# Condition Assessment of Bridges in the United States

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WJE

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# Outline

- Concrete Materials Distress in Bridges
- NDE Methods for Evaluating Materials Distress
  - Visual Assessment
  - Delamination and Void Detection
  - Corrosion Condition Assessment
- Recent Project Examples

# Materials-Related Distress

- Cracks
- Delaminations
- Spalls
- Efflorescence
- Corrosion staining
- Scaling
- Pop-outs
- …

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Shrinkage

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Shrinkage

Corrosion of Reinforcing Steel

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Freeze-Thaw Distress

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Freeze-Thaw Distress

Alkali-Aggregate Reaction (ASR, ACR)

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# NDE Methods for Evaluating Materials Distress

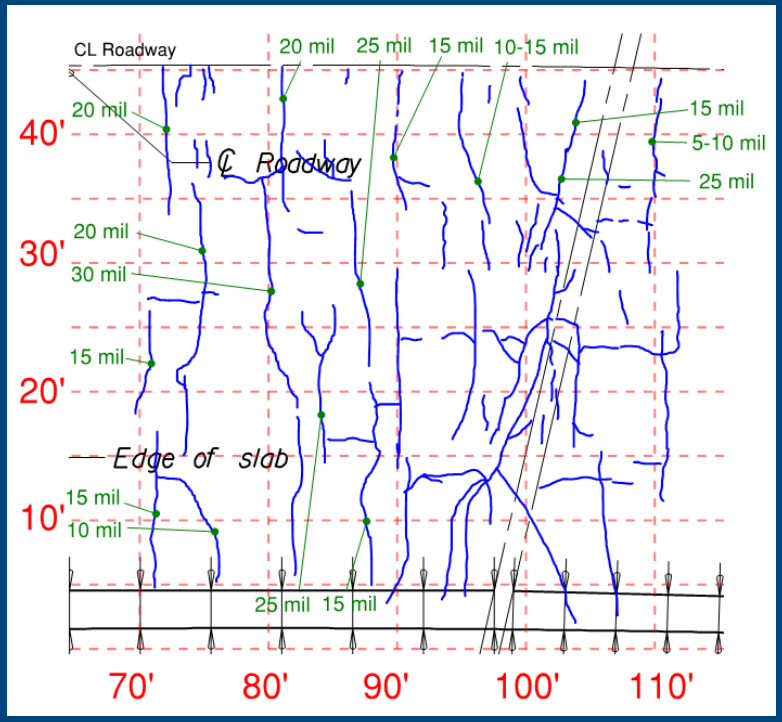
**VISUAL ASSESSMENT**

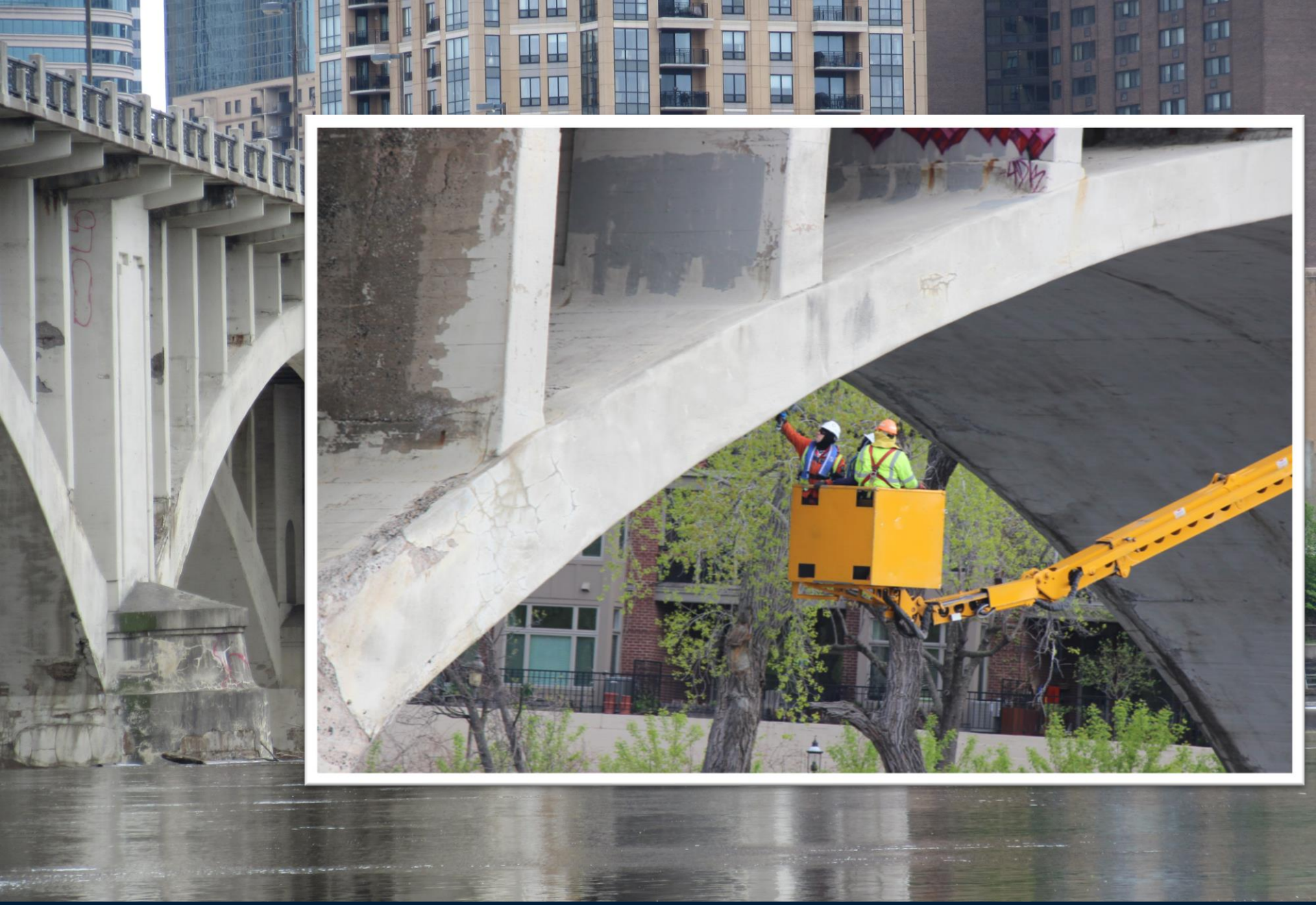
**DELAMINATION AND VOID DETECTION**

**CORROSION CONDITION ASSESSMENT**

# Visual Assessment

- Primary condition assessment technique
  - What features are present?
  - Where?
  - What size? Shape? Orientation?
  - Pattern?

