Nondestructive Evaluation of Stone Anchor Corrosion Effects

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Torin McCue
Engineer Intern III

Atkinson-Noland & Associates
www.ana-usa.com
• Consulting Engineers
• Nondestructive Testing
• Evaluation and Repair

THE MASONRY SOCIETY

Course Description

Historic stone masonry often has embedded metal anchors connecting facing stones to masonry backup materials. Anchor corrosion causes damage to surrounding stone at metal anchor embedments, and the typical approach is to repair stone damage after it manifests itself as visible cracks or spalls. A new approach has been developed to evaluate subsurface damage before it becomes visible, thereby identifying potentially dangerous conditions and reducing the scope of repairs. The method uses an ultrasonic pulse-echo array system to identify subsurface cracks at anchor positions located using surface penetrating radar or pachometer equipment. Case studies are included showing how the method successfully located damaged anchorages at stone and cast stone materials, including one project where results were validated with a series of probe openings. Recommendations will be provided for using the approach with different materials and conditions.

Learning Objectives

1. Describe methods to locate embedded metal anchors in historic stone construction.
2. List typical applications for using the ultrasonic pulse-echo method to evaluate construction materials.
3. Set up a test plan for diagnosing subsurface stone damage caused by anchor corrosion.
4. Validate nondestructive results using probe openings.

What is Anchored Stone Veneer?

- Common detail for exterior building envelopes
- **Modern** and historic constructions

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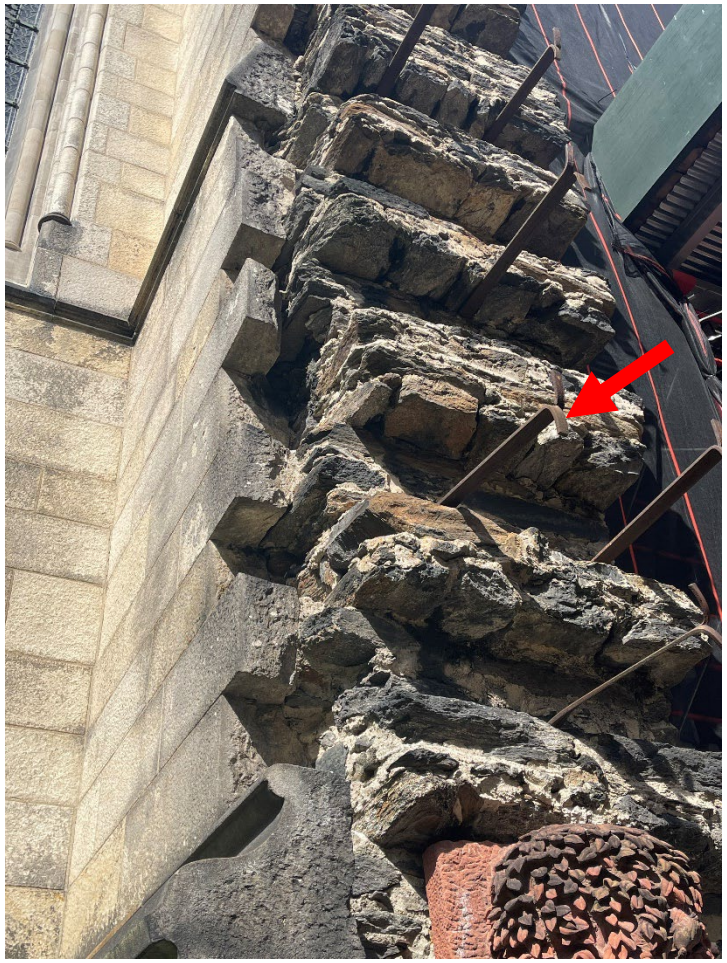
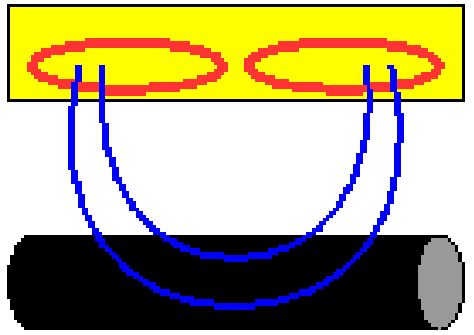


Common Problems?

- Corrosion related spalls at embedded anchors

Locating Embedded Metals

- Simplest: eddy-current pachometer scanning
  - Pulse induction method
  - Detects any conductive metal



