

REHABILITATION OF RAW-WATER CONDUIT AND PEDESTRIAN TUNNEL

BY JOHN R. KOSNAK

Clean water is essential for life. In a large populated area, a temporary loss of a water treatment facility due to an unforeseen shutdown could have a detrimental impact on the health of the community. The Northeast Water Treatment Plant was the third of five water treatment plants built for a system that serves almost 4 million people. Commissioned in 1956, the plant was built to meet the needs of suburban communities located north of the city and has a current pumping capacity of 300 million gal. (1135 million L) per day.

Water for the treatment plant is pumped from a nearby river and conveyed through a raw-water tunnel which enters a low-lift caisson at approximately 85 ft (26 m) below the ground surface. The water is lifted over 115 ft (35 m), using up to six

pumps, to a collecting channel where it enters the east-and-west parallel raw-water conduits and flows through the plant by gravity and head pressure. Before the water enters the low-lift caisson, it is initially dosed with chlorine and is again dosed within the raw-water conduits before entering the chemical building, where it is treated with alum. The remainder of the treatment process includes sedimentation and filtration before the water is sent to the final consumers. The majority of the parallel 7 ft (2.1 m) diameter raw-water conduits are underground, except for a short distance where they pass through the basement of the chemical building. Within the chemical building, the conduits transition to a double 7 ft (2.1 m) square configuration with a shared center wall. A pedestrian tunnel connects the administration building to the chemical building and runs parallel to the raw-water conduits.

PROBLEMS THAT PROMPTED REPAIR

During a routine inspection of a portion of the plant in 2010, leaks were noticed in the visible portion of the east raw-water conduit. Further inspection of these areas indicated that previous repairs were not holding up. The visible leaks prompted the owner to inspect the remainder of the conduits from the low-lift caisson to the chemical building.

During the condition assessment of the conduits and the adjacent pedestrian tunnel, major defects, including fractures and bowing of the west wall, were observed in the pedestrian tunnel, as well as delamination of a section of the floor slab.

INSPECTION METHODS

To assess the condition of the concrete conduits, the east raw-water conduit was isolated and dewatered, and manned entry inspections were conducted (Fig. 1). Due to the chlorine feed within the conduits, special precautions were taken to ensure residual chlorine was not present in the confined space. Obstacles affecting the assessment within the conduits included a limited opening on both ends of the conduit, a 36 in. (0.9 m) diameter bypass



Fig. 1: Access to raw-water conduit for manned entry inspection

pipe in the invert of the conduit, and a venturi meter in the center of the conduit, which made it unsafe to travel the entire length from one end.

To record the condition of the conduit, an optical scanner on a self-propelled tractor was used. The electronic images allowed the engineers to obtain measurements of the individual defects from their office, which reduced the time and cost associated with prolonged manned entry.

Concrete cores were obtained from within the conduit using care not to penetrate through the concrete walls. The core holes were filled with a crystalline-impregnated high-strength cementitious mortar that meets NSF 61 requirements. The concrete cores were tested for compressive strength and petrographic analysis.

The pedestrian tunnel was inspected visually as well as sounded using a chipping hammer to identify areas of delamination in both the wall and floor sections. In addition, crack gauges were installed at several of the cracks and fractures on the wall to document how much movement was occurring (Fig. 2).

INSPECTION RESULTS

The condition assessment revealed leaking cracks and fractures in the conduit (Fig. 3 and 4), as well as a softened surface on the interior of the concrete liner. Additional defects included offset joints at the connection of the conduit to the low-lift caisson, distressed stainless steel batten and rubber gaskets at the expansion joints, missing mortar at pipe joints, and spalled concrete within a portion of the chemical building.

During the investigation, it was observed that the concrete conduit varied from the details shown on the drawings provided by the owner. The most noticeable variations were the location of the chlorination chamber and venturi meter pit, and the types of materials used for the concrete conduit. The locations of the venturi meter pit and chlorination chamber were transposed from the original design drawings. The as-built plans show a 239 ft (73 m) long section of reinforced concrete pipe extending from the bypass line to the venturi meter, with concrete-lined steel-plate pipe from the venturi meter to the chemical building. However, testing revealed the entire section of reinforced pipe was constructed using concrete-lined steel-plate pipe. The initial sections of pipe from the low-lift caisson to the bypass pipes and the square configuration within the chemical building were cast-in-place reinforced concrete.

