Field Evaluations of Epoxy-Coated Bars in Inland and Marine Bridges

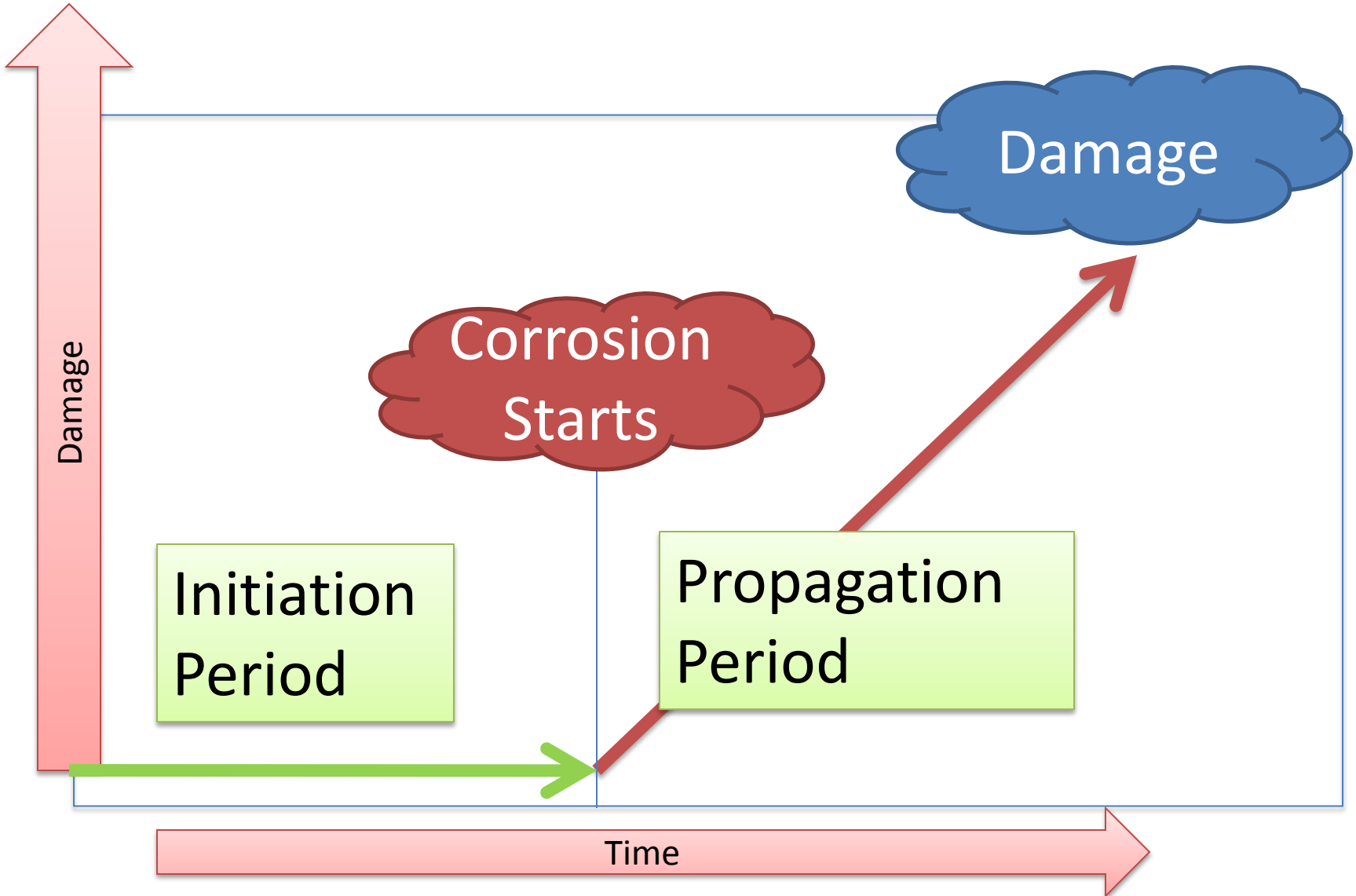
David McDonald, Ph.D., P.E.
Managing Director
Epoxy Interest Group of CRSI

Causes of corrosion

Deicing Salts

Marine Salts

Tutti model


Damage
Damage
Corrosion Starts
Initiation Period
Propagation Period
Time

HISTORY OF EPOXY-COATED REINFORCING STEEL

1960 Clear roads policy

- Led to widespread use of deicing salts
- Causing rapid deterioration of bridge decks
  - 5 to 10 years

1970s NBS study

National Institute of Standards and Technology

- Clifton, Beeghly and Mathey
  - 42 coatings evaluated
- Recommended
  - Fusion bonded epoxy

