

61st Idaho Asphalt Conference

THURSDAY, OCTOBER 28, 2021

Morning Session		Afternoon Session	
Presiding: Dave Johnson, P.E. The Asphalt Institute		Presiding: John Arambarri, P.E. Idaho Transportation Department	
8:30 am	<u>Volumetrics 101</u> Dave Johnson The Asphalt Institute	1:45 pm	<u>Performance-Based Acceptance vs. Performance-Based Design</u> Dave Johnson The Asphalt Institute
9:30 am	<u>Introduction to Paving Fundamentals</u> Todd Mansell Caterpillar Paving Products	2:20 pm	<u>Multiple Stress Creep Recovery (MSCR), State of Practice</u> Mike Anderson The Asphalt Institute
10:15 am	Break	3:00 pm	Break
10:40 am	<u>Evaluation of Mix Composition and RAP Content on HMA Performance</u> Dr. Emad Kassem University of Idaho	3:15 pm	<u>Low Volume Roads - Balance Limited Funding vs. Pavement Rehab Needs</u> Dr. Dave Jones University of California - Davis
11:20 am	<u>The Use of Plastic Waste in Pavements</u> Dr. Richard Willis National Asphalt Pavement Association	4:00 pm	<u>HMA Preservation - Seal Coat and Microsurfacing</u> Dr. Adriana Vargas National Center for Asphalt Technology
Noon - 1:45 pm	Lunch and Expo	4:45 pm	Adjourn

THURSDAY, OCTOBER 28, 2021

Presentations**2021 List of Participants****Speakers of the 61st Idaho Asphalt Conference, October 28, 2021**

Back row: John Arambarri, Dave Jones, Dave Johnson, Emad Kassem

Front row: Todd Mansell, Adriana Vargas

Not Pictured: Richard Willis, Mike Anderson

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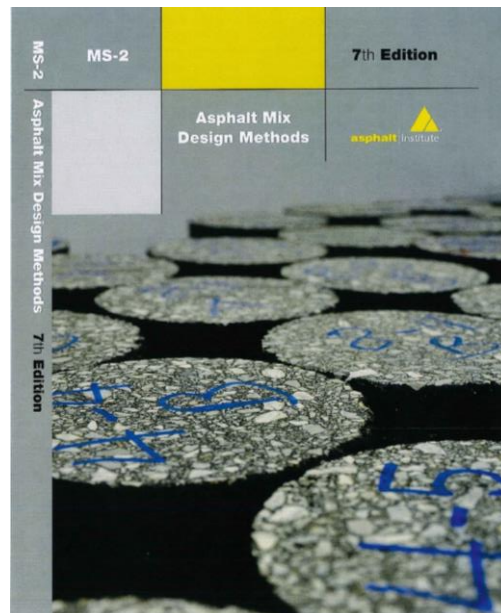
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An Introduction to Asphalt Mixture Volumetrics

Idaho Asphalt Conference
 October 28, 2021
 Dave Johnson, P.E.
 Senior Regional Engineer
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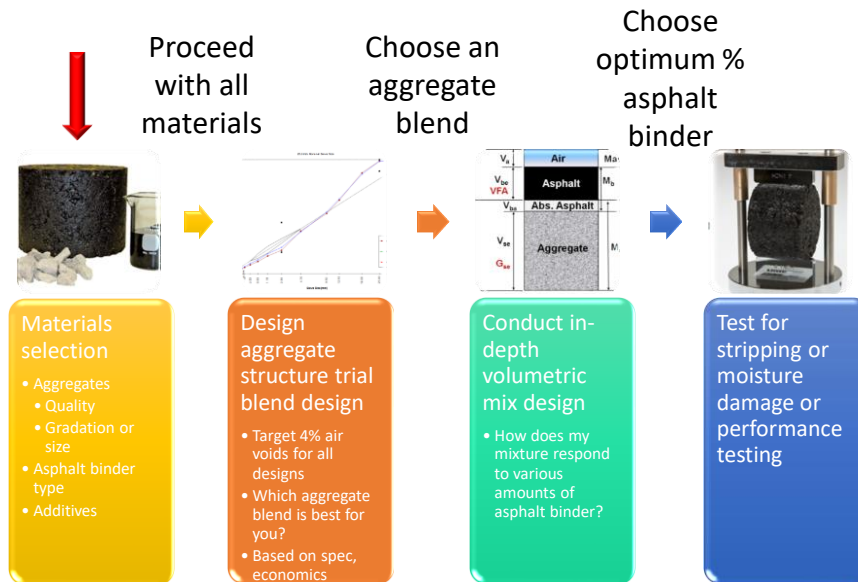
Presentation is Based on MS-2



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Mix Design Flowchart



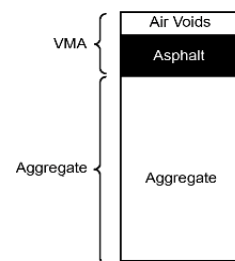
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Obtaining the Right Balance

Achieved through

- **Volumetric** Analysis of the Mixture
- Future **Performance** testing

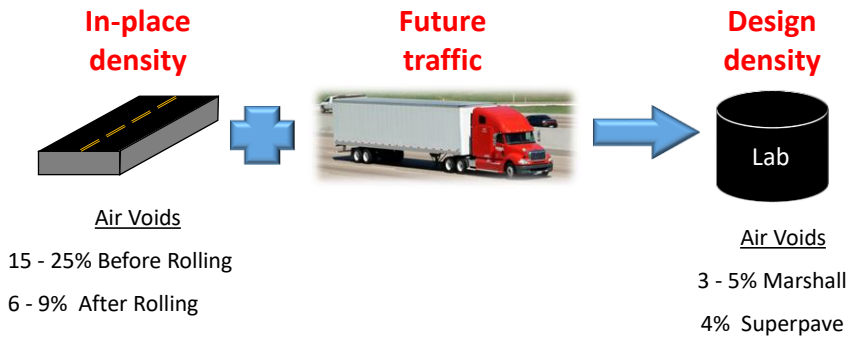


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Intent of Laboratory Compaction?

To simulate the in-place density of HMA after it has endured several years of traffic



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What Compactor Simulates Compaction Best?

- SHRP research identified the best practical compactor - Superpave Gyrotory compactor
- SGC better than Marshall or Hveem



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Gyratory Compactors



Pine



Troxler



Cooper / Cox



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Materials Selection

• Aggregate

- Makes up 93 to 96% of the mixture weight
- Acts as the skeleton of the pavement mixture
 - Skid resistance
 - Stability
 - Workability

• Asphalt Binder

- Makes up 4 to 7% of the mixture weight
- Acts as the “glue” or “muscle” of the mix
 - Flexibility
 - Durability

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Volumetrics



- All matter has mass and occupies space
- Volumetrics are the relationships between mass and volume
- Marshall and Superpave mix design based on aggregate and mixture volumetrics

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Volumetric Analysis Definition

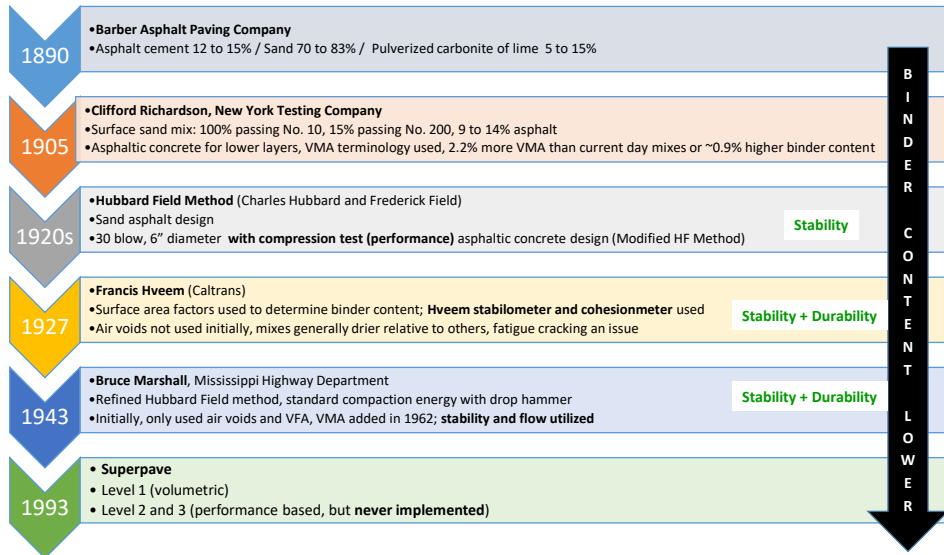


The measurement or calculation of the relative masses and volumes occupied by the aggregate, asphalt binder, and air voids in a compacted asphalt mixture

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History of Mix Design



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

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Nomenclature for Specific Gravity

- G_{xy} - Where G equals specific gravity; unit-less
 - x - Designates material
 - y - Designates type of specific gravity
- For (x):
 - s - Aggregate
 - m- Mixture
 - b - Binder
- For (y):
 - m- Maximum
 - a - Apparent
 - b - Bulk
 - e - Effective

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Aggregate Properties

Specific Gravity (G)- “a dimensionless number defined as the ratio of the density of a material to the density of water.”

$$G = \frac{\frac{m}{v}}{\rho} \quad - \text{ or } - \quad \frac{m}{v \times \rho}$$

where:

G = specific gravity

m = mass of the material

v = volume of the material

ρ = density of water

Water is really 0.997g/cc at 25C, but many use 1.000

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Aggregate Specific Gravities

- G_{sb} - largest volume, lowest value
- G_{se} - in-between volume, middle value
- G_{sa} - smallest volume, highest value

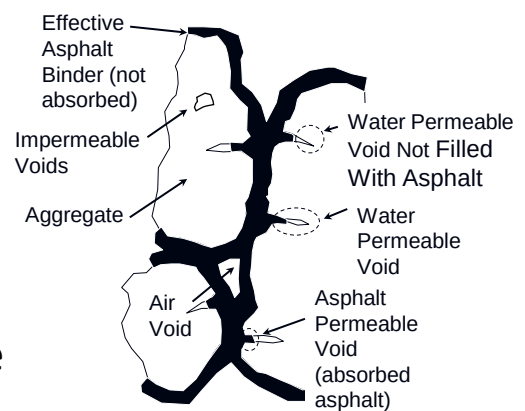


Figure 5.2 Representation of Microscopic View of Aggregate, Asphalt, and Air Mixture

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Coarse Aggregate Specific Gravity

- AASHTO T 85

- Apparent
- SSD
- Bulk
- Absorption



MS-2
Pg. 48 – 5.3.1

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Fine Agg. Specific Gravity (Cone Test)

- AASHTO T 84



Too Wet



Saturated Surface Dry
(SSD)

MS-2
Pg. 48 – 5.3.2

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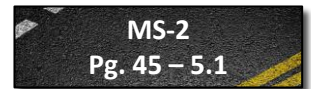
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Determine Aggregate Specific Gravities

What is Specific Gravity?

- It is the ratio between the density of anything compared to the density of water at a standard temperature

$$G = \frac{\frac{M_x}{V_x}}{\frac{M_{H_2O}}{V_{H_2O}}} = 1.000 \text{ gram / cm}^3$$



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Specific Gravity is the Bridge Between Volume and Mass



Volume

$$V = \frac{M}{G}$$

$$G = \frac{M}{V}$$

Mass

$$M = V \times G$$

In the metric system...

the magnitudes of specific gravity (no units) and unit weight (g/cc) are always the same because water weighs 1 g/cc

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Specific Gravity

- Relates Volume to Mass

$$V = \frac{M}{G \times 1.000}$$

Diagram illustrating the formula for Specific Gravity (V) relating Volume (V) to Mass (M) and Specific Gravity (G).

Labels and arrows pointing to the formula components:

- Volume of object (points to V)
- Mass of object (points to M)
- Specific gravity of object (points to G)
- Density of water (points to 1.000)

Specifically, density is 0.997 at 25.0 °C

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Specific Gravity

- Relates Mass to Volume

$$M = V \times G \times 1.000$$

Diagram illustrating the formula for Specific Gravity (M) relating Mass (M) to Volume (V) and Specific Gravity (G).

Labels and arrows pointing to the formula components:

- Volume of object (points to V)
- Mass of object (points to M)
- Specific gravity of object (points to G)
- Density of water at room temperature (points to 1.000)

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Specific Gravities



- The specific gravity of three different materials are obtained and used in volumetric analysis
 - Aggregate (G_{sb}) – *furnished by designer or producer*
 - Asphalt (G_b) – *furnished by the supplier*
 - Mixture (G_{mb}) – *cannot be determined until mixture testing is completed*

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Aggregate Specific Gravity



- Mineral aggregate is porous.
- The amounts of water and asphalt absorption differ
 - asphalt absorption is typically 30 – 80% of water absorption
- Three different specific gravities are needed to account for these variations.
 - G_{sa} = Apparent Specific Gravity
 - G_{se} = Effective Specific Gravity
 - G_{sb} = Bulk Specific Gravity

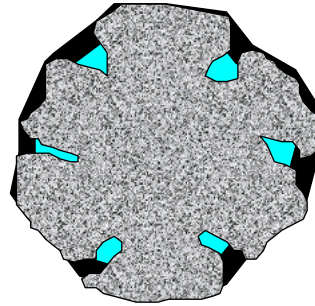
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3 Different Aggregate Specific Gravities

- Apparent (G_{sa}) Volume
 - excludes absorbed water volume
- Effective (G_{se}) Volume
 - excludes absorbed asphalt volume
 - Must use mixture testing to determine G_{sa} Volume. (G_{mm})
- Bulk (G_{sb}) Volume

Same Mass



Different
Volumes

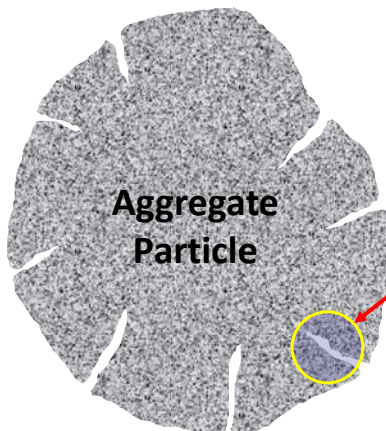
MS-2
Pg. 47 – 5.2.2

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Aggregate Bulk Specific Gravity

“SSD” Level



Aggregate
Particle

$$G_{sb} = \frac{\text{Dry Mass}}{\text{Bulk Vol.}} \div 1.000 \text{ g/cm}^3$$

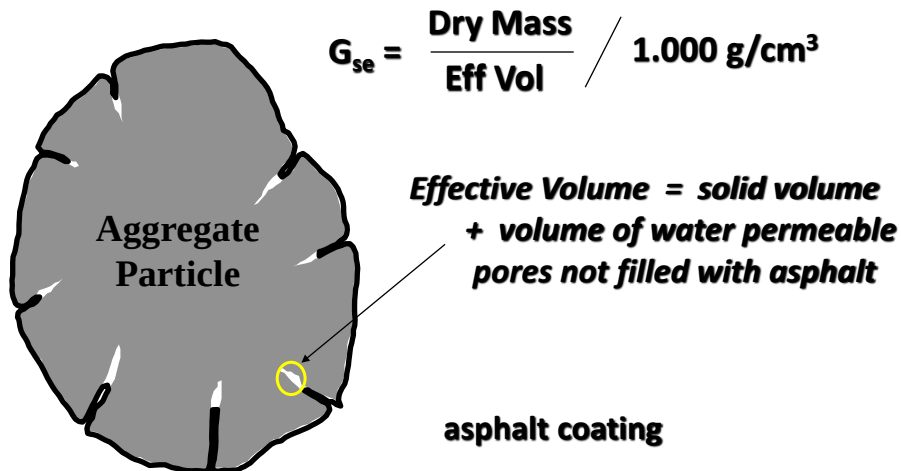
- **Bulk Volume** = solid volume + water permeable pore volume
- Uses Saturated Surface Dry (SSD) condition. The aggregate is Saturated but the Surface is Dry

This is a measured specific gravity

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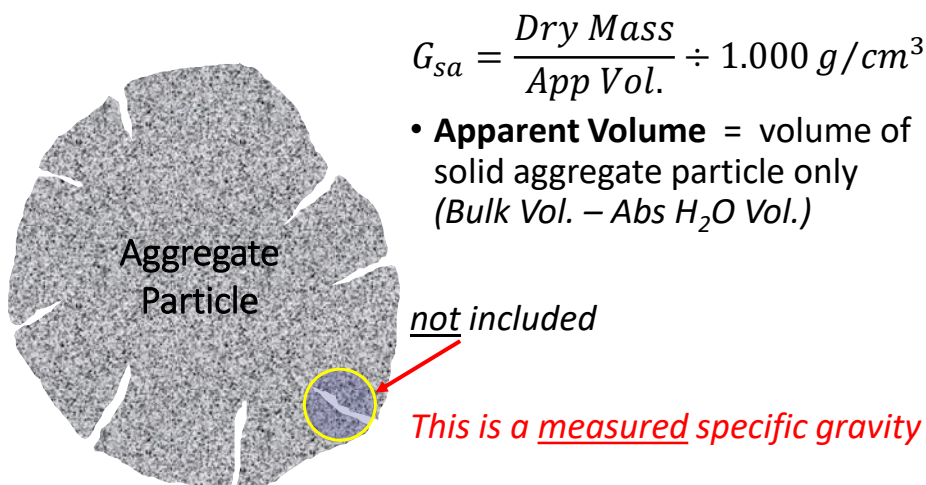
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Aggregate Effective Specific Gravity



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Aggregate Apparent Specific Gravity



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Combined G_{sb} & G_{sa} for Each Stockpile

- Laboratory testing is performed individually on the coarse and fine fractions of the stockpile.
- These values must be combined into one value for each stockpile.



