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EFFECTS OF NEAR SUBSURFACE STRUCTURES IN POST LINEAR STUDIES: A CASE STUDY OF SOME EXISTING ROADS IN EKPOMA, THE ADMINISTRATIVE HEADQUARTERS OF ESAN-WEST LOCAL GOVERNMENT AREA OF EDO STATE

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ABSTRACT
Shallow 2-D Post-linear studies of the Electrical resistivity and induced Polarization imaging were conducted on three existing roads of approximately 100m, 60m and 60m profiles respectively, in Ekpoma, initiated with a short protocol (DIPDIP4S): 2-Channel Dipole-dipole array CVES with 2 electrode cables, otherwise called the Dipole-dipole configuration, to produce models of the subsurface revealing horizontal and vertical geological variations as precipitators of its failures by using the ABEM SAS 4000 Terrameter and the Multiple-Electrode Selector (ES46-10C) along with the accessories. The data obtained were subjected to the .S4k, ERIGRAPH and RES2DINV software. A conventional iterative smoothness constrained Least-squares inversion technique using the modified Guass-Newton equation (suitable for geological formations of thick transitional weathered rocks with no sharp boundaries) was used and most of the different parameters were set to default. From the resulting tomograms, various rock types were delineated based on their resistivity and chargeability values, as well as linear geological features and low resistivity, clayey sub-grade soil and water absorbing substrata inimical to road pavements.

Keywords: Post-foundation, suburbs, inversion, Gauss-Newton, Ekpoma

INTRODUCTION

The use of geophysical methods as primary tools for investigation of the subsurface is applicable to a wide range of problems (Finkl, 2008). Despite the application of the Electrical resistivity method amongst others in prospecting for natural resources, the method is also used for example as an aid to geological surveying, as means of deriving information on the earth's internal physical properties and in engineering or archeological site investigations. Consequently, geophysical exploration is of importance not only to geophysicists but also to geologists, physicists, engineers and archaeologists (kearey *et al*, 2002). All civil engineering structures such as buildings, roads, dams, amongst others are founded on earth materials (soils/rocks). Therefore, one of the priority considerations in the design of such structures is the pre-construction investigation of the subsurface at the proposed site in order to ascertain the fitness of the earth materials. Even after construction, some structures require post-construction monitoring to ensure their integrity. To this end, geophysical methods, besides geotechnical approaches, are routinely used. However, the objectives of this particular study were to identify any subsurface structures such as faults, joints and fracture zones; as well as low resistivity, water absorbing substratum or substrata inimical to pre-existing foundation structures in the location specified. Aigbedion (2007), and Ebhohimen and Mamah (2014) conducted researches in some suburbs of the town and identified clay, and horizontal and vertical geological discontinuities, respectively, as the major causes of the roads investigated. Similar works were carried out by Adelusi and Adiat (2001), Oladapo *et al*. (2008) Salufu and Ujuanbi (2015), and Lateef and Adegoke (2011)

STUDY AREA

Ekpoma is the administrative headquarters of Esan West Local Government area of Edo State and the various campuses of the Ambrose Alli University are located in the town. Geologically, the area falls within the Anambra Basin. According to report by Salufu and Ujuanbi (2015), geological and stratigraphical studies of the area identified three major formations: Imo Shale, Bende-Ameki formation, and Ogwashi-Asaba formation, to have underlain the area. Three roads were surveyed, namely: Ujoelen road by Zonnes Fast Food of orientation N45°E and co-ordinates: N 06° 44′ 28.5″, E 006° 07′ 36.7″ to N 06° 44′ 28.4″, E 006° 07′ 40.4″; Momoh street by Omic Water Factory of orientation S20°W and co-ordinates: N 06° 44′ 26.1″, E 006° 07′ 51.3″ to N 06° 44′ 24.3″, E 006° 07′ 53.1″; and Royal market Road by Ukhun junction of orientation S60°E and co-ordinates: N 06° 44′ 33.8″, E 006° 08′ 45.1″ to N 06° 44′ 33.9″, E 006° 08′ 48.6″. The area is generally low-lying and experiences both the wet and dry seasons. The vegetation is of the forest belt and agriculture is the mainstay of the rural dwellers, whose main produce are cassava, vegetables, banana, plantain, rice, maize, varieties of citrus fruits and pineapples (Edo State Investment Guide, 2012).

