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Geophysical Investigation of Road Pavement Instability: A Case Study of Moshood Abiola Polytechnic (Mapoly) – Onikolobo Road, South Western Nigeria

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ABSTRACT
Road pavement instability has become a common occurrence especially after construction in Nigeria. This study was carried out to investigate the causes of road pavement failure on the lithology of the subsurface within the area by delineating the resistivity and thickness of subsurface layers. Four vertical electrical sounding (VES) each were carried out at four different locations of the road comprising stable and failed portions. The configurations employed in the field are Schlumberger and Wenner array. Data obtained were interpreted using a manual partial curve matching methods and a fast computer iteration technique to generate geo-electric layer of various resistivity and thicknesses. Four types of sounding curve were obtained, they include QH, K, A and HA types. The geoelectric layers generally identified are the topsoil, weathered layer, partly weathered/fractured basement and fresh bedrock. The failed and stable portions of the road are underlain by topsoil consisting of low resistive and expansive clayey soil. The stability of the stable portions of the road can be attributed to their regular maintenance and good drainage channels.

I. INTRODUCTIION

Road pavement failure in Nigeria has become a common occurrence especially after construction. Road pavement which is described as a structural materials seated upon subsoil layers (Woods and Adeox, 2002), is supposed to be a continuous stretch of asphalt laid for a smooth ride or drive, but discontinuity in the road network resulting in cracks, potholes, bulges and depressions gives rise to road failure (Mesida, 1981; Aigbedion, 2007). Poor drainage network, poor construction materials, bad design, usage factor are some of the factors considered as responsible for these failures. Geological factors are rarely considered as precipitators of road failure even though the highway pavement is seated on geological earth materials (Momohet et al., 2008). This is due to non-appreciation of the fact that proper design of highway requires adequate knowledge of subsurface conditions beneath the highway route. The non-recognition of this fact has led to loss of integrity of many highway routes and other engineering structures across the country (Oladapo, 1998;Olorunfemi et al. 2000). The rate of failure of the highway has been of major concern to the governments and all stake-holders because this has led to loss of lives, properties and undermine economic and social development of the country. Other previous studies have shown that the reliability of the road pavement can be damaged by the existence of geological features and/or engineering characteristics of the underlying geologic/geoelectric sequences (Adeleye, 2005; Ajayi, 1987;More, 1952; Telford et al., 1990). It is hence vital for engineers to carry out pre-design investigations of engineering sites

The interplay of rock formation in the subsurface and the characteristic properties of the mineral aggregates that form the rock mass of the underground determine a lot of the behaviour of the ground in term of homogeneity, stability, structure, texture, groundwater potential amongst others.

Resistivity measurements are associated with varying depths depending on the separation of the current and potential electrodes in the survey, and can be interpreted in terms of a lithologic and or geo-hydrologic model of the subsurface (Lowrie, 1997). Measurement of resistivity (inverse of conductivity) is, in general, a measure of water saturation and conductivity of pore space. Whereas the presence of water will reduce resistivity, the presence of air in voids will increase subsurface resistivity (Ogungbe, 2010). The reason for the wide use of electrical method is due to the fact that it is inexpensive, fast and it is a non-invasive technique that yields useful information about subsurface conditions.

A lot of reasons have been suggested for the incessant failure of roads in Nigeria: such as presence of expansive clays such as montmorillonite, chlorite, halloysiteetc (Mesida, 1986 and 1987), heterogeneity of the subgrade materials (Adeleye, 2005 and Mesida, 1987), presence of undetected linear features, such as joints, fractures and rock boundaries (Momoh et al., 2008), poor construction practice, poor soil grading and the use of substandard materials for road construction, among others. In addition to the aforementioned factors, bedrock relief (or depression) can also precipitate instability in road pavements.

The objective of this study is to investigate the major causes of road instability along Moshood Abiola Polytechnic (MAPOLY) – Onikolobo road using electrical resistivity method.

II. MATERIALS AND METHOD

Electrical sounding using Schlumberger and Wenner array were employed. Four different locations, Tiper garage (having four VES, TP1, TP2, TP3 and TP4) Ojere (with four VES OJ1, OJ2, OJ3 and OJ4) Gate (having four VES GT1,GT2, GT3 and GT4) and Bank (with four VES, BK1, BK2, BK3, BK4) separated at interval of between 300 m and 500 m were considered along the stretch of the road. Vertical electrical resistivity data obtained using Abem Wadi resisitivity meter along these traverses of the road were inverted using IPI2WIN to obtain the pseudosection along the traverses. Geoelectric section of the traverse and a geoelectric contouring of the area were then generated using Surfer 13.

III. RESULTS AND DISCUSSION

The processed electrical resistivity data are presented as sounding curve (Fig 1 to 8 which are for some of the VES) and geoelectric section (Fig. 9 to 12)

Table 1 gives the summary of the interpretation of VES sounding curves obtained from the study area. Four types of sounding curve have been obtained, they include QH, K, A and HA types. In all the number of layers delineated ranges from 3 to 4.

