MEETING SUMMARY

SHRP2 ADVANCED METHODS TO IDENTIFY PAVEMENT DELAMINATION (R06D) SHOWCASE, AUBURN, AL

TO	Kate Kurgan, Steve Cooper, Pam Hutton
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LOCATION	National Center for Asphalt Technology (NCAT), Auburn, AL

Purpose

This Showcase and Technology Demonstration provided state transportation agencies and others an opportunity to learn about the nondestructive testing technologies (NDT) offered through *Advanced Methods to Identify Pavement Delamination* (R06D), which was developed through the second Strategic Highway Research Program (SHRP2). Participants saw first-hand demonstrations of how to use a ground penetrating radar (GPR) system employing frequency sweep across an antenna array and a mechanical wave (IE/SASW) system assembled into a continuous scanning wheel. The goal was for participants to see how these NDT operate, learn how each system can benefit their states, and understand how their peers are using them. The agenda was divided into three components: overview of the technologies, agency experience, and full scale systems demonstrations.

Attendees

The six States participating in the SHRP2 Implementation Assistance Program (IAP) for R06D attended the event, as well as two NDT research practitioners assisting the IAP States. Five other states interested in learning more about the R06D technologies also participated in the showcase. The showcase team in attendance were FHWA, AASHTO, and CH2M. Both NDT technology equipment vendors, 3D-Radar and Olson Engineering, participated. (See Appendix A for full list of attendees.)

Executive Summary

Through the SHRP2 evaluation study *Advanced Methods to Identify Pavement Delamination (R06D)* completed in 2013, three technologies were identified that could make significant advances in detecting the extent and severity of pavement delamination in place of extensive forensic coring. The technologies are Ground-Penetrating Radar (GPR), Impact Echo (IE), and Seismic Analysis of Surface Waves (SASW). California, Florida, Kentucky, Minnesota, New Mexico, and Texas received Proof of Concept awards through the Implementation Assistance Program (IAP), administered by the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO), to evaluate the technologies in their respective states. To help support the individual state's activities, a two-day Showcase and Technology Demonstration was held in Auburn, AL to demonstrate use of the R06D technologies and allow states an opportunity to hear from their peers. All six IAP award states participated in the showcase.

Overall, the showcase achieved its intended purpose. On the first day, participants heard from AASHTO's Kate Kurgan and FHWA's Steve Cooper about the SHRP2 program overall. Two vendors, 3D-Radar and Olson Engineering, gave presentations about their NDT systems. The six states participating in the IAP presented problems they currently have with pavement delamination, their current NDT state of practice, and their plans to use the R06D technologies. On day two, participants took part in a full scale, hands-on demonstration of the NDT systems on specially built delamination test sections at the NCAT Pavement Test Track. In order to ensure everyone had enough time with the equipment, the demonstrations were done in small groups rotating to four demonstration stations. Participants valued the small group equipment demonstrations.

Based on the participant evaluations, participants left the showcase with greater knowledge of the R06D technologies. The responses indicated the showcase content, and state and vendor presentations, were moderately to extremely effective. The comments were positive with many saying it was a successful event.

Notes from the Showcase Presentations

DAY 1: VENDOR AND IAP STATE PRESENTATIONS

Welcoming Remarks: Kate Kurgan, AASHTO

Round 7 of the SHRP2 Program is implementing 79 projects in 37 states. Overall, SHRP2 has implemented more than $130M of funding to 99 entities for 63 products and 430 projects are underway. Six States (CA, KY NM, TX, MN, and FL) are involved with R06D IAP.

After this showcase, we will have a report and post PowerPoint presentations posted on the AASHTO SHRP2 website. Currently, we are working on a Primer to increase awareness of how R06D products can be used to detect pavement delamination in a nondestructive manner. The Primer is in draft form right now. AASHTO is working on marketing/communications plan on how to get word out on this product to DOTs. Near the end of this product implementation plan there will be a peer exchange. AASHTO can provide hands-on assistance for this product and all SHRP2 products.

