Continuous Galvanized Rebar

Proven protection – Innovative Process

NBPP - Orlando, FL

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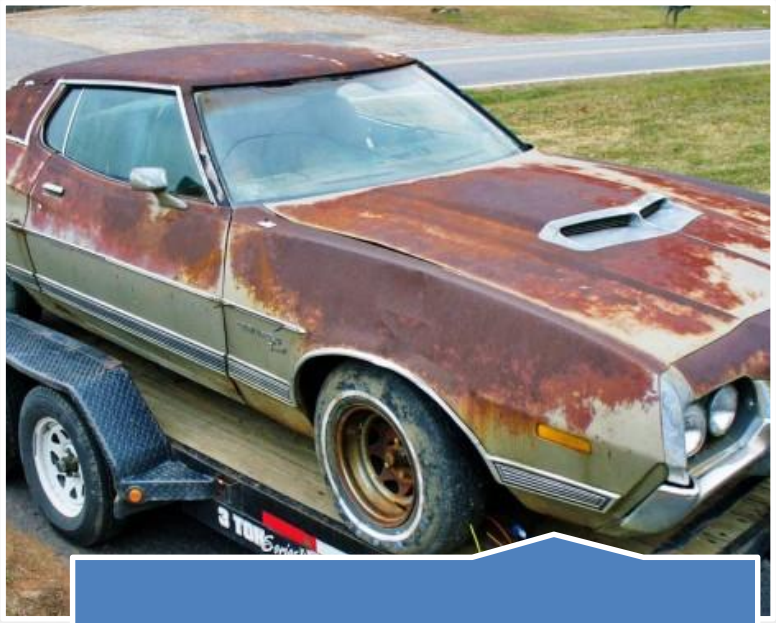
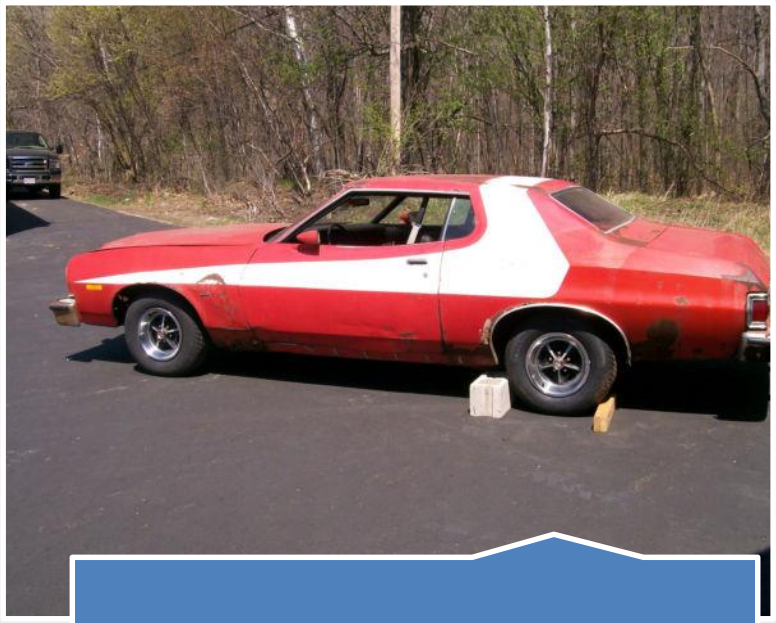
DERBY RACES
5370NN

Ford Gran Torino



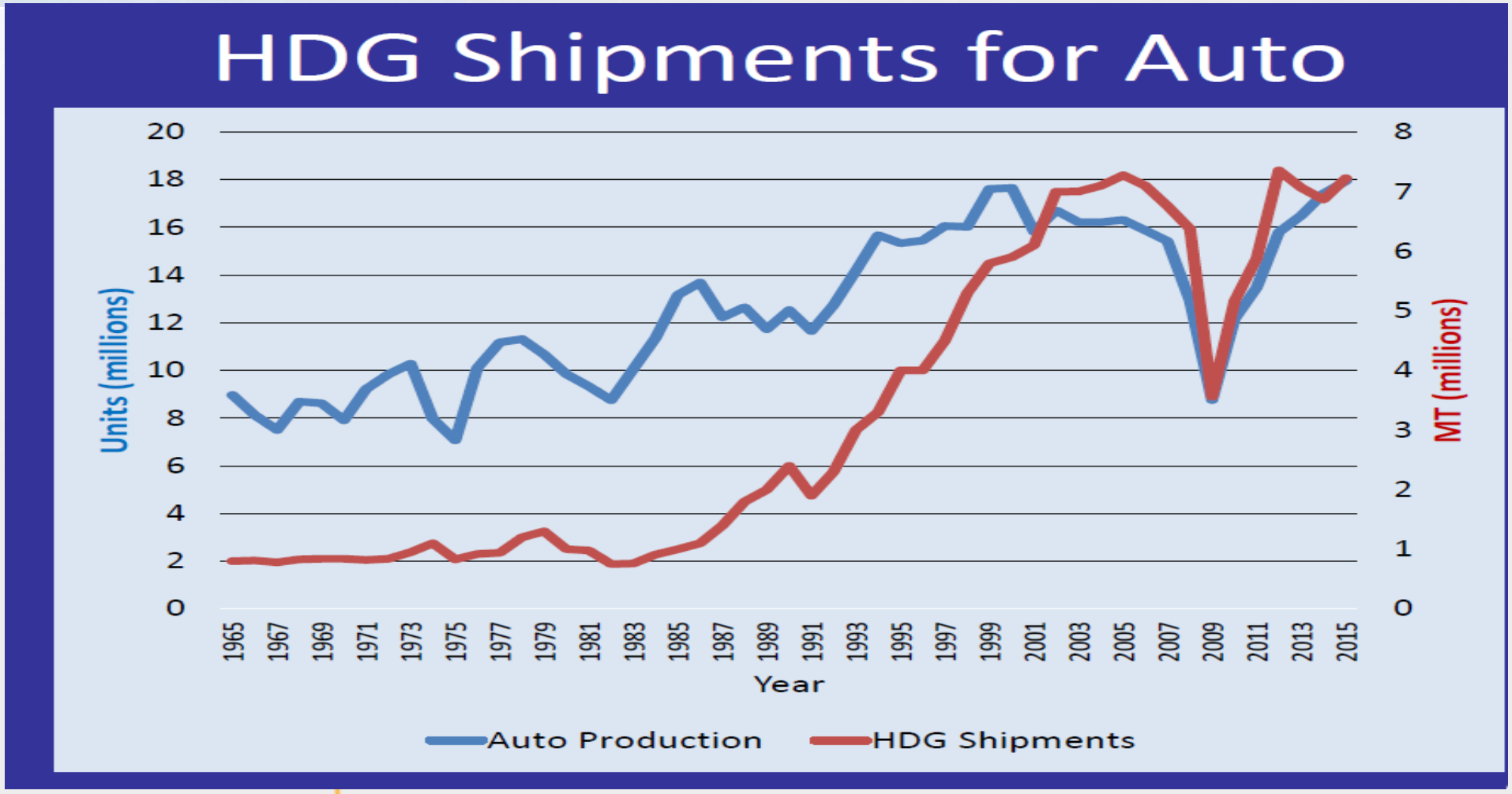
Corrosion



Kills

Cars

Galvanized Autobody Partnership

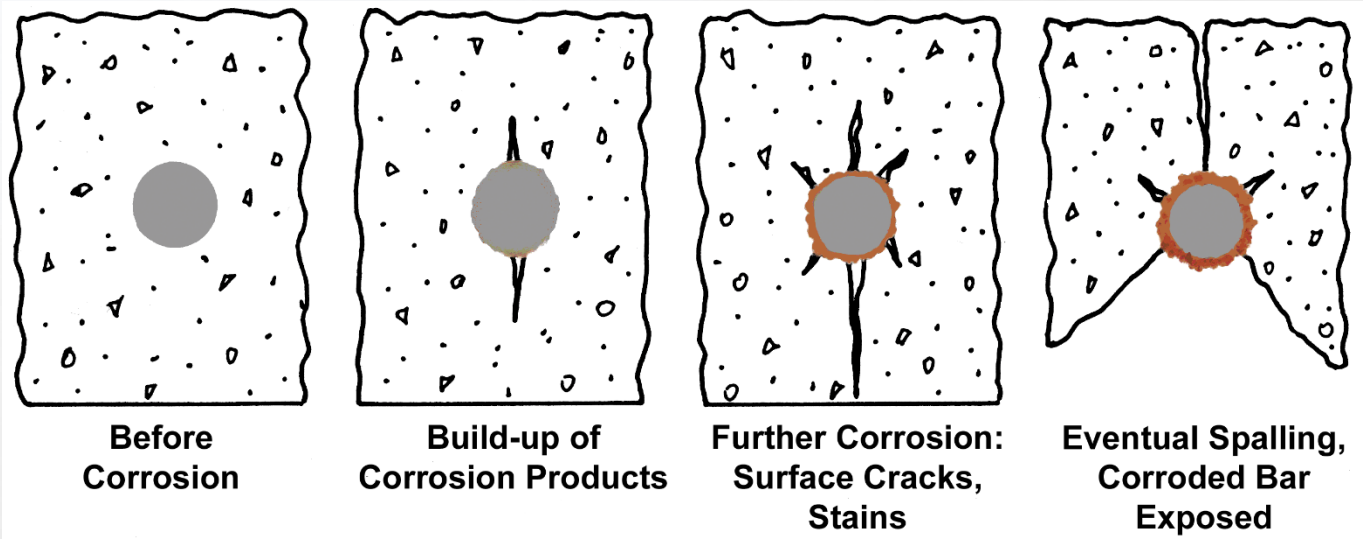


Preventing against rebar corrosion

Country	Concrete Code	Range of Concrete Cover (mm)
UK	BS:8110	25-50
EU	EN 1992 (EC2)	diameter +10 - 55
USA	ACI:318	40-50
Australia	AS:3600	15-78

