PERFORMANCE OF BRIDGE DECKS CONTAINING EPOXY-COATED REINFORCING BARS

Concrete Bridge Conference

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INTRODUCTION

EPOXY INTEREST GROUP

What we have learned

- Field
- Specifications
- Manufacturing

Epoxy Bar Use

- 2nd most common strategy to prevent reinforcement corrosion
  - After increased cover
- USA, Canada, Middle East, Japan, and India
- 700,000,000 ft^2 of decks
  - 65,000 bridges in the US alone
  - ~600,000 ton/yr
  - 10 - 15% of all rebar

SPECIFICATIONS

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Standard Specifications

- ASTM A775/A775M
  - Standard Specification for Epoxy-Coated Steel Reinforcing Bars
- ASTM A934/A934M
  - Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars
- ASTM D3963/D3963
  - Standard Specification for Fabrication and Jobsite Handling of Epoxy-Coated Steel Reinforcing Bars
- ASTM A884/A884M
  - Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Fabric for Reinforcement
- AASHTO M284
  - Standard Specification for Epoxy-Coated Reinforcing Bars
- AASHTO M317
  - Standard Specification for Epoxy-Coated Reinforcing Bars: Handling Requirements for Fabrication and Job Site

ASTM A775
Manufacturing specifications

Criteria	1980's	2007
Bar anchor profile	-	1.5-4 mil
Coating delay after blasting	< 8 hours	< 3 hours
Coating thickness	90 percent within 5-12 mil	7-12 mil (Nos. 3-5) 7-16 mil (Nos. 6-18)
Coating continuity	< 2 holidays per foot	< 1 holiday per foot
Coating flexibility	120 degree bend	180 degree bend
Cathodic disbondment test	-	Yes

D3963 Field Handling

Criteria	**1980's**	**2007**
Permissible damage	No patch for damage < 0.1 in^2 Maximum damage level 2 percent	All damages must be patched Maximum damage level 1 percent
External storage protection	-	Yes, if > 2 months

FIELD PERFORMANCE

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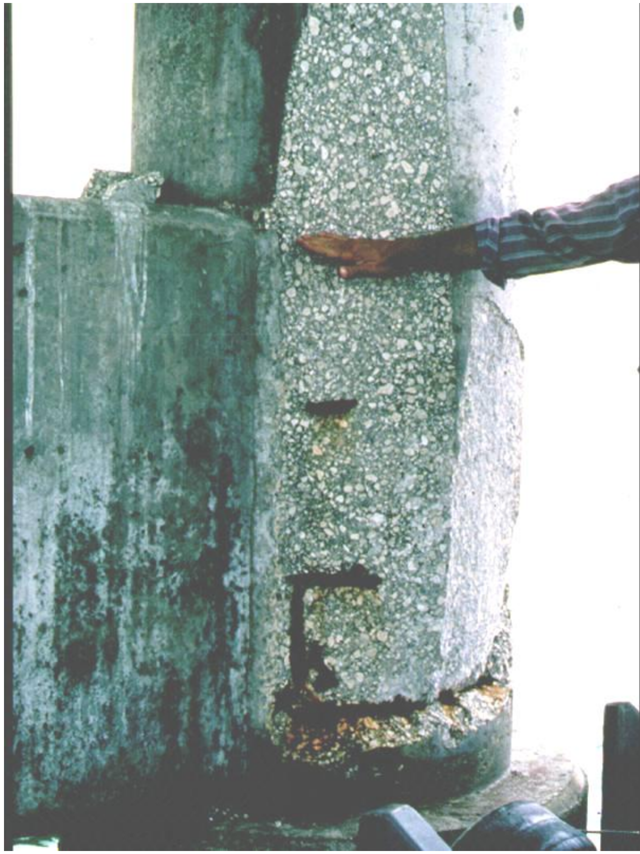
Research and Performance

- Over 200 research papers
- Approx 50% of all decks in 2008

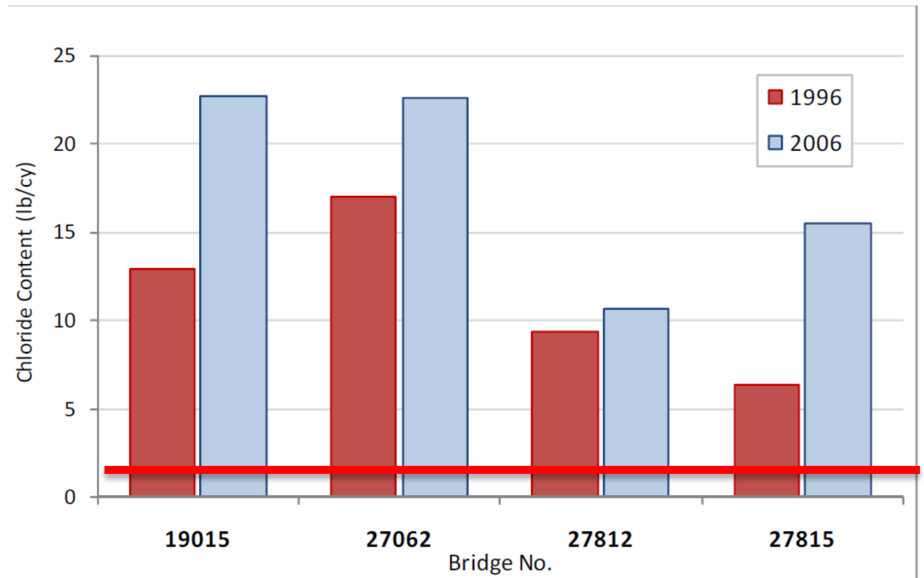
Poor concrete and poor bars

- 1986, spalls observed in Florida
  - Typically 1 x 1 ft spalls in tidal zone
- Poor concrete and poor bars
  - Bars left beside ocean
  - Highly salt contaminated concrete
  - Only 25 mm (1 in.) of cover.
  - Poor quality concrete



