Bridge Preservation: Evaluation, Repair and Protection

Webinar Wednesday Series

We Save Structures™

CONCRETE PRESERVATION ALLIANCE

The Concrete Preservation Alliance is a growing coalition of organizations committed to advancing best practices in the field of concrete preservation and infrastructure renewal.

Working together to promote education and awareness of concrete repair industry standards, new and innovative corrosion prevention technologies and sustainable construction practices.

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OUR MEMBERS

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- The construction industry is the largest user of resources and raw materials.
- Approx. 40% of solid waste comes from construction and demolition.
- Making new structures last longer and the rehabilitation and reuse of existing structures saves money compared to the cost of premature failure, demolition and rebuilding.
- In addition to economic benefits, repairing and extending the service life of structures reduces the consumption of natural resources, pollution and construction waste.
- https://www.wesavestructures.info/environmental-impact-calculator

Inputs

Volume of concrete to be preserved	10000	yd3	7645	m3
	Calculate		Calculate	

Outputs

Emissions				
Concrete CO2	2633	US tons CO2	2385	metric tons CO2
Steel CO2	2835	US tons CO2	2569	metric tons CO2
Total Carbon Dioxide	5468	US tons CO2	4954	metric tons CO2
Equivalent to annual CO2 emission of:	1243	people	1239	people
NOx (as NO2)	9747	lbs	4347	kg
SO2	2722	lbs	1214	kg
Total Pollutants	10947469	lbs	4959689	kg
Waste Generation				
Solid Waste (Rubble)	20250	US tons	18348	metric tons
Energy (heat generation from cement production, cement hydration, and steel production)	23846	GJ	22633	GJ
Equivalent energy to boiling	30	Olympic Pools	28	Olympic Pools
Natural Resources Required				
Fine aggregate	5265	US Tons	4770	metric tons
Coarse aggregate	8302	US Tons	7523	metric tons
Cement	4500	US Tons	4014	metric tons
Steel	1620	US Tons	1468	metric tons
Total tons	19687	US Tons	17775	metric tons
Potable Water	253012	gal	936512	liters
Equivalent to daily water usage for:	2530	people	2341	people

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CONCRETE
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Chris Ball

Chris Ball is Senior Vice President of Sales and Marketing for Vector Corrosion Technologies, a leading provider of solutions to preserve and extend the service life of concrete structures.

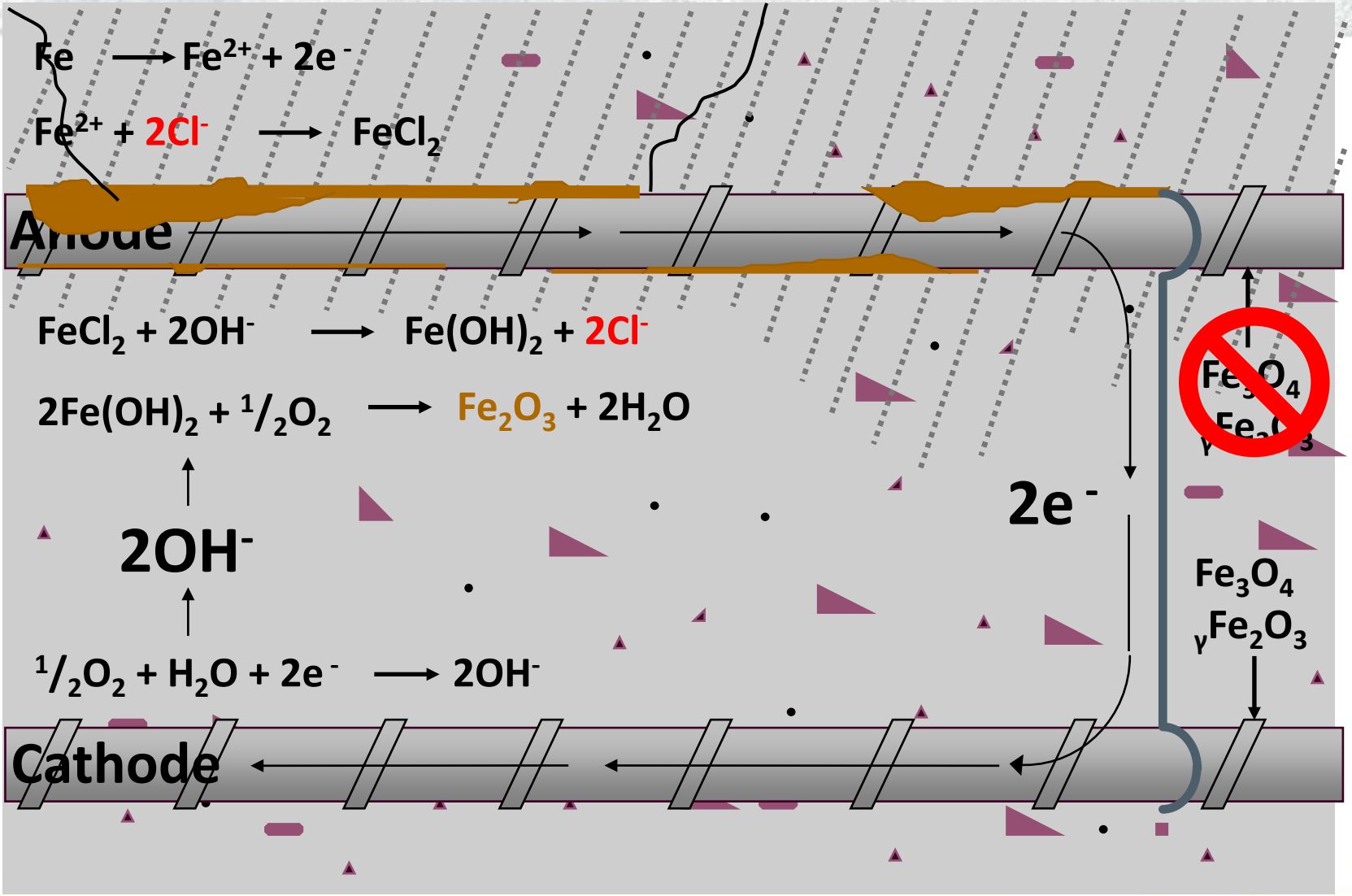
Chris has over 20 years of construction industry experience with a specialty in concrete rehabilitation and corrosion protection systems. He is a member of NACE, ICRI, and ACI where he is currently Chairman of ACI E706, Concrete Repair Education.

Repair & Protection of Severely Corroded Bridge Substructures with Galvanic Encasements

- Substructure preservation and accelerated bridge construction
- Abutments, beam and column protection with galvanic encasements

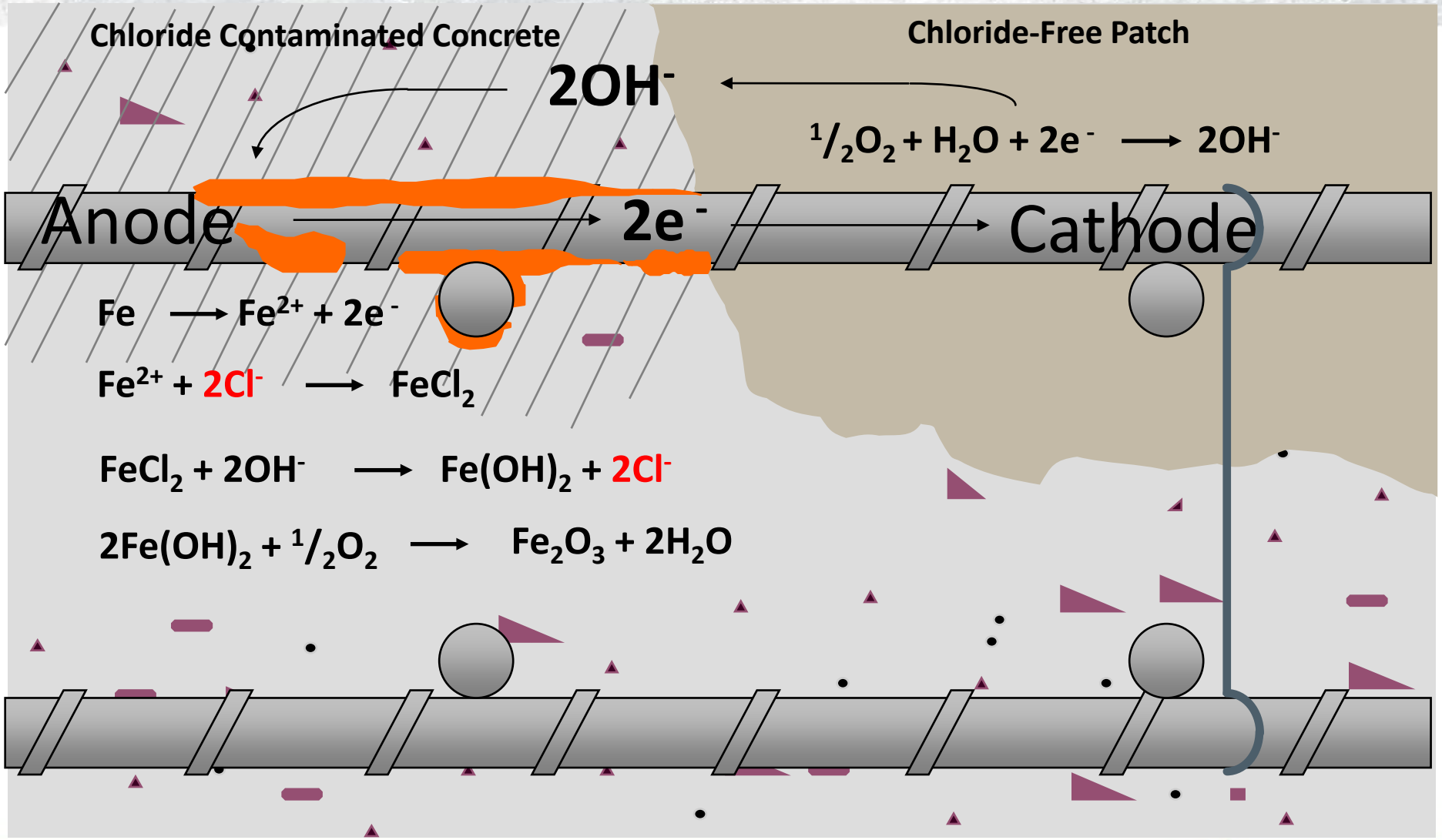

30
30

Corrosion Cell in Concrete



Corrosion of Steel in Concrete

Interface of New/Old Concrete



Corrosion Protection Options

- Electrochemical Chloride Extraction
- Impressed Current Cathodic Protection
- Localized Protection
  - Type 1 anodes around repairs
  - Distributed anodes in joint repairs or joint eliminations
- Targeted Protection

