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Application of Geophysics in Post Foundation Study: A Case Study of the Faculty of Social Science Building, Phase I, Federal University, Oye-Ekiti, Southwestern, Nigeria

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Abstract

Post foundation study of the causes of distress on the Faculty of Social Science building, Phase I, Federal University, Oye-Ekiti was carried out using geophysical approach. The geophysical methods used were the magnetic and electrical resistivity. The magnetic measurements were taking at an interval of 5 m along the established three traverses. The magnetic data were presented as profiles and interpreted using Euler deconvolution software. The Vertical Electrical Sounding data were quantitatively interpreted using partial curve matching technique and 1-D forward modelling with Win Resist software. The dipole-dipole data were inverted using DIPPRO[™] software. The magnetic profiles delineated two subsurface layers; the overburden and the Basement bedrock. Series of geological linear structures were delineated by the ground magnetic. The VES results reveal three subsurface geoelectric layers. These include; the topsoil with resistivity ranging from 20-290 Ωm and thickness ranging from 0.4-2.5 m; the weathered layer with resistivity ranging from 2.6-122Ωm and thickness ranging from 0.9-23 m; and the Basement bedrock with resistivity ranging from 83-∞Ωm. The low resistivity values of the Basement bedrock in places indicate an intense fractured basement rock. The 2-D resistivity structure also delineated three geoelectric sequences; the topsoil, the weathered layer and the Basement rock which correlate with the geoelectric sections. Geological linear features were also delineated by the 2-D resistivity imaging which correlates with the magnetic results. The depth on which the foundation of the investigated building was hosted is not known but it is suspected to have been hosted within the weathered layer. This layer predominantly composed of clayey formation which are of high swelling potential and may be subjected to subsidence under heavy load. The causes of distress on the investigated building may have being precipitated by the clayed nature of the layer where the structure was founded and the presence of linear structure suspected to be fractured or fault within the basement.

Keywords: Foundation Integrity; Resistivity; Magnetic; Swelling Potential; Subsidence

Introduction

In recent time, the statistics of failures of engineering structures such as roads, buildings and bridges has increased geometrically. Several probable reasons speculated to have been responsible for this ugly incidence have been highlighted by the engineering community. These include: inadequate supervision, poor construction materials, non-compliance to specification etc. Unfortunately, one particular major point that has always not been given serious attention is lack of adequate information on the nature of subsurface conditions prior to construction exercise. All structures erected on the earth have their own substructures (foundation). Foundation design depends on the characteristics of both the structures and the soil or rock. Therefore, the nature (i.e. competence, strength and load capacity) of the soil supporting the super structure becomes an extremely important issue for safety, structural integrity assessment and durability of the super structure [1].

However, since every engineering structure is seated on geological earth materials, it is imperative to conduct pre-construction investigations of the subsurface of a proposed site in order to ascertain the strength and fitness of the host materials as well as post-construction monitoring of such structure to ensure its integrity. The need for foundation studies therefore becomes necessary so as to prevent loss of valuable lives and properties that always accompany such failures [2].

The faculty of social science building, phase 1 is one of the important civil structures within the Federal University, Oye-Ekiti campus. It was constructed five (5) years ago. Parts of the building has

experienced visible distress (Plate 1) that may lead to total collapsing of the building if corrective measure are not carried out. The present research is necessitated as post foundation study aiming at study the causes of the distress on the building for proper mitigation.

However, engineering geophysics offers a wide spectrum of methods that can be used as post foundation investigation. The electrical resistivity method is most frequently used, because the electrical resistivity of earth material is determined by the amount and concentration of saturating fluid, degree of fracturing, rock texture, degree of grain cementation, compaction and extent of weathering that significantly determine the competence of such earth materials [3]. Hence, the study will focus on geophysical approach of post foundation study using magnetic prospecting and electrical resistivity methods.

Description of the study area

The study area lies within latitude $7^040^150.15^{11}$ to $7^040^154.10^{11}$ N and longitude $5^016^119^{11}$ to $5^016^122.5^{11}$ E, expressed in Universal Transverse

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Mercator (UTM) coordinates of zone 31, Minna datum as Northings 860400 - 860460 and Eastings 756120 - 756170 (Figure 1).

Geology of the area

The Federal University Oye-Ekiti campus is underlain by crystalline rock of the Precambrian Basement Complex of the South-western Nigerian [4,5]. The lithologic units include migmatite gneiss complex, granitic gneiss and charnokites (Figure 2). Outcrops of biotite gneiss and granite gneiss occur in some locations around the study area.

