

# Hyperbolic Cooling Tower Column and Lintel Beam Cathodic Protection

Jacksonville, Florida

Submitted by Existing Structures Engineering



Fig. 1: St. Johns River Power Park Unit No. 2 Hyperbolic Cooling Tower



Fig. 2: Corrosion-induced deterioration of the columns and lintel beam

Located at St. John's River Power Plant in Jacksonville, FL, this project featured work on the Unit No. 2 hyperbolic cooling tower (Fig. 1). Hyperbolic natural draft cooling towers are eye-catching in form, but this shape serves a functional purpose in that it cools the water received from the steam condensers at a much lower operating cost than mechanical draft cooling towers.

This particular cast-in-place tower, in operation since 1987, is 450 ft (137 m) tall and 360 ft (110 m) in diameter. The structure's purpose is to cool hot water from the generator's steam condensers through a pipeline entering at ground level. Water is pumped upward to the tower interior, through four flumes and a series of pipes, and is eventually discharged in spray form at about the 40 ft (12 m) level. During the downward movement, the water is cooled by the air being drawn upward and undergoes evaporative cooling.

During the operation, practically all surfaces in the basin are subject to "immersion" conditions. The columns and lintels are in a "splash zone" environment, subject to intermittent wet and dry conditions. As a result, these towers are extremely susceptible to corrosion-induced deterioration (Fig. 2).

The owners first noticed deterioration on the veil, perimeter columns, and lintel beam in the form of severe corrosion of the reinforcing steel. Visual inspections noted concrete cracking, spalling, rust staining, and delamination. Several factors contributed to the deterioration. First, the cooling tower uses brackish water from the nearby St. John's River that contains high volumes of chlorides—highly corrosive to reinforcing steel. Additionally, airflow from the nearby Atlantic Ocean and St. John's River traveling through and around the cooling tower produces high oxygen and chloride levels at the columns and lintel beam. Once the brackish water and salty air start the corrosion process, the reinforcing steel begins to rust and expand—causing cracks in the concrete that become greater conduits for more chloride and oxygen intrusion. The result—delamination and spalling.

## Inspection Method and Cause of Deterioration

Because of the progressive nature of the corrosion-induced deterioration, a condition evaluation including a visual and hands-on inspection was conducted by

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*Fig. 3: Delaminated concrete removed with pneumatic chipping guns*

the Engineer-of-Record. The data gathered through visual inspection was augmented with:

- Review of existing plans, specifications, and records;
- Measurement and documentation of geometry, deflections, displacements, cracks, and other damage;
- Extraction of samples and testing for chloride concentration at various depths;
- Electrical potential mapping;
- Continuity testing; and
- Pachometer testing.

The investigation found the lintel beam and columns to be in poor condition, exhibiting heavy cracking and spalling. Chloride testing results exceeded the chloride threshold value of 2.2 lb/yd<sup>3</sup> (1.3 kg/m<sup>3</sup>) at all measured depths. Active corrosion of the reinforcement was the cause of the deterioration.

## Repair Recommendation

Repairing corrosion-induced deterioration typically involves removal of deteriorated concrete, undercutting around the reinforcing steel, cleaning and protection of the reinforcing steel, and reestablishing the original concrete section. However, the principal investigator also recommended installing a protection system, recommending a cathodic protection system consisting of encapsulating zinc mesh anodes within a stay-in-place fiberglass form filled with cementitious grout. The zinc mesh is attached to the existing reinforcing steel by welding a wire to the mesh and then welding it onto the reinforcing steel of the structure. This process causes the zinc mesh on the fiberglass jacket to corrode before the reinforcing steel—giving the structure a more durable repair. Because the system is self-regulating, easy to install, maintenance-free, and cost-effective, it was ideal for this application.

The scope of the repair project included installation of 120 lintel beam jackets and 240 column jackets for a total of 34,000 ft<sup>2</sup> (3160 m<sup>2</sup>) of jacketing. Procedures included removing delaminated concrete with pneumatic chipping guns, profiling concrete surfaces to a minimum ICRI CSP No. 3 (Fig. 3), and cleaning the corroded reinforcing bars using 35,000 psi (240 MPa)

ultra-high pressure water blasting equipment and pneumatically rotated handguns prior to placing and grouting the fiberglass jackets.