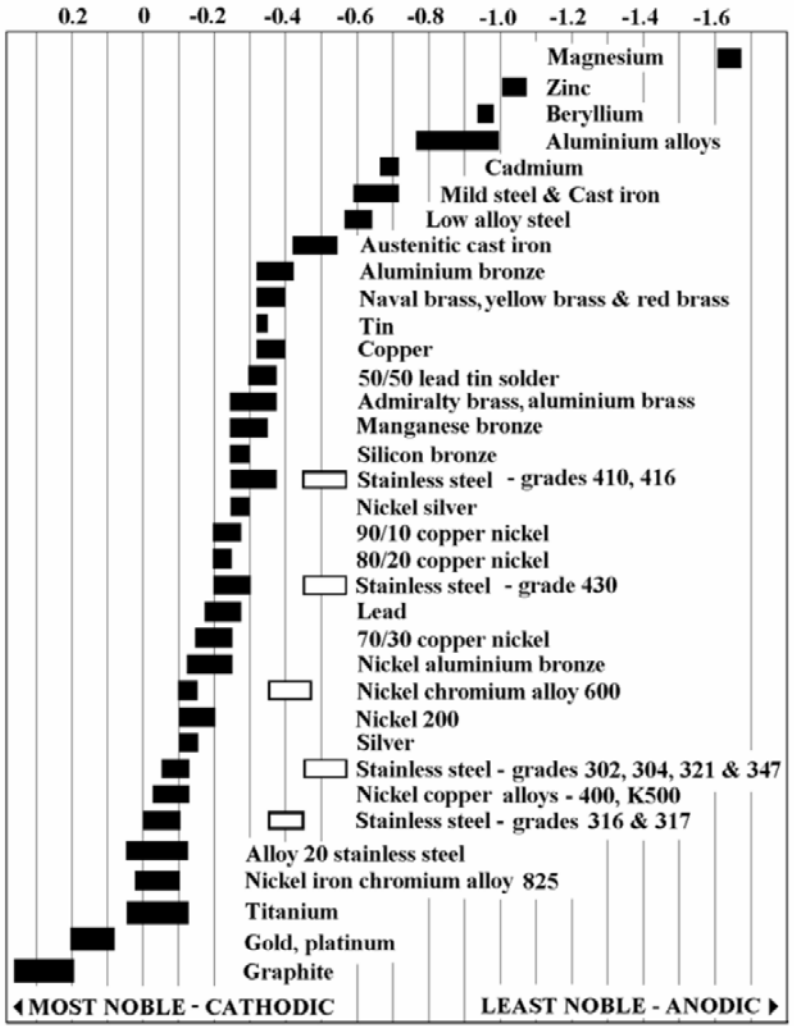
  - Areas of corrosion risk
  - Type 2 anodes or Fusion Technology
- Galvanic Cathodic Protection
  - Galvanic Encasements and Overlays
  - Arc Spray Zinc Metalizing

Rainbow Bridge, Idaho

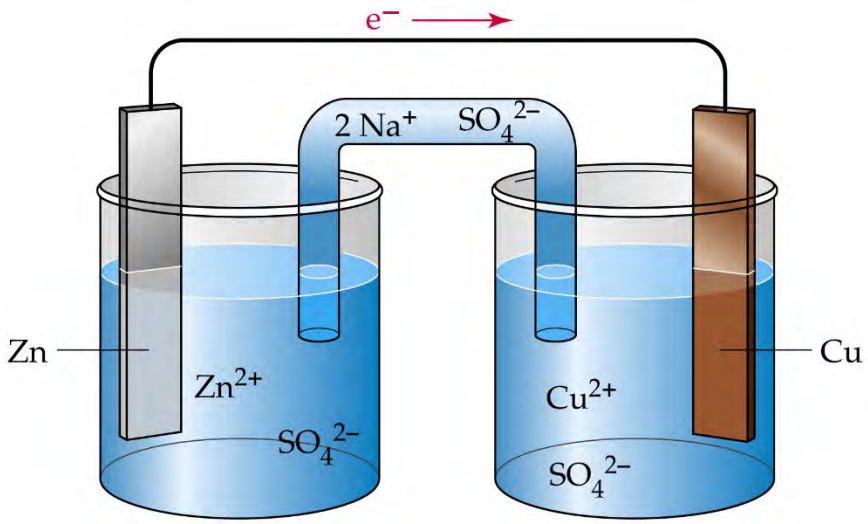
Electrochemical Chloride Extraction

ICRI 2007 Project of the Year

Galvanic Series

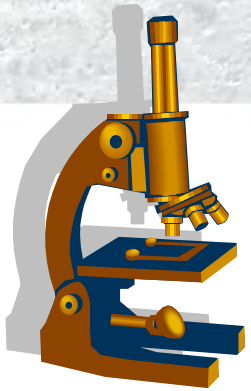


Galvanic Systems



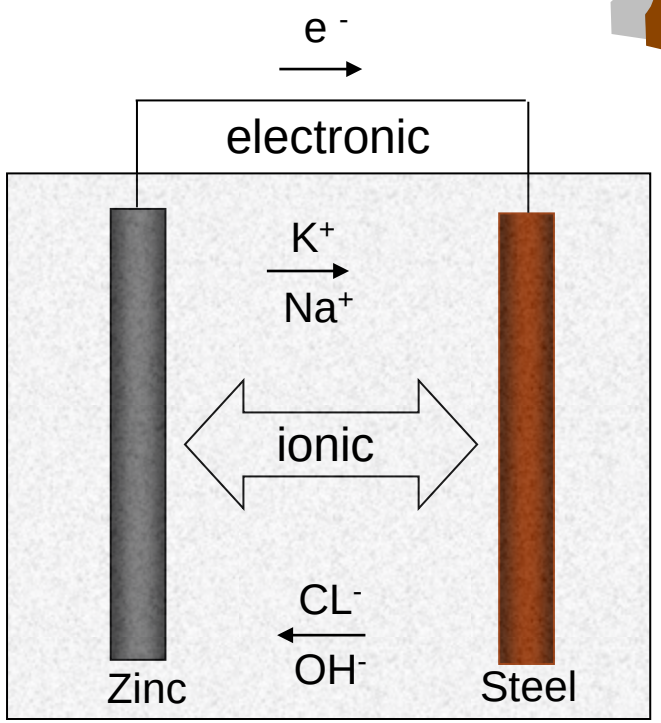
Electrochemical Cell

Galvanic Protection in Concrete



Partial Galvanic Series	
Metal	Voltage
Zinc	-1100 mV
Steel in concrete	-200 mV to -500 mV

