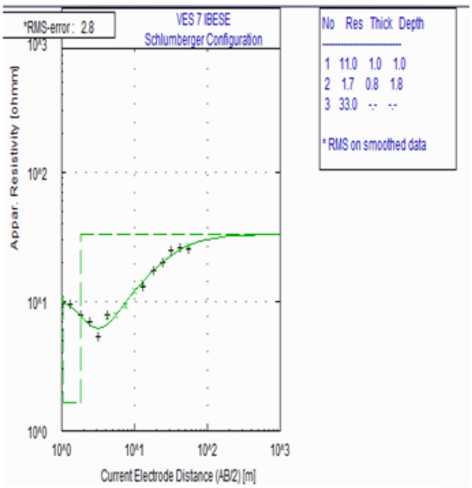

Fig. 4g, Computed iterated graph for VES7

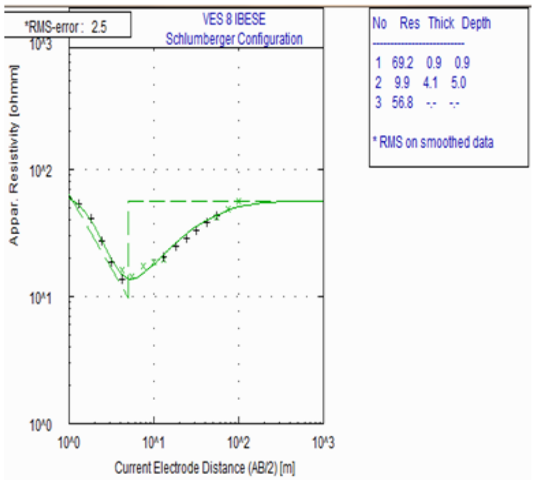

Fig. 4h, Computed iterated graph for VES8

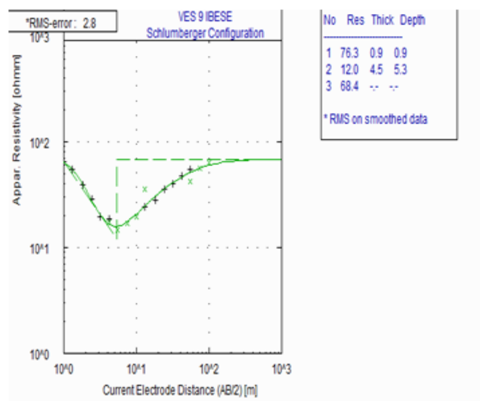

Fig. 4i, Computed iterated graph for VES9

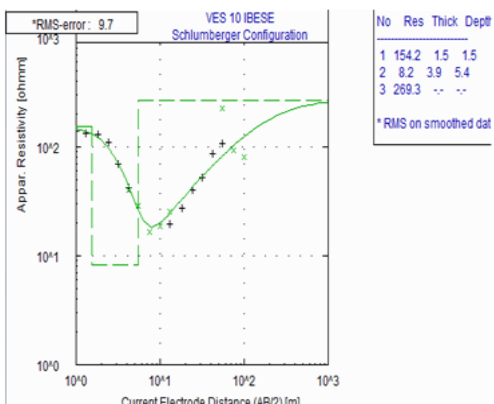

Fig. 4j, Computed iterated graph for VES10

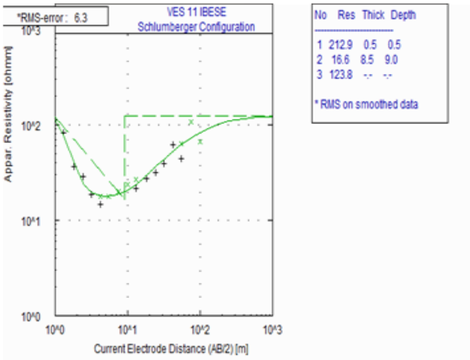

Fig. 4k, Computed iterated graph for VES11

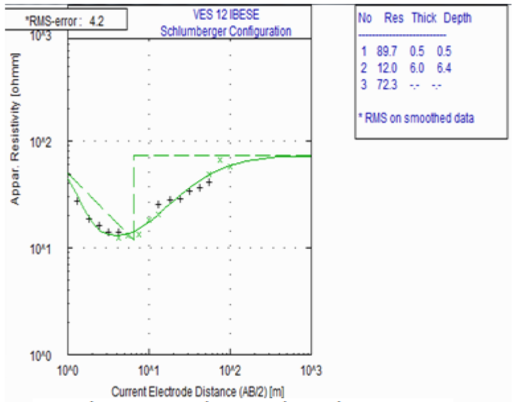

Fig. 4l, Computed iterated graph for VES12

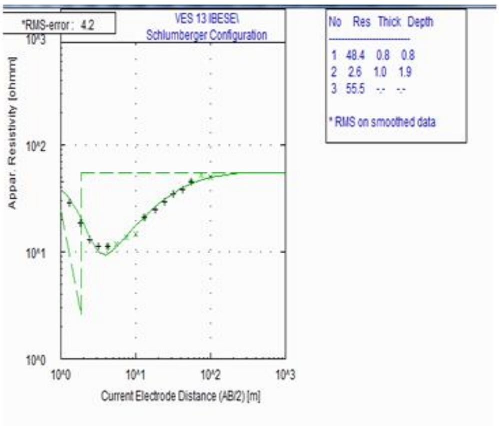

Fig. 4m, Computed iterated graph for VES13

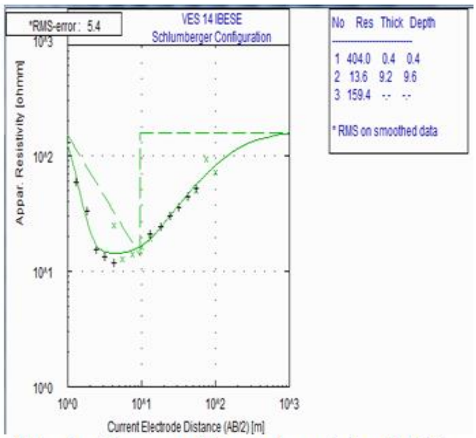

Fig. 4n, Computed iterated graph for VES14

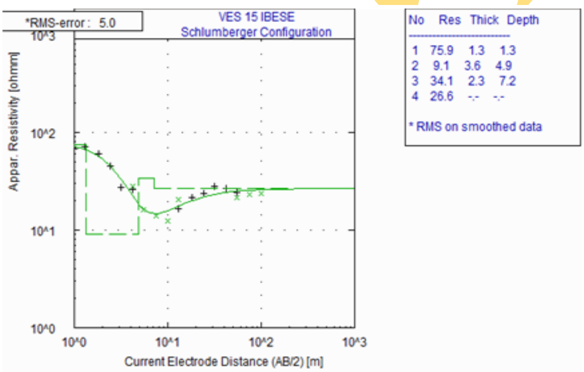

Fig. 4o, Computed iterated graph for VES15

Table 5.1: Summary of VES data interpretation

S/N	Layers	Resistivity (Ωm)	Thickness (m)	Depth (m)	Curve Type	Reflection Coefficient	Probable Lithology
VES 1	I.	296.7	0.6	0.6	H-Type	0.4245	Topsoil
	II.	14.3	6.6	7.2	$\rho_1 > \rho_2 < \rho_3$		Clay
	III.	101.0					Sandy Clay
VES 2	I.	296.9	0.6	0.6	H-Type	0.7530	Topsoil
	II.	14.4	6.7	7.3	$\rho_1 > \rho_2 < \rho_3$		Clay
	III.	102.2					Limestone
VES 3	I.	140.6	0.6	0.6	H-Type	0.6130	Topsoil
	II.	17.2	6.0	6.6	$\rho_1 > \rho_2 < \rho_3$		Clay/Limestone
	III.	71.7					Sandy clay
VES 4	I.	162.8	0.7	0.7	H-Type	0.6184	Topsoil
	II.	18.6	7.5	8.2	$\rho_1 > \rho_2 < \rho_3$		Clay
	III.	78.9					Limestone
VES 5	I.	260.2	1.1	1.1	H-Type	0.6763	Topsoil
