Confluence Journal of Pure and Applied Sciences (CJPAS)
Faculty of Science, Federal University Lokoja, Kogi State, Nigeria

Vol. 2, No. 1, June 2018
ISSN: 2616-1303 | **Web:***www.cjpas.fulokoja.edu.ng*

STABILITY ASSESSMENT OF SOME EXISTING BUILDINGS IN UNILORIN PREMISES USING SCHLUMBERGER SOUNDING TECHNIQUE

Olatunji, S.*[1]&Folorunso,I. O.[2]
[,2]Department of Geophysics, University of Ilorin, Kwara State, Nigeria.
E-mail: sam61ng@gmail.com

ABSTRACT

Geophysical electrical resistivity method of Schlumberger Vertical Electrical Sounding (VES) was carried out within the premises of University of Ilorin, along each traverse near some selected high rise buildings on the University campus. The study was aimed at mapping the subsurface geologic features such as rock layering, lithological types and sequence in the subsurface that may pose danger to the existing structures. A total of fourteen (14) VES stations were established with maximum current electrode separation of 200 m and inter VES spacing of 20 m. VES geo-electric equivalent layers ranges from three (3) to five (5) layers within the area. Geoelectric 2D sections further confirmed that the area is characterized by layering series of topsoil, laterites, sandy clay, weathered/fractured basement and fresh basement. The resistivity distribution confirmed that the vicinities of profiles 2-5 to be moderately competent and highly competent with resistivity range of about 100-2000 Ωm. However, there is an isolated low resistivity distribution (60-300 Ωm) around profile 1 in the vicinity of Faculty of Arts that terminates at about 20 m depth. This is attributable to incompetent footing. The subsurface features and overburden materials delineated in profile 5 close to postgraduate students' hostel is most favourable to civil engineering constructions as the range of resistivity distributions (200-2000 Ωm) is attributable to competent footing for the super structures.

***Keywords**:* Schlumberger, Sounding, Resistivity, Competent, Traverse and Pseudo-section

1.0 INTRODUCTION

Buildings, being primarily sheltersfor people, need to be taken care of in order to save life. During an on-the-sport assessment of collapsed buildings in Abuja one of the overall assertions by the civil engineers on site was that the incessant increase in the failure of buildings has been attributed partly to subsurface problems which have not been accorded adequate attention by the owners and building experts prior to foundation design and construction. Lives have been lost and lots of properties have been wasted due to building collapses resulting from foundation problem, poor construction practice and the use of substandard building materials among other causes.

In the last decades, the involvement of geophysics in civil and environmental engineering has become an auspicious approach. Geophysical methods are employed in a wide range of applications ranging from subsurface investigations for

***Corresponding Author**
How to cite this paper: Olatunji, S. &Folorunso,I. O. (2018).
Stability Assessment Of Some Existing Buildings In Unilorin Premises Using Schlumberger Sounding Technique
Confluence Journal of Pure and Applied Sciences (CJPAS), 2(1), 189 - 197.

Vol. 2, No. 1, June 2018
ISSN: 2616-1303 | **Web:***www.cjpas.fulokoja.edu.ng*

building constructions to the integrity tests of dam embankments and dikes (Luna and Jadi, 2000; Othman, 2005; Soupois, *et. al*., 2007). Geophysical surveys are usually aimedat exploring geologicalformations and determination of the physical parameters of the rock formations. Geophysical methods are suitable to determine depths to the basement and map subsurface characteristics prior to excavation and construction of buildings and bridges. Vertical Electrical Sounding (VES) is atechnique suitable for the investigation of geological horizontal bedding contacts (Telford *et. al.,* 2004). The method is based on the estimation of the apparent resistivity of a medium.

In the case of building stability, geophysics can be applied for exploration purposes to provide useful information regarding the detection of potential precarious subsurface conditions. Among the sources of hazards in engineering constructions are undetected near-surface structures such as cavities and/or inhomogeneities in the foundation geo-materials. Information related to the local soil conditions is vital for hazard assessment and mitigation (Soupois*et al.*, 2007).

VES involves measurement of potential due to electrical field induced by distant grounded current electrodes. The essential idea behind VES, assuming conductivity variation with depth only, is the fact that as the distance between the current and potential electrode is increased, the current flux passing across the potential electrode carries a current fraction that has returned to the surface after reaching increasingly deeper level.

The frequent cases of building collapse pose the need for investigation into the cause and the means to proffer a lasting solution to the menace. This work therefore aimed at assessing the post foundation integrity of some selected high rise buildings using the VES technique by mapping out the resistivity distribution, identifying the layers and their rock component within the subsurface and determine the geologic features such as faults, fractures, voids and clay that may pose danger to the existing structures within the campus of University of Ilorin.