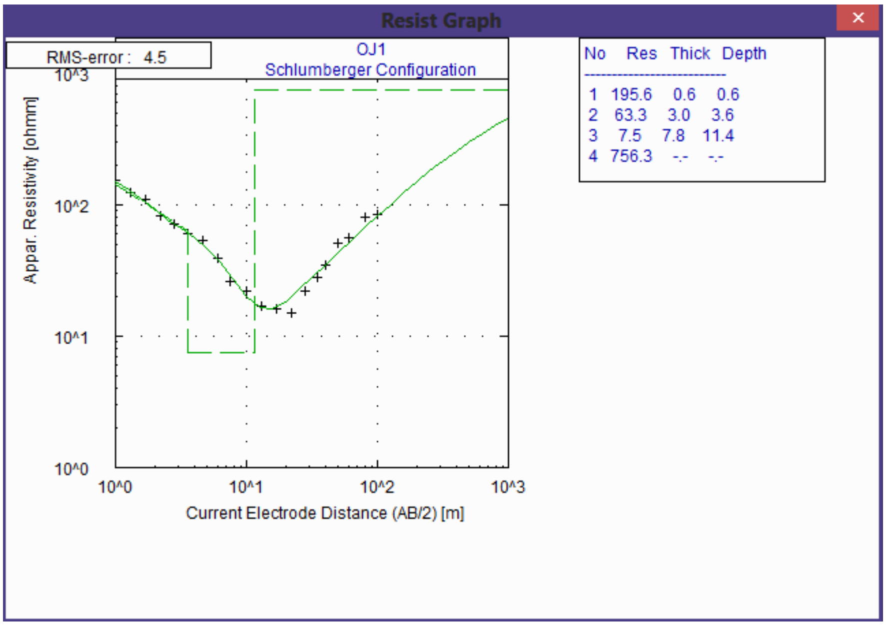

Fig.1: Sounding curve obtained from VES1 (OJ1) along Ojere part of the road

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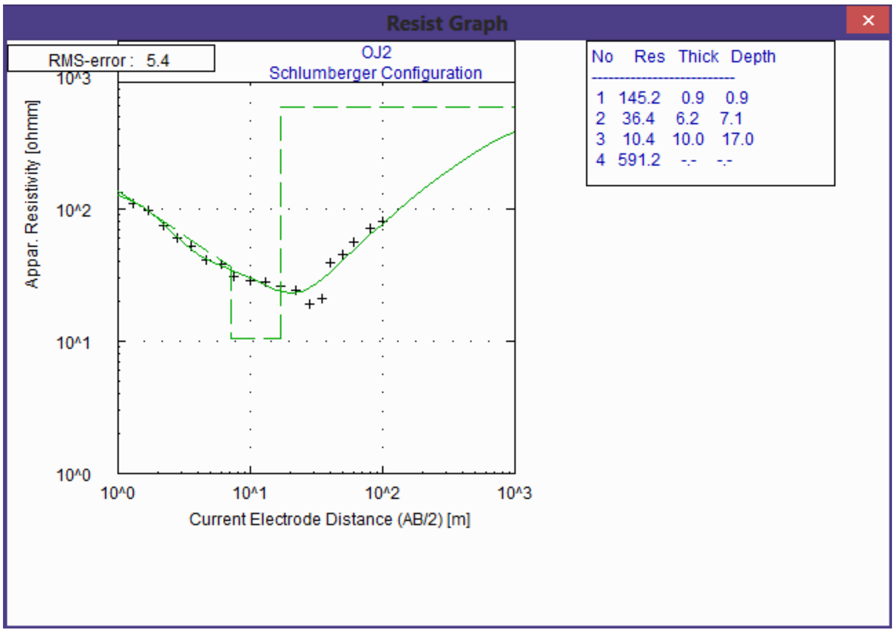

