Workshop

- Ultrasonic pulse-velocity
- Impact-echo method
- Impulse-response method
- Ultrasonic-echo method

Acknowledgement

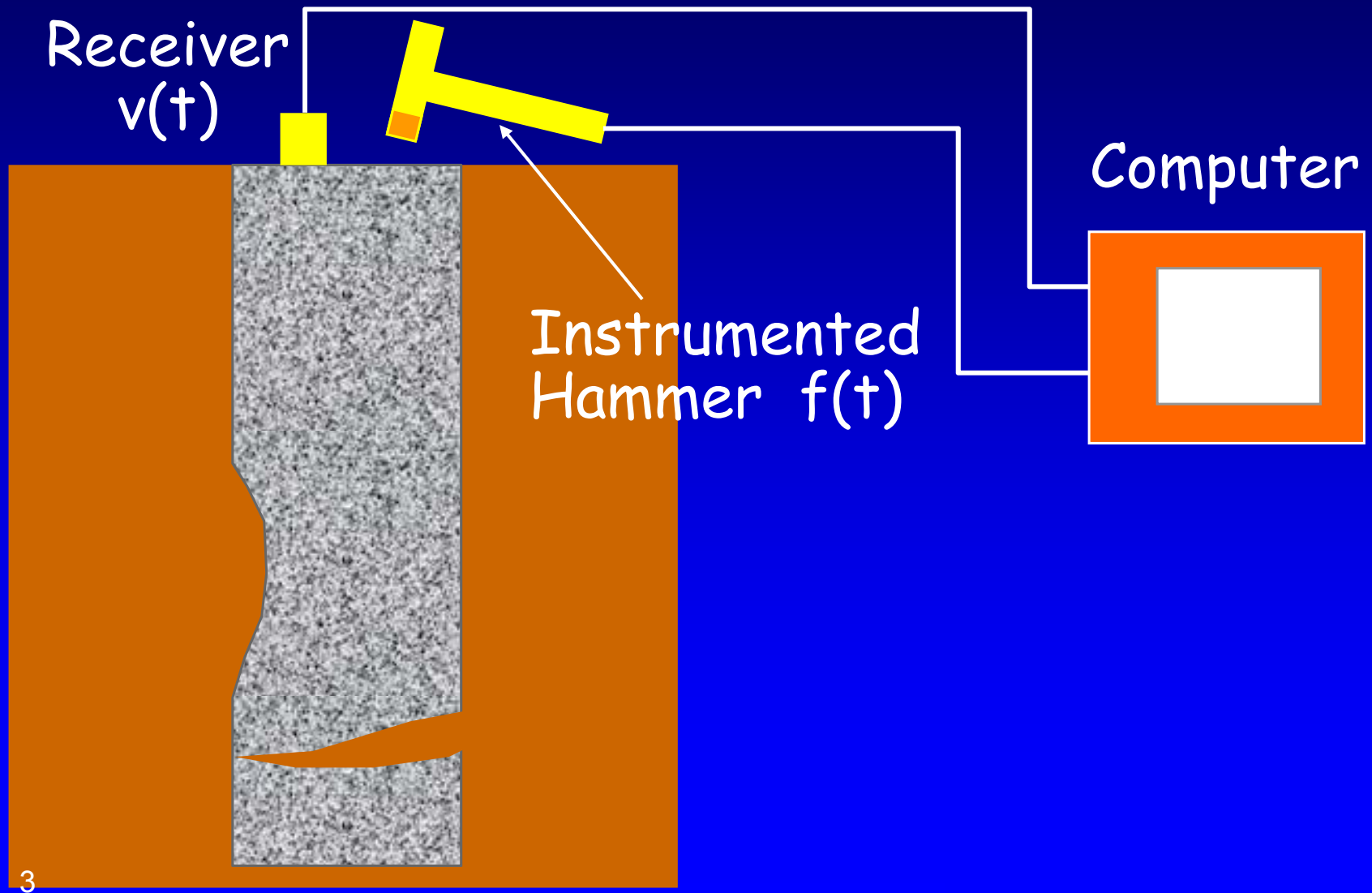
Dr. Allen Davis (Deceased)

CTL Group, Skokie, IL USA

Impulse-Response Method

- Originated as method to test deep foundations (transient dynamic response method)
- Requires measurement of impact force
- Frequency domain method
- Lower frequency than impact-echo (0 to 1 kHz)
- Signal processing examines the impact response per unit of applied force as a function of frequency

Impulse Response



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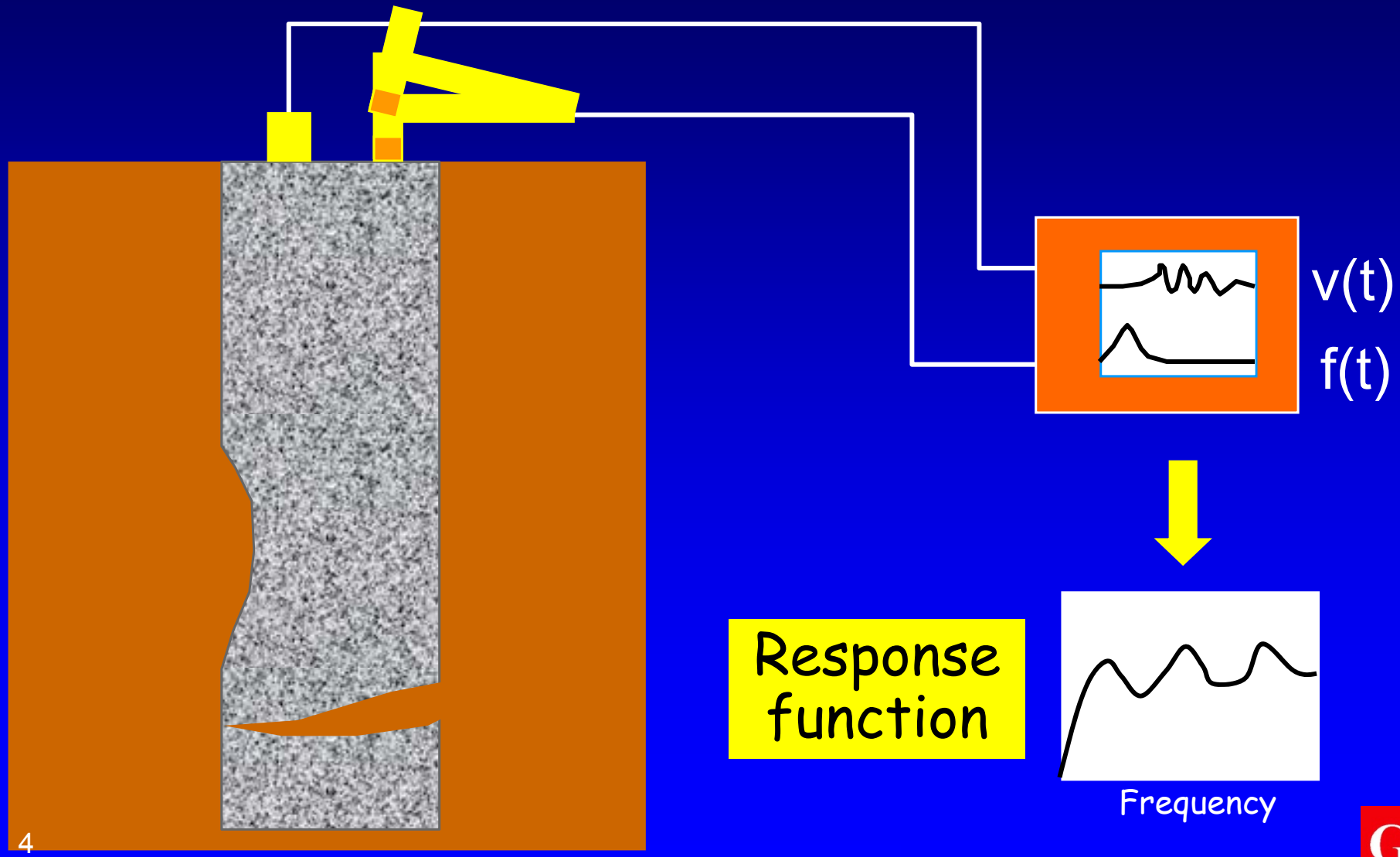
Impulse Response



Low Strain Tests of Piles

Designation: D 5882 – 00

Standard Test Method for Low Strain Integrity Testing of Piles[1]

This standard is issued under the fixed designation D 5882; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

This test method covers the procedure for determining the integrity of individual vertical or inclined piles by measuring and analyzing the velocity (required) and the force (optional) response of the pile induced by an impact device applied axially to the pile, normally at the pile head.

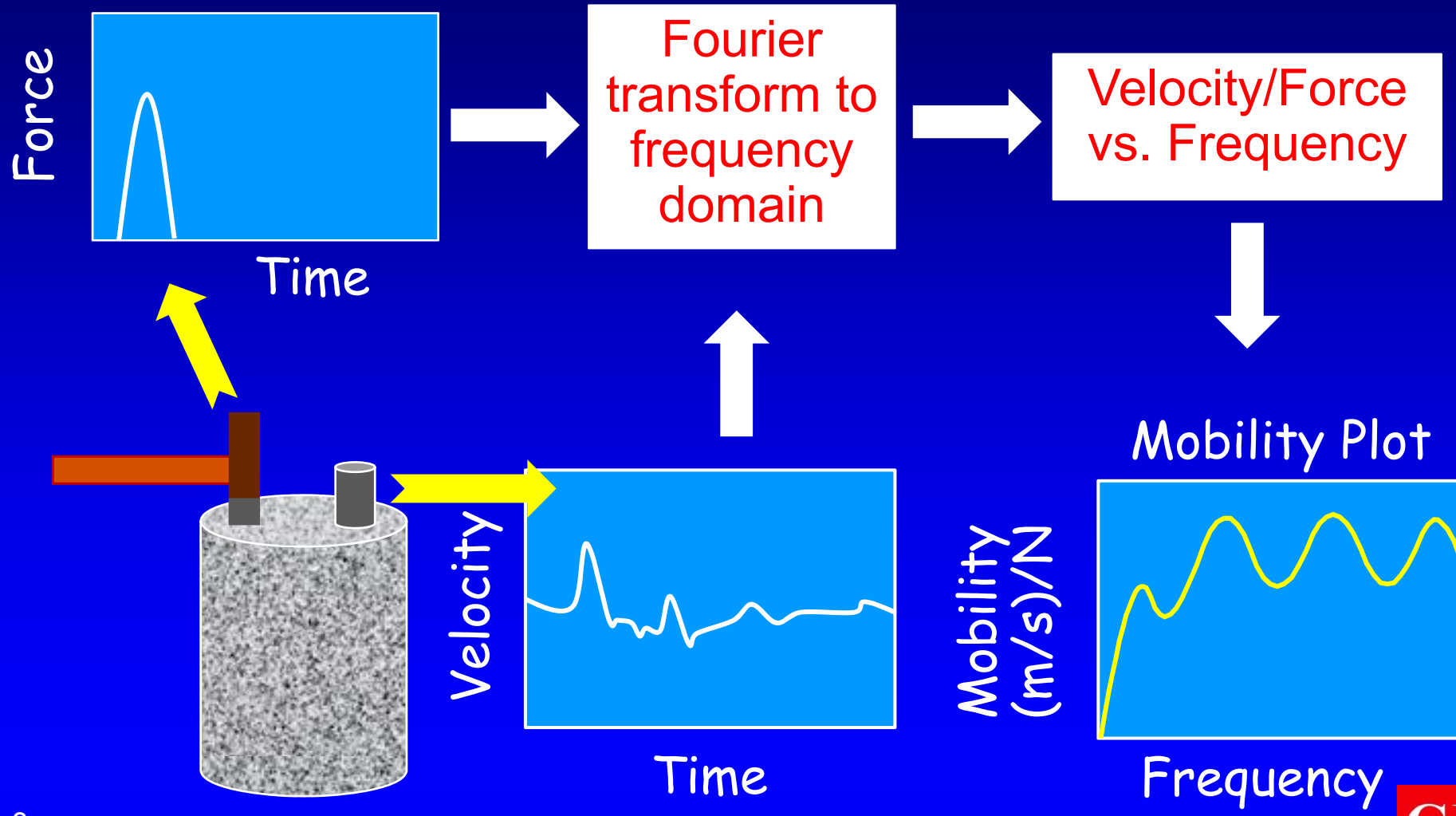
FIG. 1 Typical Velocity Traces Generated by the Apparatus for Obtaining Dynamic Measurements

