# A Fresh Look at Impulse Response as a From of NDT for Concrete Bridge Decks

presented by

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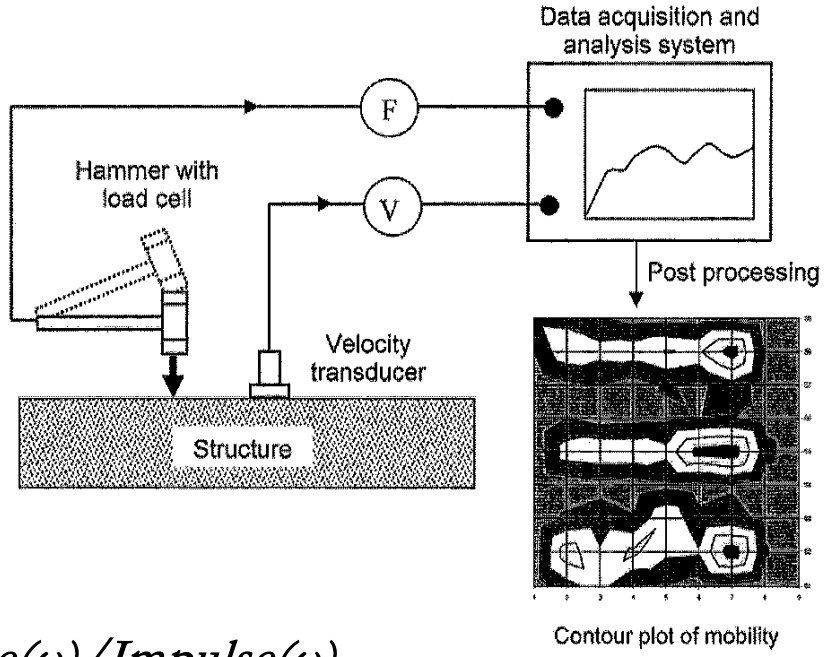
Research in Progress

**Background**:

- Originally developed for deep pile foundations
- Currently most commonly used in aircraft manufacturing
- Since the 1980s applied to concrete plate like structures (ASTM C1740)
  - Poorly consolidated sections
  - Voids in supports
  - Delaminations caused by corrosion in reinforcing steel

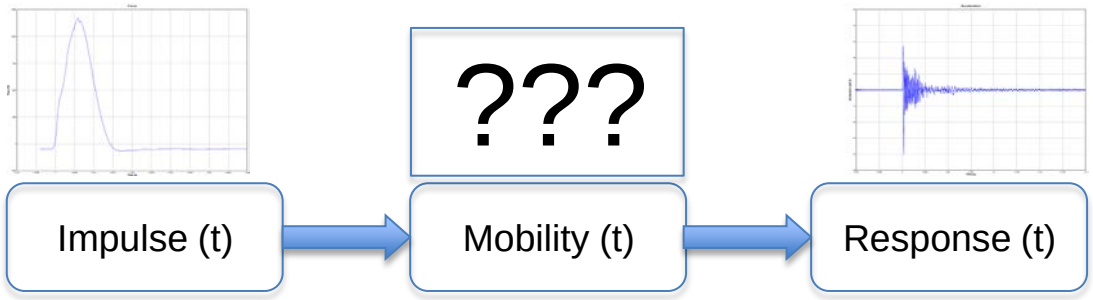
**Principle**:

- Impulse signal is recorded and transformed to frequency domain
- Response signal is recorded and transformed to frequency domain
- Dividing these response frequency by the impulse frequency gives 'Mobility'




Source: ASTM C1740-10

$$Mobility(\omega) = Response(\omega)/Impulse(\omega)$$




Known: Signal from hammer load cell

Unknown: Function of System (concrete)

Known: Signal from transducer

**Case Study**:

- Steel-concrete composite deck girder bridge in NJ

- Six, Two-span cont. deck slabs, each 36 ft long


Source: Google Maps

- Two lanes
- Total length = 216'
- Road width = 30'
- Age: 25 years

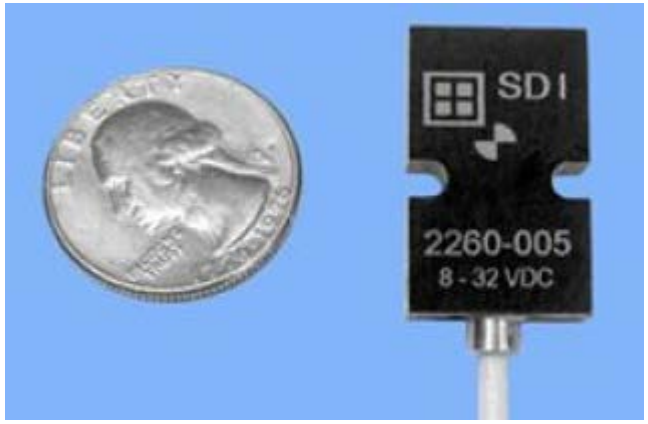
- Severe deterioration/ delamination of the concrete deck, steel reinforcement corroded

