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Geophysical Investigation of the Causes of Building Cracks in a Basement Complex Terrain of FUNAAB, Southwest Nigeria

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ABSTRACT
Building failure is of great concern in the construction industry all over the world. Several kinds of activities can result in the failure, which oftentimes leads to loss of lives and properties. Among several other causes, instability of the ground is a critical factor that causes building collapse in Nigeria particularly in the urban areas like Lagos and Abeokuta. This important factor however is often neglected in the course of many investigations before construction. Whereas early researches have shown that instability of the foundation of a structure is largely traceable to the characteristic of the soil. Crack defects have been observed on various buildings around Julius Amioba Okojie (JAO) lecture theatres of the Federal University of Agriculture, Abeokuta (FUNAAB) in which geophysical prospecting was deployed to understudy the cause. Electrical Resistivity Method (ERM) is a geophysical technique capable of giving useful information about the subsurface. Result of the electrical resistivity tomography from the study showed that the average depth and resistivity of the top soil is 0.97 m and 260 Ωm respectively, while the layers underlying the top soil are found to be compacted clay and sandy clay that can easily crack or shrink when loaded. Though, top soil is often characterized by low bearing capacity, which makes it to be unstable when load are sited over them. Conclusively, the top soil and clay rich layers in the study area must be excavated to about 1.25m depth to be able to site a good building foundation that can withstand the building stress.

INTRODUCTION

Building is one of the most essential needs of man particularly for shelter. The structure protects him and his belongings from temperature, wind and rain especially in extreme cases. However, when these functions are not guaranteed, then there is a problem somewhere. Construction type includes bridges (walkway, motorway bridge, highway bridge, suspended bridge, pedestrian bridge), pavilion, highway overpass, shopping mall, roof collapse and cooling tower. Other types include residential building, lecture theatres and other commercial building, (Okagbue *et al*., 2018).

For absolute safety of the occupants of a building and its contents, a good building is expected to be structurally safe (Ayedun *et al*., 2011). This is necessary because of the loss of lives and properties that usually come with building collapse particularly in populated areas. In 2014, over 110 people died in the collapse of the Synagogue Church building in Lagos, Southwest Nigeria. Over 40 casualties were recorded in November 2021 in the collapse of a twenty-one storey building in Lagos. A pregnant woman and her daughter died in a building collapse in Abeokuta Ogun State in March, 2016 (www.vanguardngr.com). Although government through regulatory bodies like National Emergency Management Agency (NEMA) and Lagos State Building Control Agency (LASBCA) usually identifies distressed building and mark them for demolition, execution is often delayed. For example, a marked three-story building collapsed in Ebute Meta area of Lagos State in 2022 killing about ten people. Similarly, the building contractor handling the project of the collapsed Naval building in the Federal Capital Territory were reportedly issued a stop-work order by the Federal Capital Development Authority (FCDA) before the structure eventual collapsed in January, 2012 (Adewale *et al*., 2018; Fakere *et al*., 2012).

Building collapse in Nigeria occurs mainly in the urban centers and it is widely reported (Okagbue *et al*., 2018). Victims of building collapse may include the construction workers, occupants and other people around the structure at the time. This kind of disaster is avoidable only if all stakeholders involved in the construction had played their respective roles to ensure that the building passes structural test. Ahzahar *et al*., (2011) submitted that a building must be structurally safe in order to survive, and the floors must be capable of resisting any normal imposed loads. Olusola and Atta (2002) said that in the designed lifetime of a building, it is necessary for it to be cost effective and should necessarily satisfy design performance, sustainability, quality safety requirement and timely completion. Incidences of buildings collapse are not peculiar to Nigeria; rather they are global phenomenon (Bamigboye *et al*., 2019; Amadi *et al*., 2012; Oni, 2010; Dimuna, 2010). Thus incessant building failure and collapse have attracted attention of researchers all over the world. Gajzler (2016) and Yussuf (2006) reiterated that site ecological status, technical components composition, government policies, social engineering, economic, political and human factors are all capable of causing building collapse.

