Performance of Corrosion Mitigation Systems in Iowa Bridges

Work Performed on Behalf of Iowa Department of Transportation,
Michael Todsen

James P. Donnelly, Paul D. Krauss
and John S. Lawler
Wiss, Janney, Elstner Associates

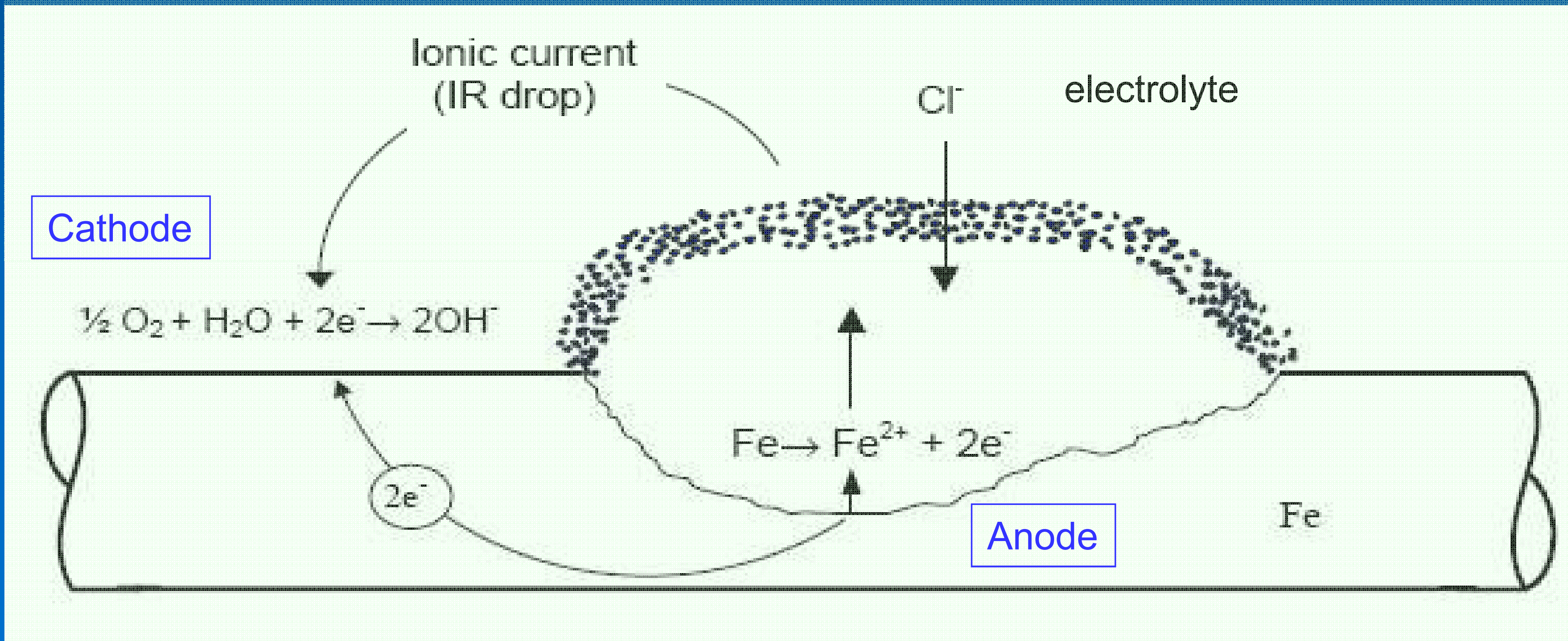
Application to 3 Iowa Bridges

- US 63 Ottumwa
  - Cathodic Protection - Arc-sprayed zinc
- IA 192 Council Bluffs
  - Chloride extraction (ECE)
  - Cathodic protection - Discrete anode
- I-380 Cedar Rapids
  - Cathodic Protection – Zinc-hydrogel sheet

Corrosion in Bridge Substructures

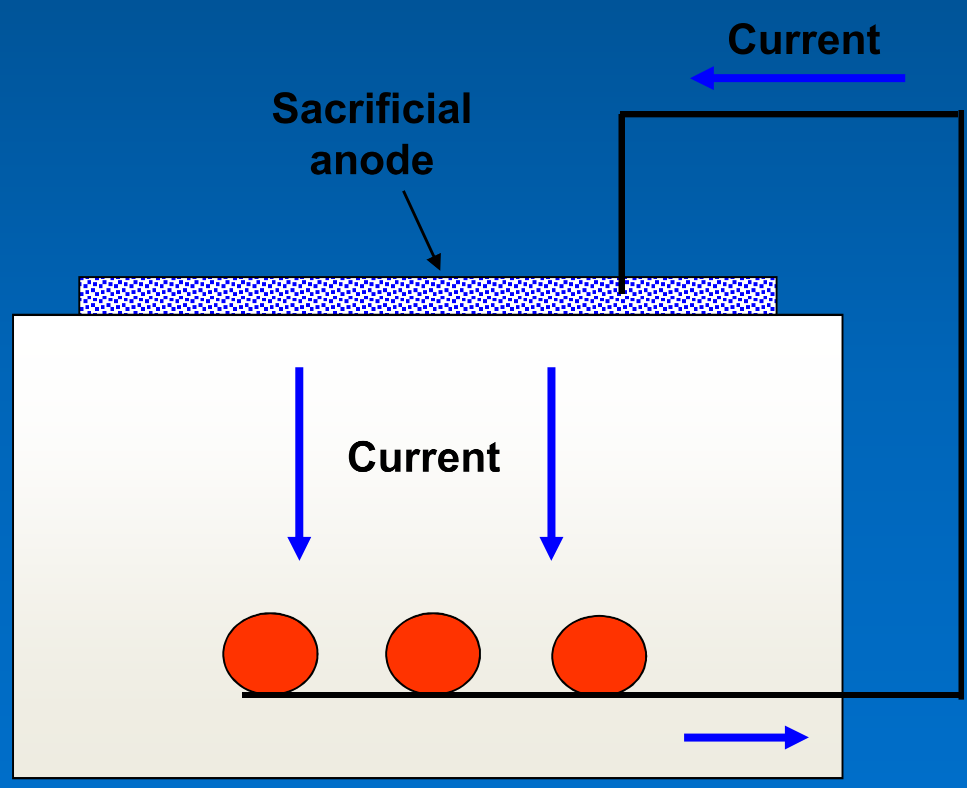
- Repair complicated and expensive since deck/superstructure must be supported
- Exposure worst at leaking joints