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HMA Volumetric Terms

- Air voids of mix, P_a
- Voids in mineral aggregate, VMA
- Bulk specific gravity of mix, G_{mb}
- Maximum specific gravity of mix, G_{mm}
- Voids filled with asphalt, VFA
- Bulk specific gravity of aggregate, G_{sb}
- Effective specific gravity of aggregate, G_{se}
- Dust Proportion, DP

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Importance of Air Voids



- Field performance has shown that typical mixtures designed with low air voids (maybe < 2%) are susceptible to rutting and shoving
- Mixtures designed over about 5% air voids are susceptible to raveling, oxidation and a general lack of durability
- 4% air void design is an empirically derived target that allows for thermal expansion of the binder along with a cushion for future compaction

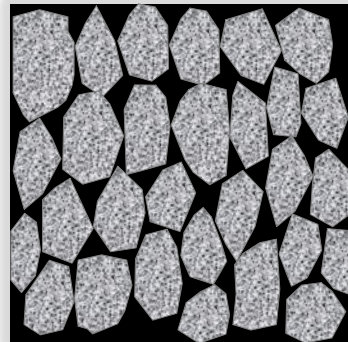
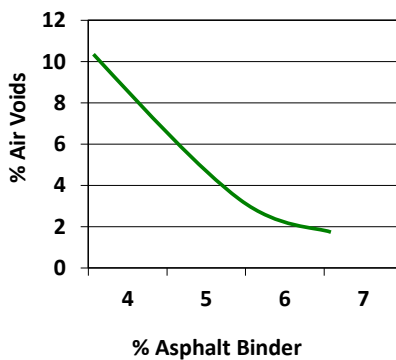
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Air Voids



Air Void Relationship

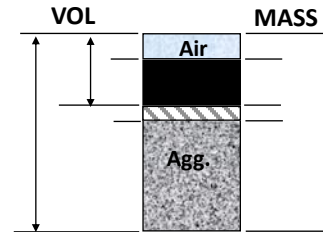


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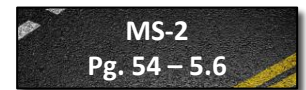
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VMA: Voids in Mineral Aggregate

- Definition
 - Volume of *inter-granular* void space in a compacted mix
- % by volume total mix
- *Does not* include volume of absorbed asphalt



Which aggregate gravity is used to calculate the VMA of the mixture?



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VMA Equation

$$VMA = 100 - \frac{G_{mb} \times P_s}{G_{sb}}$$

Where:

VMA = Voids in the Mineral Aggregate

G_{mb} = bulk specific gravity of the mix

P_s = Percent aggregate in the specimen

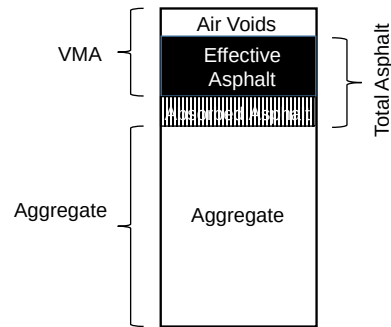
G_{sb} = bulk specific gravity of the aggregate blend

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Importance of VMA

- VMA is the volume of the voids in a compacted aggregate sample to accommodate effective asphalt and air.
 - Assure sufficient binder coating
 - Maintain 4% Air voids

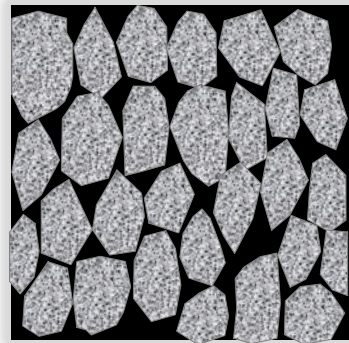
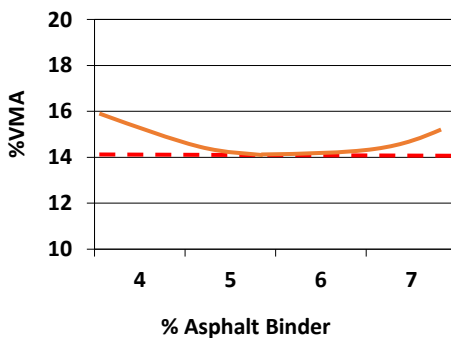


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VMA and %AC

VMA Relationship

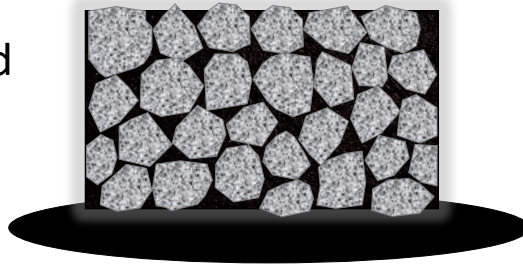


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High VMA Mixes

SMA and OGFC are specialty mixes that are designed with very high VMA and are engineered to minimize drain down

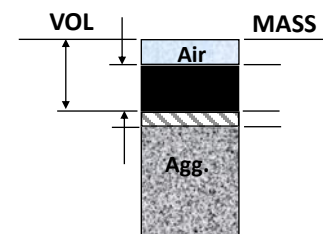


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Voids Filled with Asphalt (VFA)

- Definition
 - Percentage of VMA filled with asphalt
- Similar to degree of saturation in soils
- Limits excessive VMA



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VFA Equation



$$VFA = 100 \times \frac{(VMA - P_a)}{VMA}$$

Where:

VFA = Percent volume of VMA filled with asphalt

VMA = Percent Voids in the Mineral Aggregate

P_a = Percent Air Voids of the Total mix volume

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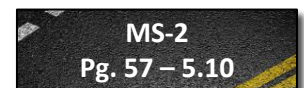
Dust Proportion



- Dust = % Passing the .075mm sieve
- Previously referred to as the Dust / Asphalt ratio
- A parameter that measures the mixture “mastic”

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Dust Proportion



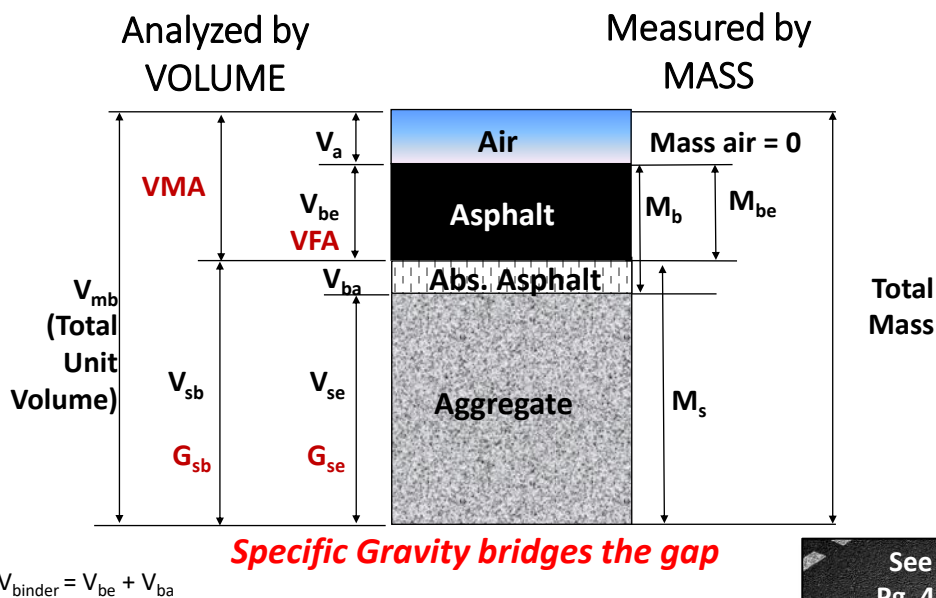
- Originally established using the total asphalt content
- P_{be} is now recommended
- Usage of P_b or P_{be} varies in different regions – Check the specifications.
- Recommended Criteria
 - 0.6 – 1.2
 - 0.8 – 1.6 for extra coarse mixtures

$$DP = \frac{P_{0.075}}{P_{be}}$$

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Phase Diagram

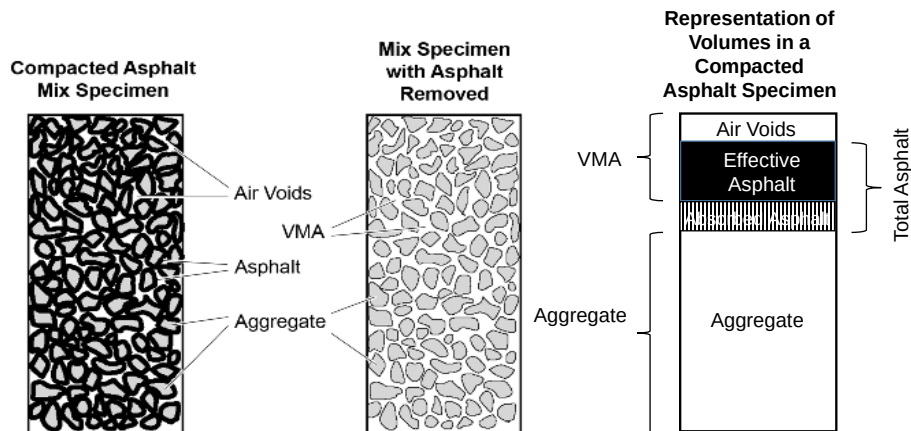


See MS-2
Pg. 48 – 5.3

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Importance of Volumetric Properties



MS-2
Pg. 13 – Figure 2.7

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Many Elements Affect Volumetric Properties

- Binder quantity & binder properties
 - Stiffness
 - Modification
 - Temperature
- Aggregate characteristics
 - Gradation
 - Particle shape
 - Surface texture
 - Hardness
 - Absorption

Every mixture can be different!

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Final Thoughts on Mix Design

- Key Points to Keep in Mind
 1. "Use What Works"
 2. "Eliminate What Doesn't"
 3. "Be as Simple as Possible, Be Practical, and Be Correct"

Engineering Flowchart



"Good doesn't have to be complicated and complicated isn't always good!"



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Thank You Asphalt Institute Membership



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Questions?



Introduction to Paving Fundamentals

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October 28th, 2021

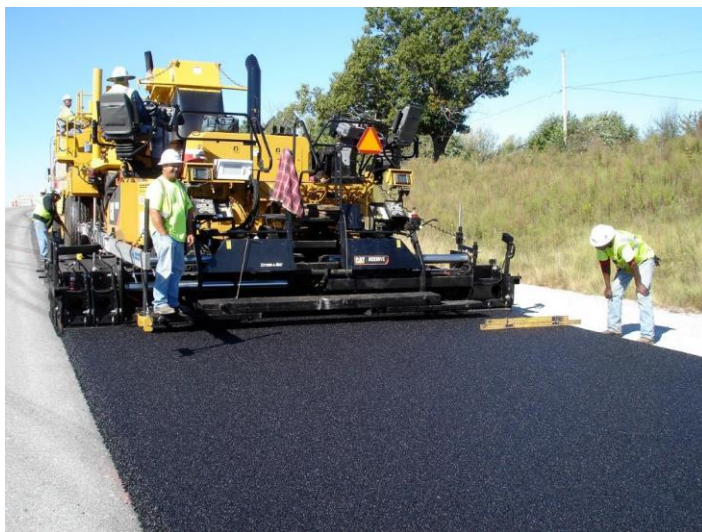


Presented by Todd Mansell, Caterpillar Paving



1

Paving Fundamentals



Caterpillar: Confidential Green

1. Paver setup and takeoff
2. Temperature
3. Continuous Paving
 - ☐ Balanced Paving & Compaction operation
 - ☐ Smoothness
 - ☐ Quick starts & stops
 - ☐ Head of Material
 - ☐ Automatic Grade & Slope Controls
4. Segregation
5. Compaction
 - ☐ Longitudinal Joints



2

Role of the Paver



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- To meet specifications for grade, texture & smoothness



3

The Paver: Tractor & Screed



Tractor

- tows screed
- Accepts mix from trucks, MTV, etc.
- Pushes trucks
- Feeds mix to screed

Screed

- Floats on the mix
- Free to rise and fall according to many factors

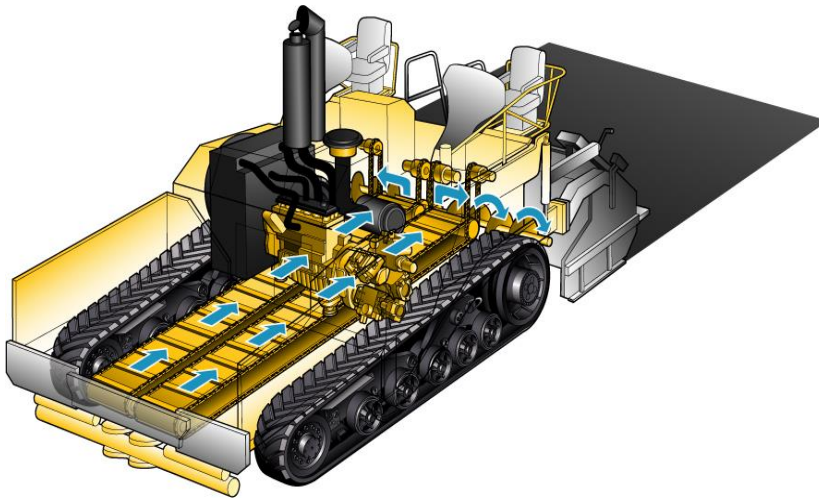


4

Tractor

Material Feed System

1. Hopper
2. Feeder bars
3. Adjustable height augers
4. Feeder sensors (not shown)



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5

Feeds mix from hopper to screed



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6

Screed



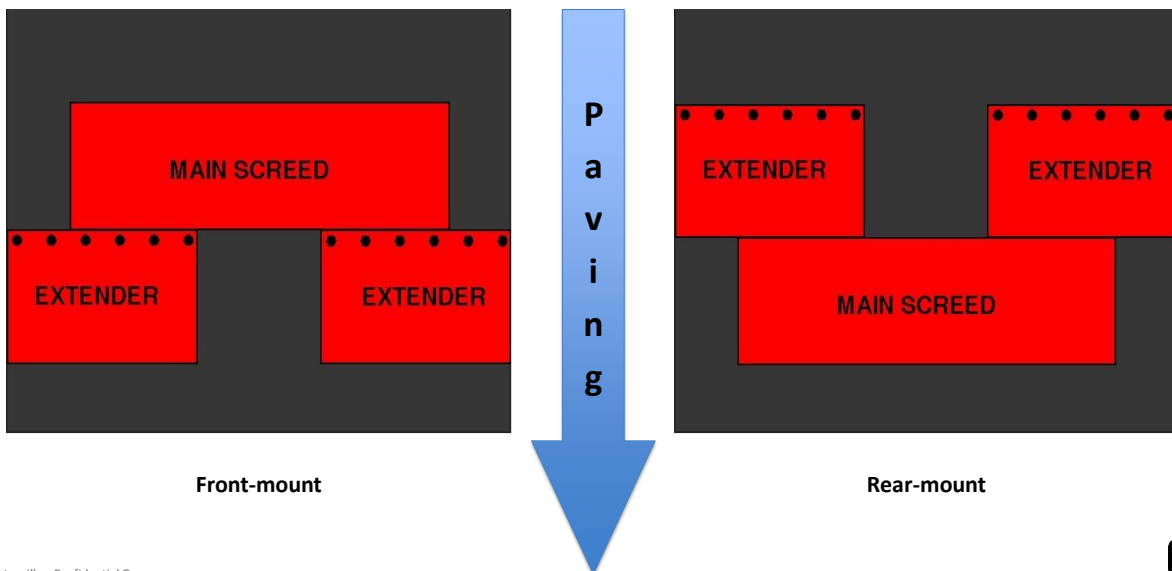
Caterpillar: Confidential Green

- Screed is extendable to pave different widths
- Hydraulic extendable and fixed-width screeds



7

Front-mount and Rear-mount Screeds



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8

Front-mount Screeds



9

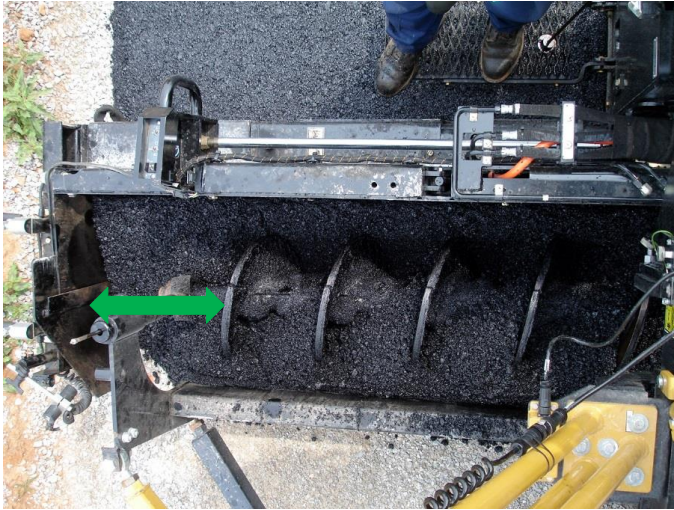
Rear-mount Screeds



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10

Auger Extensions (18" front 36" rear)