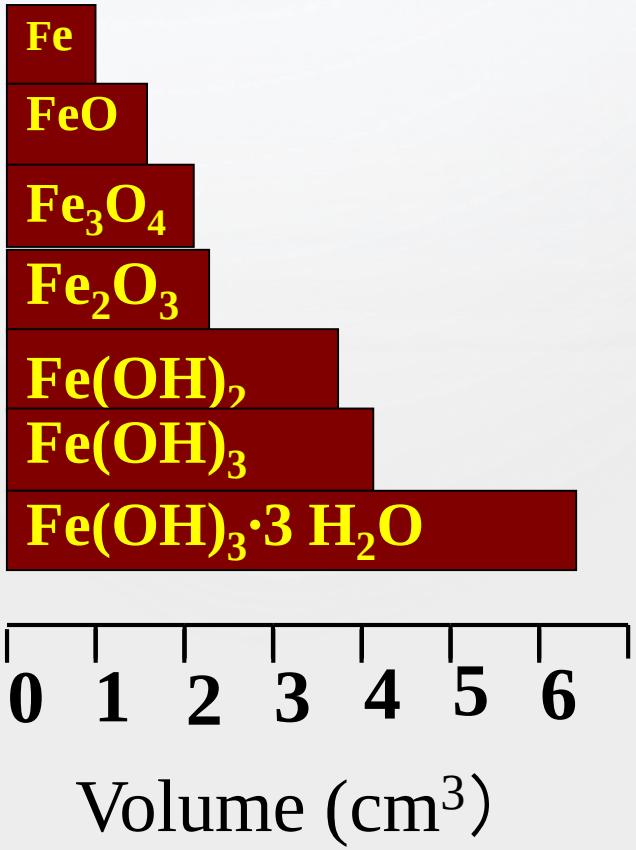
- Reduce permeability by optimal water to cement ratio (<0.55)
- Controlled compaction and curing
- Use of concrete impregnation or coatings
- Minimum depth of concrete cover
- All of these can delay corrosion of rebar but do not prevent it

In concrete, steel corrosion can cause major deterioration



Corrosive elements - water, air, chlorides, CO_2 - diffuse through the concrete matrix to reach rebar

Damage from Corrosion of Bare Rebar

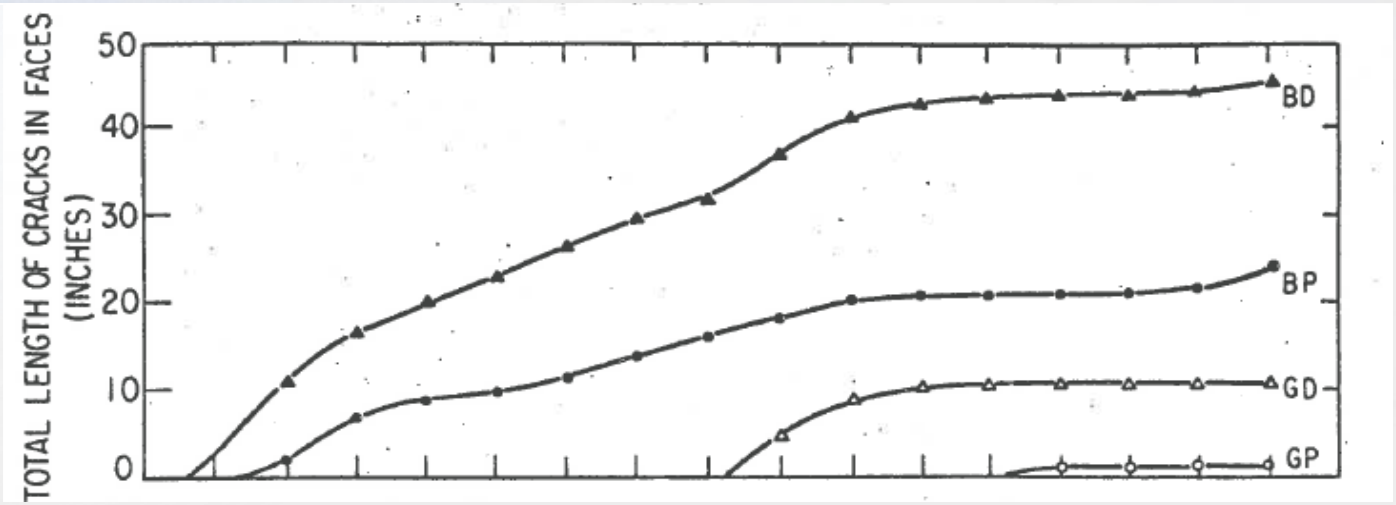


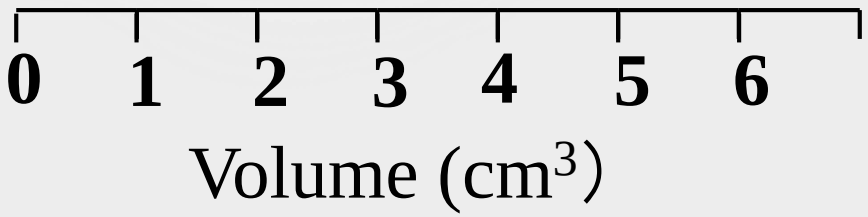
Severe Spalling

Low Cover

Difficult to Fix

Corrosion of Galvanized Rebar



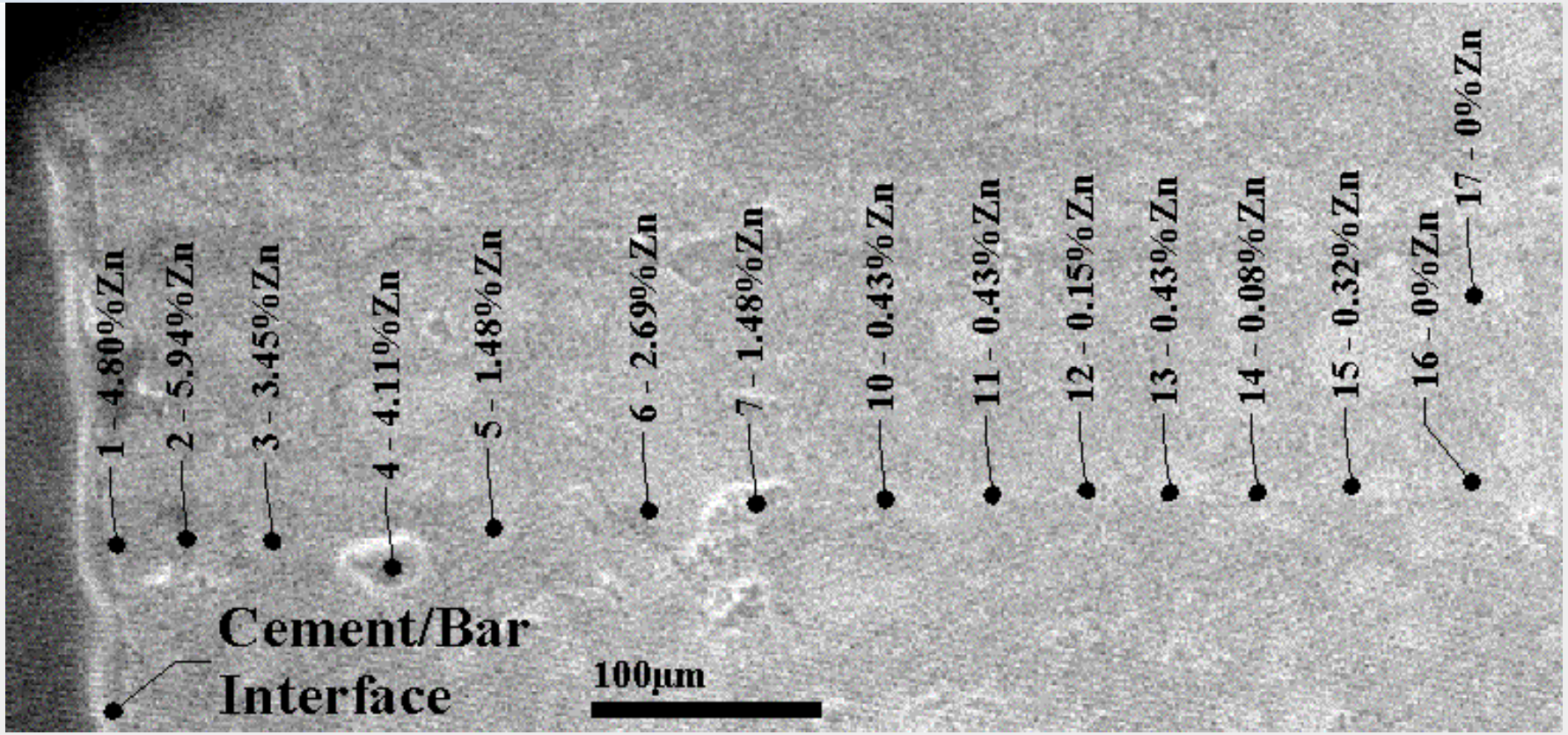


•	BLACK PLAIN	BP
○	GALVANIZED PLAIN	GP
▲	BLACK DEFORMED	BD
△	GALVANIZED DEFORMED	GD

Cornet and Bresler, NACE

A: $ZnCO_3 \cdot Zn(OH)_2$

Diffusivity of Corrosion Products



Zinc concentration as a function of depth into the cement paste for non-chromated specimen

