

Investigation of Sub Soil Corrosion Using Electrical Resistivity Method: Federal University Oye Ekiti Phase II Campus as a case study

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Abstract— Electrical Resistivity survey was carried out with the aim of identifying the degree of soil corrosion associated with the sub soil of the Federal University Oye Ekiti phase II. The sub soil resistivity of the area was surveyed and evaluated using Ohmega resistivity meter. The sub soil resistivity parameters were used to delineate the degree of the sub soil corrosion. Four electrodes were inserted into the soil/rock using the Wenner profiling, vertical electrical sounding and Dipole- Dipole array along the traverses with a spacing of 5m and $n=1$ to 5. In this method, artificially generated electric current(I) was injected into the ground via two current electrodes while the resulting potential difference (V) is measured by another pair of electrodes. The survey revealed that the Southwest and Northwest regions of the study area were associated with high resistivity (200-500 Ω -m). This implies that the soil structure of the region is not corrosive, while the southeast region was associated with low resistivity (20-80 Ω -m) value which implies that the sub soil structure is corrosive. The degree of corrosion increases from the western to eastern part of the study area which may be due to bedrock topography. Of all the layers investigated, the topsoil layer is highly corrosive compare to other layers.

Keywords— Buried metallic materials, corrosion, resistivity, sub soil, 2D-Imaging



1 INTRODUCTION

In the absence of an efficient monitoring system, the dynamic progress of corrosion may cause the buried metallic materials to leak or rupture, and a buried material failure can cause great human, environmental and financial losses (Anyanwu et al, 2014). Soil corrosion assessment of the study area is essential to safeguard underground metallic materials such as electrical material and pipes. Infrastructural assets are of great importance.

High voltage electricity (>132kV) and large diameter gas and water mains are generally founded deeper below ground level for security, engineering and design practicality (HSE, 2010). However, knowledge of soil resistivity is needed to determine the level of soil corrosion that can be safe for buried metallic materials. This information of soil resistivity was not available for the study area. This research was designed to delineate the electrical resistivity of soil structure in the study area which is an indicator of soil corrosion. As such, when corrosion is being discussed, it is important to think of a combination of a material and soil structure. The corrosion behavior of any soil cannot be described unless the geology of the soil composition is appropriately identified (Okiongbo and Ogobiri, 2004). Similarly, the corrosion or aggressiveness of an environment cannot be described unless the material that is to be exposed to that environment is also identified (Syed, 2006). Soil is a complex environmental material which has made the study of corrosion in any material vague.

However, understanding the resistivity of the soil structure is a key to monitor the level of soil corrosion (Mbamalu and Edeko, 2013). Soil corrosion is not only proposed to reduce the effect on buried material but also to reduce the danger that it can cause to human environment (Anyawu et al, 2012).

1.1 SOIL RESISTIVITY

A number of investigators have performed experiments which focused on the corrosion rate of steel and its interactions with soil parameters. In the light of this, it was reported that soil resistivity is by far the best criterion for estimating the corrosion of a given soil in the laboratory, where the vital parameter of moisture can be controlled (Dayal et al., 1988). They studied a number of Indian soils so as to identify a link between the different soil properties and its corrosive action on the underground metallic structures. Palmer (1989) suggests that resistivity is a major controlling factor in the corrosion rate. Later, Bradford (2000) regards the method of soil resistivity as being the most commonly used indicator of soil corrosivity. Rim-rukeh, (2006) suggested that resistivity alone was only capable of differentiating between three of the five corrosive classes for soils, and that seasonal variations had a significant impact. However, Burton (2001) found in his study of North London sites that resistivity correlated well with the soil corrosive classes shown in Table 1.

In addition, (Hussain and Tarig, 2014) revealed that the use of resistivity to identify corrosion rate depends on current flow between a metal and the adjacent medium.

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The duo also stated that the corrosion activity on metals in soil increases as soil resistivity decreases.

1.2 LOCATION AND GEOLOGY OF THE STUDY AREA

The study area under investigation is situated in northern part of Oye- Ekiti, Ekiti State, Nigeria. The survey covers approximate northing 755320 to 755628 and easting 860146 to 860458 as shown in Fig. 1. The study area is underlain by Precambrian rock with a basement terrain features. The major lithological rock unit present within the area is Migmatite. The superficial deposits are clay, laterite and fine sand which are believed to have been formed from weathering of the mineral present in the rock (Fajana et al., 2016).