1.1LOCATION AND GEOLOGY OF STUDY AREA

The locations of the targeted buildings are shown in Fig. I and their coordinates are presented in Table I. Ilorin metropolis, within which the study area lies, falls within the basement complex in the north central region of Nigeria (Fig. II).

The area lies entirely on the Nigerian Basement Complex comprising the crystalline basement rocks of high-grade metamorphic rock faces. The common rock types include migmatite gneiss, augen gneiss, quartzite, older granite (extensively weathered) and superficial deposit. Thus, the structures considered are located on Migmatite-gness rocks of Ilorin (Oluyide*et al.*, 1998). Oluyide (1998) furthered that these rocks generally belong to those classified as lit-par-lit magmatite which are conventional migmatite with their components disposed in parallel order encompassing banded gneiss.

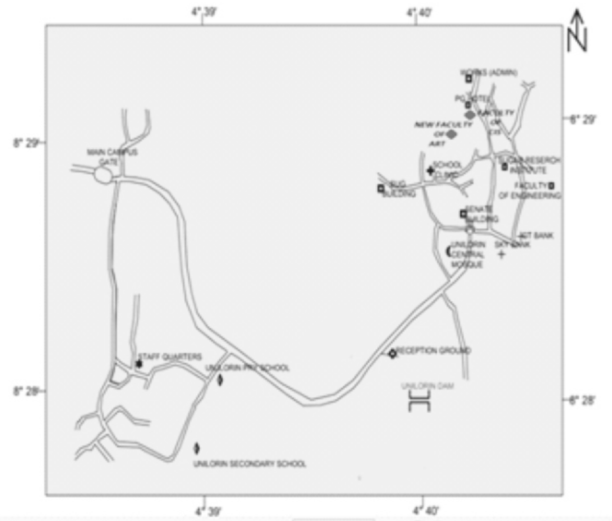

Fig. I: Layout of Unilorin showing the Location of the Buildings (*After: Olasunkanmi et. al., 2012)*

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Table I: Global Coordinates of the Studied Structures

SN	Location	Latitude (°N)	Longitude (°E)
1	Faculty of Arts Main Building	4.672267 - 4.671833	8.485117 - 8.48515
2	New Faculty of Arts Lecture Theatre	4.672767 - 4.674317	8.4851 - 8.4884
3	Faculty of Communication and Information Science Main Building	4.67445 - 4.674767	8.48845 - 8.4886
4	Faculty of Communication and Information Science New Lecture Theatre	4.674383 - 4.674317	8.489383 - 8.490233
5	Post-Graduate Hostel	4.674067 - 4.67345	8.49025 - 8.4912

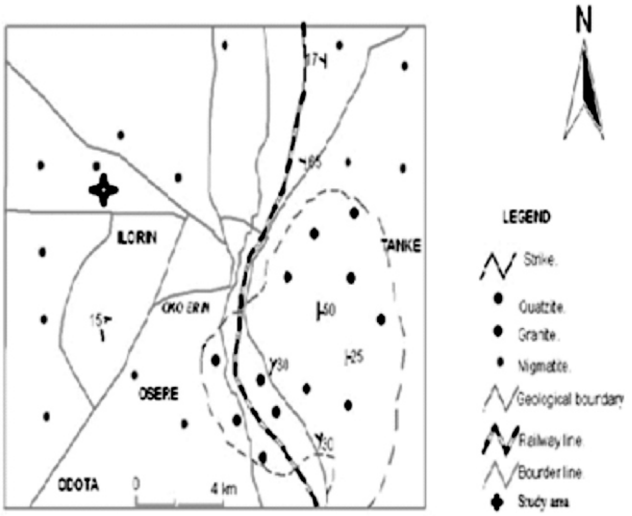

Fig. II: Fig. 2: Geological Reference of the Study Area (Oluyode et. al., 1998)

2.0 MATERIALS AND METHODS

Ground **resistivity is determined by passing an electric current through the ground using two electrodes (C_1 and C_2) and measuring the resultant potential using two potential electrodes (P_1 and P_2) The depth of investigation is often given as a function of the electrode spacing. The VES resistivity technique is based on measuring the potentials between one electrode pair while transmitting direct current between electrode pairs. The depth of penetration is proportional to the separation between the current electrodes, in homogeneous ground. Varying apparent resistivities obtained when current electrodes position are changed provide information about the stratification of the ground (Dahlin, 2000).**

Schlumberger array for vertical electrical sounding (VES) was used to collect resistivity data. This concerns symmetric arrangement about the centre of potential and current electrodes. Current sink is expands symmetrically about a common centre. This results in a semispherical current loop into the subsurface. So, the electric potential established by the flowing current is therefore monitored with the potential electrodes. A profile of multiple VES points was surveyed at closest range to each building understudied for data collection. A maximum current electrode spacing of 200 m was used.