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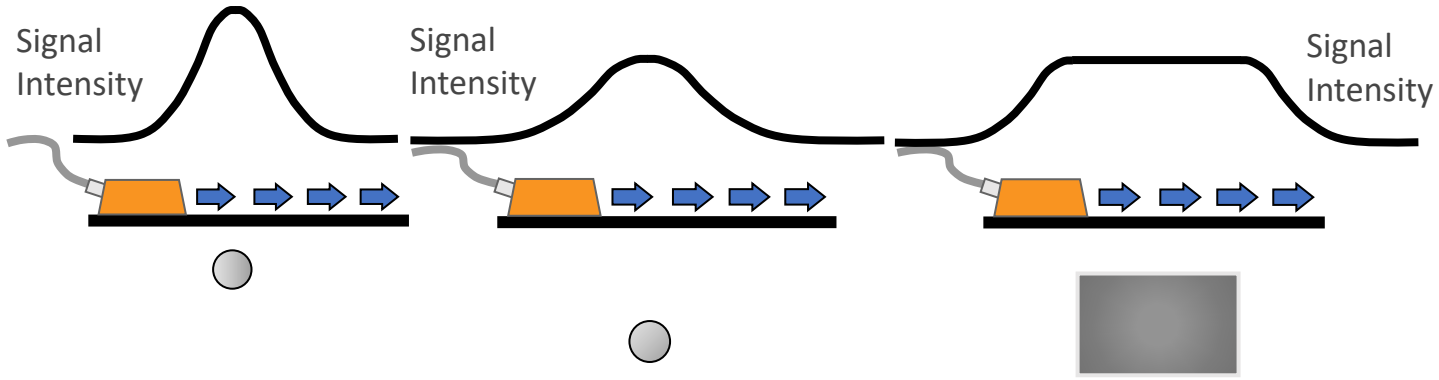
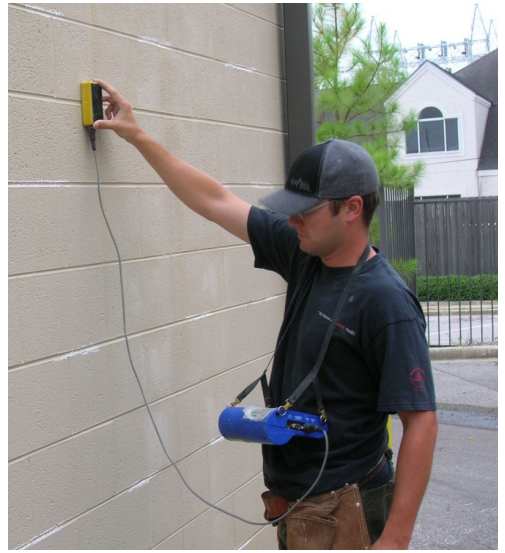
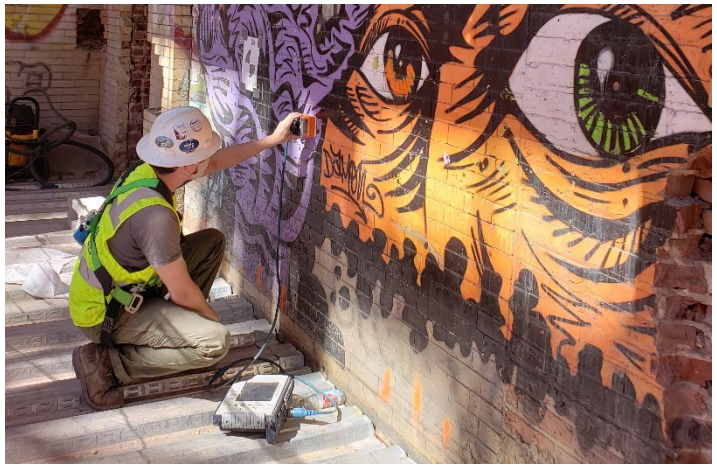
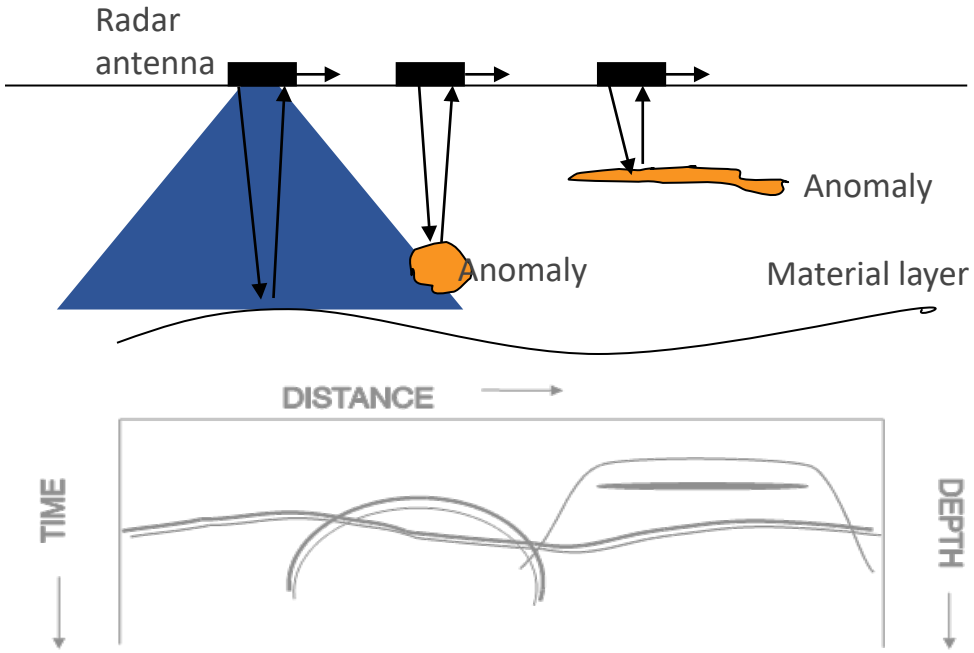


