Heritage Structural Preservation

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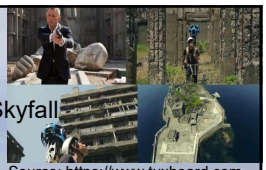
Vector Corrosion Technologies



Source: https://www.tuxboard.com

Making Vector Again

2

Contents:

- CSEA introduction
- Evaluation of Heritage Structures
- Preservation of Heritage Structures
- Case studies

3

Introduction of Canada Structural Engineers Association

The purpose/mission is to provide support and professional development for structural engineers.

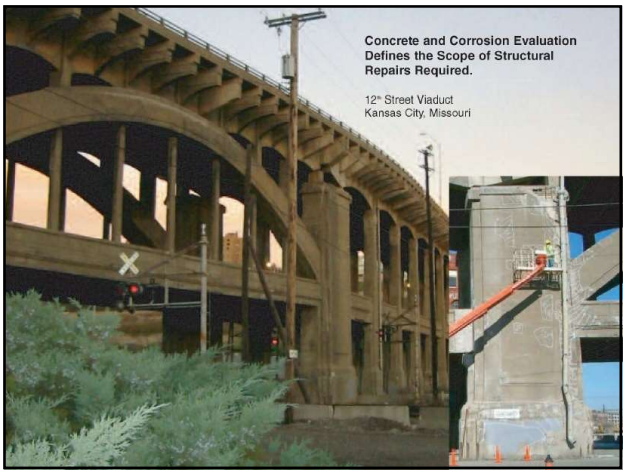
Activities: Technical discussions, technical seminars, social events, mentoring programs

4

How to Improve Concrete Repair Practice

- ACI 562-16 Code
  - Sets minimum requirements for repair
- **Encourages evaluation**
  - **Confirm existing condition / material properties**
  - **Better evaluation → Better repairs**
- Sustainable repaired structures
  - Consistent (reliable) repairs
  - Durable long-term repairs

17



28

29

30

Chloride Thresholds

- 0.2% by weight of cement (ACI)
- 0.031% by weight of concrete
- 1.2 lb Cl^-/yd^3 of concrete (0.71 kg/m^3)
- These code guidelines are rather simplistic
- Different concrete conditions have different thresholds: wet or dry concrete, pre-stressed, etc.
- In reality corrosion activity is progressive and based on the Chloride / Hydroxyl Ratio (Cl^-/OH^-)

Chloride Limit for New Construction (ACI 222R)

	Acid Sol.	Water Sol.	Water Sol.
Test Method	ASTM C1152	ASTM C1218	Soxhlet
Prestressed	0.08	0.06	0.06
Reinforced Wet	0.10	0.08	0.08
Reinforced Dry	0.20	0.15	0.15% by weight Cement

Section 1

Section 2

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31

Depth of Cover Survey

- To determine the average depth of concrete covering the rebar within the structure
- Compare depth of rebar with results of chloride and carbonation testing
- Performed using Micro Covermeter

Section 2

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32

Rebar Continuity

- Verify electrical continuity of the steel
  - Discontinuous steel may pose problems for cathodic protection
- Typical Criteria
  - Less than 1 mV or
  - Less than 1 ohm resistance

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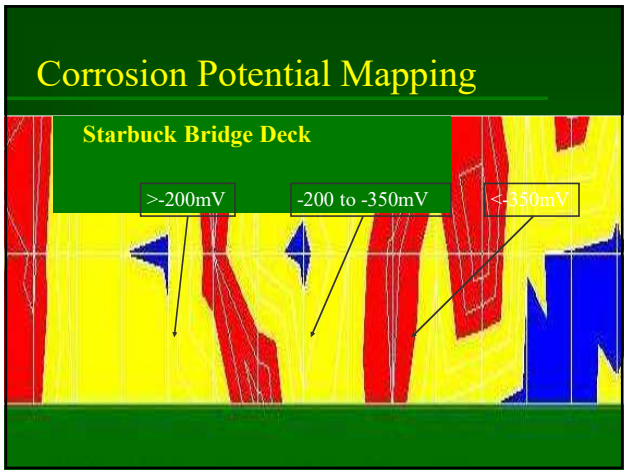
33

