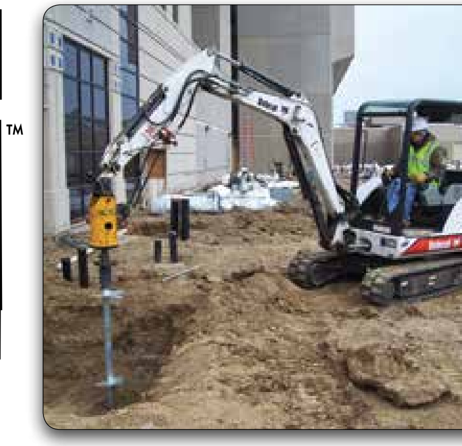
Foundation Nation™

FSI NEWSLETTER FOR DESIGN PROFESSIONALS



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.

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

Continued on back . . .

Distribution Checklist

❑ ______________

❑ ______________

❑ ______________

❑ ______________

❑ ______________

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.
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.

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
Scheduled 50 year corrosion loss for zinc coated steel per AC358	0.100	1.29	46.4	0.100	1.29	46.4
	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
Scheduled 50 year corrosion loss for plain black steel per AC358	0.035	1.83	65.6	0.130	1.04	37.5
	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

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.

Senior Structural Engineer

Foundation Nation™
FSI NEWSLETTER FOR DESIGN PROFESSIONALS
Quarterly Newsletter • Issue 6
Winter 2011

Contact Information:
For more information about Foundation Supportworks™ or to locate a Foundation Supportworks™ dealer in your area, please visit our website at www.foundationsupportworks.com or call 800.281.8545.
Foundation Supportworks

Your local dealer:

CASE STUDIES

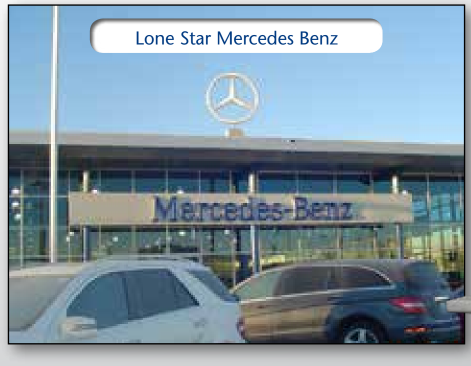
New Construction Helical Piles

Commercial

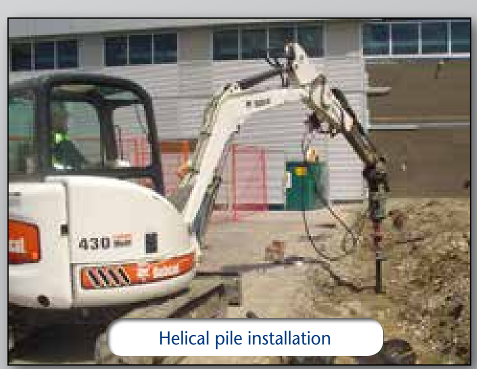
Project: Lone Star Mercedes Benz
Location: Calgary, Alberta, Canada
Foundation Supportworks™ Dealer/Installer: Foundation Supportworks of Alberta

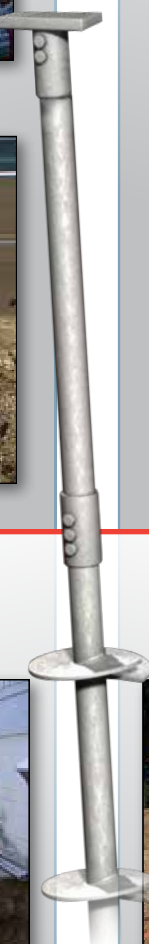
Challenge: The Lone Star Mercedes Benz car dealership planned a renovation to their existing facility that included the construction of an approximate 1,000 square foot addition. A geotechnical investigation for the project included eight soil borings advanced to depths of 16.5 to 20 feet. The general subsurface profile consisted of 10 to 13 feet of uncontrolled fill, clayey silt with organics, over native silty sand with organics over dense sandy gravel. The dense sandy gravel layer was encountered at depths of 13 to 20 feet. The geotechnical engineer recommended against supporting the new addition with spread footings bearing within the uncontrolled fill. Over-excavation of the existing fill was also not an option due to the depth of fill and the potential for undermining the existing building and pavements without extensive shoring. Several deep foundation alternatives were considered with bearing within the dense gravel.

