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Geo-Technical Sub-surface Exploration for Delineation of Structural Foundations: A Case Study of Technical University, Ibadan, Nigeria

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ABSTRACT: Sub-surface exploration provides valuable input regarding the type, age and depositional environment of geologic formations existing at a site for use in planning and interpreting the site conditions. Hence, the objective of this paper was to evaluate and provide data on the geo-technical sub-surface exploration for delineation of structural foundations in Technical University, Ibadan, Nigeria using Vertical Electrical Sounding (VES) to determine the suitability of the sub-surface competence of the site for construction purposes and building development in the institution. The results indicated that the resistivity value of different geo-electric layers showed that geologic value greater than 20 m (thick weathered bedrock) can support massive civil engineering structure while 5-10 m can support small civil engineering structure.

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The rate of buildings failure throughout the country has increased in recent times and a number of lives and properties have been lost. There are several cases of collapsed building and cracking of walls as a result of poor foundation during construction and lack of site investigation (Amadi *et al.,* 2012; Adagunodo *et al*., 2014). This may be linked to poor soil stability, since some soils are more sensitive to moisture gain or loss and also lack of knowledge of structural distributions of the subsurface (Kwaerno and Oygarden 2006). Geophysical surveys are often ignored when considering sites for construction purposes. The design of a structure which is safe, durable and has low maintenance costs depends upon adequate understanding of the ground on which such building is located (Ozegin *et al.,* 2013; Plagnes *et al.,* 2011). The necessity for site characterization for construction purposes has therefore become very important so as to prevent loss of valuable lives and properties that always accompanied such failures. The primary purpose of all site investigations is to obtain the data needed for analysis and design (Oyedele *et al.,* 2012; Gassman *et al.,* 1995). Some general reasons why buildings may be susceptible to collapse have been advanced, which include poor quality of building materials, salinity and age of buildings. Less frequently mentioned is subsurface condition of the ground on which the buildings are sited. The geology of an area plays an important role in the construction of buildings. Most buildings are constructed on soil

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that has inadequate bearing capacity to support the weight of the structure (Kwaerno and Oygarden 2006; Adiat *et al.,* 2009; El-Khabiry and Colver 1997). Constructions are affected by geological/geophysical features. These geological and geophysical features include fractures, voids, extent of depth to bedrock, depth to the water table, etc (Arshad and Ahmed 2007; Telford *et al.,* 1990). A good knowledge of the underground strata before construction will help in preventing cracks. Seepage precipitated settlement and natural differential settlement arising from the underlying clayey substratum were responsible for the failure of spilling structure (Amadi *et al.,* 2012; Kwaerno and Oygarden 2006). Electrical resistivity survey is increasingly being used in environmental, engineering and hydrological investigations as well as geothermal and mineral prospecting, where detailed knowledge of the subsurface is sought. (Agada *et al.,* 2017; Kana *et al.,* 2015; Doolittle *et al.,* 2006; Sabins 1999; Kammerling *et al.,* 1994). It is based on the fact that the subsurface structures possess varying resistivity and it provides subsurface information regarding subsurface resistivity distribution, thickness and depth of various layers when compared with other methods like gravity and magnetic. The differences in electrical properties are investigated and analyzed to delineate underground structures. Due to high spatial resolution, relatively fast field data acquisition time and low cost, the geo-electrical methods have been employed by several researchers in studying the subsurface structures (Joshua *et al.,* 2011; Keary *et al.,* 2002; Kumar 2012; Soupios *et al.,* 2010; McGregor *et al.,* 2001). Therefore, investigation of the foundation bedrock and the subsoil condition of soil is vital to determine the cause(s) of the failure of the building which manifest in form of tilting and cracks. Therefore, the need for pre-foundation studies has therefore become very imperative so as to prevent loss of lives and valuable properties that always accompany such failure. Hence objective of this paper was to evaluate and provide data on the geo-technical sub-surface exploration for delineation of structural foundations in Technical University, Ibadan, Nigeria.

