RAW DATA. REFINED RESULTS.

Nondestructive Evaluation of Steel Anchor Rods and Bolts for Tension and Integrity

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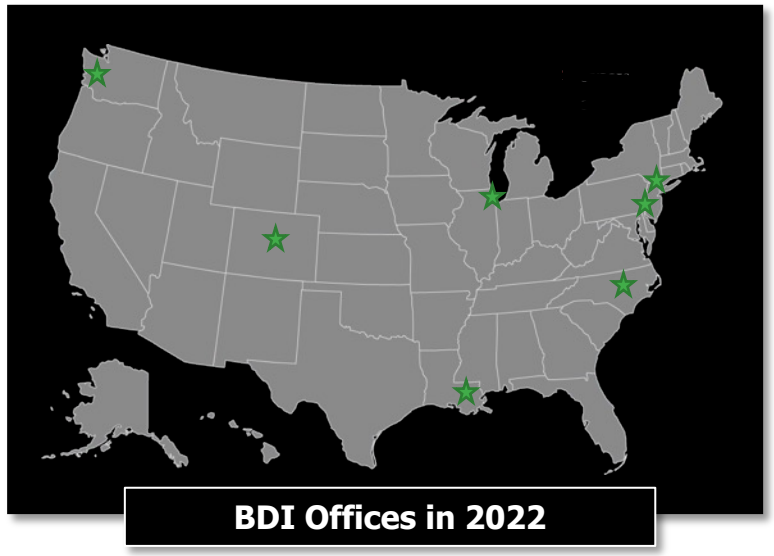
AGENDA

- INTRODUCTION
- BACKGROUND
  - WAVE THEORY
- SYSTEM DEVELOPMENT
- APPLICATION
- DISCUSSION

WHO IS BDI?

"Home" for 2 Years: 1989-1990



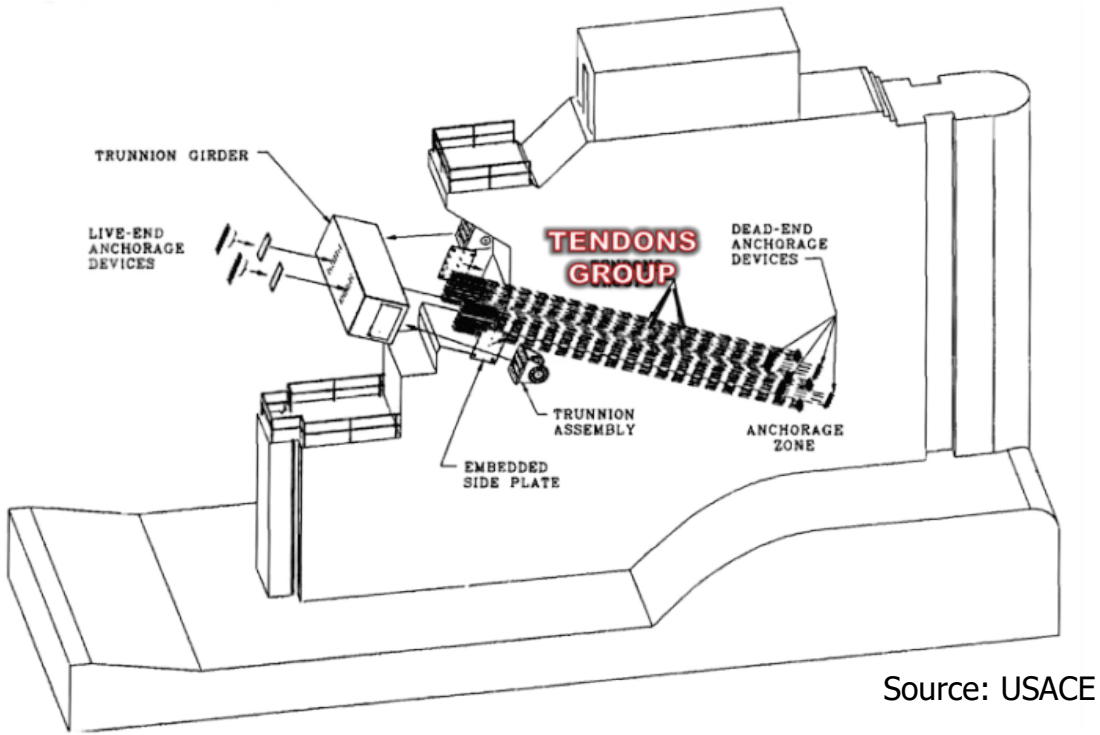
BDI Offices in 2022

- Began research in **1987** at the University of Colorado sponsored by PennDOT and FHWA where basic techniques were developed for using live-load test data to better analyze bridge behavior.
- The initial project, also **funded by the USACE**, was to develop equipment and analysis techniques to measure the integrity of existing lock systems.
- BDI formed in 1989 and began development of Structural Testing System and FE analysis software. In 1991, began adapting both hardware and software for use in field projects, and both are **still under constant development today**.
- To date, BDI personnel have tested and **evaluated thousands of structures** around the world including bridges, lock gates, and even rockets!
- We're an engineering services provider and product manufacturer – a **combination that keeps us sharp**!

