Evaluation Methods for Preservation of Bridge Decks

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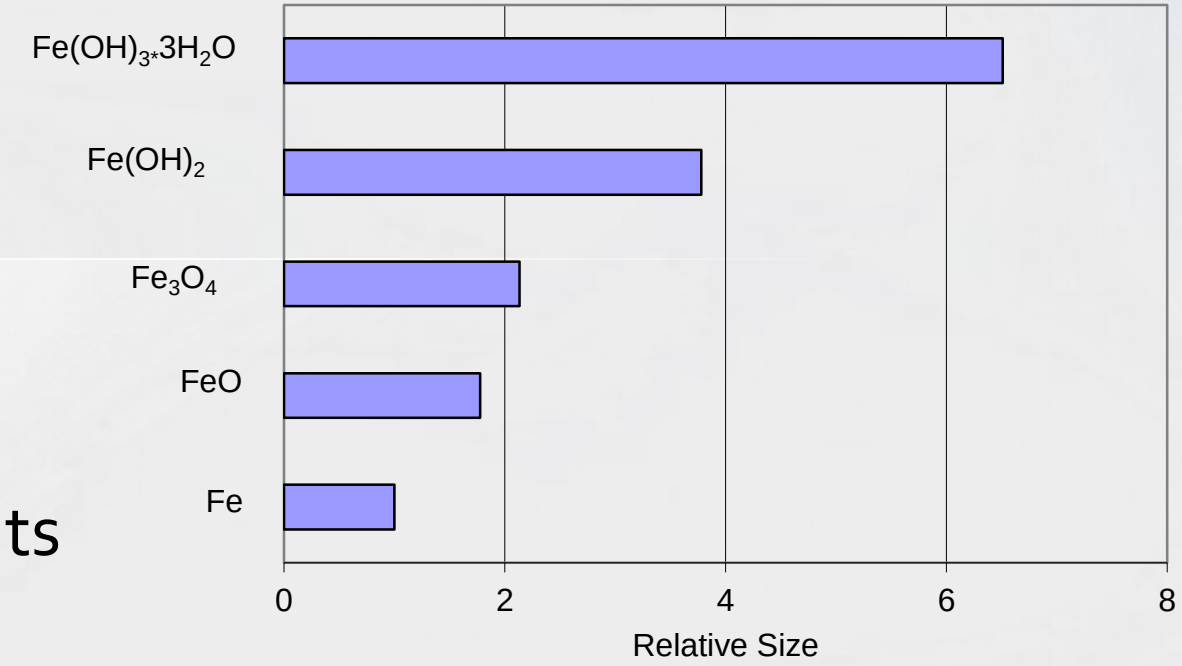
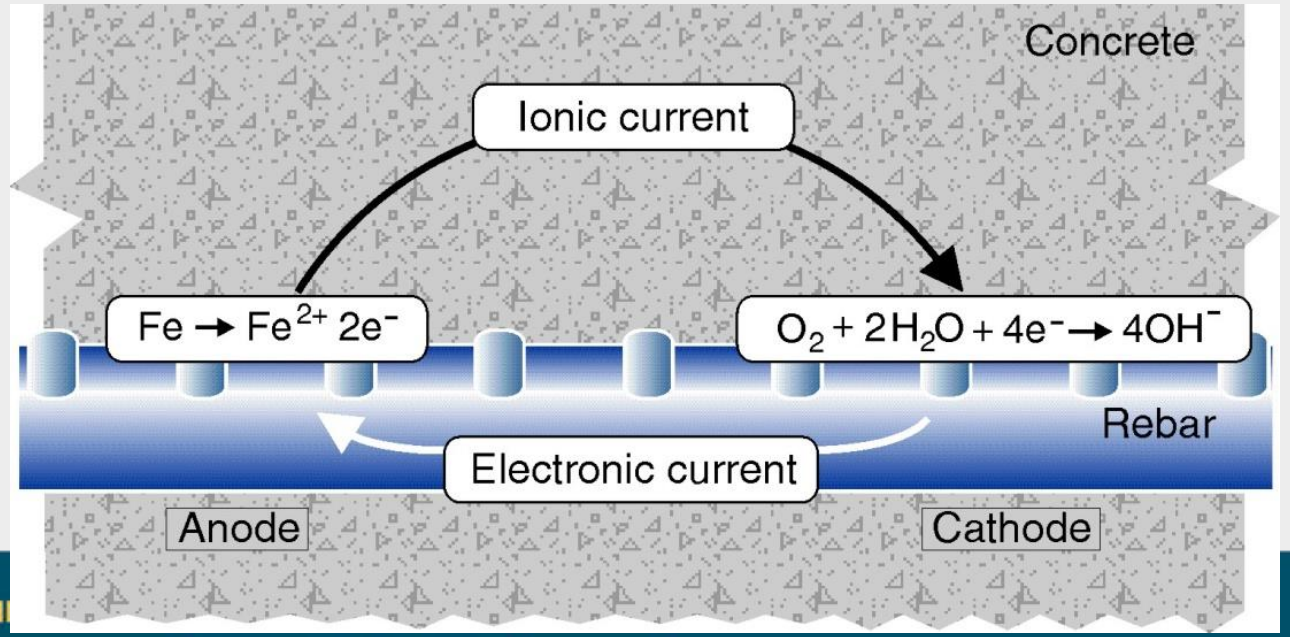
Preservation challenges for Bridge Decks

- 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?

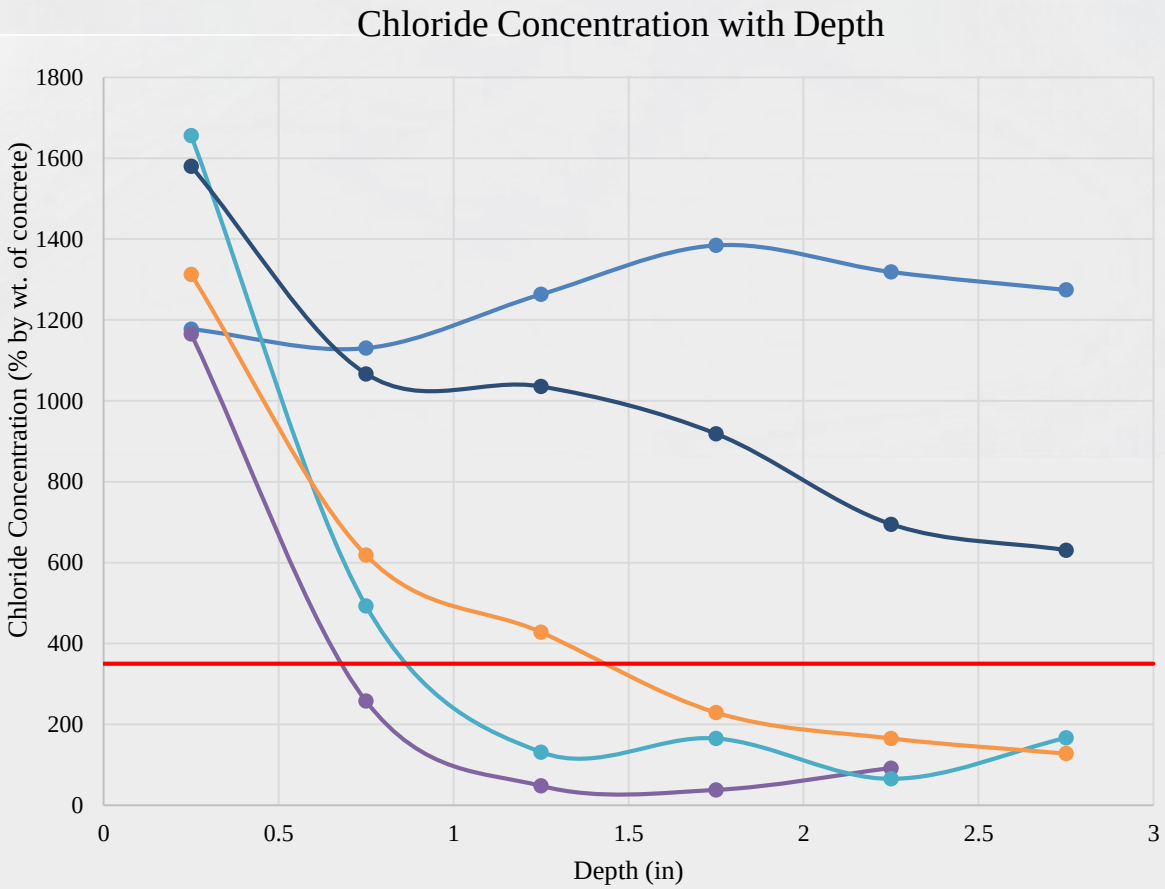
- Visual inspection
  - What is damaged today?
- Cores
  - Localized assessment of concrete materials
- Nondestructive methods
  - Global assessment of the future condition