MATERIALS AND METHODS

Location and Geology of Study Area: The study area is located inside the Technical University Ibadan along the Ibadan-Lagos express way in Ibadan, Oyo State in Southwestern Nigeria. About half of the total land mass of Nigeria is covered by the Precambrian basement complex rocks introduced by younger granites of Jurassic age. The other half is made up of Cretaceous to Recent sediments overlying the basement rocks. The basement complex rocks in Ibadan area are mainly the metamorphic rocks of Precambrian age with few intrusions of granites and porphyries of Jurassic age. The dominant rock types are quartzites of the meta-sedimentary series and banded gneisses, augen gneisses and migmatites which constitute the gneiss-migmatite complex. Other associated rock types include pegmatites, quartz, aplites, dolerites dykes, amphibolites and xenoliths. In most part of Ibadan, the rocks are overlain by weathered regolith; thus, outcrops are correspondingly few. Banded gneiss constitutes over 75% of the rocks in and around Ibadan while augen gneisses and quartzites share the remaining in about equal percentages (Sunmonu *et al.,* 2013; Rahaman 1989).

Geophysical Data Acquisition: Geophysical survey was carried out using vertical electrical sounding (VES) with the Schlumberger electrode configuration employed. The current electrode spacing (AB/2) ranges from 0m to 30m in successive steps with five traverses in the east-west direction and 4 profiles in the north-south direction. A total of 20 VES stations were carried out and measurements made with aid of a DDR1 Resistivity meter along the transverse sections forming the grid of the selected area. The grid points of the selected area were classified into 9 profiles and results were collated. The instruments and materials used for the data acquisition are resistivity meter, steel metal electrodes, connecting cables, measuring tape, hammer, compass, data recording materials, global positioning system (GPS).

Data Processing: The resistance data obtained on the field was multiplied by the Schlumberger geometric factor to obtain the apparent resistivity values. The vertical electrical data were subjected to partial curve matching which involves plotting of field data on transparent logarithm paper. The field curve is then superimposed on the master curve with the axes kept parallel to each other. It is moved around until a fit good enough for connecting as many as possible data points is achieved. The point of intersection of the master curve was then marked on the field curve tracing paper and then the curve matched. The resistivity value was obtained from the logarithm paper Y-axis while the X-axis gives the thickness of the layers. Computer iteration was carried out with the use of the WINRESIST geophysical software after the curve matching process. The advantages of the log-log plot is that it gives the possibility of the plotting both large and small value of apparent resistivity on the same log paper and also permits the comparison of the plotted curve with standard curve design for this purpose. This is important, because interpretation of the results depends largely on the small variations in resistivity occurring at shallow depth.

Fig 1: Geo sensors resistivity meter used for data gathering.

RESULTS AND DISCUSSION

The results obtained from the electrical resistivity survey is presented in table 1 and generated into geo-electric sections with respect to the elevation of each VES point (figures 5-9). The results are also presented in form of field curves and geo-electric sections (figures 2-4). The curves obtained within the study area include the H-curve and the K-curve types. A quantitative interpretation of the VES curves resulted in determination of geo-electric layer parameters (layer resistivity and thickness) for the subsurface characterization.

