Nondestructive Testing to Better Define Repair Quantities

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Issues Facing Owners

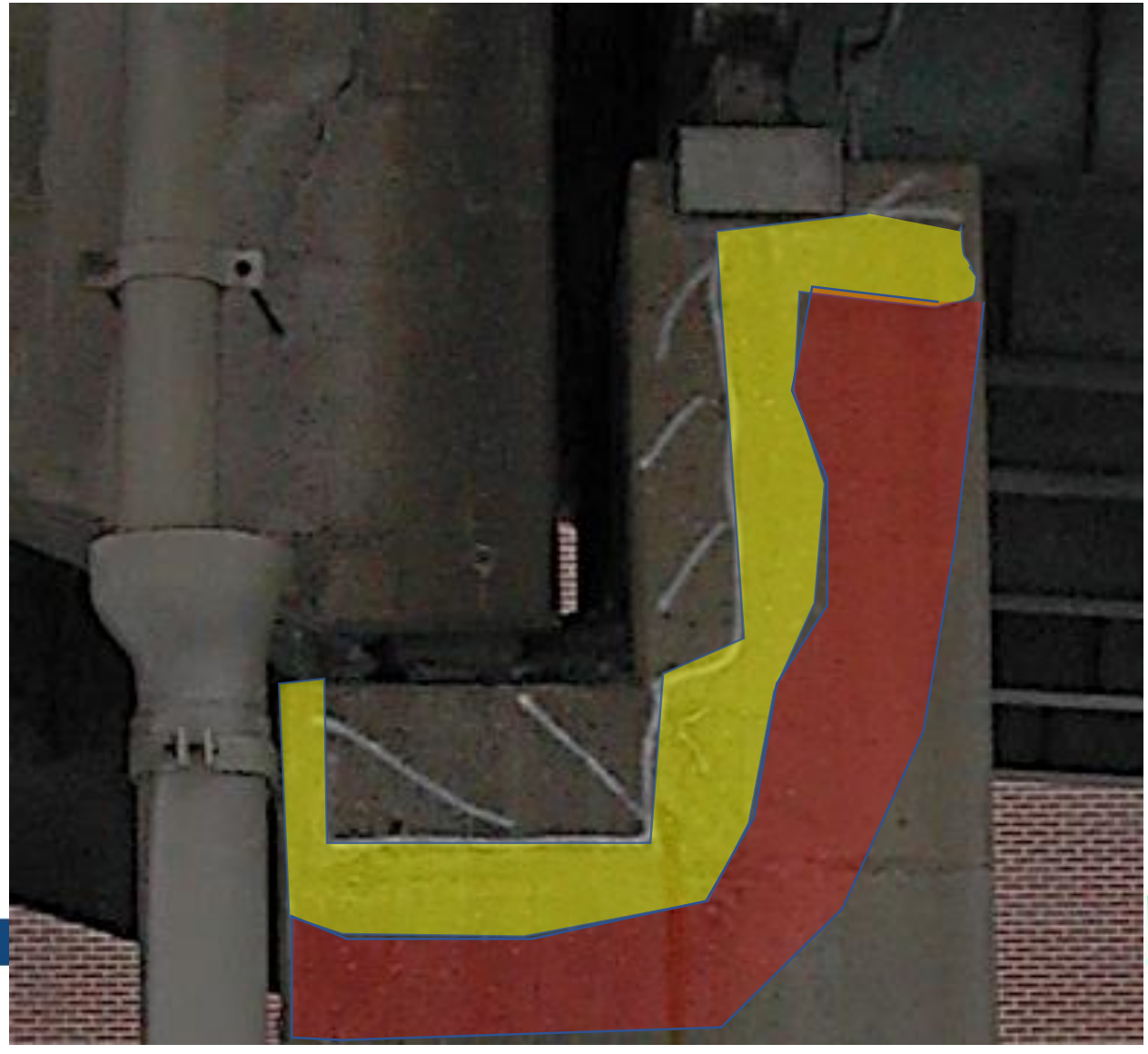
- How to properly determine repair quantities?
- Sounding and visual inspections are known to underestimate true repair area
- Impacts of underestimating repair quantities
  - Costly change orders
  - Increased project duration
- Time from inspection to construction can be long
  - Deterioration will have grown from last inspection
- **NOT JUST FOR DECKS!**

What is really happening in the concrete?

Large Near surface Delamination

Extent of delamination beyond what sounding can pick up

Corrosion is active but has not formed enough iron oxide to create significant cracking



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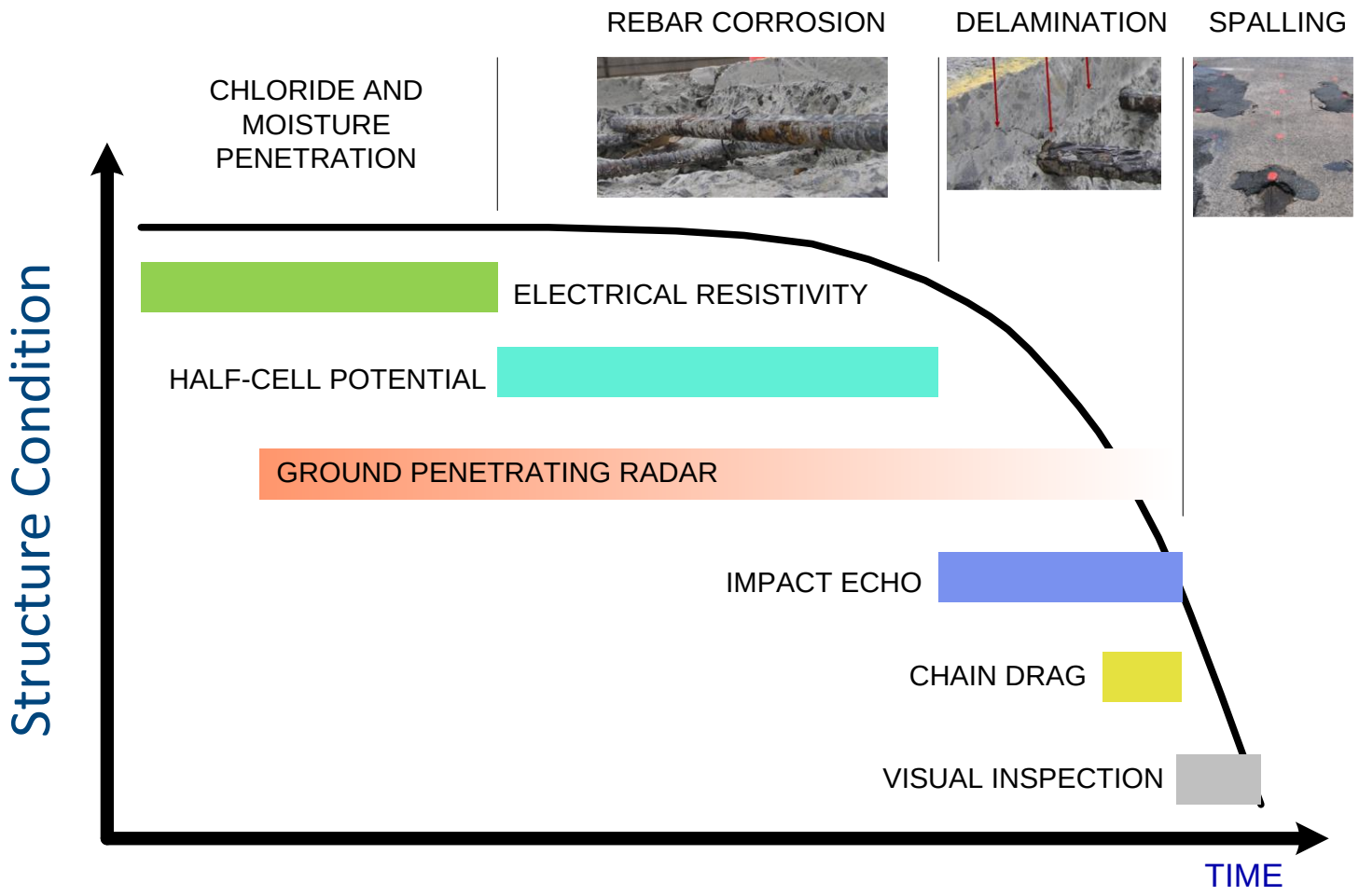
How can we better understand these incipient deterioration conditions?