Impulse-Response Test System

Response Functions

Measured Response	Transfer Function: Units
Displacement	Receptance: m/N
Velocity	**Mobility: (m/s)/N**
Acceleration	Accelerance: $(m/s^2)/N$

Signal Processing Method



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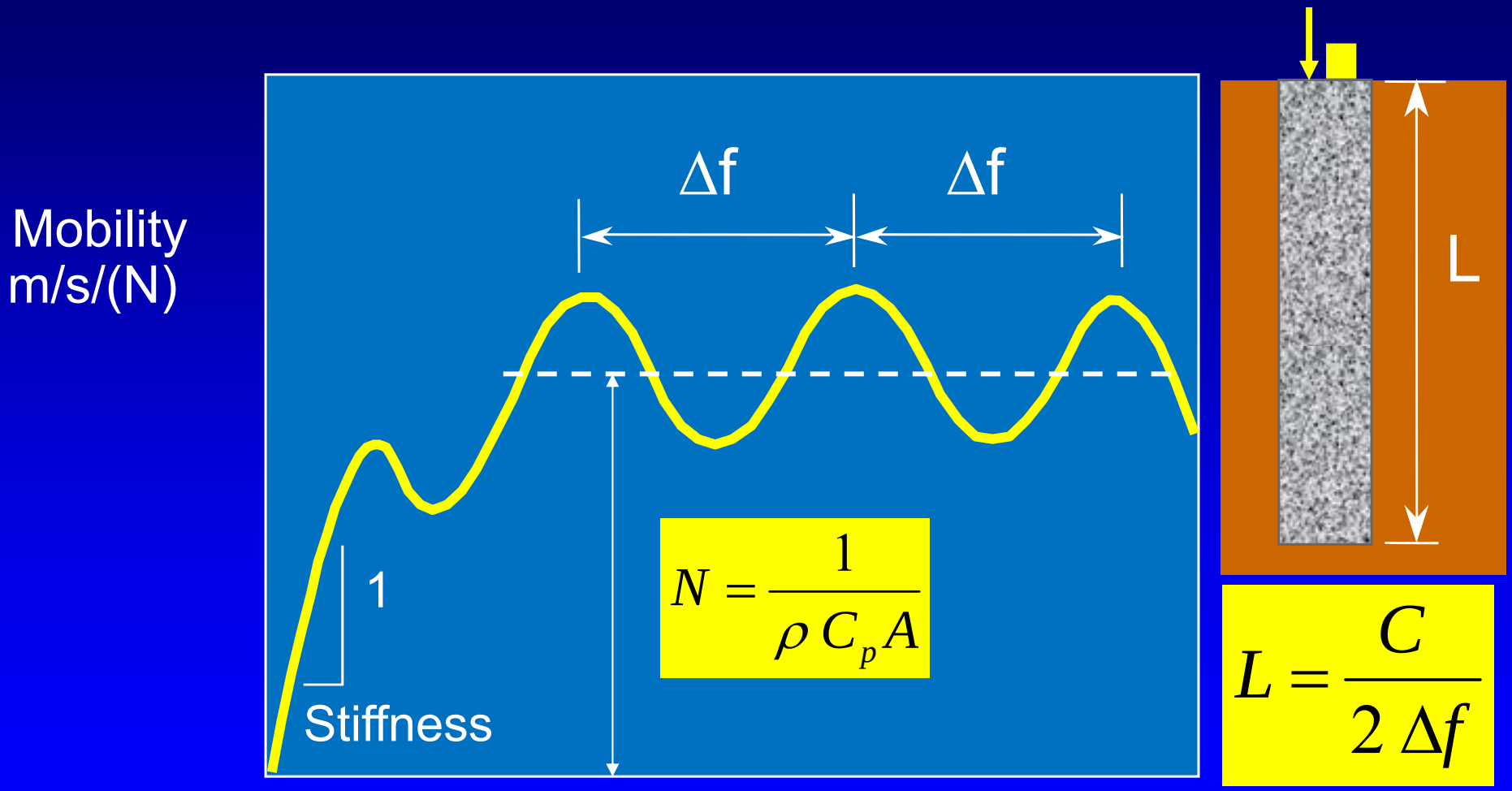
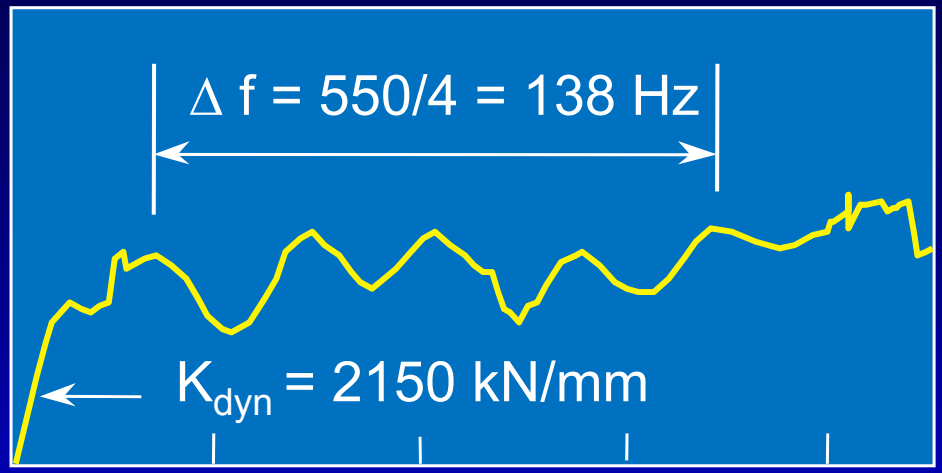
Idealized Mobility Plot of Pile



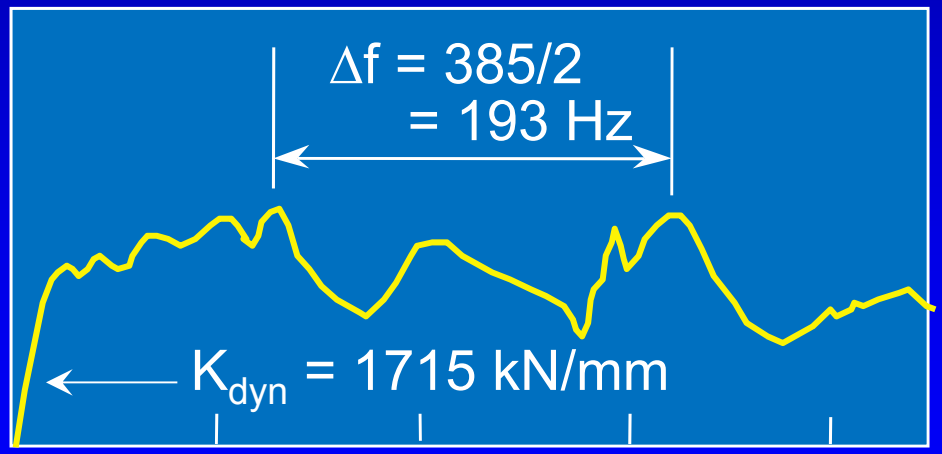
Mobility Plots From Piles

Solid



Mobility (mm/s/N)

Flawed



0 **200** **400** **600** **800**

Frequency (Hz)

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Application to Plates

- Work by Dr. Davis and colleagues demonstrated that I-R could be used successfully to assess plate-like structures
- Comparative test to assess differences in impact response within a structure
  - Locate anomalous regions
  - Verification with other techniques
- For rapid screening of suspect structures

ASTM C1740

Designation: C1740 – 10

Standard Practice for Evaluating the Condition of Concrete Plates Using the Impulse-Response Method[1]

This standard is issued under the fixed designation C1740; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice provides the procedure for using the impulse-response method to evaluate rapidly the condition of concrete slabs, pavements, bridge decks, walls, or other plate-like structures.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appro-*

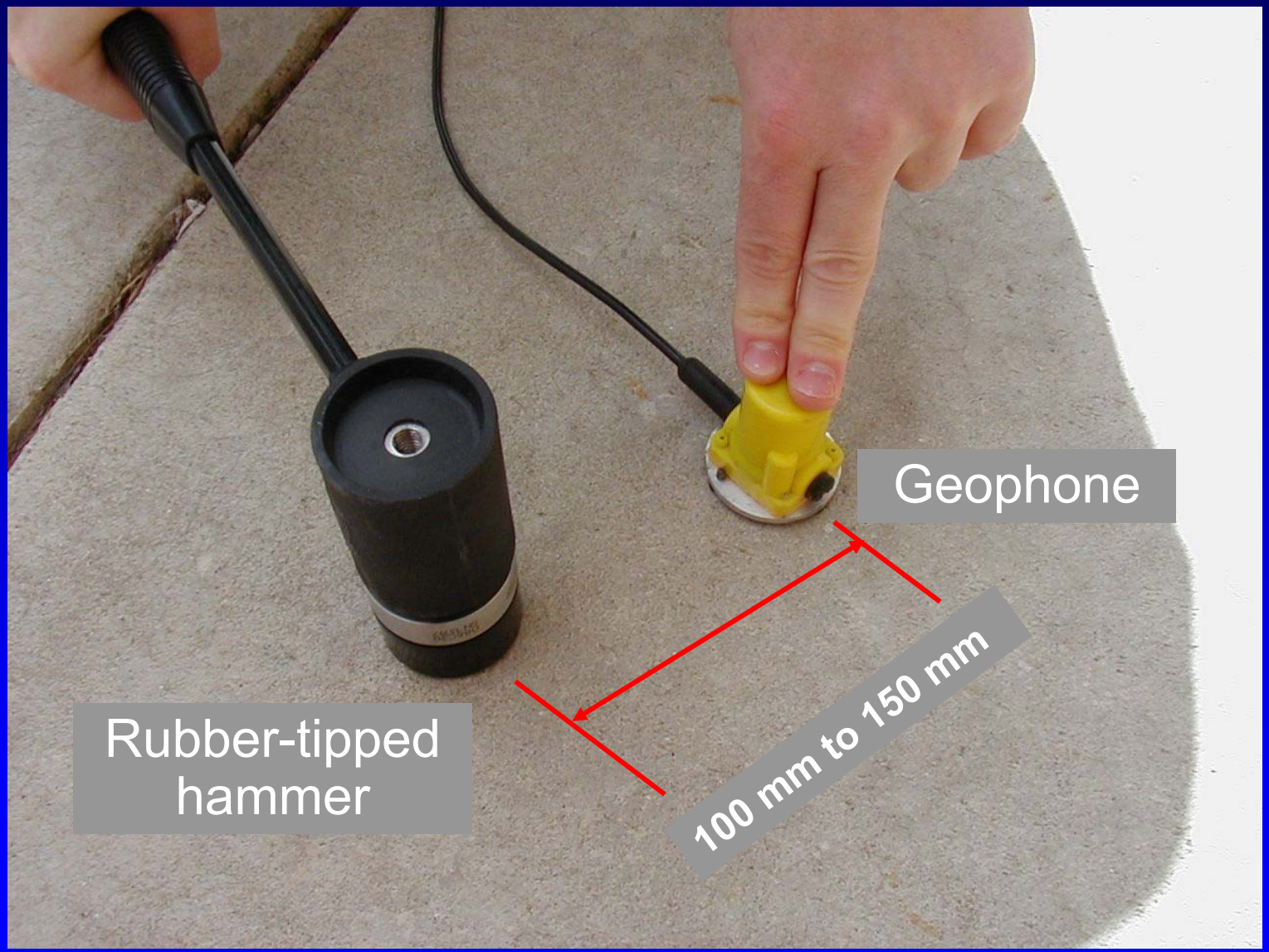
for additional terms related to nondestructive ultrasonic examination that are applicable to this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *impulse-response method, n*—a nondestructive test method based on the use of mechanical impact to cause transient vibration of a concrete test element, the use of a broadband velocity transducer placed on the test element adjacent to the impact point to measure the response, and the use of signal processing to obtain the mobility spectrum of the test element.