Corrosion Process



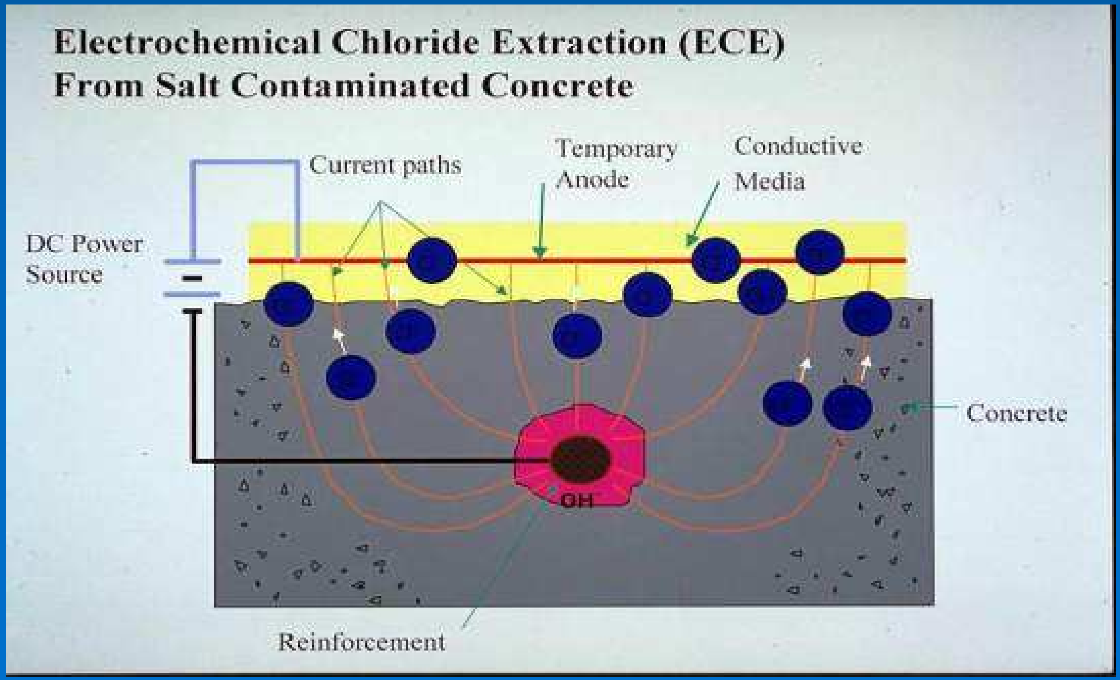
Galvanic Protection
Sacrificial Anode CP

- Sacrificial anode
  - Zinc sheets
  - Arc-sprayed zinc
  - Discrete probes
- Current flows by galvanic action
- Proven record
- Lower initial cost
- Little maintenance
- Requires electrical connection



Chloride Extraction

- Higher current
- Applied temporarily
- Electrolyte (water)
  - Ponded
  - Porous covering
- Current draws out chlorides
- Time consuming



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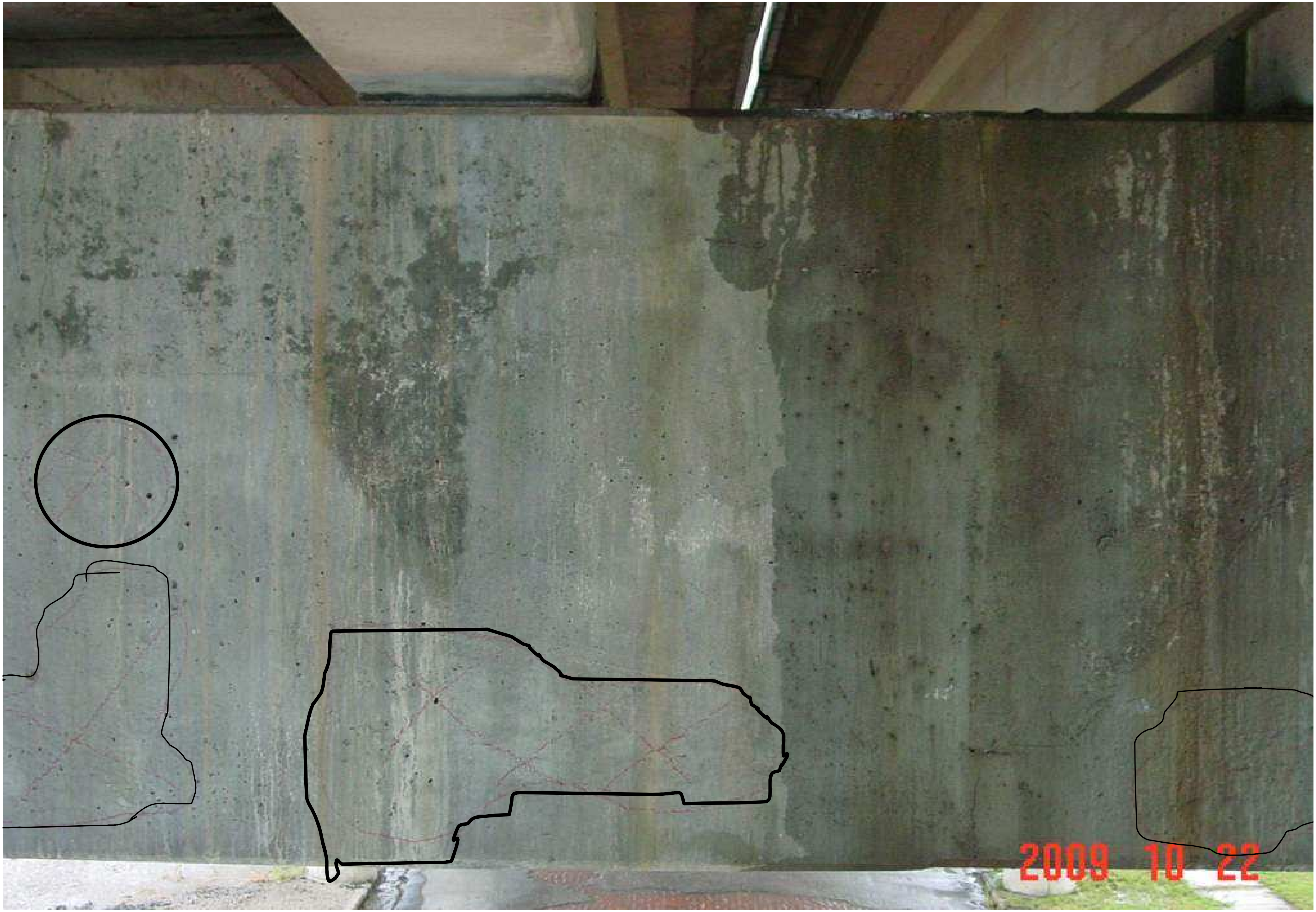
US 63 Ottumwa


