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Geophysical perspective of road pavement failure: a case study of Ikot Ekpene- Umuahia road, Nigeria

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Abstract
Geophysical survey using two dimensional resistivity methods was undertaken to investigate the causes of pavement failure along the Ikot Ekpene - Umuahia road. The study was centered on some perennial failed parts of the road namely Ariam, Awomnkwu, Ekebedi Oboro, Ogbubule Oboro, Okwe-ukwu Oboro, Ndoro Oboro, Umudike,Ahiaeke Ndume, Ehimiri using subsurface electrical method, which reveals the subsurface geology(lithology) at each location after interpretation. Abem Terrameter SAS 1000 was employed and the apparent resistivity values were used. The lithology of the subsurface reveals that their resistivity falls between >83Ωm to 103Ω. The geoelectric zones constructed from the VES resistivity structures shows that the pavement segments were founded on a shallow basement near low resistive layer bereft of vital geological features. This made it impossible for the pavement to withstand stress as a result of load from road users.
Keywords: Geophysical Survey***, Pavement Failure, Abem Terrameter, Lithology, Thickly Low Resistivity Layer.***

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I. Introduction

Road failure is defined as a discontinuity in a road pavement resulting in cracks, potholes, bulges and depression, (Aigbedium, 2007). Road pavement is supposed to be a continuous stretch of asphalt horizontally laid for a smooth ride or drive but discontinuity and distortions in road network result in road failure.

In the last two decades, the federal and state governments have spent huge amount of money in constructing new roads and rehabilitating damaged and failed ones in order to ensure smooth traffic. Poor and undulating terrains, heavy rainfall, poor texture of the subsurface alongside technical and other negative human activities contributes to these. Also, the underlying geological materials, which have varying ability to withstand loading, poor drainage network, poor road design and inferior construction materials are some out of the many factors that are responsible for these pavement failures. Several other factors are responsible for road failure, which includes geological factors, geomorphological factors, geotechnical factors, road usage, construction practices and maintenance (Adegoke and Agada 1980; Ajayi, 1987). The geological factors influencing road failures includes the nature of soil and the near surface geological sequence, existence of geological structures such as fractures and fault, existence of ancients stream channels, presence of cavities and shear zones (Momoh et. al, 2008 and Adiat et.al, 2009).

Geological factors are rarely considered as precipitators of road failure even though the highway pavement is seated on geological earth materials (Momoh et. al,. This is due to non-appreciation of the fact that proper design of highway pavement requires adequate knowledge of subsurface condition beneath the highway routes. The geomorphological factors are connected with topography and the surface/subsurface drainage system. Poor Maintenance according toJohn and Gorden (1976), Oglesby and Garry (1978), TRRL (1991); and Traffic Effects and Human Impacts on the Roads according to American Association of State Highway and Transportation Officials (AASHTO, 1976), FMWH (1995) and Ibrahim (2011), bedrock depressions (Adeyemo and Omosuyi, 2012), presence of undetected linear features, such as fractures and rock boundaries and construction of roads on weathered layer (Ibitomi et al., 2014), also contributes to pavement failure.

When a road cannot smoothly transport people, goods and services due to defects on its surface then it is regarded as a failed road.

The continuous and incessant failure of highway roads in Nigeria has assumed an unprecedented proportion and is a major cause of concern in recent times. Failed roads are usually made up of potholes, pavement surface wash, block and longitudinal cracks, drainage collapse, depressions, over flooding of the carriageway, gullies and trenches, rutting and rave. (Ogangbe, A.S. et al., 2021). These gives rise to poor road networks resulting in fatal road accidents, loss of human lives, wearing down of vehicles, damages on goods and general delay in movement of people, goods and services across the zones.

The collapse of concealed subsurface geological structure and other zones of weakness controlled by regional fractures and joint systems along with silica leaching, which has led to rock deficiency are known to contribute to failure of highways and rail tracts (Nelson and Haigh,1990).

Akwa Ibom and Abia State governments have attempted to repair the particular road in question, yet portions of the road perennially fail no sooner than the rehabilitation work on the it is concluded. Some states like Ebonyi state, instead of overlaying the road surface with asphalt concrete alone now use the cement concrete underlain with iron rods netted within (popularly known as cement technology) to increase the road strength and to stabilize the subsurface structure to enable it withstand the stress due to traffic load .

