2017 Alaska Asphalt Summit - Program - Hotel Captain Cook - Anchorage **November 6-7, 2017**

	Start	End	**Monday, November 6, 2017 - Asphalt Classes and Workshops**	Location
	Day 1			
	7:30 AM	7:55 AM	Registration / Check in	Foyer
	7:55 AM	8:00 AM	Call to Order; Richard Giessel, DOT&PF	Fore Deck
	8:00 AM	8:05 AM	Alaska's Flag Song; Lisa Hawkins	Fore Deck
	8:05 AM	8:15 AM	Welcome; Commissioner Marc Luiken, Randy Brand	Fore Deck
1	8:15 AM	9:45 AM	Part 1/2: Increased Density and Enhanced Durability for Asphalt Pavements; Danny Gierhart, Asphalt Institute	Endeavor
	9:45 AM	10:00 AM	Break	
1	10:00 AM	12:00 PM	Part 2/2: Increased Density and Enhanced Durability for Asphalt Pavements; Danny Gierhart, Asphalt Institute	Endeavor
	12:00 PM	1:00 PM	Optional Buffet Lunch (Limited to 50 attendees - Cost $10) History of Prestressed Precast Concrete - Cameron West	Adventure
	1:00 PM	1:15 PM	Check in for Afternoon Session	Foyer
2	1:15 PM	2:05 PM	Balanced Mix Design; Richard Willis, National Asphalt Pavement Association	Endeavor
3	2:05 PM	3:00 PM	Implementation of HMA Performance Specifications in WFLHD; Brad Neitzke, Western Federal Lands Highway Division	Endeavor
	3:00 PM	3:15 PM	Break	
4	3:15 PM	4:00 PM	The Bailey Method for Mix Design; Danny Gierhart, Asphalt Institute	Adventure
5	3:15 PM	4:00 PM	Warm Mix Asphalt Benefits in Cold Weather Environments; Bob Siffert, Evotherm	Endeavor
6	4:00 PM	4:45 PM	An Update on Asphalt Materials Testing; Shauna TecleMariam, US Oil	Adventure
7	4:00 PM	4:45 PM	Organosaline in Paving Products: Benefits and Challenges; Jerry Thayer, MatCon	Endeavor
	5:00 PM	7:00 PM	Hospitality Event	Quarter Deck

	Start	End	**Tuesday, November 7, 2017 - Asphalt General Sessions**	Location
	Day 2			
	7:30 AM	8:00 AM	Registration/Attendance sign in	Foyer
8	8:00 AM	8:50 AM	RAP in Asphalt Mixtures: A National Perspective; Richard Willis, National Asphalt Pavement Association	Fore Deck
9	8:50 AM	9:40 AM	Binder and Mixture Testing to Optimize RAP Mixtures; Todd Thomas, Colas Solutions	Fore Deck
	9:40 AM	10:00 AM	Break	
10	10:00 AM	10:40 AM	Intelligent Compaction & Thermal Profiling; George K. Chang, The Transtec Group	Fore Deck
11	10:40 AM	11:20 AM	Mapping Asphalt Compaction with 2.5 million tests in 22 nights on the Glenn Highway; Ronald Searcy, Richard Giessel, DOT&PF	Fore Deck
12	11:20 AM	12:00 PM	Yakutat Airport Pavement Rehabilitation; Amanda Gilliland, Knik Construction and Bob Trousil, DOT&PF	Fore Deck
	12:00 PM	1:00 PM	Optional Buffet Lunch (Limited to 50 attendees - Cost $10) Achieving the best Leadership possible in Construction - Craig Cottongim	Quarter Deck
	1:00 PM	1:15 PM	Check in for Afternoon Session	Foyer
13	1:15 PM	2:00 PM	Northern Region Highlights; Jeff Currey, Travis Donovan, DOT&PF	Fore Deck
14	2:00 PM	2:45 PM	Enhanced Durablity Through Increased Density; David Johnson, Asphalt Institute	Fore Deck
	2:45 PM	3:00 PM	Break	
15	3:00 PM	3:45 PM	RAP Mix Production Best Practices; Adam Hand, University of Nevada, Reno	Fore Deck
16	3:45 PM	4:30 PM	Cold Weather Asphalt Paving; David Johnson, Asphalt Institute	Fore Deck
	4:30 PM	5:00 PM	Summit Evaluation, Dismissal; AAPA & ACA	Fore Deck

Enhanced Durability Through Increased In-Place Pavement Density

FHWA—AI Cooperative Initiative

U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
RESOURCE CENTER

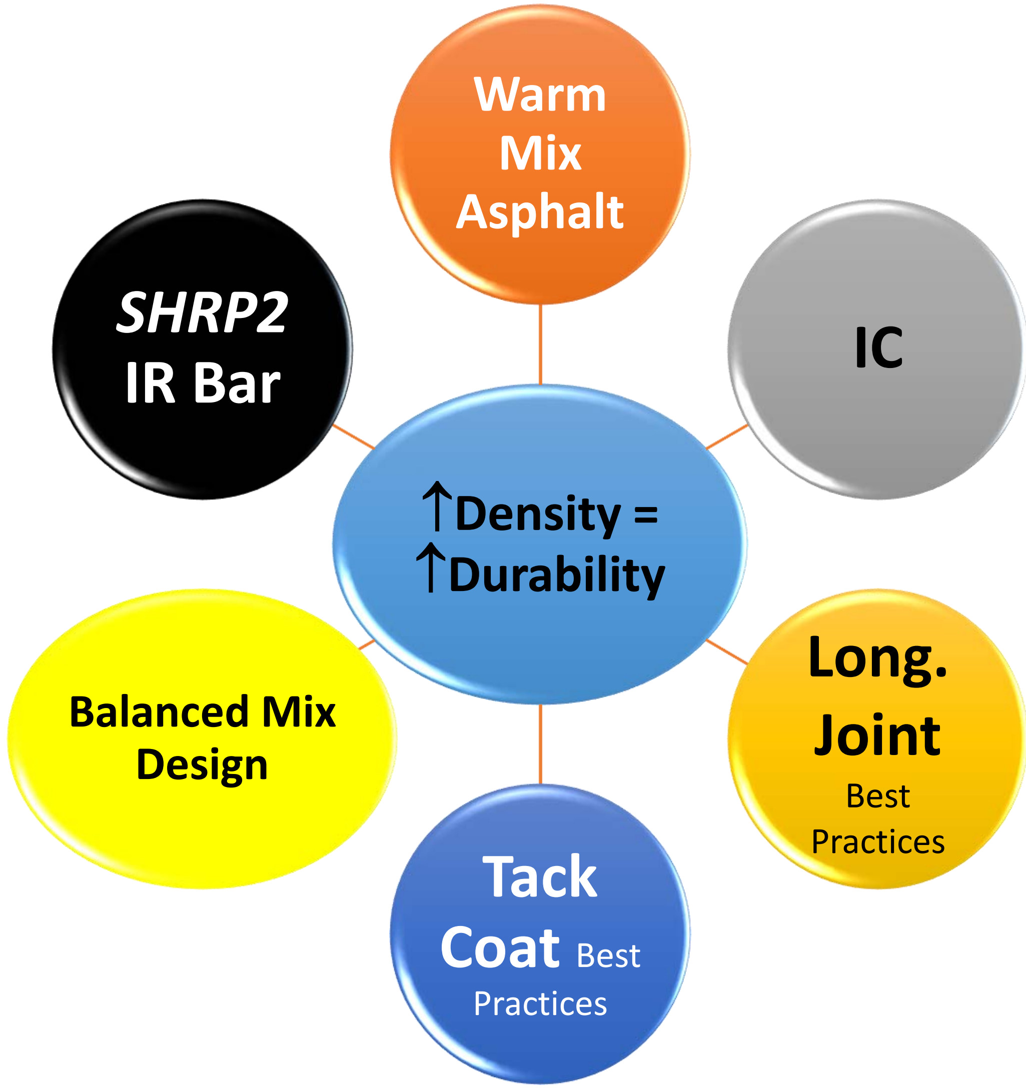
- **Danny Gierhart, P.E.**
  - Asphalt Institute
    - Senior Regional Engineer
  - Over 32 years' experience
  - Bachelor of Science – Civil Engineering
    - University of Oklahoma

- **Dave Johnson, P.E.**
  - Asphalt Institute
    - Senior Regional Engineer
  - Over 25 years' experience
  - Bachelor/Masters of Science – Civ g.
    - Montana State University

Introduction

Section 1

Current Technologies that Influence Compaction…



Enhanced Durability through Increased In-Place Pavement Density

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- Assumption – Pavement density can be increased with a minimum of additional cost
- Long-Term Objective – States will increase their in-place asphalt pavement density requirements resulting in increased pavement life

Challenges – Many Considerations

How is Density Measured?

- Nuclear density device correlated with cores

How are Results Analyzed?

- Percent within Limits (PWL)
- Minimum with Maximum
- Running Average
- Target with Tolerances

Important Considerations:

- Appropriate lift thickness for NMAS and coarse gradations
- Appropriate mix design requirements
- Appropriate test methods (both G_{mm} and G_{mb})
- Density only a surrogate for permeability

Glenn Highway Intelligent Compaction and Thermal Profiling: 10:40 Tomorrow

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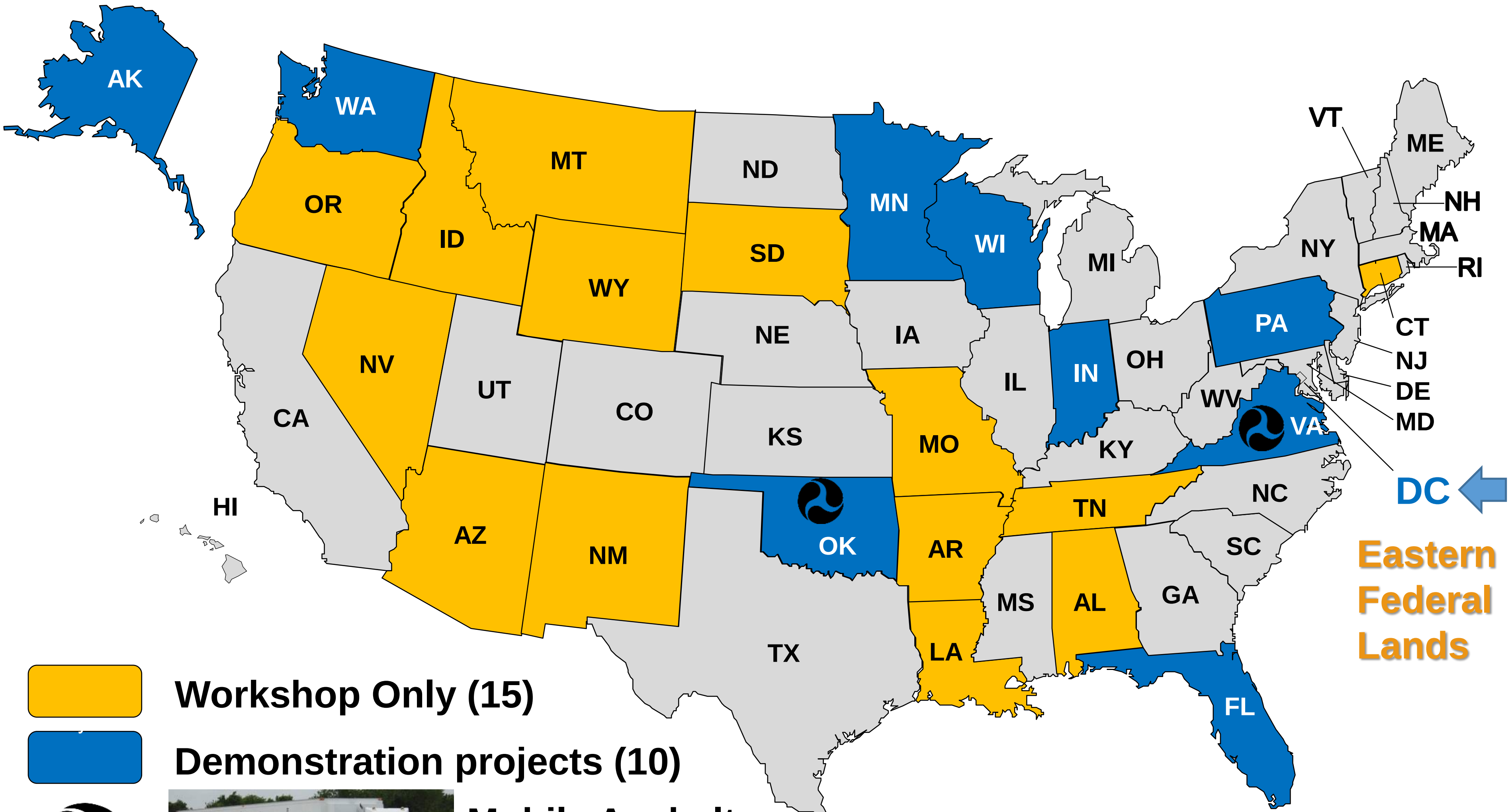

Mobile Asphalt Testing Trailer (2)

Understanding the Importance of Density

Why are we here?

To connect the link between density and durability.

“More emphasis must be placed on obtaining adequate density.”
– NCHRP Report 531 (2004)

Carl Monismith – “…we could improve the life of our pavements in California a very substantial amount with the existing materials that we have if we just changed the compaction specification for the asphalt concrete. Right now we build pavements that have shorter lives than they should.” (AAPT 1997)

Importance of Compaction

"Compaction is the single most important factor that affects pavement performance in terms of durability, fatigue life, resistance to deformation, strength and moisture damage." – C. S. Hughes, NCHRP Synthesis 152, *Compaction of Asphalt Pavement*, (1989)

"The amount of air voids in an asphalt mixture is probably the single most important factor that affects performance throughout the life of an asphalt pavement. The voids are primarily controlled by asphalt content, compactive effort during construction, and additional compaction under traffic." – E. R. Brown, NCAT Report No. 90-03, *Density of Asphalt Concrete—How Much is Needed?* (1990)

Durability Concerns

- SAPA's, AI, and NAPA all concerned with durability
  - Need for more binder in the mix
- Many DOT's looking for ways to improve durability
  - Minimum binder contents
  - Optimize mix designs
  - Balance rutting with fatigue

Improved density typically not considered

Growth in Traffic Volumes and Loadings on the Rural Interstate System

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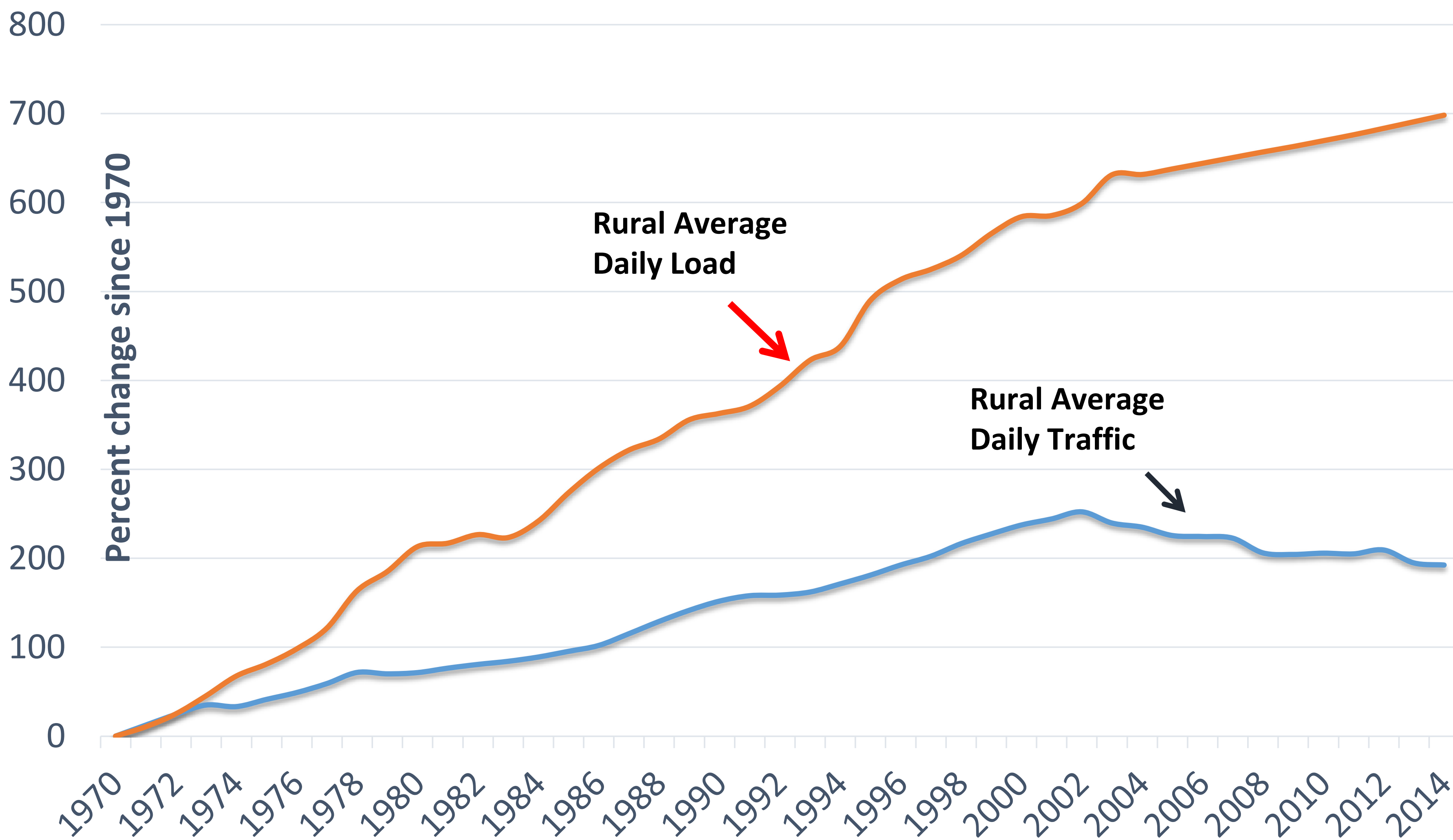

Source: FHWA Highway Statistics 2014

Led to Rutting in 1980s

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Which led to…Superpave

- Fixed the rutting problem
- Gyratory compaction lowered binder contents
- Add in higher and higher recycled materials?

Definitions

What is Durability?

The ability to resist
wear and decay,
or to be long lasting.

Reasons for Compaction

- To minimize prevent further consolidation
- To provide shear strength and resistance to rutting
- To improve fatigue cracking resistance
- To improve thermal cracking resistance
- To ensure the mixture is waterproof (impermeable)
- To minimize oxidation of the asphalt binder

Compaction also provides a smooth, quiet driving surface

All are elements of durability

Understanding the Context

We also need to understand whether "density" is used in the context of lab-molded density or in-place roadway density

- Lab-molded density gives information about the mix properties
- In-place roadway density gives information about the quality of compactive effort on the roadway

Terminology Confusion - “Density”

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Keeping with the industry jargon, this workshop uses the term “density” to mean roadway density as percent Theoretical Maximum Density *unless otherwise noted*

Density / Air Voids

The term “air voids” is also used to discuss how well the roadway has been compacted.

% Air Voids = 100 - Density

Density = 100 - % Air Voids

Link Density to Pavement Durability

Improved Compaction = Improved Performance

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A BAD mix with GOOD density out-performed a GOOD mix with POOR density for ride and rutting.

WesTrack Experiment

Density vs. Loss of Pavement Service Life

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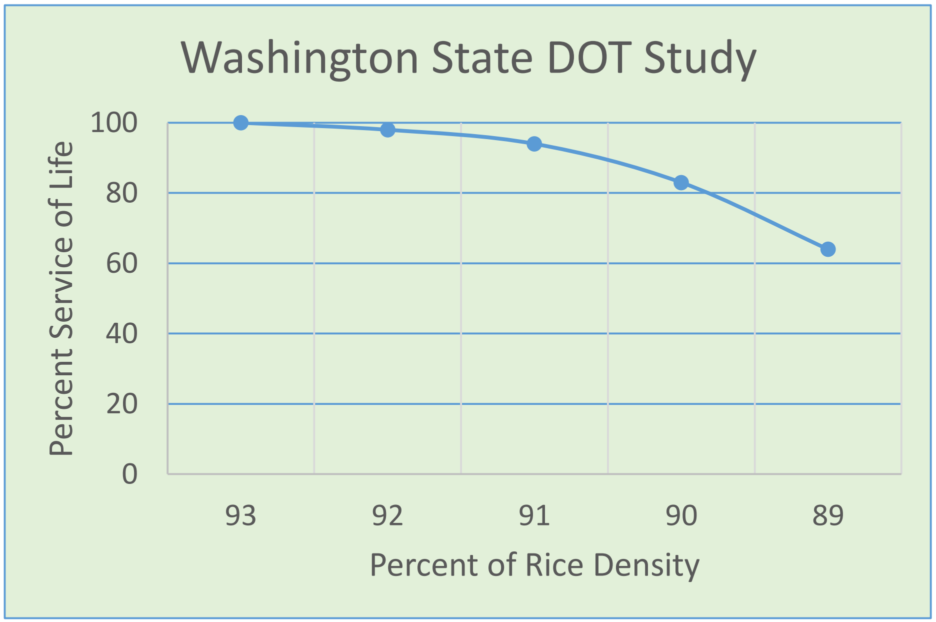
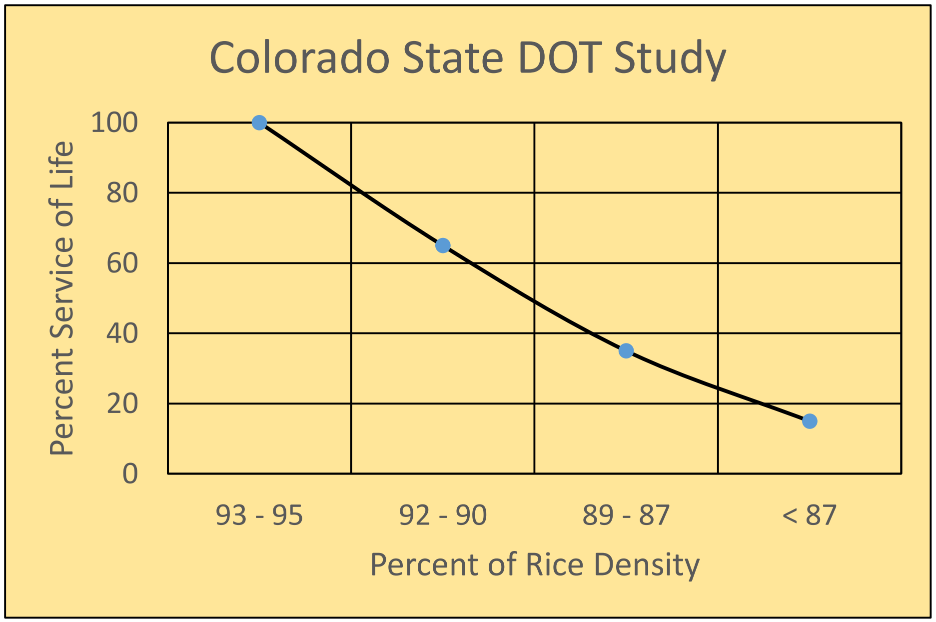


Thicker Pavements

TRR 1217, 1989

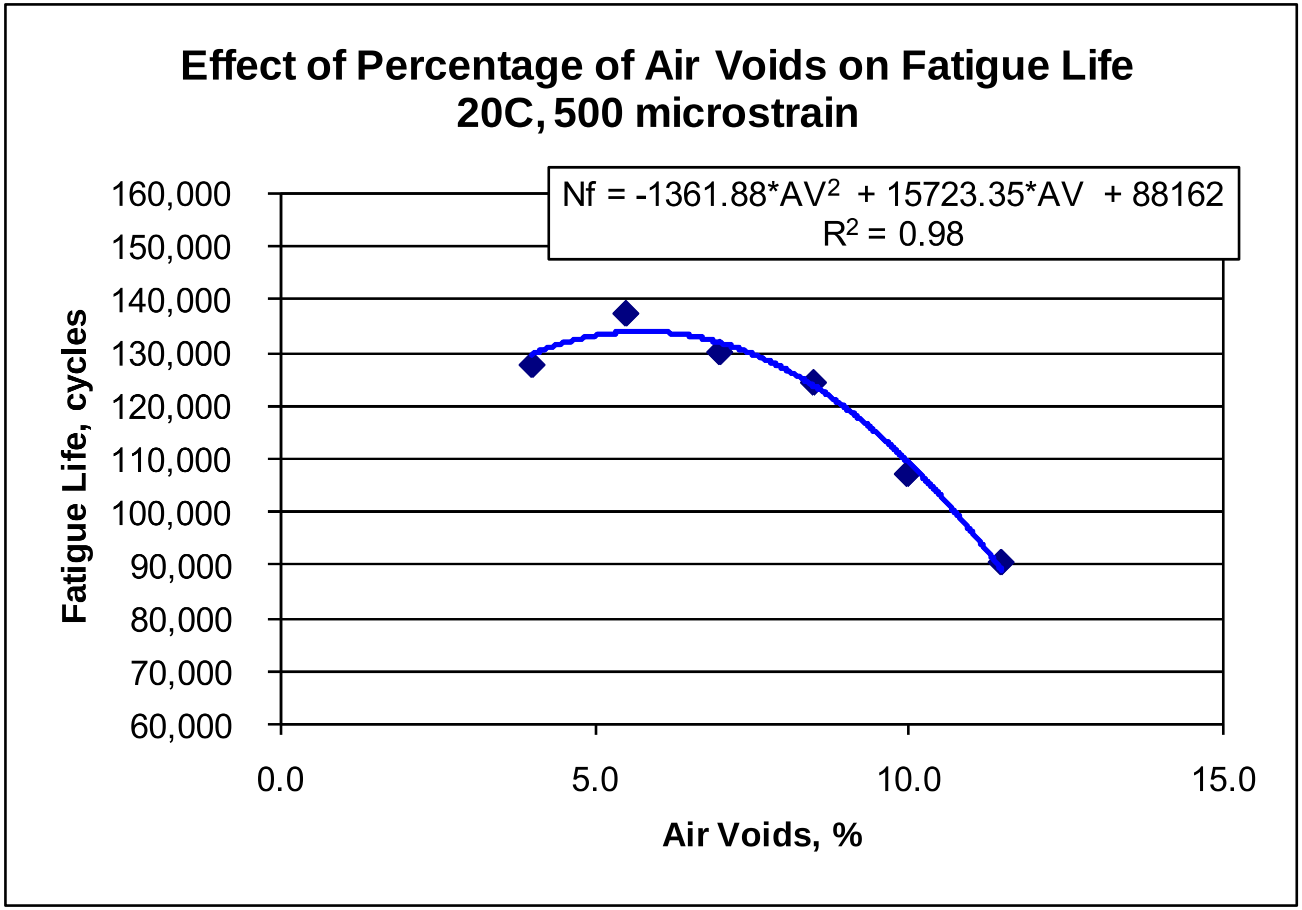


Typical Pavements

CDOT 2013-4, 2013

For both thicker and thinner, reduced in-place density at the time of construction results in significant loss of Service Life!

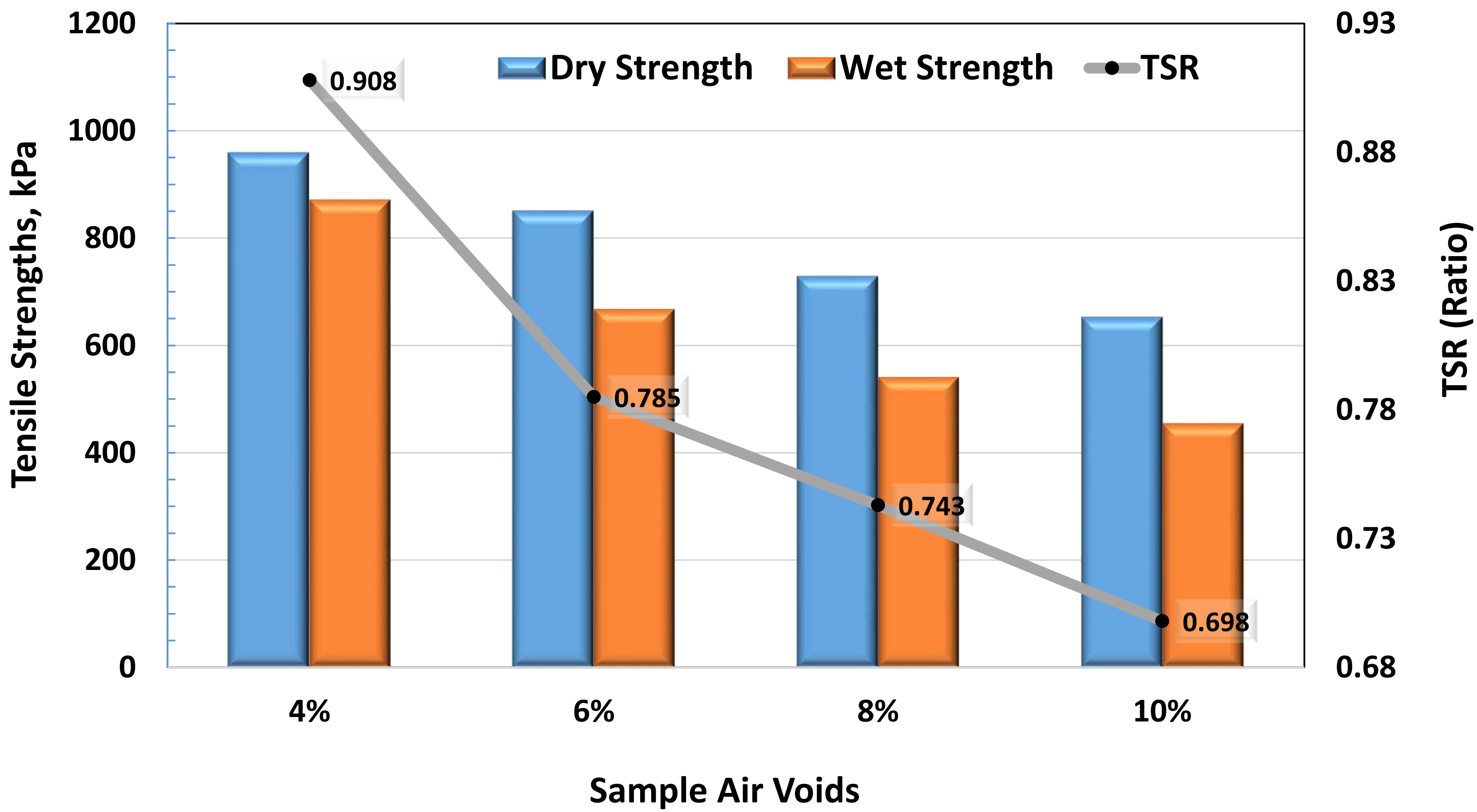
In-Place Voids vs Fatigue Life



UK-AI Study

1.5% increase in density leads to 10% increase in fatigue life.

Tensile Strength & Moisture Susceptibility vs. Air Voids
AASHTO T 283



Asphalt Institute Research

NCAT Report 16-02 (2016)

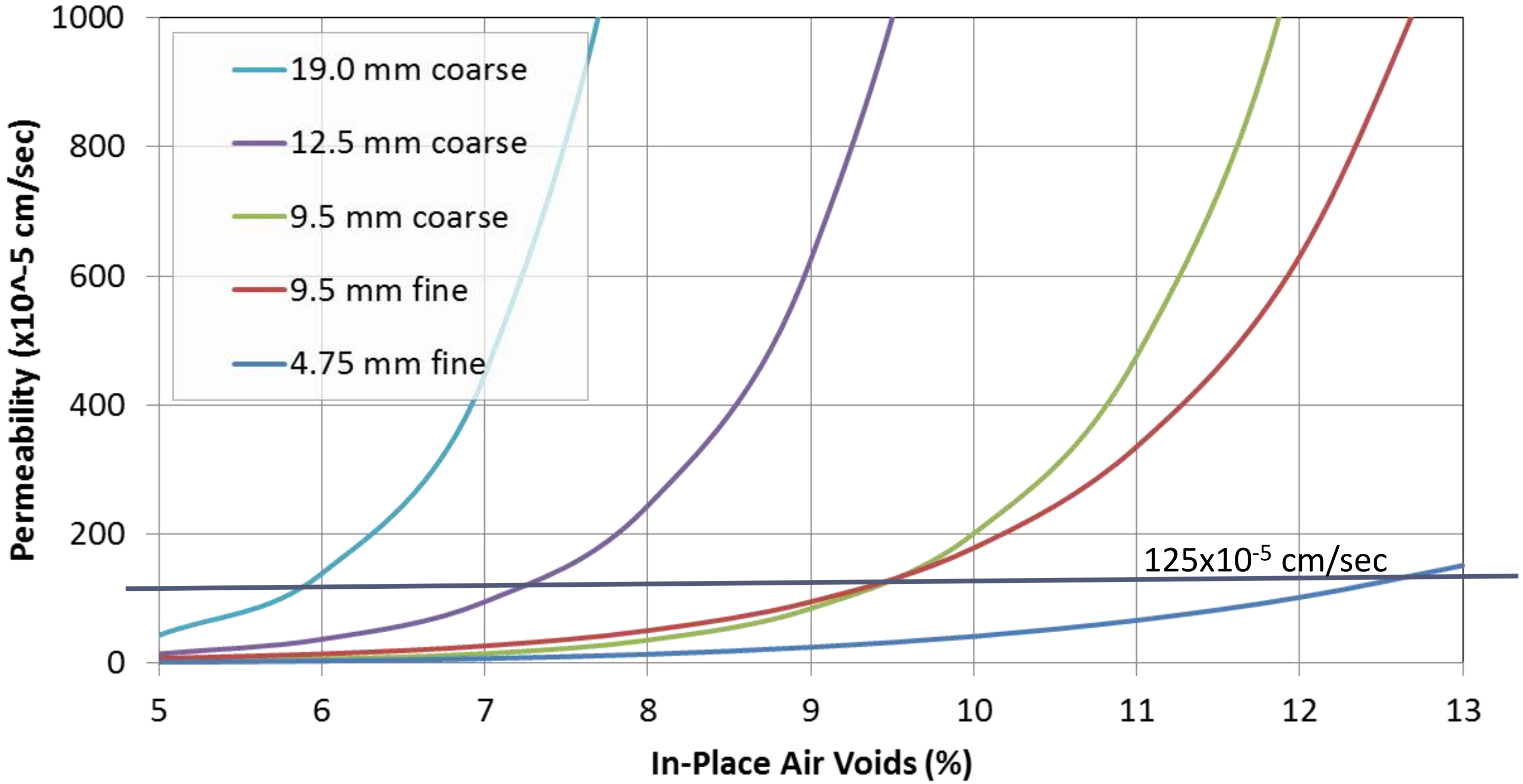
Literature Review on connecting in-place density to performance

- 5 studies cited for fatigue life
- 7 studies cited for rutting
- "A **1% decrease in air voids** was estimated to improve the fatigue performance of asphalt pavements between 8.2 and 43.8%, to improve the rutting resistance by 7.3 to 66.3%, and to **extend the service life by conservatively 10%**."


…and then there's permeability
Permeability at the Longitudinal joint
Photo: Wes McNett

Permeability can be Catastrophic

NCAT Permeability Study



Finer NMAS mixes generally less permeable at equivalent air void levels!

From NCAT Report 03-02

Research on Critical Air Void Level for Impermeability

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	Critical Voids where permeable
9.5 mm Mixes	
E. Zube - California Dept. of Highways - 1962	8.0
L. Cooley, B. Prowell, R. Brown – NCAT - 2002	7.7
R. Mallick, et al – NCAT Report No. 2003-(fine graded)	8.5
12.5 mm Mixes	
B. Choubane, et al – Florida DOT - 1998	7
J. Westerman – Arkansas HTD - 1998	6
R. Mallick, et al - NCAT Report No. 2003(coarse graded)	7

Research on Critical Air Void Level for Impermeability

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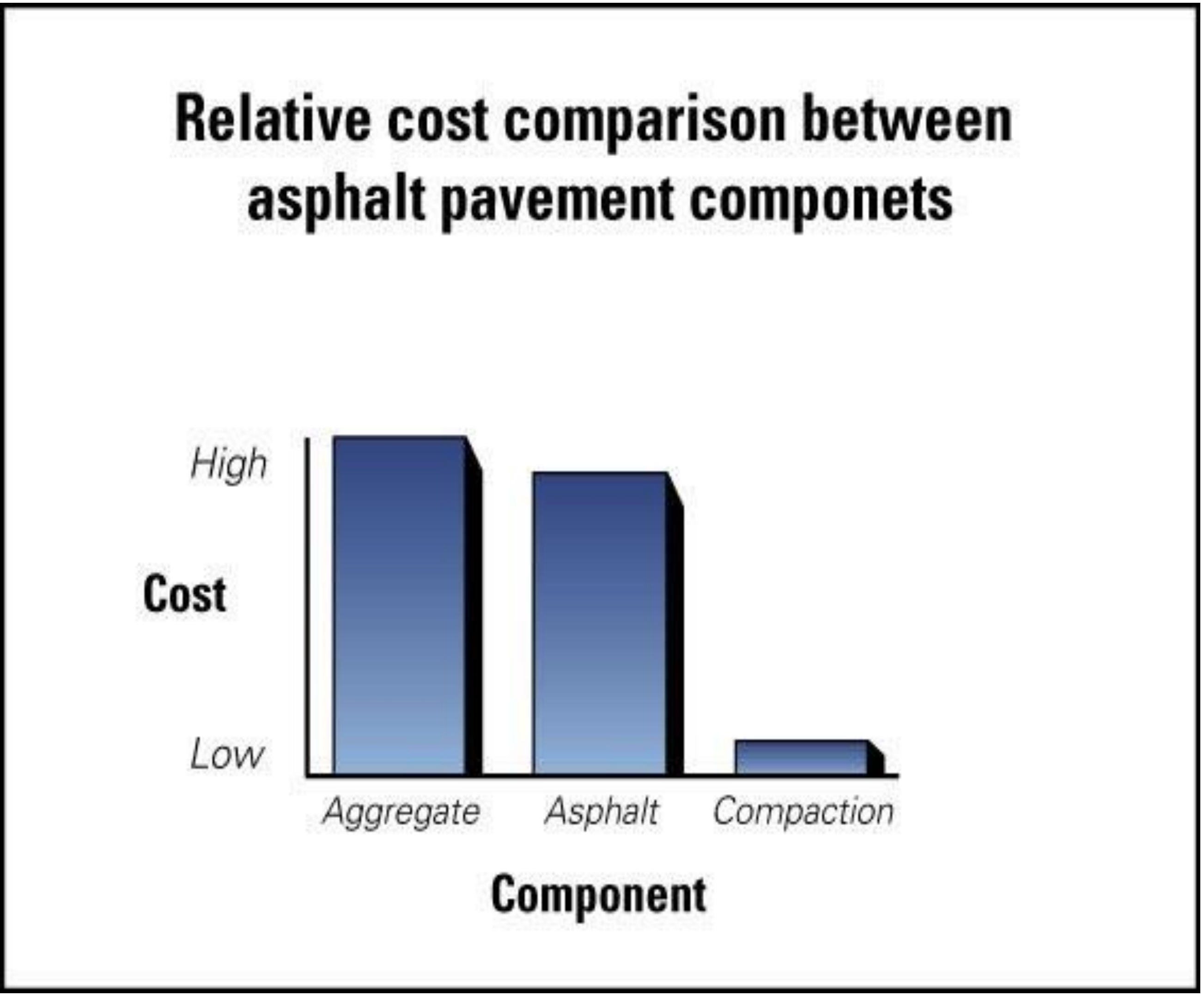
“…to ensure that permeability is not a problem, the in-place air voids should be between 6 and 7 percent or lower. This appears to be true for a wide range of mixtures regardless of NMAS and grading.” – NCHRP 531

Cost of Compaction



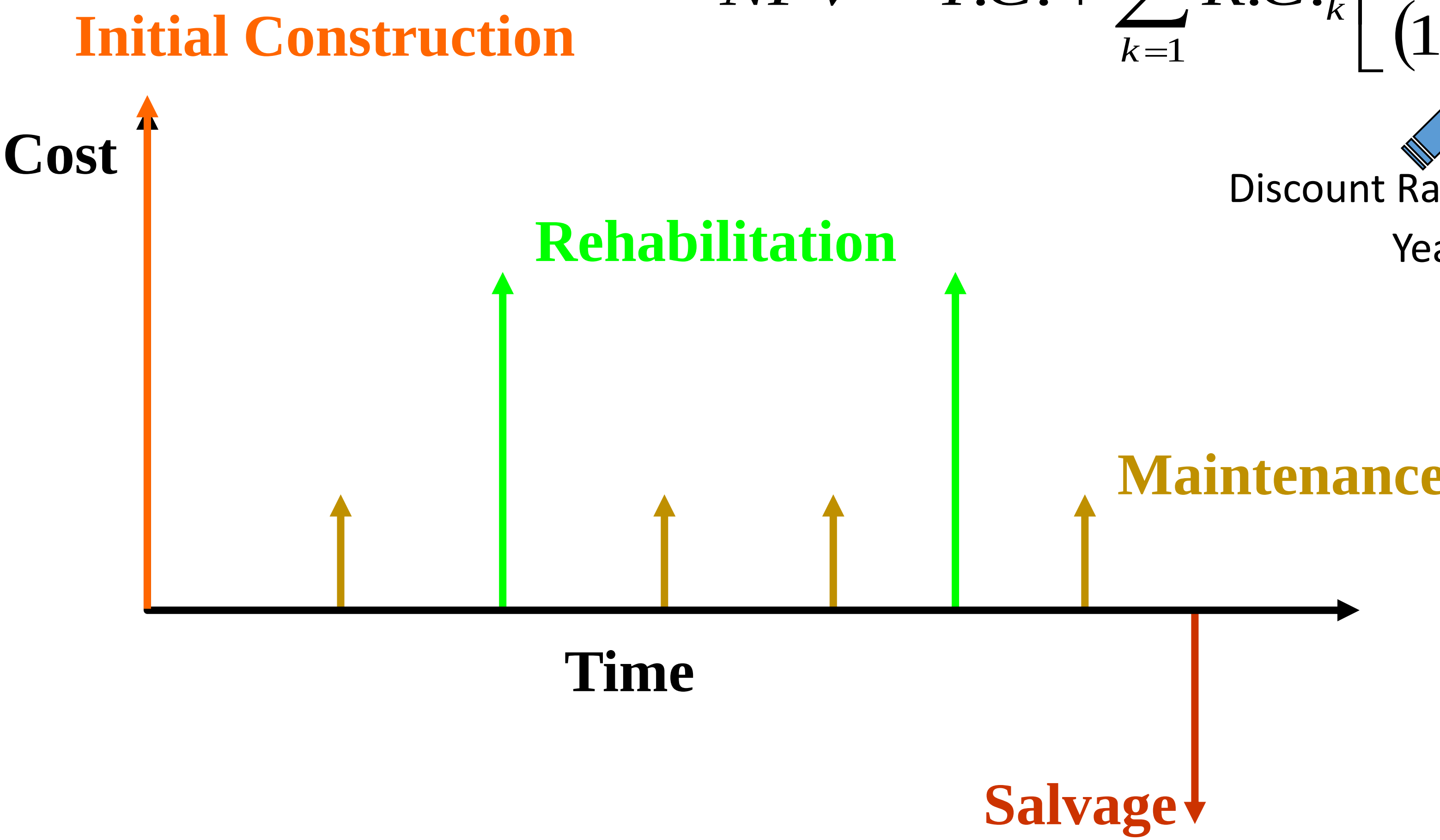
- Least expensive part of the paving process
- Aggregates and binders are expensive in comparison
- Compaction adds little to the cost of a ton of asphalt

Life Cycle Cost Components

$$NPV = I.C. + \sum_{k=1}^{N} R.C._k \left[\frac{1}{(1+i)^{n_k}} \right]$$

Discount Rate

Year of Activity



LCCA slides adapted from Dr. Dave Timm, Auburn University, presentation

Life Cycle Cost Comparison

Alternative 1: 93% Density

0 $i = 4\%$ $n = 20$ years

PV = \$1,000

$$PV = \frac{\$0}{(1+0.04)^{(20)}}$$

RV = \$0

PV = \$0

$NPV_1 = \$1,000 + \$0 = \$1,000$

Alternative 2: 92% Density

0 $i = 4\%$ $n = 18$ $n = 20$ years

PV = \$1,000

$$PV = \frac{1000}{(1+0.04)^{(18)}}$$

FV = \$1,000 RV = - \$889

PV = \$494

$$PV = \frac{-889}{(1+0.04)^{(20)}}$$

PV = \$-406

$NPV_2 = \$1,000 + \$494 - \$406 = \$1,088$

The user agency would see an NPV cost savings of \$88,000 on a \$1,000,000 paving project (or 8.8%) by increasing the minimum required density by 1%
(all else equal).

How does greater durability affects LCCA?

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- First Cost
  - More attention to density likely to increase first cost slightly ☹
- Maintenance Costs
  - Higher density should reduce maintenance ☺
  - Higher density should extend maintenance periods ☺
    - Example: longer time to first overlay
- Rehabilitation
  - Higher Density should extend or eliminate rehabilitation cycles ☺

What is Achievable?

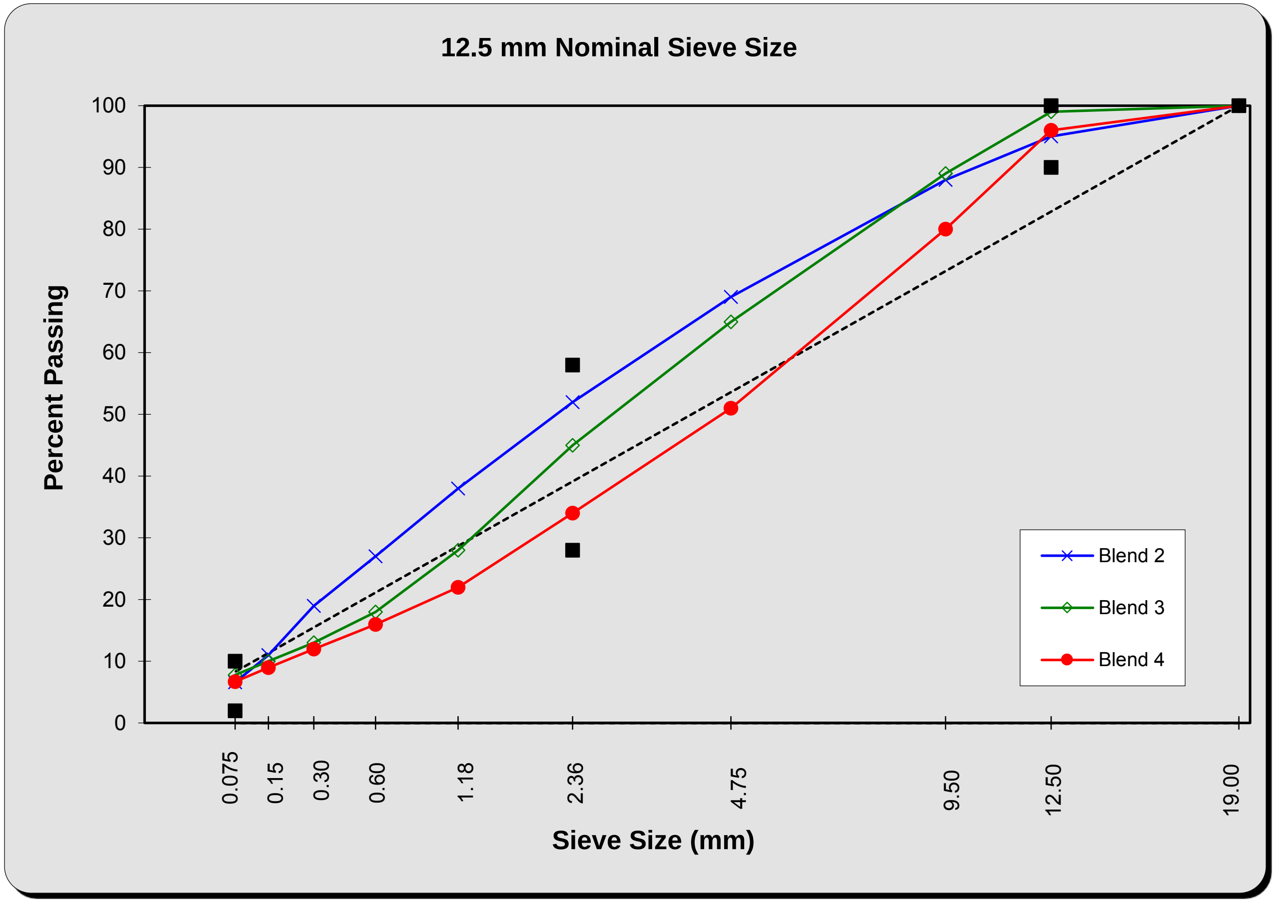
Mix Design Properties that Affect Compatibility and Durability

Section 2

Mixture Factors Affecting Compaction

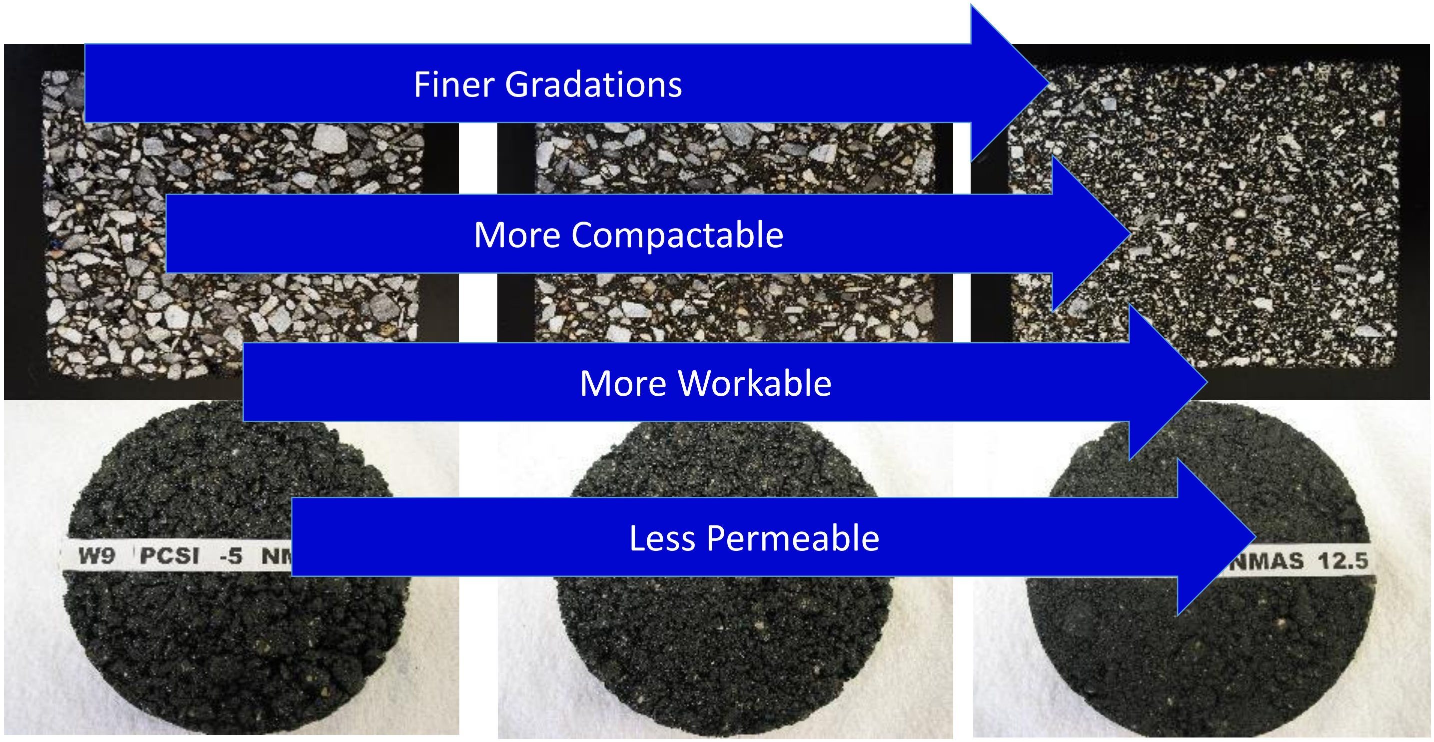
- Mix Properties
  - Aggregate
    - Gradation
    - Angularity
  - Asphalt Binder
    - Grade
    - Quantity
  - Volumetrics
    - Air Voids
    - VMA
    - VFA
  - Balancing a Mix

Choosing a Gradation



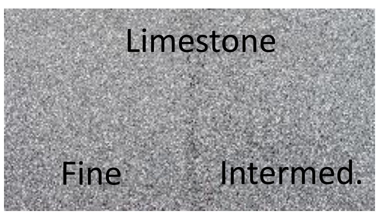
Courtesy of NCAT

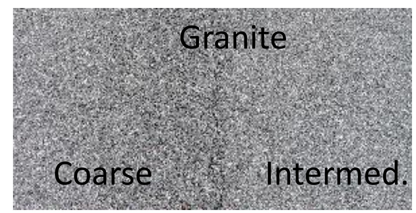
Choosing a Gradation

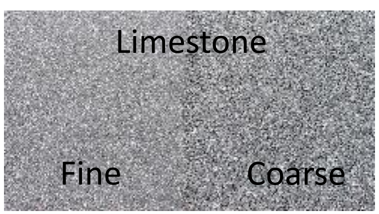


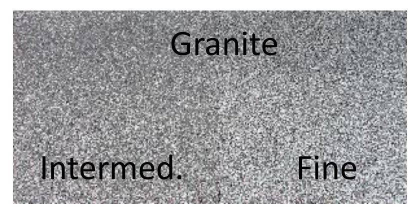
Courtesy of NCAT

NCAT Test Track 1st Cycle







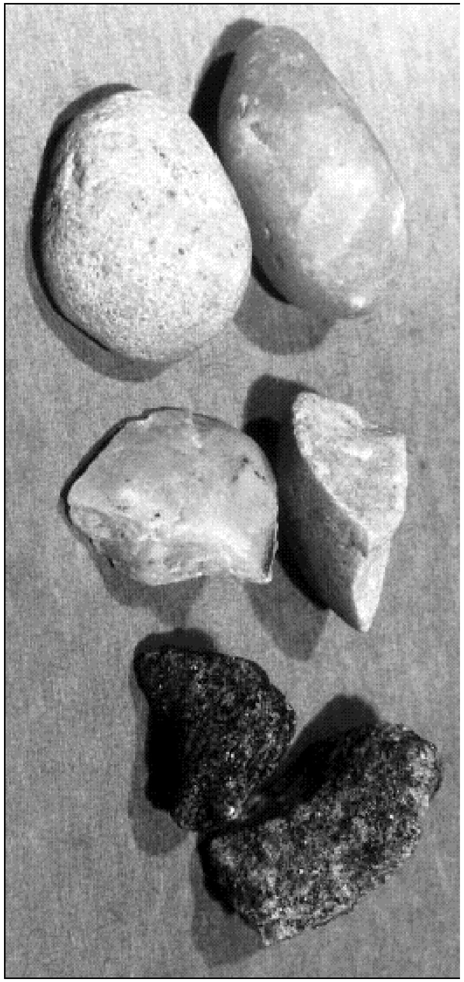


Coarse, intermediate, and fine gradations. No differences in rutting performance!

Courtesy of NCAT

Effect of Aggregate on Compaction

- **GRADATION**
  - continuously-graded, gap-graded, etc.
- **SHAPE**
  - flat & elongated, cubical, round
- **SURFACE TEXTURE**
  - smooth, rough
- **STRENGTH**
  - resistance to breaking, abrasion, etc.



Effect of Binder on Compaction

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- **PERFORMANCE GRADE**
  - Binder grades that are "stiffer" at paving temperatures can make the mix more difficult to compact

- **MODIFIED BINDERS**
  - In general, the grades with modifier added tend to be stiffer and more difficult to compact.
  - The time available for compaction tends to decrease as the amount of modifier increases.

Mix Design – Balancing Act

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Smooth Quiet Ride
Skid Resistance

Strength/
Stability

Rut Resistance

Shoving

Flushing
Resistant

Durability

Crack
Resistance

Raveling

Permeability

Balanced Mix Design

***ETG Definition*: "Asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate and location within the pavement structure."**

***Simple Definition:* A design process that incorporates performance testing to balance an asphalt mixture for rutting and cracking resistance.**

FHWA Performance Based Mix Design

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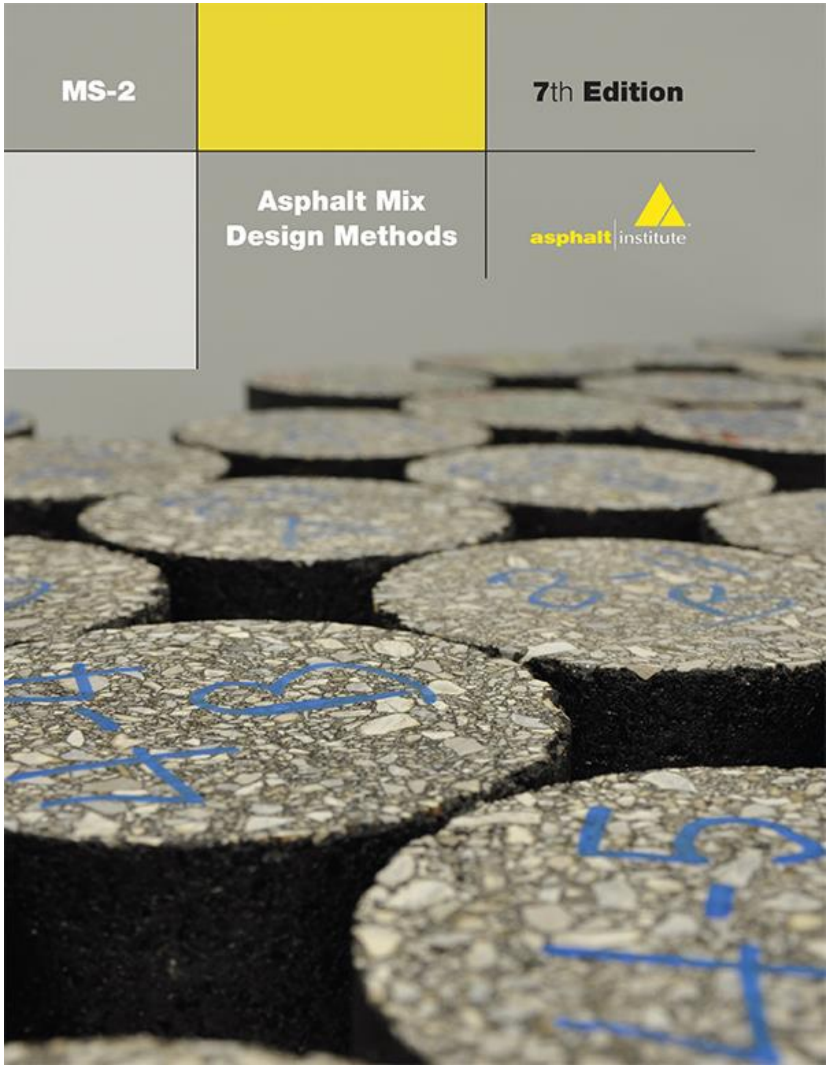
	Fatigue Cracking	Rutting
Design Air Voids For every 1% increase	40% increase	22% decrease
Design VMA For every 1% increase	73% decrease	32% increase
Compaction Density For every 1% lower in-place Air Voids **(Increasing Density Improved Both!)**	19% decrease	10% decrease

Courtesy of Nelson Gibson

Additional Information



More on mix design:
Dave will be back in Anchorage March 13-16, 2018, to teach our Mix Design Technology (MDT) certification course, which uses this manual as a text.

The manual is included in the MDT course, or it can be ordered separately on the Asphalt Institute website.

Compaction Best Practices in the Field

Section 3

Compaction Factors

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- Outside The Roller Operator’s Control
  - Factors Affecting Compaction
  - Forces of Compaction and Roller Types
- Within The Roller Operator’s Control
  - Roller Operations and Rolling Procedures

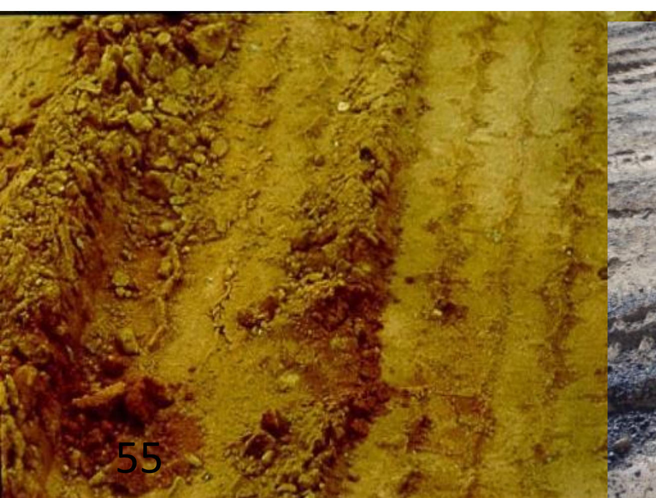
Items Outside the Roller Operator's Control

Factors in Affecting Compaction

- Base Condition
- Lift Thickness vs. NMAS
- Laydown Temperature
- Ambient Conditions
- Cooling Rates
- Balancing Production Through Compaction
- Paver Operations

Subgrade & Base Support

- Good support critical to obtain proper density
- Spongy or unstable support
  - Provides little resistance to the rollers
  - Mixture not confined, energy dissipated
- Mixture moves and cracks rather than compacts



Lift Thickness' Effect on Compaction

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- Aggregates need room to densify
- Too thin vs. NMAS leads to:
  - Roller bridging
  - Aggregate lockup
  - Aggregate breakage
  - **Compaction Difficulties**
- NCHRP Report 531 (2004)
  - Fine Graded Mix—Minimum Thickness = 3 X NMAS
  - Coarse Graded Mix—Minimum Thickness = 4 X NMAS
  - SMA Mix—Minimum Thickness = 4 X NMAS

Superpave Mix Designations

Superpave Mix Designations	Maximum Size	Minimum Compacted Lift Thickness (Fine)	Minimum Compacted Lift Thickness (Coarse)
37.5 mm (1-1/2 inch)	50.0 mm (2 inch)	112.5 mm (4-1/2 inch)	150 mm (6 inch)
25.0 mm (1 inch)	37.5 mm (1-1/2 inch)	75 mm (3 inch)	100 mm (4 inch)
19.0 mm (3/4 inch)	25.0 mm (1 inch)	57 mm (2-1/4 inch)	76 mm (3 inch)
12.5 mm (1/2 inch)	19.0 mm (3/4 inch)	37.5 mm (1-1/2 inch)	50 mm (2 inch)
9.5 mm (3/8 inch)	12.5 mm (1/2 inch)	28.5 mm (1-1/8 inch)	38 mm (1-1/2 inch)
4.75 mm (3/16 inch)	9.5 mm (3/8 inch)	14.25 mm (9/16 inch)	19 mm (3/4 inch)

Effect of Temperature on Compaction

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Compaction Temp. Vs. Density

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- Charles F. Parker (1959)
  - 275°F – standard temperature – reference air voids
  - 200°F – doubled the air voids
  - 150°F – quadrupled the air voids
- Kim A. Willoughby, et.al. (2001)
  - Mix temperature differentials
  - ≤ 25°F – generally consistent air voids
  - ≥ 25°F – greater air void spread
    - Pneumatic rollers reduced spread
    - End dumps showed a greater spread
- Robert Schmitt, et.al. (2009)
  - Most important factor in achieving density

Mat Temperature

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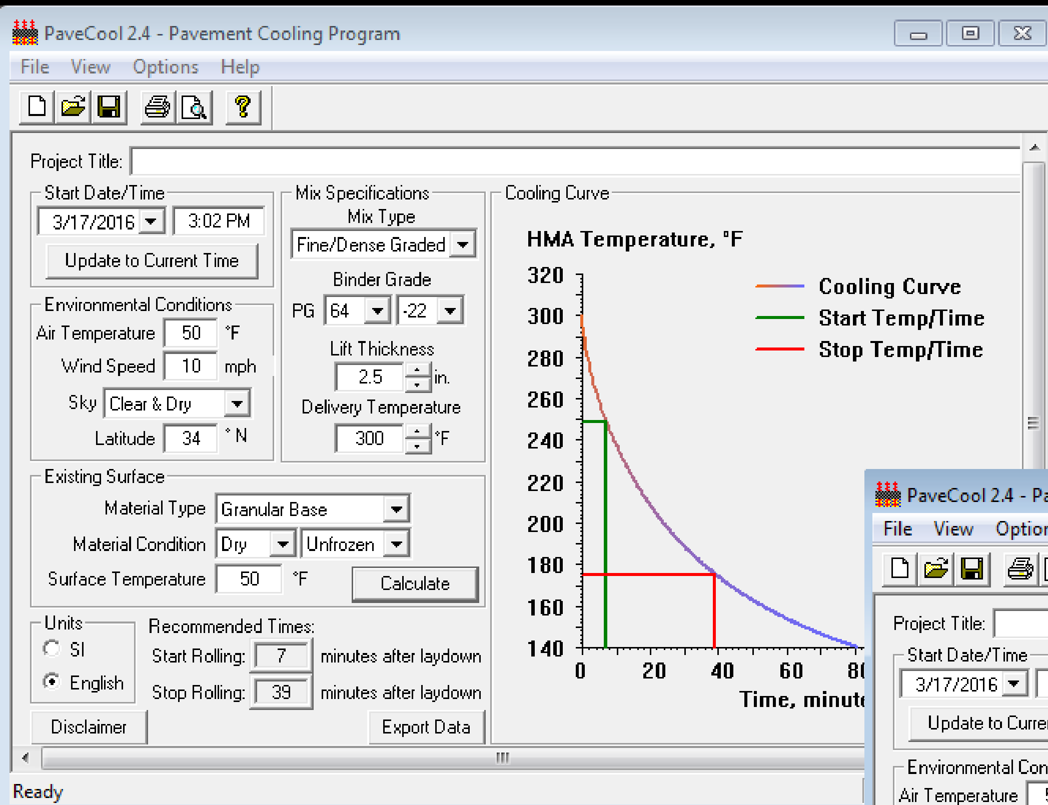
- Compacting asphalt in the correct temperature range is very important
- Temperatures must be neither too hot nor too cold
- Optimum compaction temperatures vary depending on many factors
    - Start compaction: 310 – 280° F
    - Stop compaction: 180 – 175° F

Environmental Factors and Compaction

Several factors come into play regarding how fast the mix cools onsite, affecting time available for compaction:

- Ambient air temperature
- Temperature of the existing surface
- Wind speed
- Lift thickness
- Mix temperature
- Solar Radiation

PaveCool Example

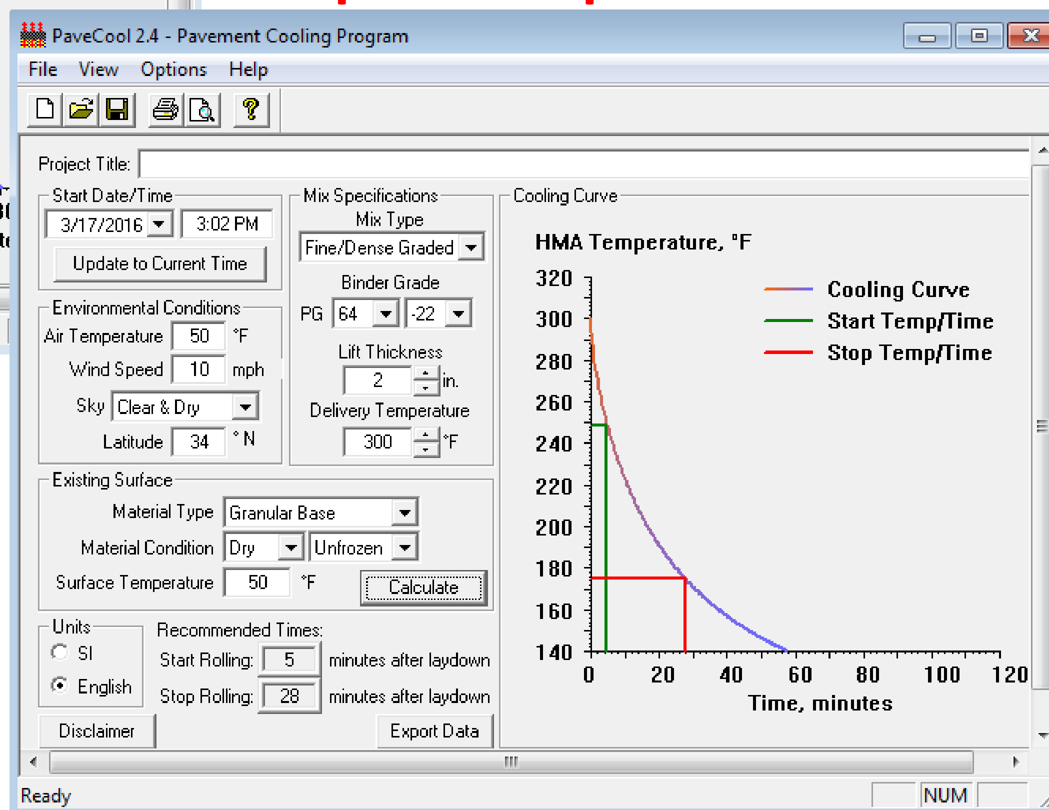


2.5 Inch Lift

50°F Air, Surface Temp

Mix Delivery temp - 300°F

39 minutes to complete compaction operations



2 Inch Lift

50°F Air, Surface Temp

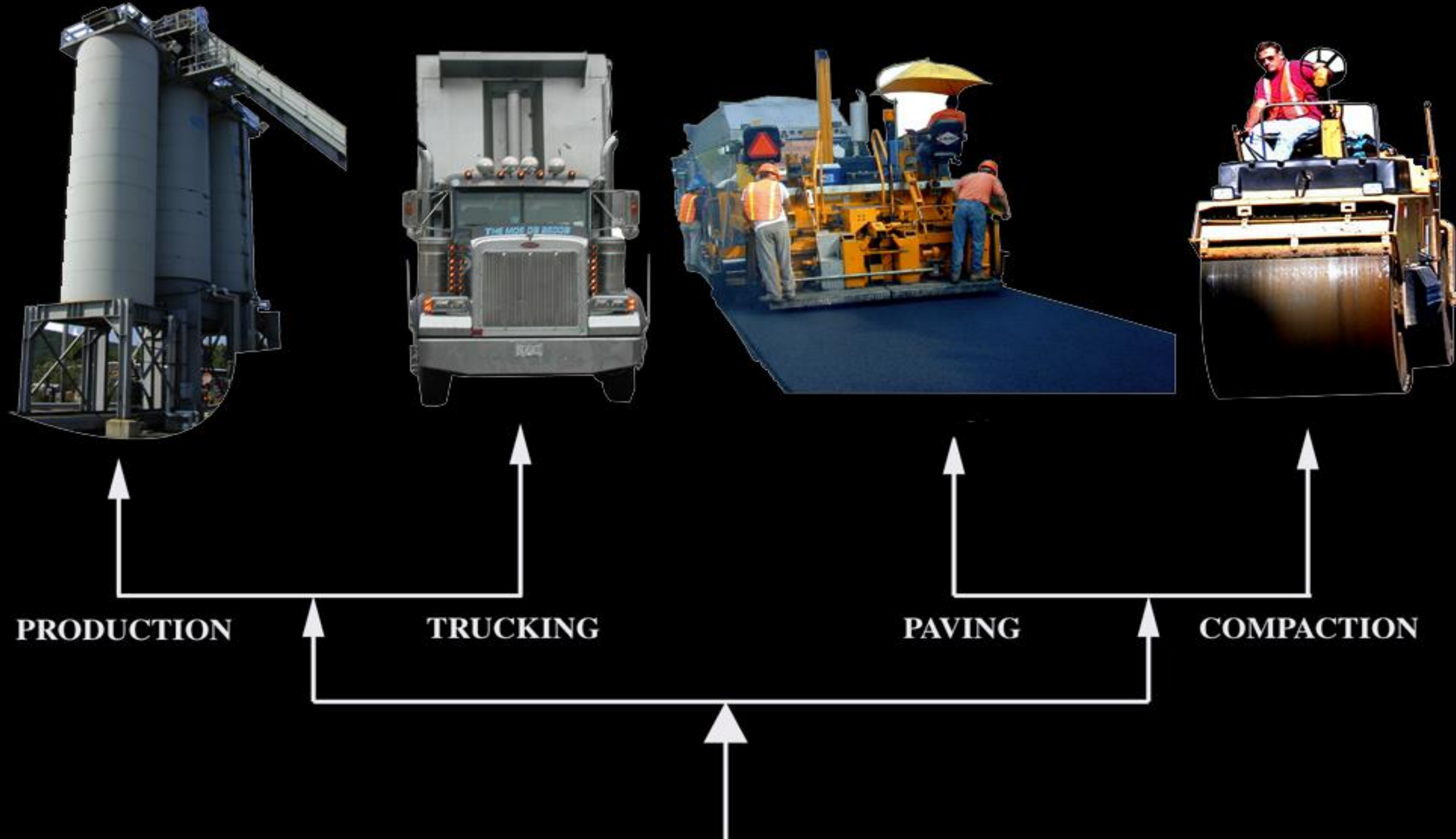
Mix Delivery temp - 300°F

28 minutes to complete compaction operations

Temperature and Weather Limitations

Many agencies specify minimum surface temperatures on which to lay, as shown in the example below:

Lift Thickness, inches	Min. Surface Temp., °F
> 3	40
2 - 3	45
< 2	50



Balancing the Paving Operation

Paving Goals

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- Continuous Operations
  - Hot plant running nonstop
  - Paver running at constant speed nonstop
- Production = Hauling = Paver Processing = Compaction Speed

Paver Speed and Output

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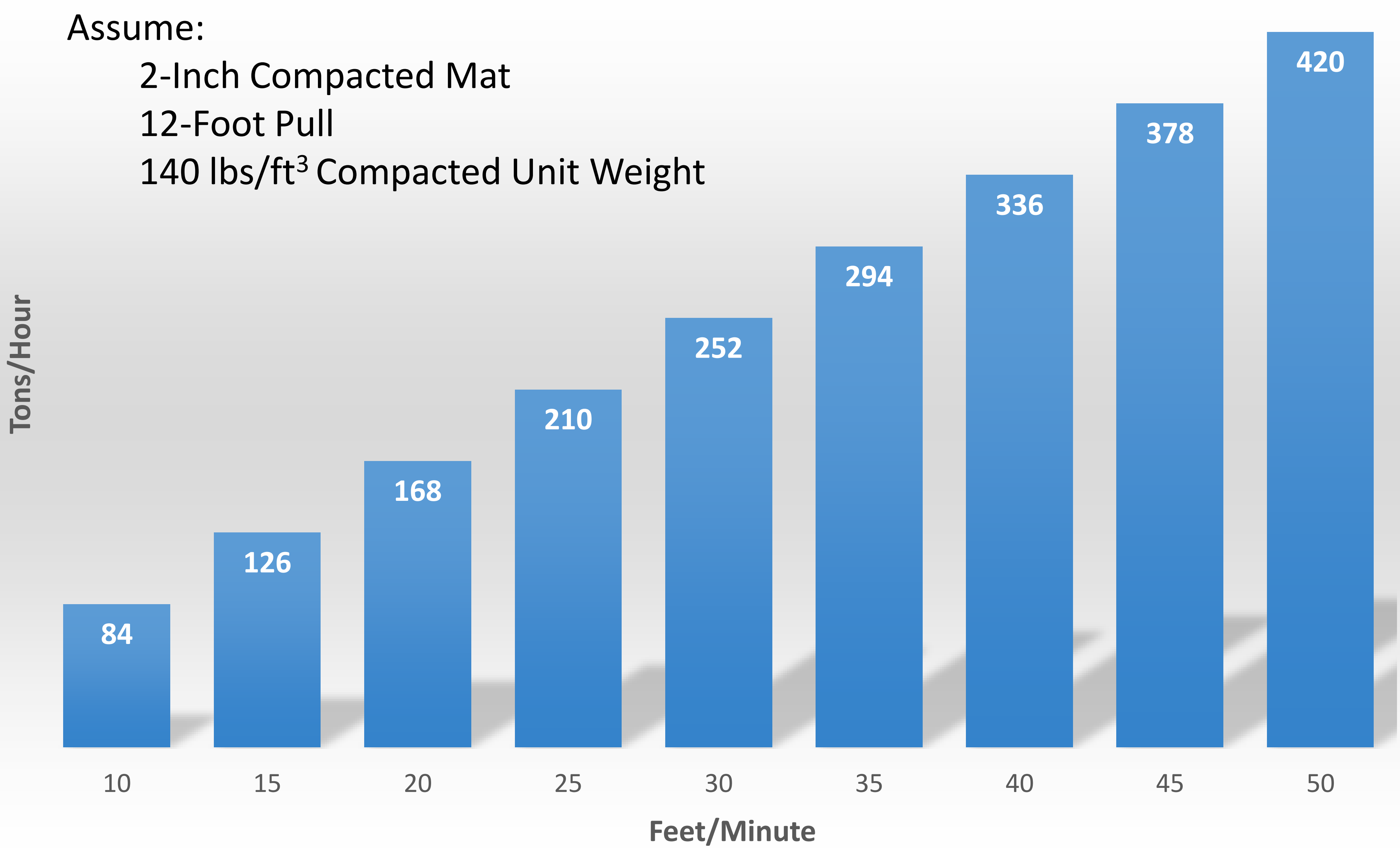

Discussion / Questions

Factors Affecting Compaction

Forces of Compaction and Roller Types

Vibratory Screed Should Always be "ON"

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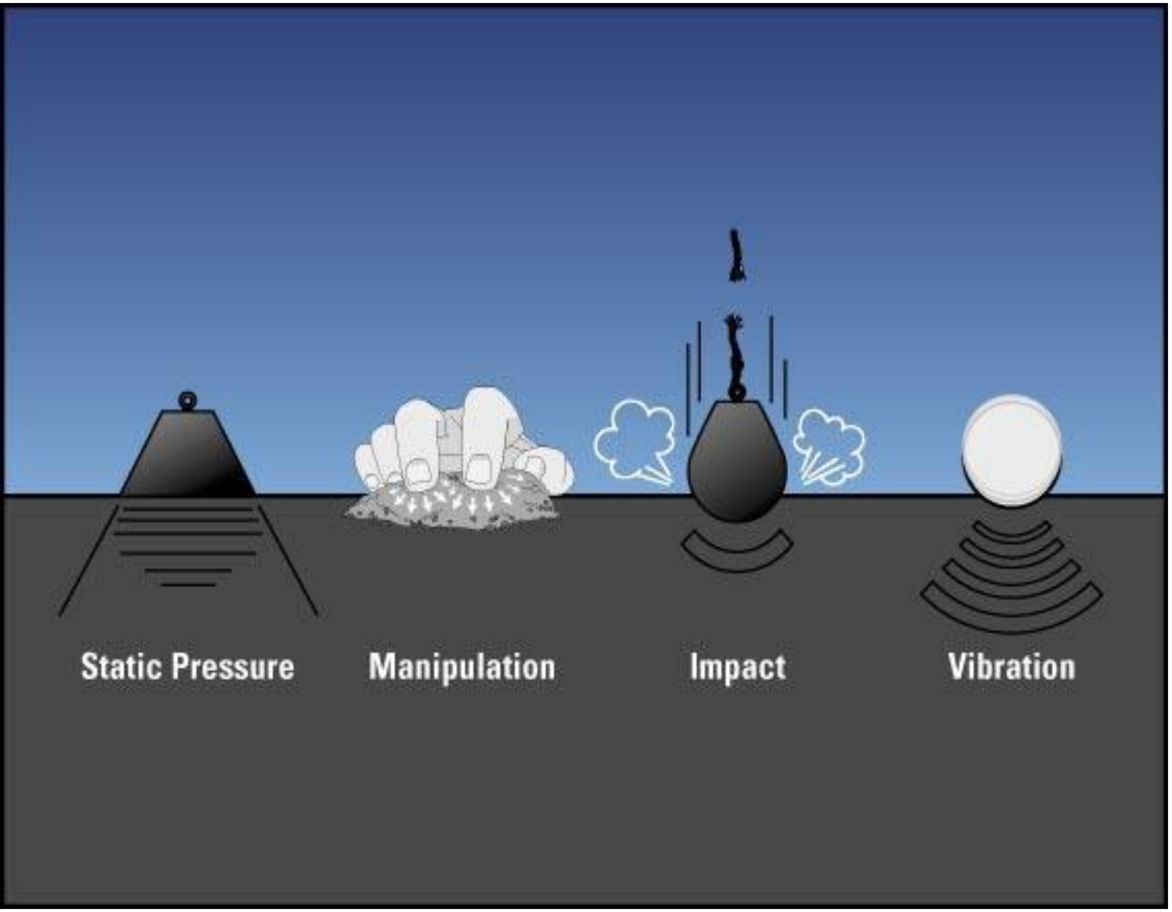
Roller Equipment

- Forces of Compaction
- Roller Type
  - Steel Drum
    - Static
    - Vibratory
  - Pneumatic
  - Newer Technology
    - Vibratory Pneumatic
    - Oscillatory Steel Drum

Forces of Compaction



Compaction forces

- Low force
  - Static pressure
  - Manipulation
- Higher forces
  - Impact
  - Vibration

Effect of Roller Type, Size, Passes

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Roller type and size affects:

- Magnitude of the load
- Manner the load is imparted to the pavement

Number of passes:

- Increases the density
- To break over point after a # of passes
  - Lowers compaction
  - If continued, damages mat

Roller Types

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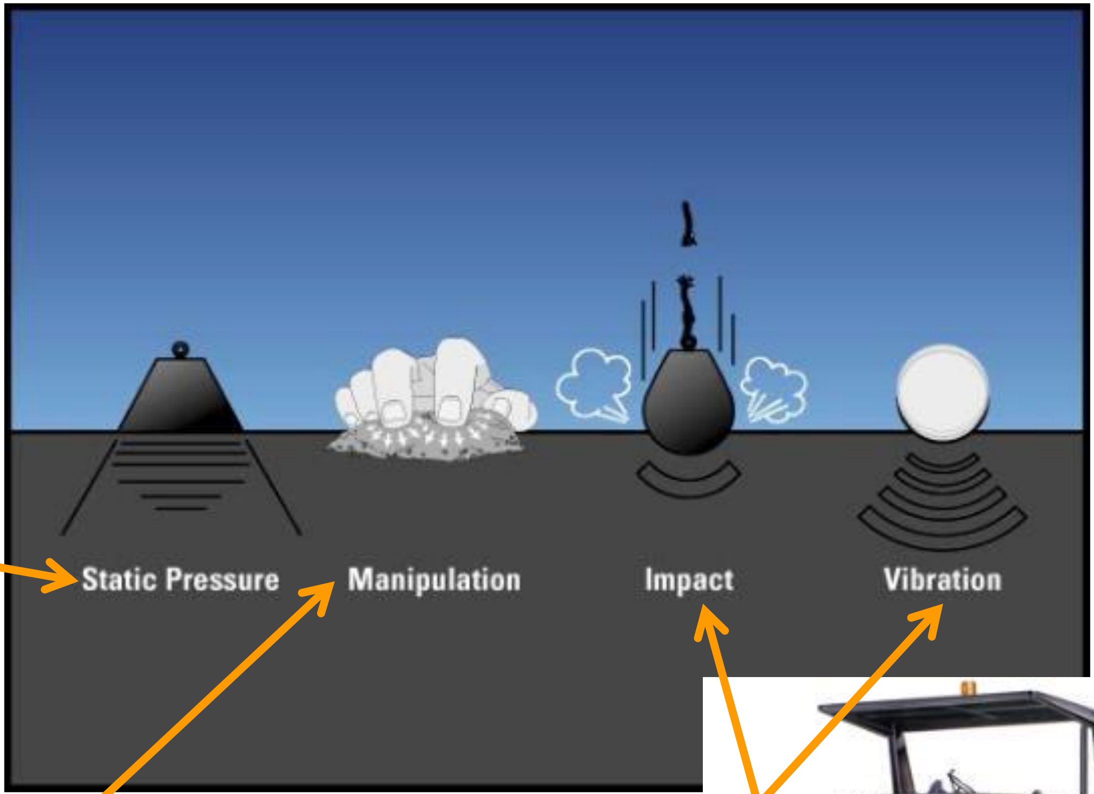
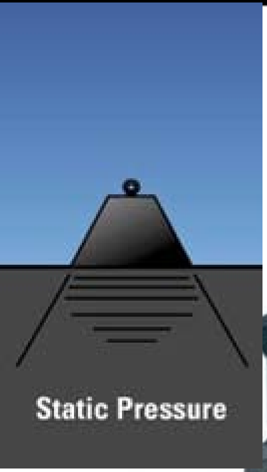
Static Steel-Wheeled



Pneumatic

Vibratory

Static Steel-Wheeled Rollers



- 8 -14 ton rollers normally used for HMA compaction
  - Commonly use vibratory rollers operated in static mode
- Lighter rollers used for finish rolling
- Drums must be smooth and clean
  - Water spray & scraper bars
- For initial compaction, drive wheel must face paver

Pneumatic Rollers

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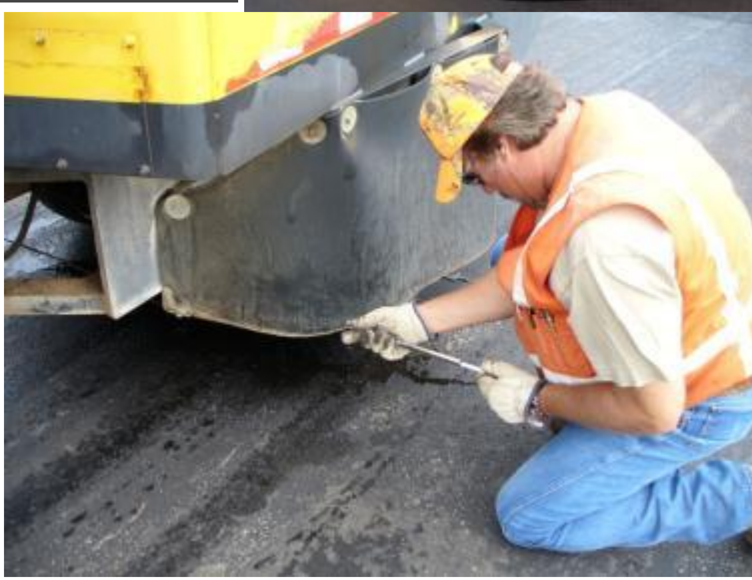

- Reorients particles through kneading action
- Tire pressures:
  - ~80 psi (cold) for compaction
  - ~50 psi (cold) for finish rolling
  - Range of tire pressures not to exceed 10 psi
- Used as Intermediate or as Breakdown Roller
- Tires must be hot to avoid pickup
- Tires must be smooth - no tread
- Not used for PFC mixes or SMA

Pneumatic Rubber Tired Rollers

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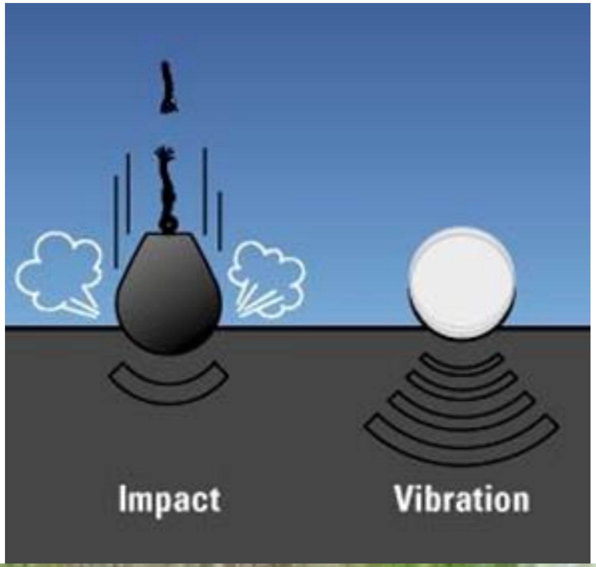
- Many experts believe kneading action helps in providing a tighter surface that is more dense and less permeable compared to drum rollers.
  - Research supports this
- But must keep these away from the unsupported edge to avoid excessive lateral movement of mat.
- Use during intermediate rolling of the supported edge.
  - Not finish rolling

Vibratory Rollers



- Commonly used for initial (breakdown) rolling
- 8-18.5 tons, 57-84 in wide ("heavy" rollers)
  - 50-200 lbs/linear inch (PLI)
- Frequency: 2700-4200 impacts/min.
- Amplitude: 0.016-0.032 in.
  - For thin overlays (≤ 2 in.) use low amplitude or static mode
- Operate to attain at least 10 impacts/ft
  - 2-4 mph

How Does a Vibratory Roller Work?

Drum Impacts per Foot

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Frequency	2 MPH	3 MPH	4 MPH	5 MPH
2000 vpm	11.36	7.58	5.68	4.55
2200 vpm	12.50	8.33	6.25	5.00
2400 vpm	13.64	9.09	6.82	5.45
2600 vpm	14.77	9.84	7.39	5.91
2800 vpm	15.91	10.61	7.95	6.36
3000 vpm	17.05	11.36	8.52	6.82
3200 vpm	18.18	12.12	9.09	7.27
3400 vpm	19.32	12.88	9.66	7.72
3600 vpm	20.45	13.64	10.22	8.18
3800 vpm	21.59	14.39	10.80	8.63
4000 vpm	22.72	15.16	11.36	9.10

Vibratory Rollers - Amplitude

- Amplitude too high
- Travel speed too fast
- Vibrating cool mat
  - Roll closer to paver
- Finish rolling too cool
  - Roll closer to intermediate roller
- Finish roller too light

Newer Roller Technology

- Technology
  - Intelligent Compaction (Stay tuned)
  - Vibratory Pneumatic
  - Oscillatory Rollers
- Purported Benefits (last two)
  - Aid in compacting difficult mixes
  - Lower cessation temperature
  - Contact suppliers for additional information

Vibratory Pneumatic Roller

Oscillatory Rollers

Sakai

Bomag

CAT

Hamm

Compaction Variables Under the Roller Operator’s Control

Roller Operations
&
Roller Procedures

Compaction Variables at the Roller

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- Roller Patters
  - Sequencing
  - Passes—A roller passing over one point in the may one time
  - Roller Speed
- Rolling Zone
- General Rolling Operations

Traditional Roller Operations Sequencing

- Breakdown Rolling
- Intermediate Rolling
- Finish Rolling

Pattern Decisions

- How many passes?
- How to be sure mix is rolled at correct temperature?
- How fast to roll?

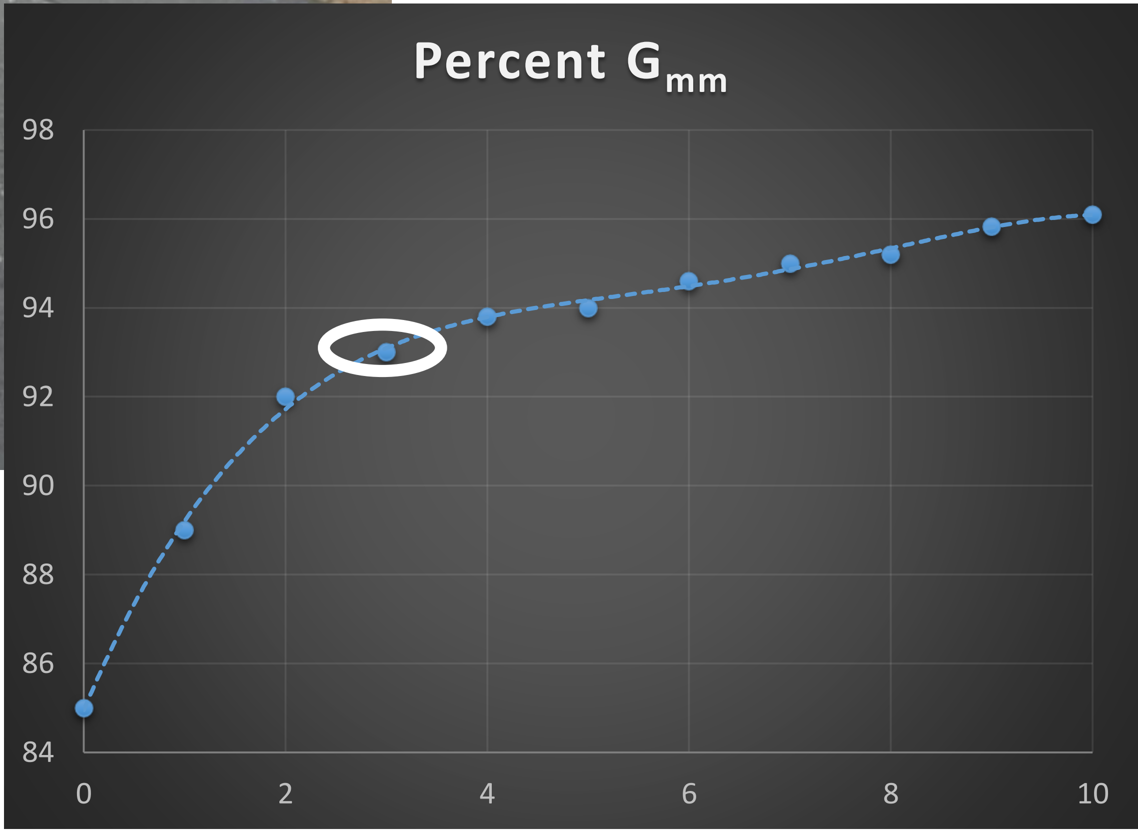
Rolling Pattern

100 - 170 ft

- Roller width should overlap 6 inches
- Odd number of passes to advance
- Repeat uniformly

Establishing Breakdown Rolling Pattern

Goal: 93.5% G_{mm}



Select: 3 Passes (Intermediate will get the rest of the density)

Rolling Pattern

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- Speed and lap pattern for each roller
- Number of passes for each roller
  - One trip across a point on the mat
  - Set minimum temperature each roller finishes

IMPORTANT:

- Paver speed must not exceed compaction!!!
- Paver makes single pass
- Roller pattern requires 3-7 passes

Roller Operations - Temperature Zones

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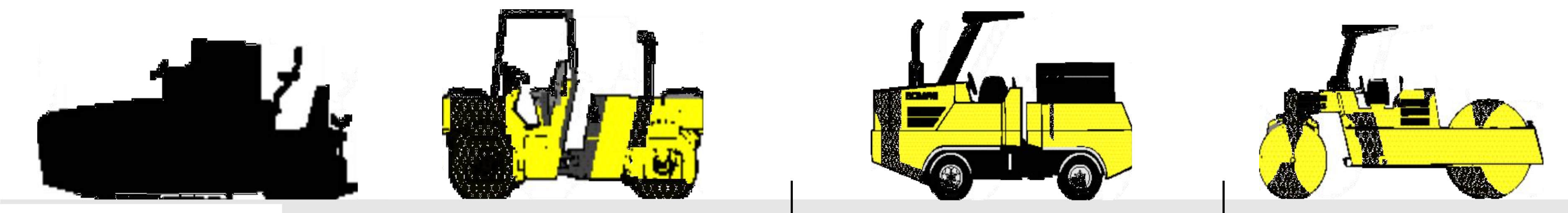
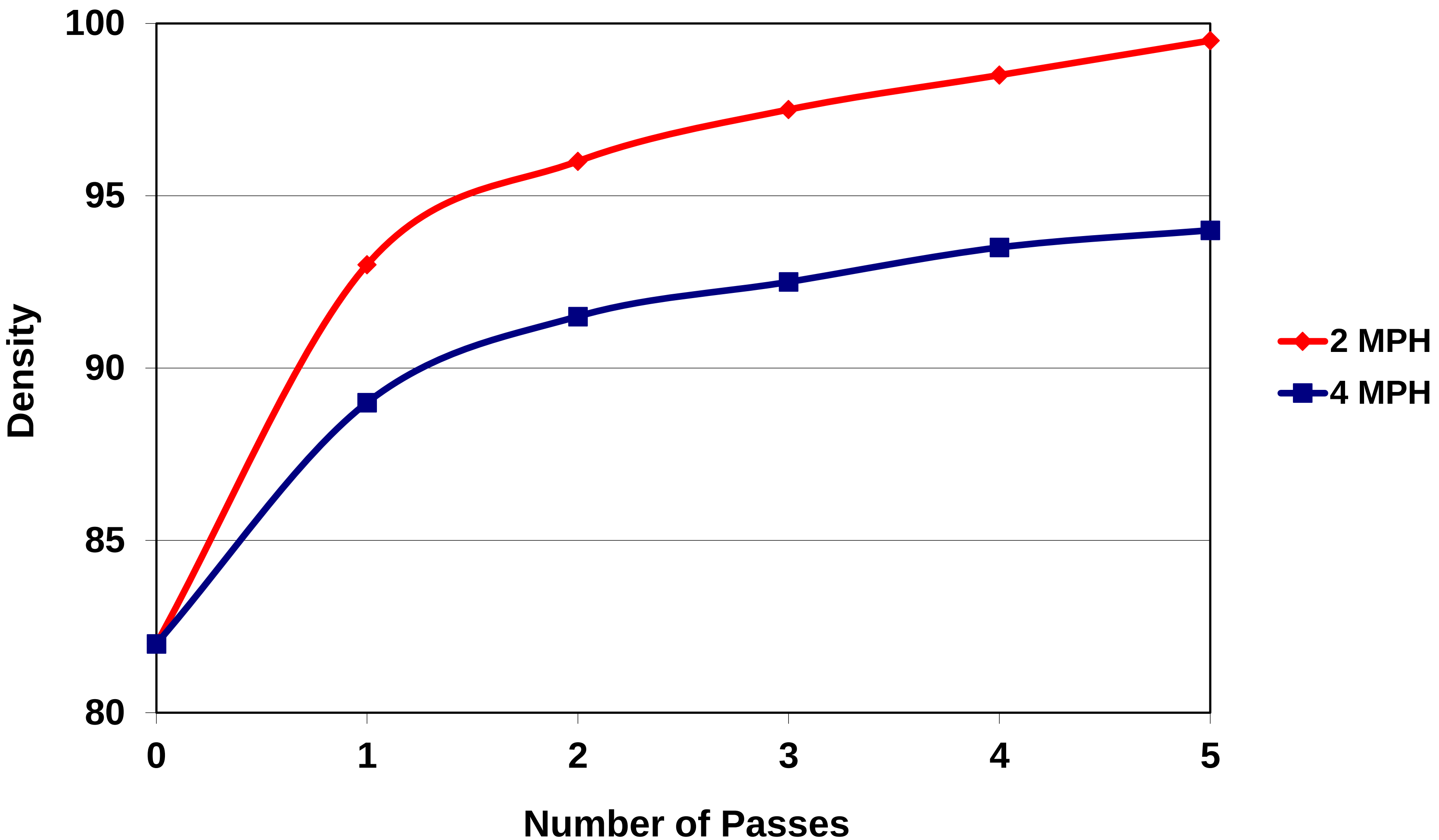
Compactive Force	Pressure Impact Vibration	Pressure Manipulation	Pressure



Temperature Ranges	300° - 260°F	250° - 220° F	200 - 180° F
	Breakdown	Intermediate	Finish

Roller Speed is Critical



Slower = More Compaction/Pass

Breakdown Rolling

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- First roller behind paver
- Gets most of density
- Begin at highest temperature without huge mat distortion
- May have to work very close to paver for some mixes
- May be performed with two coordinated rollers

Breakdown Rolling

- Traditionally 3-wheel steel
- D/D vibratory most common
- Vibration most productive during breakdown
- Pneumatics
  - Used on base courses
  - Leveling courses
    - Forces mix into cracks
    - Compacts without bridging minor ruts
  - Can leave marks – may be harder to roll out

Echelon Vibratory Rollers

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Intermediate Rolling

- Final step in getting density and initial smoothness
- Mat hot enough to allow aggregate movement
- Mat already close to final density
- Too much force will fracture aggregate
- Typical roller type:
    - Traditionally pneumatic
    - Vibratory at low amplitude and/or static mode

Pneumatic Roller

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Finish Rolling

Main purpose

- Minimal compaction
- Smoothness
- Removal of any marks
- Once smooth, stop rolling

Typical roller types:

- Tandem steel-wheel
- Pneumatic w/lower pressure
- Vibratory static mode only

General Rolling Procedures

For best results

- Roll at highest temperature without excessive displacement
- Stay close to paver
- Monitor weather
- Keep up but not too fast
  - Slower paver speed
  - Not faster roller speed

General Rolling Procedures

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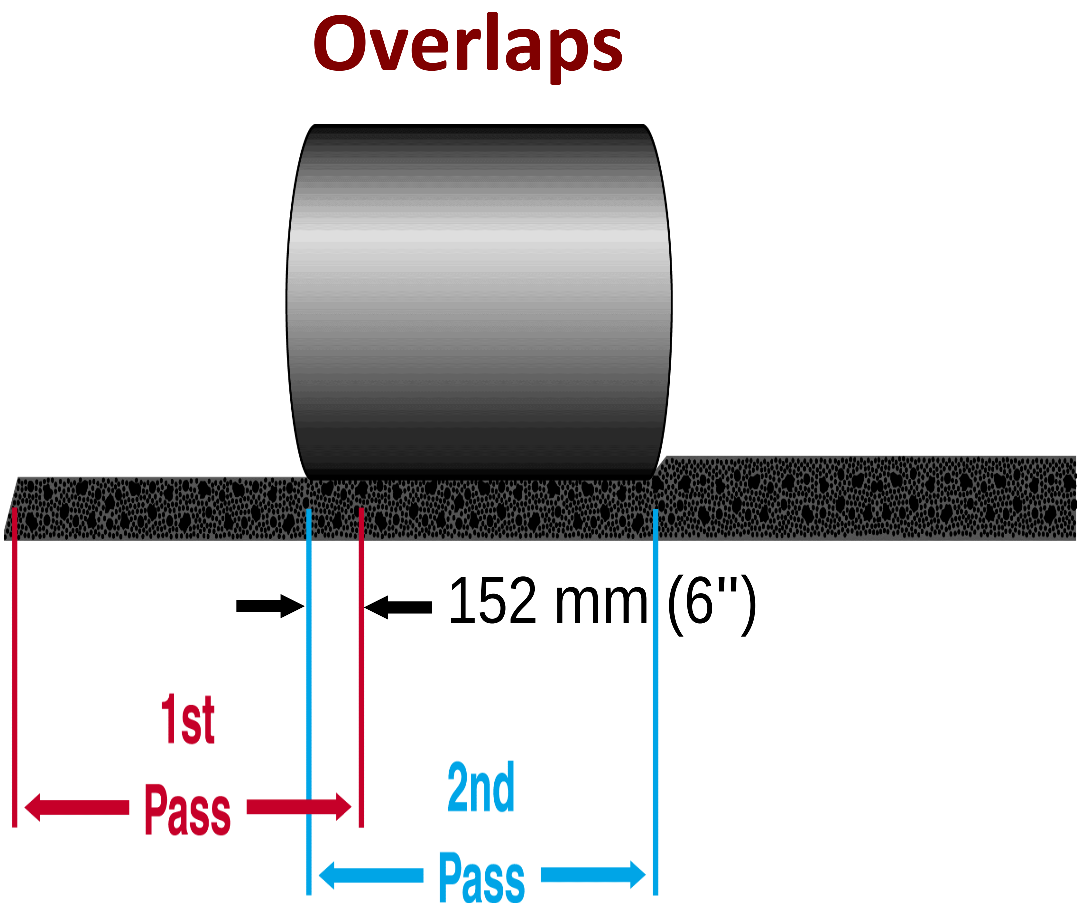
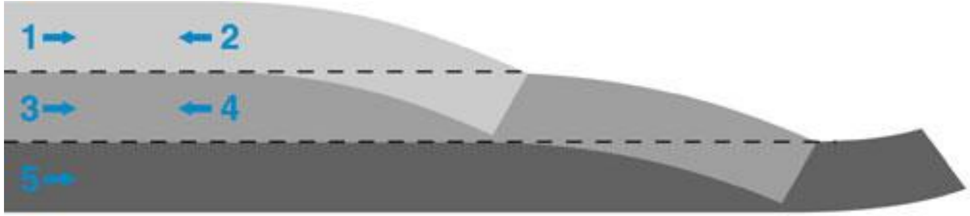


- 6” overlap assures uniform compaction
- Include overlap selecting drum width
- Roller should cover mat in no more than 3 passes

General Rolling Procedures



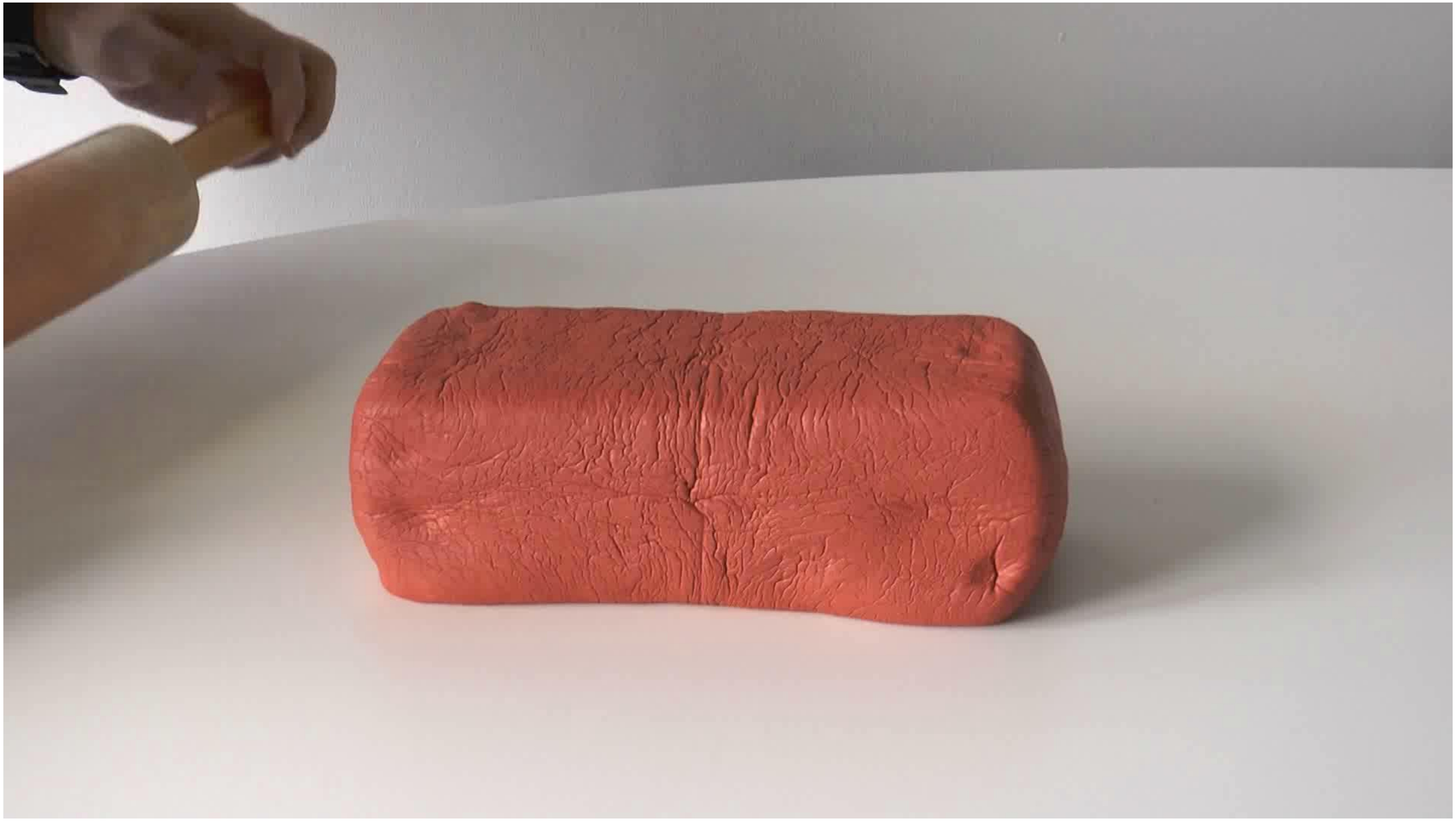
Reversing Directions

- Avoid straight stops
- Turn toward center of mat
- Don't turn drum while stopped
- Next pass should roll out any marks created by reversing

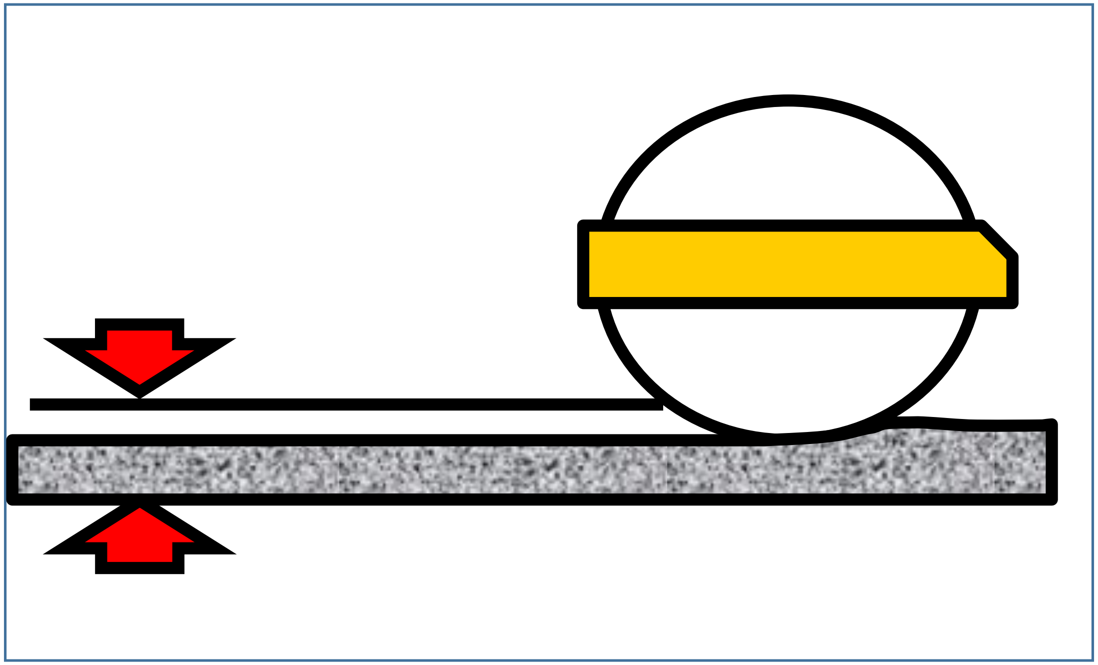
General Rolling Procedures

"Birdbath" from roller stopping on hot mat

Why Rollers Need to Turn to Stop



General Rolling Procedures



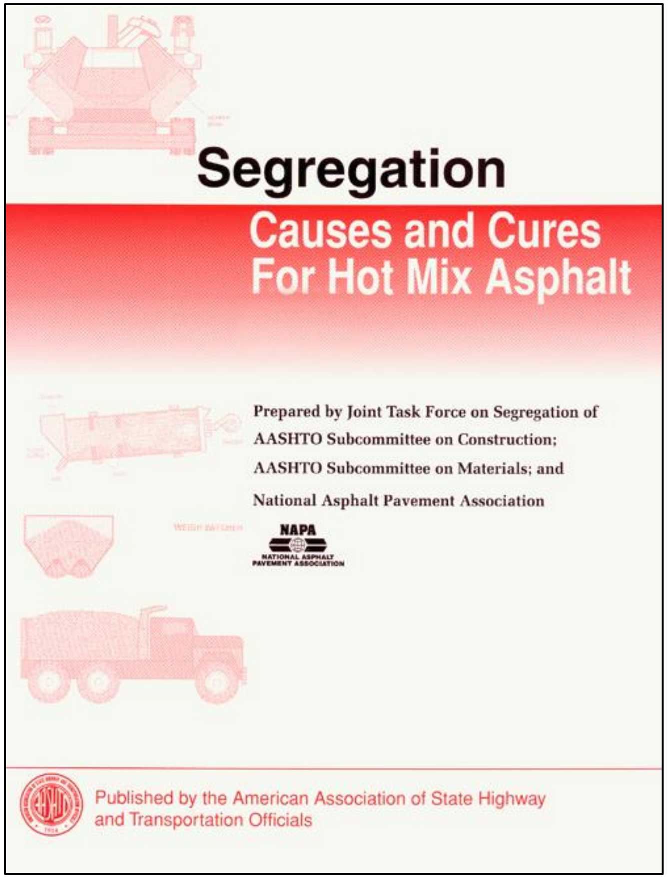
Rolldown

- Paver lays thicker lift
- Roller compacts to the design thickness
- Superpave mixes rolldown ~ 25%
- SMA, PFC & other open-graded mixes rolldown ~15%

Summary of "Good Practice"

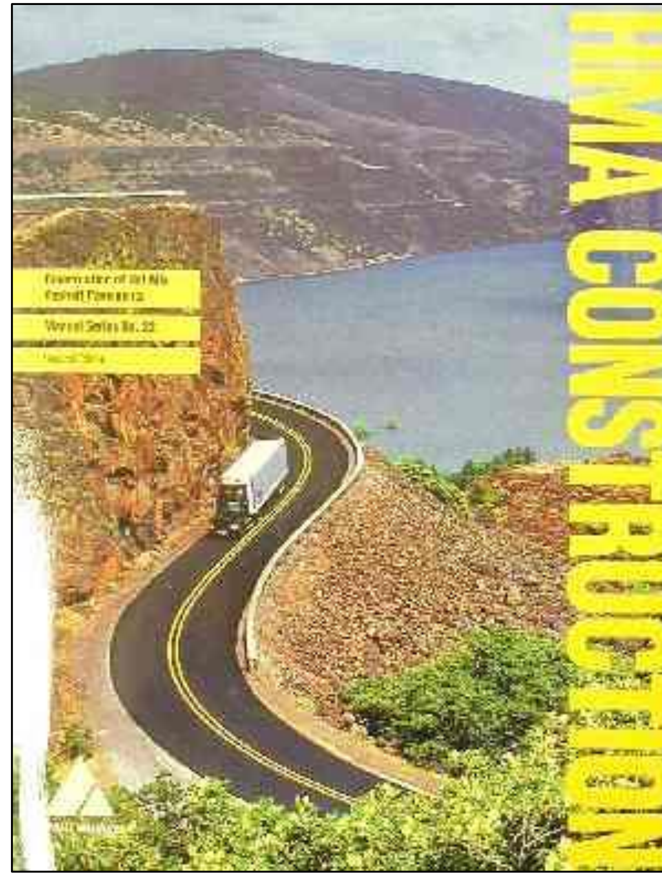
- Compact mat when it is hot!
- Conduct a density control strip at the beginning of the project
  - Determine optimum roller pattern
  - Stick with roller pattern throughout project unless something changes in the conditions
- Reverse directions properly
  - Turn into stops
  - Do not turn while standing
- Do not stop roller on hot mat
- Use proper technique when compacting longitudinal joints

Additional Resources



QIP-110, NAPA

https://store.asphaltpavement.org/index.php?productID=218



MS-22, AI

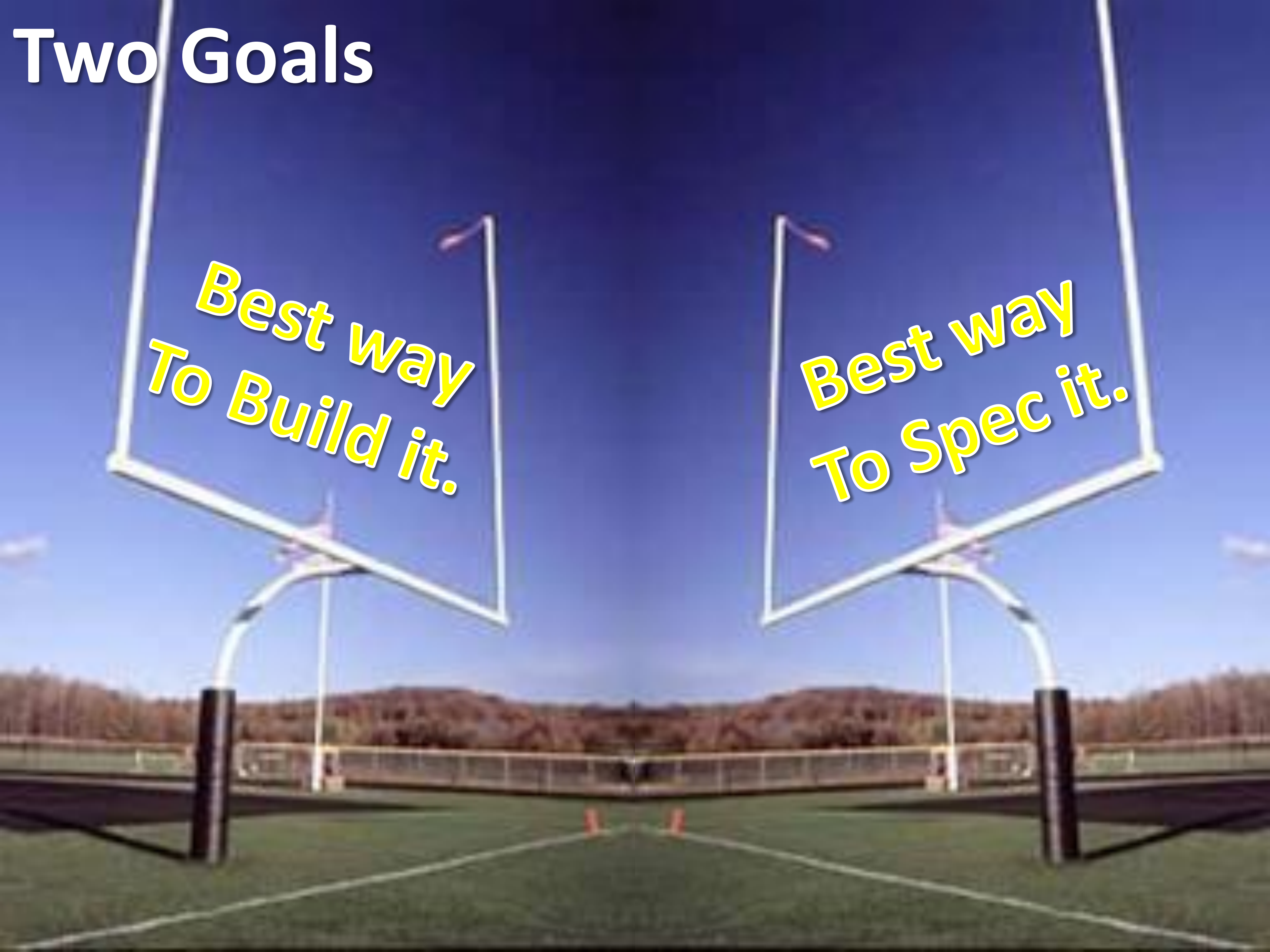
https://mxo.asphaltinstitute.org/webapps/displayItem.htm?acctItemId=317

Other Best Practices

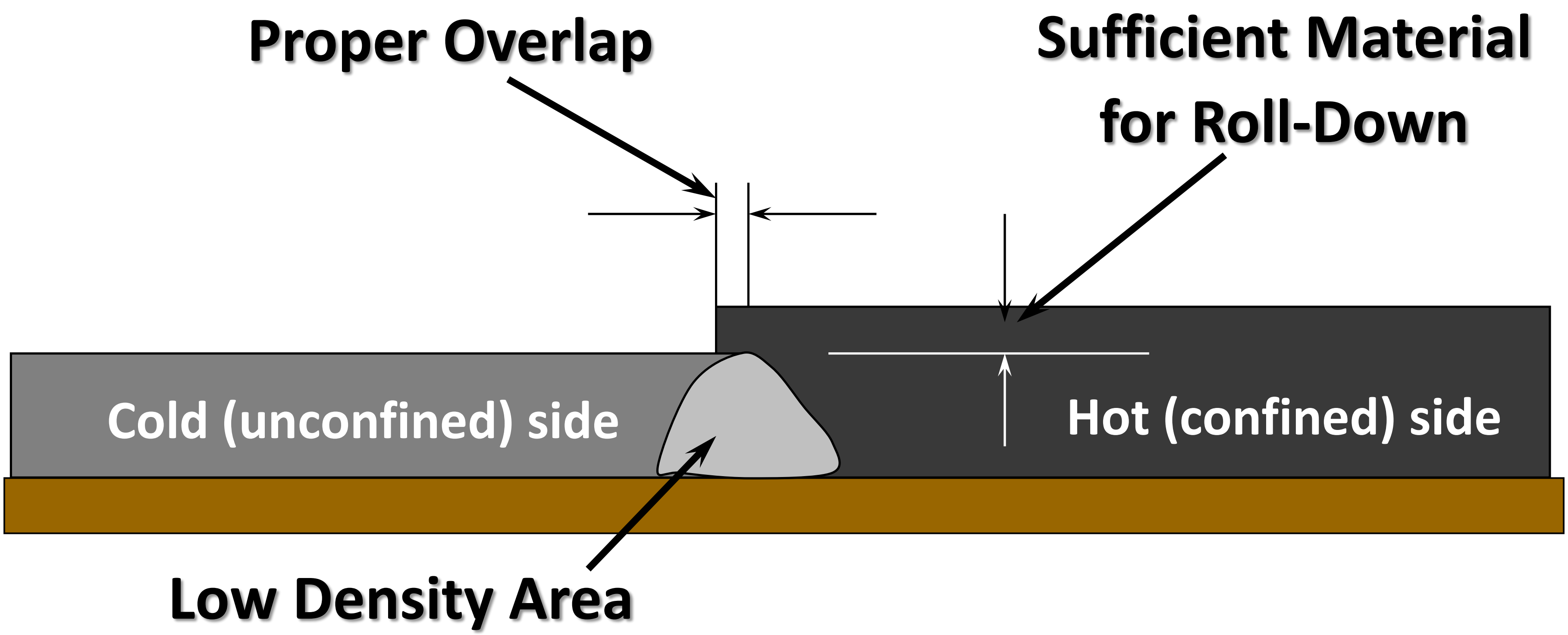
Section 4

Longitudinal Joints

Two Goals



We Know Unsupported Edge Will Have Lower Density



Please note Cold side and Hot side, as they are terms used throughout this Workshop.

Joint vs. Mat Density

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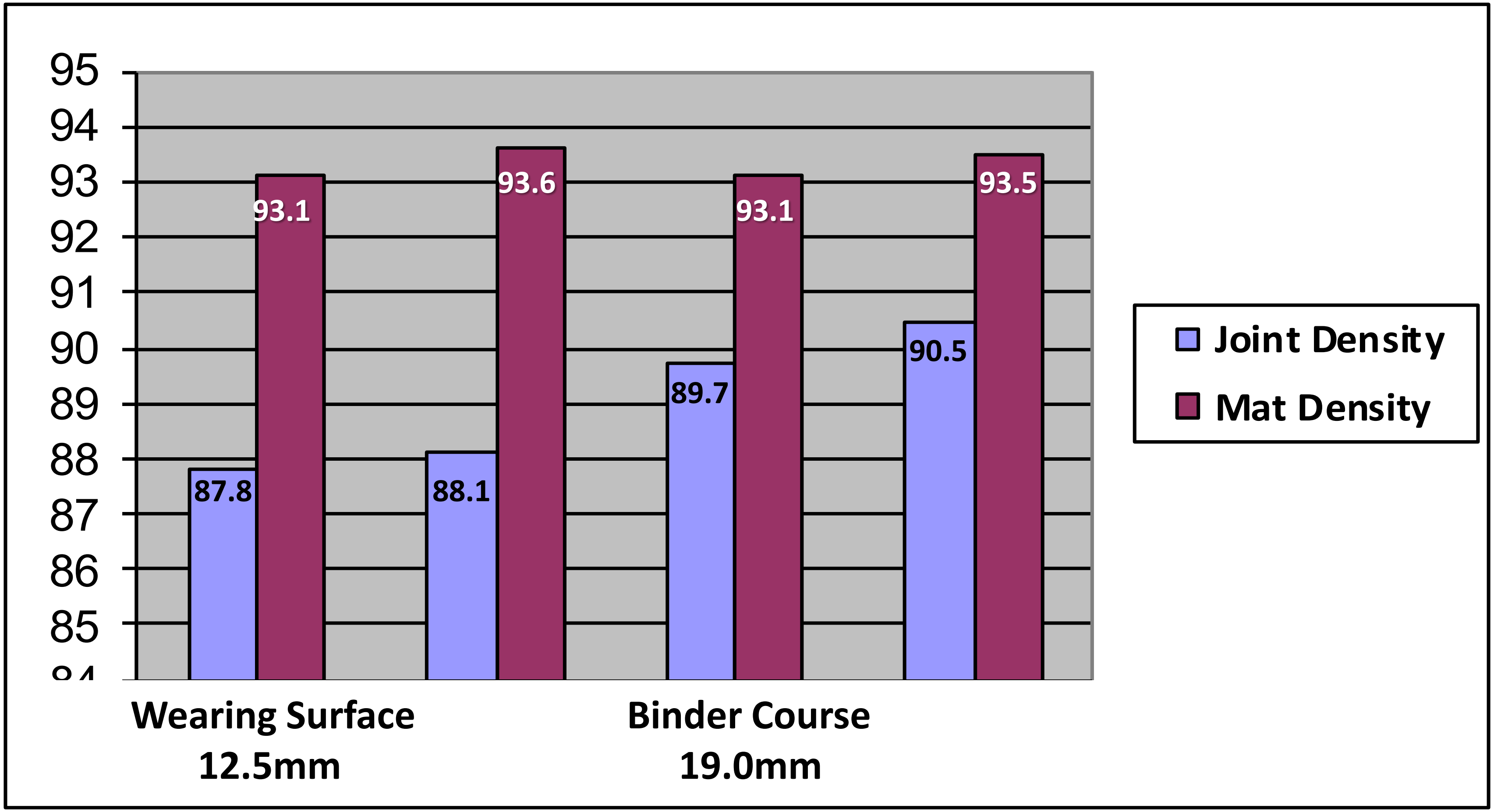

PENNDOT

2006-2007, with 6" cores taken over joint

Typical Nuclear Density Profile

Texas Transportations Institute Study

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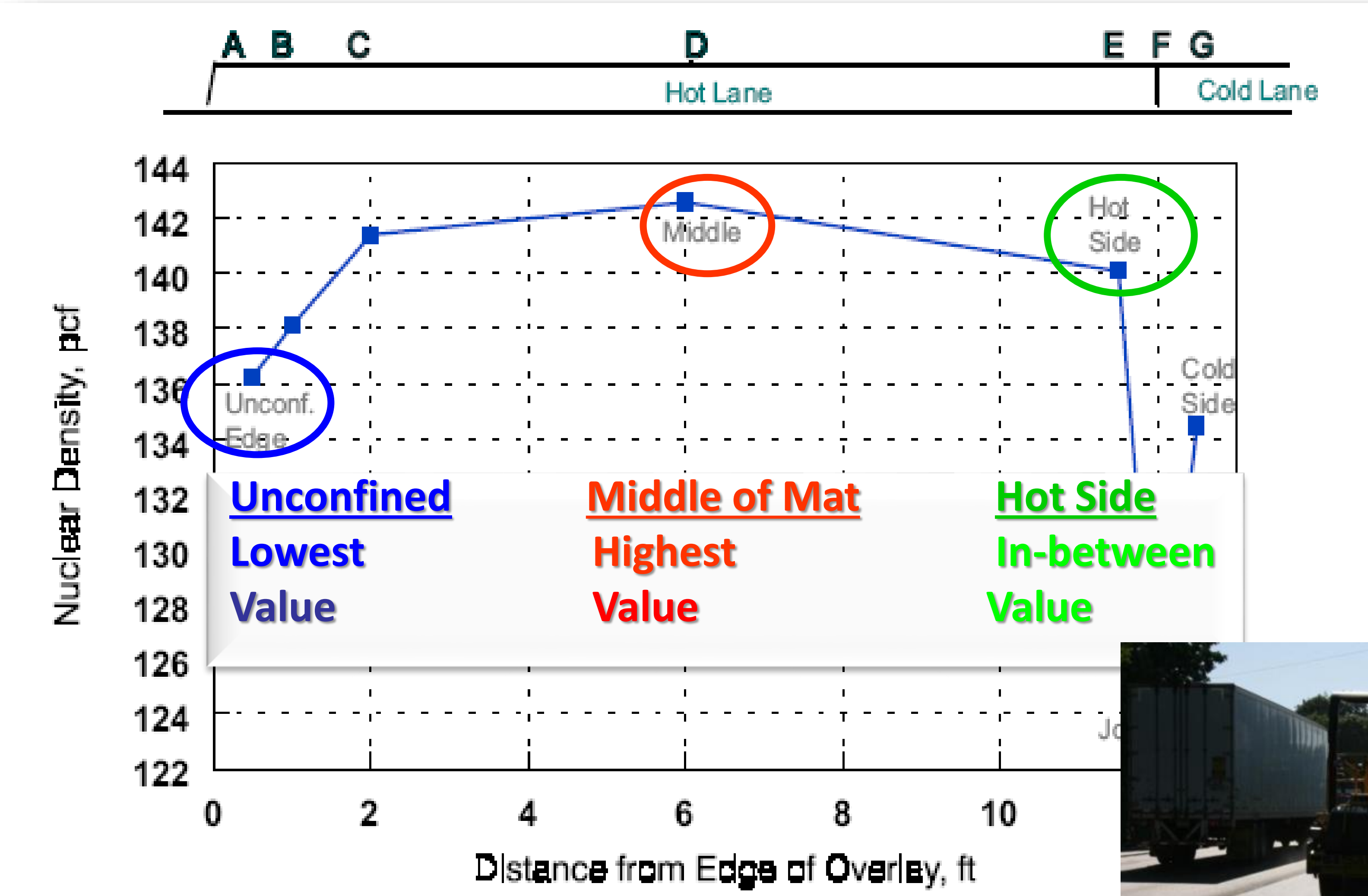

Unconfined
Lowest Value

Middle of Mat
Highest Value

Hot Side
In-between Value


1st Goal
Best way
To Spec it.

Proposed Acceptance Criteria for an LJ Density Spec

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Six-inch Cores located either directly over visible joint for butt joint, or middle of wedge for wedge joint. This gives a 50/50 split, in order to average the G_{mm} of both lots.

- $\geq$ 92% of G_{mm}: maximum bonus
- Between 92% and 90% of G_{mm}:
  100% pay, pro-rated bonus, suggest "overband" or "surface seal" joint
- < 90% of G_{mm}: reduced payment, overband or surface seal joint

PA: How Did it Work?

In-place Density Summary, Reported by PA DOT

Year	# Lots	Avg. Roadway Density, %TMD	Avg. Joint Density, %TMD	
2007	18	93.9	**87.8**	begin measuring at Jt.
2008	43	94.1	**88.9**	method spec
2009	29	94.1	**89.2**	method spec
2010	No data, transition to PWL spec			
2011	137	94.1	**91.0**	PWL, LSL 89%
2012	162	94.0	**91.6**	PWL, LSL 89%
2013	167	93.9	**91.4**	PWL, LSL 89%
2014	316	94.1	**92.3**	PWL, LSL 90%
2015	493		**92.6**	PWL, LSL 90%

PA: Annual Statewide Totals on Incentives/Disincentives for Joint Density

Year	Incentive Payments	Disincentive Payments
2011	$268K	$99K
2012	$489K	$63K
2013	$588K	$25K
2014	$1,002K	$127K

Note: MI and CT have averaged over 91.5%, and AK over 92.0% density at the joint over recent construction seasons

Next: 2nd Goal

The Best Longitudinal Joint: *Echelon Paving*


But, the need to maintain traffic limits the opportunities to pave in echelon
Consequently, most longitudinal joints are built with a cold joint.

Preferred Joint Type? Experts Evenly Divided.

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Wedge Joints and Compaction

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Vibratory Wedge Compactor

Plate Compactor

Average Joint Densities from PA DOT for Entire Paving Season

	2011	2012	2013
Notched Wedge	91.7%	91.7%	"mostly notched wedge joints"
Butt (vertical)	90.3%	90.7%	

Plan for Longitudinal Joints…

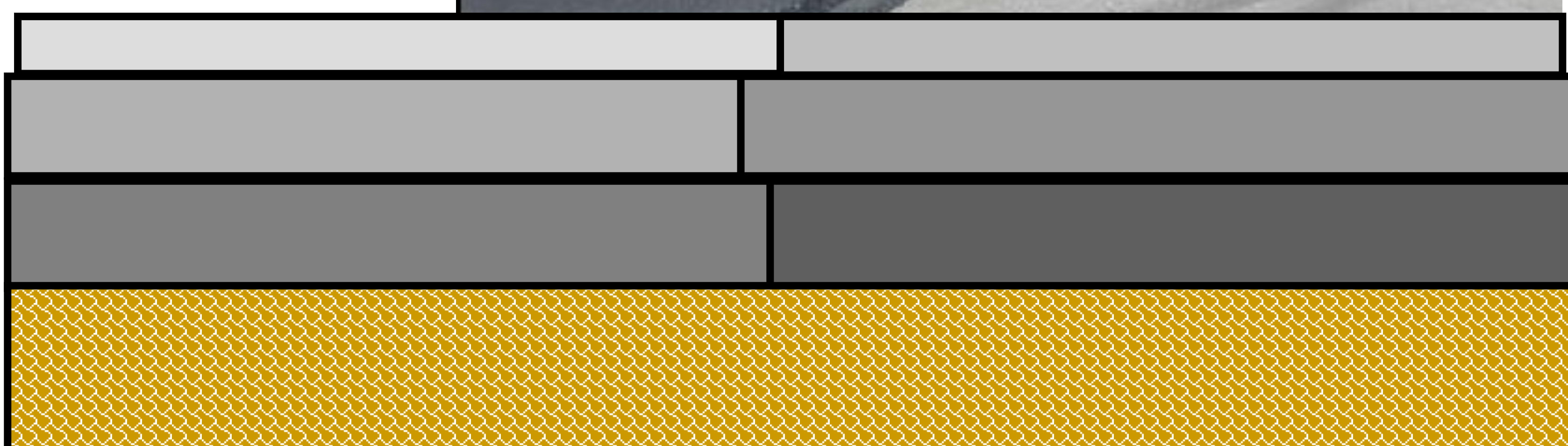
(i.e. Discuss During Pre-Con Meeting)

- Joint Type
- Layout Plan of Final Lift showing joints (DelDOT)
  - Recognize need to offset joints between layers
  - Avoid wheel paths, RPMs, striping (if possible)
- Testing of Joint
  - Type, location, schedule, by whom
- Joint Construction Practices
  - Paving, rolling, materials
- Pave low to high when possible for *shingle effect*
  - Avoids holding rain water at joint by hot side being slightly higher (recommendation later)


Poor planning –
joint in wheelpath

Offset joints between layers by at least 6-inches; surface joint should be near centerline

(not in wheelpath)



First Pass Must Be Straight!

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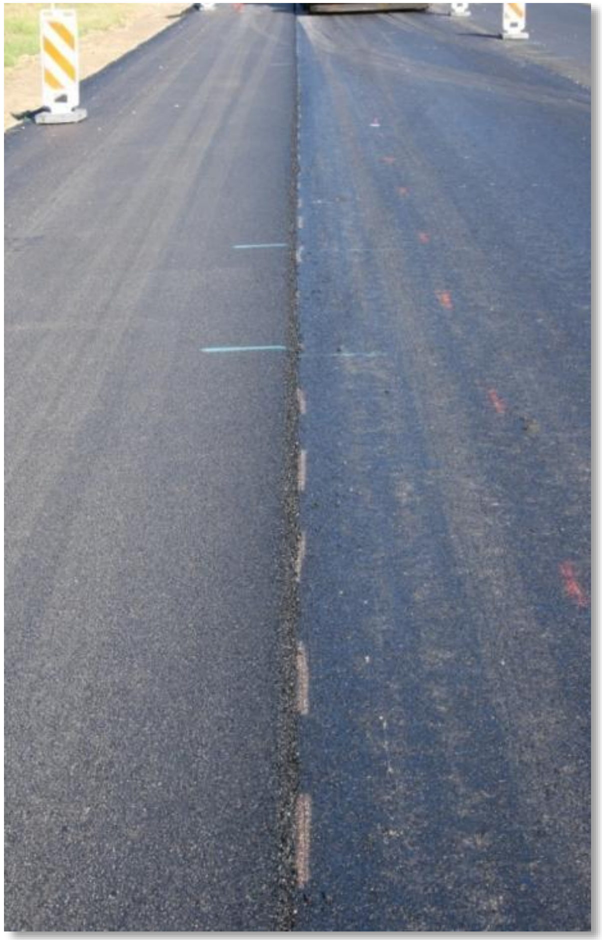
string-line should be used to assure first pass is straight



Stringline for reference, and/or Skip Paint, Guide for following

Great Results

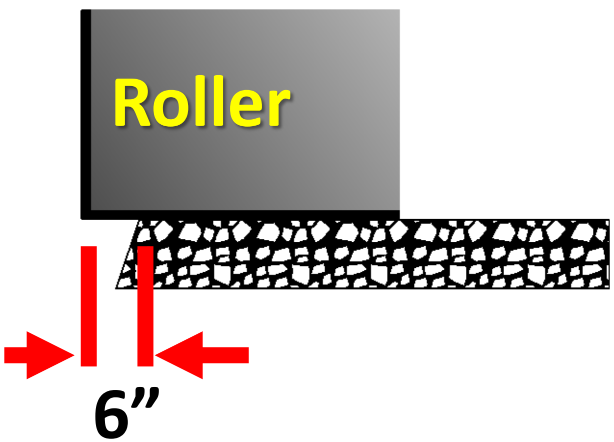
Tough to get proper overlap (1”) with next pass

Best Way to Roll an Asphalt Joint

Rolling Unconfined Side?
50-50 on Where to Put 1st Pass

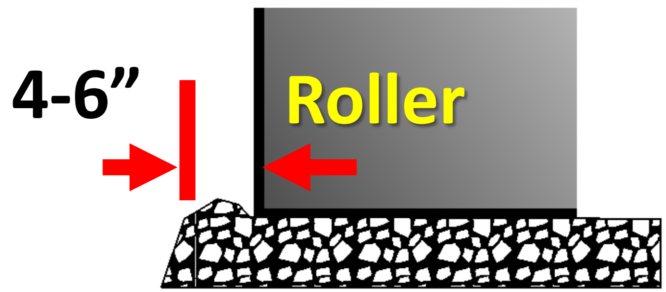
Option 1

Hang over 4-6”

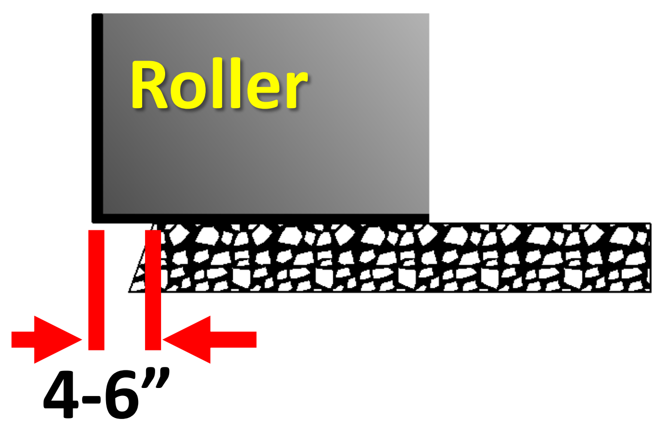


Option 2

1st Pass 4-6” inside



2nd Pass hang over 4-6”



What To Watch for With Option 2

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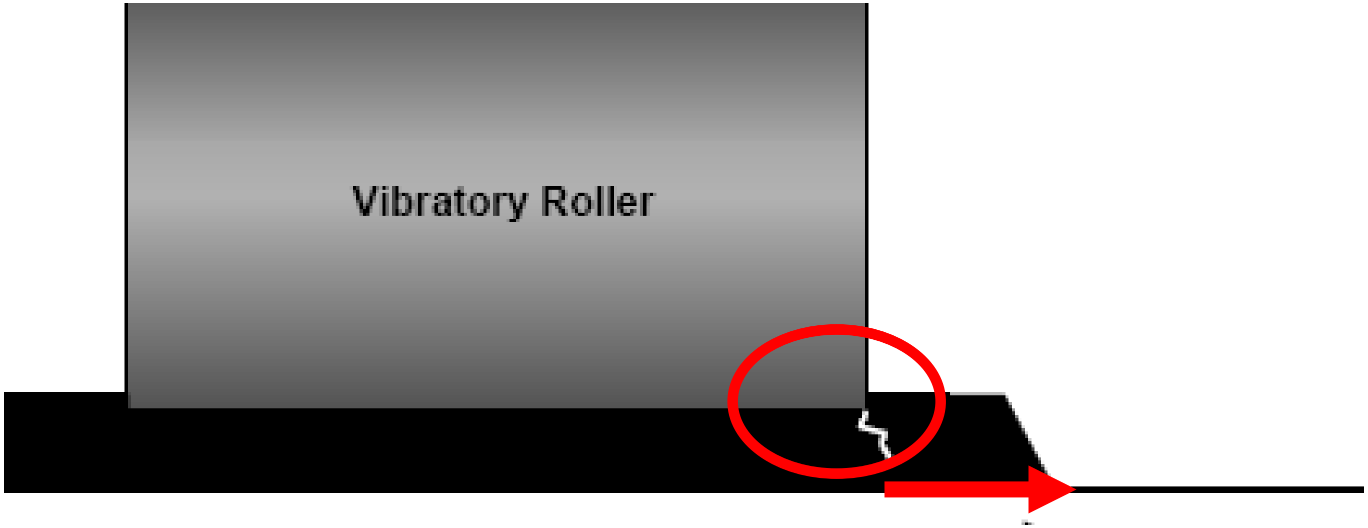
Rolling Unsupported Edge

With First Roller Pass



If edge of drum is located just inside the unsupported edge, a stress crack can occur here.

So Our Recommendation: Option 1

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1st Roller Pass Hangs Over 4-6 inches

Compacting Notched Wedge

Vibrating wedge

Paint the Side of Joint (Butt or Wedge)

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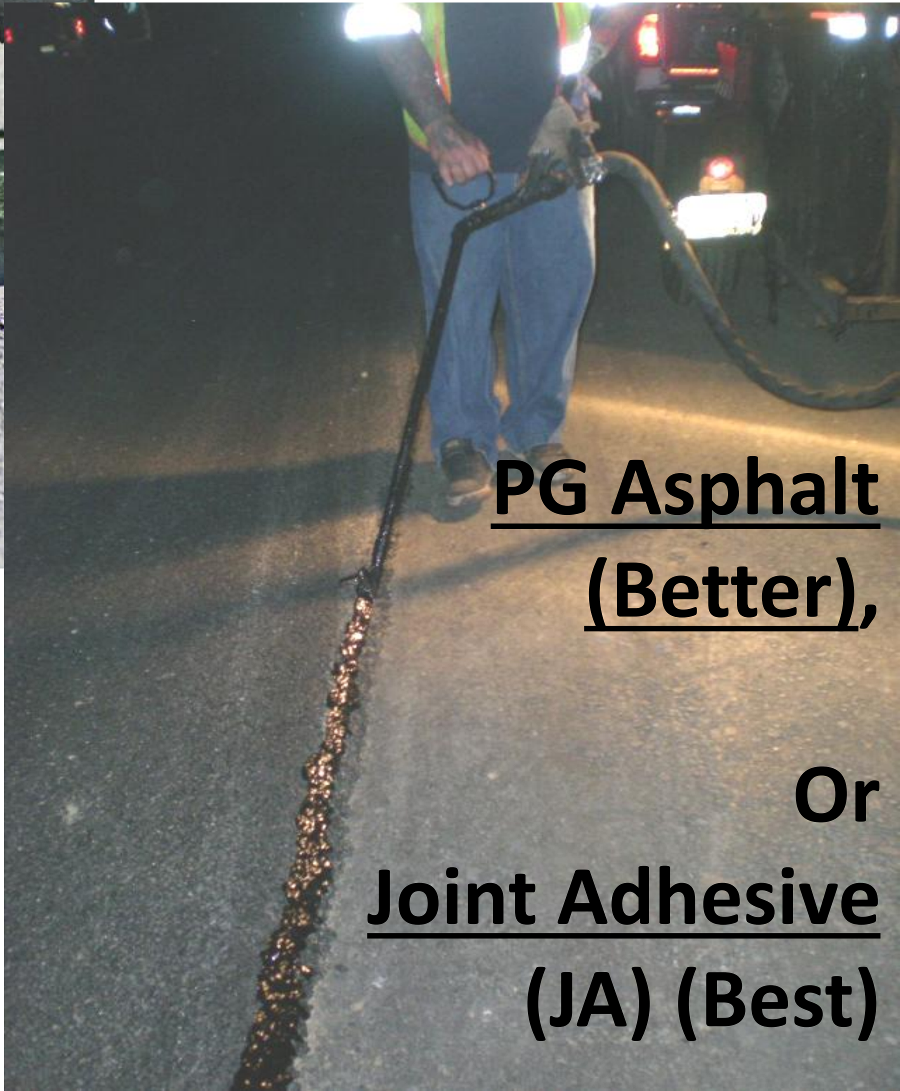
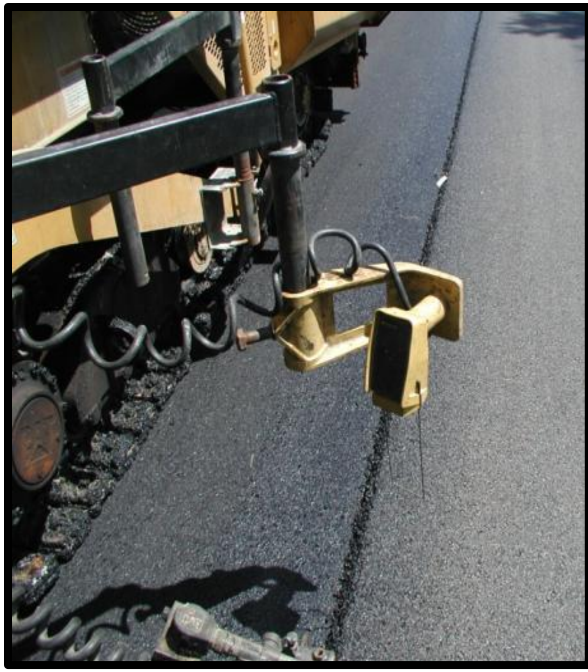


When Closing Joint, Set Paver Automation to Never Starve the Joint of Material

- Target final height difference of +0.1” on hot-side versus cold side
  - NH spec requires 1/8” higher
- Joint Matcher (versus Ski) is best option to ensure placing exact amount of material needed
- If hot-side is starved, roller drum will “bridge” onto cold mat and no further densification occurs at joint



Ski Best for Smoothness

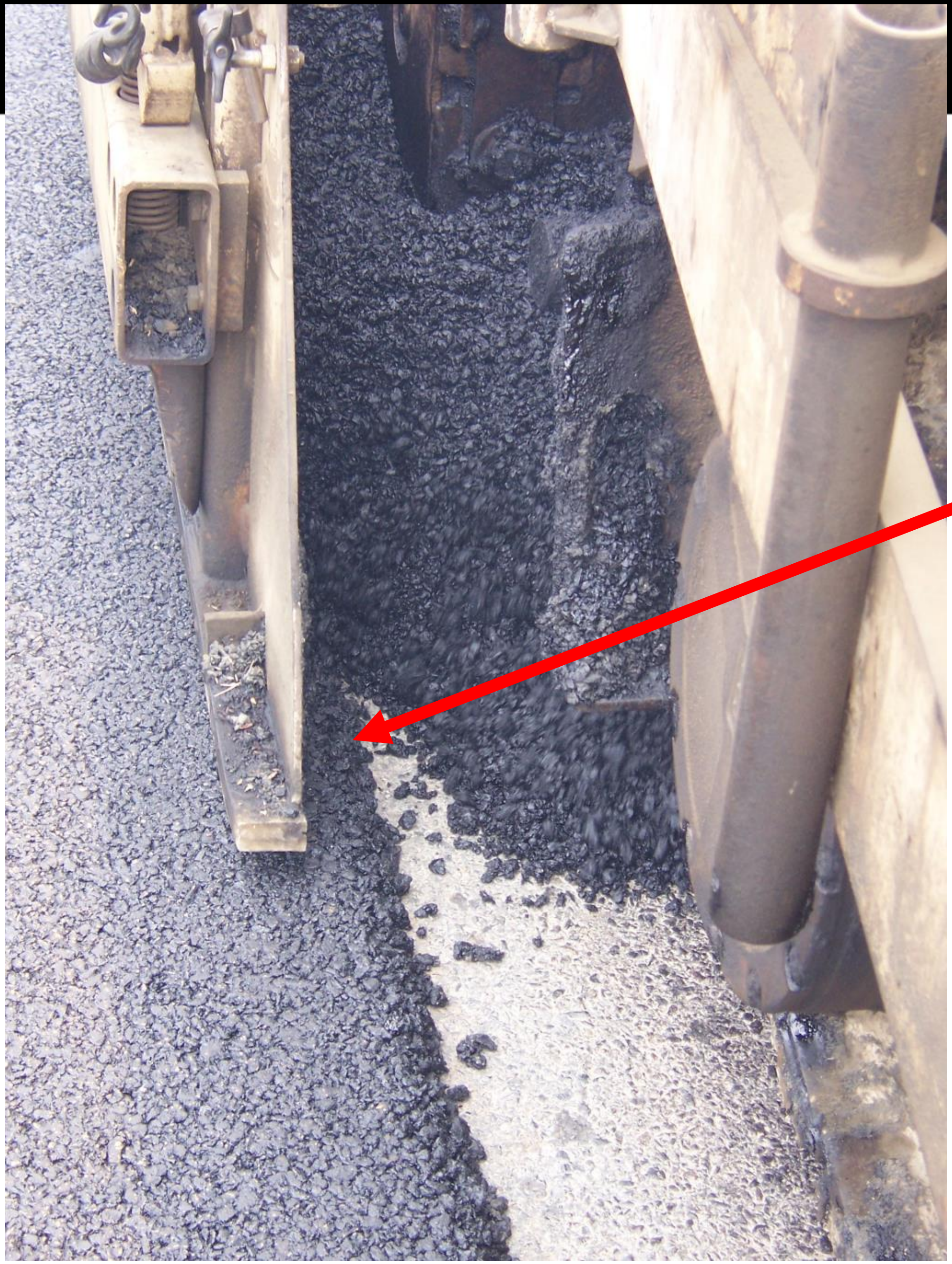
(reference is average over length of ski)

Versus Joint Matcher, which is best for joint (reference is exact location just in front of auger)

Note: If underlying pavement already smooth, some contractors feel they can get good joint with ski, but must finish 1/10” high

Destined for Failure

Likely that the hot side of joint was starved of material at these locations and bridging occurred.



