

INVESTIGATION OF ROAD FAILURES USING VERTICAL ELECTRICAL SOUNDING METHOD FOR A TYPICAL COMPLEX BASEMENT: A CASE STUDY OF ADEYEMI COLLEGE OF EDUCATION, ONDO, NIGERIA.

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Abstract

In this study, investigation of road failures on three roads within Adeyemi College of Education, Ondo State, southwestern Nigeria was carried out using Vertical Electrical Sounding (VES) method. Omega resistivity meter was used to acquire the apparent resistivity data, and a total of ten VES points were created with 50 m station intervals on each road, and 100 m spread for half-current electrode spacing. The data were subjected to a computer based iterative technique using IPI2WIN software (version 3.0) to generate sounding curves and geoelectric pseudo-sections. The results revealed varying degree of resistivity values with stable portions of the road having higher resistivity values compared with the unstable portions. The low resistivity values of the unstable zones were mainly due to the presence of massive clay contents in the subsurface as indicated in VESs 2, 3, 5, 7, 8, and 9. The stable portions VESs 1, 4, 6 and 10 revealed higher resistivity values in the subsurface. The linear fractures which indicated clay, sandy clay or lateritic clay enriched regions, and water bearing zones with characteristics of low resistivity value of less than 300 Ωm were observed on the unstable portions of the roads. Generally, the massive presence of clayey material in the subsurface of the roads was the major cause of failure along the roads.

Keywords: Road Failure, VES, Resistivity, Clay

1. Introduction

Road failure has become a major problem facing the citizens of Nigeria today as road transportation is the common means of transportation. Other means of transportation are not as convenient and affordable for the general populace, considering the economic situation of Nigeria. According to [1], roads are part of community development and should be viewed by government as a major factor that brings development to the country. Good roads promote economic growth of a nation by creating enabling environment for easy transportation of goods and services. Road failure is a discontinuity in the road network as a result of cracks, pot-holes, bulges and depressions [2]. It is actually a shift or destruction of pavement on the roads some months or years after construction. The causes of road failure are enormous [3-5], but the most likely cause which is not always considered, most especially by the indigenous contractors, is the geological structures of the subsurface in which the roads are constructed. It is quite important to always have adequate knowledge of the terrain and subsurface conditions of the area on which the road will be constructed, as this will assist in knowing areas to handle with special treatments. Geophysical investigations before constructions of roads will greatly reduce the rate of failures, and in turn reduce the government expenses on the rehabilitation of failed roads. The techniques indicate the physical properties of the subsurface on which the roads will be constructed. In addition, the geology, topography and some other physical parameters are needed to be considered to avoid incessant road failures on our roads. The choice of the three roads within the campus of

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Adeyemi College of Education was due to the multiple failed segments on the roads, and potential for recurring failure even if the management further develops the roads. The noticeable and potential patterns of the failure on these roads were cracks, pot-holes and rutting.

Electrical Resistivity method, Electromagnetic technique, Seismic refraction surveys as well as Ground Penetrating Radar are amongst the geophysical methods that can be applied effectively in mapping out the geologic structures of the subsurface on which the road will be constructed. The most commonly used is the electrical resistivity method which fundamentally measures the earth's electrical impedance or changes relative to the impedance. The technique has broad applications in environmental related problems: it is directly applicable to structural failures [4, 6], road failures [3, 7], groundwater, contaminant plumes migrations and hydrologic investigations [8, 9]. The technique can also be used to identify geological structures and lithologies [10]. Electrical resistivity method has relatively low cost, non-invasive and very rapid in generating spatial models of physical properties of the subsurface.

In resistivity surveying, information about the subsurface distribution of electrical conductivity is obtained by examining how currents flow in the earth [11]. Resistivity methods involve injecting a steady state electrical current into the ground and observing the resulting distribution of potentials (voltages) at the surface or within boreholes. Like all geophysical processes, resistivity surveys can be described in terms of input energy, the earth's physical properties, and signals or data that are measured [12]. Survey design depends on the specific characteristics of the site and the objective of the survey. The three most common modes of electrical resistivity surveying are profiling, sounding and profiling-sounding, each having its own specific purpose. Since the purpose of this survey is to map the depths and thicknesses of stratigraphic units on the roads, then the electrical resistivity data were collected in the sounding mode also called Vertical Electrical Sounding (VES) adopting Schlumberger configuration.

