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# Electrical resistivity measurements in delineating near-surface lithologic units in Federal College of Education, Asaba, Delta State, Nigeria: Implications for building foundation failure

**Esiekpe L Ese[1], Imiere E Edeki[1], Alade M Aiyeoribe[1] and Nuhu A Tafida[1]**

[1] Department of Physics/Computer Education, Federal College of Education (Technical), Asaba, Delta State, Nigeria

Corresponding E-mail: tejiriandfejiro@gmail.com

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### Abstract

An electrical resistivity investigation was carried out in parts of the College of Education (Technical) Asaba to delineate the subsurface lithologic units with special emphasis on the competence and suitability for engineering foundations. A total of ten (10) vertical electrical sounding and two (2) horizontal profiling stations were covered within the study area using the Schlumberger and dipole-dipole configurations. The acquired data was analyzed using WinResist and RES2DINV Software; the subsurface within the study area is composed of mostly 3 geoelectric layers: topsoil, clay/sandy clay/clayey sand and sand. The second and third layers have relatively low resistivity ranging between 29 – 94 Ωm and consist of incompetent clayey material underlying about 60 % of the investigated study area. The interpreted field results showed a significant clay overburden that is over 5 m thick. A fourth layer of sand with resistivity values ranging between 451 – 1258 Ωm was encountered at depths between 4.9 – 11.5 m; the thickness of this layer with reference from the borehole log is greater than 20 m. It is therefore recommended that the incompetent clayey material be avoided or excavated before constructing any structure.

Keywords: Foundation; Electrical resistivity; VES points; Failure; compressibility; Geoelectric layers.

## I. Introduction

Most structures constructed on the earth's surface have foundations that are supported mostly by the soils and rocks. The foundation of any structure is expected to transfer the load of the structure to the ground without initiating any response of the ground to any uneven and excessive movement. In the last few decades, the collapse of several buildings due to structural failure has been witnessed in Nigeria and has led to the loss of lives and properties [1, 2, 3]. Structural failure can be attributed to inadequate knowledge of certain physical properties and geologic characteristics that govern the competency of the soil/rock material for building development [4, 5, 6]. It is therefore imperative, that the nature of the soil or rock supporting the foundation be determined as this is important for the safety, durability and structural integrity of the construction. Hence, geophysical site investigations before building should be carried out to reveal the characteristics of the soil materials at a construction site, and to determine the ability of the soil to support structures placed on them [7, 8].

For a successful building process of any engineering structure, sufficient information about the subsurface soil condition are requirements that must not be neglected [9]. Subsurface geological features such as clays, fractures, voids and shallow water tables are among the inconveniences which have been recognized to pose noticeable constraints to foundations. Therefore, the knowledge of the likely cause of widespread failure of buildings due to structural differential settlement leading to cracks or outright collapse of buildings has become of great concern. The need for pre-foundation studies has therefore become imperative due to the failure of structures such as buildings, tarred roads, and bridges to prevent the loss of valuable properties and lives that always accompany such failures. This information can be obtained readily from soil investigation using conventional borehole drilling and geotechnical investigations. These methods are, however, often laborious, expensive and invasive. The electrical resistivity method offers a faster, cost-effective and non-invasive method in site characterization [10, 11]. Several studies have investigated the cause of structural failure using the electrical resistivity method [3, 12, 13, 14, 15], they attributed the failure to the clay content of topsoil.

Failure of engineering structures such as buildings by cracks is quite common at the Federal College of Education (Technical) Asaba. This present study attempts to delineate the lateral and vertical extent of the various lithological units, particularly the expected clayey layer and determine depth to competent sandy layer using vertical electrical sounding and 2D electrical resistivity imaging at the Federal College of Education (Technical) Asaba.

### *A. Location of Study Area and Geology*

The study area is within the Federal College of Education (Technical) which is in Asaba (Fig. 1). It is bounded by longitudes 6° 41' 45" E to 6° 42' 15" E and latitudes 6° 10' 44" N to 6° 11' 24" N. The geological setting of the study area, as a part of the Niger Delta, has been addressed by [16]. The subsurface lithologic units are made up of about 25 – 30 m thick alluvium which represents the aquifer in the area, the alluvium is Pleistocene to Recent; this was followed by a succession of the Eocene Ogwashi – Asaba Formation and the Oligocene – Miocene Ameki Formation.