Typical Concrete Coring

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

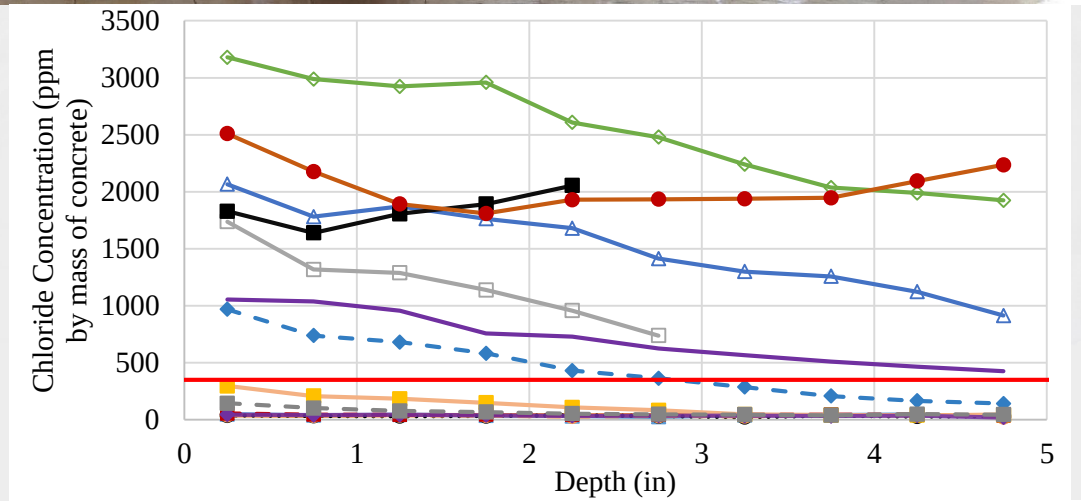
Chloride Concentration

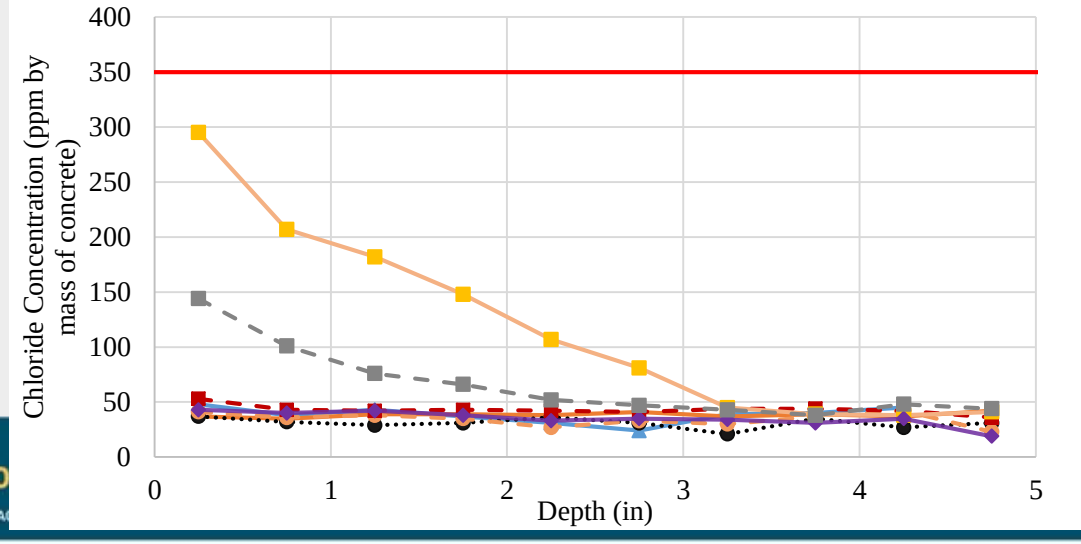
- Typically sampled in ½" increments to depth of reinforcement
- ASTM C1152 – Acid Soluble
- ASTM C1218 – Water Soluble
- Generally accepted chloride threshold
  - 350 ppm of concrete
  - ~1.5 lbs per cubic yard of concrete



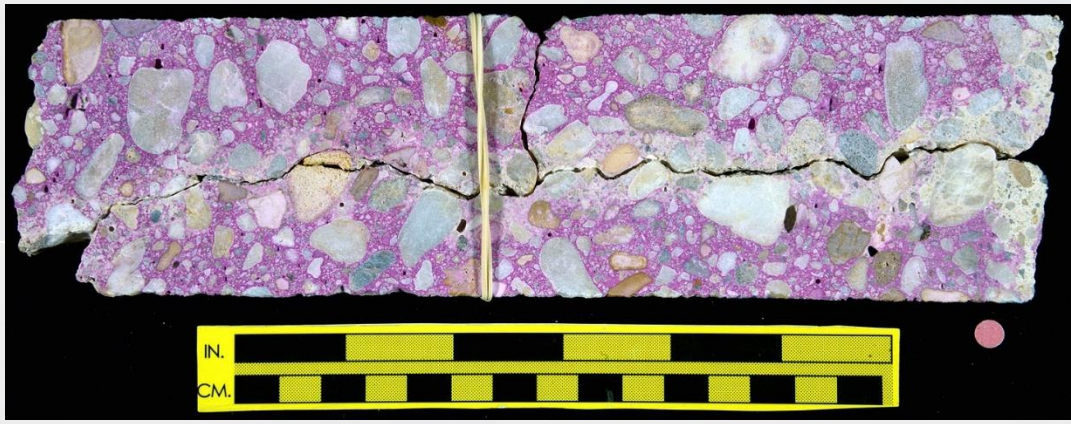
Deck Joint

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





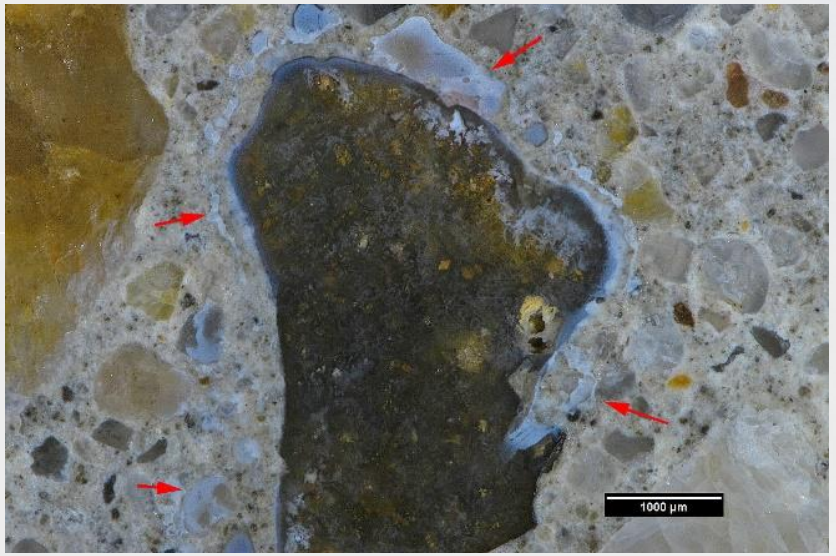
Carbonation Depth

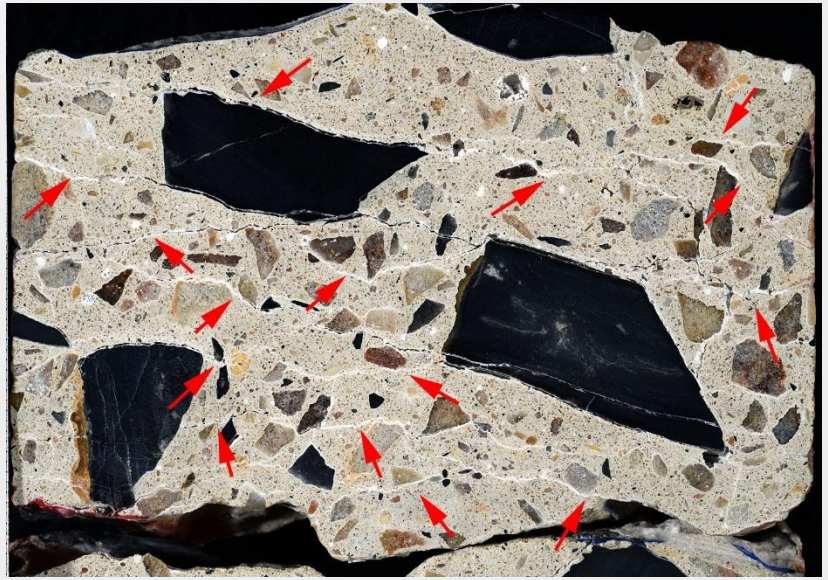


- Carbon dioxide permeates into concrete
- Reduces pH of concrete
  - CO_2 reacts with free lime, $Ca(OH)_2$, resulting in $CaCO_3$ and H_2O
- Reduced pH de-passivates steel
- Often seen when
  - Concrete permeability is high
  - Industrial sites
  - Very old structures – carbonation is a result of time and exposure

