A SHRP 2 Renewal Project Brief

Nondestructive Testing Technologies for Rapid Renewal

Reduce Traffic Disruptions, Improve Efficiency

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Many nondestructive testing (NDT) and nondestructive evaluation (NDE) techniques have the potential to inspect new construction and test existing infrastructure much faster than typical methods.

To advance the state of practice, SHRP 2 conducted a series of projects to improve existing NDT and NDE techniques. The products of this research include tools to help practitioners (a) test concrete bridge decks, (b) perform quality control of construction materials, (c) conduct uniformity measurements on new hot-mix asphalt layers, (d) detect debonding and stripping between hot-mix asphalt layers, (e) detect surface irregularities during concrete paving operations, (f) measure the structural capacity of pavement while minimizing traffic disruptions, and (g) quickly monitor the condition and deterioration of tunnel linings. This Project Brief gives an overview of advances in seven methods to help transportation agencies meet rapid renewal goals.

A Plan for Nondestructive Testing

The first SHRP 2 project in the field of NDT and NDE evaluated the existing and emerging NDE technologies and their ability to satisfy NDE requirements for rapid highway renewal. Based on the findings of this project, a research plan was devised for developing technologies to deal with the most pertinent requirements for bridges, pavements, tunnels, soils, and retaining walls through the life of the facility. The resulting seven follow-on projects are described in this brief.

Status: This project is complete. *A Plan for Developing High-Speed, Nondestructive Testing Procedures for Both Design Evaluation and Construction Inspection* (SHRP 2 Report S2-R06-RW) is available on the SHRP 2 website.
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Nondestructive Testing for Concrete Bridge Decks

The number of concrete bridge decks in poor structural condition is one of the biggest problems affecting bridges in the United States. Evaluating bridge deck condition becomes increasingly critical as highway agencies work to optimize the effective timing, scope, and approaches for preventive maintenance, repair, and replacement. NDT techniques have the potential to quickly and reliably provide the needed information about under-the-surface conditions of the deck, but further advances, standard protocols, and independent evaluations are needed.

The research objective of this project was to conduct an independent evaluation of the capabilities and limitations of the most common NDT techniques to detect and characterize typical deterioration mechanisms in concrete bridge decks. The following four defects were identified as those of the highest importance: rebar corrosion, delamination, vertical cracking, and concrete degradation.

This project created an electronic repository of NDT technologies for bridge decks, known as the NDToolbox, with which users can explore different NDT technologies and examine their

Field evaluation of an impulse response testing device

application in the detection of deterioration. The information in the NDToolbox includes a description of the technology, the principle behind the technology, applications, performance, limitations, equipment, test procedures and protocols, and sample results. The NDToolbox also provides recommendations regarding the best technologies for a particular deterioration detection application. Additional tasks were recently added to this project to expand the coverage of the NDToolbox. Once completed, the NDToolbox will include the results from all NDT research projects under SHRP 2; at that point the NDToolbox could serve as a quick reference of validated methods for identifying deterioration on concrete bridge decks, as well as those for quality control of construction materials and pavements, and condition assessment of pavements and tunnels.

Status: Project R06A (Nondestructive Testing to Identify Concrete Bridge Deck Deterioration) is active. Videos of a field validation of the technologies are available at www.TRB.org/SHRP2/Videos. The final report will be available in 2013. The NDToolbox will also be available in 2013.
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Quality Control of Construction Materials

Quality control of materials used during construction is an important issue routinely affecting highway agencies across the United States. Evaluating whether the materials delivered at the construction site agree with those specified can be resolved by existing testing techniques. Using hand-held spectroscopic equipment in the field, rather than traditional chemical tests, for testing the quality assurance of many materials (including cements, paints, and asphalt mixtures) can yield faster measurements.

Portable spectroscopy devices and their capabilities to "fingerprint" typical construction materials were evaluated by this project. Fingerprinting of typical materials requires developing acceptable spectra of the specific chemical compositions with laboratory-based equipment and then comparing the material being fingerprinted against those spectra. Additional tasks were recently added that will develop specifications and pilot them in collaboration with two transportation agencies.

