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Assessment of Highway Pavement Failure in Sedimentary Terrain Using Two-Dimensional Electrical Resistivity Tomography along Benin-Akure Expressway, Edo State, Nigeria

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Abstract

Two-dimensional Electrical Resistivity Tomography was done on failed portions of South-south Benin – Akure Expressway, in Ovia Northeast LGA, to establish the subsurface geological formations responsible for the pavement failure and provide geotechnical support for its maintenance. The survey was done on five worrisome portions of the highway, namely; Igbekhwoe, Odighi, Odiguetue, Omigie and Ugboke communities respectively, using Wenner array electrode configuration to obtain one profiles of 100 m length on both sides of the road at each location. The instrument used was ABEM Terrameter SAS 1000. The apparent resistivity data were acquired, processed and inverted using RES2DINV software producing 2D models of the subsurface of survey locations. These models revealed the resistivity variations ranging from (30.1-7089) Ωm with total depth of 19.8 m. The investigation revealed that the reasons for the pavement failure on the highway studied were the presence of near surface clay soil, sandy clay soil/ clayey sand and shale formation, having resistivity varying from (30.1- 100) Ωm. It was recommended that regular monitoring and maintenance of this road by relevant agencies by excavating these subgrade soil and replacing it with well compacted lateritic soil, and gravel will reduce the effect of regular collapse these spots on this highway.

Keywords: *Geophysical, subsurface, Wenner configuration, apparent resistivity, clay*

1. INTRODUCTION

Road failure is the inability of a road to provide a smooth running surface for vehicle movement or the inability of the road to provide its usable services

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(Akintorinwa et al., 2010). This takes place when the original shape of an asphalted road no longer run smoothly and having material stresses. A failed road will show; raveling, depressions, potholes, upheavals, cracking, shoving and rutting. A good road allow seamless and fast movement of vehicles (Ogungbe Abiola et al., 2021). In developing country like Nigeria, it is very useful for moving people, products and services from one location to another, especially where other types of transportation like air, rail and water systems are not well developed.

Benin – Akure road is a very busy road with high volume of traffic leading from Benin in the South-South to Akure in the South- West of Ondo State and other parts of the northern states through Owan. The surveyed environ lies within the Niger Delta sedimentary basin which is underlain by the Benin formation. Portions of the road are typically in a bad state because of its failed pavement, causing vehicle damage, accidents, very bad traffic conditions, travel time lose and even kidnaping by hoodlums. It is a nightmare to frequent users of this road. No previous study on road pavement failure exist on this environment and this had motivated this study.

The specific objectives of this study are to characterize subsurface lithology of the failed pavement, identify geological factors responsible for the failure and provide geotechnical recommendations to prevent future occurrence. Improper planning of a constructed road is the major reason of road failure and damage. Road built on sub-base and sub-grade materials cannot stand the test of time on a highway with heavy duty vehicles (Osinowo et al., 2011). The geological factors that causes road collapse include the condition of the soil, the subsurface geological formation, the existence of formations like faults and fractures, cavities, shear zones and the presence of old stream channels (Momoh et al., 2008), (Adiat et al., 2009), (Adenika et al., 2018).

The geotechnical knowhow required for this infrastructure design to make sure constructed roads are sustainable is got from the knowledge of geophysical and geotechnical studies. It can be used to establish the depth of subsurface rock, structural formation survey and mapping the ability of such surface to withstand pressure without failing (Burland, 1981). Electrical Resistivity Tomograghy (imaging) have become wildly used to solve different geological problems like environmental, geotechnical and hydrological issues. Two dimensional (2D) Electrical Resistivity Tomography (ERT) or imaging have become very successful for detecting irregularities and subsurface complex nature in evaluating cavities, testing on bridges, buildings, highways, underwater crack, building of dams and for agricultural purposes (Griffiths and Barker, 1993), (Andrews et al., 2013), (Enoma et al., 2023). The adoption of 2D electrical resistivity have been properly used to survey locations of complex geologies of failed road. For instance, (Ademila, 2022) used it and linked road failure to deep weathering bedrock of low resistivity (<100Ωm) water saturated clayey subgrade. (Enoma and Edo, 2024) observed that resistivity of top layer <100Ωm is a sign of abundance of clay/shale substances which might be an incompetent soils for road construction. (Adenika et al., 2018) connected failure of roads to clay under the toll road pavement and geologic elements. (Okpoli and Bamidele, 2016) attributed failure of the roads to weathering, low resistivity, water-absorbing substratum, joints and fracture zones, clayey soil and bad drainage system.

Rehabilitation of failed pavements is a serious problem to all levels of governments financially, this would not have been if detailed geophysical and geotechnical attention can always be paid on any proposed site for road construction and/ or rehabilitation before embarking on the project.

2. MATERIALS AND METHOD

The major instrument used for data acquisition was a Resistivity Meter ABEM Terrameter SAS 1000 with an in built 24V rechargeable batteries. Accessories included four (4) electrodes, current and potential reels, measuring tapes, GARMIN 12 Global Positioning System (GPS), Hammers and Umbrella.

2.1 The Study Area

The areas of investigation are namely; Igbekhwoe, Odighi, Odiguetue, Omigie and Ugboke communities respectively lies within South-South Benin–Akure expressway, Edo State Nigeria. Its connects from South-south Benin City to South-west Akure in Ondo state and to other northern states through Owan. It is observed that previous studies have not been done in this particular study environment.