Arc Sprayed Zinc CP
2009 10 22


2009 10 22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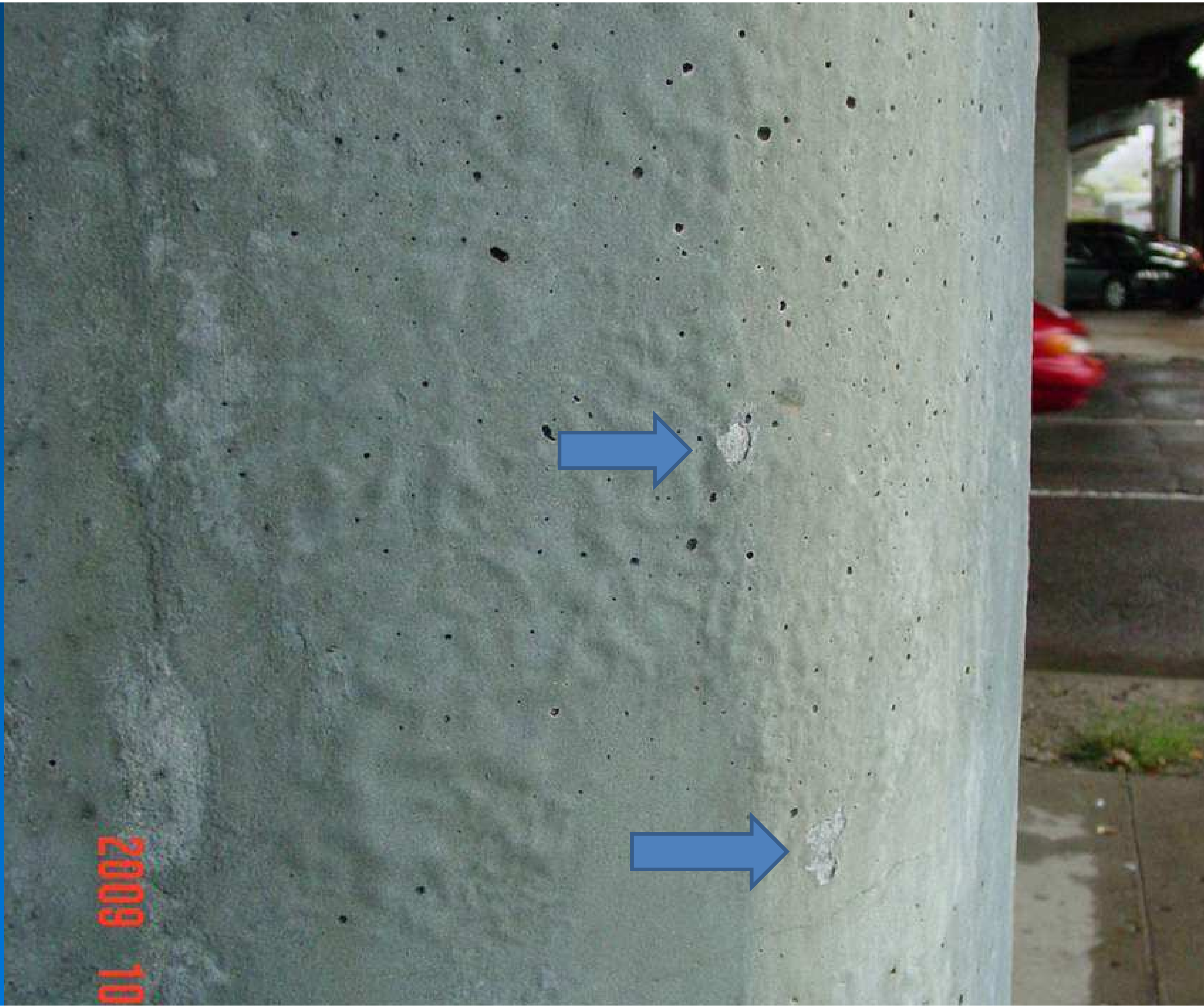