Proper Overlap:

- 1.0 ± 0.5 inches
- Exception:
  Milled or sawed joint
  should be
  0.5 inches

All Photos show Bottom of Lift (Note voids in top two from no overlap)

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Core #2 (No Overlap)

Core #7 (No Overlap)

Core #9 (Overlap 1 ½")

Core #10 (Overlap 1 ½")

Bridenbaugh & Colella

Do NOT Rake Across the Joint

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Lute the Longitudinal Joint

This lute person is doing a great job

Rolling the Supported Edge

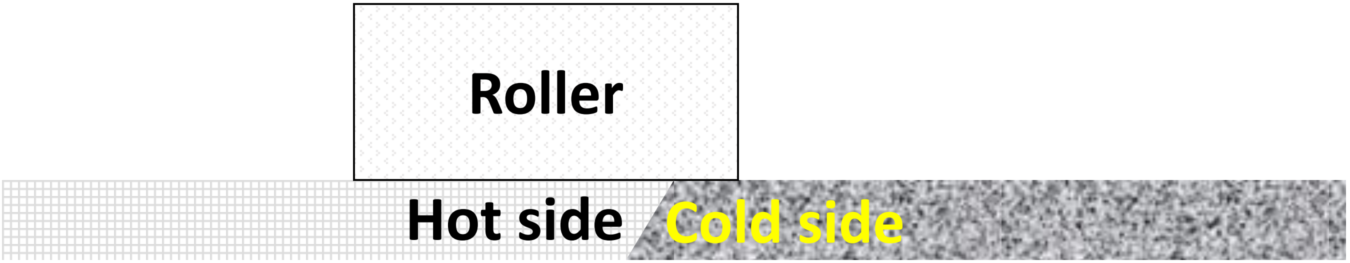
Our Recommendation:

1st pass all on hot mat with roller edge off joint approx 6-12 inches

2nd pass overlaps on cold mat 3-6 inches

Versus an Alternate Method of 1st Pass over the Supported Edge

Roller in vibratory mode with edge of drum overhanging 2 to 4-inches on cold side.



Concern with this method is if insufficient HMA laid on hot side at joint, then bridging occurs with first pass (roller supported by cold mat)

Other Options / New Products

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- Mill & Pave One Lane at a Time
- Cut Back joint
- Joint Heaters
- Joint Adhesives (hot rubberized asphalt)
- Surface Sealers Over Joint
- Rubber Tire Rollers
- Warm Mix Asphalt
- Intelligent Compaction

Details provided in full workshop

GOAL
14 year old surface

- I-65 in IN: SR252 to US31
  - 12 inches HMA over Rubblized JCP
  - Warranty Project

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Tack Coat's Important Role in Compaction and Durability

ASPHALT INSTITUTE®

Tack Coats

- Role in Achieving Compaction
- Importance in Producing Durable Pavements
- Tack Coat Costs
- Tack Coat Challenges
- Tack Coat Best Practices

Tack Coat's Role in Compaction

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Good bond between underlying and the new layer being compacted is critical to "confine" the bottom of the new lift and keep it from sliding during rolling.

Tack Coat’s Role in Compaction

Poor tack coat applications that do not properly bond the layers can impact the ability to properly compact the mix and the affect the long term durability of the pavement.

Tack Coat’s Role in Compaction

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Full width of mat to minimize movement of unsupported edge during compaction

Successful Tack Coat

The Ultimate Goal:

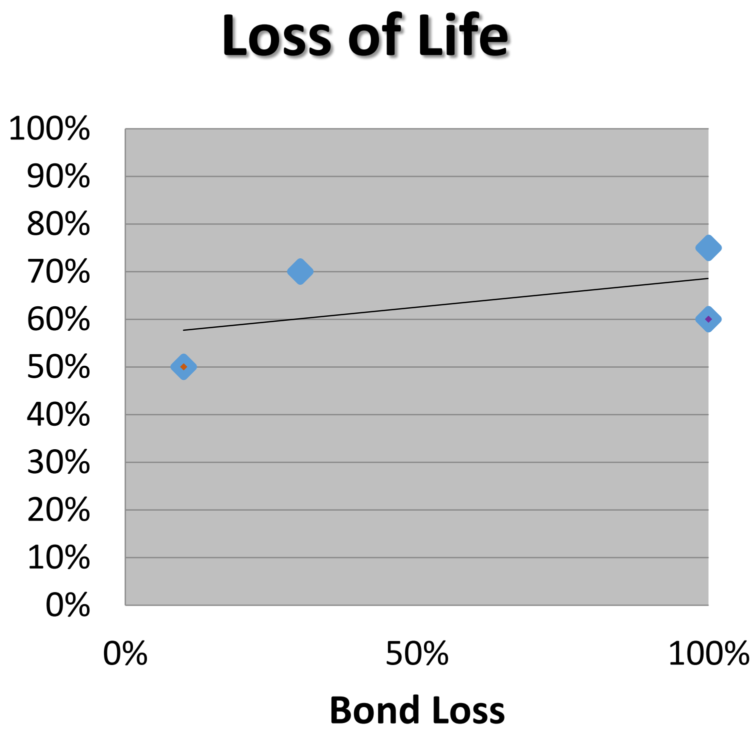
Uniform, complete, and adequate coverage

Importance of Tack Coats

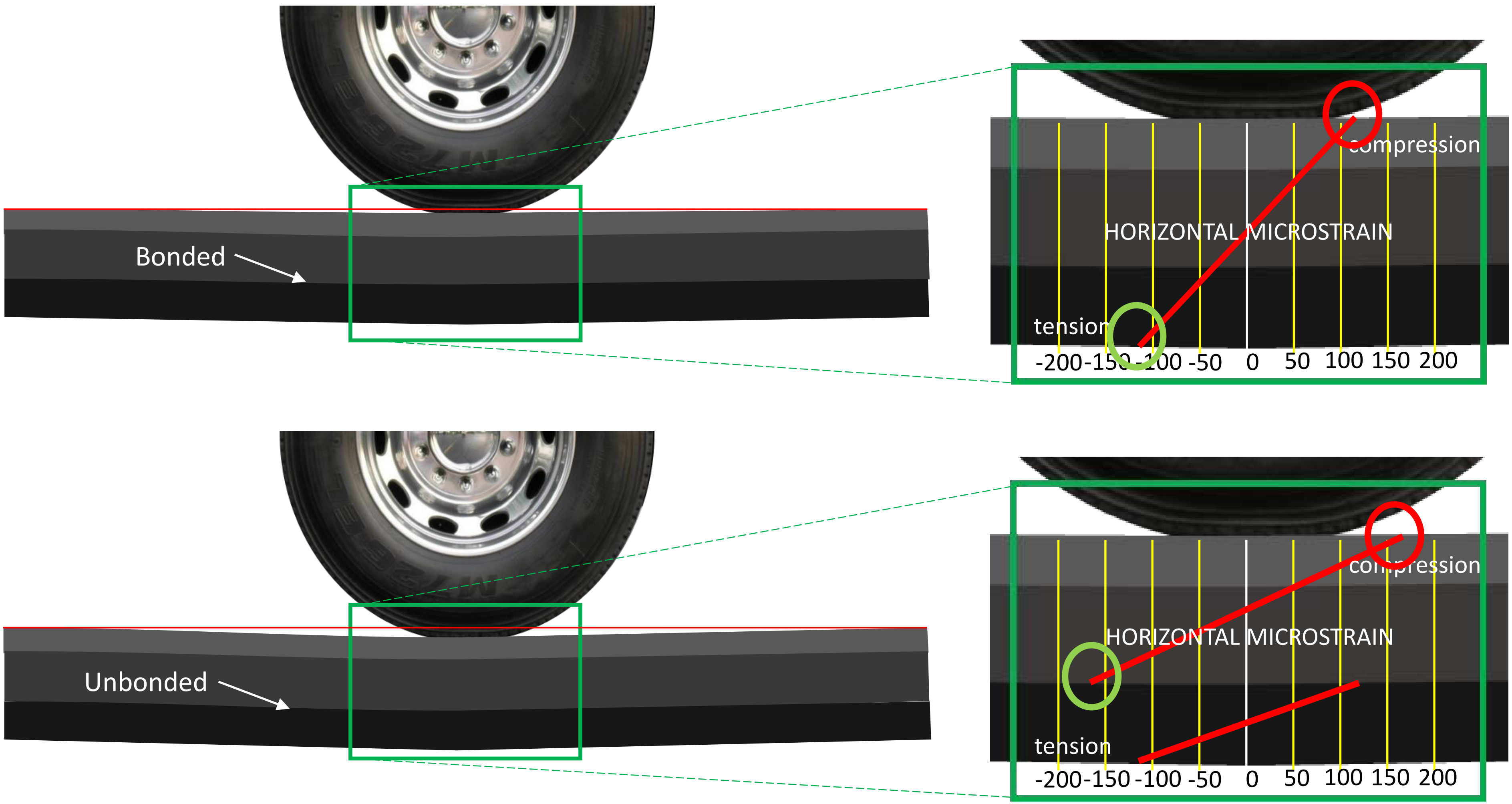
- **To promote the bond between pavement layers.**
  - To prevent slippage between pavement layers.
  - **Vital for structural performance of the pavement. (Durability)**
  - Resist rutting.
  - **Achieve optimum density.**

Loss of Fatigue Life Examples

- May & King:
  - 10% bond loss = 50% less fatigue life
- Roffe & Chaignon
  - No bond = 60% loss of life
- Brown & Brunton
  - No Bond = 75% loss of life
  - 30% bond loss = 70% loss of life



Consequences of Debonding



Courtesy of NCAT

So is it worth it to apply a tack coat?

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Cost of Tack Coat

- New or Reconstruction
  - About **0.1-0.2%** of Project Total
  - About **1.0-1.5%** of Pavement Total Cost

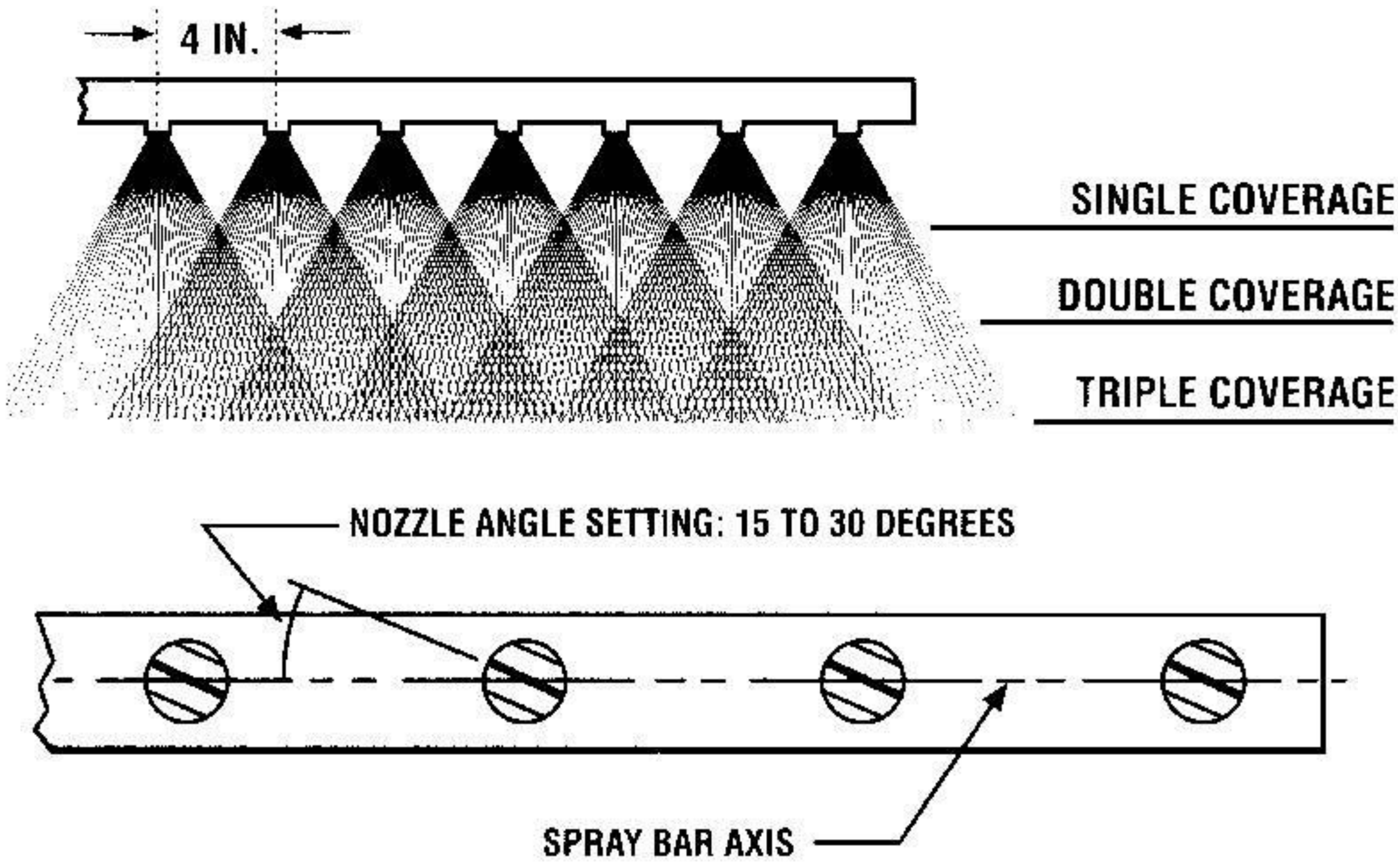
- Mill and Overlay
  - About **1.0-2.0%** of Project Total
  - About **1.0-2.5%** of Pavement Total Cost

Best Practices

- Surfaces need to be clean and dry
- Uniform application
- Tack all surfaces
  - Horizontal
  - Vertical

Road Cleaning Equipment, Showing Broom and Blower Mounted on a Fordson Tractor. The Blower Removes the Dust that has not been Entirely Swept Off by the Broom.

Spray Bar/Nozzles



Proper Nozzle Sizing

- Consult with distributor truck manufacturer to match the material to the nozzle.
- ONE SIZE DOES NOT FIT ALL

Application Rates?

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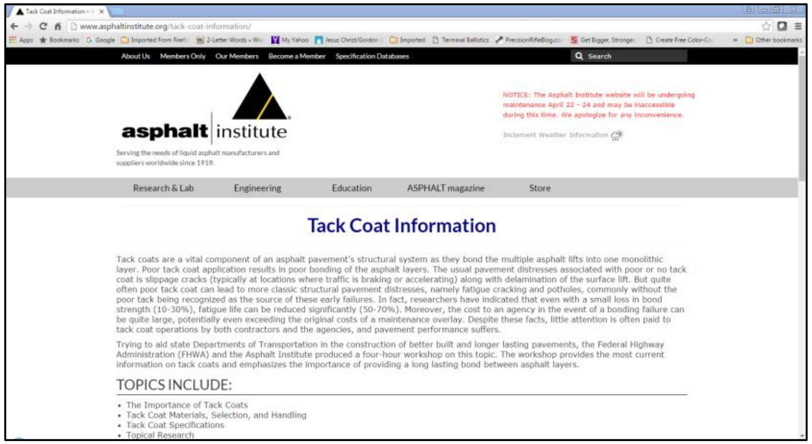
- **What is the Optimal Application Rate?**
  - Surface Type
  - Surface Condition
- **Recommended Ranges**

Surface Type	Residual Rate (gsy)	Appx. Bar Rate Undiluted* (gsy)	Appx. Bar Rate Diluted 1:1* (gsy)
New Asphalt	0.02 – 0.05	0.03 – 0.07	0.06 – 0.14
Existing Asphalt	0.04 – 0.07	0.06 – 0.11	0.12 – 0.22
Milled Surface	0.04 – 0.08	0.06 – 0.12	0.12 – 0.24
Portland Cement Concrete	0.03 – 0.05	0.05 – 0.08	0.10 – 0.16

*Assume emulsion is 33% water and 67% asphalt.

Additional Resources

http://www.asphaltinstitute.org/tack-coat-information/



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NOTICE: The Asphalt Institute website will be undergoing maintenance April 22 - 24 and may be inaccessible during this time. We apologize for any inconvenience.

Inclement Weather Information

Research & Lab Engineering Education ASPHALT magazine Store

Tack Coat Information

Tack coats are a vital component of an asphalt pavement's structural system as they bond the multiple asphalt lifts into one monolithic layer. Poor tack coat application results in poor bonding of the asphalt layers. The usual pavement distresses associated with poor or no tack coat is slippage cracks (typically at locations where traffic is braking or accelerating) along with delamination of the surface lift. But quite often poor tack coat can lead to more classic structural pavement distresses, namely fatigue cracking and potholes, commonly without the poor tack being recognized as the source of these early failures. In fact, researchers have indicated that even with a small loss in bond strength (10-30%), fatigue life can be reduced significantly (50-70%). Moreover, the cost to an agency in the event of a bonding failure can be quite large, potentially even exceeding the original costs of a maintenance overlay. Despite these facts, little attention is often paid to tack coat operations by both contractors and the agencies, and pavement performance suffers.

Trying to aid state Departments of Transportation in the construction of better built and longer lasting pavements, the Federal Highway Administration (FHWA) and the Asphalt Institute produced a four-hour workshop on this topic. The workshop provides the most current information on tack coats and emphasizes the importance of providing a long lasting bond between asphalt layers.

TOPICS INCLUDE:

- The Importance of Tack Coats
- Tack Coat Materials, Selection, and Handling
- Tack Coat Specifications
- Topical Research

http://www.fhwa.dot.gov/pavement/asphalt/pubs/hif16017.pdf

TechBrief

The Asphalt Pavement Technology Program is an integrated, national effort to improve the long-term performance and cost effectiveness of asphalt pavements. Managed by the Federal Highway Administration through partnerships with state highway agencies, industry and academia the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement guidelines, methods, procedures and other tools for use in asphalt pavement materials selection, mixture design, testing, construction and quality control.

U.S. Department of Transportation
Federal Highway Administration

Office of Asset Management, Pavements, and Construction

FHWA-HIF-16-017

April 2016

Tack Coat Best Practices

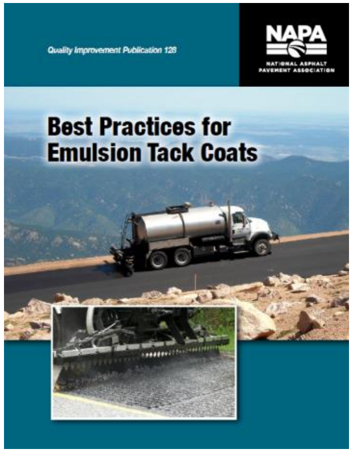
This Technical Brief provides an overview of tack coats and their vital role bonding multiple asphalt layers into one monolithic system. Poor tack coat techniques result in compromised bonding of the asphalt layers. This leads to pavement distresses. Possible slippage cracking and delamination are associated with poor bonding. Additionally, poor bonding can lead to structural distresses, namely fatigue cracking and potholes. Often this lack of sufficient bonding is not recognized as the source of failures.

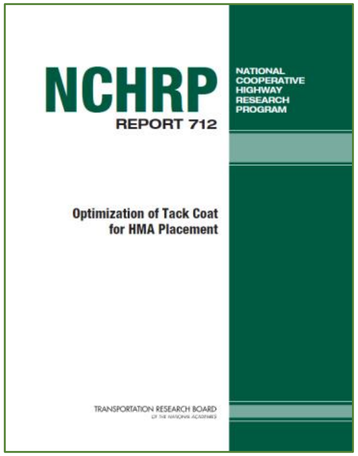
Introduction

A key, but sometimes overlooked, component of an asphalt pavement is the bond strength between asphalt pavement layers. Tack coat is a sprayed application of an asphalt binder upon an existing asphalt or Portland cement concrete pavement prior to an overlay, or between layers of new asphalt concrete. This thin membrane of asphalt binder provides the glue between the layers, creating a monolithic structure which performs as a unit as opposed to unbound, independent, layers. When properly built, a pavement will provide the desired characteristics for its users, while meeting the needs of an agency for an economical, environmentally friendly and sustainable material.

Poor bonding of a pavement surface layer is a direct result of inadequate tack coat practices resulting in slippage and shoving of the pavement, as seen in Figure 1. This type of failure is most frequently seen in locations where braking or acceleration is common, such as intersections. Other distresses can also be made related to poor tack coat bonding, most notably pavement fatigue cracking.

1





http://store.asphaltpavement.org/index.php?productID=786

http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_712.pdf

Measurement and Payment of Density

Section 5

How do we typically define quality?

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- Meets agency mixture specifications
- Meets agency density specifications
- Smooth riding surface
- Uniform texture and appearance
- Obtains expected service life
- **Long lasting asphalt pavement**

Quality Control and Acceptance

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On almost every roadway project, the component materials are tested.

Quality Control - testing that helps the *producer* ensure that they are *providing* a quality product

Acceptance - testing that helps the *owner* ensure that they are *receiving* a quality product

HMA Inspection

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- **Responsibilities**
  - Represent the owner's interests
  - Keep daily construction diary
  - Monitor ambient air and mat temperatures
  - Track tonnage with truck tickets
  - Calculate yield
  - Monitor compaction with nuclear or non-nuclear gauge
  - Observe materials and workmanship
  - Make sure that good practices are being used

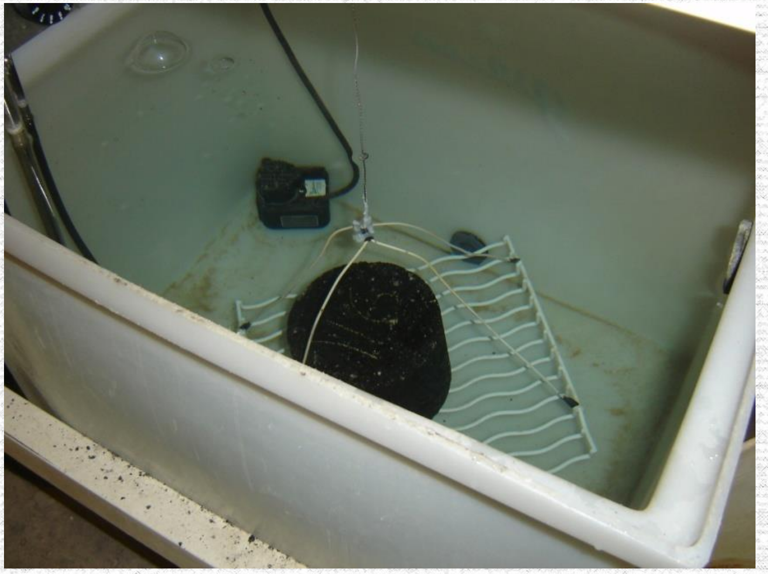
Density Acceptance/Quality Control

Measuring Density

Using cores……   or a nuclear density gauge

AASHTO T 166 - Method C

- Immerse each specimen in water at 25 ± 1°C (77 ± 1.8°F) for 4 ± 1 minutes and record the immersed mass as C.



- Remove the specimen from the water bath, damp-dry the specimen by blotting it with a damp towel as quickly as possible (not to exceed 5 seconds).
- Weigh and record the SSD mass as B. Any water that seeps from the specimen during weighing is considered part of the specimen.

AASHTO T 166 - Method C Calculation

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Calculate the bulk specific gravity :

$$\text{Bulk Specific Gravity} = \frac{A}{B - C}$$

Where:

A = mass of the specimen in air, g

B = mass of the SSD specimen in air, g

C = mass of the specimen in water, g

Is T 166 always the most accurate?

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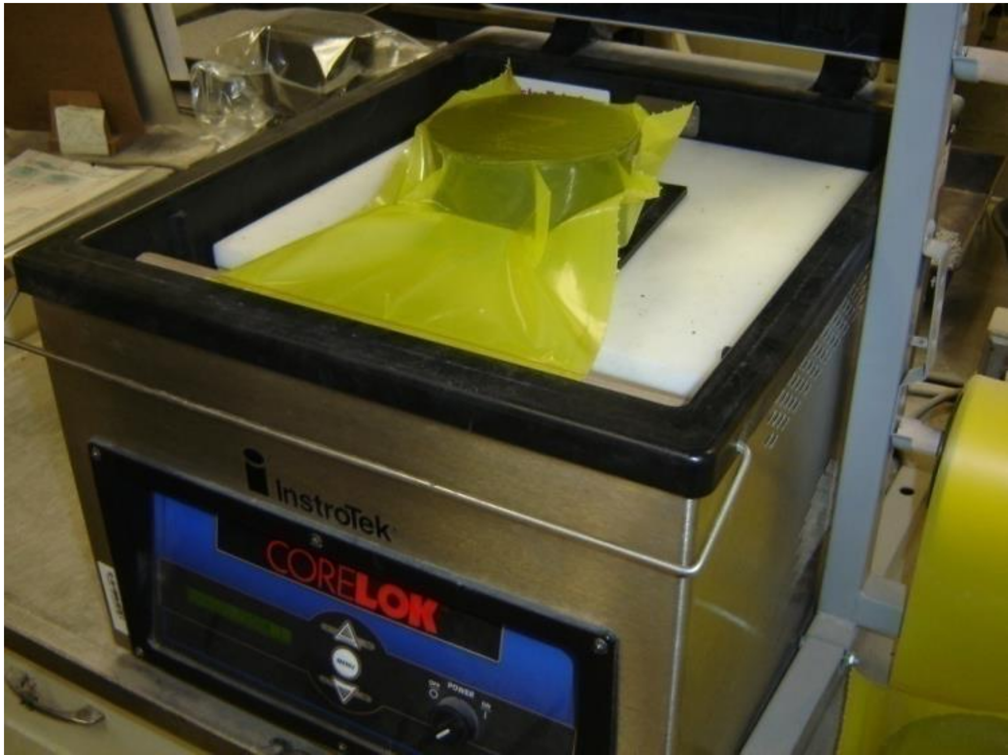
For mixtures with low density and/or coarse texture, AASHTO T 166 overestimates density because specimen volume is under measured.

Several methods are used to measure true volume, the most common of which is the CoreLok device (AASHTO T 331)



How much is the difference?

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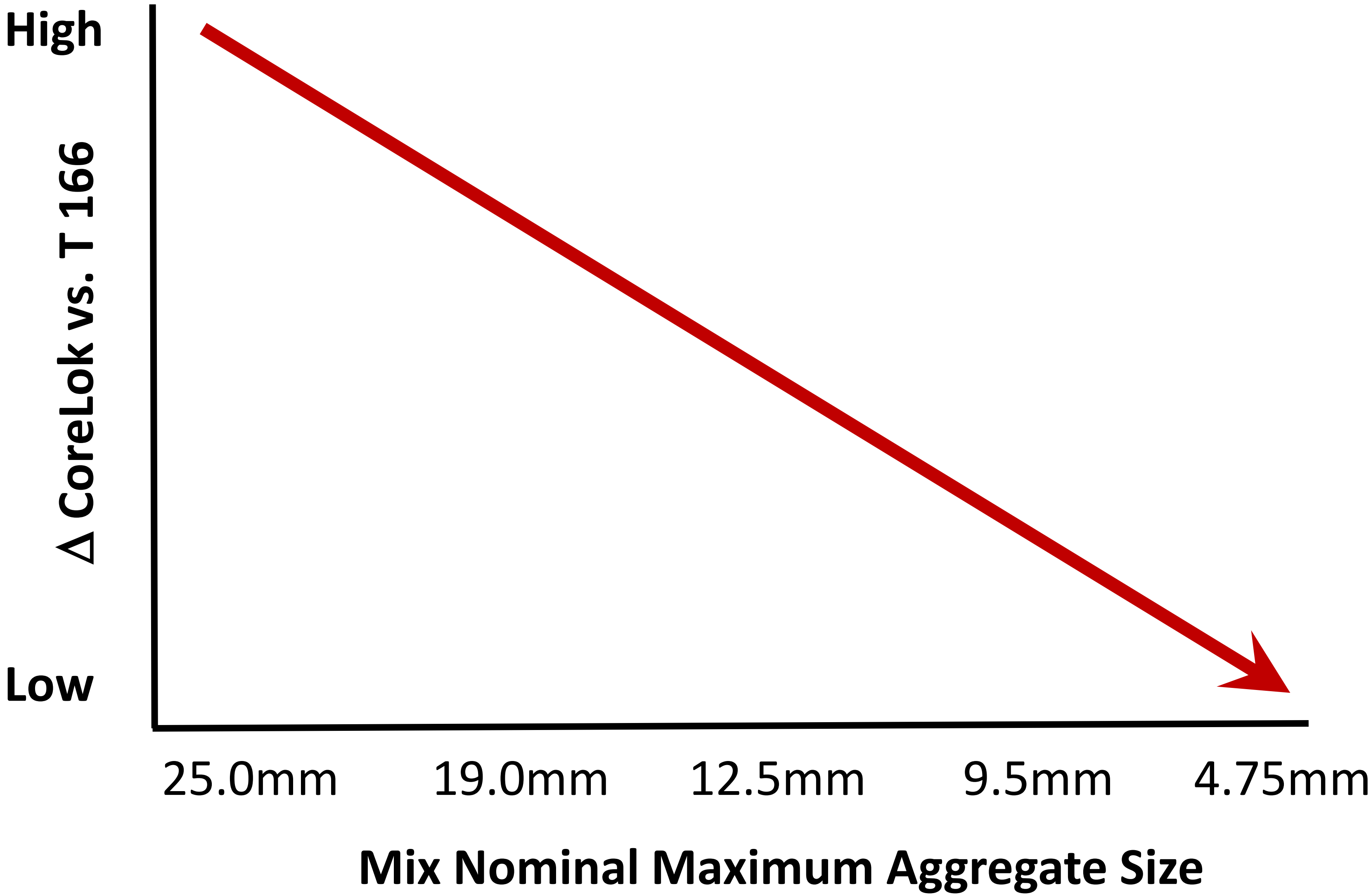
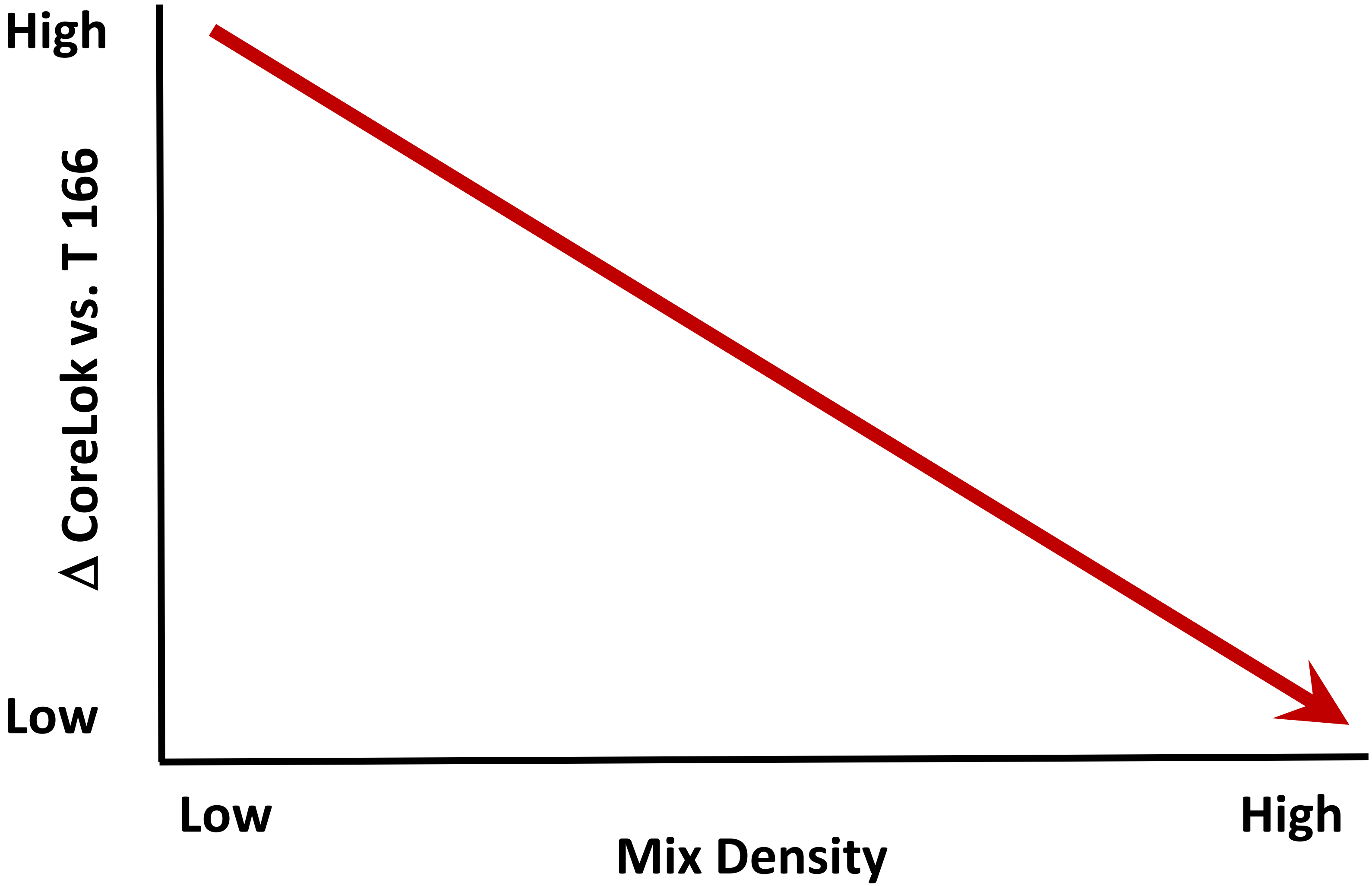


How much is the difference?



When to use CoreLok instead of T 166?

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AASHTO T 166 says CoreLok should be used if percent absorption is more than 2.0%

Based on research, FHWA recommends to use CoreLok on all specimens with absorption more the 1.0%

Types of Acceptance Specifications

- Method
  - Extreme agency control
    - Materials
    - Equipment
    - Construction methods
- End-Result
  - Less agency control
  - What does “good quality” look like?

Types of Specifications

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- Acceptance
  - Statistically based
  - QC by contractor
  - Acceptance (QA) by agency or their representative
- Performance-Type
  - Evaluation of in-place performance
  - Predetermined parameters and timeframes
  - Warranty
- Combinations

Percent Within Limits Specification

Percent-Within-Limits is a statistically-based method to estimate the percentage of a "lot" of material that falls within the required specifications.

A basic assumption is that the test values follow a normal distribution. The method then incorporates both the sample mean and standard deviation to estimate PWL.

Pay Factor

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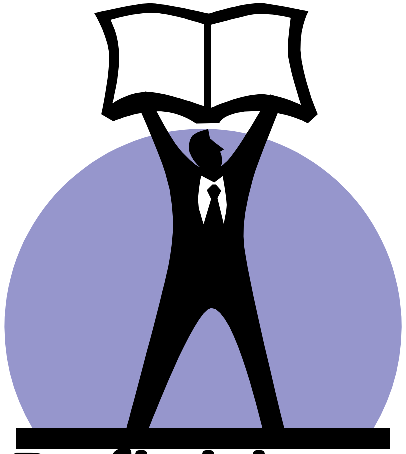


Definition

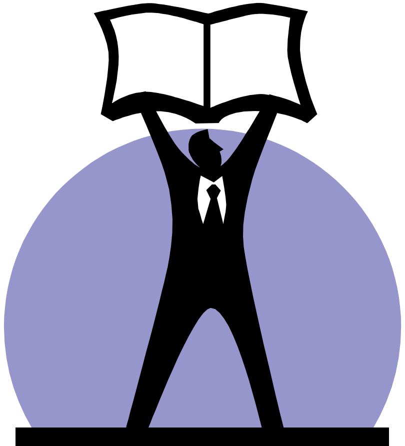
A multiplication factor, often expressed as a percentage, that considers a quality characteristic and is used to determine a contractor’s payment for a unit of work

Using PWL to Compute Pay Factors

Pay Factors:

- Recoup losses expected from poor quality work
- Reward increased performance from increases in product consistency

Composite Pay Factor



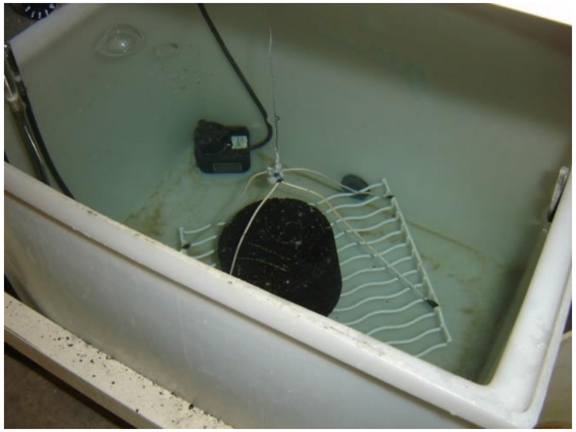
Definition

A multiplication factor, often expressed as a percentage, that considers two or more quality characteristics and is used to determine the contractor’s final payment for a unit of work

Using Composite Pay Factors

The ultimate performance of most construction items is dependent upon several quality characteristics

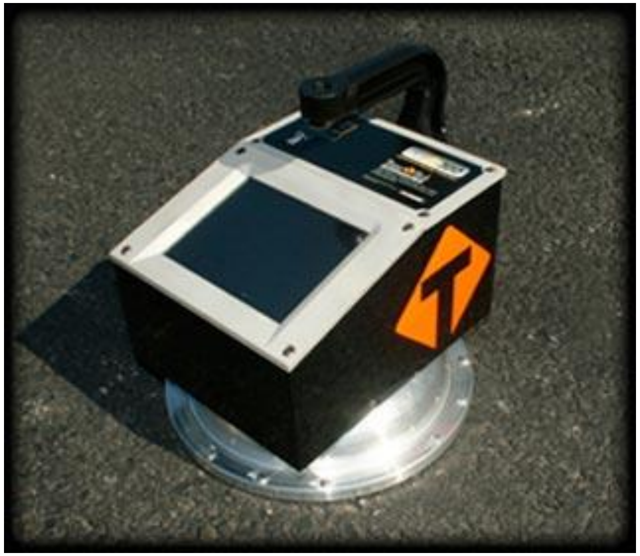
Highway construction specifications usually include multiple Acceptance requirements



When 2+ pay factor clauses appear in a single specification, they are typically combined into a *Composite Pay Factor*

Measurement of Density

- Cores taken from the field
- Nuclear gauge readings
- Non-nuclear gauge readings
- Gauges correlated to field cores



State Highway Agency (SHA) Density Specification Mining

FHWA Co-op Task 2.15 State Density Maps

Background

Goals of data mining – how to SHA's specify mat density:

- **Methods** of measure
  - Cores, gage, roller pattern
- **Baseline** measure
  - Max. Theoretical Gravity (G_{mm}), lab bulk sample (G_{mb}), control strip
- **Sampling**
  - Lot/sublot size and how averaged
- **Spec type**
  - PWL, other advanced statistics, simple average
- Specification **limits**
- Is there a compaction **incentive**?

The Process

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- Asphalt Institute Regional Engineers gathered information from latest SHA specifications and direct agency contacts
- Data was reviewed with specs as much as possible
    - **Since some specs allow for interpretation, there may be some mistakes.**
- What we looked at:
    - Focus was on a high-level review of specifications to gather density requirements for SHA highest level compaction standard (interstate / primary route pavements)

The Good, Bad and Ugly

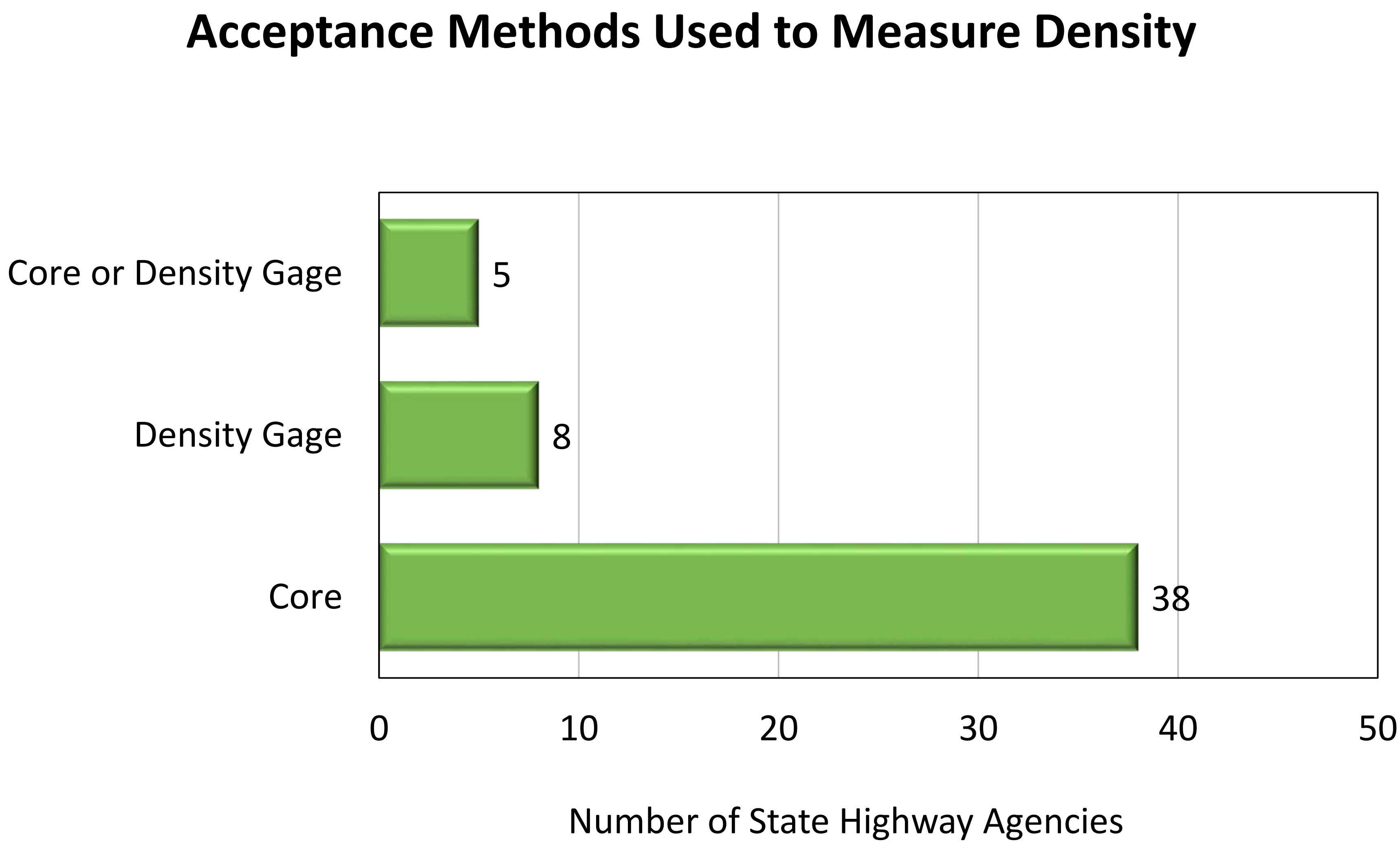
- Critical information was usually difficult to interpret or find. Seems to be known or understood locally.
  - Some specs referenced other documents which were sometimes hard to access.
  - Some specs had the critical information of G_{mm}, lots, density spread over many pages or books.
  - Some did not address when the G_{mm} is measured.
  - “Specification Creep” has set in.

The Good, Bad and Ugly

- EASY and to the POINT
  - *"Five randomly selected cores (4" min./ 6" max. diameter), from the travel lane, will be tested to determine density compliance and acceptance. One core shall be taken from each sublot. The Bulk Specific Gravity (G_{mb}) of the cores shall be determined as stated above and the average calculated. The maximum theoretical gravity (G_{mm}) from acceptance testing for that shift's production will be averaged and the percent density will be determined for compliance by dividing the G_{mb} average by the G_{mm} average."*
  - Most everything you need about density in one paragraph!

Travel Lane Density		
% Gmm		% Pay
Min	Max	
99.1	100	90
98.1	99	94
97.1	98	98
96.1	97	100
95.1	96	101
94.1	95	102
93.1	94	101
92.1	93	100
91.1	92	98
90.1	91	94

Density Acceptance Methods



Density Acceptance Methods

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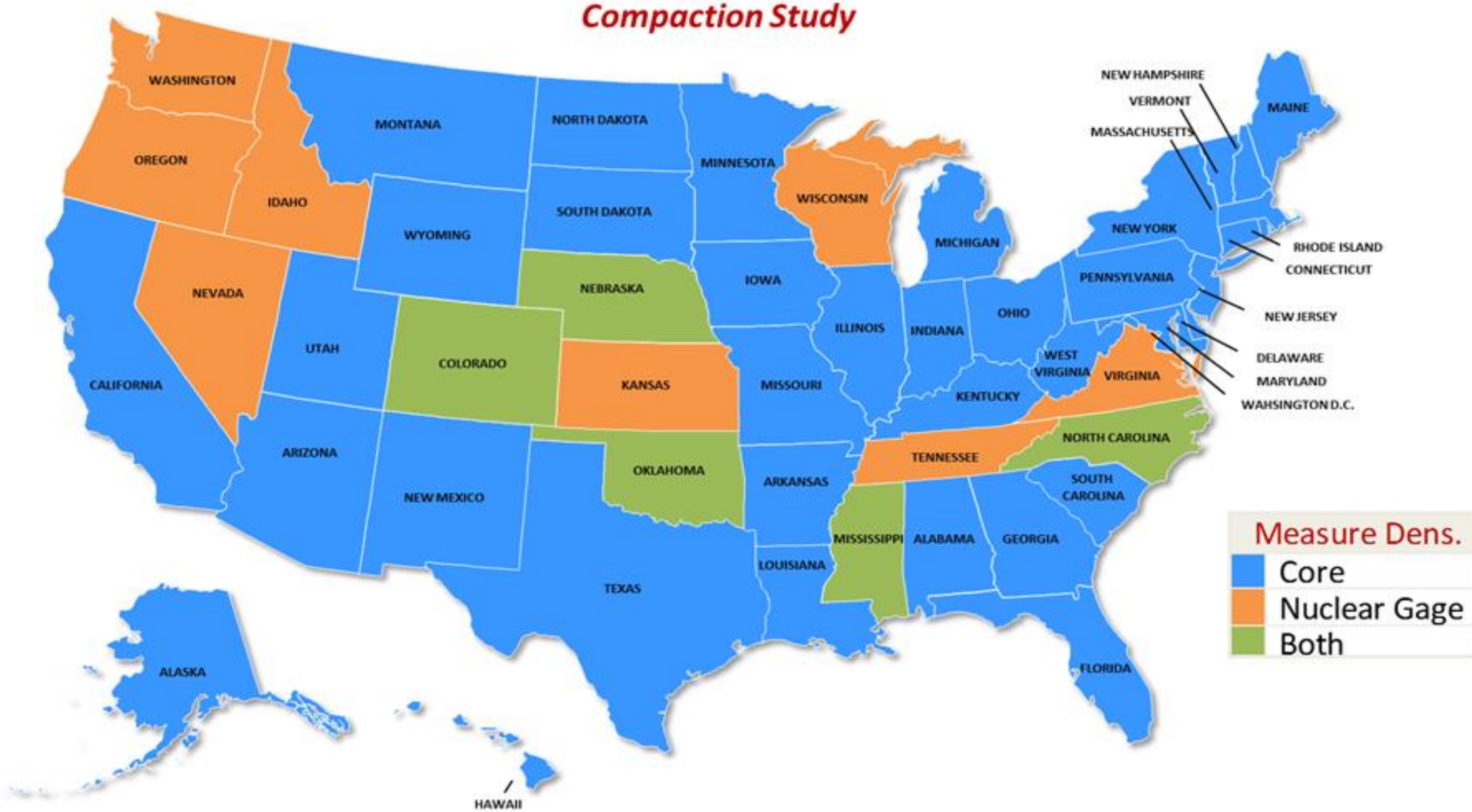
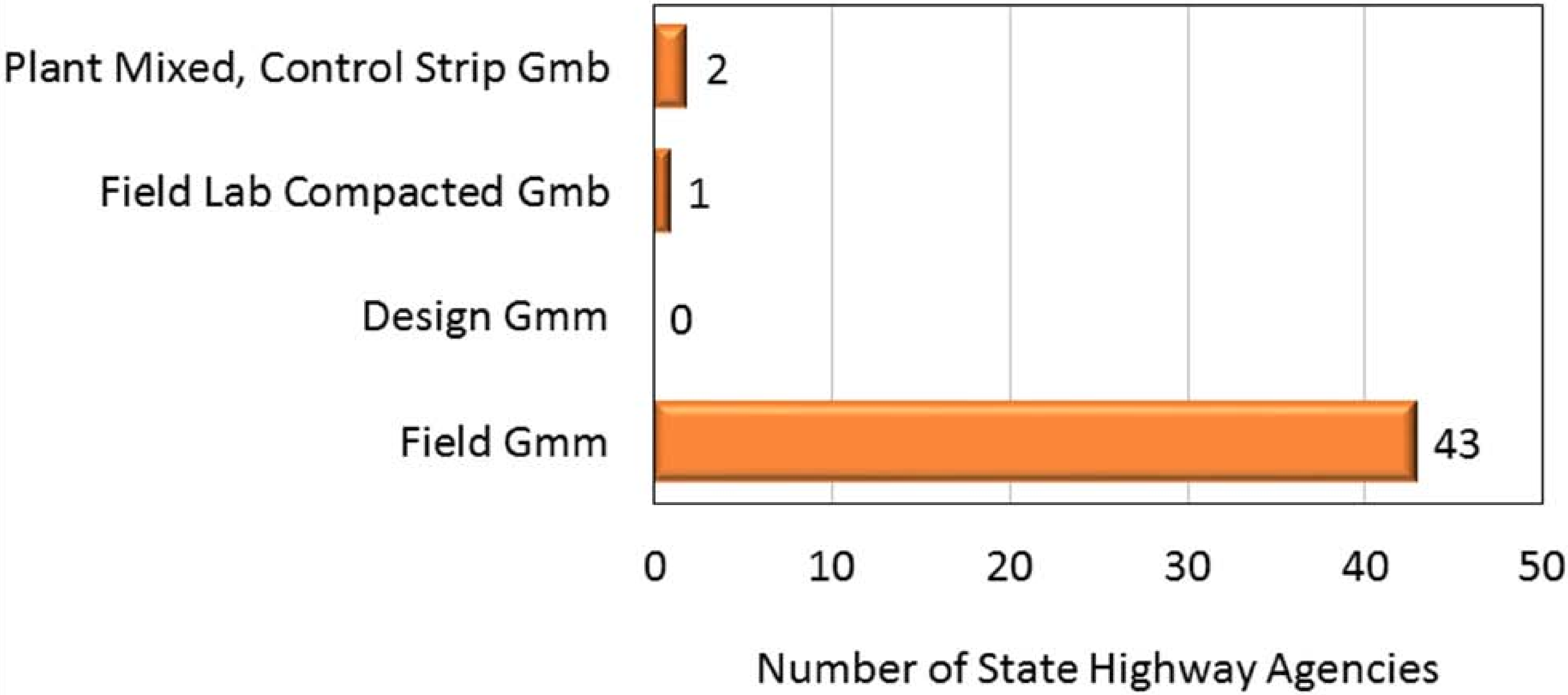
Method Used to Measure In-Place Density

Compaction Study

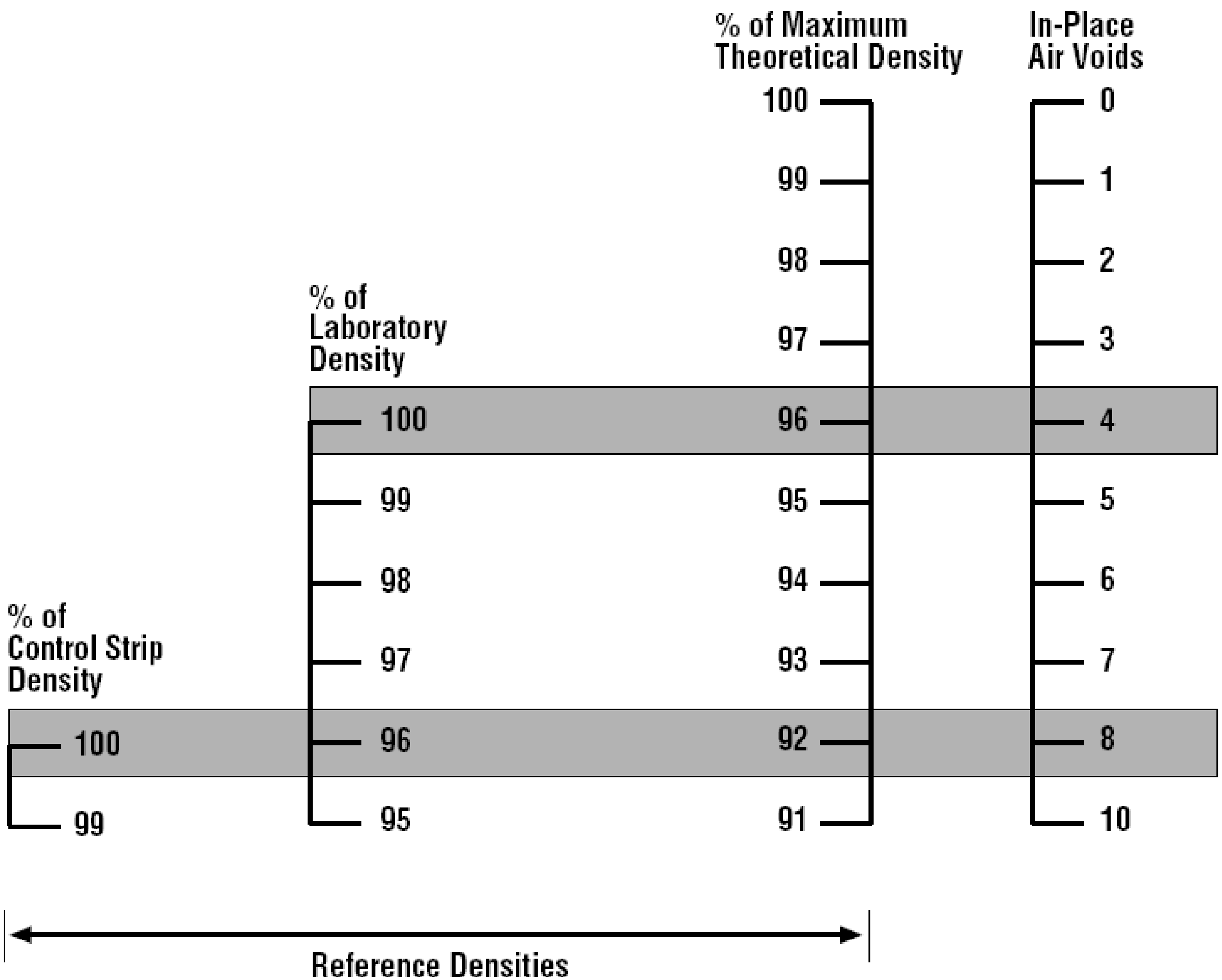


Data: SHA Specifications. Source: Asphalt Institute-FHWA Co-op

Baseline Used to Calculate Acceptance Criteria

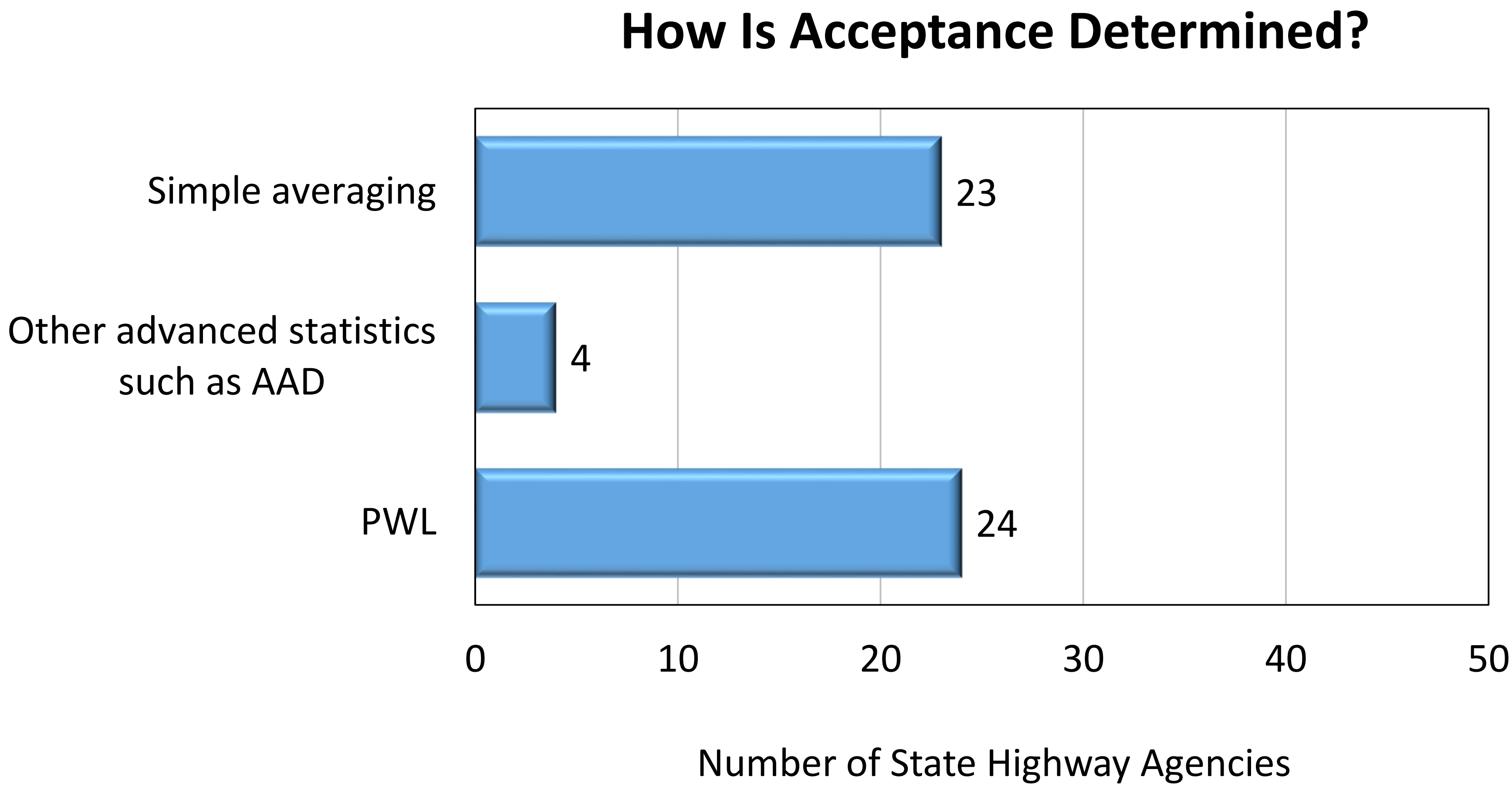


Reference Densities



Reference MS-22, Fig. 7.09

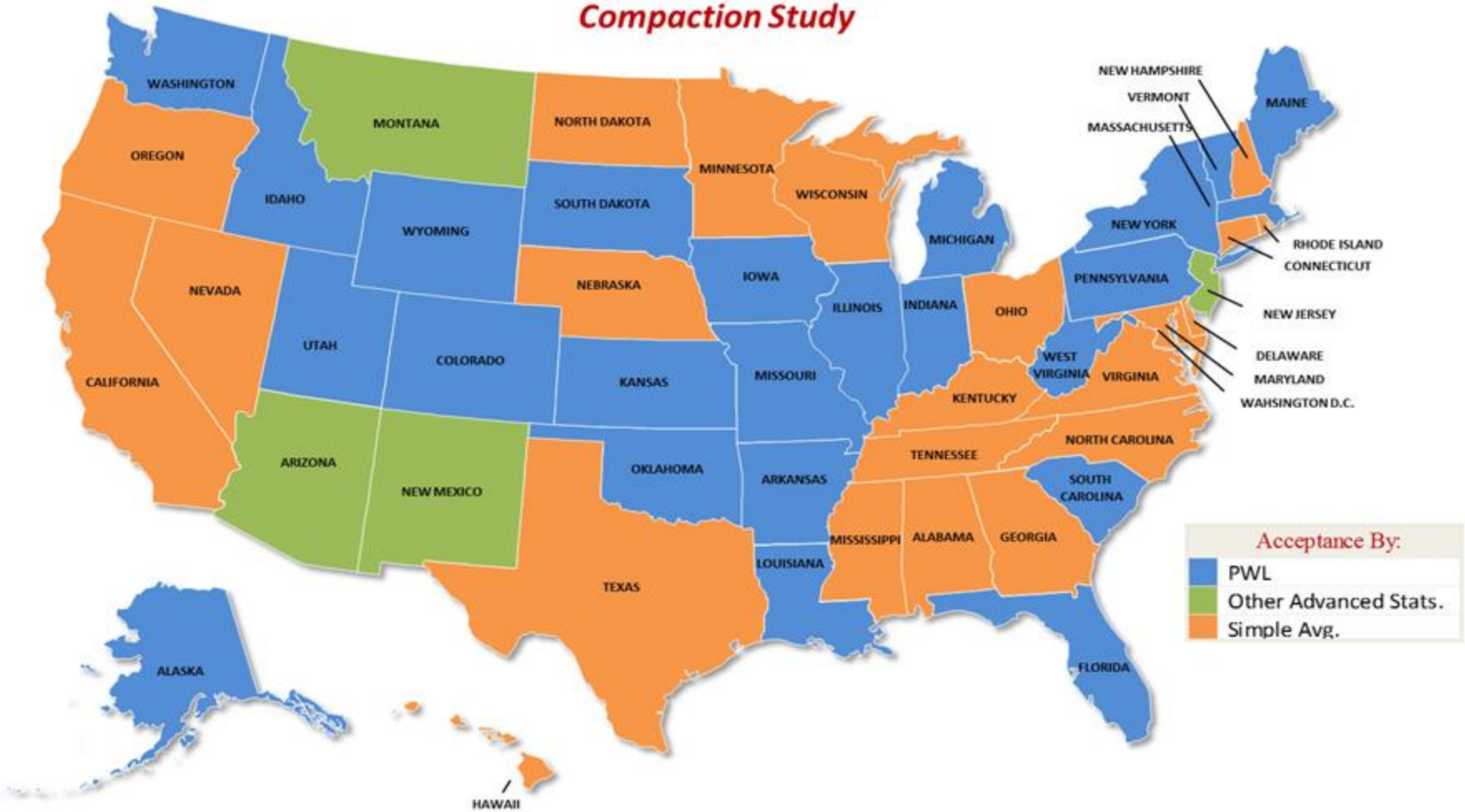
How Is Acceptance Determined



PWL or Simple Average

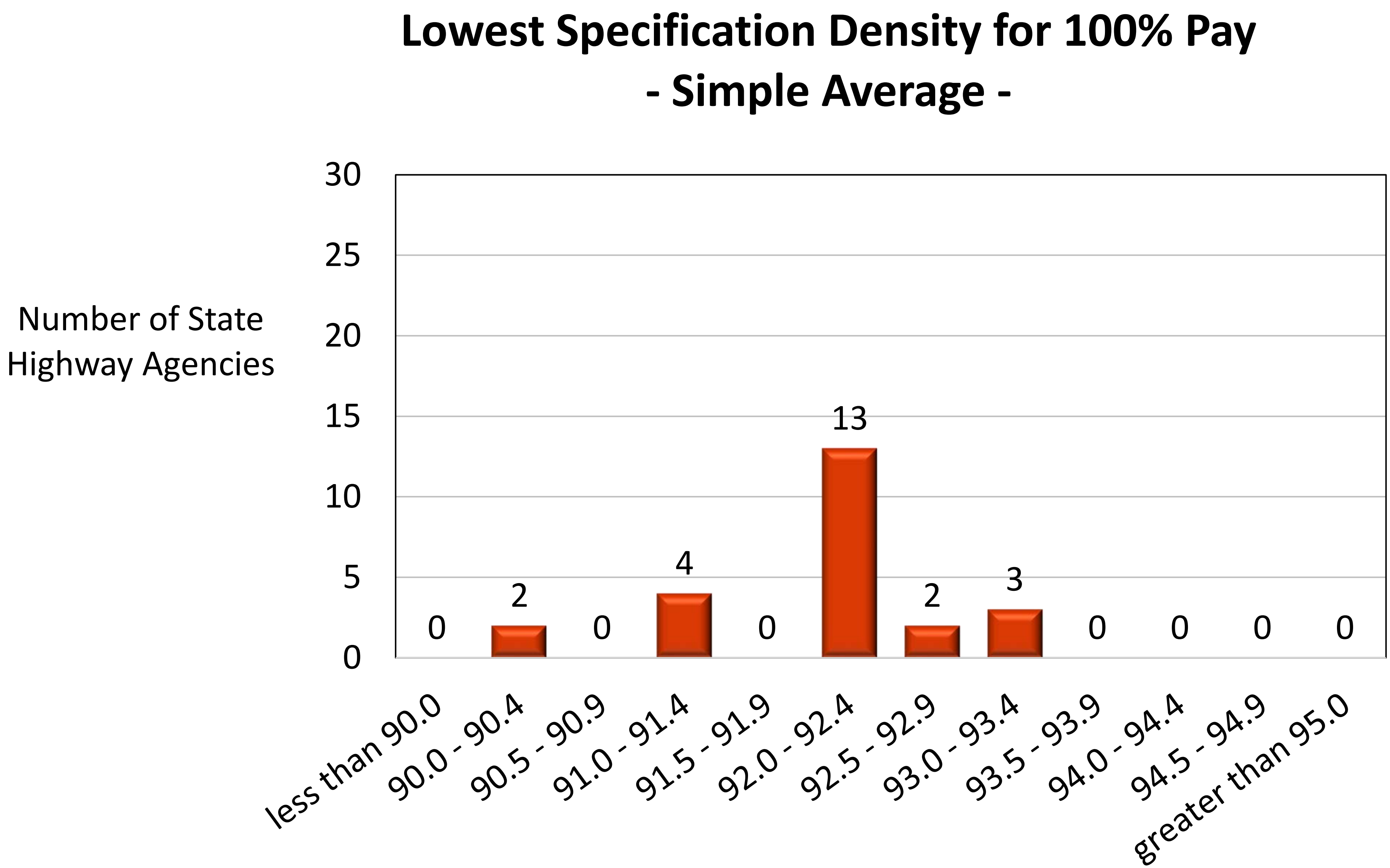
Acceptance Determination

Compaction Study



Data: SHA Specifications. Source: Asphalt Institute-FHWA Co-op

Lowest Specification Density
Simple Average



Simple Average Specs

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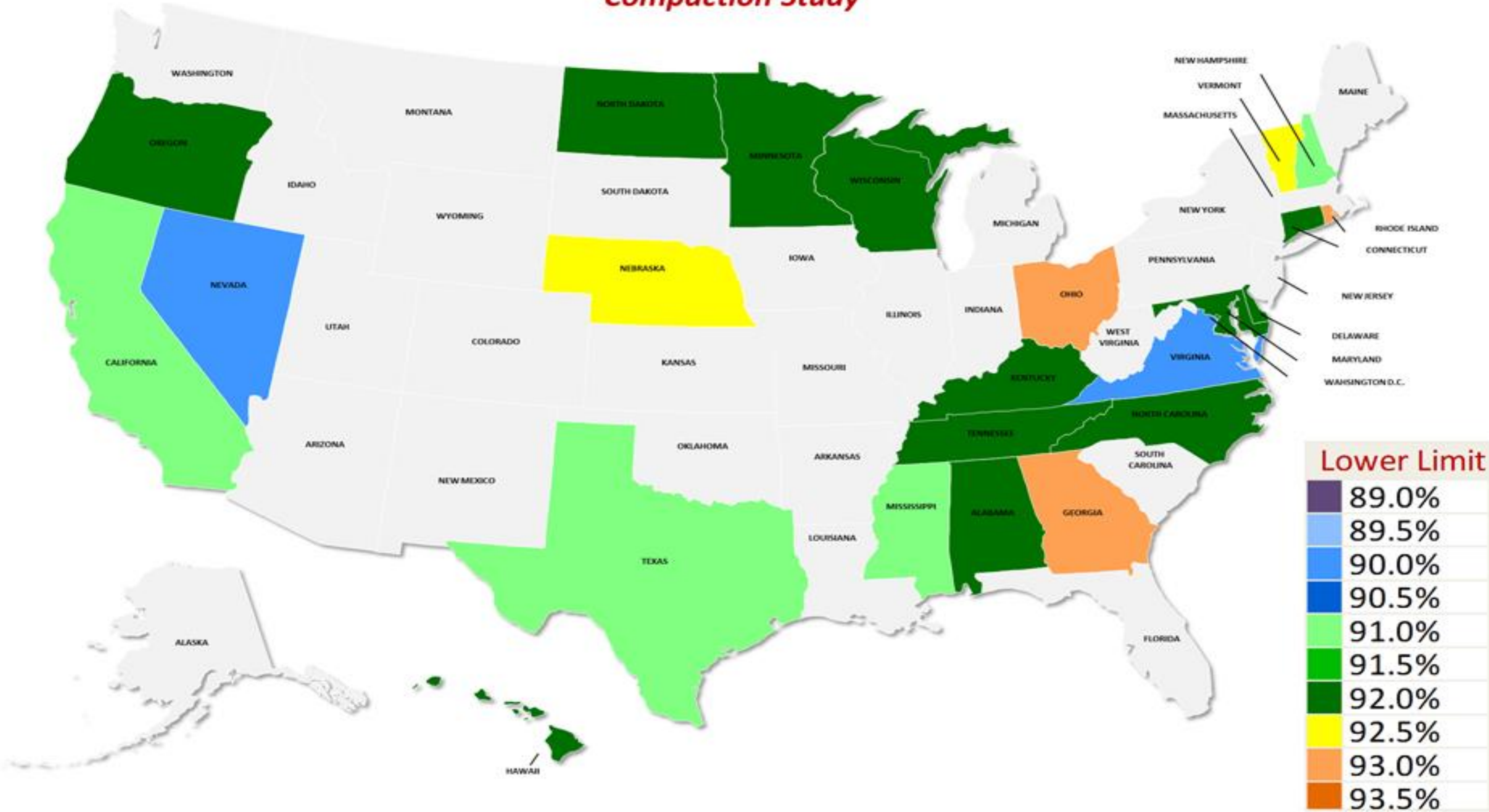
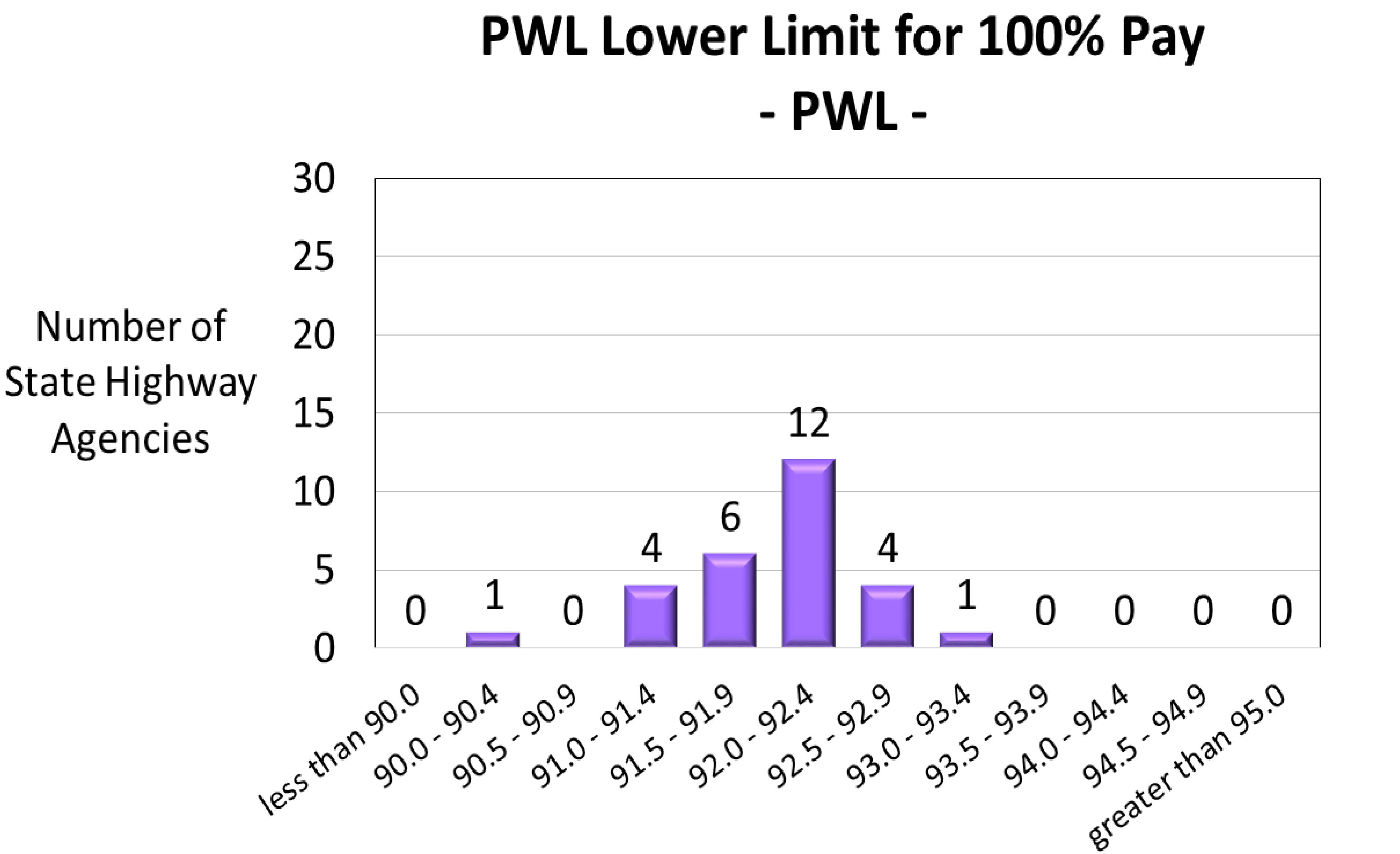
Lowest Specification Density by Simple Average (Lower Limit)

Compaction Study



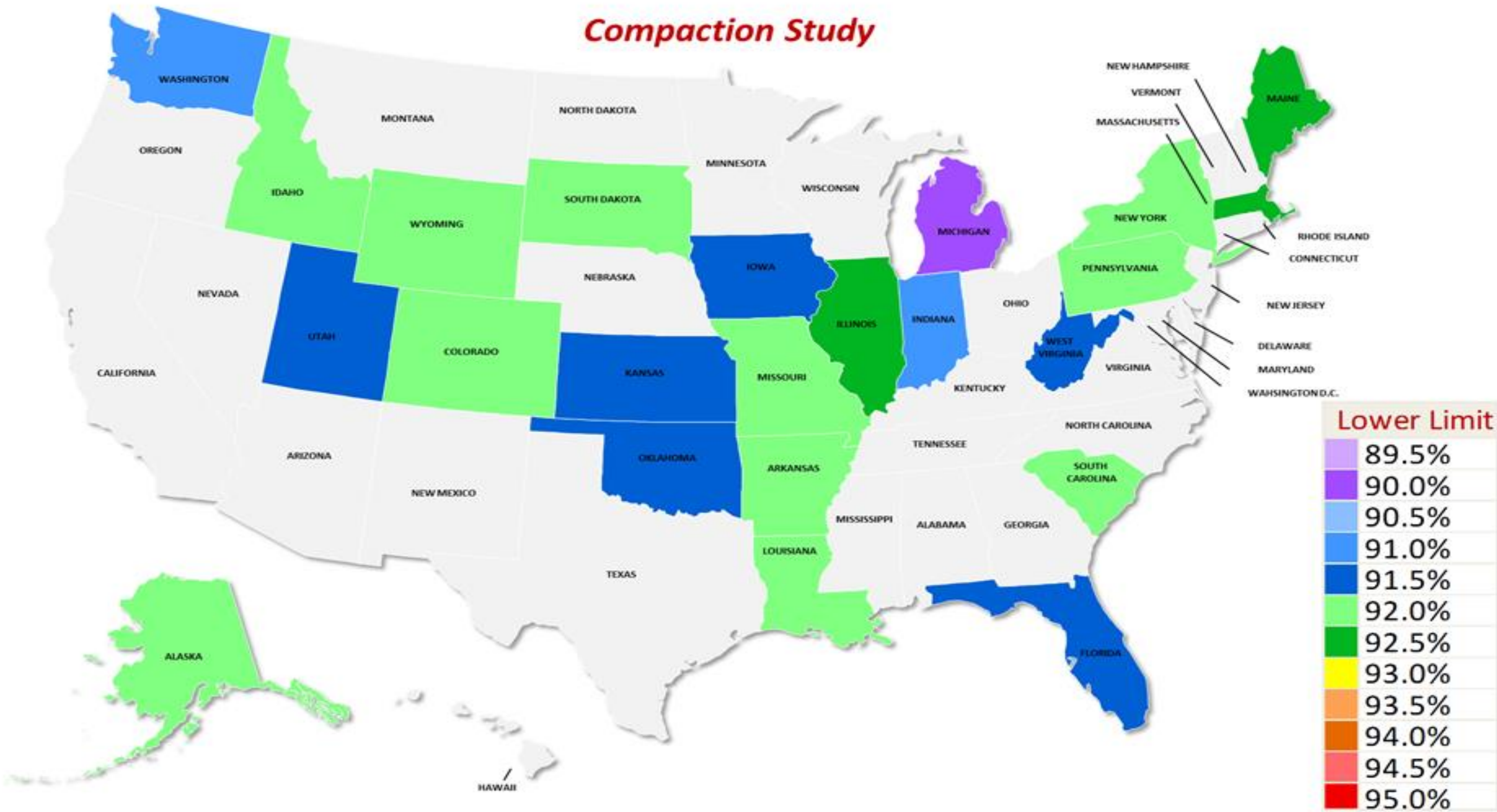
Data: SHA Specifications. Source: Asphalt Institute-FHWA Co-op

Lowest Specification Density
PWL



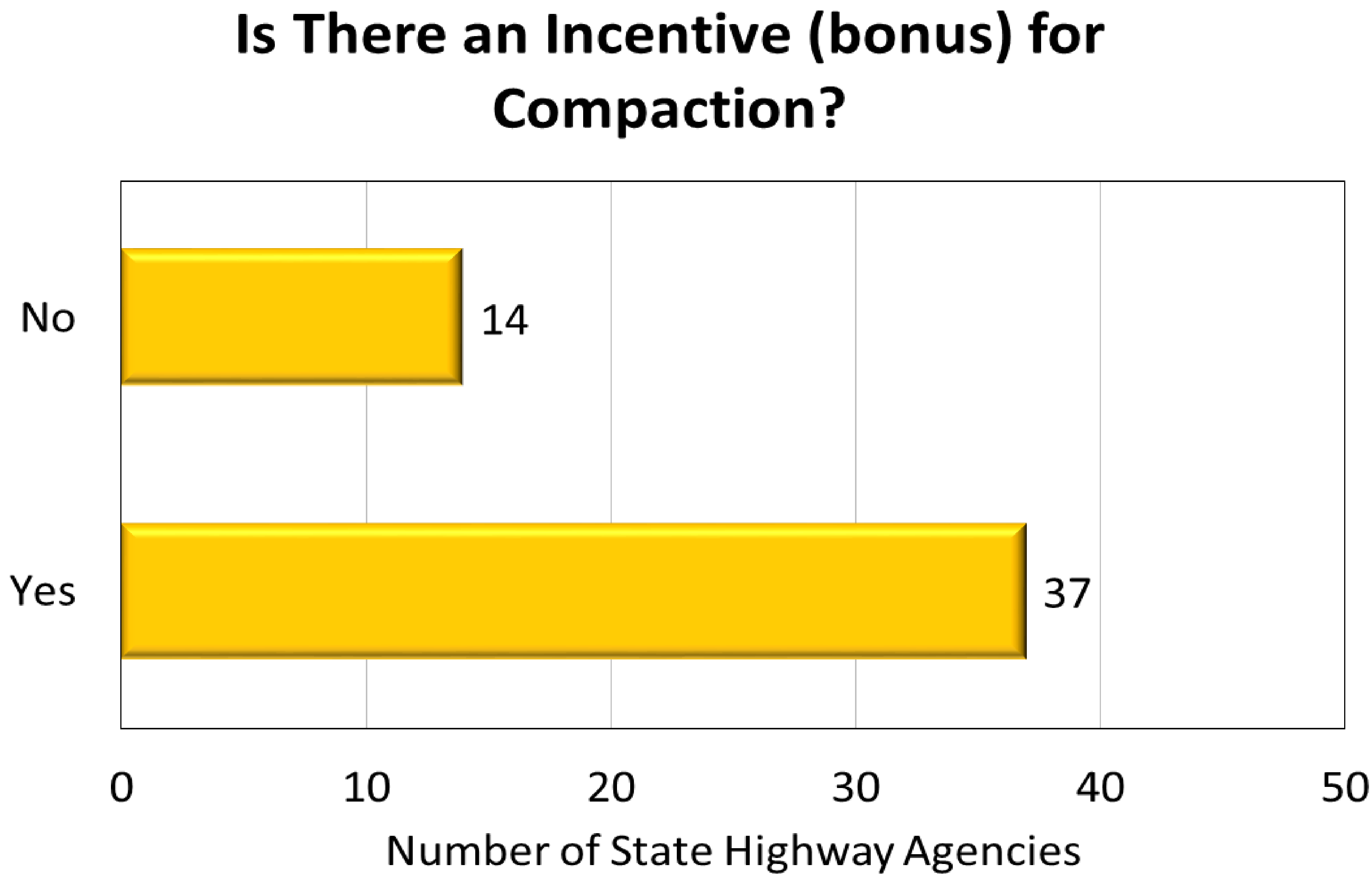
PWL Specs

Lowest Specification Density by PWL (Lower Limit)



Data: SHA Specifications. Source: Asphalt Institute-FHWA Co-op

Compaction Incentive



How Much?

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Maximum Incentive (%) for Compaction

Compaction Study

Data: SHA Specifications. Source: Asphalt Institute-FHWA Co-op

Newer Technologies to Enhance Compaction

Section 6

Improving Compaction with Technology

Newer Technologies to Enhance Compaction

- Warm Mix Asphalt (WMA)
- SHRP2 Infrared (IR)
- Intelligent Compaction (IC)

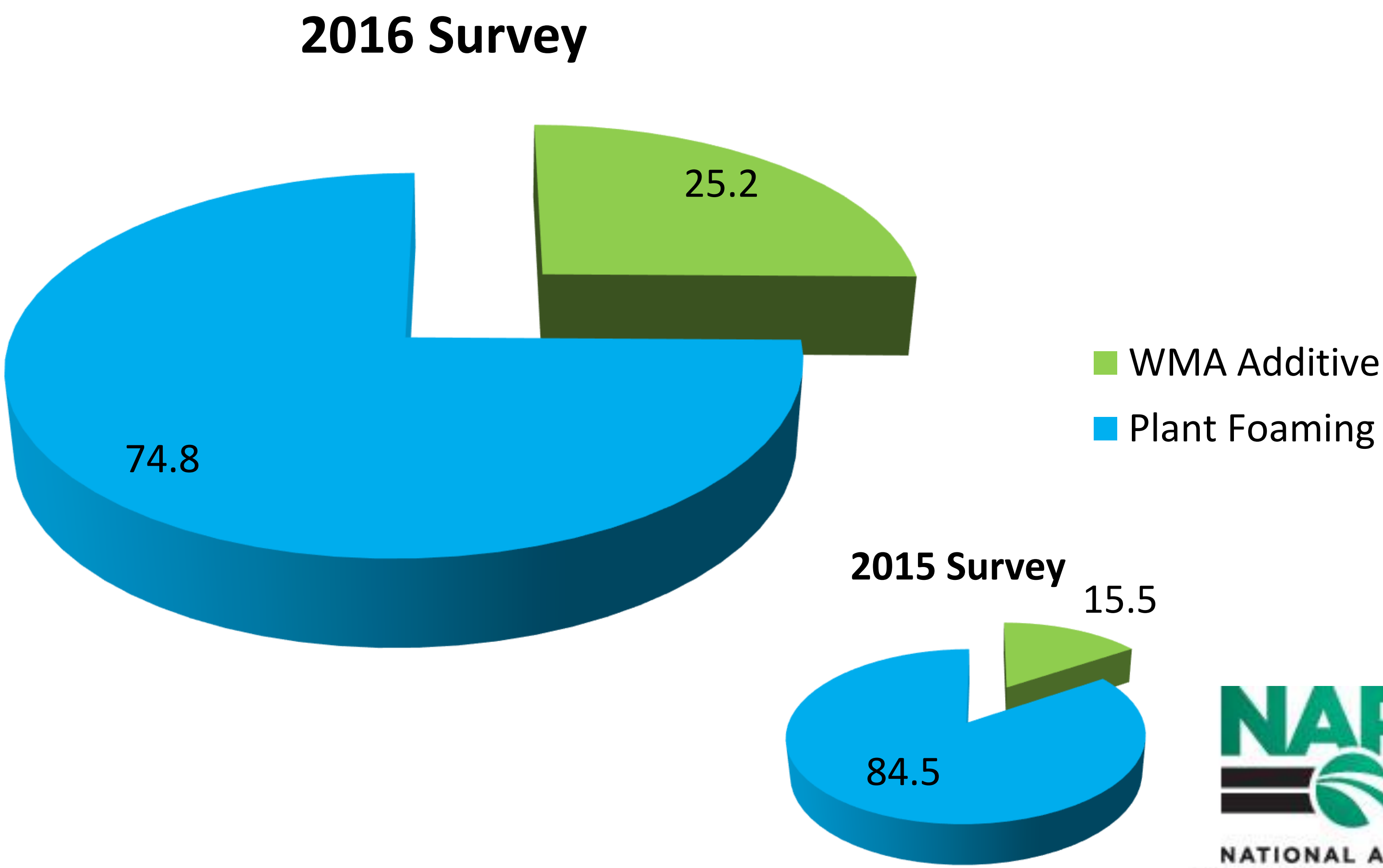
NOTE: Individual presentations during the Summit!

Warm Mix Asphalt

For more Details:

Warm Mix Asphalt Benefits in Cold Weather Environments; Bob Siffert, Ingevity at 3:15

What % of total WMA was produced using…



Warm-Mix Asphalt: Best Practices, 3rd Edition

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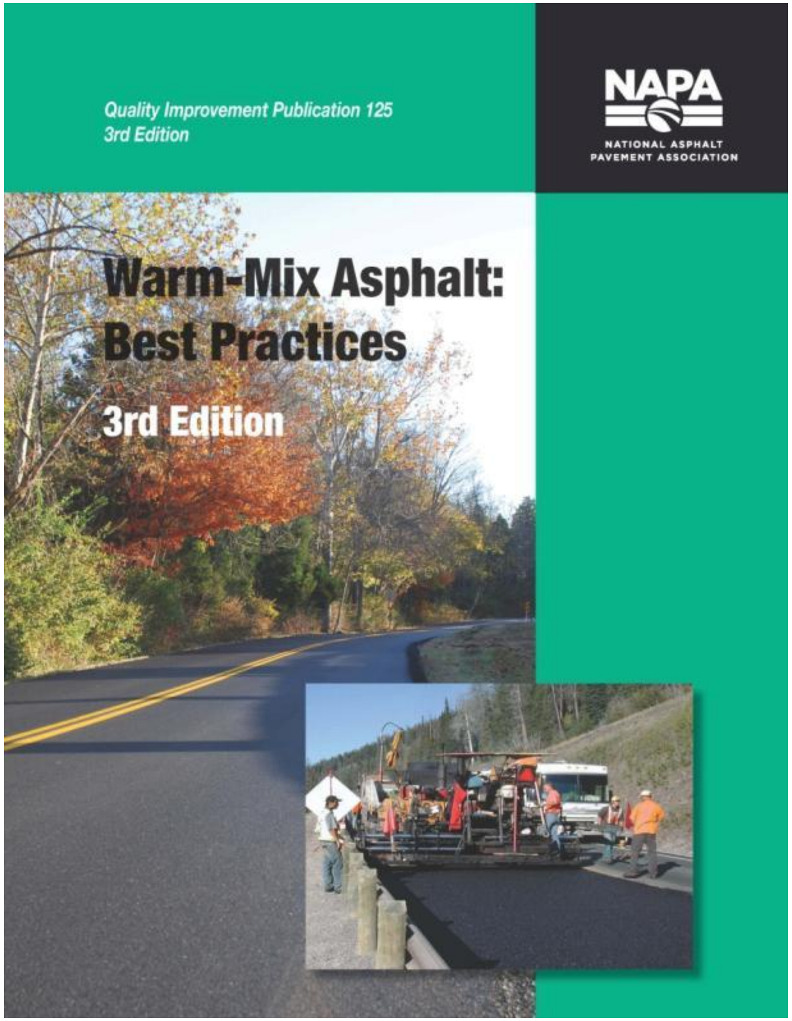


- Stockpile Moisture Management
- Burner Adjustments and Efficiency
- Aggregate Drying and Baghouse Temperatures
- Drum Slope and Flighting
- Combustion Air
- RAP usage
- Placement Changes

http://store.asphaltpavement.org/index.php?productID=552

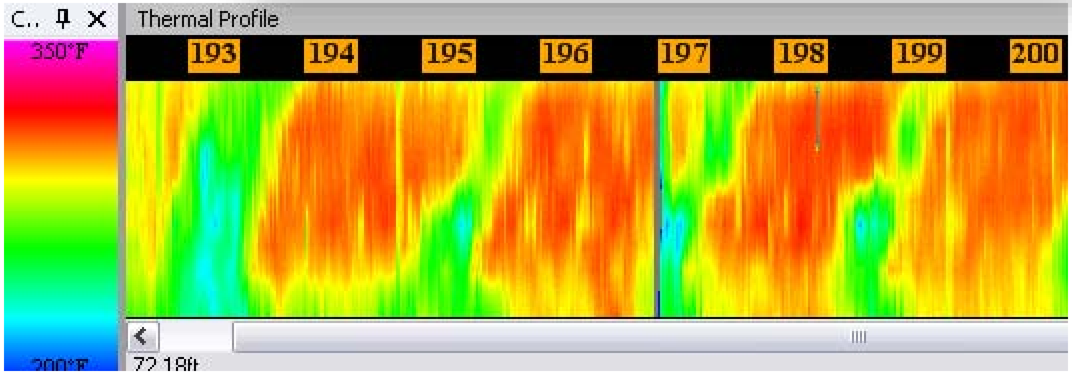
SHRP2 IR

Intelligent Compaction & Thermal Profiling; George K. Chang, The Transtec Group at 10:00 Tomorrow

IR – What is it and why use it?

Application and use of the IR-Bar and Scanner

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



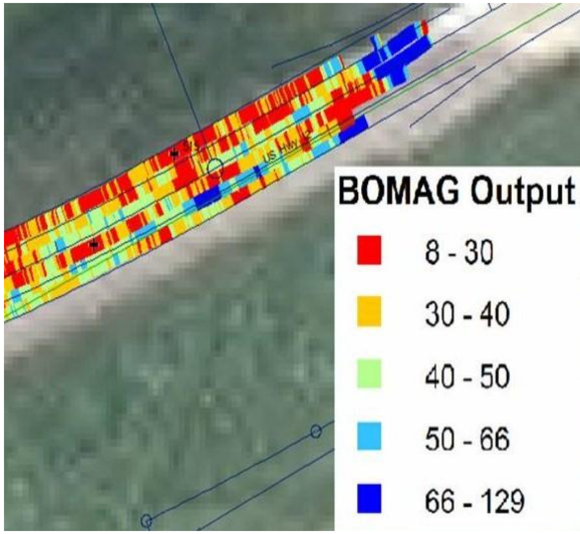
Courtesy FHWA

Intelligent Compaction

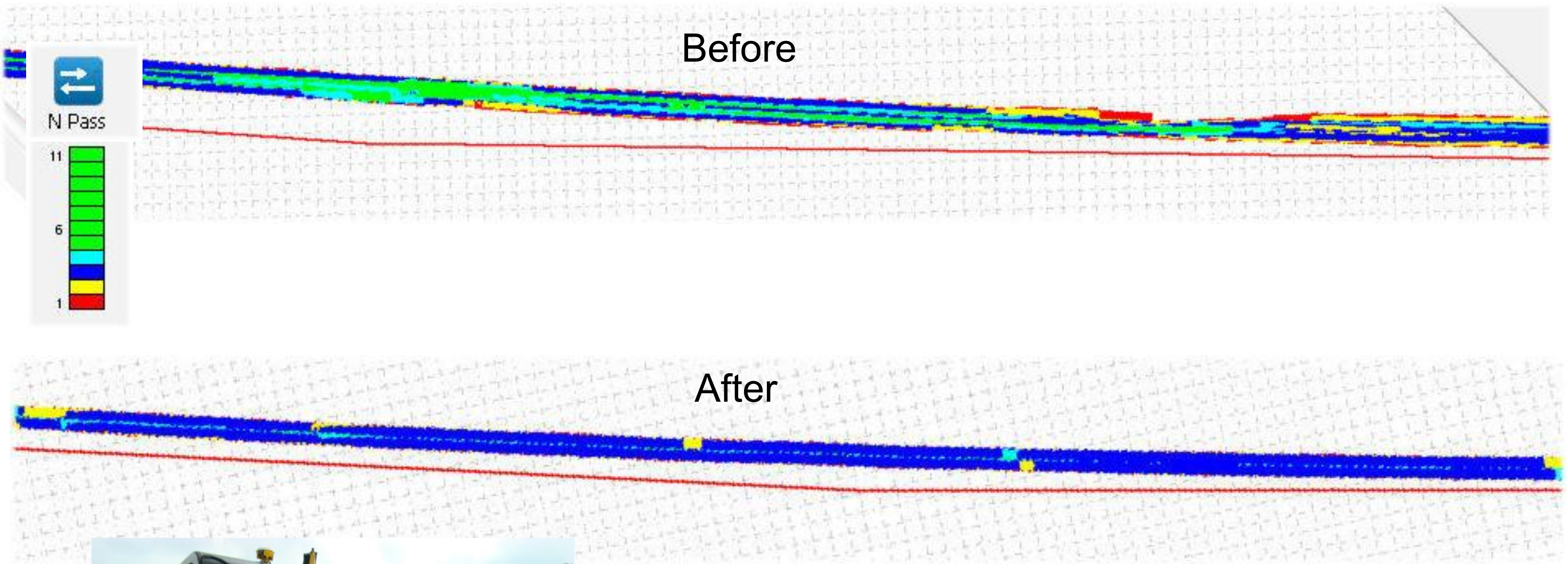
Intelligent Compaction & Thermal Profiling; George K. Chang, The Transtec Group at 10:00 Tomorrow

What is Intelligent Compaction?

An Innovation in Compaction Control and Quality Control



Improved Rolling Patterns



Sakai IC roller

Indiana ICPF Project

Sitka Alaska Airport IC Project

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Questions?

Courtesy of Bruce Christianson

Wrap Up

Section 7

Maximizing Our R.O.I.

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- Infrastructure loads continue to rise
- Budget availability continues to fall
- Increased pavement life can be economically achieved
- Research conservatively shows that a 10% increase in pavement life can be achieved by increasing compaction by 1%.

What would a 3% increase in compaction
do for our industry?

Balance the Mix Design

Smooth Quiet Ride
Skid Resistance

Strength/
Stability

Rut Resistance

Shoving

Flushing
Resistant

Durability

Crack
Resistance

Raveling

Permeability

DON'T ATTACK ONE HALF AT THE EXPENSE OF THE OTHER HALF!!

Reduce Permeability

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- Finer aggregate gradations are less permeable
  - May require higher level consensus properties
  - May require higher binder contents
- Design to a **minimum** lift thickness
  - ≥ 3X NMAS on fine graded mixtures
  - ≥ 4X NMAS on coarse graded mixtures
- Do not neglect future pavement preservation

Proper Tack Coat Application

- Specify and monitor adequate tack coat application
  - Allow the use of alternate materials
    - Low Tracking tack
    - Modified materials
    - Paving grade binders

A well compacted pavement section will not perform if it is not properly bonded!!

Improve Longitudinal Joints

Permeable Longitudinal Joints will:

- Cause safety concerns
- Necessitate premature maintenance
- Contribute to delamination
- Severely impact the life cycle performance
- Joint density no less than 2% mat density requirement

Use Best Construction Practices

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Uniform Paving Train Operation

- Determine plant production rate
- Plan for sufficient, timed mix delivery
- Establish a constant paver speed
- Assure ample rollers are available
    - Keep water trucks up to the rollers

Use Best Construction Practices

Promote Innovation

- Encourage/Require Intelligent Compaction
- Use WMA – compaction aid
- SHRP2 – IR
- Joint Heaters
- Consider alternative rollers
  - Pneumatic
  - Vibratory Pneumatic
  - Oscillatory
  - ?
- Others

Bottom Line

Increased compaction = Increased Performance

Better "Return on Investment" for the taxpayers

More Successful Pavements = More Tonnage for the HMA Industry !!!

Thank you for your time!!!

Anchorage: March 13-16, 2018

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Mix Design Technology Certification

(3.5 day course / 22.5 PDHs)

$1,195 per person

asphalt ACADEMY

Course Description
The Mix Design Technology Certification (MDT) course provides advanced technicians, designers, and engineers responsible for mix designs with a thorough understanding of the properties of the materials which compose asphalt mixtures, as well as the physical and mathematical processes involved in producing a successful asphalt mixture design. Students will receive training over the entire range of activities related to the design of asphalt mixtures: aggregate and binder selection, material properties, development of trial blends, batching, volumetric calculations and analysis, Superpave mix criteria, mix performance tests and criteria, use of RAP in asphalt mix designs, plus an overview of SMA and open-graded mixtures.

The MDT class can accommodate up to 28 students, which will allow students personal access to our experienced instructors for Q&A at any time during the course.

This course is complemented by the Asphalt Institute's Basic Mixture Technician Training (BMTT) course. While the MDT course focuses on how advanced technicians, designers, and/or engineers use laboratory and project information in the mix design process to create long-lasting asphalt mixtures, the BMTT course focuses on the actual tests and laboratory processes involved in asphalt mix design performed by technicians.

Questions/Discussion

What is Achievable?

Balanced Mix Design

Prepared by Richard Willis
(with a hat tip to Randy West, Shane Buchanan, and Audrey Copeland)

Alaska Asphalt Summit
November 6, 2017

NATIONAL ASPHALT PAVEMENT ASSOCIATION

"In order to stretch pavement life and save money, we are focused on preservation."

"Due to budget constraints, most projects are very thin overlays."

"Pavement deterioration is the issue; states need to stretch dollars further."

"…struggling with failures when trying to keep costs down."

Are existing pavement and mix design methods and specifications adequate to achieve goals for value, performance, and driveability?

Possible causes of these early pavement distresses

Mix Design Issues	Construction Issues	Design Issues
• Not enough asphalt in mixes (mixes are too dry) • Gradations are too coarse • Ndesign too high • RAP content, RAP variability • RAS making mixes brittle	• AC content lowered • Segregation • Insufficient density • Temperature concerns • Not enough tack • Insufficient specifications or enforcement	• Incompetent pavement layers are not removed • Wrong mix type specified for the job • Heavier traffic than structure can carry • Lifts too thin

NATIONAL ASPHALT PAVEMENT ASSOCIATION

Limitations of Current Mix Design

- Volumetric properties alone are insufficient to assure satisfactory performance
  - Different layers should be designed for different critical stresses
  - VMA is highly dependent on accurate Gsb which is challenging to measure and verify
  - The impact of modified binders, recycled binders, and other additives is unclear
- Mix performance tests are needed to better engineer mixes and overcome limitations of the legacy specifications

NAPA
NATIONAL ASPHALT PAVEMENT ASSOCIATION

“We’re going to use research & technology to change how we build things, we are going to engineer our way to get longer life…with little funding increase”

“If industry can show us how to get more value out of the pavement, we’re listening.”

“The problem is a lack of funding. If we focus on extending or preserving the life of pavements, that will appeal to DOT leadership. Just a 10% increase in pavement life will take care of funding the entire system.”

What is our future?

A **performance-**based system based on engineered solutions for the pavement industry; to eventually replace the recipe or method based specification system.

History of Mix Design

(Courtesy of Shane Buchanan)

1890
- **Barber Asphalt Paving Company**
- Asphalt cement 12 to 15% / Sand 70 to 83% / Pulverized carbonite of lime 5 to 15%

1905
- **Clifford Richardson, New York Testing Company**
- Surface sand mix: 100% passing No. 10, 15% passing No. 200, 9 to 14% asphalt
- Asphaltic concrete for lower layers, VMA terminology used, 2.2% more VMA than current day mixes or ~0.9% higher binder content

1920s
- **Hubbard Field Method** (Charles Hubbard and Frederick Field)
- Sand asphalt design
- 30 blow, 6” diameter **with compression test (performance)** asphaltic concrete design (Modified HF Method)

Stability

1927
- **Francis Hveem** (Caltrans)
- Surface area factors used to determine binder content; **Hveem stabilometer and cohesionmeter** used
- Air voids not used initially, mixes generally drier relative to others, fatigue cracking an issue

Stability + Durability

1943
- **Bruce Marshall**, Mississippi Highway Department
- Refined Hubbard Field method, standard compaction energy with drop hammer
- Initially, only used air voids and VFA, VMA added in 1962; **stability and flow utilized**

Stability + Durability

1993
- **Superpave**
- Level 1 (volumetric)
- Level 2 and 3 (performance based, but **never implemented**)

BINDER CONTENT LOWER

http://asphaltmagazine.com/history-of-asphalt-mix-design-in-north-america-part-2/

What is Balanced Mix Design?

Balanced Mix Design is NOT

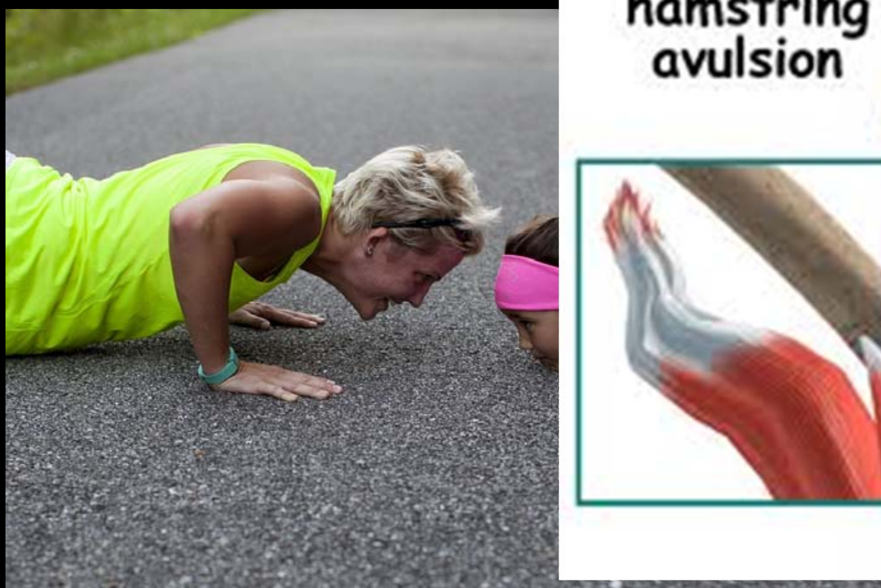
- A mix design as we define it today
- The silver bullet
  - Vulnerability current exists
  - Find the chinks in the armor & put research there

Balanced Mix Design Definition

- ***"Asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate and location within the pavement structure."***

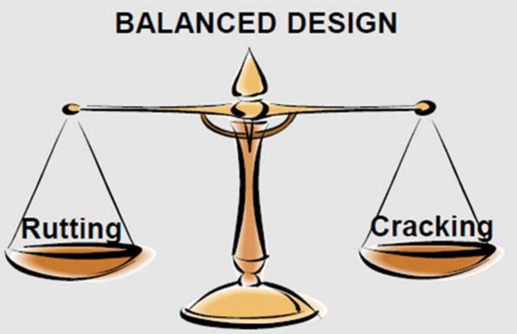
- Use the right mix for the job!

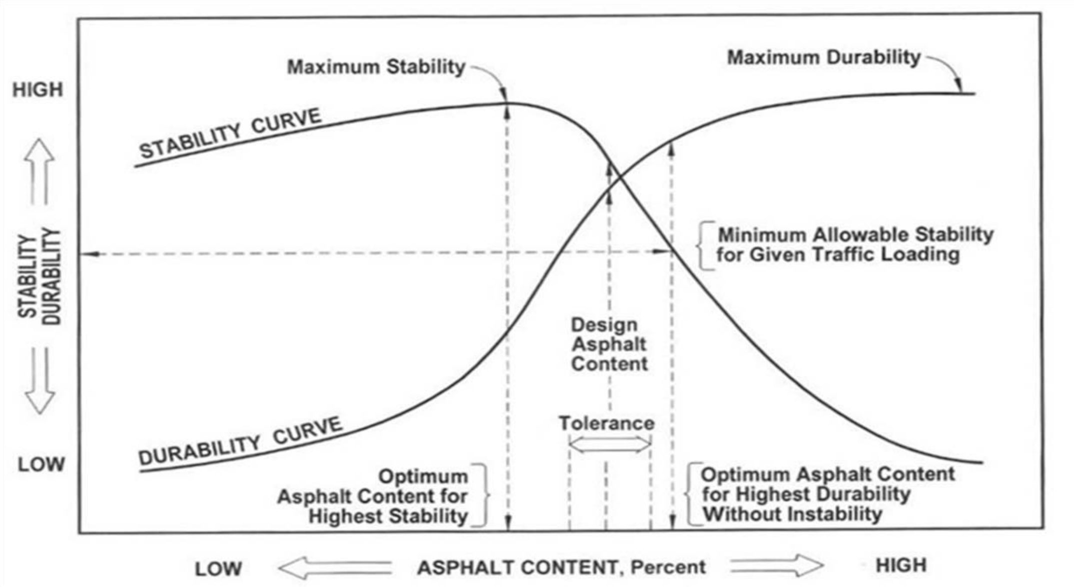
Finding the Balance



Pavement Performance General Overview

- Achieving Balanced Mixture Performance is Key to a Long Lasting Pavement

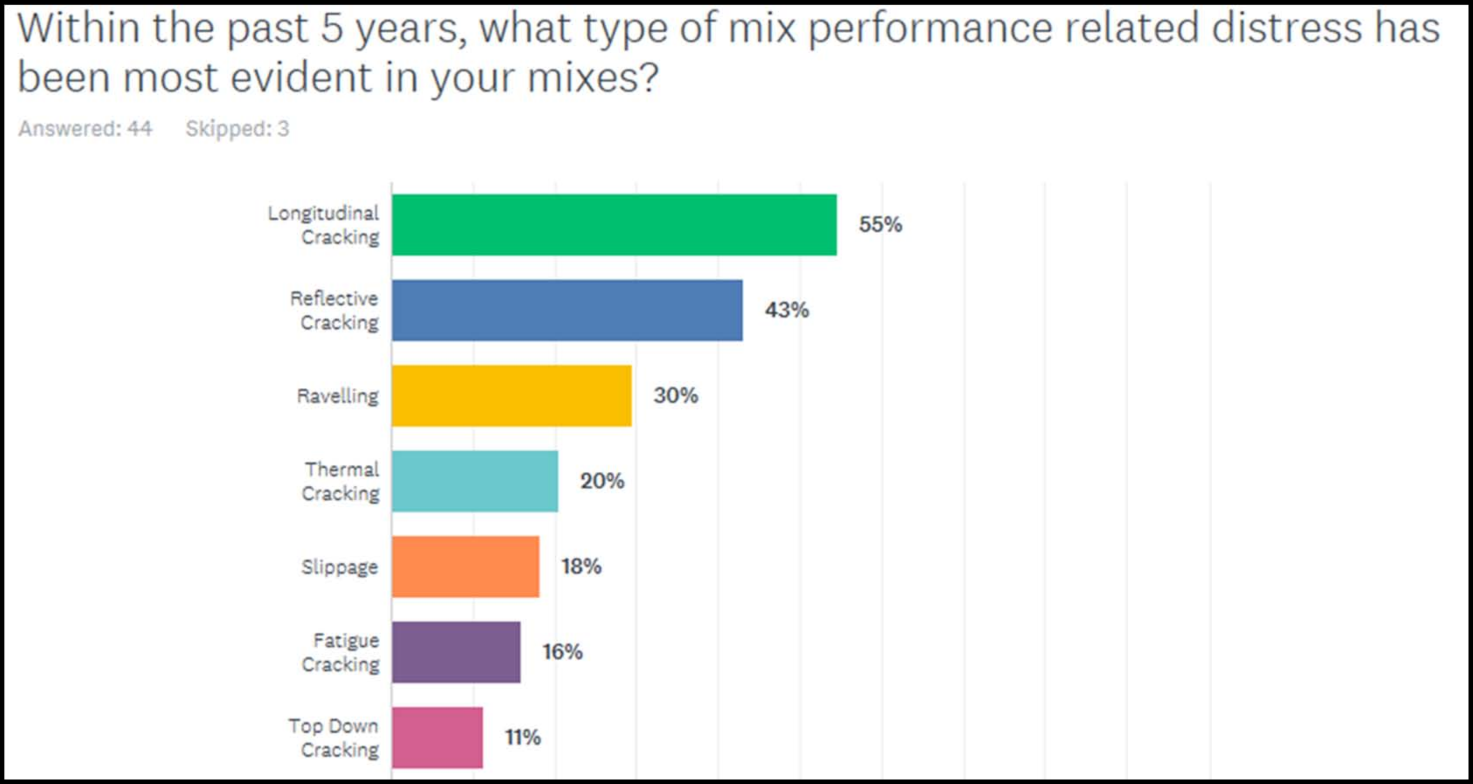




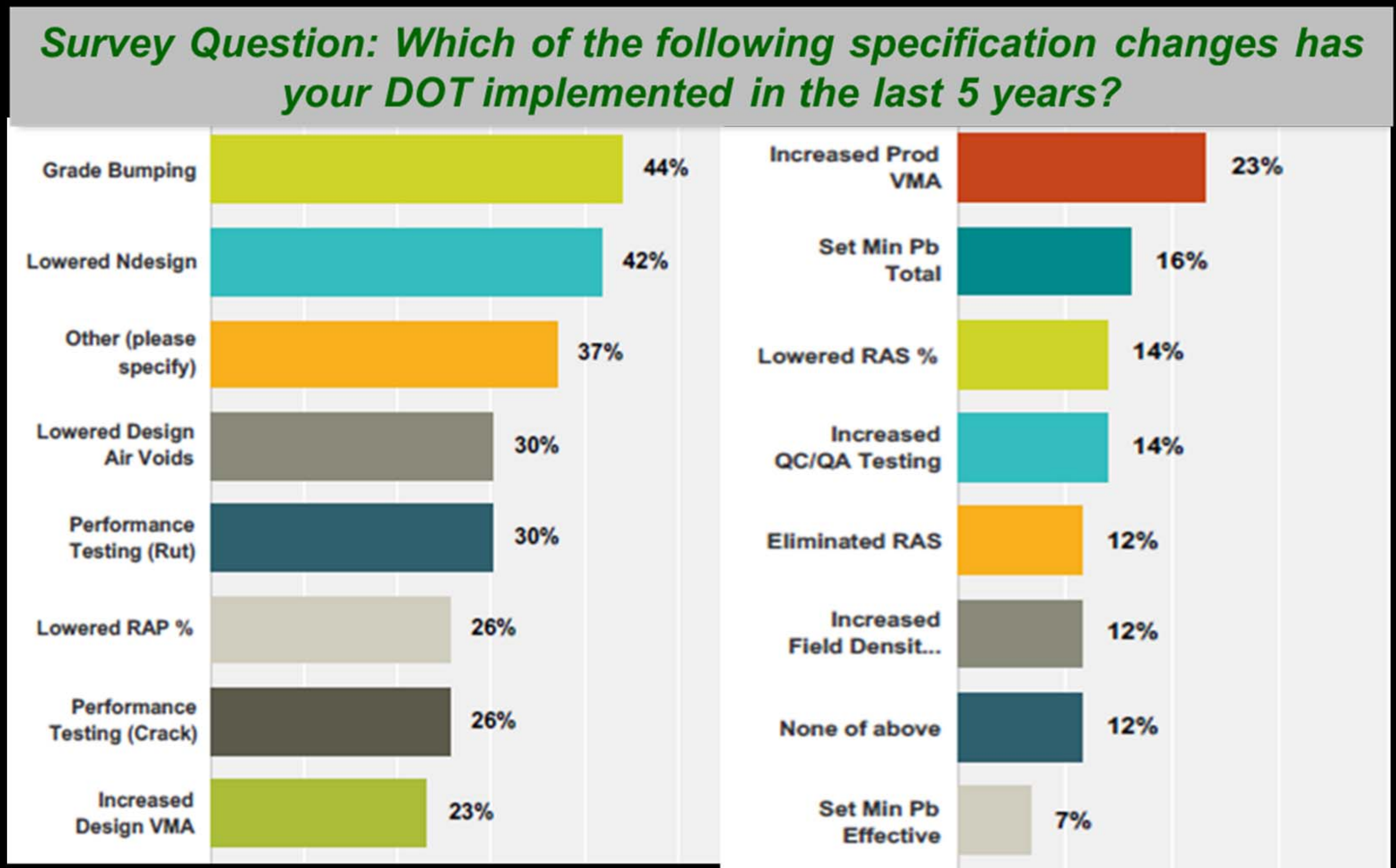
Oldcastle Materials

(Shane Buchanan)

What Are States Seeing?



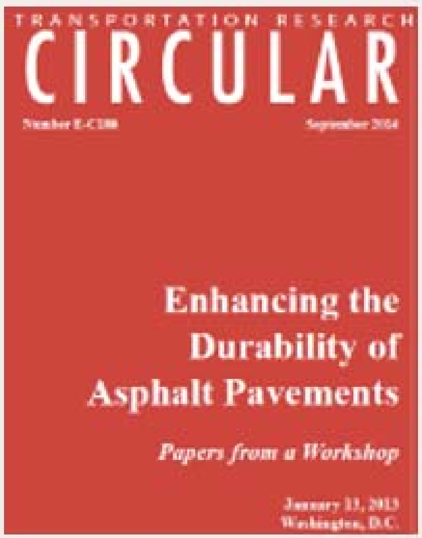
What Are they Doing?

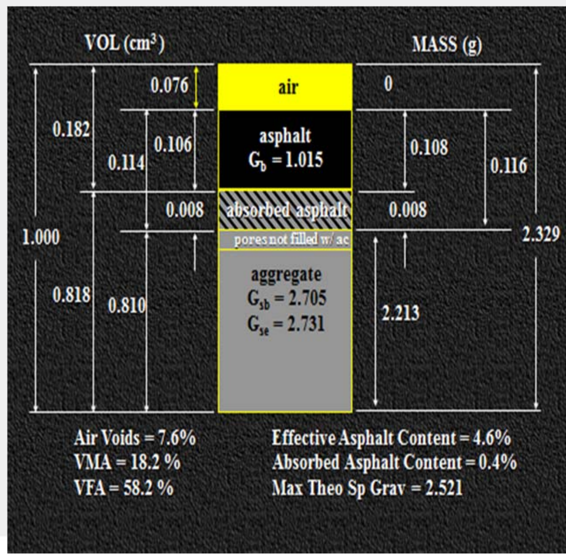


So How Do We Do This?

What is the Main Key to Enhancing the Durability of Asphalt Mixtures?

- "**Volume of Effective Binder (Vbe)** **is the primary mixture design factor affecting both durability and fatigue cracking resistance**."
  - ***Vbe = VMA – Air Voids***





Oldcastle Materials

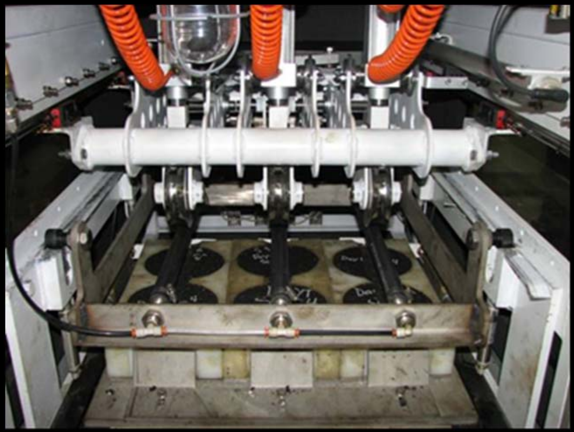
(Shane Buchanan)

Field vs Lab

The Same, But Different

Stability (Rutting)

Rutting Tests – Seem to Be Regionalized



Asphalt Pavement Analyzer

AMPT Flow Number

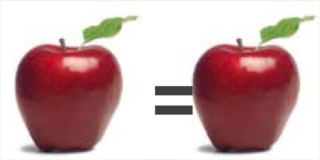
Hamburg Wheel Tracking Test

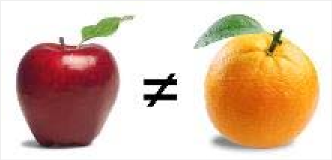
Durability (Cracking)

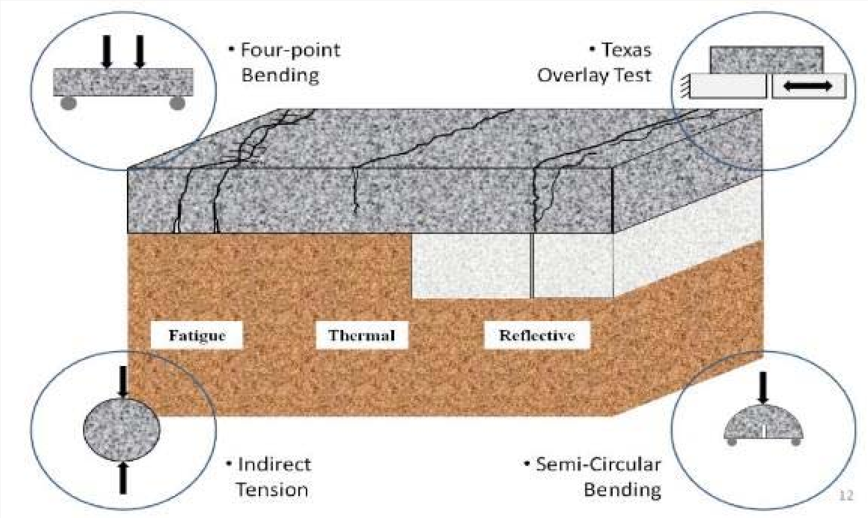
- Cracking is more challenging
- What type of cracking?
  - Thermal
  - Reflective
  - Top-down load related
  - Bottom-up Fatigue

What is the Anticipated Mode of Distress for Testing?

- Typical distress modes
  - Fatigue cracking (top down/bottom up)
  - Low temperature (thermal) cracking
  - Reflection (reflective) cracking
- Various empirical and mechanistic tests are available for use.
- Match apples to apples, not apples to oranges!





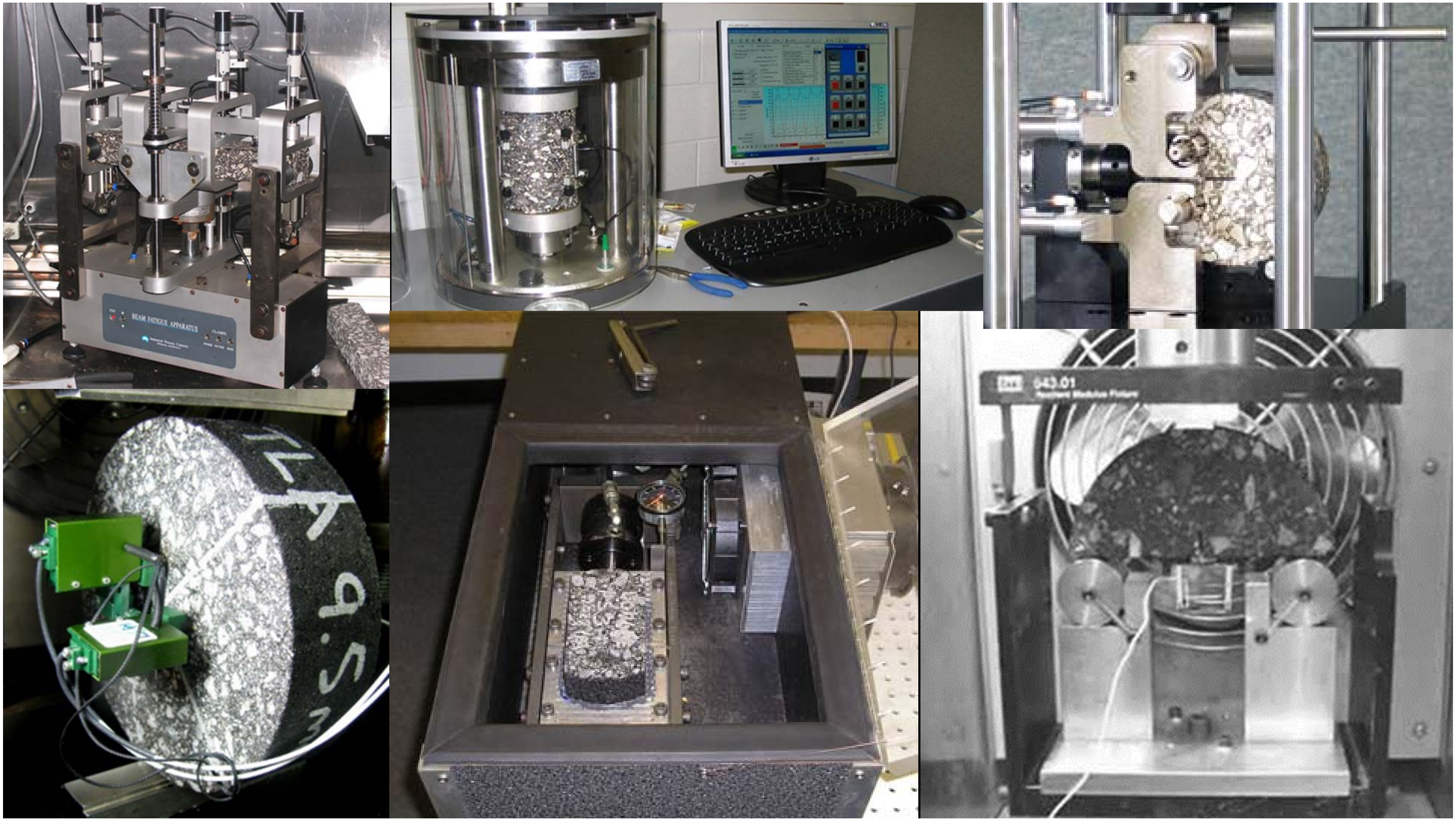


GOALS

1. **MATCH THE TEST TO THE DISTRESS**
2. **SET APPROPRIATE FAILURE THRESHOLDS**

Oldcastle® Materials

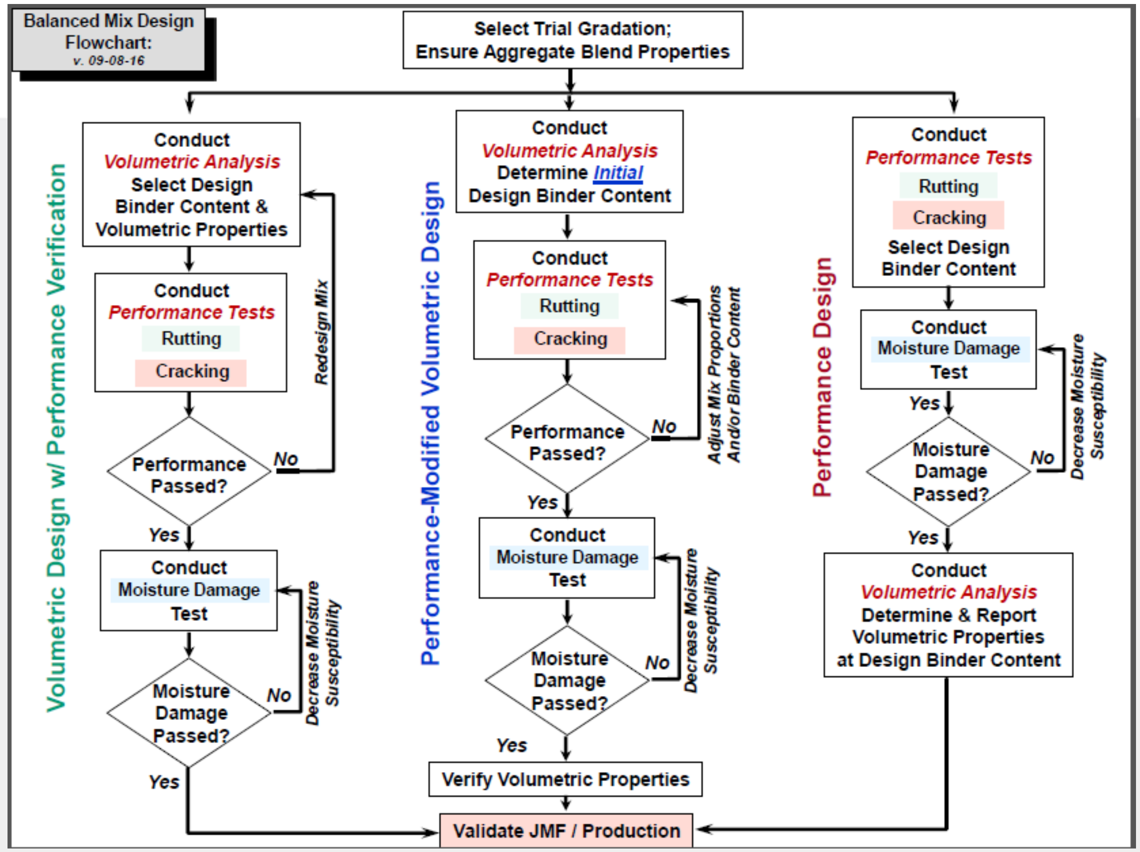
(Shane Buchanan)


BEAM FATIGUE APPARATUS
643.01

BMD Approaches

- Three general mix design approaches.

1. Volumetric Design w/ Performance Verification
2. Performance Modified Volumetric Design
3. Performance Design



Graphic Developed by Kevin Hall (FHWA BMD Task Force), 2016

Oldcastle Materials

RW1

Volumetric Design w/ Performance Evaluation

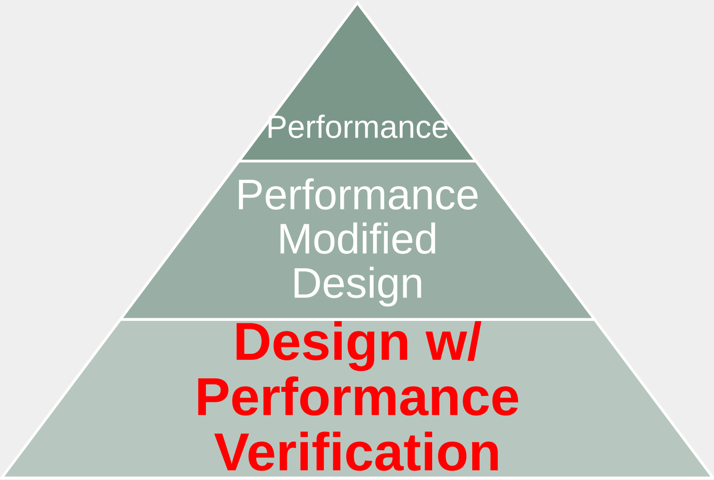
or

Slide 26

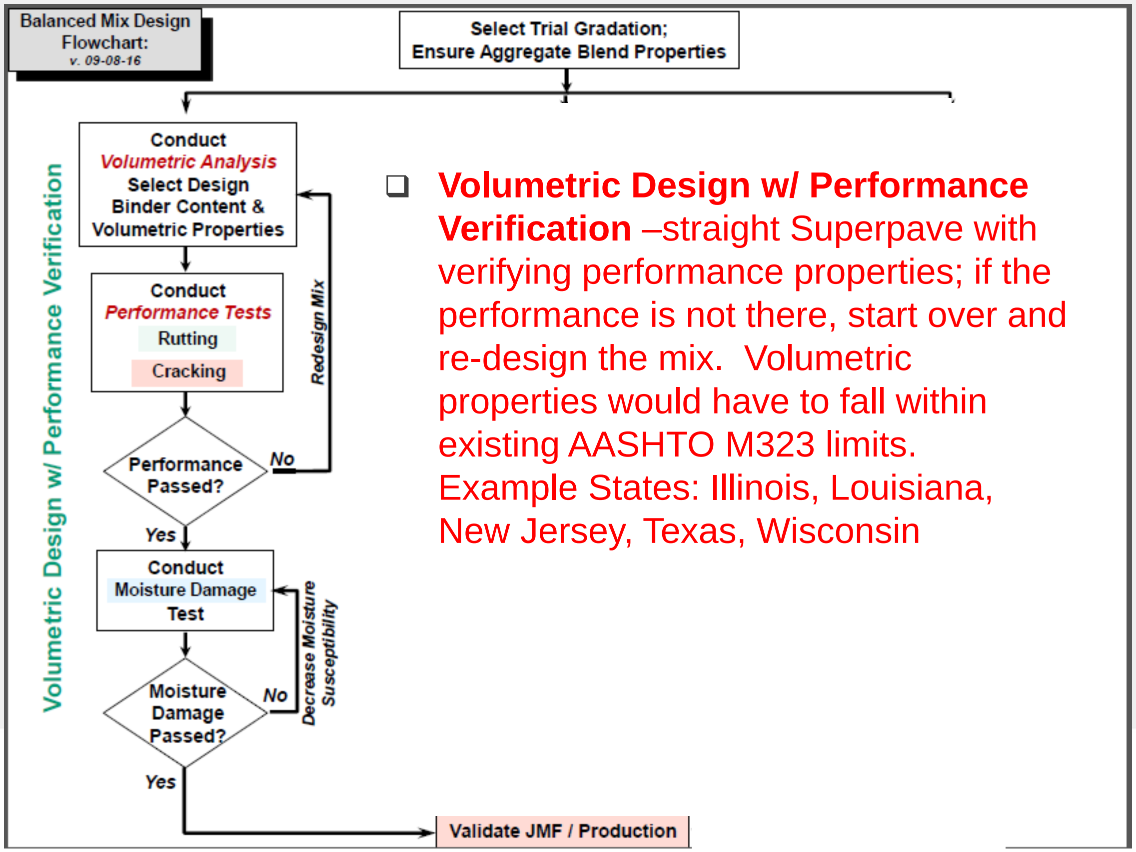
RW1 Richard Willis, 11/6/2017

Little Debbie Mix Design

Volumetric Design w/ Performance Verification



Innovation Potential = Very Low



- **Volumetric Design w/ Performance Verification** –straight Superpave with verifying performance properties; if the performance is not there, start over and re-design the mix. Volumetric properties would have to fall within existing AASHTO M323 limits. Example States: Illinois, Louisiana, New Jersey, Texas, Wisconsin

Oldcastle Materials

RW1

Performance Modified Volumetric Design

or

Slide 29

RW1 Richard Willis, 11/6/2017

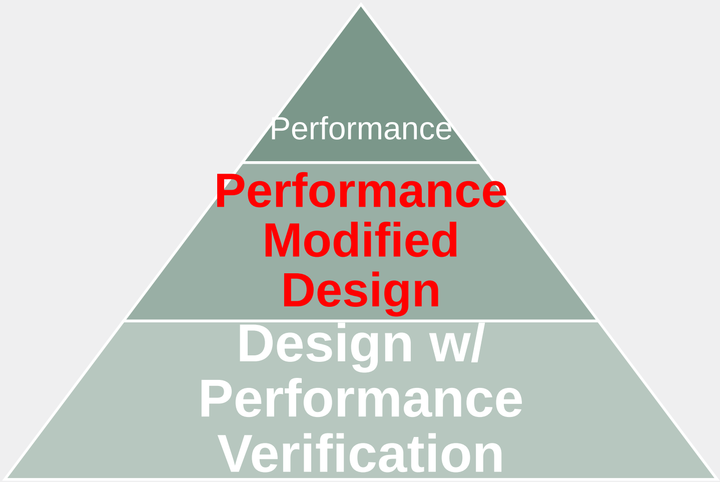
RW1

Amy Willis School of Mix Design

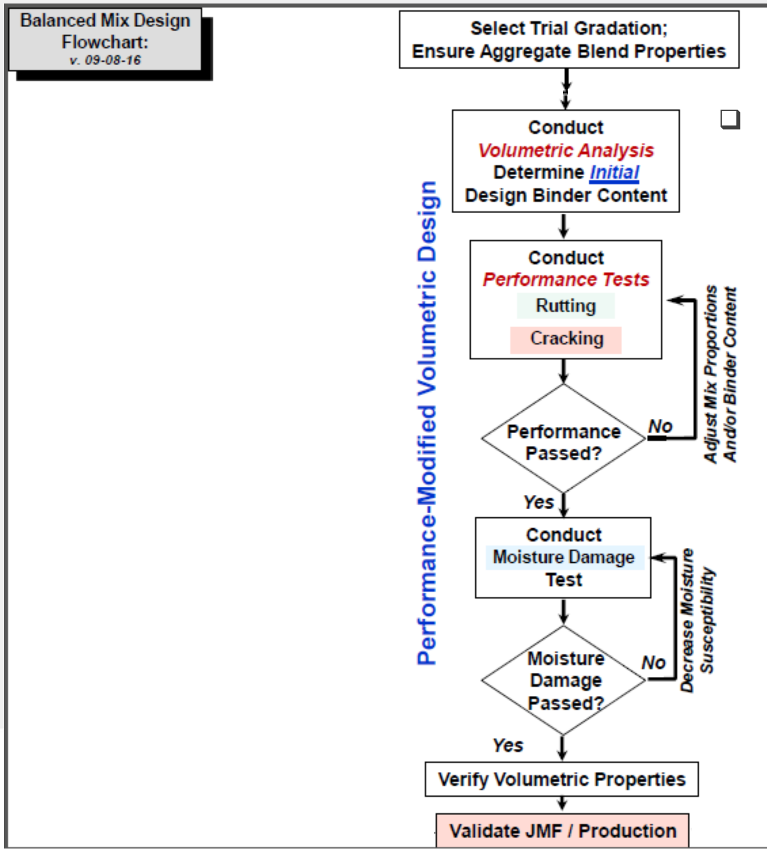
Slide 30

RW1 Richard Willis, 11/6/2017

Performance Modified Volumetric Design



Innovation Potential = Low



- **Performance-Modified Volumetric Design** – the initial design binder content is selected using AASHTO M323/R35 prior to performance testing; the results of performance testing could 'modify' the mixture proportions (and/or) adjust the binder content – and the final volumetric properties may be allowed to drift outside existing AASHTO M323 limits. Example State: California

RW1

Performance Design

or

Slide 32

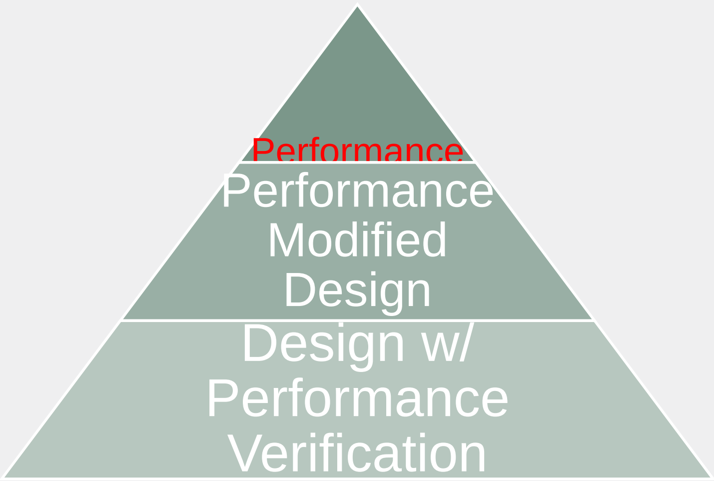
RW1 Richard Willis, 11/6/2017

RW1

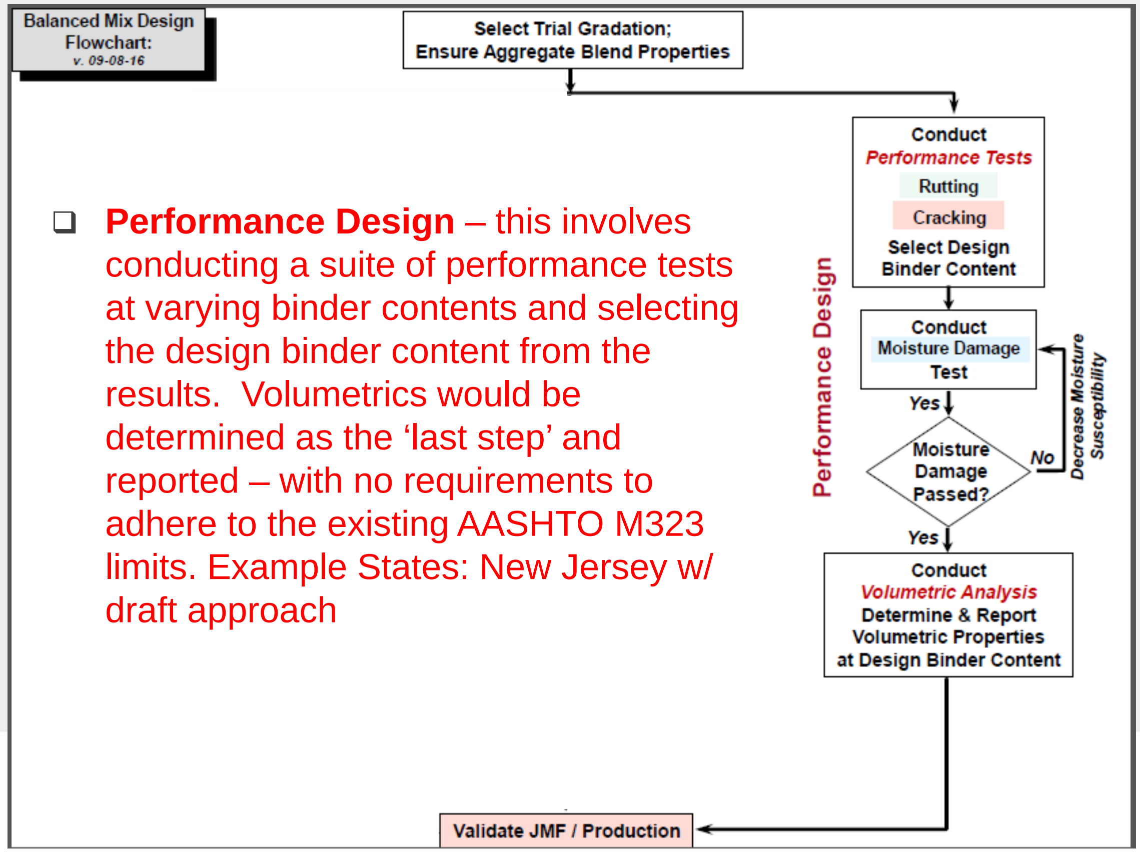
Slide 33

RW1 Richard Willis, 11/6/2017

Performance Design

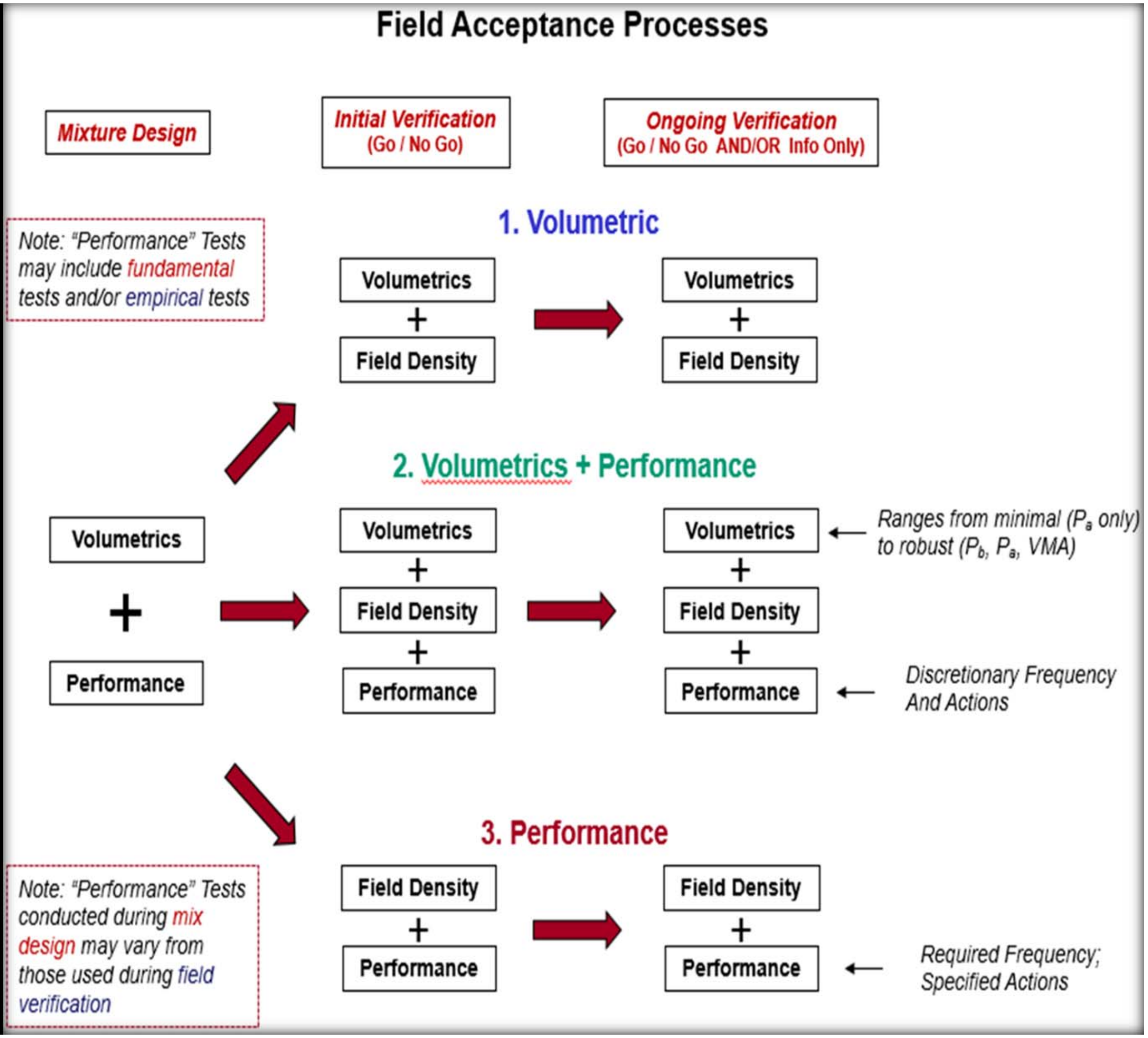


Innovation Potential = Medium / High



- **Performance Design** – this involves conducting a suite of performance tests at varying binder contents and selecting the design binder content from the results. Volumetrics would be determined as the 'last step' and reported – with no requirements to adhere to the existing AASHTO M323 limits. Example States: New Jersey w/ draft approach

BMD:
Field Acceptance



Graphic Developed by Kevin Hall (FHWA BMD Task Force), 9/14/2017

Solutions for Today's Problems

1. **Recognize performance issues** related to dry mixes in some areas. (Note: Many performance issues are caused by factors outside the mix design.)
2. **Increase understanding** of the factors which drive mix performance
3. **Design for performance** and not just to "the spec".
4. **Start thinking** outside of long held "rules and constraints"
5. **Innovate!**

Closing Thoughts

- BDM won’t happen overnight
- We still need to get a few answers
    - Cracking and aging
- Don’t forget about moisture sensitivity
- Not all BMD approaches are created equally
- Performance is ultimately what matters
    - Specifying both performance and recipe (volumetrics) stifles innovation

Thank you!

Implementation of HMA Performance Specifications In WFLHD

Brad Neitzke
Western Federal Lands Highway Division
Materials Engineer

Alaska Asphalt Summit
November 6, 2017

U.S. Department of Transportation
Federal Highway Administration

SHRP2 R07 Targeted Assistance Program Furthering the use of performance specifications

Project Partnership within FHWA

Richard Duval, FHWA Turner Fairbank Highway Research Center

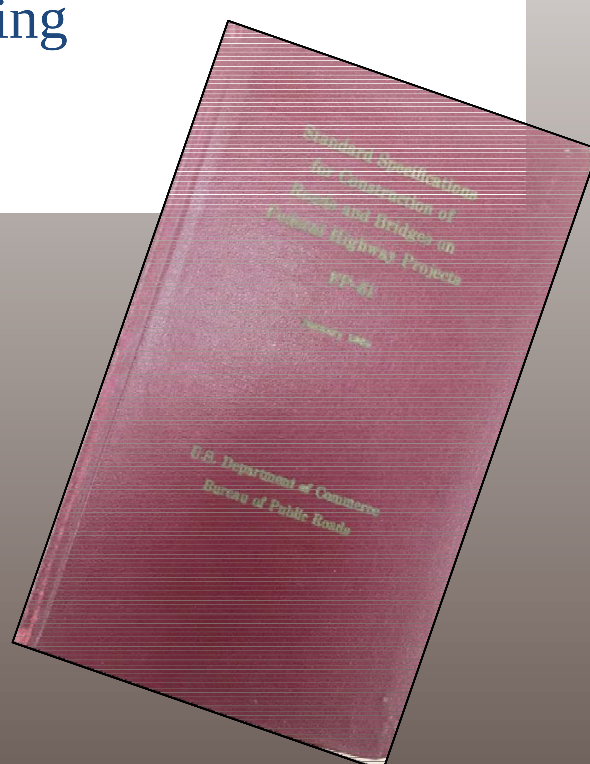
U.S. Department of Transportation
Federal Highway Administration

Other Agency Involvement

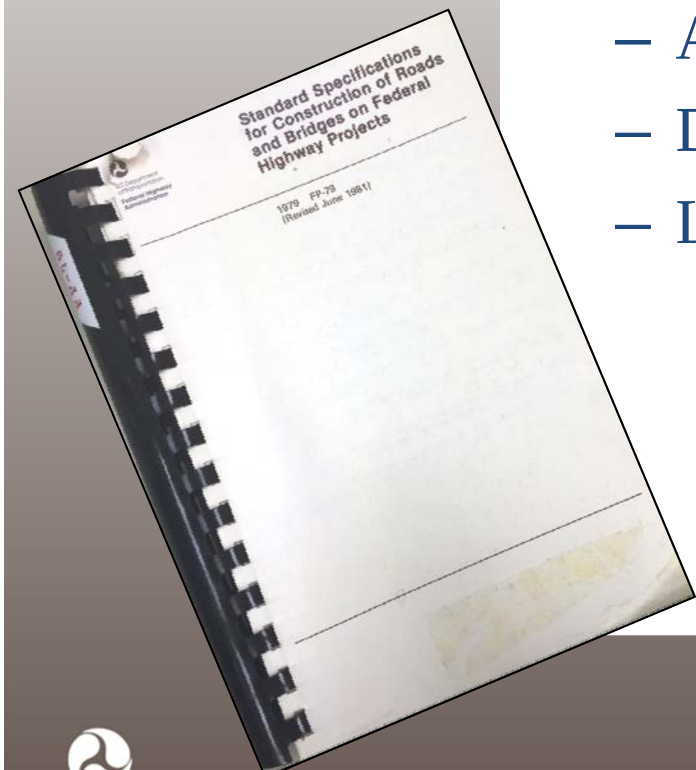
- Maine DOT
- Maryland SHA
- Missouri DOT
- Ontario MOT

HMA Progression of Specifications

- **1960's Federal Specifications**
  - Broadband gradation requirements
  - Asphalt content by weight during mixing
  - Asphalt cement by certification
  - Methods of manufacture



HMA Progression of Specifications



- **1970's Federal Specifications**
  - Gradation target values and tolerances
  - Asphalt content target and tolerance
  - Density
  - Limited asphalt cement testing (primarily certification)

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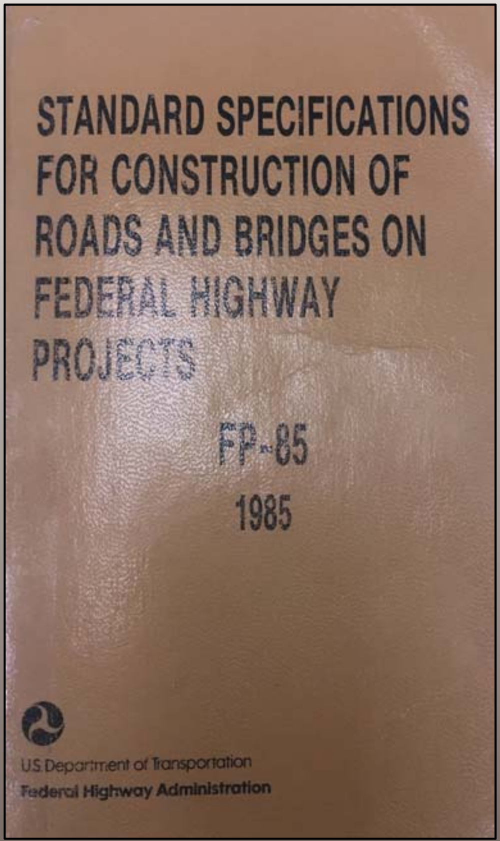
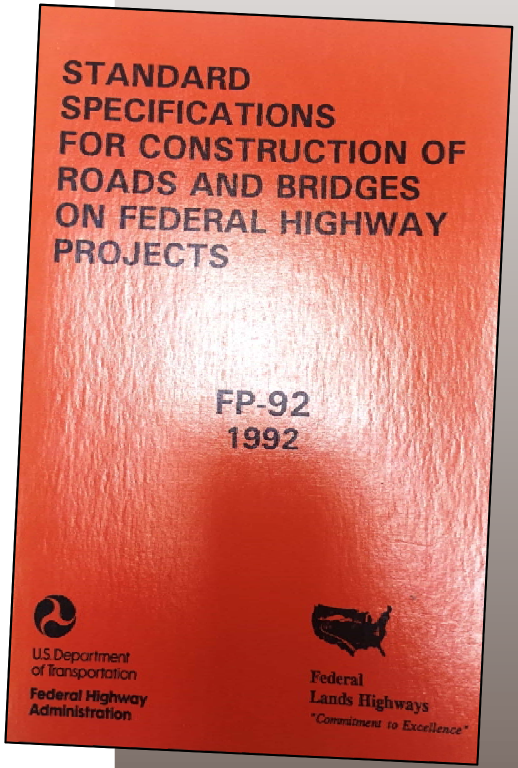
HMA Progression of Specifications

- **1980's Federal Specifications**
  - Gradation with target value and tolerance
  - Asphalt content with target value and tolerance
  - Density
  - Thickness
  - Asphalt cement testing – limited certification
  - Statistical acceptance
  - Pay lots and pay factors



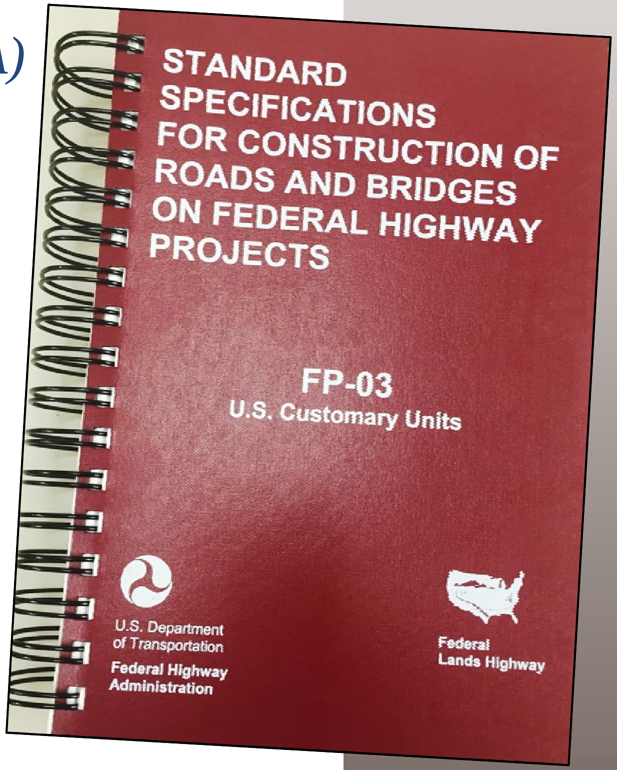
HMA Progression of Specifications

- **1990's Federal Specifications**
  - Gradation with target value and tolerance
  - Asphalt content with target value and tolerance
  - Density
  - Asphalt binder testing *(Performance Grades)*
  - Smoothness measurement with pay adjustments *(Profilograph)*
  - Contractor testing with agency verification
  - Statistical acceptance
  - Pay lots and pay factors



HMA Progression of Specifications

- **2000's Federal Specifications**
  - Asphalt mixture volumetrics *(VMA, Air Voids, VFA)*
  - Asphalt content with target value and tolerance
  - Minimum VMA
  - Density
  - Asphalt binder testing *(Performance Grades)*
  - Smoothness measurement with pay adjustments *(Inertial Profilers)*
  - Contractor testing with agency verification
  - Statistical acceptance
  - Pay lots and pay factors



Additional Mixture Tests

- **Immersion – Compression**
- **Tensile Strength Ratio**
- **Hamburg Wheel Track Testing**
- **Asphalt Pavement Analyzer**
- **TSRST**
- **Others**

Empirical Tests

Performance Specifications

- **Can we…**
  - Optimize and Improve Performance?
  - Determine how volumetrics relate to performance and pavement life?
  - Develop quality adjusted pay factors that reflect "as-constructed" pavement life?

These are the objectives for this project

Performance-Related Specifications (PRS)

DR(18

"QA specifications that describe the desired levels of key materials and construction quality characteristics that have been found to ***correlate with fundamental engineering properties that predict performance****"*

Transportation Research Circular Number E-C137
Glossary of Highway Quality Assurance Terms

U.S. Department of Transportation
Federal Highway Administration

Slide 11

DR(18 Another pic in the background
Duval, Richard (FHWA), 8/16/2017

Benefits of PRS – The Future

- Long term pavement performance predicted from fundamental engineering properties
- Incentives and disincentives justified through reduction or increase in pavement life
- Allow contractors to be more innovative and more competitive

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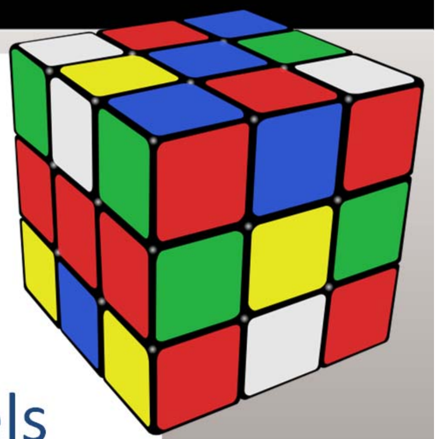
Federal Highway Administration

Challenges with PRS



- Testing efficiency and simplicity
  - Completed/Continuous
- Standardization of test methods
  - Ongoing
- Reliability of performance prediction models
  - Complete
- Performance volumetric relationships
  - Ongoing
- Same principles and methods between mix design and PRS
  - Ongoing

Project Outline

- Perform desktop study (past project)
- Shadow projects
  - Performance testing / analysis
  - Demonstrates how PRS could be used
  - Understanding PRS testing and acceptance operations
  - Collect data for PRS development

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Federal Highway Administration

Past Project – Desktop Study

- **Perform desktop study**
  - Past project
  - Collect test results from construction
  - Mix design information
  - Obtain field cores of existing pavement
  - Advanced laboratory testing
  - Traffic data
- **Compare predicted life vs. "as-constructed"**
- **Compare against pay factors for completed work**

Past Project
Yellowstone National Park

- **East Entrance Road**
  - First WMA project constructed in 2007
  - Excellent traffic data
  - Extensive testing *(FHWA mobile lab)*

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East Entrance Road
Yellowstone National Park

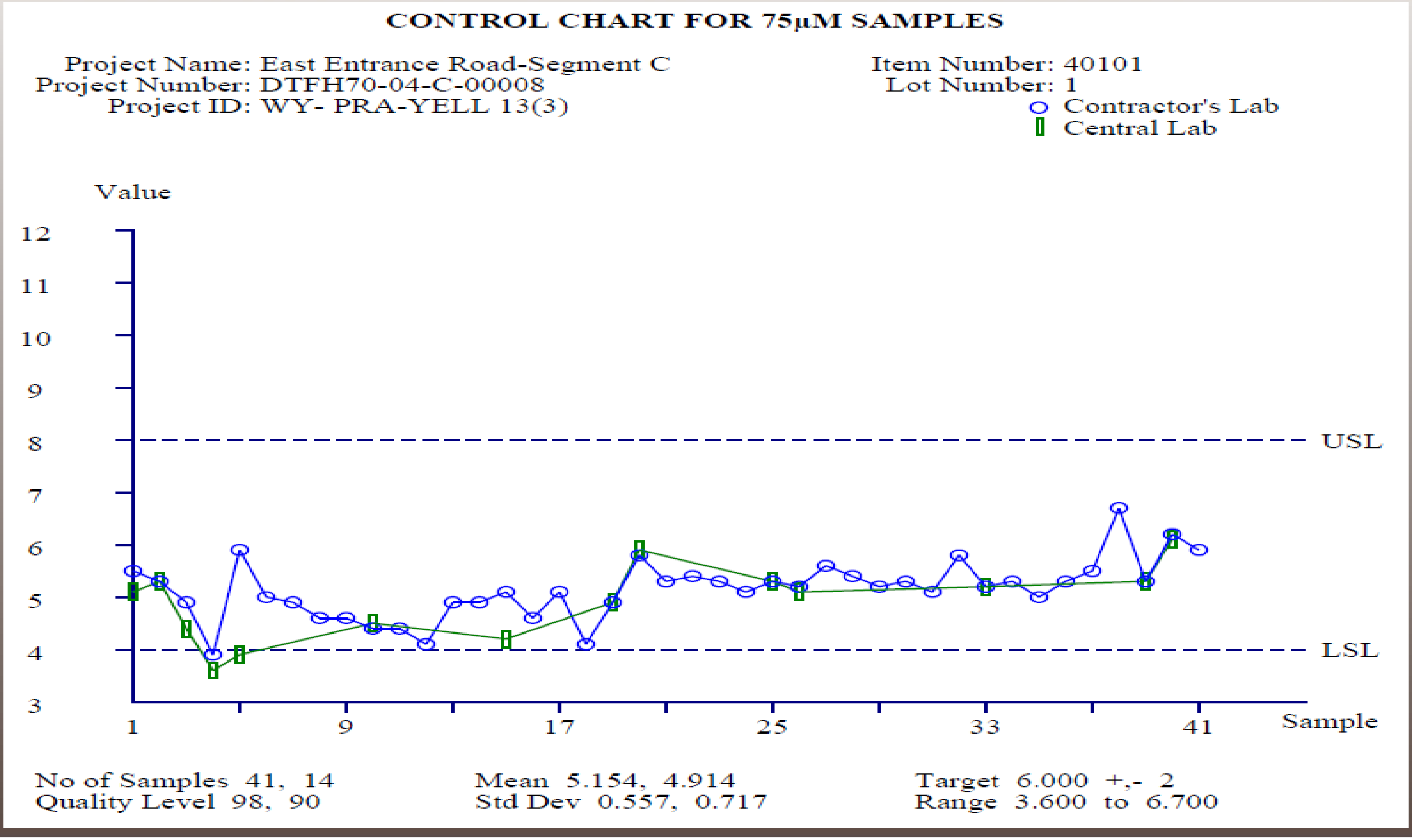
Typical Data – Pay Factors

Quality Levels and Pay Factors

Quality Charac-teristic	Actual Target Value		Mean	Standard Deviation	PWL	Pay Factor
12.5mm	85.00	+,- 5	87.18	2.738	85	0.96
9.5mm	71.00	+,- 6	70.13	3.365	92	1.00
4.75mm	46.00	+,- 7	43.97	2.985	95	1.03
2.36mm	30.00	+,- 5	28.06	1.903	95	1.03
425µm	12.00	+,- 3	11.15	1.092	98	1.00
75µm	6.00	+,- 2	5.15	0.557	98	1.04
AC-m	5.30	+,- .5	5.44	0.329	84	0.96
SE	45.00	min	65.37	3.137	100	1.00
% FRAC	90.00	min	99.80	0.267	100	1.05
% DEN	90.00	min	93.42	1.207	100	1.05

TESTING COMPLETED
FINAL PAY FACTOR: 0.96

Agency Verification Data

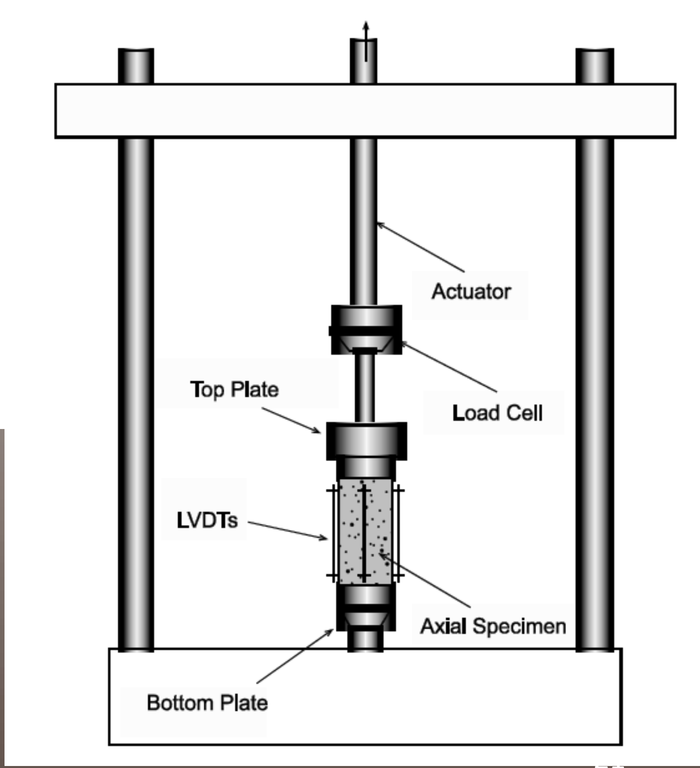


Performance Testing

- **Obtain cores from existing pavement**
- **Advanced laboratory testing – fundamental AMPT**
- **In-service traffic data** *(vehicle counts / traffic mix)*
- **PMS / RIP data**
- **Performance relationships**

Key Information for Desktop Study

- **Good traffic data**
- **Good "as-constructed" project data**
- **Obtain cores for AMPT testing**
  - – Dynamic Modulus
  - – Cyclic fatigue



Shadow Projects
Current / Recently Constructed

- **Shadow Project**
  - Skyliners Road near Bend, OR *(completed 2016)*

  - Lake Crescent – Highway 101 in Olympic National Park *(currently under construction)*

Why Shadow Projects?

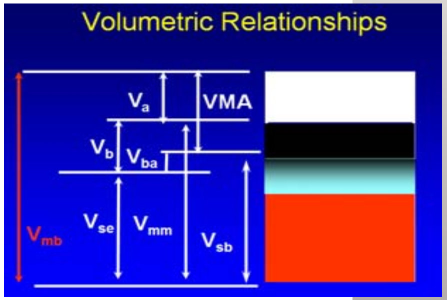
- Understanding testing and analysis
- Demonstrate how project would be accepted using PRS
- Understand processes and testing for PRS type operations
- Collect data for improvement and implementation

Shadow Project Data

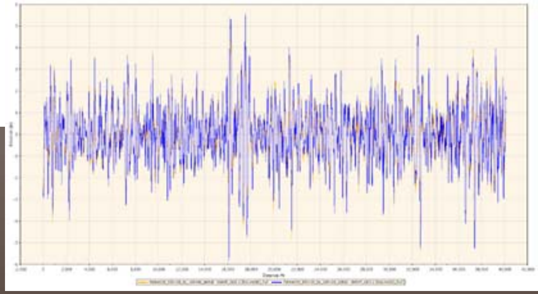
- **Additional sampling of current project materials**
  - Performance testing
  - Use of calibrated performance models
  - Predicted pavement life vs. volumetric properties
  - “As constructed” pavement life vs. pay factors

Shadow Project Data

- **Asphalt concrete mix design information**
  - Contractor mix design
  - Agency verification
  - TFHRC confirmation and comparison



- **Acceptance Quality Characteristics** *(AQCs)*
  - Asphalt content
  - VMA
  - Density
  - Asphalt binder
  - Roughness *(IRI Evaluation)*



Shadow Project
Performance Testing at TFHRC

- Verified mix design
- Laboratory Batched Mix
  - 3 air void contents (4%, 7%, 10%)
- Plant Produced Loose Mix
  - 3 air void contents (4%, 7%, 10%)
- Field Cores
  - Specimens obtained from field cores

Performance Testing for Shadow Projects

Performance Testing	Plant Produced Loose Mix			Laboratory Batched Mix			Field Core	
	4% V_a	7% V_a	10% V_a	4% V_a	7% V_a	10% V_a	2015	2016
Dynamic modulus	X	X	X	X	X	X	X	X
Direct Tension Fatigue	X	X	X	X	X	X	X	X
Stress Sweep Rutting Test	X	X	X	X	X	X	n/a	n/a

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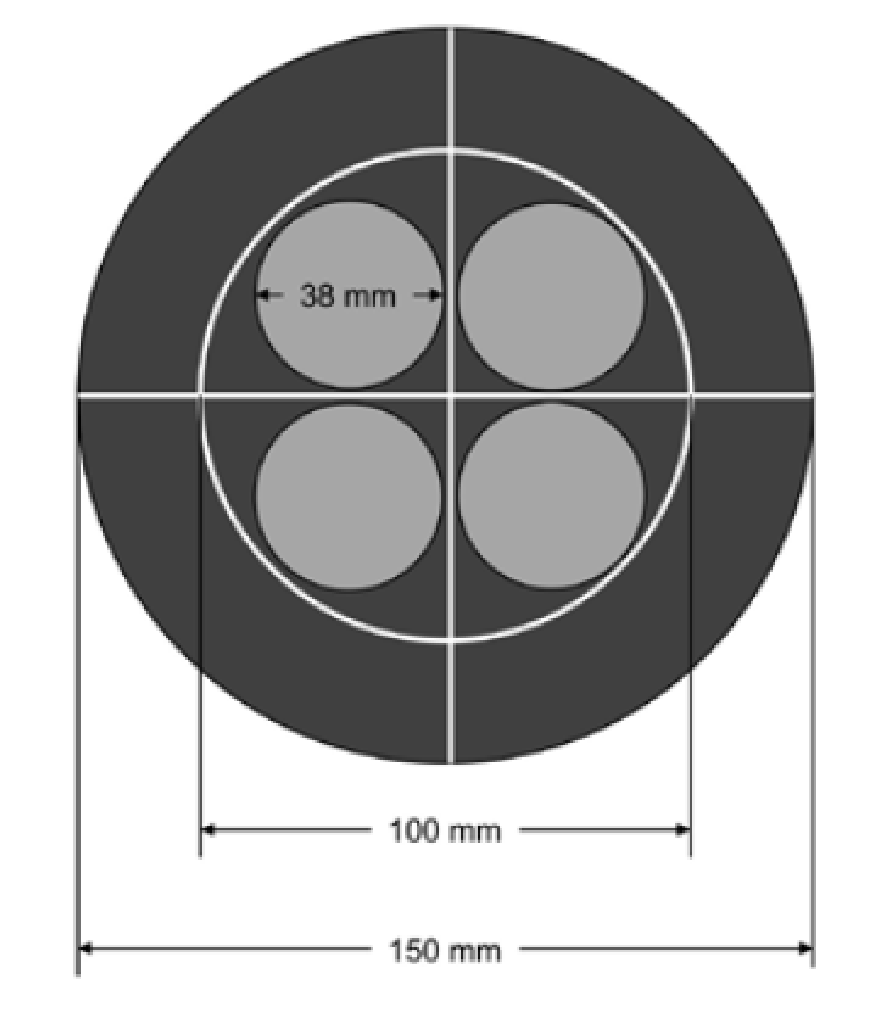
Testing Efficiency and Samples

- Needs to be more efficient
  - Manufacture and production of specimens
- Simplicity
  - Straight forward methods
- Standardization of methodology
  - Provisional standards currently with AASHTO
- Use of available equipment
  - Asphalt Mixture Performance Tester (AMPT)

Test Specimens
Lab Manufactured

Test Specimens
Lab Manufactured



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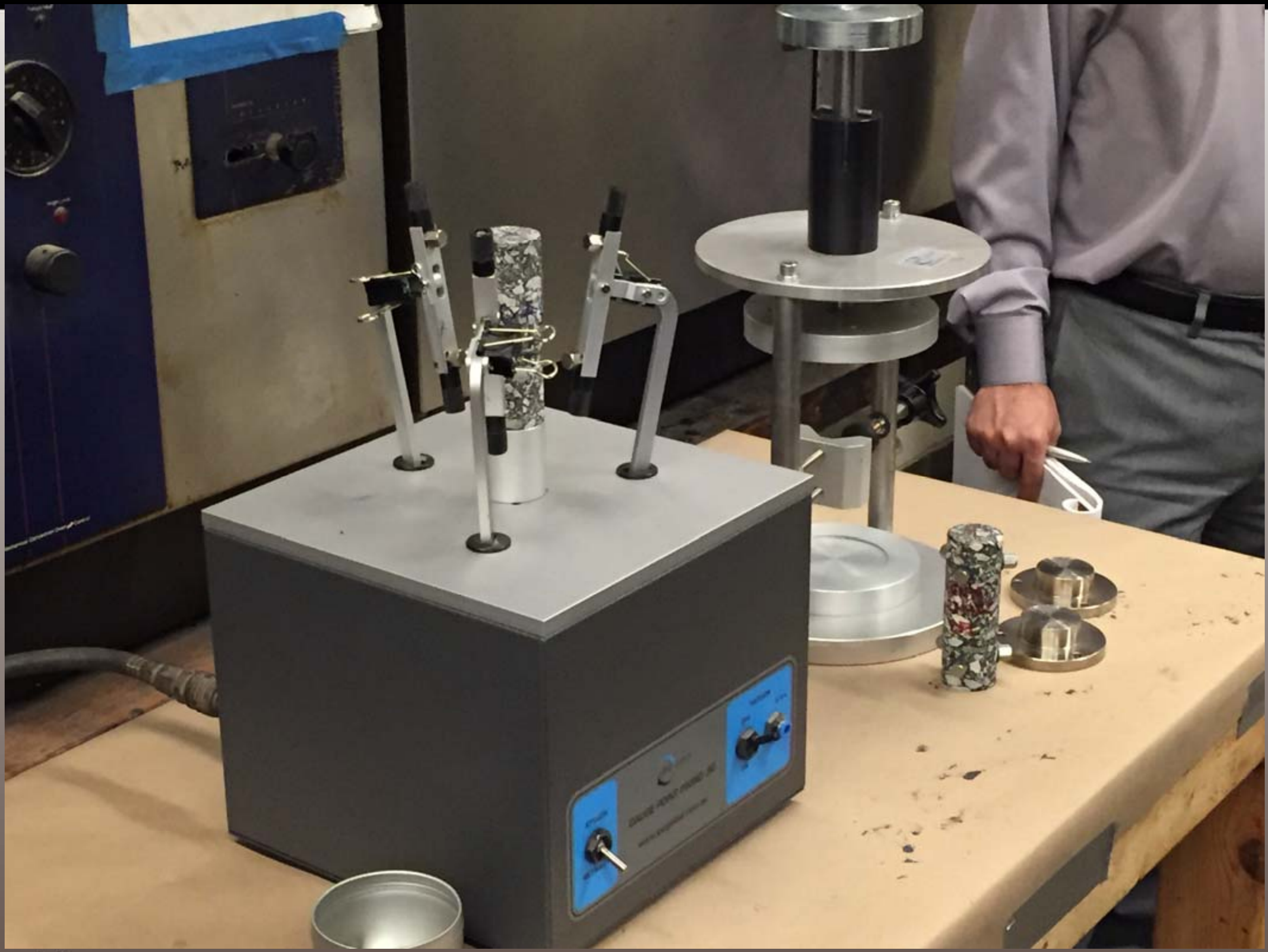
Test Specimens
Lab Manufactured

Test Specimens
Lab Manufactured

Test Specimens
Lab Manufactured



Test Specimens
Lab Manufactured

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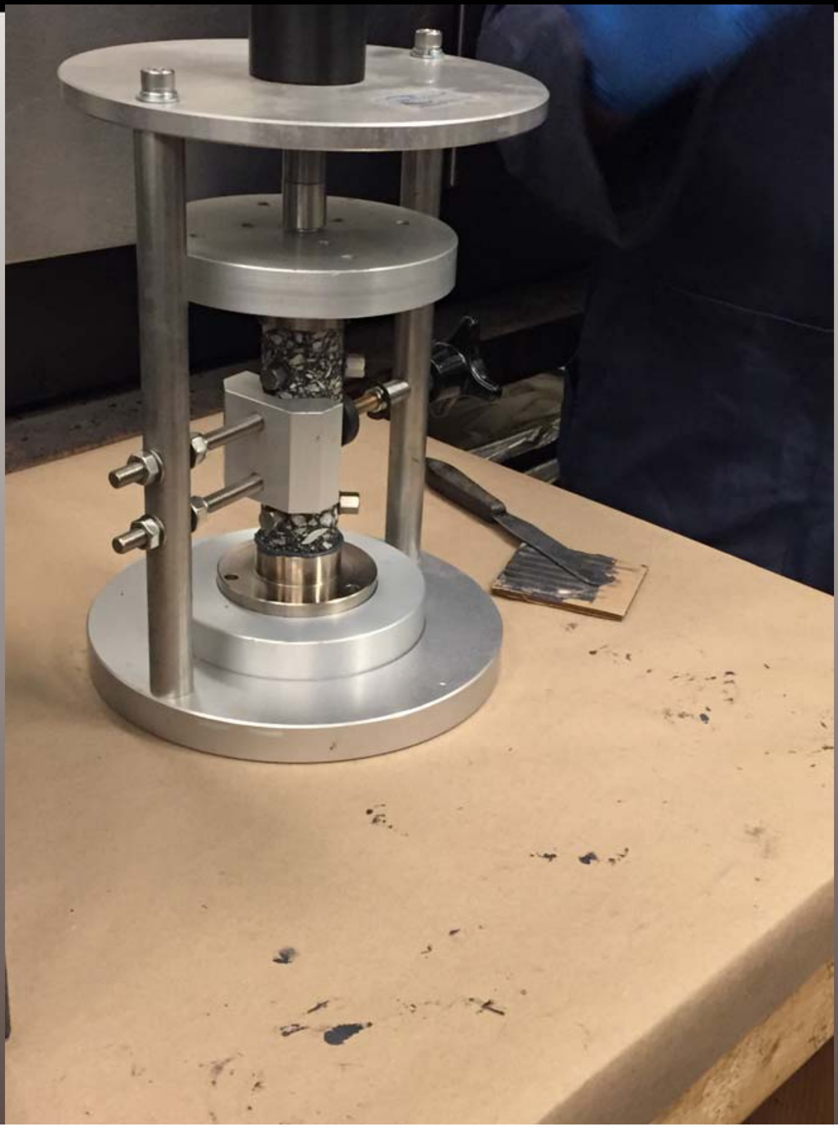
Test Specimens
Lab Manufactured



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Test Specimens
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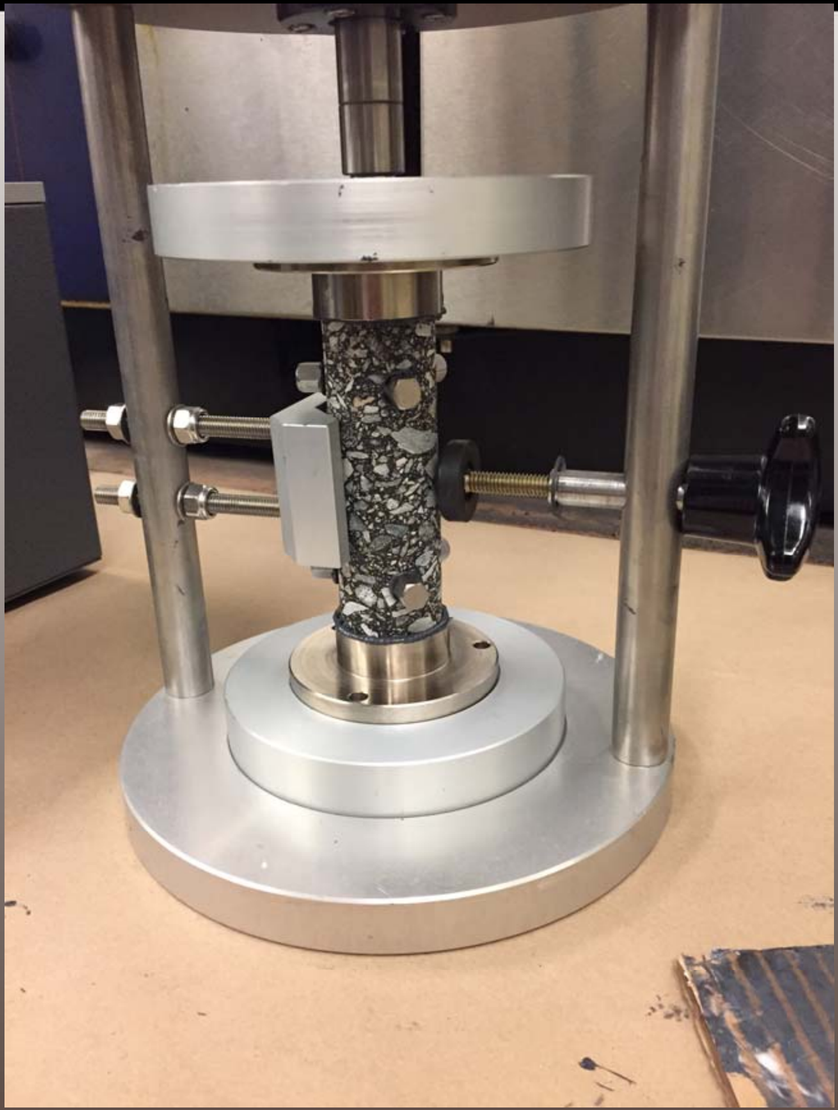
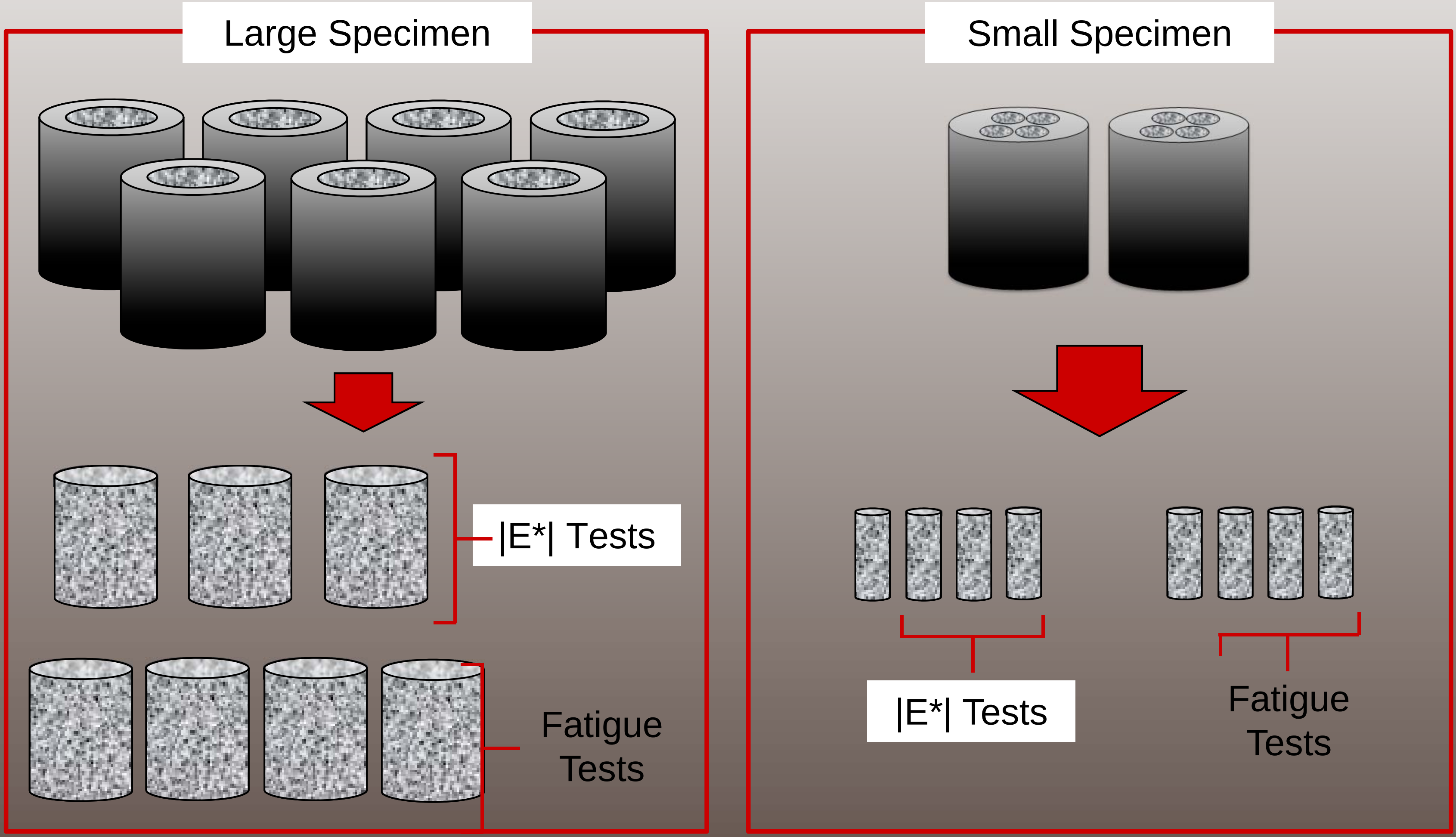


Testing Efficiency and Simplicity



Testing Efficiency and Simplicity

	Large Specimen	Small Specimen
Steel Putty	Devcon 10110	Devcon 10240
Working Time	10 – 20 min.	5 min.
Functional Cure	16 hours	1 hour
Amount of Putty (per specimen)	100 g	3 g

AMPT Cyclic Fatigue Process

Preparation

- Cylindrical specimen

- 100 mm x 130 mm

- Small-specimen:

38 mm x 110 mm

- End plate gluing, clamp system being explored

- 2-3 days for mix

Testing

- Dynamic modulus fingerprint for specimen variability

- Pull-pull fatigue test

- Strain level based on TFHRC database

- Test temperature based on location of interest

- Load until crack forms

- 1-2 days for mix

Analysis

- AMPT automatically captures data for analysis

- Calculate damage via FlexMAT or FlexPAVE

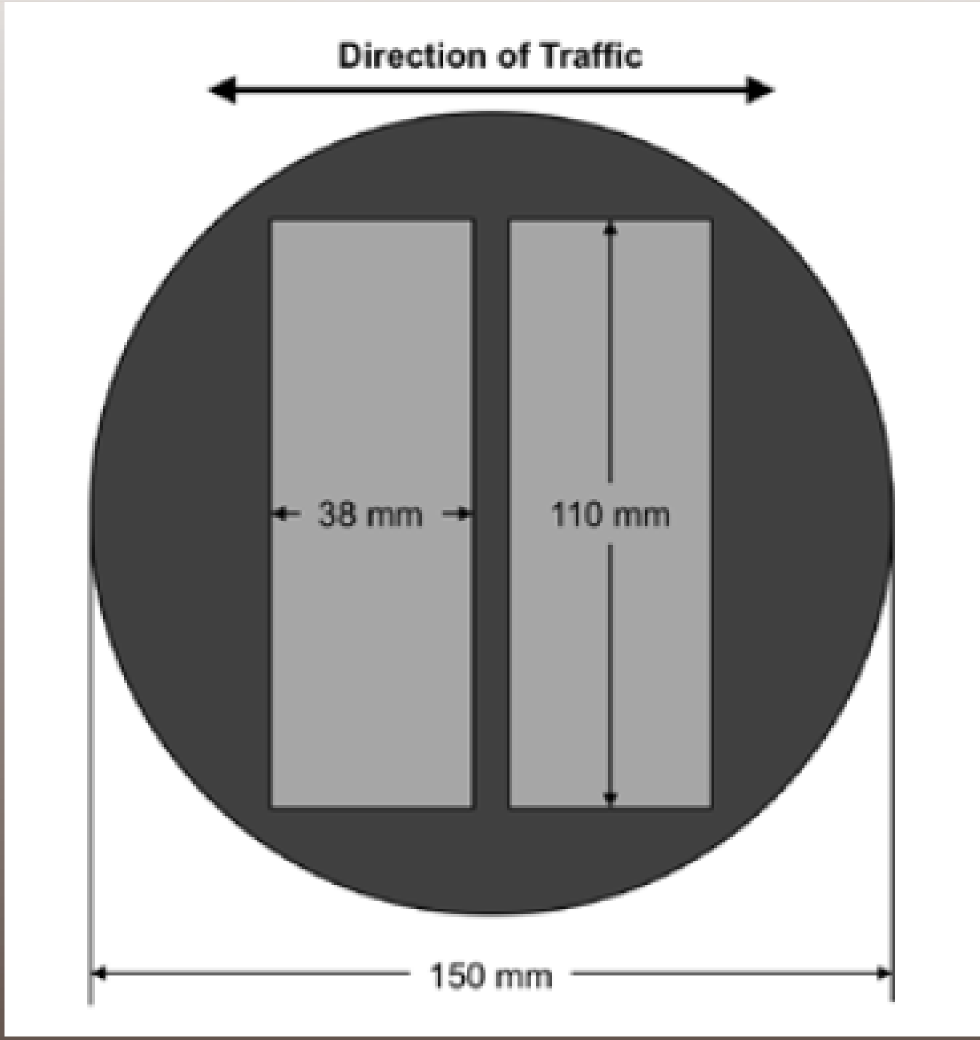
- Assign mixture rankings or use FlexPAVE

- 1-2 hours for mix

About one week per mixture…worth it when considering the cost of premature failure?

Test Specimens from Field Cores

Test Specimens from Field Cores

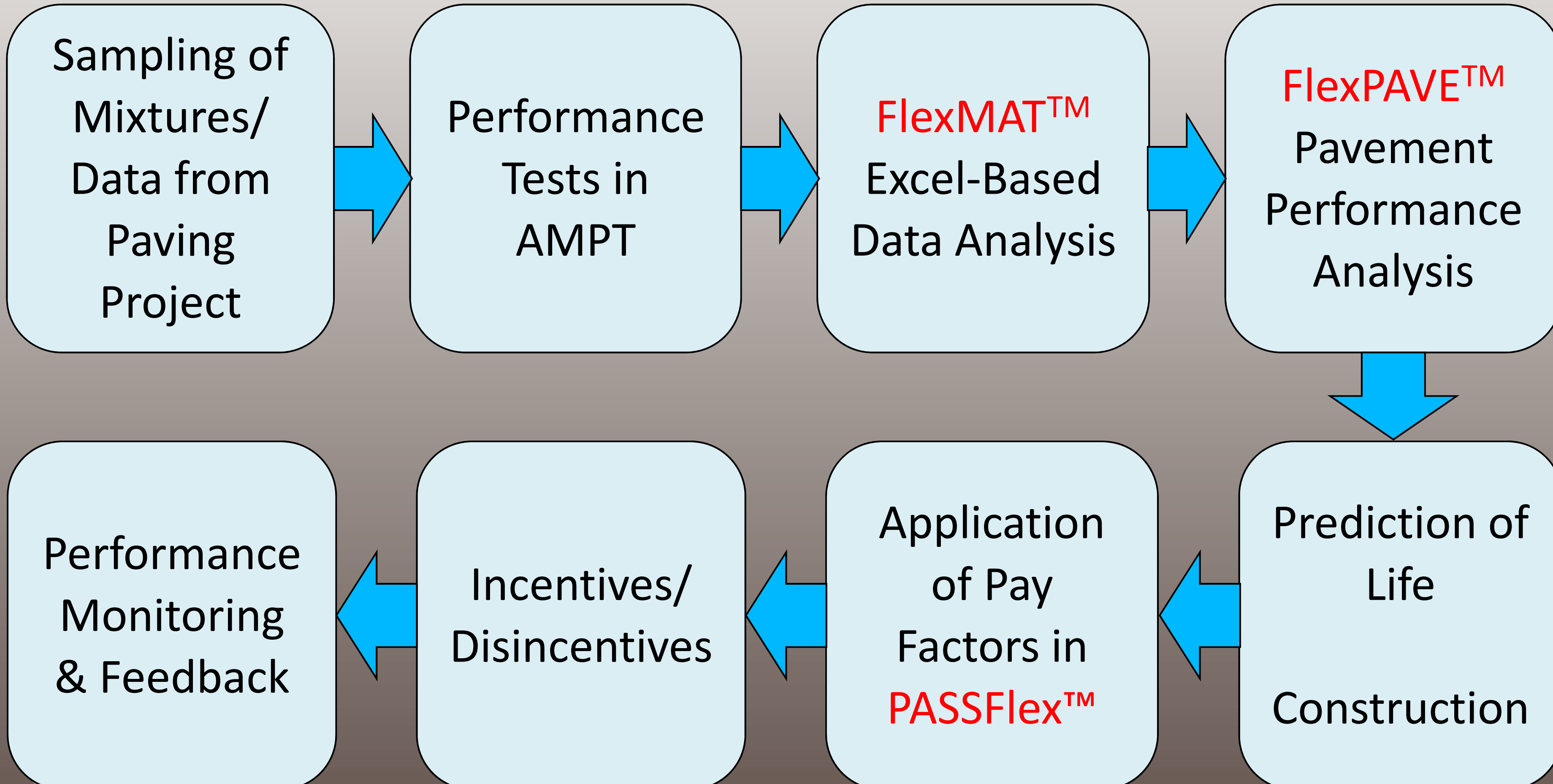


PRS Software

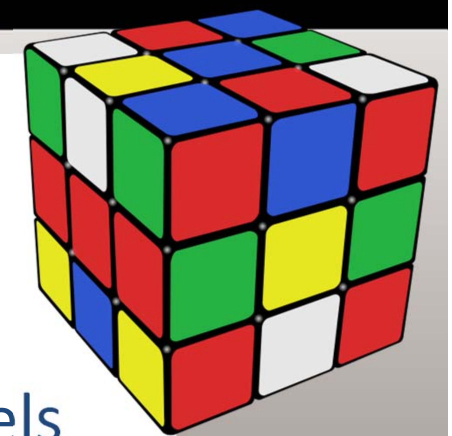
FlexMAT™ and FlexPAVE™ Available

- FlexMAT – Excel spreadsheet
  - Analyzes cyclic fatigue, |E*|, and SSR data
  - Import files directly
  - Output → FlexPAVE
- FlexPAVE – performance prediction tool
  - Pavement design
  - Simulate as-design and as-built performance

Asphalt PRS Framework



Challenges with PRS



- Testing efficiency and simplicity
  - Completed/Continuous
- Standardization of test methods
  - Ongoing
- Reliability of performance prediction models
  - Complete
- Performance volumetric relationships
  - Ongoing
- Same principles and methods between mix design and PRS
  - Ongoing

Deliverables

- Predicted Pavement Performance vs. Volumetrics
- Determine as-constructed pavement life compared against as-design
- Pavement life vs. PWL pay factors
- Superpave Volumetrics relation to performance testing – PVR Relationship
- Development of draft performance specification

Outcomes

- Further the advancement and deployment of PRS for asphalt pavements
- Viable option for construction
- Construction industry has confidence in processes used for acceptance

Anyone Interested in participating?

- FHWA still looking for shadow projects
- Contact information (PRS and Shadow)
  - Richard Duval
  - 202.493.3365
  - Richard.duval@dot.gov

Questions?

Brad Neitzke
WFLHD Materials Engineer
brad.neitzke@dot.gov
360.619.7725

asphalt institute

An Introduction to the Bailey Method for Achieving Volumetrics and Asphalt Compactability

Danny Gierhart, P.E.
Senior Regional Engineer
Tuttle, OK

The Bailey Method

- Originally developed by Robert D. Bailey
  - The **Bailey Method** was developed by Bob Bailey in the early 1980’s.
  - A civil engineer who worked with the Illinois DOT, District 5 Materials Bureau for over 35 years
  - Research and Development of the Method has been continued by the Heritage Research Group of Indianapolis, primarily by Bill Pine

IMPORTANT DISCLAIMER!!!

- This presentation will only serve as a BASIC introduction to the Bailey Method
  (45 minutes)
- A *proper* study of the method can be undertaken by attending "Optimizing Volumetrics and HMA Compactibility Utilizing the Bailey Method" with instructor Bill Pine
  (5 DAYS)
- Next course is February 26 - March 2, 2018 at Asphalt Institute headquarters in Lexington, KY

Aggregate Packing

What Influences the Results?

- **Gradation**
  - continuously-graded, gap-graded, etc.
- **Shape**
  - flat & elongated, cubical, round
- **Surface Texture** (micro-texture)
  - smooth, rough
- **Type & Amount of Compactive Effort**
  - static pressure, impact or shearing
- **Strength**

The Main Principles

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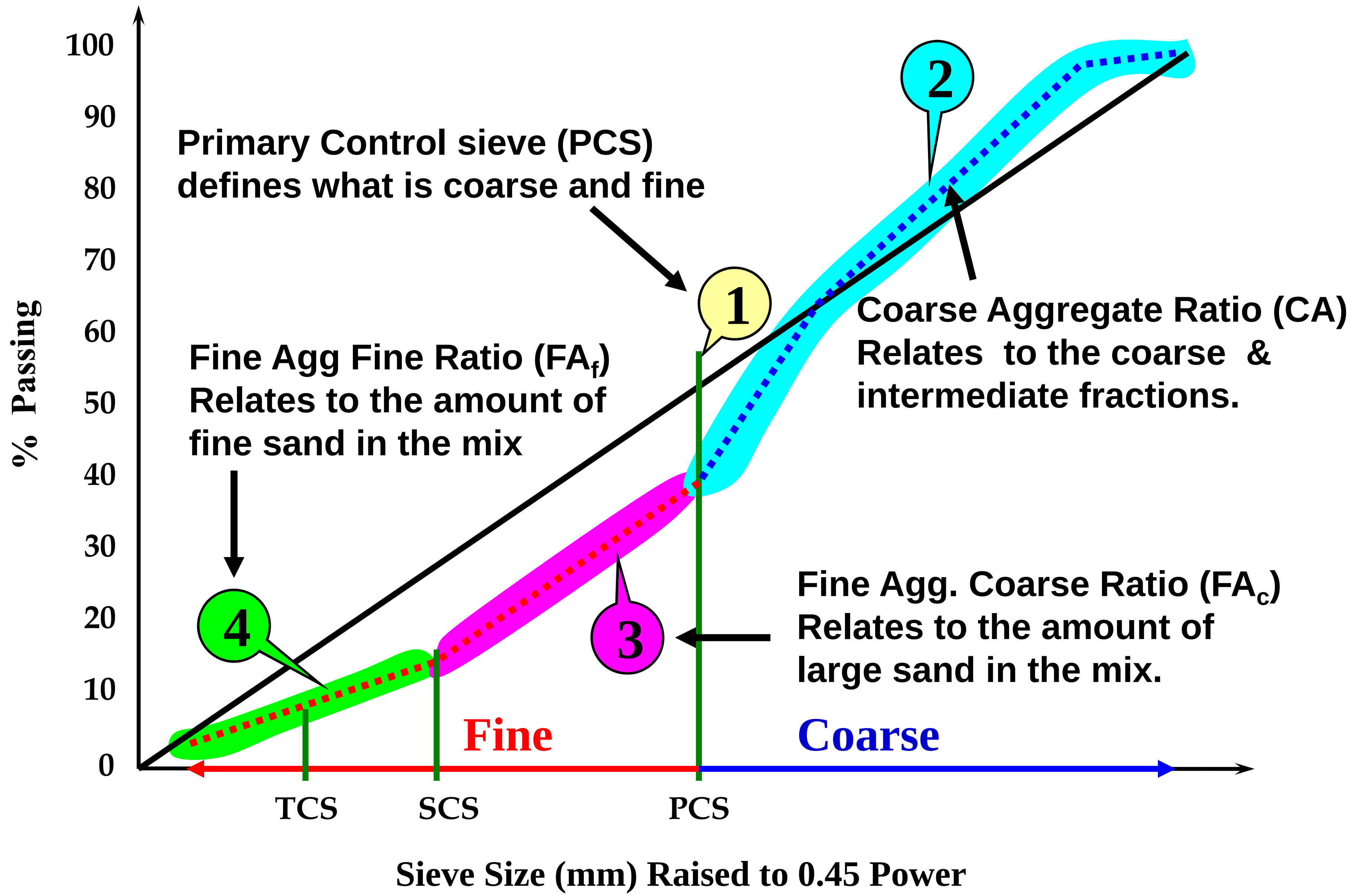

Principle #1 – P.C.S.

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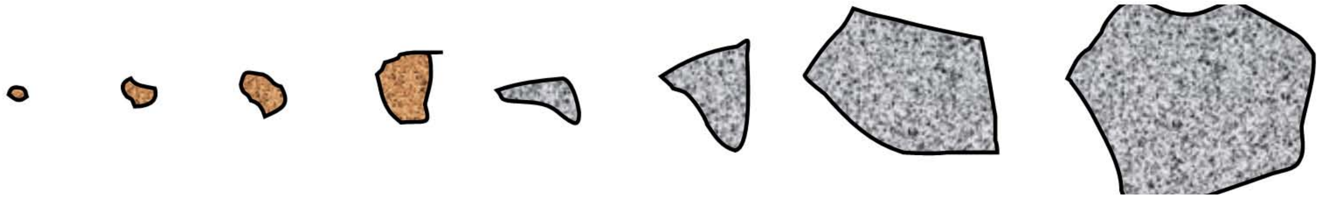
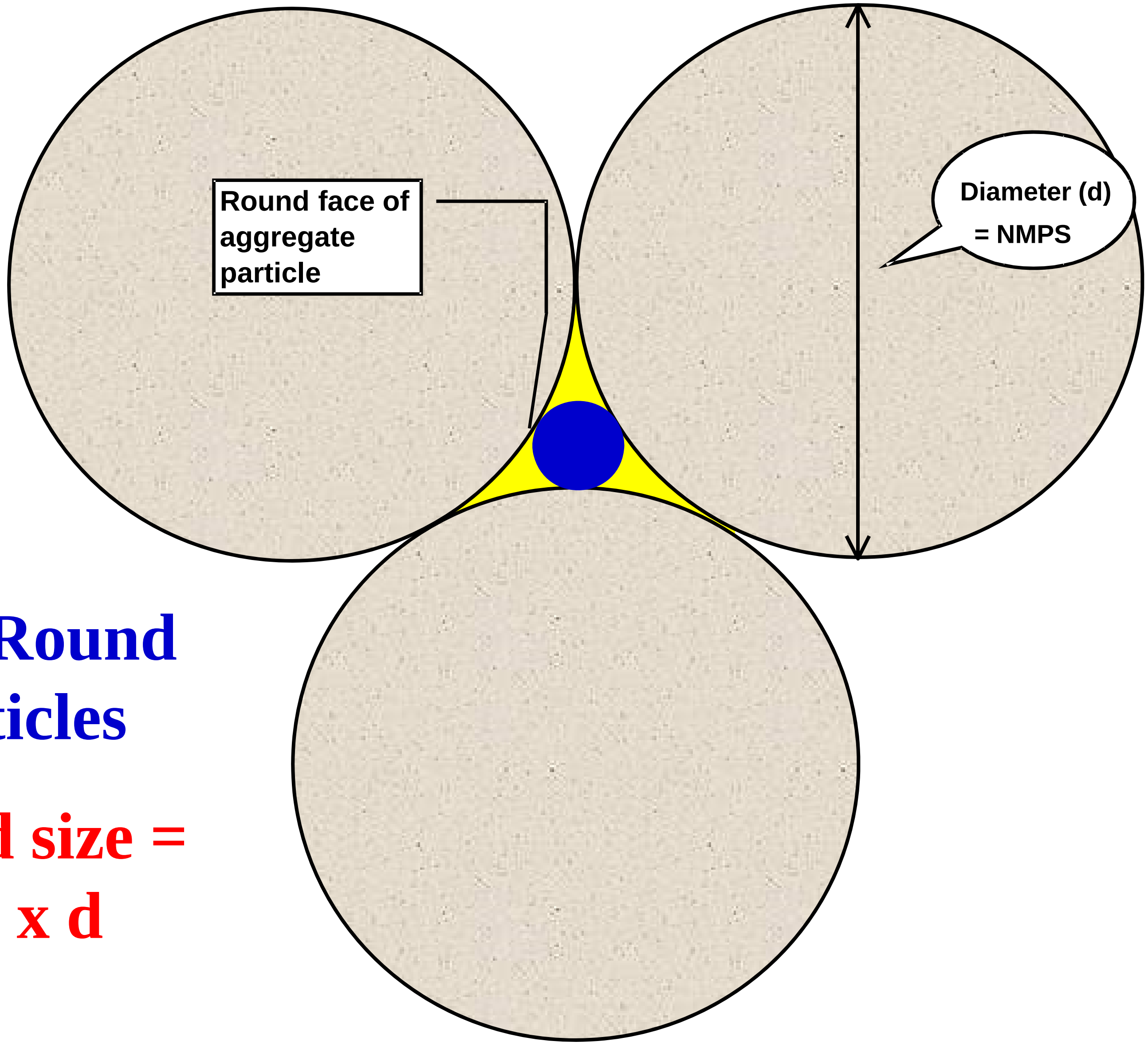
Defining "**Coarse**" and "**Fine**"

- "**Coarse**" fraction
  - Larger particles that **create** voids
- "**Fine**" fraction
  - Smaller particles that **fill** voids
- Estimate void **size**
  - Using **N**ominal **M**aximum **A**ggregate **S**ize (**NMAS**)
  - **Defined using 15% (NOT 10%)**
- **Break** between "**Coarse**" and "**Fine**"
  - **Primary Control Sieve (PCS)**



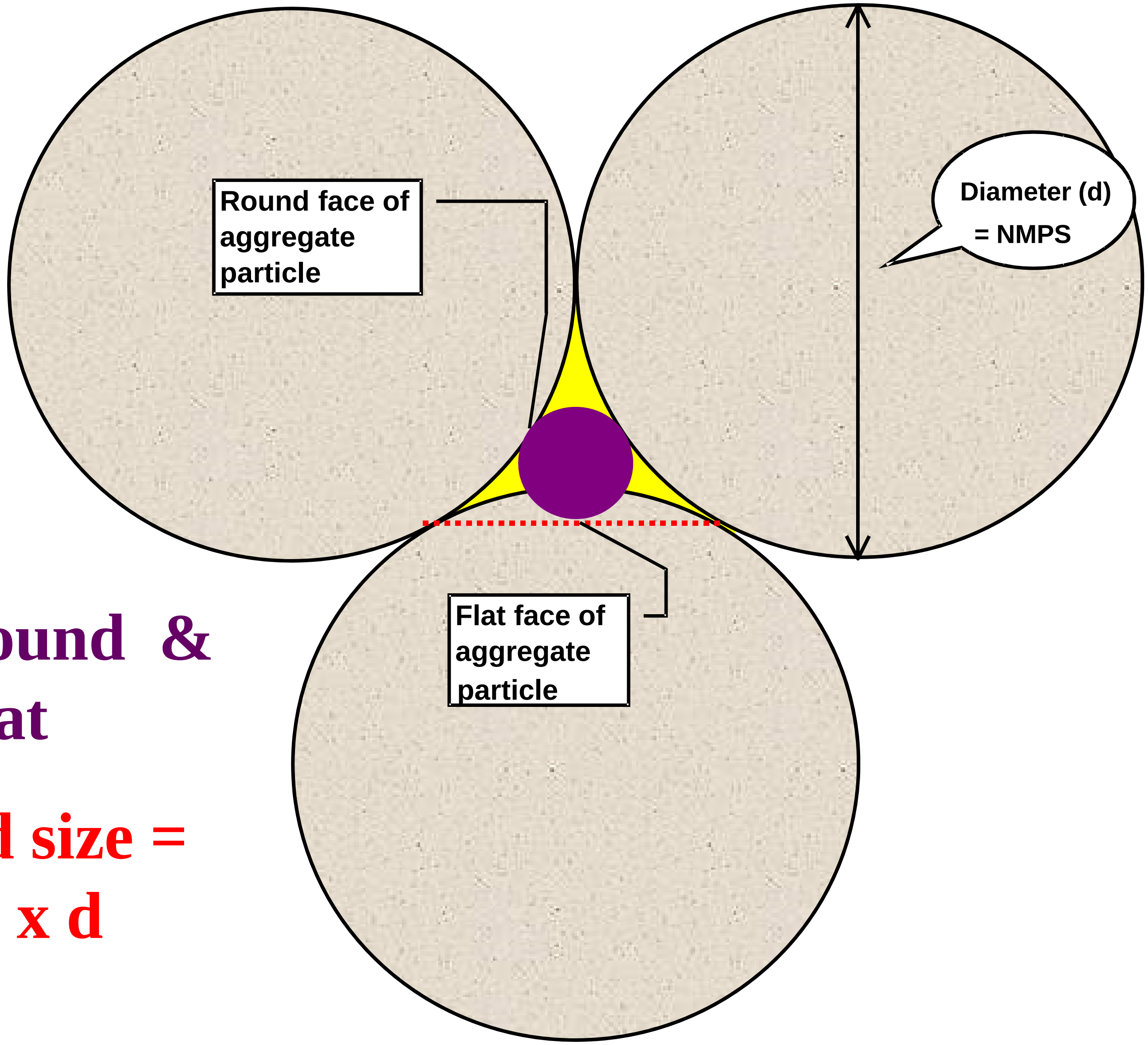
Principle #1 – P.C.S.



All Round particles

Void size = 0.15 x d

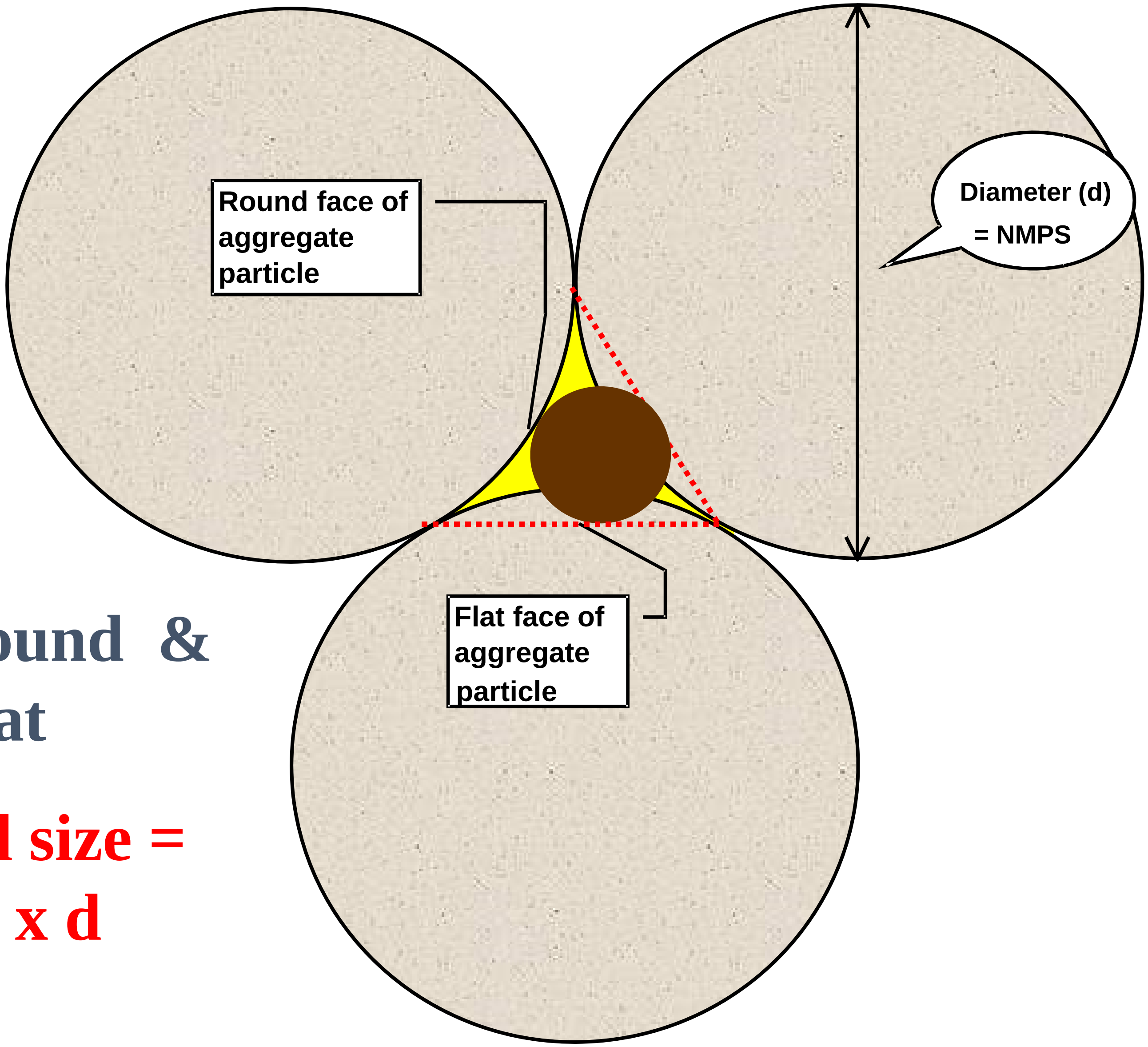
Principle #1 – P.C.S.



2 Round & 1 Flat

Void size = 0.20 x d

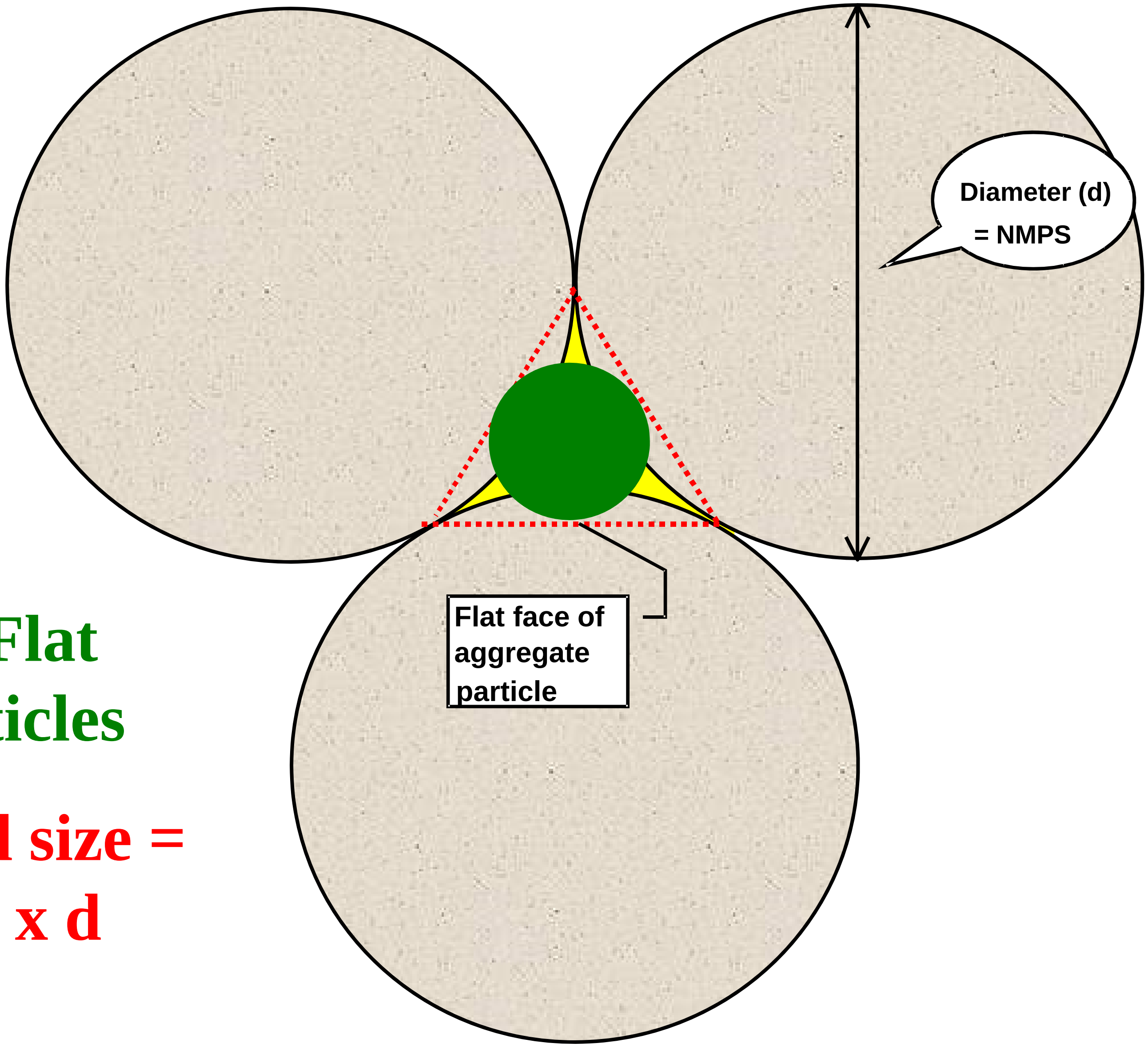
Principle #1 – P.C.S.



1 Round & 2 Flat

Void size = 0.24 x d

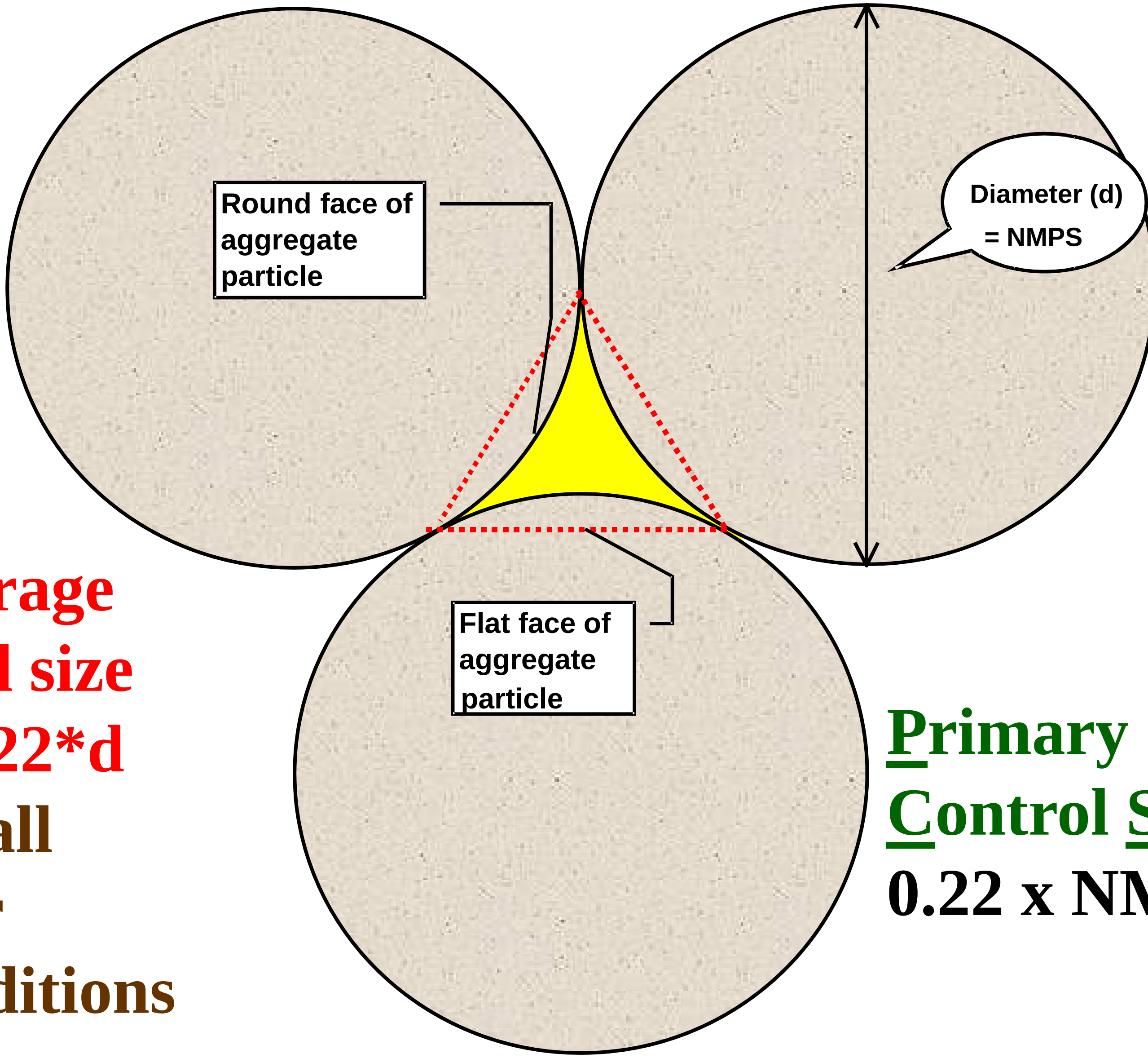
Principle #1 – P.C.S.



All Flat particles

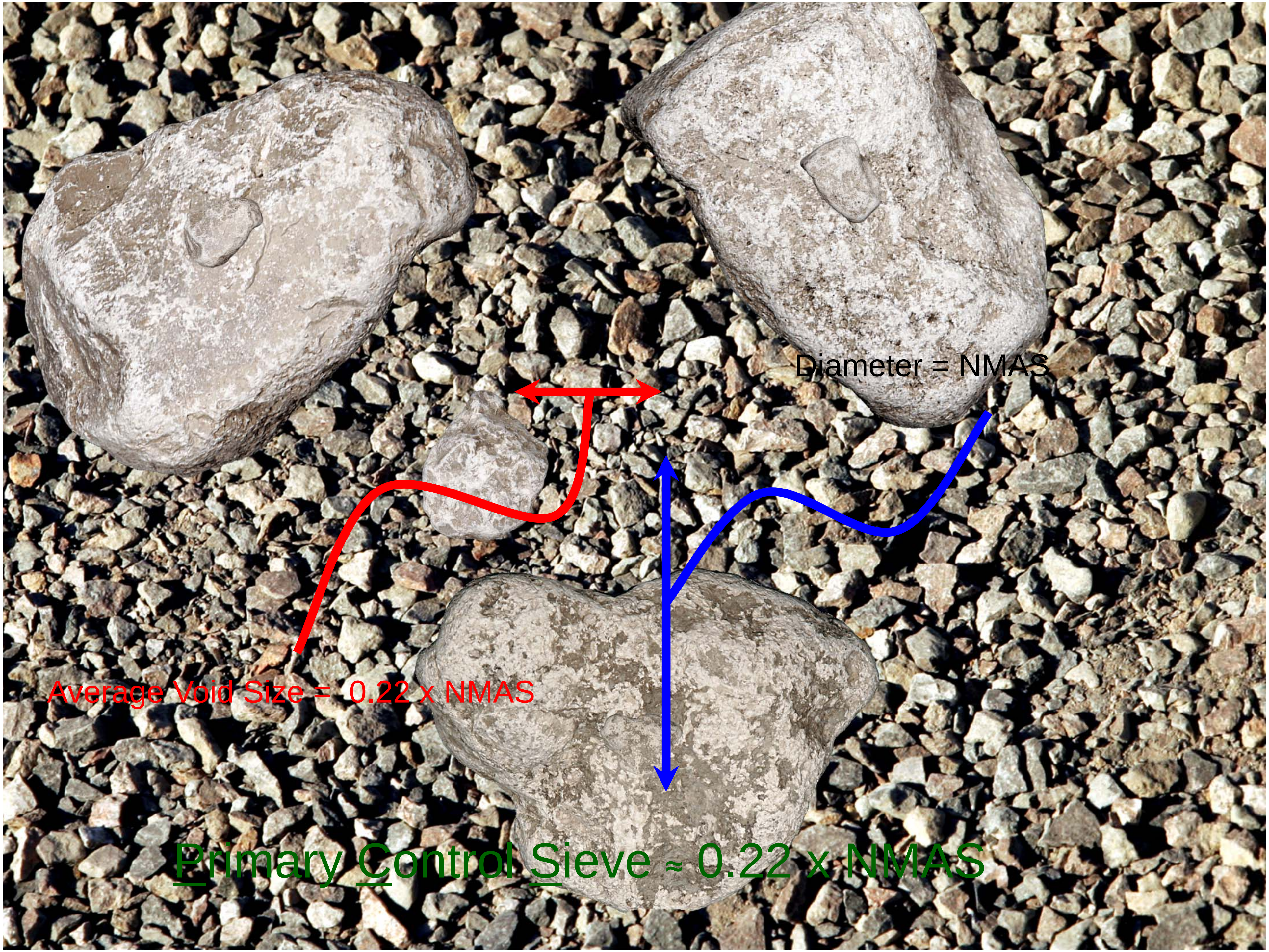
Void size = 0.29 x d

Principle #1 – P.C.S.



Average Void size = 0.22*d for all four conditions

Primary Control Sieve = 0.22 x NMAS


Diameter = NMAS
Average Void Size = 0.22 x NMAS
Primary Control Sieve ≈ 0.22 x NMAS

Primary Control Sieve

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Mixture NMAS	NMAS x 0.22	Primary Control Sieve
37.5mm	8.250mm	**9.5mm**
25.0mm	5.500mm	**4.75mm**
19.0mm	4.180mm	**4.75mm**
12.5mm	2.750mm	**2.36mm**
9.5mm	2.090mm	**2.36mm**
4.75mm	1.045mm	**1.18mm**

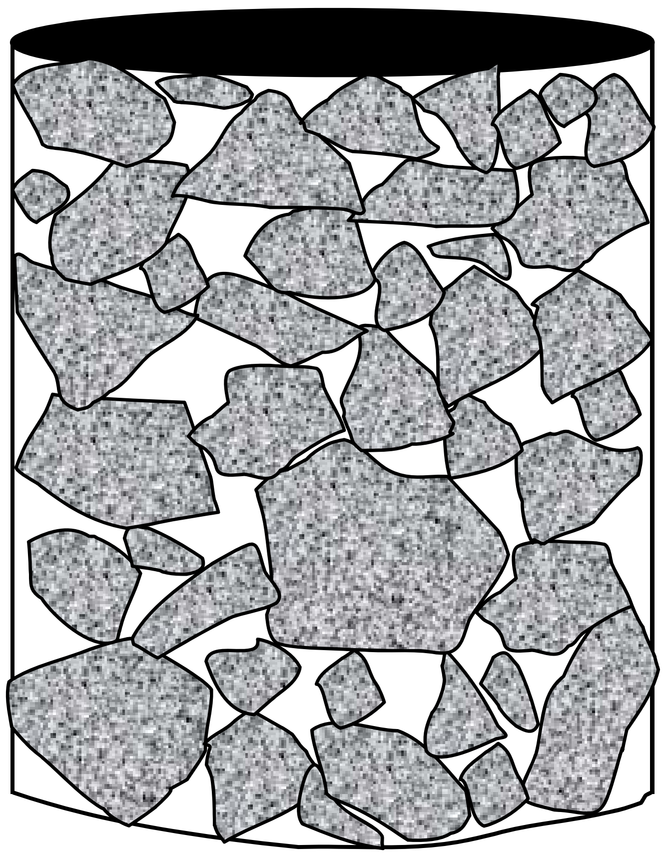
PCS determines the **break** between **Coarse** and **Fine** in the combined blend **and** if a **given** aggregate is a **CA** or **FA**

Bailey Method Mix Types

The Bailey Method defines the mix type by volume of CA in the mix.

Laboratory unit weight tests are conducted to determine the volume of coarse and fine aggregate stockpiles.

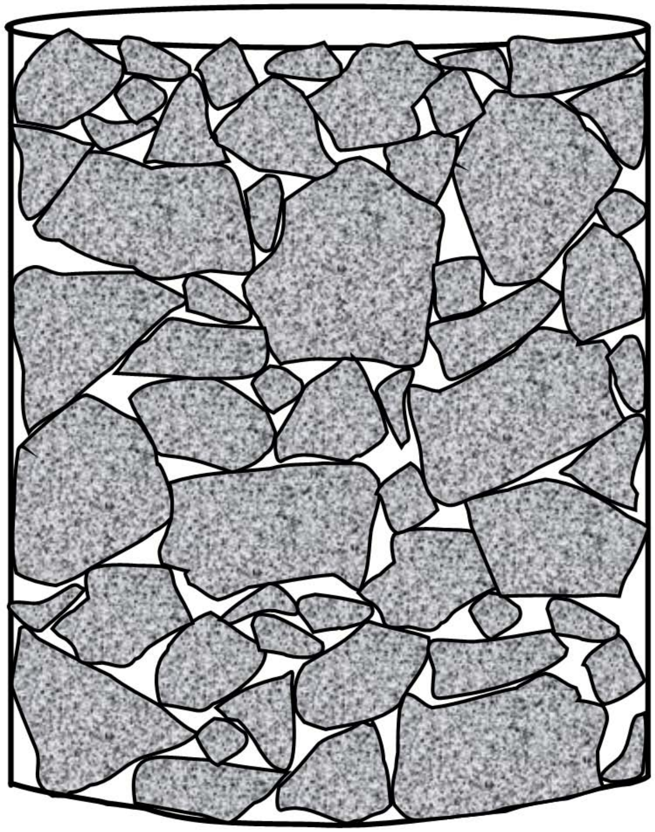
Loose Unit Weight - CA



AASHTO T19

- **NO** compactive effort applied
- **Start** of particle-to-particle contact
- Use **shoveling** procedure
- Strike off ~ level
  - Careful **not** to compact
- Determine **LUW**
  - Kg/m^3 or $lbs./ft^3$
- Determine **volume** of **voids**

Rodded Unit Weight - CA



AASHTO T19

- **With** compactive effort applied
- **Increased** particle-to-particle contact
- **Three** equal lifts using **shoveling** procedure
- Rod **25** times per lift
- Strike off ~ level
  - Careful **not** to compact
- Determine **RUW**
  - Kg/m^3 or $lbs./ft^3$
- Determine **volume** of **voids**

Fine Aggregate Unit Weight Tests

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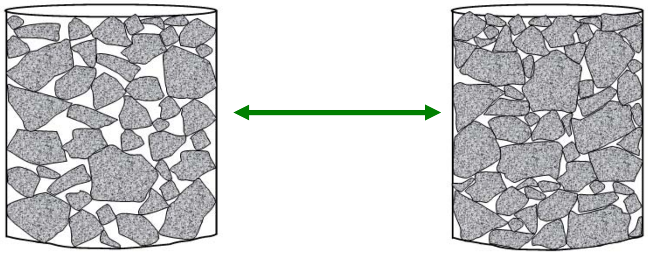
- Representative **oven dried** sample
  - Gradation, shape, specific gravity and absorption
- Use **entire** gradation on well split materials
  - No material removed by sieving
  - Different than FAA
- **Unit Weight's** are **required**
  - Kg/m^3 or lbs./ft^3
- **Dry** Bulk Specific Gravity (**Gsb**)
  - **May** be used to determine the **volume** of **voids**
- Mold volume ~ 0.00094 m^3 (~ 1/30th ft^3)

AASHTO T 19

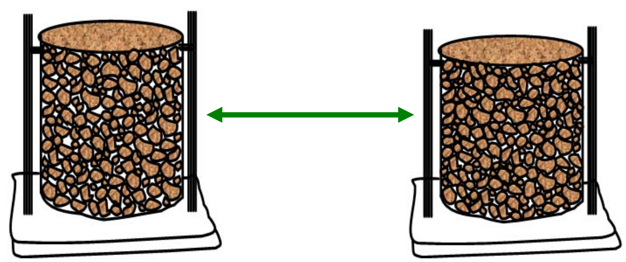
CA - Rules of Thumb

- **LUW** voids normally range from 43-49%
- **RUW** voids normally range from 37-43%
- 4-8% between **Loose** and **Rodded** conditions
  - Example:
    - **LUW** voids = 46.2%
    - **RUW** voids = 40.2%
    - Difference = 6.0%



FA - Rules of Thumb

- **LUW** voids normally range from 35-43%
- **RUW** voids normally range from 28-36%
- 4-8% between **Loose** and **Rodded** conditions
  - Example:
    - **LUW** voids = 38.4%
    - **RUW** voids = 32.2%
    - Difference = 6.2%



What's Next?…………

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- Normal Agg Information
  - Gradation, specific gravity, etc.
- **U**nit **W**eight Tests
  - Completed for **CA**
  - Completed for **FA**
- Where do you start?
  - Determine Mix **TYPE**

Why is mix type Important ?

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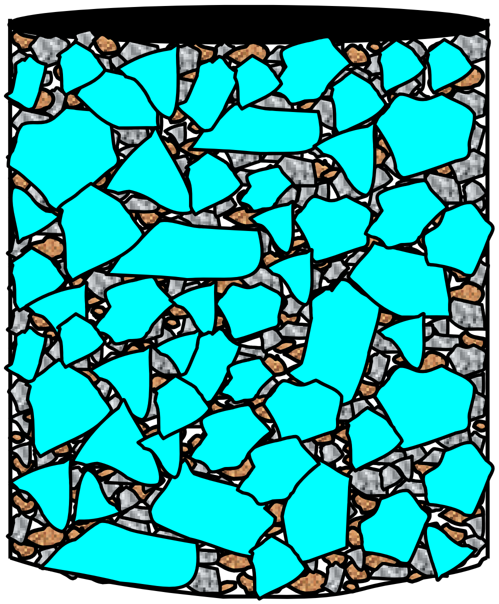
The Bailey Method has the ability to estimate both the direction of VMA change and rate of VMA change in mixtures, due to gradation movement.

The rate of change and direction of change is different for each type of mix!!!

How can mix type change?



- A mix may start out as a CG 19.5 mm mix
- As rock is removed it will become a 19.5 mm FG mix
- As we continue to remove large stone it may become a 12.5 mm CG Mix

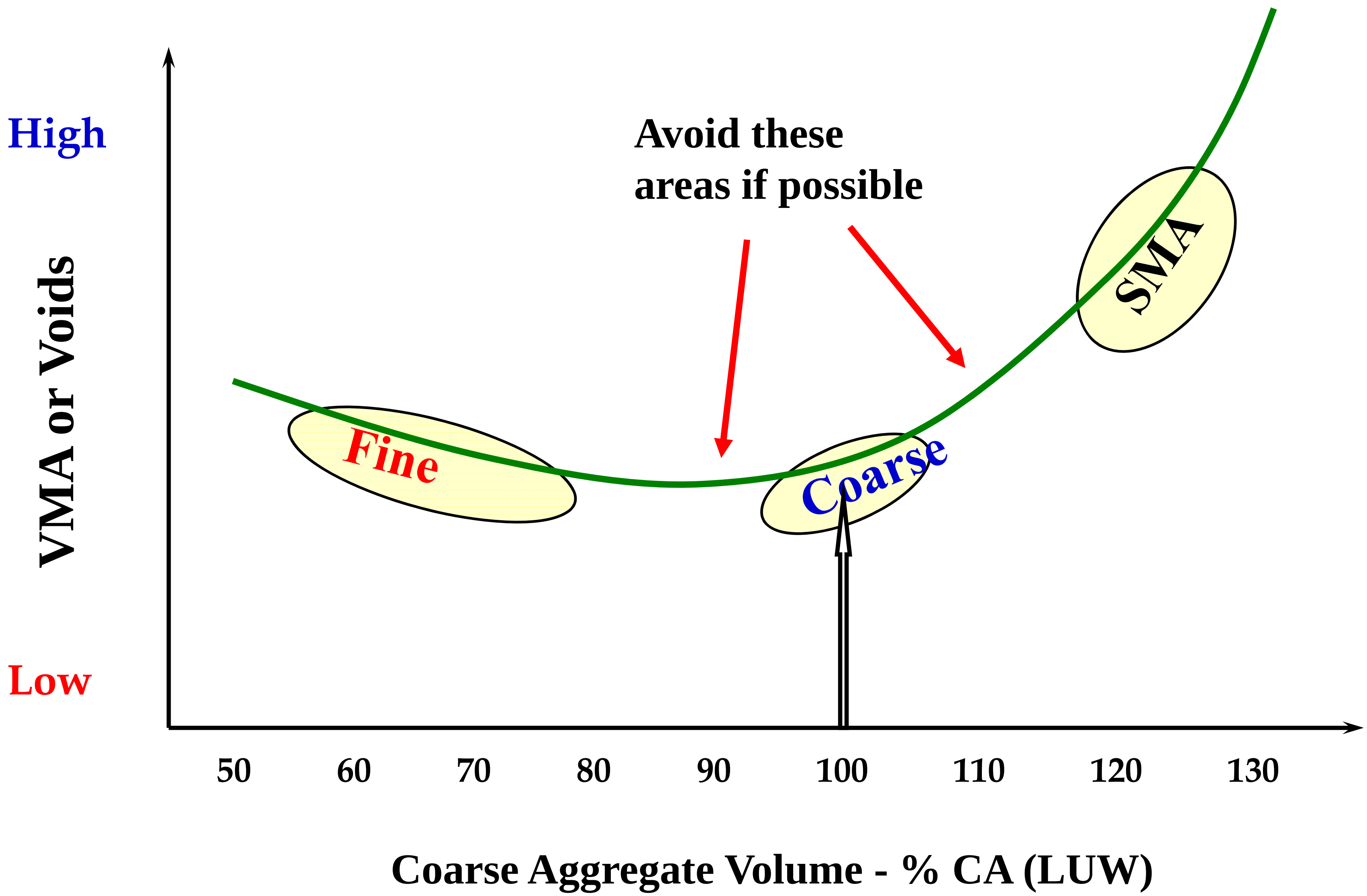
Bailey Method Perspective

- **<u>Fine-graded mix</u>** is a dense-graded mix that has a CA volume less than the amount needed to establish CA Interlock - which means the coarse fraction is spread apart and floating in the fine aggregate

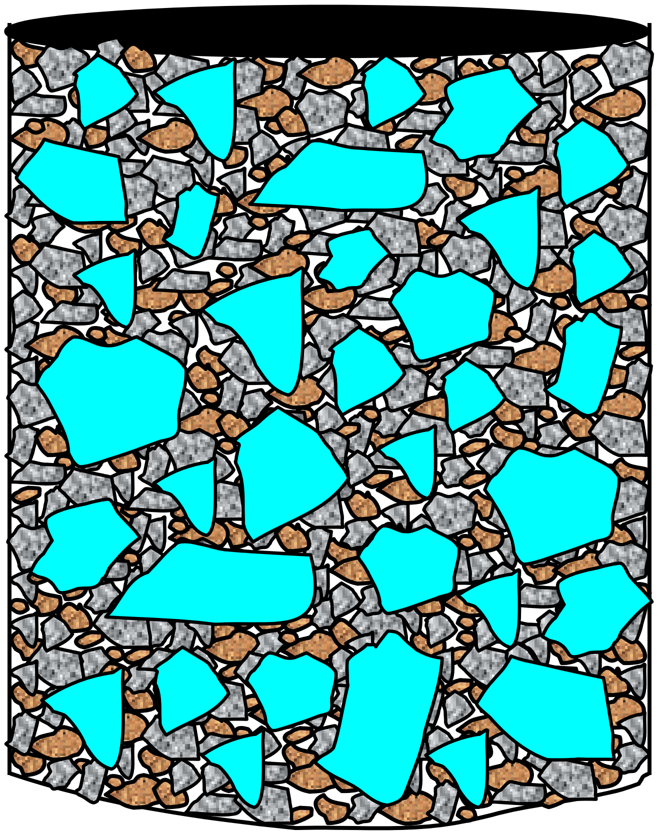
- A **<u>Coarse-graded mix</u>** is a dense-graded mix that has a sufficient amount of CA volume to initiate CA interlock.

- A **<u>Stone Matrix Asphalt (SMA</u>**) is a gap-graded mix that is essentially all CA and uses the coarse fraction skeleton to carry the load.

VMA or Voids vs. CA Volume



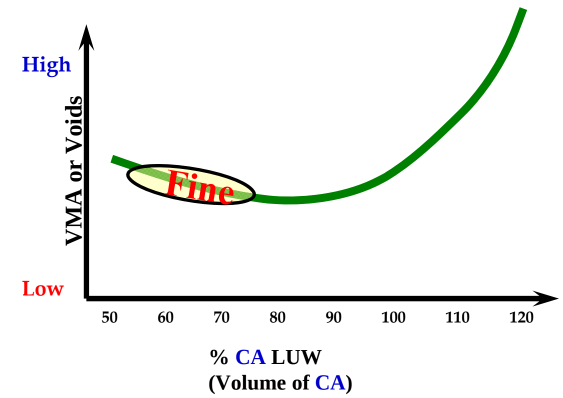
Fine-Graded Mixes

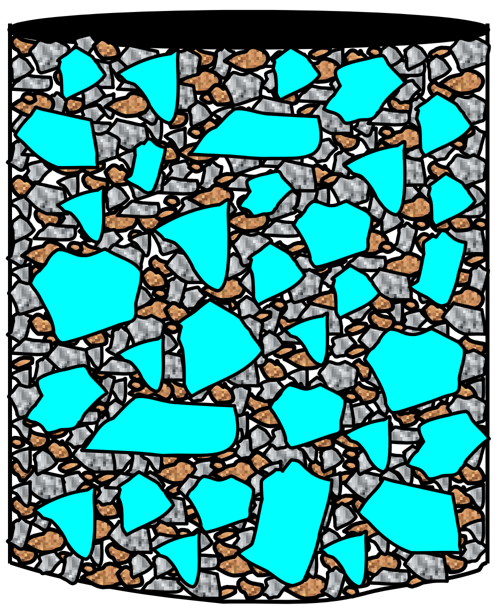


- **CA Volume < LUW**
- **% CA < 85% CA_{LUW}**
- **Little to No** particle-to-particle contact of **CA**
- **Fine** fraction carries most of the load
- Increased amount of **FA** support needed

Fine Graded Mix Characteristics

- Stay **below 85% CA LUW**
  - Ensure **FA** volume **exceeds** **CA LUW** voids
  - Closest to Max Density line, **lowest** VMA
- **As the %CA LUW decreases**
  - **VMA Increases**
    - provided **fine** fraction characteristics remain constant
  - "Floating" **coarse** particles are replaced with multiple **fine** particles
    - **Increased number** of particles to orient
- **6% change in % Passing PCS ≅ 1% change in VMA or Voids**





Coarse-Graded Mixes

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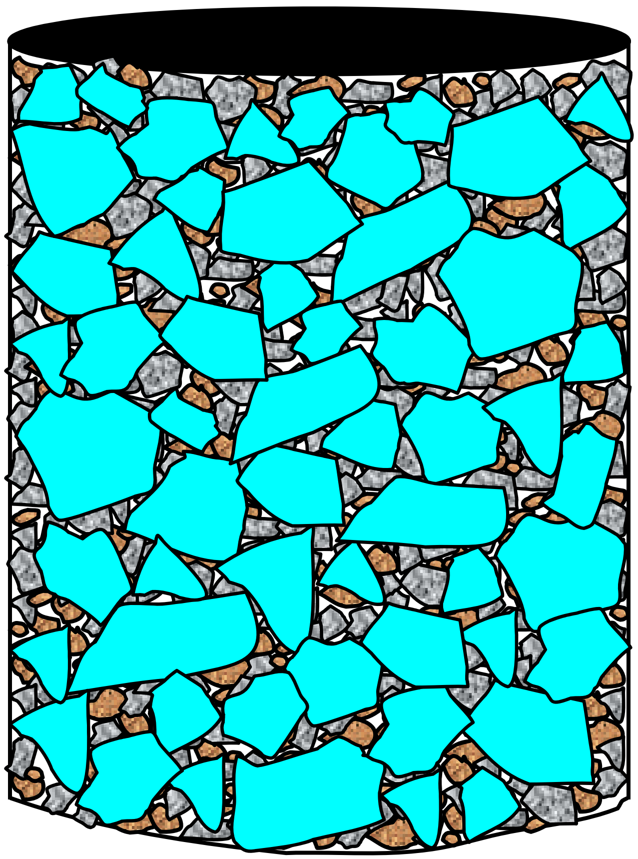

- **CA Volume ≈ LUW**
- **95 - 105% CA LUW**
- **Some** particle-to-particle contact of **CA**
- **Coarse <u>and</u> Fine** fractions carry load
- Reduced **FA** strength needed

Coarse Graded Mix Characteristics

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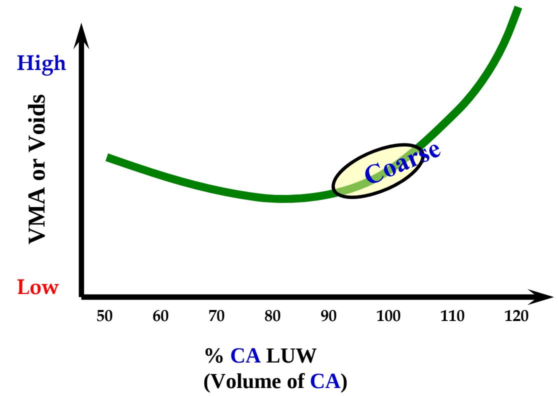

- **95 - 105% CA LUW – Target 100%**
  - Most compactible blend **~ 95% CA LUW**
    - Closest to Max Density line, **lowest** VMA
    - May vary **in and out** of **CA** interlock
- **Increasing % CA LUW** towards **105%**
  - **Increases VMA**
    - **Increases CA** interlock and **decreases** compaction of **FA**
  - Higher type mixes
    - **Increases compactive effort** required in **field**
    - **Increases degradation** susceptibility
- **95 – 105% CA LUW ≅ 4% change in PCS ≅ 1% change in VMA or Air Voids**

Principle # 2 - Coarse Aggregate Ratio

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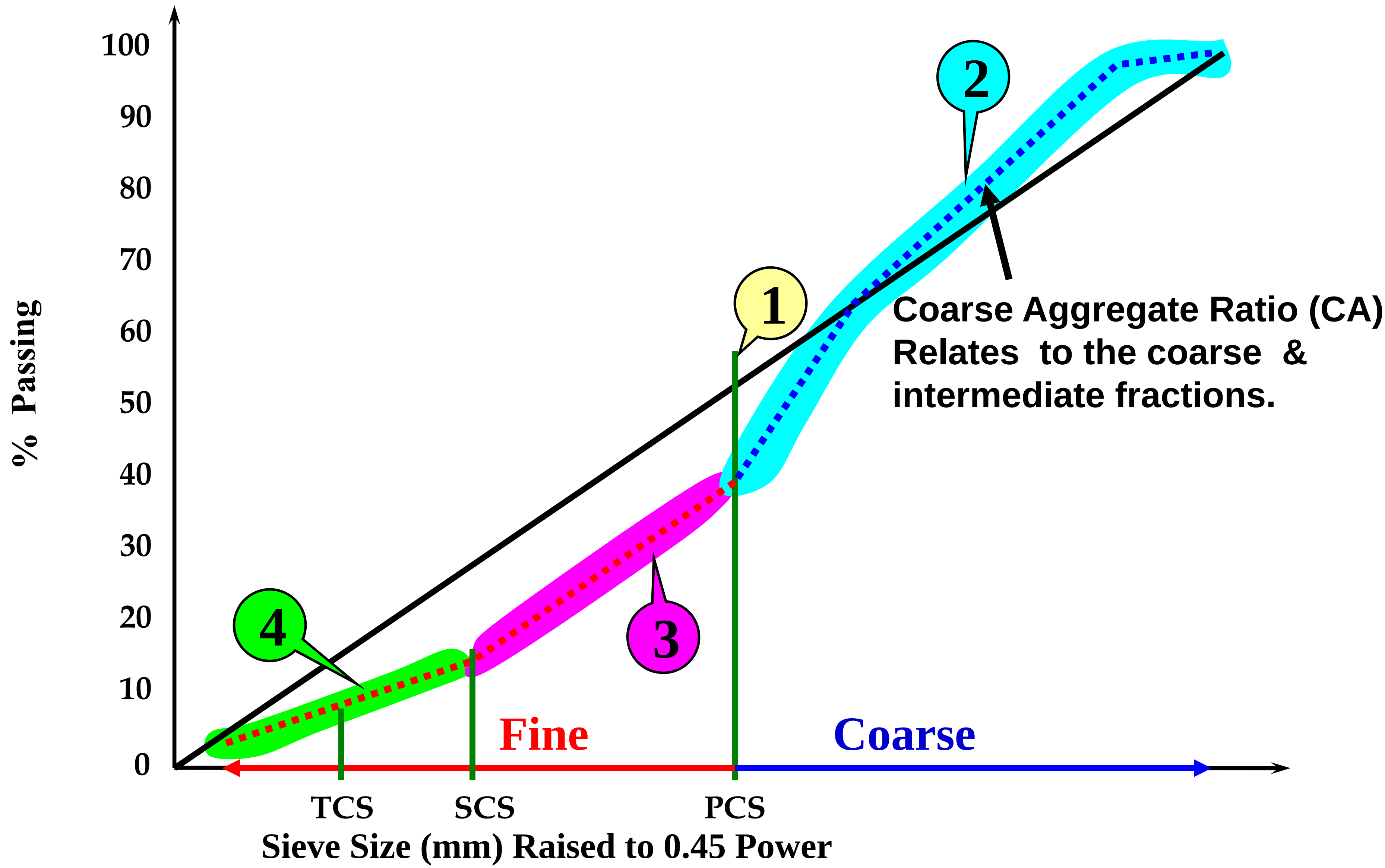

CA Ratio Example

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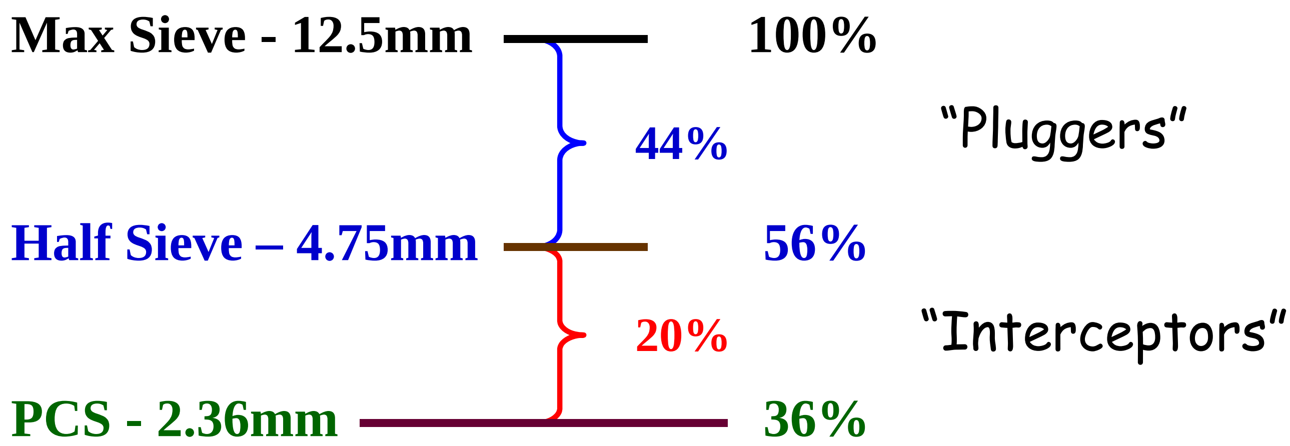
9.5mm NMAS **Coarse**-Graded Mix



$$\text{CA Ratio} = \frac{\%\ \text{Half sieve} - \%\ \text{PCS}}{100\% - \%\ \text{Half sieve}} = \frac{20}{44} = 0.455$$

NMAS	37.5	25.0	19.0	12.5	9.50	4.75
Half Sieve	19.0	12.5	9.50	6.25	4.75	2.36
PCS	9.50	4.75	4.75	2.36	2.36	1.18

"Interceptors" increase VMA by reducing the packing achieved in Coarse fraction, which in turn reduces the packing achieved in the Fine fraction

CA Ratio Effects
Coarse Graded Mixes

CA Ratio = **<u>Intermediate Chips</u>** / **Large Coarse Particles**

- As the **CA** Ratio **<u>increases</u>**, **VMA** **<u>increases</u>**
  - **Coarse** fraction **below** the **"Half"** sieve, **decreases** the compaction of **Coarse** and **Fine** fractions

- As the **CA** Ratio **approaches** the **high** end of the range suggested for the given **NMAS (see next slide)**
  - **Coarse** fraction becomes "**balanced**" and neither sized material **controls** the **<u>overall</u>** **Coarse** fraction

- As the **CA** Ratio **exceeds** the **high** end of the range suggested for the given **NMAS (see next slide)**
  - **Coarse** fraction **below** **"Half"** sieve begins to **control** **<u>overall</u>** **Coarse** fraction and **<u>reduce</u>** the **Coarse** fraction **void <u>size</u>**

0.20 change ≅ **1%** change in **VMA or Voids**

CA Ratio Guidelines

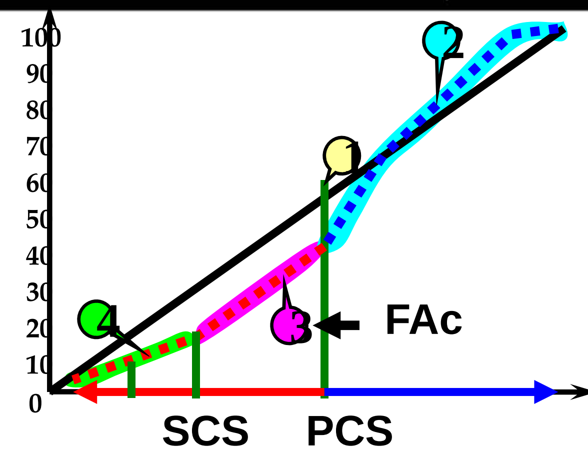
Coarse-Graded Mixes

$$CA_{Ratio} = \frac{\text{Intermediate Chips}}{\text{Large Coarse Particles}}$$

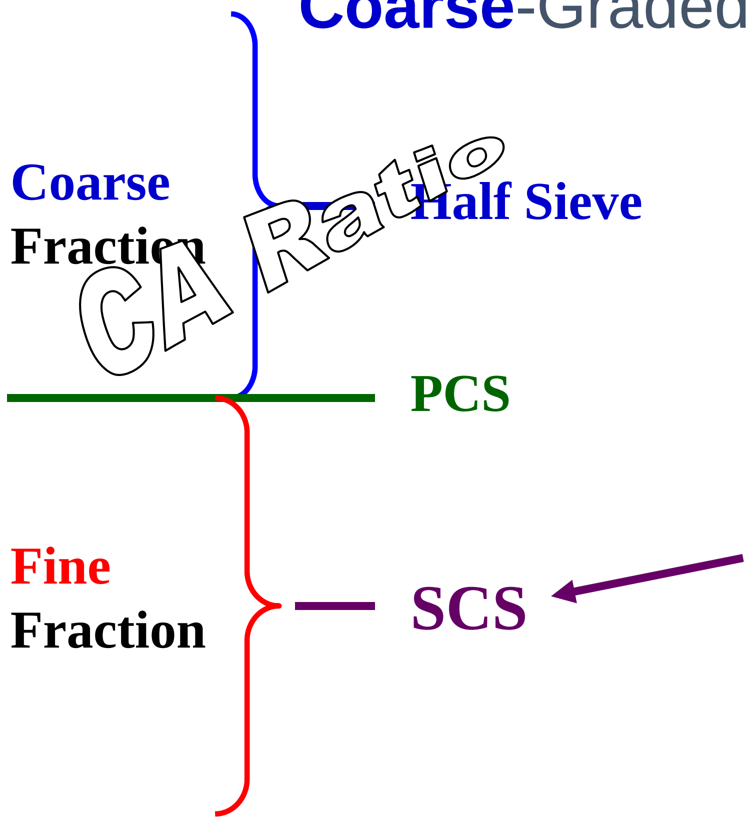
- Ratio **increases** with **NMAS** due to wider range of "**Coarse**" sizes (**plus PCS**)
- Ratios **outside** these suggested ranges **may** work, **but**:
  - **Low** ratios are more **susceptible** to **segregation**
  - **High** ratios are more **difficult to compact** in the **field**

NMAS	37.5mm	25.0mm	19.0mm	12.5mm	9.5mm	4.75mm
CA Ratio	0.80–0.95	0.70–0.85	0.60–0.75	0.50–0.65	0.40–0.55	0.30–0.45

Principle # 3 - Fine Aggregate Coarse Ratio (FAc)



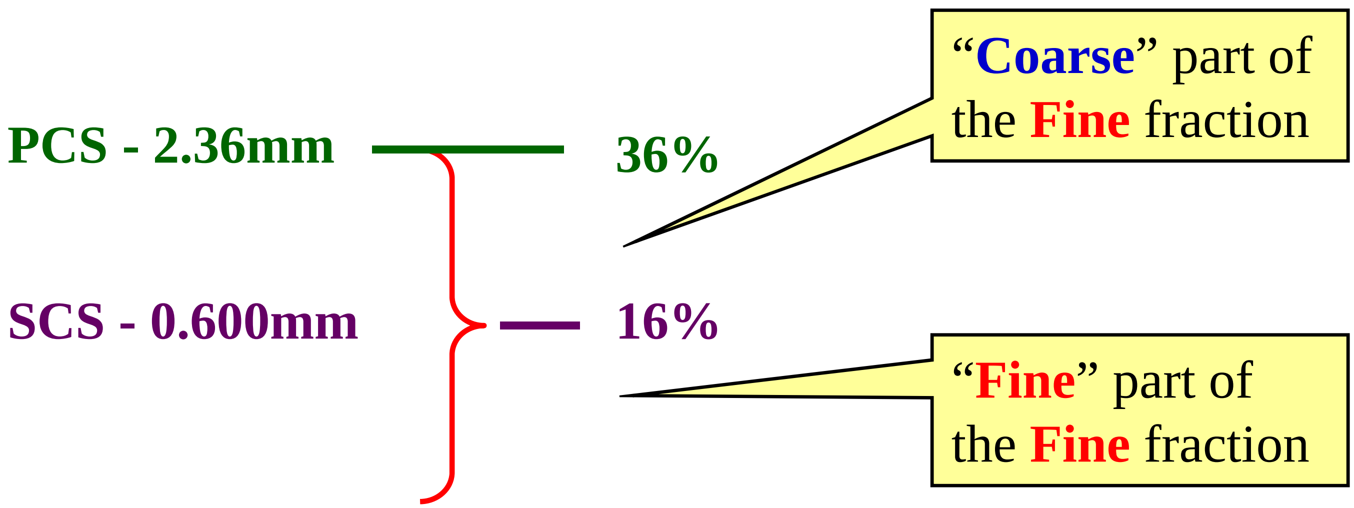
Coarse-Graded Mixes



- **Fine** Fraction:
  - Contains material that **will** fit into the **voids** it creates
- **Secondary Control Sieve (SCS)**
  - View **fine** fraction as a "blend"
  - New **coarse** and **fine** break
  - **SCS** = **0.22 x PCS**
- **PCS** ***generally*** serves as the maximum **and** NMAS of overall **fine** fraction

FA_c Example

9.5mm NMAS **Coarse**-Graded Mix



$$FA_c \text{ Ratio} = \frac{SCS}{PCS} = \frac{16}{36} = 0.444$$

FA_c Characteristics

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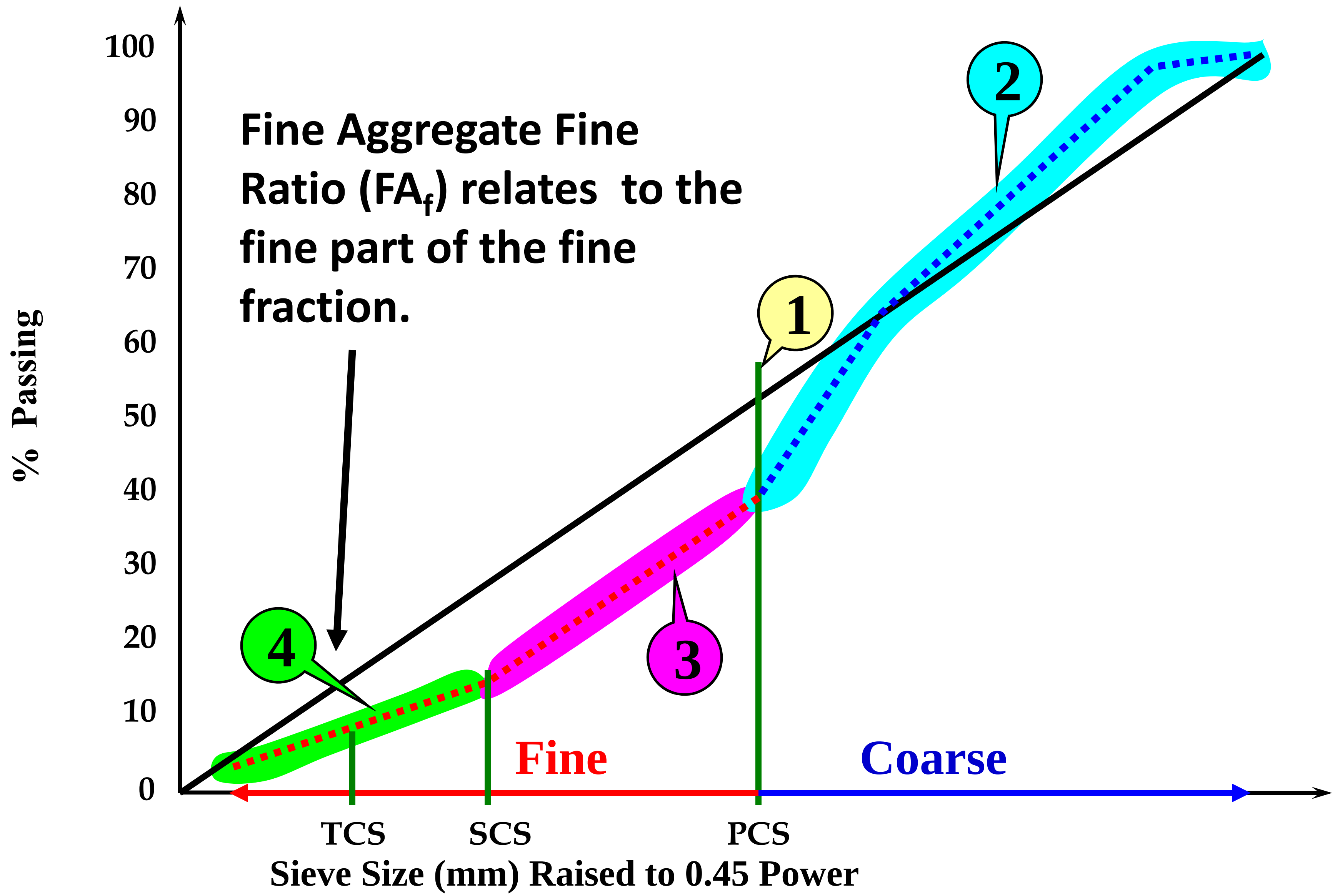
Coarse-Graded Mixes

- As the FA_c Ratio increases up to ~0.55, VMA decreases
- As the FA_c Ratio increases beyond ~0.55, VMA increases
- **FA_c Ratio range ~ 0.35 - 0.50**
- **0.05** change ≅ **1%** change in **VMA or Voids**

$$FA_c \text{ Ratio} = \frac{SCS}{PCS}$$

PCS	SCS
9.50	2.36
4.75	1.18
2.36	.600
1.18	.300

Principle #4 – FA_f Ratio



Fine Fraction Evaluation - FA_f Ratio

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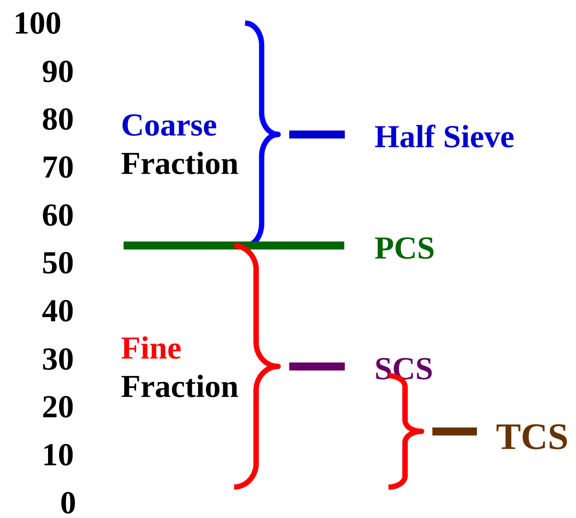
Coarse-Graded Mixes

- FA_f Ratio = $\dfrac{\% \text{ TCS}}{\% \text{ SCS}}$



Where:

% **TCS** = percent passing the **TCS** sieve

(0.22 x SCS)

% **SCS** = percent passing the **SCS** sieve

PCS	SCS	TCS
9.50	2.36	.600
4.75	1.18	.300
2.36	.600	.150
1.18	.300	.075

FA_f Example

9.5mm NMAS **Coarse**-Graded Mix

SCS - 0.600mm — **16%**

TCS - 0.150mm — **7%**

"**Coarse**" part of the "**Fine**" part of the **Fine** fraction

"**Fine**" part of the "**Fine**" part of the **Fine** fraction

$$FA_f \text{ Ratio} = \frac{TCS}{SCS} = \frac{7}{16} = 0.438$$

Fine Fraction Evaluation - FA_f Ratio

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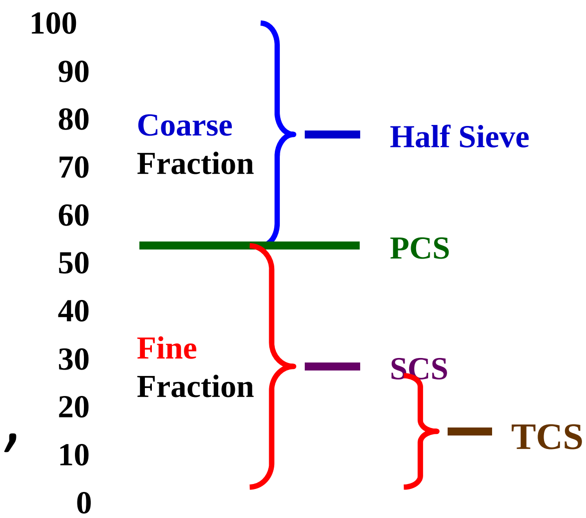
Coarse-Graded Mixes



- As the FA_f Ratio increases up to ~0.55, VMA **decreases**
- As the FA_f Ratio increases beyond ~0.55, VMA **increases**

PCS	SCS	TCS
9.50	2.36	.600
4.75	1.18	.300
2.36	.600	.150
1.18	.300	.075

FA_f Ratio range ~ 0.35 - 0.50

Lower values may be difficult to compact

0.05 change ≅ **1%** change in **VMA or Voids**

$$FA_f \text{ Ratio} = \frac{TCS}{SCS}$$

Combined Blend Evaluation Summary
Coarse-Graded Mixes

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NMAS

Coarse Fraction

Half Sieve = 0.5 x NMPS

PCS = 0.22 x NMPS

Fine Fraction

SCS = 0.22 x PCS

TCS = 0.22 x SCS

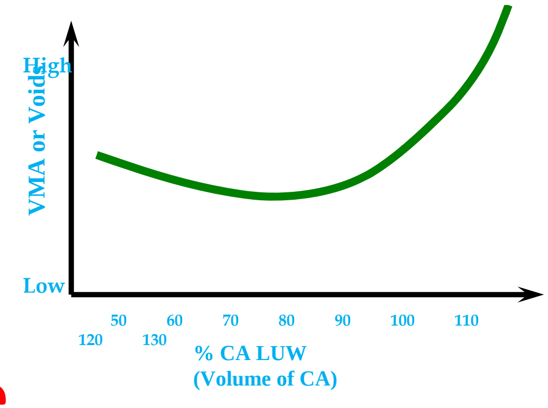
2 — **CA Ratio**

1 — **% CA LUW**

3 — **FA_c Ratio**

4 — **FA_f Ratio**

Combined Blend Evaluation Summary



Coarse-Graded Mixes

- **%CA LUW increase = VMA increase**
  - **4%** change in **PCS** ≅ **1%** change in **VMA or Voids**
- **CA Ratio increase = VMA increase**
  - **0.20** change ≅ **1%** change in **VMA or Voids**
- **FA_c Ratio increase = VMA decrease**
  - Up to a value of **~0.55**, then VMA begins to **increase**
  - **0.05** change ≅ **1%** change in **VMA or Voids**
- **FA_f Ratio increase = VMA decrease**
  - Up to a value of **~0.55**, then VMA begins to **increa**
  - **0.05** change ≅ **1%** change in **VMA or Voids**

Has the most influence on VMA or Voids

Ratio Ranges Summary
Coarse-Graded Mixes

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NMAS	37.5mm	25.0mm	19.0mm	12.5mm	9.5mm	4.75mm
CA Ratio	0.80–0.95	0.70–0.85	0.60–0.75	0.50–0.65	0.40–0.55	0.30–0.45
FA_c Ratio	0.35 – 0.50					
FA_f Ratio	0.35 – 0.50					

Ranges shown to provide a *starting* point. Review *acceptable* existing mixes to determine a narrower range to target for future designs.

Questions?

Safety First…

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WMA Benefits in Cold Weather

Bob Siffert – Technical Marketing Manager, Evotherm

Benefits of Chemical WMA in Cold Weather

1. WMA in AK?
2. Improved compaction
3. Longer season
4. Longer hauls
5. Reduced thermal segregation
6. Longer binder life
7. Liquid anti-strip replacement
8. Maintain RAP usage

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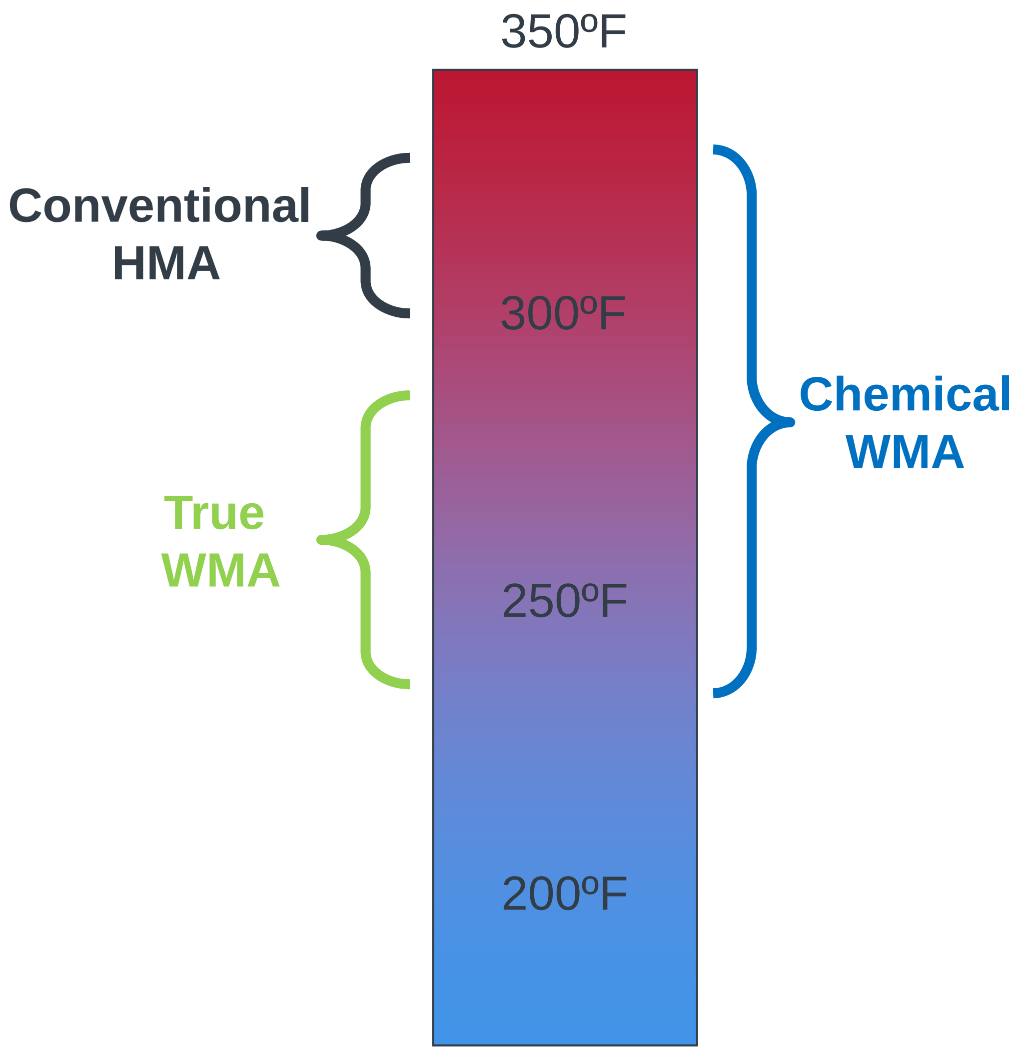
WMA in AK?

Production Temperature Ranges



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Improved Compaction

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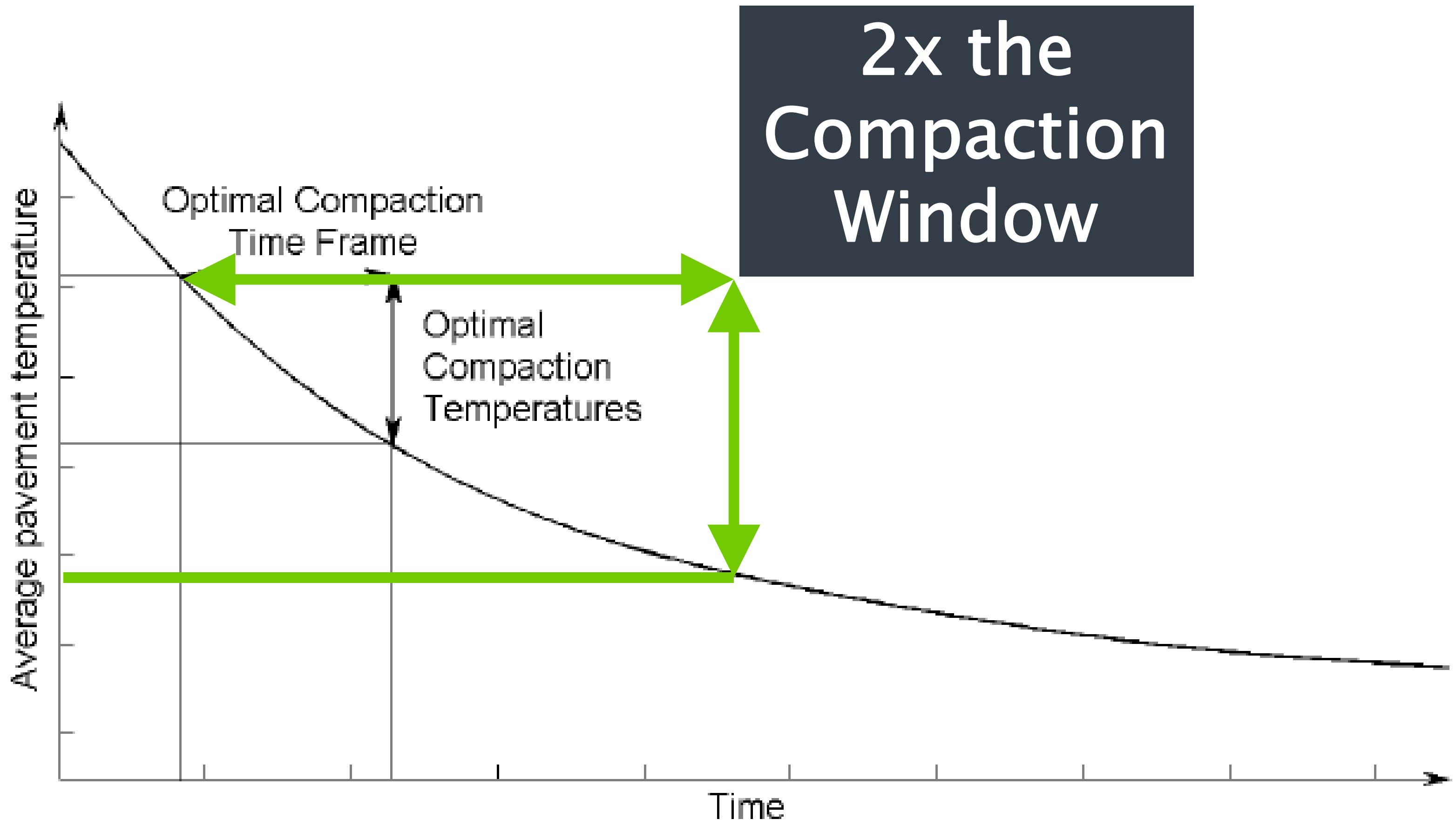
Increasing the Compaction Window



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Compaction Aid: Wisconsin

Air temperature of 22°F with winds at 5 mph.

SHUTDOWN…

- HMA failing densities (PG64-22).

ADD CHEMICAL WMA…

- Achieved density and full bonus.

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Longer Season, Longer Days

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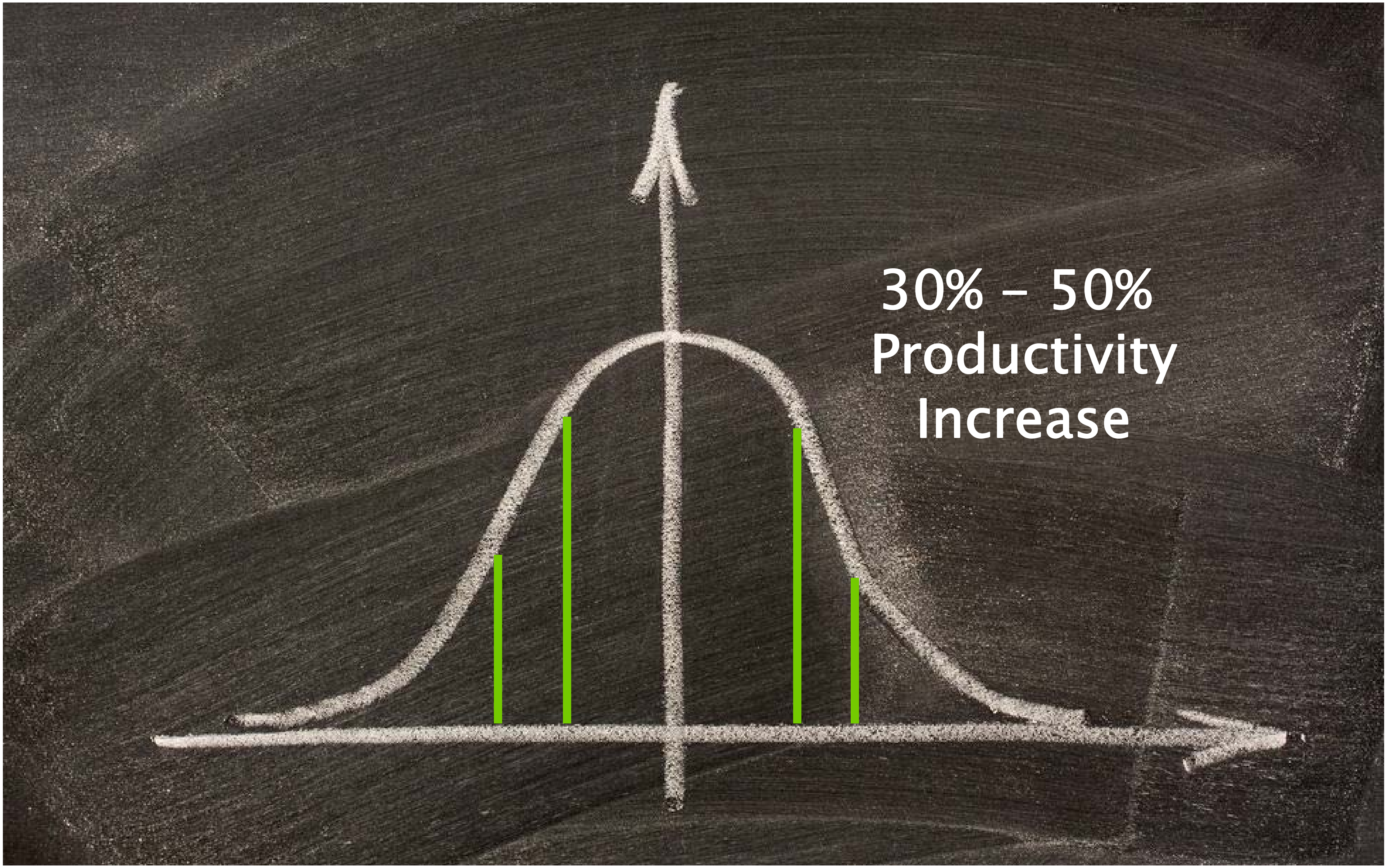
Longer Season, Longer Days



Early start: Lake Tahoe

- US 50 Echo Summit (near south Lake Tahoe) @ 7,382 ft
- Cold mornings with lows in the 20s
- 1½—2 hour haul (from Truckee on the north shore)
- Mix temperatures behind the screed of 210°F
- Achieved density with less effort (no falling rocks)

PG64-28, 15% RAP

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Benefits of using chemical WMA

Early Start

- Getting a jump on the competition
- Continuing large projects

Late Season

- Finishing jobs
- Squeezing in extra jobs
- Emergency paving

Longer Day

- Starting earlier in the day
- Minimizing crew wait times
- Increasing production

Longer Haul

- Expanding market reach
- Additional bid opportunities
- Handles unexpected wait times

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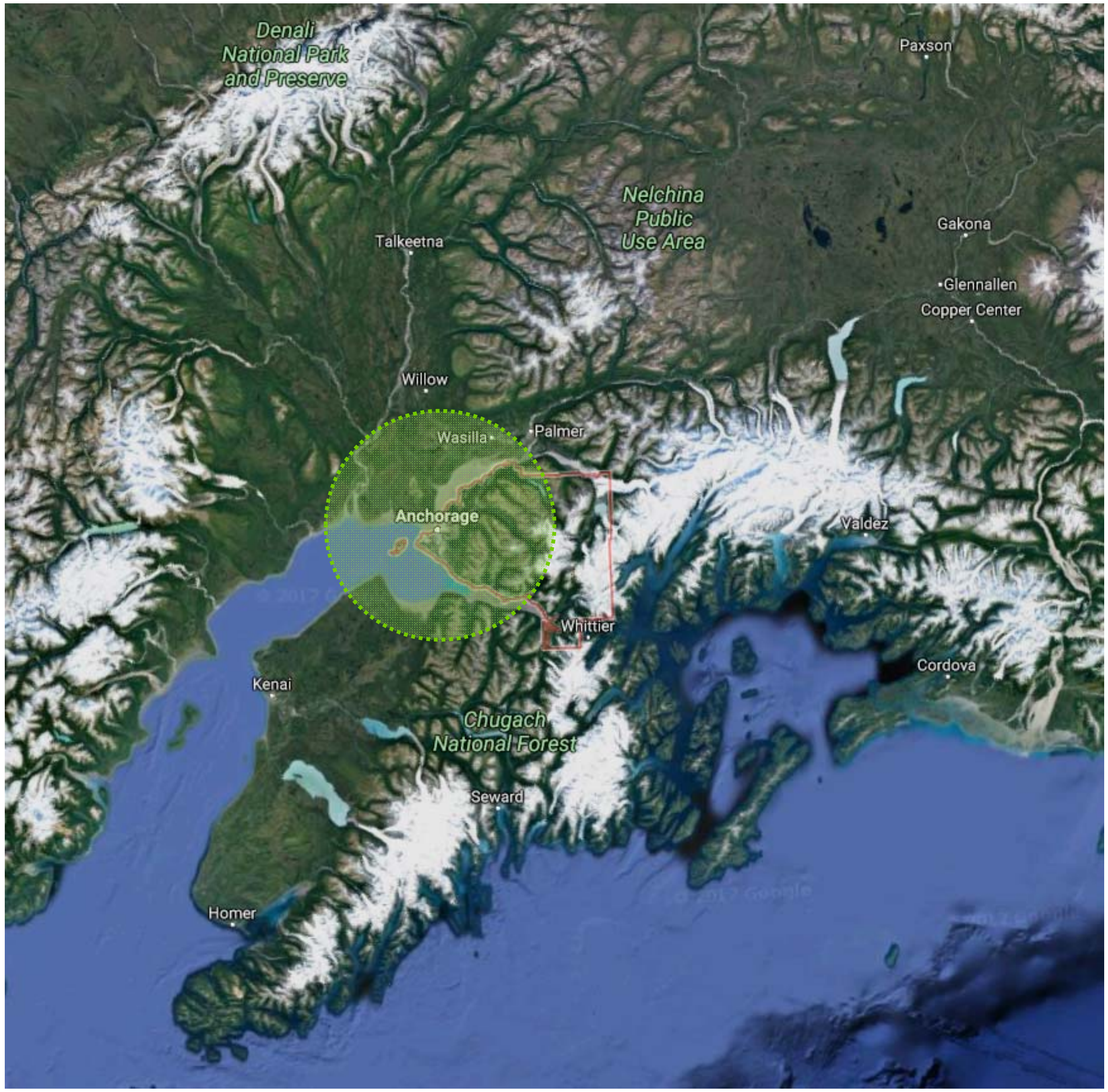
Longer Hauls

Reach with HMA...



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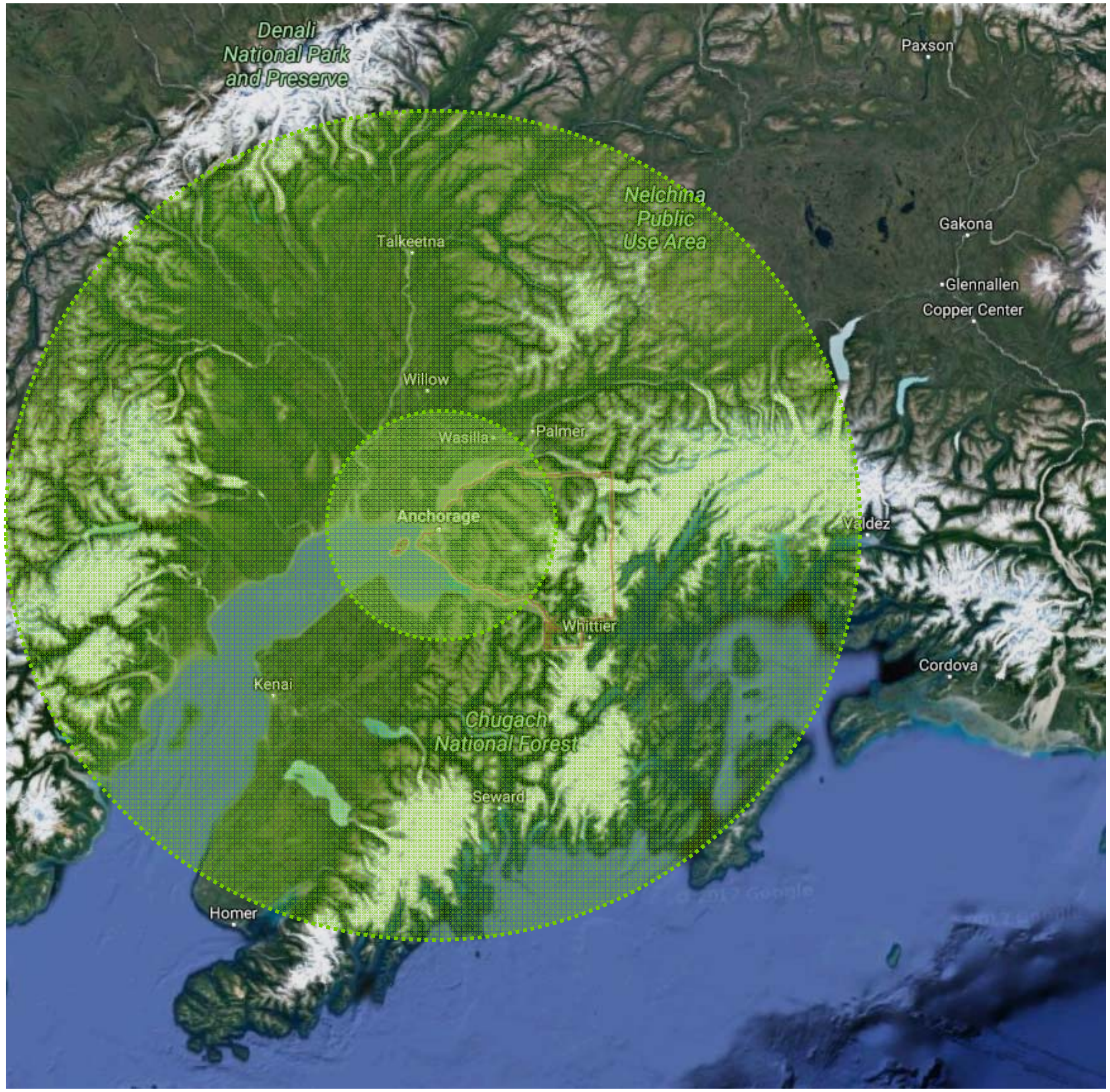
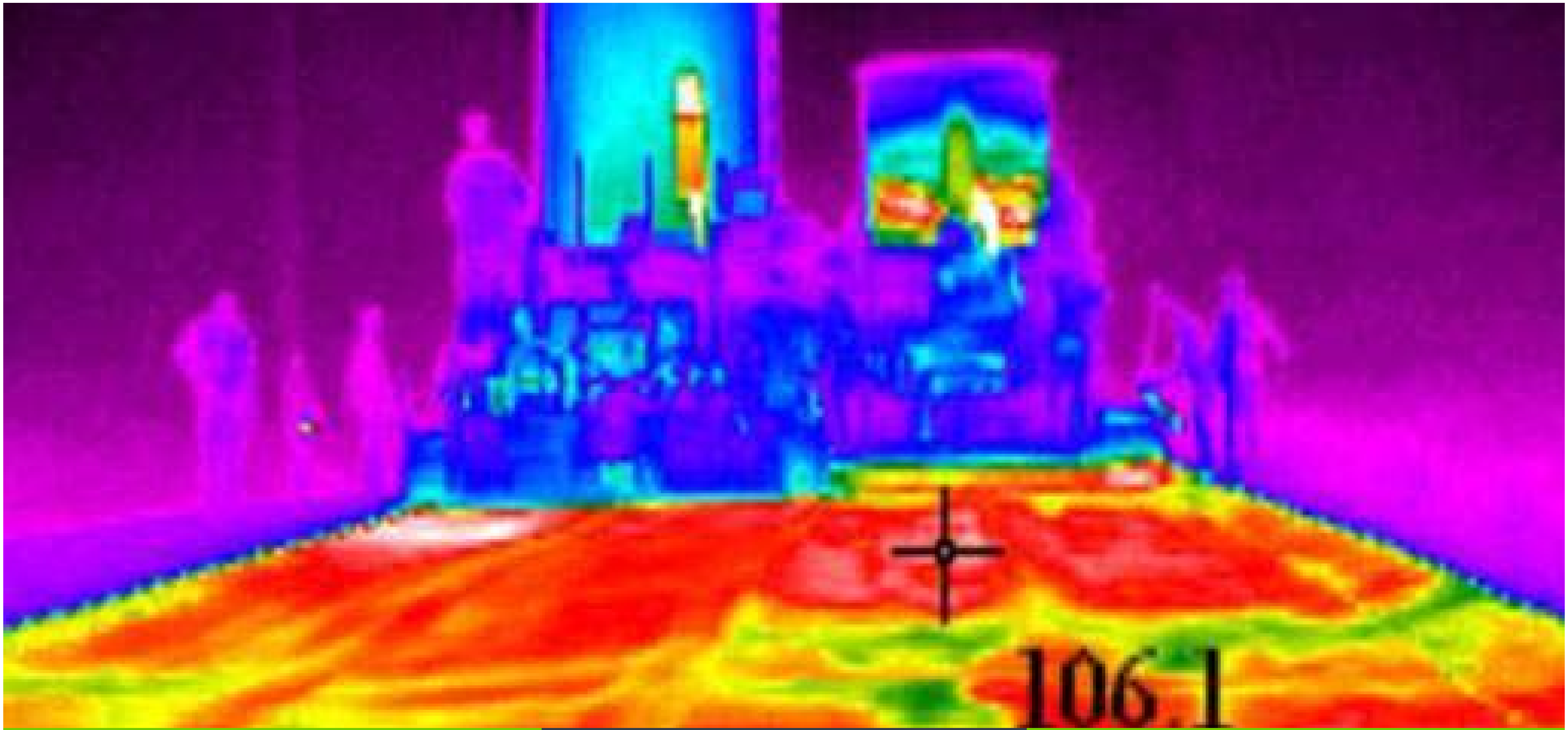
Reach with Chemical WMA…





Reduced Thermal Segregation

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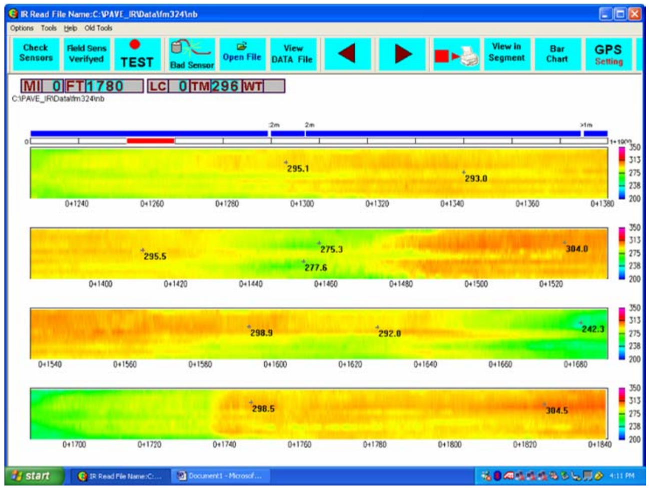
Reduced Thermal Segregation

High Production Temps



Lower Production Temps

More consistent temperature

↓

Reduces "hot/cold" spots

↓

Improved compaction

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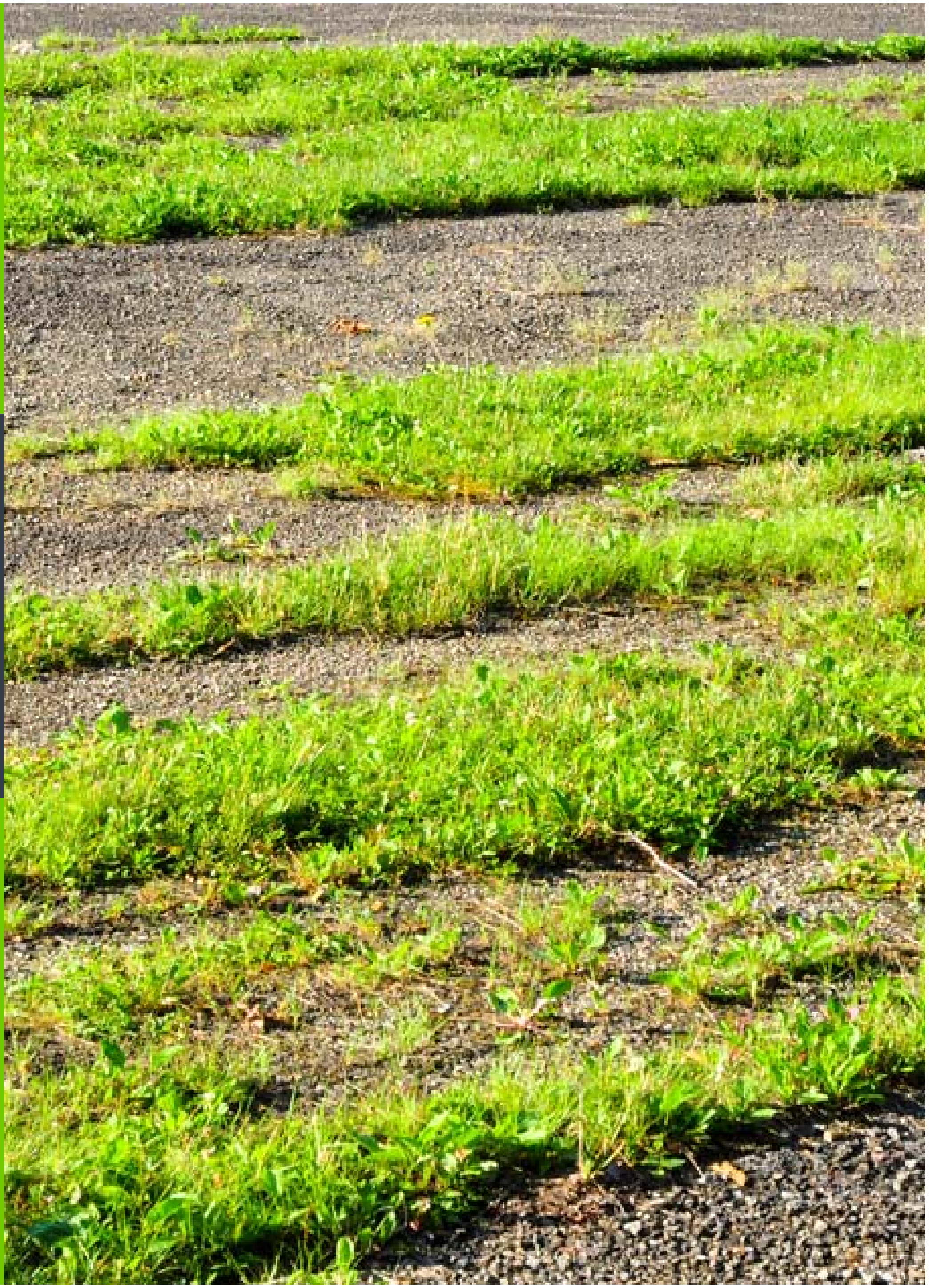
Longer Binder Life



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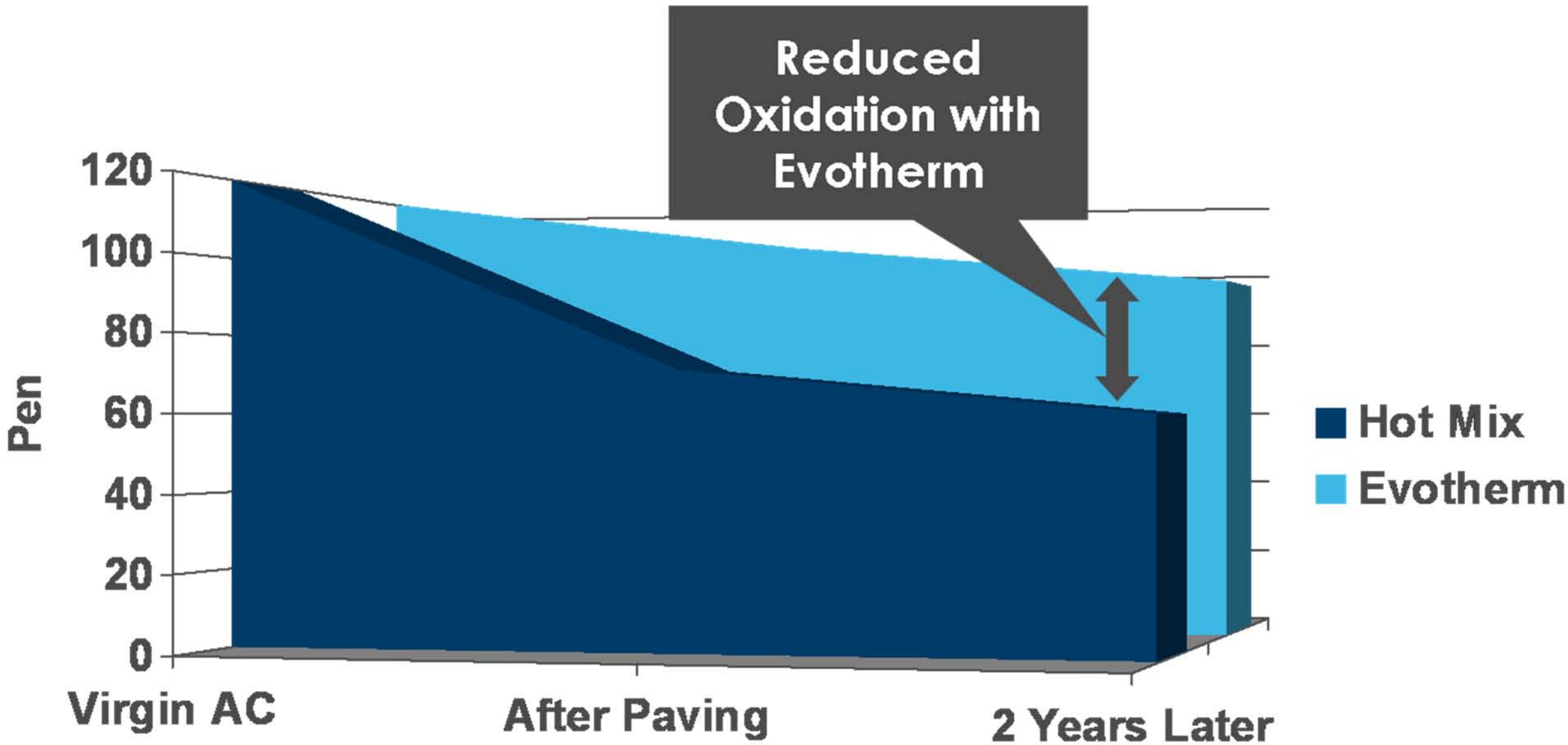
Binder hardening



Liquid Anti-Strip Replacement

Maintain Use of RAP

Increased recycled content: Chicago

PG 58-22

37 percent RAP

5 percent RAS

- ✓ Using high amounts of RAP and RAS even in cold temperatures like 25ºF
- ✓ Reduced equipment wear and tear by lowering the production temperature to 325ºF from 365ºF (winter production temps)
- ✓ Better workability
- ✓ SAVINGS from lower asphalt content

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Questions?

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WARM MIX ASPHALT TECHNOLOGY

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Safety First…

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AN UPDATE ON ASPHALT MATERIAL TESTING

Alaska Summit November 2018

OUTLINE

- Goal for more testing
- Anti-strip test
- Balanced Mix Design
- 40 Hour PAV
- Glover-Rowe Parameter
- Delta Tc
- MSCR
- True Grade
- Performance testing
- Summary

GOALS OF FHWA ETG

- Fatigue is a mix cracking issue
  - Structural affects
  - Gradation affects
  - Binder volume affects
  - Binder brittleness– this is the only item that a binder specification can address
- Balanced Mix Design

ANTI-STRIP TESTING

- **Hamburg**
- **AASHTO T-283**
- **Boiling Test**

AASHTO T-283

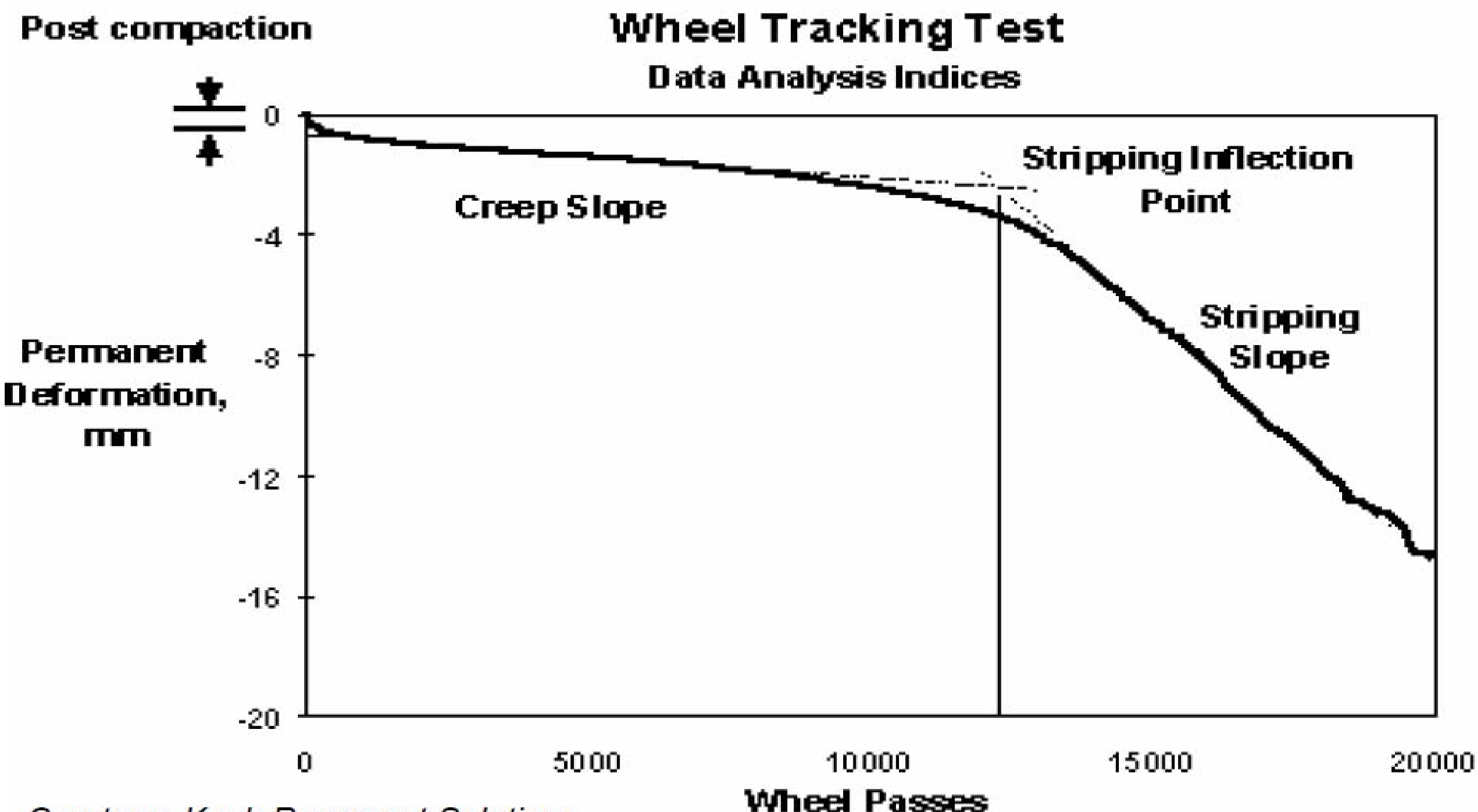
- Standard method in mix designs
- Need special equipment
- Take specimen determine the strength dry and conditioned to get % retained strength
- Large variability in the results
- Have to cut Gyratory specimens to fit

HAMBURG TESTING

- Stripping can be determined at the same time as rutting
- Many states went to Hamburg because they can use gyratory specimens
- Eliminate AASHTO T-283 testing
- Problem is how to determine that inflection point when not very clear
- Study going on to use a calculation, which is done by the machine to determine the inflection point
- Expensive piece of equipment
- Few machines out there

Wheel Tracking Test

Data Analysis Indices



Courtesy, Koch Pavement Solutions

BOILING TEST

- NCDOT Research Project 2014-04 by North Carolina State University[1]
- It is an Alaska test.

[1]Tayebali, Kusam, and Bacchi. An Innovative Method for Interpretation of Asphalt Boil Test. Journal of Testing and Evaluation, ASTM, 2017.

BOILING TEST

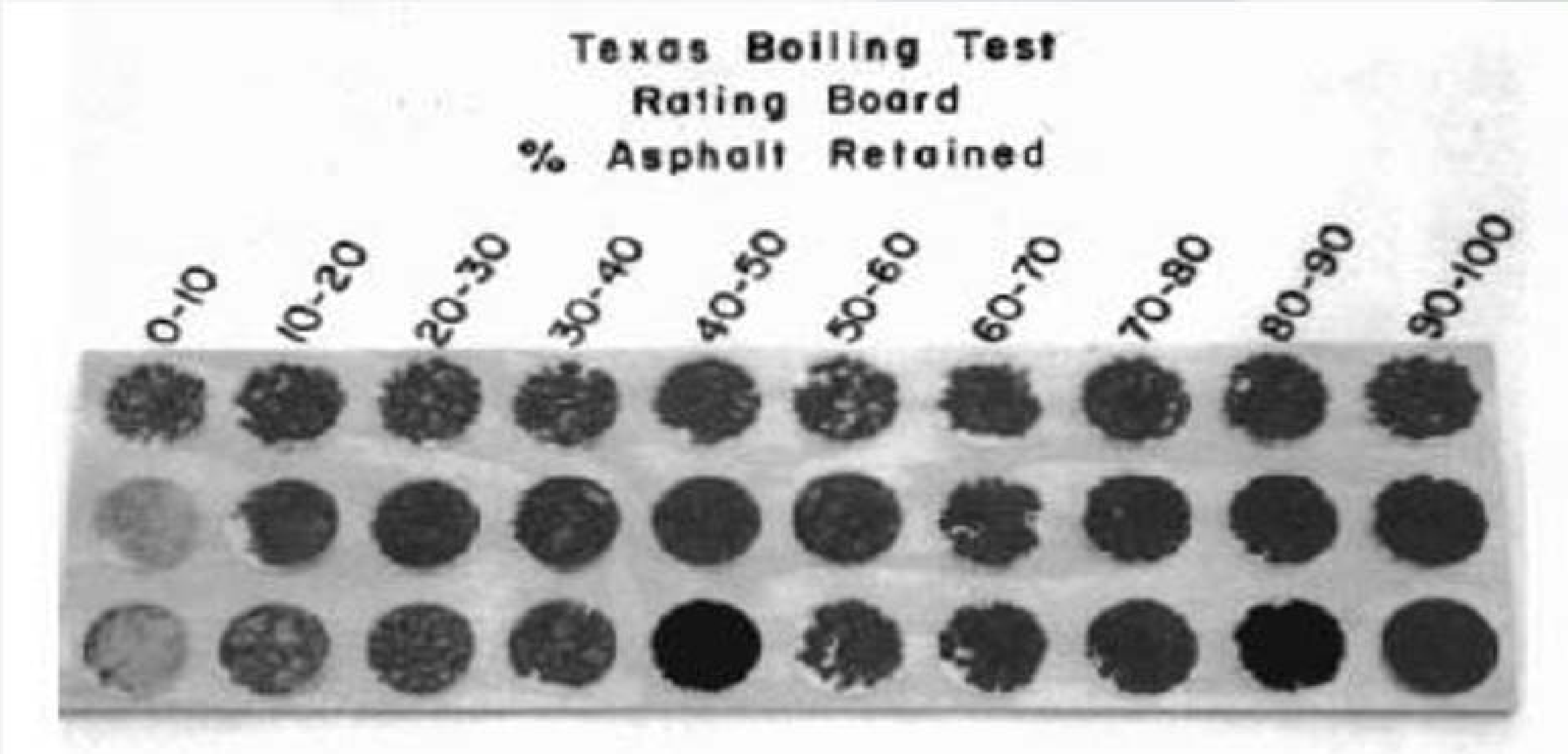
- Simple test anyone could run it in their laboratory
- Easy to improve the method currently in the book
- Make a visual display of a mix with either different degrees of stripping or a pass/fail test
- Contractor could do their own test and include it in the mix design
- There is a piece of equipment that can read the color and then put into a equation

Boil Test
(ASTM D3625)

InstroTek®

Texas Boil Test

(Kennedy, et al. 1984)

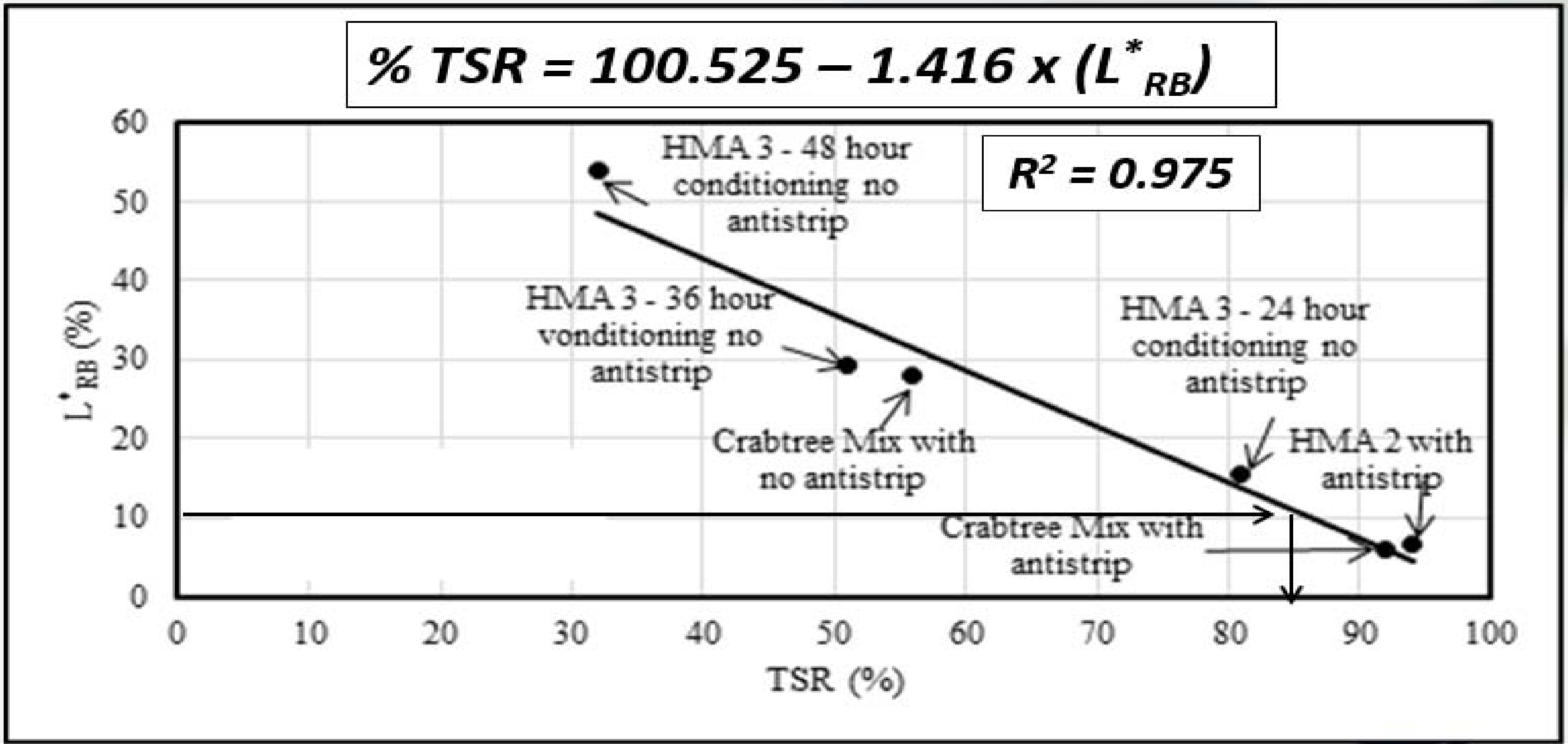


Colorimeter

- ASTM E284 color definition is used as a basis to measure the color index
- L* determines light-dark index (gray scale)

$$L^{*}(\%) = \frac{(Conditioned\ L^{*} - Dry\ L^{*}) * 100}{Dry\ L^{*}}$$

TSR (T283) Prediction



WHAT NEXT IN MIX DESIGN

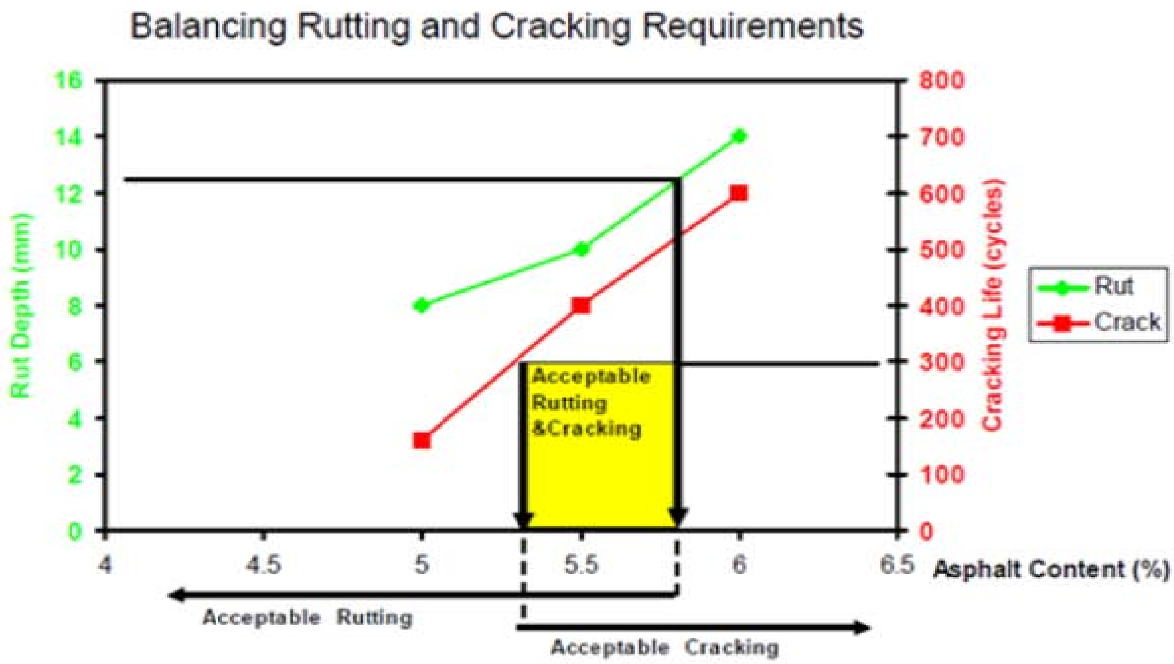
Balanced Mix Design

BALANCED MIX DESIGN

- If a mix is too dry: cracking, if too wet: rutting, so what is optimum?
- There can be many design binder content but only one true optimum
- Optimum here indicates the best binder content based on intended application, performance requirements/needs and ultimately economics
- Goal to get as close as possible to optimum for the mix
- Performance requirement is test for multiple modes of distress
- After Volumetric tests, performance testing would be done including moisture damage

BMD Basic Example – Volumetric Design w/ Performance Verification

- **Texas DOT**
  - Volumetric design conducted
  - Hamburg Wheel Tracking Test (HWTT) AASHTO T 324
  - Overlay Tester (OT) Tex-248-F
  - Three asphalt binder contents are used: optimum, optimum +0.5%, and optimum -0.5%.
  - The HWTT specimens are short-term conditioned.
  - The OT specimens are long-term conditioned.



Within this acceptable range (5.3 to 5.8 percent), the mixture at the selected asphalt content must meet the Superpave volumetric criteria.

PRODUCTION VERIFICATION

- QC testing
- Volumetric comparison to baseline
- Surrogate ("Quick") test
- Performance test at "X" frequency

FINISHED MIX TESTS

Moving on to asphalt tests

NEW ASPHALT TESTS

- 40 Hour PAV
- Glover-Rowe Parameter
- Delta Tc
- MSCR
- True Grade
- Carbonyl group- too new not discussing here

40 HOUR PAV

- Current 20 hour PAV does not represent long enough aging condition to identify critical conditions
- Possible solutions:
  - A. thinner film thickness (less in the pan)
  - B. Longer time to age (40 hours)

  It is agreed that the G*sinδ (PAV DSR) does not correlate well with fatigue or durability

AGING

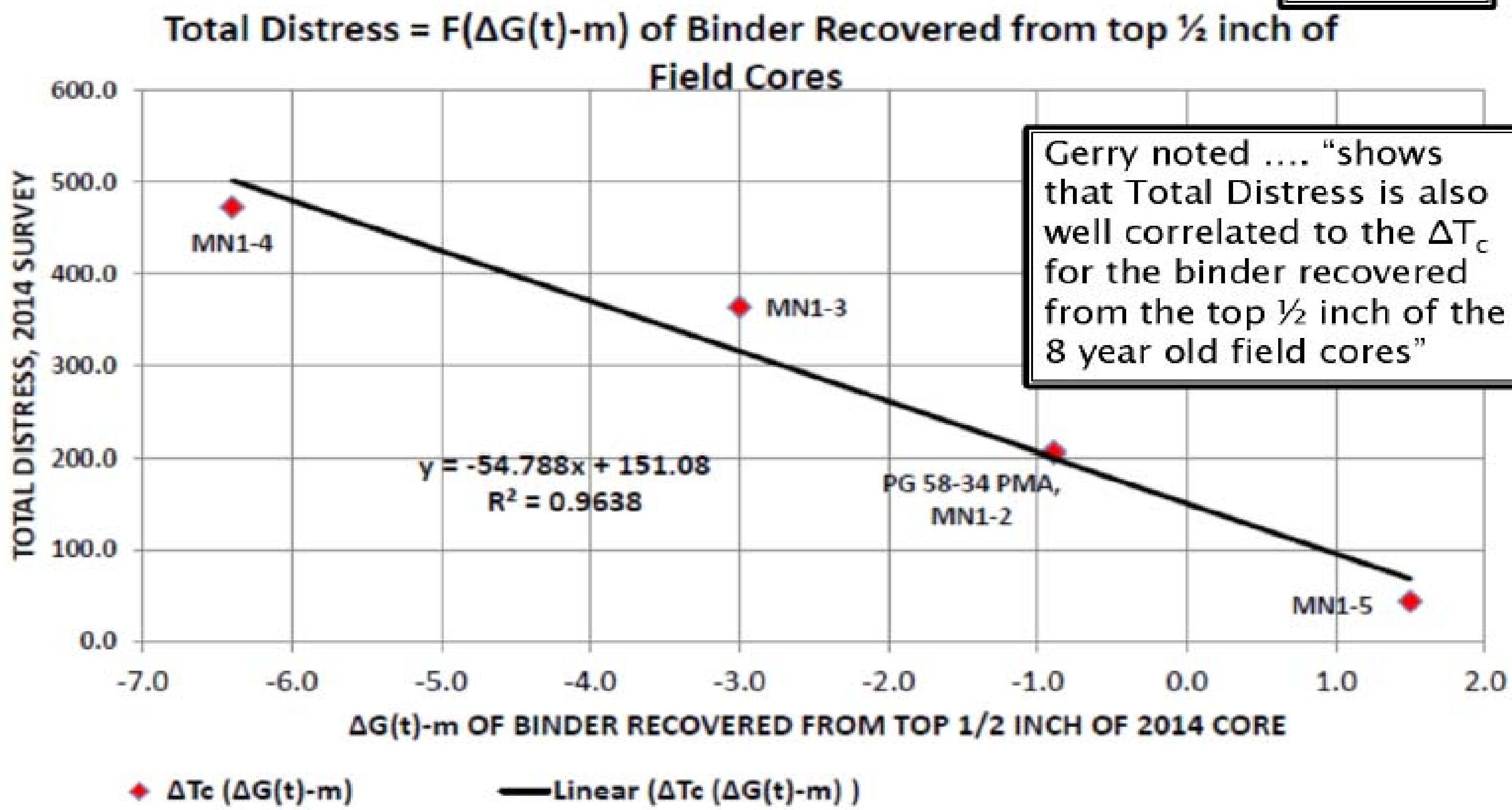
- There are many factors that influence aging on the road besides the binder characteristics
- Aggregate Mineralogy
- Aggregate Surface Texture
- Interaction between Asphalt and Aggregate
- Mix voids
- Temperature
- Binder content

DELTA T_C

- ΔTc is intended to capture brittle cracking
- $\Delta Tc = Ts_{(300)} - Tm_{(0.300)}$ where T = grade temperature
- ΔTc does show when REOB is used
- $\Delta Tc = +/- 5.0$ then cracking limit proposed
- Negative is m control and Positive is S control

ΔT_c vs Distress

Reinke



Gerry noted …. "shows that Total Distress is also well correlated to the ΔT_c for the binder recovered from the top ½ inch of the 8 year old field cores"

	Delta Tc
Grade	
52-28	-2.1
58-28	-2.3
58-28 Plus	-1.9
58-34	-2.0
64-28	-2.1
64-40	-1.5
52-40	-2.0
52-40	-1.9
64-28*	-6.2
52-40*	-5.5
58-28 Plus*	-5.8

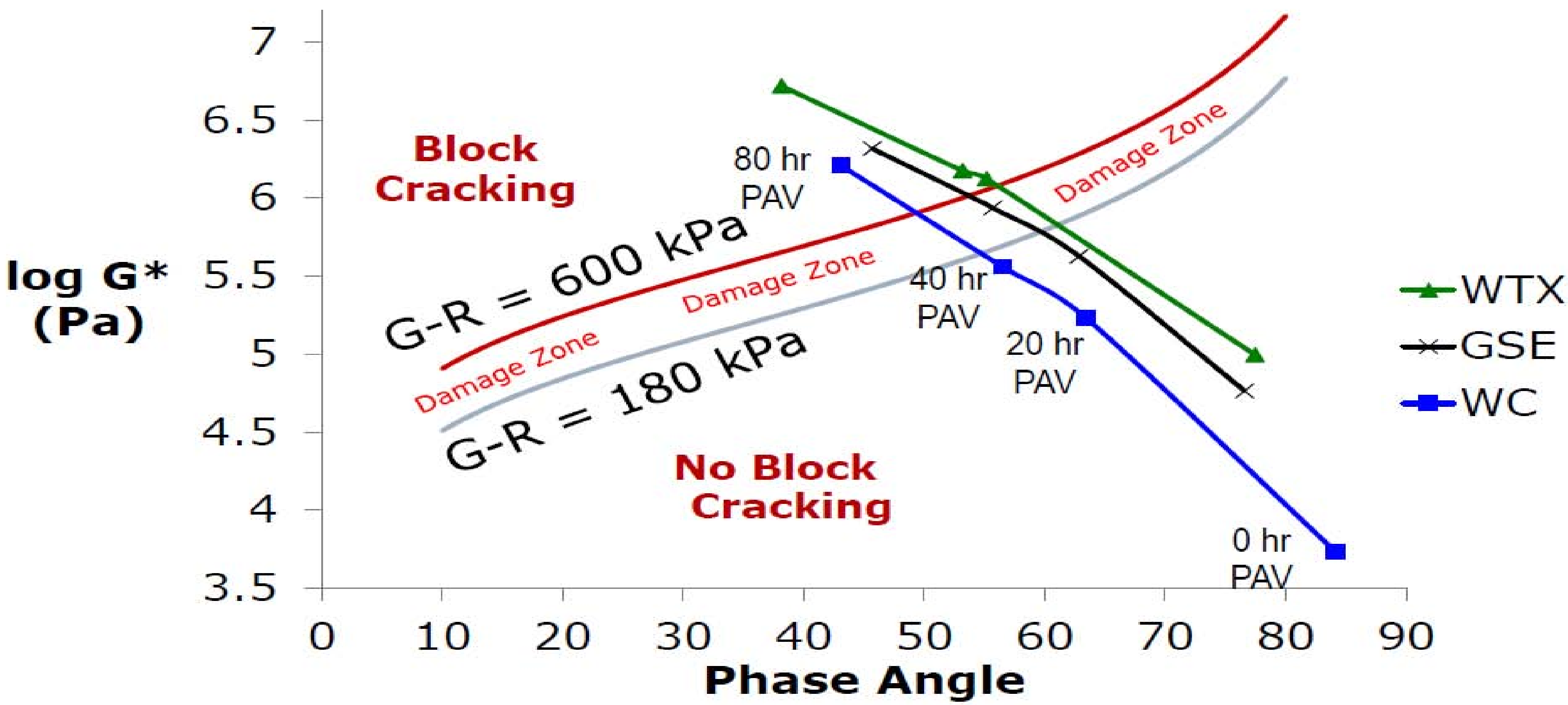
* made with PPA and REOB or REOB

GLOVER ROWE

- There is no published method for this but there are people publishing papers about their results
- Basically it is = $G^*(\cos\delta)^2/\sin\delta$
- The theory is that the Damage on is at 180KPa and significant cracking is at 450KPa
- Using Master curves will help eliminate errors in this procedure which requires software
- The Black Space is plotted, just like when Superpave first started with gradations.

Glover-Rowe Plot in Black Space: DSR on Aged Binders (15°C; 0.005 rad/s)

asphalt institute



Rowe: Prepared Discussion to M. Anderson paper - AAPT 2011

MSCR

- Multiply Stress Creep Recovery test (MSCR)
- Jnr is for high temperature rutting
- % Recovery is to show presence of polymer
- There is no repeatability or reproducibility for this test
- Pacific Coast Conference on Asphalt Specification did a study and their reproducibility (between different labs) was 43 %

MSCR DATA IN ONE LAB

	Jnr			Percent Recovery		
Grade	Min.	Max.	Average	Min.	Max.	Average
52-28	0.9	2.9	2.1	5.2	16.4	10.0
58-28	1.6	4.8	3.0	0.5	2.5	1.3
58-28 Plus	0.48	0.67	0.59	14.2	45.9	30.1
58-34	0.85	2.6	1.6	16.4	55.7	29.4
64-28	0.74	1.9	1.5	11	44.9	22.2
64-40	0.07	0.21	0.12	90.4	97.6	94.6
52-40	1.1	2.7	1.8	9.2	37.8	16.6
52-40	0.06	0.24	0.09	91	96.7	93.3

TRUE GRADE OF BINDER

- Designed for research tool
- Uses two points to determine value because of time involved
- Two points will always make a line but is it correct
- True grade would increase the number of grades
- There is no reproducibility or repeatability since it is a research tool
- To get true grade a person run two temperatures on all the parameters
  - Original, RTFO and PAV data

Grade	True Grade
52-28	57.3-39.1
58-28	60.5-35.6
58-28 Plus	61.2-37.9
58-34	65.6-46.4
64-28	69-37.1
64-40	74.5-42.5
52-40	55.5-46.3
52-40	72.1-43.3
64-28*	70.6-33.2
52-40*	63.2-43.8
58-28 Plus*	61.6-35.5

* made with PPA and REOB or REOB

WHAT'S NEXT

- Binder testing is a good starting point

- Performance testing would start the validation of changing binder specifications

- Field performance is required in two ways
- One performance testing of mix to see if earlier performance results are still validate
- Second evaluation is the road over time

PERFORMANCE TESTING

Mixes from 2017

THANK YOU

- Northern DOT for mix sample
- Granite Construction for mix samples
- Southeast Roadbuilders for mix samples
- Asphalt Institute for doing the work

MIXES USED IN STUDY

Table 1: Project Mixtures and Identification

Asphalt Mixture	Project ID
PG 52-28 Type IIB/25% RAP	713
PG 58-34 Type VH	720
PG 58-34 Type VS	721
PG 58-34 Type IIA/20% RAP	722
PG 52-40 (Northern Region)	723
PG 58-34 (Southern Region)	724

Table 2: Test Specimen Air Voids

Mix ID	G_{mm}	Individual Sample P_a, %			
		1	2	3	Average, %
713	2.508	7.1	6.7	6.7	**6.8**
720	2.496	6.8	6.8	6.7	**6.8**
721	2.495	7.5	6.8	6.8	**7.0**
722	2.508	6.7	6.8	7.3	**6.9**
723	2.479	6.6	6.6	6.8	**6.7**
724	2.779	7.1	6.8	6.8	**6.9**

INDIRECT TENSILE (IDT)

- Project Scope
- Test six (6) mixtures in accordance with AASTHO T322 for Indirect Tensile (IDT) Creep Compliance and Tensile Strength for low temperature mixture property testing.
- Identify the potential for thermal cracking in the test mixtures and report results.
- Test specimens at -20, -30, and -40°C to determine the compliance of the mixture at the low-end performance grade (PG) of the binder.

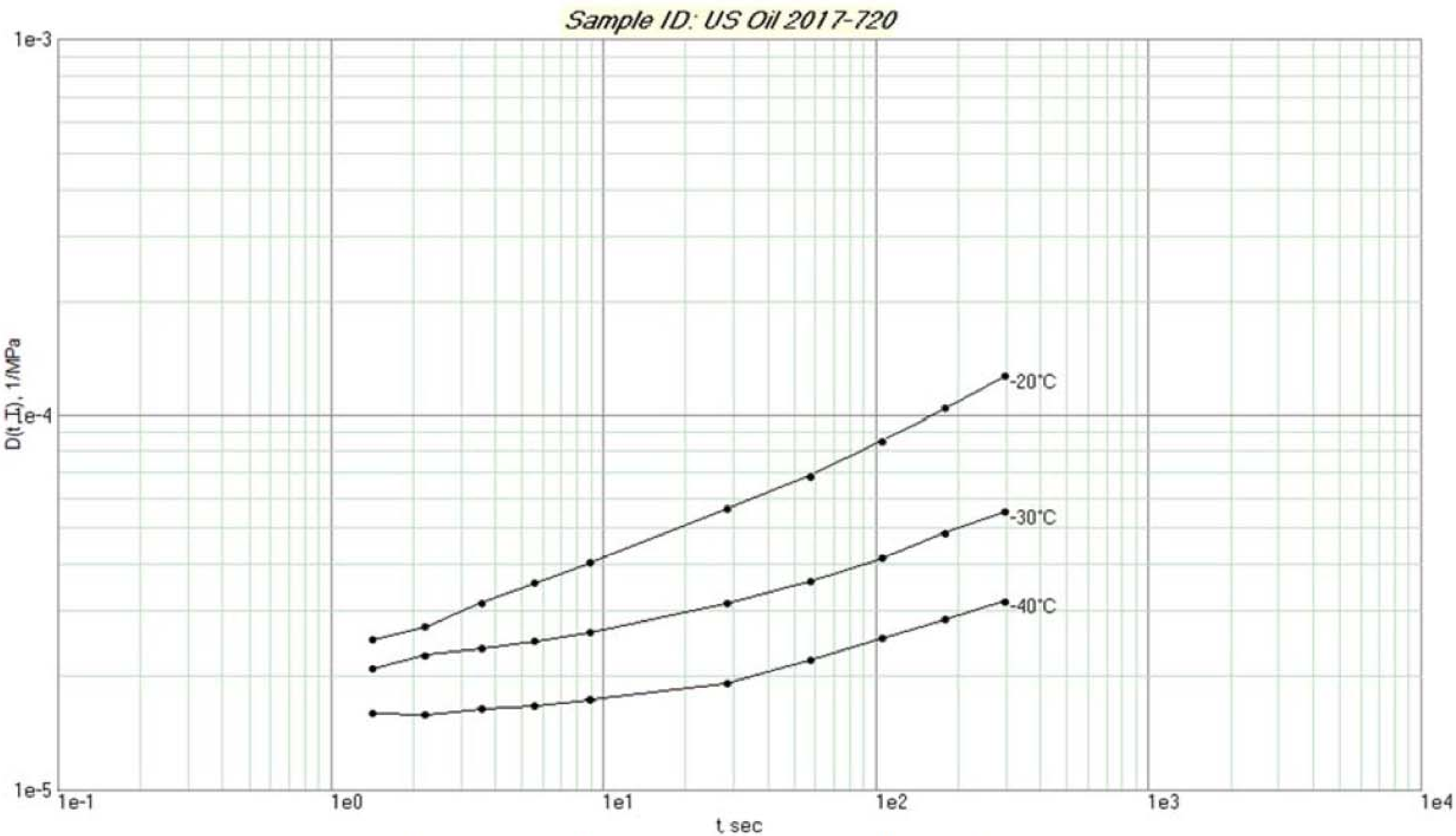


Figure 1: Isotherm Data from IDT Creep Compliance Testing – Mix 720

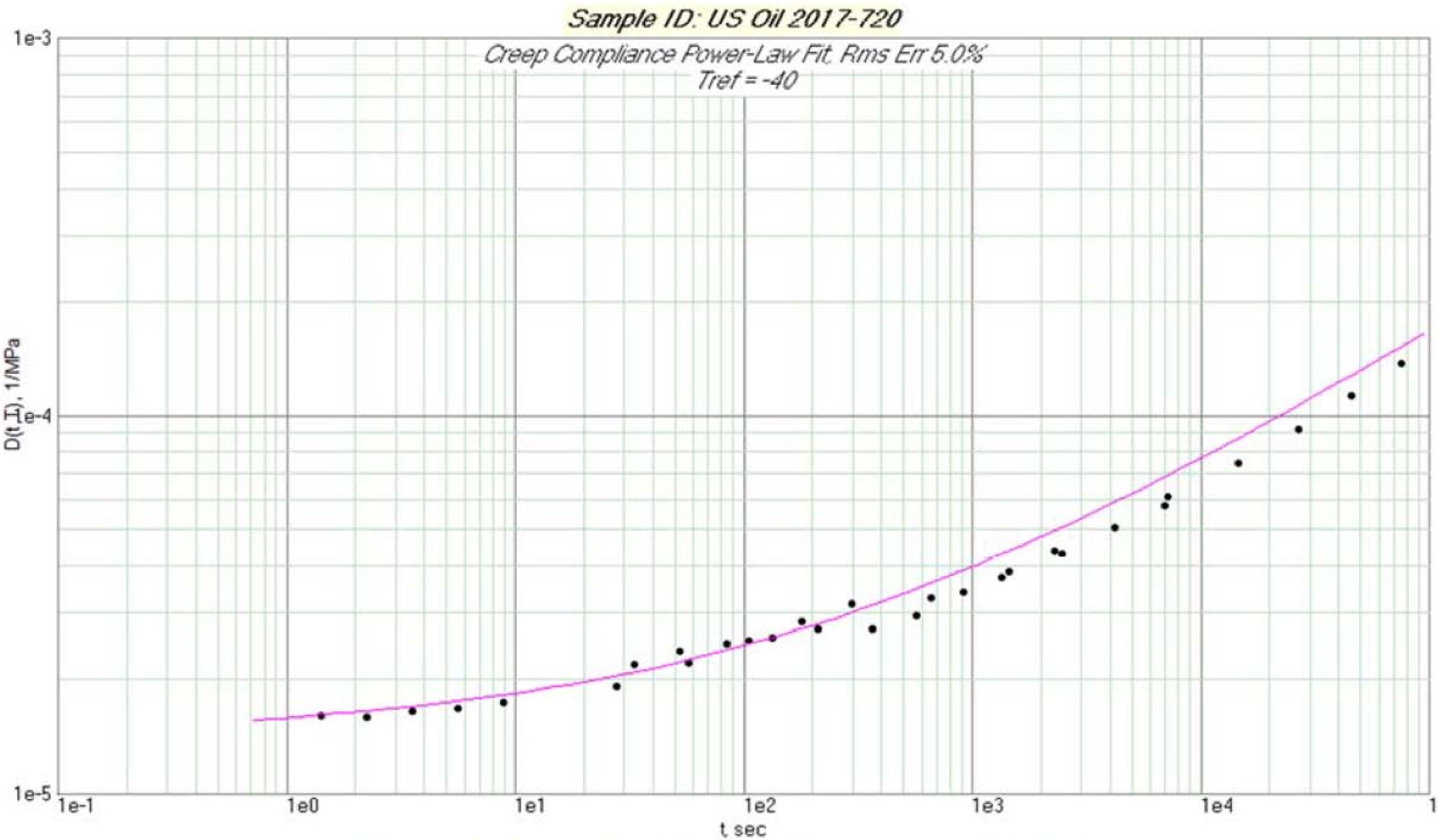


Figure 2: Creep Compliance Mastercurve – Mix 720

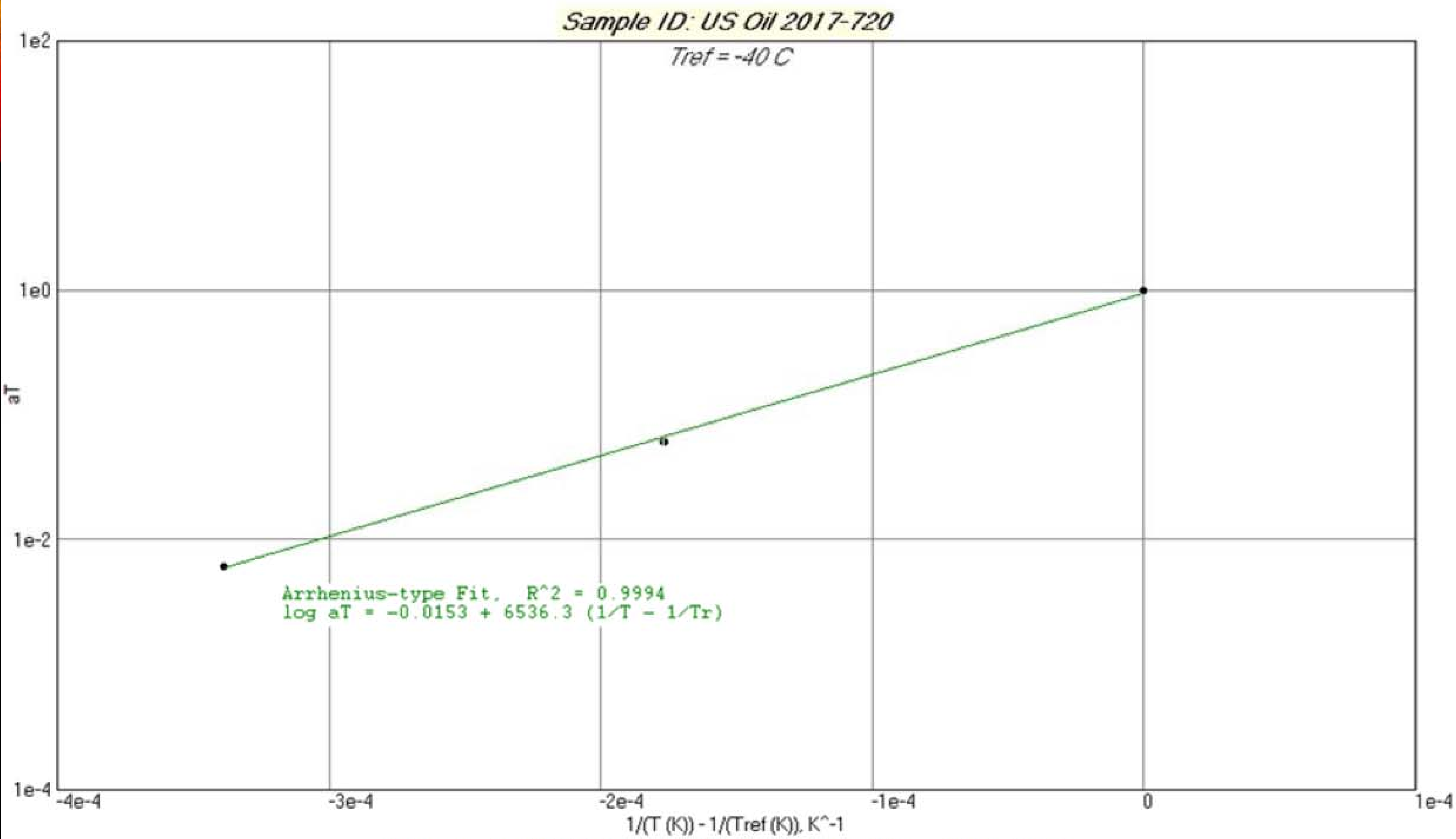


Figure 3: Shift Factors (Arhenius Fit) – Mix 720

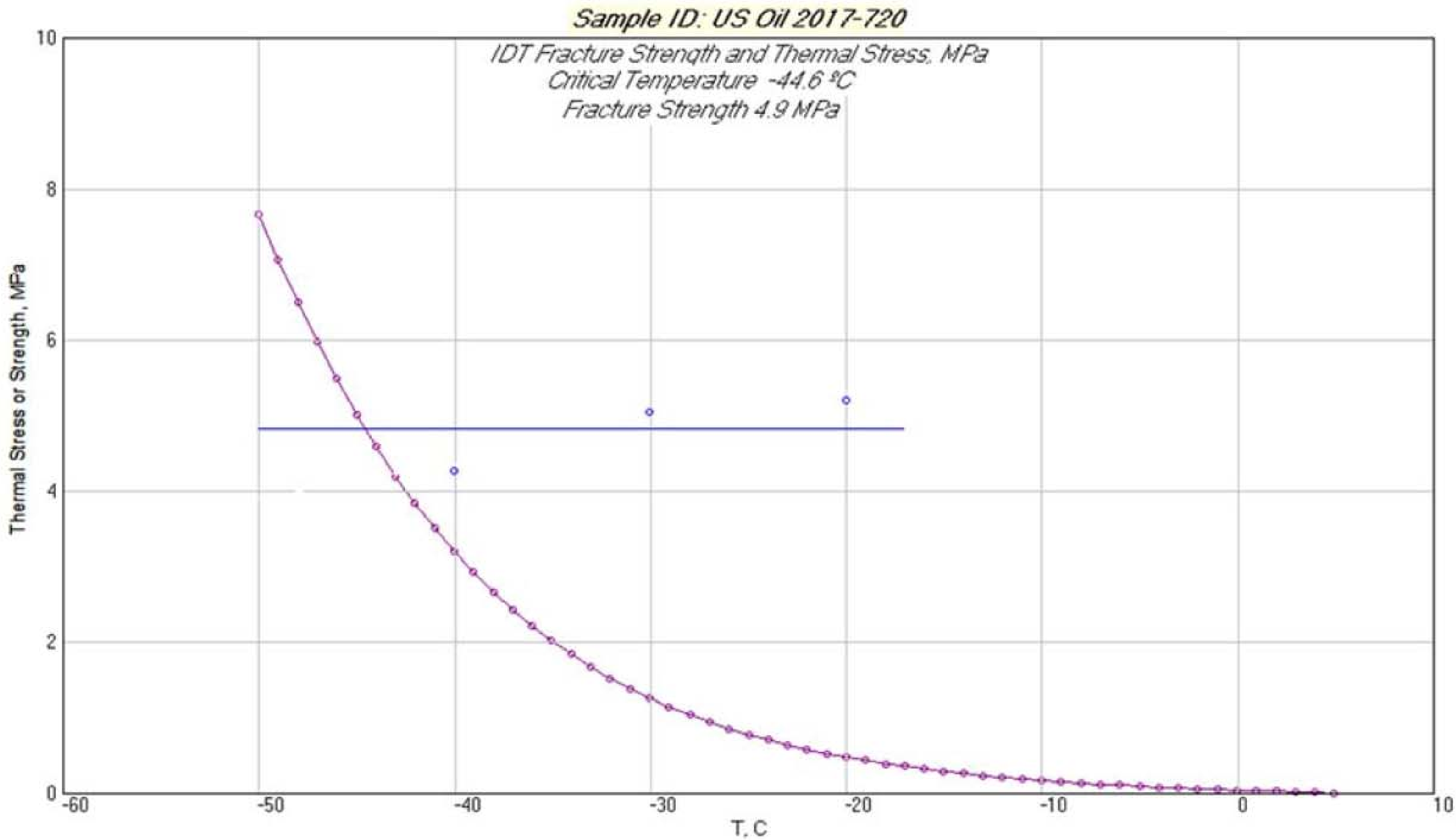


Figure 4: Determination of Critical Cracking Temperature Using Thermal Stress and Strength – Mix 720

The creep compliance parameters –
D0, D1, and m describe the compliance curve at low temperature using the following equation:

$D(\xi) = D0 + D1\xi m$

where: $D(\xi)$ = creep compliance at reduced time, ξ

D0, D1, m = creep compliance curve-fitting values

D0 is an initial creep compliance value intended to represent the creep complianc e at t=0 seconds.

Lower values of D0 indicate a lower initial creep compliance (higher initial stiffness). D1 and m describe the shape of the creep compliance mastercurve.

Table 3: IDT Creep Compliance and Strength with Estimated Critical Cracking Temperature

Mix	D_0, MPa^{-1}	D_1, MPa^{-1}	m	RMS Error, %	S_t, MPa -20°C	S_t, MPa -30°C	S_t, MPa -40°C	S_t, MPa Average	CCT, °C
713	1.418E-05	9.126E-07	0.4397	6.58	4.46	3.91	3.65	4.01	-41.3
720	1.417E-05	1.732E-06	0.3902	4.95	5.22	5.07	4.28	4.86	-44.6
721	8.841E-06	3.915E-06	0.3428	8.37	n/a	n/a	3.82	3.82	-44.1
722	1.443E-05	2.838E-06	0.3499	3.65	4.97	4.26	3.62	4.28	-44.1
723	1.268E-05	4.013E-06	0.3701	3.36	3.63	3.84	3.91	3.79	-47.4
724	1.692E-05	2.030E-06	0.3762	1.93	n/a	n/a	4.47	4.47	-44.9

Notes: T_{ref} = -40°C for development of the creep compliance mastercurve.
"n/a" indicates that data is unavailable.
"CCT" is the critical cracking temperature of the mix, determined using the creep compliance curve and the following assumptions:

- 0.00002 linear expansion / °C
- 2°C/hour cooling rate
- Average indirect tensile strength used to determine intersection with thermal stress curve

GRADE	CTT IN C
PG 52-28 W/ 25% RAP	-41.3
PG58-34 TYPE VH	-44.6
PG 58-34 TPYE VS	-44,1
PG 58-34 TYPE IIA/ 20% RAP	-44.1
PG52-40 NORTHERN	-47.4
PG 58-34 SOUTHERN	-44.9

SUMMARY

- There is no perfect test for binder
- Mixes are a system and maybe balanced mix design is the right path
- Changing a specification on binder may not give the end user what they want
- Most original testing for new specifications are done on current binders which maybe completed different when specified in a contract
- Do performance testing before changing specifications
- Do one or two jobs with new specifications

QUESTIONS

RAP: A National Perspective

Richard Willis
Director of Pavement Engineering and Innovation

Alaska Asphalt Summit
November 7, 2017

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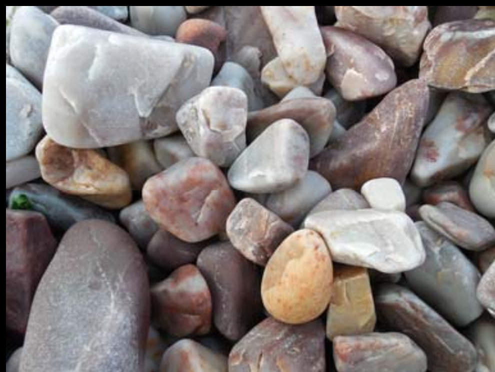

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Reclaimed Asphalt Pavement

Milling
Pavement removal
Reject material
Start up waste materials
Laboratory materials

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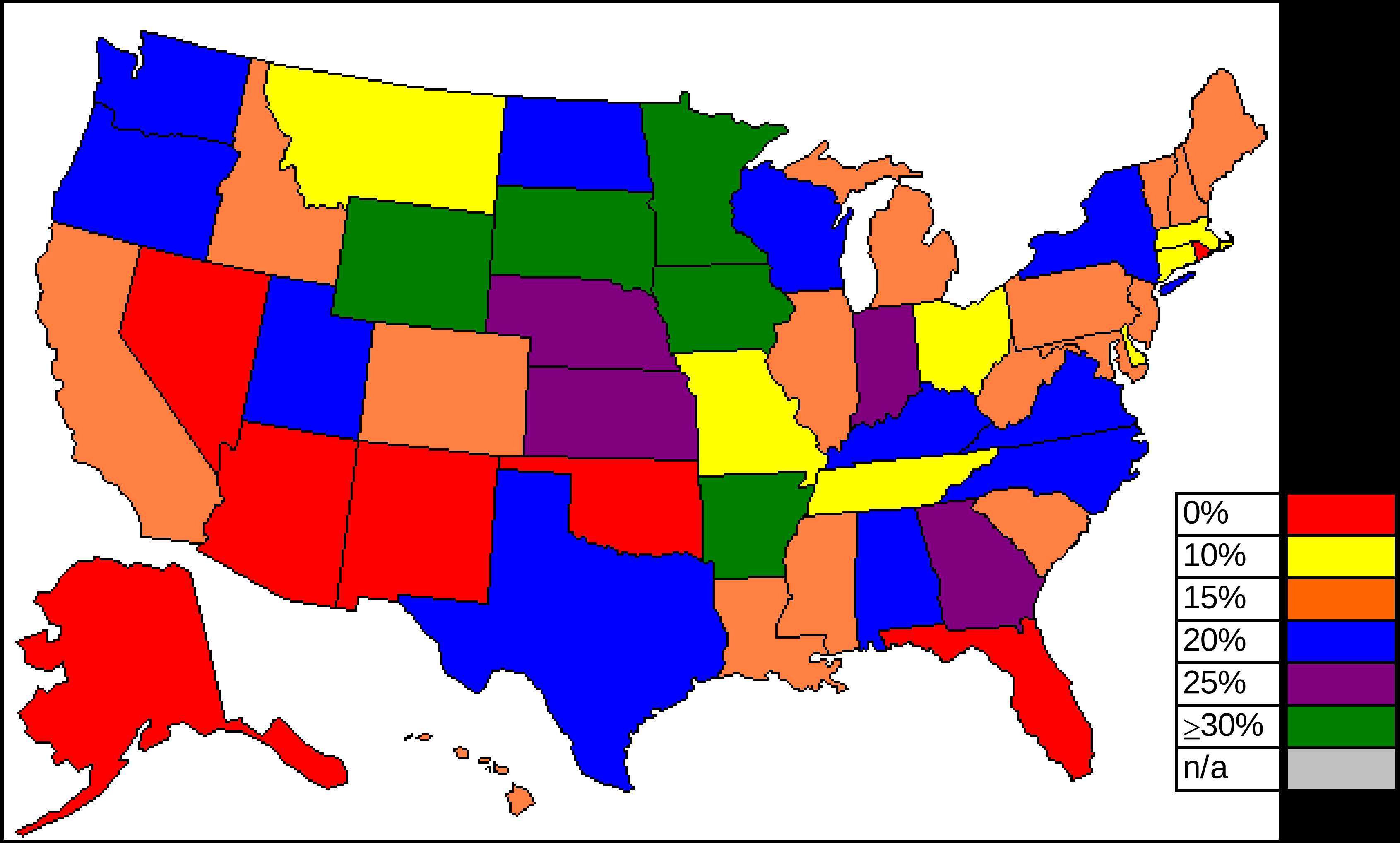
Sources of RAP

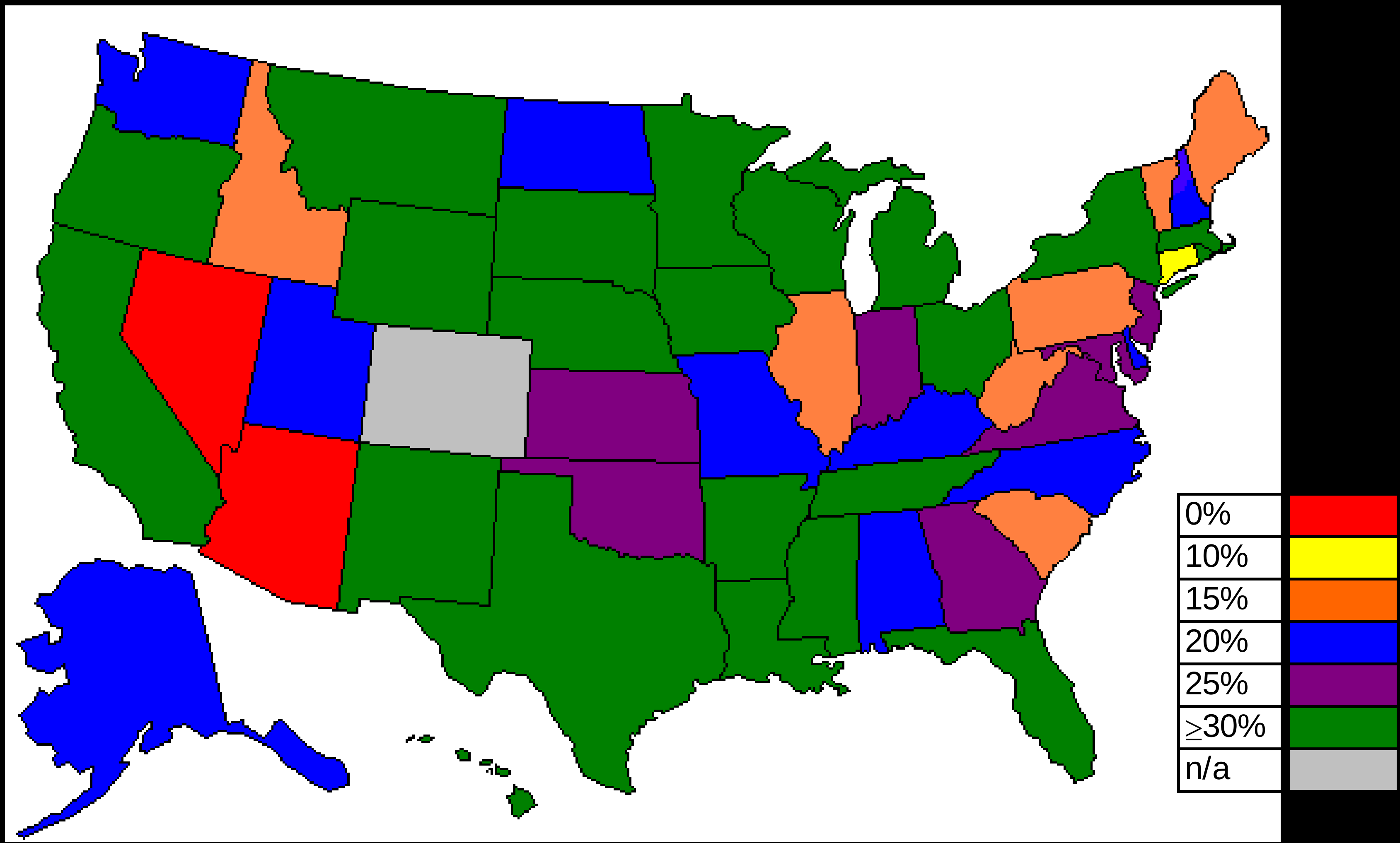
RAP Approval

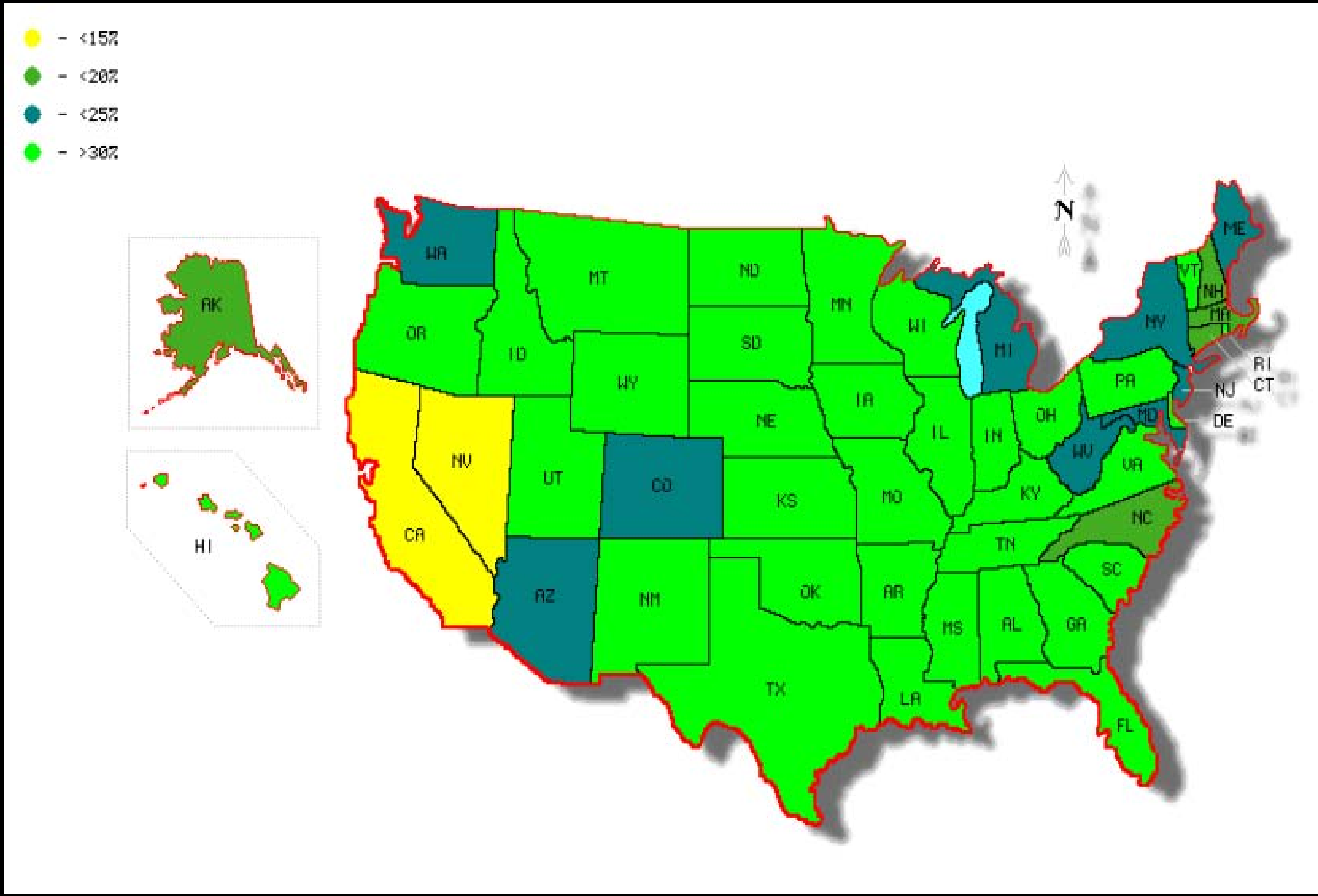
- Some states require that RAP be recovered from certain projects if used in mixtures
- Most require that the RAP used in mixtures be based on measured properties regardless of source
- A growing number of states set limits for RAP and RAS based on "binder replacement"

Surface Mixes: % RAP Allowed



Base Mixes: % RAP Allowed





(Pappas, 2011 – RAP Survey Results)

- Blue smoke
  - RAP being fed directly into the hot gasses
  - Plant evolution has fixed most of this issue
- Effect on volumetric properties
- Lack of understanding on effect of long-term performance
  - Binder grade

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Perceived Limitations

- Availability of RAP
- Ability to control the quality of the mix
  - Moisture
  - Amount of material passing no. 200 sieve
  - Workability
  - RAP variability
- Requirement to test recovered binder
- Softer virgin binder availability and/or tankage issue

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Why Less?

- Some DOTs required fractionation
- Some allow more RAP with fractionation
- Some reduce amount of RAP allowed when batch plants used
- Some allow higher RAP content before requiring change in grade of asphalt
- Some don’t change grade of AC regardless of amount of RAP used
- Some allow more RAP when WMA is used

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Use of RAP

National RAP Survey

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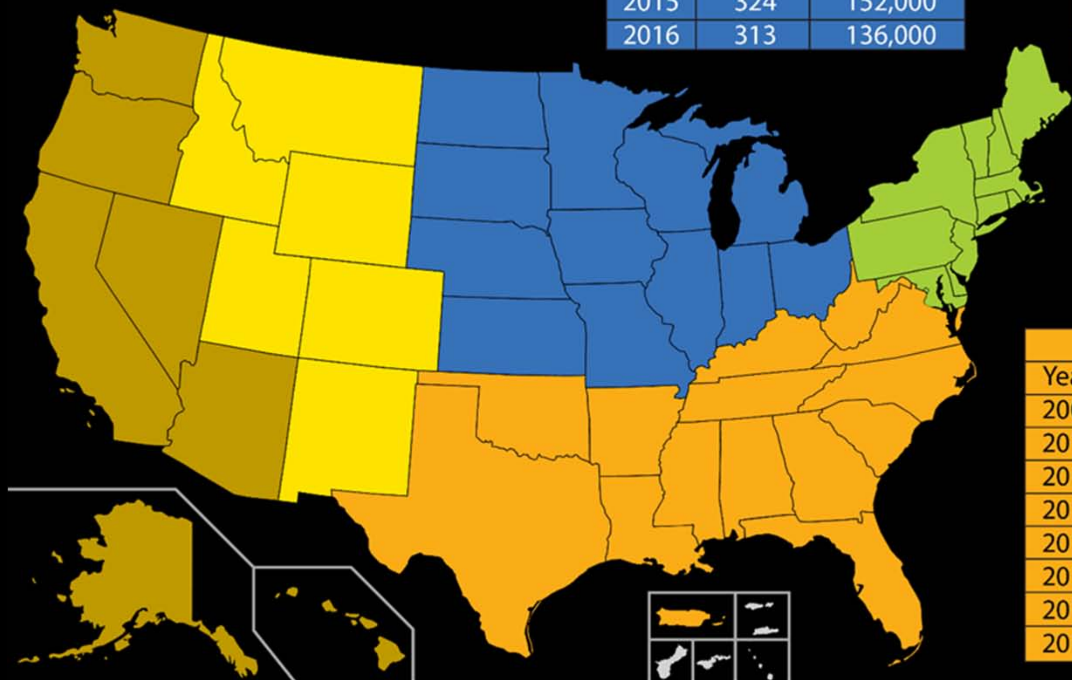
RMAUPG/PCCAS		
Year	Plants	Tons/Plant
2009	208	118,000
2010	208	112,000
2011	179	124,000
2012	161	113,000
2013	212	110,000
2014	202	122,000
2015	186	123,000
2016	214	128,000

NCAUPG		
Year	Plants	Tons/Plant
2009	239	106,000
2010	239	106,000
2011	311	114,000
2012	298	116,000
2013	377	123,000
2014	374	136,000
2015	324	152,000
2016	313	136,000

NEAUPG		
Year	Plants	Tons/Plant
2009	232	123,000
2010	232	122,000
2011	195	115,000
2012	252	119,000
2013	258	111,000
2014	193	122,000
2015	207	137,000
2016	218	136,000



SEAUPG		
Year	Plants	Tons/Plant
2009	348	106,000
2010	348	106,000
2011	406	114,000
2012	430	116,000
2013	434	113,000
2014	416	125,000
2015	402	129,000
2016	401	140,000

RAP Usage	2015	2016
Accepted	78.0	81.8
Used in Asphalt Mixtures	74.2	78.9
Used in Aggregate	5.5	3.7
Used in Cold-Mix Asphalt	0.2	0.2
Other	1.6	0.4
Landfilled	1.0	0.1
Stockpiled	85.13	93.59

*In million tons

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National RAP Survey

Average % Used	2015	2016
DOT	17.8	19.3
Other Agency	18.2	19.7
Commercial and Residential	22.3	24.2
National Average	21.4	21.0

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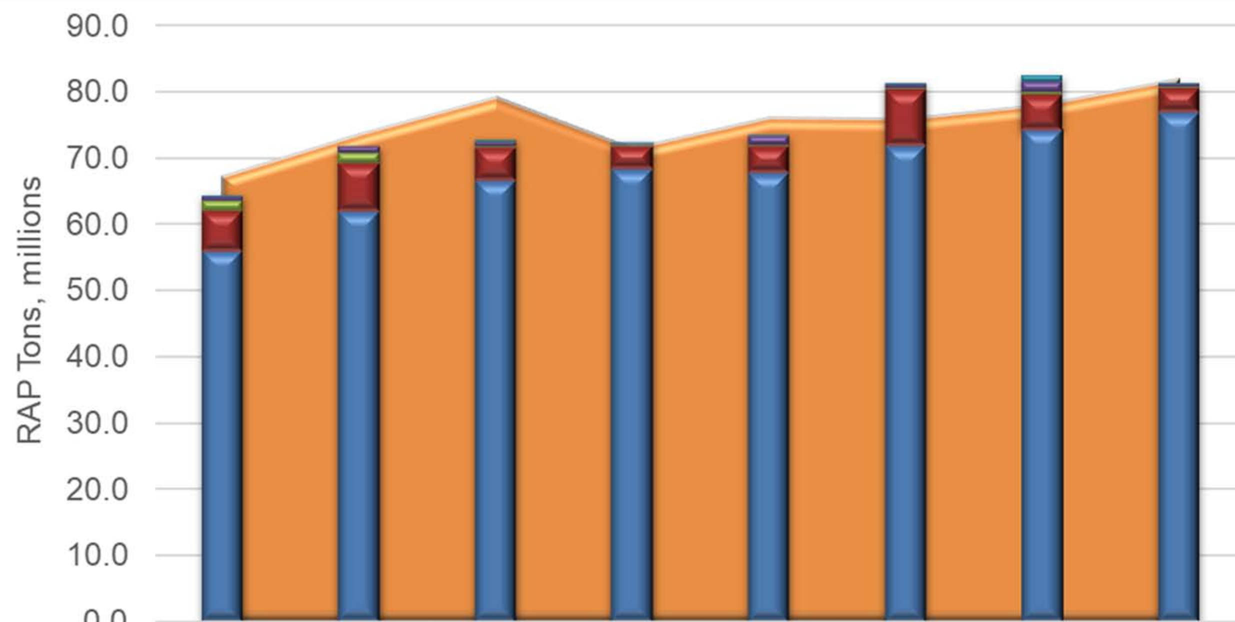
National RAP Survey



	2009	2010	2011	2012	2013	2014	2015	2016
Accepted	67.2	73.5	79.1	71.3	76.1	75.8	78.0	81.8
Landfilled	0.1	0.0	0.3	0.2	0.1	0.2	1.0	0.1
Used in Other	0.7	0.8	0.7	0.2	1.5	0.6	1.6	0.4
Used in Cold Mix	1.5	1.6	0.2	0.2	0.2	0.2	0.2	0.2
Used in Aggregate	6.2	7.3	4.9	3.6	4.0	8.5	5.5	3.7
Used in HMA/WMA	56.0	62.1	66.7	68.3	67.8	71.9	74.2	76.9

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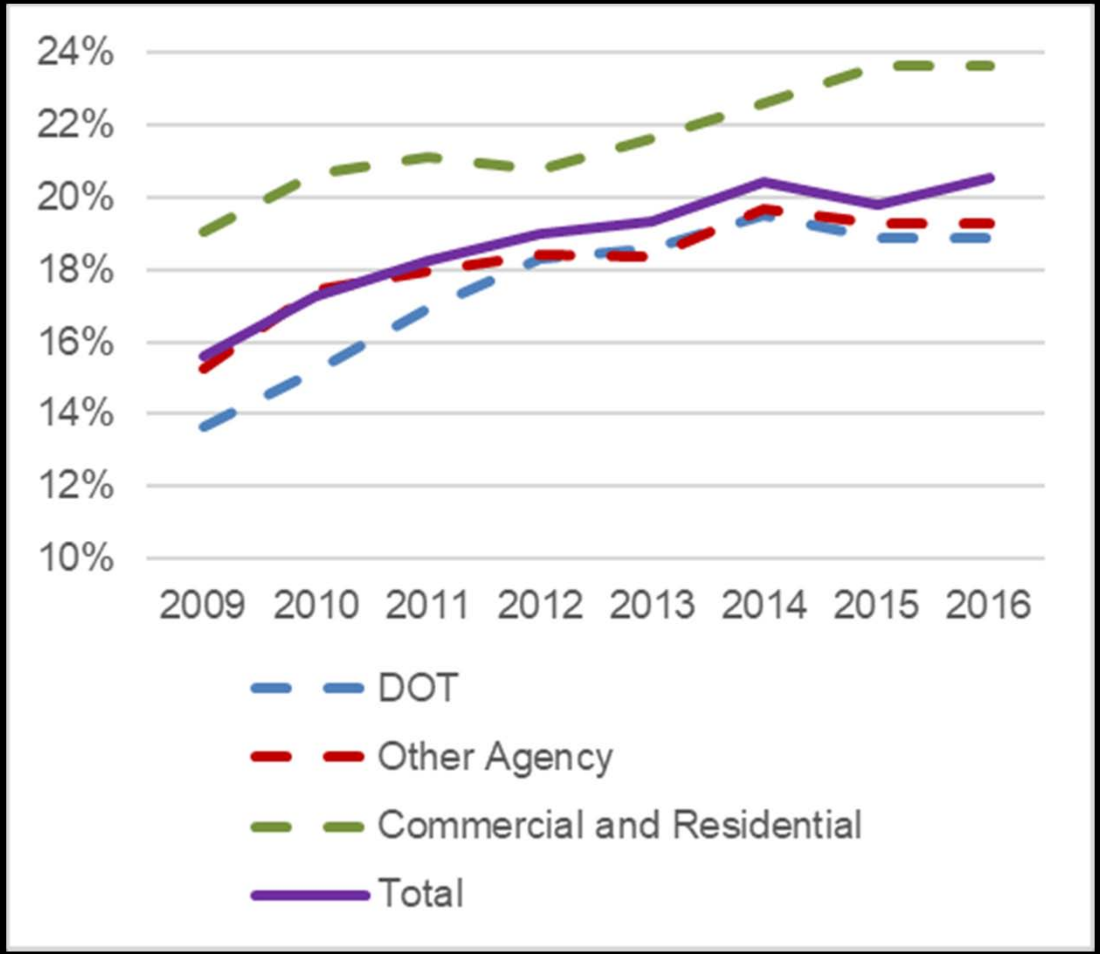
National RAP Survey



National RAP Survey

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- Pavement Benefits
- Economic Payoff
- Energy Savings
- Natural Resource Conservation

Photo courtesy of Astec, Inc

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Why Recycle?

Benefits of RAP

Economics

- Aggregate
- Asphalt
- No/low hauling costs

Environment

- Reduces demand on non-renewable resources
- Reduces landfill space demands
- Reduces transportation emissions

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Benefits of Milling

- Removes cracked and aged pavement layers
- Helps improve pavement smoothness and cross-slopes
- Maintains curb heights, drainage inlets, and bridge clearances
- Creates a rough texture that bonds better with the overlay

Material savings will depend on . . .

- Virgin binder cost
- Asphalt content of mix design
- Aggregate cost
- RAP cost
- Asphalt content of the RAP
- Percentage of RAP

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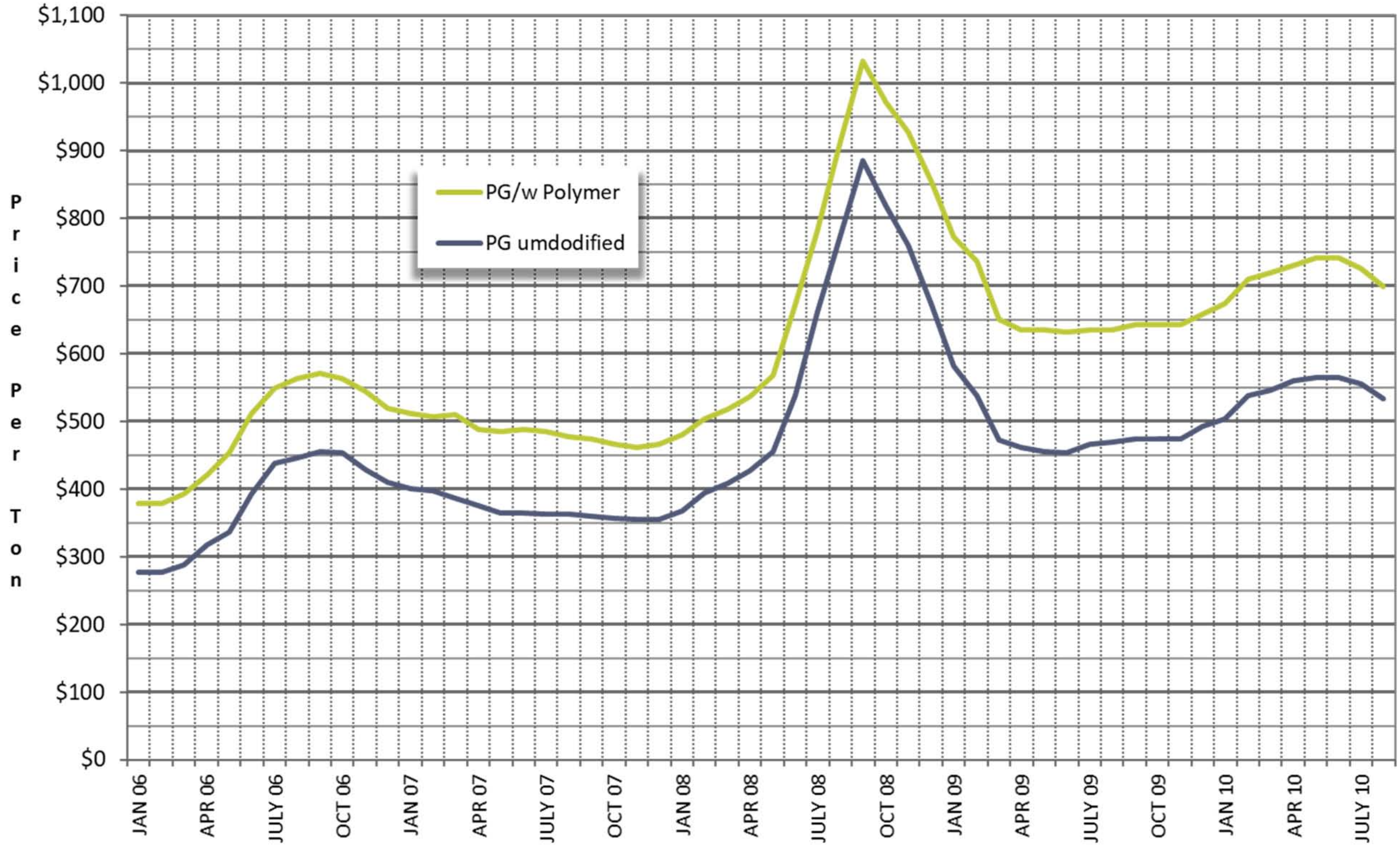
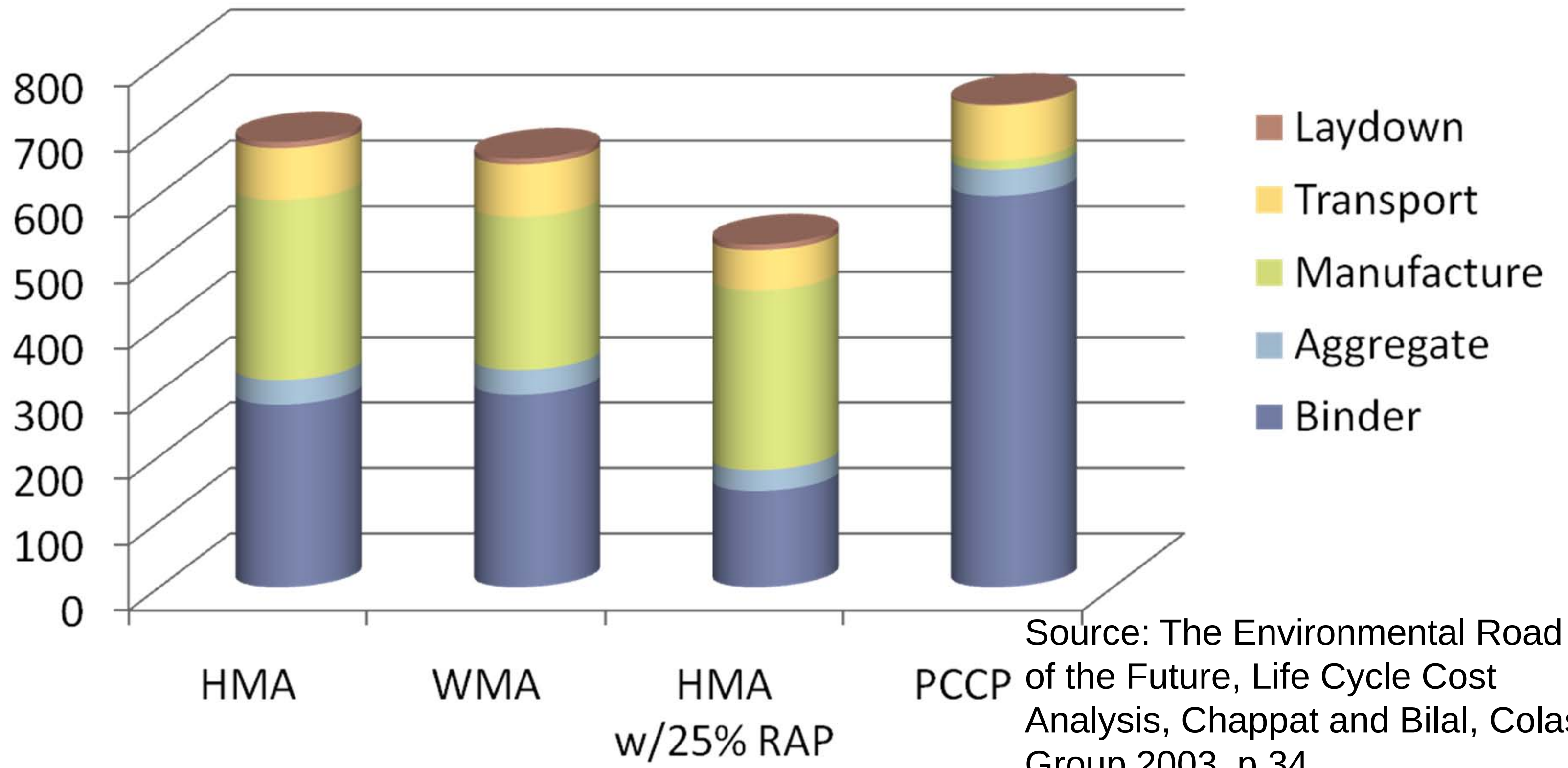
Economics



Data from Alabama DOT



Source: The Environmental Road of the Future, Life Cycle Cost Analysis, Chappat and Bilal, Colas Group 2003, p.34

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Energy Consumption

Material	Recycled Content	RAP AC,%	Value per Ton of Mix (% savings)				
			Price, $	Energy, Btu	CO2e, lb	Asphalt, ton	Agg, Ton
Asphalt Mix	0	0	67.87	533,333	104.89	0.052	0.948
RAP	15.0	4.0	61.17 (5.71)	501,778 (5.92)	98.59 (6.01)	0.046 (11.54)	0.804 (15.19)
		5.0	60.43 (6.85)	495,544 (7.09)	97.76 (6.79)	0.045 (14.42)	0.806 (15.03)

(Robinette and Epps, 2010)

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Value Analysis

U.S. Department of Transportation

Federal Highway Administration

Memorandum

Subject: **ACTION:** Recycled Materials in Asphalt Pavements

Date: October 20, 2014

Recently there have been an increasing number of state highway agencies reporting pre-mature cracking in relatively new asphalt pavements. A similarity in many of these pavements is the high content of recycled asphalt binder.

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Challenges

1. Is RAP more variable than virgin aggregates?
2. Does fractionation reduce the variability of RAP stockpiles?
3. Is single source RAP more consistent than processed RAP from multiple sources?

All are NO!

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Challenges: RAP Variability

Based on stockpiles at contractors plant site…

- Analysis of variance on the median coefficient of variation revealed that RAP had a lower variation than virgin aggregates
- The statistical analysis revealed that increasing the percentage of RAP does not increase the coefficient of variation of the mix. (This is in the RAP range of 15 to 40% and most of the mixes had between 25-35 percent RAP).

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Challenge: Aged Binders

The Same, But Different

- It requires the contractor knowing their materials
- Material properties of RAP
- Material properties of virgin materials
- What binder grade to use

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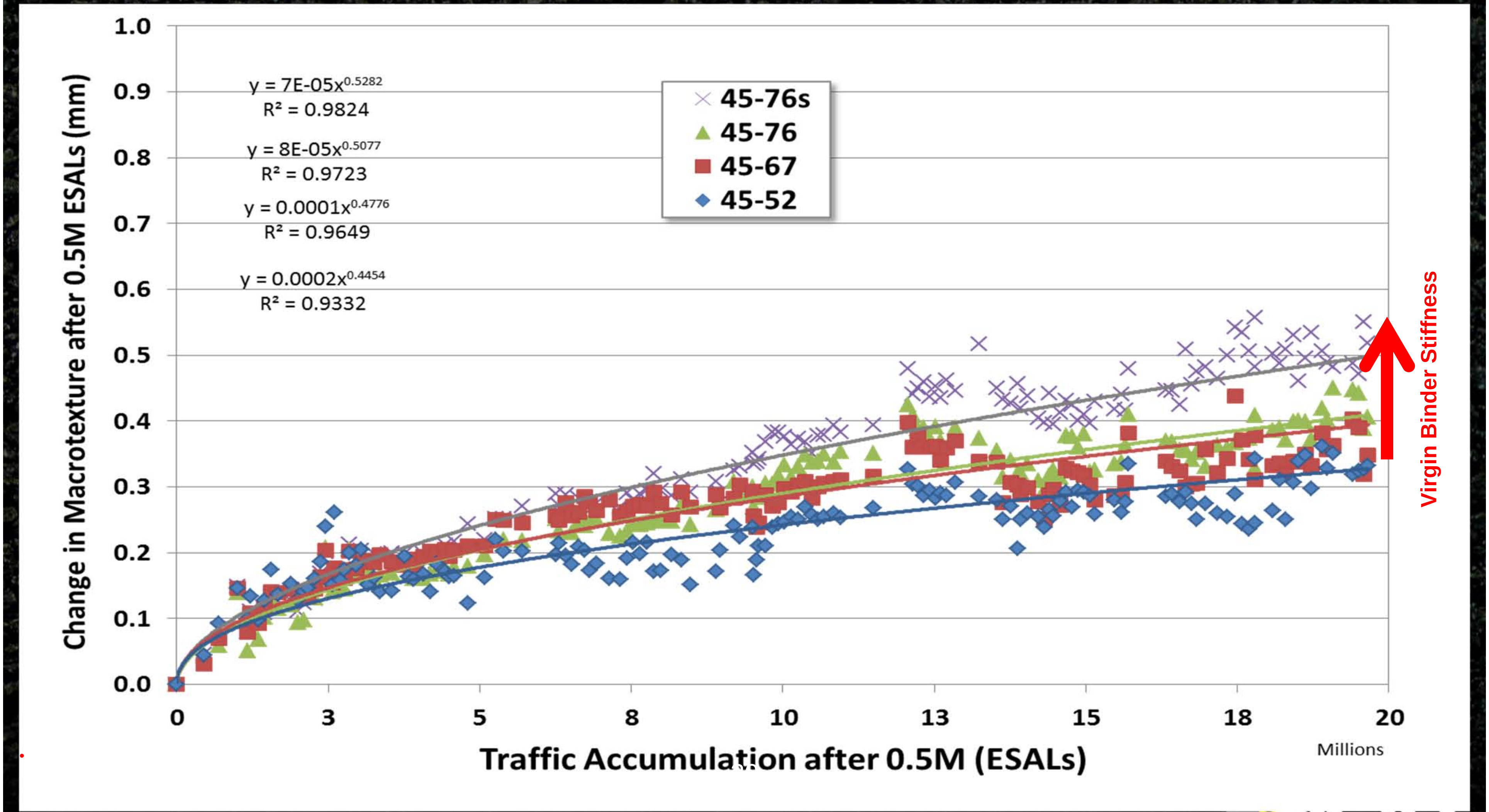
RAP Mixtures Can Perform

2006 45% RAP Test Sections

2006 High RAP Surface Mix Study



NCAT at AUBURN UNIVERSITY

45% RAP Sections

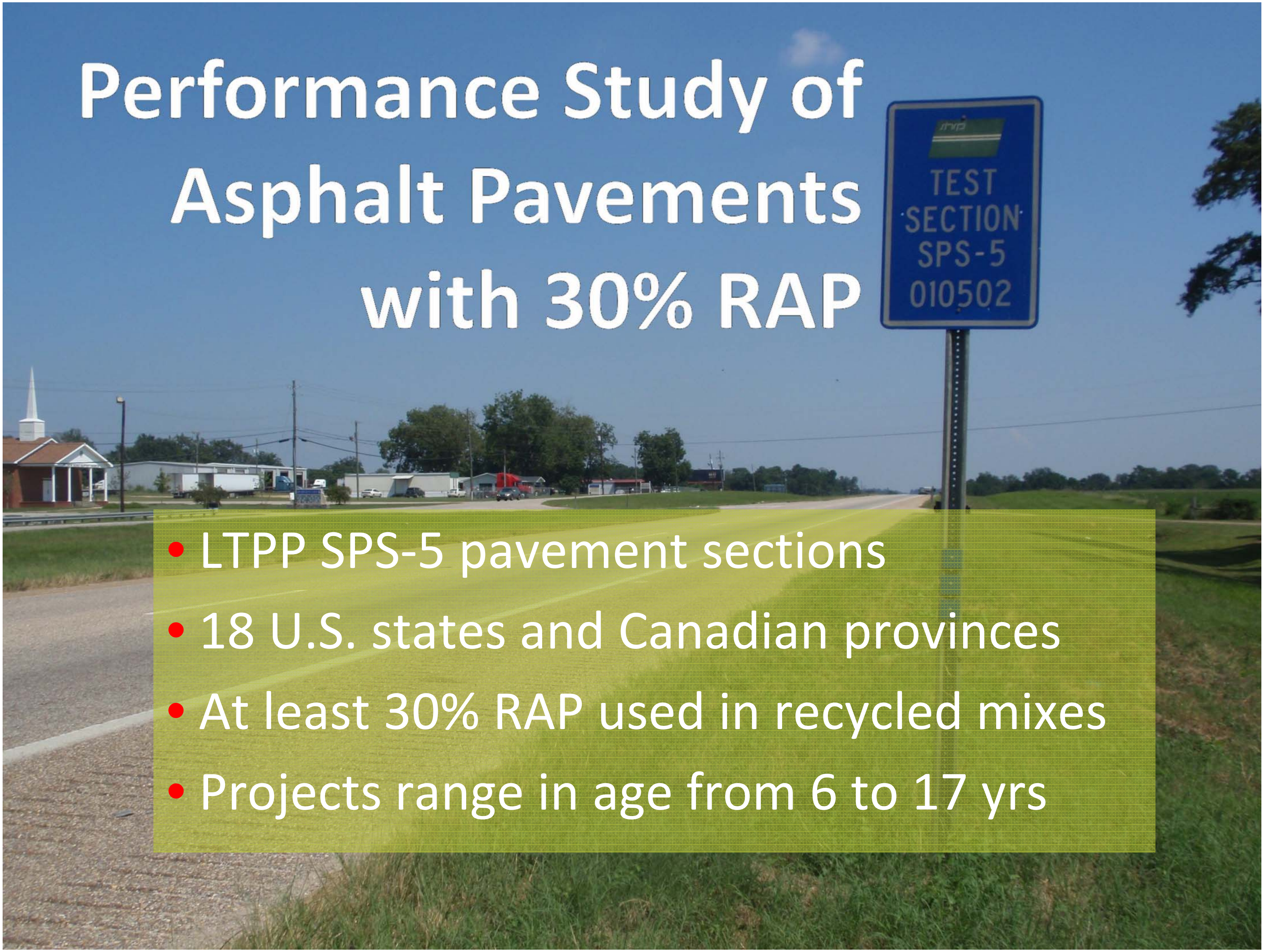
1 m ***4.2 m*** ***16.4 m*** ***44.3 m***

Total Length of Cracking after 2 cycles

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Performance Study of Asphalt Pavements with 30% RAP

- LTPP SPS-5 pavement sections
- 18 U.S. states and Canadian provinces
- At least 30% RAP used in recycled mixes
- Projects range in age from 6 to 17 yrs



Summary of Statistical Analyses

Distress Parameter	Virgin Performed Better than RAP	RAP Performed Better than Virgin	Insignificant Difference Between RAP and Virgin	RAP Performed Equal or Better Than Virgin
IRI	42	39	19	58
Rutting	33	29	38	67
Fatigue Cracking	29	10	61	71
Longtnl. Cracking	15	10	75	85
Transverse Cracking	32	15	53	68
Block Cracking	3	1	96	97
Raveling	7	15	78	93

Possible Causes of More Cracking in RAP Sections

State/Province	**# Pairs: Rec.>Vir.**	**Softer Vir. Binder in Rec. Mix?**	**Asphalt Content**		**P200**	
			Vir.	Rec.	Vir.	Rec.
Alabama	2	Y	4.8	5.0	4.0 √	5.1
California	2	N	5.3 √	3.8	4.3 √	6.2
Mississippi	3	N	5.9	5.7	5	5
Montana	4	Y	4.8 √	3.7	5 √	7.8
New Jersey	2	Y	4.8	4.8	n.a.	n.a.
Alberta	4	Y	5.4	5.4	8.6 √	10.5
Manitoba	2	N	5.9	5.9	5 √	6

- RAP usage has increased over the past 10 years
- There are numerous benefits for RAP usage, but also challenges as we try to move forward
- RAP mixtures <u>can</u> perform in the field.

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Final Thoughts

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Guidance Documents

Richard Willis, PhD

Director of Pavement Engineering and Innovation

rwillis@asphaltpavement.org

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Thank you!

Binder and Mixture Testing to Optimize High-RAP Mixtures

Todd THOMAS

Laboratory Director, Colas Solutions, Cincinnati

Outline

- Problem statement
  Why asphalt pavements crack
  Potential issues if the RAP content is too high
- Current US and Alaska specifications
  RAP content limits
- Binder properties
  Effects of RAP binder on PG grading and ways to measure low temperature susceptibility
- Mixture properties
  Effects on the mixture and various tests used in the industry
- Alaska mix data
- Summary and conclusions

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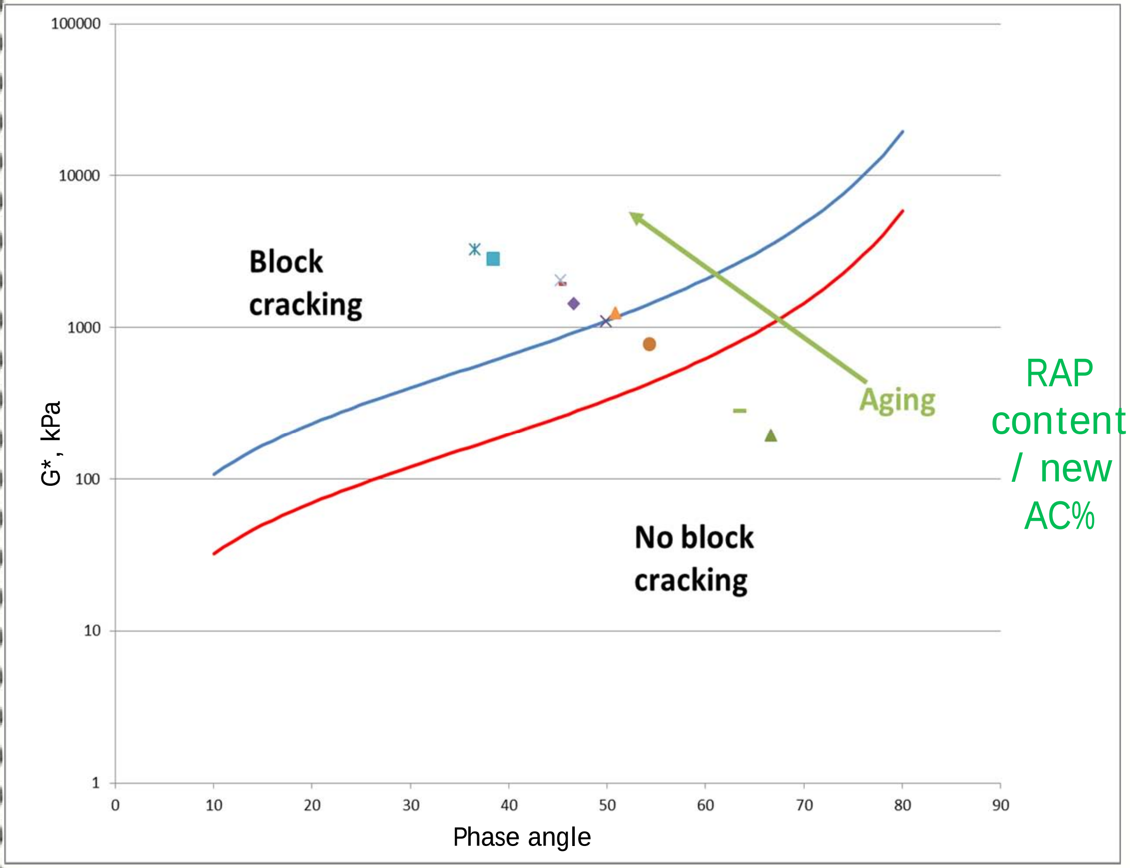
Why asphalt pavements crack



Ability of the layer to relax the thermal distresses decreases with time

- Oxidation and loss of the light ends
- Initial stiffness and binder selection
- Sensitivity of binder to aging

- Bending stresses (load related)

Problem statement

- High RAP content is defined as being higher than 25 percent RAP
- Cracking potential increase
- Workability and handling are more difficult with higher RAP mixes
- Raise RAP contents – Sustainability. Cost. Performance?

- Possible solutions include:
  - Use a softer grade of asphalt or use a rejuvenator; apply specific binder criteria
  - Limit the RAP binder contribution
  - Use mixture performance-based testing / criteria

RAP specifications

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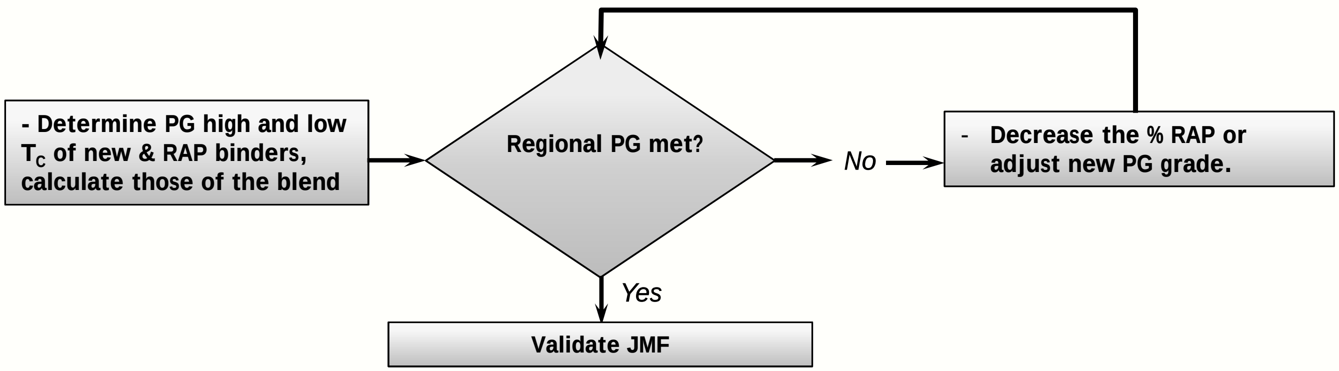
Current specifications – AASHTO M 323

- **Tiered RAP specifications**
  - **Level 1:** up to 15% RAP (weight RAP / total mix): PG unchanged, AC% adjusted
  - **Level 2**: 15% to **25**% RAP – PG one grade softer on low and high T°, AC% adjusted
  - **Level 3**: over **25%** RAP – recovered RAP binder PG properties determined & blending chart used to determine virgin PG and/or allowable % RAP

    But does current volumetric criteria work with high RAP contents?
  - Alternatively, if the RAP binder ratio is > 0.25, use blending calculations based on the true PG grades of the binders



Example – AASHTO M 323

- **Desired binder grade for 25% RAP**
  - Mixture – Total asphalt content of 5%. Final grade of the blend desired of PG 52-40
  - RAP binder: 5.5% asphalt and true grade of PG 62 – 26
  - RAPBR = 0.28
  - Need true grade of PG 49 – 45
- **Allowable RAP content to meet PG 52-40**
  - Virgin binder true grade: PG 54 - 42
  - No limit on PG high
  - 12.5% RAP limit to meet -40°C

Current specifications – Alaska

- **Allowable RAP**
  - 15% maximum RAP on A mixes
  - 25% maximum RAP on B mixes
  - 35% maximum RAP on base mixes
  - No binder grade adjustment required

Binder properties

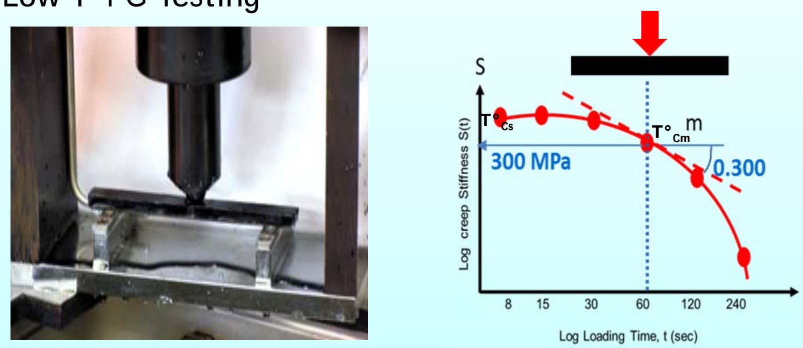
Performance Grades - *AASHTO M320 / ASTM D6373*

Max. Design Temp. (7 days Avg.)	PG 46	PG 52	PG 58	PG 64	PG 70	PG 76	PG 82
Min. Design Temp. (1 day)	-28 -34 -40 -46	-22 -28 -34 -40 -46	-16 -22 -28 -34 -40	-10 -16 -22 -28 -34 -40	-10 -16 -22 -28 -34 -40	-10 -16 -22 -28 -34 -40	-10 -16 -22 -28 -34
Original							
≥ 230˚C	**Flash Point** AASHTO T48 / ASTM D92						
≤ 3 Pa.s	**Rotational Viscosity at 135˚C** AASHTO T316 / ASTM D4402						
≥ 1.00 kPa	**DSR G*/sin δ** (**D**ynamic **S**hear **R**heometer) AASHTO T315 / ASTM D7175						
	46	52	58	64	70	76	82
RTFO (Rolling Thin Film Oven) AASHTO T240 / ASTM D2872	***Short-term Aging (Mixing Transportation & Compaction)***						
< 1.00%	**Mass Change**						
≥ 2.20 kPa	**DSR G*/sin δ** AASHTO T315 / ASTM D7175						
	46	52	58	64	70	76	82
PAV (Pressure Aging Vessel) AASHTO R28 / ASTM D6521	***Long-term Aging (4 to 7 Years Service)***						
20 hours, 2.10 MPa	90	90	100	100	100 (110)	100 (110)	100 (110)
≤ 5000 kPa	**DSR G*sin δ** AASHTO T315 / ASTM D7175						Intermediate Temp. = ((Max.+Min.)/2)+4
	13 10 7 4	19 16 13 10 7	25 22 19 16 13	31 28 25 22 19 16	34 31 28 25 22 19	37 34 31 28 25 22	40 37 34 31 28
S ≤ 300 MPa	**BBR S** (Creep Stiffness) & **m-value** (Relaxation) AASHTO T313 / ASTM D6648						
m ≥ -0.300	-18 -24 -30 -36	-12 -18 -24 -30 -36	-6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24
if BBR m ≥ -0.300 and Stiffness is between 300 and 600 MPa, the Direct Tension failure strain requirement can be used in lieu of the stiffness requirement.							
ε_f ≥ 1.00%	**DTT** (Direct Tension Tester) AASHTO T314 / ASTM D6723						
	-18 -24 -30 -36	-12 -18 -24 -30 -36	-6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24

PG binder properties

- **PG low determination is important for RAP mixes due to cracking**

BBR - stiffness S, m-value after RTFO and PAV
Low T°PG Testing

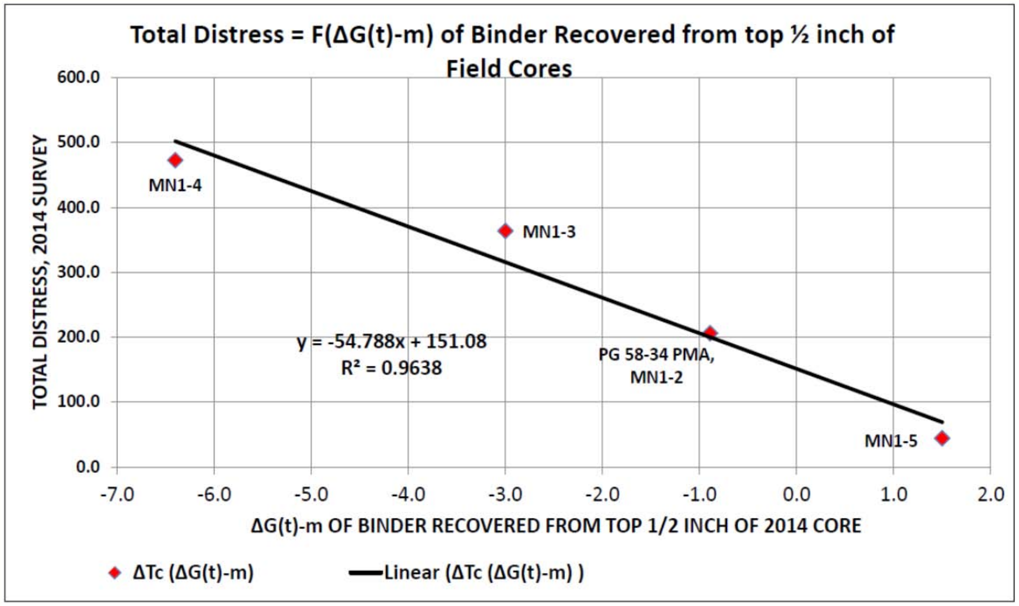


- PG low from previous RAP example
  - Stiffness criteria of 300 MPa met at -28°C
  - m-value criteria of 0.300 met at -26°C
  - Therefore, it's m-value controlled
  - **ΔTc (delta TC) = -28 – (-26) = -2 (one PAV)**

- **Indication of cracking susceptibility through binder testing**
  - ΔTc after two PAVs is being looked - sensitivity to aging
    - Criteria of -5 or higher for reduced cracking
  - PG-low (M 320) of final blended binder

More on ΔTc

- **As ΔTc gets more negative, total pavement cracking increases**
- **2 x PAV (40-hour) ΔTc of -5°C may be too strict of a criteria for high RAP mixes to choose a PG grade or rejuvenator content (i.e. check rutting)**
- **2 x PAV ΔTc good for ranking alternatives or understanding aging sensitivity in blends with RAP**



Data from Gerald Reinke, Binder ETG meeting, April 2015

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Mix properties

Mixture properties

- **Adjust volumetrics – increase % binder or VMA requirements based on RAP%**
- **Rutting is generally not a concern with mixes containing high RAP**
- **Cracking – fatigue or low temperature – is the greater concern**
- **Some agencies looking at the balanced mix design concept**
- **Is complete blending occurring?**

RUTTING

APA AASHTO TP340

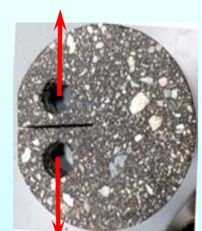
HLWT AASHTO TP324

MOISTURE DAMAGE

HLWT AASHTO TP324

TSR AASHTO T283

CRACKING

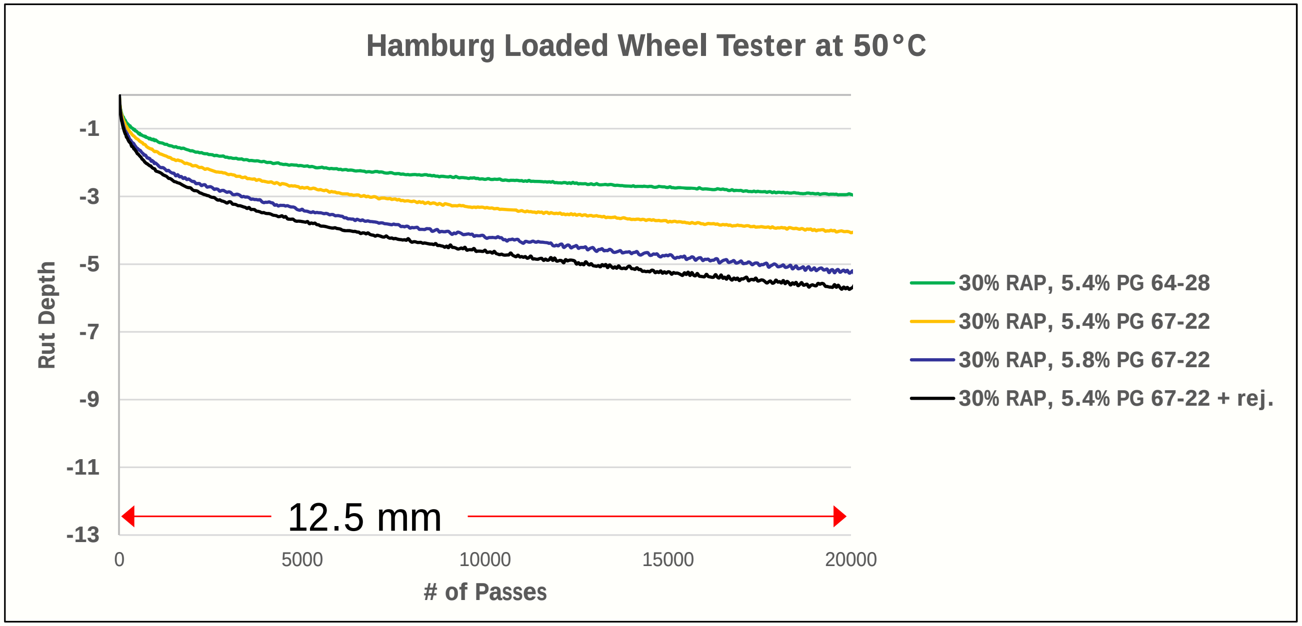


DCT ASTM D 7313

SCB I-FIT AASHTO TP124

Mixture rutting

- **Rutting is generally not a concern with mixes containing high RAP**
  - If new asphalt grade is softened, AC content raised, rejuvenator used - check

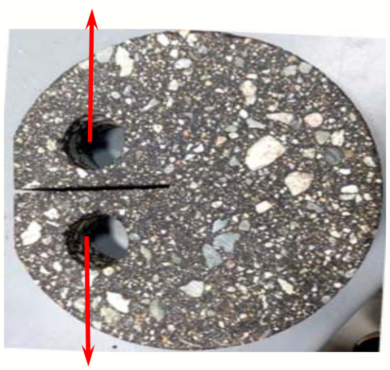


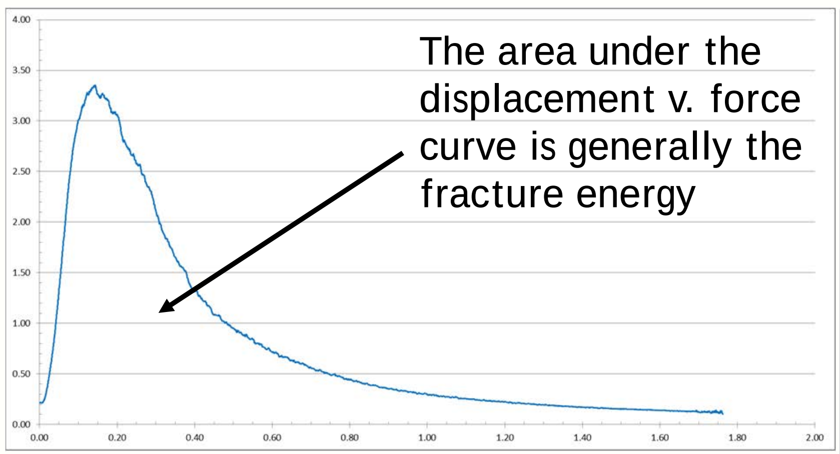
Mixture cracking

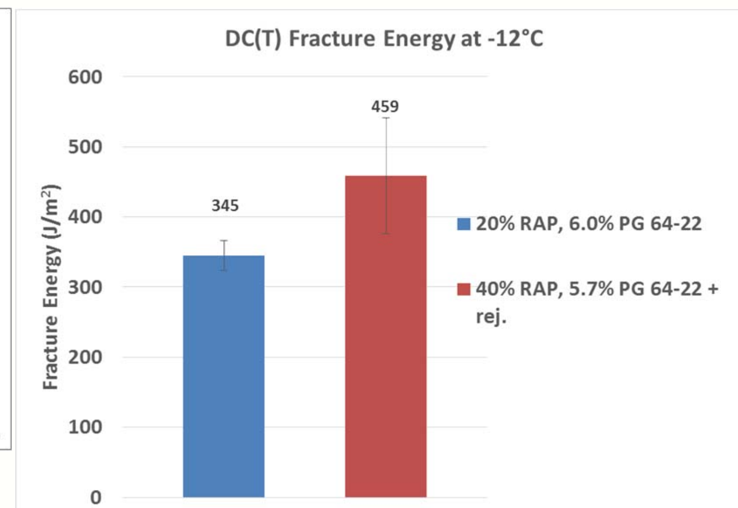
- **Cracking and durability**
- **Several tests available** *Match the test with the distress*
  - **Disk-shaped compact tension (DCT) – cold temperature**
  - **Illinois flexibility index test (I-FIT) – intermediate temperature**
  - **Overlay tester – intermediate temperature**
  - **Bending beam fatigue – intermediate temperature**
  - **Creep compliance indirect tension – cold temperature**
- **Mixture conditioning**

Mixture cracking - DCT

- **Testing performed at 10°C warmer than climate cold temperature grade**
- **A brittle material will require low energy to break the specimen**
- **400 J/m² is the generally accepted cracking threshold**







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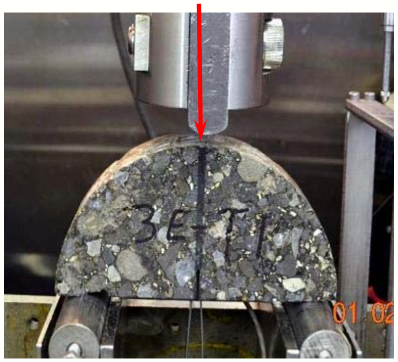
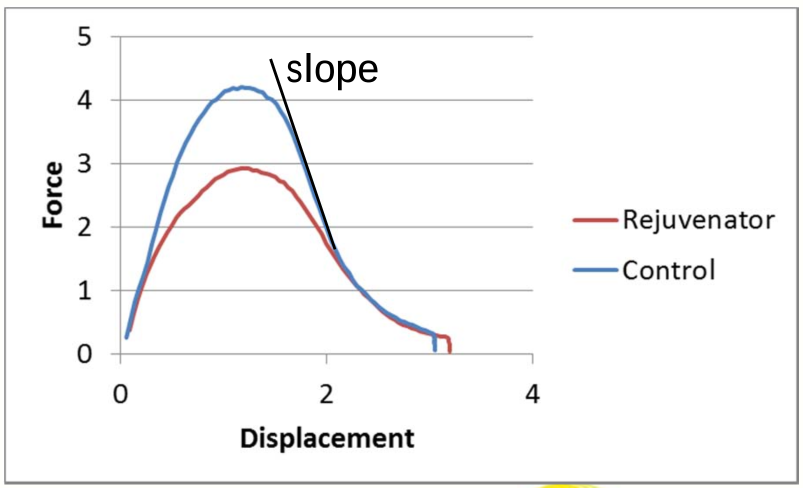
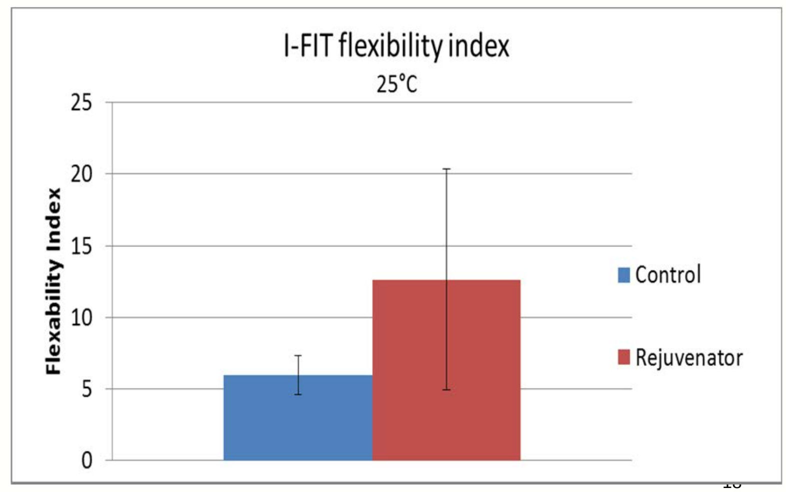
Mixture cracking - I-FIT

- **Testing performed at 25°C**
- **A brittle material will require low energy to break the specimen**
- **8.0 flexibility index is the generally accepted cracking threshold**
- **FI affected by the post-peak slope (steeper - worse)**



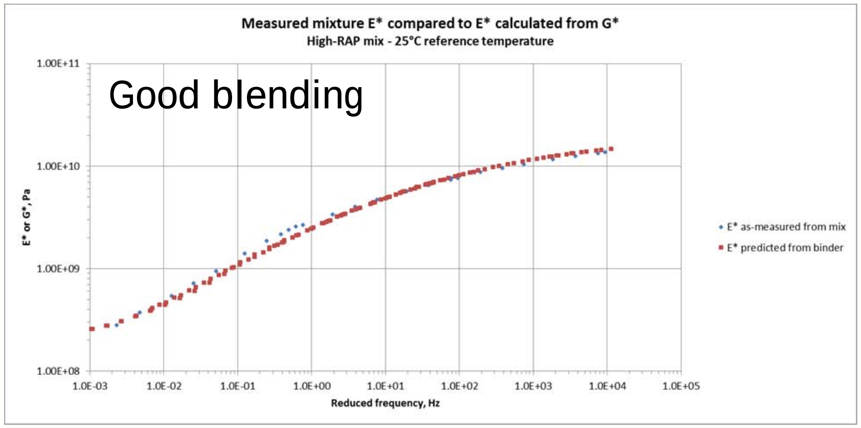


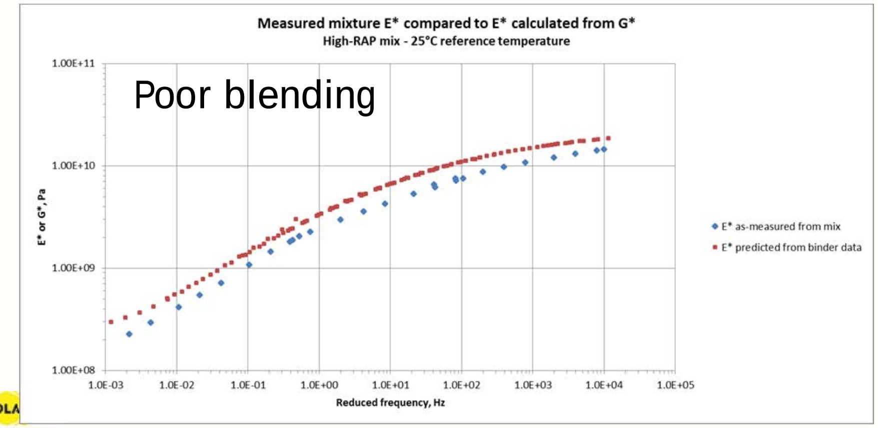


Blending of RAP and new binder

- **Differing points of view on blending of RAP binder and new binder**
  - **Partial blending v. full blending**
  - **Amount of RAP, temperature, mixing time**
  - **TSR, rut tests, crack tests, etc.**
  - **Hirsch model on mix and testing of extracted binder:**

Extraction and recovery





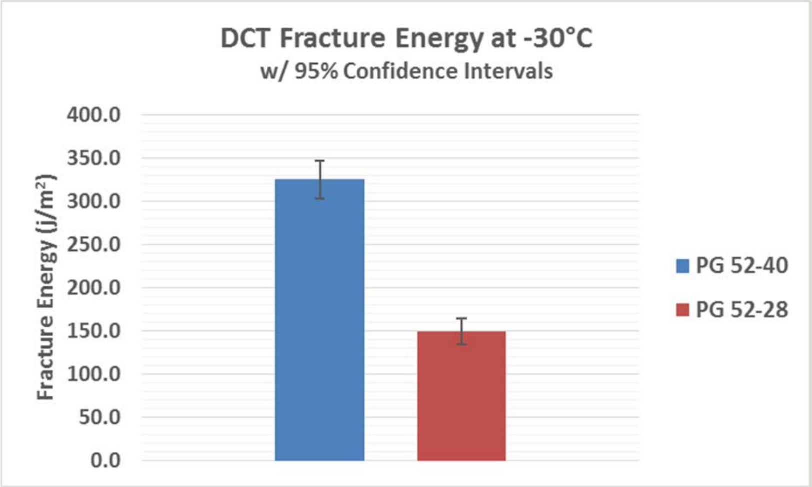
Alaska mix data

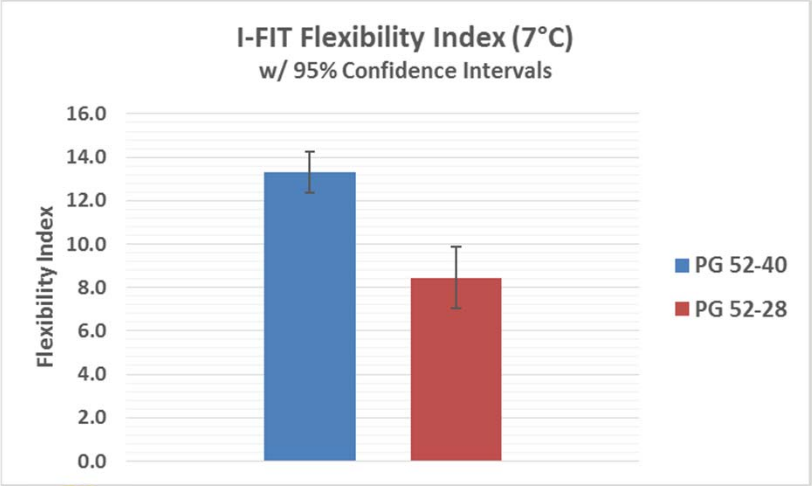
Data on Alaska mixes and recovered binders

- **Type IIB mix with 25% RAP**
- **PG 52-28 or PG 52-40**
- **Total 5.0% asphalt (1% from RAP)**
- **Extracted and recovered binder:**

	Mix with 52-28	Mix with 52-40
Grade	PG 58 - 30	PG 58 - 37
2 PAV PGL	-29°C	-36°C
2 PAV ΔTc	-1.1	-3.6

- **PG benefits in the -40 binder**
- **Good ΔTc values, even with RAP**





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Summary

Binder effects and tests

- Increasing amounts of RAP cause a more brittle binder in the mix
- As RAP content increases, PG-low and ΔTc are negatively impacted
  - Use PG-low of blend with RAP to determine virgin binder grade or rejuvenator type and amount
  - Using ΔTc criteria of -5 to determine virgin grade or rejuvenator content could create a more tender mix with RAP -> use to determine aging sensitivity and to rank choices

Mixture effects and tests

- High amounts of RAP can cause loss of flexibility and premature cracking that can be corrected with softer binders, rejuvenators, or more asphalt
- Several mixture performance tests are available to design for high and low temperature properties

Combining mixture and binder tests

- Adjust volumetric criteria, use the binder tools, and perform rut testing
- Use full suite of performance tests (rutting and cracking) to design a balanced mix
- Don't use traditional mixture and binder criteria and impose performance tests

COLAS

THANK YOU FOR YOUR ATTENTION

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2017 AKDOT Asphalt Summit

Intelligent Compaction & Paver-Mounted Thermal Profiling

By

Dr. George K. Chang, PE

THE TRANSTEC GROUP
The World's Pavement Engineering Specialists

Outlines

- Intelligent Compaction (IC)
- Paver-Mounted Thermal Profiles (PMTP)
- Other Tests and Measurements
- Veta for Data Management
- US National Implementation
- Benefits of Using IC-PMTP
- Future Development and Further Information

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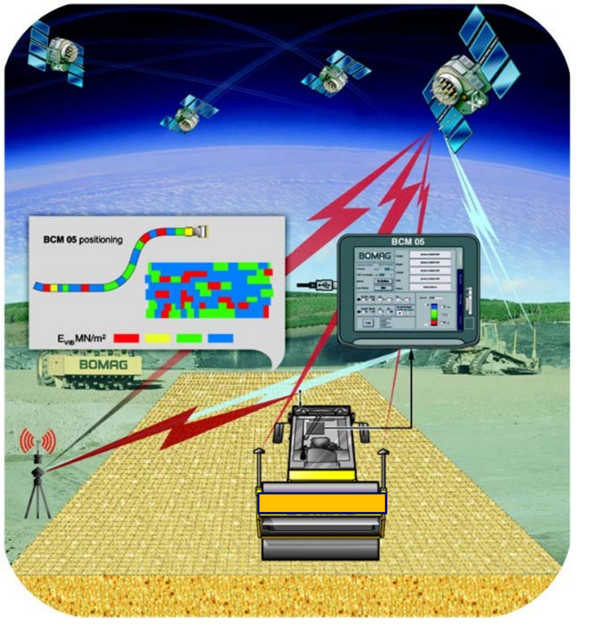

Intelligent Compaction

OEM IC Systems

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Example IC Retrofit System

Courtesy of Topcon/RDO

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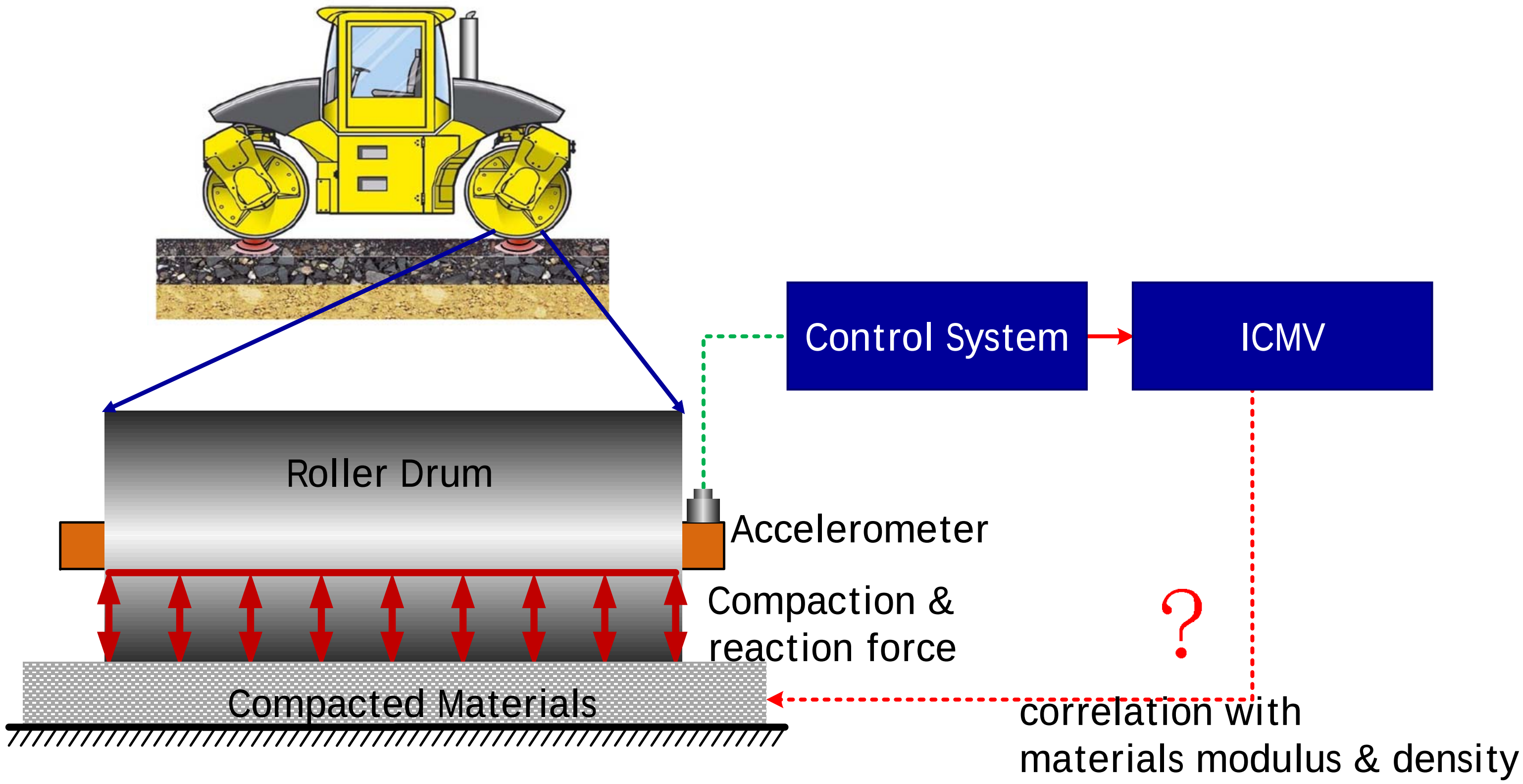
Intelligent Compaction Measurement Values (ICMV)



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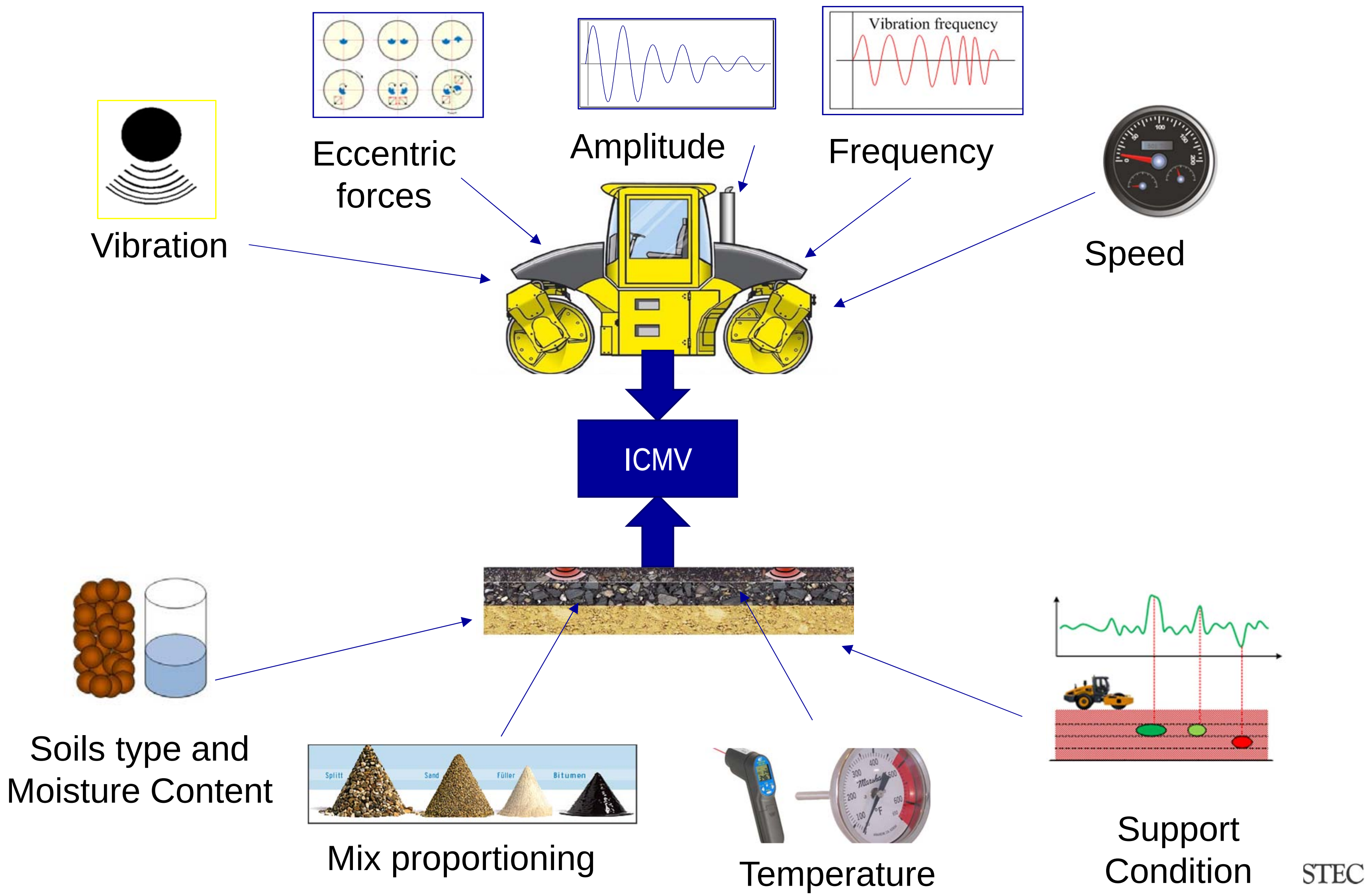

Vibration
Eccentric forces
Amplitude
Vibration frequency
Frequency
Speed
ICMV
Soils type and Moisture Content
Mix proportioning
Temperature
Support Condition

STEC GROUP

Various ICMVs

Asphalt Density vs ICMV (Stiffness)

THE TRANSTEC GROUP

GPS Validation **AASHTO PP81 Diff < 6 in.**

THE TRANSTEC GROUP

Temperature sensor validation

AASHTO PP81 Diff < 5°F

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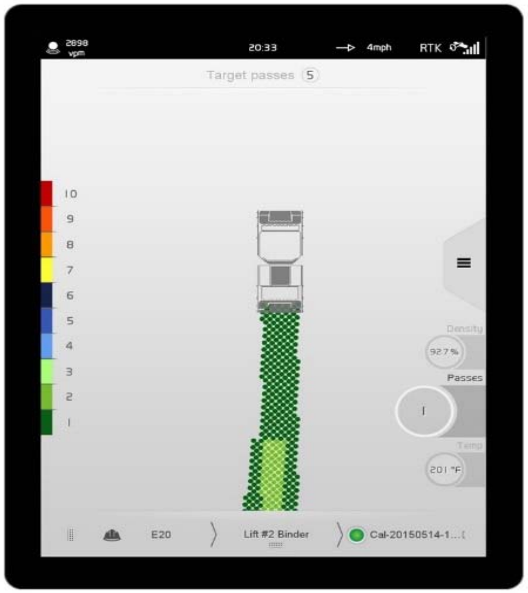
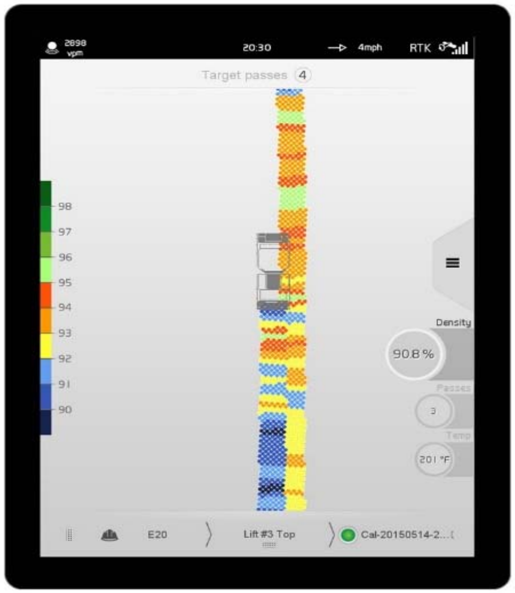
Example IC Color-Coded Displays



Roller Passes

Asphalt Temperature



ICMV

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Paver-Mounted Thermal Profiles (PMTP)

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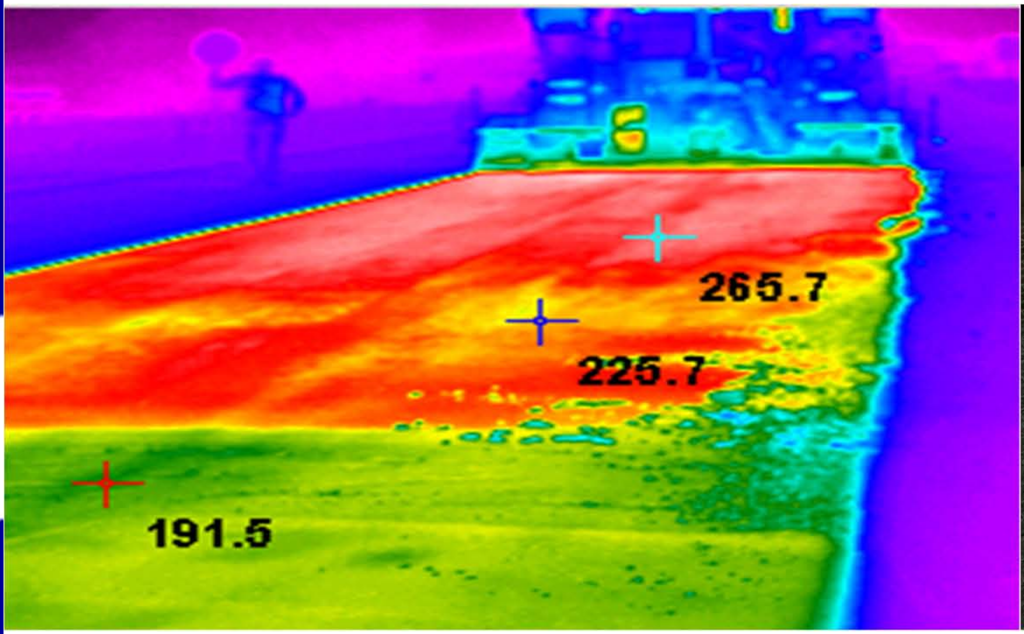
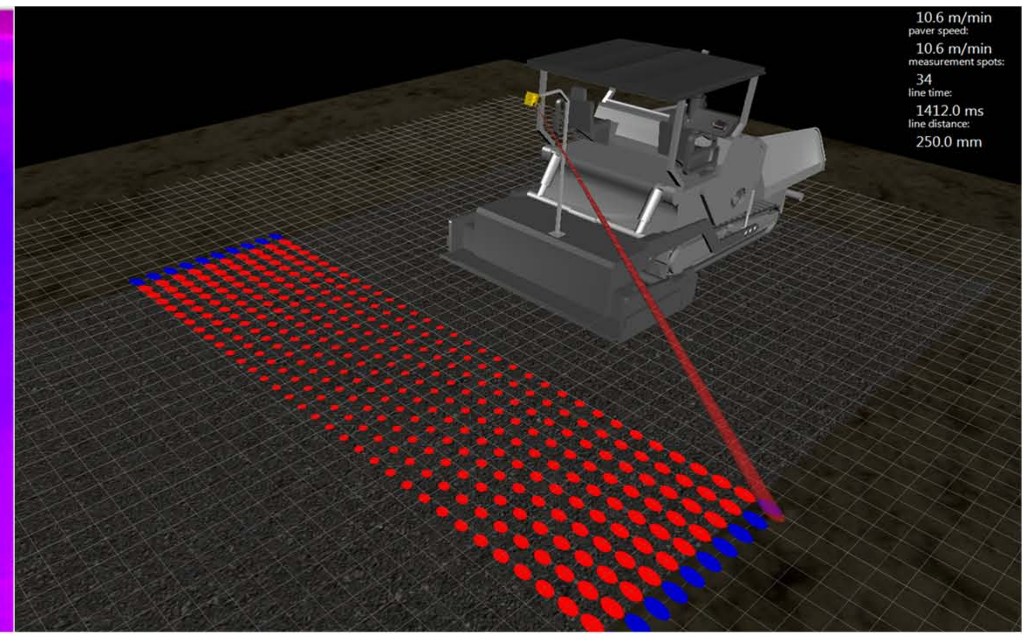
Thermal Camera vs PMTP





Courtesy of MOBA

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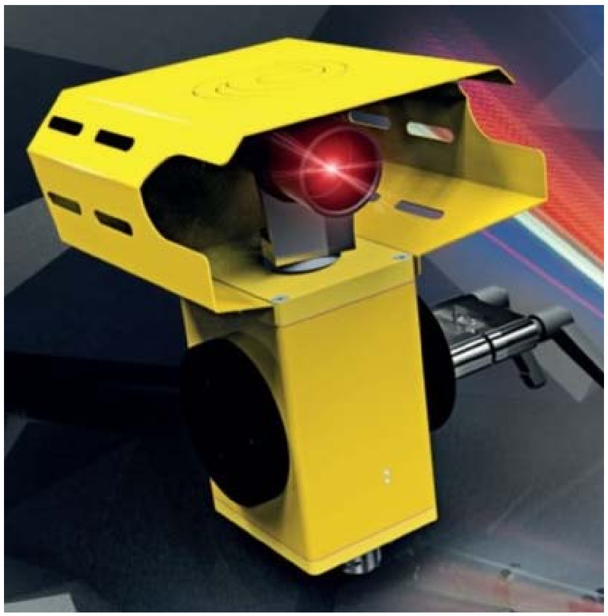
An Example PMTP

Example PMTP Components



Courtesy of MOBA

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PMTP DMI Calibration

Courtesy of MOBA

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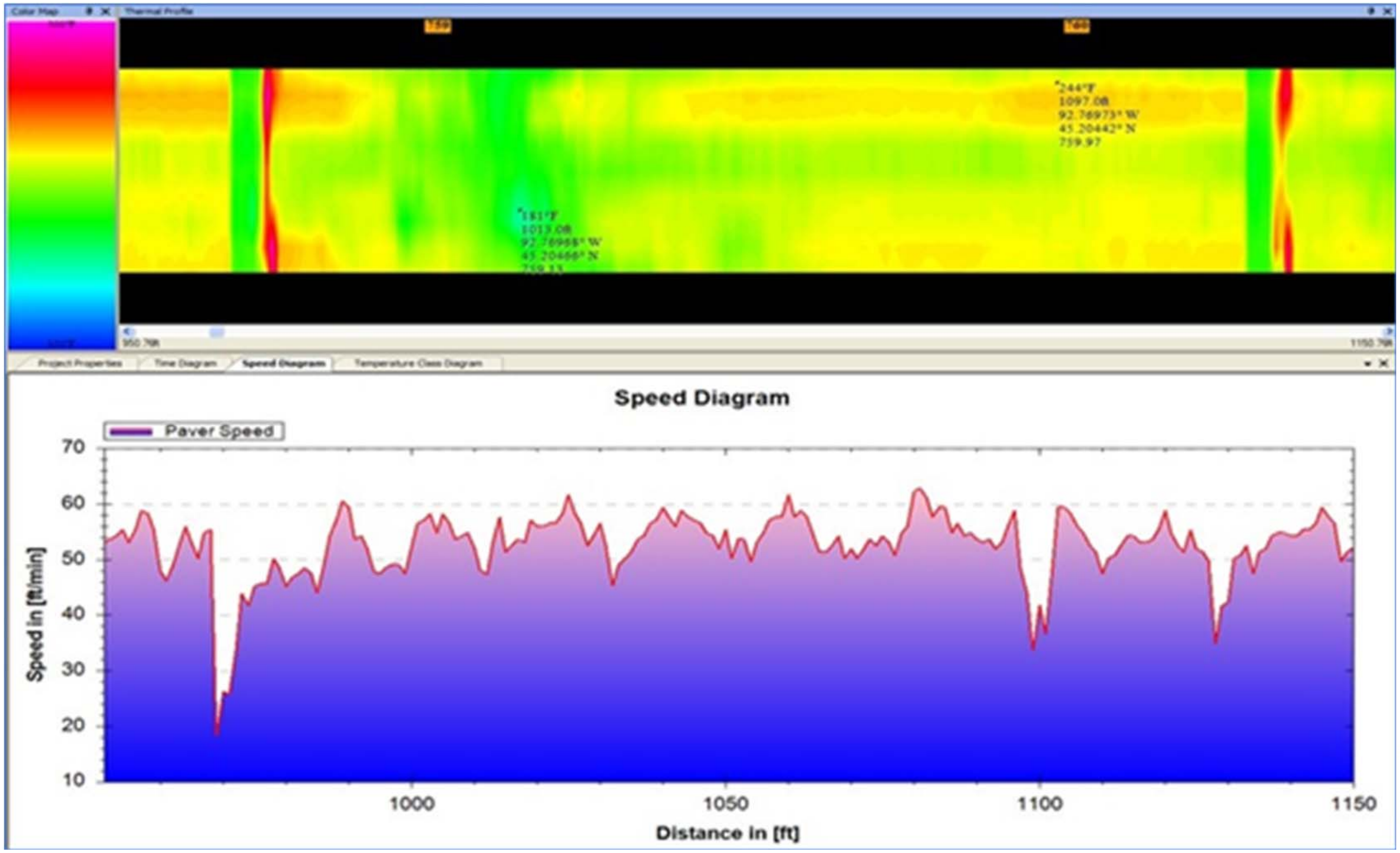
Display of Thermal Profiles and Paver Speed, etc.



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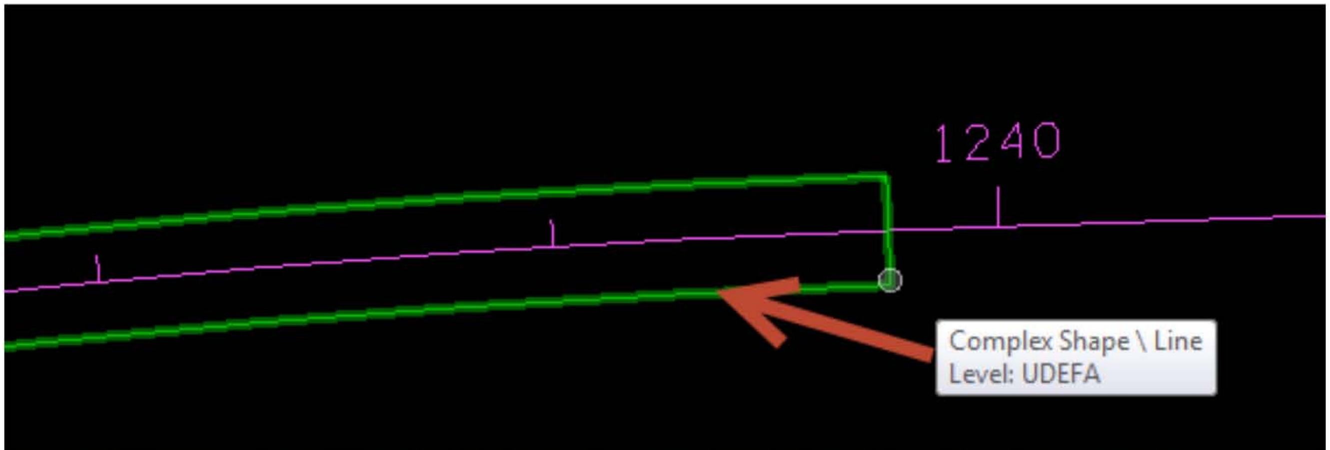
Other Tests and Measurements

Spot Tests and GPS Data

Daily Production Boundary

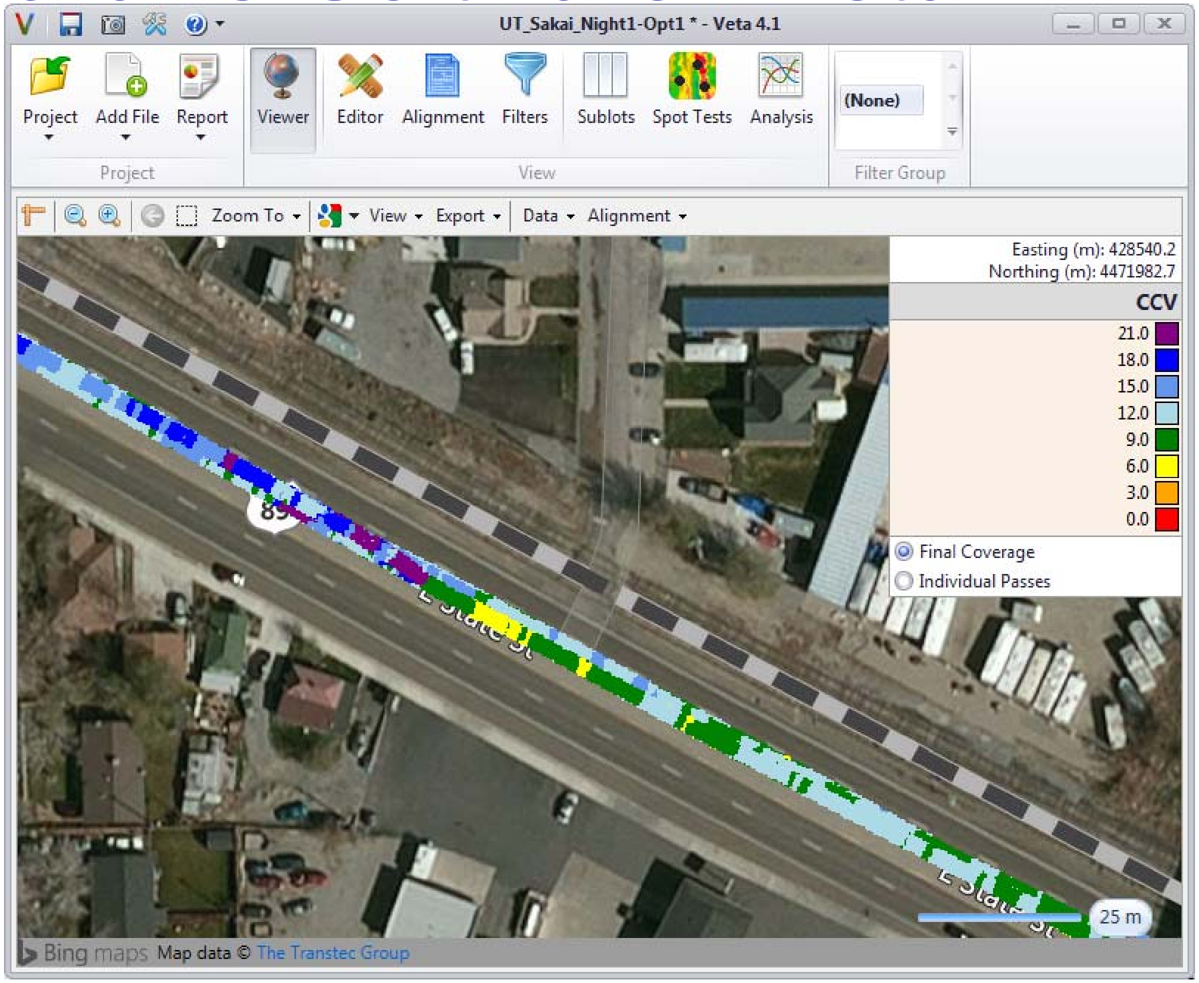
Alignment File – KMZ, LandXML



Courtesy of MnDOT

Veta for Data Management

Standard IC Software - Veta



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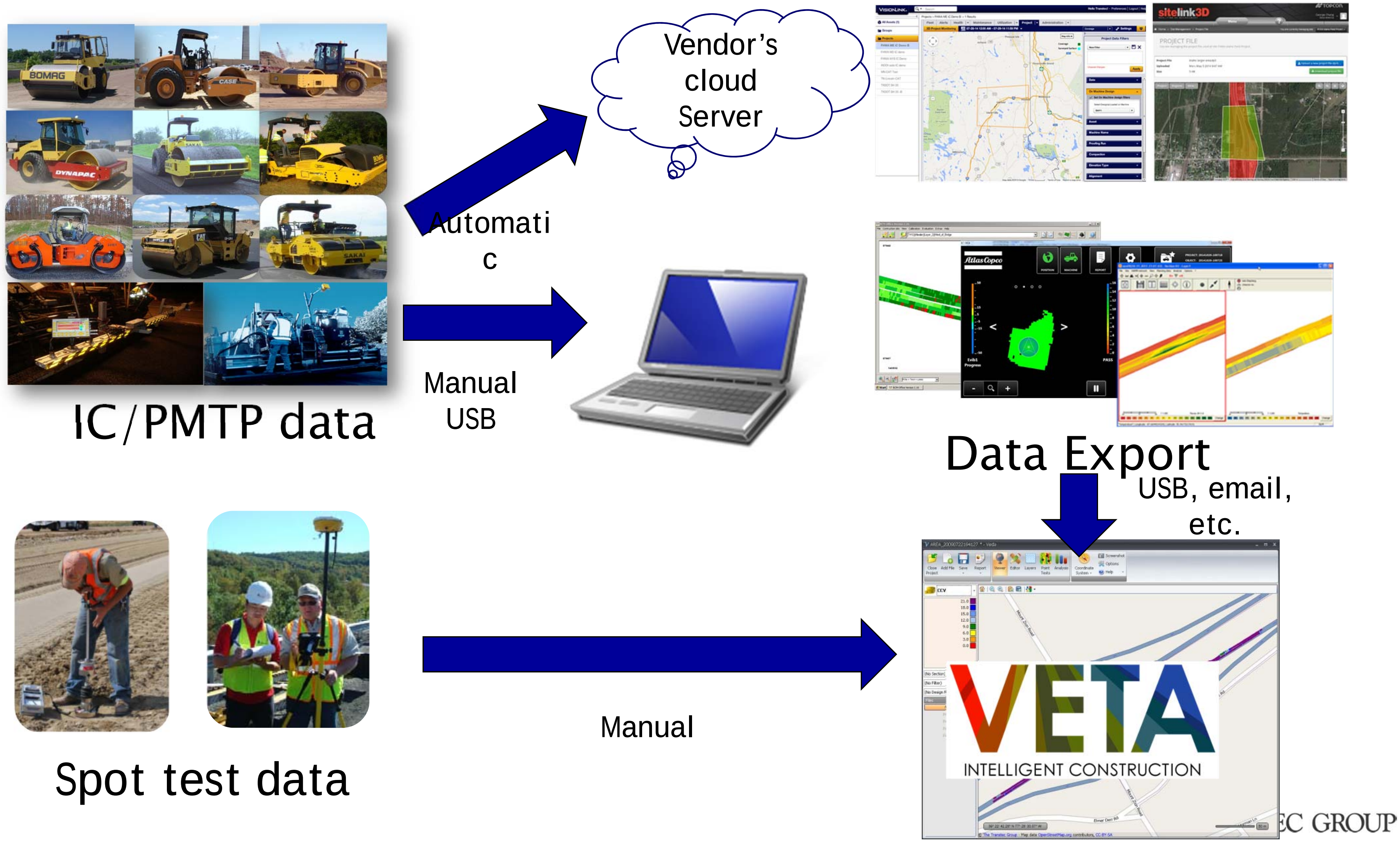
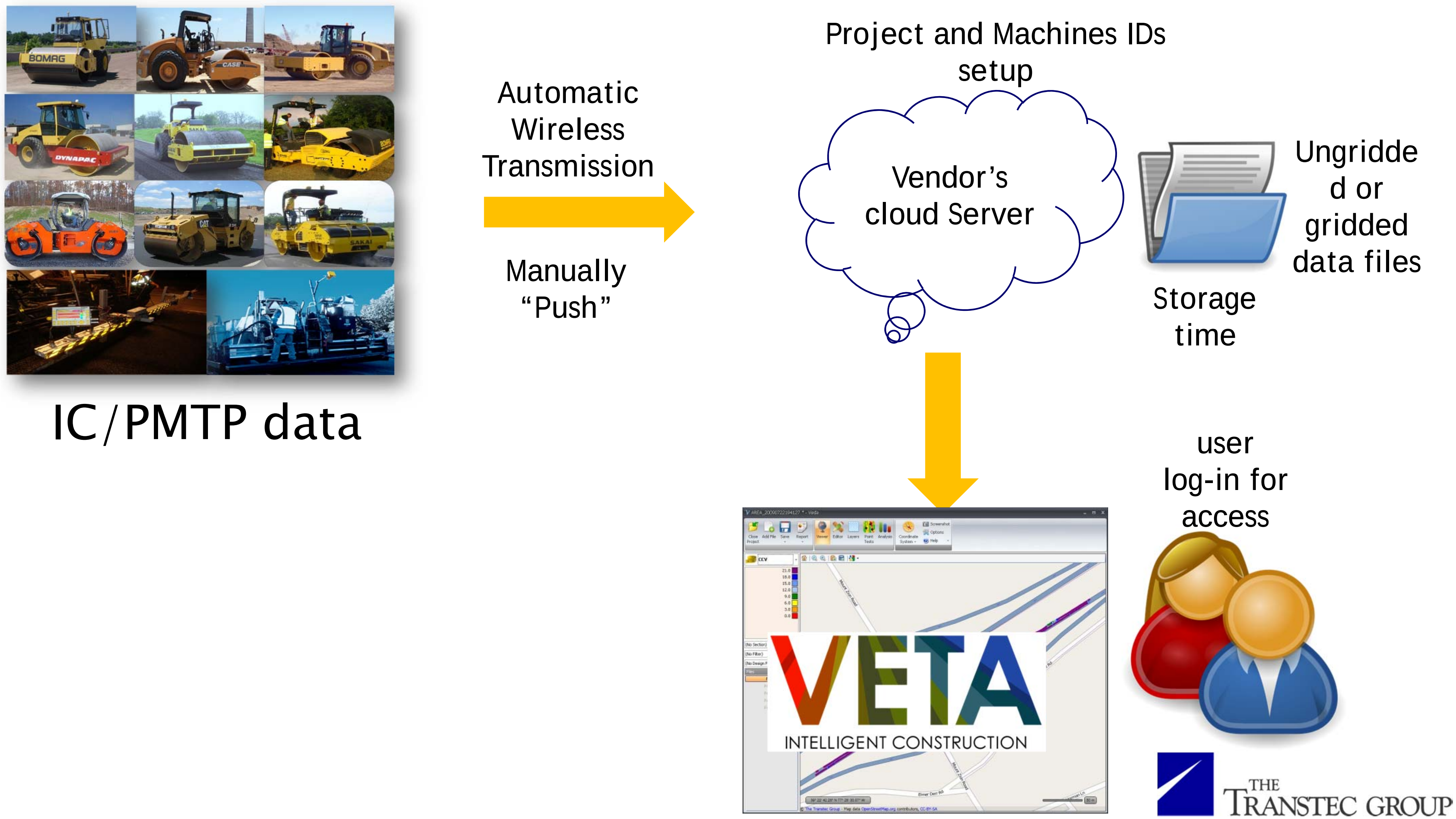
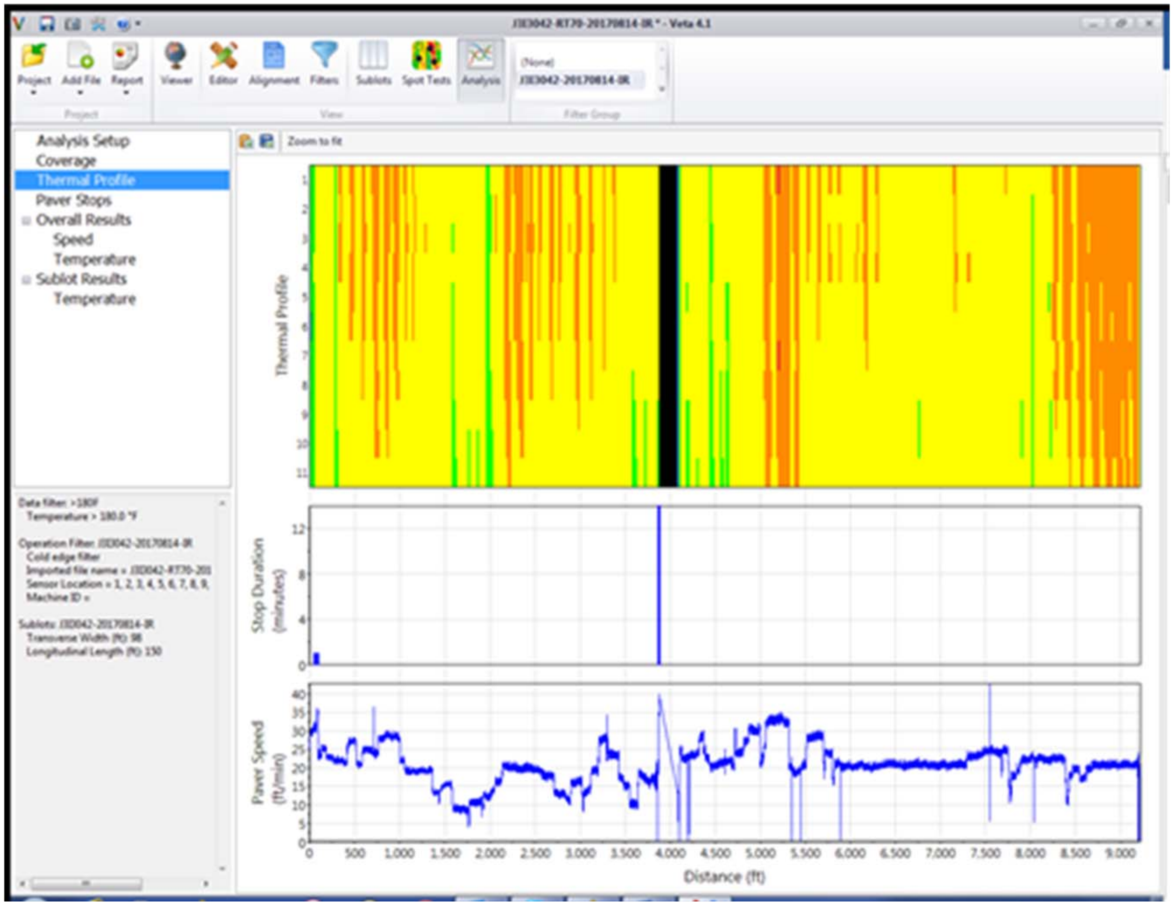
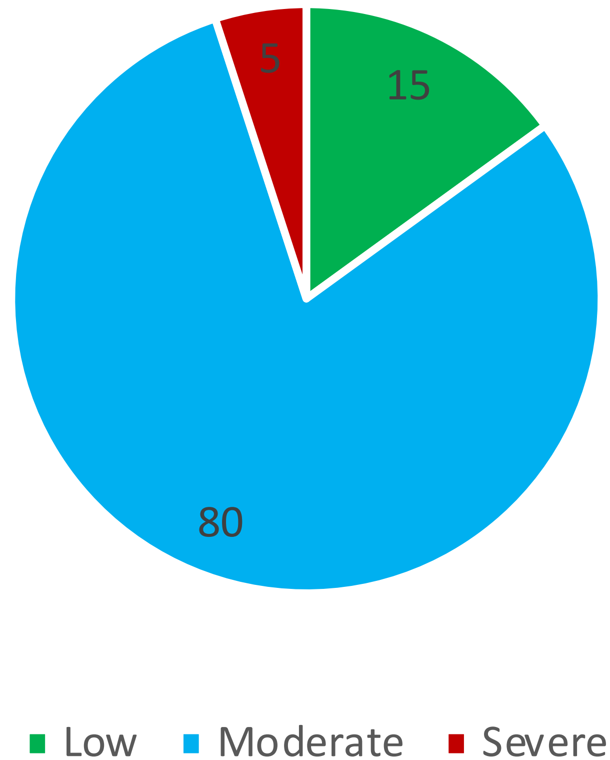

Vendor's cloud Server
Automatic
Manual USB
IC/PMTP data
Data Export
USB, email, etc.
Spot test data
Manual
VETA
INTELLIGENT CONSTRUCTION


IC/PMTP data
Automatic Wireless Transmission
Manually "Push"
Project and Machines IDs setup
Vendor's cloud Server
Ungridded or gridded data files
Storage time
user log-in for access
VETA
INTELLIGENT CONSTRUCTION
THE TRANSTEC GROUP

Veta PMTP Data Analysis





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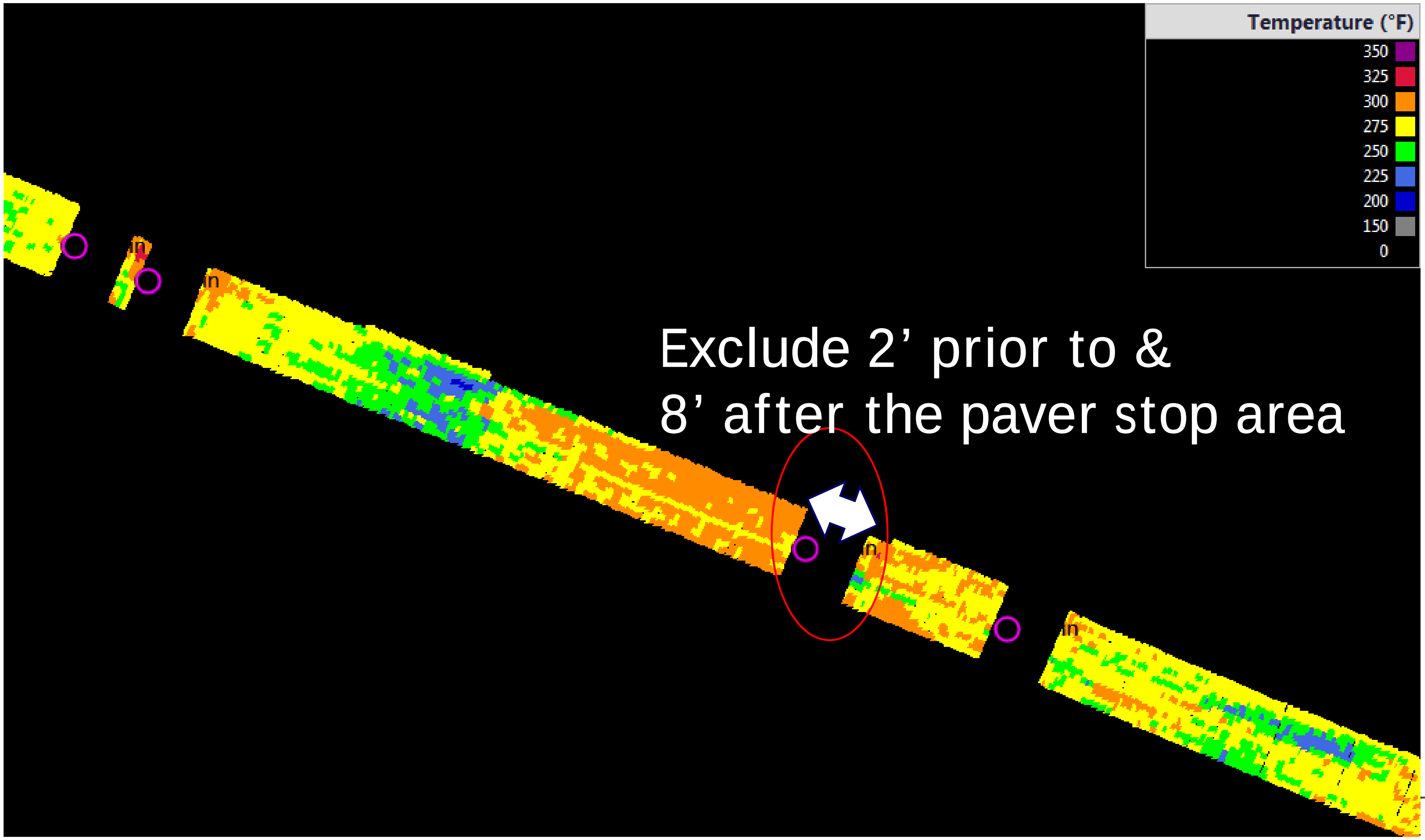
Exclusion of Paver Stops



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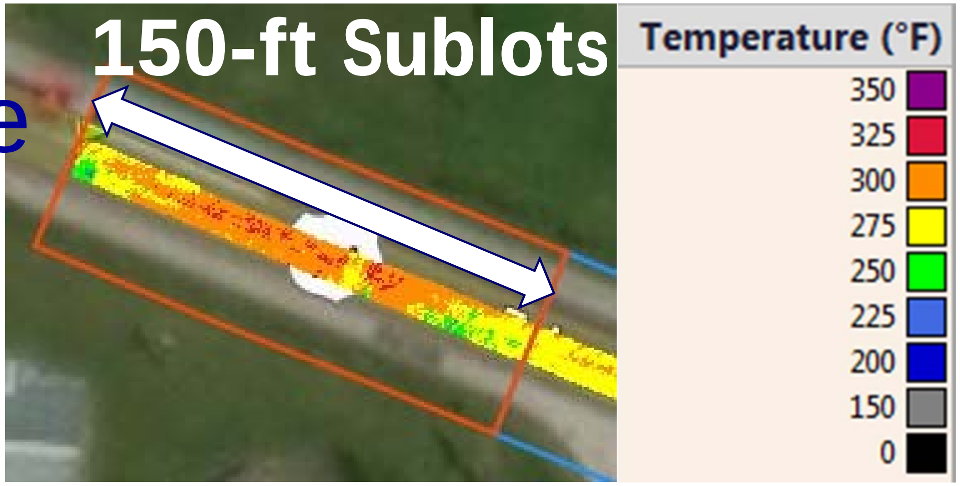
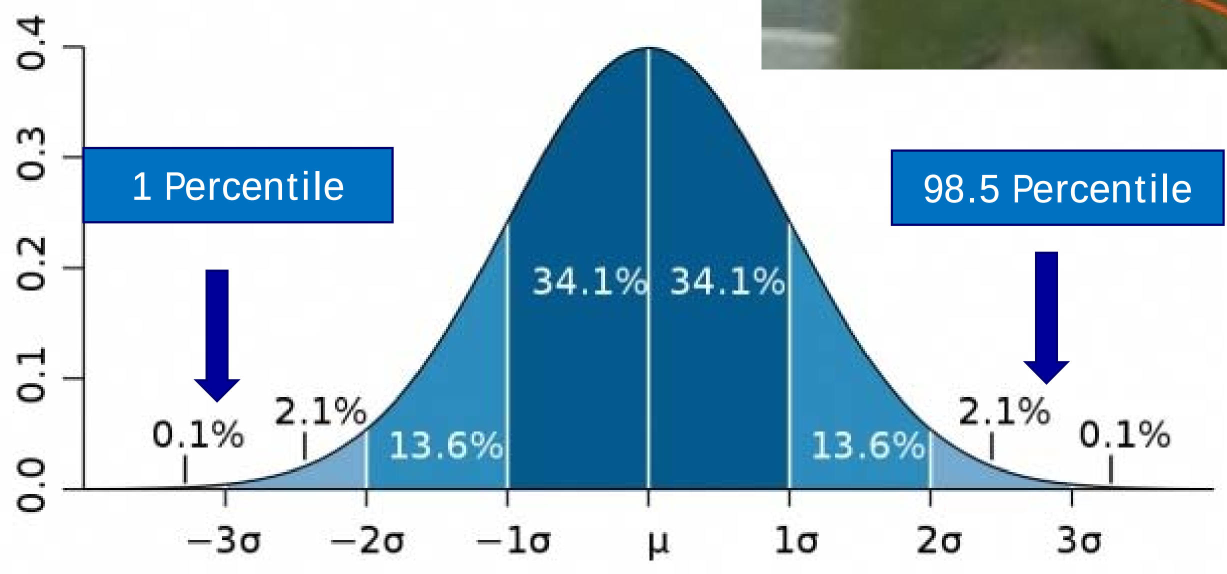
AASHTO Range Value





Range = $\text{Temp}_{98.5\text{Percentile}} - \text{Temp}_{1\text{Percentile}}$

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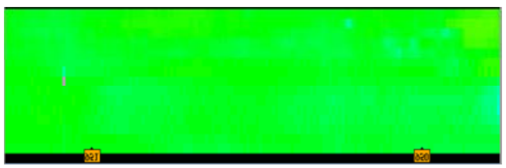
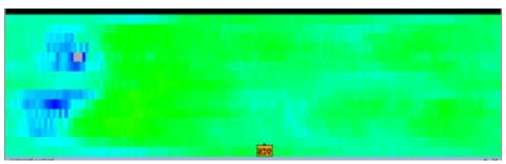
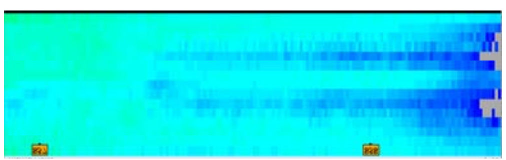
AASHTO Temperature Segregation

150-ft Sublots	Range	Segregation
	ΔF≤ 25°F	NO SEG
	25°F<ΔF≤ 50°F	MODERATE
	ΔF> 50°F	SEVERE

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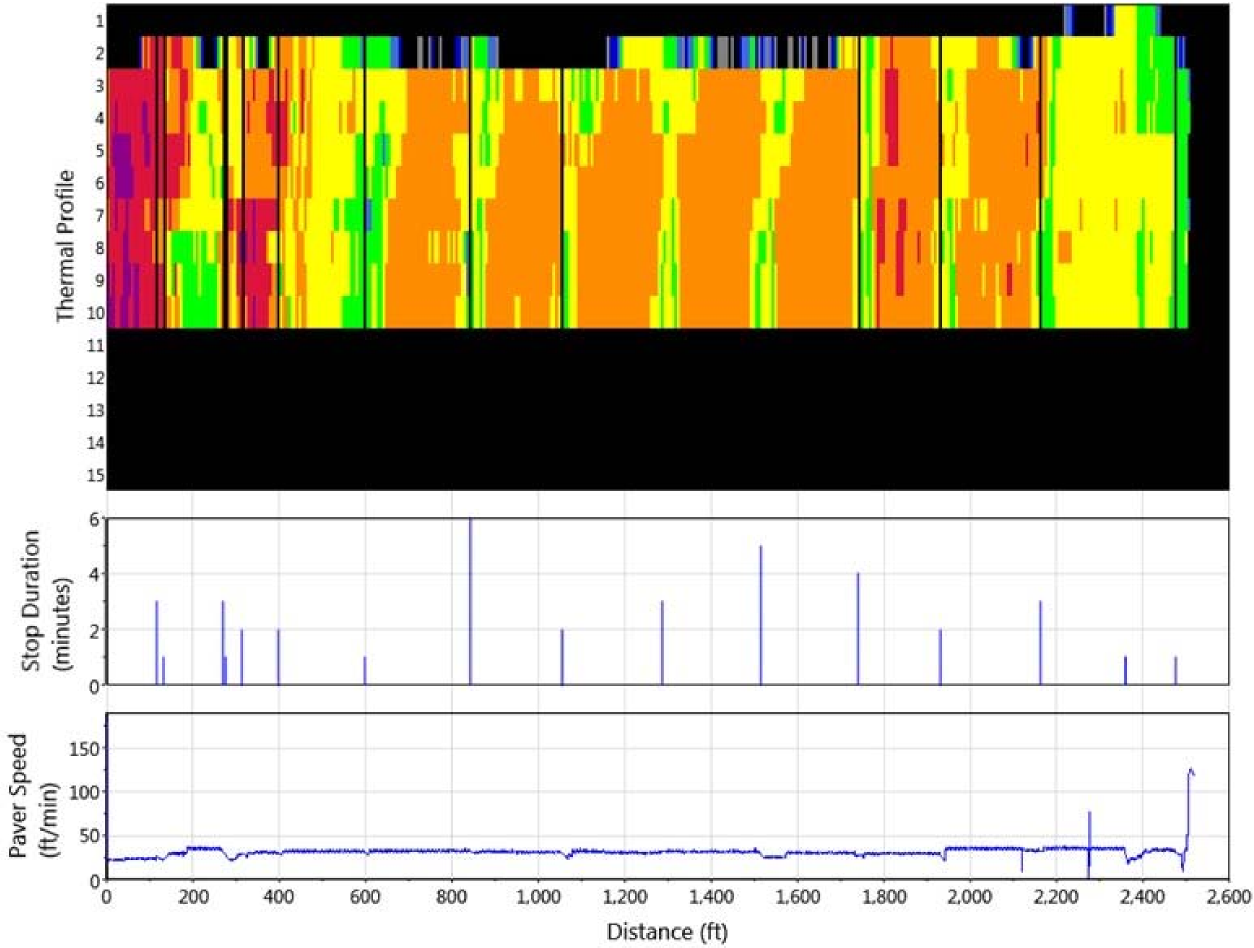
Veta PMTP Report

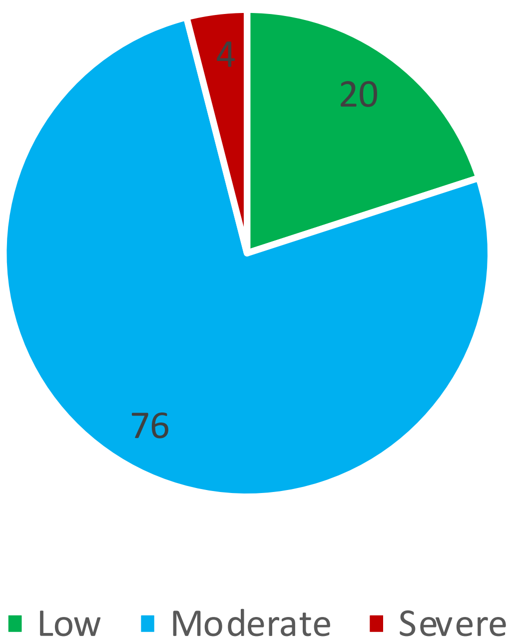
Name	Actual Area (ft²)	Length (ft)
Section1	42,531	2,520
Overall Results	42,531	2,520



Veta Thermal Segregation Report

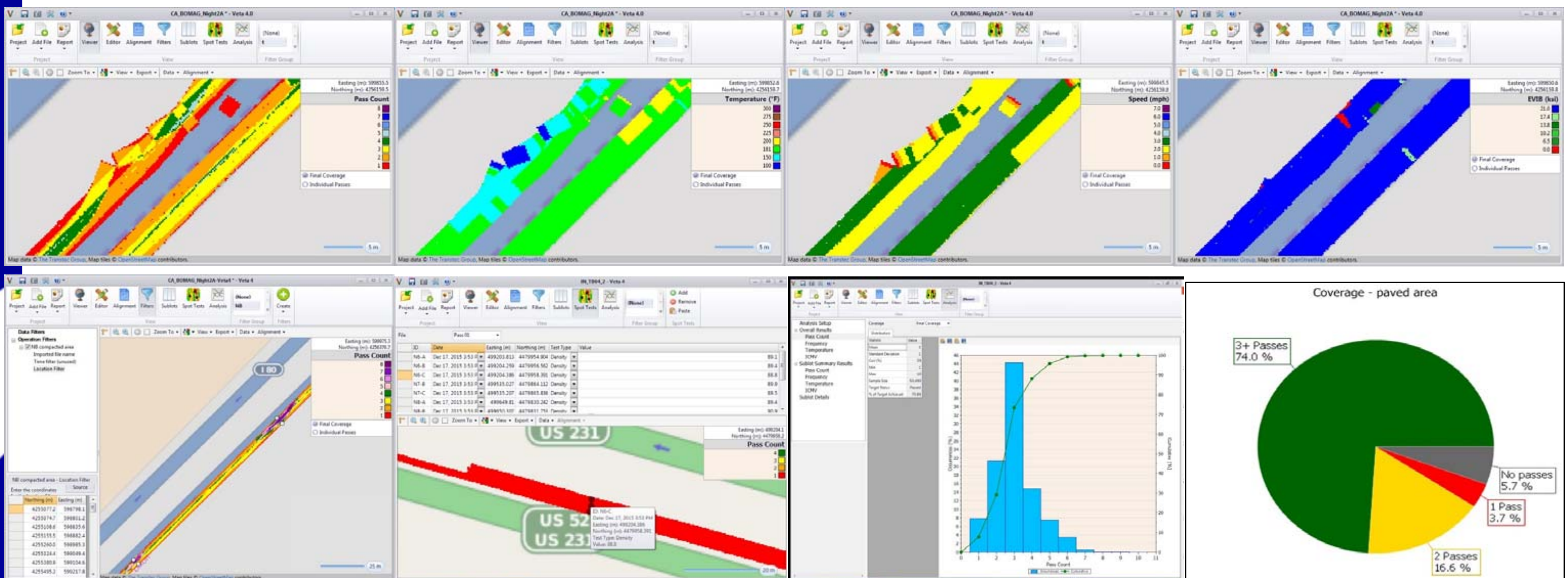
Distribution | Mean | Differential

Category	Count	Percent (%)
Low	16	20
Moderate	61	76
Severe	3	4



Start distance (ft)	Length (ft)	Category	Minimum (°F)	Maximum (°F)	Differential (°F)
0	150	Moderate	234	281	47
150	150	Moderate	250	282	32
300	150	Moderate	260	293	33
450	150	Moderate	252	286	34
600	150	Moderate	264	293	29
750	150	Low	263	287	24
900	150	Moderate	259	285	26
1,050	150	Low	258	283	25
1,200	150	Moderate	264	292	28
1,350	150	Moderate	270	302	32
1,500	150	Moderate	270	318	48
1,650	150	Low	275	297	22
1,800	150	Moderate	253	292	40
1,950	150	Moderate	259	285	26
2,100	150	Moderate	251	300	48
2,250	150	Moderate	269	303	34
2,400	150	Moderate	266	305	39
2,550	150	Moderate	269	313	44
2,700	150	Moderate	277	310	33
2,850	150	Low	271	294	23
3,000	150	Moderate	278	305	28

Veta IC Analysis



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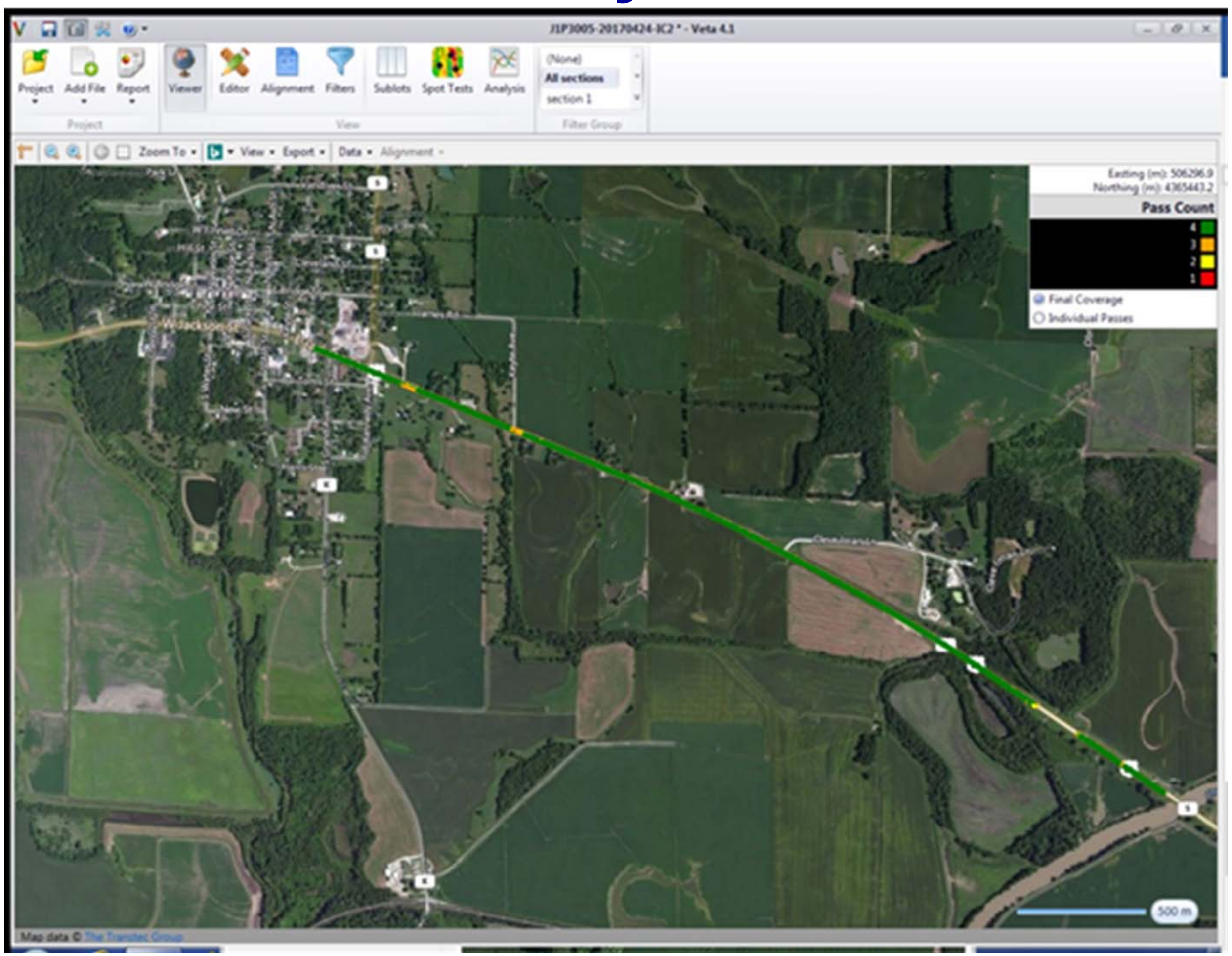
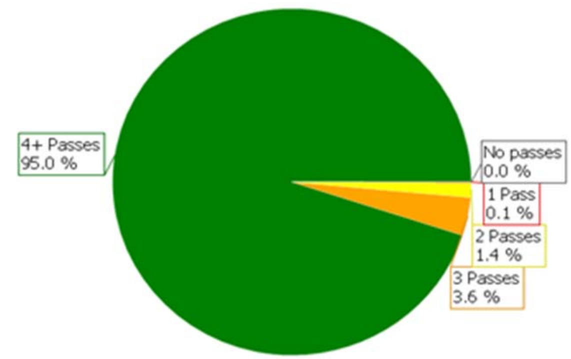
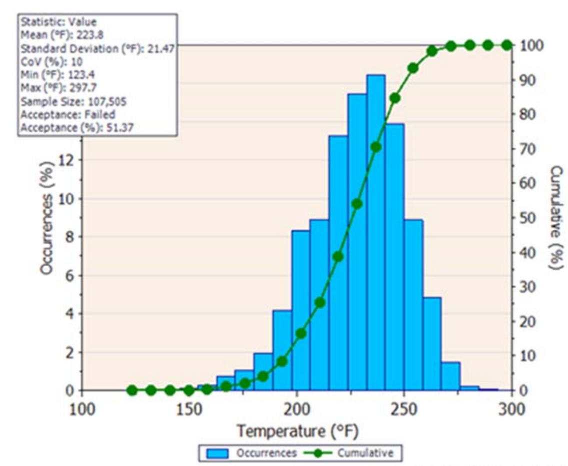
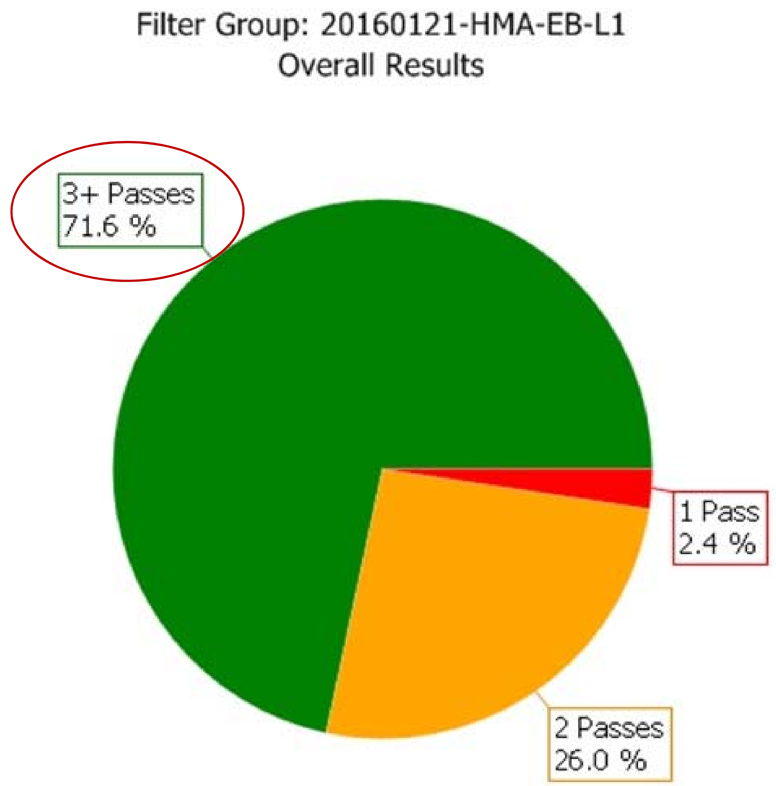
IC Data Analysis



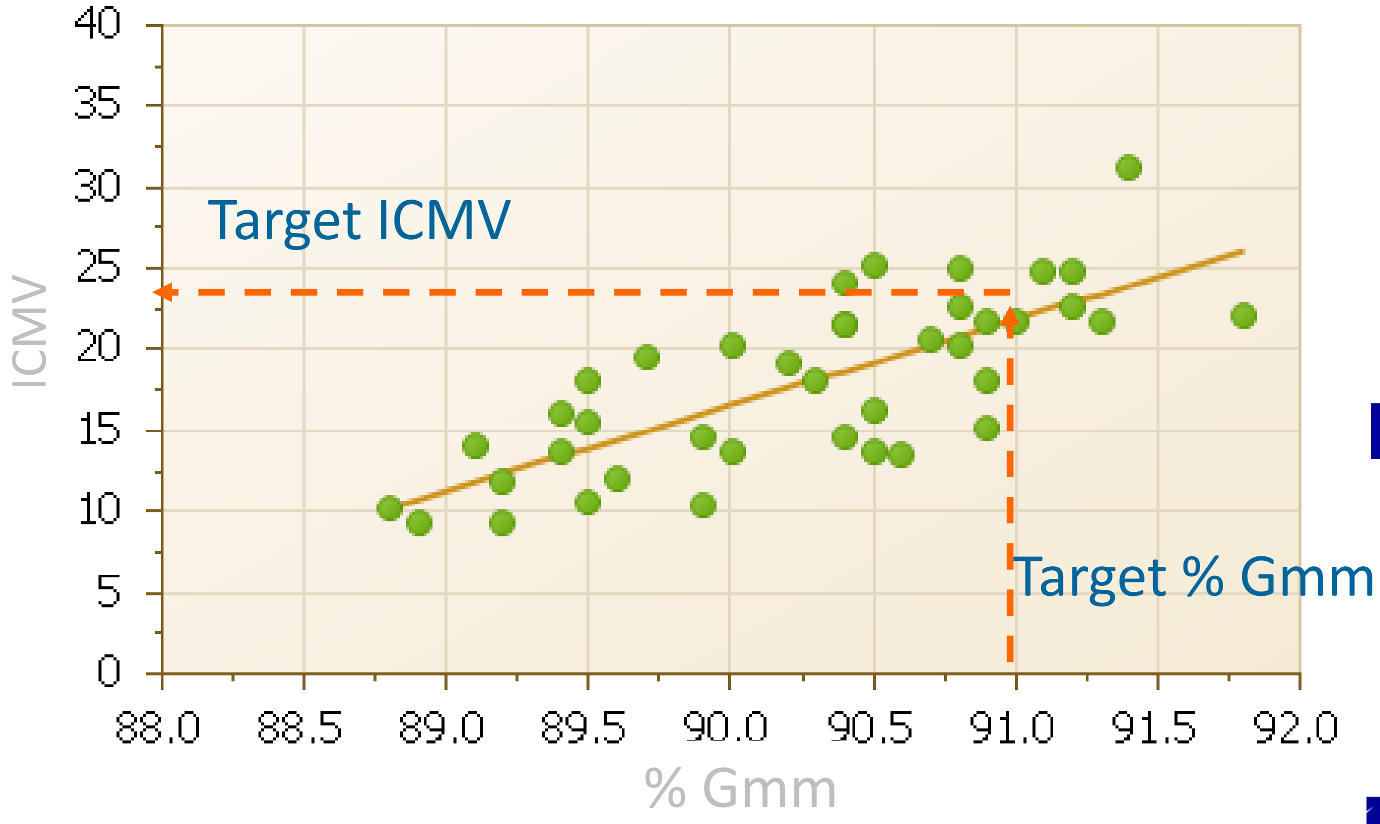




Veta Analysis – Coverage of Target Passes



Target ICMV from Trial Section Data



Passing
R > 0.7
Or
R^2 > 0.5

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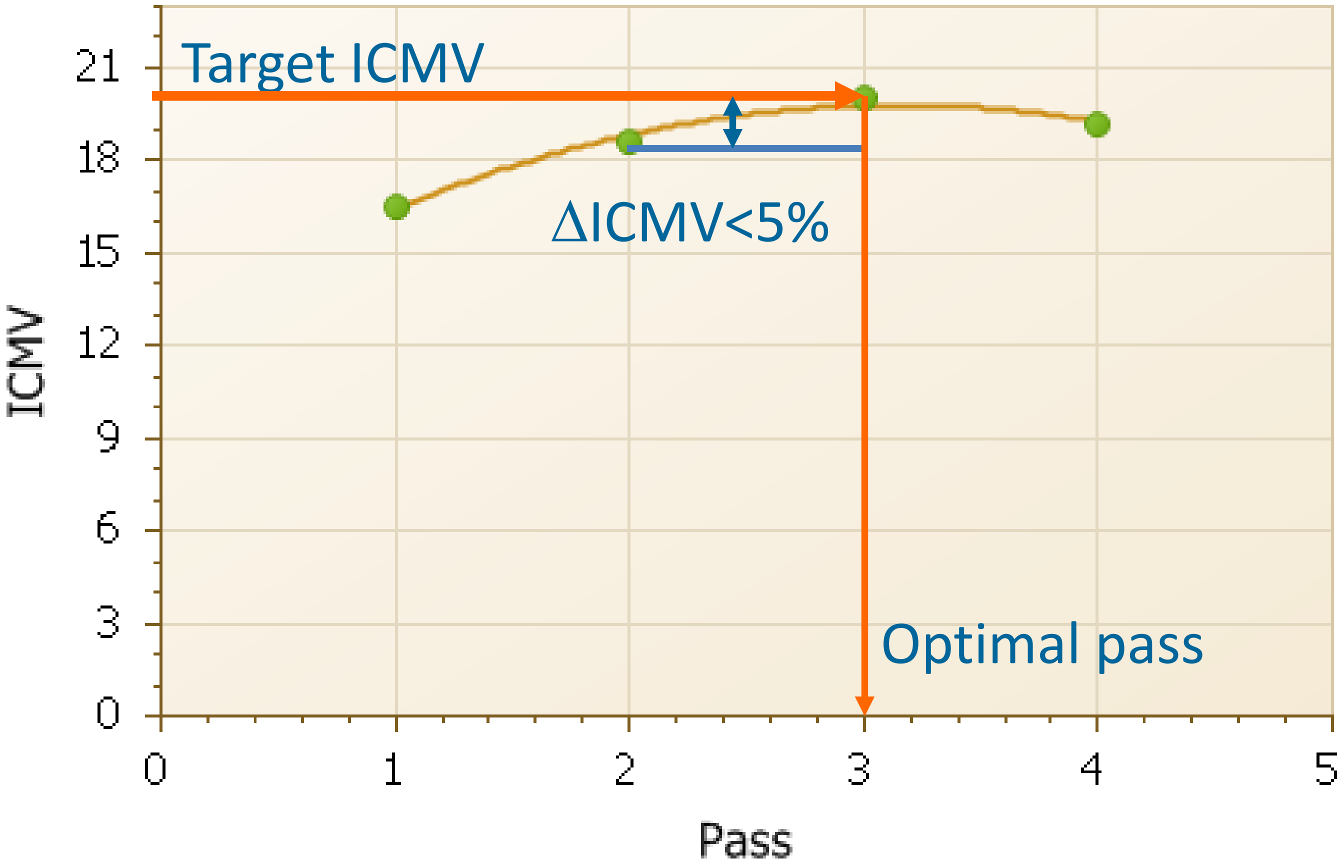
Target ICMV for QC



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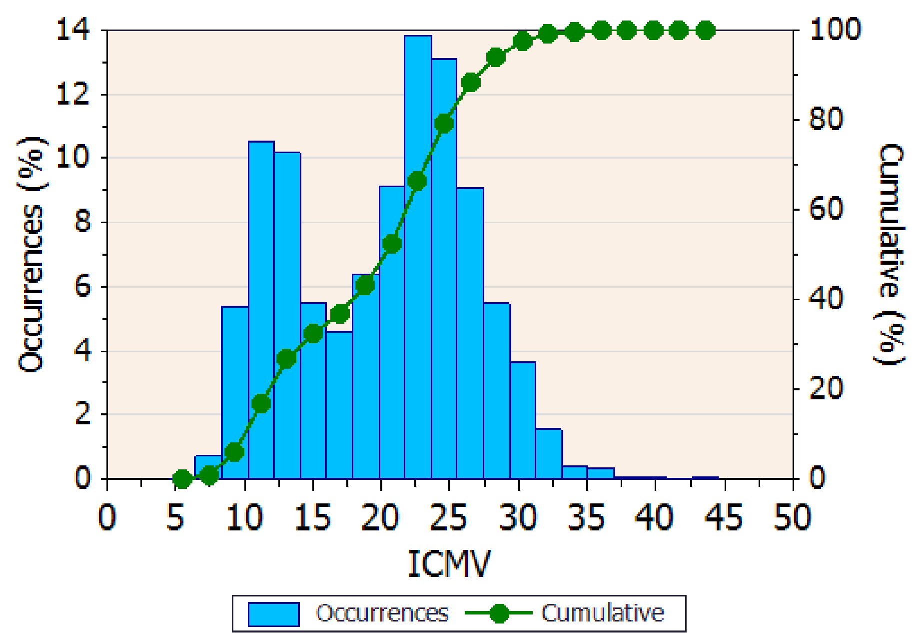
Veta Analysis – Coverage of Target ICMV

Coverage: Final Coverage

Distribution

Statistic	Value
Mean	19.06
Standard Deviation	6.43
CoV (%)	34
Min	5.50
Max	43.60
Sample Size	44,216
Acceptance	Passed
Acceptance (%)	78.53



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National Implementation

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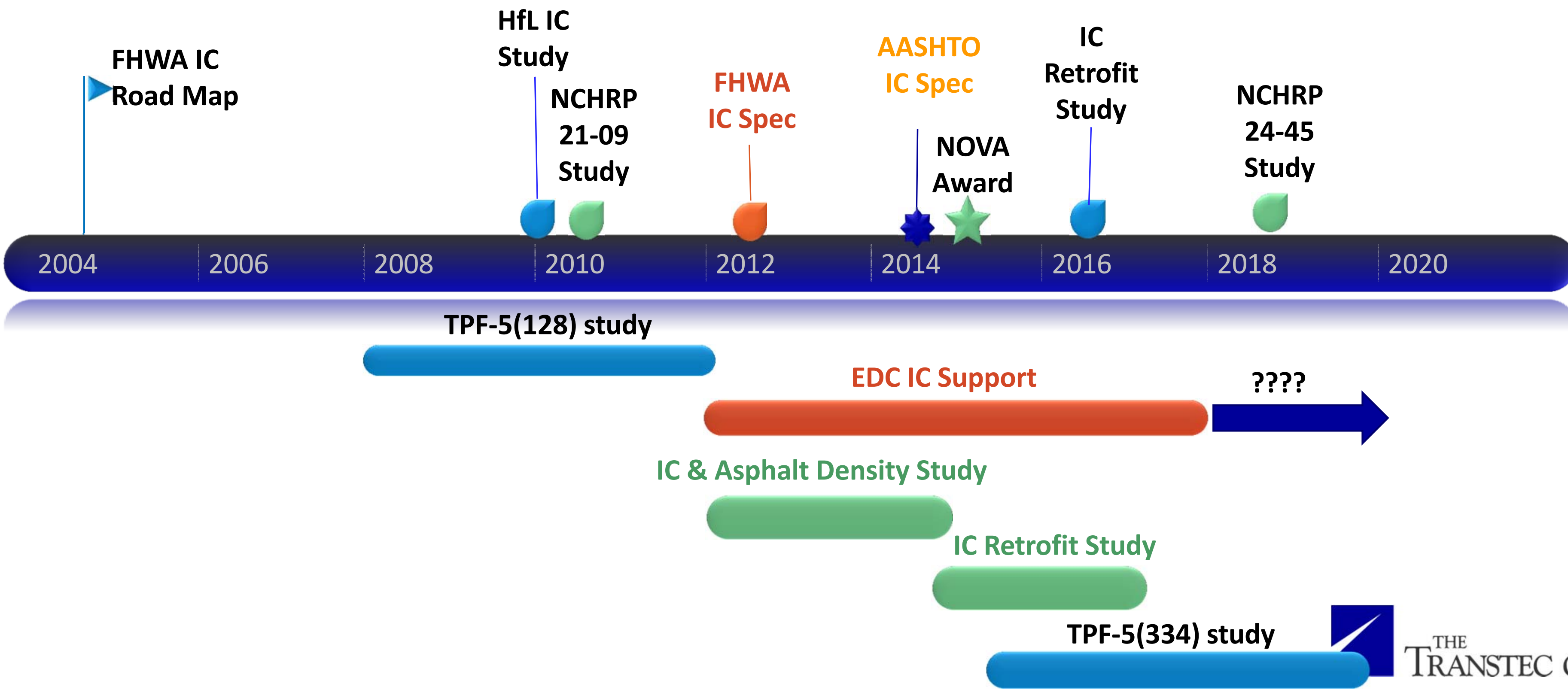
A BRIEF HISTORY OF IC IN US



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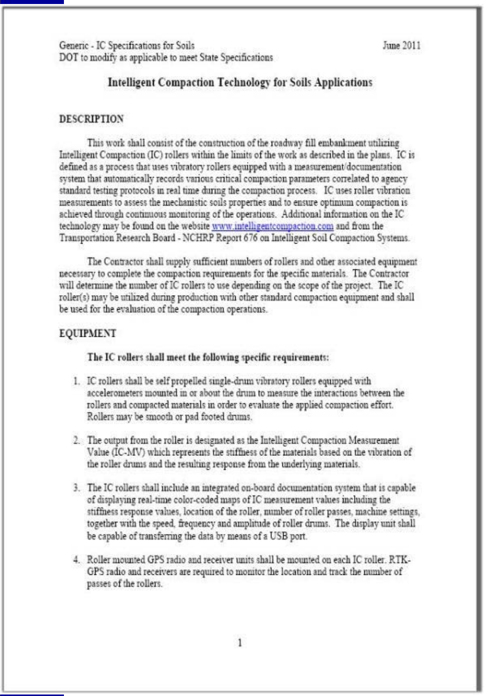
FHWA Tech Brief

US National IC Guide Specs

FHWA Soils/Asphalt IC



Generic - IC Specifications for Soils — June 2011
DOT to modify as applicable to meet State Specifications

Intelligent Compaction Technology for Soils Applications

DESCRIPTION

This work shall consist of the construction of the roadway fill embankment utilizing Intelligent Compaction (IC) rollers within the limits of the work as described in the plans. IC is defined as a process that uses vibratory rollers equipped with a measurement/documentation system that automatically records various critical compaction parameters correlated to agency standard testing protocols in real time during the compaction process. IC uses roller vibration measurements to assess the mechanistic soils properties and to ensure optimum compaction is achieved through continuous monitoring of the operations. Additional information on the IC technology may be found on the website www.intelligentcompaction.com and from the Transportation Research Board - NCHRP Report 676 on Intelligent Soil Compaction Systems.

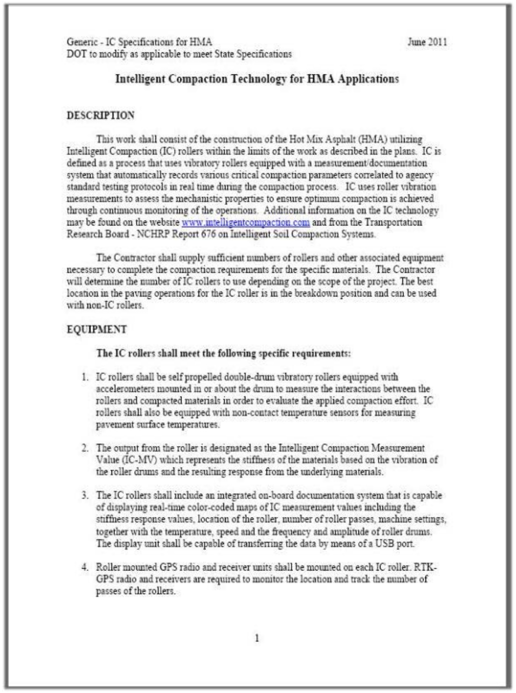
The Contractor shall supply sufficient numbers of rollers and other associated equipment necessary to complete the compaction requirements for the specific materials. The Contractor will determine the number of IC rollers to use depending on the scope of the project. The IC roller(s) may be utilized during production with other standard compaction equipment and shall be used for the evaluation of the compaction operations.

EQUIPMENT

The IC rollers shall meet the following specific requirements:

1. IC rollers shall be self propelled single-drum vibratory rollers equipped with accelerometers mounted in or about the drum to measure the interactions between the rollers and compacted materials in order to evaluate the applied compaction effort. Rollers may be smooth or pad footed drums.
2. The output from the roller is designated as the Intelligent Compaction Measurement Value (IC-MV) which represents the stiffness of the materials based on the vibration of the roller drums and the resulting response from the underlying materials.
3. The IC rollers shall include an integrated on-board documentation system that is capable of displaying real-time color-coded maps of IC measurement values including the stiffness response values, location of the roller, number of roller passes, machine settings, together with the speed, frequency and amplitude of roller drums. The display unit shall be capable of transferring the data by means of a USB port.
4. Roller mounted GPS radio and receiver units shall be mounted on each IC roller. RTK-GPS radio and receivers are required to monitor the location and track the number of passes of the rollers.

1



Generic - IC Specifications for HMA — June 2011
DOT to modify as applicable to meet State Specifications

Intelligent Compaction Technology for HMA Applications

DESCRIPTION

This work shall consist of the construction of the Hot Mix Asphalt (HMA) utilizing Intelligent Compaction (IC) rollers within the limits of the work as described in the plans. IC is defined as a process that uses vibratory rollers equipped with a measurement/documentation system that automatically records various critical compaction parameters correlated to agency standard testing protocols in real time during the compaction process. IC uses roller vibration measurements to assess the mechanistic properties to ensure optimum compaction is achieved through continuous monitoring of the operations. Additional information on the IC technology may be found on the website www.intelligentcompaction.com and from the Transportation Research Board - NCHRP Report 676 on Intelligent Soil Compaction Systems.

The Contractor shall supply sufficient numbers of rollers and other associated equipment necessary to complete the compaction requirements for the specific materials. The Contractor will determine the number of IC rollers to use depending on the scope of the project. The best location in the paving operations for the IC roller is in the breakdown position and can be used with non-IC rollers.

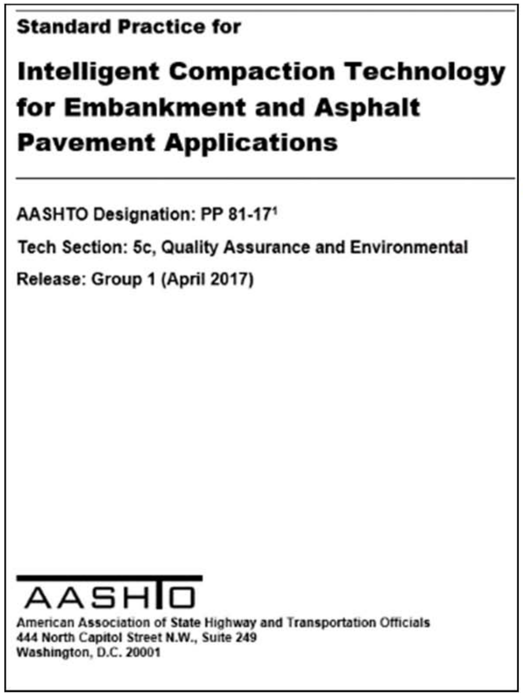
EQUIPMENT

The IC rollers shall meet the following specific requirements:

1. IC rollers shall be self propelled double-drum vibratory rollers equipped with accelerometers mounted in or about the drum to measure the interactions between the rollers and compacted materials in order to evaluate the applied compaction effort. IC rollers shall also be equipped with non-contact temperature sensors for measuring pavement surface temperatures.
2. The output from the roller is designated as the Intelligent Compaction Measurement Value (IC-MV) which represents the stiffness of the materials based on the vibration of the roller drums and the resulting response from the underlying materials.
3. The IC rollers shall include an integrated on-board documentation system that is capable of displaying real-time color-coded maps of IC measurement values including the stiffness response values, location of the roller, number of roller passes, machine settings, together with the temperature, speed and the frequency and amplitude of roller drums. The display unit shall be capable of transferring the data by means of a USB port.
4. Roller mounted GPS radio and receiver units shall be mounted on each IC roller. RTK-GPS radio and receivers are required to monitor the location and track the number of passes of the rollers.

1

AASHTO PP 81-17 & Data Spec.



Standard Practice for

Intelligent Compaction Technology for Embankment and Asphalt Pavement Applications

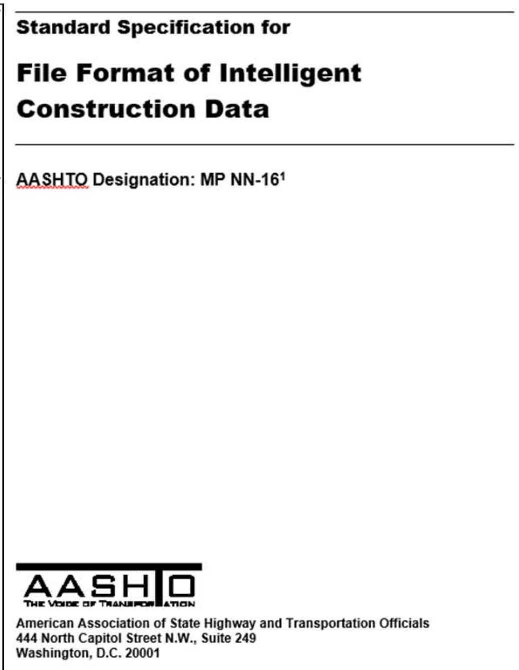
AASHTO Designation: PP 81-17[1]

Tech Section: 5c, Quality Assurance and Environmental

Release: Group 1 (April 2017)

AASHTO

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



Standard Specification for

File Format of Intelligent Construction Data

AASHTO Designation: MP NN-16[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

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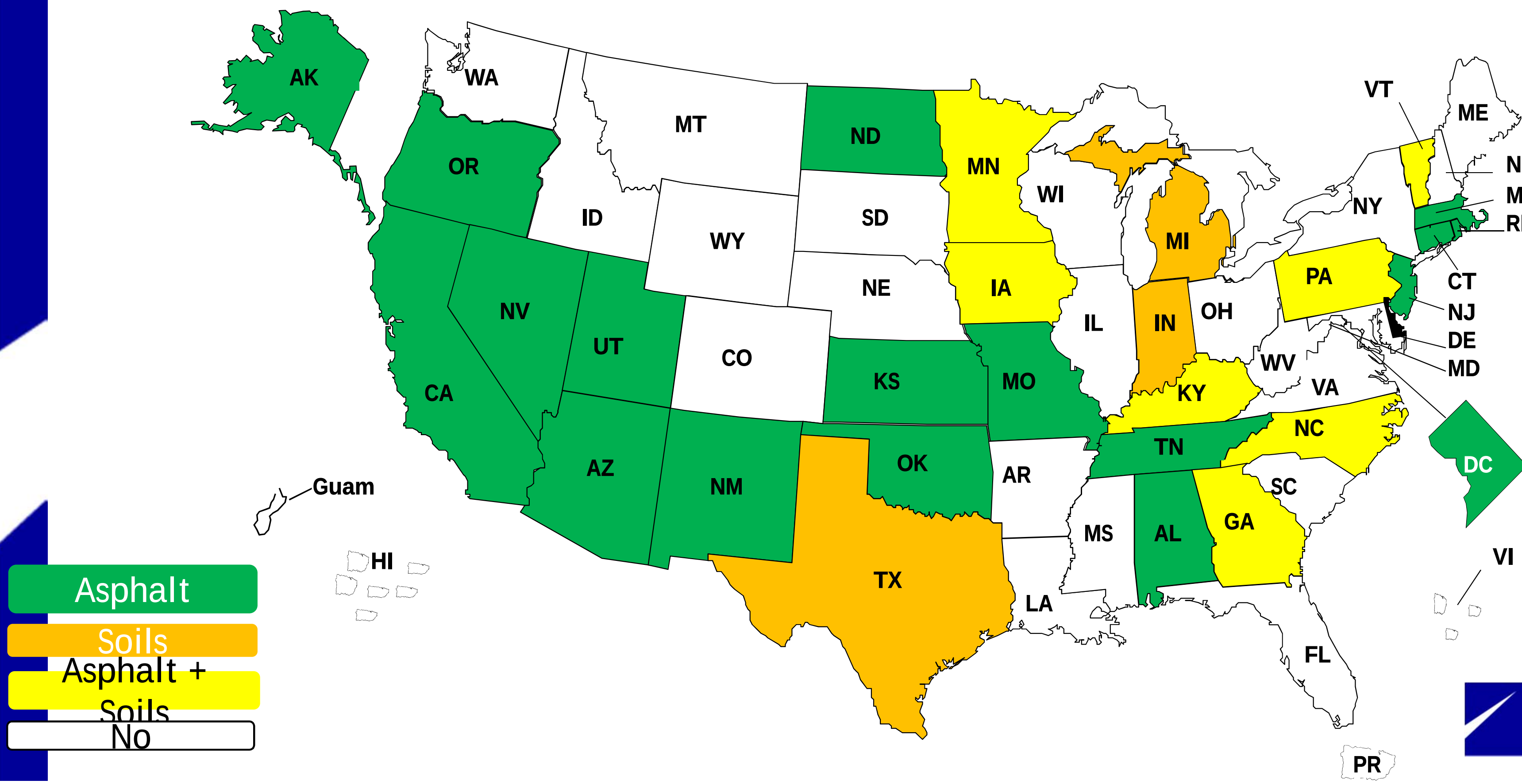
US DOT IC Specs



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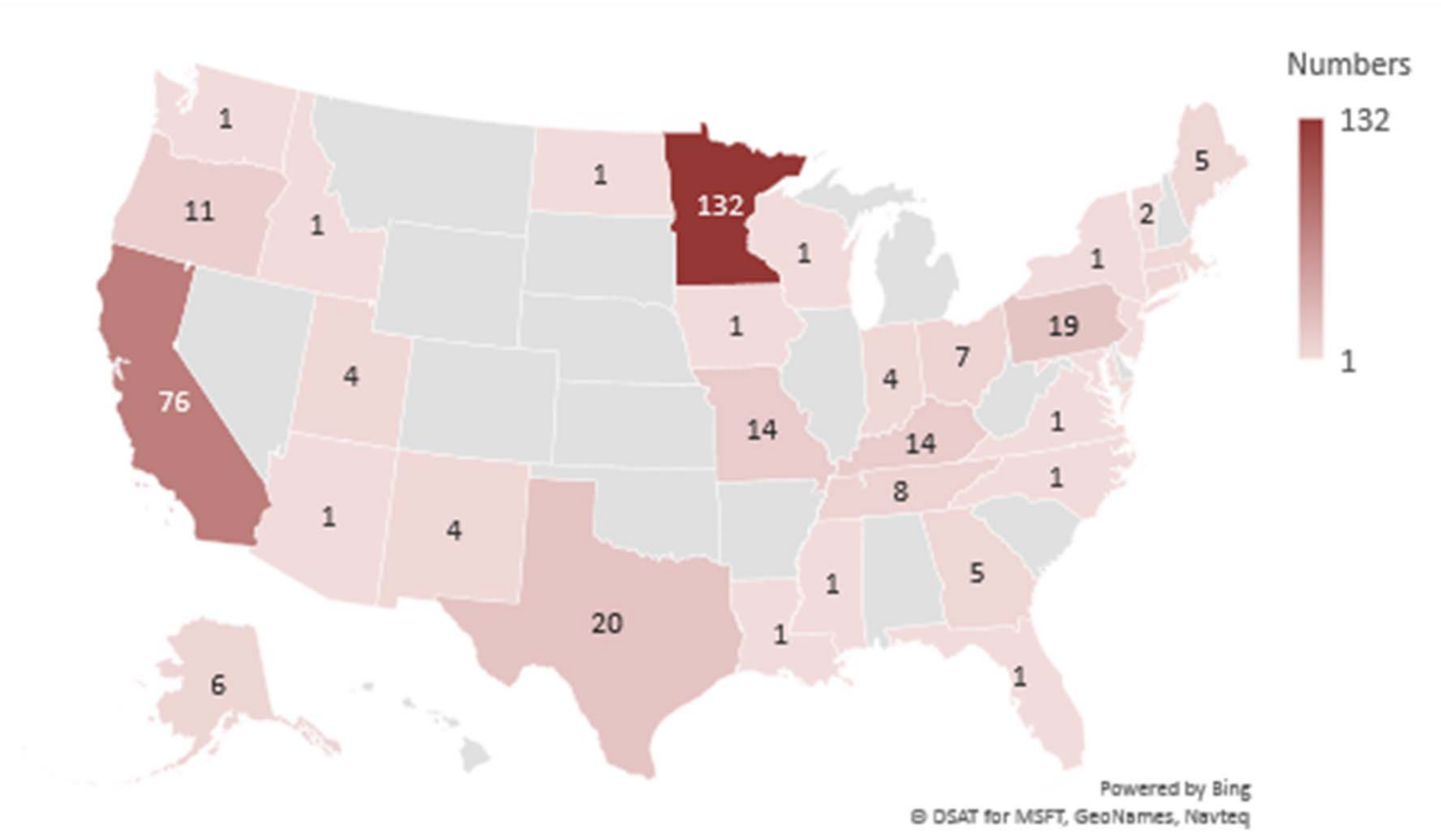
US Dot IC projects



Limited survey 2017

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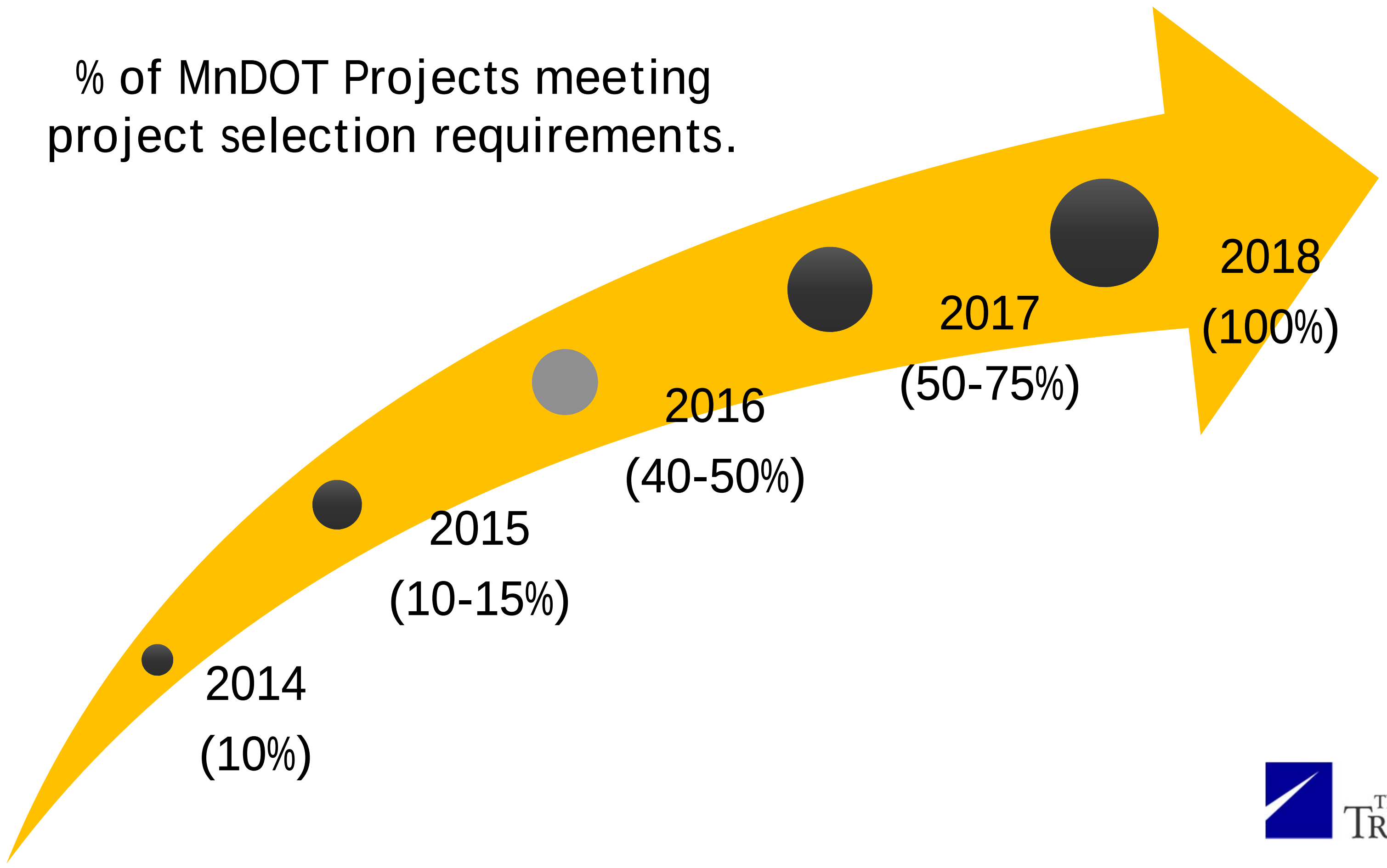
MnDOT IC Implementation plan



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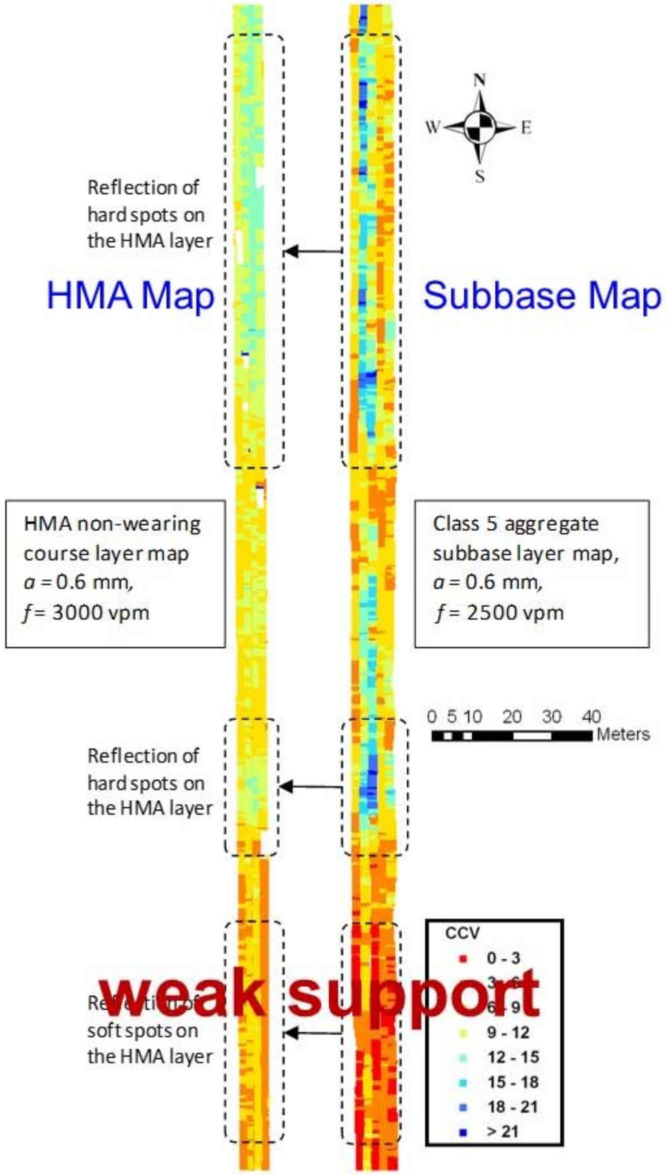
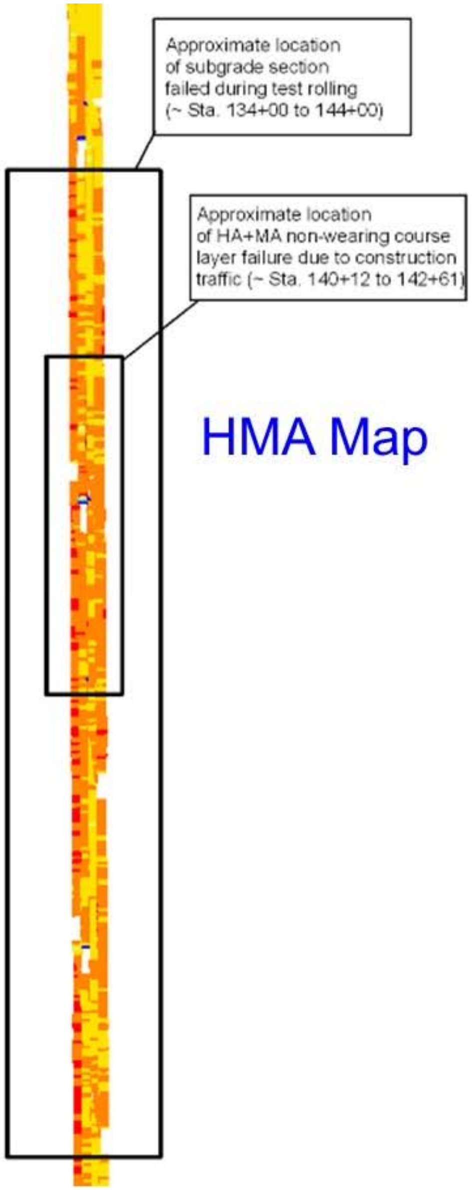
Benefits of Using IC and PMTP



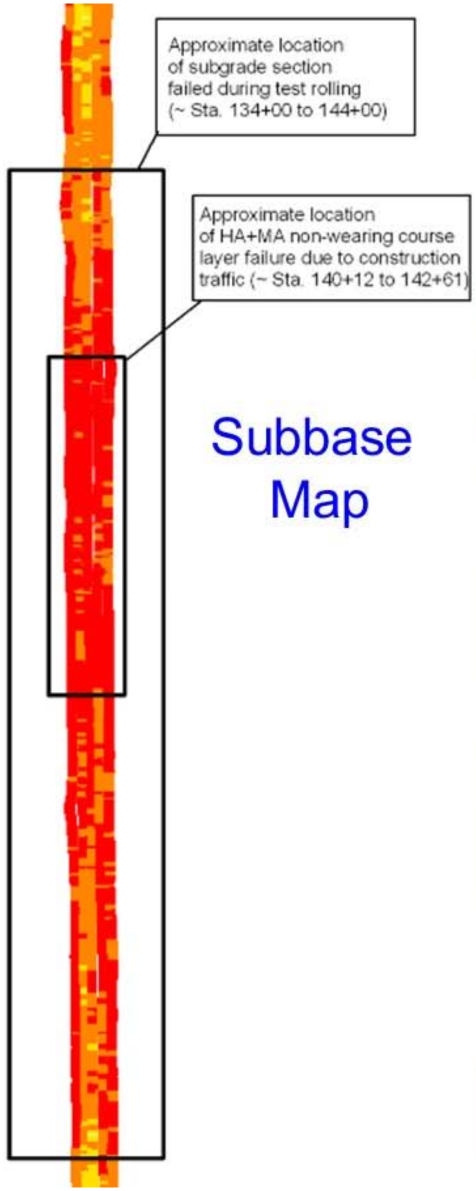
Pre-Mapping Subbase

Asphalt Compaction

Premature Failure



HMA Map

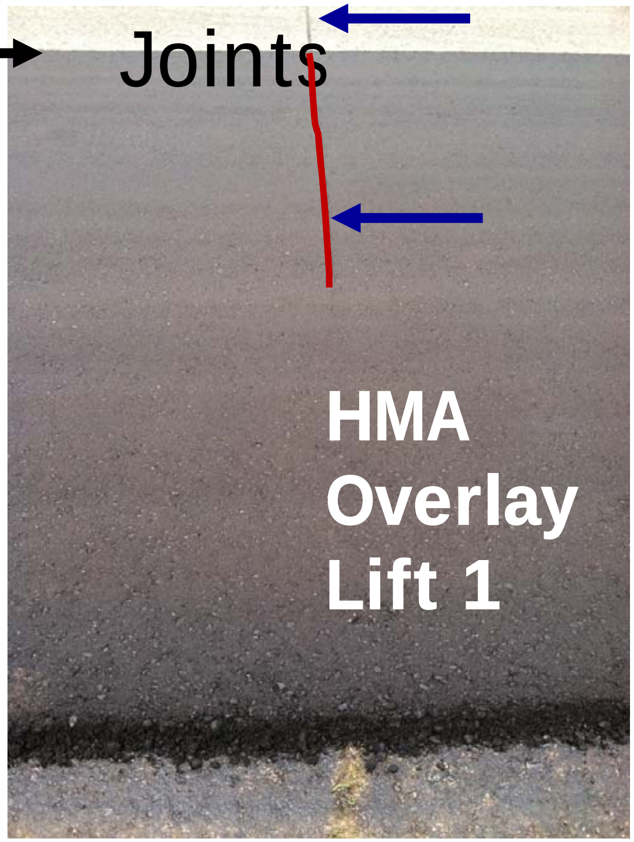


Subbase Map

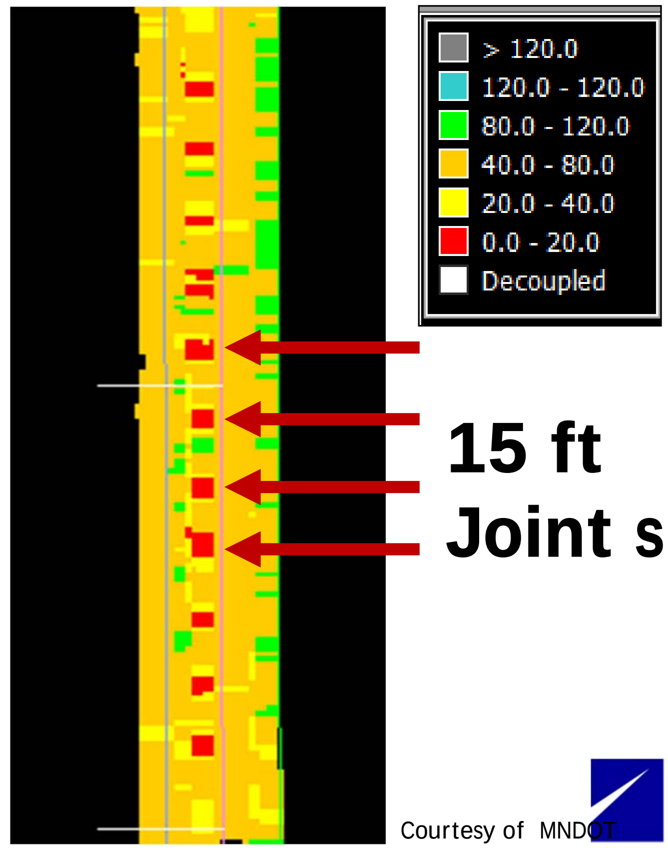
Identify Underlying Joints

Centerline

PCC Joints



CMV



15 ft Joint spacing

Courtesy of MNDOT

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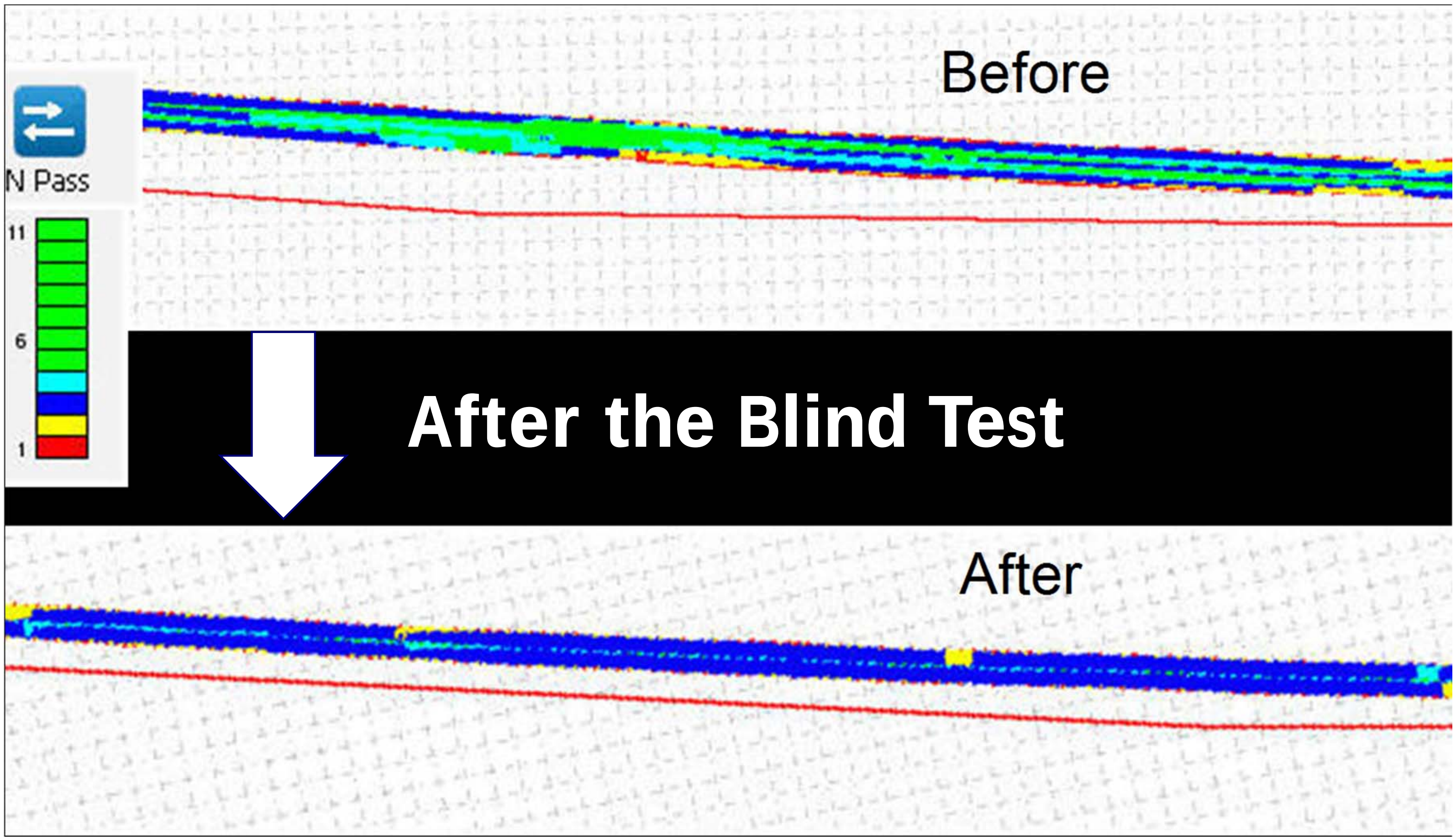
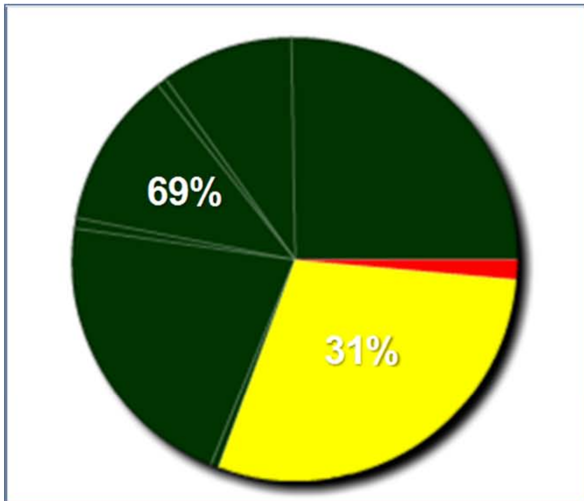
Improved Rolling Pattern

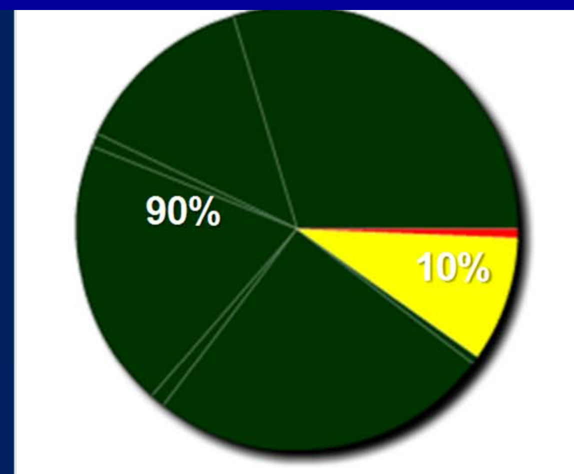


Improved Roller Coverage

First Time Use of IC



30% Increase in Compaction Efforts



Lift 1 without IC

< 3 Passes: 31 %
≥ 3 Passes: 69 %
COV : 71%

Lift 2 with IC

< 3 Passes: 10 %
≥ 3 Passes: 90 %
COV: 55%

Courtesy of MNDOT

Improved Consistency

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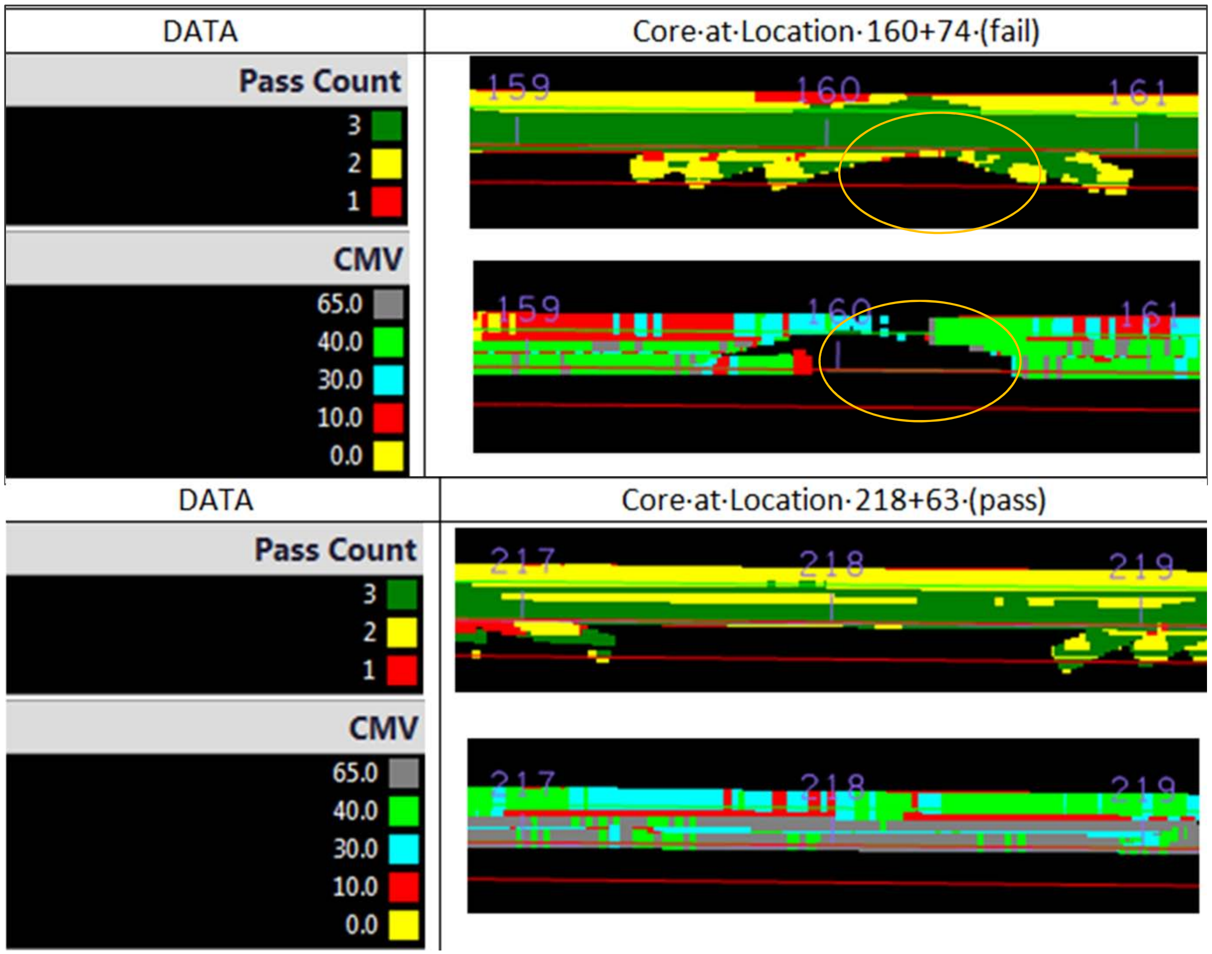
Identify Causes of Failed Density



Failed

Turn off Vib Too Early

Passed

Consistent Vib Thru Out

Courtesy of MnDOT

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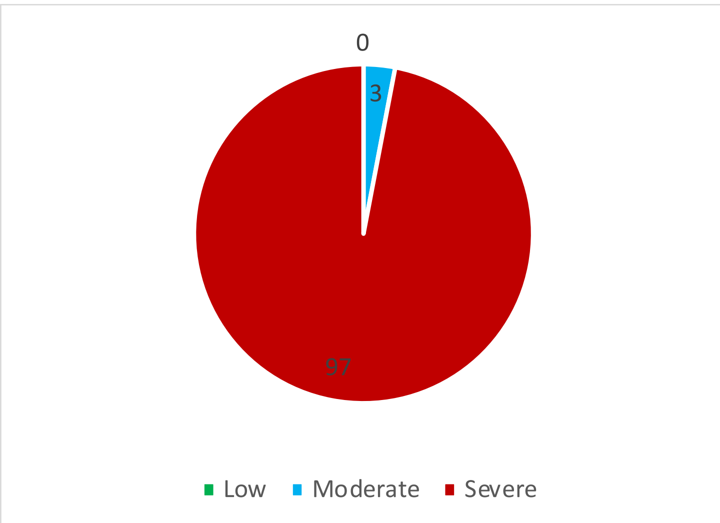
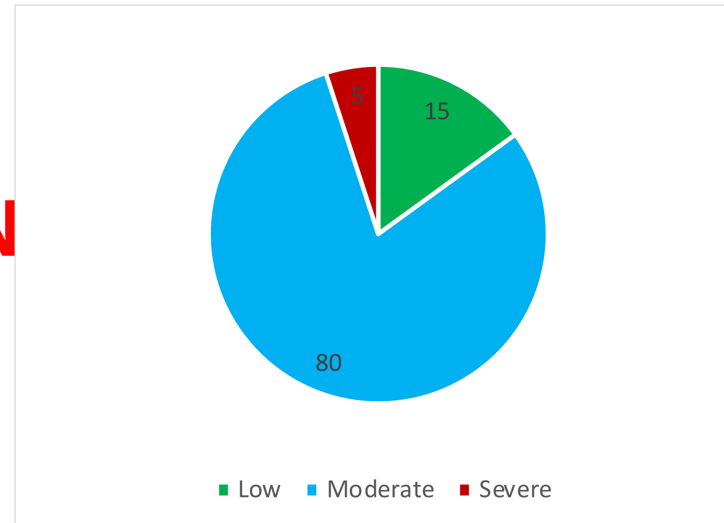
Temperature Segregation – MTV Usage



% SEVERE SEGREGATION

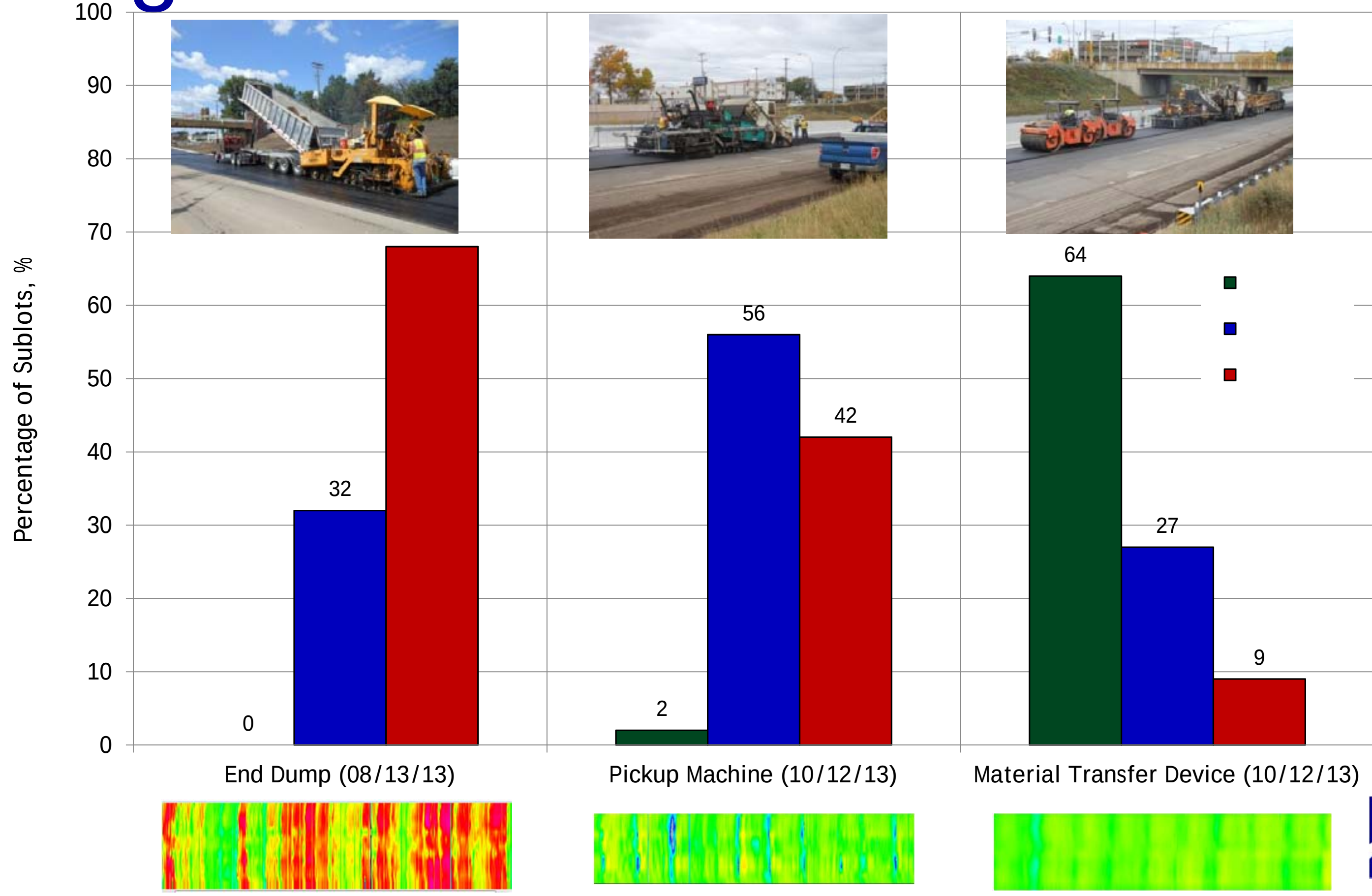
97 5



All Else Are Equal

Courtesy of MODOT

Temperature Segregation – Types of Paving



Courtesy of MNDOT

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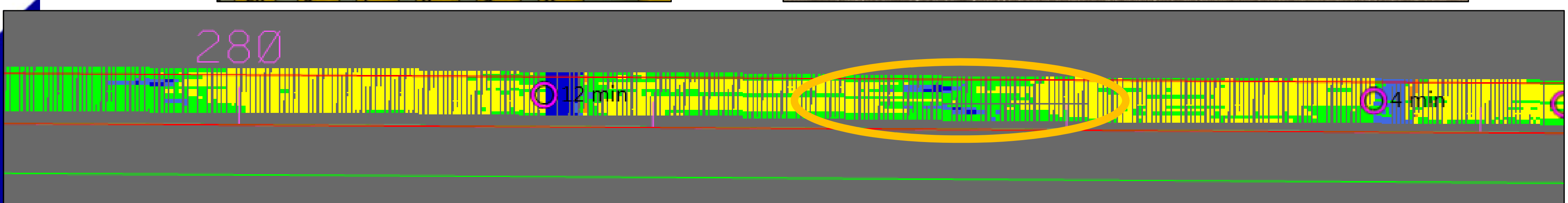
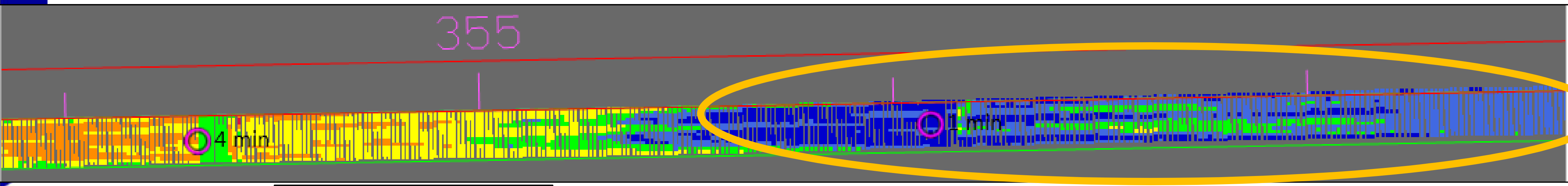
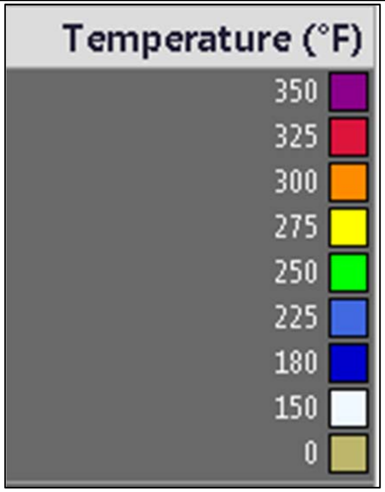
Identify Inconsistent Windrows

Material and Thermal Segregation



Monitor Material Changes





Courtesy of MNDOT

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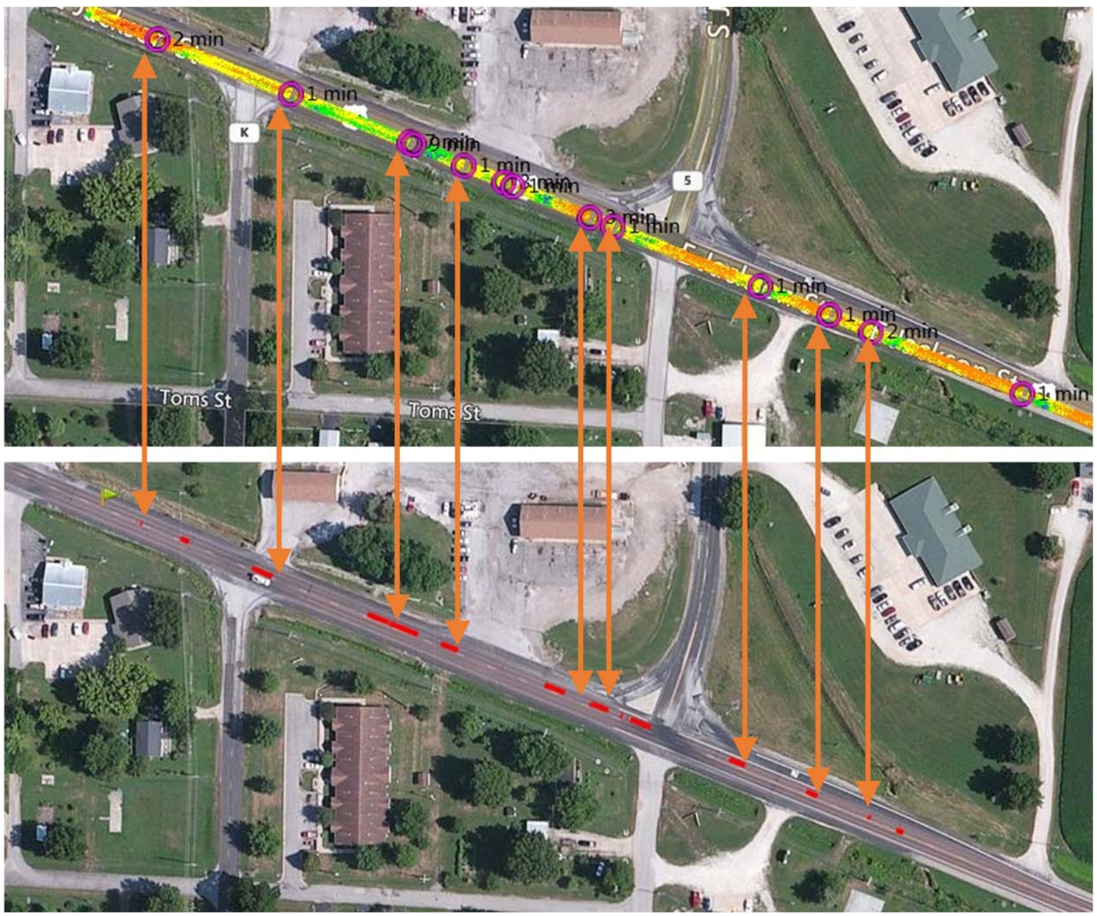
Mirror of Paver Stops with ALR

IR & Paver Stops

IRI ALR



Courtesy of MODOT

EB, 2017-04-24

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Future Development & Further Information

Advancements of ICMV

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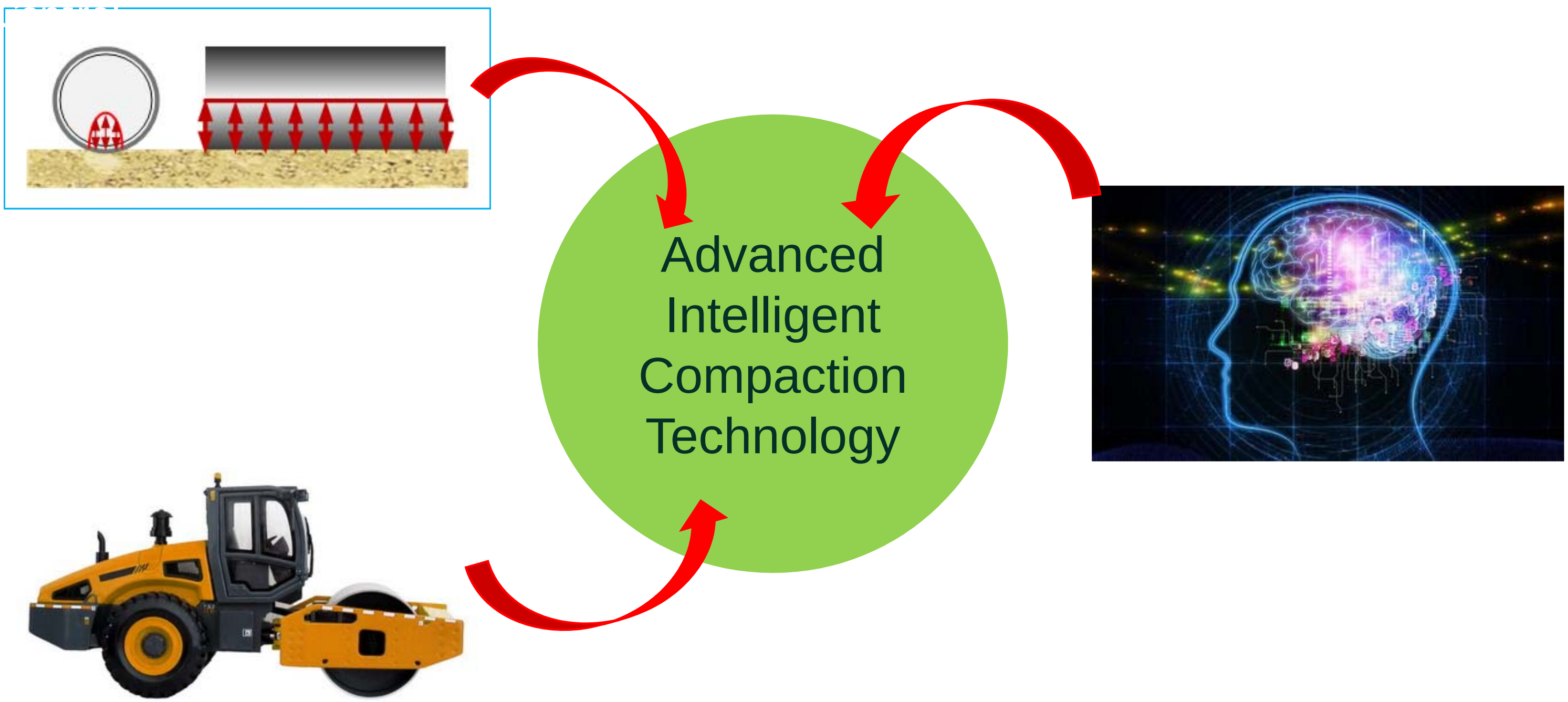
True Intelligent IC



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TPF-5(334) ICDM-Veta Pooled Fund Study

TPF TRANSPORTATION POOLED FUND PROGRAM

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Study Detail View

Print

Enhancement to the Intelligent Construction Data Management System (Veta) and Implementation

General Information

Study Number: TPF-5(334)
Status: Cleared by FHWA
Contract/Other Number:
Lead Agency: Minnesota Department of Transportation
Last Updated: Jul 26, 2017
Contract Start Date:
Est. Completion Date:
Contract End Date:
Solicitation Number: 1381
Partners: x , AK , AL , CA , CT , GA , ME , MN , MO , MS , NY , OR , PA

Contact Information:

Lead Agency Contact(s):

Debra Fick
deb.fick@state.mn.us
Phone: 651-366-3759

FHWA Technical Liaison(s):

Richard Duval
Richard.Duval@dot.gov

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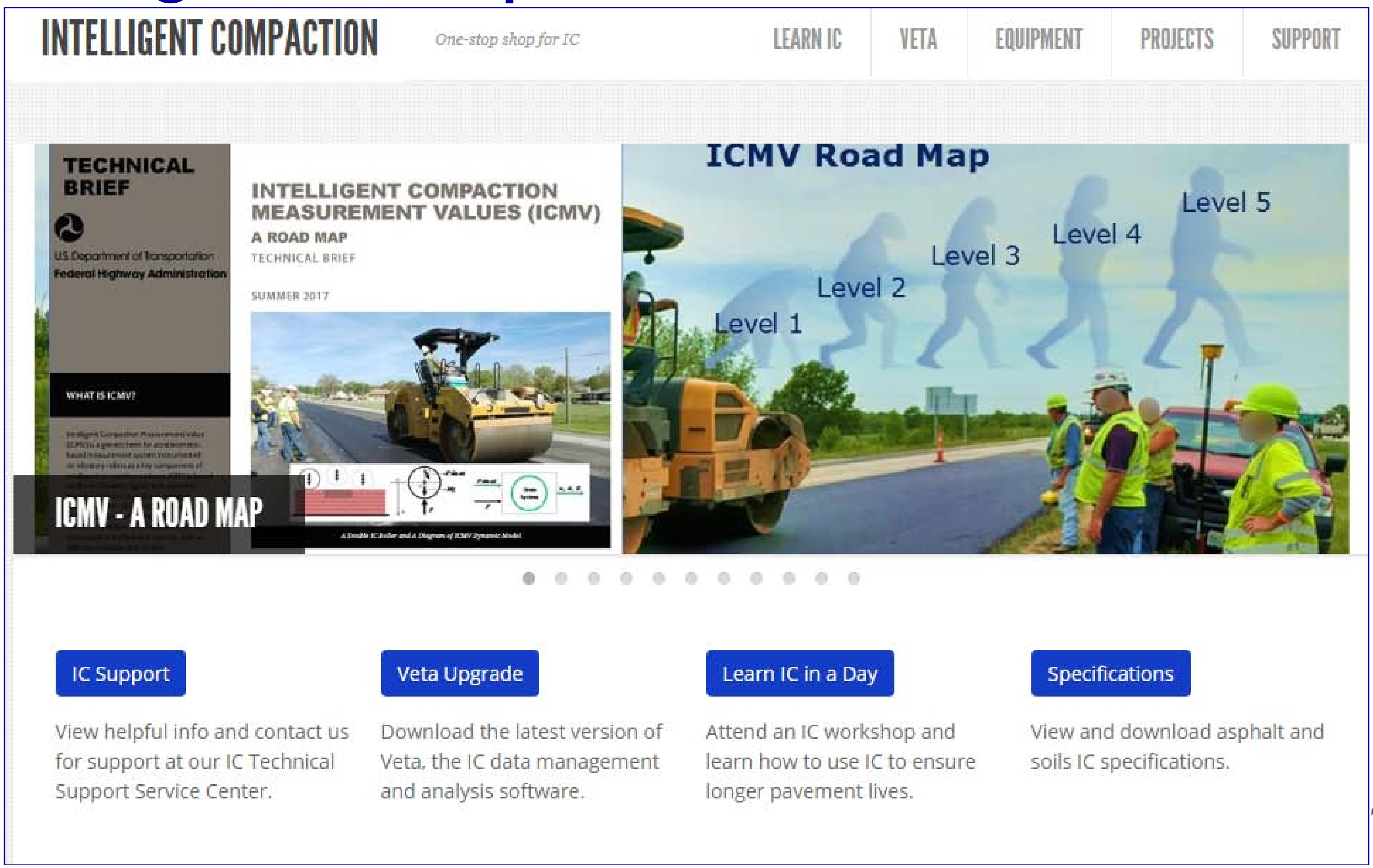
IntelligentCompaction.com



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IICTG

International Intelligent Construction Technologies Group

Thank You!

Dr. George K. Chang, PE
Director of Research, Transtec Group
GKChang@TheTranstecGroup.com

THE TRANSTEC GROUP

Alaska Department of Transportation & Public Facilities

Mapping Asphalt Compaction with 2.5 Million Tests in 22 Nights on the Glenn Highway

Ronald A. Searcy, P.E. & Richard Giessel, P.E.

November 7, 2017

Pop Quiz

- According to an 2007 Asphalt Institute Study, what is the single most important factor that determines asphalt life?
  A. HMA Type, Binders Used and Thickness
  B. HMA Temperature when Placed
  C. Compaction at Time of Construction
  D. Subgrade and Subbase Materials

HMA Compaction

- Answer: C – Compaction at time of Construction

HMA Compaction

Why?

HMA Compaction

- FHWA quoted a 2007 Asphalt Institute Study that said, “In-place density is one of the most important factors that influence the performance of an asphalt pavement.”
- FHWA went on to say, “Past studies have shown that a small increase in in-place density can lead to a 10 to 30 percent increase in service life of asphalt pavements.”
- Potential annual savings in pavement preservation expenditures ranges from $1.75 to $8.75 billion in the United States.
- Alaska DOT&PF understands the annual savings potential from enhanced compaction of asphalt pavements.

HMA Compaction

- If the compacted mix has a high air-void content (greater than 8%), the mix will not perform as well under traffic.
- Similarly, if the compacted mix has a low air-void content (less than 3%), the mix will be susceptible to permanent deformation or rutting (not from studded tires) and also to distortion under the applied traffic loads.
- Thus, for the mix to perform as expected, the contractor must be able to compact the mix to the desired level of density or air-void content.

HMA Compaction

- The air-void content (or density) of the asphalt-concrete mix controls its durability.
- All of the following factors are related to the air-void content of the HMA material:
  - fatigue life;
  - permanent deformation;
  - oxidation;
  - moisture damage;
  - distortion;
  - disintegration.

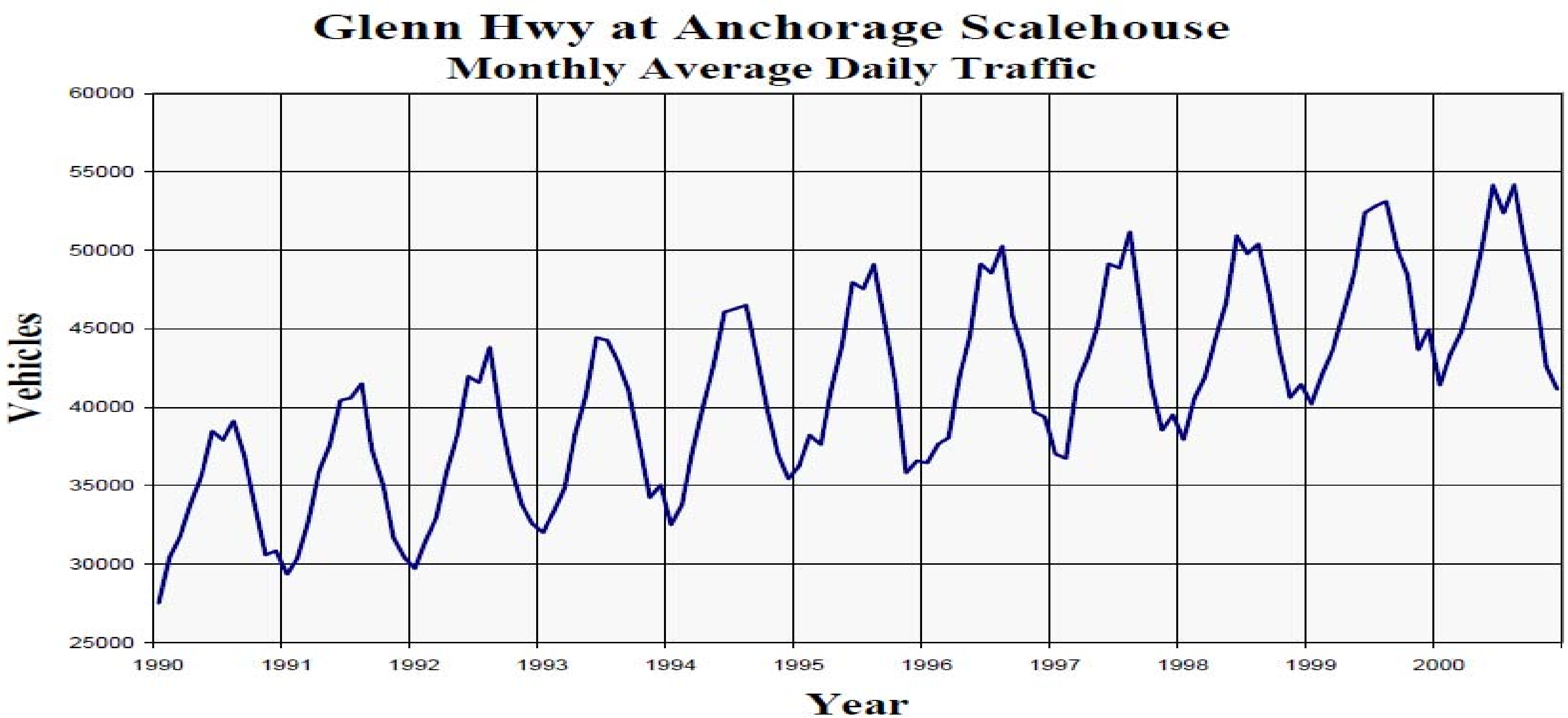
HMA Compaction

- When properly placed, a HMA mix should have an air-void content in the range of 3 to 5 percent.
- High air-void content in the mat (i.e., low density) means more water infiltration. More water infiltration means greater potential for potholes.

Glenn Hwy (Airport Heights to Parks Highway) Issues

- Most Traveled Roadway in Alaska
- Most Frequently Resurfaced (Estimated construction cost is $30 million for current 3 Phases)
- Wheel Path Wear (i.e., Ruts from Studded Tires (Wear rates are 1/8-inch per year).

Glenn Hwy Traffic 1990 to 2001



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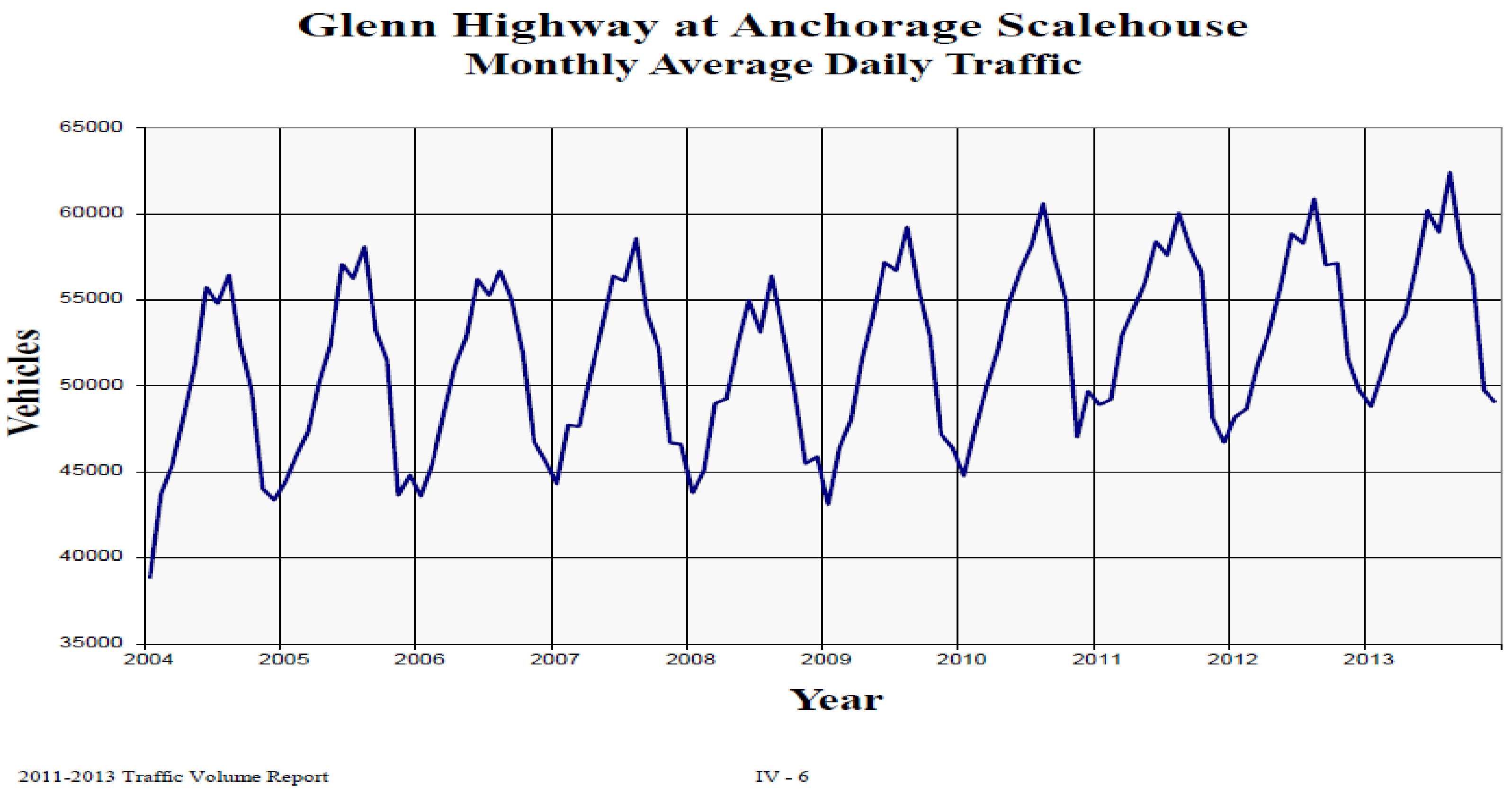
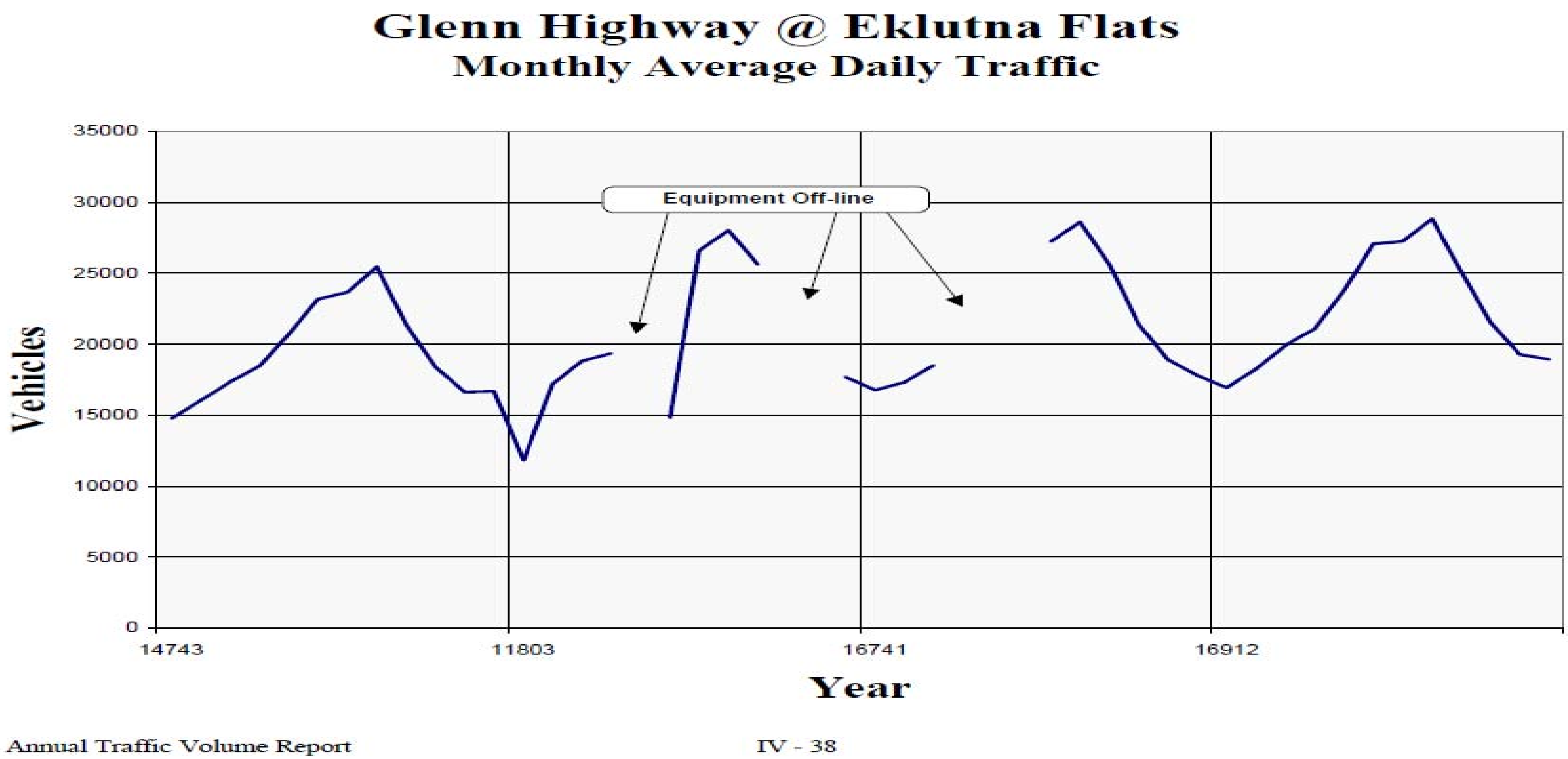
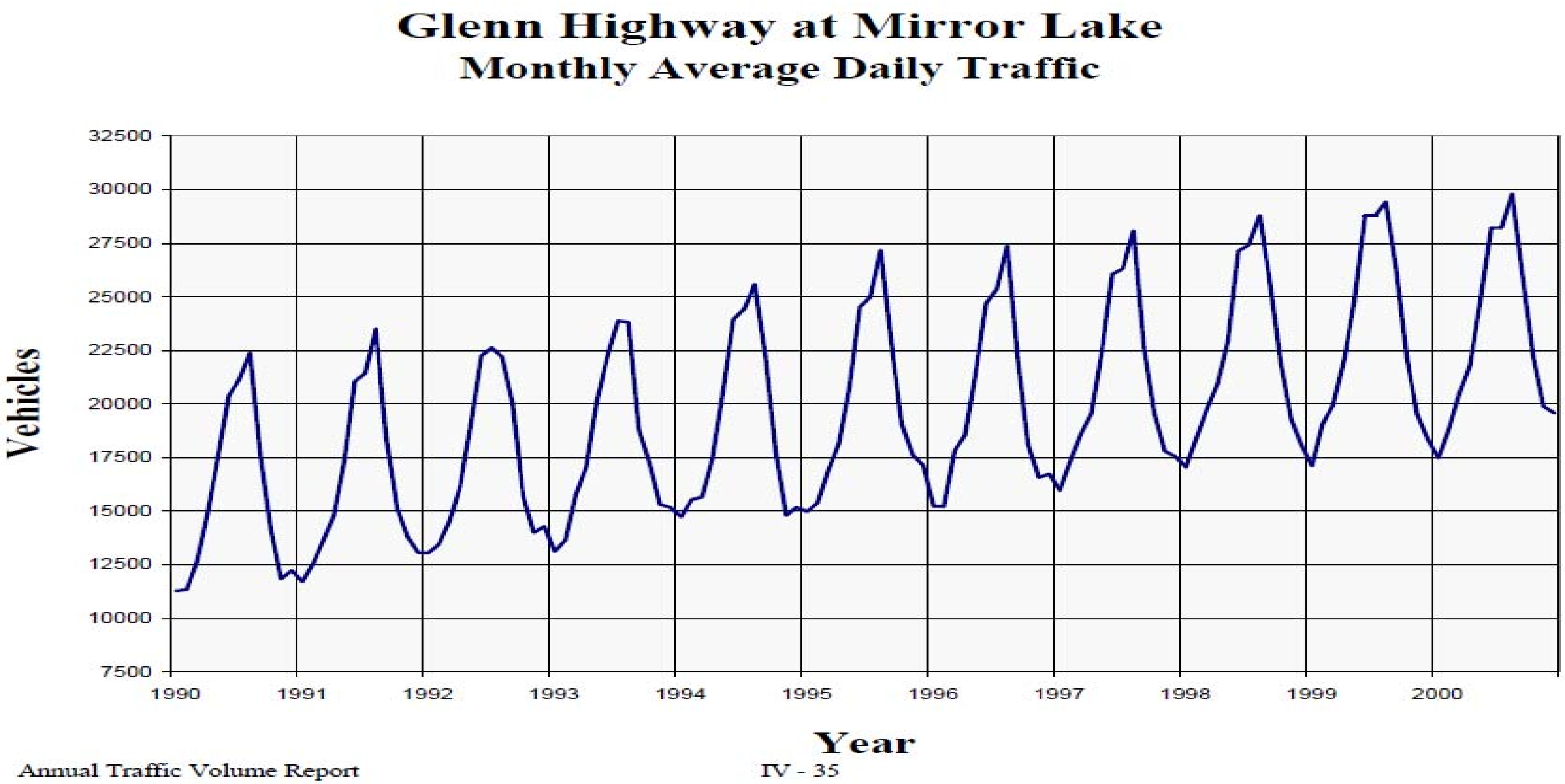
Glenn Hwy Traffic 2004 to 2014



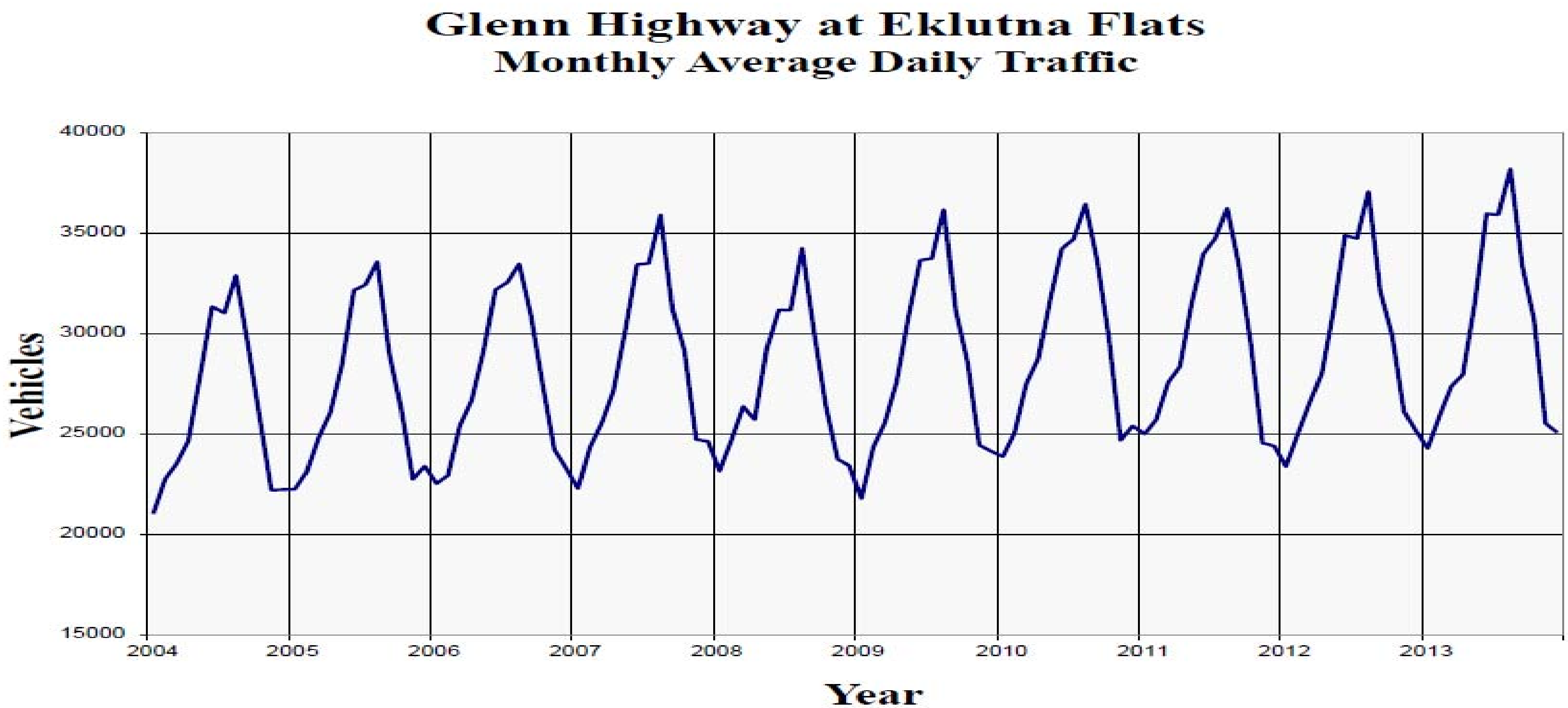
Glenn Hwy Traffic 1990 to 2001



Glenn Hwy Traffic 1990 to 2001



Glenn Hwy Traffic 2004 to 2014



2011-2013 Traffic Volume Report IV - 8

Glenn Hwy Recent Pavement History

- 1990 – 1992: Constructed the four lane Section between Eklutna and Parks Highway
- 1993 – 1995: Pavement Preservation Airport Heights to Eklutna
- 2000 – 2003: Gambell Street to Parks Highway
- 2009 – 2011: Airport Heights to Parks Hwy
- 2014 – Boniface to Knik River Bridge (pavement repairs only)
- 2016 – 2018: Airport Heights to Parks Hwy

HMA Compaction Demonstration Project on the Glenn Highway

- In March 2016, ADOT&PF applied to participate in a Demonstration Project for Enhanced Durability of Asphalt Pavements through Increased In-Place Pavement Density sponsored by FHWA.

HMA Compaction Demonstration Project on the Glenn Highway

- A. Section 408–HMA, Type VH Requirements:
  - Type VH (Superpave)
  - Warm Mix Additive
  - Min. HMA Compaction: 92.0 Percent of Maximum Specific Gravity as determined by Alaska Test Method 409.
  - Min. Joint Density: 91.0 Percent of Maximum Specific Gravity as determined by Alaska Test Method 409.
- B. Paving Train:
  - Material Transfer Vehicle (MTV)

HMA Compaction Demonstration Project on the Glenn Highway

- C. Compaction Monitoring:
  - ➢ Continuous Thermal Profiling
  - ➢ Intelligent Compaction
- D. Documentation
- E. HMA Price Adjustments (or Bonuses):
  - ➢ HMA Price Adjustments (Pay Factors)
  - ➢ Longitudinal Joint Density Price Adjustment:
    - ❖ If greater that 92 percent - $0.50 per Linear Foot of Joint
    - ❖ If greater that 93 percent - $1.00 per Linear Foot of Joint
    - ❖ If greater that 94 percent - $1.50 per Linear Foot of Joint
  - ➢ Pavement Smoothness Price Adjustment
- F. Thermal Profiling Price Adjustment ($75.00 per 150-foot long Lane Segment when Temperature Differential Less than 25 degrees Fahrenheit)
- G. PaveScan

A. Section 408–HMA, Type VH Requirements

- Summary:
  - Goal was for HMA Type VH mix to last up to 15 years
  - Superpave with modified asphalt binder, Grade PG 64-40
  - Warm mix additive required
  - Used hard aggregate to combat wear from studded tires

A. Section 408–HMA, Type VH Requirements WMA Technologies)

Warm-Mix Asphalt Required

- Warm-mix asphalt is the generic name of technologies that allow the producers of hot-mix asphalt pavement material to lower the temperatures at which the material is mixed and placed on the road.
- Such drastic reductions have the obvious benefits of cutting fuel consumption and decreasing the production of greenhouse gases.

A. Section 408–HMA, Type VH Requirements WMA Technologies)

Warm-Mix Asphalt Required (continued)

Engineering and construction benefits include:

- Better compaction of pavements;
- Reductions of 50 to 100 degrees Fahrenheit have been documented;
- The ability to extend the paving season;
- The potential to be able to recycle at higher rates.

A. Section 408–HMA, Type VH Requirements WMA Technologies)

Warm-Mix Asphalt Required (continued)

702-2.07 WARM MIX ASPHALT (WMA). WMA additives, processes and technologies shown in Table 702-3 are preapproved for use on Department projects. Satisfy asphalt binder and mix specification requirements after incorporating additives in the asphalt binder and/or mix.

TABLE 702-3
WMA TECHNOLOGIES

WMA Technology	Process Type	WMA Supplier
Advera WMA	Foaming (Synthetic Zeolite)	PQ Corporation
Aspha-min	Foaming (Synthetic Zeolite)	Aspha-min
Double Barrel Green / Green Pac	Foaming	Astec Industries, Inc.
Eco-Foam II	Foaming	AESCO/Madsen Inc.
Evotherm	Chemical Additive	MeadWestvaco Asphalt Innovations
Rediset	Chemical Additive	Akzo Nobel Surfactants
Sasobit	Organic Additive	Sasol WaxAmericas, Inc.
Ultrafoam GX System	Foaming	Gencor Industries Inc.

A. Section 408–HMA, Type VH Requirements (Hard Aggregate)

TABLE 703-3
COARSE AGGREGATE QUALITY FOR HMA

Description	Specification	Type II, Class A	Type I; Type II, Class B; Type III	Type IV	Type VH
LA Wear, % max.	AASHTO T 96	45	45	45	45
Degradation Value, min.	ATM 313	30	30	30	30
Sodium Sulfate Loss, % max. (5 cycles)	AASHTO T 104	9	9	9	9
Fracture, % min.	ATM 305	90, 2 face	80, 1 face	90, 2 face	98, 2 face
Flat-Elongated Pieces, % max.	ATM 306				
1:5		8	8	8	8
Absorption, % max.	ATM 308	2.0	2.0	2.0	2.0
Nordic Abrasion, % max.	ATM 312	-	-	-	8 [a]

a. Hard Aggregate that meets the Nordic Abrasion values specified may be obtained from, but not limited to, the following sources:

- MS 52-068-2, located at MP 217 on the Parks Highway near Cantwell
- Alaska Lime Co, Jim Caswell, located at MP 216.5 on the Parks Highway near Cantwell
- CalPortland plants located in Dupont Washington
- Jack Cewe Ltd located in Coquitlam British Columbia, Canada

B. Paving Train

- Paving Train (Section 408–HMA, Type VH):
  - ➢ Use Material Transfer Vehicle (MTV) to transfer HMA to the paver.
  - ➢ MTV commonly known as a Shuttle buggy. However, Shuttle buggy is a brand name and is manufactured by Roadtec.
  - ➢ Note: MTV required on FAA-funded airport paving projects.

B. Paving Train

- Paving Train (continued):
  - MTV commonly known as a Shuttle buggy. However, Shuttle buggy is a brand name and is manufactured by Roadtec.
  - Keeps paving train moving (functions as additional storage); continuous operation.
  - Places a more consistent mix on the mat; prevents load and thermal segregation.
  - Mix temperature is more uniform.
  - Note: MTV required on FAA-funded airport paving projects.

B. Paving Train

B. Paving Train

B. Paving Train

B. Paving Train

C. Compaction Monitoring (Continuous Thermal Profiling)

- Section 412 – HMA Continuous Thermal Profiling
  - We've recognized the existence for a long time
  - Often confused with aggregate segregation.
  - Results in early potholing or alligator cracking
  - Makes uniform compaction nearly impossible

C. Compaction Monitoring (Continuous Thermal Profiling)

- Section 412 – HMA Continuous Thermal Profiling (Continued):
  - Goal: 25 degree F temperature differential between the hottest and the coldest place in the mat within a 150-foot section
  - Thermal segregation can not be seen with the naked eye. Now, we can easily see thermal segregation instantly.

C. Compaction Monitoring (Continuous Thermal Profiling)

- HMA Continuous Thermal Profiling (Continued):
  - ➢ It isn’t normally evidenced until the pavement fails from the effects of water permeation and oxidation of the binder. Now, we can make corrections immediately.
  - ➢ Can Map and Document the Entire Mat for future use and research.

C. Compaction Monitoring (Continuous Thermal Profiling)

- HMA Continuous Thermal Profiling
  - Colorado Research Branch in 2005 found:

C. Compaction Monitoring (Continuous Thermal Profiling)

Table 6. Relative compaction readings.

Mix	Binder	Mix Temp out of screed	Relative Comp. Cold Area	Relative Comp. Hot Area
SX75	58-28	262	92.1	92.9
		262	90.8	93.3
		262	92.3	93.1
		290	91.6	92.9
SX75	58-34	290	89.9	93.4
		293	90.7	92.8
S75	64-22	300	94.3	96.4
		300	93.7	93.3
		305	94.5	93.8
		310	94.0	93.7
		310	93.3	92.7

Mix	Binder	Mix Temp out of screed	Relative Comp. Cold Area	Relative Comp. Hot Area
S75	64-28	283	90.9	92.6
		283	92.0	93.6
S100	64-28	290	89.1	90.0
		290	90.2	92.0
		290	92.4	93.2
		290	91.0	92.0
		290	91.3	92.1
S100	64-28	272	94.4	95.8
		272	93.0	94.2
		272	93.0	95.8
		272	91.1	91.7
		272	94.0	93.9

C. Compaction Monitoring (Continuous Thermal Profiling)

Segment Temperature Price Incentive adjustment is measured according to Table 412-3.

TABLE 412-3
SEGMENT TEMPERATURE PRICE INCENTIVE

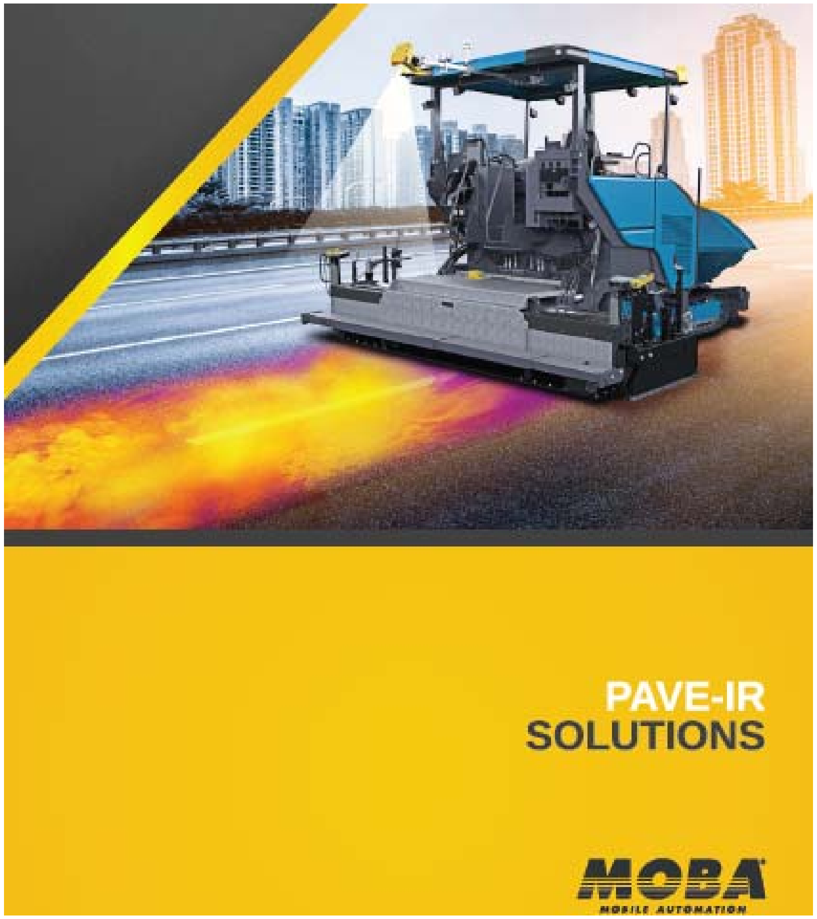
Segment Temperature Differential		Monetary Adjustment
Range	Category	Adjustment per 150-ft Segment
< = 25.0°F	Good	$75 incentive
> 25.1 and < = 50°F	Moderate	No pay adjustment, check with density profile, repair per 408-3.19
> 50 °F	Severe	No pay adjustment, check with density profile, repair per 408-3.19

412.5.01 BASIS OF PAYMENT. The contracted price will be paid for at the Contract lump sum price. Payment will be full compensation for preparing and installing the equipment including software, providing support, maintenance, and training, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

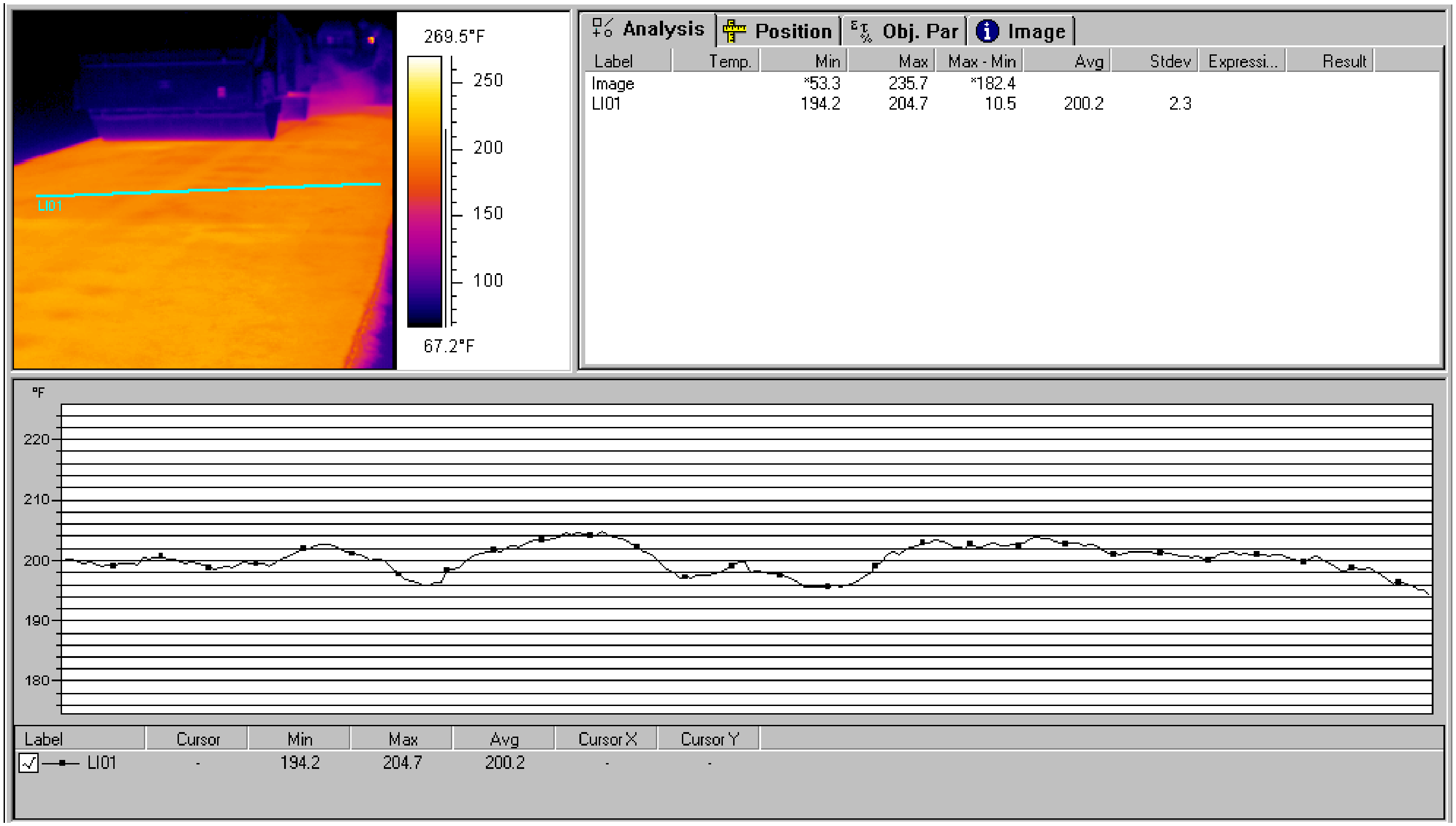
This work will be paid under the following pay items.

Pay Item No.	Pay Item	Pay Unit
412(1)	Continuous Thermal Profile	Lump Sum
412(2)	Segment Temperature Price Incentive	Contingent Sum

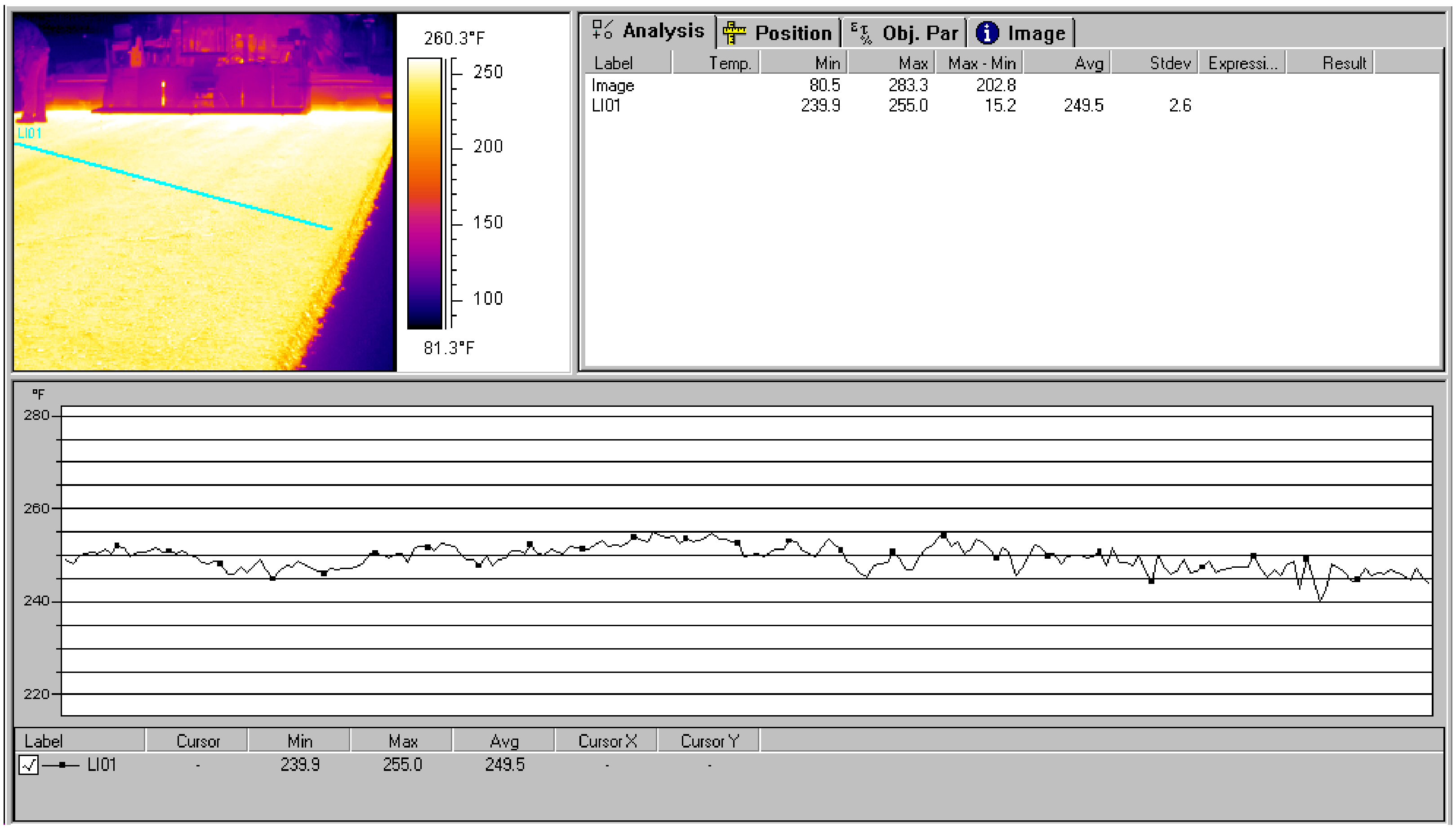
C. Compaction Monitoring (Continuous Thermal Profiling)



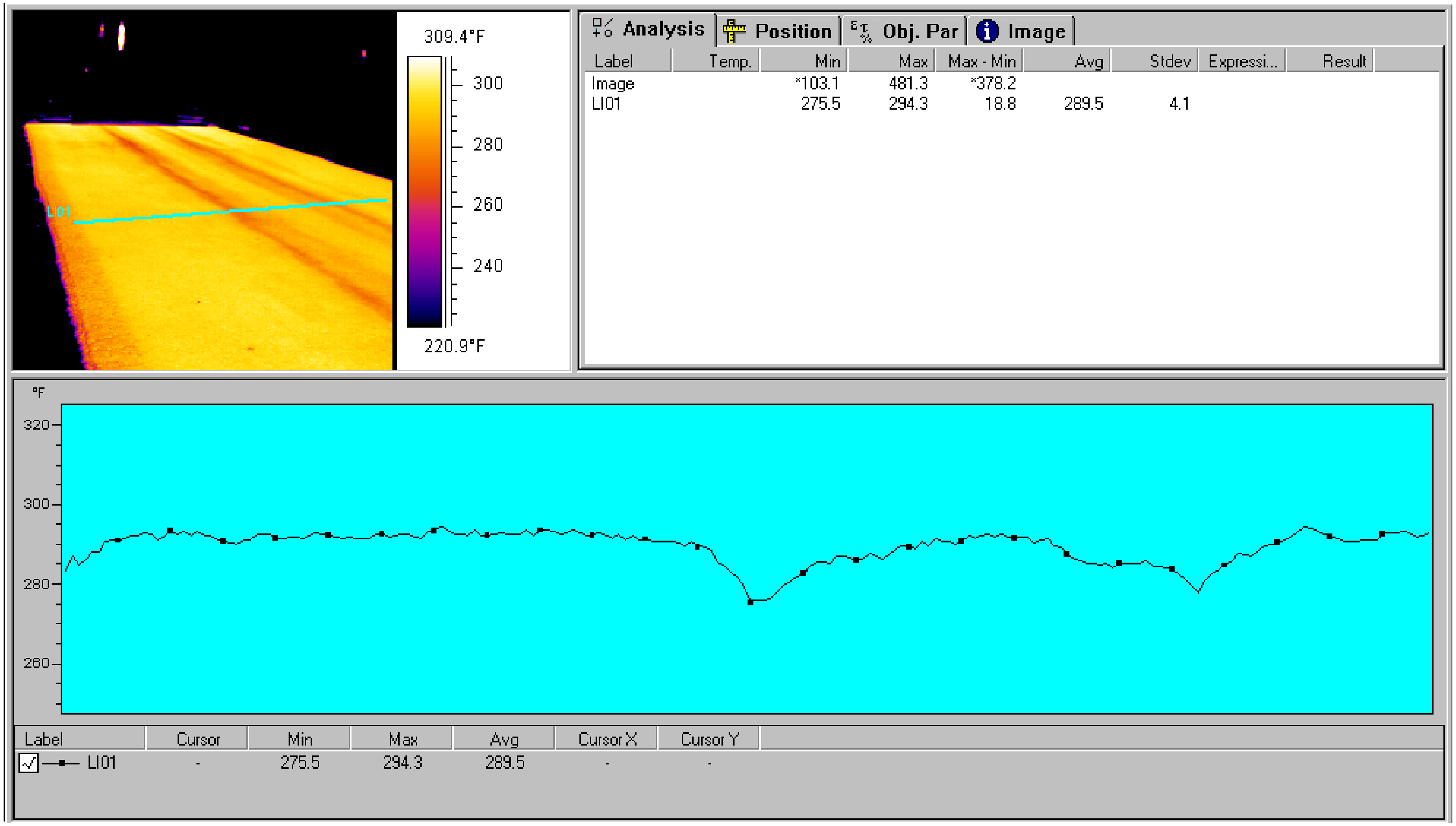
Example of Uniform Mat



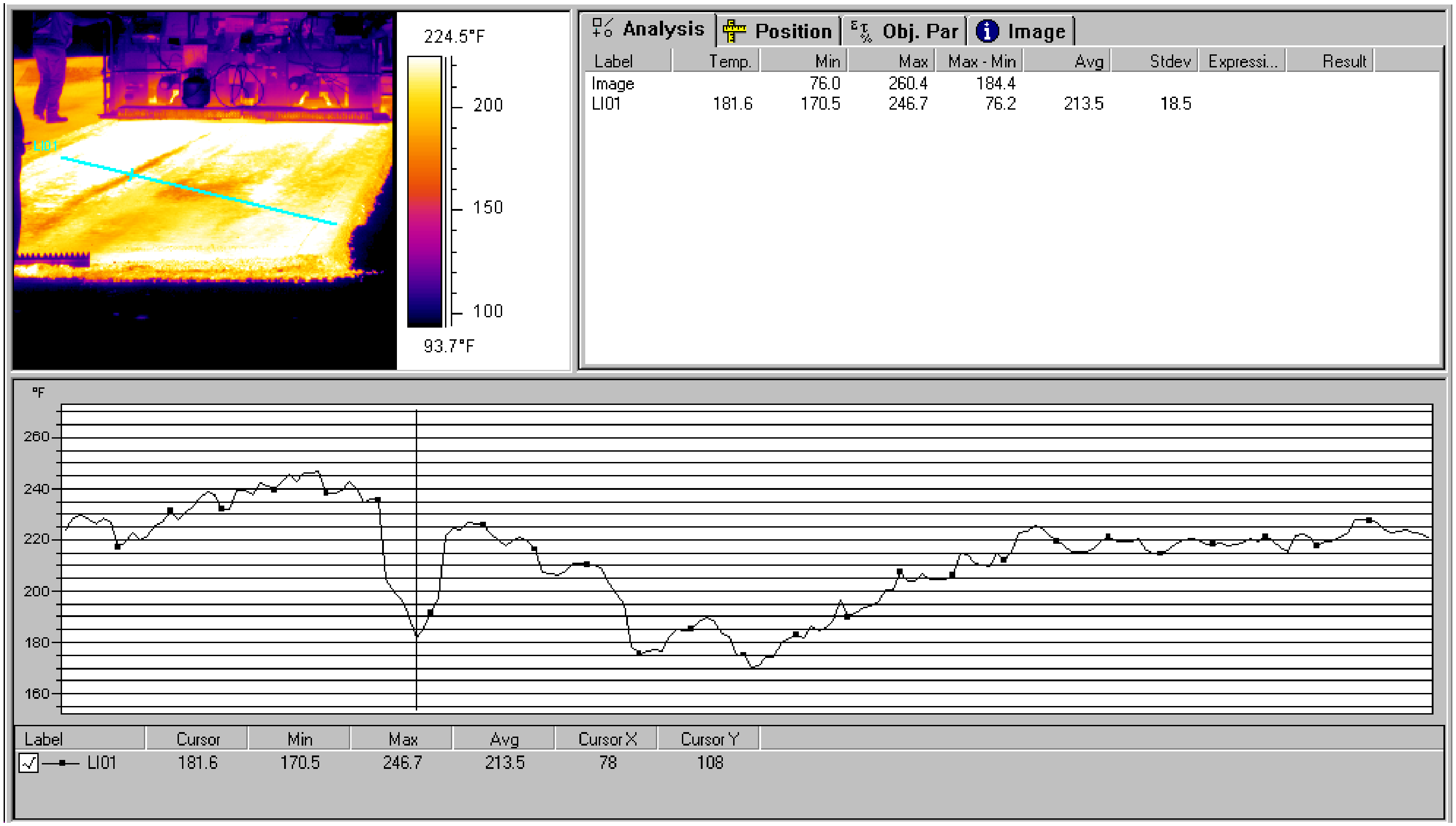
Example of Uniform Temp Profile



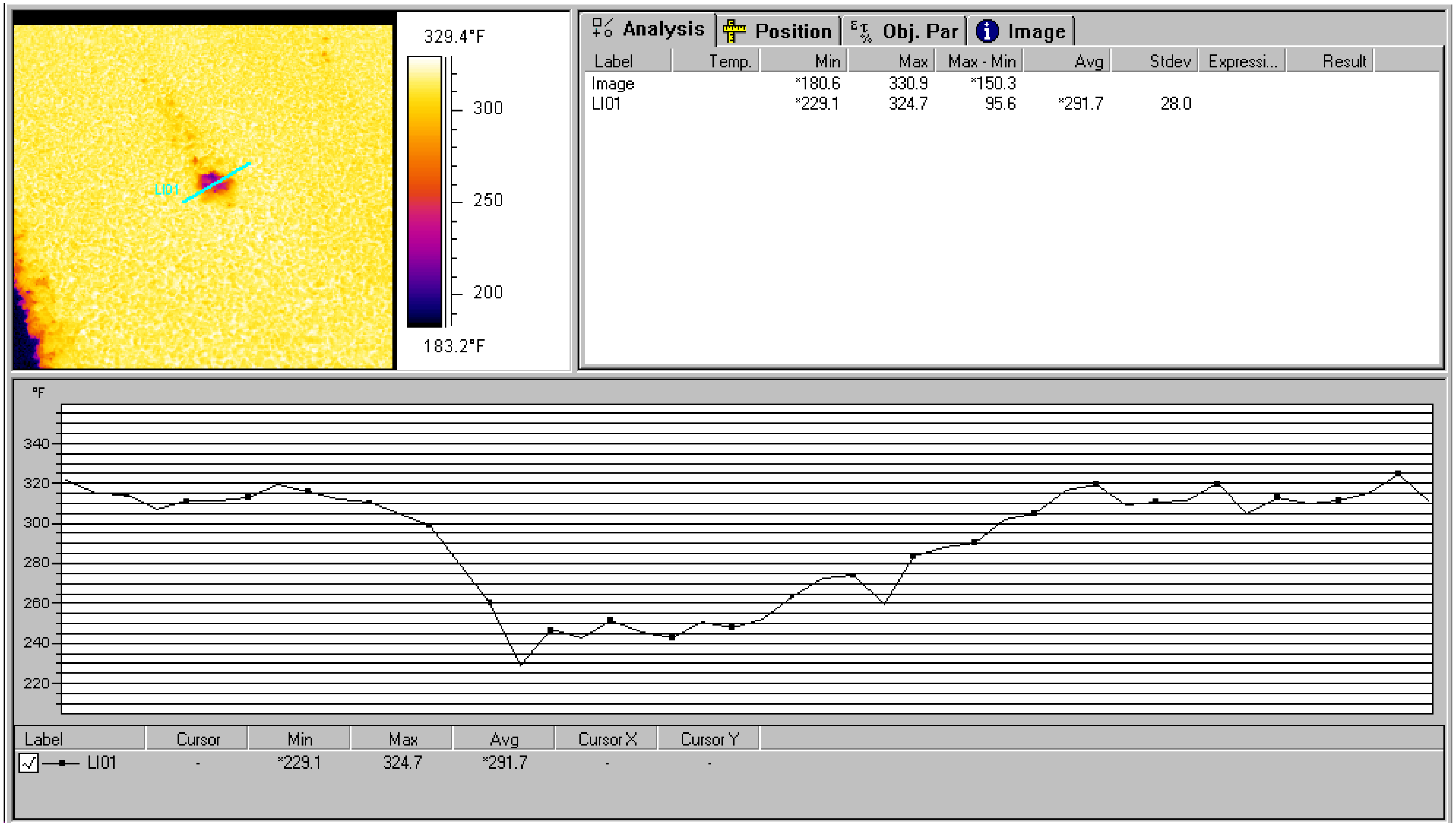
Example of Thermal Segregation



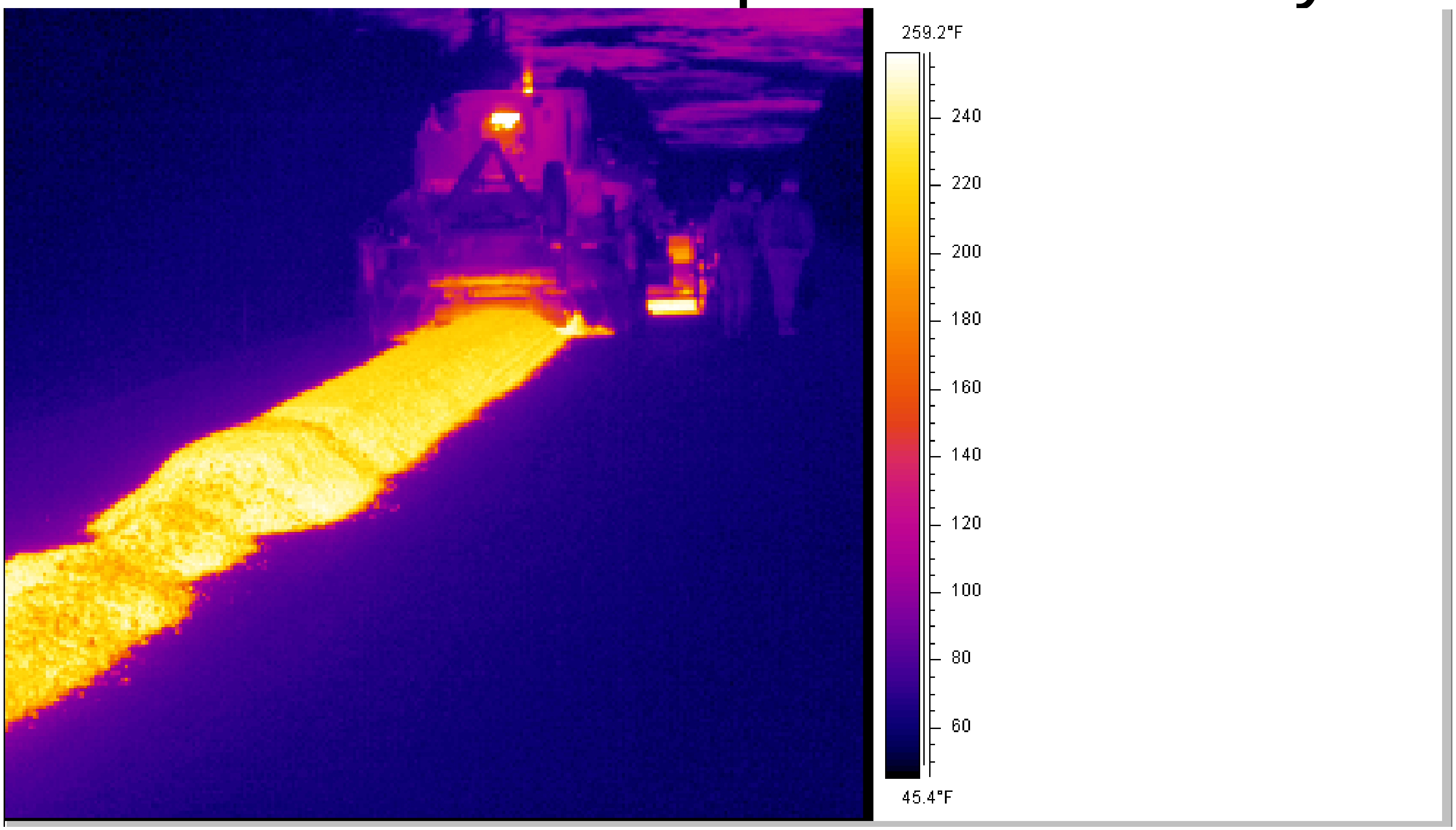
Thermal Segregation Across Mat



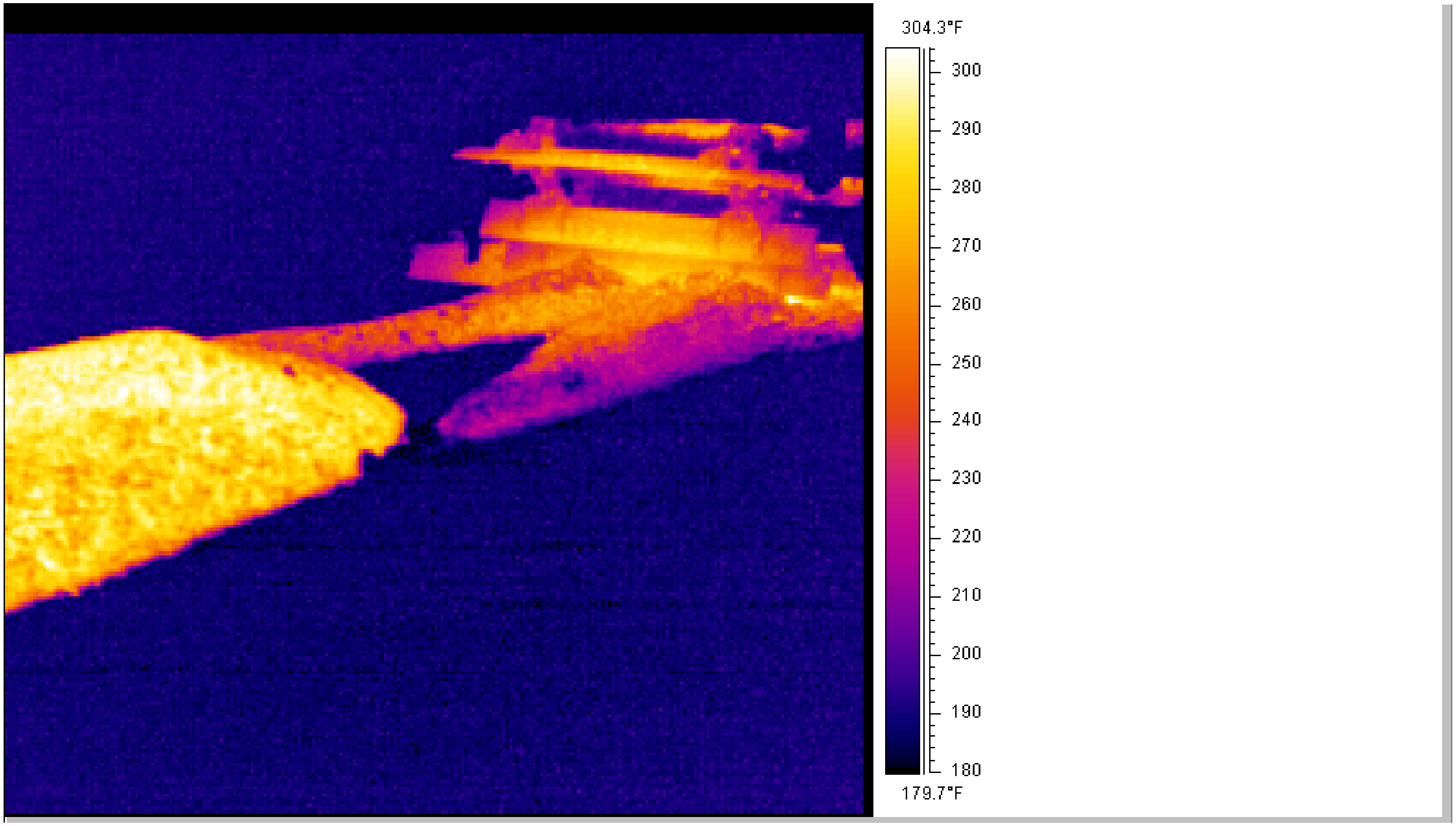
Example of Silt Ball in Mat



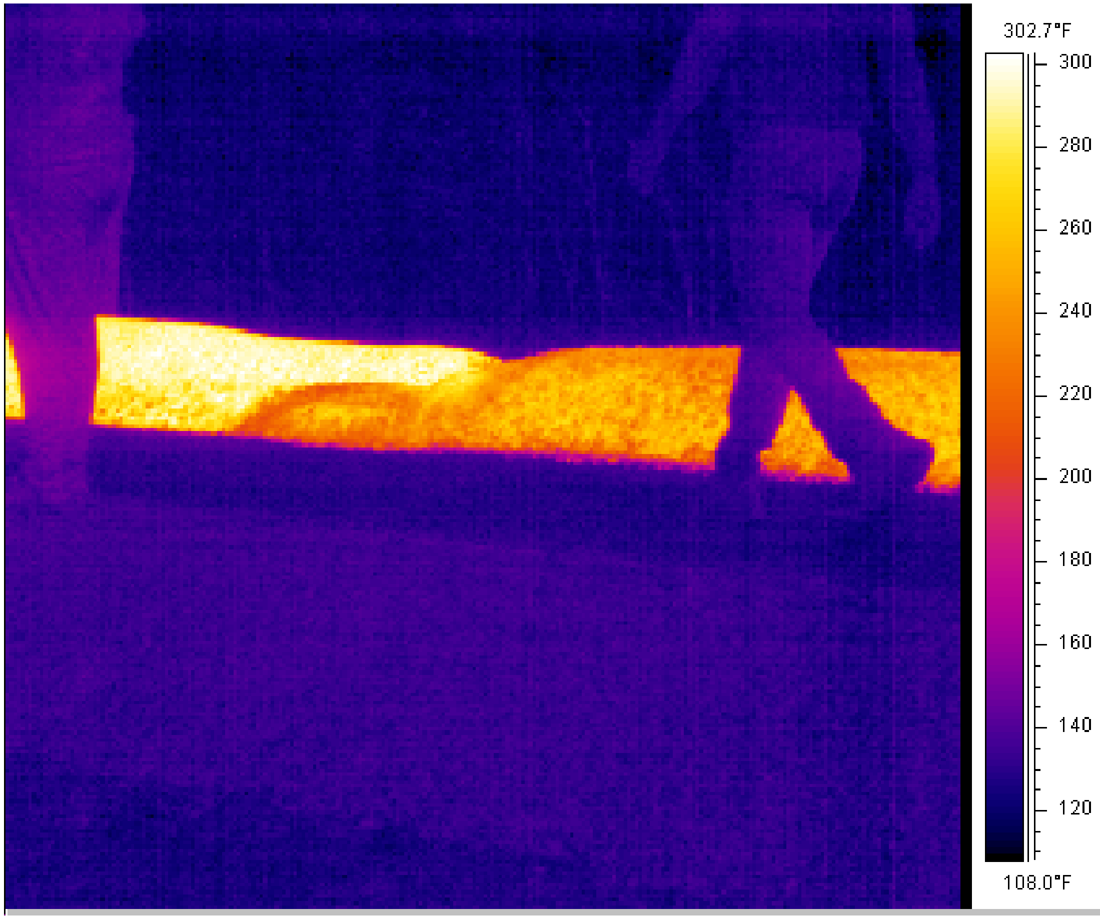
Gap in the Windrow and Second Windrow Dumped Too Early



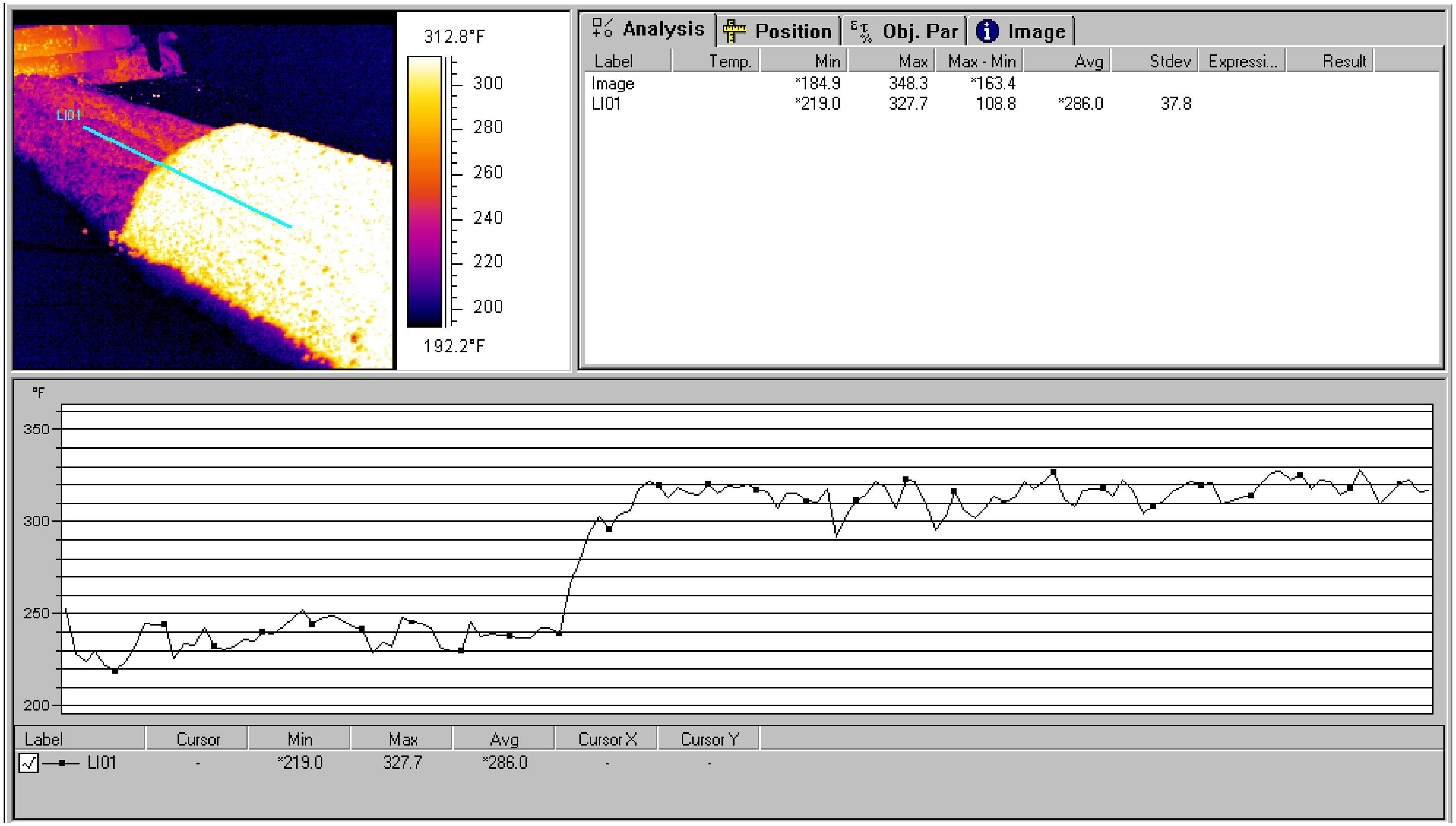
Gap In Windrow



Windrow Temperature Variance



Windrow Setting Too Long



C. Compaction Monitoring (Continuous Thermal Profiling)

C. Compaction Monitoring (Continuous Thermal Profiling)

C. Compaction Monitoring (Continuous Thermal Profiling)

C. Compaction Monitoring (Intelligent Compaction)

- Intelligent Compaction:
  - Intelligent compaction (IC) refers to an improved compaction process using rollers equipped with an integrated measurement system that consists of a highly accurate GPS, accelerometers, onboard computer reporting system, and infrared thermometers for HMA/WMA feedback control.
  - By integrating measurement, documentation, and control systems, the use of IC rollers allows for real-time monitoring and corrections in the compaction process.
  - IC rollers also maintain a continuous record of color-coded plots that indicate the number of roller passes, compaction level, temperature measurements (for HMA/WMA applications), and the precise location of the roller drum.

C. Compaction Monitoring (Intelligent Compaction)

Transportation Pooled Fund Program

U.S. Department of Transportation
Federal Highway Administration

Intelligent Compaction for Asphalt Materials

TechBrief

The Transportation Pooled Fund (TPF) study, "Accelerated Implementation of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base and Asphalt Pavement Material" is being conducted under TPF-5 (128). It is a three year study beginning September 2007 and ending September 2010.

Visit the IC project website for further details on IC technologies:

IntelligentCompaction.com

Introduction

Intelligent compaction (IC) is a construction method relatively new to the USA that uses modern vibratory rollers equipped IC components and technologies.

Though used for decades in the rest of the world, the IC technology is less mature for its application in the asphalt compaction than its counter part for the soils and subbase compaction. Under the on-going FHWA/TPF IC studies, tremendous amount of knowledge has been gained on HMA IC.

Components of asphalt IC include: double-drum IC rollers, roller measurement system, global position system (GPS) radio/receiver/base station, infrared temperature sensors, and integrated reporting system.

Therefore, an asphalt IC roller can "adapt its behavior in response to varying situations and requirements" - being "intelligent"!

There are many benefits using asphalt IC rollers. To name a few: proof rolling (mapping) to identify soft spots, achieve consistent roller patterns, monitor asphalt surface temperature (to keep up with the paver) and levels of compaction for 100% coverage area, and many more...

IC System (courtesy of Bomag)

Top Three Factors for Asphalt Compaction:

Temperature! Temperature! and... Temperature!

Asphalt IC Rollers in the US

There are at least 6 vendors around the world have been developing HMA IC rollers. Currently, there are two type of HMA IC rollers available in the US that meet the above IC roller requirements: Sakai America and Bomag USA.

It is anticipated more HMA IC rollers from other vendors (such as Caterpillar, Case/Ammann, Dynapac, and Volvo) will be available in the US during the next few years.

Sakai asphalt IC roller

Bomag asphalt IC roller

C. Compaction Monitoring (Intelligent Compaction)

C. Compaction Monitoring (Intelligent Compaction)

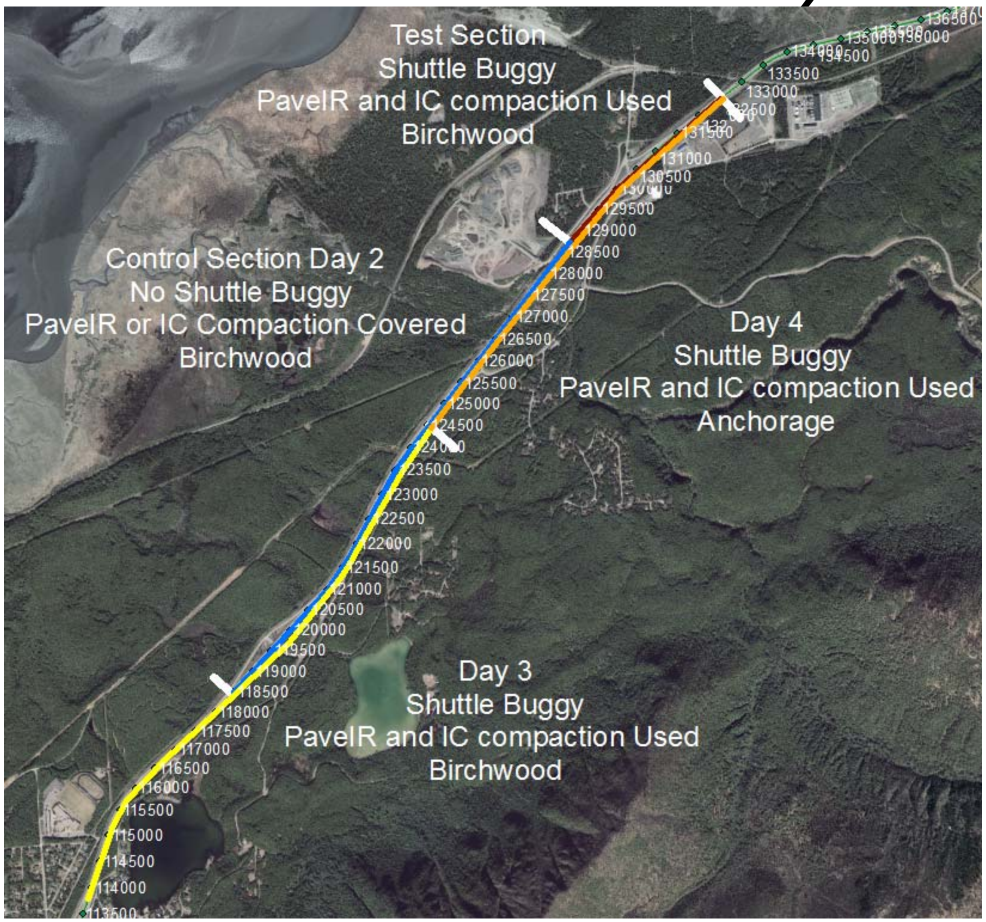
C. Compaction Monitoring (Intelligent Compaction)

D. Documentation

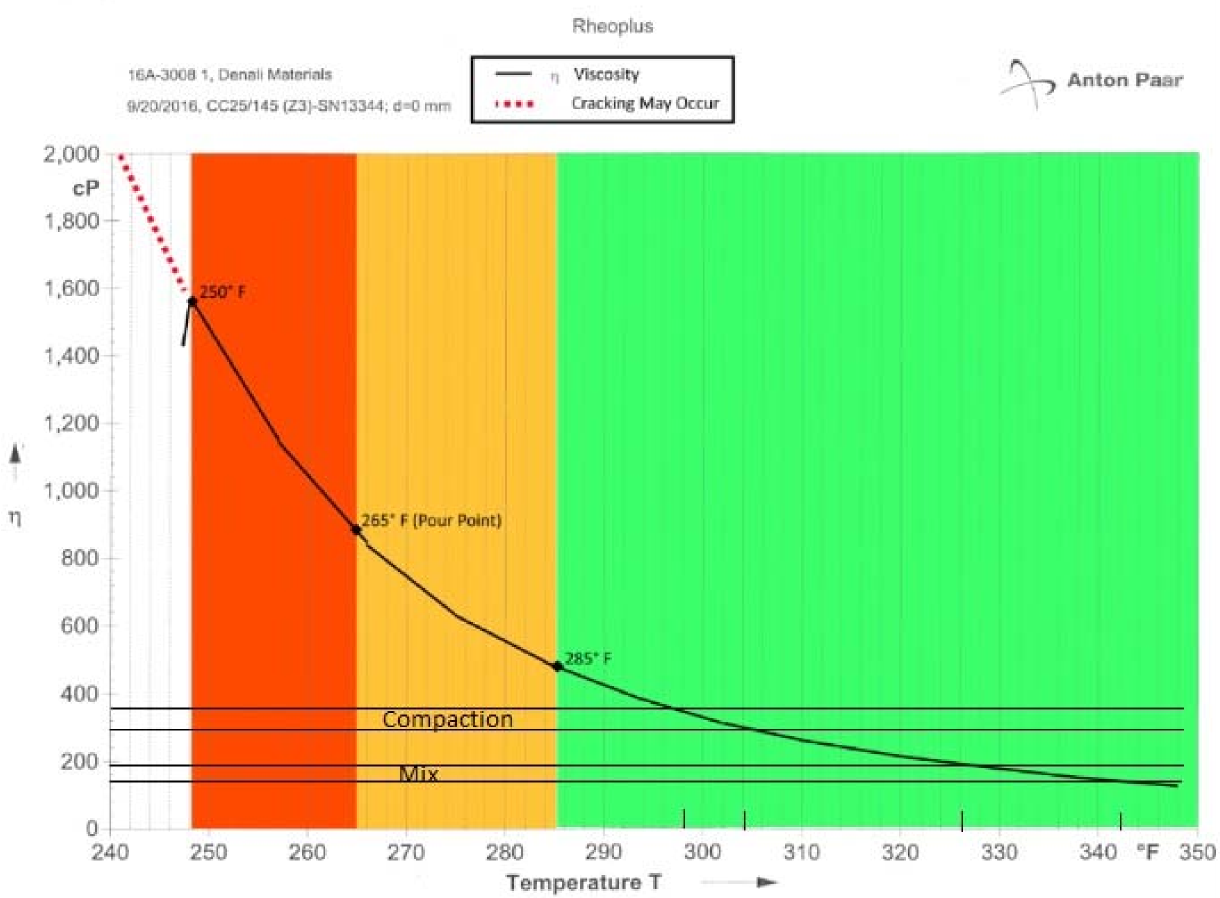
Contract Requirements:

- Test Strip (First Night): Use Intelligent Compaction (Section 411) and Pave IR Scan (Section 412)
- After Test Strip Approved (Second Night): Use Pave IR Scan and Intelligent Compaction. However, cover screens to that operators cannot see them
- After that: Use Intelligent Compaction and Pave IR Scan

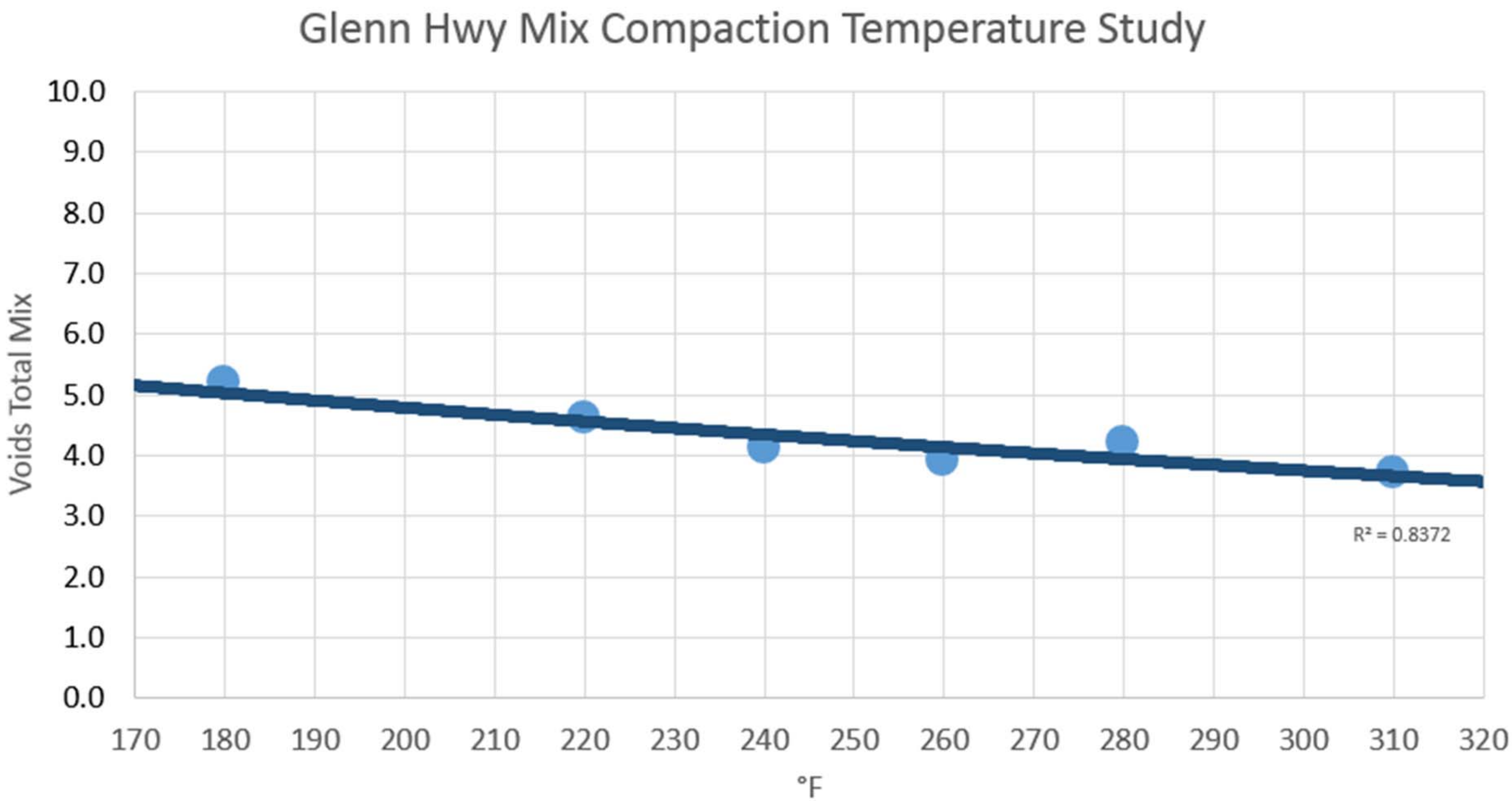
D. Documentation (2016 Construction)



D. Documentation (2016 Construction)



D. Documentation (2016 Construction)

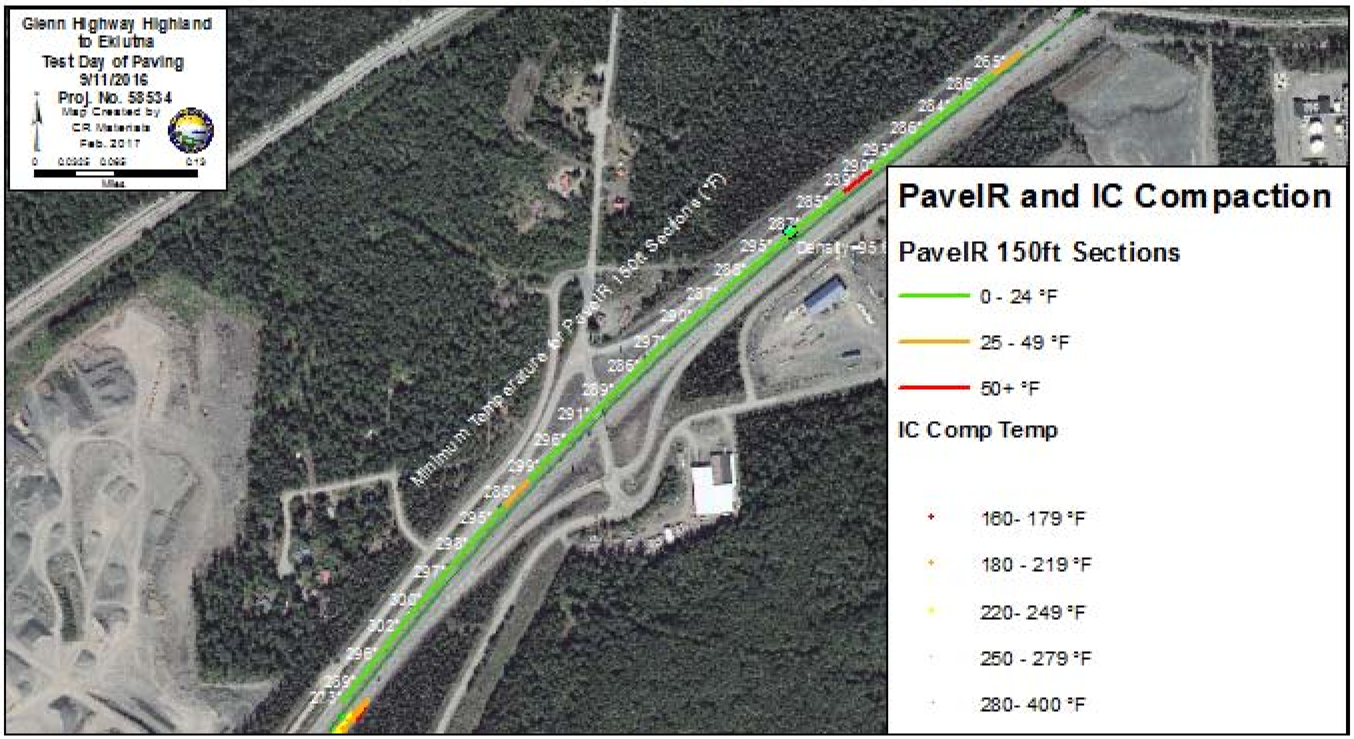


D. Documentation (First Night – Test Strip with Pave IR and IC)

Paving with Birchwood Supplied HMA
12 IR sections meet bonus for $75 ea.
25 * 75 = $1875

IR 0-25 (green) = 25/28 sections
IR 25-50 (orange) = 2/28 sections
IR 50+ (red) = 1/28 sections

Station 1327+00 - 1287+00 SB

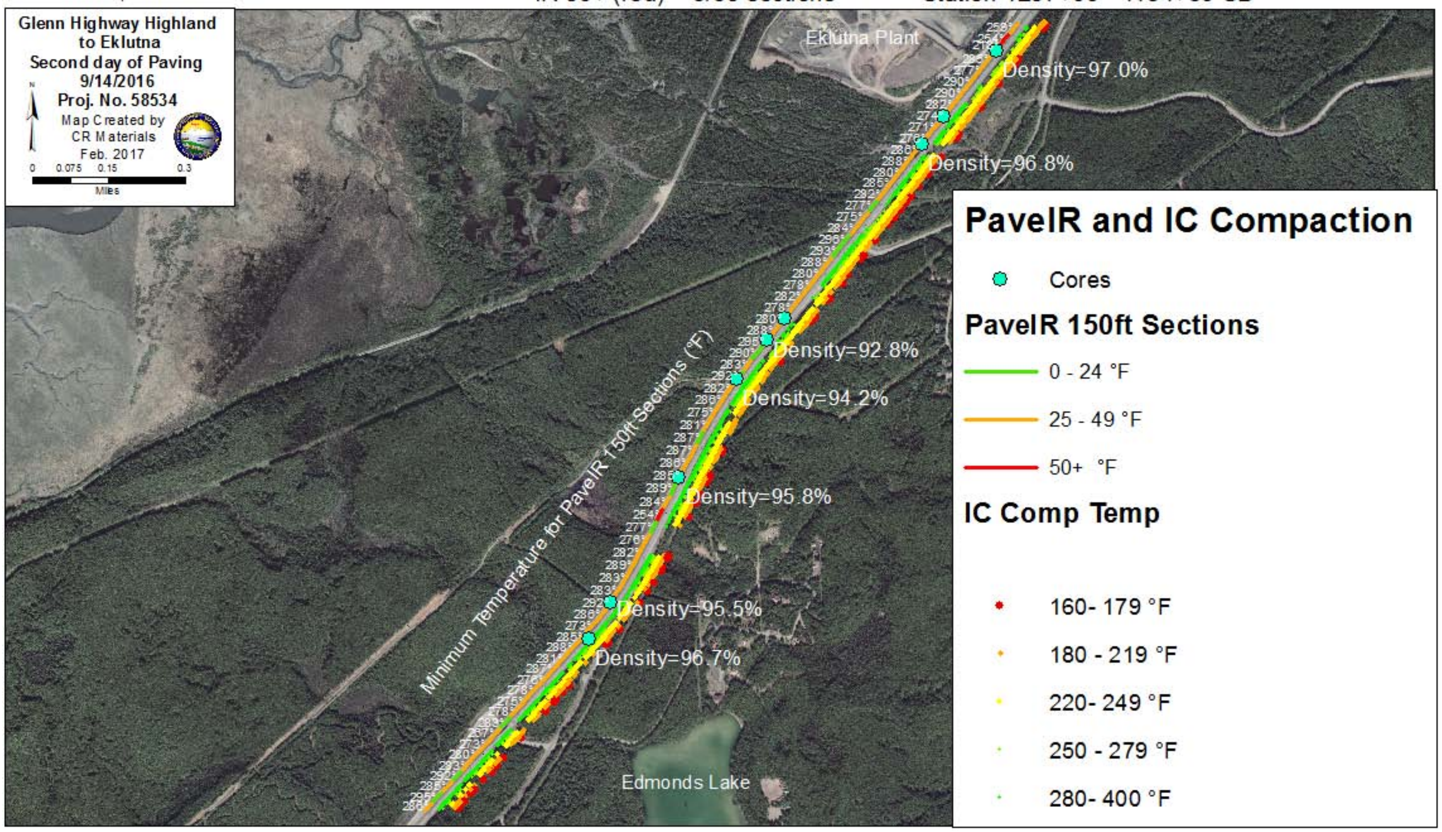


D. Documentation (Second Night with Covered Pave IR & IC)

Paving with Birchwood Supplied HMA
12 IR sections meet bonus for $75 ea.
12 * 75 = $900

IR 0-25 (green) = 12/69 sections
IR 25-50 (orange) = 54/69 sections
IR 50+ (red) = 3/69 sections

Station 1287+00 - 1184+50 SB

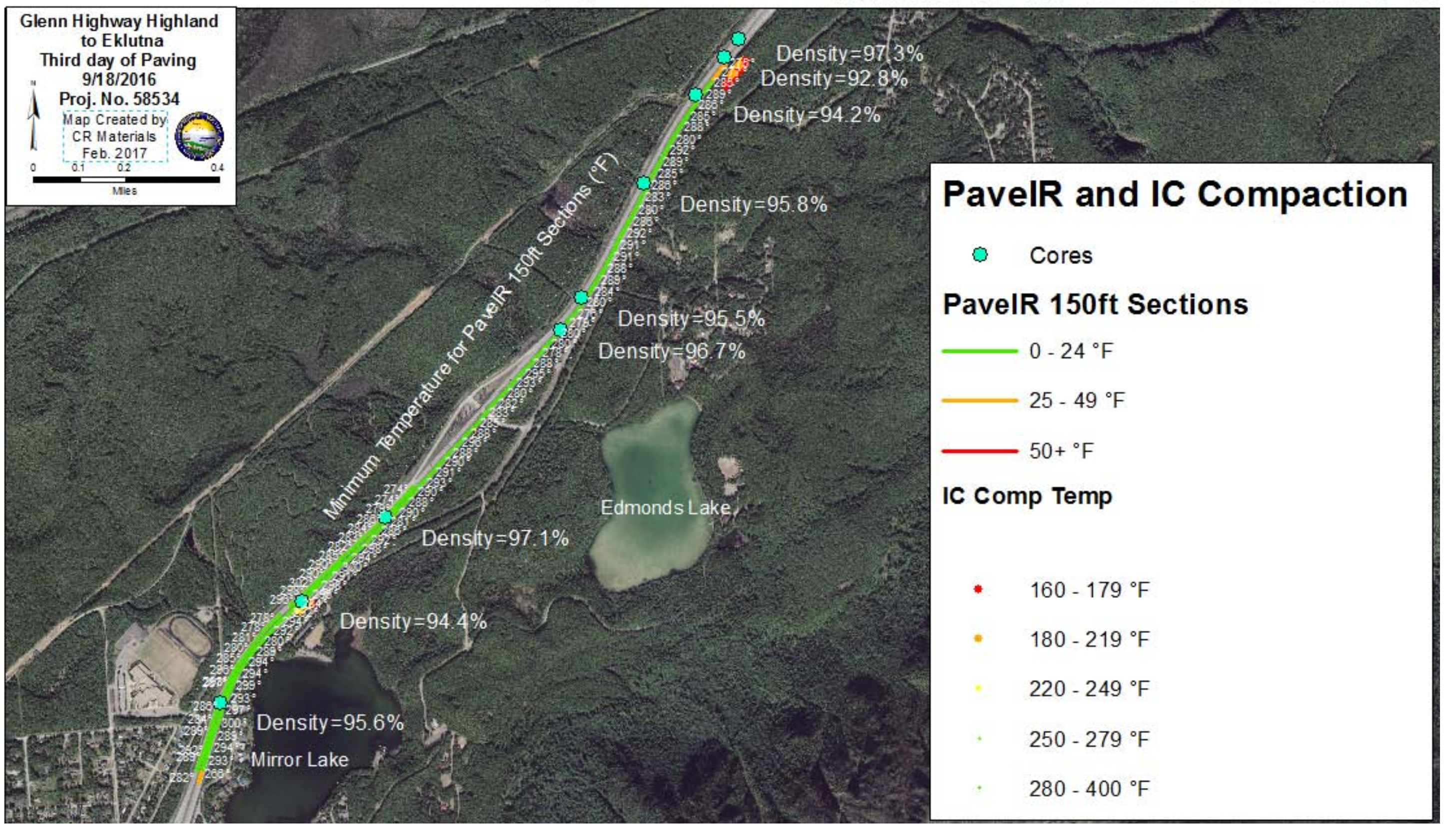


D. Documentation (Third Night with Pave IR and IC)

Paving with Birchwood Supplied HMA
12 IR sections meet bonus for $75 ea.
92 * 75 = $6,900

IR 0-25 (green) = 92/96 sections
IR 25-50 (orange) = 4/96 sections
IR 50+ (red) = 0/96 sections

Station 1184+50 - 1143+00 SB & 1142+00 - 1245+25 NB

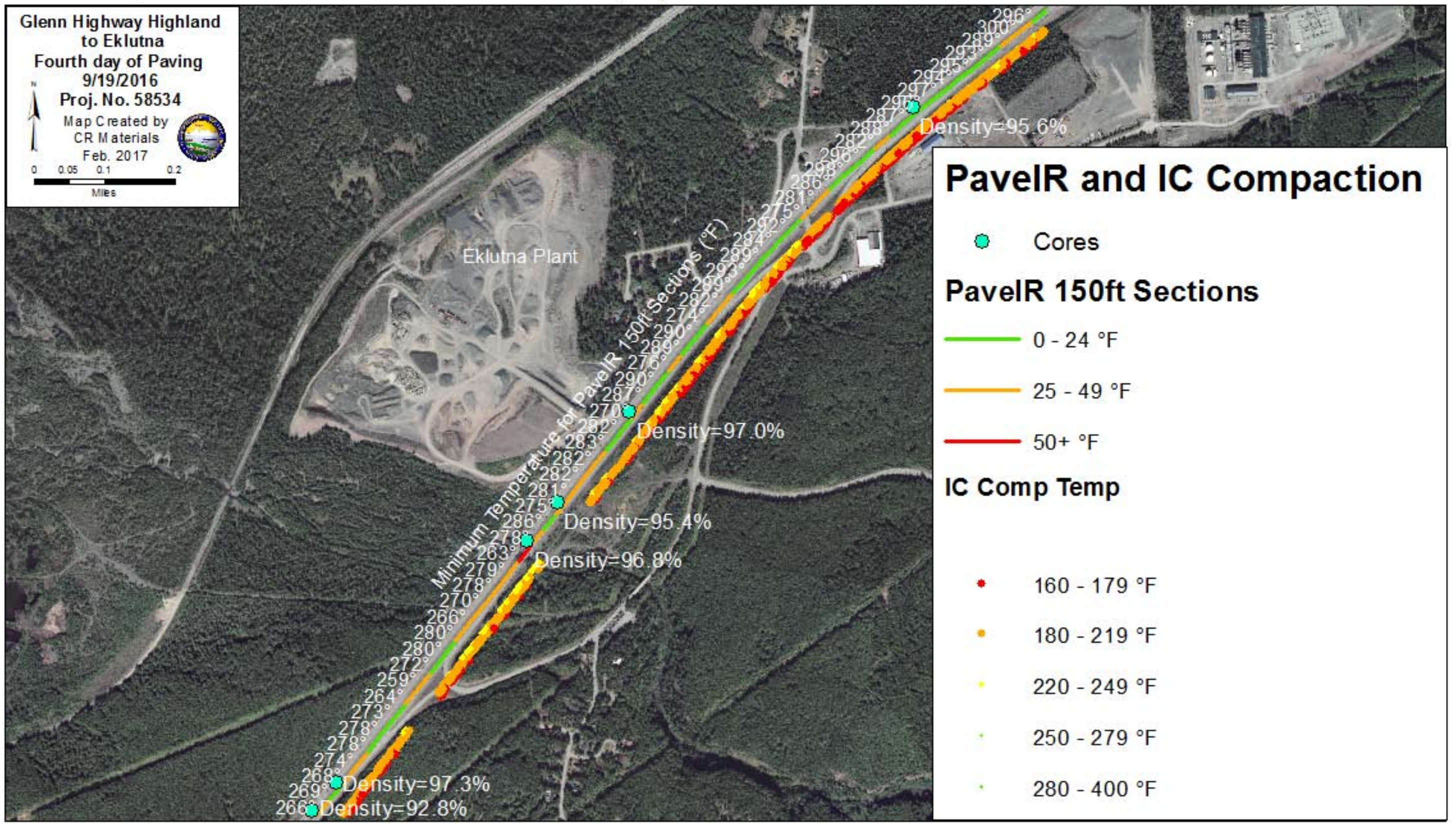


D. Documentation (Fourth Night with Pave IR & IC)

Paving with Anchorage Supplied HMA
12 IR sections meet bonus for $75 ea.
29 * 75 = $2,175

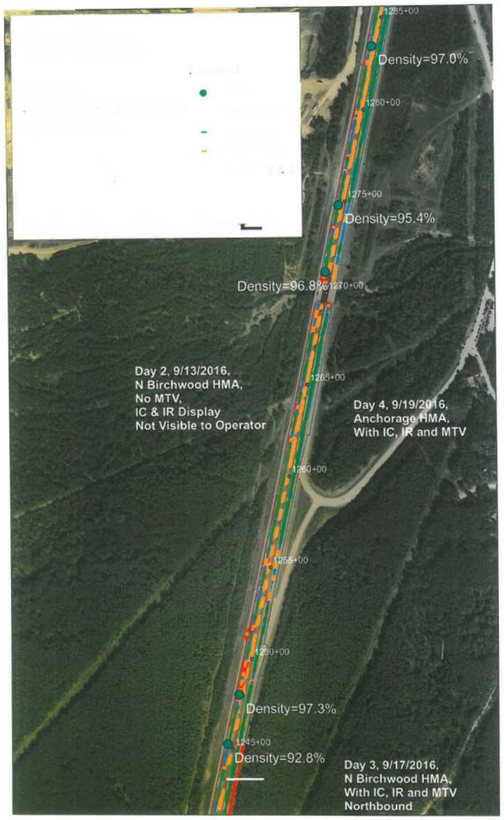
IR 0-25 (green) = 29/55 sections
IR 25-50 (orange) = 26/55 sections
IR 50+ (red) = 0/55 sections

Station 1245+25 - 1327+00 NB



D. Documentation (Minimum Mat Temperature)

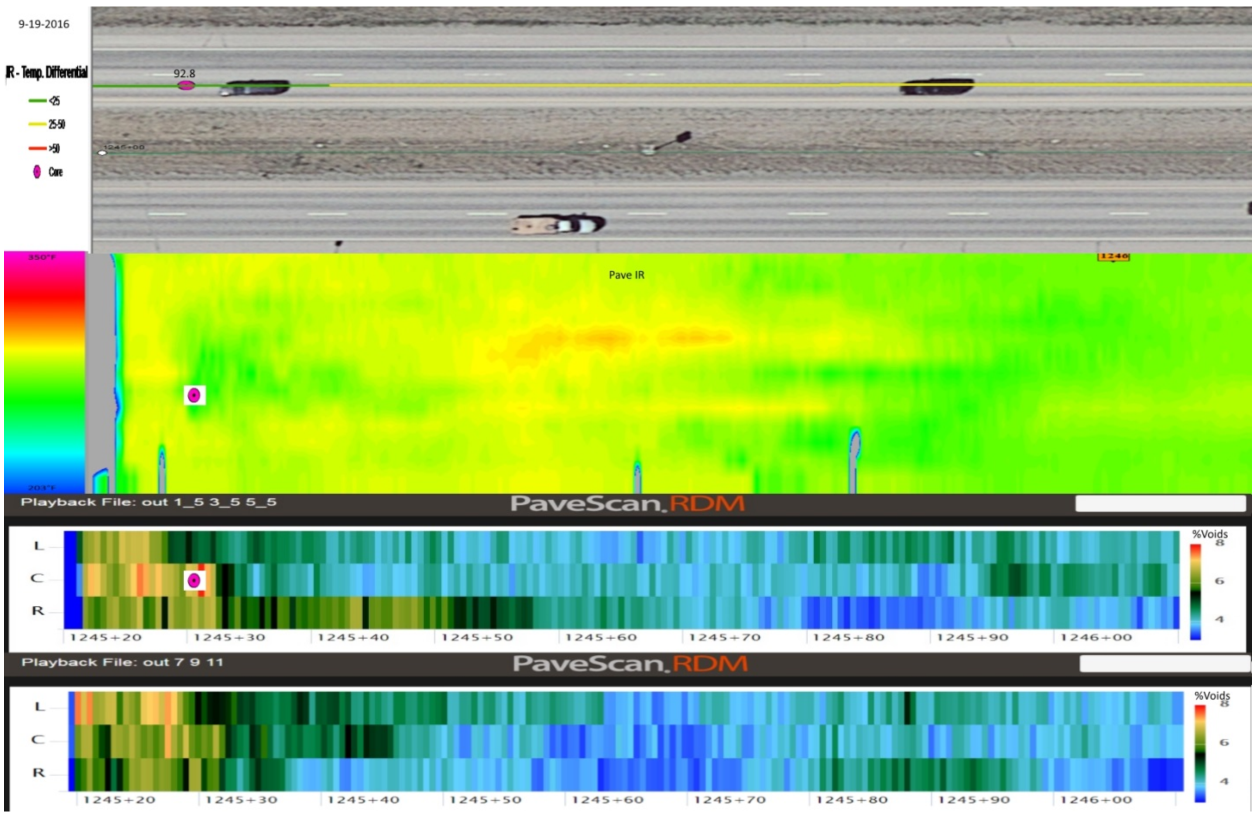
D. Documentation (Intelligent Compaction)



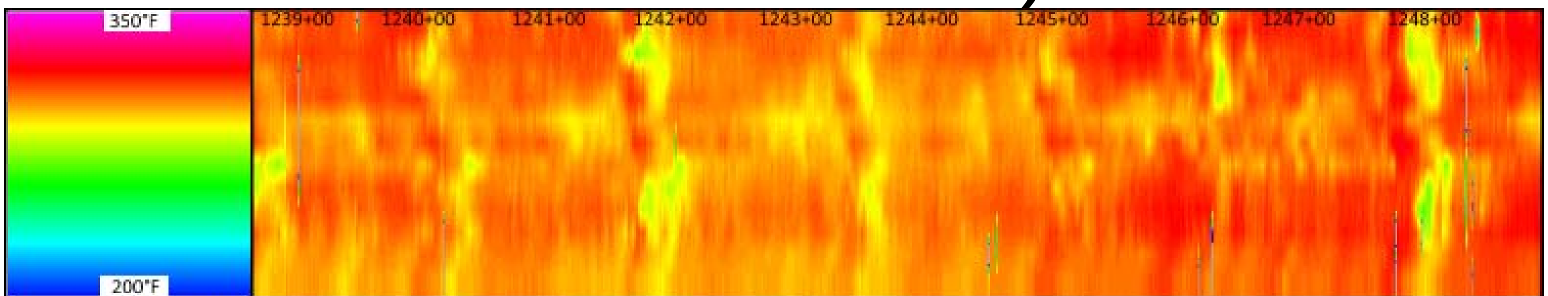
D. Documentation (Temperature Differential – First 4 Shifts only)

Day	NB/SB	Begin Station	End Station	Total Daily Square Yards (100's)	Total Daily Tonnages	Total Daily Square Yard with ΔT > 25 °F	# of 150 ft Sections with T ≤ 285°F	% Area at ΔT ≥ 25°F	% Area at ΔT ≥ 50°	Number of 150 ft Bonus Sections	% IR Available Bonus	Number of 150 ft Sections with ΔT between 25°F & 50°F	Number of 150 ft Sections with ΔT ≥ 50°F
9/11/2016 Test Strip N. Birchwood HMA With IC, IR & MTV	SB	1327	1287	53.33	614.83	3.99	1	7.5%	3.8%	25	89.3%	2	1
9/13/2016 Normal Paving N. Birchwood HMA No MTV No IC, IR Visible	SB	1287	1184.5	136.67	1666.09	108.80	42	79.6%	2.9%	12	17.4%	54	3
9/17/2016 N. Birchwood HMA With IC, IR & MTV	SB	1184.5	1143	55.33	2269.15	1.99	4	3.6%	3.6%	92	95.8%	4	0
	NB	1142	1245.25	137.67		5.49		3.6%	0.0%				
9/19/2016 Anchorage HMA With IC, IR & MTV	NB	1245.3	1327	109.00	1298.51	50.79	21	46.6%	0.0%	29	52.7%	26	0

D. Documentation (Pave IR and PaveScan)



D. Documentation (Density Evaluation)



IR - Temp. Differential

- Green: < 25
- Yellow: 25 - 50
- Red: > 50

IR - Min. Temperatures

- Blue: Less Than
- White: Average

Pass	Type	Section A	Section B	Section C	Section D	Section E	Section F	Section G	Section H	Section I	Section J	Section K
1	Temp Avg.	285	269	268	252	241	252	246	260	256	241	234
	Viscosity Color	Green	Orange	Orange	Red	Cold	Red	Cold	Red	Red	Cold	Cold
	CMV Avg.	38	29	27	26	32	39	32	32	31	30	33
3	Temp Avg.	289	270	257	240	234	241	248	245	240	232	224
	Viscosity Color	Green	Orange	Red	Cold	Cold	Cold	Cold	Cold	Cold	Cold	Cold
	CMV Avg.	51	51	48	58	55	53	54	48	52	51	51
5	Temp Avg.	258	279	260	263	232	222	235	246	236	225	216
	Viscosity Color	Red	Orange	Red	Red	Cold	Cold	Cold	Cold	Cold	Cold	Cold
	CMV Avg.	69	64	52	55	60	63	61	59	60	52	51

- Glenn Hwy: Hiland to Eklutna Info
  - **Construction Length:** 15.2 miles in 4 lanes
  - **Project Total Tons:** 56,225.94 tons
  - **Project Total Joint Length:** 294,128 linear feet

E. HMA Price Adjustments
F. Thermal Profiling Price Adjust

- **E. HMA Price Adjustments:** $809,539.40

- **F. Thermal Profiling Price Adjustment:** $136,800.00

Questions?

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Alaska Dept. of Transportation and Public Facilities
Central Region Construction Section
Email: Ronald.Searcy@alaska.gov
Phone: (907) 269-0656

G. PaveScan

- Richard Giessel, P.E.

Alaska Department of Transportation & Public Facilities

2.5 Million Density Tests in 22 Nights on the Glenn Hwy - Rich Giessel

November 2017

Continuous Full Coverage (CFC)

- FHWA and AASHTO through SHRP2 have invested 9 years and $232 Million promoting adoption of CFC testing technologies.

- Why should Alaska DOT&PF change from random testing to CFC testing technologies?

Donald M. Burmister (1948)

- "The primary problem is not so much to determine the average conditions, as it is to make reasonably certain that possibly the most unfavorable conditions are known over a given area that may give rise to soft spots."

Advantages of Systematic Testing

Burmister advocated for Systematic Testing:

- Uses multiple inputs to “look for” failure zones
- Materials/grade inspectors used accumulated knowledge and observations to look for defects
- Test locations selected in “Worst” area
- High probability of detecting defects

Problems with Random Testing

- Assumes a Bell Curve or Gaussian Distribution of values, thus PWL specs are Not suitable for heterogeneous materials
- Not suitable for finding defects on paving projects as there is almost zero probability of locating pot hole size defects

Advantages of CFC Testing

Continuous Full Coverage Testing:

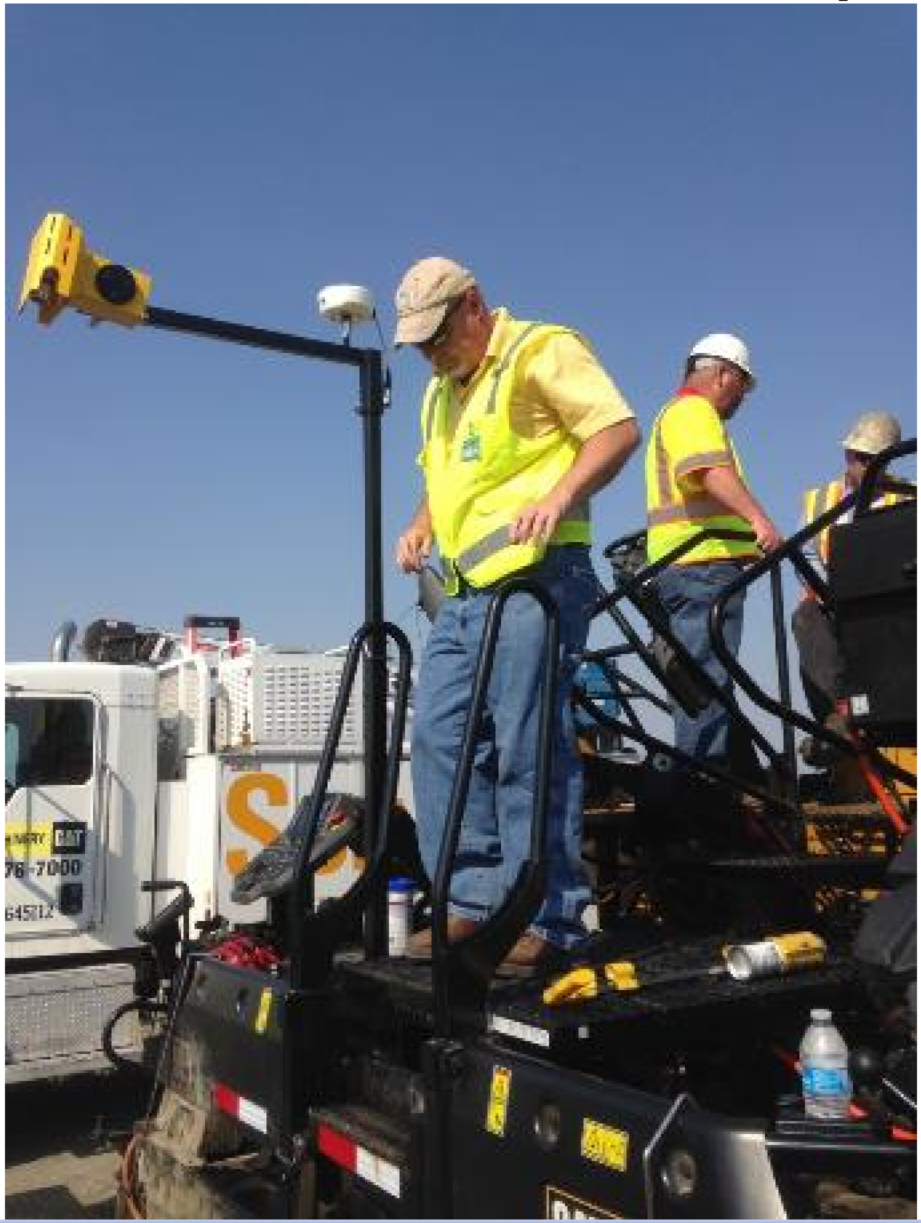
- Takes a test every square foot
- Locates every test with GPS coordinates
- Has the potential to produce a nearly defect free project with open communication of data and proper incentives/corrective actions

IC, PaveIR, PaveScan-AK History

- Alaska DOT began using Intelligent Compaction (IC) at Sitka Airport 2013
- Following demonstration projects in 2011 with the PaveIR Bar and in 2015 with the PaveIR Scanner, PaveIR was specified on the Glenn Highway-Hiland to Eklutna Project in 2016
- First demonstration of PaveScan RDM was performed on same project in September 2016

Pave IR Bar (2011)

PaveIR Scanner (2015)



PaveScan RDM (2017)

Intelligent Compaction (IC)

- Intelligent Compaction provides:
  - Geo-located Data
  - Pass Coverage
  - Relative Stiffness
  - Temperature mapping at time of roller pass

Infrared Scanner

- PaveIR provides
  - Geo-located Data
  - Complete map of asphalt mat surface temperature
  - Viewable in real time
  - Calculates degree of thermal segregation / 150’
  - Provides a permanent temperature record

PaveScan RDM

- PaveScan Rolling Density Meter Provides:
  - Geo-located Data
  - 60 scans (dielectric readings) per second recorded to Raw Data File
  - ~10 Dielectric readings per foot of travel at 4 mph walking speed per antenna

PaveScan RDM

- Example Display Settings, Walk (4 mph)
  - If user selects 0.5 ft Data Display interval, then ~5 consecutive Raw Data readings are averaged to display color coded “Density” blocks every 0.5’
  - Typical 2’ antenna spacing gives 0.5’ x 2’ density blocks, or One density value/square foot/antenna

PaveScan RDM

- Example (Continued)
  - At walk rate of 4 mph (352 ft/min) the operator covers a half-lane width of 6 ft x 352 ft = 2112 ft^2
  - With the user selected settings, 2112 Density values will be added to the display every minute
  - Or 60 x 2112 = 126,720 Densities/hour with five times as much raw data available for post processing at any time.

What is Dielectric?

- Related to Speed of RADAR through a Material

$$e = C^2 / V^2 \quad \text{or} \quad V = C / \sqrt{e}$$

Where: V = velocity of RADAR in material

C = Speed of light in a vacuum

e = Dielectric

Relative Speeds of RADAR

RADAR is fastest in Air e = 1

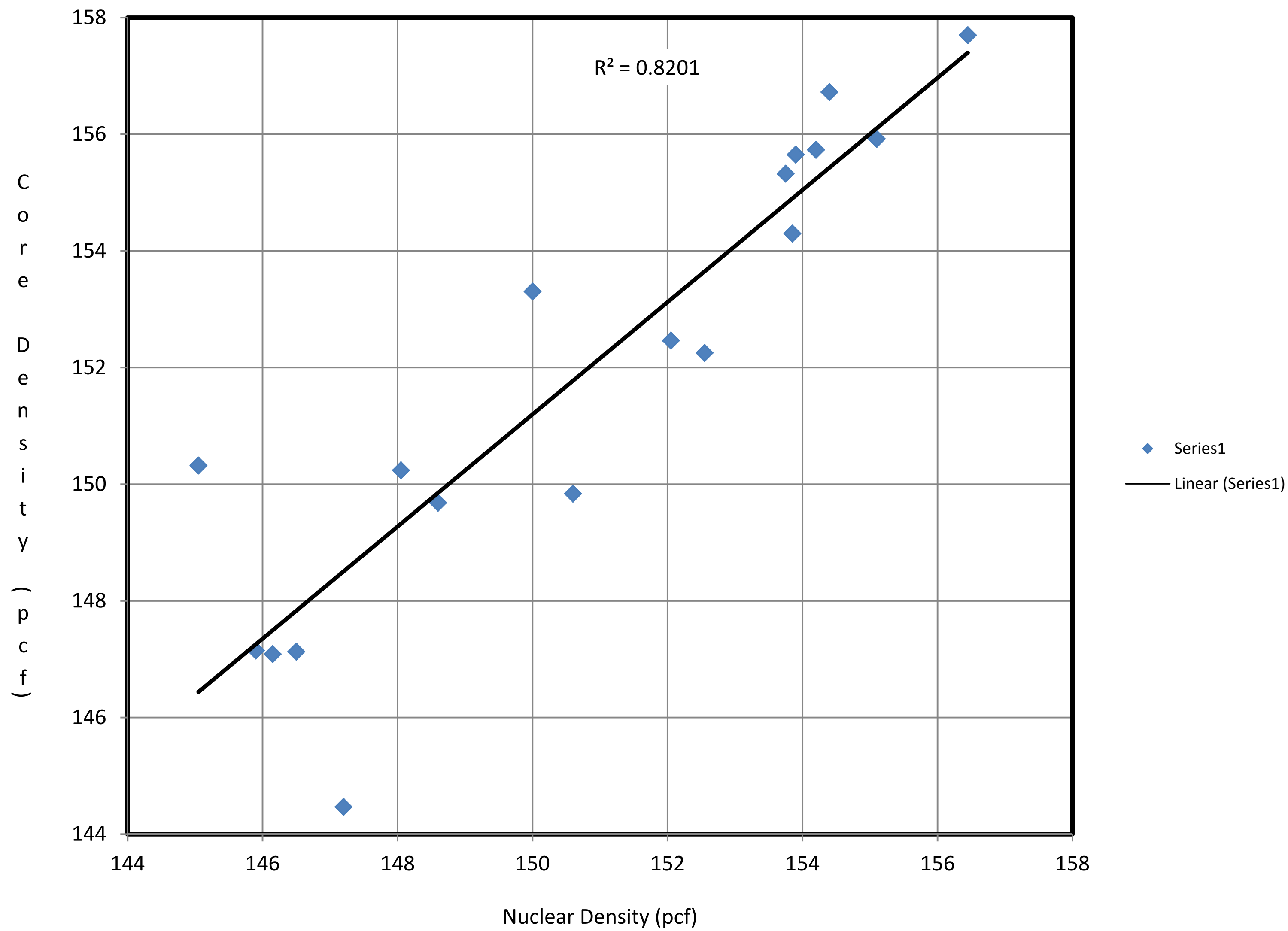
RADAR is slowest in Water e = 81

Asphalt Concrete e = 4 to 7

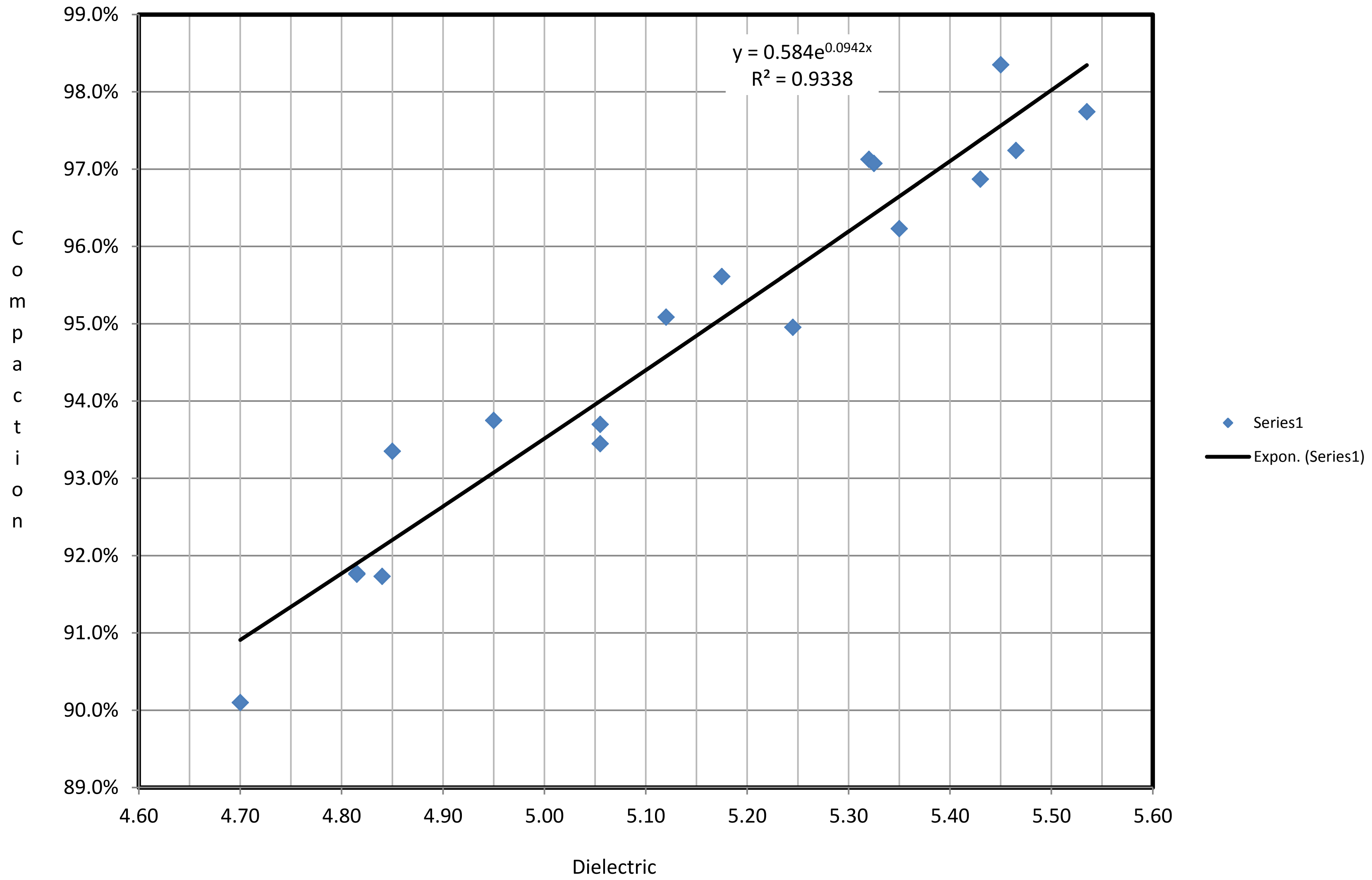
(note more air gives lower dielectric, i.e. RADAR passes through porous asphalt faster)

LOW DIELECTRIC = LOW DENSITY

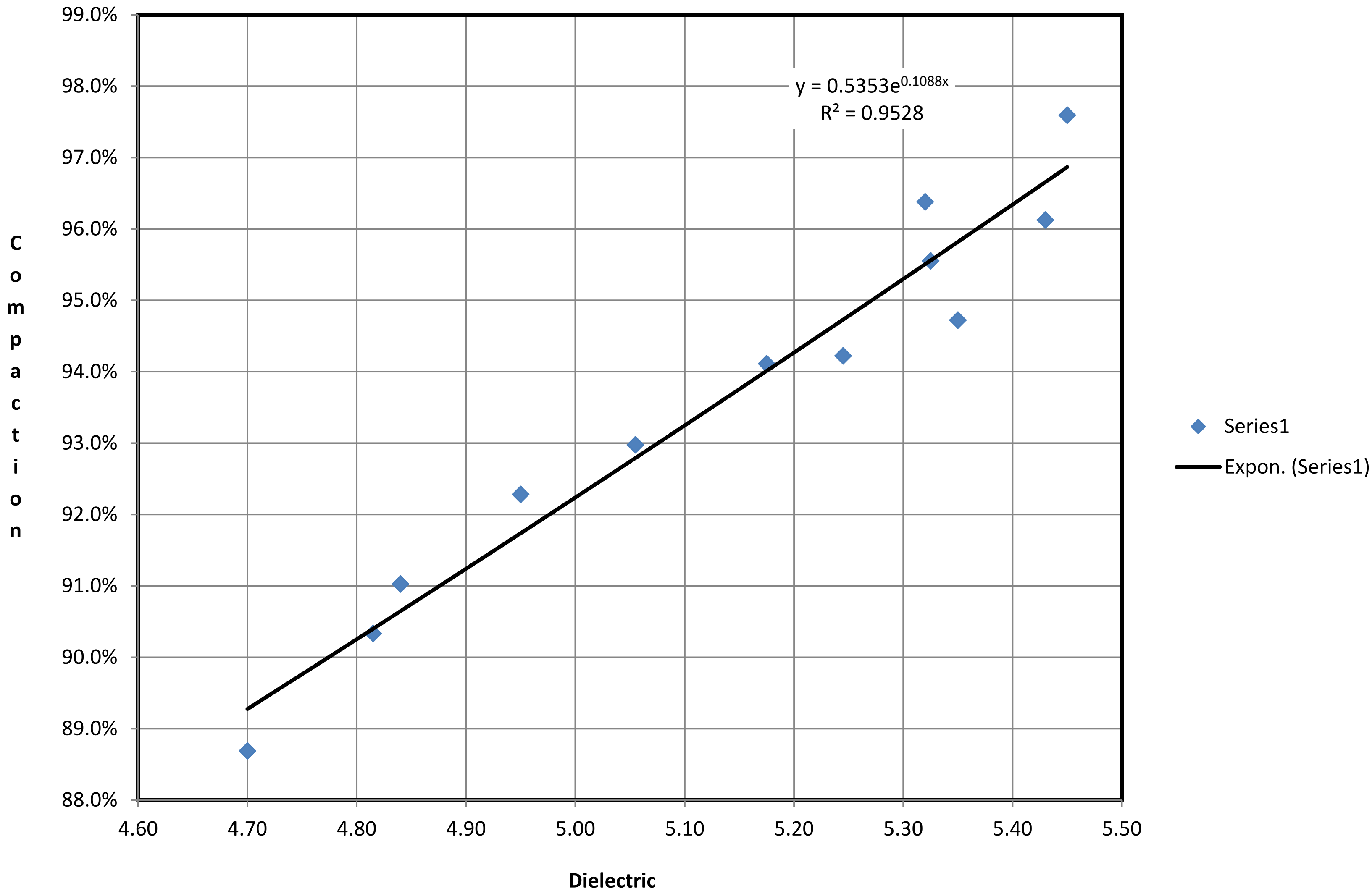
Calibration: Cores vs Nuke, R^2 = 0.82



Calibration: Cores vs RDM, $R^2 = 0.93$



Calibration w/Cores after 1 Day of Traffic
Cores vs RDM $R^2 = 0.95$



Pursuing Calibration w/ R^2 = 1.0

- Use of PaveScan algorithm for selecting coring locations is better than “user-selected fishing”.

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- Multiple 200’ lane sections w/6 Cores from each. Three 200’ sections 500’-1200’ apart.

Pursuing Calibration w/ $R^2 = 1.0$

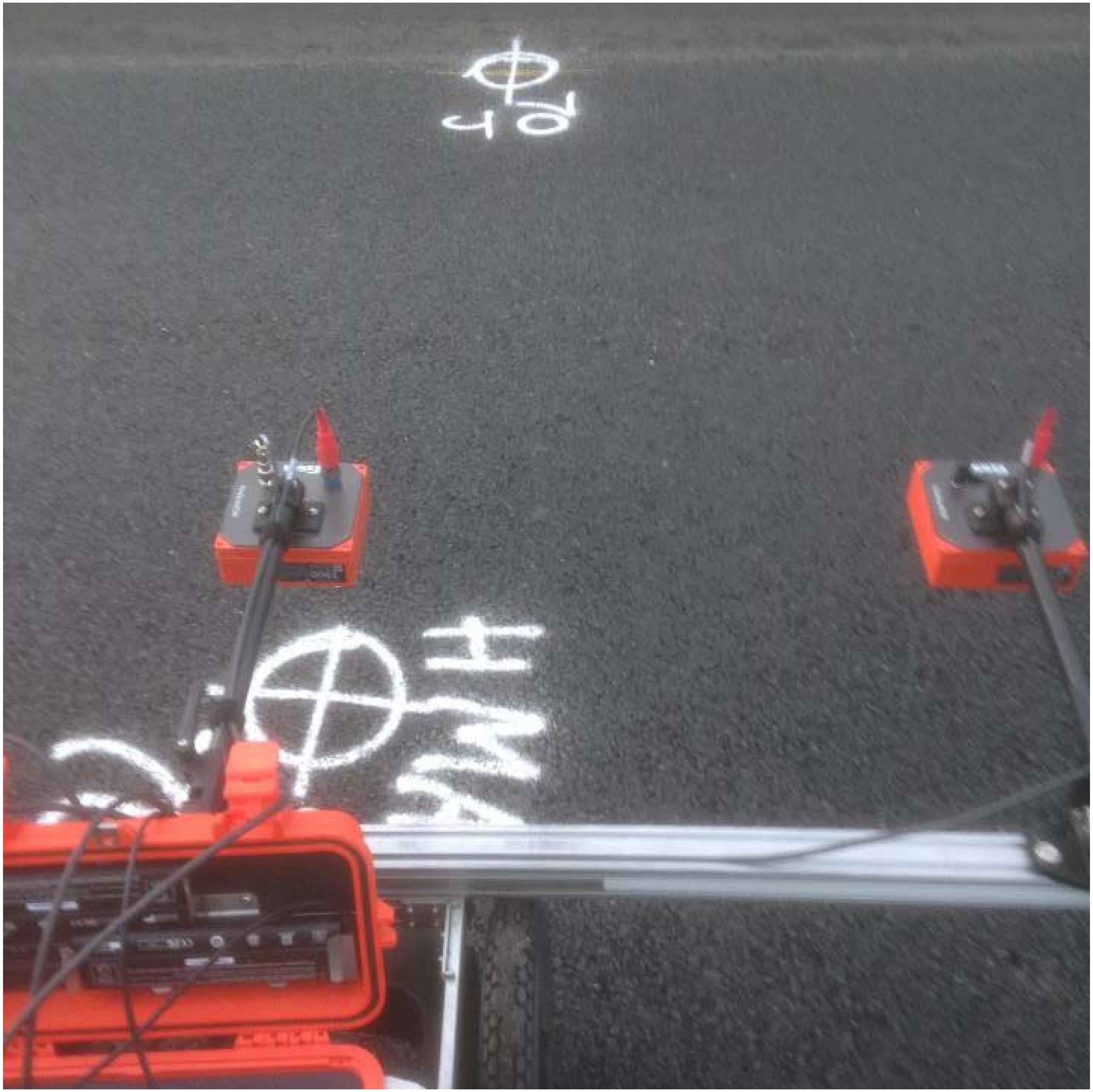
- Use of PaveScan algorithm for selecting coring locations is better than “user-selected fishing”.
- It is important keep track of one’s location by marking stations and core locations.
- Multiple 200’ lane sections w/6 Cores from each. Three 200’ sections 500’-1200’ apart.
- Day old pavement gives better calibration than hot mat.

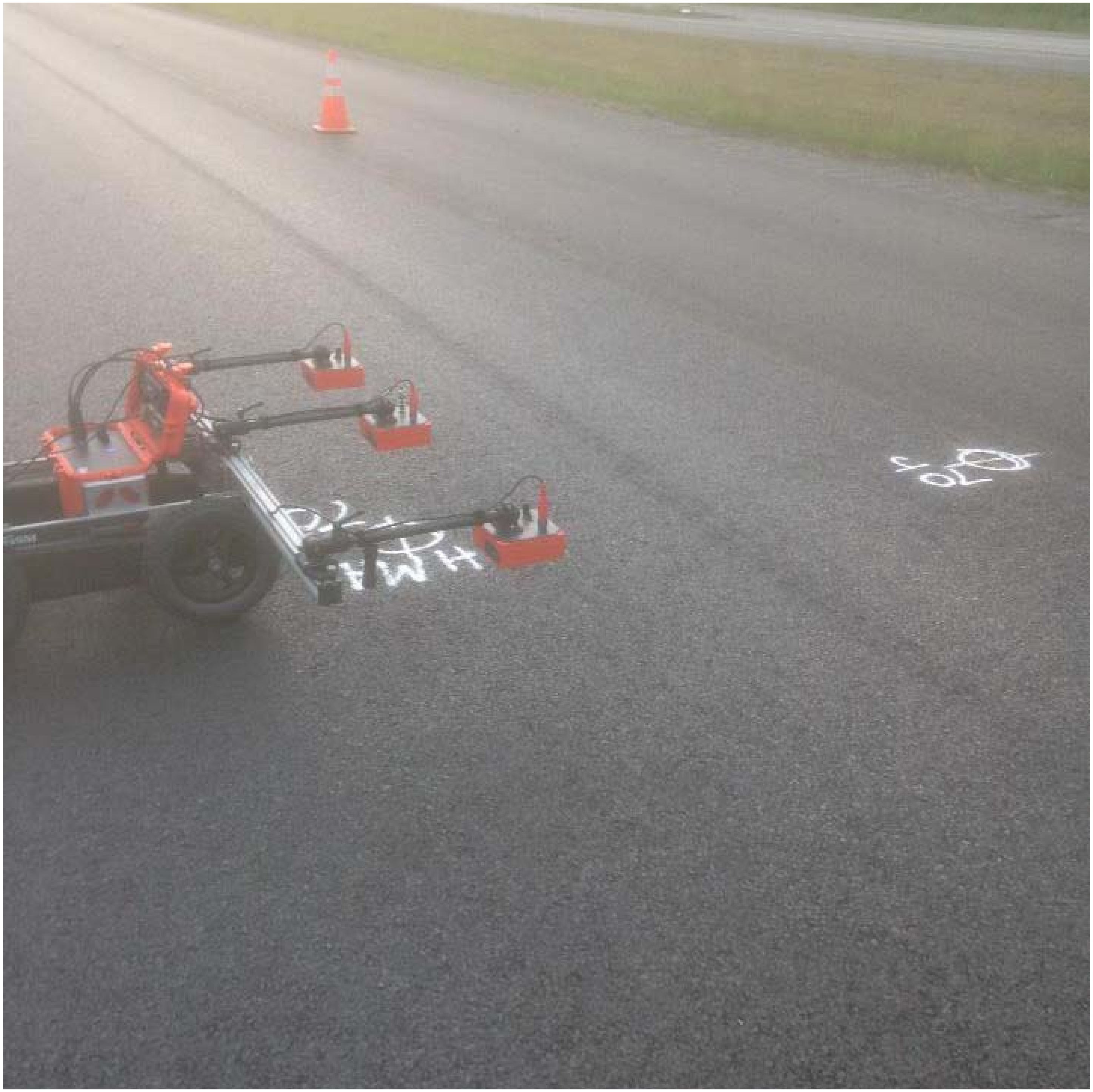
Pursuing Calibration w/ R^2 = 1.0

- Next step for Alaska DOT&PF will be performing a Maximum Specific Gravity test on each calibration core and using the core specific MSG to calculate each density.
- Our goal is to keep R^2 above 95% for each mix design placed on a project evaluated with the RDM.

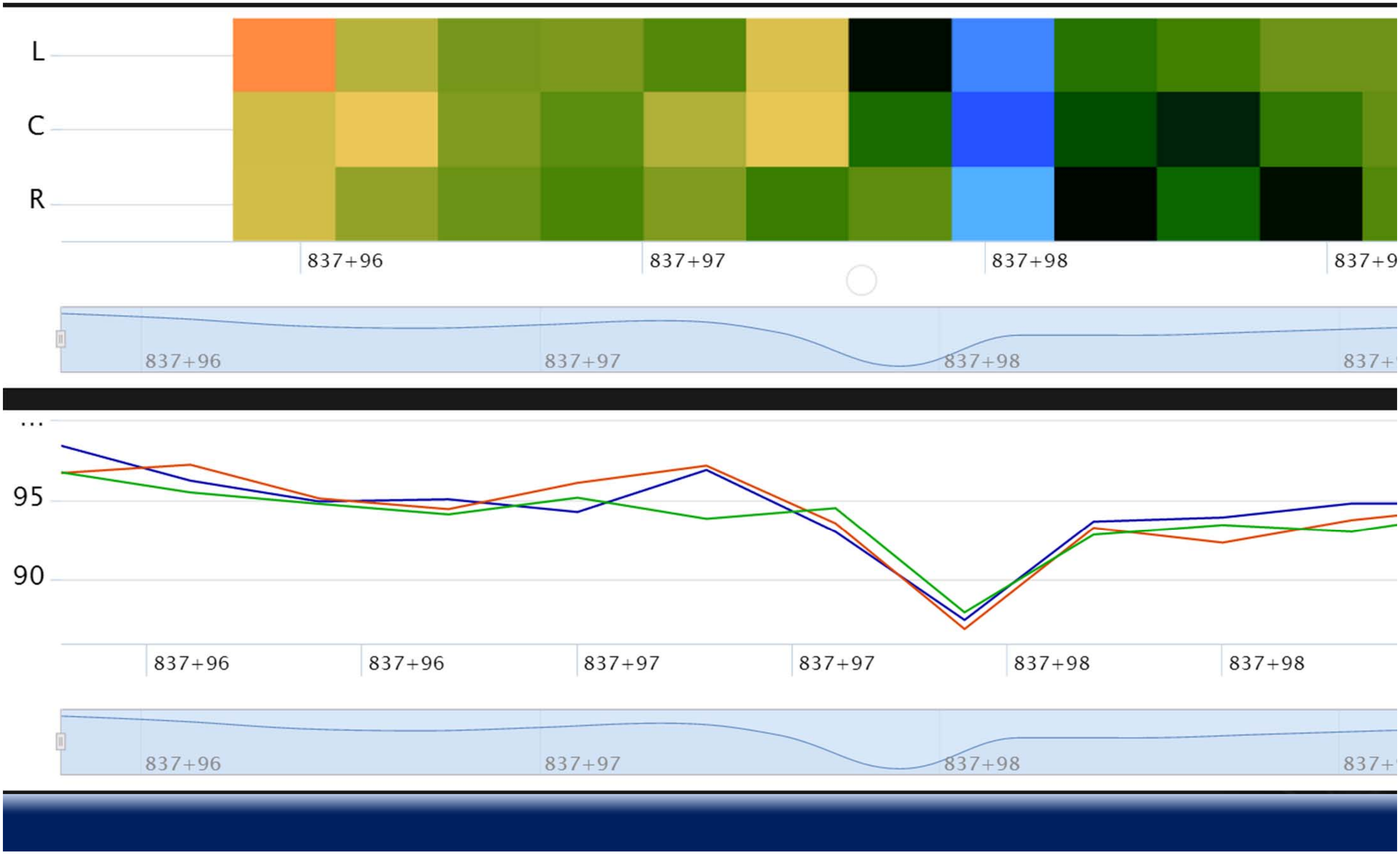
What can we "SEE" with GPR?

- Answer: Defects we have never "SEEN" before
- For example, density variation across a longitudinal joint

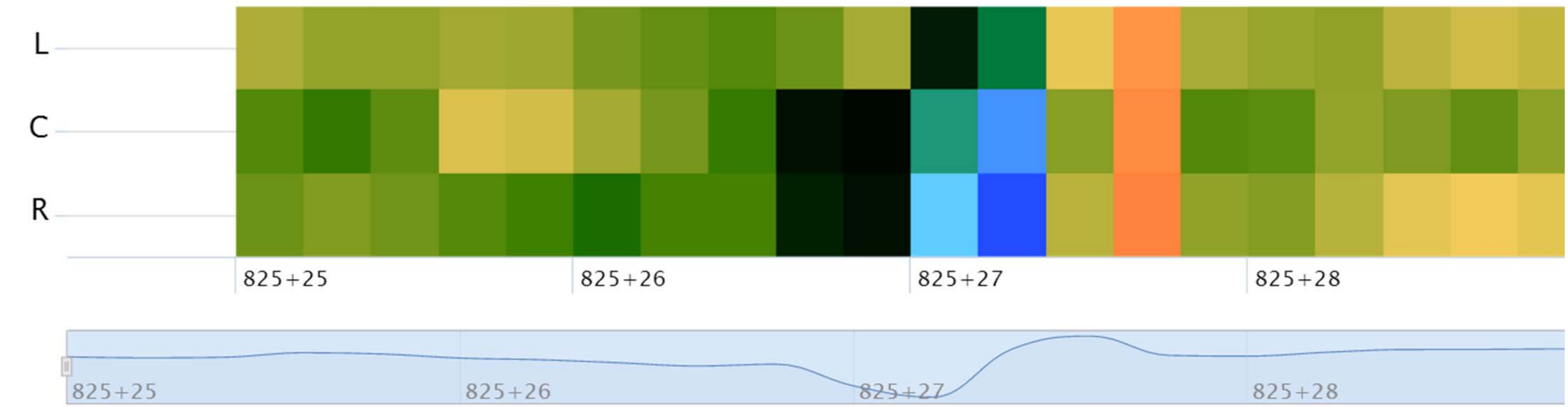




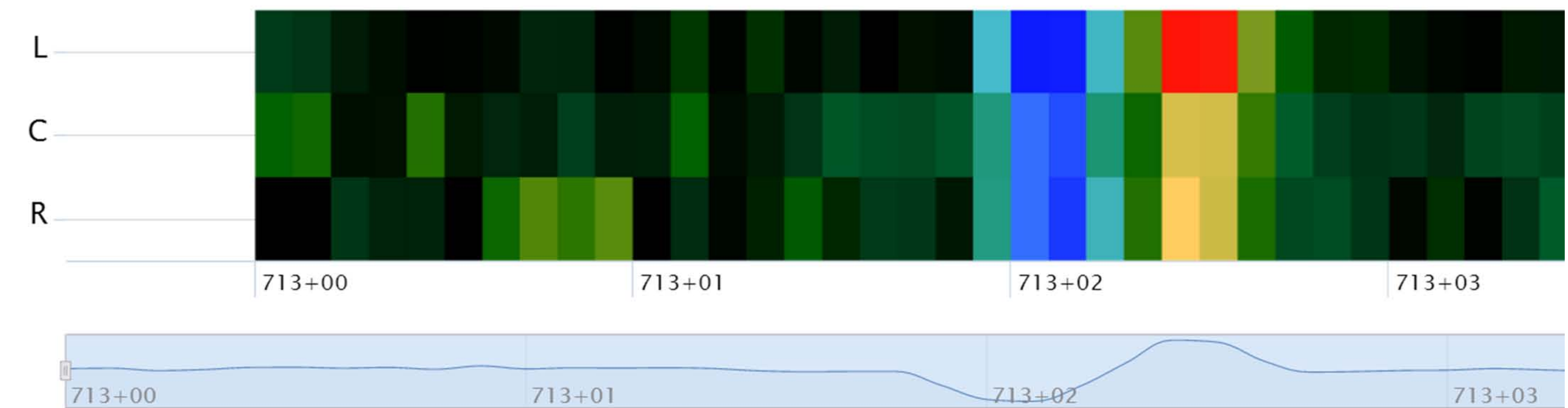
Core 69J (92.9%) – Resolution 0.25 ft

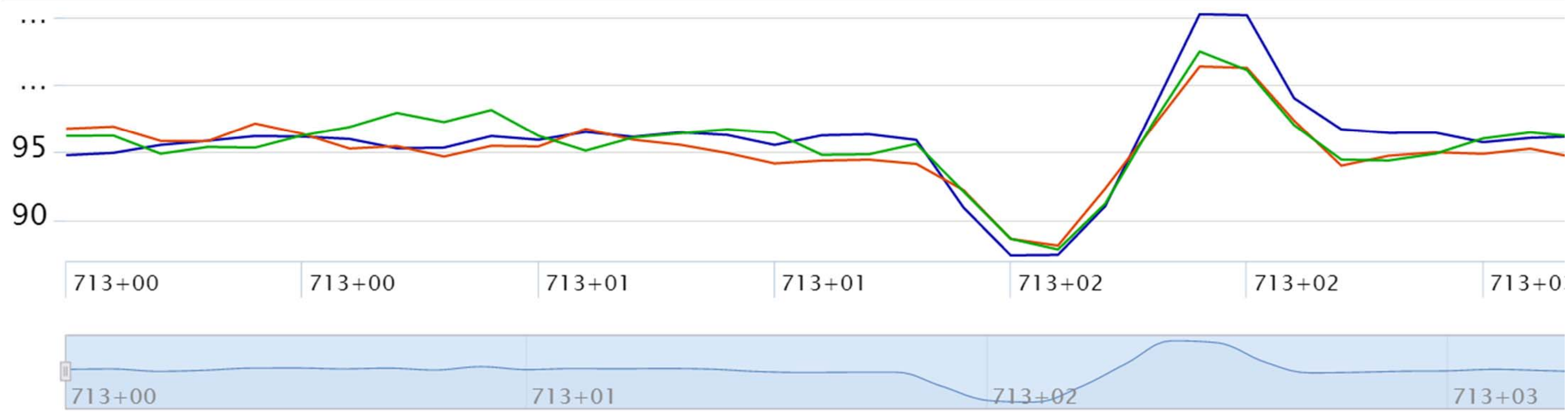


Core 70J (91.7%) – Resolution 0.25 ft



Core 87J (94.9%) – Resolution 0.10 ft





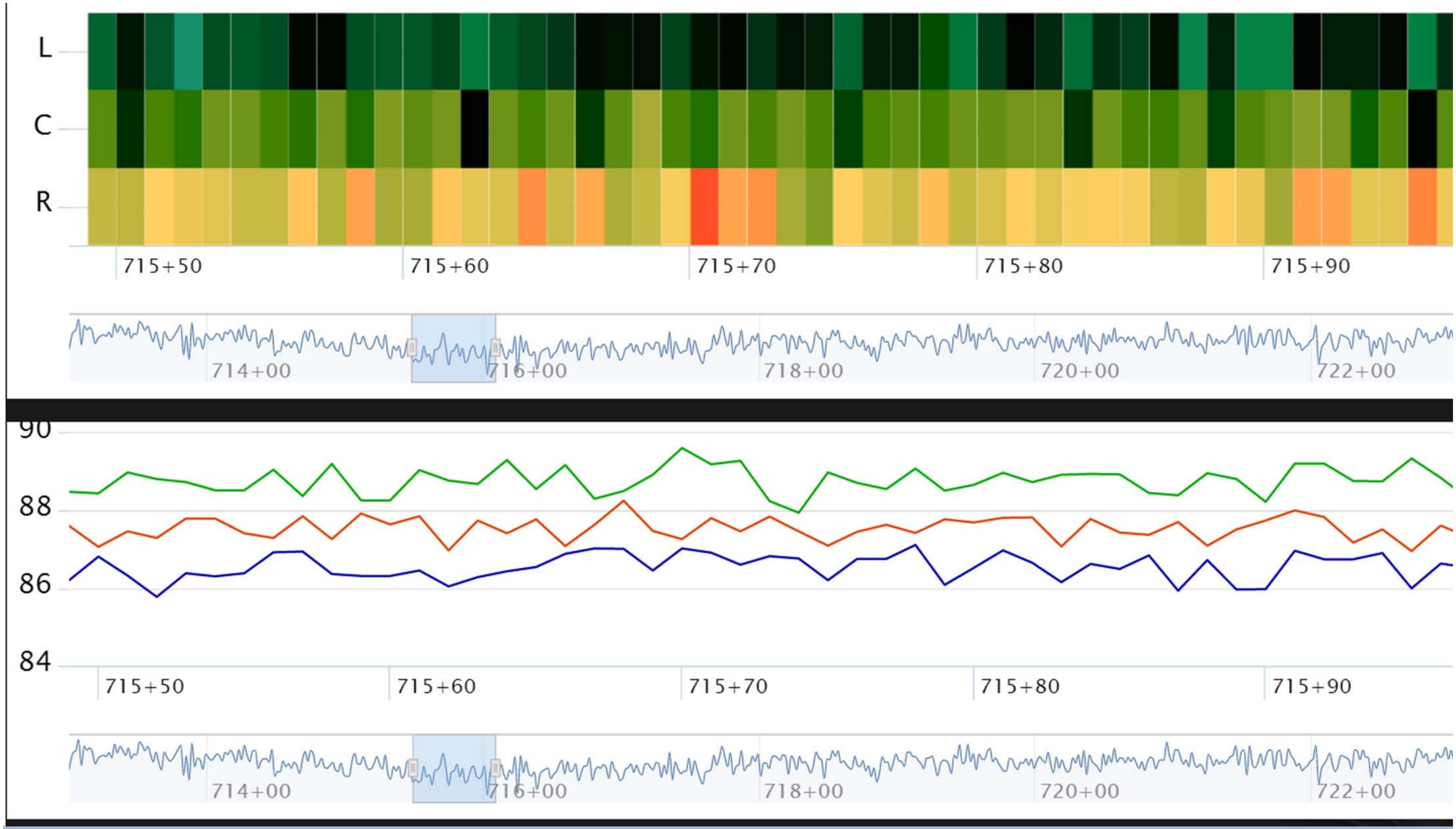
Core 87J – Distance Statistics

Sensor Position	Total Dist	Median	Average	Min	Max	Standard Dev
Center	4.2	95.2647	95.2054	88.1275	101.343	2.28774
Left	4.2	96.161	95.9437	87.4141	105.199	3.10059
Right	4.2	96.0255	95.6037	87.8418	102.452	2.49736

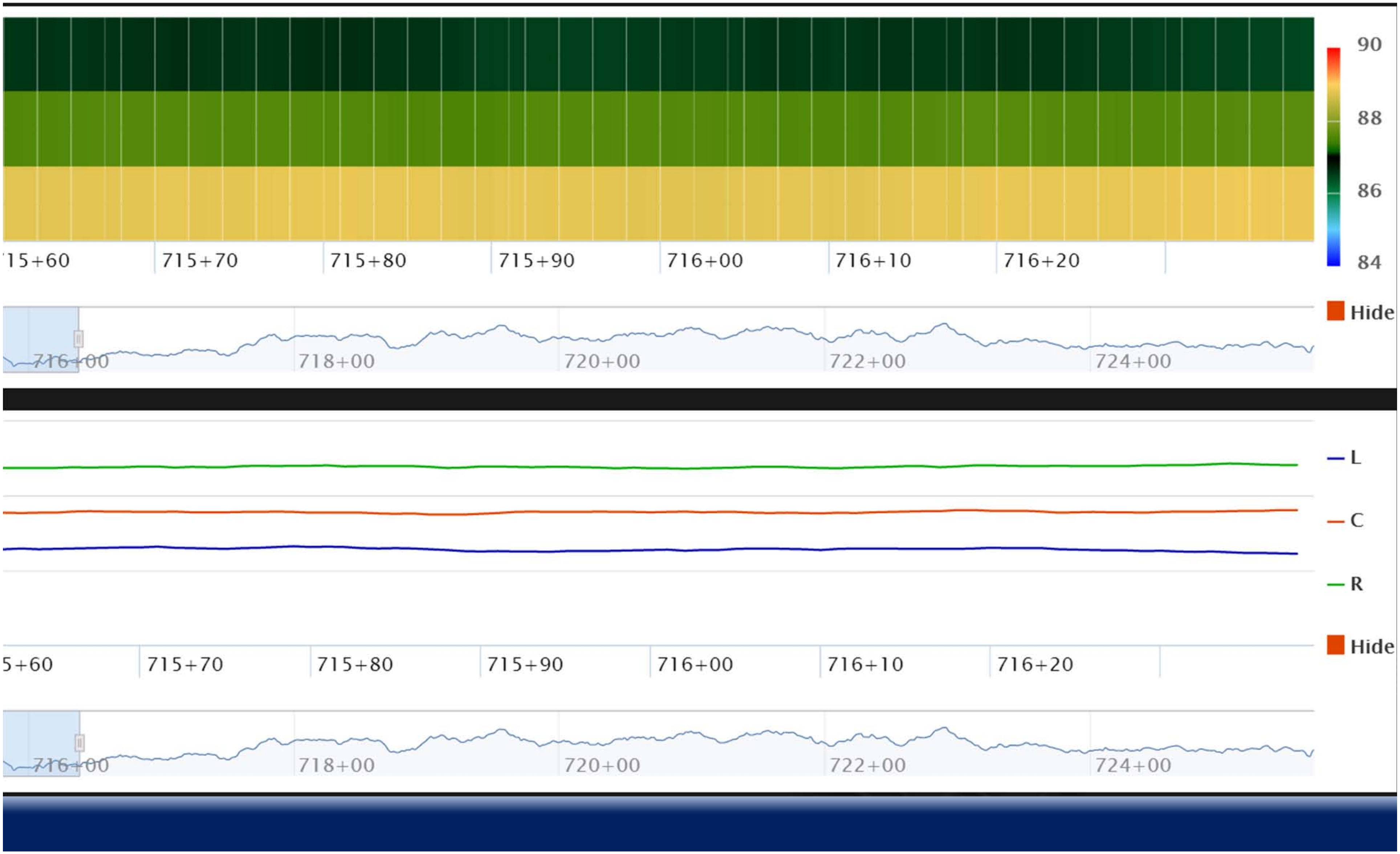
Core 87J – Time Statistics

Sensor Position	Total Dist	Median	Average	Min	Max	Standard Dev
Center	1269	87.8607	87.8692	86.8951	88.8963	0.306642
Left	1269	86.557	86.5422	84.4503	87.6718	0.34858
Right	1269	88.985	88.9778	87.8945	90.2777	0.352063

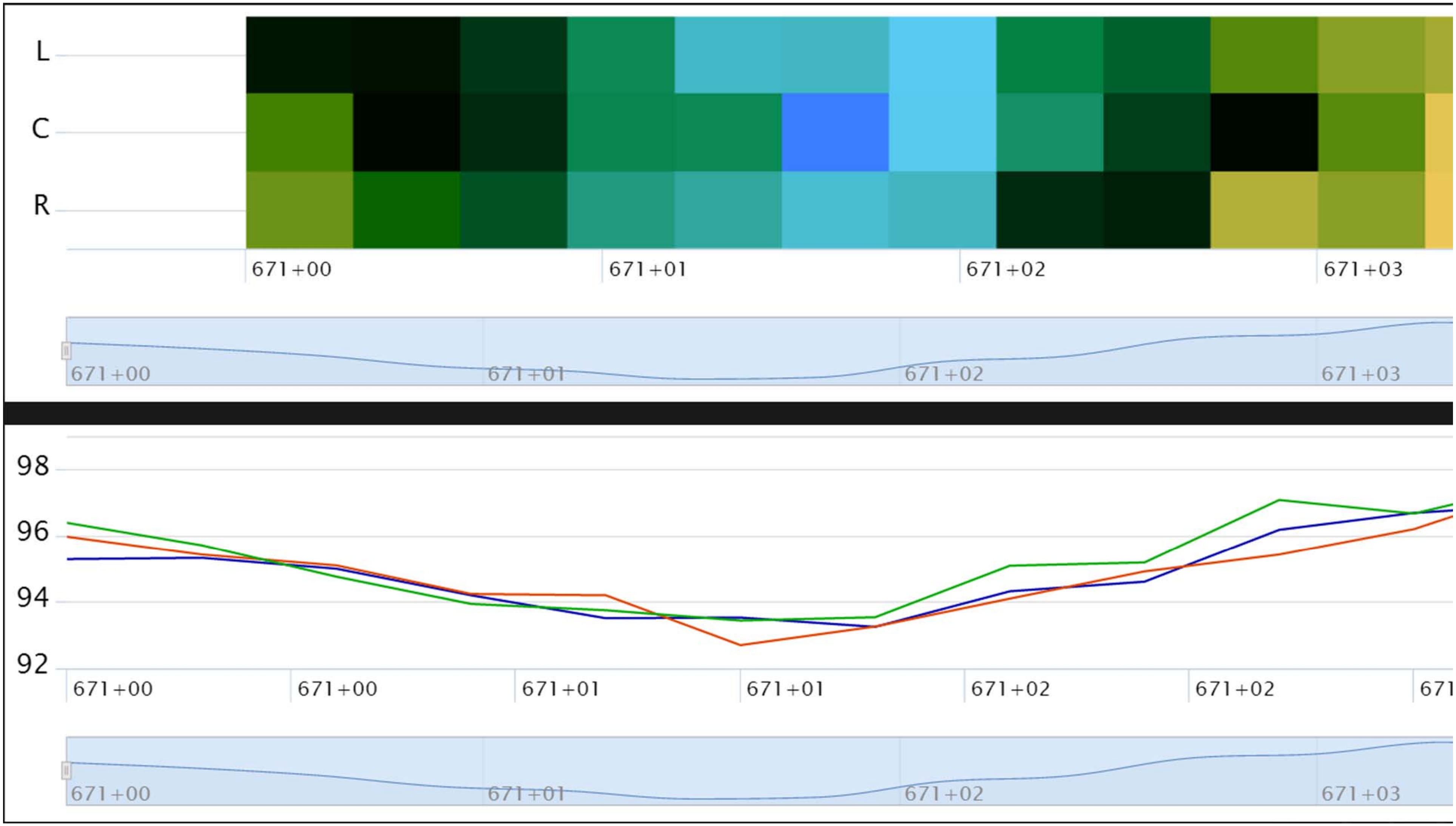
Core 87J – Time Graphic, 0.1 ft



Core 87J (94.9%) – Time, 3 ft Ave



Core 85J (92.4%) – Resolution 0.25 ft



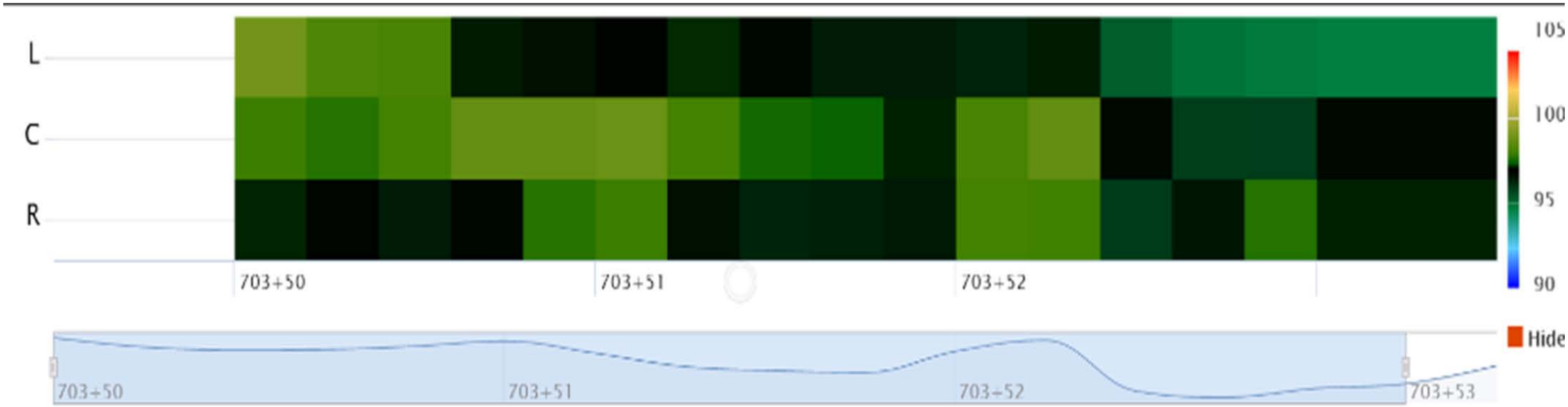
Core 85J – Distance Statistics

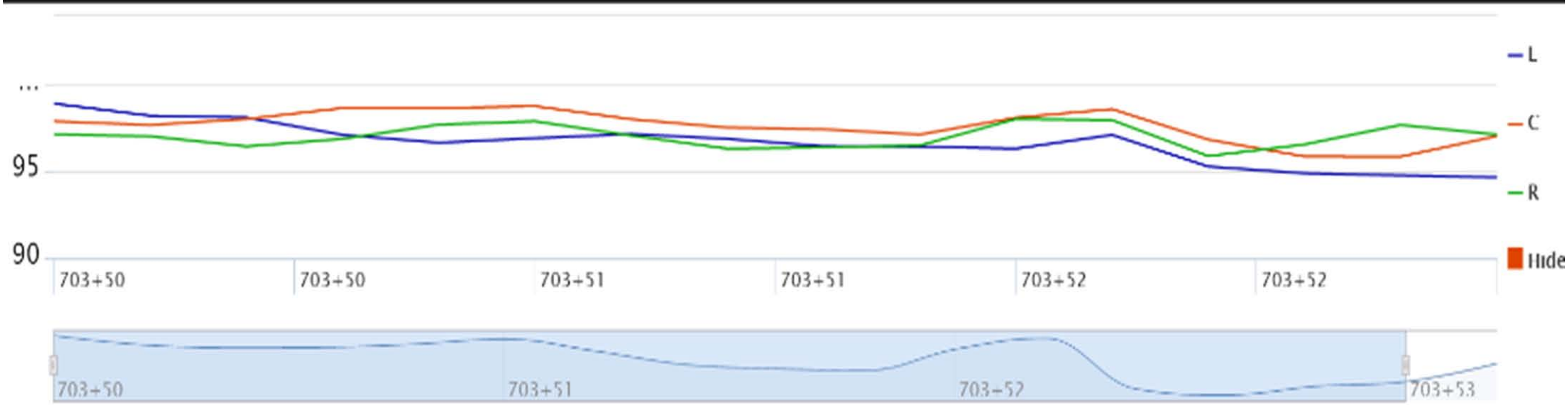
Sensor Position	Total Dist	Median	Average	Min	Max	Standard Dev
Center	4.3	95.2377	95.1644	92.0473	98.6728	1.44811
Left	4.3	95.1536	95.1277	92.6158	98.0502	1.31434
Right	4.3	95.7133	95.6349	93.0337	99.1354	1.63348

Core 85J – Time Statistics

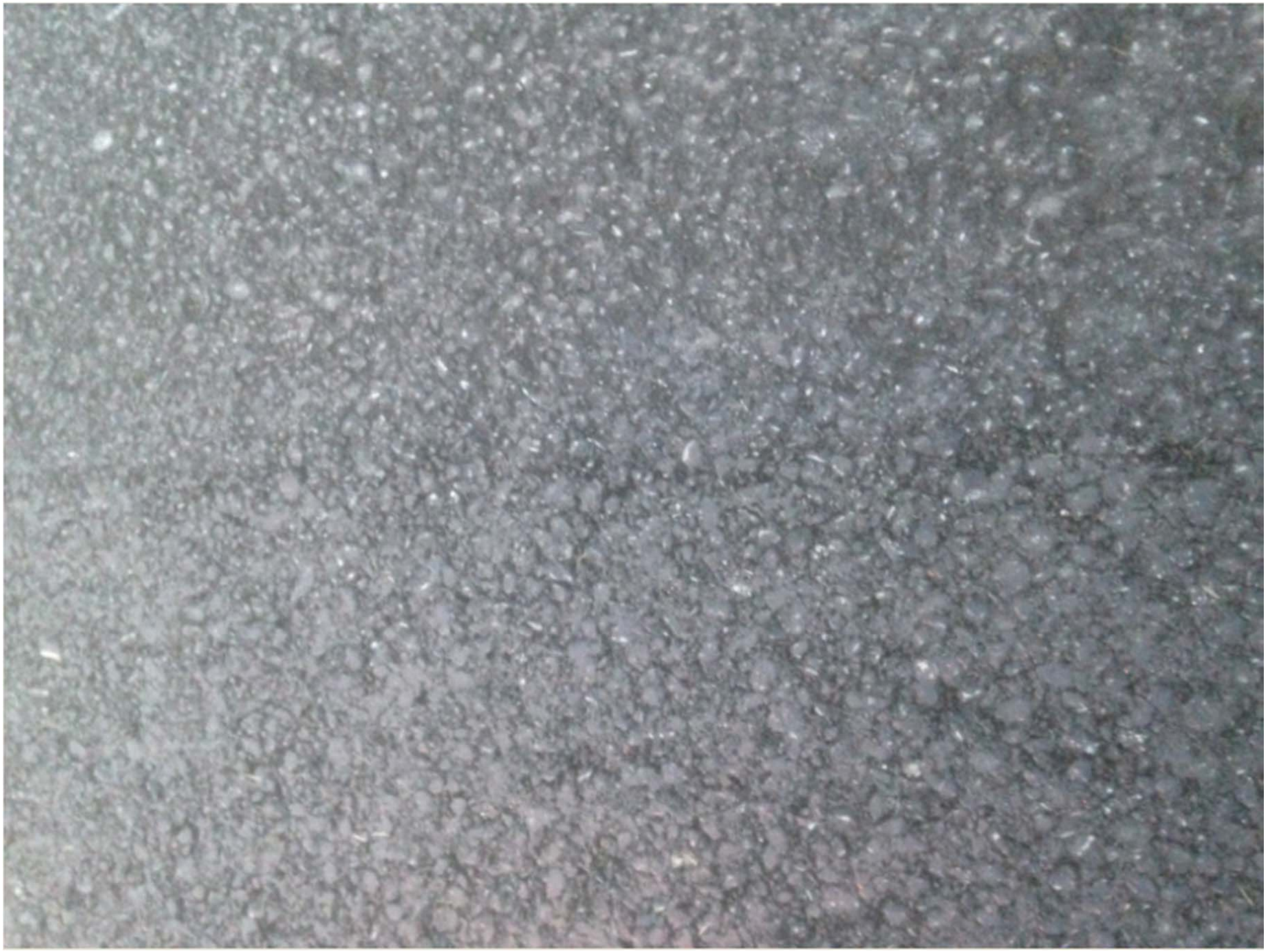
Sensor Position	Total Dist	Median	Average	Min	Max	Standard Dev
Center	1406	94.93	95.0007	93.6112	98.9016	0.496972
Left	1406	94.3386	94.3408	92.922	97.3542	0.426824
Right	1406	94.8968	94.874	92.179	96.719	0.47235

Calibration Core 19J (96.2%) 0.25 ft

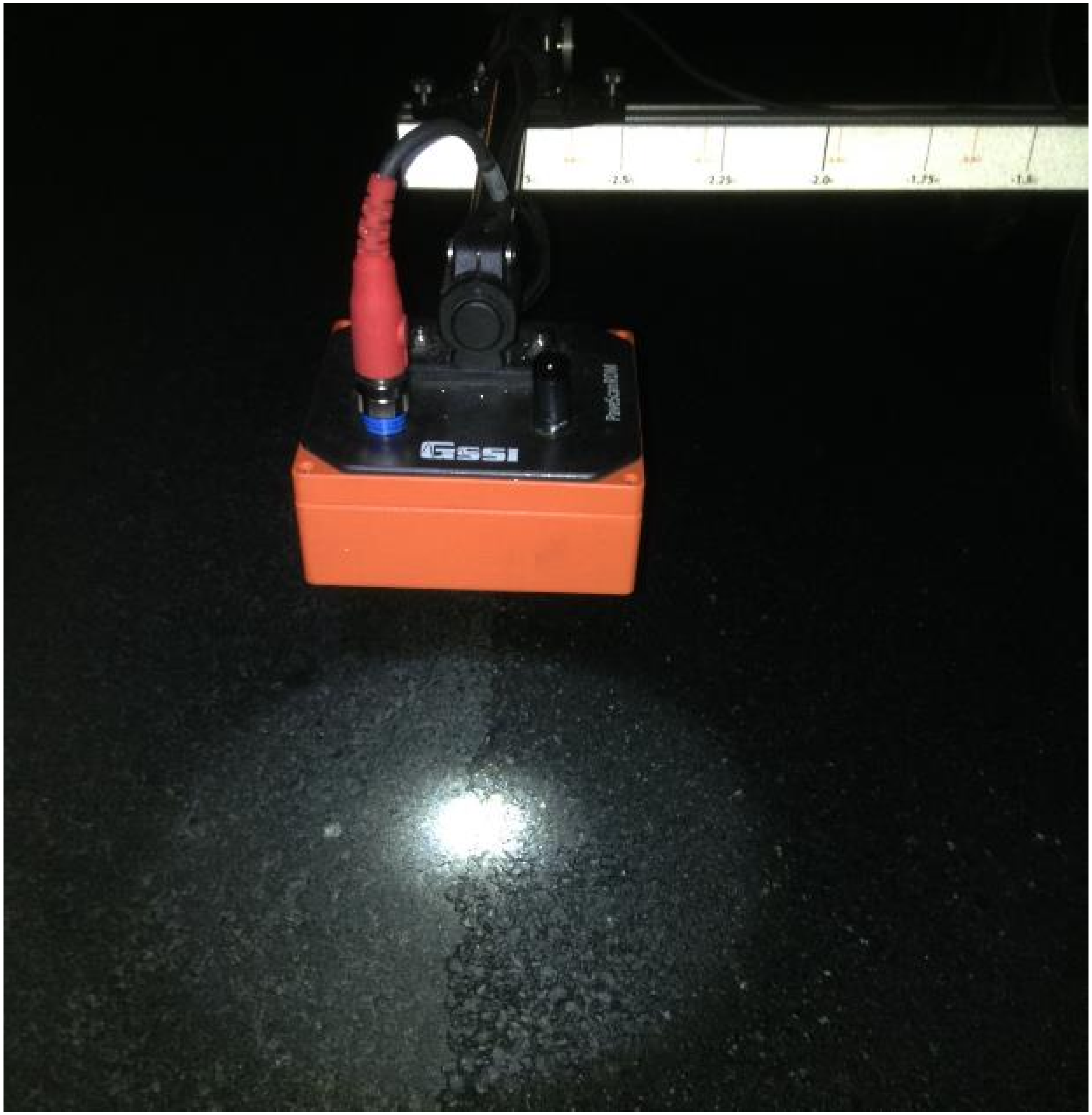




Longitudinal Joint at Core 19J



Keeping Antenna Centered on Joint



PaveScan RDM on Night Paving

Same Operator Repeatability?

How Repeatable is PaveScan RDM on Joint Centerline?			
200' Run		Same 200' of 9000' Run	
Station	File 032-R	Station	File 029-R
(SB Lane 2)	Dielectric	(SB Lane 2)	Dielectric
952+0.00	5.18	951+87.50	5.21
to	-	to	-
953+99.00	5.60	953+86.50	5.38
Ave Dielectric:	5.2950		5.2679
Ave Comp:	**96.2%**		**96.0%**
Note:			
Filtered out > 99.5% Compaction Values			

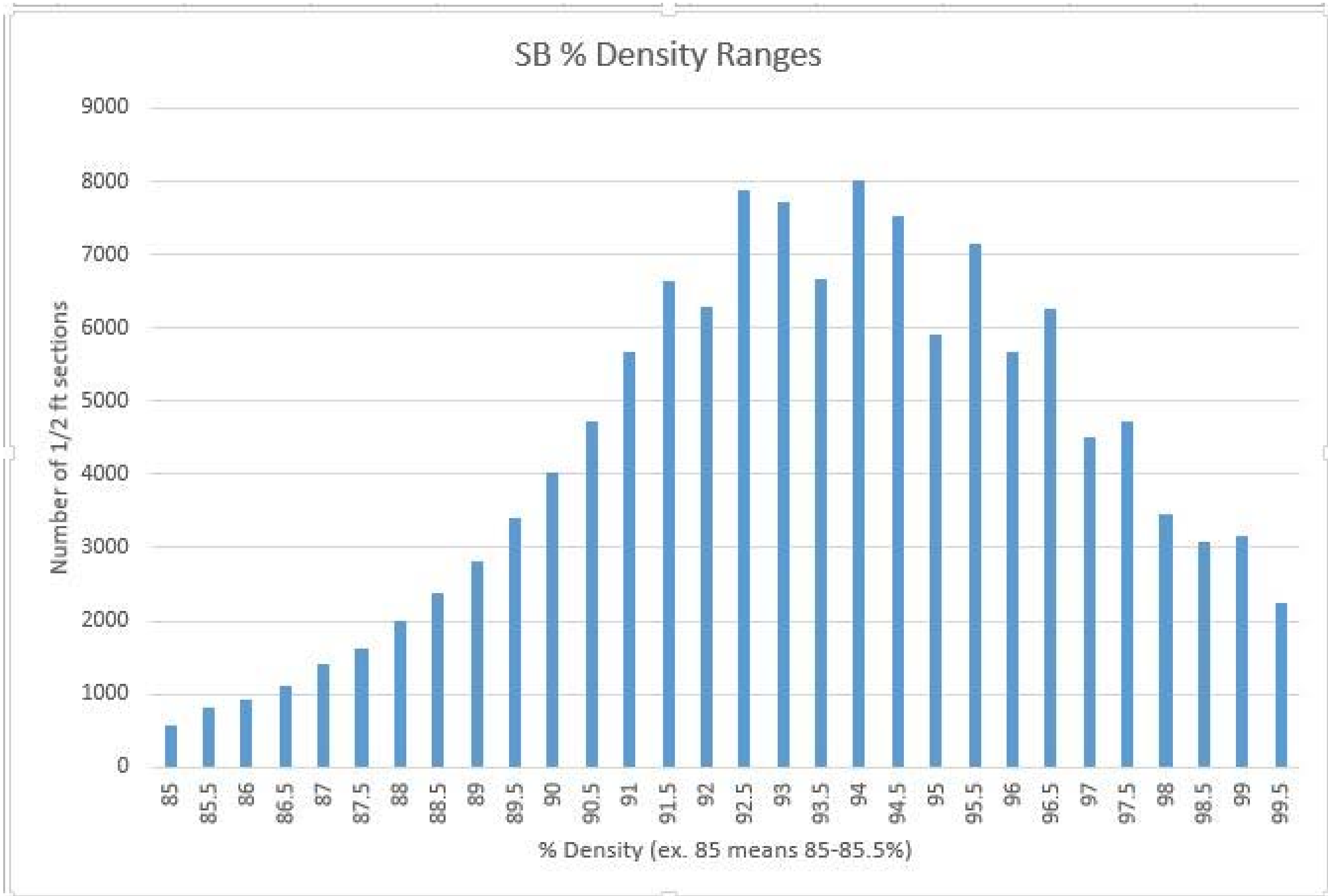
165 Core Densities: 90.9 to 97.8%

Compaction Summary - 2017 Data		
	% Compaction	
	Bulk/MSG	Bulk/MSG
	Panel	Joint
SB-L1 Average Panel Density (20 Cores)	94.8	
NB-L1 Average Panel Density (17 Cores)	95.4	
SB-L2 Average Panel and Joint Densities (33 Cores)	94.9	94.1
SB-L3 Average Panel and Joint Densities (3 Cores)	95.5	93.4
NB-L2 Average Panel and Joint Densities (28 Cores)	94.7	95.0
Project Averages	**94.9**	**94.5**
Max	97.6	97.8
Min	92.3	90.9
Note:		
50 of 101 (50%) of Panel Cores 95.0% or Higher		
26 of 64 (41%) of Joint Cores 95.0% or Higher		

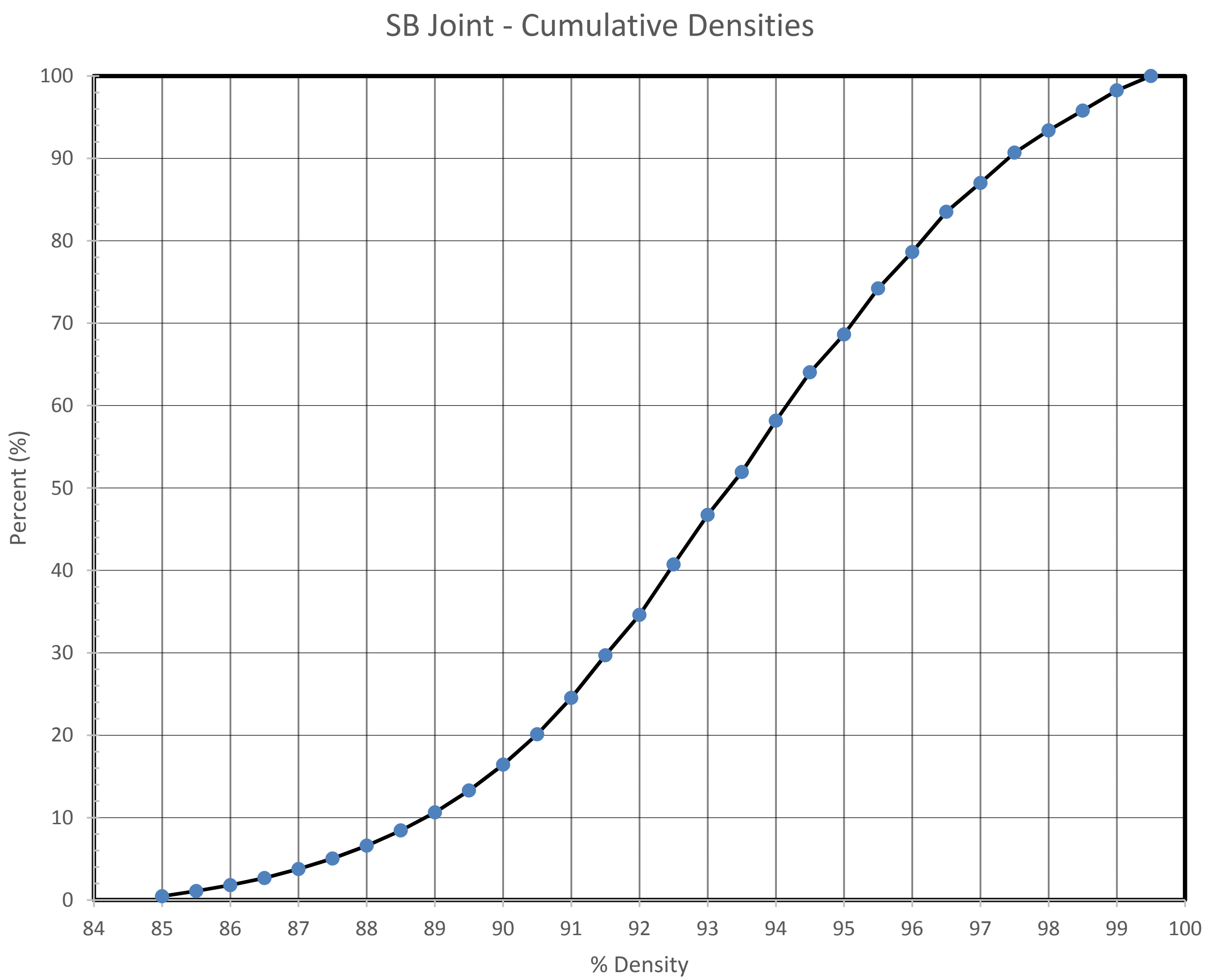
RDM vs Core - Joint Density Summary

South Bound Joint Density - Antenna on Joint Centerline			
Distance (ft)		% Compaction	
Station	DMI		Joint Ave
75,810 ft	75,686 ft	RDM Raw Data	94.0
14.36 miles			
RDM Filtered Data (85-100%)			**93.6**
36 SB Joint Cores =			**94.1**
North Bound Joint Density - Antenna on Hot Side of Joint			
53,860 ft	53,624 ft	RDM Raw Data	94.0
10.2 miles			
RDM Filtered Data (85-100%)			**94.2**
28 NB Joint Cores =			**95.0**

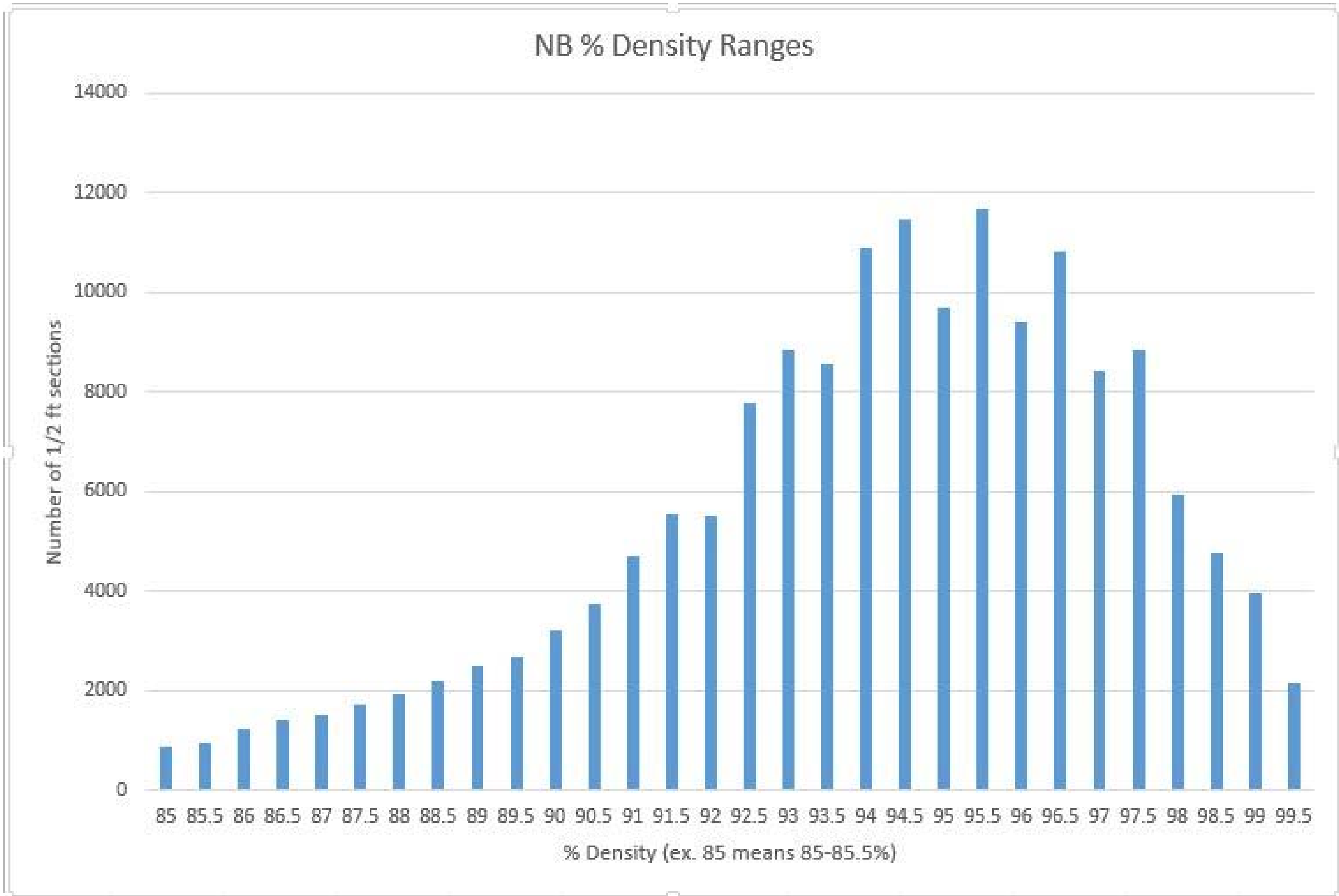
SB(Joint CL) Density Histogram



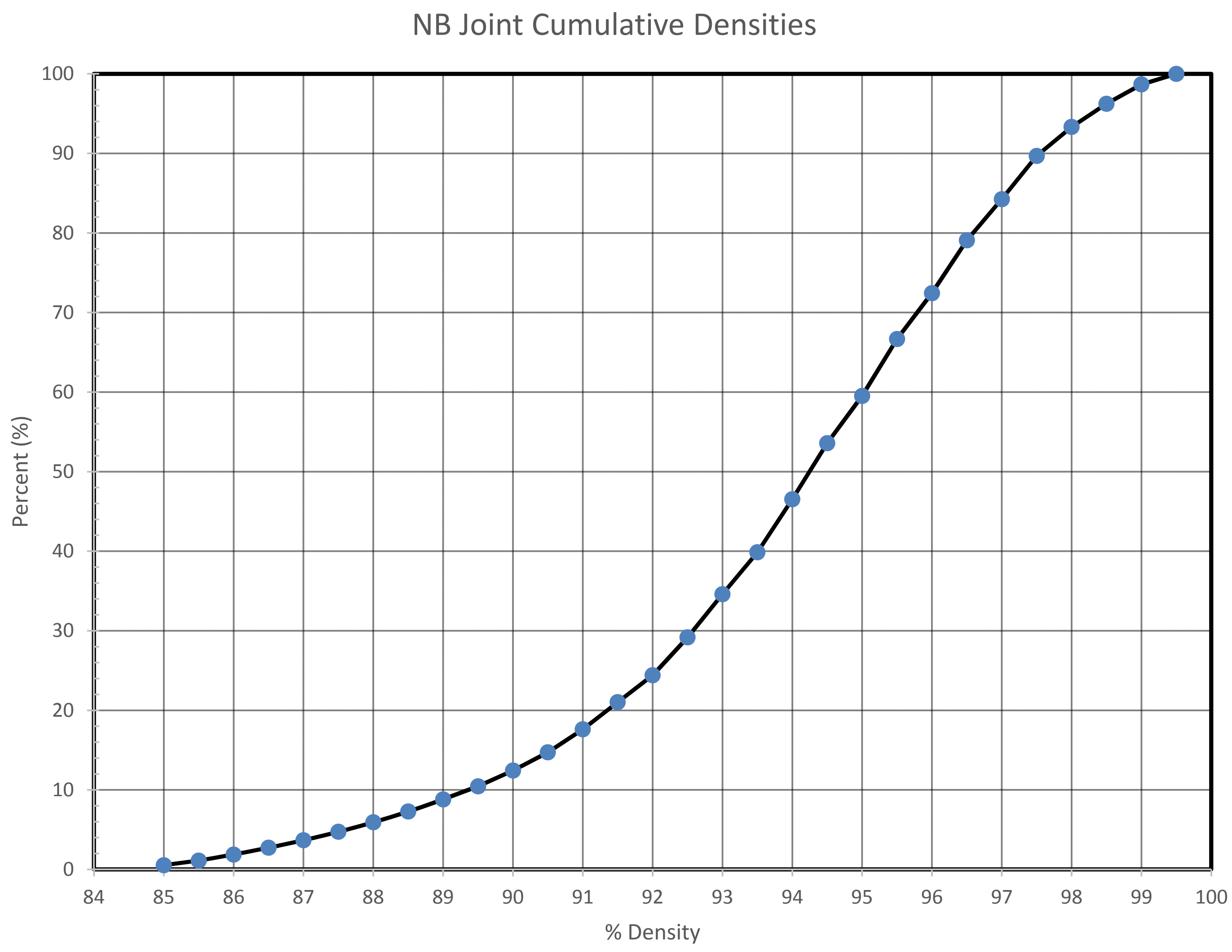
SB Joint 24.5% below 91% Density



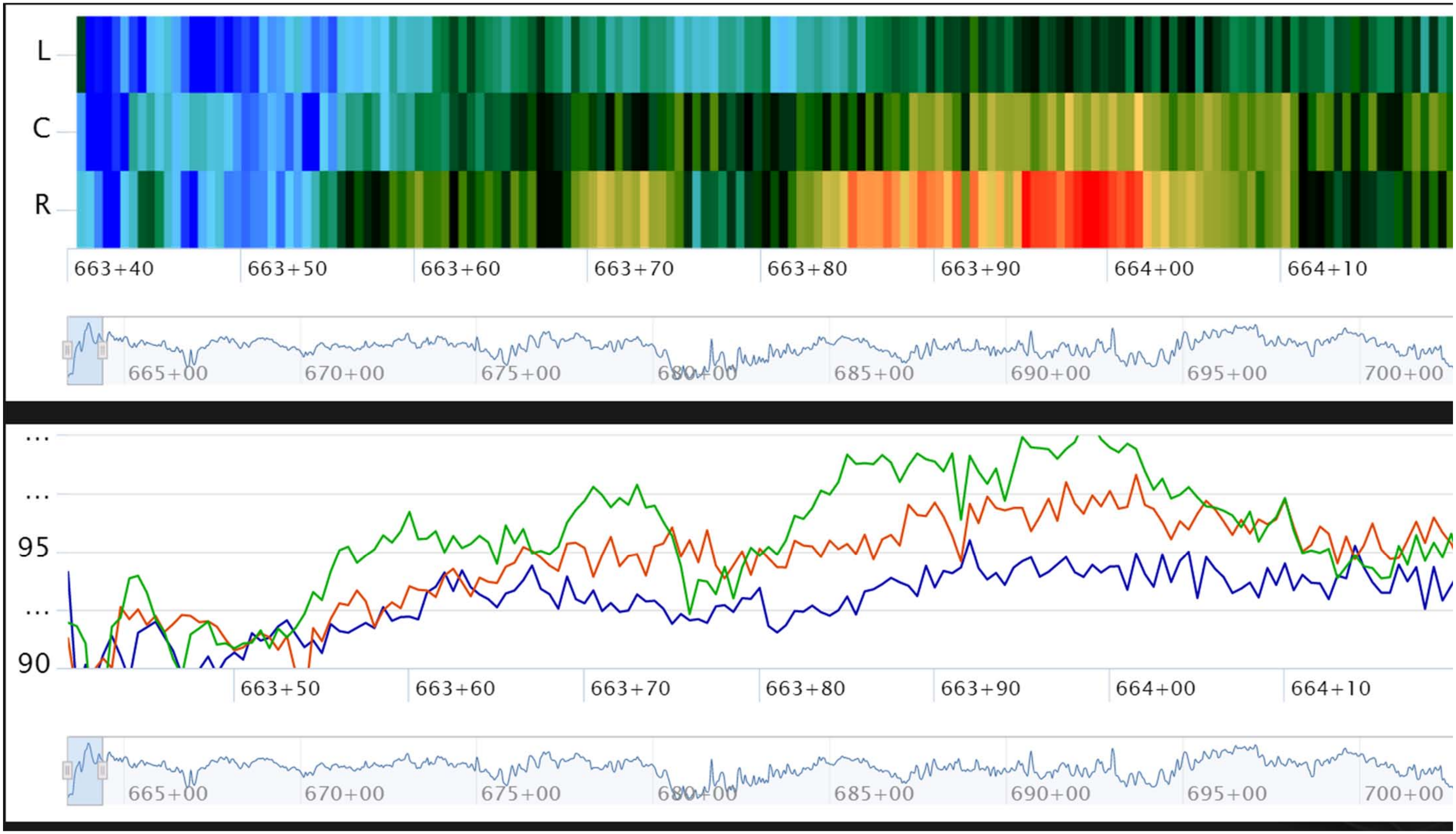
NB(Hot Side) Density Histogram



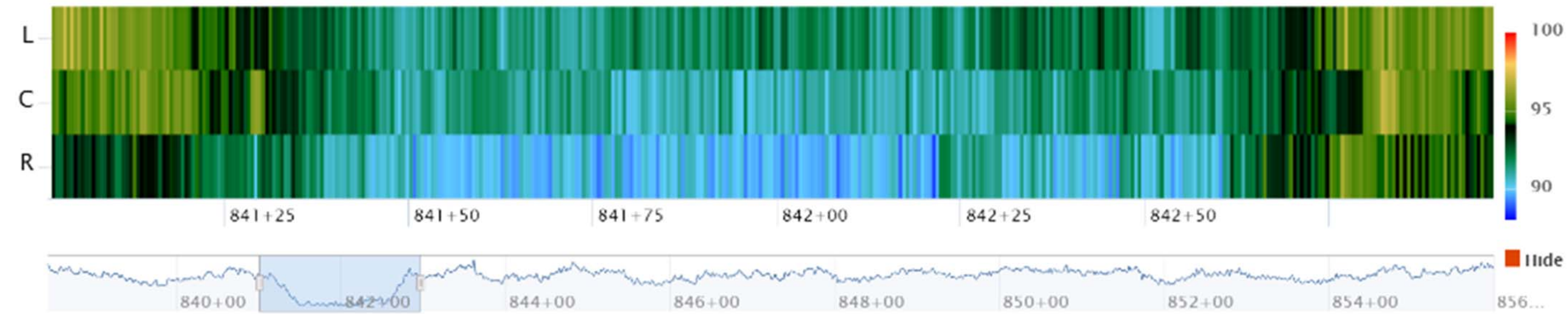
NB Joint 17.6% below 91% Density

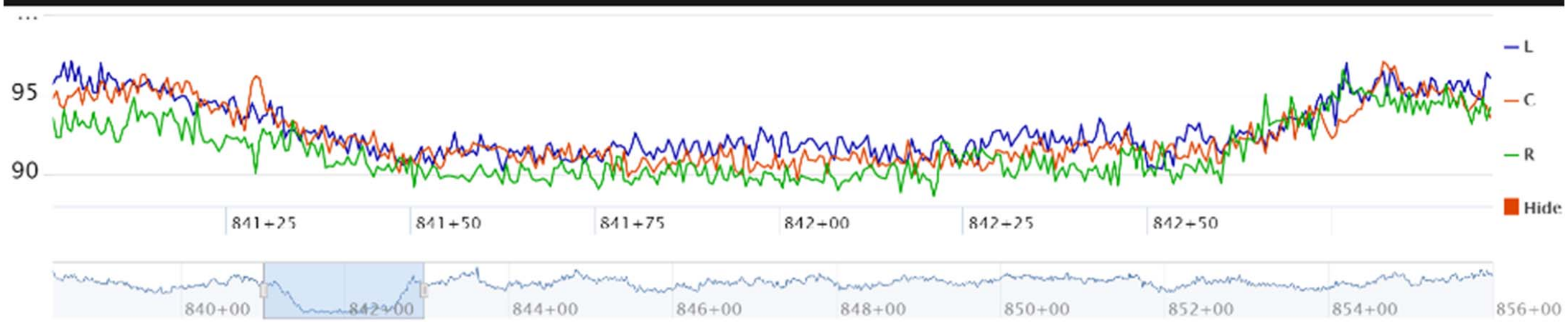


Start of Paving = Low Density

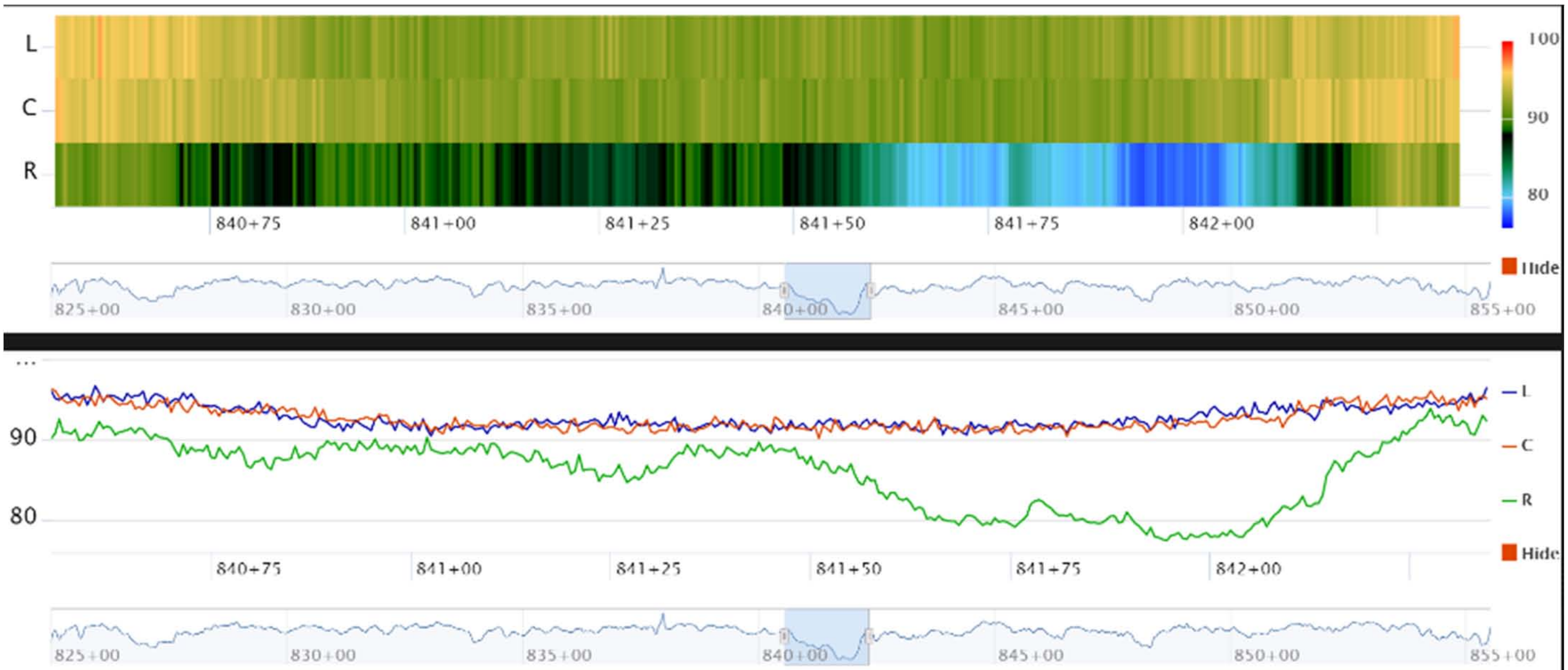


Low Density is Typical at Bridges
S. Birchwood Bridge,
SB Lane 2, 18-24' LT

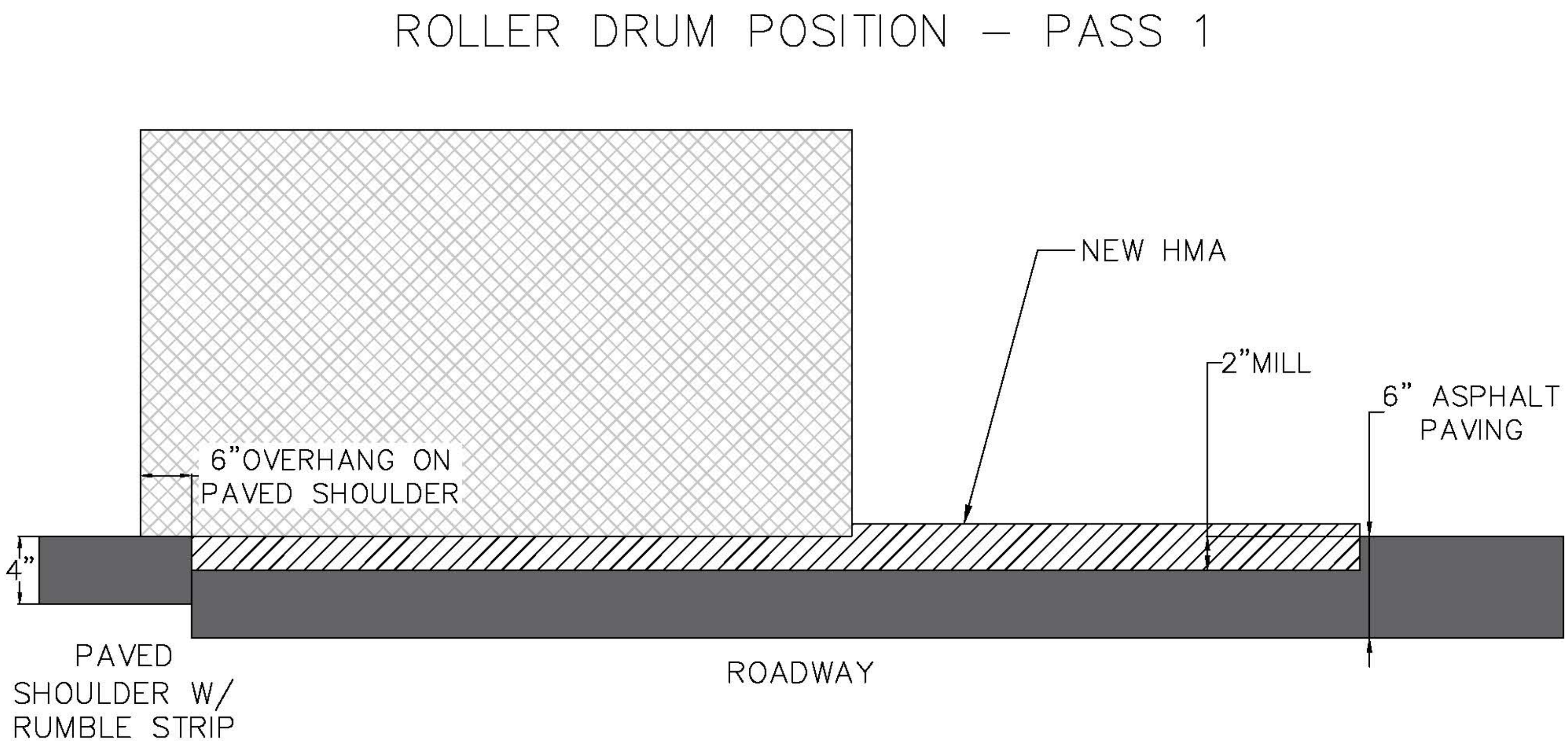




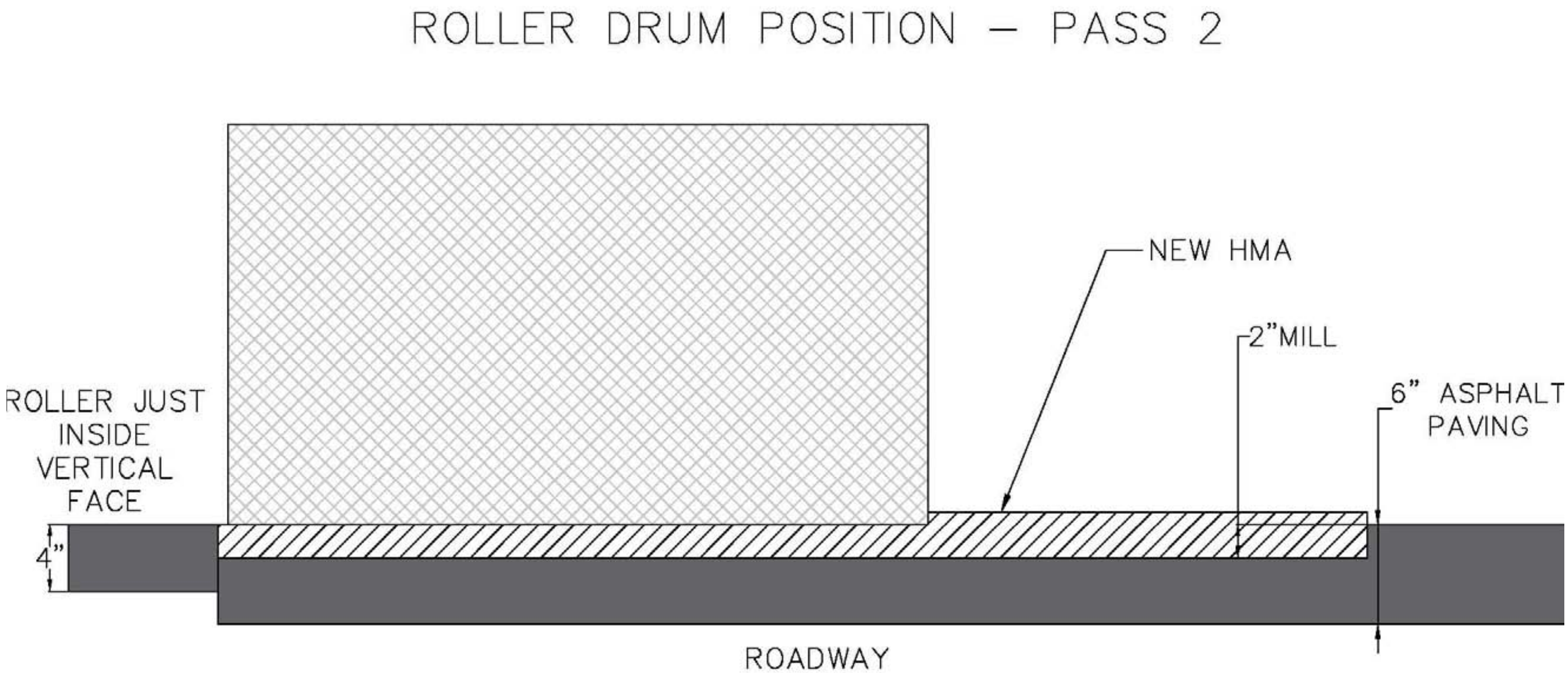
S. Birchwood Bridge, SB Lane 2, 12-18' LT



We don't want a "Pretty" edge joint



We Want a “Compacted” edge joint



Next Steps

- Increase joint bonus to \$2.00/ft but raise the bar to 96% compaction for the full bonus

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- Raise the minimum joint density to 92.0%

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- Raise the minimum joint density to 92.0%
- Have joint bonus increase linearly from minimum acceptable value to 96.0% in 0.1% increments.

Next Steps – Density Bonus

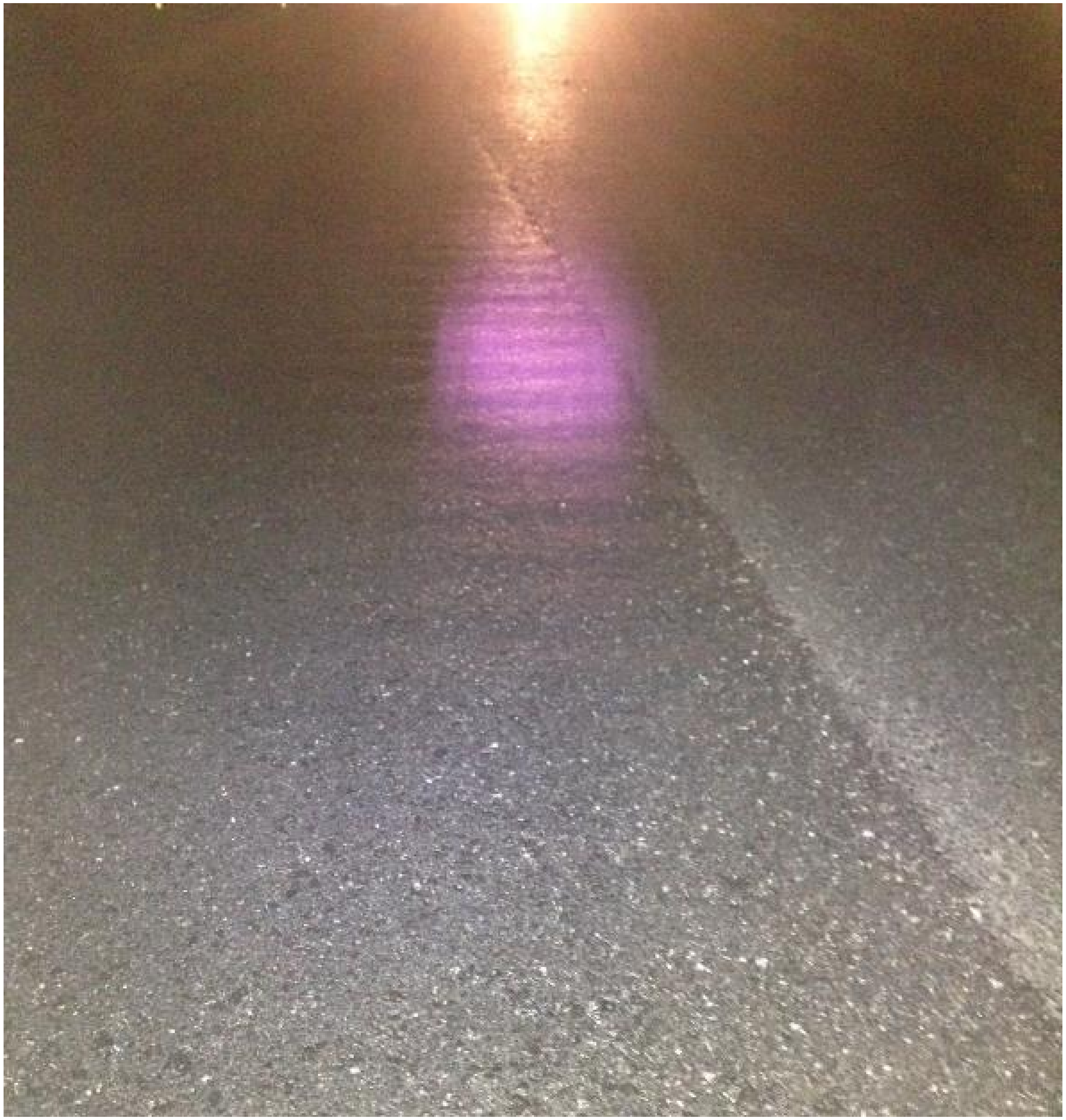
- Increase joint bonus to $2.00/ft but raise the bar to 96% compaction for the full bonus
- Raise the minimum joint density to 92.0%
- Have joint bonus increase linearly from 92.0% to 96.0% in 0.1% increments
- Have mat density bonus increase linearly from zero at 92% to 5% Bonus at 96%
- Require sealant application on all mat sections and joints below 92.0%, including Bridges

What equipment might one see when incentives are given for superior joint compaction?


16-8527
E650

Joint Heater Longitudinal Joints

What you don’t want to see



Questions?

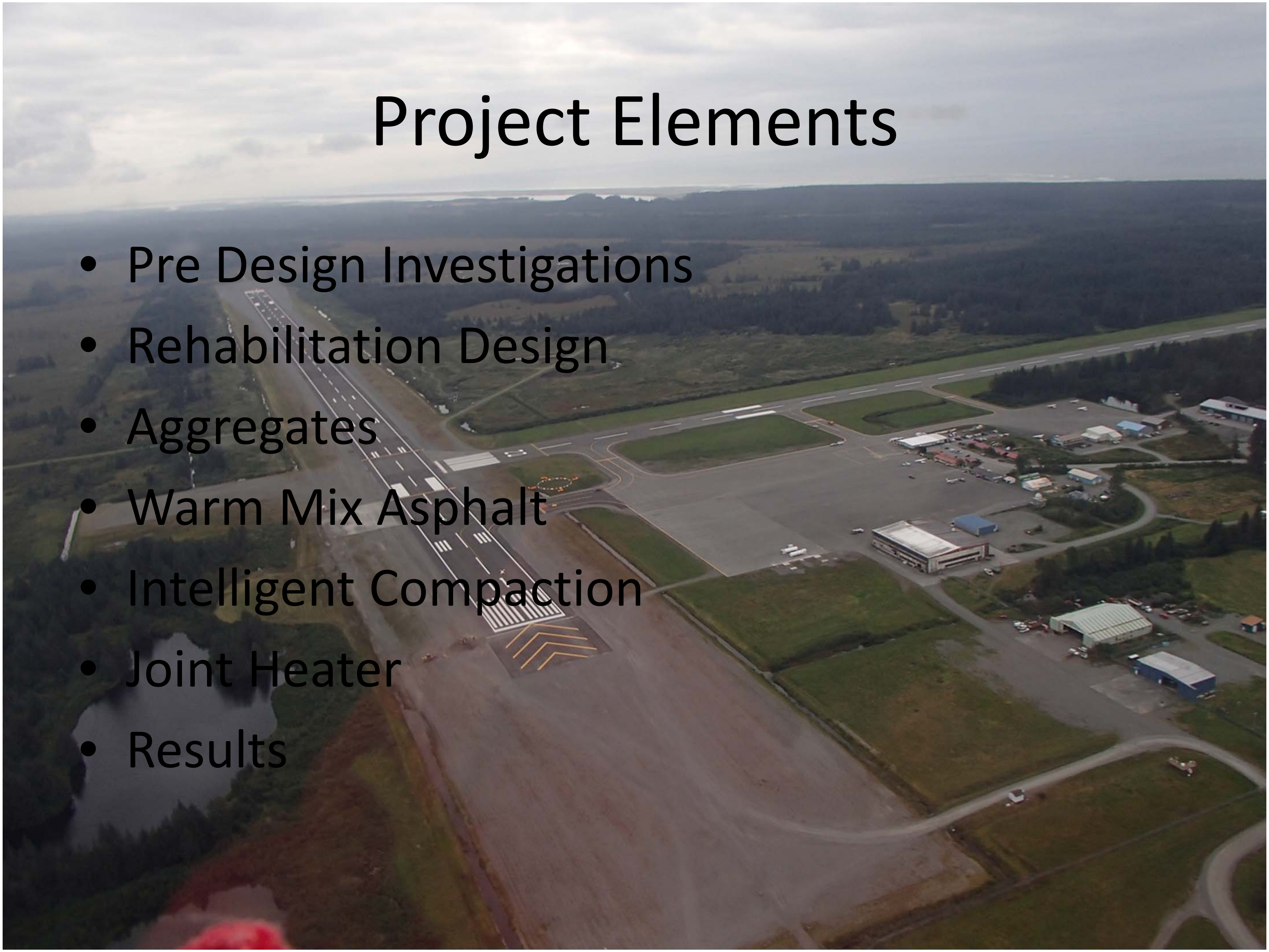
Yakutat, AK

Airport Runway 11/29 Rehabilitation

September 2015 through September 2016

Project Elements

- Pre Design Investigations
- Rehabilitation Design
- Aggregates
- Warm Mix Asphalt
- Intelligent Compaction
- Joint Heater
- Results



History

- Except for the last 2,125 feet, the pavement for runway 11/29 consists of three layers.
- World War II vintage: Portland cement concrete 6 inches thick, 150 feet wide.
- 1981: Nominal asphalt pavement thickness 3.5 inches.
- 2004: Nominal asphalt pavement thickness 3-inches. 3-foot width of a non-woven geotextile (Amoco Petromat) placed over the existing joints to isolate joint sealing efforts.
- This project: Nominal asphalt concrete pavement thickness 6-inches at.

Airport Layout

Main Runway 11/29 @ Crosswind 2/20

Pre-rehabilitation Conditions

“Bird Baths” & Cold Weather Weeping of Longitudinal Joints


"Bird Baths" Runway 11/29

Heave Cracking Runway 11/29

Pre-rehabilitation Conditions

Ice Lens Beneath Last Overlay

ALASKA DEPARTMENT OF TRANSPORTATION & PUBLIC FACILITIES

Hydrologic Monitoring & Evaluation
Yakutat Airport, Alaska

Prepared by:

SE Region Materials Section

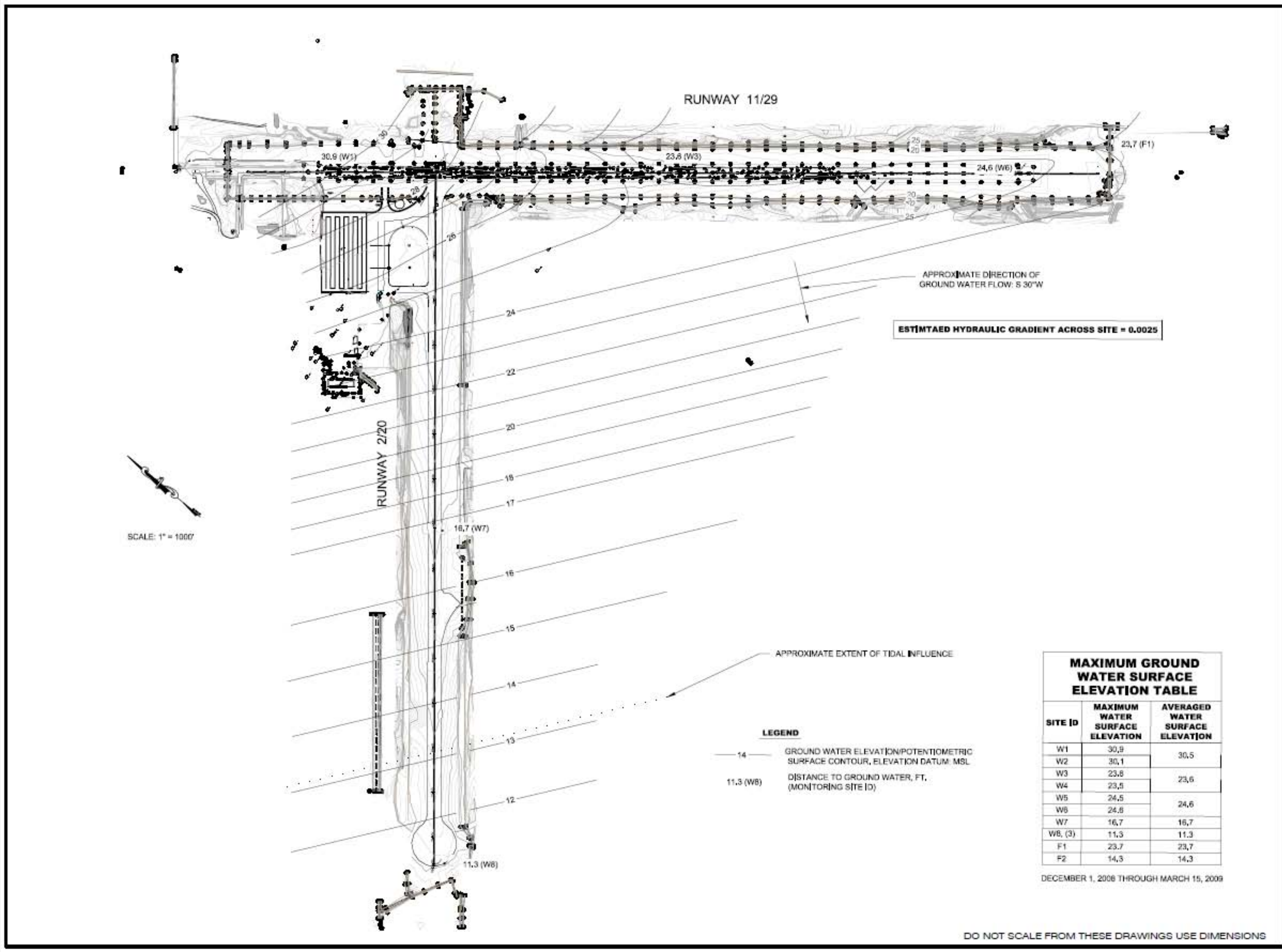
April 2010

Abstract: The Alaska Department of Transportation & Public Facilities assessed hydrologic conditions at the Yakutat Airport. These conditions, in conjunction with freezing weather, has compromised the integrity of the runway pavement. Surface ice forms predominantly along joint-lines due to shallow ground water conditions that exist throughout the site. Ice lenses form at the pavement interfaces by capillary action, causing localized heave. Ground water surface elevations were determined to be within the calculated active freeze-thaw zone at all monitoring locations. The lack of subsurface drainage and capillary breaks beneath the runway structure causes differential heave of the runway sub-grade and finished surface. The installation of dewatering mechanisms, such as French drains and dewatering wells, are not anticipated to significantly reduce ground water elevations across the site. Similarly, ditch improvements that include widening and deepening have limited impacts on reducing the water table beneath the runways. Installation of a capillary break above the water table, the removal of frost susceptible soils and the addition of non-frost susceptible fill materials is recommended to provide adequate separation between the ground water and pavement surfaces.

Groundwater & Surface Water Monitoring

- Insitu LevelTroll 300
  1. Non-Vented Transducers
  2. Data Recorded: Temperature and Water level
  3. Monitoring Interval 15 minutes
  4. Collection Interval: November 4, 2008 through April 22, 2010
  5. Eight (8) Wells and Two (2) Surface Water Monitoring Stations

Hydrological Monitoring Network



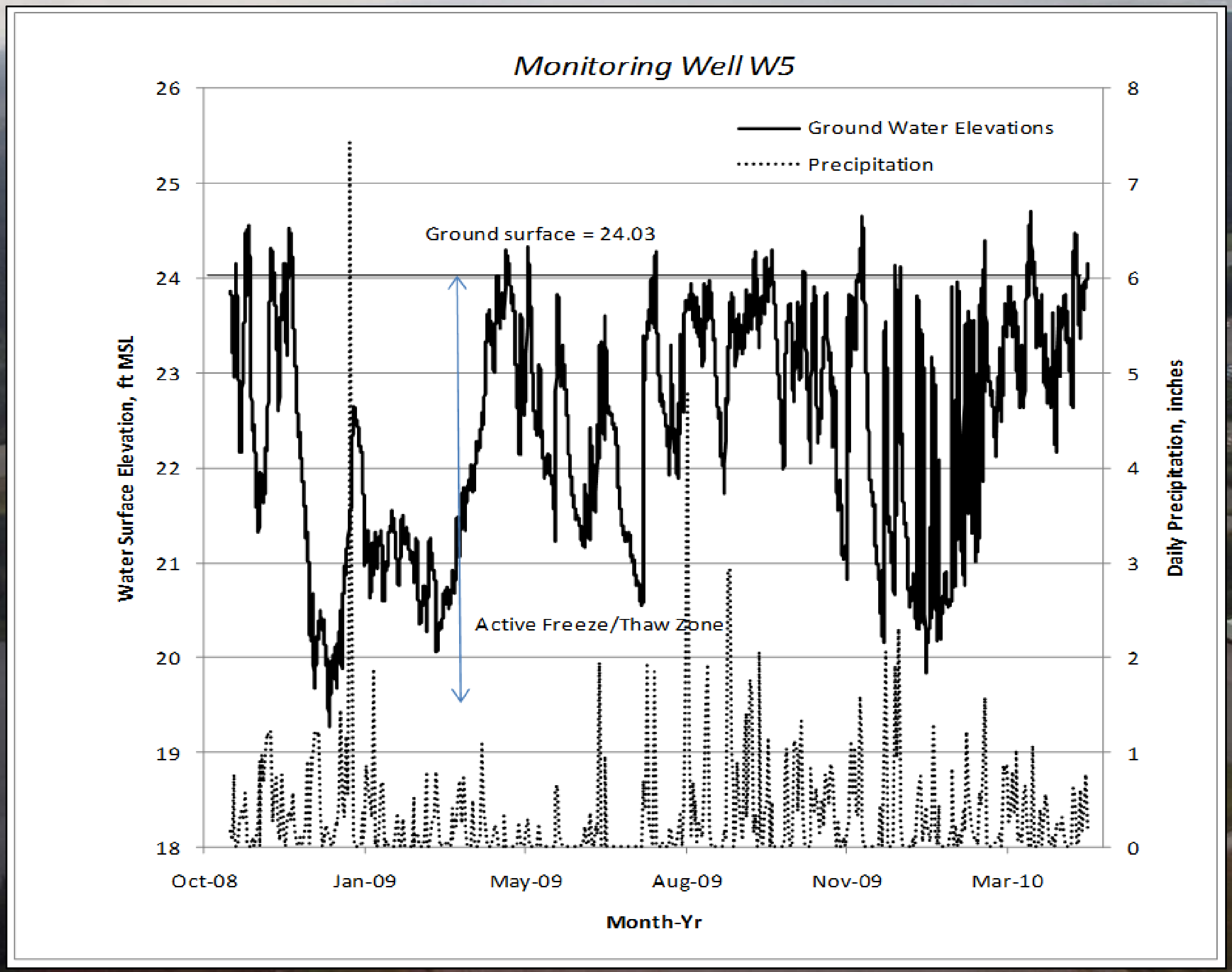
MAXIMUM GROUND WATER SURFACE ELEVATION TABLE

SITE ID	MAXIMUM WATER SURFACE ELEVATION	AVERAGED WATER SURFACE ELEVATION
W1	30,9	30.5
W2	30,1	
W3	23,8	23,6
W4	23,5	
W5	24,5	24,6
W6	24.6	
W7	16,7	16,7
W8, (3)	11,3	11.3
F1	23.7	23,7
F2	14,3	14,3

DECEMBER 1, 2008 THROUGH MARCH 15, 2009

Logging Equipment

Plotted Data-Well 5



Tidal Influence

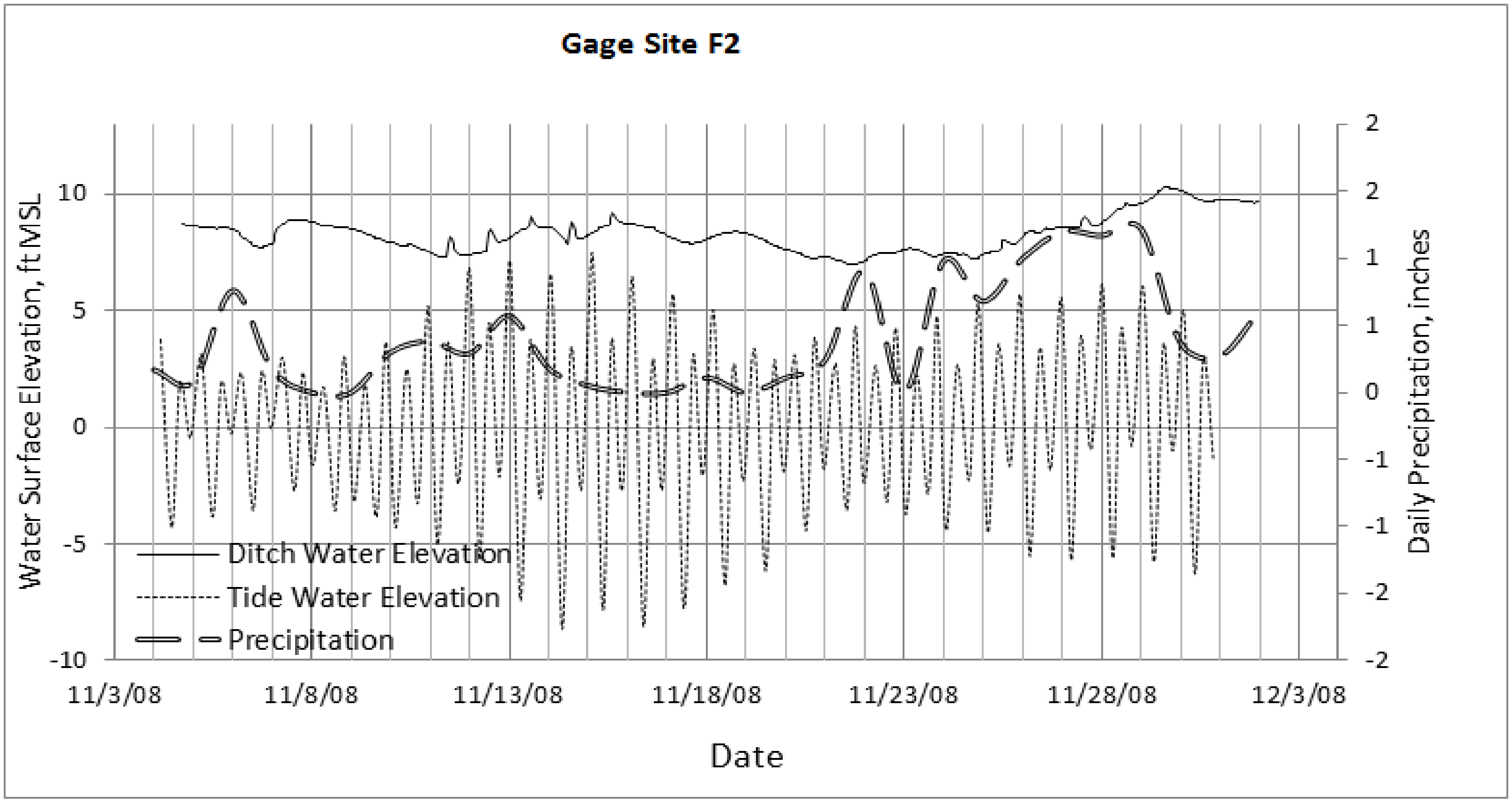
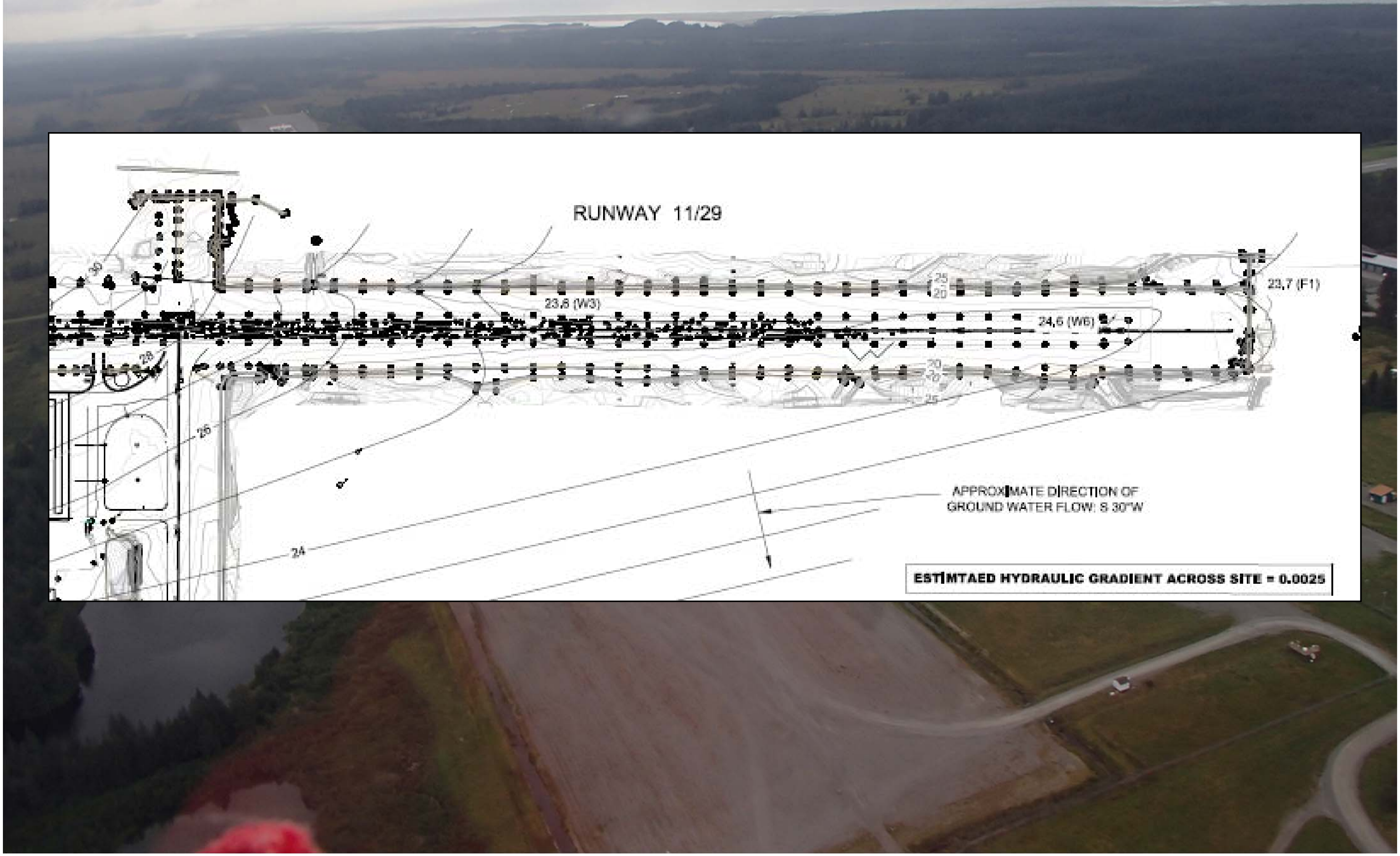
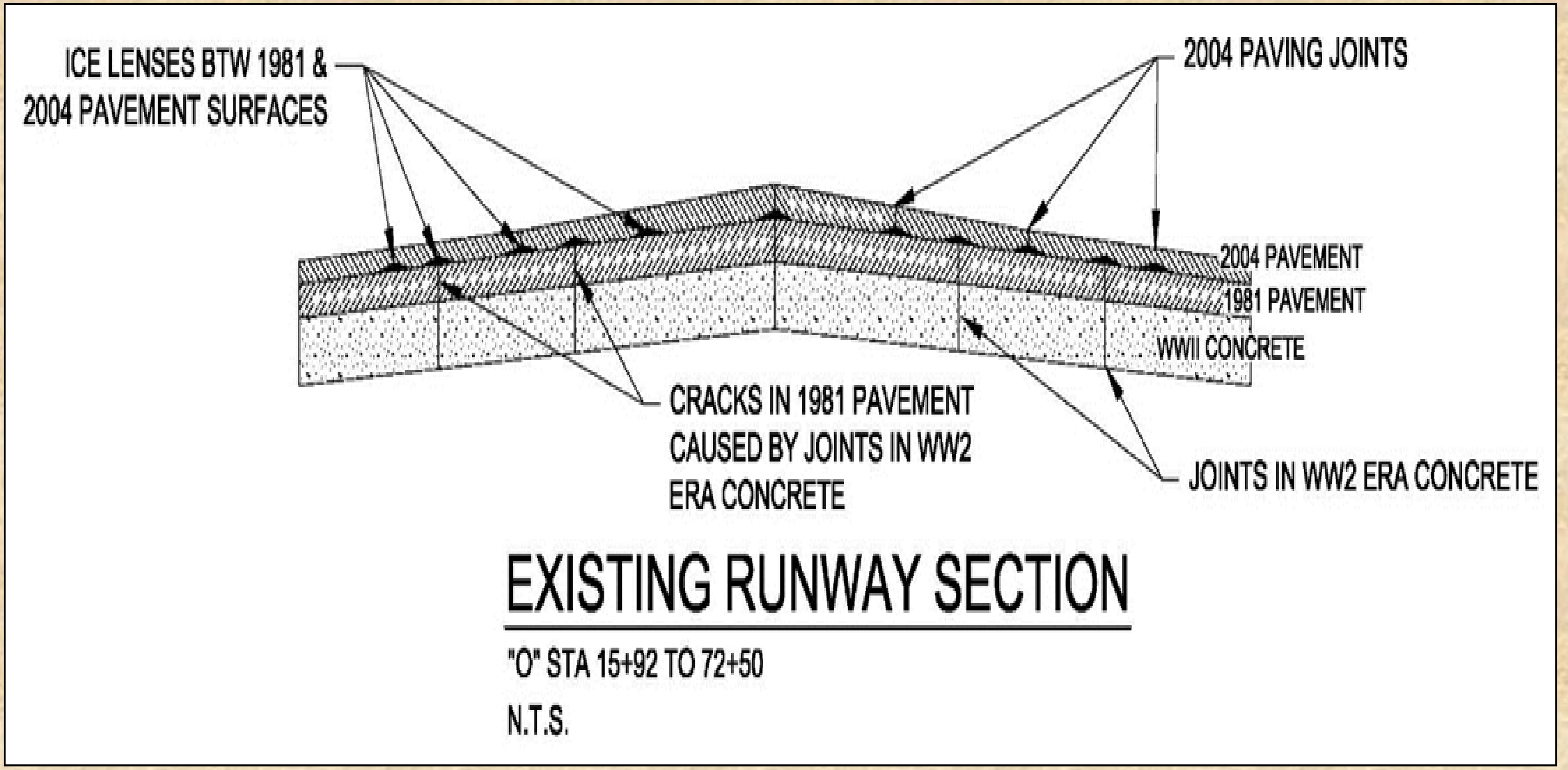


Figure 5. *Plot of water surface, daily precipitation and tide elevation, Monitoring Site F2.*

Groundwater Surface Elevation



Ice Lenses Between Pavement



Dewatering Options

- Deepen existing network of ditches to enhance surface water flow.
- Pump water adjacent to Runways into ditches & streams.
- Expand exiting ditch network.

Engineering Conclusions & Recommendations

- A shallow water table persists at the airport site throughout the year, and resides within the active freeze/thaw layer beneath the entire length of both runways.
- The existence of frost-susceptible materials beneath runway pavement structures encourages capillary action, resulting in localized heaving of the pavement surface.

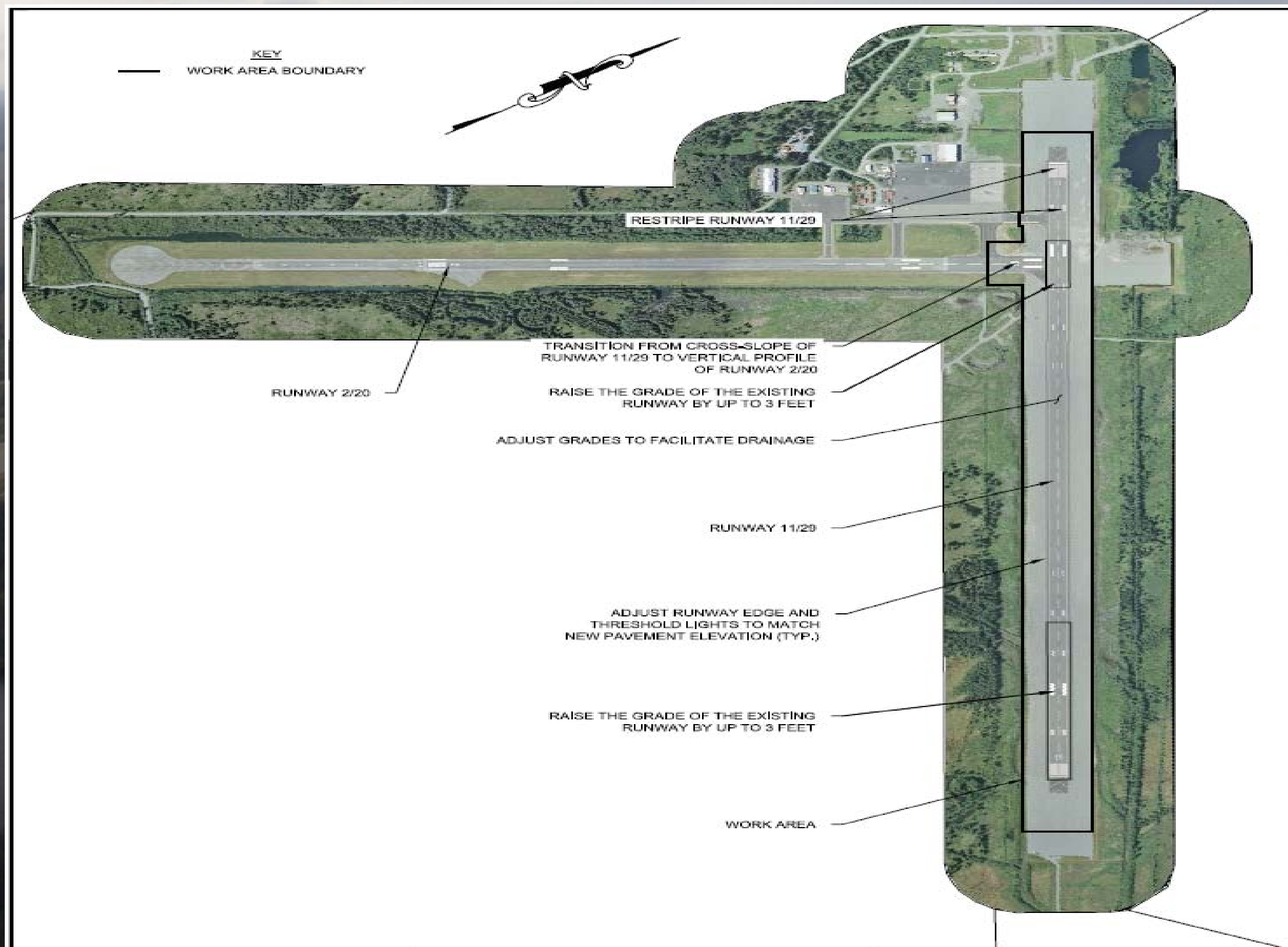
All of the following contribute to the poor pavement condition at the Yakutat Airport:

- High Ground Water
- Restrictions associated with Surface Water Conveyance
- Capillary Action
- Active Freeze/Thaw Depth within Pavement Structure
- Tidal Influence Restricts Drainage Potential
- Winter Maintenance Alters Pavement Surface

Project Elements

- Cold-plane ½ inch runway 11/29 and repave with 6-inches of hot mix asphalt pavement in two lifts.
- Raise the threshold at the 29 end by 2.5-feet with transition beginning 2,000 feet from the threshold.
- Adjust grade of runway 11/29 in vicinity of the intersection with runway 2/20 to facilitate drainage.
- Remove full depth the paving joint from previous overlay project.
- Re-groove and re-stripe runway 11/29.
- Relocate NAVAIDS and lighting as necessary.

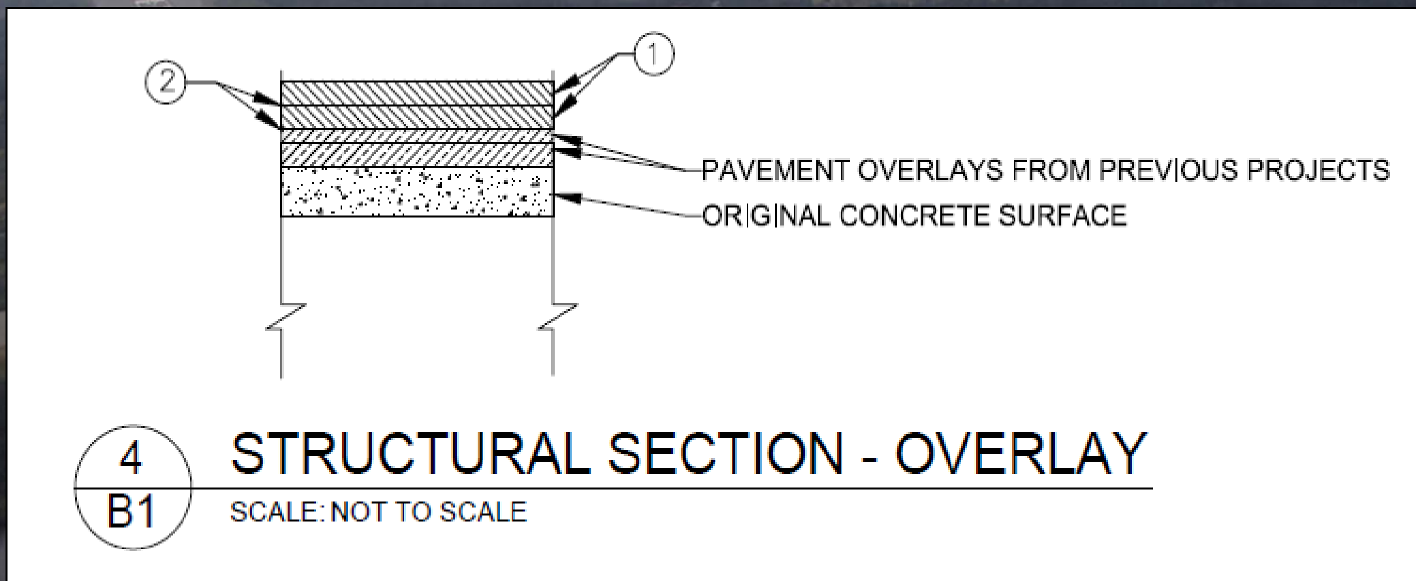
Construction Sequencing



Quantities

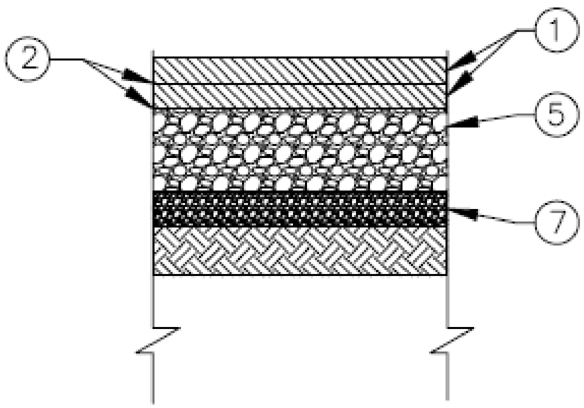
- Crushed Aggregate Base Course: 83,000 tons
- HMA Type II Class E: 62,900 tons
- Asphalt Cement PG 64-28: 3,800 tons

Typical Section-Overlay



1. 6" HOT MIX ASPHALT, TYPE II; CLASS E, IN 2 LIFTS
2. TACK COAT

Typical Section-Grade Raise



4
B2

STRUCTURAL SECTION - RAISE RUNWAY

SCALE: NOT TO SCALE

(1) 6" HOT MIX ASPHALT, TYPE II; CLASS E, IN 2 LIFTS

(2) TACK COAT

(5) CRUSHED AGGREGATE BASE COURSE

(6) 3" HOT MIX ASPHALT, TYPE II, CLASS E

(7) EXISTING 4" PAVEMENT COLD PLANED AND RECYCLED IN PLACE AND COMPACTED

EXISTING SUBGRADE

HMA

- Aggregates
- Mix Design
- Asphalt Plant and Paving Equipment
- Warm Mix
- Quality Control Plan and Implementation

Materials

- Local aggregate – Dangerous River Road Pit
  - Outwash Gravels and Sands
  - Quarry Used on Previous Airport Paving Jobs
  - Yakutat Quarry is Characterized to have low voids high flat and elongated
  - PG 64-28 with 0.30% evotherm from US Oil
- HMA design IIE using central region broad band specification after first attempt low VMA

Materials

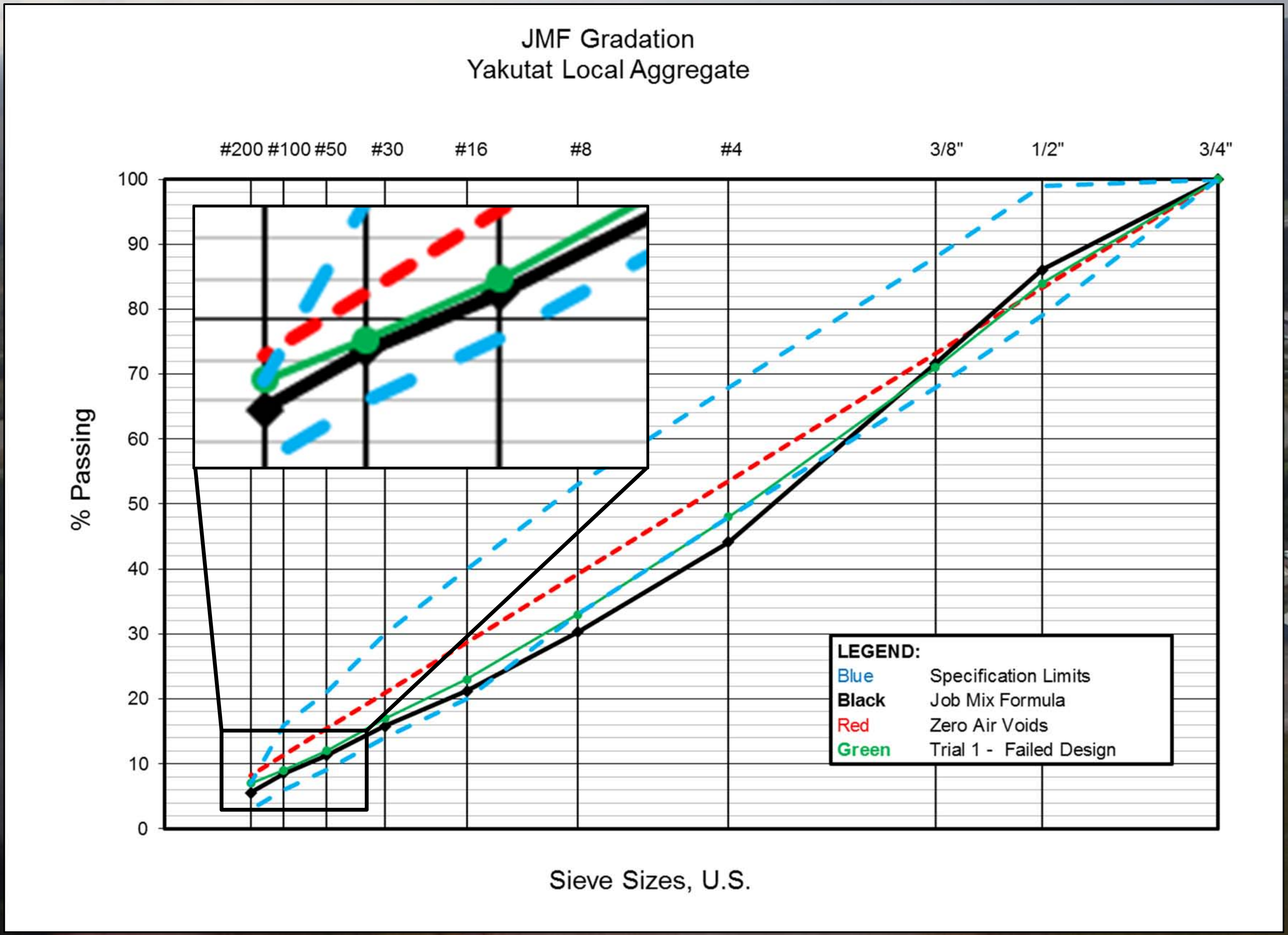
Local Aggregate Sources – THE STRUGGLE IS REAL

First Attempt →
1. Failed VMA
2. Low Voids

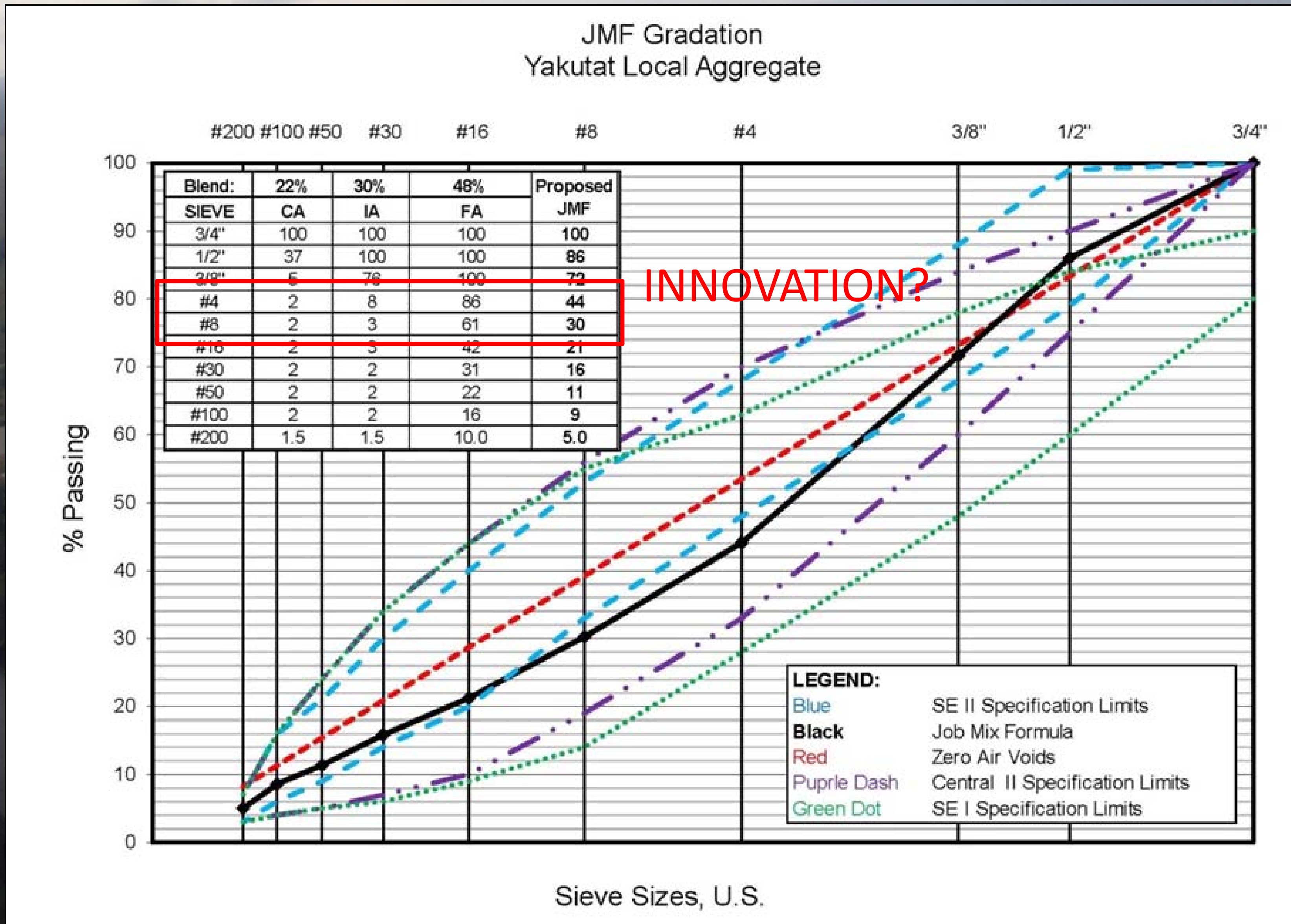
Third Party Trial Batches →
1. Adjust blends
2. Remove natural sand
3. Bailey Analysis
4. Fudge dust content – reject at plant
5. Request broad band change to change #4 and #8 sieve aviation IIA

Final Design
Passed with adjustments made after trial batches

First Attempt to Final



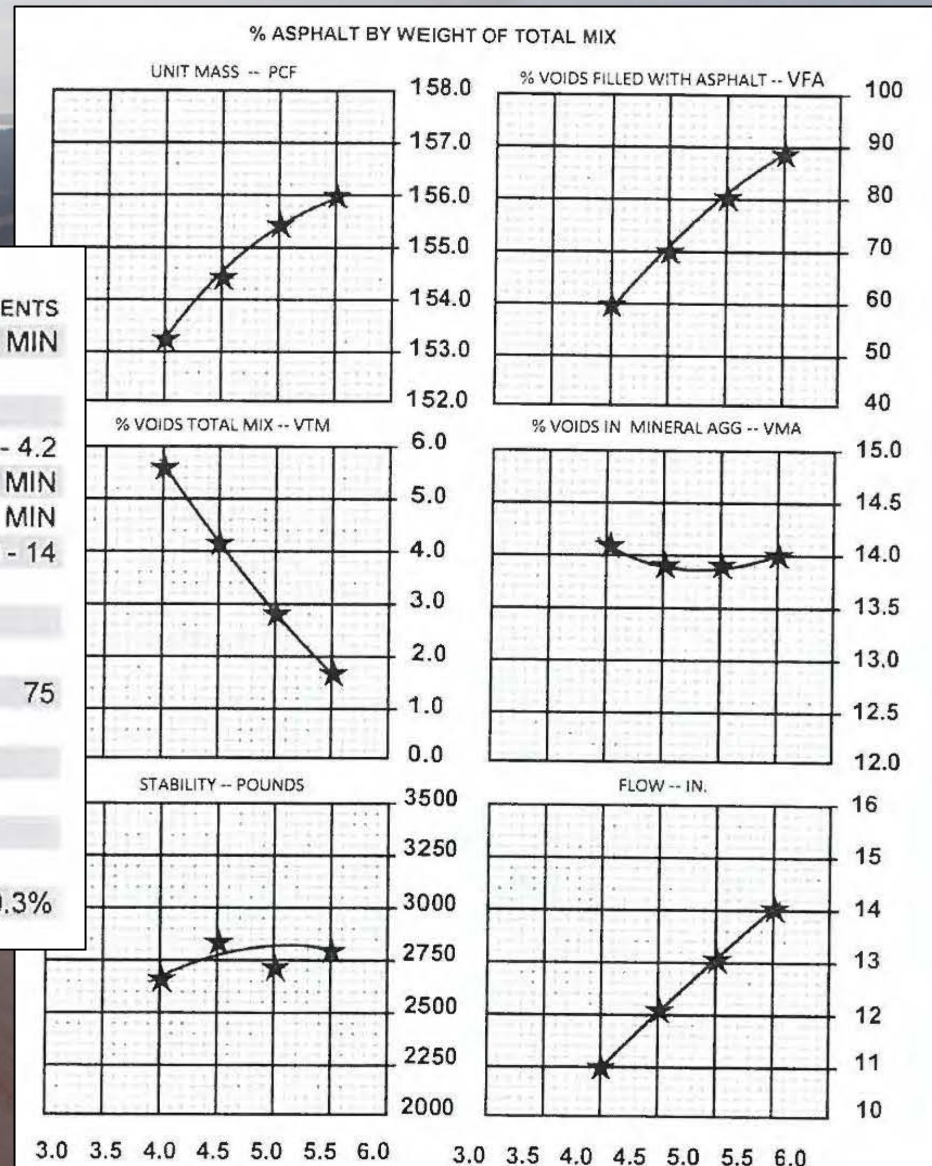
Aggregates: Type II Class E



Blend:	22%	30%	48%	Proposed
SIEVE	CA	IA	FA	JMF
3/4"	100	100	100	100
1/2"	37	100	100	86
3/8"	5	76	100	72
#4	2	8	86	44
#8	2	3	61	30
#16	2	3	42	21
#30	2	2	31	16
#50	2	2	22	11
#100	2	2	16	9
#200	1.5	1.5	10.0	5.0

Spec Mix Design: Type II Class E

	MIXTURE AT OPTIMUM MARSHALL	REQUIREMENTS
ASPHALT CONTENT %	5.0	5.0 MIN
UNIT MASS-PCF	155.6	
VOIDS FILLED-%VFA	80	
VOIDS TOTAL MIX-%VTM	2.8	2.8 - 4.2
VOIDS MIN AGG-%VMA	13.9	13.0 MIN
STABILITY-LBS	2700	2150 MIN
FLOW-IN	11	10 - 14
MAXIMUM SPG Gmm	2.568	
MAX UNIT MASS-PCF	159.8	
DUST / ASPHALT RATIO	1.1	
NUMBER OF BLOWS	75	75
MIX TEMP-DEG F	330	
COMP TEMP-DEG F	305	
ASPHALT BRAND	U.S. OIL	
ASPHALT TYPE	PG 64 -28	
ASPHALT SPG Gb	1.018	
ANTI STRIP	EVOTHERM*	0.3%



Crushing Operations

Aggregate Stock Piles

HMA Plant

400 TPH plant – ran at 400 TPH during top lift echelon paving

Astec Double Barrel Continuous Drum

Paving Train

- Paver: Models: PF-5510 Blaw-Knox
- Shuttle Buggies: SB-2500C with pickup attachment
- (6) Belly Dumps
- Breakdown (IC) and finish rollers

Quality Control

Defined: The system used by a contractor to monitor, assess, and adjust their production or placement processes to ensure that the final product will meet the specified level of quality. Quality control includes sampling, testing, inspection, and corrective action (where required) to maintain continuous control of a production or placement process

Quality Control

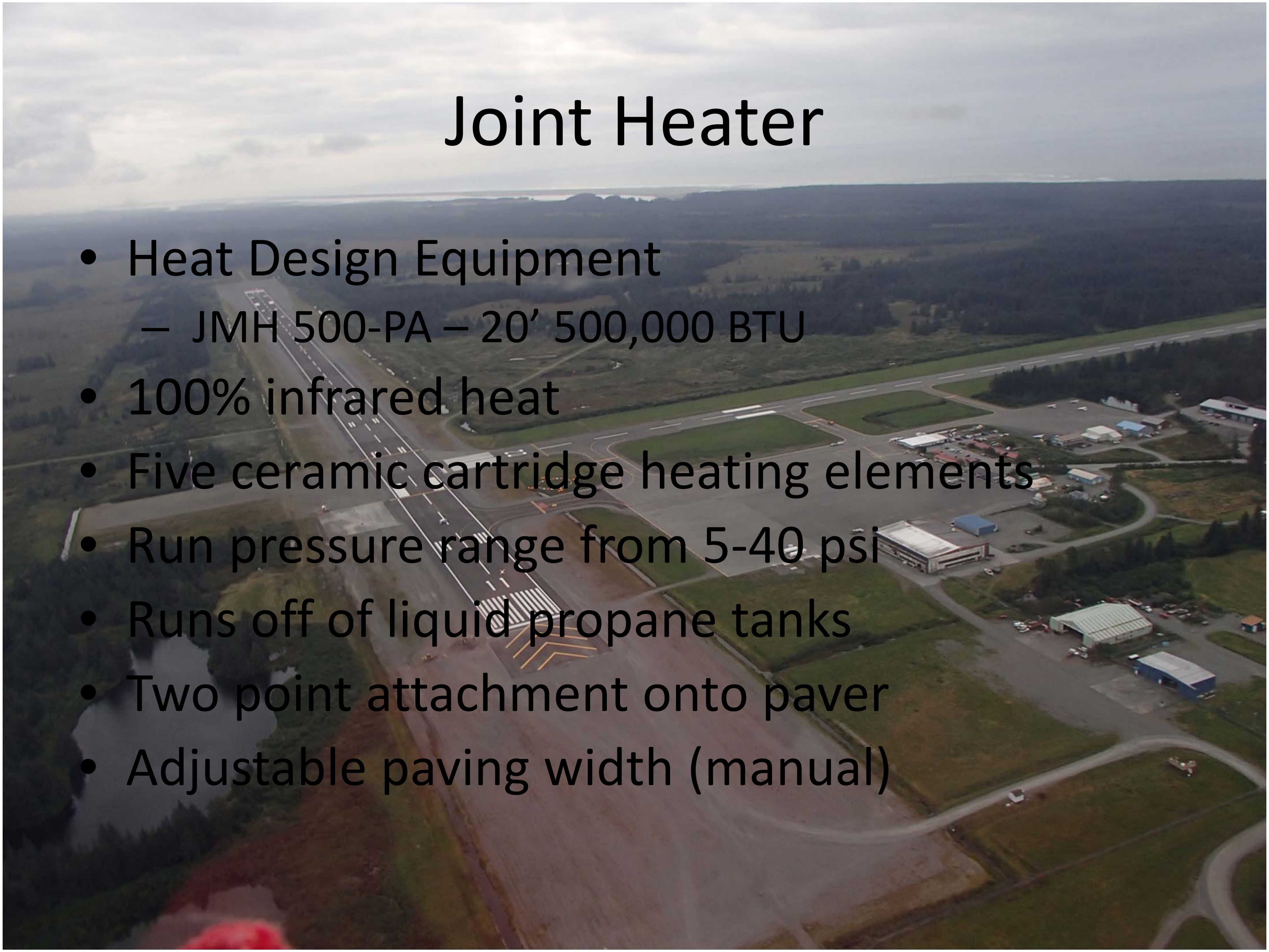
What is good QC?

- Collecting the right data
- Keeping the data organized for easy analysis and adjustments
- Informing the right people
- Having authority to direct and stop work

Quality Control

Tips for “good” QC

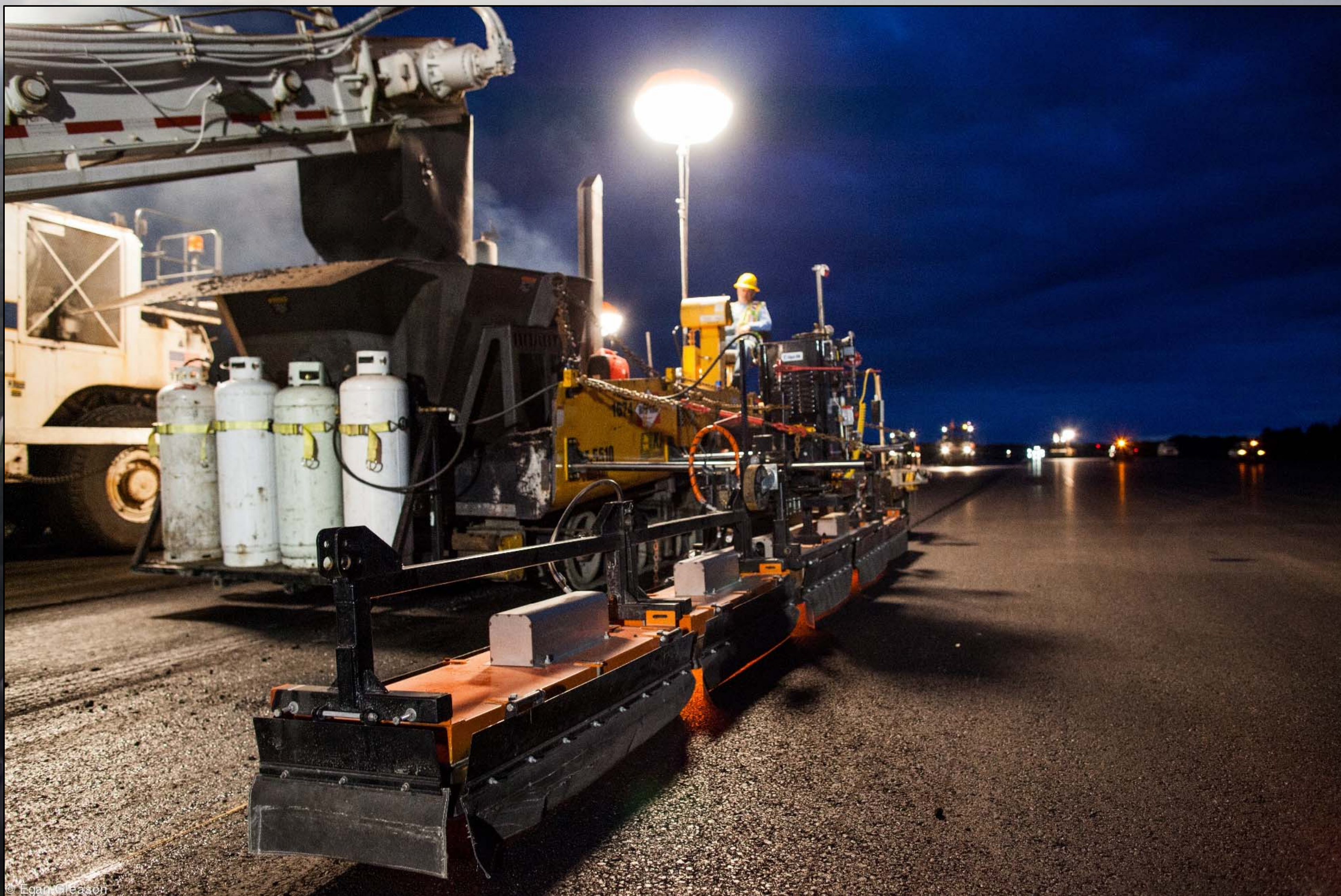
- Needs to be much more than just testing the final product
- Does not mean no issues will arise
- Gives data required to make quick and educated adjustments
- Needs communication and cooperation with Agency QA to be effective
- Communication between plant and field foremen is key



Joint Heater

- Heat Design Equipment
  - JMH 500-PA – 20’ 500,000 BTU
- 100% infrared heat
- Five ceramic cartridge heating elements
- Run pressure range from 5-40 psi
- Runs off of liquid propane tanks
- Two point attachment onto paver
- Adjustable paving width (manual)

Joint Heater



Joint Heater Density

- Achieved with warm mix asphalt temperatures at 0.4% evotherm by weight of AC – target 260 behind screed
- Plant production at 400 tph with two pavers @ 3” deep @ 18’ wide (per paver) – slow production around 15 feet per minute
- Temperatures from 300-325 easily achieved – avoid temps higher than 325 degrees

LOWER				
				90.0
Sample No.	Date	Lot MSG	TEST RESULTS	Mix Design MSG = 2.568
D- 25 (M-11	7/4/16	2.571		93.1
D-26 (M-11	7/4/16	2.571		93.0
D-27 (M-11	7/4/16	2.571		93.3
D-28 (M-11	7/5/16	2.571		94.4
D-29 (M-11	7/5/16	2.571		94.0
D-30 (M-11	7/6/16	2.571		95.3
D-31 (M-11	7/7/16	2.571		94.7
D-32 (M-12	7/7/16	2.571		94.3
D- 33(M-12	7/7/16	2.571		92.0
JD- (M-)				
(M-)				
JD- (M-)				
JD- (M-)				
JD- (M-)				
JD- (M-)				
JD- (M-)				
JD- (M-)				
JD- (M-)				
AVERAGE TEST RESULT				93.8
NUMBER OF SAMPLES			JOINT DENSITY	9

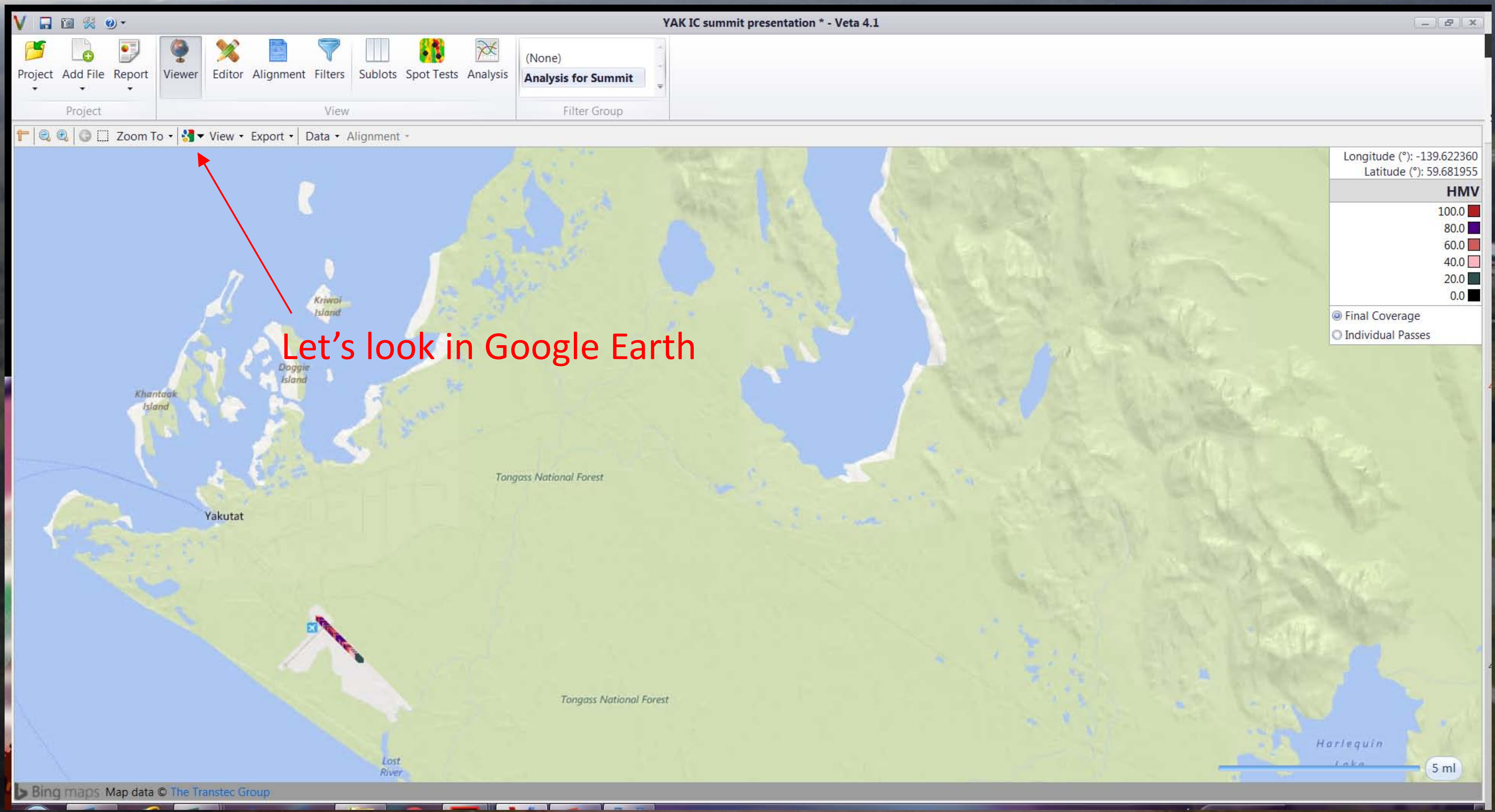
Joint Heater Density

- Used approximately (4) 100 pound bottles of liquid propane per 8100 feet of runway
- Saved approximately 250 tons of asphalt from being placed then wasted by cutting (4" wide)
- All "hot" joints on top lift
- Five total joints
- Full joint bonus achieved
- No joint prep before paving adjacent panel

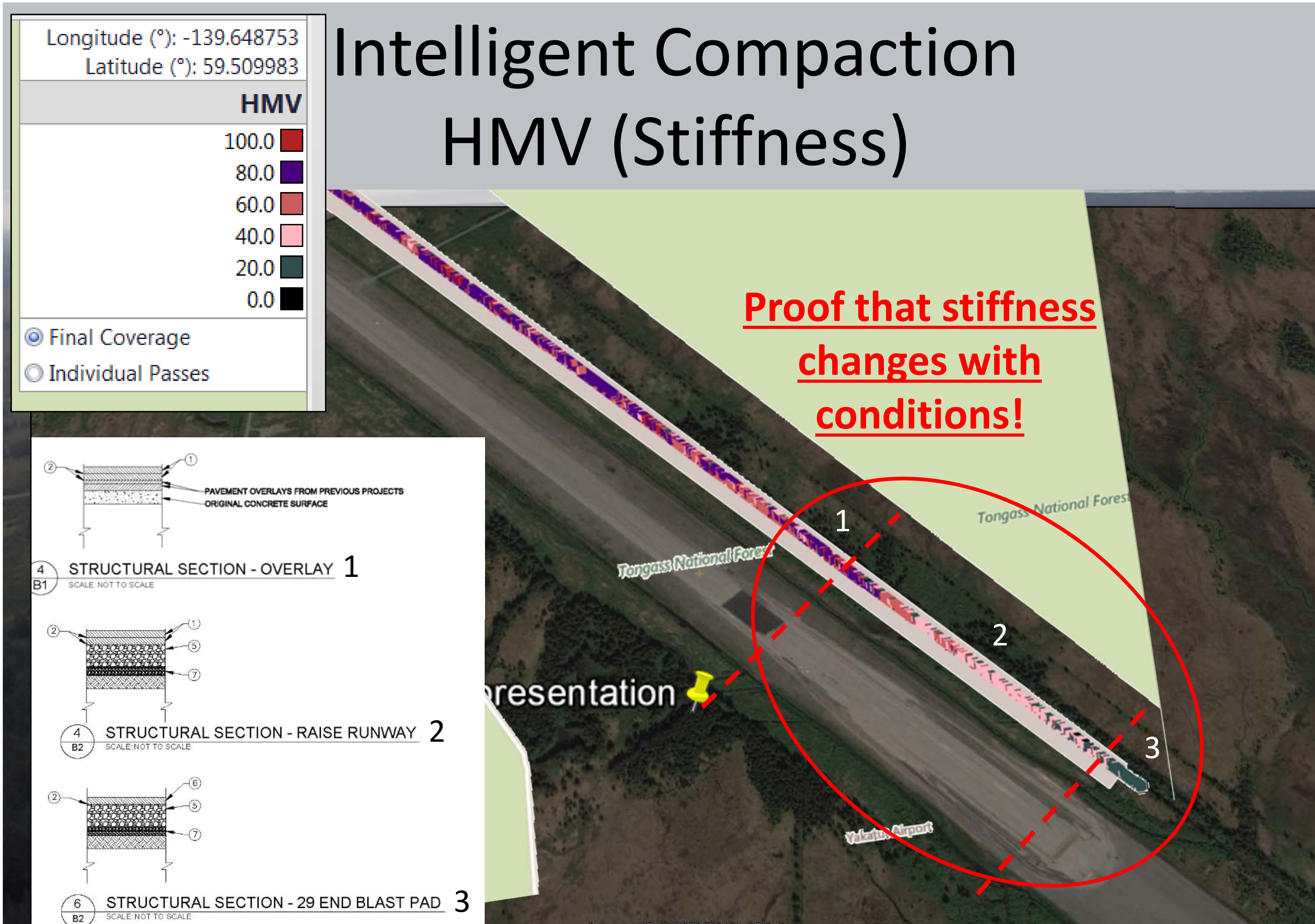
Intelligent Compaction

- Equipment
  - HAMM
  - HD+140 VO
- Topcon GPS
- Data analysis
- Pre-paving mapping
- Paving QC tool

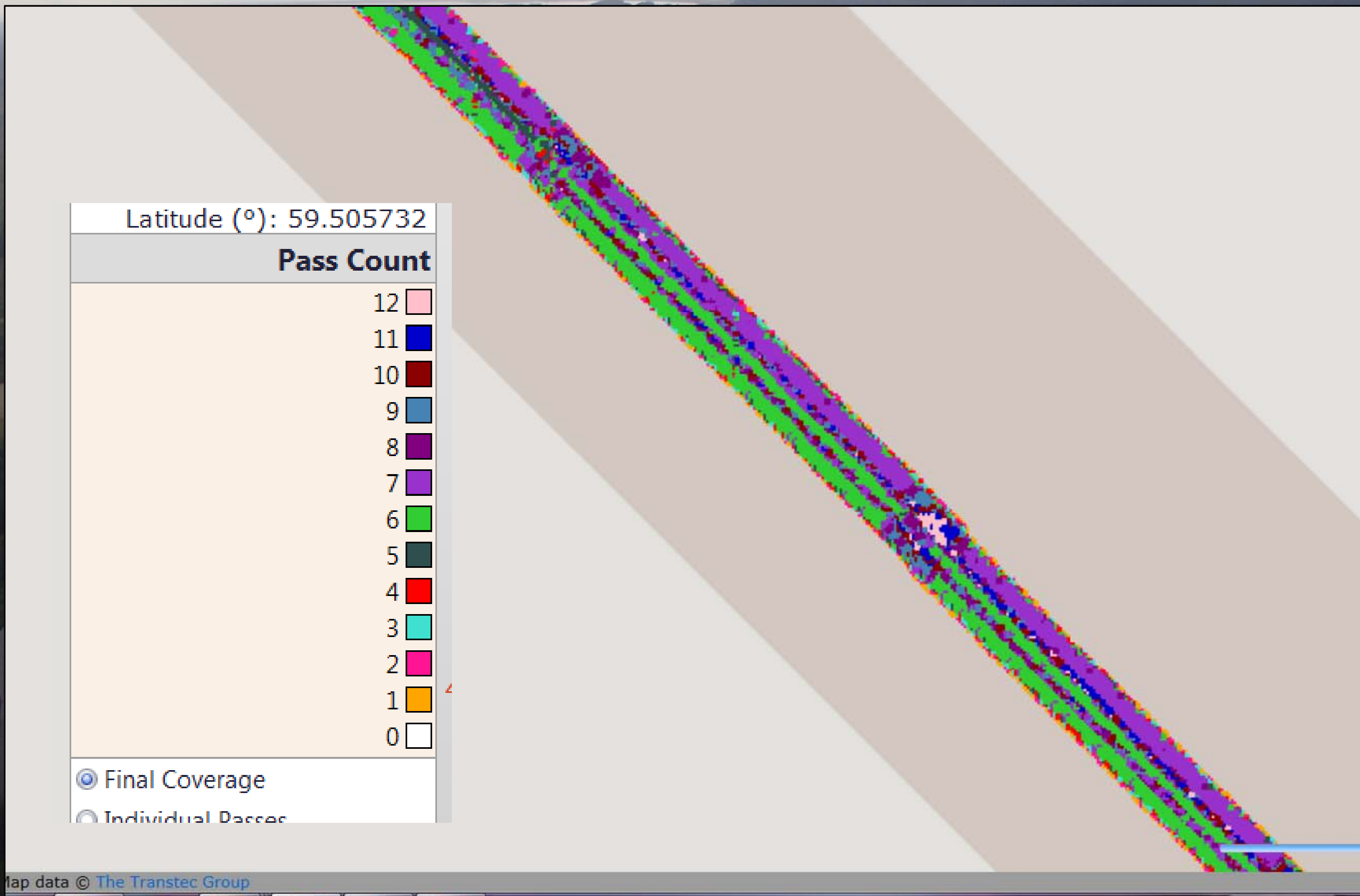
Intelligent Compaction



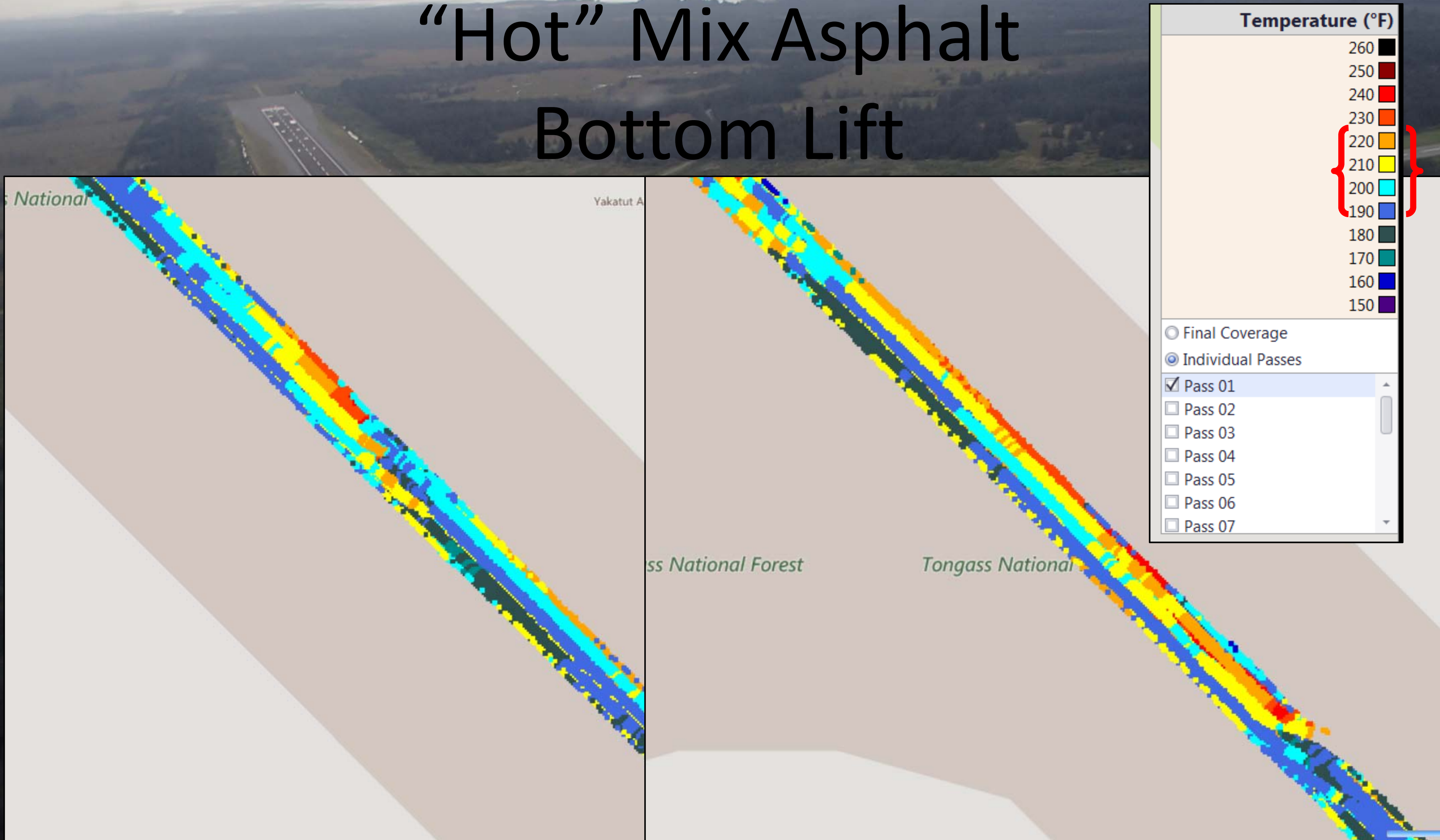
Intelligent Compaction HMV (Stiffness)



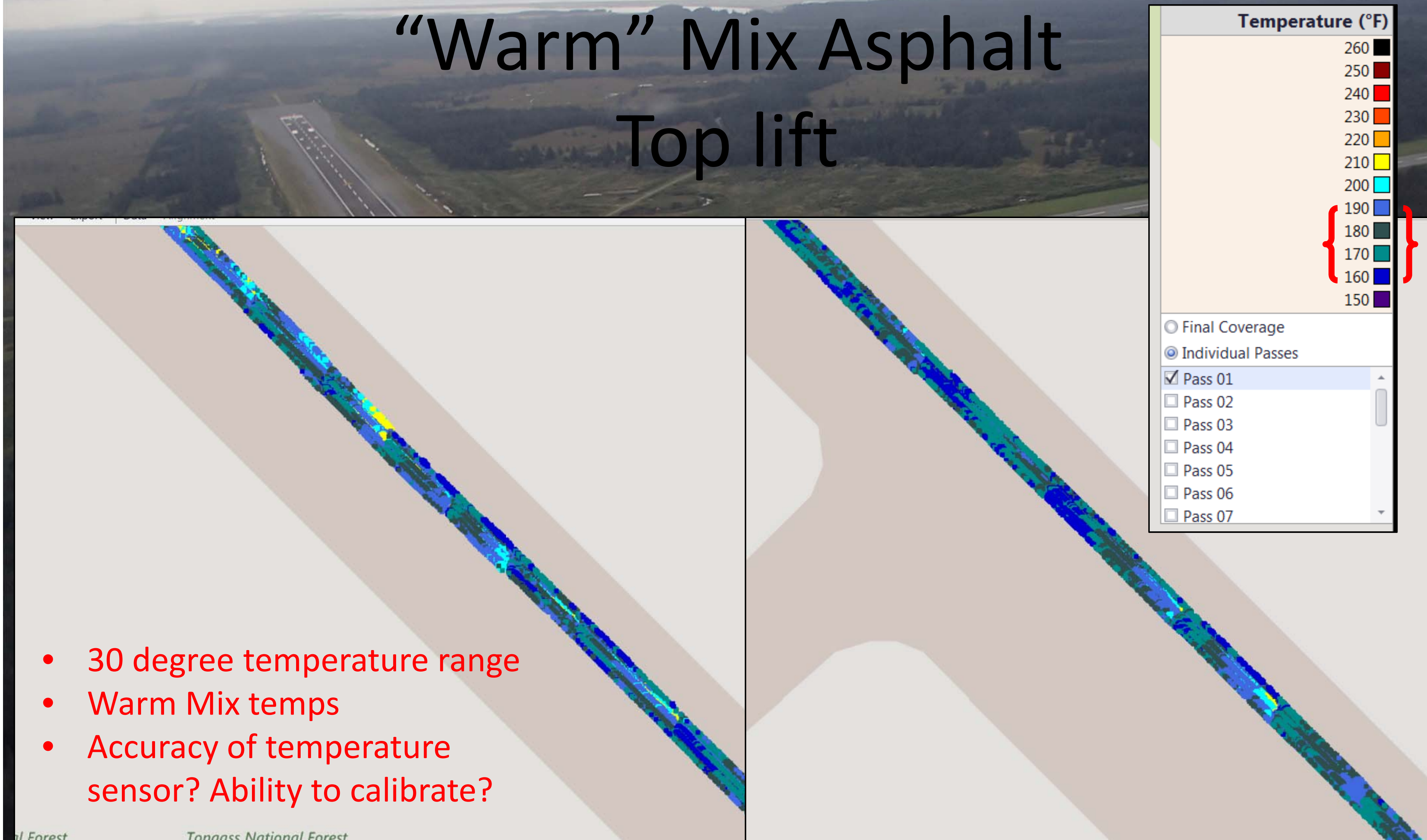
Intelligent Compaction
Pass Count



Intelligent Compaction
Breakdown Temperatures
"Hot" Mix Asphalt
Bottom Lift



Intelligent Compaction
Breakdown Temperatures
“Warm” Mix Asphalt
Top lift

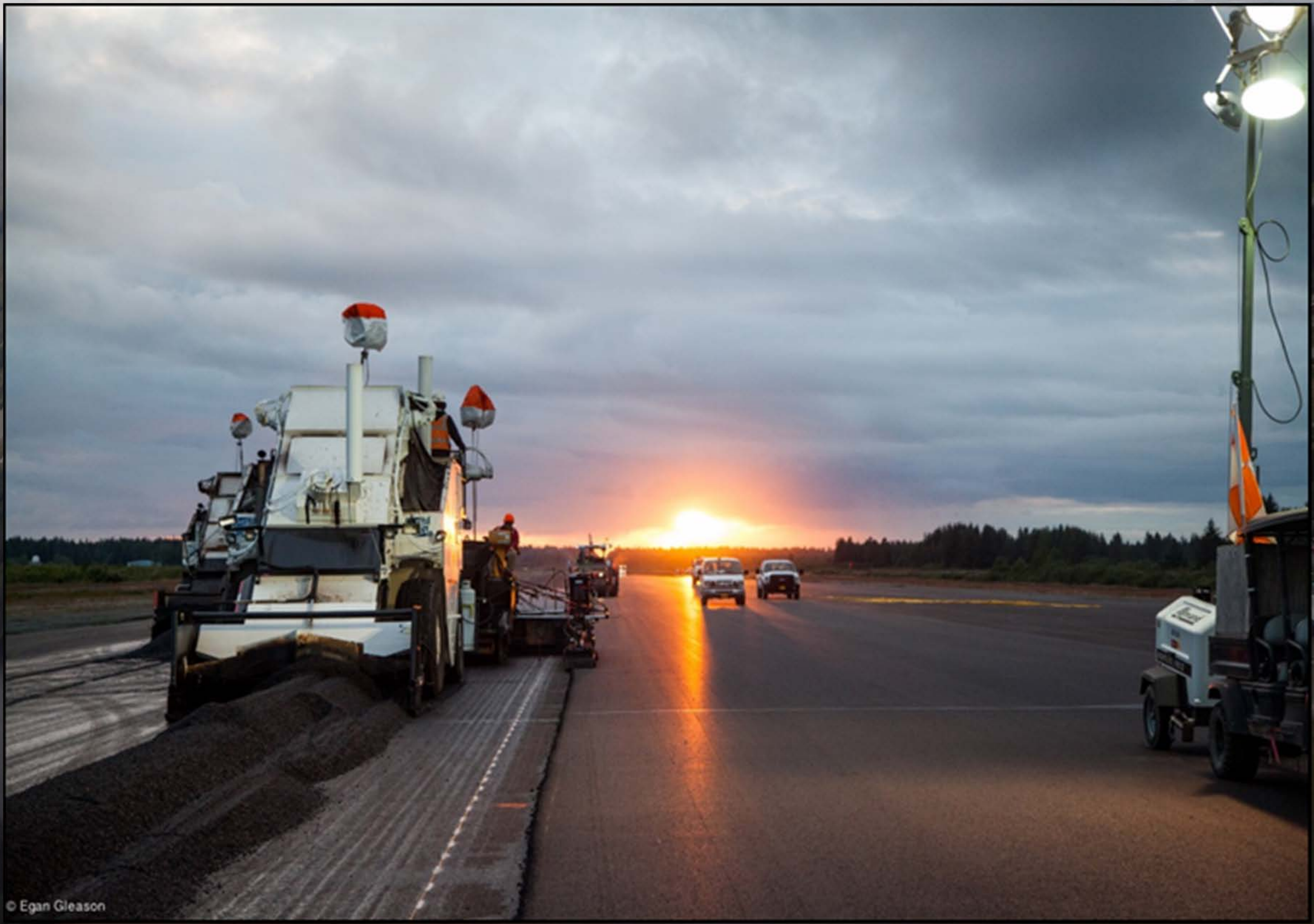


- 30 degree temperature range
- Warm Mix temps
- Accuracy of temperature sensor? Ability to calibrate?

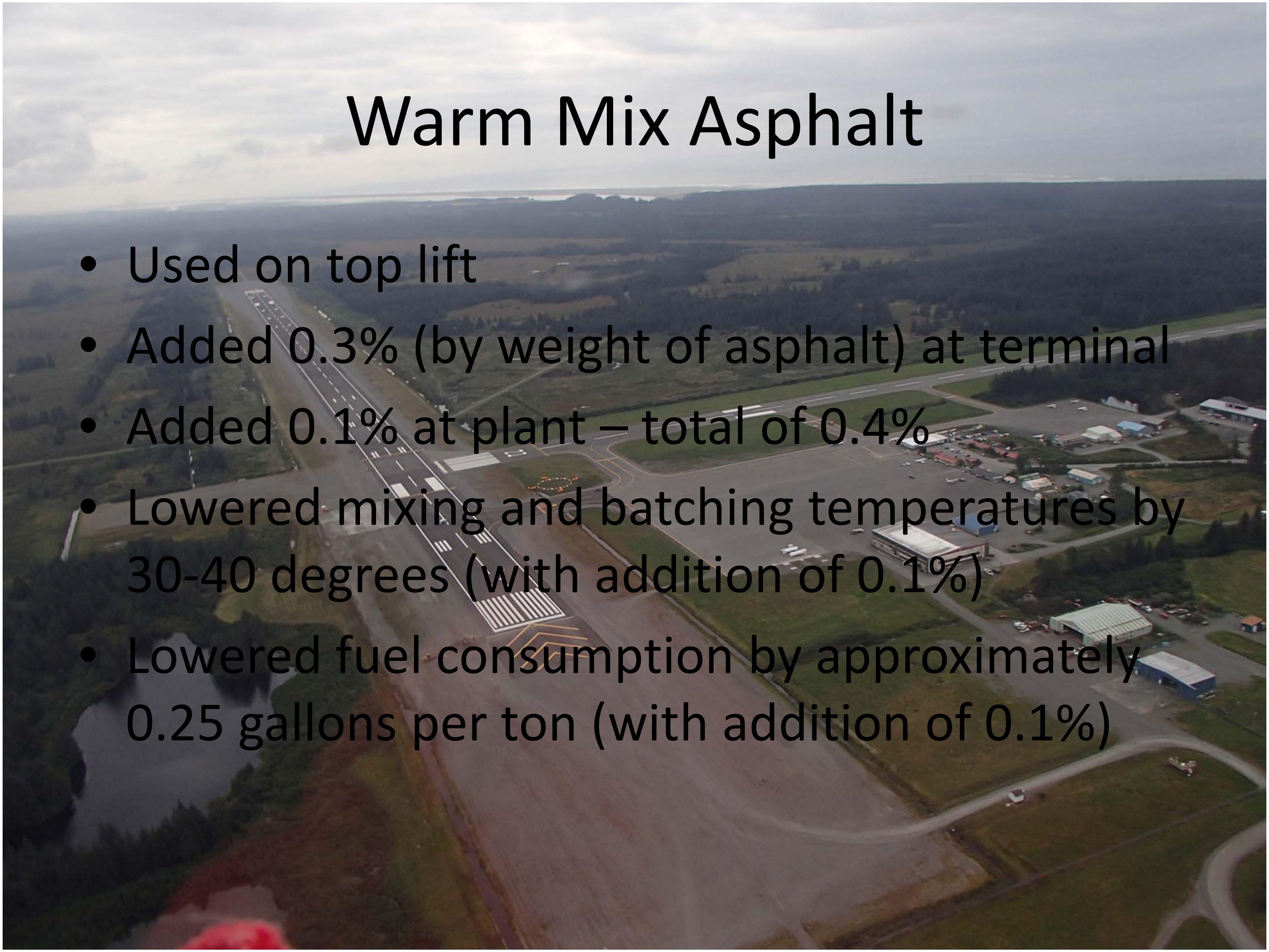
Intelligent Compaction Benefits

- Coverage assurance
- Density troubleshooting
- Subgrade/ subbase assurance
- Real time data
- Great QC tool

Warm Mix Asphalt

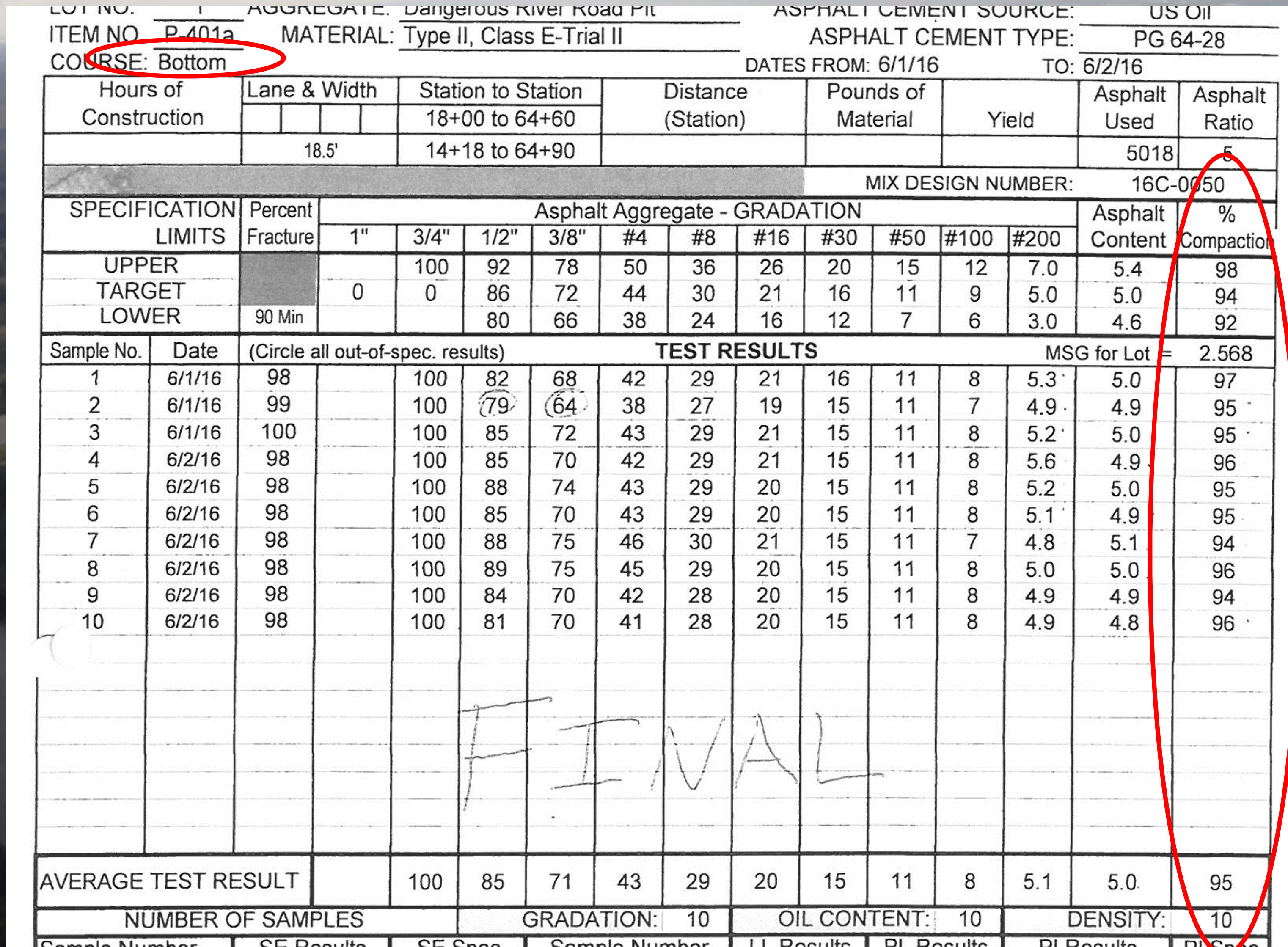


Warm Mix Asphalt



- Used on top lift
- Added 0.3% (by weight of asphalt) at terminal
- Added 0.1% at plant – total of 0.4%
- Lowered mixing and batching temperatures by 30-40 degrees (with addition of 0.1%)
- Lowered fuel consumption by approximately 0.25 gallons per ton (with addition of 0.1%)

Density Results - HMA



LOT NO: 1 AGGREGATE: Dangerous River Road Pit ASPHALT CEMENT SOURCE: US Oil

ITEM NO: P-401a MATERIAL: Type II, Class E-Trial II ASPHALT CEMENT TYPE: PG 64-28

COURSE: Bottom DATES FROM: 6/1/16 TO: 6/2/16

Hours of Construction	Lane & Width	Station to Station	Distance (Station)	Pounds of Material	Yield	Asphalt Used	Asphalt Ratio
		18+00 to 64+60					
	18.5'	14+18 to 64+90				5018	5

MIX DESIGN NUMBER: 16C-0050

SPECIFICATION LIMITS	Percent Fracture	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200	Asphalt Content	% Compaction
UPPER			100	92	78	50	36	26	20	15	12	7.0	5.4	98
TARGET		0	0	86	72	44	30	21	16	11	9	5.0	5.0	94
LOWER	90 Min			80	66	38	24	16	12	7	6	3.0	4.6	92

(Circle all out-of-spec. results) **TEST RESULTS** MSG for Lot = 2.568

Sample No.	Date	Percent Fracture	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200	Asphalt Content	% Compaction
1	6/1/16	98		100	82	68	42	29	21	16	11	8	5.3	5.0	97
2	6/1/16	99		100	(79)	(64)	38	27	19	15	11	7	4.9	4.9	95
3	6/1/16	100		100	85	72	43	29	21	15	11	8	5.2	5.0	95
4	6/2/16	98		100	85	70	42	29	21	15	11	8	5.6	4.9	96
5	6/2/16	98		100	88	74	43	29	20	15	11	8	5.2	5.0	95
6	6/2/16	98		100	85	70	43	29	20	15	11	8	5.1	4.9	95
7	6/2/16	98		100	88	75	46	30	21	15	11	7	4.8	5.1	94
8	6/2/16	98		100	89	75	45	29	20	15	11	8	5.0	5.0	96
9	6/2/16	98		100	84	70	42	28	20	15	11	8	4.9	4.9	94
10	6/2/16	98		100	81	70	41	28	20	15	11	8	4.9	4.8	96
AVERAGE TEST RESULT				100	85	71	43	29	20	15	11	8	5.1	5.0	95

FINAL

NUMBER OF SAMPLES GRADATION: 10 OIL CONTENT: 10 DENSITY: 10

Sample Number	SE Results	SE Spec	Sample Number	LL Results	PL Results	PI Results	PI Spec

Density Results WMA

PROJECT# 3-02-0327-20-2015 # 68386 PROJECT NAME: Yakutat Airport Runway Pavement Rehabilitation

LOT NO. 12 AGGREGATE: Dangerous River Road Pit ASPHALT CEMENT SOURCE: US Oil

ITEM NO. P-401a MATERIAL: Type II, Class E-Trial II ASPHALT CEMENT TYPE: PG 64-28

COURSE: TOP DATES FROM: 7/3/16 TO: 7/8/16

Hours of Construction	Lane & Width	Station to Station TAXIWAY A	Distance (Station)	Pounds of Material	Yield	Asphalt Used	Asphalt Ratio
	37-55'RT & 75'-95'RT	23+00 - 95+56				6500	5.1

MIX DESIGN NUMBER: 16C-0050

SPECIFICATION LIMITS	Percent Fracture	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200	Asphalt Content	% Compaction
		Asphalt Aggregate - GRADATION												
UPPER			100	92	78	50	36	26	20	15	12	7.0	5.4	98
TARGET		0	0	86	72	44	30	21	16	11	9	5.0	5.0	94
LOWER				80	66	38	24	16	12	7	6	3.0	4.6	92

(Circle all out-of-spec. results) TEST RESULTS MSG for Lot = 2.571

Sample No.	Date	Percent Fracture	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200	Asphalt Content	% Compaction
111	7/3/16			100	89	76	48	32	23	17	12	9	5.9	5.0	96
112	7/4/16			100	84	72	46	31	21	16	12	8	5.5	4.9	95
113	7/4/16			100	89	74	47	32	23	17	12	9	6.0	5.1	93
114	7/4/16			100	87	73	46	30	21	16	12	8	5.6	5.1	95
115	7/5/16			100	90	77	49	32	23	17	13	9	6.5	5.4	96
116	7/5/16			100	83	70	45	30	22	16	12	9	5.9	5.0	96
117	7/5/16			100	83	72	46	30	21	16	12	9	5.8	5.2	95
118	7/6/16			100	89	75	49	33	23	17	13	9	6.3	5.2	97
119	7/7/16			100	84	72	46	31	22	16	12	9	6.0	5.0	96
120	7/7/16			100	82	70	46	31	23	17	13	9	6.1	5.0	96
121	7/7/16			100	82	72	46	31	22	16	12	9	5.8	5.0	95
122	7/8/16			100	85	73	48	33	24	18	13	9	6.4	5.2	95
123	7/8/16			100	84	72	48	32	23	17	12	9	6.0	5.1	96
124															
125															
AVERAGE TEST RESULT				100	85	73	47	31	22	17	12	9	6.0	5.1	95

NUMBER OF SAMPLES GRADATION: 13 OIL CONTENT: 13 DENSITY: 13

Final Inspection

Runway 11/29

Before

After

Crosswind Intersection

Before

After

11 End Threshold of 11/29

Takeaways

- Pre-design Evaluation & Investigation
- Interdisciplinary, DOT&PF Technical Design Team
- Proactive & Collaborative QC program
- Positive relationship and good communication with owner and contractor
- Consistent, predictable outcomes
- Joint Heater and IC provided means to achieve mat and joint densities
- Quality infrastructure
- Decrease maintenance, longer lifecycle

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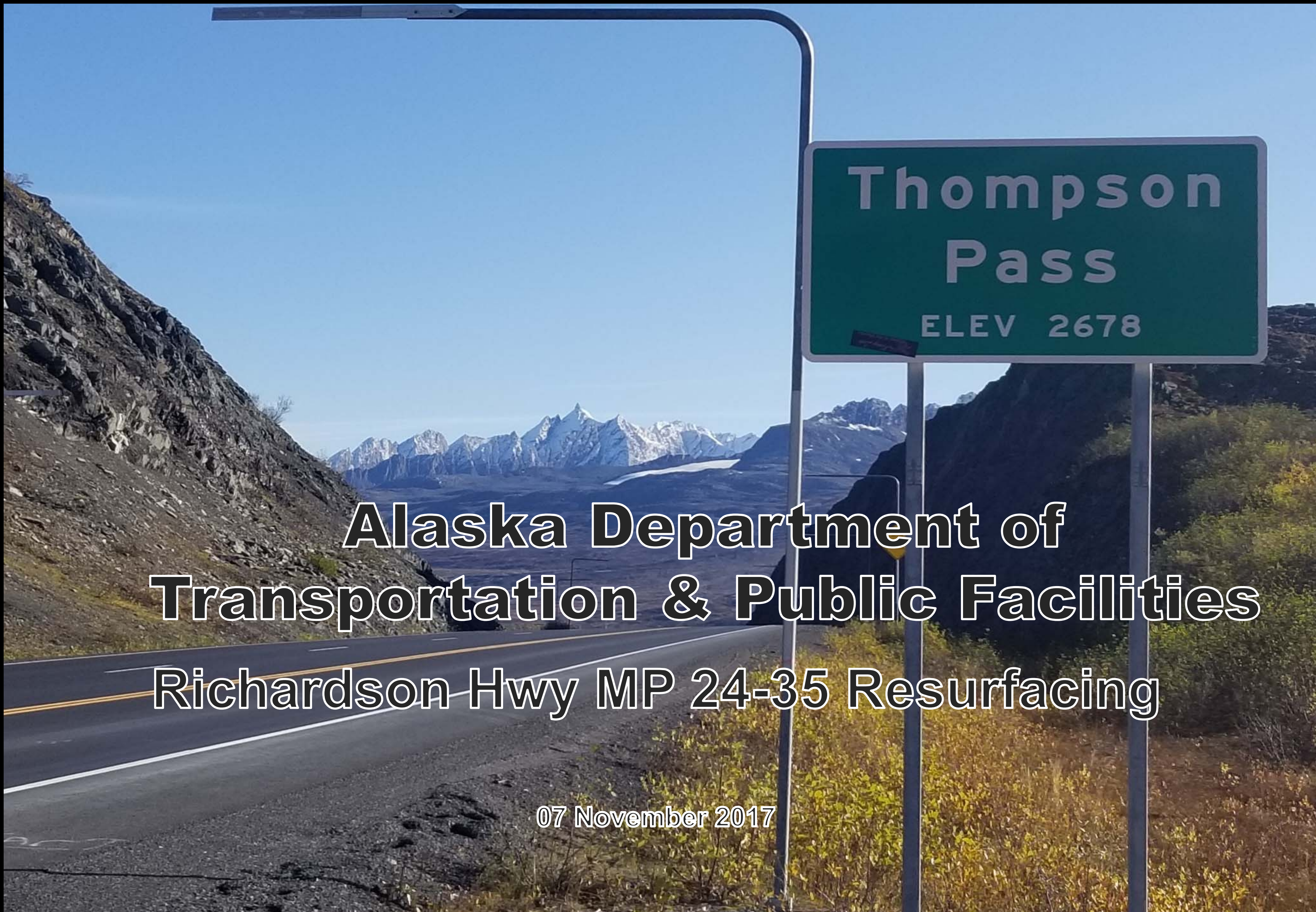
Thank you.


A 11-29
TRANSPORTATION & PUBLIC FACILITIES
STATE OF ALASKA
Alaska
KNIK
CONSTRUCTION



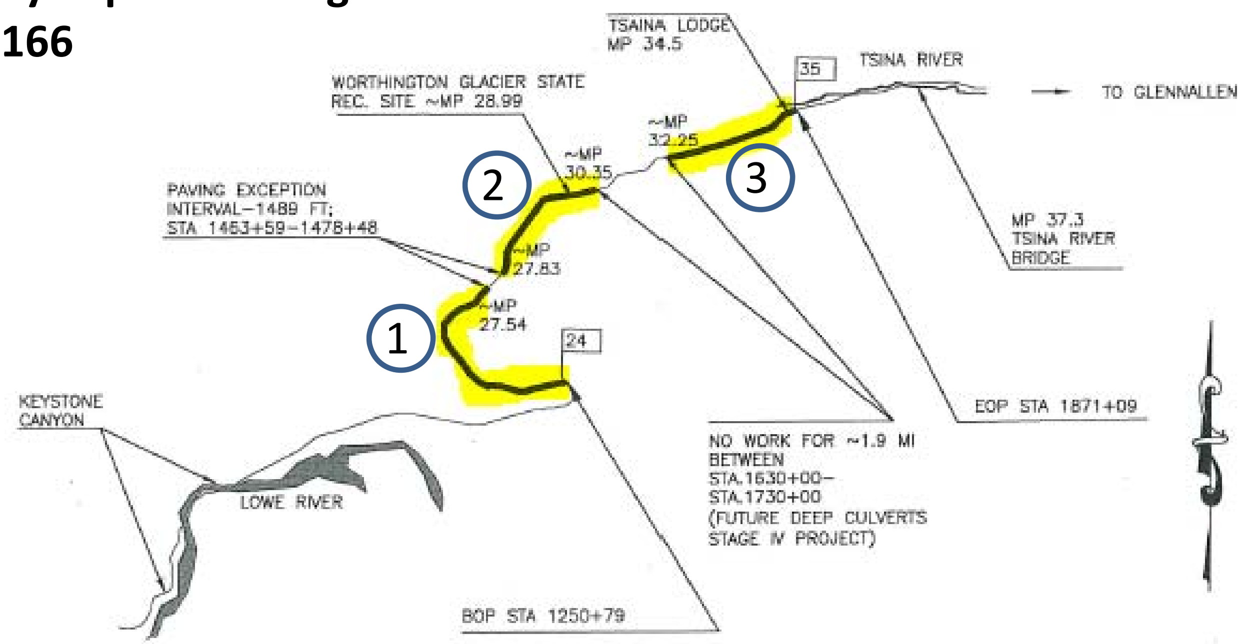
Alaska Department of Transportation & Public Facilities

Richardson Hwy MP 24-35 Resurfacing

07 November 2017

Project Overview/Highlights

General Contractor – Quality Asphalt Paving
Contract Amount - $8,986,166



Pavement Resurfacing

- Cold Plane to 2” depth
- Pave 2” HMA Type II; Class B
- 9.6 Miles Long
- 36’ width
- 3 segments

Drainage Improvements

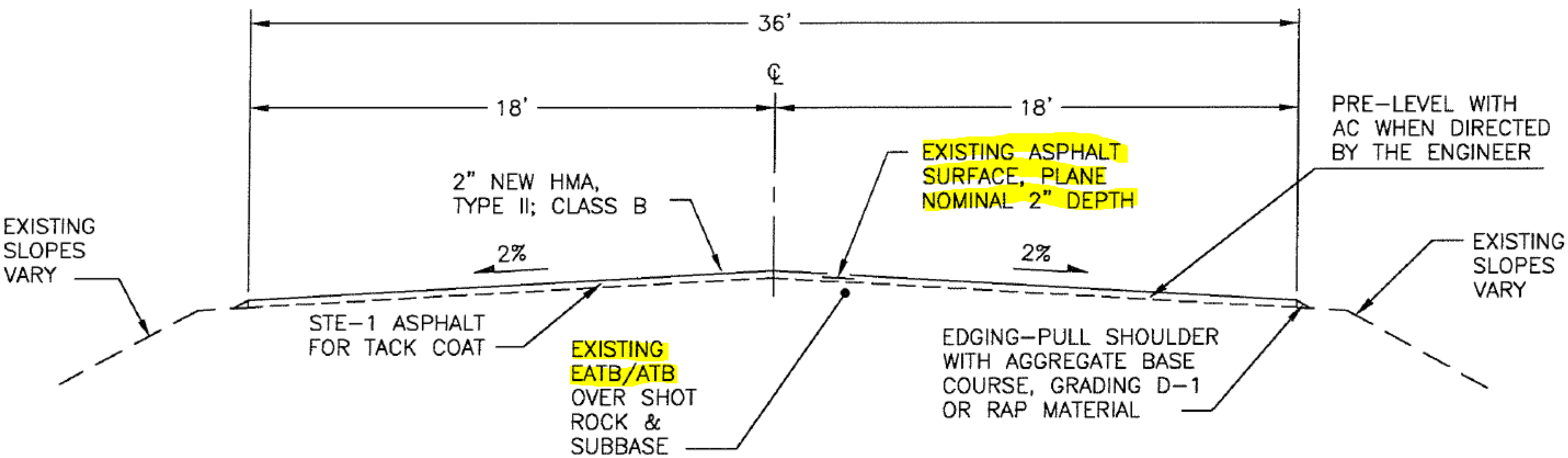
- 28 new culverts total
- 2 each Precast Box Concrete Culverts
- 6 each deep culvert excavations

Other Improvements

- 15,000’ Box Beam Guardrail
- 2,000’ W Beam Guardrail
- Signs
- Snow Poles

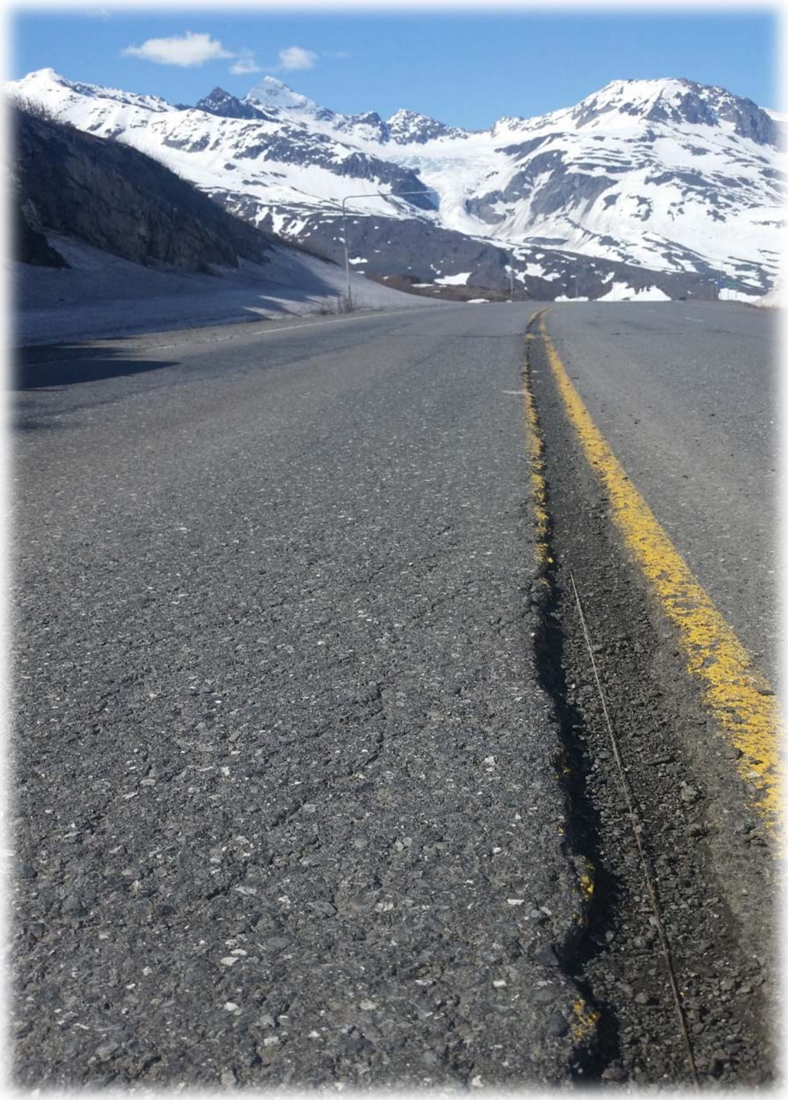
Pavement Planing

Original Plan



TYPICAL SECTION 1
RICHARDSON HWY
NO SCALE

Segment 1 Existing Pavement



Pavement Planing

<u>New Plan</u>

- <u>Segment 1 – Thompson Pass</u>
    - Full Depth Reclaim (5-6”) Crushed Asphalt Base Course
    - 2” of HMA Type II Class B

- <u>Segment 2 – Worthington Glacier Area</u>
    - Plane 2”
    - 2” of HMA Type II Class B

- <u>Segment 3 – Tsaina Lodge Area</u>
    - Plane 2”
    - 2” of HMA Type II Class B

Segment 3 Planing

Pavement Planing

Good

Not so Good

Pavement Planing

<u>New Plan</u>

- Segment 1 – Thompson Pass
  - Full Depth Reclaim (5-6”) Crushed Asphalt Base Course
  - 2” of HMA Type II Class B
- Segment 2 – Worthington Glacier Area
  - Full Depth Reclaim (5-6”) Crushed Asphalt Base Course
  - 2” of HMA Type II Class B
- Segment 3 – Tsaina Lodge Area
  - Plane 2”
  - 2” of HMA Type II Class B

Segment 1 CABC

Segment 1 Paving

Precast Concrete Box Culverts

16 Ft Span & 14 Ft Span
7 Ft Rise
84 Ft Length

Design by ReidMiddleton

Precast at D&S Concrete

Precast Concrete Box Culverts

Precast Concrete Box Culverts

Precast Concrete Box Culverts

Precast Concrete Box Culverts

Thank You

Alaska Department of Transportation & Public Facilities

Northern Region Highlights for 2017 Asphalt Summit

Jeff Currey, P.E., NR Materials Engineer

November 7, 2017

Keep Alaska Moving through service and infrastructure

NR PaveScan GPR Demo

Rich Giessel brought the PaveScan GPR equipment to NR to demonstrate "on-the-fly", continuous density testing this summer-pretty slick!

Fighting Thermal Cracks: NR PG 52-40 Asphalt Projects

0610(007)	Airport Way PM - Stg II, NR Signal Intercon, & NR Ped Impr	401(004C)	Asphalt Binder, Grade PG 52-40
0002247	Birch Hill Bicycle & Pedestrian Facility	401(004C)	Asphalt Binder, Grade PG 52-40
IM-DP-065-4(8)	Dalton Highway MP 197-209 Rehabilitation	401(002C)	Asphalt Cement, Grade PG 52-40
000S413	Fairbanks Noble Street Upgrade	401(004C)	Asphalt Binder, Grade PG 52-40
0002344/0644018	Farmers Loop Resurfacing & Farmers Loop Signal Interconnect	306(102C)	Asphalt Binder, Grade PG 52-40
0002344/0644018	Farmers Loop Resurfacing & Farmers Loop Signal Interconnect	401(004C)	Asphalt Binder, Grade PG 52-40
0002402	FMATS Area Surface Upgrades FFY2017	401(004C)	Asphalt Binder, Grade PG 52-40
AIP302011000520	Gulkana Airport Apron & Taxiway Repaving	P-401c-3	Asphalt Cement,Grade PG 52-40
0002257	Old Nenana/Ester Hill Rehabilitation	401(004C)	Asphalt Binder, Grade PG 52-40
0A44(019)	Parks Hwy MP 237 Riley Creek Bridge Replacement (CMGC)	401(002C)	Asphalt Cement, Grade PG 52-40
0002(304)	Peger Rd Resurf / FMATS Ped Impr / NR Signal Interconnect	401(004C)	Asphalt Binder, Grade PG 52-40
BR-071-4(18)	Richardson Highway MP 228 One Mile Creek Bridge Replacement	401(002C)	Asphalt Cement, Grade PG 52-40
BR-0714(22)	Richardson Hwy MP 201 Phelan Creek Bridge #0579	306(002C)	Asphalt Binder, Type PG 52-40
BR-0714(22)	Richardson Hwy MP 201 Phelan Creek Bridge #0579	401(002C)	Asphalt Cement, Grade PG 52-40
0714023	Richardson Hwy MP 235 Ruby Creek Bridge #0594	401(004C)	Asphalt Binder, Grade PG 52-40
0A23022	Richardson Hwy MP 337 Eielson AFB Intersection Impr	306(002C)	Asphalt Cement, Grade PG 52-40
0A23022	Richardson Hwy MP 337 Eielson AFB Intersection Impr	401(004C)	Asphalt Binder, Grade PG 52-40
0712034	Richardson Hwy MP 80-82 Resurf & Drainage Impr	401(004C)	Asphalt Binder, Grade PG 52-40
	Dalton Highway MP 179-197 Rehabilitation		
	Richardson Hwy MP 265-267 Rehabilitation		
	Nome Airport		
	Barrow Airport		
	Deadhorse Airport		
	Kotzebue Airport		
	Shishmaref Airport		

Peger Road Resurfacing-2016

Used PG 52-40, Type II, Class B HMA

Project Included:

- Mill & Fill (Cold Planing + Overlay)
- Reclamation (Crushed Asphalt Base Course)
- Shallow Remove & Reconstruct

- "Leapfrog" En Echelon Paving
- Fed by Shuttle Buggy
- IR Scanner Demo

En Echelon Night Paving-Peger

Geotextile Specifications

Specs are being adopted, should be in 2018 Std Hwy Specs
The Big Take-Aways:

Creates Standard Pay Items for Geotextile, Reinforcement

Increases minimum permittivity of Geotextile, Separation to preclude Slit-Film fabric

Does not yet address Geotextile, Wicking (H2Ri)-Special Provisions still evolving

Some items strength (survivability) specs changed

Wicking Fabric Experimental Feature

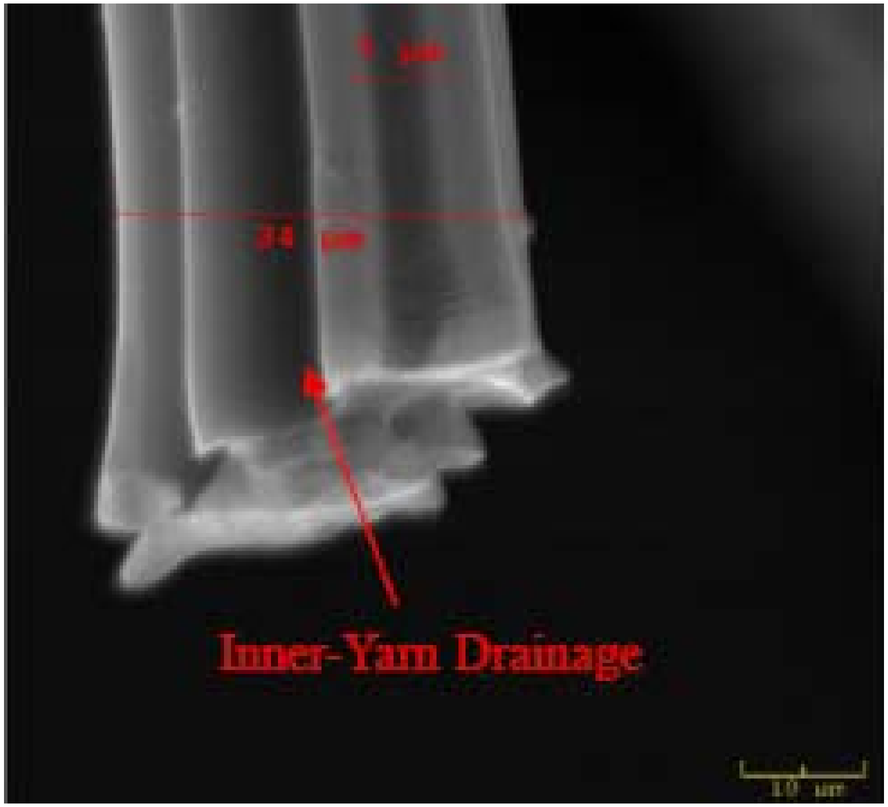
H_2Ri Wicking Fabric Experimental Feature Final Report
Dalton Highway MP 197-209 Rehabilitation
Project No. IM-DP-065-4(8)/61214
December 23, 2016

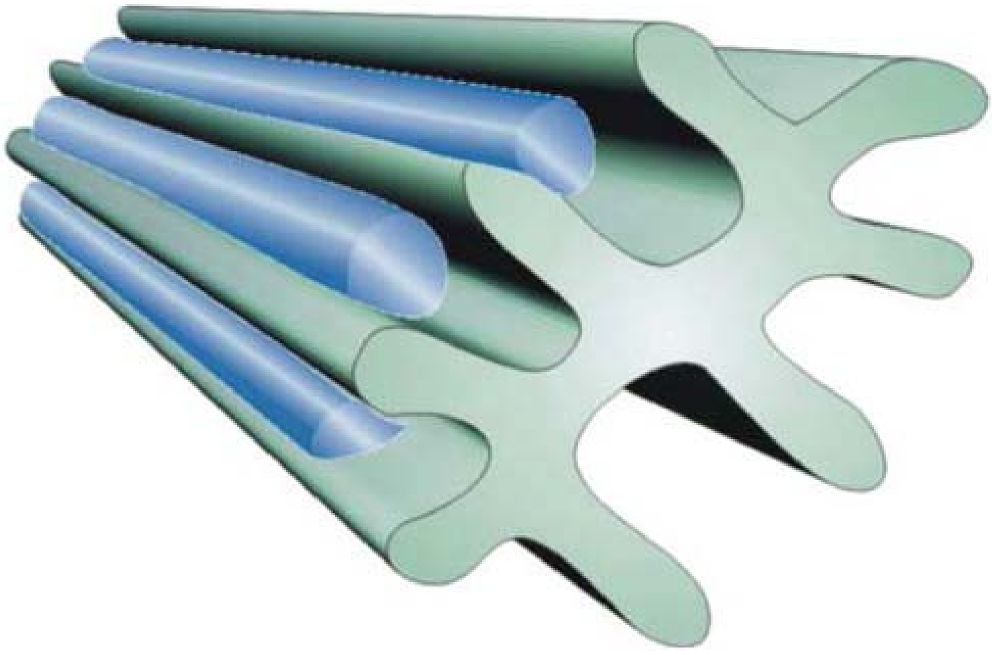
There should be a recording of presentation

http://dot.alaska.gov/stwddes/research/

http://dot.alaska.ecatts.com/lmsShowClass?classId=574&month=5&year=2017&id=0.33499714783685053

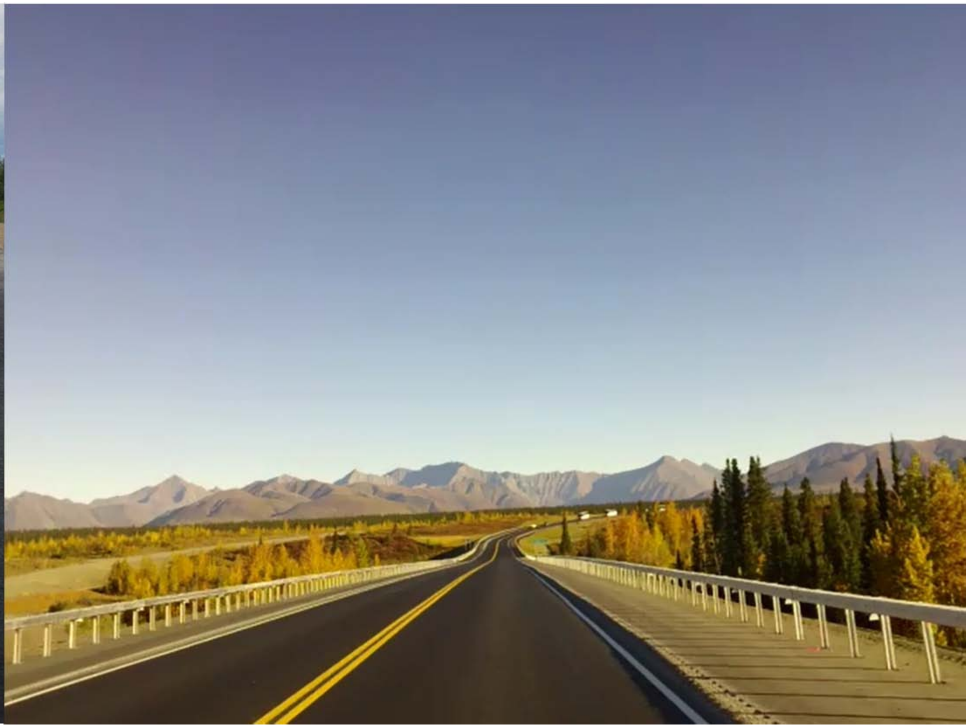
H2Ri Capillary Channels





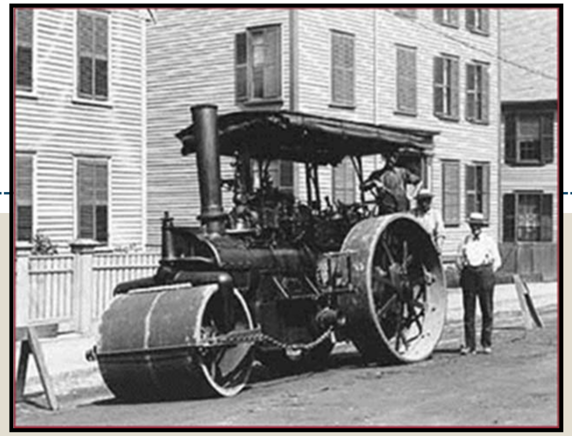
Dalton 197-209 Experimental Feature

Broad Pass-Before & After



Any Questions????

Enhanced Durability Through Increased Density



TIM ASCHENBRENER, P.E.
MATERIALS AND QUALITY ASSURANCE TEAM
OFFICE OF PRECONSTRUCTION, CONSTRUCTION AND PAVEMENTS
FHWA

KANSAS ASPHALT PAVING CONFERENCE
DECEMBER 7, 2017

Overall Objective

NAPA
NATIONAL ASPHALT
PAVEMENT ASSOCIATION

Ultimately,

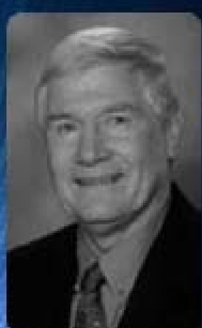
achieving increased in-place asphalt pavement density that results in the highest asphalt pavement performance.

Premise:

- ✓Compaction is essential for long-term pavement performance
- ✓There are many compaction enhancements currently in use
- ✓Compaction goals can be improved

Density is Important

- Hughes, C.S., "Compaction of Asphalt Pavement." NCHRP Synthesis 152, Washington, D.C., 1989.
  - Compaction is the **single most important factor** that affects pavement performance in terms of durability, fatigue life, resistance to deformation, strength and moisture damage.
- Geller, M. Synthesis 152
  - "Compaction is the **most economical** alternative for achieving an increase in the life expectancy of new and rehabilitated pavement."



- Brown, E.R., "Density of Asphalt Concrete – How Much is Needed?" NCAT Report 90-03. 1990.
  - "The amount of voids in an asphalt mixture is probably the **single most important factor** that affects performance throughout the life of an asphalt pavement. The voids are primarily controlled by asphalt content, compactive effort during construction, and additional compaction under traffic."

Reasons for Obtaining Density

Cracking

- To improve fatigue cracking resistance
- To improve thermal cracking resistance

Rutting

- To minimize prevent further consolidation
- To provide shear strength and resistance to rutting

Moisture Damage

- To ensure the mixture is waterproof (impermeable)

Aging

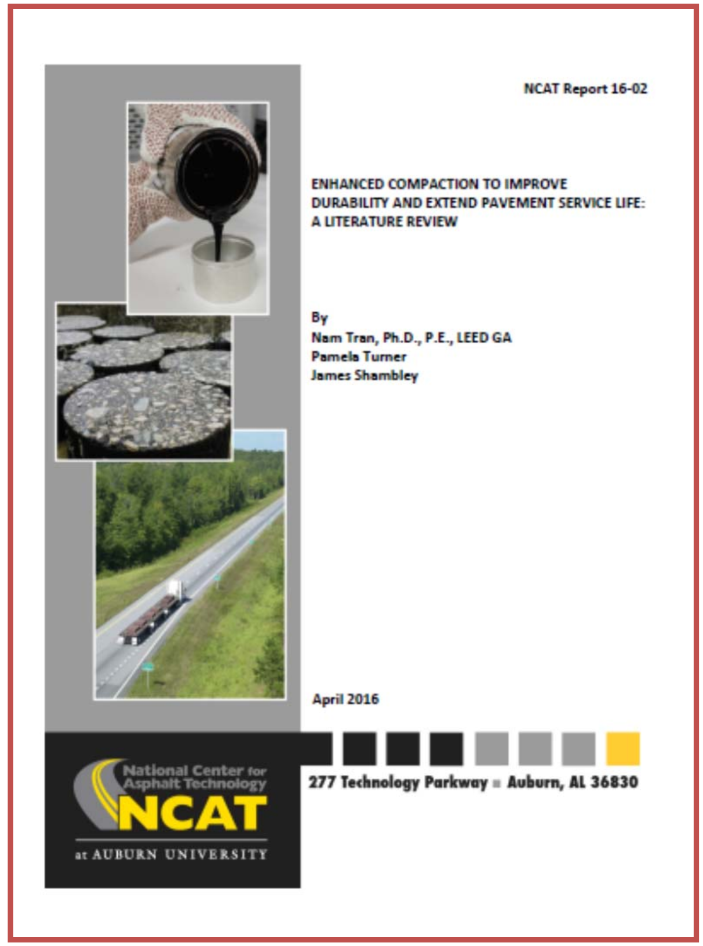
- To minimize oxidation of the asphalt binder

Density is important, but not a cure-all remedy

NCAT Report 16-02 (2016)

"A **1% decrease in air voids** was estimated to:

- <u>improve fatigue</u> performance by 8.2 and 43.8%
- <u>improve the rutting</u> resistance by 7.3 to 66.3%
- **<u>extend the service life</u> by conservatively 10%**."