2.2 Scope of the Study

The investigation was carried out on five failed portions of the expressway as shown in Figure 1

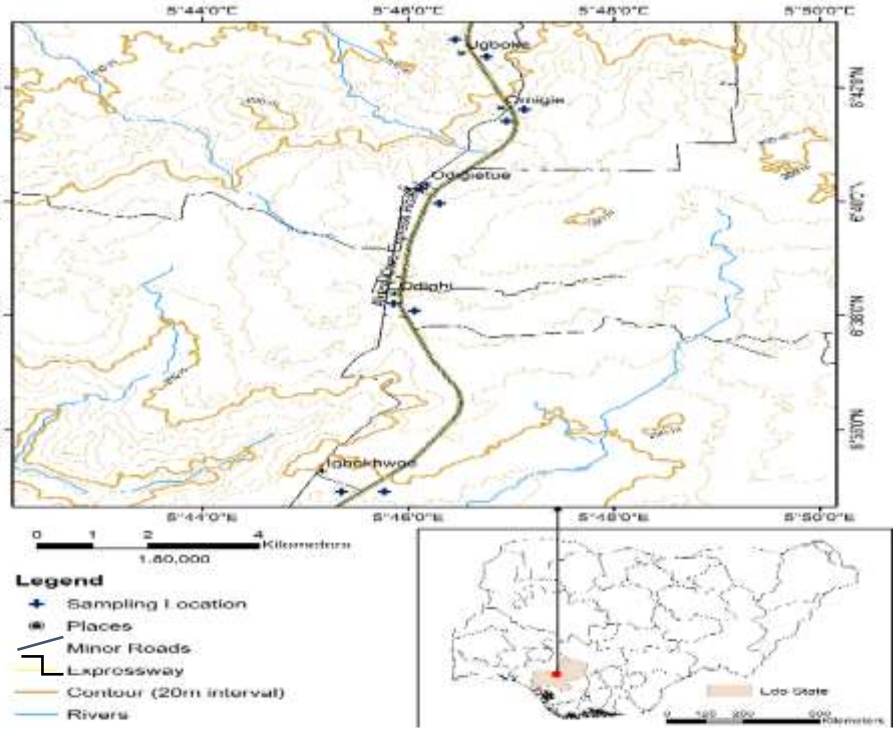

Figure 1: *The Topographic and Position map of study areas along Benin- Akure expressway Edo State*

2.3 Geology of study area

The study area is located in Nigeria Niger Delta Basin. Its lies between (6^0 35' 0'', 6^0 43' 0'') N and (5^0 44' 0'', 5^0 50' 0'') E it is predominantly underlain by the Benin formation (also known as the coastal plain sands). This formation is part of the extensive Niger Delta sedimentary basin and consists mainly of thick, poorly sorted, reddish-brown to pinkish sands with discontinuous clay and shale beds. The thickness of this formation can be up to 800m under the city, and it is a major aquifer region (water-bearing unit) (Ighodalo and John, 2024).

The sites were selected based on safety, its gentle slope, accessibility terrain where instruments and cables can be laid out straight (for profiling method) bends and breaks complicate interpretation.

2.4 Data Acquisition Method

ERT was adopted for this survey. Using Wenner array electrode configuration, Four symmetrically positioned electrodes were used along a profile parallel to the road with distance 2 m away from it. Two current and two potential electrodes. The current electrodes are positioned within, while the potential electrode are positioned outside with the same electrode separations (spacing). Both current and potential electrodes are moved along the profile with constant spacing. This is repeated by increasing the electrode spacing for the same entire spread but in a reversed direction. One person is needed to move each of the four (4) electrodes and connecting cables, and one other person handled the recording Terrameter.

Electrode spacing for data collection for each of the profiles are 5 m, 10 m, 15 m, 20 m, 25 m, 30 m with a total length of 100 m for each profile. ABEM Terrameter SAS 1000 was utilize for the field survey. Five (5) failed locations were surveyed as shown on (Figure 1), with one traverse taken 2 m from both edges of the road for each failed location, making a total of ten (10) spots surveyed. Readings were taken in earth resistance in ohms (Ω) and milli ohms (mΩ) and were converted to resistivity in ohms- meter (Ωm) by calculating with the geometric factor (K) of wenner array used.

2.5 Data Processing

The software used to analyze 2D field data is Res2dinv software program. This software is based on windows application, which automatically evaluates the 2D resistivity images from the field data we have acquired. Evaluation of the apparent resistivity values, forward modeling subroutine is used, the inverse procedure depends on an iterative smoothness constrained least-squares algorithm, validating data by removing outliers or points of inconsistencies. Apparent resistivity values are measured using the forward simulation subroutine, and an iterative smoothness-constrained least-square algorithm is used to construct the inverse method. With iterations not more than 5 or 6 for the data to converge and RMS error target of less than 10%. This inversion procedure remove geometric effects that are false segments and provides a true picture with depth and actual resistivity values. The process comes up with apparent resistivity measured and apparent resistivity calculated, its compare these two resistivity using iteration procedure. This process is continued until combined smoothness is achieved.

3. RESULT AND DISCUSSION

3 .1 Results

ERT (models) of surveys acquired on the failed portions of Benin- Akure road are as shown in Figure (2- 6). One profile were surveyed on both sides of the failed pavement at each location the model displayed measured apparent resistivity pseudosection, calculated apparent resistivity pseudosection and an inverse model resistivity section as shown on figures 2- 6

