SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Infrared Technology (IR)

What is it and why use it?

Harold L. Von Quintus, P.E.

November 9, 2015

U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO

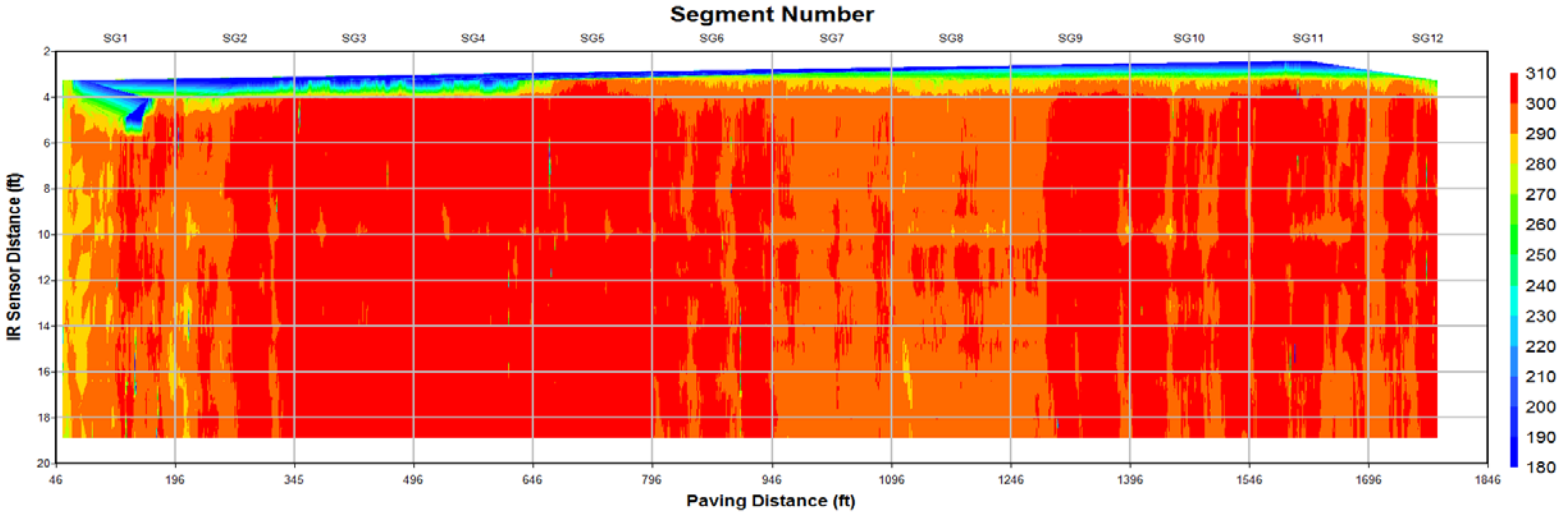
IR – What is it & why use it?

1. IR - Defined.
2. How is it measured?
3. Why is it important?

IR – What is it & why use it?

Infrared Thermography:

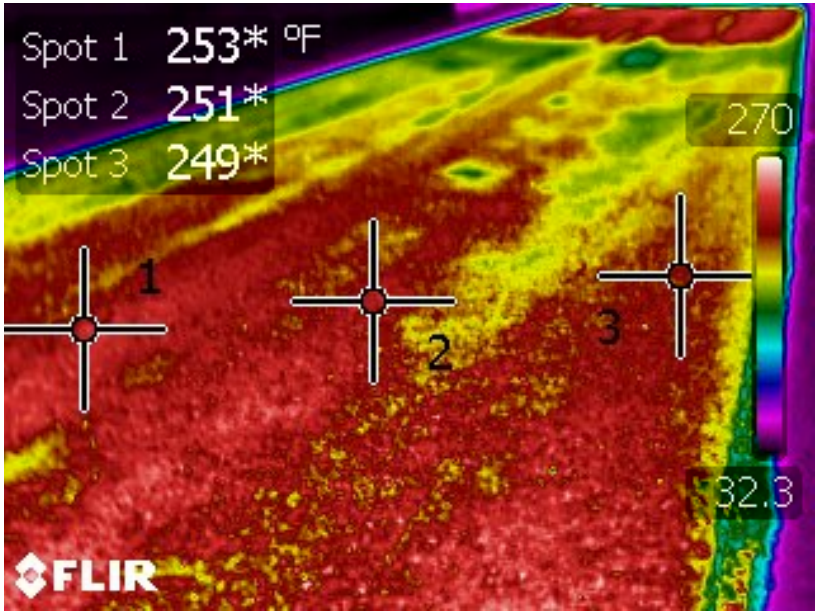
- The mapping of temperature contours (equal temperature) over the surface of a material.
- Contours are used to evaluate materials by measurement of their surface temperature and its variation.

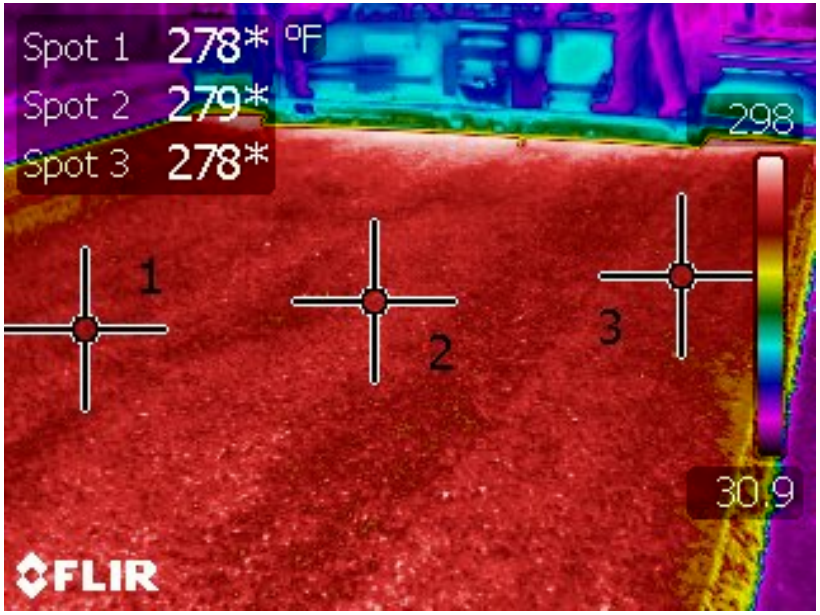


IR – What is it & why use it?

Temperature segregation:

- More than 25 ºF difference in mat temperature behind screed.

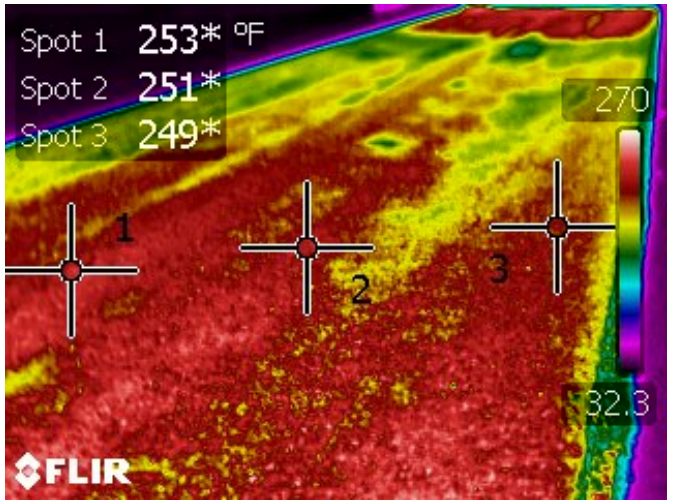


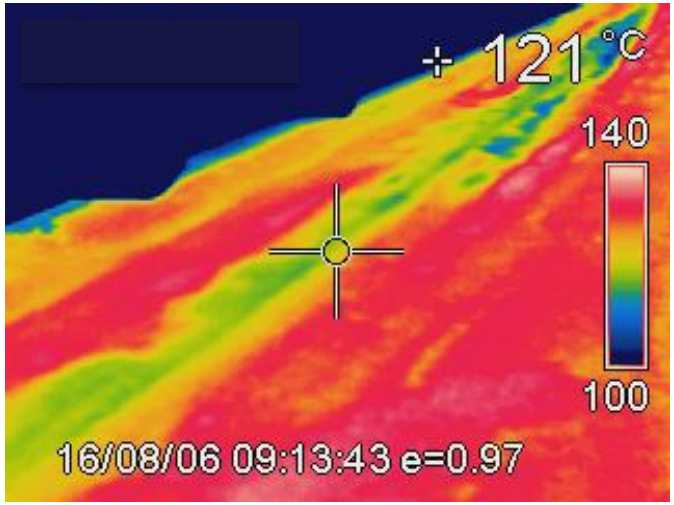


IR – What is it & why use it?

Types of Temperature Differences:

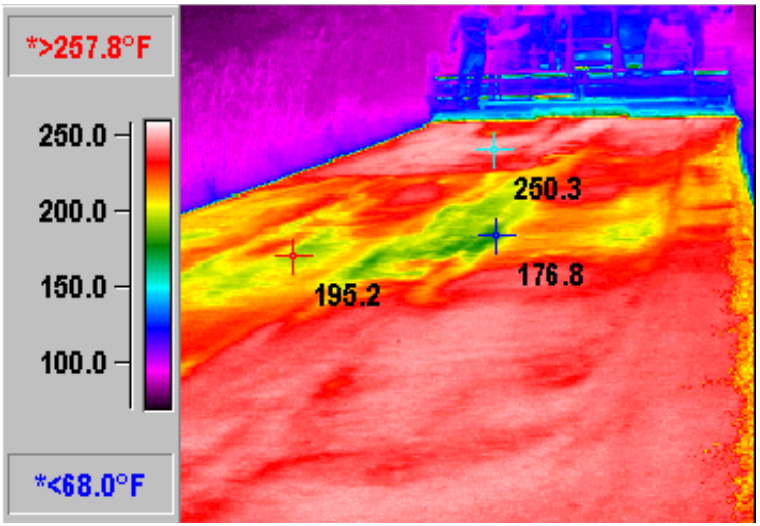
1. Cold spots
   - Truck to truck temperature differences
   - Improper loading and unloading of trucks
2. Thermal streaks
   - Longitudinal segregation
   - Inadequate or non-uniform amount of material across the mat





IR – What is it & why use it?

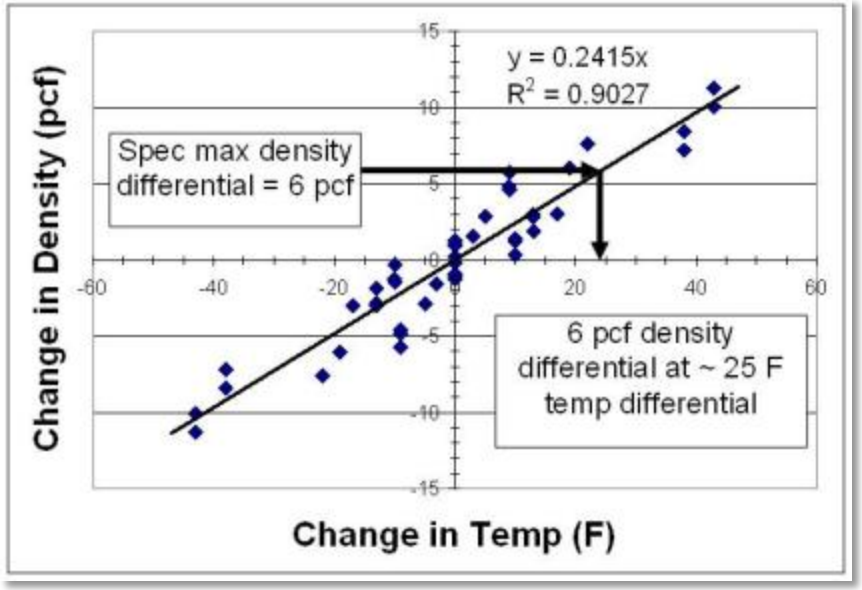
- Cold spots
  - Temperature difference of mat between truck exchanges – common.
  - Areas with higher air voids
- Focused testing have validated higher air voids
  - Coring
  - Radar (full coverage)
  - Nuclear gauge



IR – What is it & why use it?

Background

- 1996 through 2000s – field work concluded temperature differences could be accurately detected and quantified:
  - Low temperatures result in low density zones in mat
  - A few States adopt temperature uniformity specification



Temperature profile criteria based on desired density uniformity.

IR – What is it & why use it?

1. IR - Defined.
2. How is it measured?
3. Why is it important?

IR – What is it & why use it?

History; Mat Temperature Measurements

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

IR – What is it & why use it?

