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TECHNICAL REVIEW
CORROSION CONTROL REQUIREMENT
HELICAL PILE FOUNDATION
DANE COUNTY AIRPORT PROJECT
MADISON, WISCONSIN

A. Review Engineer Qualifications: The helical pile corrosion control requirement technical review was conducted by Craig Meier of Corrosion Control Incorporated (CCI). Mr. Meier is certified by the National Associated of Corrosion Engineers (NACE) as a Cathodic Protection Specialist and a Coating Inspector. Mr. Meier is also certified by the American Petroleum Institute as an API-570 piping inspector. Craig is a degreed Chemical Engineer, with more than 28 years of experience providing professional corrosion engineering services. This experience includes extensive work with steel piles on marine and in-shore structures. Mr. Meier has presented more than 20 papers on corrosion-related topics, has been a guest speaker at more than 50 conferences on corrosion, and has been an instructor on coating, cathodic protection and corrosion failure analysis. The list of clients for whom Mr. Meier has provided services is extensive and includes the military, marine, petro-chemical, pulp and paper, power and municipality sectors.

B. Project Background: A new snow removal equipment storage and maintenance facility will be constructed at the Dane County Regional Airport in Madison, Wisconsin. A geotechnical soils report was commissioned by the project engineering firm, Mead & Hunt, Inc. The soils study was conducted by Soils & Engineering Services in November of 2012. The study determined that a pile foundation will be required to support the proposed building. Plans and specifications were developed by Mead & Hunt for the construction of the facility. Miron Construction was contracted to construct the facility. Lunda Construction Company was, in turn, subcontracted to install the required support piles. Materials and equipment to install the piles were provided by American Piledriving Equipment.

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Specification 316615 addresses the requirements for the supply and installation of the support piles. In this case, a helical pile will be used which is screwed into the soil to a prescribed depth. Section 2.1-B-3 prescribes the corrosion control measures to be provided for the helical piles. The specification states that; "Helical Piles and Brackets shall be hot-dip galvanized (per ASTM A13 or A153 as applicable) after fabrication. Apply zinc-rich field coating to any/all galvanized surfaces damaged by welding or other operations." Project Drawing No. S-501 shows how the galvanized steel piles and cap plates are to be embedded in the concrete building foundation footings.

Lunda Construction Company was concerned as to whether hot-dipped galvanizing was an appropriate method of corrosion control. Lunda Construction Company subsequently contracted CCI to assess the corrosion control requirements for the new helical piles.

C. Corrosion Control Analysis: There are two significant problems with using hot-dip galvanized metal cladding to control corrosion on the new helical piles. The first issue is that galvanizing is designed to control corrosion on carbon steel structures in the atmosphere. When a carbon steel structure is first dipped in molten zinc, it is bright silver. After a brief period of time, the outer surface of the galvanized structure turns a dull gray color. The change in color is due to the formation of a zinc oxide film. This film will resist further metal loss. When a galvanized conduit or pile is placed underground, it is no longer exposed to the air. The zinc will not form the protective oxide film. Within a couple of months, the buried surface of the galvanized structure is caulky-white. In a couple of years, the surface will be milky yellow with brown rust streaks. After as little 5 year's exposure, the zinc will be completely consumed and the conduits or piles will freely corrode. This explains why, when galvanized conduits are installed below grade, they must have a tape wrap or PVC coating. These wraps actually provide the corrosion control, not the galvanizing. If the piles are galvanized, the zinc will not provide any significant corrosion control and will be completely depleted within 2 to 5 years.

The second problem is one of embedding the galvanized piles, cap plates and brackets in the concrete footings. Zinc is an amphoteric metal. An amphoteric metal is subject to accelerated rates of corrosion when exposed to acidic or basic environments. The pH of the concrete in the footings can be expected to range from 12 to 14. This pH is in the strong base range. As soon as the piles are embedded in the concrete, the zinc will dissolve. This will leave bare steel in contact with the high pH concrete. When carbon steel is exposed to high pH concrete, it forms a gamma oxide which protects the embedded steel. This is good for the portion of each pile and the cap plate that are embedded. However a severe corrosion cell will develop between the steel embedded in the concrete and the steel pile exposed to the soil below the concrete. The electro-

chemical energy potential of the steel embedded in the concrete will be between -100 and -200 millivolts. This is about the same potential level as copper. The electro-chemical energy potential of the steel exposed to the soil will be in the -450 to -550 millivolt range. A natural battery cell will be created in which the steel exposed in the soil will corrode like an anode to protect the embedded steel. Over time, the piles would fail due to corrosion just below the foundation.

The piles should not be hot-dipped galvanized. There was an extensive study on pile corrosion conducted by Dr. Melvin Romanoff for the United States Department of Commerce and the National Bureau of Standards. The study was titled "*Corrosion of Steel Pilings in Soil*". Under this study, steel piles were driven into the soil at locations throughout the United States. The locations were selected to cover a variety of soil conditions. Piles were removed from each site on a set frequency and were examined for corrosion-related metal loss. The periods of exposure were up to 40 years. The extensive study concluded; "In general, no appreciable corrosion of steel piling was found in undisturbed soil below the water table regardless of the soil types or soil properties encountered. Above the water table and in fill soils, corrosion was found to be variable but not serious." This study and other similar studies have found the rate of corrosion on piles in undisturbed soils is very low.

On the subject project site, corrosion on bare helical piles at a depth of 5 feet below the foundation footings would be minimal. No corrosion control measures are required beyond a depth of 5 feet below the foundation. The piles below this depth can be installed bare. From a depth of 5 feet below the foundation footing, extending into the foundation including the cap plate, corrosion is a concern. The piles and cap plates should be cleaned and coated with two 5 to 10 mil coats of Carboline Carbomastic 90 in this zone, for a total dry film coverage of 10 to 20 mils. The coating will mitigate the corrosion cell between the steel in the concrete and the pile in the soil. Prior to pouring the foundation footings, the exposed piles should be holiday tested and any coating damage repaired. It is also important that none of the reinforcing rods in the concrete come in contact with the pile caps. Contact with reinforcing steel would act to increase corrosion on that specific pile. Plastic spacers should be installed, as needed, between the rebar and coated pile caps. Taking these steps will ensure with significant confidence that the support piles provide more than 50 years of service.

If there are any questions or concerns regarding the conclusions or recommendations set forth in this report, please address them to Craig@corrosioncontrolinc.com.