Products from this research include proposed American Association of State Highway and Transportation Officials (AASHTO) standards of practice for the analysis of titanium content in traffic paints by X-ray florescence (XRF) and identification of cement admixtures and RAP-modified asphalt by attenuated total reflectance (ATR), and field operation manuals for ATR and XRF instruments. The library of spectra for the tested materials can be used to identify these materials in the field. The proposed AASHTO standards will be useful to quality assurance and quality control personnel and research and material divisions in transportation agencies. The field operation manuals were developed for ATR and XRF instruments to supplement the standards. These manuals will be useful to field personnel who will conduct spectroscopic testing; however, the variability in the available instruments requires that the specific technical manual for each instrument should also be consulted.

Status: Project R06B (Evaluating Applications of Field Spectroscopy Devices to Fingerprint Commonly Used Construction Materials) is active. The final report will be published in 2013.
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Mitigate Segregation in Hot-Mix Asphalt Construction

The most common form of hot-mix asphalt (HMA) segregation, truck-end, occurs when HMA at the ends of the truckload is colder and sometimes coarser in gradation than normal. These segregated locations deteriorate early, typically due to their lower density and higher susceptibility to raveling and fatigue cracking. This early distress not only results in poorer ride quality but also requires agencies to use resources earlier than planned to maintain the pavement condition.

An automated thermal profiling system offers a means for passive inspection. Using these technologies can produce higher-quality, longer-lasting new HMA pavements.

This project summarized the availability of infrared and radar systems suitable for testing essentially the entire surface area during new HMA construction, and then it demonstrated an infrared sensor bar system and two ground-penetrating radar (GPR) systems on construction projects in each of the four AASHTO regions.

Products include recommendations for equipment and testing protocols for using infrared and GPR for testing the entire surface area during new HMA construction.

The thermal profiling system can provide a real-time view of thermal uniformity. This infrared system is now commercially available and can be implemented into agency specifications. The GPR systems are suitable for evaluating pavement uniformity and, in general, can detect low-density defect areas in new overlays; however, streamlining of the data collection and processing needs to take place before GPR can be widely implemented and incorporated into specifications. A framework was developed for automating the GPR process to achieve an implementable system.

Status: SHRP 2 Project R06C (Using Both Infrared and High-Speed Ground-Penetrating Radar for Uniformity Measurements on New HMA Layers) is active. A video showing a demonstration of the infrared system is available at www.TRB.org/SHRP2/Videos. The final report will be published in 2013.
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Detect Debonding and Stripping in Hot-Mix Asphalt

Several types of surface distress in pavements can be attributed to delamination in HMA layers, including longitudinal cracking in the wheel path and tearing in the surface. HMA delamination is primarily due to layer debonding or stripping. Debonding occurs when there is imperfect tack between paved HMA layers or between an HMA overlay and concrete pavement; stripping develops when the aggregates and asphalt binder are incompatible, adhesion is lost, and water separates the asphalt binder from the aggregate. The distress (cracking or tearing) is the first indication that delamination may be occurring within the pavement layers. A test method is needed to detect the location and severity of delamination before the pavement deficiency causes visual pavement distress.

This project evaluated the capability of NDT technologies to detect the extent, depth, and severity of delamination in HMA pavements. The technologies that were evaluated include GPR, infrared thermography, mechanical waves, and deflectometers.

Technical briefs and details were developed for NDT technologies that can identify delaminations, namely GPR (which uses an air-launched antenna array with frequency sweep measurements) and a scanning mechanical wave system (which measures impact echo and spectral analysis of surface waves). Both systems are ready for project-level use but need more data analysis software for network-level assessment.

Status: SHRP 2 Project R06D (Nondestructive Testing to Identify Delaminations between HMA Layers) is active. The final report will be published in 2013.
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Detect Surface Irregularities on Portland Cement Concrete Pavements during Construction

Most states have implemented smoothness specifications for concrete pavements. These specifications require measurements of surface profile on the finished pavement for acceptance testing. Because of this, smoothness measurements are not made until after the concrete has hardened and problems are not corrected in real time, resulting in significant expenditures to correct surface irregularities. There is a need for further development of a construction quality-control tool for detecting surface irregularities during concrete paving operations. With this information, deviations could be detected in real time and corrections could be made.

