ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2521-0890 (Print)
ISSN: 2521-0491 (Online)
CODEN: GBEEB6

Geological Behavior (GBR)

DOI: http://doi.org/10.26480/gbr.02.2022.88.92

RESEARCH ARTICLE

GEOPHYSICAL POST-FOUNDATION STUDIES OF MINISRTY OF JUSTICE BUILDING, EKITI-STATE SECRETARIAT, ADO-EKITI, EKITI-STATE, NIGERIA

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ARTICLE DETAILS

Article History:

Received 16 June 2022
Accepted 18 July 2022
Available online 21 July 2022

ABSTRACT

Geophysical investigations were carried out around the ministry of Justice building, Ekiti State Secretariat, Ado-Ekiti, with the aim of investigating the possible cause(s) of failures from the foundation of the building in the government Secretariat. The Electromagnetic and Electrical Resistivity methods were used for the investigation. The Electrical Resistivity method involves Vertical Electrical Sounding (VES) and 2D Electrical Resistivity Tomography using Schlumberger and dipole-dipole configuration. Three (3) VES points were conducted along the traverse within the investigated area with half current electrode separation (AB/2) varying from 2 m to a maximum of 65 m. The electromagnetic measurements were taken at distance separation of 10 m along the traverse line in the SE-NW direction. The VES curve types obtained in the area are H and HKH. Four geoelectric layers were delineated within the investigated area which includes the topsoil, lateritic clay, clay, and partly weathered basement which is a quartzite rock with resistivity values ranging from 47-280 ohm-m, 383-435 ohm-m, 47-78 ohm-m, and 239-4999 ohm-m and the thickness ranges from 1-1.6 m, 2.8-4.2 m, and 9.1-27.9 m respectively. The dipole-dipole results also delineate four geologic formations that revealed the differential settlement within the clayey zone of the building foundations. The electromagnetic method also delineated seven subsurface geologic formations which revealed that most of the materials characterizing the subsurface are of clayey composition. The integration of the results showed that the possible cause(s) of failures in part of the building is due to the presence of clayey formations and geologic fractures within the foundation of the studied area.

KEYWORDS

Building foundation, Dipole-Dipole, VES, Geolectric Section, Electromagnetic

1. INTRODUCTION

Geophysical methods have been embraced over the years by most technologically advanced countries as a vital tool in engineering site investigations for estate development and management. Geophysics has been used to solve many civil engineering problems that had hitherto proved costly, complex, or unattainable by other civil engineering methods. Methods employed in the geophysical investigation are considered to be non-destructive, time-saving, less expensive, and very effective in site probing for engineering studies (Adebiyi et al., 2018; Adebo et al., 2019; Aigbedion et al., 2019; Aigbedion et al., 2021). Over the years, the geophysical prospecting method applied with geotechnical analysis has been successfully helpful in determining the condition of the subsurface for civil engineering investigation (Akintorinwa and Adeusi, 2009; Bawallah et al., 2019a). Architectural designs without adequate knowledge of the subsurface conditions may eventually prove abortive. The competence of the subsurface rocks in terms of their mechanical strength can be used to justify a proposed structure to be erected on them. The condition of the bedrock needs to be properly investigated for high-rising and high load impact buildings (Fadamiro, 2002; Frolova et al., 2014; Ilugbo et al., 2018a; Bawallah et al., 2019b; Bawallah et al., 2020). Although, geophysical methods are not all-encompassing when integrated, they can solve pressing problems in estate development and management.

