DOI: http://dx.doi.org/10.4314/gjpas.v22i1.5

GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL. 22, 2016: 37-41
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GEOPHYSICAL INVESTIGATION OF ABANDONED BACK-FILLED RAILWAY LINE: IMPLICATION ON ADJACENT BUILDINGS

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(Received 01 April 2016; Revision Accepted 28 June 2016)

ABSTRACT

A geophysical investigation was carried out on a back-filled segment of an abandoned railway route at Okebadan Estate, Ibadan using electrical resistivity imaging. The study is aimed at depicting the cause(s) of settlement that led to building foundation failure. Five profile lines were established during the study and the apparent resistivity values obtained from the traverse were plotted against the mid-point of electrode separation using least-squares inversion algorithm. Pockets of low resistivity region were obtained from the inverted sections with resistivity values ranging from 77 Ω-m to <400 Ω-m. The suspected back-filled earth materials were suspected to be clay and clayey sand. Results indicated that materials used in back filling the abandoned rail route were not well compacted. Consequently, the structural failure of buildings along this abandoned route was attributed to differential settlements of clays and clayey sands on which they were erected.

KEYWORDS: Backfill, Foundation, Resistivity, Settlement

INTRODUCTION

The residents of Okebadan Estate in Ibadan observed conspicuous failure on some buildings in the area, thus drawing the attention of the public to deduce the cause(s) of the failed foundation via jagged spaces noticed on the walls of some buildings (Plates1 to 4). This study stemmed from the failure associated with buildings constructed on the back-filled railway route at Okebadan Estate. A fish pond cited along the failed section leaked into the nearby hand dug well, thus, contaminating the groundwater in the vadose zone. Geophysical mapping of the subsurface foundation material in the failed segment was carried out using electrical resistivity method. Electrical resistivity method has shown wide usage in foundation investigation because of its simplicity and cost effectiveness, hence it is a rapid tool for geotechnical investigations (Loke (2000), Momoh et al. (2008), Sudha et al. (2009), Oyedele and Olorode (2010)). Two-dimensional (2-D) resistivity tomography has been a vital tool in depicting subsurface layers due to its continuous lateral and vertical imaging along a traverse (Ayolabi et al., 2009). Akintorinwa and Adeusi (2009) studied the foundation material for a proposed engineering structure using combined geophysical and geotechnical approaches; the geo-electric units were established from the resistivity study and also to locate possible fracture which could lead to foundation failure. The result corroborated the geotechnical findings. Sudha et al. (2009) made an attempt to integrate electrical resistivity and geotechnical data in characterising subsurface soil conditions, and also established the suitability and rapid approach of resistivity technique in geotechnical studies. Oyedele and Ekpoette (2011) reported the use of resistivity survey in characterising the soil conditions for engineering structure; the study suggests that shallow foundation is not feasible due to presence clayey material near the surface. The presence of subsurface cavity beneath engineering structure could lead to possible source of foundation failure. Studies have shown that electrical resistivity is a functional tool in isolating areas characterized with voids (Muhammad et al. 2012). Adeyemo and Omosuyi (2012) conducted geophysical investigations on a road pavement to determine the reasons for its failure at some portions. Adegbola et al. (2010) delineated the subsurface geological unit via Vertical Electrical Sounding (VES) at Badagry, Nigeria, the VES derived geoelectric section (2-D) showed the adequate bed that can withstand the engineering load. The use of two-dimensional (2-D) imaging has given better information than one-dimensional (1-D) imaging. Ozegin et al. (2013) examined the geologic unit around a building site using 2-D technique; the pre-investigation carried out shows that the unconsolidated soil exhibits low resistivity value at shallow depths, and this could be the possible source of foundation failure. This study is targeted at depicting the cause(s) of settlement that proceeded to the foundation failure of buildings and also to deduce the efficiency of electrical resistivity technique in foundation studies.

2.0. SITE DESCRIPTION AND GEOLOGICAL SETTINGS

The study area is located in Okebadan Estate, Ibadan (Figure1). The area is bounded by Latitudes $7^{0}26^{l}00^{ll}$N and $7^{0}26^{1}40^{ll}$N and Longitudes $3^{0}57^{1}00^{ll}$E and $3^{0}59^{l}00^{ll}$E. It is accessible by roads and footpaths, the terrain has gentle undulation and relatively flat and its

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elevation ranges from 220m to 260m above mean sea level. Rock types in the area comprise quartzite and pegmatite schist. Agboola and Ojeleye (2007) reported that the mean annual rainfall in Ibadan is 180mm.