*Typical potentials measured with respect to copper-copper sulfate electrode

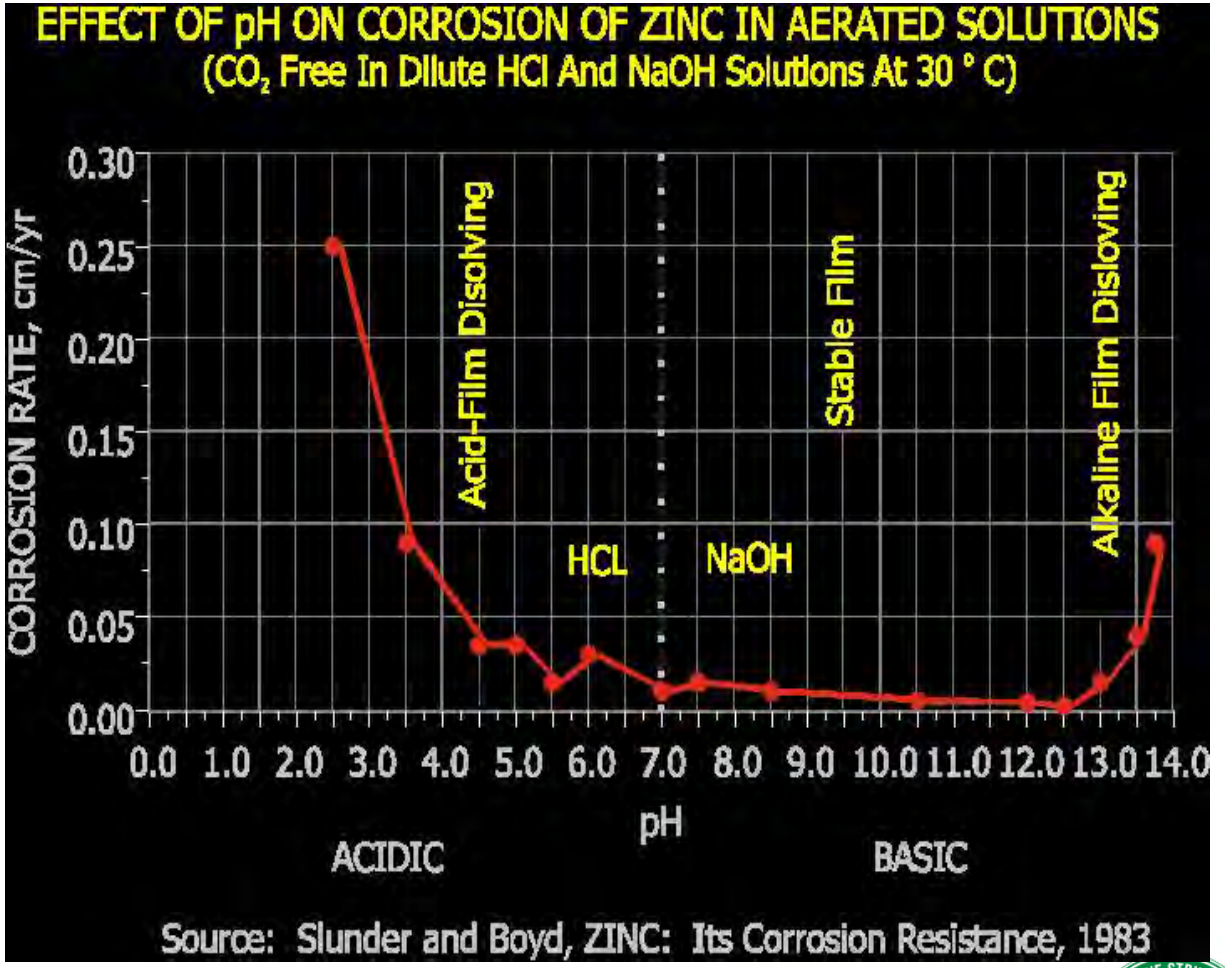


Galvanic Anodes for Concrete

Zinc Activation Technology

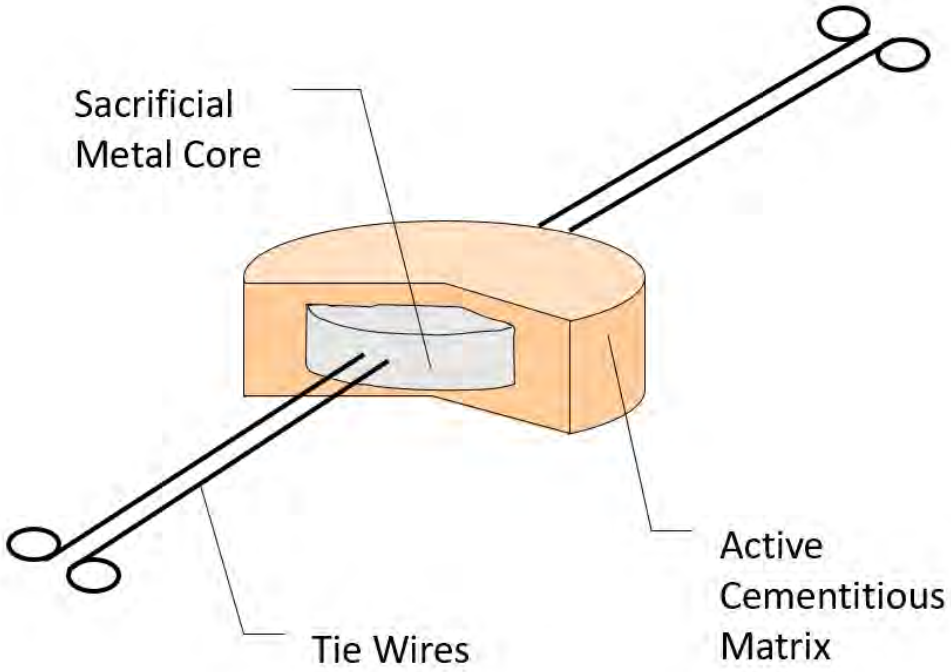
Alkali Activated

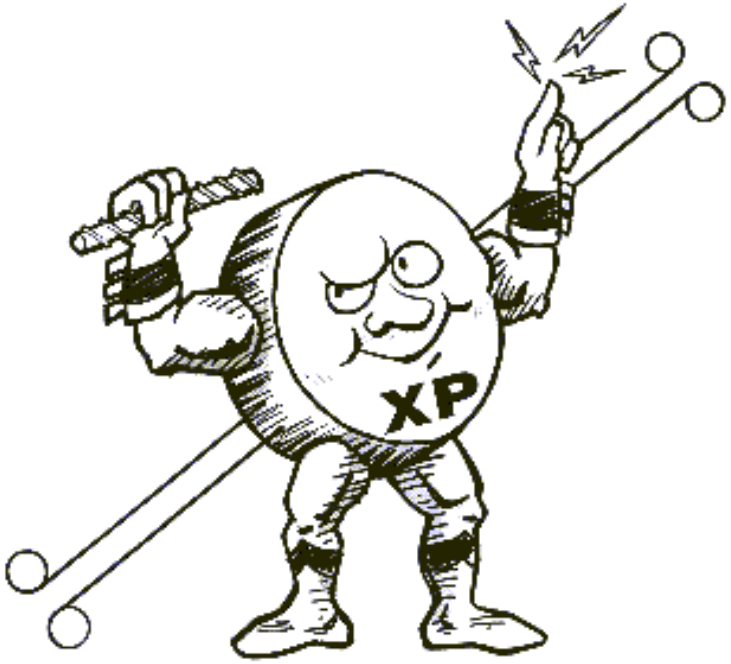
- Bare zinc anodes in concrete will be extremely passive.
- Create high pH environment around the zinc anodes.
- High pH is corrosive to zinc but not to steel like chloride or bromide.
- Allows zinc anodes to remain active and provide protection to reinforced concrete over time.



