TEXAS TRANSPORTATION INSTITUTE
THE TEXAS A&M UNIVERSITY SYSTEM

PROJECT SUMMARY REPORT

Project Summary Report 0-4126-S
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Project 0-4126: Development of Infrared Photography and Ground-Penetrating Radar Procedures for Identifying Mixture Segregation

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Detecting Segregation with Infrared Imaging and Ground-Penetrating Radar

Segregation of any type is a serious problem in hot-mix asphalt and typically leads to poor performance, poor durability, shorter life, and higher maintenance costs. There are obvious performance and financial benefits from developing techniques to minimize segregation. Currently, longitudinal density measurements are being used in attempts to measure segregation. However, this method of quality control is considered quite labor-intensive and may not always accurately identify problem areas. Clearly, there is a need for new and innovative techniques for detecting segregation.

What We Did…

Texas Transportation Institute (TTI) researchers focused on using two non-destructive testing (NDT) technologies, infrared imaging (IR) and ground-penetrating radar (GPR), to evaluate the uniformity of newly placed hot-mix overlays. Researchers tested four sections by conducting an infrared imaging survey at the time of placement of the hot mix. They noted and marked anomalous locations for follow-up investigation. At each test site, researchers subsequently collected GPR data in five passes at different lateral offsets from the pavement edge (outer edge, outer wheel path, centerline, inside wheel path, and inside edge). Cores were taken where anomalies were identified in either of the NDT readings. TTI laboratories conducted a range of tests on the cores to measure important materials properties such as percent air voids, percentage asphalt, and gradation.

The laboratory cores were used to develop a relationship between the measured field dielectric and core air voids. Using a software package, these data points were displayed as a contour map for each project. Figure 1 illustrates an example of an infrared image and the corresponding predicted mat air voids from radar data.

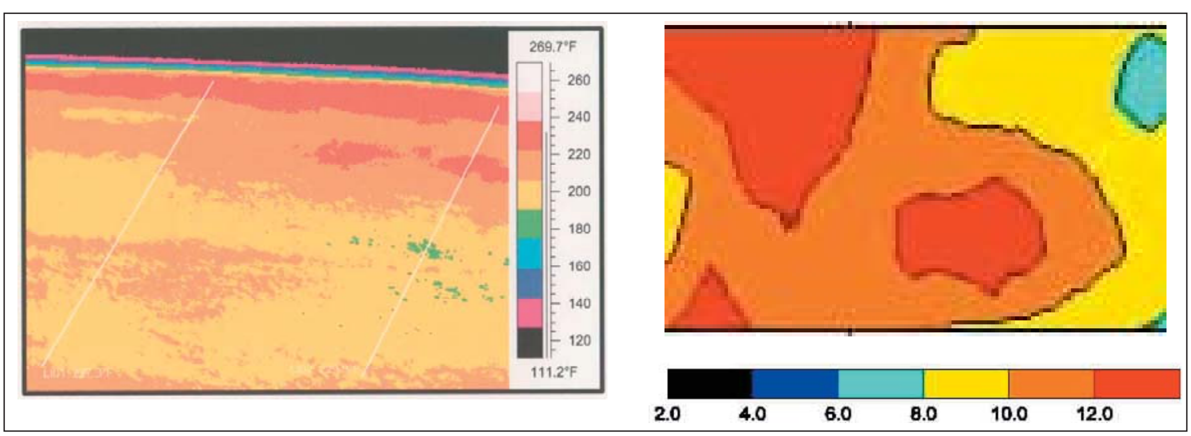

Figure 1. Infrared Image with Corresponding Mat Void Predictions.

Researchers also examined the relationship between the NDT data and the hot-mix properties in order to develop mix acceptability limits based upon the NDT data.

What We Found…

Analysis of data collected revealed that data from both infrared imaging and GPR can be related to changes in hot-mix properties. Changes in temperature showed significant relationships to changes in air voids at three test sites, asphalt content at two test sites, and gradation at two test sites. Changes in surface dielectric from the radar data were found to be strongly related to changes in air voids at all test sites, asphalt content at one test site, and gradation at one test site.

