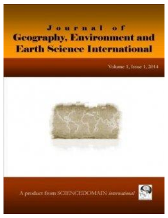

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Modeling of Subsurface Integrity Using Dar-Zarrouk Parameters: A Case Study of Ikekogbe UBE Primary School, Ekpoma, Edo State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author AI designed the study. Authors BMA and ISO performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AAO and OAA managed the analyses of the study. Authors BMA, AI and ISO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

In this present study area, most building failures often start with minor/major cracks which widen over time, and it is often followed by post construction remedial measures which fail after sometime, thereby leading to total collapse and sinking of such buildings. The research was carried out in order to be able to unravel the causes of major cracks along the side of a major class room block at Ikekogbe, UBE Primary School, Ekpoma, Edo State, Nigeria in less than five (5) years after it was constructed. The cracks were visible both at the front and at the back of the building along the same axis and almost at this same distance as it was at the front of the building. The investigation involved Electrical Resistivity method using three techniques; Vertical Electrical Sounding (VES), 2-D Electrical Resistivity Tomography (ERT) and Horizontal Profiling (HP). The traverses were

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established along E-W directions and Eight (8) VES were carried out using Schlumberger array with current electrode spacing varying from 1 to 40 m, with 2-D ERT using Dipole-Dipole electrode array with inter-station separation of 5 m and an expansion factor that varied from 1 to 5 and HP using Wenner array with an electrode spacing of 5 m interval. The VES interpretation results were used to determine the second order parameters for modeling of subsurface integrity/competence. The 2 D imaging (Dipole-Dipole) gave information on the subsurface characteristic and the Wenner profile was characterised by low resistivity at the region of 30 to 45 m considered as the weak zone. Correlating the results with subsurface integrity model along traverses one and three, there was a high degree of correlation as this region coincides with the very low/low integrity/competence with the foundation of the classroom overlying this layers. The research revealed that the problem of structural failures/crack noticed along the building walls and axis was not as a result of human problem alone but mainly the existence of very low/low integrity/competence layers which contributed greatly to the cracks observed on the classroom block. These results reveal that the three Electrical resistivity techniques used for this study are complimentary to each other.

Keywords: Dipole-dipole; Wenner profiling; total longitudinal conductance; total transverse resistance; incompetent materials; foundation integrity.

1. INTRODUCTION

The problem of building failure is first becoming a matter of daily occurrence, be it in our village, towns and big cities, to an alarming proportion, with its attendance loss of life and valuable properties running to millions of Naira as is being the case with recent occurrence throughout the federation [1]. Previous works over the years in geosciences have attributed these failures to lateral inhomogeneity of the subsurface, differential settlement and failure due to the presence of weak zones beneath the buildings [2,3,4,5]. The subsurface geologic factors and features which make it possible for building to readily collapse even at short notice, and a times sink even when accorded the very best attention, in term of construction, design or building materials [2]. Subsequently, the need for geophysical and geological site investigation becomes inevitable, for any civil engineering or building structure [6]. For the purpose of civil engineering, site investigation, construction and other structural engineering work, engineering geophysics offer a fast, cheap, cost effective and reliable way forward to engineering and other related problem before construction work [7]. Hence, this research work became necessary, giving the growing concern about the causes of building failures, which most people readily attribute to poor building materials, poor designs or poor construction or finishing without taking into consideration subsurface geological factors.

2. SITE DESCRIPTION AND GEOLOGY OF THE STUDY AREA

The study was carried out at Ikekogbe Primary School Eguare-Ekpoma, Edo State, Nigeria (Fig. 1). It is situated between the UTM coordinates of Ekpoma datum of Eastings 745800 - 746000 m and Northings 185460 - 185620 m. The elevation ranges from 241.5 to 425.7 m above the sea level. It falls within the Anambra Basin covering Eguare Ekpoma town and Ukpenu extension in Esan West Local Government area of Edo State, Nigeria (Fig. 2). Three major formations underlay the study area vis-à-vis Imo shale, Bende-Ameki formation and Ogwashi-Asaba [8,9,10,11]. The area of study is underlain by Bende – Ameki formation while the nearby area is underlain with 3% of Imo shale and Ogwashi – Asaba. The area is underlain by clay, shale, sandstone, limestone and sand. The Niger Delta sediment include Basin Agbada and Akata formations and they range in age from Eocene to recent [11].

3. METHODOLOGY

Three traverses of about 50 m were established in an approximate E - W direction (Fig. 3). The electrical resistivity method utilized the horizontal profiling (HP) technique, the vertical electrical sounding (VES) and the combined horizontal profiling and vertical electrical sounding techniques. The horizontal profiling utilizing wenner electrode configuration of station separations and electrode spacing of both 5m were used for the traverses. The combined horizontal profiling (HP) and vertical electrical sounding (VES) using dipole-dipole configuration to determine the lateral and vertical variation in apparent resistivity of the subsurface beneath the three established traverses, electrode spacing of 5m was used along same traverses as for the wenner electrode configuration. Resistivity values were obtained by taking readings using the R50 resistivity meter. The horizontal profiling data were plotted on excel work sheet while the dipole-dipole data were inverted into 2-D subsurface images using the DIPPRO™ 4.0 inversion software [12]. 2-D electrical imaging of the subsurface was obtained using dipole-dipole configuration. The inter-electrode spacing of 5 m was adopted while inter-dipole expansion factor (n) was varied from 1 to 5. The VES involved the use of Schlumberger array. Eight (8) sounding stations were occupied along the three established traverses, and the current electrode spacing (AB/2) was varied from 1 to 40 m. In order to process the electrical resistivity data, the apparent resistivity values were plotted against the electrode spread (AB/2). This was subsequently interpreted quantitatively using the partial curve matching method and computer-assisted 1-D forward modeling with WinResist 1.0 version software [13]. The results from the VES interpretation was used to determined second order parameters such as the total transverse resistance (T) and the total longitudinal conductance (s). The second order parameters were used to generate subsurface integrity model. The results from the three techniques were integrated in order to determine the consequences of the differential settlement and their degree of correlation.

4. RESULTS AND DISCUSSION

The results of the study were presented as pseudo sections, profiles, Sounding curves and subsurface integrity model.

4.1 Dipole-dipole Pseudosection

The 2-D Pseudosection was produced from the dipole-dipole data taken along the three (3) traverses Fig. 4 (a-c). The Dipole-Dipole traverses covered a distance of about 60 meter along East to West Orientation. It delineated three to four major subsurface material/layer components, identified with various colour for easy characterisation; The layer lithological materials varies from Topsoil comprises of clay, clayey sand and sandy clay material as indicated in green/blue colour with layer resistivity variation of 119 to 207 Ωm. Following this layer is another characterised by moderately low resistivity variation from 207 to 459 Ωm with the dominant resistivity being between 15.6 Ωm and 112.6 Ωm. These was characterised by lithologic units that

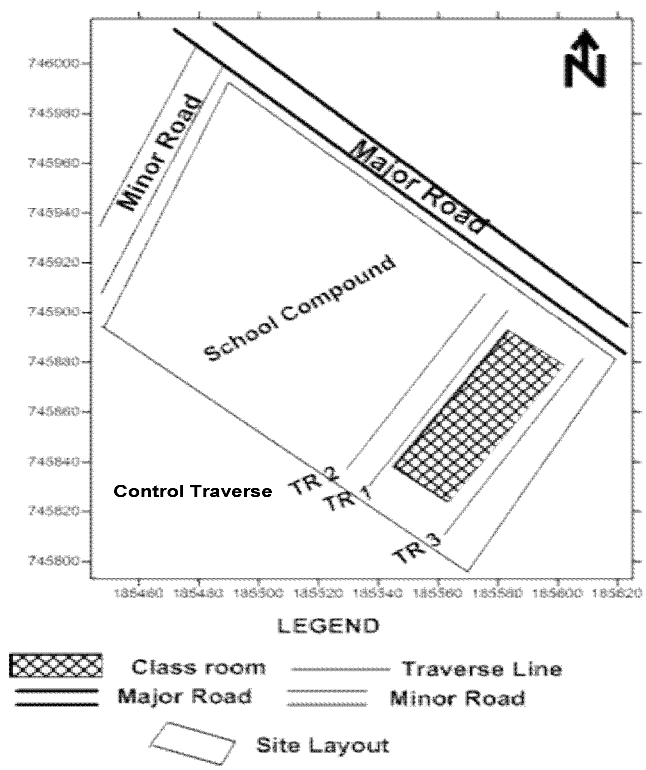

Fig. 1. Base map of the study area

can be classified as sandy shales, and shaly sands, with layer thickness varying from 1 to 25 m they are indicated with green, light green, and green/blue colour. These zones are characteristically weak and made up of attributes of low foundation integrity. The few zones with materials of high/moderate integrity can be found around 10 to 15 m and 40 to 45 m to a depth of 5 m along traverse one and two, also within 10 to 25 m along traverse three.

