Techniques to Fingerprint Construction Materials–R06B

Verifying Construction Materials Faster and Easier

SHRP2 Can Help

Real-time feedback to ensure quality in transportation construction is the goal for both the contractor and the responsible agency on any given project. Contractors need to monitor progress and detect problems during construction. With this knowledge, contractors can make changes to their work processes, enabling them to meet the contract requirements and be as efficient as possible. Responsible agencies also need to quickly track whether contractors are working according to the specification requirements. The agency role is a matter of quality assurance and ensuring the project requirements that contractors need to follow. In both cases, having a strong materials certification process that can deliver answers expediently without needing days of lab work would benefit both contractors and agencies. That is the goal of this Second Strategic Highway Research Program (SHRP2) product deployment involving Techniques to Fingerprint Construction Materials (commonly referred to as R06B). In fact, several state departments of transportation are trying out the technology in R06B to test their readiness for widespread implementation.

> *"Products included in the SHRP2 program allow us to try out new innovations and see how they help our DOTs save money, time, and most importantly, lives. Techniques to Fingerprint Construction Materials is a perfect example of one of those products. We are evaluating using the technologies identified in this product to verify materials in the field before being placed at project sites, which will cut down on time and money to test these materials. This will allow us to make our roadways safer, as we have greater confidence in our construction materials and a lower likelihood of material failure for the driving public."*
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> —John Schroer, Tennessee DOT commissioner and AASHTO president

Verifying that construction materials meet project specifications is necessary but can be a time-consuming and expensive endeavor. Some materials require extensive sampling and then testing in a laboratory setting. This often results in delays or taking shortcuts in getting test results for acceptance, which could impact product quality and long-term project performance. In the end, this all results in higher project costs, as delays, rework, and/or reduced performance equals money and can impact safety.

Demonstration of the Alpha Fourier-Transform Infrared Spectroscopy (FTIR) to attendees at a technology showcase at the University of Connecticut.

SHRP2 SOLUTIONS TOOLS FOR THE ROAD AHEAD
U.S. Department of Transportation Federal Highway Administration
AASHTO

To combat this issue, state DOTs and transportation agencies can now use R06B, born from SHRP2—a program by the Federal Highway Administration and the American Association of State Highway and Transportation Officials to deliver solutions for transportation agencies that save lives, money, and time. R06B features two portable technologies that can probe specific construction materials in real time and right at the project site, saving time and costs stemming from delays.

More specifically, the technologies included in R06B may:

- Aid in ensuring material quality standards are met in real time
- Allow for faster and easier testing because the technologies used are portable
- Provide an accelerated way to identify the composition of construction

Two Technologies, One Goal

In order to test these construction materials at project sites, R06B adopted two market-ready technologies: X-Ray Fluorescence Spectroscopy (XRF) and Fourier-Transform Infrared Spectroscopy (FTIR). Both these technologies allow fast and easy testing of transportation materials, ultimately saving time and money and making the process safer.

X-Ray Fluorescence Spectroscopy (XRF)

XRF is a nondestructive method that is used to determine which chemical elements are present in a material and at what concentrations. Portable XRF devices in the market are pre-calibrated for a variety of applications, in terms of material types, elements and concentration ranges, so that little training and experience is required to use them. Additional calibrations may be needed for new materials and calibrations, which can be implemented by end users with some experience. Current portable XRF devices are generally capable of detecting elements between magnesium (Mg) and uranium (U) in the periodic table, although detection limits and calibrations vary for different models and applications.

Although the X-Ray power of handheld XRF spectrometers is very low, some simple precautions need to be taken. The test duration lasts less than three minutes, and the results are provided automatically in tabulated format for each element in the calibration range, in milligrams per kilograms (mg/kg) which corresponds to parts per million (ppm), or percent by weight.

The XRF technology is best utilized in:

- Detecting heavy metals in solids, suspensions, or liquids (such as lead in paint or glass beads)
- Determining steel grades
- Detecting phosphoric acid in asphalt
- Detecting some waste admixtures in asphalt binders using characteristic metals
- Quality assurance/quality control of paints and epoxies
- Quality assurance/quality control of Portland cement

The XRF technology adopted in R06B is handheld, which has the form of a gun with a trigger that activates the X-ray tube. That requires the user to hold that trigger for between 30 seconds to three minutes to get results. Those results will appear on the screen of the instrument. It is also possible to connect the instrument directly to a computer and use a test stand for more convenient testing of multiple samples.

There are some limitations to the XRF technology. It cannot measure any element lighter than sodium, so that carbon based materials cannot be analyzed. There are detection limits that vary from a few ppm for the heavier elements (e.g. lead)

FTIR spectrometer testing an asphalt grain.

Handheld FTIR being demonstrated to state DOTs.

to several thousand ppm for light elements such as magnesium and silicon. Finally, additional calibrations may be necessary if the type of material tested has a very different composition from the type of material used to generate the original calibrations. If practitioners use calibrations without taking such effects into account, they may misinterpret the results provided by the equipment.