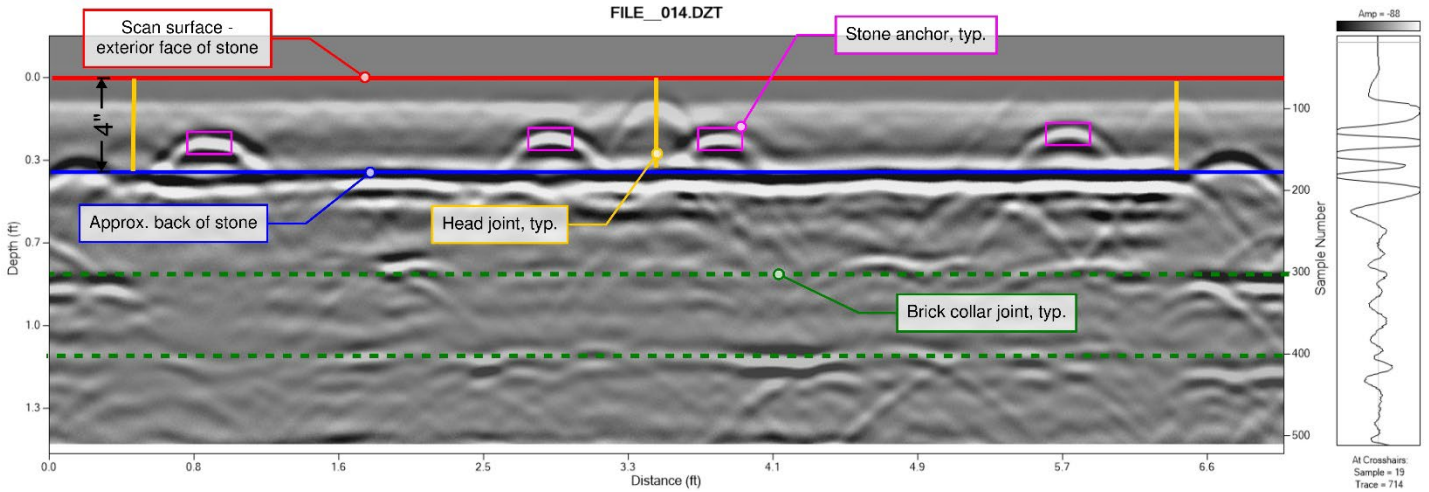


Locating Embedded Metals

- More detail: surface penetrating radar
  - High frequency electromagnetic radio (radar) pulses
  - Detects any change in wave speed







Source: GSSI

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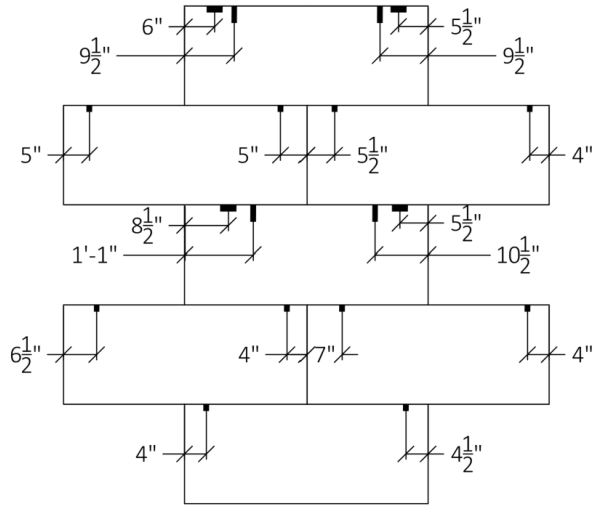
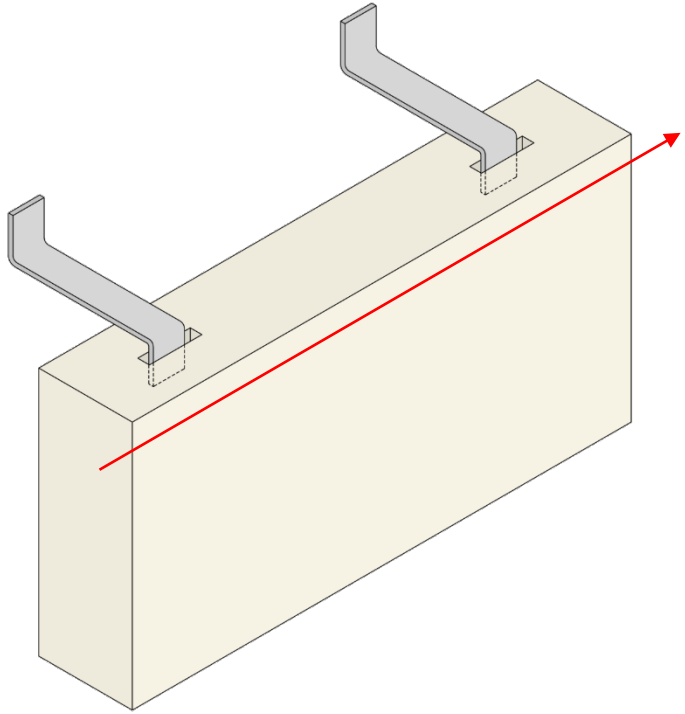
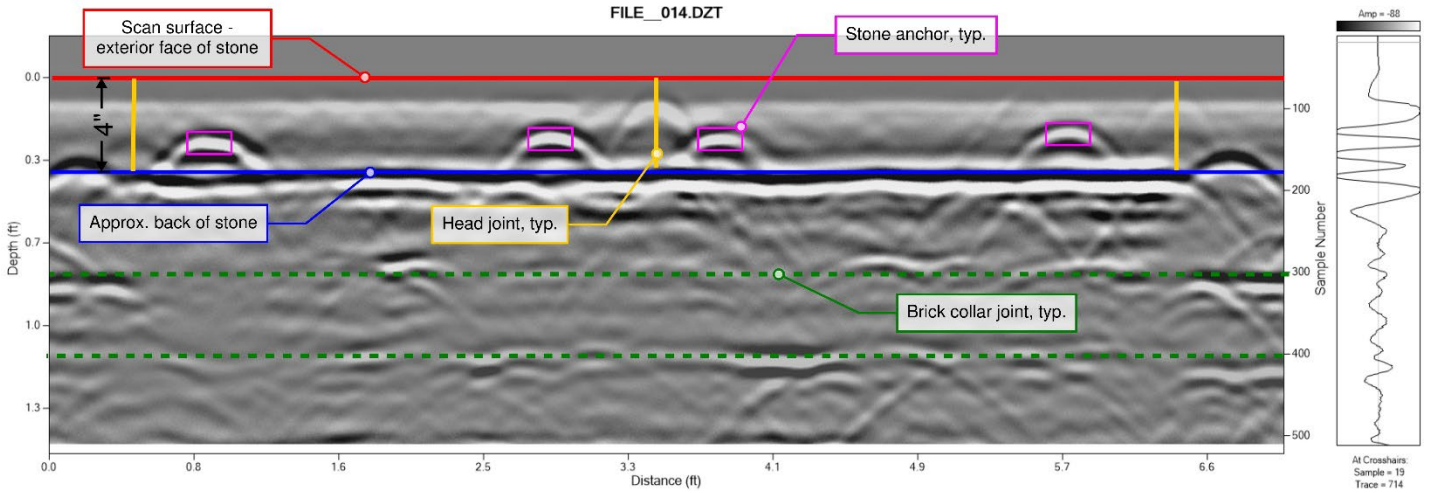