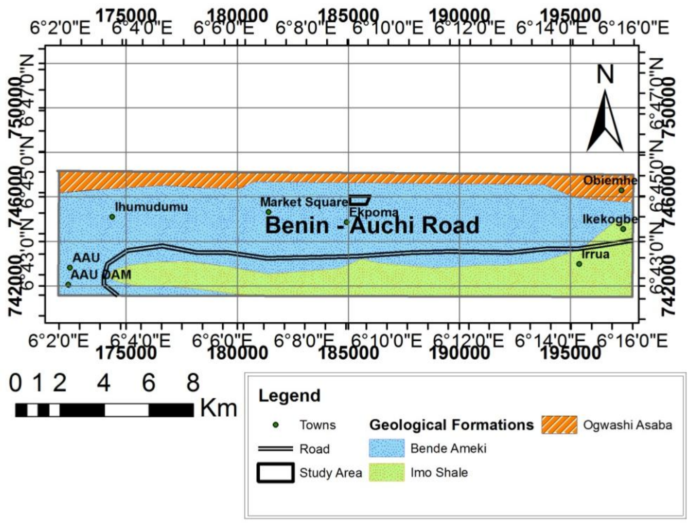

Fig. 2. Geological map of Ekpoma showing the study area [modified after 14]

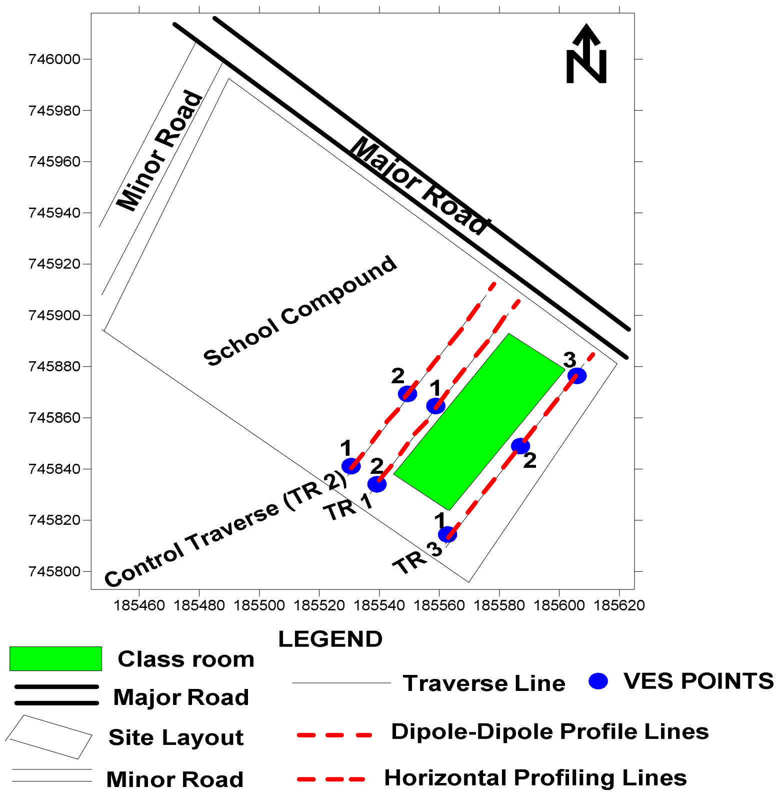

Fig. 3. Data acquisition map of the study area

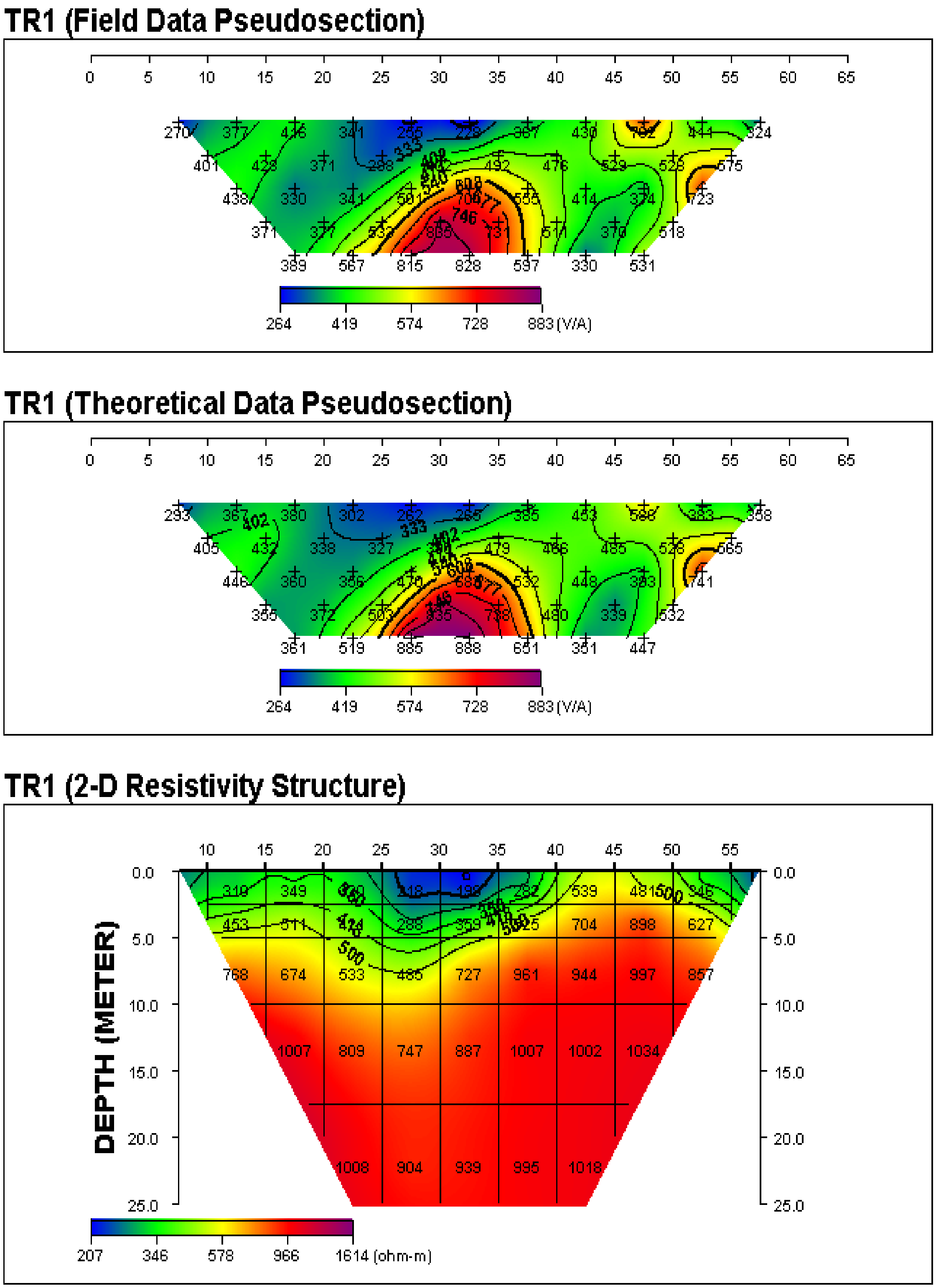

Fig. 4a. Dipole – Dipole Pseudo-section along traverse one

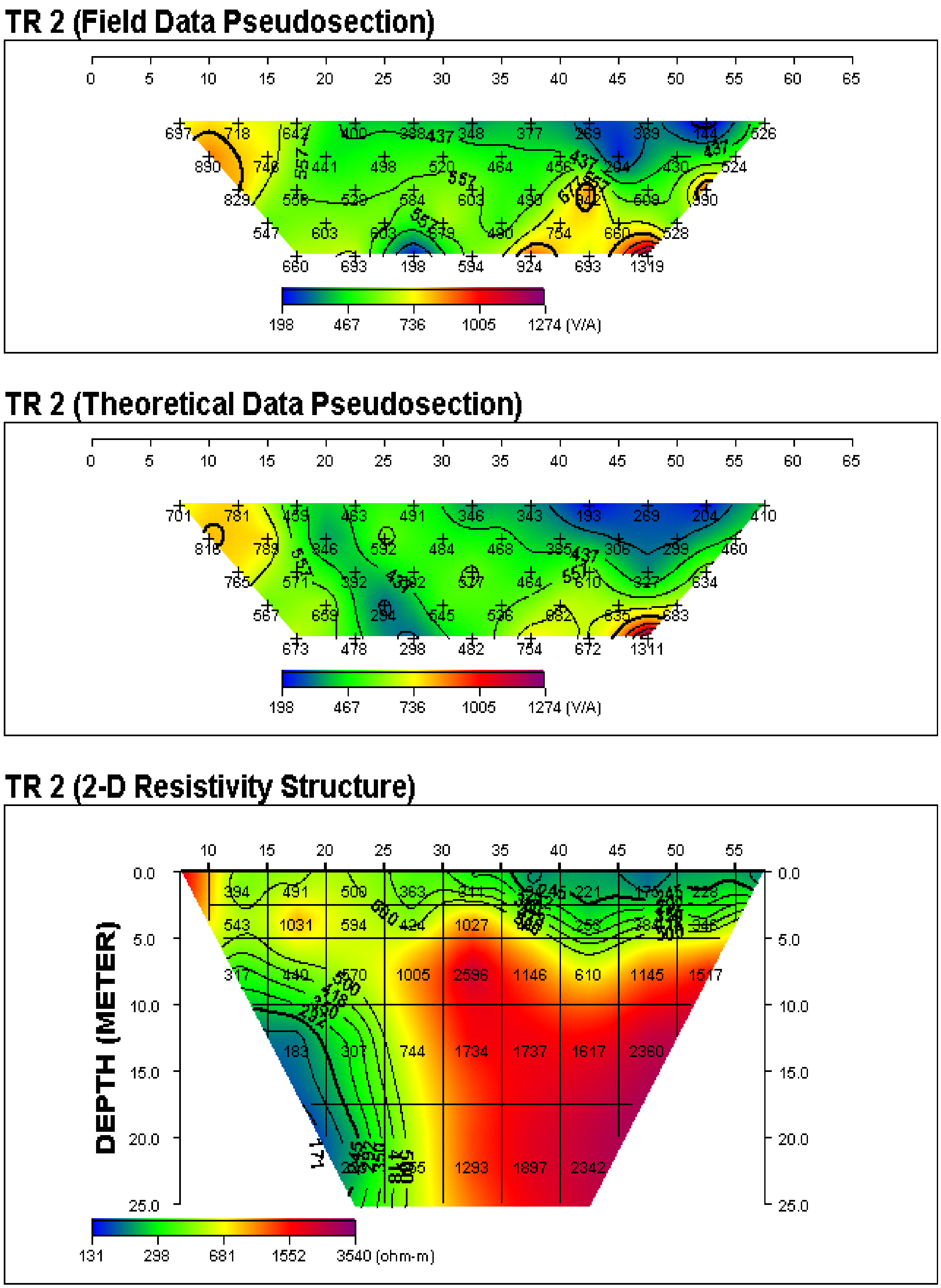

Fig. 4b. Dipole – Dipole Pseudo-section along control traverse two

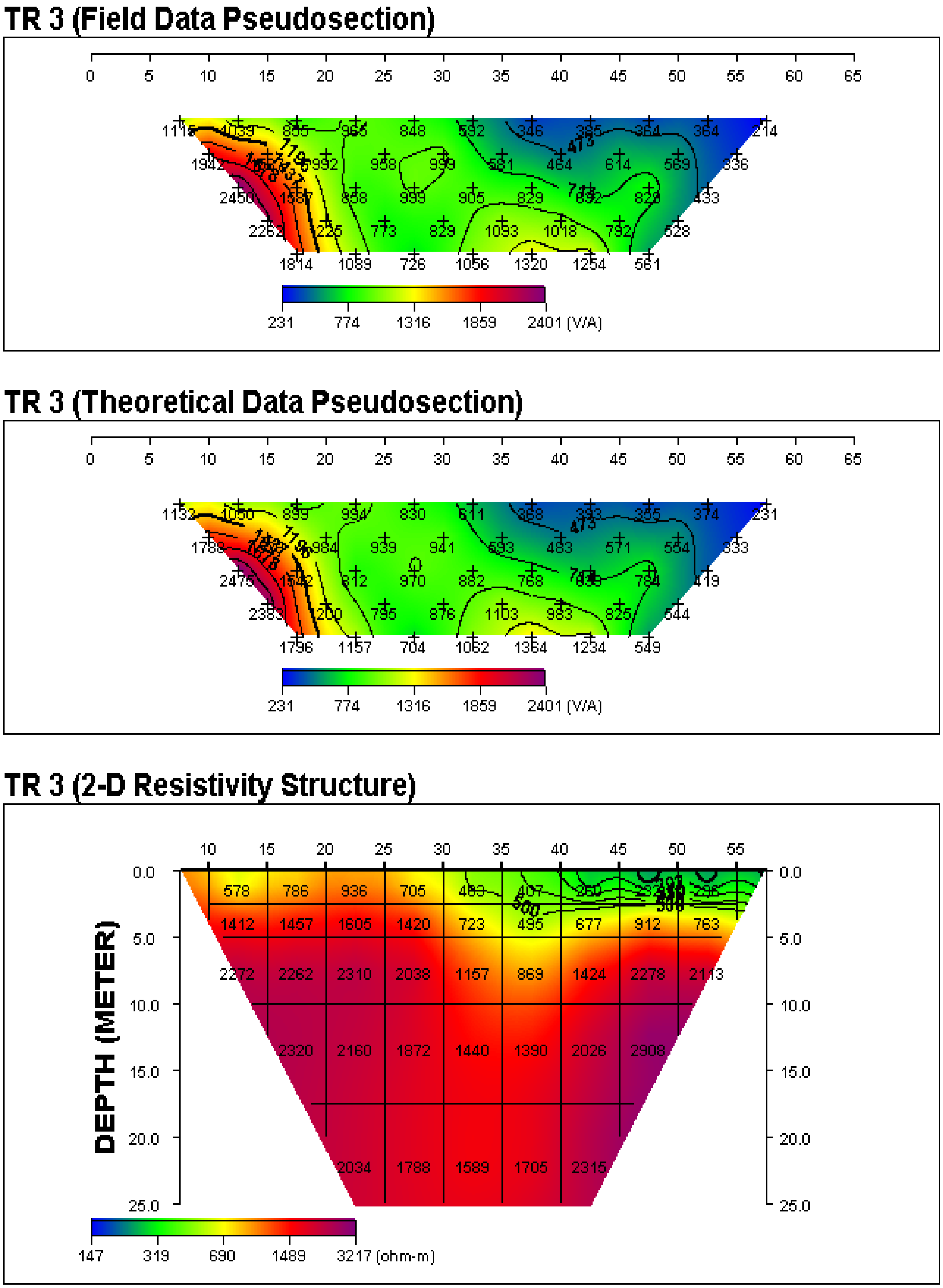

Fig. 4c. Dipole – Dipole Pseudo-section along traverse three

4.2 Horizontal Profiling

Horizontal profiling was produced from the Wenner data obtained along the traverse one and three (Fig. 5a and 5b). The result obtained further revealed that the zone is generally weak with apparent resistivity varying from 10 to 200 Ωm between 30 to 40 m along traverse one while within 5 to 25 m demonstrated fear competence with apparent resistivity value ranging from 380 to 400 Ωm (Fig. 7a). Weak zone was also observed within the 30 to 55 m along traverse three with apparent resisitivity varying from 200 to 280 Ωm (Fig. 7b).

4.3 Characteristic of the VES Curves

Curves types identified ranges from A, KH and HK varying between three to four geo-electric layers. The A curve type was predominant. Typical curve types in the area are as shown in Fig. 6(a-c).