30+ YEARS IN THE TESTING/MONITORING/NDE BUSINESS

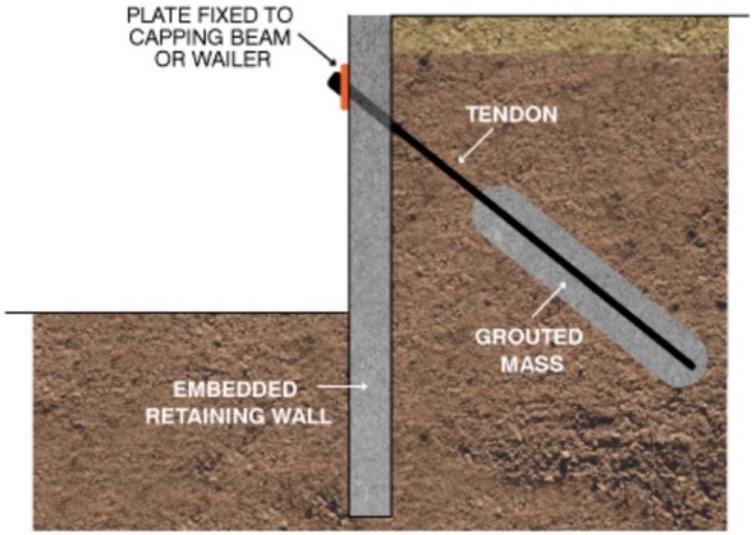
BACKGROUND

TRUNNION ANCHOR RODS

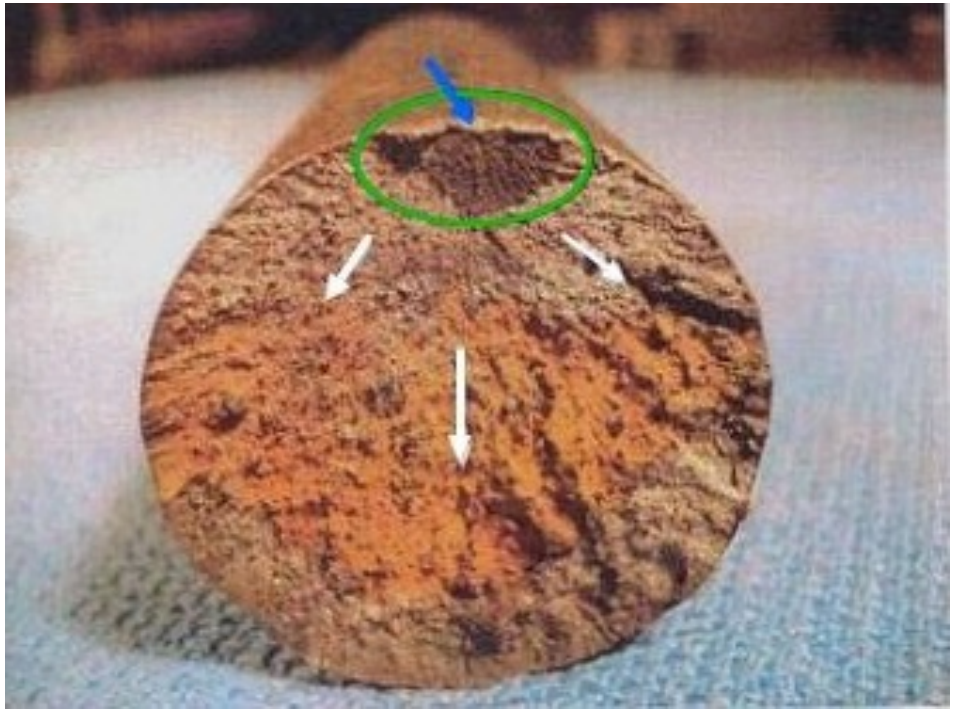


Source: USACE

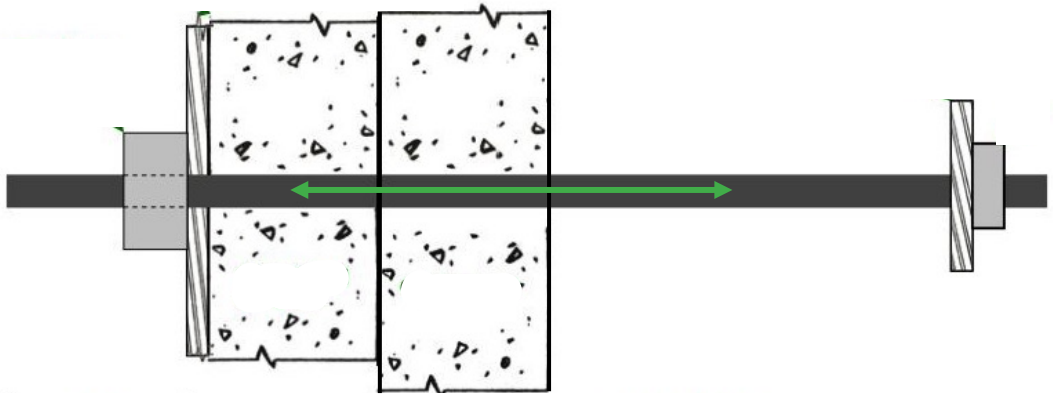
OTHER TENSIONED ANCHOR BOLTS

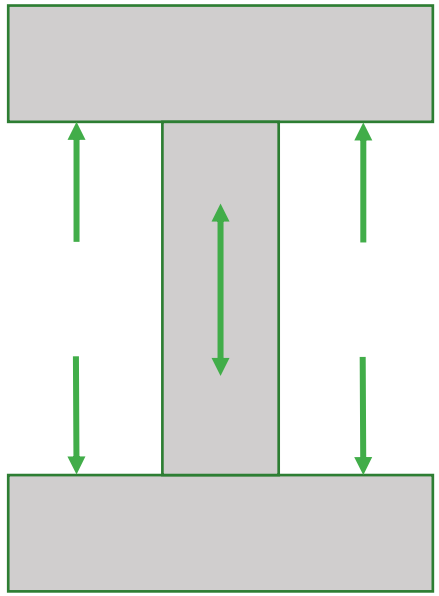


FAILURE OF STEEL ANCHORS

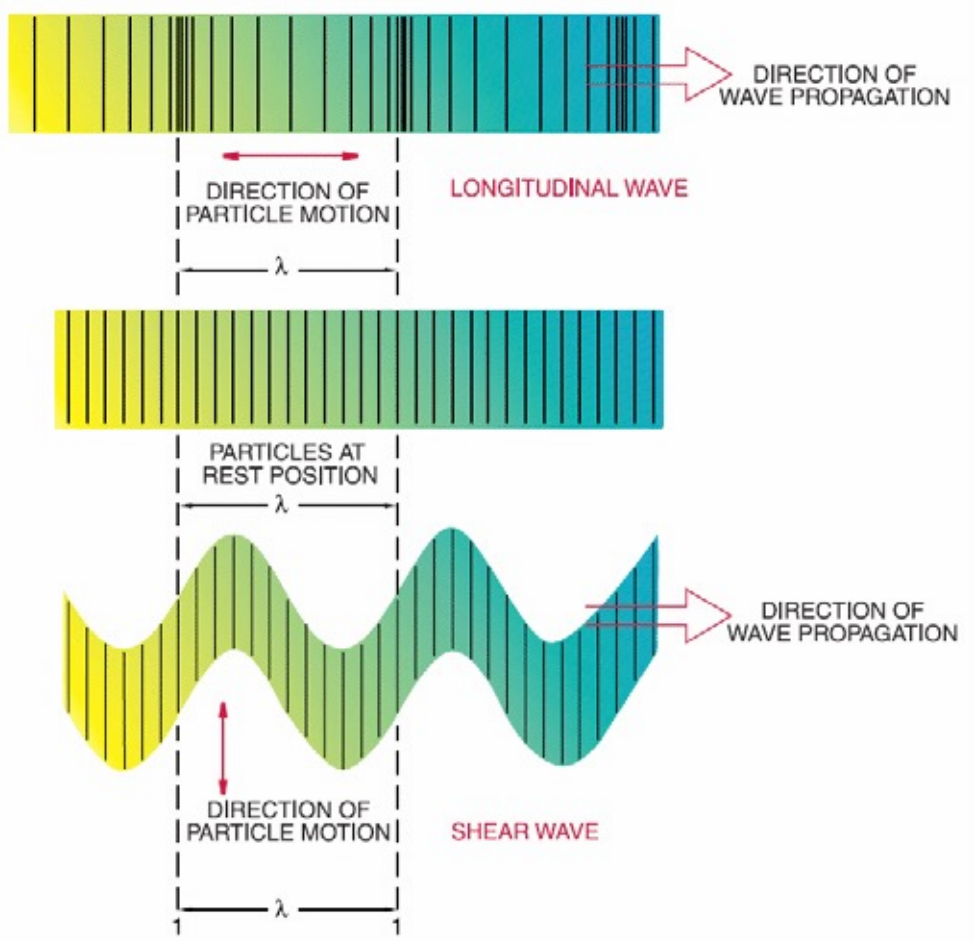


STEEL RODS AND BOLTS IN TENSION





WAVE TYPES

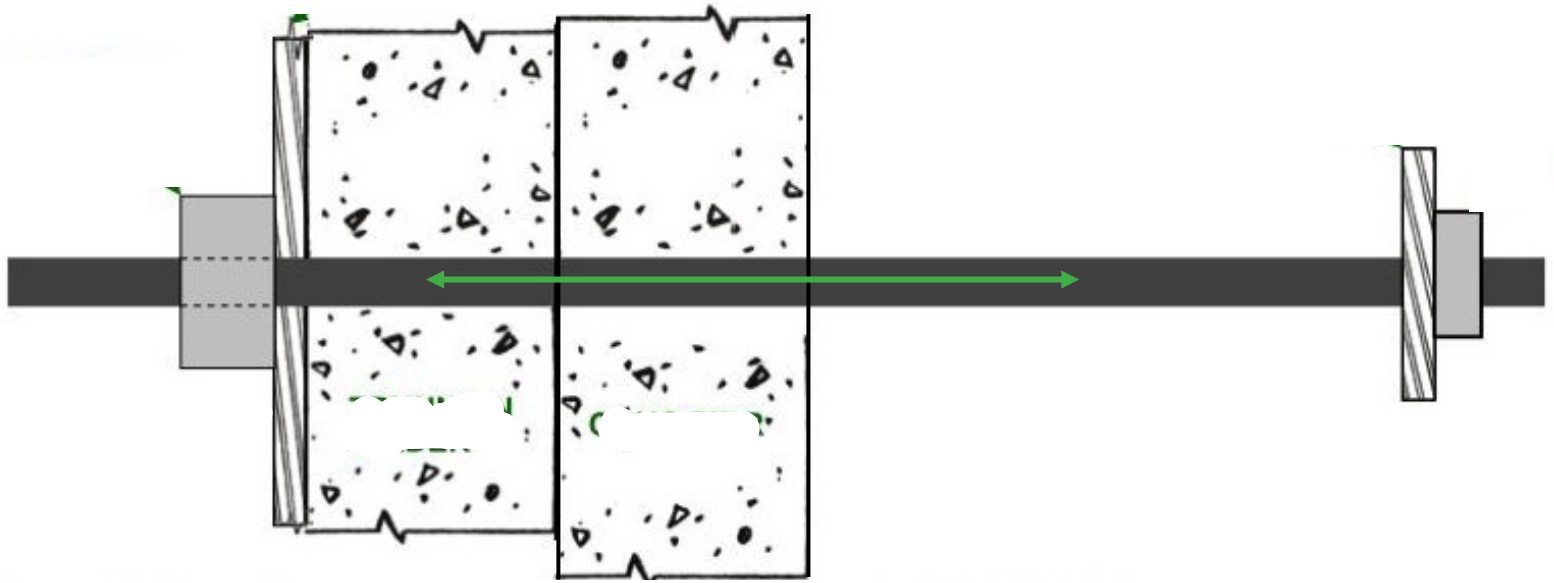


- Compression Waves, V_P
  - Wave propagation is longitudinal
  - Particle propagation is longitudinal
  - Wave velocity ***is*** directly affected by longitudinal tension
- Shear Waves, V_S
  - Wave propagation is longitudinal
  - Particle propagation is transverse
  - Wave velocity ***is not*** affected by longitudinal tension

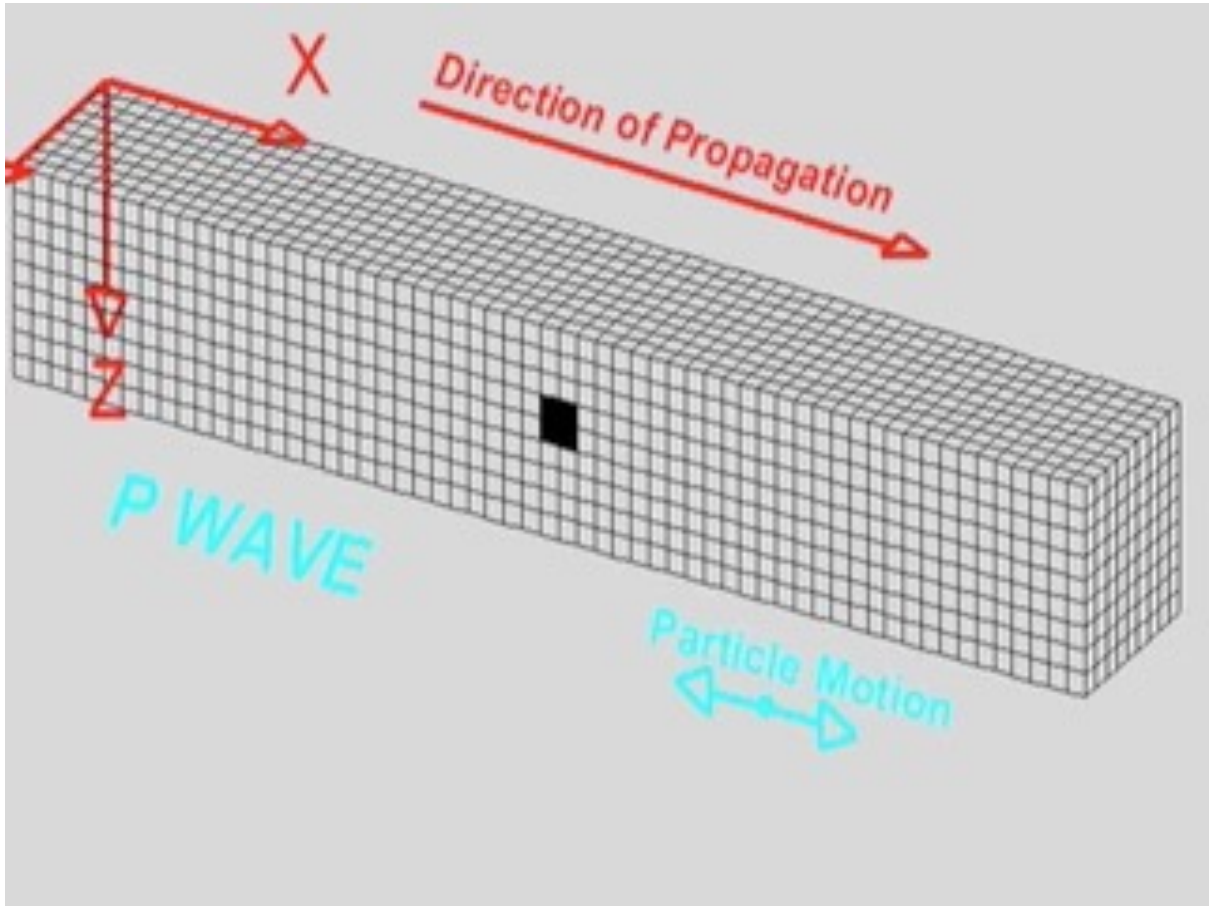
WAVE TYPES FOR LONGITUDINAL TENSION SYSTEMS