Introduction of the Technologies in Advanced Methods to Identify Pavement Delamination (R06D): Mike Heitzman, NCAT

Asphalt pavements are built in layers and, if they are not bound together, they have significantly less structural capacity to carry traffic load than if they were bound into one monolithic structure. Delamination is one of the highway community's main problems. A long-term goal is to build asphalt pavements with no debonding so that the pavement performs as designed. Debonding, as defined for R06D, also includes the condition when a single intermediate layer in the asphalt pavement is weakened due to mixture stripping.

The goal of this SHRP2 research was to determine if (1) we can detect delamination, (2) operate the measurement system at reasonable speed such that traffic control is not required or reduce, and (3) measure the full lane width in one single pass. The research project was performed in 7 steps.

1. Identify candidate NDT technologies
2. Evaluate potential to meet goal

3. Select NDT technologies with high potential to achieve goal
4. Promote development of hardware and software
5. Validate equipment improvements
6. Examine performance in the field
7. Demonstrate NDT to interested agencies

What is Spectra Analysis of Surface Waves (SASW)?
Mechanical energy is introduced into a pavement layer. The mechanical energy wave traveling through the pavement is changed if there is delamination with in the pavement layer. The equipment is simple. The hardware includes a mechanical energy source tapping on the pavement surface and two sensors reading how that surface wave is carrying horizontally through the pavement.

What is Impact Echo (IE)?
The same mechanical energy is introduced into the pavement. This portion of the energy wave travels down to the bottom of the pavement layer and rebounds to the surface. The energy source tap is the same and the receiving sensor is immediately next to it. Sensor is measuring the speed of the energy wave as it bounces down and up.

The hardware package and set-up for SASW/IE testing includes an impactor, receiver sensors, sensor spacing, measurement frequency, data logger, data processing equipment, DMI, and field display. For SASW, spacing of sensors is very important. The challenge for these contact point tests is to take measurements rapidly and cover the full lane width. Olson Engineering, a selected vendor for R06D, developed a hardware system that significantly improves the ability to take field measurements rapidly. The IE test has the potential to immediately display pavement layer thickness as the testing progresses in the field.

What is Ground Penetrating Radar (GPR)?

A GPR antenna system sends radar energy into the pavement and measures the change in that energy as it reflects back to the GPR receiver antenna. If there is a change in the pavement material, the radar signal response reflects that change. Unfortunately, if there is simply two sequential layers with no bond, there is no change in the GPR signal so we cannot detect simple debonding. If the debonded zone includes water or air, then the GPR signal encounters a change in material properties and the receiving antenna measures a change in the signal.

Typical hardware systems for GPR have one or multi-antennas mounted on a vehicle. Most systems are single frequency antenna, which influences the quality of the measured response. 3D-Radar, a selected vendor for R06D, has a hardware system that measures with a range (sweep) of radar frequencies across an antenna array that can cover up to the entire lane width.

Both SASW/IE and GPR successfully identified delamination on the NCAT Test Track. Both of these NDT technologies continues to improve, particularly in the area of data analysis software. The pavement engineer can use these NDT systems to assess the condition of the pavement and determine if their project should be full rehabilitation, just patching in isolated areas, and where cores should be taken.

Overview of 3D-Radar GPR technology**: Kent Martin, 3D-Radar**

Major transportation applications for GPR are to locate structure defects, provide accurate data for maintenance and rehabilitation, asset monitoring, quality inspection, and utility mapping. GPR can be used on roads, highways, bridges, tunnels, railways, airport runways and taxiways, dikes and levees.

Basic GPR theory involves electro-magnetic wave transmission. The antenna sends electromagnetic pulses into the ground that encounter differences in transmission through different materials. The system measures the dielectric constant of each material. Every material has a different dielectric constant and a change in the measured pulse is a change in a material. The GPR reflected signal can determine when layers are changing and when there is a delamination issue. The quality of the GPR signal varies by material. Clay is the most difficult. Dry sand really good. The GPR signal frequency and strength are used to identify anomalies. The basic idea of all GPR is each frequency (going from low to high) will have different penetration and measured response. Lower frequencies penetrate deeper below the surface. Different frequencies will highlight different pavement features.