Concrete Deterioration



Visual Inspection

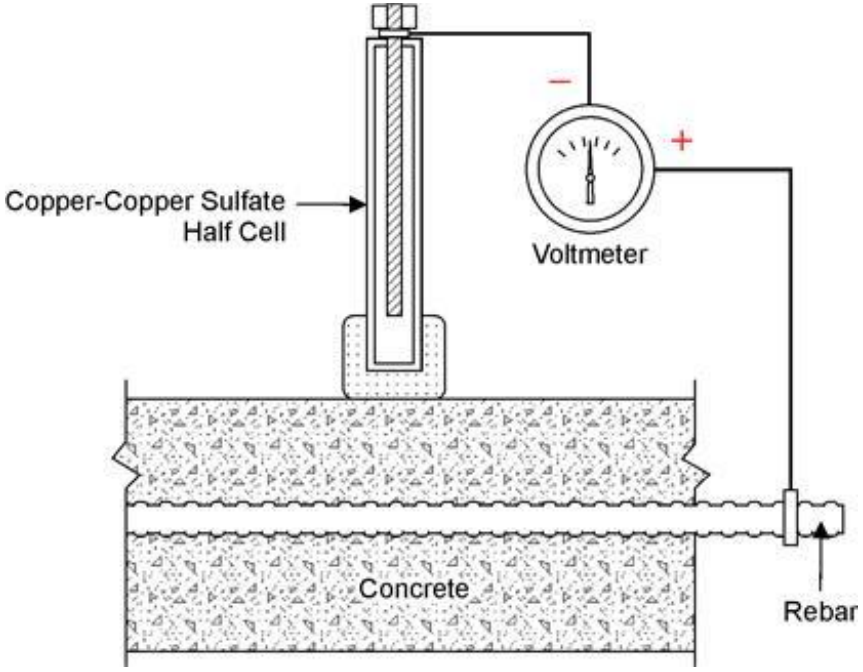
- Rust staining
- Cracking
- Spalls
- Exposed steel
- Water infiltration
- Efflorescence

Sounding Survey

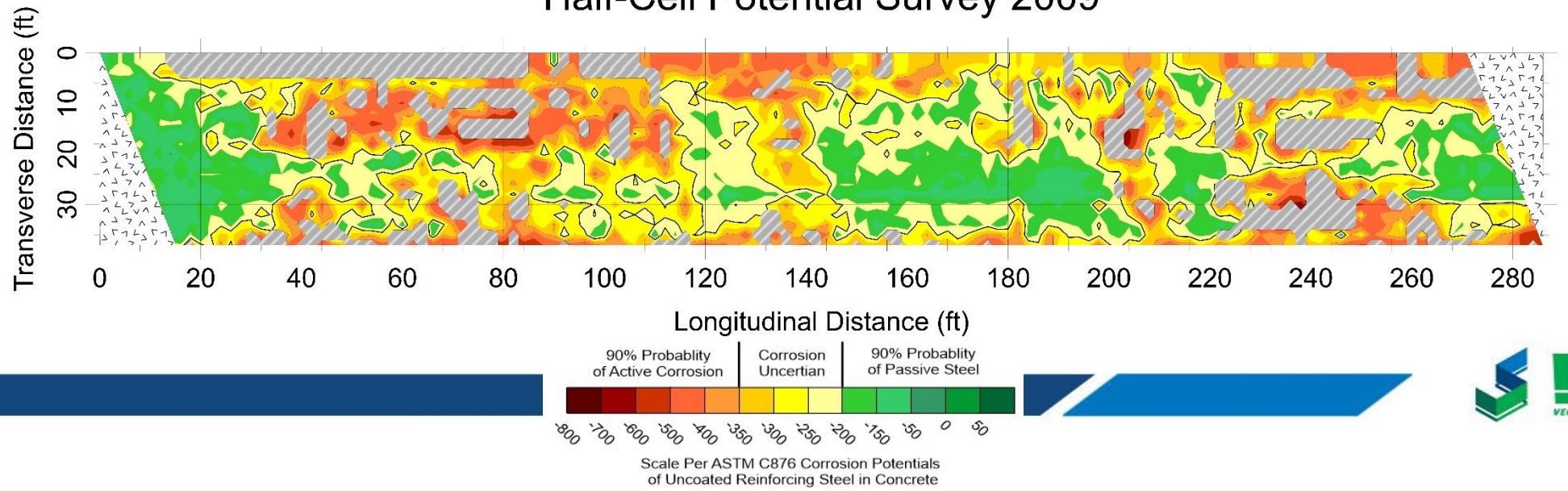
- Hammer sounding or chain drag
- Locates areas of large near surface delaminations
- Incipient delaminations cannot be identified
- **False positives are rare**
- False negatives are common

Corrosion Potential Measurements

- ASTM C876 - also known as half-cell potential
- Determines probability of active corrosion



Corrosion Potential – Bridge Deck



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Corrosion Potential – Bridge Substructure