Table 1: Geo-Electric Parameters and Inferred Lithology of the study area

VES Station	Possible lithology	Top Soil	Weathered Basement	Fresh Basement	Curve Type
	Resistivity (Ωm)	481.8	159.2	203.5	
VES 1	Thickness (m)	0.6	10.1	Infinity	H
	Depth (m)	0.6	10.6	Infinity	
	Resistivity (Ωm)	164.2	35.1	364.1	
VES 2	Thickness (m)	3.6	5	Infinity	H
	Depth (m)	3.3	9.1	Infinity	
	Resistivity (Ωm)	121.2	39	831.8	
VES 3	Thickness (m)	3.3	5.9	Infinity	H
	Depth (m)	3.3	9.1	Infinity	
	Resistivity (Ωm)	192.4	84.6	1503.5	
VES 4	Thickness (m)	2.7	17.2	Infinity	H
	Depth (m)	2.7	19.9	Infinity	
	Resistivity (Ωm)	194.7	68.5	395	
VES 5	Thickness (m)	0.8	25.5	Infinity	H
	Depth (m)	0.8	26.6	Infinity	
	Resistivity (Ωm)	132.8	240.2	93.7	
VES 6	Thickness (m)	1.6	1.1	Infinity	K
	Depth (m)	1.6	2.8	Infinity	
	Resistivity (Ωm)	123.3	210.9	97.9	
VES 7	Thickness (m)	1.4	1.4	Infinity	K
	Depth (m)	1.4	2.8	Infinity	
	Resistivity (Ωm)	100.9	177.4	80	
VES 8	Thickness (m)	2.3	2.9	Infinity	K
	Depth (m)	2.3	5.2	Infinity	
	Resistivity (Ωm)	232.2	83.5	630.4	
VES 9	Thickness (m)	0.8	13.9	Infinity	H
	Depth (m)	0.8	14.7	Infinity	
	Resistivity (Ωm)	248.6	116.2	203.6	
VES 10	Thickness (m)	1.1	19.2	Infinity	H
	Depth (m)	1.1	20.3	Infinity	
	Resistivity (Ωm)	135.2	98.7	130.1	
VES 11	Thickness (m)	0.6	9.3	Infinity	H
	Depth (m)	0.6	9.9	Infinity	
	Resistivity (Ωm)	182.2	90	142.4	
VES 12	Thickness (m)	0.4	2.7	Infinity	H
	Depth (m)	0.4	3.1	Infinity	
	Resistivity (Ωm)	66.4	92.2	213.5	
VES 13	Thickness (m)	0.6	10.5	Infinity	A
	Depth (m)	0.6	11	Infinity	
	Resistivity (Ωm)	297.5	85.5	351.2	
VES 14	Thickness (m)	0.7	16.9	Infinity	H
	Depth (m)	0.7	17.6	Infinity	
	Resistivity (Ωm)	244.9	67	144.5	
VES 15	Thickness (m)	0.9	16.1	Infinity	H
	Depth (m)	0.9	16.9	Infinity	
	Resistivity (Ωm)	254.4	105.9	79.2	
VES 16	Thickness (m)	0.6	6.6	Infinity	Q
	Depth (m)	0.6	7.2	Infinity	
	Resistivity (Ωm)	335	104.6	324.4	
VES 17	Thickness (m)	0.6	18.5	Infinity	H
	Depth (m)	0.6	19.1	Infinity	
	Resistivity (Ωm)	210	67.6	693.5	
VES 18	Thickness (m)	4.2	11.9	Infinity	H
	Depth (m)	4.2	16.1	Infinity	
	Resistivity (Ωm)	222.7	125.4	1328	
VES 19	Thickness (m)	1.8	14.6	Infinity	H
	Depth (m)	1.8	16.3	Infinity	
	Resistivity (Ωm)	117.7	43	902.9	
VES 20	Thickness (m)	1.2	9.3	Infinity	H
	Depth (m)	1.2	10.4	Infinity	