3.2.1.1 *Discussion*—Fig. 1 shows the testing configuration

Hammer and Geophone Position



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s'MASH System for Impulse-Response Testing

Hammer and Geophone

Computer with Software

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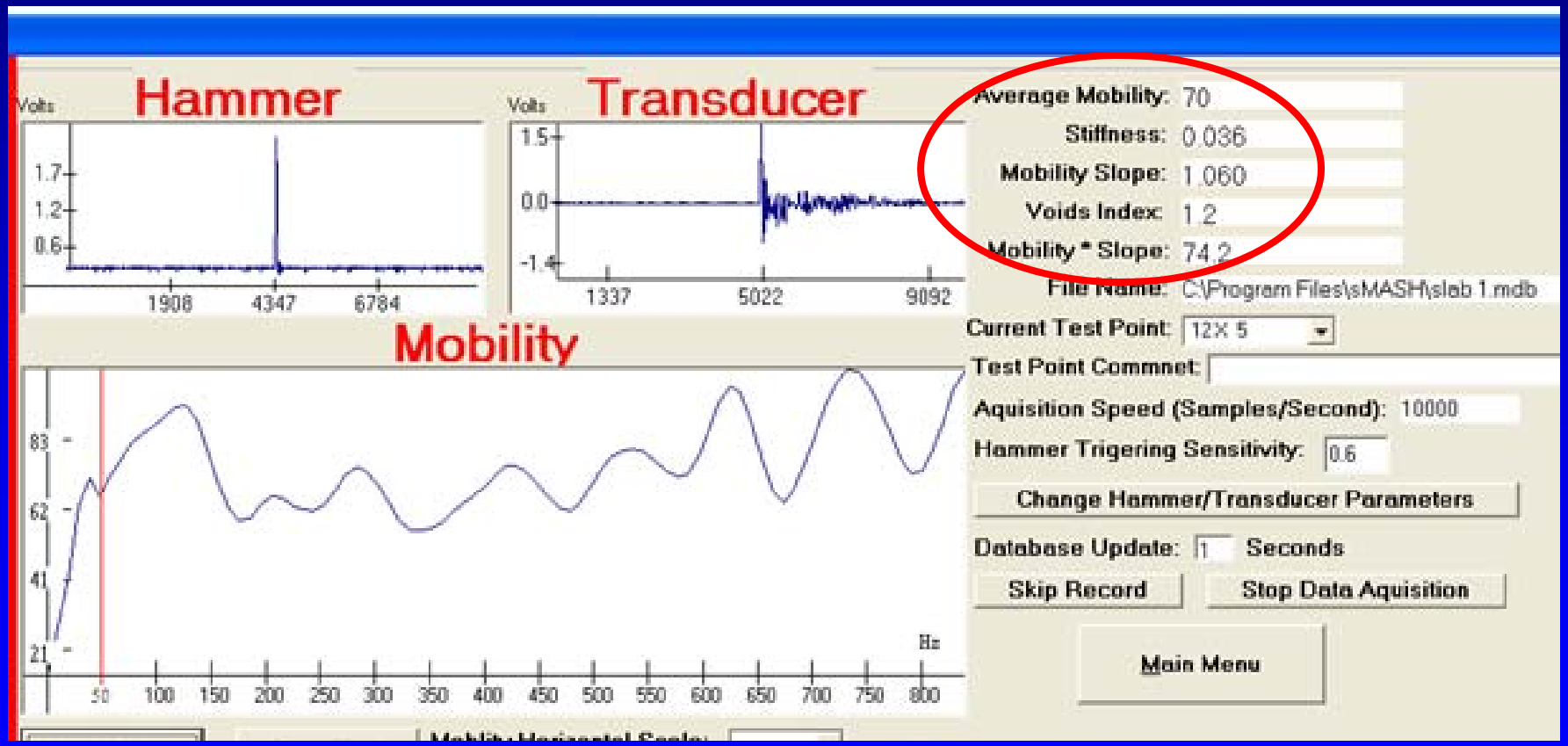
s'MASH Software and Display

Computed parameters



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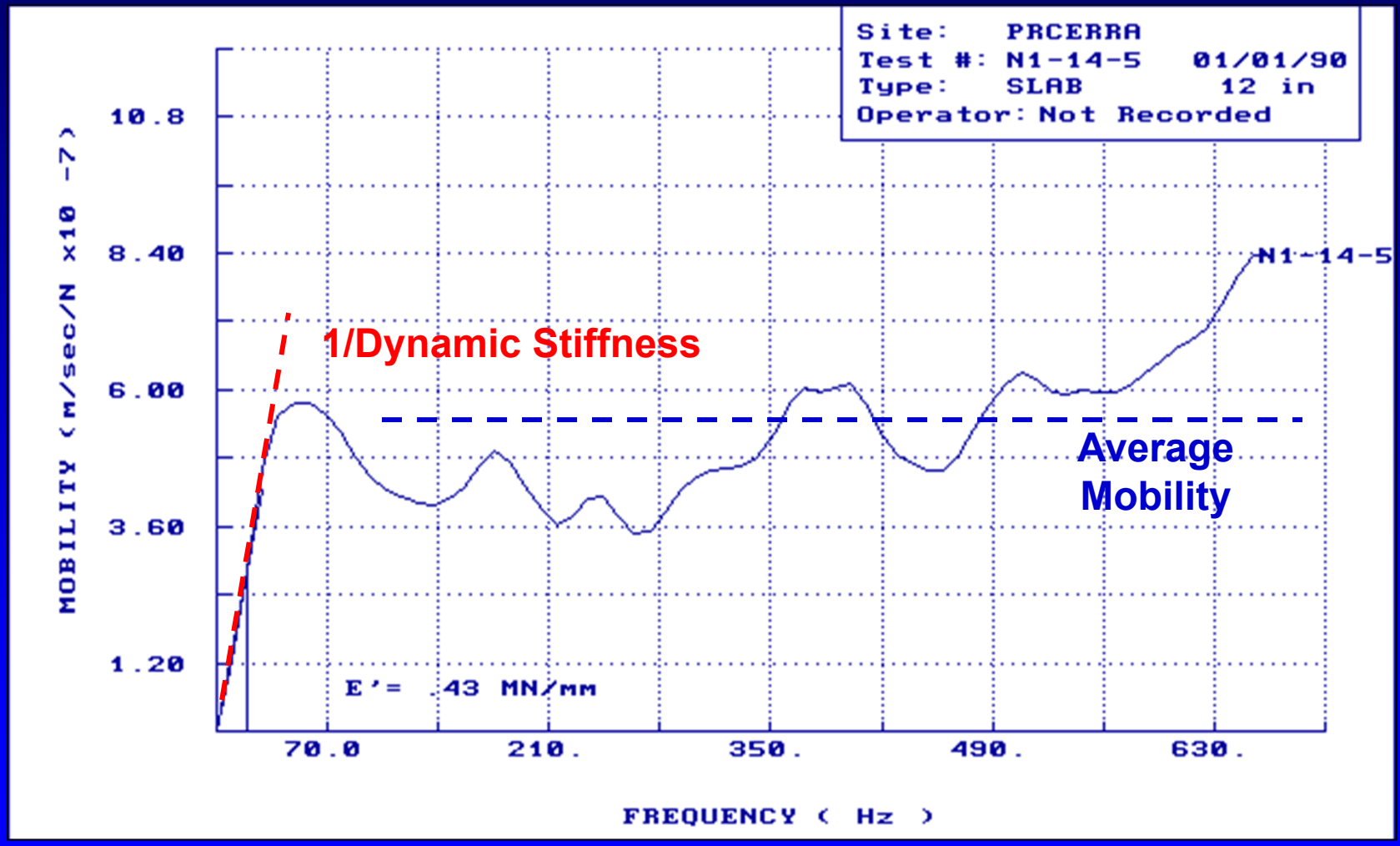
Parameters from Mobility Plot

- Various parameters computed from the mobility plot are used as indicators of conditions at test point
  - Dynamic stiffness (initial slope 0 to 50 Hz)
  - Average mobility (100 to 800 Hz)
  - Ratio of peak mobility to mean mobility (voids index)
  - Slope of mobility vs. frequency

