SHRP2 Technologies to Enhance Quality Control on Asphalt Pavements
Infrared (IR) Paver Mounted Thermal Profiler

Hosted by:
Arkansas Asphalt Paving Association
January 4, 2019
Welcome & Introductions

1. AAPA
2. AASHTO
3. ARA

Reminders:
Workshop Evaluation
Photo Release Forms
Professional Development Hours
SHRP2 R06C Technology to Enhance Quality Control on Asphalt Pavements:
Paver Mounted Thermal Profiler (PMTP) 
Ground Penetrating Radar (GPR) Density Profiling Systems (DPS)
Focus Areas

**Safety**: fostering safer driving through analysis of driver, roadway, and vehicle factors in crashes, near crashes, and ordinary driving

**Reliability**: reducing congestion and creating more predictable travel times through better operations

**Capacity**: planning and designing a highway system that offers minimum disruption and meets the environmental and economic needs of the community

**Renewal**: rapid maintenance and repair of the deteriorating infrastructure using already-available resources, innovations, and technologies
SHRP2 Implementation:
INNOVATE – IMPLEMENT - IMPROVE

- **304,406** Participants Engaged
- **12,378** Outreach Activities
- **16,629** Hours Technical Assistance

**Results**
Save lives, money, and time
- Bridges being built more quickly
- Smoother traffic flows and less congestion
- Reduced construction costs
- Safer roadways
- Smarter environmental reviews
THE CHALLENGE: Develop solutions to measure and quantify non-uniformity of asphalt pavement construction

Localized non-uniform areas fail prematurely. Random testing seldom catches problem

Increased use of night paving makes inspection more difficult
SHRP2 R06C Goal

Advance solutions to measure and quantify non-uniformity of asphalt mixture construction

Paver Mounted Thermal Profiler (PMTP)

Ground Penetrating Radar (GPR) Density Profiling Systems (DPS)

MOBA IR Scanner

GSSI PaveScan Rolling Density Meter (RDM)
Proof of Concept Pilot (2) $100k/ea (GPR) + In kind

Lead Adopter Incentive (10) $40,5k/ea (IR) or In kind

User Incentive

Northern Mariana Islands / Guam

American Samoa

EFL
R06C PMTP Implementation
Deliverables:

- Equipment Fielding & Initial Training:
  - 10 Conducted
- Showcase - St. Joseph, MO on 1 June 2016
- Training:
  - 17 4-hr Workshops Conducted
  - NJ DOT Outreach training
  - 90-Min Webinar – 31 Jan 2018
  - Possibly more workshops for 2019 (NY, PA, OK, MS)
- Written Deliverables: Primer, Case Study on Deployment
GPR DPS Technology
(GSSI PaveScan Rolling Density Meter)

Push Cart Type RDM

Vehicle Mounted RDM

Courtesy of MN DOT
R06C GPR DPS Implementation Highlights:

• Testing protocols established by UMN.
• 3 units fielding to MN, ME & NE and initial demos starting in 2016
• GPR RDM User-Group Peer Exchange - Oct 2017
• GPR DPS User-Group Peer Exchange - Jul 2018
• Training:
  ➢ 90-min Webinar on 8 Mar 2018
• Outreach & Marketing:
  ➢ Promoted during PMTP Workshops
  ➢ TRB 2017
  ➢ NESMEA/NEAUPG 2017
  ➢ NESMEA/NEAUPG 2018
• Written Deliverables:
  ➢ Testing Protocols for the RDM
  ➢ July 2018 User-Group Peer Exchange Minutes
Post SHRP2 FHWA Support:

PMTP:
• Participation in Pooled Fund TPF-5 (334)
• Provide continued FHWA support for those agencies interested in receiving training.

Density Profiling Systems (DPS):
• Assist MN DOT in advancing future Pooled Fund to address technical and deployment needs for advancing DPS in support of Quality Assurance.
• Provide support in facilitating another User-Group Peer Exchange in Fall 2019.
• Establishment of Technical Advisory Committee (TAC).
• Provide continued FHWA support for those agencies interested in demonstrating technology.
Contacts for More Information:

- Stephen Cooper: Stephen.J.Cooper@dot.gov
- Kate Kurgan: kkurgan@aashto.gov
- Joe Reiter: jreiter@ara.com
- Harold Von Quintus: hvonquintus@ara.com

Websites:

- http://shrp2.transportation.org/Pages/R06C_RapidTechnologies_to_Enhance_Quality_Control.aspx
Our Focus for Today

Workshop Objectives …

1. Describe use of the Infrared (IR) Technology.

2. Identify equipment and understand the installation and use of the Thermal Profiler equipment & software.

3. Discuss results/findings from the field demonstration projects.

4. List contractor’s and agency’s opinions and/or perspective of IR as a QC or QA tool.

5. Know the implementation strategies used by the lead agencies and how to apply them in Arkansas.
The Challenge: Develop solutions to measure and quantify non-uniformity of asphalt mixture at construction.