To ensure the durability of our road network, relevant geological and geophysical techniques should be adopted before construction work commences. Geophysical investigation carried out before road construction is expected to provide adequate geotechnical information needed to make the highway pavement formidable in strength to withstand any form of traffic. The application of such geophysical investigations will be used for the determination of bed rock, structural mapping and evaluation of sub soil competence (Burland and Burbridge, 1981; Burger 1992).

This research intends to engage the use of electrical resistivity survey, an integrated geophysical investigation which of late is not only found to be cost effective, but an efficient tool that can provide the geotechnical information needed to handle reoccurring of issues in our environment.

The Ikot Ekpene - Umuahia road that is being investigated has a long history of repeated pavement failure such as cracks, weathered basement, shallow valleys, bed rock depression and after drained channel.

Location, geology and hydrogeology of the study area

The road under study is the Ikot Ekpene - Umuahia road. The locations investigated are mainly in the Abia state portions of the road namely Ariam, Awomnkwu, Ekebedi oboro,Ogbubule oboro, Okwe-ukwu oboro, Ndoro oboro, Umudike,Ahiaeke Ndume and Ehimiri. The road links Akwa Ibom state with Abia state and Imo state.

Geology: Abia state is located between lat. 4°49.30'N and 6°02'N and between long. 7°08 'E and 8°04'E in the south eastern part of Nigeria (**Figure 1**). Geologically**,** there are two principal geological Formations in the state namely Bende-Ameki and the Coastal Plain Sands otherwise known as Benin Formation. The Bende-Ameki Formation of Eocene to Oligocene age, which Consists of medium–coarse-grained white sand stones, (**Figure 1**). The late Tertiary-Early Quaternary Benin Formation is the most predominant and completely overlies the Bende-Ameki Formation with a south westward

Dip. The Formation is about 200m thick. The lithology is unconsolidated fine-medium-coarse-grained cross bedded sands occasionally pebbly with localized clay and shale.

Hydrogeologically, There are two principal geological formations have a with comparative groundwater regime. They both have reliable groundwater that can sustain regional borehole production. The Bende-Ameki Formation has less groundwater when compared to the Benin Formation. The numerous lenticular sand bodies within the Bende- Ameki Formation are not extensive and constitute minor aquifer with narrow zones of sub-artesian conditions. Specific capacities are in the range of 3 - 6 m^3 per meter per hour. On the other hand, the high permeability of Benin Formation, the overlying lateritic earth, and the weathered top of this Formation as well as the underlying clay shale member of Bende-Ameki series provide the hydrogeological condition favouring the aquifer formation in the area.

Vertical electrical sounding (VES) or electrical resistivity imaging is now being used to detect fractures andcavities in the subsurface, geotechnical investigations for buildings, roads, bridges and dams. The method can also be used for delineating archaeological features, locating surface utilities and for monitoring pollution seepage through the earth's subsurface. The method has been proven to be an effective tool for identifying anomalies and defining the complexity of the subsurface geology (Griffiths and Barker, 1993; Loke and Barker, 1996a; Giano et. al., 2000; Ugwu, 2012; Andrews et. al., 2013). The 2D electrical resistivity imaging in which the subsurface is assumed to be varying vertically down and laterally along the direction of profile but constant in the perpendicular direction has been used to investigate areas with moderately complex geology (Griffiths and Barker,1993; Andrews et al., 2013).

II. Materials and methods

Data acquisition method

To provide this information above, a thorough hydro geophysical survey was carried out. The type used here was Electrical drilling or sounding (VES). The electrode array used was the schlumberger arrangement because of its advantage over other arrays. The configuration is made up of 4 electrodes. Two current electrodes and two potential electrodes were deployed. Here current is introduced into the ground through the current electrodes and because the various geologic units offer resistance to the current flow, a drop in the potential (voltage) occurs. Apparent resistivity, ρ_a is obtained from the ratio of the potential difference to the current flow multiplied by the array (spacing constant). The resistivity is called apparent because each resistivity value for a certain depth is really an average resistivity for all the materials, above this depth.