First epoxy-coated bars used in 1973

Epoxy-coated reinforcing steel

ASTM A775: Green
Bendable

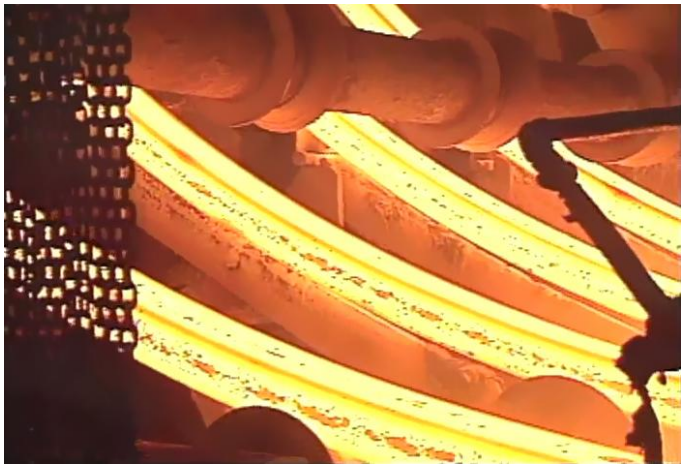
ASTM A934: Purple or Grey
Non-bendable

Used in over 70,000 bridges

EPOXY-COATED BAR MANUFACTURING PROCESS

Reinforcing steel

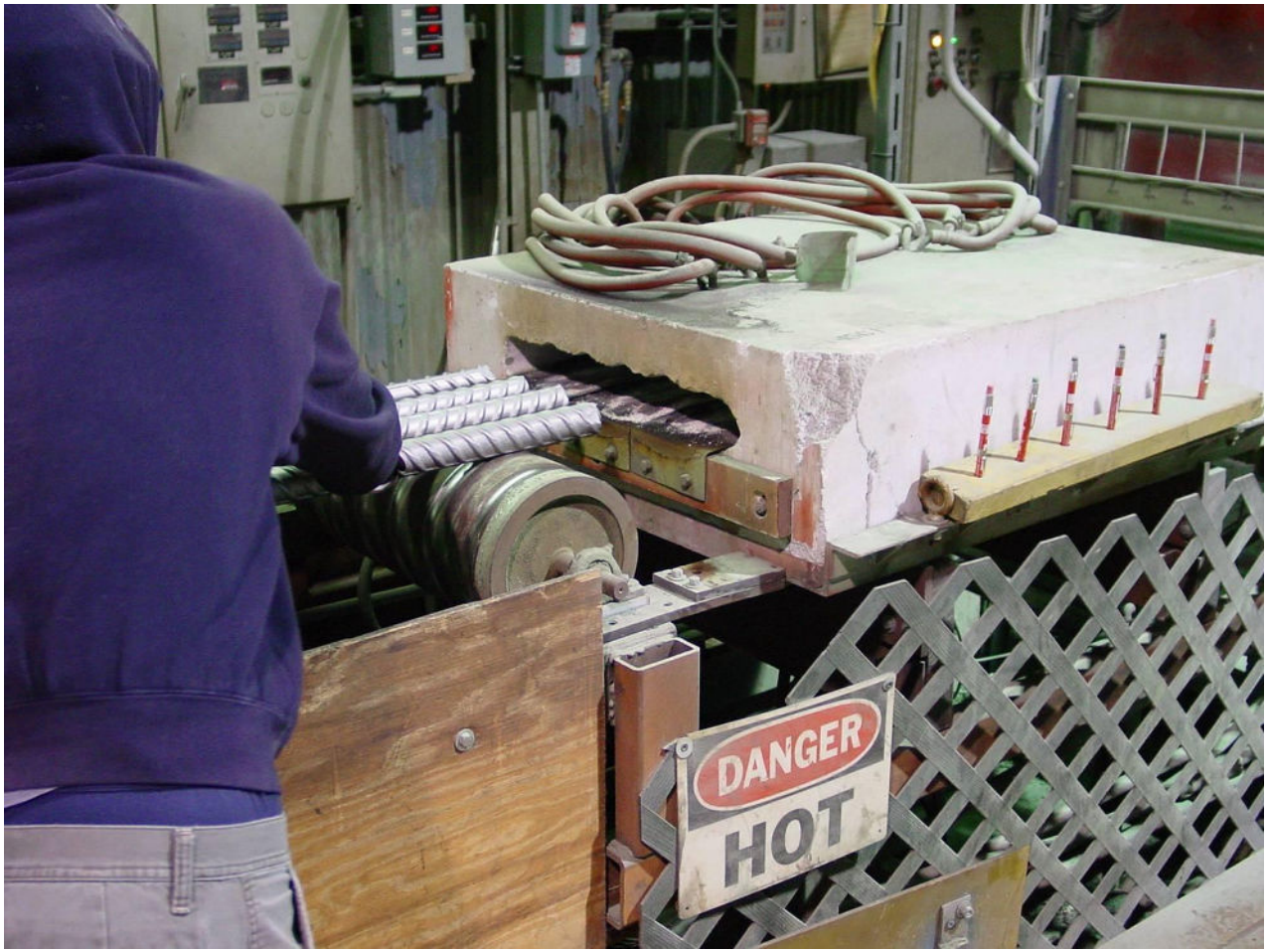
- Manufactured from scrap metal
- Melted and cast into billets
- Billets rolled into reinforcing steel
- Reinforcing steel delivered to coating plant



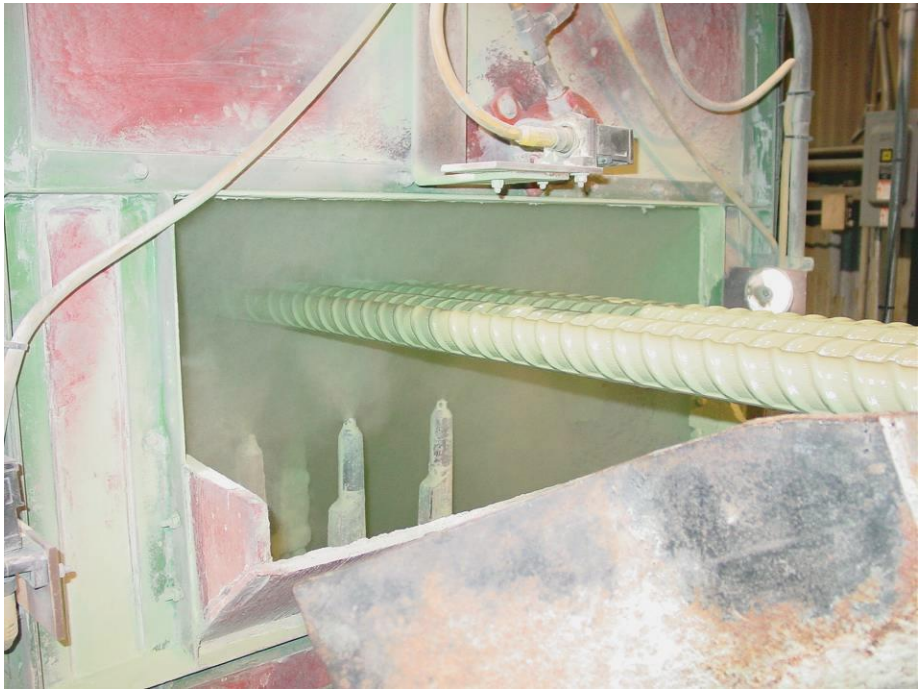
As-received and shot-blasted

Cleanliness, chloride, mill scale, profile (roughness)

Induction heating



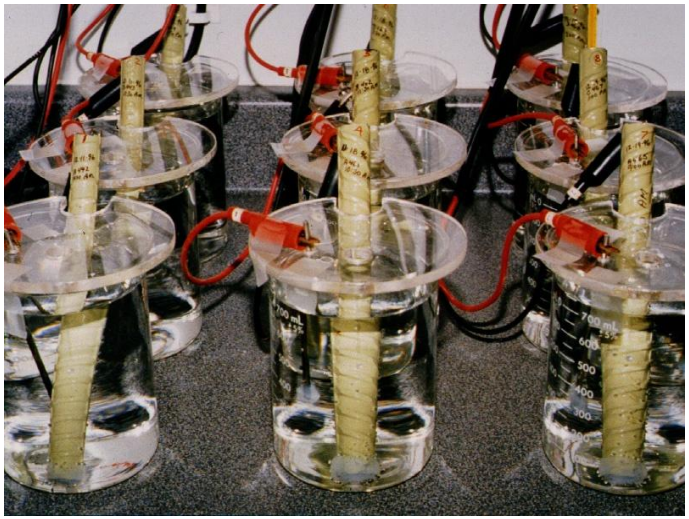
Powder application



Coated bars

Quality checks

- CRSI Certification
- Continuity
  - Holidays
- Thickness
- Flexibility
- Cathodic debonding



FIELD STUDIES

1993 WVDOT survey

- Bridges built in the mid-1970s
- Uncoated bars (19 decks)
  - 1% to 29% delamination (all decks)
- Epoxy-coated bars (14 decks)
  - 0% to 1% delamination
  - Distress identified on only three decks

