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Electrical resistivity application for road failure assessment at an industrial hub in Ogun State, Nigeria

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Abstract. This paper employs the geophysical surveying technique of two-dimensional electrical resistivity imaging (2D ERI) for gaining insights into the causes of incessant road failures being encountered at an industrial hub, along Idiroko Road, in Ota, Ogun State, Nigeria. These utilises occupation of three traverses, each of 100 m for the 2D ERI, constituting a control of a stable road portion, and a stable and unstable portions of a crucial turning along the dual carriage highway of Idiroko Road in Ota. The obtained 2D ERI measurements were rendered to the processing of the RES2DINV software for the derivation of the 2D resistivity inverse model. Results show that the portions of the roads that are stable exhibited higher values of apparent resistivity compared to portions exhibiting frequent road failures. Ensuing sub-surface layer characterisations by the 2D ERI revealed geo-electrical layers exhibiting permeable soil formations that allow water to percolate in the stable portion of the road while the unstable portion depicted presence of water in an impermeable soil formation. These engender recommendations for road construction durability issues that can culminate into system of sustainable road network at the studied industrial hub location in Ogun State, Nigeria.

Keywords: Road failure; apparent resistivity; 2D electrical resistivity imaging; industrial hub; Ota, Nigeria

1. Introduction

The condition of roads impact socio-economic well-being in the society because it serves as infrastructural facility for crucial linkages in human social interactions and economic activities [1, 2]. It is for this reason that road failures disrupt timely access to work places, hospitals, schools, markets, religion places of worship and other locations that serve for exchange of goods and services as well as for the sustenance of healthy socio-psychological dispositions [3]. Delays of motor vehicles in traffics, causative of bad roads, increase emissions from motor engines, apart from the economic losses form the consequently increased fuel combustions. Ensuing transportation cost increment imposed by drivers ensures the populace partake in the crunch of the bad road implications. These further engender costly repairs and maintenance by governments or other stakeholders, especially, industries that are also usually affected by the failed road networks.

Such forms of industries abound in Ota and its environs, in Ogun State, due to the sharing of boundary by this environ with Lagos State, the commercial hub of Nigeria. The location of Ota within Ogun State, Nigeria, has been detailed, with requisite map, in studies wherein the boundary shared with Lagos, Nigeria was also depicted [4 – 6], just as the regional geology of the area has been detailed to belong to that of the Dahomey Basin in Oladejo et al. [6], Adagunodo et al. [7, 8] and Bayowa et al. [9]. Thus, this location of Ota makes it that much more industries are localised there than in other parts of Ogun State. Also, the proximity of Ota to raw materials procurement via import from the port in Lagos and some major markets in Lagos state makes it more industrialised than other parts of Ogun State. In addition to the manufacturing industries, Ota is home to three Universities, namely Covenant University (within the Living Faith Church, Winners Chapel), Bells University of Technology and Crawford University [4]. These are apart from other government-owned and private polytechnics and tertiary institutions that are also located in Ota, Ogun State, Nigeria.

Many of the industries in Ota, utilized the principles of locations and localisations of industries to be co-located in a form of industrial estate (akin to a business district in developed countries) and these make Idiroko Road in Ota to be a major link road in the environ. Apart from these, Idiroko Road, in Ota, is one of the linking roads from the country, Nigeria, to the neighbouring country of Republic of Benin. By these, studies [1, 4], have identified Idiroko Road in Ota as the Lagos – Cotonou linking highway; a strategic route that has contributed immensely to the trade between Nigeria and her West African counterparts, viz. Benin, Togo and Ghana. These would constitute reasons by which Idiroko Road in Ota has been characterised with common occurrences of congestions and uncontrolled high-capacity junctions in the literature [4]. As a consequence, many portions of the road are subjected to extreme and incessant failures. This is such that costly repair works and maintenance frequently carried out on the road either by government and/or (oftentimes) by other stakeholders have not abated the continual spoilages of the road.

While the stress that the road is being subjected to could be attributed to the high capacity of vehicular movement, it is also observed that road repairs on the axis do not actually last long. Also, just as some portions of the Idiroko Road remain stable, other portions deteriorate faster, despite the same exposure to the same range of vehicular movements. These raises the suspicion that the more frequent failures of portions of the road, relative to other portions, may not be due to the vehicular loading alone, but also the geological and the lithological units of the subsurface on which the road portions are situated. This consideration serves as motivation for the geophysical survey investigation embarked on in this study for the stable and the unstable portions at selected junctions that are known to be usually congested along Idiroko Road in Ota, Ogun State. It is also worth noting that while the geophysical survey techniques has been used in many studies for groundwater assessment [10, 11], flooding problem [3, 13], landfill conditions [13, 14], among others, only a few studies [15, 16] had employed this method for road failure assessment. None has used this method for studying road failure in Ota and its environs. Therefore, the objective of this study was to investigate causes of road failure at an industrial hub in Ota, Ogun State, where incessant road failures persist using the electrical resistivity method of geophysical survey approach.

