Detecting Delamination with New NDT Systems

Advanced Methods to Identify Pavement Delamination

When pavements begin to deteriorate, everyone notices—especially drivers and the maintenance crews whose job it is to keep them in good repair. Delamination (debonding and stripping) between asphalt layers underneath the highway surface can lead to several types of pavement surface problems, such as cracking in the wheel paths and tearing in the surface. Once pavement starts deteriorating, it may not easily be detected, especially in the early stages.

As part of the second Strategic Highway Research Program (SHRP2), three new technologies to detect problems in the asphalt pavement beneath the surface were tested and evaluated by six state departments of transportation (DOTs) as part of a "proof of concept" implementation effort.

The project, Advanced Methods to Identify Pavement Delamination (or R06D), field tested ground penetrating radar (GPR) equipped with stepped frequency antenna array (3D-GPR) and a scanning system employing Spectra Analysis of Surface Waves (SASW) and Impact Echo (IE). These nondestructive technologies may enable DOTs to obtain reliable results for project-level planning and forensics in a safer, faster, and less expensive way.

Details of how each of these technology systems work can be found in the companion brochure: Safer, Faster, and More Cost-Efficient Ways to find Deficiencies in Pavement (access by clicking the link to http://shrp2.transportation.org/Documents/Renewal/508%20compliant%20R06D%20brochure.pdf). In this brochure, brief descriptions of the outcomes of the six implementation efforts are discussed, along with the benefits of the technology.

Six States Evaluated 3D-GPR and Scanning IE/SASW in SHRP2 Proof-of-Concept Effort

Minnesota DOT

The Minnesota Department of Transportation (MnDOT) has been using GPR technology for pavement evaluations for more than 15 years, mostly to determine and assess pavement thickness and conditions.

During the R06D proof-of-concept evaluation, measurements were collected with MnDOT's 3D-GPR system on multiple pavements and at MnDOT's MnROAD pavement test track. These measurements were evaluated and correlated with data from 200 cores taken in 2016.

MnDOT found that 3D-GPR is a great tool to assist in detecting stripping in asphalt mixtures and in providing continuous coverage of the pavement structure profile. Overall, the technology correctly identified stripping on 43 percent of the sites.

Contact: Shongtao Dai (who can be emailed at shongtao.dai@state.mn.us)

Kentucky Transportation Cabinet

The Kentucky Transportation Cabinet (KYTC) evaluated both technology systems at locations across the state.

For the 3D-GPR analysis, KYTC collected measurements at two locations, one in an urban environment in downtown Paris, Kentucky, on US 60 with a speed limit of 25 miles per hour; the other on a limited-access freeway (KY-4) in Lexington, Kentucky, with a posted speed limit of 65 mph.

The agency elected to use a rolling lane closure during data collection, with the equipment traveling at normal operating speed. To validate the recorded 3D-GPR data to actual field conditions, KYTC took several full-depth core samples from the US-60 project.

Notably, the ability to collect data at highway speeds improves safety for workers and the traveling public.

This experience led to the KYTC to purchase the 3D-GPR system for its pavement forensic investigations to replace its single-channel radar system. Kentucky estimated it achieved a $3.7 million savings by using single channel GPR on several forensics projects. Using 3D-GPR may be able to improve this savings since it can collect data more quickly and provide more in-depth detail about the existing pavement structure.

The scanning IE/SASW was tested on three segments of the urban US-60 route with numerous portions of the pavement showing severe distress. Measurements were taken in both wheel paths and the center of the lane. The data analysis identified pavement damage comparable to the 3D-GPR analysis.

“The KYTC/KTC intends to adopt the 3D-GPR system in lieu of other single-channel radar systems on selected pavement rehabilitation projects in the future, with hopes that the multi-channel unit will provide superior depth resolution and detail to that of a single-channel unit,” said Brad W. Rister, Program Manager, Pavements, Materials, GeoTech, and IA Group, Kentucky Transportation Center, University of Kentucky.

Contact: Brad Frasier (who can be emailed at brad.frazier@ky.gov)

Florida DOT

The Florida Department of Transportation (FDOT) consistently searches for high-speed, nondestructive pavement evaluation techniques to minimize traffic delays and maintain safe roadways. FDOT’s interest in implementing 3D-GPR was based in part on the possibility that it could be used for other applications beyond pavement delamination detection.

Measurements were collected with two GPR units on 17 locations across the state involving asphalt pavements, concrete pavements, and bridge decks.

Based on the system evaluation and testing results, FDOT found that the system appears to be capable of identifying stripping, debonding, segregation, settlement, density variations in asphalt pavement, thickness variations, "road worms" phenomenon, construction variations in concrete/composite pavement, dowel bar location, damage within the asphalt layer, and bridge deck deterioration.

In addition, Florida found a return on investment (ROI) of five over a 10-year period by using 3D-GPR instead of traditional approaches for planning pavement and bridge rehabilitation projects. Florida noted the 3D-GPR system greatly improves safety, reduces data collection time, provides higher resolution, and a greater depth of penetration range compared to conventional GPR systems.

Contact: Bouzid Choubane (who can be emailed at bouzid.choubane@dot.state.fl.us)

New Mexico DOT

New Mexico Department of Transportation (NMDOT) evaluated both technologies at locations across the state and in different climates and altitudes.

NMDOT has a Pavement Management System database for surface distresses; however, one of the key parameters that is currently missing is structural condition. The state's current GPR system picks up moderate and severe stripping, but does not have the capacity to offer network-wide information on delamination due to software limitations.

