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Evaluation of Near-Surface Conditions for Engineering Site Characterization Using Combined Geoelectrical and Seismic Methods in the Faculty of Engineering Open Field, University of Benin, Nigeria

***Airen, J. O., [1]Osifo J. O.**

Department of Physics, Faculty of Physical Sciences, University of Benin, Benin City, Nigeria

*Corresponding author's email: osariere.airen@uniben.edu Phone: +2348039591347

ABSTRACT

At the University of Benin's Faculty of Engineering open field, integrated geophysical methods utilizing seismic refraction and electrical resistivity have been used to assess the near-surface conditions for engineering site assessment. In order to create three (3) profiles, seismic and electrical refraction methods were used. Seismic refraction within the research region was recorded using an ABEM Terraloc Mk.6 equipped with a 24-channel recording system, while electrical resistivity was measured using a PASI terrameter (model 16GL). The 2D electrical resistivity imaging was conducted using the Wenner electrode arrangement. Software called DIPROWIN was used to process the 2D resistivity data, while Seisimager/SW (version 1.0.8) was used for quality checking and processing of the seismic recorded data.Three resistivity structures—representing sandy clay, laterite, and clayey sand—were identified using 2D electrical imaging, and the seismic data display the velocities associated with different layers as well as the dip interface between the profiles' layers. The sections showed three layers, which are indicative of lateritic clay/shaly materials, with average velocities of 450–547 m/s for the first layer, 575–601 m/s for the second layer and 700–900 m/s for the third layer. The results of the study provide credence to the usefulness of seismic and electrical resistivity methods in evaluating the appropriateness of subsurface materials. When selecting the foundation materials, one must take into account the properties of the sandy clay in the soil. To establish an appropriate foundation design for structures, it is suggested that engineering soil testing procedures be applied.

Keywords:
Wenner,
Laterite,
Seisimager,
Terraloc,
Integrated.

INTRODUCTION

A building is a structure that has been specifically constructed and designed to offer the room and amenities required for that use. They protect people, their belongings and their activities.

In order to deliver the intended well-being for its occupants, enhance the environment, and promote national development, buildings must be carefully planned, designed, built, managed and maintained (Babalola 2015). According to Oni (2010), well-built structures offer their occupants comfort, protection, security, and social, psychological, and financial well-being. According to Omole (2001), building condition refers to the entirety of a certain dwelling's surroundings, physical state and overall well-being as determined by characteristics related to habitability at a given period.

Thus, it is required of buildings to satisfy present demands as well as those of the future and to demonstrate their sustainability. Additionally, most large cities in the world experience building collapse on a regular basis, which presents a significant risk to sustainable urban growth. Climate change-related issues imply that the likelihood of disasters may rise since the most devastating events tend to occur in regions that are vulnerable to extreme weather (Boateng and Wright, 2018).

A lot has been put into addressing the critical issue of auxiliary collapse, particularly in the field of subterranean investigations, in order to identify and treat the underlying reasons. It is impossible to overestimate the value of shallow geophysical techniques in enhancing geotechnical concerns in architecture design (Chu et al., 2018). Numerous fundamental issues arise from inadequate development planning and the absence of geophysical or geotechnical evaluations prior to development. Catastrophic structural conditions frequently evolved, showing up as building collapse, collapse or uniform subsidence, bulkhead fractures (differential subsidence), and eventually building collapse.

Prior to developing foundations for significant engineering structures, foundation surveys must characterize the subsurface and determine the ground's strength (Folorunso et al., 2012). Assessing the area's feasibility requires extensive subsurface exploration utilizing geophysical technologies. for construction projects other than building works. There are numerous instances of high-rise building collapse, but the primary reason is the deficiency of sufficient geophysical surveys conducted before embarking on construction, which offer insights into the characteristics of the subsurface and recommend areas for construction activities.

The majority of structures are constructed on weak soil that cannot hold up the weight of the building. Expanded clay, which swells or contracts in response to variations in water content, may be present in near-surface soils (Andrew et al., 2013). When clay dries unevenly and becomes hydrated, bedrock motion can happen (Andrew et al., 2013). Some of the damaging elements that limit building structures, especially foundations, include subsurface geological features like voids, fissures and depths near bedrock.

Geophysics is a vital tool for the investigation and identification of subsurface materials and structures in engineering and foundation research. In order to evaluate the suitability of different soil types for foundation construction, geophysical methods like resistivity and seismic refraction offer a large temporal and spatial capacity, speed, economic feasibility, reduced labour costs and cost-effectiveness due to their ability to cover a larger area quickly (Jung-Ho et al., 2007; Soupios et al., 2007; Suhda et al., 2009; Chalikakis et al., 2011; Ayolabi et al., 2012; Ishola et al., 2014; Kowalczyk et al., 2015; Adeoti et al., 2018; Chu et al., 2018; Prudhomme et al., 2019).

