INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN MULTIDISCIPLINARY EDUCATION

ISSN (print): 2833-4515, ISSN (online): 2833-4531

Volume 03 Issue 11 November 2024

DOI: 10.58806/ijirme.2024.v3i11n16, Impact factor- 5.138

Page No. 1838-1846

Application of Electrical Resistivity Method in Building Foundation Study around Ansarudeen Primary School Adehun Area of Ado-Ekiti, Southwestern Nigeria.

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ABSTRACT: The study evaluated the structural competency of the subsurface geological materials around Ansarudeen Primary school in Bolorunduro community, Adehun area of Ado Ekiti, Ekiti State, Nigeria to delineate the area that is suitable for building development. The ABEM SAS 1000 was employed for transmitting current and recording the resistivity value of the subsurface layers across the two traverses using the dipole-dipole and the Schlumberger arrays for horizontal profiling and vertical electrical sounding of the survey area respectively. Five VES points were occupied along traverses 1 and 2 with AB/2 of 150m. The field resistivity data were processed using Win RESIST and the Dipro software to generate the geoelectric sections of the survey area. The sounding curves generated were HK, KHA, and A, with HK having the highest number of occurrences. The interpreted result showed that the geoelectric section consist of five layers which are the topsoil, weathered layer, fractured basement layer, partly fractured layer and the fresh basement rock. The resistivity value and subsurface layer thickness for the top soil varied from 115.3 - 752.7 Ωm and 0.3 - 2.1 m respectively. The general overburden thicknesses were estimated at 11m and 23m respectively for traverse 1 and 2. The pseudo section of the horizontal profiling and the geoelectric section of the Vertical electrical sounding revealed similar subsurface lithology along traverse 1 and 2. The result however suggested foundation placement on traverse 1along VES 3 and VES 2 of the geoelectric section or point 16-19 of the horizontal profiling pseudo section.

KEYWORDS: Geoelectric, horizontal profiling, pseudo section, Schlumberger array, vertical electrical sounding

1.0. INTRODUCTION

In the last decade, the interest of geophysics in civil and environmental engineering has being the increase. The incessant failures of engineering structures such as bridges, roads, and building collapse in Nigeria has reached an alarming rate that both Federal and State Governments are worried and have instructed their town planning department to come up with regulatory code for any building above a storey (Omowumi, 2014, Fajana *et al.,* 2016). The advancement of modern civil engineering construction projects has occurred in nearly every accessible part of the world's land areas. In specific, in the underground complex regions where the construction of extremely tall buildings has presented various engineering challenges, especially in creating foundations that can endure significant vertical and horizontal forces. Lagos Island in Southwestern Nigeria, situated in the Dahomeyan plain underground complex region, is a suitable location for erecting high-rise structures. Regrettably, several of these projects have encountered structural issues due to inadequately designed and insufficient foundational plans prior to the commencement of construction. The inherent weaknesses observed have been attributed mainly to the absence of first-hand geological information about the initial foundation bedrock. Foundation typically refers to the base or substructure upon which a building or structure is constructed. It is an essential component of any construction project and is responsible for distributing the weight of the structure to the underlying soil or rock in a safe and stable manner. However, foundation investigation is paramount in preventing long-term maintenance issues and ensuring the sustainability of buildings. It provides valuable data that informs the choice of foundation type (whether a deep foundation like piles is needed or a shallow foundation will suffice). This decision directly influences the cost, time, and complexity of construction projects.

