EPOXY-COATED REINFORCING STEEL BARS IN NORTH AMERICA

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Introduction

• Direct cost of corrosion for highway bridges
  – $8.29 billion (400 billion INR)

• Total bridges
  – 700,000
  – 71,000 structurally deficient
HISTORY
History

• 1950’s “clear road” policy
  – Effective snow fighting cuts injury accidents by 88%
• 1970’s significant corrosion problem
• 1973 First use of epoxy-coated reinforcing steel
Strategy to prevent corrosion

NCHRP Synthesis 333
STANDARD SPECIFICATIONS
Specifications

• ASTM A775/A775M (AASHTO M284)

• AASHTO M254
  – Standard Specification for Corrosion-Resistant Coated Dowel Bars
APPLICATIONS
Use in North America

• 10 percent of all rebar
  – Approximately 600,000 ton/year
• 72 million sq m of ECR (~28 sq mile)
• 65,000 bridges out of 700,000
Types of structures

- Bridges
- Parking decks
- Buildings
- Power plants
- Wharfs and other marine
- Water treatment facilities
- Concrete Repair
Performance vs. Cost
CORROSION PROTECTION MECHANISMS
Black bars

**ANODE:** $\text{Fe} \rightarrow \text{Fe}^{++} + 2e^-$

**CATHODE:** $\frac{1}{2} \text{H}_2\text{O} + \frac{1}{4} \text{O}_2 + e^- \rightarrow \text{OH}^-$

Salts

Electron Flow

No Reduction

Charge balance through electrolyte

Plain reinforcing
Epoxy-Coated Bars
Top mat only

**ANODE:** $\text{Fe} \rightarrow \text{Fe}^{2+} + 2e^-$

**CATHODE:** $\frac{1}{2} \text{H}_2\text{O} + \frac{1}{4} \text{O}_2 + e^- \rightarrow \text{OH}^-$

**60-93% Reduction**

**Charge balance through electrolyte**

**Salts**
Epoxy-Coated Bars
Both mats

**ANODE:**  \[ \text{Fe} \rightarrow \text{Fe}^{++} + 2e^- \]

**CATHODE:**  \[ \frac{1}{2} \text{H}_2\text{O} + \frac{1}{4} \text{O}_2 + e^- \rightarrow \text{OH}^- \]

**Charge balance through electrolyte**

**98+% Reduction**

**Salts**
MANUFACTURING AND QC PROCESS
CRSI Program: What is it?

- Ensures that applicator plants are capable of producing epoxy-coated steel reinforcing bars in accordance with industry standards and recommendations.
Program activities

- Records
- QC inspector
- QC equipment
- Production equipment
- Bar cleaning and coating
- Handling
Thickness, Cathodic disbondment, flexibility, storage
FIELD HANDLING
Understand the material

- Improper handling may reduce performance
Storage

- Timber cribbing
- Opaque covering
- Store coated and uncoated bars separately
Shearing and Bending

- Minimize damage to the coating
Loading, Securing and Lifting

• Protect against damage
  – Padded material
  – Nylon strapping
  – Spreader bar
  – Multiple pick-up points
  – Unload as close as possible to the point of concrete placement
  – No bare chains or cables
Setting, Bar Supports & Tie Wire

- Lift and set bars into place
- Use non-conductive material or plastic bar supports
- Coated tie wire
- Do not drag
Patching

- Inspect bars
- Patch all damage
- Two-part epoxy repair material
- Follow manufacturer’s directions
FIELD PERFORMANCE
Research and Performance

• Over 200 research papers
• Widespread use continues
Norway

• 50% of all the larger concrete bridges had steel corrosion or had been repaired due to steel corrosion

• **Most were built during the last 25 years**

• One had to be demolished already after a service period of only 25 years
Example locations

- Minnesota
- South Dakota
- Kansas
- New York
- Virginia
- Georgia and North Carolina
- Florida Keys
Florida Keys

- 1986, spalls observed
- 23 years later, still only five of the 300 structures using ECR exhibit corrosion
- Extremely poor bar manufacturing
  - Bars left beside the ocean for up to a year
  - Embeded in highly salt contaminated concrete
  - Only 25 mm (1 in.) of cover.
Minnesota Department of Transportation 2008

• Four bridges built between 1973 and 1978

• Overall condition
  – good to very good, with no or modest levels of corrosion activity.
  – One bridge (bridge 19015), corrosion activity appears to be moderate to severe.
    • Corrosion constrained to the area around the joints over the bridge piers

• Amount of delamination in all decks is very low
New York State Department of Transportation 2009

• Pool of 17,000 structures
  —“structural decks with epoxy-coated rebars perform significantly better than those with uncoated rebars, especially in the later years.”
South Dakota Department of Transportation 2009

- Celebrated a 33-year career of Mr. Wilson from their Bridge Office.
- During this time 1,300 bridges were built.
- Implemented the use of epoxy coated reinforcing steel in bridge decks.
- To date, not one of those bridge decks has needed repairs or overlay due to rebar corrosion.
West Virginia Bridge 2930

- Constructed in 1974
- Black bar - significant delamination in 1993
- Epoxy-coated bar – no delaminations or repair in 2009
Bridge 2930 Clarksburg WV
Other reports

• A researcher has postulated that any adhesion reduction will lead to catastrophic corrosion failure
  – Adhesion reduction, corrosion and concrete distress are NOT directly related
  – Widespread corrosion failure has not been observed, despite bars being in concrete with relatively chloride levels.

• Other conclusions about poor coating cure could not be substantiated
Example locations

- Minnesota
- Chicago
- Ohio
- Virginia
- Mississippi
Woodrow Wilson Bridge

Bridge of Honor, Ohio

I-35 Minneapolis

Biloxi Bay Bridge
2006/2008: Woodrow Wilson, Virginia/DC

- 6075 ft (1850 m)
- 4200 tons
- 200,000 VPD
- $680 million
  - 32,500 million INR
Parking Garage and Buildings

Trump International Hotel and Tower
Aqua, Chicago
Pavements
Water Treatment
CONCLUSIONS
Conclusions

• Epoxy-coated steel reinforcing bars have been used in over 65,000 bridge structures and numerous other structures

• 2\textsuperscript{nd} most common strategy to prevent reinforcement corrosion

• Cost/performance better than other materials

• Manufacturing and handling must be done well to optimize performance

• Many favorable field studies
ACKNOWLEDGMENTS