Electromagnetic Investigation into the Cause(s) of Road Failure along Takie-Ikoyi Road, Ogbomoso.

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Abstract

One of the problems Nigeria has is unreliable road networks which has cause several untimely death and damages beyond recognition to human life. Non-destructive geophysical method involving very low frequency electromagnetic profiling was used to investigate the cause(s) of failure that occurred in the road that was constructed in less than two (2) years. Very low frequency electromagnetic profiling data were taken at 10 m interstation spacing along 2 traverses (the dual lane constructed there). KHFILT software was used for the processing of the data obtained. Conducting bodies which indicate clayey materials or linear geologic features such as faults, fractures, joints, and contact between two rocks were inferred from the interpretation. It was concluded that the road was probably constructed on clayey materials which was supposed to be excavated and refilled with laterites. From another angle, it was viewed that may be the engineers intentionally filled the sub-base with clayey materials during construction in order to get their financial returns which the masses are now paying for.

Keywords: Conducting materials, Electromagnetic Prospecting, Geologic Features, Road Failure, Sub-base.

Introduction

Road can be defined as a wide way leading from one place to another, especially one with a specially prepared surface that vehicles can use. Major roads in Nigeria are known to fail shortly after construction and well before their design age. Poor construction materials, bad design, usage factor, poor drainage network are some of the factors considered as responsible for these failures. Geological factors are rarely considered as precipitators of road failure even though the road is founded on the geology. In some cases, ‘road’ is been termed as ‘pavement’. A pavement section may be generally defined as the structural material placed above a sub-grade layer. In asphaltic pavement, it is typically a multi-layered system comprising the sub-grade (support), sub-base, base course and surfacing. Its principal function is to receive load from the traffic and transmits it through the layers to sub-grade (Adams and Adetoro, 2014).

A pavement is said to be defective, when it can no longer perform this function during its design life. Most roads in Nigerian cities today are characterized by failure of all kinds like potholes, cracks, depression, ruts and bulges on our roads which have adverse effect on both vehicles and passengers. Many have met their untimely death by plying through these failed roads.Studies of past road failures showed some major causes; usage, poor design and construction problems (Levik, 2002), use of substandard material for road construction (Momoh et al., 2008), bedrock depressions (Adeyemo and Omosuyi, 2012), presence of undetected linear features, such as fractures and rock boundaries (Akintorinwa et al., 2010), and construction of roads on weathered layer (Ibitomi et al., 2014).

The present study is carried out to unravel the cause of road failure along Takie-Ikoyi road, Ogbomoso, Southwestern Nigeria. The road that was constructed in less than 2 years ago has presently been abandoned due to its deterioration. Non-destructive, environmental friendly, cost effective, and efficient geophysical technique: Very low frequency-electromagnetic method was used to carry out this research.

Location and Geology of the Study Area.

Takie-Ikoyi road is located at the heart of Ogbomoso, a major link between Oyo and Ilorin. This road serves as major route for heavy vehicles travelling from Northern part to the Southwestern part of Nigeria and vice-versa. The area under study covers about 300 m long (figure 1) and lies between latitude 08^0 08.180^1 to 08^0 08.336^1 N and longitude 004^0 14.162^1 to 004^0 14.250^1 E.

Ogbomoso is underlain by rocks of the Precambrian complex. The rock formations in the study area are supracrustals and intracrustals rocks (figure 2). The rock groups in the area include quartzites and gneisses (Ajibade et al., 1988). Schistose quartzites with micaceous minerals alternating with quartzo-feldsparthic ones are also experienced in the area. The gneisses are the most dominant rock type. They occur as granite gneisses and banded gneisses with coarse to medium grained texture but the main rock types especially in the study area is granite gneisses.

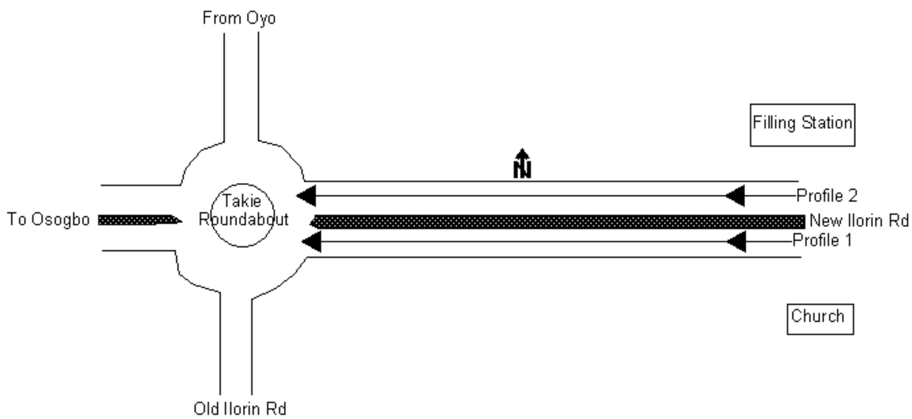

Figure 1: Base map of the study area.