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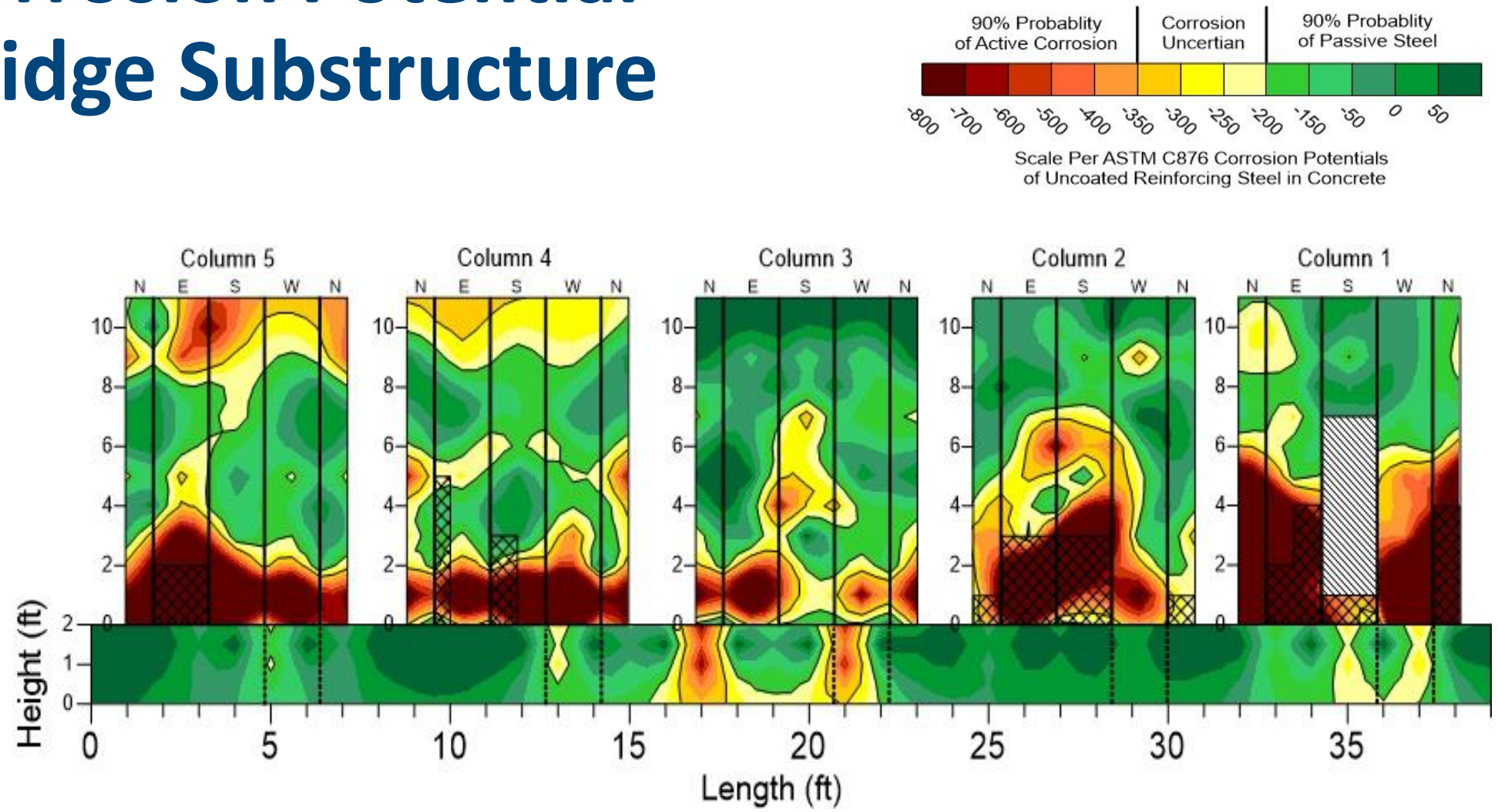
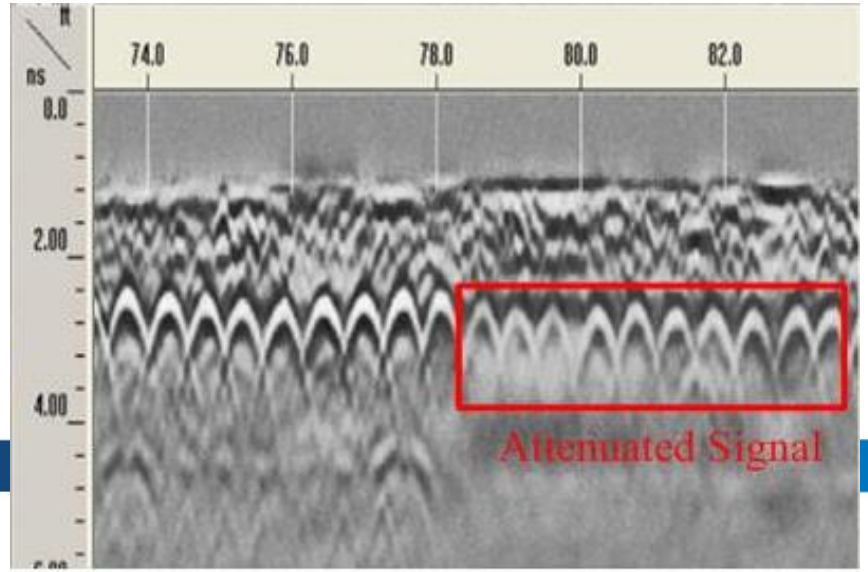


Ground Penetrating Radar

- 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 Survey

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

- Cover depth is an important factor in the service life of a structure
  - Reduced cover depths allow for chlorides and carbonation to reach steel faster

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

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

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GPR Cover Survey of Bridge Columns