3D-Radar's antenna system emits a sequence of frequencies between 150MHz-3,000MHz every time the radar triggers. It uses the full range of frequencies to optimize response resolution at each depth slice. The system is equivalent to having a massive array of antennas with different frequencies in one compact antenna array. The width of each scan is only determined by how many channels you want to use. The GeoScope is the central processing unit and wide antenna array makes the measurements. The system can also accommodate an optional external GPS unit to allow for more accurate geographic positioning. The system is easy to operate and the antenna itself has a very small footprint.

A unique feature of the operating software is real time three-dimensional processing and display that confirms the system is acquiring good data. It also monitors vehicle speed related to GPR test frequency speed. 3D-Radar's stepped frequency combined with the antenna array significantly exceeds older systems with single frequency technology. 3D-Radar's Examiner software puts the data into a cube matrix and slices the data into x, y, z planes (slices) to allow engineers a practical way of visualizing 3-dimensional features on a 2-dimension screen. It can be over-laid with a satellite image of the ground to link the GPR data to a visual location. The data can be exported into AutoCAD. Examiner software can trace layers, annotate them, and place GPR features into depth layer maps.

There are options for mounting the antenna in the front of a vehicle, in back of a vehicle, or with a trailer. Mounting depends on the flexibility of vehicles used to operate the system.

A stepped frequency, antenna array GPR system is very different from other GPR systems. It is a true multi-channel, three-dimensional GPR system with an air coupled or ground-couple antenna. Examiner software provides real-time data processing and visual analysis using three-dimensional slices.

Overview of Olson Mechanical Wave Technology: Larry Olson, Olson Engineering

This system was originally developed as an NCHRP IDEA research project to detect delaminations in concrete bridge decks. The use of the system has expanded to include concrete pavement deterioration, asphalt pavement delamination, and layer thickness. It performs point testing rapidly with a slow-rolling scanning system.

The Impact Echo Test (IE) is based on impacting the pavement surface and measuring the resonant echo response. A uniform flat slab has a single peak resonant echo frequency based on the slab material. A prototype array with multiple scanners was designed for vehicle towing to increase the measurement process at a slow rolling speed of 2km/h on concrete and asphalt. The system now incorporates a very good ruggedized Dell notebook to acquire the field data. The scanning IE measurement hardware is a 293 mm (11.5 inch) diameter wheel with six individual displacement transducers and six individual impactors. Impacts are spaced 150 mm apart along a scan line.

The Spectral Analysis of Surface Waves Test (SASW) is based on acoustic wave measurement. Short wavelength waves indicate shallow and longer wave lengths indicate thicker slabs. SASW Phase Plot diagrams display the relationship of wave velocity as a function of wave frequency and wavelength. For example, sound concrete has a wave velocity passing through concrete of 6900 ft/s based on a wave frequency of 2628 Hz and wavelength of 2.62 ft. In asphalt pavement slabs, the wave velocity slows as the material stiffness decreases due to temperature increases.

The SHRP2 R06D research on stress wave detection of delamination within asphalt pavements started with evaluation of test sections at the NCAT Test Track delamination research site were the SASW and IE measurements were compared to known conditions of delamination. This provided ground truth for simple debonding and moderate stripping. The system was expanded to a matrix of three pairs of scanning wheels to demonstrate quicker evaluation of the pavement. After evaluation at NCAT, the system was applied to test sections in Florida and Kansas.

The IE/SASW scanner is now mounted to a manually pushed cart which allows the operator to control the testing line and monitor test results. The scanner can perform IE tests from all wheels for concrete deck applications or IE from the first wheel and SASW from both wheels for asphalt pavements. The system has been used on over 30 bridge decks, mostly in Colorado. The system can be equipped with up to six wheels. Although the speed is limited, each scan covers large areas in one run. Achieving sensor contact on rough pavement surfaces is a factor and will result in some missed measurements.