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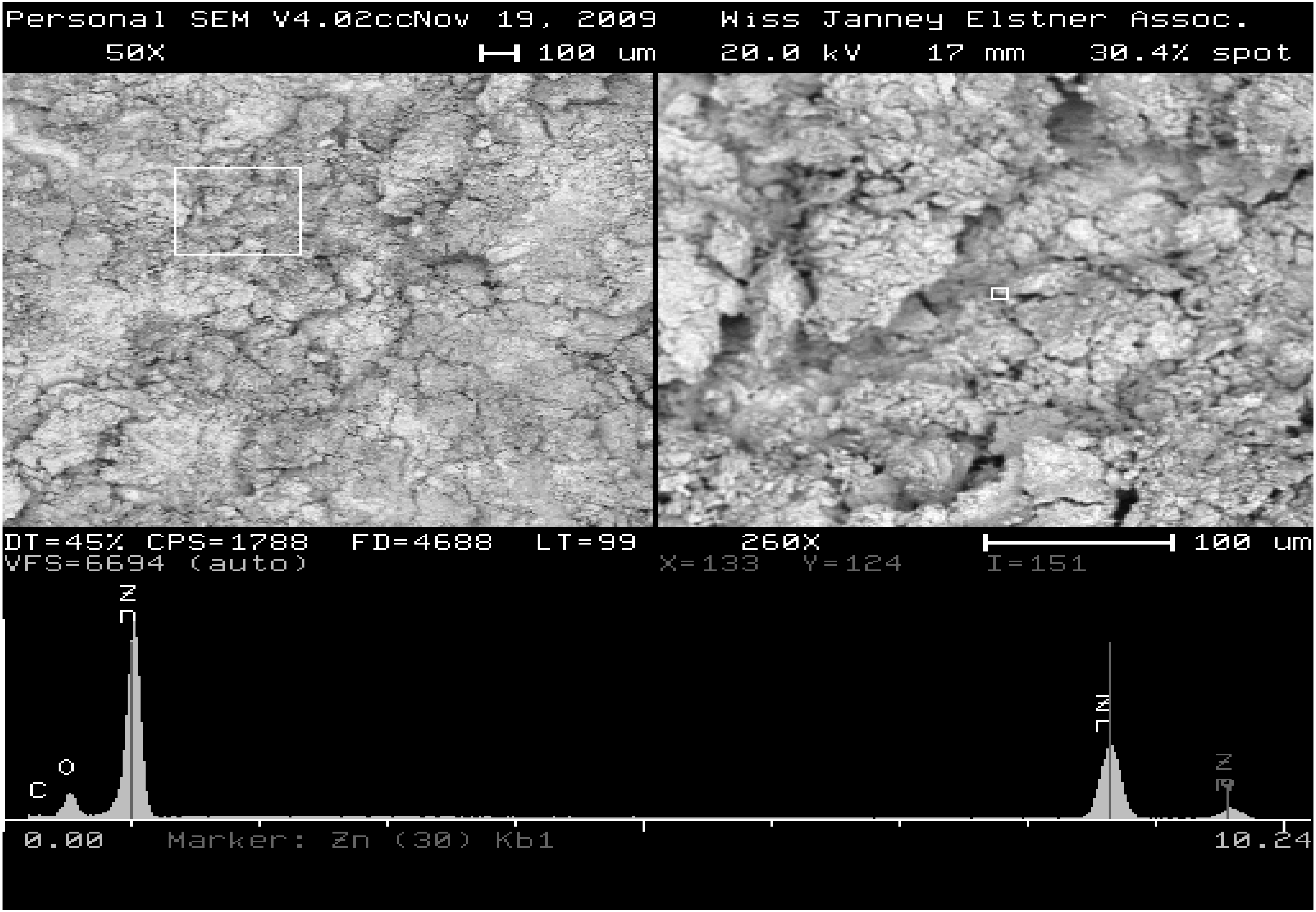
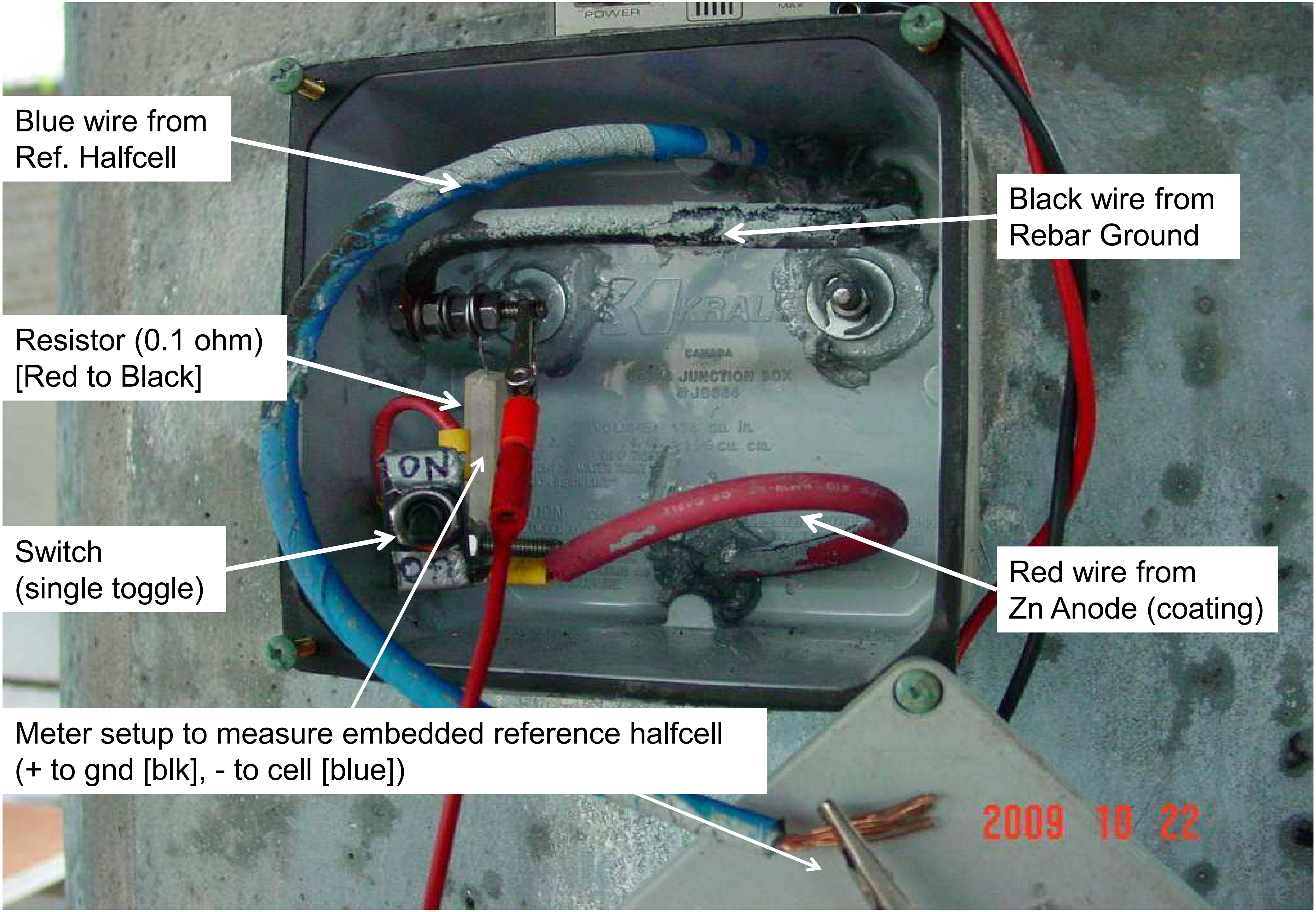
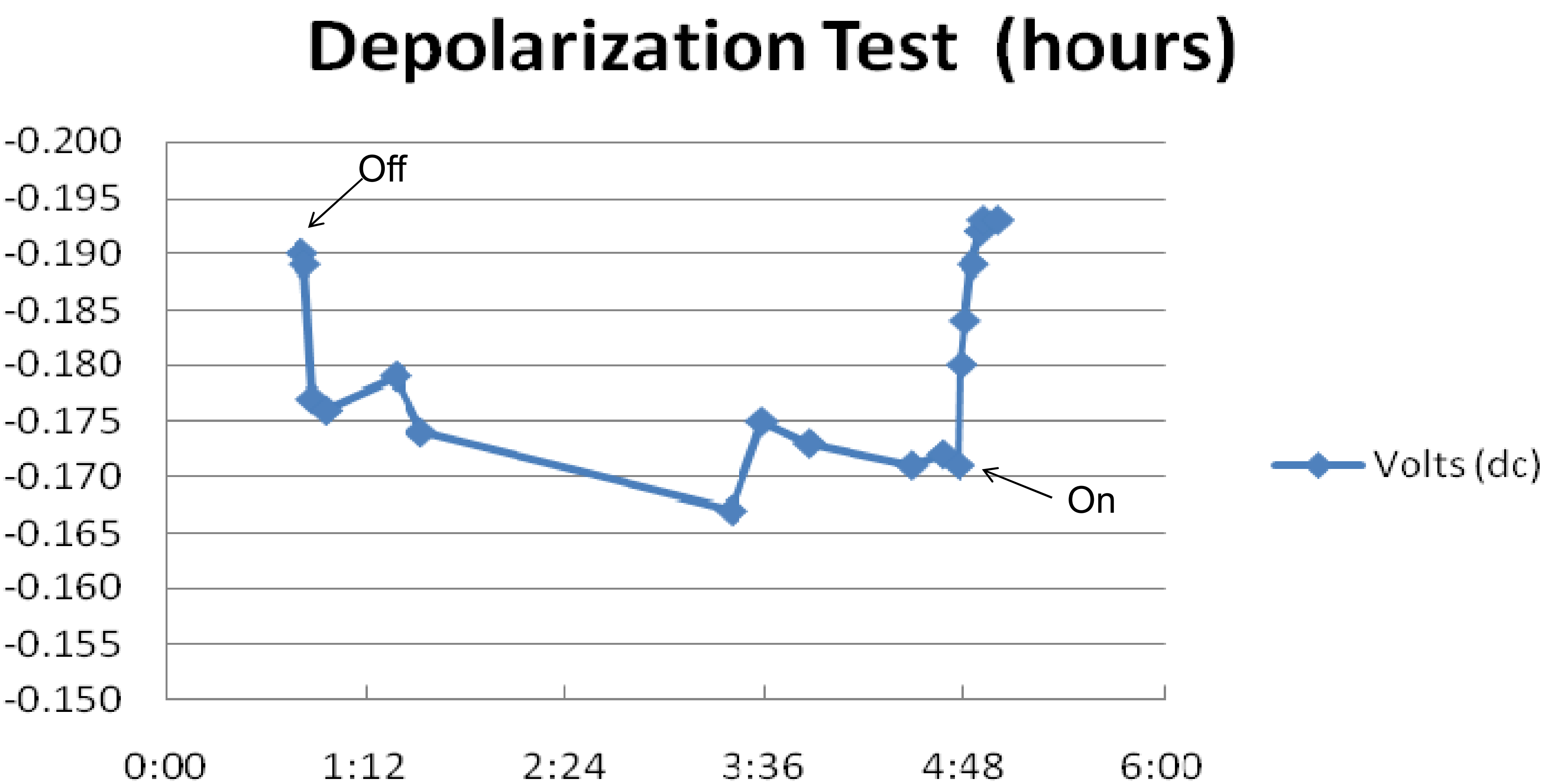