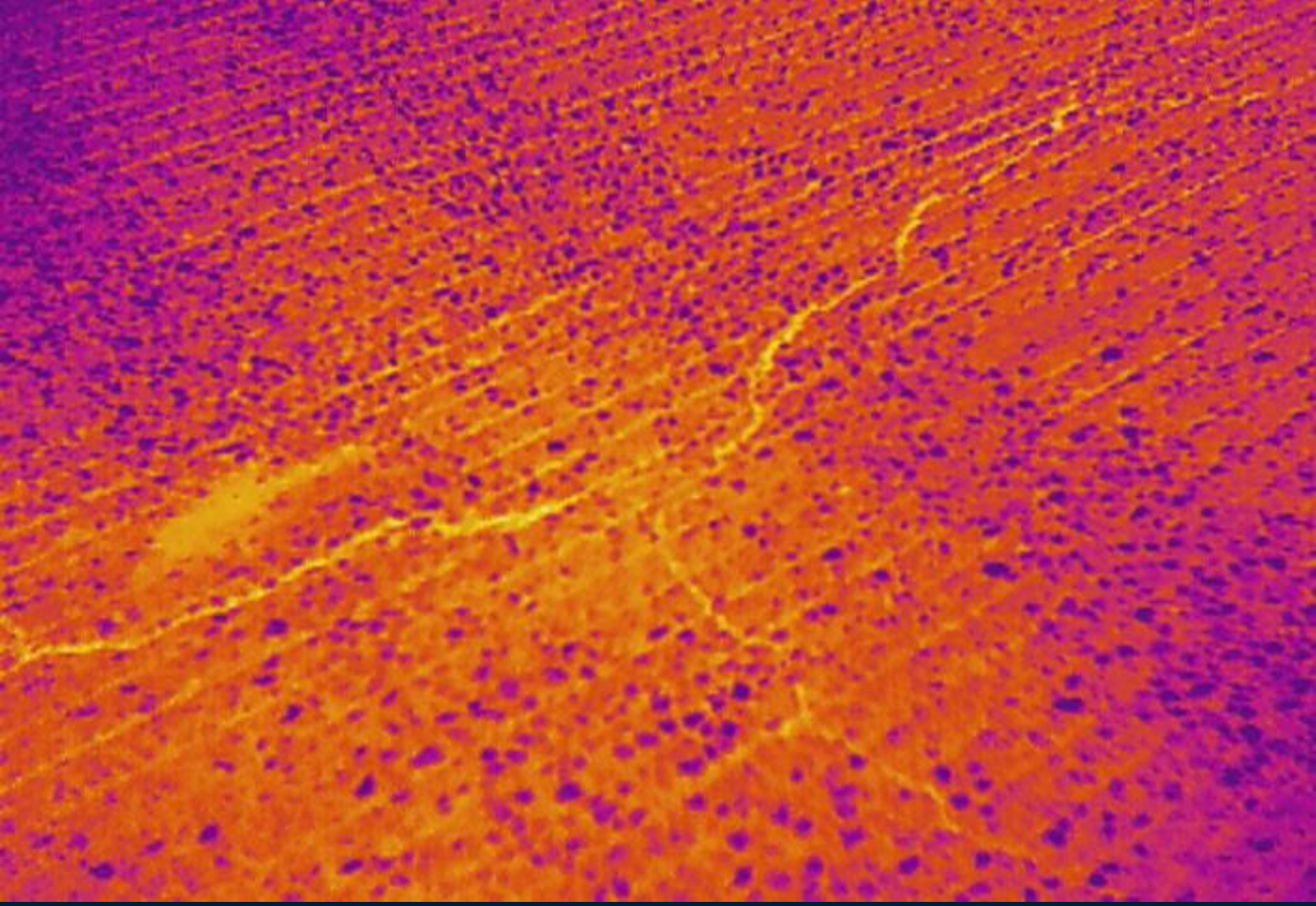




# Visual Assessment

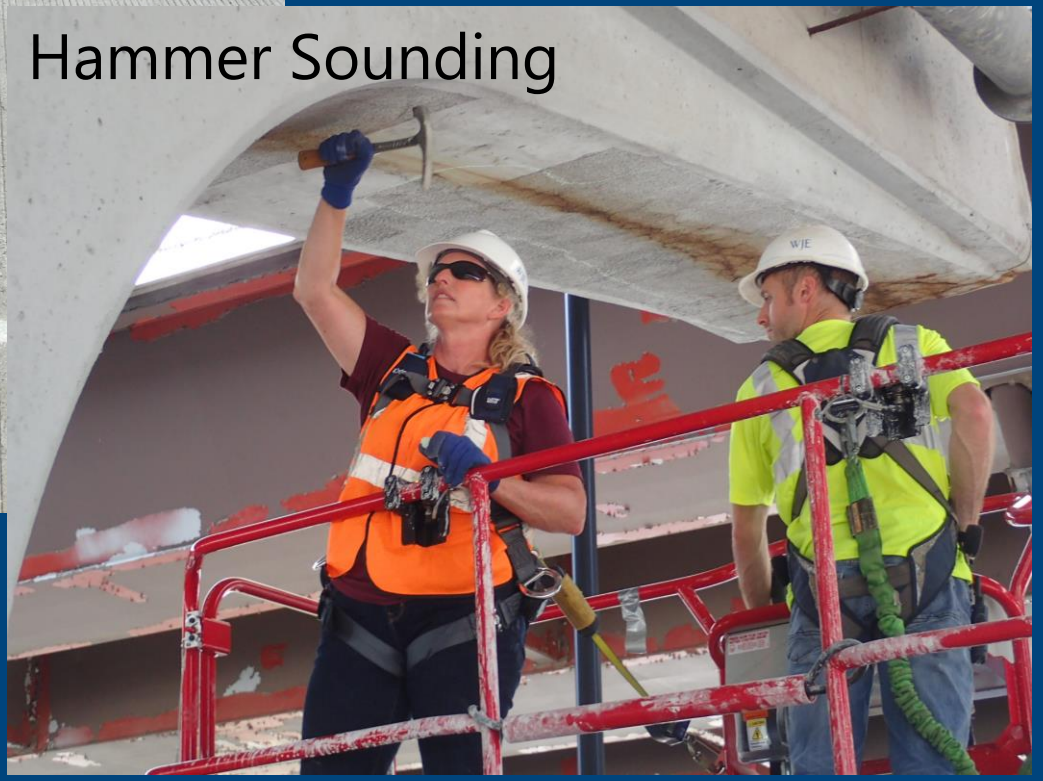
- Advanced option:
  - UAV-assisted visual assessment