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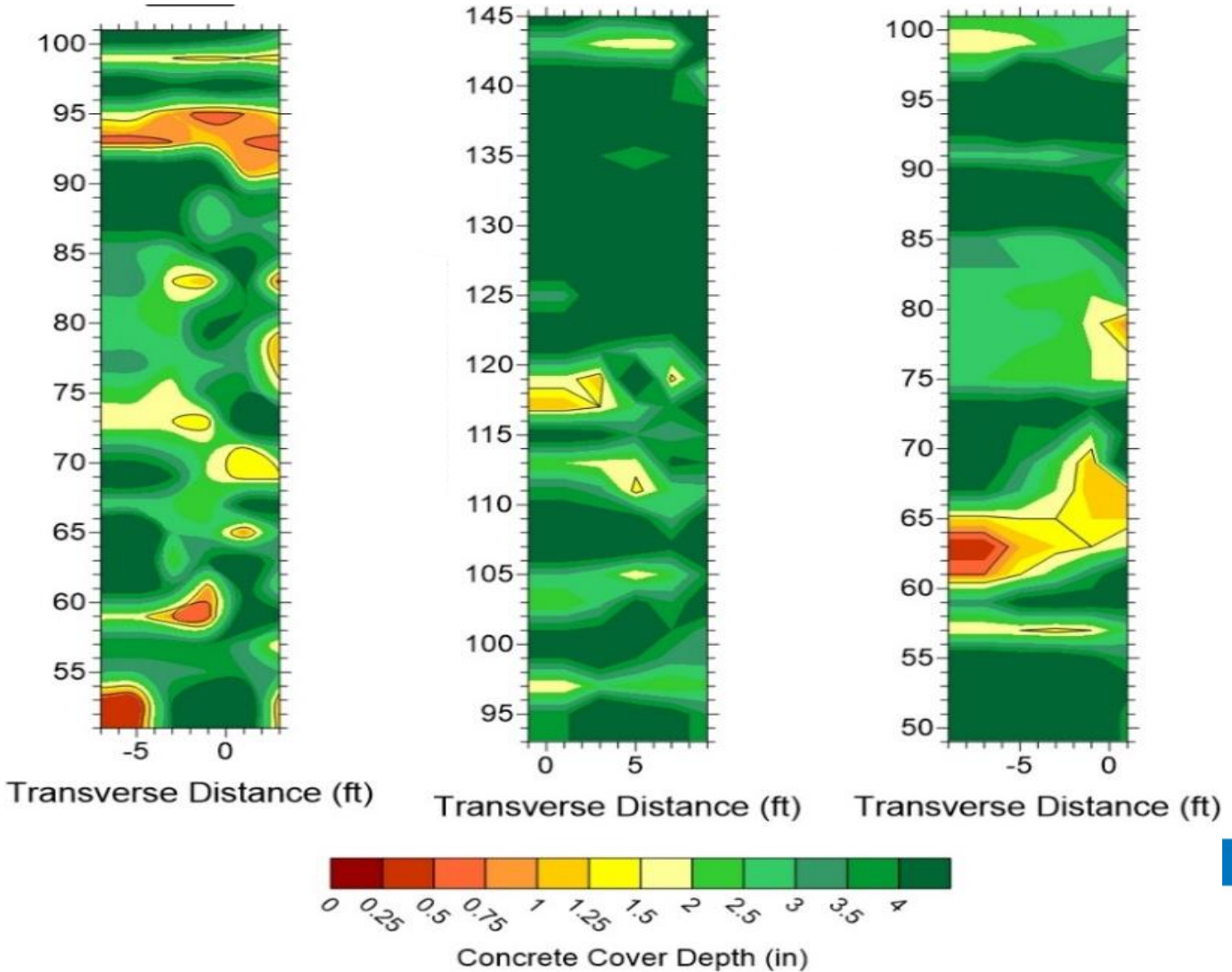
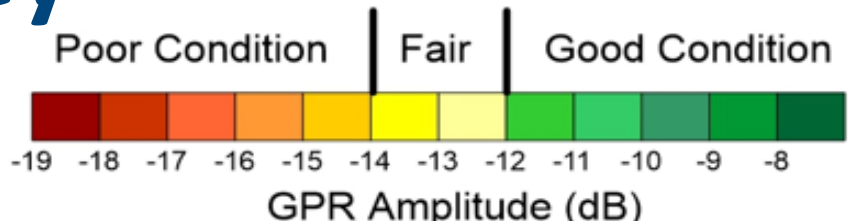
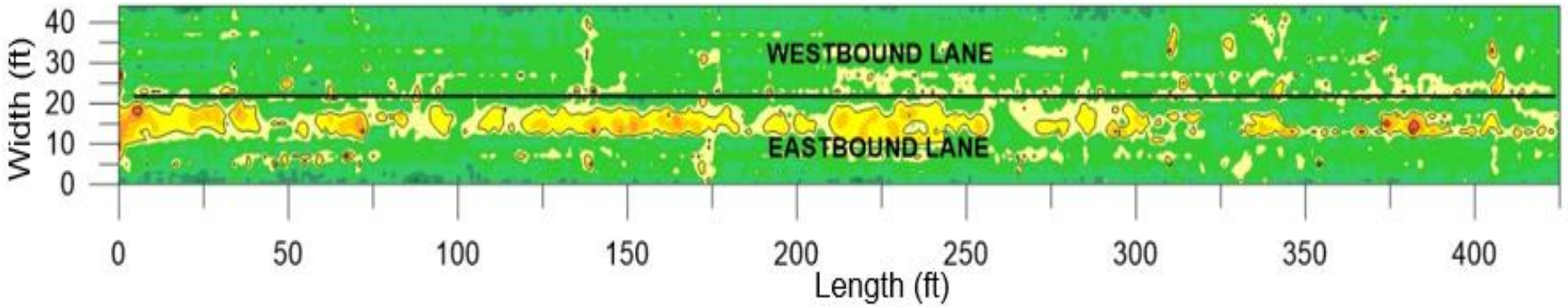
GPR Cover Survey of Bridge Columns

