2011

ICRI Project Awards

CATEGORY:

WATER SYSTEMS

Cooling Tower

Strengthening and Rehabilitation

Project Description:

Not many people know the anatomy of a cooling tower unless they work within the industry. Here's an interesting analogy, the cooling tower and heat exchanger of a cooling tower facility is what the lungs and heart are to the human body; when either aren't working properly, it affects other parts of the body and your health suffers. Similarly, when a cooling tower and heat exchanger doesn't remain clean, or the heat exchange process can't work efficiently, the health of your production and process cooling system suffers.

It is important to realize that cooling towers are gigantic air scrubbers that capture all airborne debris that happen to be floating nearby, and if the system doesn't have effective filtration, the debris can clog the filtering systems and get circulated and trapped in the heat exchanger where it can build-up, restrict water flow and cause the process equipment to malfunction due to overheating.

If problems can surface just from airborne debris, imagine the impact that broken pieces of concrete could have on a system should pieces break off of the structure and get caught in the exchanger. As mentioned above, with restricted water flow and equipment malfunctioning, shut downs can occur. Not to mention the overall stability of the structure as the steel reinforcement corrodes, spreading rapidly through the concrete like cancer through a body.

Built in 1976, the 255 foot by 68 foot cooling tower is divided into six different chambers. The "overflow channel" is 8 feet wide by 255 feet long. This area is where the majority of the concrete repairs took place. An extremely corrosive environment, combined with limited access, excessive slab reinforcement, poor concrete condition, and nearly impossible working conditions, posed a significant challenge to overcome.

Problems That Prompted Repair / Causes of Deterioration

It would be simple to say the problem that prompted the repair of this structure was corrosion. However, anyone in the concrete repair industry knows that corrosion is anything but simple. The scope of work included designing the repair and strengthening system of the walkway which suffered the most severe loss of rebar cross section. This area is constantly exposed to the chlorinated water in what could be considered a "splash" zone similar to that of a bridge piling.

The corrosion was so severe under the walkway it caused all 8 of the 1-3/8" diameter steel tie-back rods to corrode completely off. This allowed the retaining wall to shift, opening large cracks in the corner of the structure.

Due to the advanced corrosion and extremely poor condition of the concrete, operation of the facility became dangerously close to forcing a shut down and the site conditions were becoming unsafe for the employees at the plant.

Severe damage to the retaining wall required large sections of concrete to replaced

Inspection/Evaluation Methods

In addition to a visual survey, a nondestructive, delamination detection, sounding system was used to determine areas of delaminating concrete that was not easily visible. The recorded data was then used to map out all potential problem areas ahead of time. A thorough inspection and evaluation provided the owner with insight into possible future repair locations. *(Pulse velocity testing, defined in ASTM International C597-02, was used.)*

Test Results

The root cause of the damage was a direct result of the corrosive atmosphere created from the chlorinated water and unprotected concrete over an unspecified amount of time. The data that was collected indicated that the entire area examined was susceptible to continuous corrosion. The passivating protective layer from the original concrete placement was non-existent. Most cracks were found to go full depth exposing the steel reinforcement to the corrosive particulates which continuously ate away at the steel.

Site Preparation / Surface Prep

The top side of the walkway was sounded one last time by chain dragging and all hollow sounding areas were marked for concrete removal. The many facets of surface preparation required for the entire project were according to the following ICRI Guidelines: **Guideline No. 310.1R-2008** - Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion; **Guideline No. 310.2-1997 –** Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and polymer Overlays. Additionally, materials and application methods were determined by adhering to the recommendations of **Guideline No. 320.1R-1996 –** Guide for Selecting Application Methods for the Repair of Concrete Surfaces; **Guideline No. 320.2R-2008 –** Guideline for Selecting and Specifying Materials for the Repair Concrete Surfaces.