2. Materials and methods

2.1 Study location

The geophysical surveys were carried out at two traverses, each of 100 m. These were setup at locations that are proximate to the access linkage of the Idiroko Road passing along the industrial hub in Ota, Ogun State Nigeria (Fig. 1). Notable among the industrial hub at this location are Honda Manufacturing Nigeria Limited, Nestle (Nigeria), among others. The first traverse was setup at location A, which is at latitude 3° 11′ 52″ E, longitude 6° 40′ 53″ N and an above sea level elevation of 60.0 m. The second traverse was set at location B of latitude 3° 12′ 06″ E, longitude 6° 40′ 53″ N and an above sea level elevation of 57.0 m. The choice of the traverse location follows the consideration of reconnaissance surveys and visual inspections that showed the conditions of the highway. These surveys identified location A to be in the portion of the road that usually attracts frequent repairs and maintenance in the past, thus the tagging of this portion as an unstable part of the road. Also, location B, by the recce, depicts the portion of the road that had maintained relative durability in the past, hence the tagging of this portion as “stable”.

Fig. 1. Aerial map of the study location showing the traverse locations A and B on Idiroko Road access link to the industrial hub in Ota, Ogun State, Nigeria.

Just as is the practice in study of Adiat et al [17], this study also established a base station, for comparison of measured data, beyond the industrial hub, but at the portion of the road that had exhibited stable durability in times past. The chosen base stations, for serving as a control of stable portion of the Idiroko Road, is located at latitude 3° 10′ 07″ E, longitude 6° 40′ 56″ N and an above sea level elevation of 59.0 m (Fig. 2). The traverse of 100 m employed at the base station also followed what was used for the study location.

Fig. 2. Aerial map of the traverse location for the control base station at location S on Idiroko Road passing Winners Chapel in Ota, Ogun State, Nigeria

2.2 Survey method

The Wenner configuration was used in this work for sourcing data of electrical resistivity from the study locations [13], with the aid of the ABEM® SAS1000® Terrameter. For this, four steel metal electrodes were laid with a separation of 10 m to cover the length of profile of 100 m, and were conveniently spaced so as not to obstruct vehicular movements. The measurements obtained from the measurements were rendered to the RES2DINV® software [18] for requisite data processing that culminate into the creations of 2D resistivity image of the earth subsurface, for each of the location in the study area. This makes the acquired results useful for ascertaining the qualitative information of the subsurface formation that is prevalent in the study locations. By this, therefore, pseudo-section plots were obtained for gaining insights into the pictorial attributes of the subsurface soil structure existing in the study area. Detailed reports on the data processing of 2D ERI could be found in Loke [18], Adagunodo et al. [19] and [20].

3. Results and discussion

The rendering of the measurements from the electrical resistivity geophysical surveys to the RES2DINV software produced the 2D Electrical Resistivity Imaging (2D ERI) in Fig. 3, for the traverses at Base Station S, Fig. 4 for Location A, and Fig. 5 for Location B.

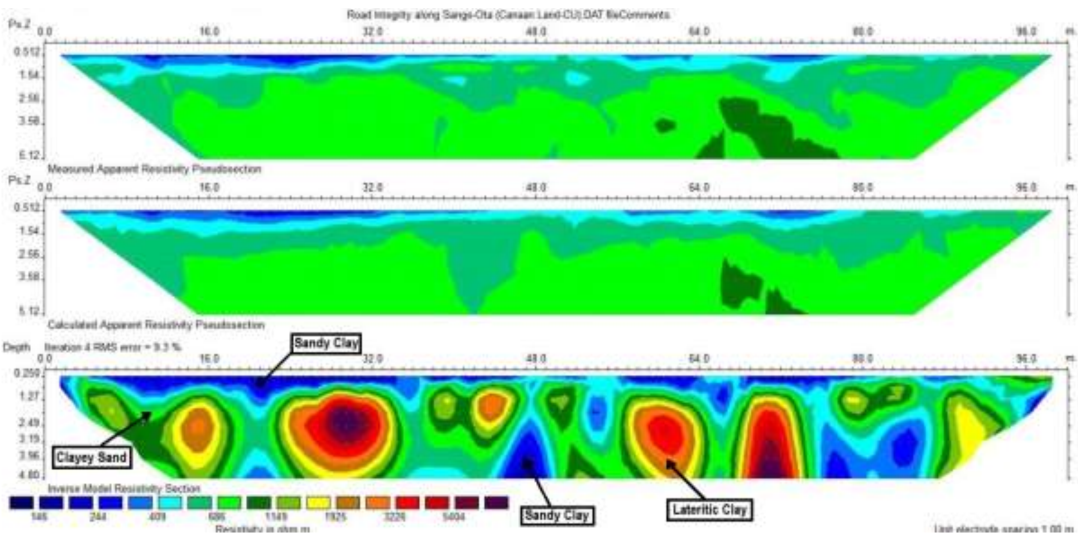

Fig. 3. 2D ERI for the traverse at base station S Idiroko road passing Winners Chapel, Ota, Ogun State, Nigeria.