## Design Challenges

The tower was originally built to withstand a 110 mph (177 kilometer/hour) wind load. An evaluation of the tower stability was measured when subjected to not only the design lateral forces of a 110 mph (177 kilometer/hour) wind load but also a 72 mph (116 kilometer/hour) wind load, which was determined to be the required design criteria for the non-hurricane seasonal repair.

Using collected data, the tower was recreated using a structural engineering computer modeling program called STAAD Pro 2004, including model generation, static, dynamic, p-delta, and non-linear analyses. First, the tower was modeled under its original design criteria of a 110 mph (177 kilometer/hour) wind load, followed by modeling under its demolished state with a 72 mph (116 kilometer/hour) wind load. It was determined that concrete could be safely removed from all lintel sections and 40 of the 80 columns of the tower at one time. Additionally, the lintel and columns could be stripped of 3 in. (7.6 cm) of concrete on all faces.

Because the lintel jackets were an odd shape and size, the contractor had to determine how to lift them into place and support them while grouting. Several methods were considered, but the contractor chose to install all components as one, creating only one lift per unit. This method involved building a grillage in which the jacket would be placed prior to mounting—keeping it in place and fastened to the structure until the grout dried.

For this method, structural steel brackets were first mounted to the interior and exterior of the tower and were used, along with steel rods, to suspend the grillage formwork and jacket. Using an aerial lift, the jackets were attached to the lintel beam and 4000 psi (28 MPa) cementitious grout was pumped through ports on the back face of the jackets.

Jacket installation on the columns was challenging because of the compound angle of the columns. To address this concern, the contractor designed and fabricated a lifting bracket that, once lifted off the ground, was at the correct angle to slide the jacket into place.

For each column, the jacket was actually in six pieces—two pieces each for the bottom, middle, and top. Placement started at the bottom with the two pieces resting on the foundation and subsequent pieces supported by the ones below. Each section of jacket was lap spliced and held in place with stainless steel fasteners. Brackets held up the jackets through the grout port-holes and the jackets held open with straps attached to the lifting bracket (Fig. 4). Once the jacket was around the column, the strap was released and the jacket would close around the column. Next,



*Fig. 4: Jackets for the columns being lifted into place, held open with quick-release straps attached to the lifting bracket*



*Fig. 5: Ratchet straps being wrapped around each column jacket to increase hoop strength and keep the jacket from warping during grouting*

ratchet straps were wrapped around each section of jacket to increase hoop strength and to keep the jackets from warping during grouting (Fig. 5). Grouting was performed through ports built into the jacket at 2.5 ft (0.8 m) vertical intervals, alternately placed on either face of the column.

Gaining access to the repair areas was a significant challenge. Nearly all of the work on this project was done off of aerial lifts. This type of activity was new to most of the crew, so the contractor arranged for instructors to come to the job site and perform field and classroom training. This gave the crews the opportunity to practice operating the lift, and these sessions taught the crews the dangers involved in using this equipment and what needed to be checked daily before using the lift.

## “Outage” Schedule

Because the cooling tower had to be shut down for this project, work was scheduled for a 5-week period during an outage. An unforeseen delay unrelated to the concrete repair resulted in an 8-day loss in an already tight schedule. In response, the contractor worked a 24/7 work week.

Besides the scheduling challenges, three other contractors were working on the tower during the same period. One was working inside the structure using Bobcats and other machinery below the contractor’s work area. Two other contractors were working on the veil of the tower—one performing hydrodemolition and the other applying zinc mesh and shotcreting an overlay above the contractor’s scope of work. Both had multiple 120 to 150 ft (37 to 46 m) aerial lifts that required constant vigilance to avoid mishap.

With this incredibly busy work environment, coordination and communication were essential.



*Fig. 6: Finished work on 120 lintel beams and 240 column jackets*

Daily meetings with the owner and other contractors were invaluable. Coupled with the skill of the crew of 35, which put in more than 16,000 hours with no injuries, these challenges were successfully addressed and the client’s aggressive schedule met to complete what turned out to be the largest cathodic protection system installation for the contractor (Fig. 6).

## Hyperbolic Cooling Tower Column and Lintel Beam

### Owner

Jacksonville Electric Authority—  
St. Johns River Power Plant  
Jacksonville, Florida

### Project Engineer/Designer

Existing Structures Engineering  
Cape Canaveral, Florida

### Repair Contractor

Structural Preservation Systems, Inc.  
Deer Park, Texas

### Material Supplier/Manufacturer

Jarden Zinc Products  
Greeneville, Tennessee