To assess mat uniformity, researchers created probability distributions of mat air voids from the relationship between the surface dielectric and in-place mat air voids. Figure 2 gives an example of such a distribution. Furthermore, the GPR data make it possible to generate a surface plot of the predicted voids of the entire section. Figure 1 shows an excerpt from one of these plots.

Based upon Texas Department of Transportation (TxDOT) specifications for allowable operational tolerances and the relationship between changes in NDT data with changes in mix properties, researchers developed the following material acceptability limits:

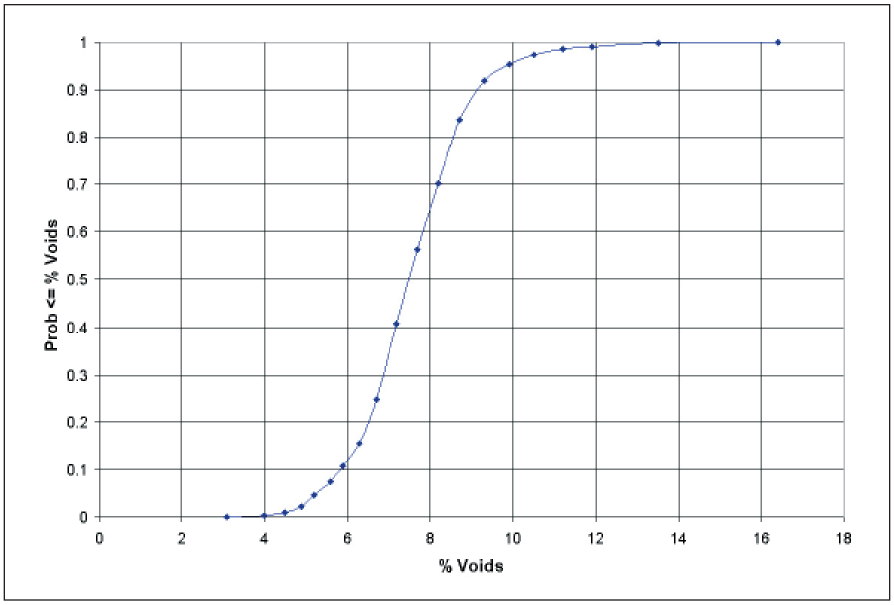

Figure 2. Example Distribution of Mat Air Voids from GPR Data.

- Significant changes in mix properties will occur if changes in surface temperature of more than 25 °F are measured in the field.
- Significant changes in mix properties will occur if the surface dielectric changes by more than 0.8 for coarse-graded coarse matrix high binder (CMHB) mixes and 0.4 for dense-graded materials.

Additionally, the surface dielectric from the radar data was considered to be the best indicator of mix density. This is a non-contact measurement, so it is not impacted by surface texture, as are other density-measuring technologies. Infrared imaging worked well as a screening tool for locating potential problem areas. With some modifications for easier field use and data processing, both infrared and GPR technologies could potentially serve as effective quality control (infrared) or quality assurance (radar) methods. Infrared could provide a means of assessing mat quality and identifying potential problems as placement is taking place, thus allowing the opportunity for corrective action, and radar could provide a rapid and reliable method for obtaining density estimates.

The Researchers Recommend…

TxDOT should consider future implementation of these technologies. However, neither of the two devices used in this project were thought optimum for full implementation. The infrared cameras are expensive, in the range of $20,000 to $50,000, and the angle of operation and limited field of view make development of a field test and acceptance protocol difficult. A typical image covers about 20 to 30 feet of pavement; therefore, multiple images need to be collected and merged as the paving train passes along the highway. Coming back to an exact location is nearly impossible unless the area is marked immediately upon imaging.

The 1 GHz radar system used is relatively large and bulky. A slightly higher operating frequency system, such as 2 GHz, would have the advantages of smaller size (factor of 2) and greater near-surface accuracy. With recent advances in GPR systems it should be possible to build a handheld unit for spot-specific measurement. This system could potentially replace the nuclear density gauge and would have significant advantages over alternative density-measurement systems in that it would be non-contact and therefore not impacted by surface texture.