B3



# Delaminations and Voids

# Delamination and Void Detection

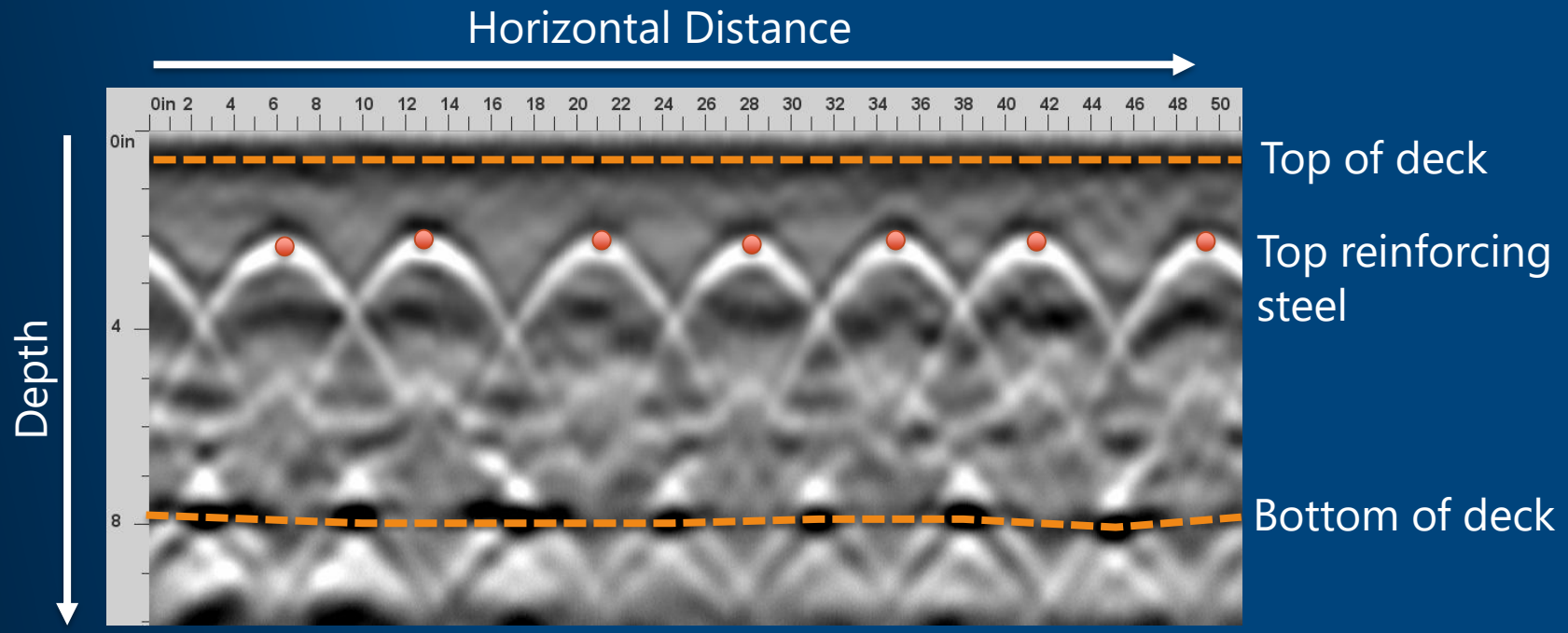



# Delamination and Void Detection

- Advanced Options:
  - Ground Penetrating Radar (GPR)
  - Infrared Thermography
  - Impulse Response
  - Impact-Echo
  - Ultrasonic Methods
  - Shearwave Tomography

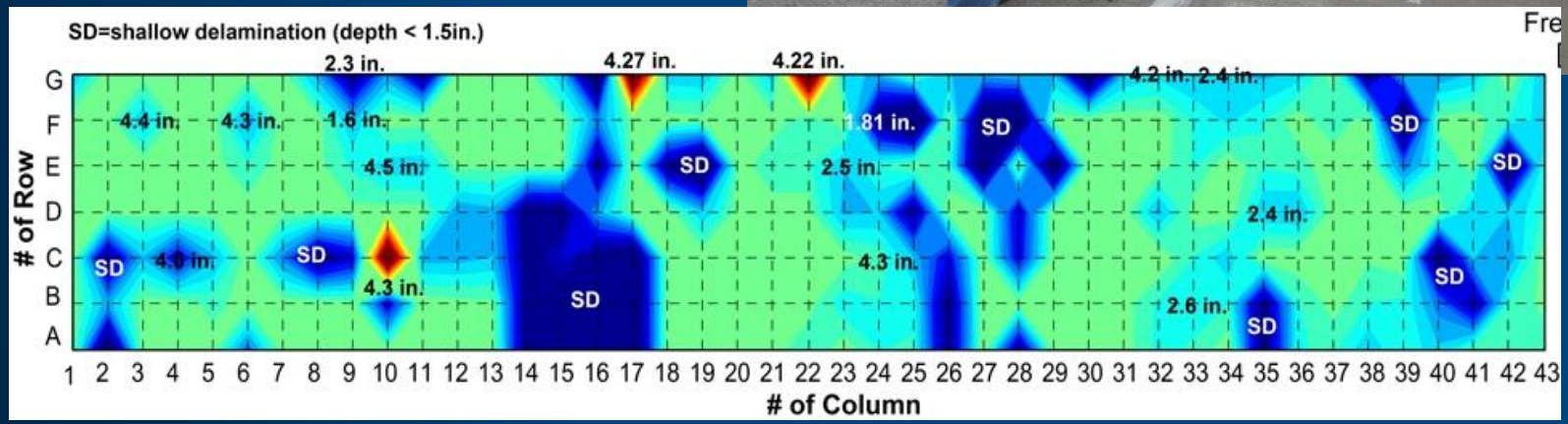
# Ground Penetrating Radar (GPR)