Personal SEM V4.02ccNov 19, 2009
Wiss Janney Elstner Assoc.
50X
100 um
20.0 kV
17 mm
30.4% spot
DT=45% CPS=1788 FD=4688 LT=99
260X
100 um
VFS=6694 (auto)
X=133 Y=124
I=151
Zn
C
O
Zn
Zn
0.00
Marker: Zn (30) Kb1
10.24

30” by 48” test area


Blue wire from Ref. Halfcell
Black wire from Rebar Ground
Resistor (0.1 ohm) [Red to Black]
Switch (single toggle)
Red wire from Zn Anode (coating)
Meter setup to measure embedded reference halfcell (+ to gnd [blk], - to cell [blue])
ON
2009 10 22



Depolarization Test (hours)
-0.200
-0.195
-0.190
-0.185
-0.180
-0.175
-0.170
-0.165
-0.160
-0.155
-0.150
0:00
1:12
2:24
3:36
4:48
6:00
Off
On
Volts (dc)

US 63 Ottumwa - Arc Sprayed Zinc

- Current was minimal
- Total shift of test area only about 20 mV (Instant off and depolarization)
- Blisters filled with zinc corrosion products have formed in coating (no chloride)
- Zinc coating thickness at blisters was 0.026” (0.018” to 0.047”), [Spec was 0.020”]
- No initial data
- Minimal concrete deterioration

US 63 Ottumwa - Arc Sprayed Zinc Comments and Questions

- No site installation report was available
- Should install more than one test area and in both highly exposed and lightly exposed areas

- When is protection lost due to blisters and zinc consumption?
- Is it possible to consume all zinc applied?

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IA 192 Council Bluffs

- Corrosion-induced deterioration widespre under expansion joints
- Repaired in 1998
  - Conventional repair
  - ECE on caps & cols.
  - ECE and discrete anodes exterior beams
  - Sealer

Photo from www.vector-corrosion.com

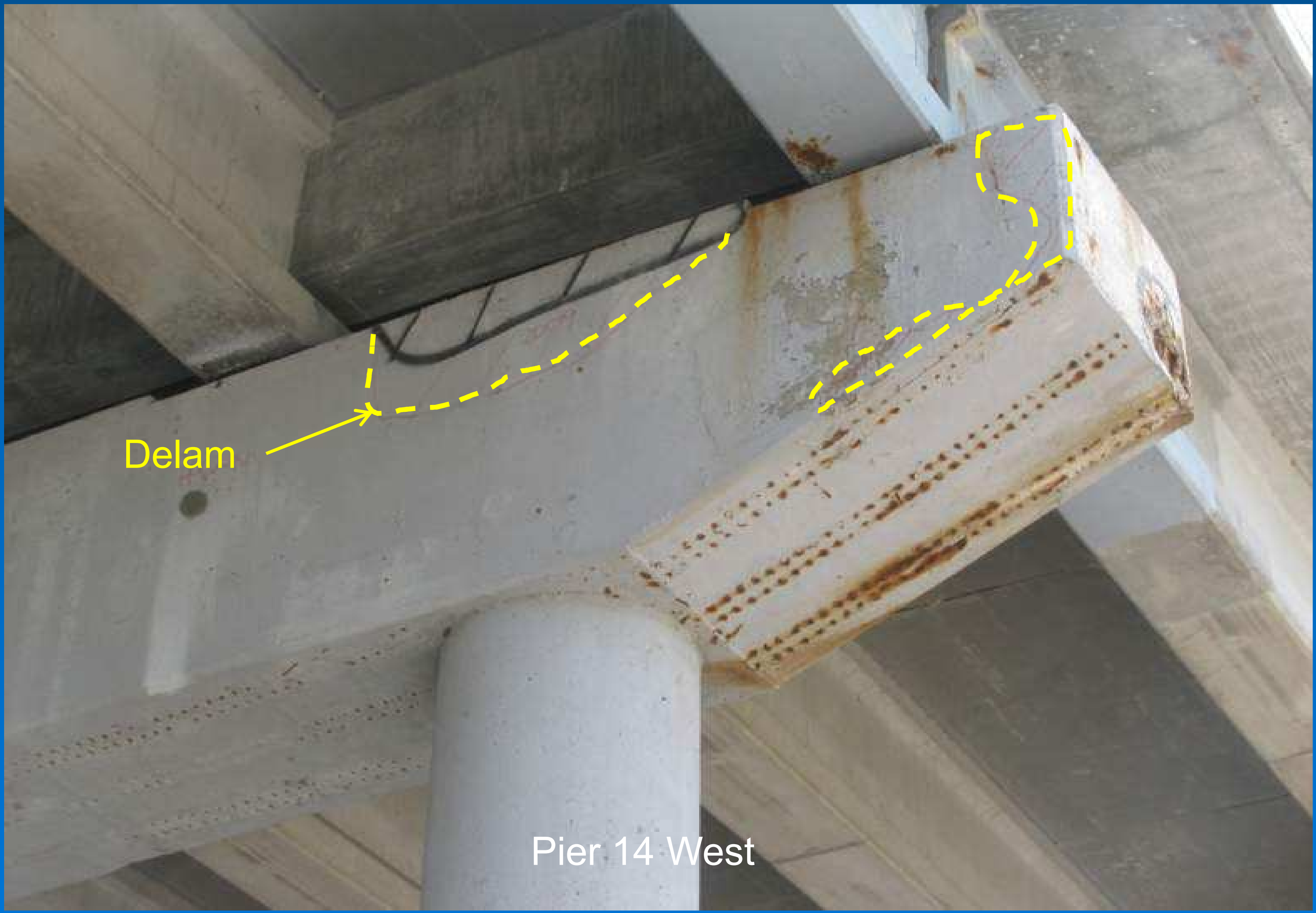
Electrochemical Chloride Extraction (ECE)