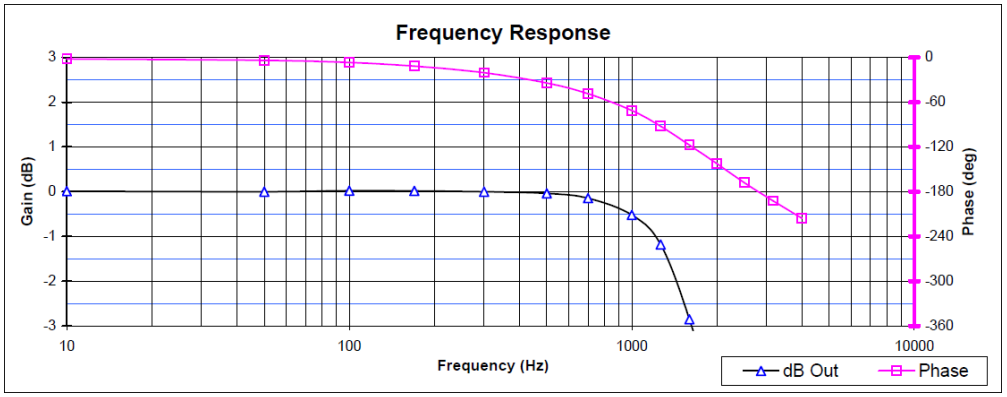
- IR performed on a 2' x 2' grid on 5 of 6 deck slabs

**Testing System**:

- PCB Instrumented Hammer

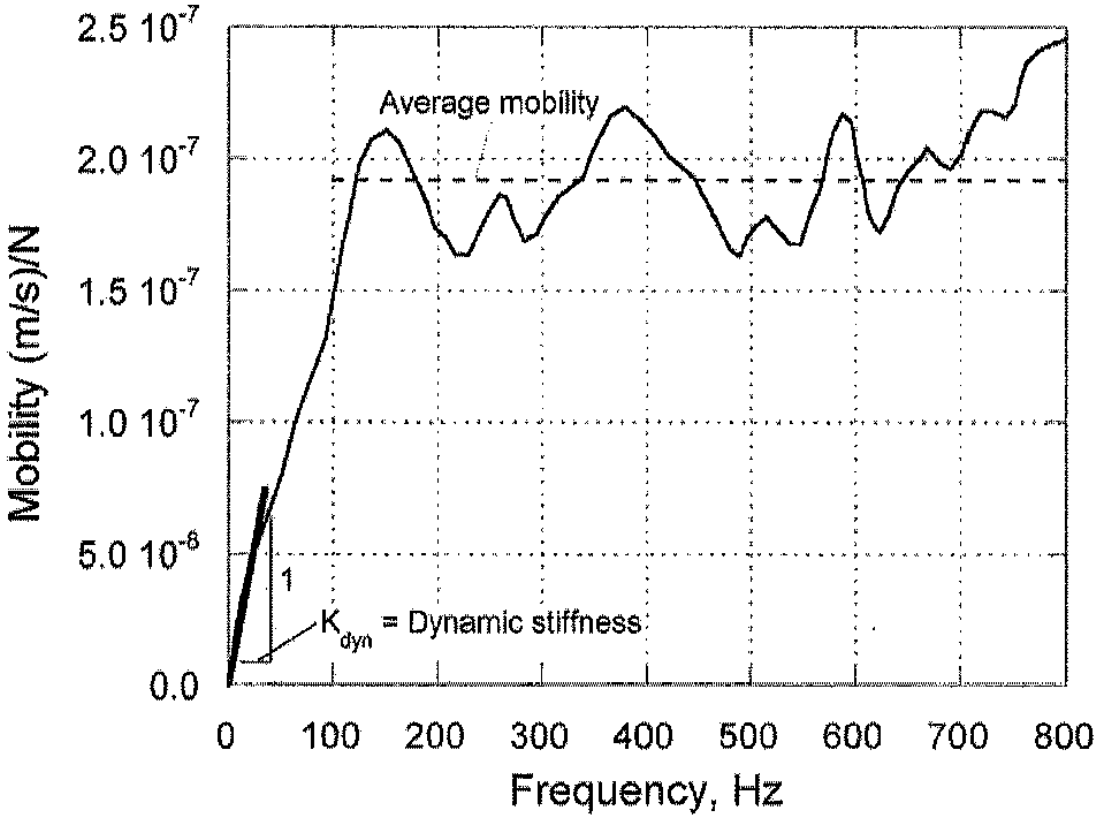
- Accelerometer
  - Used for flat response at low frequencies
- DAQ system
- Post Processing System