- Uses high-frequency electromagnetic waves to acquire subsurface information



# Ground Penetrating Radar (GPR)

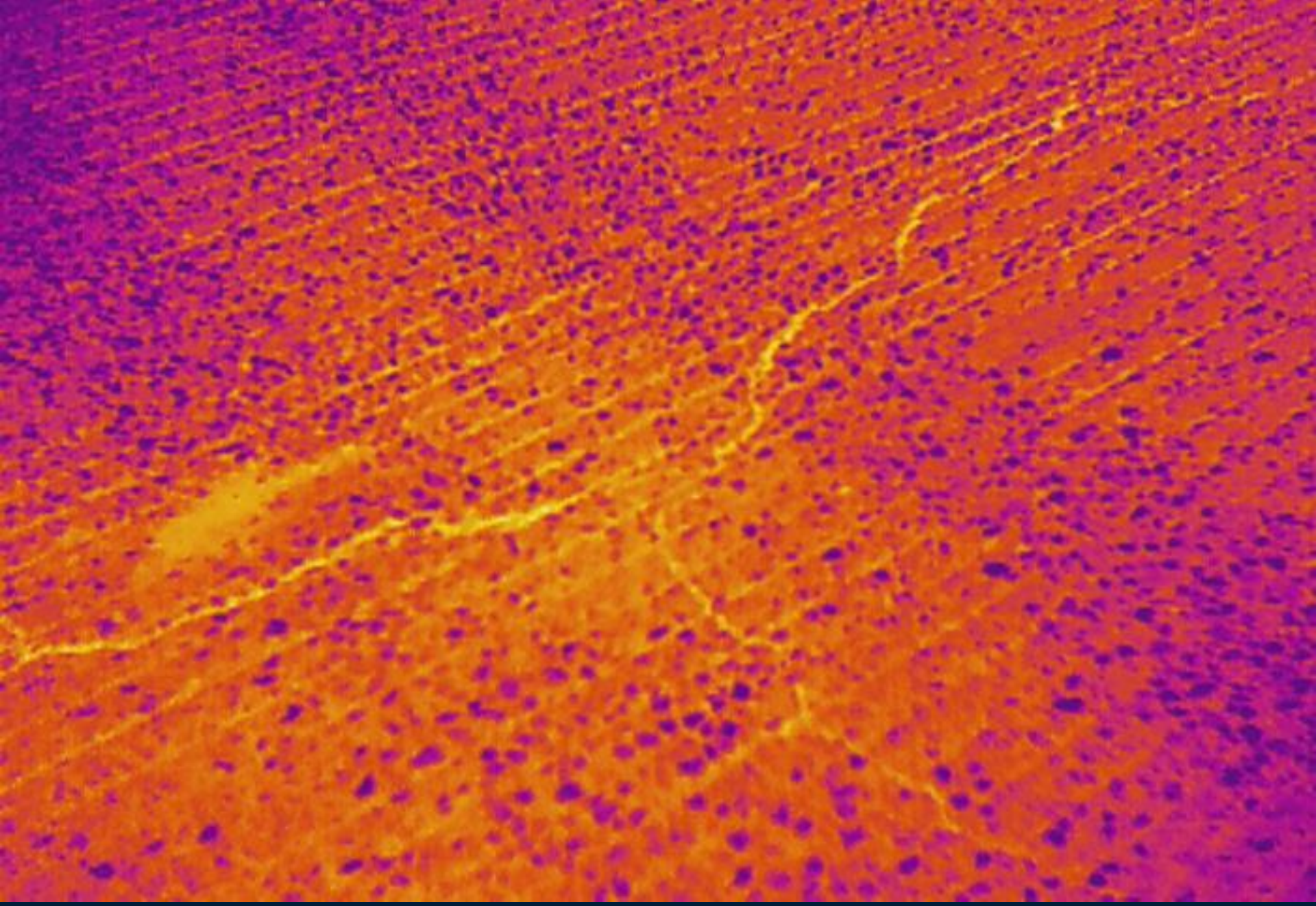
Can also perform area scans to map delaminations in bridge decks

# Infrared Thermography

- Cracked, voided and delaminated concrete emits different thermal radiation than sound concrete