I-79 Bridges 1993

- Eight bridge decks on I-79
  - Uncoated bars (4)
  - Epoxy-coated bars (4)
- Similar age
- Exposed to identical conditions and traffic
  - Uncoated bars
    - 8.5% delamination
  - Epoxy-coated bars
    - Essentially no delamination (1 ft^2)

2009 Survey

- Updated the 1993 survey
- Wiss, Janney and Elstner Associates
- WVDOT bridge engineers
  - *All decks constructed with uncoated bar have been rehabilitated with latex-modified or microsilica overlays since 1993.*

WJE

FIELD SURVEY 2009

Decks studied

Bridge	ECR	Year Built	ADT	Area
2668	Both	1976	10700	39200
2672N	Top	1976	10000	7000
2672S	Top	1976	10000	7000
2673	Top	1975	500	17000
2930	Both	1974	7000	17800
2953	Both	1975	6000	9000

I-79 Bridges

I-79 Bridges

Low traffic bridge

Moderate traffic bridges

2930

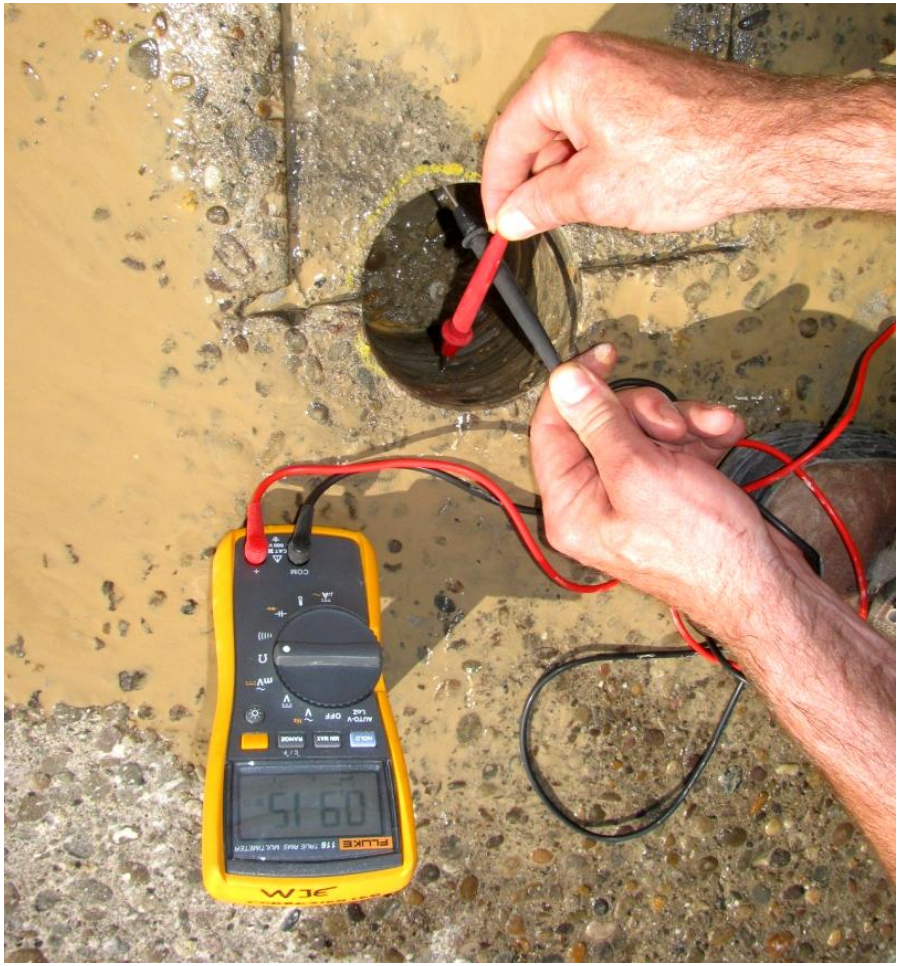

2953

SURVEY METHODS

Delamination and crack survey

Cover survey and cores

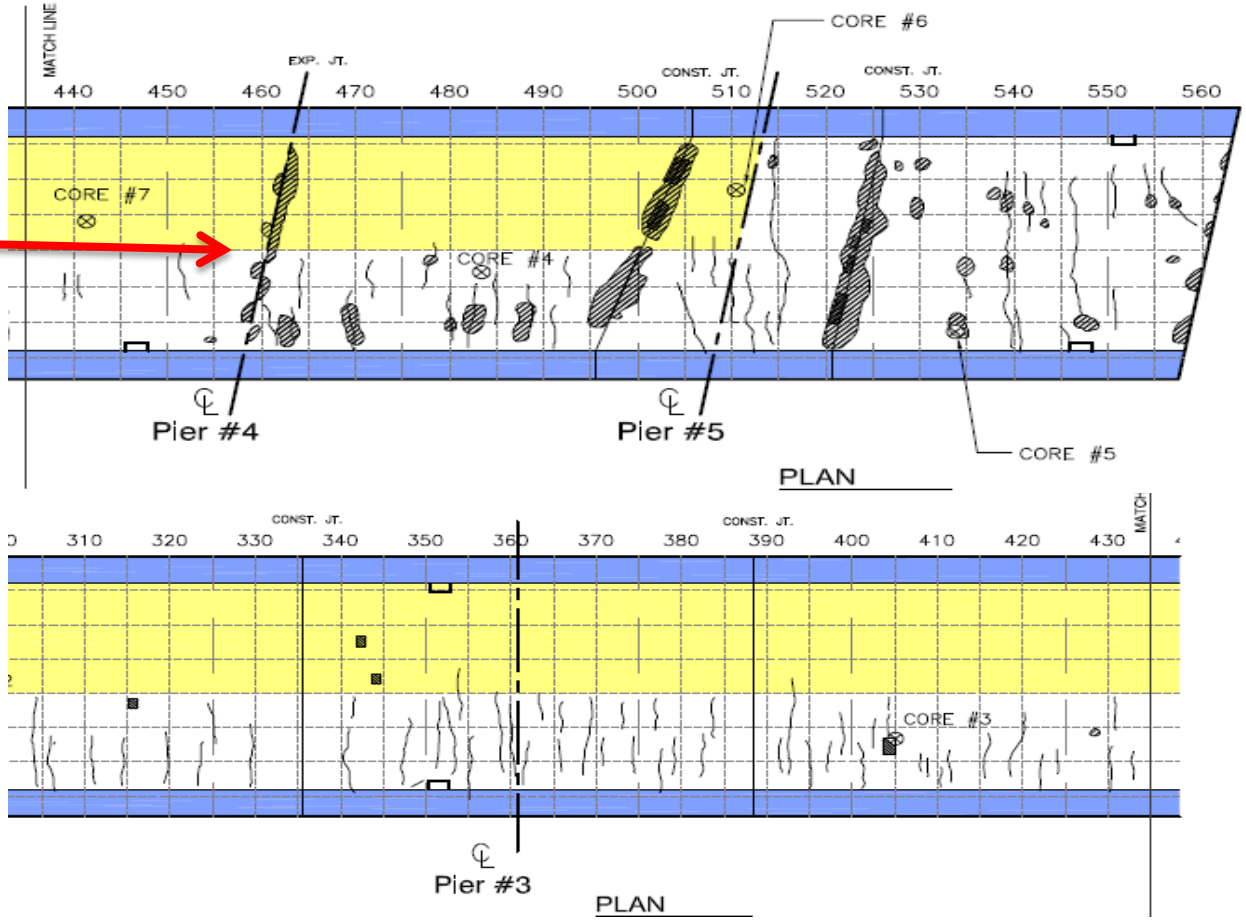
Electrical continuity



West Virginia 2009

Black - Delaminated concrete after 17 years

Epoxy - No delaminations after 34 years



Deck with both epoxy and black bar sections

Deterioration

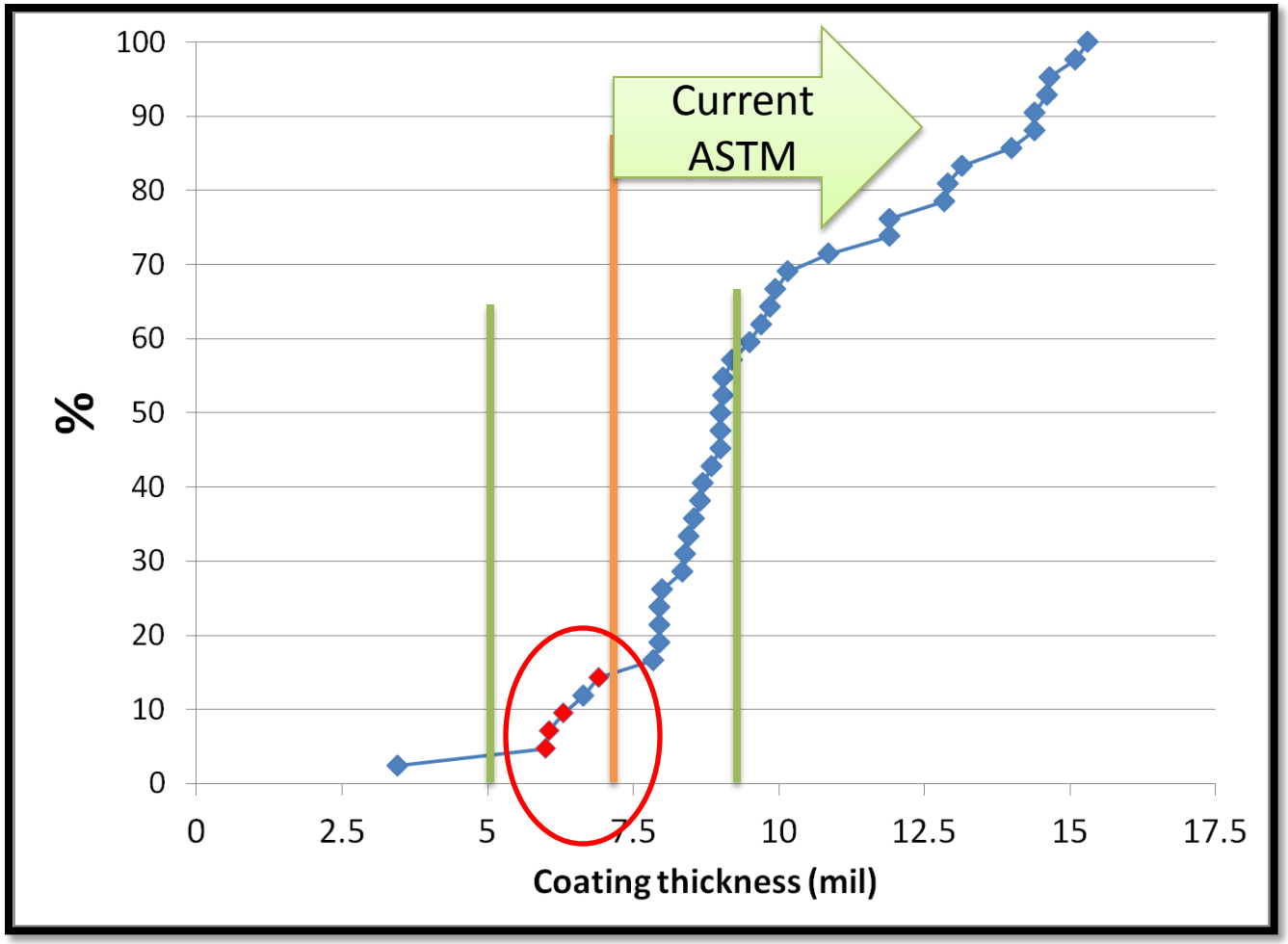
~0.1% delam.

Bridge	Area Surveyed (ft^2)	Area Delamination (ft^2)	Area Delamination (%)
2668	12444	9	0.07
2672N	4272	6	0.14
2672S	4272	3	0.07
2673	16618	25	0.15
2930 ECR	13722	0	0.00
2930 Black	3050	165	5.41
2953	8306	0	0.00

