Beyond Chain Dragging – Concrete Bridge and Parking Deck Assessments Impact Echo and Surface Waves Scanning for Bare and Asphalt Overlaid Decks

Larry D. Olson, P.E.

President and Chief Engineer

Olson Engineering, Inc.
Olson Instruments, Inc.

Rockville, Maryland Branch office (metro Washington, DC)
Athens, Ohio Branch office
Corporate office in Wheat Ridge, Colorado (metro Denver)
Email – Larry.Olson@OlsonEngineering.com

INTERNATIONAL CONCRETE REPAIR INSTITUTE
2017 Spring Convention | March 15-17 | Montreal, Canada

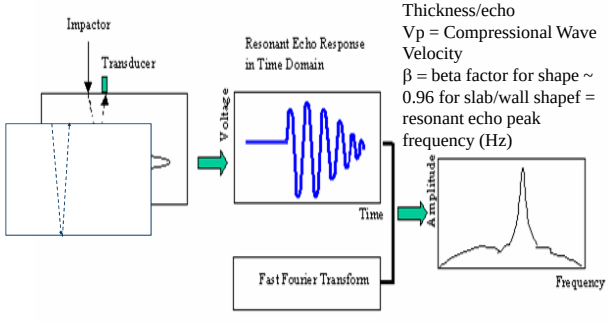
Bridge Deck Scanning – NCHRP IDEA Contract 132 Research Project

- Objectives
  - To detect top delaminations in concrete bridge decks
  - To identify internal conditions; including cracks, crack depth, concrete deterioration and bottom deck delamination mapping
  - To detect delaminations between asphalt layers or other deterioration
  - To profile thickness
  - To perform these tasks rapidly with a rolling scanning system
  - Compared with radar and acoustic sounding

Nondestructive Testing Methods Utilized in the Bridge Deck Scanner (BDS)

- Impact Echo (IE) – ASTM C1383 and ACI 228.2R
- Spectral Analysis of Surface Waves (SASW) – ACI 228.2R

Impact Echo Test



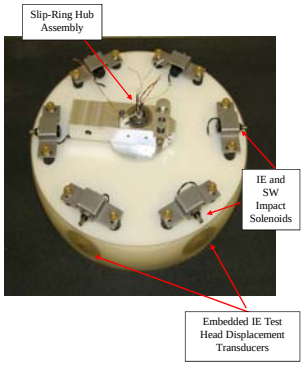
D = βVp/(2*f) = Thickness/echo
Vp = Compressional Wave Velocity
β = beta factor for shape ~ 0.96 for slab/wall shapef = resonant echo peak frequency (Hz)

Spectral Analysis of Surface Waves (SASW)

Surface Sonic Scanner S^3 slow-rolling IE/SASW on Cart on Virginia Asphalt Overlaid Deck with tests every 6 inches and latest S^3 on right with bright sunlight viewable screen

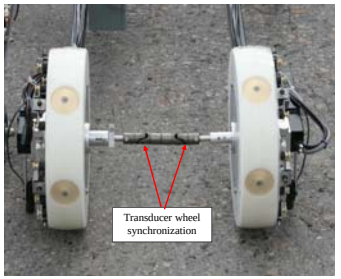
Scanning Impact Echo Testing

- Diameter of Wheel = 293 mm (11.5 inches)
- Six individual displacement transducers
- Six individual impactors
- Impacts spaced 150 mm (6 inches) apart along a scan line (around the wheel circumference)
- The 6 transducers were spring mounted with rubber isolators and captured with a thin urethane tire approximately 60 mm (2.5 inch) wide
- The thin urethane tire was added as a dust cover and to improve coupling

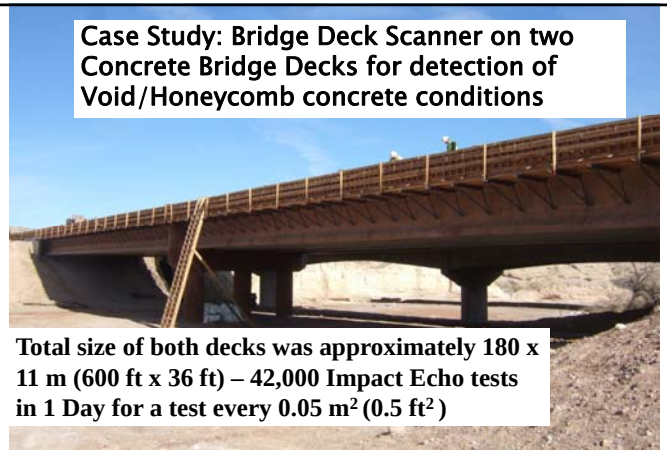


Scanning Spectral Analysis of Surface Waves

- Use 2 identical sensor/impactor wheels
- Only one wheel with the impactor turned on
- The spacing between the transducers is 1 foot
- Can rotate the wheels 30 degree out of phase to perform IE testing on both wheels simultaneously