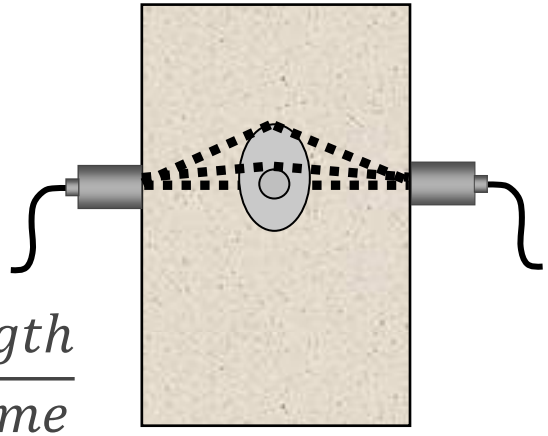




Ultrasonic Methods

- Ultrasonic Pulse Velocity (UPV) & Impact Echo (IE):
  - Direct or "through" transmission
  - Used for years

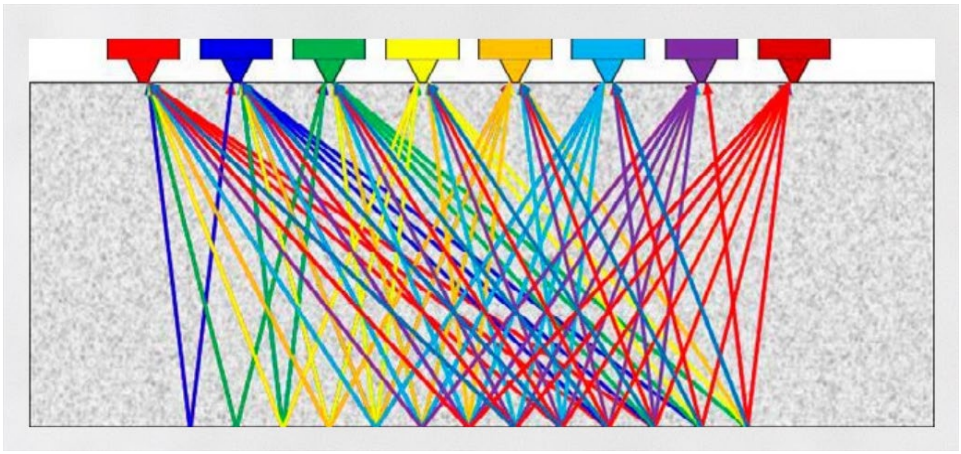
  - Limitations:
    - One pair of transducers = single ray path
    - Tomography is time intensive



$$Pulse\ Velocity = \frac{path\ length}{travel\ time}$$

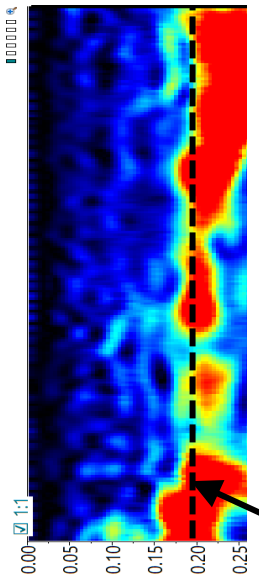
Ultrasonic Pulse-Echo

- Ultrasonic Pulse-Echo (UPE):
  - Array of 24 dry-contact transducers pulsing 50 kHz shear wave
  - SAFT algorithm converts travel times into B-scan (2D scan)
    - Essentially real-time tomography combing multiple A-scans (1D scans)
    - Based on time and not frequency like IE



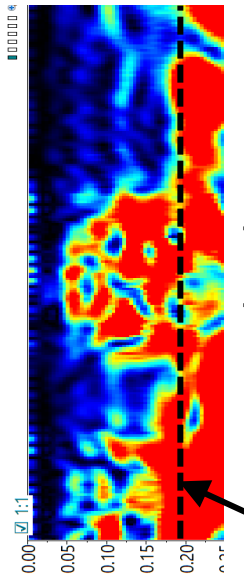
Ultrasonic Pulse-Echo

- Typical applications:
  - Thickness of solid substrate (typ. concrete or stone)
  - Homogeneity of concrete or masonry – honeycombing, voiding, internal cracking, etc.
  - Detection of separation or poor bond between substrate and repair (patch)
  - Stone anchor locating - qualitative look at face spalling due to rust jacking