Carbonation Testing

34

35

36



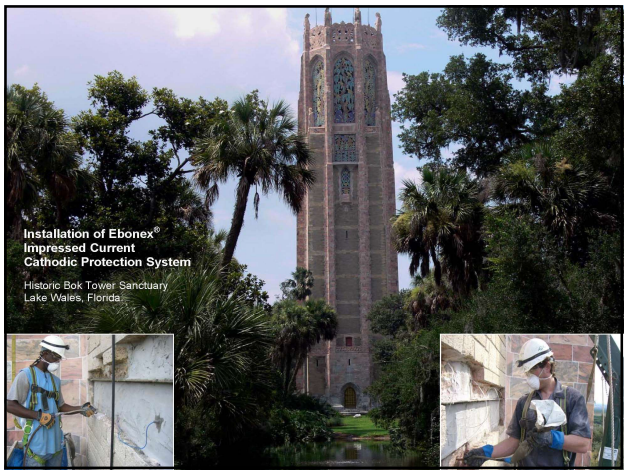
37

38

Electrochemical Corrosion Mitigation Systems for Concrete

- Galvanic Protection
- Impressed Current Cathodic Protection
- Corrosion Passivation using Electrochemical Treatments
  - Chloride Extraction
  - Re-alkalization

39

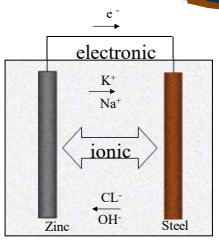


40

41

Galvanic protection – Potentials and Current Flow

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	



43

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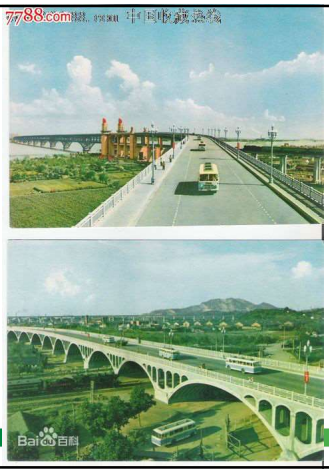

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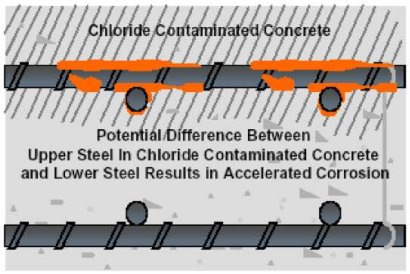
60

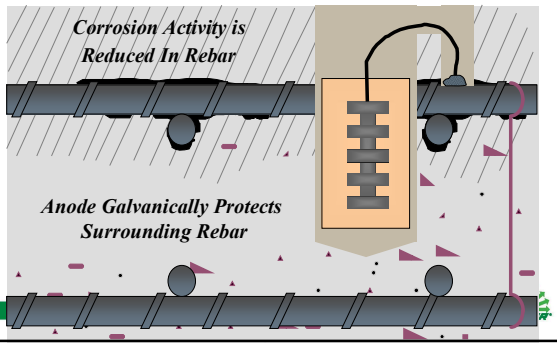
61

Corrosion Control



69

Galvashield CC Installation



70

The Global Centre for Pluralism – 330 Sussex Dr, Ottawa

- Background

- Steel-framed building with load bearing masonry
- Wing A built in 1904, Wing B built in 192
- Has served as National Archives and the Canadian War Museum
- Extensive repurposing of building to serve as the Global Centre for Pluralism