- Can use thermograms to identify cracks, voids, and delaminations



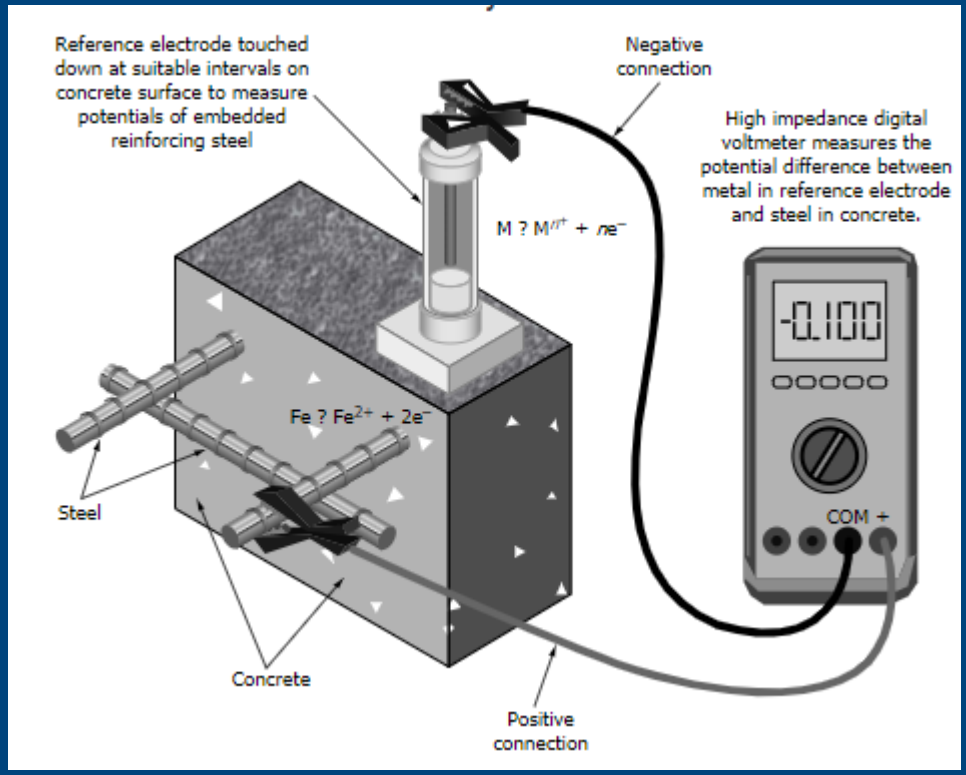
# Corrosion Assessment

# Corrosion Assessment

- Half-cell potential (HCP)
- Surface resistivity
- Corrosion rate measurement
  - Contactless electrical pulse response analysis (CEPRA)
  - Linear polarization resistance (LPR)

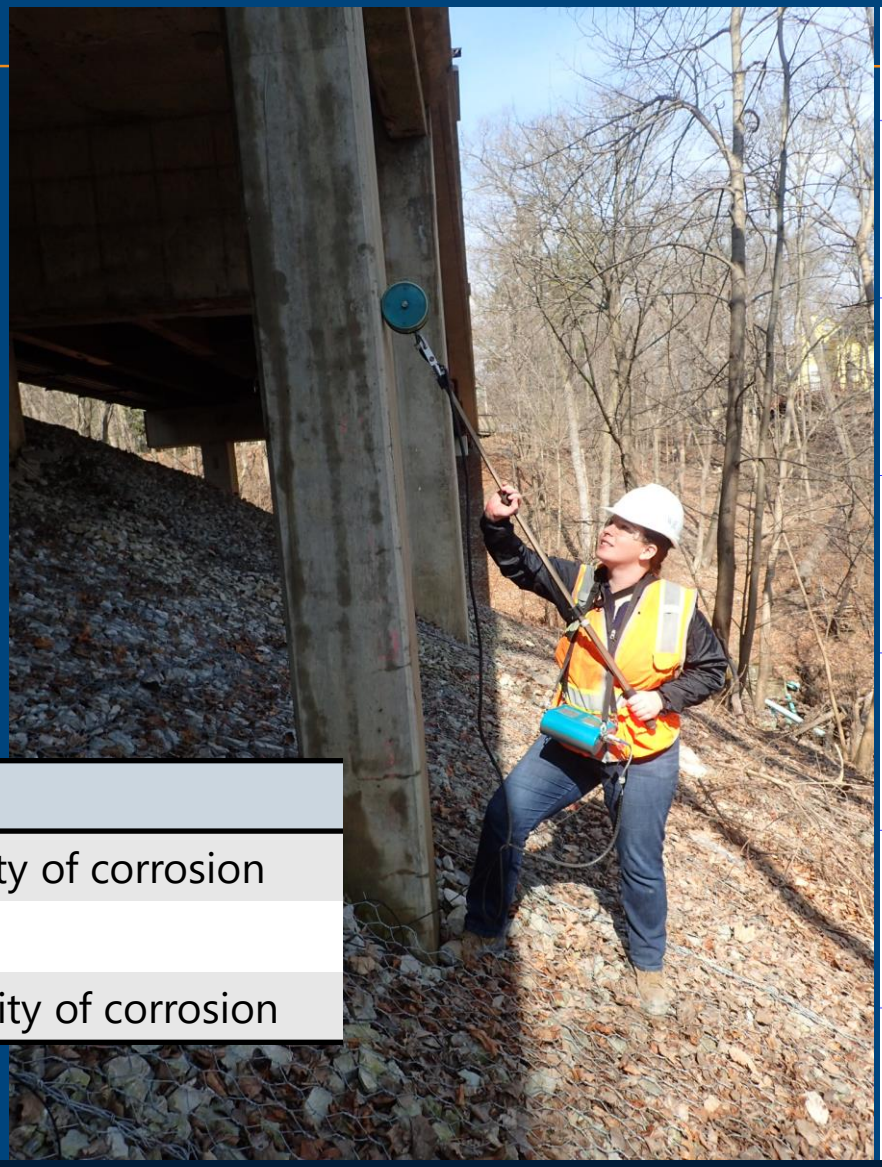
# Half-Cell Potential

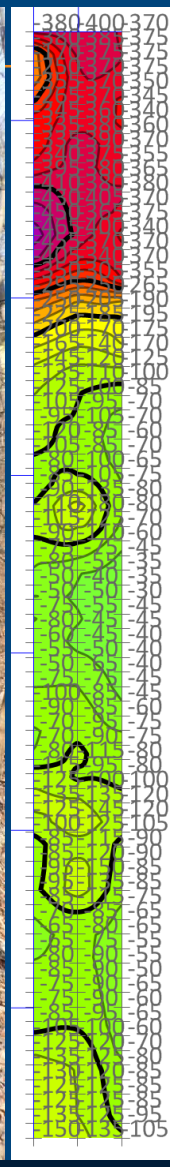
Electrical method used to detect areas of active corrosion that have not yet resulted in delaminations or spalls



# Half-Cell Potential

Surveys conducted over area of element (deck, column, pier, etc.)