Longevity Case Study

Athens Bridge

ATHENS, PA

- 1973

Jesup Bridge

Jesup County, Iowa • 2013

Autoroute 40 Reconstruction

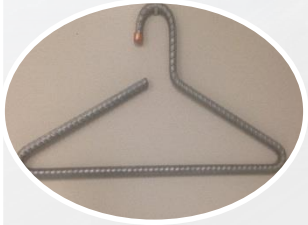
Montreal, QC • 2014

National Bridge Inventory

- Over 611,000 Bridges
- 337,051+ have no protection
- **87,601 have epoxy coated reinforcement**
  - 386 with other coated reinforcement
- 1,226 are **Galvanized**
  - 41 states
- 794 are Polymer
- 322 Cathodic Protection
- Less than 15% Corrosion resistant reinforcement

What is Continuous Galvanized Rebar

Durable, Flexible Zinc Coating



Fabricate after coating (bending, forming)

Pure Zinc Layer increases corrosion initiation threshold

Reduced cost

ASTM Specifications

Designation: A1094/A1094M

Standard Specification for
Continuous Hot-Dip Galvanized Steel Bars for Concrete Reinforcement[1]

Designation: A1055/A1055M

Standard Specification for
Zinc and Epoxy Dual-Coated Steel Reinforcing Bars

Proven Protection + Innovative Processing

Utilization of current supply chains. Steel Mills, Independent Fabricators, Distributors

Rebar can be staged in stock lengths prior to being released by fabrication creating a consistent flow of product and allowing for field changes to be addressed on the fly

No special equipment or special handling. Utilize the most efficient machinery in lengths up to 60'+

Seamless supply of CGR to projects through current supply chain without double handling resulting in better product flow and customer satisfaction.

CGR Process Video

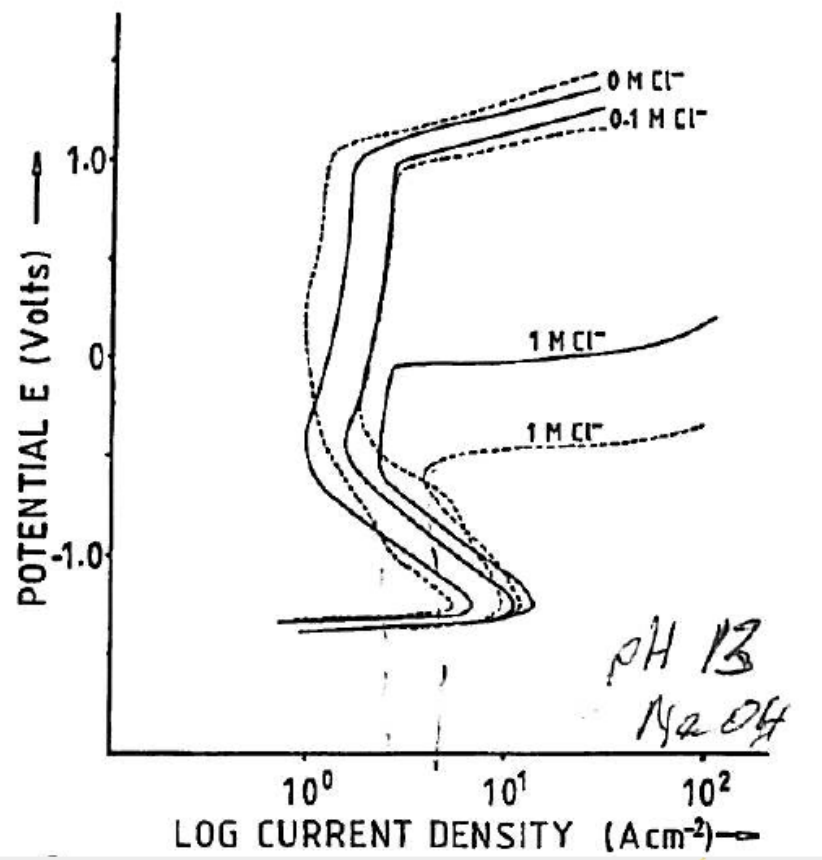
Coating Thickness

- 50um (2 mil) thick pure zinc coating
- Equivalent corrosion protection to thicker Zn-Fe alloy layers
- Faster passivation, slower corrosion rate

Coating Type	Average depth loss to passivation
Annealed	1.18 um (.0464 mils)
Pure Zinc	0.45 um (.0177 mils)

Tan & Hansson, Corrosion Science

Comparison of 50 µm CGR coating corrosion resistance to the 85µm HDG coating. Results of potentiodynamic polarization tests

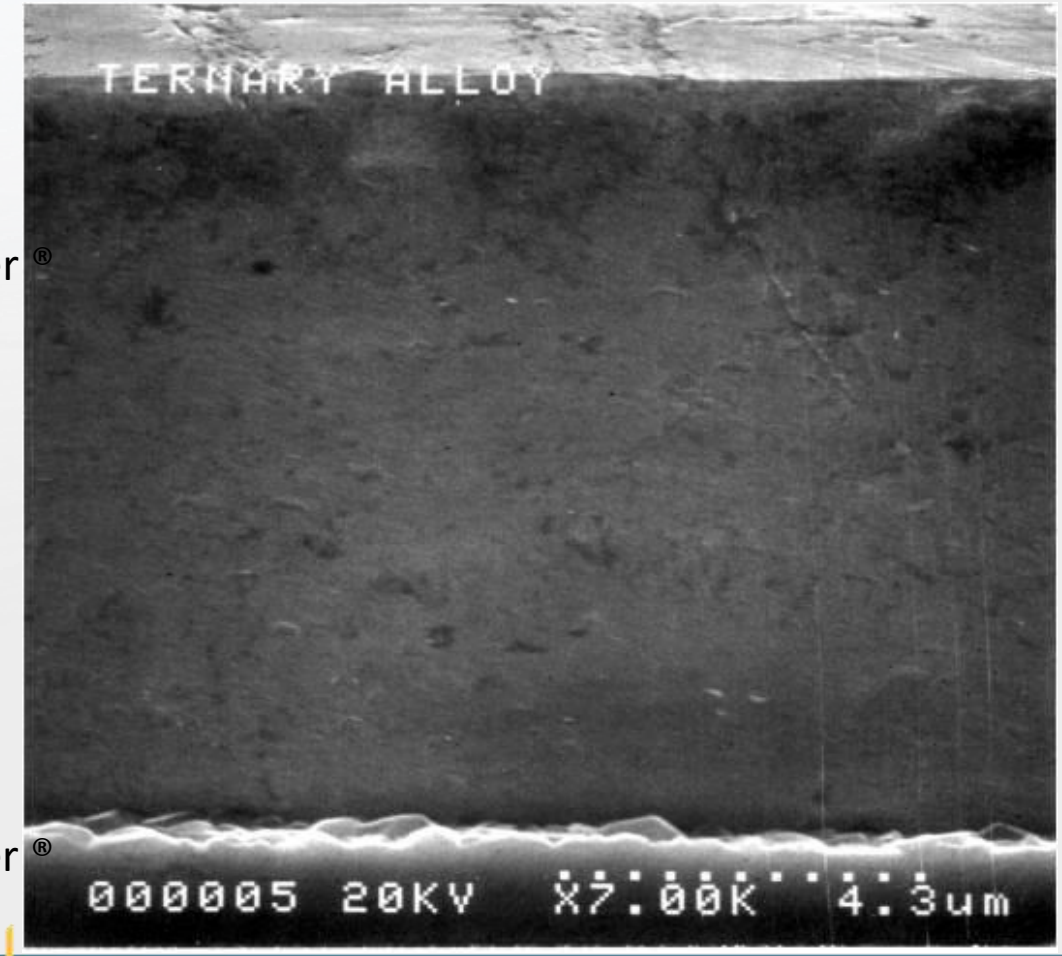


Zn (eta) phase current density = 2.38 A/cm2 (_____ line)
Zeta (Zn-Fe) phase current density = 3.98 A/cm2 (_ _ _ line)
Therefore Zn 1.7 times more corrosion resistant than Zn-Fe in the concrete corrosion cell
Sergi et al, NACE Corrosion, Vol 41, No.11, November, 1985

Photomicrograph

Zinc (ŋ) Layer ®

Ternary $Fe_2Al_{5-X}Zn_X$ Layer ®




SCHNELL
Bar Wiser 3D 22N

How CGR protects rebar

Protective Reaction Product (CaHZn)

High Chloride Threshold (2 - 4X black steel)