18" with front-mount

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36" with rear-mount

11

Free-Floating Screed

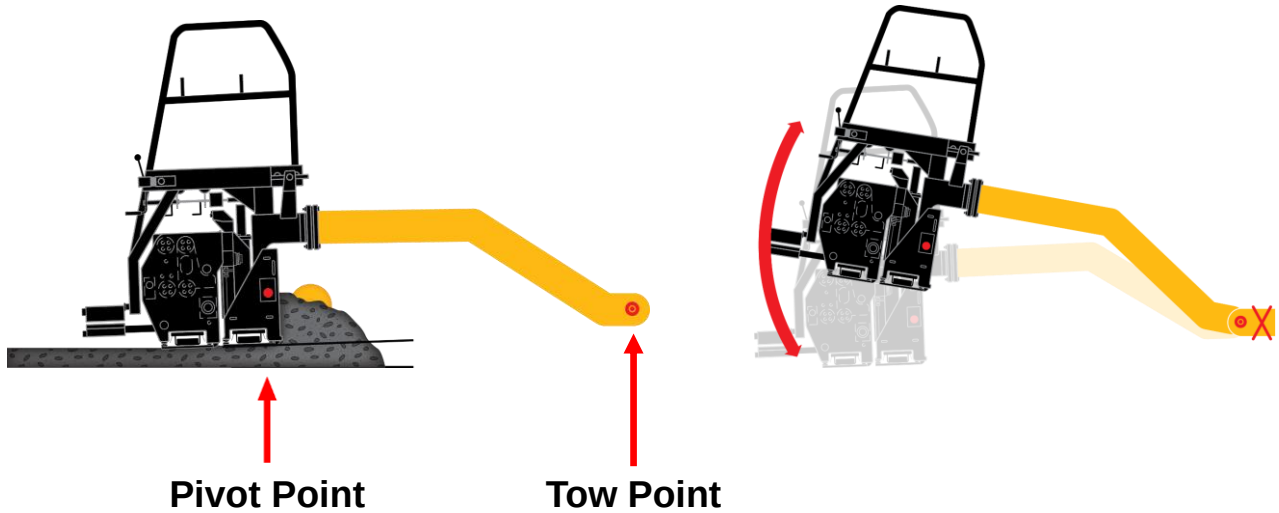


- Principle has not changed since Barber-Greene invented the free-floating screed in 1934

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12

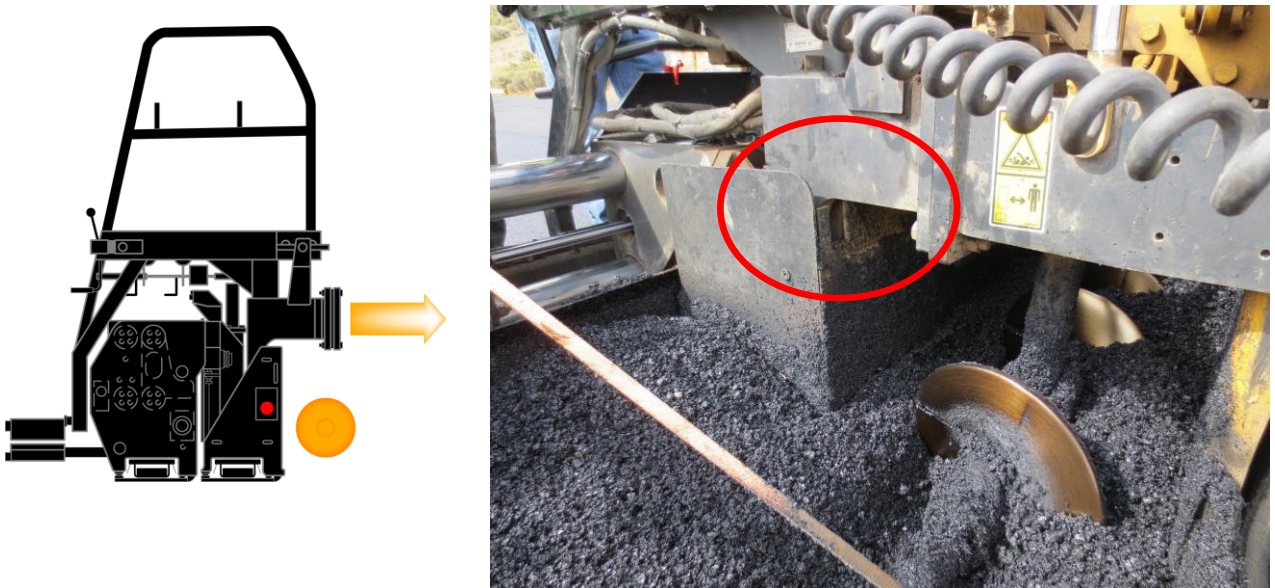
Pivot Points & Tow Points must be clean!



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Pivot Points can get plugged up



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14

Pivot Points - keep clean & free 😊



View looking down on top of pivot point



Remove side cover

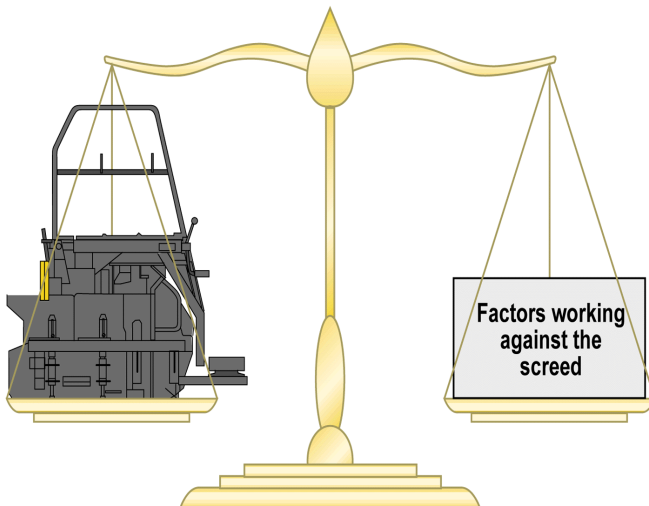


Clean hardened mix out

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15

Free-Floating Screed

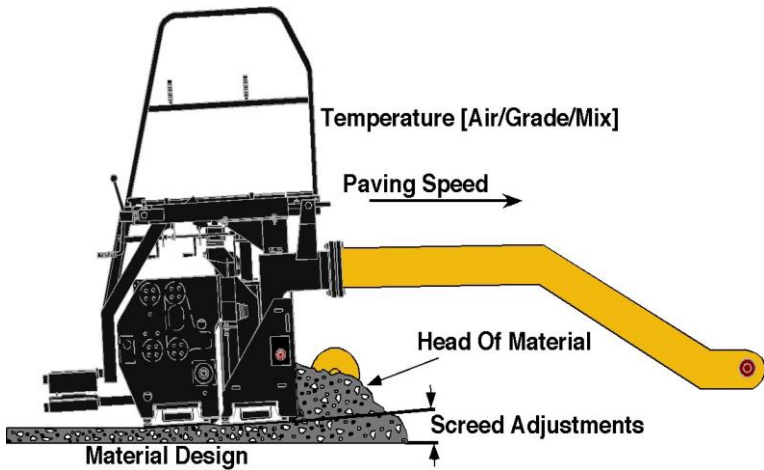


- Screed position determines mat thickness
- Screed position is constant as long as all factors remain constant

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16

Factors Affecting the Screed

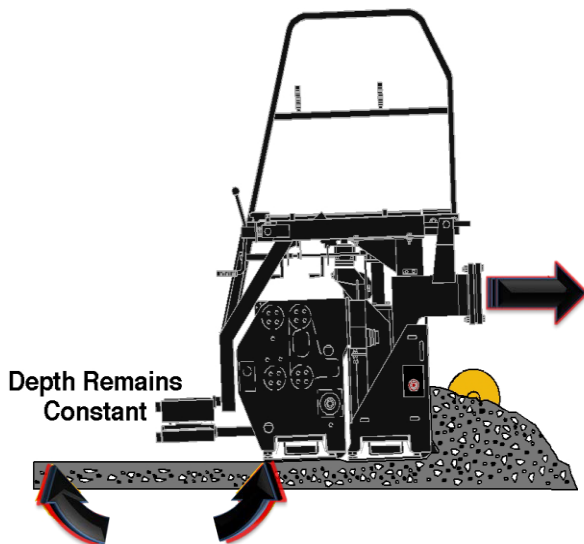


- Paving speed
- Head of material
- Screed adjustments
- Mix design
- Mix temperature
- Air temperature
- Grade temperature

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17

Factors Affecting Screed – Crew Controls



1. Constant Speed
2. Consistent Head of Material
3. Screed Adjustments

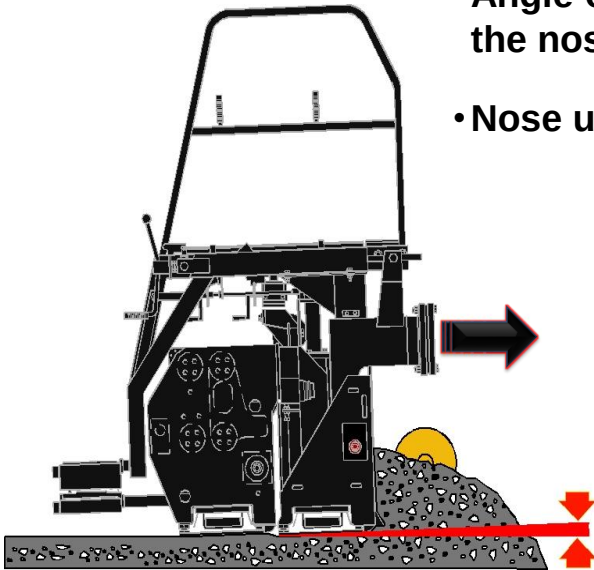
- Shear factor is constant
- Depth remains constant

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18

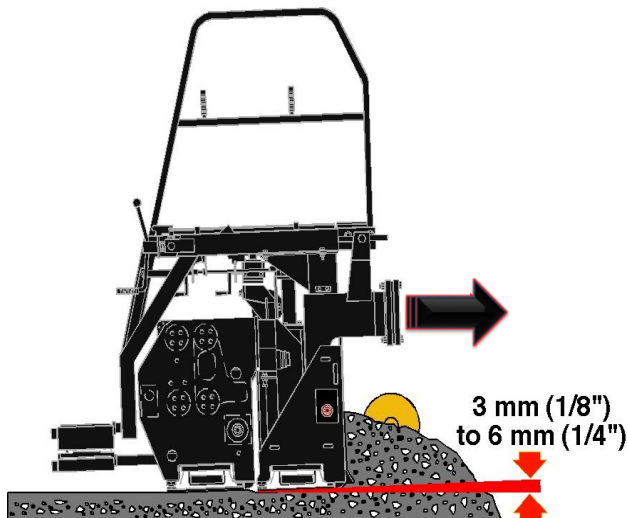
Angle of Attack

- Angle of attack is the relationship between the nose of the screed & the grade
- Nose up attitude



19

Angle of Attack



- Normally 1/8" to 1/4"
- Angle too high
 - compacts with trailing edge
 - shiny appearance
- Erratic screed behavior
- Angle too low increases shear factor and wear
 - open mat texture

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20

Change Thickness and Slope by Changing Angle of Attack

- Use depth control cranks or “screws”
- Use tow points

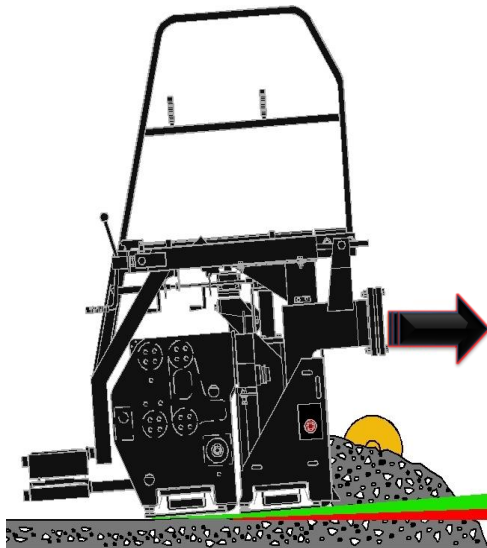


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21

Increase Angle of Attack



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- More material passes under screed
- Screed rises to new level
- As screed climbs, angle of attack decreases
- Re-establish same angle, but at increased depth
 - remember, screed travels through arc and reaches equilibrium @ new thickness

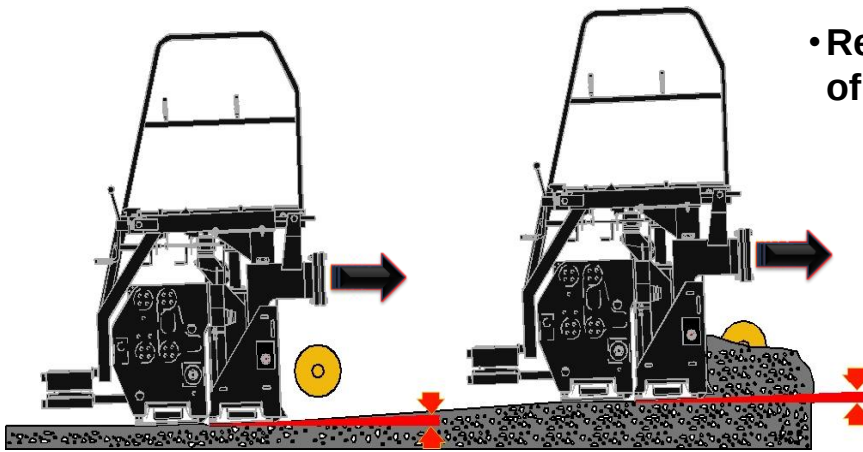


22

Changing Thickness

- Achieves equilibrium at new thickness

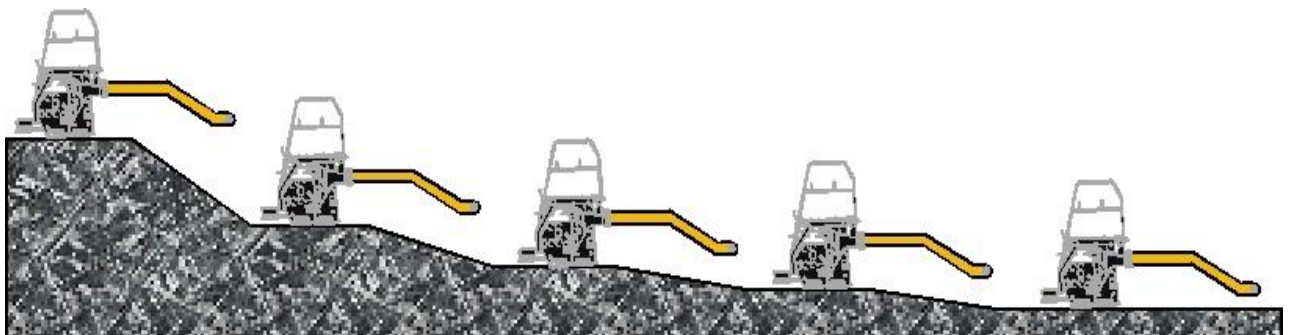
- Resumes original angle of attack



23

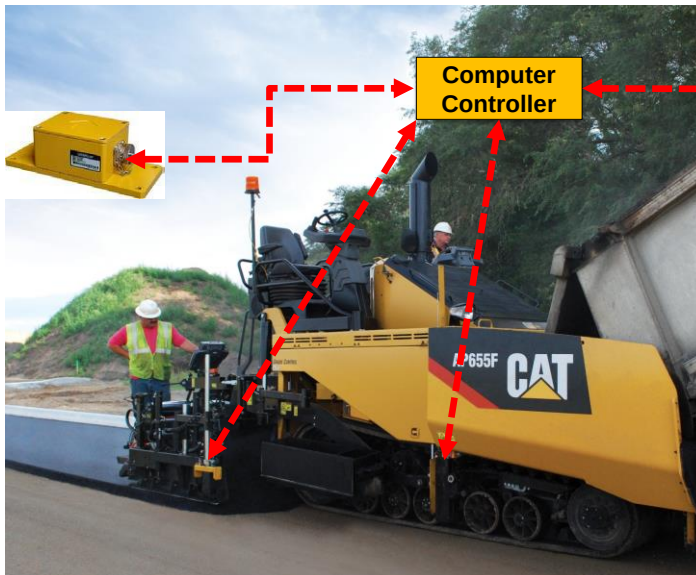
Change Over 5 Tow Arm Lengths

- 65% of change occurs in the first tow arm length
- 35% of change occurs over 4 tow arm lengths



24

Automatic Grade & Slope



Controls tow point movement based on sensor inputs to change thickness and/or slope



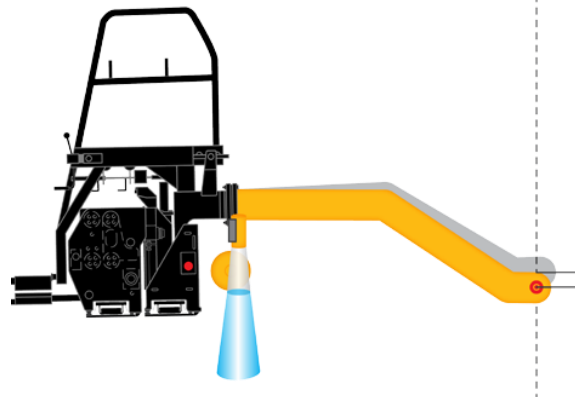
Caterpillar: Confidential Green

25

Sensor Position for Joint Matching = Yield



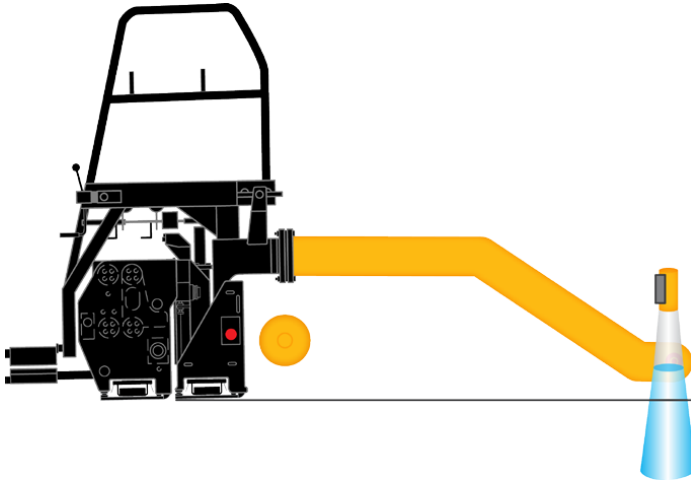
- Sensor at auger for joint matching
- Follows existing grade - no improvement
- Precise yield
- Fast reaction
- Tow point movement = 4x measured deviation, or 4:1