Failures in government buildings in Nigeria today call for more concern particularly when factors like age and type of use of the structure are ruled out. It is an embarrassment for the government and the stake holders in the construction industry. In the past, investigations have revealed that the causes of collapse of most government owned building are substandard/fake materials or technical failure. In either case, corruption is largely blamed (CIB, 2008). Presently, the country is facing the consequences and if the situation is allowed to continue, the country is likely to be faced with (a) foreign contractors never want to take the Nigerian government serious and (b) local building contractors losing their reputation and will not be able to favorably compete with their foreign counterparts. Therefore, researches will never be too much in the area of building construction in Nigeria to provide hints for the construction engineers and other stake holders, with the sole aim of finding lasting solution to incessant building collapse in the country.

All engineering structure must have a foundation, and in some cases of structural damage in buildings, damages are not due to structural design but caused by poor condition of the ground (Alyaa *et al*., 2021). Thus, to be able to understand the strength and behaviour of the ground as well as prevent engineering problems, there is need for detailed assessment of the ground in terms of strength and integrity (Alyaa *et al*., 2021).

In FUNAAB, one of the more recent lecture halls is the JAO lecture theatre building and it comprises of about three separate structures with visible cracks observed on all, running from their foundation levels to lintel. Various palliative measures like re-plastering and screeding had been done yet the cracks became wider which mean that the possible causes are not from substandard materials but foundation failure.

Instead of blindly erecting the foundation, geophysical technique like the ERM can potentially provide comprehensive and cost-effective information about the site. Researchers earlier showed that for précised mapping of the vertical and lateral soil dynamic properties variation, the geophysical methods can be very useful. Like many other geophysical methods, electrical resistivity method has been found very useful in areas of soil testing and investigation (Åhnberg and Holmén, 2011; Groves *et al*., 2011; Hayashi *et al*., 2014; Bery *et al*., 2017; Adamo *et al*., 2020). Therefore, the ERM has been employed in this work to investigate the building failure on the campus of the Federal University of Agriculture, Abeokuta Nigeria.

MATERIALS AND METHODS

Methodology of the Research

Location of the Study Area

The study was carried out on the campus of the Federal University of Agriculture, Abeokuta (FUNAAB). It is a government owned institution located around Latitude 7.2297° N, and Longitude 3.4392° E in the ancient city of Abeokuta, Odeda Local Government area of Ogun State Southwestern Nigeria. Geologically, it is located in the basement complex of Abeokuta formation of Ogun State section of the popular Dahomey Basin. Ogun State is characterized by heavy rainfall between April and October every year followed by sunshine of the dry season that runs from November through March. Thus buildings and other engineering structures quickly weather as they age in the state.

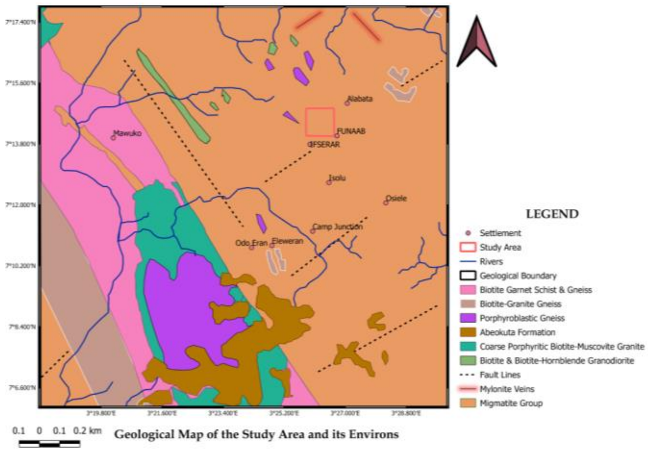

Figure 1: Geologic Map of the Study Area (Layade *et al*., 2023)

Geophysical Field Procedure and Data Acquisition

In electrical resistivity method, the potential difference V, pushes electrical current, I through the ground. The resistivity meter takes ratio of the voltage and current to give measured resistance, R of the lithology according to the popular Ohm's law.

$$(R = V/I) \quad (1)$$

Apparent resistivity (ρ) is then obtained automatically as the product of the measured resistance of the rock and the corresponding geometric factor (k).