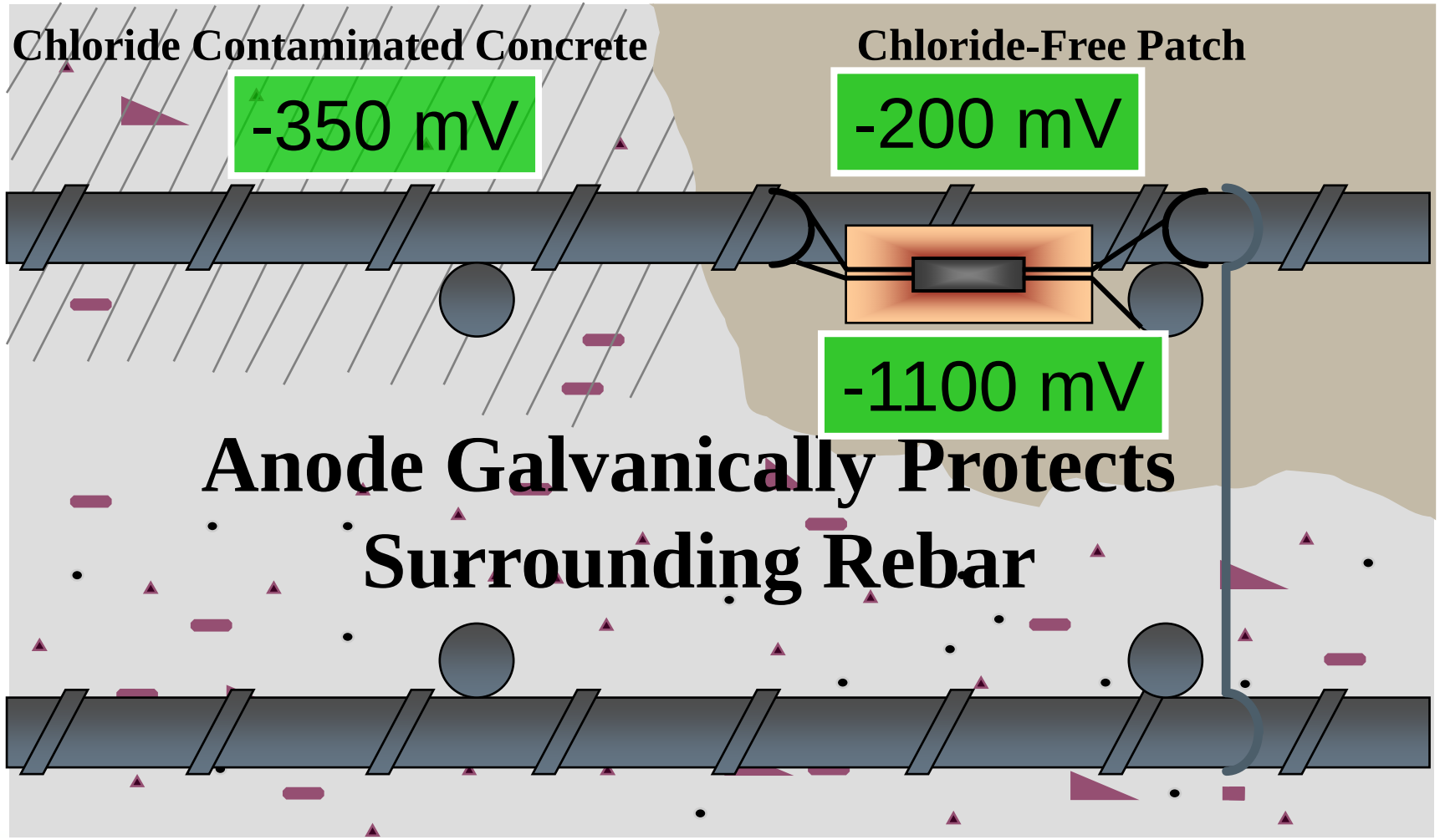
The Original Embedded Galvanic Anode

Circa 1999

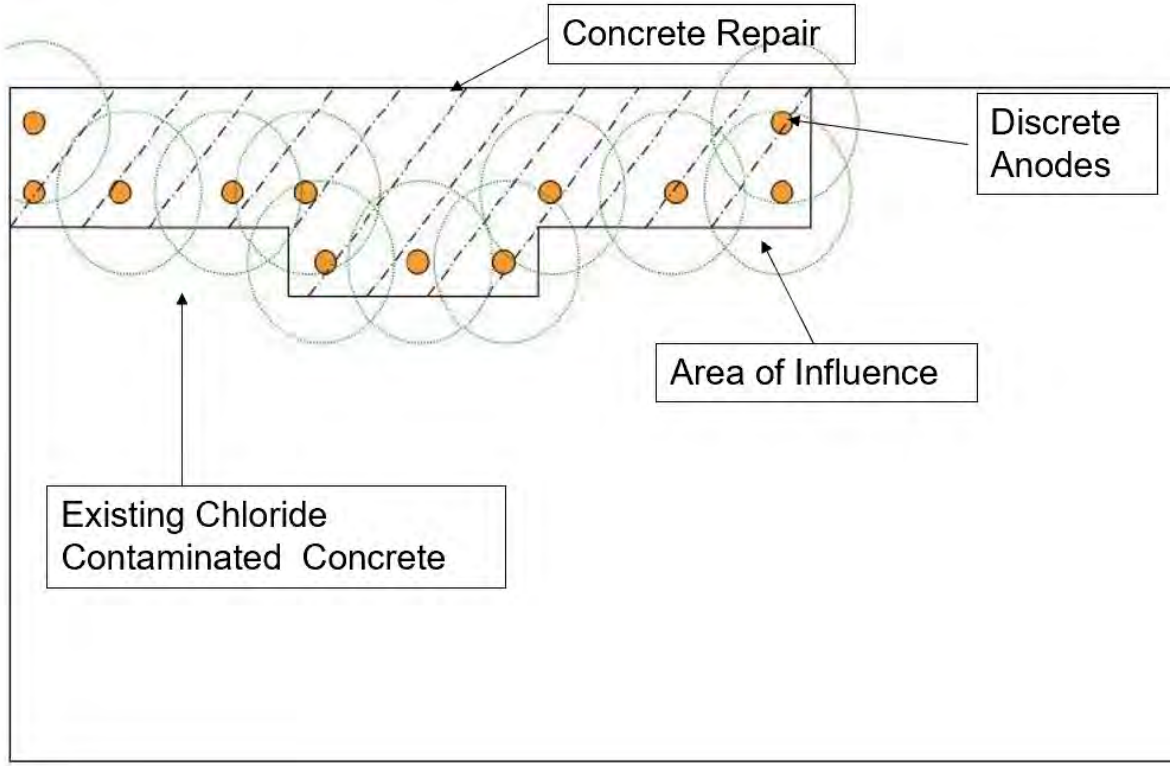




Embedded Galvanic Anode



Type 1 Anodes – Extend the Life of Repairs



Other Applications for Type 1 Anodes

Bridge Widening

New Construction

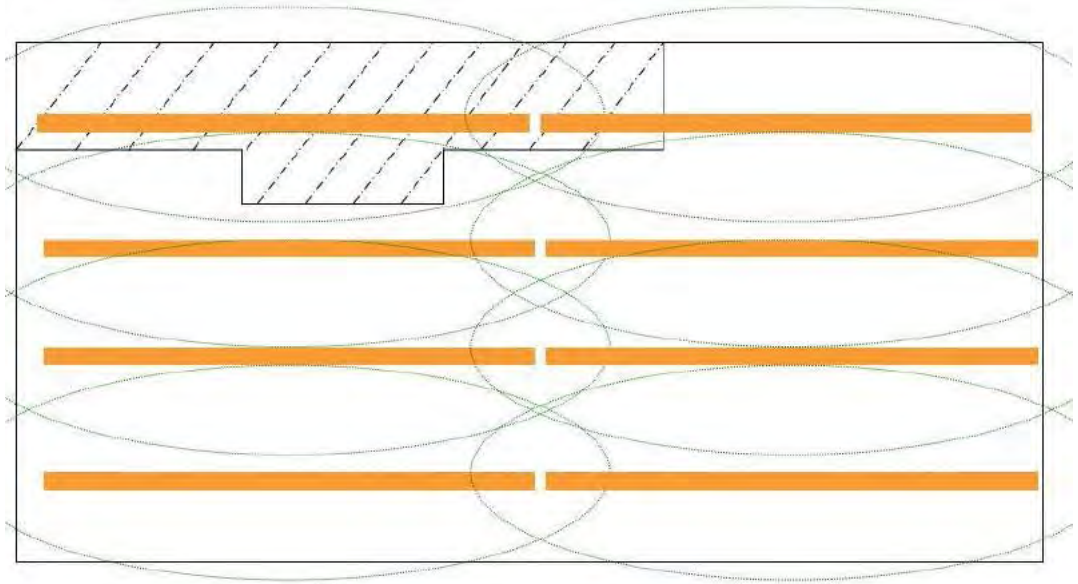
Corrosion Control Anodes in Sound Concrete

Circa 2001

Precast Box Beam Protection

Galvanic Cathodic Protection

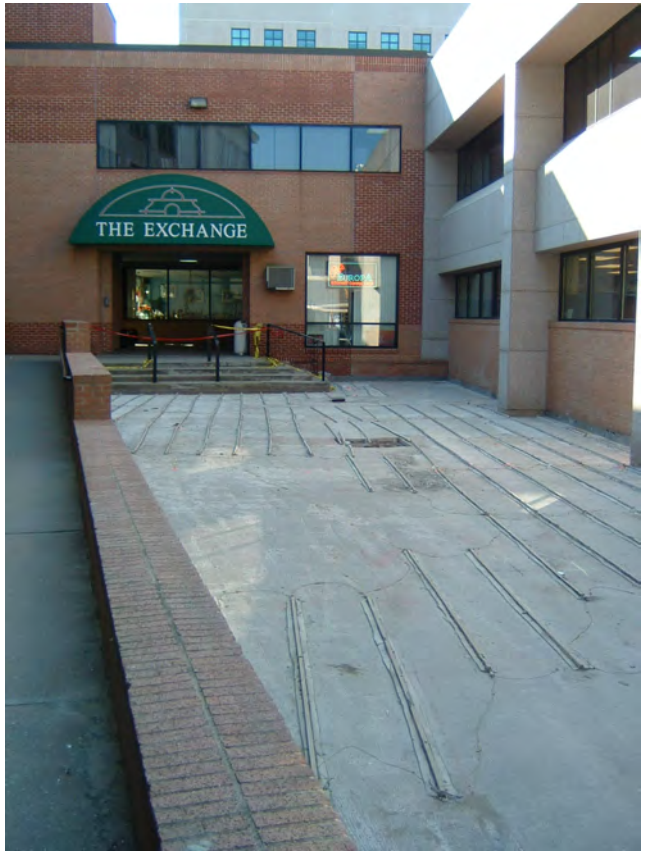
- Distributed Anode Systems
- Global or Large Area Protection
- Higher Current Density
- Long Life 20-40+ years



Galvanic Encasement with
Distributed Anodes

Distributed Galvanic Anodes
Circa 2003

Bridge Deck Overlay
Global Protection



Plaza Deck Overlay
High Potential Areas Only

MTO Galvanic Bridge Deck Overlay (2003)

MTO Bridge Deck Overlay

Date	Temp C / F	Current (mA)	Current/m2 (mA/m2)	Polarization (mV)
Oct. 3, 2003	7 / 45	169	6.5	273
May 10, 2004	20 / 68	99	3.8	271
Jan. 18, 2005	-20 / -4	14	0.55	142
July 27, 2005	20 / 68	47	1.8	313
Nov. 17, 2005	0 / 32	30	1.1	276
Apr. 19, 2006	10 / 50	38	1.4	330
July 26, 2006	25 / 76	43	1.6	353
Apr. 11, 2007	-3 / 27	27	1.0	201
Aug. 23, 2007	22 / 71	41	1.5	501
Jan. 10, 2008	0 / 32	29	1.1	322
May 12, 2009	21 / 70	38	1.4	285
Sept. 25, 2010	19 / 66	35	1.3	305
June 7, 2012	22 / 71	46	1.8	278
Nov. 7, 2013	4 / 39	29	1.13	388
Oct. 6, 2015	13 / 55	28	1.1	423

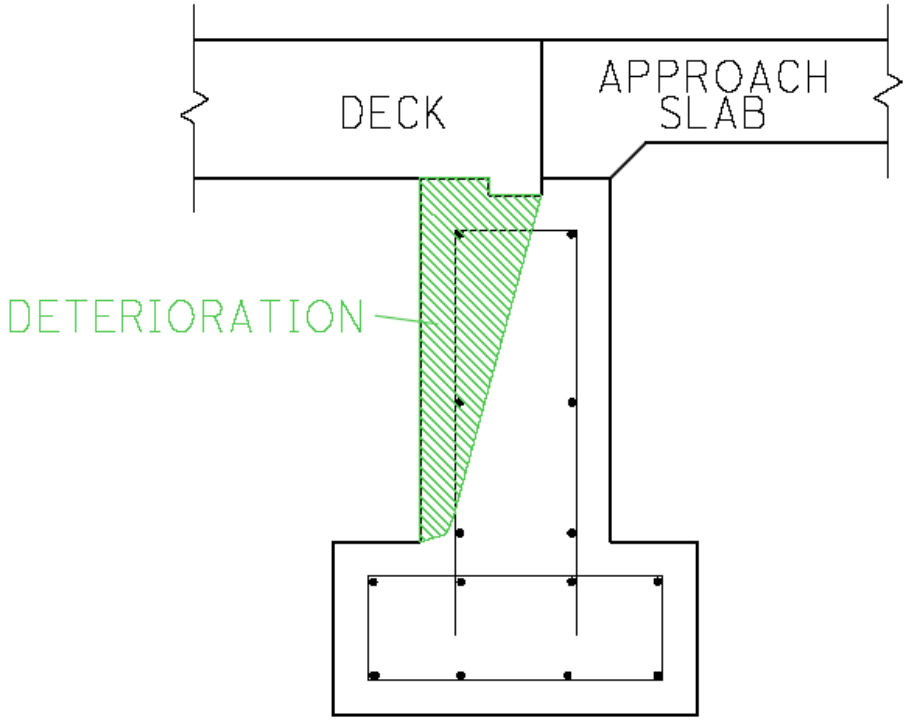
- Most recent data collected was in July 2020.
- Steel is cathodically protected.
- Current density is still greater than 1 mA/m2 after almost 17 years.