**ASTM C1740-10 Parameters**:

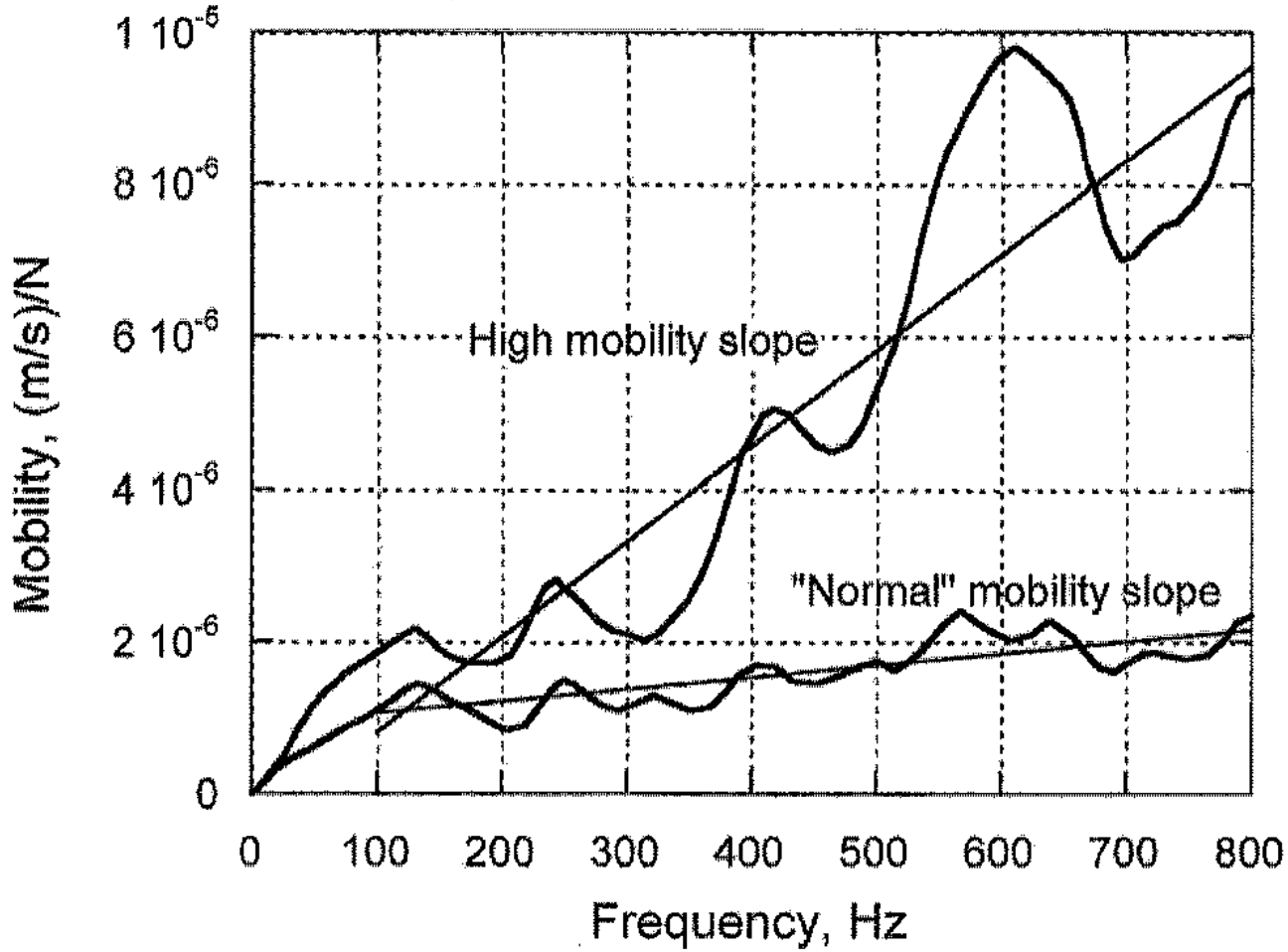
- Average Mobility
  - Average mobility value from 100 to 800 Hz
- Dynamic Stiffness
  - Inverse of the slope of the mobility from 0 to 40 Hz




Source:
ASTM C1740-10

**ASTM C1740-10 Parameters**:

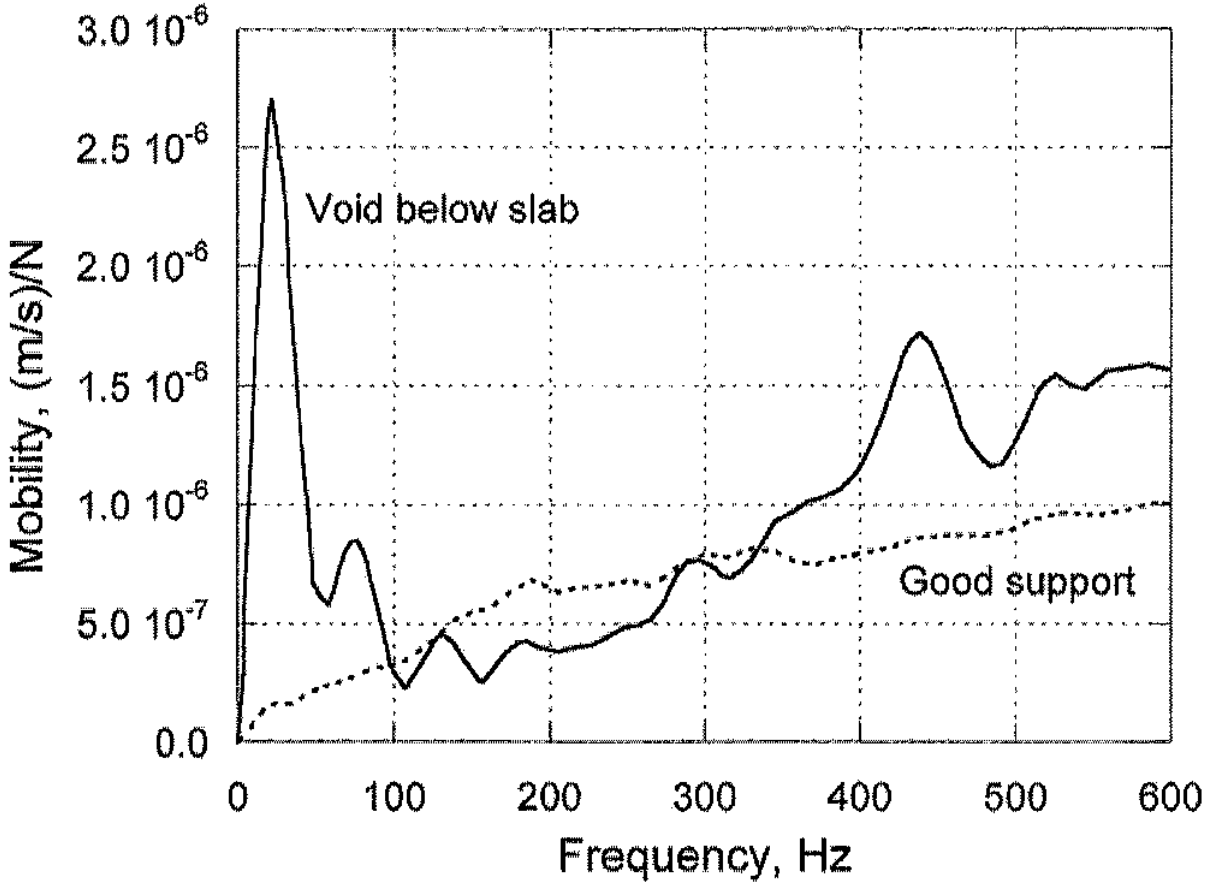
- Mobility Slope
  - Slope of mobility from 100 to 800 Hz




Source:
ASTM C1740-10

**ASTM C1740-10 Parameters**:

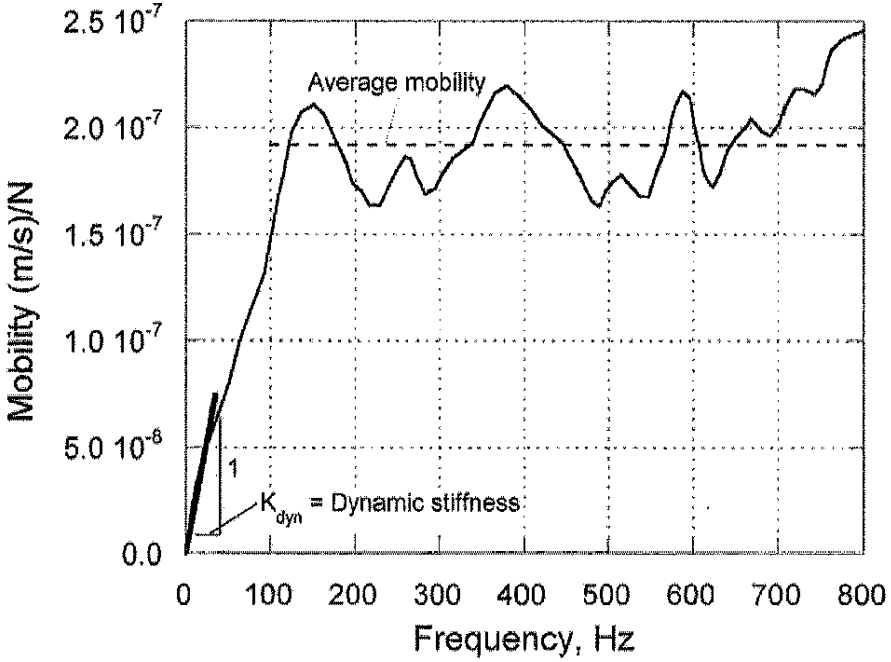
- Peak-Mean Mobility Ratio
  - Ratio of the peak mobility from 0 to 100 Hz, and the 'Average Mobility'



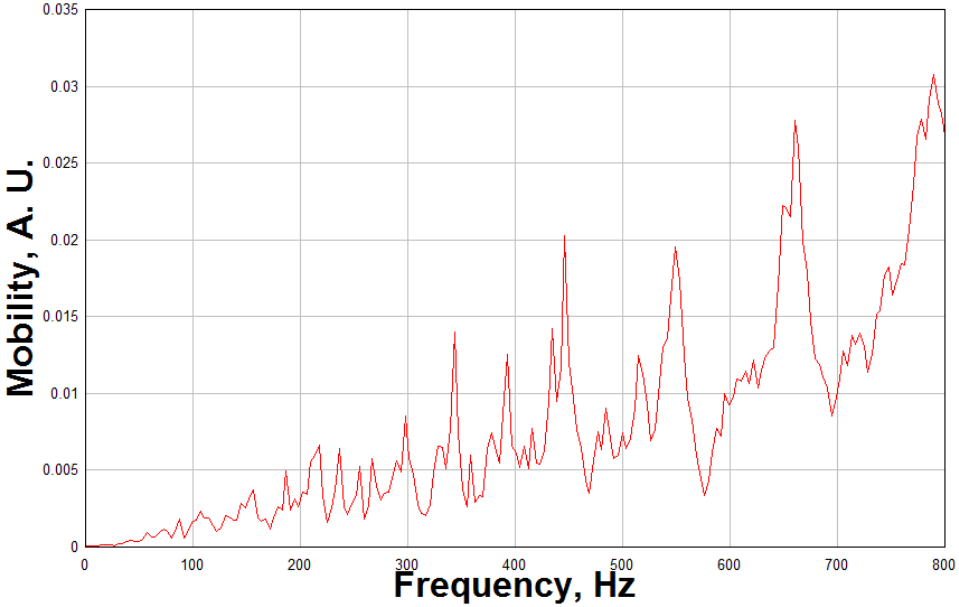

Source:
ASTM C1740-10

**Current Standard**:

- Inconsistent definition of parameters
- Mobility in frequency domain is not uniquely defined
- Idealized Mobility plot is difficult to observe
- Qualitative and relative



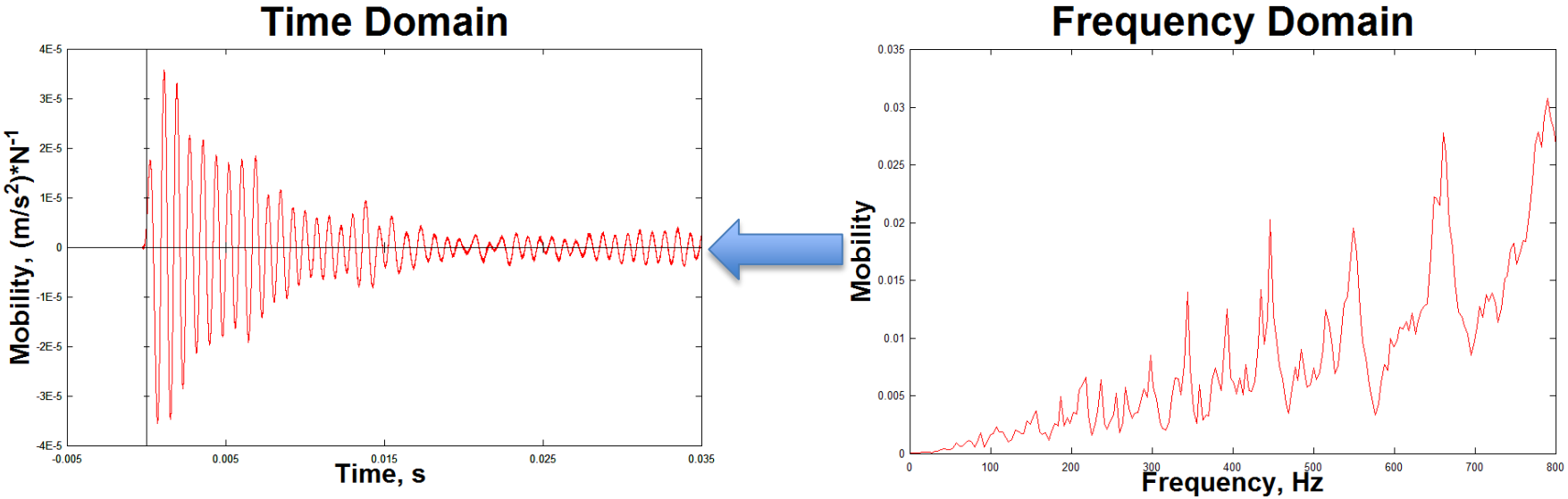

ASTM C1740-10




Concrete Bridge Deck Test (2011)