Additionally, a number of academics have characterized the suitability of near-surface materials for building constructions, roadways and foundations using combined geophysical and geotechnical investigations (Igwe and Umbugadu, 2020; Naji et al., 2020; Ferguson and Gautreau, 2022; Jusoh et al., 2022). Since these techniques are dependable, noninvasive, and affordable for engineering applications to identify potentially unsuitable geological conditions, determine small-strain stiffness of soil and rock, analyze foundation instability and identify site classes, multichannel analysis of surface waves (MASW) is frequently used in this regard to measure the shear wave velocity (Vs) of near-surface materials (Rubaiyn et al., 2019; Le Ngal et al., 2019; Ishola et al., 2022).

Seismic refraction techniques have also been widely applied in dam safety, groundwater studies, engineering objectives, environmental projects, geotechnical investigations, and identifying the interfaces between layers of different seismic velocities (Bridle, 2006; Yilmaz et al., 2006; Hodgkinson and Brown, 2005; Lankston, 1989). According to Zhang and Toksöz (1998), SSR is applied because of its evident data analysis and expensive successful fieldwork. In this investigation, seismic refraction was chosen since it covers a fair amount of ground.

MATERIALS AND METHOD

Location and Geology

The Niger Delta Basin includes the southern state of Nigeria, Edo State. At the mouths of the Niger-Benue and Cross River systems, the basin is a vast continental margin basin that was formed during the Eocene and is located in the Gulf of Guinea. It is part of the Central South Atlantic Ocean (Figure 1). This delta is mostly shaped by waves and tides, and its sand bodies may have varying thicknesses due to growth faulting. Roughly 90% of the intercalations of sandstone and shale are found in sedimentary rock. Nigeria's southwest is where Edo State is located. Because of its proximity to the oil reserves in the Niger Delta, it is a significant sedimentary basin in Nigeria.

With over 40,000 people attending the University of Benin and with two separate seasons—wet from April to October and dry from November to March, the Ugbowo Campus of the University of Benin in Benin City, Edo State, is situated amid a tropical rain forest. Between latitudes 6019'57" N and 6020'03" N and longitudes 5036'22" E and 50'36'26" E is where it is located. The research area is contained within the Benin Formation (Fig. 1), which stretches southward past the current shoreline and from the west throughout the entire Niger Delta region.

