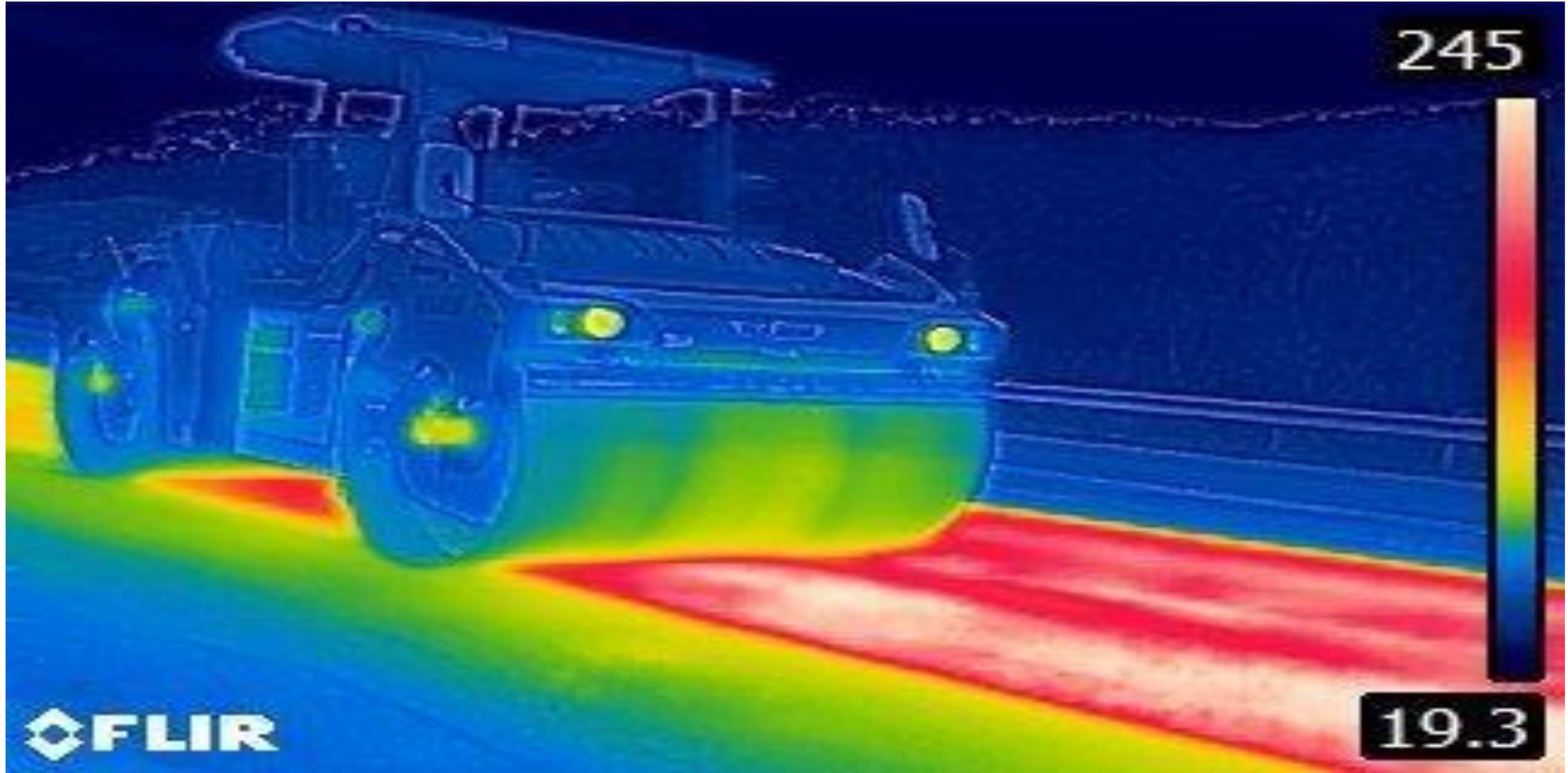


# Battling Segregation Using Pave IR System



# What is Thermal Segregation

- Thermal segregation is defined as temperature differences in the hot mix asphalt (HMA) mat as it is placed and is a potential cause of premature failure in asphalt roads. It can cause a significant reduction in pavement life due to low density from cold spots in the HMA mat.



# SYMPTOMS OF THERMAL SEGREGATION



- **Localized spots of coarse texture**
  - May hold water after rain event
- **Premature failure due to fatigue cracking, raveling, and moisture damage**
- **Increased roughness**
- **Same as insufficient compaction**

