Gardiner Expressway Strategic Sustainable Substructure Rehabilitation Using Galvanic Protection

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Abstract

Due to aging, heavy daily usage, weather and de-icing-salt induced corrosion, the City of Toronto decided to undertake a major multi-year, multi-phased rehabilitation of the F.G. Gardiner Expressway to keep it operational for the future. The expressway was built between 1955 and 1966 across several areas of the City, including established neighbourhoods, two river mouths and the City's downtown core. a Strategic Rehabilitation Plan was created by the City to deal with this large, complex and important project. This strategic plan divides the rehabilitation into 6 sections.

In 5 out of the 6 sections, depending on the conditions, either the superstructure or the deck of bridge structures will be replaced while substructure will be rehabilitated and re-used. To minimize disruption to commuters, the substructures were structurally repaired using a galvanic protection that will provide corrosion protection for the next 30 to 40 years without major repairs.

This presentation will first introduce the background of Gardiner Expressway and the strategic rehabilitation plan, present galvanic protection and discuss its application in the long-term rehabilitation and re-use of substructures.

Introduction

The F. G. Gardiner Expressway (Gardiner) is an approximately 18 kilometres long, limited-access highway within the City of Toronto stretching from Highway No. 427 at its western limit to the Don Valley Parkway at its eastern limit. The Gardiner was originally built by the Municipality of Metropolitan Toronto easterly from The Humber River between 1955 and 1966. In 1997, the Province of Ontario downloaded the portion of the Queen Elizabeth Way between Highway No. 427 and the Humber River to the City of Toronto, thus extending the Gardiner limits further west. It includes an elevated section in the downtown core of Toronto for a length of 6.8 kilometres (4.2 mi), unofficially making it the longest bridge in Ontario. The elevated section is supported by reinforced concrete columns and portions of it run above Lake Shore Boulevard through downtown Toronto. Traffic volumes travelling on the elevated section are as high as 160,000 vehicles per day.

The highway has deteriorated over the 60+ years of its existence. De-icing salt caused corrosion of the reinforcing steel within the concrete bents (vertical columns and horizontal pier caps), which expanded, weakening the steel and causing pieces of concrete to delaminate, spall and fall off. Remedial work on the elevated Gardiner began in the 1980s at a cost of approximately $8 million per year. With corrosion accelerating damage, the annual maintenance costs for the elevated Gardiner were estimated at $12 million per year in 2011. The remedial work included the yearly removal of loose concrete from the deck soffit and bents to minimize incidents of falling concrete - a safety risk to pedestrians and vehicles alike.

In 2014, Toronto City Council approved the Gardiner Expressway Strategic Rehabilitation Plan. This plan defined six major project areas depicted in the Figure below and described in the following sections.

Section 1. Jarvis Street to Cherry Street (Complete)

Section 1 from Jarvis Street to Cherry Street was completed in 2021. Accelerated bridge construction was used to replace the steel girders and concrete deck with pre-fabricated sections.

Section 2: Dufferin Street to Strachan Avenue

Section 2 involves replacing 700 metres of concrete deck and girders, rehabilitating the associated substructure and installing new street lighting. Construction of the Gardiner Section 2 from Dufferin Street to Strachan Avenue began in November 2023 and is anticipated to be completed spring 2026.

Section 3. Highway 427 to the Humber River

Section 3 from Highway 427 to the Humber River will reconstruct 6.5 km of at-grade expressway and include rehabilitation of 15 bridges, the rehabilitation/replacement of watermains, sewers, retaining walls, noise walls and high mast lighting upgrades.

Advanced work began in early 2025 with repairs to the Gardiner Expressway bridges over Park Lawn Road and Mimico Creek, the westbound on-ramp from Park Lawn Road over Mimico Creek, and the Kipling Avenue and Islington Avenue bridges over the Gardiner Expressway.

Section 4: Grand Magazine Street to York Street

This section will rehabilitate 2 kilometres of the elevated section of the Expressway from Grand Magazine Street to York Street.

