Design and Construction Practices That Can Result in Improved Service Life of Concrete Structures to 150 Years or More

Western Bridge Engineers' Seminar

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WSDOT

New Focus on Durability Without Any Guidance

- Design for 75 Years
- Current Codes Fail to Identify and Quantify Durability

Mostar Br., Bosnia

Pantheon, Italy

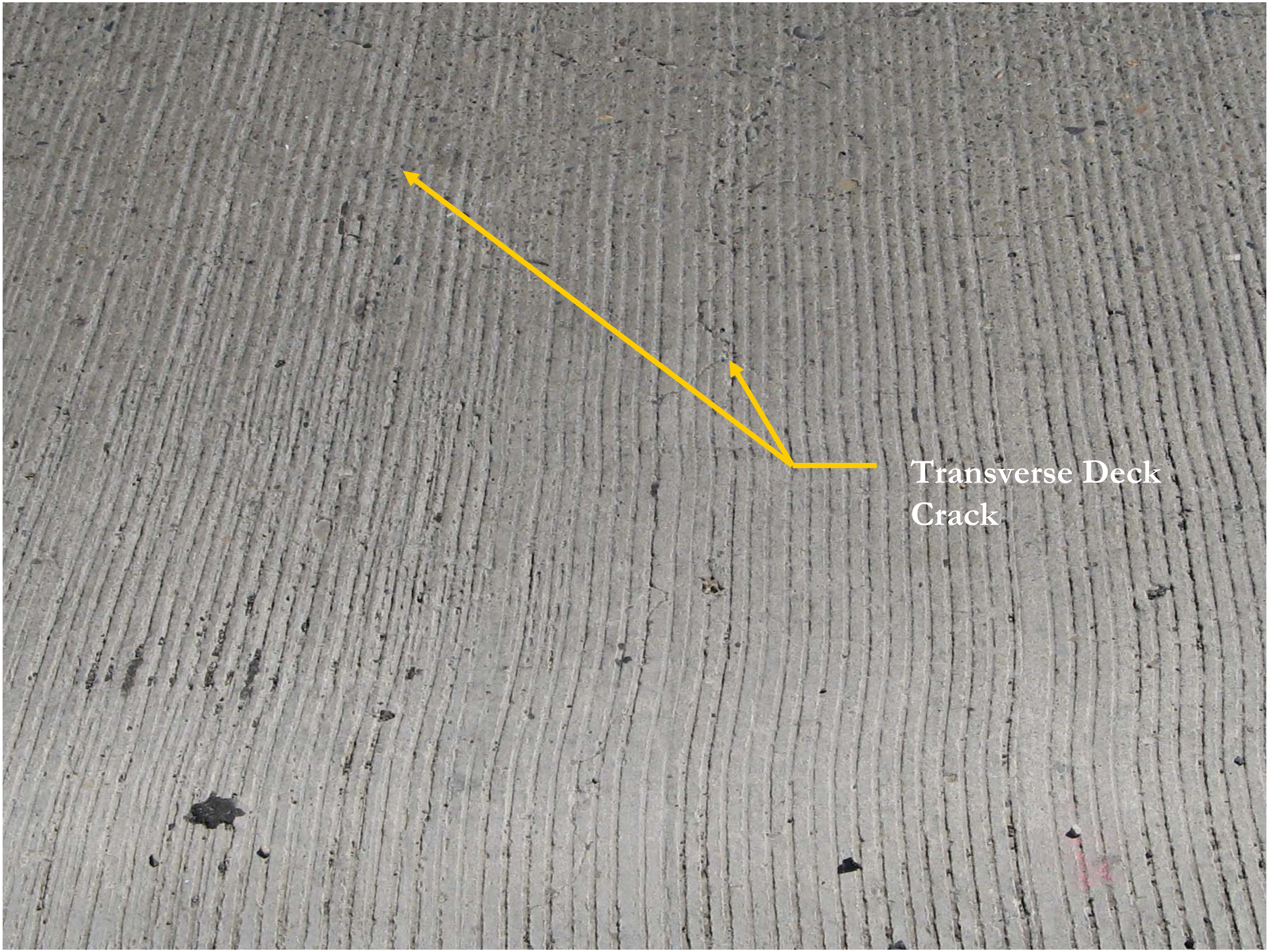
Mud bay Br., WA