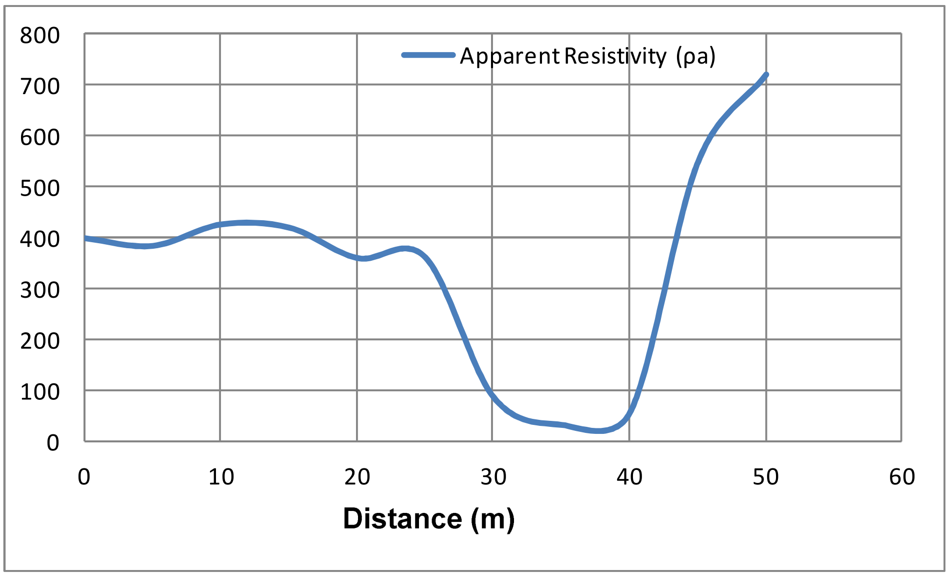

Fig. 5a. Horizontal profiling along traverse one

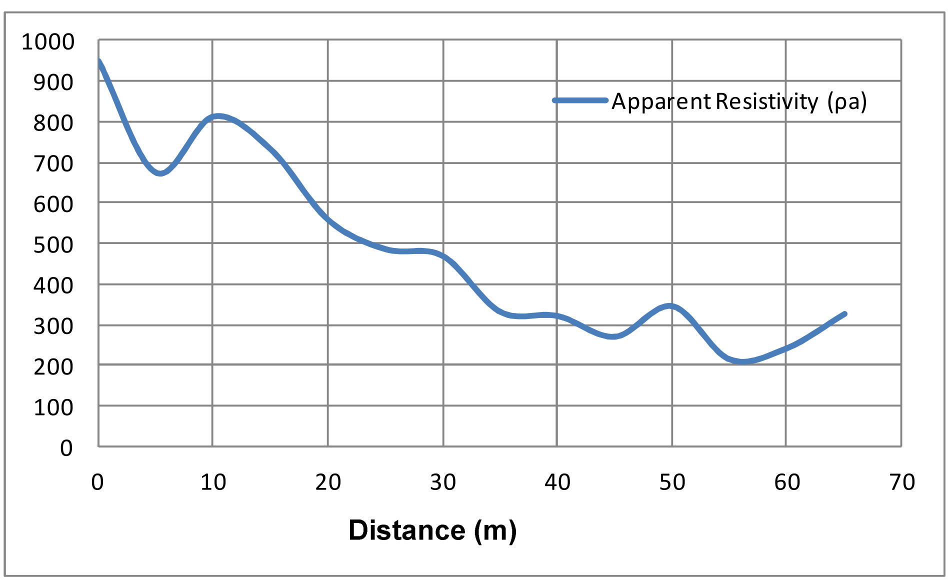

Fig. 5b. Horizontal profiling along traverse three

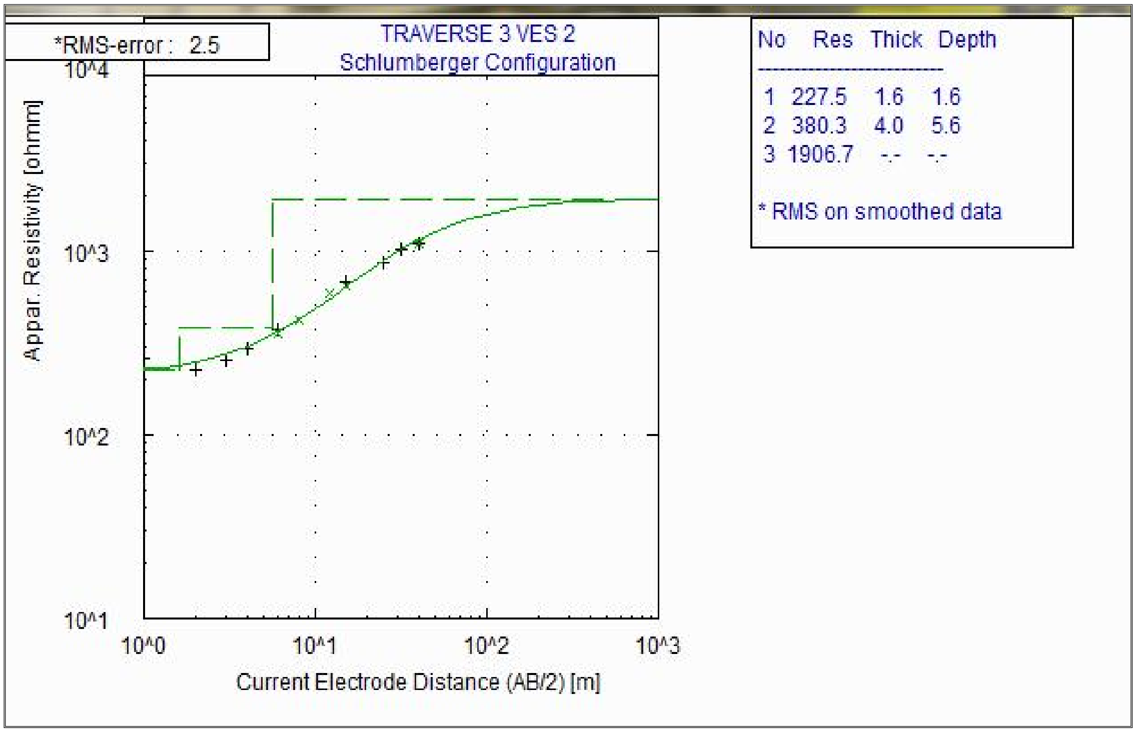

Fig. 6a. Typical 'A' sounding curve

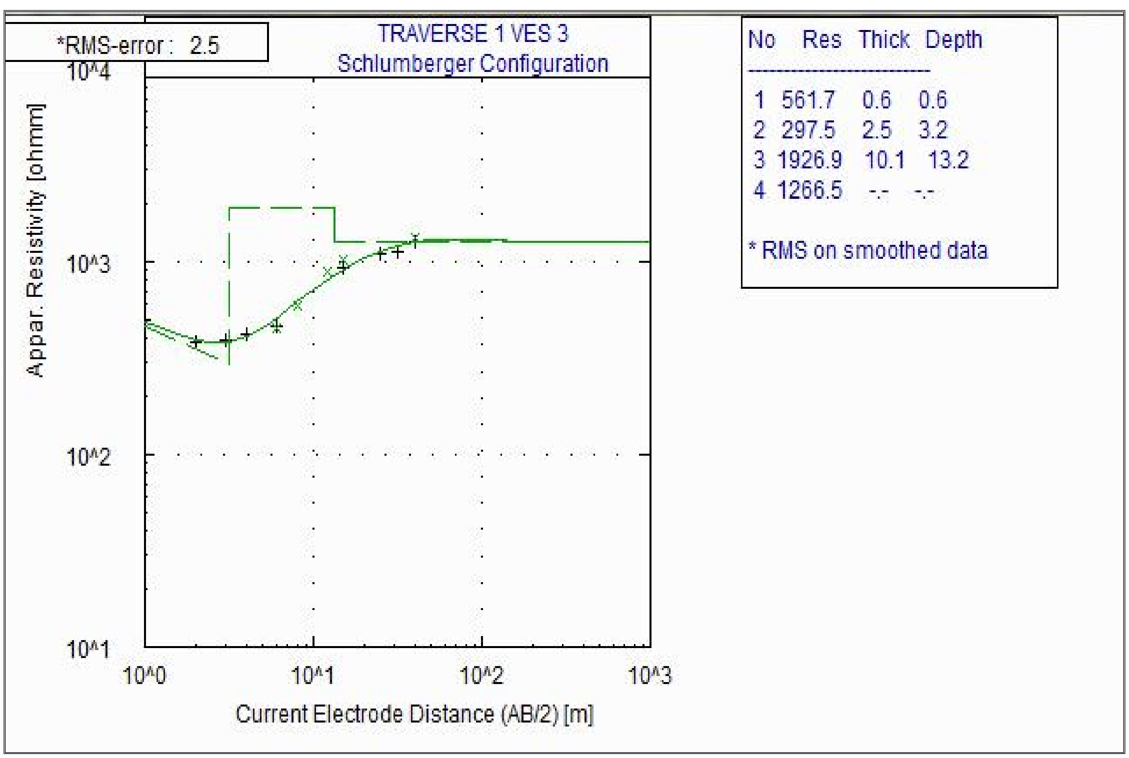

Fig. 6b. Typical 'HK' sounding curve

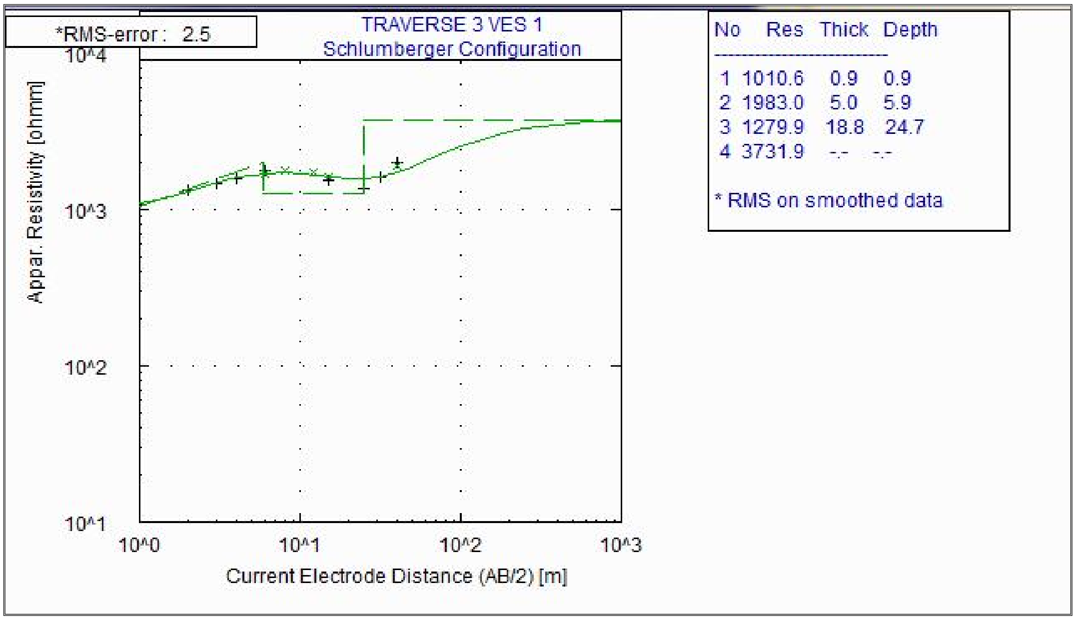

Fig. 6c. Typical 'KH' sounding curve

4.4 Dar Zarrouk Parameters

Result obtained from the VES interpretations were used to determine the second order parameters (Table 1). Second order parameters was involved in order to be able to have a better understanding of the dynamics of layers parameter in studies of this nature. The findings illustrates that the total longitudinal conductance (S) varies from 0.0011 –0.0147 Ω^{-1} in the area and qualitative use of these parameters is to demarcate changes in total thickness of low resistivity materials. The total transverse resistance (T) ranges from 104 to 24062 Ωm, which gives information both about the thickness and resistivity of the area. The product of the S and T was used to model subsurface integrity/competence. The result revealed that at each of the location, the lower layer is more competent than the overlying upper layers. Furthermore, the research also revealed that the soil integrity increased at a ratio of not less than 1:10 in term of soil competence with depth and increased, even in some instance at a ratio of not less than 1:30 as shown by the result contained in Table 1.

4.5 Integrity/Competence Model of the Study Area using the product of S and T

The integrity models were represented by the 2-D view of the second order parameters (total longitudinal conductance and total transverse resistance) derived from the inversion of the electrical resistivity sounding data. The integrity model along Traverse 1 to traverse 3 (Fig. 7a to 7c) attempted to correlate the subsurface integrity/competence across the study area. Three (3) to four (4) subsurface integrity models were identified within the investigated area and integrity/competence were summarized in Table 2. The very low integrity/competence values ranges from 0.36 to 1.0 m to a depth of 1.2 m, the low integrity/competence has a value of 2.56 m with depth of 2.2 m. the moderate integrity/competence values ranges from 6.25 to 16 m to a depth of 6.3 m while high/very high integrity/competence values ranges from 25 to 353.4 m. The values from very low to low integrity/competence are an indicative that this layer may not be of any major interest since it is expected to be excavated and more so that it is not competent enough. However, the foundation of part of the building/structures was located within the upper 1.5 m which was of very low to low integrity/competence.

4.6 Synthesis of Results with Subsurface Integrity Model

Fig. 8 displays the correlation of result obtained from the geophysical techniques. The Wenner profiling observed at a distance 28 to 42 m demonstrated low integrity/competence with apparent resistivity value ranging from 10 to 200