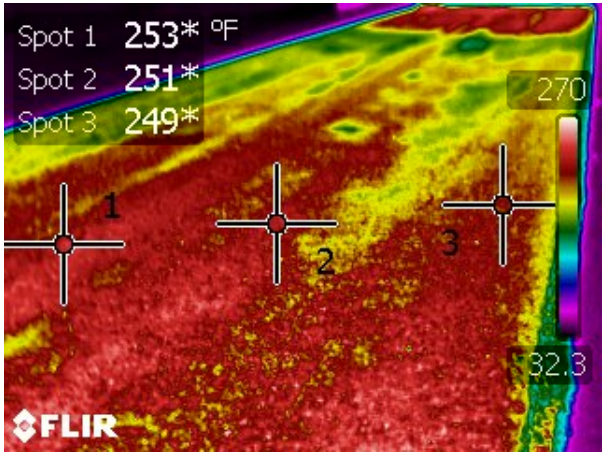
History; Mat Temperature Measurements

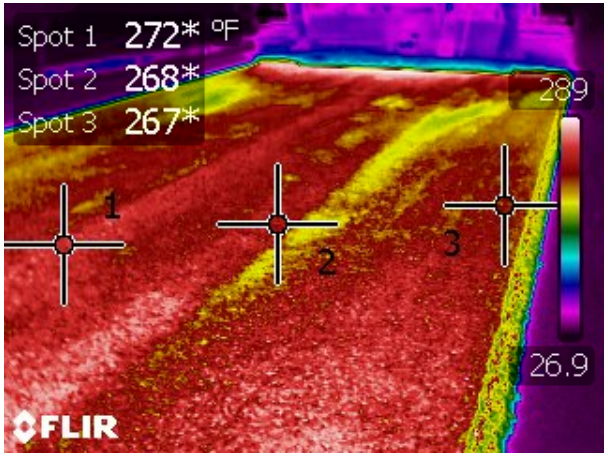
- IR sensors, IR-Bar; first device for continuous readings
- Pave-IR Scanner; second generation device for continuous readings

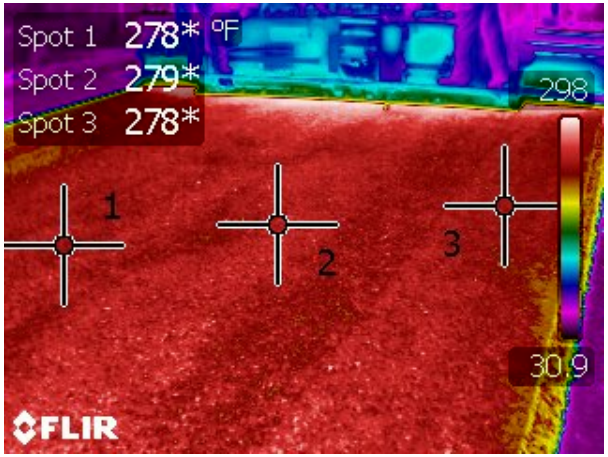
IR – What is it & why use it?

Application & use of temperature cameras

- Identify areas with cold spots for biased sampling in density specification
- Identify thermal streaks



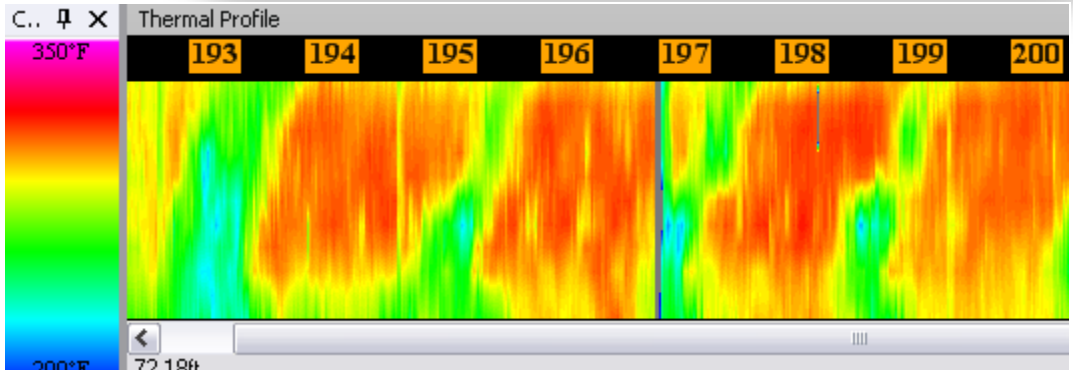




IR – What is it & why use it?

Application & use of IR-Bar and Scanner

- Continuous readings to evaluate mat uniformity through temperature uniformity.
- Non-uniform temperatures usually mean, non-uniform densities.



IR – What is it & why use it?

1. IR - Defined.
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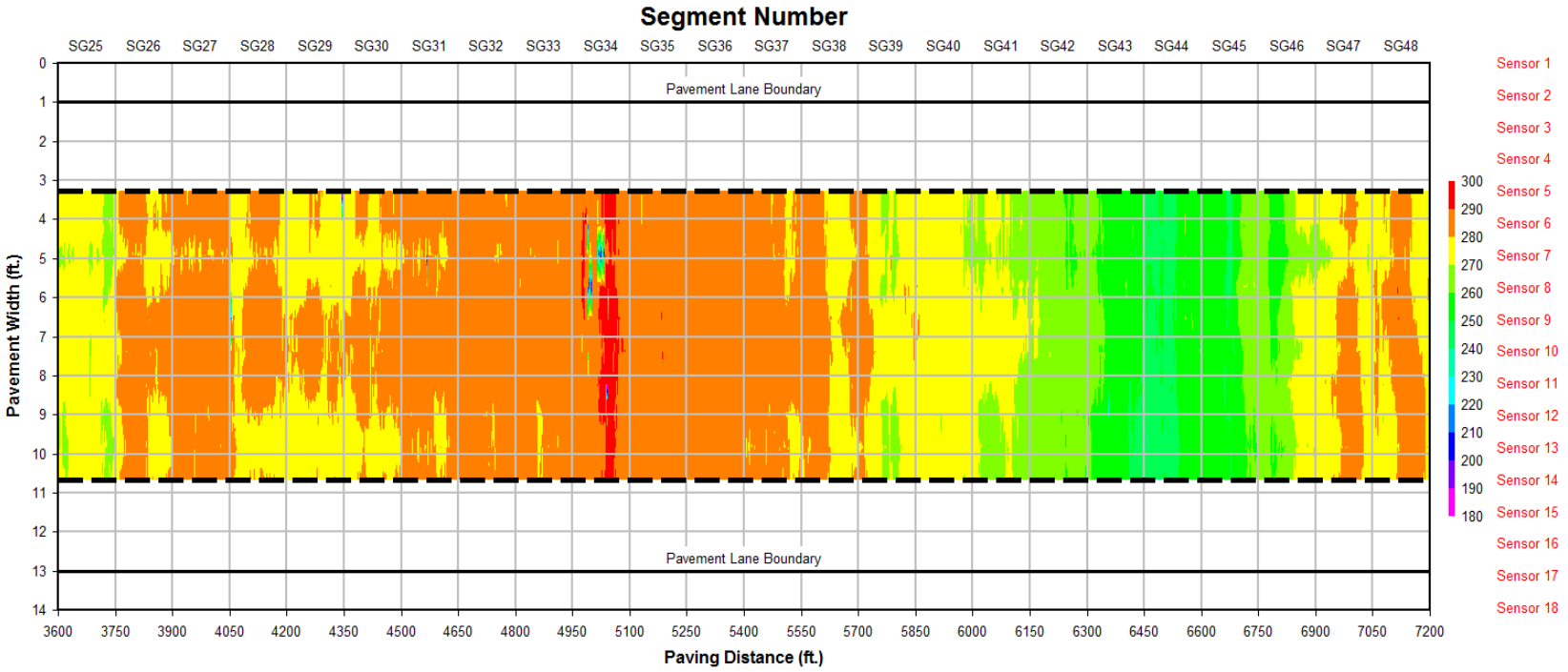
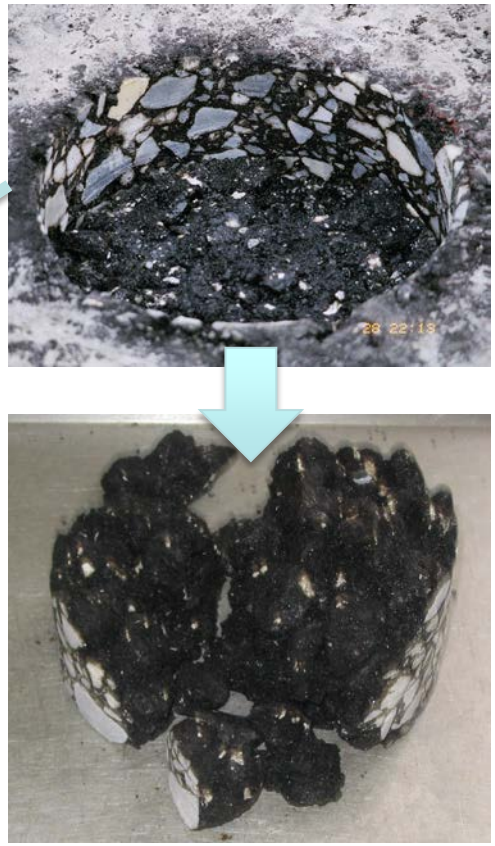
IR – What is it & why use it?

- Aggregate segregation in mat = temperature segregation
- Non-uniform temperatures usually result in non-uniform densities



IR – What is it & why use it?

Segregation – A difficult issue to resolve, when it is difficult to identify or confirm.



IR – What is it & why use it?

- Truck to truck segregation results in cold spots; IR can accurately identify these areas.

IR – What is it & why use it?

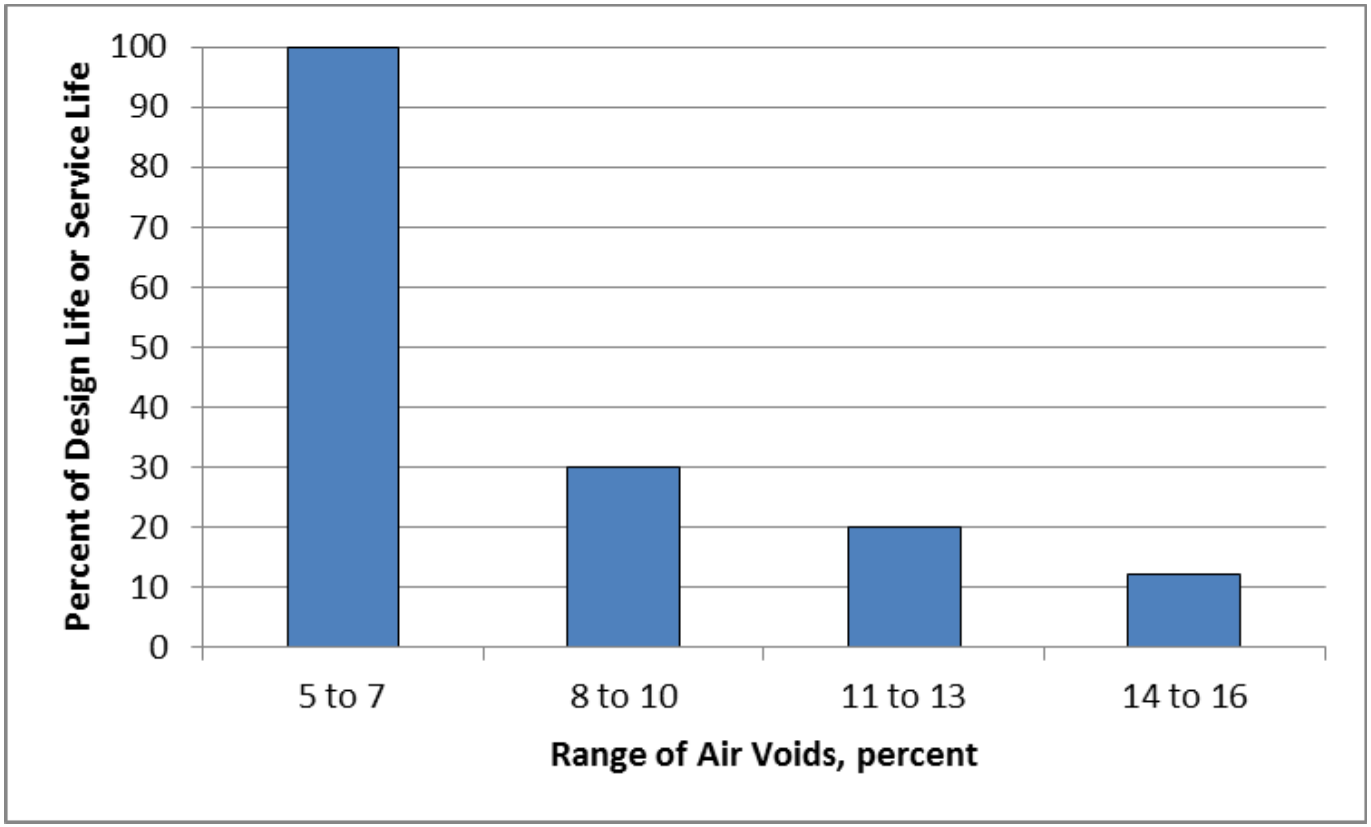
- Both sided longitudinal and centerline segregation result in thermal streaks; IR can identify these areas.