Minnesota Department of Transportation 2008

- Four bridges
  - 1973 to 1978
- Overall condition
  - good to very good, with no or modest levels of corrosion activity.
- Corrosion constrained joints over piers
- Amount of delamination in all decks is very low



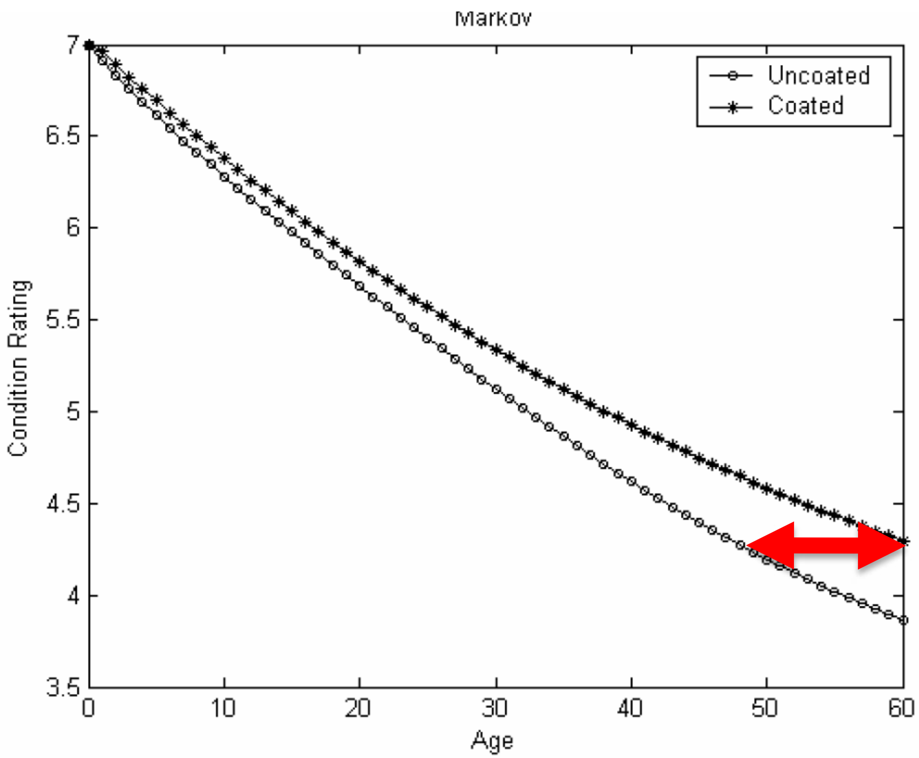
Delaminations in 1996 and 2006

Bridge	Total Delaminated Area 1996		Total Delaminated Area 2006	
	(ft^2)	(%)	(ft^2)	(%)
19015	0	0.0%	39	1.1%
27062	2	0.0%	84	1.1%
27812	0	0.0%	20	0.3%
27815	0	0.0%	21	0.4%

<<10%

New York State Department of Transportation 2009

- Used extensive statistical analysis of all state bridge inspection data
- Pool of 17,000 structures
  - **"structural decks with epoxy-coated rebars perform significantly better than those with uncoated rebars, especially in the later years."**