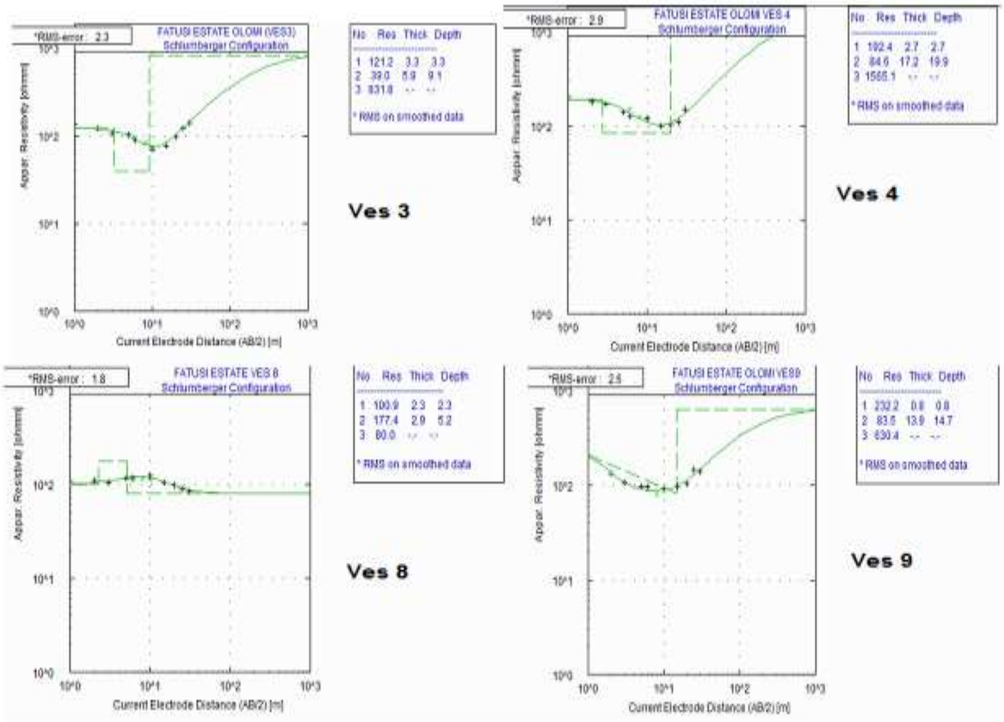

Fig 2: Representative curve type of VES 3, 4, 8 and 9 obtained in the study area

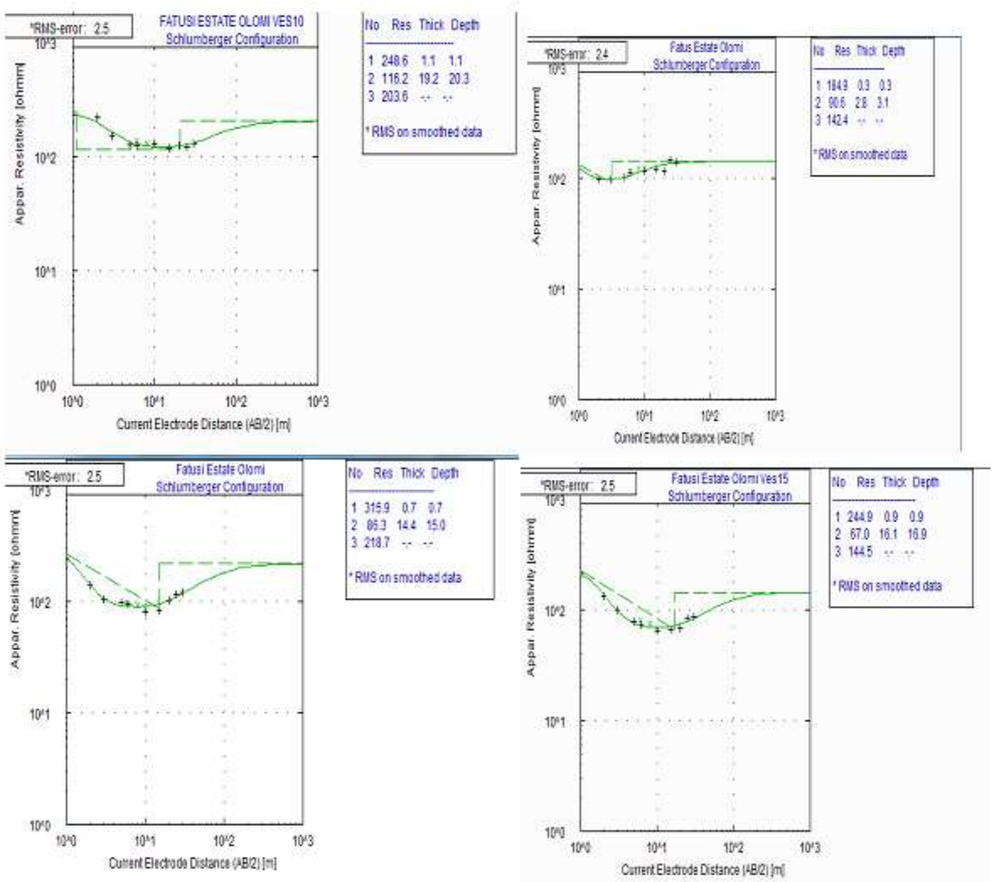

Fig 3: Representative curve type of VES 10, 15 obtained in the study area

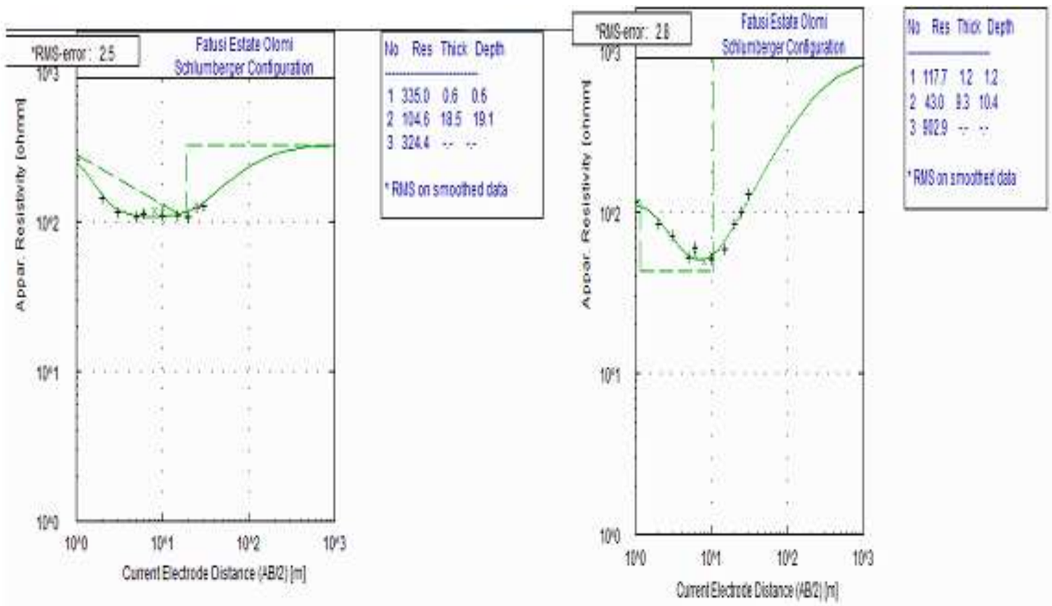

Fig 4: Representative curve type of VES 12 obtained in the study area

Geoelectric Section: Figures 5-9 shows the geoelectric section generated along the profiles established within the study area. All the sections revealed a maximum of three layers which could be classified into three major geologic layer. This includes the top soil, the weathered/ fractured basement rock, and lastly the fresh basement rock. The resistivity of the top soil ranges from 100Ωm to 481.1 Ωm with depth ranging from 0.4m to 4.2m below the surface. The weatherd basement value ranges from about 35Ωm to 240Ωm with thickness ranging from 1.1m to 25.5 m. it is composed of already weathered rock. The third layer which is the fresh basement rock has resitiivty values reanging from 79.2Ωm to 1503Ωm and it consitiute the last layer. High degree of inhomogeniety in the top soil is responsible for the variations of the topsoil and of the other subsequent layers. Regions with low resistivity distribution resulted from water saturation at those points and regions of high resistivity value resulted from low porosity and permeability rate which leads to reduction in the level of water stauration. The top soil is generally thin but the depth to bedrock varies across each geoelctric sections with as deep as 25.5m in VES 5 (Table 1).