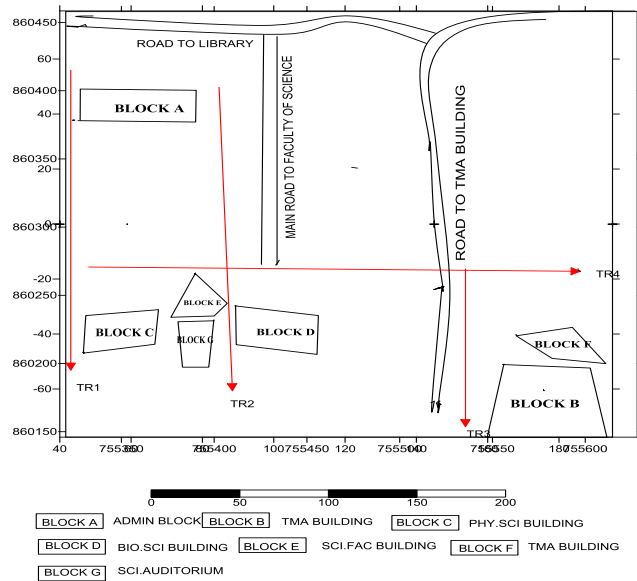


Fig. 1. Base map of the study area

Table 1. Soil resistivity and corrosion effect

Resistivity Values (Ωm)	corrosion effect
0-10	VSC-(very strongly corrosive)
10-60	SC-(strongly corrosive)
60-180	SA-(slightly corrosive)
180 above	PNA-(practically not corrosive)

Table 2. Layers and Resistivity values

VES	LAYERS				RESISTIVITY			
	1	2	3	4	1	2	3	4
1	1.0	11.7	4.9		261.4	443.6	123.7	385.8
2	0.5	7.4			60.7	143.5	158.4	
3	1.0	8.7			182.3	413.5	663.1	
4	0.7	10.0	26.5		172.0	364.7	674.6	189.0
5	1.1	8.1			102.4	125.3	332.5	

2 METHODOLOGY

The electrical resistivity method is commonly used for the delineation of horizontal and vertical discontinuities in the electrical properties of the subsurface and also for the detection of three-dimensional bodies of anomalous electrical conductivity. In the electrical resistivity method, artificially generated currents are introduced into the ground, and in the presence of variations in the conductivity of subsurface layers, the current flow path is altered which affects the electric potential distribution, and the resulting potential differences are measured at the surface. The corrosivity of soils is inversely related to the soil resistivity, with low resistivity indicating high probability of corrosion (Hussein and Tarig, 2014).

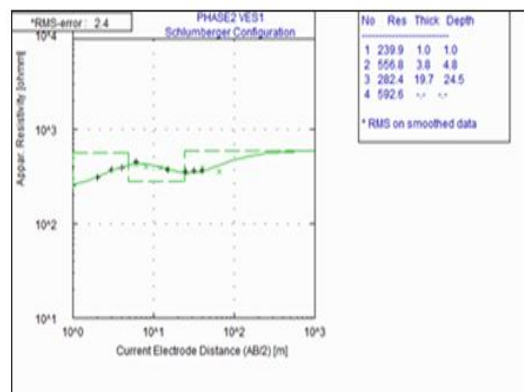


Fig. 2. VES 1

In this research, the resistivity measurements were conducted by using Ohmega Resistivity Meter. Four electrodes were inserted into the soil/rock utilizing the Wenner Arrangement profiling with a=10 m. Dipole dipole array was also chosen for 2D profiling along the traverse with a spacing of 5m and n =1 to 5. In this method, artificially generated electric (I) current was injected into the ground via two current electrodes while the resulting potential difference (V) is measured by another pair of electrodes. The soil resistance is given by $R = V / I$. This needs to be standardized over a unit length. The apparent resistivity ρ measured in ohm-m was obtained from the equation, $\rho = 2\pi dR$ where, d is spacing between the electrodes (in m).