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26

Sensor Position for Smoothness ≠ Yield

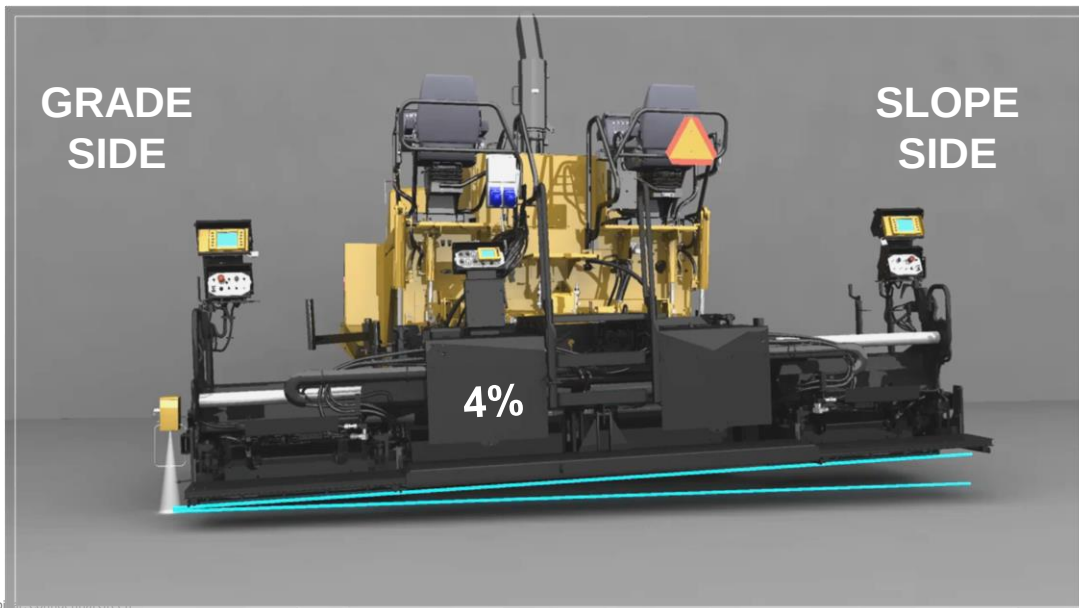


- Sensor at tow point for smoothness
- Slow reaction
- Fills in lows, smooths off high spots
- Difficult to control yield
- Tow point movement = 1x measured deviation, or 1:1
- Screed reacts over 5 tow arm lengths

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27

Slope FOLLOWS Grade Side Changes

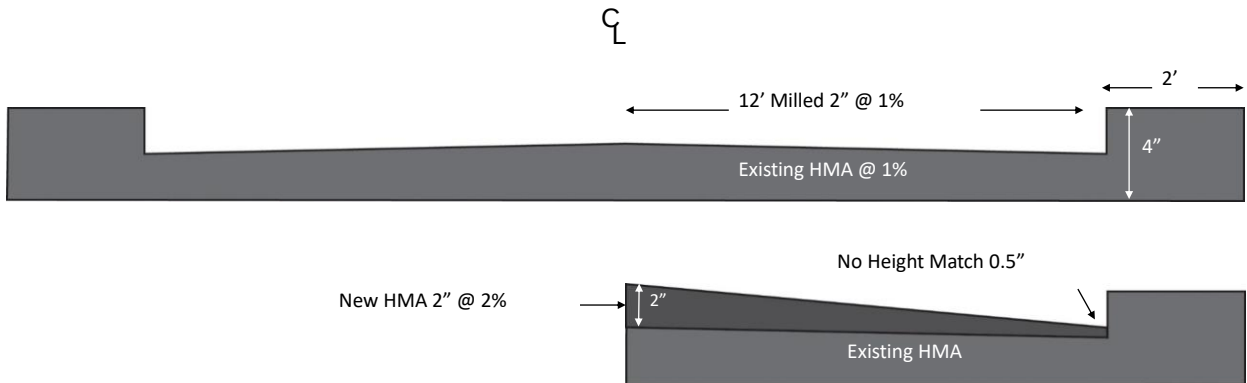


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This is why I can't have both yield & slope!

- Unless my base is already profiled (milled) PERFECTLY!
- This is why I want my BASE to be right!!



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29

Taking off: Is this a good place to start?



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30

Good Starting Point



- Cut straight starting joint
- Butt joint flat



- Tack butt joint
- Clean area where screed will set down

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Paver Setup & Take Off



PAVING BY THE NUMBERS

1. Heat the screed
2. Set the tow points
3. Set paving width
4. Set crown
5. Set extender height
6. Set extender slope
7. Lower screed and remove slack
8. Null the screed
9. Position end gates
10. Set auger height
11. Position feeder sensors
12. Set feeder controls
13. Fill auger chamber/place in auto
14. Set accessory functions
15. Pull off starting reference



CEX01403-01
(Replaces CEX01403-00)

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Build a Pad or use Starter Boards

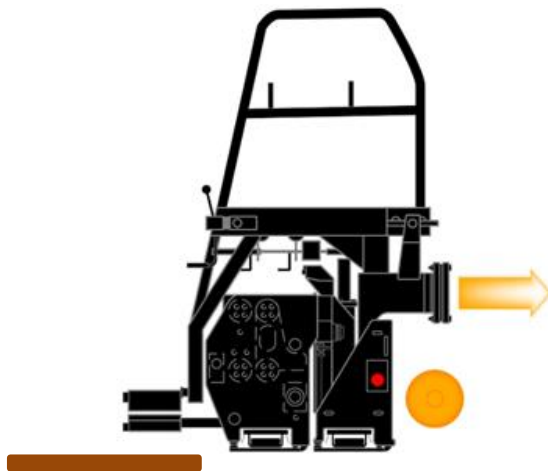


Caterpillar: Confidential Green

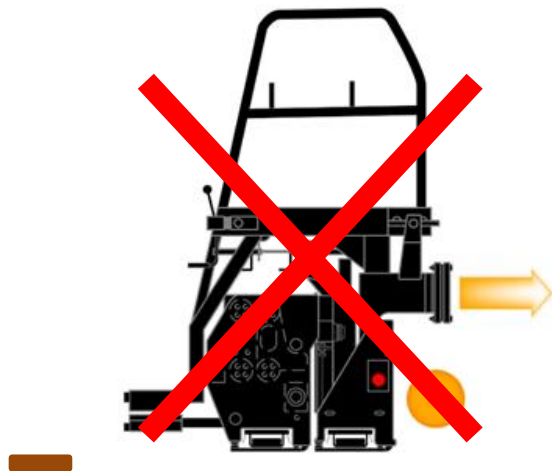
- Support full length of screed & extensions
- 3 to 4 feet long boards
- Based on uncompacted mat thickness (1/4" per 1")

33

Boards must support main & extenders



Full Support Main & Extenders



Screed will drop or 'nose over'

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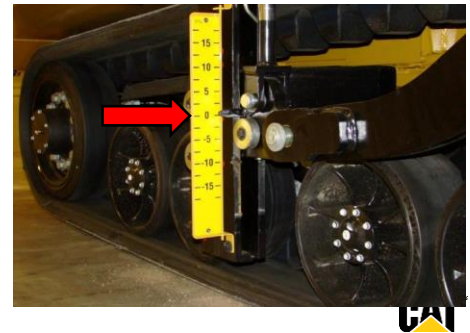
34

Position Tow Point Cylinders



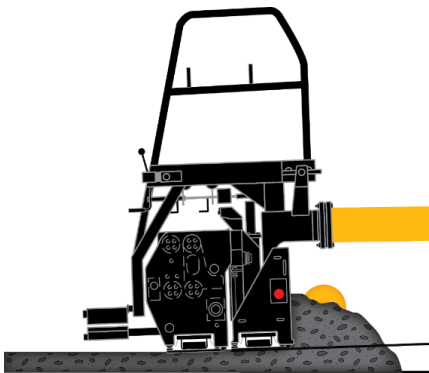
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- Straight line-of-pull

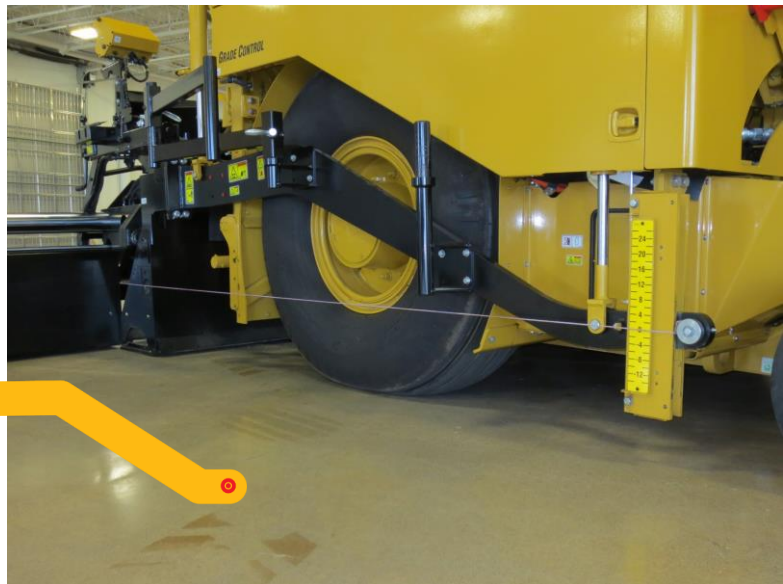


35

Straight Line of Pull



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36

Null the Screed



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- Nulling the screed removes all the tension in the screed
- Use depth screws on each side until no tension is felt
- Go to tension both sides
- The screed must be “free-floating” on the mix



37

Null the Screed



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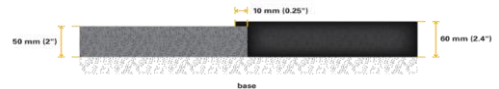
38

Why are end gates important?

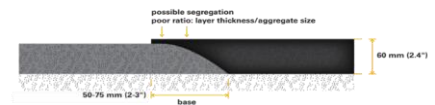


Keep end gates down to build a good longitudinal joint

CORRECT SQUARE JOINT – END GATE DOWN



INCORRECT SQUARE JOINT – END GATE UP



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39

Managing Temperature



- At the plant
- During the haul
- Through the paver
 - smoothness
- During compaction
 - Uniformity of compaction

CONSISTENCY!

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Managing Temperature - silos



Batchers working?



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Managing Temperature



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42

Continuous Paving



- MTVs can help
 - Windrow elevators
 - Re-mixing type
- Approximately 15% improved smoothness

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Paver Stops & Starts...



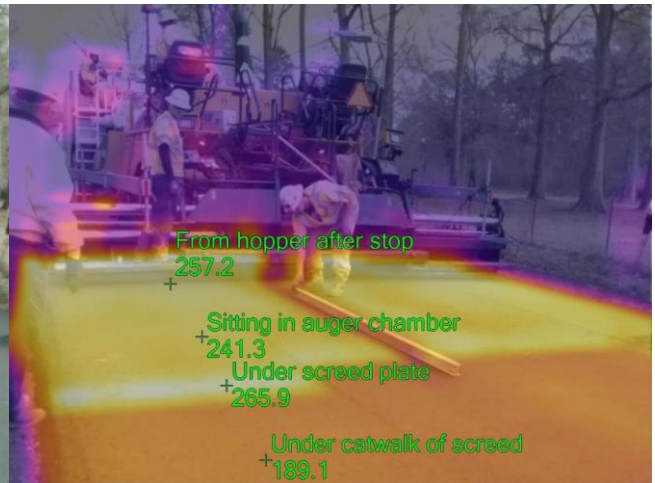
- Smoothness issue
 - Will it roll out?
- Non-uniform compaction
 - Temperature differentials
- Inefficient trucking?
- Stops > 6 min = bump

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Paver Stops - density & smoothness



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45

Planning a Balanced Paving Operation



- Goal is non-stop paving
- Set to match mix delivery
- Balance with rollers
- Quick starts/stops
- 60 fpm maximum

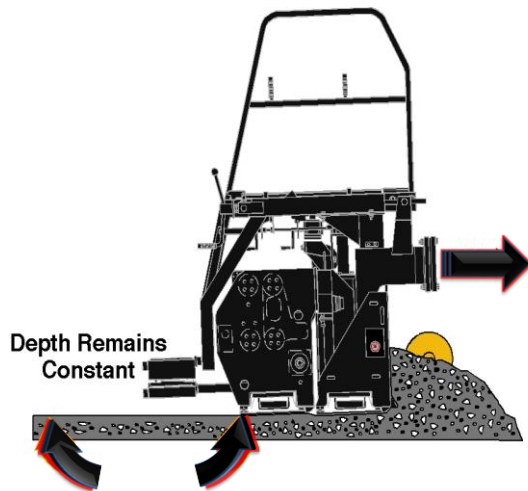


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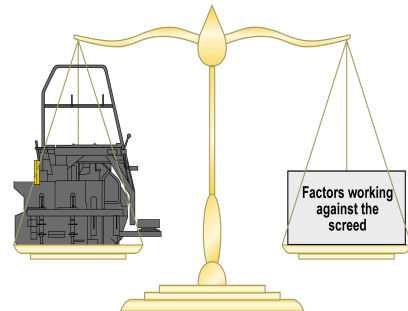


46

Pavement Smoothness



- Shear factor is constant
- Depth remains constant

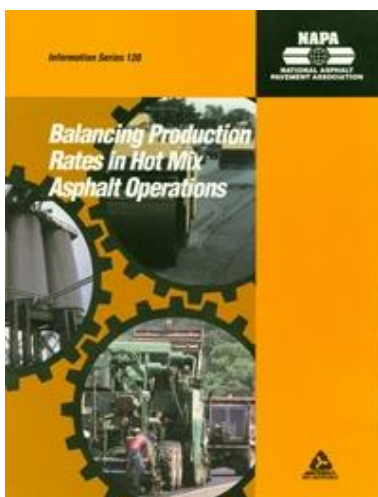


Caterpillar: Confidential Green



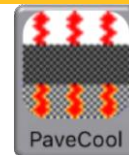
47

Planning ≈ 20 minutes



Pre- paving planning

- Tons per day
- Number of trucks needed
- Paver speed
- Roller speed
- Rolling Pattern
 - Density
 - Smoothness



Tools available

- NAPA IS-120
- Paving Production Calculator App
- PaveCool App

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Paver Speed - Real World Paving

- Do not panic
- Stay with the plan
- Get rid of trucks in an orderly fashion
- Establish a uniform trucking pattern
- Will help density & smoothness



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49

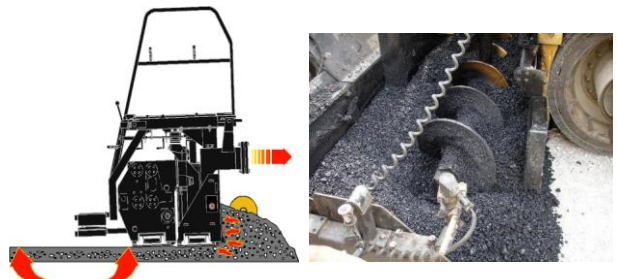


CAT

Managing Head of Material @ ½ Auger



1. Ratio dials (or flow gates)
2. Auger height
3. Feed sensor position
4. Auger speed

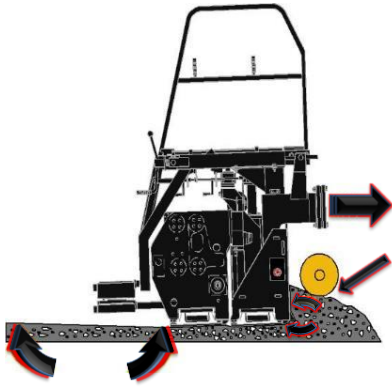


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50

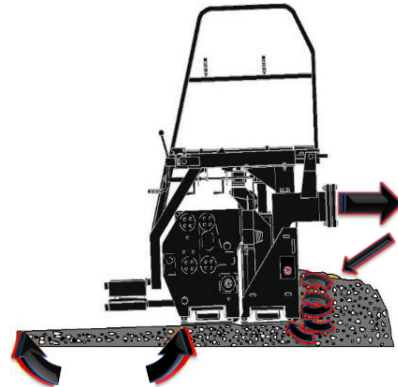
CAT

Changes in Head of Material



Head of Material Decreases

- Resistance decreased
- Depth decreases



Head of Material Increases

- Resistance increased
- Depth increases

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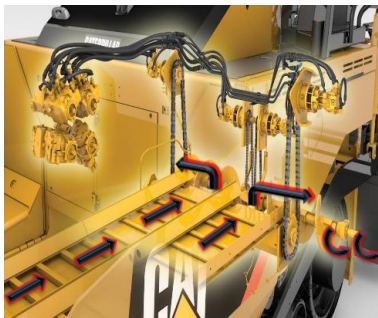


51

Controlling Head of Material: Mix Feed



- Material level at center of auger chamber
- Material level in center area controls auger speed
- Flow gates on some pavers

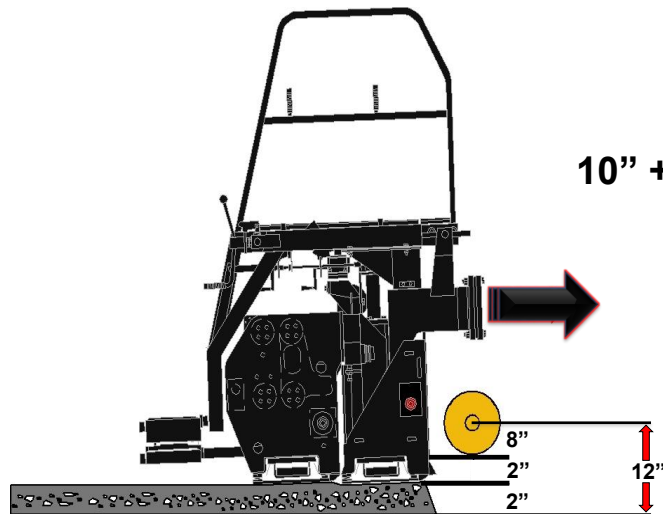


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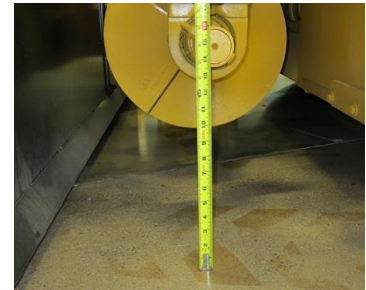
52