Given the rising need for site development and the risk of construction failures, there is a growing demand for thorough site investigations to uncover potential subsurface issues. Geophysics has become increasingly important in civil and environmental engineering over the last decade. A wide variety of geophysical methods are now being used in different applications, from investigating ground conditions for construction to examining dams and dykes. The goal is to understand geological structures and determine the physical properties of rock formations. Foundation investigation is crucial for building and engineering projects, and various methods have been employed to ensure its success. Geophysical techniques, particularly the electrical resistivity method, have been widely used to address a diverse range of engineering and environmental challenges (Olorunfemi *et al.*, 2004, Adeyemi and Oyediran, 2005, Soupios et al., 2007, Oyedele, 2009). As a result, geophysical investigations play a crucial role in evaluating the physical properties of the subsurface, including soil type, soil competence, soil corrosivity, depth to bedrock, and lithologic sequence (Lapena et al., 2005, Ayolabi et al., 2012, Ibitoye *et al.*, 2013, Ariyo et al., 2013, Ojo et al., 2020).

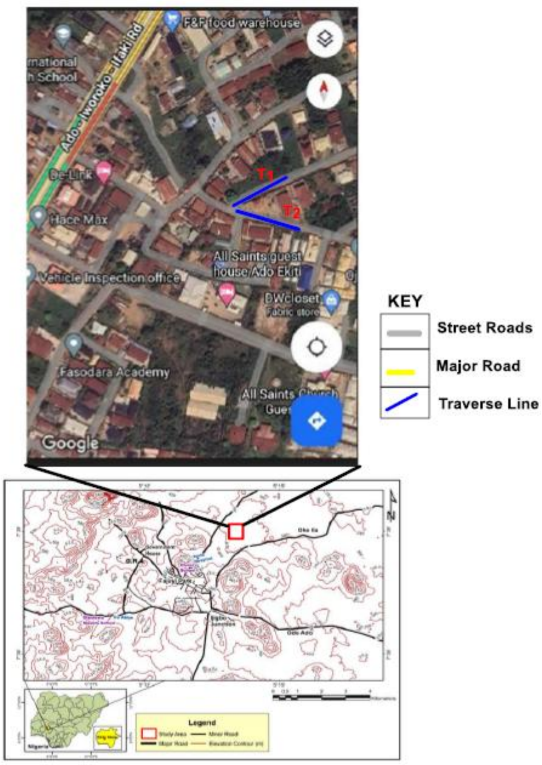
The need for proper pre-foundational study has increased significantly (Fajana *et al.,* 2016) as such; proper foundational procedures such as subsurface investigation need to be achieved to ascertain the longevity of buildings. The study area although situated within the basement complex is affected by overburden thickness which has affected foundation thickness and caused a weakened foundation procedure, visible signs of cracks and partial building collapse are very prominent within the area. To address these issues, proper integration of geophysical method is adopted to properly investigate the study area and make systematic decision on the type of foundation to be constructed providing detailed insight into the subsurface.

The electrical resistivity method has extensively been used for computer-aided imaging of the subsurface in areas that have become interesting, particularly in the sitting of sources of groundwater, location of groundwater disposal areas, delineation of subsurface fractures, engineering construction, archaeological studies, environmental studies, rainfall recharge analyses of aquifers, and in seismic and earthquake hazards analyses of the ground (Samouelian et al., 2005, Kowalczyk et al., 2015, Lech et al., 2020). Several soil research workers have performed electrical resistivity surveys, much less than a few are covered to relate to issues to help practicing engineers in their design execution of construction of facilities. Site engineers, for reasons of cost and other considerations such as assumptions in structural design, sometimes fail to incorporate pre-construction investigations in their job schedule. A geophysical investigation is therefore necessary for the site to reveal possible future subsurface problems and proffer possible solutions before the erection of buildings.

2.0. LOCATION OF STUDY

The study area is located at the Bolorunduro community, Adehun area situated within the basement complex of Ado Ekiti, opposite the Anssarudeen School and few meters away from the major road. The area is situated within the geographical coordinate approximately latitude 7° 36’65”N and longitude 5°14’15.6” E (Fig. 1). The area is accessible by local roads which are of rugged terrain. Regionally, Ado- Ekiti in which Bolorunduro community, Adehun area is situated is bordered by Ikere-Ekiti, an annex local Government of the state in the south, Iyin in the west, Oye in the north and Aare and Iworoko towns in the East. The study area is characterized by rainy and dry seasons with annual rainfall that spans from 1200mm to 1400mm.