ECE and Discrete Anodes

IA 192 Council Bluffs - 2009 Survey

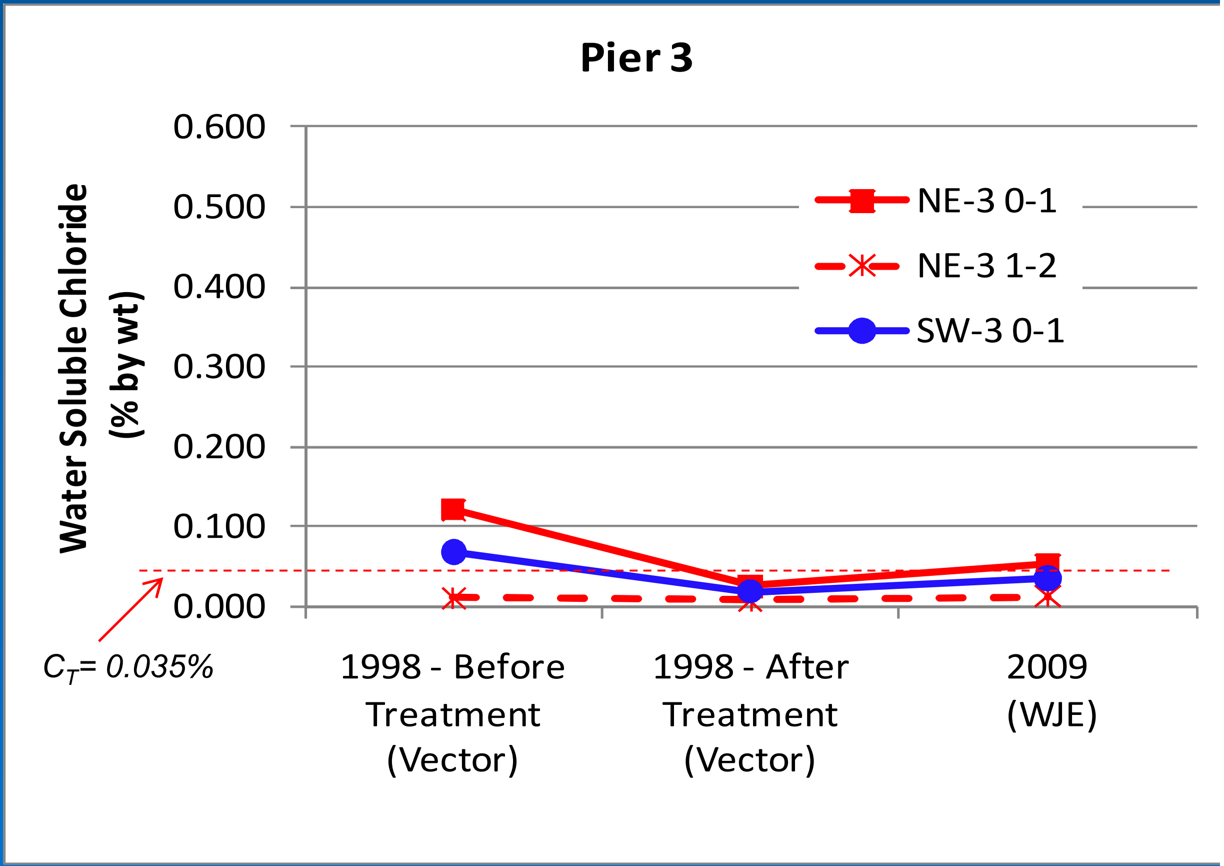
- Visual condition
- Sounding
- Half-cell testing
- Chloride sampling
- Electrical testing of discrete anode performance