Generally $$\rho_a = \pi \cdot \left[\frac{(AB/2)^2 - (AB/2)^2}{MN} \right] \cdot R_a$$

For Schlumberger method. AB, MN are respectively current electrode separation and potential electrode separation. The entire term multiplied by apparent resistance R_a .

Geologic section (also geologic profile) is a vertical section of the earth's crust from its surface to a depth. Geologic sections are made on the basis of geologic maps and data from geologic observations, mine works, boreholes, geophysical investigations, and so on.

It highlights the diagrammatic section of stratified layer which is deduced from electrical (resistivity) depth probing or drilling, where layers are identified by their apparent resisitivities was constructed. The survey stations were Ariam, Awomnkwu, Ekebechi oboro, Ogbu bule oboro, Okwe-ukwu oboro, Ndoro oboro. (Ikwuano L.G.A). Umudike, Ahiaeke-Ndume, Ehimiri. (Umuahia North L.G.A). To examine the geological factors responsible for highway pavement failure, detailed subsurface geo-electric sequence, subsurface structural features mapping and delineation of the bedrock relief were carried out to establish the cause/s of road pavement failure.

Table 1: GEOECTRIC SECTIONS FOR NINE SOUNDINGS

VES1 ARIAM

Resistivity (ohm. m)	Depth(m)	Description
98.0	0 .5	loamy top soil
3640	2.3	clay soil.
1470	4.6	Unsaturated zone
642	15.2	Medium grain sand

VES 2 AWOMUKU

Resistivity (ohm. m)	Depth(m)	Description
100.0	1 .5	loamy top soil
4620.0	2.8	Silty clay soil.
296.0	32.7	Unsaturated zone
6430.0	45.0	Medium grain sand

VES 3 OGBUBULE(IKWUANO L.G.A.)

Resistivity(ohm. m)	Depth(m)	Description
89.0	0.4	loamy top soil
1276	2.6	Overburden
182.0	13.7	unsaturated zone
746.0	16.0	Fine sand.

VES 4 EKEBEDI – OBORO (IKWUANO L.G.A.)

Resistivity(ohm. m)	Depth(m)	Description
100	0.9	Agric. soil/clay
6880.0	7.4	Clay/ laterite
2864	25.6	Fine sand

VES 5 OKWE-UKWU OBORO (IKWUANO L.G.A.)

Resistivity (ohm. m)	Depth(m)	Description
94.6	0.7	loamy top soil
6800.0	3.2	silty clay
1080.0	6.6	loose sand
178.0	14.3	Medium grain sand.

VES 6 NDORO OBORO (IKWUANO L.G.A.)

Resistivity (ohm. m)	Depth (m)	Description
103.0	0.8	loamy top soil
189.0	4.3	Clay soil
1438.0	13.5	unsaturated layer

7306.0	32.6	Fine grain sand.