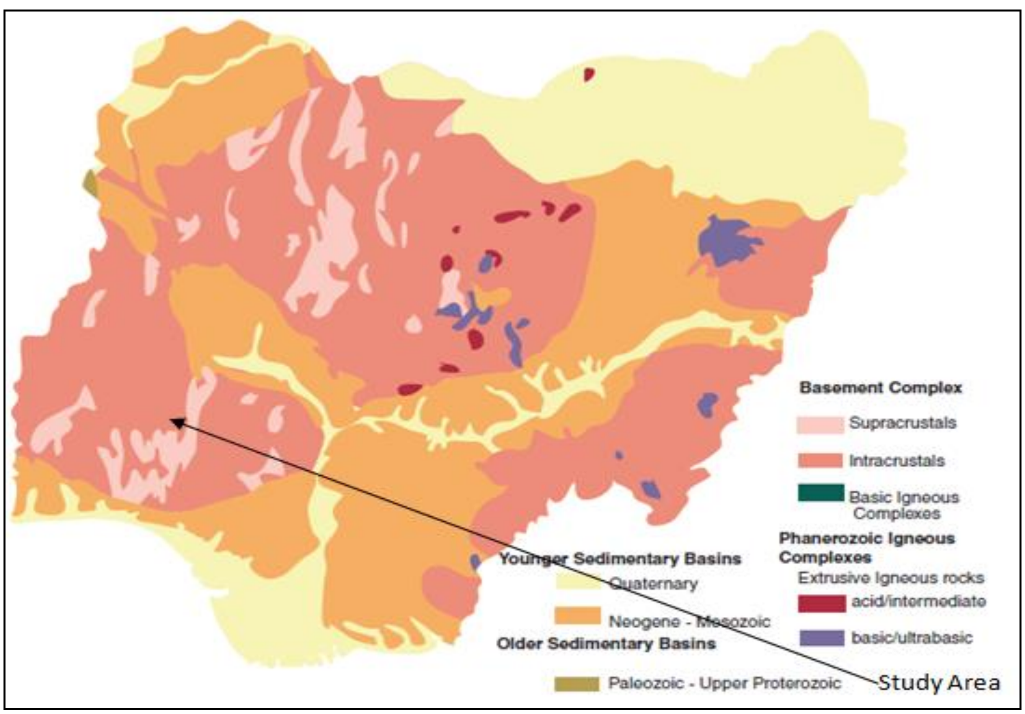

Figure 2: The geological map of Nigeria showing the study area.

Basic Principless of VLF

VLF surveying involves measurement of the earth's response to EM waves generated by transmitters at remote distance from the survey site through current induction. Ground VLF survey provides a quick and powerful tool for the study of geological structures to a maximum skin depth of about 100 m (Fischer et al., 1983) though variation in the skin depth is based on changes in subsurface conductivity. Since induction flow results from the magnetic component of the electromagnetic field, physical contact of the transmitter and receiver with the ground is unnecessary, as a result, ground VLF survey requires only one operator for measuring the EM response and is faster than electrical surveys. Furthermore, airborne VLF surveys are possible.

The VLF-EM prospecting is fundamentally based on EM wave impedance (the ratio of the electric field to the magnetic field, E/H) over 2-D geologic structures using the boundary conditions forced on the electric and magnetic fields when an EM wave propagating through air interacts with the earth's surface. The behavior of EM fields at any frequency is concisely depicted by the Maxwell’s equations as formulated utilizing the geometry of Figure 3, with the x-axis as the strike direction, and the z-axis positive downwards, describing the interaction between the vector functions of an EM field.