Petrography

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



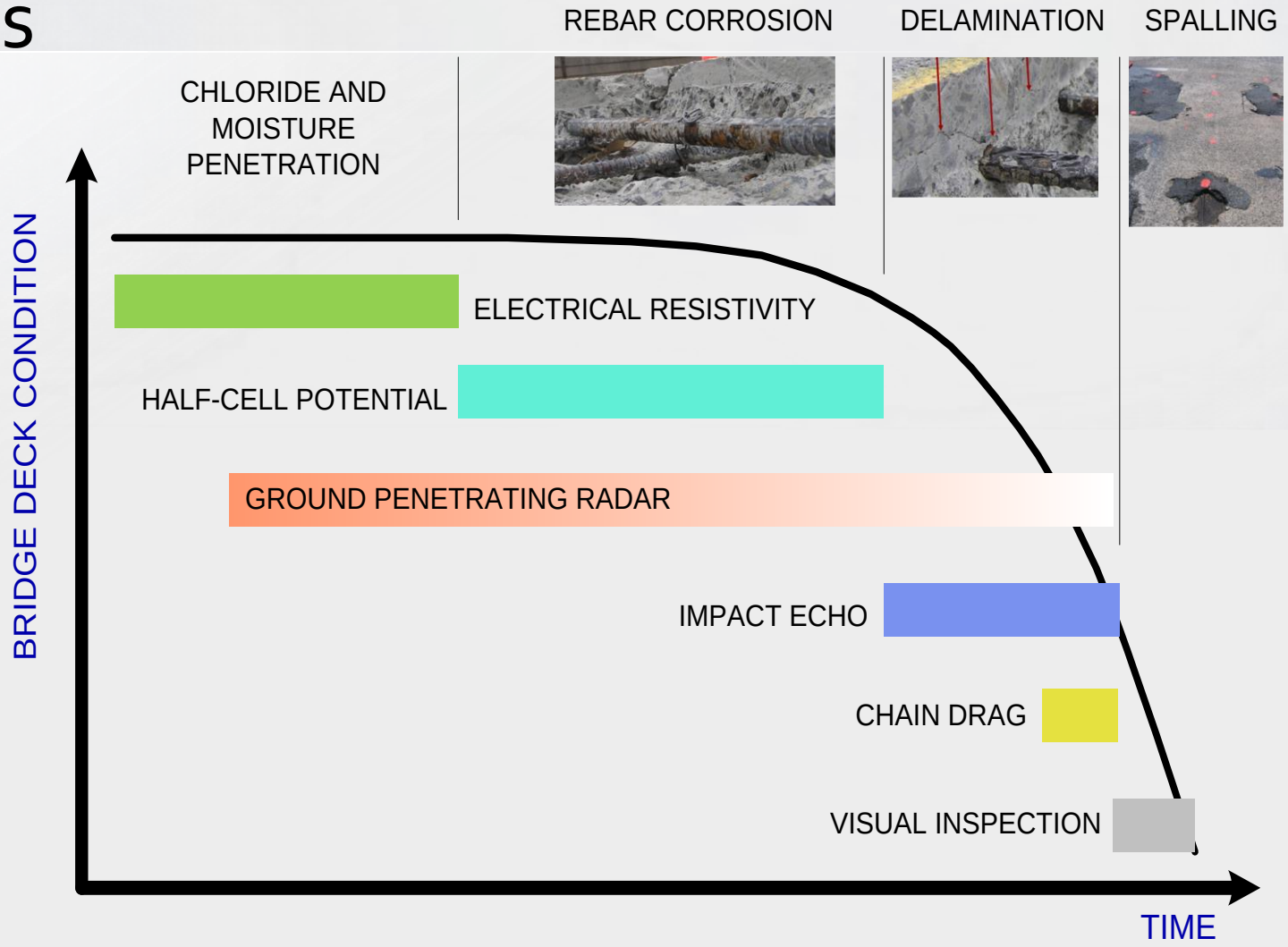


Peach St Bridge

- 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

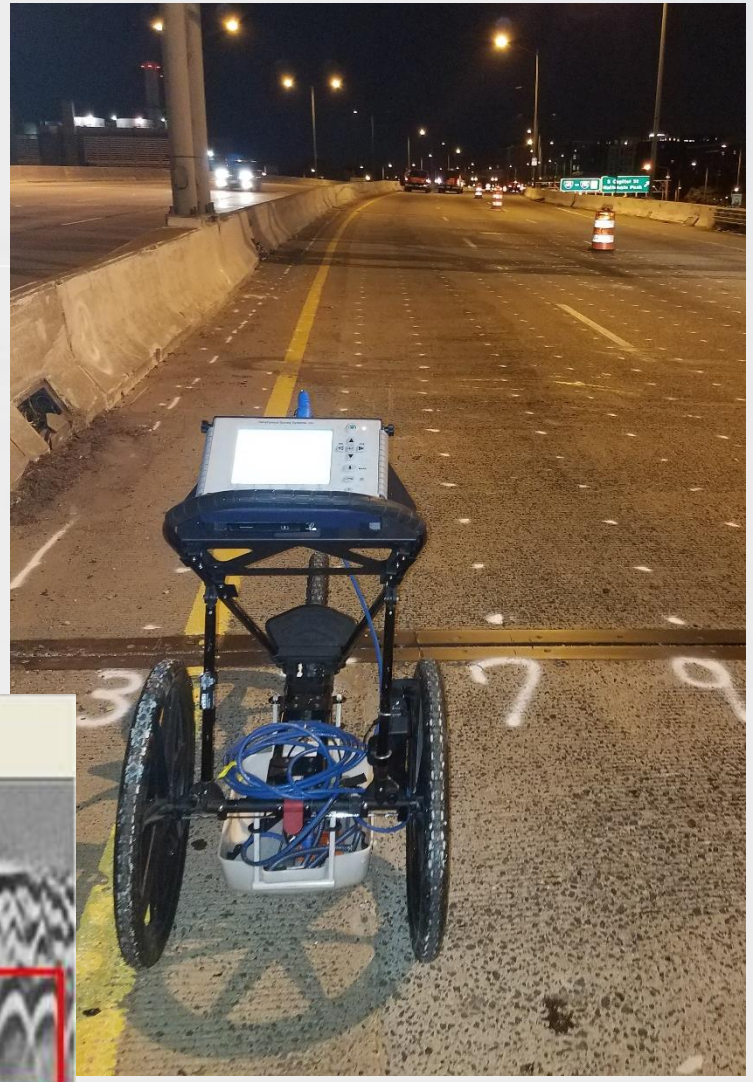
- Identify areas of visual damage
  - Rust staining
  - Cracking
  - Spalls
  - Exposed steel
  - Water infiltration
  - Efflorescence
- Note exposure conditions and other observations