73

The Global Centre for Pluralism

Problems

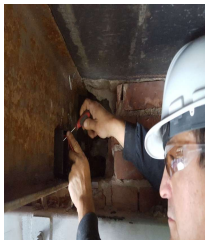
- Corrosion identified on beams and columns embedded in masonry walls
- With current wall assembly, very difficult to eliminate moisture in the walls

74

The Global Centre for Pluralism

Solution

- Install small anodes within the wall assembly to mitigate corrosion at beam ends
- Encase beam ends in concrete to ensure that the entire beam end is protected



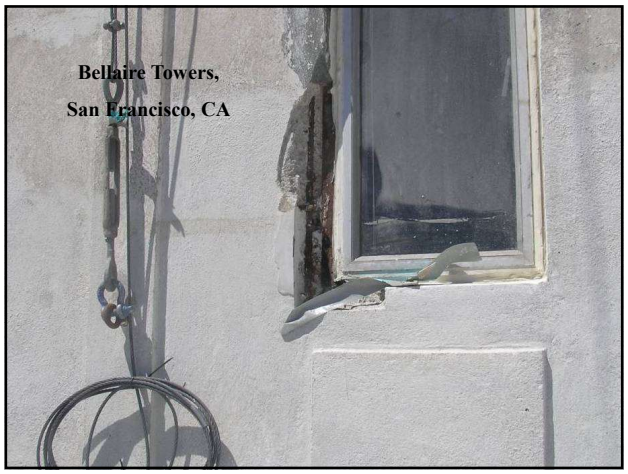
75

Global Centre for Pluralism

- Benefits
  - Mitigate ongoing risk of corrosion
  - Reduced costs as anodes could be installed from the interior
  - The external steel connections allow for future monitoring

76

78



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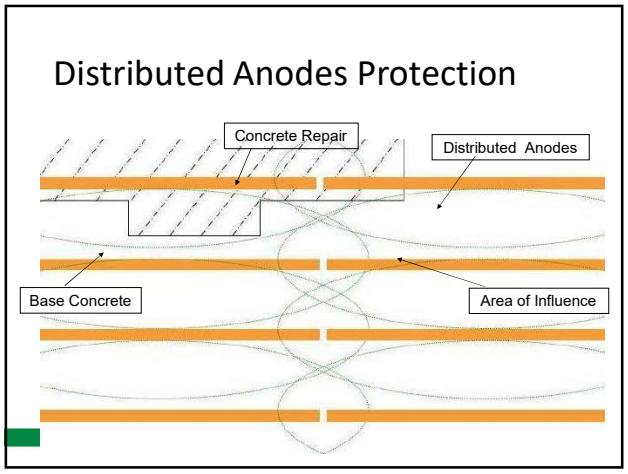
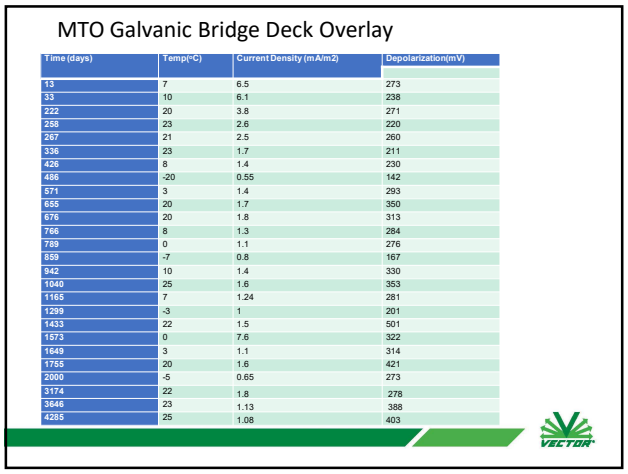
80



