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Geophysical Investigation of Foundation Condition of A Site in Ikere- Ekiti, Ekiti State, South-Western Nigeria

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Abstract: A geophysical investigation has been performed using Vertical Electrical Sounding (VES) at a site behind Sammy Guest House in Ikere-Ekiti, Ekiti-State to examine the geophysical parameters that can be used to evaluate the structural competence of the shallow section of the subsurface for construction purposes and building development. The schlumberger configuration was used for the data acquisition. The half- currents electrode (AB/2) was used and the quantitative interpretation of the VES involved partial curve matching and 1-D computer iteration. The field data acquired was presented as geoelectric curves and geoelectric section. The interpretation of the field results showed a significant overburden that is up to 8m. The major subsurface layers are the topsoil (mainly clayey sand and sandy clay), lateritic layer and weathered formation. The northern part of the study area shows the lowest resistivity values that suggest high clay content or possible fracture which have impact on the competence and integrity of the soil construction and building development. Therefore, for building development in the study area, the topsoil must be excavated to a reasonable depth at which the soil is adequately competent and choice of foundation material must take into account the characteristics of the clayed material.

Key words: geoelectric, overburden, lateritic, resistivity, foundation

INTRODUCTION

Man has come up with the art of proper designing, accessing and constructing structures, e.g. buildings, tunnels, roads, dams and bridges to suite his immediate needs and future purposes with consideration for competency of the soil over which the structures are built. All structures created on the earth surface have its own substructure that is, foundation that are supported by the soils and rocks. 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 safety, structural integrity and durability. 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.

The geophysical investigation of the earth involves the taking of a set of measurements, usually by a systematic pattern near or at the surface that are influenced by the internal distribution of physical properties either by land, sea or air or vertically in borehole.

Geophysical methods are therefore helpful in delineating and evaluating the subsurface geological structures or bodies that is, anomalies and their geometries.

The sporadic increase both in population and infrastructural development in Nigeria especially in Ikere Ekiti and its environs have necessitated the need for proper structural planning and development of these infrastructures and building. However, poor planning and inability to carry out pre-development geophysical studies have led to a lots of structural problems which results in dilapidation of buildings with conspicuous fracture and cracking on the walls, lost of properties and resources, sinking of buildings and total collapse of buildings which eventually leads to loss of properties and lives. In other to emphasis importance of pre-developmental survey, a geophysical investigation was carried out in this project using electrical resistivity method to examine the subsurface structural integrity and competence of the subsoil for foundation bearing The aim of this study is to use Electrical Resistivity method for structural evaluation of near-surface geological structures such as cavity, sinkhole, fault and near surface rock.

Several geoscientist especially geophysicist have proved the sensitivity and efficiency of geophysical and geotechnical method on engineering site investigation. For instance, Adeyemo [2004] used dipole-dipole array to investigate the causes of road failure along Ilesa-Akure-Benin federal highway. He reported that the road failure was due to the clay content of the topsoil and the heterogeneous nature of the sub-base and sub-grade material on which the road was constructed. Mesida [1987], observed that there is a slight but noticeable differences in the geotechnical properties of the residual soils derived from older granite rock and charnockite

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found in Akure. He observed that granite derived soil gave x-ray diffraction peaks, which is an indicative of abounded quartz and kaolinite, while charnockite derived soil contains a mixture of kaolinite[65-75%]. The varied clayey content of charnockite derived soil gave it a higher plasticity tendency and a higher optimum moisture content and lower dry density, and on the other hand, granite derived soil have limited or lower plasticity, lower optimum moisture content and higher maximum dry density.

Akintorinwa and adesoji (2009) combined the geophysical and geotechnical method to study the sub-soil conditions and the electrical properties of the soil which may have effect on the foundation of the proposed switch station facility for telecommunication site. He employed the vertical electrical sounding techniques using the Schlumberger configuration. He observed that areas with low resistivity have soil that can lead to severe corrosion and high concentration of dissolved salts in the soil.