Example: I-R Test of Slab



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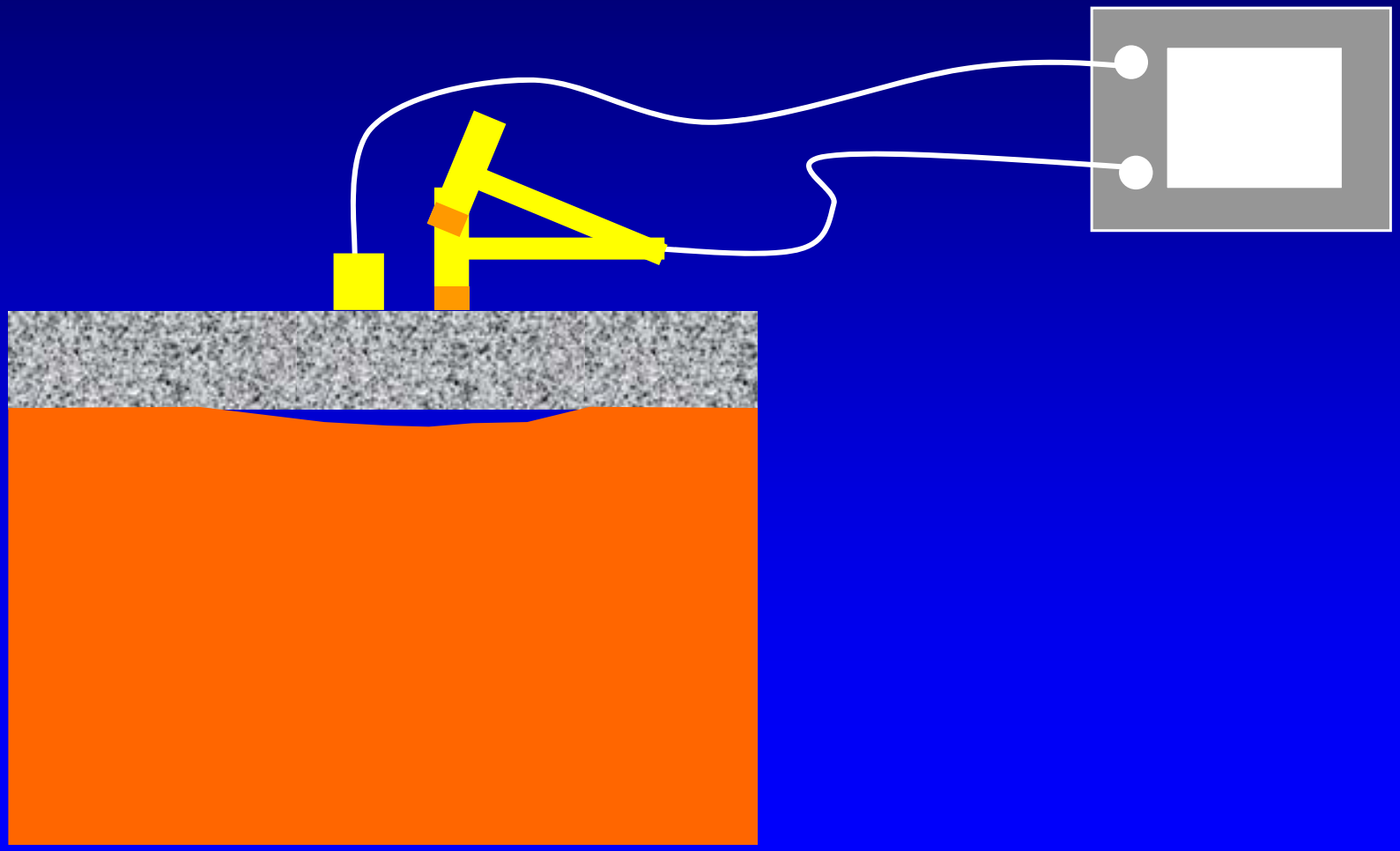
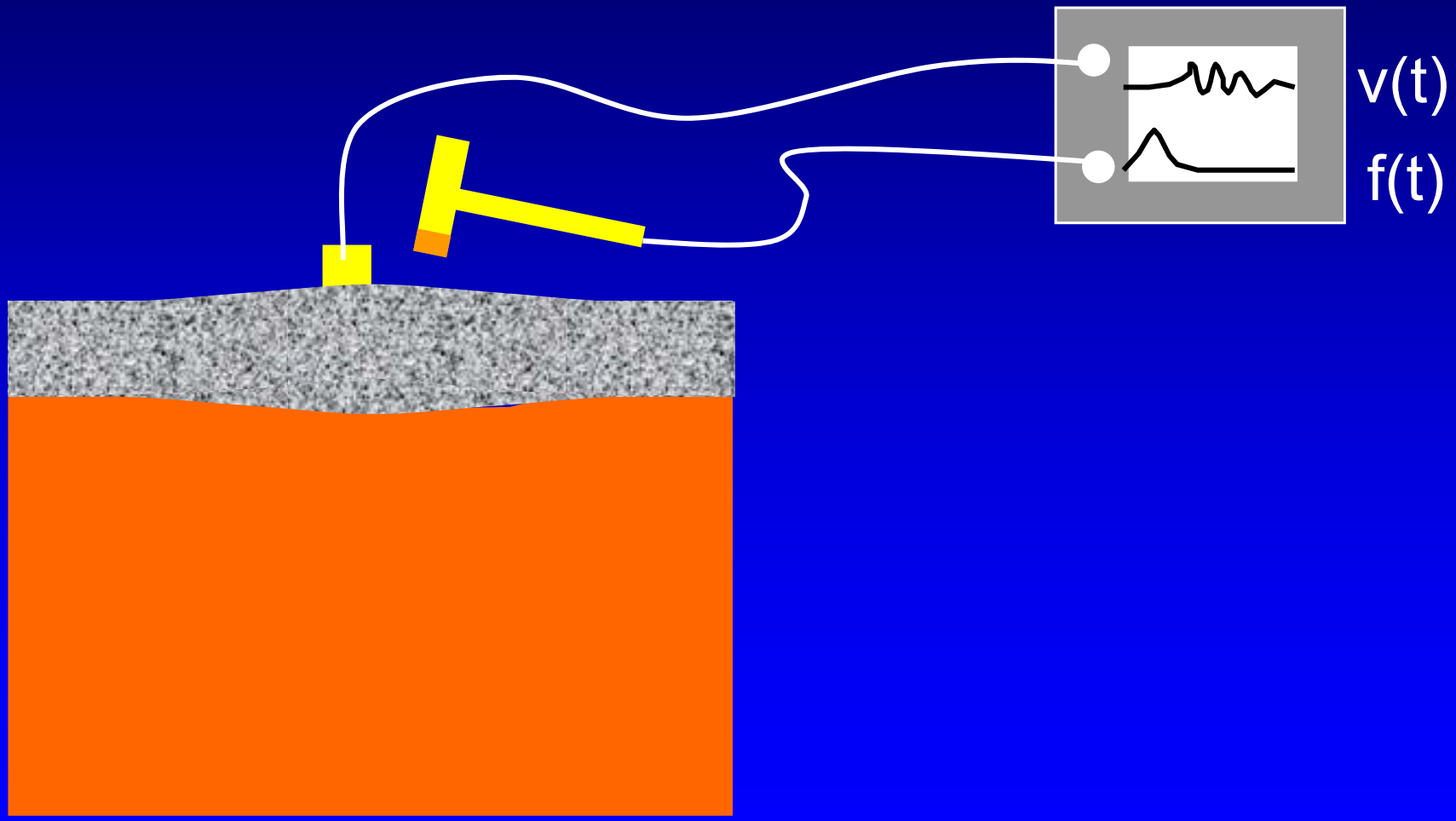
Average Mobility of Plate

- I-R test causes flexural vibration of plate within vicinity of impact (≈ 600 mm radius)
- Average mobility is affected by
  - Quality of the concrete (C_p)
  - Presence of internal voids or damage
  - Plate thickness
  - Support conditions
- High mobility means that plate is more flexible at the test point

Void Below Slab



Void Below Slab



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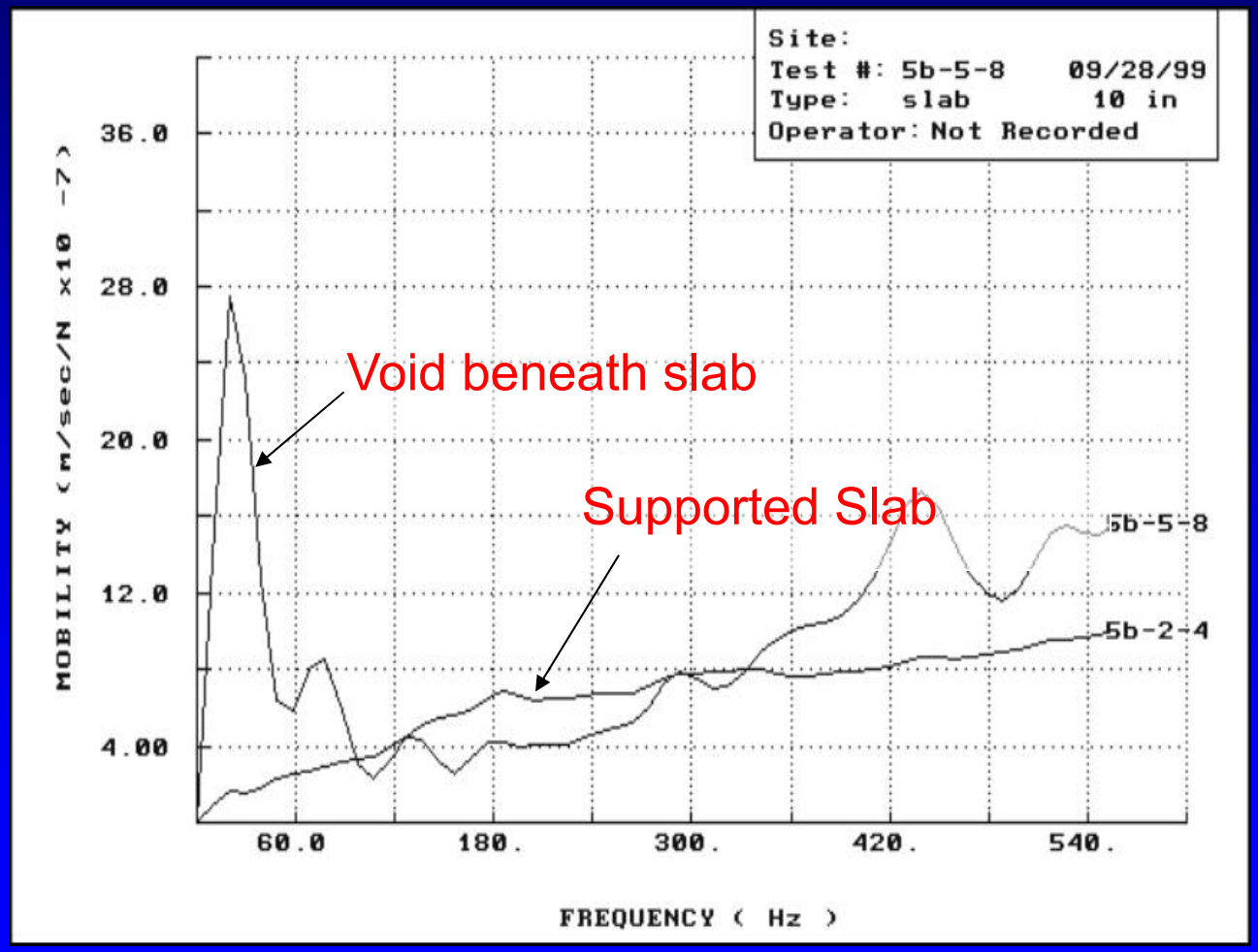
High Peak at Low Frequency: Indicates Void Below Slab



