Evaluation of Pave-IR Thermal Imaging for Asphalt Pavement Uniformity

Prepared by:
Craig E. Landefeld, P.E.

Prepared for:
The Ohio Department of Transportation,
Office of Statewide Planning & Research

State Job Number 495059

April 2014

Final Report
# Abstract

The goal of this internal study was to evaluate if the Pave-IR system could potentially be integrated into the Ohio DOT specifications for asphalt pavements. With the known performance we can expect of pavements with adequate density levels, we were interested so see if the Pave-IR system could predict areas of low density, which should also capture problematic areas of segregation.

**Keywords**

- Thermal imagery
- Pave-IR
- thermal segregation
- segregation, asphalt temperature uniformity
- hot mix asphalt
- asphalt pavement
- density differentials
- density profile
- thermal differentials
- thermal profile
- in-place density.

**Distribution Statement**

No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.
Project Background

Segregation is a problem that the asphalt industry has tried to solve for many years. “Segregation creates non-uniform mixes that do not conform to the original job mix formula in gradation or asphalt content. The resulting pavement exhibits poor structural and textural characteristics, provides poor performance and durability, and has a shorter life expectancy and higher maintenance costs.” Random sampling techniques used for quality assurance is not adequate to capture low density areas in asphalt pavement that can lead to reduced performance life. The Ohio Department of Transportation (ODOT) is not unique in that premature pavement distresses that were a result of segregation of the asphalt mixture are a cause of universal concern and reduction of potential pavement life. While segregation has been an issue on many projects, ODOT’s current methods of evaluation of an asphalt mat for segregation are mainly based on visual uniformity and are very subjective. This subjectivity and varying levels of staff experience, leads to disputes as to the degree the mat is segregated, whether remediation is required, and inconsistent enforcement of the uniformity requirements of construction specifications statewide. In an effort to improve uniformity of enforcement and to remove the subjectivity from locating problematic areas of segregation, ODOT began to look at ways to evaluate asphalt mats for uniformity with discrete measurement criteria. Review of other state DOT specifications and research documents identified thermal imagery as a potentially viable tool for evaluation of asphalt for thermal segregation. Washington DOT began research in 1998 utilizing infrared temperature guns, and later infrared cameras, to correlate temperature differentials to segregation and density variability. Later the Texas DOT along with Texas Transportation Institute (TTI) developed a methodology for collection of real time infrared temperature data utilizing infrared temperature sensors and GPS technology. The results of this effort led to a commercially available unit, Pave-IR, that could measure and map the asphalt mat temperature in real time. This thermal map and data could then be analyzed for areas of concern.

Study Objectives

The goal of this study was to evaluate if the Pave-IR system could potentially be integrated into the Ohio DOT specifications for asphalt pavements and to answer questions that remained such as:

- What temperature differentials could be expected with different paving methods and equipment?
- How does in-place density correlate to thermal differences?
- Can this tool be used to measure and detect areas of problematic segregation?

Description of Work

After review of other state specifications, research reports, and meetings with industry, a methodology was developed for data collection. Based on the conclusions from NCHRP 441 and others, which determined that thermal technology correlated well with mat uniformity and could be used to estimate the severity of physical segregation, the decision was made to not replicate that effort. Instead, the decision was made to focus more on the in-place density of the thermal profiles in comparison to the temperature
variability. With the known performance we can expect of pavements with adequate density levels, we were interested so see if the Pave-IR system could predict areas of low density, which should also capture problematic areas of segregation. The Pave-IR system has a default thermal profile length of 150 feet in order to capture a truck change in each profile. The profiles maximum and minimum temperature is extracted and then used to calculate the temperature differential for each profile. Nuclear density gauges were chosen to collect density data to match the 150 foot thermal profiles that would be provided by the Pave-IR system. All nuclear gauge data would be correlated to roadway cores per ODOT Supplement 1055 procedures. Density data would be systematically collected every 10ft resulting in 15 measurements per 150 foot profile and would be taken in the full range of temperature conditions encountered at each project site. Contractor personnel were responsible to collect the project density data and record the measurements on the form found in Appendix A. Additionally, the contractor was required to attach the Pave-IR bar to the paver and collect continuous thermal profiles for each day of paving. The thermal and density profile data could then be compared and analyzed individually.