MATERIALS AND METHODS

Measurement of resistivity were made using ABEM WADI (SAS 300B) Terameter, 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 after taking permission from the land owner. Having established these points, they were marked on the base map and Vertical Electrical Sounding (VES) with Schlumberger array was carried our. Five soundings with three traverses 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 get too large, it becomes necessary to increase the distance between the potential electrodes in order to have a measurable potential difference.

Data Presentation and Interpretation:

Data generated from the Vertical Electrical Sounding using Schlumberger configuration were presented as geoelectric sounding curve and geoelectric section. Geoelectric section shows the subsurface layer resistivity and thickness while geoelectric Sounding Curves were obtained by plotting the apparent resistivity value against the 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 Resist 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. Generally, the layer resistivity and thickness are calculated

$$\rho_2 = \rho_1 K_1$$

$$\rho_3 = \rho_{2r} K_2$$

$$\rho_4 = \rho k_3$$

$$\rho_n = \rho_{(n-1)r} K_{n-1}$$

Where,

K_1, K_2, K_3 .... K_{n-1} are reflection coefficient of each layer

ρ_1, ρ_2, ρ_3, ... ρ_n are resistivities of 1st, 2nd, 3rd .... nth layer respectively

ρ_{2r}, ρ_{3r}, ... $\rho_{(n-1)r}$ are reflection apparent resistivity of 2nd, 3rd, ... n-1 layers respectively.

Similarly

$$h_2 = h_1 D_n/D_{r1}$$

$$h_3 = h_{2r} D_n/D_{r2}$$

$$h_4 = h_{3r} D_n/D_{r3}$$

$$h_n = h(n-1)r\ D_n/D_{r(n-1)}$$

Where,

$h_1, h_2, h_3, h_4, \ldots h_n$ are the thickness of 1st, 2nd, 3rd, 4th, ... nth layer respectively

h_{2r}, h_{3r} .... $h_{(n-1)r}$ are the reflected thickness of the 2nd, 3rd, ... n-1 layer respectively

$\frac{D_n}{D_{rn}}$ = depth ratio

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 Resist package (Vander Velper BPA 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.

