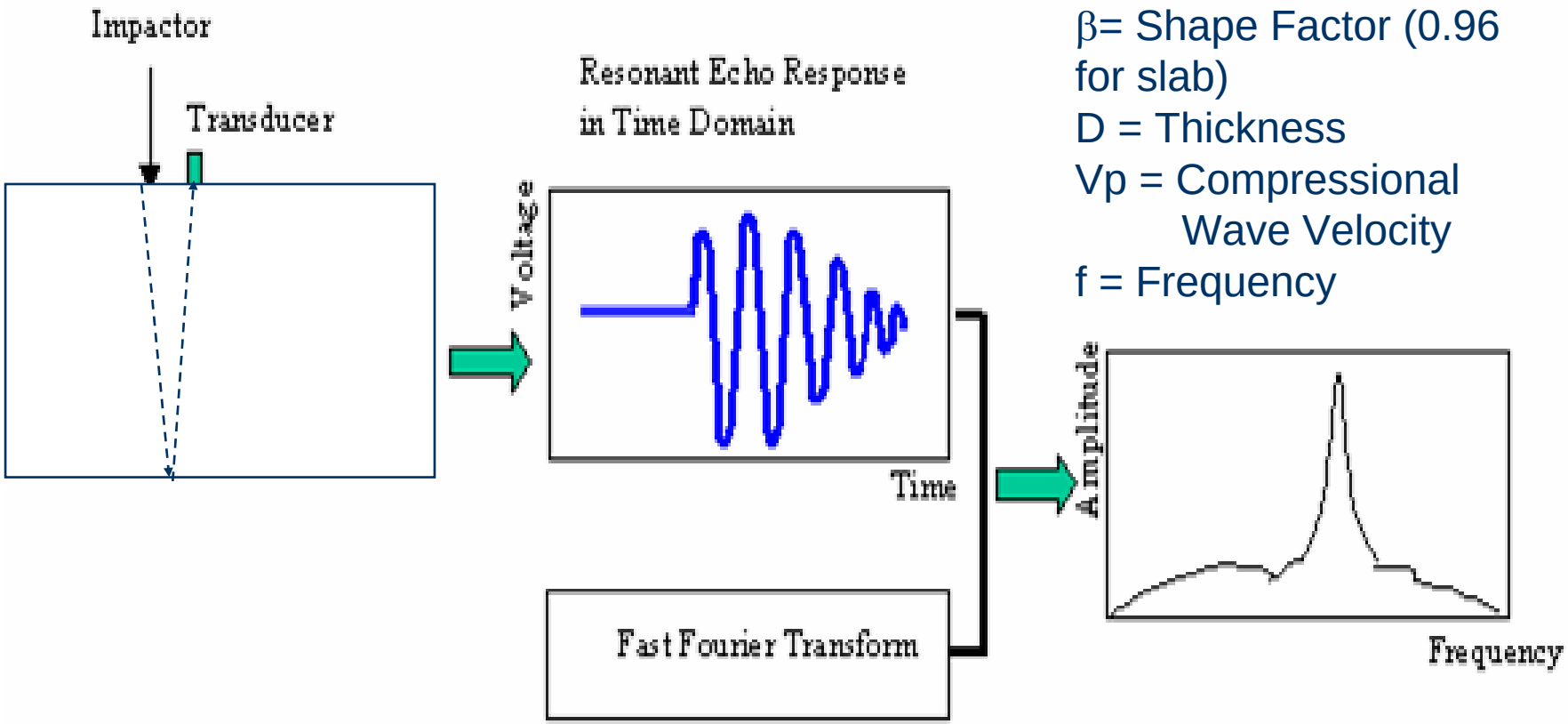
Internal Imaging of Concrete Using Impact Echo Scanning

Patrick K. Miller, Project Engineer
Yajai Tinkey, Ph.D., P.E.
Larry D. Olson, P.E.
Olson Engineering, Inc.

Wheat Ridge, CO – Rutherford, NJ – Hercules, CA – Socorro, NM

Impact Echo Test Basic Theory



$D = \beta Vp/(2*f)$

β= Shape Factor (0.96 for slab)

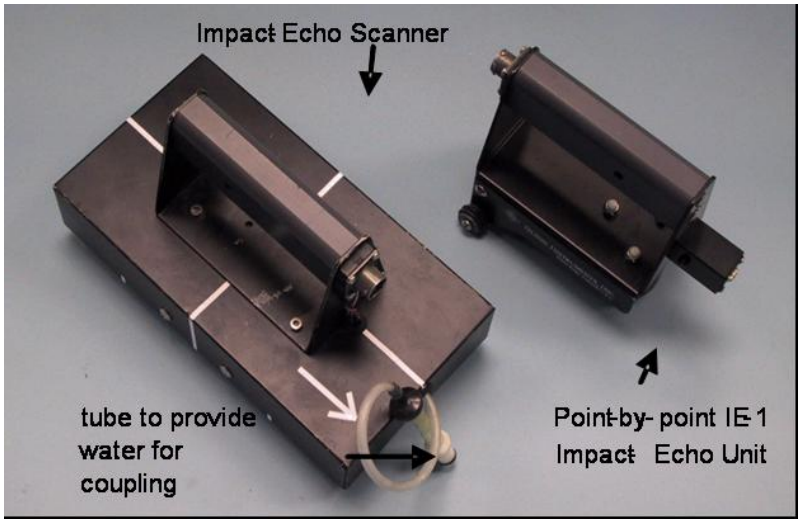
D = Thickness

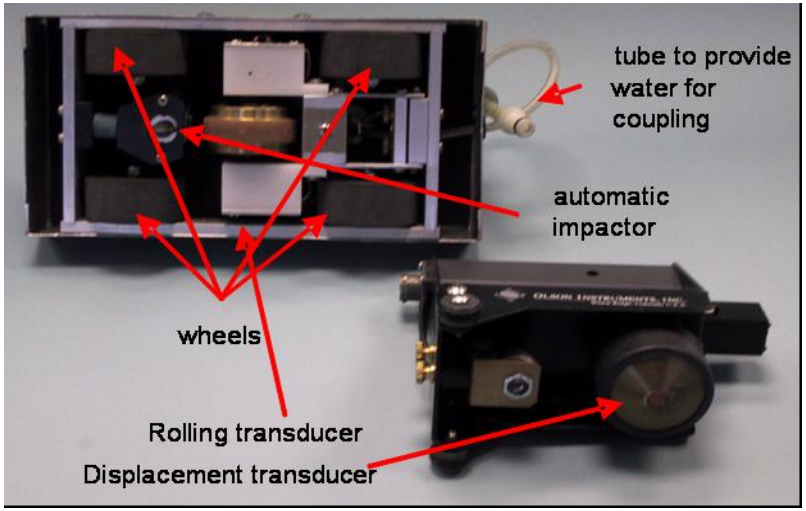
Vp = Compressional Wave Velocity

f = Frequency

Impact Echo Scanner (IES)

- Add wheels to the unit
- Add a rolling transducer
- Calibrated to test every 25 mm or 1” interval
- Speed ~ 20 ft/min



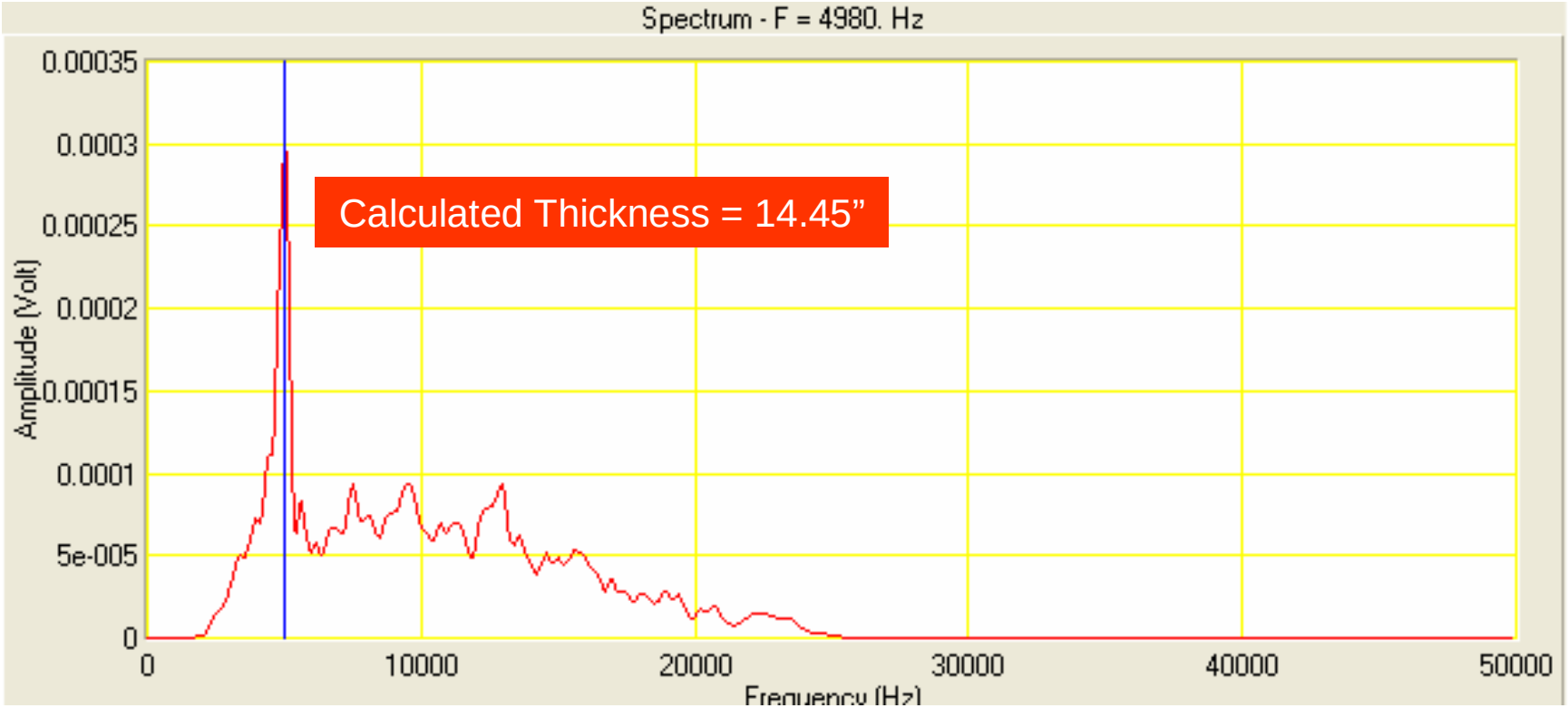


Olson Instruments IES System

Olson Instruments Freedom Data PC
and IES-1 system

Impact Echo Scanner with rolling displacement
Transducer and non-contact microphone