In this study, six ERT profiles of 50 m spread in the N-S direction at 20 m apart were acquired using the Wenner electrode configuration, a total of eighteen Vertical Electrical Sounding (VES) data were acquired on the ERT profile with each ERT profile containing 3 VES at 25 m intervals as shown in figure 2; one at the starting or zero point, one at the midpoint (25 m) and the third one at the end point (50 m). The profiles are at 20 m constant interval from each other, which gives a total of 100 m from the first to the sixth profile line (Figure 2).

Ohmega resistivity meter was used for the VES data collection adopting Schlumberger array configuration. Layer thickness and depth were obtained using WinResist while Res2dinv software was employed to generate inverted sections for the 2D analysis (Adewoyin *et al*., 2017; Olorode *et al*., 2012; Ogungbe *et al*. 2012). The combination of VES data on each ERT profiles generated the geo-electric sections, figure 4(a) and 4(b)

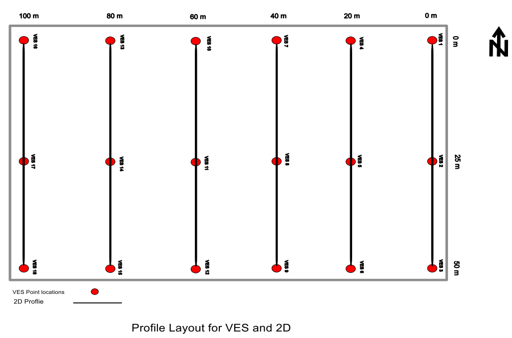

Figure 2: Profile Layout for 2D and VES Points

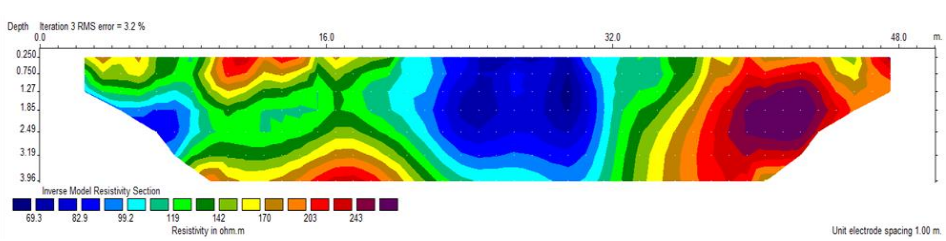

Figure 3a: Traverse 1

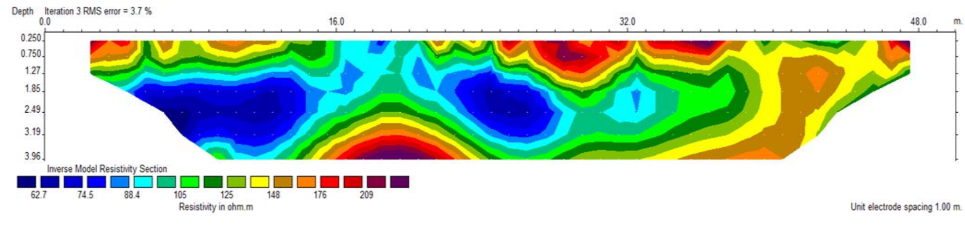

Figure 3b: Traverse 2

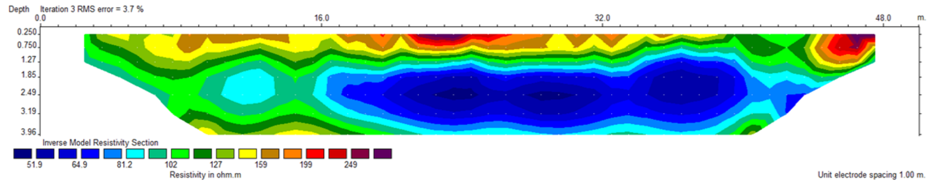

Figure 3c: Traverse 3

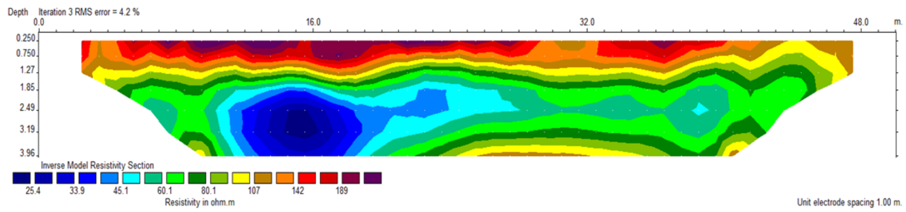

Figure 3d: Traverse 4

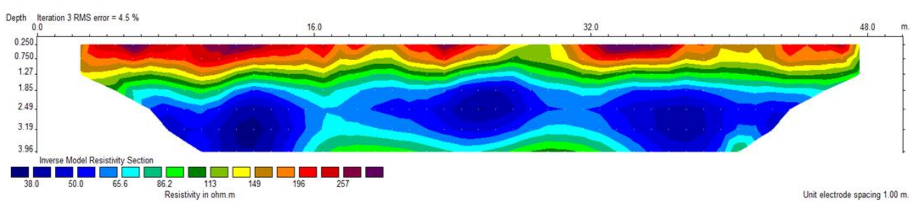

Figure 3e: Traverse 5

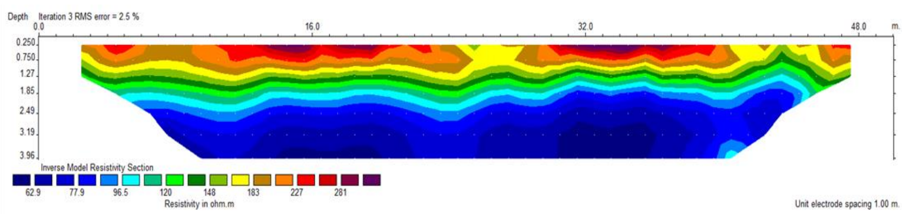

Figure 3f: Traverse 6

RESULTS AND DISCUSSION

Resistivity data for the six profile lines and the eighteen VES points were analyzed and the results for the 2D are as shown in figures 3 and 4.