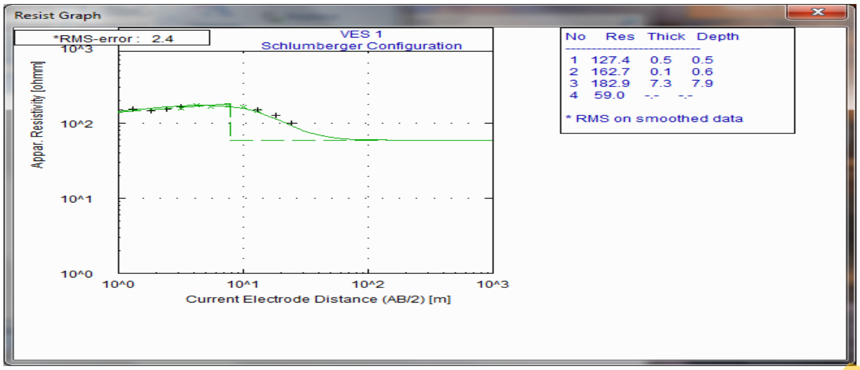
RESULTS AND DISCUSSION

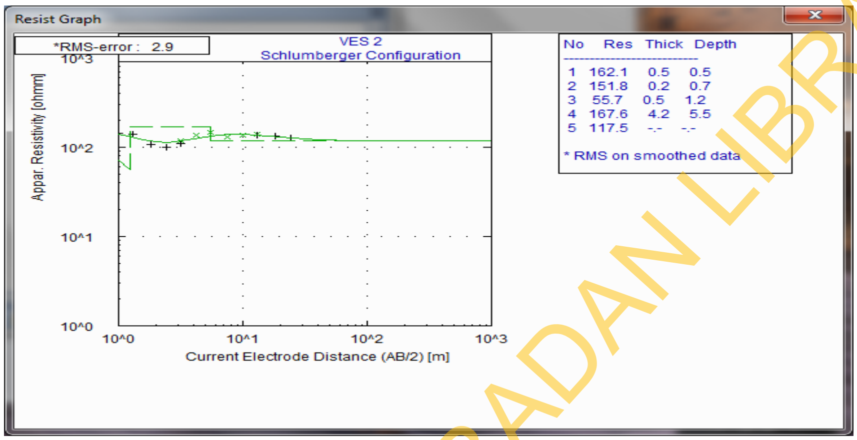
The electrical resistivity method of geophysical prospecting using Vertical Electrical Sounding (VES) technique was utilized to map the subsurface layers to a maximum depth of about 12m. The VES curves generated are shown below. From the geoelectric section, the four major geoelectric layers were laterite, clayed, sand and weathered formation, as obtained from the result of the partial curve matching which was refined by computer iteration. These are tabulated in the table below. Geoelectric sections were generated to cover the entire study area; three traverses were drawn in the study area, one traverse along North – south direction of the study area and two traverses along the East – West direction of the study area. The results of interpreted results of electrical resistivity survey have made it possible to map the area from the ground surface to depth of about 8m. The major geoelectric sequences that were delineated were: topsoil (mostly clayey sand and sandy clay), laterite, and weathered formation. The first layer is made up of topsoil (clayey sand and sandy clay) which has resistivity values ranging from 93 to 340 ohm – meter. The thickness of the layer is between 0.3 and 0.5m. Beneath the topsoil is the laterites which are mainly wet lateritic of highest thickness with resistivity values vary from 163 to 433 ohm-meter. The thickness ranges from 0.1 to 7.3m. The second layer of the study area is predominately lateritic in nature which has the highest thickness of about 7.3m. It has a very low thickness at the northern parts of the study area which is about 0.4m.

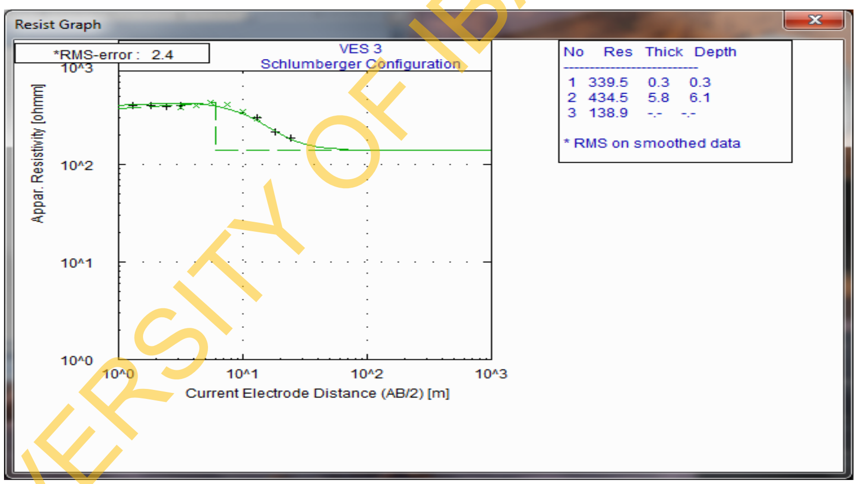
The third layer is made up of the weathered formation that has resistivity values ranging from 59 to 139 ohm-meter. The depth to the bedrock varies from 5.5 to 7.9m. Table below shows the summary of the results. The topsoil consists mainly of clayey, clayey sand, and sandy clayey. The northern part of the study area has the lowest resistivity values (< 93 ohm-meter) which is an indicative of a clay environment. But the thickness is very low, of about 0.5m. Towards the eastern part of the study area, we have a closure of very high resistivity value reaching about 435 ohm-meter.

