INNOVATIVE REPAIRS PRESERVE 40-YEAR OLD COOLING TOWER

COAL CREEK POWER STATION:
UNDERWOOD, ND

INTRODUCTION

Located about 50 miles north of Bismarck, Coal Creek Station is North Dakota's largest power plant and distributes electricity into the Twin Cities of Minnesota, Minneapolis and St. Paul. Coal Creek Station operates two late 70's vintage lignite-fired generators and combined have a capacity of more than 1,100 MW.

To power the turbines, water flows through tubes that form the walls of the plant's 205 foot tall furnaces. At the top of the boiler, heated water enters a steam drum where it is pressurized and turns to steam. From there, the steam is superheated—to 1,005 degrees Fahrenheit and at 2,620 pounds per square inch—and then released as high-pressure steam into the turbines. Lower pressure steam is captured, cooled, condensed and sent back to the boiler.

Three mechanical draft cooling towers operate at the power station, each 42' high and 225' in diameter, equipped with eight 28' diameter fans. Hot water from the plant is introduced to the top of the tower and is cooled by a counter-flow of air drawn from below. The water is finally collected in the cool water basin at the base of the cooling tower. The cooling water basin and the interior beams and columns are built with cast-in-place reinforced concrete and the elevated hot water basin is constructed with precast concrete elements.

Cooling Tower Restoration

After 40 years of use, cooling tower #91 was showing its age and required lots of attention. If the entire cooling tower was demolished and rebuilt, including the interior concrete structure, it would be very costly and require a long downtime. Even though the cooling tower was showing signs of advanced deterioration, it was determined that the concrete could be preserved, and so an extensive restoration and rebuild of the cooling tower was planned during an extended 6-½ week shutdown in May, 2017.

A lot of work was to be completed in a short amount of time; planning and coordination between the owner and contractors was critical to completing the time sensitive project efficiently and safely. It was determined that the cooling tower rebuild required the following steps:

1. Demolition of the exterior structure (Fig. 1) which was originally built with pressure treated lumber framing and sheet metal, thus exposing the interior concrete structure.

2. Concrete rehabilitation work including structural concrete repair, crack repair, waterproofing, beam replacement, and protective coatings.

3. Installing the new field-erected FRP exterior structure connected to the rehabilitated concrete frame.

Fig.1: Demolition of the outer structure of the cooling tower to expose the interior concrete structure.

The structure's age, years of constant heavy use, leaking water through joints (Fig. 2) in the precast concrete hot water basin and freeze thaw cycling were the primary sources of the concrete deterioration as evidenced by rust staining, cracking, spalling, concrete delaminations and general wear. The North Dakota environment is rather extreme with a 181 ^{o}F variation between its highest and lowest recorded temperatures, the 3rd largest variation of any U.S. State.

Fig. 2: Leaking joints in precast concrete hot water basin led to deterioration throughout the concrete structure.

Project Planning

Months before the May cooling tower reconstruction, the tower was shut down for one week in the autumn of 2016. During this time, the project team was able to inspect to gather information for pre-planning an efficient shutdown the following May. A visual inspection and sounding survey was conducted to identify defects, estimate quantities, develop a repair strategy, and to create a detailed project schedule. This planning phase was a key to successfully completing the critical path concrete repair work within an allotted 5 weeks' timeframe.

To preserve the structure, the concrete repair scope of work included:

- Epoxy injection to bond and seal cracks
- Remove delaminated and spalled concrete and replace with high performance concrete
- Installation of Type 1A alkali-activated embedded galvanic anodes to mitigate patch accelerated corrosion
- Precast concrete joint repair and waterproofing
- Removal and replacement of severely deteriorated precast concrete beams
- Installation of new reinforced concrete pedestals into the cold water basin and trench to support the new FRP structure
- Installation of epoxy coating on the hot water basin's vertical directional fins

Hot Water Basin Repair

The floor of the hot water basin was essentially constructed using upside-down precast double tee beams such that the beam stems (or upright "fins") created a channel for steady water flow and reduced turbulence.

The primary deterioration in the floor was the vertical fins. Deteriorated and freeze-thaw damaged concrete was removed and additional steel, anchors and galvanic anodes were installed to protect the corroding fins (Fig. 3). After temporary formwork was installed, the concrete was replaced with a high early strength / high performance concrete consisting of microsilica, fly ash, water reducer, air entrainment and a 0.45 water:cement ratio that was custom designed for the application. High range water reducers were added to achieve the desired slump for workability.