Fig.1. Location of Study



Mean monthly temperature of the area is 27˚C while the hottest months are in February and March with high humidity close to 82% occasionally (Adebayo and Arohunsoro, 2014). The study area has no visible outcrop; however, it is part of the basement rocks of southwestern Nigeria. Nearby outcrops indicate granite and charnockite of Pan–African orogeny.

3.0. METHODOLOGY

The electrical resistivity method was adopted for this research. Two sets of data were acquired on the field using the Schlumberger and Dipole-Dipole arrays to conduct the vertical electrical sounding and electrical resistivity tomography respectively. The geophysical survey were performed in batches, the dipole dipole array was conducted to delineate the horizontal anomalies of the subsurface while the vertical electrical sounding was employed to prospect to much more greater depth. The choice of method is based on the ability of the dipole dipole to visualize the subsurface diagonally in 2D which is more efficient compared to the Werner array and also the ability of the dipole dipole to investigate to a greater depth than the Werner array. Although the Dipole-dipole cannot prospect vertically, the Schlumberger vertical electrical sounding complements this shortcoming (Wisen et al., 2004).

3.1. Data Acquisition

Two traverses were occupied with the first oriented in the east-west and the second in north- south directions respectively within the study area (Fig.1). Schlumberger and Dipole-dipole configurations were adopted for Vertical Electrical Sounding (VES) and Electrical Resistivity Tomography (ERT) respectively. The Dipole-Dipole configuration was first conducted on both traverses along a length of 210m with 5 numbers of movements and 10m difference between the two current electrodes observed for data acquisition all through the length of both traverse lines. The Vertical Electrical Sounding (VES) technique survey was carried out on the two traverses, and four VES points were occupied having lower resistivity value each at traverse 1 and 2, VES 1 serving for both traverses making it 5 total VES points with a total maximum spread (AB) of 300 m

Data Analysis and Processing

The data were analyzed on the field to generate the apparent resistivity (ρa) or the true resistivity value of the subsurface by multiplying the geometric factor of the Schlumberger array and Dipole-Dipole array with the generated resistivity value. The observed data were plotted on a log-log graph before being curve-marched with a standard curve to derive the model parameters that were used to iterate field data on the WinResist software which delineated the subsurface to layer by layer with their resistivity values and depth in meters. Data from the dipole-dipole were processed using the Dippro-Win software and was iterated using the Jacobian principle to produce the 2D-resistivity structure of the study area. However, Surfer 12 software was employed to produce the geo-electric sections from geo-electric parameters obtained from the vertical electrical soundings (VES) (Loke, 2011).

4.0 RESULTS AND DISCUSSION

The results are produced as a 2D geoelectric section and sounding curves, the Dipro software employed for 2-D modeling produced a high-resolution color image of the field data,
theoretical pseudo section, and 2-D resistivity structure.

4.1 Electrical Resistivity Tomography (Ert)

The result generated is a two-dimensional (2D) representation of the subsurface of the Earth, displayed in pseudo sections (Fig. 2a and 2b), the pseudo sections represent the field data pseudo section, the theoretical pseudo section, and the 2d resistivity structure of the surveyed traverse, the 2d resistivity structure showed the resistivity values of the subsurface to a depth of 50m. In the the 2d resistivity structure of the surveyed traverse, the color-coded zones indicate varying degrees of geological features and their resistivity values (Ω-m) as indicated in the colour gradient;

i. **Bluish Hue Zones**: These areas correspond to regions of high weathering and fracturing with low resistivity value of 16Ωm on traverse 1 and 14Ωm on traverse 2

ii. **Greenish Colored Zones**: These regions indicate weathered areas with resistivity value of 57 Ωm on traverse 1 and 64 Ωm on traverse 2.

iii. **Yellowish Colored Zones**: These zones represent moderately fractured areas with resistivity value of 196 Ωm on traverse 1 and 280 Ωm on traverse 2.

iv. **Reddish Colored Zones:** These areas signify the presence of the unweathered, fresh basement rock with higher resistivity value.