In this present age, pre-foundation applicability is becoming more significant, in light of the present state of collapsing construction engineering structures such as roads, building, dams, and bridges across the nations (Ilugbo et al., 2018b). Unfortunately, building collapse incidences are common in the Southwestern part of Nigeria despite the development of proactive, non-destructive, time-saving, low cost, and effective engineering idea of applying geophysical parameters to delineate the subsurface condition, the usage of substandard engineering materials, lack of proper design and foundation, and building aging mostly lead to attributed to structural failures (Ozegin et al., 2019a; Oyedele et al., 2020). Moreover, undetected geological fissures such as sinkholes, faults, and cavities are other major causes associated with the properties of earth materials are often trivialized by foundation designers and structural engineers before infrastructure development and construction (Parolai et al., 2001; Parolai et al., 2002; Delgado et al., 2002). The mentioned near surface geological fissures create a great impact, including loss of property, life, and buildings (Olusola, 2002; Chary et al., 2006; Oke, 2011; Ozegin et al., 2019b). However, there is need for proper subsurface geological soil properties delineation for providing the necessary subsurface information for the proper competent engineering constructions. (Makris, 2007; Magawata et al., 2020). Ado-Ekiti being the capital of Ekiti-State is witnessing rapid structural development such as fly-over bridges, proposed high rising buildings e.t.c. Despite this rapid

Quick Response Code	Access this article online	
	Website: www.geologicalbehavior.com	DOI: 10.26480/gbr.02.2022.88.92

Cite The Article: Ajayi Christopher Ayodele, Aderemi Sunday Adeoye, Ilugbo Stephen Olubusola, Adebo Babatunde A., Adewumi Olajumoke Abisola (2022). Geophysical Post-Foundation Studies of Minisrty of Justice Building, Ekiti-State Secretariat, Ado-Ekiti, Ekiti-State, Nigeria, *Geological Behaviour 6(2): 88-92.*

growth and development, the impact of sub-surface geologic structures in the area of durability and maintenance of the erected structures has been seldom talked about. Cracks were noticed on some of the walls of the Secretariat building, which necessitated the aim of determining the possible causes of pronounced cracks observed on the building walls of the study area.

2. Site Description and Geology of The Study Area

Ado-Ekiti lies between Longitude 5^0 8.35'E and 5^0 18.05'E and Latitude 7^0 33.44'N and 7^0 43.26'N (Fig1.1), covering a total area of 346.5km^2. The study area is located at Ekiti-State Government Secretariat Office in Ado-Ekiti (Figure 1). The topography of the study area indicates a general gentle slope. The area is defined by extensive hills which are surrounded by settlements. The majority of the rocks are as high as 250 m above mean sea level (Rahaman, 1976). The study area is generally upland. Ado-Ekiti and its environs are dominated by crystalline rocks (Figure 2) which consist mainly of migmatite-gneiss-quartzite complex, older granites, quartzite, charnockites, and fine to medium-grained granites. In the study area, there is a close association between the charnockites and granitic rocks due to their field relationship as documented in the Basement complex rocks of Nigeria (Rahaman, 1979). The State Government Secretariat is located within the quartzite zone of Ado-Ekiti.