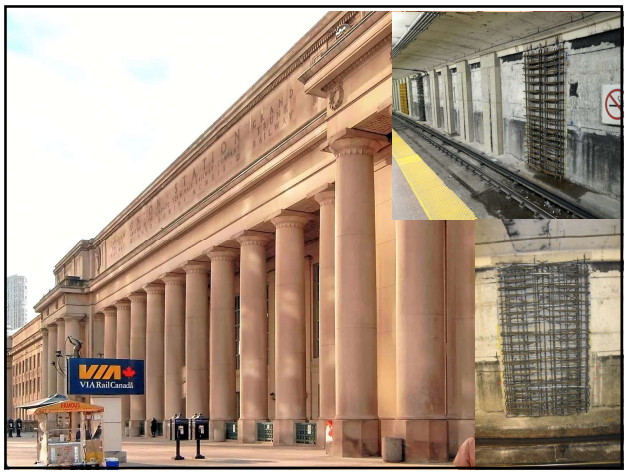
82

83



Time (days)	Temp(°C)	Current Density (mA/m2)	Depolarization(mV)
13	7	6.5	273
33	10	6.1	238
222	20	3.8	271
258	23	2.6	220
267	21	2.5	260
336	23	1.7	211
426	8	1.4	230
486	-20	0.55	142
571	3	1.4	293
655	20	1.7	350
676	20	1.8	313
766	8	1.3	284
789	0	1.1	276
859	-7	0.8	167
942	10	1.4	330
1040	25	1.6	353
1165	7	1.24	281
1299	-3	1	201
1433	22	1.5	501
1573	0	7.6	322
1649	3	1.1	314
1755	20	1.6	421
2000	-5	0.65	273
3174	22	1.8	278
3646	23	1.13	388
4285	25	1.08	403

84



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86

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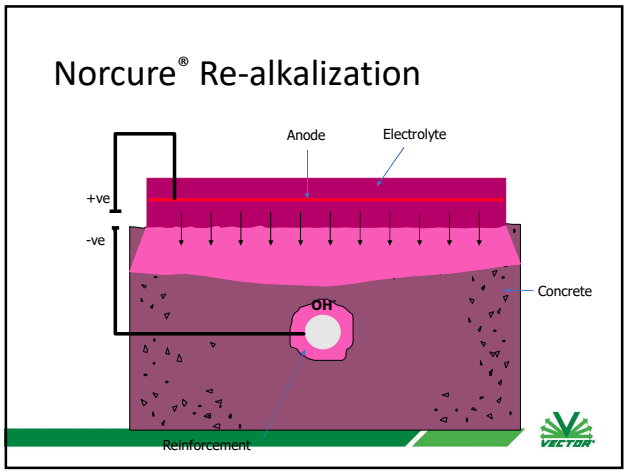
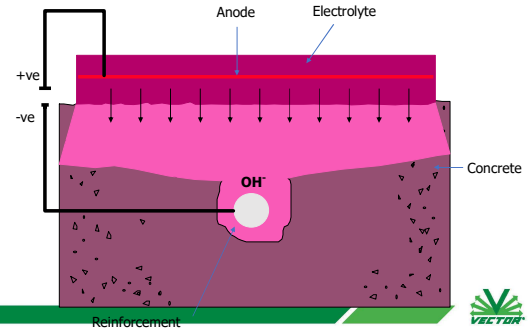


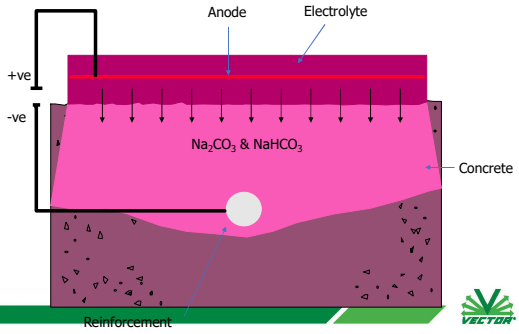
92

Norcure® Re-alkalization



93

Norcure® Re-alkalization



94

HISTORIC CONCRETE CONSERVATION

Terminal A, Ronald Reagan Washington National Airport, Washington, DC

95

Conditions

99

Norcure® Re-alkalization

Reagan National Airport Facade
Washington, DC

100

101

Realkalization Installed

- Realkalization media is a paper mache material that is saturated with an alkaline solution