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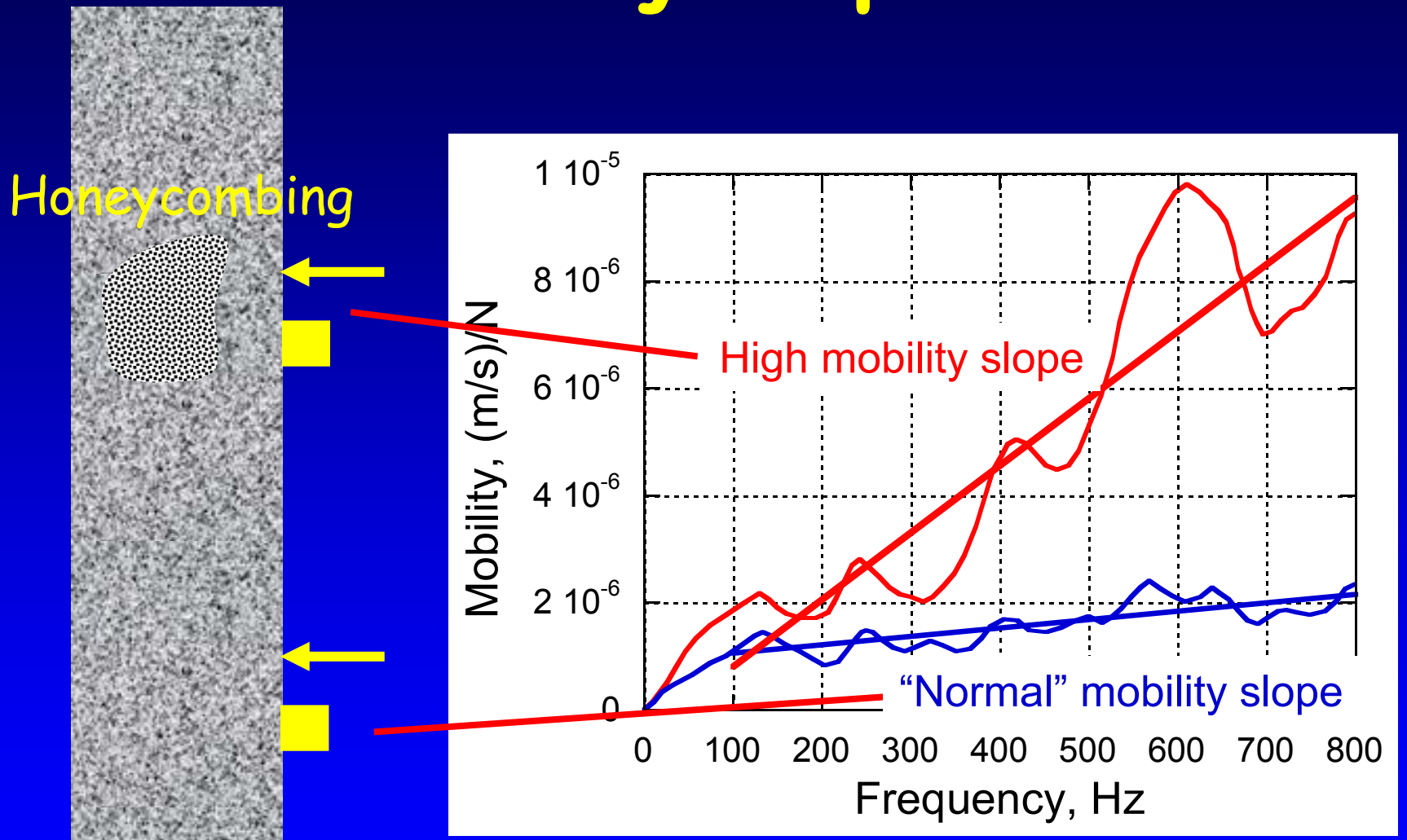
Peak-to-Mean Mobility Ratio (Voids Index)

- The ratio of peak mobility value between 0 to 100 Hz to average mobility between 100 to 800 (ASTM C1740)
- If value exceeds 2, there is high probability of void below slab at test point
- Principle is also applicable to detection of delaminations

Mobility Slope

- Slope of best-fit line to mobility spectrum between 100 and 800 Hz
- A high mobility slope has been found to correlate with presence of poorly consolidated concrete

Mobility Slope



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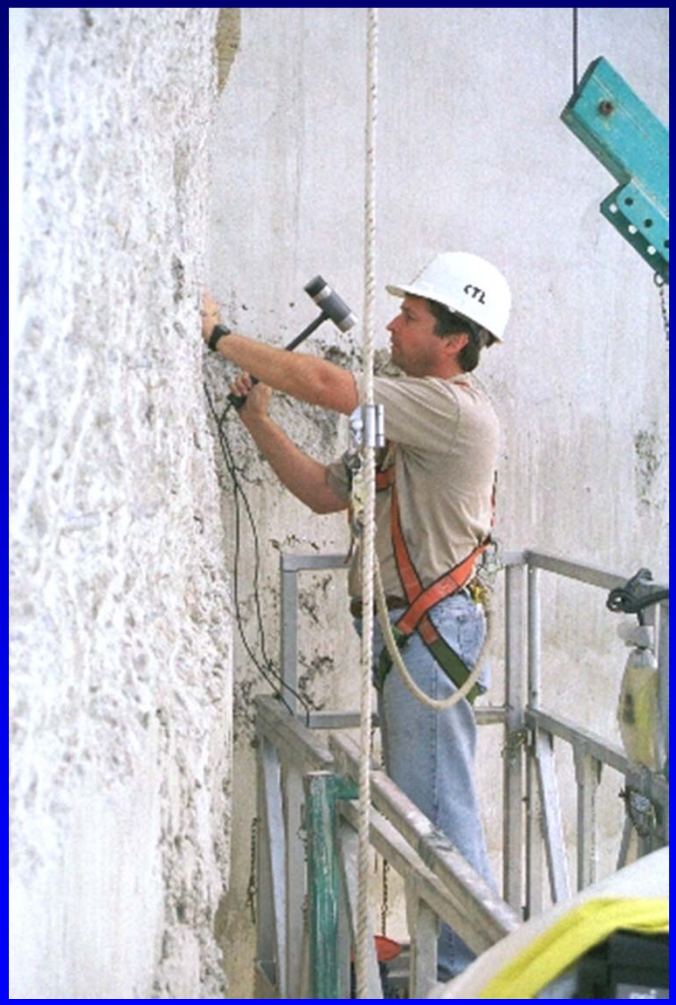
Use of Impulse Response

Testing for voids behind tunnel lining

Use of Impulse Response

Testing for honeycombed concrete in slip-formed silo



Use of Impulse Response

Testing for delaminations in dam spillway

Use of Impulse Response

Testing for load transfer at joints between panels of tank

Use of Impulse Response

Testing for delaminations and honeycombed concrete of bridge piers

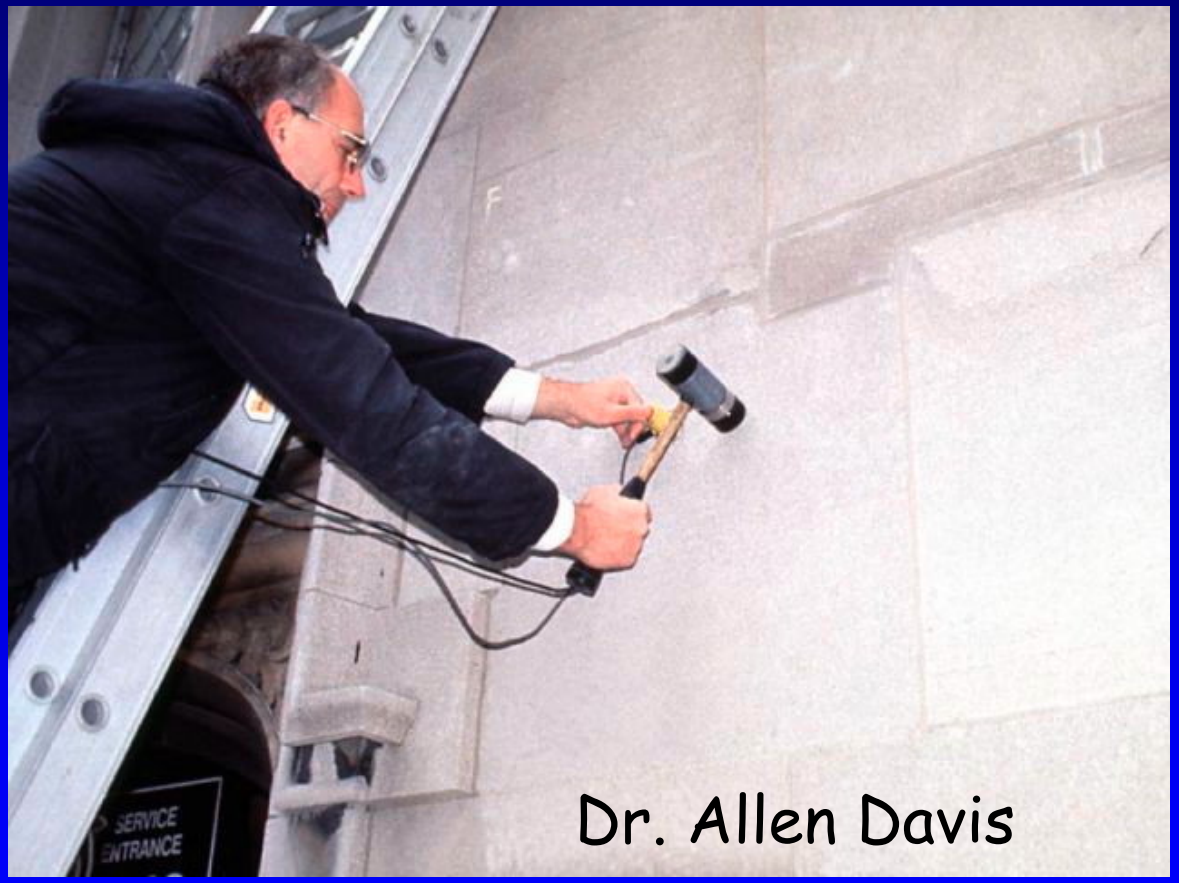
Use of Impulse Response

Testing for quality of anchorage of granite panels on high-rise building

Use of Impulse Response

Testing for internal cracking and debonding of terracotta cladding

Use of Impulse Response



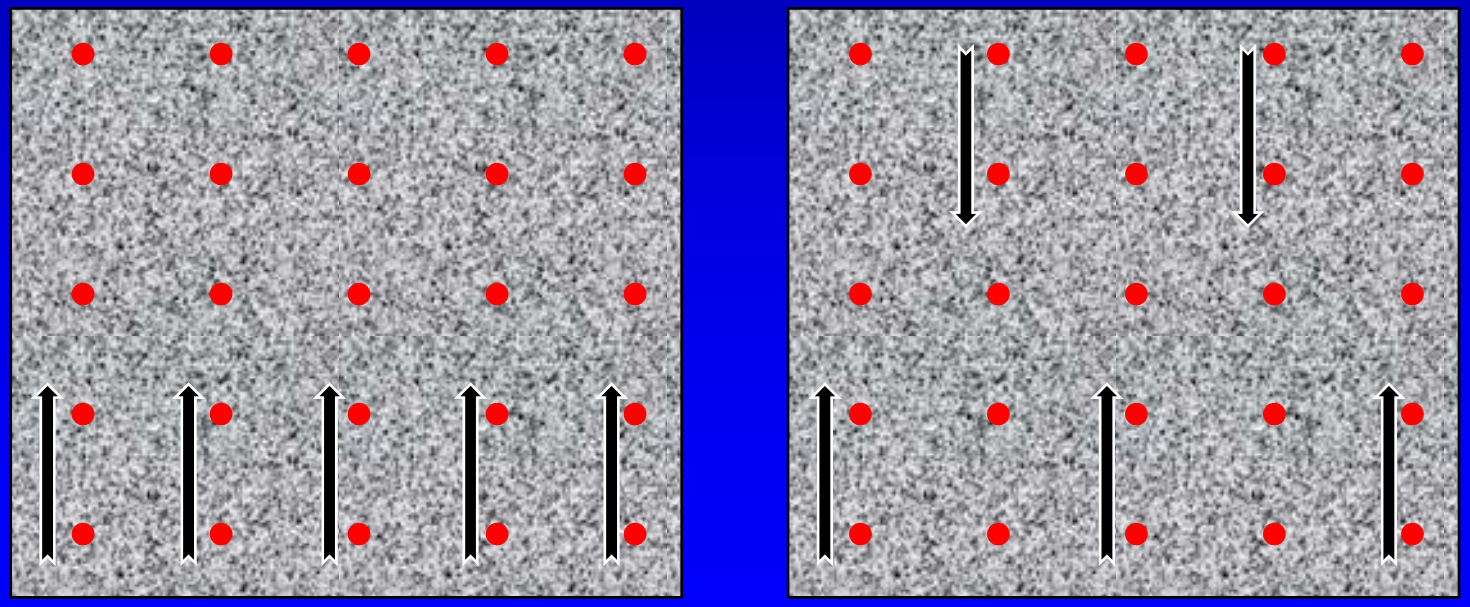
Testing limestone cladding for cracks and debonding