Localized non-uniform areas fail prematurely. Random testing seldom catches problems.

Increased use of night paving makes inspection more difficult.
R06C Technologies to Enhance QC on Asphalt Pavements

Thermal Profile during Placement: *Pave-IR*

Density uniformity after Compaction: *Rolling Density Meter*
Infrared Technology Workshop

Part 1: What is it and why use it?

January 4, 2019
Introduction to IR Technology

Part 1: What is it and why use it?

1. IR - Defined.
2. How is it measured?
3. Why is it important?
4. How was criteria established?
Infrared Thermography Defined:

- The mapping of temperature contours (equal temperature) over the surface of a material.
- Contours are used to evaluate materials by measurement of their surface temperature and its variation.
IR Defined

Type of Temperature Differences:

Temperature Segregation (Differential) Defined:
• More than 25 ºF difference in mat surface temperature behind screed through 150 foot segment.

Thermal Streaks Defined:
• More than 14 ºF difference between adjacent IR locations down the mat (longitudinal line).
IR Defined

Type of Temperature Differences:

1. Cold spots
   - Truck to truck temperature differences
   - Improper loading and unloading of trucks

2. Thermal streaks
   - Longitudinal segregation
   - Inadequate or non-uniform amount of material across the mat
Introduction to IR Technology

Part 1: What is it and why use it?
1. IR - Defined.
2. How is it measured?
3. Why is it important?
4. How was criteria established?
IR Measurements

History; Mat Temperature Measurements

- Temperature guns
  - Point readings
- Temperature cameras
  - Time specific to identify areas with cold spots or thermal streaks
IR Measurements

History; Mat Temperature Measurements:

• *IR-Bar*, first device for continuous readings.
• *Paver Mounted Thermal Profiler*, second generation device for continuous readings.
IR Measurements

Thermal Profiler:
- IR Sensor—detects infrared radiation emitted from the mat.
- Scans the mat 6 to 10 ft. behind the screed.
- Creates thermal profile of the mat surface.

Non-uniform temperatures usually mean, non-uniform densities.
Part 1: What is it and why use it?

1. IR - Defined.
2. How is it measured?
3. Why is it important?
4. How was criteria established?
IR Importance

- Aggregate segregation in mat = temperature differentials
- Non-uniform temperatures = non-uniform densities
**Segregation** – A difficult issue to resolve, when it is difficult to identify or confirm.
IR Importance

- Lower mat temperatures in localized areas results in lower mat density (reduced compaction) and reduces the service life or increases maintenance.
Cold spots: increased potential for:

- Fatigue cracks
- Raveling
- Pot holes
Thermal streaks: increased potential for longitudinal cracking and raveling.

Loss of service life or increase in maintenance costs.
Introduction to IR Technology

Part 1: What is it and why use it?
1. IR - Defined.
2. How is it measured?
3. Why is it important?
4. How was criteria established?
Temperature profile criteria based on desired density uniformity.

Initial Work/Studies:

- 1996 through 2000s – field work concluded temperature differences could be accurately detected and quantified:
  - Low temperatures result in low density zones in mat.
IR Criteria

- Cold spots
  - Temperature difference of mat between truck exchanges – common.
  - Areas with higher air voids
- Focused testing have validated higher air voids
  - Coring
  - Radar (full coverage)
  - Nuclear gauge
- Thermal Streaks: much less work to validate criterion.
IR Criteria

- Effect of cold spots, low mat temperatures on percent compaction; densities are:
  - Lower
  - More variable

TTI Study:
$\Delta 25 \, ^{\circ}F \sim \Delta 6 \, \text{pcf}$

Maine DOT:
$\Delta 20 \, ^{\circ}F \sim \Delta 4 \, \text{pcf}$
Infrared Technology Workshop

Part 2: Equipment & Software – Installation and Use
Part 2: Equipment and Software – Installation and Use

1. Equipment and Its Installation
2. Software Features and Parameters
3. Data Collection and Reports
Equipment and Its Installation

Equipment
- Mast Base
- Mast Extension
- Mast Arm
- IR Scanner
- DMI
- GPS Unit
- Wiring
- Connection bolts & materials
Equipment and Its Installation

IR mast base and extension attached to paver.