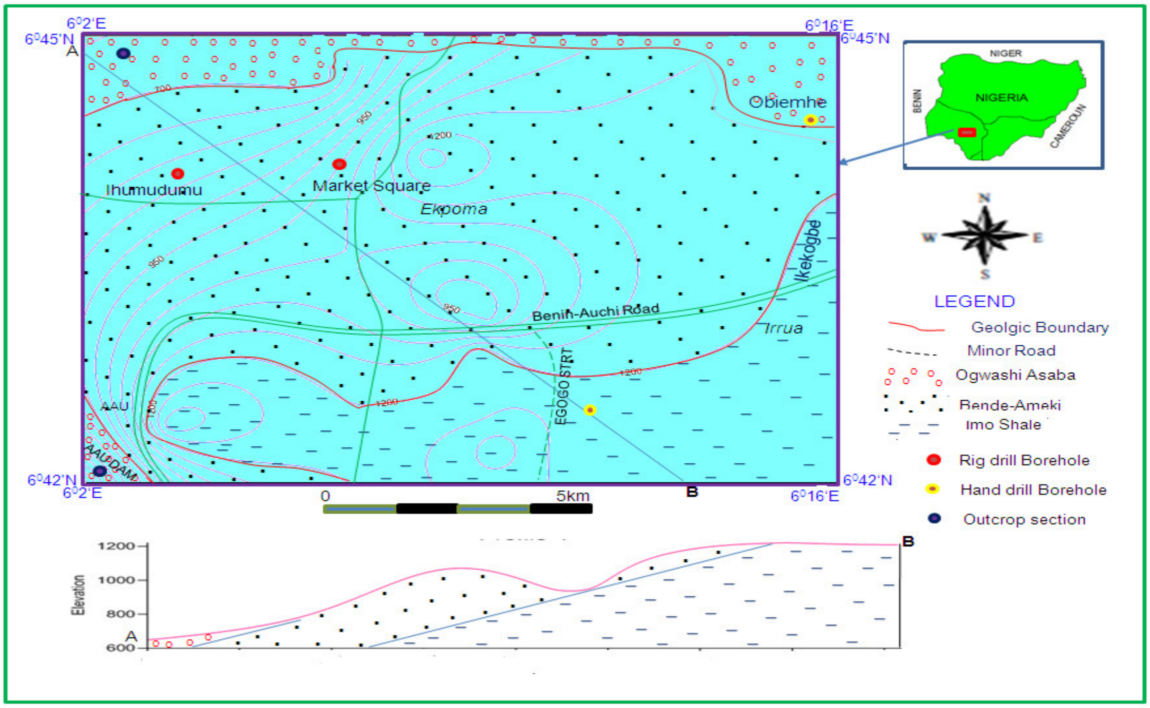

Fig.1: The Geology Map of the study area (Salufu and Ujuanbi, 2015).

MATERIALS AND METHODS

The materials employed for this work were the Global Positioning System (GPS), Compass Clinometers, the ABEM Lund Imaging System comprising of Terrameter SAS 4000 supplemented with automated ES 46-10C Multiple Electrodes Selector and all its accessories, as well as the needed computer software (SAS4000, ERIGRAPH and RES2DINV) for the various stages of the data interpretation and modeling.

The Electrical resistivity and Induced Polarization methods were employed, the configuration used was the Dipole-dipole because of its preferred high signal strength to delineate vertical and inclined (near vertical) geological structures as well as its minimized coupling effect, not undermining the vertical resistivity variations.

Three profiles (one for each road) were conducted with the Multi-electrode selector of a minimum of forty-two electrodes at 2.5m/1.25m interval for the 2-D earth imaging. Resistivity measurements have been used for many decades in hydrological, mining and geotechnical investigations. The calculated resistivity value is not the true resistivity of the subsurface, but an "apparent" value which is the resistivity of a homogeneous ground which will give the same resistance value for the same electrode arrangement. The relationship between the "apparent" resistivity and the "true" resistivity is a complex relationship. To determine the true subsurface resistivity, an inversion of the measured apparent resistivity values using a computer program must be carried out. In other words, principles of Physics allow for the calculation of synthetic data from earth models. Such calculations are said to solve "forward" problems. However, the geophysical interest is the reverse calculation, which is, computing earth models from data. This reverse calculation is called Inversion. The word "inversion" is derived from "matrix inversion" (Claerbout, 2004). The data obtained were retrieved with the utility software and subjected to conversion by the ERIGRAPH to a format usable by the RES2DINV software. The data from the three traverses were inverted by the enhanced Gauss-Newton least-squares equation, modified so as to minimize the spatial variation in the model parameters (that is, the model resistivity values change in a smooth orgradual manner), otherwise called the Smoothness-constrained Least-squares method, which has the following mathematical form:

$$\left(J^{T}J+\lambda F\right)\Delta q_{k}=J^{T}J-\lambda Fq_{k} \qquad (1)$$

Where

$$F=\alpha_{x}C_{x}^{T}C_{x}+\alpha_{y}C_{y}^{T}C_{y}+\alpha_{z}C_{z}^{T}C_{z} \qquad (2)$$

and C_x, C_y and C_z are the smoothing matrices in the x-, y- *and* z-directions. And α_x, α_y and α_z are the relative weights given to the smoothness filters in the *x*-, *y*- and *z*-directions. Also, where:

F= a smoothing matrix

J^T= the Jacobian matrix of partial derivatives

q_k= a vector containing the logarithm of the model resistivity values

λ= the damping factor

Δq_k= model perturbation vector

J= the discrepancy vector (Loke, 2002).

RESULTS AND DISCUSSION

Results of surveyed profile comprising of the resistivity and chargeability sections for each location are presented in the figures below, wherein each consideration of the Profile is from left to right.

According to Owen *et al*. (2005), the pseudo-sections are a qualitative way of presenting the spatial variation of the measured or calculated apparent resistivity in cross section and do not reflect the true depth. However, the inverted model section shows the true depth and true formation resistivity. Because boundaries in geo-electric layers do not often coincide with the corresponding boundaries in geologic sections deductions from the geo-electric sections are made using relevant lithological and geophysical information as controls. These controls are used to calibrate the geophysical data to produce a theoretical geophysical model based on the expected geo-electric signatures for the various hydro-geological units. This model can be used to assist with the interpretation of the actual resistivity profile data, giving rise to a more realistic interpretation of the earth model.

PROFILE 1:

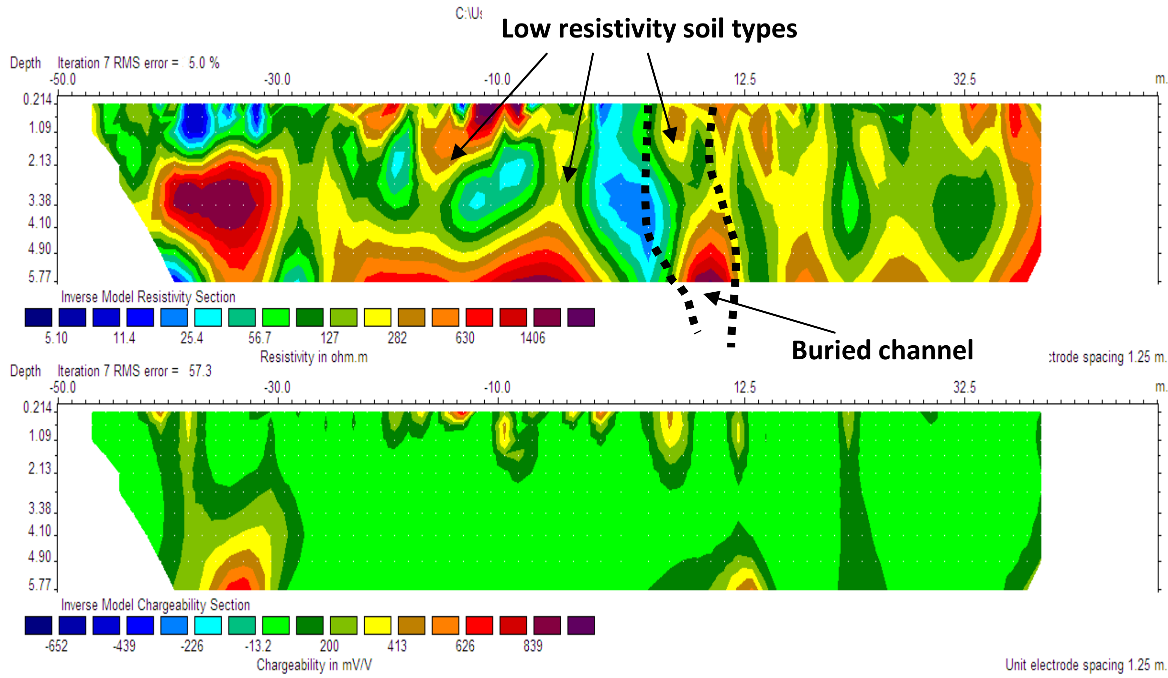

Fig.2: Combined resistivity and chargeability inverse model sections of Profile 1.