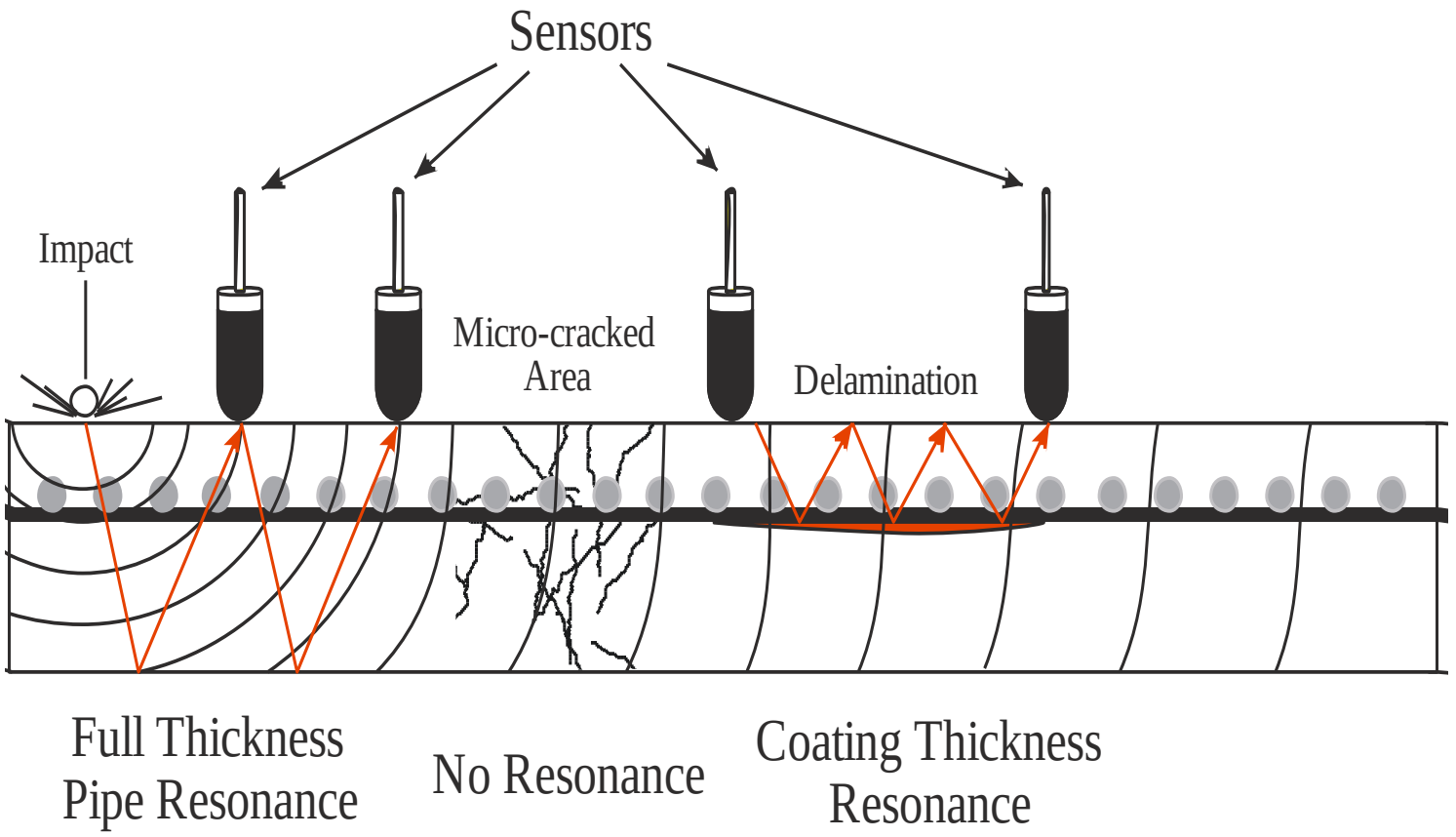


GPR Amplitude Survey
Bridge deck

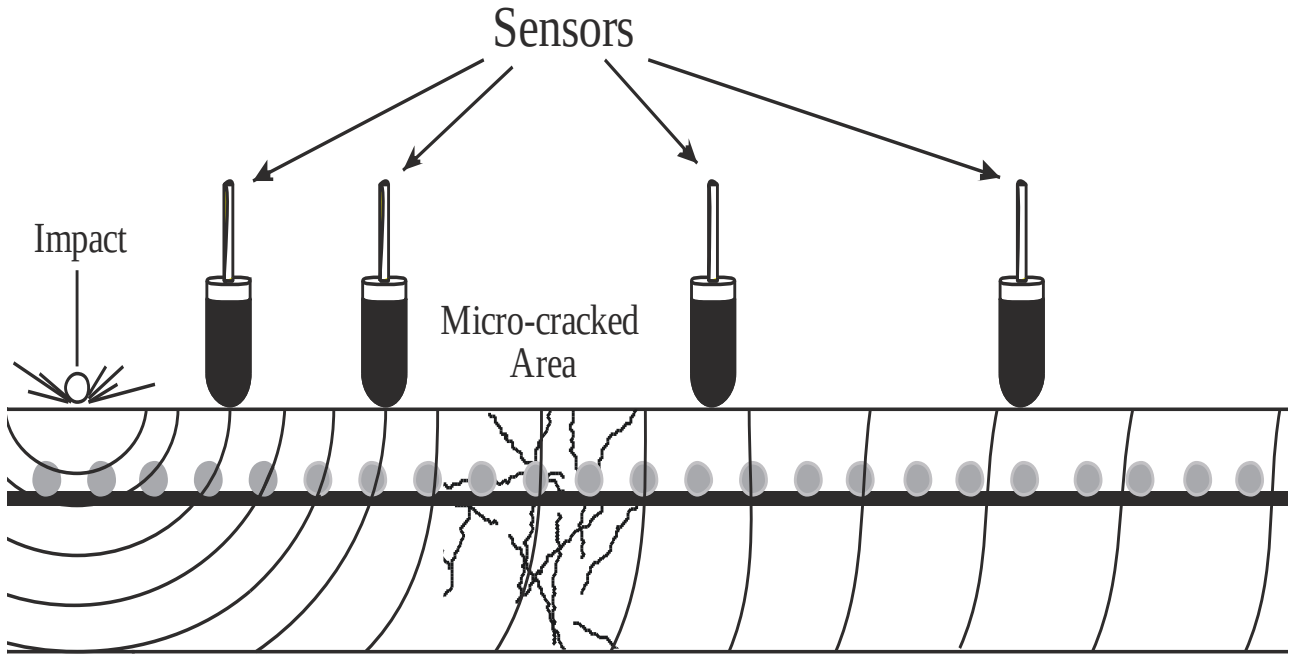




Acoustic Methods – Impact Echo



Acoustic Methods – Surface Wave Velocity



Normal Compressional and Shear Wave Velocity Values

Lower Compressional Velocity and Lower or Loss of Shear Velocity Values

STRENGTH OF CONCRETE VERSUS VELOCITY

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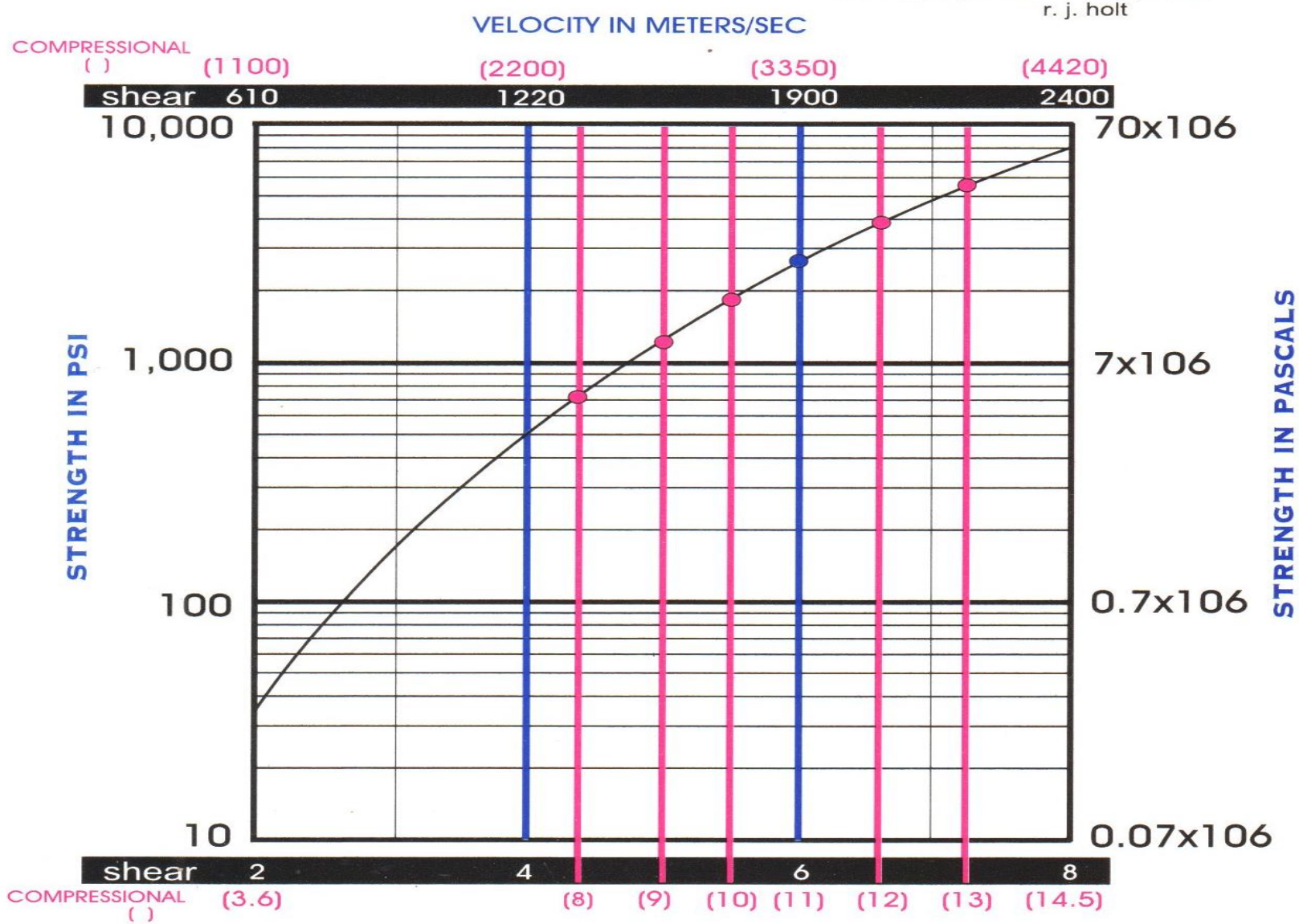

