

Introduction to Corrosion of Steel Push Pier Foundations

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Abstract

A basic review of steel push pier foundation corrosion is presented. The review includes an introduction to the electrochemical process of corrosion, various forms of corrosion, soil and pore water effects on corrosion rates, and soil classification based on conductivity. Minimum and average steel push pier foundation life-expectancy are estimated for different soil types.

Introduction

In order that steel push pier foundations provide support for the design life of a structure, it is important that they be protected from corrosion. The most common method of assurance that push pier foundations have the desired lifespan is adjusting the thickness of the steel so that corrosion can take place without loss of structural support. A fundamental review of corrosion is presented. The review is intended to aid foundation engineers in approximately judging the expected lifespan of a steel push pier foundation.

Corrosion

Corrosion is the exothermic chemical transformation of a metal or metal alloy to a non-reactive covalent compound such as an oxide or silicate that is often similar or even identical to the mineral from which the metals were extracted. Thus, corrosion has been called “extractive metallurgy in reverse” (Payer, et al., 1980).

“Rust” is a general term often used for the covalent compounds formed during the corrosion of iron and steel. The composition of rust depends on the abundance and species of other chemicals available during corrosion. Metallic corrosion occurs most prevalently in aqueous solutions which conduct electric charge through ions. The electrochemical

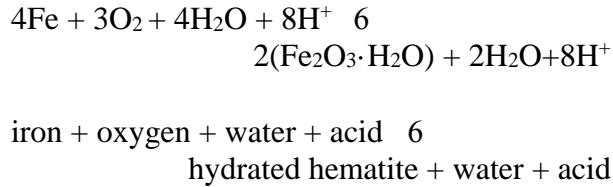
composition of the aqueous solution almost always governs the rate of corrosion and the composition of rust.

With regard to steel push pier foundations and other underground metallic structures, corrosion rate is generally governed by the flow of electricity in soil and is a function of moisture content, presence of dissolved salts, acidity, soil density, soil type, and permeability. A measure of the rate of flow of electrical current is conductivity. Ground water by itself does not have very high conductivity. However, all ground water contains some soluble salts. Higher salt content increases conductivity.

The acidity of a ground water is a measure of the concentration of hydrogen ions. Recall that the concentration of hydrogen ions is typically represented by the pH (negative of the logarithm base 10 of the concentration of H^+ ions). High acidity (low pH) indicates more hydrogen ions. Hydrogen ions remove electrons from iron making it more chemically reactive. The rate of corrosion is also a function of the quantity of dissolved and free oxygen and the diffusion rate of oxygen.

Of many possible reactions, one example of the net chemical reaction for the corrosion of iron and steel in the presence of acidic water with ample dissolved oxygen is given below. Note that hydrated hematite is

the reddish-brown mineral most often associated with the term rust.



Although all hydrogen ions and some water are conserved on both sides of the net reaction given above, these chemicals are important facilitators of the corrosion reaction for the reasons stated above.

The opposite of electrical conductivity is resistivity. Either term is often used to describe the corrosivity of soil. A guide to characterizing the corrosivity of soil based on resistivity is provided in Table 1 (Modified from Miller, Foss, and Wolf, 1981).

Table 1. Soil Corrosivity Classification

| Corrosivity | Resistivity (Σ cm) |
|-------------|--------------------|
| Very Low | >10,000 |
| Low | 5,000 to 10,000 |
| Moderate | 2,000 to 5,000 |

| | |
|-----------|----------------|
| High | 1,000 to 2,000 |
| Very High | <1,000 |

Long-term soil-testing programs conducted by the National Bureau of Standards between 1910 and 1955 comprise much of the data on soil corrosivity in the United States (Romanoff, 1989). These data are shown graphically in Fig. 1 and represent the rate of corrosion as a function of soil resistivity for over 300 buried iron and steel samples from 54 locations across the United States. It can be seen in the figure that low resistivity (high electrical conductivity) is generally associated with high rates of corrosion. In general, soils with high moisture content, ample supply of dissolved oxygen, considerable salt content, and high acidity are most corrosive.

There are various forms of corrosion including uniform, galvanic, crevice, pitting, intergranular, cracking, erosion, dealloying, and hydrogen damage (Jones, 1996). Uniform corrosion accounts for the greatest amount of metal transformation, however crevice and pitting forms of corrosion are more insidious. It is important that damaged pipe be discarded and not used on push pier installations.