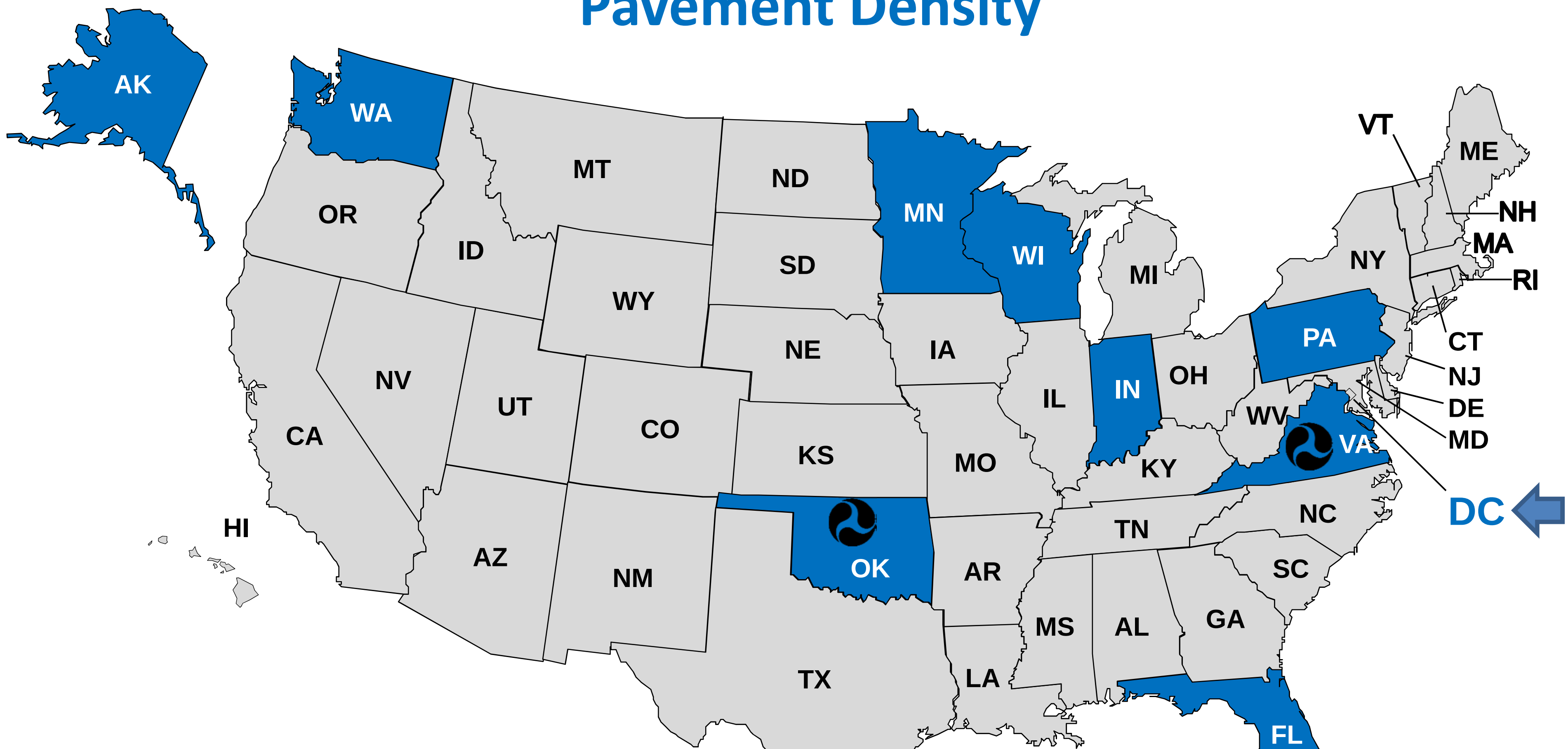


http://eng.auburn.edu/research/centers/ncat/files/technical-reports/rep16-02.pdf

Project Support

- Compaction Workshop
  - Feedback Very Positive
  - Formal training
  - Comprehensive
- Field Projects
  - Pre-paving meeting attendance and advice
  - On-site technical advice

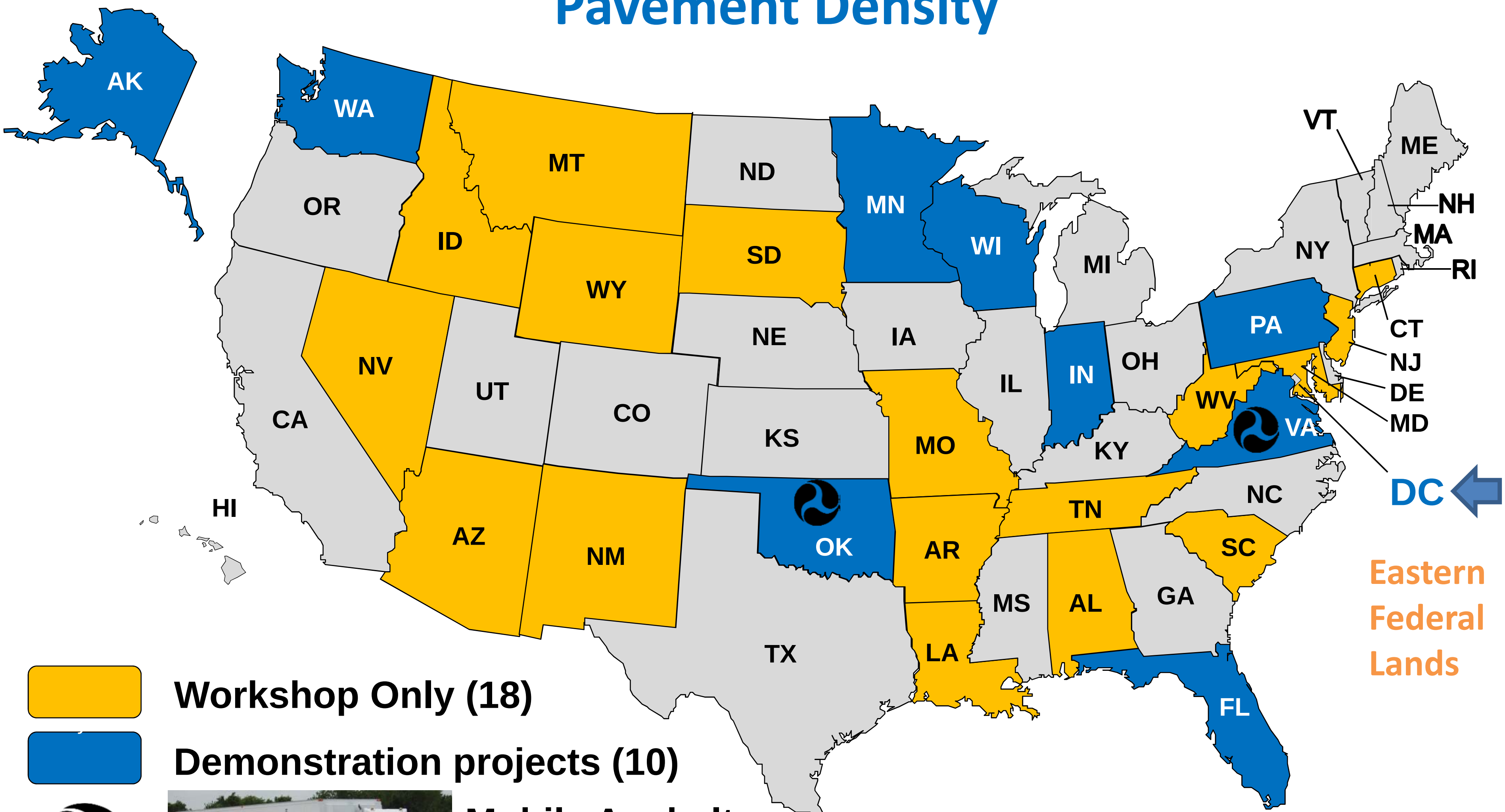
Enhanced Durability of Asphalt Pavements through Increased In-Place Pavement Density



Demonstration projects (10)

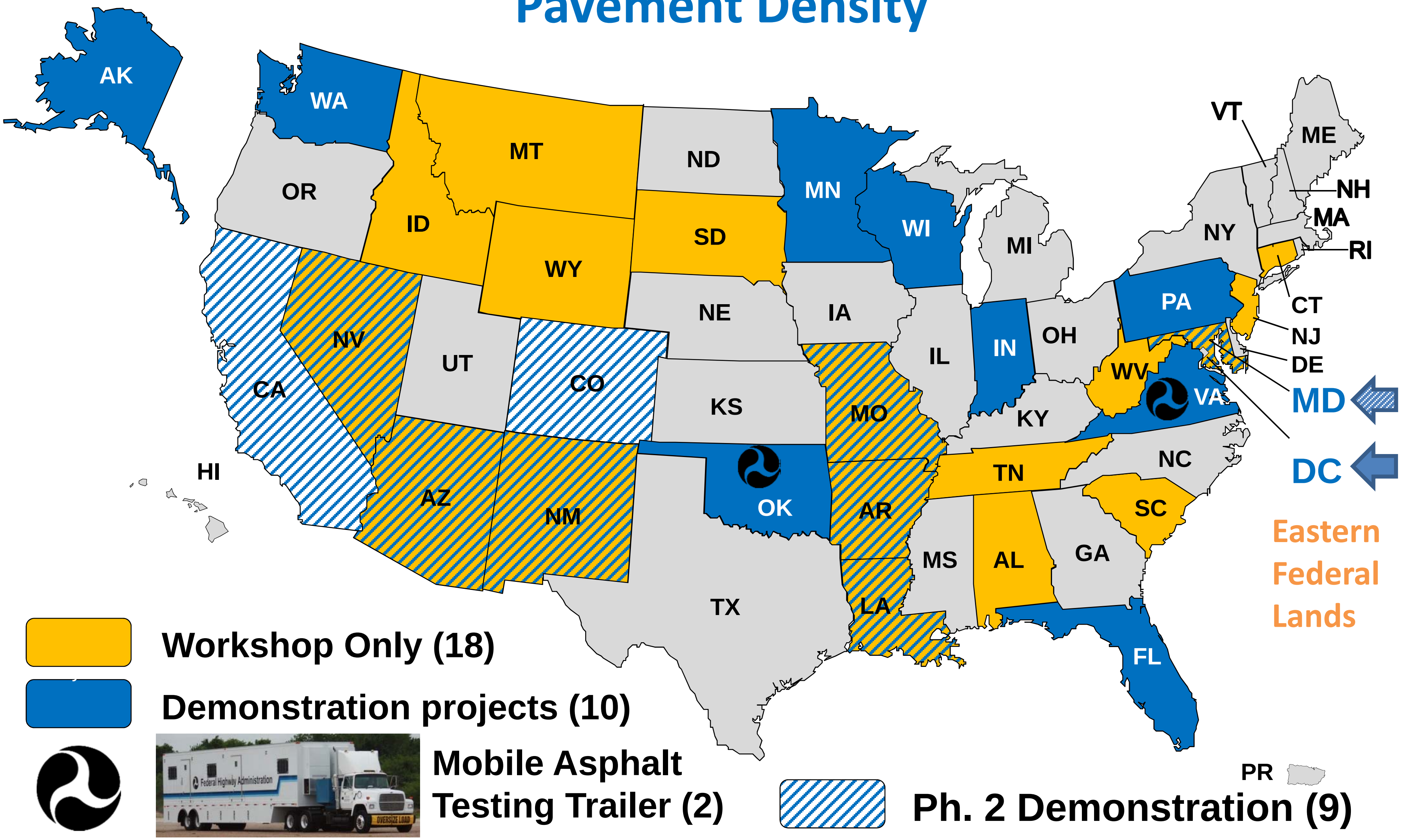
Mobile Asphalt Testing Trailer (2)

Enhanced Durability of Asphalt Pavements through Increased In-Place Pavement Density



Mobile Asphalt Testing Trailer (2)

Enhanced Durability of Asphalt Pavements through Increased In-Place Pavement Density



Achieving Increased In-place Density

1. % Density Requirement
2. Optimum Asphalt Content
3. Consistency
4. Best Practices
5. New Technology

State #1

	Location	Mode	Passes	Equipment
	Delivery	MTV		Roadtec SB-2500
Control	Breakdown	Static	9	CAT CB54
		Static	9	CAT CB54

State #1

Experiment	Contractor's Compactive Effort
Test Section 1	**Added 1 to 2 vibratory passes**
Test Section 2	**Added pneumatic** - CAT CW34

State #1

Experiment	Density Results (%)	Change
Control	93.5	---
Test Section 1	93.2	Not significant
Test Section 2	95.4	+ 1.9

Average of 10 core densities each / Reference is G_{mm}

- 2 static rollers achieved full incentive
- Using vibratory mode resulted in no change in % density
- Adding pneumatic increased % density

State #2

	Location	Mode	Passes	Equipment
	Delivery			End Dumps
Control	Breakdown	Vibratory	7	BW 161 AD-5 (10 ton)
	Finish	Static	7	BW 138 AD-5 (4 ton)
Test Section	Breakdown	Vibratory	9	Same

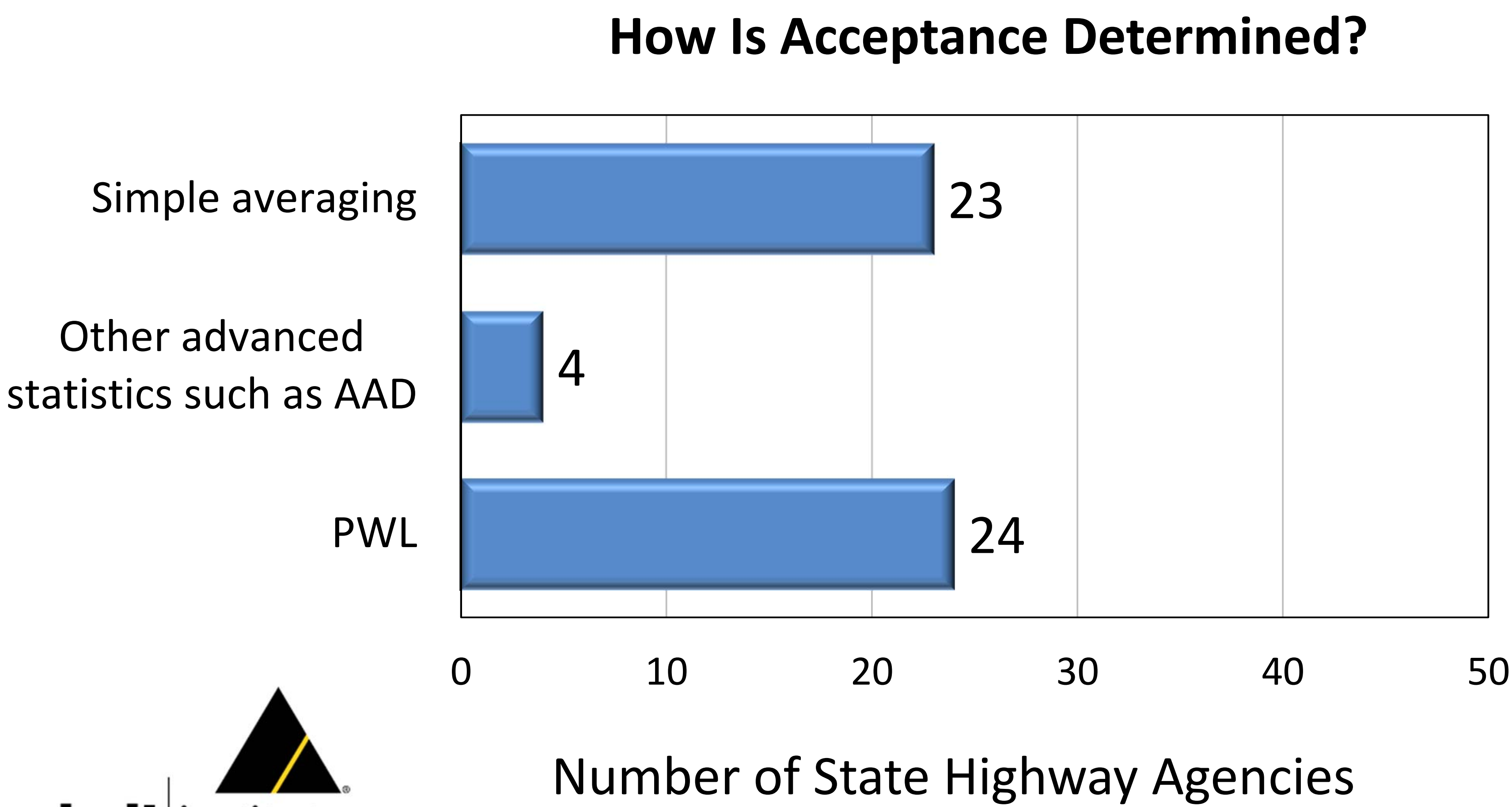
State #2

Experiment	Density Results (%)	Change
Control	91.0	---
Test Section	91.8	≈ + 1

Average of 6 cores each / Reference is G_{mm}

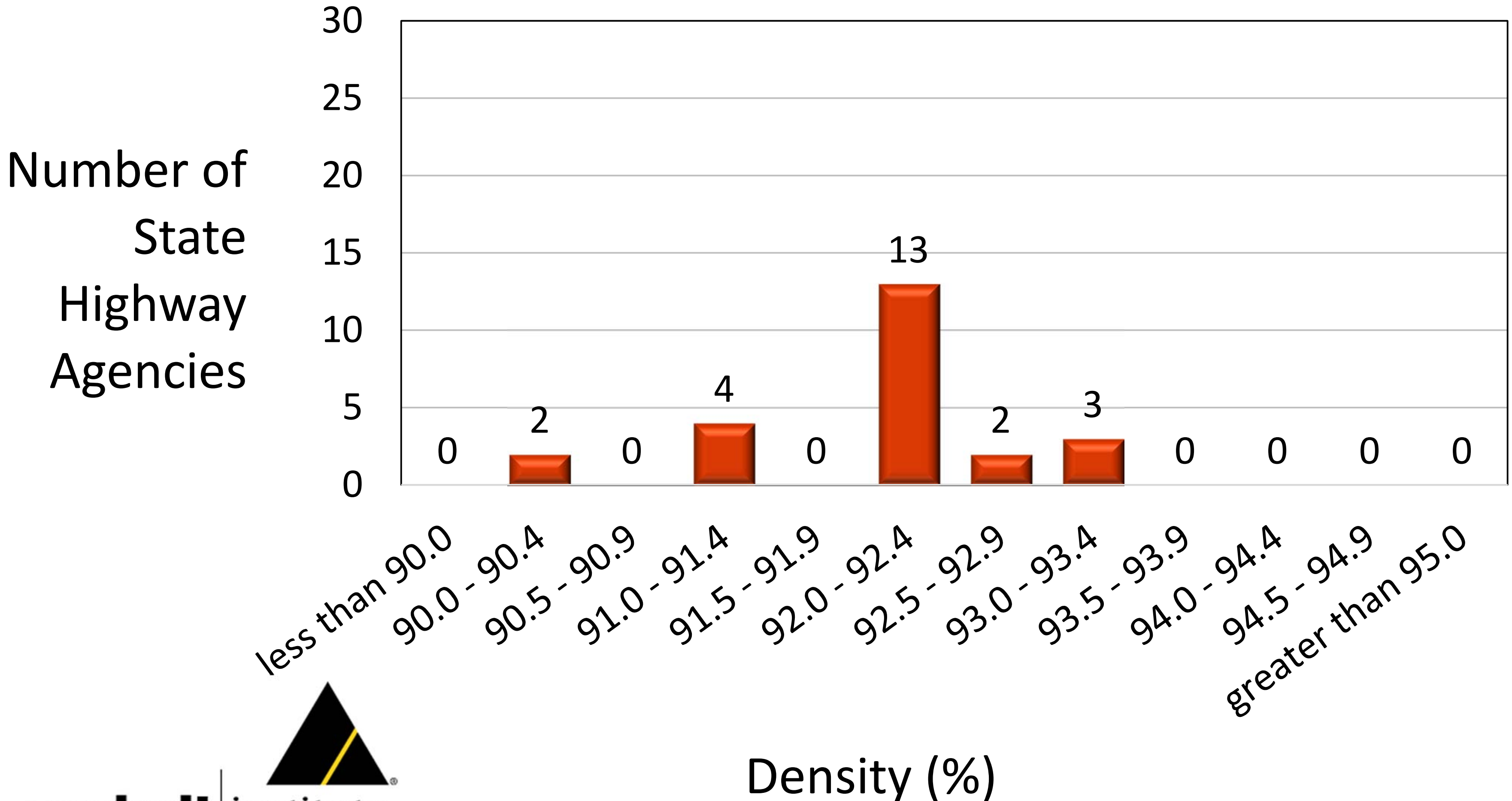
- Only 1 compaction roller needed to meet specification
- Adding 2 passes increased % density

How Is Acceptance Determined



2016

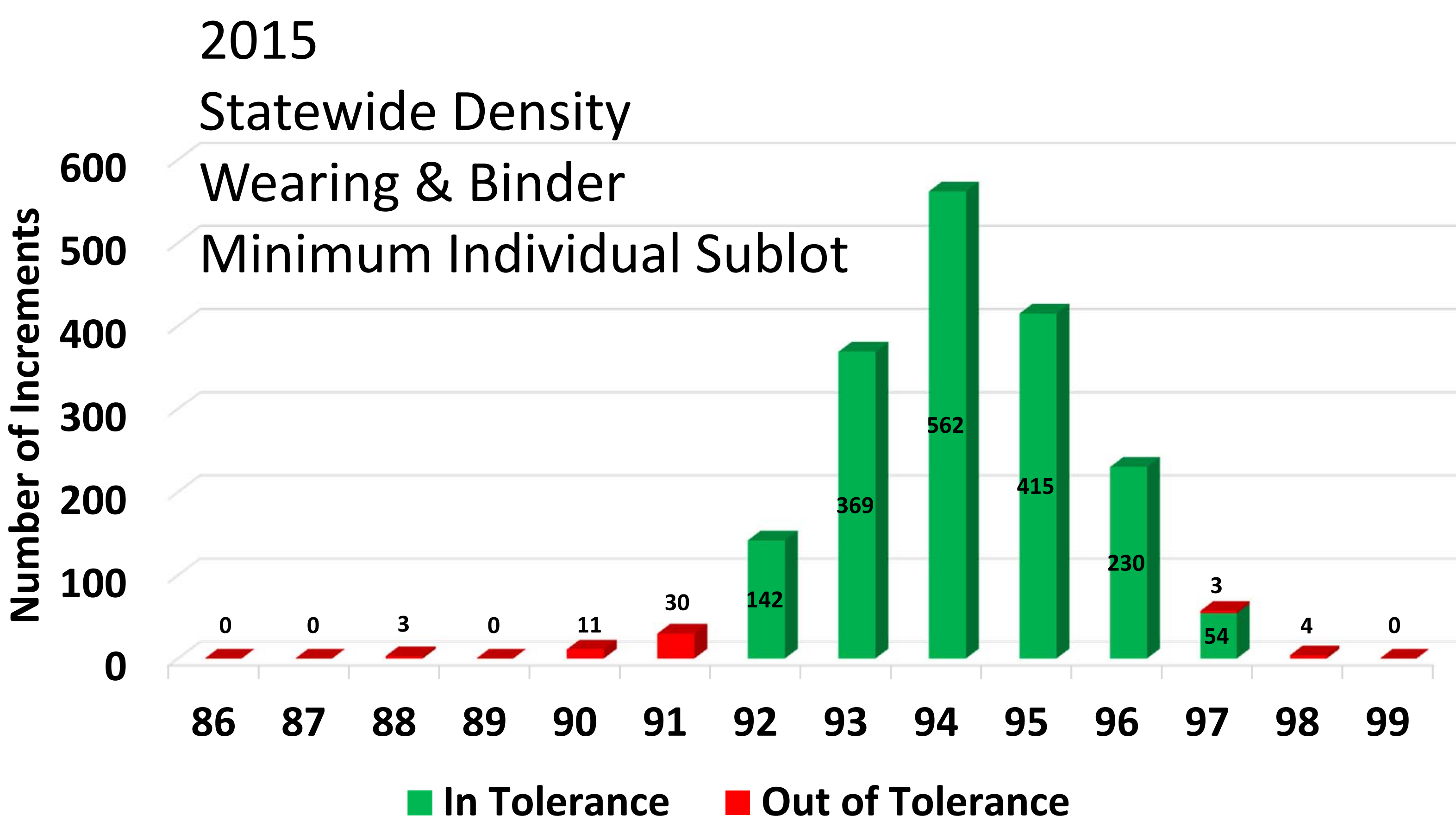
Minimum Lot Average



asphalt institute

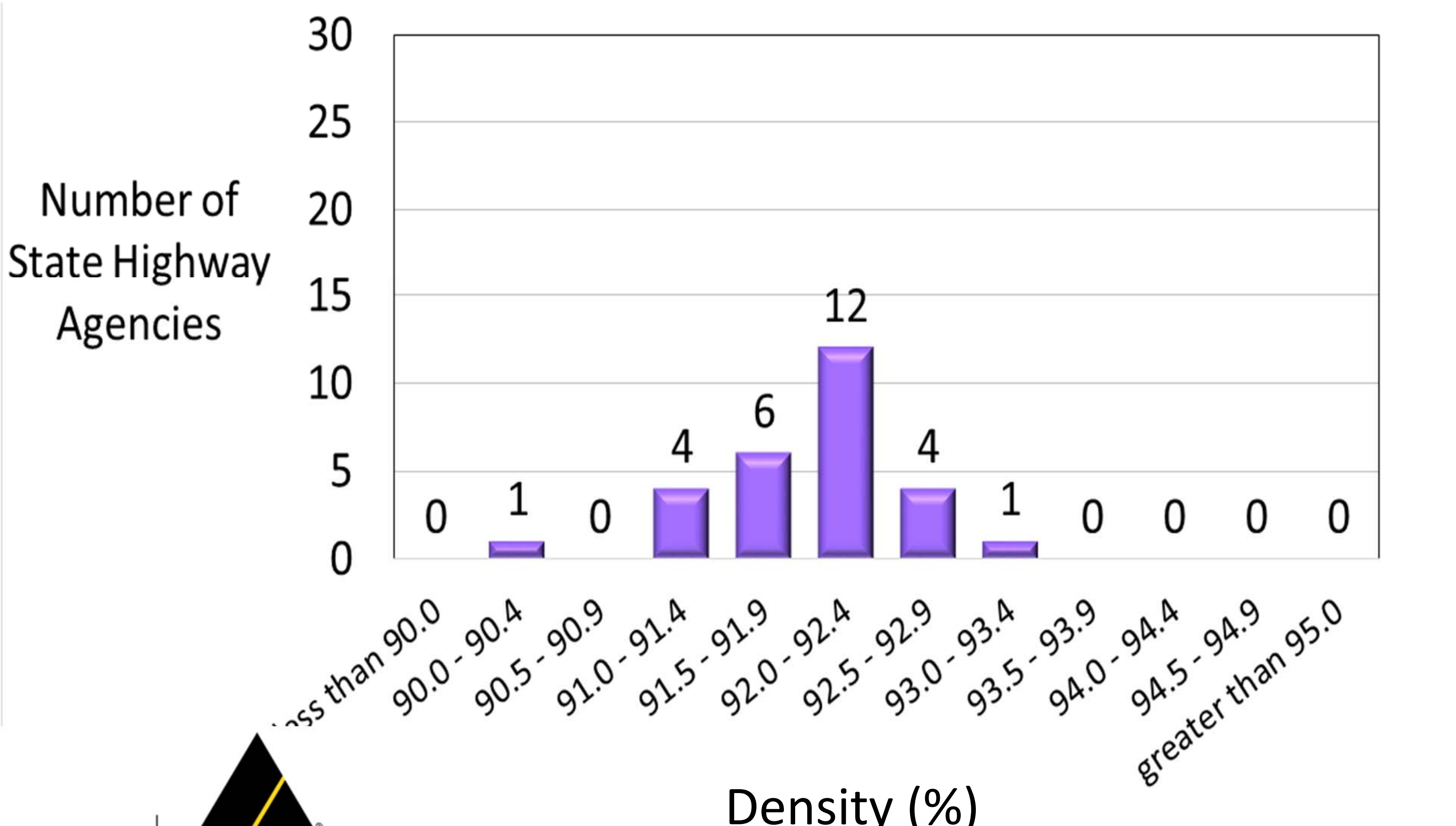
2016

PennDOT Case Study



pennsylvania
DEPARTMENT OF TRANSPORTATION

PWL: Lower Specification Limit

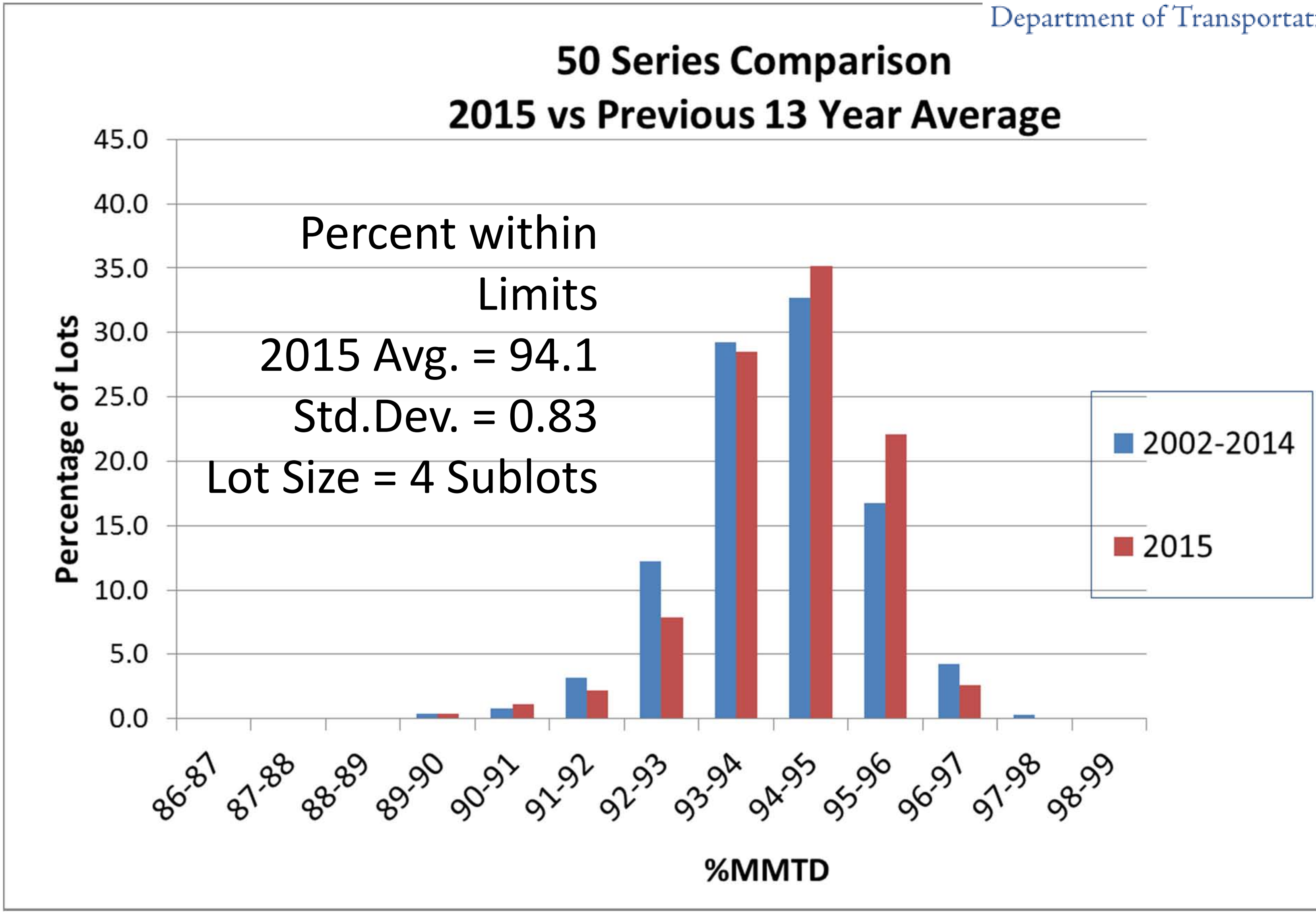


asphalt institute

2016

NYSDOT Case Study

New York State
Department of Transportation



Achieving Increased In-place Density

1. % Density Requirement
2. Optimum Asphalt Content
3. Consistency
4. Best Practices
5. New Technology

State #3

	Location	Mode	Passes	Equipment
	Delivery	Bottom Dumps		Cedar Rapids MS2
Control	Breakdown	Vibratory	5	Dynapac CC 624
		Vibratory	5	Dynapac CC 624
	Intermediate	Pneumatic	7	CAT CW35
		Pneumatic	7	Hamm GRW18

State #3

Experiment	Contractor's Compactive Effort
Test Section 1	**Added 1 vibratory roller** – Hamm HD130 (5 total rollers)
Test Section 3	**Added 0.3% asphalt** (5 total rollers)

State #3

Experiment	Density Results (%)	Change
Control	92.9	---
Test Section 1	92.9	No change
Test Section 3	94.1	+ 1.2

Average of 8 core densities each / Reference is G_{mm}

- 4 compaction rollers needed to meet specification
- 1 additional roller did not change % density
- Mix design adjustment resulted in % density increase
- Added new technology: IC, IR, and RDM

State #4

	Location	Mode	Passes	Equipment
	Delivery	MTV		Weiler E2850
Control	Breakdown	Vibratory	5	Dynapac CC 624 HF
		Vibratory	5	Volvo DV 140B
	Intermediate	Pneumatic	11	Hamm GRW280

State #4

Experiment	Contractor's Compactive Effort
Test Section 1	**Added 1 vibratory roller** – Dynapac CC 524 HF (4 rollers)
Test Section 3	**Added 0.3% asphalt** (4 rollers)

State #4

Experiment	Density Results (%)	Change
Control	93.5	---
Test Section 1	95.0	+ 1.5
Test Section 3	95.4	+ 1.9

Average of 12 nuclear gauge readings each / Reference is G_{mm}

- Control achieved maximum incentive
- Additional roller and mix design adjustment resulted in % density increase

Selecting Optimum with Superpave

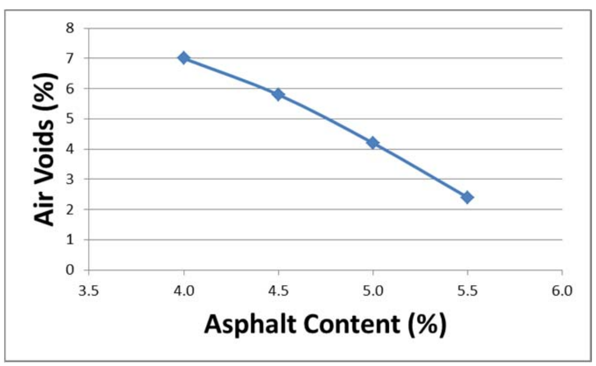
What Changes Were Made to AASHTO Standards?

- Gyrations
- Air Voids
- Voids in the Mineral Aggregate (VMA)
- Is There Additional Criteria?

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
AASHTO
THE VOICE OF TRANSPORTATION

Asphalt Mixture Adjustments

State	Adjustments	Additional Asphalt
3	↓ Gyrations (Regression)	0.3%
4 & 5	↓ Air Voids (Regression) ↑ VMA	0.3%
6	↓ Gyrations ↑ Air Voids ↑ VMA	≈ 0.1%

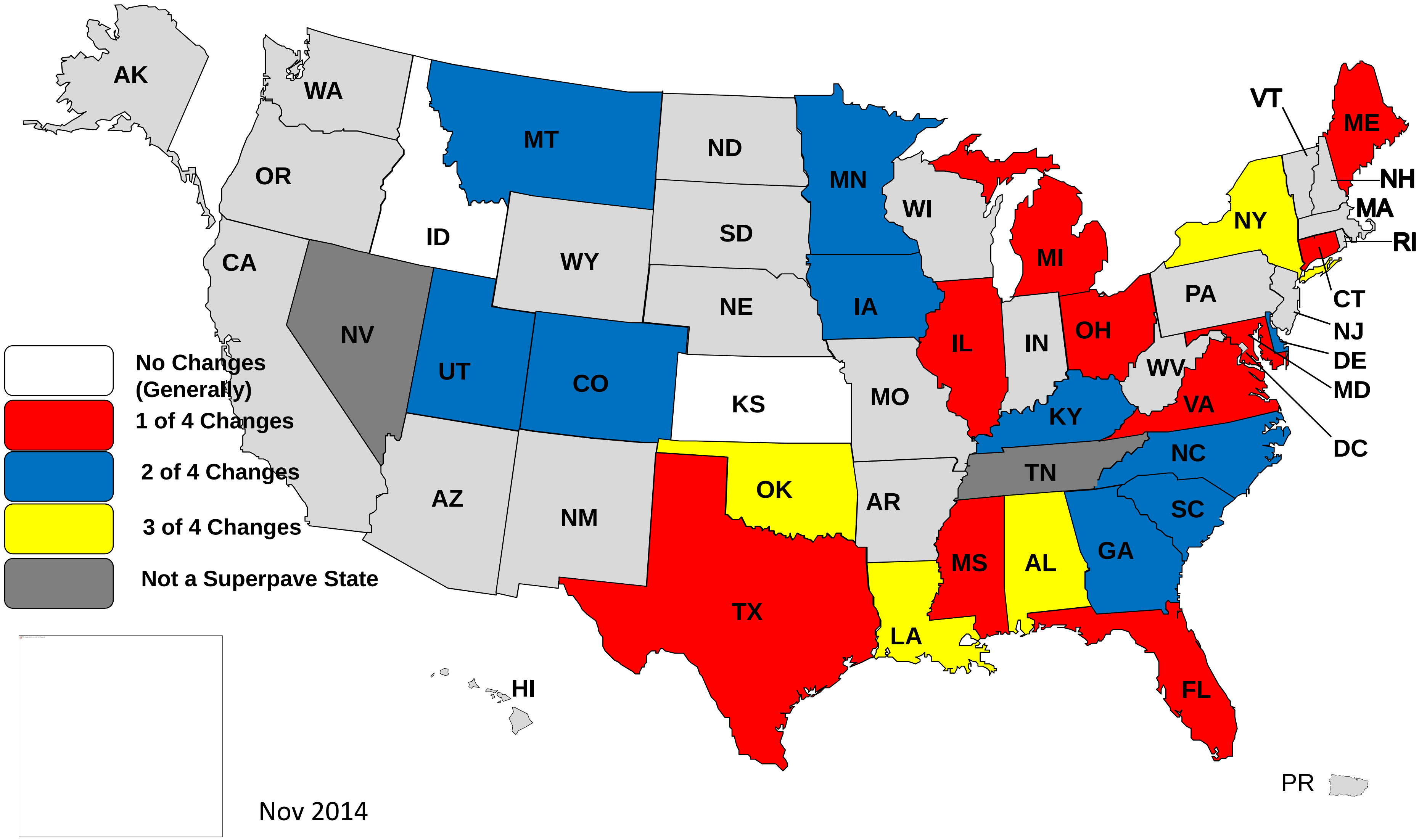


Important Note:

Be sure to update minimum % density requirements

Combination of Changes

54% (14 of 26) Made 2 or More Changes



Nov 2014

FHWA Tech Brief

TechBrief

The Asphalt Pavement Technology Program is an integrated, national effort to improve the long-term performance and cost effectiveness of asphalt pavements. Managed by the Federal Highway Administration through partnerships with State highway agencies, industry and academia the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement guidelines, methods, procedures and other tools for use in asphalt pavement materials selection, mixture design, testing, construction and quality control.

US Department of Transportation
Federal Highway Administration

Office of Pavement Technology

FHWA-HIF-11-031

December, 2010

SUPERPAVE MIX DESIGN AND GYRATORY COMPACTION LEVELS

This Technical Brief provides an overview of the intent of the Superpave volumetric mix design and a suggested process to evaluate effects of changes to the gyration levels.

Issues with N_{design}

Superpave mix design was first introduced in 1993 with the completion of the Strategic Highway Research Program (SHRP). This new design system was not an evolution in mix design but a revolution. The Superpave (Superior Performing Asphalt Pavements) system introduced a new compactor, the Superpave Gyratory compactor (Figure 1) for densifying mixes in the lab. In addition the new design system introduced aggregate and binder requirements and mixture compactive effort tied to traffic.

Currently the Superpave mixture design system is the predominately used system in the US. Since its introduction many miles of roadway, using the Superpave system have been placed across the country. There has been some concern by various highway agencies that the Superpave mixture design system produces asphalt mixes that are too dry (too low asphalt binder content) and may have resulted in durability issues. A National Cooperative Highway Research Program (NCHRP) project 9-9(1), Report 573 "Verification of Gyration Levels in the N_{design} Table," recommended a reduction in gyratory compaction levels based on studies of densification in the field. Though this study was quite extensive, the relationship in the study between gyratory compaction levels and densification in the field was not strong, as shown in Figure 2. Based on some general trends and statistical correlations the study produced a table that reduced the gyratory levels and recommended their use. The Federal Highway Administration's (FHWA) Asphalt Mixture & Construction Expert Task Group (Mix ETG) concluded after extensive evaluations that no general recommendation could be established for reductions of the gyratory levels. The ETG believed that the data has too wide a

Title: Superpave Mix Design and Gyratory Compaction Levels

Purpose: Evaluate Effects of Changes to Gyratory Levels

Achieving Increased In-place Density

1 • % Density Requirement

2 • Optimum Asphalt Content

3 • Consistency

4 • Best Practices

5 • New Technology

State #7

	Construction Information
Delivery	MTV: Roadtec SB-1500
Control	Current minimum sublot specification
Test Section	New PWL specification

State #7

	Location	Mode	Passes	Equipment
Test Section	Breakdown	Vibratory	4V 1S	CAT CB 54B
		Vibratory	4V 1S	Sakai WS800
		Vibratory	4V 1S	CAT CB 54B
	Joints	Vibratory		??

State #7

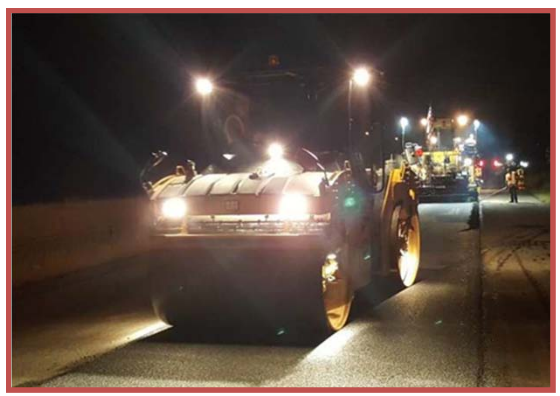
Experiment	Density Results (%)	Change	Pay Factor	Std. Dev. (* Statewide)
Statewide Avg.	93.6	---	---	---
Control	94.4	---	0.97	1.55*
Test Section 1	96.1	+1.7	1.04	0.95*

Average of 5 cores each / Reference is G_{mm}

- Implementing PWL specification

State #8

	Location	Mode	Passes	Equipment
	Delivery	MTV		Weiler E2850
Control	Breakdown	Vibratory	8V 1S	CAT CB 68B
	Intermediate	Pneumatic	15	Dynapac CP30
Test Section	Decrease roller spacing			Same



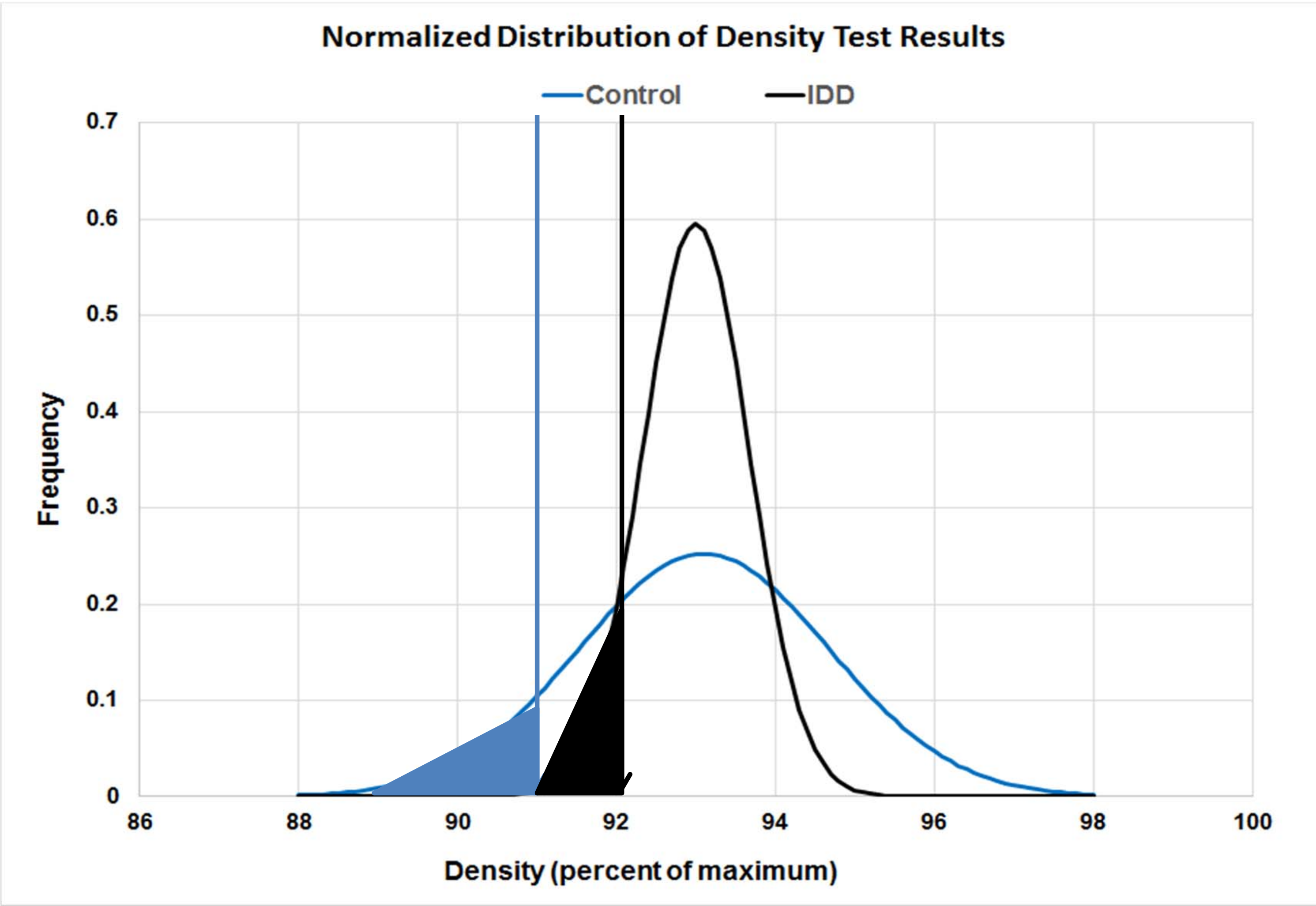
State #8

Experiment	Density Results (%)	n	LSL	PWL
Control	93.1	77	**91.0**	90.3
Test Section	93.0	11	**92.0**	93.3

Standard deviation changes from 1.58 to 0.67 from individual tests
Reference is G_{mm}

- Additional effort by contractor was minimal
- Consistency improvements showed LSL could be 1% higher

Percent Within Limits



Consistency is Important

Standard Deviation

- State #7
  - Cores with lot size = 5 sublots
  - Old Spec: S.D. = 1.58
  - New Spec: S.D. = **0.98**
- State #8
  - Nuclear from individual tests
  - Control: S.D. = 1.58
  - Test Section: S.D. = **0.67**
- NYSDOT PWL Statewide
  - Cores with lot size = 4 sublots
  - 2007: S.D. = 0.92
  - 2015: S.D. = **0.83**

Achieving Increased In-place Density

1. % Density Requirement
2. Optimum Asphalt Content
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4. Best Practices
5. New Technology

State #9

	Location	Mode	Passes	Equipment
	Delivery	MTV		IR MC 330
Control	Breakdown	Vibratory Static	3 6	CAT CB 64B
	Intermediate	Static	7	Hamm HD+ 90

State #9

	Location	Mode	Passes	Equipment
Test Section #1	Breakdown	Vibratory Static	5 2	CAT CB 64B
	Intermediate	Static Oscillatory	2 3	Hamm HD+ 90
Test Section #2	Breakdown	Vibratory	7	CAT CB 64B
	Intermediate	Static Oscillatory	2 3	Hamm HD+ 90

State #9

Experiment	Density Results (%)	Change
Control	92.2	---
Test Section 1	92.0	Not significant
Test Section 2	92.0	Not significant

Average of 10 cores each / Reference is G_{mm}

- % density increase was not significant
- % density results exceeded current specification

Equipment Manufacturer Feedback
Other Best Practices

- Roller settings
- Vibration frequency vs. roller speed
- Amplitude
- Vibrating screed
- Mat temperature
- Paver speed

BOMAG FAYAT GROUP

CAT®

HAMM

SAKAI MASTERS OF COMPACTION

VOLVO

Field Compactive Effort Control Sections

State ID	Total		Vibratory		Pneumatic		Echelon		Focus Area
	Rollers	Passes	Rollers	Passes	Rollers	Passes	Brkdn.	Inter.	
2	1	7	1	7	0	0	No	No	More passes
9	2	16	1	3	0	0	No	No	Oscillation
6	2	14	2	10	0	0	Yes	No	More AC
7	3	15	3	12	0*	0	Yes	No	Std. Dev.
5	3	15	2	10	1	5	Yes	No	More AC
10	2	18	2	18	0*	0	No	No	New Tech.
1	2	18	0	0	0*	0	Yes	No	Pneumatic
4	3	21	2	10	1	11	Yes	No	More AC
3	4	24	2	10	2	14	Yes	Yes	More AC and New Tech.
8	2	24	1	8	1	15	No	No	Std. Dev.

* Polymer Modified Asphalt

% Density
Test Sections

State ID	Total		Breakdown Roller	Field Density (% G_{mm})	Δ from control	Specification	Require-ment	Incentive / Disincentive
	Rollers	Passes						
2	1	9	No echelon	91.8	+ 0.8	Min. Sublot	92.0	D
9	2	12	No echelon	92.0	- 0.2	% Control Strip	98.0	D
6	2	14	Echelon	95.4	+ 2.1	PWL	91.0	I / D
5	3	15	Echelon	95.2	+ 2.7	PWL	92.0	I / D
7	3	15	Echelon	96.1	+ 1.7	PWL	92.0	I / D
10	2	18	No echelon	95.7	+ 0.1	PWL	92.0	I / D
8	2	24	No echelon	93.0	+ 1.0	PWL	91.0	I / D
4	4	26	Echelon	95.4	+ 1.9	Min. Lot Avg.	91.5	D
1	3	27	Echelon / No vibratory	95.4	+ 1.9	PWL	91.8	I / D
3	5	29	Echelon	94.1	+ 1.2	Min. Lot Avg.	92.0	I / D

PWL = Percent within Limits

State 4:
Cost / Benefit of Best Practices

- Benefit of 1 Percent Density Increase
  10 percent of $60 / ton mix = $$$$$$
- Cost of 1 Percent Density Increase
  Additional rollers ≤ $
  AVR to 3% W/binder ≤ $$
  WMA Additive ≤ $
  9.5mm vs. 12.5mm ≈ $$

Achieving Increased In-place Density

1. • % Density Requirement
2. • Optimum Asphalt Content
3. • Consistency
4. • Best Practices
5. • New Technology

QC Tools

SHRP2 Products

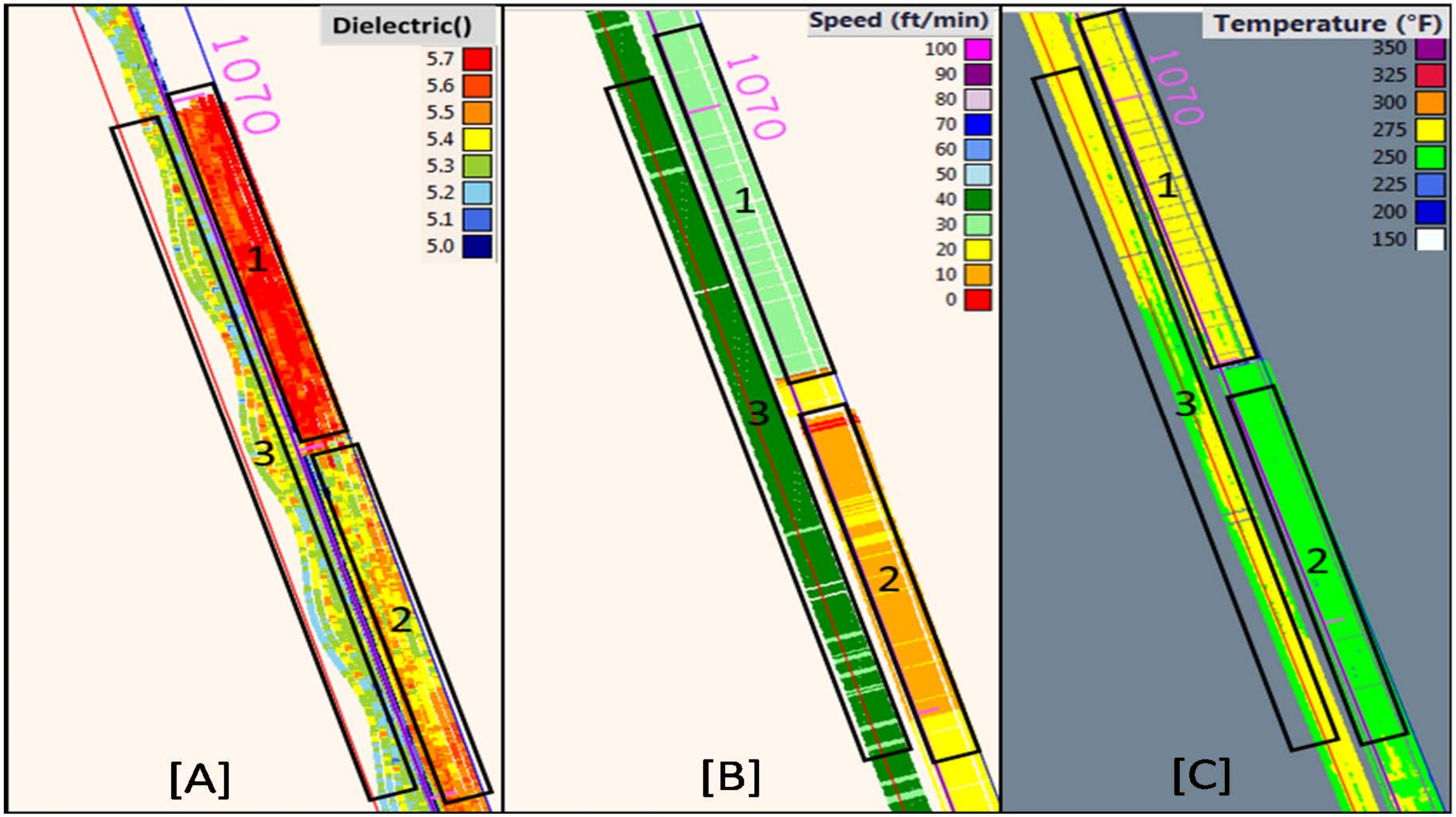
Rolling Density Meter (RDM)

- Density from dielectric constant

Thermal Temperature Scanner (IR Scan)

- Paver speed
- Temperature

States #3 and #10



[A] Density RDM

[B] Paver Speed IR Scan

[C] Temp. IR Scan

Can We Achieve Increased In-place Density?

Test sections had increased % TMD:

- 8 of 10 states achieved > 1.0% increase
- 7 of 10 states achieved > 94.0% G_{mm}
- 6 of 10 states achieved > 95.0% G_{mm}

Will there be changes?

- 7 of 10 states are changing specifications

How Do We Achieve Increased In-place Density?

Measuring density (1)

Reference density (1)

Density of pavement to meet requirements (4)

- Some at 90 to 91% G_{mm}
- Others at 94% G_{mm}

Type of specification (2)

- 22 states use minimum lot average
- 25 states use PWL
  - Impacts contractors' target and consistency

Consistency (2)

- Standard deviations <1.00 were achievable

(#) – States making changes or in the process

How Do We Achieve Increased In-place Density?

Incentives (3)

- 37 states have incentives: range from 1 to 10%
- Average 2.9%

Mixture design changes (5)

- Many states changing Superpave to get more asphalt
- Must also look at density specification

New technologies (2)

- Did not help improve density, but were a good trouble-shooting tool

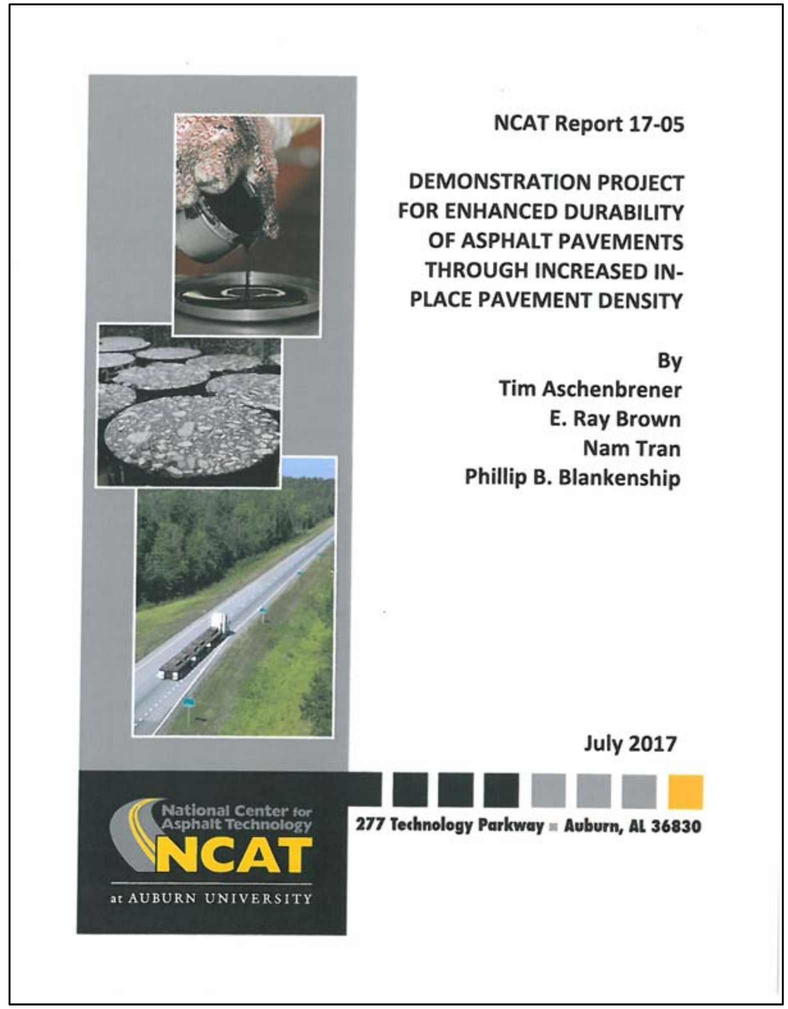
(#) – States making changes or in the process

Summary Document

NCAT Report 17-05:

"Demonstration Project for Enhanced Durability of Asphalt Pavements through Increased In-place Pavement Density"

July 2017



http://eng.auburn.edu/research/centers/ncat/files/technical-reports/rep17-05.pdf

Next Steps

- Extend field experiment – Phase 2
  - 9 states selected
  - Projects under construction in 2017 and early 2018
- FHWA's best practices communication
  - Summary document
  - Tech Brief
  - Additional workshops
    - Funding dependent

Thank you

QUESTIONS / COMMENTS:

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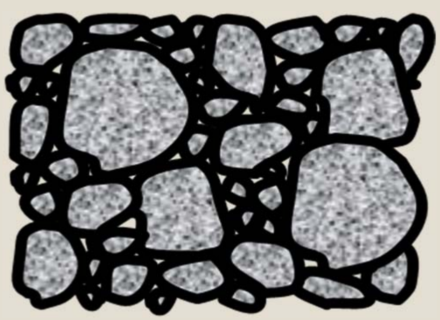
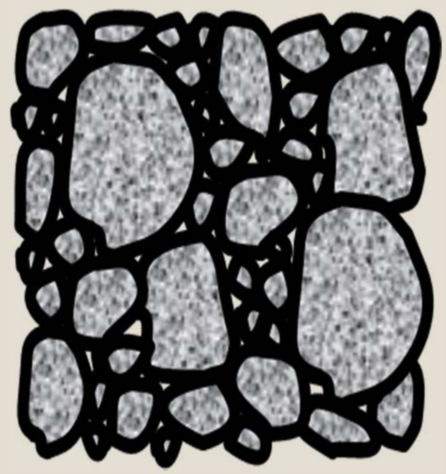
Changing Gyrations

100 Gyrations

75 Gyrations

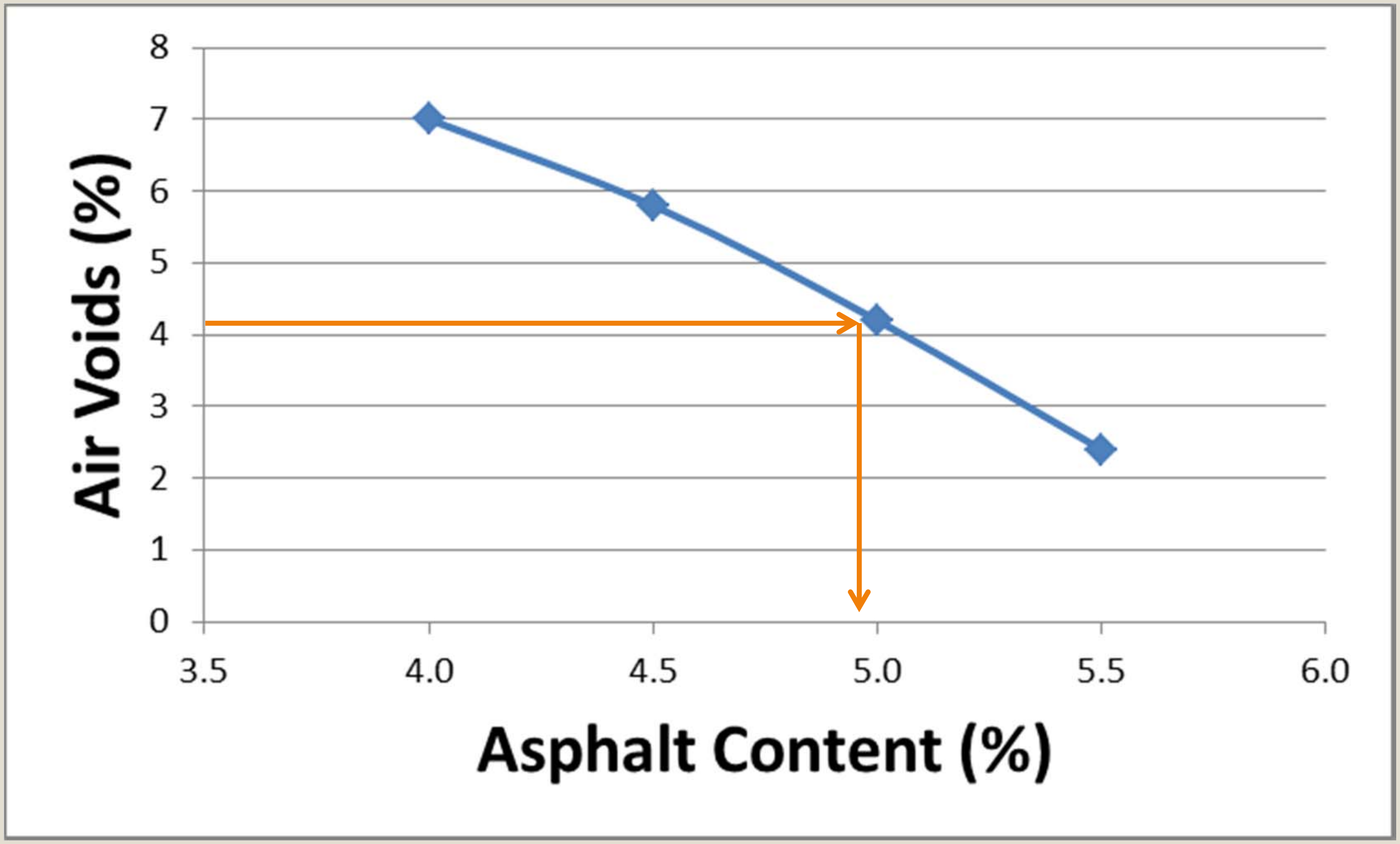


Will there be 0.3% more asphalt content?

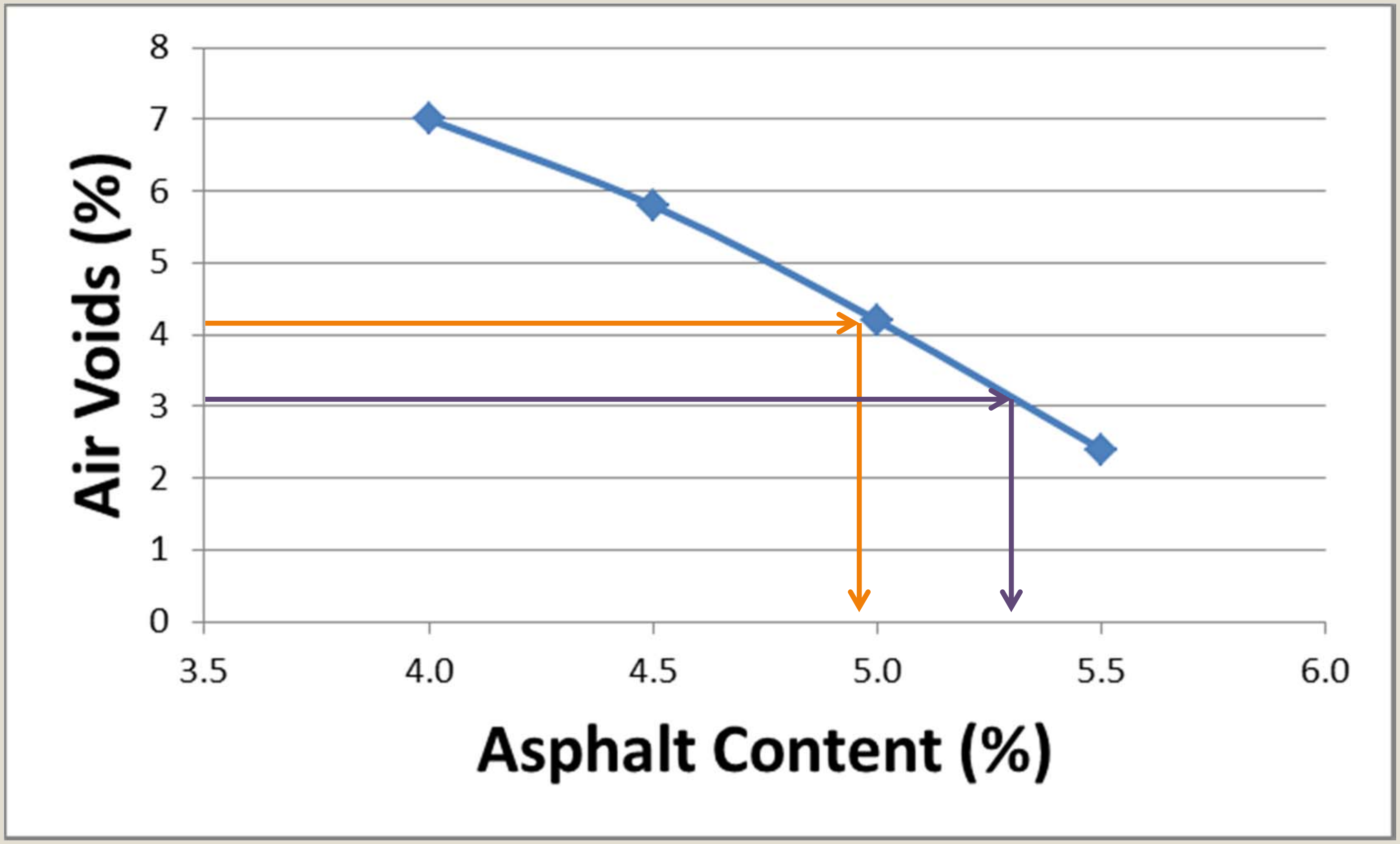


Not to Scale

Selecting Optimum Asphalt Content with Air Void Regression



Selecting Optimum Asphalt Content with Air Void Regression



RAP Mix Production Best Practices

Adam J.T. Hand, PhD, PE

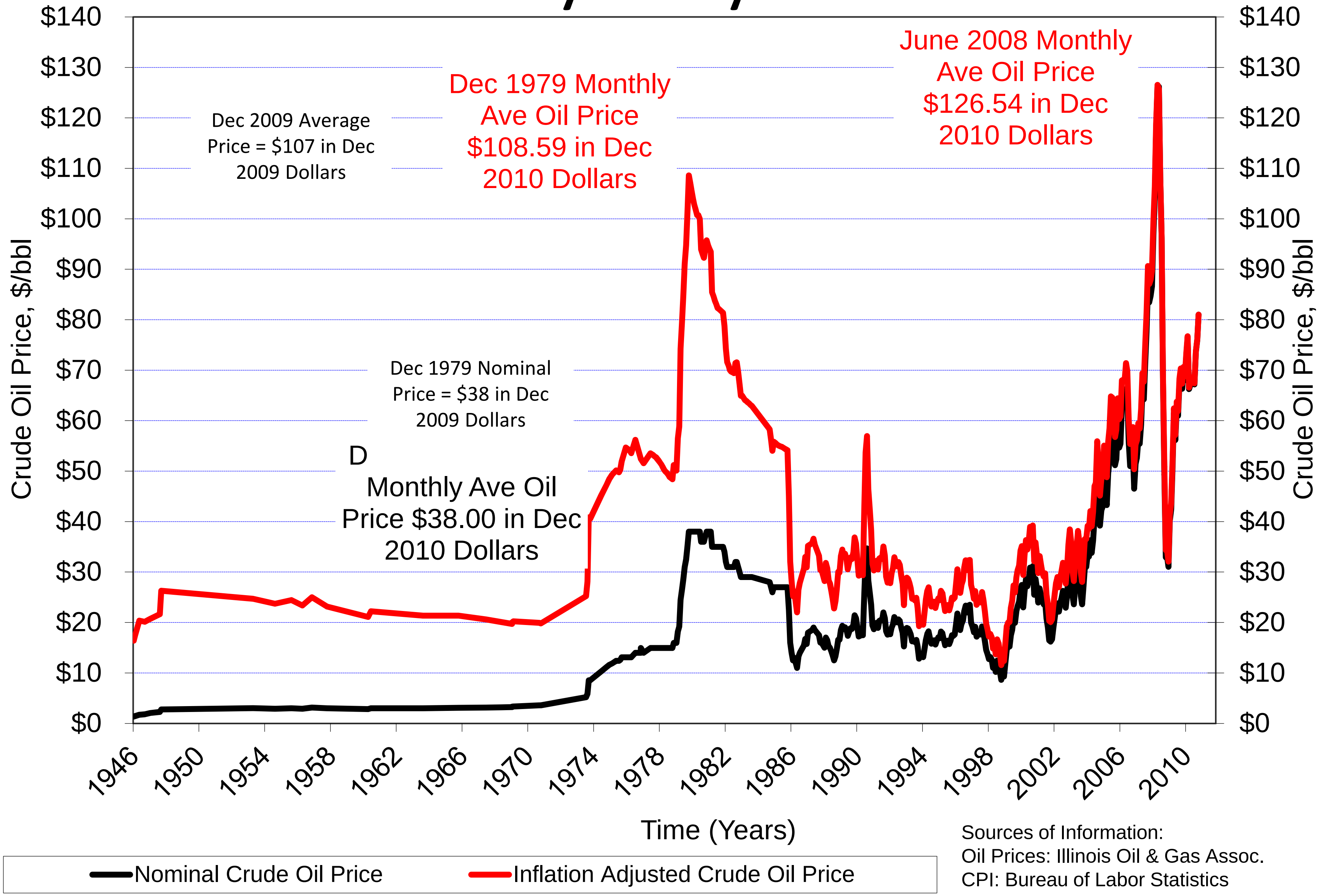
Alaska Asphalt Summit

Anchorage, AK   November 7, 2017

RAP Mix Best Practices

- Why Recycle
- Materials BPs
- Performance
- Production BPs
- What Works/Doesn’t
- Lessons Learned

Why Recycle?



Sources of Information:
Oil Prices: Illinois Oil & Gas Assoc.
CPI: Bureau of Labor Statistics

Recycling Benefits

(In-place or Other)

- Conservation
  - Materials (aggregate, asphalt and cement binders)
  - Energy (raw materials, finished materials, trucking, etc.)
- Preservation of Environment
  - Landfill
  - Greenhouse Gases (GHGs)
  - Sustainability
- Economics
  - Reduce first and life cycle cost
  - Life cycle assessment based selection coming
  - Owner ultimately benefits from cost savings

Green C, R & M Alternatives

- Processes
  - In-place PCC Recycling
  - Cold In-place Recycling HMA
  - Hot In-place Recycling HMA
  - Hot Central Plant Recycling HMA
- Materials
  - Reclaimed Asphalt Pavement (RAP)
  - Reclaimed Asphalt Shingles (RAS)
  - Crumb Rubber Modified Asphalt (CRM)
  - Recycled Concrete Aggregate (RCA)
  - Warm Mix Asphalt (WMA)
  - Porous HMA and PCC *
  - Two Lift PCC *
  - Existing HMA, PCC, and Aggregate Base as Base

Hot Central Plant Recycling

- Pros
  - *Cost Savings*
  - *Materials Savings*
  - Energy Savings
- Cons
  - *Production Rate*
  - Supply
  - Additional
    - Tankage
    - Feeder Bins
    - Separate Silos
  - Washing Crusher Fines

Recycled Materials in HMA
% Savings

Material / Process	Recycled Material Content, %	Recycled Asphalt Binder Content, %	Price	Energy	CO_{2eq}	AC	Agg
Conventional HMA	0	0	-	-	-	-	-
RAP	15	4	5.7	6.1	4.7	11.5	15.2
	25	4	9.5	10.1	8.0	19.2	25.3
Post Industrial Shingles	5	18	6.6	7.6	4.5	17.3	4.3
Post Consumer Shingles	5	32	12.0	13.2	7.4	30.8	3.6
WMA	0	0	0.8	4.3	1.5	0.0	0.0

RAP is Green!

	Annual Consumption/ Production	Estimated Annual Savings		
		15% RAP	25% RAP	50% RAP
Asphalt Binder, tons	29M	3.5M	5.5M	11.3M
Aggregate, tons	521M	31.2M	52.1M	114.6M
HMA Price, $	44B	1.3B ($2.40/ton)	2.2B ($4.00/ton)	4.8B ($8.70/ton)
Energy, 10^{12} Btu	300	15	24	48
CO_2, tons	55.5M	3.9M	6.7M	13.9M

RAP Economics

- Assuming Optimum %AC = 5.0%
  - AC cost ≈ $600/ton ($30/mix ton)
  - Aggregate cost ≈ $20/ton ($19/mix ton)
  - Plus production, trucking, laydown…

- Examples:
  - If 20% ABR ≈ $6/mix ton
  - If 25% ABR ≈ $7.5/mix ton

  - RAP Production Cost
    - Milling, trucking, crushing, stockpiling …
    - *It isn't Free!*

RAP

- Reclaimed Asphalt Pavement

- Removed and/or reprocessed pavement materials containing

  ≈ 5% asphalt binder

  ≈ 95% aggregate

- RAP asphalt binder stiffness
  - PG 80^{+} - 10^{ish}

Reclaimed Asphalt Pavement (RAP)

- **Source: Millings, Plant Waste, R&R (chunks)**
- **Processing: Direct to Crushing, Screening, and Stockpiling**

RAS

- Reclaimed Asphalt Shingles
- Removed and/or reprocessed asphalt roofing shingles or manufacturing waste
  - Tear-Offs
    - ≈ 20% AC
  - Manufacture Waste
    - ≈ 30% AC
- AASHTO PP53/TP78

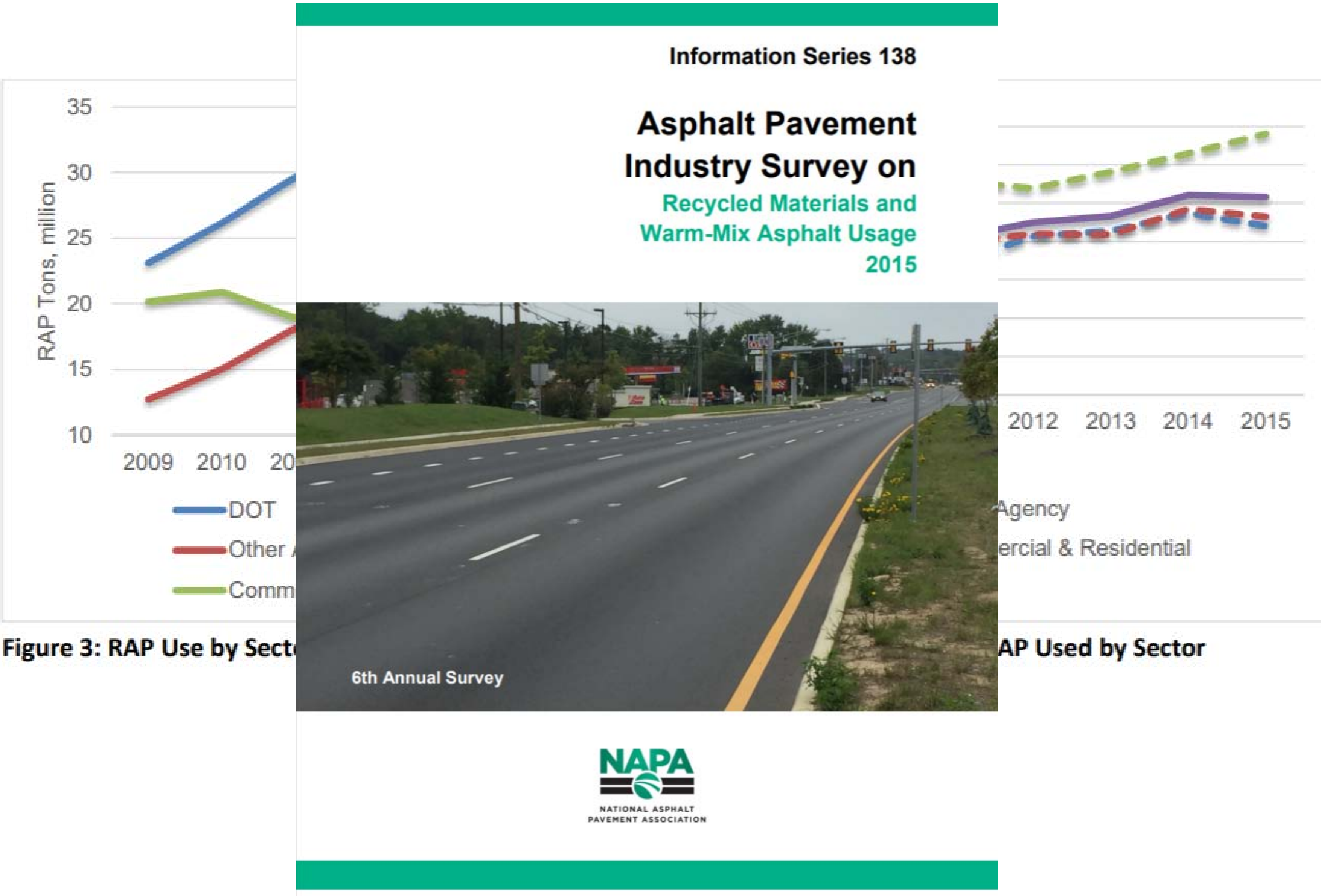
Sources of RAS

- Existing Roofs
  - Primarily Houses
- Manufacturing Waste
  - Tabs
- RAS asphalt binder stiffness
  - PG 120^{+} - 0^{ish}

Reclaimed Asphalt Shingles (RAS)

- **Source: Tear-Offs, Manufacture Waste**
- **Processing: Shredding, Screening, and Stockpiling**
- **1% RAS ≈ 6% RAP**
- **20-30% AC vs. 5% AC**

Recycled Materials Trends



Current NCHRP Projects

- Many Related to High ABR Performance

http://www.trb.org/NCHRP/NCHRPProjects.aspx

Bituminous Materials

NCHRP 09-45	Test Methods and Specification Criteria for Mineral Filler Used in HMA
NCHRP 09-46	Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content
NCHRP 09-47	Engineering Properties, Emissions, and Field Performance of Warm Mix Asphalt Technologies
NCHRP 09-47A	Properties and Performance of Warm Mix Asphalt Technologies
NCHRP 09-48	Field versus Laboratory Volumetrics and Mechanical Properties
NCHRP 09-49	Performance of WMA Technologies: Stage I--Moisture Susceptibility
NCHRP 09-49A	Performance of WMA Technologies: Stage II--Long-Term Field Performance
NCHRP 09-50	Performance-Related Specifications for Asphaltic Binders Used in Preservation Surface Treatments
NCHRP 09-51	Material Properties of Cold In-Place Recycled and Full-Depth Reclamation Asphalt Concrete for Pavement Design
NCHRP 09-52	Short-Term Laboratory Conditioning of Asphalt Mixtures
NCHRP 09-53	Properties of Foamed Asphalt for Warm Mix Asphalt Applications
NCHRP 09-54	Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction
NCHRP 09-55	Recycled Asphalt Shingles in Asphalt Mixtures with Warm Mix Asphalt Technologies
NCHRP 09-56	Identifying Influences on and Minimizing the Variability of Ignition Furnace Correction Factors
NCHRP 09-57	Experimental Design for Field Validation of Laboratory Tests to Assess Cracking Resistance of Asphalt Mixtures
NCHRP 09-58	The Effects of Recycling Agents on Asphalt Mixtures with High RAS and RAP Binder Ratios

What Defines How Much?

- Specifications
- Availability
- Consistency/Variability for Design and Production
- Moisture Content
- Plant Processing/Production Capabilities
- Environmental Drivers and Other Materials

- How Do We Responsibly Maximize the Amount?
  – ***That is a Best Practice!***

Specifications

- % Limits: RAP, RAS, or Binder Replacement
- Rational Specs Key

- If No % Limit
  - RAP Binder Stiffness
  - RAP Gradation
  - RAP Aggregate Source Properties
  - Variability
  - Quality Product
    - We are the Stewards

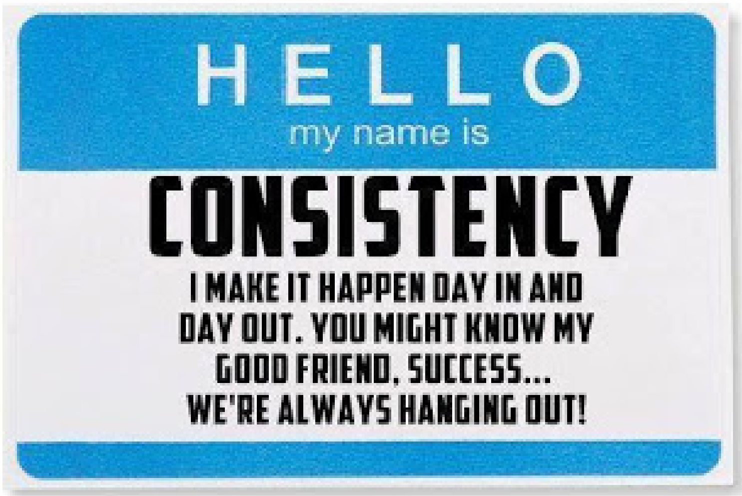
Availability of RAP

- In the Market
  - Amount
  - Recycling Volume (% & Total)
  - Annually 25% Milled
- Competing Use
  - Shoulder Backing
  - Base Course
  - CIPR, HIPR
  - Haul
- Agency Asset
- Cost if Not a Generator

Consistency/Variability

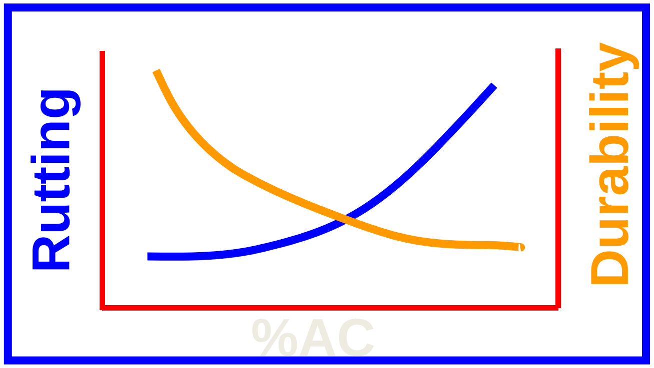
- Gradation and Aggregate Source Properties
  - Acceptance
  - Volumetric Specs – Any Bailey Method Users?
  - Pay Factors - What RAP Amount Maximizes PF?
    - Optimum vs. Change Cost
  - RAP & HMA Production QC Critical

- Feeding
  - Processing
  - Type & Number of Feeders
  - Fractionation of RAP



Design and Consistency/Variability

- Mix Design
  - Asphalt Binder Properties
    - Blending and Additives
  - Gradation, Volumetrics, Agg Props
  - Use Performance Tests!
    - WHY?



- Determine Optimum %RAP – Not All the Same!
  - QC - Material Properties, Design, Pay Factors
  - Plant Ops – Generating, Production, CapEx Options, Washing Fines, Fractionating to ↑ %RAP

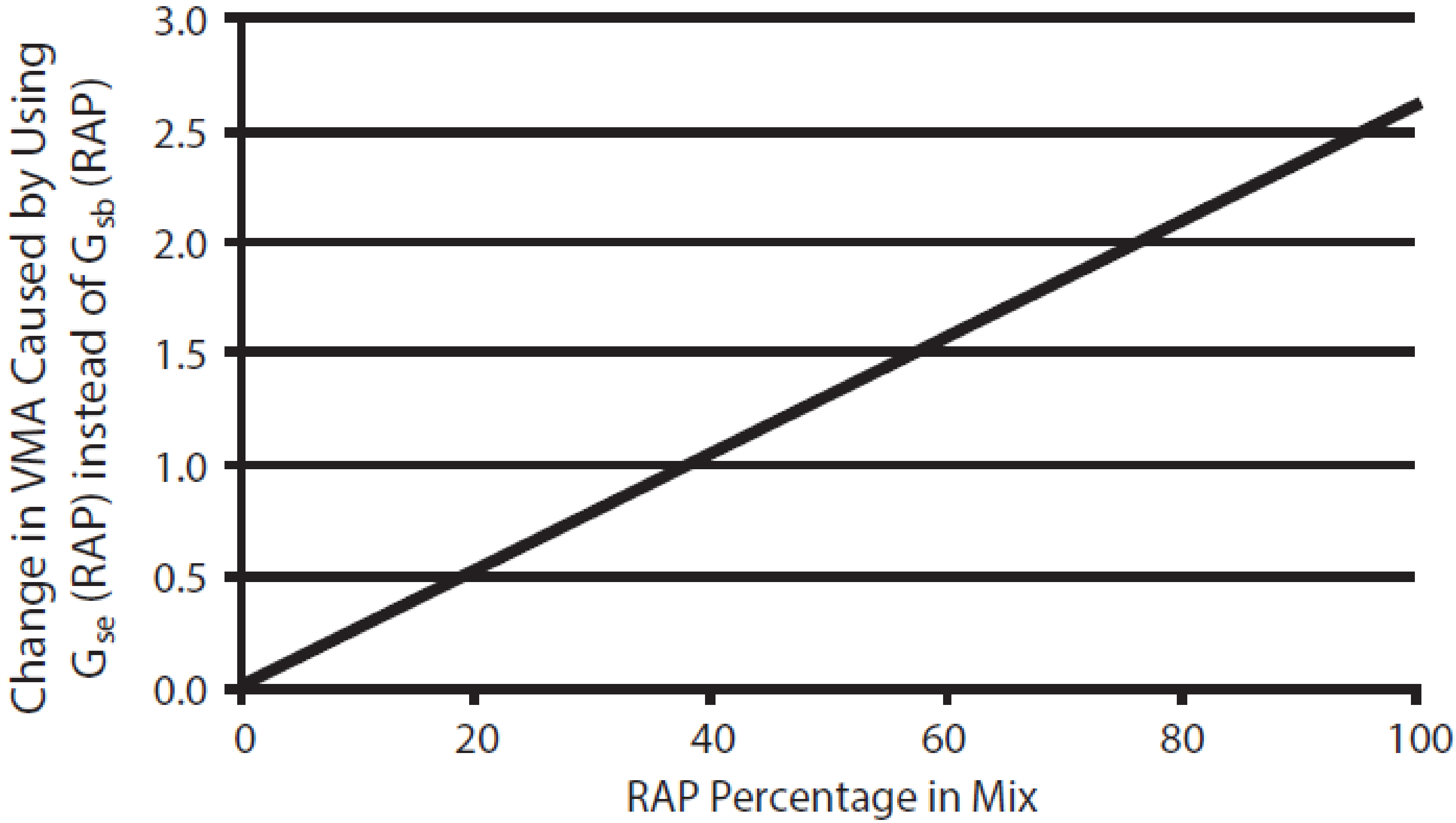
RAP Specific Gravity Determination

Characterize RAP

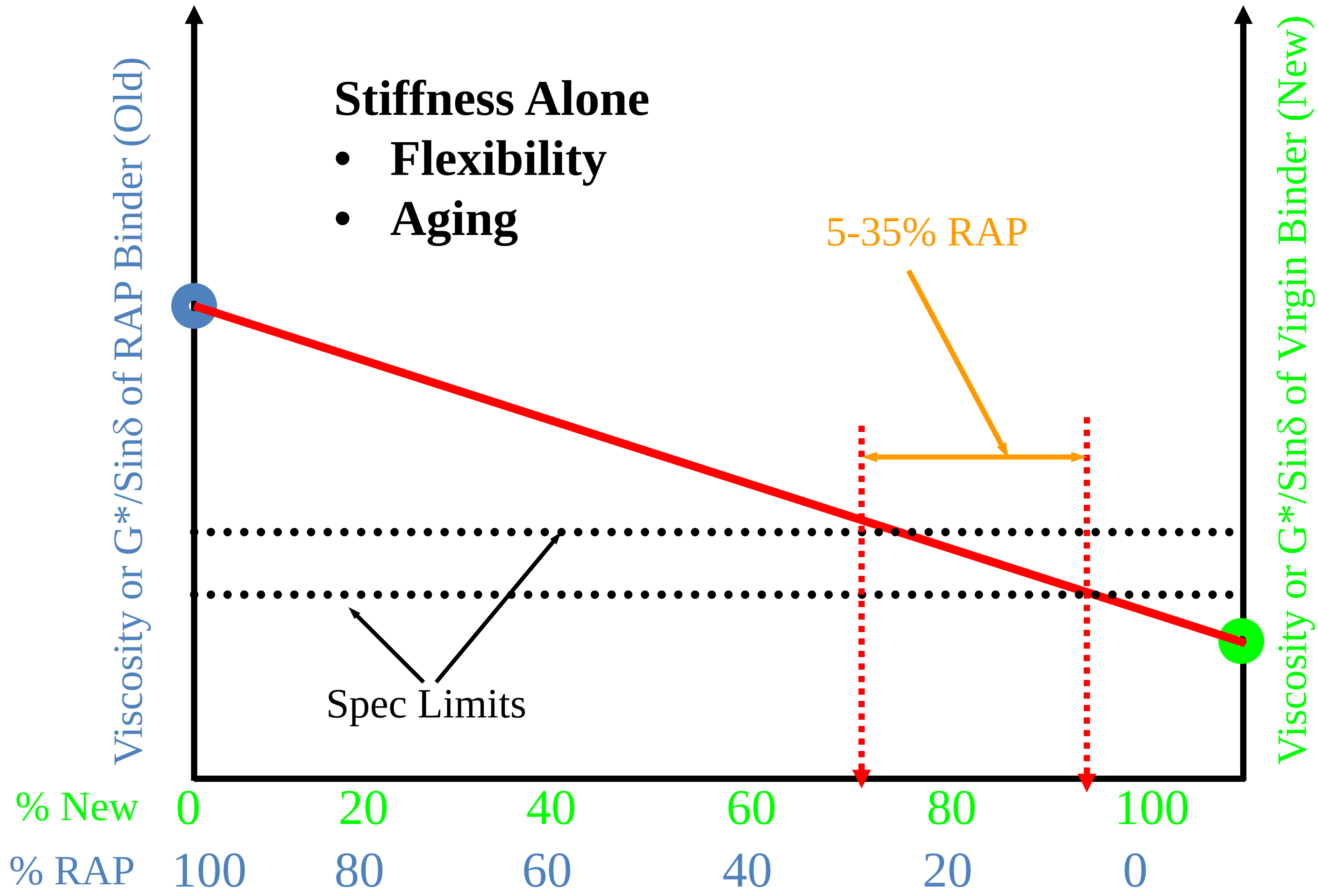
RAP aggregate specific gravity (G_{sb})

- **Method A**
  - Measure extracted RAP aggregate SG
  - Measure % Fine Materials
- **Method B**
  - Assume P_{ba} for RAP aggregate
  - Measure RAP mix G_{mm}
- **Method C**
  - Use RAP aggregate G_{se} in lieu of G_{sb}
  - Measure RAP binder content & G_{mm}

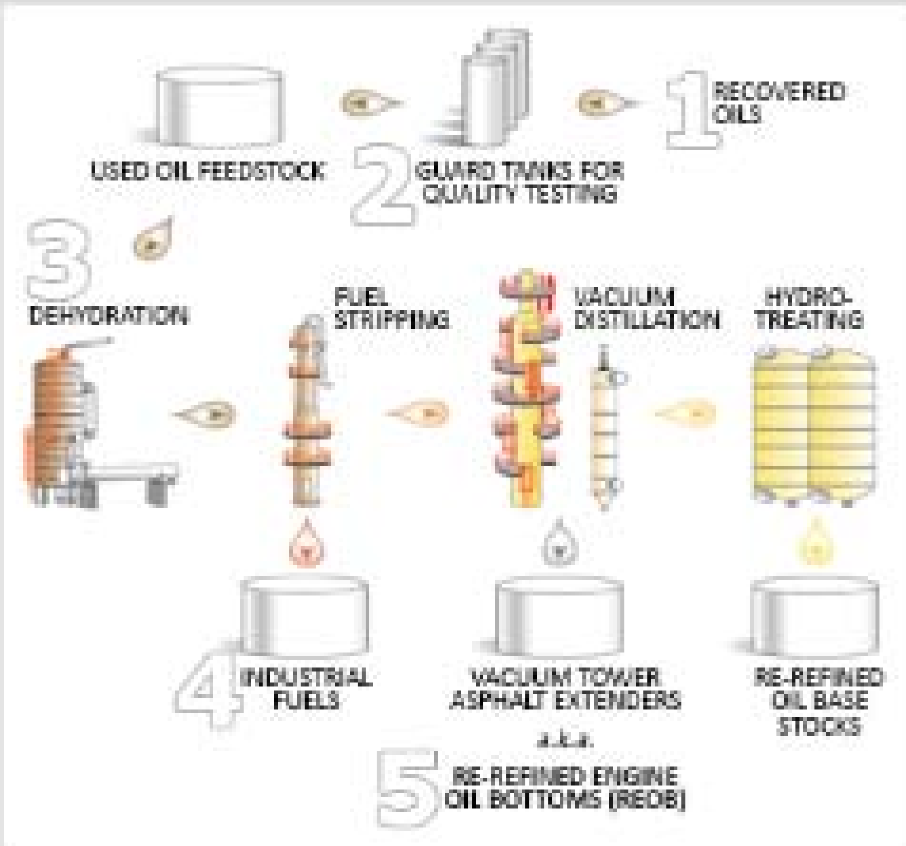
RAP G_{sb} impact VMA



Blending Charts – do they work alone?



REOB and ΔT_c Concept



From recovered oil to REOB: The re-refining of (1) recovered engine oils starts with (2) quality control testing in guard tanks to reject unwanted contaminants. (3) Dehydration drives off water (sent to city treatment), followed by (4) stripping of fuel for internal use or resale. Vacuum distillation extracts gas oils, leaving (5) REOB as the non-distillable fraction (images courtesy of SafetyKleen)

ΔTc Background

- Concerns with long term pavement performance related to binder durability is not new
  - ➢ Predates Superpave & PG binders
  - ➢ Focus of many studies simply related to binder aging
- Asphalt Institute - Anderson 2011 – REOB Concerns
  - – Rheological & ductility of PAV binders and binders recovered from aged field mixtures
  - – Relationship to non-load associated distress
  - – ΔTc of -2.5°C = cracking warning limit, ΔTc =- 5°C point where binder durability lost

So Why is Any of This Important?

- As Binders age they lose the ability to relax stresses, mechanical or thermal
  - Stiffness Increases
  - Ductility Decreases
  - Brittleness Increases
- Having a means of identifying when we can expect field problems would be worthwhile
  - Spread between BBR S & m $T_{critical}$ values increase, ΔT_c becomes more negative

Dry Tensile Strength at 25°C

NCHRP 9-58 (Dec 2017)

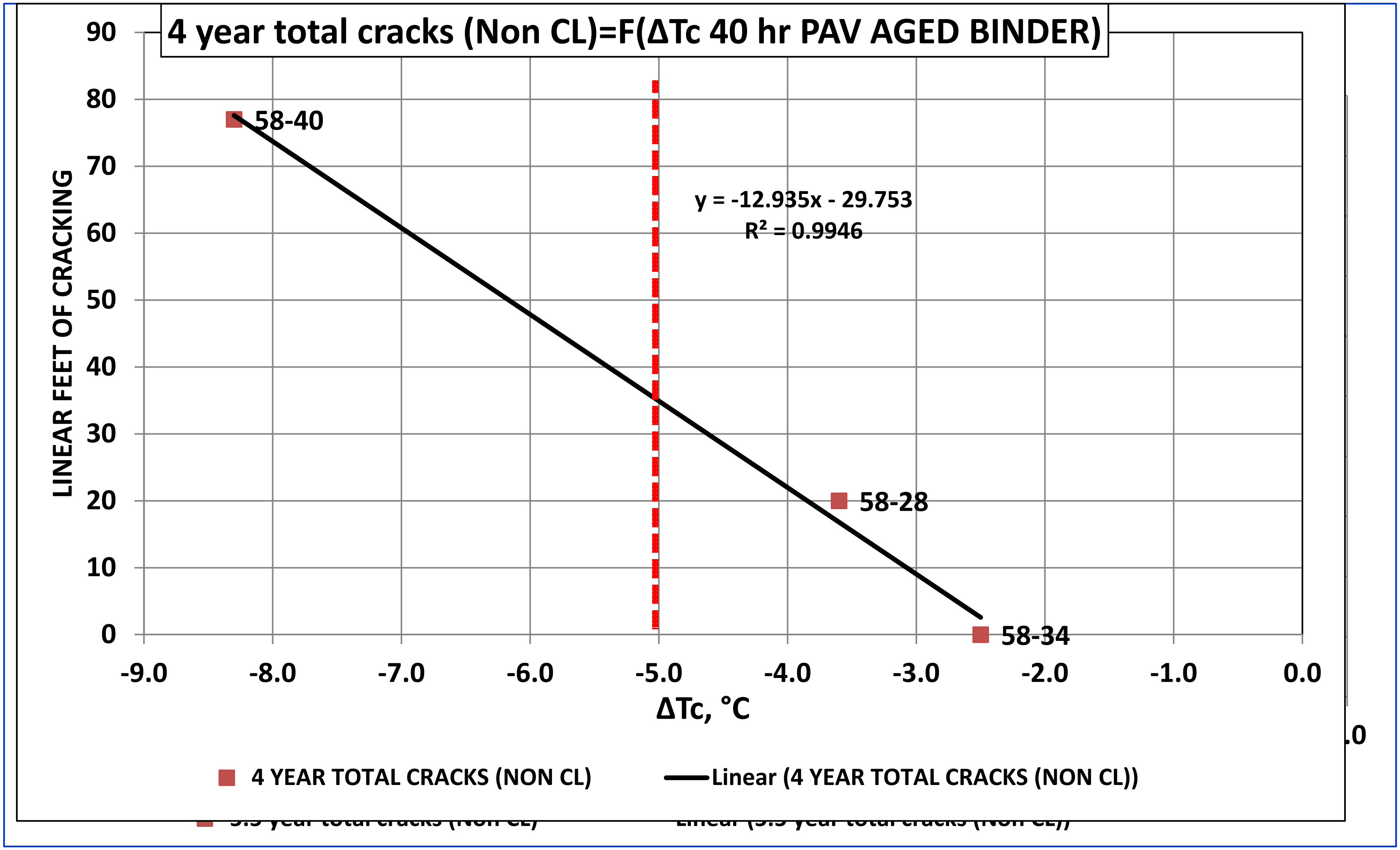
Effects of Recycling Agents on Asphalt Mixtures with High RAS and RAP Binder Ratios

- Recycling Agent or Rejuvenator
- Some Rejuvenators are Very Susceptible to Rapid Aging and Should NOT be used
  - (ΔTc method identifies them)
- Minimum Rejuvenator Dose
  - Different for PG Grade Requirement than Mix Rutting vs. Cracking
- Use Balanced Mix Design

2 Year Old HMA

3 Year Old HMA

MnROAD COMPARATIVE BINDER STUDY



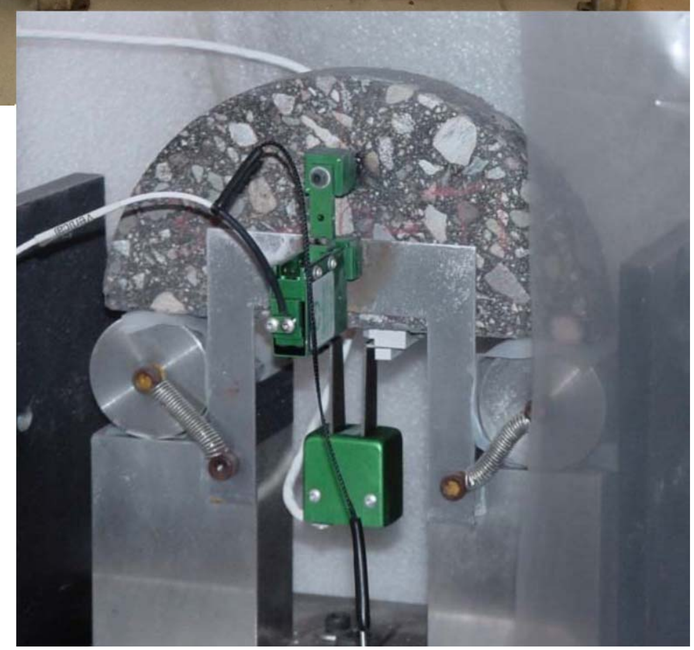
Findings

- Blending Charts and ΔT_c Provide DIFFERENT Answers
- $\Delta T_c < -5°C$ (i.e. more negative) for the 40 hour PAV is associated with the increased levels of pavement distress after approximately 5 years of service
- Use of some blend additives can accelerate the decrease of ΔT_c at equal dosage levels
  - This is exacerbated when trying to accommodate high RAP &/or RAS binder replacement levels
- Use of RAS in mixes at levels ≈ 4% will significantly accelerate the decrease in ΔT_c as mixes age

Our Future

- State DOTs
  - Hamburg for Durability
  - Cracking Test
    - NCHRP 9-57 - $60k
    - SCB or DCT?

- Balanced Mix Design Concept
  - Volumetrics Plus Durability and Cracking Requirements



Processing RAP BPs

RAP Consistency/Variability

- Stockpile and Crush for Consistency
  - Stockpile Uncrushed RAP Horizontally & Mine Vertically w/ Dozer
  - Horiz Impact or Jaw/Roll Crusher with Uniform Feed
  - Cool Weather

Stockpile Management

Impacts of Moisture – Plant Operation

Aggregate Moisture Impacts on Drum Plant Operation

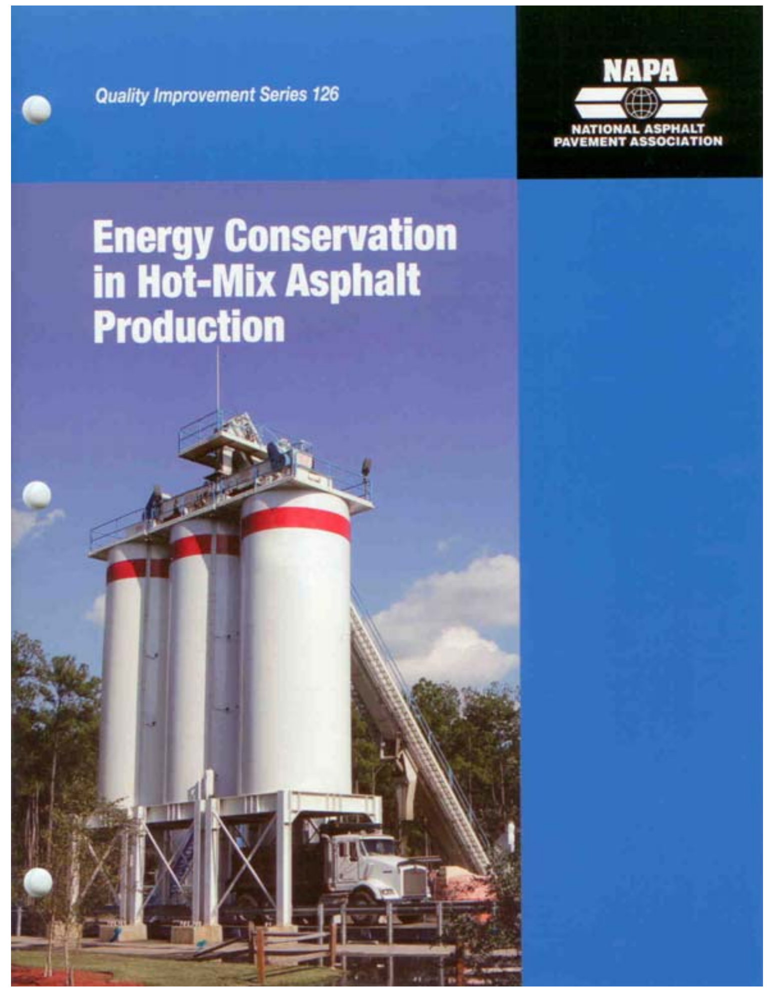
- Drum plant rated capacity is determined by many variables.
  - **Aggregate blend moisture content**
  - Mix discharge temperature
  - Plant elevation
  - Drum diameter
  - Fuel type
  - Exhaust gas velocity
  - Exhaust fan capacity
  - Excess burner air
  - Air leakage
  - Atmospheric conditions
  - Etc.

RAP Moisture

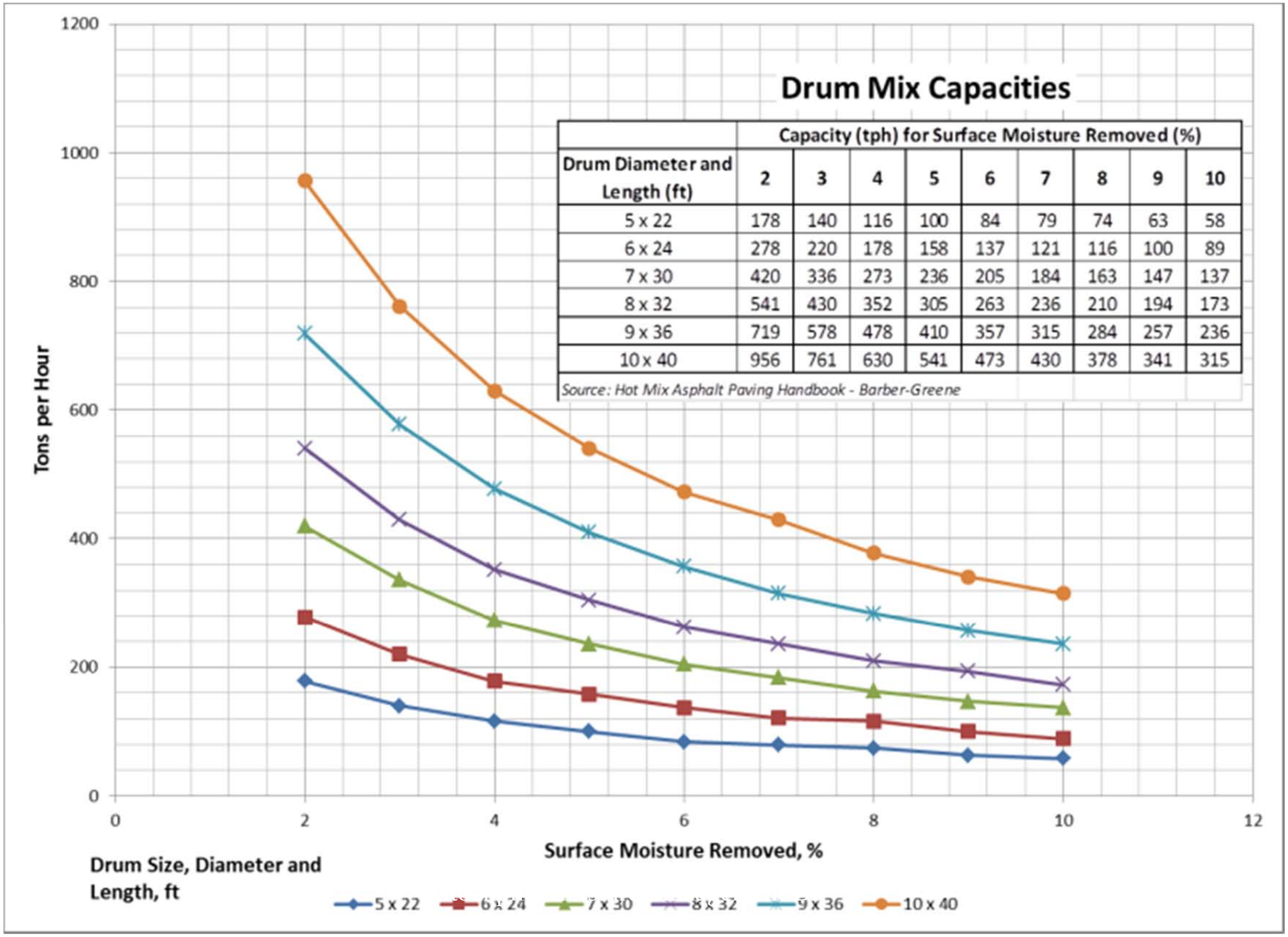
- Impacts:
  - % RAP Usable
  - Production Rate
  - Drying Cost
  - Mix Quality
- Reduce Moisture By:
  - Tall Stockpiles
  - Paving Under Stockpiles
  - Covering Stockpiles

RAP Moisture

- Rule of Thumb:
  - Every ↕ 1% MC, ↕ 10% Energy or Fuel Demand
  - RAP p200, Washed Fines
  - RAP MC + Washed Fines MC
  - See Examples in IS-126



Moisture Impact on Production Capacity



Drum Mix Capacities

Drum Diameter and Length (ft)	Capacity (tph) for Surface Moisture Removed (%)								
	2	3	4	5	6	7	8	9	10
5 x 22	178	140	116	100	84	79	74	63	58
6 x 24	278	220	178	158	137	121	116	100	89
7 x 30	420	336	273	236	205	184	163	147	137
8 x 32	541	430	352	305	263	236	210	194	173
9 x 36	719	578	478	410	357	315	284	257	236
10 x 40	956	761	630	541	473	430	378	341	315

Source: Hot Mix Asphalt Paving Handbook - Barber-Greene

Moisture Impact on Fuel Consumption

- **Rule of Thumb:**
  - **1% Moisture = 24,000 BTU = ~11 to 13% BTU Change**

DRUM DIAMETER	PROCESS GASES THRU DRUM	Percent of Moisture Removed and Gallons of Fuel per Ton										TOTAL EXHAUST THRU SYSTEM
		3% / 1.39	4% / 1.63	5% / 1.78	6% / 1.99	7% / 2.19	8% / 2.42	9% / 2.63	10% / 2.87	11% / 3.02	12% / 3.32	
6'	28,000	274	270	197	171	152	135	122	111	102	94	32,200
7'	38,500	379	316	270	236	208	186	168	153	140	129	44,275
8'	50,000	491	411	351	306	271	242	218	198	182	167	57,500
9'	63,500	624	521	446	389	344	307	277	252	231	212	73,025
10'	78,500	772	644	551	481	425	380	343	312	285	262	90,275

(240°F Stack / 300°F Mix)

- 50% EXCESS COMBUSTION AIR IN DRUM
- 15% LEAKAGE THROUGH RAP INLET AND DISCHARGE CHUTE AND SEALS
- MATERIAL TO WEIGH 110#/FT³

NOTE: MIXING CAPACITY IS LIMITED TO 4% MOISTURE DRYING RATE

PRODUCTION RATES OF COUNTER FLOW DRUM MIXERS (IMBEDDED BURNER) INCLUDING LIQUID ASPHALT F15

DRUM DIAMETER	PROCESS GASES THRU DRUM (CFM)	Percent of Moisture Removed and Gallons of Fuel per Ton										TOTAL EXHAUST THRU SYSTEM (CFM)
		3% / 1.32	4% / 1.51	5% / 1.71	6% / 1.90	7% / 2.10	8% / 2.30	9% / 2.51	10% / 2.72	11% / 2.94	12% / 3.17	
6'	28,000	287	239	205	178	157	140	127	115	105	97	30,800
7'	38,500	394	329	281	245	216	193	174	158	145	133	42,350
8'	50,000	512	427	365	318	280	251	226	205	188	173	55,000
9'	63,500	651	542	463	403	356	318	287	261	239	219	69,850
10'	78,500	804	670	573	499	440	393	355	322	295	271	86,350

300°F Mix with 240°F Stack

- 50% EXCESS COMBUSTION AIR IN DRUM
- 10% LEAKAGE THROUGH RAP INLET AND DISCHARGE CHUTE AND SEALS
- MATERIAL TO WEIGH 110#/FT³

- 4% MOISTURE
- 5.5% LIQUID ASPHALT

PRODUCTION RATES (TPH) OF DOUBLE BARREL DRUM MIXERS F16

Moisture Content Management BPs

- **Paved - Sloped Stockpile Areas**
  - Benefit / Cost Decision Process
- **Covered Stockpiles**
  - Benefit / Cost Decision Process
- **Loadout Best Practices**
- **Aggregate Supply Management**

Paved – Sloped Stockpile Areas

- **Paved – sloped** stockpile area benefits
  1. Lowers drying costs
  2. Increases production capacity
  3. Lowers paving costs
  4. Decreases material loss
  5. Lowers equipment and electrical power costs
  6. Reduces penalties from segregation and gradation problems
  7. Lowers maintenance cost for loader

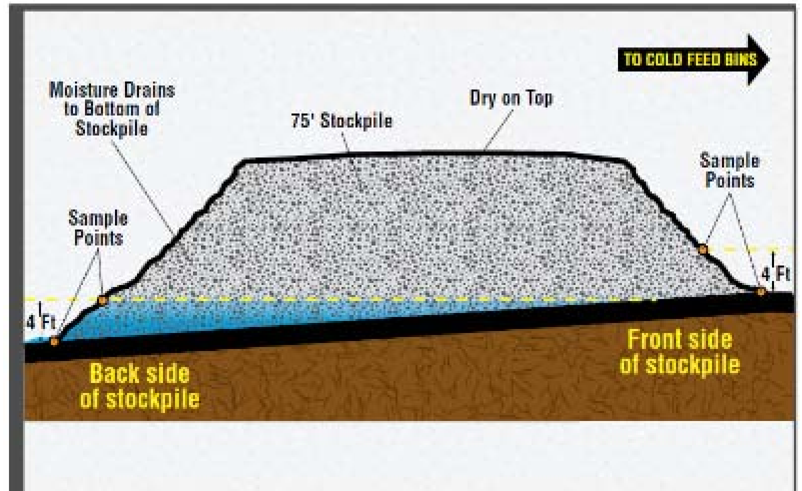
WATER DRAINS FROM SLOPED STOCKPILE F2

From: Astec T-129 Stockpiles

Paved – Sloped Stockpile Example

- Moisture measurements taken from five (5) freshly stockpiled materials.
  - Clean stone, fines, and RAP were evaluated.
- Points were taken at ground level and 4 ft. above stockpile toe on front and back side.
- Findings
  - Clean stone normally drain quickly
  - Fine aggregate and RAP are critical products to have sloped, paved stockpile surfaces

From: Astec T-129 Stockpiles



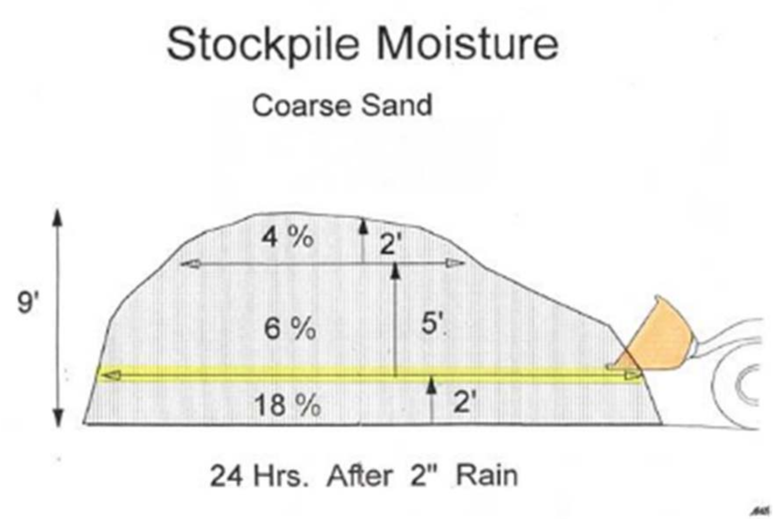
STOCKPILES WITH IDEAL 4 PERCENT SLOPE F6

Material type	Front side ground level	Front side 4' level	Back side ground level	Back side 4' level	Avg. moisture use level
Sand	5.6%	5.2%	23.3%	5.8%	5.4%
Screenings	7.0%	6.0%	14.0%	7.2%	6.5%
No. 78	1.4%	—	4.4%	—	1.4%
No. 67	0.5%	—	1.5%	—	0.8%
No. 5 (-1-1/2")	—	—	—	—	—
RAP (-1/2")	5.7%	5.6%	9.6%	5.7%	5.7%

MOISTURE IN STOCKPILES FROM HMA PLANT IN NORTH CAROLINA F7

Moisture Variation in Stockpile

- Evaluated moisture in a coarse sand stockpile 24 hours after a 2” rain event
  - Moisture varied widely (18 to 4%) throughout 9’ tall stockpile
  - Simple prompt and constant reminder to the loader and plant operators of the importance of proper *stockpile moisture management fundamentals*

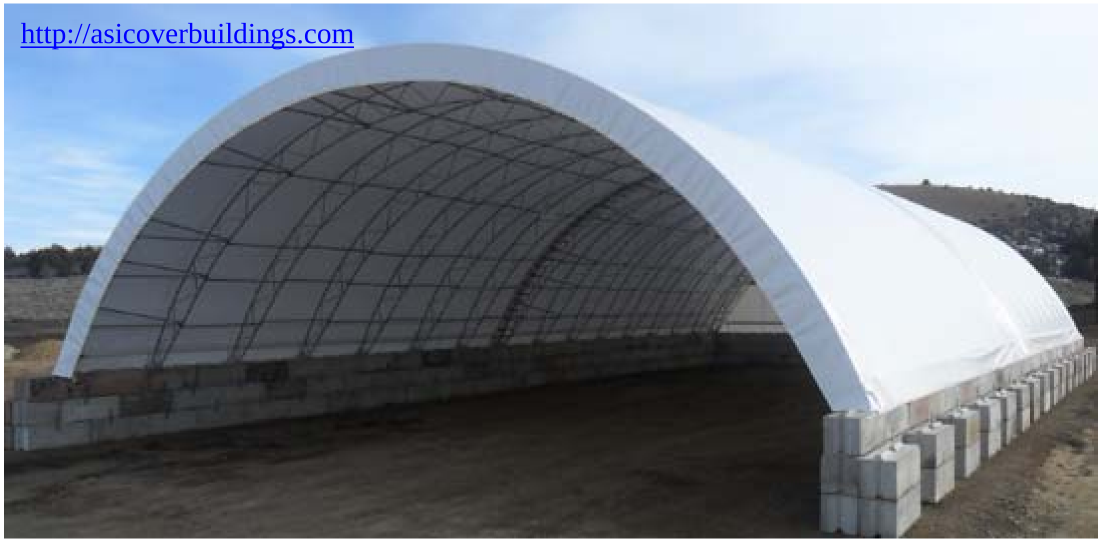


Covered Stockpiles - Types

- Covered stockpiles more active approach at managing stockpile moisture
  - Eliminate the moisture from entering the stockpile
- Variety of covering options
  - Clear span
  - Pole barn

Covered Stockpiles - Considerations

- Ensure the size is adequate for the material quantities needed
- Ensure access is adequate for loading/loadout
- If possible, orientate parallel to primary wind direction to promote drying



Fractionation and Feeding?

- Is Fractionation Necessary?
- Up to 30% RAP without Fractionation
  - Multiple Plants, with Volumetric Specs
- Fractionate Typically on ±3/8”
- RAP Feed Bins, Scalping Screens, RAP Gator
- Benefits
  - Increase Binder Replacement with Binder Rich Fraction (-3/8” Fraction)
  - Control of Properties (Grad, Volumetrics, …)
  - Reduced Variability
  - Is it Cost Effective?

Fractionated Stockpiles

Fractionation and Feeding

A Valuable Lesson Learned

- Marketing to Public Agency
- RAP BP Outcome
- Three RAP Types
  - A - Hot Plant Transfer RAP
  - B - HMA RAP
  - C - Agg Base RAP

- Keep A & B Separate or Blend
- C is Always Separate

RECYCLED ASPHALT PRODUCT MANAGEMENT PLAN

The following procedures are established as a means to maintain consistency and quality of HMA products produced by Granite Construction Company. This document outlines procedures used during handling and processing of Recycled Asphalt Product (RAP) at our Crushing facilities and incorporating RAP into Hot Mix Asphalt (HMA) in our Hot Plants.

The plan includes methods for handling internally generated unprocessed RAP product, initial inspection of imported unprocessed RAP products, grading and sorting unprocessed RAP by quality level, stockpiling unprocessed RAP, blending and processing RAP (crushing, screening), quality control testing performed during processed RAP production, stockpiling of processed RAP, RAP mix design procedures, and introduction of RAP products into HMA products.

We have established three categories of unprocessed RAP

1. "A" HOT PLANT TRANSFER RAP
2. "B" HMA RAP
3. "C" AGGREGATE BASE RAP

Only "A" and "B" category unprocessed RAP will be used to produce HMA quality RAP. "C" category RAP will be used to produce aggregate base.

Inspection Procedure for imported RAP

1. The Crushing facility will accept RAP Monday – Friday, 7:00 am to 3:00pm
2. Upon entry into the plant facility, trucks importing unprocessed RAP stop at an inspection platform and contact the QC laboratory by CB radio or other means to request inspection. Laboratory supervisor will dispatch a technician to inspect load.
3. An inspection will be made to determine composition / quality and assign grade for each load of imported RAP. Technicians will be trained to determine the quality level of the inspected load. Empirical knowledge of local aggregate sources will be relied upon in the inspection process.
4. Loads containing excessive amounts of debris, steel, or other deleterious materials will not be accepted.

A, B, C Piles

- A and B RAP Piles
  - Maximize %RAP
  - Low Binder Stiffness
  - Best Agg Qualities
  - Minimize Binder Grades
- C RAP Pile
  - EnviroBase

Process - Inspect, Crush, Pile, Design, Blend, Verify

- Every Load Inspected by QC
- Plant Transfer = A Pile Source
- Project and Import = B Pile Source
- Import (including PCC) = C Pile Source

RAP or CRAP – you be the judge!

- There is More Value in High Quality RAP Products

Hot Plants

Production Capacity – Plant Type

- Batch Plants
  - Steam
  - Practicality of Delta Virgin Agg Temps for Mix Types
  - 50% RAP at 280ºF discharge
    - 3%MC = 700^{+}ºF Aggs, 400^{+}ºF Exhaust (BH)-Not Real
    - Typically up to ≈ 20-25%

- Parallel Flow Drums
  - Blue Smoke Limitations
  - Collar Location
  - External Mixers
  - Typically ≤ 25%

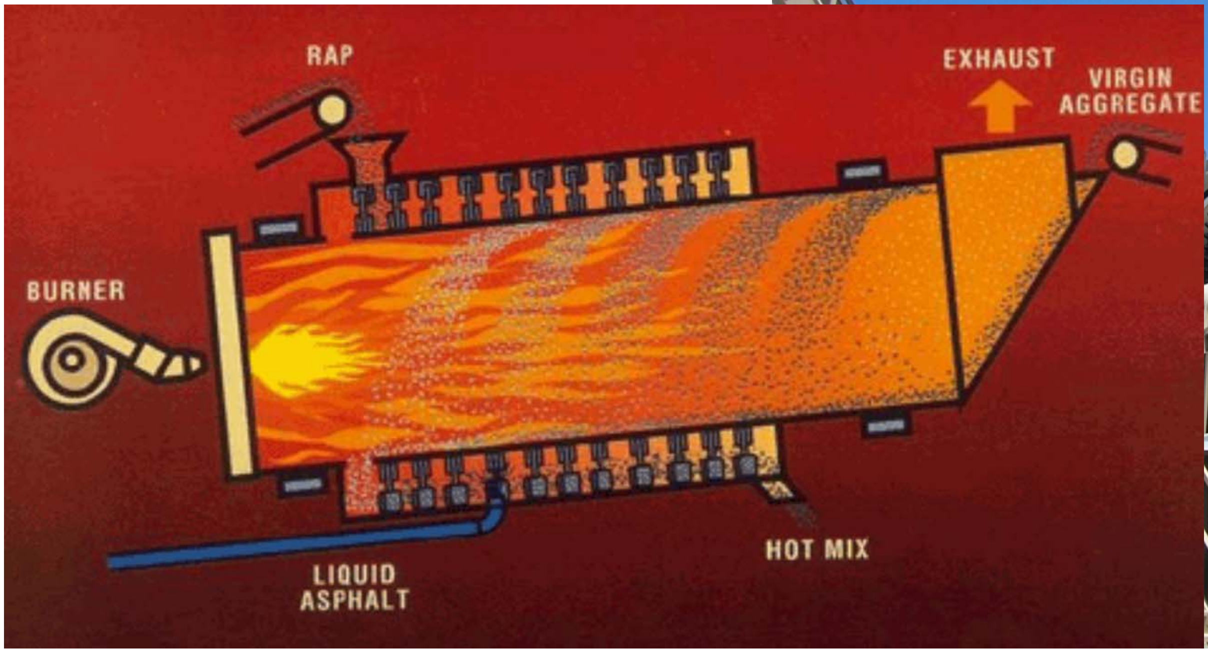
- Have Realistic Expectations

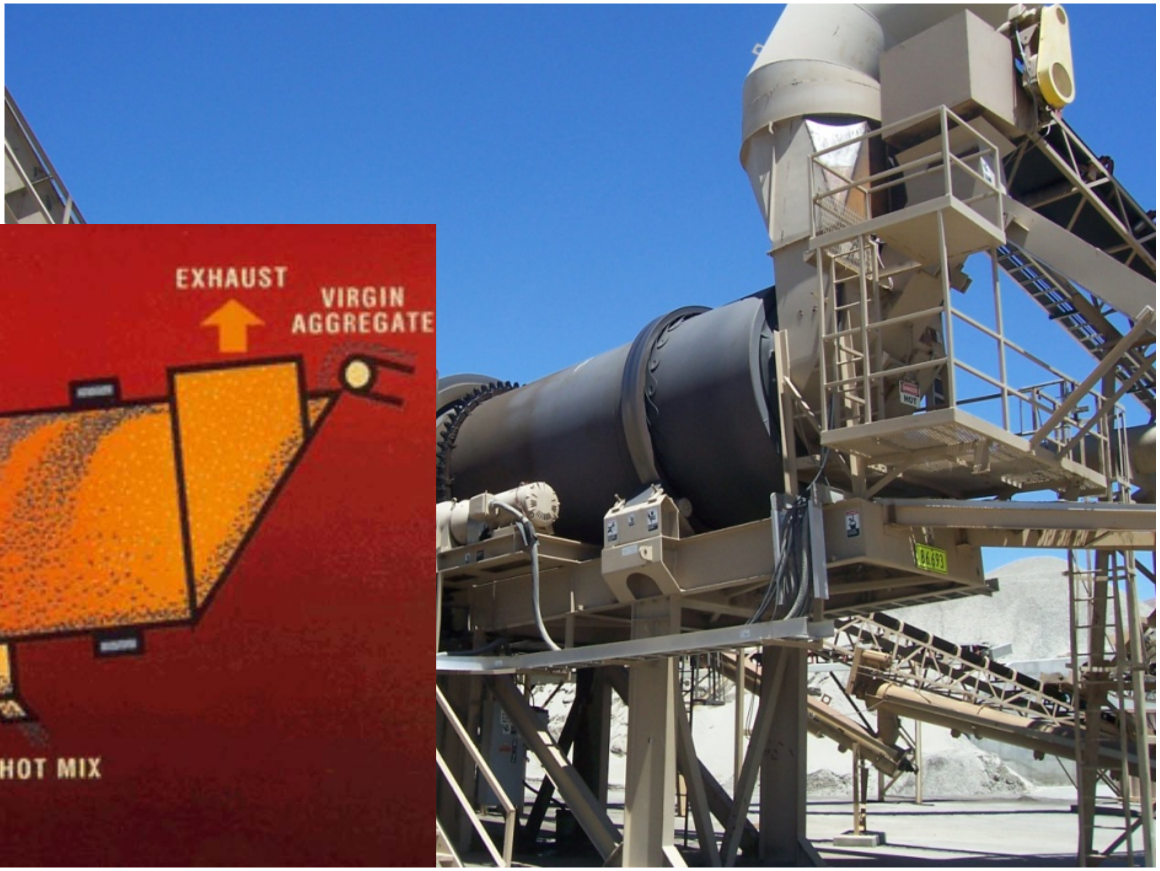
Production Capacity – Plant Type

- Counterflow Drum with Volumetric Specs
  - 25% w/ Single Feeder
  - 35% w/ Twin Feeders
  - 30% RAP WMA
    - Flighting

Production Capacity – Plant Type

- Double Barrel Drum with Volumetric Specs
  - 45% w/ Two Feeders
  - 45% RAP WMA
  - External Mixing
  - Consistency





Blending / Coating

- Look at Discharge to Slat

Temperature and Fires

- RAP ↑ Temperature ↑

High RAP
Fire

Lessons Learned

- What RAP Does Work Well With
- What RAP Does Not Work With

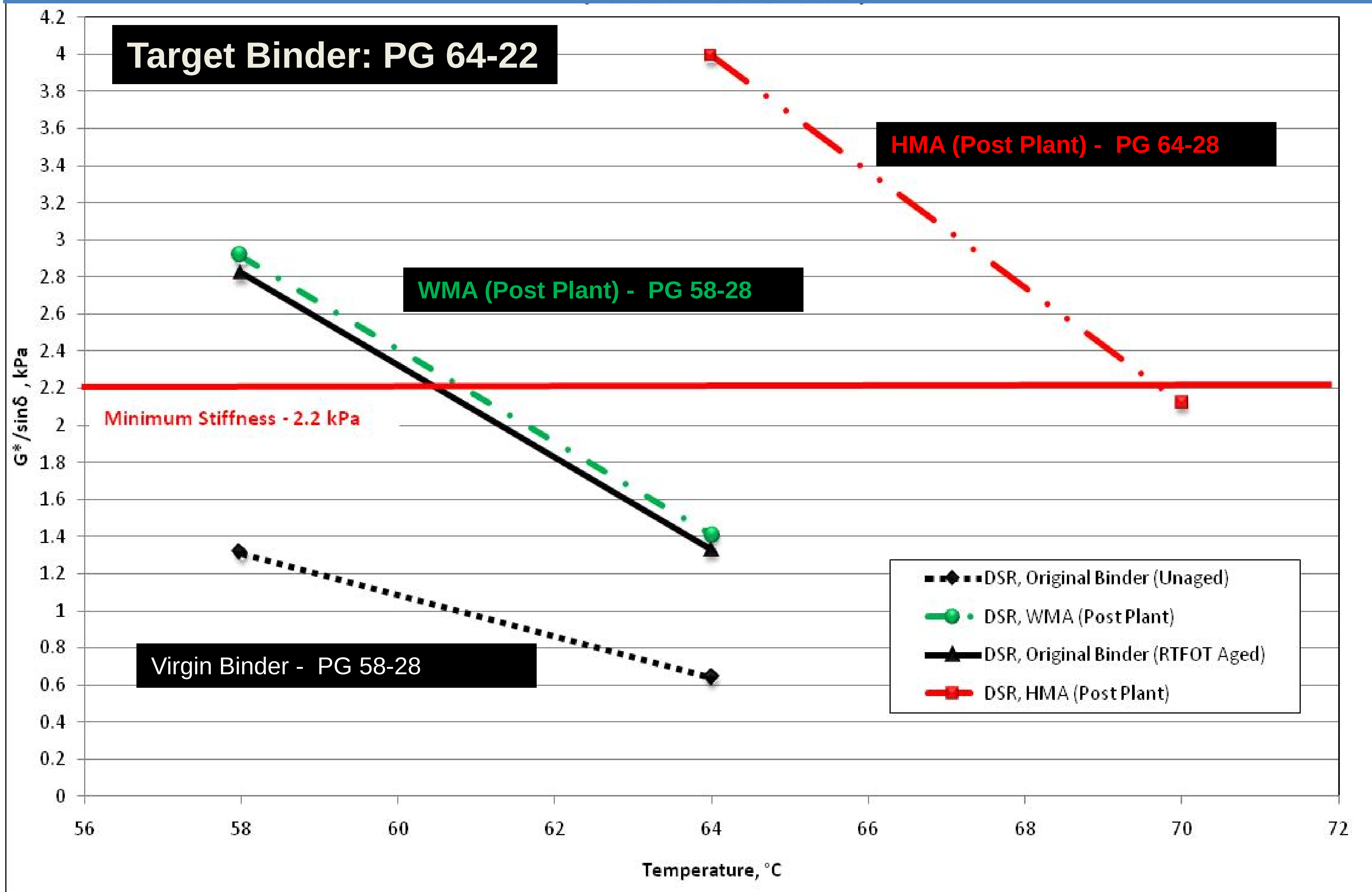
What RAP Works Well With

- Responsible Design
- Consistent Materials (Virgin & Recycled)
- Bailey Method
- ABR Definition
- Neat and Modified Binders
- Wet Process Crumb Rubber
- Warm Mix Technologies
- Anti-Strip Additives
- Rejuvenators
- Fibers
- RAS?

Other Materials

- Neat & Modified Asphalt
- Anti-Strip Additives
- Warm Mix Asphalt
  - 2 x Green (RAP + WMA)
  - What is Correct Virgin Binder Grade
  - X% RAP and WMA = No Grade Change Required
    - ≈ 25-30%
  - X^{+} % RAP and WMA = 1, not 2 Grade Drop
    - 50% ?

Astec DBG Foam WMA with 25% RAP vs. HMA - Fall 2008



What RAP Doesn't Work Well With

- Inconsistent Materials
- Some Rejuvenators/RA
- Blending Charts Alone
- High Moisture
- Watch Zone
  - Mixing
  - High % with High PM?
  - High % without Fractionation

- *Is it really any Different than Virgin Mix?*

Our Future Nationally?

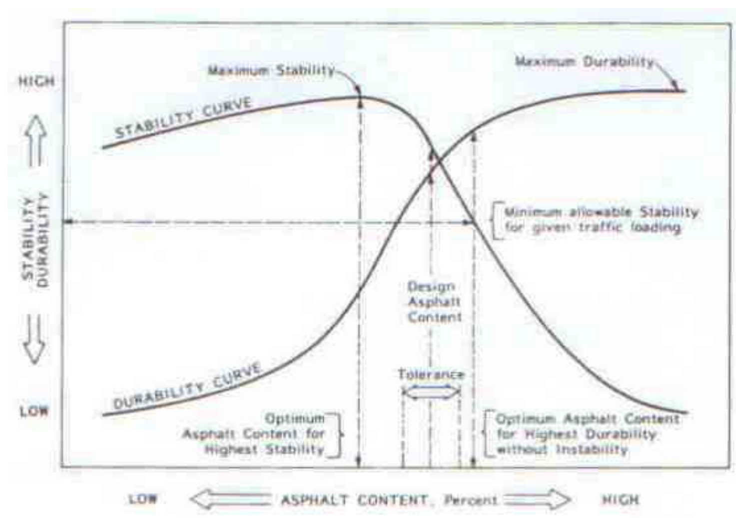
- ABR used vs. % RAP or %RAS
- Typical RAP ABR likely
  - 15-35%?
- High RAP ABR
  - 50-100%, Cold Central Plant?
- Allowable %RAS ABR↓
  - 2-3%
- RAP &/or RAS with HPMA ↓
- Allowable RAP &/or RAS different for
  - Surface vs. Base Mixes
- REOB Disallowed &/or ΔTc in Specs
  - Especially if RAP &/or RAS Mixes
- "Balanced" Mix Design
  - New Lab Aging Conditions in Mix Design
  - "Optimum %AC+"
- Sustainability Focus

Balanced Mix Design
Volumetrics + Rutting/MS Test + Cracking Test

- Raw Material Properties
- Volumetrics

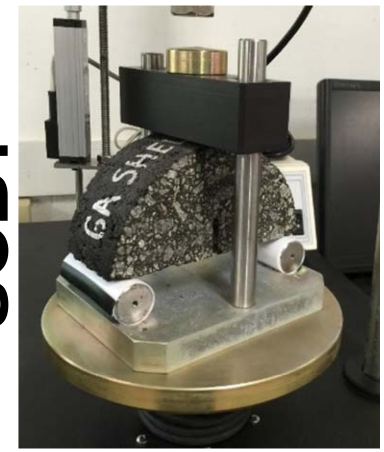
Rutting/MS

HWTD?



Durability

SCB?



DCT?


CATERPILLAR
Workability or Performance Test?

BP's - What Matters

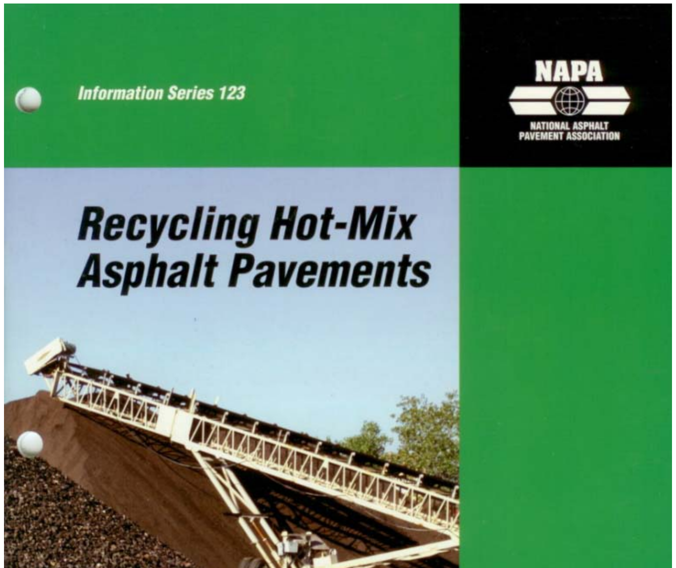
- Responsible Design & Material
- Product Quality
  - Not All Rejuvenators/RAs =
  - 40hr ΔTc in Specs
- Aggregate Properties Too (G_{sb})
- Variability
  - Understand, Control & Leverage It
- Balanced Mix Design
- Moisture Content
  - Manage It

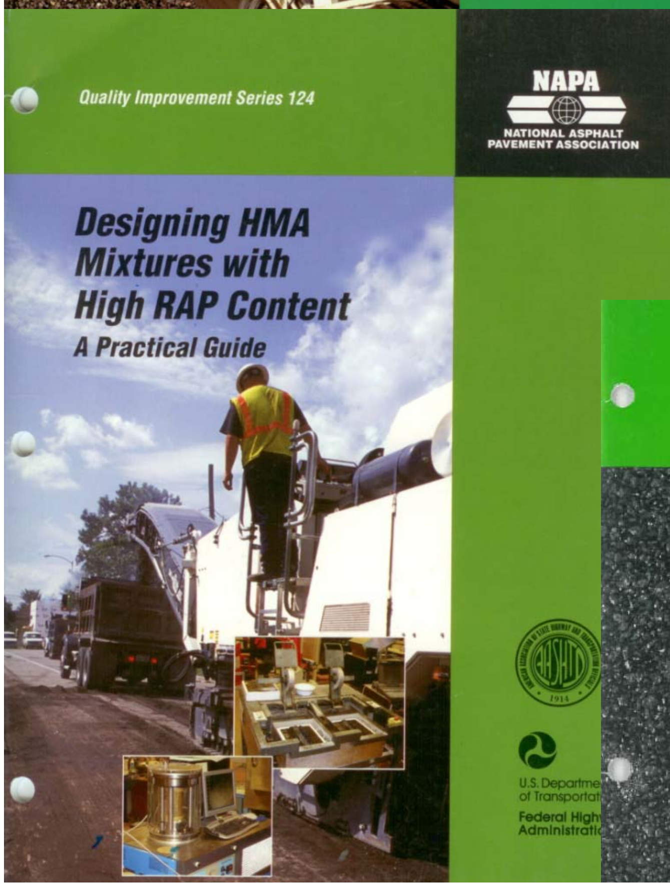
BP's - What Matters

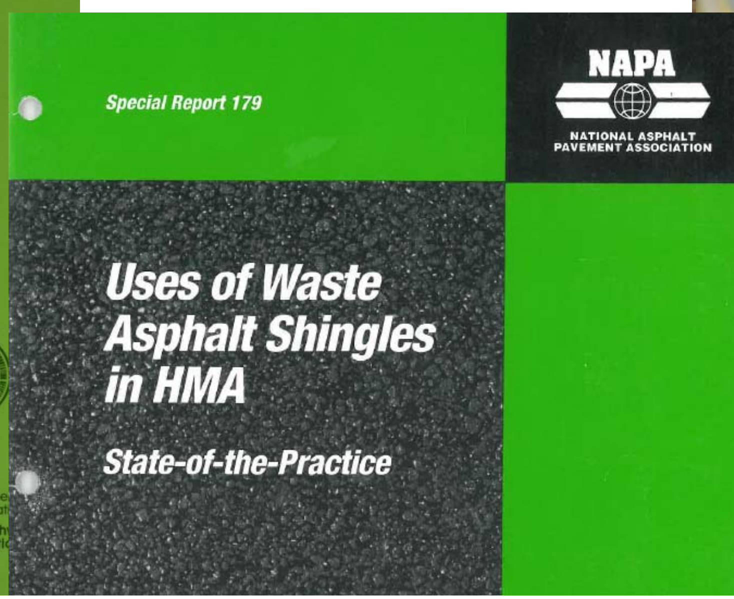
- Fractionation
  - To or Not To…
- RAP Management Plan
  - Piles A, B, C, …
- Plant Capabilities
  - Right Equipment, Set up Right
  - Manufacturers Help
- Other Materials
  - WMA, Anti-Strips, …
- Good Performance with Responsible Design & Production
  - Taxpayers
  - Companies
  - Our Industry
- Our Future Depends on It!

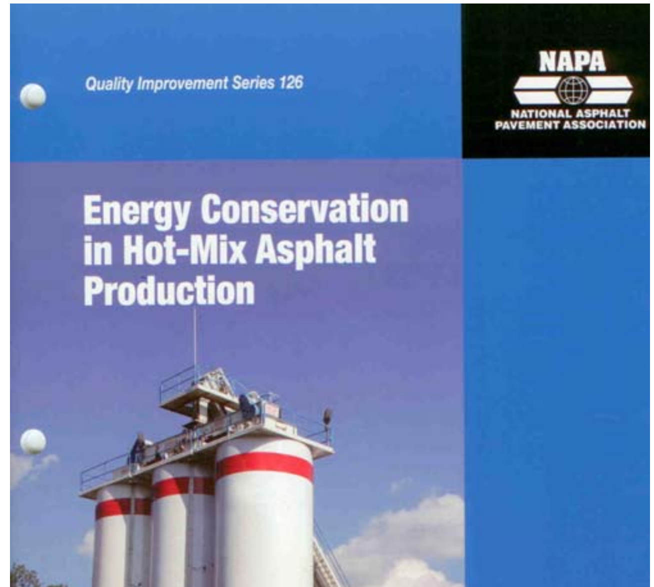
Resources

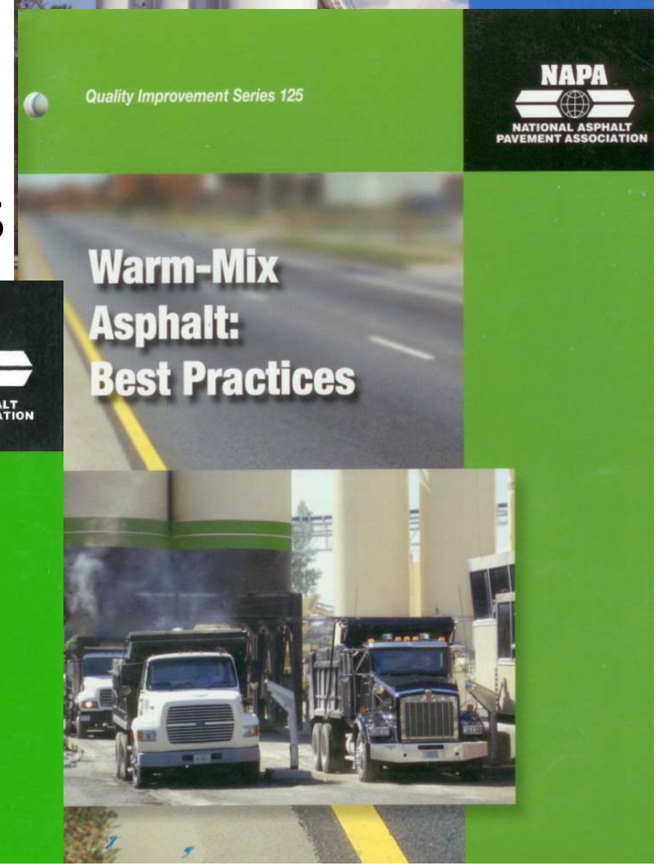
- Suppliers
- NAPA
  - www.aphaltpavement.org
- State APA
- Equipment Manufacturers











Questions / Feedback

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Cold Weather Asphalt Paving

A reality of every season!

Dave Johnson, PE
Senior Regional Engineer
Asphalt Institute
Billings Montana
Nov. 7, 2017

Factors that Affect Compaction

- Materials
  - Mix Design
  - Binder
    - Viscosity
    - Modification
  - Aggregate
    - Gradation
    - Angularity
- Environmental Factors
  - Air temperature
  - Surface temperature
  - Wind conditions
  - Solar radiation
- Layer Thickness
  - Cooling
    - MultiCool
    - PaveCool
    - Tables/Charts

Alaska 2015 Standard Specifications

- **401-3.03 WEATHER LIMITATIONS.** Place HMA on a stable/non-yielding roadbed. Do not place HMA when the base material is wet or frozen, or when weather conditions prevent proper handling or finishing of the mix. **Do not place HMA leveling course when the roadway surface temperature is colder than 40° F.**

- **What about your other lifts?**

When Winter Comes and the Project is not Done

- Options
  - Wait
  - Ignore it

Does this look like your morning start-up?

General Mixture Factors

Effect of Mix Design on Compaction

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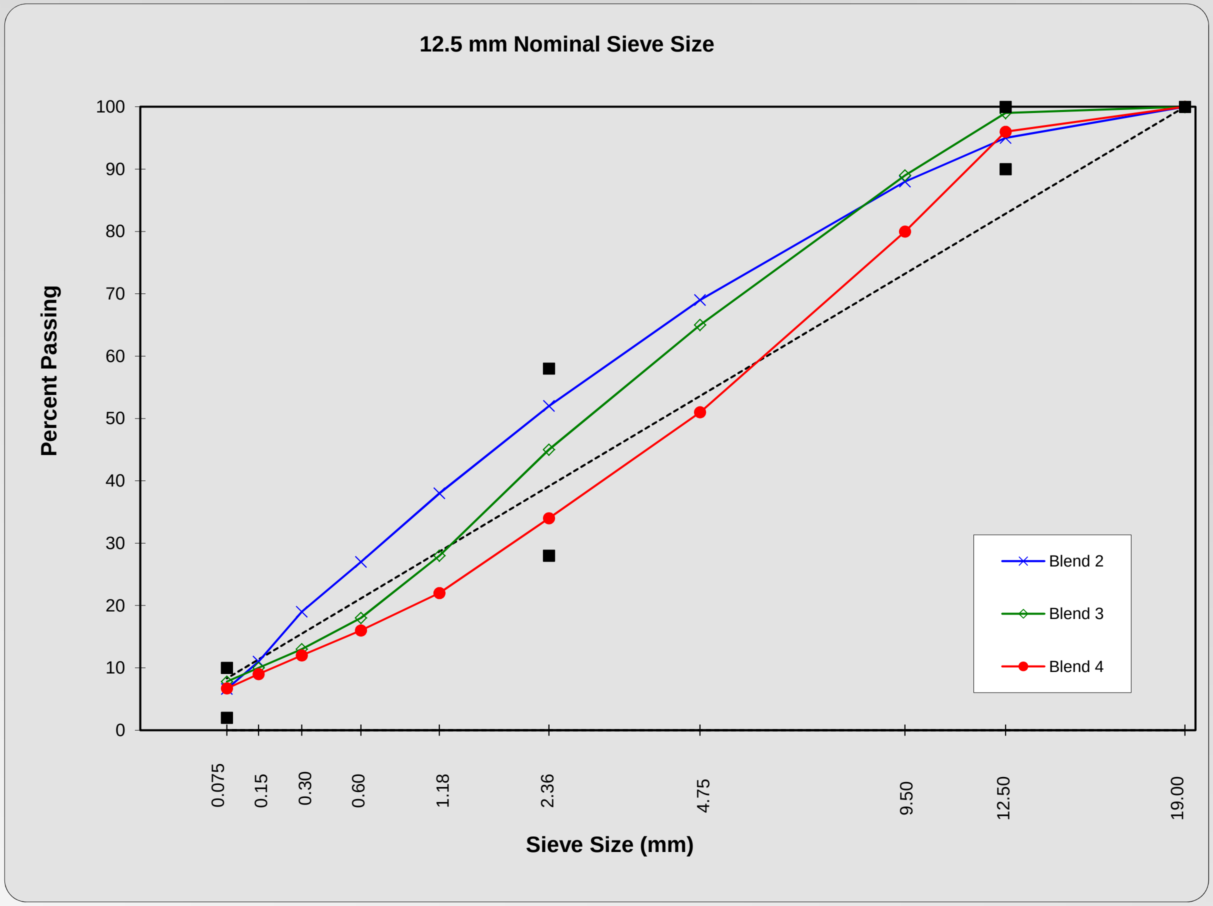
- Binder
  - Effective binder content
  - Binder properties
- Gradation
  - NMAS
  - Fine vs. Coarse



Effect of Binder on Compaction

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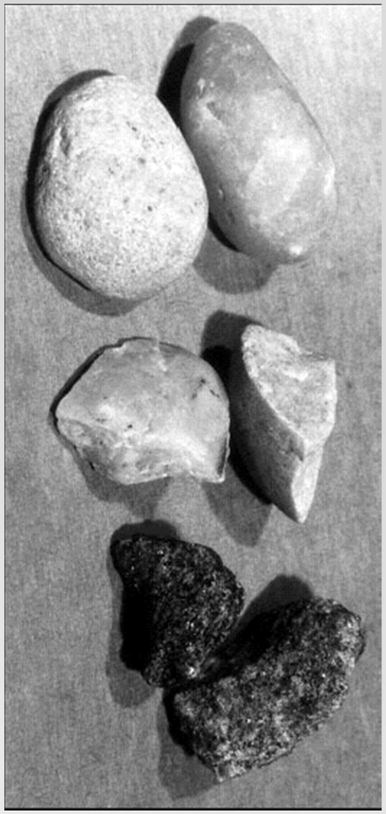
- **PERFORMANCE GRADE**
  - Binder grades that are "stiffer" at paving temperatures can make the mix more difficult to compact
- **MODIFIED BINDERS**
  - In general, the grades with modifier added tend to be stiffer and more difficult to compact.
  - The time available for compaction tends to decrease as the amount of modifier increases.

Effect of Aggregate on Compaction

- **GRADATION**
  - continuously-graded, gap-graded, etc.
- **SHAPE**
  - flat & elongated, cubical, round
- **SURFACE TEXTURE**
  - smooth, rough
- **STRENGTH**
  - resistance to breaking, abrasion, etc.



Trucking's Effect on Cold Weather Paving

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- Have Adequate Numbers
- Maintain Truck Spacing
- Choose the Best Trucks
  - Insulated beds
  - Use cover tarps

Paver Operations Effect

- Maintain Constant Speed
  - Maintains the balance of forces (smoothness)
  - Minimizes cold spots
  - Minimizes segregation
- Don't Wing the Hopper
- Maintain Hopper Volume
  - Full – 1/2-full
- Quick Starts and Stops

Environmental Factors and Compaction

Several factors come into play regarding how fast the mix cools onsite, affecting time available for compaction:

- Ambient air temperature
- Temperature of the existing surface
- Wind speed
- Lift thickness
- Mix temperature
- Solar Radiation

Material Cooling

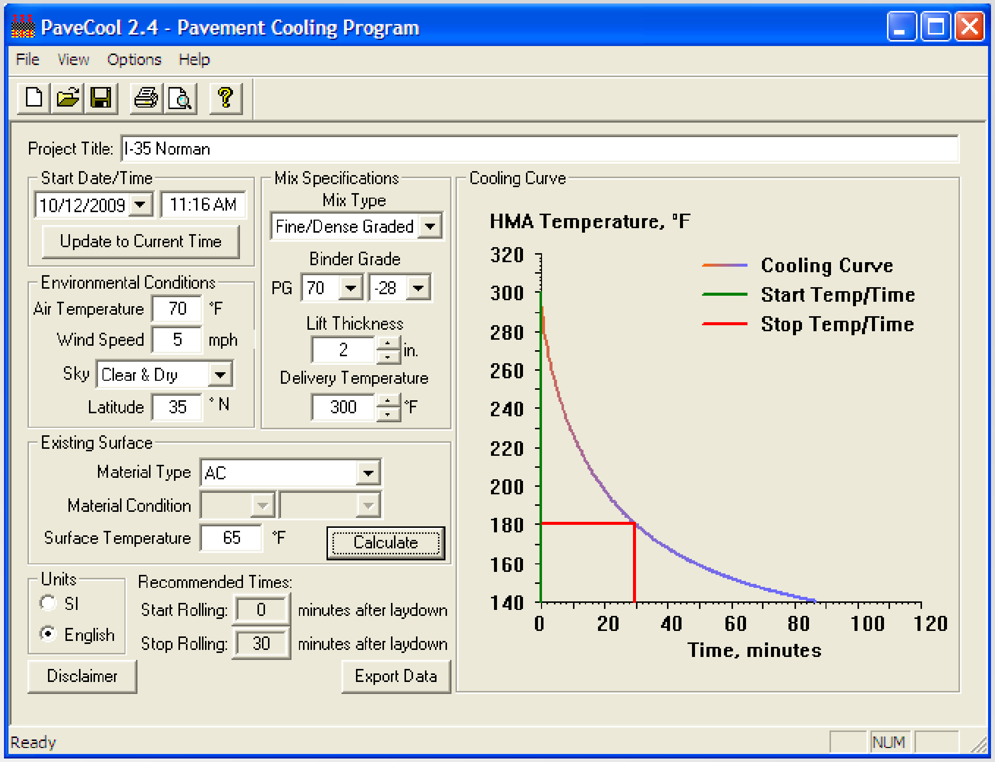
- Thicker = More Time for Compaction
  - Thicker mats are commonly EASIER to compact
  - So more time available & less time needed
  - Consider 1 lift vs. 2 for the same thickness
- Hotter Mix = More Time for Compaction
  - Do not exceed supplier's recommendations
  - Ages (stiffens) the binder
  - Shortens its overall life

Free Tools for Estimating Compaction Time

- PaveCool—single lift (generation 1)
  - PC
  - iOs App
  - Google App
- MultiCool—multiple lifts (generation 2)
  - PC
  - Google App
  - Mobile Web

PaveCool Example

- Key Inputs
  - Temperature
    - Air
    - Base
    - Mix Delivery
  - Wind Speed
  - Lift Thickness



- Output
  - Cooling Curve
  - Estimated Compaction Time

PaveCool Example

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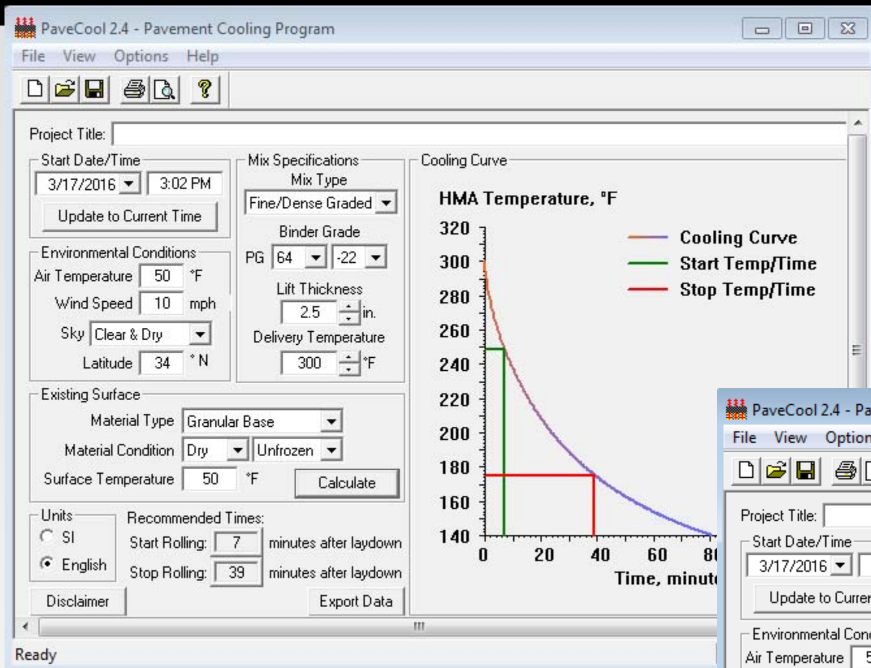


2.5 Inch Lift

50°F Air, Surface Temp

Mix Delivery temp - 300°F

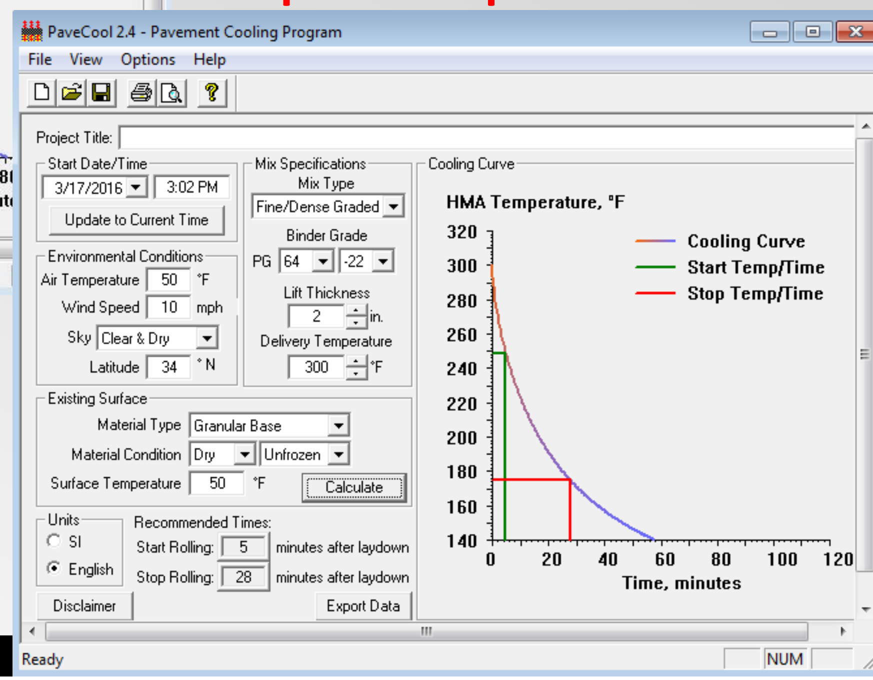
39 minutes to complete compaction operations

2 Inch Lift

50°F Air, Surface Temp

Mix Delivery temp - 300°F

28 minutes to complete compaction operations



One Lift Versus Two

- Example: 3 Inches Compacted Thickness
  - Typical fall paving conditions in Billings
  - Estimate time available for compaction with MultiCool
  - One 3-inch lift = 64 minutes to compact
  - Two 1.5-inch lifts
    - First lift on grade = 20 minutes to compact
    - Second lift = 18 minutes to compact

  - About half the overall time with two lifts vs. one lift
  - Each of the two have only about a third the time vs. one lift

Adjust Operations

- Add Equipment to Speed Construction
  - Echelon paving?
    - Sufficient plant capacity
    - Adequate trucks
    - Enough rollers
  - More rollers
    - Slow them down
    - Add pneumatics
  - Utilize Intelligent Compaction
- Speed up the plant
  - Adequate trucks
  - Enough rollers

Heating the Iron-Hot Plant

Heating the Iron-Hot Plant

- Drum
- Slant Conveyor
- Storage Silo/Surge Bin

Heating the Iron-Material Transfer Vehicle

Heating the Iron-Material Transfer Vehicle

- Pug Mill/Surge Bin
- Slat Conveyor
- May need to bring a "Heating Load"
  - Heated aggregate
  - Runs through MTV
  - Also verifies agg. drying
- Take Second or Third Truck of the Day

Heating the Iron-Paver

Heating the Iron-Paver

- Hopper
- Tractor
- Screed

Heating the Iron-Paver

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- Take Second or Third Truck of the Day
- Maintain Hopper Volume
  - Full – 1/2-full

Consider a Warm Mix Additive

- Use Warm Mix at Hot Mix Temperatures
  - Compaction aid
  - Lower cessation temperature
- Easier Compaction
- More Time

What About Tack Coats?

- Potential Freezing of the Emulsion When Applied
- Slower Braking and Setting of Emulsion
- Consider Using Paving Grade Binder for Tack

Bring Your A-Game!

Anchorage: March 13-16, 2018

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Mix Design Technology Certification

(3.5 day course / 22.5 PDHs)

$1,195 per person

asphalt ACADEMY

Course Description | Optional Certification Testing | Software | Class Schedule | Who Should Attend | Fees, Registration, Dates & Seminar Location | Transfer, Cancellation & Refund Policy | Hotel Info | Inclement Weather Info | Contact Info

Course Description

The Mix Design Technology Certification (MDT) course provides advanced technicians, designers, and engineers responsible for mix designs with a thorough understanding of the properties of the materials which compose asphalt mixtures, as well as the physical and mathematical processes involved in producing a successful asphalt mixture design. Students will receive training over the entire range of activities related to the design of asphalt mixtures: aggregate and binder selection, material properties, development of trial blends, batching, volumetric calculations and analysis, Superpave mix criteria, mix performance tests and criteria, use of RAP in asphalt mix designs, plus an overview of SMA and open-graded mixtures.

The MDT class can accommodate up to 28 students, which will allow students personal access to our experienced instructors for Q&A at any time during the course.

This course is complemented by the Asphalt Institute's Basic Mixture Technician Training (BMTT) course. While the MDT course focuses on how advanced technicians, designers, and/or engineers use laboratory and project information in the mix design process to create long-lasting asphalt mixtures, the BMTT course focuses on the actual tests and laboratory processes involved in asphalt mix design performed by technicians.

Questions?

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