Fig.2: Sounding curve obtained from VES2 (OJ2) along Ojere part of the road

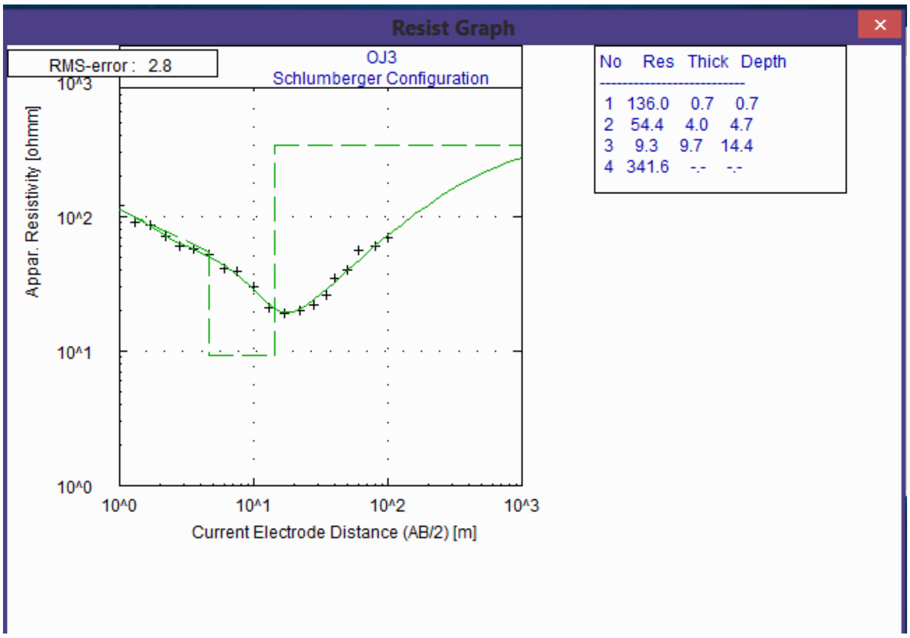

Fig.3: Sounding curve obtained from VES3 (OJ3) along Ojere part of the road

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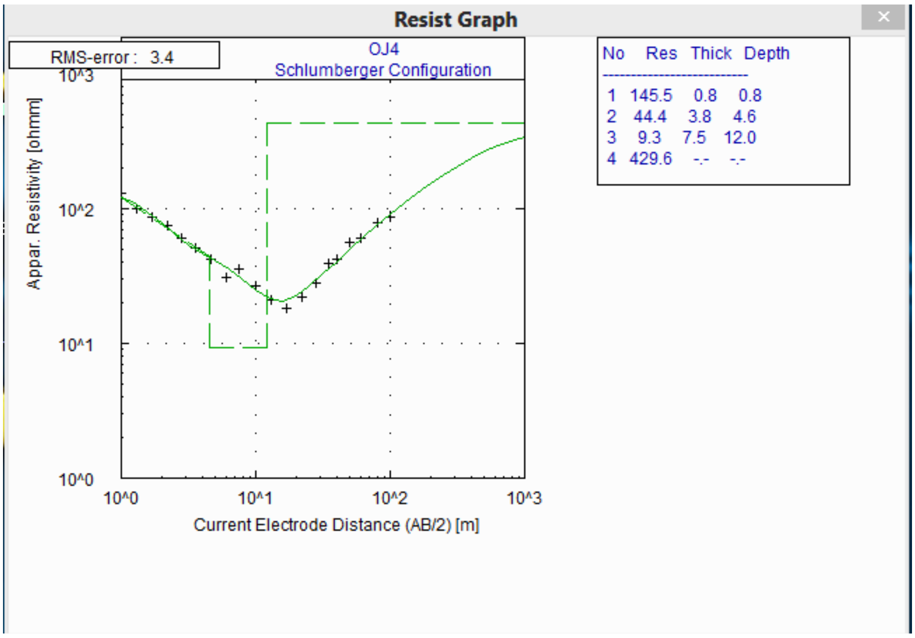