Case Study: Bridge Deck Scanner on two Concrete Bridge Decks for detection of Void/Honeycomb concrete conditions



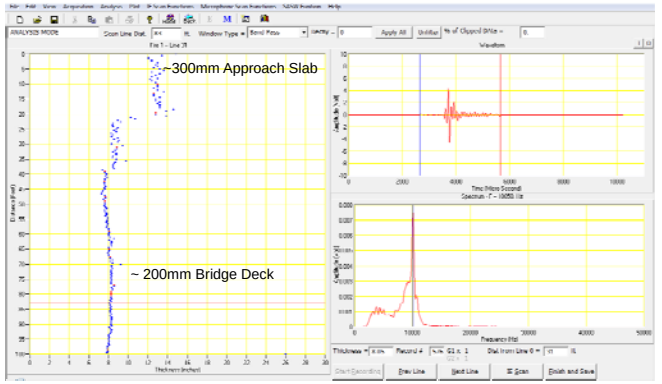
Total size of both decks was approximately 180 x 11 m (600 ft x 36 ft) – 42,000 Impact Echo tests in 1 Day for a test every 0.05 m^2 (0.5 ft^2)

Tests on Grid Lines at 0.3 m (1 ft) spacing across width of decks with cart – Deck 1

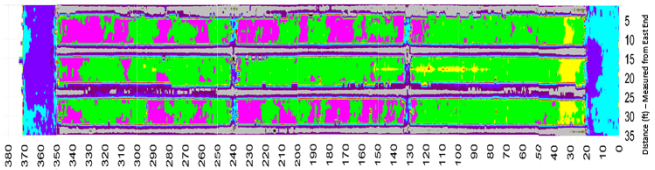
Bridges supported by concrete I-beams, diaphragms, and piers

Bridge Deck Scanner w/ hand-pulled cart for rapid testing – note rough concrete tested well

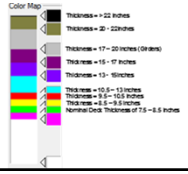
Bridge Deck Scanner Impact Echo Thickness Plot Single Scan Line along Deck 1



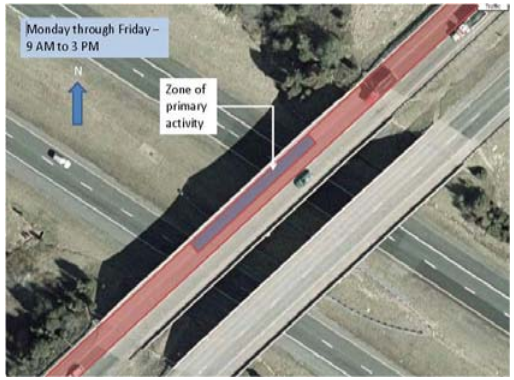
Impact Echo Thickness Results No significant void/honeycomb found – Green is Deck Echo Thickness



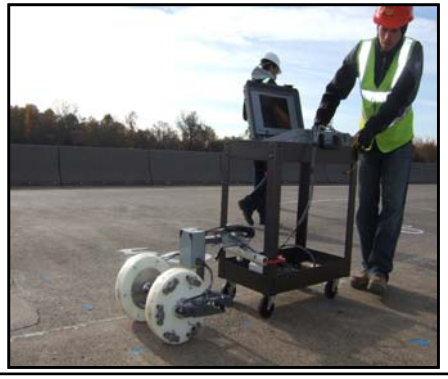
Thickness changes such as the approach slabs, piers, diaphragms and girders can all be observed in the IE thickness data.