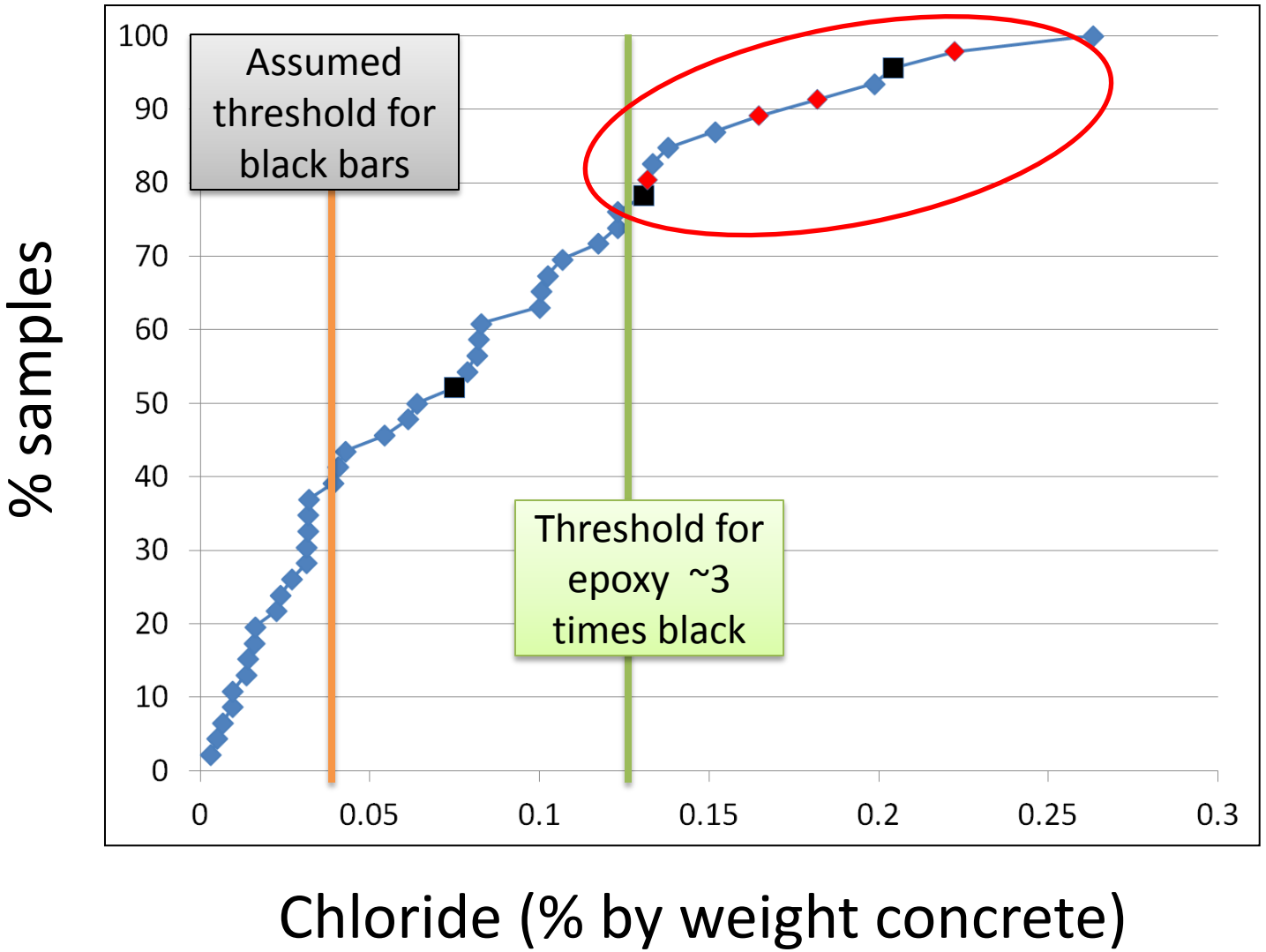
Laboratory analysis

- Bar extracted
  - Visual inspection
  - Adhesion
  - Backside cleanliness
  - Coating thickness
- Cores
  - Acid-soluble chloride analysis
  - Chloride surface concentration
  - Diffusion coefficient

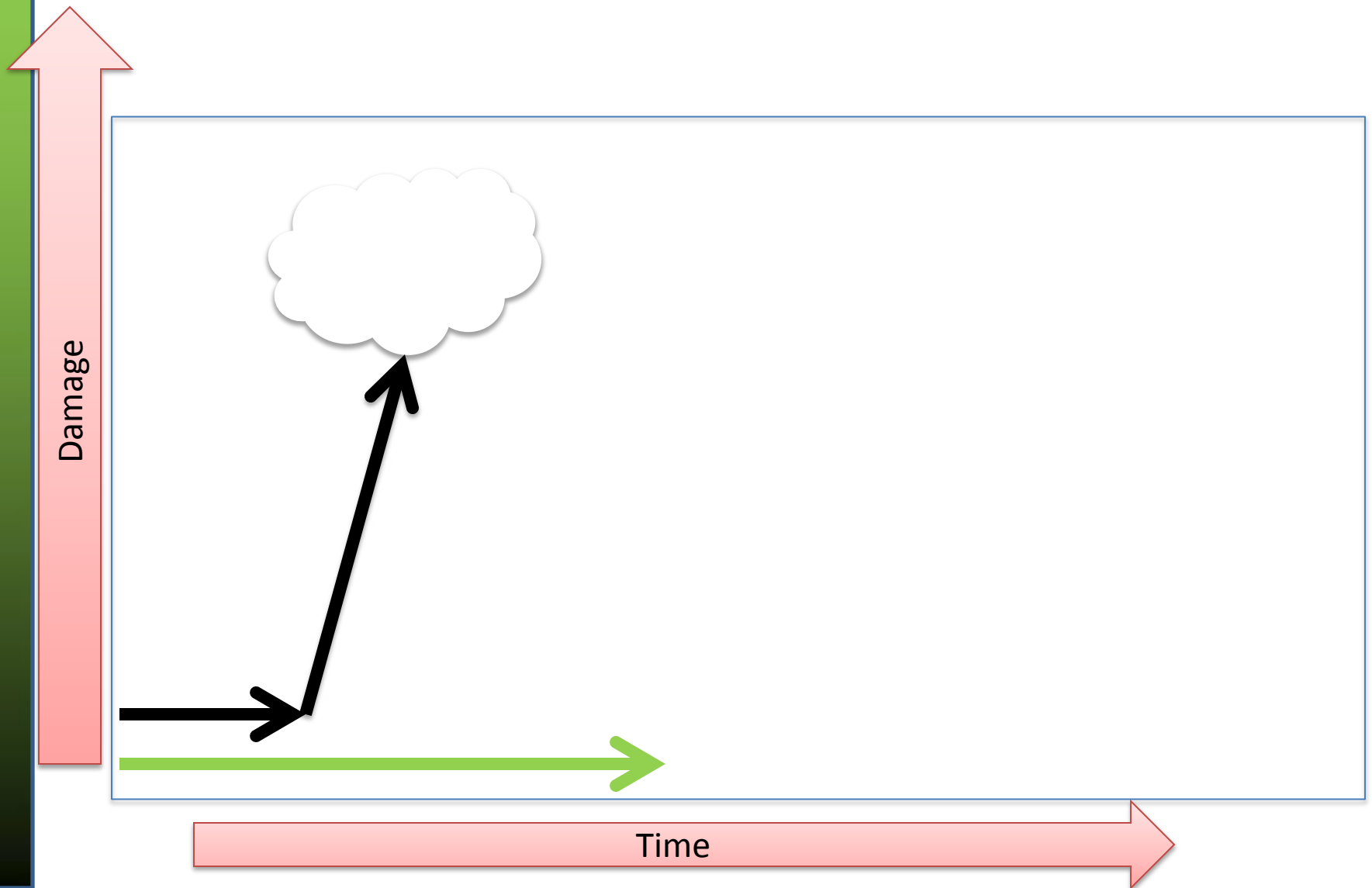
Coating thickness



Chloride at bar level



Tutti Model - West Virginia



Conclusions from WV study

- Decks of similar design, concrete, location
- Black bar decks repaired
  - 18 to 21 years
- Epoxy bar decks
  - Good to excellent condition
  - Deterioration observed only at cracks and construction joints
- Deck with both epoxy and black bar spans
  - Epoxy exhibited no delamination
  - Black exhibited more than 5 percent