IR – What is it & why use it?

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

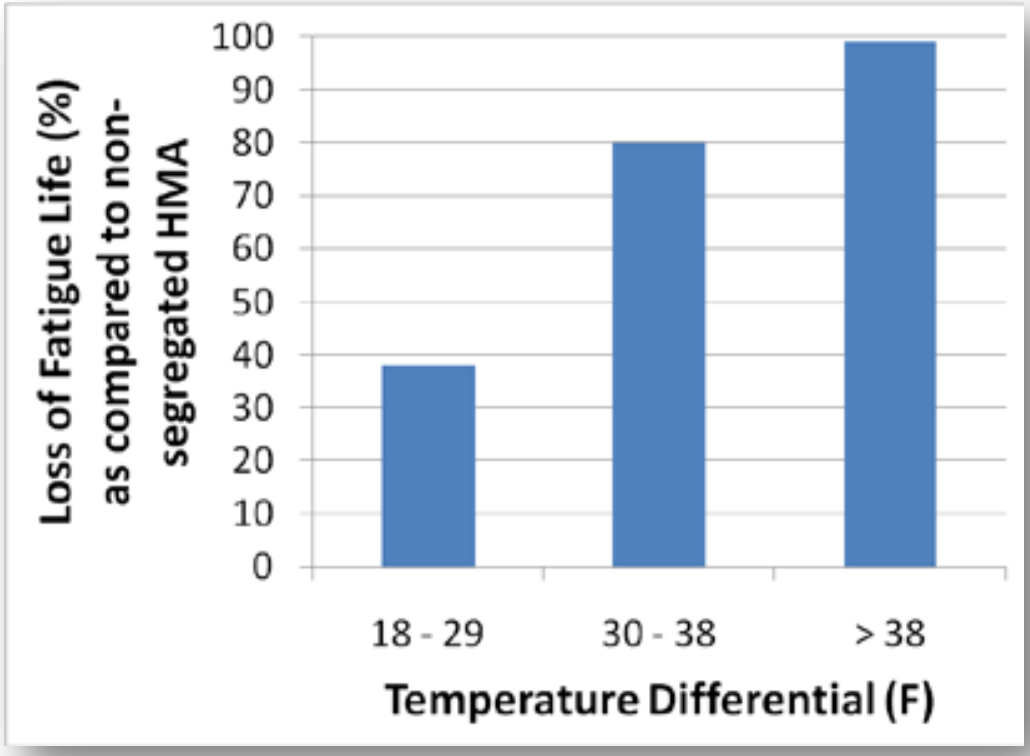
IR – What is it & why use it?

- Effect of reduced compaction or higher air voids because of lower mat temperatures.



IR – What is it & why use it?

- Fatigue life can be substantially reduced, as a result of lower densities because of lower mat temperatures.



Source: NCAT (2000)

IR – What is it & why use it?

Impact of temperature differences or areas with low temperatures.

IR – What is it & why use it?

Cold spots; areas with increased potential for:

- Fatigue cracks
- Raveling
- Pot holes

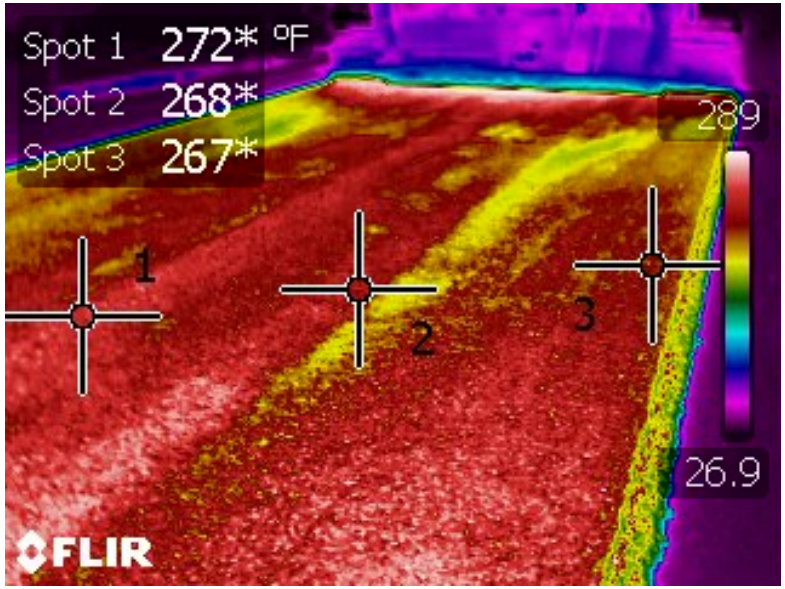
IR – What is it & why use it?

Thermal streaks; longitudinal areas with increased potential for:

- Longitudinal cracking

IR – What is it & why use it?

- Thermal streaks can be very damaging, depending on the level of density achieved in localized areas.
- Measuring the density, accurately, in a localized area is complicated.



Infrared Technology (IR)

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Data Analyses and Findings

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Data Analyses & Findings
Anchorage Airport

1. Project Overview
2. Data Collection
3. Data Processing
4. Data Summary

Data Analyses & Findings
Anchorage Airport

Data Analyses & Findings
Anchorage Airport

Mixture delivered to site with bottom-dump trucks.

Mixture placed with Caterpillar paver.

Data Analyses & Findings
Anchorage Airport

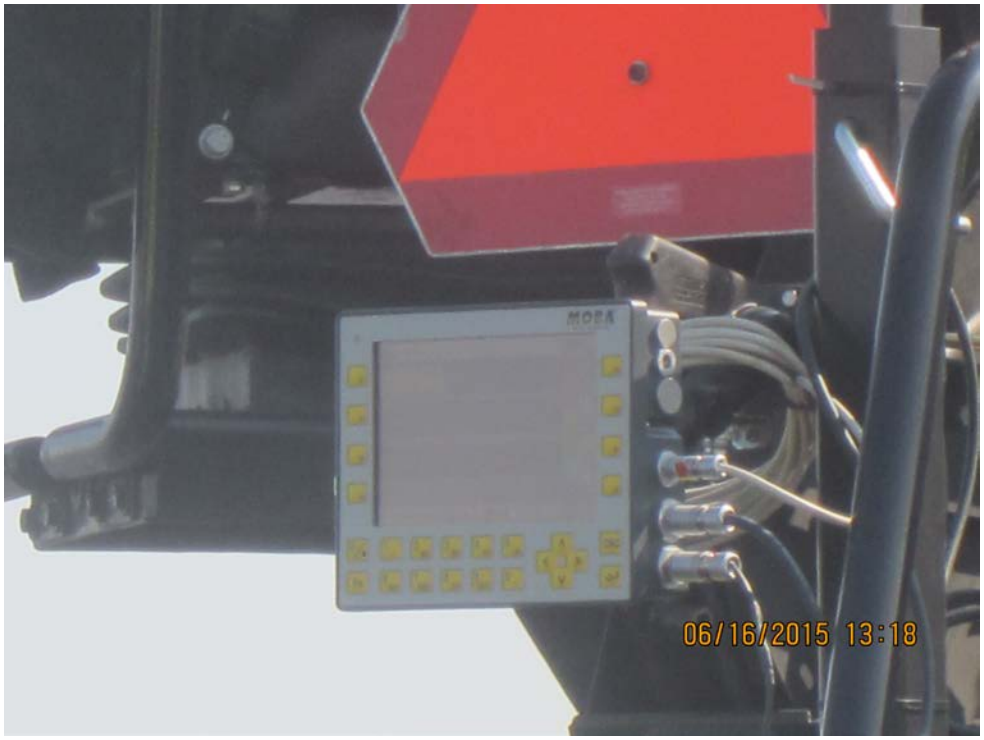
- Pave-IR Scanner attached to paver
- DMI on wheel hub.

Data Analyses & Findings
Anchorage Airport

- IR Scanner attached to paver and scans mat behind screed in one direction.
- GPS attached to the scanner arm.

Data Analyses & Findings
Anchorage Airport

IR scan screen to monitor mat temperatures on real time basis; attached to the scanner post.



Data Analyses & Findings
Anchorage Airport

Compaction Train:

- Breakdown; Dynapac vibratory IC roller
- Intermediate; Dynapac vibratory IC roller
- Finish; Caterpillar static steel wheel drum

Data from the IC accelerometers were not used to control the density or compaction operation.

Data Analyses & Findings
Anchorage Airport

Data Analyses & Findings
Anchorage Airport

Nuclear density gauge used to measure mat density

Data Analyses & Findings
Anchorage Airport

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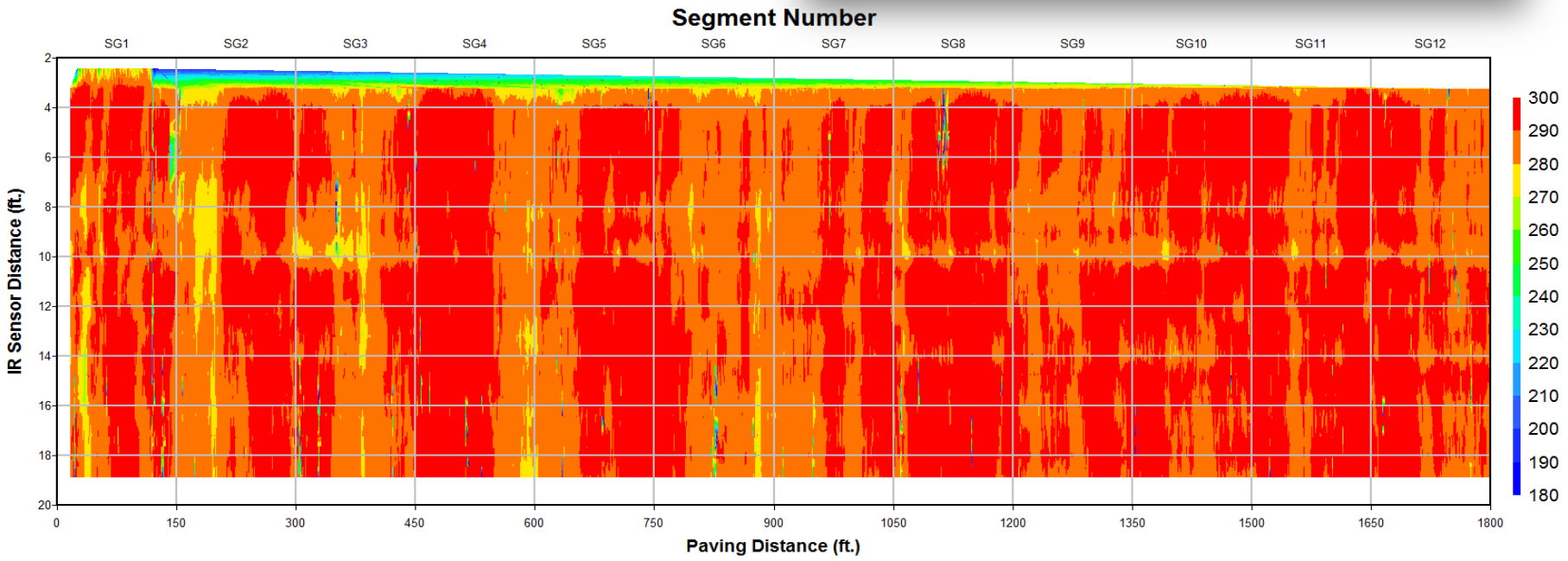
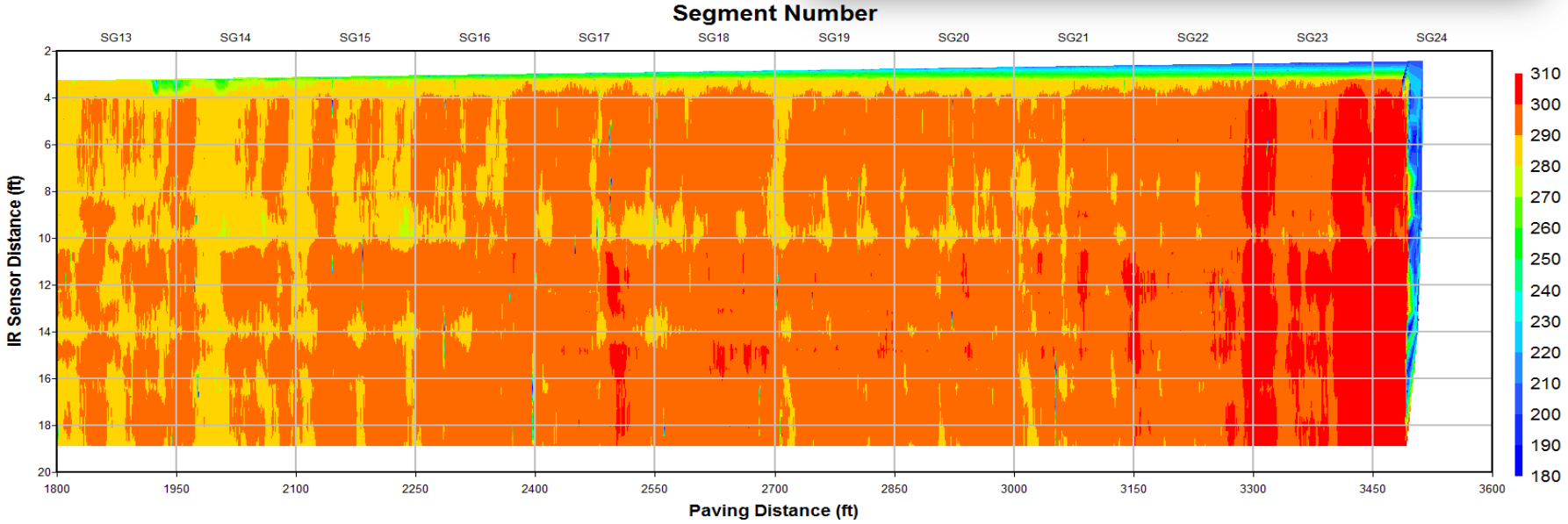
Data Analyses & Findings
Anchorage Airport

Raw Temperature Profile for first part of the first path.