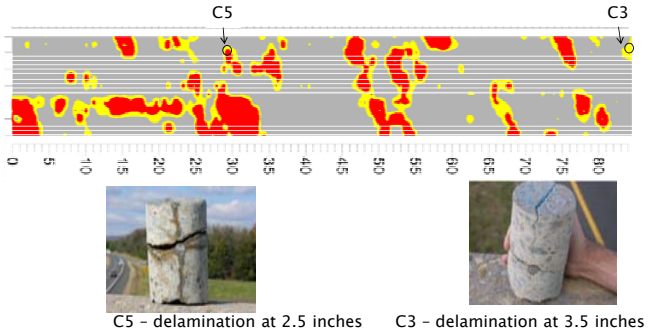
Case Study – Corroded Delaminated Virginia Bridge Deck, James Madison US Highway 15 over I-66



Corroded Virginia Bridge Deck (concrete) - SHRP 2 R06A
Research by Dr. Nenad Gucunski of Rutgers University



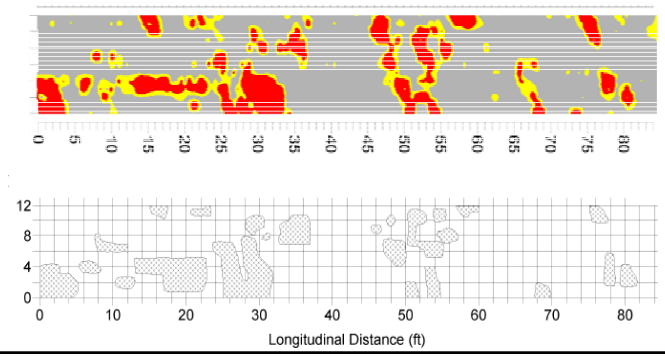
Comparisons between IE Test Results and Cores



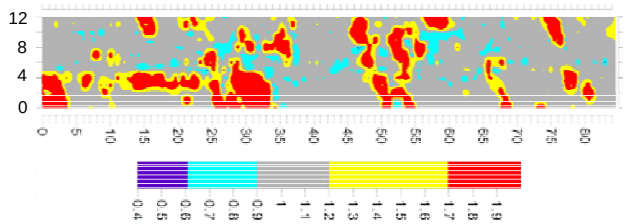
C5 – delamination at 2.5 inches

C3 – delamination at 3.5 inches

Top Delamination Test Results from the Surface Sonic Scanner (top) and Chain Dragging Acoustic Sounding Results by Rutgers University (bottom)



Impact Echo Scanning Test Results
VA Deck – Full Deck Depth Results



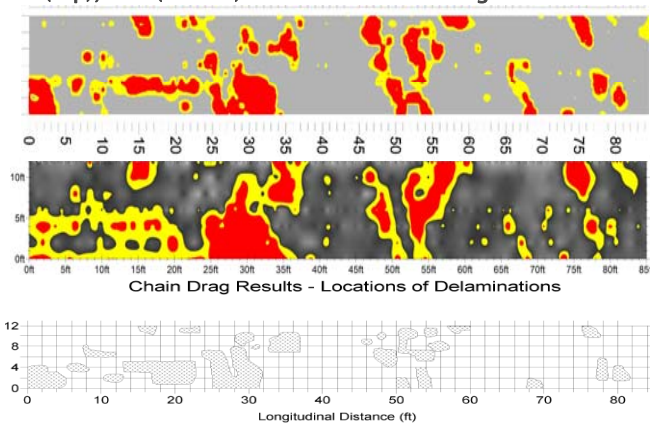
Areas with Probable Top Delaminations = 14%
Areas with Probably Incipient Top Delaminations = 13%
Areas with Probable Bottom Delaminations (or Thin Section) = 5.7%

IDS Aladdin GPR

1 OPERATIONAL CASE | 2 PSG: INNOVATIVE SURVEY KIT- THE "MAGIC GROOVED CARPET | 3 FULL POLAR ANTENNA- UP TO 4 COMBINATIONS | 4 3D SOFTWARE FOR ON-SITE PROCESSING FOR REBAR IMAGES

1. DEDICATED TRANSPORT/OPERATIONAL CASE
2. PSG: INNOVATIVE SURVEY KIT FOR AN EASY AND TOTAL 3D ACQUISITION DATA WITH GROOVED RUBBER CARPET
3. FULL POLAR ANTENNA (2 GHz): IMPROVES THE IMAGING OF SHALLOW AND DEEP REINFORCING BARS FOR REBAR MATS AND ANGLED BARS
4. QUICK ON-SITE DATA PROCESSING

