11th International Conference on Short and Medium Span Bridges
Toronto, Ontario, Canada
July 19 – 22, 2022

SUBSTRUCTURE REHABILITATION USING GALVANIC ENCASEMENT OF THE FREDERICK G. GARDINER EXPRESSWAY

Dixon, Doug[1, 4] and Liao, Haixue[2, 5], and Suleman, Muhammad [4,6]
[1] Doug Dixon & Associates Inc, Canada
[2] Vector Corrosion Technologies, Canada
[3] City of Toronto, Canada
[4] ddixon@dougdixonassociates.com
[5] LiaoH@Vector-Corrosion.com
[6] muhammad.suleman@toronto.ca

Abstract: Substructure rehabilitation and re-use was instrumental in minimizing traffic congestion in the renewal of the Frederick G. Gardiner Expressway (the Expressway) in Toronto, Ontario, the fourth largest city in North America. The frequently traffic congested structure is over 60 years old with significant deterioration due to chloride-induced corrosion. To minimize disruption to commuters, the concrete substructures in a section of the Expressway, were structurally repaired in 2019 using a galvanic encasement that will provide corrosion protection for the next 30 to 40 years.

1 INTRODUCTION

Toronto, Ontario, Canada, the fourth largest city in North America unfortunately, lays claim to some of the busiest roads in North America. Carrying more than 100,000 vehicles per day, The Frederick G. Gardiner Expressway, commonly known as the Gardiner Expressway is a key route to move traffic into and out of the core of the City. It runs East/West along Lake Ontario at the south end of the city.

The highway has deteriorated over the 60+ years of its existence. Extensive repairs have been ongoing since the 1980 while significant commercial and residential development has occurred directly adjacent to the route. As a result, the Gardiner Expressway has been the subject of several proposals to demolish it, or move it underground as part of downtown waterfront revitalization efforts.

The primary cause of the aforementioned deterioration of the Expressway substructure is chloride induced corrosion which has been left unchecked and has led to deterioration of the substructure. Originally designed as a series of simply supported spans, expansion joints at each substructure component deteriorated resulting in the leakage of chloride contaminated drainage onto the piers.

Figure 1: Pier Concrete Corrosion due to Leaking Expansion Joints and Chloride Contamination

Figure 2: Pier Corrosion Due to Chloride from Leaking Joints and Roadside Splash

As an alternative to demolition and replacement, the bridge deck is being replaced using Accelerated Bridge Construction (ABC) techniques. The severely deteriorated substructure is being repaired utilizing a galvanic encasement technique that both structurally upgrades and cathodically protects the substructure. The ability to keep the existing substructure in service and utilize Accelerated Bridge Construction (ABC)

techniques has been instrumental in minimizing the impact of the rehabilitation on traffic. Galvanic cathodic protection provides an effective and low maintenance option for engineers and owners of infrastructure to extend the useful service life.

Preservation of the substructure using a galvanic encasement combined with an overlay/refacing of self-consolidating concrete was used in 2019 on a series of some 13 substructure components. Rehabilitation of the substructure of the Expressway is a key component in the Strategic Plan to rehabilitate the Expressway over the next 10 years.

This paper presents the "Gardiner Expressway" 2019 Contract case study on the use of galvanic encasements to structurally repair and protect existing reinforced concrete substructures by extending the service life and providing effective cathodic protection for 30 to 40+ years.

1.1 Bridge Description

This 6-lane Gardiner Expressway is elevated for a length of 6.8 kilometers (4.2 mi), unofficially making it the longest bridge in Ontario. It runs above Lake Shore Boulevard through downtown Toronto. The elevated section are supported by reinforced concrete columns. The concrete deck was constructed on both steel and precast concrete box girders.

De-icing salt caused corrosion of the steel within the concrete piers (vertical columns and horizontal pier caps), which expanded, weakening the steel and causing pieces of concrete to fall off. Remedial work had to be completed starting in the 1980s at a cost of $8 million per year. With corrosion accelerating damage, the annual maintenance costs for the Gardiner Expressway were estimated in 2011 at $12 million per year. In 2011 and 2012, multiple incidents of falling concrete caused damage to the vehicles and created a safety risk to pedestrians and vehicles alike.

The city developed the Gardiner Expressway Strategic Rehabilitation plan that for the most part will:

- Replace the superstructure using Accelerated Bridge Construction techniques, and
- Rehabilitate and protect the substructures to support the brand-new superstructure (beams and deck).