Taking into account the constitutive relations between magnetic induction and magnetic field intensity, and between electric current density and electric field for 2-D earth structures,

$$\nabla \times E = -\frac{\partial B}{\partial t} \quad (1)$$

$$\nabla \times H = \sigma E \quad (2)$$

Where

E = Electrical field intensity (in volts per meter, V/m),

H = Magnetic field intensity (in ampere-turns per meter, A/m),

B = μ H is the magnetic induction (in Tesla, T), and

σ = Electrical conductivity (in Siemens per meter, S/m).

Therefore,

$$\nabla \times H = J = \sigma E \quad (3)$$

The optimal configuration of the survey is to have the orientation of the geologic strike parallel to the direction of the transmitter so that a vertical magnetic component is generated for any electrical conductivity variation by the propagating horizontal and concentric magnetic field and the orthogonal electrical field (figure 3). This response is a powerful tool for study of variety of different geologic targets. The method also requires detection and incessant use of a precise transmitter with stable and sufficiently strong VLF signal for the entire survey. In figure 3, σ = Conductivity, H_P = Primary Magnetic Field, H_Z = Secondary Magnetic Field, E_P = Primary Electrical Field, and E_Z = Secondary Electrical Field.

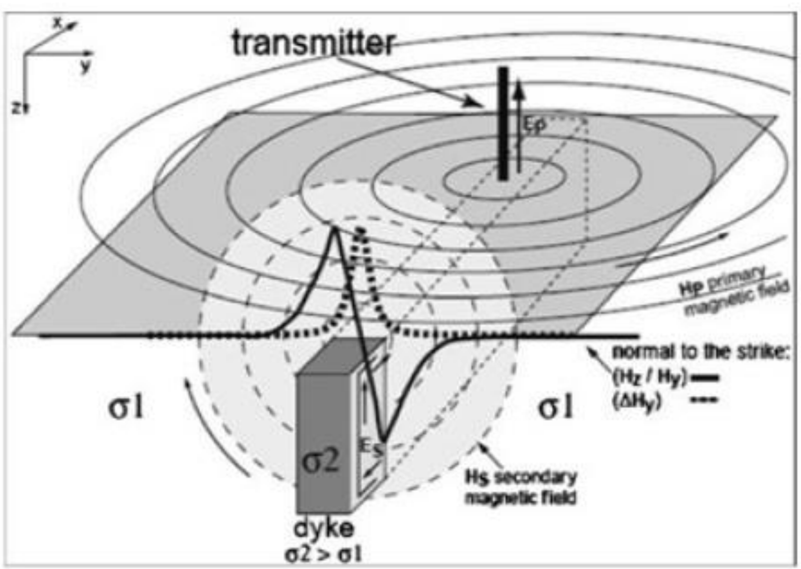

Figure 3: Components of VLF Field from Transmitter at Remote Distance (Ezepue, 1984).

Materials and Methods

Very low frequency electromagnetic (VLF-EM) method was used on 2 traverses along the road where each traverse covers a total length of 300 m each (figure 1). VLF-EM measurements were taken at 10 m interval along each traverse with ABEM Wadi portable VLF-EM surveying equipment (plate 1).

This equipment makes no contact with the ground, but utilizes very low frequency band of 15–30 kHz with a fixed transmitter measuring the raw and filtered real components of the vertical to horizontal magnetic field ration (Karous and Hjelt, 1983). The raw and filtered real values (%) are plotted against station positions (m) using Microsoft Excel while the 2-D pseudosection map is obtained by using 'KHFILT' software. Global Positioning System (GPS), Compass, measuring tape of 50 m long, and photographs (plate 2) were all used in order to achieve the aim of the study.

Plate 1: The VLF-EM equipment

Plate 2: Snapshot of some stable and deteriorated portion of the study area.

Results and Discussion

The results of the processed Very Low Frequency Electromagnetic profiling data were presented as VLF-EM profile and 2–D VLF-EM pseudosection. In order to aid good comparism between the two processing techniques used, VLF-EM pseudosection map was placed directly under VLF-EM graph of the same profile. Figure 4a and figure 4b show the corresponding results of the profiling and pseudosection analysis for profile 1 while figure 5a and figure 5b show the corresponding results of the profiling and pseudosection analysis for profile 2 respectively.

