GEOPHYSICAL INVESTIGATION FOR ROAD PAVEMENT FAILURES ON NEW EKU ROAD SAPELE, DELTA STATE, SOUTHERN NIGERIA

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ABSTRACT

Road transportation greatly enhances the economic growth of a country, especially developing countries like Nigeria where other forms of transportation are still underdeveloped. However, the deplorable state of roads and the rampant road failures has caused amongst other things, road accidents leading to the loss of valuable properties and even human lives. This study employs geophysical investigation into road pavement failures along New Eku road, Sapele, Delta State, Nigeria, to determine the nature and integrity of the subsurface beneath which the road pavement lies. The two-dimensional electrical resistivity tomography (ERT) method involving the Wenner-Schlumberger configuration was used on three (3) different failed sections of the road covering a distance of approximately 70m. Three (3) profiles, each parallel to the failed sections of the road pavements were established. Data sets were collected using the Petro Zenith Earth Resistivity meter. The observed resistivity data from the field measurements were processed and then inverted with the aid of an electrical resistivity interpretation software (RES2DINV). The results show low resistivity values typical of, and suspected to be expansive clay and clayey materials at different portions of each profile. In profile 1, resistivity values of less than 30.5Ωm to about 130Ωm was observed down to a depth of about 13.4m from the top soil, while resistivity values ranging from 47.7Ωm to 128Ωm and 7.94Ωm to 45Ωm were observed in profiles 2 and 3 respectively. These values indicates that the presence of unsuitable road pavement subgrade possibly clayey soil, which expands and contracts under varying weather conditions, could be mostly responsible for the road pavement failures in the study area.

Keywords: 2D Electrical resistivity tomography, Wenner-Schlumberger, Road pavement failure.

INTRODUCTION

The need for good and durable roads for transportation across the towns and cities of Nigeria has been a major desire of her citizens. Particularly because the economic development of a country is closely related to the quality or state of the road networks within the country. For Instance, in the Niger Delta region Southern Nigeria, there is a great demand for the development of good road network amongst other things. In order to meet this demand, and for the very obvious fact that road transportation in Nigeria is by far the most popular form of transportation and thus enhances economic and social development of the country, the Nigerian government through the relevant agencies, have embarked on several road construction and maintenance projects to ensure smooth vehicular movement. Unfortunately, most of these roads and highways are seen to go bad or deteriorate shortly after construction without reaching their expected serviceability age. They usually display a lot of features including haunching, pitting, rutting, waviness etc. which may develop into cracks, potholes, bulges and depression (Adeyemi, 1992; Adeleye, 2005). Although, in most parts of Nigeria, it is a common phenomenon to have failed roads (Oladapo *et al*, 2008), the consequent daily loss of human lives and economically significant properties (Peter *et al*, 2018), should cause the Nigerian government and its citizens to take road failure as an alarming and very serious matter.

Some of the factors often considered responsible for the deterioration and eventual failure of roads include initial design and construction practice, traffic loading on the road, inadequate drainage networks, poor maintenance culture etc. Amazingly, factors relating to the geology of a place are seldom regarded as contributors to the failure problems seen on our roads, despite the fact that the road pavement lies on the surface of the earth. For proper design and construction of lasting and durable roads, a thorough investigation using geophysical methods should be carried out on any proposed site to determine and obtain adequate knowledge and information of the subsurface conditions, before the commencement of any construction work. The negligence of this has brought about the continuous failures of several roads, travel routes and some monumental structures in Nigeria (Olorunfemi *et al*, 2000a; Olorunfemi *et al*, 2000b Olorunfemi *et al*, 2005).

The relevance of geophysics in the investigation of highway failure problems has been proven in most recent years (Nelson and Haigh, 1990). Geophysical surveys feature efficiency and reduced cost in providing information of the subsurface, because of its high speed together with considerable accuracy in supplying subsurface information. In particular, two-dimensional Electrical Resistivity Imaging (ERI) surveys, presents to the highest degree a very practical and economic method that provides accurate results at very reduced costs of survey (Dahlin, 1996).

Considering the efforts of the Federal and the various State Governments through their various agencies such as the Federal Road Maintenance Agency (FERMA) now Federal Road Agency (FRA), to repair failed portions of roads across the country, the causes of this incessant and rampant road and road pavement failures must be investigated, in order to forestall future occurrence and avoid continuous waste of the countries limited resources. It is therefore important that a geophysical investigation (survey) be conducted before and after construction on a road to ascertain the integrity and suitability of its base materials.

In this study therefore, the two-dimensional (2-D) electrical resistivity tomography (ERT) or electrical resistivity Imaging (ERI) survey using the Wenner-Schlumberger array was conducted, with a view to examine the conditions and state of the subsurface beneath the road pavements along selected failed portions on the New EkuRoad in Sapele area of Delta State, Southern Nigeria.