Low pH Tolerance (Carbonation)

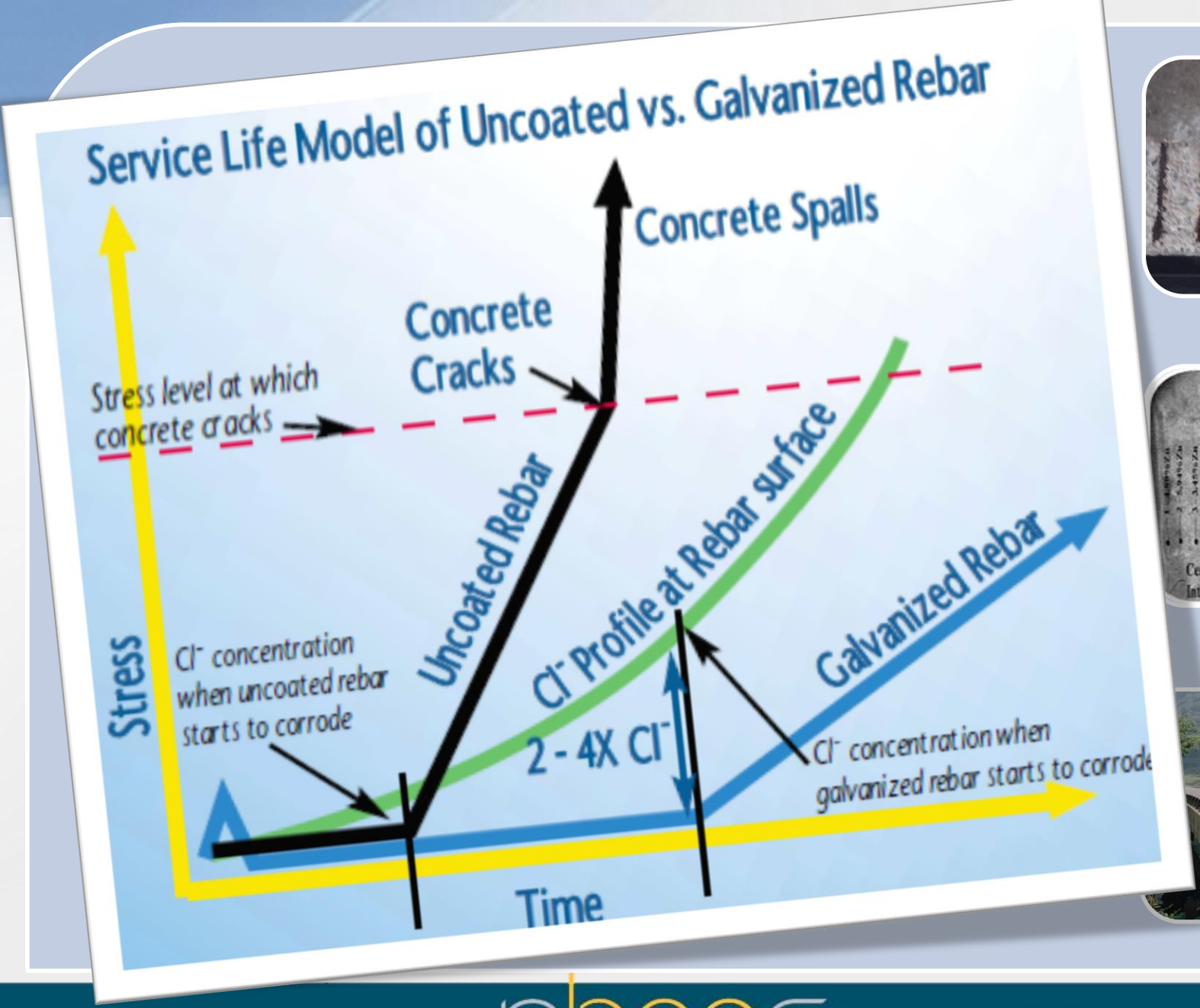
Corrosion Product Migration

-Concrete Matrix Densification

-Lower Unit Stress Generation

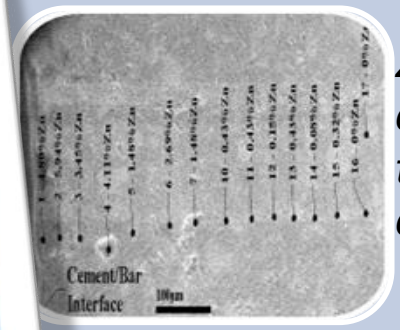
-Good bond strength

Barrier coating (Metallurgical Bond) w/Cathodic Protection



Zinc coatings have a higher chloride (Cl -) corrosion threshold (2-4 times) than that of uncoated steel, significantly extending the time until corrosion initiation.

+

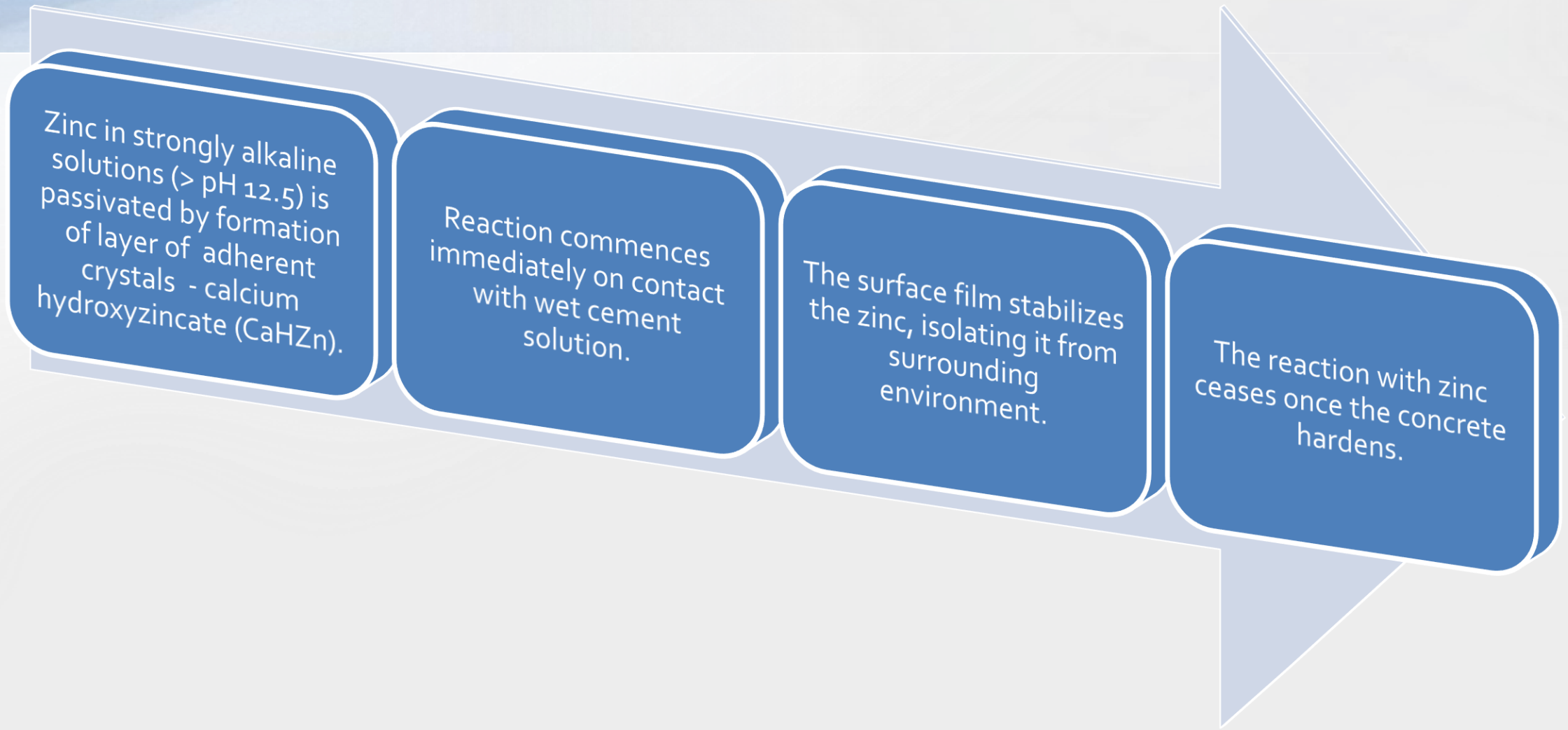


Zinc byproduct properties of the corrosion products and their ability to migrate into the concrete matrix reduces stress