Testing

- Tests are typically carried out on grid
  - Grid spacing depends on size of defects to be detected (400 to 600 mm is typical)

One-way Testing

Two-way Testing



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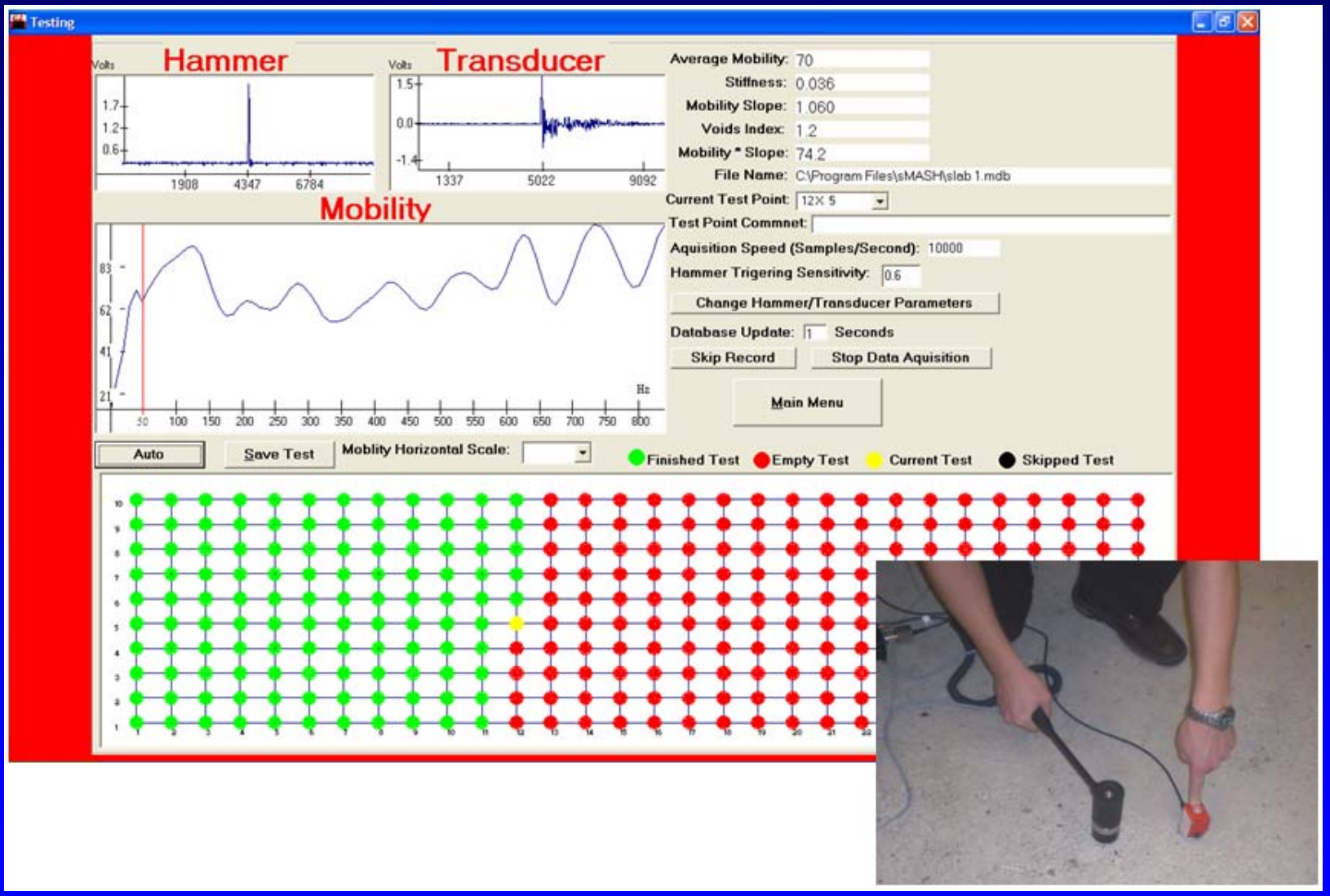
Testing—New Software



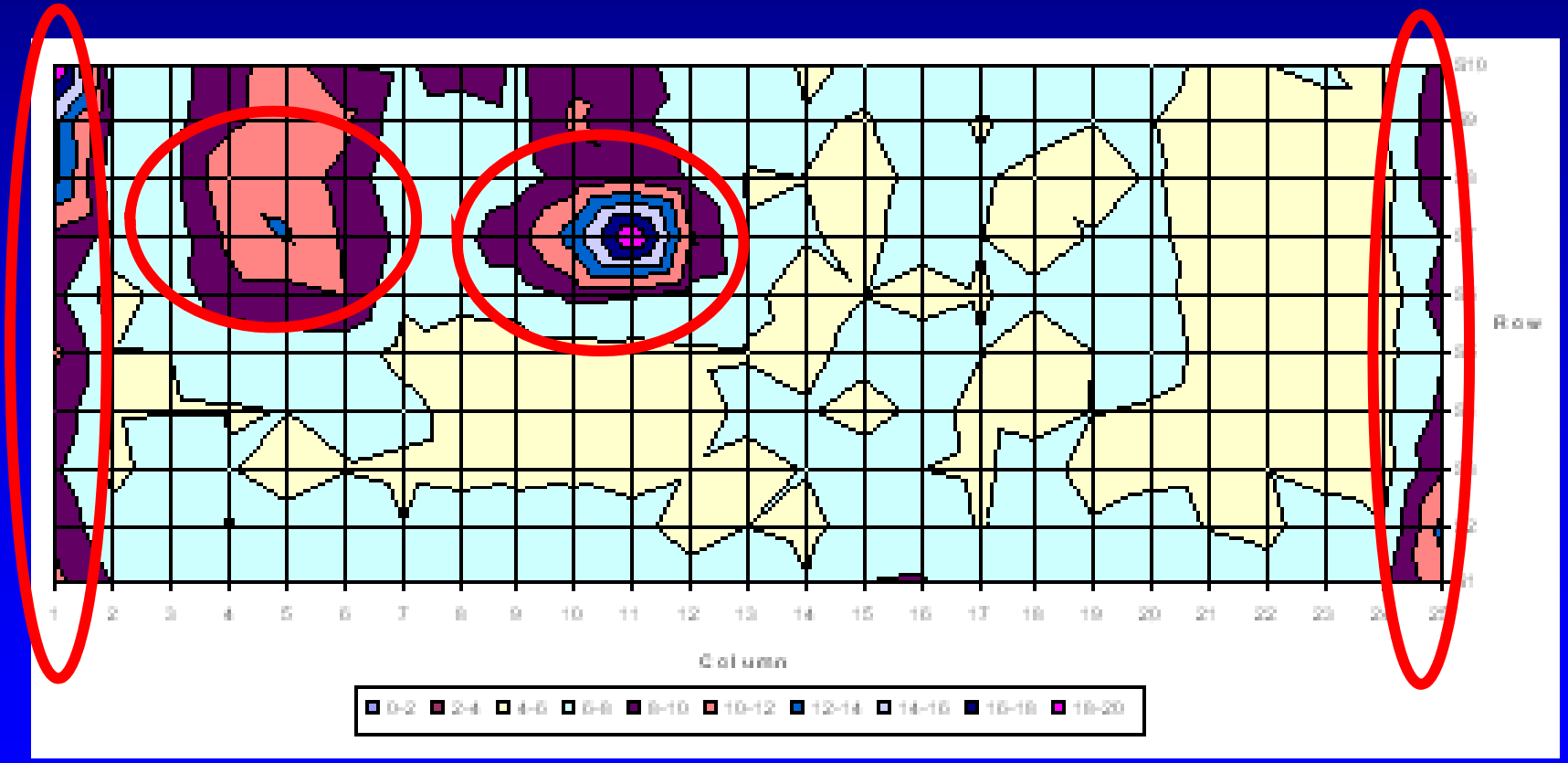
Testing in Progress

Data Presentation

- Mobility values at test points are evaluated on a comparative basis
- Calculated values at grid points are displayed as contour plots
  - Data transferred to Excel for contour plots of calculated parameters
- Anomalous regions are identified
- Further testing to confirm findings
  - Impact-echo
  - Invasive probing (coring, drilling)

Example of Contour Plot

- Average mobility for slab-on-ground



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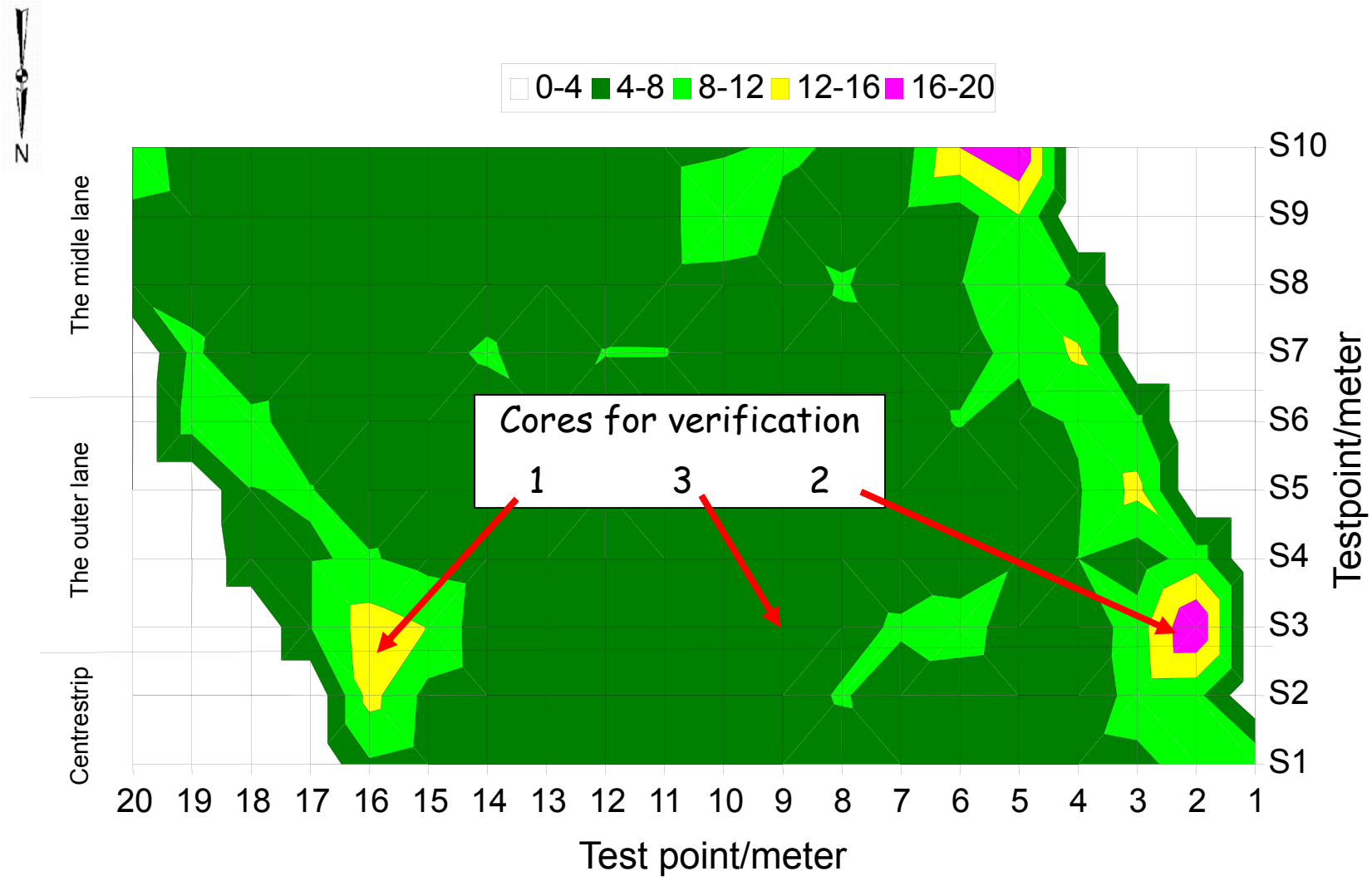
Examples