4.2 Vertical Electrical Sounding

Five sounding curves were generated along the two traverses indicating the resistivity value, thickness, and depth of each layer penetrated by the current. The sounding curves (Fig. 3) were classified as HK, KHA, and A with HK having the highest number of occurrences. The geo-electric section for traverse 1 and traverse 2 of the vertical electrical soundings are presented in Figs. 4a and 4b respectively. Five different lithologic sequences were established namely; the topsoil materials, the weathered layers, fresh basement, fractured basement and the partly fractured basement (Table 1).

4.2.1 Geo-electric units

The geo-electric section (Figs. 3 and Fig. 4) shows the variation of the resistivity and thickness values of layers within the depth penetrated in the study area. The geoelectric sections displayed the lithological units of the penetrated depth of the VES (Table 1).

Topsoil

As shown in the geo-electric section, the topsoil layer is relatively thin along both traverses with an average depth of 2.4m, and 2.1m and resistivity values of 115Ωm and 118Ωm respectively.

Weathered Layer

The weathered layer is a prominent signature recorded at all five VES Stations (Fig. 3), the average resistivity value and thickness of the layer are 432 Ωm and 5.4m respectively.

Fractured Basement and Partly Fractured Basement

The fractured basement was encountered at on VES 2 along traverse 1 with a resistivity value of 84.3Ωm.