The top layer here is basically of fairly high resistivity rock type except at 10m to about 20m on the profile line (to a depth of 1.09m), and at about 50m on the Profile line where low resistivity rock types are seen to extend downwards right into the bedrock (just by the Zonnes' Pub and the Uncle Sam Hotel entrance) in what seemed to be like a buried stream channel/water way, adduced to be composed of more shale and little mineralized rocks. The observed fracture and the suspected buried stream channel are adduced to be partly responsible for this pavement failure, besides other factors. Coincidentally, this fractured zone happens to be at the entrance to the Uncle Sam Hotel, just by the fence of Zonne's. We inferred therefore that the failure cause here was partly geologic.

PROFILE 2:

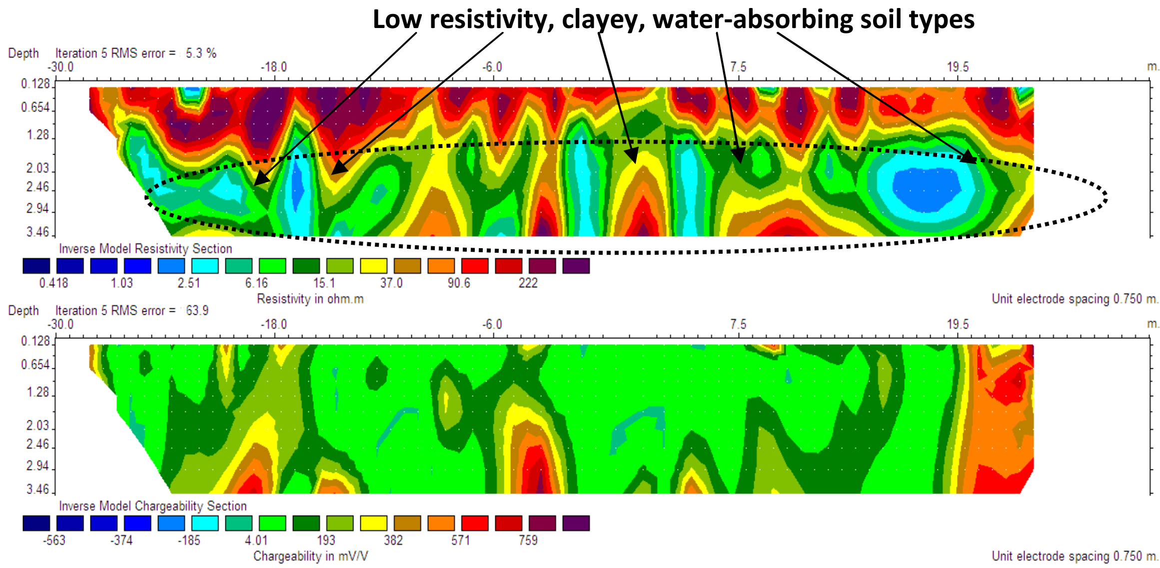

Fig.3: Combined resistivity and chargeability inverse model sections of Profile 2.

Here, we observed varying thicknesses of very low resistivity rock types underlying a fairly higher resistivity rock types, adduced to be a blend of shale, clay and weathered bedrock containing clay, spanning almost the entire profile line to an approximate depth of 3.46m. No geological feature was identified. However, the suspected massive thickness of low resistivity, clayey sub-grades soil and water absorbing substratum call for great concern. As a result, there is heavy differential settlement of the sub-grade. The undulating feeling of driving on it even when some parts of it appear stable further confirms the fact. Hence, we say the cause of failure here was highly geologic.

PROFILE 3:

