Port of Canaveral North Cargo Piers Concrete Repair and Cathodic Protection

Cape Canaveral, Florida

Submitted by Vector Corrosion Technologies

Port of Canaveral

The North Cargo Piers at the Port of Canaveral, Cape Canaveral, FL, consist of four concrete wharves, having a total 2053 ft (626 m) of docking space and a combined area of approximately 118,400 ft^2 (11,000 m^2). Each wharf consists of 18 in. (46 cm) square prestressed concrete piles, cast-in-place concrete pile caps and beams, and prestressed hollow-core deck units with a cast-in-place topping slab.

After many years of exposure to the Atlantic Ocean's corrosive saltwater environment, there existed mild to severe corrosion of the prestressing strands in the piles and deck units and of the conventional reinforcement in the pile caps due to chloride contamination of the concrete. This corrosion had caused extensive spalling and delamination of the concrete structure.

A structural engineering consultant was contracted to perform a condition evaluation of the four wharves, documenting the extent of the damage to the structure. From this evaluation, a major rehabilitation was planned to extend the service life of the existing structures and prevent a very costly removal and reconstruction of the cargo piers.

Repair System Selection

An all-galvanic cathodic protection system tailored to the specific conditions and service-life expectations was selected for the rehabilitation of the piers. Galvanic protection systems rely on the electrochemical energy difference between the anode material and the material of the structure for the production of current. The anode material, in this case zinc, has a higher potential for corrosion than reinforcement steel in concrete. When connected together, the zinc anode will corrode, producing a protective galvanic current for the steel.

The benefits of this approach include:

- No need for on-going system monitoring, and there are no components that may fail or be damaged over time;
- No need for an outside source of energy such as commercial power;
- Well-suited for the protection of electrically isolated structures in which each component is provided with its own galvanic anode; and
- Low potential operation seldom produces significant corrosive interference (stray current) on

other structures, nor will the system produce currents high enough to cause damage (hydrogen embrittlement) to prestressed strands.

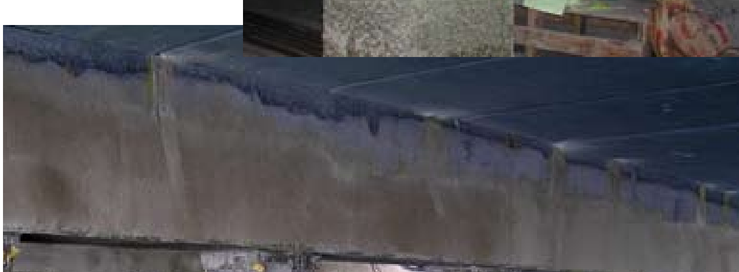
Activated Distributed Anode Strips for Protection of Pile Caps

The cast-in-place pile caps were generally showing signs of deterioration along the bottom section that experiences the highest exposure to the chloride-contaminated seawater. A protection system using an activated distributed anode system was designed to protect the bottom of the pile cap and the interface between the repair and the existing chloride contaminated concrete.

Installation Procedure

1. All lower longitudinal reinforcing bars were exposed by removing concrete from the underside of the pile cap around the entire circumference of the bars;
2. Exposed reinforcing steel was cleaned to bare metal by sandblasting. New bar was installed where necessary;
3. Electrical continuity was verified between reinforcing bars. The maximum DC resistance allowed was 1 mV. Any discontinuous bars were made continuous by tying to other bars with steel tie wire;
4. Two continuous rows of distributed galvanic anode strips were installed along the bottom of the exposed reinforcing steel along the length of each pile cap using nonmetallic ties;
5. Reinforcing steel connections were made by tightly twisting the integral connection wires to the reinforcing steel. Continuity was verified between the anode and the reinforcing steel. The connections were then coated with 100% silicone sealant;
6. If the concrete removal extended upwards more than 9 in. (23 cm) from the distributed anodes, discrete galvanic anodes were used to provide additional localized protection; and
7. The repair was completed by forming and pouring with new concrete, ensuring no damage to the galvanic anodes or the creation of air voids around the anodes.

