

CORRELATION BETWEEN SOIL ELECTRICAL RESISTIVITY AND METAL CORROSION BASED ON SOIL TYPES FOR STRUCTURAL DESIGNS

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Abstract: Soil resistivity measurements are an important parameter employed in the designing earthing installations. Thus, the knowledge of soil resistivity with respect to how it varies with related parameters such as moisture content, temperature and depth, at the intended site, is very vital in order to determine how the desired earth resistance value can be attained and sustained over the life of the installation with the lowest cost and effort. The relationship between corrosion and soil resistivity has been investigated in this work. Various soil samples; Sand, Gravel, Loam, Clay, and Silt, were collected from different spot within the vicinity of Ogbomosho land, Nigeria. The resistivity of the soil sample was determined through the Wenner method. The result shows that clay sample has resistivity ranging between 500 and 2000 Ω cm which indicates high corrosion potential while sand sample with resistivity in the range of 10,000 to 500,000 Ω cm indicates low corrosion potential. Corrosion of the soil samples was found to be enhanced by low resistivity and low hydraulic conductivity in soils.

Index Terms: corrosion, Resistivity, Clay, hydraulic Conductivity

I. INTRODUCTION

Soil resistivity is a measure of how much the soil resists the flow of electricity. It is a critical factor in the design of the grounding system in an electrical substation, or for lightning conductors. It is needed for design of grounding (earthing) electrodes for high-voltage direct current transmission systems. Because soil quality may vary greatly with depth and over a wide lateral area, estimation of soil resistivity based on soil classification provides only a rough approximation. Actual resistivity measurements are required to fully qualify the resistivity and its effects on the overall transmission system and corrosion of buried metals. Corrosion, typically defined as the deterioration of metals through the combined actions of oxygen, other metals and salts, has a major impact on industrial economies. But despite the damage it does, and the seriousness of the issue in economic terms, awareness of ways corrosion can be controlled is in surprisingly short supply. In most of the countries in the world, studies of the economics of corrosion have indicated that its cost to the economy runs in the vicinity of 3-4 per cent of Gross National Product. Further, in a world where businesses are looking for ways to simultaneously stretch budgets and address

concerns about the sustainability of their processes, corrosion presents another problem. Out of the new steel consumed every year around the world, it is estimated that roughly 20 per cent is used to replace metal lost to corrosion. Most metals, with the exception of precious metals, such as gold and platinum, do not occur in metal form in nature – they exist as ore. When ore is processed into metal, the refining process transfers its latent energy to the ore. It is the taking on of this latent energy that transforms ore into metal, but by taking on this energy, the metal elevates to a higher energy state, which means it also becomes less thermodynamically stable.

The reaction of carbon steel to soil corrosion depends primarily on the composition of the soil and other environmental factors, including the presence and abundance of moisture and oxygen. The extreme variability of these factors amounts to extreme variation in the rate of attack by corrosion. Consider, for instance, that a buried iron vessel in the worst possible soil conditions may perforate in less than a year, and yet iron tools hundreds of years old have been unearthed by archeologists in arid desert regions. As a rule, soils with high moisture content, high electrical conductivity, low resistivity, high acidity, and high dissolved-salt content will be most corrosive. For this reason, exposed steel is not often buried in the ground in electrical applications, and as a result, soil corrosion of steel is rarely a concern.

Soils constitute the most complex environment known to metallic corrosion. Corrosion of metals in soil can vary from relatively rapid material loss to negligible effects. Obviously, some soil types are more corrosive than others. The origin of soils, along with climate, geologic location, plant and animal life, and the effects of man all influence a given soils corrosive potential. Chemical analysis of soils is usually limited to determinations of the constituents that are soluble in water under standardized conditions. The elements that are usually determined are the base-forming elements, such as sodium, potassium, calcium, and magnesium; and the acid-forming elements, such as carbonate, bicarbonate, chloride, nitrate, and sulfate. The nature and amount of soluble salts, together with the moisture content of the soil, largely determine the ability of the soil to conduct an electric current. Therefore, fine-grained soils such as clays and some silt are considered to have a greater corrosion potential because they typically have lower hydraulic conductivity—resulting in the accumulation of acid and base forming materials,

which cannot be leached out very quickly. However, granular soils such as sands and gravels are considered to have a reduced corrosion potential because they typically have increased hydraulic conductivity – resulting in the leaching of accumulated salts.

II. MATERIAL AND METHOD

To understand why metallic corrosion occurs, it is necessary to understand how a metal, such as carbon steel, is formed. During the steel making process, natural low energy iron ore is refined into metal. This process adds a great deal of energy to the metal. Once the steel is placed into a corrosive environment, it will, by natural means, return to its low energy state over time. To make the return trip, the steel must give up the energy gained at the mill. This is the essence of the reduction process that we call corrosion. Mechanical strength, physical size and shape, and chemical composition of the steel are all properties that must be considered when designing helical screw foundations. Mechanical and physical properties are typically well defined and controlled during the manufacturing process. This is also true of the chemical composition – primarily due to the superior process controls put in place by the steel mills. Of the three properties, chemical composition is the primary factor with respect to corrosion.

Electrically, two points (or areas) on a metallic structure must differ in electrical potential (anode and cathode). The anode is defined as the electrode of an electrochemical cell at which oxidation occurs as the negative terminal of a galvanic cell. The cathode is defined as the electrode of an electrochemical cell at which reduction occurs: the positive terminal of a galvanic cell. An electrical potential can be caused by differences in grain orientation within the steel structure, i.e. different orientations of the steel grain structure can cause some grains to act as anodes while others act as cathodes, while the rest of the steel material exhibits excellent electrical conductivity. In addition, chemical anisotropy, nonmetallic inclusions, strained and unstrained areas, and other imperfections on the surface of a metal can create potential differences – which drive the corrosion process.