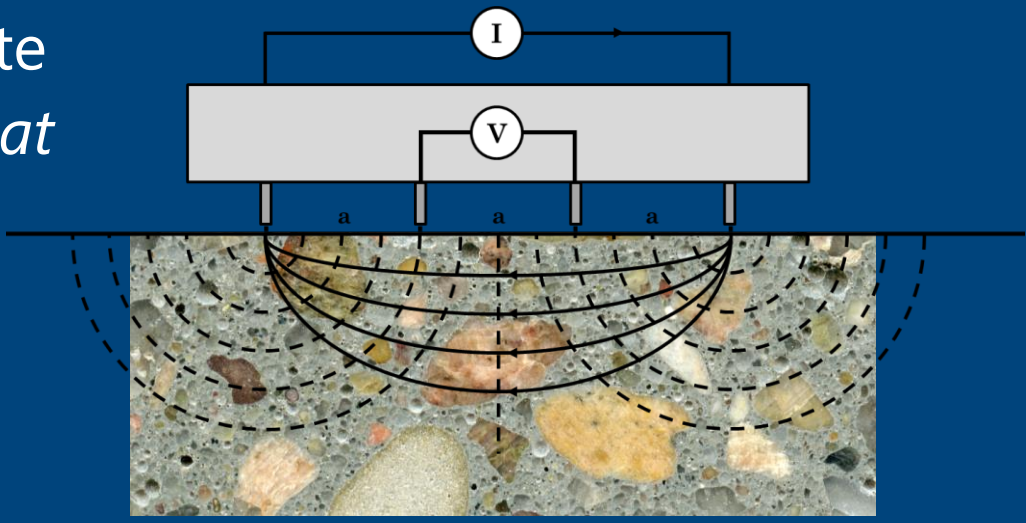


ASTM C876, uncoated black bar

| HCP vs. CSE | Corrosion Activity |
|---|---|
| > -200 mV | Low: <10% probability of corrosion |
| -200 to -350 mV | Moderate |
| < -350 mV | High: >90% probability of corrosion |

# Surface Resistivity

Electrical property of concrete correlated with *conditions that promote* increased risk of active corrosion



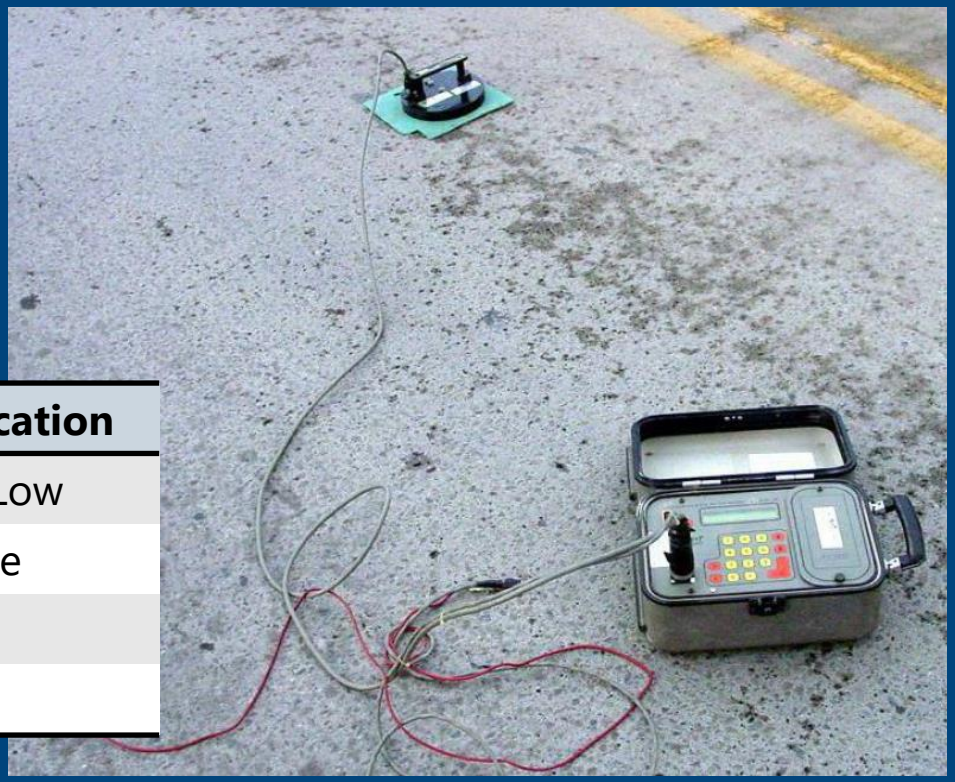

| Resistivity (kOhm-cm) | Corrosion Rate and Damage Risk |
|---|---|
| > 100 | Negligible |
| 50 to 100 | Low risk; corrosion rates likely to be low |
| 10 to 50 | Moderate risk; moderate to high corrosion rates possible in active areas |
| < 10 | High risk; resistivity is not controlling factor |

# CEPRA

- Connectionless Electrical Pulse Response Analysis
- Measures electrical response of reinforcing to AC current
  - Corroding and non-corroding bars have different responses at different frequencies → estimation of corrosion rate

# Linear Polarization Resistance (LPR)

- Applies small potential shift to tested steel
- Resulting current is proportional to corrosion rate



| Corrosion Rate | | Classifiication |
|---|---|---|
| < 1.0 μA/cm$^2$ | < 10 μm/yr | Passive/Low |
| 1 to 3 μA/cm$^2$ | 10 to 30 μm/yr | Moderate |
| 3 to 10 μA/cm$^2$ | 30 to 100 μm/yr | High |
| > 10 μA/cm$^2$ | > 100 μm/yr | Severe |