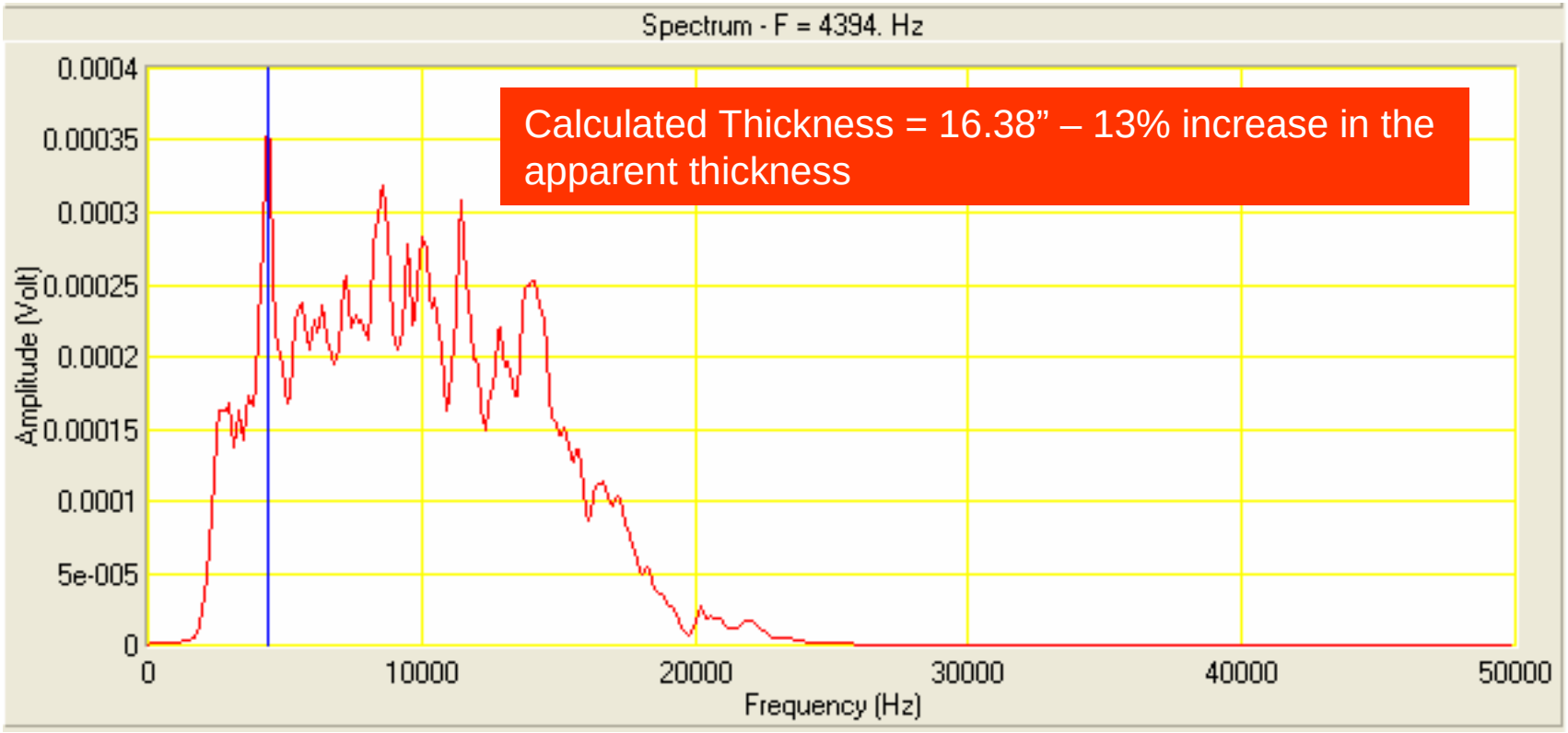
Example Impact Echo Data



From a 15” transfer wall

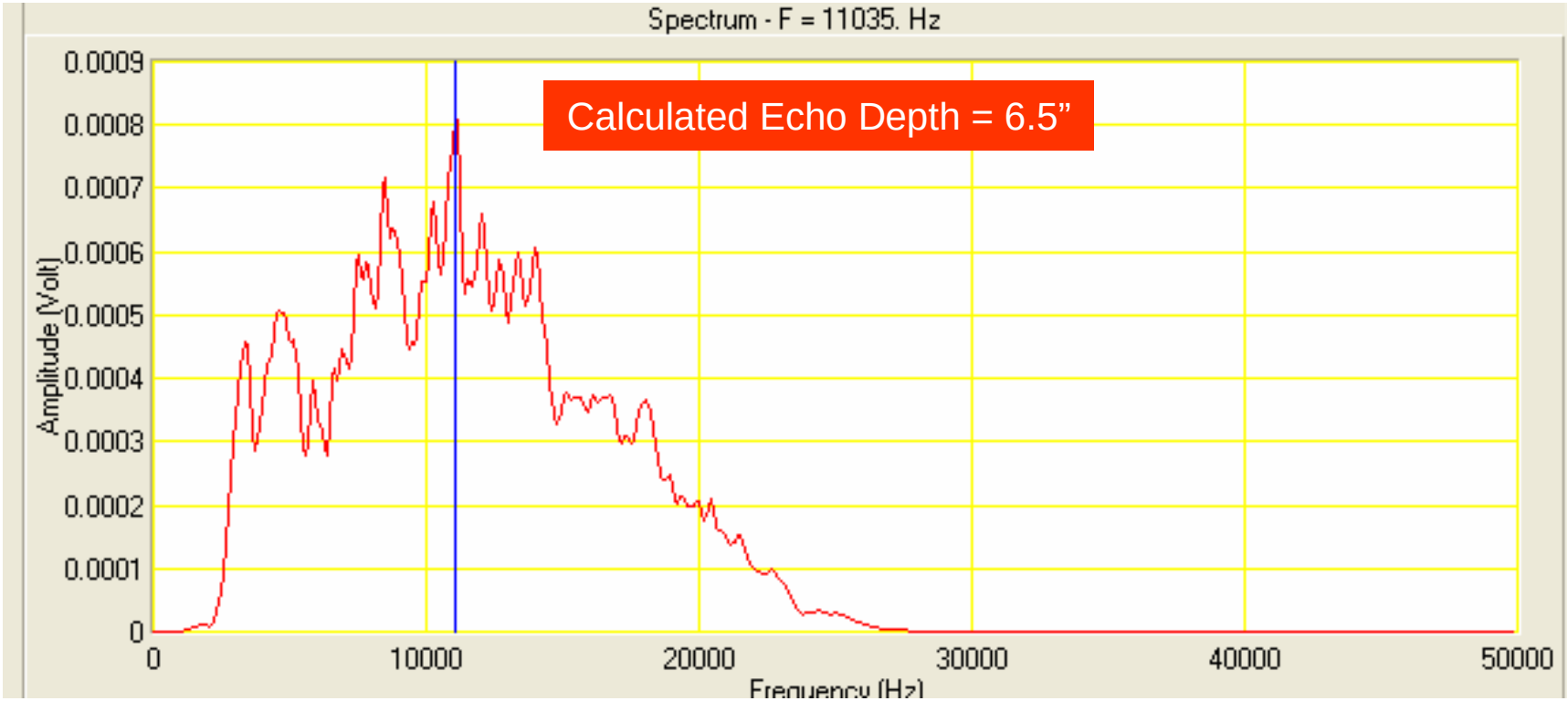
Typical Data Interpretation - Sound

Example Impact Echo Data



Typical Data Interpretation – Poor Consolidation or Voids

Example Impact Echo Data

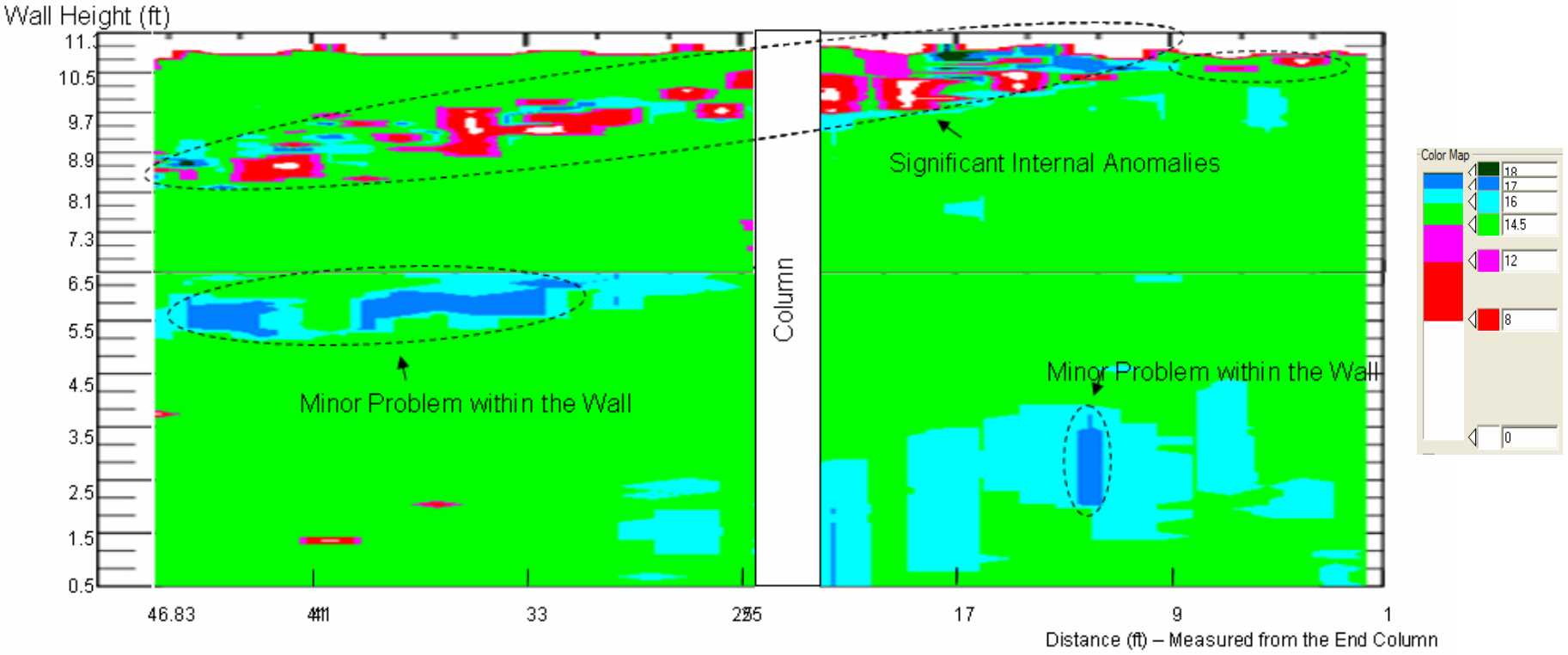


Typical Data Interpretation – Internal Cracks

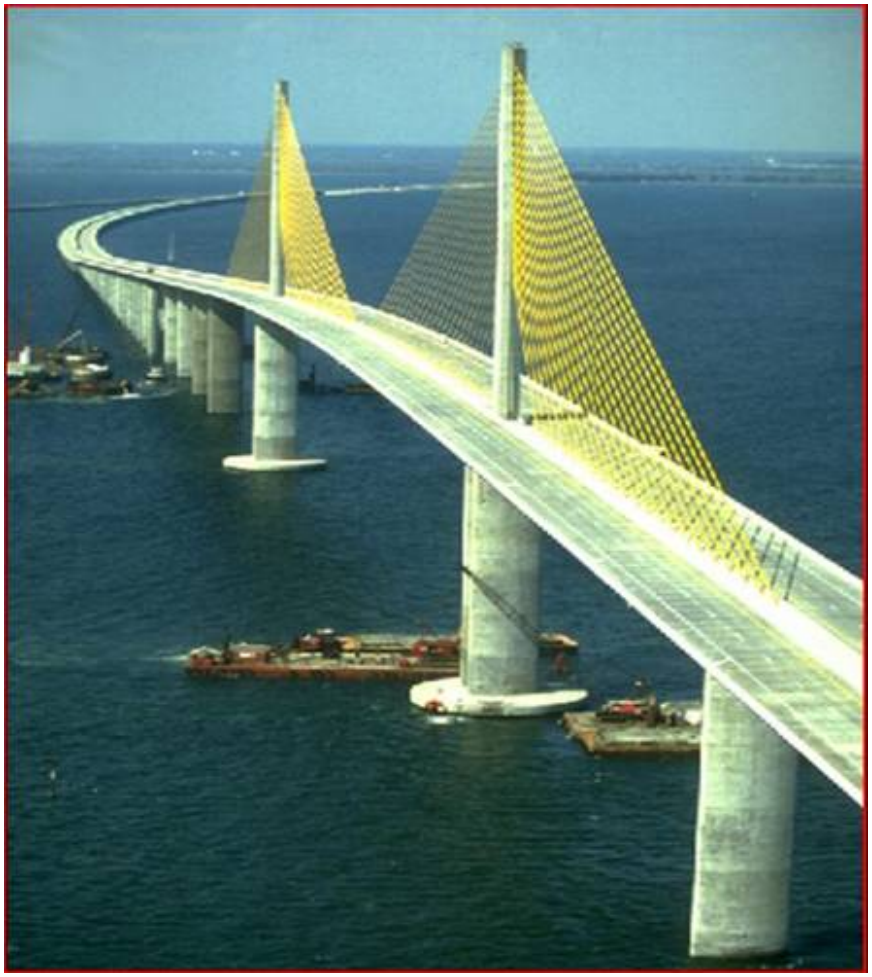
1st Case History – Determination of Internal Integrity of Concrete Transfer Wall

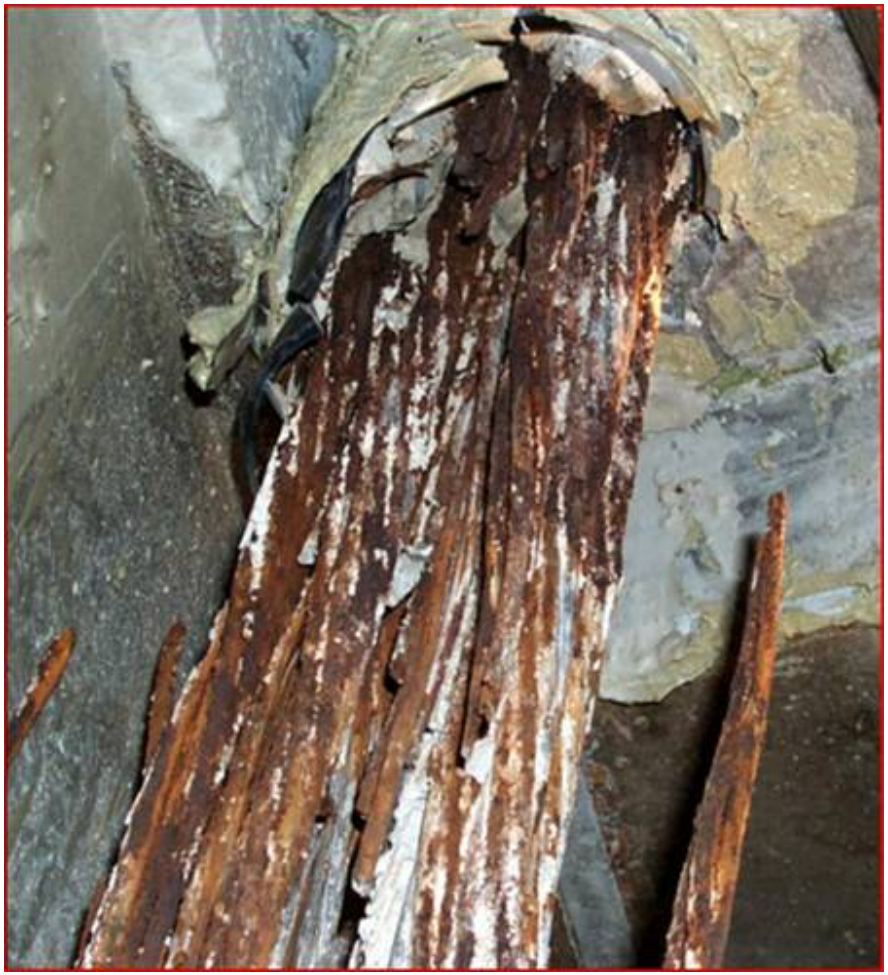
- Impact Echo (IE) tests were conducted using an Impact Echo Scanner (IES) system.
- Grid spacing of 18 inches between each scan line and approximately 1 inch spacing between tests along the scan