The basic field equipment used for the study is DDC-8 terrameter which displays apparent resistivity value. Theterrameter is powered by 12V DC power source. Other accessories that accompanied the equipment are: measuring tape, 4 hammers, and 4 metal electrodes. The four electrodes were positioned symmetrically along a straight line, the current electrodes on the outside and the potential electrodes on the inside. To change the depth range of the measurements, the current electrodes are moved outwards while the potential electrodes were left at the same position. When the ratio of the distance between the current electrodes to potential electrodes becomes too large, the potential electrodes were also moved outwards otherwise the potential difference becomes too small to be measured with sufficient accuracy. (Alile*et. al.*, 2008; Olatunji and Osazuwa, 2012).They recommended that potential

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electrode separation expansion should be within the limit of not more than one-tenth of current electrode separation at any time.

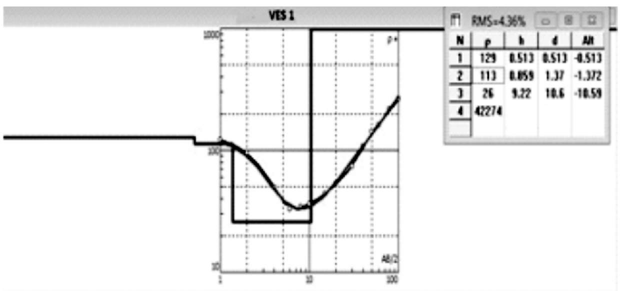
In the VES configuration used, Geometric factor G is given by:

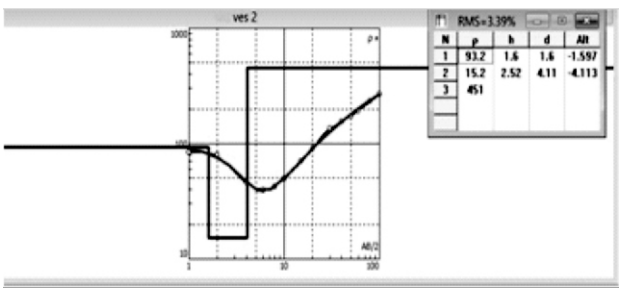
$$G = \pi \frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{2\left(\frac{MN}{2}\right)}$$

Thus, Apparent Resistivity $\rho_a = \frac{\Delta v}{i} \cdot G$

3.0 RESULT AND DISCUSSION

The VES data were processed using a third party software package, *IP2Win* developed by Bobachev, (2003) of Moscow State University. The output of the VES data is a log-log plot of apparent resistivity versus electrode separation. Some typical sounding curves obtained from the computer iteration of resistivity data are presented in figure III for VES 1 to VES 3. Additional information obtained includes the number of layers, resistivity of the different lithological layers and corresponding thickness of layers (Fig. III).The summary of the interpretation as obtained from *IPI2Win* is as shown in Table IIa and IIb.





