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[WHITE PAPER]

Corrosion of Helical Anchors In Soil

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May 2008

OVERVIEW

Underground corrosion of steel and iron in soil has been studied extensively over the past century, with most research consisting of burying samples of known dimensions and composition, then recovering the samples after some time and observing them for indications of corrosion. Numerous attempts have been made to form a predictive model of corrosion by correlating various soil parameters with observed rates of corrosion, but with limited success. Instead, empirical observations have yielded generally accepted formulas for calculating the expected rate of corrosion, and consequently, loss of metal.

The most widely referenced work, and basis for essentially all subsequent research in this regard, is *Underground Corrosion*, National Bureau of Standards No. 579, by Melvin Romanoff, first published in 1957 and later re-released *in 1989. In 1972 the U.S. Department of Commerce published the NBS Papers on Underground Corrosion of Steel Piling*, 1962-1971, wherein Romanoff reported the results of multi-year studies of buried steel pilings in a variety of soils. Romanoff noted that pilings in undisturbed soils encountered very little to no corrosion, except in one case where the piling had been driven into fill that contained a considerable amount of cinders and was exposed to a large variation in water table level (it should be noted that despite the deep corrosive pitting observed, the piling was still serving its useful purpose after exposure in the environment for 23 years).

RATE OF CORROSION

In general, the corrosion behavior of structural steel in soil can be divided into two categories: corrosion in disturbed soil, and corrosion in undisturbed soil. Disturbed soil is soil in which digging, backfilling, or other soil upheaval has taken place. Oxygen is introduced into the soil as a natural consequence of soil disturbance in the presence of air.

The corrosion rate of steel in disturbed soil is influenced by a number of corrosion-related parameters. These include soil resistivity, pH, chloride content, sulfate content, sulfide ion content, soil moisture, and oxygen content within the soil. Measurement of these parameters can give an indication of the corrosivity of a soil. However, because of the number of factors involved and the complex nature of their interaction, actual corrosion rates of steel helical anchors cannot be conclusively predicted by measuring these parameters. Instead, an estimate of the potential for corrosion can be made by comparing site conditions and soil corrosion parameters at a proposed site with historical information at similar sites. The potential for corrosion in disturbed soils varies widely, and is most consistently associated with conductivity (lowered resistance to electric current) in the soil.

The observed corrosion rate of steel in undisturbed soil, on the other hand, is negligible. Romanoff reported that "soil environments which can be predicted to be severely corrosive to iron and steel under disturbed conditions in excavated trenches were not corrosive to steel pilings driven in undisturbed soils.... The difference in corrosion was attributed to the differences in oxygen concentrations. It was indicated that undisturbed soils are so deficient in oxygen at levels a few feet below the ground line, or in and below the water table zone, that steel pilings are not appreciably affected by corrosion, regardless of the soil types or the soil properties."

Romanoff's findings were corroborated in 1979 in the study "Corrosion and Corrosivity of Steel in Norwegian Marine Sediments" by K.P. Fischer and Bente Bue [*Underground Corrosion*, ASTM Special Technical Publication 741]. For steel piles with 10 to 70 years of service, the maximum corrosion rate was only 0.030mm per year in highly corrosive soil (resistivity = 1 ohm/meter).

Steel helical anchors generally have the majority of their length in undisturbed soil. However, the region of disturbed soil near the top of the anchor shafts has increased availability of oxygen and the potential for corrosion, so it may become necessary to protect steel in this region from corrosion. Mitigation may include a corrosion allowance (sacrificial metal loss), or the use of coatings such as hot-dipped galvanization or epoxy. Sacrificial metal or corrosion allowance is increased thickness of metal needed to compensate for the loss of metal that will occur as the anchor corrodes. This extra metal thickness is added to all surfaces of the anchor exposed to the corrosive environment.