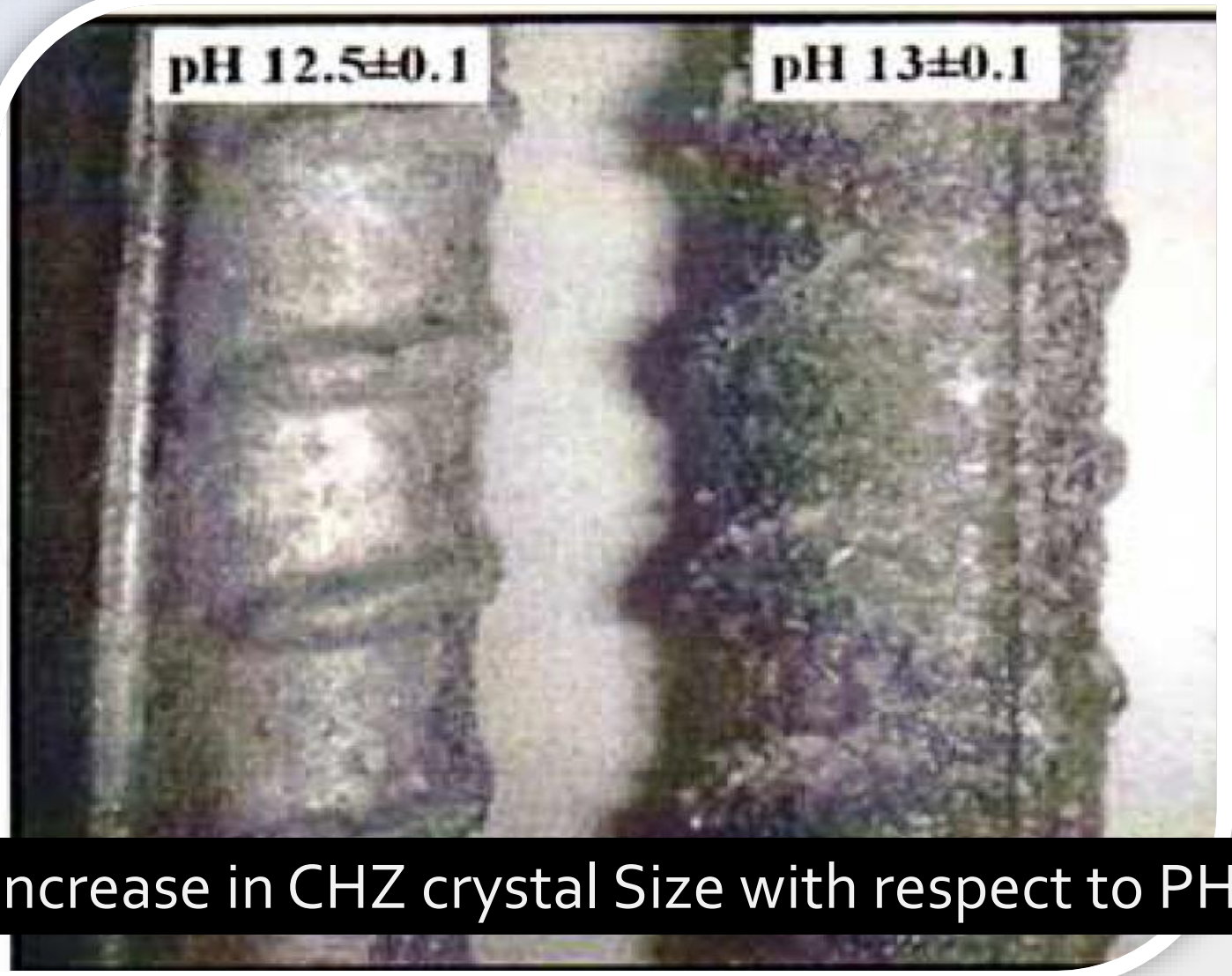
=

Extended Life

Zinc passivates in wet alkaline concrete

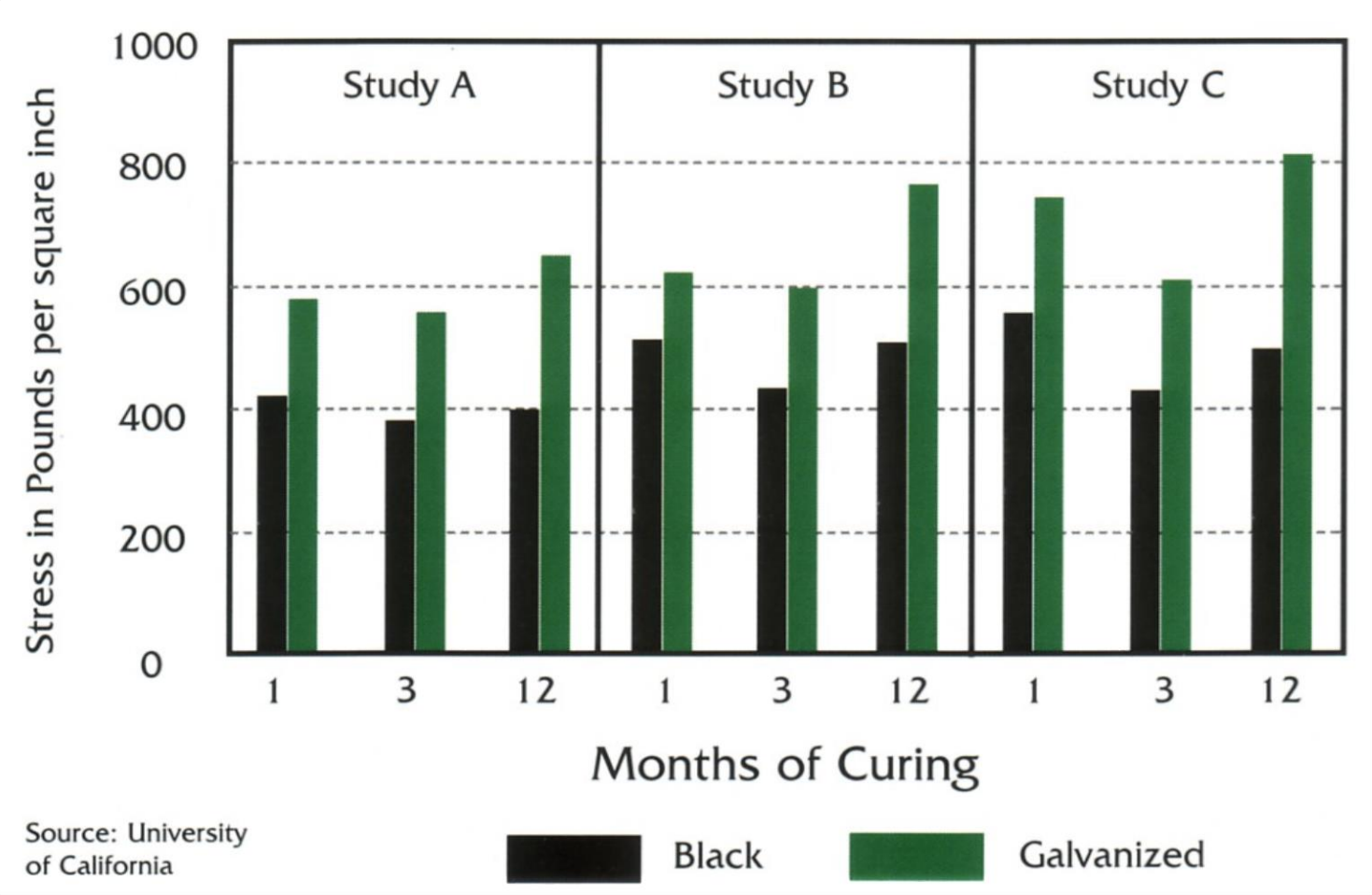


Z.Q. Tan and C.M. Hansson,
Corrosion Science, 50 (2008) 2512-2522

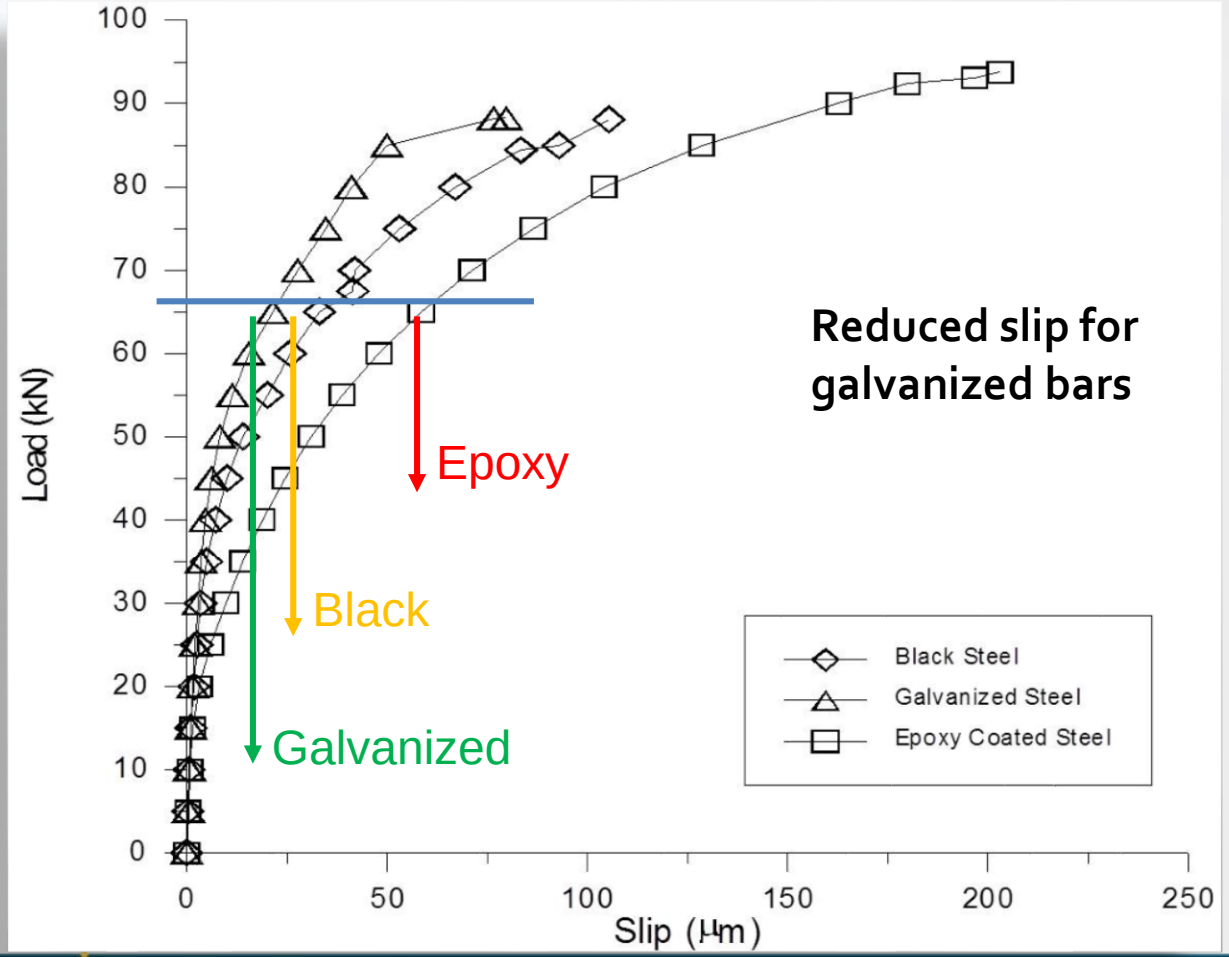


Increase in CHZ crystal Size with respect to PH

Bond Strength

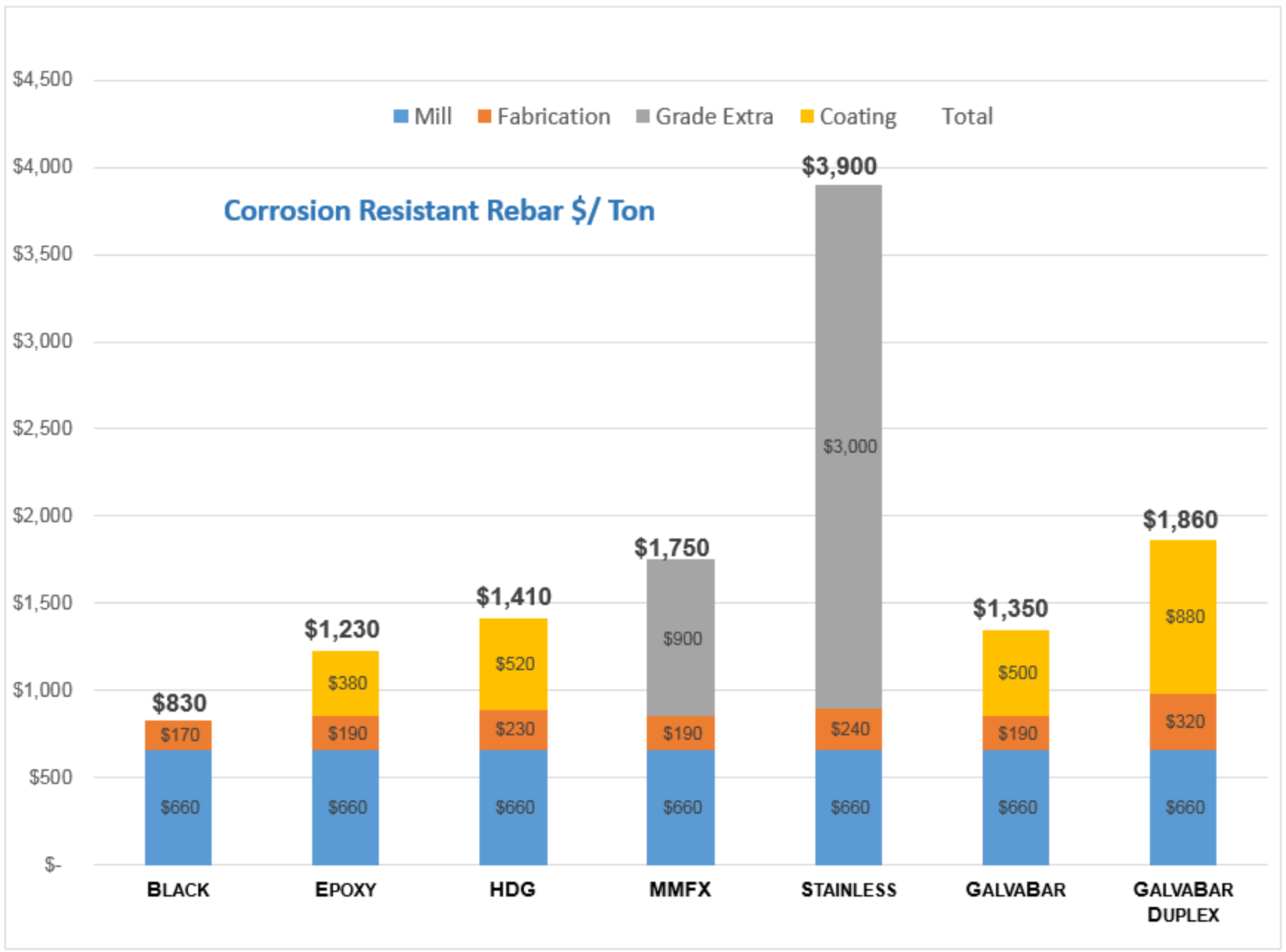


Load-Slip Characteristics

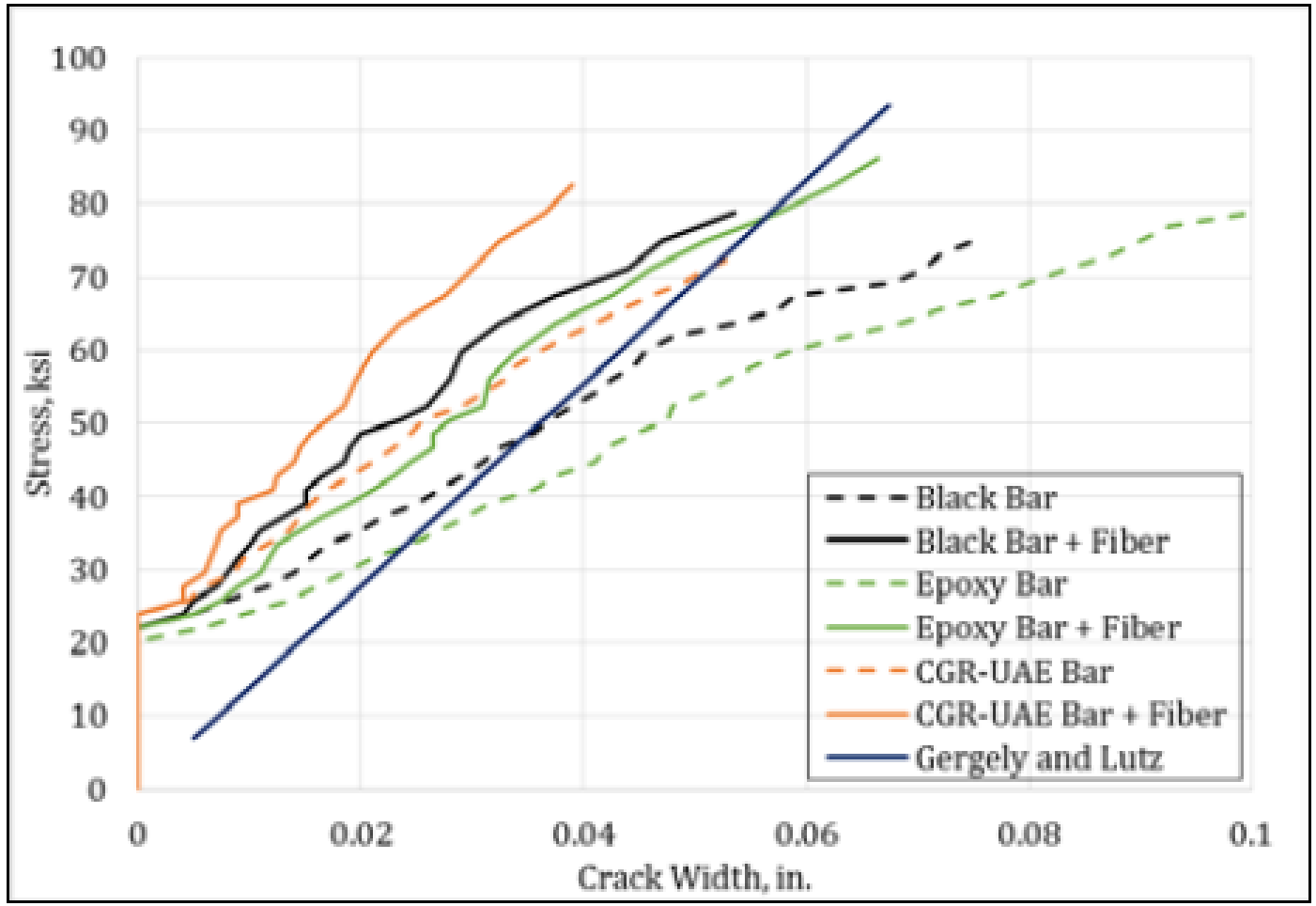


Installation

- Same as Black rebar:
- Same overlap links
- Same handling procedures
- No weather restrictions
- No sensitivity to UV light
- No touchup (except field-cut ends)
- Use galvanized or plastic connectors (where permissible)