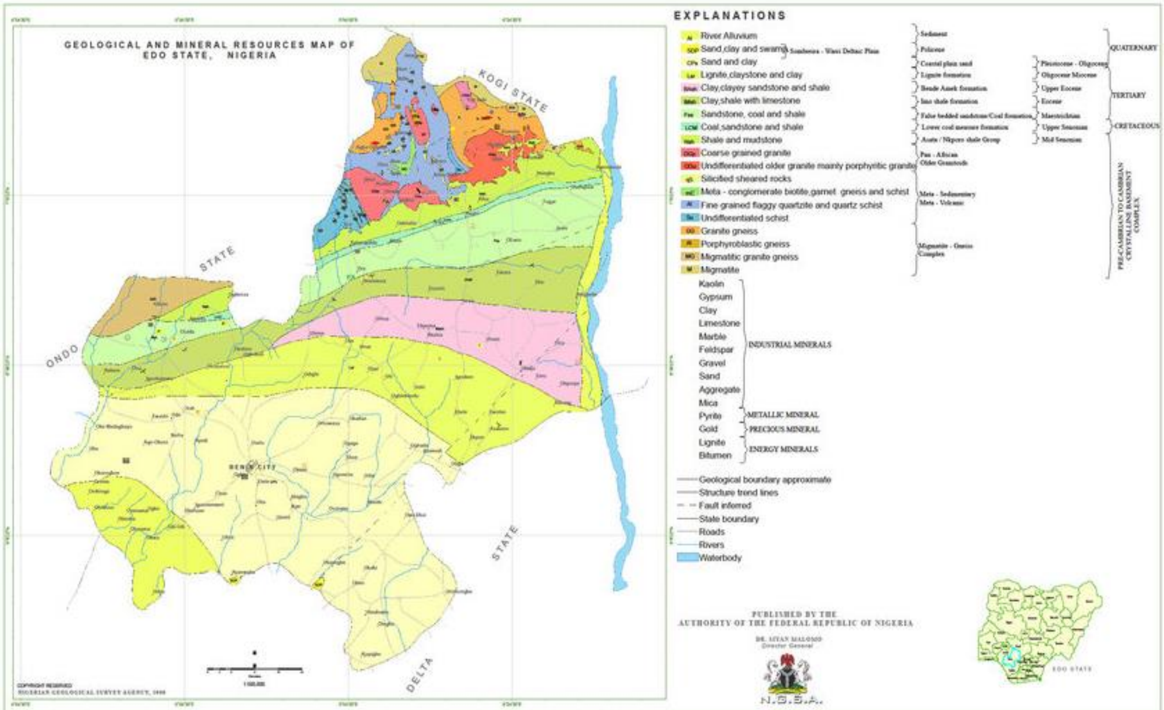

Figure 1. Geological Map of Edo State Showing Benin City and other Locations (Nigerian Geological Survey Agency, 2006).

Basic Concept of Electrical and Seismic Method

The geophysical techniques of seismic refraction and 2D electrical resistivity were employed in this study. The resistivity was measured using the PASI earth resistivity meter 16GL model, while the seismic data was acquired using the 24-Channel ABEM Terraloc Mark 6 seismograph equipment.

By measuring the potential at the surface, which is the outcome of a known current flowing into the ground, one can apply the electrical resistivity method (Bhattacharya and Patra 1968; VanNorstrand and Cook 1966; Ritz et al. 1999). It makes use of two current electrodes (A and B) and two potential electrodes (M and N) and get the apparent resistivity ρ_a from this. On the other hand, circular wavefronts are created by seismic waves moving through a homogenous layer at a constant seismic velocity; these wavefronts' propagation can be represented by straight lines. Furthermore, seismically homogenous layers are uncommonly encountered close to the earth's surface, where large spatial differences in seismic velocity are caused by changes in the composition and structure of the geological layers as well as rising litho-static pressure. These changes are typically discontinuous at layer interfaces and gradual within a layer.

Data Acquisition

The Wenner electrode array design, seismic refraction method, and the PASI earth resistivity meter 16GL model were utilized to capture the data set throughout three (3) traverses. Four electrodes, spaced at 10 m intervals and with a maximum length of 200 m each, were used to make measurements at sequences of electrodes at 10, 20, 30, 40, 50, and 60 m intervals. Using a 15 kg hammer struck on a 0.3 m iron disc and a 5 m geophone spacing, seismic refraction was performed.

Data Processing

The software RES2DINV was utilized to reverse the 2D apparent resistivity data. The 2-D Inverse Resistivity structure/model was created by processing and reversing the measured and computed resistivities. The distribution of locations with low and intermediate resistivities allowed for the delineation of several anomalous features along each profile. Additionally, gradational changes in resistivity with depth and different subsurface topographies are shown by the model. SeisImager/SW software was used to process and interpret the obtained refraction data in order to calculate the shear-wave velocity (Vs). For the seismic wave data utilizing SeisImager/SW, this package also includes three additional programs: Pickwin, WaveEq, and GeoPlot.

RESULTS AND DISCUSSION

Using soil resistivity data to rate the competence of distinct lithologies, the Idornigie and Olorunfemi (2006) model was utilized to separate the study's competence zones. In Table 1, the model is displayed.

Table 1: Soil competence Rating (Idornigie and Olorunfemi, 2006)

Apparent Resistivity (Ωm)	Lithology	Competence Rating
< 100	Clay	Incompetent
100 - 350	Sandy Clay	Moderately Competent
350 - 750	Clayey Sand	Competent
> 750	Sand/Laterite/Bedrock	Highly Competent