Resistivity plot of profile 1 shows a very thin layer of top soil that discontinues between lateral distances of about 21 to 32 m. Evidently from the inversion, the top soil from the profile towards the eastern part of the study area has been washed away by erosion. On profile 2, which is 20 m from profile 1 in the western direction, the top soil becomes distinct exhibiting a thickness of up to about 0.75 m and resistivity value ranging between 160 and 250 Ωm. This layer is underplayed by sandy clay layer that ranges from 0.75 to 1.27 m depth. The lateral discontinuity of the top soil could still be seen however between 16.0 and 21.0 m lateral distance. Profile 3 exhibits a thickness of about 0.80 m with resistivity ranging between 150 and 300 Ωm. On this profile, the low resistivity lithology intruding is completely overplayed by the top soil and the compacted clay layer. The top soil of profile 4 is characterized by resistivity value ranging between 130 and 230 Ωm with thickness of about 1.30 m. The sandy clay layer with resistivity of about is up till 1.85 m depth. The top soil thickness is about 1.0 m on profile 5 and 6 with resistivity ranging between 200 to 280 and 220 to 300 Ωm respectively.

Average depth of the top soil to the compacted clay in the study area is 0.97 m. It is mostly sandy loam with high porosity and low density. Also, average resistivity values of the first layers of profiles 2 to 6 are 205, 225, 180, 240 and 260 Ωm respectively which correspond to sand and gravel rock units according to table 1.

To be able to further picture the lithology, VES results were combined on the profiles and the results for the VES combination on profiles 1 and 2 are as shown in figure 4 as geo-electric sections.

From the geo-electric sections, figure 4(a) and 4(b), the shallow depth of the less dense top soil is clearly evident and it is found in good agreement with the 2D resistivity profiling results.

