Corrosion - Part 1

by Rich Davis, Editor-in-Chief, Helical Pier World

How fast does steel really corrode?

Corrosion is that pesky process that may erode helical piers from the moment they are installed. In this article, the contributing factors to corrosion, the studies that have been performed to address this issue, and the corrosion rates that these studies have spawned will be reviewed. This article will address bare carbon steel only while galvanization and other corrosion prevention techniques will be addressed in Corrosion, Part II.

This article is not meant to be the final word on corrosion rates, nor should it be taken as such. This article intends to consolidate available information on the subject so the HPW readership will be better informed about corrosion and the effect the process can have on helical piers.

Soils:
In order to better grasp the rate of corrosion, we should first review the soil characteristics that affect corrosion the most. While there are many factors that can be involved in the corrosion process, the five main factors are listed below:

1. *Soil Resistivity*: generally speaking, the higher the resistivity, the lower the corrosion potential of the soil.
2. *Soil PH*: generally speaking, the lower the PH, the higher the corrosion potential of the soil. In some cases, very high pH also increases corrosion potential.
3. *Soil Particle Size*: generally speaking, the smaller the particle size, the higher the corrosion potential of the soil. Since particle size and resistivity are positively correlated, these two factors could be considered redundant, although there are case histories that belie this correlation.
4. *Soil Oxygen Content*: the greater the oxygen content of the soil, the greater the corrosion potential of that soil.
5. *Soil Salinity*: generally speaking, the higher the salt content of the soil the higher the corrosion potential.

The difference between soils with high versus low soil resistivity can have significant consequences on foundation design. It is not practical to perform a battery of soil resistivity tests on each job site. “A general consensus has emerged from publications on studies of buried metals that resistivity is the most accurate indicator of corrosion potential.”(FHWA, 1990) Resistivity testing is fairly easy and inexpensive, however it does add time and some cost to projects. Building codes and government standards tend to adopt a standard based on worst case scenarios in order to remove the guess work and to keep projects on schedule.

Studies:
For helical piers, corrosion rates are determined almost exclusively by the soils into which they are installed. There have been studies done where bare steel and galvanized steel have been buried in the ground and then periodically retrieved to measure metal loss due to corrosion. One of the best documented studies of this kind is the National Bureau of Standards study (NBS Circular 579, Underground Corrosion, 1957), which was conducted from the early to mid 1900s. Steel samples were buried in 54 locations across the United States in a variety of soil conditions.

Other such studies have produced more qualitative rather than quantitative results, but they generally agree with the results of the NBS study. Another significant study is the Terre Armee Internationale study. This study involved the retrieval and analysis of reinforcement strips from 40 MSE structures that had been in place for up to 20 years. This study is significant because it studies the effects of mobilized soil and corrosion.

One research study and one task force project have been conducted in the last twenty years, both of which offer significant findings about corrosion. The research study was conducted by the United States Federal Highway Administration (FHWA-RD-89-186, Durability/Corrosion of Soil Reinforced Structures). The task force (Task Force 27) was a collaborative effort between American Association of State Highway Officials (AASHTO), the Associated General Contractors (AGC), and the American Road and Transportation Builders Association (ARTBA). Both of these efforts focused on MSE construction and the effects of mobilized soils and the process of corrosion.
It is important to note that the two studies generally agree in most of their findings, formulas, and conclusions. Of particular interest is the common conclusion that the rate of corrosion on both bare and galvanized steel is greatest in the first few years. After that the corrosion process tends to level off to a steady but significantly lower rate.

The Formulas

The generally accepted formula to determine the average loss of steel thickness as a function of time is known as the Romanoff formula. Note: Romanoff was the author of NBS circular 579.

$\Delta e = kT^n$

Where:

Δe = the average loss of thickness on each surface (in microns)
k = a site characteristic
T = time in years
n = site dependent constant (always less than 1)

The FHWA study states: “The generalized corrosion rate relationship developed by Romanoff has been found to be a reasonable predictive model to determine the range of corrosion rates.” The study goes on to say “Using the NBS model, the data reviewed suggests that for carbon steel loss determinations…the following equation may be used:

$\Delta e = 40T^{0.8}$ (Average)

$\Delta e = 80T^{0.8}$ (Maximum)

This formula reveals an average annual steel loss of 16.9 microns (average), and 33.7 microns (maximum) where T=75. The total steel loss for 75 years would be 1265 microns and 2530 microns respectively. It is important to note that round shaft helical piers will realize corrosion on both the outside and the inside of the pipe effectively increasing the corrosion rates listed above.

The NBS data was analyzed by Stuttgart University in an attempt to compare corrosion rates during the first few years compared to the corrosion rates over longer periods of time. The following formulas were derived from the study:

Metal loss = 45 um/year (First two years)
Metal loss = 9 um/year (Subsequent years)

Applying this formula to a 75 year design life, the total steel loss is 747 microns. Needless to say, there is a considerable difference between 747 microns and 1265 microns derived from the Romanoff formula. It is important to note that the Stuttgart University study was conducted only on sites with resistivity levels greater than 1000 ohm/cm. By excluding soils with lower resistivity levels, this study does not provide data across a wide spectrum of soil resistivity classifications. However, for soil types used in the study, the difference in steel loss rates in the first two years vs. subsequent years is noteworthy.

Throughout the helical pier industry, there are different formulas in use that result in varying corrosion rates. Is there a silver bullet? Is there one formula that should be used throughout the industry? It is not HPW’s place to make this suggestion. HPW is here merely to provide information. We have provided the formulas that are accepted by AASHTO, ACG, ARTBA, and the FHWA. The Romanoff formula is accepted by these organizations for buried steel, and the Stuttgart University formula is accepted for MSE construction in soils with relatively high resistivity ratings.

Additional information may be found in an article written by Howard A. Perko, Ph.D., P.E., titled "Introduction to Corrosion and Galvanizing of Helix Foundations."

In **Corrosion, Part II,** we will discuss the effects of galvanization and powder coating on corrosion rates. How much do these methods help? How expensive does corrosion protection have to get in order for it to be more cost effective to just put more steel in the ground instead? We’ll try to answer these and a few more questions in part deux.