Corrosion Considerations For Helical Pile Foundations

Kyle Olson, P.E. Senior Structural Engineer

The term "corrosion" is used to describe the degradation of a material or its properties due to reaction with its environment. Although most materials are known to corrode over time, corrosion is typically considered as the destructive attack of a metal by chemical or electrochemical reaction. During this process, ions from the base metal migrate from the surface, resulting in material loss. As the corrosion process and metal loss continues, there can be a reduction in material thickness and area, which could result in loss of structural capacity of a given member.

The following conditions must be met for corrosion to occur:

1. There must be two points (anode and cathode) on a metal structure with different electrical potential and these two points must be electrically connected to complete the circuit. The difference in electrical potential could be caused by inconsistencies in the metal, varying stress/strain points, contact with dissimilar metals or materials, etc.

2. There must be an electrolyte to carry current, and for below ground pile applications, soil moisture serves this purpose. The presence of soluble salts increases the electrical conductivity (or lowers resistivity) of the electrolyte, thereby increasing corrosion potential.

There is still much discussion and debate about corrosion and corrosion rates for buried metal, with the central argument typically being the amount of available oxygen. The amount of oxygen within soil decreases significantly just a few feet from the surface, unless the soil is loosely-placed fill or an open-graded, granular soil. The presence of a water table further complicates the discussion as you'd expect less oxygen below the water table than above. Although oxygen starved environments will inhibit rusting, which is a specific type of corrosion, other types of galvanic or bacterial corrosion are still possible.

Galvanized helical pile being installed.

Helical lead sections receiving hot dip galvanized coating

The International Code Council Evaluation Service (ICC-ES) defines corrosive soils within Acceptance Criteria 358, Acceptance Criteria for Helical Foundation Systems and Devices, by: (1) soil resistivity less than 1,000 ohm-cm; (2) soil pH less than 5.5; (3) soils with high organic content; (4) soil sulfate concentrations greater than 1,000 ppm; (5) soils located in landfills, or (6) soil containing mine waste. In such environments, the steel can be protected with a hot-dip galvanized zinc coating or with other means such as sacrificial anodes. A site-specific evaluation of the soil can be conducted in order to determine an appropriate level of protection. FSI recommends that a corrosion engineer be consulted when site or project conditions warrant further evaluation.

While it's true that steel does corrode over time, it is actually quite rare that corrosion will govern the design. This is because of the nature of how helical piles are designed and installed. To state it simply, the amount of steel which is required to develop the necessary torque during installation far exceeds the amount of steel that is required to resist the design axial compressive forces. This can be demonstrated in the following example:

A helical pile is required to resist an allowable compressive load of 35 kips. The FSI Model 288 (2.875-inch OD) helical pile is selected for the project. The pile is installed to a torque of 7,800 ft-lb to provide an ultimate torque-correlated soil capacity of 70 kips (FOS = 2). The pile has an uncorroded cross-sectional area of the shaft of 2.11 in² and an allowable axial capacity of 75.9 kips on the day the pile is installed. This capacity would also be referred to as the allowable mechanical capacity. However, the overall allowable pile capacity would remain at 35 kips, limited by the installation torque and the correlated allowable soil capacity, even though the steel shaft section in the ground is capable of a great deal more.

Following installation, we can now consider the effects of corrosion. ICC-ES AC358 provides scheduled losses or "sacrificial thicknesses" for black steel or steel with protective coatings, and these sacrificial thicknesses must be considered for design purposes. These sacrificial thicknesses are based on moderately corrosive soils over a period of 50 years. This is a design criteria only and should not be confused with service life. In our example, after 50 years in the ground, a black, uncoated steel pile would have lost a steel thickness of 0.036 inch due to corrosion. The pile would have a remaining cross-sectional area of the shaft of 1.82 in² and an allowable (mechanical) axial capacity of 65.3 kips. This is the value that Foundation Supportworks® lists as the allowable mechanical axial capacity in compression for the Model 288. The overall allowable pile capacity still remains 35 kips, limited by the installation torque which was applied 50 years earlier.

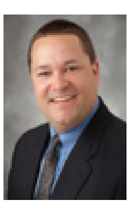
Black steel beginning to show corrosion

So how much steel would have to be lost before corrosion would begin to govern the design? See Table 1. From this table, remaining allowable mechanical capacity does not fall below the allowable pile capacity of 35 kips from our example until the sacrificial thickness reaches somewhere between 0.135 inch and 0.140 inch. This is nearly four times greater than the scheduled 50-year corrosion loss rate for black steel and over 10 times greater than the scheduled 50-year corrosion loss rate for hot-dipped galvanized steel.

Corrosion is a very complex subject involving many factors which can affect loss rates. With some understanding, it quickly becomes apparent that even if the corrosive properties of the soil at a particular site are especially aggressive, it is still quite rare for corrosion to govern the design of a helical pile solution.

TABLE 1.

	Sacrificial Thickness (in)	Steel Area (in²)	Allowable Mechanical Capacity (k)	Sacrificial Thickness (in)	Steel Area (in²)	Allowable Mechanical Capacity (k)
Day of installation	0.000	2.11	75.9	0.090	1.37	49.3
	0.005	2.07	74.5	0.095	1.33	47.9
	0.100	1.29	46.4	0.100	1.29	46.4
Scheduled 50 year corrosion loss for zinc coated steel per AC358	0.013	2.01	72.1	0.105	1.25	44.9
	0.015	1.99	71.5	0.110	1.21	43.4
	0.020	1.95	70.0	0.115	1.17	42.0
	0.025	1.91	68.6	0.120	1.13	40.5
	0.030	1.87	67.1	0.125	1.09	39.0
	0.035	1.83	65.6	0.130	1.04	37.5
Scheduled 50 year corrosion loss for plain black steel per AC358	0.036	1.82	65.3	0.135	1.00	36.1
	0.040	1.78	64.1	0.140	0.96	34.6
	0.045	1.74	62.6	0.145	0.92	33.1
	0.050	1.70	61.2	0.150	0.88	31.6
	0.055	1.66	59.7	0.155	0.84	30.1
	0.060	1.62	58.2	0.160	0.80	28.7
	0.065	1.58	56.7	0.165	0.76	27.2
	0.070	1.54	55.3	0.170	0.72	25.7
	0.075	1.50	53.8	0.175	0.67	24.2
	0.080	1.46	52.3	0.180	0.63	22.8
	0.085	1.41	50.8	0.185	0.59	21.3



Kyle Olson, P.E. Senior Structural Engineer

Kyle focuses on the development and verification testing for many of FSI's products and equipment. He provides technical support to installing contractors and their consultants. Kyle is often involved in unique projects, especially those that include specialty connections, brackets or other custom products. Kyle also assists with the development of technical documents and presentations.

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