Ideas for achieving an effective implementation of these technologies for detecting segregation are:

- *Infrared Temperature Bar:* A bar with spot infrared sensors at known transverse offsets could be pulled behind the paver. A distance-measuring instrument would trigger data acquisitions at preset intervals. This process would create a data file of mat temperatures at known locations, eliminating the uncertainty of accurately locating a spot on the mat when an infrared camera is used. Surface mapping software could be used to plot the data, and anomalous areas could be identified, located, and investigated. This method of implementation would enable easy investigation of overall temperature variability of the entire section. Figure 3 illustrates this concept.
- *Ground-Penetrating Radar:* A small, high-frequency handheld unit could be developed to replace the nuclear density and capacitance-based gauges. The system would be non-contact and thus not impacted by surface texture. In addition, multiple antennas of a high-frequency system could be mounted across the front of a vehicle, and a single pass could collect all the data necessary to generate a surface plot of the air voids for the entire mat. High air void areas could be located, and the data could be used to generate the distribution of voids in the section. This method of implementation would provide a means of examining mat uniformity and could also be used for assessing bonuses and/or penalties.

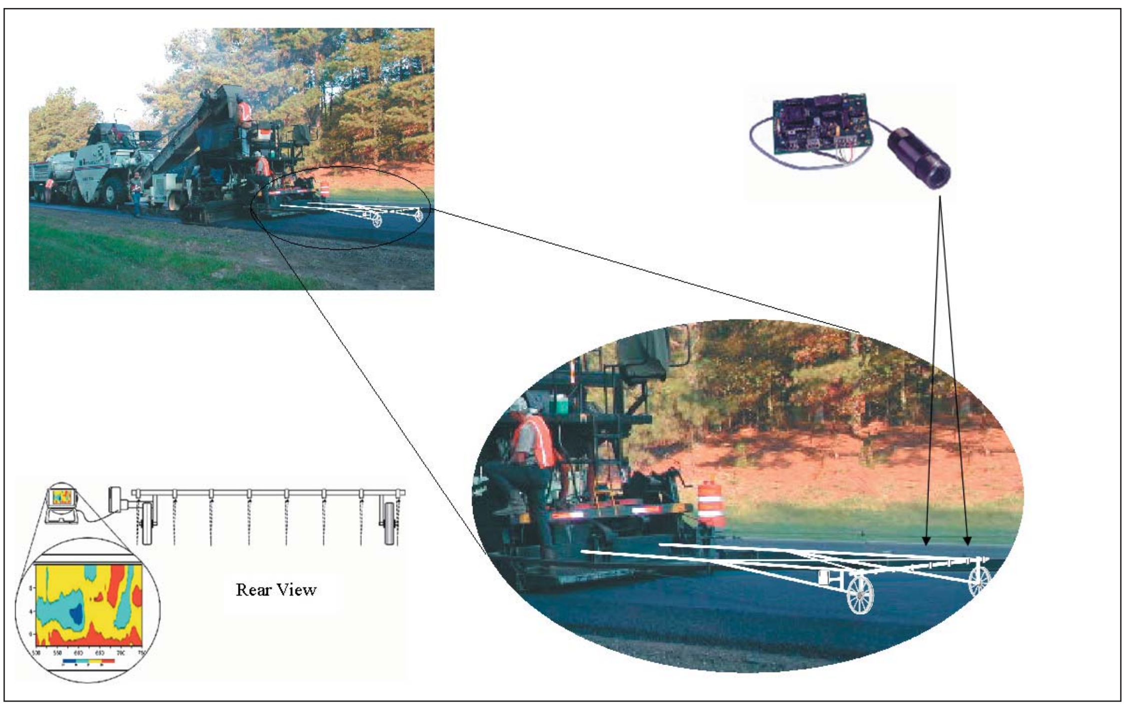

Figure 3. Concept Infrared Sensor Bar for Quality Control.

For More Details...

This research is documented in Report 4126-1, *Using Infrared Imaging and Ground-Penetrating Radar to Detect Segregation in Hot-Mix Overlays*.

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Disclaimer

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