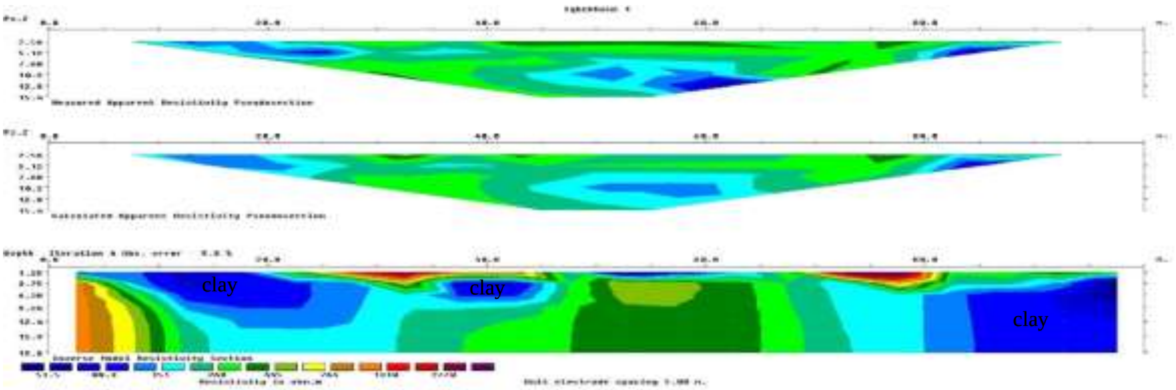

Figure 2a: *2D model of profile 1 at Igbekhowe*

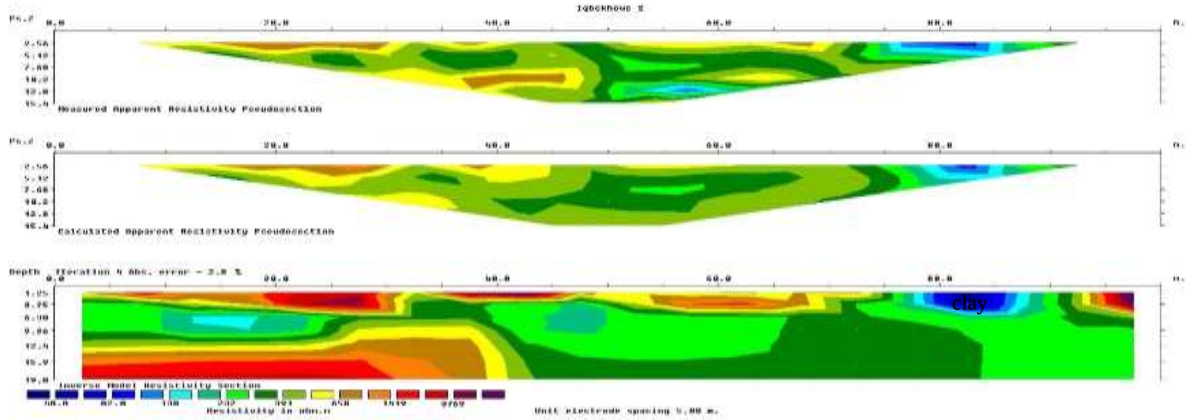

Figure 2b: *2D model of profile 2 at Igbekhowe*

At Igbekhowe, for survey profile 1 (Figure 2a), the survey length is 100 m. At a distance of 2.0 m to 23.0 m, to a depth of 19.8 m, with resistivity range from 51.5 Ωm to 151.0 Ωm probably indicating formation of clay, clayey sand / sandy clay was observed while clay deposit with resistivity slightly above 51.5 Ωm is observed within the sand formation from a depth range of 3.75 m to 6.38 m at distance of 35 m to 45 m. At distance of 80 m and above, to a depth of 3.75 m, sand formation was also observed having resistivity value of 151 Ωm.

Survey profile 2, Figure (2b), at the distance of 75 m to 87 m along the surface to a depth of 6.38m, clayey sand formation was observed with resistivity range of value from 48.8 Ωm to 135 Ωm. These clay and sand formation may have also contributed to the road failure at this study location.