Ωm which coincides with the low resistivity zone observed on the dipole-dipole pseudo-section at a distance at a distance 25 to 33 m. This also agree with subsurface integrity model at the same distance which indicate very low/low integrity/competence that lead to crack on the building (Fig. 8a). Also the low resistivity zone (weak zone) 0bserved on the dipole-dipole pesudosection at distance between 10 to 25 m at depth of 0 to 25 m coincide with the very low subsurface integrity model on Fig. 8b. The Wenner profiling zone is generally weak with apparent resistivity varying from 180 to 300 Ωm at a distance of 38 to 60 m correlate with the low resistivity zone observed on the dipole-dipole pseudo-section at distance between 38 to 55 m and with the subsurface integrity model which indicate very low/low integrity/competence (Fig. 8c). Correlating the results with subsurface integrity model along traverses one and three highly show a very low/low integrity/competence with the foundation of the classroom designated on this layers. The information obtained from this attempt correlated effectively with the result obtained from the lateral resistivity profiling as well as the dipole – dipole techniques. The 2D imaging reveals that there is a weak zone that existed between 25 to 35 m. The information further revealed that it occurred from the near surface to depth of about 2 meters before the competent layer. A similar situation also occurred at about 55 m towards the end of the profile. However, the control traverse (TR2) gave useful information on the possibility of a major weak zone occurring between 15 to 35 m along the control profile which gradually thins out towards the end of the control traverse. It is suspected that the major weak zone that occurred at the control traverse (TR2) could have given rise to near surface water flow channel/seepage which could have affected profile 1 geodynamics in such a way as to create a weak zone to allows for underground near surface water flow channel/seepage, while considering the fact that Ekpoma sedimentary environment is noted to be prone to flood zone challenges occasioned by strong surface and near surface high current water flow. Hence, the problem may not be unconnected with near surface groundwater flow emanating from the weak zone region from the control traverse 2. In view of this situation, there is a need for proper and well planned drainage control and management in the study area. The research revealed that the problem of structural failures/crack noticed along the building walls and axis was not as a result of human problem alone, but mainly the existence of very low/low integrity/competence upper layers which contributed a great deal to the cracks observed on the classroom block. These results reveal that the Electrical resistivity techniques used for this study are complimentary.