The ready mix repair material placed into a concrete bucket and lifted by crane to the hot water basin where it was wheel barrowed to the fins to complete the form and pour concrete repairs (Fig. 4). To protect the fins, a 100% solids hybrid novolac protective coating was applied at an approximate 15 mils dry film thickness. The selected protective coating exhibits excellent water immersion resistance after only 3 days of curing.

Fig. 3: Prepared precast fins with Type 1A galvanic anodes awaiting new high performance concrete.

Fig. 4: Concrete fins repaired, prior to protective coating application.

Construction joints between the precast floor and wall sections, a source of unwanted water leakage onto the lower columns and beams, were waterproofed with an elastomeric urethane asphalt membrane system for concrete. First, 3/8" wide by 1" deep grooves parallel to the joints were sawcut about 4" on both sides. After the concrete surface was sandblasted, an epoxy primer was placed. Finally the chemically cured urethane asphalt membrane was placed across the epoxy primer and anchored into the sawcut grooves (Fig. 5). The system is designed to remain elastic to temperatures as low as -40°F (-40°C) with very good physical abrasion resistance.

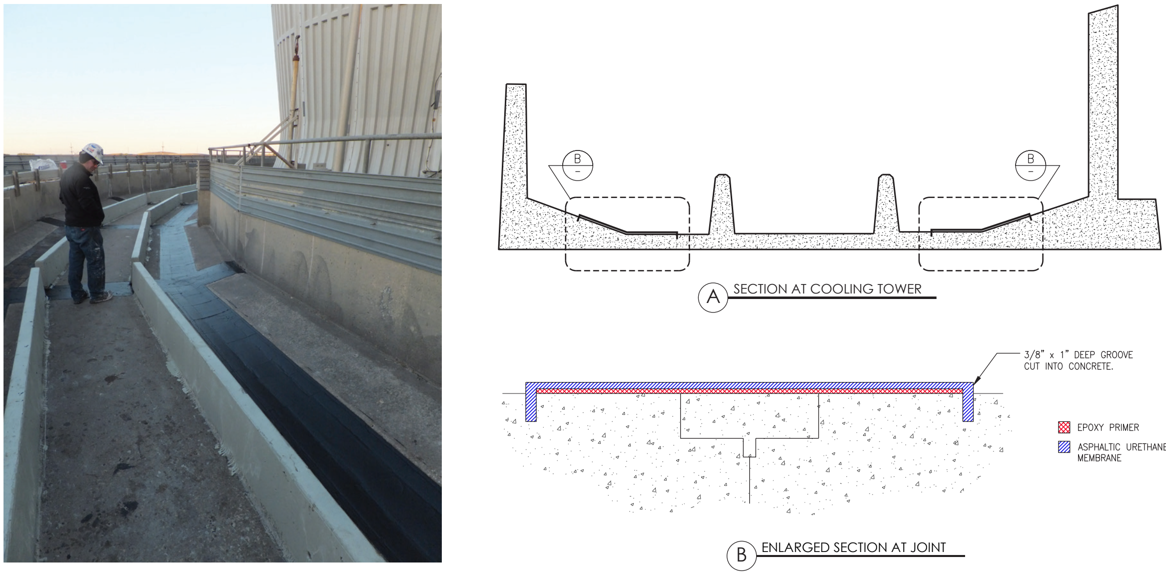

Fig. 5: Completed hot water basin floor repairs including concrete repairs and waterproofing.

Basin wall cracks were repaired using the epoxy injection process (Fig. 6). Plastic injection ports and epoxy paste seals were placed over cracks as thin as 4 mils in width and filled under pressure using purpose-built plural component pumps capable of maintaining the proper mix ratio under pressure. The injection port spacing was relatively narrow to promote adequate filling of the fine cracks.

Fig. 6: Epoxy adhesive injected to seal fine cracks in the basin walls.