- Evaluation of delaminations in soffit of 35-year old bridge to plan repair work
- Evaluation of delaminations in bare concrete bridge deck (U.S. research project)

Bridge Soffit

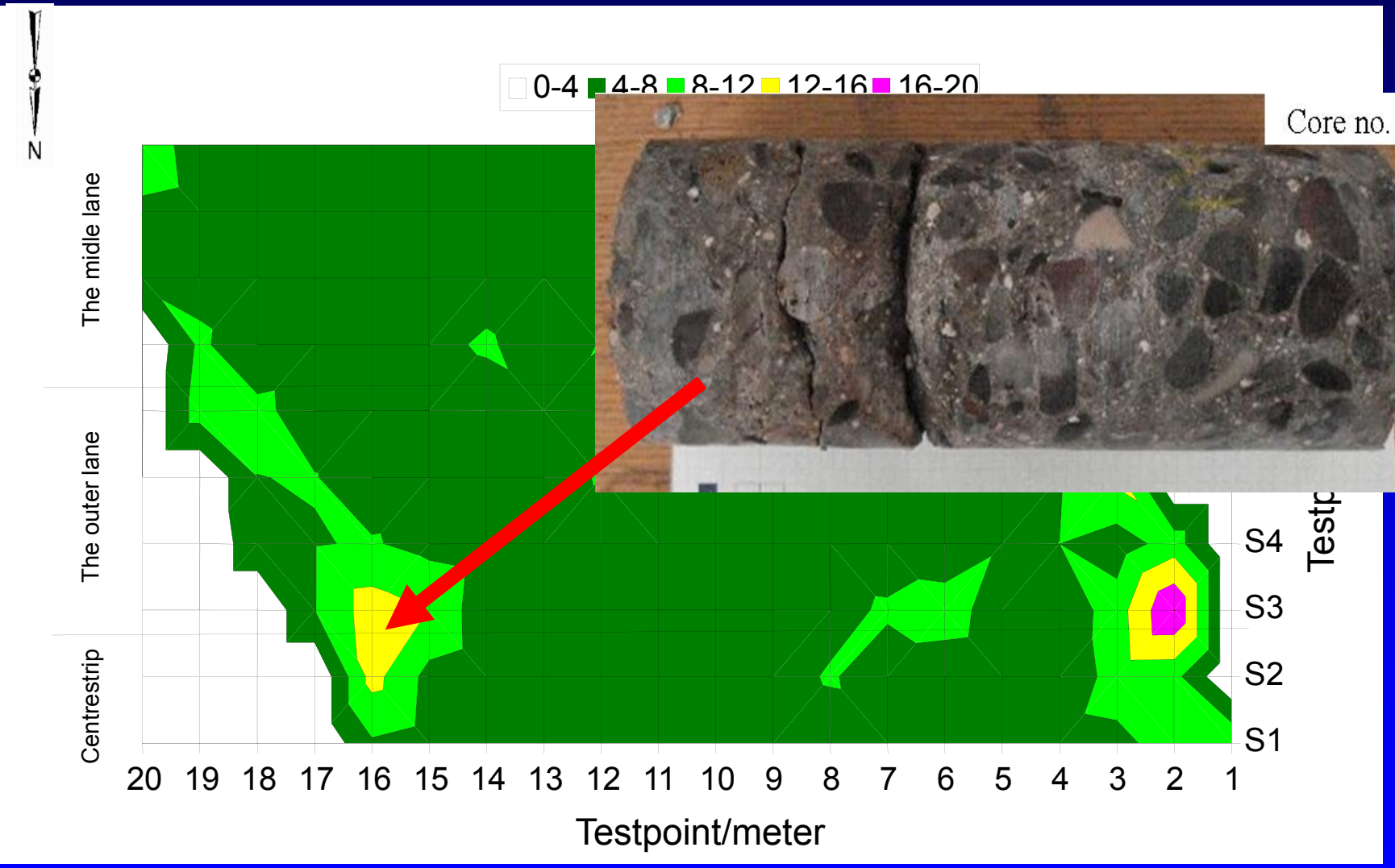
Courtesy: Ramboll

Average Mobility



Courtesy: Ramboll

Core 1, Delamination



Courtesy: Ramboll

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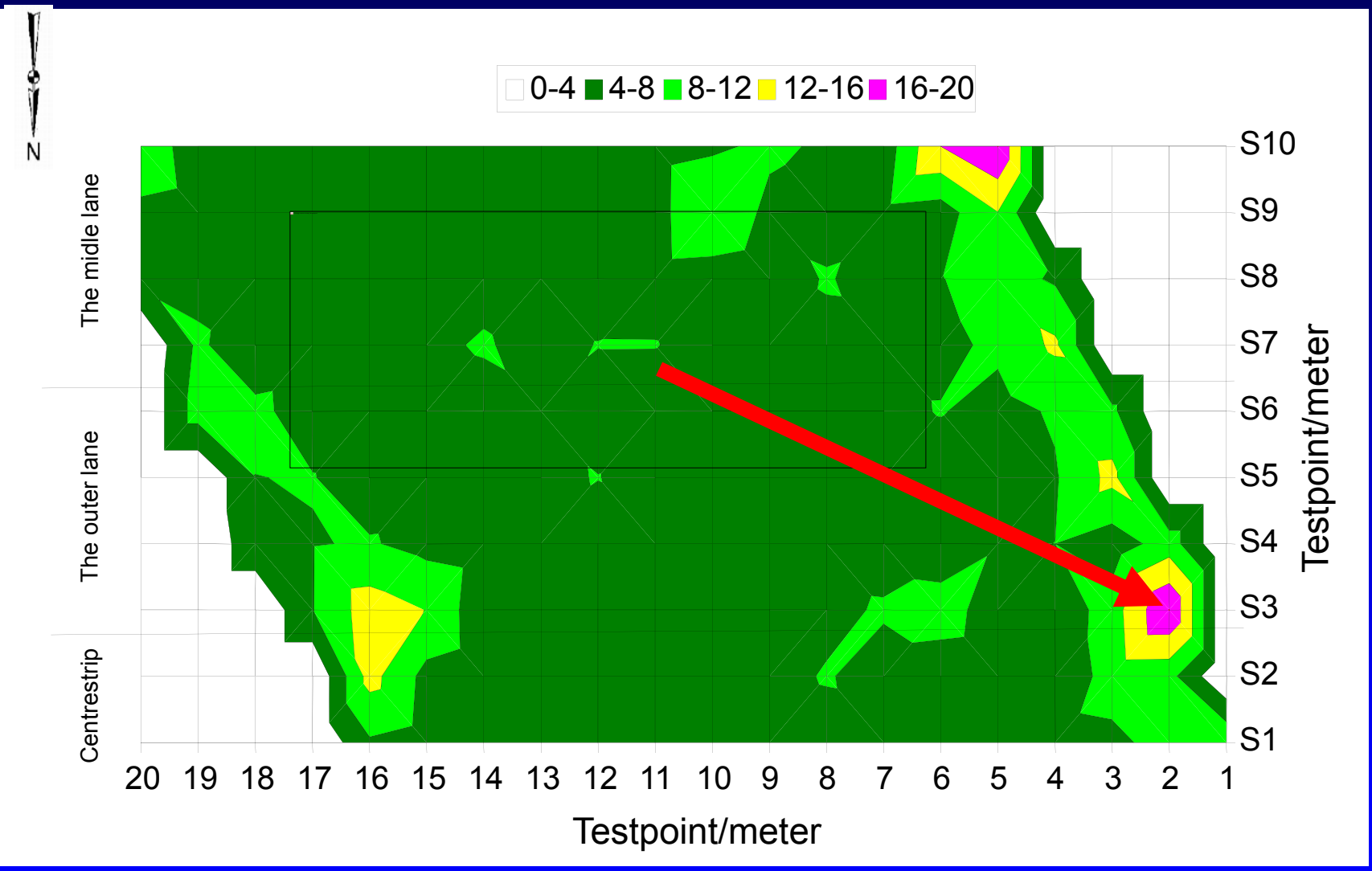
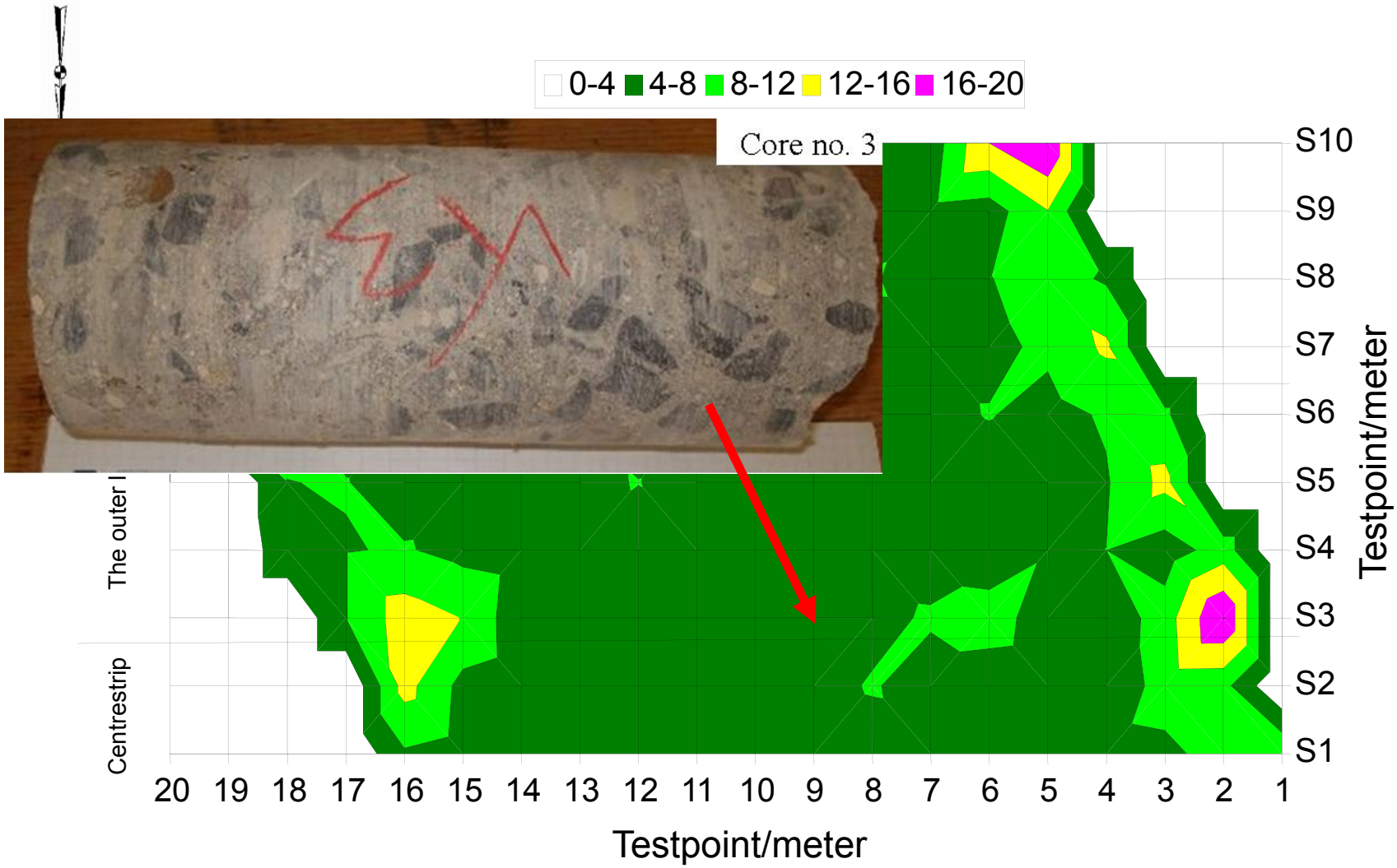
Core 2, Delamination