Solution: Helical piles were selected to support the new addition due to the relatively low (mobilization) costs compared to the other deep foundation alternatives. The smaller installation equipment could also access and maneuver more easily within the congested construction site. The foundation design for the addition included twenty-one new construction helical piles. Twelve retrofit helical piles were also installed along the foundation of the existing building to support load transferred from the addition. The helical piles were designed for a working load of 15 tons (30 kips). The helical pile configuration consisted of 2 7/8-inch O.D. by 0.276-inch wall round shaft with 10"-12" double-helix lead sections. At several pile locations extension sections with 14" helix blades were added in order to provide the torque-correlated soil capacity of at least twice the design working load (FOS ≥ 2). From start to finish, the pile installation and all related prep and finish work were completed in 4 days and ahead of schedule.



Lone Star Mercedes Benz

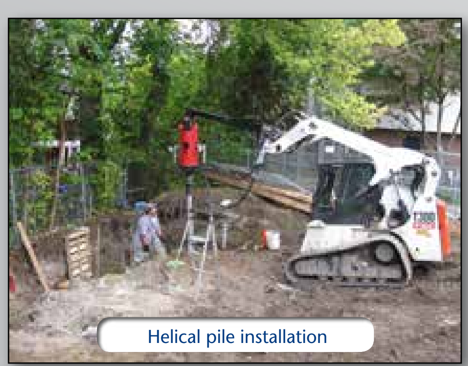

Helical pile installation



Commercial

New Construction Helical Piles

Signage on the job site


Helical pile installation

Project: New Maintenance Storage Building
Location: Springfield, MA
Foundation Supportworks™ Dealer/Installer: Foundation Supportworks Northeast

Challenge: The Springfield Housing Authority planned the construction of a new maintenance building. The one-story, slab-on-grade building had plan dimensions of 20 feet by 36 feet with construction consisting of concrete block walls with pre-manufactured wood roof trusses. Springfield was once a city heavily involved in manufacturing, with many of the old factories burning coal for heat. Areas around the city were then designated as coal ash dump sites. The property selected for the proposed maintenance building was one of those sites. A single test pit was excavated on the property to a depth of 8.5 feet, exposing fill soil, ash, cinders and brick the entire depth. Supporting the building on shallow spread footings was not an option since bearing within the upper loose fill soils would likely result in damaging differential settlements.

Solution: Deep helical pile foundations were proposed to minimize the risk of structural settlement. The intent was to either penetrate the existing fill soils or bear within deeper, dense fill. With limited subsurface information available, the original foundation detail included helical piles with 10"-12" double-helix lead sections extending to a depth of 19 feet to support a design working load of 55 kips. The foundation details and pile configuration were later modified following the installation of a test pile and completion of a load test. The revised foundation details included fifteen Model 350 (3.5-inch O.D. by 0.313-inch wall) round shaft helical piles with 10"-12"-14" triple-helix lead sections and 14"-14" double-helix extensions. The design working load was reduced to 45 kips. The piles were advanced to depths ranging from 14 feet to 83 feet. At the termination depths, the torque-correlated ultimate capacities were at least twice the design working load. The pile installation was completed in 4 days.

New Construction Helical Piles

Commercial

Project: Foremost Farms USA
Location: Rothschild, WI
Foundation Supportworks™ Dealer/Installer: Foundation Supportworks of Wisconsin

Challenge: A $3 million dryer addition was proposed with new foundations within and adjacent to an existing one-story building with basement. The basement floor slab of the existing building is approximately 15 feet below exterior grade. An interior pile cap was planned within the basement and an exterior pile cap was planned adjacent to the existing foundation wall. The two pile caps essentially created continuous support (although at different elevations) for a new foundation wall. The bottom of the exterior pile cap was 4 feet below grade to provide frost protection. With the new exterior pile cap abutting the foundation wall of the existing building, piles would have to be installed to depths below the existing footings to prevent excessive lateral loads from being applied to the existing basement wall. A geotechnical investigation included one soil boring to a depth of 30 feet. The boring encountered very loose to loose sand fill from the surface to 8 feet, over loose sand from 8 to 13 feet, over medium dense sand from 13 to 30 feet.