STUDY AREA

New Eku Road is located in Amukpe town of Sapele Local government area of Delta State, Southern Nigeria. It is part of the Niger Delta formation. It is therefore characterised by the geology of the Niger Delta in which three major sedimentary cycles have occurred since the early Cretaceous. The sub-surface stratigraphic units associated with the cycles are the formation which consists of loose and unconsolidated sand, the Agbada formation which consists of sandstone and shales and this is underlain by the Akata Formations (Kogbe, 1976).

It lies roughly within latitude $05.642.14^0$N, longitude $05.722.61^0$E to latitude $05.711.36^0$N, longitude $05.781.16^0$E. As at the time of carrying out this research the road was in a deplorable state.

Plate 1: Photoshot of failed portions along New Eku Road, Sapele, Delta State, Nigeria

MATERIALS AND METHODS

Field investigation for the study was conducted on three (3) different failed sections of the road, thereby establishing three (3) profiles, each parallel to the failed sections of the road pavements. The geophysical investigation method used was the two-dimensional electrical resistivity imaging applying the Wenner-Schlumberger configuration. A minimum electrode spacing of 5metres (5m) was used for each of the profile with a total length of 70m surveyed for each profile due to available space and the unavoidable vehicular (traffic) obstructions.

The materials used for collecting field data includes the Petro-Zenith earth resistivity meter (popularly called a Terrameter), metal electrodes, cable reels, hammers, measuring tapes, global positioning satellite (GPS) and writing pads.

In a typical electrical resistivity survey, as was the case for this study, current is introduced into the ground through two electrodes C_1 and C_2 and the potential drop is measured across two other electrodes P_1 and P_2. The Wenner-Schlumberger array used for this study has a spacing rule which is constant with a factor "n" and the electrodes arranged in the order C_1, $P_{1,}$ P_2 and $C_{2,}$ as shown in Figure 1.

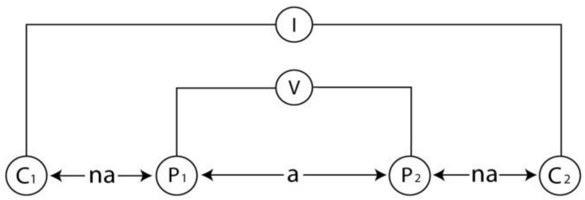

Figure 1: The electrode setting of Wenner-Schlumberger configuration electrode

A series of measurements were taken throughout the profile length with the electrodes equally spaced at an interval of **a** = 5m and the spacing factor **n** = 1. Subsequent measurements were taken in the same pattern and procedure as the first. In each case, the spacing between C_1-P_1 and P_2-C_2 was increased to 2**a**, 3**a**, 4**a**, and so on, while the spacing between P_1-P_2 remained constant at **a** = 5m (that is, n = 2 for the 2^{nd} series of measurements, n = 3 for the 3^{rd} series of measurements and so on). From the several measurements taken, it was then possible to generate a series of data which were recorded in a data sheet or writing pad and thereafter inputted into a computer for computerized inversion and processing with the RES2DINV software. The data processing and inversion is done to obtain a pseudo-section/images (figure 2-4) of the subsurface under investigation. These 2D resistivity images (pseudo-section) gives an approximate picture of the subsurface characteristics, which then becomes easy interpret.

After the data processing, qualitative interpretation was performed by correlating the data processing with basic knowledge of the apparent resistivity of rocks and minerals and geological conditions of the study area.

RESULTS

The following are the results of the processed and interpreted 2D electrical resistivity measurements obtained from the field work and are presented in form of Pseudo-sections which gives an approximate picture of the subsurface characteristics. These images and apparent resistivity range gotten were studied and used for a detailed exposition/interpretation of the different profiles.