The 2D ERI from traverse S revealed the presence of three geo-electrical layers. This includes the topsoil that is composed of soil formation having apparent resistivity values ranging from 142.6 Ωm to 397.6 Ωm, the second layer having 571.8 Ωm - 1089.4Ωm and which shows high amount of sand that indicate the area as being permeable. The third layer exhibited apparent resistivity between 1925 Ωm and 5404 Ωm that indicate clayey sand. The inverted 2D (ERT) resistivity models from Fig. 3 shows that sandy clay and clayey sand, are high towards the top of the soil with lateritic clay not evenly distributed and these make the area suitable as the control where the road is very stable.

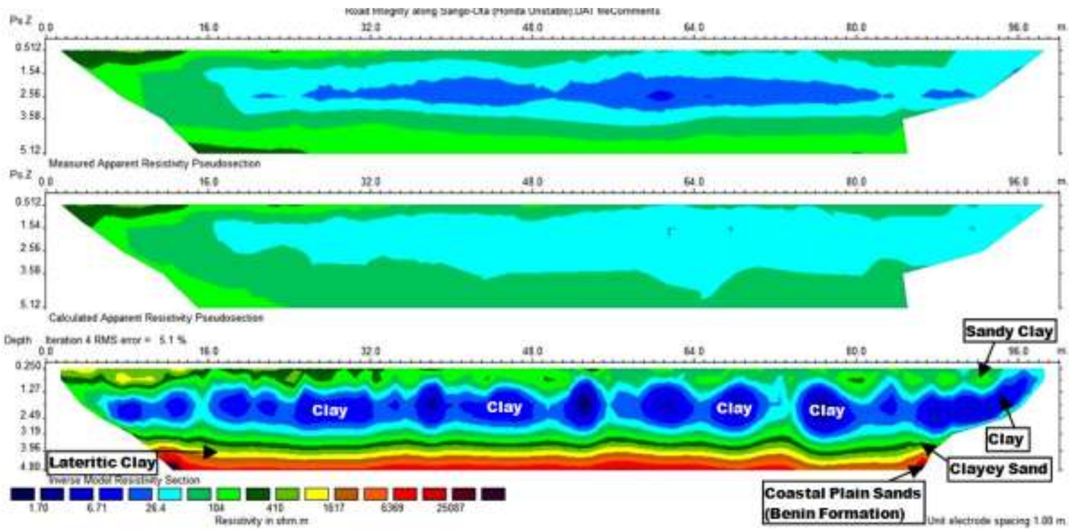

Fig. 4. 2D ERI for the traverse at location A (unstable portion of Idiroko Road access link to the industrial hub in Ota, Ogun State, Nigeria).

The 2D ERI from the resistivity models of traverse A, Fig. 4, showed the presence of four geo-electrical layers wherein the topsoil comprises of sandy clay followed by clay, then clayey sand and lateritic clay. The soil formation at this location exhibited apparent resistivity values from 90.7 Ωm to 108 Ωm that is characteristic of sandy clay. This is followed by the layers having 32.8 Ωm to 268.1 Ωm range of apparent resistivity values, which depict the presence of water hindered from percolation and the consequent implication of the location not being permeable. These low apparent resistivity results, when viewed in the light of previous study from the literature [21], are typical of expansive clay and sandy clay prevalence that are known to contribute to instability of road materials.

The 2D ERI models from the traverse at traverse B, from Fig. 5, also showed the presence of four geo-electrical layers that includes sandy clay at the topsoil, clay at the second layer

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followed by clayey sand, before lateritic clay that undulated through Benin formation, which is composed of coastal plain sands. Thus, the location is characterised with topsoil formations with apparent resistivity values from 156.9 Ωm to 203 Ωm indicating the presence of sandy clay, followed by soil layers of apparent resistivity between 1.64 Ωm to 80.0 Ωm indicating a clayey zone. The third layer is of apparent resistivity 156 Ωm and 269.9 Ωm, which further ran into deeper layer of lateritic clay that makes the area permeable. In comparison, traverse A and traverse B relatively have the same formations, while traverse A is highly deteriorated, traverse B shows to be stable and maintained relative durability in the past. This suggest that though the geological formation at the second layer (which is interpreted as a clayey zone) could be the major causative factor for this deterioration, the loaded trucks from Badagry, Agbara and other industrial settings along this axis to other parts of the country could also be another contributing factor to this deterioration. Generally, clay contains very tiny particles that could store water. Due to its low permeability, it exhibits a tight grasp on water which expands when wet and shrinks when dry [19]. This characteristic has made clay unsuitable to support heavy loads [22], because pressure on pavement components could lead to cracks in the cause of swelling (upward movement) and shrinking (downward movement) of the clayey zone in the near surface [23].