- Over 4,000 IE data points were obtained from the 50 x 12 ft test area in approximate 2 hours of field time

1st Case History – Determination of Internal Integrity of Concrete Transfer Wall



2nd Case History - Void Detection in Post-tensioned Bridge Ducts



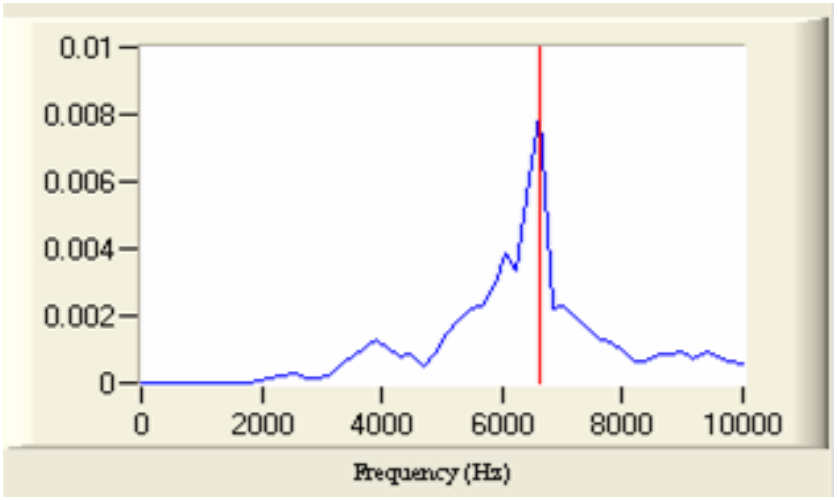


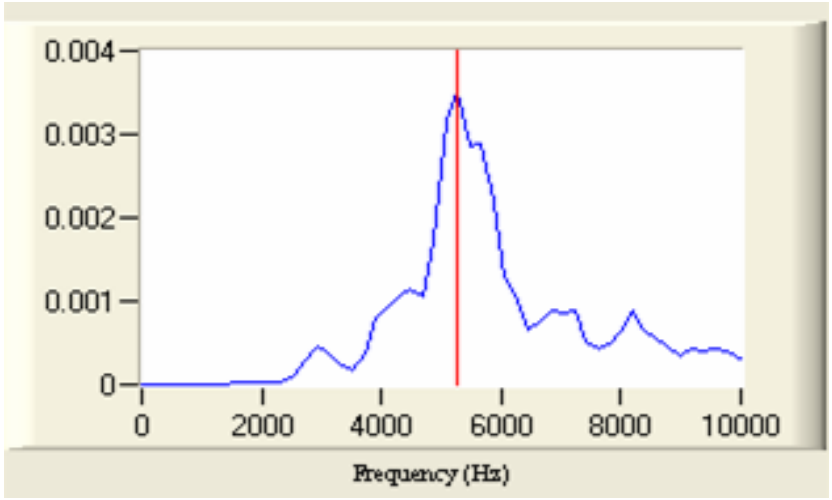
Courtesy of Florida Department of Transportation

Void Detection in Post-tensioned Bridge Ducts Using Impact Echo Scanning

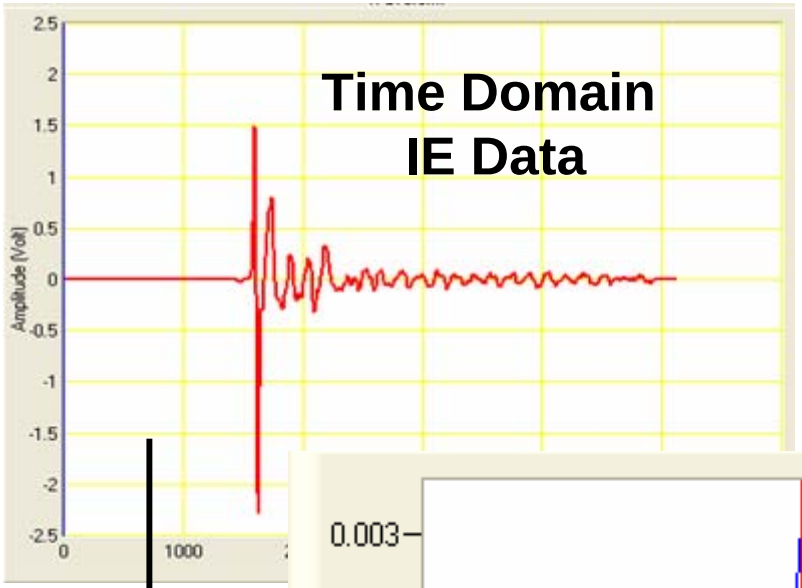
- Fully Grouted Duct
  - Frequency peak = 6,445 Hz
  - Apparent Thickness = 11.17 inches (11% increase)
- Empty Duct
  - Frequency peak = 5,274 Hz
  - Apparent Thickness = 13.65 inches (36% increase)
- 20% increase in the thickness between the fully grouted and empty ducts

