Soil Electrical Resistivity as an Indicator for Soil Corrosivity

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Abstract: Soil electrical resistivity is the property of the soil that impedes or resists the flow of electric current through it. It is a function of the soil moisture and the concentrations of the soluble salts present in the soil and is one of the most comprehensive parameters to test soil corrosivity. The corrosiveness of the soil is enhanced by low electrical resistivity. In general sand samples have a resistivity in the range of 100 – 5000 Ω·m which suggests low corrosion potential. Clay samples, with a resistivity in the range of 5 – 20 Ω·m, are highly corrosive.

1. Introduction

All infrastructures are supported on earth. Most of these structures, whether they are structures built on the ground such as buildings, bridges, roadways or underground structures such as pipelines and tunnels, all depend on the soil for some degree of stability. However, not all soils are ideal for civil engineering projects. Some soils, depending on their composition, can be quite hazardous to metallic structural components. It is, therefore, advised to check the soil for corrosiveness before taking on any form of civil engineering work. Electrical resistivity is one such parameter that influences the soil's corrosiveness. Electrical resistivity of a substance is the measure of the difficulty with which an electric current can be made to flow through it [4]. In soil, it varies with depth and width due to the changes in the soil composition, moisture content and temperature. With increasing moisture, the resistivity decreases to a certain minimum value. The presence of soluble salts along with moisture also reduces the resistivity [3]. While designing underground pipelines and similar buried structures, soil resistivity and its variation with the change in moisture content and temperature is considered. Lower values of resistivity can worsen corrosion on the outer surface of the pipelines and as a result additional costs may have to be incurred for the application of suitable protective coating on the outer surface prior to laying of the pipes.

2. Objective

The objective was to investigate the relationship between corrosion and soil resistivity.

3. Literature Review

There are several ways of measuring the resistivity of soil. The Wenner four-pin method is the standard testing method for field measurement of soil resistivity as per ASTM G57-06 (2012) [2]. It makes use of four metallic probes or electrodes that are driven into the ground along a straight line, equidistant from each other, as shown in Figure 1. Soil resistivity is derived from the potential drop between the center pair of probes, with the current flowing between the two outer probes. An alternating current from the resistivity meter causes the current to flow through the ground between the two outer probes C1 and C2. The potential drop is then measured across the two inner probes P1 and P2. A resistance reading is noted on the resistivity meter.

Resistivity of the soil is then calculated using the following expression (Fig. 1):

$$\rho_E = \frac{4\pi a R_W}{1 + \frac{2a}{\sqrt{a^2 + 4b^2}} - \frac{a}{\sqrt{a^2 + b^2}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where

ρ_E is the measured apparent soil resistivity (Ω·m)

a is the distance between the electrodes (m)

b is the depth of the electrodes (m)

R_W is the Wenner resistance measured as "V/I" in (Ω)

If b is small compared to a as is in the case of the electrode penetrating the ground for a short distance (which is the case most of the time) then the previous expression can be reduced to:

$$\rho_E = 2\pi a R_W \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad [2]$$

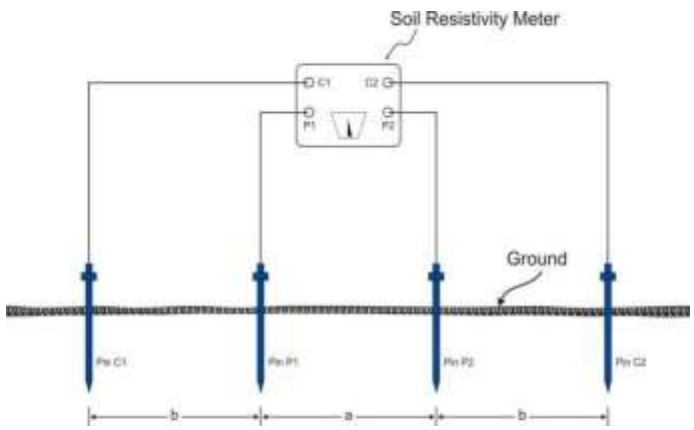

Figure 1: Wenner Four-Pin Soil Resistivity Set Up

Note: Adapted from https://corrosion-doctors.org/Corrosion-Kinetics/Ohmic-drop-soil.htm

The ranges for the resistivity values of different soil types are given in Table 1.

Table 1: Resistivity ranges of different types of soil

Type of Soil	Resistivity (Ω·m)
Sand	100 – 5000
Gravel	200 – 4000
Loam	30 – 200
Clay	5 – 20
Silt	10 – 20

Note: From "Correlation between Soil Electrical Resistivity and Metal Corrosion based on Soil Types for Structural Design" by Oyinkanola L.O.A et al., Scientific Research Journal (SCIRJ), Volume IV, Issue I, January 2016 [5]

The soil corrosiveness is classified based on the soil electrical resistivity given by the ASTM G57-06 (2012) standard as follows [2].

Table 1: Soil Corrosivity Rating based on Electrical Resistivity

Soil Resistivity (Ω·m)	Corrosivity Rating
>200	Essentially non-corrosive
100 to 200	Mildly corrosive
50 to 100	Moderately corrosive
30 to 50	Corrosive
10 to 30	Highly corrosive

<10	Extremely corrosive

4. Conclusion:

Based on the literature review study the following observations are made:

1. Higher the soil resistivity, lower is the corrosiveness of the soil. We could say that high soil resistivity arguably slows down the corrosion reactions.
2. Soil resistivity generally decreases with increasing soil moisture content.
3. Sandy soils, because of their relatively large particle size, offer better aeration and therefore allow for quicker drainage and evaporation of moisture than clayey soils. Hence, sandy soils have a high resistivity in the range of a few hundreds or thousands Ω·m and therefore are considered least corrosive.
4. Clayey and silty soils with resistivities in the range of 5 to 20 Ω·m are corrosive in nature. This is likely since they have higher water retention capacity than other types of soil. Since the resistivity of clay and sand is largely dependent on their moisture content, dry clay and silt would, in theory, have a higher resistivity.

From the above observations we can conclude that soil electrical resistivity is a broad indicator of the corrosivity of a given soil sample.

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