SASW appears to be most promising technology for measuring asphalt pavement delamination and IE is best for concrete. Concrete delamination tests results were correlated well with the delamination maps from chain dragging, core results, and hydro blasting.

Agency Experiences

New Mexico Department of Transportation: Naomi Gaede

NM DOT has been using a GSSI GPR system for the last 2-3 years with 2 GHz air coupled antennas and 400 to 900 MHz ground coupled antennas. The predominant applications are locating base and subgrade moisture, subgrade settlement, layer thickness, and asphalt pavement delamination. Using GPR as a forensic tool allows the forensic team to target coring in suspect areas. This avoids extensive regularly spaced coring to examine a pavement section, reduces field crew exposure, improves repair and rehabilitation effectiveness, and reduces construction overruns due to changed conditions.

The observed limitations of GPR are related to data interpretation and field hardware setup. Data interpretation problems are noise and interference from radio towers and time consuming visual data analysis Field setup problems are time to change between antenna hardware, speed for ground coupled data collection, and matching multiple files for full lane coverage.

The expectation for evaluating 3D-Radar will show improvement of data interpretation, ability to measure multiple assets with a single field pass, reduce currently observed limitations. The evaluation will determine if 3D-Radar's system can distinguish between 4-5 categories of delamination. Evaluation will include bridge deck capabilities, bridge support, dowel bar placements, anomaly detection, and look at the system's software data export abilities and ease of use. NMDOT is hoping that utilizing the GPR data will provide additional project assessment not readily available through destructive means which should translate into better pavement-related treatment selection.

NM DOT recently started preliminary research into use of PSPA (same SASW and IE technology used by Olson). Preliminary concerns are sound contact with the pavement surface, need for multiple tests at each test location, and testing within a lane closure. If pavement temperature is a critical test parameter, testing with SASW and IE may be limited to use in cold regions.

California Department of Transportation: Bill Owen

Caltrans current use of GPR is within the Geophysics and Geology Branch to provide non-destructive evaluation for geotechnical studies and for pavement construction projects and repairs. Use of GPR dates back to 1998. Between 2009 and 2012 GPR was performed on 58,000 lane miles to provide a one-time NDT evaluation of the state highway network. Caltrans is involved in multi-channel GPR through SHRP2's R06A/G for bridge decks as a user incentive, R06D for pavement proof of concept evaluator and R01B for underground utilities as a lead adopter. Involvement in all three SHRP implementation efforts gives Caltrans leverage to acquire the GPR system to address numerous uses.

There are areas in CA where GPR doesn't work and areas where it works really well. Many applications examine relatively small areas and use GPR mounted to handcarts. A PE Pro vehicle mount is used to cover long sections of pavement. The 2009 to 2012 Pavement Management Survey ran GPR survey of 58,000 lane miles of state highway network. The GPR analysis was calibrated to pavement cores and generated several products, including an interactive structural section database. GPR is used by our districts to screen and analyze pavements ahead of repairs, rehabilitation, and reconstruction. Three-dimensional visualization provides emphasis to features of concern.

Caltrans has validated that GPR technology is useful for multiple applications, can be used at high-speed for pavement and bridge deck applications, and generates a significant level of detail not achieved by other systems. Additional effort is needed to automate data processing and better locate and plot our measurements. For Caltrans, the next steps are to use the R06D project award to acquire the 3D-Radar equipment and software, obtain training for data acquisition and processing, bring forward candidate projects for pilot study, complete data acquisition, and report results. Based on these results we will evaluate optimal workload mix for pavement studies (mix between in-house and contract service using statewide or district contracts).

Texas Department of Transportation: Darhao Chen

TX DOT experiences pavement failures in relatively short rehabilitation cycles of less than 5 years. Moisture damage in the asphalt pavement layer(s) is a key cause of distress that leads to stripping and debonding. GPR is a common tool used to locate moisture damage in pavements and cores are often taken to validate the GPR results. GPR has also been used to measure mixture segregation after construction. Higher voids (lower density) can be detected by GPR. Debonding due to poor tack coat application is detectable with SASW/IE technology using MIRA. In addition to asphalt pavement distress, GPR has been used to measure rebar location on concrete pavement and bridge decks. Olson's SASW/IE system was used to identify delamination in concrete bridge decks.