3.0. MATERIAL AND METHODOLOGY

The suspected back-filled segment was traced out through the series of failed sections observed on buildings along a single file. Electrical resistivity imaging (tomography) was carried out using an Allied Ohmega Earth Resistivity Meter.

A total of five profile lines were established, such that four electrical resistivity imaging lines were established perpendicular to the suspected back-filled section, while the fifth imaging line serves as a control. Wenner alpha (α) array was adopted for the electrical resistivity tomography with constant separation of 3m between electrodes, and successive measurements were taken at 3m interval. The separations were further increased to 6m and 9m and a profile length of 60m was maintained for all the image lines. The inverted resistivity sections were produced from the plot of the apparent resistivity values obtained for each profile line against the mid-point of each electrode spacing. The inverted resistivity sections were generated using RES2DINV programme. The apparent resistivity (ρ_{ap}) is calculated using the formula stated below:

$$\rho_{ap} = K\Delta V/I$$

where K is the geometric constant of the configuration applied. Its value is expressed in units of ohm-m.

4.0. RESULTS AND DISCUSSION

Profile 1 (Figure 2) shows that the inverted section is characterised with non-uniqueness in the subsurface material as compared with the control segment. It could be observed that the less resistive material (248-376 Ω-m) is sandwiched between the more resistive units (>900 Ω-m) from electrode position 30 m to 42 m and to a depth of about 4 m, and this region is denoted with 'A' on the inverted section. The low resistivity region was assumed to be made up of clayey sand material and this region is suspected to be back-filled railway route. This earth material could be responsible for structural displacement of building sited along this particular route. Profile 2 (Figure 3) shows a very low resistivity value (<106 Ω-m) around the suspected back-filled railway route. This low resistivity region is denoted by letter 'A' on the inverted section, it indicates the presence of clayey material which extends from 39m to 45m and extends to a depth of about 3m. The less resistive unit is encompassed by high resistive material (>450Ω-m -1182Ω-m) on the either side, indicating a saturated region being enclosed by unsaturated units. This geologic material is presumed to be contributing to the foundation failure observed along the suspected backfilled rail route. Profile 3 (Figure 4) is characterised by pocket of low resistive (<232 Ω-m) material occurring between station 12m and 24m, which extends to a depth of less than 4m. The observed resistivity value within this region corresponds to clayey sand material. This geomaterial is apparently unable to bear the load of the erected structures leading to the known failure in this environment. The suspected failed portion is denoted with 'A'. Along profile 4 (Figure 5), low resistivity value (77 Ω-m to <281Ω-m) is noticed between 33m and 42m, this low resistive region was presumed to be made up of clay and clayey sand materials. These earth materials could be the source of structural failure of buildings located on the suspected back-filled railway route. The inverted section of profile 5 (Figure 6) represents the resistivity distribution obtained from a control line conducted where there is no back-filled railway route. This image line shows that the resistivity of the subsurface materials decreases with depth. There was no localized low resistivities region as observed along Profiles 1-4 where the back-filled railway route passes. It is therefore safe to adduce that the localized low resistivities region observed along Profiles1, 2, 3, and 4 is as a result of material used in back filling the abandoned route. The clay materials are not permeable but porous, and they exhibit unstable structure because they are subjected to change and alterations. The swelling and shrinking of these clay materials may be suspected as a likely source of the failure. The clayey sand tends to re-arrange its mineral grains as a result of overlying load thereby leading to reduction in volume and tight packing. Certain portion of the foundation that falls on this material tends to settle rapidly compared to the rest portion constructed on stable material.

2-D resistivity imaging was resolved to give a better lateral view of the subsurface layers than VES-derived geoelectric section from 1-D due to continuous record of subsurface image (Ayolabi, et al., 2009 & Ozegin et al., 2013).

CONCLUSIONS

Electrical resistivity imaging technique was adopted to examine the failed section of some buildings at Okebadan Estate. The failure being experienced in this area could be attributed to the settling rate of the less resistive (saturated) earth material along the suspected railway route. The geo-material used in back-filling the abandoned railway route settles due to the effect of the overlying building (load). This result in distinctive settling of these materials compared with that of undisturbed segment; therefore, the observable displacement noticed on the walls of buildings could be attributed to this effect. The land section reclaimed from the back-filled railway line failed due to uneven settling rate of the following suspected earth materials; clay and clayey sand with respect to the competent segment around which they were situated, thus, leading to noticeable structural failure of the walls of the building. Electrical resistivity imaging has proved to be effective geophysical tool in unravelling the structural displacement of buildings within this estate. Excavation and replacement of the materials with more competent fill materials and properly compacted will rectify the situation. Alternative approach involves the use of pile foundation to depth at which the subsurface materials would be able to bear the weight (load) of the building to be erected along the back-filled part.