Methodology

Three traverses were established approximately in the North-South direction (Figure 3). Magnetic measurements were taken at 5 m interval along the traverses. Measurements were made with the GM 8 Proton Precession Magnetometer (PPM). To increase the accuracy, two magnetic measurements with the sensor height well above the ground were taken per station together with the time. The mean of the magnetic measurement was adopted as the raw data for each observed station. A set of readings was taken at an established base station before and after data acquisition. The base station values were plotted against time of taking the reading on a linear graph, with this; diurnal and offset corrections was carried out. The 1-D Euler deconvolution software was used for magnetic interpretation [6].

For the electrical resistivity method, two techniques were adopted; Vertical Electrical Soundings (VES) using Schlumberger array and 2-D profiling using the dipole-dipole array. In vertical electrical sounding (VES), the vertical variation in ground apparent resistivity values was measured with respect to a fixed centre of array. The survey was carried out by gradual increase in the electrode spacing (AB) with respect to the centre of the electrode array. The half electrode spacing (AB/2) was varied from 1 to 65 m. The apparent resistivity values (ρ_a) at each station were plotted against half electrode spacing (AB/2) on a bi-logarithmic graph. Partial curve matching was carried out for the quantitative interpretation of the curves. The results of the curve matching (layer



thickness and resistivity) were fed in to the computer as starting model parameters in an iterated forward model using Win Resist software [7].



From the interpreted results, geoelectric sections along the traverse were constructed. The 2-D resistivity profiling was carried out along the traverses using dipole-dipole configuration. This was done in order to measure the ground apparent resistivity both laterally and vertically. The inter-electrode spacing of 5 m was adopted while inter-dipole separation factor (n) was varies from 1 to 5. 2-D inversion modelling of the dipole-dipole data was carried out using Dippro for window computer software [8,9].

Results and Discussion

Magnetic survey

The Magnetic profile and geomagnetic section along Traverse TR1 (Figure 4) show that the traverse is characterized by relatively flat magnetic anomaly except between distance 10 and 30 m where a thin dyke magnetic anomaly was identified with the top around distance of 20 m. The anomaly is striking northeast – southwest (NE – SW). The 1-D Euler deconvolution software using vertical gradient estimates depth to the inclined body at about 5 m. This anomaly is a typical geological feature suspected to be fracture and/or fault/lithological contact.

The Magnetic profile along traverse TR2 shows two major magnetic anomalies between distances 20-40 m and 55 -77 m (Figure 5). The corresponding geomagnetic section reveals a relatively thin overburden ranging from 2-6 m. The 1-D Euler deconvolution estimates depth to the identified inclined linear feature at distances 25 and 62.5 m to be 2.5 and 4 m respectively. The structure at 25 striking northeast – southwest (NE–SW) while the suspected structure at 62.5 m is relatively vertical.

The Magnetic profile and geomagnetic section along traverse TR3 is as shown in Figure 6. The magnetic profile shows one major anomaly at a distance between 10 and 30 m. The causative body is actually located at distance of about 17.5 m and striking northeast – southwest (NE – SW). It is typical of linear geological structure suspected to be fracture



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or fault. The estimated depth to the top of the body is about 4 m.

The Magnetic anomalous zones suspected to be fracture/fault/ lithological contact are all striking northeast – southwest (NE – SW). These are weak zones that could be inimical to the stability of foundation of any civil structures. This may have contributed to the distress witness on the investigated structure.

Resistivity sounding curves and geoelectric sections

The resistivity sounding curves obtained from the study area vary from 3-layer (H and A) to four layer (HA) and five layer (HKH) type as shown in the Table 1. Figure 7 shows that H curve types is the predominant curve in the area. In order to evolve a geological model along each traverse, the VES interpretation results (Table 1) were used to prepare the 2-D geoelectric sections. These sections give respective layer resistivity values and thicknesses.

Figures 8-10 shows the geoelectric sections along each traverse. The sections identified three geoelectric/geological subsurface layers comprising the topsoil, weathered layer and fractured/fresh Basement rock. The geoelectric characteristics are as following:

Topsoil: The topsoil varies in composition from clay to sandy clay with resistivity varying from 25 to 288 Ω -m and generally less than 200 Ω -m (Figure 11). The thickness of the topsoil varies from 0.4 to 2.5 m but generally less than 1.0 m (Figure 12).

Weathered Layer: The weathered layer varies in composition from clay to sandy clay with resistivity varying from 20 to 153 Ω -m but generally less than 50 Ω -m (Figure 13). The thickness of the weathered layer varies from 0.9 to 23 m (Figure 14).

Partly Weathered/Fractured Basement Bedrock: The resistivity of the Basement varies from 91 to $\infty\Omega$ -m.

The low resistivity values at some Vertical Electrical Sounding (VES) station is an indicative of non-compacted Basement rock which may be due to fracturing of the Basement rock.

The foundation depth of the investigated civil structure is not known but it is suspected to have been hosted within the weathered layer. This layer is predominantly composed of clayey formation which is of high swelling potential with tendency for structure subsidence.