CURVE IS FOR THE RATIO: $v_{SHEAR} / v_{COMPRESSIONAL} = 0.55$
WHICH IS EQUAL TO A POISSON'S RATIO OF 0.28

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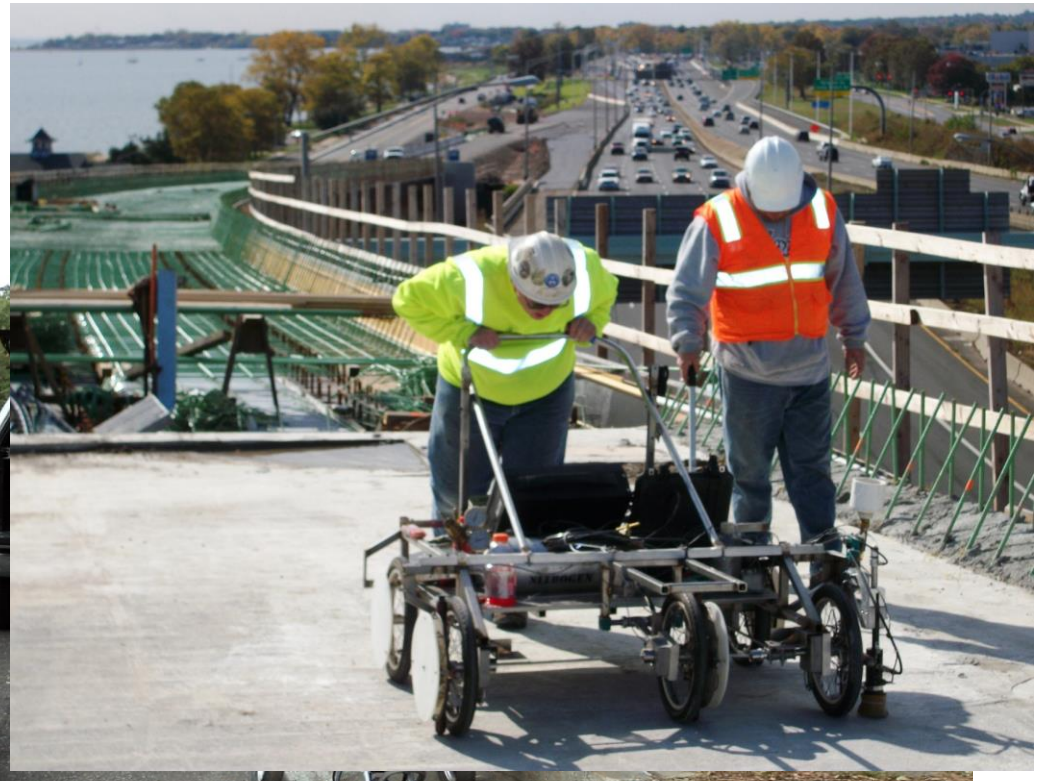
Deck Testing



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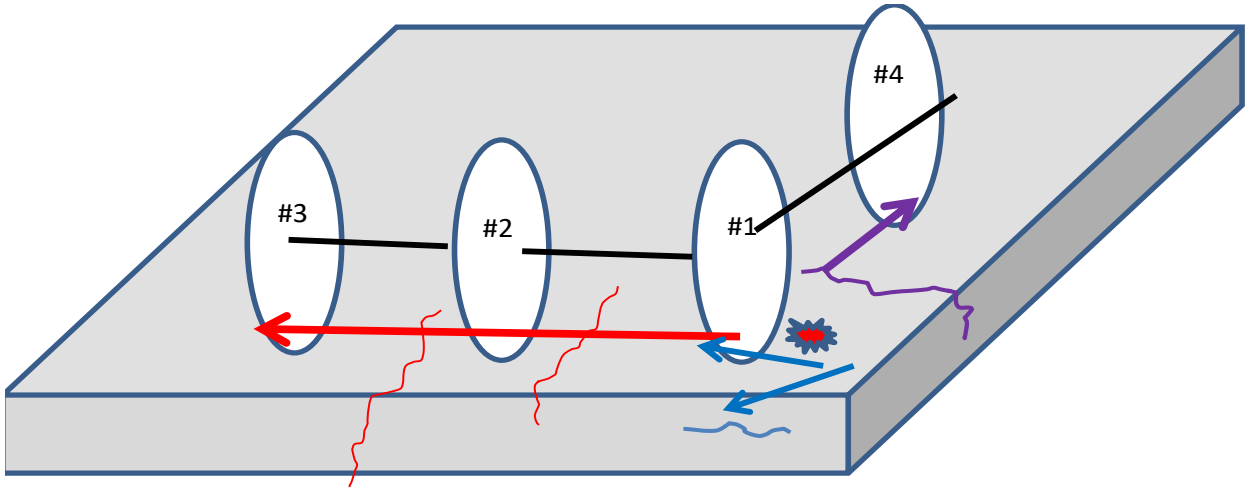
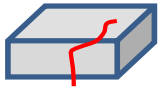
Deck Testing