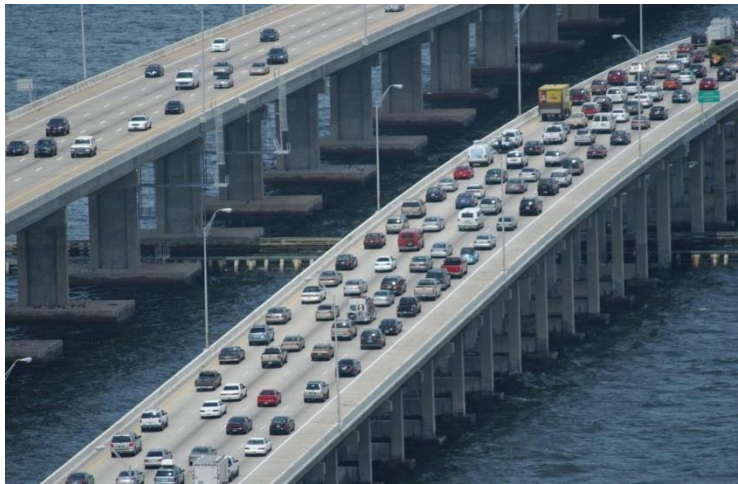
Conclusions from WV study

- Active corrosion in the epoxy-coated bars correlated to three factors:
  - high chloride concentration
  - low coating thickness
  - extended exposure to high chloride concentrations
- Many more years of service life are expected

FLORIDA BRIDGES

Background

- Florida
  - 11,803 bridges
  - 300 structures with epoxy-coated reinforcing steel in substructure
  - 55 with epoxy-coated reinforcing steel in deck



Observations

- Severe corrosion in five bridges
  - Built between 1978 and 1983
- Defects
  - Portions had very low cover
  - 2% allowable damage to the epoxy
  - Bare steel tie wires
  - High permeability concrete

Bridge groups

- Group 1
  - Poor concrete
  - Poor cover
- 5 bridges

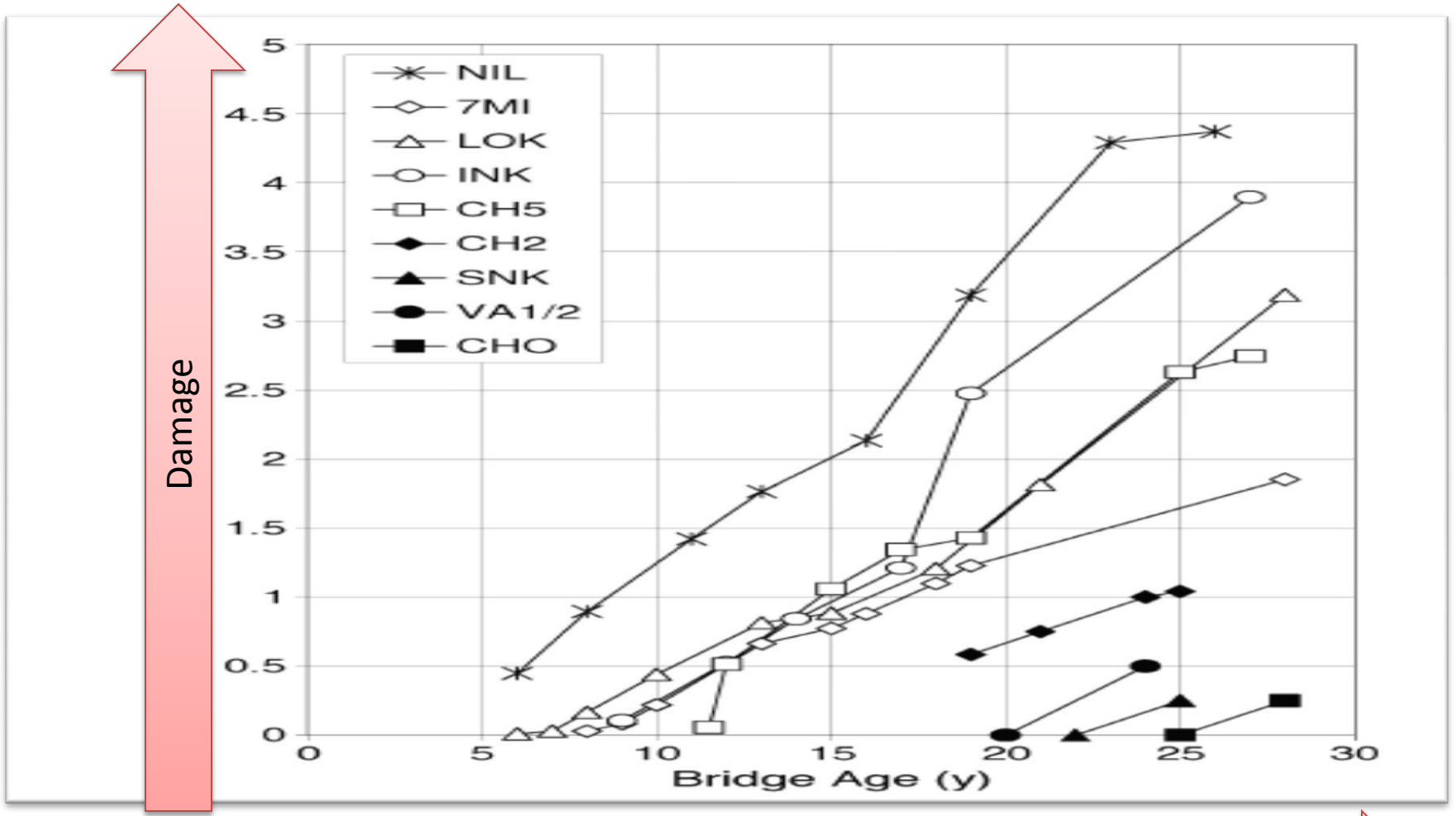
- Group 2
  - Poor concrete
  - Good cover
- 4 bridges

- Group 3
  - Good concrete
  - Good cover
- ~290 bridges

Bridge groups

Group 1	Group 2	Group 3
Cover	Cover	Cover
3 in.	3.5 in.	4 in.
D_{eff} (m^2/s)	D_{eff} (m^2/s)	D_{eff} (m^2/s)
2×10^{-11}	1.3×10^{-12}	3×10^{-13}