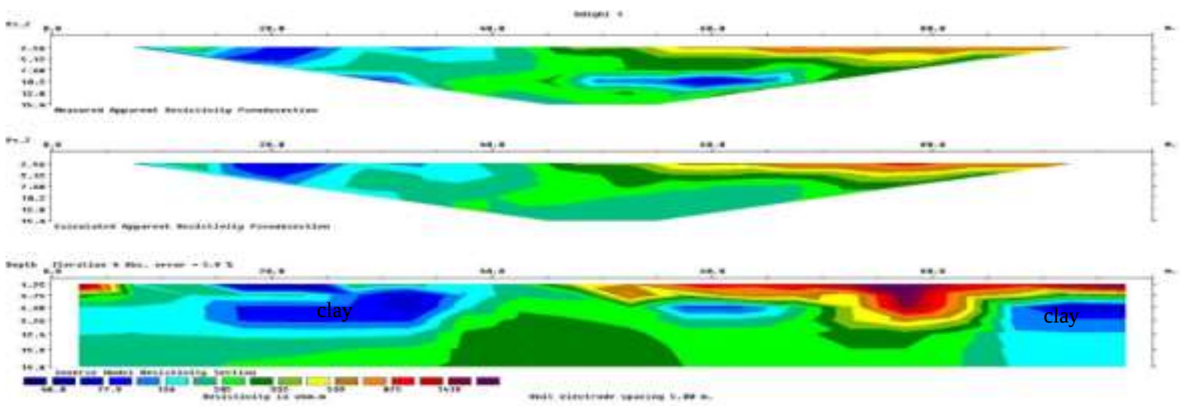

Figure 3a: *2D model of profile 1 at Odighi*

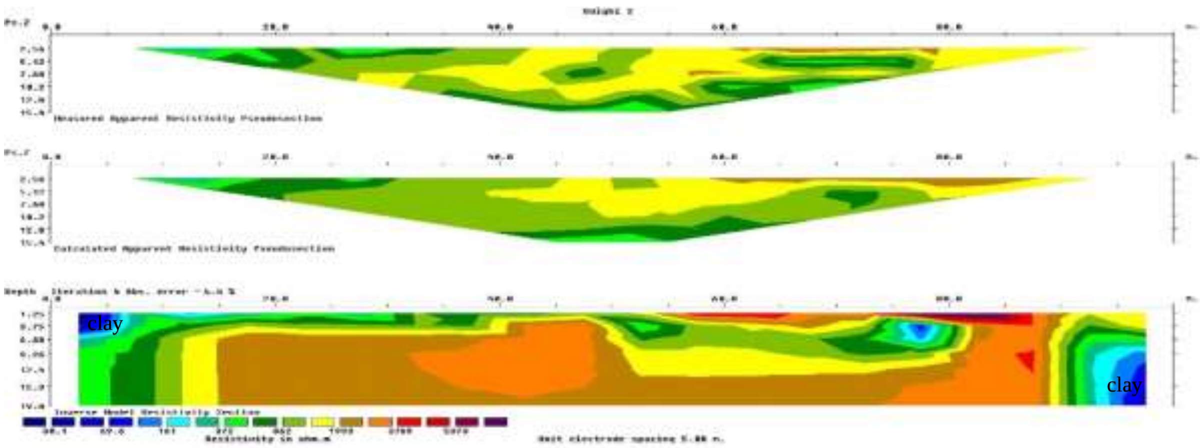

Figure 3b: *2D model of profile 2 at Odighi*

Figure 3a shows the model of survey profile 1 at Odighi. At a surface distance of 10 m to 40 m along the length of the profile to a depth of 12.4 m from the surface, with resistivity value 40 Ωm probably indicate clay formation, while a formation of sandy clay having resistivity ranging from 40.0 Ωm to 205Ωm was observed between 85 m and above along the same profile length to a depth of 19.8 m.

Figure 3b also shows the model of survey profile 2 at Odighi. Clay formation can probably be found at a surface distances from 0 m to 5 m and 95 m to100 m at depth of about 0 m to 6.38 m and 6.38 m to 19.8 m respectively from the surface having resistivity range from 30.1 Ωm to 161 Ωm, and sandy sediments are found under the clay at 0 m to about 80 m, along the profile at depth 6.38 m from the top soil with the resistivity range 161 Ωm to 372 Ωm.

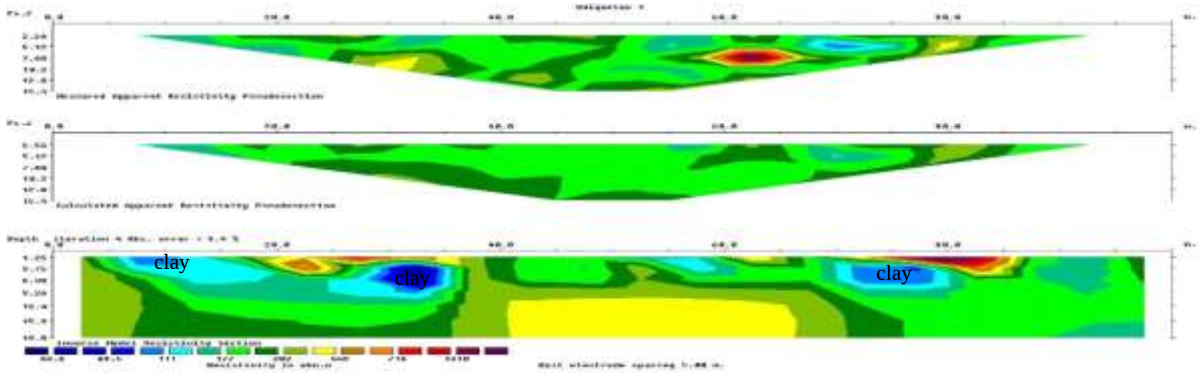

Figure 4a: *2D model of profile 1 at Odiguetue*

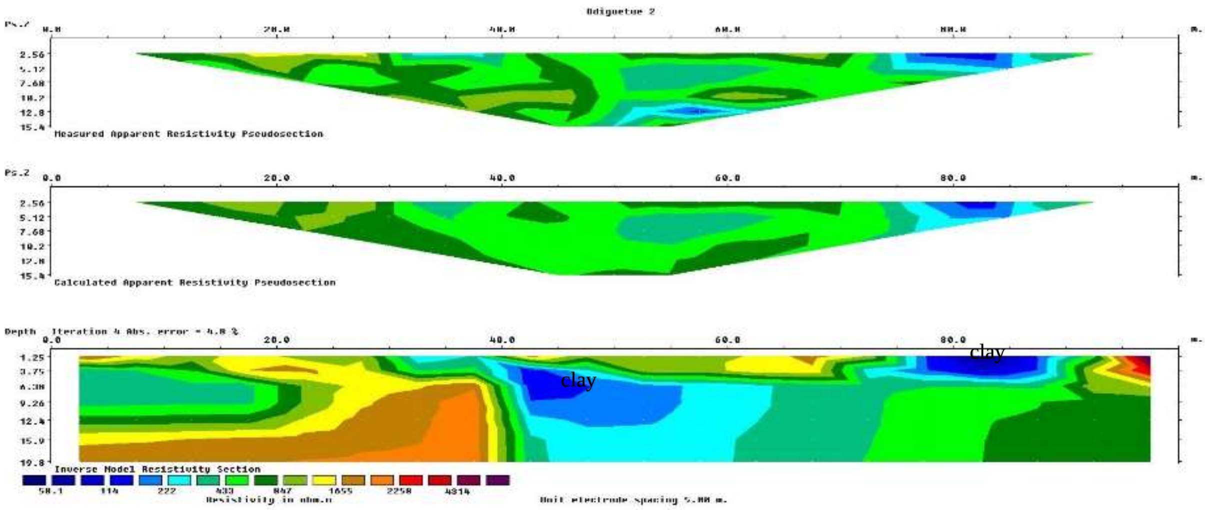

Figure 4b: *2D model of profile 2 at Odiguetue*

Figure 4a shows the model of survey profile 1 at Odiguetue community, there is also a relatively low resistivity range of 43.6 Ωm to 111 Ωm at surface distance of 5m to 35m to a particular depth of 9.26m from the top soil. This was found to be probably clay mixed with sand. There is also, clay presence at depth of 3.75 m to 9.26 m and resistivity interval 43.6 Ωm to 177 Ωm, from 66 m to 80 m position along the profile. Below this formation, a layer of high resistivity (282-449) Ωm of sandy formation is present.

