Repairs to Historic Centralia Dam

By Michael J. Moroni

The Centralia Dam is located on the Wisconsin River in central Wisconsin. The facility consists of five distinct structures: powerhouse, forebay training walls, guardlock structure, gated spillway, and the overflow spillway.

The powerhouse is a unit masonry construction above the operating waterline of the river founded on several concrete piers and intake structures. The forebay training walls are unreinforced cast-in-place concrete walls founded directly on local bedrock formations. The 230 ft-long (70 m) guardlock bridge structure is an entirely cast-in-place concrete structure with the support piers founded on the bedrock formations and the deck supported from pier to pier by spandrel beams. The gated spillway section is 340 ft (105 m) long and constructed of unreinforced cast-in-place concrete founded on bedrock formations. There are 13 steel tainter gates and three fixed concrete spillway weirs. The overflow spillway is 525 ft (160) long and is a rock-filled timber crib structure that originally had a wood-sheathed shell, which was updated with a concrete cap cast-in-place over the structure in the 1950s.

Guardlock bridge deck prior to repairs (4/12/00).

Completed guardlock bridge deck replacement (9/12/02).

Site History

The first recorded dam on the site was built in 1838 and was originally erected for a sawmill pond for logs that floated downriver from northern Wisconsin. The current dam was constructed in 1872 with major upgrades and additions in 1905, 1912, 1914, 1925, and 1950. The first hydrogenerators were installed in 1912. Pulping operations ceased in the mid- to late 1920s. Portions of the current facility are recognized in the National Register of Historic Places for Industrial Buildings.

Repair Issues and Survey Methods

The problems that prompted the repair were general deterioration of the structure from weathering, freezing and thawing actions, corrosion-induced deterioration, and use over the last 90 to 110 years. The overflow spillway was severely settled and in peril of potential failure under the stress of a major flooding event. The last major maintenance or repair project was completed in the 1950s.

Inspection and evaluation methods that were used included a visual survey to inventory the condition of site structures, nondestructive inspection using chipping hammers and delamination survey instruments to reveal unsound concrete near the surface, and an underwater video survey to evaluate the stability and condition of the foundations of the structures below the waterline. A topographical survey of the structures was also performed to generate a current map of the facility. Research of the owner's historic photographs and engineering drawings also yielded key information.

Guardlock Structure

The guardlock bridge deck and superstructure were in seriously poor condition. Evidence of delamination, corroded reinforcing steel, and failing repairs was extensive. Much of the deterioration

SE forebay wall pre-existing condition, leaning in 8 in. 10 ft (9/27/02).

Completed SE forebay wall rock-anchored buttress wall repair (11/8/02).

was corrosion-induced; however, freezing-and-thawing damage was also present at the waterline of the support piers. The bridge safety railings and vehicle capacity were also found to be substandard.

Consideration was given to repair the bridge, but the anticipated life expectancy was insufficient and repair costs were near the estimated replacement cost for the bridge. Therefore, a new precast box girder bridge was designed that would give the owner 20 to 50 years of low-maintenance operation. Demolition of the bridge deck was performed in 60 ft-long (18 m) sections. The top 2.1 ft (0.64 m) of the piers were removed to accept the new precast girders and provide a consistent deck elevation.

The original guardlock bridge was a cast-in-place concrete structure that effectively pinned the top of each bridge pier. The new precast girders, however, were not going to provide top-of-pier fixity for 2/3 of the piers because only every third pier was used to support the girders. To provide fixity, pipe struts were installed between each of the piers from abutment to abutment. Struts consisted of prestressed 10 in-diameter (25 cm) pipes located near the tops of the piers.

After placing the girders and installing a cast-in-place deck, new vehicle guard railings were installed. New bridge deck lighting was installed that was consistent with 1920s period-type fixtures. Bridge replacement was completed in fall 2001 and provided safe access to the gated and overflow spillway sections for the 2002 construction season. The bridge is now approximately 4 ft (1.2 m) wider than the previous structure and capable of carrying today's current highway loadings for semi-truck access.