Compressive strength results from the concrete conduit cores indicated concrete strengths well above the original design strength. However, results from the petrographic analysis indicated the surface of the concrete was softened and carbonated to a



Fig. 2: Crack gauges installed at cracks in pedestrian tunnel



Fig. 3: Fracture in raw-water conduit



Fig. 4: Active leak in common wall

depth of 5/16 in. (8 mm). This finding raised concerns for the integrity and durability of the concrete-lined steel plate pipe because the inner concrete lining was only 2 in. (50 mm) thick.

Concrete cores were also obtained from the pedestrian tunnel wall and a structural analysis was performed using the as-built drawings for reference. The concrete core strengths were above the design strength. The location of the bowing in the tunnel west wall suggested that it may have been caused by loads positioned outside of the building.

Crack gauges revealed the wall was actively moving. Concrete sounding identified the limits of the delamination on the floor of the tunnel as well as adjacent to some fractures within the wall.

SYSTEM REPAIR SELECTION

To restore the structural integrity of the system, the leaking cracks and fractures in the conduits

would need to be sealed and repaired, the softened concrete surface restored, the pedestrian tunnel wall stabilized, and the observed delamination repaired. Work on the conduits/tunnel had to be completed within a short time period during the low water demand season in the winter months. Because the plant needed to remain in operation at all times, only one conduit could be taken out of service at a time.

Because work had to be completed during cold weather and the parallel conduits continued to convey cold water from the river, the curing time and temperature of the repair materials became an issue. In addition, the repair materials that were to be exposed to water within the raw-water conduits had to meet the NSF 61 criteria for drinking water.

For sealing the leaking cracks and fractures, a temperature-tolerant, flexible, hydrophobic expanding polyurethane grout was used. The hydrophobic grout worked well to stop the infiltration, even in the shared wall with pressure on the opposite side. An accelerator was added to the grout to speed up the reaction time in the low temperatures. The deeper fractures were repaired using a crystalline-impregnated cementitious repair mortar, which was coated with a layer of crystalline waterproofing agent to prevent the fractures from reopening.

After the leaks were sealed, the entire interior surface of each concrete conduit was treated with a crystalline waterproofing agent to protect the surface from further softening and help prevent future leakage from developing (Fig. 5). The crystalline waterproofing agent seals concrete by the development of fibers within the concrete matrix.

The pedestrian tunnel wall was repaired by excavating along the outside face and placing a new reinforced concrete wall against the existing wall (Fig. 6). A new foundation drain was installed and controlled backfill was placed along the wall to prevent any additional loads from groundwater collection. In addition, steel brackets were installed under the ceiling of the pedestrian tunnel to provide load transfer for the new wall (Fig 7).

SURFACE PREPARATION

Repairs to an existing concrete surface are only as good as the surface preparation performed prior to the repair material application. For this project, ICRI Technical Guideline 310.1R,¹ "Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion," and 310.2R,² "Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays," were followed closely to ensure that proper prepara-



Fig. 5: Completed conduit following leak repair and installation of waterproofing agent



Fig. 6: Installation of reinforcing steel in new wall at pedestrian tunnel

tion was performed (Fig. 8). The existing cracks and fractures were routed out with a square edge to ensure that the repair mortar would remain in place.

In addition, the owner was concerned with possible delamination and debonding of the repair materials, which would cause major problems with the filtration elements within the plant. ICRI concrete surface profile (CSP) chips were used to make sure the water blasting operations provided an adequate bonding surface following removal of the softened concrete and prior to the placement of the crystalline cementitious repair mortar and waterproofing agent.

PROJECT CHALLENGES

The initial repairs to seal the leaks within the raw-water conduits were intended to dry the conduit for the remainder of the rehabilitation project. Some of the leaks entering under pressure required more than one repair application to stop the water from entering the conduit, especially along the shared wall in the chemical building. Prior to removal of the stainless steel baton and rubber water stop, the contractor sealed the leaking joints behind the rubber by installing packers outside of the rubber and injecting hydrophobic grout. Once the grout expanded behind the rubber and sealed the leak, the rubber water stop was removed and the joint was repaired (Fig. 9).