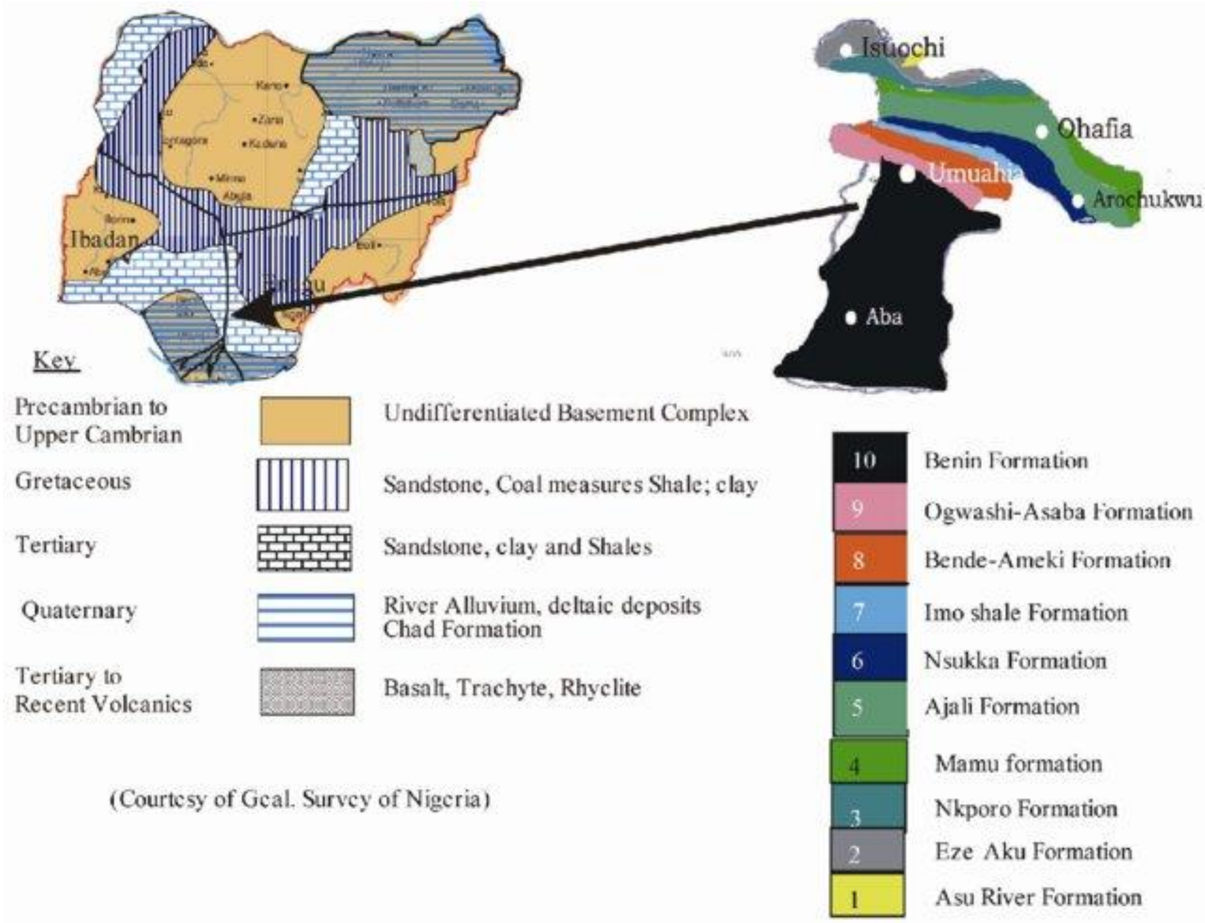

Fig. 1: Geographic location and geologic map of Abia State.

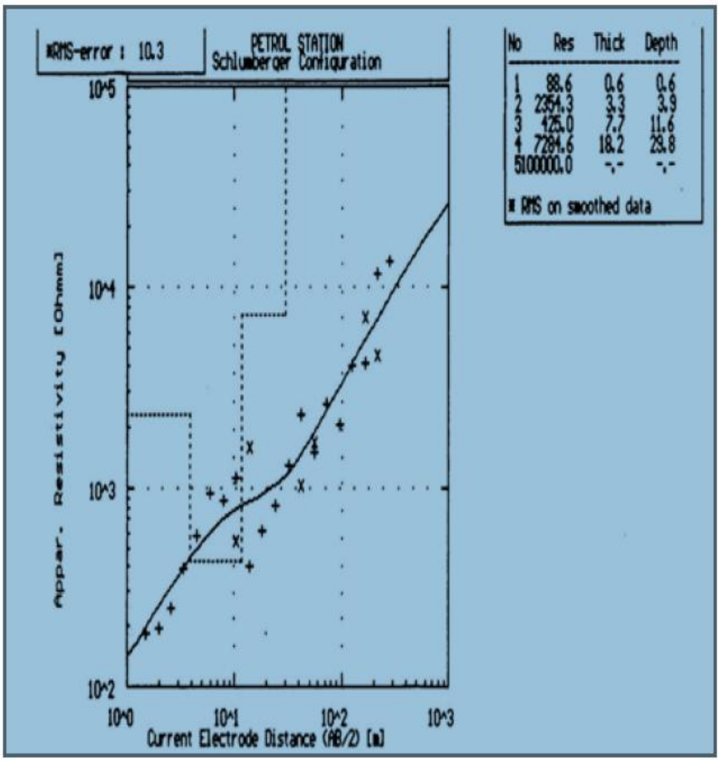

Fig 2: VES for MOUAU Umudike.