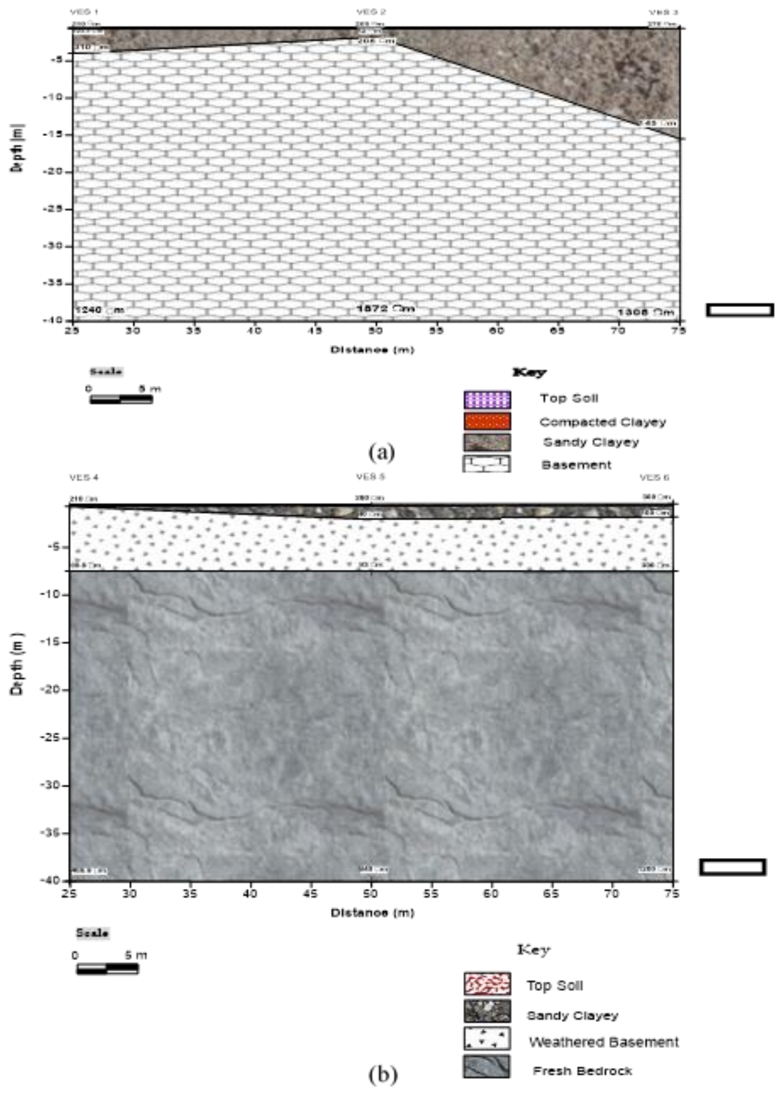

Figure 4: Geosection Plot of VES Combination on (a) Profile 1 and (b) Profile 2

Table 1: Resistivity Values for Some Common Geological Materials (Modified, Telford W.M-1990)

Materials	Nominal Resistivities (Ωm)
Clays	1-100
Clay (very dry)	50-150
Sand clay	30-215
Sand and Gravel	30-260

CONCLUSION

Building failure is of great concern in the construction industry all over the world. Several kinds of activities can result in the failure, which often time leads to loss of lives and properties. It is obvious that the JAO buildings are more recent and not distressed due to age or type of use, substandard material and unskilled workers. The cracks can be traced to poor excavation (complete removal of loose top soil and clay-rich layers) before siting the foundation. The result presented here predicted the top soil of resistivities 310Ωm (Table 1). in the study area with average depth of 0.97 m. The layers underlying the top soil possibly depict compacted clay, sandy clay and clayey with resistivities 260Ωm (Table 1). These layers are often characterized by low bearing capacity, which make it to be unstable when loaded with buildings. Conclusively, the top soil and clay rich layers in the study area must be excavated to about 1.25m depth to be able to site a good building foundation that can withstand the building stress.

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