2. The Study Area

The study area is located within Adeyemi College of Education, Ondo, Ondo State Southwestern Nigeria. Three roads were considered, namely, Unity road which lies within latitudes $N7^{\circ} 4' 13.48''$ and $N7^{\circ} 4' 20.88''$ and longitudes $E4^{\circ} 49' 20.21''$ and $E4^{\circ} 49' 23.15''$, Agric road which is within latitudes $N7^{\circ} 4' 14.18''$ and $N7^{\circ} 4' 08.18''$ and longitudes $E4^{\circ} 49' 14.40''$ and $E4^{\circ} 49' 13.10''$, and Chapel road between latitudes $N7^{\circ} 4' 09.50''$ and $N7^{\circ} 4' 05.90''$ and longitudes $E4^{\circ} 49' 24.60''$ and $E4^{\circ} 49' 28.30''$ (Fig. 1). Different kinds of vehicles ply these roads on daily basis. Generally, Ondo State experiences dry and wet seasons, and the mean annual rainfall ranges between 1270 and 1524 mm, while the mean temperature varies between 27°C and 31°C [13]. There are two distinct geological terrains within Ondo State. The south is underlain by the Sedimentary rocks while the north subsurface is composed of Precambrian basement complex rocks. The geology of Adeyemi College of Education falls

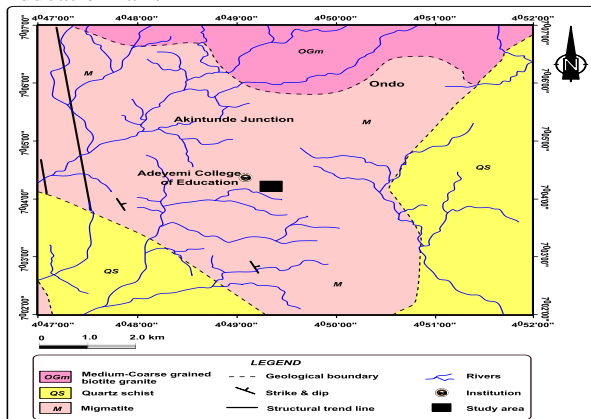


Fig. 1: Geological Map of Ondo Town showing Adeyemi College of Education within basement complex of South-west Nigeria (Fig. 2). It cuts across some rock units such as migmatite, granite-gneiss, quartz-schist and quartzite, porphyritic granite and charnockite. The basement terrain which comprises igneous and metamorphic basement complex can be found in the central, South-western and South-eastern parts of the country with cretaceous rocks partitioning them into zones. The basement complex of Southwestern Nigeria predominantly composed of migmatite and granitic gneiss; quartzite; slightly migmatized to unmigmatized metasedimentary schist and metaigneous rocks; charnockite; gabbro and diorite; and the members of the older granite suite, mainly granites, granodiorites, and syenites [7, 14-15].

3. Methodology

Vertical Electrical Sounding (VES) using Schlumberger array electrode configuration was used in this investigation, and it was carried out by applying current into the ground through two electrodes and then measuring the resultant potential difference (voltage) between the potential electrodes (Fig. 2). Increasing deeper measurements to obtain the information about the stratification of the subsurface are achieved by using a wider separation between the current electrodes [16]. The Schlumberger field data are mostly taken in overlapping segments because at each step of current electrodes (AB) spacing, the signals of the resistivity meter become weaker. Therefore, potential electrodes (MN) spacing was enlarged and two values for the same AB/2 were measured, one for the short and one for the long MN spacing [9].