Mounted Directly to Screed

Mounted to a Steel Plate Attached to Work Platform
• IR Scanner attached to paver; scans mat behind screed in one direction.
• GPS attached to the mast arm.
Equipment and Its Installation

DMI placed on wheel hub to measure distance during paving operation.
IR scan screen used to see/monitor mat temperatures in real time; attached to the mast post or extension.
Equipment and Its Installation
Two models of data transfer and extraction

1. Automated; GPS
2. Manual; Memory stick
Part 2: Equipment and Software – Installation and Use

1. Equipment and Its Installation
2. Software Features and Parameters
3. Data Collection and Reports
Software Features

- Online Web App: https://eroutes.info/paveappweb/
- Login is user specific
Software Features

Explore Data: MOBA Pave Project Manager Main Screen

- Color Map
- Thermal Profile
- Properties
- Diagrams & project information
Software Features

Color Map and Properties for Screen

<table>
<thead>
<tr>
<th>Properties</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Color Map</td>
<td></td>
</tr>
<tr>
<td>Temperature range</td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td>407°F</td>
</tr>
<tr>
<td>Min</td>
<td>61°F</td>
</tr>
</tbody>
</table>
Software Features

Thermal Profile Properties Screen

- **Actions**
  - Interpolation: Linear
  - Sample Spots of Interest: Enabled
  - Stations: Show
  - Tooltip: Visible

- **Profile View**
  - Ignored Sensors
  - Length: 1513.78 ft
  - Start: 0.33 ft
  - Units: Feet
  - Zoom: 100.0%
Software Features

Project Properties Screen

Meta Information

Metrics

Beginning location
Comment
Ignored Sensors
Layer thickness
Lift
Measure height
MINDS Upload
Operator Name
Paving width
Project ID

houlton off ramp
passing lane w/4shld

1.5in
1
9.5ft
No
paul
11.48ft
670f0ef1-e942-4b24-a035-3a74f6367793

Beginning location
The name of the location where the project began.
Software Features

Adding Density Point Measurements

Click any location on the thermal profile to add additional data & information.
Data diagrams reviewed during production:
1. Paving Location Map
2. Paver speed diagram
3. Time plot
4. Average temperature plot
Software Features

Paving Location Map Diagram Screen
Software Features

Paver Speed Diagram Screen
Paver Speed Diagram

Paver Speed, Ft./min.

Distance

Paver Speed Diagram

Meta Information

Project Duration: 1:22:20 h:m:s
Paver Total Stop Time: 0:2:37 h:m:s
Paver Average Speed: 18.39 ft/min
Last data collected: 9/16/2015 9:22:37 AM
Software Features

Paver Time Diagram Screen

Paver Stop Times

Distance
Software Features

Temperature Class Diagram Screen

Temperature Class Diagram

Temperature Histogram
Part 2: Equipment and Software – Installation and Use
1. Equipment and Its Installation
2. Software Features and Parameters
3. Data Processing and Reports
Raw Temperature Profile; all data collected and retained in the data file.
Summary of Raw Data for One Lot
Avg. Temp. = 285 ºF

Not mat temperatures

<table>
<thead>
<tr>
<th>Basic Temperature Statistics (F)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>285.0</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>49.6</td>
</tr>
<tr>
<td>Minimum</td>
<td>76.1</td>
</tr>
<tr>
<td>Maximum</td>
<td>336.7</td>
</tr>
<tr>
<td>98.5 %-tile</td>
<td>321.6</td>
</tr>
<tr>
<td>1 %-tile</td>
<td>114.8</td>
</tr>
<tr>
<td>Temp. Differential</td>
<td>206.8</td>
</tr>
</tbody>
</table>
Data Processing and Reports

Data Processing—eliminate invalid temperature measurements, 3 steps:
1. Eliminate measurement locations within 2 feet of the mat’s edge.
Data Processing and Reports

Data Processing—eliminate invalid temperature measurements, 3 steps:

2. Eliminate temperature readings < 170 ºF and > 400 ºF.
3. Eliminate data with paver stops greater than 60 seconds, between locations:
   - 2 feet behind measurement location of stop
   - 8 feet in front of measurement location of stop

Step 3 can be excluded.
Summary of Processed Data for one day of paving

Raw IR data: $T_{\text{avg.}} = 285$ °F
Processed data: $T_{\text{avg.}} = 305$ °F
Data Processing and Reports

- Temperature Differential Criteria, each 150 foot segment:

\[ T_{\text{Diff}} = T_{98.5} - T_{1.0} \]

- \( T_{\text{diff}} \leq 25 \, ^\circ\text{F} \)  
  **Minor temperature difference**

- \( 25 \, ^\circ\text{F} < T_{\text{diff}} \leq 50 \, ^\circ\text{F} \)  
  **Moderate temperature difference**

- \( T_{\text{diff}} > 50 \, ^\circ\text{F} \)  
  **Severe temperature difference**
Review results in real time.
Data Processing and Reports

Generating Reports

Generates PDF Report
Data Processing and Reports

Report; Tex 244-F

Tex 244-F
Thermal Profile Summary Report

<table>
<thead>
<tr>
<th>Profile ID:</th>
<th>95sb</th>
<th>Profile Date:</th>
<th>9/24/2015 9:18:13 AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profile Number:</td>
<td>Letting Date:</td>
<td></td>
<td></td>
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<tr>
<td>Status:</td>
<td>Controlling CSJ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>County:</td>
<td>Spec Year:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tested By:</td>
<td>Spec Item:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Location:</td>
<td>Special Provision:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material Code:</td>
<td>Mix Type:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material Name:</td>
<td>Producer:</td>
<td></td>
<td></td>
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<tr>
<td>Area Engineer:</td>
<td>Project Manager:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Course/Lift: 3
Segment Length (ft): 150
Temperature Differential Threshold: 25.0

Thermal profile summary:

<table>
<thead>
<tr>
<th>Number of Profiles</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>25.0°F &lt; differential &lt;= 50.0°F</td>
<td>differential &gt; 50.0°F</td>
</tr>
<tr>
<td>Number</td>
<td>Percent</td>
<td>Number</td>
</tr>
<tr>
<td>------</td>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
<td>0</td>
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</table>

Locations without thermal segregation:

<table>
<thead>
<tr>
<th></th>
<th>Lat</th>
<th>Long</th>
<th>Lat</th>
<th>Long</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>194.49</td>
<td></td>
<td>193.00</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>192.99</td>
<td></td>
<td>191.50</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>191.49</td>
<td></td>
<td>189.99</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>189.99</td>
<td></td>
<td>187.00</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>186.49</td>
<td></td>
<td>184.99</td>
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<td>6</td>
<td>183.99</td>
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<td>182.99</td>
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<td>7</td>
<td>182.99</td>
<td></td>
<td>180.99</td>
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<td>8</td>
<td>179.99</td>
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<td>9</td>
<td>177.99</td>
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<td>175.99</td>
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<td>10</td>
<td>174.99</td>
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<td>172.99</td>
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<td>11</td>
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<td>170.99</td>
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<td>167.99</td>
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<td>165.99</td>
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<td>164.99</td>
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<td>162.99</td>
<td></td>
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<td>159.99</td>
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<td>158.99</td>
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</tr>
<tr>
<td>17</td>
<td>155.99</td>
<td></td>
<td>155.99</td>
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</tr>
</tbody>
</table>

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Data Processing and Reports

Report; Tex 244-F

Distribution of mat temperatures.

Location of paver stops.
Infrared Technology Workshop

Part 3: IR Field Demonstration Projects—Findings
Field Demonstration Projects

Northern Mariana Islands / Guam

American Samoa

EFL
Field Demonstration Projects

Some summary results from field demonstration projects for making decisions in real time to:

- Place a uniform mat.
- Minimize risks and penalties.

Use of best paving practices; reduced temperature differentials.
Reinforcement of good paving practice; Maine demonstration project:

- Continuous improvement, more uniform mat temperatures, as paving progresses.

**EFFECT:** Reduced contractor’s risk of being penalized.
Effect of communication; Missouri demonstration project:

- Continuous improvement, more uniform mat temperatures, as paving progresses.

Near the beginning of day’s production.

Later that morning.

Near end of day’s production.
Effect of trucking; Virginia DOT demonstration project:

- Average temperature differential at start of paving was about 30 °F.
- Average temperature differential after adding 2 trucks was about 15 °F.