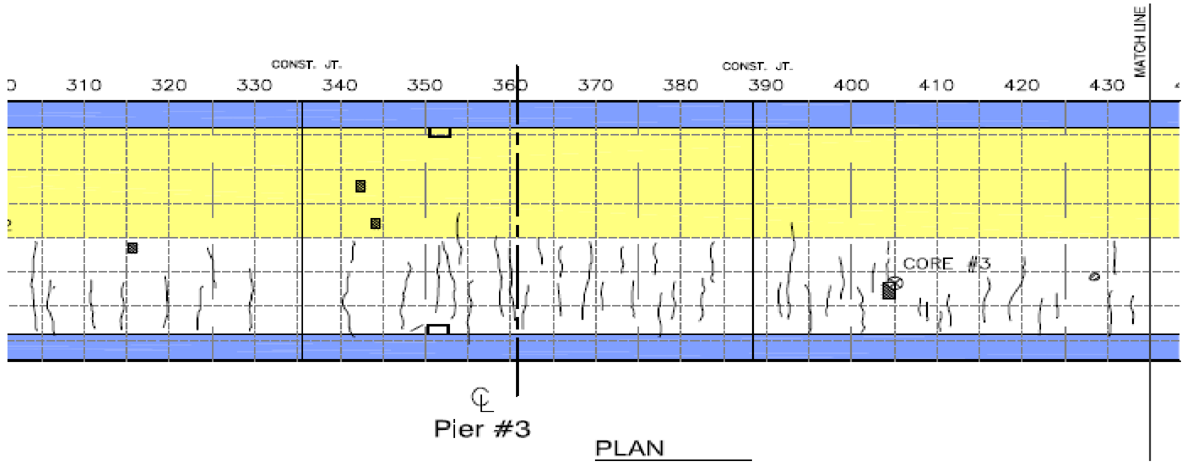


2009 West Virginia Study

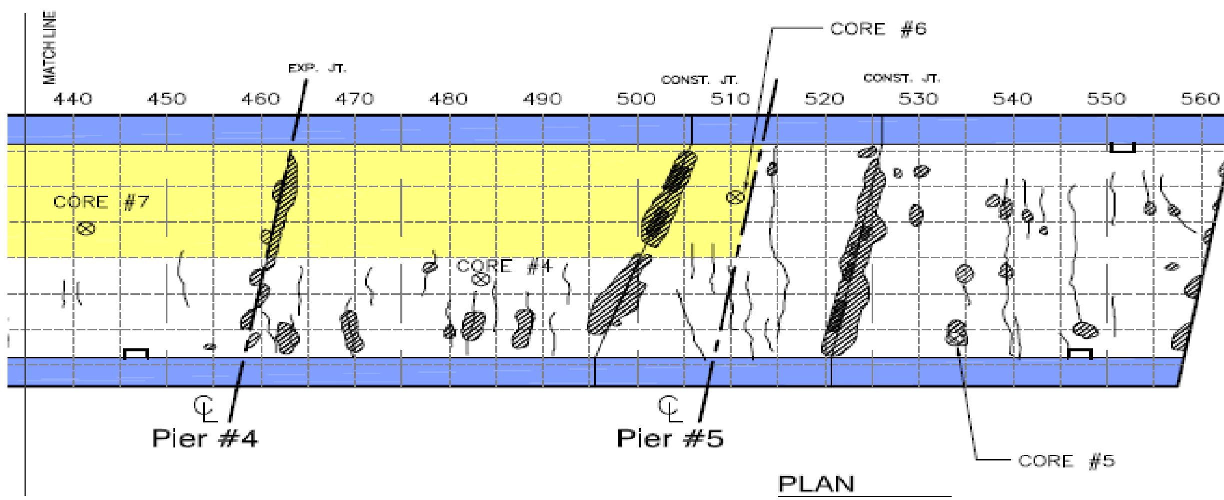
Lawler and Krauss

- Detailed study of six bridges built 1974 – 1976
  - Deck area: 62,000 sq ft
- After 34 -36 years
  - Total delamination: 22.7 sq ft
  - Chloride levels above threshold
- Black Bar performance
  - Repaired in 1993 with overlays