VES 7 UMUDIKE (IKWUANO L.G.A.)

Resistivity(ohm. m)	Depth(m)	Description
88.6	0.7	Lateritic soil
2354.4	3.6	Shal/ Clay
425.0	11.6	fine sand
7284.5	29.8	gravely sand

VES 8 AHIAEKE NDUME (UMUAHIA NORTH L.G.A.)

Resistivity (ohm. m)	Depth(m)	Description
92.0	1.2	Top soil
347.0	2.5	laterite/Sandy clay
268.0	7.4	Fine sand
732	12.3	gravely sand

VES 9 EHIMIRI (UMUAHIA NORTH L.G.A.)

Resistivity (ohm. m)	Depth(m)	Description
87.0	1.2	top soil
824.0	5.4	laterite/clay
530.0	13.6	gravely sand.
2160.0	21.8	Sandy soil

Table 2:Interpreted layer parameters from geoelectric soundings along Ikot Ekpene – umuahia road. {ρ resistivity in Ωm, h depth in (m) }.

VES No	Location	ρ1 h_1	ρ2 (Ohm-m) h2 (m)	ρ3 (Ohm-m) h3(m)	ρ4 (Ohm-m) h4 (m)	Curve type
1	Ariam	98 0.5	3640.0 2.3	1470.0 4.6	620 15.2	KQ
2	Awomuku	100.0 1.5	4620.0 2.8	296.0 32.7	6430.0 45.0	KH
3	Ogbubule	89.0 0.4	1276 2.6	182.0 13.7	746.0 16.0	KH
4	Ekebedi –Oboro	100.0 0.9	6800.0 7.4	2864.0 25.6	-- _	K
5	Okwe-Ukwu	94.6 0.7	6800.0 3.2	1080.0 6.6	178.0 4.3	KQ
6	Ndoro –Oboro	103 0.8	189.0 4.3	1438.0 13.5	7308.0 32.6	AA
7	Umudike	88.6 0.7	2354.4 3.6	425 11.6	7284.5 29.8	KH
8	Ahiaeke	92.0 1.2	347.0 2.5	268.0 7.4	732 12.3	KQ
9	Ehimiri	87.0 1.2	824.0 5.4	530.0 13.6	2160.0 21.8	KH

III. Result and Discussions

Location 1 : (Ariam VES I) . The failed portion of the road spans a lateral distance of 126m on a straight road. At that location, the top soil (shallow basement) on which the road pavement is founded bulges and cracks out and of a low resistivity of 98Ωm, at a depth of 0.4m to 2.3m. Four lithological layers made up of thick top soil, clay layer, weathered layer and faulted basement were delineated.

Location 2: **(Awomuku VES II).** Most segments of this profile is characterized by relatively low resistivity of about 100Ωm stretching a horizontal distance of 192m and observed to be of loamy topsoil/silty clay formation with a depth extent of 2.8m. Three subsurface layers were identified; top soil/overburden, clay and sandy soil.

Location3: (ogbubule oboro VES III). This location captures a formation with a low resistivity value of 89Ωm spread along a straight distance of 216m, from the surface to a depth of 16.0m. Depression, and longitudinal cracks as a result of poor construction materials were observed. Four geoelectric sections were identified. These include; agricultural soil, clayey soil/ shale, unsaturated zone and fine sand.

Location 4: (Ekebedi 1V). The failed portion of the road stretches through a distance of 82m with a low resistivity of100–Ωm at a depth of 7.4m . Buried stream channels, pot holes and collapse basement were identified within the failed segment. Four lithological layers made up of loamy top soil, clayey sand, laterite layer and medium grained sand were identified.