Few trucks with high local traffic = more paver stops.

More trucks = fewer paver stops & more uniform temp.
Field Demonstration Projects

**Effect of trucking; EFL demonstration project:**

- Significant paver delay between trucks.
- Reduced paver delay between successive trucks.

**EFFECT:** Less variability in mat density, and reduced contractor’s risk of being penalized.
Field Demonstration Projects

**Effect of loading trucks:** Multiple demonstration projects:

- One dump of mix in truck bed – severe temp. differential
- Two dump, no stockpile – reduced temp. differential.

Properly loading trucks significantly reduced the number of severe temperature differentials.
Field Demonstration Projects

**Effect of loading trucks:** Multiple demonstration projects:

Trucks with improperly installed tarps.

Trucks with properly installed tarps.

Temperature differences between trucks.
Field Demonstration Projects

Effect of tarps; Multiple demonstration projects:

Properly installed and maintained tarps significantly reduced the temperature differentials by about 40 percent.
Two Illinois demonstration projects: both used a MTV, so why the difference in temperature differentials?
Effect of speed; Illinois demonstration projects:

- Paving time = 640 min.
- Total Stop time = 106 min.
- Effective paving time = 534 min.
- Distance = 23,900 ft.
- Average speed = 44.8 ft./min.
- Average speed (effective) = 37.3 ft./min.
### Effect of MTVs; All field demonstration projects:

<table>
<thead>
<tr>
<th>Project</th>
<th>Delivery Truck Type</th>
<th>MTV Included</th>
<th>Percent Severe Temp. Differentials</th>
<th>Thermal Streaking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska</td>
<td>Bottom-Dump</td>
<td>Windrows</td>
<td>17</td>
<td>None</td>
</tr>
<tr>
<td>WV</td>
<td>End Dump</td>
<td>Yes</td>
<td>5</td>
<td>None</td>
</tr>
<tr>
<td>Maine</td>
<td>End Dump</td>
<td>Yes</td>
<td>5</td>
<td>None</td>
</tr>
<tr>
<td>Virginia</td>
<td>End Dump</td>
<td>Yes</td>
<td>5</td>
<td>None</td>
</tr>
<tr>
<td>NC</td>
<td>End Dump</td>
<td>Yes</td>
<td>18</td>
<td>None</td>
</tr>
<tr>
<td>NJ</td>
<td>End Dump</td>
<td>Yes</td>
<td>21</td>
<td>None</td>
</tr>
<tr>
<td>Missouri</td>
<td>End Dump &amp; Flow Boys</td>
<td>Yes</td>
<td>25</td>
<td>None</td>
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<tr>
<td>Illinois</td>
<td>End Dump</td>
<td>No</td>
<td>40</td>
<td>None</td>
</tr>
<tr>
<td>WV</td>
<td>End Dump</td>
<td>No</td>
<td>41</td>
<td>None</td>
</tr>
<tr>
<td>EFL</td>
<td>End Dump</td>
<td>No</td>
<td>83</td>
<td>None</td>
</tr>
</tbody>
</table>

Above includes paver stops.
Field Demonstration Projects

As a reminder; effect of cold spots on percent compaction; densities are:

- Lower
- More variable

TTI Study: 
$\Delta 25 \, ^{\circ}F \sim \Delta 6 \, pcf$

Maine DOT: 
$\Delta 20 \, ^{\circ}F \sim \Delta 4 \, pcf$
Impact on Contractor’s compaction operation:

Monitoring Densities during Rolling

Rolling the mat within the temperature sensitive zone.
Field Demonstration Projects

Impact on Contractor’s compaction operation:

After recognizing the effect of temperature sensitive zone; VA DOT demonstration project.
Field Demonstration Projects

Impact on contractor’s compaction operation:

Standard QC Plan; density measured after rolling.

Aggressive QC Plan

Areas with high temperature differentials can be marked and checked with nuclear density gauge during rolling.
Field Demonstration Projects

Percent within limits specification: higher variability implies greater risk for being penalized.
Break: Be back in 15 Minutes

REMINDERS:
SIGN-IN SHEET
PHOTO RELEASE FORM
PDH FORM
Infrared Technology Workshop

Part 4: Perspective of IR Scanner as a QA Tool
Application & Use:

- Continuous readings to evaluate mat uniformity through temperature uniformity.
- Non-uniform temperatures imply non-uniform densities, which usually mean higher maintenance.
Role of IR in Quality Assurance Programs:

1. Contractor QC plan
   - Monitor production/placement operations to minimize temperature differentials of mat.
   - Minimize risk of being penalized.
   - Forensic tool to trouble shoot low or non-uniform mat densities.

