

Chesapeake Bay Bridge-Tunnel Pile Repair and Protection

Cape Charles, VA

Submitted by Electro Tech CP



Overall view of bridge structure

The Chesapeake Bay Bridge-Tunnel includes a combination of bridges and tunnels carrying U.S. Highway 13 across the Chesapeake Bay. First open to the public in 1964, the Chesapeake Bay Bridge-Tunnel has a total length of 23 miles (37 km) and a shore-to-shore length of 17 miles (27 km). The bridge-tunnel is the world's largest bridge-tunnel complex, according to the Chesapeake Bay Bridge and Tunnel Commission.

The structure was built in two phases. The current northbound section was completed in 1964 for \$200 million and is composed of 2523 piles to support the structure. The southbound section, sharing the original tunnel system with the northbound section, was completed in 1999 at a cost of \$250 million. There are 2951 piles supporting the southbound structure.

Problems that Prompted Repair

Corrosion of the reinforcing steel encased within the structure's support piles caused the concrete bridge piles to crack and spall. The cracks and spalls on the bridge's piles were patched and repaired, but the reinforcing steel in some of the bridge's oldest piles continued to corrode. Therefore, the Bridge and Tunnel District hired a concrete repair contractor to correct the problem and prevent further corrosion.

Inspection and Evaluation Methods

Following inspection of the structure, it was determined that a variety of repair methods would be integrated into the overall repair strategy. Pile conditions were rated on a severity scale and categorized according to the types of repairs needed. The most severe piles required carbon fiber strengthening to retain the piles from further separation, particularly at the top region where they exhibited the most localized damage during installation. Piles that were moderately damaged but still structurally sound were to be fitted with the cathodic protection (CP) jackets and bulk anodes to provide galvanic protection over the entire length of the affected area. Piles with minor damage, including hairline cracks, were routed, packed, and then coated with a cementitious concrete overlay.

Causes of Deterioration

When the first section of the bridge was constructed in 1961, crews used a floating barge and a crane to drive the concrete bridge piles into the floor of the bay. When the piles were driven, the hammer did not squarely hit each pile, causing hairline fractures in the tops of the concrete piles. At the time, the bridge construction team did not anticipate these hairline fractures would cause problems.

2008 Award of Excellence

Inspections in 1989 revealed that the reinforcing steel in the piles with installation fractures was corroding and expanding, causing the concrete to crack and spall. Fracture repairs were made using epoxy crack injection. Although a standard material used to repair concrete at the time, the epoxy material did not adequately protect the steel reinforcements



Corrosion of vertical pressed steel



Work platforms and scaffolding under the bridge



Jackets strapped into place to maintain uniform shape during grouting operations

from chloride exposure. Thus, the reinforcing steel continued deteriorating.

In 2000, bridge inspectors found that the cracks had formed again. In addition, chloride levels in the fissures were more concentrated due to the aeration and capillary action resulting from the cracks.

Repair System Selection

Assessments revealed that 623 bridge piles required repair. The Chesapeake Bay Bridge and Tunnel District (CBB&T) determined that piles with extensive cracking, defined as cracks wider than 1/16 in. (1.6 mm), would be repaired with a zinc mesh cathodic protection jacket system (CP jackets). This system was selected based on requirements for a long-term, proven protection system that could operate maintenance free. CP jackets were installed on 215 pilings and will help prevent future corrosion by creating a barrier against chlorides, moisture, and oxygen.

For the piles with cracks smaller than 1/16 in. (1.6 mm), repairs were made by routing out the cracks and packing them with cementitious material. Any spalls on the piles were also patched with cementitious material.

In addition, a cementitious overlay coating was applied on the rectangular concrete caps, which run horizontal across each set of three piles. The road rests atop these caps.

Site Preparation

Preplanning and safety orientation was instrumental to the success of this project. The contractor needed to design a safe method of accessing the structure and performing work during adverse weather conditions. This involved acquiring a jack-up barge system capable of being self-supporting—complete with a batch mix plant, desalinated water production, lift hoists for product movement, and safe work areas for staging different construction activities.