Figure 4b also shows the model of survey profile 2 at Odiguetue. From distance 0 m to 20 m lateral length, is a portion of resistivity which ranges from 222 Ωm to 433 Ωm. This is observed to be probably sandy formation. From 40 m to 90 m length along the surface to a particular depth of 19.0 m from top, is a low resistivity with range of values from 58.1 Ωm to 222 Ωm. This can be the result of well compacted clay formation which can also influence the road's instability.

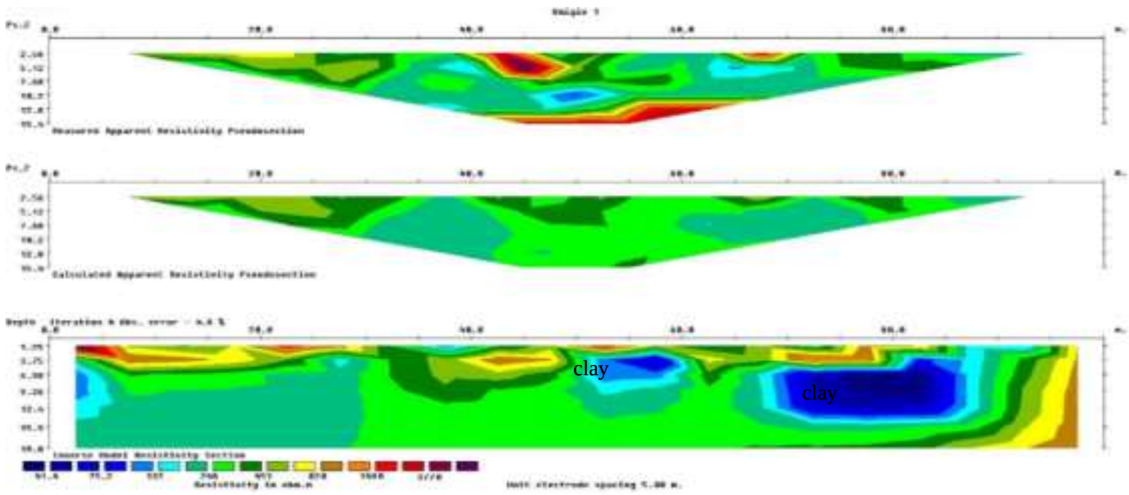

Figure 5a: *2D model of profile 1 at Omigie*

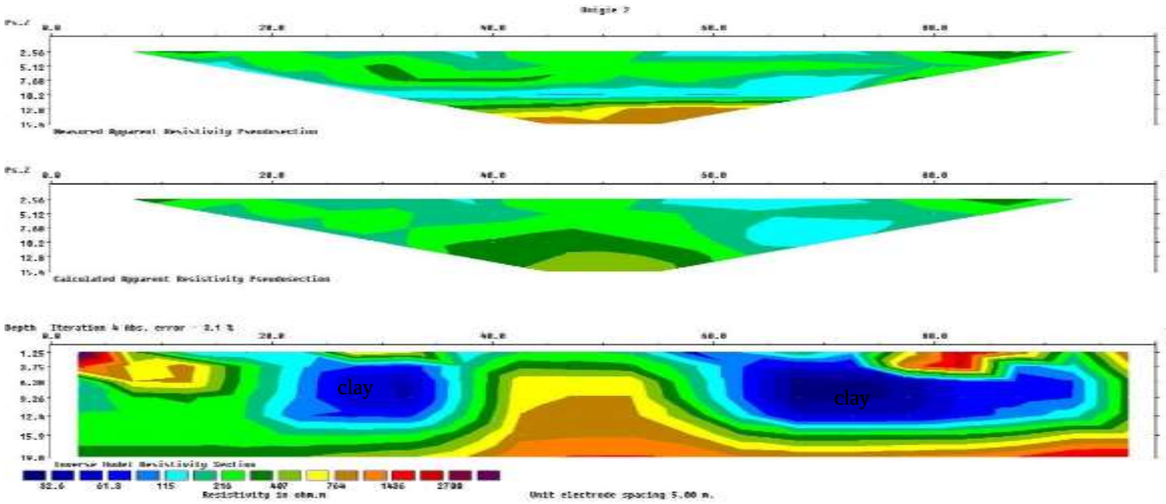

Figure 5b: *2D model of profile 2 at Omigie*

Figure 5a shows model of survey profile 1 at Omigie. It displays values of resistivity readings from 248 Ωm to 1490 Ωm from the surface up to about 3.75 m depth from distance 0 m to 80 m length along the profile shows a sandy formation. However, within this sandy formation is another zone having low resistivity range (41.4-137) Ωm at 65 m to 85 m via the profile length to a particular depth 6.38 m to19.8 m this range is probably made up of clay formation.

Figure 5b shows model of survey profile 2 at Omigie. This profile has a large section with resistivity range 216 Ωm to 2200 Ωm at distances 0 m to 20 m, 40 m to 60 m, 90 m and above along the spreads to depth of 1.25 m to 19.8 m. its indicates that sandy formation can be found in this formation. Another region of low resistivity varying between 32.6 Ωm and 115 Ωm at the top from 20 m to 40 m, and 60 m to 90 m along the profile and to 1.24 m and 12.4 m in depth from the top soil. It is probably a clay sand formation at this position of the model.