Pile Cap Repair
Circa 2005

Form and Pour Repairs with Distributed Anodes

Beam Condition in 2017

Slab Bridges in Ohio

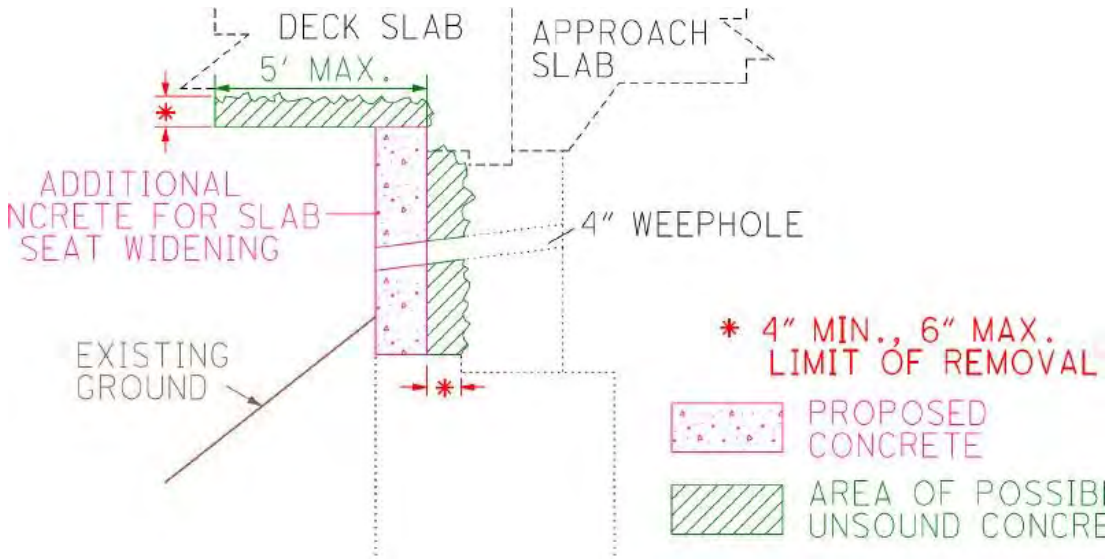


Options and Previous Repair Practices

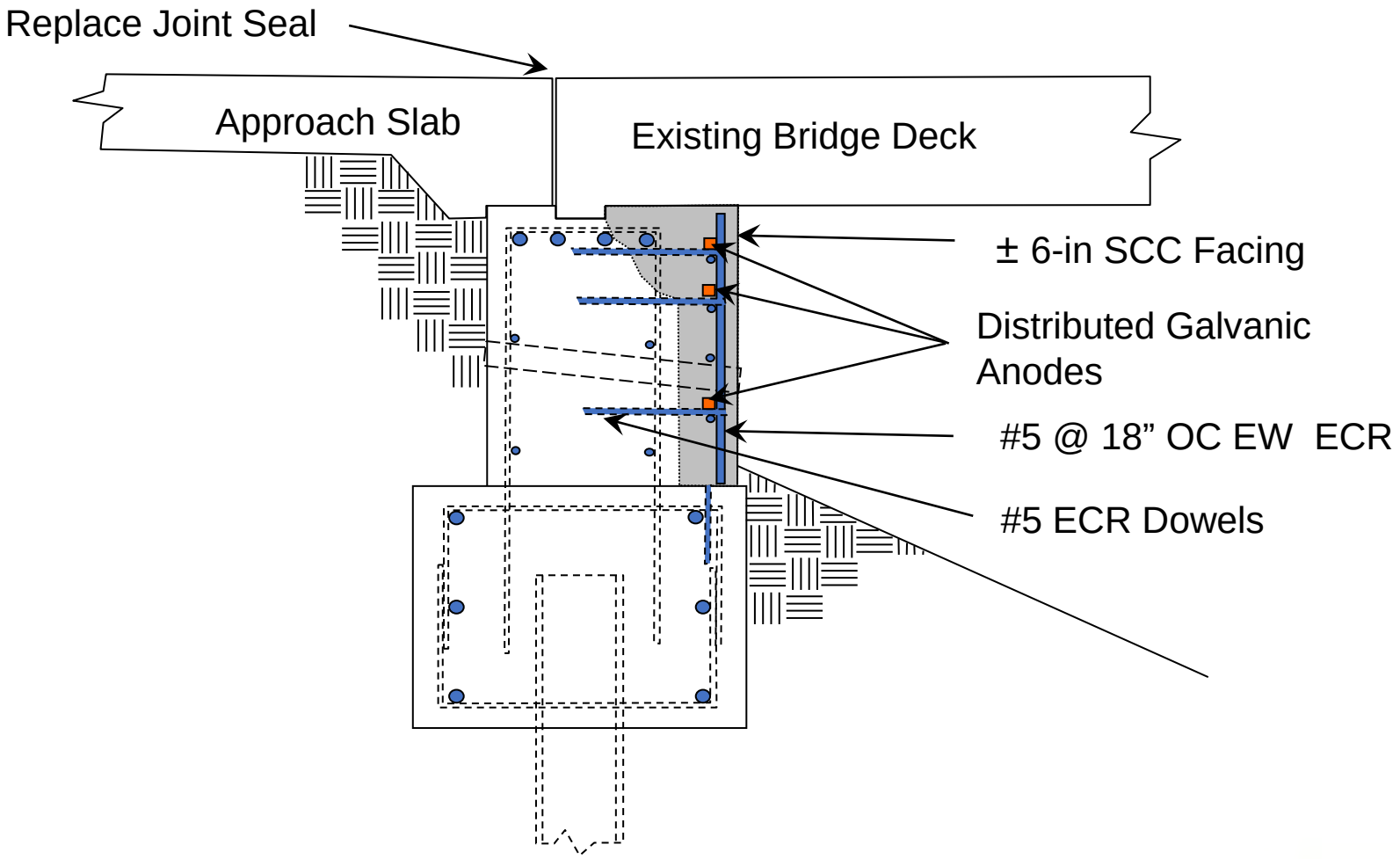
- Do Nothing
  - Not a feasible alternative for deficient bridges on the interstate system
- Repair bridge
  - With appropriate repair, most of these bridges have remaining service life
- Replace bridge
  - Not cost-effective to remove a good slab

- Repair Practices
  - Slab would be temporarily supported
  - Abutments would be replaced
  - Requires closure or part-width construction

Early Repair with Discrete Anodes



Galvanic Encasement of ODOT Abutment
Circa 2005



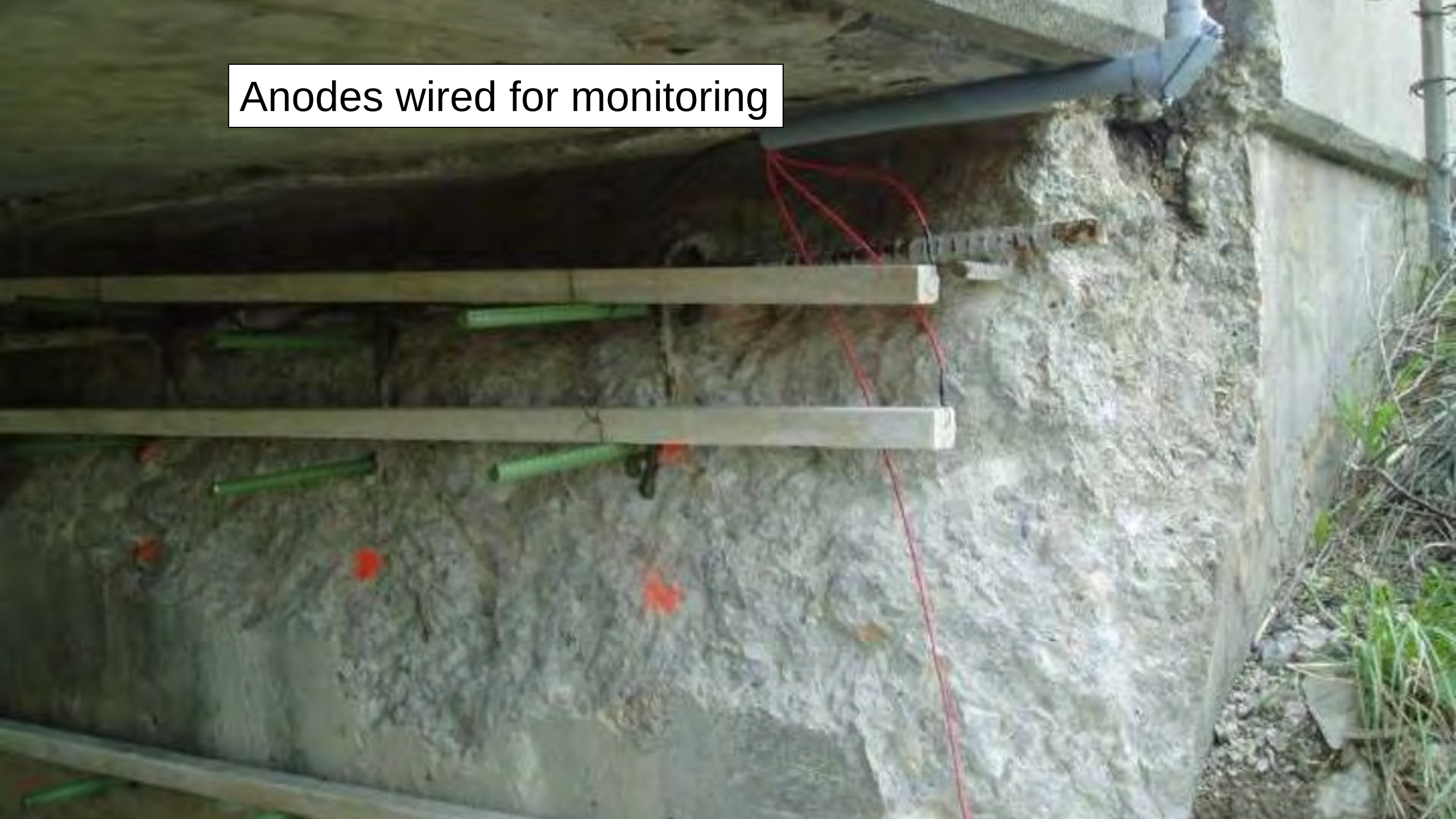
Kirkwood Road Bridge Before Repair May, 2005