3 RESULTS AND DISCUSSION

3.1 IMPLICATION OF SOIL RESISTIVITY VARIATION ALONG THE TRAVERSES

The 2-D resistivity structure shows the sub surface image produced from the field data and its calculated theoretical data pseudo section (Fig. 8). This reveals both the lateral and horizontal variation in apparent resistivity values of the sub surface. The soil resistivity is relatively low at the stations 10 m- 15m; 30-35m; 165m - 200m and 200m – 400m with a probing depth of 0 - 5m. This implies that at this range of depth, these stations are delineated with high soil corrosion indicating that the stations are not suitable for the installation of underground or buried metallic or electrical materials. Beyond this depth, the soil resistivity increases significantly. This is an indication that the regions are delineated with low soil corrosion beyond 5m. Therefore, beyond 5m in all these regions, underground or buried metallic and electrical materials are safe from soil corrosion if installed, which is not economically visible. At a station of 35 m -165 m, the relative resistivity is high at a probing depth of 0-10 m, which indicates that this station is delineated with low soil corrosion.

3.2 SUB SOIL CONDITION

The resistivity values obtained for each of the five VES (vertical electrical sounding) stations are presented in Fig. 2 – 6. The data in Table 1 correlates resistivity values with degree of corrosivity. VES 1 and 3, which are in the southwestern and northwestern zones of the study area, are characterized by resistivity values above 180 Ωm.

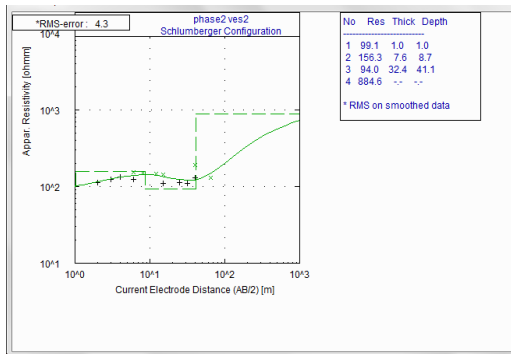


Fig. 3. VES 2

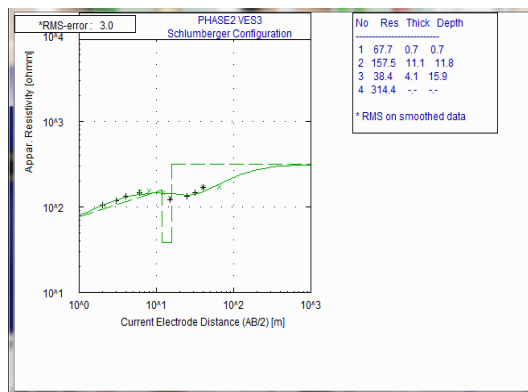


Fig. 4. VES 3

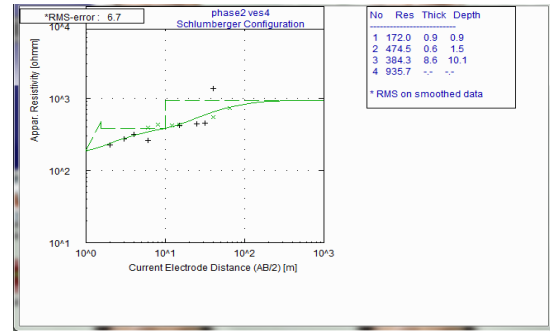


Fig. 5. VES 4

These zones are underlain by the sub soil that is practically non corrosive. VES 2 in the southeastern zone of the study area is characterized by soil resistivity values ranging from 60Ωm - 10Ωm. This lower resistivity value implies that the sub soil in this zone is highly corrosive. VES 4 and 5 in the eastern zone are characterized by resistivity values ranging from 180Ωm – 60Ωm which is an indication that the sub soil associated with this zone is also corrosive (Table 1).

3.3 GEOELECTRIC SECTION

The geoelectric section drawn in the W-E directions within the study area shown in Fig. 7, reveals the 2-Dimensional view of the geoelectric parameters (resistivity and depth) obtained from the forward modelling of the electrical sounding data. Three to four geoelectric layers within the study area which are: the topsoil, lateritic, weathered layer and fresh basement rock were delineated.

The topsoil resistivity ranges from 60.7 to 261.4 ohm meter with thickness ranging from 0.5 to 1.1 meter (Table 2). It is likely composed of clay to sandy clay. This layer is more corrosive since some of the resistivity value is below 100 ohm meters. Therefore, the topsoil of the zone under consideration is not suitable for underground installation of metallic material. The lateritic layer ranges from 125.3 to 443.6 ohm-meter and its thickness varies from 7.4 to 11.7 meter (Table 2). This layer is partially corrosive since some of the resistivity value is below 180 but above 100 ohm meters. Hence, the area is partially not suitable for underground installation of metallic material.