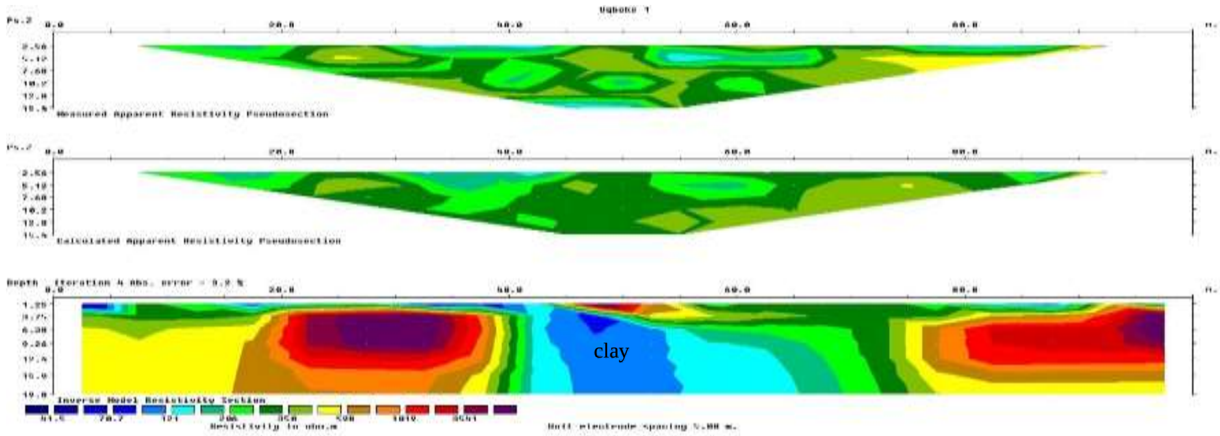

Figure 6a: *Result of 2D of profile 1 at Ugboke*

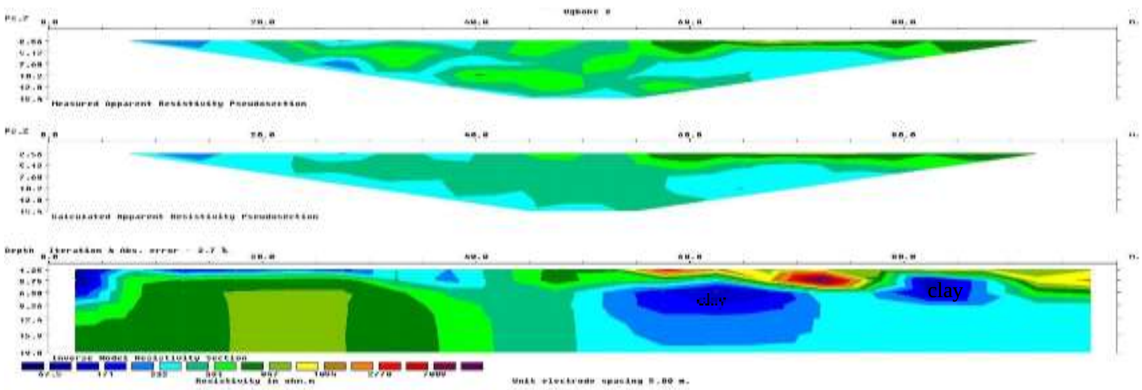

Figure 6b: *2D model of profile 2 at Ugboke*

Figure 6a is the model of survey profile 1 at Ugboke. Regions of low resistivity range of 41.5 Ωm to 286 Ωm, at 1 m, 20 m, 40 m and 80 m respectively along the profile to a depth of 1.25 m on the surface of the profile. It is probably a mixture of clay and water. Below this position is resistivity range from 286 Ωm to 3541 Ωm at depth of 3.75 m to 19.8 m. It is observe to be sandy formation which might have spread from 0 m to 40 m and 60 m to 90 m along the profile length.

Figure 6b shows model of survey profile 2 at Ugboke. This profile also have regions of low resistivity, with interval 67.5 Ωm to 232 Ωm and found to be sandy clay formation. This spreads from 0 m to 40 m with depth 1.25 m to 6.38 m from the top and also from 50 m to 80 m and above. This profile has resistivity from 391 Ωm to 7809 Ωm, at 0 m to 40 m spread along the surface to a depth of 19.8 m from the top. At 50 m to 80 m and above also with depth 1.25 m to 6.38 m. This was found to be sandy formation.

3.2 Discussion

Table 1: *Survey Location Data*

S/N	PROFILE	MID POINT Latitude / Longitude	RESISTIVITY RANGE(Ω m)	LENGHT (m)	DEPTH (m)	RMS VALUE (%)
1	Igbekhowe L1	6⁰ 34' 43.2"/ 5º 45' 23.1"	51.5-2778	100	19.8	5.8
2	Igbekhowe L2	6º 34' 43.3"/ 5º 45' 23.2"	48.7-3769	100	19.8	2.8
3	Odighi L1	6º 38' 23.1"/ 5º 45' 17.6"	40.0-1419	100	19.8	5.9
4	Odighi L2	6º 38' 23.0"/ 5º 45' 17.8"	30.1-5373	100	19.8	4.4
5	Odiguetue L1	6º 40' 25.1"/ 5º 46' 11.0"	43.6-1310	100	19.8	9.4
6	Odiguetue L2	6º 40' 24.7"/ 5º 46' 11.2"	58.1-4314	100	19.8	4.8
7	Omigie L1	6º 41' 35.2"/ 5º 47' 03.5"	41.4-2770	100	19.8	4.8
8	Omigie L2	6º 41' 35.1"/ 5º 47' 03.3"	32.6-2700	100	19.8	3.1
9	Ugboke L1	6º 43' 43.3" /5º 46' 42.1"	41.5-3541	100	19.8	3.2
10	Ugboke L2	6º 42' 42.2"/ 5º 46' 42.2"	67.5-7089	100	19.8	2.7