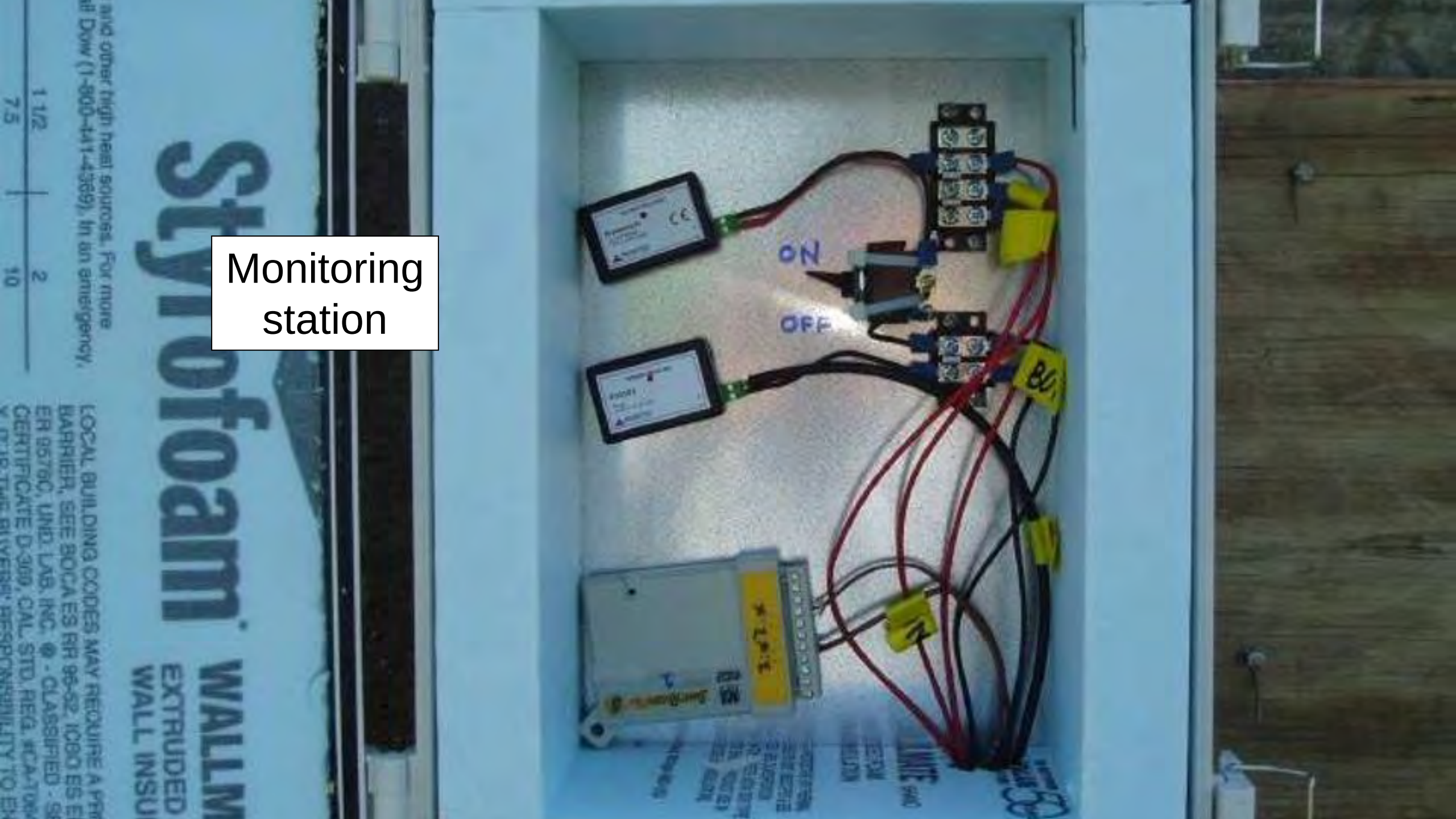

Abutment Condition Before Repair


Spall removal


Dowels and anodes installed

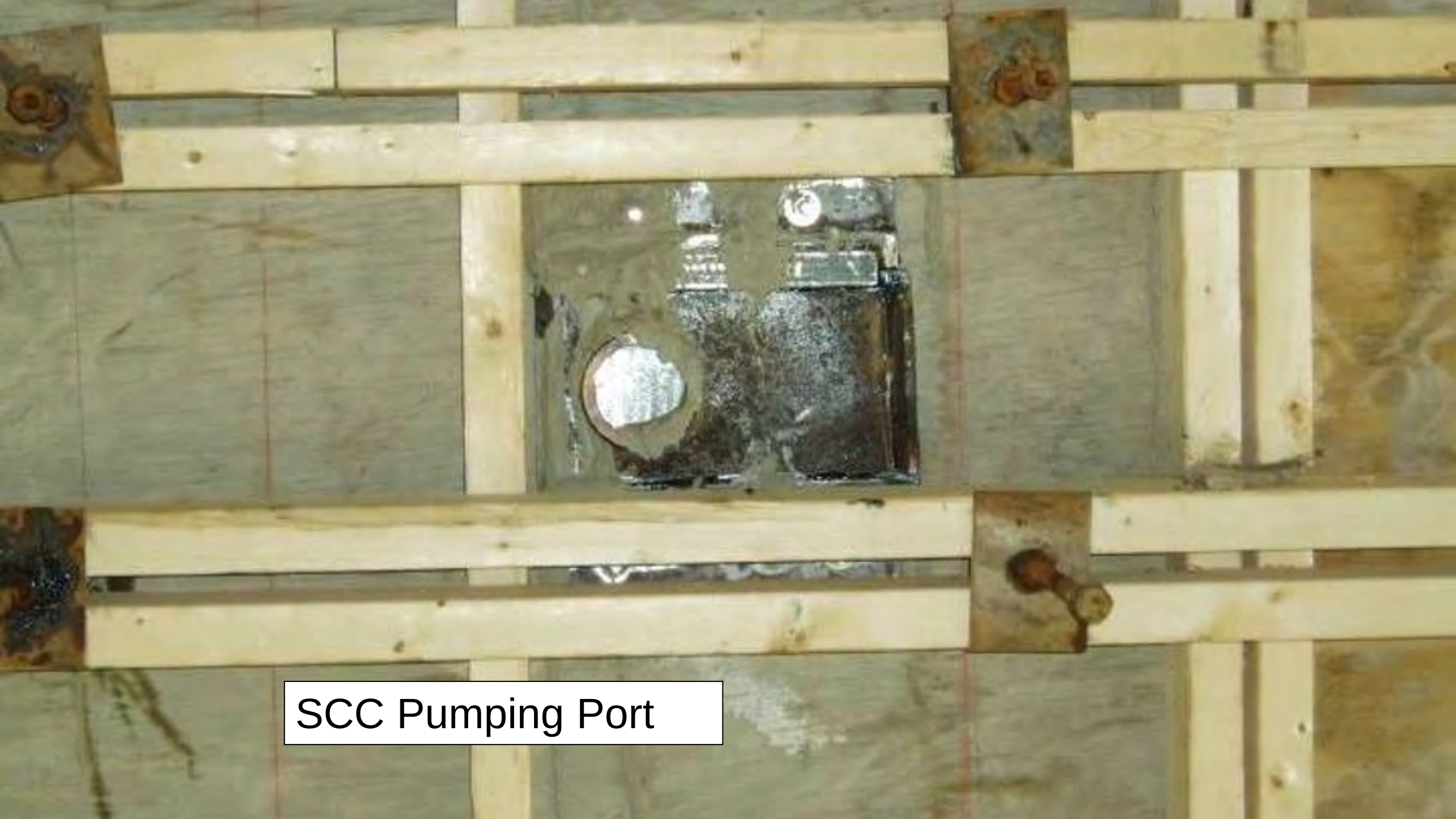
Anodes wired together and to reinforcing


Anodes wired for monitoring


Monitoring station
ON
OFF
Styrofoam
WALLMATE
EXTRUDED
WALL INSU


Ready for Forms


Forms installed


SCC Pumping Port


Forms removed

Completed Repair

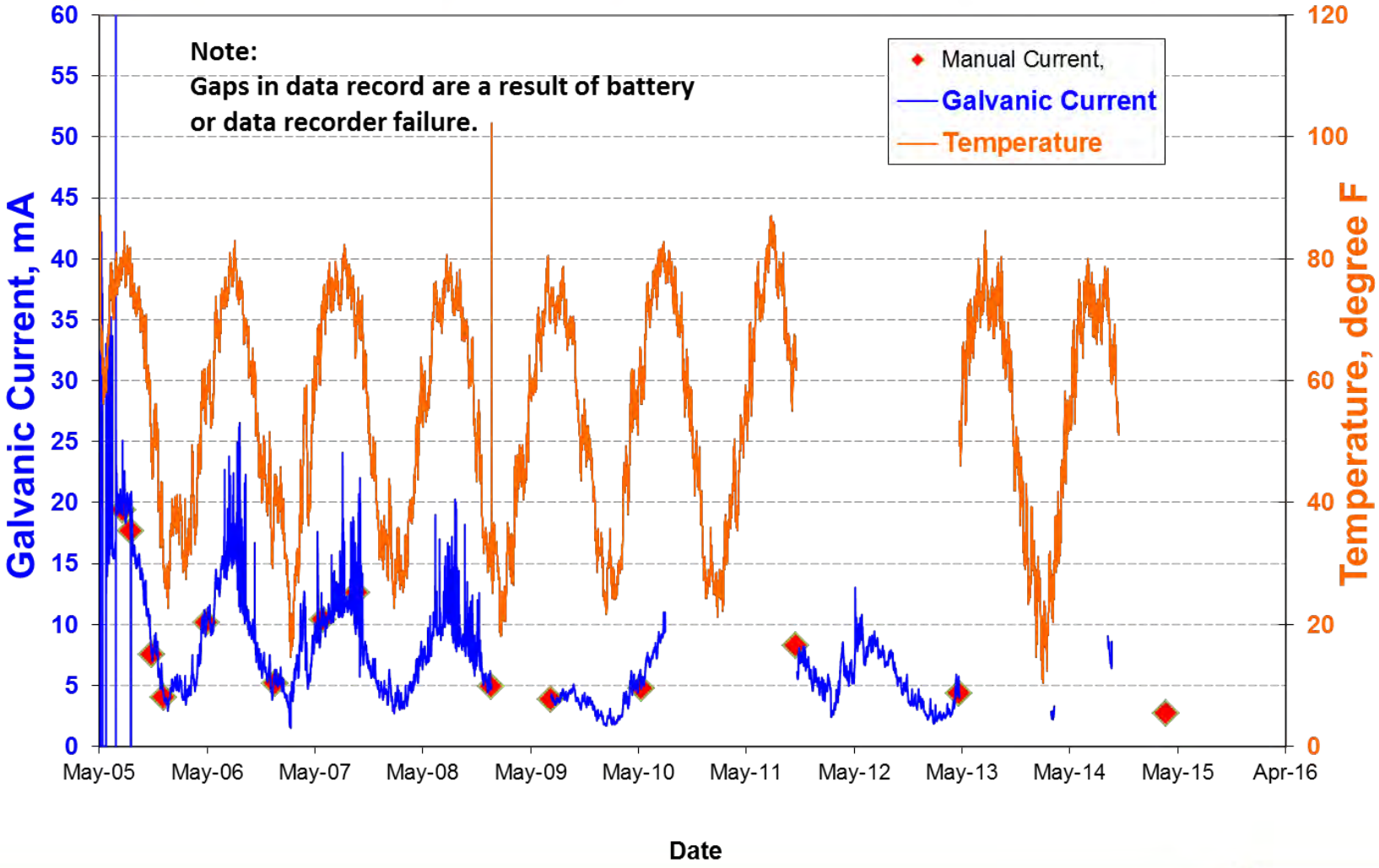
2005

2020

Galvanic Anode Monitoring

- Data logger installed in junction box
- Measurements taken every 4 hours
  - Anode Current Output
  - Internal and Ambient Temperatures
- Corrosion potentials and depolarization data collected on periodic site visits
  - Surface readings with copper-copper sulfate reference electrode
- Information used to determine level of protection and estimate anode service life

Current & Temperature Monitoring



15 Year Performance Summary

Date	Temperature, degree C	Instant Off E_{IOFF}, mV	Anode Current Icp, mA/m^2	Polarization, Epol, mV
5/6/2005	(*Native*)	*-654*	37.7	
7/20/2005		-990	14.0	346
8/16/2005	30.6	-998	12.7	344
10/26/2005	12.2	-1023	5.4	369
12/7/2005	10.6	-964	2.9	310
5/1/2006	13.9	-967	7.3	313
12/20/2006	4.6	-1113	3.7	459
5/30/2007	26.3	-1104	7.5	450
9/20/2007	23.9	-1136	9.1	482
12/19/2008	4.4	-1105	3.5	451
7/9/2009	23.3	-1125	2.8	471
5/11/2010	12.2	-1139	3.4	485
10/16/2011	22.2	-1142	5.9	488
4/22/2013	21.1	-1079	3.1	425
3/24/2015	1.7	-1035	2.0	381
9/17/2018	25.6	-1007	5.3	353
9/9/2020	26.7	-1005	3.6	351

- Current demand varies with temperature and is generally decreasing over time
- Instant off < -850mV
- Greater than 100mV off potential vs native
- > 35 year estimated anode service life
- Structure is Cathodically Protected