1)  Deck delaminations impact echo measurements at sensor #1

2)  Longitudinal partial deck cracking measurements at sensor #2

3)  Longitudinal full deck cracking measurements at sensor #3

4)  Transverse deck cracking measurements at sensor #4

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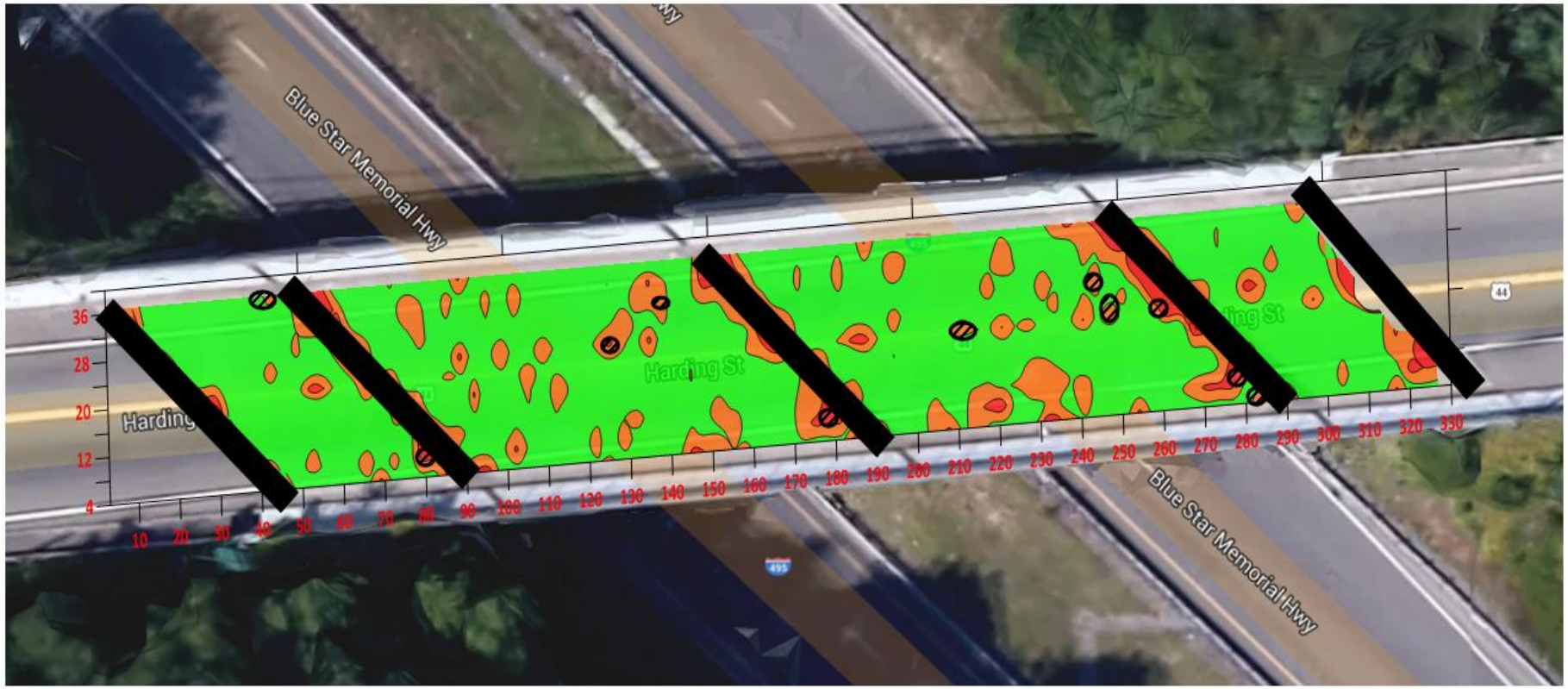
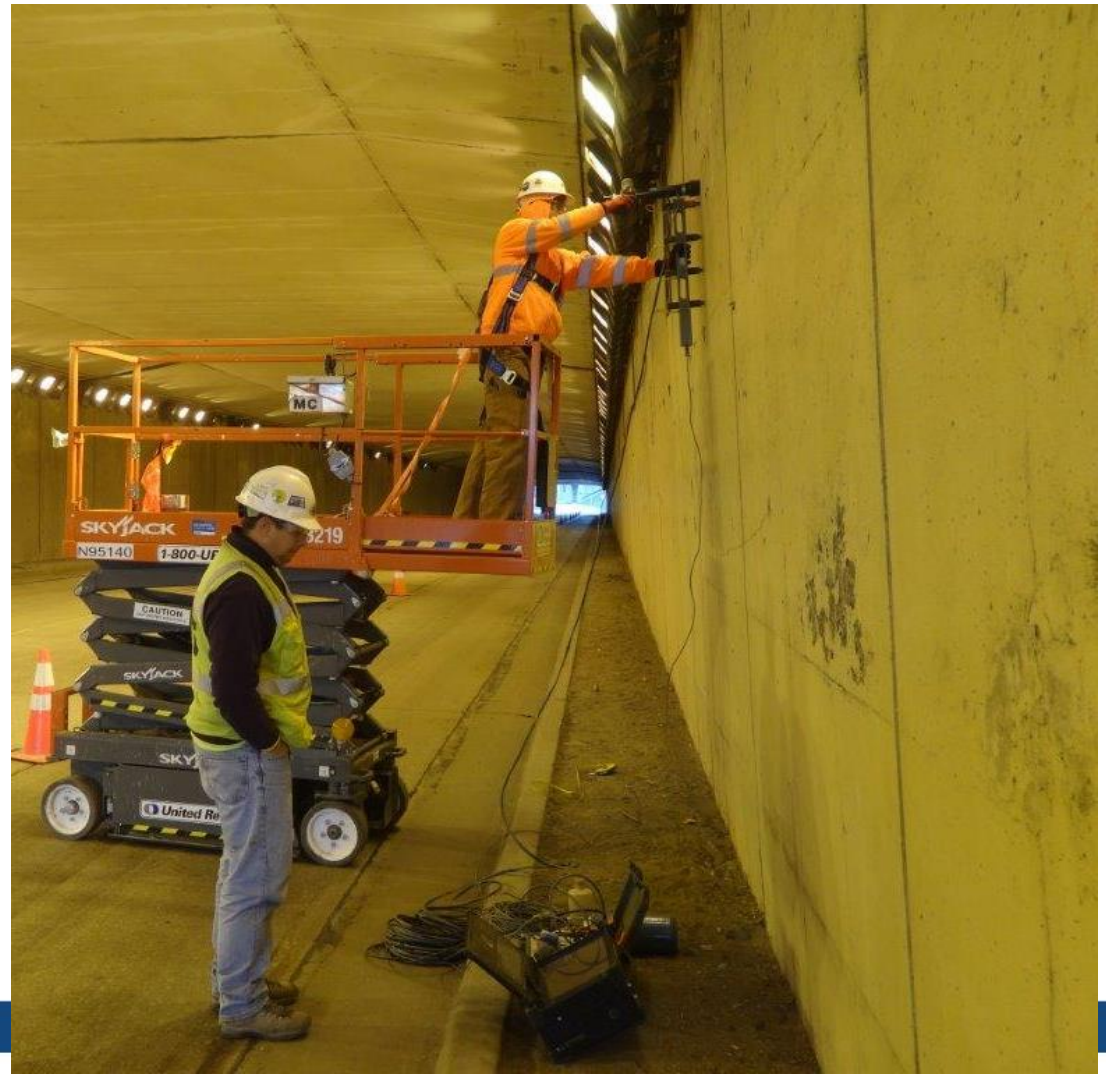
Location of Delaminations