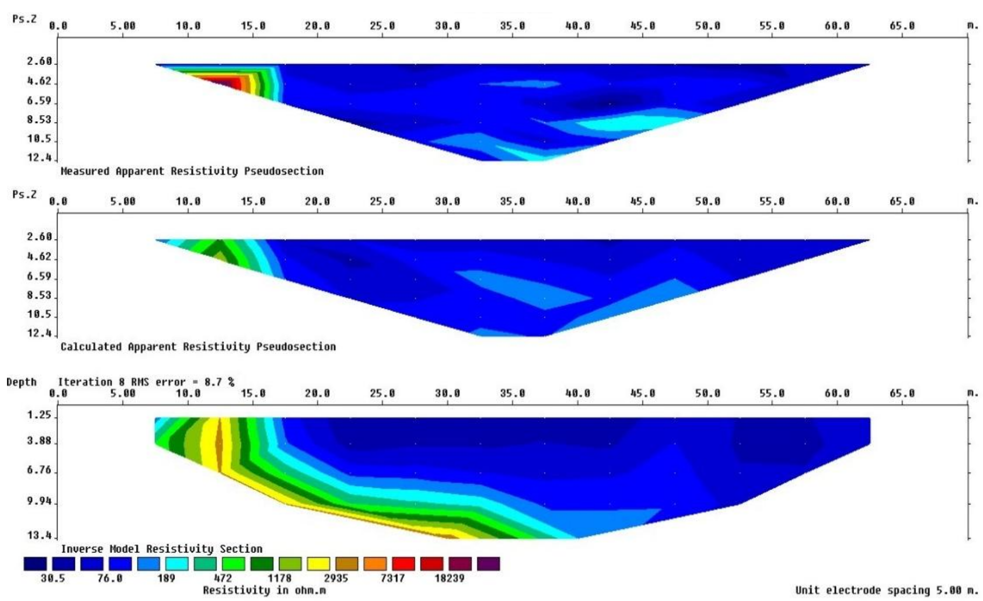

Figure 2: Pseudo-section plots showing the measured apparent resistivity, calculated apparent resistivity and inverse model resistivity section of profile 1

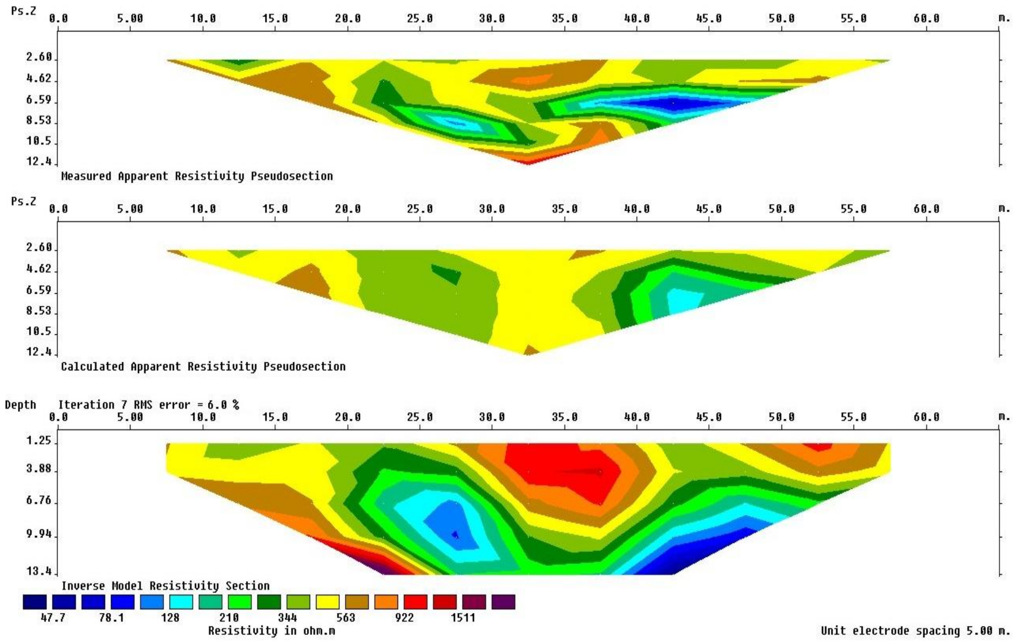

Figure 3: Pseudo-section plots showing the measured apparent resistivity of profile, calculated apparent resistivity and Inverse model resistivity section of profile 2