INTACT STONE

Back of stone

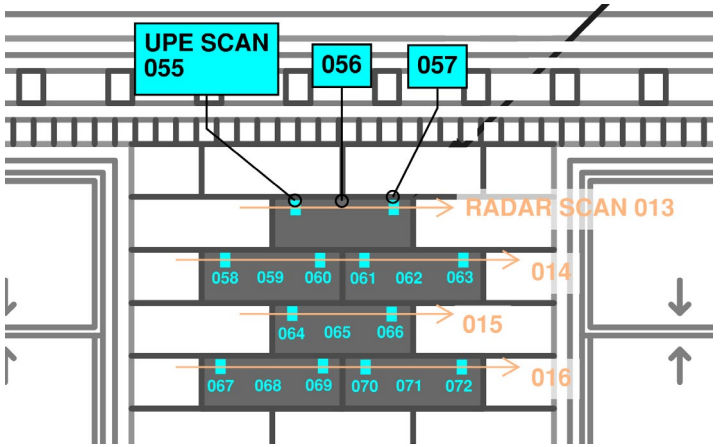


DAMAGED STONE

Back of stone

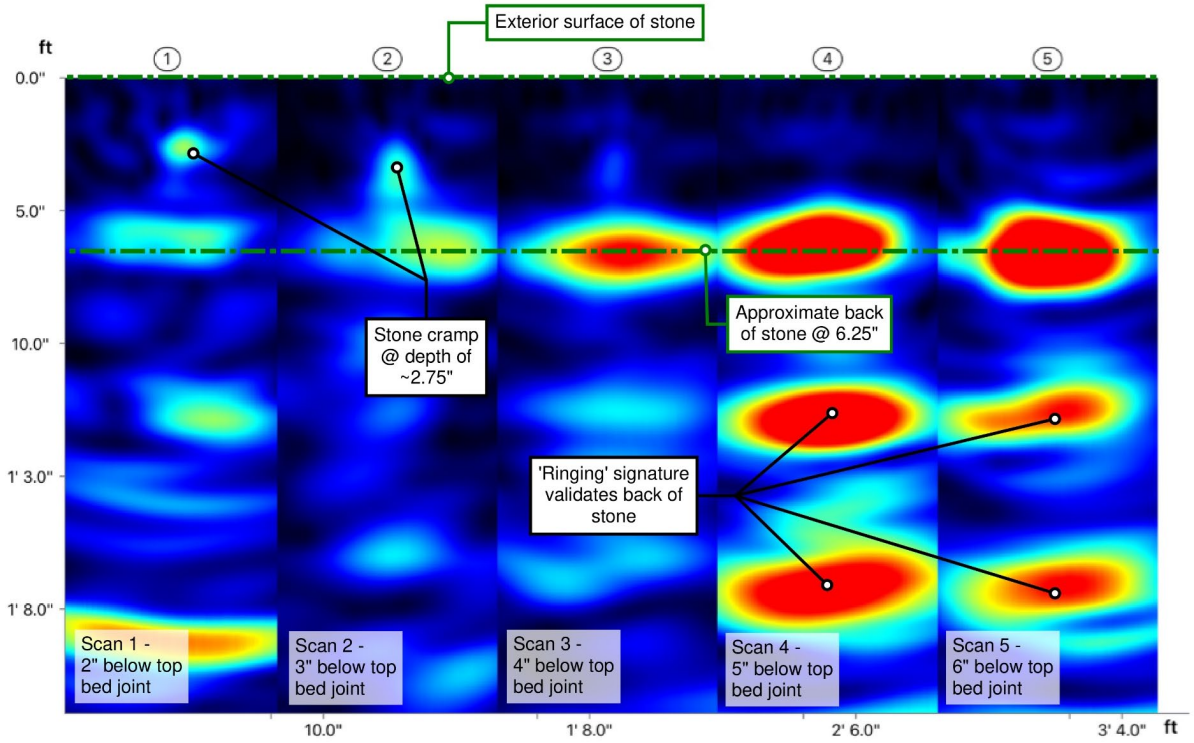
UPE Test Plan – Locate and Test Stone Anchors

1. Use pachometer and surface penetrating radar to locate stone anchors
2. Mark out location, approx. size, depth of each anchor
3. Collect 'control' scan adjacent to anchor
4. Collect 'test' scan at anchor



UPE Test Plan – Data Interpretation

1. In the field or in the office compare ‘control’ scan with ‘test’ scan at each anchor location



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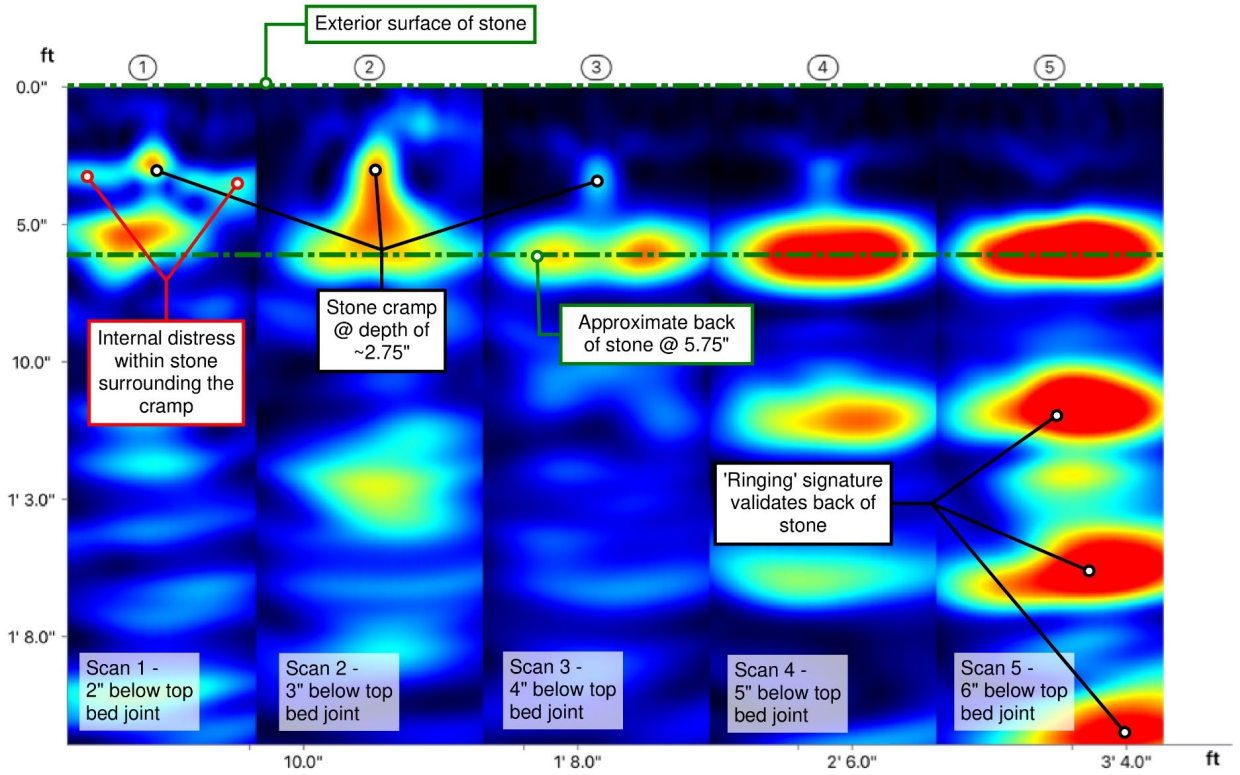