Forebay Training Walls

Shallow repairs to competent forebay walls between the guardlock and the powerhouse were anticipated mainly at the waterline. During construction, however, the east wall was found to have had a concrete cap placed from the waterline up to protect an inner deteriorated concrete core. This created a construction joint highly susceptible to freezing-and-thawing damage. During construction, it was determined that it was not feasible from a cost or scheduling standpoint to replace the entire upper portion of the wall. After analyzing these conditions, it was determined that the existing deteriorated upper wall core and repaired upper cap—which was tied into the lower sound portion of the wall—were adequate for strength and stability. Therefore, the repair along the construction joint was actually feasible to execute as expected. The total area and volume of repair concrete, however, was much greater than anticipated.

A second unforeseen problem in the forebay was at the south end of the east wall. Here, a 30 ft-long (9 m) section of the wall was leaning in approximately 3 degrees to the inside of the forebay. This was due, in part, to wall construction, wall deterioration, and decay of the bedrock. Much of the bedrock formation in the area is fractured granite, and, over time, the fissures weather and deteriorate the bearing capacity. This problem area is approximately 35 ft (10.6 m) upstream of the No. 1 hydro bay intake, so a large mass of riprap or concrete would not provide an acceptable repair, as it would starve that hydro turbine of water. Therefore, a narrow section repair was needed.

For the repair, the bedrock was cleaned, loose materials were removed, and a reinforced concrete mat was placed to further protect the bedrock from weathering and river current forces. Rock anchors were then drilled through the mat 20 ft (6.1 m) into competent bedrock, grouted, and then locked off under tension to secure the mat. A new reinforced concrete wall was then cast immediately adjacent to the failing wall and fixed to the mat footing. This repair gave the owner a stable wall, which did not impact the operation of the No. 1 hydro turbine.

On the west training wall, the condition of the wall was consistent with what was anticipated, and the repair to the deteriorated waterline area was executed as planned. Surface runoff seeping along the soil side of the west wall, however, was causing some sinkholes to develop. This condition was mitigated by the design and installation of a passive drain system.

During repairs, the exposed west wall bedrock foundation showed signs of deterioration during construction. The granite bedrock had partially deteriorated and portions of the concrete wall were not in contact with the bedrock. This region was approximately 1 ft (0.3 m) in depth, 2 in. (5 cm) in height, and 35 ft (10.6 m) long. To correct this, a coarse granular material was dry-packed into voids between the bedrock and footings. Once the dry-packed material was installed, stainless steel screens were bolted over the opening to retain the materials but prevent excessive soil-side hydrostatic pressure during river draw-down. Armoring riprap was then placed along the area of the exposed bedrock-wall interface to further protect the area from the river currents and keep the dry-packed materials in place. The riprap also served to relieve overturning stresses from outside of the wall pushing in toward the river, particularly when the river was drawn-down.

Gated section repairs in progress (9/5/02).

Completed gated section repairs (11/18/02).

Gated Spillway

Gated spillway repairs were designed and performed at the waterline upstream and downstream of the tainter gates. These repairs were completed by removing the poor concrete down to a level of solid concrete using impact hammers. Final preparation of the repair surfaces was completed by hydro-blasting prior to placement of concrete forms. For repairs less than 4 in. (10 cm) in depth, a latex-modified concrete mixture was used for increased bond strength and higher resistance to wear. In areas where repairs were deeper than 4 in. (10 cm), new reinforcing steel was drilled and epoxied into the sound concrete and conventional cast-in-place concrete used. Less than 30 yd^3 (23 m^3) of latex-modified concrete was used on the project, as the repairs were found to be much deeper than originally anticipated. Repair depths in some cases were in excess of 18 in. (46 cm) but averaged 6 to 7 in. (15 to 18 cm) in depth.

Several spillway slabs downstream of the tainter gates were in poor condition due to erosion from passing water. At these locations, the slab concrete was removed to competent material with impact hammers, the surface water cleaned, and reinforcing steel drilled and epoxied into the remaining concrete. The repair was completed by placing conventional concrete over the prepared surface. Using this procedure, seven spillway slabs were repaired from the tainter gate to the downstream edge of the spillway.

The tailrace end of the entire gated spillway structure was deteriorating from scour caused by water spilling into the downstream portion of the river. A sheetpile and concrete armor system was designed to protect this area from future scour. Steel sheetpile was anchored into the concrete tailrace structure with stainless rods. The space between the existing structure and the sheetpile was then filled with conventional concrete. New spillway slabs were then placed over the top of the concrete fill to match the elevation of the top of the sheetpile so the water would flow smoothly over the spillway.