V_P

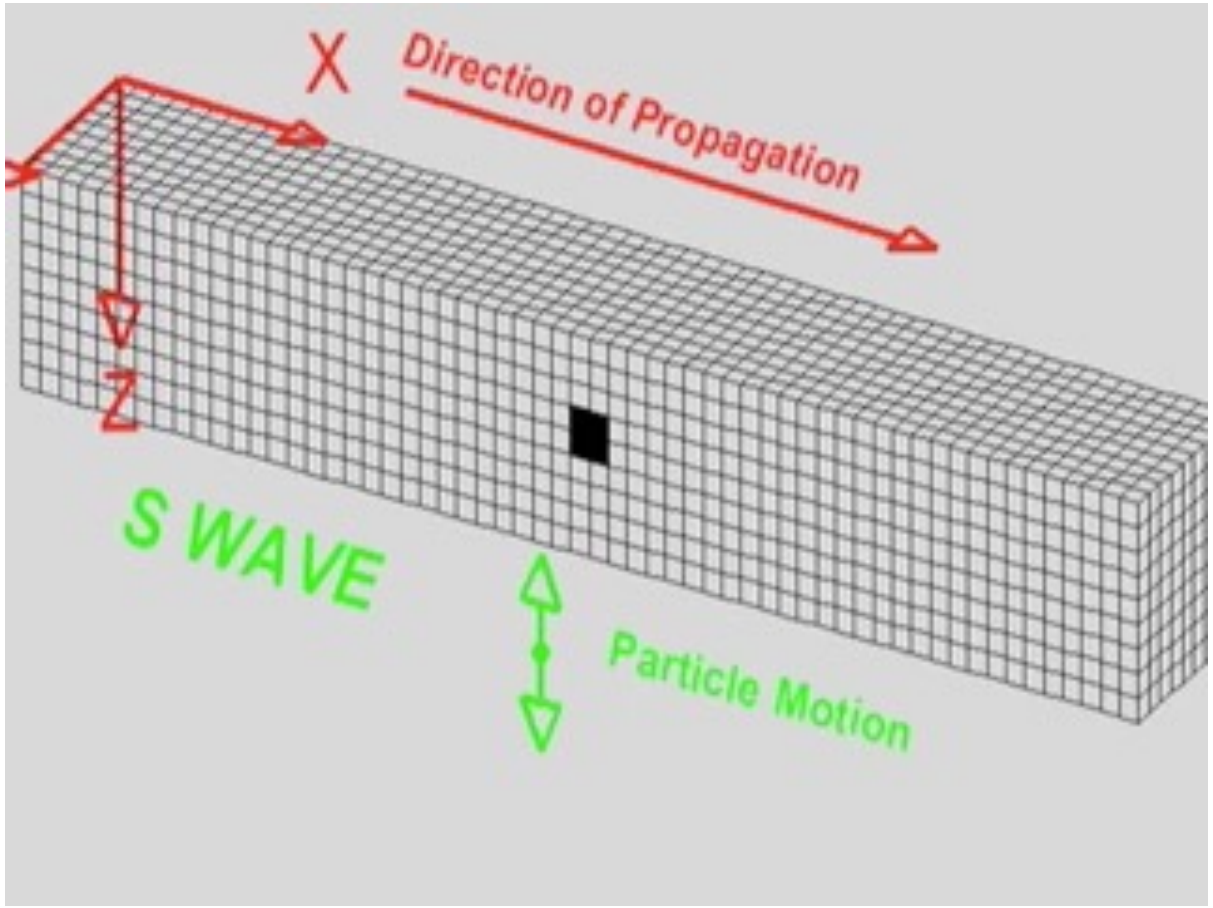
V_S



COMPRESSION WAVES



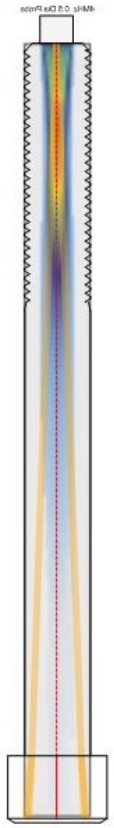
SHEAR WAVES

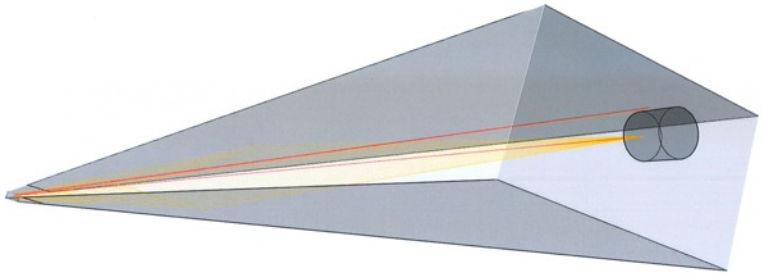


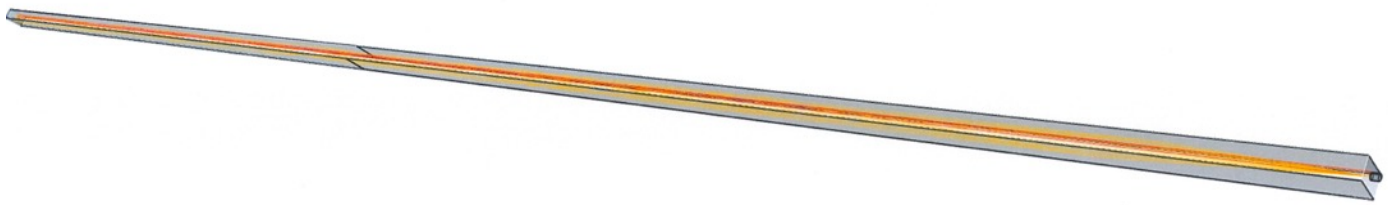
SYSTEM DEVELOPMENT

BUILDING THE SYSTEM – WAVE GUIDES

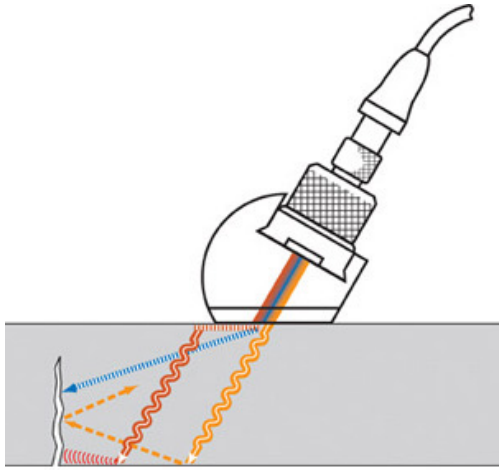
- First step – is this feasible for long bars?
- Beam Tool – modeling of wave propagation and sensor design
- Both V_P and V_S can propagate through the material length:
  - True shear wave transducer
  - Correct frequency
  - Enough amplitude