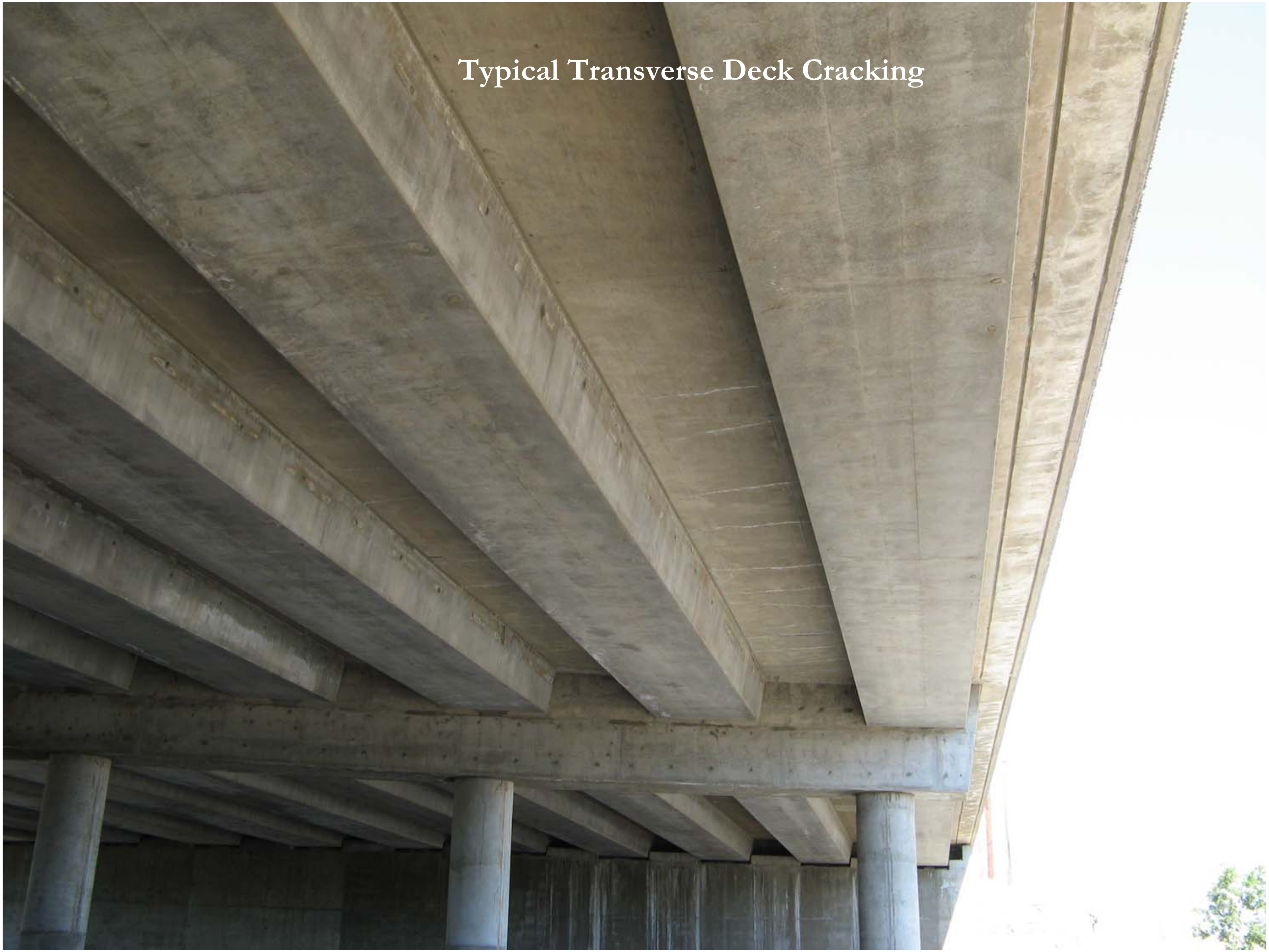

Grass Ck, WA


Manette Br., WA


Manette Br., WA

Construction


Transverse Deck
Crack


Typical Transverse Deck Cracking


BIDWELL
CONCRETE PAVING EQUIPMENT


.1
.2
mm/cm
10ths & 100ths./FT.
7.6m/25'
2
3
4
5
6
7
8


04/30/2004

Maintenance

Use of Chemical De-icers

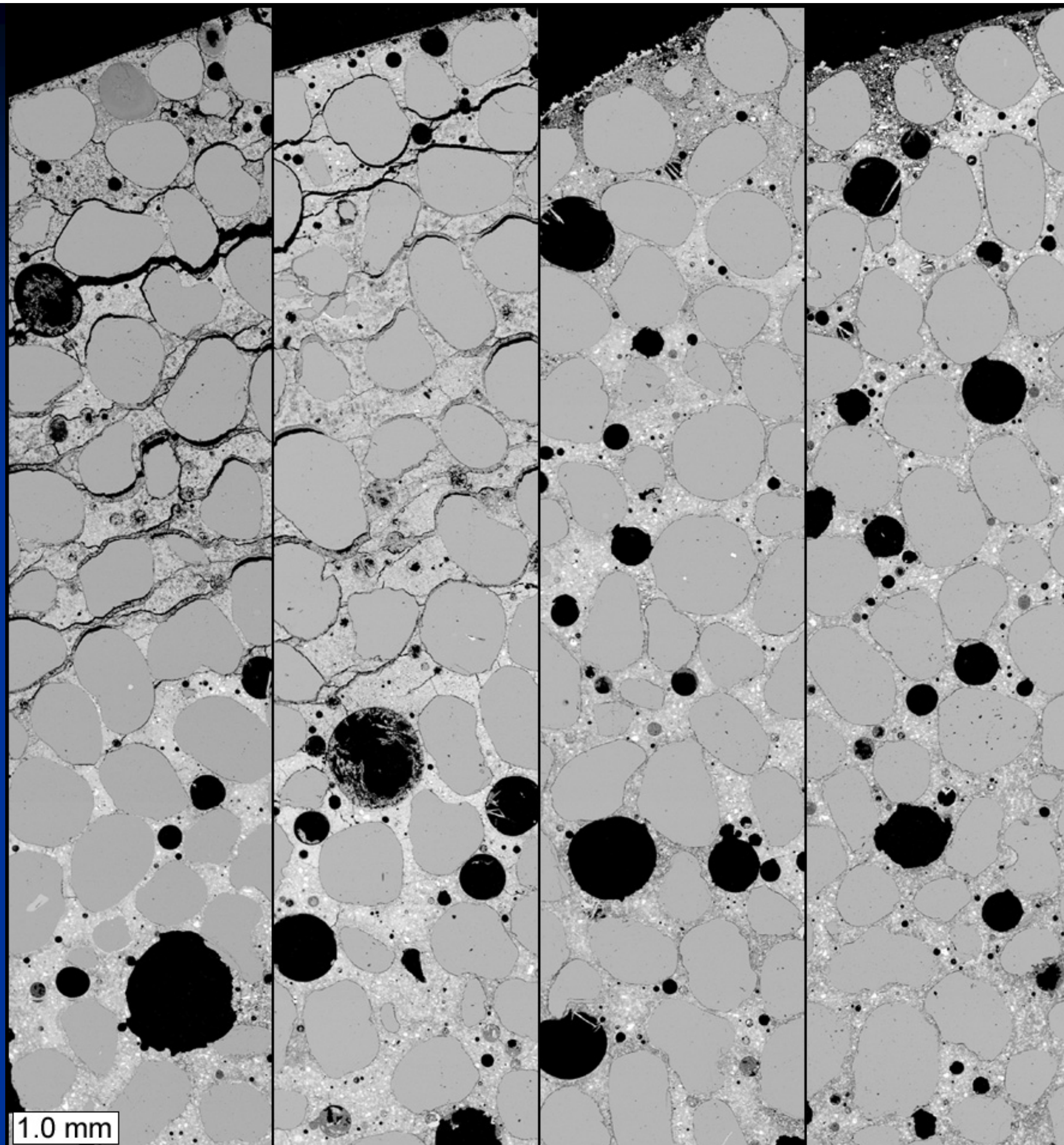
- Magnesium Chloride –Reacts with Ca(OH)2
- Calcium Chloride- Reacts with Ca(OH)2
- Potassium Acetate –Reacts with Zinc Based Paints
- Rock Salt – Rebar Corrosion
- Brine- Rebar Corrosion

Cylinders (2 in by 4 in) exposed to MgCl2 solution after 84 days of constant low temperature test. From left to right: 0.40, 0.50. 0.60 w/c ratio

Courtesy 2005
TRB Paper
Larry Sutter, PhD

Cylinders (2 in by 4 in) exposed to CaCl2 solution after 84
days of constant low temperature test. From left to right: 0.40, 0.50,
and 0.60 w/c mortar cylinders.

Cylinders (2 in by 4 in) exposed to NaCl
solution after 84
days of constant low temperature test. From
left to right: 0.40, 0.50, 0.60 w/c ratio



MgCl2 **CaCl2** **NaCl** **Lime**

Courtesy 2005
TRB Paper
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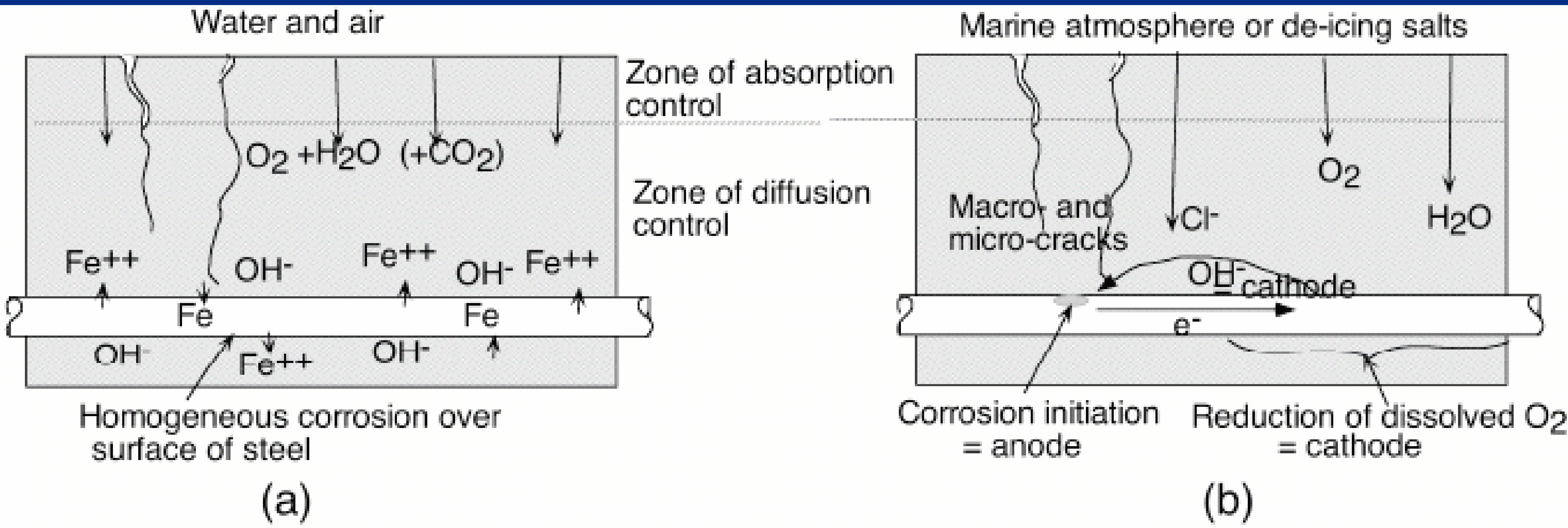
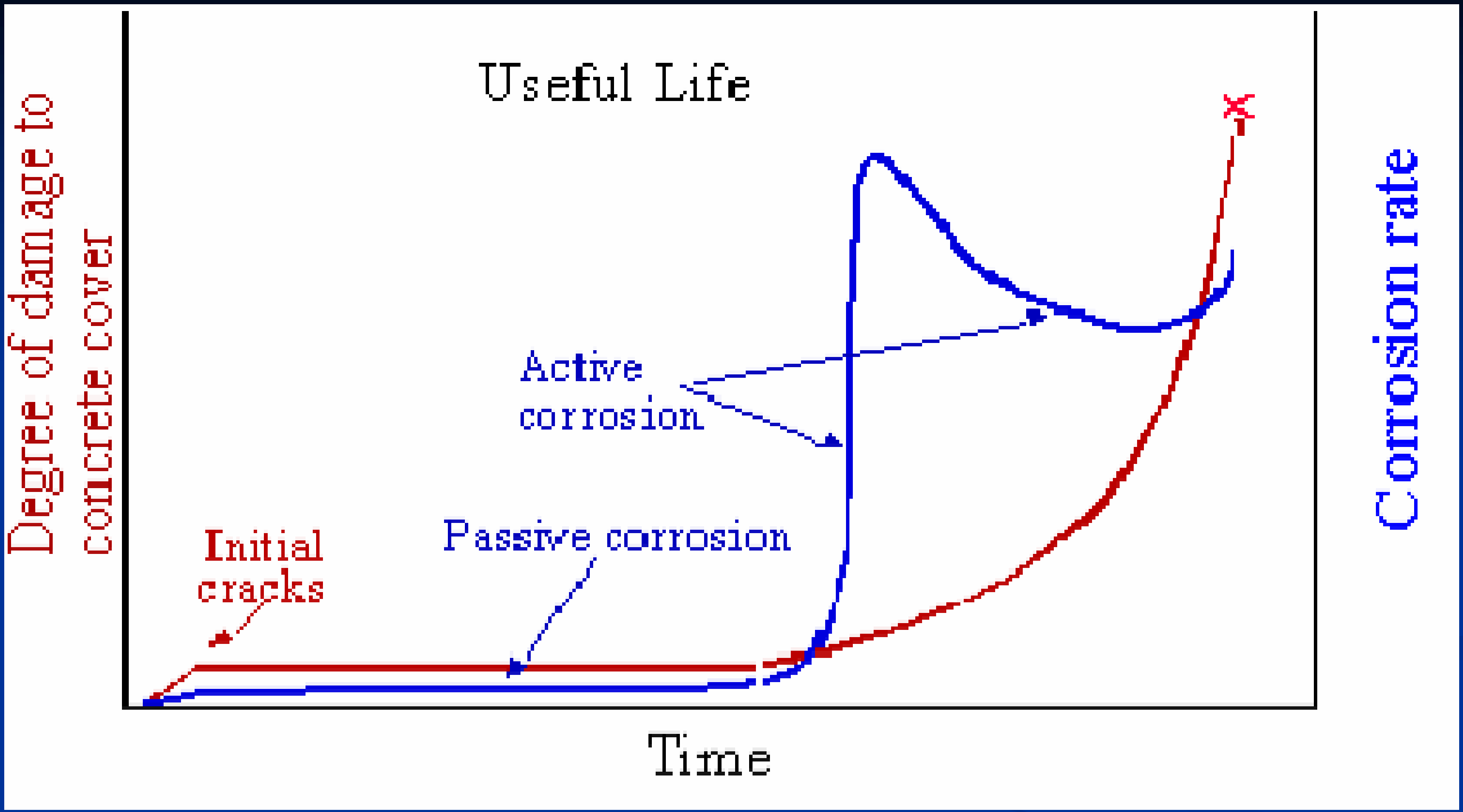
Durable Concrete

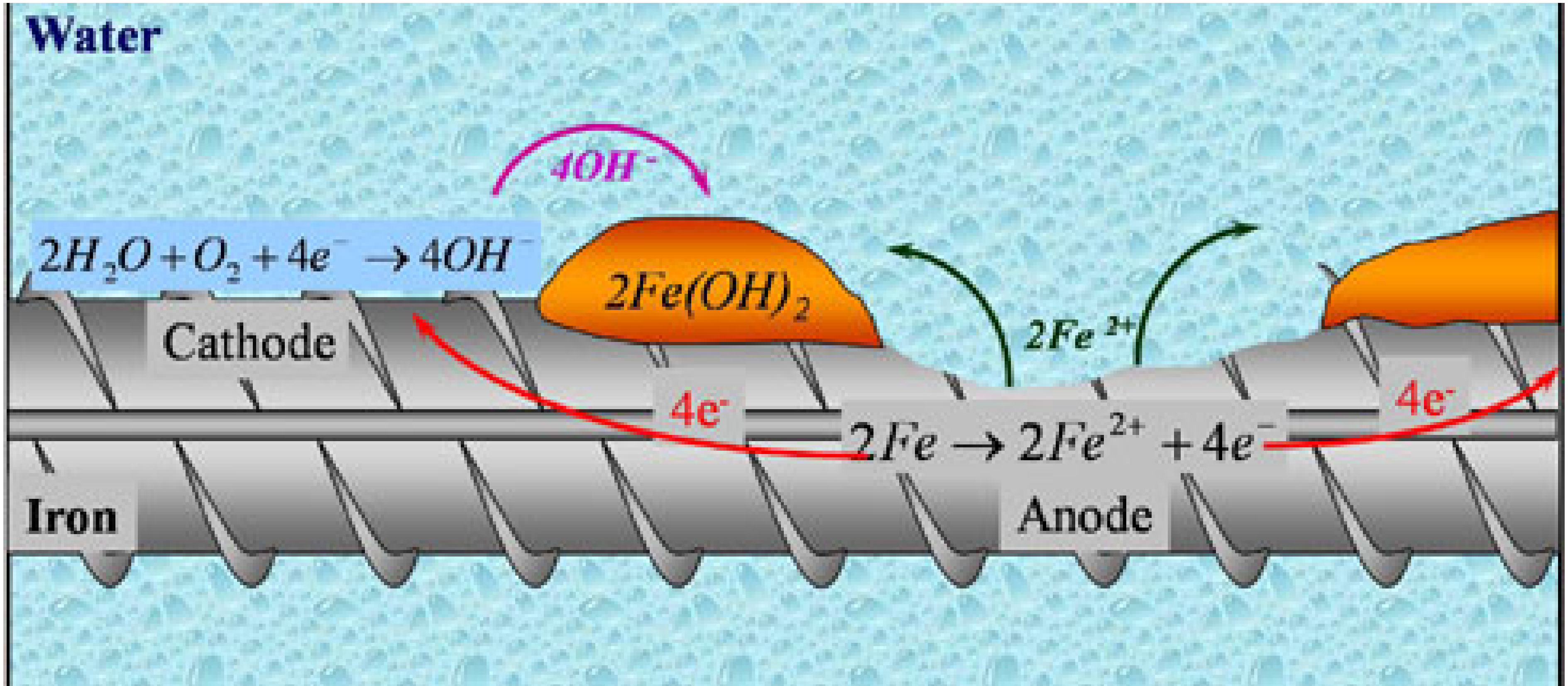
- Protect Rebars with Coating
- Concrete Mix