2. Agency acceptance plan
   - Identify areas to be sampled.
   - Dispute resolution.
   - Reduce future distress and maintenance costs.
Perspective as QA Tool

IR role in QC plan, answering specific questions:

- What changes need to be made, if any?
  - Paver delays and speed.
  - Paver maintenance; augers, kick-back flights, slat conveyor, etc.
  - Number & loading of trucks
  - Tarps
  - Etc.

- When to make changes to placement operations?
IR role in QC plan—Missouri demonstration project:

- Increased communication between plant and paver to minimize temperature differentials of mat.
IR role in QC plan—Maine demonstration project:

- Monitor average temperature differential on a lot by lot basis for identifying need to take action.
- 85 percent of segments exhibited < 25 °F.
- If average temperature differential exceeds 15 °F, risk for penalty increases.

Maine DOT: \( \Delta20 \, ^\circ F \sim \Delta4 \, pcf \)
Illinois demonstration project – Contractor Comments:

- Full integration into the paving process from the paver operator to the Management level
  - How the use of an MTV can be a great tool.
  - Management’s decisions have consequences; increased paver speed – increased risk of being penalized.
  - Makes meeting PWL better to reduce penalties
Perspective as QA Tool

IR Role in Acceptance Plan; examples:

1. Identify cold spots
   - Alaska, Minnesota, Missouri, Quebec, Texas, Washington

2. Identify thermal streaks
   - Quebec
IR Role in Acceptance Plan

- Determine biased areas for sampling and testing: Washington DOT
- Modify QA process/suspend paving operations: Texas DOT
- Price adjustments for temperature: Minnesota and Missouri DOT and Quebec
  - Independent verification is an issue.

WS DOT SOP 733
Determination of Pavement Density Differentials Using the Nuclear Density Gauge

1. Scope
   This test method describes the procedure for locating and testing areas of suspected low cyclic density. Lower pavement density has been related to temperature differentials and areas of “spots, streaks” or visual pavement irregularities. This method uses infrared detection devices and visual inspection to identify areas of potentially low cyclic density.

2. Definitions
   a. Temperature Differential Area: Any area where the temperature of the newly placed HMA pavement is greater than 25°F different than the surrounding area.
   b. Aggregate segregation: “Spots, streaks” or visual pavement irregularities in the newly placed HMA pavement that has a significant difference in texture when compared to the surrounding material.
   c. Systematic Density Testing: The testing of temperature differential areas or areas of aggregate segregation to determine if there is a pattern of low cyclic density.

3. Equipment
   a. An approved infrared camera OR a handheld noncontact infrared thermometer (features for both should include continuous readings, minimum, maximum, and average readings, laser sighting, and a minimum distance to spot size ratio (D:S) of 30:1.
   b. Nuclear moisture-density gauge.
   c. Tape measure.
   d. A can of spray paint for marking test locations.
   e. Required report form.

4. Testing Criteria
   a. Where temperature differentials are 25°F or greater a systematic HMA compaction test is required.
   b. Where temperature differentials are less than 25°F a systematic HMA compaction test is not required unless, an area shown signs of visual pavement irregularities, surface segregation or a significantly different texture.

5. Determination of Systematic Density Testing Locations
   Use either an infrared camera or a handheld non-contact infrared device to locate temperature differential areas as follows:
IR Role in Acceptance Plan:

- Paver stops excluded in most specifications from determining temperature differentials.
- Paver stops defined as more than 1 minute.
- Question answered from field demonstration projects;
  - Should paver stops be excluded or included in defining temperature differentials?
<table>
<thead>
<tr>
<th>Paver Stops</th>
<th>Total Number of Increments</th>
<th>Number of Increments within Temp. Regimes</th>
<th>Thermal Streaking</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Minor</td>
<td>Moderate</td>
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### Perspective as QA Tool

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<tr>
<td>Included</td>
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Recommended that paver stops be included in defining temperature differentials from thermal profile.
Required paver stops due to sampling should be eliminated from temperature difference profiles.
PWL specification: Higher density variability implies greater risk of being penalized.
**Perspective as QA Tool**

PWL Specification, example of contractor making real time decisions.