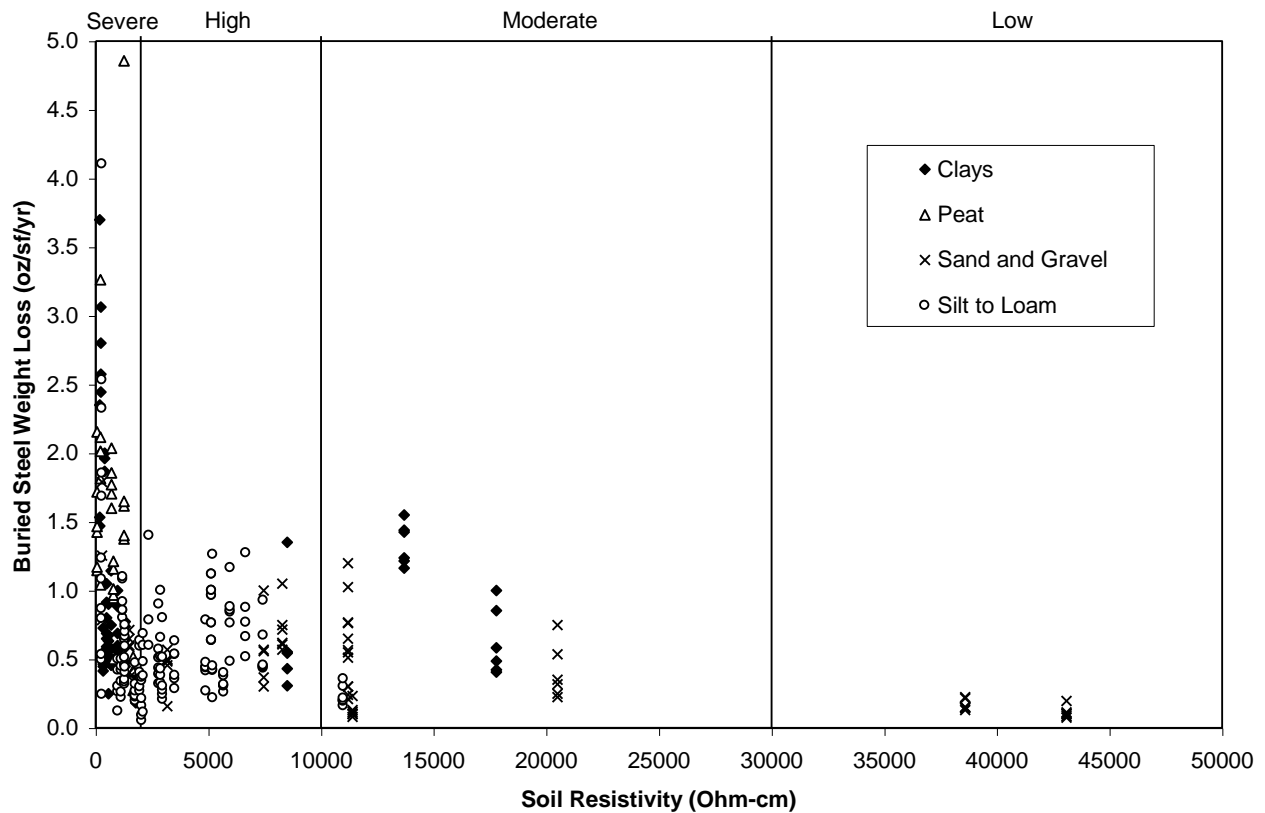


Fig. 1 Corrosion Rates

Life Expectancy

Expected steel push pier foundation life can be defined as the point in time when 1/3 the required steel pipe thickness is lost to corrosion. The data of Ramanoff (1989), shown in Fig. 1, and that of Uhlig and Revie (1985), shown in Fig. 2, were statistically analyzed to obtain a more comprehensive estimate of steel push pier foundation life expectancy for different soil types. The calculations consisted of determining the amount of time that would be required to transform 1/3 of the helical blade thickness and 1/2 the central shaft thickness of a steel push pier foundation into rust by uniform corrosion. Galvanization was considered to reduce corrosion rates by 50%, which is the most conservative and least effect shown in Fig. 2.