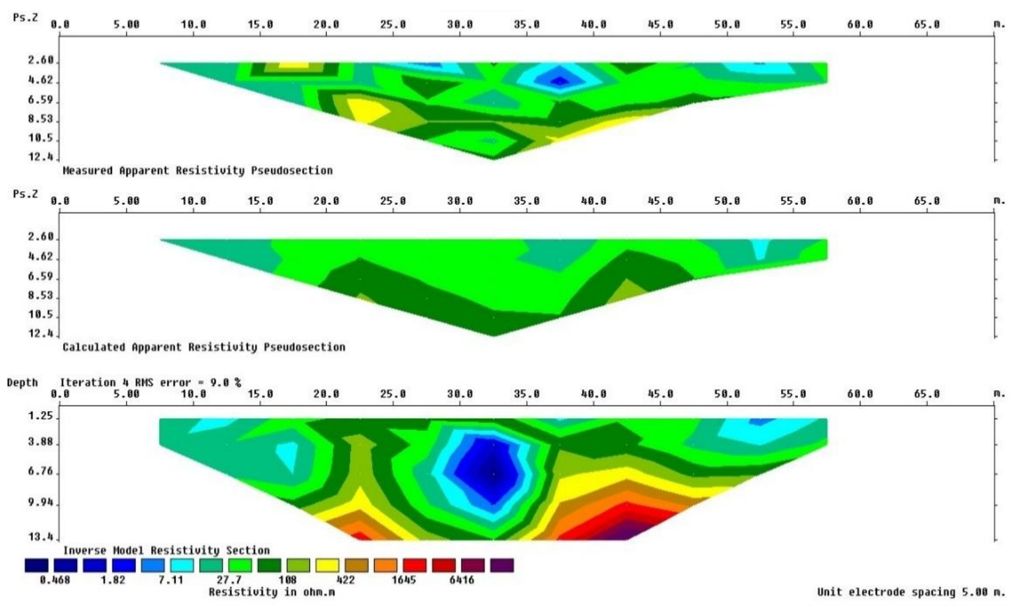

Figure 4: Pseudo-section plots showing the measured apparent resistivity, calculated apparent resistivity and inverse model resistivity section of profile 3

DISCUSSIONS

The inverse resistivity model revealing resistivity sections is shown on figure 2. It is characterized by low resistivity starting from less than 30.5Ωm-130Ωm which is seen throughout the profile length, particularly at distance 17m-60m to depths of 13.4m beneath the surface. The inversion has clearly shown that the entire area clearly depicts areas of low resistivity which could possibly be the cause of the road failure due to its suspected clayey nature. This very road section is one of the areas where the damaged road showed clear evidence of the suspected clayey soil as seen in Plate 1.

The inverse resistivity model revealing resistivity sections is depicted in Figure 3. This profile reveals an intercalation (insertion) of very low resistivity clayey subgrade with values ranging from 47.7Ωm-128Ωm and water absorbing substratum clastic rock types at an appreciable depth of about 6m downwards at the 20m-30m length of the profile and subsequently cuts across the base of the profile length. These low resistivity rock types were inferred to be sandstone, clay and clayey sands.

The inverse resistivity model revealing resistivity sections on Figure 4.It shows that there is a fair distribution of moderately high resistive rock types an average depth of about 9m and below. There is also water absorbing clastic rock types cutting across the whole profile length and forming the upper layer of the profile. Distinctive zones with low resistivity values ranging from 7.94Ωm-45Ωm are seen at a distance between 22m-35m and 50-58m to a depth of 7m and 9.94m respectively from the top soil. The absorption of surface water by these low resistive rocks could possibly be a reason why there is failure at this very portion since there is no competent or resistive rock to compensate for the weight of the vehicles plying this road.

Delta State during rainy season are very wet with high precipitation rate. Thus, during this period subsurface clay remains much more humid through ingress of surface water. Contextually, the detected anomaly is expected to exhibit much lower resistivity compared to the surrounding geology. However, the clay, due to its low plasticity, granularity and porosity, is only slowly moistened compared to the surrounding soil types and thus appears highly conductive. Therefore, the low Resistivity behaviour of the clay and the surrounding rocks agrees with the measured resistivity and the literature (Butler and Knight 1998, Soupios, 2007).

CONCLUSION

Geophysical investigation involving the Wenner-Schlumberger electrical resistivity tomography (Imaging) was carried out along New Eku Road so as to examine the nature of the subsurface and its relation to the road pavement failures in the study area.

The study has shown and re-validated the fact that Electrical resistivity tomography (or Imaging) is a very significant tool for the investigation of road, buildings and other engineering structures, since resistivity values have a wide range (Reynolds, 1997) which makes it possible to make a distinction between the different geologic materials.

In profiles 1, 2 and 3, the road pavements were underlain with materials having low resistivity values ranging from an average of 28.7Ω.m-101.0Ω.m (indicating the possible presence of expansive clay) with the clay layer making it to the surface at some points. Whereas, the subsurface soil below a functional road pavement is required to have adequate strength so it can support the weight of vehicles without collapsing, these clay materials are unsuitable as subgrade materials for road pavements and cannot be described as competent road pavement foundation materials. Though it is extremely porous, it is less permeable due to the poor interlink of its pores, it will therefore expand and retain water easily but will collapse if exposed to sufficient pressure from the weight of vehicles. This repeated expansion and collapse is inimical to road construction and will eventually lead to road failure. It is therefore clear from this study that, a possible cause of road failure in the study area is the presence of clay and clayey soil on which the road pavement is constructed. Although, other parameters like inadequate drain systems, improper care and maintenance, thin pavement coating and poor construction materials used, may also have contributed to the failure of the roads but these are outside the scope of this study.

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