	II.	21.2	6.9	8.0	$\rho_1 > \rho_2 < \rho_3$		Clay/Limestone
	III.	109.8					Sandy clay
VES 6	I.	10	3.5	3.5	H-Type	0.8824	Topsoil
	II.	4	1.9	5.4	$\rho_1 > \rho_2 < \rho_3$		Clay
	III.	64					Clay/Limestone
VES 7	I.	11.0	1.0	1.0	H-Type	0.3542	Topsoil
	II.	1.7	0.8	1.8	$\rho_1 > \rho_2 < \rho_3$		Clay
	III.	33.0					Clay/Limestone
VES 8	I.	69.2	0.9	0.9	H-Type	0.7031	Topsoil
	II.	9.9	4.1	5.0	$\rho_1 > \rho_2 < \rho_3$		Clay
	III.	56.8					Sandy clay
VES 9	I.	76.3	0.9	0.9	H-Type	0.7015	Topsoil
	II.	12.0	4.5	5.3	$\rho_1 > \rho_2 < \rho_3$		Clay/Limestone
	III.	68.4					Sandy/Limestone
VES 10	I.	154.2	1.5	1.5	H-Type	0.9387	Topsoil
	II.	8.2	3.9	5.4	$\rho_1 > \rho_2 < \rho_3$		Clay
	III.	259.3					Limestone
VES 11	I.	212.9	0.5	0.5	H-Type	0.7635	Topsoil
	II.	16.6	8.5	9.0	$\rho_1 > \rho_2 < \rho_3$		Clay
	III.	123.8					Limestone
VES 12	I.	89.7	0.5	0.5	H-Type	0.7153	Topsoil
	II.	12.0	6.0	6.4	$\rho_1 > \rho_2 < \rho_3$		Clay
	III.	72.3					Sandy/Clay
VES 13	I.	48.4	0.8	0.8	H-Type		Topsoil
	II.	2.6	1.0	1.9	$\rho_1 > \rho_2 < \rho_3$	0.9105	Clay
	III.	55.5					Clay/Limestone
VES 14	I.	404.0	0.4	0.4	H-Type		Topsoil
	II.	13.6	9.2	9.6	$\rho_1 > \rho_2 < \rho_3$		Clay
	III.	159.4				0.8428	Clay/Sand
VES 15	I.	75.6	1.3	1.3	H-Type		Topsoil
	II.	9.1	3.6	4.9	$\rho_1 > \rho_2 < \rho_3$	0.5787	Clay
	III.	34.1	2.3	7.2			Clay/Limestone
	IV	26.6					Clay

GEOELECTRIC AND LITHOLOGICAL CHARACTERISTIC