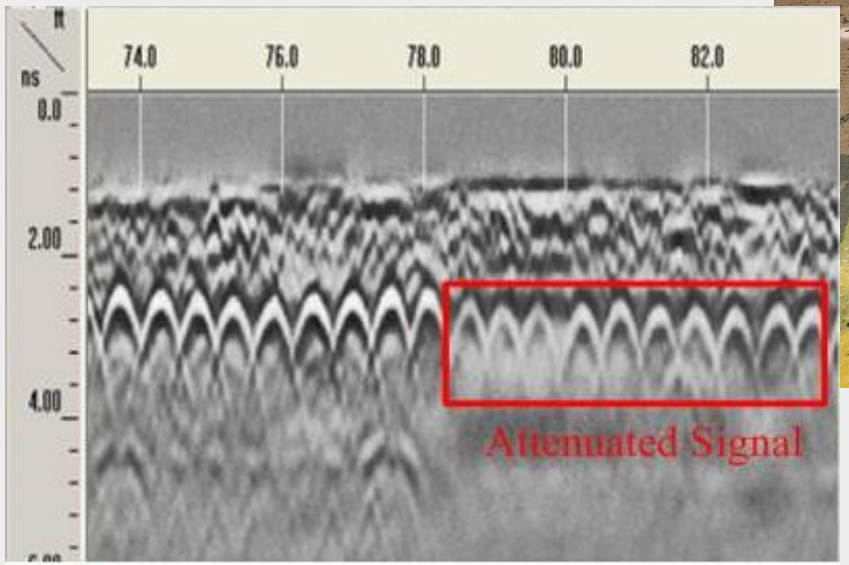
Chain Drag/Hammer Sounding

- 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





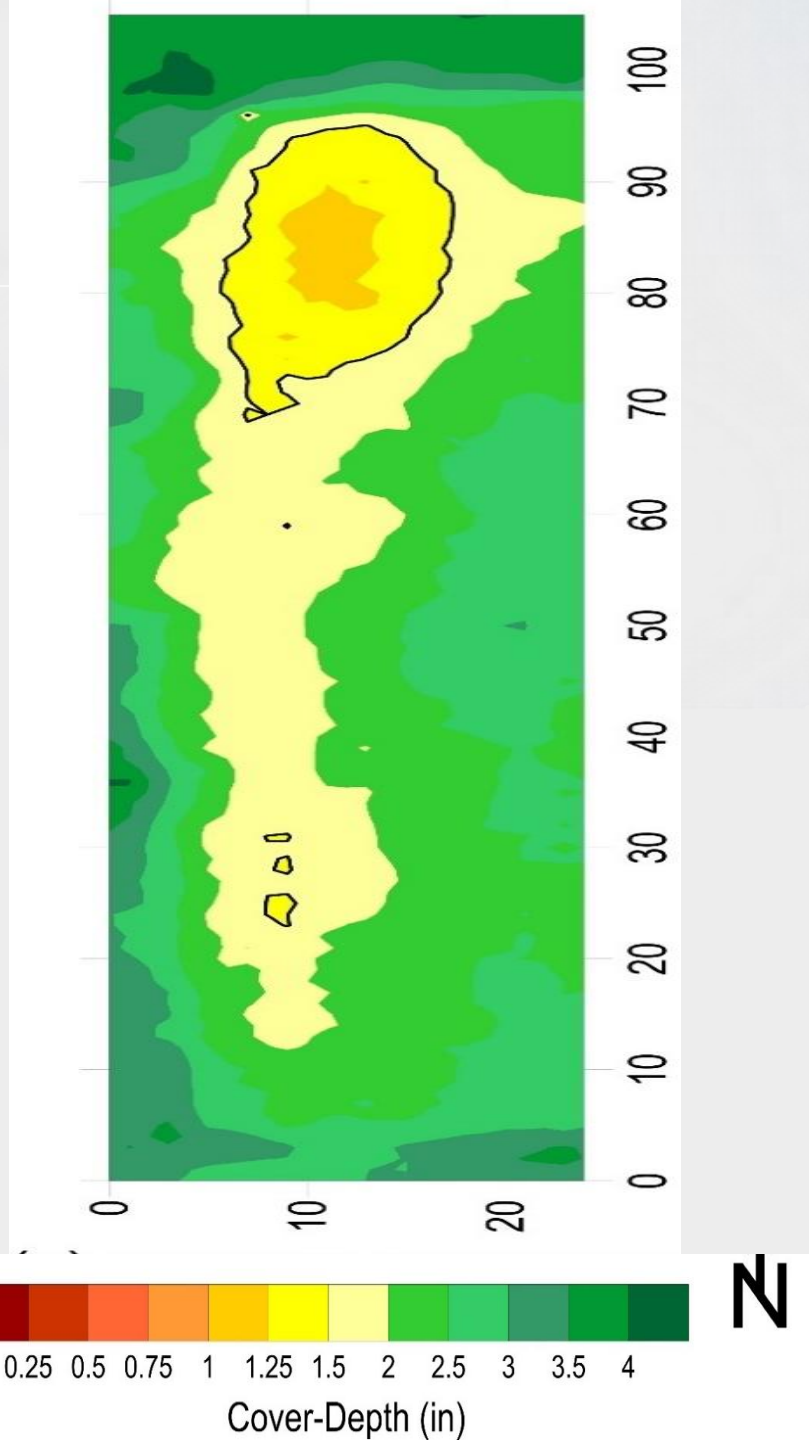
Cover-depth

- 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

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

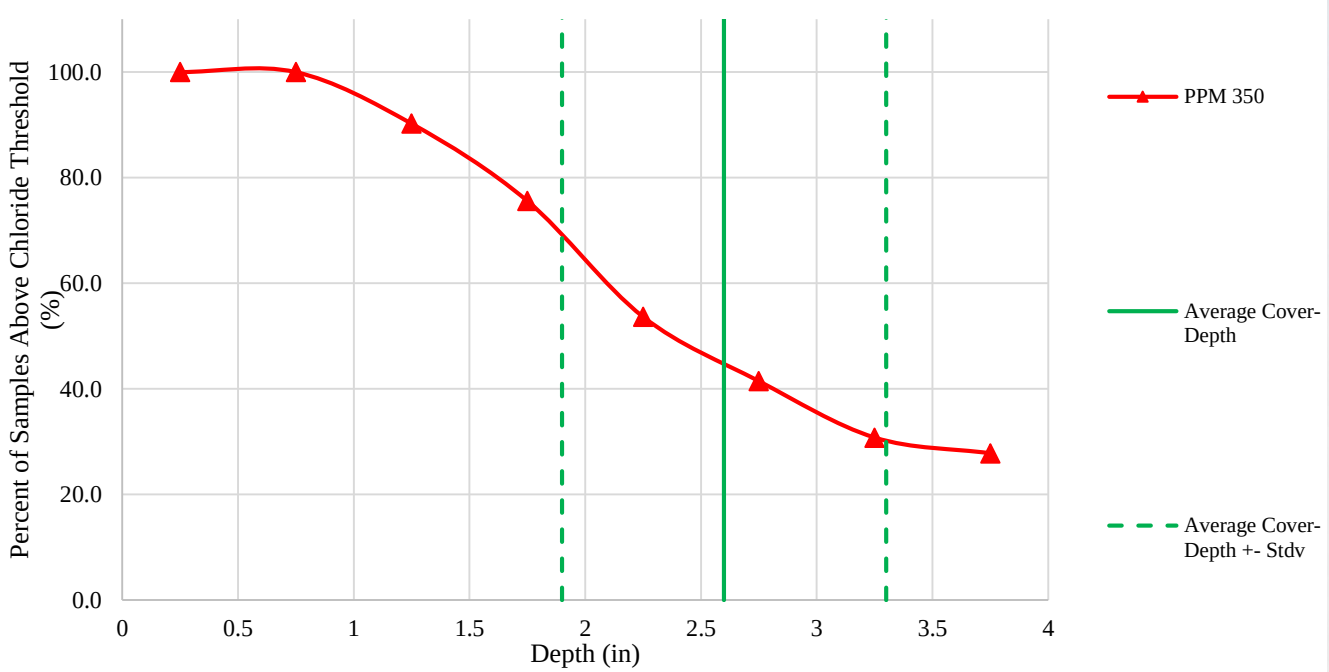
$$t = \frac{1}{D_c}\left[\frac{x}{2 \times inverf\left(1 - \frac{C_{x,t}}{C_o}\right)}\right]^2$$

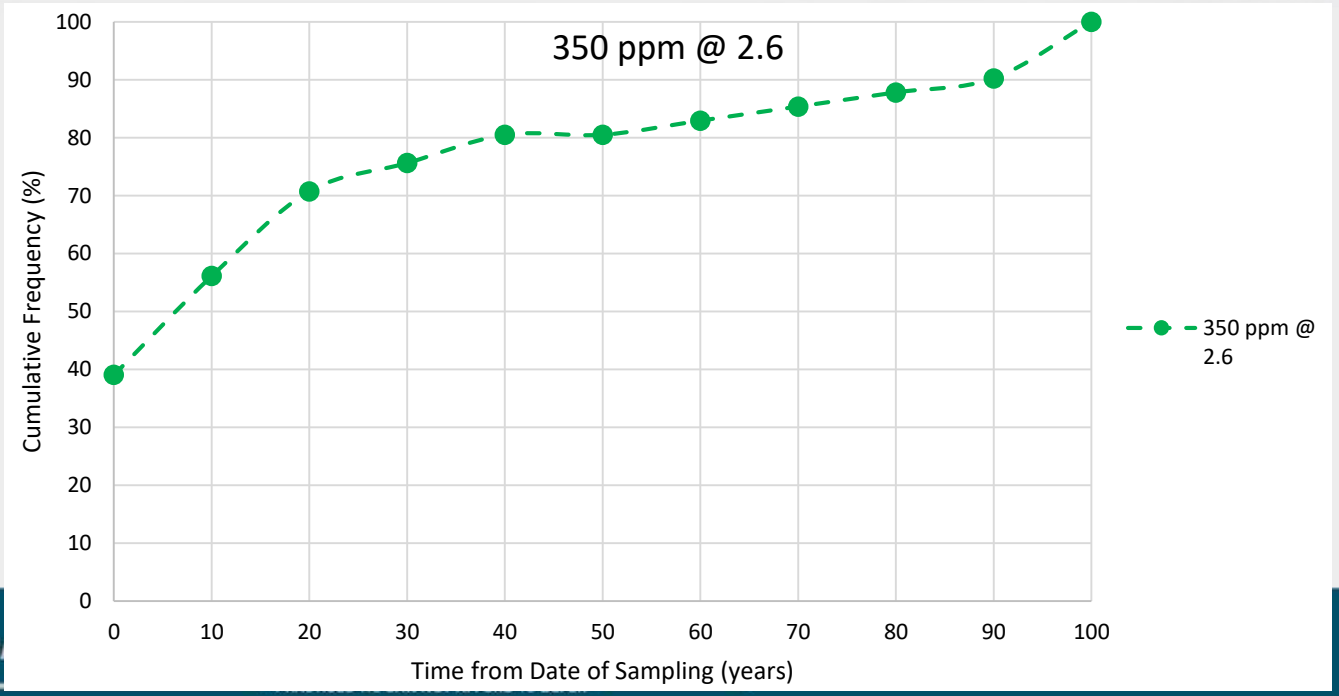
$$t = \left(\frac{d}{A}\right)^2$$



Service Life Analysis

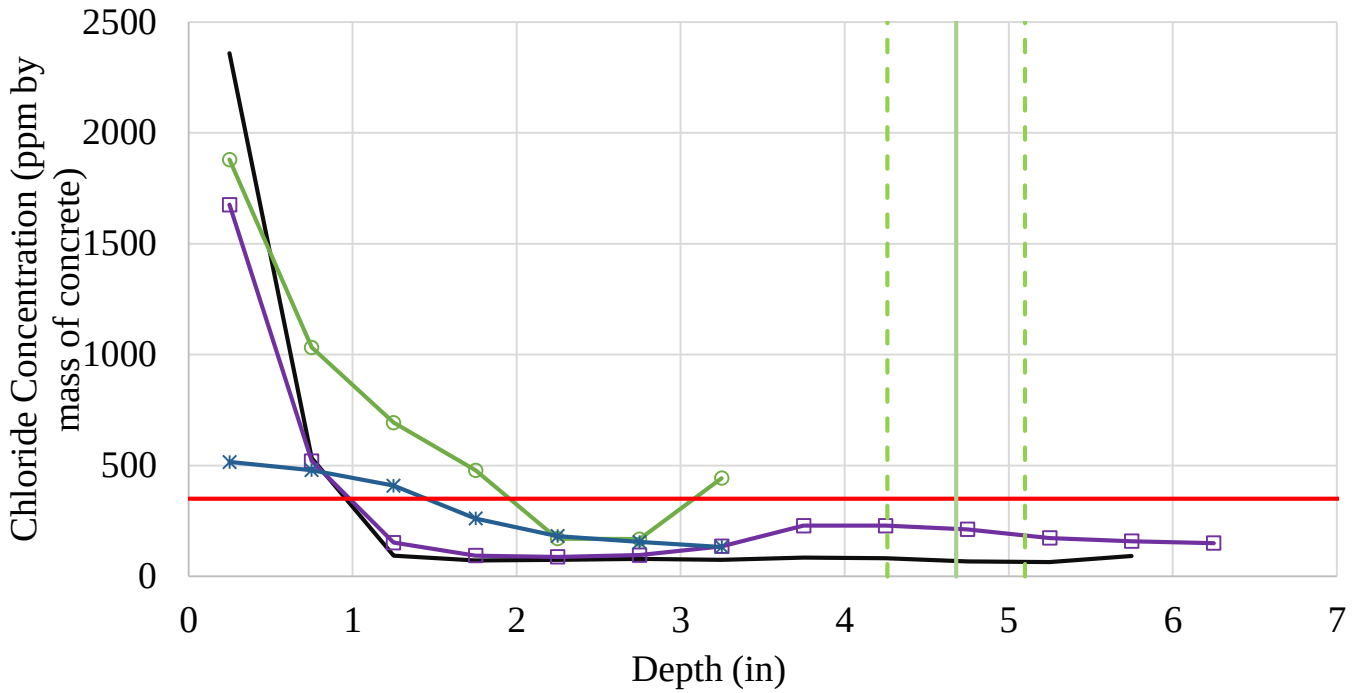
- Cover-depth and chloride concentration are critical inputs regarding service life analysis
  - Calculate diffusion coefficient
- How much of the steel has reached chloride threshold?
- How will that increase over time?