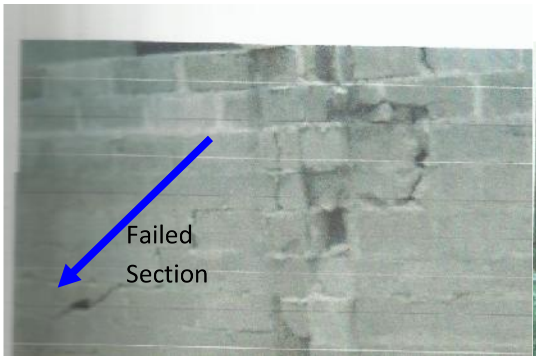

Plate 1: Structural failure as observed on the wall

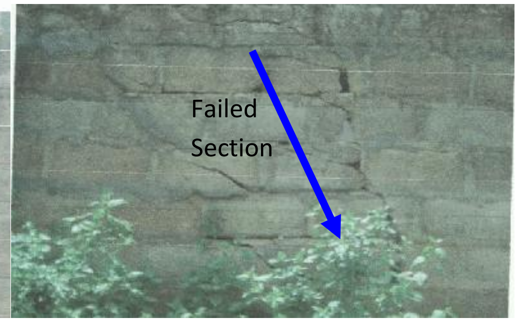

Plate 2: Structural failure as observed on the wall

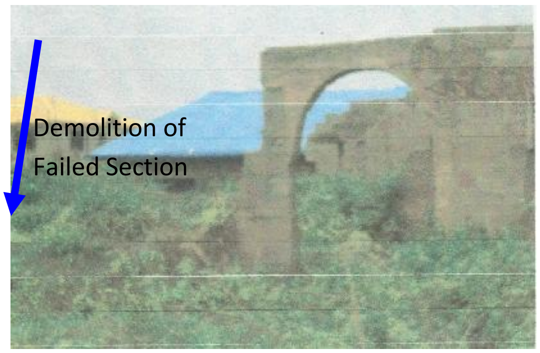

Plate 3: Failed segment led to demolition of some part of the building

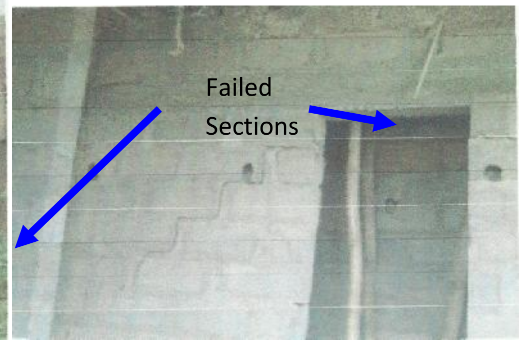

Plate 4: Structural failure as observed on the wall