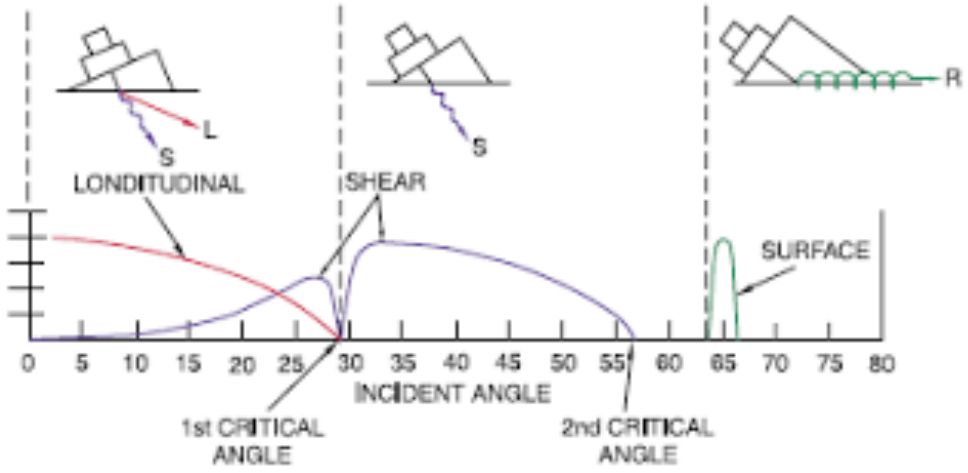






BUILDING THE SYSTEM – SHEAR WAVE TRANSDUCER

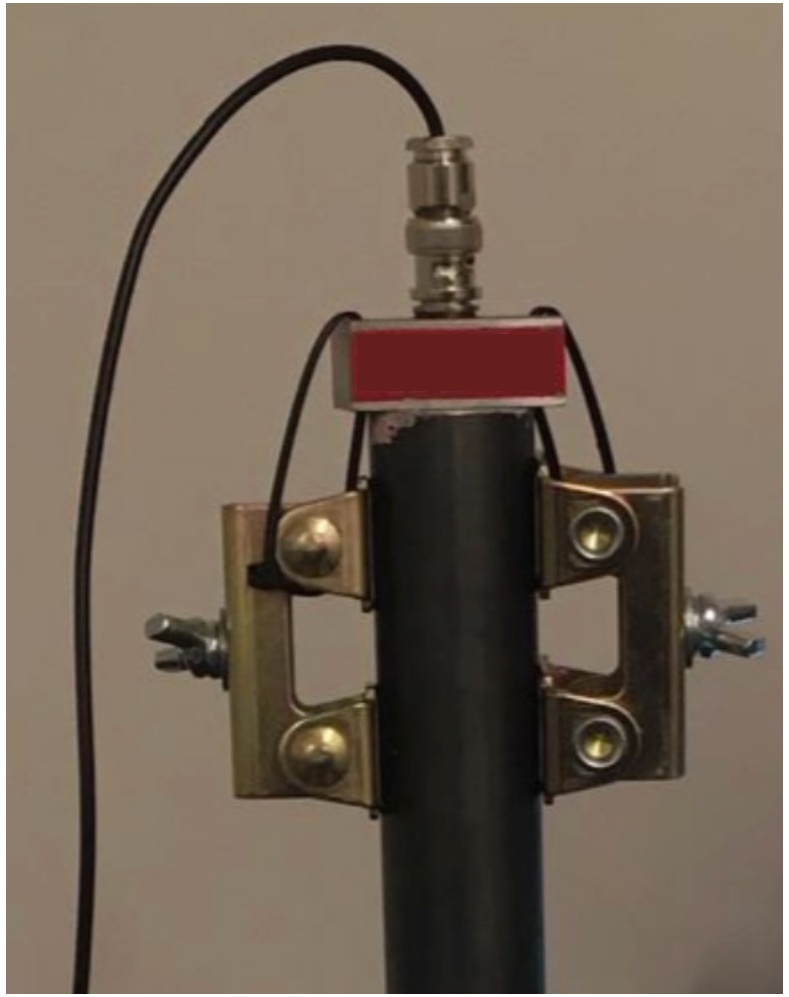




- Most shear wave transducers are actually straight beam transducers with a wedge
- Wedge introduces incidental shear waves through longitudinal wave mode conversion (refraction)

Source: Olympus

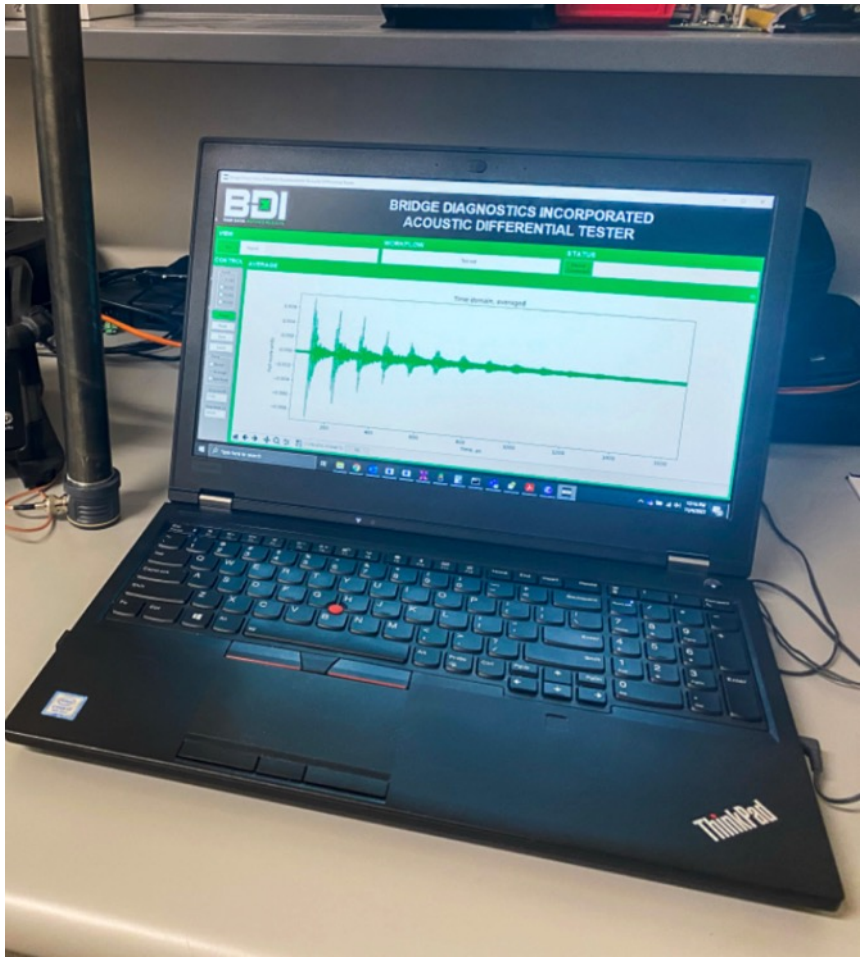
BUILDING THE SYSTEM – SHEAR WAVE TRANSDUCER



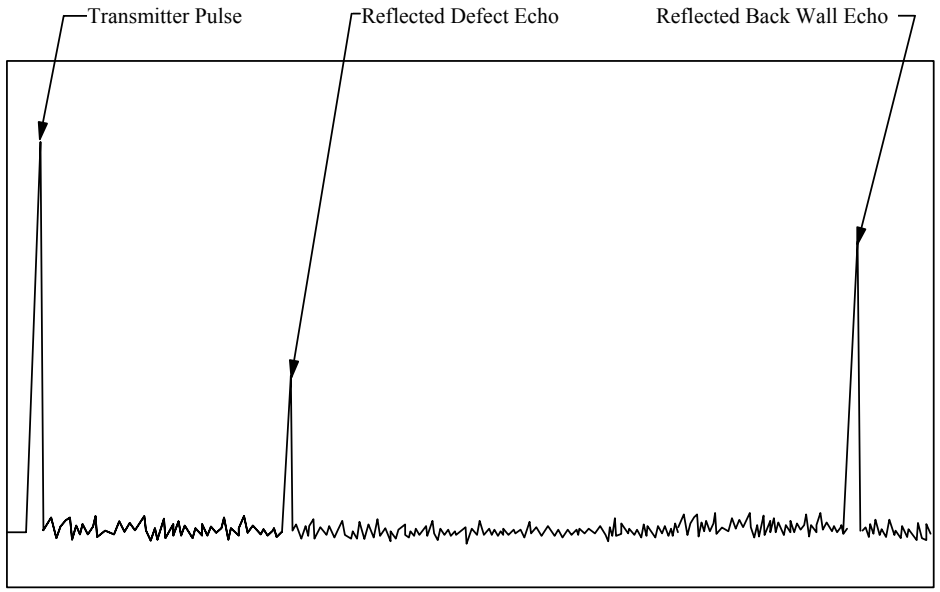
- Normal Incidence shear wave transducers are available
- Needed a normal incidence shear wave transducer that could handle very high amplitudes
- So, we designed and built them

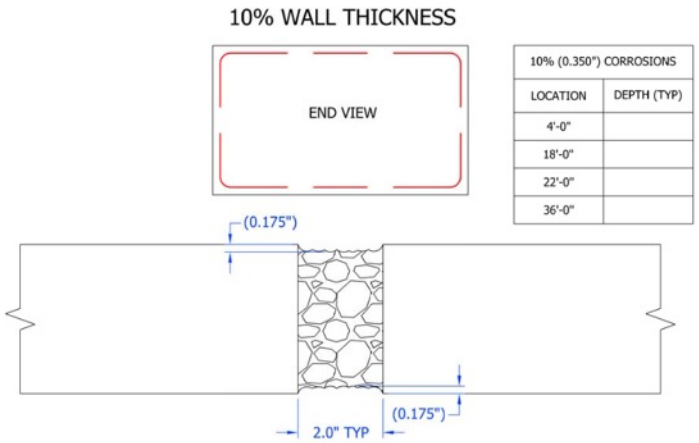
BUILDING THE SYSTEM – DATA ACQUISITION

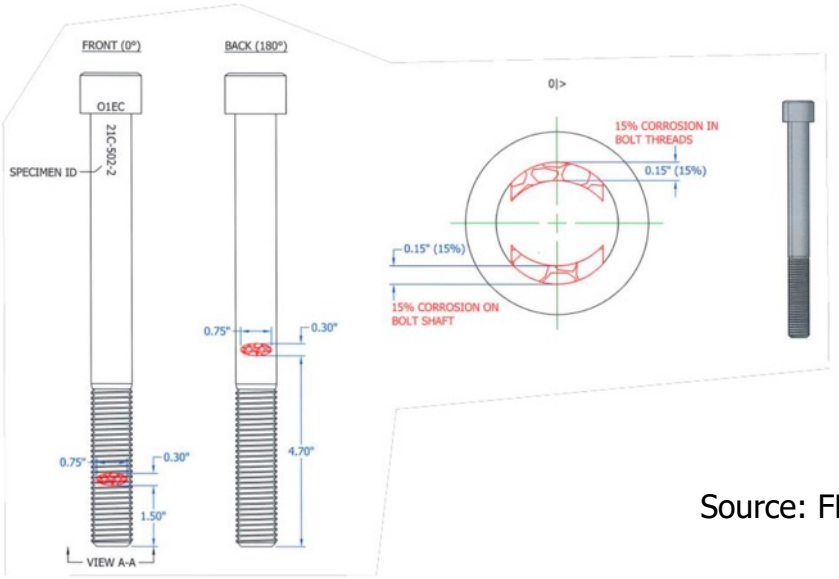
- With wave mechanics and transducer design finished, the next step was data acquisition
- System built to take continuous measurements, average, and filter ambient noise
- System is robust enough to handle field environments and can handle multiple measurements simultaneously
- Software was built to acquire, manipulate, save, and recall data.