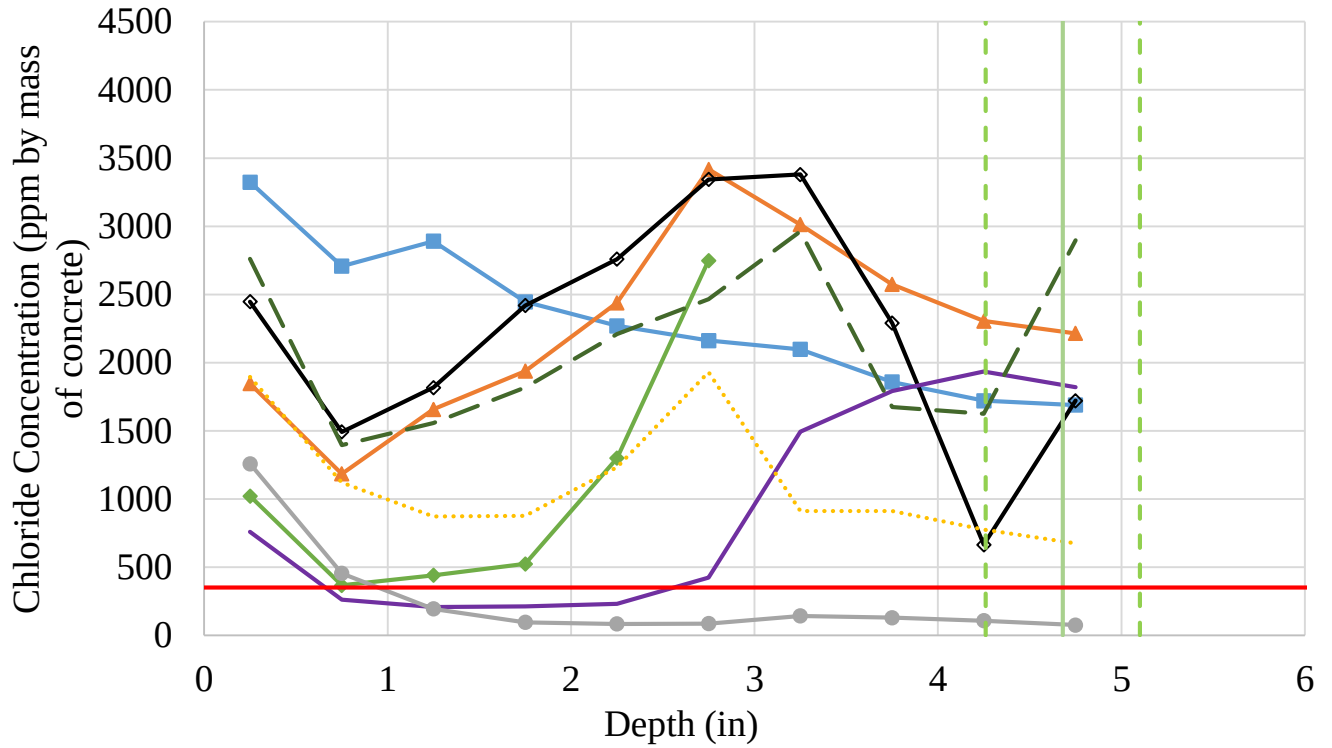




Cracking

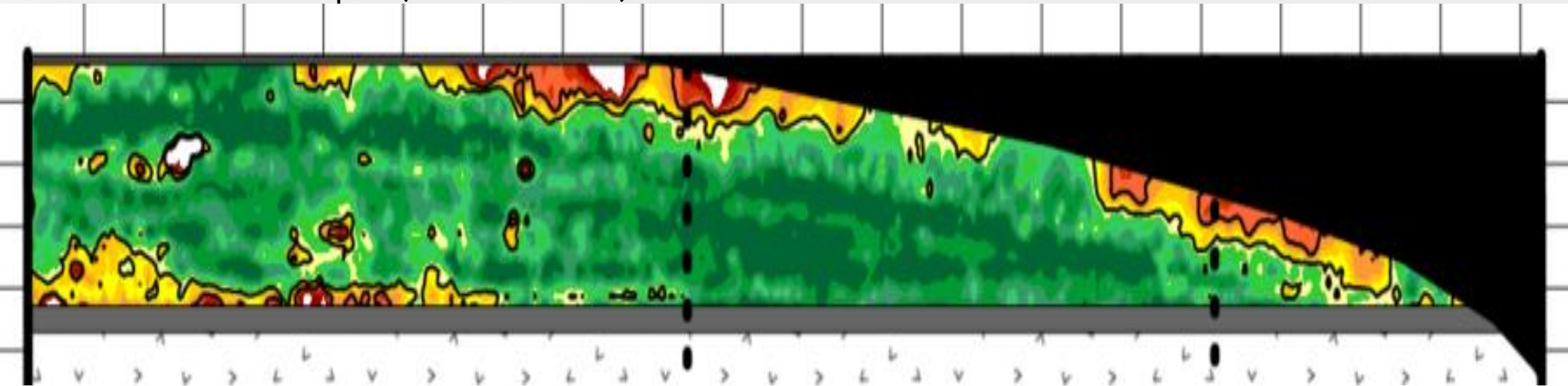
- Cracking in the concrete provides a direct pathway to reinforcement for contaminates
- Many causes of concrete cracking
  - Concrete shrinkage
  - Mechanical stress due to overloading or improper concrete strength, under reinforced
  - ASR
  - Freeze thaw damage