2012 Projects:

PIK-32-13.84
The first test site was Project 12-0074 located on US32 in Pike County. The project consisted of a 1.75 inch 19.0mm intermediate course placed on a milled surface followed by a 1.5 inch 12.5mm surface course. The contractor utilized a Vogele 5200 paver with the Terex MS4 transfer device on both courses. The project haul length was approximately 5 miles using end dump trucks.

ADA-32-0.00
The second test site was Project 11-0508 located on US32 in Adams County. The project consisted of a 1.75 inch 19.0mm intermediate course placed on a milled surface followed by a 1.5 inch 12.5mm surface course. The contractor utilized a Vogele 5200 paver with the Terex MS4 transfer device on both courses. Due to equipment issues data was only able to be collected with the Pave-IR unit on the 19.0mm course for this project.

MRW-IR-71-12.19
The third test site was Project 11-3011 located on I-71 in Morrow County. This project consisted of a new full depth section of 10 inches of 302 big rock asphalt base course, 1.75 inches 19.0mm intermediate course and 1.5 inches 12.0mm surface course. Data was collected on the 302 asphalt base and the 19.0mm intermediate course for this season. The contractor used end dumping and paved 30ft width on the 302 asphalt base course and placed the intermediate course with a mix of end dumping and use of the Cedar Rapids transfer device.
2013 Projects:

LIC-16-14.10 / LCI-37-15.93
The first test site was Project 12-0679 located on SR 16 in Licking County. The project consisted of a 1.75 inch 19.0mm intermediate course placed on a milled surface followed by a 1.5 inch 12.5mm surface course. The contractor utilized a Vogele 5200 paver with the Terex MS4 transfer device on both courses.

GUE-IR-70-22.80
The second test site was Project 13-0124 located on IR-70 in Guernsey County. The project consisted of a 1.75 inch 19.0mm intermediate course placed on a milled surface followed by a 1.5 inch 12.5mm surface course. The contractor utilized a Vogele 2219T paver on both courses. The contractor used end dump trucks discharging into the paver hopper on the intermediate course and the Roadtech Roadmix CR662 RM transfer device on the surface course.

MAR-37-0.00
The third test site was Project 13-0465 located on SR37 in Marion County. This project consisted of a 1.5 inch overlay with Type 1 Surface Course. The contractor utilized end dump trucks discharging directly into the paver hopper. Unfortunately due to data collection errors with the Pave-IR unit we were unable to gather any useful thermal information from this project. All data was captured but the stationing was improperly entered making it impossible to match the thermal and density profiles accurately.

Figure 1: Contractor Paving With Pave-IR Unit

The following Figures 2-7 provide examples of project data output collected with the Pave-IR unit. As you can see from Figure 4 in some cases density correlated well with the thermal data and in the case of Figure 7 density data correlation was poor.
Figure 2: Project Thermal Plot

Figure 3: Project Thermal Profile

Figure 4: Profile Thermal & Density Plot
Figure 5: Project Thermal Data Image

Figure 6: Project Thermal Profile

Figure 7: Profile Thermal & Density Plot
Research Findings & Conclusions

Density data from the sites was broken down by individual project, mix types and methods of placement to look for general trends. Most notably, there was interest in the density variability that exists from different material placement methods. The density deviation from each profile was calculated and the statistical results from all density profiles are summarized in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>End Dump</th>
<th>MS4</th>
<th>Remix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Density</td>
<td>94.3%</td>
<td>93.8%</td>
<td>92.3%</td>
</tr>
<tr>
<td>Mean Δ Den</td>
<td>3.6%</td>
<td>1.9%</td>
<td>1.9%</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>1.7%</td>
<td>1.1%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Range</td>
<td>14.0%</td>
<td>6.5%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Minimum</td>
<td>1.1%</td>
<td>0.4%</td>
<td>0.7%</td>
</tr>
<tr>
<td>Maximum</td>
<td>15.1%</td>
<td>6.9%</td>
<td>4.2%</td>
</tr>
<tr>
<td>Count</td>
<td>116</td>
<td>188</td>
<td>88</td>
</tr>
</tbody>
</table>

As was expected, the mean density variation was lower with the use of transfer devices when compared to end dump paving. Over 78% of End dump profiles had a density variation greater than 3%, while only 18% of the Remix and 19% of the MS4 profiles showed density variation greater than 3%. In addition to the lower mean density variation achieved from the transfer devices, there was significantly less variation in the temperature data using the transfer devices as well. A Histogram of density data for each method of placement is shown in Figure 8. From this plot we can see the reduction in variability as we move from End Dump to MS4 to Remix profile data.
Site temperature data was also broken down by individual project, mix types and methods of placement to look for general trends. The Temperature deviation from each profile was calculated and the statistical results from all thermal profiles are summarized in Table 2. As expected the mean temperature deviation improved with the use of transfer devices over end dumping. The remix device showed the lowest average temperature deviation of 31.7 °F and had significantly lower range in temperature data compared to the other placement methods.