102

Phenolphthalein (pH) Testing

- Before Treatment After Realkalisation

103

Net Result - Realkalisation

- Cover zone impregnated with high pH solution
- Low alkalinity rectified
- Entire surface treated
- Life of structure is extended

104

125

Rainbow bridge, Niagara Falls

Table 1: Pier Reinforcement Cover-Depth Statistics

Side	Reinforcement Direction	Average (in)	Standard Deviation (in)	Minimum (in)	Maximum (mm)	Less than 2 in (%)
US	Vertical	4.6	1.4	2.4	7.3	0
	Horizontal	4.2	1.8	1.5	6.3	20
Canada	Vertical	3.7	0.6	2.1	4.2	0
	Horizontal	4.6	1.3	2.5	6.0	0
Overall	Vertical	4.4	1.3	2.1	7.3	0
	Horizontal	4.3	1.7	1.5	6.3	14

126

Rainbow bridge, Niagara Falls

Table 3: Statistical Analysis of the Corrosion Potential Data

Pier ID	Pier Face	Area Indicating 90% Probability of Active Corrosion (%)	Area Indicating Uncertain Corrosion Activity (%)	Area Indicating 90% Probability of Passive Steel (%)
S/A1	W	0%	0%	100%
S/A2	E	0%	0%	100%
S/A3	E	0%	0%	100%
N/A1 Area 1	W	81%	19%	0%
N/A1 Area 2	W	95%	5%	0%
N/A2	N	0%	0%	100%
N/A3	E	0%	0%	100%
S/C3	W	0%	33%	67%
S/C2	W	0%	0%	100%
S/C1	E	0%	0%	100%
N/C3	N	0%	0%	100%
N/C2	W	0%	0%	100%
N/C1 Area 1	E	0%	0%	100%
N/C1 Area 2	E	67%	33%	0%
Overall		15%	5%	81%

127

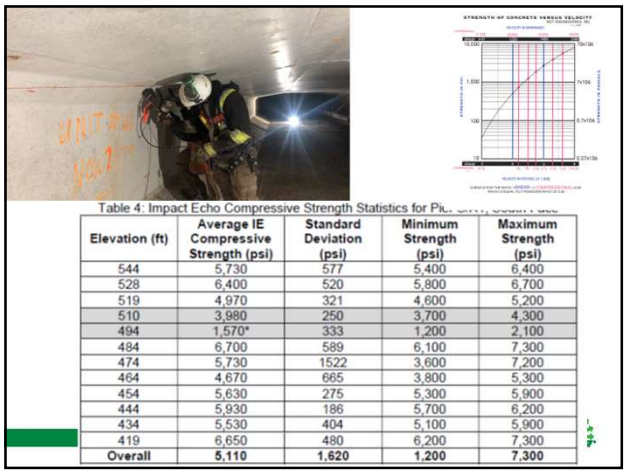
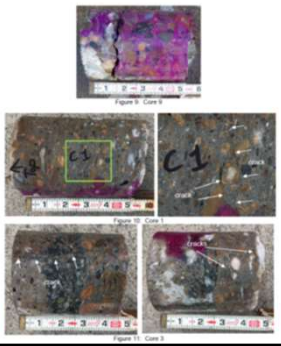


Table 4: Impact Echo Compressive Strength Statistics for Pi...