From Table 1 above it is precisely observed that the resistivity range of values for low, moderate/high resistivity values were (30.1 – 7089) Ω m, total depth attained is 19.8 m and Root Mean Square (RMS) range (2.7- 9.4) %. This implies that under this failed pavements are portions of low resistivity values ranging between (30.1-100) Ω m as shown on figures (2- 6) which is termed low resistivity range indicating the presence of clay, sand clay/ clay sand, shale and weathered geologic materials with low resistivity values. These formation are capable of undergoing swelling when mixed with water leading to failure under pressure. Also, regions with resistivity range (100-1000) Ω m term moderate and (1000-7089) Ω m high resistivity. The moderate/high values of resistivity are indications of competent soils such as; sand, gravel, sandstone, laterite, and lateritic soils which are good construction materials existing in the stable portions of the road pavement. These findings are in agreement with the findings of (Bisong et al., 2021), (Adiat et al., 2017), (Ademila, 2022), (Akinlabi and Adegboyega, 2021) and (Jekayinfa and Osinowo, 2021) who reported that the causes of road failure is due to clayey materials which have low resistivity values and areas with clay are weak zones that are unable to withstand heavy traffic on it. They also asserted that Clays swell and shrinks during seasons and this give rise to several cracks and deformations on the road leading to failure because of reduced shear strength and incompressibility (Egwuonwu et al., 2011), (Eebo and Abiodun, 2021). This findings are also in consonance with the findings of (Ebhohimen, 2013) who revealed that highly resistive soils are competent zones and low resistive zones are incompetent zones. Also (Nnamdi et al., 2019) asserted the present findings and observed that moderate and low resistivity values correspond to partially stable and failed sections of any road.

Validating this results with figure 7, we compare the lithology with that of a standard borehole log drilled 50 m from one of the survey location at Odighi community which show that there are similarities in the lithology sections with depth of the surveyed locations and the borehole log.

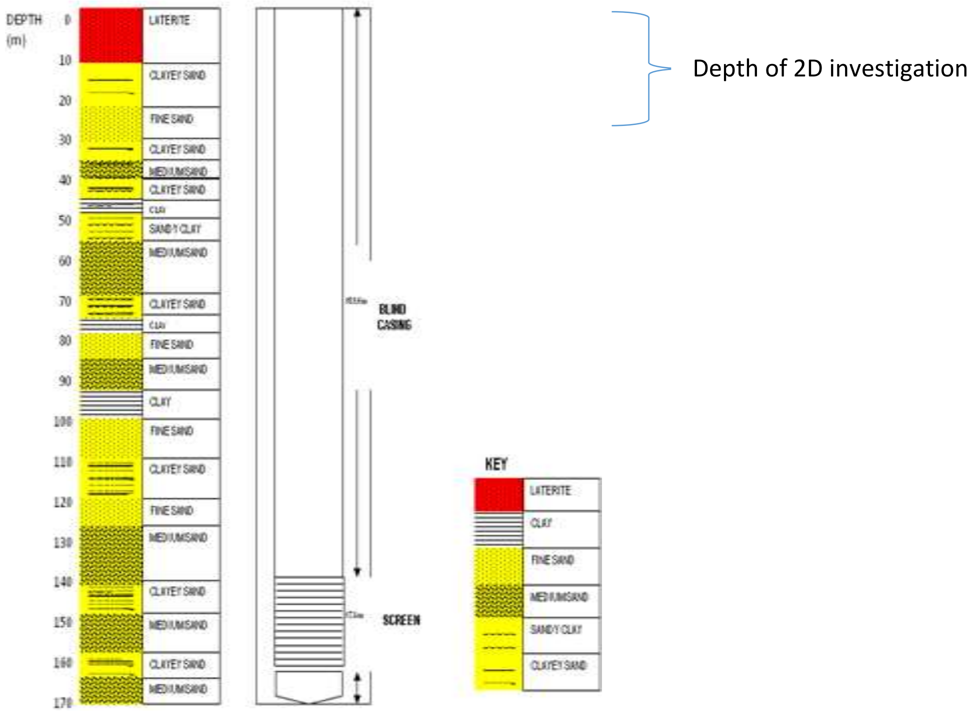

Figure 7: *Lithology Section of Odighi Borehole log.*

4. CONCLUSION

From this survey it was observed that the resistivity values for the study location lies within the resistivity range (30.1 – 7089) Ωm. This classify the environment into a sedimentary basin. The objectives of this study are to characterize subsurface lithology of the failed pavement, identify geological factors responsible for the failure and provide geotechnical recommendations to prevent future occurrence. The survey indicates that the remote causes of road failure in the study area are due to geologic materials such as clay/shale materials/highly weathered materials especially at top layer. It was recommended that to prevent or mitigate pavement failure geotechnical maintenance will involve regular inspection and monitoring, soil stabilization technique like excavating and replaced subgrade materials with more competent materials like gravel, laterite, or sandstone before laying the asphalt for the rehabilitation, drainage improvement, design and construction upgrades of the road. To the best of my knowledge this is the first road pavement failure survey done on Benin- Akure road environ within Edo state. The study limitations observed during the acquisition of data is the state of insecurity involving kidnapping by bandits and harassment from the host community youths.