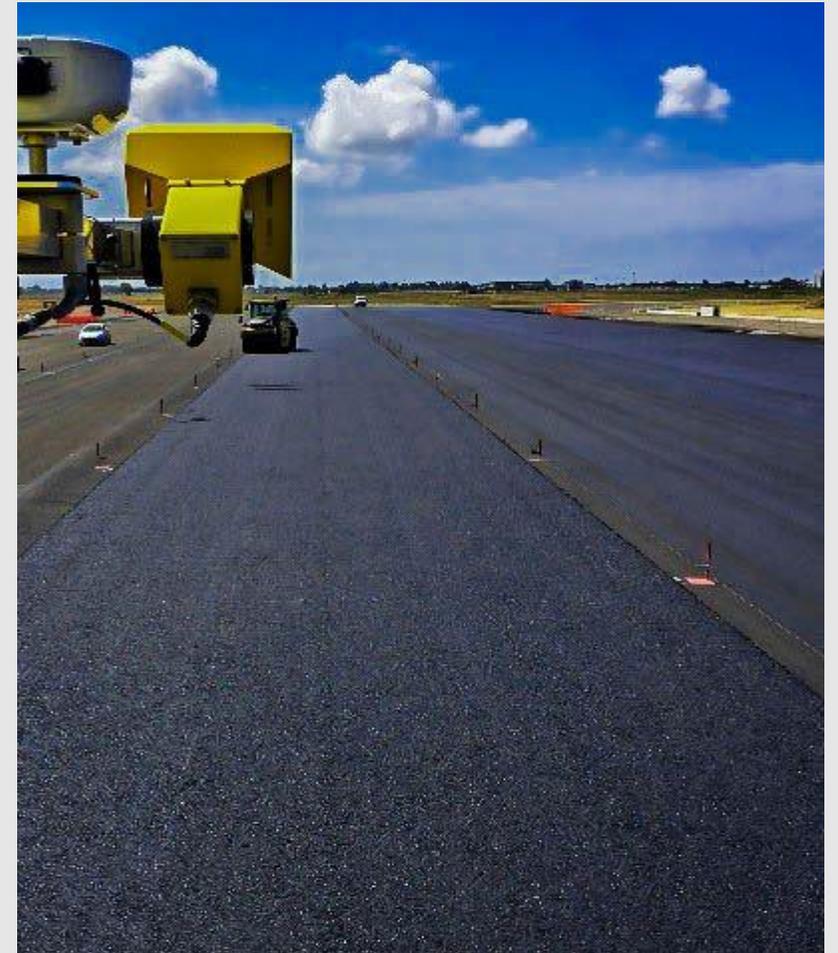
## Rules of Thumb – Why Does it Matter

- For dense graded HMA, 1% increase in air voids (above a baseline value of 7%) will result in a minimum 10% decrease in pavement life
- 25 ° F temperature differential = 1-2% more air voids
- No significant compaction occurs below cessation temperature (about 175 ° F).



# Methods for Identifying Thermal Segregation

## Handheld Infrared Thermometers – Camera – Bar - Scanner



## Handheld Infrared Thermometers 1<sup>st</sup> Generation of Thermal Detection



**Handheld Infrared Thermometers are not allowed for temperature profiles in the 2014 Specification**



# TxDOT's 2014 Specification Regarding Thermal Segregation

- Use a hand-held thermal camera or a thermal imaging system to obtain a continuous thermal profile in accordance with Tex-244-F.



# Methods for Identifying Thermal Segregation

## Pave-IR Bar System



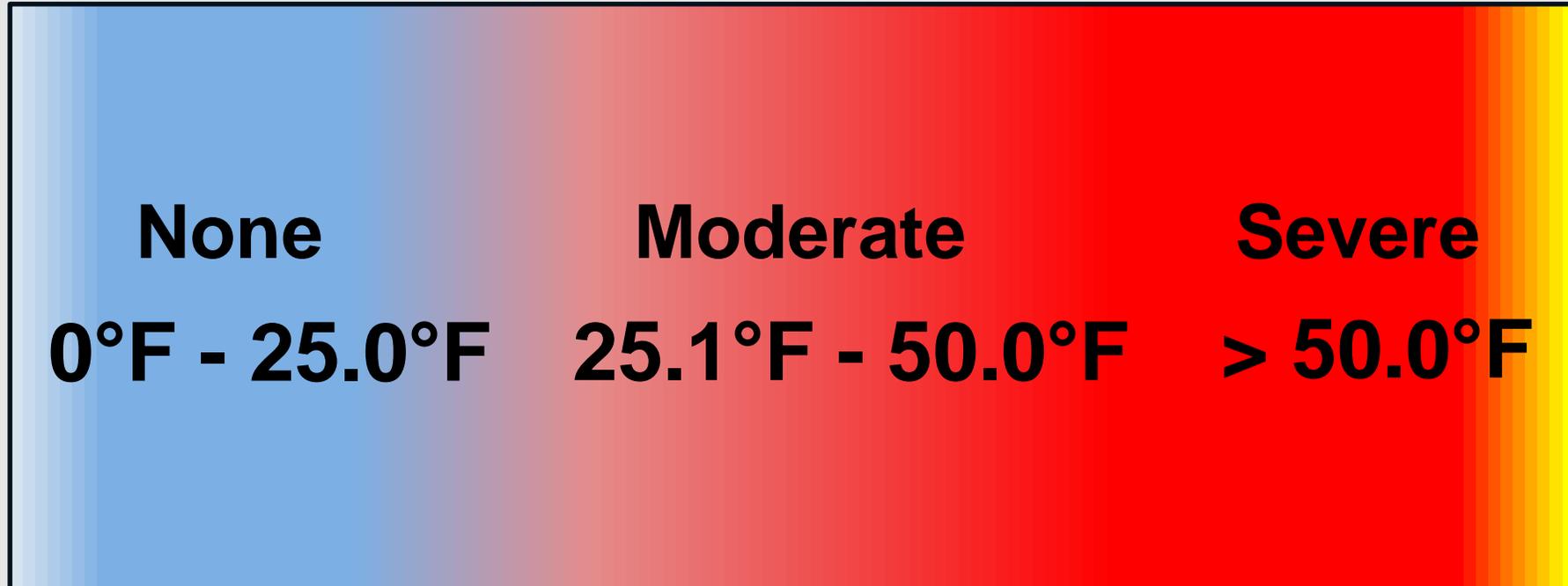
## Pave-IR Scan System



## Thermal Camera



# TxDOT's Classification of Thermal Segregation



# Thermal Imaging System Vs Thermal Camera (Item 344)

## Thermal Imaging System

– May pave any time roadway is dry and surface temperature is 32°F

– The Engineer may suspend paving operations for recurring severe thermal segregation

– Density profiles are not required and not applicable

– Do not lose bonus for severe thermal segregation

## Thermal Camera

– Minimum surface temperatures depend on PG grade and subsurface or surface layer; but minimum may be upwards of 60°F

– ~~Take immediate corrective action to eliminate recurring moderate thermal segregation~~

– Suspend operations and take corrective action to eliminate severe thermal segregation, unless otherwise directed

– Evaluate areas with moderate and severe thermal segregation by performing density profile

– No production or placement payment bonus for sublots with severe thermal segregation

# Thermal Camera Requirements

- Thermal camera requirements are outlined in Tex-244-F, “Thermal Profile of Hot Mix Asphalt”
  - Minimum resolution of 19,200 pixels
    - Older cameras may not meet this requirement
- TxDOT Selected
  - Camera is FLIR E6
  - Handheld (not mounted, portable)
  - Thermal image is displayed in real time
  - Pull the trigger to take thermal images
  - A digital image is also taken