Solution: Several deep foundation systems were considered, but helical piles were selected as the ideal option given the limited access to the interior pile locations and the ability to quickly mobilize equipment and product to the job site. The foundation design included two helical pile configurations. Eleven Model 287 (2 7/8-inch OD by 0.203-inch wall) round shaft helical piles with 10"-12" double-helix lead sections were included to support the design working load of 10 kips per pile, and three Model 288 (2 7/8-inch OD by 0.276-inch wall) round shaft piles with 10"-12"-14" triple-helix lead sections were included to support the design working load of 22.5 kips per pile. Seven piles were installed on the inside of the building and seven piles were installed on the outside. The exterior piles closest to the existing foundation wall were installed so the uppermost helix blades were at least 3 feet below the existing footings. The piles were installed to torque values of at least 2,300 ft-lb (Model 287) and 5,000 ft-lb (Model 288) to provide correlated ultimate soil capacities of at least two times the design working loads (FOS ≥ 2). Foundation Supportworks of Wisconsin installed the 14 piles in one day to depths ranging from 15 to 26.5 feet.

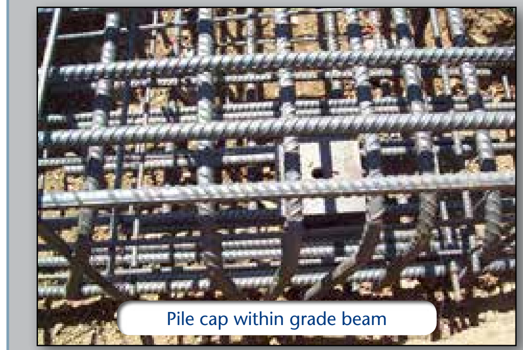

Lead section advanced


Exterior pile installation complete

Commercial

New Construction Helical Piles


Helical pile installation


Pile cap within grade beam

Project: Lion and Baboon Exhibit
Location: Knoxville, TN
Foundation Supportworks™ Dealer/Installer: American Basement & Foundation Repairs, LLC

Challenge: The proposed site for the new Knoxville Zoo Lion and Baboon Exhibit was within a previously developed area of the property. The six test borings completed for the project encountered undocumented fill to depths ranging from 11 to 17 feet. The fill was primarily described as silty clay with rock fragments, although isolated pieces of debris and trash were also observed. Standard penetration test blow counts (N-values) within the fill ranged from 2 to 14 blows per foot. The fill is underlain by residual silty clay and bedrock. The test borings refused on apparent limestone layers at depths of 11 to 23.5 feet. The geotechnical engineer recommended that the exhibit be supported by deep foundations extending down to the bedrock surface. Design working loads for the 56 piles ranged from 20 to 70 kips, but were mostly in the range of 20 to 50 kips.

Solution: Helical pile foundations were selected to extend through the fill and native residual soils for bearing on or within the limestone bedrock. The piles would likely "spin-off" on top of the hard bedrock surface rather than cut into the material with the helix blades and develop a torque to capacity correlation. The allowable mechanical capacity of the pile shaft was therefore considered in the pile selection. The foundation design included 37 Model 288 (2.875-inch O.D. by 0.276-inch wall) and 19 Model 350 (3.5-inch O.D. by 0.313-inch wall) round shaft helical piles. All piles had an 8"-10" double-helix lead section with the 8-inch blade being ½-inch thick and a special order V-style cut. The beveled tips of the lead sections were cut off straight to allow for better end bearing of the shaft on the bedrock surface. The 56 piles were installed to depths ranging from 8 to 33 feet. The pile installation was completed in three days.