Activated distributed anode strips installed in pile cap



Finished pile cap repair

Galvanic Jackets for Protection of Prestressed Piles

Galvanic jackets were used to protect the prestressed piles primarily in the tidal zone, where most of the corrosion of the prestressing strands was taking place. In the event that significant concrete damage existed on the pile extending downwards below the tidal zone, the length of the jacket was increased to fully encapsulate all repairs.

Installation Procedure

1. All piles to receive cathodic protection were inspected for deterioration, and all cracked, spalled, or delaminated concrete was removed from the pile;
2. The surface of the concrete and the exposed reinforcement steel was cleaned;
3. The bulk zinc anode was clamped onto the pile at an angle using two 2 in. (5 cm) galvanized steel channels. Inside the jacket, the wire was routed upward along the closest corner and positioned between the fiberglass form and the zinc mesh anode. At the top of the jacket, the wire was routed in conduit to the PVC terminal box located immediately above the jacket.
4. Continuity between all prestressing strands and spiral tie was established by securely connecting a standard tie wire to each strand and spiral tie;
5. Two No. 10 AWG THWN copper strand wires were brazed to the spiral tie to provide a negative electrical connection for the cathodic protection jacket. The brazed part of the negative connection wire received a coat of epoxy such that no wire or brazing material would be in contact with the filling material (grout or concrete);
6. The two sections of zinc mesh comprising the anode in the jacketed area were secured to the pile using tie wire. Plastic standoffs were installed on the mesh before placement to ensure encapsulation of the zinc mesh with the filling material;
7. The fiberglass forms were composed of a one-piece, durable, inert, corrosion-resistant material with an interlocking joint along one side that permitted the form to be assembled and sealed in place around the pile. All joints were filled with epoxy and stainless steel screws to form a grout-tight seal before placing any of the fill material;
8. Filling material for the jackets was pumped from the bottom upward using staged pumping

ports. The pumping process continued until no water was present at the highest discharge point of the jacket and a uniform grout consistency was achieved;
9. After the filling material had cured for a minimum of 72 hours, all temporary form support and/or bracing was removed from the piles; and
10. A PVC terminal box was attached to the concrete above the jackets to house the anode-to-steel connections. The negative lead wires were connected to the wires originating from the mesh anode and the bulk anode wire in the terminal box. The connections were properly insulated using epoxy after completion, and weather tight covers were fastened to the terminal boxes.

Activated Arc-Sprayed Zinc for Protection of Precast Deck Units

The precast concrete deck units were protected using activated arc-sprayed zinc applied to the deck soffit. After installation of the metalized zinc coating, humectant activator solution was applied to the surface of the zinc to achieve a higher level of current output and protection.

Installation Procedure

1. A 2 in. (5 cm) wide continuity trench was excavated along the entire underside of each deck unit, exposing the surface of all prestressing strands. Each prestressing strand was checked for continuity and then zinc was sprayed across the exposed strands in the trench and onto the deck surface. The purpose of this procedure was to provide negative connections from the zinc anode coating to the reinforcing in the deck unit;
2. The surface of the concrete was prepared by light abrasive blasting to clean the concrete and to provide an anchor profile for the zinc spray;
3. The zinc spray was applied in multiple passes of approximately 4 to 5 mils per pass with each layer overlapping the last in a crosshatch pattern. Sufficient zinc was applied to achieve a nominal thickness of 20 mils. The continuity trench received a total of 40 mils of zinc coating;
4. The continuity trench was coated with two layers of epoxy to protect and maintain the connections during the life of the system. The trench was then filled with patching mortar and resprayed with zinc for aesthetic purposes;
5. Humectant activator was then sprayed over the entire surface of the zinc; and
6. Inorganic, zinc-rich paint was then applied over the humectant-activated zinc to help prevent self corrosion of the zinc and extend the service life of the galvanic protection.

Longevity

This project is expected to increase the service life of the piers by at least 20 years. In total, approximately 57,000 ft^2 (5300 m^2) of deck was protected with activated arc-sprayed zinc, 6000 linear ft (1830 m) of pile cap was protected with activated distributed galvanic anodes, and 668 piles were protected with galvanic pile jackets. The long-term view of the Port Authority allowed for significant investment in cathodic protection in addition to traditional concrete repair.

Typical pile before repair and galvanic jacket installation

Finished jackets

Application of activated arc sprayed zinc

Port of Canaveral North Cargo Piers

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