Test Procedure for

## THERMAL PROFILE OF HOT MIX ASPHALT



TxDOT Designation: Tex-244-F

Effective Date: December 2015

### 1. SCOPE

- 1.1 Use this test method to obtain a thermal profile that identifies the presence of thermal segregation of an uncompacted mat of hot mix asphalt. This method includes procedures for determining thermal profile using:
- a hand-held thermal camera immediately behind the paver during uninterrupted paving operations, or
  - a paver-mounted thermal imaging system.
- 1.2 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

### 2. APPARATUS

- 2.1 Thermal camera or thermal imaging system.
- 2.1.1 Hand-held thermal camera must be capable of:
- measuring from 40°F to 475°F with an accuracy of  $\pm 4^\circ\text{F}$  or  $\pm 2\%$  of reading, whichever is greater;
  - producing an IR image minimum resolution of 19,200 pixels;
  - displaying the maximum temperature and minimum temperature using a LCD viewing screen with a minimum diagonal dimension of 3.0 in.;
  - storing a minimum of 50 images and capable of opening images while in operation;
  - a thermal sensitivity less than 0.15°F; and
  - a variable emissivity from 0.1 to 1.0.
- 2.1.2 Paver-mounted thermal imaging system must be capable of:
- measuring at a maximum transverse spacing of  $12 \pm 1$  in.;
  - using infrared sensors to measure from 40–475°F with an accuracy of  $\pm 3.5^\circ\text{F}$  or  $\pm 1.5\%$  of reading, whichever is greater, when the object temperature exceeds 32°F and the ambient temperature is  $73 \pm 9^\circ\text{F}$ ;

## ■ Camera Settings

- Emissivity = 1.00
- Reflected Temperature = 68°F
- Distance = 10 feet
- Language = English
- Temperature Unit = °F
- Distance Unit = Feet
- Set Correct Date and Time
- Color = Rainbow
- Image Mode = Thermal MSX