IA 192 Council Bluffs - 2009 Survey

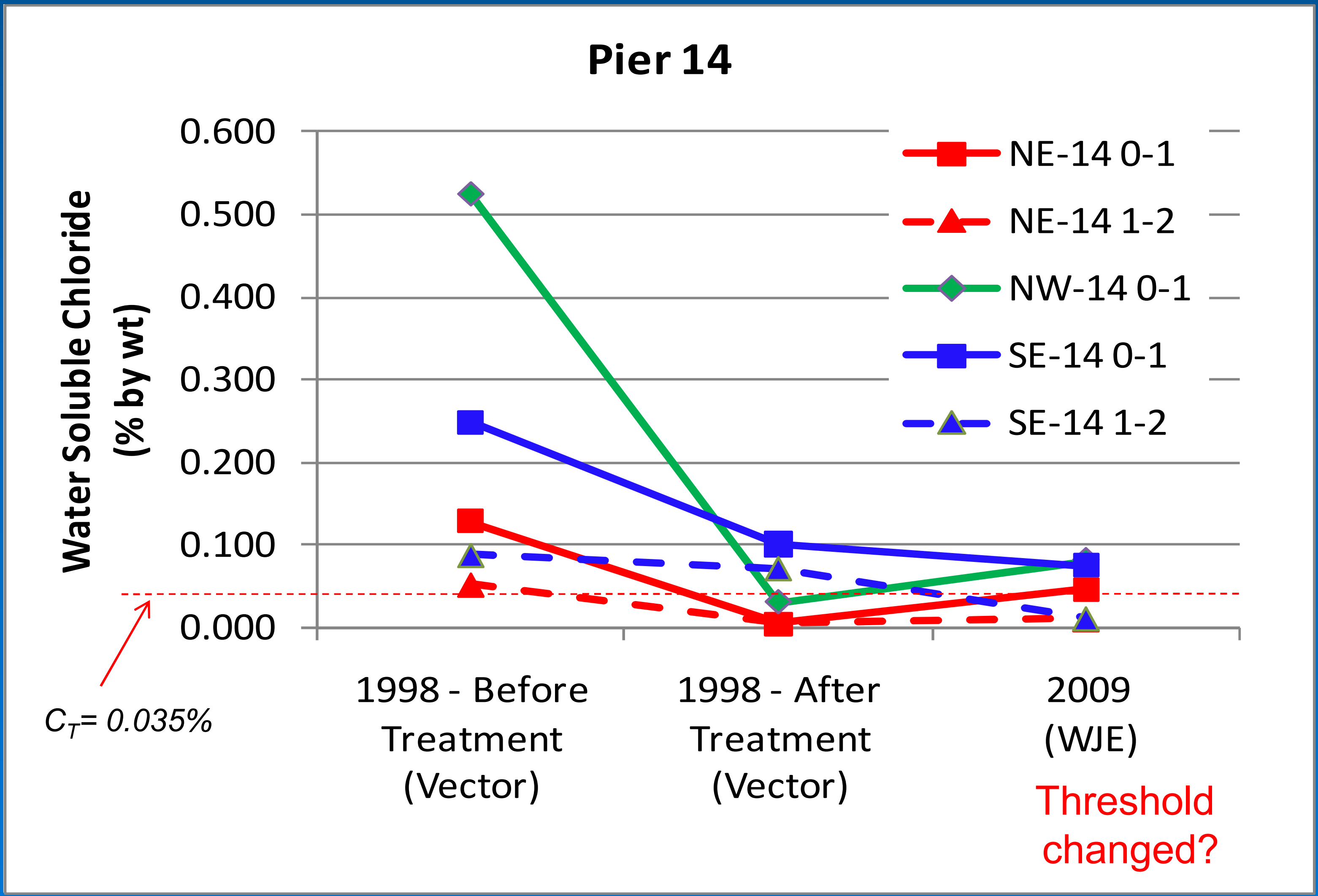


IA 192 Council Bluffs – Chloride in Pier Caps

- Core samples taken for comparison with values reported by contractor



IA 192 Council Bluffs – Chloride in Pier Caps



IA 192 Council Bluffs - 2009 Survey

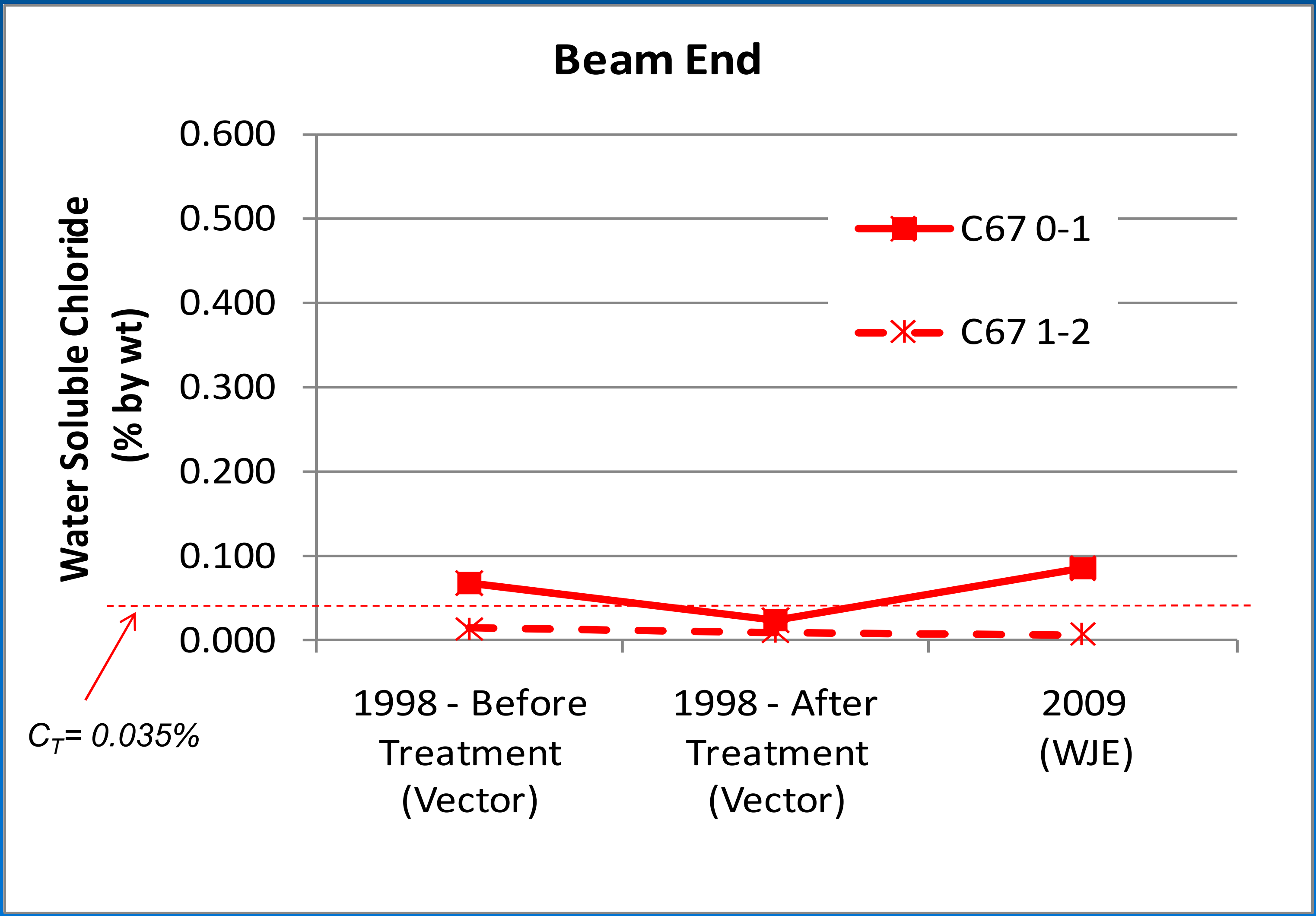
East Beams at Pier 3 – Discrete Anodes

West Beams at Pier 3 - ECE

IA 192 Council Bluffs – Discrete Anode Performance

- Test station not functional
  - Embedded ref. cell
- Current from anode to reinforcing bars was negligible
  - Zinc may be consumed
  - Minimal potential
- Limited installation

IA 192 Council Bluffs – Chloride in Beam Ends



IA 192 Council Bluffs - Conclusions

- Study limited by imperfect baseline test information
- Effectiveness of ECE:
  - Chloride concentration in pier caps was apparently reduced and has stayed lower than before test
  - Corrosion-related damage is growing 11 years after treatments
- Effectiveness of Discrete Anodes:
  - Discrete anode protection limited: Corrosion evident at protected ends, but not a good test

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I-380 Cedar Rapids

- Corrosion of beam ends at abutments and under expansion joints
- Repaired in 2000
  - Zinc sheet

I- 380 Cedar Rapids - 2009 Survey

- Visual condition
- Sounding
- Debonding
- Anode evaluation

Northbound Lanes: Not Protected

Southbound Lanes: Zinc-Hydrogel Sheet

I-380 Cedar Rapids –
Condition of beam ends at abutments

Location	Area of Delam. or Spall (in^2)	Number of Beams with Damage
Southbound Lanes (with CP system)	815	8
Northbound Lanes (without CP system)	2129	20