Location 5: (Okwe-ukwu OboroV). This segment is characteristic of thick and low resistive substratum of resistivity 94 .6Ωm at near depth 14.3m over a lateral undulating distance of 276m. Shallow valley, rut, cracks, gullies and potholes characterize the segment. Four lithological sections of loamy top soil, clay soil, loose sand and sandy soil were delineated.
Location 6: (Ndoro oboro V1).The failed segment covers a distance of 154m. Stream channels and cavities were identified in the area. Silty clay sand and laterite was evident on the road basement. Generally low resistivity values of ≻103Ωm about 83m were observed at a near depth of 4.3m from the surface. Four geoelectric sequences were interfaced from the geophysical survey. These includes loamy agriculture soil, clay, unsaturated layer and fine sand.
Location7: (Umudike VES 7). Profile 7 spreads over a distance of 66m adjacent the University (MOUAU) gate from the surface with a resistivity of 88.6Ωm. Weathered/fractured segments and cracked portions were prevalent. Four lithological sections comprising laterite, shale/clay and fine sand were delineated. The failed portion of the pavement has a layer with thickness varying from 0.7 – 29.8m (fig.2)
Location 8: (Ahiaeke NdumeV111). Beneath this formation, is a zone of low resistivity of 92Ω at a depth of variation of 1.2 to 12.3m stretching over a horizontal distance if 102m. Weathered and cracked substratum was observed. Four geo-electrical sections were delineated from the geophysical survey, they include; laterite, clay, silty sand and loose sand.

Location 9: (Ehimiri VES 9). This profile is made up of a zone with a low resistive substratum of 87Ωm to a depth of 5.4m from the surface. Ancient stream channels, shallow valley and drainage collapse as result of poor construction characterized the segment of this road. Four lithological layers; overburden top soil, laterite, clayey sand and sandy soils were delineated.
Curve frequency
In the nine locations considered, four group of curves(table 2) were delineated, which show high degree of variability of geologic units. The curve types are: KQ $(\rho_1 < \rho_2 > \rho_3 < \rho_4)$ with 44.5%; KQ $(\rho_1 < \rho_2 > \rho_3 > \rho_4)$ with 33.3% and K $(\rho_1 < \rho_2 > \rho_3)$ and AA $(\rho_1 < \rho_2 < \rho_3 < \rho_4)$ which respectively 11.1%. The spread is as given in Fig. 3. Generally, the knowledge of the resistivity values for different types of subsurface materials (table 1) and the geology of the study locations is significant in converting resistivity picture into geologic formations. Table 1 shows the geologic sections distributed along the different profiles chosen along the study area.

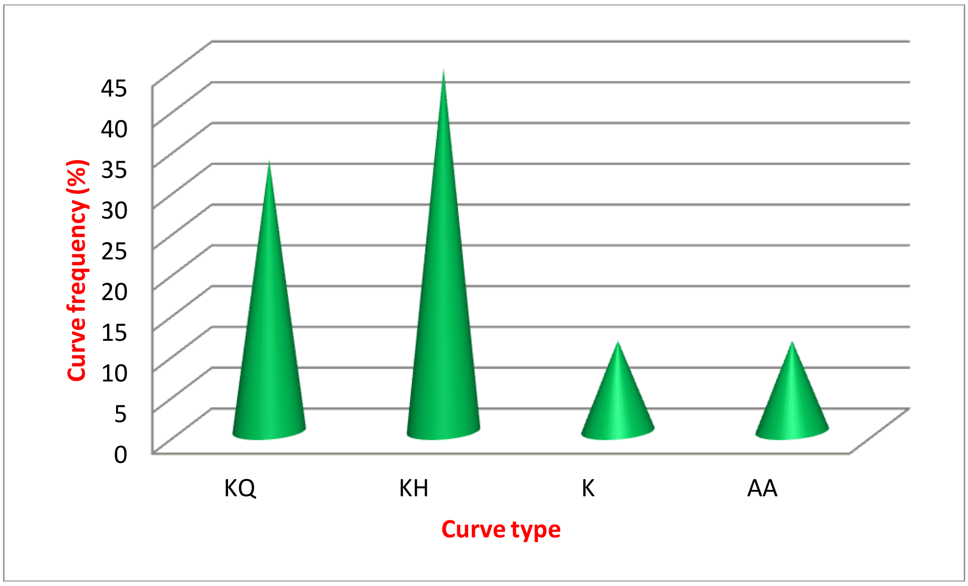

Figure 3: Significant curve type spread in the study area.