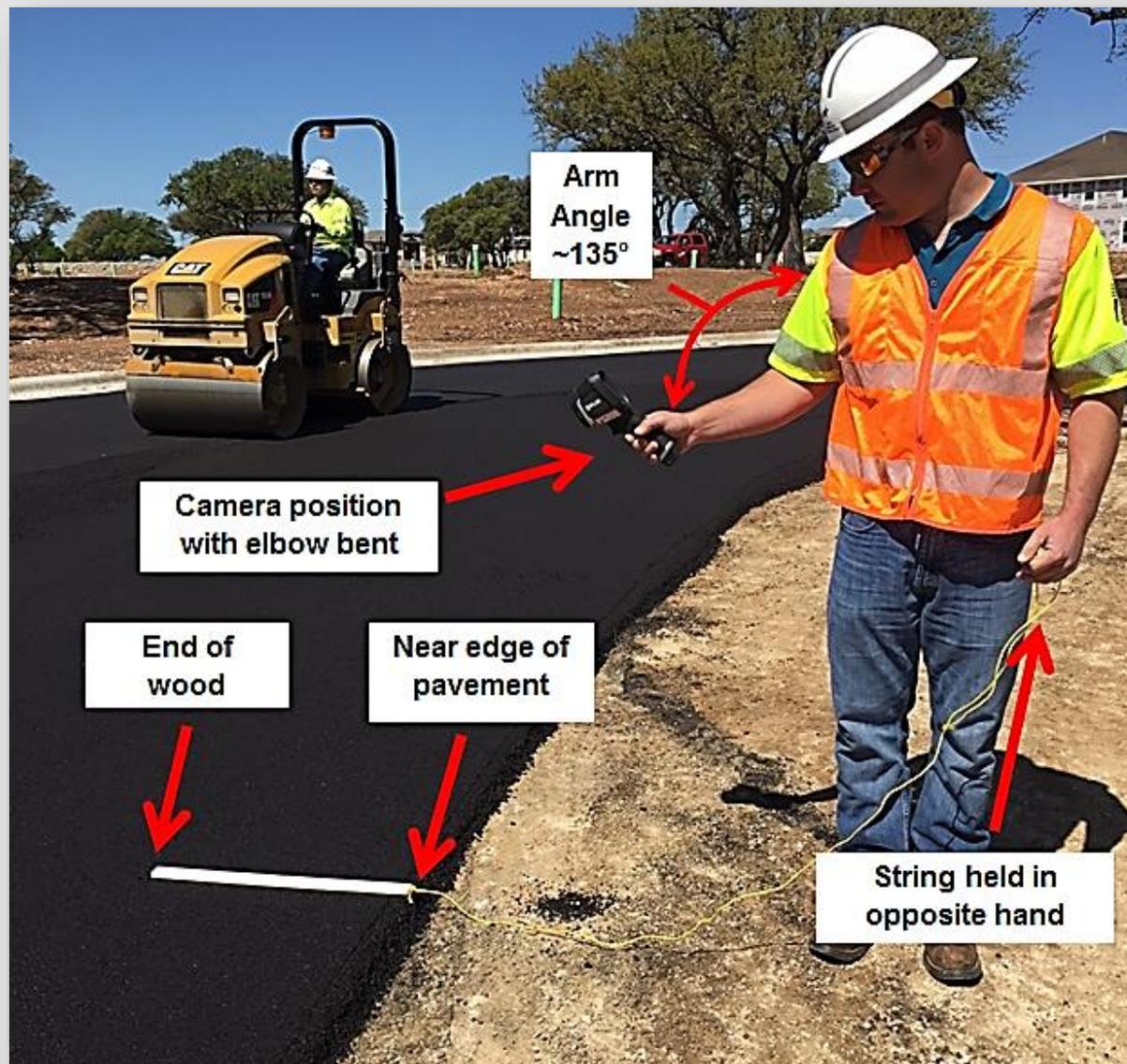


# Thermal Camera Guidelines

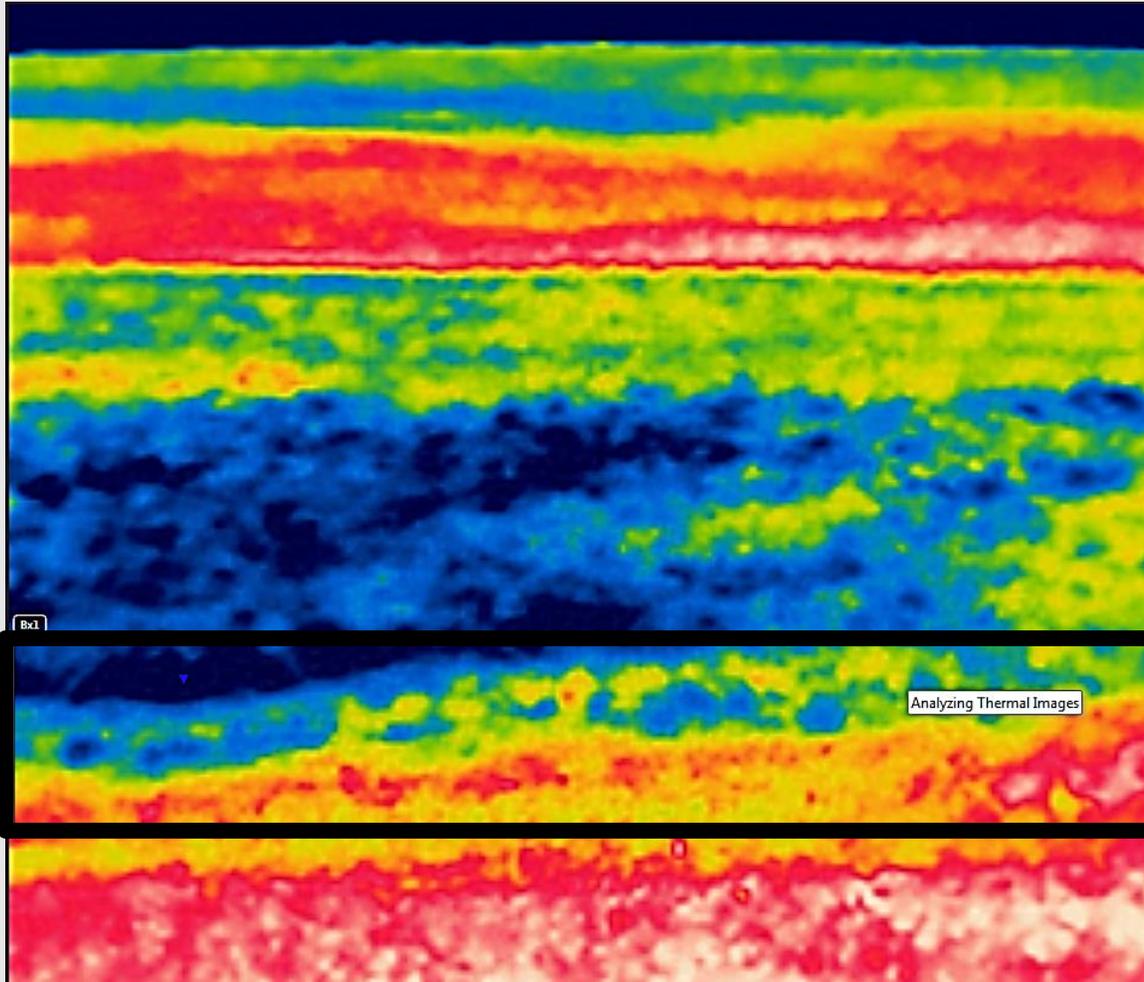
- Take several thermal images for each thermal profile
  - Recommendation is 2 to 3 photos for the first 20 feet (max. baseline)
  - 13 to 15 photos for the remaining 130 feet
- Take corrective action to eliminate recurring moderate thermal segregation
- Suspend operations and take immediate corrective action to eliminate severe thermal segregation unless otherwise directed
- Use the camera to mark areas of moderate and severe segregation, which can be followed up with a density profile