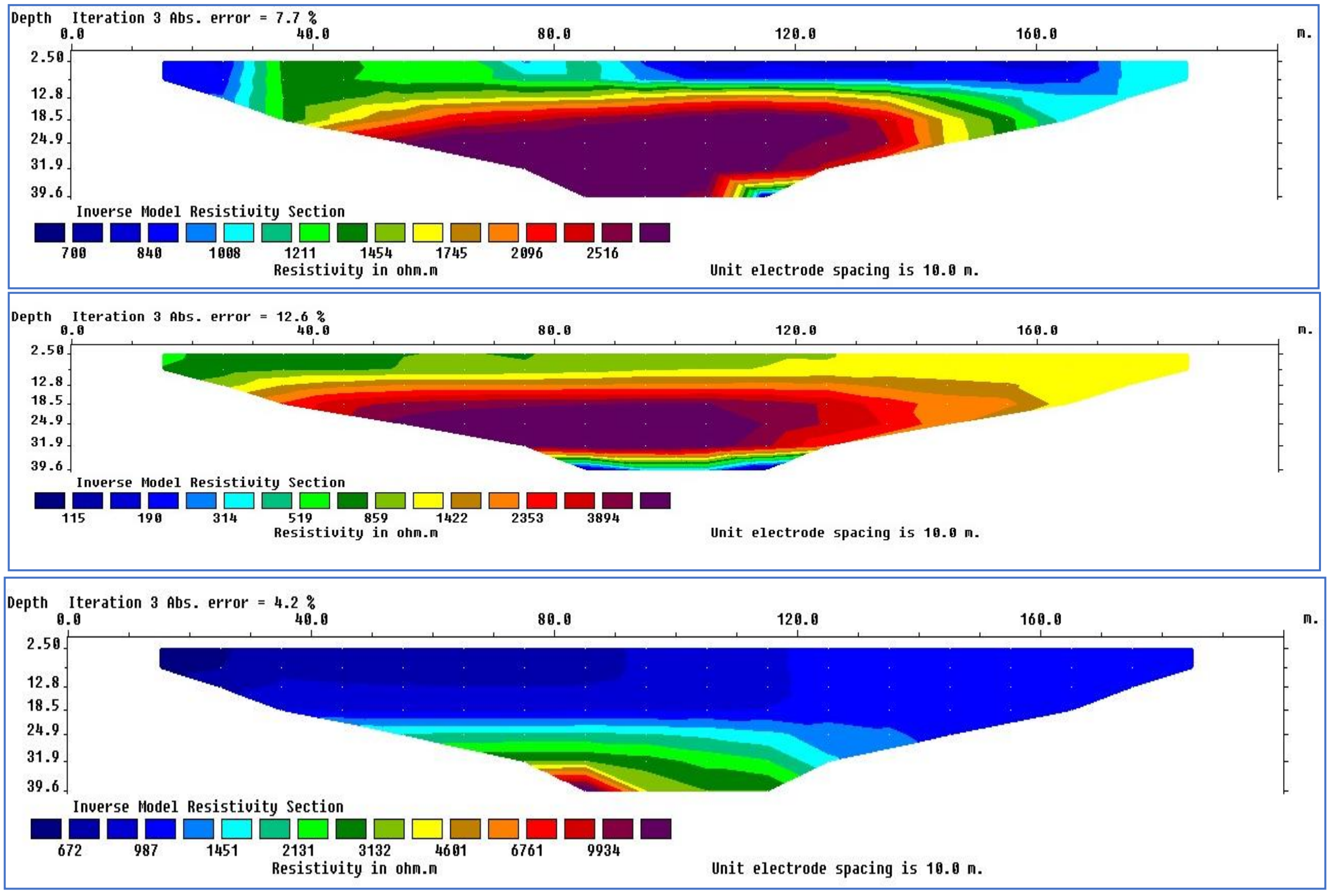

Figure 2: 2D Electrical Resistivity Image along traverse 1- 3.

The 2D resistivity structure along traverse (1 – 3) is shown in Figure 2. The profiles examined a 200 m horizontal and a total depth of 39.6 m. The distribution of resistivity below the three portions varies from around 115 ohm-m to more than 9934 ohm-m. Three (3) primary subsurface strata are visible in the cross-sections, and they are indicative of laterite, clayey sand, and sandy clay. Between 70 and 130 meters on either side of the traverse, and between 31.9 and 39.6 meters at the same depth, the sandy clay exhibits resistivity values ranging from 115 to 190 ohm-m. The laterite is found over traverses 1–3 at lateral distances of 15–185 m, 30–160 m, and 25–185 m. Its resistivity values range from 840–9934 ohm–m, and its corresponding depths are 2.5–39.6 and 18.5–31.9 m, respectively. The sand layer, also known as clayey sand, is found exclusively in traverses 1 through 3. Its resistivity values range from 314 to 700 ohm-m, with lateral distances of 15 to 25 m, 15 to 120 m, and 95 to 175 m, and depths of 2.5 to 12.8 m and 2.5 to 18.5 m, respectively.