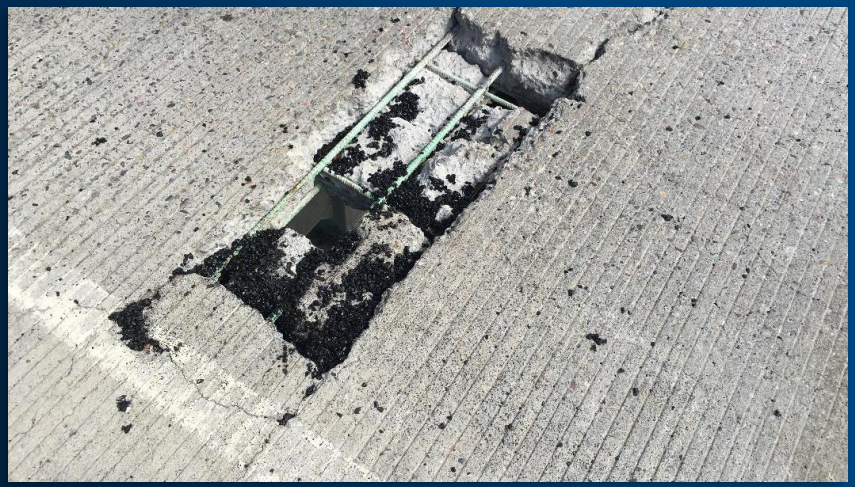
# Recent Examples

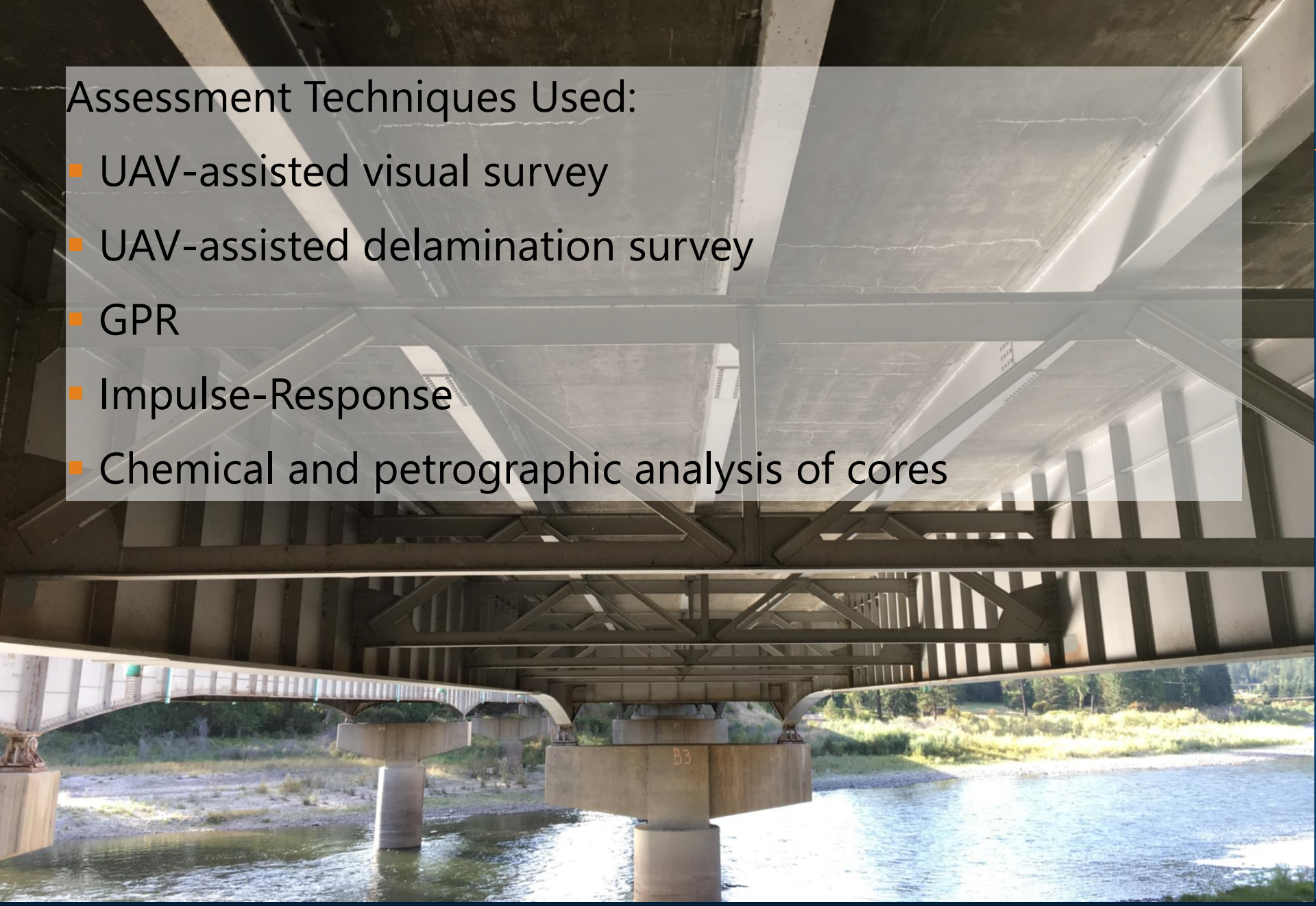
**BRIDGE DECKS IN MONTANA**

**BRIDGE PIERS IN NEBRASKA**

# Example: Bridge Decks in Montana

22 bridge decks in western Montana experiencing advanced deterioration after 2-10 years of service






Assessment Techniques Used:

- UAV-assisted visual survey
- UAV-assisted delamination survey
- GPR
- Impulse-Response
- Chemical and petrographic analysis of cores