Controlling Head of Material: Auger Height



- Start at 2" above level of mat
- Adjust up or down depending on mix type and appearance of mat

10" + mat thickness = auger height



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Aiming Sonic Feed Sensors



- Mechanical or sonic
- Control level of material
- Position Sensor 18" from end of augers



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Controlling Head of Material: Auger Speed



- Auger speed uniform
- 20-40 rpm
- 2s per revolution
- Auger speed too high or too low can cause stripes in the mat

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55

Truck Exchange – HoM – Bumps & Dips



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56

Quick Starts & Stops



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Managing Segregation



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58

Managing Segregation – Truck Exchange



Four step procedure

1. Release truck
2. Continue paving
3. Pave & fold hopper wings
4. Stop quickly

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Managing Segregation – Truck Exchange



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60

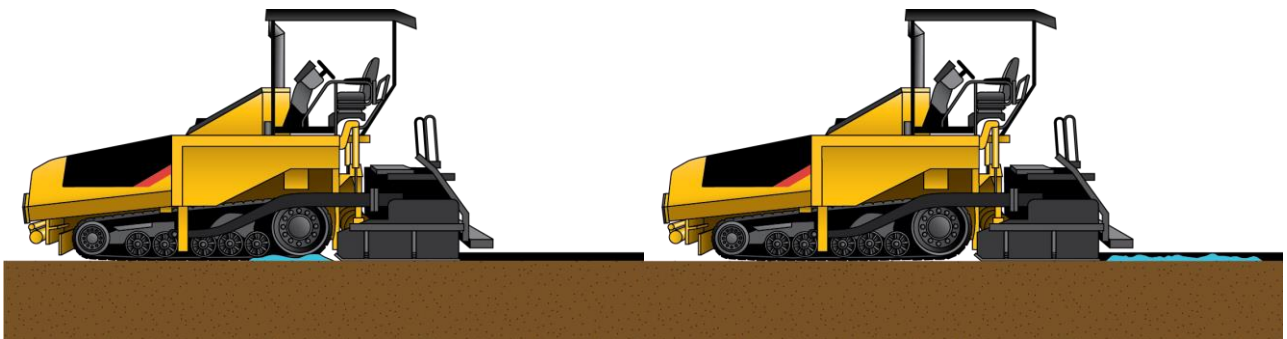
Defects Related to Truck Exchange



CAT

61

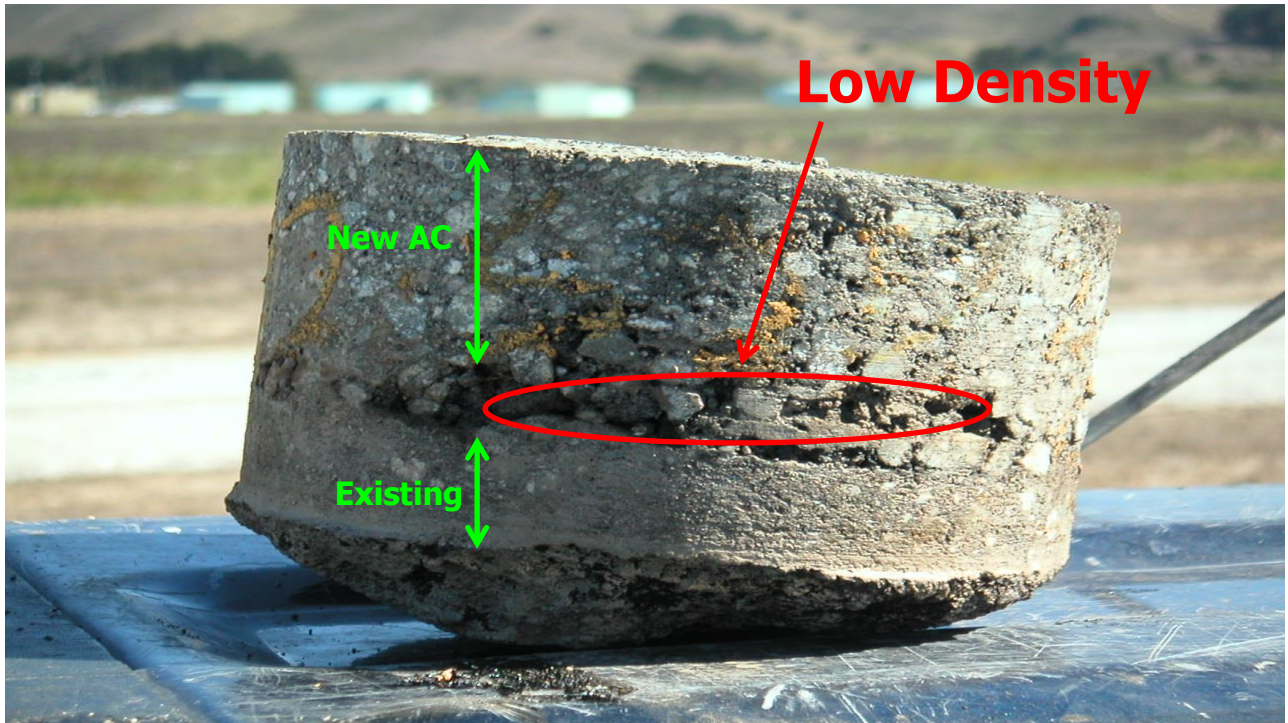
Spills on grade are BIG mistakes!



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CAT

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Trucks Bumping the Paver



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Compaction & Rolling Patterns

	Breakdown	Intermediate	Finish
%TMD	90-92%	92-94%	94% + take out marks
			
Temp	280-252°F	252-230°F	200-163°F
Coverage	2	3	2 (1 vibrate/1+ static)
Settings	High A, Low F	90 psi	Low A, High F, static
Distance	← 120 feet →	← 200 feet →	← 200 feet →
Speed	252 fpm	300 fpm	350 fpm

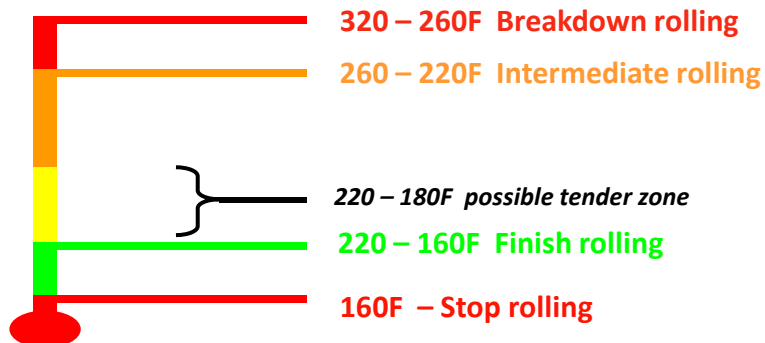
Caterpillar: Confidential Green



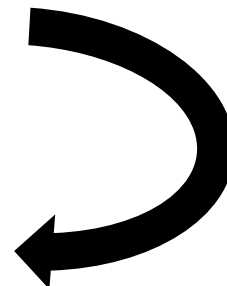
65

Temperature is Critical

Internal mat temperatures



Keep steel drums off the mix!!!



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66

10 – 14 Impacts per Foot (ipf)



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Don't Stop Square to the Mat = Bump



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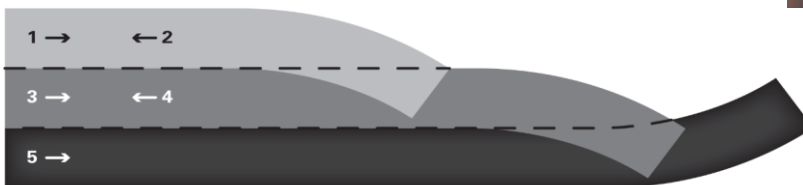
68

Stop at an angle to the mat

- Roller stops at an angle
- Turn off vibration before roller turns out
- Next pass rolls through stop mark
- Stop marks are staggered



REVERSING



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69



Smooth Arcing Stop = No Bump

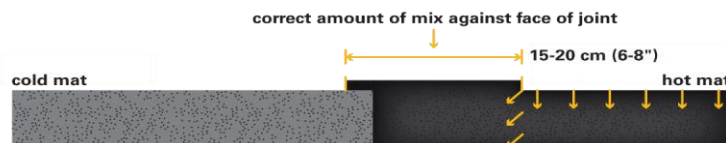


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Longitudinal Joints



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71

CONSISTENCY is the Key to Success!

- Do the fundamentals right
- Avoid BIG mistakes
- Quality costs nothing

1. Paver setup and takeoff
2. Temperature
3. Continuous Paving
 - ☐ Balanced Paving & Compaction operation
 - ☐ Smoothness
 - ☐ Quick starts & stops
 - ☐ Head of Material
 - ☐ Automatic Grade & Slope Controls
4. Segregation
5. Compaction 10-14 ipf

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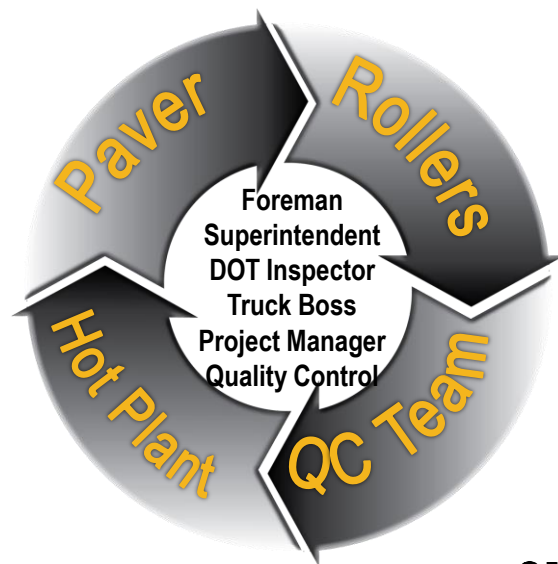


72

Who's responsibility is it? TEAM WORK!



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Mat Defects - Troubleshooting

Problem	Causes																							
	Excessive Pay in Screed	Overconnecting Thickness Control Screed	Too Much Lead Crown in Screed	Initial Screed Too Fast	Fluctuating Load of Material	Screed Paving Too Fast	Screed Riding on Lift Cylinders	Running Hopper Too Fast	Midboard or Sward Too Low	Kicker Screws Worn Out or Warped	Screed Plates Worn Out or Warped	Screed Extensions Installed Incorrectly	Grade Control Hunting (Sensitivity Too High)	Grade Control Hunting (Sensitivity Too Low)	Grade Control Hunting (Sensitivity Too High)	Grade Control Hunting (Sensitivity Too Low)	Improper Mat Thickness	Slinging Low Payed Between Mats	Grade Control Hunting (Sensitivity Too High)	Grade Control Hunting (Sensitivity Too Low)	Reversing or Turning Too Fast of Rollers	Improper Mix Design (Aggregate Size)	Improper Mix Design (Moisture)	Improper Mix Design (Temperature)
Wavy Surface – Short Waves (Ripples)	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Wavy Surface – Long Waves	✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Tearing of Mat – Full Width		✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Tearing of Mat – Center Streak			✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Tearing of Mat – Outside Streaks				✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mat Texture – Nonuniform	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Screed Marks						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Screed Not Responding to Correction		✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Auger Shadows		✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Poor Precompaction		✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Poor Longitudinal Joint	✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Poor Transverse Joint		✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Transverse Cracking (Checking)						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mat Shoving Under Roller						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Roller Marks						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Poor Mix Compaction						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Procedure for Using Table

1. Find problem above.
 2. Checks indicate causes related to the paver.
- X's indicate other problems to be investigated.

NOTE: Many times a problem can be caused by more than one item, therefore, it is important that each cause listed be eliminated to assure solving the problem.

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Thank-you for your attention!





Effect of Mix Composition and RAP Content on HMA Performance

Emad Kassem, Fouad Bayomy, Mohammed Abu Saq, Ahmed Muftah, and Austin Corley

October 28, 2021



1



Introduction

- RP 175 **developed** a mathematical algorithm for determining a **Gyratory Stability (GS)** index for asphalt mixtures based on the Servopac gyratory compactor
- **The GS index** describes the ability of asphalt mixtures to resist rutting
- **The GS index** is determined during the mix design stage **without additional required testing**
- **The GS index** was found to have **good correlation** with the **Flow number** and **APA rutting tests**

2



Introduction

- The **current GS index** algorithm was developed for the **Servopac gyratory compactor**
- **ITD has adopted** the use of **Pine gyratory compactor** in all districts as well as at headquarter labs. **Therefore**, it is essential to **develop a modified mathematical** algorithm for **Pine Gyratory Compactor**
- **Furthermore**, there is a need to examine the **sensitivity of GS index** to the **binder** and **RAP contents** in asphalt mixtures

3



Study Goal

- **Investigate** the **Gyratory Stability** and or other gyratory compaction indicators to detect the **variability of RAP content** and **binder content** in HMA mixes
- **Evaluate** the effect of **mix composition** (binder and RAP content) on **mix performance**

4

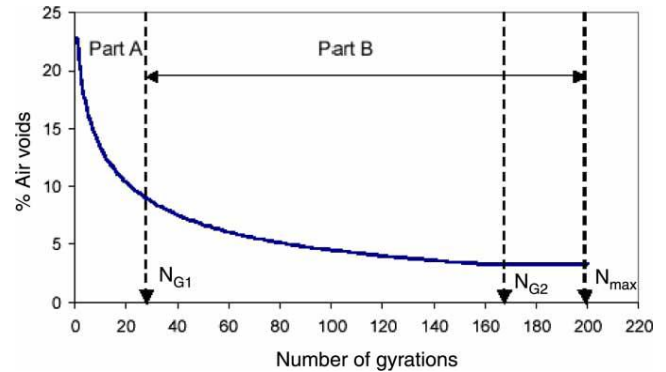
Compaction Curves

Part A

- represents **densification** of loose mixes (steep change in slope)
- aggregates **do not experience** significant amount of shear forces

Part B

- **height** does not change significantly and **air voids** relatively **constant**.
- aggregates experience more **particle contacts** and **shear stresses**.
- Most of the energy is dissipated through aggregate sliding. Consequently, **it increases sample shear strength**.
- Therefore, Part B is of interest to **calculate the mix stability** at ambient temperature



Typical Compaction Curve

5

Compaction Indices

- Various compaction indices were investigated including:
 - Gyratory Stability (**GS**)
 - Construction Densification Index (**CDI**)
 - Laboratory Compaction index (**LCI**)
 - Compaction Force Index (**CFI**)
 - Locking Point (**LP**)
 - Compactability Energy Index (**CEI**)
 - Workability Energy Index (**WEI**)
- Different studies showed that some indices are **more sensitive** to the change in mix composition than others.

6

Development of Testing Matrix

Laboratory-Mixed Laboratory-Compacted (LMLC) Test Specimens

Mix type	SP5			
RAP	0%	25%	50%	
RAP Sources	1	2		
AV%	4%	7%		
Aggregate Type	Basalt	River Gravel		
Binder Grade	PG 76-22	PG 64-28	PG 58-34	
Binder Content	OBC	OBC+0.75%	OBC-0.75%	
Anti-Stripping agent	0%	1.50%		

7

Development of Testing Matrix

Plant-Mixed Laboratory-Compacted (PMLC) Test Specimens

Mix #	District	Project ID	Construction Year	Project Key No.	Location
1	1	D1-P1-b1	2020	20794	US-95, JCT SH-53 OIC, UPRP BR Kootenai Co.
2		D1-P1-b3			
3		D1-P1-b3			
4	3	D3-P5-b1	2020	21858	US20/26, SH16 to Linder Road, sh55 Marsing to SR
5		D3-P5-b2			
6		D3-P5-b3			
7	6	D6-P1-b1	2019	19711	US-Ashton Bridge to Dumpground Road
8		D6-P1-b2			
9		D6-P1-b3			
10	1	D1-P2-b1	2020	20795 & 19794	US-95, Garwood Rd GS 4 Frontage Rds & H-57, Priest River Boat Access
11		D1-P2-b2			
12		D1-P2-b3			
13	4	D4-P1-b1	2020	18881	I-84/I-86 Interchange System
14		D4-P1-b2			
15		D4-P1-b3			
16	4	D4-P2-b1	2020	20170	Sh-81, Declo to Burley
17		D4-P2-b2			
18		D4-P2-b3			

8

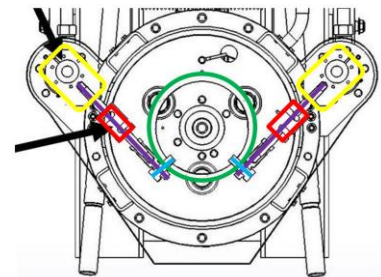
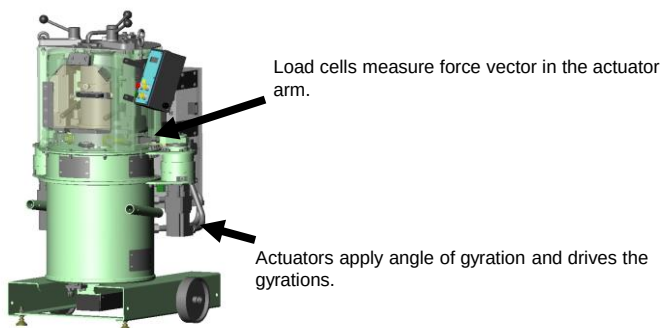
Task 2: Development of Testing Matrix