2 GALVANIC ENCASEMENT

Galvanic Encasements can extend the service life of existing columns, abutments, piers & beams by encasing the structural elements in concrete jackets with a distributed galvanic anode corrosion protection system. There are many benefits to this approach including economic, environmental and minimizing traffic disruption. There are also many applications:

- Repair, protect and strengthen existing bridge elements
- Repair and corrosion protection of severely corroded structures, and
- Accelerated Bridge Construction

3 IMPRESSED CURRENT CATHODIC PROTECTION

Since 1974, impressed current cathodic protection has been used in North America as part of the corrosion protection strategy to rehabilitate chloride contaminated bridges containing unprotected reinforcing steel. It has been well documented that for cathodic protection to function properly and arrest corrosion the systems must be monitored and maintained on an ongoing basis. Many transportation agencies, port authorities and facility owners do not specify impressed current cathodic protection, either because of a lack of understanding of cathodic protection technology or inability to provide dedicated staff to conduct the required ongoing monitoring and maintenance. The need for ongoing monitoring and maintenance of the power supply is a major drawback for impressed current systems.

4 GALVANIC CORROSION PROTECTION SYSTEMS

Galvanic anode systems do not require specialized knowledge for commissioning, and they can significantly minimize the need for future monitoring and maintenance. The Ontario Ministry of Transportation conducted the first application of distributed galvanic anodes in a bridge deck overlay in September 2003. The installation was completed on the North Otter Creek Bridge.

Figure 3: First installation of distributed galvanic anodes on a bridge deck prior to bridge deck overlay, Ontario, Canada, 2003

The distributed galvanic anodes in this project have been performing well. The 15-year monitoring data has shown the polarization of 100mV has been achieved except during the winter period or when the depolarization period is not sufficiently long (Lai, Langendeon & Liao 2018). Many transportation agencies including MTO have used this type of anode in many different components, including abutment refacing, concrete deck overlays, and concrete jackets for columns, piers and marine piles.

5 GALVANIC ENCASEMENT OF GARDINER EXPRESSWAY

Over 60 years of exposure to de-icing salts has resulted in reinforcing steel bar corrosion and significant damage to the substructure of the Gardiner Expressway. The City of Toronto has invested significant time and money in concrete repairs in the substructure. In the past, repairs were predominantly removal and concrete refacing/jacketing of the piers without addressing the corrosion of the reinforcing steel.

Figure 4: Corrosion Damage of Columns and Pier Caps with Patch-Accelerated Corrosion Evident

Figure 5: Corrosion Damage of Columns and Pier Caps with Patch-Accelerated Corrosion Evident

To address this situation the City of Toronto has developed a strategic rehabilitation plan. The strategic rehabilitation plan will replace the superstructure using Accelerated Bridge Construction (ABC) techniques. The existing substructure will be rehabilitated, protected and re-used/maintained.

A galvanic encasement was used to repair and provide corrosion protection to a series of deteriorated substructure components (columns and pier caps) in 2019. Specifications required the galvanic cathodic protection supplier to design and install a system based on long-term field performance data for galvanic anodes in a similar environment. Anode size and spacing was designed to protect all reinforcing steel in each pier for the specified 30-year service life requirements.

6 CONSTRUCTION

The 2019 Contract using galvanic corrosion protection combined with jacketing using self-consolidating concrete was tendered in January 2019. Construction was completed in December of that same year. Twelve (12) Bents under the main section of the Expressway between Spadina Ave and Dan Leckie Way and an additional five (5) piers under the Rees Street on-ramp were rehabilitated.

Over 320 m³ of concrete removal and 400 m³ of refacing concrete were used to rehabilitate 2700 m² of substructure. Average depth of removal was approximately 100 mm and the total thickness of the refacing/jacket was 125 mm. The total Contract cost was approximately $6,800,000.00. Due to the advanced state of concrete deterioration “staged” repairs as well as some shoring of the steel beams at the bearing locations were required.