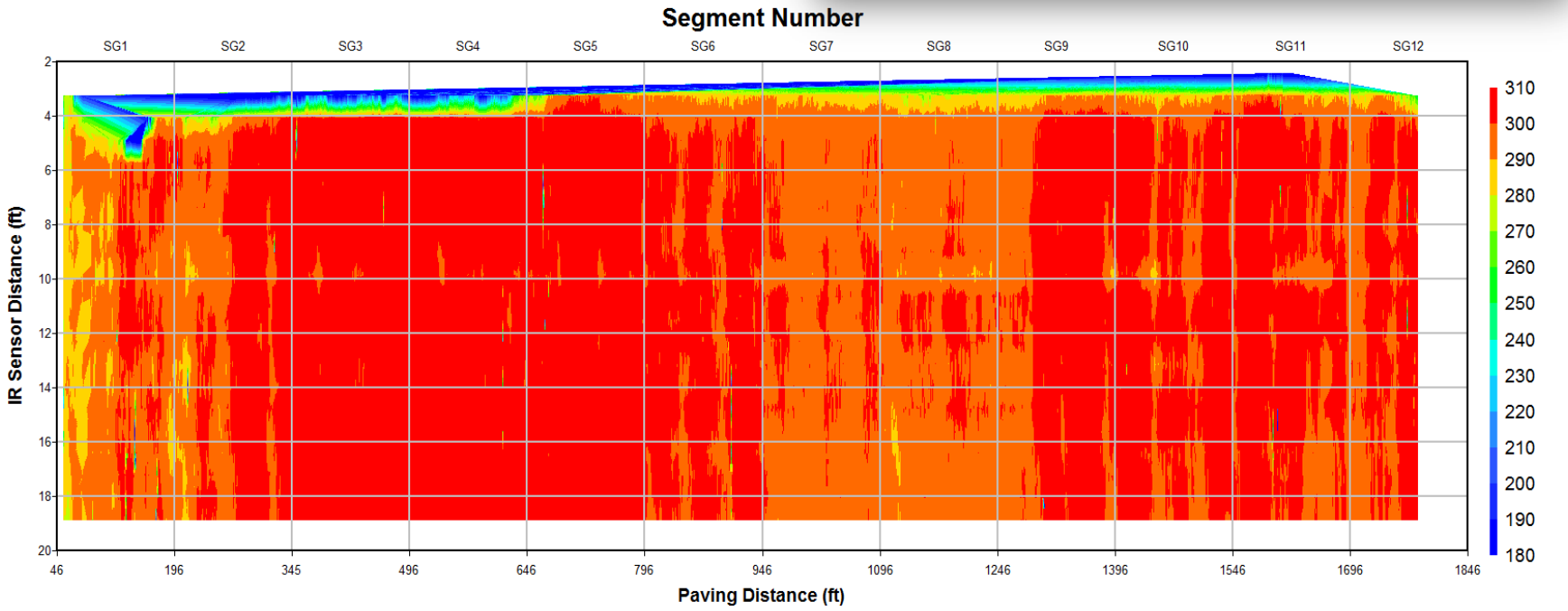
Data Analyses & Findings
Anchorage Airport

Raw Temperature Profile for second part of the first path.



Data Analyses & Findings
Anchorage Airport

Raw Temperature Profile for fifth path.



Data Analyses & Findings
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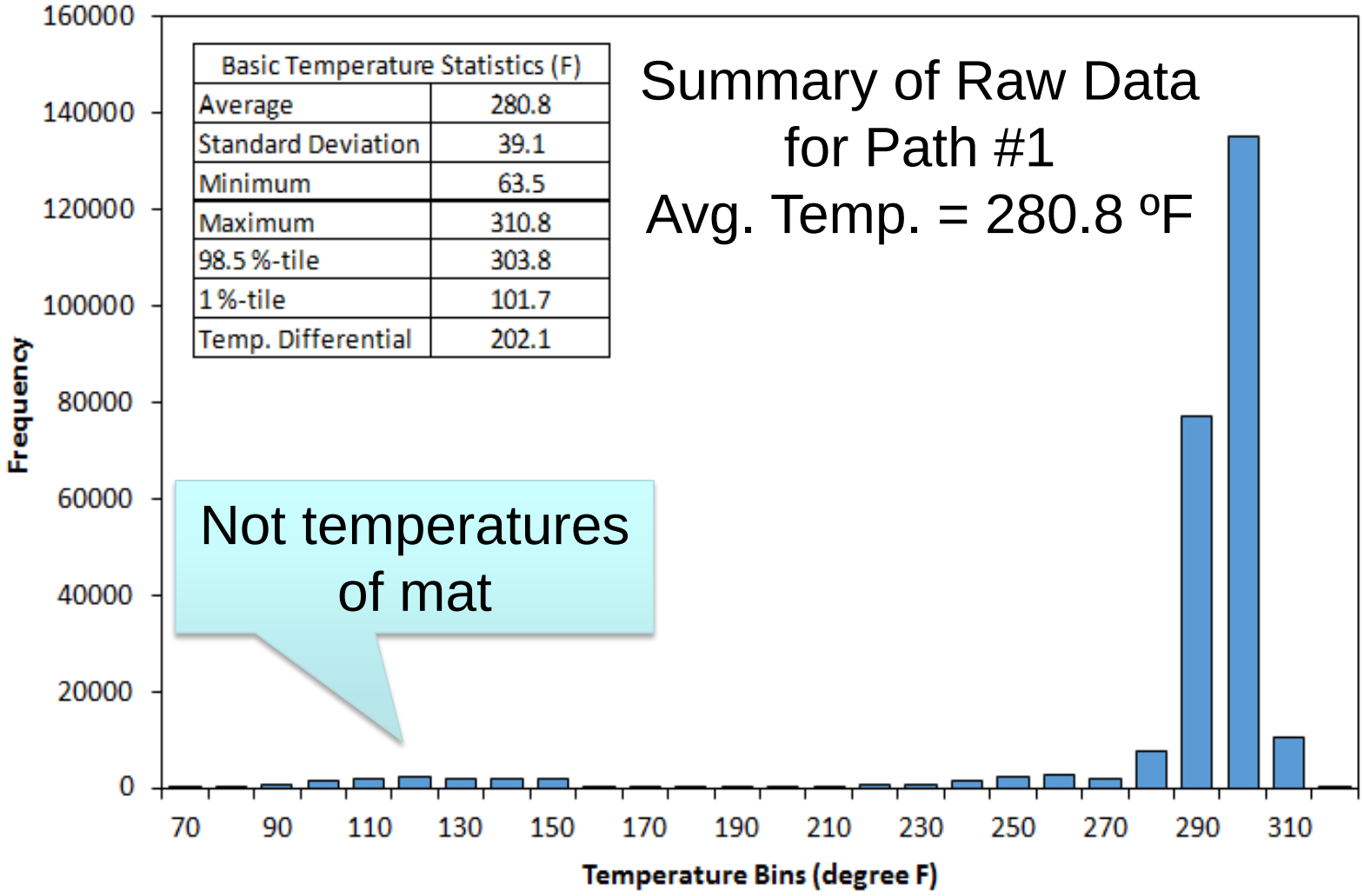

Data Analyses & Findings
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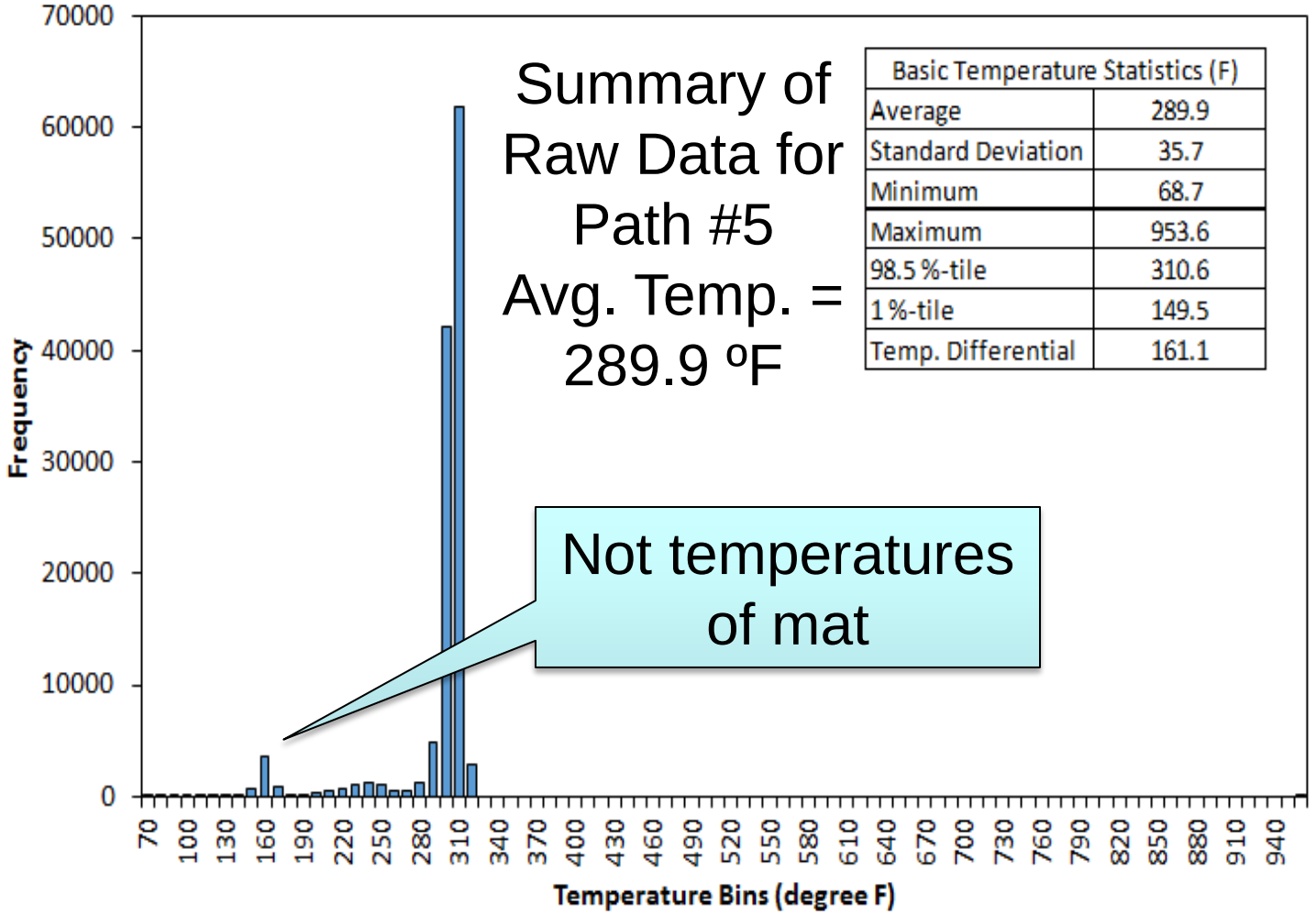
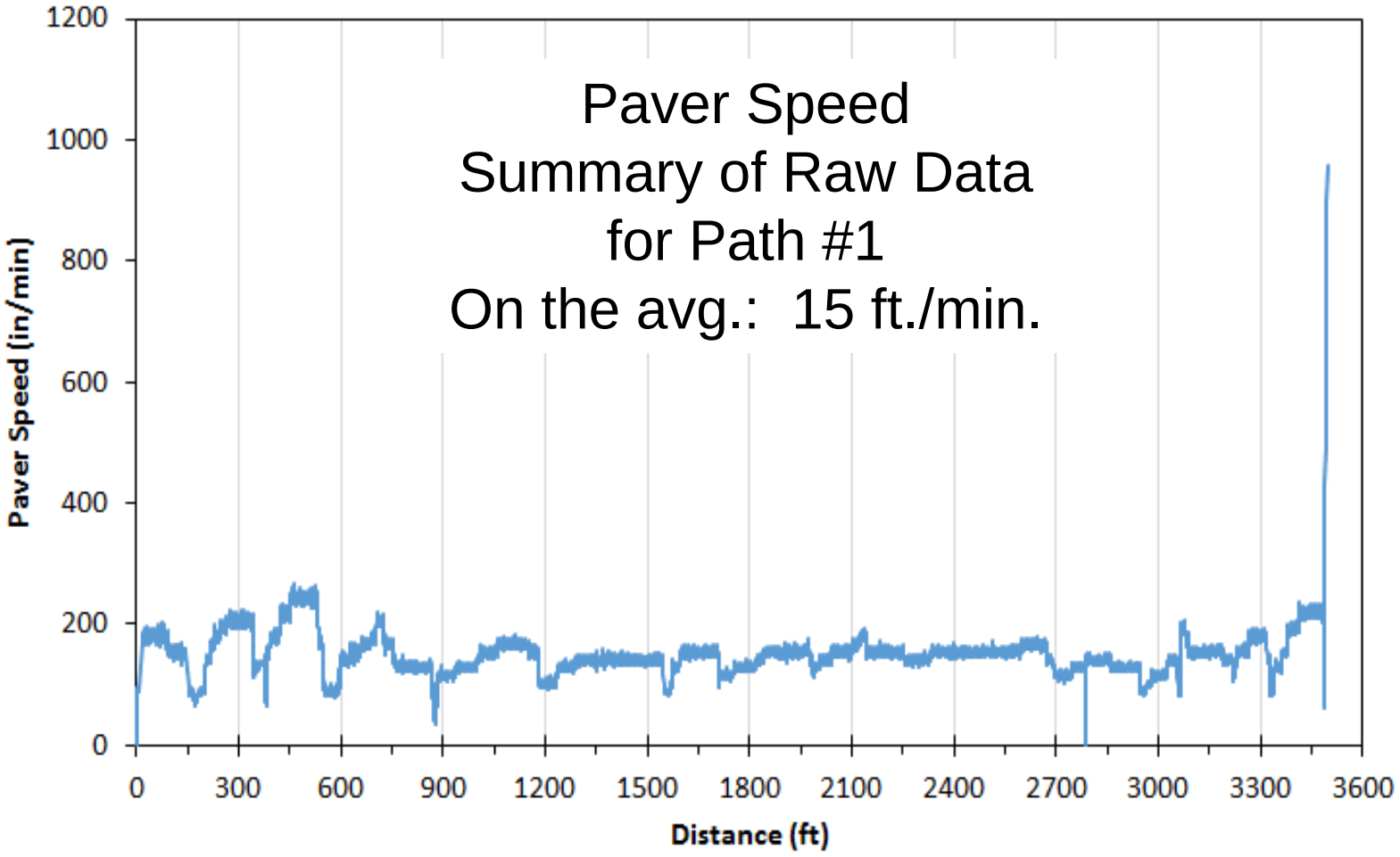