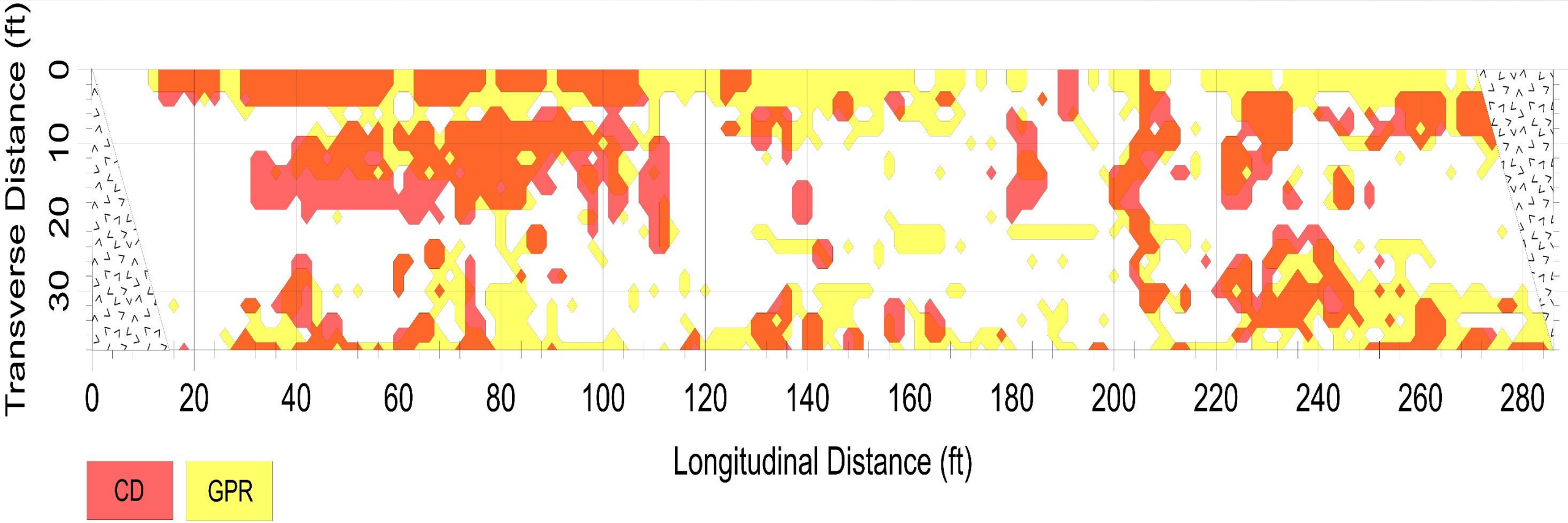


GPR Amplitude Analysis

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

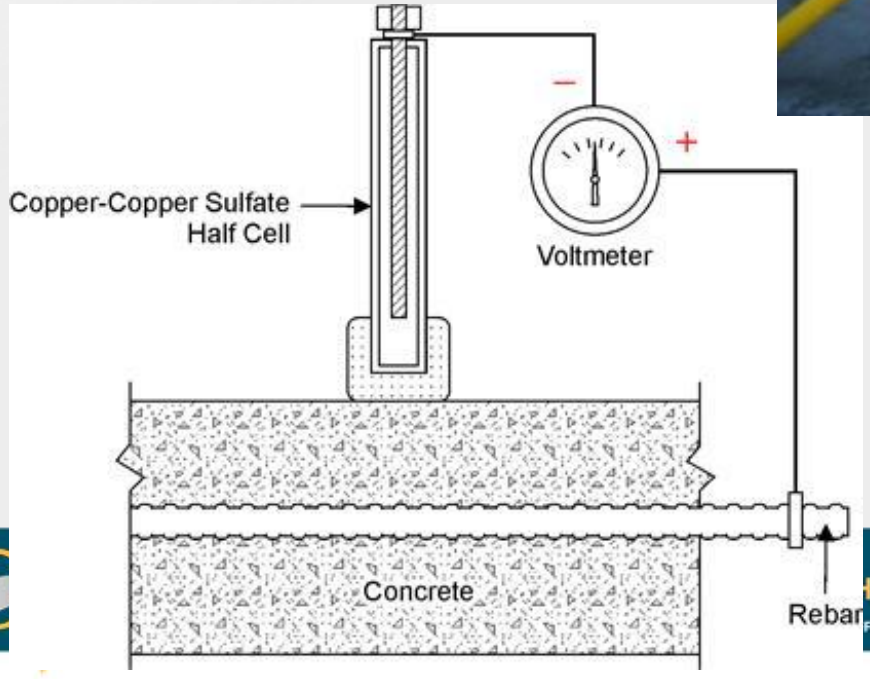


GPR vs Chain Drag



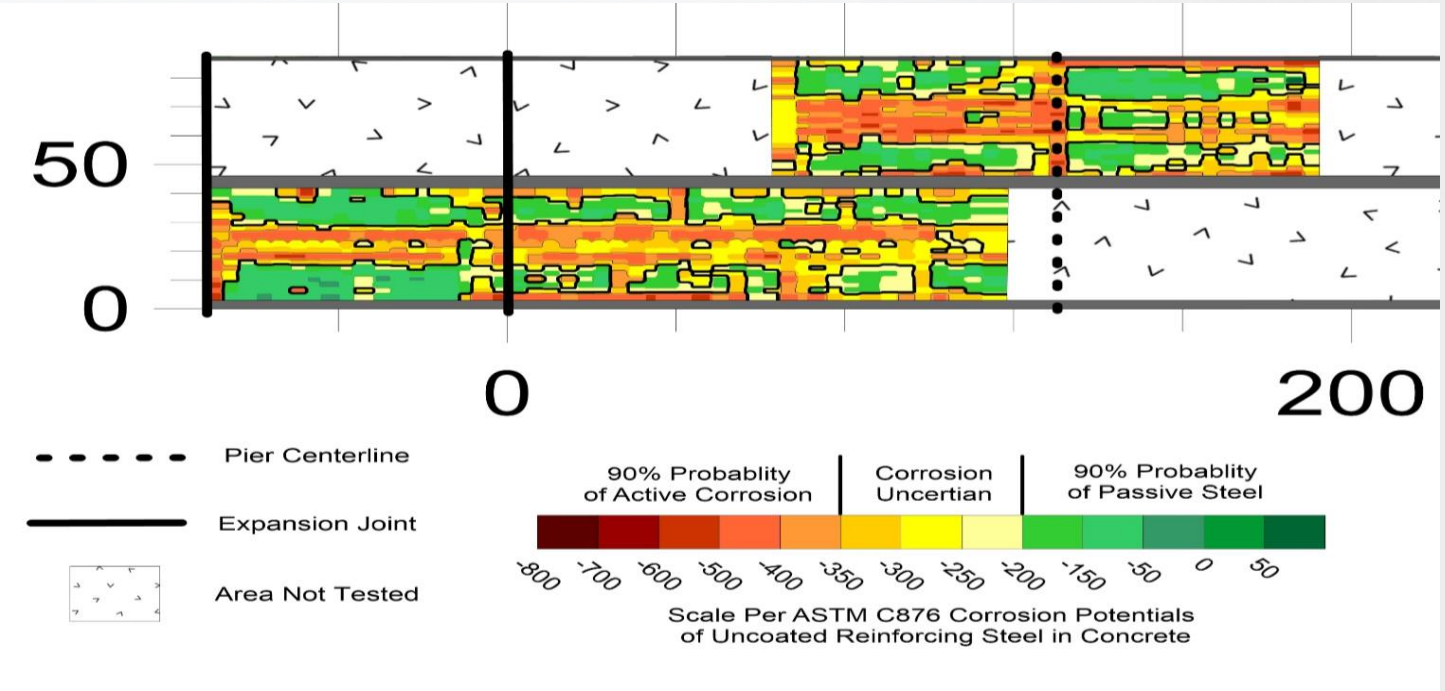
Corrosion Potential (Half-Cell)