Concrete Column and Beam Repairs

Leaking water from the hot water basin had contributed to the deterioration of the substructure. Deteriorated beam ends and columns were repaired with the same high performance ready mix concrete as used for the precast fin repairs. Preparation of the cast-in-place beam ends followed procedures as outlined in ICRI Technical Guidelines such as 310.1R-2008 - Surface Preparation for the Repair of Deteriorated Concrete. The concrete repairs also include Type 1A embedded galvanic anodes for enhanced long term durability (Fig. 7). For the column repairs, only spalled and delaminated concrete cover was removed to save time and to mitigate the need for structure shoring which would impact the budget and schedule (Fig. 8). To improve durability of the column repairs, additional anchors were installed into the repair areas such that the repairs would have both chemical and mechanical bond.

Fig. 7: Deteriorated beam end with concrete removed and Type 1A embedded galvanic anodes installed.

Fig. 8: Example of damaged column under the hot water basin, prior to concrete repair.

Cold Water Basin

As previously mentioned, Cooling Tower #91 is one of three. When repairing the adjacent cooling towers, the precast beams that support the outer wood/sheet metal structure were repaired then strengthened using surface bonded carbon fiber (Fig. 9).

Fig. 9: Previously repaired beams strengthened with CFRP.

The same strengthening technology was expected to be used on Tower #91 however advanced deterioration was discovered during the fall inspection. Based on this new information, it was decided to completely replace the severely deteriorated precast beam that spanned the outlet flume. Based on the relatively short shutdown schedule, utilizing precast concrete was deemed to be the most effective approach to replace the roughly 24’x4’x1.5’ beam.

Fig. 10: Precast concrete beams were cast in temporary beds inside the contractor’s shop.

In preparation of the shutdown, new precast concrete replacement beams were constructed in the contractor's shop months before they were taken to site (Fig. 10). The beams were constructed with a high performance ready mix concrete and shop-fabricated stainless steel connection plates were used for added long term durability. The new replacement beam was precast in two sections to facilitate easy of handling. The controlled environment of the shop provided excellent curing conditions for the new beams. The existing beam was wire cut, removed and replaced with the new beam (Fig. 11).

Fig. 11: Severely deteriorated beam was wire cut, removed and replaced with new freeze-thaw resistant precast beams.

In addition to the beam replacement, major concrete repairs were required at the wall-to-floor joint in the cold water basin. The concrete repairs were also completed according to ICRI guidelines with the same high performance ready mix concrete mix.

Fig. 12: Concrete repairs at the wall-to-floor cold joint in the cold water basin.

Another aspect of the repairs in the cold water basin was to fix the deterioration and leakage at the vertical joints between the cold water basin wall to the flume wall, which is the outlet for water passing under the new beam. This joint was completely rebuilt with epoxy anchored dowels and waterproofing was provided with the use of hydrophilic butyl rubber waterstops and elastomeric sealant at the new construction joints.

Finally, in the cold water basin, new reinforced concrete pedestals were installed into the floor to support the new FRP framing. According the design, the round pedestals were to be of various diameters and heights. As part of the project planning process, innovative adjustable formwork was devised using multiple rings of engineered concrete fiber forms to allow the proper pedestal elevation to be efficiently achieved in the field.