Fig.4: Sounding curve obtained from VES4 (OJ4) along Ojere part of the road

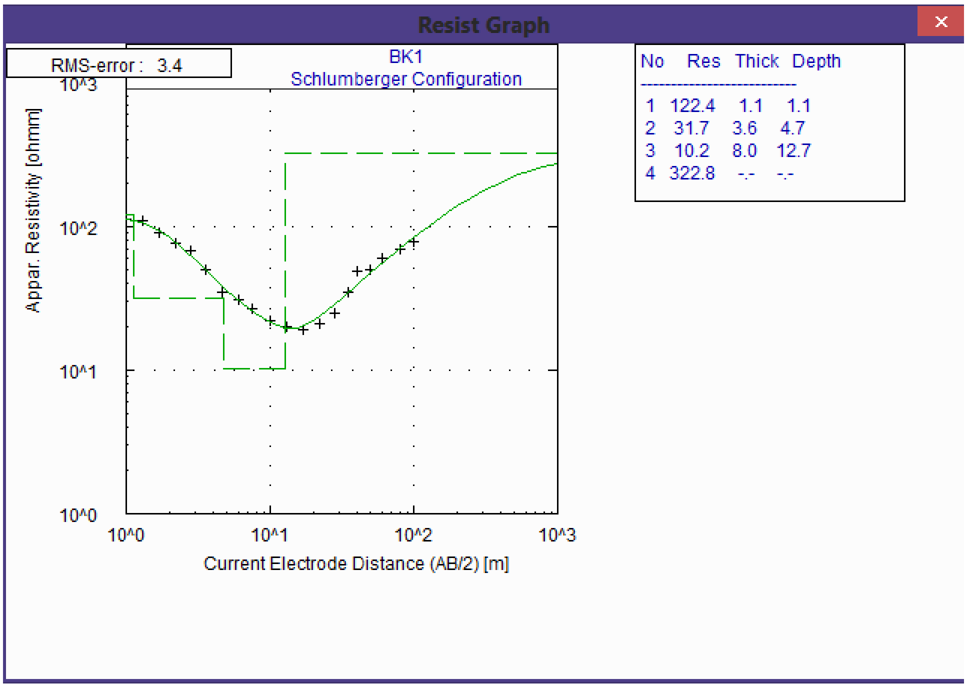

Fig.5: Sounding curve obtained from VES1 (BK1) along Bank area of the road

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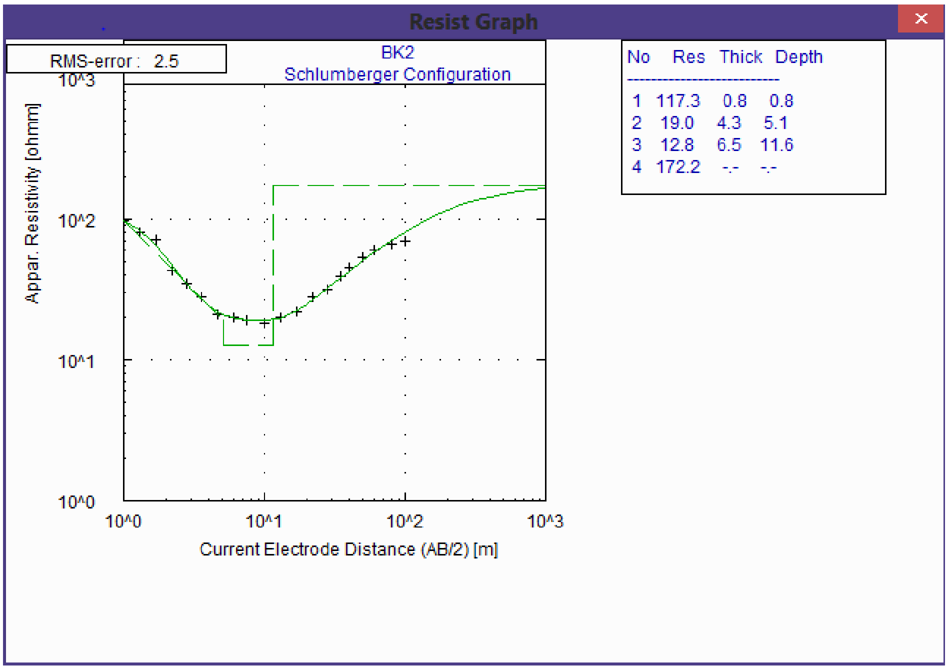