The VES results were used to prepare 2-D geo-electric sections Figures 5a-c. The geo-electric sections revealed three geo-electric/geologic subsurface layers comprising the topsoil (resistivity varies from 11-404 Ohm-m and thickness range from 0.4 to 1.5 m); second layer clay/sand horizon (resistivity varies from 2 to21 Ohm-m and thickness range from 0.8-9.2m); and the resistivity value of the limestone horizon range from 33-160 Ohm-m.

Isoresistivity and Isopach map of the topsoil

Figure 6a-b shows the 2-D and the 3-D surface of the topsoil. The thickness of the top soil ranges from 0.4-1.5m towards the western part of the area. There is a closure of highest thickness up to 3.4m. The Isoresistivity map shows that the southwestern parts of the study area have the highest resistivity value 380 Ohm-m. The southeastern and Northwestern part showed low resistivity value (<160 Ohm-m).

Isoresistivity and Isopach map of the second layer

Figure 6c-d show the Isopach and Isoresistivity maps of the second layer. The Isopach map indicates thickness ranging from 0.8-9.2m. The map shows the largest thickness in the southwestern part of the study area with thickness up to 9m while the Isoresistivity map indicates a resistivity range of 1.7-21.2 Ohm-m.

The highest resistivity values were identified towards the southwestern and southeastern parts of the area up to (200 Ohm-m) and lowest resistivity values were identified in the Northern part of the study area (≤100 Ohm-m).