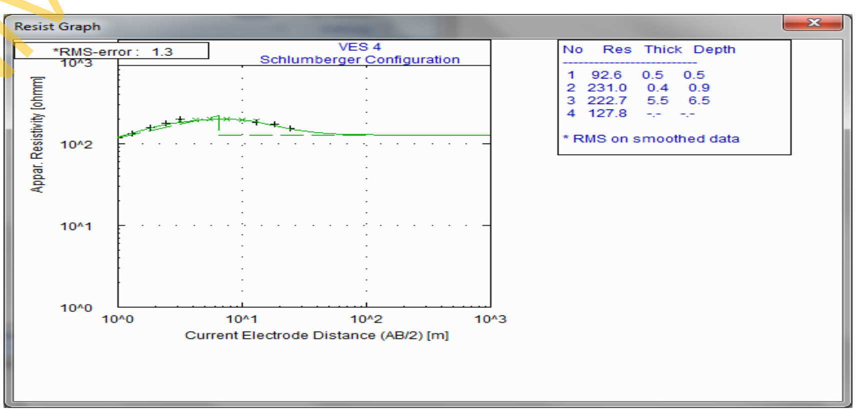
Table: Showing The Results of the Interpreted Ves Curves.

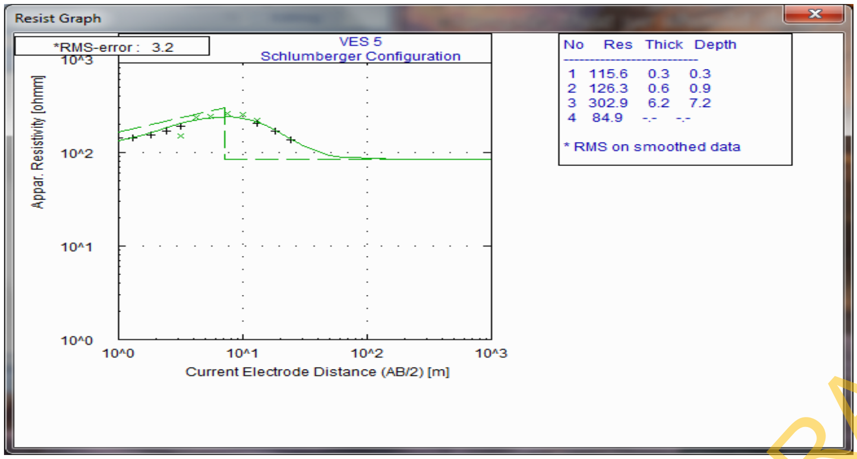
Ves No	Number of layers	Apparent Resistivity(Ω/m)	Thickness	Depth (m)	Lithographic unit	Curve type
1	1	127.4	0.5	0.5	Clayey sand	K
	2	162.7	0.1	0.6	Wet laterite	
	3	182.9	7.3	7.9	Laterite	
	4	59.0	--	--	Weathered formation	
2	1	162.1	0.5	0.5	Sandy clayey	QHK
	2	151.8	0.2	0.7	Sandy clayey	
	3	55.7	0.5	1.2	Clayey	
	4	167.6	4.2	5.5	Wet Laterite	
	5	117.5	--	--	Weathered formation	
3	1	339.5	0.3	0.3	Coarse grained sand	AK
	2	434.5	5.8	6.1	Laterite	
	3	138.9	--	--	Weathered formation	
4	1	92.6	0.5	0.5	Clayey	K
	2	231.0	0.4	0.9	Laterite	
	3	222.7	5.5	6.5	Laterite	
	4	127.8	--	--	Weathered formation	
5	1	115.6	0.3	0.3	Clayey sand	
	2 3	126.3	0.6	0.9	Clayey sand	AK
		302.9	6.2	7.2	Laterite	AK
	4	84.9	--	--	Weathered formation	


Resist Graph
*RMS-error : 2.4
VES 1
Schlumberger Configuration
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0 10^1 10^2 10^3
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 127.4 0.5 0.5
2 162.7 0.1 0.6
3 182.9 7.3 7.9
4 59.0 -.- -.-
* RMS on smoothed data


Resist Graph
*RMS-error : 2.9
VES 2
Schlumberger Configuration
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0 10^1 10^2 10^3
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 162.1 0.5 0.5
2 151.8 0.2 0.7
3 55.7 0.5 1.2
4 167.6 4.2 5.5
5 117.5 -.- -.-
* RMS on smoothed data