# Guidance Document – Procedure



# Thermal Camera Examples of Thermal Segregation

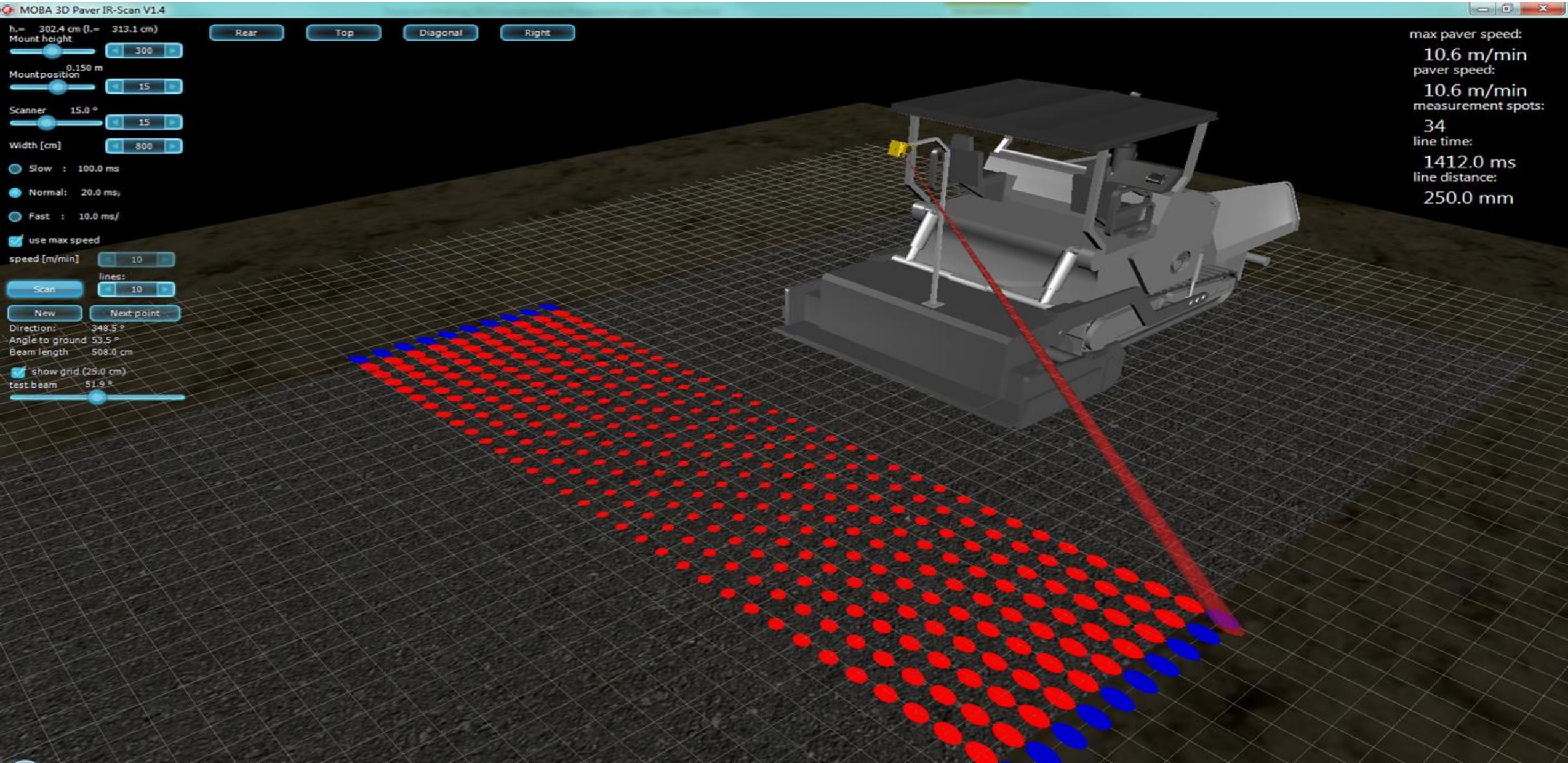


| Measurements       |                   |       | °F   |
|--------------------|-------------------|-------|------|
| Bx1                | Max               | 235.5 |      |
|                    | Min               | 187.9 |      |
|                    | Average           | 217.6 |      |
| Dt1                | Bx1.Max - Bx1.Min | 47.7  | ⚙️ ✕ |
| Parameters         |                   |       |      |
| Emissivity         | 1.00              |       |      |
| Refl. temp.        | 68.0°F            |       |      |
| Distance           | 10.0ft            |       |      |
| Atmospheric temp.  | 68.0°F            |       |      |
| Ext. optics temp.  | 68.0°F            |       |      |
| Ext. optics trans. | 1.00              |       |      |
| Relative humidity  | 50.0%             |       |      |
| Hide ▲             |                   |       |      |