<table>
<thead>
<tr>
<th>Air Voids</th>
<th>No IR Scanner Used for QC</th>
<th>IR Scanner Used for QC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Limit</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.5</td>
<td></td>
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<tr>
<td>PWL</td>
<td>76</td>
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<tr>
<td>Percent Defective</td>
<td>24</td>
<td></td>
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</tbody>
</table>

Air voids = 100 – Percent compaction

\[ \mu = 6.5\text{ percent} \]

\[ \mu = 6.8\text{ percent} \]

USL = 8 percent

Profiler used.

Profiler not used.
Infrared Technology Workshop

Part 5: Implementation Strategies of IR Technology
Implementation Strategies

1. Some Common Steps for Deployment
2. Lead Agencies Strategies and Status
3. Summary Comments from Agency and Contractor Personnel
Agencies participated in the IR field demonstration project.

Lead state agencies that developed IR specifications.

Agencies beginning use or drafted specification for IR thermal profiler.

Agencies that have used the IR thermal profiler on recent projects.

Agencies attended an IR workshop & are planning to move forward with the IR thermal profiler.
Deployment Strategy, Common Steps/Tasks:

1. **Define temperature differences that cause significant distress**, increasing maintenance cost & reducing service life (Minnesota, Ontario, Texas, Washington).
   a) Many published reports that document the importance of temperature

2. **Identify mat property changes** between areas with severe temperature differentials (Ontario, Texas).
   a) Many research reports that identify how density affects the mat’s properties related to performance

3. **Draft IR specification** (Minnesota, Ontario, Texas, Washington)
4. Obtain comments from industry for revising specification; getting input from other partners (Ontario, Minnesota, Texas)
5. Host/sponsor training sessions with equipment/software
Steps for Deployment

Deployment Strategy, Common Steps/Tasks:
6. Execute pilot projects over 1 to 2 years (Minnesota, Ontario)
7. Educate industry/agency personnel on results (Ontario)
8. Update/revise specification (Minnesota, Ontario, Texas, Washington)
9. Establish actions based on temperature profile differences (all)
   a) Increased density testing (Texas)
   b) Biased testing (Washington)
   c) Incentives/disincentives based temperature differentials (Minnesota, Ontario)
10. Confirm appropriateness of acceptance plan (Ontario)
11. Full deployment
Implementation Strategies

1. Some Common Steps for Deployment

2. Lead Agency Strategies and Status
   - Washington, Texas, Minnesota DOT and Quebec Province—full deployment
   - Alaska, Maine, Missouri DOT—in deployment

3. Summary Comments from Agency and Contractor Personnel
Focus – Determine biased areas for sampling and testing:

- Based on use of IR camera; IR scanner is an option, and still allows an IR handheld device.
- Core density locations defined by cold spots.
Goal – Improve pavement performance by encouraging Contractors to optimize paving operations.

- Optional for all paving projects.
- Specification incentives:
  - No density profiles or thermal profiles.
  - Can pave at lower temperatures.
  - Bonuses not waived for non compliance.
  - Automated documentation.
  - Contractor’s ticket taker not required to measure mix temperature and record station # on haul tickets.
Agency Strategies—Texas

Current Specification:
- “Pave-IR” replaced with “Thermal Imaging” system to include the scanner.
- Removes the option of using the thermal gun to perform thermal profiles.
- Updated thermal camera testing procedure.
Agency Strategies—Texas

Experience to Date:

• Eliminates the QC technician from having to perform segregation density profiles, and thermal profiles;
• Improves placement and ride bonus opportunities and minimizes penalties, resulting in a prompt return on investment cost;
• Data can be viewed locally at the paver and remotely in real time;
• Improves QC/QA confidence level when paving and compacting mix in cooler temperatures;
• Knowledge gained provides instantaneous feedback from the paver back to the plant.
Agency Strategies—Minnesota

<table>
<thead>
<tr>
<th>Percentage of Sublots, %</th>
<th>End Dump</th>
<th>Pickup Machine</th>
<th>Material Transfer Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>32</td>
<td>2</td>
<td>27</td>
</tr>
<tr>
<td>Moderate</td>
<td>68</td>
<td>56</td>
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</tr>
<tr>
<td>Severe</td>
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</table>

End Dump, Pickup Machine, Material Transfer Device.
Update – Minnesota will move away from pay factors using the Thermal Profiler

Looking to move to full coverage density testing using the Rolling Density Meter GPR system
Goal – Identify thermal streaks using the IR camera:

• Locations or IR photos determined at random.