Resist Graph
*RMS-error : 2.4
VES 3
Schlumberger Configuration
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0 10^1 10^2 10^3
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 339.5 0.3 0.3
2 434.5 5.8 6.1
3 138.9 -.- -.-
* RMS on smoothed data


Resist Graph
*RMS-error : 1.3
VES 4
Schlumberger Configuration
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0 10^1 10^2 10^3
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 92.6 0.5 0.5
2 231.0 0.4 0.9
3 222.7 5.5 6.5
4 127.8 -.- -.-
* RMS on smoothed data



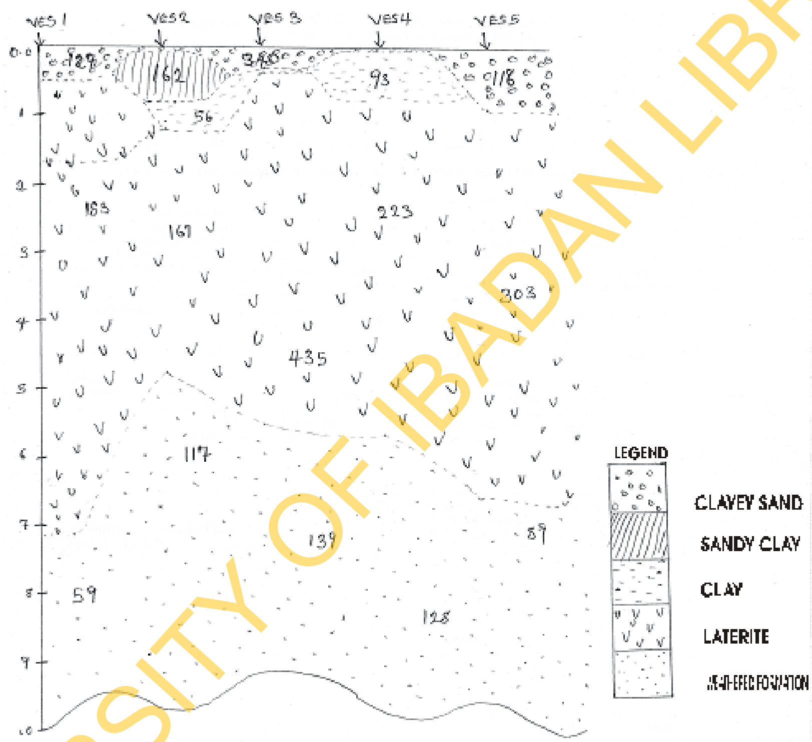


Fig. 4.2: Geoeletric section of the study area.

Conclusion:

The interpretation of five Vertical Electrical Sounding in the study area shows that four major layers were delineated from the study area which comprise topsoil which are mainly clay, clayed sand and sandy clay, laterite, sand, and weathered formation. At the northern part of the study area, the topsoil is mainly clay, which means that the topsoil has to be excavated beyond the depth of 0.5m for the choice of shallow foundation in the study area. It is observed that the lateritic layers are between the depth of 0.6 to 7.9m below the earth surface which means that, for building development in the study area, the topsoil must be excavated to a reasonable depth in between the lateritic layer at which the soil is adequately competent to bear the load because lateritic soil has a greater load bearing capacity. The choice of foundation materials must take into account the characteristic of the wet lateritic material and the sandy clay of the soil.

Based on the interpretation of the data and field results obtained, I would like to make the following recommendation

1. Excavation of soil to a depth at which the soil is lateritic in nature (adequately competent and highly consolidated) to sustain the structure of any kind.
2. Shallow type of foundation such as strip footing in the competent area of high bearing capacity and raft foundation in the area of less competence are recommended

3. High rise buildings can be built in the study area because there is no near surface geologic structure and the choice of foundation materials should be carefully chosen and deep type of foundation should be employed at a reasonable depth most especially along the wet lateritic layer.
4. 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 an increased 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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