Corrosion Resistant Rebar $/ Ton
Mill
Fabrication
Grade Extra
Coating
Total
$4,500
$4,000
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$-
$830
$170
$660
$1,230
$380
$190
$660
$1,410
$520
$230
$660
$1,750
$900
$190
$660
$3,900
$3,000
$240
$660
$1,350
$500
$190
$660
$1,860
$880
$320
$660
BLACK
EPOXY
HDG
MMFX
STAINLESS
GALVABAR
GALVABAR DUPLEX

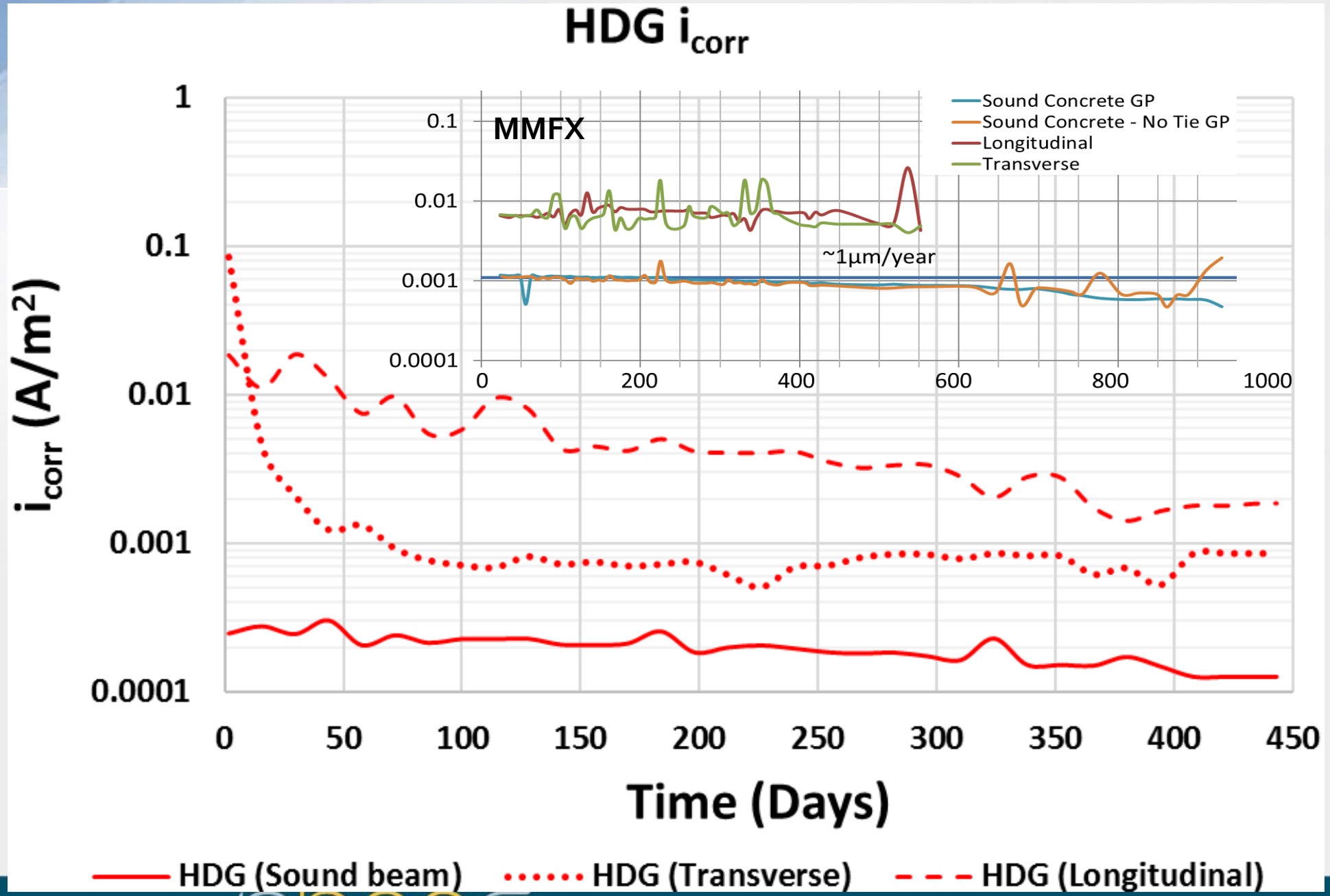
Summary - Reduction of Bridge Deck Cracking through Alternative Material Usage – University of Akron