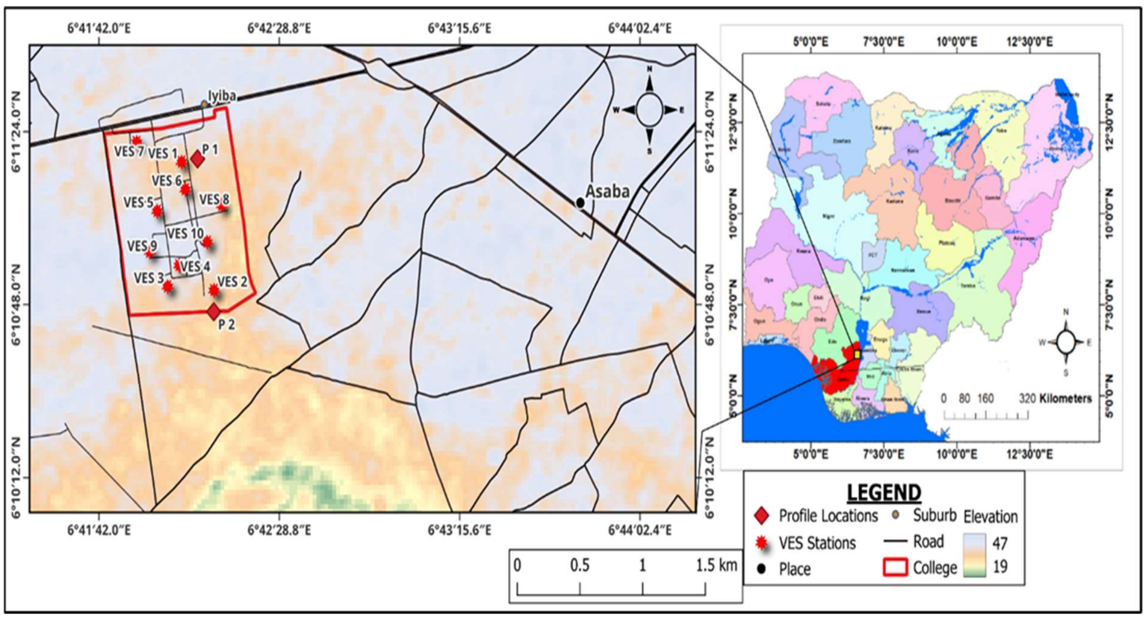



Fig. 1 Map of study area showing VES points and Dipole-Dipole Profiling.

## II. Materials and Methods

In this study, resistivity was measured using ABEM SAS (1000) Terrameter. The resistivity investigation involved Vertical Electrical Sounding (VES) with Schlumberger configuration and horizontal profiling using dipole-dipole configuration. Ten (10) soundings and two (2) profiling were performed in the study area as shown in Fig. 1. The choice of the dipole-dipole configuration is because it is very sensitive to horizontal resistivity variations with depth. The VES data was measured with current electrode spacing (AB) varying from 1 to 200 m. Horizontal profiling was carried out using electrode separation, $a = 5\ m$, while $n$ was increased from 1 to 2 and up to 3 to increase the depth of investigation.

The resistivity measured on the field with Schlumberger and dipole-dipole configurations were converted to apparent resistivity ($\rho_a$) using (1).

$$\rho_a = \frac{\Delta V}{I} K \quad (1)$$

Where ΔV is potential difference between electrodes, I, is current while K is geometric factor dependent on field configuration. The geometric factor for Schlumberger and dipole-dipole configurations are given by (2) and (3) respectively.

$$K = \frac{2\pi}{\left(\frac{1}{r_1} - \frac{1}{r_2}\right) - \left(\frac{1}{r_3} - \frac{1}{r_4}\right)} \quad (2)$$