Summary of Raw Data for Path #5 Avg. Temp. = 289.9 ºF

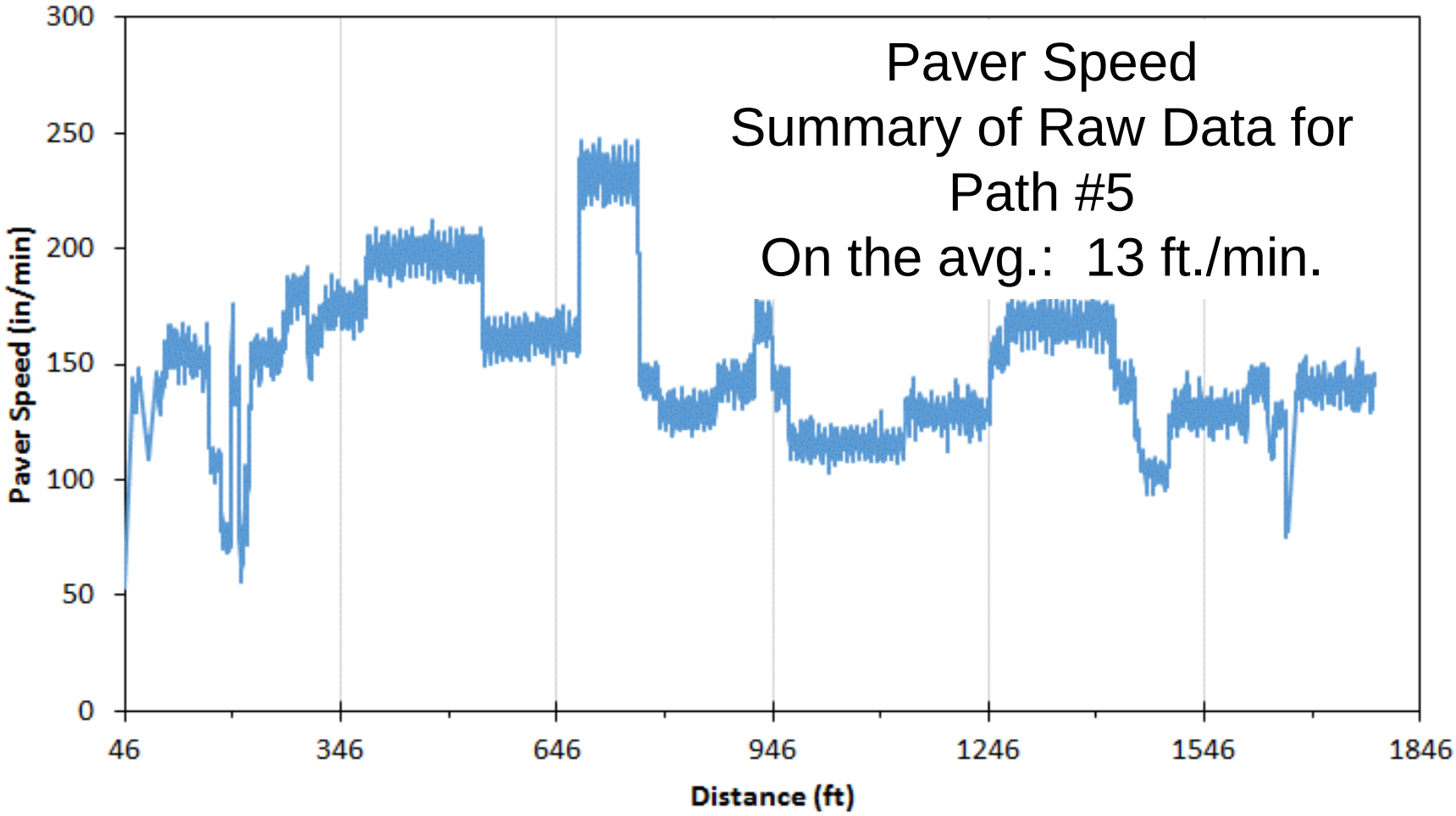
Basic Temperature Statistics (F)	
Average	289.9
Standard Deviation	35.7
Minimum	68.7
Maximum	953.6
98.5 %-tile	310.6
1 %-tile	149.5
Temp. Differential	161.1

Not temperatures of mat

Data Analyses & Findings
Anchorage Airport



Data Analyses & Findings
Anchorage Airport



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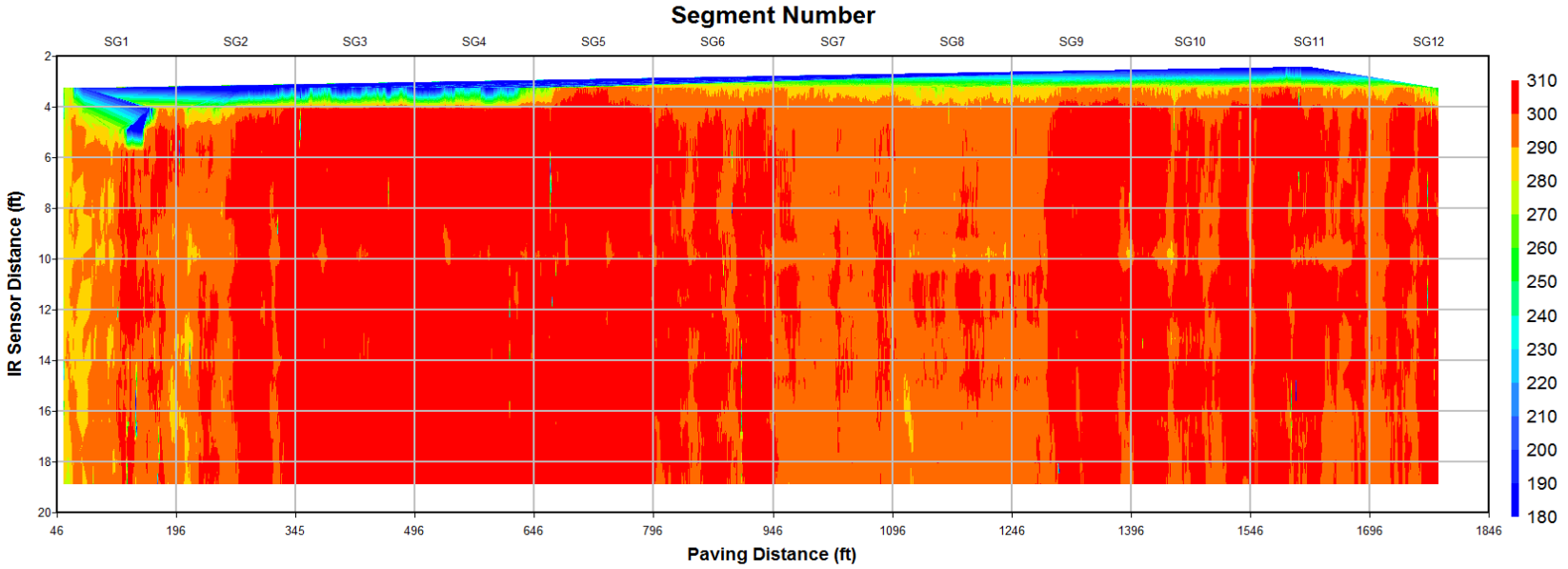
Data Analyses & Findings
Anchorage Airport

Data Processing—eliminate invalid temperature measurements:

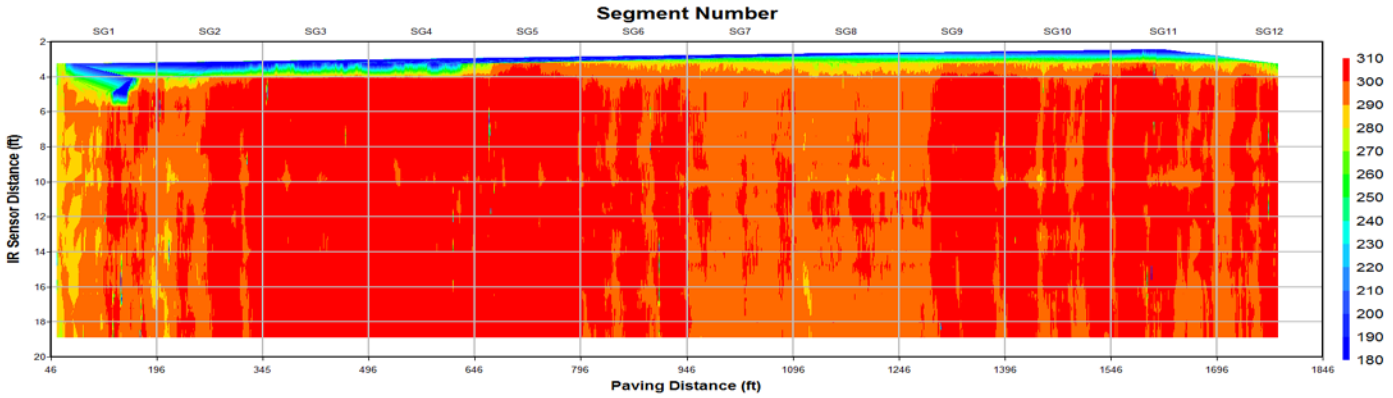
1. Eliminate measurement locations within 2 feet of the mat's edge.