Section 5: Cherry Street to the Don Valley Parkway

Section 5 will reconstruct the elevated Expressway from Cherry Street to the Don Valley Parkway. The alignment of both the Expressway and Lake Shore Boulevard will shift slightly to the north of the current location. Some initial work as part of this transformation has already been completed, such as removing the Logan Street on/off ramps to allow the construction of a longer and wider bridge for Lake Shore Boulevard over the Don River.

Section 6: Humber River to Dufferin Street

The scope of work for this section of the Gardiner Expressway is pending an engineering evaluation. The Gardiner is frequently inspected and the City conducts regular maintenance to keep this and other portions in a state of good repair.

This paper’s topics include:

- Concrete corrosion
- Galvanic corrosion protection
- Discussion of some repairs and strengthening in the past prior to the strategic rehabilitation plan
- Section 2 and 4 pier Jacketing
- Section 3 abutment refacing
- Temporary protection for the piers in section 5.

Reinforced Concrete Corrosion

Corrosion of reinforcing steel is recognized as the major cause of the deterioration of reinforced concrete structures. Exposure to de-icing salts, seawater and chloride-containing set accelerators, play a significant role in reinforcing steel corrosion. Long-term exposure to carbon dioxide is also cited as a contributor to the corrosion of steel in concrete as well. The two major causes of rebar corrosion are as follows, which destroy the passivated protective film on the rebar surface:

Carbonation

- ✓ Acidification of the concrete (lowering pH)
- ✓ CO2 + Ca(OH)2 = CaCO3 + H2O (pH=8-9)

Chlorides (salts) (figure 1)

- ✓ additive (CaCl2) accelerator
- ✓ Sand contaminated with salt,
- ✓ Salt penetration, seawater, salt-spray, sea air, etc.

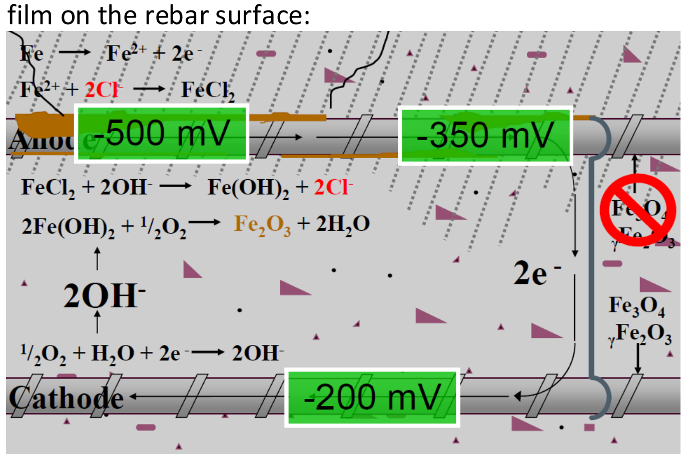


Figure 1. Corrosion Cell in Reinforced Concrete

Conventional repairs, abutment refacing, column jacket and deck overlay can also cause accelerated corrosion in existing concrete.

Figure 2. Patch-accelerated corrosion: Conventional repairs can cause patch-accelerated corrosion in adjacent concrete.

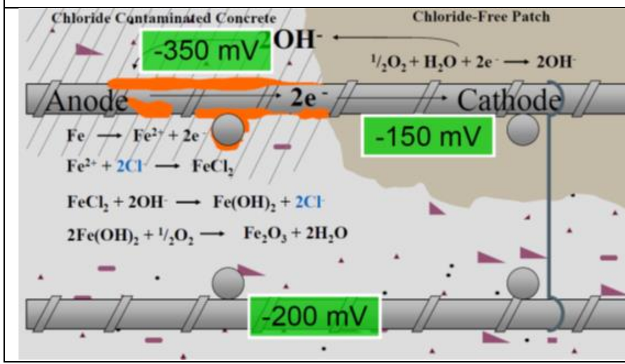
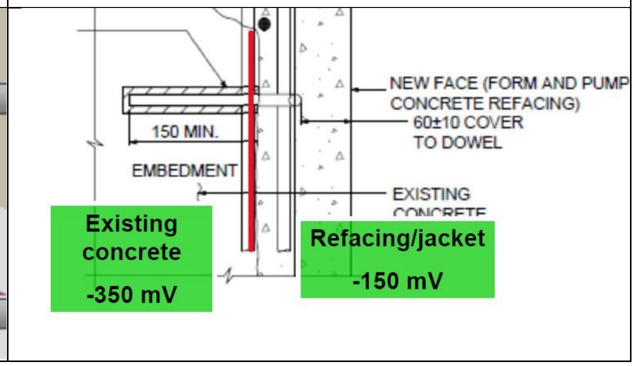


Figure 3. Accelerated corrosion in abutment refacing, column jacket and deck overlay: Bridge deck widening and structural extension can accelerate the corrosion in the existing concrete.