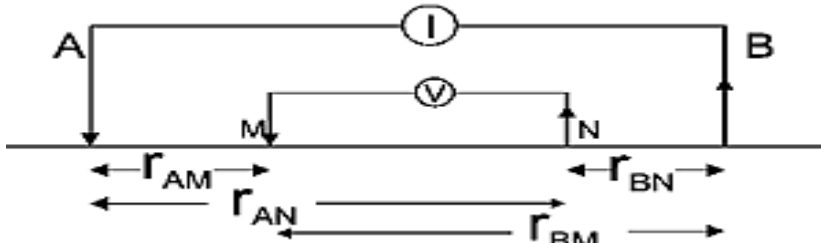


Fig. 2: Schlumberger Four - Electrode Survey Technique

Measuring the current (I) between the two current electrodes A and B, and the associated potential differences between the potential electrodes M and N, the apparent resistivity (ρ_a) is given as:

$$\rho_a = K \frac{V}{I} \tag{1}$$

where K is the geometric factor of the Schlumberger electrode configuration, which is given by

$$K = \frac{\pi \left(\frac{AB}{2} \right)^2 - \left(\frac{MN}{2} \right)^2}{MN} \tag{2}$$

The apparent resistivity (ρ) values were measured by taking the product of the resistance as measured and the geometric factor. By repeating the Schlumberger measurements with the entire setup moved one step to the side, VESs were performed continuously and the resistivity values along a section were measured [9, 17-18].

The VES data were acquired using Omega resistivity meter with 50 m station intervals on each road, and the spread for current electrode spacing (AB/2) ranged between 1-100 m. The choice of this equipment was based on the fact that it has the capacity to transmit signals to a very deep depth of the subsurface. The current variation was in the range of 3-5 A which is found suitable found suitable in the basement terrain. A total of ten VES point data were acquired (Fig. 3); Four VES points were established on Unity road, and three VES points each on Agric and Chapel roads. The coordinates of each station were recorded with their respective elevation above sea level using Global Positioning System. The apparent resistivity values obtained were plotted against the half-current spacing (AB/2) by subjecting the data to a computer based iterative interpretation using IPI2WIN 3.0 version [19]. This software was used to generate the sounding curves (Figs. 4-13) and profile pseudo-sections (Figs. 14-16). Carefully guided by the trend of the sounding curves, the resulting geo-electric parameters were used to interpret these sounding curves.

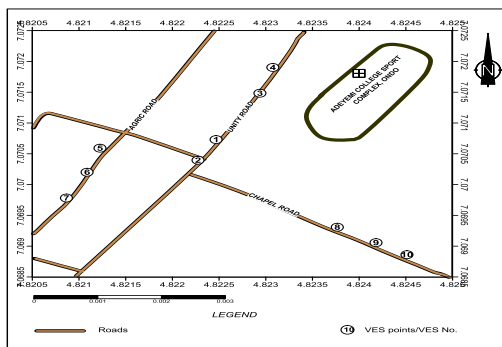


Fig. 3: Data Acquisition Map

4. Results and Discussion

Geoelectric data can be presented in various ways [20]. Electrical sounding technique was used to investigate road failure on some roads within Adeyemi College of Education, Ondo, South-western, Nigeria. The resulting sounding curves are shown in Figs. 4-13. The curve types are; H, A, HA, AH, KH and KHK, with H, HA and KH being the predominant curve types. Table 1 below summarizes the results by showing the layers resistivity, depth, thickness, curve types and possible lithology at various VES points. Also, the apparent resistivity pseudo-sections indicating the lithological arrangements of the subsurface of the three roads are presented as figs. 14-16.