Plant-Mixed Laboratory-Compacted (PMLC) Test Specimens

Project #	District	Project ID	Mix Type	Specified Binder PG	Virgin Binder PG	Binder Content Pb (%)	RAP (%)	NMAS	Theoretical Specific Gravity (Gmm)	Bulk Specific Gravity (Gsb)
1	D1	D1-P1	SP3	PG64-28	PG 58-34	5.2	30	1/2"	2.473	2.646
2	D3	D3-P5	SP3	PG64-34	N/A	5.4	0	1/2"	2.430	2.571
3	D6	D6-P1	SP5	PG64-34	PG64-34	5.9	16	3/4"	2.382	2.481
4	D1	D1-P2	SP3	PG64-28	PG 58-34	5.3	30	1/2"	2.476	2.654
5	D4	D4-P1	SP5	PG70-28	N/A	5.1	17	3/4"	2.414	2.559
6	D4	D4-P2	SP3	PG64-28	N/A	6.2	17	1/2"	2.293	2.417

9

Develop Mathematical Algorithm for GS



Generating a Value for Gyratory Shear
Pine's Gyratory Shear Measurement



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Develop Mathematical Algorithm for GS

$$\Sigma M_O = 0$$

$$2R \cdot e \cos(\delta) - (F_g \cdot h/2) - (w/2 \cdot h/2 \sin(\delta)) = 0$$

Since δ is small angle, we can assume $\sin(\delta) = 0$ and $\cos(\delta) = 1$

$$2R \cdot e - F_g \cdot h/2 = 0 = 0$$

$$F_g = \frac{2R \cdot e}{h/2} = \frac{4R \cdot e}{h} \text{ at half of the sample}$$

So, the shear force (F_g) can be calculated at any gyration number.

$$F_g = \frac{2R \cdot e}{h}$$

$$M = R \cdot e$$

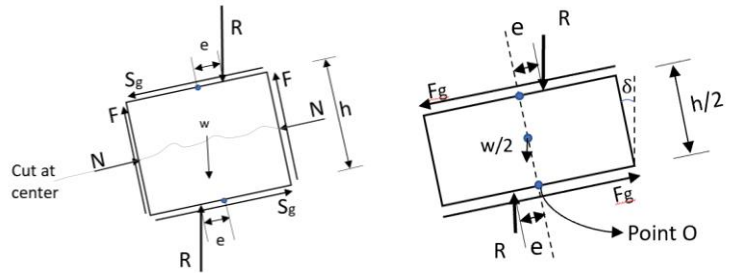
$$F_{gi} = \frac{2M_i}{h_i}$$

The shear stress (S_g) can be calculated at any gyration number as following:

$$S_g = \frac{F_g}{A}$$

$$S_{gi} = \frac{2M_i}{Ah_i}$$

Calculate shear stress during compaction through conventional static equilibrium analysis



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Develop Mathematical Algorithm for GS

GS: the summation of shear energy increments between N_{g2} and N_{g1}

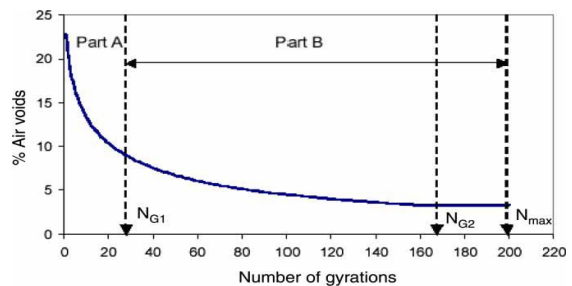
$$GS = \sum_{N_{g1}}^{N_{g2}} \{ (2M_i/h_i) (\Delta h_i) \}$$

where:

N_{g1} = the number of gyrations at which the second derivative of the air voids function with respect to the number of gyrations is zero. It is assumed that particle contacts are developed at N_{g1} .

N_{g2} = the gyration number corresponding to 96% Gmm

M_i = the moment at each gyration number, which is readily measured and provided in the Pine Excel spreadsheet.

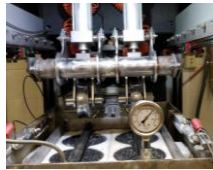


12

Laboratory Testing



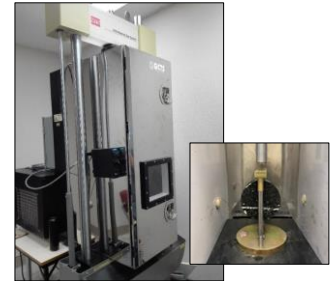
Gyratory Stability and other compaction Indices



Asphalt Pavement Analyzer (APA-Jr)



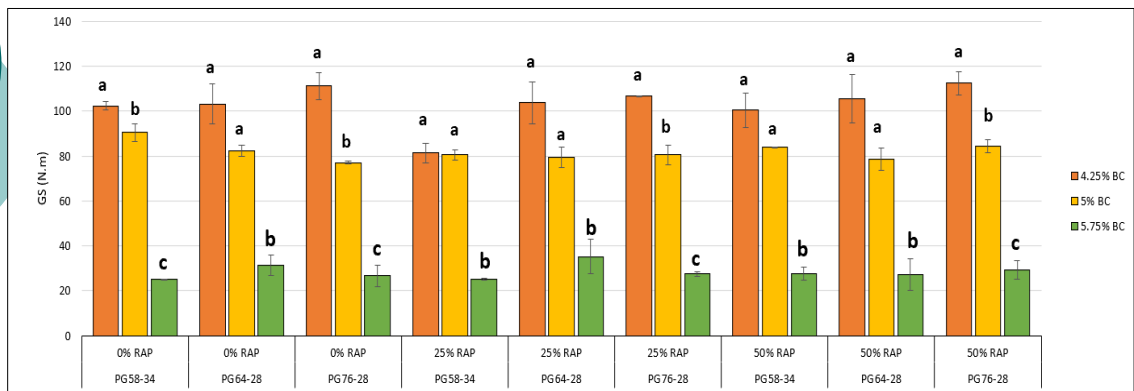
Hamburg Wheel Tracking Test (HWTT)



Indirect Tensile Strength (IDT)
Dry and Wet

13

Compaction Indices

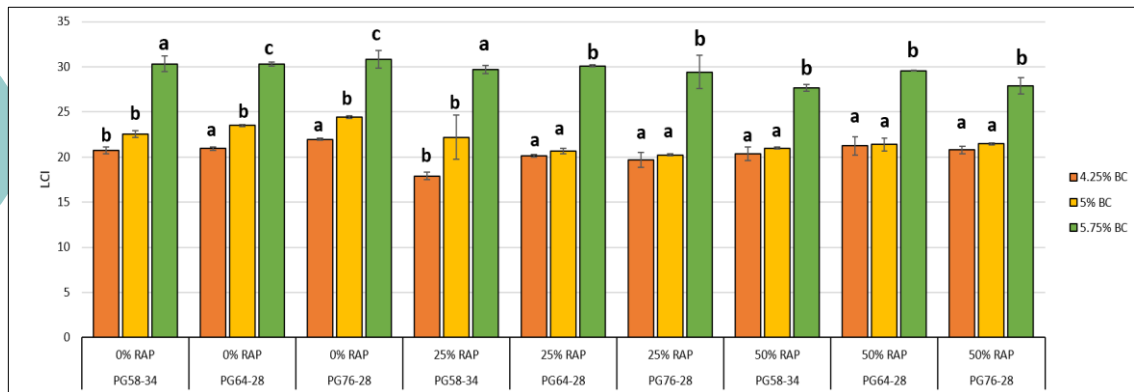


Gyratory Stability (GS) Sensitivity to Different Binder Contents

GS decreased with the increase in binder content; there was statistically significant difference between (dry vs. wet) samples but not between 4.25% and 5% for all cases

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Compaction Indices



Laboratory Compaction Index (LCI) Sensitivity to Different Binder Contents

LCI increased with the increase in binder content; there was statistically significant difference between (dry vs. wet) samples but not between 4.25% and 5%

15

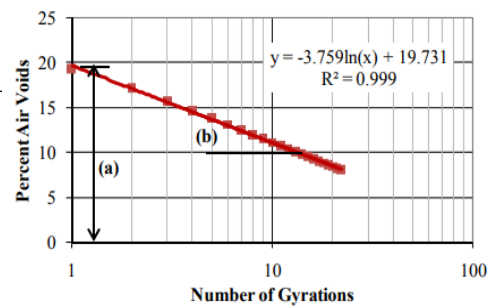
Laboratory Compaction Index

$$LCI = 100 * \frac{b^{1.2}}{a}$$

where,

a = The intercept of the compaction curve

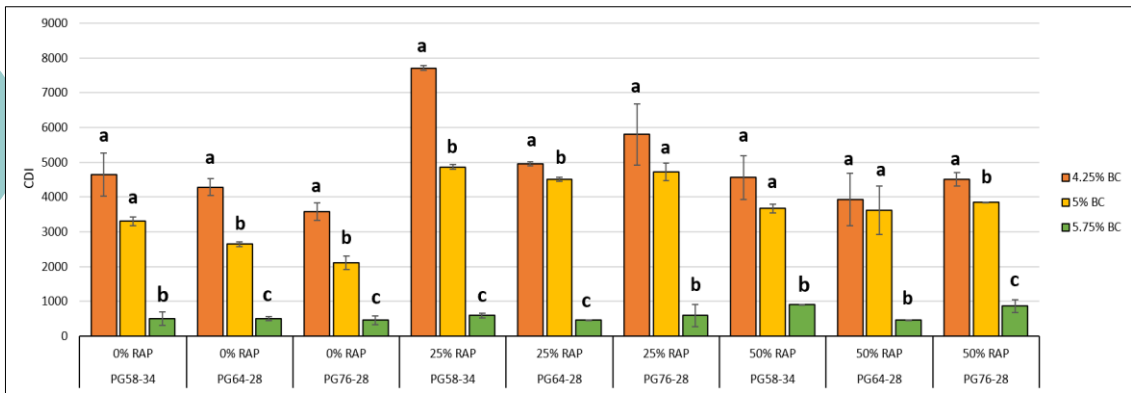
b = The slope of the compaction curve (absolute value)



- The LCI: A function of the absolute value of the slope (b) and intercept (a), of the laboratory compaction curve
- Asphalt mixtures with higher LCI values are easier to compact compared to those with lower LCI values

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Task 4: Laboratory Testing Compaction Indices



Compaction Density Index (CDI) Sensitivity to Different Binder Contents

CDI decreased with the increase in binder content; there was statistically significant difference between (dry vs. wet) samples but not between 4.25% and 5% for all cases

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Construction Density Index (CDI)

$$CDI = \sum_{N=8}^{N_{92}} \%G_{mm}$$

$\%G_{mm}$ = Percent maximum density

$N=8$ = Gyration number 8

N_{92} = Number of gyrations at 92% G_{mm}

The CDI: the area measured under the densification curve from the eighth gyration to the number of gyrations at 92% of the theoretical maximum specific gravity (G_{mm})

18

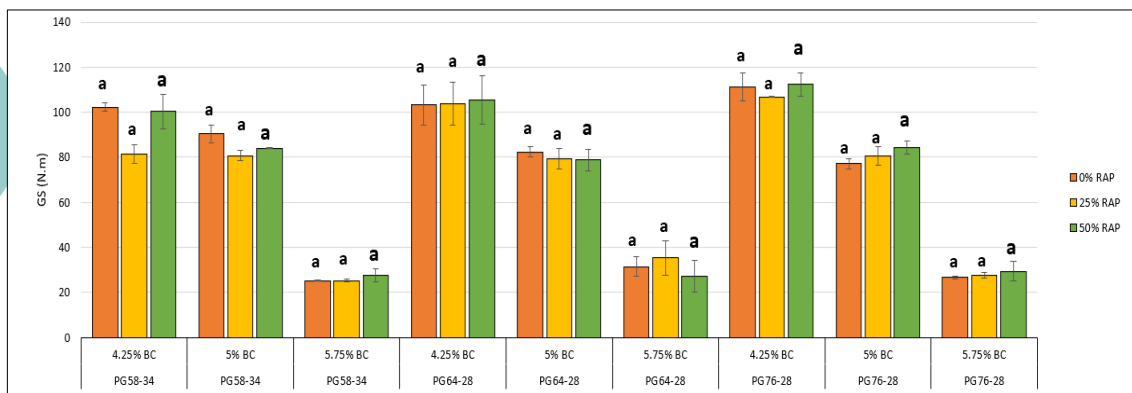
Compaction Indices

Other compaction Indices

- Compaction Force Index (CFI)
- Locking Point (LP)
- Compactability Energy Index (CEI)
- Workability Energy Index (WEI)

19

Compaction Indices

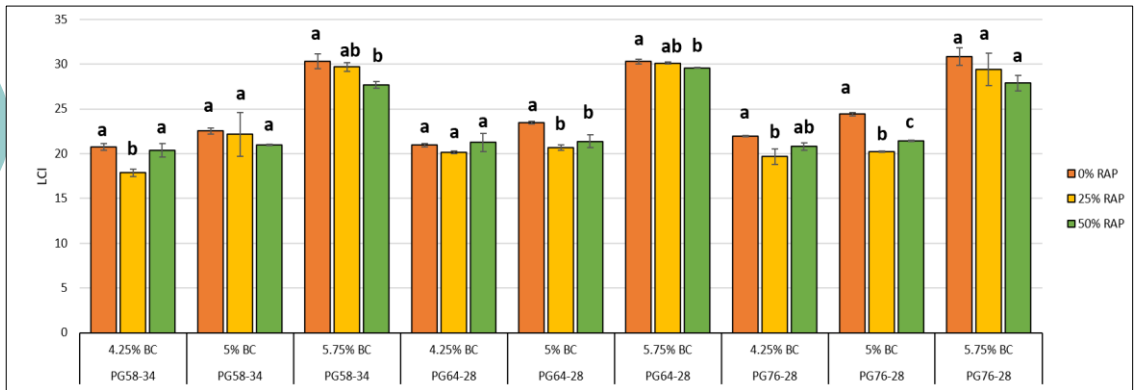


Gyrotory Stability (GS) Sensitivity to Different RAP Contents

No consistent trend for the effect of RAP content on GS;
No significant difference in the results

20

Compaction Indices

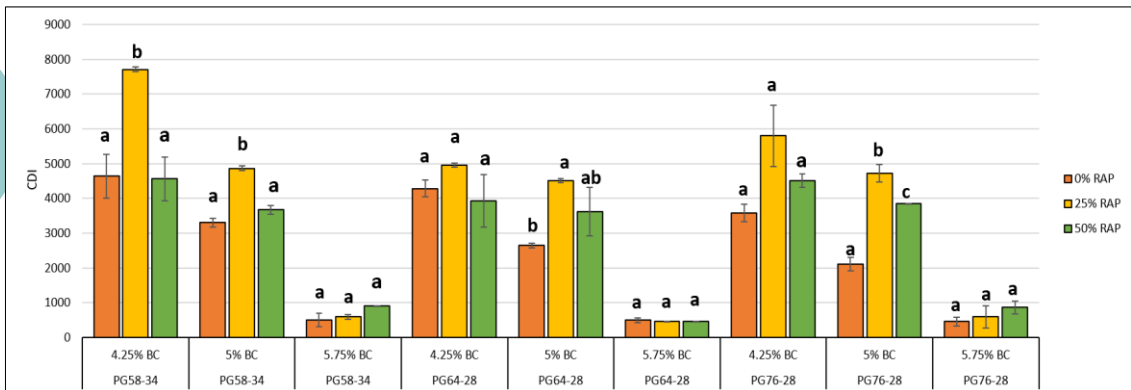


Laboratory Compaction Index (LCI) Sensitivity to Different RAP Contents

No consistent trend for the effect of RAP content on LCI;
No significant difference in the results

21

Compaction Indices

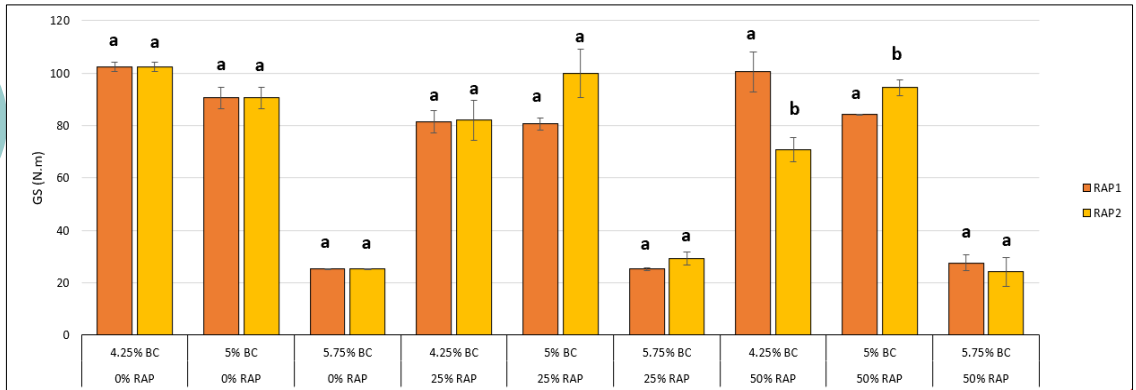


Compaction Density Index (CDI) Sensitivity to Different RAP Contents

No consistent trend for the effect of RAP content on CDI;
No significant difference in the results

22

Compaction Indices

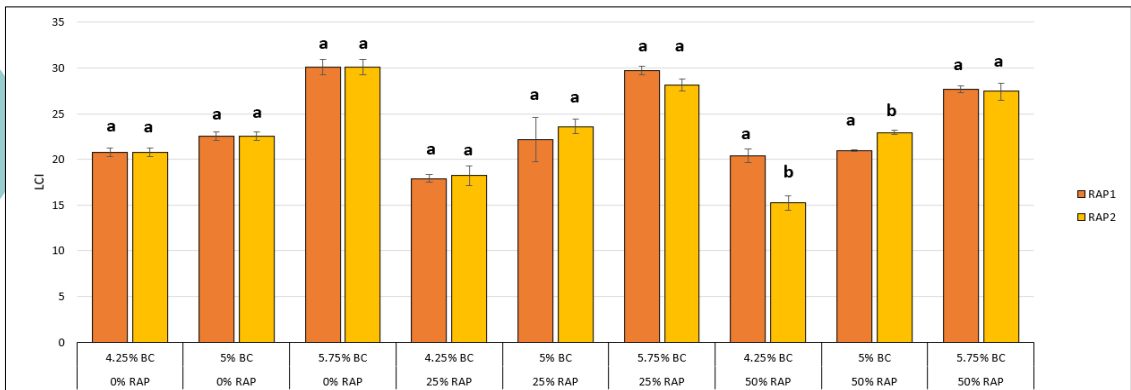


Gyrotory Stability (GS) for RAP1 and RAP2

No consistent trend for the effect of binder source on GS;
No significant difference in the results