Galvanic Corrosion Protection for Reinforced Concrete

Suitable galvanic anodes for reinforced concrete are produced from a more active metal - zinc encased in a specially formulated porous cementitious mortar (Figure 4) saturated in high alkaline environment. Such an environment maintaining a constantly high pH, which is corrosive to the zinc and protective to the steel, was shown to sustain the zinc in an active condition producing soluble zinc corrosion products that do not stifle the corrosion process of the metal. Galvanic corrosion protection can be used for patch repairs, column jacket, abutment refacing and deck overlay to prevent and control corrosion.

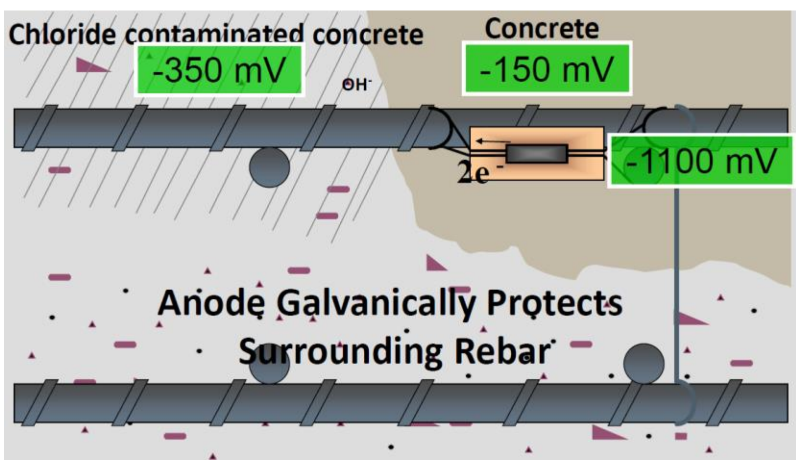


Figure 4. Galvanic anodes in patch repair to prevent patch-accelerated corrosion

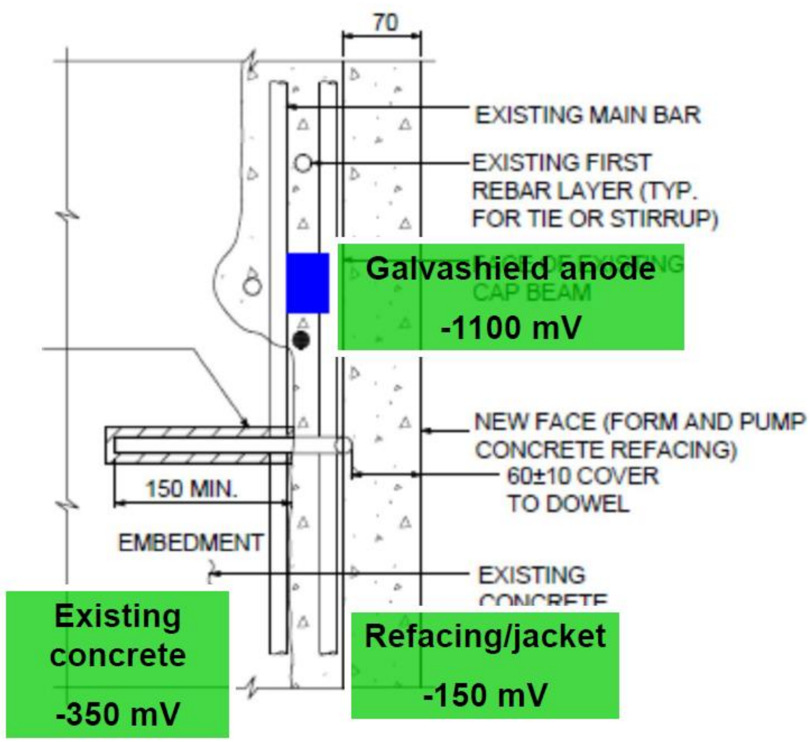


Figure 5. Galvanic anodes in column jacket/ abutment refacing/ deck overlay to control on-going corrosion