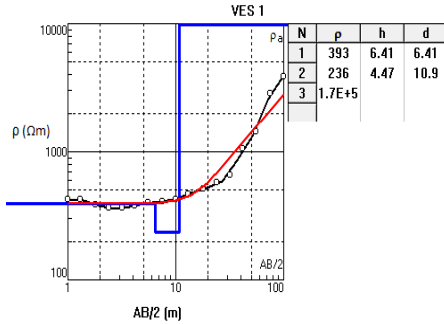


Fig. 4: Sounding Curve of VES 1

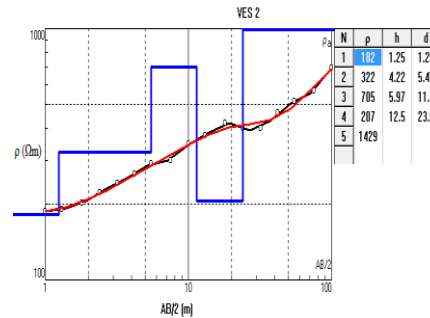


Fig. 5: Sounding Curve of VES 2

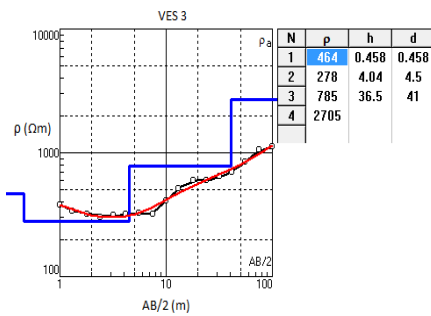


Fig. 6: Sounding Curve of VES 3

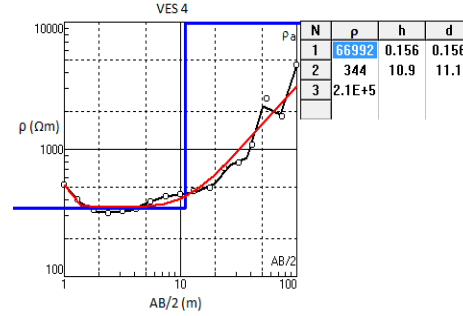


Fig. 7: Sounding Curve of VES 4

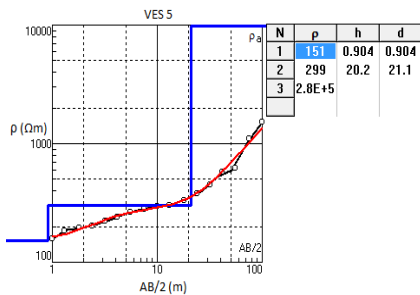


Fig. 8: Sounding Curve of VES 5

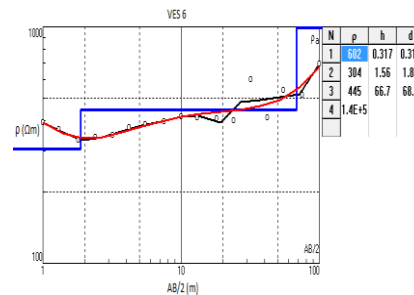


Fig. 9: Sounding Curve of VES 6

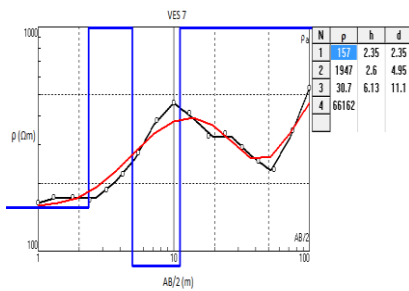


Fig. 10: Sounding Curve of VES 7

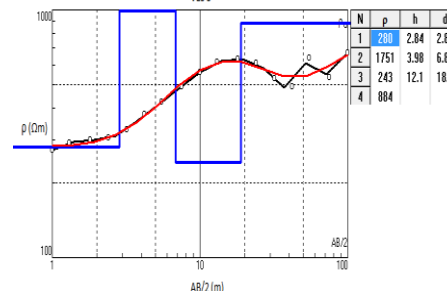


Fig. 11: Sounding Curve of VES 8

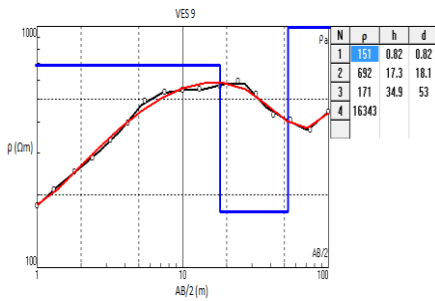


Fig. 12: Sounding Curve of VES 9

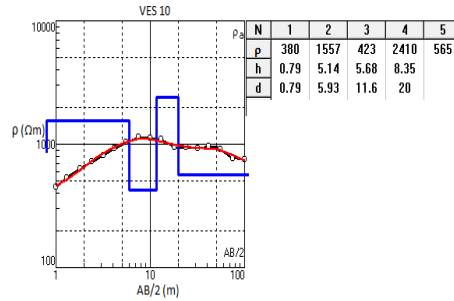


Fig. 13: Sounding Curve of VES 10

Table 1: Summary of VES Results

VES	Layers	Resistivity (Ωm)	Depth (m)	Thickness (m)	Curve Type	Possible Lithology
1	1	393	6.41	6.41	H	Topsoil
	2	236	10.90	4.47		Sandy clay
	3	170000				Fresh basement
2	1	182	1.25	1.25	AH	Topsoil
	2	322	5.47	4.22		Lateritic clay
	3	705	11.40	5.97		Fractured Basement
	4	207	23.90	12.50		Weathered Basement
	5	1429				Fresh basement
3	1	464	0.46	0.46	HA	Topsoil
	2	278	4.50	4.04		Sandy clay
	3	785	41.00	36.50		Fractured Basement
	4	2705				Fresh basement
4	1	66992	0.16	0.16	H	Topsoil mainly Granite
	2	344	11.10	10.90		Fractured bedrock
	3	210000				Fresh basement
5	1	151	0.90	0.90	A	Topsoil
	2	299	21.10	20.20		Sandy clay
	3	280000				Fresh basement
6	1	602	0.32	0.32	HA	Topsoil
	2	304	1.88	1.56		Lateritic clay
	3	445	68.60	66.70		Fractured basement
	4	140000				Fresh basement
7	1	157	2.35	2.35	KH	Topsoil
	2	1947	4.95	2.60		Fractured bedrock
	3	30.7	11.10	6.13		Clay deposits
	4	66162				Fresh basement
8	1	280	2.84	2.84	KH	Topsoil
	2	1751	6.82	3.98		Weathered rock