Courtesy: Ramboll

Core 3, Solid



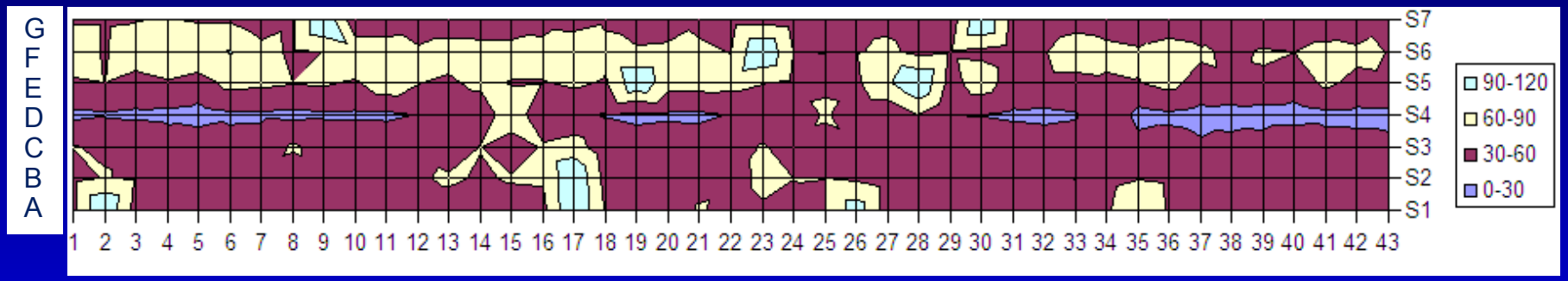
Courtesy: Ramboll

Bridge Deck Evaluation
SHRP 2 Program

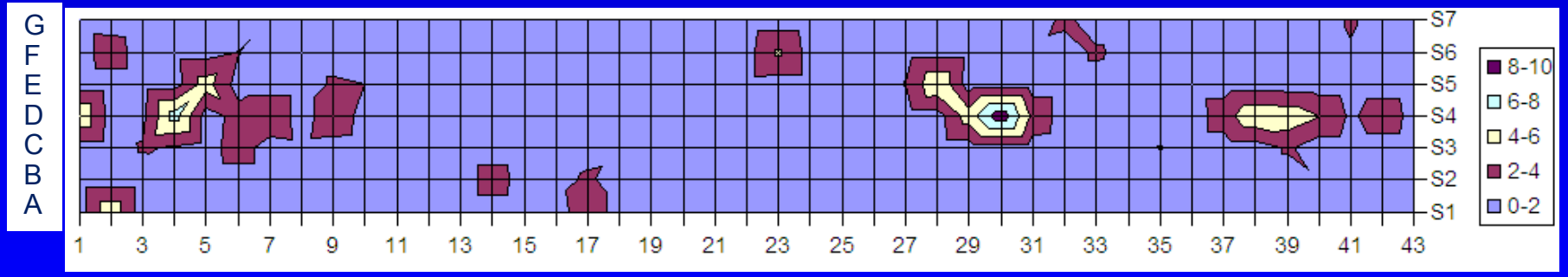
Test Grid

Results

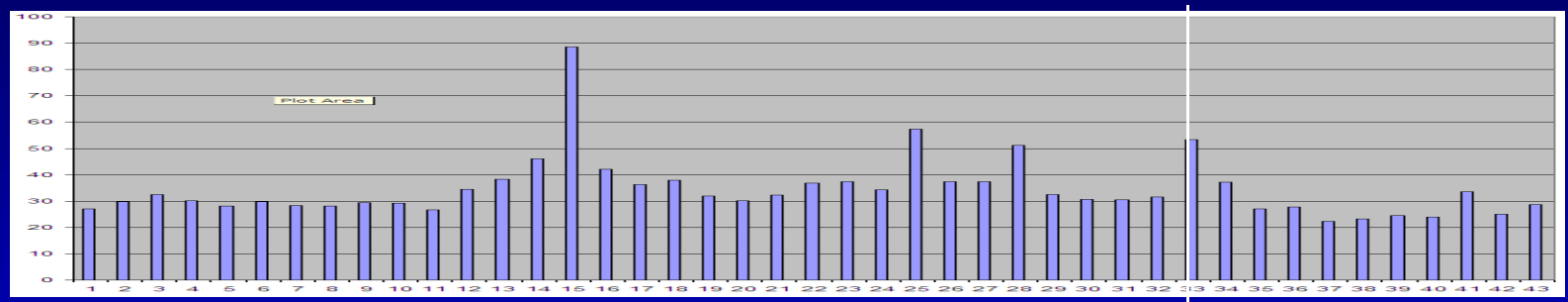
Average Mobility



Voids Ratio

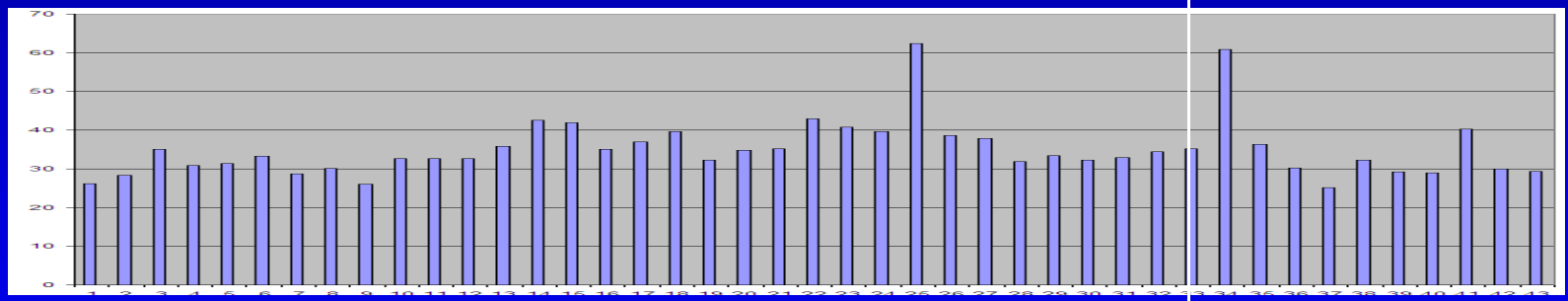


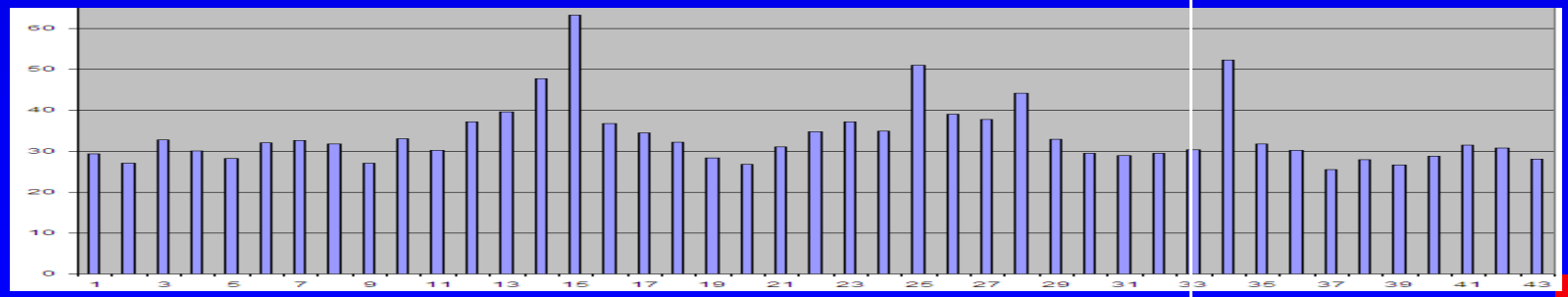
Repeatability-Line D



Row 15 25 33

Mobility





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Verification of Delaminations by Impact-Echo

Summary

- Impulse-response provides a means for rapid screening of suspect structures
- Test results are analyzed on a comparative basis within tested structure
- Identifies potentially anomalous regions for further investigation

SHRP 2 Program
www.trb.org

- Renewal Program: Investigate technologies and institutional solutions to support systematic rehabilitation of highway infrastructure in a way that is rapid, presents minimal disruption to users, and results in long-lasting facilities.
- NDT Toolbox: Summaries of NDT technologies; recommended test procedures; samples of data output; guidance on interpreting and presenting results; and equipment features.

NDT Toolbox
www.ndtoolbox.org

SHRP2 STRATEGIC HIGHWAY RESEARCH PROGRAM

Home | Bridges | Pavements | Tunnels

NDToolbox

Home

Condition Assessment

Technologies

- Electrical Resistivity
- Galvanostatic Pulse Measurement
- Ground Penetrating Radar
- Half-Cell Potential
- Hammer Sound / Chain Drag
- Impact Echo
- Impulse Response
- Infrared Thermography
- Ultrasonic Surface Waves

Deterioration

- Rebar Corrosion
- Deck Delamination
- Cracking
- Concrete Deterioration

QA/QC

Technologies

- Spectroscopy

Description

The Impulse Response method, also known as the Transient Dynamic or Mechanical Impedance method, is a non-destructive testing method that has been utilized in quality control and condition assessment of pavements and deep foundations. The method was first developed in France in the late 1970's as an extension of a Vibration test, used in the quality control of drilled shafts. The IR method has been used to determine the subgrade modulus and presence of voids or loss of support in rigid pavements, concrete tunnel linings, historic reinforced concrete bridges, bridge decks, and concrete slabs. The method was recently introduced as a screening tool for bridge decks, slabs and tunnel linings for detection of potentially damaged areas.

Sections

- Description
- Physical Principle
- Applications
- Performance
- Limitations
- Equipment
- Test Procedures
- Data Presentation