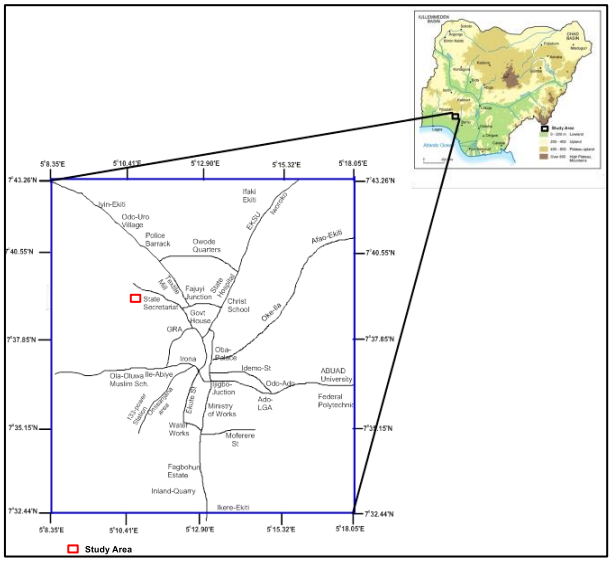

Figure 1: Location Map of the Study Area

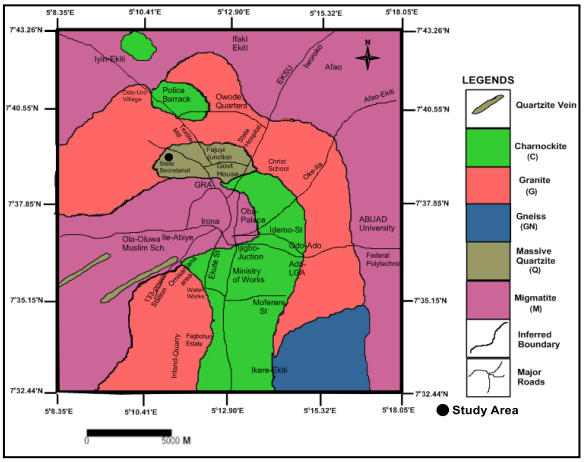

Figure 2: Geology Map of Ado-Ekiti Showing the Study Area.

3. Materials and Methods

Two geophysical methods involving the Electrical Resistivity and Electromagnetic Methods were adopted for the survey. Traverse lines were established for the data measurement at SE-NW direction along the distressed part of the building with twenty-one station points which were 105 m long, while inter-station spacing was 5 m and five numbers of movements. The Electromagnetic method utilized two rods; one is to transmit the primary field and the other is to receive the ratio of primary to secondary EM field. The Electrical Resistivity method utilized 2D ERT using dipole-dipole configuration, which was conducted across the study area along a single traverse with a length of 105 m beside the distressed part of the building (Figure 3). It gave information on the subsurface characteristic in the area with low apparent resistivity which indicates low competence material. Three Vertical Electrical Sounding (VES) station points were carried out using Schlumberger electrode configuration along the traverse. The Electrical Resistivity data was processed by plotting the apparent resistivity values against the electrode spread (AB/2). This was subsequently interpreted quantitatively using the partial curve matching method and computer-assisted 1-D forward modeling with WinResist 1.0 version software (Vander, 2004). The dipole-dipole data were inverted into 2-D subsurface images using the DIPPRO(TM) 4.0 inversion software to obtain 2-D electrical imaging of the subsurface. Resistivity values were obtained by taking readings using the Omega resistivity meter (DIPPRO, 2000). All three techniques were integrated to determine the possible causes of pronounced cracks on the building walls of the study area.

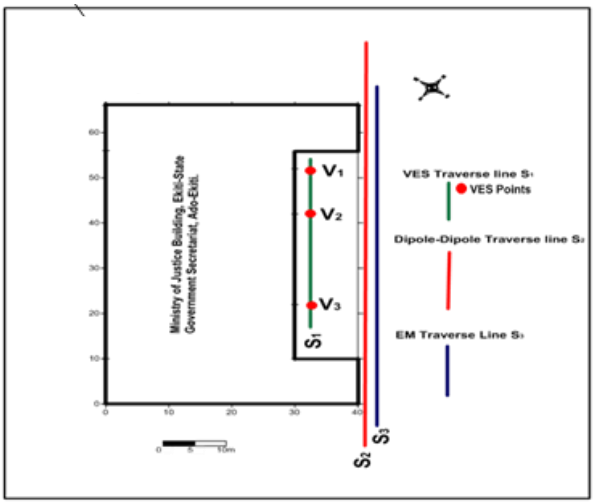

Figure 3: Data Acquisition Map of the Study Area

4. Results and Discussion

4.1 Dipole-Dipole Technique

Figure 4 shows the pseudo-section of the 2D-Electrical Resistivity Image derived from the dipole-dipole array conducted along the traverse. The investigation was able to probe down to a depth of 15 m. The 2D-image was able to delineate four geologic formations namely; clay, lateritic clay, weathered basement, and partly fresh basement with resistivity values ranging from 6-20, 21 – 64, 65 – 180, and 181 – 631 ohm-m. The 2D-Resistivity image shows the presence of clayey materials between the distance of 0 – 30 m to a depth of 10 m; 35 – 45 m to a depth ranges from 10 -15 m; 55 – 70 m within depth range from 0 -15 m and 70 – 85 m to a depth range from 0 – 10 m. This shows that the building was constructed on an incompetent formation of clay. The cracks observed on the walls must be a result of differential settlement within the foundation of the building.