Minnesota Department of Transportation: Dai Shongtao

MN DOT started using GPR in 1998 and has updated and acquired additional equipment over time, specifically acquiring additional antennas. The GPR program includes 1.0 GHz and 2.0 GHz air-coupled antennas and 2.6 GHz, 1.5 GHz, 400 MHz and 100 MHz ground-coupled antennas. The air-coupled antennas are used to evaluate near-surface features, such as asphalt pavement thickness profile. The ground-coupled antennas provide shallow measurements (1-2 feet below the surface) with high frequency and deep measurements (down to 40 feet) with low frequency. More recently FHWA loaned the 3D-Radar system to MN DOT which provides both an antenna array and frequency sweep capability. MN DOT is involved in evaluation of a GPR rolling density meter under SHRP2 R06C.

GPR is used to measure pavement layer thickness profile and special conditions such as missing concrete pavement tie bars, underground objects such as utilities, and voids below the surface. As noted before, current research is applying GPR to assess HMA compaction uniformity and density. Using GPR to measure pavement thickness has been successful but using GPR to identify stripping has had mixed results. GPR is an excellent screening tool to identify problems and guide the location of cores to verify the condition. This has significantly reduced the use of cores to assess long sections of pavement.

MN DOT worked with Infrasense, Inc to develop software that automatically calculates a surface dielectric constant from the collected GPR measurements using GSSI air-coupled antennas. Using multiple passed of the antenna, we can create a map of the pavement density. This has evolved into a manually pushed cart with three antennas called a rolling density meter being evaluated in SHRP2 R06C.

MN DOT's objectives under the R06D project are to have effective tools to detect stripping in asphalt pavements and identify free water under the pavement during Spring thaw periods. We will evaluate R06D research results through field validation at MnROAD and other locations.

Florida Department of Transportation: Bouzid Choubane

FL DOT has been using GPR since the 1980s and have ground coupled and air launched systems. GPR is used on a lot of forensic investigations for the state. The goals of the GPR program are the use of a high-speed non-contact technology to gather data and software to transform the data into information. The air launched GPR System is multiple 2 GHz antennas supported by DMI and GPS. The ground coupled GPR is a single antenna with a frequency range of 80 MHz to 1.5 GHz also supported by DMI and GPS and is useful for non-high-speed testing.

The GPR program provides predesign evaluation of in service roadways, specifically used to measure pavement layer thickness. The program performs forensic investigations such as moisture related distress, sinkholes, utility locations, and buried object searches. The bridge program uses GPR for forensic investigations of bridge deck deterioration and measurement of rebar cover depth. The GPR program is currently experimenting with asphalt pavement density measurement.

The advantages of high frequency GPR for pavement surveys are (1) it operates at highway speed which requires no traffic restrictions, (2) it rapidly estimates pavement thickness continuously with a significant reduction in the need for coring, and (3) the reduced coring limits worker exposure. The limitations of GPR systems are (1) ground-coupled units require traffic control, (2) GPR signal resolution is sometimes noisy due to roadside communications towers, (3) the antennas only operate at one frequency, and (4) analysis software is limited.

The SHRP2 R06D IAP funding will be used to evaluate the GPR system requirements for detection of pavement delamination, detection of voids under concrete pavement, evaluation of dowel bar alignment, evaluation of density variations in new asphalt pavement, quality assurance of new bridge deck construction, identify/quantify delamination in older bridge decks, and detection of voids at culverts and sink holes.