The VLF-EM raw real data have been converted to the pseudosection using the KHfilter software. The visual inspection of this section allows depth of occurrence, width, and dip of the body to be determined. Figures 4b and 5b are typical VLF-EM pseudosections obtained on the traverses. From the figures, the attitude of the body, the length of fractures and depth to top and bottom of fractures can be determined. The occurrence of the fractures on the sections coincides with the delineated fractures obtained on the profiles using Microsoft Excel.

Figure 4b shows the corresponding K-H pseudosection of profile 1. Conductivity is relatively high throughout the profile but some are extremely high. The pseudosection is a measure of conductivity of the subsurface as a function of depth. The conductivity is shown as colour codes with conductivity increasing from left to right (i.e. from negative to positive). Different features of varying degree of conductivity trending in different directions were delineated on the section, for instance, from stations 70 m to 95 m and 120 to 145 m, a dome-like highly conductive body trending in W – E direction is shown. The depths of this conductive body extend up to 50 m. A conductive body at depth of 20 m to 35 m is also noticed beneath stations 196 m to 212 m. This cannot cause road failure due to the depth of investigation. Conductive body towards the surface (from station 35 m to 45 m, 70 m to 95 m, 120 m to 145 m, and 188 m to 200 m) are expected to be excavated and refilled with laterites before the construction began but unfortunately, these zones of weathered layer (clay) were ignored. These zones are the areas that will later fail though some still look stable as at the time of geophysical field survey.

In figure 5b, different features of varying degree of highly conductive zones were delineated on the section, for instance, from stations 12 m to 40 m, 112 m to 162 m, 187 m to 195 m, and 205 to 218 m show highly conductive body. Pocket of conductive body noticed from station 112 m to 162 m, and 187 m to 195 m extend to the depth of 50 m. The two profiles show extension of weathered layer (clay) from station 120 m to 145 m (on profile 1) and 112 m to 162 m (on profile 2) respectively. For the purpose of road construction, these weathered zones (clay) needed to be excavated and refilled with laterites before the road was constructed but it seemed this precaution was not taken into consideration before the construction started.

Generally, apart from the highly conductive zones indicated on 2-D pseudosections, the subsurface conductivity is relatively high. This means that the geology of the study area doesn’t favour road construction initially.

However, the plot of Raw Real and Filtered Real plotted against station distances are shown as profile (figure 4a and figure 4b). The interpretation of these profiles are mere qualitative and this involves visual inspection of the profile for points where the maximum peak of the Filtered Real coincides with the point of inflections of raw real as such points are usually suggestive of presence of conductive (weak) zones. One of merits of using this interpretation technique is that the filtered real plot is better used to identify real anomalies, while the raw real plot is better used to identify anomaly positions (Reynolds, 1997). Several of such points were identified on the profiles. Furthermore, the presence of multiple peak Positive filtered real anomalies (as observed on the profiles) is suggestive of inhomogeneity of near surface material.

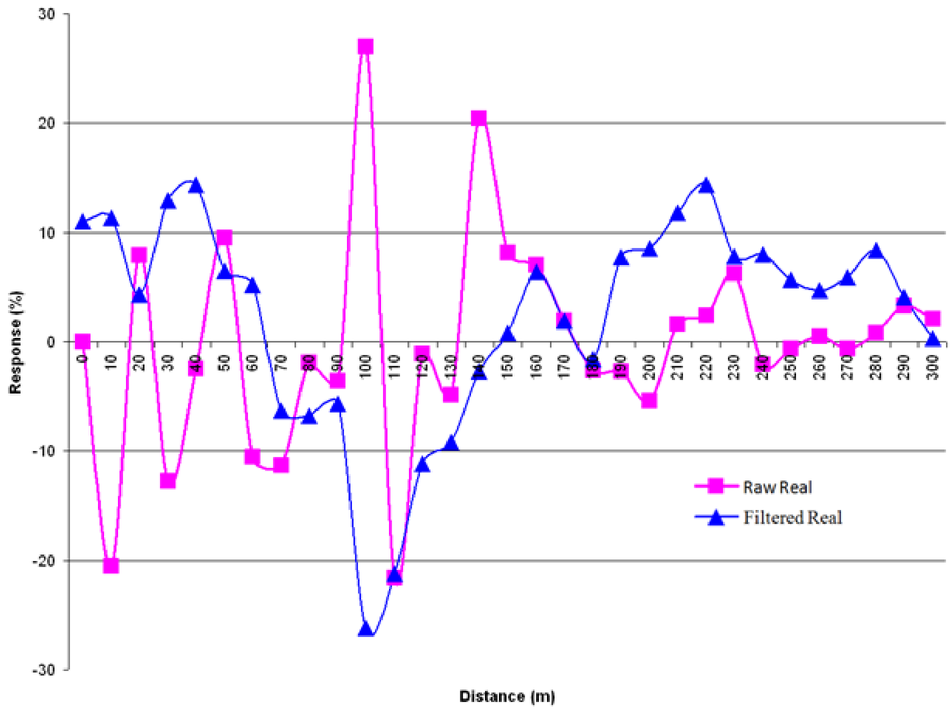

Figure 4a: VLF-EM profile along traverse 1.