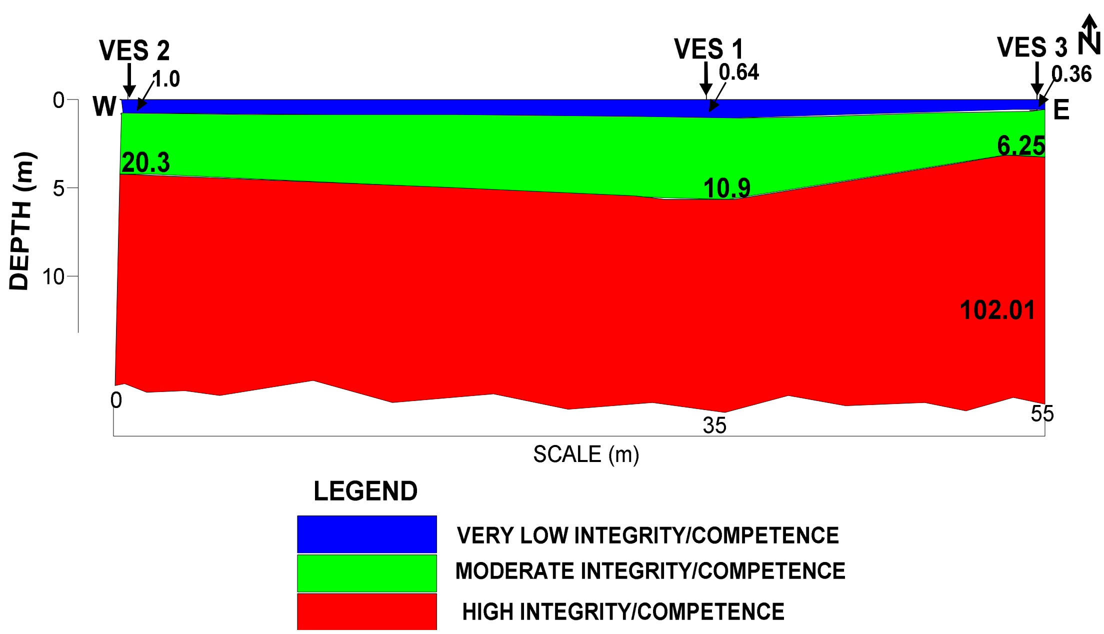

Fig. 7a. Subsurface integrity model of the study area along traverse one

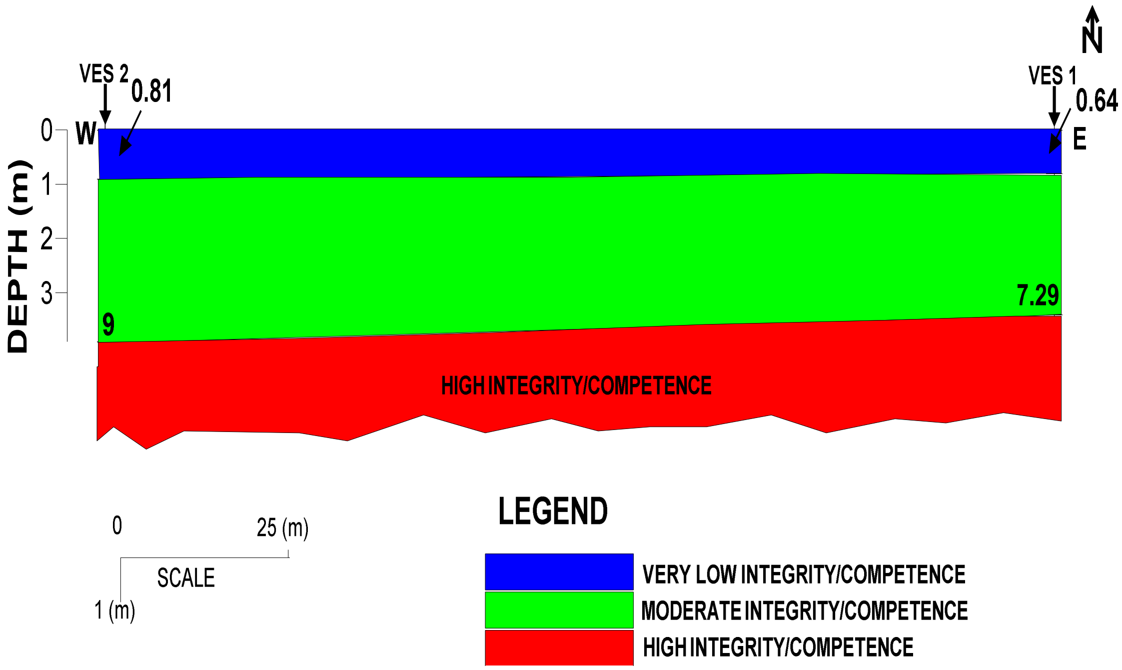

Fig. 7b. Subsurface integrity model of the study area along control traverse two

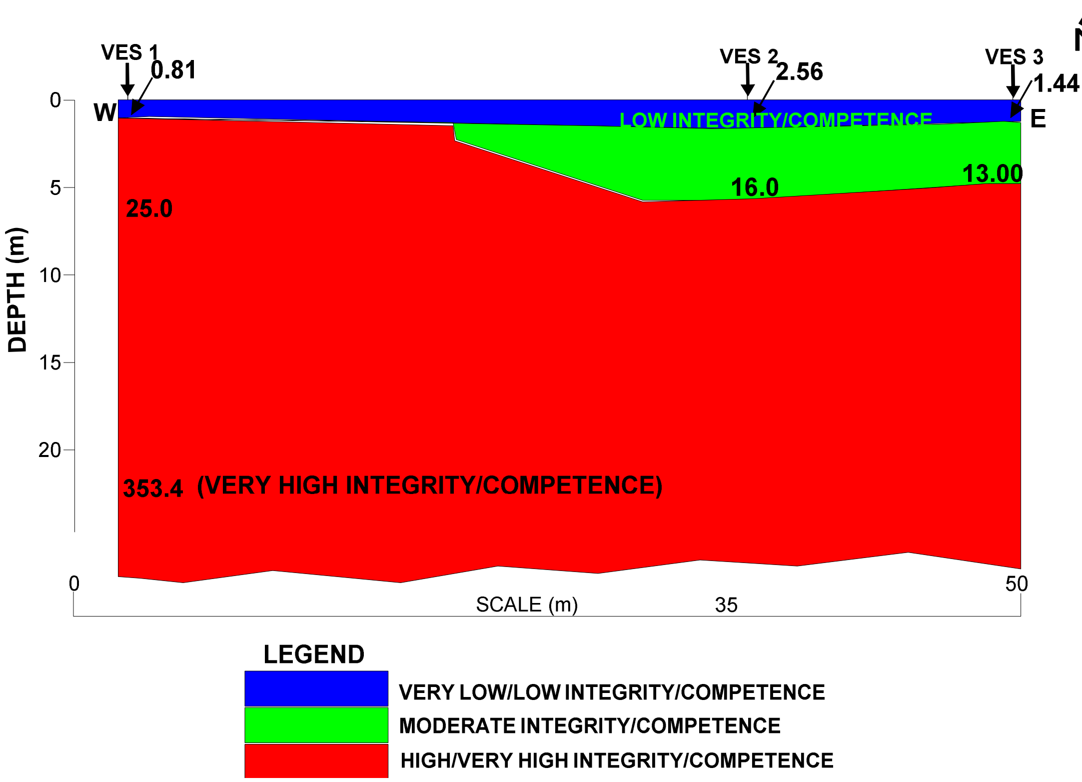

Fig. 7c. Subsurface integrity model of the study area along traverse three