Repairs and Strengthening prior to the strategic rehabilitation plan

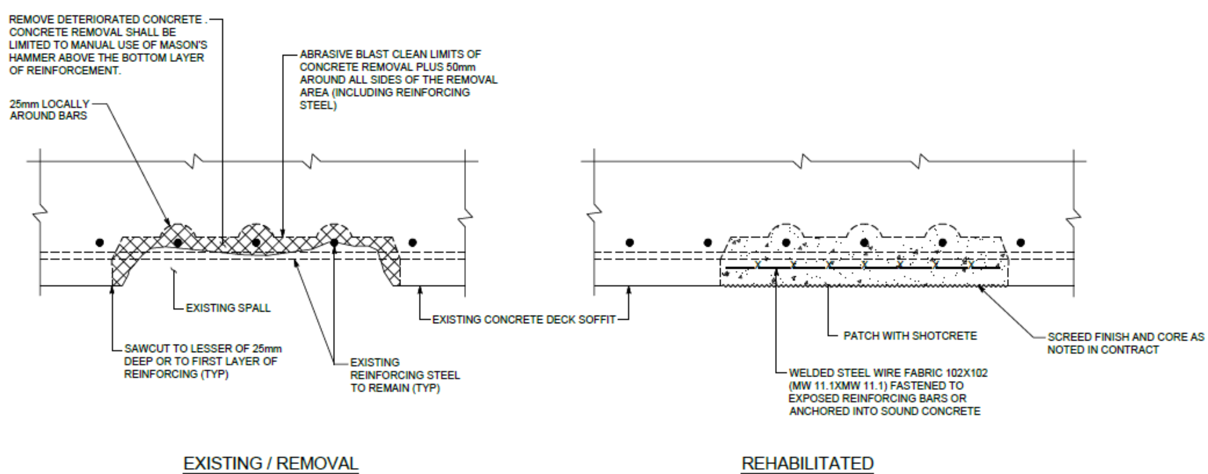


Figure 6. Typical soffit repairs

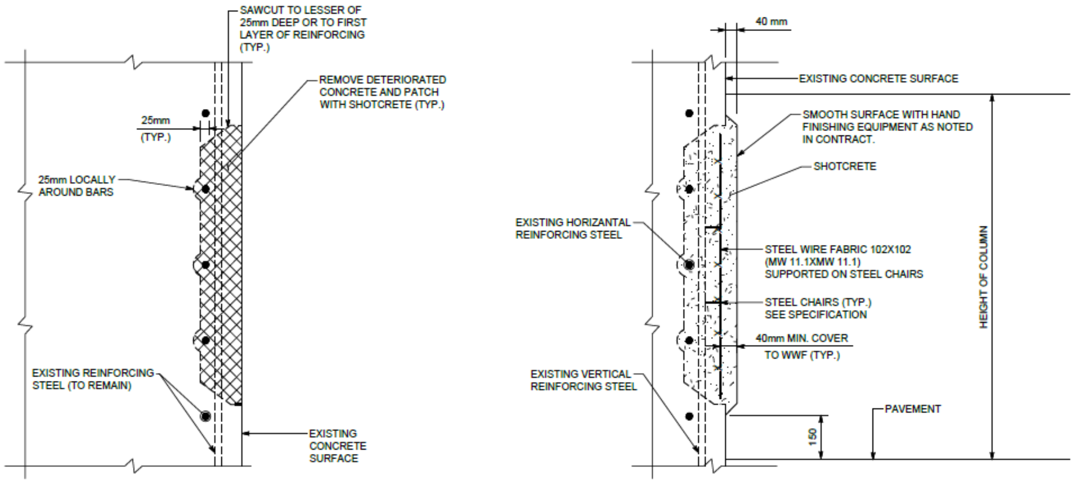


Figure 6. Typical vertical repairs

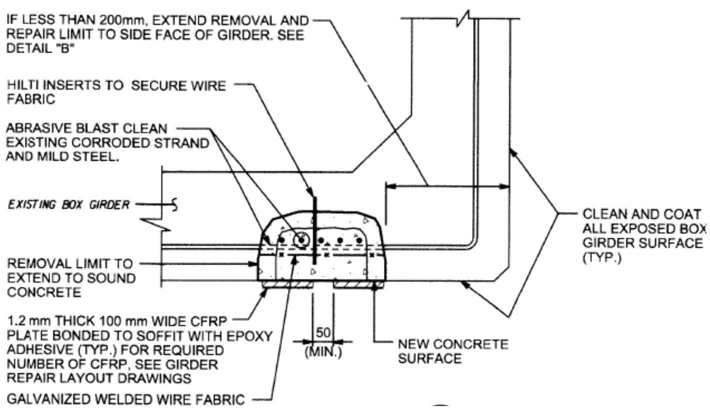


Figure 7. Carbon Fibre strengthening required for girders with corroded strands

Figure 8. Patch-accelerated corrosion

Similar to Figure 2 and 3, conventional concrete repair in Figure 8 can cause patch-accelerated corrosion in existing concrete.