Fig.2a. ERT profile map across Traverse 1

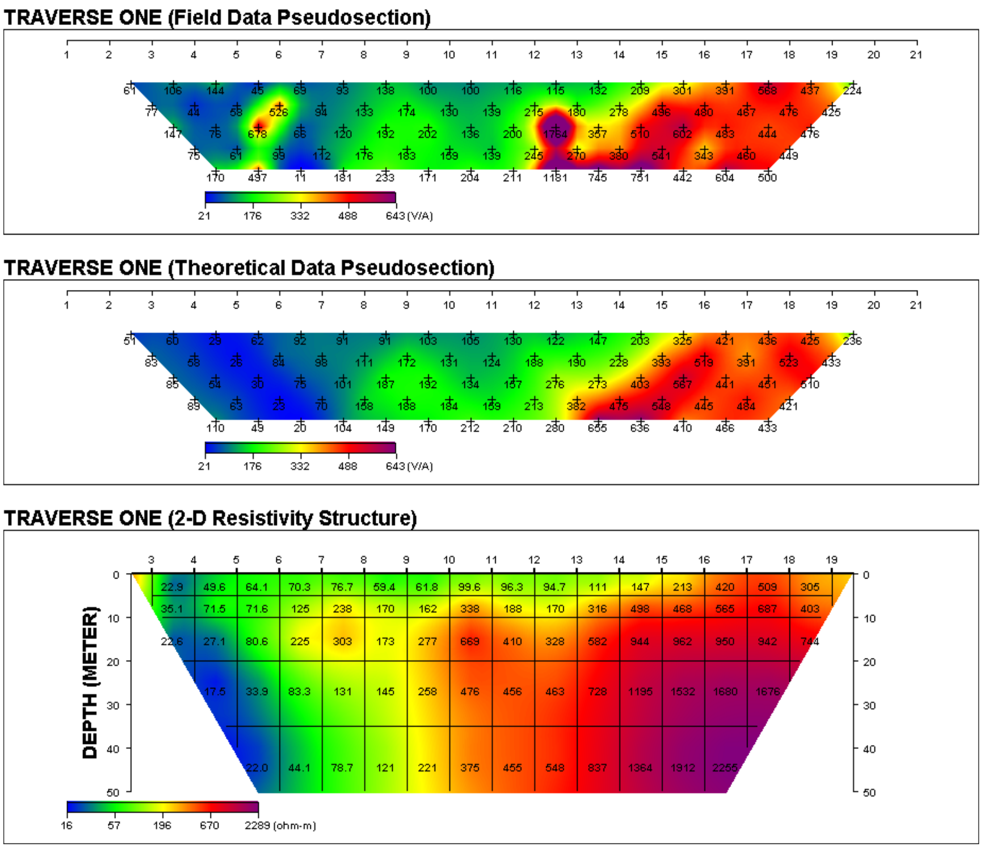


Figure 2b. ERT profile map across Traverse 2

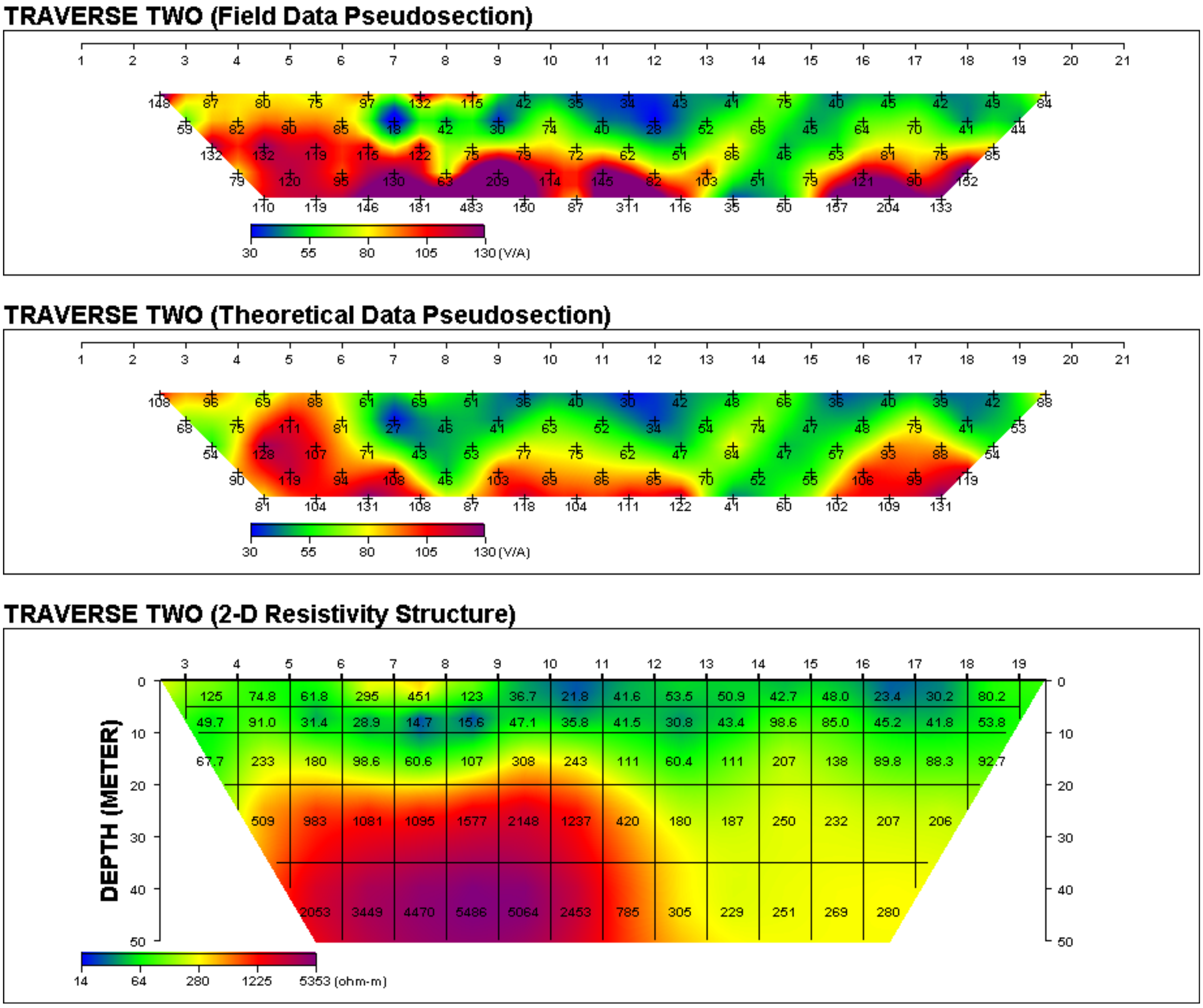


Fig. 3. Typical Geoelectric Curves from Data interpretation

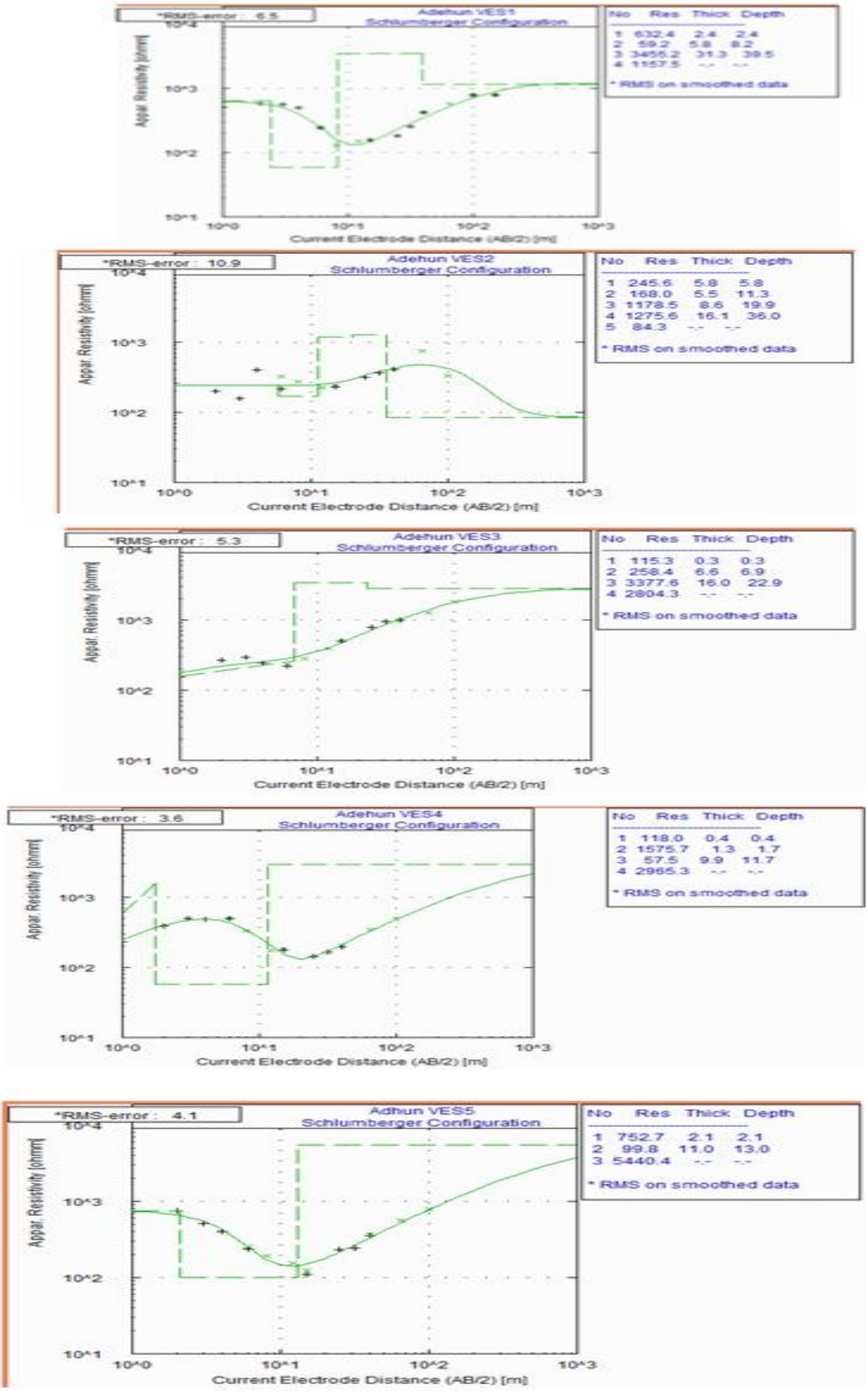


Table 1. Table of correlation

VES	RESISTIVITY (Ω-M)	THICKNESS (M)	DEPTH (M)	CURVE TYPE	NO OF LAYERS	REMARK
VES 1	632.4	2.4	2.4	HK	4	Top soil
	59.2	5.8	8.2			Weathered layer
	3455.2	31.31	39.5			Fresh basement
	1157.5	-	-			Fractured basement
VES 2	245.6	5.8	5.8	KHA	5	Top soil
	168.0	5.5	11.3			Weathered layer
	1178.5	8.6	19.9			Fresh basement
	1275.6	16.1	36.0			Fresh basement
	84.3	-	-			Fractured basement
VES 3	115.3	0.3	0.3	A	4	Top soil
	258.4	6.6	6.9			Weathered layer
	3377.6	16.0	22.9			Fresh basement
	2804.3	-	-			Fractured basement
VES 4	118.0	0.4	0.4	KH	4	Top soil
	1575.7	1.3	1.7			Weathered layer
	57.5	9.9	11.6			Fractured basement
	2965.3	-	-			Fresh basemen
VES 5	752.7	2.1	2.1	H	3	Top soil
	99.8	11.0	13.1			Weathered layer
	5540.4	-				Fresh basement

INTEGRATION OF RESULTS

The results from the ERT and VES indicate similar subsurface layers which show the consistency and effectiveness of the electrical resistivity method to properly delineate the subsurface materials (Zarroca, 2011, Adenuga, 2020, Oni et al., 2022). As indicated in the ERT (Figs. 2a and 2b) that is point 16-19 indicate shallow and thin topsoil materials and weathered layers characterizing the subsurface of that region. Thereafter, a fresh basement and a partly fractured basement with a red – purple hue colours lie below. This same similar anomaly is observable on the geo-electric section generated for traverse 1 and two (Figs. 4a and 4b).

RESULT EVALUATION FOR BUILDING FOUNDATION

Analysis of result generated from both methods indicated that Traverse 1 is more suitable for sitting a foundation for building due to the shallow depth of top soil materials as well as the shallow depth of the weathered layer. To avoid differential settlement of foundations, foundation is always advised to be setup on consolidated stable surface like the basement rock with higher compressibility strength as a means of estimating for the load bearing capacity of the subsurface materials to withstand the structure impact on the subsurface.

CONCLUSION

This study evaluated the efficiency of the electrical resistivity method adopting the Schlumberger array for vertical electrical soundings and the dipole-dipole array for electrical resistivity tomography. The result generated describe VES 2 and VES 3 as areas most suitable for sitting a