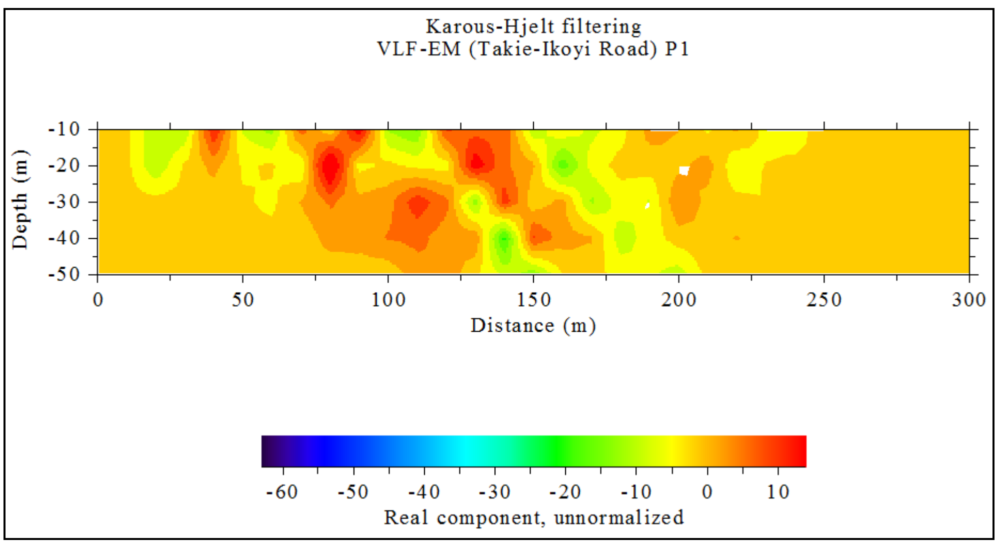

Figure 4b: 2-D pseudosection of traverse 1.

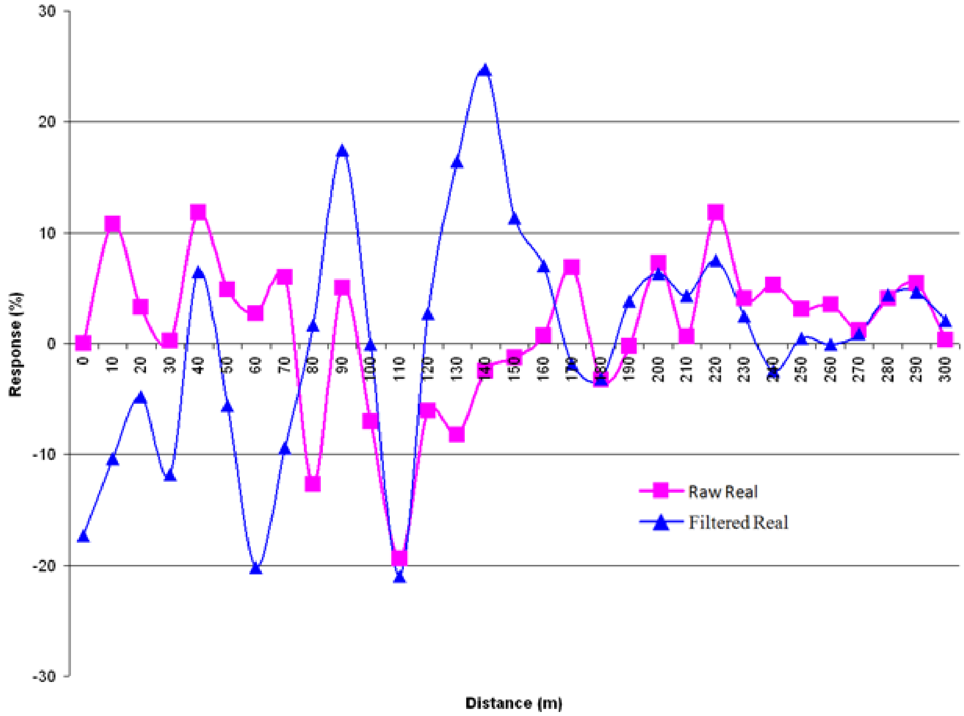

Figure 5a: VLF-EM profile along traverse 2.