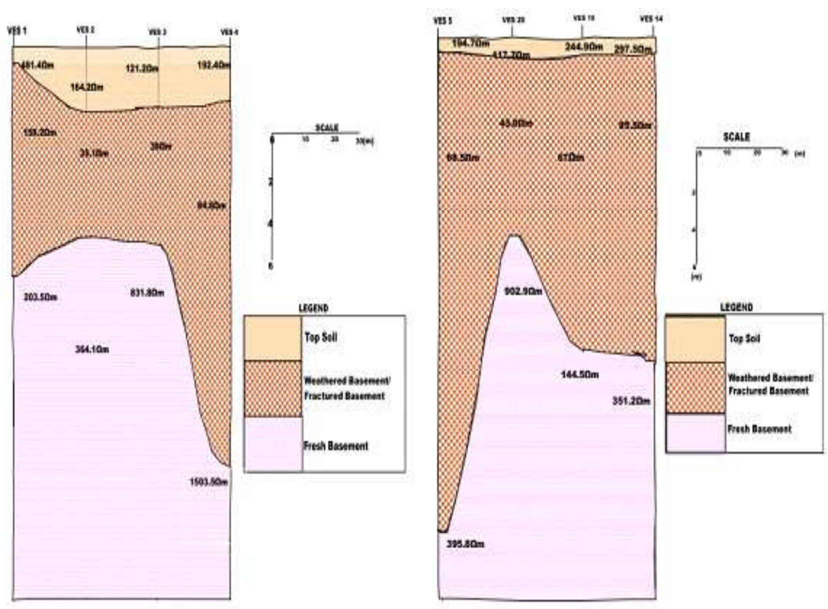

Fig 5: Geo-electric section along: a: Profiles 1,2,3 and 4, b: Profiles 5,20,15 and 14

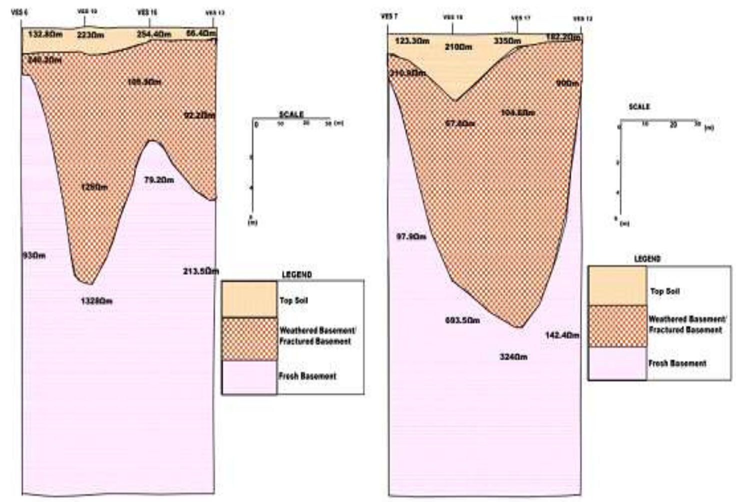

Fig 6: Geo-electric section along a: Profiles 6,19,16 and 13 b: Profiles 7,18,17 and 12

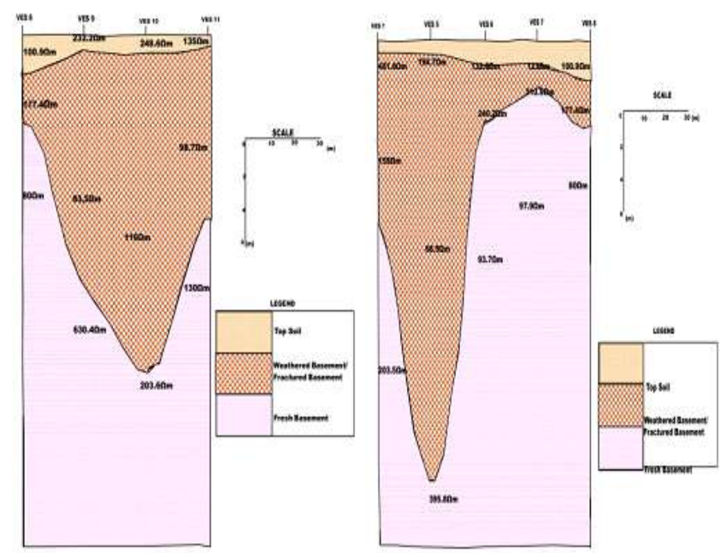

Figure 7: Geo-electric section along a: Profiles 8,9,10 and 11 b: Profiles 1,5,6,7 and 8