According to ACI 440 and CSA 806, FRP are not recommended for corroding substrate, unless the corrosion is stabilized.

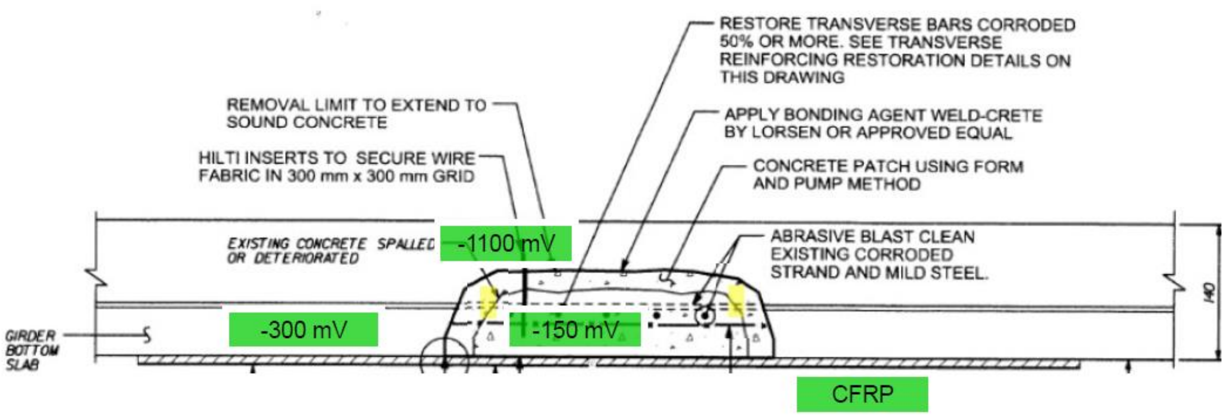


Figure 9. Galvashield Anodes added to control the corrosion prior to CFRP strengthening

Section 2 and 4 Pier Jacketing

In piers receiving concrete jacketing, Galvashield DAS anodes were provided corrosion protection to the deteriorated substructure components (columns and pier caps). 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 were designed to protect all reinforcing steel in each pier for the specified 30-year service life requirements.