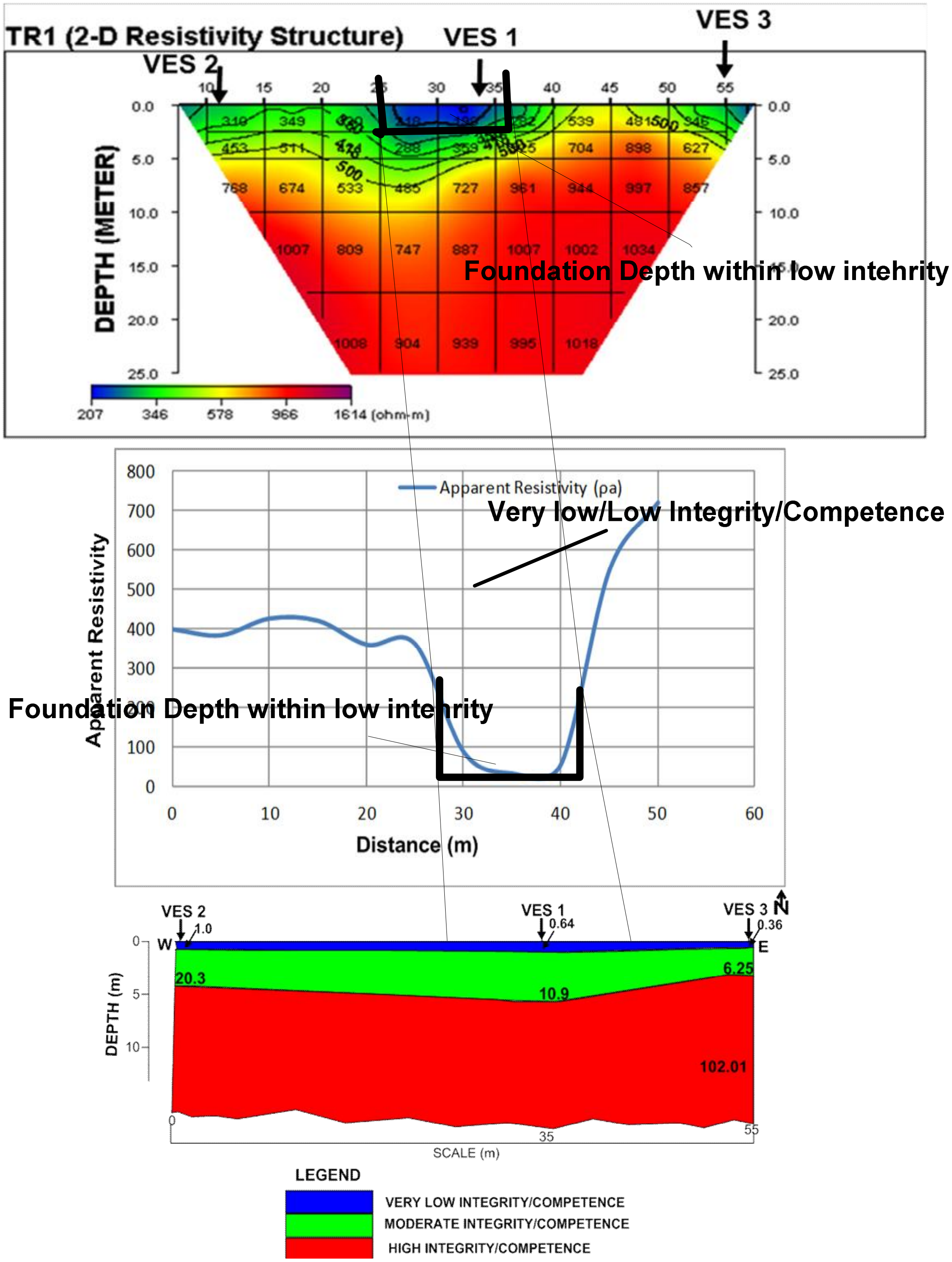

Fig. 8a. Correlation of Dipole-Dipole Pseudo-section, horizontal profiling with subsurface integrity model along traverse one

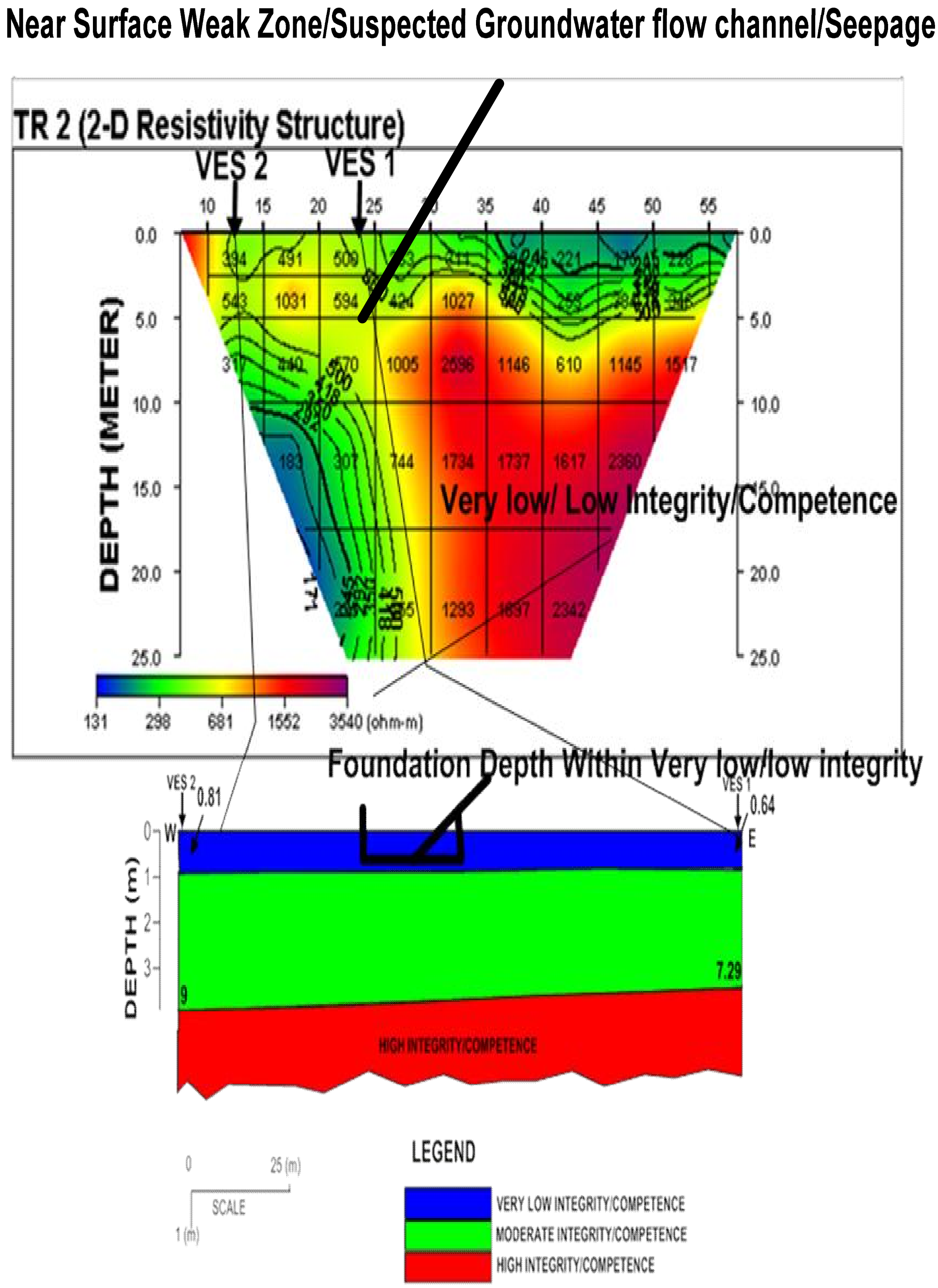

Fig. 8b. Correlation of Dipole-Dipole Pseudo-section with subsurface integrity model along control traverse two