Note: Nominal thickness of the girder is 10 in with 4 in diameter duct

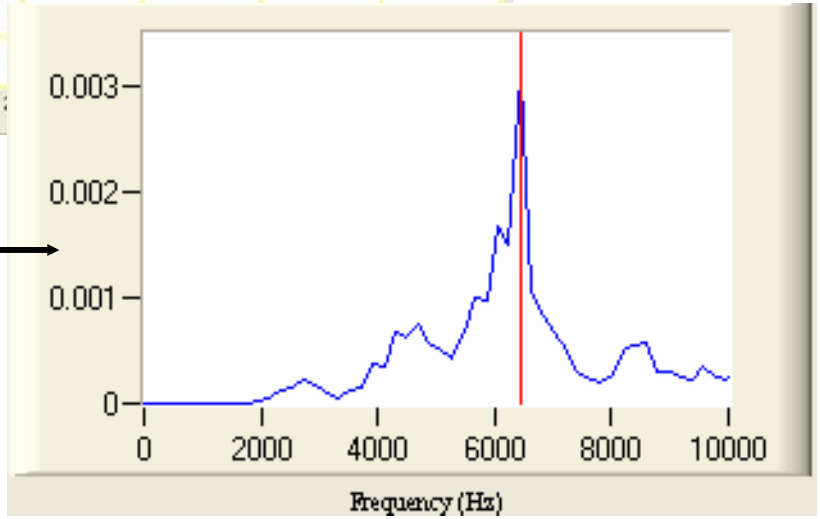


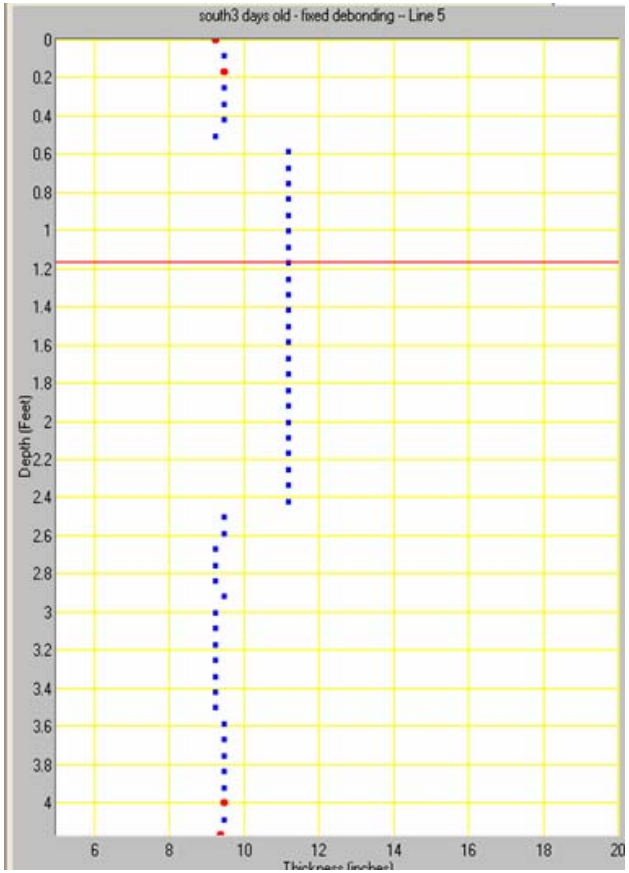


Void Detection in Post-tensioned Bridge Ducts Using Impact Echo Scanning



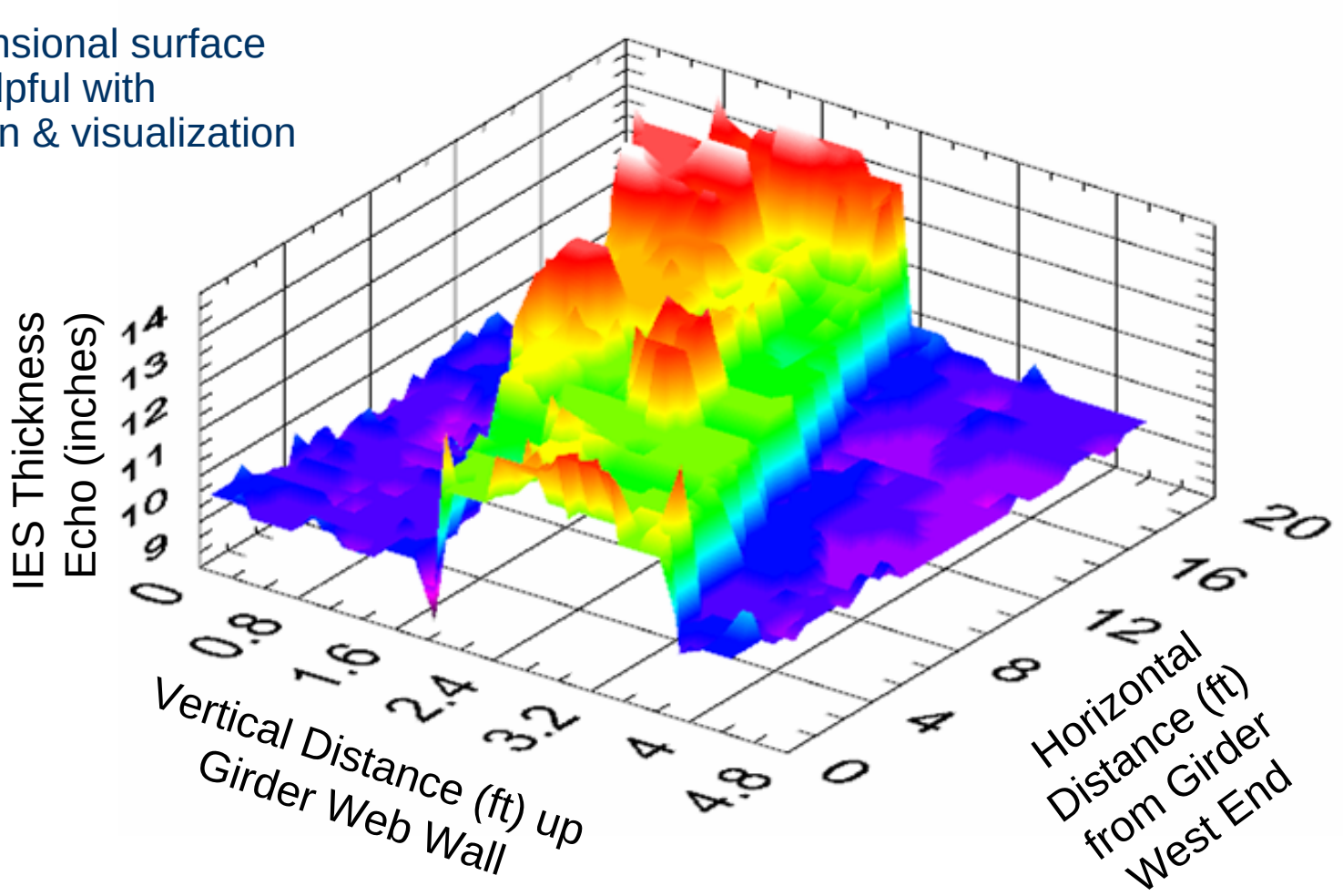
Fast Fourier Transform



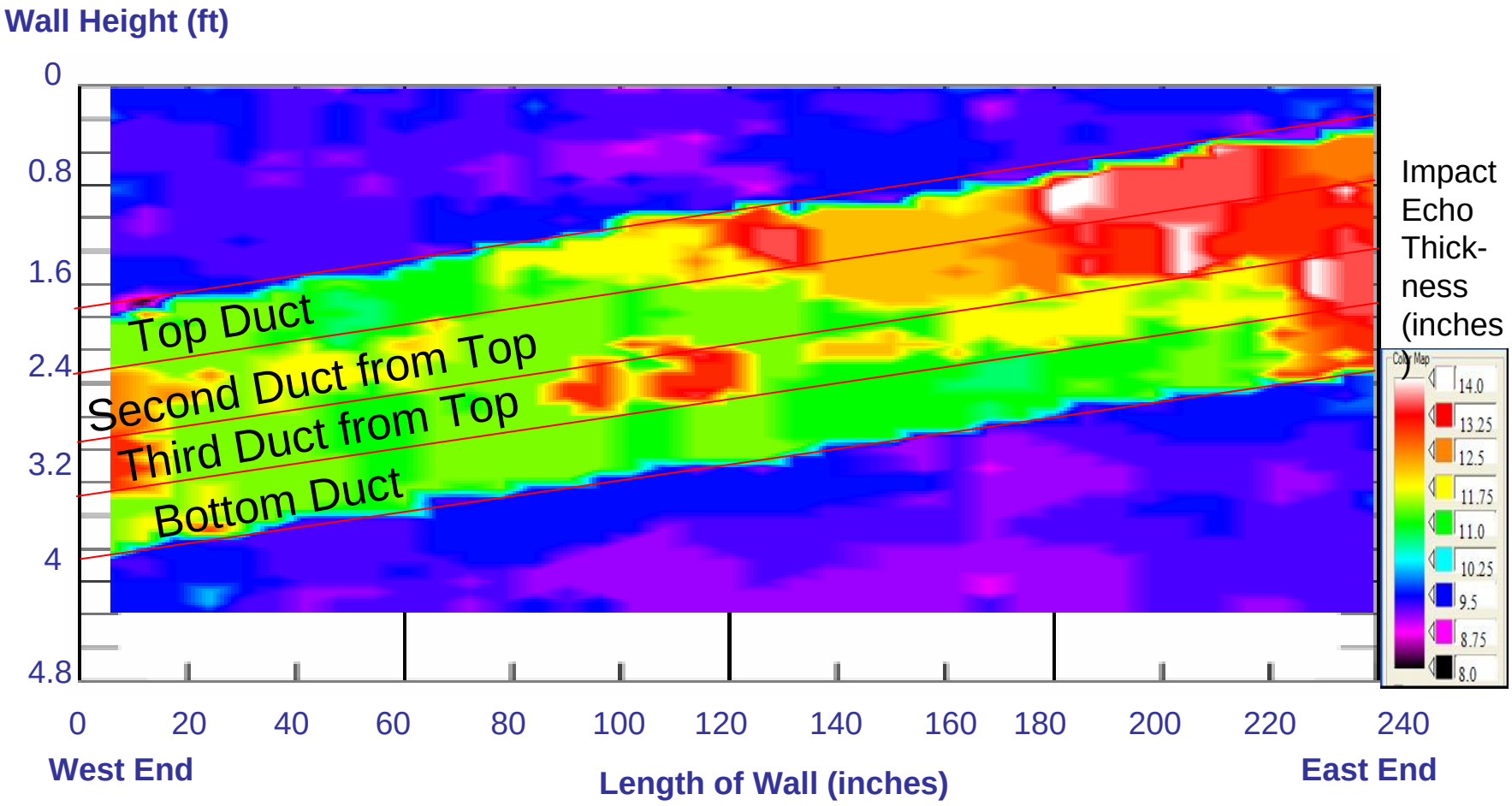


Void Detection in Post-tensioned Bridge Ducts Using Impact Echo Scanning

- Three dimensional surface plots are helpful with interpretation & visualization of defects

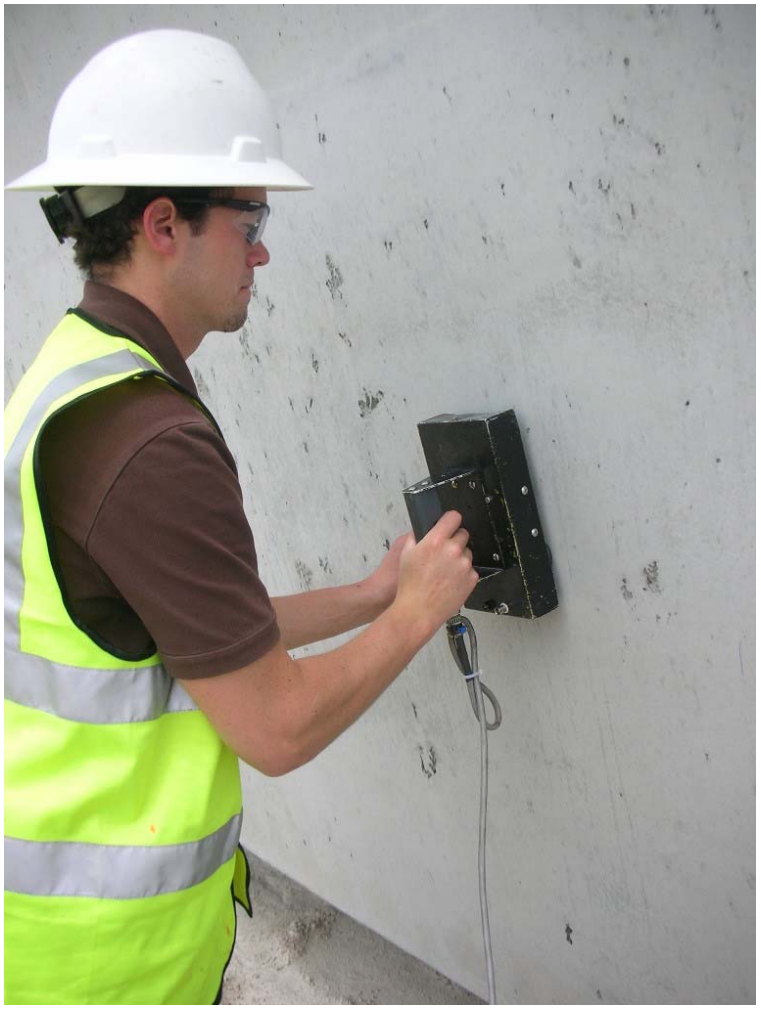


Void Detection in Post-tensioned Bridge Ducts Using Impact Echo Scanning



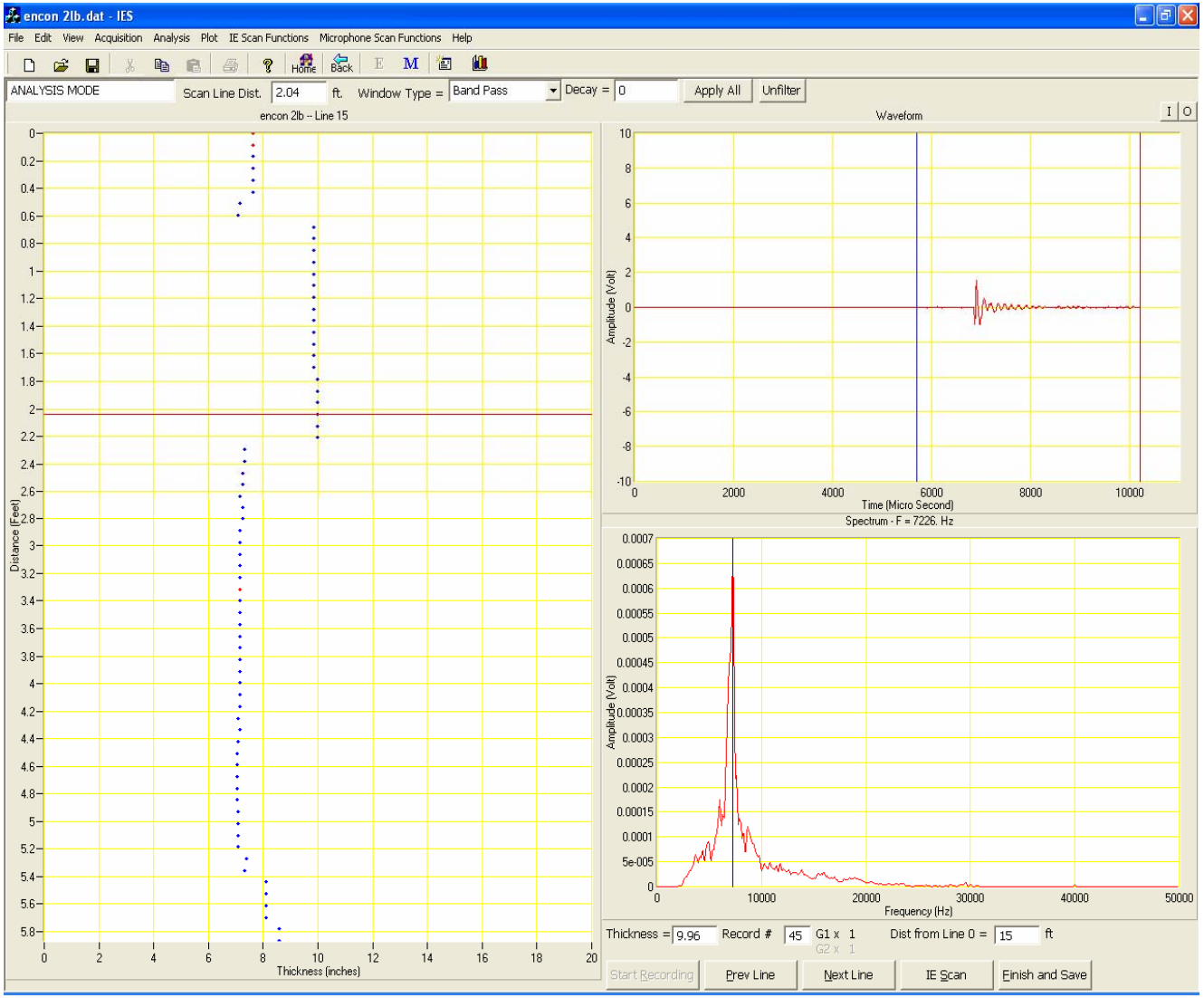
3rd Case History: Detection of Internal Voids between PT-Ducts on Concrete Box Girder

- Precast concrete box girder with four 3” diameter PT ducts in each web.
- PT ducts empty at the time of testing, concern is for voiding between ducts due to poor vibration during placement.
- Web wall 7.5” thick, approximately 6’ tall.
- Scans performed vertically at 1 foot intervals.



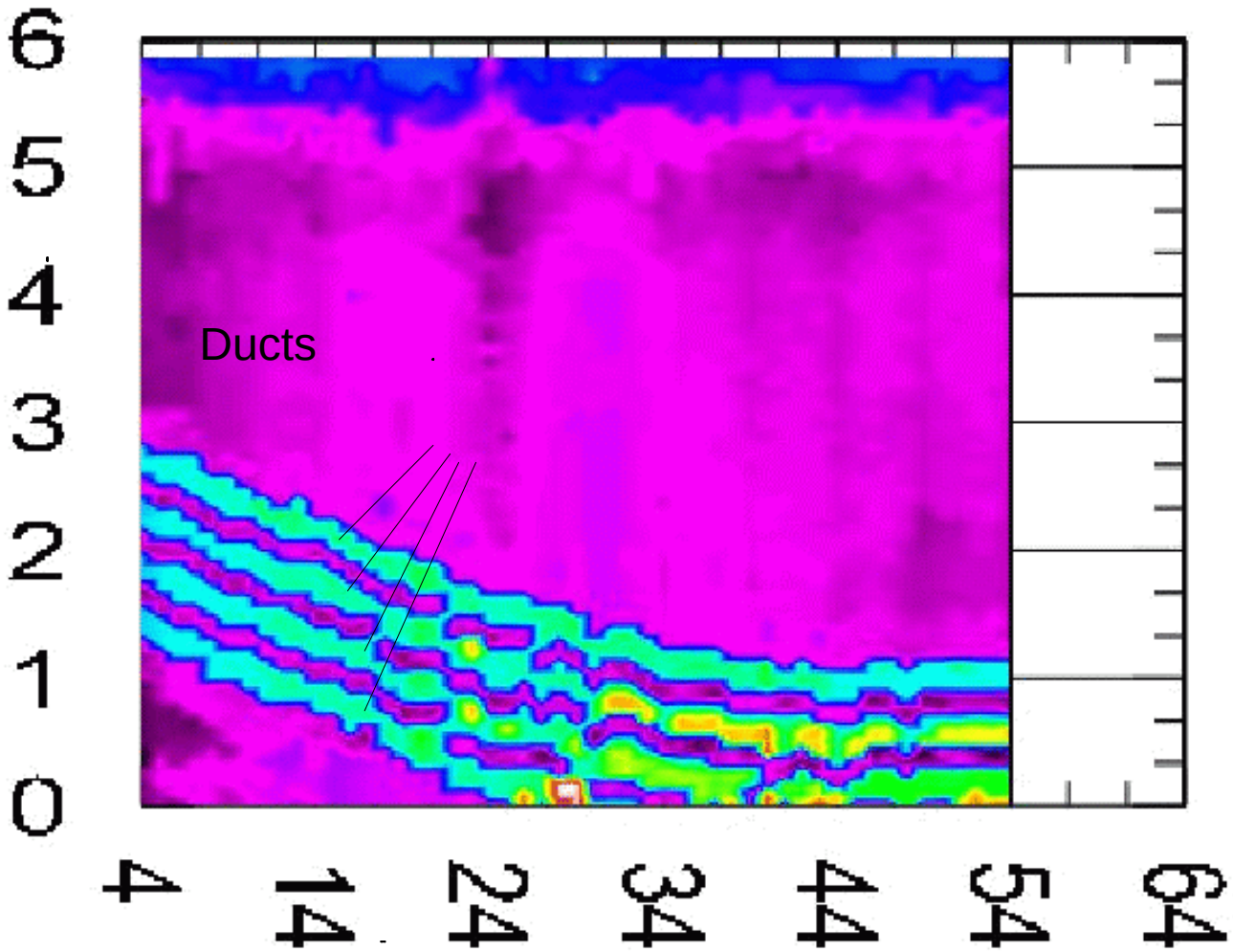
Example Impact Echo Scanning Data

- IES data from web wall.
- Vertical scan showing wall thickness and duct bank.
- Wall = 7.5” thick, the empty ducts show a substantial thickness increase.



Impact Echo Image Results

- The 7.5” thick wall is shown in purple.
- The empty ducts are shown in Blue.
- Four distinct ducts are observed, therefore no voiding between the ducts at this location.
- Conclusion is that all voiding between the ducts was apparent from the surface.

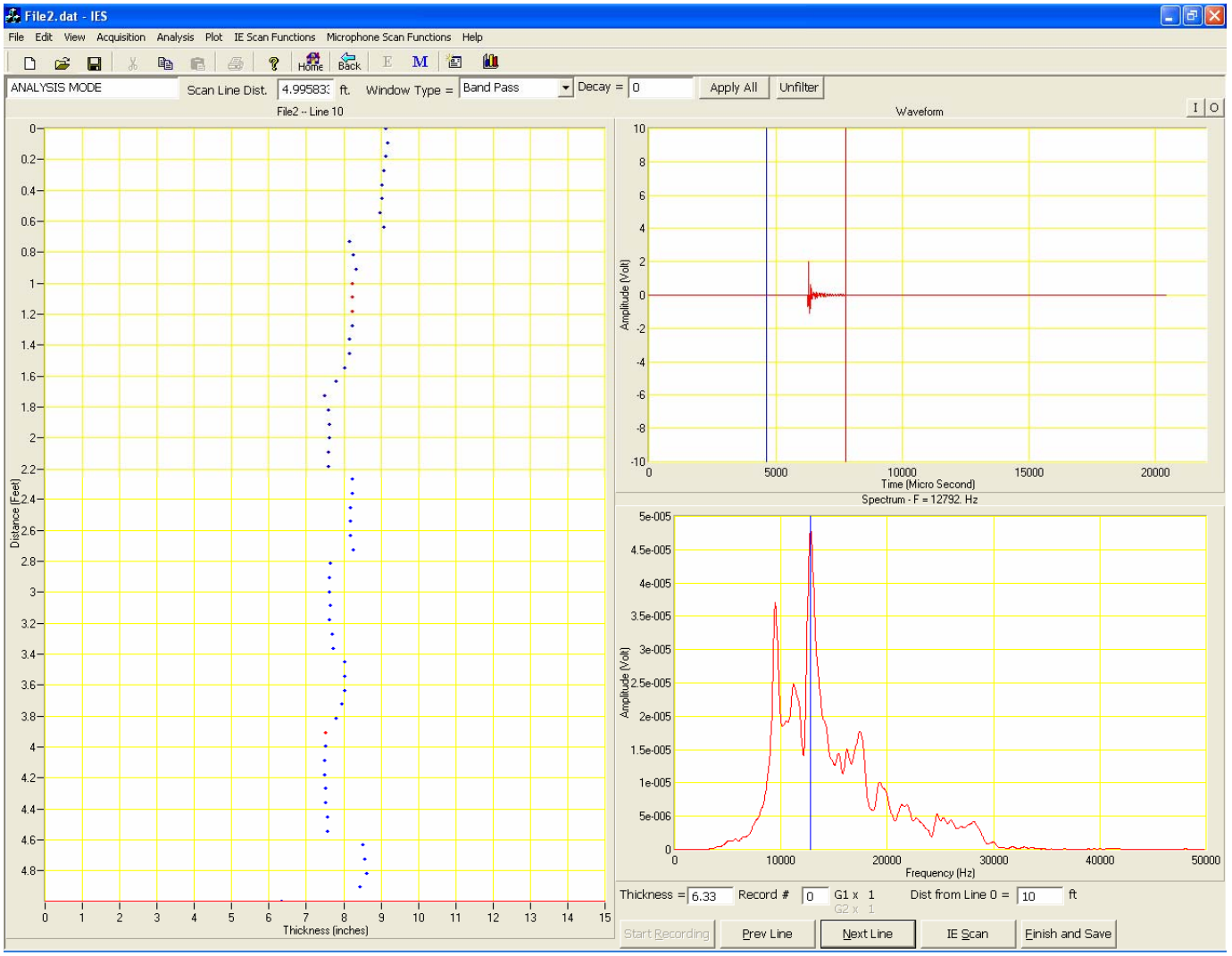


4th Case History: Detection of Internal Voids within PT-Ducts on Concrete Box Girder

- Precast concrete box girder with four 3” diameter PT ducts in each web.
- PT ducts grouted, concern is for voiding within the grouted ducts.
- Web wall 7.5” thick, approximately 6’ tall.
- Scans performed vertically at 10 foot intervals, to spot check the grout condition.
- Significant voids discovered.

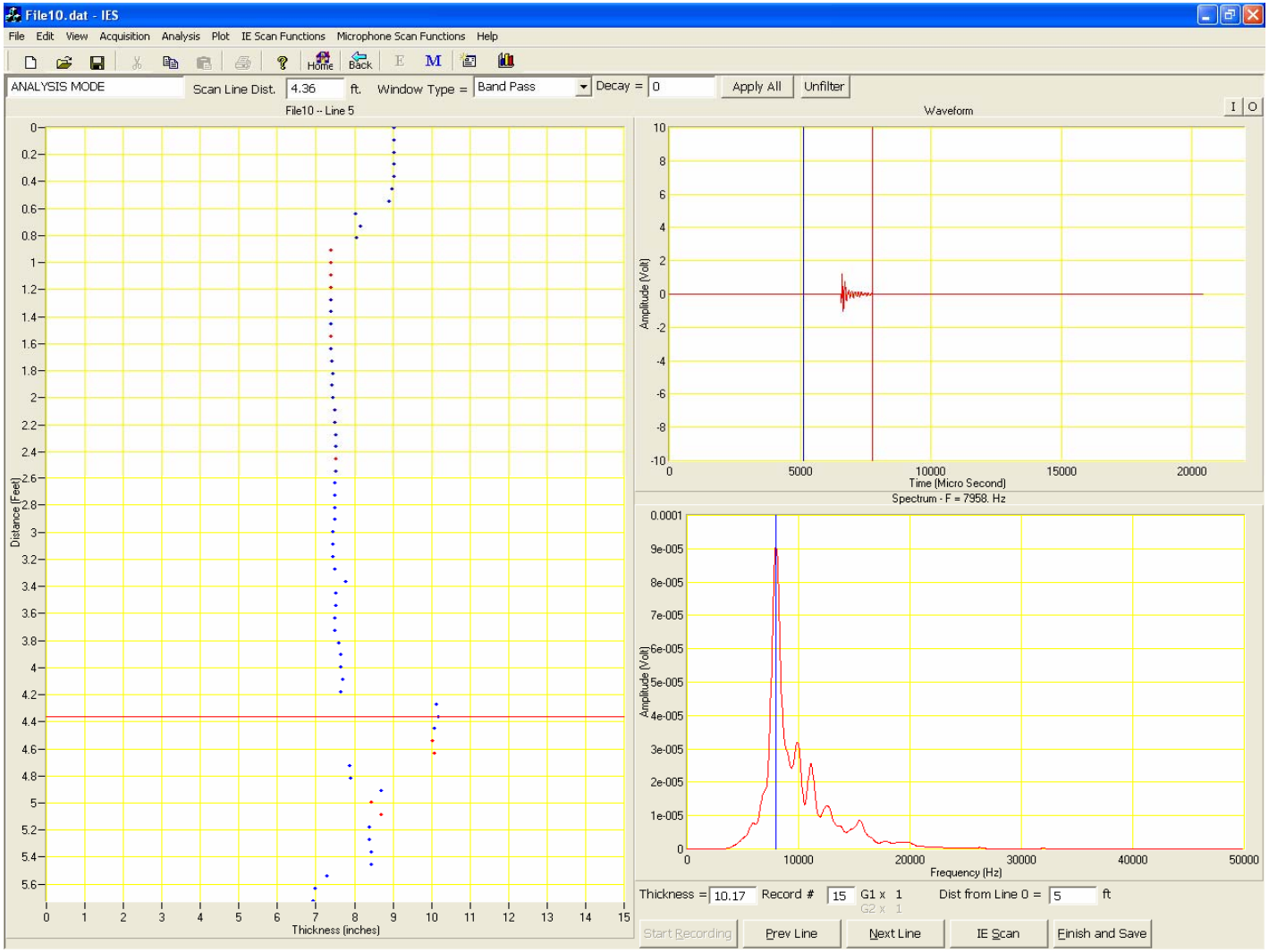
Example Impact Echo Scanning Data

- IES data showing the typical wall thickness and four fully grouted ducts.
- The fully grouted ducts show a slight increase in thickness.
- Sound condition.