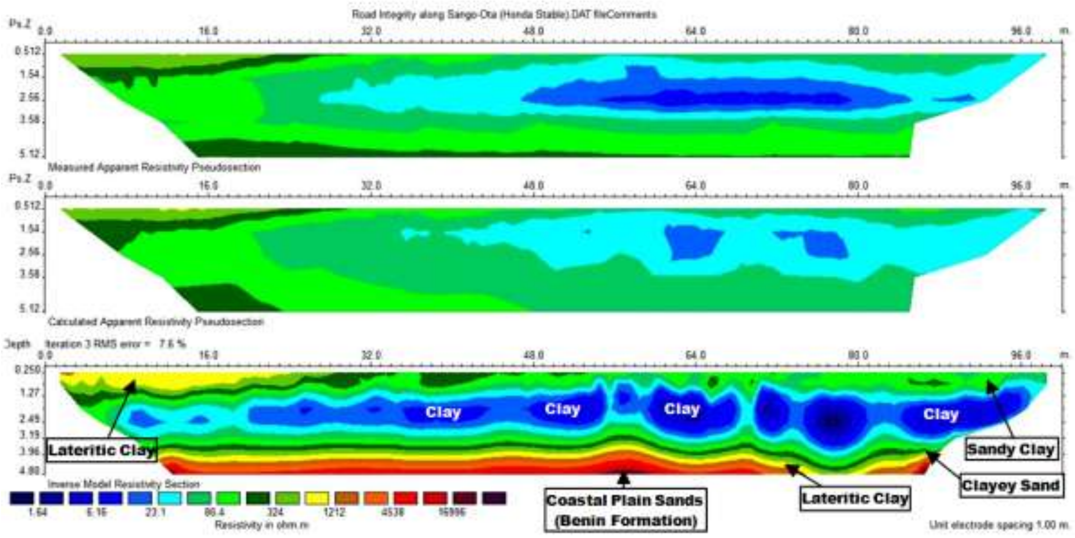

Fig. 5. 2D ERI for the traverse at location B (stable portion of Idiroko Road access link to the industrial hub in Ota, Ogun State, Nigeria)

The results from the study show that the base station, traverse S maintains relatively stable road due to its subsurface soil formation that is permeable to the percolation of water. Meanwhile, the stability of traverse B could be attributed to the weight of the vehicles plying through the spot, because the trucks and other industrial vehicles would have offloaded their luggae while returning back to the factories along this axis. This is in agreement with the work of Akinola et al. [24]. In contrast, the unstable portion of the road exhibited subsurface soil formation that is impermeable (clay), which makes the portion harbour water close to its surface, in the rainforest region wherein the industrial hub in Ota, Ogun State, Nigeria is located. This would have accounted for the inability of the road to withstand the stress of excess capacity being imposed on it and heavy industrial loaded trucks that are known to ply through the study area [4]. The results from this study is therefore giving indications that the condition being imposed by the subsurface soil formation had to be addressed in the course of carrying out further repair and maintenance of the Idiroko road in the high capacity junction of the industrial hub in Ota, Ogun State, Nigeria.

4. Conclusion

In this paper, the geophysical surveying technique of geoelectrical resistivity has been used to investigate the causes of road failures at an industrial hub, along Idiroko Road, in Ota, Ogun State, Nigeria. The work has compared results from stable portion and unstable portion of the road, while also employing data from a stable base station for comparison control. Findings from the study showed that the control exhibited resistivity values that are higher than the resistivity values obtained from traverse A (that exhibited failures more frequently) and traverse B (that seemed to be stable). The 2D ERI revealed geo-electrical layers of permeable soil formations that allow water to percolate in the control (traverse S) unlike the unstable portion (at traverse A) and stable portion (at traverse B) that exhibited the presence of water in an impermeable soil formation. While traverse A is highly deteriorated, traverse B with relatively same lithological sequences is noticed to be stable. This could have been attributed to dynamics of the loaded trucks on clayey zone in traverse A in comparison to the offloaded trucks plying through the clayey zone in traverse B. By this conclusion, it is recommended that additional measures need to be incorporated into the road construction of the study area. This will serve to address the road failures ensuing from the subsurface condition of the study location, so that an improved system of sustainable road network will be attained at this industrial hub location in Ogun State, Nigeria.

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