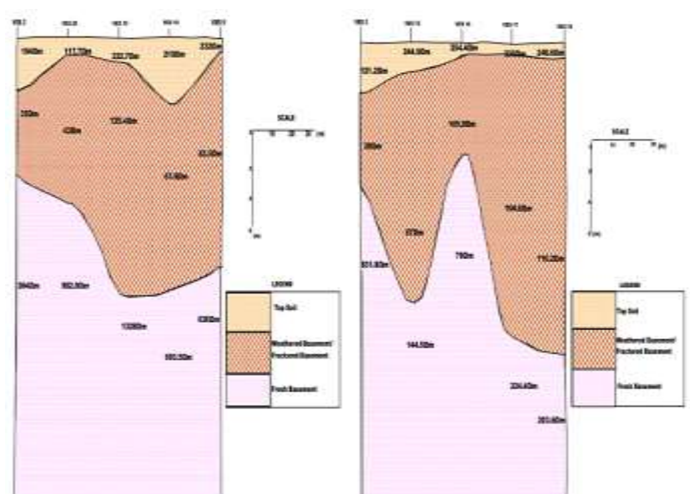

Fig 8: Geo-electric section along: a: Profiles 2,20, 19,18 and 9; b: Profiles 3, 15, 16, 17 and 10

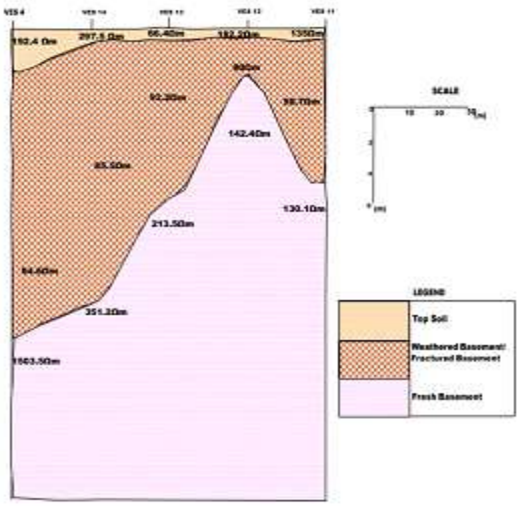

Fig 9: Geo-electric section along Profiles 4,14,13, 12 and 11

Conclusion: Results revealed three subsurface layers of topsoil, weathered/fractured basement and fresh basement and Curve types include H, A, K, and Q. The H-type curve is dominant and accounts for 75% of the curve types obtained from the study area which indicates the presence of highly resistive layers typical of Basement Complex areas. Based on the resistivity values of the different geo-electric layers, the geologic units greater than 20m like the thick weathered bedrock are competent and can support massive civil engineering structures while units between 5m–10m can support small civil engineering.

Declaration of competing interest: The authors declare that they have no competing interest

Availability of data and material: Data for the work is provided in the work

Consent to participate: The authors participated fully in the research and therefore take public responsibility for the research and have agreed to have our name listed as contributors of the manuscript

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REFERENCES

Adagunodo, TA; Sunmonu, LA; Oladejo, OP. (2014). Effect of Constructing High-Rise Buildings without a Geophysical Survey. *Nig. J. Phy.* Special Edition September 2014, 91–100

Adiat, KAN; Adelusi, AO; Ayuk, MA (2009). Relevance of geophysics in road failures investigation in a typical basement complex of Southwestern Nigeria. *Pacific J. of Sci. Tech.*,5:528-539

Agada, I; Ibuot, JC; Ekpa, M; Obiora, DN (2017). Investigation of subsurface for construction purposes in Makurdi, Benue State, Nigeria, using electrical resistivity method. *J. Geol. Mining Res.*, 9:9-17