Table 2 : Profile Temperature Variation by Placement Method

<table>
<thead>
<tr>
<th></th>
<th>End Dump</th>
<th>MS4</th>
<th>Remix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>49.4 °F</td>
<td>40.0 °F</td>
<td>31.7 °F</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>14.0 °F</td>
<td>12.9 °F</td>
<td>6.7 °F</td>
</tr>
<tr>
<td>Min</td>
<td>25.4 °F</td>
<td>18.7 °F</td>
<td>16.6 °F</td>
</tr>
<tr>
<td>Max</td>
<td>98.8 °F</td>
<td>114.7 °F</td>
<td>51.3 °F</td>
</tr>
<tr>
<td>Range</td>
<td>73.4 °F</td>
<td>96.0 °F</td>
<td>34.7 °F</td>
</tr>
<tr>
<td>Count</td>
<td>116</td>
<td>188</td>
<td>88</td>
</tr>
</tbody>
</table>
A Histogram of temperature data for each method of placement is shown in Figure 9. From this plot we see reduction in variability as we move from End Dump to MS4 to Remix profile data and follow the same general trend as the density variability.

**Figure 9: Normalized Temperature Histogram**

**Conclusions**

- Thermal segregation does not always indicate that a pavement will have density issues. Logically this makes sense, as many of the super-pave mix designs used in the study are difficult to over-densify when properly produced. Compaction effort at the high temperature ranges will not likely result in over compaction. Conversely, with Pave-IR measuring mat temperature prior to rolling activity, lack of uniform roller coverage could cause low density areas within profiles of low thermal differential.

- While thermal profiles do not always correlate to density problems, this technology can be used to detect and measure levels of segregation. As presented in the Tables 1 & 2 the density deviations are much lower with improved thermal control. These correlations indicate that areas of high thermal segregation are extremely suspect for density issues and should be investigated further.

- Acceptance cores taken under ODOT Item 446 are not sufficient to find isolated areas of low density material placed on paving projects. Pockets of low density found by profiling tended to be less than 20ft in length and could easily be missed or skew acceptance core density data for the lot.
• The use of transfer devices significantly improved both density and thermal uniformity compared to end dump paving. These devices tended to minimize the thermal and density deviation. While they are not replacements for good production and placement practices, these tools will significantly improve the uniformity of asphalt mat placement.

• The average density variation of 3.6% with end dump paving raises further concern about the amount of low density material that is being placed. This variability will lead to areas of low density that will not perform as well as the surrounding pavement and cause increased maintenance costs in the future.

Recommendations

ODOT should continue to collect thermal and density data on future projects with both end dump and remixing transfer devices to further populate our thermal and density database. ODOT should work with Industry to develop a procedure to measure and evaluate localized areas of concern, if found, in asphalt pavement mats. ODOT should work with industry to improve the uniformity measurement and specification requirements for asphalt pavements. This should reward excellent process control and/or expand the use of transfer devices on surface and intermediate courses placed on the primary system. While this equipment is not a cure all for segregation issues, when properly operated, transfer devices help to improve the uniformity and ultimately the long term performance of the pavement.

References


Appendix A: Density Profile Data Collection Form

<table>
<thead>
<tr>
<th>No.</th>
<th>Begin Site</th>
<th>End Site</th>
<th>Offset</th>
<th>Profile Type</th>
<th>O1</th>
<th>O2</th>
<th>O3</th>
<th>O4</th>
<th>O5</th>
<th>O6</th>
<th>O7</th>
<th>O8</th>
<th>O9</th>
<th>O10</th>
<th>O11</th>
<th>O12</th>
<th>O13</th>
<th>O14</th>
<th>O15</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>Density Location</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>Density Location</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>Density Location</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>Density Location</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>Density Location</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td>Density Location</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td>Density Location</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td>Density Location</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments:

P1 - No visible segregation ΔT < 25°F (Control)
P2 - No visible segregation ΔT > 25°F
P3 - Visible segregation
P4 - Paver Stop > 2 min.