Damage rates over time



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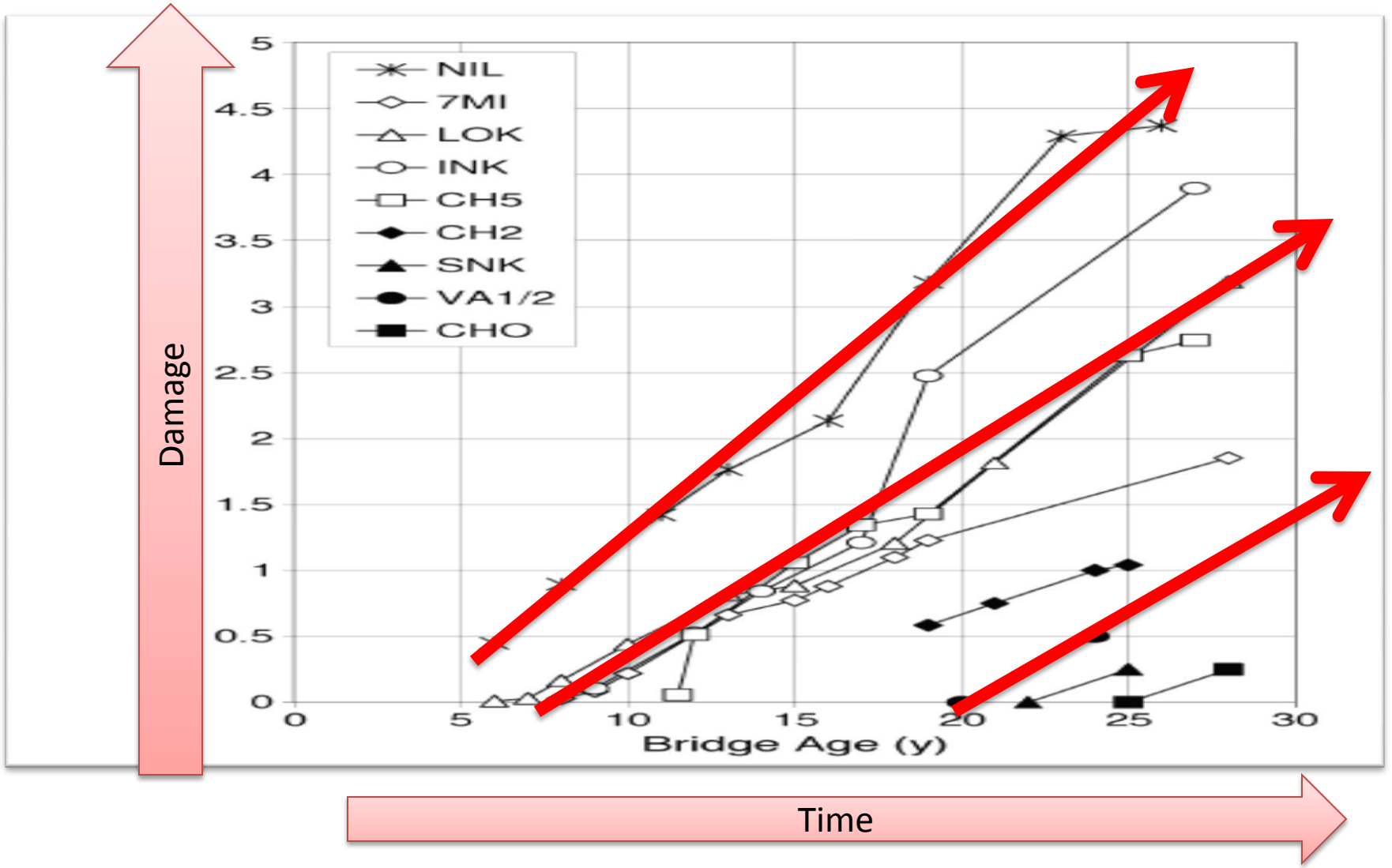
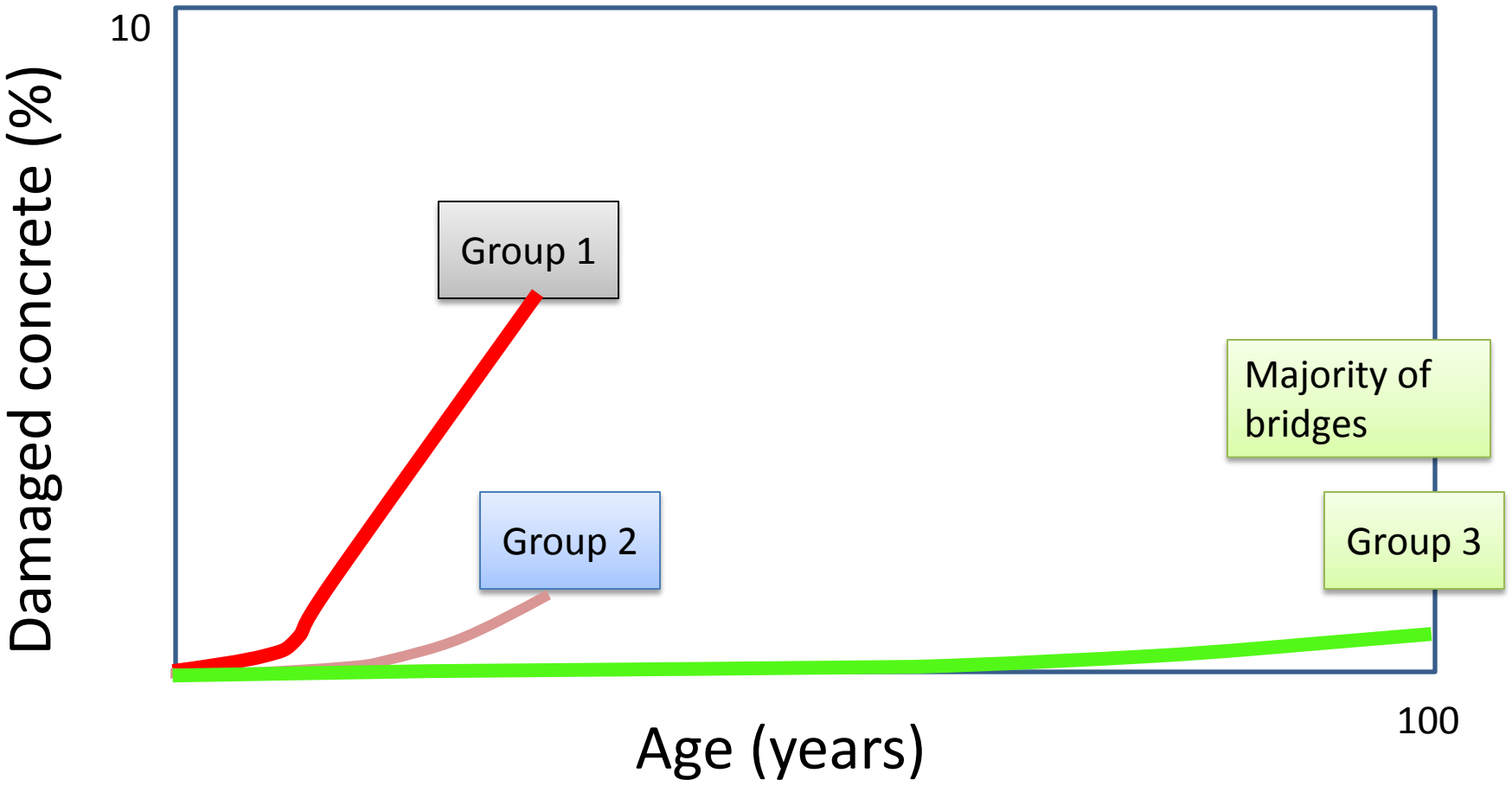