Amadi, AN; Eze, CJ; Igwe, CO; Okunlola, IA; Okoye, NO (2012). Architect's and Geologist's View on the Causes of Building Failures in Nigeria, 6:31

Arshad, MC; Ahmed, JM (2007). Determination of lithology and groundwater quality using electrical resistivity survey. *Int. J. Agriculture and Biology*, 9:143-146

Doolittle, JA; Jenkinson, BH; Ulmer, D; Tuttle, MW (2006). Hydrogeological investigations with ground-penetrating radar (GPR): Estimating water-table depths and local ground-water flow pattern in areas of coarse-textured soils. *Geoderma*, 131:317-329

El-Khabiry, S; Colver, GM (1997). Drag reduction by dc corona discharge along an electrically conductive flat plate for small Reynolds number flow, *Physics fluids*, 9:587-599

Gassman, J; Owen, J; Walter, W; Kuntz, TE; Martin, JP; Amoroso, WP (1995). Data quality assurance, monitoring, and reporting. *Controlled clinical trials*. 16:104-136

Joshua, EO; Odeyemi, OO; Fawehinmi, OO (2011). Geoelectric investigation of the groundwater potential of Moniya Area, Ibadan. *J. Geol. Mining Res.* 3(3):54-62

Kammerling, RC; Scarratt, KB; George, JE; Alan, K; Robert, E; Gübelin, EJ; Levinson, AA (1994). Myanmar and its gems-an update. *J. Gemmology*. 24:3-40

Kana, J; Domra, D.N; Raïdandi, D; Nouck, PN; Dadjé, A (2015). A review of geophysical methods for geothermal exploration. *Ren. Sustainable Energy Rev.*. 44:87-95

Keary, P; Brook, M; Hill, I (2002). An Introduction to Geophysical Exploration. *Blackwell Scientific Publication. Oxford, U.K*, pp. 198 – 269.

Kumar, D (2012). Efficacy of electrical resistivity tomography technique in maping shallow subsurface anomaly.'' *J. geol. Soc.India*:80(3):304-307.

Kwaerno, SH; Oygarden, L (2006). The influence of freeze-thaw cycles and soil moisture on aggregate stability of three soil in Norway. *Catena* 67(3):175-182.

McGregor, L; Sinha, M; Constable, S (2001). Electrical resistivity structure of the Valu Fa Ridge, Lau Basin, from marine controlled-source electromagnetic sounding. *Geophy. J. Int.* 146:217-236

Oyedele, KF; Okoh, C (2012). Subsoil investigation using integrated methods at Lagos, Nigeria. *J. Geol. Mining Res.* 5:169-179

Ozegin, KO; Oseghale, AO; Audu, AL; Ofotokun, EJ (2013). An application of the 2–D DC Resistivity method in Building Site Investigation–a case study: Southsouth Nigeria. *J. Environ. Earth Sci.* 3:108-112

Plagnes, VG; Chalikakis, KR; Valois, RB; Frank, P (2011). Contribution of geophysical methods to karst-system exploration: an overview. *Hydrogeology J.* 19:1169

Rahaman, MA (1989). Review of the basement geology of South western Nigeria. In CA Kogbe 2nd Ed. of Geology of Nigeria, Rock view, Jos, Nigeria 39-56.

Sabins, FF (1999). Remote sensing for mineral exploration. *Ore Geology Reviews*. 14:157-183

Soupios, PM; Georgakopoulos, PP; Nikos, S; Vasilios, AA; Vallianatos, F; Sarris, AM (2010). Use of engineering geophysics to investigate a site for a building foundation. *J. Geoph. Engr*. 4:97-103

Sunmonu, LA; Olasunkanmi, NK; Alagbe, OA (2013). Aeromagnetic data interpretation for geostructural analysis of Ibadan, southwestern Nigeria. *Int. J. Eng. Res. Tech.* 2(10): 3058-3065.

Telford, WM; Geldart, LP; Sheriff, RE (1990). Applied Geophysics. Cambridge University Press. Cambridge, Vol. 1, pp. 770. https://doi.org/10.1017/CBO9781139167932