The experiment was carried out in four different areas in Ogbomoso town of Oyo state namely Otamokun, Idiaraba, Ori-oke and Oke ado areas. Physical assessment was used to classify the soil types into sand, loam, silt and gravel. Five sample sites for each of the soil types mentioned above were chosen where soil resistivity investigations were carried out. The mean value of the resistivity values are presented in table 1 to 6. Resistivity investigation of the soil types based on structural composition is in progress. It is intended that values obtained from such analysis will be correlated with the values obtained based on physical assessment. This is to confirm whether physical assessment of soil classification can be used in the field instead of the more laborious structural analysis which also consumes time.

We have several ways of measuring soil resistivity but two methods are common that is, the Wenner four-pin method and the

Schlumberger method. The most commonly used of the two is Wenner method.

Using the Wenner method, the apparent soil resistivity value is:

where

ρ_E = measured apparent soil resistivity (Ωm)

a = electrode spacing (m)

b = depth of the electrodes (m)

R_W = Wenner resistance measured as “V/I” in (Ω)

If b is small compared to a , as is the case of probes penetrating the ground only for a short distance (as normally happens), the previous equation can be reduced to:

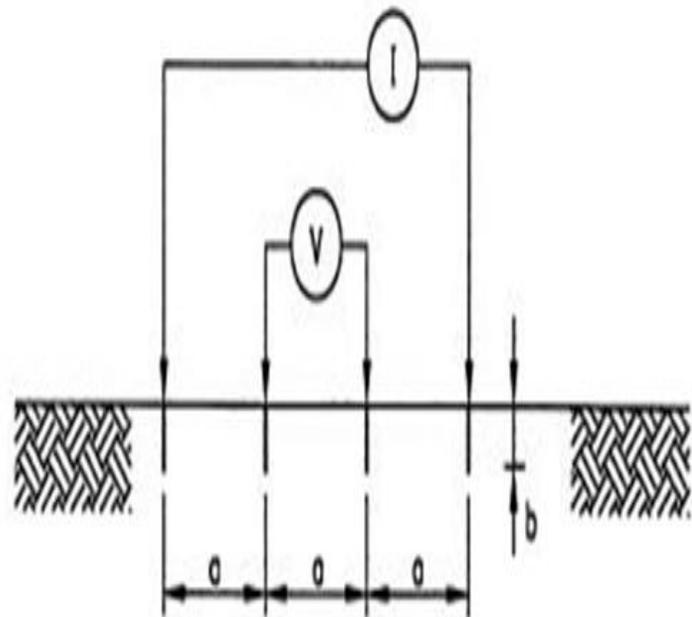


Figure 1: Experimental setup for measuring of soil resistivity

III. RESULTS

Tables: Soil classification in relation to Resistivity.

Table 1; Sand soil

Place	Soil type	Resistivity ($\Omega \cdot \text{cm}$) *
Otamokun	Sand A1	400,000
Idiaraba	Sand B1	15,000
Orioke	Sand C1	10,000
Oke ado	Sand D1	500,000

Table 2: Gravel soil

Place	Soil type	Resistivity ($\Omega \cdot \text{cm}$) *
Otamokun	Gravel A2	300,000
Idiaraba	Gravel B2	20,000
Orioke	Gravel C2	400,000
Oke ado	Gravel D2	250,000

Table 3: Loam soil

Place	Soil type	Resistivity ($\Omega \cdot \text{cm}$) *
Otamokun	Loam A3	3,000
Idiaraba	loam B3	13,000
Orioke	loam C3	9,000
Oke ado	loam D3	20,000

Table 4: Clay soil

Place	Soil type	Resistivity ($\Omega \cdot \text{cm}$) *
Otamokun	clay A4	1,500
Idiaraba	clay B4	700
Orioke	clay C4	500
Oke ado	clay D4	2,000

Table 5: Silt soil

Place	Soil type	Resistivity ($\Omega \cdot \text{cm}$) *
Otamokun	Silt A5	1,300
Idiaraba	Silt B5	1000
Orioke	Silt C5	2,000
Oke ado	Silt D5	1,500

*mean values

Table 6 : Range values for Type of Soil against Resistivity

Type of Soil	Resistivity($\Omega \cdot \text{cm}$)**
Sand	10,000 to 500,000
Gravel	20,000 to 400,000
loam	3,000 to 20,000
clay	500 to 2,000
Silt	1,000 to 2,000

**Range values of several measurements.

IV. CONCLUSIONS

Resistivity is a broad indicator of soil corrosivity since corrosives is associated with electrochemical reaction in soils, high soil resistivity (see table 1), slow down corrosion reactions. Soil resistivity generally decreases with increasing moisture and the concentration of chemical species. Based on limited experience to soil conditions, stainless steel could be subject to corrosion if the soil resistivity is less than $700 \Omega \cdot \text{cm}$ indicative of a wet soil containing chlorides. Sandy soils have a high resistivity (more than $20,000 \Omega \cdot \text{cm}$) and therefore considered the least corrosive. On the opposite, clay soils with a resistivity of the order of $1,000 \Omega \cdot \text{cm}$ are considered to be highly corrosive. The soil resistivity is widely used and generally considered to be the dominant parameter in the absence of micro-biological activity. On a practical standpoint, well-drained soils are recognized to be less corrosive than poorly drained ones.

V. RECOMMENDATIONS

It is highly recommended that in the design metallic structures consideration should be given to the soil properties such as its resistivity etc and environmental effects. Also, it is recommended that structures to be built on clay soils should be well reinforced to prevent early collapse and coated where necessary to prolong the lifespan of the structure.

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