Data Analyses & Findings
Anchorage Airport

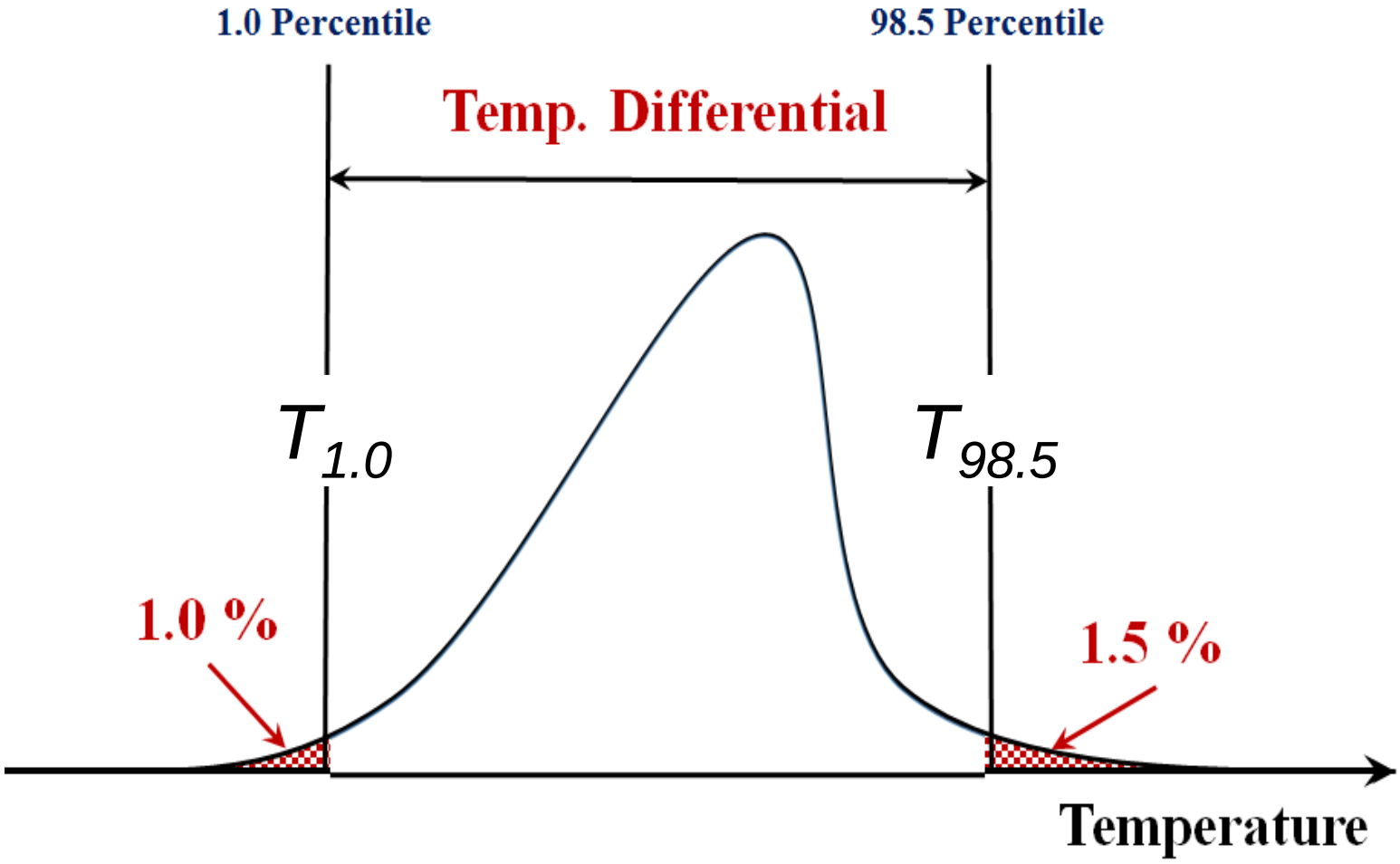
Data Processing—eliminate invalid temperature measurements:

2. Eliminate data with paver stops greater than 10 seconds, between locations:
   - 2 feet behind measurement location of stop
   - 8 feet in front of measurement location of stop
3. Eliminate temperature readings < 170 ºF and > 400 ºF.



Data Analyses & Findings
Anchorage Airport

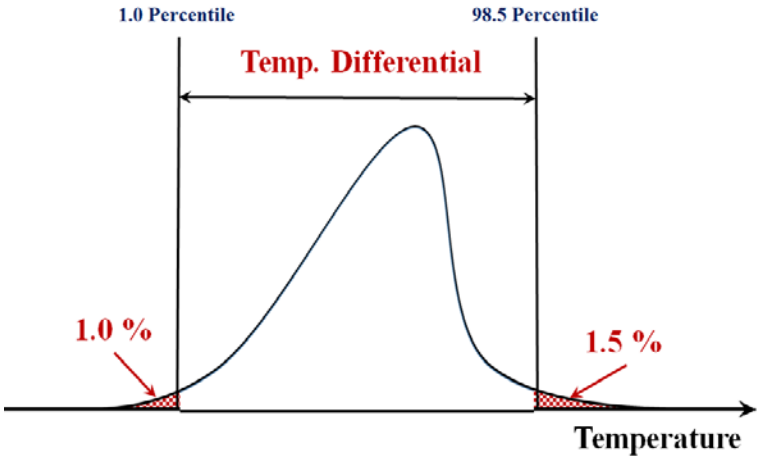
- Temperature Differential, each 150 foot segment



Data Analyses & Findings
Anchorage Airport

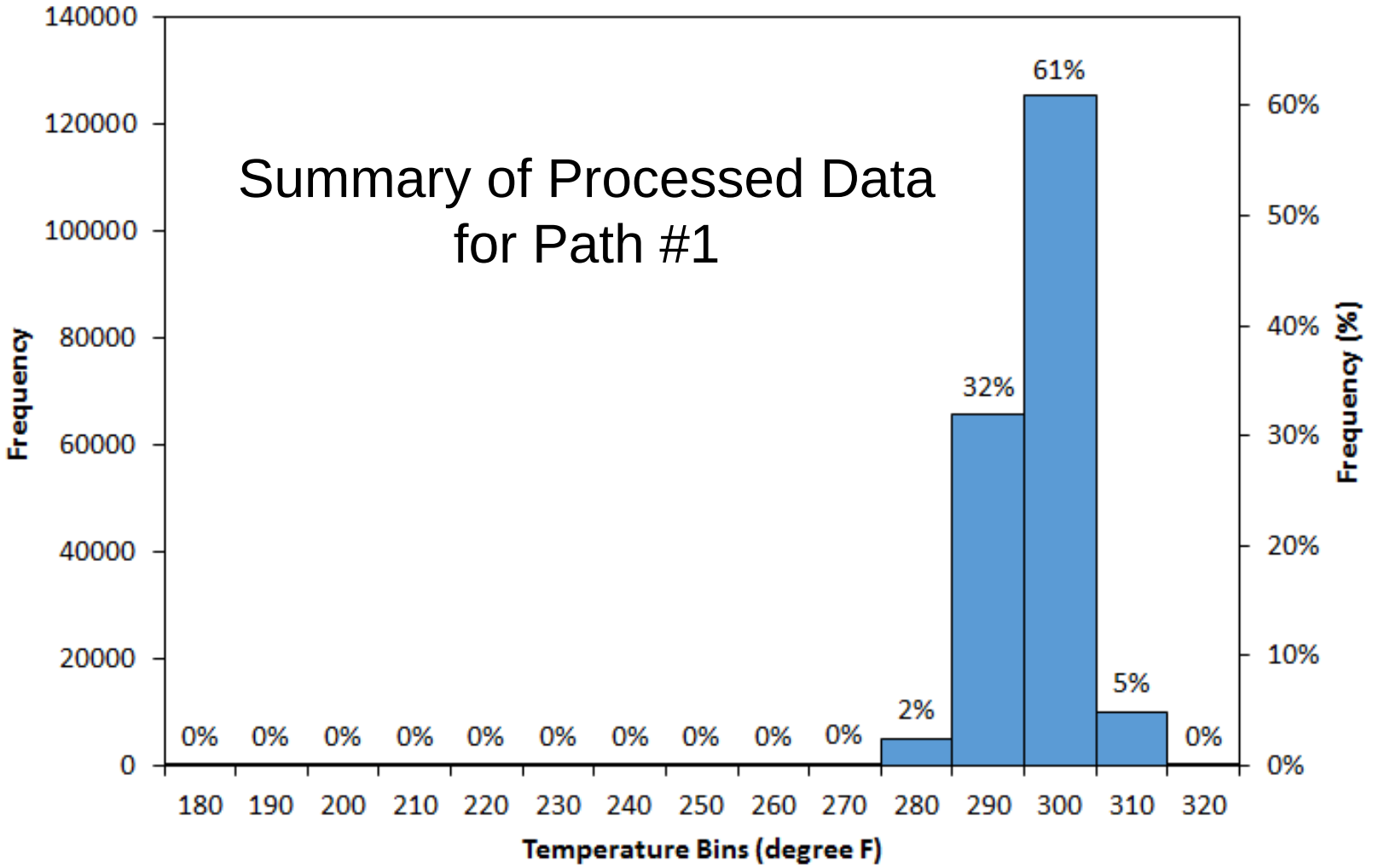
- Temperature Differential Criteria, each 150 foot segment:

$$T_{Diff} = T_{98.5} - T_{1.0}$$



- **$T_{diff} \leq 25$ ºF** — **No temperature difference**
- 25 ºF < $T_{diff} \leq 50$ ºF — Moderate temperature difference
- **$T_{diff} > 50$ ºF** — **Severe temperature difference**

Data Analyses & Findings
Anchorage Airport



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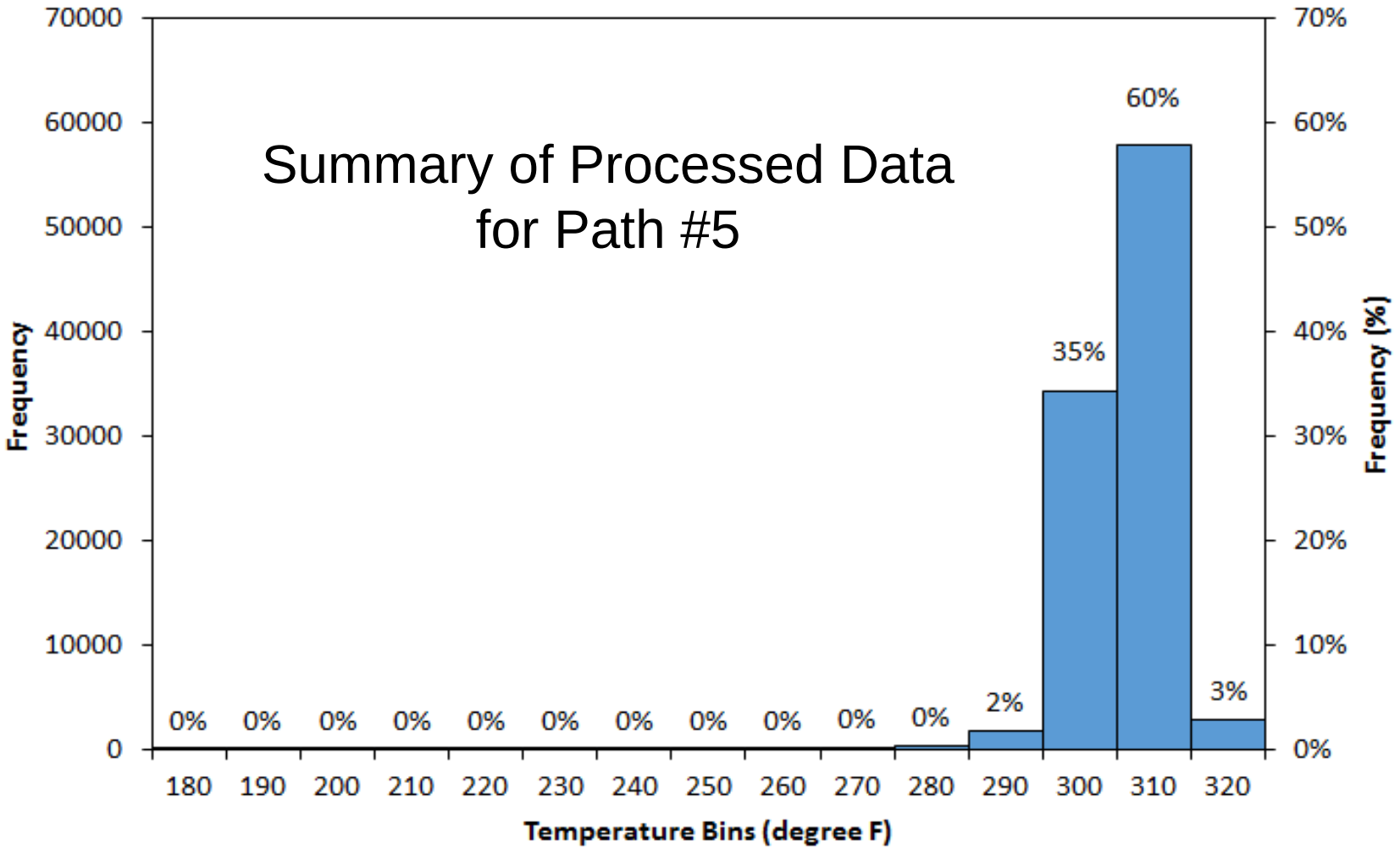

Data Analyses & Findings
Anchorage Airport

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Data Analyses & Findings
Anchorage Airport

Processed Data, **excluding** paver stop locations.