	3	243	18.90	12.10		Lateritic clay
	4	884				Fractured basement
9	1	151	0.82	0.82	KH	Topsoil
	2	692	18.10	17.30		Lateritic clay
	3	171	53.00	34.90		Sandy clay
	4	16343				Fresh basement
10	1	380	0.79	0.79	KHK	Topsoil
	2	1557	5.93	5.14		Weathered basement
	3	423	11.60	5.68		Lateritic Clay
	4	2410	20.00	8.35		Weathered basement
	5	565				Fractured bedrock

The interpreted geo-electric subsurface layers as indicated in Table 1 are; three (VESs 1, 4 and 5); four (VESs 3, 6, 7, 8 and 9) and five (VESs 2 and 10). On unity road, VES 1 revealed the resistivity values of the first and second layers to range between 236 and 393 Ωm, indicating sandy or lateritic clay at a depth of about 10 m in the subsurface. At depths beyond 10

compose of topsoil, sandy clay, lateritic clay, weathered layer, fractured basement and fresh basement bedrocks. On Unity road, VES 2 had the most pronounced unstable zones with very low resistivity values, followed by VES 3. VESs 1 and 4 revealed stable portions in the subsurface of the road. On Agric road, VESs 5 and 7 had low resistivity zones close to the surface, and they could be regarded as unstable zones. VES 6 was considered to be more stable than VESs 5 and 7, although with more of weathered and fractured zones. On Chapel road, VESs 8 and 9 revealed unstable zones due to the massive presence of low resistive regions close to the surface (topsoil). VES 10 was considered a stable zone with pronounced fractured basement. This study had established that the clayey, sandy clayey or lateritic clayey materials in the subsurface on which the roads were constructed have high tendency of absorbing water, which make the area porous and liable to collapse under stress, thereby leading to road failure.

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