Repair Process Execution

To install the CP jacket, the first step was to connect each piece of steel in the concrete sections to the pile's CP system. Installers drilled from the face of the pile into the concrete to expose a portion of the reinforcing steel, including the spiral wire and each prestressing strand. Then, they brazed a copper wire onto the steel. Crew members then applied epoxy at the connection point and plugged the drill hole with grout material.

The piles have a unique reinforcement configuration because the reinforcing spiral wire in each segment is independent rather than continuous. As such, the spiral wire in each pile segment under the jacket had to be connected. As a result, installers used as many as 60 wires per pile for a single jacket system to ensure the protection of all the steel reinforcement.

Each fiberglass jacket was installed in four sections. Crew members pumped grout comprising portland

cement and sand from the bottom of the jacket to the top from alternate pumping ports to create a single monolithic fill approximately 2 in. (50 mm) thick.

When the cement fill cured, the repair contractor connected lead wires from the reinforcing steel in the pile with the zinc anode in the junction box. The existing concrete and the concrete fill in the jacket work together to form a common electrolyte.

Finally, the repair contractor bolted two 48 lb (22 kg) bulk zinc anodes to the bottom of each jacketed pile and connected them to the pile's CP system to provide extra protection to the submerged portion of the pile and prevent current dump-off from the jacket's lower region.

To complete the installation, testing was performed to ensure the system was delivering protection to the reinforcing steel.

Unforeseen Conditions Found

Originally, it was assumed that the steel reinforcement of the vertical strands would be continuous for the segmented piles and that only one negative connection would be needed for each vertical steel element. It was found, however, that the vertical strands were discontinuous and required additional wiring to make them continuous and provide adequate protection to the entire area being covered with the CP jackets. This required considerably more wires, clusters of wires, and a larger dimension terminal junction box than was originally designed. Additionally, several of the piles were off-center of the pile caps making the direct routing of conduit sections to the terminal junction boxes a challenging process.

Another unpredictable condition was the difficulty of working around changing weather patterns. Depending on the wind direction and tidal movements, shallow water passes became quite rough, making barge access to the lower pile elevations very challenging. Even on what appeared to be good weather days, sea swell would break in shallow water depths, creating sometimes unworkable wave conditions. In addition, extreme fog presented challenging work conditions in the bay. On some days, the fog becomes so intense due to cool water conditions and warmer air masses that the contractor could not safely navigate to and from the structure to perform even routine repair procedures.

Special Features

The Chesapeake Bay Bridge-Tunnel is one of the most significant, vitally important transportation structures in North America. As such, repairs to this structure are critically important to ensure the transportation needs of people living and working in the Chesapeake Bay area. The bridge-tunnel complex and its repairs are further significant due to its location in a high traffic area for naval vessels stationed at Naval Station Norfolk, the world's largest naval base. Special considerations to home-



Completed installation

land security had to be made regarding working conditions and accessibility to the structure.

The repair system itself is an innovative method for concrete repair and maintenance. The CP jacket system is designed to protect the piles for 25 years or more. The system will self-adjust to meet changes in temperature, humidity, concrete resistivity, and other factors. The system is capable of providing a very low maintenance repair strategy without extensive operational costs such as power, utilities, and monitoring. The terminal junction boxes were located on the pile caps for convenience of long-term monitoring with access from the topside surface of the bridge. The CP jacket system enabled the repair to reach its goals of being long lasting and easy to maintain.

Chesapeake Bay Bridge-Tunnel

Owner

Chesapeake Bay Bridge & Tunnel District
Cape Charles, Virginia

Project Engineer/Designer

Jacobs Engineering Group, Inc.
St. Louis, Missouri

Repair Contractor

Precon Marine, Inc.
Chesapeake, Virginia

Material Suppliers/Manufacturers

Electro Tech CP
Tequesta, Florida

Jarden Zinc Products
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