Concrete Repair and Corrosion Mitigation of Disraeli Bridges Concrete Piers

Winnipeg, MB, Canada

Submitted by Vector Construction, Ltd.

The Disraeli Freeway connects the Henderson Highway with Main Street in downtown Winnipeg—the provincial capital of Manitoba, Canada—and provides a major link between the northeast Winnipeg and the busy downtown district. The Freeway consists of two bridges spanning the Red River and a CP Railway line, built in 1959 and 1960, respectively. Since the construction of the original Disraeli Freeway Bridges, Winnipeg's population has increased by approximately 50%, so these structures are well-traveled.

The original bridges were built as open-grate structures, which was a popular method of inexpensive, lightweight construction at the time. The open grating, combined with increasing use of winter deicing salts, led to significant corrosion and a high level of maintenance. In 2006, the City hired a consulting engineer to develop a rehabilitation plan, with the expectation that a comprehensive rehabilitation project would be the lowest cost approach but would have the downside of significant bridge closures and disruption.

Arial view of the Disraeli Bridges project over the Red River with traffic diverted onto the new bridge

PROJECT DELIVERY MODEL

Ultimately, this project was carried out using a Design-Build-Finance-Maintain (DBFM) structure, one of the first municipal infrastructure DBFM projects in Canada. After a comprehensive procurement process, a private entity that consisted of major financing, design, construction, and maintenance partners was selected to execute the project. The DBFM entity was responsible for all engineering, construction, and ongoing maintenance over the following 30 years, at which time the structure will be returned to the City. Because the DBFM entity is contractually accountable for structure maintenance over this period of time, there is a substantial financial incentive to implement innovative, cost-effective practices that achieve long-term durability.

After the project reached substantial completion, a one-time commissioning payment of $75 million was provided to the DBFM entity followed by annual service payments of $12 million to cover capital and maintenance costs. An independent review of the project confirmed that the DBFM contract resulted in a $47,000,000 savings to the City compared to a traditional project delivery approach. The consultant also stated that the DBFM model provided advantages in terms of innovation, risk, project delivery, quality, and cost certainty.

PROJECT APPROACH

The DBFM entity provided a design solution that would keep all four lanes of the Disraeli Freeway open during the 4-year construction process. A new bridge would be constructed over the railway adjacent to the existing bridge, with the existing bridge demolished after the new bridge is completed. A similar approach would be taken with the Red River Bridge. However, the existing bridge would remain and be redesigned for use as a separate pedestrian and bicycle crossing to increase public safety.

The Red River bridge superstructure was demolished and rebuilt to suit its new function. However, a key component to meeting the cost and schedule restraints was to use the existing reinforced concrete piers and foundations. With the DBFM entity responsible for maintaining the structure for 30 years, a long-term cost-effective repair solution was necessary to extend the life of the piers so that they have minimal maintenance and are in good condition when the structure is handed back to the City. With significant chloride contamination, any repair strategy would require the overall corrosion problem to be addressed.

Repair and corrosion mitigation of piers proceeded inside heated enclosures

Plywood formwork in place for form-and-pour repairs

Temporary anode mesh and wiring in place for electrochemical chloride extraction treatment for the two land-based piers

RED RIVER BRIDGE—CONCRETE REPAIR

The Red River Bridge has an approximate length of 1050 ft (319 m) and spans over four concrete piers: two on land and two in the river. To complicate matters, the repairs would need to be completed during difficult winter conditions. Access to the middle two piers would be off the frozen river and all structures would be heated to allow work to proceed.

After the damaged concrete was removed, the repairs were sandblasted to remove any loose material and create a rough but sound surface for mechanical bond of the repair material. Prior to placing the flowable concrete, the substrate was maintained in a saturated surface-dry condition, then concrete was placed using a concrete pump. A total of 2120 ft^2 (197 m^2) of structural concrete repairs were completed from January to March of 2012. Structural cracks in the piers, potential areas of vulnerability for future chloride-ingress, were epoxy-injected using low-viscosity resin and a plural component pump.

RED RIVER BRIDGE—CORROSION MITIGATION

Due to the level of chloride contamination and corrosion, a globally applied corrosion mitigation solution was required to meet the needs of the DBFM entity—long-term protection with low-maintenance requirements. Two technologies were identified and implemented; the two land-based piers would undergo an electrochemical corrosion treatment procedure and the two water-based piers would use surface-applied galvanic corrosion protection.

ELECTROCHEMICAL CHLORIDE EXTRACTION

Electrochemical treatments such as electrochemical chloride extraction (ECE) are nondestructive technologies that directly address the root cause of corrosion problems by changing the environment around the steel and mitigating active corrosion. The ECE treatment generates increased alkalinity while significantly reducing the amount of chloride around the reinforcing steel. This dual action positively alters the chloride-hydroxide ratio to ensure continued reinforcing steel protection. The first structure in North America to be treated with the ECE in was the Burlington Skyway in Ontario in 1989 and the treated area remains in a noncorroding state.

A total area of 6860 ft² (637 m²) was treated by the ECE process between November 2012 and March 2013. Because of the project schedule constraints, the ECE treatment duration lasted as long as possible with all equipment and materials removed prior to the spring thaw. Each zone was energized for 41 days, achieved an average current of 1508 A-hrs/m², and chlorides at the level of the steel were reduced by 68 to 88%.

For the two piers over water, it was determined that the duration of the ECE process was too lengthy to meet the project schedule. As an alternate, impressed current cathodic protection and galvanic protection systems were considered and galvanic protection was chosen.

GALVANIC PROTECTION

With a galvanic system, the protective current is generated by the potential difference between the zinc anode and the steel reinforcement. The metalized zinc anode is applied to the surface of the concrete and serves as a sacrificial anode that corrodes in preference to the reinforcing steel. The zinc anode can be applied to complex concrete surfaces and the finished surface has a similar appearance to concrete.

In certain environments such as non-marine bridge piers, "unactivated" arc spray zinc may not provide an adequate level of protection unless the anode is subject to periodic direct saltwater wetting. In some cases, the current generated by arc spray zinc without periodic wetting can decrease to nearly zero. Humectants were developed to improve the performance of arc spray zinc systems. The humectant solution promotes the retention of moisture which lowers the system resistance, thus allowing the anode to function more efficiently.

On this project, a humectant activated arc spray zinc system was installed to protect a total area of 9392 ft² (873 m²). High-purity zinc was applied onto the prepared concrete surface at a thickness of 20 mils (500 µm). Connection to the reinforcing steel was made using flattened expanded zinc mesh plates bolted to the surface over threaded reinforcing bar connections with galvanized nuts and washers. After zinc application, the humectant activator solution was sprayed on the surface of the zinc anode at rate of 0.0026 gal./ft² (100 mL/m²).

Quality control procedures included verification testing of anode thickness and bond strength. The thickness was confirmed by coupon testing every 64 ft² (6 m²) of anode surface. The bond of the anode to the concrete was tested using the direct tension method every 1000 ft² (92 m²) to verify that the bond strength exceeded 145 psi (1 MPa).

PROJECT SUCCESS

The innovative design-build-finance-maintain project delivery model used by the City of Winnipeg to address the deteriorating Disraeli Freeway Bridges was a success. The concrete repair and protection work was successfully performed over a 5-month period from November 2012 to March 2013, and the structure was open to the public in the autumn of 2013.

Humectant-activated arc sprayed zinc was used to protect the two interior piers

Completed project

Disraeli Bridges Concrete Piers

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