



Dealing with **Piling Corrosion**

Introduction

Piling has been used to support man-made structures since the Middle Ages. The Romans used wooden piles to build homes, bridges, roads and viaducts all over Europe. When the first steel piles became available around the turn of the 20th Century, piles became capable of being driven down into adverse soil conditions more than ever before. H-piles, pipe piles, and sheet piles are specified today for demanding marine and deep foundation applications in all types of soil conditions. Despite the historical success of driven steel piles, corrosion still remains an Achilles heel that should be accounted for when engineering the piling for any construction project. A cost effective approach to combating the effects of corrosion over the expected service life of the piles can significantly reduce overall project costs.

Corrosion of Iron and Steel

Corrosion of iron and steel in soil, water or moist outdoor environments is caused by electro-chemical reactions. It is a natural process where the binding energy within the steel atoms is weakened to the point that one or more electrons leave the atomic structure of the metal. Electric current is carried through water by the transport of metal ions. It requires the presence of oxygen, an electrolyte, and conditions that produce anodic and cathodic surface areas on the metal. The anodic reaction (oxidation) represents the acquisition of charges by the corroding metal, while the cathodic reaction (reduction) represents the loss of charges by the hydrogen ions that are discharged. The corrosive metal loss occurs at the anodic regions on the surface of the metal where the passage of current out of the metal is accompanied by the dissociation of ferrous ions.

Corrosion of Steel Piling in Soil

The corrosion of steel piles requires the diffusion of oxygen from the soil to the steel surface in the presence of a conductive liquid or soil (electrolyte). Corrosion usually requires the soil to be pervious to air. Variations in soil conditions create a differential aeration on the surface of the pile that serves to create the cathodic and anodic areas on the piling surface.

In general, the corrosion behavior of structural steel in soil can be divided into two categories: corrosion in disturbed soil and 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, soil moisture, and oxygen content within the soil. For piling driven into recent fill soils and particularly industrial fill soils, some protection may be necessary due to elevated levels of corrosive chemicals or low pH. The potential for corrosion in disturbed soils varies widely, and is most consistently associated with conductivity (lowered resistance to electric current) in the soil. Where protection is required, a durable protective corrosion layer should be applied to the piles.

Generally, undisturbed soils are so deficient in oxygen at levels a few feet below the ground line or below the water table zone; steel pilings are not appreciably affected by corrosion. Since the groundwater surface acts as a diffusion barrier, corrosion is most significant in the unsaturated zone between the ground surface and a level just below the groundwater level. Corrosion decreases with depth on piles or sheet piles in stationary, fresh water or salt water, due to the reduced oxygen content. Steel piles driven into undisturbed ground usually require no protection irrespective of the soil types encountered.

In flowing ground water however, corrosion can be significant also at greater depth.

Corrosion of Piling in Marine Environments

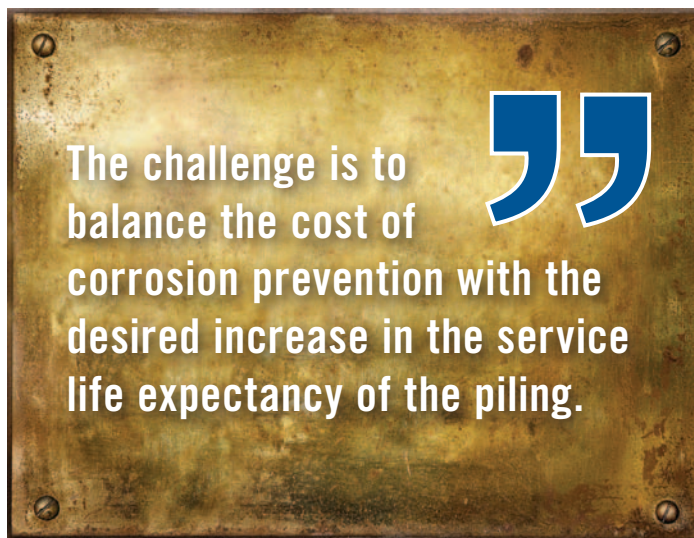
The life of unprotected steel piling in marine installations varies with the conditions of exposure. Wharf or pier construction in protected harbors can be expected to have a considerably longer life than shore structures that are subject to salt spray, wave action, and sand abrasion. Seawater causes more corrosion due to the high salt content than fresh water. Salt water can be mixed with fresh water, especially in harbors and river deltas.

Vegetation on steel can influence the rate of corrosion. The most important factor in corrosion is the duration of exposure of the steel surface to water and the presence of corrosion-stimulating agents in the moist zone. The risk of corrosion is more serious for piles in direct contact with polluted and/or seawater. In marine splash zones, protections can be employed in the form of coatings or concrete encasement.