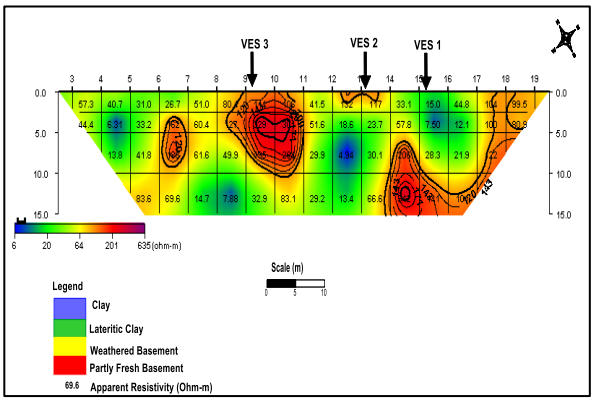

Figure 4: 2D-Electrical Resistivity Image of the Study Area

5. Vertical Electrical Sounding

5.1 Characteristic of the VES Curves

Curves types identified ranges from H and HKH varying between three to five geoelectric layers and HKH curve type was predominating (Figure 5).

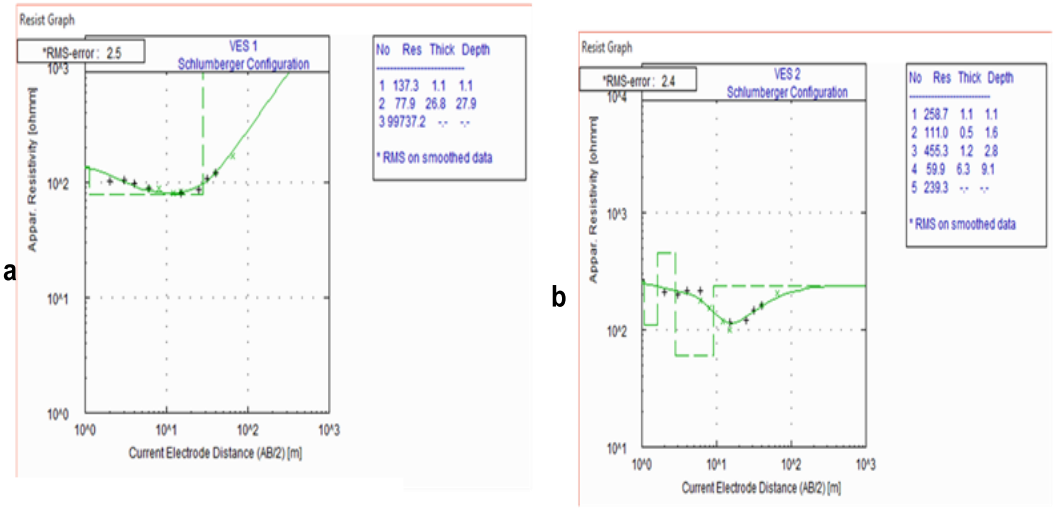

Figure 5: Typical curves Types of the Study Area (a) H (b) HKH

5.2 Geolectric Sections

In order to have better understanding of the nature of the lithologies underlying the study area, and to have a detailed description of the lateral and vertical variation in resistivity, thickness and topography of the subsurface lithologies, the VES interpretation results were used to prepare geoelectric sections across the study area, that align approximately along E-W direction. Figure 6 display the geoelectric section from the three Vertical Electrical Sounding obtained from the study area. Four geologic formations were delineated, these are; topsoil, lateritic clay, clay, and partly weathered basement which is quartzite rock with resistivity values of 47 -280, 383 – 435, 47 – 78, and 239 – 4999 Ohm-m, and thickness range of 1 – 1.6, 2.8 – 4.2, 9.1 - 27.9 and 2.8 - ∞ m respectively. The thick clay and lateritic clay observed in the study further confirm that the building was constructed on plastic clay and a very loose formation.