Lot or Paver Path ID	Total Number of Increments	Number of Increments within Temp. Regimes			Thermal Streaking
		Minor	Moderate	Severe	
1	24	17	7	0	None
2	12	10	2	0	None

Minnesota DOT's specification:

- Minor Temperature Difference: +$20 per Increment
- Moderate Temperature Difference: $0 per Increment
- Severe Temperature Difference: -$20 per Increment

Total Incentive to Contractor: $540 for the two Path IDs.

Data Analyses & Findings
Anchorage Airport

Processed Data, **including** paver stop locations.

Lot or Paver ID	Total Number of Increments	Number of Increments within Temperature Regimes		
		Minor	Moderate	Severe
Path 1	24	17	5	2
Path 5	12	5	3	4

Total Incentive to Contractor: $320 for the two Path IDs.

Data Analyses & Findings
Anchorage Airport

Data Analyses & Findings
Anchorage Airport

Contact Information:

- Richard Giessel; richard.giessel@alaska.dot.gov
- Stephan Saboundjian; steve.saboundjian@alaska.dot.gov
- Steve Ayers; stephen.ayers@gninc.com
- Paul Angerhofer; pangerhofer@moba.de
- Harold Von Quintus; hvonquintus@ara.com
- Paul Dalbey; pdalbey@ara.com
- Monica Jurado; monica.jurado@dot.gov
- Stephen Cooper; stephen.cooper@dot.gov

Infrared Technology (IR)

Data Analyses and Findings

SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Infrared Technology (IR)

Implementation & Application of Products

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November 9, 2015

U.S. Department of Transportation
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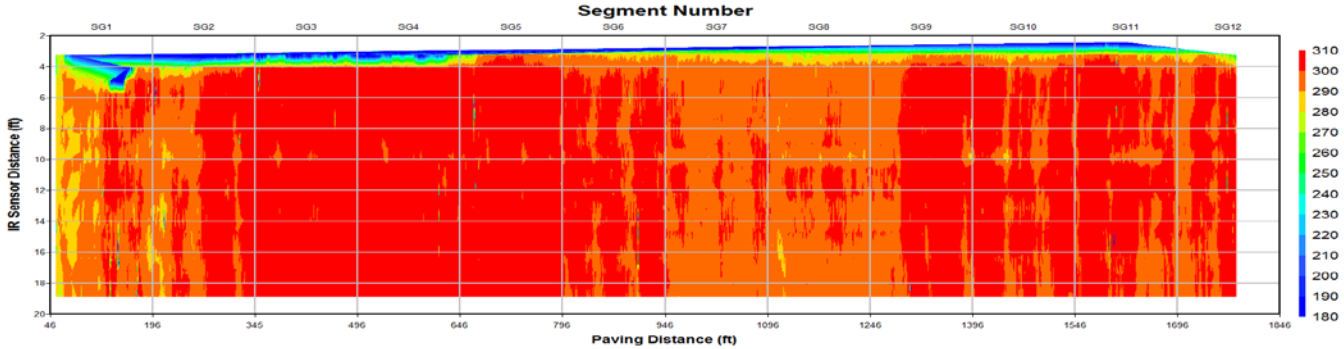
Implementation & Application

Application & use:

- Continuous readings to evaluate mat uniformity through temperature uniformity.
- Non-uniform temperatures imply non-uniform densities, which usually mean penalties.



Implementation & Application

Role of IR in Quality Assurance Programs

1. Quality control plan; contractor
   - Monitor production/placement operations to minimize temperature differentials of mat.
   - Trouble shooting
2. Acceptance plan; agency
   - Reduce future distress and maintenance costs
   - Dispute resolution

Implementation & Application

IR Role in Quality Control Plans; 3 examples

1. Missouri demonstration project
2. Virginia demonstration project
3. Federal Lands demonstration project

Implementation & Application

1. Missouri demonstration project
   – Monitor production/placement operations to minimize temperature differentials of mat.

Implementation & Application

2. Virginia demonstration project
   – Identify reason for severe temperature differentials and take action.
     - Avg. temperature differential at start of paving project; about 30 ºF.
     - Avg. temperature differential after adding two trucks; bout 15 ºF.

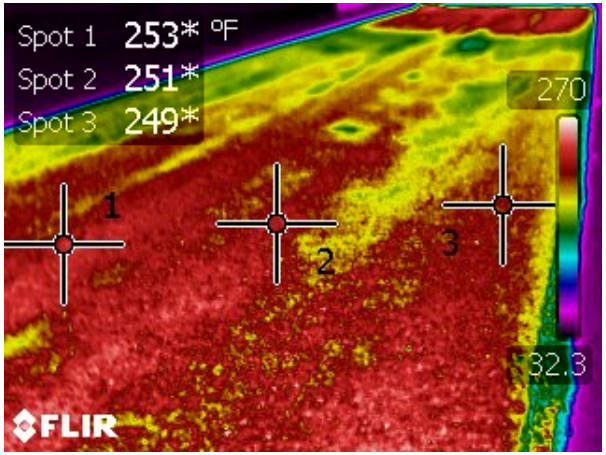
Implementation & Application

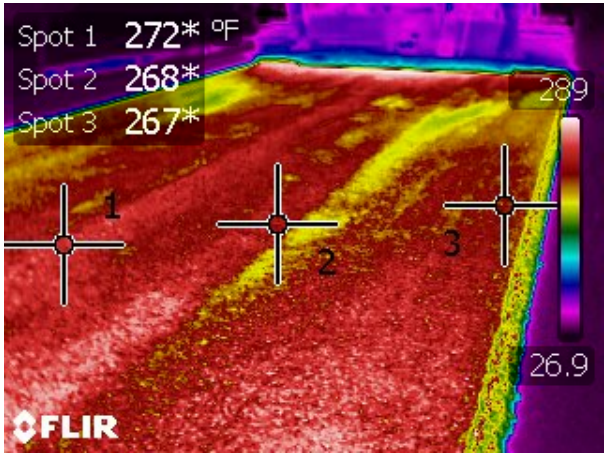
3. Federal Lands demonstration project
   - Identify reason for severe temperature differentials and take action; loading of trucks.
     - One dump of mix in truck bed – severe temp. differential
     - Two dump, no stockpile – less temp. differential.

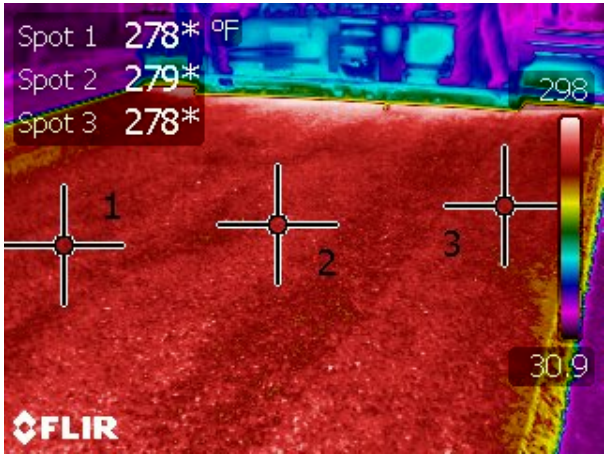
Implementation & Application

IR Role in Acceptance Plans; identify:

- Cold spots
  - Colorado, Michigan, Minnesota, Quebec, Texas, Washington
- Thermal streaks
  - Quebec







Implementation & Application

Cold spots; areas with increased potential for:

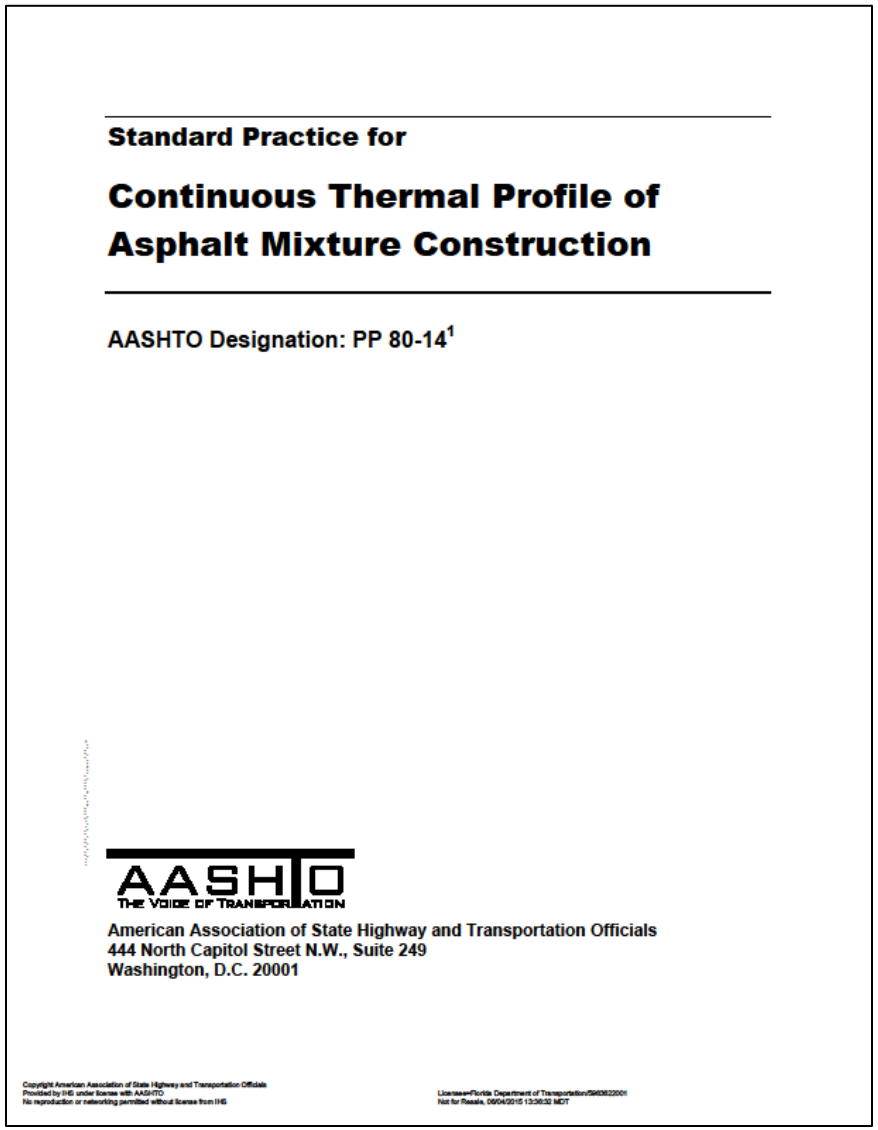
- Fatigue cracks
- Raveling
- Pot holes

Implementation & Application

Thermal streaks; areas with increased potential for longitudinal cracking.

Implementation & Application

Specification Guide;
AASHTO PP 80-14



Standard Practice for

Continuous Thermal Profile of Asphalt Mixture Construction

AASHTO Designation: PP 80-14[1]

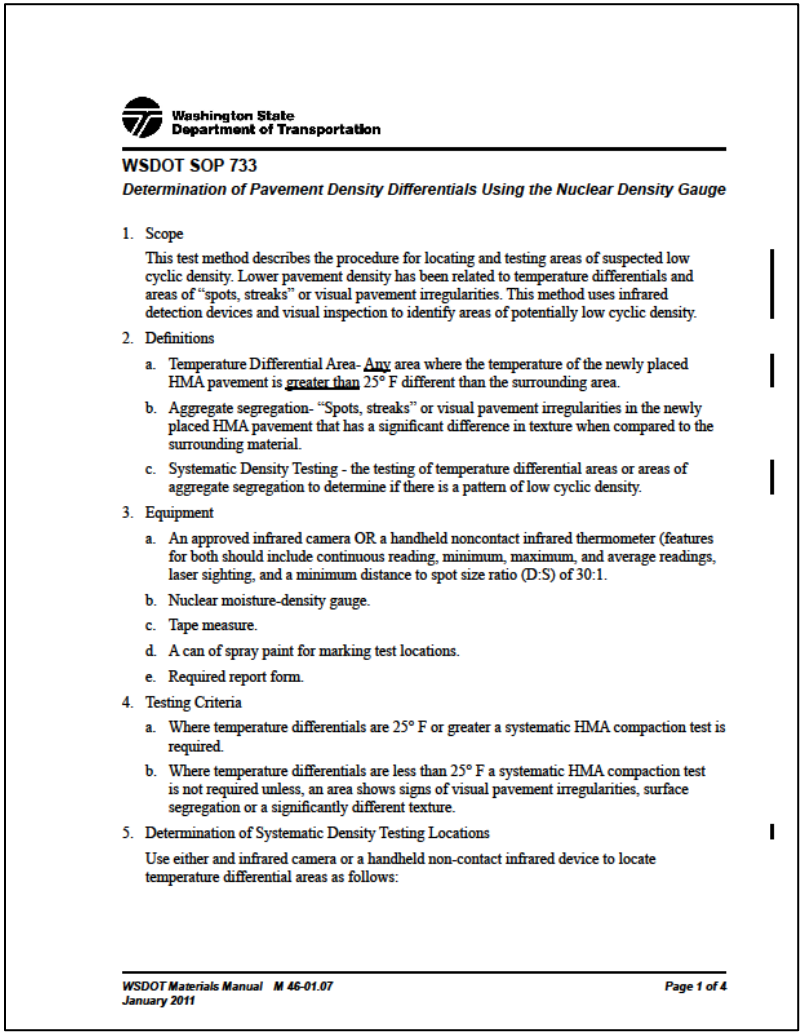
AASHTO
THE VOICE OF TRANSPORTATION

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Implementation & Application

IR Role in Acceptance Plan

- Determine biased areas for sampling and testing
  - Washington DOT
- Determine pay factors
  - Minnesota DOT
  - Quebec
- Minnesota pay factors for each 150 foot segment:
  - $200 bonus; <25ºF
  - $200 penalty; >50ºF



Washington State Department of Transportation

WSDOT 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 reading, 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 shows signs of visual pavement irregularities, surface segregation or a significantly different texture.

