Measuring Pavement Segregation

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Historically segregation (both physical & thermal) has been a major contributor to premature failures in flexible pavements with HMA surfaces.

- TxDOT’s 2004 Standard Specifications attempted to address these concerns by requiring thermal profiles, density profiles & restricting paving when the surface temperature is below 60°F (70°F for SMA - 50°F for unmodified binders).
- Many TxDOT districts also required the use of MTVs (shuttle buggies) to mitigate the problem.
- Method of measuring thermal segregation with a hand held infrared thermometer proved to be relatively ineffective.
- For the past 10 years, TxDOT has been working with TTI to develop a better methodology to measure thermal segregation.
- TxDOT is now implementing the Pave-IR system developed by TTI and manufactured by Moba Corp.
How TxDOT Specifications Address Segregation

- A minimum of one “Thermal Profile” is required on every sublot of HMA. (Thermal profiles are 150 ft. in length)
  - No QCQA bonus is paid if there is “severe” thermal segregation.
  - A “failing” thermal profile requires additional an additional density profile. Failing is defined as > 25°F thermal segregation.

- A “Density Profile” is required a minimum of once on every sublot. (11 density gauge readings taken 5 feet apart in a line parallel to paving direction)
  - And every time the paver stops,
  - And at locations where thermal segregation is identified
  - And where visible segregation is identified
  - Contractor waives QCQA bonus if profile fails
  - Remove and replace sublot if it fails the density profile and has severe thermal segregation.

- Note: density profiles are never required and not applicable if the Contractor opts to use the Pave-IR system.
Visibly Segregated Areas

Paver Stops

Placement Testing
Segregation (Density Profile)

Random Locations
Pave-IR Output Showing Thermal Segregation (Truck End)
**TxDOT Definition of Thermal Segregation**

- **Moderate**
  >25°F to 50°F

- **Severe**
  >50°F
Implementation of the Pave-IR System

- **Goal**: Improved pavement performance by encouraging Contractors to improve paving operations

- **Optional** for use on TxDOT HMA paving projects

- **TxDOT specifications incentives**
  - No density or thermal profiles
  - Can pave at lower temperatures
  - Potential QCQA bonuses not waived for non compliance to density profile or thermal segregation requirement

- Used in lieu of an MTD – End dumps not allowed w/o MTD

- Automated documentation

- Contractor’s ticket taker not required to measure mix temperature and record station # on haul tickets

- Other minor incentives included in specification
Historically segregation thought of as mechanical (gradation) phenomenon

1996 – WSDOT discovered thermal imaging could detect segregation

- Cold spots became low density areas
- 89 percent of locations with $\Delta t > 25 \, ^\circ F$ failed density uniformity criteria

Thermally segregated locations holding water (courtesy WSDOT)
Placement Testing
Tex-207-F, Part V

- Profile a 50 foot section
  Include any visually segregated areas
- Offset of 2 ft or more from pavement edge
- Take density readings every 5 ft
Example of a Density Profile (in pcf)

Note: TxDOT allows a maximum differential of 6 pcf from high to low or 3 pcf from low to average.
• NCAT (2000) and TTI (2002) similarly found thermal uniformity suitable for detecting segregation
  – NCAT – low severity segregation when $\Delta t > 18 \, ^\circ F$
  – TTI – when $\Delta t > 25 \, ^\circ F$, TxDOT density uniformity requirements not met

![Graph showing the relationship between change in temperature (F) and change in density (pcf).](image)

- Spec max density differential = 6 pcf
- 6 pcf density differential at ~ 25 F temp differential
- $y = 0.2415x$
- $R^2 = 0.9027$
Sampling Distributions of Segregated and Non-Segregated HMA

![Graph showing sampling distributions of segregated and non-segregated HMA](image)
Why is Thermal Segregation Important?

- Recall cold spots typically become low density
- Density is “a” or “the” primary contributor to pavement performance
- Contractor and agency risk are impacted
  - Acceptance and pay schedules are based on density
  - Segregated locations distress prematurely
  - Ride quality ultimately impacted by thermal segregation
Early observations: coarser texture and holding water
Raveling and Cracking Follow
Fatigue Life Substantially Reduced

Source: NCAT (2000)
Common Methods of Measuring Thermal Segregation

- Infrared Thermometers – less than $200
- Infrared Cameras – less than $5K
- Pave-IR System – less than $30K
Measuring Thermal Segregation

- Test Method Tex-244-F
  - Handheld IR thermometer
  - Thermal camera
  - Pave-IR
Current Usage of Pave-IR