MOCKUPS FOR INTEGRITY MEASUREMENTS

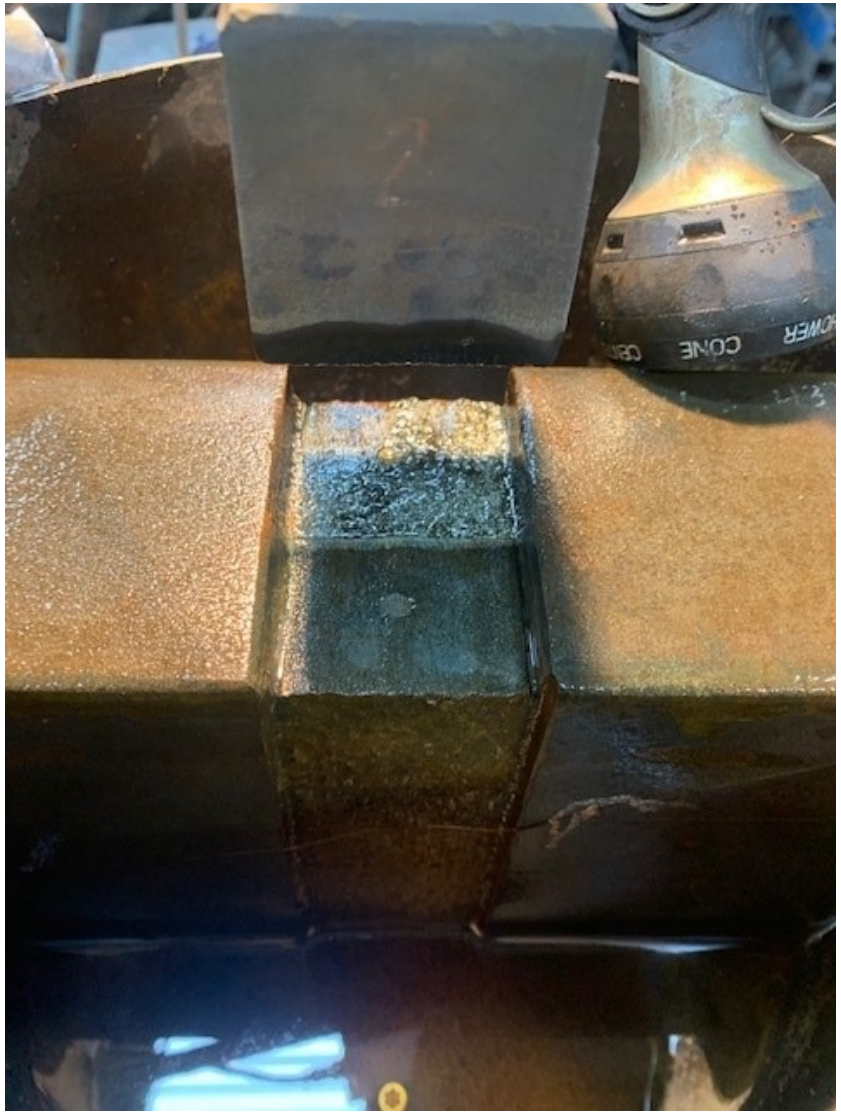






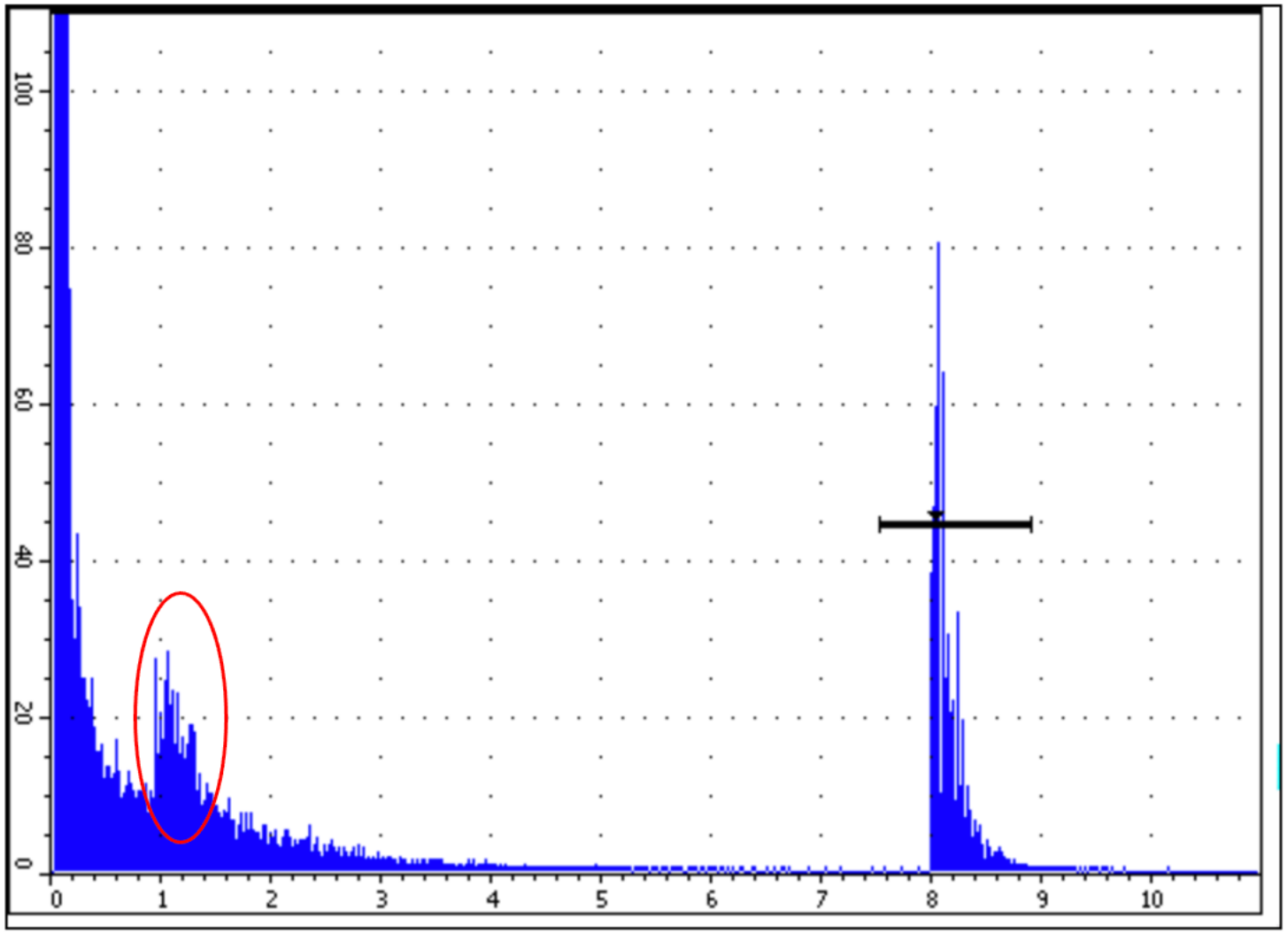
Source: FHWA, Flawtech

INTEGRITY MOCKUP FABRICATION



Source: Flawtech

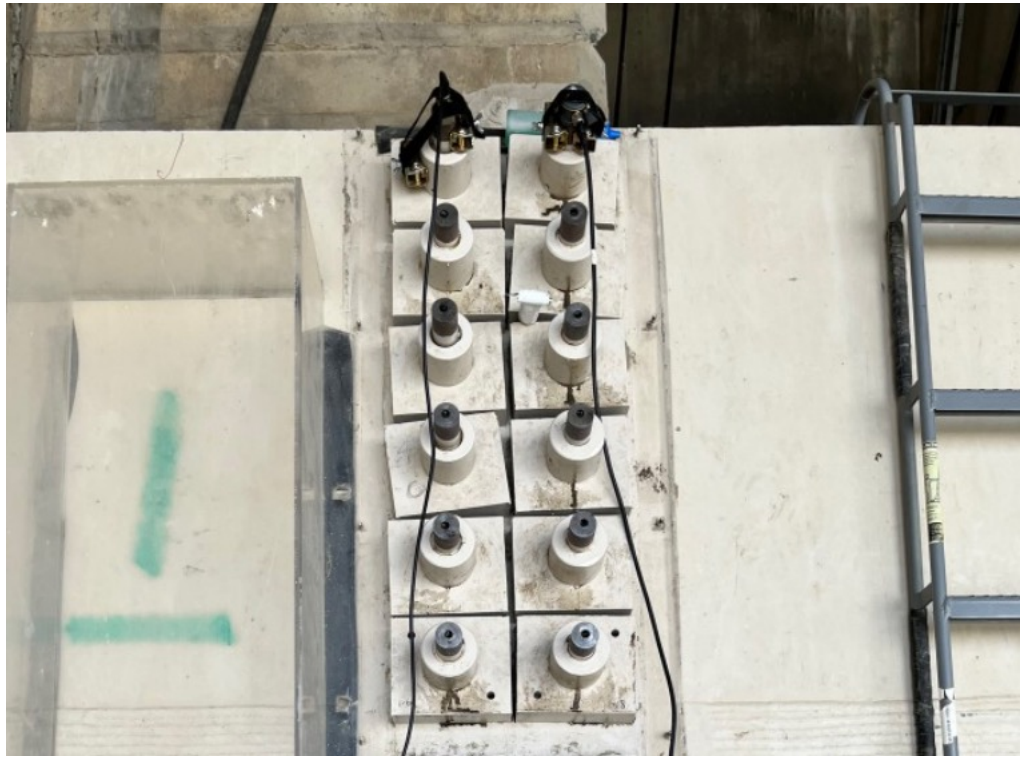
INTEGRITY MOCKUP TESTING - RESULTS

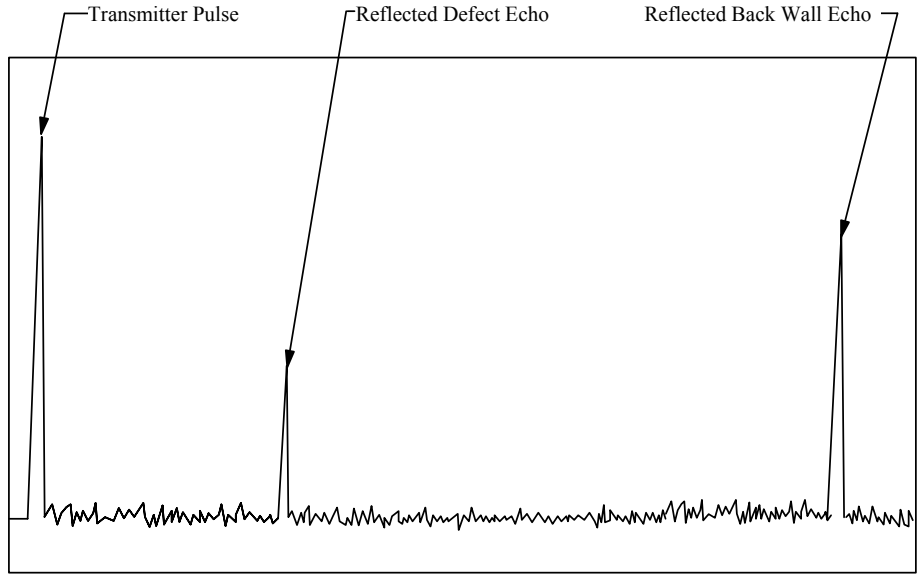


- With thresholds known of verified cross section loss, measurements can be made to determine location and approximate section loss.