# Example: Bridge Decks in Montana

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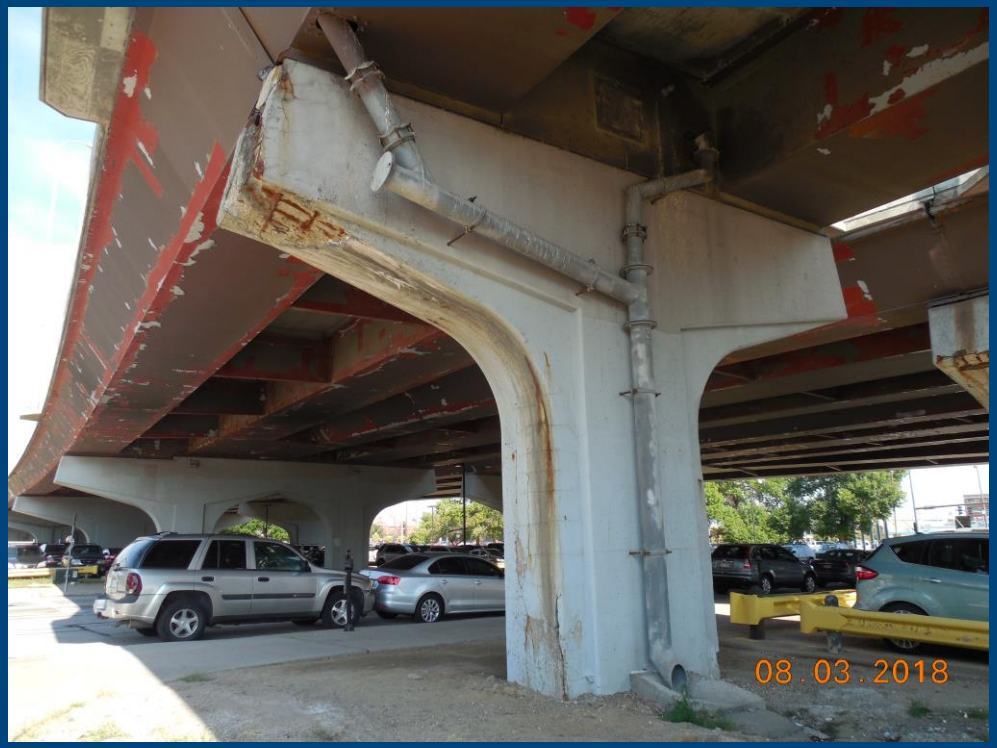
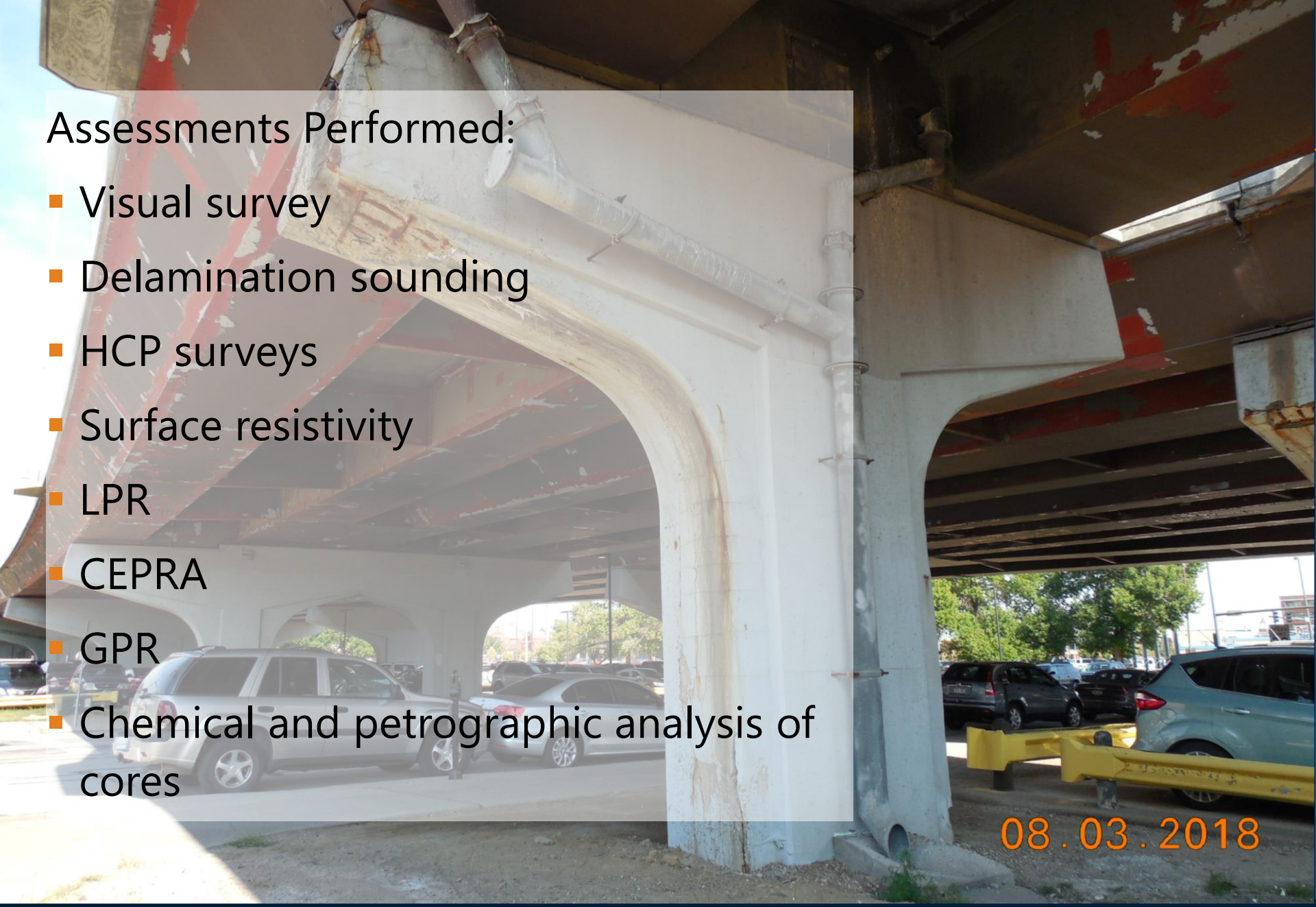
# Example: Bridge Piers in Nebraska

- Corrosion assessment of 10 bridge piers after 48 years in service
  - Varying levels of corrosion-related distress






Assessments Performed:

- Visual survey
- Delamination sounding
- HCP surveys
- Surface resistivity
- LPR
- CEPRA
- GPR
- Chemical and petrographic analysis of cores

# Summary

- A variety of NDE techniques can be used to identify and troubleshoot materials-related distress in concrete bridge structures

- Often rely upon a variety of tools to get a more complete picture of the structure and its distress mechanisms

- Emerging NDE technologies add more tools to the toolbox

# Thank you!

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