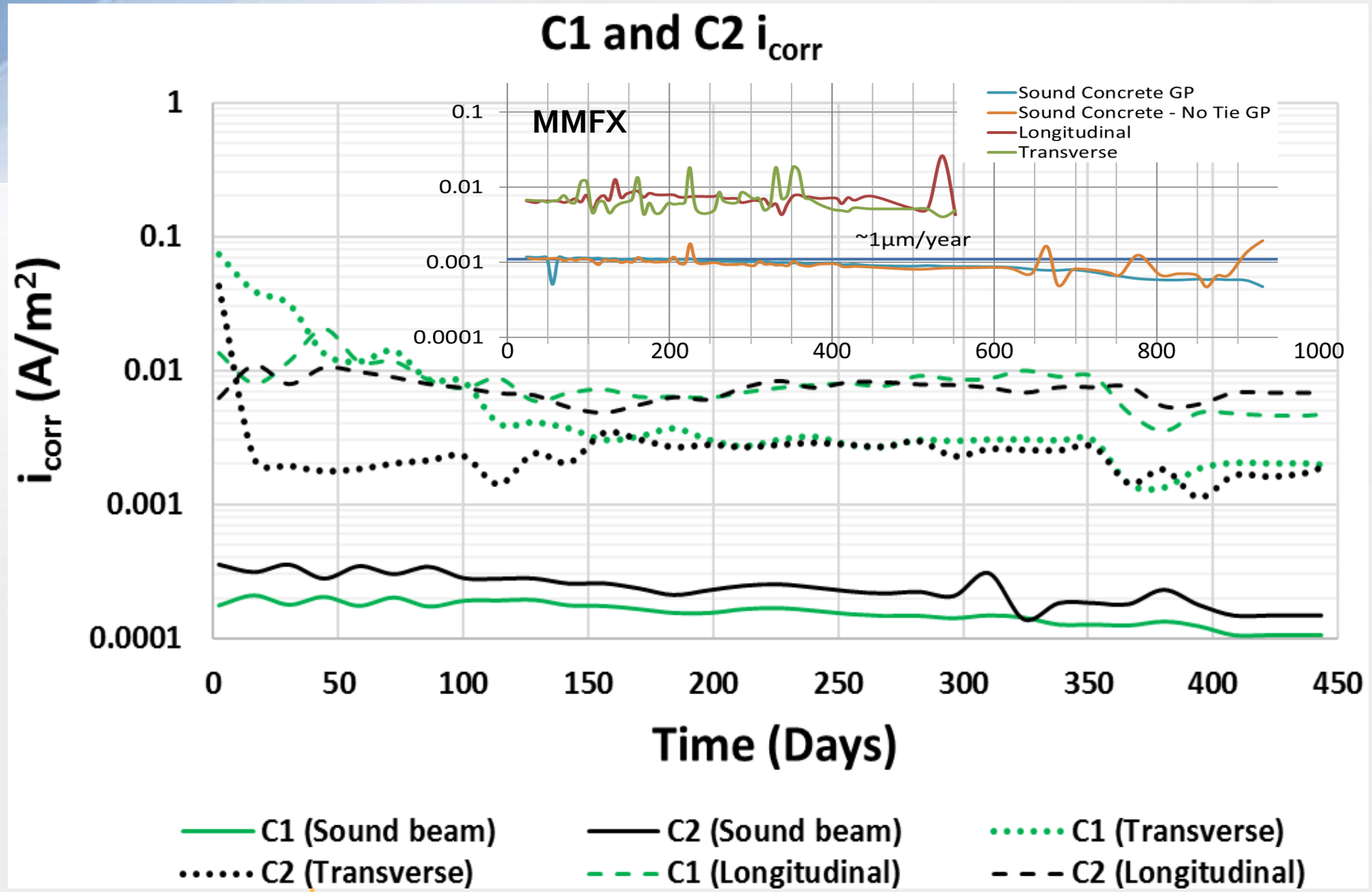


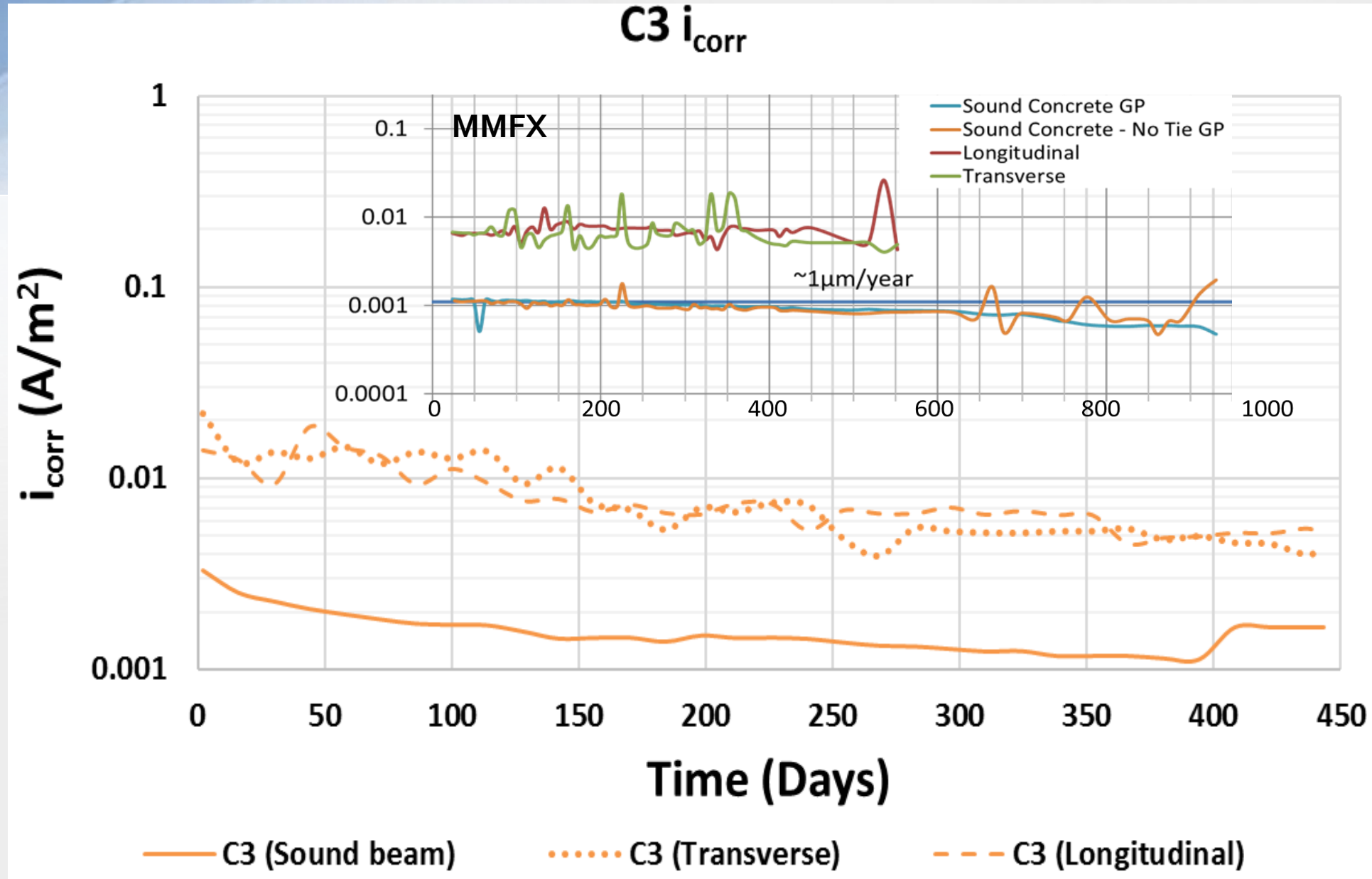
Structural slab tests with different bar types without and with fiber revealed that slabs with ECB have larger crack widths than those with all other bar types. Of all the alternatives studied in this project, continuous zinc galvanized bars (CGR) and corrosion-resistant alloy steel bars (MMFX) performed the best in terms of cracking behavior and corrosion resistance, particularly when fiber is used. Fiber reduced the crack widths in test specimens under static loading by 35% to 48% compared to crack widths of identical specimens with no fiber.

UW Corrosion Testing

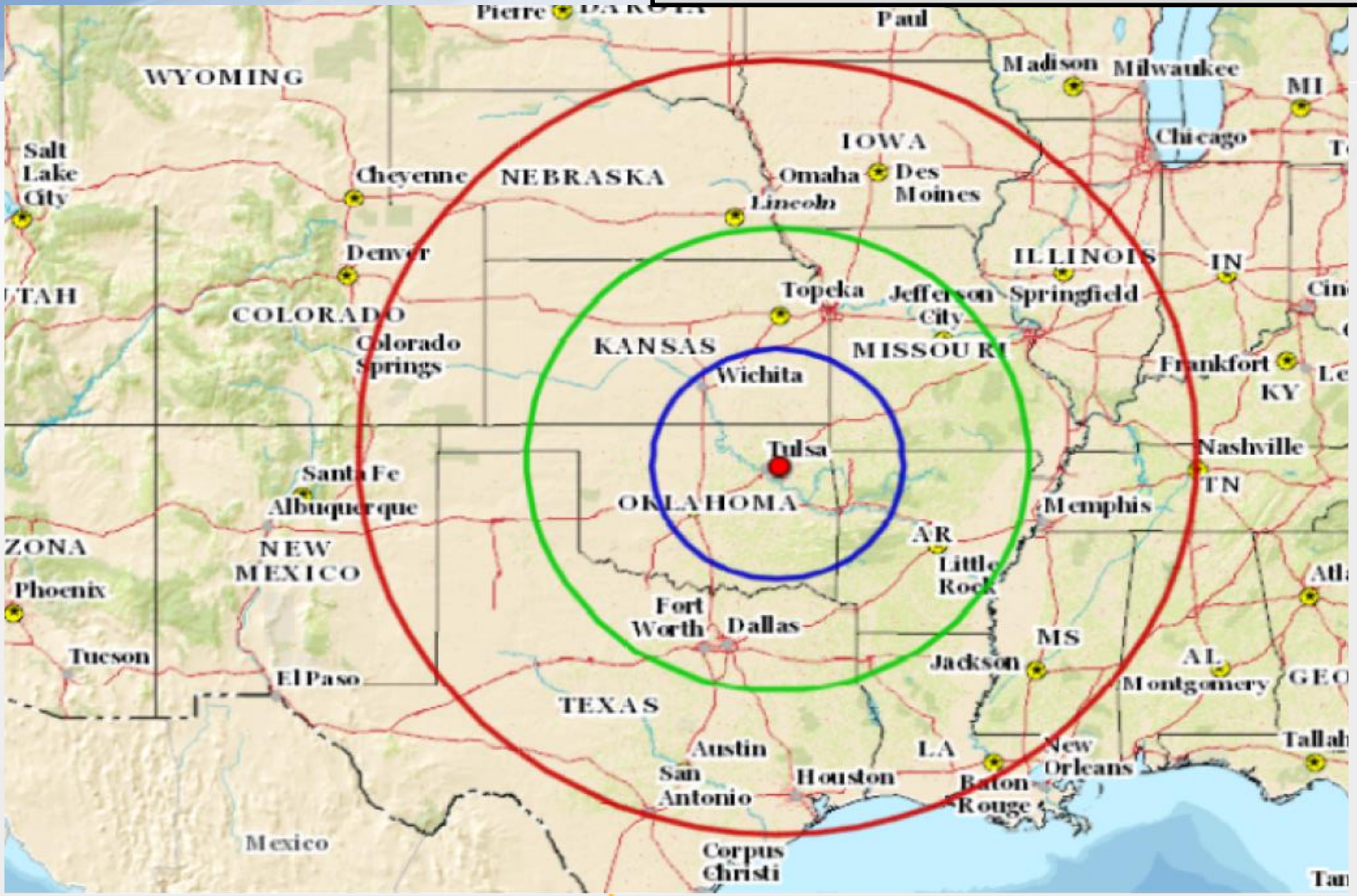
- Tombstone samples
  - Hot-dip, Continuous coated rebar
    - C1&C2, 30-40um thick continuous coatings
    - C3 experimental Zn-Al coating
  - Sound, longitudinal and transverse cracks
- Cyclic Ponding
  - 21% Brine solution
- Comparable Performance
  - Equivalent corrosion rate in sound concrete


HDG i_{corr}
i_{corr} (A/m^2)
1
0.1
0.01
0.001
0.0001
0
50
100
150
200
250
300
350
400
450
Time (Days)
MMFX
0.1
0.01
0.001
0.0001
0
200
400
600
800
1000
~1µm/year
Sound Concrete GP
Sound Concrete - No Tie GP
Longitudinal
Transverse
HDG (Sound beam)
HDG (Transverse)
HDG (Longitudinal)


C1 and C2 i_corr
MMFX
Sound Concrete GP
Sound Concrete - No Tie GP
Longitudinal
Transverse
~1µm/year
0.1
0.01
0.001
0.0001
0
200
400
600
800
1000
1
0.1
0.01
0.001
0.0001
i_corr (A/m²)
0
50
100
150
200
250
300
350
400
450
Time (Days)
C1 (Sound beam)
C2 (Sound beam)
C1 (Transverse)
C2 (Transverse)
C1 (Longitudinal)
C2 (Longitudinal)


C3 i_{corr}
MMFX
Sound Concrete GP
Sound Concrete - No Tie GP
Longitudinal
Transverse
~1µm/year
i_{corr} (A/m^2)
Time (Days)
C3 (Sound beam)
C3 (Transverse)
C3 (Longitudinal)

CGR Location #1



Plant: Port of Catoosa, OK

Distribution across North America

Thank You