Bridge 2930, West Virginia

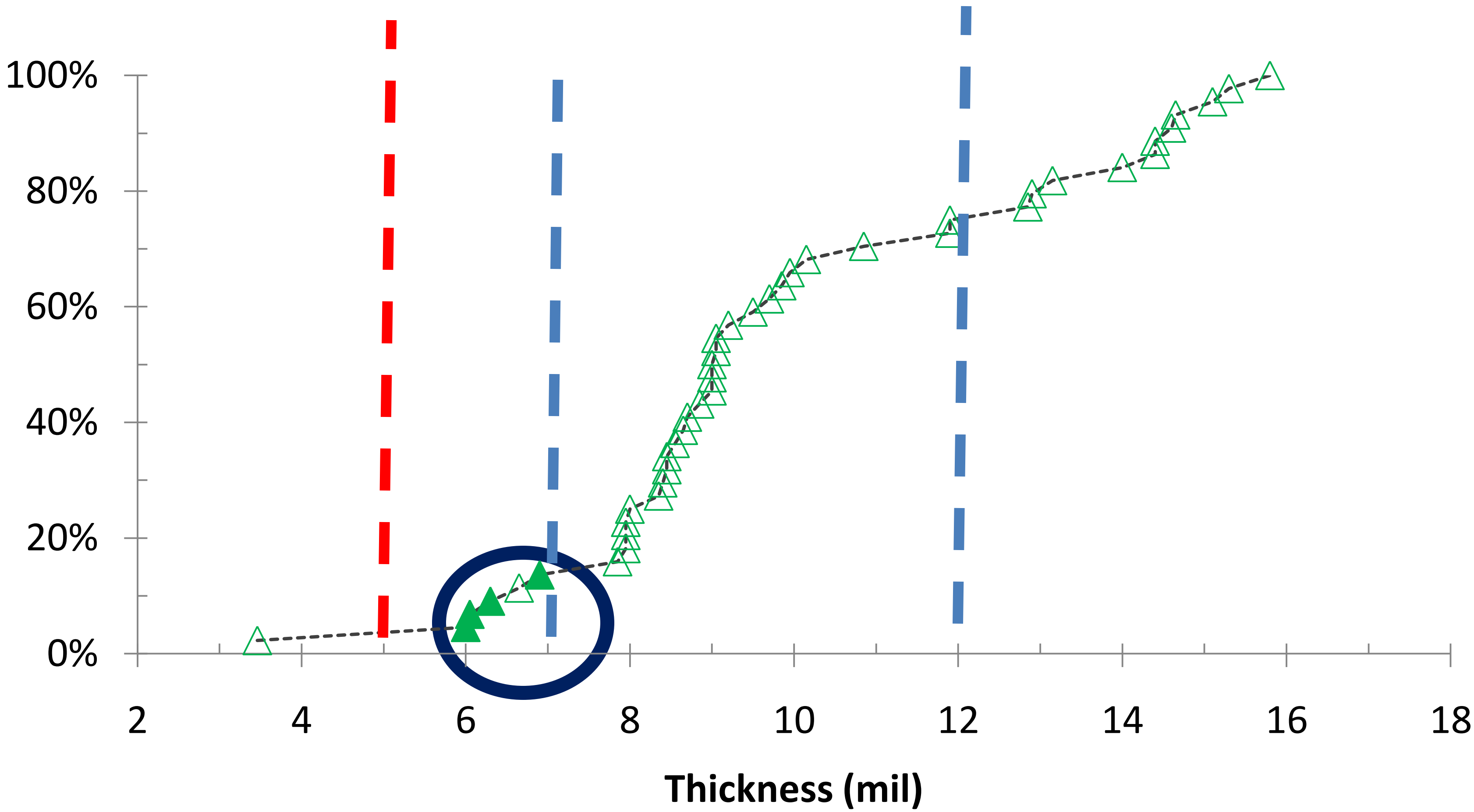


Epoxy-coated bars

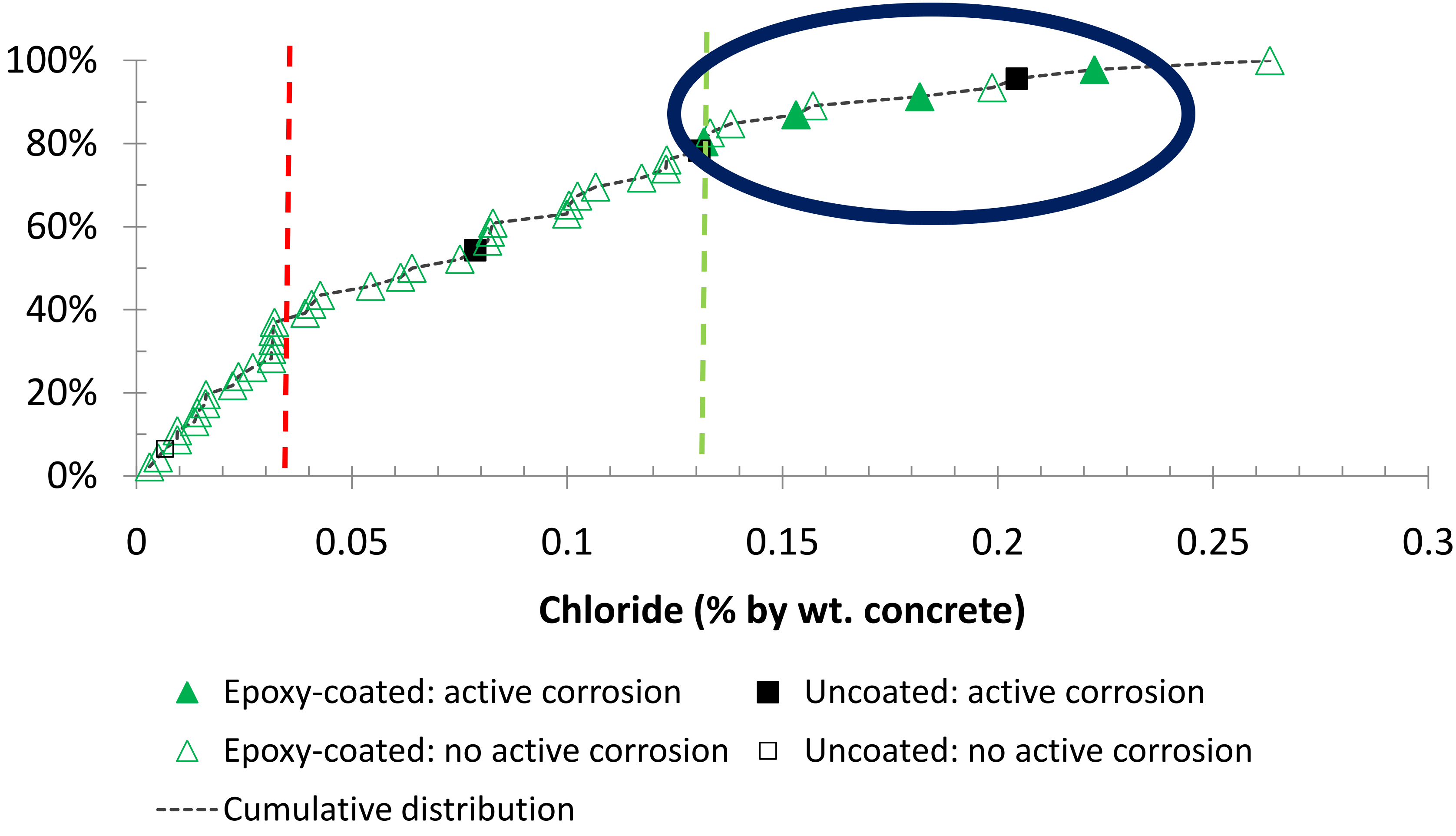


Black Bars

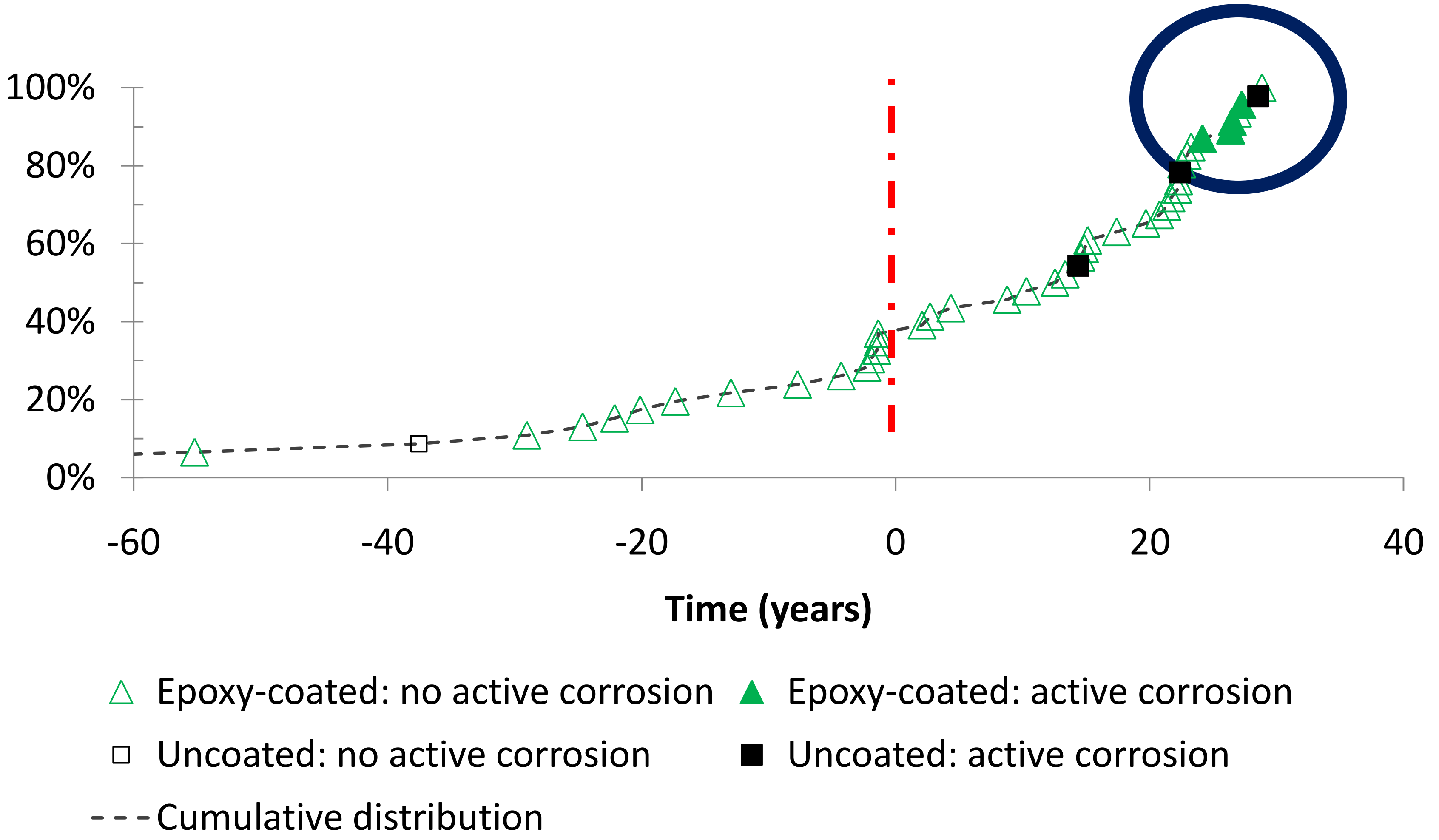
Effect of coating thickness



Effect of chloride level



Effect of time



Conclusions from WV bridges 33 – 35 years old

- Good to excellent condition (33 – 35 years)
- Black bar decks were overlaid or otherwise rehabilitated at 18 to 21 years
- No delaminations where both mats epoxy-coated reinforcing steel
  - High chloride contents in the concrete
- Factors:
  - high chloride
  - low coating thickness
  - extended exposure to chloride concentrations above the black bar chloride threshold