Accelerated Bridge Construction Island Park Bridge

Island Park Bridge Abutment Encasement

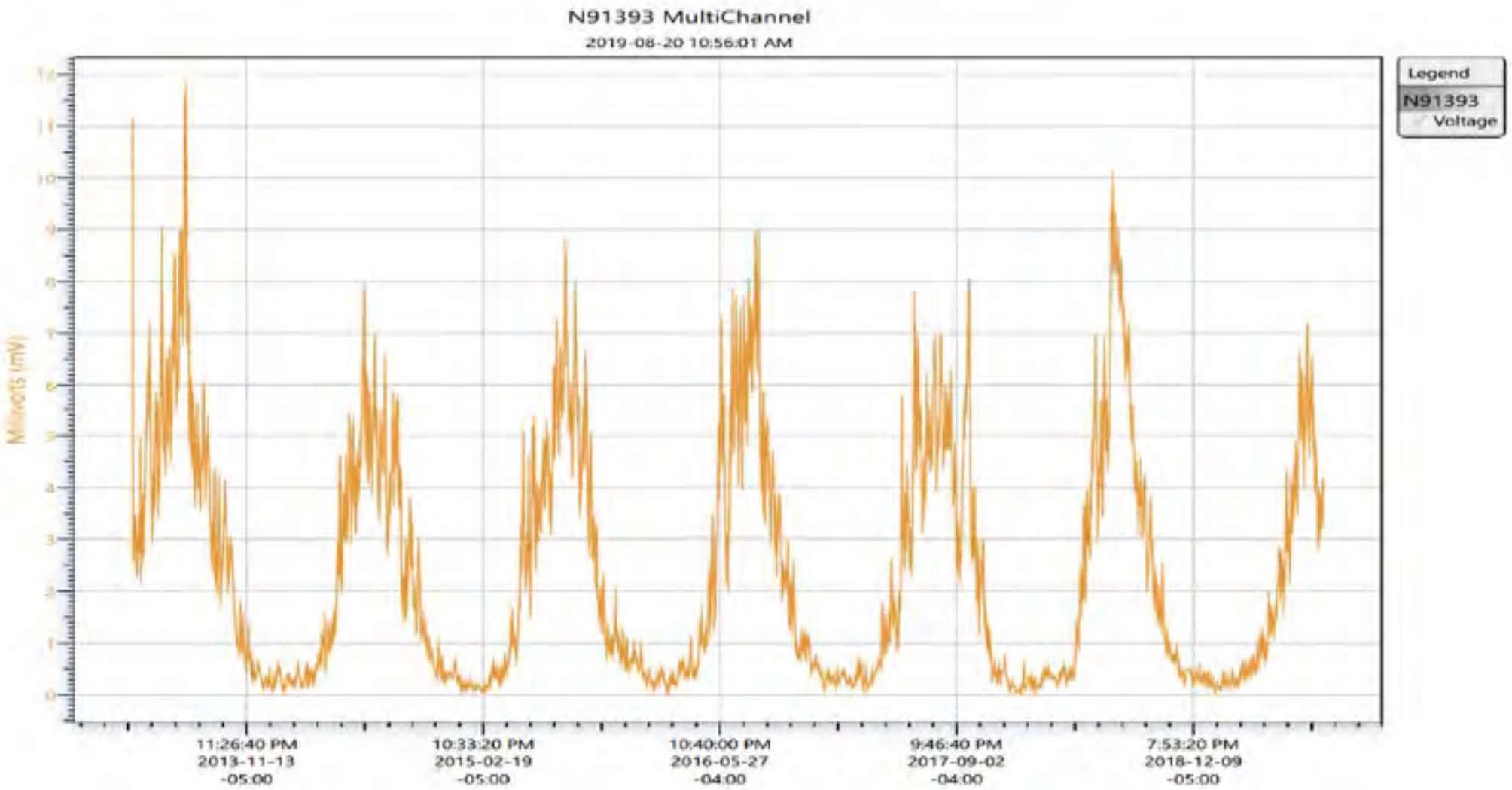
After the Abutments were Repaired, the Superstructure was Removed and Replaced Overnight

Highway 417 Kirkwood Ave Overpass DAS Monitoring

Reading interval: one hour
2m Long Anodes: 8 pieces

Total Readings: 55872
Area: 8m2

Average Readings: 2.37mV = 2.37mA



George N. Wade Memorial Bridge

- Carries I-81 and the Capital Beltway across the Susquehanna River in Harrisburg, Pennsylvania
- 5,188 feet (1,581 m) long
- Construction completed in early 1970’s
- $42 million Repair Project from 2009-2012

Concrete Deterioration

- Pier caps were repaired, protected and strengthened using galvanic encasements.
- Columns and abutments were protected using arc spray zinc metalizing with humectant

Distributed Anodes and Additional Steel Installed Around Pier Cap

Galvanic Encasement and Concrete Forms

Surface Preparation and Installation of Activated Arc Spray Zinc

Frederick G. Gardiner Expressway

- Built in late 1950s in Toronto, Ontario
- 6-lane, 6.8 kilometers (4.2 mi), elevated expressway
- The elevated section is supported by reinforced concrete columns. The concrete deck was constructed on steel girders or concrete girders.
- De-icing salt caused severe corrosion of the reinforcing steel within the concrete piers (vertical columns and horizontal pier caps), which expanded, weakening the steel and causing pieces of concrete to dislodge.

Severe Corrosion Damage

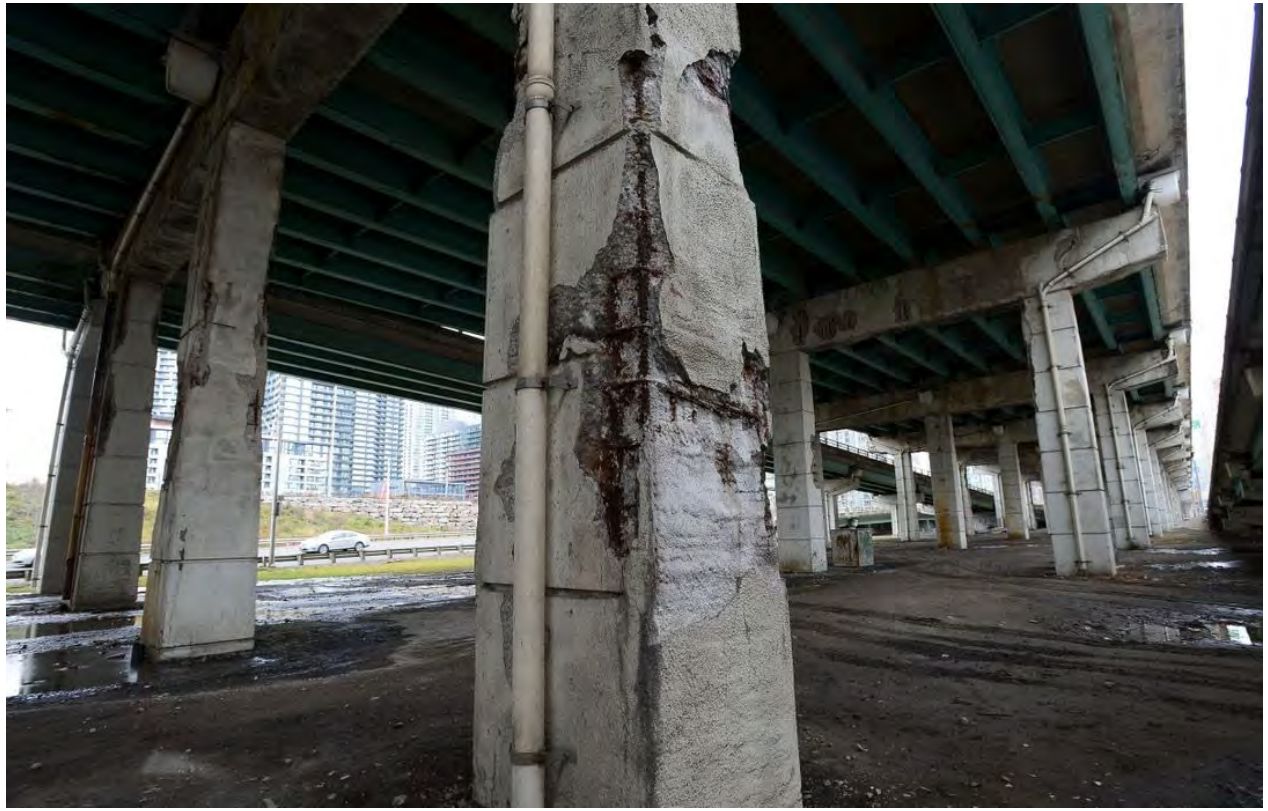
Toronto

Falling concrete on the Gardiner is often from trucks, not the aging highway

City numbers show only 25% of 86 cases of falling concrete were from the Gardiner

Nicole Martin · CBC News · Posted: Jun 06, 2017 12:11 PM ET | Last Updated: June 6, 2017

Chunk of concrete that fell from the Gardiner Expressway (City of Toronto)



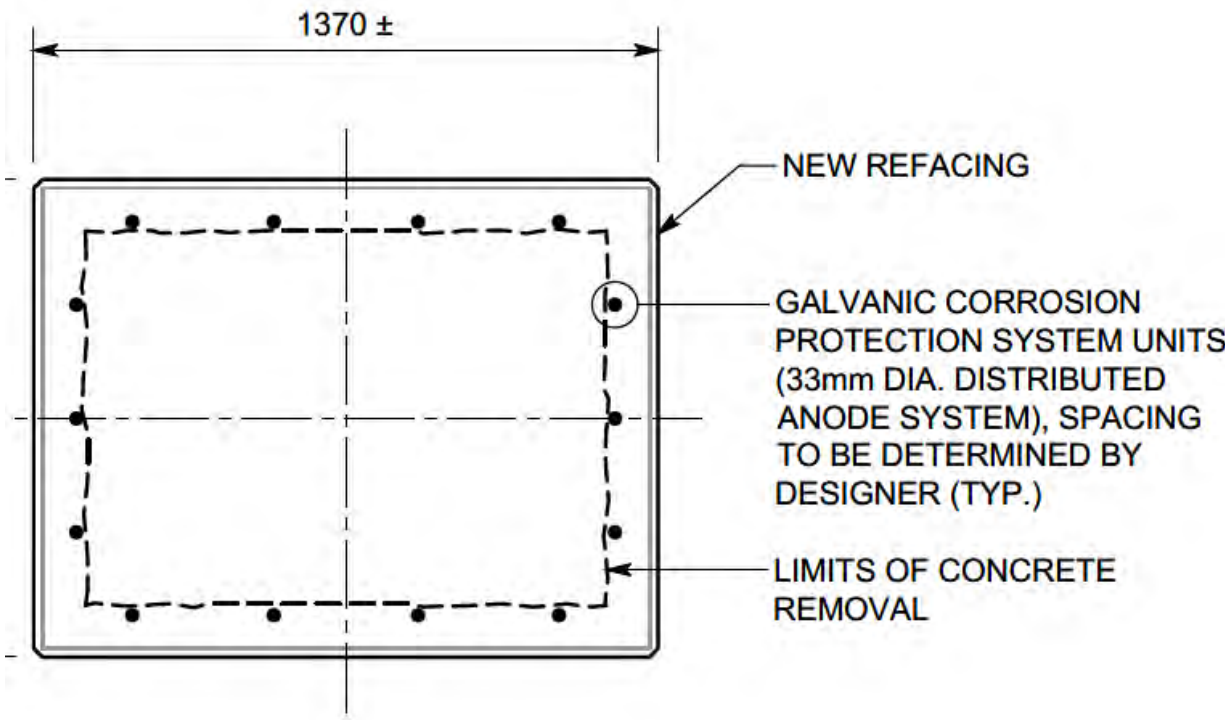
Gardiner Expressway Strategic Rehabilitation