A steel push pier foundation with 3/8 inch thick blade and Schedule 80 pipe shaft was used as the model in the analysis. This configuration is representative of round-shaft steel push pier foundations manufactured by Magnum Piering, Inc. (standard and heavy duty series), Atlas Foundations, Inc., Precision

Pier USA, Inc., and the A.B. Chance Company, among others. The computations are considered valid approximations for square shaft steel push pier foundations with nominal dimensions of at least 1.5x1.5 inches, however the computed life expectancies should be divided by 2 for thinner wall pipe shaft steel push pier foundations such as the Magnum Piering, Inc. light duty series.

Results of the analysis are shown in Table 2. Different soil types were categorized according to electrical resistivity. Some examples of soil types comprising each category are given in the table. Estimated life expectancy is shown for bare metal and galvanized steel push pier foundations. The minimum life expectancy, which represents the most rapid rate of corrosion measured in each category of soil corrosivity, is given by the top number in each row. The mean life expectancy for each category is the lowest number in each row. Life expectancy with approximately 95% probability, the point located two standard deviations from the mean, is given by the bold-font middle number in each row. The results indicate that

a galvanized steel push pier foundation of the configuration described above has an approximately 95% probability of a lifespan between 75 and 800 years depending on soil type.

There are many different soil types that are listed in more than one category in Table 2. In order to determine the corrosivity of soil at a particular job site, it is necessary to obtain soil resistivity measurements. One frequently used method of field resistivity testing consists of placing several copper rods into the soil and directly measuring the flow

accurate determination of the life expectancy of a steel push pier foundation or anchor supported structure is required, site specific field resistivity testing should be performed.

General Discussion

A more realistic mode of steel push pier foundation failure may be the corrosion induced fracture of the shaft near the ground surface where there is increased oxidation. This effect may be diminished by proper site drainage and encapsulation of the steel push pier foundation shaft in concrete at the ground

Table 2. Estimated Steel push pier Foundation Lifespan

| Soil Resistivity (Ohm-cm) | Corrosivity Category | Example Soils | (Minimum) 95% Probability (Average) Helix Foundation Life Expectancy | |
|---------------------------|----------------------|--|--|-------------------------------|
| | | | Bare Metal | Galvanized |
| 0-2,000 | SEVERE | soil in marine environments; organic soils and peat; soft, wet silts and clays; wet shales | (15) 30 (80) | (40) 75 (200) |
| 2,000-10,000 | HIGH | stiff, moist clays; medium dense silts and loams; wet clayey to silty sand; wet sandstone | (55) 70 (135) | (140) 170 (340) |
| 10,000-30,000 | MODERATE | dry to slightly moist clays; dry silts and loams; sand and gravel; limestone | (50) 55 (140) | (125) 140 (350) |
| > 30,000 | LOW | dry shales; dry sandstone; clean and dry sand and gravel; slate and granite | (345) 325 (555) | (865) 810 (1385) |

of electrical current between them. Municipal water districts often maintain a data base of soil resistivity measurements for their area. These records are used as a guide for determining the degree of corrosion protection required for buried water pipes. These data often can be obtained by contacting local municipal water districts. Where there is a risk of severely corrosive soils and where

surface.

Soil resistivity does not provide a measure of the permeability, diffusivity, and therefore the residence time of water on buried surfaces. There is no single easily measured soil parameter that can be used to determine soil corrosivity. Rather, low soil resistivity values indicate areas of potentially high

corrosivity that warrant further study. (Jones, 1996)

Electrically coupling the steel push pier foundation to ungalvanized steel reinforcing or structural steel in a building, bridge or other types of construction may change the galvanic corrosion rate of the zinc coatings on steel push pier foundations and may alter the electric potential of the steel push pier foundation with respect to the soil pore-water aqueous solution. Whenever possible, the steel push pier foundation should be electrically isolated from the rest of the structure.

A corrosion engineer should be consulted when very high corrosive soils are encountered. It may be appropriate to provide additional corrosion protection to extend the life of the steel push pier foundation system. A potential solution is cathodic protection. Cathodic protection reduces the corrosion rate by providing an excess supply of electrons to a corroding metal surface. The excess electrons slow the rate of metallic ionization. The level of cathodic protection must be carefully controlled.

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