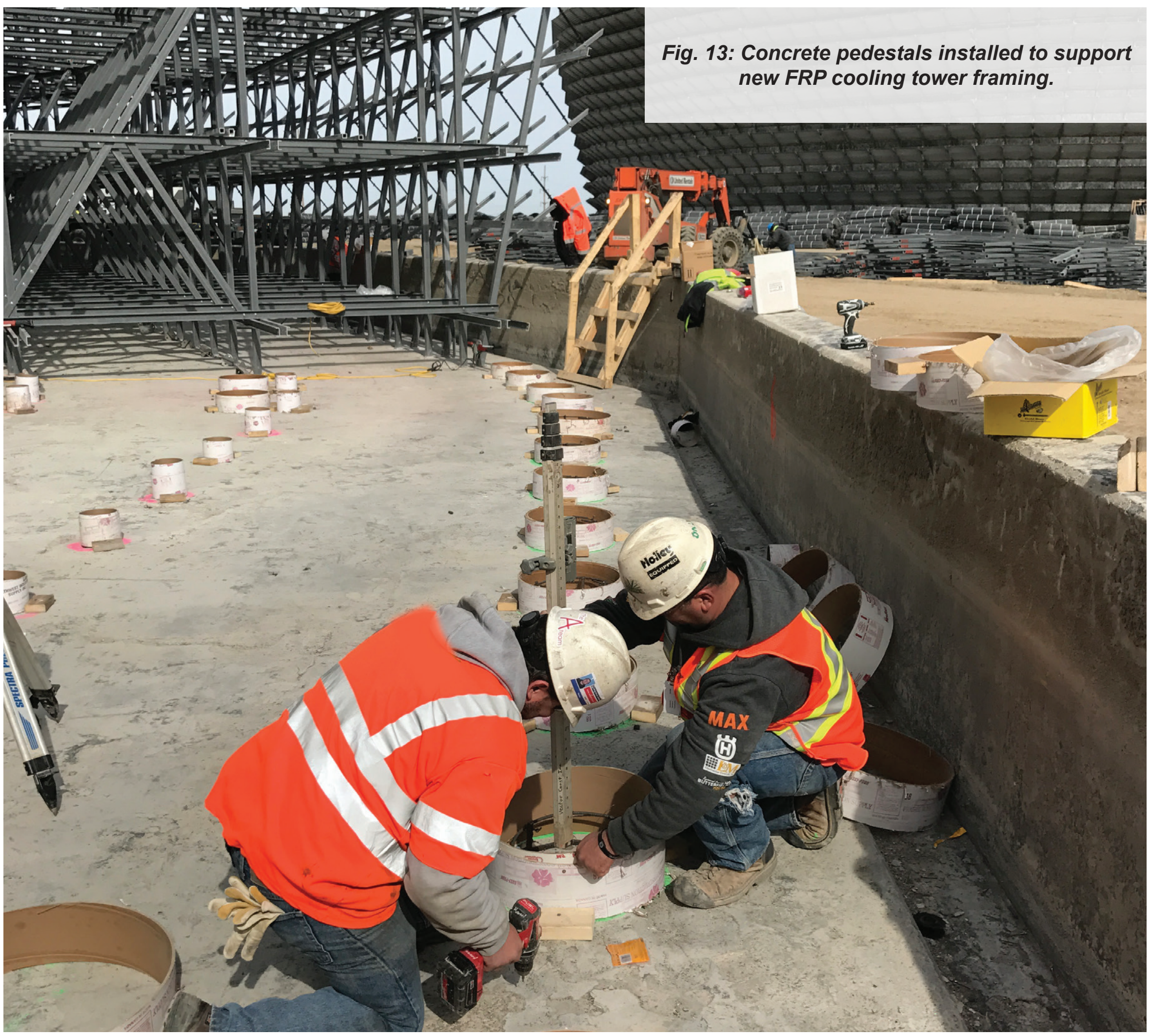

Fig. 13: Concrete pedestals installed to support new FRP cooling tower framing.

Safety

Industrial plant shutdowns consist of long hours and lots of moving parts. Project planning must also take into consideration how to perform the work safely and with unnecessary damage to plant equipment and materials. Site access included working at heights with barriers or life lines with fall protection and working off of boom lifts. Personal protective equipment such as eye and hand protection is critical for injury prevention. Additionally, appropriate respirators were utilized by laborers completing all mixing, chipping, grinding and drilling operations. In total, over 5,000 manhours were dedicated to the concrete repair and protection operations without any safety incidents.

A Final Note on Sustainability

According to Great River Energy, protecting the environment has always been a priority at Coal Creek Station and in 1998 the plant received ISO 14001 certification of its environmental management system. As a certified plant, Coal Creek is committed to continuously evaluating and improving their environmental performance. One obvious initiative relates to fly ash; every ton of fly ash captured at Coal Creek Station and sold to produce concrete reduces the carbon dioxide produced by a portland cement kiln.

Maybe not so obvious is the benefit concrete preservation provides to the environment. Extending the life and reusing of concrete structures:

1. reduces the amount of solid waste in landfills

2. reduces air and thermal pollution

3. conserves energy and natural resources.

"The importance to society of sustainability for concrete repair cannot be overestimated. Nations rely upon continuously deteriorating concrete and masonry infrastructures to satisfy ever-increasing demands. It is necessary to consider the effects of concrete repair upon society because of its potential impact upon expected economics, safety, and quality of life."

- ICRI Committee 160 – Sustainability

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