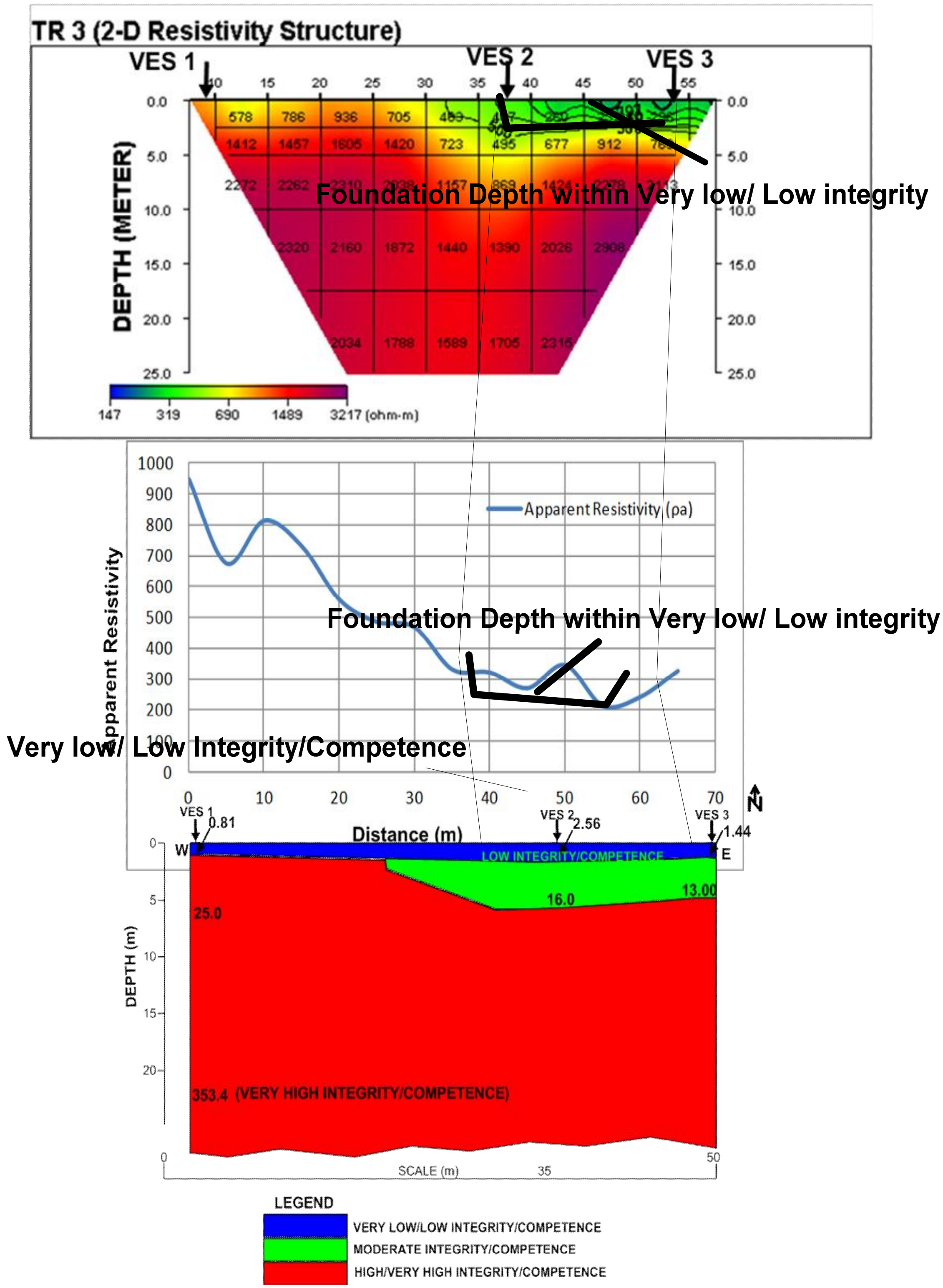

Fig. 8c. Correlation of Dipole-Dipole Pseudo-section, horizontal profiling with subsurface integrity model along traverse three

Table 1. Result showing Dar Zarrouk parameters

	Layers	Total longitudinal conductance (S) (Ω^{-1})	Total traverses resistance (T) (Ωm)	S * T (m)	Inter-layer integrity ratio (FL:SL:TL) (S*T)
TR 1 (VES 1)	First layer	0.0075	133.3	1.0	
	Second Layer	0.0118	1722.2	20.3	1:20
TR 1 (VES 2)	First layer	0.0062	104	0.64	
	Second layer	0.0113	965.6	10.9	1:17
TR1 (VES3)	First layer	0.0011	337.02	0.36	
	Second layer	0.0084	743.8	6.25	1:17
	Third layer	0.0052	19461.7	102.01	1:16
TR2 (VES1)	First layer	0.0040	202.9	0.81	
	Second layer	0.0108	830.1	9.0	1:11
TR2 (VES2)	First layer	0.0063	102.2	0.64	
	Second layer	0.0106	688.5	7.29	1:11
TR3 (VES1)	First layer	0.0009	909.5	0.81	
	Second layer	0.0025	9915	25	1:31
	Third layer	0.0147	24062.1	353.4	1:14
TR3 (VES2)	First layer	0.0070	364	2.56	
	Second layer	0.0105	1521.2	16	1:6
TR3 (VES3)	First layer	0.0052	274.68	1.44	
	Second layer	0.0115	1126.8	13.0	1:9

Note: FL = First Layer, SL = Second Layer, TL = Third Layer

Table 2. Subsurface integrity/competence classifications

Integrity/Competence values	Classifications
0.01 – 1.0	Very low
1.0 – 5.0	Low
5.0 – 20	Moderate
20 – 50	High
>50	Very high

5. CONCLUSION

The present study was carried out in order to be able to unravel the causes of major cracks along the side of a major class room block at Ikekogbe UBE Primary School, Ekpoma, Edo State, Nigeria in less than five (5) years after it was constructed. The investigation involved Electrical Resistivity method using three techniques; Vertical Electrical Sounding (VES), 2-D Electrical Resistivity Tomography (ERT) and Horizontal Profiling (HP) and three traverses were established along E-W directions The results from the VES interpretation was used to determined second order parameters such as the total transverse resistance (T) and the total longitudinal conductance (s). The second order parameters were used to generate subsurface integrity model which comprises of very low, low, moderate, high and very integrity/competence. Correlating the results with subsurface integrity model along traverses one and three, there was a high degree of correlation as this region coincides with the very low/low integrity/competence with the foundation of the classroom overlying this layers. This model can be applied in any part of the sedimentary environment. The research displays that this problem was an avoidable problem if the building engineers and the contractors should have availed themselves of services of geophysicist who would have advised on the way to go about the construction. Furthermore, it is recommended that thick drainage be constructed as a remedy along the flow direction of the erosion part.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bawallah M. Post foundation studies of collapsed building project using geophysical and geological approach. Unplished M.Tech Thesis, Department of Applied Geophysics, Federal University of Technology Akure; 2006.

2. Adelusi A, Akinlalu AA, Nwachukwu AI. Integrated geophysical investigation for post construction studies of buildings around School of Science area, Federal University of Technology Akure, Southwestern, Nigeria. Int. J. of Physical Sciences. 2013;8(15):657-669.
3. Akintorinwa OJ, Adeusi FA. Integration of geophysical and geotechnical investigations for a proposed lecture room complex at the Federal University of Technology, Akure, SW, Nigeria. Journal of Applied Sciences. 2009;2(3):241–254.
4. Ako BD, Olorunfemi MO. Geoelectric survey for groundwater in the newer basalts of Vom, Plateau State. Journal of Mining and Geology. 1989;25(1-2):247-250.
5. Ozegin KO, Bawallah MA, Ilugbo SO, Olaogun SO, Oyedele AA, Iluore K. Susceptibilty test for road construction: A case study of Shake Road, Irrua, Edo State, Global Journal of Science Frontier Research: H Environment & Earth Science. 2019;19(1):45–53.
6. Ilugbo SO, Adebo AB, Ajayi OA, Adewumi OO, Edunjobi H O. Geophysical and geotechnical studies of a proposed structure at Akure, Southwestern Nigeria. Journal of Engineering Research and Reports. 2018a;2(2):1-12.
7. Ilugbo SO, Adebiyi AD, Olaogun SO, Egunjobi T. Application of electrical resistivity method in site characterization along Ado – Afao Road, Southwestern Nigeria. Journal of Engineering Research and Reports. 2018b;1(4):1-16.
8. Kogbe CA. Geology of Niger Elizabelt publishing company Lagos – Nigeria; 1978.
9. Okeke OC, Onyekuru SO, Uduehi G, Israel HO. Geology and hydrogeology of Northern Ishan district, Edo State, Southwestern Nigeria. 2011;1(1):1-11.
10. Oyedele KF, Oladele S, Adedoyin O. Application of geophysical and geotechnical methods to site characterization for construction purposes at Ikoyi, Lagos, Nigeria. J. Earth Sci. Geotech. Eng. 2011;1(1):87-100.
11. Aigbedion I. Geophysical investigation of road failures using electromagnetic profile, along Uhiele Uwenlegbe road, Ekopma, Edo State, Nigeria Middle East Journal of Scientific Research. 2007;2(3):1-4.
12. Dippro for Windows Dippro TM Version 4.0 Processing and Interpretation software for Dipole Dipole electrical resistivity data. KIGAM, Daejon, South Korea; 2000.
13. Vander Velpen BPA. WinRESIST Version 1.0 Resistivity Depth Sounding Interpretation Software. M.Sc. Research Project, ITC, Delf Netherland; 2004.
14. Salufu SO, Ujuanbi O. The geology and structural geology of Ekpoma and Irrua: Implication for the hydrology and hydrogeologic setting of the areas. Nigerian Annals of Natural Sciences. 2015;15(1):131–138.

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