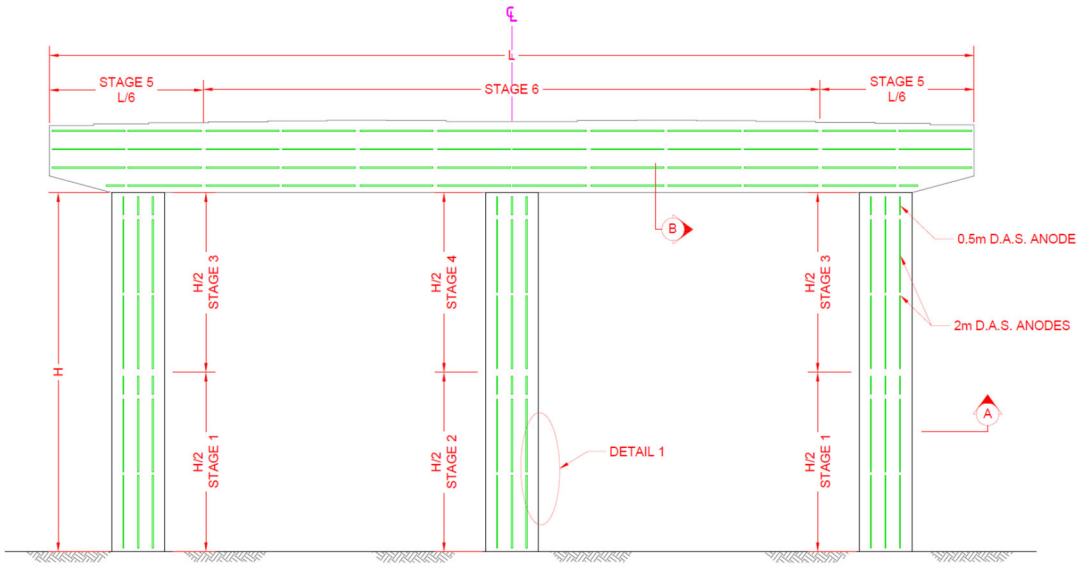

Figure 6: Distributed Galvanic Anode Layout for a Typical Pier

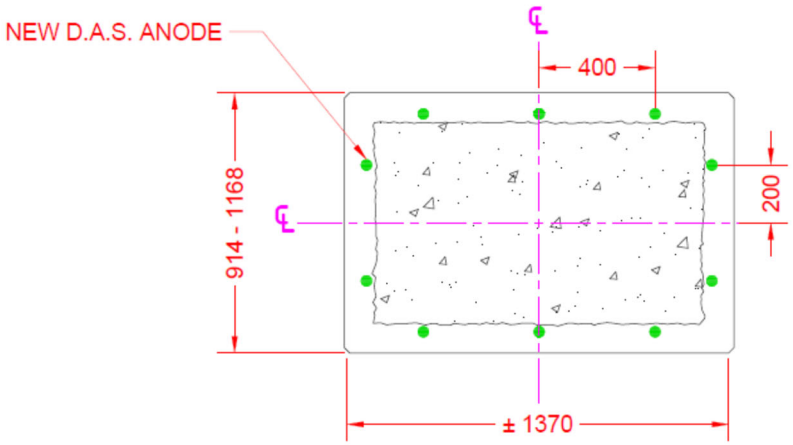

Figure 7: Distributed Galvanic Anode Layout around a Typical Pier Column

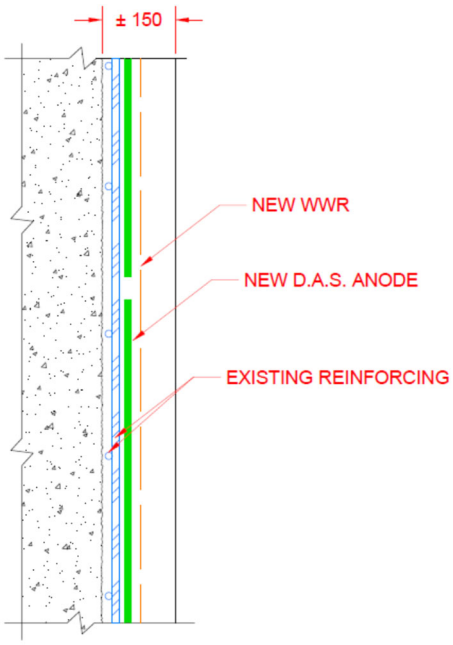

Figure 8: Galvanic Encasement Details

Figure 9: Galvanic Encasement for Hammer Head Pier (Green “bars” are the Distributed Galvanic Anodes)

Figure 10: Completed Piers in the Background with a Partially Completed Pier in the Foreground

7 SUMMARY

Despite spending millions of dollars on conventional concrete repairs over many years, corrosion accelerated, and the quantity and frequency of repairs increased over time. As a result, it became clear a major rehabilitation strategy which included effective corrosion mitigation would be required. Traffic considerations and the inability to divert the volume of traffic carried by the Gardiner Expressway onto city streets was also a consideration. The current strategy to keep the structure in service during construction, to complete a phased replacement of the superstructure using Accelerated Bridge Construction (ABC) techniques and to maintain/re-use and protect the substructure using long term galvanic corrosion protection addresses the project constraints.

Galvanic encasements and the use of ABC techniques are practical and efficient ways to extend the service life of existing bridges. This approach can reduce the project schedule, on-site construction time, and the impact to traffic, public and the environment. Galvanic cathodic protection has been tested and proven to resolve one of the major ABC challenges – extending the service life of existing substructures to match the service life of the new superstructure components.

Acknowledgements

We would like to thank Muhammad Suleman, Sherif Sidky, Hangang Li and Joyce Zhang from City of Toronto for their reviews and inputs.

References

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