Review of NCAT Test Track Delamination Features: Mike Heitzman, NCAT

The SHRP2 R06D research project was accomplished in seven steps as noted in the Introduction presentation. A key component of the study was the use of ten delamination sections built on the NCAT Test Track. Three of the sections were built as control sections with full bond between layers. Two sections are asphalt overlays over concrete with one control and one debonded. Eight sections are asphalt pavements with various types and depth of debonding and stripping. Baghouse dust was used to create debonding and coarse RAP was used to simulate stripping. Some section were built with full section delamination and others were built with wheel-path or isolated delamination squares. There were lessoned learned about building delamination into a pavement. The initial plan used two layers of heavy kraft paper, but this proved to be a problem during paving and was abandoned.

The evaluation of GPR and IE/SASW concluded that each technology was successful at locating one or more type of delamination. SASW clearly distinguished between the bonded and unbonded asphalt over concrete and shallow delamination in the asphalt sections. IE was notably valuable as a field measure as the testing proceeded and was successful identifying the deeper delamination. GPR clearly identified the stripping, but could not distinguish the debonding when the pavement layers were dry. Once we injected water into the debonded seam, the GPR signal picked-up the moisture.

***Full-scale Equipment Demonstration*: NCAT Pavement Test Track**

A full-scale demonstration of the 3D-Radar GPR system and the Olson IE/SASW system on the second day of the showcase allowed all participants time with the field measurement hardware and analysis software. Each individual was assigned to one of eight groups. Four groups cycled through the four stations from 8:00 to 10:00 and the remaining four groups started at 10:00 and ended at noon. The four stations were GPR testing, GPR data analysis, IE/SASW testing, and IE/SASW data analysis. The hands-on demonstration was the last agenda item of the showcase.

Appendix A – Attendee List

Organization/Agency	Last Name	First Name	Title
SHRP2 R06D IAP STATE			
California DOT	Owen	William	Chief, Geophysics and Geology
Florida DOT	Choubane	Bouzid	State Pavement Materials Engineer
Florida DOT	Holzschuher	Charles	Pavement Performance Engineer
Florida DOT	Wang	Guangming	Pavement Performance Evaluation Engineer
Kentucky TC	Tucker	Joe	TEBM
Minnesota DOT	Dai	Shongtao	Research Operations Engineer
Minnesota DOT	Hoegh	Kyle	
New Mexico DOT	Gaede	Naomi	Pavement Engineer
Texas DOT	Chen	Dar Hao	Pavement Engineer
IAP STATE CONSULTANTS			
Infrasense, Inc.	Maser	Ken	Senior Principal
Texas A&M Transp. Inst.	Scullion	Tom	
INVITED STATES			
Arkansas HTD	Su	M. Mert	Pavement Mgmt/GPR Specialist
New Jersey DOT	Ganarajan	Vasudevan	Assistant Engineer
Pennsylvania DOT	Koser	Steven	Chief, Pavement Testing and Asset Mgmt.
Alabama DOT	Hoffman	Douglas	
Alabama DOT	Golson	Thomas	Special Projects
Alabama DOT	Shugart	Robert	Materials Engineer
Alabama DOT	Jennings	John	Assistant State Materials Engineer
Maryland SHA	Rubin	Jacquae	Transportation Engineer
FHWA - SPONSOR			
FHWA - HQ	Jacoby	Ken	SHRP2 Renewal Coordinator
FHWA - HQ	Cooper	Stephen	SHRP2 R06D Product Lead
FHWA – AL Division	Harris	Kristy	PME
FHWA - EFLHD	Deppmeier	Stephen	Pavements Engineer
AASHTO SHRP2 TEAM			
AASHTO	Kurgan	Kate	SHRP2 Implementation Assoc. Program Mgr.
ARA	Chesnik	Kevin	Principal Engineer
CH2M	Martinez	Natalia	Communications & Marketing Associate Mgr.
Natl Ctr for Asphalt Tech	Heitzman	Michael	Subject Matter Expert
NDT SYSTEM VENDORS			
Olson Engineering	Olson	Larry	President
Olson Engineering	Miller	Pat	Senior Engineer
3D-Radar	Martin	Kent	US Sales Manager
3D-Radar	Sala	Jacapo	Field Applications Engineer