23

Compaction Indices

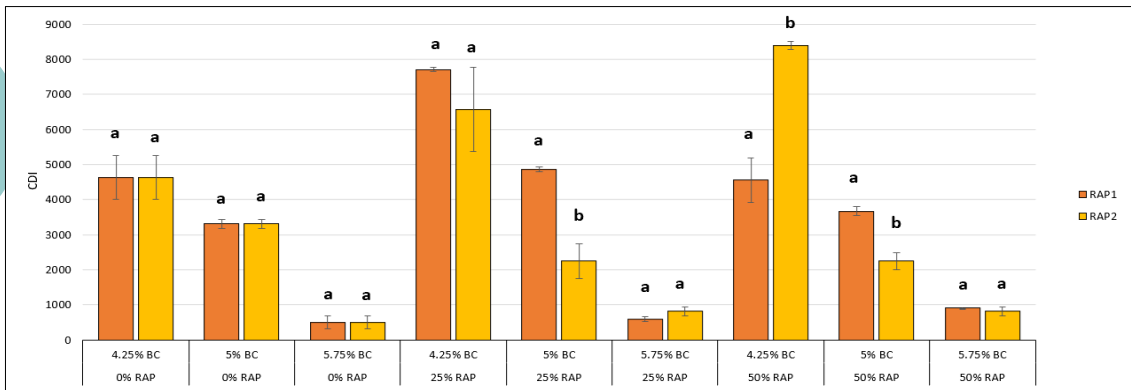


Laboratory Compaction Index (LCI) for RAP1 and RAP2

No consistent trend for the effect of binder source on LCI;
No significant difference in the results

24

Compaction Indices

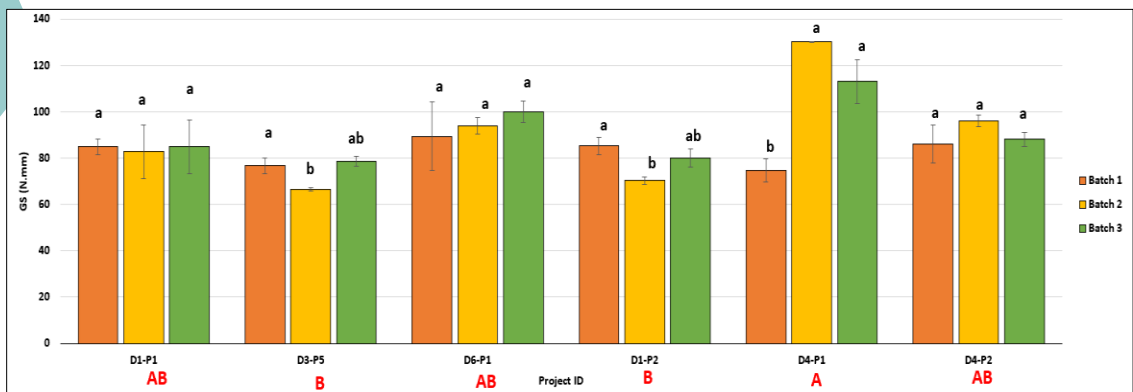


Compaction Densification Index (CDI) for RAP1 and RAP2

No consistent trend for the effect of binder source on CDI;
No significant difference in the results

25

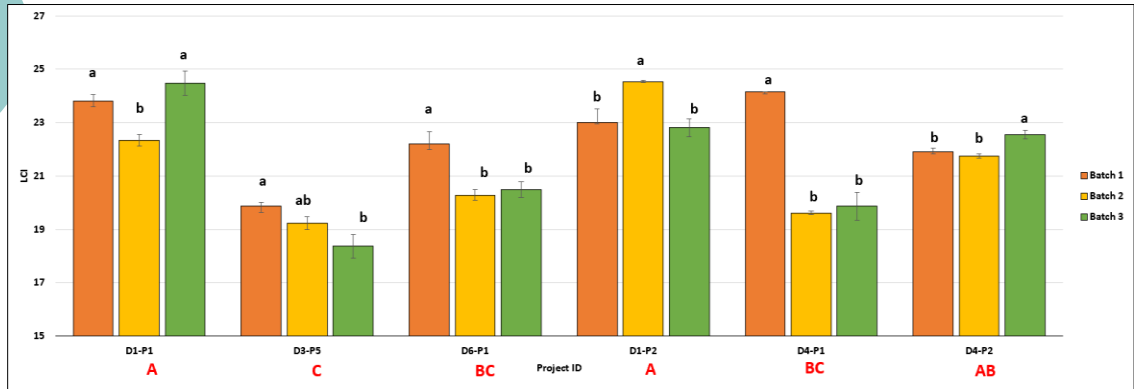
Compaction Indices



Gyrotory Stability (GS) of PMLC Mixes

26

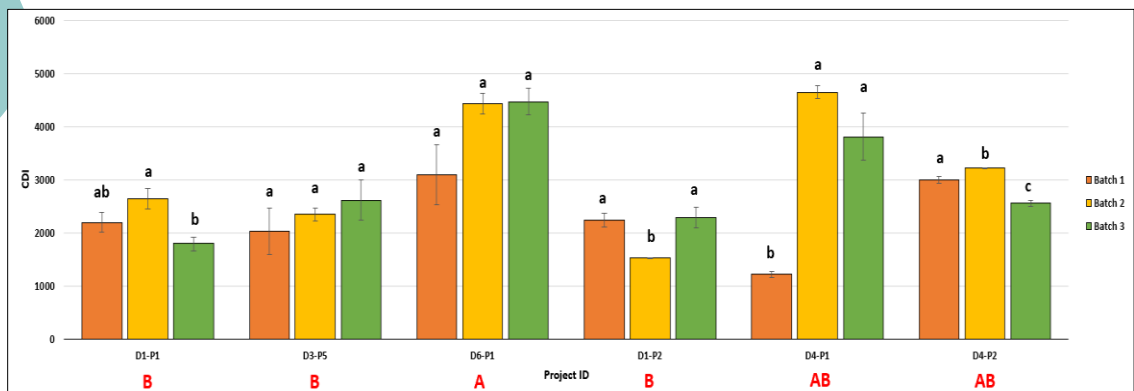
Laboratory Testing Compaction Indices



Laboratory Compaction Index (LCI) of PMLC Mixes

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Laboratory Testing Compaction Indices



Compaction Densification Index (CDI) of PMLC Mixes

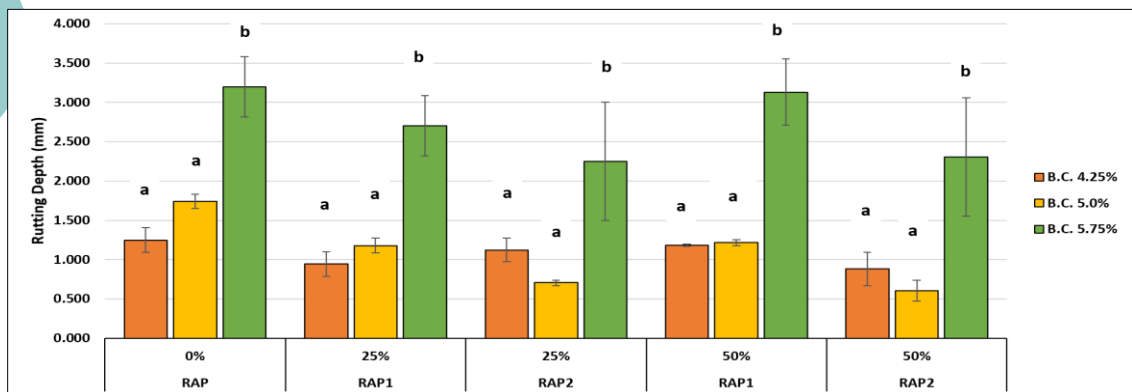
28

Laboratory Testing Rutting

Rutting Performance Results

29

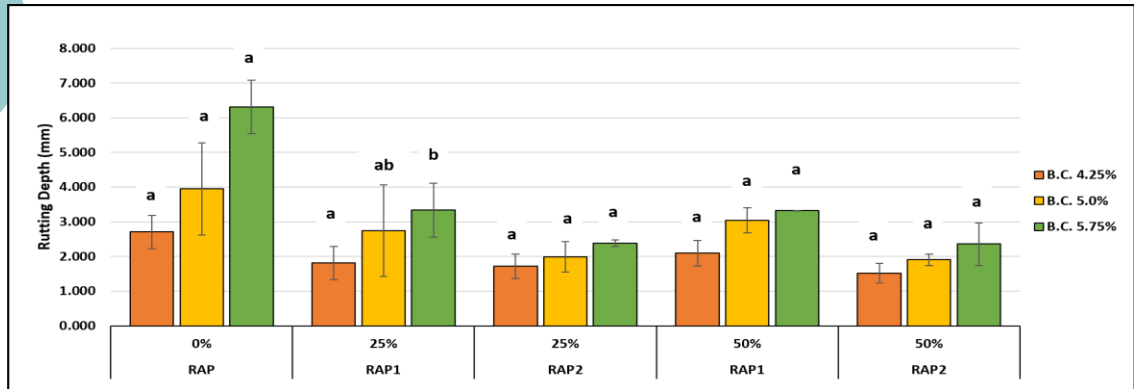
Laboratory Testing Rutting



APA Rutting Depths at Different Binder Contents (PG58-34)

30

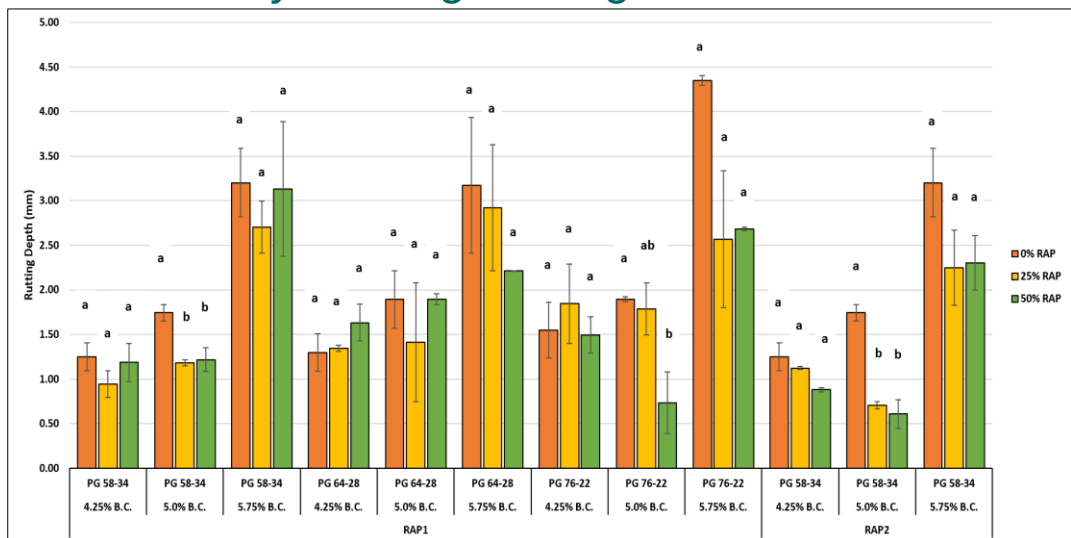
Laboratory Testing Rutting



Hamburg Rutting Depths at Different Binder Contents (PG58-34)

31

Laboratory Testing Rutting

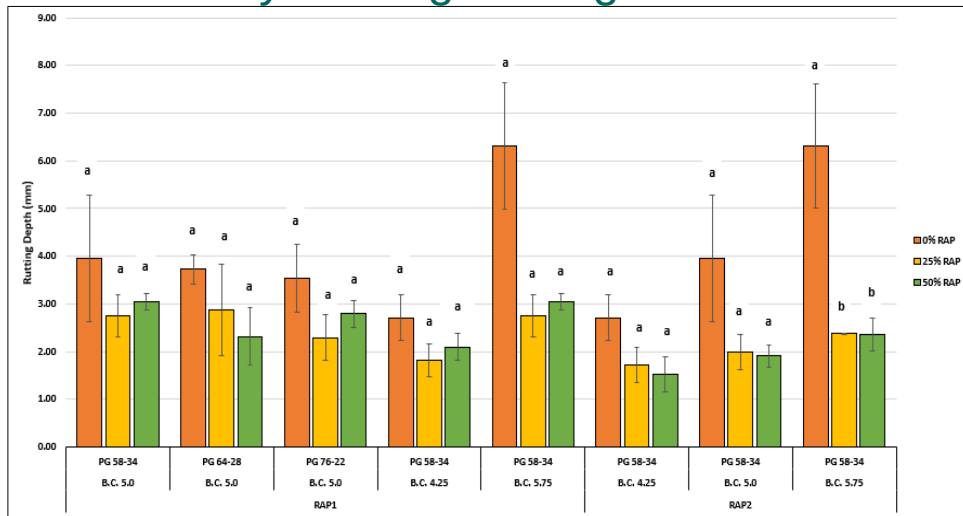


APA Rutting Depths at Different RAP Contents

APA rut depth is less than 5 mm

32

Laboratory Testing Rutting

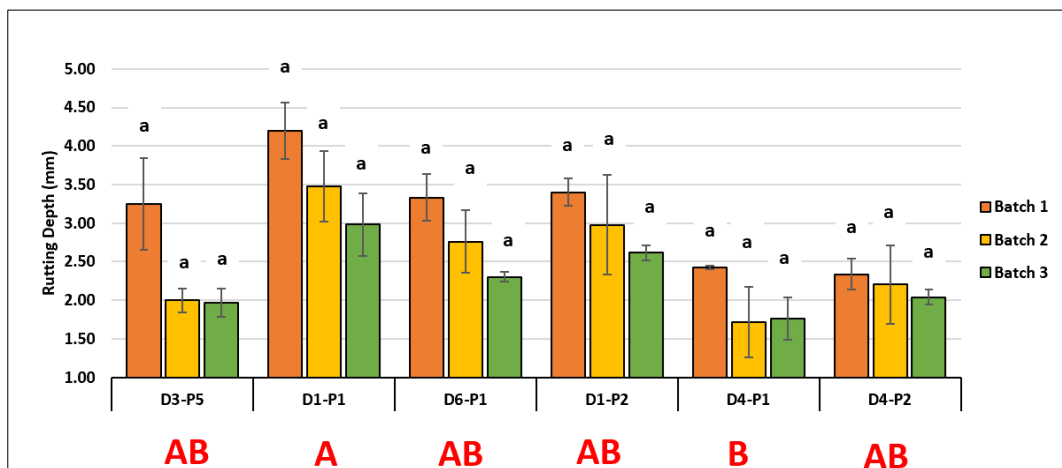


Hamburg Rutting Depths at Different RAP Contents

Overall, mixtures with RAP had less HWTT rut depth; HWTT was less than 12.5 mm

33

Laboratory Testing Rutting

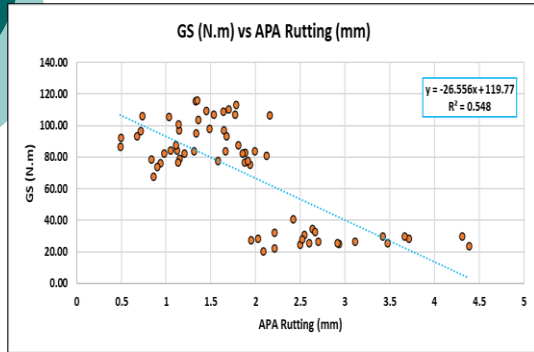


Hamburg Rutting Depths of PMLC Mixes

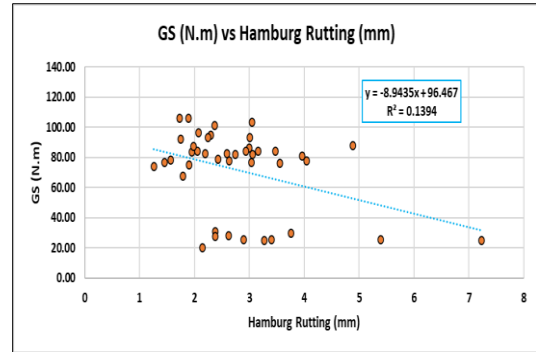
HWTT was less than 12.5 mm after 20,000 passes

34

Laboratory Testing Rutting



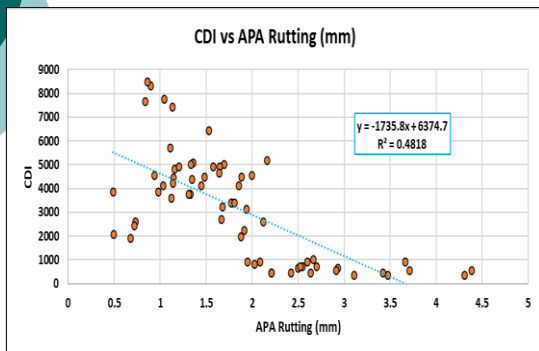
Correlation between **GS** and **APA** Rutting Data of LMLC Mixes



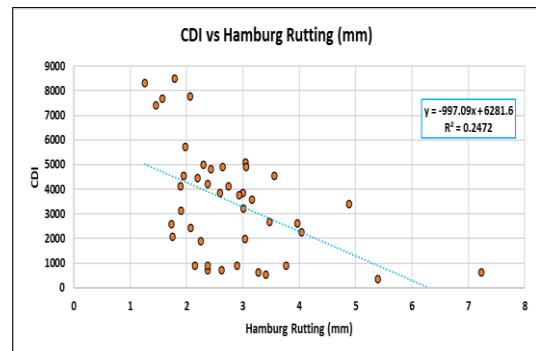
Correlation between **GS** and **Hamburg** Rutting Data of LMLC Mixes