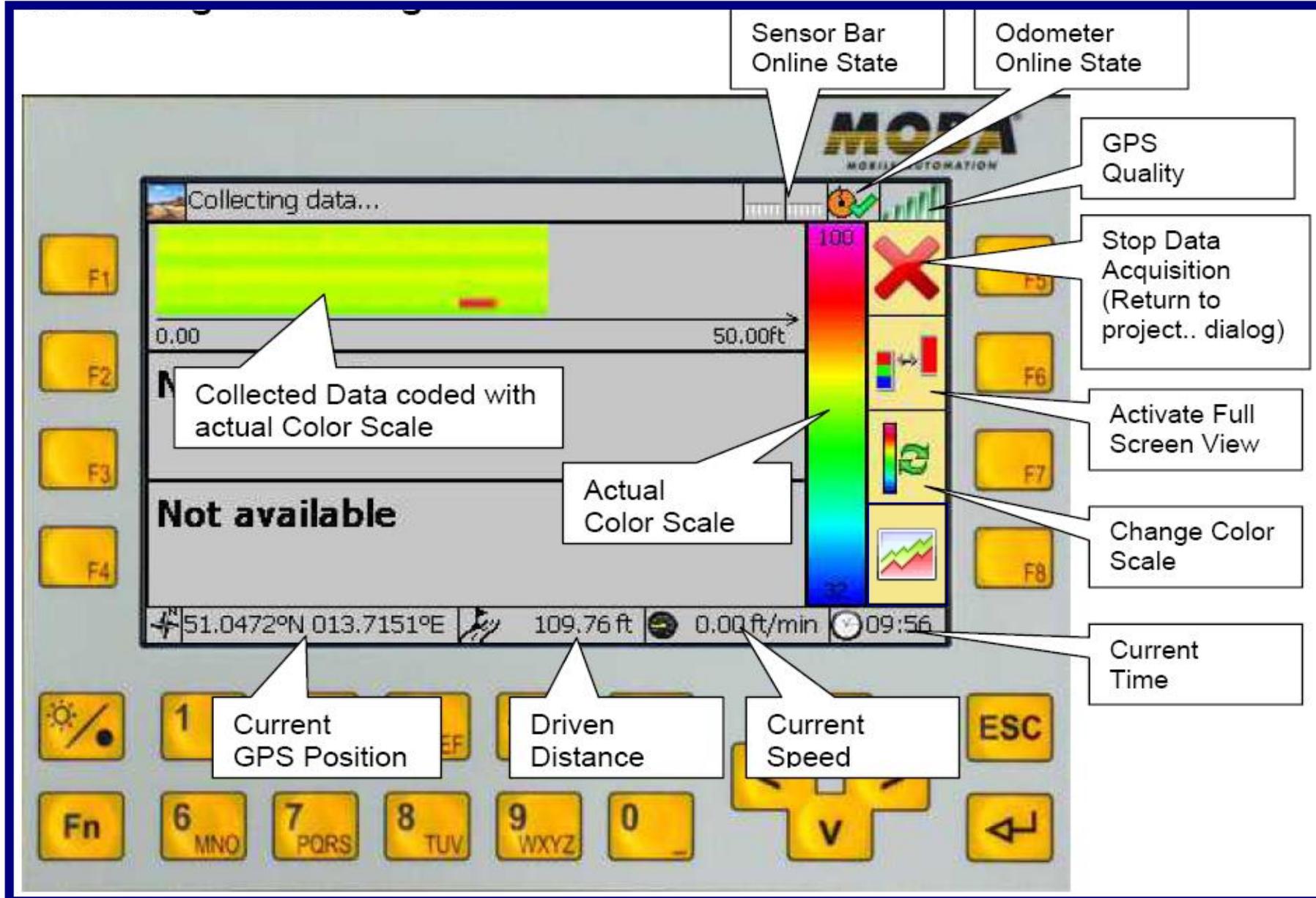
# Cause



# Segment sampling across the mat every 9"



# DATA COLLECTION SCREEN



The screenshot displays the MOBA (Mobile Automation) interface for data collection. The main display area shows a color-coded data collection strip from 0.00 to 50.00ft. A vertical color scale legend is visible on the right side of the strip, ranging from blue at the bottom to red at the top, with '100' at the top. The text 'Not available' is displayed in the lower-left area of the data strip.

Annotations and callouts include:

- Sensor Bar Online State**: Callout pointing to the top status bar.
- Odometer Online State**: Callout pointing to the top status bar.
- GPS Quality**: Callout pointing to a small icon in the top right.
- Stop Data Acquisition (Return to project.. dialog)**: Callout pointing to a red 'X' button on the right side.
- Activate Full Screen View**: Callout pointing to a button with a double-headed arrow icon.
- Change Color Scale**: Callout pointing to a button with a color scale icon.
- Current Time**: Callout pointing to the time '09:56' in the bottom status bar.
- Current GPS Position**: Callout pointing to the coordinates '51.0472°N 013.7151°E'.
- Driven Distance**: Callout pointing to the value '109.76 ft'.
- Current Speed**: Callout pointing to the value '0.00 ft/min'.
- Collected Data coded with actual Color Scale**: Callout pointing to the data strip.
- Actual Color Scale**: Callout pointing to the vertical color scale legend.

Function keys (F1-F8) are visible on the left and right sides of the screen. The bottom of the screen shows a keyboard with function keys (Fn, 1-0) and navigation keys (ESC, arrow keys).

*Dump men are important! Can't stress this enough*

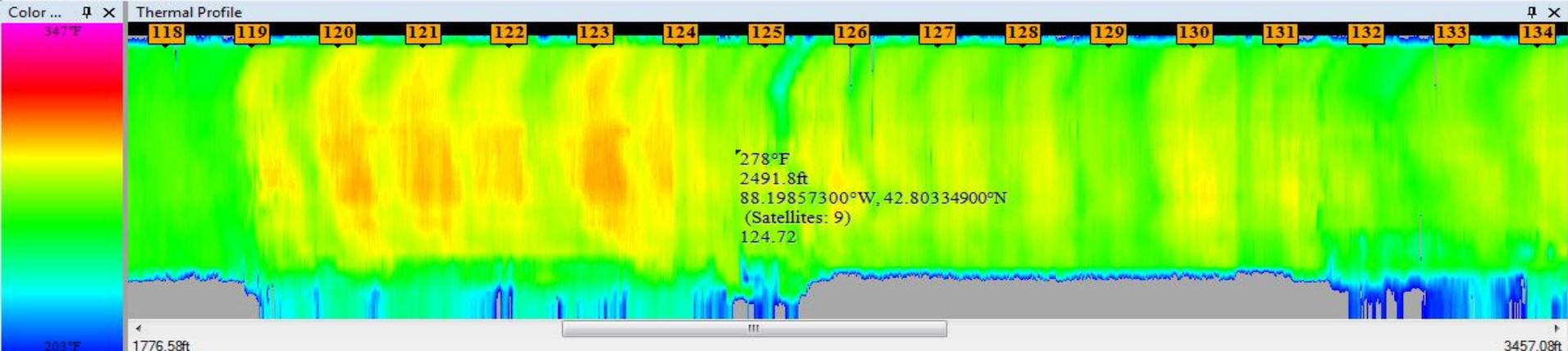


# End of load segregation

Pave Project Manager - TemporaryInternetProject.paveproj (Finished on 10/23/2013 6:28 PM)