Fig.6: Sounding curve obtained from VES2 (BK2) along Bank area of the road

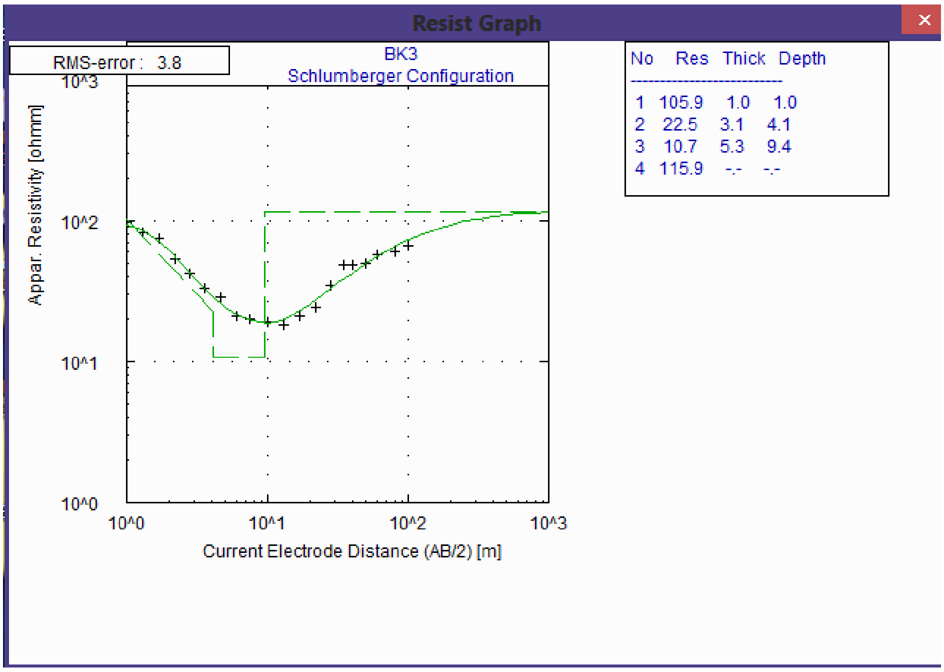

Fig.7: Sounding curve obtained from VES3 (BK3) along Bank area of the road

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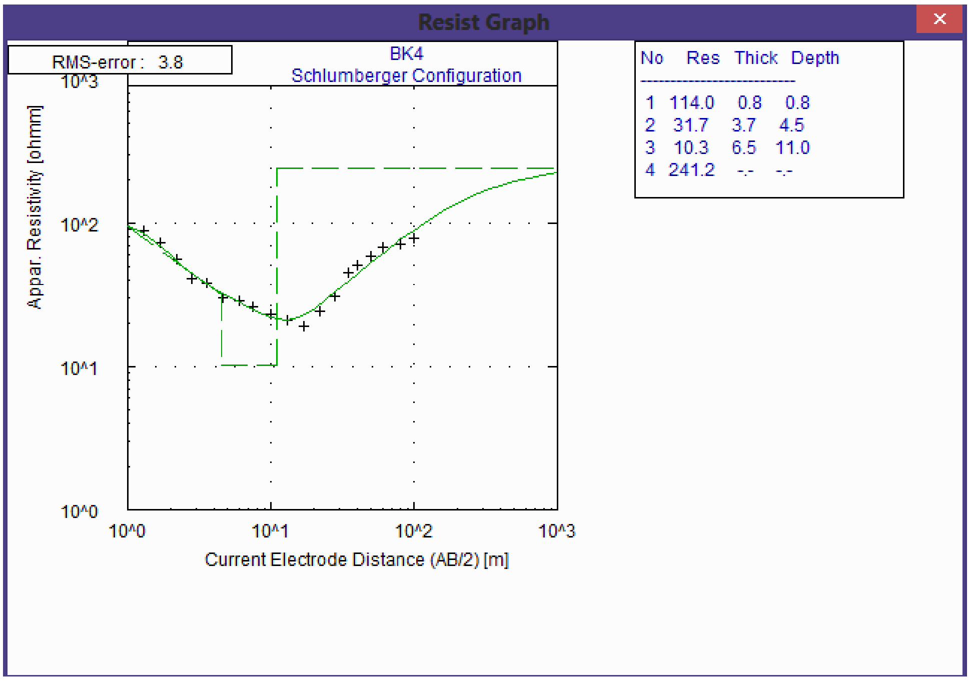
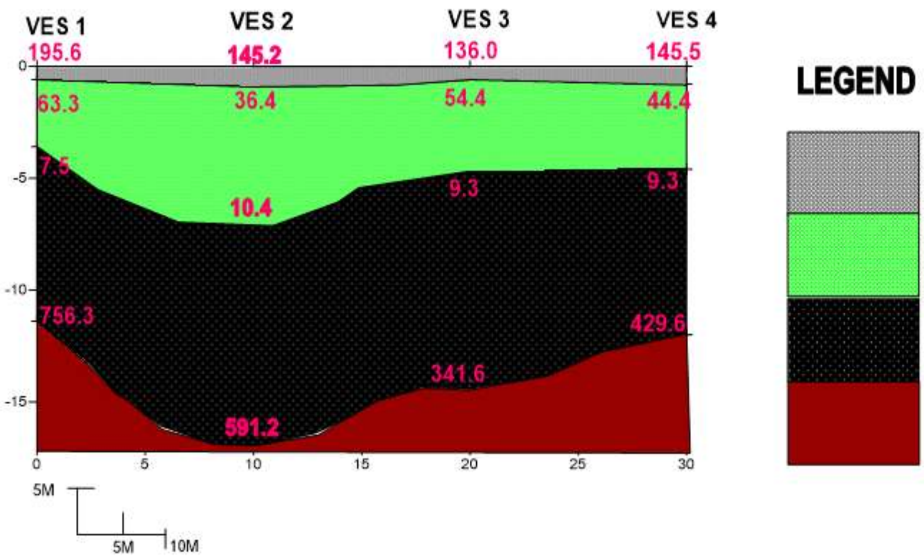
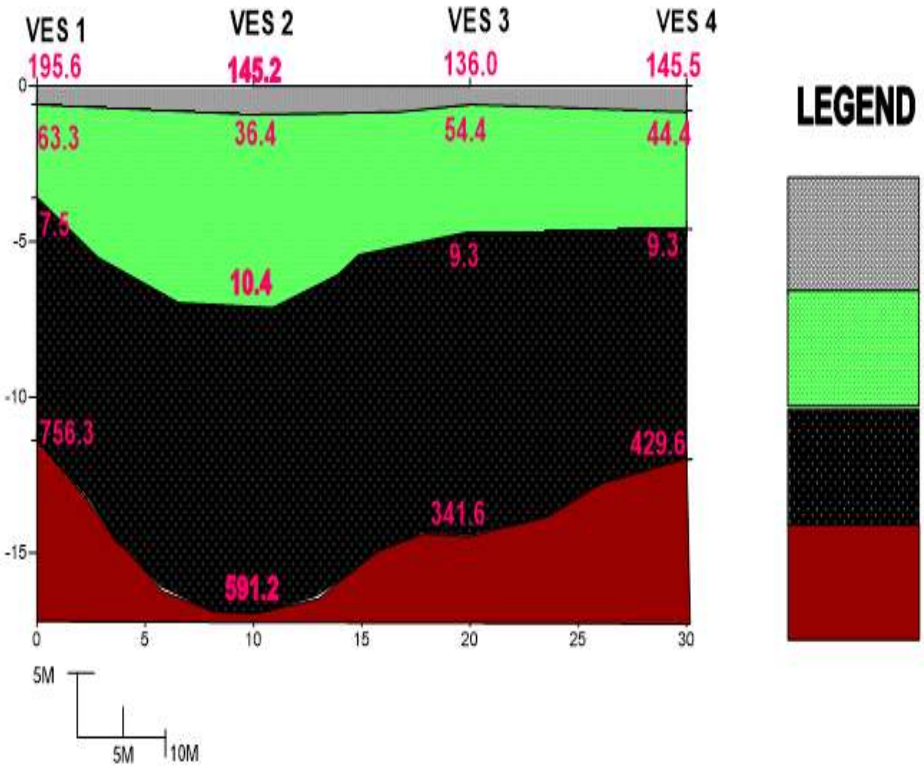