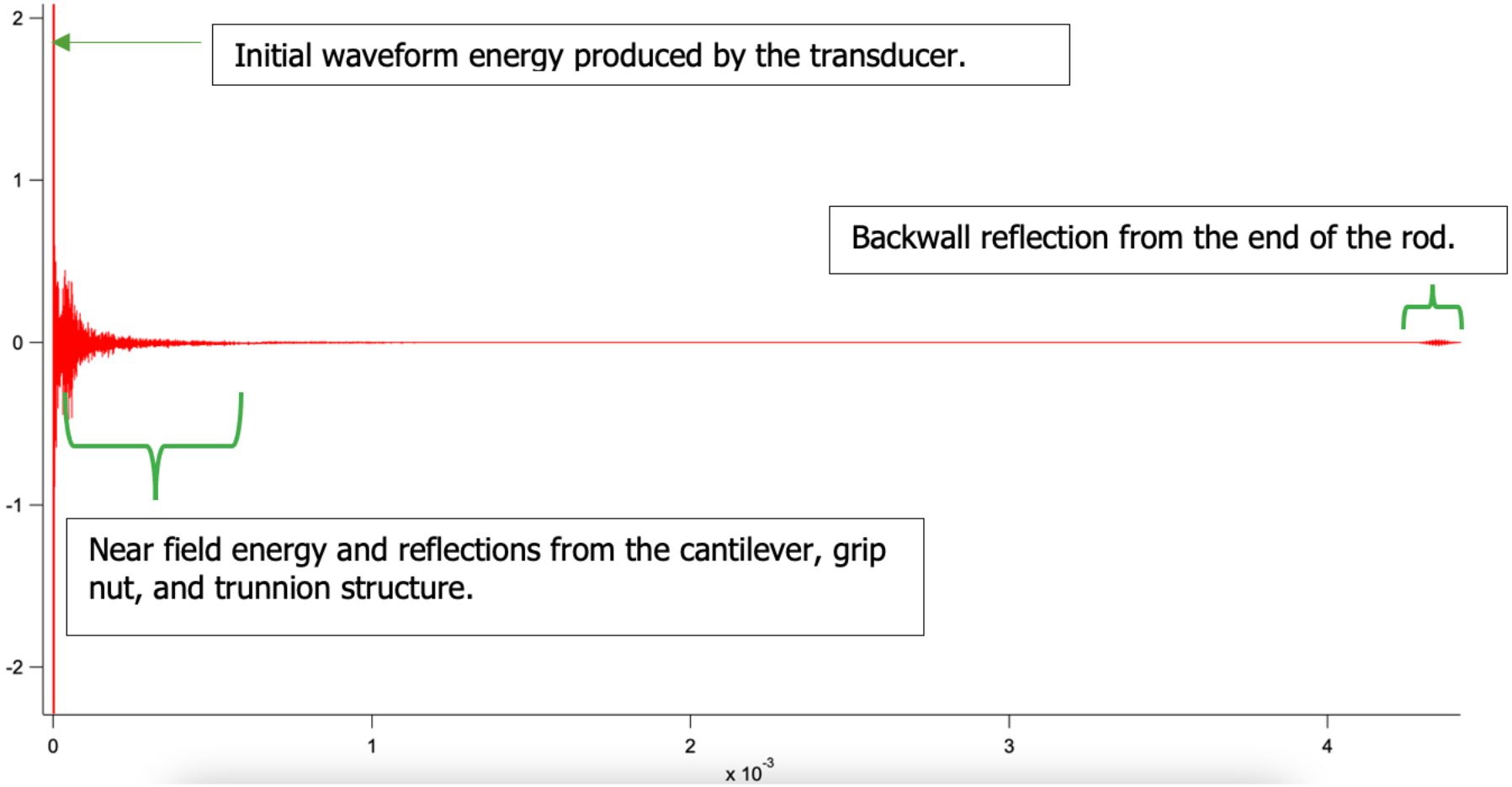
APPLICATION

TESTING OF TENSIONED ANCHOR RODS

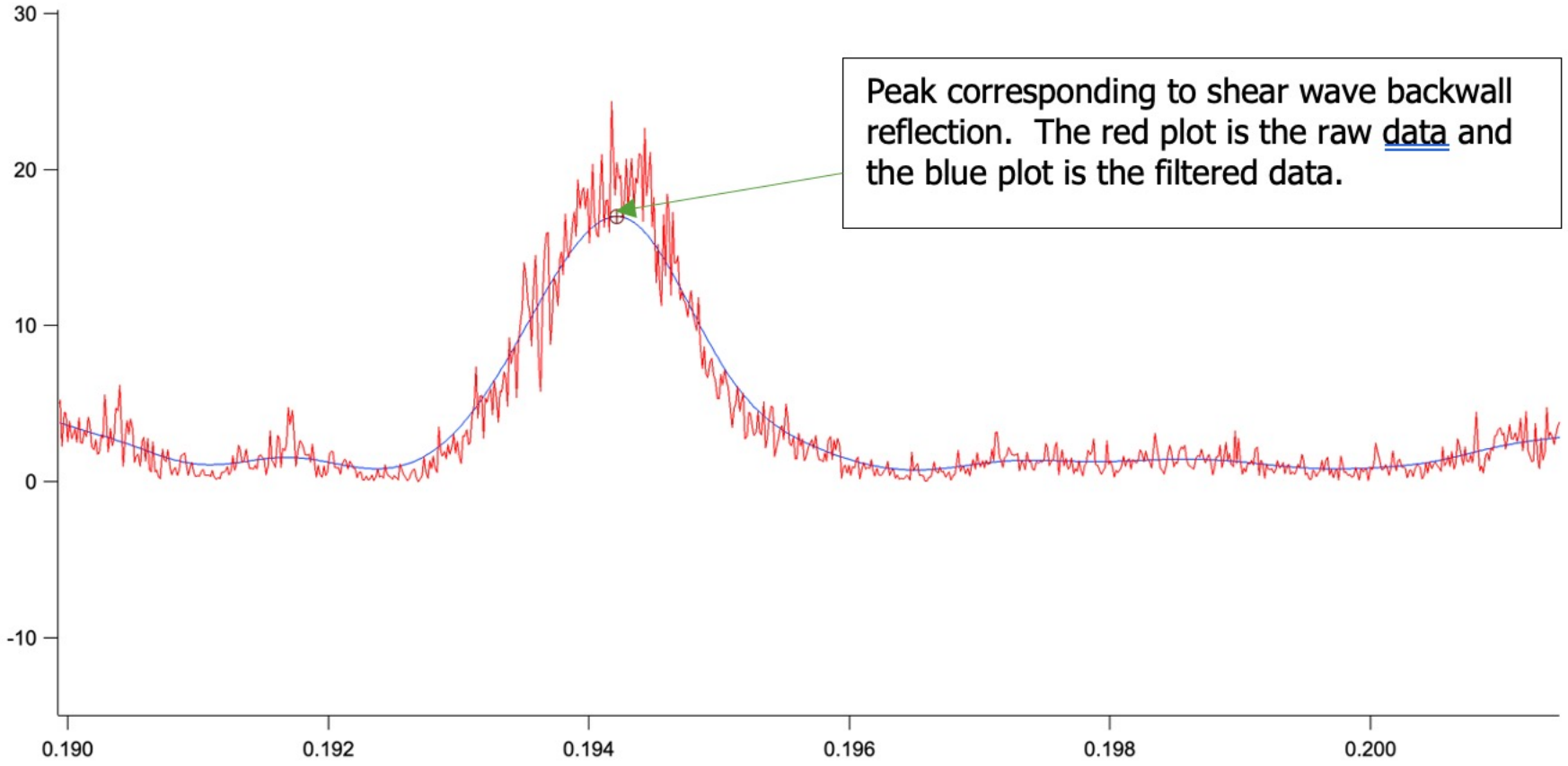




COMPRESSION WAVE TIME DOMAIN

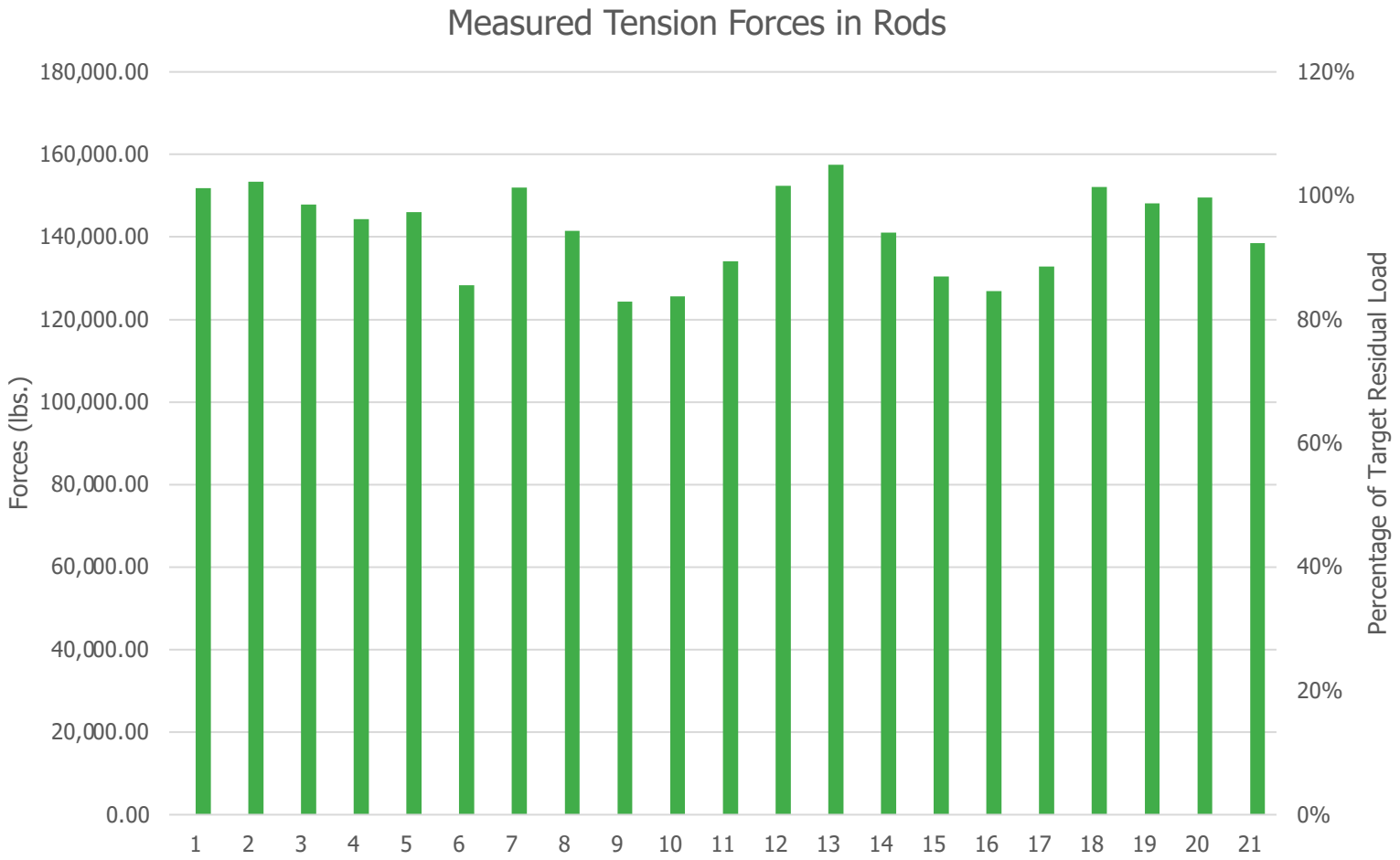


SHEAR WAVE FREQUENCY RESPONSE (ZOOMED)



$$V = f\lambda$$

TYPICAL RESULTS



TESTING OF BOLTS FOR TENSION

- Methodology is the same, but the need for high amplitude transducers is reduced
- Tension can be measured in the anchor bolts with smaller hand-held systems and performed quickly with less filtering and results provided on site