File View Report Options Help

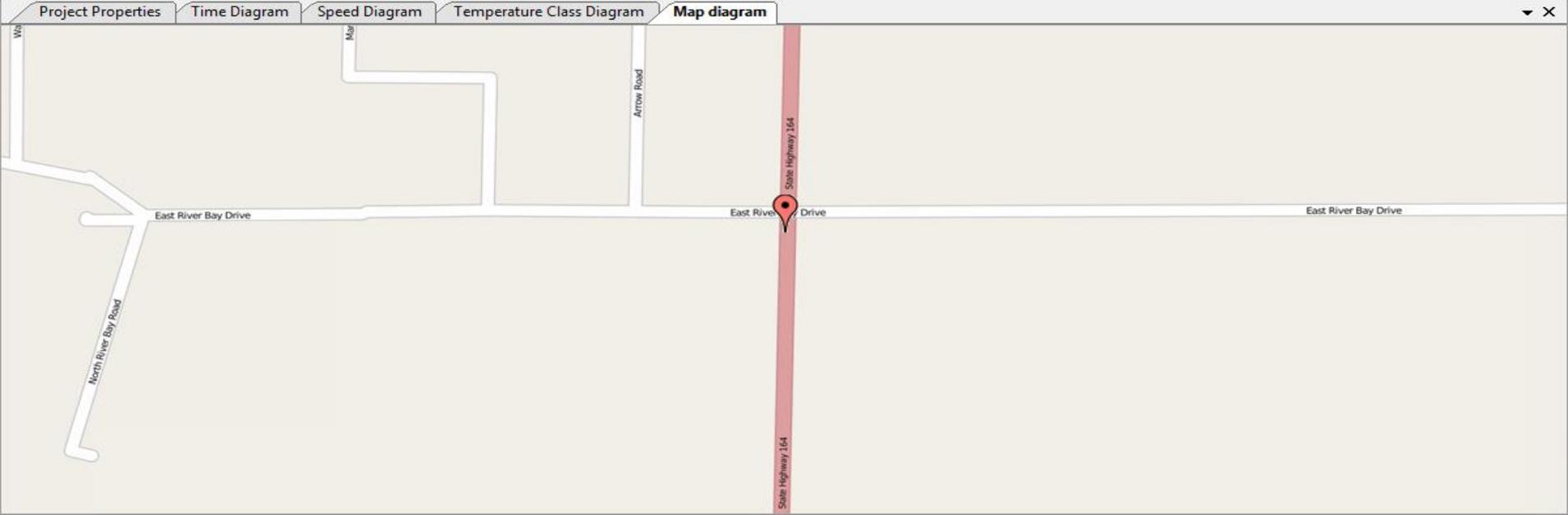
Color ... Thermal Profile



278°F  
2491.8ft  
88.19857300°W, 42.80334900°N  
(Satellites: 9)  
124.72

1776.58ft 3457.08ft

Project Properties Time Diagram Speed Diagram Temperature Class Diagram **Map diagram**



North River Bay Road  
East River Bay Drive  
Arrow Road  
State Highway 164  
East River Drive

**Properties**

Thermal Profile

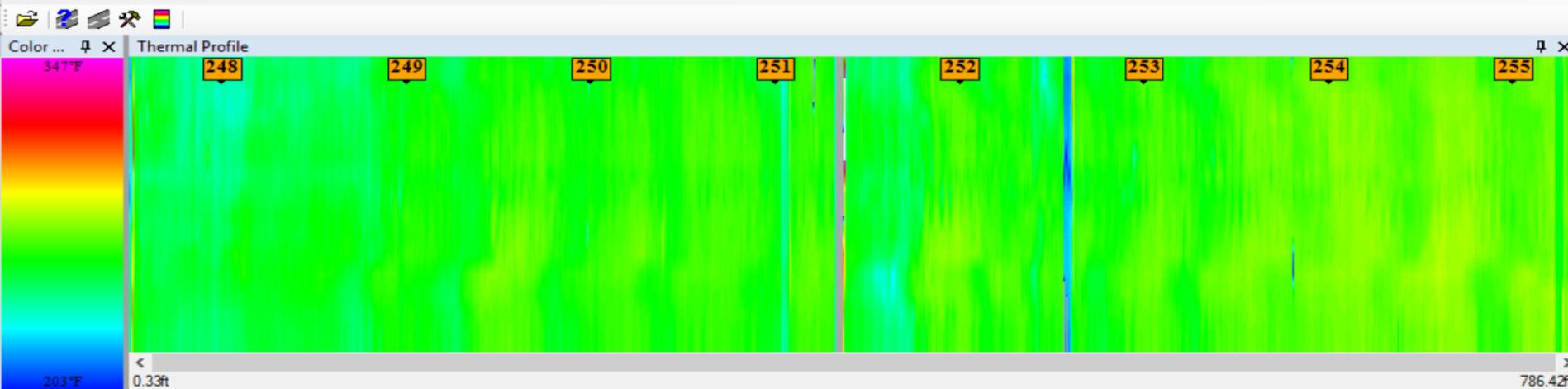
- Actions
  - Interpolation: **Linear**
  - Sample Spots of Interest: **Enabled**
  - Stations: **Show**
  - Tooltip: **Visible**
- Profile View
  - Ignored Sensors: **None**
  - Length: **1680.49ft**
  - Start: **1776.58ft**
  - Units: **Feet**
  - Zoom: **27.8%**

**Interpolation**  
Determines the kind of algorithm used when displaying the Profile.



Pave Project Manager - TemporaryInternetProject.paveproj (Not finished)

File View Report Extras Options Help

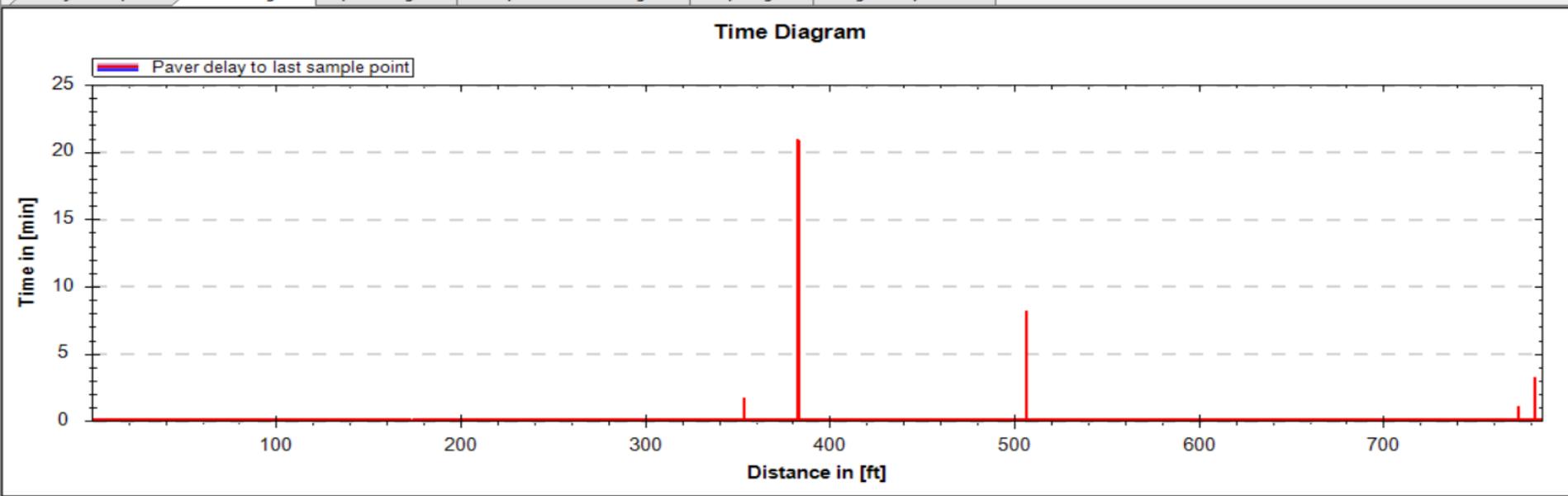


Properties

Thermal Profile

- Actions
  - Interpolation: **Linear**
  - Sample Spots of Interest: Enabled
  - Stations: **Show**
  - Tooltip: Visible
- Profile View
  - Ignored Sensors
  - Length: **786.09ft**
  - Start: **0.33ft**
  - Units: **Feet**
  - Zoom: **100.0%**