Fig. 4a. Geoelectric section across traverse 1

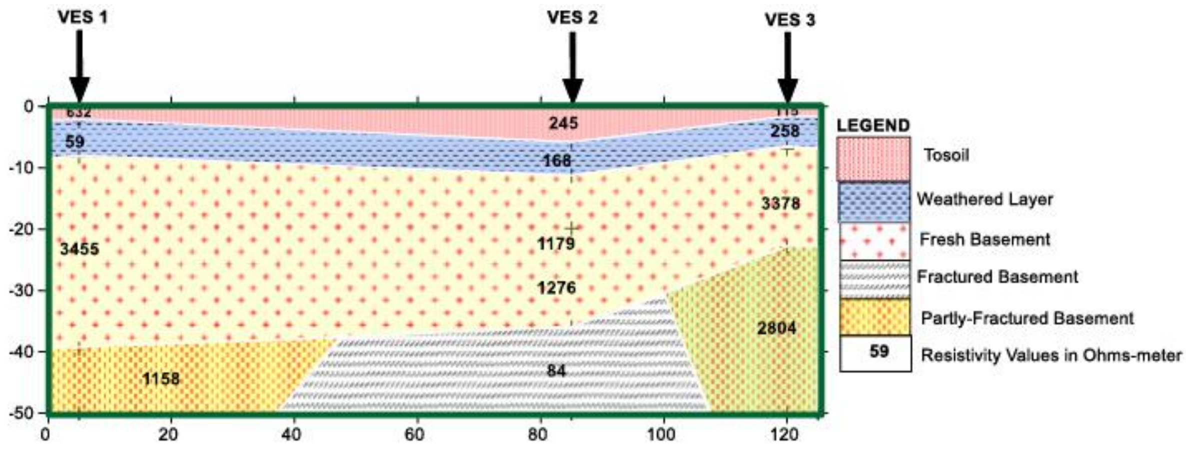
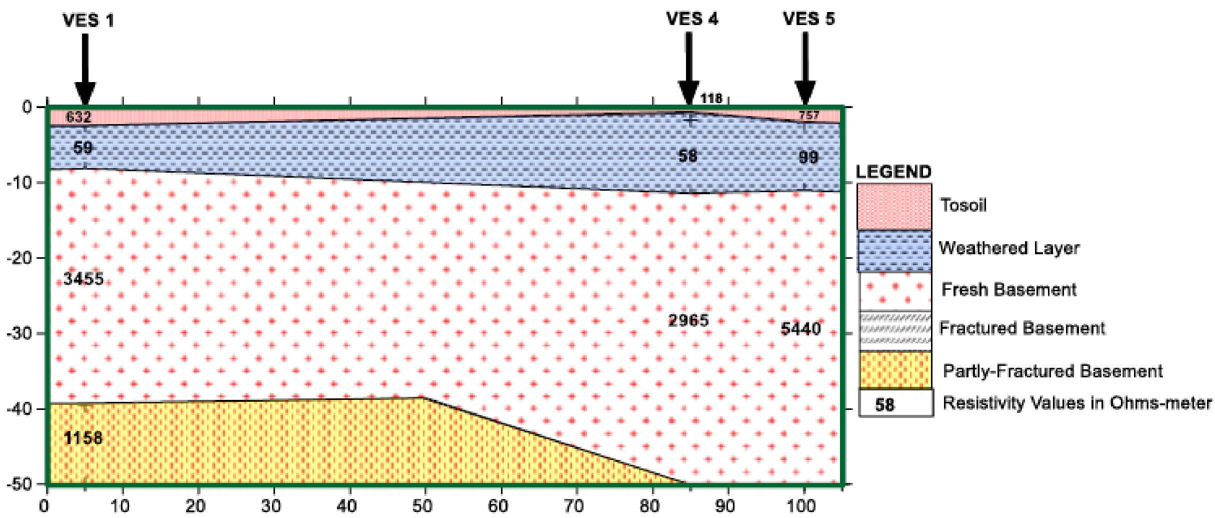


Fig. 4b. Geoelectric section across traverse 2



building construction project due to the shallow depth of the basement layer with higher resistivity values. The weathered and top soil layers are relatively thin. The higher resistivity values indicate layers with high compressibility strength for potential building foundation. However in case of consideration of other areas along traverse 2, a deep a foundation such as the pile foundation should be considered so as to transfer the loads to a deeper, and more stable soil or rock layers.

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