Top Delamination Test Results from the Impact Echo (top), GPR (middle) and Acoustic Sounding – VA Deck



Bridge Deck Scanner Summary

- Impact Echo Scanning had the most resolution of Top Delaminations on concrete bridges
- IE identified bottom delaminations as well as profiling deck thickness echoes. GPR method is not sensitive to bottom delaminations
- Spectral Analysis of Surface Waves (SASW) for cracking damage due to freeze-thaw, Alkali-Silica/Aggregate Reactions, general condition assessment

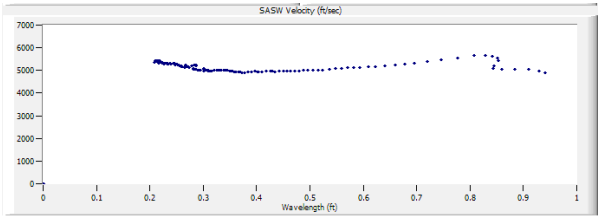
SHRP 2 R06(D) Research on Stress Wave Detection of Delaminations within Asphalt Pavements, Three project sites: National Center for Asphalt Technologies at Auburn University in Alabama, Florida and Kansas

Prototype Pavement Scanner on Kansas Asphalt Pavement site with 3 pairs of wheels spaced 150 mm (0.5 ft) apart for combined Impact Echo and Spectral Analysis of Surface Waves scanning.

BDS Scanner for Debonded Asphalt Pavement Summary

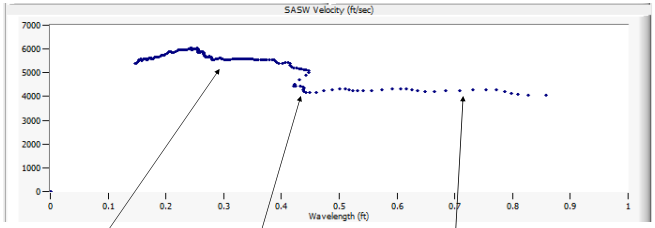
- Spectral Analysis of Surface Waves (SASW) provided the best results of detecting asphalt pavement delaminations
- Velocity = frequency x wavelenth
- Dispersion curve plots of Surface Wave Velocity vs. Wavelength show velocity decreases at debonded asphalt lift depths
- Initial Research on Asphalt Overlaid Concrete Deck Delamination Evaluations

Example SASW Dispersion Curve from Sound HMA Asphalt Pavement on Concrete Pavement Delamination Conditions on Asphalt Pavement



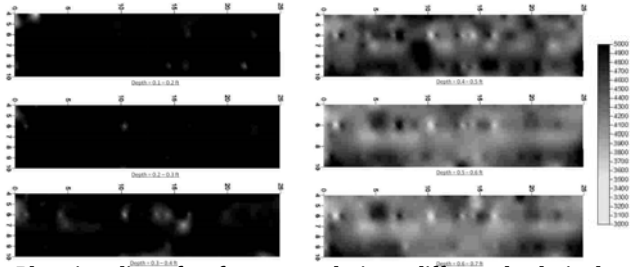
Note surface wave velocity between 1500 to 1650 m/s (5000 to 5500 ft/s

Example SASW Dispersion Curves from 12.5 cm (5 inch) deep Thin Paper Delamination Condition on Asphalt Pavement



Delamination due to Thin Paper Delamination built at 12.5 cm (5 inches) deep – note surface wave velocity decrease from ~1590 m/s (~5300 ft/s on vertical scale) to ~1290 m/s (~4300 ft/s) at a wavelength of 12.5 cm (0.43 ft - ~ 5 inches)

Example SASW Dispersion Curves from depths of 0 to 18 cm (0 to 7 inches) - Delamination Conditions on Asphalt Pavement noted by light gray to white



Plan view slices of surface wave velocity at different depths in the pavement showing a significant drop in velocity at a depth of 12-15 cm (0.4-0.5 ft) which correspond to delaminations