Elevation (ft)	Average IE Compressive Strength (psi)	Standard Deviation (psi)	Minimum Strength (psi)	Maximum Strength (psi)
544	5,730	577	5,400	6,400
528	6,400	520	5,800	6,700
519	4,970	321	4,600	5,200
510	3,980	250	3,700	4,300
494	1,570*	333	1,200	2,100
484	6,700	589	6,100	7,300
474	5,730	1522	3,600	7,200
464	4,670	665	3,800	5,300
454	5,630	275	5,300	5,900
444	5,930	186	5,700	6,200
434	5,530	404	5,100	5,900
419	6,650	480	6,200	7,300
Overall	**5,110**	**1,620**	**1,200**	**7,300**

128

Core extraction and testing



129

Chloride tests

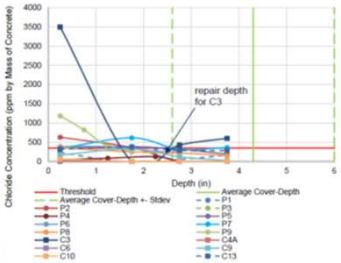
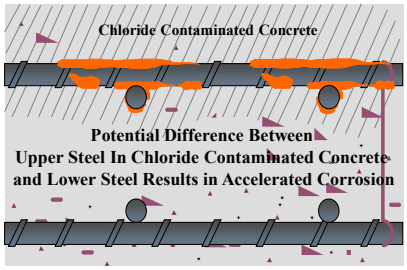


Figure 12: Corrected Chloride Concentrations for the Columns

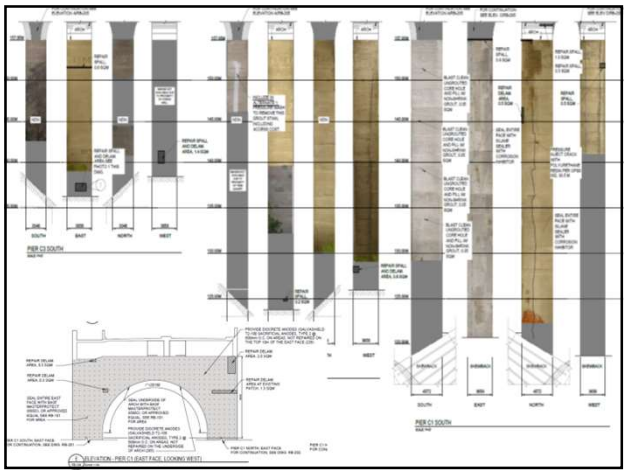
130

131

132

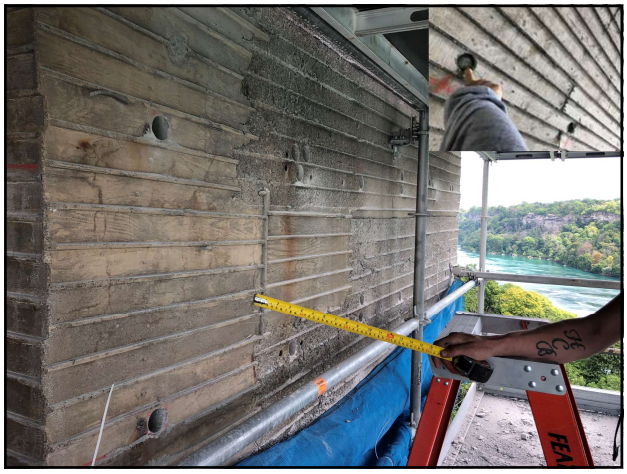


133



134

135



136

137

Want a certificate? please register your rename and email with CSEA: info@csea.ca

Canada Structural Engineers Association (CSEA)

Certificate of Attendance

This certificate is presented to

For attending the seminar entitled "Evaluation and Preservation of Heritage Structures" held on September 11, 2023.

Signature:

Cancan Yang
Director of Event Operations

163

Future events of Canada Structural Engineers Association (CSEA)

- Tree Planting, John Fraser Secondary School, 14 October
- Engineers FC, fun games
- Annual Lunch and Election, December 10, 2024
- Joint CSEA, info@csea.ca

164

Heritage structural preservation

Corrosion evaluation
Preservation of heritage structures
Galvanic protection
Re-alkalization
Case studies

Liaoh@vector-corrosion.com

165