Florida predictions



Most structures containing epoxy reinforcement are **predicted to have a 100 year life**

Florida bridges

- Good concrete
- Good cover
- Aggressive environment
- Well manufactured and stored reinforcement

Good quality concrete and coatings lead to long life

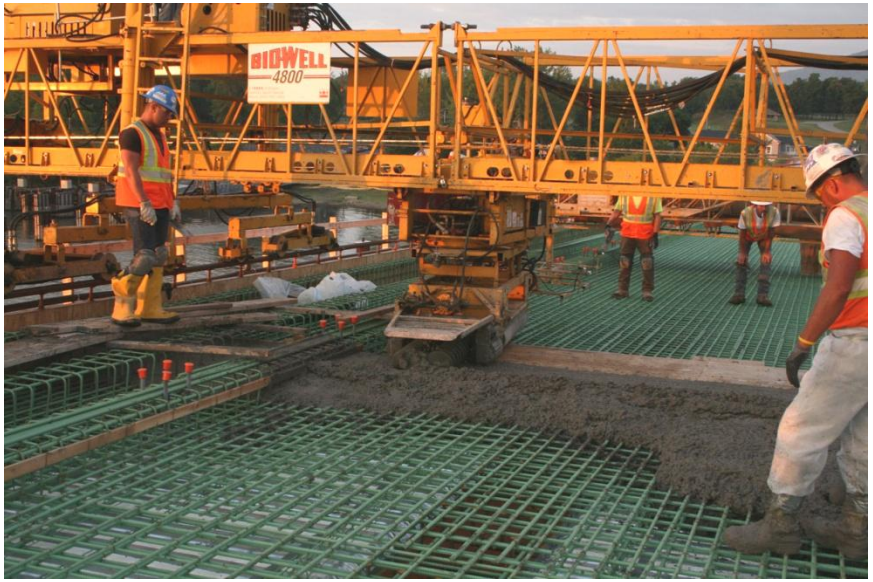
New York State Department of Transportation 2009

- Statistical analysis of 17,000 structures
- Structural decks with epoxy-coated reinforcement perform significantly better than those with uncoated reinforcement, especially in the later years.

CURRENT USE

Lake Champlain

Vermont and New York Departments of Transportation



Indian River Inlet Bridge
Delaware Department of Transportation

St. Louis Bay Bridge
Mississippi Department of Transportation

Skyway Bridge
California Department of Transportation

Galena Creek Bridge
Nevada Department of Transportation

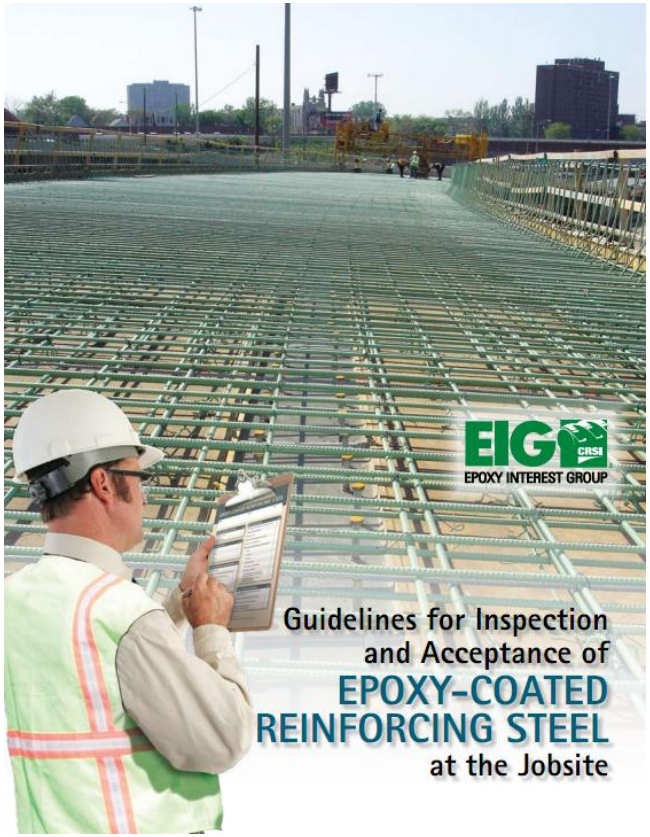
CONCLUSIONS

Conclusions

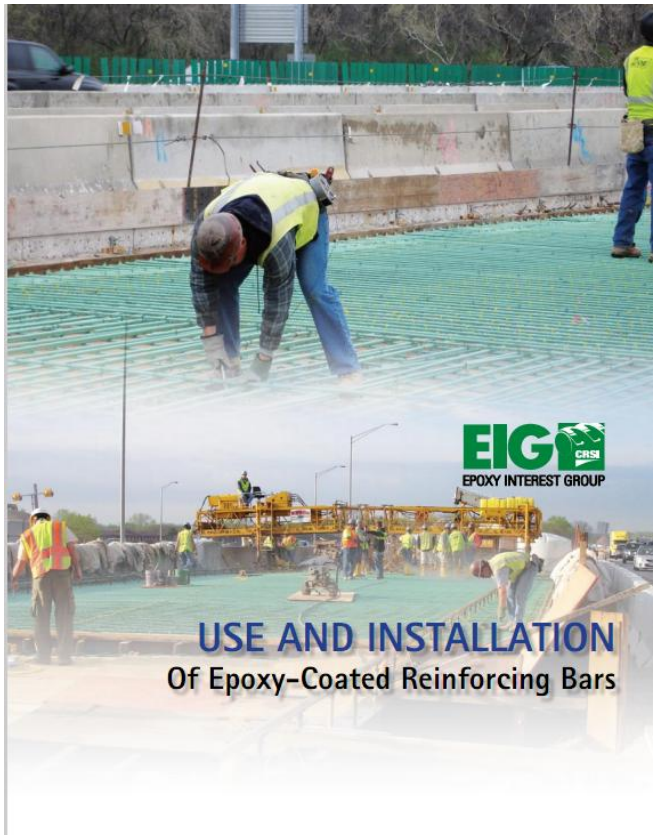
- Epoxy-coated reinforcing bars have performed well in both marine and inland environments
- Side-by-side analysis shows epoxy at least doubling life in West Virginia structures
- Florida analysis shows 100 year design life in marine waters
- Improved coating thickness will reduce damage and corrosion

Additional Information

Inspectors



Field Crews

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