Evaluation Methods for Preservation of Bridge Decks

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Preservation challenges for Bridge Decks

- Corrosion is the number one issue
  - Deicing chemicals
- Corrosion Reaction – four components
  - Anode – rust
  - Cathode – protected
  - Electrolyte – concrete
  - Electronic path - steel
How do we find the deterioration?

- Visual inspection
  - What is damaged today?
- Cores
  - Localized assessment of concrete materials
- Nondestructive methods
  - Global assessment of the future condition
Typical Concrete Coring

- Compressive strength
  - ASTM C43 – Proper collection of the cores
  - ASTM C39 – Compressive strength test
- Chloride concentration
- Carbonation depth
- Petrographic analysis
Chloride Concentration

- Typically sampled in ½” increments to depth of reinforcement
- ASTM C1152 – Acid Soluble
- ASTM C1218 – Water Soluble
- Generally accepted chloride threshold
  - 350 ppm of concrete
  - ~1.5 lbs per cubic yard of concrete
Deck Joint

- Location and condition of deck joints have a profound affect on substructure elements.
Carbonation Depth

- Carbon dioxide permeates into concrete
- Reduces pH of concrete
  - CO₂ reacts with free lime, Ca(OH)₂, resulting in CaCO₃ and H₂O
- Reduced pH de-passivates steel
- Often seen when
  - Concrete permeability is high
  - Industrial sites
  - Very old structures – carbonation is a result of time and exposure
Petrography

- ASTM C856
- Identify chemical characteristics of concrete
  - Air entrainment
  - Supplemental cementitious materials
  - Reactive aggregate
Peach St Bridge

- Freeze thaw damage lead to major deterioration and extensive corrosion activity
Nondestructive Methods

- Visual inspection
- Chain drag
- Ground penetrating radar
- Corrosion potential
- Impact echo/pulse velocity
Visual Inspection

- Identify areas of visual damage
  - Rust staining
  - Cracking
  - Spalls
  - Exposed steel
  - Water infiltration
  - Efflorescence

- Note exposure conditions and other observations
Chain Drag/Hammer Sounding

• Identifies delaminations
  – Late stage, large, near surface delaminations
Ground Penetrating Radar

- Electromagnetic evaluation of concrete
  - Reinforcement layout
    - Location of embedded metals
  - Cover-depth
  - Qualitative condition of reinforced concrete
    - Chlorides, moisture, and concrete deterioration attenuate GPR signal
Cover-depth

- Most important factor in the service life of a bridge
  - The best quality concrete does no good if it isn’t sufficiently over the reinforcement

\[ C_{(x,t)} = C_o \left(1 - \text{erf} \frac{x}{2\sqrt{D_c t}}\right) \]

\[ t = \frac{1}{D_c} \left[ \frac{x}{2 \times \text{inverf} \left(1 - \frac{C_{x,t}}{C_o}\right)} \right]^2 \]

\[ t = \left(\frac{d}{A}\right)^2 \]
Service Life Analysis

- Cover-depth and chloride concentration are critical inputs regarding service life analysis
  - Calculate diffusion coefficient
- How much of the steel has reached chloride threshold?
- How will that increase over time?
Cracking

- Cracking in the concrete provides a direct pathway to reinforcement for contaminants
- Many causes of concrete cracking
  - Concrete shrinkage
  - Mechanical stress due to overloading or improper concrete strength, under reinforced
  - ASR
  - Freeze thaw damage
GPR Amplitude Analysis

- Is not a delamination survey
  - Amplitudes can be affected by delaminations but also
  - Variations in moisture content
  - Chloride exposure
  - Cracking
  - Cover-depth (corrected for)
Corrosion Potential (Half-Cell)

- Measures the potential difference between the steel reinforcement and a reference electrode to identify the probably of active corrosion
  - ASTM C876
Corrosion Potential Survey

- Corrosion survey of a bridge in Washington DC
Progression of Corrosion
Epoxy Coated Rebar

- In most cases isolated reinforcement
- Measuring the concrete resistivity can give an indication as to the corrosive environment provided around the steel.
  - Can provide similar information as corrosion potential in a chloride exposure environment
Corrosion Potential vs Resistivity
Impact Echo

- Identify thickness of a slab
- Defects will affect the apparent thickness
IE Deck Testing
Post Tension Grout Inspection with Impact Echo

- Identify issues like soft grout
- Water or air voids
Rogers Overpass

- Pedestrian overpass in Victoria British Columbia
  - 4 PT tendons
- Construction inspector noted that contractor may have made a mistake during PT grouting
Velocity of a shear wave is proportional to the compressive strength of the concrete.
Identification of deteriorated concrete
Thank You