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

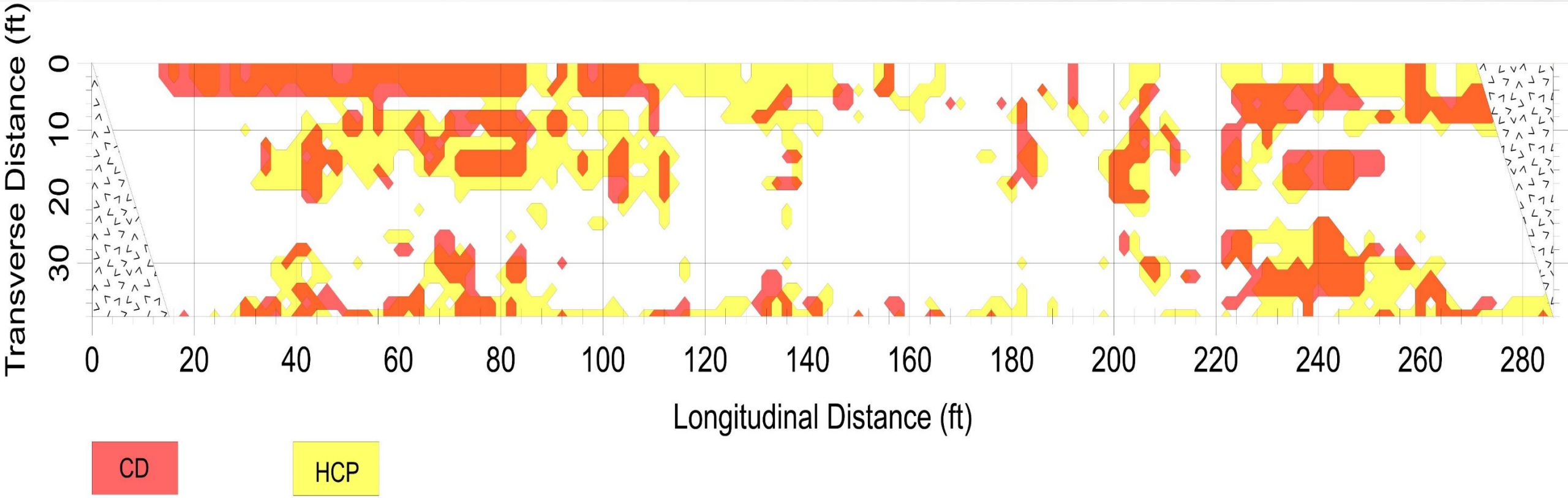


Corrosion Potential Survey

- Corrosion survey of a bridge in Washington DC

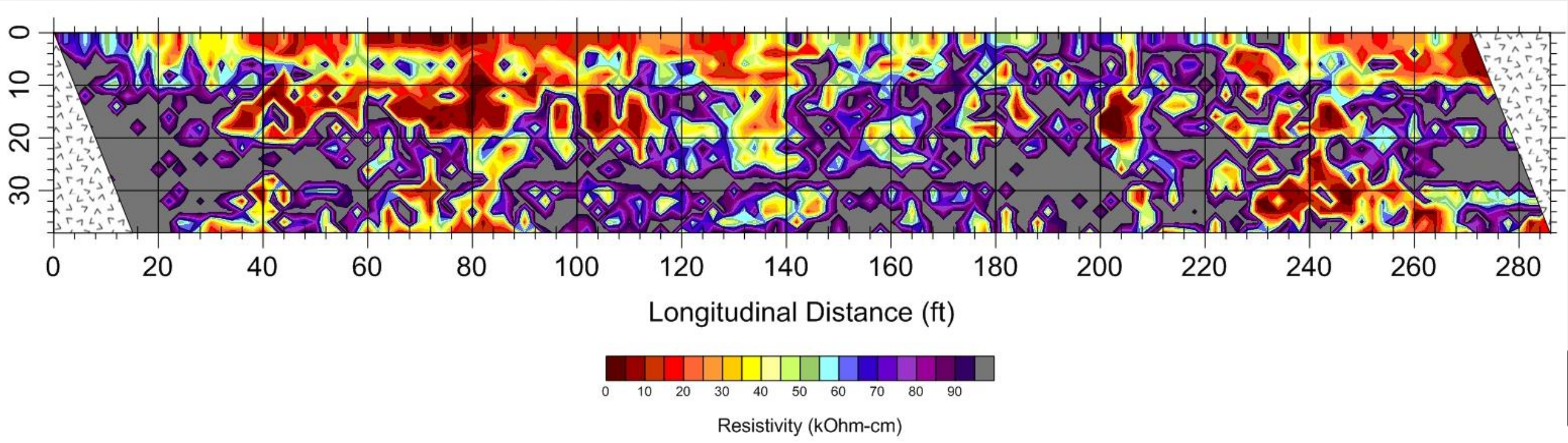


Progression of Corrosion

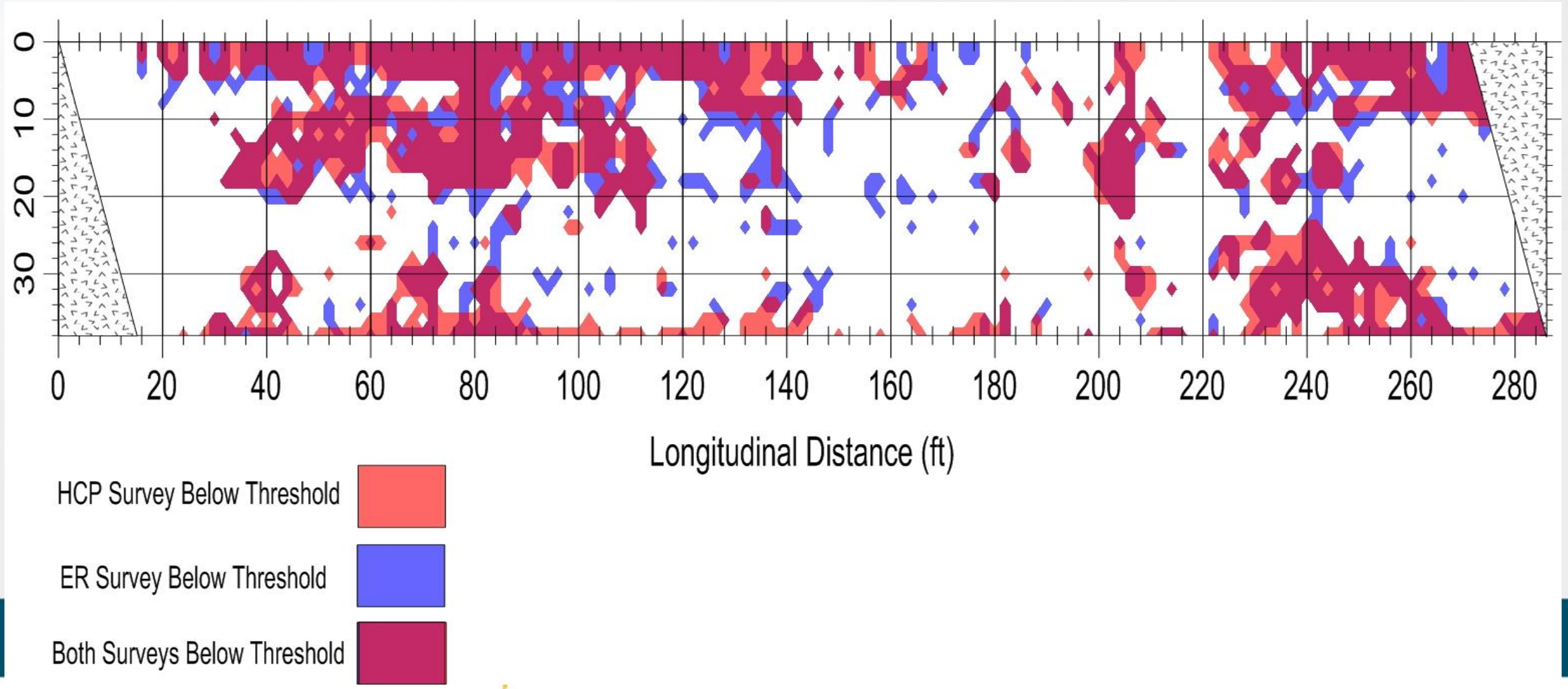


Epoxy Coated Rebar

- 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

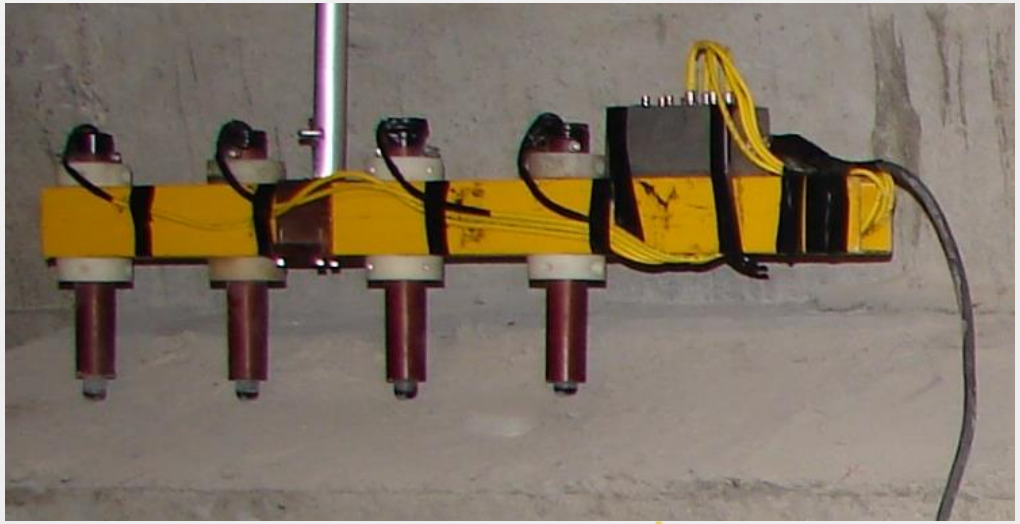


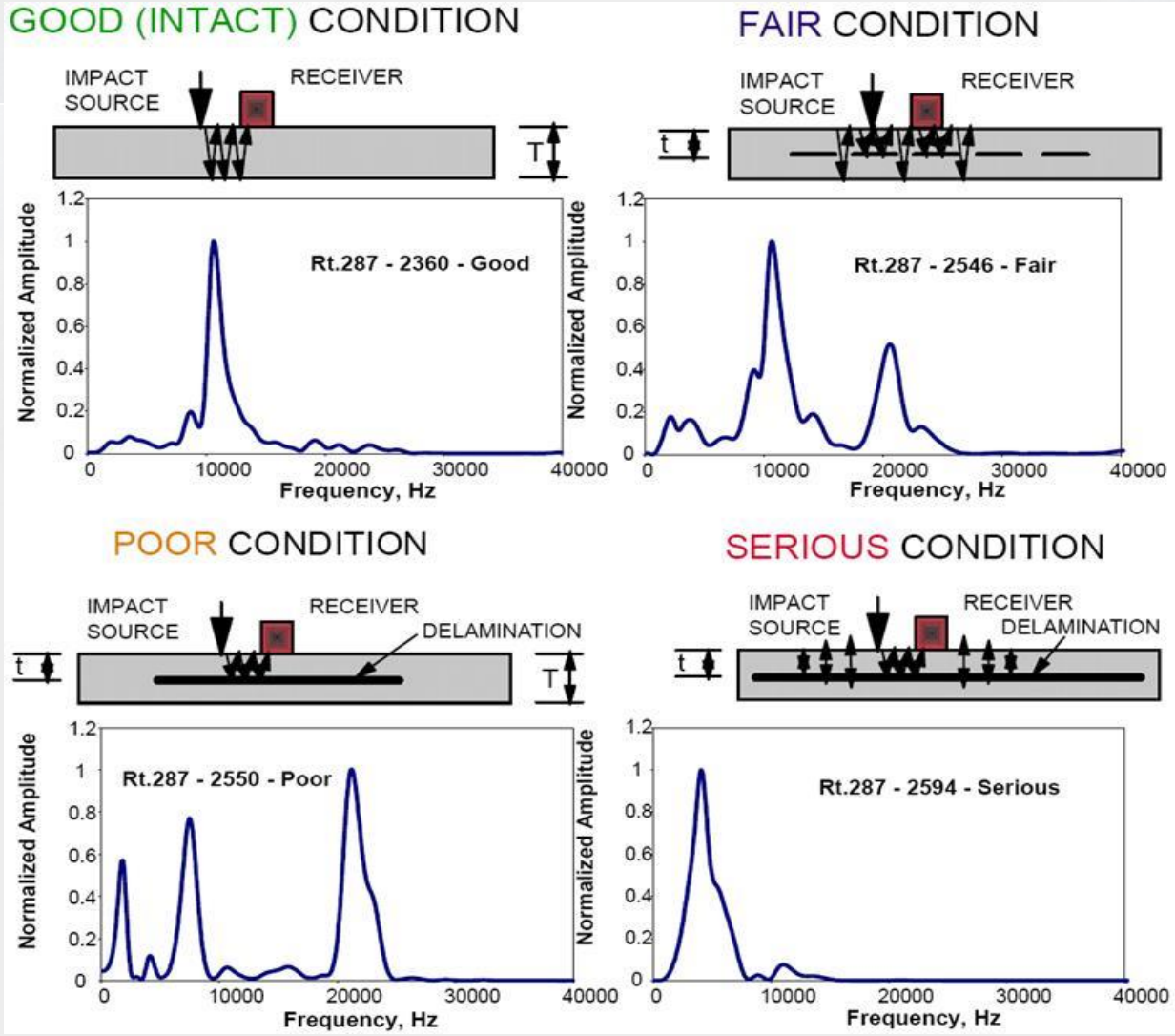
Corrosion Potential vs Resistivity



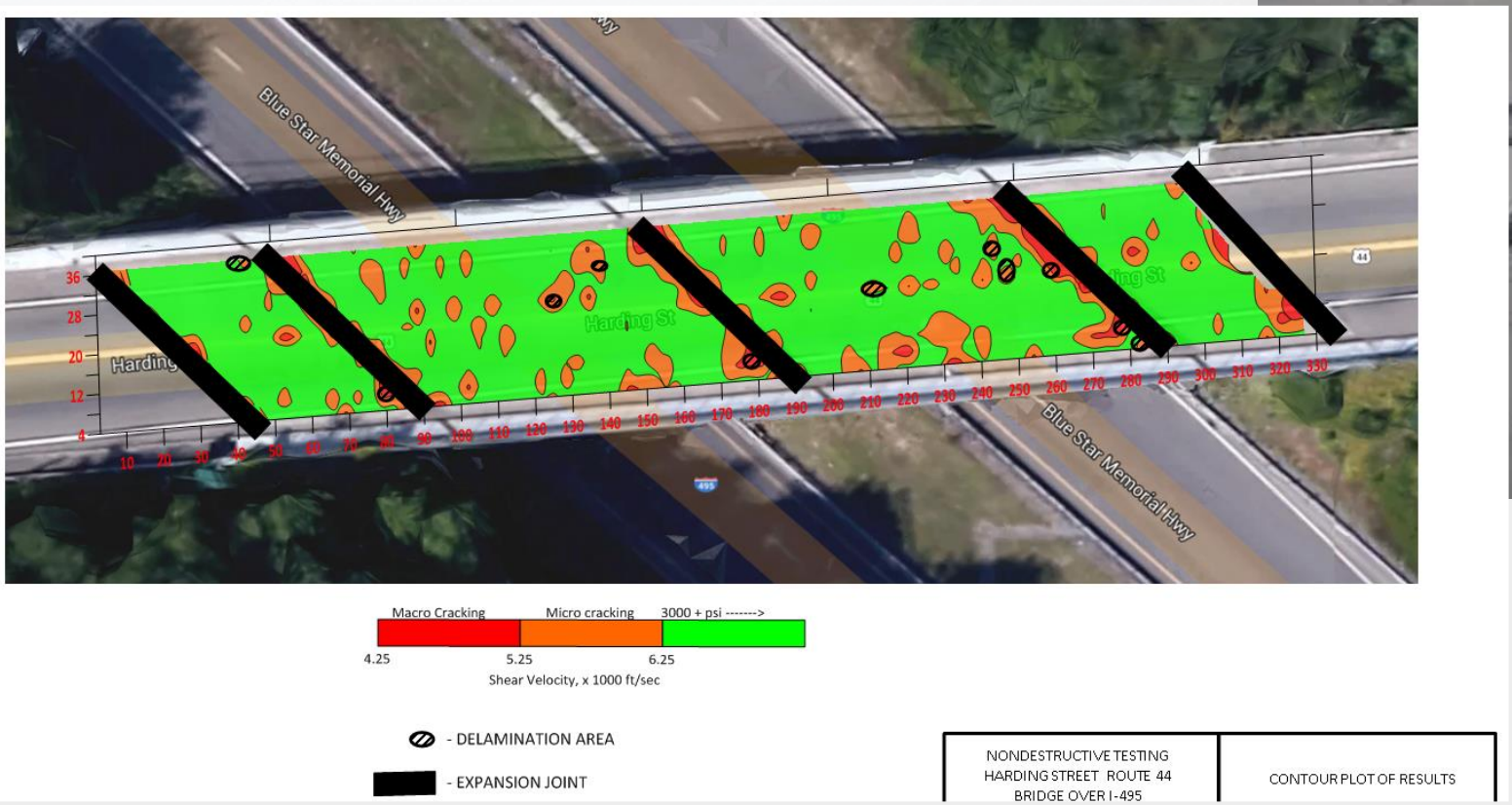
Impact Echo

- Identify thickness of a slab
- Defects will affect the apparent thickness



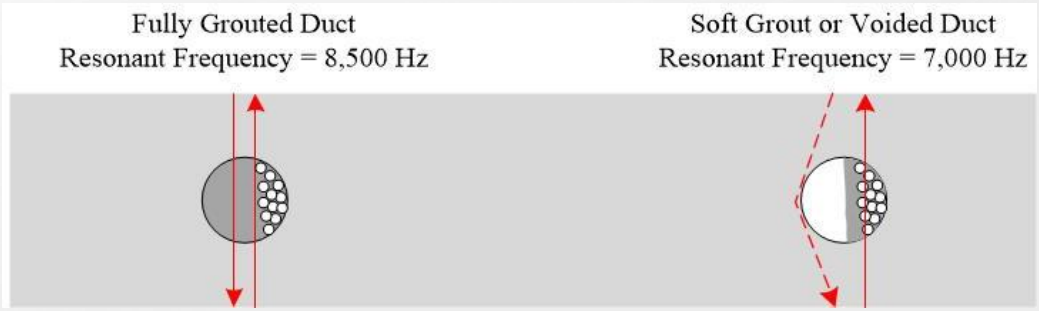