Fig.8: Sounding curve obtained from VES4 (BK4) along Bank area of the road

Table 1: Summary of sounding curve obtained from the study area

VES	RESISTIVITY ρ (Ω m)				THICKNESS (m)				CURVE TYPE
	ρ_1	ρ_2	ρ_3	ρ_4	h_1	h_2	h_3	h_4	
OJ1	195.6	63.3	7.5	756.3	0.6	3.0	7.8	-	QH
OJ2	145.2	36.4	10.4	591.2	0.9	6.2	10.0	-	QH
OJ3	136.0	54.4	9.3	341.6	0.7	4.0	9.7	-	QH
OJ4	145.5	44.4	9.3	429.6	0.8	3.8	7.5	-	QH
BK1	122.4	31.7	10.2	322.8	1.1	3.6	8.0	-	QH
BK2	117.3	19.0	12.8	172.2	0.3	4.3	5.5	-	QH
BK3	105.9	22.5	10.7	115.9	1.0	3.1	5.3	-	QH
BK4	114.0	31.7	10.3	241.2	0.8	3.7	6.5	-	QH
GT1	43.8	24.4	150.7	-	2.5	12.6	-	-	K
GT2	62.6	27.2	125.9	-	1.4	8.7	-	-	K
GT3	64.1	27.6	122.2	-	0.8	12.7	-	-	K
GT4	56.5	23.4	135.8	-	0.8	9.3	-	-	K
TP1	49.2	309.5	7.6	214.7	0.4	1.0	6.3	-	A
TP2	93.6	171.1	11.1	183.7	0.7	0.7	6.2	-	A
TP3	105.6	13.7	19.3	272.4	1.7	4.3	4.8	-	HA
TP4	100.9	11.9	25.1	120.8	1.1	2.1	1.8	-	HA


VES 1
VES 2
VES 3
VES 4
195.6
145.2
136.0
145.5
63.3
36.4
54.4
44.4
7.5
10.4
9.3
9.3
756.3
591.2
341.6
429.6
0
-5
-10
-15
0
5
10
15
20
25
30
5M
5M
10M
LEGEND


VES 1
VES 2
VES 3
VES 4
195.6
145.2
136.0
145.5
63.3
36.4
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7.5
10.4
9.3
9.3
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591.2
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-5
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20
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30
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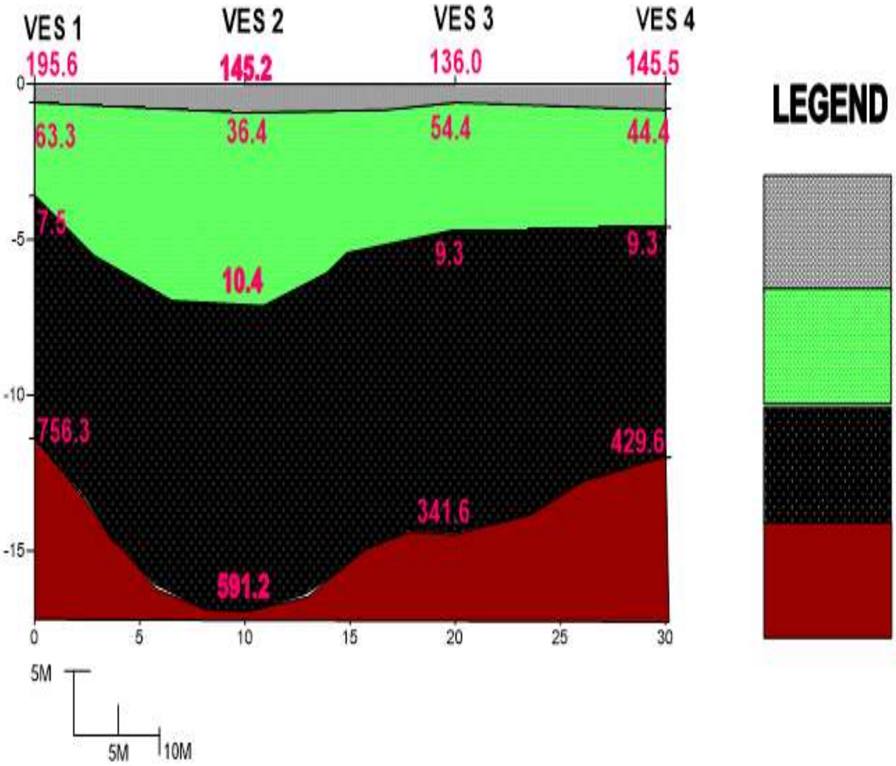

Fig 9: Geo-electric section showing resistivity values of VES1 TO VES4 traverse along Ojere village area

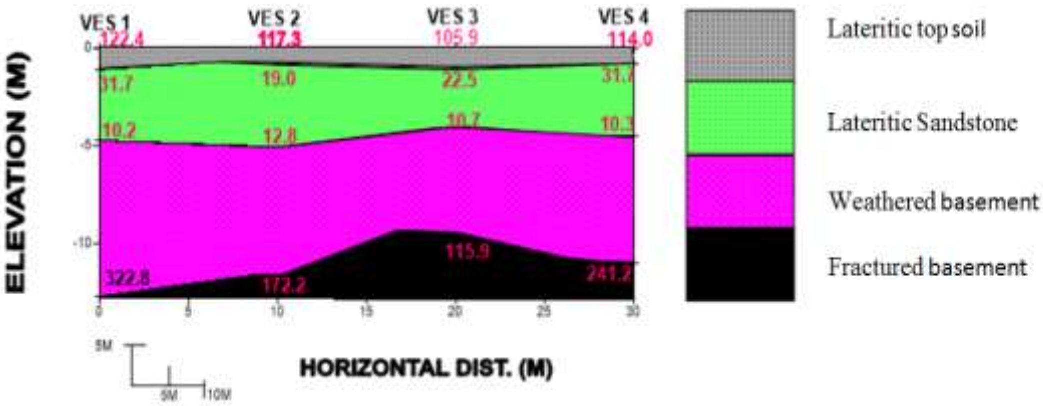

Fig 10: Geo-electric section showing resistivity values of VES1 TO VES4 traverse along Bank area