For future research studies it is recommended that other failed portions of road pavement along this same direction should be investigated with increase survey lengths in other to obtain a deeper sections of the subsurface for more subsoil lithology information, as weak zones may be beyond the depth already investigated.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

REFERENCES

[1] Ademila, O. (2022). Engineering geophysical investigation of OkaIsuaIbillo highway failure; remedy and road sustainability in Nigeria. *J. of Sci. Res. of the Banarus Hindu University, 66(1), 41 – 52.*

[2] Adenika, C.I, Ariyibi, E.A, Awoyemi, M.O, Adebayo, A.S, Oluwaseyi, A, Dasho, O.A & Olagunju, E.O (2018). Application of geophysical approach to highway pavement failure: a case study from basement complex terrain southwestern Nigeria. *Geo-Eng, 9{8), 1-22.*

[3] Adiat, K. A. N, Adelusi, A. O, Ayuk, M. A. (2009). Relevance of Geophysics in Road Failure Investigation in a typical Basement Complex of Southwestern Nigeria. *Pacific Journal of Science and Technology, 5(1):528 – 539.*

[4] Adiat, K.A.N., Akinlalu, A.A & Adegoroye, A.A (2017). Evaluation of road failure vulnerability section through integrated geophysical and geotechnical studies. *NRIAG Journal of Astronomy and Geophysics, 6(1), 244 – 255.*

[5] Akinlabi, I.A & Adegboyega, C.O (2021). Engineering geophysical investigation of road failure in a basement complex terrain, Southwestern Nigeria. *Journal of Geography, Environment and Earth Sciences International, 25(2), 40-51.*

[6] Akintorinwa, O. J, Ojo, J. S, Olorunfemi, M. O. (2010). Geophysical Investigation of Pavement Failure in a Basement Complex Terrain of Southwestern Nigeria. *Pacific Journal of Science and Technology, 11(2):649-663.*

[7] Andrews, N. D, Aning, A. A, Danuor, S. K, Noye, R. M. (2013). Geophysical Investigations at the proposed site of the Kwame Nkrumah University of Science and Technology (KNUST) teaching hospital building Kumasi, Ghana, using 2D and 3D resistivity imaging techniques. *International Resource Journal of Geology and Mining, 3(3):113- 123*.

[8] Bisong S.A., Abong A.A. and Egor A.O. (2021). Geophysical Investigation Of Pavement Failure Along Jonathan By-Pass - Akansoko And Atimbo -Parliamentary Roads In Calabar Metropolis Cross River State, Nigeria. *Science World Journal Vol. 18(No 3). DOI: https://dx.doi.org/10.4314/swj.v18i3.8*

[9] Burland, J. B, Burbidge, M. C. (1981). Settlement of Foundations on Sand and Gravel *Proceedings of the Institution of Civil Engineers, 78(1):1325- 1381.*

[10] Ebhohimen, V.O (2013). Geophysical investigation of road failure using electrical resistivity imaging method, a case study of Uhiele – Opoji road Edo State. *An MSc thesis Department of Geology, Faculty of Physical Sciences, University of Nigeria, 1-115.*

[11] Eebo, F. O & Abiodun, O (2021). Geophysical investigation of causes and characteristics of road failure along part of IlaraIpogun, Ondo State, Nigeria. *Global Scientific Journals, 9 (7), 27 – 38.*

[12] Egwuonwu, G. N., Ibe, S.O & Osazuwa, I.B. (2011). Geophysical assessment of foundation depths around a leaning superstructure in Zaria Area, Northwestern Nigeria using electrical resistivity tomography. *The Pacific Journal of Science and Technology, 12(1), 472 - 486.*

[13] Enoma, N. and Edo T.M (2024). Near Surface Investigation of Clay Mineral using 2Dimensional Electrical Resistivity Survey. *The journal of the Nigerian institution of production Engineers vol.28 (3): 60-70*

[14] Enoma, N., Wilkie, S.O and Ighodalo J.E (2023). Geophysical and Contamination Investigation of Soil Spatial Distribution for Sustainable Agriculture in Usen, Ovia Southwest Local Government Area, Nigeria. *The journal of the Nigerian institution of production Engineers vol.27 (2):102-112*

[15] Griffiths, D. H, Barker, R. D. (1993). Two-dimensional Resistivity Imaging and modelling in areas of Complex Geology. *Journal of Applied Geophysics, 29:211-226.*

[16] Ighodalo, J.E. & John, O.J (2024) Application of 2D Electrical Resistivity Tomography (ERT) techniques to site investigation at Iguoviemwen community South- South Nigeria. *Journal of the association of mathematical physics vol.67 NO 2*

[17] Jekayinfa, S. & Osinowo, O (2021). Geophysical and geotechnical investigation of road pavement failure in part of Ibadan Metropolis southwestern Nigeria Asian. *Journal of Geological Research, 4(4): 17-31.*

[18] Momoh, L. O, Akintorinwa, O, Olorunfemi, M. O. (2008). Geophysical Investigation of Highway Failure- A Case Study from the Basement Complex Terrain of Southwestern Nigeria. *Journal of Applied Sciences Research, 4(6):637-648.*

[19] Nnamdi, J.A, Zander, C.C.A & Osita, C. O (2019). Geophysical and geotechnical investigation of failed section of Orsu-Ihiala Road Southeastern Nigeria. *International Journal of Scientific & Engineering Research, 10(6): 461-467.*

[20] Ogungbe, A. S, Afolabi, T. O, Onori, E. O and Ogabi, C. O (2021). Geophysical investigation of road failure along lagos Badagry expressway using electrical resistivity imaging *J. Phys.: Conf. Ser. 1734 012041*

[21] Okpoli, C.C & Bamidele, A.A (2016). Geotechnical investigation and 2D electrical resistivity survey of a pavement failure in Ogbagi road, Southwestern Nigeria. *Intern. Basic and Appl. Res. J., 2(7): 47- 58.*

[22] Osinowo, O.O, Akanji, A. O, Akinmosin, A. (2011). Integrated Geophysical and Geotechnical Investigation of the failed portion of a road in basement complex Terrain, Southwest Nigeria. *Materials and Geoenvironment, 58(2):143–162.*