EXAMPLES OF RECENT USE

Maryland State Highway Administration

Woodrow Wilson Bridge, Virginia/Maryland

VDOT Virginia Department of Transportation

I-35 Minneapolis, Minnesota

Minnesota Department of Transportation

Bridge of Honor, Ohio

State of Ohio Department of Transportation

Biloxi Bay Bridge, Mississippi

MDOT Mississippi Department of Transportation

WHAT WE HAVE LEARNT ABOUT CORROSION MECHANISMS

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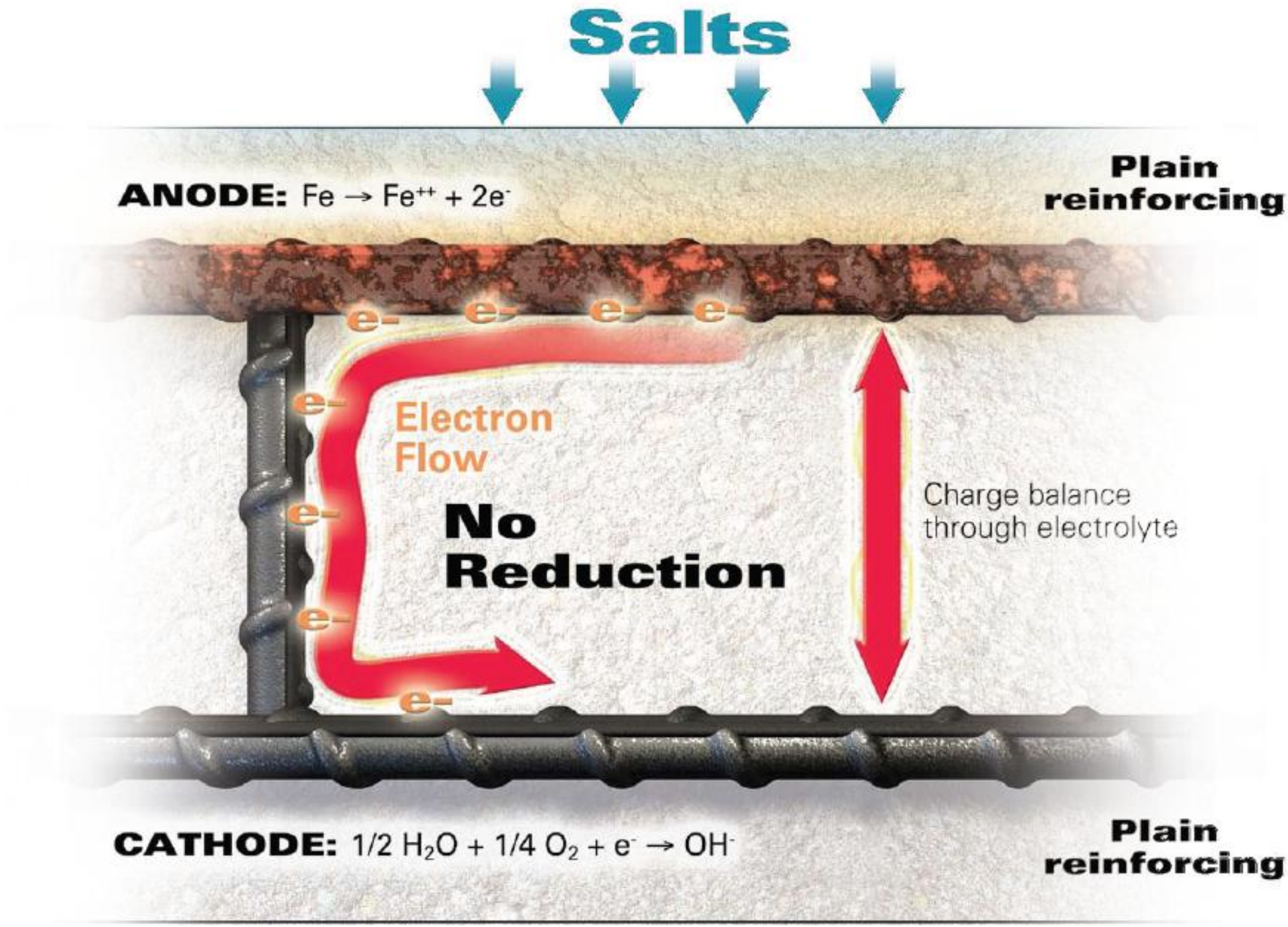
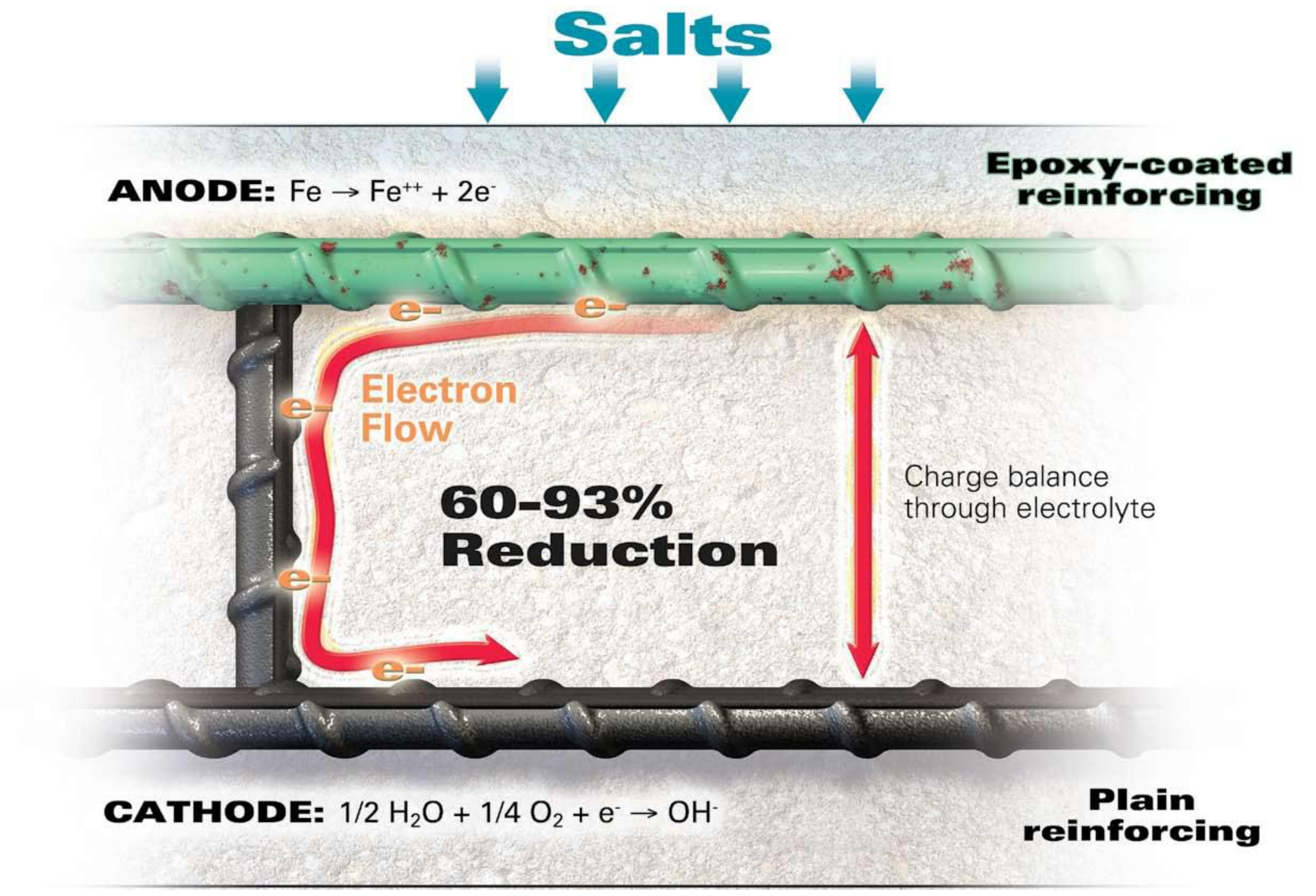
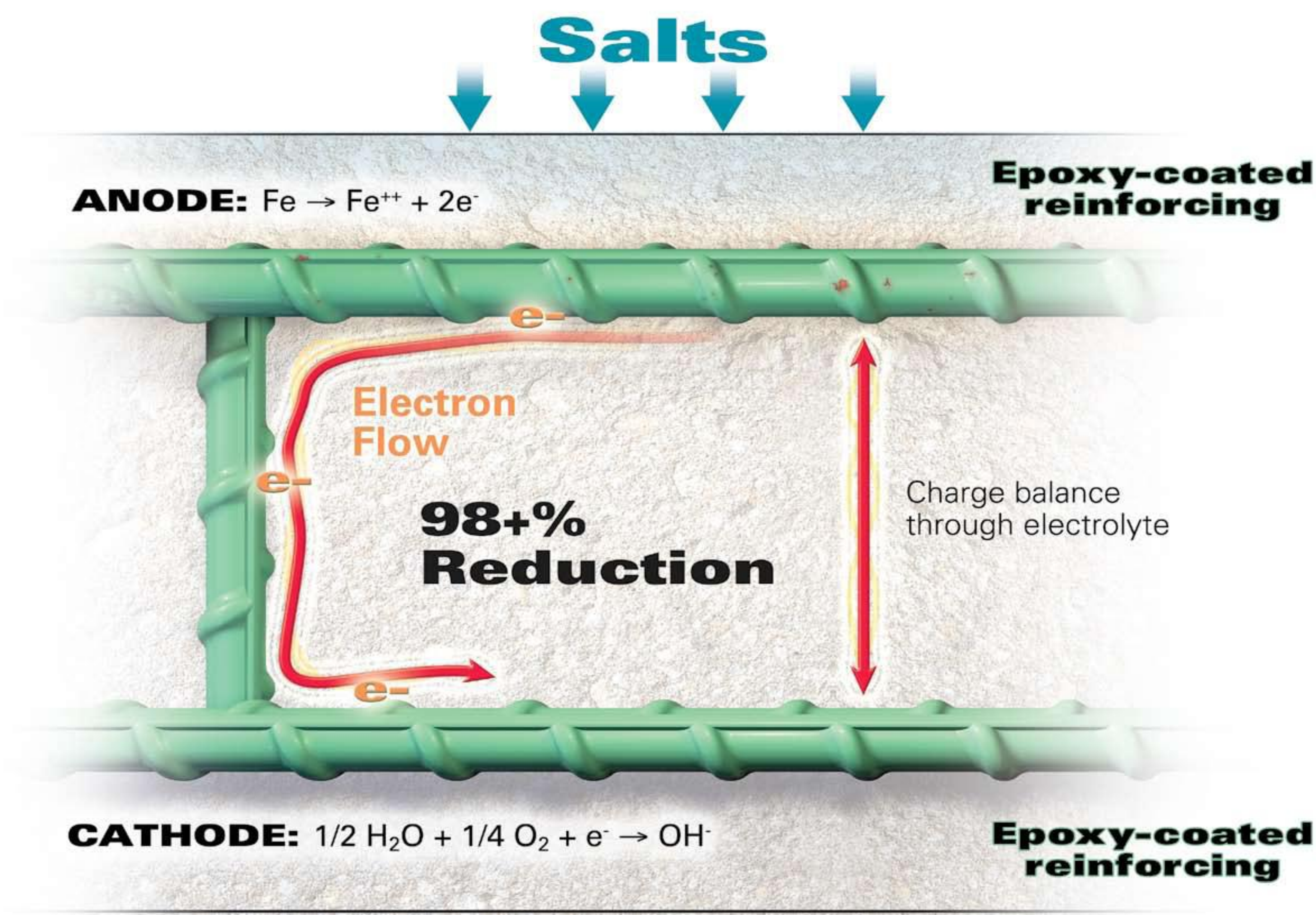
Black bars