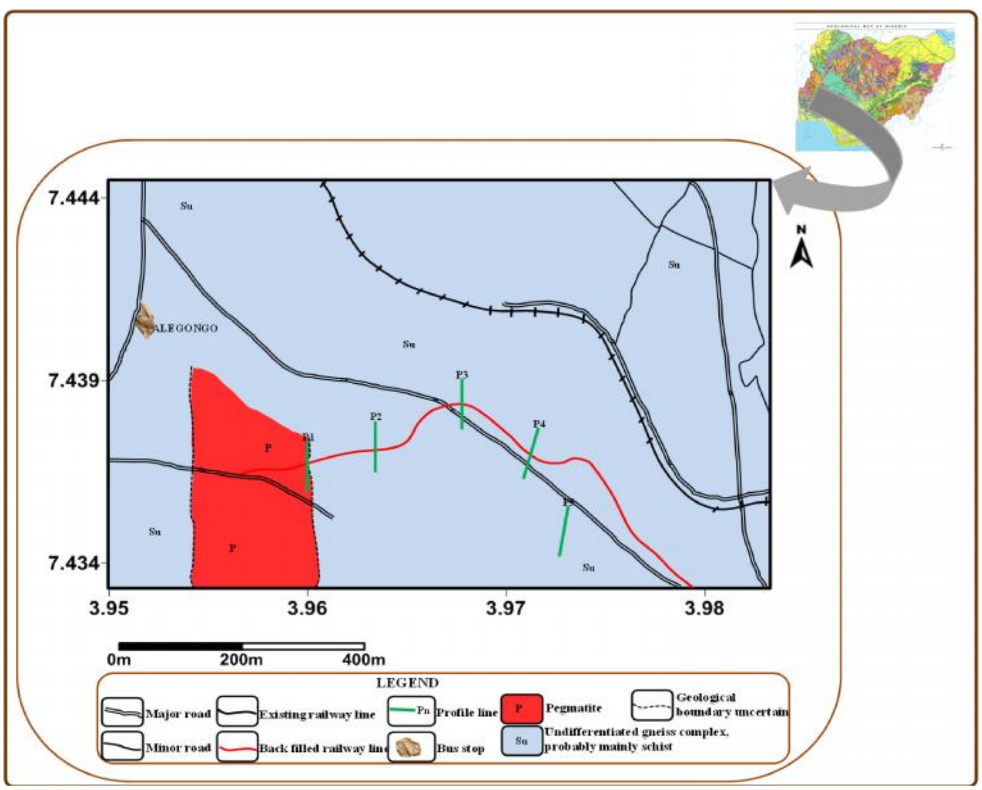

Figure 1: The location and geological map of the study area

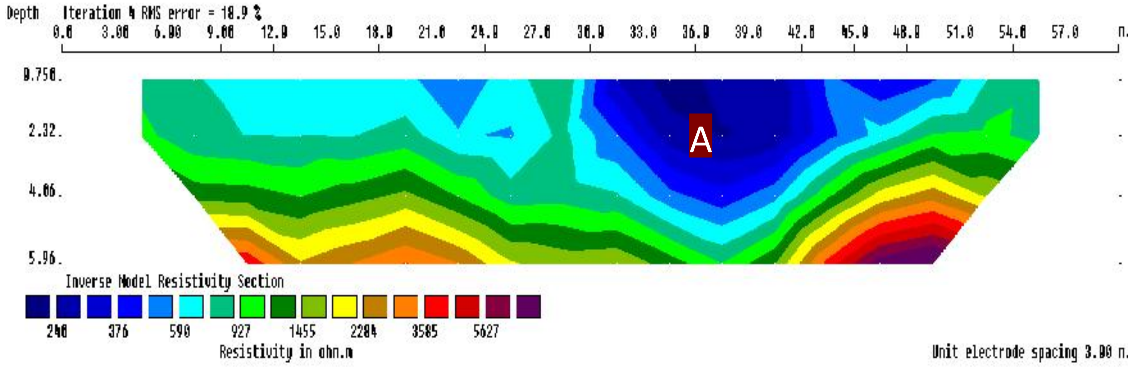

Figure 2: Resistivity distribution generated from the inverted section along Profile 1

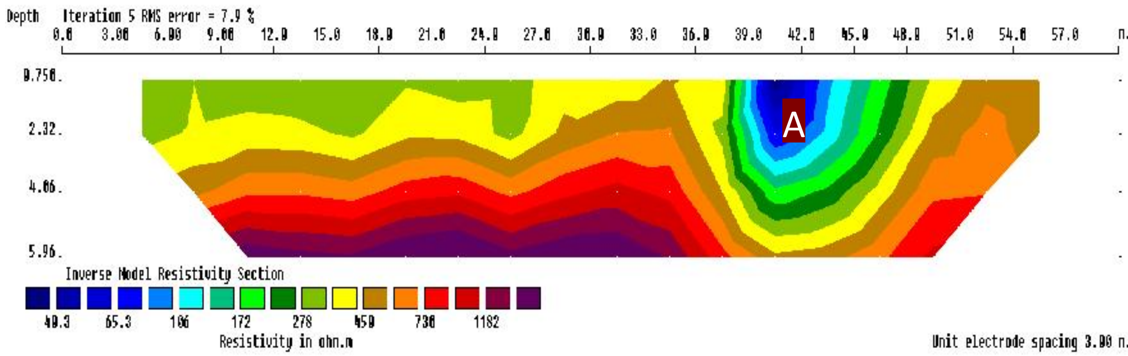

Figure 3: Resistivity distribution generated from the inverted section along Profile 2