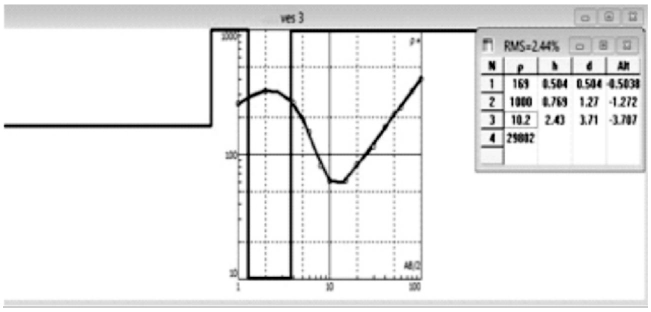


Fig.III: Sample Field Curves

Table IIa: Summary Interpretation of VES 1-7

VES STATION	Curve Type	No. of Layers	Resistivity (Ωm)	Thickness	Depth to Bedrock	Remark
VES1	QH	4	129	0.513	10.6	Topsoil
			113	0.859		Laterites
			26	9.22		Weathered Basement
			42274			Fresh Basement.
VES2	H	3	93.2	1.6	4.11	Topsoil
			15.2	2.52		Laterites,
			451			Weathered Basement
VES3	KH	4	169	0.504	3.71	Topsoil
			1000	0.769		Laterites,
			10.2	2.43		Weathered Basement
			29802			Fresh Basement.
VES4	HA	4	1018	4.7	10.1	Topsoil
			15.9	3.52		Laterites
			54.2	1.91		Weathered Basement
			10766			Fresh Basement
VES5	KH	4	340	0.5	2.5	Topsoil
			2373	0.677		Laterites,
			12	1.32		Weathered Basement
			121			Fresh Basement.`
VES6	KH	4	103	0.419	23	Topsoil
			3275	1.002		Laterites,
			243	21.6		Weathered Basement
			4264			Fresh basement
VES7	KH	4	187	0.637	4.26	Topsoil
			1871	1.5		Laterites,
			100	2.13		Weathered Basement
			695			Fresh Basement.

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Table IIb: Summary Interpretation of VES 8-14

VES STATION	Curve Type	No. of Layers	Resistivity (Ωm)	Thickness	Depth to Bedrock	Remark
VES8	KH	4	165	1.52	9.08	Topsoil
			1475	1.42		Laterites
			102	6.14		Weathered Basement
			1338			Fresh basement
VES9	HKH	5	416	1.02	17.1	Topsoil
			2064	1.49		Laterites
			27.3	4.04		Weathered Basement
			736	10.5		Fracture basement
			10.5			Fresh Basement.
VES10	HA	4	398	3.04	54.6	Topsoil
			109	1.2		Laterites,
			190	50.4		Weathered Basement
			35227			Fresh basement
VES11	KH	4	219	0.5	3.16	Topsoil
			818	0.643		Laterites
			16.1	2.02		Weathered basement
			25083			Fresh basement
VES12	HKH	5	298	0.5	25.5	Topsoil
			1030	0.836		Laterites
			136	8.22		Weathered Basement
			8220	15.9		Fracture basement
			113			Fresh Basement.
VES13	HKH	5	484	0.5	29.6	Topsoil
			4580	0.836		Laterites
			213	2.23		Weathered Basement
			11576	26		Fractured basement
			98.2			Fresh basement
VES14	A	3	53.3	0.544	7.11	Topsoil
			650	6.57		Laterites
			156910			Weathered basement

The competence of soil with respect to the resistivity value, according to Idornigie and Olorunfemi 2006, for engineering construction purposes is rated as follow:

i. Incompetent (≤100 Ωm); this could be clay or water-bearing zone.

ii. Moderate (100-350 Ωm); this may be sandy clay environment.

iii. Competent (350-750 Ωm);

iv. Highly competent (≥ 750 Ωm); this could be fresh basement area depending on the state of freshness.

Based on the benchmark above, 2D pseudo-sections from all the profiles along the high-rise buildings were produced (Fig. IV-VIII) for the purpose of competence rating. The result is summarized in table III. The area falls between moderate and highly competent ratings.

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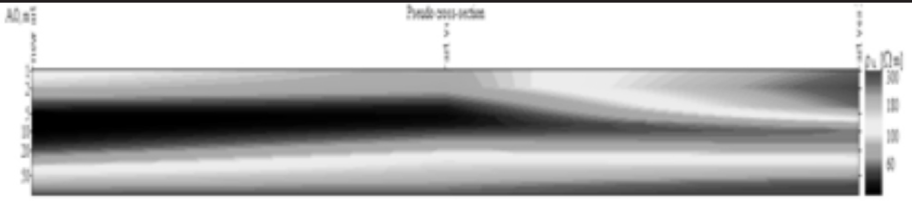

Fig. IV: 2D pseudo-section for Profile 2, (VES 1, VES 2 and

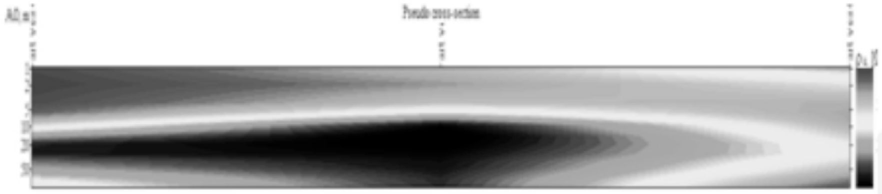

Fig. V: 2D pseudo-section for Profile 2, (VES 4, VES 5 and VES 6)