- Applications:
  - Movable bridges,
  - Wind Towers,
  - Lift structures,
  - Pressure vessels,
  - Sign Structures.

TESTING OF ANCHORS FOR INTEGRITY

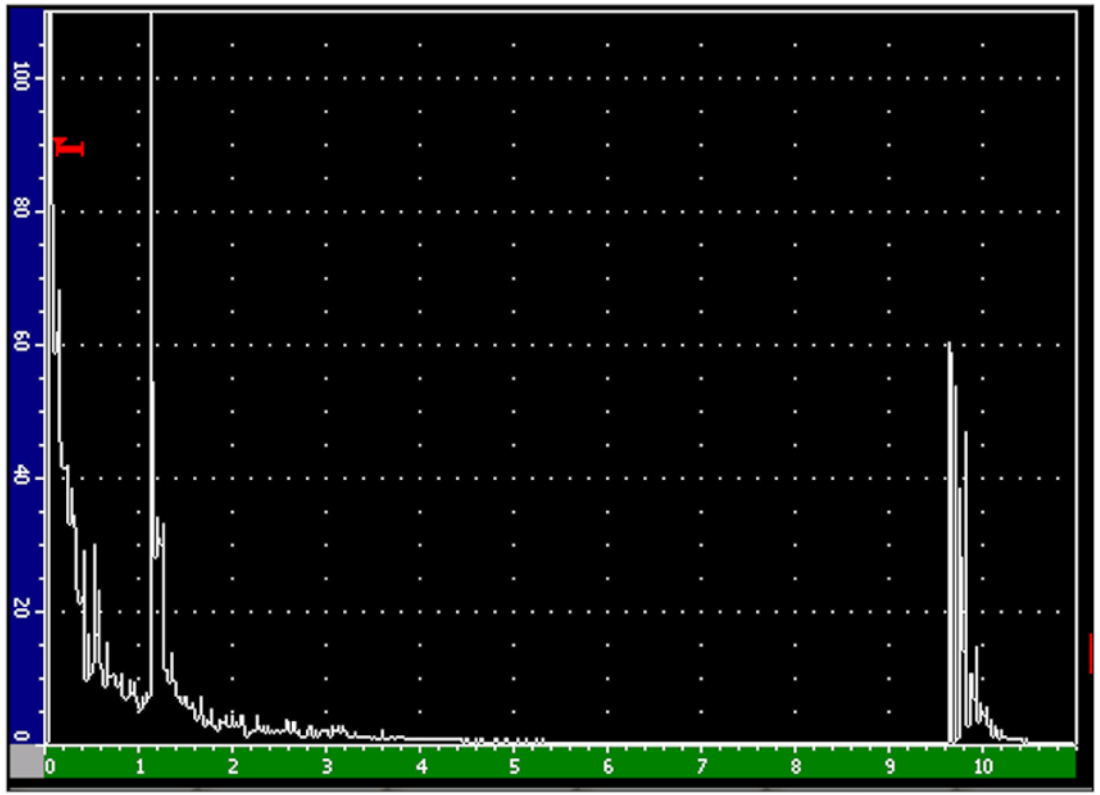
Dead Men Anchors

Anchor Bolts

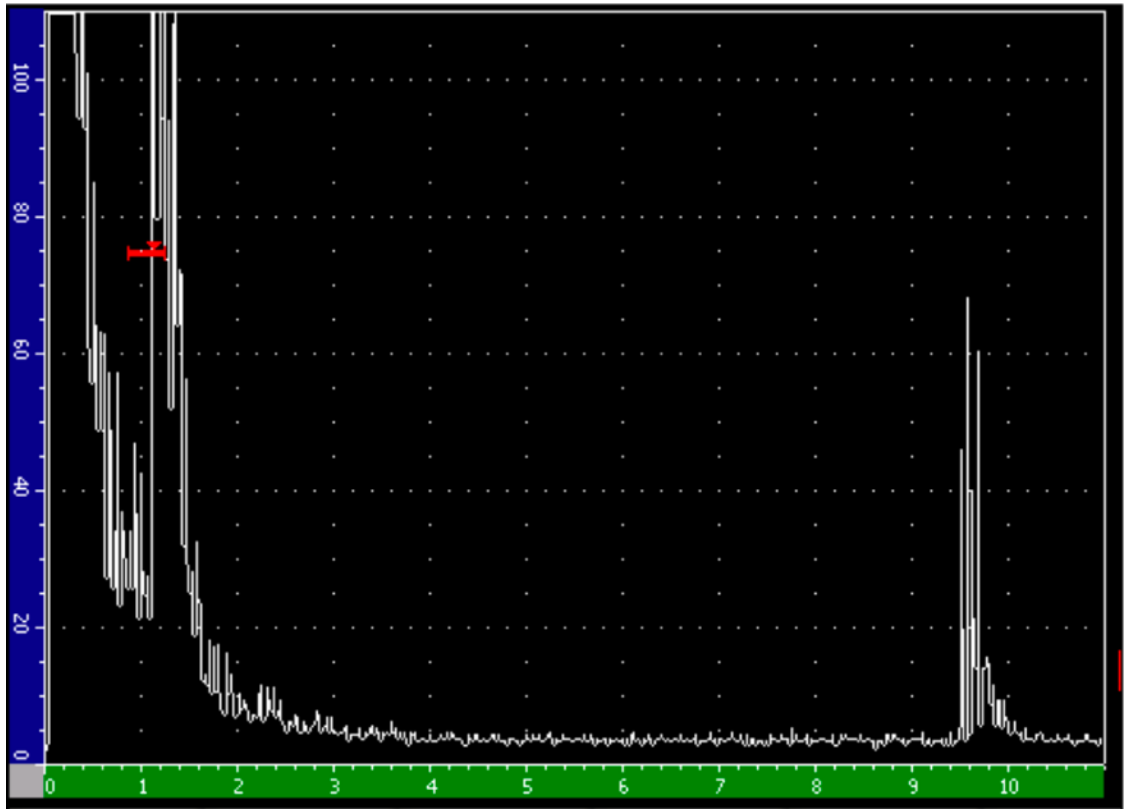
FIELD TESTING – GRINDING PICS

FIELD TESTING – TESTING PICS

FIELD TESTING – NO INDICATIONS FOUND

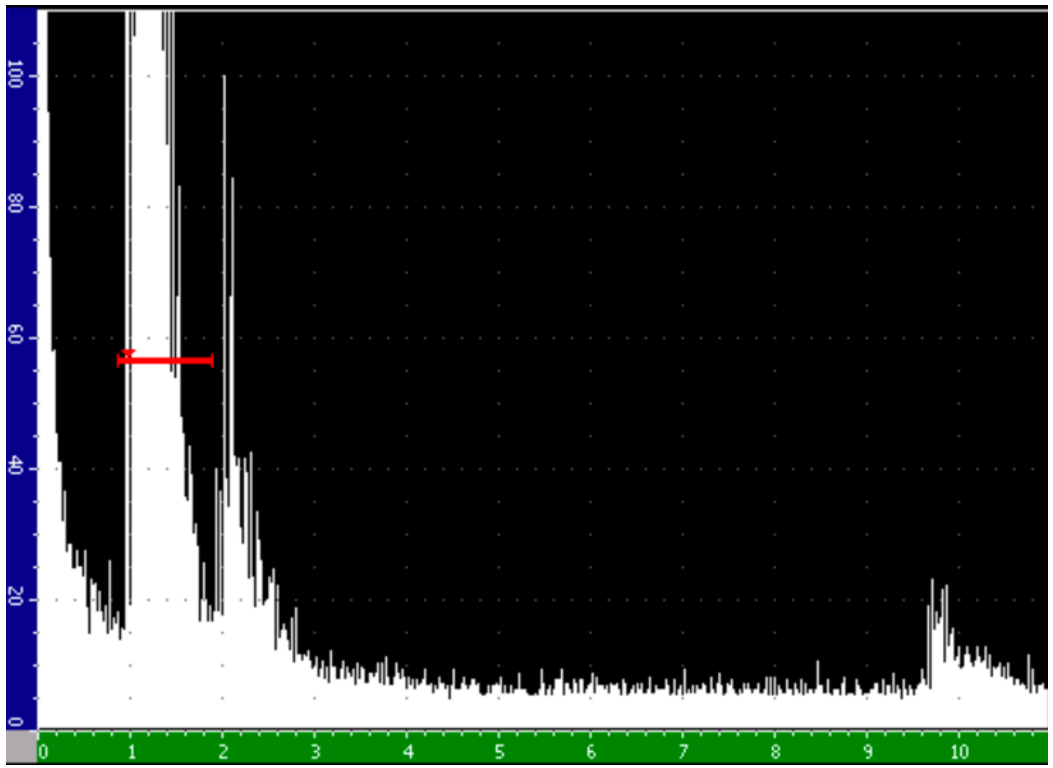


Mockup Data (Baseline)