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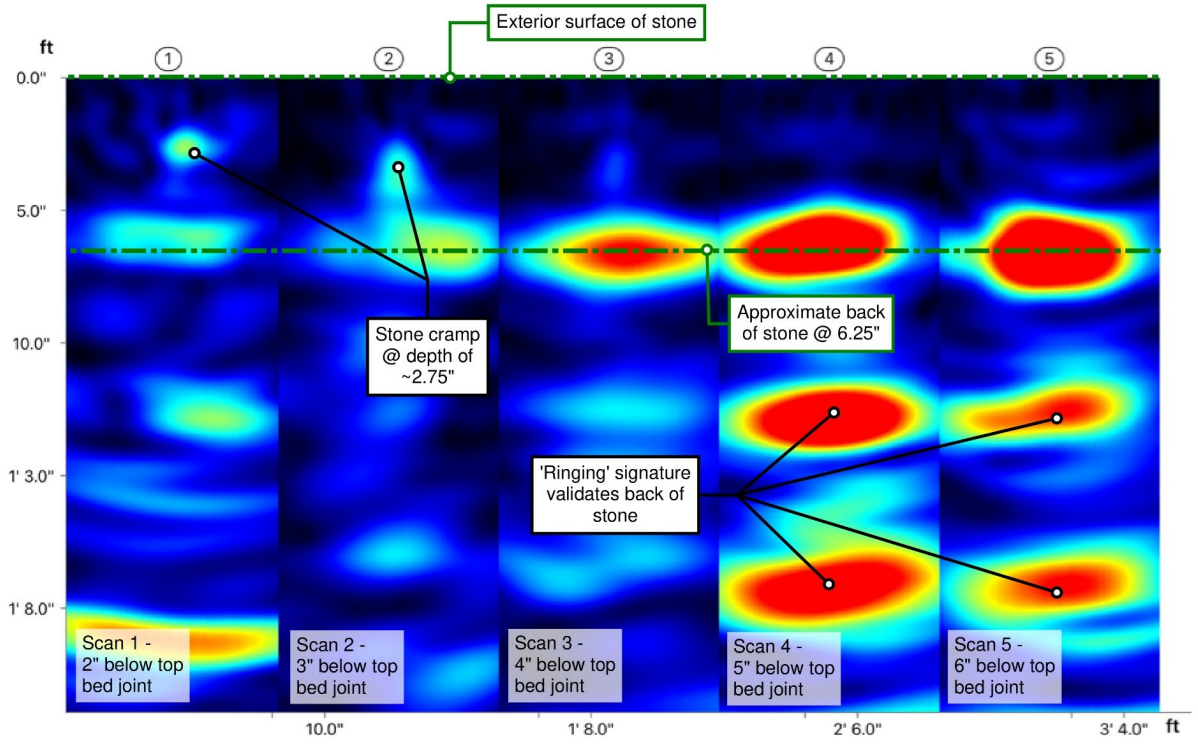