$$K = \pi n a(n+1)(n+2) \quad (3)$$

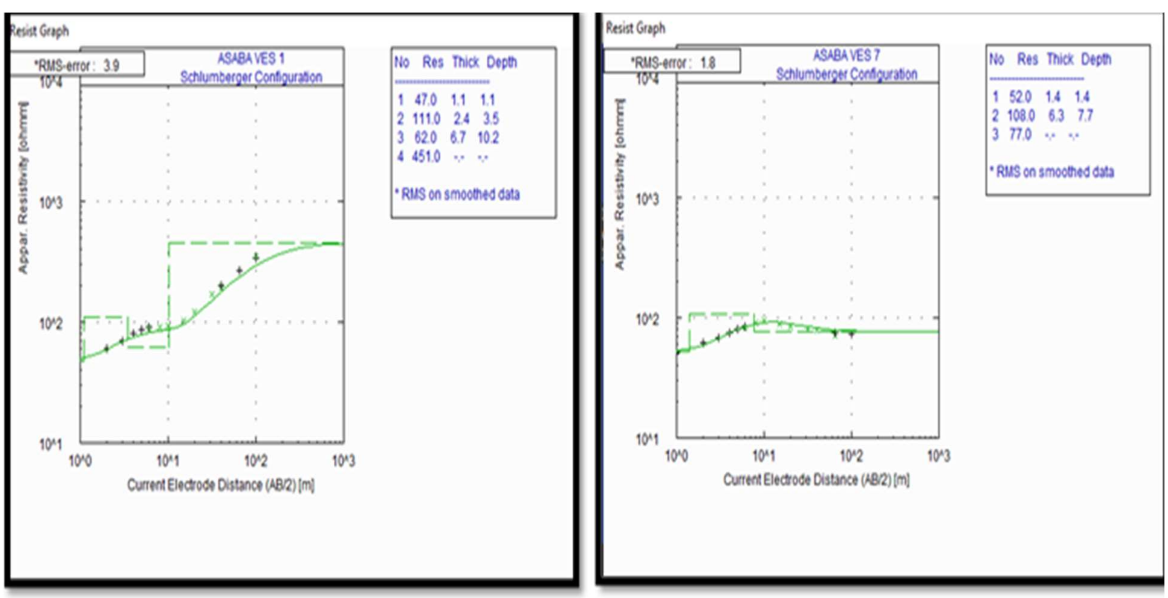
The measured resistivity by sounding were interpreted using partial curve matching and computer iteration using WinResist software while resistivity observed via profiling was interpreted using RES2DINV software. The field procedure and processing of acquisition of resistivity data using the Schlumberger and dipole-dipole configurations are abundant in the literatures [17, 18, 19, 20, 21, 22, 23].

## III. Results and Discussion

The results of the resistivity soundings are shown in Fig. 2 and Table I, the geoelectric section (Fig. 3) indicated the presence of three (3) to four (4) geoelectric sequences that include: topsoil; clay/sand; clay/sand and sand. The first layer is made up of topsoil composed of mostly clay, clayey sand and sand; resistivity values ranged from 37 – 552 Ωm. The thickness of the layer is between 0.7 and 1.4 m. Beneath the topsoil is clay with resistivity values vary from 29 – 321 Ωm. The thickness ranges from 2.4 – 11.5 m. The second layer in the study area is predominately clayey that underlie about 80 % of the area. The third layer is also made up of clay and sand; the proportion of clay in this layer has reduced to 40% especially in the central parts of the campus. The resistivity values ranging from 50 – 846 Ωm, the thickness of this layer could not be ascertained as current terminated with this layer. However, inference from VES location 8 the thickness of this layer could be over 7 m thick. A fourth layer of mainly sand existing at depths ranging from 6.4 – 11.5 m was delineated at locations 1, 8 and 10; the resistivity of this layer ranged from 451 – 1258 Ωm.

Table I. Layer resistivity model and probable lithologic units.

| S/N | Layers | Resistivity (Ωm) | Thickness (m) | Depth (m) | Probable Lithology |
|---|---|---|---|---|---|
| 1 | 1 | 47 | 1.1 | 1.1 | Clay |
| | 2 | 111 | 2.4 | 3.5 | Sandy clay |
| | 3 | 62 | 6.7 | 10.2 | Clay |
| | 4 | 451 | - | | Sand |
| 2 | 1 | 116 | 1.4 | 1.4 | Sandy clay |
| | 2 | 65 | 7.2 | 8.6 | Clay |
| | 3 | 846 | - | | Sand |
| 3 | 1 | 121 | 1.4 | 1.4 | Clayey sand |
| | 2 | 52 | 11.5 | 12.9 | Clay |
| | 3 | 312 | - | | Sand |
| 4 | 1 | 37 | 1.1 | 1.1 | Clay |
| | 2 | 94 | 9.7 | 10.8 | Clay |
| | 3 | 206 | - | | Sand |
| 5 | 1 | 241 | 1.2 | 1.2 | Sand |
| | 2 | 302 | 8.5 | 9.7 | Sand |
| | 3 | 134 | - | | Clayey sand |
| 6 | 1 | 552 | 0.9 | 0.9 | Sand |
| | 2 | 129 | 9.6 | 10.5 | Clayey sand |
| | 3 | 85 | - | | Clay |
| 7 | 1 | 52 | 1.4 | 1.4 | Clay |
| | 2 | 108 | 6.3 | 7.7 | Sandy clay |
| | 3 | 77 | - | | Clay |
| 8 | 1 | 282 | 1.2 | 1.2 | Sand |
| | 2 | 87 | 3.4 | 4.6 | Clay |
| | 3 | 50 | 6.9 | 11.5 | Clay |
| | 4 | 972 | - | | Sand |
| 9 | 1 | 495 | 1.0 | 1.0 | Sand |
| | 2 | 113 | 3.1 | 4.1 | Sandy clay |
| | 3 | 629 | - | | Sand |
| 10 | 1 | 98 | 0.7 | 0.7 | Clay |
| | 2 | 321 | 4.2 | 4.9 | Sand |