For this project, measurements were collected with three GPR units on multiple pavements, including asphalt pavements on I-40, US 491, and Route 264, as well as flexible pavements, bridge decks, and concrete pavements.

After reviewing three GPR systems—a 2d-GPR developed in Texas, SHRP2's 3D-GPR, and its existing GPR—the state determined that the benefits found in the 3D-GPR system were not enough to overcome the equipment costs, staff training, and other resources that would be needed to go beyond their existing system.

NMDOT was particularly interested in evaluating the scanning of IE/SASW in specific conditions such as high temperatures with high daily temperature variation, roughness, Open Graded Friction Course surfaces, and pavements thicker than five inches. The state has highway varied weather conditions from the southeast where it is rarely below freezing to the northwest that can experience snowfall into late May.

The scanning IE/SASW technology was tested on three pavement sections, including a full day of repeated measurements on one site to evaluate the influence of pavement temperature on measurement signal quality. Following testing, NMDOT found that general trends observed in the data appear repeatable even across a wide range of temperatures. At shallow depths, debonding was detected and matched to the cores; however, it was not picked up at larger depths.

Contact: Shawn Romero (who can be emailed at shawn.romero2@state.nm.us)

Texas DOT

Texas Department of Transportation (TxDOT) evaluated both technologies at locations across the state. In general, both systems—3D-GPR and scanning IE/SASW—met expectations to identify pavement delamination. Measurements were collected with two GPR units on nine pavements. Overall, TxDOT found that the patterns generated by the 3D-GPR were consistent with past experience. Because of false patterns, however, cores still had to be taken to verify the data. Generally, TxDOT found it very difficult to distinguish between severities of deterioration/delamination using the GPR equipment.

TxDOT recognized the benefits of creating a wide area of data with the antenna array and is acquiring a 3D-GPR system and plans to work with the Texas Department of Transportation Institute to develop and implement the technology.

In Texas, the scanning of IE/SASW was used to evaluate one 1,000-foot pavement section on US 59, making six passes two feet apart to cover the entire lane width. The process identified the location and depth of delamination and correlated well with the pavement cores and GPR data.

Contact: Enad Mahmoud (who can be emailed at enad.mahmoud@txdot.gov)

Caltrans

The California Department of Transportation (Caltrans) also evaluated both technology systems. Caltrans acquired the 3D-GPR system for use on pavement and bridge deck investigations, as well as for subsurface utility investigations over pavement. Caltrans collected measurements with 3D-GPR on pavements in San Bernardino, Yolo, and San Luis Obispo counties. Caltrans also collaborated with the University of California at Davis to incorporate thermal and visual imaging cameras with the 3D-GPR system to improve its capabilities for pavement and deck investigations.

Caltrans' results demonstrated an 80 percent success rate in identifying areas of delamination in asphalt pavement. Caltrans results also emphasized the importance of moisture content in the asphalt to the success of the analysis. Dry pavement negatively affects the result, as lack of moisture in the delaminated or stripped zone decreases GPR response and can increase the rate of false negatives in the analysis.

California concluded the multichannel 3D-GPR arrays make large area surveys more cost-effective. Caltrans realized a ROI of 120:1 for data acquisition, compared to equivalent applications during a single-channel GPR system. For subsurface utilities, ROI against construction costs of 20:1 or better are anticipated based on existing analyses.

Caltrans evaluated scanning IE/SASW on one pavement project on State Route 247, Lucerne Valley, with known areas of distress identified through previous GPR results.

The scanning IE/SASW was partially successful for detecting pavement delamination and provided a good indication of general pavement conditions; subsequent milling of the pavement surface ahead of overlay placement showed good agreement between areas of poor condition identified with the IE/SASW and stripping observed during milling. The results did not, however, appear to detect some delamination identified in the GPR data (and confirmed by coring).

"We believe that IE/SASW hardware and software show future promise, and we will continue to monitor its development and revisit the economics of acquisition as the technology matures and additional data needs develop within Caltrans for pavement evaluation and monitoring," said William Owen, chief, Geophysics Branch, Caltrans.

Based on the demonstrations of the system capabilities and performance, 3D-GPR was incorporated into the Field Investigation protocol within the State Transportation Laboratory for nondestructive testing of pavements and structures. In turn, that has increased and improved communication, cross-collaboration and teamwork between different groups within the agency.

Contact: Bill Owen (who can be emailed at bill.owen@dot.ca.gov)

Lessons Learned from the R06D Proof-of-Concept Evaluations

- 3D-GPR collects measurements at reasonable highway speed, eliminating the need for a lane closure and reducing the risk to agency personnel and the traveling public.
- The comprehensive data on the condition of the existing pavement generated through the 3D-GPR system enable the DOT to make better and more cost-effective project development decisions while avoiding costly construction revisions or reducing the performance life of the rehabilitation.
- The IE/SASW technologies show future promise, but also require further development. It was generally recommended that advancements such as simplifying the data analysis and increasing the speed of data collection would be helpful.

Resources

For additional information on these technologies, go to the R06D webpages at http://shrp2.transportation.org/Pages/R06D.aspx.

- Primer (provides guidelines for GPR and SASW/IE to detect delamination)
- Peer exchange presentations by state DOTs and resulting report
- Recordings of two topic webinars (SASW/IE and GPR)
- Showcase summary report
- Promotional video
- Brochures

FHWA Staff Resources

- Steve Cooper, FHWA, can be reached by emailing stephen.j.cooper@dot.gov
- Monica Jurado, FHWA, can be reached by emailing monica.jurado@dot.gov