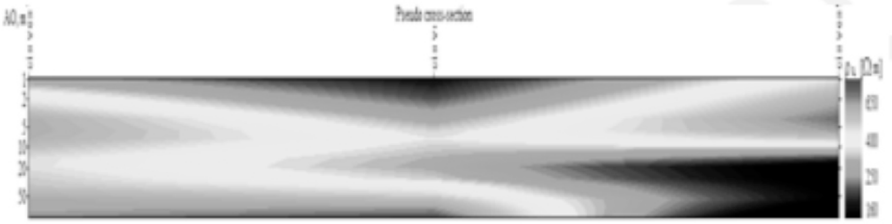

Fig. VI: 2D pseudo-section for Profile 3, (VES 7, VES 8 and VES 9)

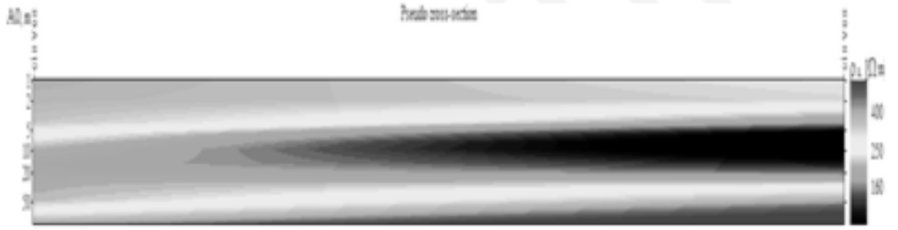

Fig. VII: 2D pseudo-section for Profile 4, (VES 10 and VES 12)

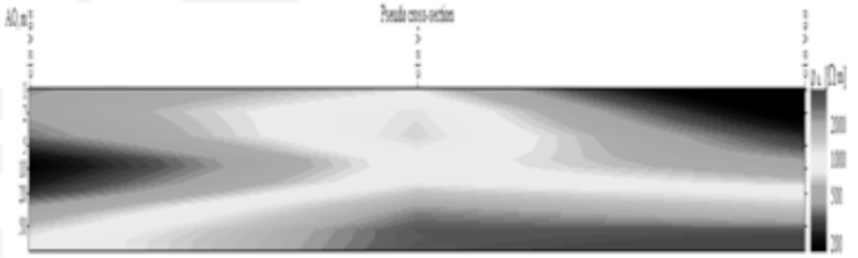

Fig. VIII: 2D pseudo-section for Profile 5, (VES 12, VES 13 and VES)

Table III: Subsurface Competence Rating Around the Structures

SN	Building	Resistivity Range on the Associated Profiles (Ωm)	Competence Rating
1	Faculty of Arts Main Building	Profile 1: 60 - 300	Moderate
2	New Faculty of Arts Lecture Theatre	Profile 2: 100 – 500	Moderate
3	Faculty of Communication and Information Science Main Building	Profile 3: 160 - 650	Competent
4	Faculty of Communication and Information Science New Lecture Theatre	Profile 4: 160 - 400	Competent
5	Post-Graduate Hostel	Profile 5: 200 - 2000	Highly Competent

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The resistivity pseudo-sections show continuous high resistivity zone close to the surface in all the profiles. Resistivity of the layer from depth 0-5m varies from 60 -300 Ωm along profile 1. Hence, this layer is rated to be moderately competent. Also, the lithological unit is made up of sandy clay and possibly the bedrock may be encountered very close to the surface. However, from profile 2 high resistivity layer runs from depth 0-5m and varies from 100 -500 Ωm. Hence, the layer is rated to be moderately competent. Also the lithology is made up of sandy clay. We now consider the highest resistivity zone on the surface. Resistivity of this layer from depth of about 50m increases downward and varies from 200Ωm – 2000Ωm along profile 5. Hence this layer is rated to be highly competent. The lithology is made up of sand/laterite/bedrock. Moreover, profiles 1 to 5 are suitable for construction because of their high resistivity and therefore the existing buildings on them could be stable and not suffer stability threat.

4.0 CONCLUSION

The number of geo-electric layers in the area ranges from 3 to 5. These layersare mostly identified to be the top soil, lateritic, sandy clay, weathered basement and fresh basement. The competence rating is from moderate to high. No area was found incompetent. That is there is no construction threat base on the results obtained. Though, fresh basement is at varying depths in all the profiles but it is shallow around postgraduate hostel. This could be responsible for the high competence obtained in the area. The knowledge of the depth to basement is very necessary when high-rise building is to be constructed. This will give a clue to the choice of foundation depth. Therefore in case of any plan to construct high-rise buildings in the area more geophysical study to reveal the basement topography is recommended.

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