Winnipeg Aqueduct Water-Leakage Repair

Winnipeg, MB, Canada

Submitted by Vector Construction, Ltd.

Photo of aqueduct during original construction

The Winnipeg Aqueduct is a unique structure that has supplied the city of Winnipeg with 100% of its water supply since the 1920s. It is a 90 mile (140 km) long unreinforced cast-in-place concrete arch pipe that is capable of transporting 100 million gal. (378,540 kL) of water per day. The aqueduct transports the water entirely by gravity flow (no pumping along its length). To ensure that the flow in the pipe remains constant, the cross section of the aqueduct varies along its length from about 5.3 ft (1.6 m) equivalent diameter in the steepest sections to over 8 ft (2.4 m) in the flatter sections.

The aqueduct was originally constructed through a wilderness area with no roads, so a railway was built along the proposed route to provide access for the construction.

THE PROBLEM THAT REQUIRED REPAIR

In the early 1990s, the city of Winnipeg engaged an engineering firm to review the water requirements of the city and investigate the aqueduct. The physical investigation of the aqueduct showed the concrete was in excellent condition, but that due to settlement/movement over the years, a consistent cracking pattern existed along much of the length of the pipe. Although the unreinforced arch was fully capable of carrying the design load, it was cracked in the roof and often part way up the walls. The engineers also determined that the actual flow at the outlet was only 85 million gal. (321,760 kL) per day, which was barely more than current demand. Approximately 15 million gal. (56,780 kL) per day was leaking out of the aqueduct along its length.

Two options were investigated:

1. Build a parallel aqueduct to increase the capacity; and
2. Seal the leaks in the existing aqueduct to extend its service life.

After extensive discussion and debate, option 2 was chosen.

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WATERSTOPS

To prevent leakage from the aqueduct, two different types of waterstop were used. Copper sheet waterstop was installed to seal the joint between sections. To stop leakage at the joint between the floor slab and the arch section, the waterstop was made of 1.25 x 0.75 in. (32 x 19 mm) wood. The wood waterstop ran the full length of the aqueduct (both sides).

Realizing the full length of the pipe would need to be accessed, manholes were installed approximately 1 mile (1.6 km) apart with equipment access holes located between 10 and 20 miles (16 and 32 km) apart.

To maintain as consistent a slope as possible, the aqueduct is 8 to 10 ft (2.4 to 3 m) underground in some places and rises above the surrounding ground in others.

REPAIR SYSTEM SELECTION

Once the decision was made to seal the leaks, a pilot project was performed to evaluate several methods for ease of application, long-term durability, and cost, and the method chosen as the best long-term economical solution was urethane chemical grouting.

Urethane injection was chosen for a number of reasons: ease of application, compatibility with potable water, relative cost, and expandability when it reacts with water in the cracks. Expansion was a key consideration. During installation, the grout was injected through port holes drilled to the center of the wall and the inside surface of the crack was sealed. With this configuration, once the grout expanded in the crack, it was stopped by the inside surface seal and the expansion squeezed the grout out of the crack at the exterior of the pipe creating a double seal. This way, the crack was filled and an exterior dam seal was created on the outside of the wall.

Worker preparing to inject urethane

Inside of aqueduct after injection

THE PROJECT

Because the aqueduct is Winnipeg's only water supply, it could only be shut down for short periods of time. Fortunately, there is a large storage reservoir in Winnipeg that receives the water from the aqueduct and helps regulate the flow into the city. From the time that draining of the aqueduct started (which took over a day) until it was back in full operation allowed for a maximum shutdown of only 3 weeks.

This created the first challenge and required the project to be extremely well-planned and well-managed to get the allotted amount of work done within this time frame. Planning started weeks in advance, organizing and assembling the required equipment, material, and people.

To ensure quality, an extensive Quality Control and Quality Assurance program was in place. Batches were tested prior to injection to ensure proper curing would occur in place, and all this was documented by both the contractor and the engineer. In addition, core samples of injected area were taken on a regular basis to ensure full penetration was being achieved.

The project was started in 1994 and continued over 10 years. In total, over 150,000 ft (45,720 m) of crack and joint were injected using over 25,000 gal. (94,635 L) of urethane chemical grout.

PROJECT CHALLENGES

The greatest challenges on this project were the logistics that needed to be overcome. These included:

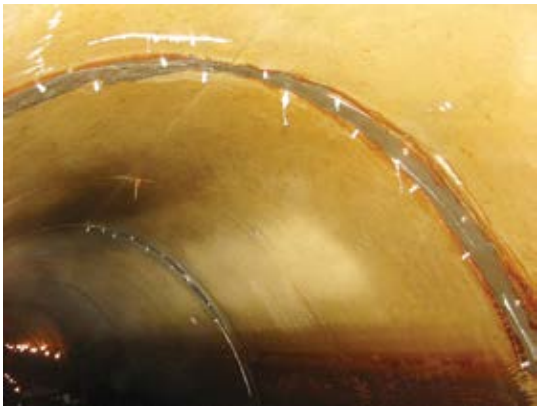
1. Completing the work during short shutdowns
   - To ensure no lost production, every piece of equipment on site had a backup; up to 50% more material than anticipated was available.
2. Water flowing through the pipe.
   - There was always some water flowing in the aqueduct, mostly from infiltration at cracks and joints. Dams were built at the upstream end of the work area and the water was pumped out the manhole. Transportation methods, work procedures, and safety procedures were developed to take this into account.

- Using water-reactive materials in a 100% humidity environment caused many equipment issues. A full-time on-site repair mechanic kept the equipment working.

3. Working in a confined space with access manholes 1 mile (1.6 km) apart
   - The first concern was safety. As this was a confined space, man-watches with personnel hoisting equipment and first aid stations were located at access manholes at each end of the 1 mile (1.6 km) long work areas.
   - Although there was a natural flow of air through the aqueduct from upstream to downstream, ventilation was enhanced using special high-flow fans that were designed to fit over the access manholes along with large high-volume fans within the pipe along the work area.
   - The height in the pipe varied along its length with some sections requiring scaffolding to reach the 8 ft (2.4 m) high ceiling and other sections that were only 5.3 ft (1.6 m) high, requiring the workers to walk hunched over to transport material and equipment then work all day without being able to stand up.
   - Moving material and equipment through the pipe required ingenuity and creativity. During the project, special trailers with wheel configurations that adapted to curvature in the aqueduct and were light enough to easily move were created.
4. Electrical power supply
   - To get electrical power to midpoint locations, two different methods were used. If there was easy access to the top of the pipe, holes were cored through the roof and power lines were dropped into the work area. If this access was not available, large-gauge wire was run down the aqueduct and hung on the wall to keep it out of the water.
5. Remote location
   - Much of the aqueduct had no road access—only the railway that had been used during the original construction and ran alongside the aqueduct. Offices, storage trailers, and sometimes sleeping quarters were loaded on flat-deck railcars and moved to the worksite.

OVER 10 YEARS LATER

The city of Winnipeg still has a reliable water supply thanks to this project. As a result of overcoming all the challenges and performing these repairs, the aqueduct provides 10 million additional gal. (37,855 kL) of water per day to the city of Winnipeg and will continue to supply all drinking water requirements into the foreseeable future.



Sealed joints and cracks

Manhole in section of underground aqueduct

System of moving materials and equipment using original railway

Winnipeg Aqueduct

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