Project Properties Time Diagram Speed Diagram Temperature Class Diagram Map diagram Single Temperatures



Ignored Sensors  
Enter the sensor IDs you don't want to be displayed. ID 1 is the outer left sensor. Examples: "1:2;11:12", "1-3;10-12"

## Tex 244-F

### Thermal Profile Summary Report

|                 |                           |                    |                       |
|-----------------|---------------------------|--------------------|-----------------------|
| Profile ID:     | fm969 wb                  | Profile Date:      | 4/19/2017 10:23:17 AM |
| Profile Number: |                           | Letting Date:      |                       |
| Status:         |                           | Controlling CSJ:   | 1186-01-087           |
| County:         | Travis                    | Spec Year:         | 2014                  |
| Tested By:      | Jason Shellnut            | Spec Item:         | 347                   |
| Test Location:  | 2                         | Special Provision: |                       |
| Material Code:  |                           | Mix Type:          | TOM-C-SAC-A (76-22)   |
| Material Name:  | TOM-C-SAC-A (76-22)       |                    |                       |
| Producer:       | Asphalt Inc.-Harold Green |                    |                       |
| Area Engineer:  | Mike Mckissick            | Project Manager:   |                       |

|                      |     |                                     |      |
|----------------------|-----|-------------------------------------|------|
| Course/Lift:         | 1   | Temperature Differential Threshold: | 25.0 |
| Segment Length (ft): | 150 | Sensors Ignored:                    | -    |

| Thermal Profile Results Summary |   |         |                                 |         |
|---------------------------------|---|---------|---------------------------------|---------|
| Number of Profiles              | Moderate<br>25.0°F < differential <= 50.0°F |         | Severe<br>differential > 50.0°F |         |
|                                 | Number                                      | Percent | Number                          | Percent |
| 72                              | 25  | 35      | 8                               | 11      |

### Summary of Locations with Thermal Segregation

| Profile Nr | Beginning Location |                                 | Ending Location |                                 | Max Temp | Min Temp | Temperature Differential |
|------------|--------------------|---------------------------------|-----------------|---------------------------------|----------|----------|--------------------------|
|            | Station            | GPS in °                        | Station         | GPS in °                        |          |          |                          |
| 1          | 882.78             | 97.4865733 W,<br>30.22058855 N  | 881.29          | 97.48701203 W,<br>30.22073817 N | 307.0    | 277.9    | 29.2                     |
| 2          | 881.28             | 97.48701398 W,<br>30.22073885 N | 879.79          | 97.48745313 W,<br>30.22089044 N | 342.7    | 283.8    | 58.9                     |
| 3          | 879.78             | 97.4874551 W,<br>30.22089109 N  | 878.29          | 97.48789832 W,<br>30.22104061 N | 319.6    | 283.6    | 36.0                     |
| 11         | 867.78             | 97.49046222 W,<br>30.22274057 N | 866.29          | 97.49067959 W,<br>30.22309564 N | 313.0    | 243.0    | 70.0                     |
| 12         | 866.28             | 97.49068053 W,<br>30.22309747 N | 864.79          | 97.49084766 W,<br>30.22347458 N | 313.3    | 287.1    | 26.3                     |
| 13         | 864.78             | 97.49084907 W,<br>30.22347841 N | 863.29          | 97.49096076 W,<br>30.22386956 N | 325.4    | 295.9    | 29.5                     |
| 14         | 863.28             | 97.49096164 W,<br>30.22387357 N | 861.79          | 97.49100902 W,<br>30.22427473 N | 322.2    | 256.6    | 65.5                     |
| 15         | 861.78             | 97.4910091 W,<br>30.22427682 N  | 860.28          | 97.49101879 W,<br>30.22468371 N | 324.7    | 298.2    | 26.5                     |
| 25         | 846.78             | 97.49101605 W,<br>30.22836899 N | 845.29          | 97.49102347 W,<br>30.22877644 N | 323.2    | 288.5    | 34.7                     |
| 29         | 840.78             | 97.49125126 W,<br>30.22999480 N | 839.29          | 97.49140525 W,<br>30.23038121 N |          |          |                          |

**Location of Paver Stops greater than One Minute**

| Location (stations) | Duration (h:min:sec) |
|---------------------|----------------------|
| 818.90              | 0:2:17               |
| 817.35              | 0:2:55               |
| 811.63              | 0:10:45              |
| 805.53              | 0:1:42               |
| 799.56              | 0:5:14               |
| 799.53              | 0:2:38               |
| 796.86              | 0:17:56              |
| 792.01              |                      |

## *Contractors Perspective who use Thermal Imaging Systems Today*

- TxDOT Specification Compliant;
- Eliminates placement QC technician from having to perform segregation density profiles, and thermal profiles
- Improves placement QC use of time, better monitoring of tack coats, membrane seals, rolling, compaction , density and smoothness;
- Thermal segregation can be a predecessor to pavement bumps and raveling;
- Thermal segregation can disrupt an otherwise effective rolling pattern and appropriate compaction effort;
- Improves placement and ride bonus opportunity and minimize penalty, resulting in a prompt return on investment cost;
- Real time Data collection can be viewed locally at the paver and remotely in real time;
- Data can be stored and evaluated at most convenient time and location;
- Improves quality control/assurance confidence level when paving and compacting mix in cooler temperatures;
- Knowledge gained enables more effective asphalt pavement trouble shooting from the paver back to the plant;
- Contractor may pave anytime the roadway is dry and the roadway surface temperature is at least 32°F by using the Pave-IR system and demonstrating to the Engineer that no recurring severe thermal segregation exists.
- Thermal Segregation kept to a minimum leads to best practices and ultimately better long term pavement performance;