Fourier-Transform Infrared Spectroscopy (FTIR)

FTIR spectrometers look at molecules. The output of the spectrometer is a spectrum (a graph or pattern) which contains peaks and valleys. The peaks are in certain positions depending on the chemical structure of the material being analyzed. Many materials used in the paving industry like styrene butadiene (SBS) polymers, lime and the oxidation products found in aged asphalt are well known. It is a simple matter to identify such peaks. For example, the size of the peak can give an indication of how much SBS may be present at the test sample or at the test site. It is often not necessary to identify individual peaks. Matching just the spectrum or pattern to that of known material may be all that is needed.

The FTIR technology could be used to:

- Identify curing compounds and other admixtures in wet cement prior to placement
- Identify lime in asphalt
- Detect miscellaneous modifiers in asphalt
- Identify and quantify polymers in asphalt
- Detect contaminants (diesel, tar, waste oil) in soils and aggregates

The FTIR equipment can be benchtop-portable or handheld, suitable for both lab and field use. Testing time is about three to five minutes.

Like XRF, FTIR does have its limitations. First off, a library of reference spectra must be developed for construction materials. Additionally, there is some training and experience required to interpret spectra. Finally, detection limits are fairly high for admixtures. The selected deployment state DOTs, described below, are helping the industry further develop this technology with the end users in mind.

Main image: **Testing XRF technology and its ability to determine the chemical elements of the material and at what concentrations.**

Small image on left: **Screen of XRF displaying metal concentrations.**

Testing the Technology Out in the Field

Three states were selected to receive funding assistance to implement R06B in round 7 as part of the SHRP2 Implementation Assistance Program (IAP). Alabama Department of Transportation and Maine Department of Transportation are working with both the XRF and FTIR technologies, while Tennessee Department of Transportation is focusing its efforts mainly on the XRF technology.

Alabama

For the XRF technology, ALDOT will develop a procedure for use of the portable handheld technology to field measure the quantity of titanium dioxide in thermoplastic products. They will also compare field measurements with lab measurements to ensure consistency between submitted plant samples and thermoplastic stripe placed on projects. This is being done by comparing results with existing standards and procedures, developing procedures for field application, and identifying field projects and validating procedure.

Field testing of titanium-based paint using portable XRF.

Working with the FTIR, ALDOT's goal is to identify materials and applications of interest that show promising use of the benchtop technology. This will be used to evaluate whether FTIR spectra can be used to assess the oxidation levels of RAP and RAS stockpiles.

Maine

For XRF, the Maine DOT's goals are to develop a procedure for field analysis of Portland cements, measure chloride intrusion in concrete, determine steel grade and thickness of galvanized rail coatings, and quality control of glass beads and traffic paints. To achieve these goals, Maine will develop a testing protocol, evaluate the accuracy of existing calibration curves in the portable XRF equipment and develop new ones for each material necessary. They will then conduct field tests to validate the lab procedure for all the aforementioned materials.

Another objective for MaineDOT is to investigate the use of FTIR in testing material properties such as hydrated lime content of asphalt mixture and the polymer content of asphalt binder. MaineDOT will report back on lessons learned, pros and cons of the technology, training protocols and methods, and results of lab and field work plan execution.

Tennessee

TDOT is using XRF for rapid lab and/or field evaluation of thermoplastics, glass beads, and aggregates. The department is in the process of demonstrating the technology's ability to verify the composition of field materials before they are placed on the project site. TDOT is also including verification of materials and/or products from the department's qualified products list.

Through its testing of the technology, TDOT will further evaluate applications of interest that have shown promise in previous stages, testing a range of materials and developing appropriate standards, and comparing results with existing standards and procedures and wherever possible, continue with the current testing on split-samples to show comparisons. They will also develop protocol for field and lab applications.

Like the other states, when complete, Tennessee will provide lessons learned, training protocols and methods, results of lab and field work, and report whether the technology is ready for implementation.

What's Next for R06B?

Be on the lookout for additional information from the IAP states. They are currently in the middle of a Proof of Concept Pilot, which is intended for SHRP2 products that need additional testing to learn their readiness for widespread implementation.

Learn more or look for upcoming webinars and reports at **http://shrp2.transportation.org/Pages/R06B.aspx.** Here you will also find more in-depth information on the two technologies being tested.

How to Get Involved

To learn more about Techniques to Fingerprint Construction Materials, contact FHWA's Steve Cooper at Stephen.j.cooper@dot.gov or AASHTO's Kate Kurgan at kkurgan@aashto.org.

Stay up-to-date on R06B or other SHRP2 product news by visiting **www.fhwa.dot.gov/goshrp2/** or **http://shrp2.transportation.org**, where you can also sign up to join the SHRP2 email list.