Sheet piling when utilized for marine applications provide the maximum strength and durability at the

lowest weight which good design can achieve. The effective life of unprotected piling, either mild steel or high yield steel, depends upon the stresses imposed on it in service along with the reduction of its cross section due to corrosion. Protective systems for sheet piling require knowledge of the stress levels and ranges in the product and the conditions of the soil/water in which it is to be driven. Whenever possible it is best to design the piling so that high bending moments or tensile stresses occur in areas away from concentrated corrosion. When necessary, cathodic protection may be appropriate in order to significantly reduce the corrosion rate of the piles.

In waterfront structures actually standing in seawater, the area immediately above water level—the so-called splash zone—is wet with a thin film of water that is saturated with oxygen.



The area below water level is, by comparison, oxygen-starved, and is anodic to the splash zone. The most severe corrosion usually occurs within a zone about four feet high, extending from two feet below to two feet above low-water level.

In some cases there is an increase in corrosion at the mud line, not usually serious. Although oxygen cannot penetrate the soil, corrosion can occur by sulphate-reducing bacteria present in the soil. Sulphate reducing bacteria, which can exist in water and soil, colonize on steel pile faces and form a corrosion cell in which the steel becomes the anode. Accelerated Low Water Corrosion (ALWC) is defined as the localized and aggressive corrosion phenomenon that typically occurs at or below low-water level and is associated with microbial induced corrosion.

Atmospheric Corrosion

Mild carbon steels will rust in moist atmospheres, a relative humidity of over 50 percent provides the necessary amount of water, and at 80 percent or above, corrosion of bare steel is worse. The critical factors determining the atmospheric exposure rate of steel are moisture (humidity or precipitation) especially in marine salt-water environments. Piles exposed to the atmosphere are generally subject to low corrosion. However, conditions do exist in foundation structures that are conducive to severe corrosion where moisture, chlorides, and oxygen are abundant such as road runoff on a bridge deck or roadway.

Dealing with Piling Corrosion

Steel piles and sheet piles in soil and water must remain in place for a long time without corrosion affecting their load bearing capacity. Engineers usually rely upon a theoretical approach when dealing with corrosion when difficult corrosive conditions are anticipated. Ideally their designs must not result in steel piles that prove more costly for the client than the actual service conditions ultimately warranted. The challenge is to balance the cost of corrosion prevention with the desired increase in the service life expectancy of the piling. In situations where elevated rates of corrosion are likely, presented below are methods commonly utilized to protect the piles or to counter the anticipated effects of corrosion over their designed service life.

Over Dimensioning

The easiest method to provide for any corrosion damage is to over dimension the cross-sectional area of the steel piles. Increasing the wall thickness of the piling provides a corrosion allowance to insure adequate load bearing over the planned service life of the foundation structure. If a site is characterized as noncorrosive, then no corrosion allowance (sacrificial metal loss) is necessary. A common practice is to include an additional 3.2 mm (1/8 in.) to piling thickness as a contingency measure to counter higher than anticipated corrosion rates.

The amount of sacrificial metal will also depend on the amount of piling surface area exposed to the soil or water. Sheet piles and H-piles can experience corrosion over their entire surface area. Whereas for close-ended steel pipes, significant corrosion occurs normally only to the external surface of the pile; open-ended steel pipe piles may also be susceptible to internal corrosion. If the point of the open-ended pile is permanently below the ground water level and the upper head of the pile is hermetically sealed, the pile forms a closed, air-tight casing and corrosion of the internal surface of the pile becomes negligible.

High Yield Steels

Specifying higher yield strength steel in lieu of a mild steel piling grade is another method to counter potential corrosion losses over the life of the project. Increasing the minimum yield strength of the piling provides an extra measure to enable it to maintain its load bearing capability if and when any corrosion is experienced.

Coatings

Corrosion protective coatings are rarely used on piles in soil because of potential damage while the piles are driven. However when deemed necessary, organic resin coatings can be an economical choice. There are specialized paint and coating systems specifically designed for steel sheet and support piles in soil, fresh water and salt water marine applications. Concrete jacketing and fiber wraps can also be very cost effective for marine applications.



Cathodic Protection

Cathodic protection is a corrosion protection method where the corrosion current in the piling is compensated with a protective reverse current. The effect of the DC current is to force the metallic surface to become cathodic (i.e., collecting current). If the current is of sufficient magnitude, all metallic surfaces will become cathodic to the external anode. Using cathodic protection, the corrosion of steel piles can also be monitored with high reliability.

Summary

A review of the literature dealing with the various types of steel piling corrosion can yield a tremendous amount of data and helpful information. There are many case studies covering corrosion of driven steel piles in various marine and inland installations. The historical corrosion rates observed in these studies can provide the engineer with an informed insight as to how he may cost effectively adapt his piling design criteria to deal with corrosion over the service life of his project. ▼

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Soil corrosion

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