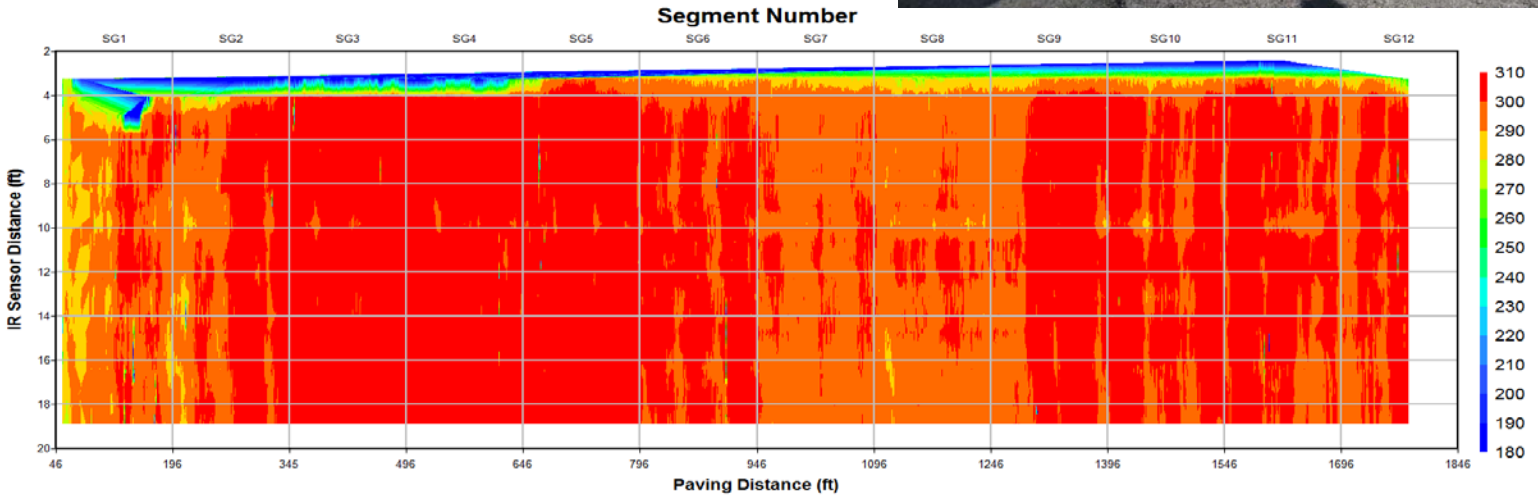
5. Determination of Systematic Density Testing Locations

   Use either and infrared camera or a handheld non-contact infrared device to locate temperature differential areas as follows:

Implementation & Application

Conclusion from demonstration projects, to-date:

- Pave-IR scanner is one tool to confirm a uniform, high-quality mat.



Infrared Technology (IR)

Implementation & Application of Products

SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Infrared Technology (IR)

Products from Demonstration Projects

Harold L. Von Quintus, P.E.

November 9, 2015

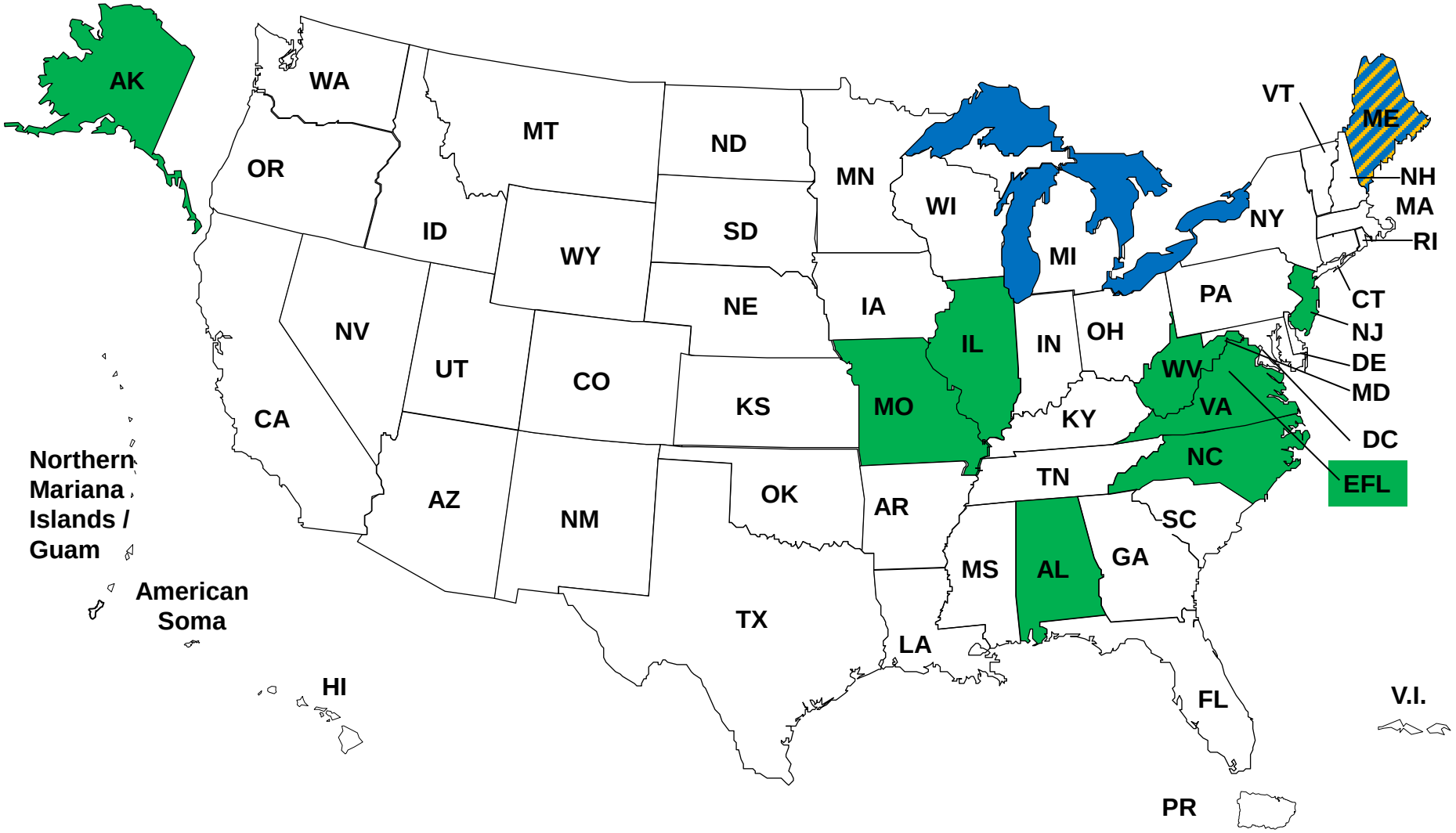
U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO

Products from Demonstration Projects

1. Case Study/Demonstration Project
2. Showcase
3. Trouble Shooting and Best Practices Guide
4. Specification Guide
5. IR Guide/Primer

Products from Demonstration Projects



Products from Demonstration Projects

1. Case Study/Demonstration Projects:

- 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.

Products from Demonstration Projects

1. Case Study/Demonstration Projects:

- Outcome
  - Case Study Report
  - Workshop
    - Demonstrate and discuss value added using IR technology to agency and contractor.

Products from Demonstration Projects

2. Showcase:

- Showcase for IR Technology
  - Maine DOT is the host agency
  - June time frame
- Purpose
  - Highlight IR technology, provide training & operation.
  - Attendance includes agencies, contractors, industry, consultants and academia.
- Outcome
  - Report to document showcase

All participating agencies in IR demonstration projects will receive invitation.

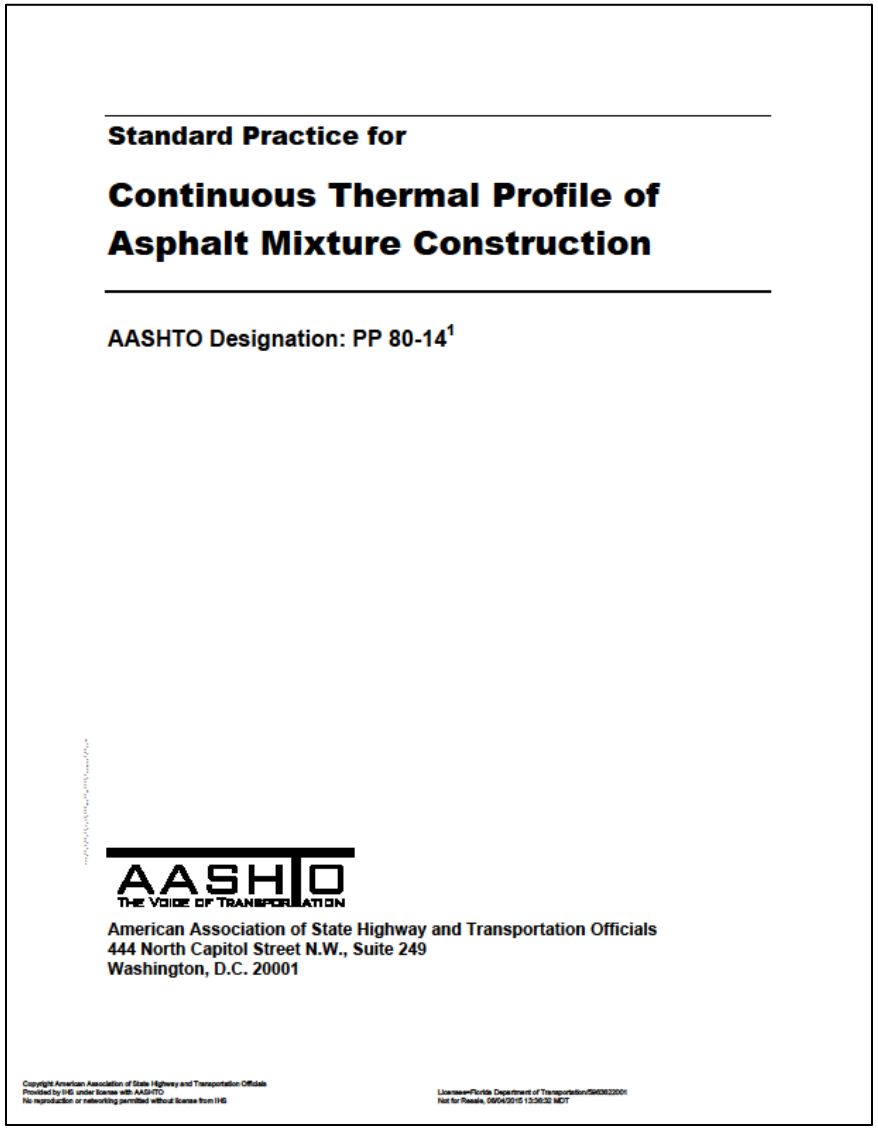
Products from Demonstration Projects

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 demonstration projects
  - Experience of agencies & consultants

Products from Demonstration Projects

4. Specification Guide; AASHTO PP 80-14



Standard Practice for

Continuous Thermal Profile of Asphalt Mixture Construction

AASHTO Designation: PP 80-14[1]

AASHTO
THE VOICE OF TRANSPORTATION

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Products from Demonstration Projects

4. Specification Guide

- Purpose
  - Advance standardization of IR equipment and testing protocols through AASHTO.
  - Agencies can customize it to their needs
- Outcome
  - Revised/Enhanced AASHTO PP 80-14
- Based on:
  - Demonstration Projects
  - Agency Experience: Minnesota DOT, Texas DOT, etc.

Products from Demonstration Projects

5. IR Guide/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.

Infrared Technology (IR)

Products from
Demonstration Projects