(a) (b)

Fig. 2 Typical computer iterated sounding curves of the study area.

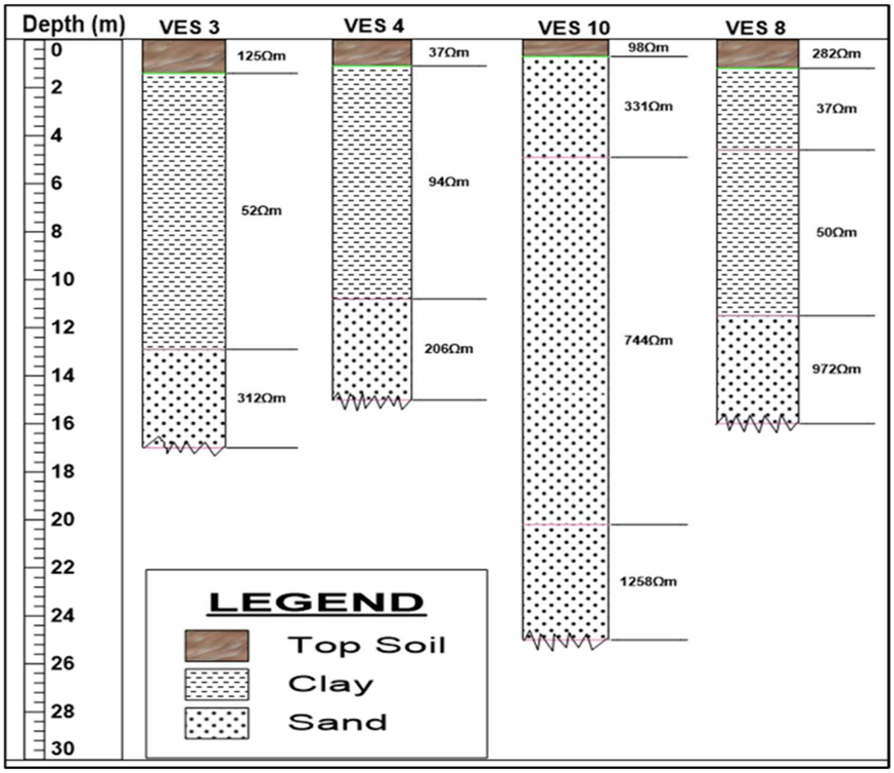



Fig. 3 Geoelectric section of the study area.