On all concrete repairs, saw cutting around the spalled areas was completed creating right angles wherever possible. As per ICRI and ACI standards, the poor concrete was removed from behind the rebar to allow for placement of the repair material to completely encapsulate the primed rebar and re-establishing the protective passivating environment.

The topside of concrete walkway was marked prior to saw cutting a straight edge.

Repair & Protection System Selection

It was decided early in the planning stages of the repair materials selection that a carbon fiber system would be added to the rehabilitation. Because of the severe loss of steel reinforcement and rebar cross section on those that would remain, it was thought a carbon fiber system would not only add to the strength of the concrete where the rebar had been compromised as well as add a corrosive barrier to prevent any chlorine fumes to penetrate the repaired concrete slab and beams.

Utilizing **Guideline No. 320.2R-2008,** a guide for selecting and specifying materials for the repair of concrete surfaces made the selection of repair materials an easy process. Following the guideline parameters it was determined that several concrete repair and restoration materials would be required. This was not a situation where one product could do it all.

Materials selected for use on this project included but were not limited to: a two-component, 100% solids epoxy bonding agent; a fast setting, one-component repair mortar with a corrosion inhibitor; a one-component, form and pour repair mortar with a corrosion inhibitor; a non-sag epoxy gel and a low viscosity epoxy resin was utilized for crack injection; an epoxy gel was utilized to dowel new steel reinforcement into existing concrete; and a 30 oz./sq. yd. of tri-axial carbon fiber was utilized to strengthen and protect the concrete.

Repair Process Execution / Application Method

An extremely corrosive environment, combined with limited access, excessive slab reinforcement, poor concrete condition, and continuous exposure to chlorinated water, posed a significant challenge to overcome.

The first area to address was the southeast corner of the retaining wall that supported the 255 foot walkway. With the steel tie-backs corroded off and the large cracks within the wall it was imperative to strengthen this area prior to proceeding with repairs to the walkway above or the inside of the narrow water flumes. After repairing the spalls and cracks, both the inside and outside areas were wrapped with CFRP to secure the structure.

Formwork is assembled and a pre-packaged polymer concrete was used to fill in the voids and rebuild the interior edge beam of the walkway. The slab to wall exterior edge was reinforced using a 24" wide strip of 27 oz./sq. yd. of FRP composite.

The majority of the concrete repairs for the project would be overhead repairs, possibly the most labor intensive type of repair. Accordingly, the contractor utilized state-of-the art methods and materials to speed up the process. Large volumes of overhead repair would have proven to be too costly to have attempted a hand-applied or trowel application of a repair mortar.

Because of the volume of the overhead repairs, many were completed using a one component, polymer-modified, corrosion inhibitor enhanced form and pour repair material which was pumped from the topside of the walkway through saw cut openings in the slab. Wooden forms were erected in an already difficult work area where head room was scarce.

After all of the concrete repairs to the underside were completed and properly cured a layer of 30 oz/sq. yd. of tri-axial carbon fiber was installed over the entire underside of the slab.

Challenges to Overcome

The client could only shut down one cell out of six of the cooling tower at a time. This meant that all work had to be completed while the cooling tower was running and fully operational. The total length of each cell was approximately 40 feet and the width of the return flume (cell) was approximately 8 feet. The largest obstacle was the fact that there was only 4 feet of clearance from the bottom of the slab to the top of the water.

Value Engineering

The clearance problem was overcome by fabricating a floating platform 40 feet long and 8 feet wide. The contractor dismantled the platform and brought it to the project piece by piece and erected it in the water. The platform had two floats approximately 2 feet wide on each side enabling the water to run between the the "pontoons" and not impede the flow of the water in the flume area. There were handrails constructed at both ends. When one cell was complete it was simply floated down to the next one. At the end of the project, the floats were dismantled, placed on a trailer and shipped back to their shop.

Customer Satisfaction with Final Results

All work was completed while the cooling tower was 100% operational, incurring NO DOWNTIME for the client. Completion was reached safely, on time and to the clients delight on budget!