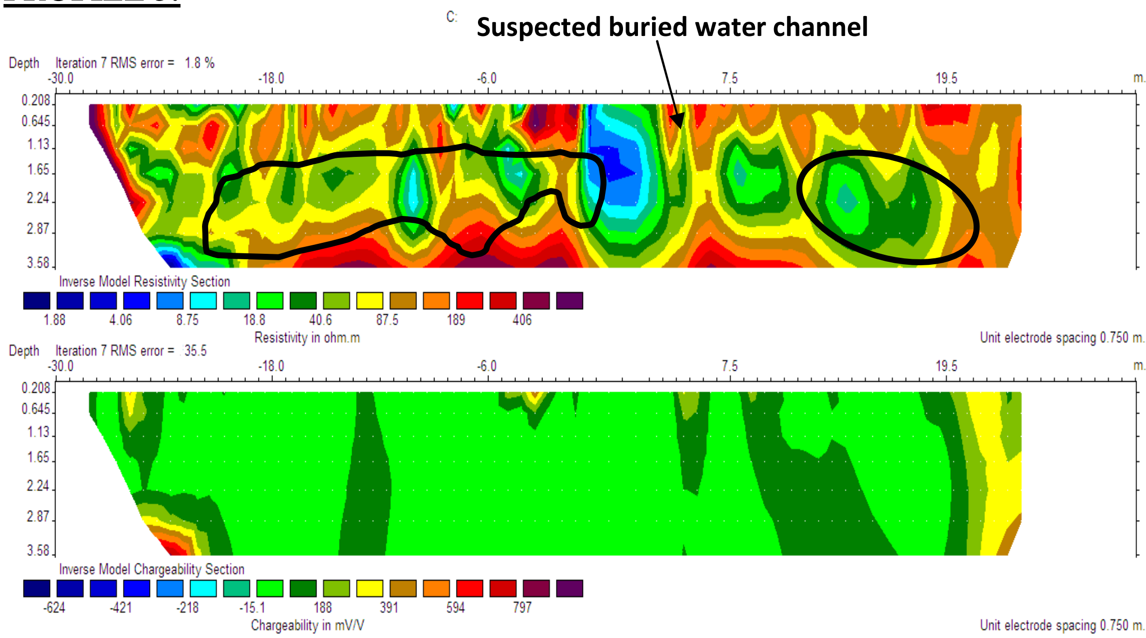

Fig.4: Combined resistivity and chargeability inverse model sections of profile 3.

The tomograms depict a fairly high resistive top layer though with intercalations of low resistivity rock type suggestive to be shale and/or soil of clay minerals circled in thick black colour. A major feature is observed at about 30-33m of the profile line extending to a an approximate depth of 2.87m suspected to be a concealed/buried channel or water way composed of either shale, granite and/or granodiorite. The fractures as a result of the suspected buried water channel could have been the initiator of the pavement failure, despite few catches of low resistivity subsoil whose effects might not have been that significant in terms of much differential settlement. As such, we inferred the failure cause of this pavement as partly geologic.

The above discussions were based on the chargeability values of geologic materials by Asani (2015) and typical ranges of electrical resistivities of earth materials and minerals (Loke, 2000), and the findings were observed to be in harmony with the works of Aigbedion (2007), Ebhohimen and Mamah (2014) and Amadasun *et al*. (2015).

Table 1: Summary of the Profiles, location, orientation, coordinates and inferred cause of failure

PROFILE NUMBER	LOCATION	ORENTATION	CO-ORDINATES	FAILURE INFERENCE
1	UJOELEN ROAD BY ZONNES FAST FOOD	N 45° E	N 06° 44′ 28.5″, E 006° 07′ 36.7″ to N 06° 44′ 28.4″, E 006° 07′ 40.4″	PARTLY GEOLOGIC
2	MOMOH STREET, BETWEEN UJOELEN AND UKPENU ROADS.	S 20° W	N 06° 44′ 26.1″, E 006° 07′ 51.3″ to N 06° 44′ 24.3″, E 006° 07′ 53.1″	GEOLOGIC
3	ROYAL MARKET ROAD BY UKHUN JUNCTION.	S 60° E	N 06° 44′ 33.8″, E 006° 08′ 45.1″ to N 06° 44′ 33.9″, E 006° 08′ 48.6″	PARTLY GEOLOGIC

CONCLUSION

The observed failures in the profiles carried out showed that geologic features such as faults, joints and fracture zones; as well as low resistivity, water absorbing substratum or substrata, as it were, are likely responsible besides other factors. The work also re-emphasized the flexible nature and significance of carrying out a Non-destructive technique (NDT) in geophysical survey, without stalling any economic involvements within the areas of study while also buttressing the fact that the cost implication of carrying out such surveys is minimal.

RECOMMENDATIONS

For profiles with near surface soil that is considered incompetent, the topsoil must be excavated to a reasonable depth at which the soil is adequately competent and choice of the refill material must take into account the characteristics of the clayed material (low resistivity, water absorbing substratum or substrata), by requiring proper engineering reinforcement to be determined by the proposed load in order to enhance the bearing capacity of the soil/rock. Also, where geologic features are observed, the activeness of such should be determined and properly fortified in the course of its rehabilitation or reconstruction.

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