The high resistivity depicts competent geologic materials, such as sand or clayey sand formation. Very low resistivity suggests clay or sandy clay materials, or water saturated materials, often less competent to support the stability of heavy engineering structures. The depth of the aquifer units range between 0.35 m and 5.80 m in the area. Soils below the groundwater tables generally saturated (Coduto, 1998). An important factor often considered in foundation design is the water table and water table fluctuation (Bowles, 1984; Coduto, 1998). In addition, raised water table may create a wet basement or foundation, and consequently engenders instability of the overlying structure (Bowles, 1982; Othman, 2007).

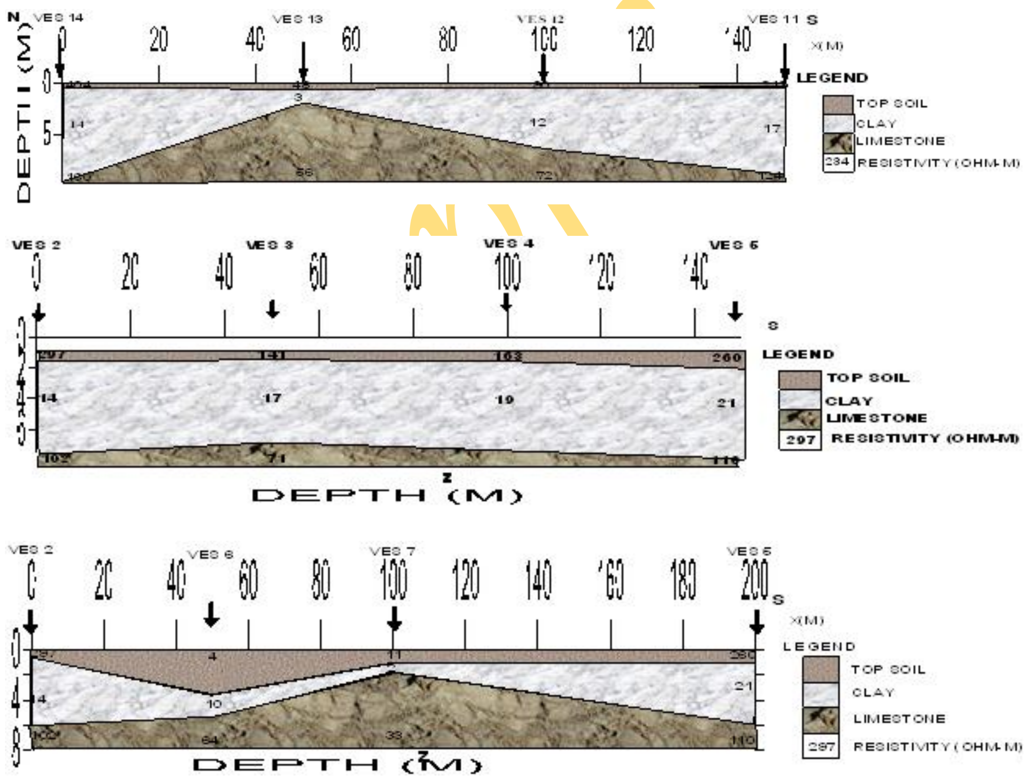

Figure 5 a-c: The Geoelectric section of the VES.