• Specific procedure identified for taking photos with IR camera and calculating streaks.

• Thermal streaks defined as $\Delta T$ greater than 5°C along a longitudinal line.

• Penalty determined based on sealing longitudinal cracks.
1. Some Common Steps for Deployment
2. Lead Agencies Strategies and Status
3. Summary Comments from Agency and Contractor Personnel
Summary Comments

Comments from Contractors and Agencies that have used the IR Paver Mounted Thermal Profiler:

1. If the IR scanner technology **saves one grind of a project, the equipment paid for itself**; Maine DOT.
2. The IR scanner equipment is a **self-policing tool**.
3. Pike Industries purchased their first IR unit about 2 years ago and used it on a project in Vermont. Pike Industries found it to be a **good tool to make real time adjustments**.
4. It is a **good forensic tool**, compared to cores, especially to explain why an area has low density. A drop of 15 ºF can result in a significant drop in mat density.
5. The scanner helps in adding trucks for increased uniformity, adjusting practices, and shows the benefits of short hauling.
Comments from Contractors and Agencies that have used the IR Paver Mounted Thermal Profiler:

6. Contractors see it as a great training tool for new operators or additional training for experienced crews.

7. The scanner data is a vivid tool for showing how rideability is influenced by the uniformity of temperatures.

8. Even though the EFL project had extensive thermal differences throughout the project, the contractor still achieved desired density – so PaveIR is not the whole story.

9. If the agency provided the scanner equipment for free, then contractors would most likely take and use the equipment.
Summary Comments

Other Comments:

1. Real-time thermal mapping with color display on paver provides immediate feedback to DOT and paving crew.
2. The dump man can see cold spot created when loads are not tied together.
3. A truck driver can be shown the effect of cold crust from an untarped or improperly tarped truck.
4. The paver operator can see the cold spots created by stopping or dumping the wings of the paver.
5. Malfunctions of the paver will show up as streaking on the mat.
Infrared Technology Workshop

Part 6: Products from Field Demonstration Projects
1. IR Primer

• Purpose
  – Introduce the Pave-IR method to transportation agencies and contractors.
  – Increase awareness of how IR can improve paving operations and increase uniformity of mat.
  – Demonstrate use of Pave-IR as a QC Tool.

• Outcome
  – Based on all 10 demonstration projects.

Draft available and issued as a handout for workshop.
3. Trouble Shooting and Best Practices Guide

• Purpose of Guide
  – Provide guidance on:
    • Setting up the equipment and getting started.
    • Interpreting the raw data for making decisions.
  – Identify data collection and maintenance issues with the equipment and software.

• Outcome
  – Based on all 10 field demonstration projects.
  – Experience of agencies & consultants.

Draft Available.
Other products available include the MOBA Installation Manual.

The Trouble Shooting, Best Practices, and Lessons Learned Guide are intended to supplement the MOBA User and Installation Manuals.
4. Specification Guide

• Purpose
  – Advance standardization of IR equipment and testing protocols through AASHTO.
  – Agencies can customize it to their needs.

• Outcome

• Based on:
  – Field demonstration projects
  – Agency Experience: Minnesota DOT, Texas DOT, etc.
5. Case Study Report on Deployment:
   • Purpose
     – Enhance the deployment and use of the IR technology.
     – Identify/summarize lessons learned from field trials.
     – Confirm Pave-IR can identify the different types of temperature differentials that affect mat density and pavement performance.

6. Case Study Report on Performance:
   • Purpose
     – Document impact on performance by increased mat uniformity.

Drafts Available.
IR Paver Mounted Thermal Profiler Showcase

Questions/Answers and Closing Comments
Contacts for More Information:

- Stephen Cooper: Stephen.J.Cooper@dot.gov
- Kate Kurgan: kkurgan@aashto.gov
- Joe Reiter: jreiter@ara.com
- Harold Von Quintus: hvonquintus@ara.com

Websites:

- http://shrp2.transportation.org/Pages/R06C_RapidTechnologies_to_Enhance_Quality_Control.aspx
• Complete workshop forms
• R06C: additional information on Thermal Profiler
  ▪ AASHTO Site: http://shrp2.transportation.org
  ▪ FHWA Site: www.fhwa.dot.gov/goshrp2