Substructure Testing



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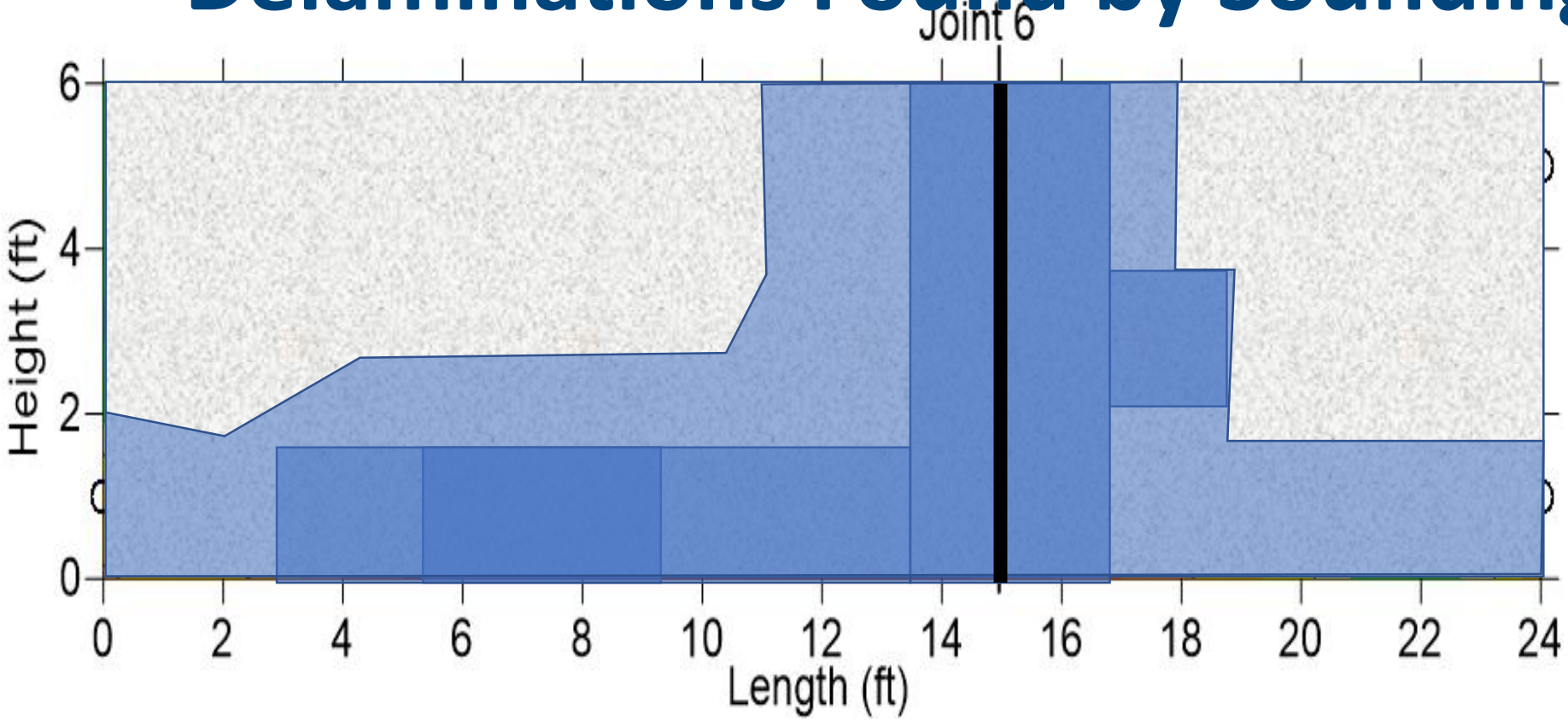
Acoustic In-Situ Compressive Strength

Delaminations Found by Impact Echo

Repair Area

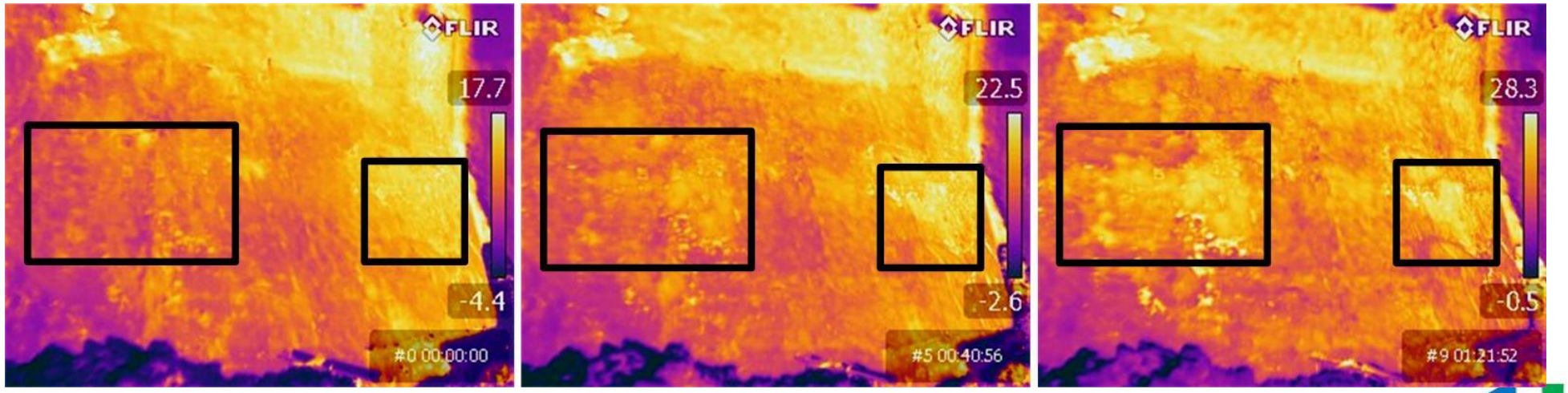
Delaminations Found by Sounding



Infrared Thermography – Basic Theory

- Delaminations have different thermal properties than sound concrete
  - Result of air-gap caused from the separation of the concrete
  - In the morning sun, delaminations heat up faster than sound concrete section
  - During evening cooling, delaminations cool down faster than sound concrete section
  - Allows for very quick assessment of large areas
  - Results are similar to chain drag and hammer sounding

IR – Equipment



IR – 10th Avenue Bridge in Minneapolis

- Hammer sounding survey done several years prior
- Wanted to know growth of deterioration from last survey
- IR provided a quick method to resurvey the concrete

Figure 2: Upstream: Arch Spalling under Spandrel Columns A (left) and B (right)

Figure 3: Upstream: Arch delaminations around pipe bracket and corners

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Thank you!

Questions?