Schematic representation of (a) passive corrosion and (b) chloride-induced active corrosion of steel in concrete.



Schematic representation of the variation of corrosion rate of the reinforcement as a function of time (shown in blue) and the corresponding damage produced in the concrete cover



Corrosion of embedded metals in concrete can be greatly reduced by placing crack-free concrete with low permeability and sufficient concrete cover. Low-permeability concrete can be attained by decreasing the water to cementitious materials ratio of the concrete and the use of pozzolans and slag. Pozzolans and slag also increase the concrete resistivity thus reducing the corrosion rate even after it initiates. ACI 318, *Building Code Requirements for Structural Concrete* provides minimum concrete cover requirements that will help protect the embedded metals from corrosive materials. Additional measures to mitigate corrosion of steel reinforcement in concrete include the use of corrosion inhibiting admixtures, coating of reinforcement (for example, with an epoxy resin), and use of sealers and membranes on the concrete surface. Sealers and membranes, if used, have to be periodically reapplied

Rebar Coatings

- Epoxy
- Galvanized
- Stainless
- MMFX
- Stelex
- “Z” Bars
- Non-metallic

Define Exposure

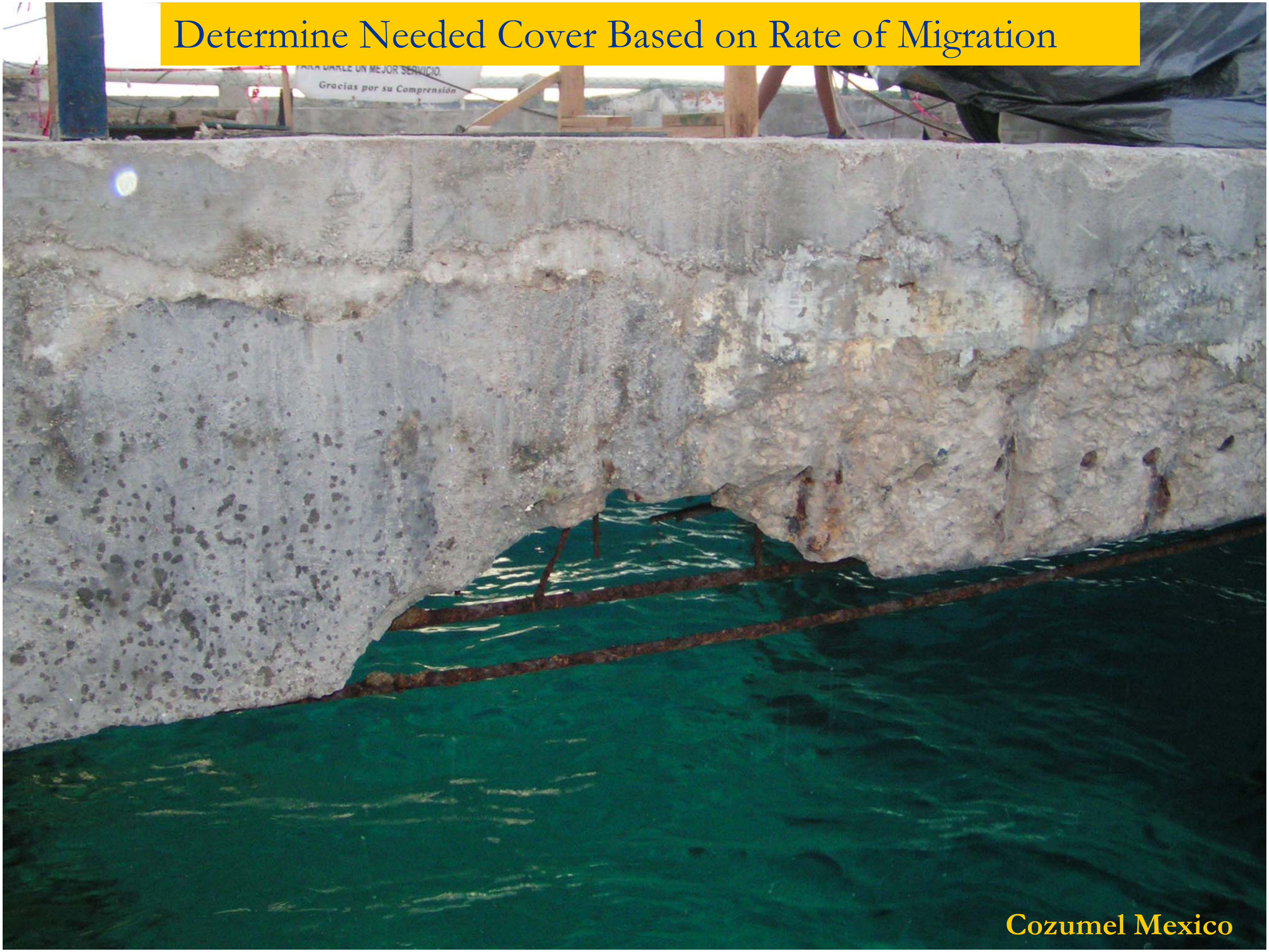
- Surface and Exposure Environment
- Chloride Exposure
- Freeze and Thawing Exposure
- Exposure to Chemical Attack
- Exposed to Sulfate Attack

Surface and Exposure Environment

ACI 318-08

- **F1** Moderate Freezing
- **F2** Severe Freezing
- **S1** Negligible Sulfate SO4<0.10% or SO4<150 ppm
- **S2** Moderate Sulfate SO4<0.20% or 1,500 ppm
- **S3** Severe Sulfate SO4<2% or SO4<10,000 ppm
- **S4** Very Severe SO4>2% or SO4> 10,000 ppm
- **C1** Low Perm. When Exposed to Water
- **C2** Exposed to De-icing Chemicals
- **C3** Exposed to Sea Water, Brackish Water or Spray

Determine Needed Cover Based on Rate of Migration



Define Performance

- Strength
- Modulus, Creep
- Permeability
- Scaling
- Early Shrinkage
- Freeze Thaw