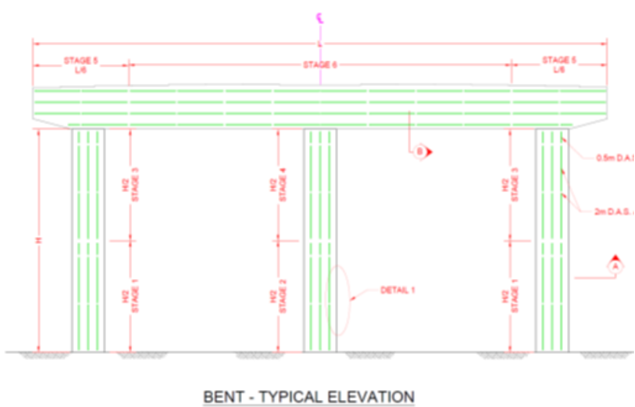


Figure 10. Distributed Galvanic Anode Layout for a Typical Pier and Pier cap

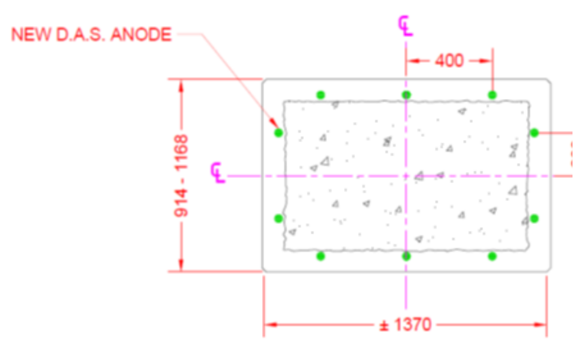


Figure 11. Distributed Galvanic Anode Layout around a Typical Pier Column

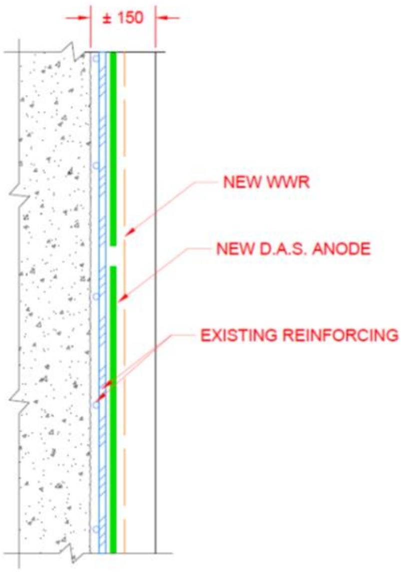


Figure 12. Galvanic Encasement Details

Figure 13. Galvanic Encasement for Hammer Head Pier (Green Rods are the Distributed Galvanic Anodes)

Figure 14. Completed Piers in the Background with a Partially Completed Pier in the Foreground

Section 3 Abutment refacing

In the abutment refacing at Mimico Creek Bridge, Mimico Creek Ramp and Park Lawn Bridge, Galvashield DASX anodes have been designed to provide 30+ years of protection. The design current density requirements of the existing steel were selected according to the risk levels of the abutments.

site	Chloride contents by weight of concrete	Risk category of existing steel	Current density requirements at year 30
Gardiner Expressway over Mimico Creek DASX at 700mm	0.331%	Extremely high	2.4mA/m2
Gardiner Expressway over Park Lawn	0.101%	Low to moderate	0.6mA/m2
Gardiner Ramp over Mimico Creek	0.5%	Extremely high	2.4mA/m2