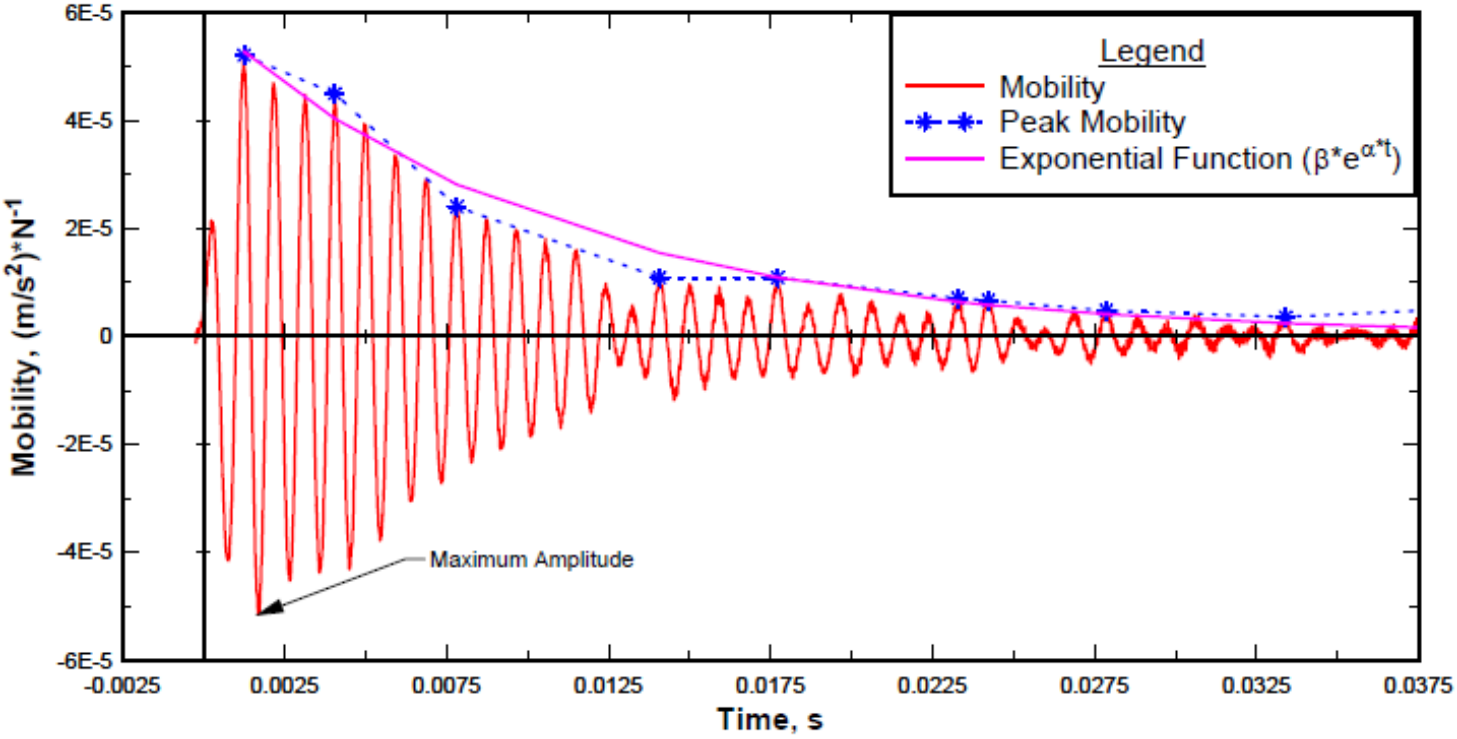
**New Approach**:

- Same testing procedure; different post-processing
- Transform Mobility spectrum back into time domain
- Use mobility time signal to find parameters that theoretically characterize the concrete

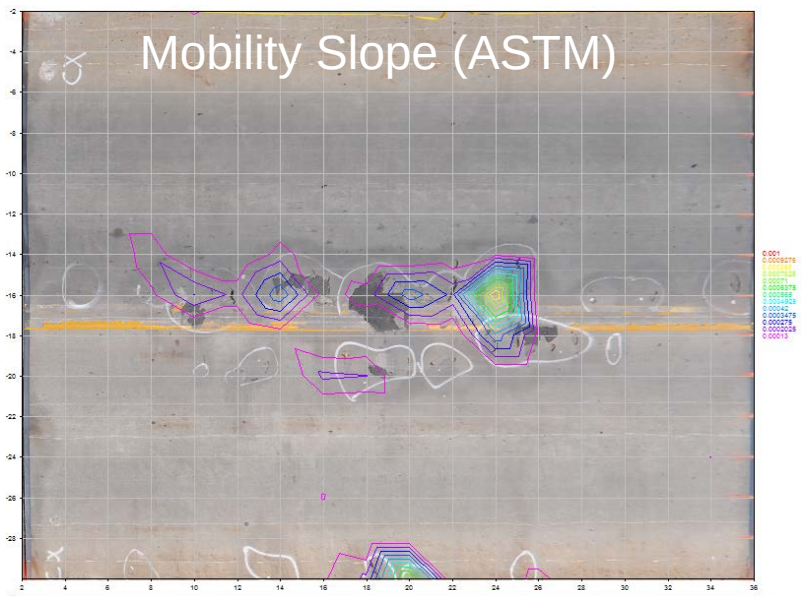


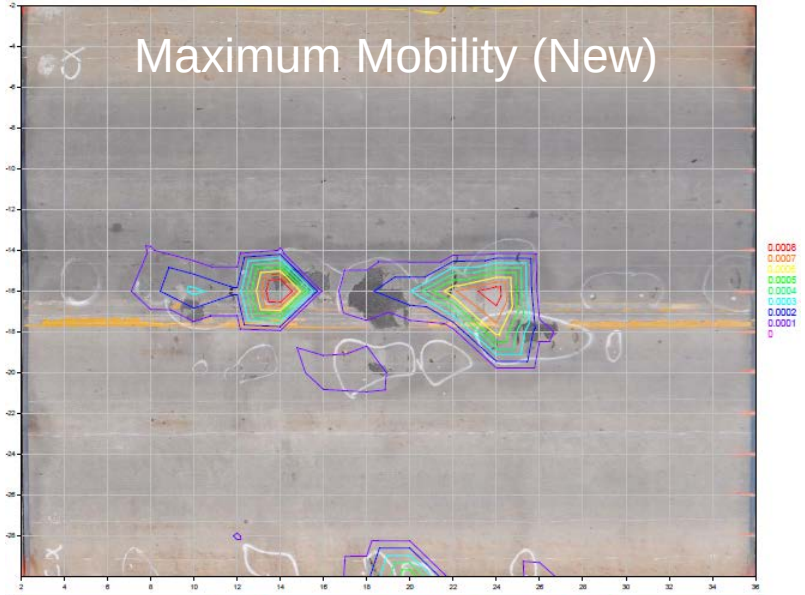
**New Parameters**:

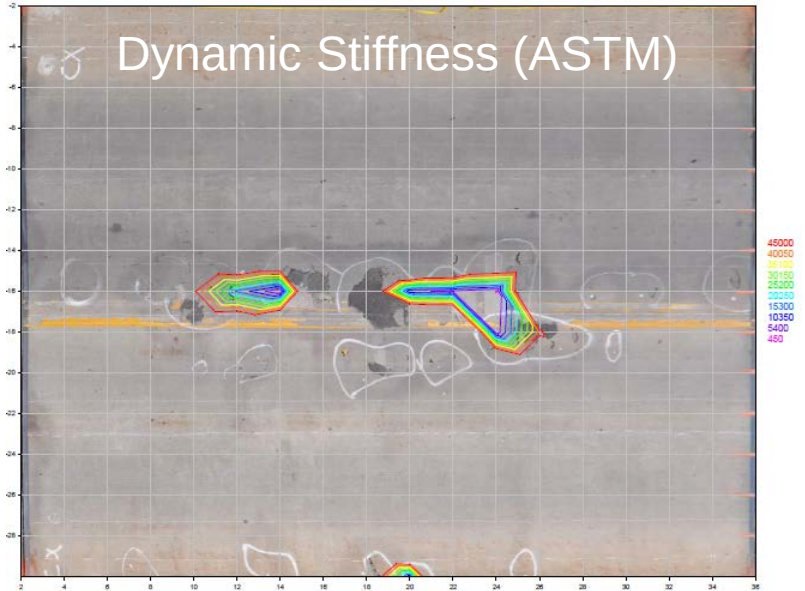
- Maximum Mobility Amplitude
  - Large values indicate low stiffness, possibly due to delaminations
- Exponential Rate of Decay
  - Large values of α suggest high damping, possibly due to delaminations