This project evaluated and conducted demonstrations of both emerging and proven technologies. Based on those results, the project developed model specifications and construction guidance to expedite the implementation of technologies that can provide an indication of smoothness in real time. In this project, of the seven potential measurement devices identified and studied, two warranted subsequent evaluation and demonstration: (1) the GOMACO Smoothness Indicator and (2) the Ames Engineering Real-Time Profiler. Field tests found that these technologies have (a) reasonable agreement to reference profiles, (b) ability to provide a relative estimate of roughness, and (c) ability to recognize areas where roughness accumulates the most aggressively—that is, localized roughness. It should be noted that these technologies do not measure the smoothness of hardened concrete directly; they identify areas where the relative smoothness is affected.

Status: SHRP 2 Project R06E (Real-Time Smoothness Measurements on Portland Cement Concrete Pavements during Construction) is complete. The final report will be published in 2013.
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Measure the Structural Capacity of Pavement while Minimizing Traffic Disruptions

The structural capacity of pavement is a critical input for performing structural analysis of in-service pavements, identifying sections with structural capacity deficiencies at the network level, and designing pavement renewal or rehabilitation treatments at the project level. The use of continuous deflection measuring devices, which in some cases operate at traffic speed, allows for better spatial coverage with less impact on traffic.

This project assessed the demand and the potential value of continuous deflection devices for supporting pavement renewal decisions, and identified the technologies best suited for effectively supporting the most critical decisions identified by potential users. This project demonstrated that at least one of the continuous deflection-measurement devices—the traffic speed deflectometer—can (a) provide adequate repeatability for network-level data collection; (b) collect deflection measurements and/or indices that are broadly comparable to those collected by traditional measurement devices; and (c) provide measurements that can be used for supporting some of the most critical network-level applications identified by potential users. However, the study also showed that the technology is only just maturing and identified possible improvements to make it even more useful and practical.

Products include a catalogue of existing continuous deflection measuring technologies, detailed assessment of the capabilities of the most promising devices, case studies illustrating the application of the technology for supporting various pavement management decision-making processes, a fact sheet describing the main technologies identified for continuously measuring pavement deflections and their potential uses, training materials for a workshop on the technology, research needs statements for the most pressing research identified, and a dissemination and implementation plan for the technology.

Status: SHRP 2 Project R06F (Development of Continuous Deflection Device) is complete. The final report will be published in 2013.
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Quickly Monitor the Condition and Deterioration of Tunnel Linings

Monitoring the condition and deterioration extent of tunnels is essential for determining the appropriate schedule of maintenance and/or rehabilitation activities to remedy structural and safety problems, which might lead to accelerated deterioration and sudden tunnel failures that could cause serious injury and even fatalities. Tunnels typically service high-volume traffic and operate in aggressive environments. NDT technologies have the potential to conduct (1) a rapid screening of the testing area and (2) an in-depth, although slower, assessment of an area deemed problematic during screening. In both cases, dependable NDT techniques can minimize disruption to traffic.

The objective of this project is to identify NDT technologies for evaluating the condition (including moisture, voids, and corrosion) of various types of tunnel linings (including unreinforced concrete, reinforced concrete, shotcrete, and steel) and finishes on tunnel linings (such as tile). The technologies must be capable of analyzing conditions within the tunnel lining and the surrounding substrate. The evaluation criteria include applicability, accuracy, precision, repeatability, ease of use, capacity to minimize disruption to vehicular traffic, and implementation and production costs. This project is also conducting development in hardware and software for techniques with demonstrated potential for technological improvement. The project is also conducting field evaluations to test the validity of the selected technologies/techniques to detect flaws within or verify conditions of the targeted tunnel components, and recommend test procedures and protocols to successfully implement these techniques.

Products will include a user's manual for NDT technologies that can detect defects behind or within tunnel linings. The manual will include information on equipment and systems integration requirements, test procedures, inspector's training requirements, data management procedures, data analysis procedures, limitations, and interpretation guidelines.

Status: SHRP 2 Project R06G (High-Speed Nondestructive Testing Methods for Mapping Voids, Debonding, Delaminations, Moisture, and Other Defects Behind or Within Tunnel Linings) is active. The final report will be published in 2014.
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