The California Department of Transportation uses the corrosion rate of 0.025mm (0.001 in) per year for steel piling exposed to corrosive soil. The corrosion rate applies only if the soil is corrosive. If a site is characterized as non-corrosive, then no corrosion allowance (sacrificial metal loss) is necessary. [*Corrosion Guidelines, Version 1.0*, California Department of Transportation, September 2003]

This calculates to a maximum expected loss of less than 2mm of steel in 75 years. The length of time required to experience 3.2mm (1/8 in.) metal loss is often defined as the service life for piles; at this rate, the useful life could be expected to exceed 125 years.

CORROSION PROTECTION

Experience has shown corrosion problems associated with helical anchors are extremely rare, but in areas with a history of corrosion problems, corrosion control measures such as galvanizing or epoxy coating may be appropriate. In all cases, a professional corrosion engineer should be consulted if there is any question or concern regarding the potential for corrosion.

Galvanized Coating

A common method to protect carbon steel from corrosion is hot dip galvanizing. This consists of depositing the bare steel into a bath of molten zinc. Coatings of this type initially protect the underlying metal mechanically. Hot dip galvanizing is also extremely durable. When scratched or subjected to abrasion during construction, the galvanized coating will continue to supply protection (unlike other types of coatings). When the continuity of the coating is destroyed by potential difference on the surface, the underlying metal may be protected either galvanically or mechanically by the formation of a protective film of zinc oxides. The protection process is of a sacrificial nature in which zinc acts as the sacrificial anode to the bare portions of the steel until it is all consumed.

Epoxy Coating

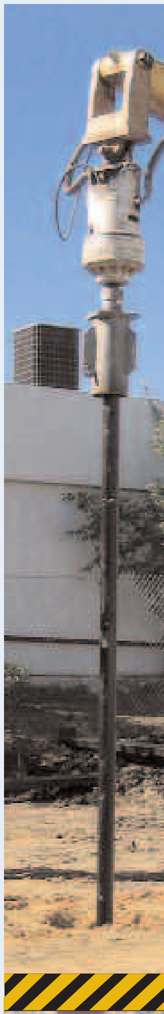
Epoxy coating is non-conductive, impermeable to moisture and gases, and adheres strongly to the base metal, ensuring longevity. It protects the metal from oxidation and corrosion by coating the metal, thus preventing interaction with corrosive elements. In highly corrosive soils, coatings are generally recommended only for the upper part of the anchor, down to a depth slightly below the disturbed soil.


It has been observed that epoxy coating on the auger portion of the anchor can be significantly abraded during the installation process. However, and oftentimes, the epoxy coating remains intact and relatively undisturbed on the shaft portion of the anchor. Because only the upper portion of the exterior shaft near the surface needs protection, epoxy coating may actually be superior to galvanizing for protecting the anchor from corrosion on a long-term basis.

In addition, the inner surface of the anchor shaft can be coated with epoxy to prevent corrosion from condensation or ground water that may enter the shaft.

TESTING SOILS FOR CORROSIVE POTENTIAL

The standard tests for estimating expected corrosion rate of underground steel are ASTM G57-06 *Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method*, and ASTM G51-95(2005) *Standard Test Method for Measuring pH of Soil for Use in Corrosion Testing*. Protocols are available from the ASTM International web site (http://www.astm.org). However, and as previously mentioned, testing of soils at proposed building sites should be conducted by a qualified soils or corrosion engineer as part of the process of determining suitable corrosion protection for each specific application.



CONCLUSION

Corrosion of underground steel has been studied and characterized for decades, resulting in widely accepted formulas for predicting the rate of metal loss over time in various soil conditions. Steel in disturbed soils is subject to corrosion due to available oxygen in the soil. Steel in undisturbed soils corrodes at a much slower rate than in disturbed soils, and the rate of corrosion in undisturbed soils is largely unrelated to soil parameters such as pH, conductivity, and salt content. Corrosion is effectively deterred by coating the steel that is in contact with disturbed soil, either by galvanizing or using epoxy or some other durable non-conductive coating. If the steel exposed to corrosive disturbed soils is properly protected, service life of helical anchors can be expected to be longer than 75 years, and may exceed 125 years in many cases.

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Publication No. FHWA-NHI-00-044, Mechanically Stabilized Earth Walls And Reinforced Soil Slopes, Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes