MATC Overview and National Trends in Asphalt Pavement Research

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U.S. Department of Transportation
Federal Highway Administration

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ACRONYMS

- AASHTO: American Association of State Highway and Transportation Officials
- AMPT: Asphalt Mixture Performance Tester
- ASTM: American Society for Testing and Materials
- BMD: Balanced Mix Design
- DPS: Dielectric Profiling System
- |E*|: Dynamic modulus of asphalt
- FHWA: Federal Highway Administration
- FTIR: Fourier Transform Infrared Spectroscopy
- I-FiT: Illinois Fatigue Test
- LTS: Laser Texture Scanner
- MATC: Mobile Asphalt Technology Center
- MPD: Mean Profile Depth
- NDE: Nondestructive Evaluation
- PMTP: Paver Mounted Thermal Profiler
- QA: Quality Assurance
- SSR: Stress Sweep Rutting
- TFHRC: Turner-Fairbank Highway Research Center
- XRF: X-Ray Florescence

FHWA Mobile Asphalt Technology Center (MATC)

Technologies Demonstrated by MATC

Mixture Tests	Materials Tests	Field Tests
IDEAL-CT for crack resistance	X-Ray Fluorescence (XRF) Spectrometer for binder's or markings' chemical elements	Paver-mounted thermal profiler for real-time mat temperatures
Overlay Test for reflective cracking	* FTIR looks at molecules in binder (lime, polymers,…)	Pulse induction test for in-place pavement thickness
Flexibility index test (I-FIT) for fracture resistance	* Binder characterization testing (delta T_c, delta T_f)	Circular Track Meter for measuring mean profile depth
* Hamburg Wheel Track Tester		Dielectric profiling system (DPS) for in-place density
IDEAL-RT for rutting resistance		Laser-based measurement of mean profile depth
AMPT suite of tests (|E*|, cyclic fatigue, SSR)	** Done at FHWA TFHRC labs*	

Other support activities:

PaveME Design analysis

* FlexMAT & FlexPAVE for mix design performance comparisons

Asphalt pavement spec review

Construction density spec review (mat and joints)

Example of Typical MATC Site Visit

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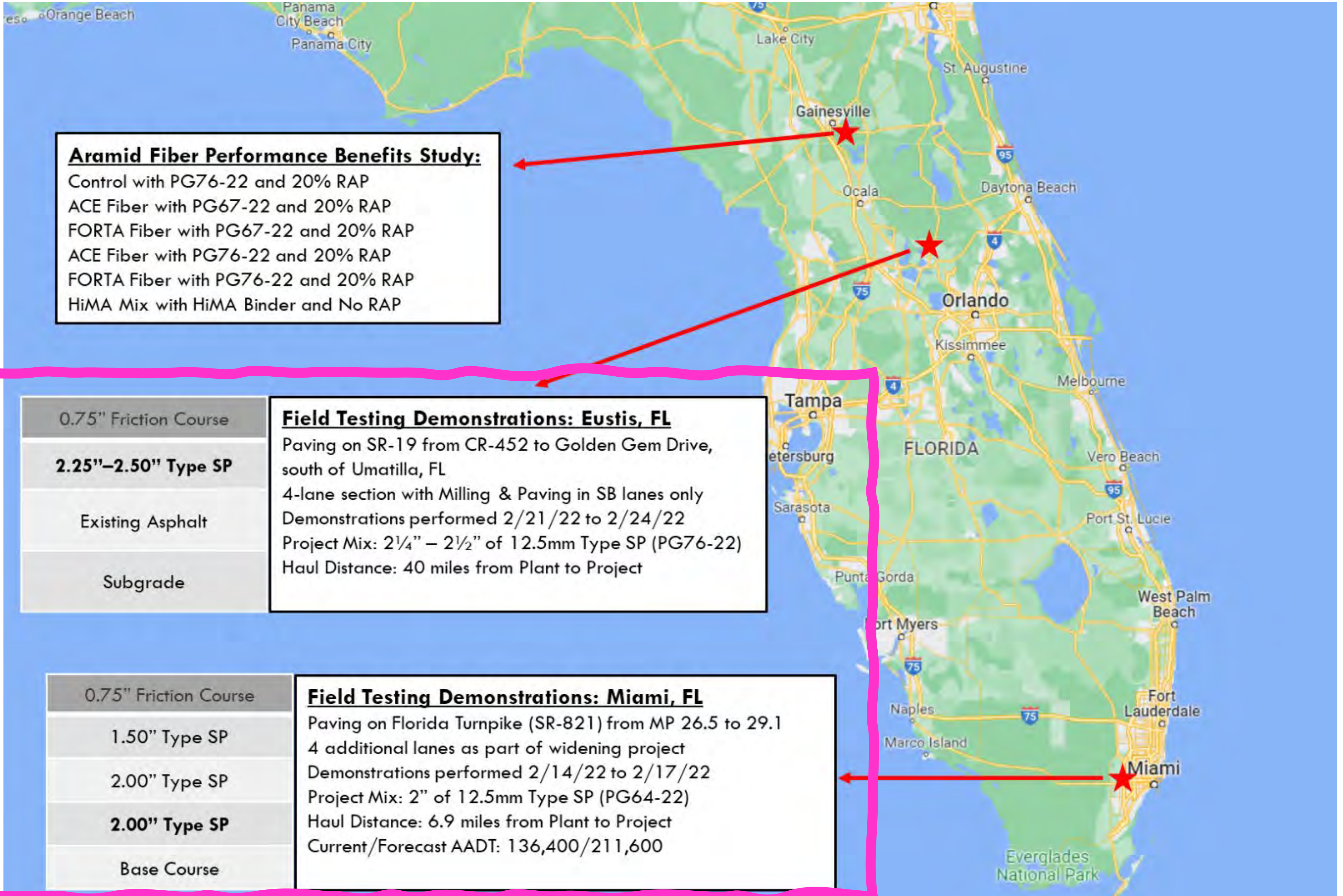
Feb 2022



Aramid Fiber Performance Benefits Study:

Control with PG76-22 and 20% RAP
ACE Fiber with PG67-22 and 20% RAP
FORTA Fiber with PG67-22 and 20% RAP
ACE Fiber with PG76-22 and 20% RAP
FORTA Fiber with PG76-22 and 20% RAP
HiMA Mix with HiMA Binder and No RAP

0.75" Friction Course
2.25"–2.50" Type SP
Existing Asphalt
Subgrade

Field Testing Demonstrations: Eustis, FL

Paving on SR-19 from CR-452 to Golden Gem Drive, south of Umatilla, FL
4-lane section with Milling & Paving in SB lanes only
Demonstrations performed 2/21/22 to 2/24/22
Project Mix: 2¼" – 2½" of 12.5mm Type SP (PG76-22)
Haul Distance: 40 miles from Plant to Project

0.75" Friction Course
1.50" Type SP
2.00" Type SP
2.00" Type SP
Base Course

Field Testing Demonstrations: Miami, FL

Paving on Florida Turnpike (SR-821) from MP 26.5 to 29.1
4 additional lanes as part of widening project
Demonstrations performed 2/14/22 to 2/17/22
Project Mix: 2" of 12.5mm Type SP (PG64-22)
Haul Distance: 6.9 miles from Plant to Project
Current/Forecast AADT: 136,400/211,600

Deployment of Field Technologies to Assist Asphalt Pavement Constructability

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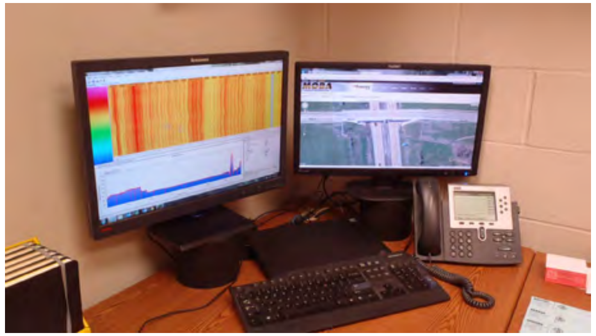
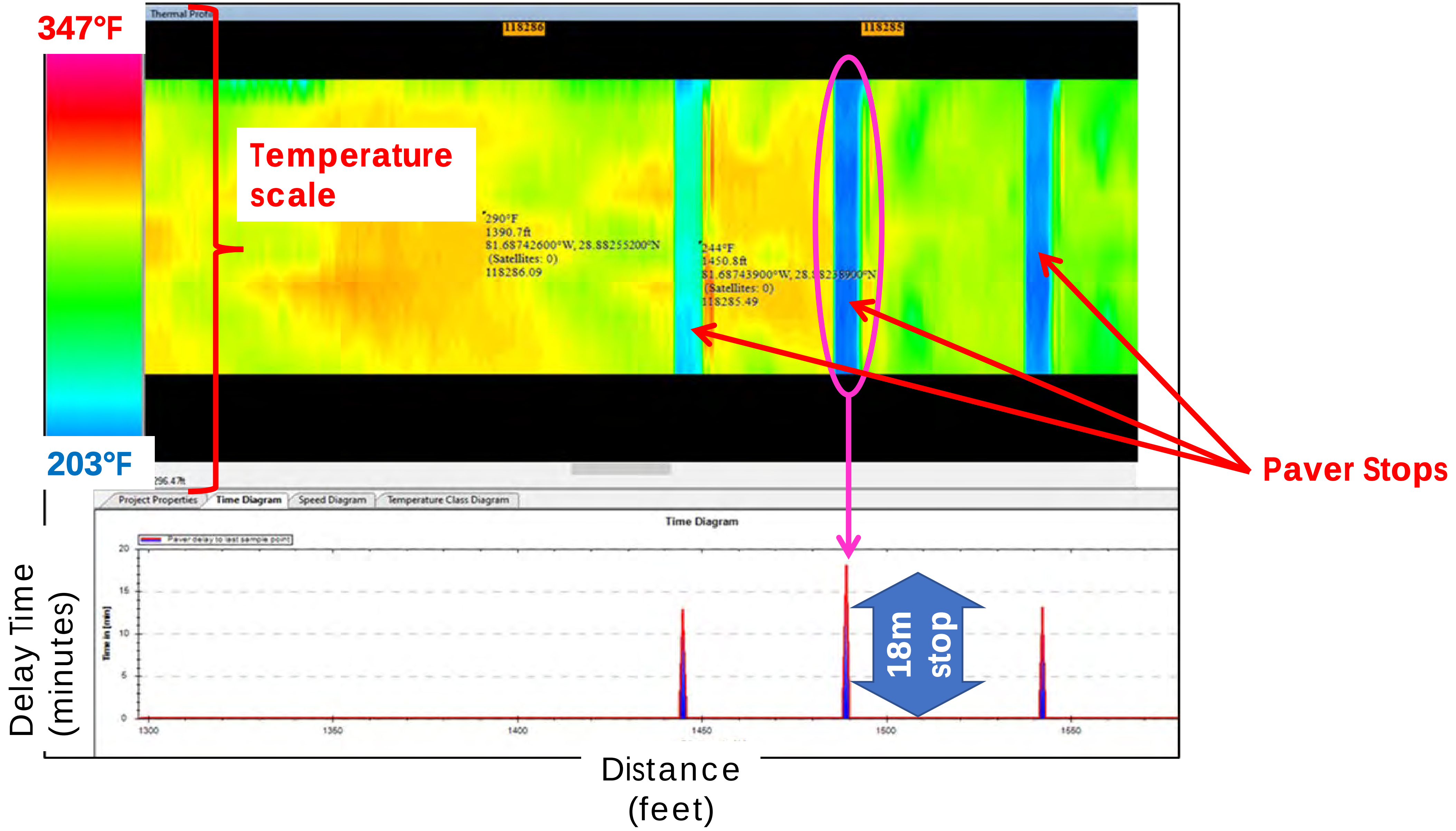
Paver-Mounted Thermal Profiler (PMTP)

Imaging of Mat Surface: 2 to 3 meters behind screed



All images source: Travis Walbeck

PMTP Thermal Map: SR-19 near Eustis, FL



Use of PMTP Devices Nationally

Benefits

+ Identify cold spots, segregation, thermal streaks
+ Identify low density areas
+ Control paver delays
+ Adjust speed between trucks

Current Limitations

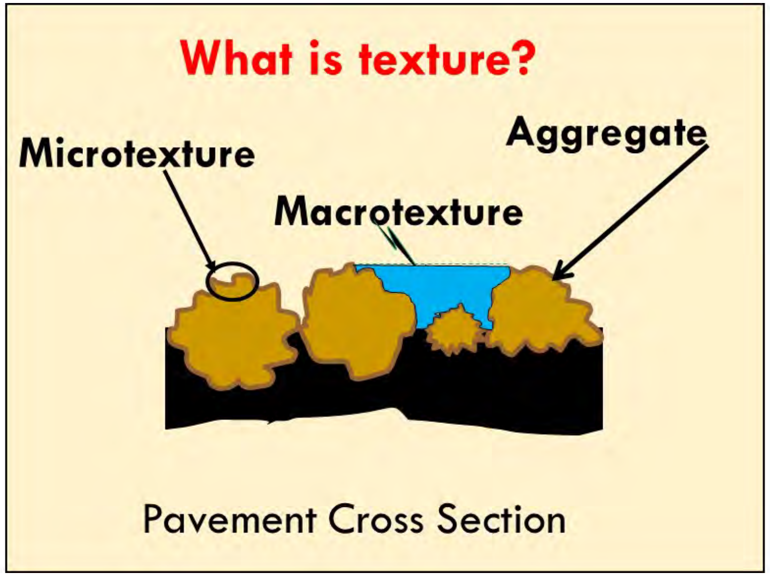
- Installation on contractor's equipment
- No existing direct correlation between severe thermal segregation & pavement density

Implementation in 12 states & Eastern Federal Lands

- Alabama, Alaska, Illinois, Maine, Minnesota, Missouri, New Jersey, North Carolina, North Dakota, Texas, Virginia, & West Virginia

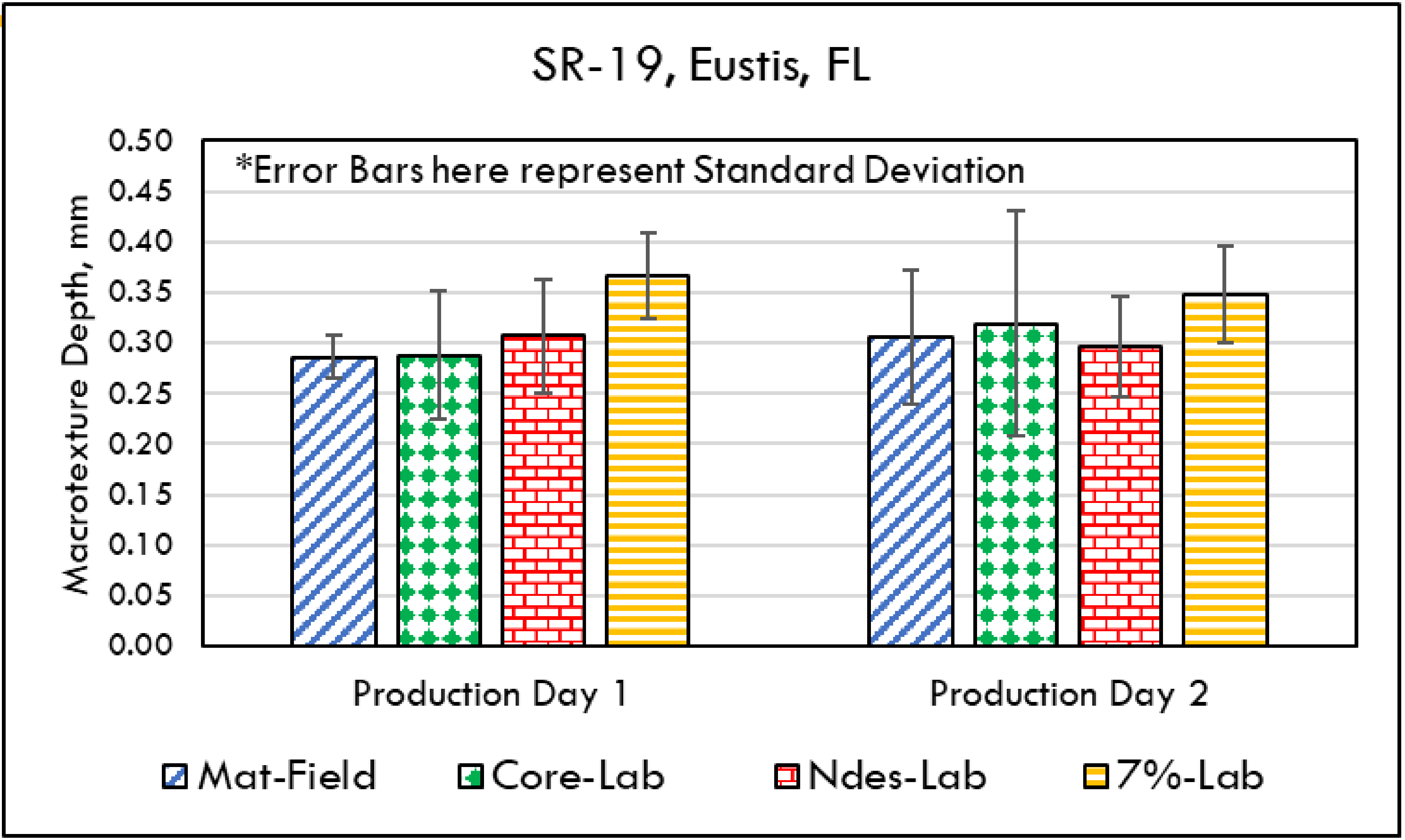
Macrotexture Testing

Laser Texture Scanner: Use in Lab or Field



- Lightweight, portable, rapid, 3D scanner
- Utilizes a 100-mm laser line and travels 100 mm to collect a square area
- Measures macrotexture on freshly compacted mats in field and on cores or gyratory specimens in lab

Mean Profile Depth (MPD) Measurements SR-19 near Eustis, FL



12.5mm Dense Fine-Graded HMA **– typical MPD values between 0.4 to 0.8 mm -** according to 2022 AASHTO Guide for Pavement Friction

Laser Texture Scanning

Benefits

+ Easy to use & nondestructive
+ High accuracy
+ Takes 90 seconds to run
+ Good for QC use
+ Can be used in lab during mix design & production

Current Limitations

- Standards still under development
- Surface must be dry, if used on field mat
- Sensitive to shiny mixes so spray needed to dull reflectance
- Not a direct correlation to friction

Current under consideration for implementation

- California, Illinois, Kentucky, North Carolina, Ohio, Washington

In-Place Asphalt Thickness Testing

Pulse Induction Technology

Nondestructive Pavement Measurement

- Quality control and agency acceptance
- AASHTO test method (AASHTO T 359-18)
- ASTM test method in the works
- *Not Federal requirements*

Step 1

Place the target

Step 2

Pave over it

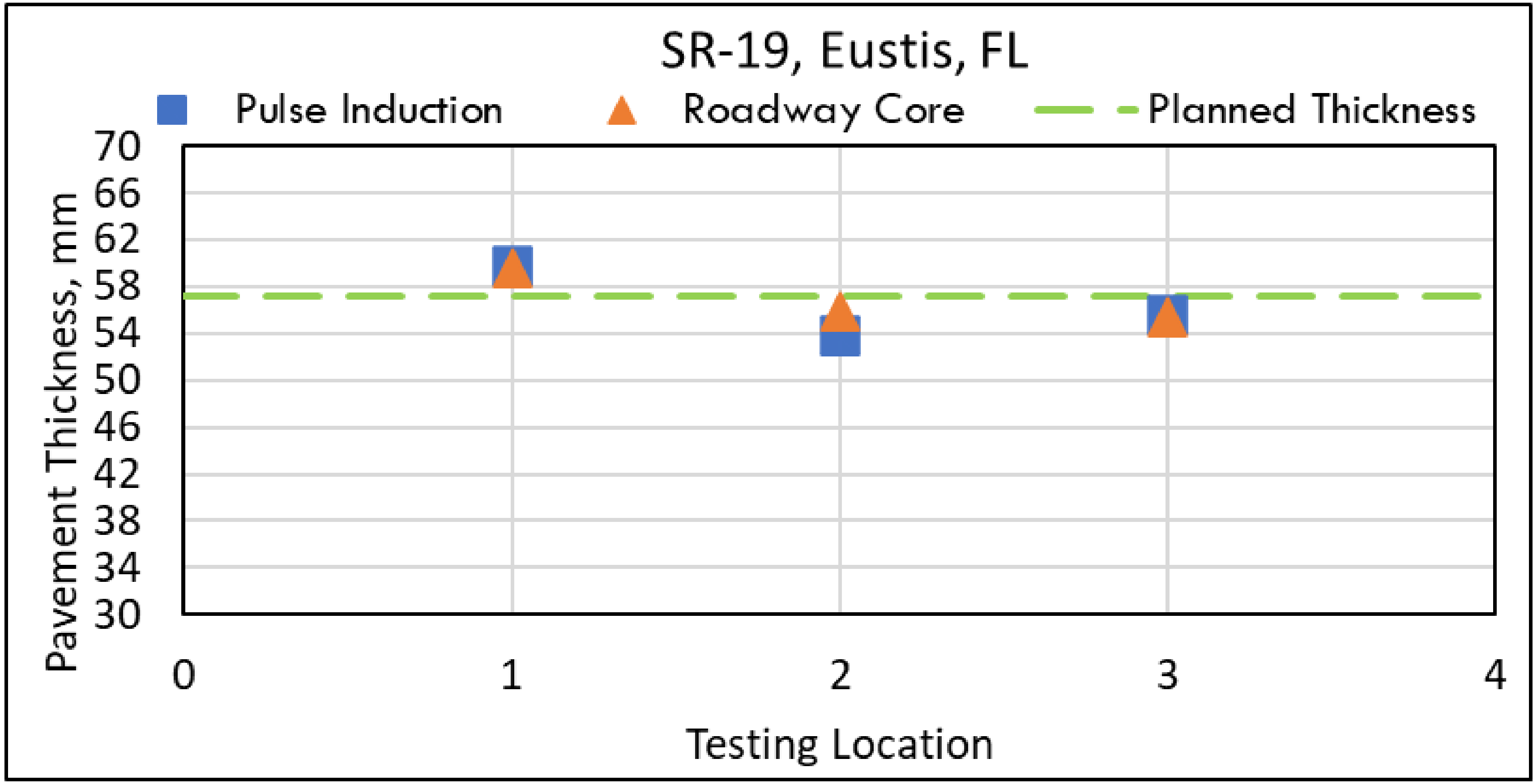
Step 3

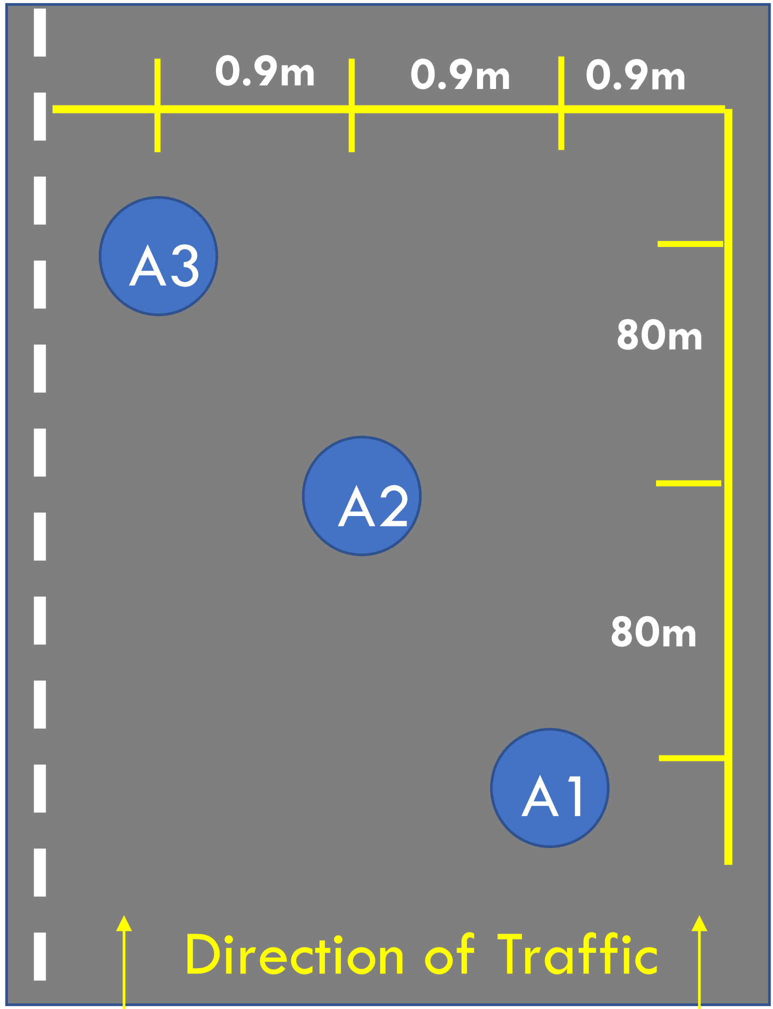
Find targets; measure thickness

Optional Step

Core & confirm thickness

Pulse Induction Technology - SR-19 near Eustis, FL





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Pulse Induction Technology

Benefits

+ Easy to use
+ High accuracy
+ Non-destructive
+ Almost real time (rapid)
+ Good for QC use e.g., test strips, informing paver adjustments

Current Limitations

- Presence of existing rebar in existing layers
- Presence of excessive moisture on surface
- Windrow paving
- Surface irregularities (inadequate removal of scabs, unlevel existing surface)

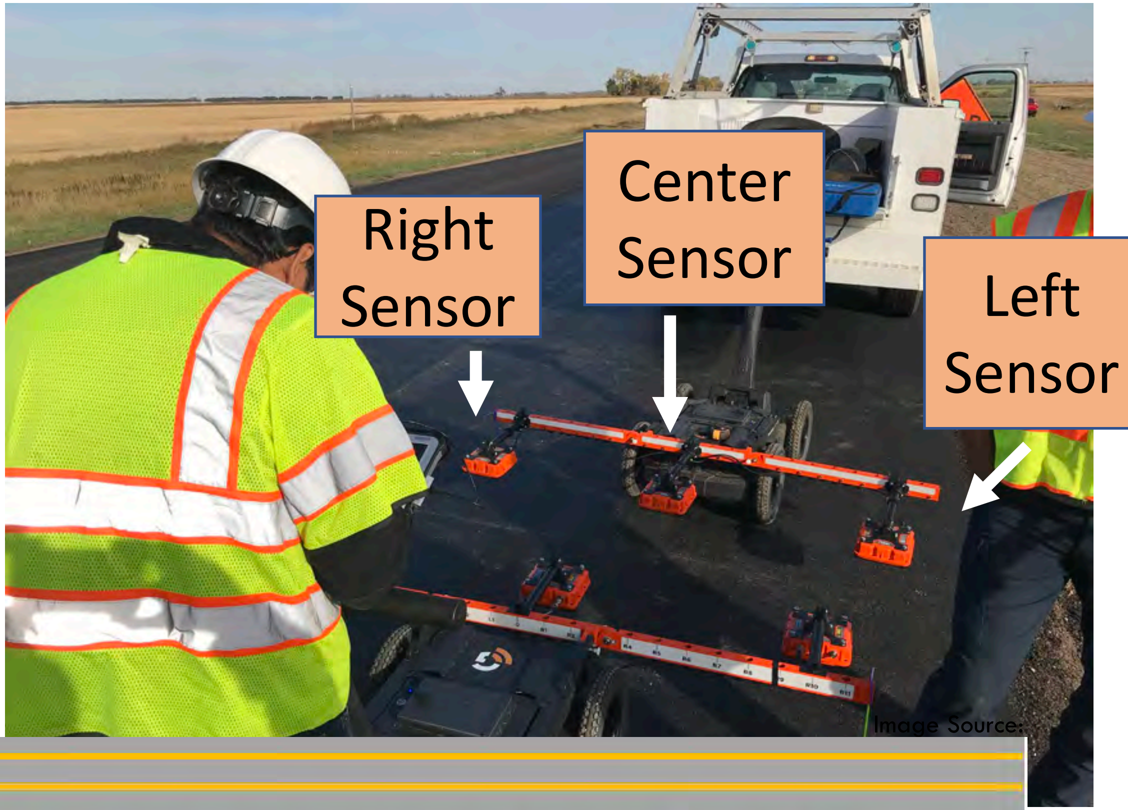
Current practice

- Iowa, Minnesota, Pennsylvania, Washington, Wisconsin

In-Place Asphalt Density & Mat Uniformity Testing

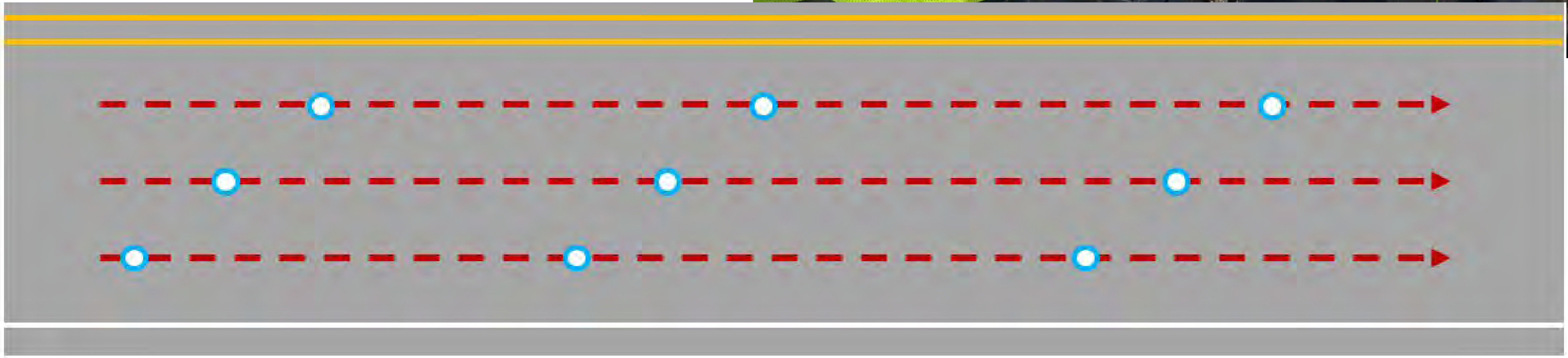
Dielectric Profiling Systems (DPS)

- Coring and nuclear density gauge only used for spot checks on predetermined, random locations
- DPS provides continuous density profile along testing path
- Reduce turnaround times

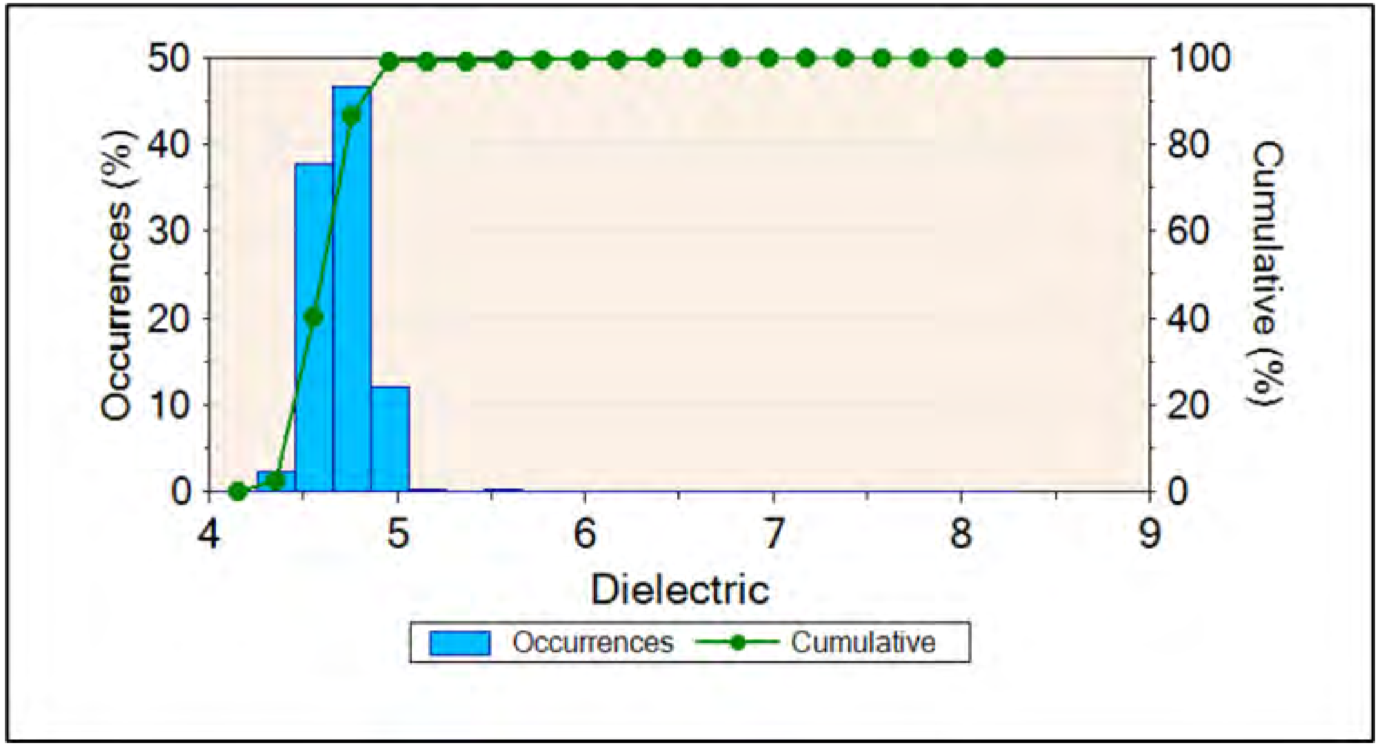


DPS measurements

Nuclear density gage or coring spots



DPS Mapping & Dielectric Distribution - SR-19 near Eustis, FL



Low Dielectric Value → Higher Air Void Content → Lower Density

Benefits and Challenges of DPS

Benefits

+ Use as QC tool to identify potential issues with paving & compaction operations
+ Nondestructive
+ Helps identify high and low compaction areas
+ Help improve density of mat & longitudinal paving joints

Current Challenges

- Obstacles to use for acceptance (agency resources, proper validation of contractor data, time to collect, etc.)
- Incorporation in specifications & bids
- Staffing the data collection
- Device is run manually

Density Profiling System - Office of Materials and Road Research - MnDOT (state.mn.us)

Technology Transfer


Spotlight on Pavement Density

Use of Dielectric Profiling Systems for Asphalt Density

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FHWA-HIF-21-XXXX

For more information on DPS and related technology, contact Monica Jurado, Pavements & Materials Engineer, FHWA Resource Center, monica.jurado@dot.gov

This equipment and more are available on loan at the MATC. www.fhwa.dot.gov/pavement/asphalt/trailer/equipment_loan_program.pdf

The dielectric profiling system series shares information on pavement testing programs.

To access the full series, visit www.fhwa.dot.gov/pavement/asphalt/trailer/initiatives.cfm

Background

Highway agencies seeking a more viable way to check the quality of asphalt construction than through sample cores are considering dielectric profiling systems (DPS) as a solution.

DPS use a ground-penetrating radar (GPR) to collect dielectric values from the underlying surface that help measure air voids or nonuniformity of newly laid hot-mix asphalt. In this way, a DPS unit rolled along a road segment can collect continuous data on asphalt density. Asphalt density is a key indicator for long-term performance of new pavement or resurfacing construction jobs. Improving pavement performance can extend maintenance cycles and save millions of dollars in transportation budgets.

State Departments of Transportation (DOTs) have been field-testing DPS units in their pavement testing programs through the second Strategic Highway Research Program (SHRP2) Initiative (R06C), which advanced the DPS technology as a nondestructive method for checking asphalt density.

DOTs describe initial difficulties in interpreting the intricate data and managing the enormous data output. However, DOTs observe that the data produces a more uniform and immediate picture of a new pavement layer than the process of obtaining sample cores at random spots along a new section.

How DPS Work

DPS units come in various models from multiple commercial vendors, costing about $70,000 per unit. Also known as density profiling systems, they often are in the form of lightweight carts that one person easily pushes along a test path. A three-channel GPR mounted near the wheels continuously collects data that transmits to the unit's computer system.

The unit determines the dielectric readings of the materials that make up the asphalt layer by measuring the velocity of reflected waves to about 2.5 inches. All material has a dielectric constant, ranging from 1 for air to 81 for water. HMA dielectric constants typically range from 3 to 6, depending on the aggregate type, asphalt content, and percentage of air voids.

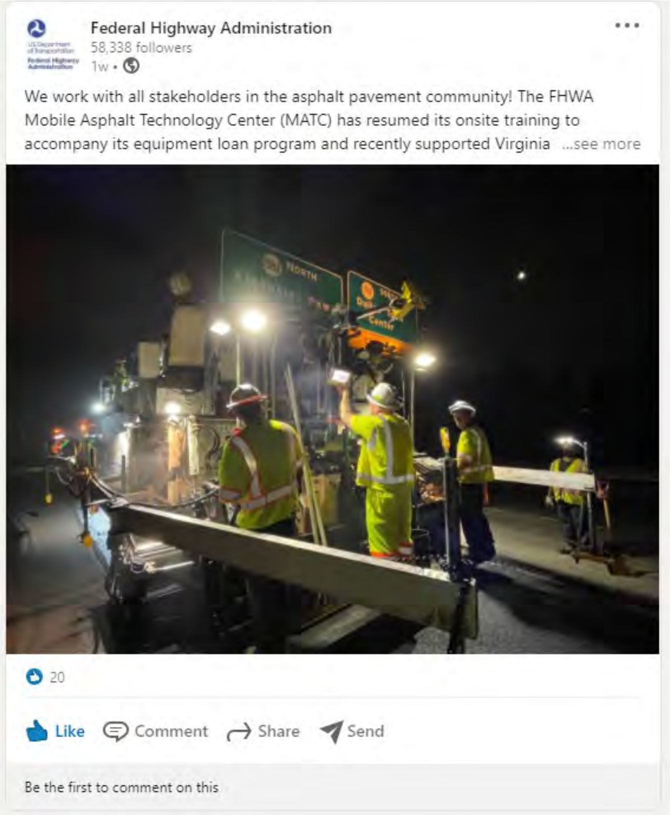
The paving crew can view the data immediately on the unit's trackpad and then export the data to other software for further analysis. The dielectric constants along the test path display as statistical data, histograms, box plots with outliers identified, or heat maps of the production lot.

Considering DPS? Technical assistance is available from the Federal Highway Administration (FHWA) through the Mobile Asphalt Technology Center (MATC) or FHWA division offices. There is also a national pooled fund study on DPS use.

A DPS unit side view (above) and in use (below). Photo sources: GSSI, ODOT

Benefits

- Ability to detect and identify areas of concern. Contracting crews can adjust or remediate while the work zone is intact and before a job's acceptance.
- More uniform results than with sample cores, which may miss variations in the new mat.
- Significant reduction of cores per project. This avoids risks of new defects from removal and return of cores. It also can save on contract costs.
- Data applies to other uses, such as simulating changes to construction specifications, mapping locations and data, and other quick visualizations.
- More efficient and safer than coring. A DPS unit can be walked behind the paving equipment without additional road closures against fast-moving traffic.



[Technical Documents - Mobile Asphalt Technology Center - Asphalt - Pavement & Materials - Pavements - Federal Highway Administration (dot.gov)]

- Communication bursts to raise awareness on FHWA efforts
- MATC "Lunch-n-Learn: Asphalt" Series
- Examples of Topics:
  - **Enhancing in-place density**
  - Spotlight on **Pavement Density**: Dielectric Profiling System Series
  - Spotlight on **Constructability**: Pave-IR Series
  - Spotlight on **Pavement Safety**: Macrotexture Series

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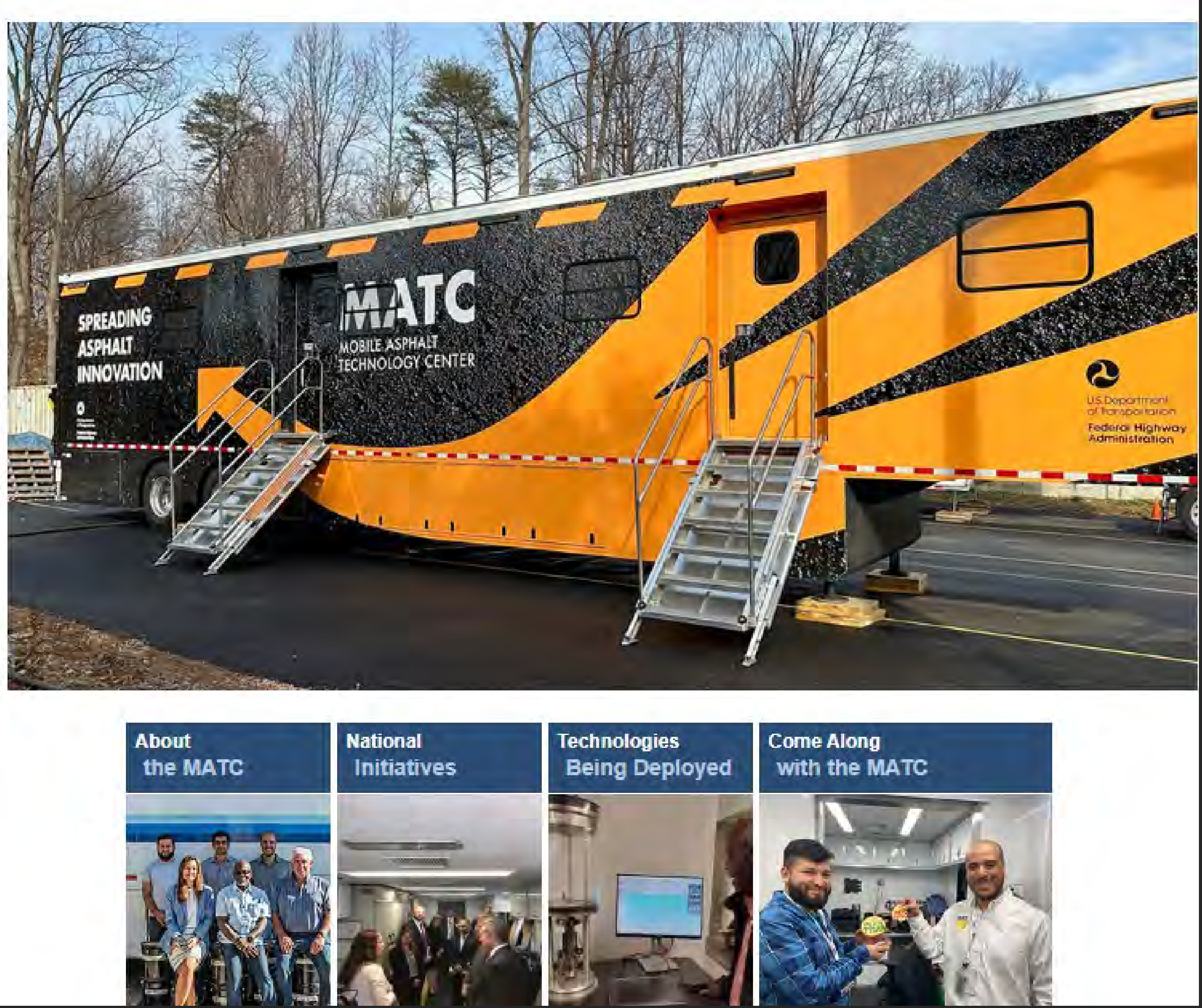
https://www.fhwa.dot.gov/matc



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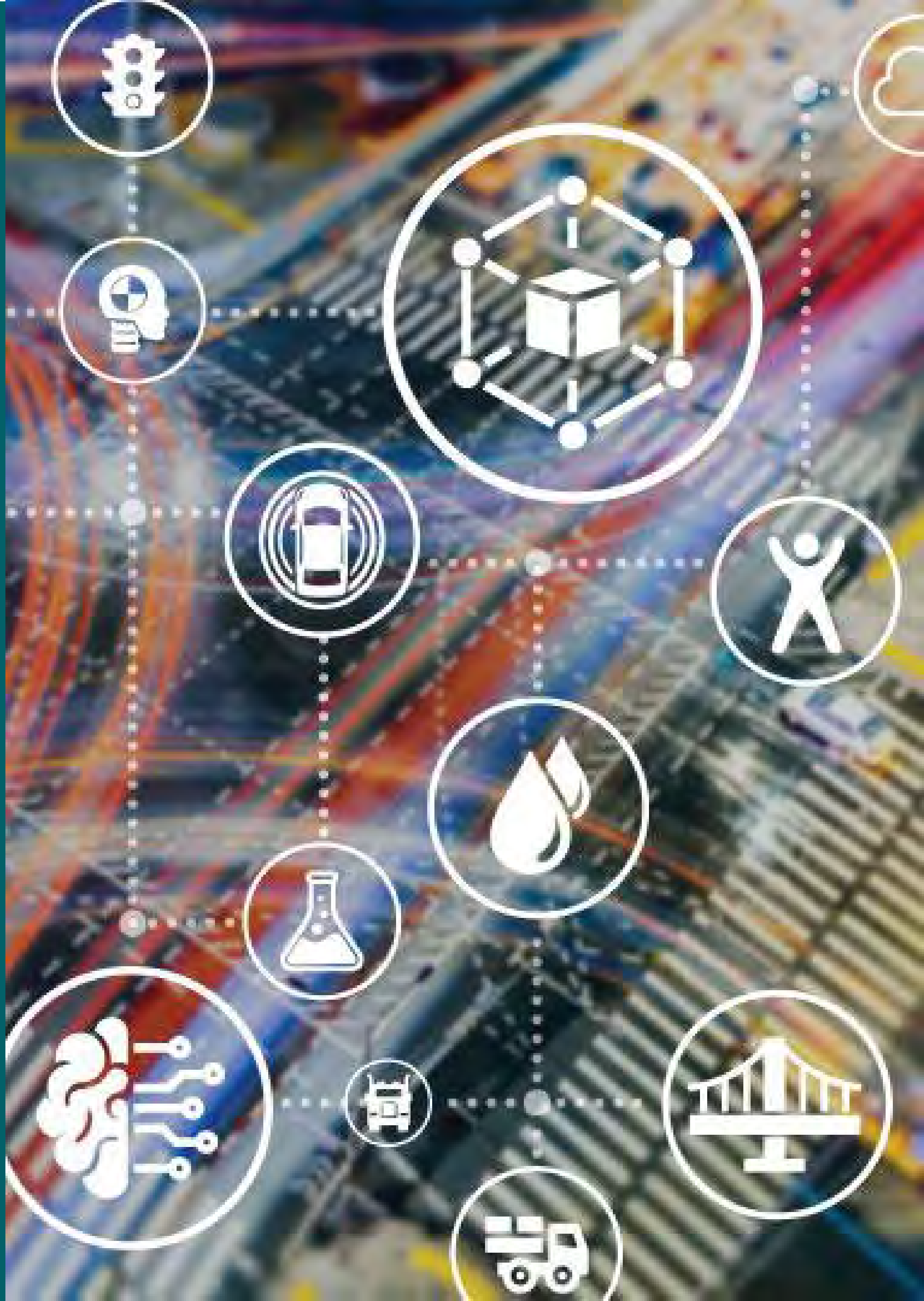
Recycling Agent Dosage Optimization Procedures



Abbreviations

- AASHTO: American Association of State Highway and Transportation Officials
- ABQT: asphalt binder quality test
- BBR: bending beam rheometer
- CTOD: critical tip opening displacement
- DENT: Double Edge Notched Tension
- DSR: dynamic shear rheometer
- G-R: Glover-Rowe
- h: hour
- m-value: relaxation constant
- PAV: pressure aging vessel
- PG: performance grade
- RA: recycling agent
- RAB: reclaimed asphalt binder
- RAP: reclaimed asphalt pavement
- RTFO: rolling thin-film oven
- S-value: stiffness

Pavement Testing Facility

Drawings Not to Scale

A			B			C			D	
Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7	Lane 8	Lane 9	Lane 10	Lane 11
Mix Types Study			*Premium Binders Study*			*Top-down / Durability / High RAP Study*			*Inverted Pavement Study*	
SMA Study		Resiliency Study	Premium Binders Study		Resiliency Study	High RAP Study		Resiliency Study	Short-term Studies AC Thickness < 2"	
2" DGA 64H-22 20%RAP (SBS)	2" SMA 64H-22 20%RAP (SBS+Fiber)	2" Control-DGA 64S-22 20%RAP	2" DGA 64E-22 20%RAP	2" DGA 64S-22 40%RAP (Bio RA)	2" Control-DGA 64S-22 20%RAP	2" DGA 64S-22 40%RAP Bio RA	2" DGA 64S-22 40%RAP Petroleum RA	2" Control-DGA 64S-22 20%RAP	1.5" DGA PG 64S-22 0% RAP 9.5mm mix	2" DGA PG 64S-22 0% RAP 9.5mm mix
2" DGA 64H-22 20%RAP (SBS)	2" SMA 64H-22 20%RAP (SBS+Fiber)	2" Control-DGA 64S-22 20%RAP	2" Control-DGA 64S-22 20%RAP	2" Control-DGA 64S-22 20%RAP	2" Control-DGA 64S-22 20%RAP	2" Control-DGA 64S-22 20%RAP	2" Control-DGA 64S-22 20%RAP	2" Control-DGA 64S-22 20%RAP		

4" AC Layer	4" AC Layer	4" AC Layer	4" AC Layer	4" AC Layer	4" AC Layer	4" AC Layer	4" AC Layer	4" AC Layer	1.25" AC Layer	1.75" AC Layer
Base 21A Existing Material at 12"			Base Blend of 21B: No.8-GR @ 90:10 at 8"			8" ATB at <3% Asphalt			Base Blend of 21B: No.8-GR @ 90:10 at 8"	
Subbase #10 Screenings 8"			Subbase #10 screenings 12"			Subbase #10 Screenings 12"			Subbase 8" CTB 21A-GR 8" CTB No. 10-GR	Subbase 12" CTB 21A-GR 12" CTB No. 10-GR
Subgrade 6" conditioned			Subgrade 6" conditioned			Subgrade 6" conditioned			Subgrade Depth Varies conditioned	
Poor Permeability Pit			Medium Permeability Pit			Good Permeability Pit			Inverted Pavement Pit	

Objective

To evaluate different approaches, including PG, G-R, DENT, ABQT, creep rate (m-value), and stiffness (S-value), based on the BBR test, to optimize the dosage of RAs.

Materials and Methods

U.S. Department of Transportation
Federal Highway Administration
Turner-Fairbank Highway Research Center

Materials

Binder/Mix Composition	Source of RA	ID	RA Dosage (%)
80 percent Virgin + 20 percent RAP	—	20RAP	—
60 percent Virgin + 40 percent RAP		40RAP	
40RAP+RA	Bio-based	40RAP-B1	5, 10
		40RAP-B2	5, 10
	Petroleum-based	40RAP-P1	10, 25
		40RAP-P2	10, 25

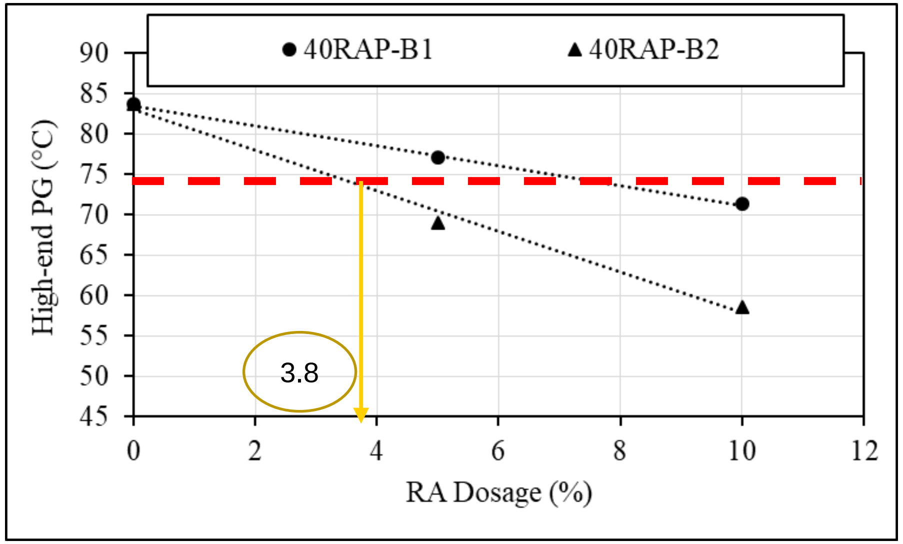
— = No data.
B = Bio-based RA; ID = identification; P = Petroleum-based RA; V = Virgin binder.

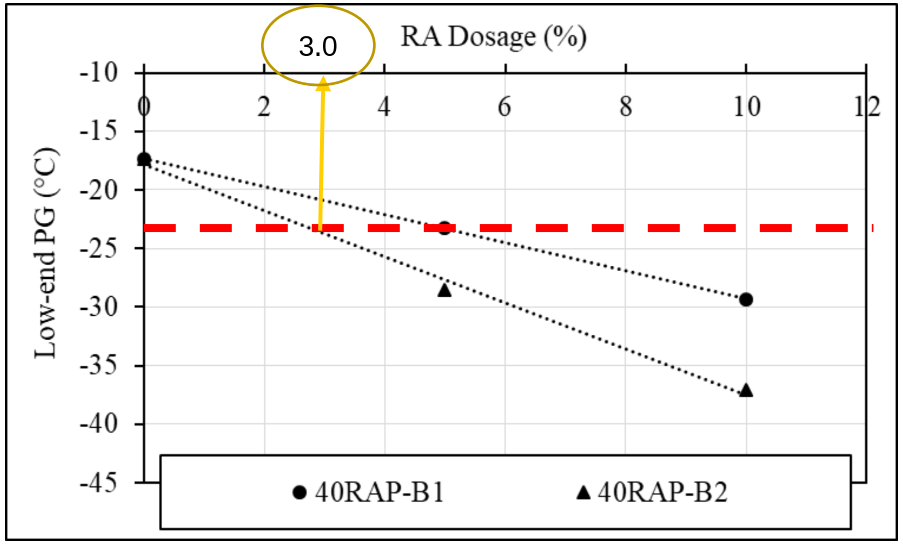
Experimental Plan

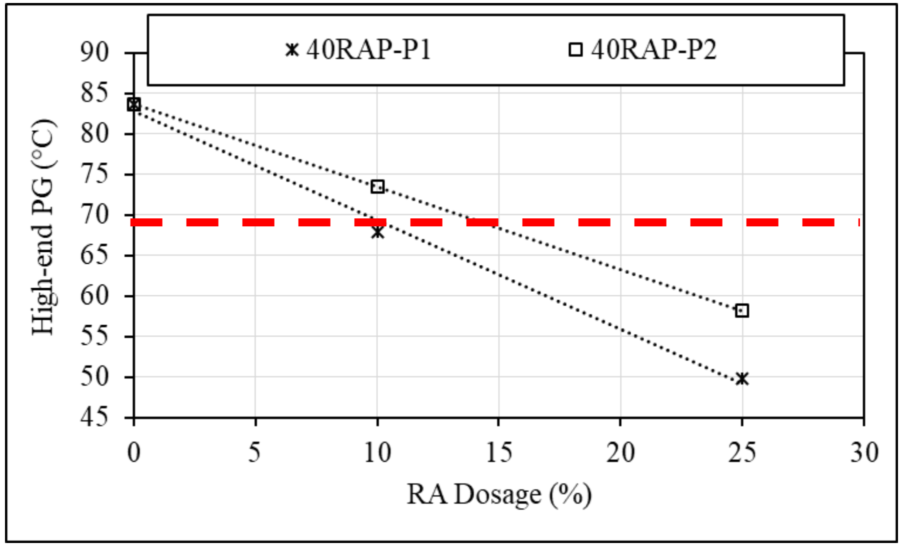
- Tests:
  - DSR: PG and G-R.
  - ABQT.
  - BBR: m-value and S-value.
  - DENT.
- Aging conditions: RTFO and RTFO + PAV.

Results and Discussions

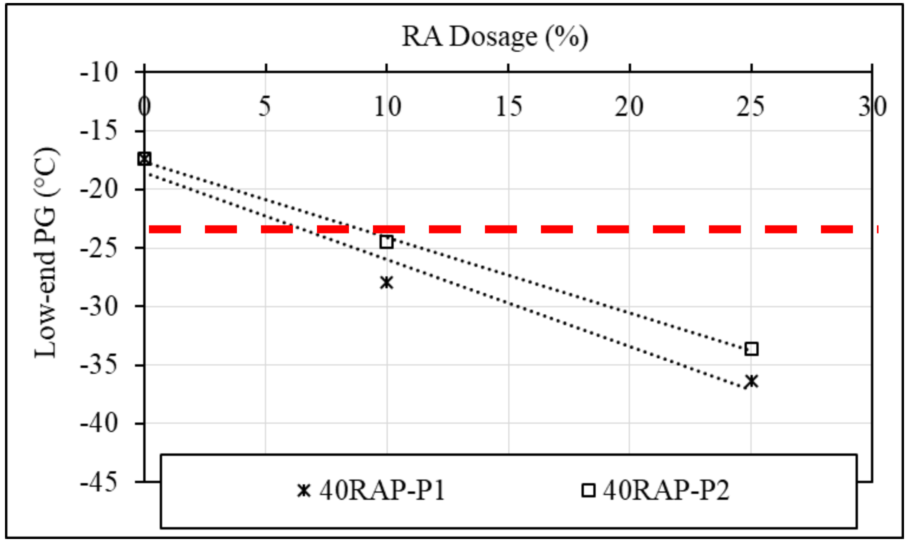
PG (Target Binder PG 73.5–23.7 °C)







All images source: FHWA.



RA Optimization

Binder/Mix Composition	ID	RA Dosage (%)
80% Virgin + 20% RAP	20RAP	—
60% Virgin + 40% RAP	40RAP	
40RAP+RA	40RAP-B1	5.3–8.1
	40RAP-B2	3.0–3.8
	40RAP-P1	6.9–6.9
	40RAP-P2	9.4–10.0

— = No data.

[red dashed box] = used to highlight row of results.

Comparison Between Different Optimization Methods

Binder ID	PG		ABQT		m-value	S-value	G-R			CTOD
	Min	Max	Min	Max	Min	Min	Min (Onset crack)	Min (Severe crack)	Min (Log (G-R))	Min
	RA Dosage (%)									
40RAP-B1	5.3	8.1	5.3	9.9	4.9	4.3	1.5	0.6	6.7	4.8
40RAP-B2	3.0	3.8	2.2	4.0	3.0	2.7	1.4	0.1	4.5	2.7
40RAP-P1	6.9	6.9	5.8	7.2	5.8	5.5	2.4	0.4	6.8	5.0
40RAP-P2	9.4	10.0	8.1	10.8	10.8	11.8	4.4	1.6	11.0	6.1

Max. = maximum and Min. = minimum.

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Findings

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Findings

- Results indicated that optimization based on PG could NOT meet all the rheological and failure parameters of the target binder.
- ABQT and Log(G-R) approaches proved useful as surrogate methods for estimating the amount of RA required to recover the properties of 40% RAB-blended binders and achieve the target binder (i.e., 20RAP).
- The DENT approach provided a more cost-effective dosage of RAs which should be further evaluated through future mixture and in-situ experiments.

Future Work

- Utilizing extended aging protocols and other aging and weathering methods, such as UV aging, should be considered.
- Evaluating the mixture design and testing protocols, source dependency of materials, including virgin binder, virgin aggregate, and RAP is important when drawing any conclusions about the compatibility and effectiveness of RAs.
- Conducting a lifecycle assessment to evaluate the long-term impacts of these additives is crucial, not only for evaluating pavement durability, but also for gauging their environmental sustainability.

Recycling Agent Rodeo

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Objective

- Assess various methods for optimizing RAs dosage.
- Examine the influence of different sources and grades of virgin binders on the optimal dosage of RAs.
- Gain insights into how changes in RAs dosages determined in binder level could affect the mechanical performance of asphalt mixtures.
- Create machine learning models to predict the performance of asphalt binders and mixtures that incorporate high percentages of recycled materials, various sources and grades of virgin asphalt binders, and RAs.

Materials

Dry Freeze			
Utah	Received	64-34	70-28
Nevada	Received	64-28	76-22
Nebraska	Received	58S-34	58E-34
South Dakota	Waiting	64-34	58[illegible]
Iowa	Waiting	58S-34	[illegible]
Montana	Received	64-28	[illegible]
Wet Freeze			
New Jersey	Received	[illegible]	[illegible]
Vermont	Recei[illegible]	[illegible]	[illegible]
Louisiana	[illegible]	[illegible]	[illegible]
Illinois	[illegible]	[illegible]	[illegible]
New Yor[illegible]	[illegible]	[illegible]	[illegible]
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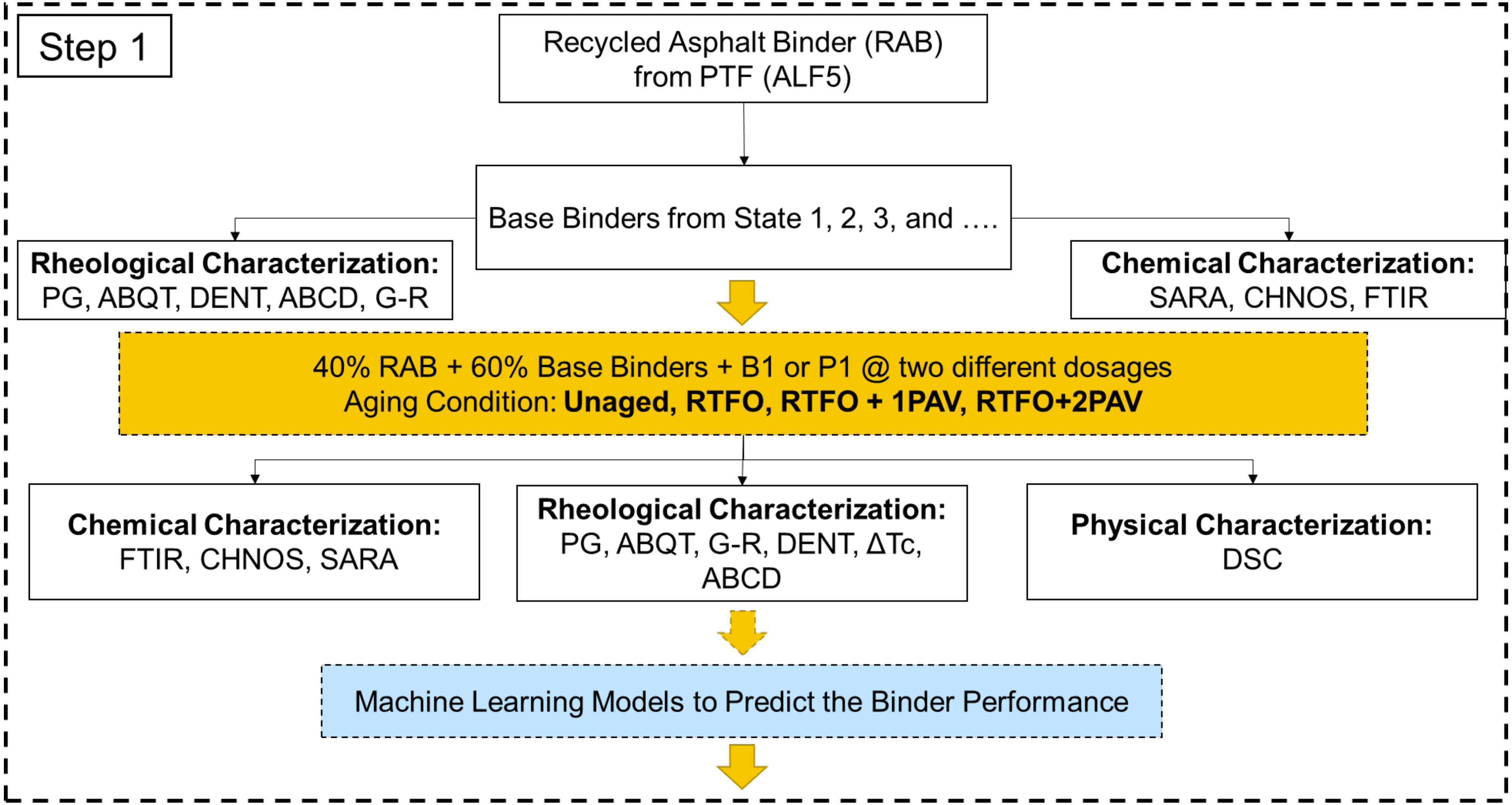
[illegible]	[illegible]	[illegible]	[illegible]34
[illegible]	[illegible]	[illegible]	64E-22
[illegible]	[illegible]	[illegible]	76-22
[illegible]	[illegible]	[illegible]28	52E-40
[illegible]	[illegible]	58-28	76-28
[illegible] No Freeze			
[illegible]	[illegible]ceived	64-22	76-22
[illegible]	Received	64-22	76-22
[illegible]	Received	52-28	76-22
[illegible] Carolina	Received	58-28	64-22
Mississippi	Received	67-22	76-22
Alabama	Received	67-22	76-22
Oklahama	Received	58-28 and 64-22	76-28
Arkansas	Received	64-22	76-22
Dry-No Freeze			
Texas	Received	64-22	76-22
California	Shipped	64-16	70-10
New Mexico	Waiting	58-28	76-28

30 states
61 binders

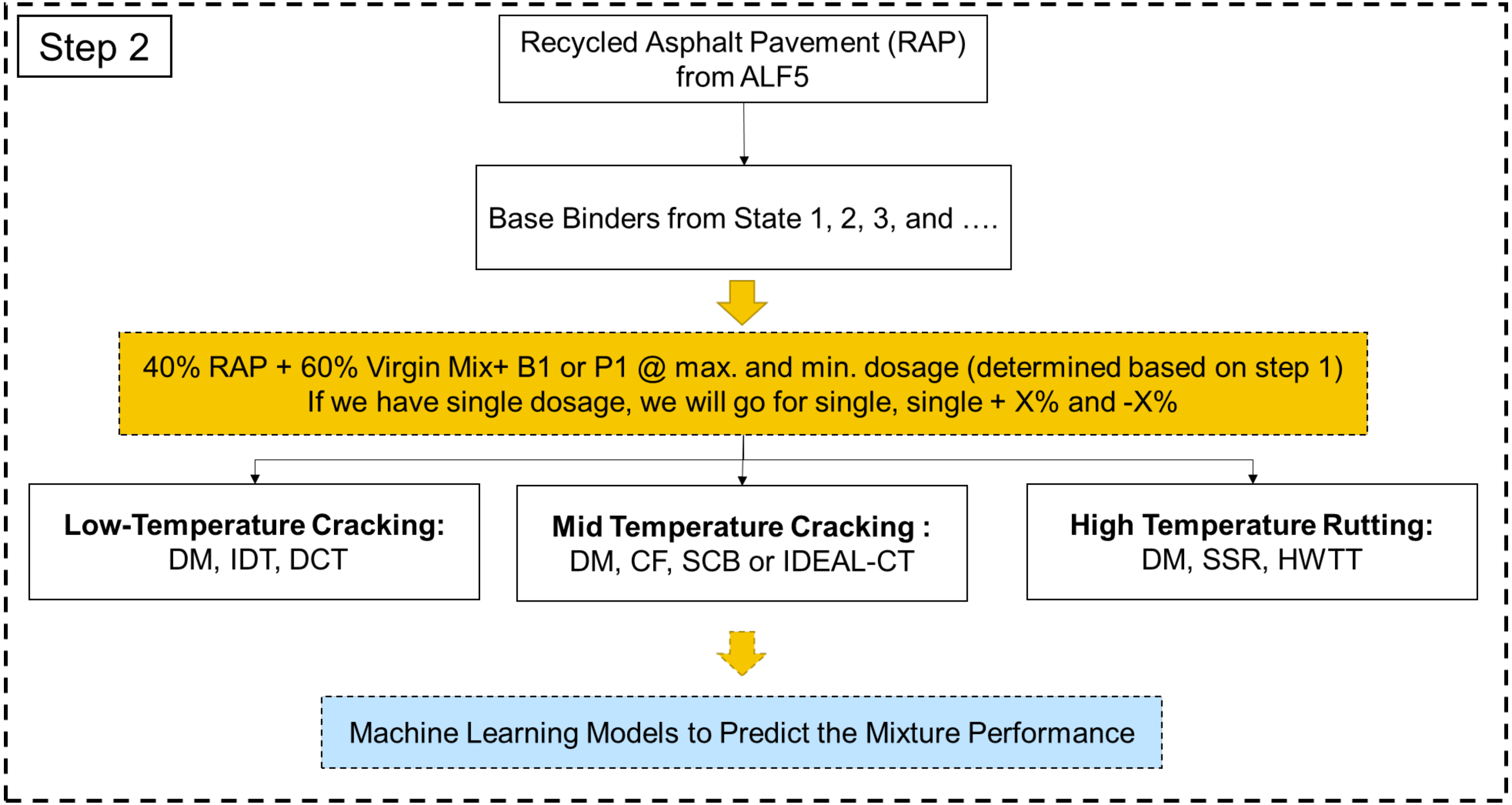
Climate Zone	Annual Rainfall (Inch)	Freezing Index (°F-Days)
Wet Non-Freeze	> 28	< 100
Wet Freeze	> 28	> 100
Dry Non-Freeze	< 28	< 100
Dry Freeze	< 28	> 100

Note: 1 inch = 2.54 cm;
Temperature (unit in °F) = Temperature (unit in °C) × 1.8 + 32.

Experimental Plan



Experimental Plan



Expected Outcomes

- Provide implementation guidelines for common binder grades and mixes used in the United States containing RAP materials and RAs.
- Develop a framework for evaluation of carbon-reducing/alternative flexible pavement materials such as bio-based RAs.
- Establish performance benchmark information and inform specification development for wider-scale implementation and thus further advancement of net-zero initiatives nationwide.
- Aid researchers and pavement engineers in determining the validity of optimization based on the binder testing approaches.
- Improve the efficiency of RAs at the mixture level.

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