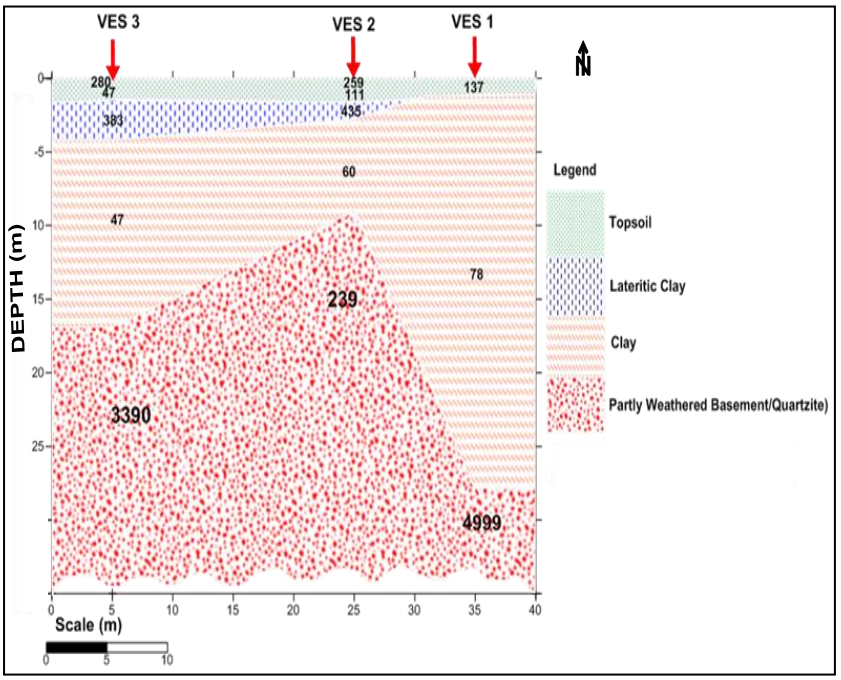

Figure 6: Geo-electric Section of the Study Area

5.3 2-D Subsurface Electromagnetic Method

Figure 7 shows the result of the electromagnetic survey conducted along the single traverse developed behind the building, 2D-image of subsurface representing the ratio of the secondary field to the primary field measured in percentage. The higher the percentage, the higher the induration of the formation characterising the subsurface. Seven geologic formations were generated from the study which are; clay, sandy-clay, lateritic-clay, partly weathered zone, weathered zone, fractured basement, and fresh basement. The EM method was able to delineate down to 300 m depth of the study area. The study also revealed that most of the materials characterizing the subsurface are of clayey composition which is very inappropriate for building construction, especially high rising engineering construction works. This result shows that the incompetent clay content was noticed within distance 8 – 32 m to a depth of 32 m; 35 – 44 m to depth of 35 m; 46 – 52m to a depth of 20 m and 54 – 68 m to a depth of 62 m are all made of clayey materials.

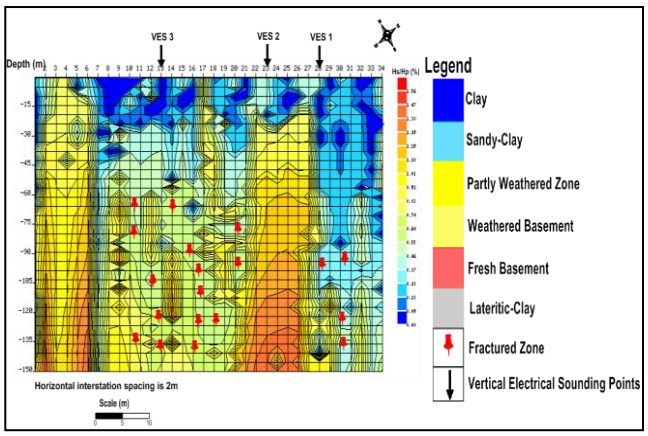

Figure 7: 2-D Hs/Hp (%) Image of the Electromagnetic Survey

5.4 Integration of Results

From the integration of results as indicated in Figure 8, the techniques used probably supports some initial hypothesis. Synchronising the three results together revealed that the building was constructed on very thick clayey materials formed within the vicinity of highly weathered quartzite rock. No high-loading civil engineering construction works can take place on such terrain. The result of the highly deformed formation underlying the study area generated the weaknesses indicated on the walls of the building. Future researchers should complement the stated approach (geophysical method) with geotechnical method to have a proper understanding of the geology of area, and information on the low bearing capacity of the soil. Due to inavalability of fund, this research was unable to carried out geotechnical analysis of the soil within the study area.