Due to an untimely stretch of extremely cold weather, which affected the inlet temperature of the water in the parallel conduit, the contractor provided temporary heat throughout one of the conduits. This action was taken to raise the surface temperature of the existing concrete prior to the application and curing of the crystalline repair mortar and waterproofing agent.

One of the biggest challenges during repairs was the replacement of the distressed rubber water stop at the transition joints between the cast-in-place concrete and the concrete-lined steel pressure pipe. During the condition assessment, it was not possible to obtain a sample of the rubber material and there was no record of its material type on the as-built drawings. When the contractor removed the rubber, they discovered it was made of built-up layers of Hypalon® reinforced with organic fiber scrim. It appeared that the organic fibers had swelled and were partially causing the distress to the rubber gasket.

A new seal consisting of EPDM (ethylene propylene diene monomer), which required approval for use by the Michigan Department of Environmental Quality, was selected and installed (Fig. 10). Use of this new EPDM seal required special approval because the size required was not readily

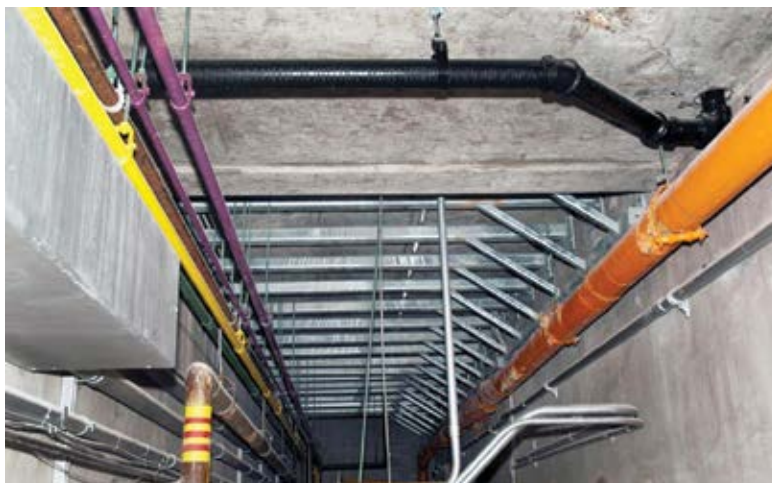


Fig. 7: New steel brackets at ceiling inside pedestrian tunnel



Fig. 8: Surface preparation within conduit



Fig. 9: Construction joint repair after removal of rubber seal

available on the market and had not been pretested and approved for NSF 61 standards.

CONCLUSIONS

Through careful planning and use of proper repair and preparation techniques, repairs were performed on a working facility with minimal disruptions. Paying close attention to and taking special measures during surface preparation resulted in a quality repair that will perform as intended. As with many rehabilitation projects, unforeseen conditions and project challenges arose and impacted the progress of the project. By working closely together, the owner, contractor, and engineer were able to carefully address the



Fig. 10: Installation of new EPDM seal in conduit

challenging conditions while completing the project on time and within budget.

REFERENCES

1. ICRI Technical Guideline 310.1R, "Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion," International Concrete Repair Institute, Rosemont, IL, 2008, 12 pp.
2. ICRI Technical Guideline 310.2R, "Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays, and Concrete Repair," International Concrete Repair Institute, Rosemont, IL, 2013, 48 pp.



John R. Kosnak, PE, is a Principal Engineer with NTH Consultants, Ltd. He received his Bachelor of Science degree in chemical engineering from Michigan Technological University and his Master of Science degree in hazardous materials management and waste

technology from Wayne State University. In his career of over 25 years, he has experience with condition assessment surveys, construction material evaluation and testing, geotechnical engineering, and restoration of concrete structures. He has been involved with evaluation services on parking structures, pipelines, underground structures and manholes, and has performed condition assessments on over 100 miles of concrete pipelines as well as CSO basins. Kosnak is currently the Vice President of the ICRI Michigan Chapter, is active with the Greater Michigan Chapter – ACI, and serves on ICRI Committee 150, ICRI Notes on ACI 562 Code Requirements.