Several areas of spillway undermining had been identified in the underwater survey. These voids were filled with concrete by tremie placements and grout bags after the bedrock surface was cleared of debris utilizing an airlift device.

Overflow Spillway

The flashboard spillway section was a very tired rock-filled timber crib structure with a 50-year-old concrete cap. The cap relied entirely on the timber crib and rock fill for support and over time settled along with the timber crib structure. The new concrete cap design used the existing upstream and modified downstream walls for support independent of the timber crib section. Therefore, as the timber crib section continued to settle, the remaining cap would be an independent, stable structure. There was an approximately 400 ft-long (122 m) section of the spillway that did not have a downstream wall or footing. This was addressed by the construction of a tremied strip footing on bedrock. Due to the thickness of the river debris and the extreme variability of the bedrock formation in this area, the contractor could not clean out the bedrock sufficiently. Therefore, to achieve the desired performance, the footing would need to be anchored to the bedrock in lieu of intimate contact. The strip footing for the downstream wall consisted of approximately 850 yd^3 (650 m^3) of concrete. Rock anchors were installed on 8 ft (2.5 m) centers, 6 ft (1.8 m) into the bedrock along the entire length of the footing to resist rotational and lateral forces pushing the structure downstream. The new downstream wall and cap slab elements were then installed on the new foundation.

Powerhouse Support Beam Repairs

The final element of the project consisted of powerhouse beam repairs. The concrete support beam above Flumes 6, 7, and 8 was deteriorated, exposing reinforcing steel at and below the waterline. It was originally anticipated that the concrete was in sound enough condition that only a surface repair would be required. During demolition, it was found that 8 to 15 in. (20 to 38 cm) of concrete was in poor condition and was removed. The repair was completed by installing new reinforcing stirrups into the competent concrete above the repair area and using the sound existing horizontal reinforcing. A conventional concrete mixture was used for these deep repairs.

This project involved numerous challenges (mainly due to unforeseen conditions), which were addressed expeditiously by the owner, contractor, and engineer. The project team, however, was able to successfully overcome these challenges, as well as those posed by the stipulated project schedule and unpredictability of the Wisconsin River.

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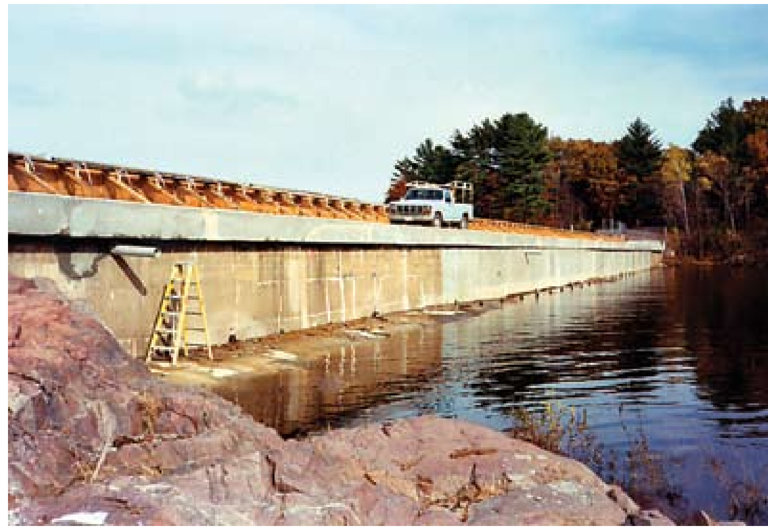
Michael J. Moroni *has been involved in several dam repair and rehabilitation projects, including the 1999 ICRI award-winning Port Edwards Dam Rehabilition. Moroni has also been involved in many construction projects including new structures, deep foundation systems, pipelines, and solid waste impoundments. He has been with STS Consultants, Ltd., a Midwest engineering firm, since 1986, the past 8 years serving as engineering project manager.*



Completed overflow spillway deck replacement (10/30/02).

Completed powerhouse support beam repair (10/16/02).

Centralia Dam

Owner
Domtar Industries, Inc.
Port Edwards, Wisconsin

Project Engineer/Designer
STS Consultants, Ltd.
Green Bay, Wisconsin

Repair Contractor
O. J. Boldt Construction Co.
Appleton, Wisconsin

Material Suppliers
Wisconsin Valley Concrete Products
Wisconsin Rapids, Wisconsin

Spancrete
Green Bay, Wisconsin