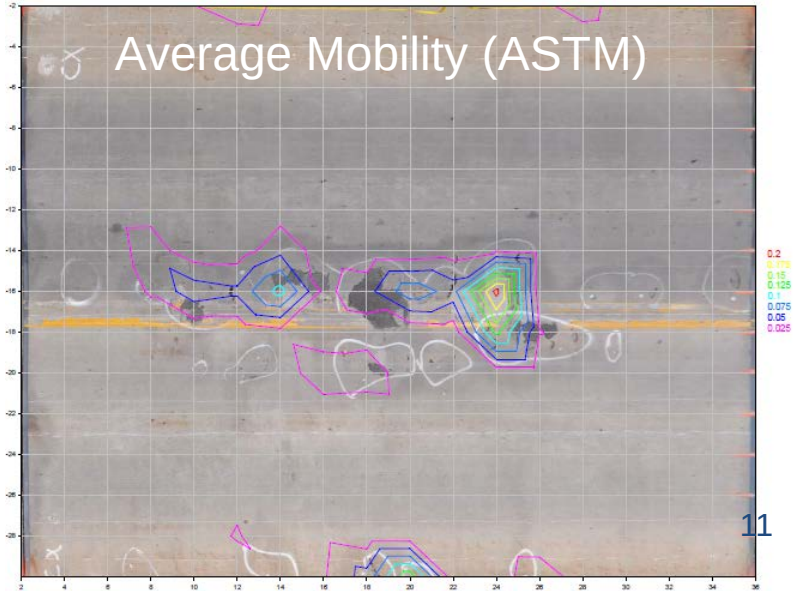


## Maximum Mobility Amplitude Results (Example: deck 4):

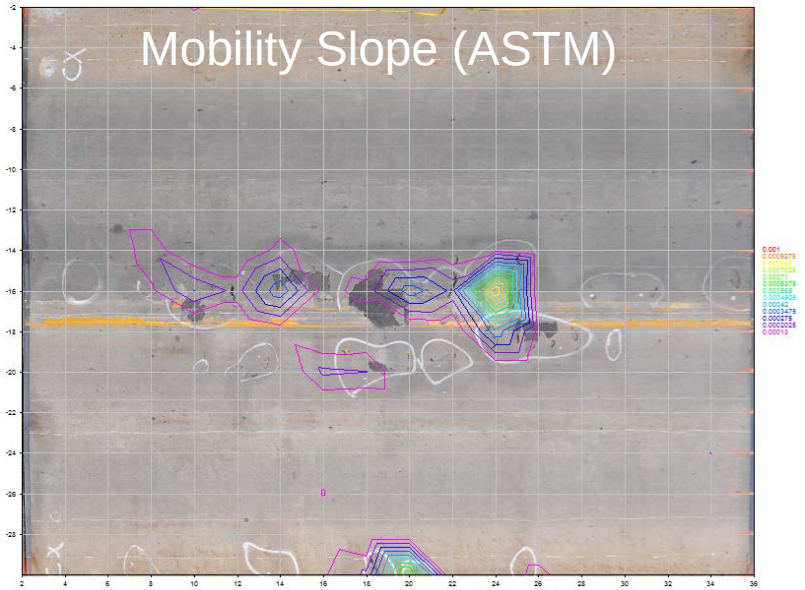


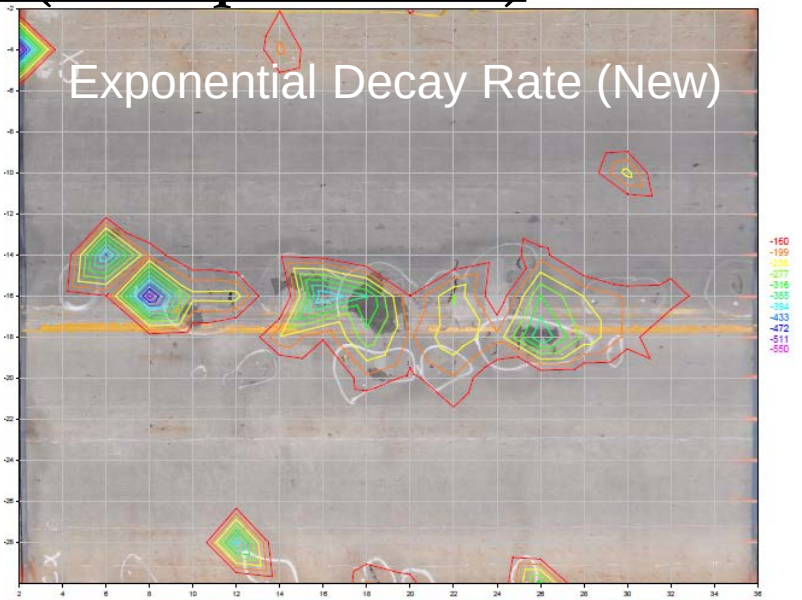



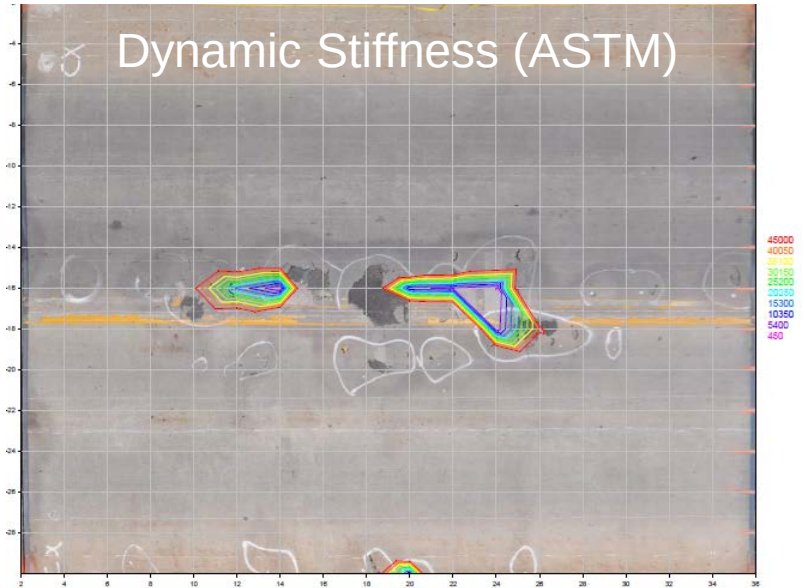



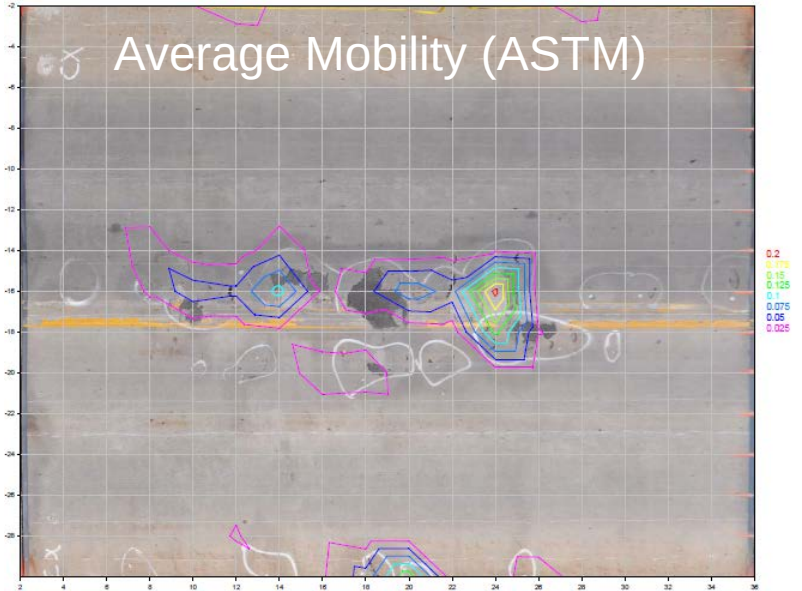



## Exponential Rate of Decay Results (Example: deck 4):



**Continuing Research** :

- Continue evaluating new approach and parameters

- Testing other effects:
  - Proximity of impact to accelerometer
  - Magnitude of impact
  - Repeatability
  - Slow Dynamics

- Verification of results during deck repair in August 2012

- Combining with other methods (ultrasonic) to confirm results and locate depth of delaminations

Project sponsor: Delaware Department of Transportation

# Questions?