Salts
ANODE: Fe → Fe⁺⁺ + 2e⁻
Plain reinforcing
e-
Electron Flow
No Reduction
Charge balance through electrolyte
CATHODE: 1/2 H₂O + 1/4 O₂ + e⁻ → OH⁻
Plain reinforcing

Epoxy-Coated Bars - Top mat only with deliberate damage



Epoxy-Coated Bars - Both mats with deliberate damage



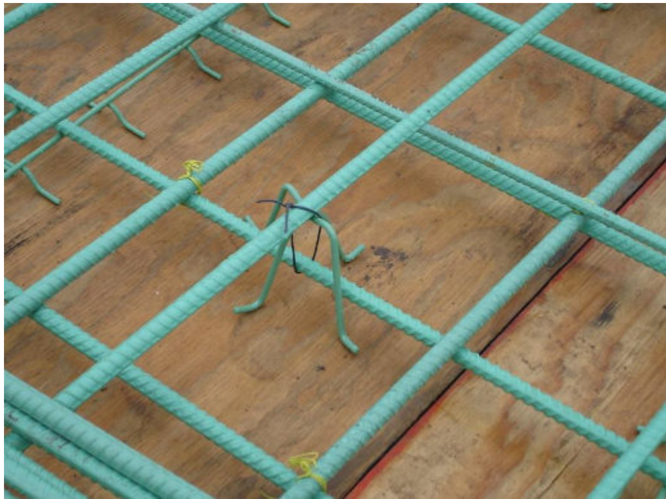
What has been learnt

- The cathodic reaction is important
  - Use ECR on both top and bottom mats coated to reduce cathodic area
  - Most agencies are now doing this
  - But some are not…
- Even damaged bars perform considerably better than black bars