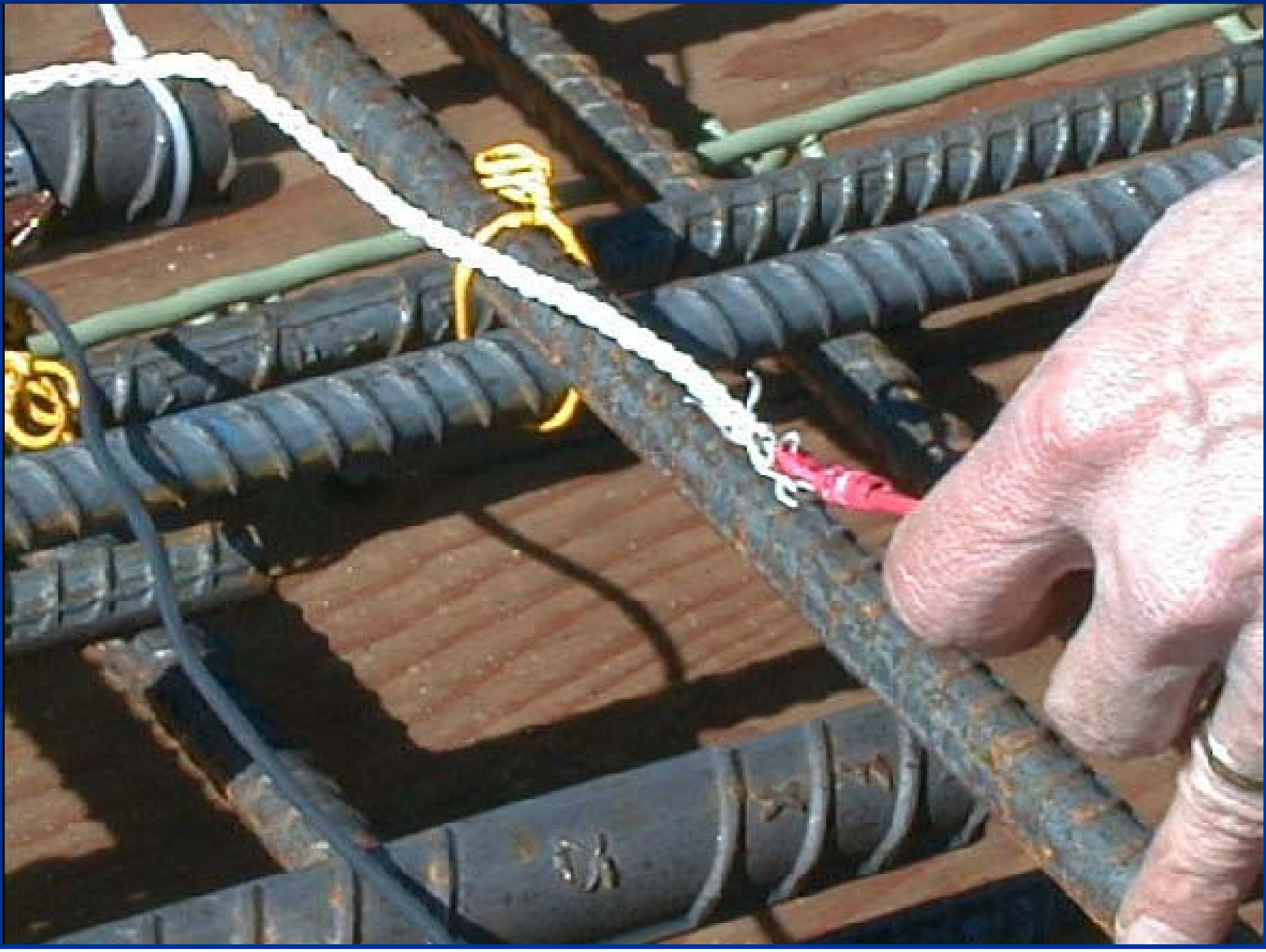
Test Methods

- **T 22** Compressive Strength
- **T 160** Free Shrinkage & Ring Test
- **T 277** Permeability
- **T 161** Freeze/Thaw
- **C 672** Scaling
- **C 1260 & C 1293** ASR

Prescriptive to Performance
P2P

- Owner Defines Performance
- Contractor Provides Mix design
- Owner Acceptance Based on Field Verification & Contractor's Test Results

Monitor Performance of the Bridge



RECAP

- Select Structure Type to Match Intended Longevity
- Account for the Environmental Exposure
- Develop Concrete Mix Performance Criteria
- Avoid Design Practices That Lead to Const. Difficulties
- Address Construction Outcome Without Dictating Methods
- Address Level of Maintenance During Design


Khajoo Bridge, Iran