IV. Summary Of Findings

The geo-electric sequence obtained from the ves geophysical survey shows that the pavement segments of the road sits on a weathered/ porous basement near a thickly low resistive layer. It can be inferred that the cause of the continuous pavement failure along this federal road are;

- Shallow valleys and poor drainage of runoff due to undulated nature of the road and the topographic alterations.

- Low resistive subsurface of <100m, loamy top soil/overburden, clay/laterite basement causes pavement failure.
- Fractured basement, cracked/weathered depression an ancient stream lines which cause the road to absorb water, bulges out and depresses as a result of heady traffic stress.
- Poor construction and low grade construction materials used lead to quick collapse of the road pavement.

Reference

[1]. Adegoke - Anthony, W.C. and Agada, O.A. 1980. Geotechnical characteristics of some residual soils and their implications on road design in Nigeria. Technical Lecture. Lagos, Nigeria. P. 1 – 16.

[2]. Adeyemo, I.A. and Omosuyi, G.A. 2012. Geophysical Investigation of Road Pavement Instability along Akure Owo express way, South Western Nigeria. American Journal of Research. 3(4), P.191-197.

[3]. Agwae, G. O., Geology, geochemistry and industrial potentials of marble deposits in Igarra Area, Southwestern Nige- ria 2011.University of Nigeria Nsukka, An Unpublished M.Sc Thesis.

[4]. Aigbedion, I. 2007. Geophysical Investigation of Road Failure Using Electromagne-tic Profile along Opoji Uwelench and Illeh in Ekpoma, Nigeria.

[5]. Aigbedion, I., "Geological and geophysical evidence for the road failures in Edo state, Nigeria". *Environmental Geology*, 2007. Berlin, pp 101- 103

[6]. Ajayi, L.A. 1987. Thought on road failures in Nigeria. The Nigerian Engineer. 22 (1): P. 10 – 17.

[7]. American Association of State Highway and Transportation Officials (AASHTO), 1976. Manual for bridge maintenance.

[8]. Anambra State Ministry of Works and Housing (ANSMWH), 1998. "Seminar on Cost of Road Maintenance in Anambra State", June, 1998.

[9]. Burland, J.B. and Burbidge, M.C. 1981. Settlement of Foundations on Sand and Gravel. Proceedings of the Institution of Civil Engineers, 78(1), P. 1325- 138

[10]. Federal Ministry of Works and Housing(FMWH), 1992. Highway Road Maintenance Manual, part II.

[11]. Federal Ministry of Works and Housing(FMWH), 1995." Seminar on the Importance of Drainage System in All Nigerian Roads". Kano March, 1995.

[12]. Ibitomi, M.A., Fatoye, F.B. and Onsachi, J.M. 2014. Geophysical Investigation of Pavement Failure on a portion of Okene-Lokoja Highway, North Central Nigeria. Journal of Environment and Earth Science. 4(13), P. 44-50.

[13]. Igboekwe, M.U. and Udoinyang, I. E.(2011). Modelling the Transport of Suspended Particulate Matter by Kwa Ibo River, Umudike South eastern Nigeria: Implications for pollution dispersion. International Journal of Water Resources and Environmental Engineering, Vol.3(6), NO. 1 pp. 109-116.

[14]. Jain, S. S. and Kumar, P. 1998. Report on Causes of Cracks Occurrence in Ramghat - Aligarh Roadin U.P. Report Submitted to PWD, Aligarh.

[15]. John, H. and Gorden, H. 1976. A practical Guide to Earth Road Construction and Maintenance, Engineering Manual Vol. 2, No. 1. P. 43-45

[16]. Loke, M.H. and Barker, R.D. 1996a. Practical Techniques for 3D Resistivity Surveys and Data Inversion. Geophysical Prospecting, 44, P. 499- 523.

[17]. 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): P. 637-648.

[18]. Magnus Uzoma Igboekwe and Cyril Ngozi Nwankwo (2011). Geostatistical Correlation of Aquifer Potentials in Abia State, South-Eastern Nigeria. International Journal of Geosciences Vol. 2 pp. 541-548

[19]. Osinowo, O. O., Akanji, A.O. and 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): P.143– 162.

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