MANUFACTURING AND QC PROCESS

Plant Certification Program

- CRSI in 1991
- *…capable of producing epoxy-coated steel reinforcing bars in accordance with industry standards and recommendations.*
- Almost all plants are certified
- Required by 21 DOT's



FIELD HANDLING

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Understand the material

- Improper handling on ANY MATERIAL may reduce its performance
- Any material can be misused or misapplied

Improper handling

- Dragging
- Lifting using chains
- Flexing bundles while lifting
- Using non-approved patching material
- Leaving uncovered in storage for more than 30 days
- Using uncoated bar supports
- Using uncoated tie wire
- Flame cutting
- Using unprotected concrete vibrator

Epoxy-Coated Bar DON'TS

COST/PERFORMANCE CONSIDERATIONS

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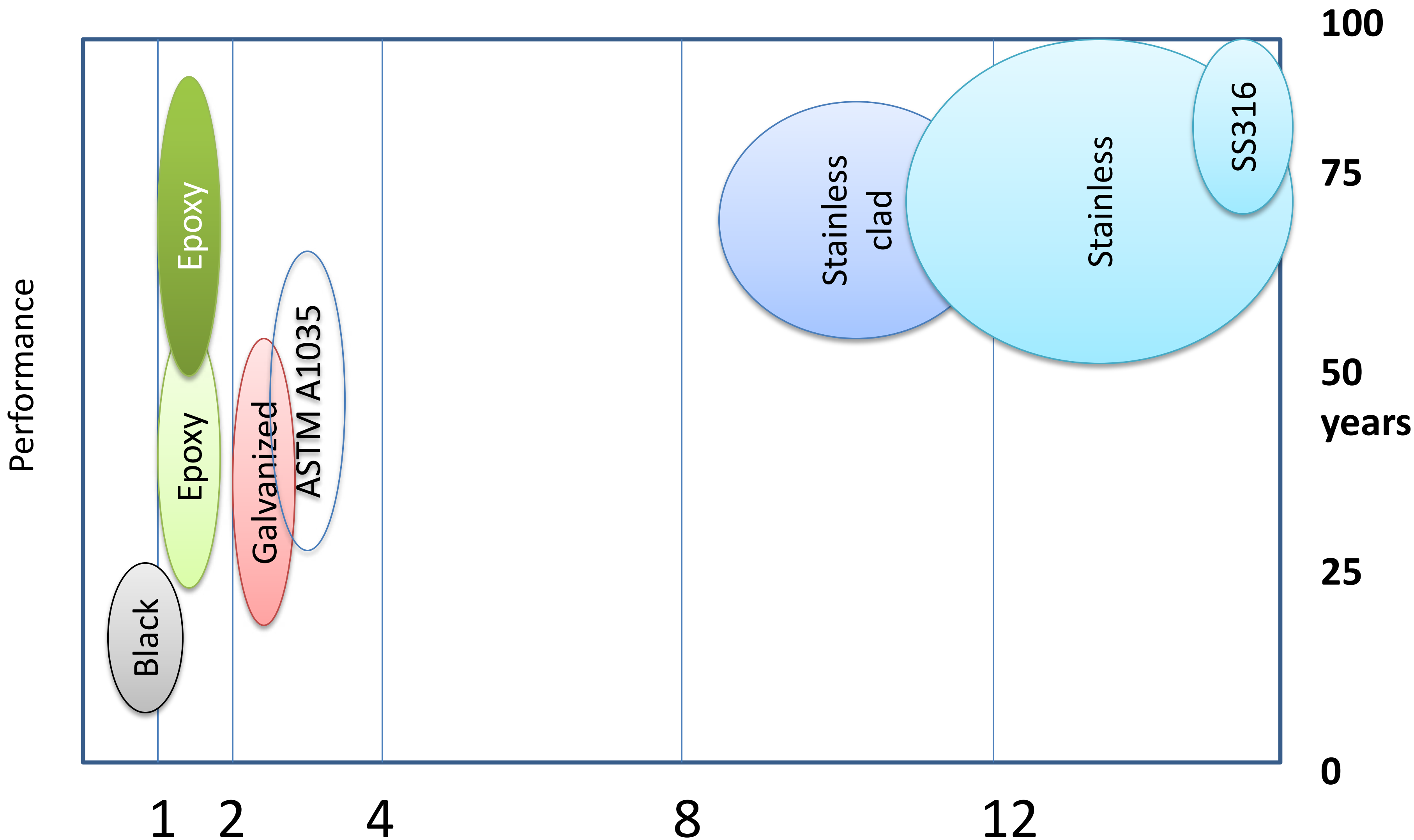
Performance vs. Cost



SUMMARY AND CONCLUSIONS

Conclusions

- ECR used in 65,000 bridge structures
  - Still excellent performance
- 2nd most common strategy to prevent reinforcement corrosion
- Many favorable field and laboratory studies
  - Even Gen 1 product provided substantial increases in design life
- Cost/performance better than other materials

Materials have changed

- Improved manufacturing specifications
  - ASTM A775
- Improved manufacturing
  - CRSI certification
- Improved field handling
  - ASTM D3963
- Improved concrete technology
- Improved design
  - Both mats using epoxy-coated bars

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www.epoxyinterestgroup.org