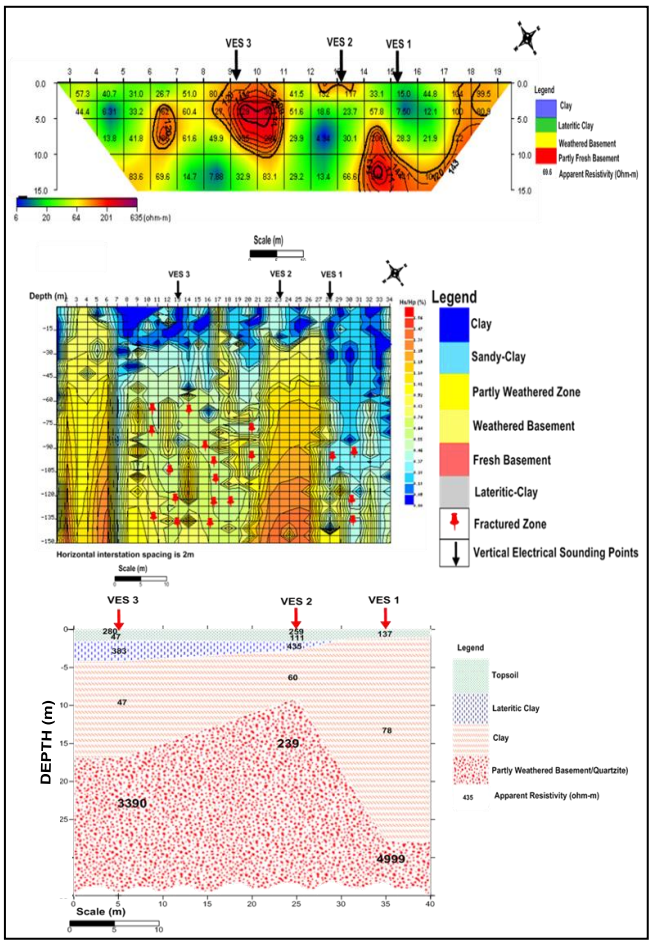

Figure 8: Correlation of 2D-Electrical Resistivity Image, Geoelectric Section and the 2D-image of EM Potential Field ratio in Percentage

6. Conclusion

Two geophysical methods were adopted for the geotechnical investigation of the studied area around the distressed building of the Ministry of Justice, Ekiti-State Federal Secretariat, Ado-Ekiti. The interpretation of these methods showed the delineation of incompetent zones in the area which is inimical to engineering works. These identified weak zones expose the building to future failure and eventual collapse. The result shows that the formation characterising the subsurface is mostly clayey down to a depth of about 15 – 45 m. Clay, though highly porous but less permeable owing to poor connectivity of its pores, retains water without releasing it thus making it swell up and collapse at the exertion of pressure. Also, the presence of geologic features such as fractured zones within the subsurface structure in the area creates structurally weak zones. These have resulted in deformations observable on the walls of the building under investigation. The result of the study has established that most of the overburden materials under the foundation of the building was mostly clay. Since the clay is so thick, such that in some parts of it is as thick as 40 m and above, no treatment can be adopted in the foundation or the building itself that can prevent it from future total collapse. The formations of the cracks down to the foundation are indications of imminent collapse. Therefore, there is a need to evacuate the whole building structure with the subsurface down to a depth of 30 m within distances 12 – 44 m; depth of 20 m within distances 48 – 52 m, and depth of about 40 m within distances 54 to 68 m. Synchronising the three results together revealed that the building was constructed on very thick clayey materials formed within the vicinity of highly weathered quartzite rock. No high-loading civil engineering construction works can take place on such terrain. The result of the highly deformed formation underlying the study area generated the weaknesses indicated on the walls of the buildingThese proposed portions for evacuation should be refilled with boulders and hardcore before construction of any high rising building could take place there.

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