I-380 Cedar Rapids - 2009 Survey

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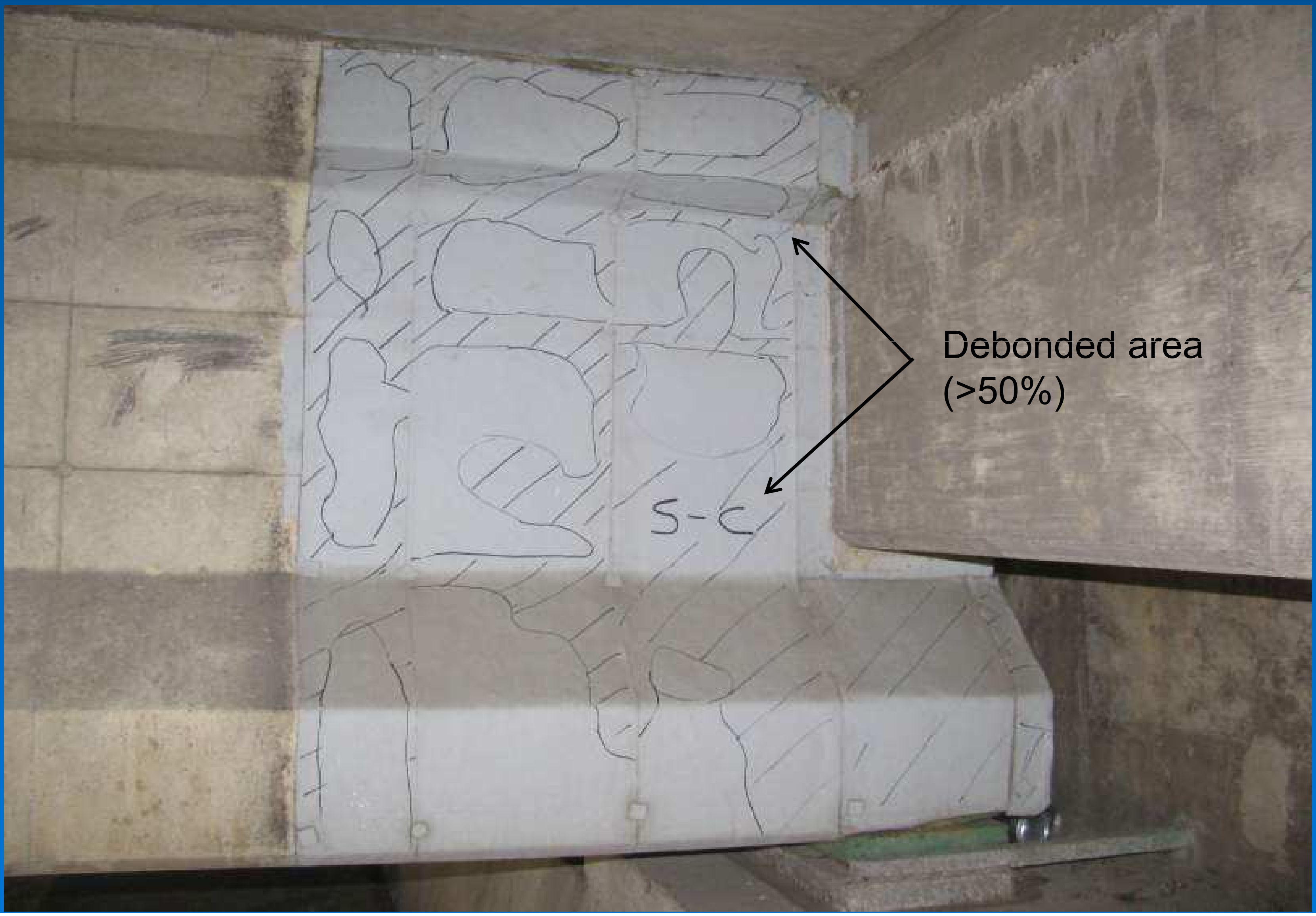


I-380 Cedar Rapids - Anode Performance

- Despite specification requiring test stations and report, stations were minimal and vandalized and report not available

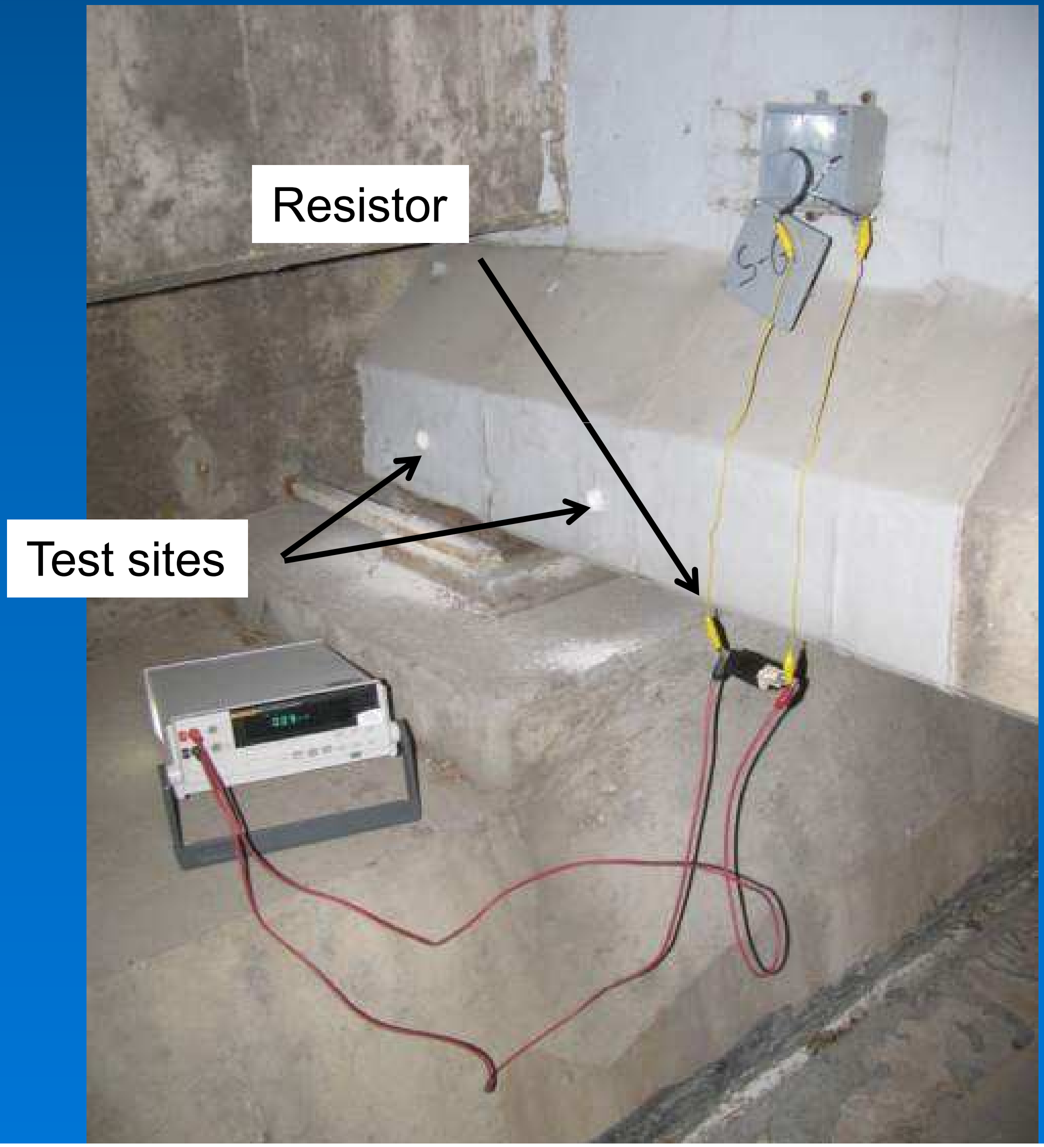
I-380 Cedar Rapids - 2009 Survey

I-380 Cedar Rapids – Performance

- Current ranged from 0.7 to 4.4 mA/sq m [Design: 10 mA/sq m]

- For North Abut.:

Distance from end of beam (in.)	Average depol. after 15 hrs (mV)
6	94
18	151



I-380 Cedar Rapids - Conclusions

- No baseline data
- Zinc sheet debonded in many areas and consumed at areas of greatest exposure
- Zinc sheet protecting beam ends
  - Depolarization adequate
  - Delam. or spalled area in southbound lanes only 40% of unprotected northbound lanes

Conclusions

- Comparison of system performance in these three bridges:

System	Protection
CP Discrete Anodes	Limited (may be poor test)
CP Arc-Spray Zinc	Likely but uncertain
CP Zinc Sheet	Good
Chloride Extraction	Some protection, may have extended life

Conclusions

CP systems offer promise to reduce ongoing corrosion of substructure and superstructure elements