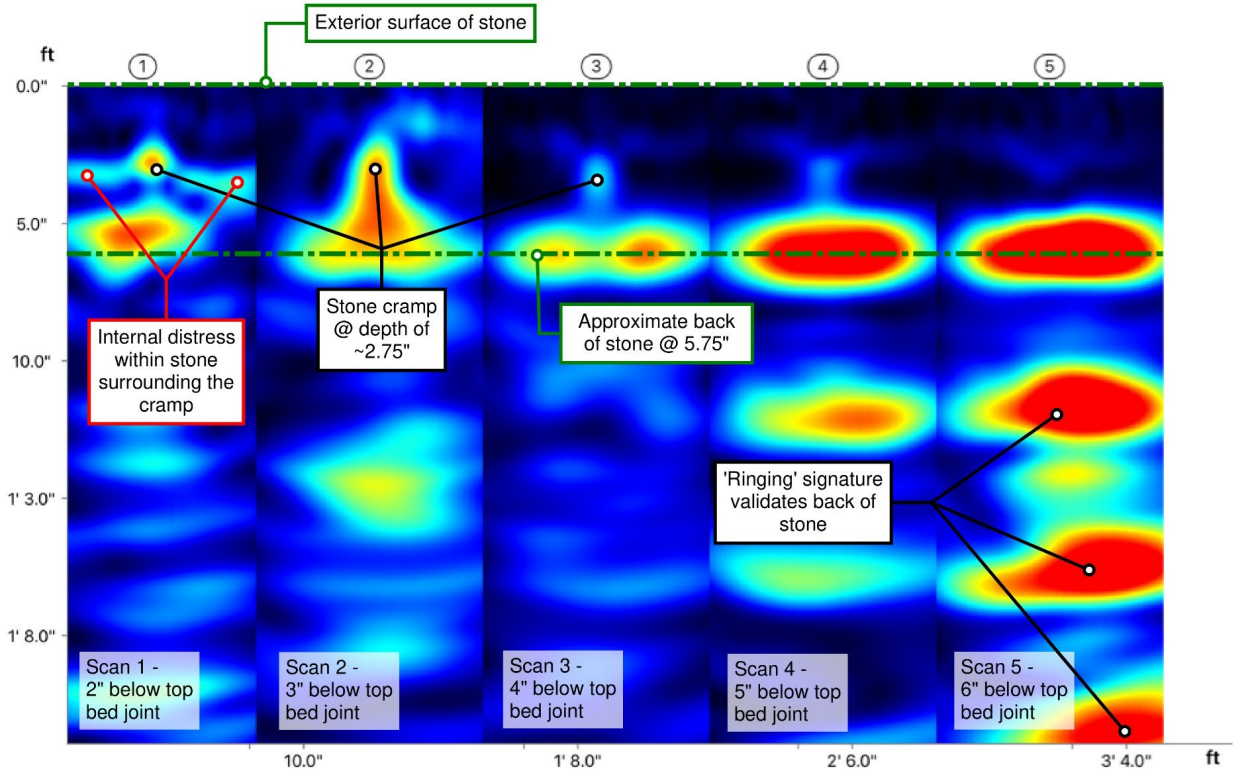
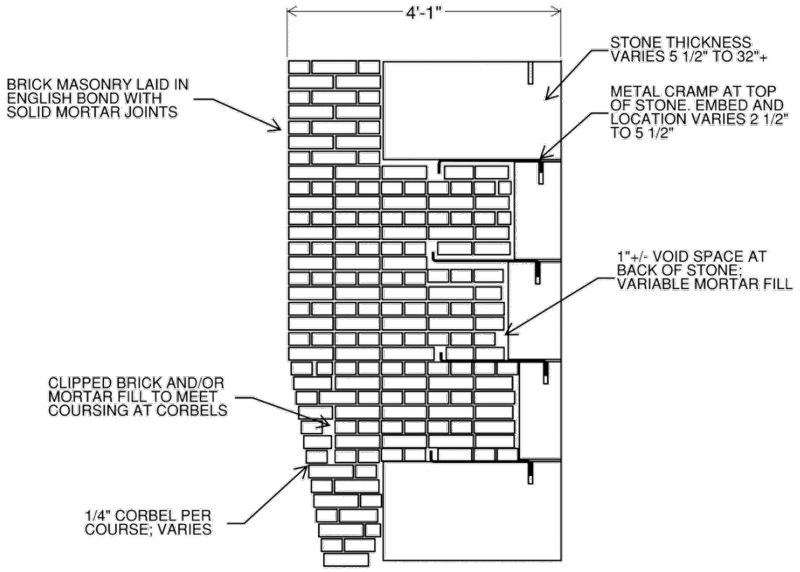
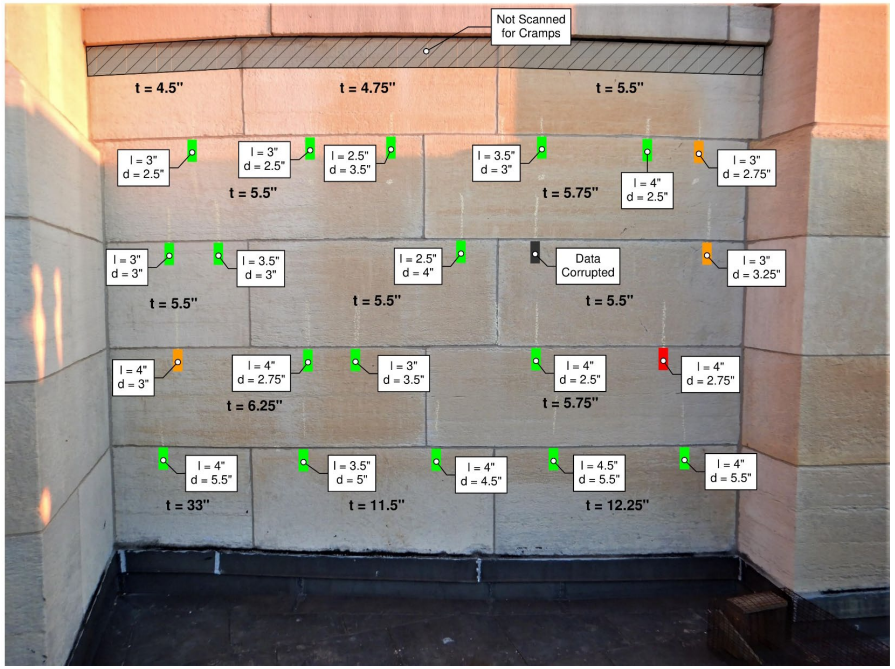