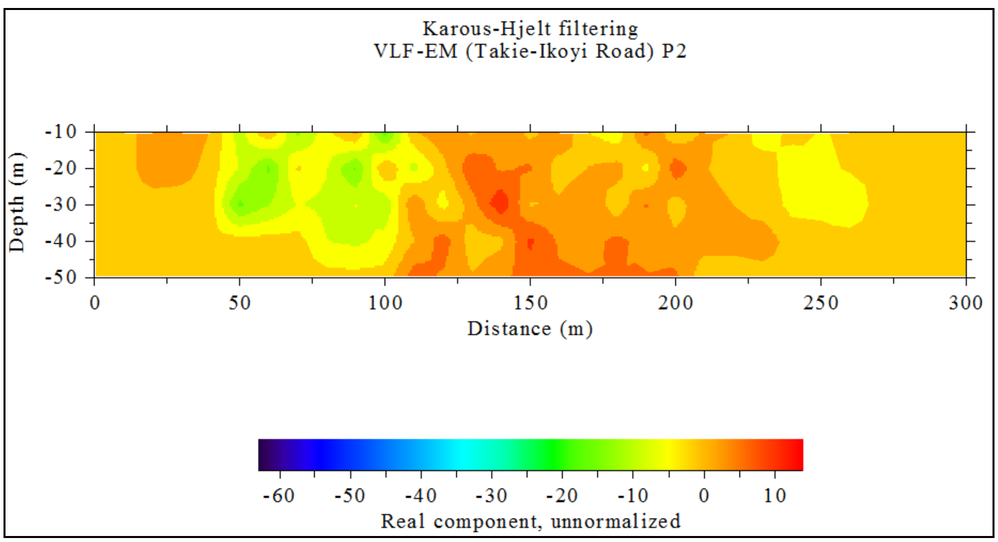

Figure 5b: 2-D pseudosection of traverse 2.

Conclusion

A passive method, cost effective and efficient very low frequency electromagnetic (VLF-EM) geophysical prospecting technique had been used to investigate the causes of failure along Takie-Ikoyi road, Ogbomoso, Southwestern Nigeria. The result obtained revealed anomalously high current density which could be indicative of clayey material or linear geological features such as faults, fractures, joints and lithological contacts. This clay has the ability of absorbing water which makes them swell and fail under the action of stress (movement of heavy vehicles) as Ogbomoso-Ilorin road is one of the major roads linking Southwestern to Northern part of Nigeria. However, another geophysical technique such as electrical resistivity is recommended to confirm the predictions in the study area.

References

Adams, J.O. and Adetoro, A.E. (2014). Analysis of Road Pavement Failure caused by soil Properties along Ado-Ekiti Road, Nigeria. *International Journal of Novel Research in Engineering and Applied Sciences*. 1(1), 1-7.

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), 191-197.

Ajibade, A.C., Rahaman, M.A. and Ogezi, A.E.O. 1988. The Precambrian of Nigeria, a Geochronological Survey. *Publication of the Geological Survey of Nigeria*.

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

Ezepue, M. C. (1984). The Geologic Setting of Lead-Zinc Deposits at Ishiagu, Southeastern Nigeria. *Jour. of Afri. Earth Sci*. 2, 97-101.

Fischer, G., Le Quang, B.V. and Muller, I. (1983). VLF Ground Surveys, a Powerful Tool for the Study of Shallow 2-D Structures. *Geophys.Prosp*. 31, 977-991.

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), 44-50.

Karous, M. and Hjelt, S.E. (1983). Linear filtering of VLF Dip-angle measurements. *Geophysical Prospecting*. 31, 782–794.

Levik Kjell (2002). How to sell the message ‘Road maintenance is necessary’ to decision makers. Published by the *Norwegian public road administration*. 1-4.

Momoh, L. O., Akintorinwa, O. and 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.