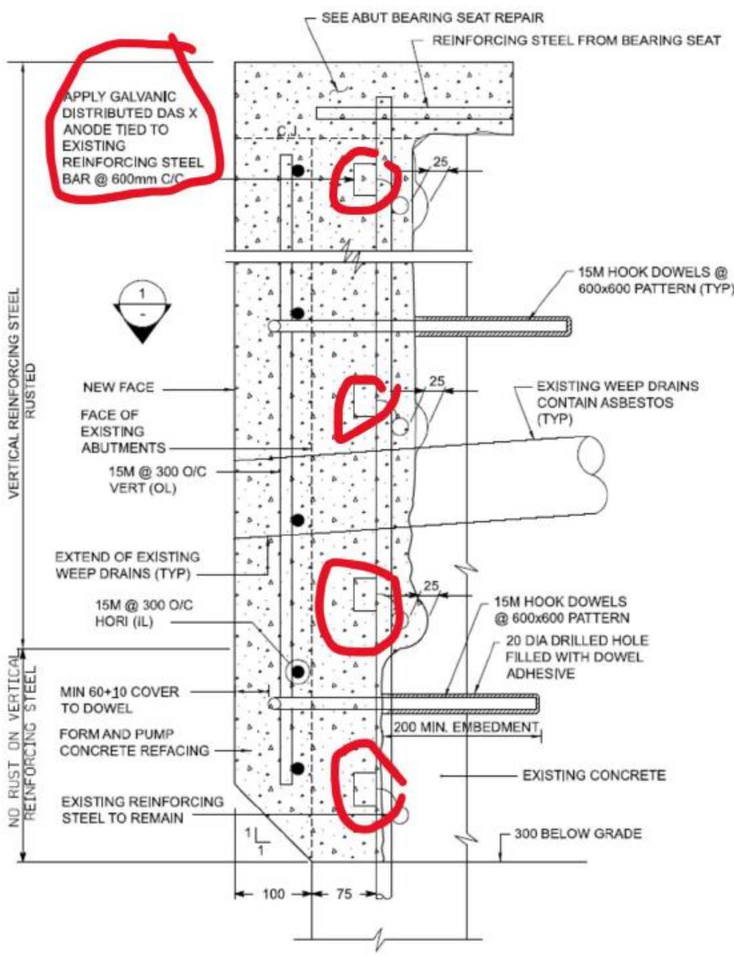


Figure 15. Corrosion protection for abutment refacing

<u>Section 5 Temporary protection of the piers</u>

Before section 5 is re-aligned and completely rebuilt, the existing piers need temporary protection for 5-10 years. After loose concrete were removed, ASZ+ anode were installed in the spalled area and surrounding concrete to prevent further deterioration. With the ASZ+ process, a thin coating of metallic zinc is sprayed onto the surface of the concrete and electrically connected to the embedded reinforcing steel. After installation of the metalized zinc coating, Humectant activator solution is applied to the surface of the zinc to achieve a higher level of current output and protection over time.

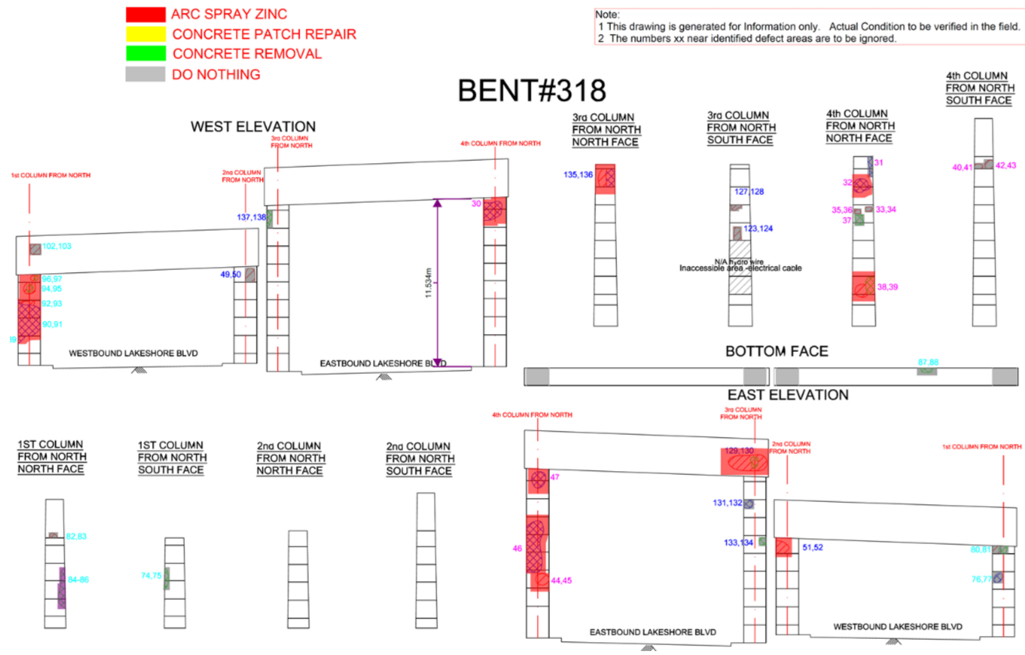


Figure 16. Holding strategy for a typical pier

Figure 17. Spalled and surrounding areas protected with ASZ+ anodes

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 and to maintain, re-use and protect the substructure using long term galvanic corrosion protection addresses the project constraints. Galvanic corrosion protection is added to Section 2, 3 and 4 to protect the piers and abutments to achieve 30+ years of protection. However, for Section 5, which will be re-aligned and re-constructed, a holding strategy with ASZ+ anodes was implemented to prevent further corrosion and associated concrete deterioration.