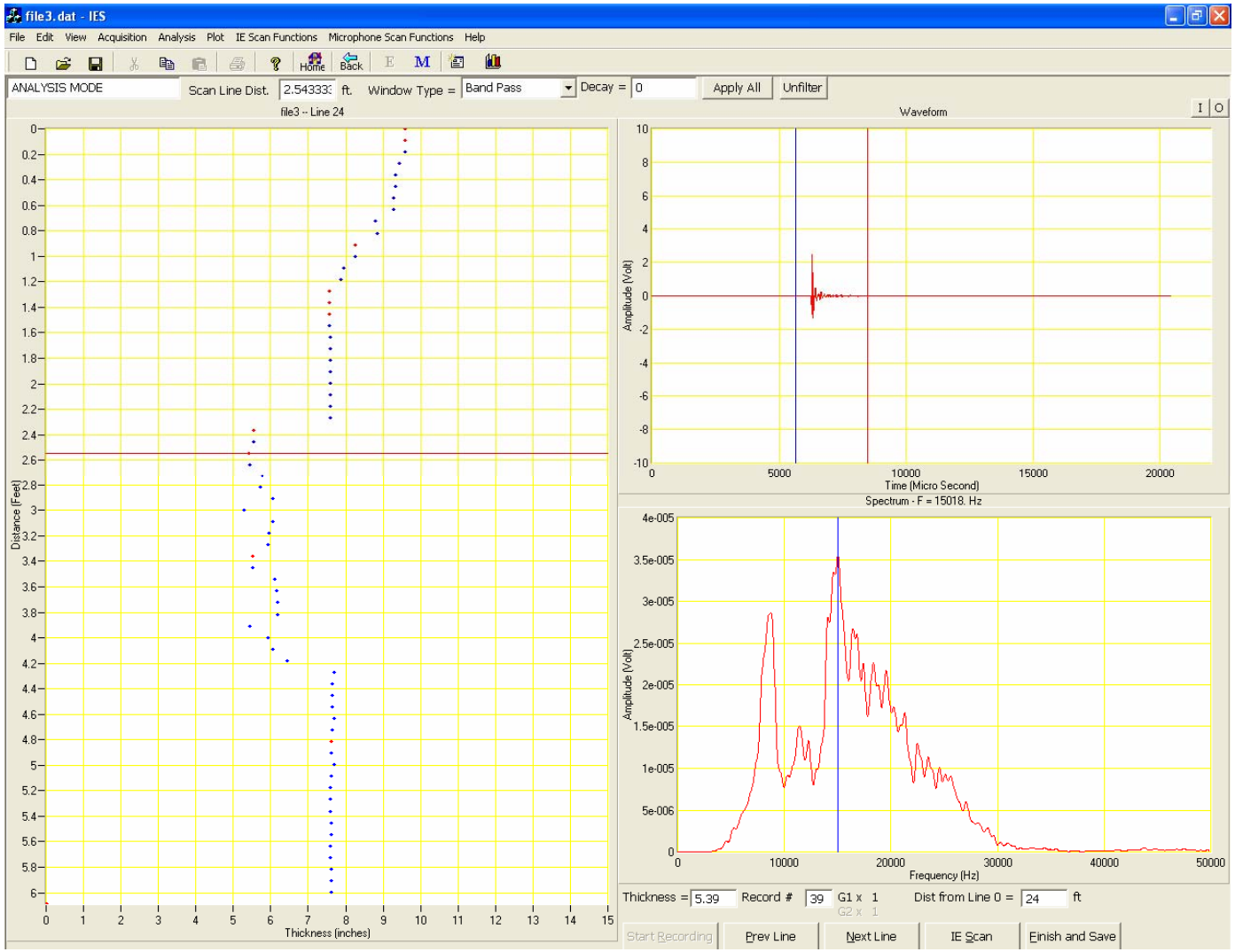
Example Impact Echo Scanning Data

- IES data showing the typical wall thickness.
- The four ducts are near the bottom of the scan. The distance between ducts varies over the length of the girder.
- A confirmed voided duct is highlighted by the red cursor.
- Voided condition.



Example Impact Echo Scanning Data

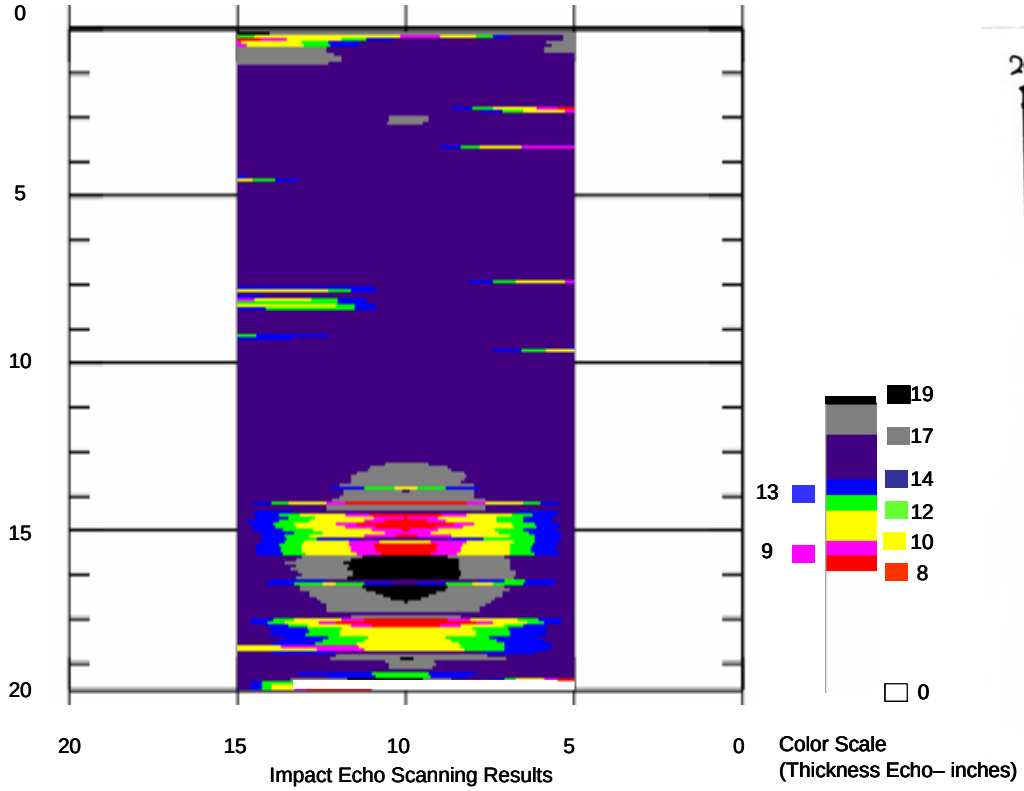
- IES data showing the typical wall thickness.
- The four ducts all display thin echoes, thought to be duct debonding or other defect condition.
- Questionable condition.



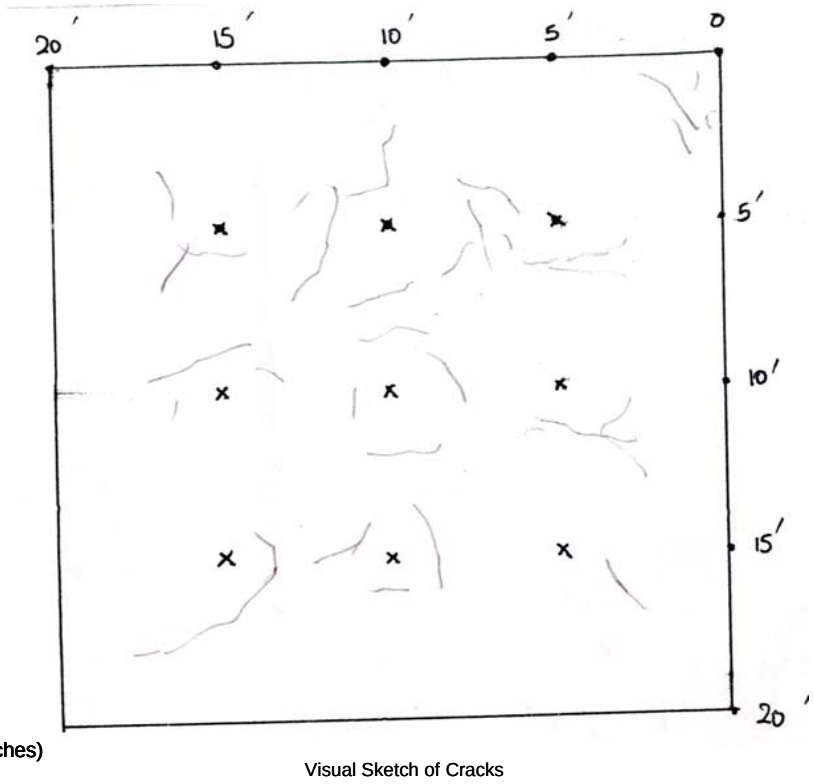
5th Case History: Detection of Internal Cracks within Concrete Pavement Exposing to the ASR Problem

- ASR is a reaction between reactive silica (in the concrete aggregates) and an alkali (usually present in the cement), which results in the formation of a gel
- This gel increases in volume with water and exerts expansive pressure on the concrete, causing failure of the concrete
- Typical visual indicator of ASR includes a network of cracks on the concrete surface
- In many cases, ASR causes internal cracking damage prior to the development of surface cracks.
- Detection of the internal micro-cracking could lead to early detection of an ASR problem Early detection of the problem can, in turn, lead to an improved management and maintenance program for the structure

5th Case History: Detection of Internal Cracks within Concrete Pavement Exposing to the ASR Problem