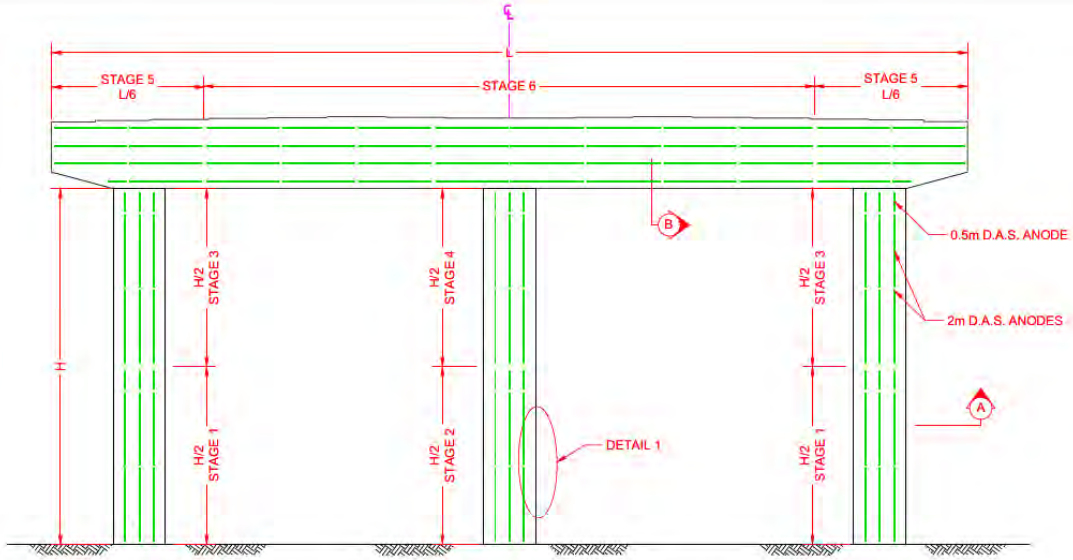
- The City's first project as part of the Gardiner Expressway Strategic Rehabilitation Plan will:
  - Rehabilitate the westbound off-ramp leading to Yonge, Bay and York Streets,
  - Replace the entire concrete deck and steel girders of the Expressway between Jarvis Street and Cherry Street, and
  - Replace the westbound off-ramp at Sherbourne Street and the eastbound on-ramp at Jarvis Street.
- This rehabilitation plan will:
  - Rehabilitate and protect the substructures from Jarvis to Cherry St. to support the brand-new superstructure.
  - Replace the concrete deck and steel girders superstructure using Accelerated Bridge Construction techniques

Gardiner Pier Rehabilitation Plan

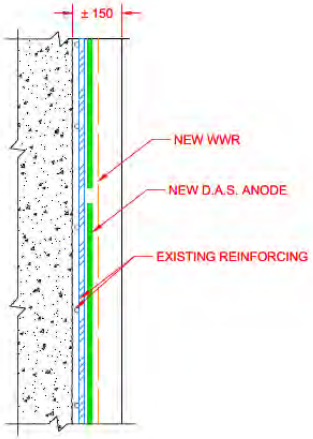
- To implement city's strategic rehabilitation plan successfully, the piers are repaired, strengthened and protected with galvanic encasement.
- The pier repairs were to match the service life of the new bridge deck.
- A galvanic encasement was used to repair and provide corrosion protection to the deteriorated 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 was designed to protect all reinforcing steel in each pier for the specified service life requirements.

Galvanic Encasement Plan

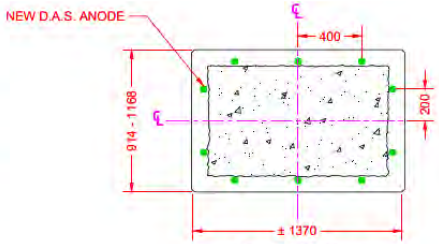




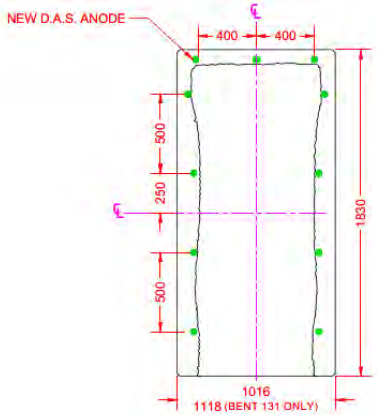
BENT - TYPICAL ELEVATION



DETAIL 1



SECTION A



SECTION B

VECTOR CORROSION TECHNOLOGIES

8620 ESCARPMENT WAY, UNIT 14
MILTON, ON L9T 0M1
WWW.VECTORGROUP.COM

Do not scale drawings.
Verify all dimensions and conditions on site

PROJECT NAME

CITY OF TORONTO

CONTRACT # 19ECS-TI-01GE

SHEET TITLE

D.A.S ANODES ON BENTS 120-131

DRAWING BY WM	SCALE N.T.S.
APPROVED BY JP	DATE APR 29 2019
VECTOR PROJECT No.	06A190220N
SHEET NUMBER V-01	REVISION

LEGEND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MOBILEASE
VECTOR
CORROS
TECHNO

Gardiner Expressway

Galvanic Encasement of Piers to Extend Life of Substructure

Gardiner Expressway Pier Rehabilitation

- 25+ year service life extension.
- 53,865 m^3 of concrete was maintained in service.
- Reduced potential CO_2 emissions by 35,000 metric tons, the annual equivalent 8,726 people.
- Prevented the generation of 130,000 metric tons of solid waste.
- Saved 1.8 million gallons of potable water, the daily usage of 17,000 people.

Approximate values estimated by the WeSaveStructures.Info Environmental Impact Calculator at https://www.wesavestructures.info/environmental-impact-calculator

Inputs

Volume of concrete to be preserved	70455	yd3	53865	m3
	Calculate		Calculate	

Outputs

Emissions				
Concrete CO2	18547	US tons CO2	16806	metric tons CO2
Steel CO2	19974	US tons CO2	18099	metric tons CO2
Total Carbon Dioxide	38521	US tons CO2	34905	metric tons CO2
Equivalent to annual CO2 emission of:	8755	people	8726	people
NOx (as NO2)	68672	lbs	30626	kg
SO2	19175	lbs	8552	kg
Total Pollutants	77130390	lbs	34943490	kg
Waste Generation				
Solid Waste (Rubble)	142671	US tons	129276	metric tons
Energy (heat generation from cement production, cement hydration, and steel production)	168007	GJ	159468	GJ
Equivalent energy to boiling	209	Olympic Pools	198	Olympic Pools
Natural Resources Required				
Fine aggregate	37095	US Tons	33612	metric tons
Coarse aggregate	58495	US Tons	53003	metric tons
Cement	31705	US Tons	28279	metric tons
Steel	11414	US Tons	10342	metric tons
Total tons	138709	US Tons	125236	metric tons
Potable Water	1782596	gal	6598463	liters
Equivalent to daily water usage for:	17826	people	16496	people

Disclaimer: Calculations are based on the following typical values

Concrete Density	*Cement Content*
English - 150 lb/ft3	*600 lb/yd3*
Metric - 2400 kg/m3	*350 kg/m2*

Note that these values are not direct equivalents and will lead to slight variations in calculated results

Print Form

Florida DOT
Galvanic Encasement (Above High Tide)

Florida DOT
Galvanic Encasement (Above Tide)

FRP or PVC
Stay-in-place Forming Systems

Preformed FRP Jackets

Modular PVC Forms

Florida Keys Column Encasement

	mA	On (mV)	Off (mV)	Pol. (mV)	Notes
Static/native		-458			
On	725				
16 hrs	228	-997	-825	-367	vs static
20 days	98	-931	-652	-238	4 hours
90 days	72	-912	-657	-293	21 hours
118 days	n/a	-905	-667	-205	vs static
270 days	54	-867	-664	-236	2 hours
594 days	67	-924	-679	-330	14 hours

Conclusions

Galvanic encasements are an option to save severely damaged bridge substructures.

The galvanic encasement is a one-step repair and protection option that can also incorporate additional reinforcement.

The protection is provided by alkali-activated discrete anodes.

Alkali-activated discrete anodes installed in early 2000’s are providing cathodic protection to with an estimated service life of 20-40+ years.

Sustainability

IN ADDITION TO SHORTENING CONSTRUCTION TIME AND REDUCED DISRUPTION TO THE PUBLIC, WE USE LESS CONCRETE AND OTHER CONSTRUCTION MATERIALS BY EXTENDING THE SERVICE LIFE OF EXISTING STRUCTURES.

THIS IS A CHALLENGE, BUT IT IS POSSIBLE IF WE MAKE IT A PRIORITY.

QUESTIONS?

Contact Chris

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WEBINAR RECORDING & FUTURE EVENTS

HOME EVENTS PRESERVATION REPAIR TECHNOLOGIES TESTING & EVALUATION RESOURCES CONTACT

CONCRETE PRESERVATION ALLIANCE

Nov 11, 2020 | Pile Protection for Coastal Bridges

Jason Chodachek

Vector Corrosion Technologies

Description: Marine environments are among the most corrosive exposure conditions for reinforced concrete or steel structures. Tidal action and salt water splashing on piles creates ideal conditions for corrosion and the effects can wreak havoc on marine structures of all kinds. While the marine environment presents significant challenges for service life, there are proven methods of extending the life of both concrete and steel piles in fresh, brackish and even salt water. This webinar will compare the various marine pile protection options available today and explore methods of evaluating and protecting steel sheet piles.

Click Here to Register - 7:00 AM EST / 1:00 PM CEST

Click Here to Register - 2:00 PM EST / 11:00 AM PDT

Dec 9, 2020 | Targeted Proactive Corrosion Protection for Bridges with Embedded Galvanic Anodes

David Simpson, Icorr Level IV Senior Cathodic Protection Engineer

Vector Corrosion Technologies

Description: Corrosion potential surveys have long been an effective non-destructive method of quantifying corrosion risk and locating "hot spots" in concrete structures before repairs are required. High corrosion risk areas can be proactively targeted using embedded galvanic anodes to halt corrosion before the active corrosion causes concrete failure and a need for repair. This webinar will discuss this proactive approach in detail and introduce an innovative "two-phase" anode technology combining the benefits of both impressed current and galvanic protection in a single unit.

Click Here to Register - 7:00 AM EST / 1:00 PM CEST

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