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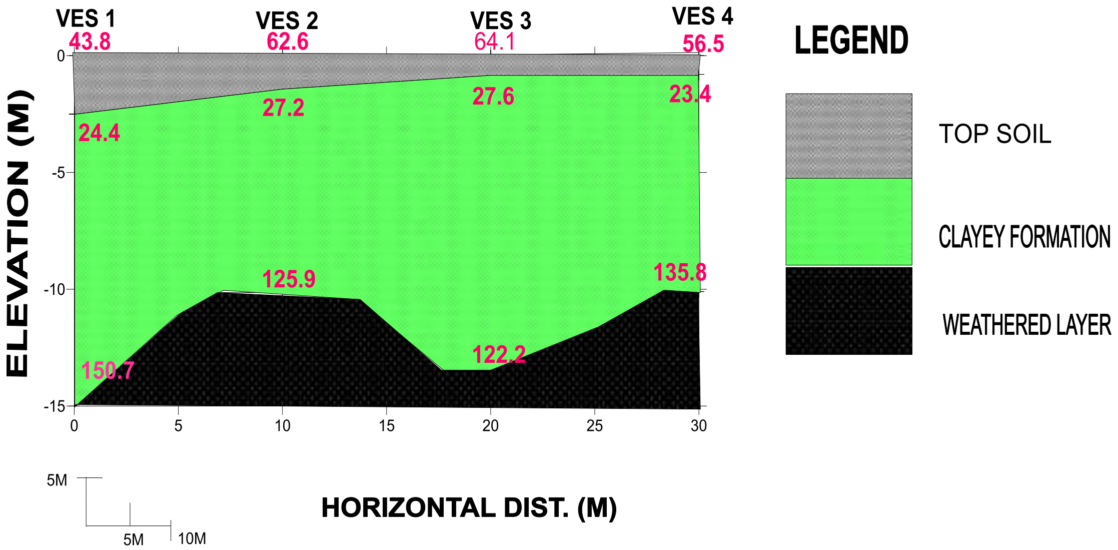

Fig 11: Geo-electric section showing resistivity values of VES1 TO VES4 traverse along Gate area

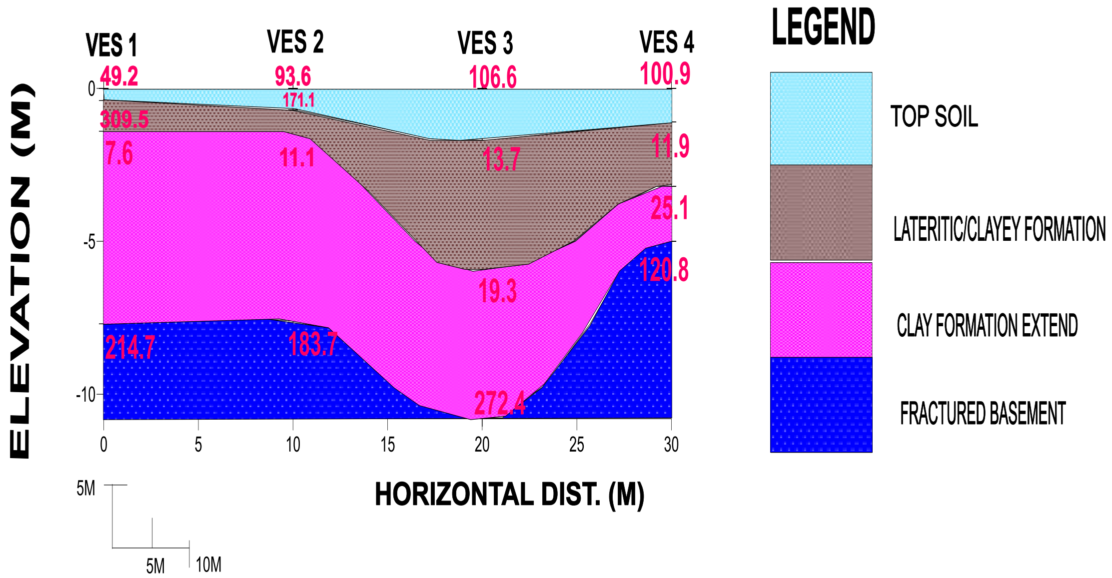

Fig 12: Geo-electric section showing resistivity values of VES1 TO VES4 traverse along Tipper Garage area

VERTICAL ELECTRICAL SOUNDING

From the vertical electrical sounding (Fig 1 to 8), four types of sounding curve have been obtained, they include QH, K, A and HA types. In all, the number of layers delineated ranges from 3 to 4. For QH curve, $\rho1 > \rho2 > \rho3 < \rho4$, for K curve, $\rho1 < \rho2 > \rho3$, for A curve, $\rho1 < \rho2 < \rho3$ and for HA curve, $\rho1 > \rho2 < \rho3 < \rho4$. The Geo – electric sections were then produced from this series of results of vertical electrical sounding.