Traverse 1 and 2 displays significant variable depths to the competent basal Basement rock with the thickest overburden beneath the northern segments (Figures 8 and 10). It is suspected that the Basement rock

along these traverses may have been faulted with the down thrown side on the northern segment. In the alternative, the profiles may be located on a lithological boundary (or contact) between the biotite gneiss and granite gneiss. Either way, it could be inferred that the





VES Station	Resistivity (Ohm-m)					Thickness (m)				0
	ρ_1	ρ_2	ρ_3	ρ_4	ρ ₅	h ₁	h ₂	h ₃	h_4	Curve Types
1	189	49	1303			1.2	12.2			Н
2	78	49	94	1548		0.8	1.8	13.7		HA
3	105	153	1015			2.5	16.5			A
4	201	145	478			1.1	4.8			Н
5	186	43	593			0.4	1.2			Н
6	190	27	540			0.4	0.9			Н
7	151	20	63507			0.5	0.9			Н
8	104	06	3133			0.9	1.1			Н
9	54	12	642			1.0	1.7			Н
10	102	18	91			0.7	1.2			Н
11	76	23	93			0.8	1.0			н
12	67.3	16.6	148			0.8	1.1			Н
13	63	29	580			0.8	1.5			Н
14	288	80	432			0.7	2,2			Н
15	25	8	8622			1.0	1.1			Н
16	809	27	36	05	122	0.4	4.3	4.8	11	НКН
17	135	17	1079			1.2	22.3			Н
18	278	29	215			1.0	16.8			Н
19	180	18	1495			1.0	18.0			Н
20	123	19	7401			0.8	1.2			Н
21	138	26	5140			0.8	1.4			н

 Table 1: Summary of VES interpretation results.



Figure 12: Bar chat of topsoil thickness.

investigated building may have been founded on a formation underlies by faulted Basement rock/lithological contact. This with incompetent clayey materials which is suspected to have hosted the foundation of the



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investigated building may have contributed significantly to the distress witness by building.

Weathered Layer Thickness (m)

Figure 14: Bar chat of weathered layer thickness.

2.0-5.0 5.0-10.0 10.0-20.0 20.0-30.0

Electrical imaging

2

0

0.0-1.0

1.0-2.0

The pseudosections and 2-D resistivity structures along Traverses are shown in Figures 15-17. The 2-D resistivity structure depicts three geoelectrical/geological layers. These include thin topsoil, weathered layer and the partly weathered layer/Basement rock. The topsoil and the weathered layer have virtually merged together due to thinness of the topsoil and non-significantly contrast. They are represented by blue and green colours. The yellow colour within these layers occurs when the

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traverse 2 (TR2).



Figure 20: Correlation of the suspected geological linear structure along traverse 3 (TR3).



resistivity value of the topsoil and weathered layer is not significantly different from that of the Basement rock. The uneven nature of the Basement bedrock was revealed by the 2-D resistivity structures (Figures 15-17) which correlated with the geoelectric sections (Figure 8-10).

The bedrock shows several vertical discontinuities typical of linear structures (fracture/fault/lithological contact) along the traverses. These linear structures are located at different distances and are steeply dipping with significant depth extent (>5 m). The delineated linear structures on the magnetic profiles (Figures 4-6) and geoelectric sections (Figure 8-10) coincide with the suspected linear geological structures on the 2-D resistivity structures (Figure 18-20). Figure 21 is the structural map of the study area generated from the magnetic profiles (Figures 4-6), geoelectric sections (Figures 8 and 10) and 2-D resistivity structures (Figures 15-17). It displays the location of the suspected linear structure (fracture/fault and/or geological boundaries) within the study area. The distressed segment of the building is located within the zone. This may have significantly influence the structural failure observed on the buildings.

Conclusion

Post foundation study of the causes of distress on the Faculty of Humanity and Social Science Phase Ibuilding, Federal University, Oye-Ekiti was carried out using geophysical approach. The geophysical survey methods employed were the ground magnetic and electrical resistivity methods.

The geophysical data were processed and interpreted qualitatively and quantitatively to image the subsurface beneath the investigated area. The results show that the investigated building may have located within the incompetent clayey weathered layer with resistivity generally less than 100 Ω -m. The results also delineated geological linear features Citation: Aroyehun MT, Akintorinwa OJ, (2018) Application of Geophysics in Post Foundation Study: A Case Study of the Faculty of Social Science Building, Phase I, Federal University, Oye-Ekiti, Southwestern, Nigeria. J Geol Geophys 7: 324. doi: 10.4172/2381-719.1000324

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suspected to be fracture/ fault/ithological contact. These are weak zone that are inimical to stability of any civil engineering structures. It can be concluded that the manifested visible distress on the investigated building may have been precipitated by incompetent subsoil and the presence of geological linear structures.

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