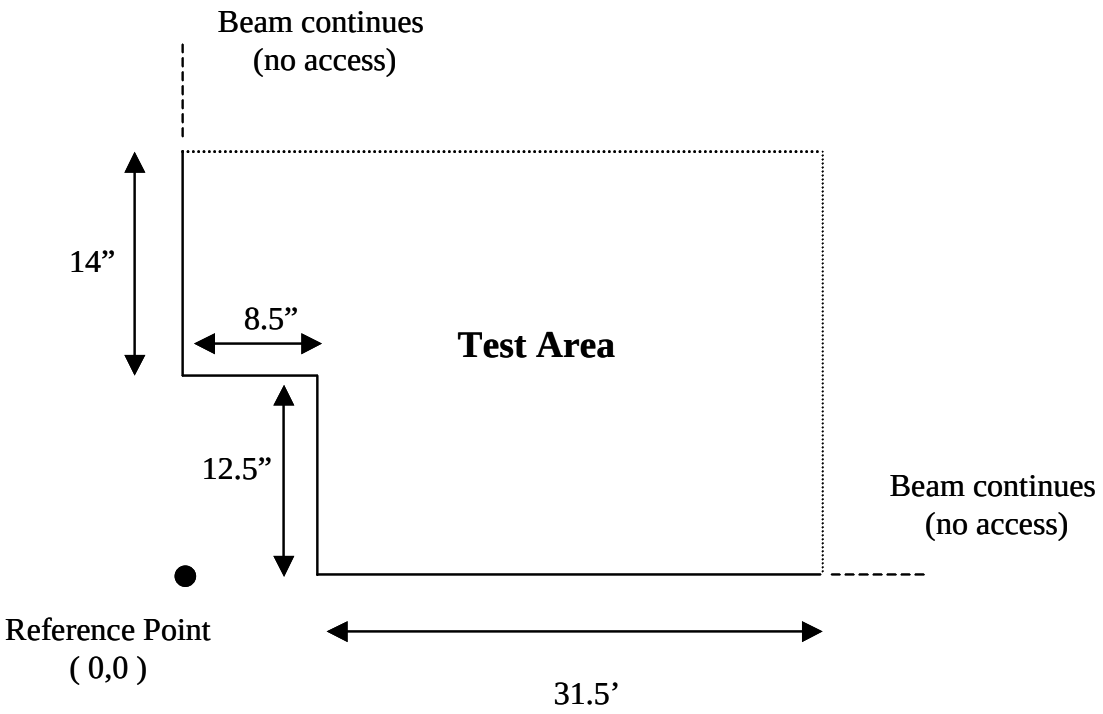
Results from the IES Tests



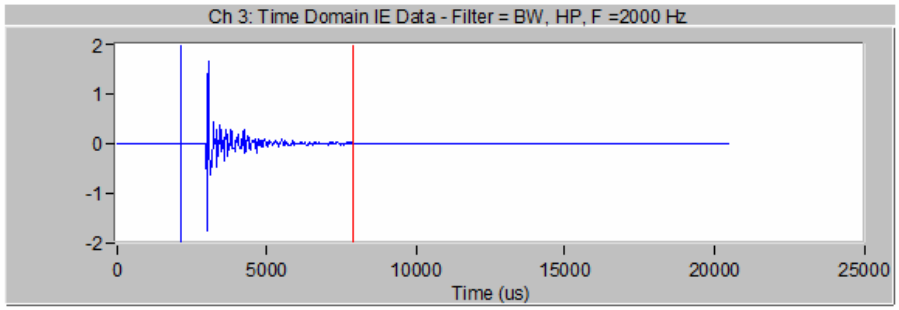
Visual Inspection of Surface Crack

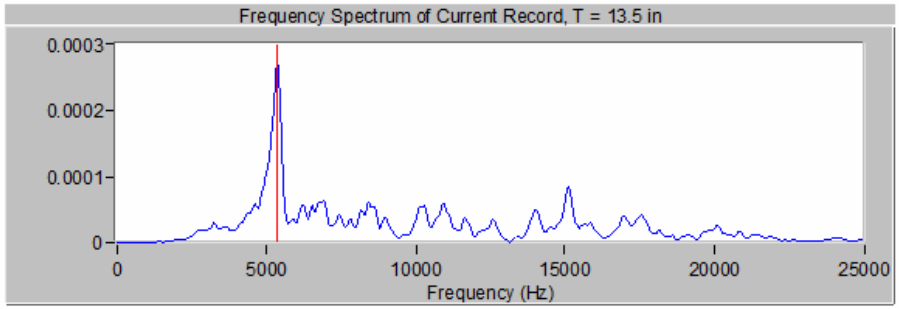
6th Case History: Detection of Internal Cracks and Backside Spalling on a Precast, Prestressed Concrete Beam

- The concrete beam rotated on its bearing support and applying torsional stresses within the
- A portion of the concrete was spalled.
- There was no access to the side of the concrete beam which underwent damage.
- Impact Echo testing from the opposite side of the beam was done to image the spall and any internal cracking.

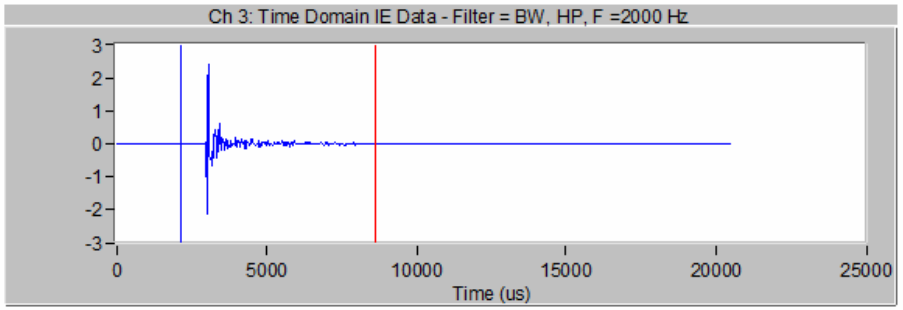


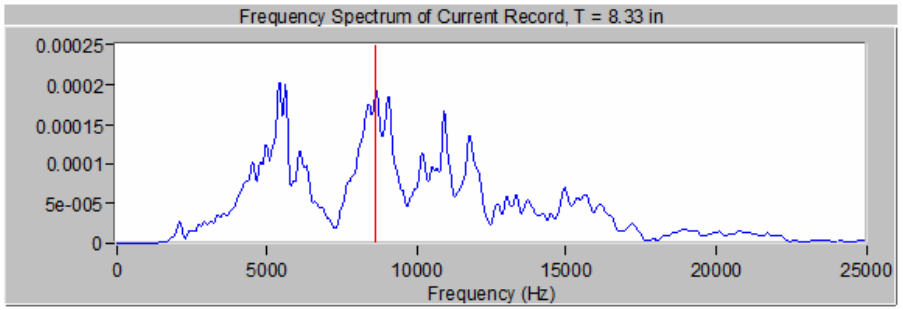
Example Impact Echo Data





Single Predominant Resonance

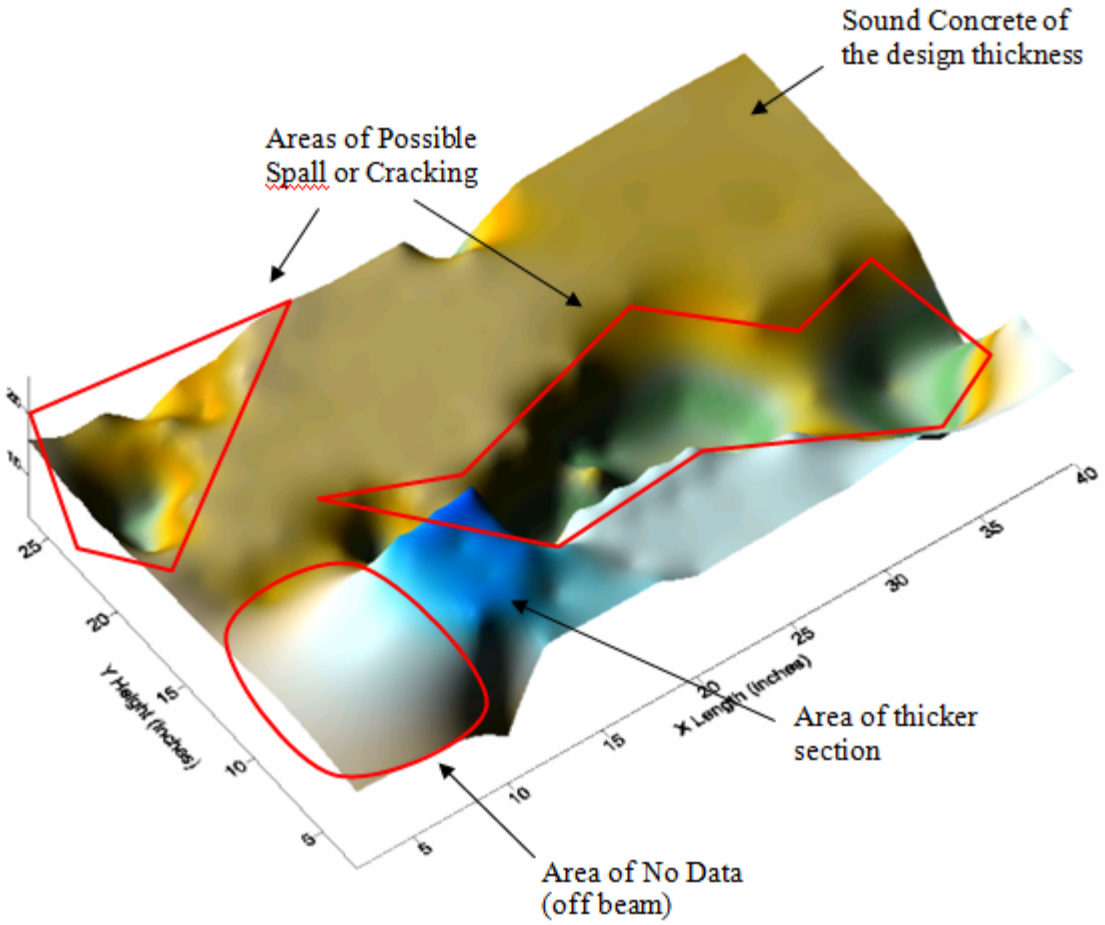




Multiple Predominant Resonances

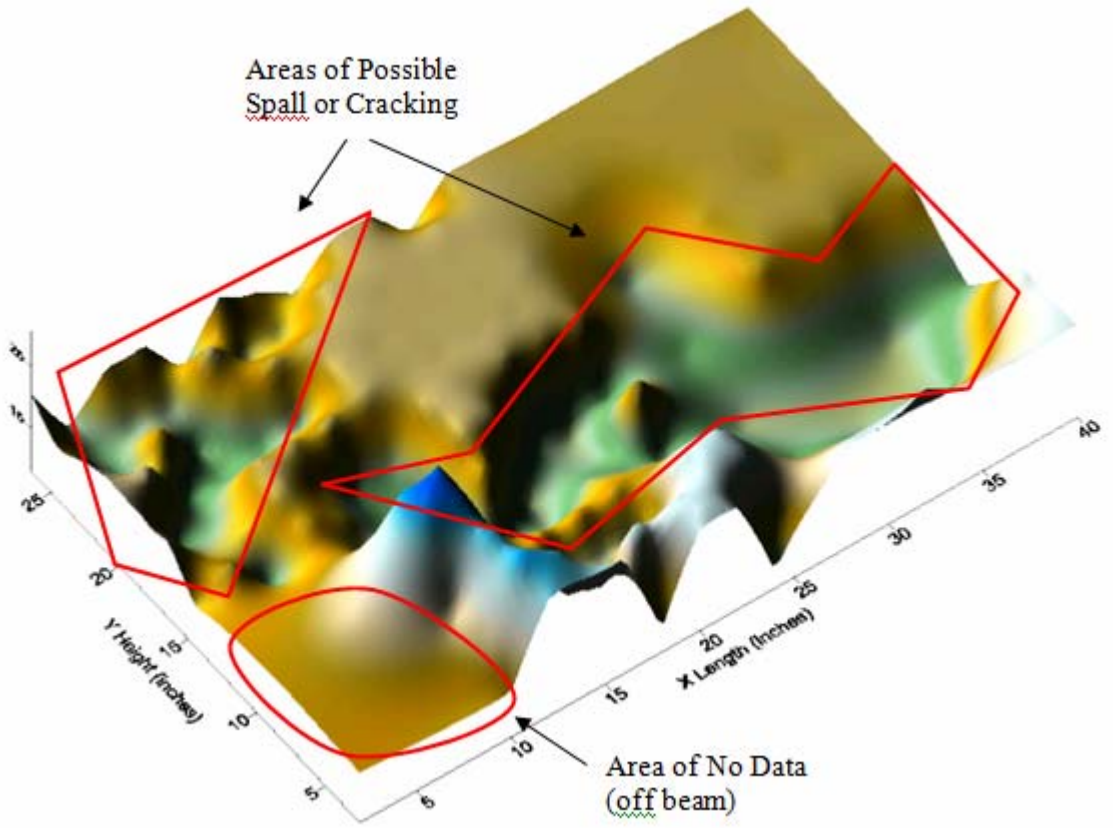
Impact Echo Image Results

- Plot of the most predominant resonant frequencies from the Impact Echo results.
- Sound concrete as well as likely spalled or severly cracked areas are aparent.



Impact Echo Image Results

- Plot of the second most predominant resonant frequencies from the Impact Echo results. If no secondary peak occurred, than the primary resonance is plotted.
- Sound concrete as well as likely spalled or severly cracked areas are aparent.



Thank You!

Questions???