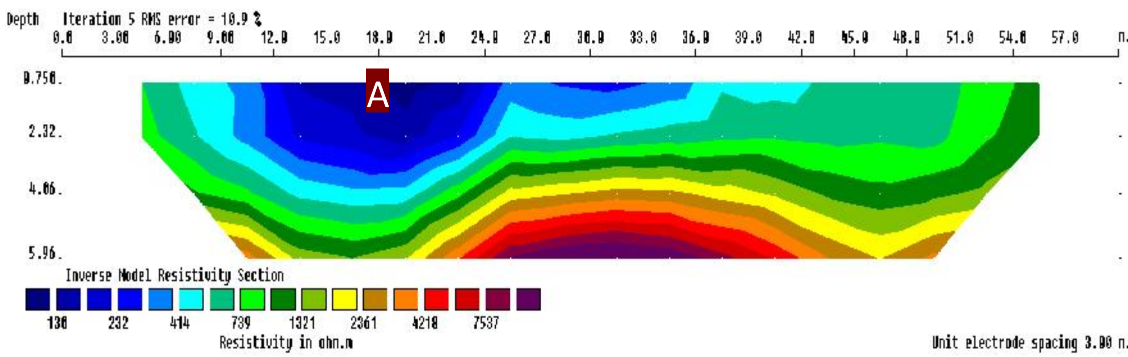

Figure 4: Resistivity distribution generated from the inverted section along Profile 3

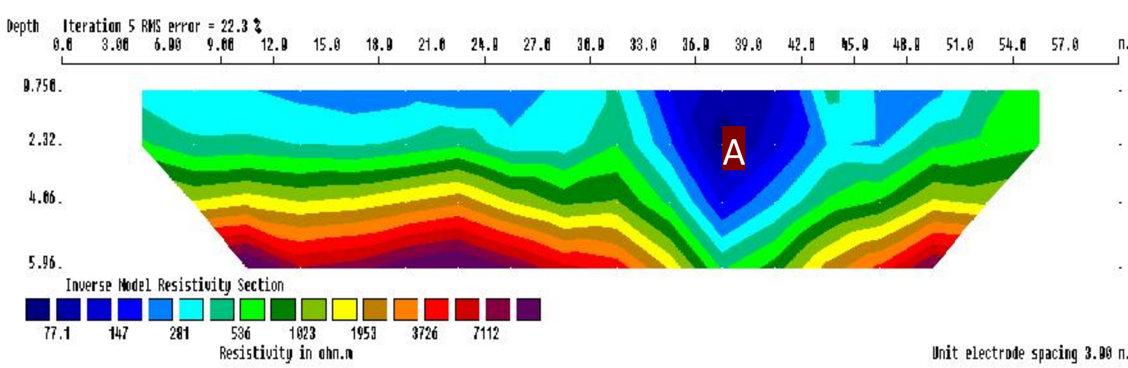

Figure 5: Resistivity distribution generated from the inverted section along Profile 4

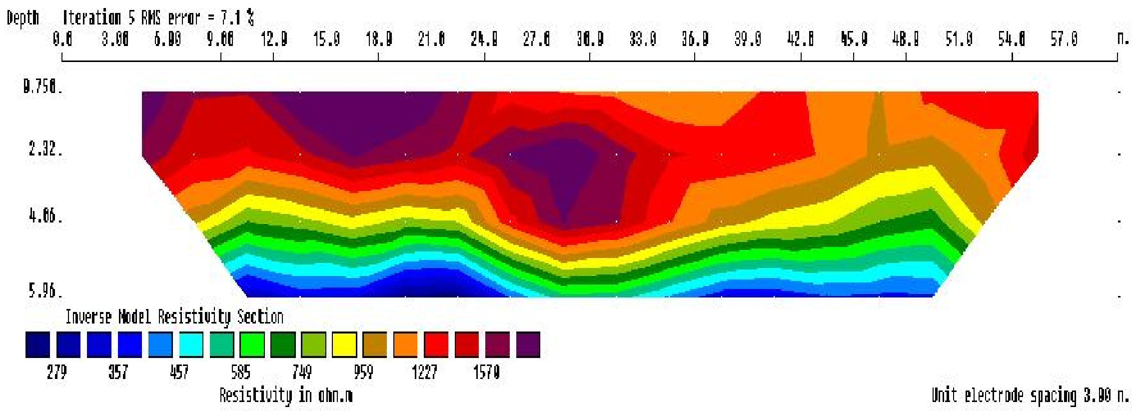

Figure 6: Resistivity distribution generated from the inverted section along Profile 5

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