Available Technologies for Condition Assessment of Asphalt Overlaid Decks

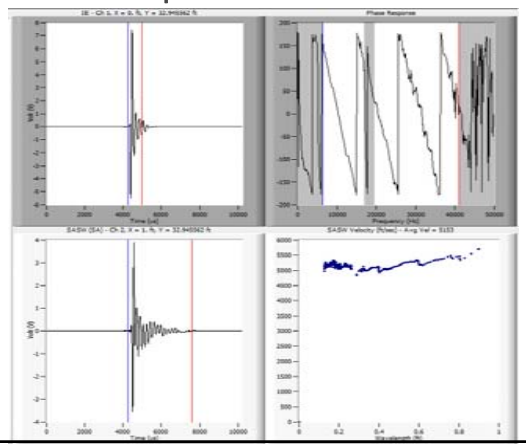
- Sounding – hard to hear through the asphalt
- Infrared Thermography – hard to apply the heat source to the concrete layer through the asphalt plus debonding of asphalt/concrete interface
- Impact Echo Scanning – asphalt absorbs the energy (unless cold) and it can be debonded
- Ground Penetrating Radar
  - Heavily dependent on the bonding condition between the top asphalt and concrete and really only works on thin debonding in water-filled interface

Internal Research Project on 2 Asphalt Overlaid Decks with the Colorado DOT using BDS with Surface Waves and Impact Echo

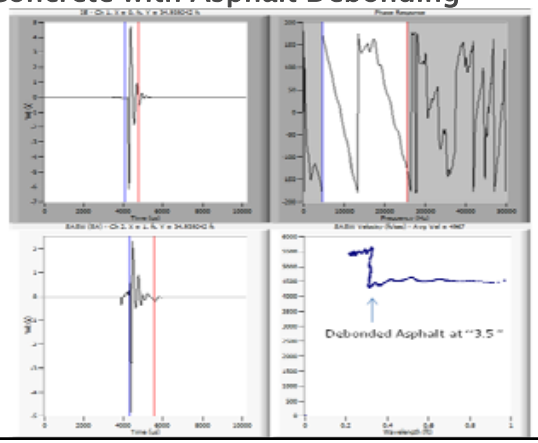
- Structure E-17-IN: I-270 westbound bridge over Dahlia Street (asphalt covered concrete deck with water-proofing membrane)
- Structure E-17-IE: I-270 eastbound bridge over South Platte River (asphalt covered concrete deck without water-proofing membrane)

Over 30 asphalt overlaid decks have been tested since this successful demonstration along with GPR and coring

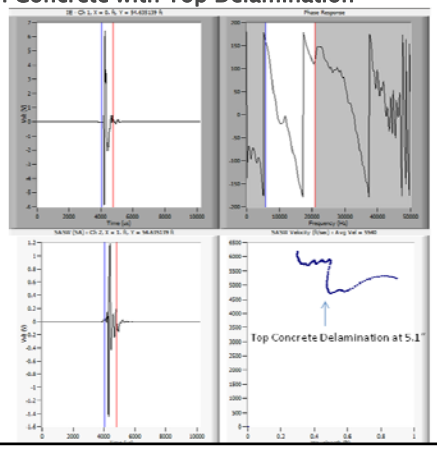
Findings – Bonded Asphalt on Sound Concrete



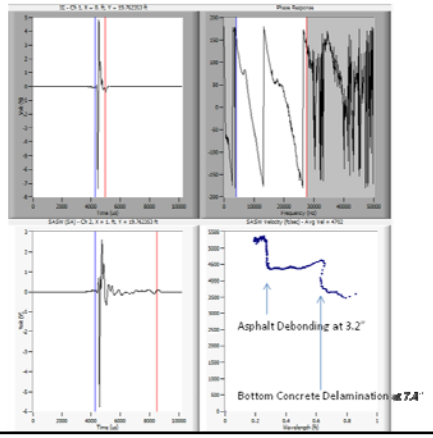
Sound Concrete with Asphalt Debonding



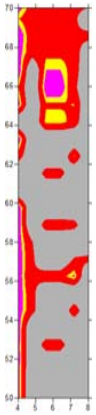
Bonded Asphalt on Concrete with Top Delamination

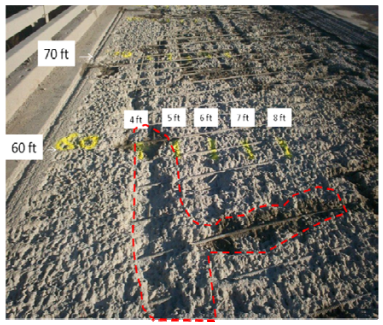


Debonded Asphalt / Concrete with Bottom Delamination



Ground Truthing – Hydrodemolition to reveal Delaminations





Thanks and Questions!