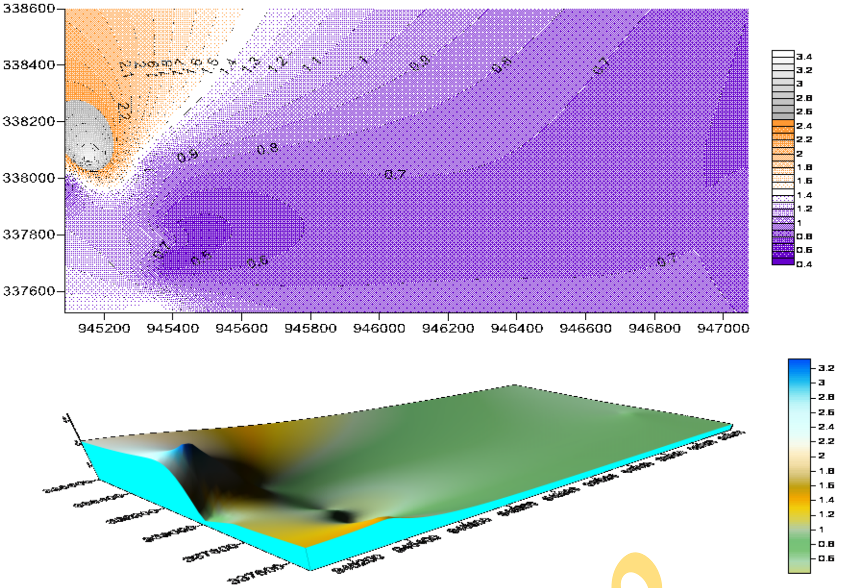

Fig 6a: Isopach map and 3-D surface of the top soil

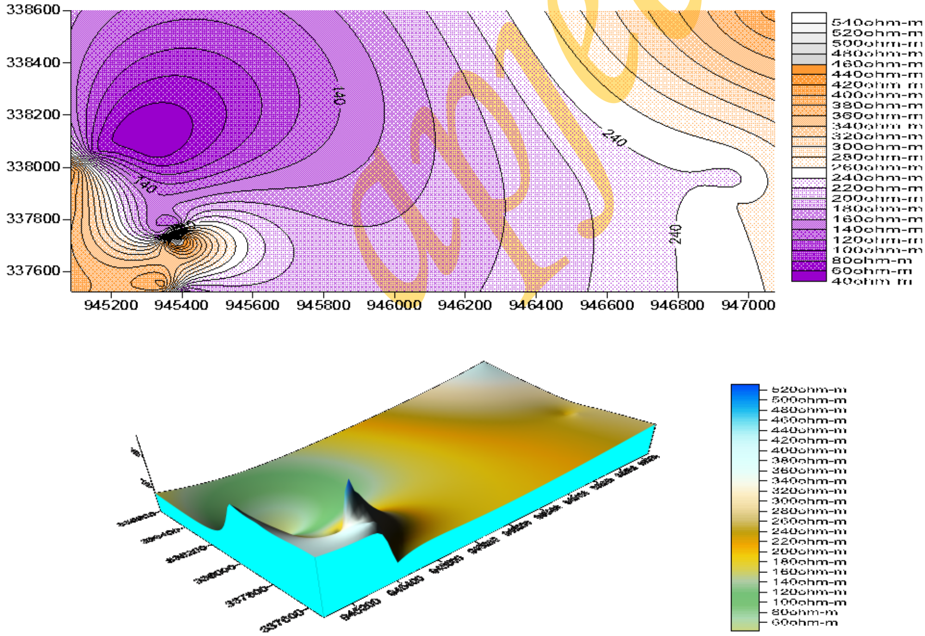

Fig 6b: Isoresistivity map and 3-D surface of the top soil

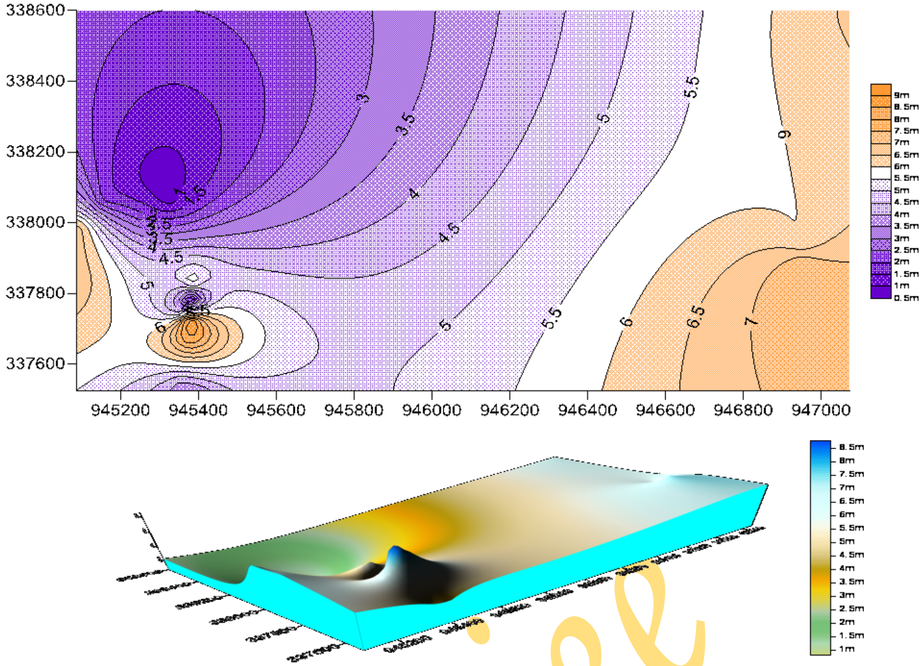

Fig 6c: Isopach map and 3D map of the second layer

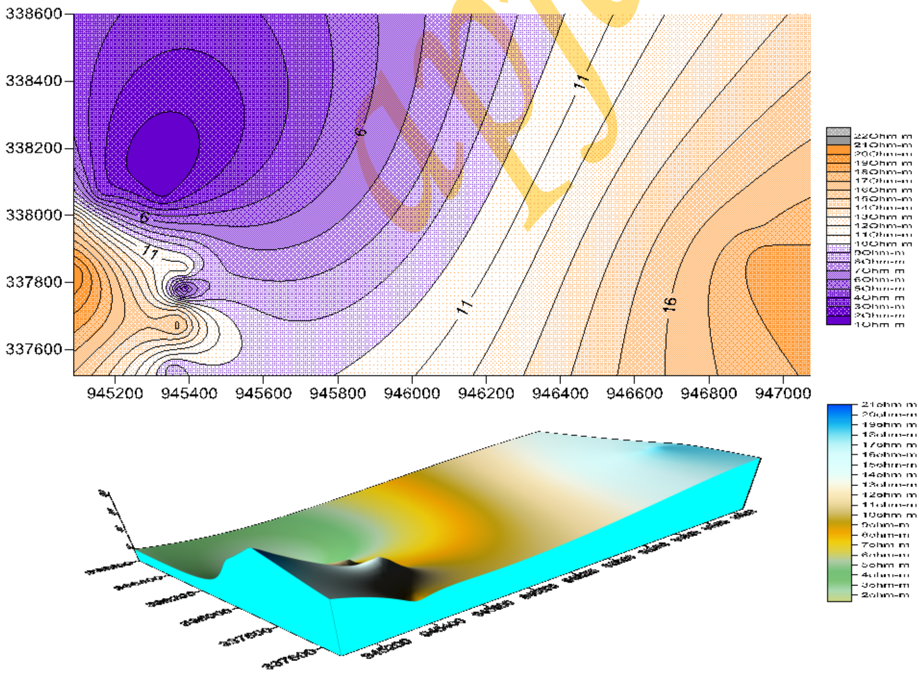

Fig 6d: Isoresistivity and 3D map of the second layer

Conclusion

The application of Electrical resistivity method has been employed in delineating the various litho units at a proposed building site in Ibese, Southwestern Nigeria. Based on the fifteen VES measurements taken, three major layers were delineated from the study area which comprise topsoil, clayey sand/sandy clay and limestone. The depth of the topsoil range from 0.4m at the Southeastern part of the study area to 3.4 m towards the Western part of the area. The depth of the partially competent bed ranged from 3.4 – 13.0 m. The first and second layers are highly saturated, and it is rated incompetent. This has been attributed to the waterlogged nature of the site.

Based on the conclusion stated above, the following recommendations are made:

(i) Ground treatment such as dewatering and in-situ compaction should precede use of reinforced concrete during the construction of shallow foundation.

(ii) Depending on the size of structures to be erected, the use of piling may be necessary for the structures to rest directly on the competent bed

(iii) It is important to take into cognizance all other engineering construction criteria that may be relevant considering the waterlogged nature of the site.

(iv) Further geological and geotechnical analysis should be carried out on the soil sample of the study area. Further studies in this respect, could adopt integrated geophysical methods and increase in area of coverage in other to enhance accurate delineation of the stratigraphic layers of the subsurface in the study area.

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