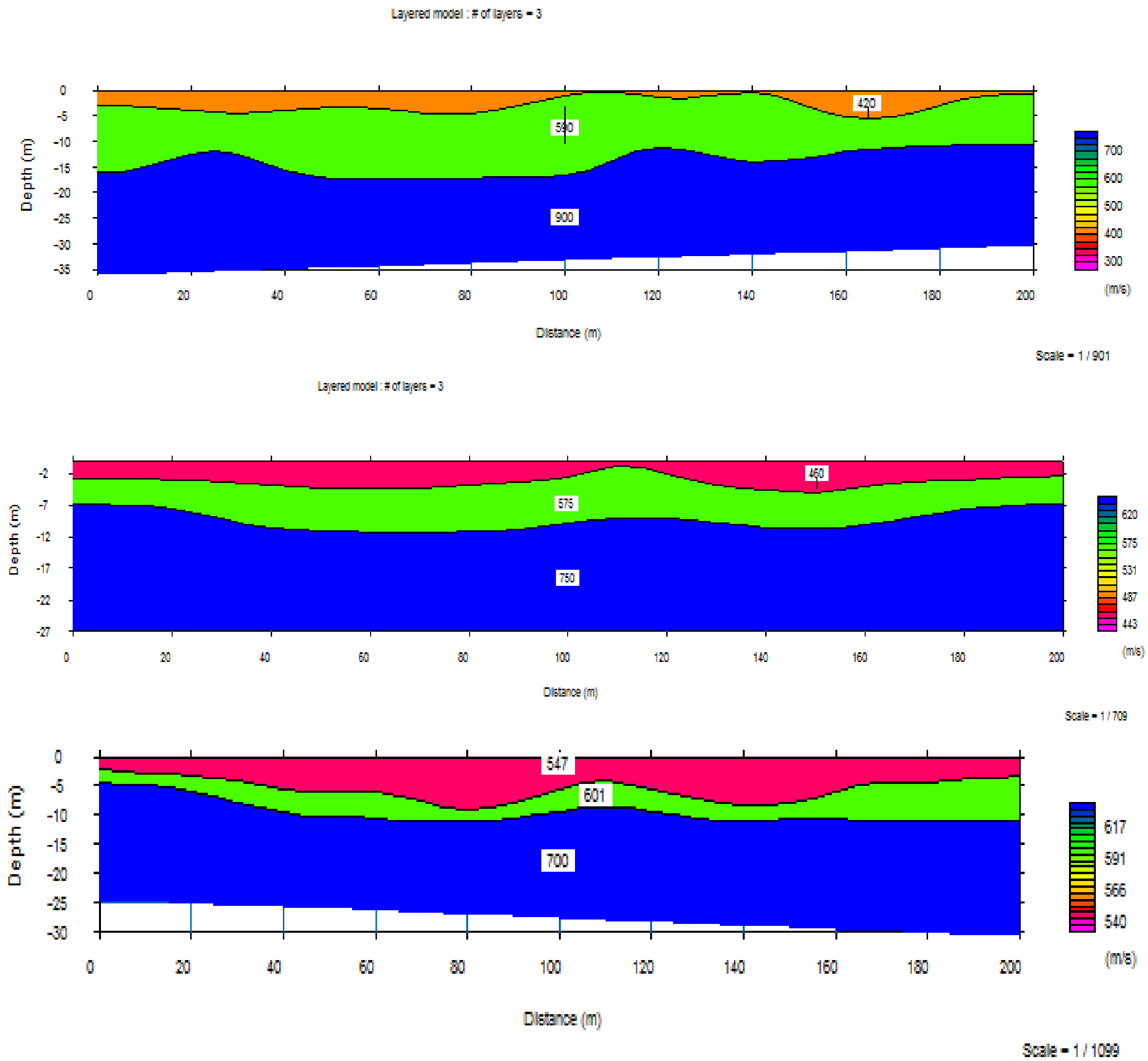

Figure 3: 2D Electrical Resistivity Image along traverse 1- 3.

The dipping interface between the traverses (1–3) layers and the velocities of the various layers, along with their corresponding thicknesses are depicted in Figure 3. The sections showed a 200 m lateral dispersion and a depth range of 27 to 35 m, respectively. The traverses display three layers, with the first, second, and third layers having average velocities of 450–547 m/s, 575–601 m/s, and 700–900 m/s, respectively.

CONCLUSION

In the University of Benin, integrated geoelectrical and seismic methodologies has been used to evaluate near-surface conditions for engineering site characterization in an attempt to delineate the various lithological units within the research region. Three to four primary layers—saturated clayey materials, sandy clay, clayey sand/sand, and laterite were identified from the research region based on the findings of the resistivity and seismic tests. The moderately competent layer is found between 31.9 and 39.6 meters below the surface. The competent layer was between 2.5 and 12.5 meters deep. The research area's seismic data and the depth to the highly competent zones range from 2.5 to 39.6 meters.

The results of the study provide credence to the usefulness of seismic and electrical resistivity methods in evaluating the appropriateness of subsurface materials. When selecting the foundation materials, one must take into account the properties of the sandy clay in the soil. It is advised that engineering soil testing processes be used to determine an adequate foundation design for projects.

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