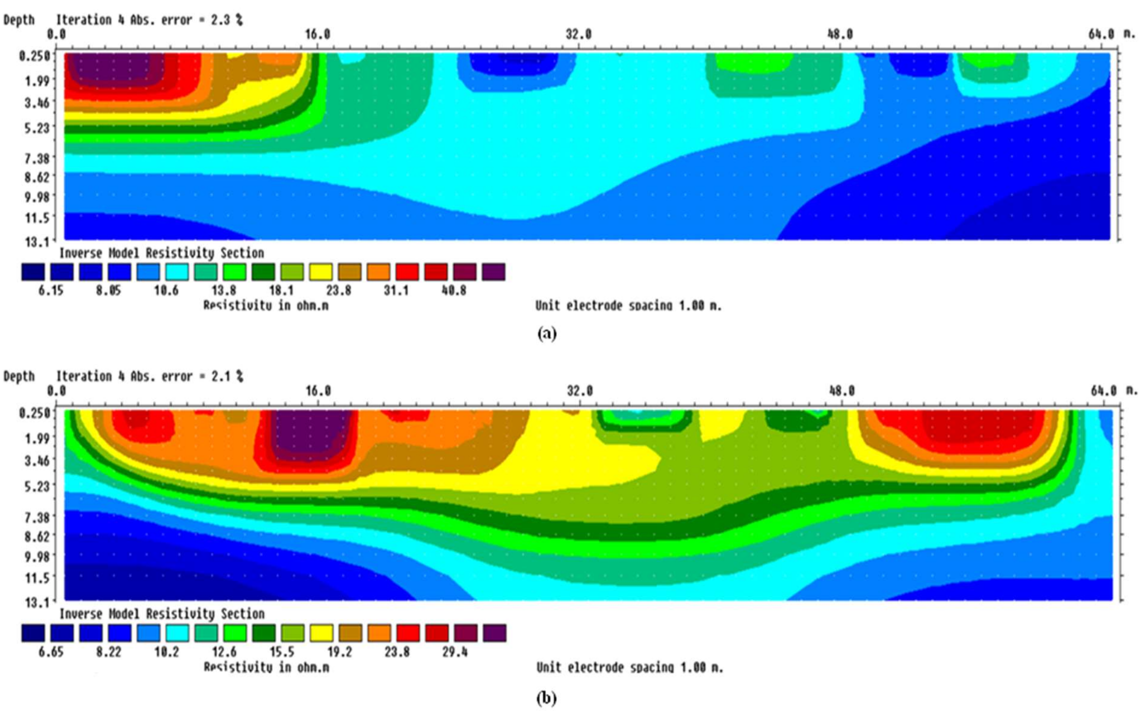



Fig. 4 Inverted 2D electrical resistivity imaging of profile 1 and 2.

(a) (a)

Plate 1 Cracks on the walls of (a) Physics Department building, (b) School of Science building, due to failure of foundation at College of Education (Technical) Asaba.

The result of 2D resistivity imaging at the 2 profiles in the study area is shown in Fig. 4. The inverted section revealed zones of very low resistivity varying between 6.15 – 40.8 Ωm. The low resistivity zones which clearly dominates the entire profiles consists of probably clays mottled with sandy clays and clayey sand. The maximum thickness of the clayey material underlying the area is greater than 13 m correlates with the thickness derived from VES data (> 10 m). Resistivity values decrease with depth indicating saturation of clays with water; according to [24] an increase in moisture content of soil cause resistivity to decrease. Clayey soils are characterized by high compressibility, low coefficient of permeability and this gives the soil a high-water holding capacity. According to [23], the high natural moisture content lowers the strength and dry density of the soil while high compressibility can result in differential settlement. These can result in cracks (see Plate 1) and subsequent failure of engineering structures; generally, clayey soils which contain a lot of water are not good for engineering construction purposes.

Hence, the cracks on the walls of some buildings could be attributed to laying of the foundation within these clayey layers, which triggered off movement and subsequently led to the failure of the foundation of some building which appeared at the surface as cracks on the wall. The competent layer of this study as suggested by the investigation is the fourth layer and it is suitable for laying of foundations. Shallow foundation is possible around locations 5, 8 and 10 because of presence of competent sandy layer. The low resistivity clay layer should be avoided because they are subject to differential settlement and possible flow under load as they display poor geotechnical properties, shear strength and high compressibility.

## IV. Conclusion

The result of resistivity investigation undertaken at the College of Education (Technical) Asaba campus shows that 70% of the study area is underlain by 3 layers of different lithological composition, namely the topsoil, clay/sandy clay/clayey sand and sand. The second layer in the area is predominantly clayey that underlie about 80% of the area. The third layer is also made up of clay and sand; the proportion of clay in this layer has reduced to 40%. The sandy layer in the area is mostly characterized by high resistivity values indicative of fine – medium grained sand suitable for massive load bearing sustainability are confined to the central parts of the campus. The presence of thick clays with thickness greater than 10 m has been established in this study. The cracks on buildings within the campus have been attributed to inability of the engineers to dig the foundation to the required depth or the construction of heavier structures on very weak subsurface layers which may have triggered off movement within the foundation of these structures, thus causing failure. The incompetent clayey materials should be excavated and refilled with suitable materials for the foundation of super-engineering structures in the campus, raft foundation and deep foundations in form of piles in the area of less competence are also recommended.

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