UPE Test Plan – Data Interpretation

1. In the field or in the office compare ‘control’ scan with ‘test’ scan at each anchor location
2. Categorize severity of internal deterioration for reporting
3. *(Optional) coordinate probe removals to confirm/calibrate results*





Data Validation – Probe Openings

1. Eighteen (18) stone units were removed
   - 100% NDE results correct (thickness)
2. Sixteen (16) anchors were located via the probes
   - 75% NDE results correct (anchor)
3. UPE results were varied – see next slide

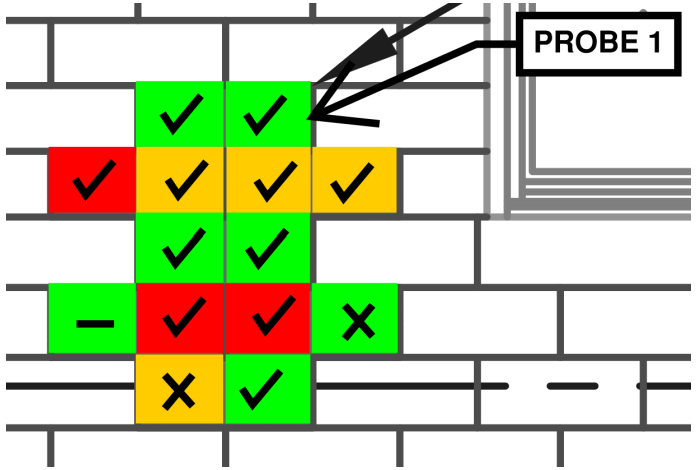
Data Validation – Probe Openings

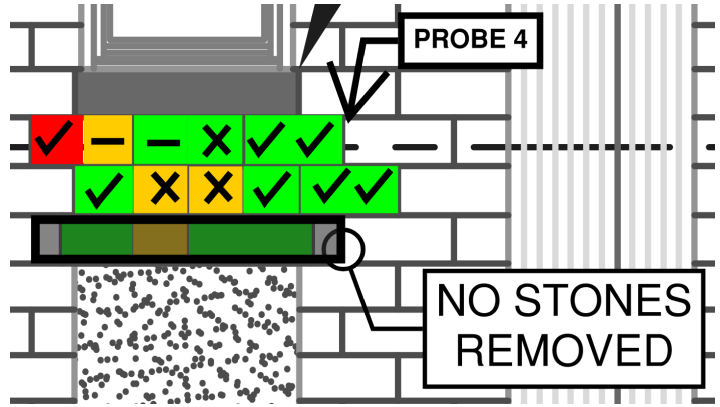
ADDENDUM LEGEND:

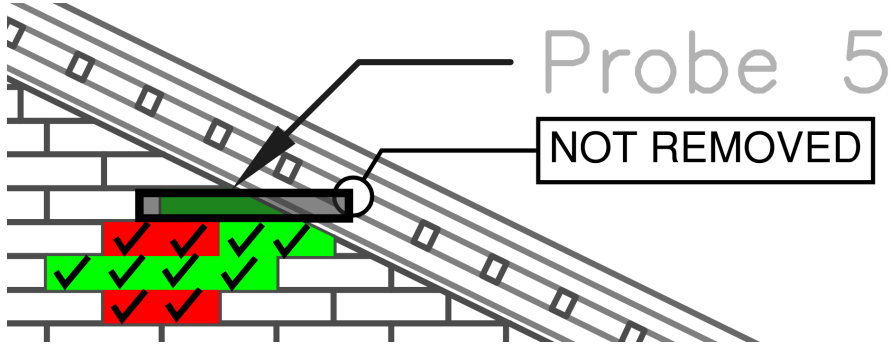
- ✓ NDE RESULTS AGREE WITH RESULTS FROM PROBE OPENING
- – DATA FROM PROBE OPENINGS INCONCLUSIVE FOR DETERMINATION OF STONE CONDITIONS
- ✕ NDE RESULTS DO NOT AGREE WITH RESULTS FROM PROBE OPENING
- NO STONES REMOVED - NO COMPARISON

LEGEND:

- NO DAMAGE DETECTED
- POTENTIAL CRACKING
- CRACKING DETECTED





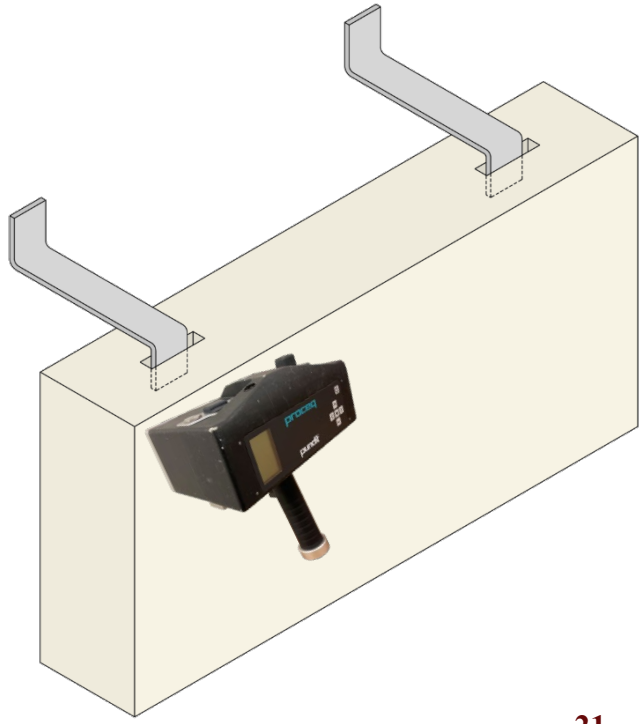


Data Validation – Future Improvements

- The eddy-current pachometer and SPR need to be used together
  - Could reduce false positives (empty kerfs, missing anchors)
- Videoscoping would be beneficial
- Calibrating UPE interpretations **concurrent** with probe removals would help greatly

Summary

1. Surface penetrating radar and pachometer → locate veneer anchors
2. Ultrasonic pulse echo advances → evaluate incipient stone spalls
   - **Reduces** repair costs, targets specific distress areas
3. Developed a site workflow: locate, scan, document
4. Data validation via probe openings is invaluable



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Thank You!!

Questions?

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