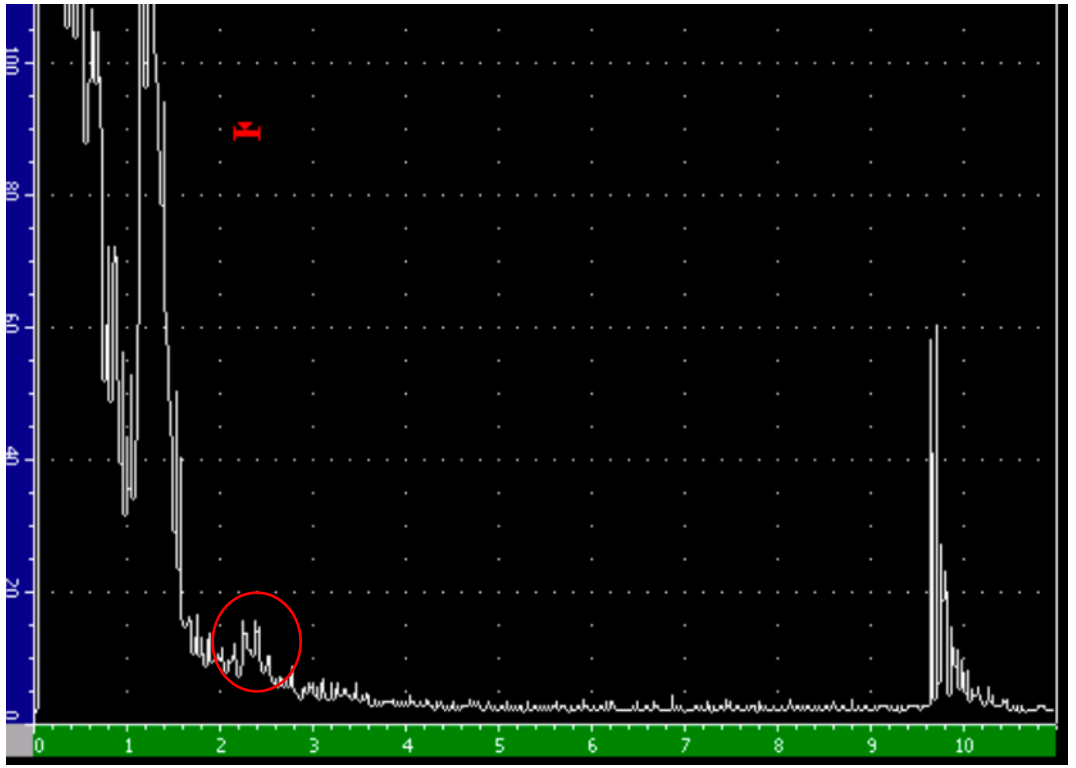


Field Data

FIELD TESTING

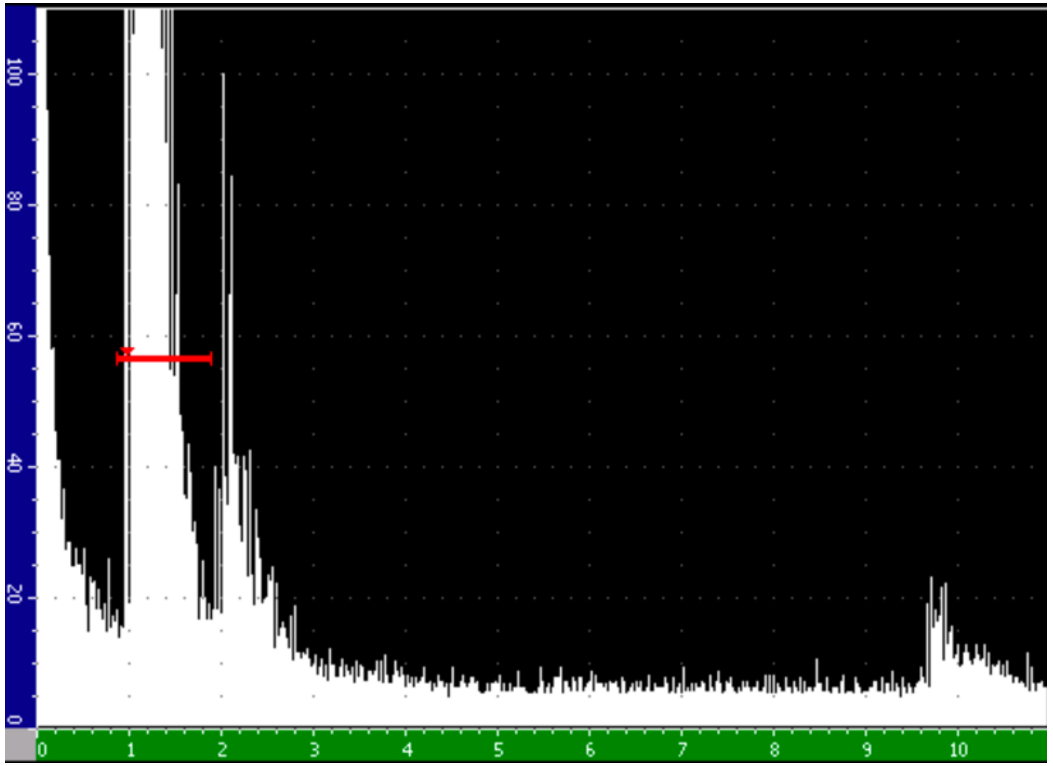


Mockup Data (25% Corrosion)

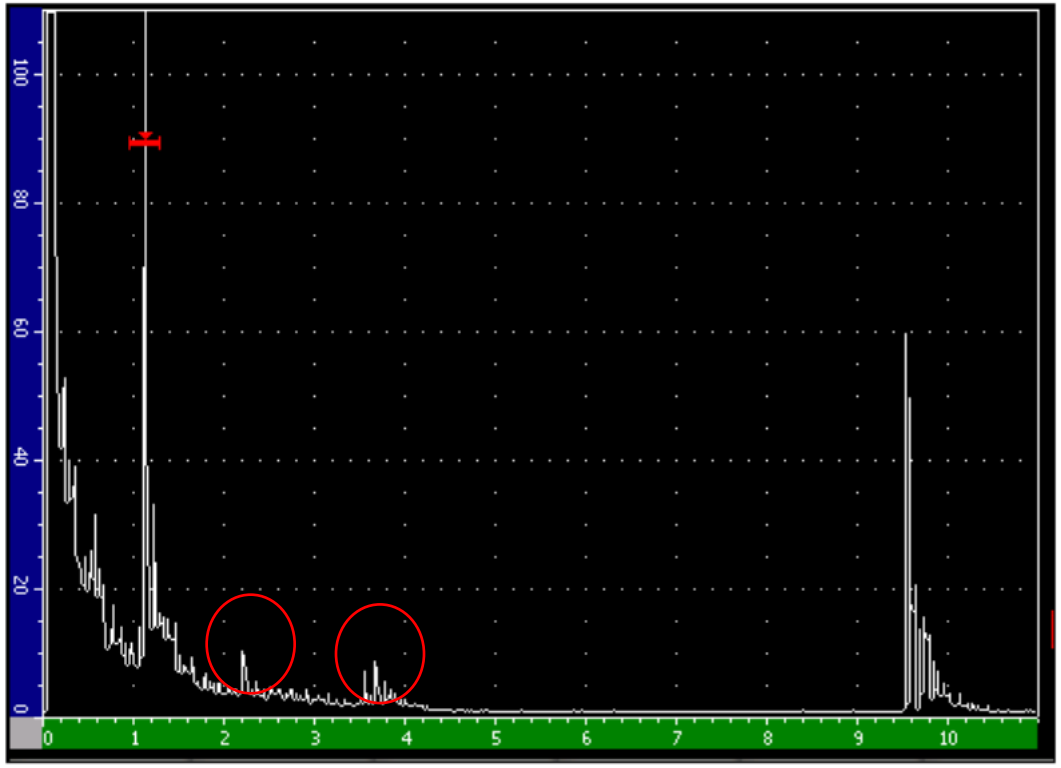


Field Data (~5% Corrosion

FIELD TESTING



Mockup Data



Field Data (~3% corrosion at two locations

CONCLUSIONS

- Nondestructive testing utilizing ultrasonics can be utilized for steel anchors to determine:
  - In-situ tension
  - Locations and quantities of degradation
- A specific methodology, specialized equipment, and analysis techniques have been developed for these tests.
- Testing is safe, quick, and reliable
- Most analysis can now be performed in the field for initial results with final analysis taking several minutes per steel anchor.

CLOSING

- INTRODUCTION
- BACKGROUND
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- SYSTEM DEVELOPMENT
- APPLICATION
- DISCUSSION

RAW DATA.
REFINED RESULTS.

QUESTIONS?

RAW DATA. REFINED RESULTS.

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