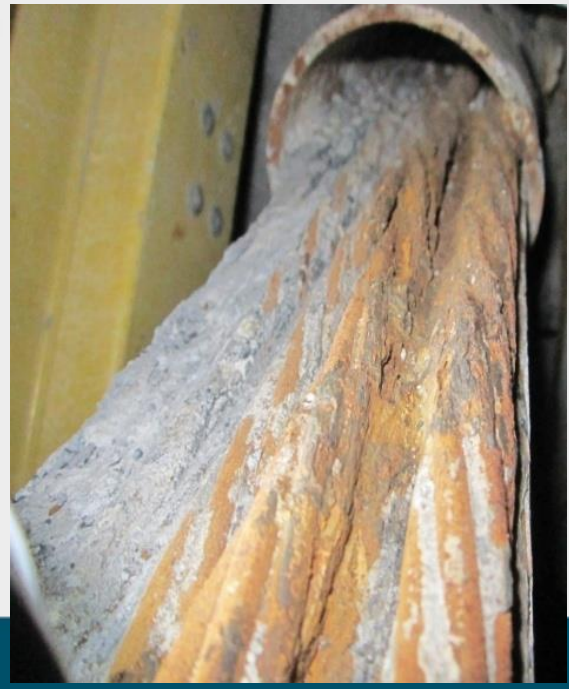
IE Deck Testing



Post Tension Grout Inspection with Impact Echo

- Identify issues like soft grout
- Water or air voids



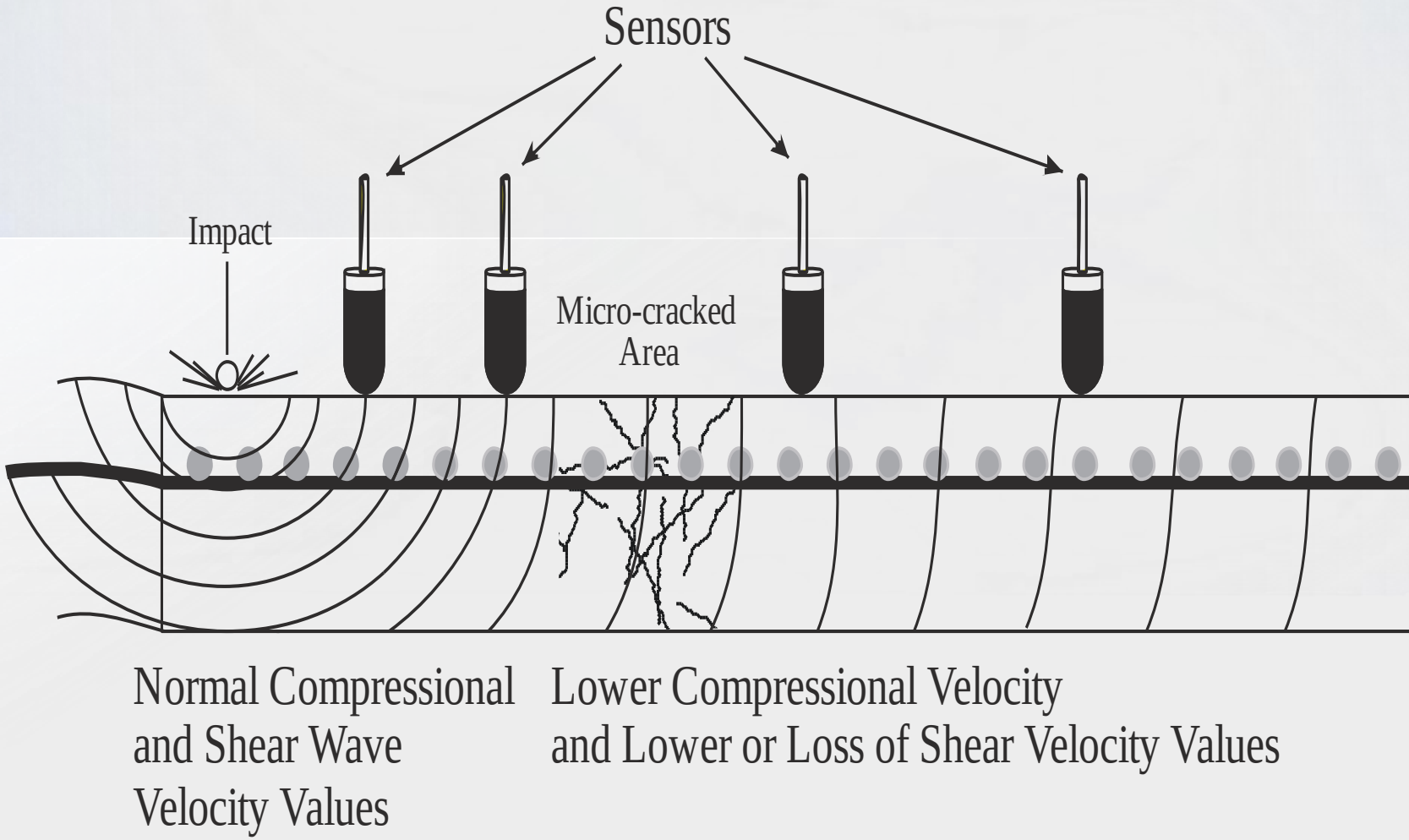


Rogers Overpass

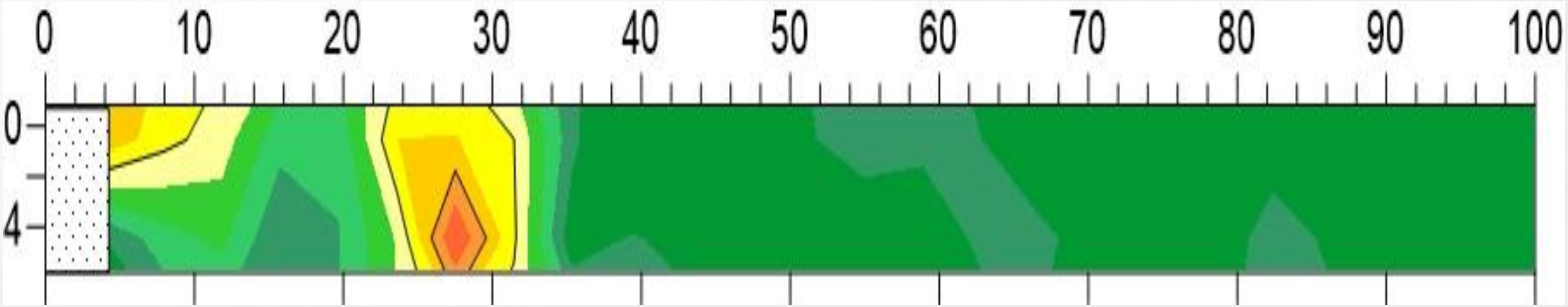
- Pedestrian overpass in Victoria British Columbia
  - 4 PT tendons
- Construction inspector noted that contractor may have made a mistake during PT grouting

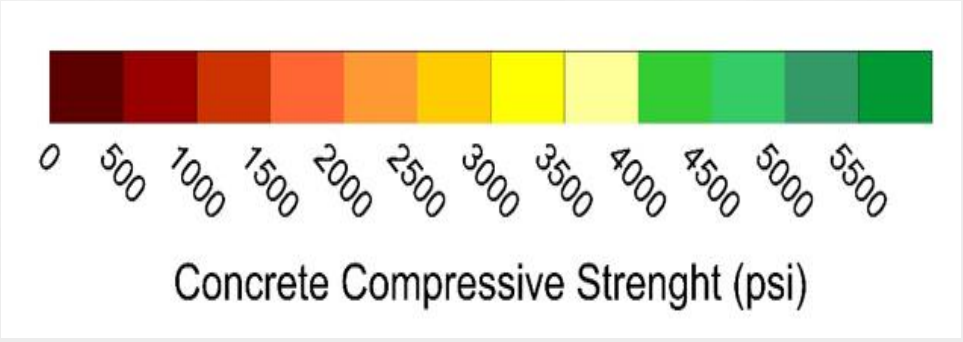
Pulse Velocity

- Velocity of a shear wave is proportional to the compressive strength of the concrete



Identification of deteriorated concrete





Thank You