- Texas – 25+ Units
- Other users:
  - Minnesota
  - Wisconsin
  - NCAT
- Other interested regions:
  - Washington
  - Alaska
  - Quebec
  - Ohio
  - Michigan
  - Germany
  - China
<table>
<thead>
<tr>
<th>Test Device</th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
</table>
| Handheld IR Thermometer | - Inexpensive.  
                        - Simple to use.  
                        - Tests independent of paving train. | - Requires constant operator attendance.  
                        - May miss localized defects.  
                        - No permanent record. |
| IR Camera            | - Inexpensive.  
                        - Simple to use.  
                        - Tests independent of paving train.  
                        - More coverage than thermometer. | - Requires constant operator attendance.  
                        - May miss localized defects.  
                        - No permanent record (usually). |
| Pave-IR              | - Does not require constant operator attendance.  
                        - Provides real-time feedback.  
                        - Tests virtually full-coverage.  
                        - Automated data reduction.  
                        - Permanent record. | - Most costly device.  
                        - Testing coverage could impact risk of finding defects.  
                        - May include artificial cold spots in data set. |
Summary Results during Data Collection

- Press the button to view summary results

Pave-IR Summary Results Screen
Example report from project with minimal thermal segregation
Summary of Locations with Thermal Segregation

<table>
<thead>
<tr>
<th>Profile Nr</th>
<th>Beginning Location</th>
<th>Ending Location</th>
<th>Max Temp</th>
<th>Min Temp</th>
<th>Temperature Differential</th>
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<tbody>
<tr>
<td></td>
<td>Station GPS in °</td>
<td>Station GPS in °</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1020.37</td>
<td>97.57571 W, 33.21001 N</td>
<td>255.4</td>
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<td>25.8</td>
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<tr>
<td>5</td>
<td>1020.83</td>
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<td>265.6</td>
<td>229.6</td>
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<tr>
<td>6</td>
<td>1021.29</td>
<td>97.57491 W, 33.20965 N</td>
<td>265.6</td>
<td>238.8</td>
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<tr>
<td>8</td>
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</tr>
<tr>
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Summary of Locations Without Thermal Segregation

<table>
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<th>Min Temp</th>
<th>Temperature Differential</th>
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<tbody>
<tr>
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<td>Station GPS in °</td>
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<tr>
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Distribution of Placement Temperatures

Mean: 263 °F
Median: 265 °F
σ: 0.40 °F
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<thead>
<tr>
<th>Location (stations)</th>
<th>Duration (h:min:sec)</th>
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<td>1039.91</td>
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</table>
Example report from project with severe thermal segregation
### Summary of Locations with Thermal Segregation

<table>
<thead>
<tr>
<th>Profile Nr</th>
<th>Beginning Location</th>
<th>Ending Location</th>
<th>Max Temp</th>
<th>Min Temp</th>
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<td>GPS in °</td>
<td>Station</td>
<td>GPS in °</td>
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</table>

### Distribution of Placement Temperatures

- **Mean**: 289 °F
- **Median**: 296 °F
- **σ**: 2.25 °F

### Location of Paver Stops greater than One Minute

<table>
<thead>
<tr>
<th>Location (stations)</th>
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<tbody>
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<tr>
<td>196.78</td>
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</table>

ID: Demo - severe thermal segregation
When Moderate Thermal Segregation (25°F – 50°F) is Detected

- If Contractor uses hand held thermometer or thermal camera for specification compliance: Take corrective action and:
  - Perform a density profile at the location thermal segregation was detected
  - If density profile fails – contractor waives QCQA production and placement bonus
  - If density profile passes – QCQA bonus if applicable will be paid provided contractor provides all documentation of thermal and density profiles

- If Contractor uses Pave-IR for specification compliance
  - Modify the paving process as necessary to eliminate any (moderate or severe) thermal segregation identified by the Pave-IR system.
  - No further action (density profile) required
  - QCQA bonus if applicable will be paid provided contractor provides automated documentation of Pave-IR output
When Severe Thermal Segregation (> 50°F) is Detected

- If Contractor uses hand held thermometer or thermal camera for specification compliance
  - Suspend operation & take immediate corrective action
  - **No applicable QCQA bonus will be paid for production or placement if severe thermal segregation is identified**
  - Perform a density profile at the location thermal segregation was detected
  - If density profile fails – Contractor must remove and replace the sublot

- If Contractor uses Pave-IR for specification compliance
  - Engineer **may suspend operations if recurring severe thermal segregation is identified**.
  - No further action (density profile) required
  - QCQA bonus if applicable will be paid provided contractor provides automated documentation of Pave-IR output.
Conclusions

- Physical & thermal segregation are the “Cancer of HMA Paving Industry”
- You cannot always see it. It grows with time. It often results in the early death of the pavement - often the only reason some HMA pavement are in need of rehabilitation
- There are many known & suspected causes & cures – No consensus
- Identifying & Eliminating Thermal Segregation is a Major Goal for TxDOT
**Conclusions**

- TxDOT is implementing better specifications & better techniques to address the problem of thermal segregation
- The Pave-IR System is an excellent “Passive Inspection” device that allows end result versus method specifications
- It allows contractors to see what they are doing and improve their operations
- Contractors can focus on causes & cures
- Every contractor that has used the Pave-IR system state that they have improved their paving process from the feedback they get from the system.
- Pave-IR not required except: End dumps w/o shuttle buggy

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“**What Gets Measured Gets Done**”