The weathered layer resistivity varies from 123.7 to 674.6 ohm-meter with thickness ranging from 4.9 and 37.2 meter (Table 2). This layer is slightly corrosive since some of the resistivity value is below 180 but above 100 ohm meters. Therefore, the area is partially not suitable for underground installation of metallic material. The partly weathered layer/fresh basement rock resistivity varies from 189.0 to 385.8 ohm-meter.

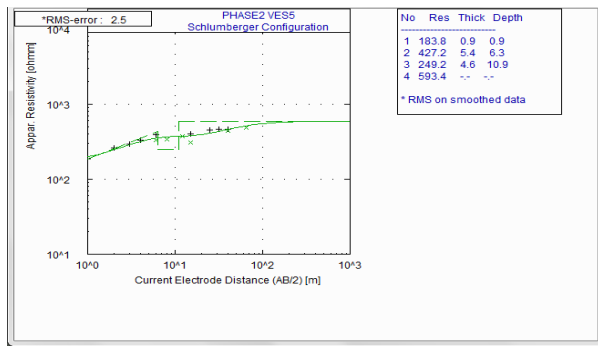


Fig. 6. VES 5

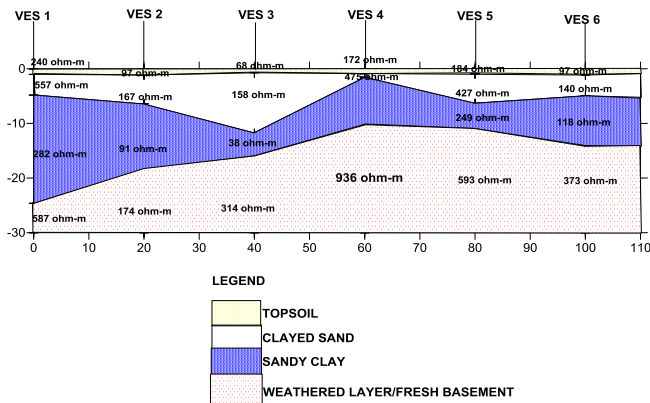


Fig. 7. Goelectric section of the VES

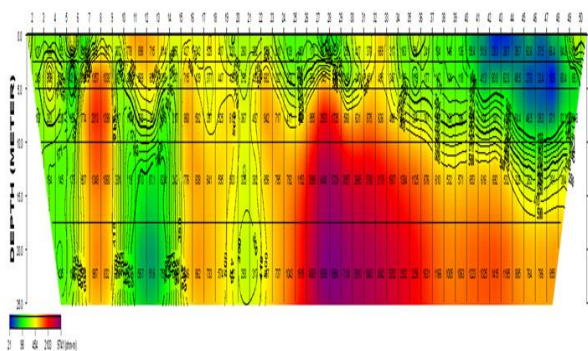


Fig. 8. 2-D Resistivity Structure (Imaging Section)

4 CONCLUSION AND RECOMMENDATION

4.1 CONCLUSION

Electrical resistivity technique was applied to investigate the degree of soil corrosion at phase II campus of the Federal University, Oye-Ekiti, Nigeria. The soil resistivity along the traverses reveals both the lateral and horizontal variation in ground apparent resistivity values of the sub surface. The soil resistivity varies inversely with the soil corrosion. Thus, soil resistivity could be used to predict the degree of soil corrosion. At the depth of 0 – 5m, due to low soil resistivity, the soil corrosion is relatively high at various stations investigated along the traverses. The 2-D Imaging technique revealed both lateral and vertical variation of resistivity with depth. The degree of corrosivity is observable in two dimensions. The degree of corrosion of sub soil in this depth (0-5 m) range along the southeastern zone of the study area is very high. The Southwestern and Northwestern region of the study area

are associated with high resistivity which indicates that the regions are not corrosive. Of all the layers investigated, the topsoil layer is highly corrosive compare to other layers.

4.2 RECOMMENDATION

Based on the result of this research work, it is therefore recommended that:

1. The research on investigation of sub soil corrosion should be carried out in other parts of the FUOYE Campus; to generate the corrosivity map of the entire campus.
2. All metallic material to be buried in partly corrosive areas should be coated appropriately to prevent the corrosion of the materials.

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