GEOELECTRIC SECTION

Fig. 9 represents the geoelectric section obtained from the VES along Ojere village area of the road. This geo-electric section shows the spatial distribution of each layer of the subsurface.. The section shows four distinct layers which include the top soil, the lateritic soil, the weathered basement and the fracture basement respectively from top to bottom. The topsoil comprises sand/lateritic sand whose resistivity ranges from 136.0 Ωm to 196.6 Ωm, the thickness of this layer varies along the traverse and less than 1 m, it is thickest at VES 2, about 0.9 m. the average thickness along this layer is 0.75 m. The second layer is the lateritic medium to silty grained sandstone having a resistivity range of 36.4 to 63.3 Ωm with an average thickness of 4.25 m, it is thickest at VES 2 with a thickness of 6.2 m. Weathered basement is the third layer with resistivity range of 7.5 to 16.4 Ωm. The third layer, the vweathered basement has a resistivity range of 7.5 to 10.4 Ωm. This low value of resistivity as a result of highly weathered disaggregated minerals which are essentially clay. The fourth layer being the fresh fractured basement has a resistivity range of 341.6 to 756.3 Ωm. The overburden is thickest at VES 2 and a gentle depression is noticed at VES 2. The portion of the road, Ojere village, area where these VES 1 to VES 4 lies is in a serious failed state and this is due to clay composition of the underlying layers of low resistivity values which is characteristics of clay minerals. The basement depression under VES 2 might also havre contributed to the failed state of this portion of the road.

Fig. 10 represents the geo-electric section of the stretch of the road beside the microfinance bank within the study area. There are four layers within the subsurface in this area. The first layer with resistivity range of 104.0 - 122.4 Ωm (average value of 114.9 Ωm) is the lateritic topsoil with an average thickness of 0.93 m. The second layer, the lateritic sandstone has a resistivity range of 10.0 - 22.5 Ωm Occupying the third layer is the weathered basement with a much lower average resistivity value of 11.0 Ωm, this low resistivity value may be accounted for by the presence of clay mineral which are the end product of weathering of migmatite and gneiss. The fourth layer is the fractured basement with a resistivity range of 115.9 – 241.2 Ωm (an average value of 213 Ωm). the low resistivity values of these layers within the subsurface of this traverse is an indication of clay composition which is capable of causing road instability. The relative stability of this stretch of the road may not be unconnected with the lateritic topsoil with relatively higher resistivity, regular maintenance and good drainage.

Fig. 11 is the geo-electric section of the stretch of the road close to the school gate. Three layers have been delineated in this area. They are the topsoil, clayey formation and weathered layer. The topsoil has its resistivity varying from 43.8 – 62.6 Ωm with thick overburden that is thickest at VES1. This topsoil is composed of clayey sand, sand and lateritic sand owing to its resistivity value. The second layer is clayey formation with characteristic resistivity range of 23.4 – 27.6 Ωm. The third layer is weathered basement with resistivity range of 122.2 – 150.7 Ωm and having basement depression at VES 3. Obviously al the layers within the subsurface of this section of the road are characterized with large clay content owing to their low resistivity values. The section of the road which falls in this area is stable despite this indication of clay content and basement depression within its subsurface layer. This stability, also, may be as a result of regular maintenance carried out on it and presence of good drainage on its sides.

Geo-electic section of VES 1 to VES 4 along the tipper garage of stretch of the road is shown in fig. 12. Four geo-electric layers which are topsoil, lateritic clayey formation and fractured basement were delineated. The topsoil comprises clay with resistivity ranging from 49.2 to 100.9 Ωm, on this layer the overburden is thick and thickest at VES 3, the thickness ranges from 0.6 to.25 m. The second layer is lateritic clay formation having resistivity range of 13.7 – 300.5 Ωm, this layer is made up of clay and lateritic sand with the thickness varying from 1.3 to 6.0 m. The third geo-electric layer comprising of clay has resistivity range of 19.3 – 29.1 Ωm. The fourth layer is the fractured basement; its resistivity varies from 120.8 – 214.7 Ωm with basement depression at VES 3. Underlain by the road pavement along this stretch of the road, though not with good drainage, is the topsoil of low resistivity and this is in addition with the lack of good drainage channel may be responsible its failed state. Even with construction of good drainage channel the road may still record failure without regular maintenance.

IV. CONCLUSION

Causes of road failure along Moshood Abiola Polytechnic (MAPOLY) – Onikolobo road have been investigated using geophysical methods. The subsurface of the failed segments of the road investigated have been found to comprise topsoil comprising clayey sand, sand and lateritic sand with resistivity ranging from 49.2 – 195.6 Ωm. Presence of fragment of road pavement material deposited over time may be responsible for the relatively higher resistivity values recorded. The relatively stable potions of the road are underlain by topsoil layer having slightly lower resistivity range of 43. 8 – 122. 4 Ωm which is characteristic of clayey sand and sand. This stability is attributed to regular maintenance and good drainage the stable portions enjoy,

Going by the results of this study, it can be said that likely causes of road failure in the study area are:

i. Presence of clayey sand in the topsoil. This takes in large amount of water, swells up and crumbles as a result of pressure and stress from traffic load plying it.
ii. Presence of basement depressions suspected to be linear features (faults) .
ii. Lack of good drainage channels in some portions of the road.

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