35

Laboratory Testing Rutting



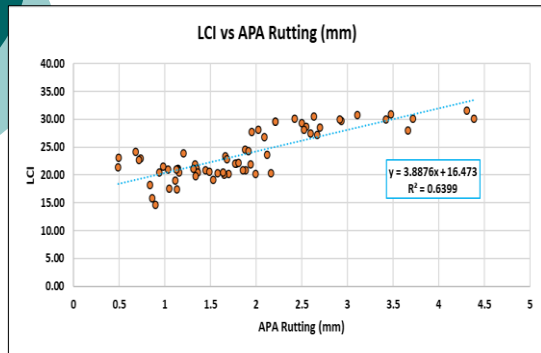
Correlation between **CDI** and **APA** Rutting Data of LMLC Mixes



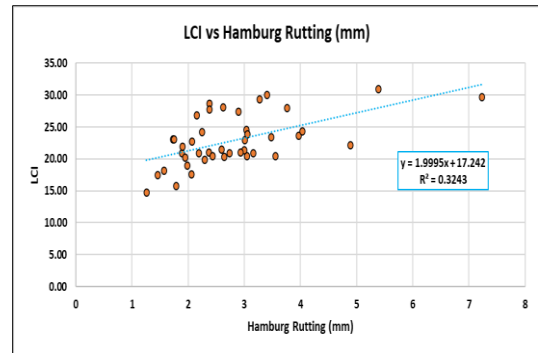
Correlation between **CDI** and **Hamburg** Rutting Data of LMLC Mixes

36

Laboratory Testing Rutting



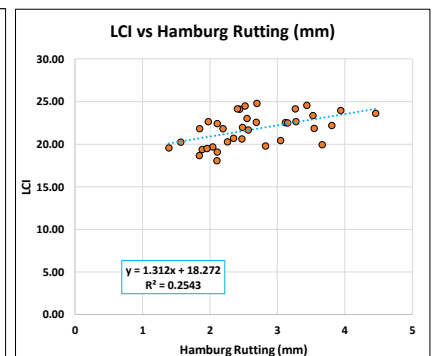
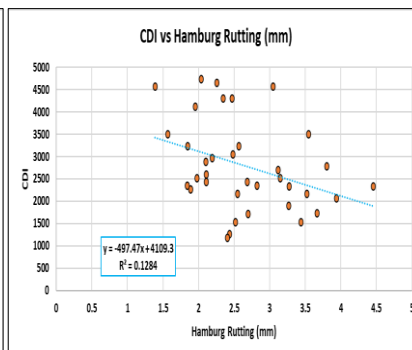
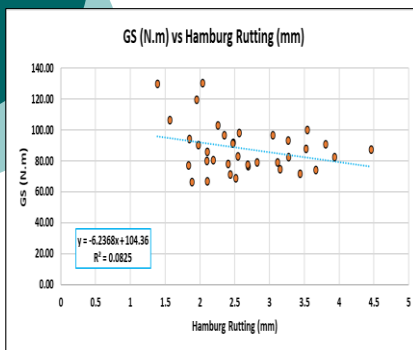
Correlation between **LCI** and **APA** Rutting Data of LMLC Mixes



Correlation between **LCI** and **Hamburg** Rutting Data of LMLC Mixes

37

Laboratory Testing Rutting



Correlation between **GS**, **CDI**, **LCI** and **Hamburg** Rutting Data of **PMLC** Mixes

38

Laboratory Testing Cracking

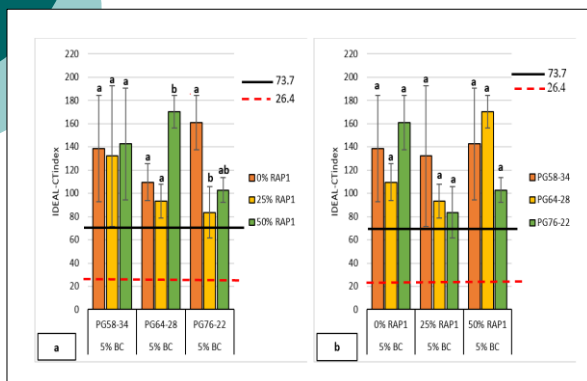
○ Monotonic IDT Cracking resistance indicators

- IDEAL-CT_{Index}
- Cracking Resistance Index (CRI)
- N_{flex}
- Weibull_{CRI}
- Fracture Energy (G_f)
- IDT_{Strength}
- IDT_{Modulus}
- Flexibility Index (FI)

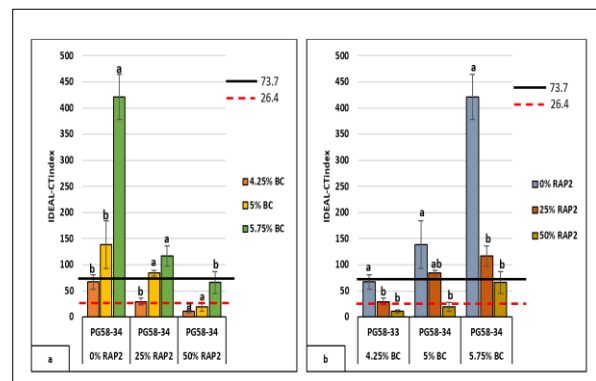
39

Laboratory Testing Cracking

RAP1



RAP2

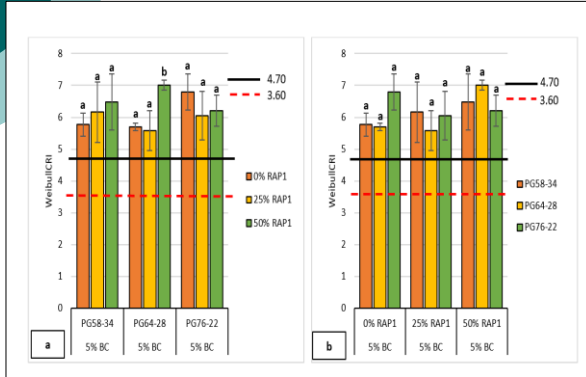


Effect of Binder Grade/Content and RAP Content on IDEAL-CTIndex

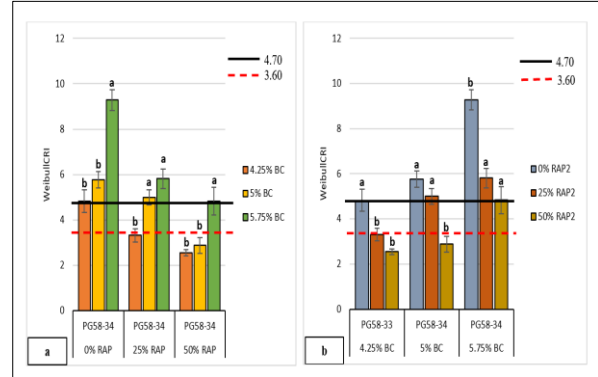
40

Laboratory Testing Cracking

RAP1



RAP2

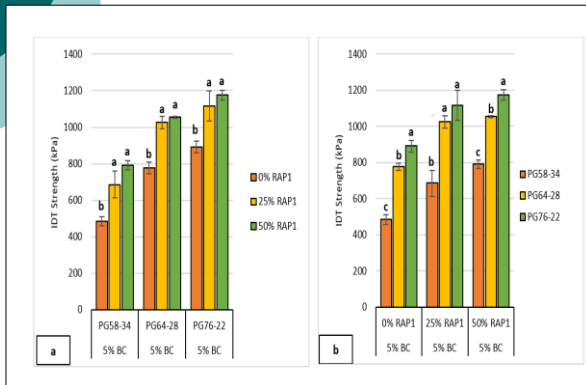


Effect of Binder Grade/Content and RAP Content on WeibullCIRI

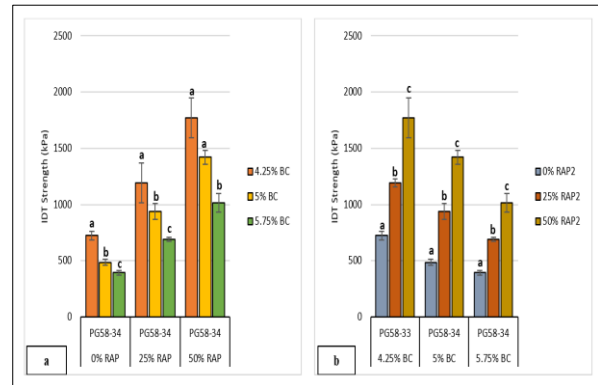
41

Laboratory Testing Cracking

RAP1



RAP2

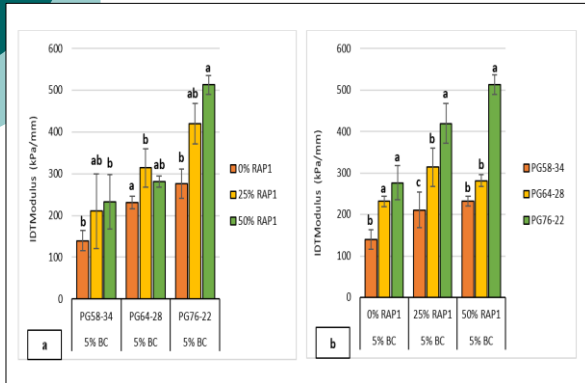


Effect of Binder Grade/Content and RAP Content on IDT strength

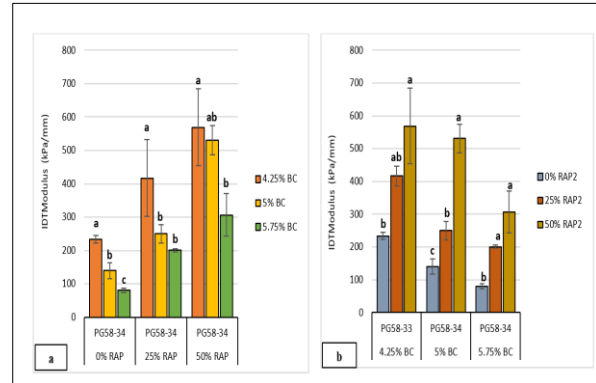
42

Laboratory Testing Cracking

RAP1



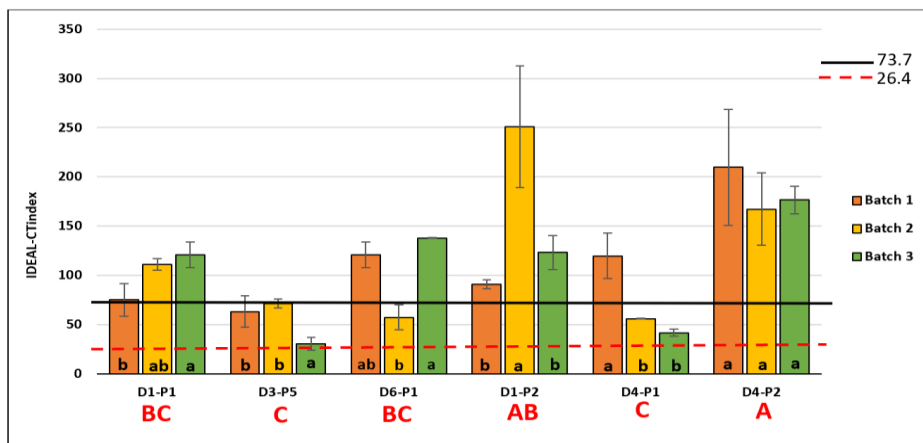
RAP2



Effect of Binder Grade/Content and RAP Content on IDT Modulus

43

Laboratory Testing Cracking

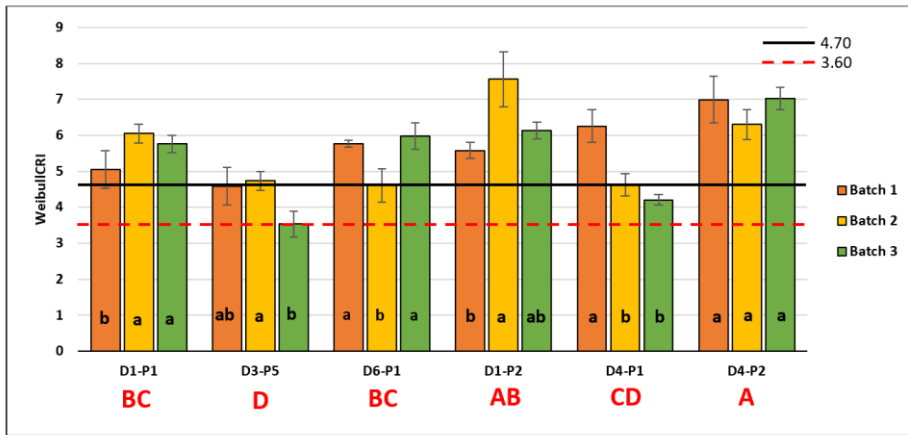


IDEAL-CT Index of PMLC

- D4-P2: higher binder content (6.2%) and lower RAP content (17%)
- D3-P5: 0% RAP and 5.4% binder content; was dry during compaction

44

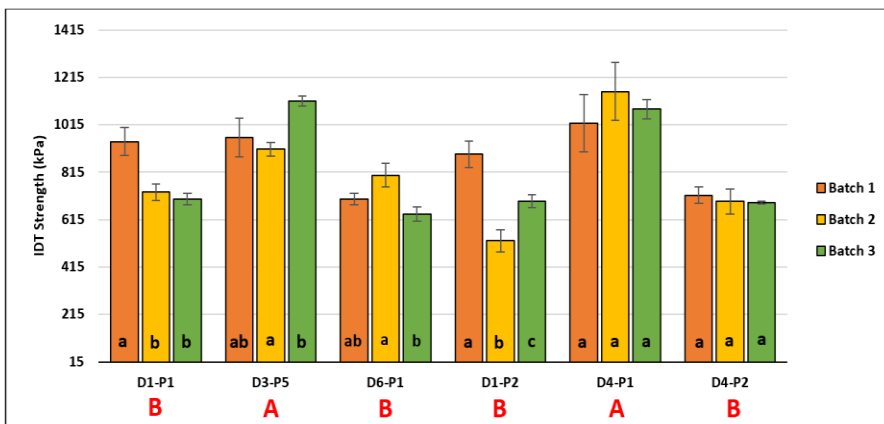
Laboratory Testing Cracking



WeibullICRI of PMLC

45

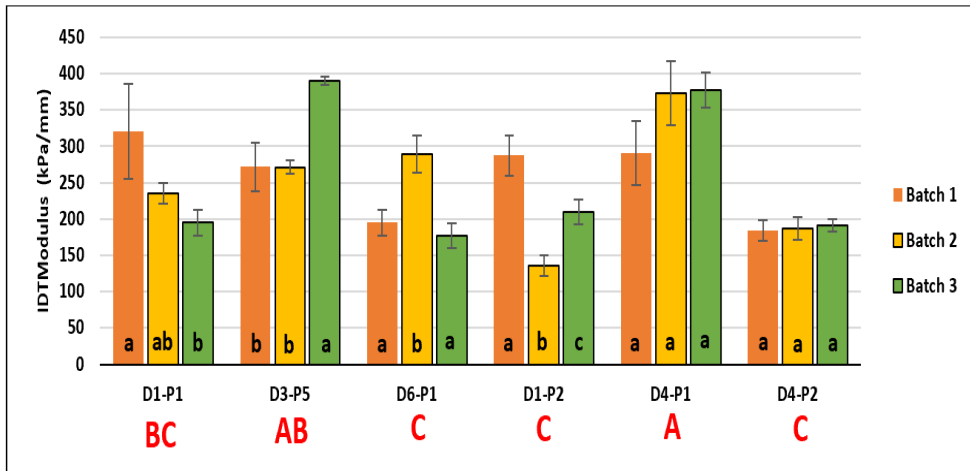
Laboratory Testing Cracking



IDT Strength of PMLC

46

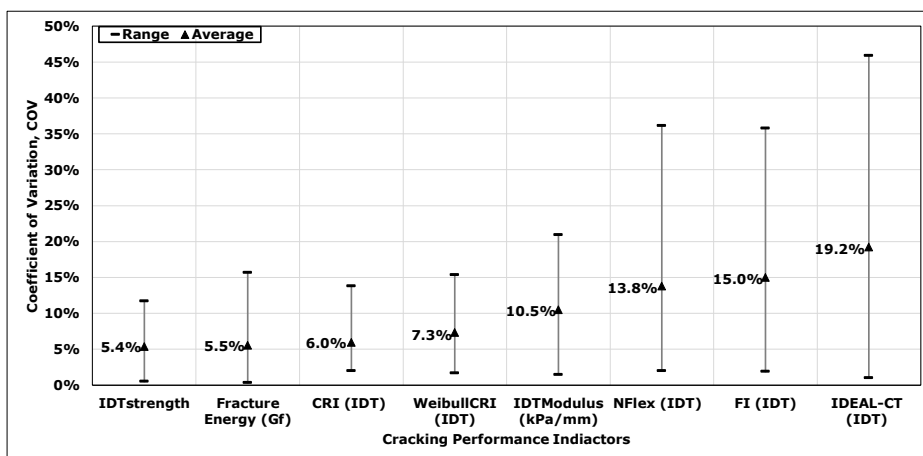
Laboratory Testing Cracking



IDT Modulus of PMLC

47

Laboratory Testing Cracking



Coefficient of Variation (COV) in Cracking Performance Indicators of Mixes

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Evaluation of Compaction and Stability Indices

- Based on the comprehensive evaluation of the results of the compaction indices, the **GS**, **CDI**, and **LCI** were found to be **sensitive to binder content**; however, all the compaction indices were less sensitive to the change in the RAP content and binder grade.
- The **GS** decreased with the **increase in binder content** for all mixes (**with and without RAP**) for different binder grades. Drier mixtures required more energy needed for compaction than softer mixtures.

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Evaluation of Rutting Performance and Moisture Susceptibility

- The rutting performance evaluation using the **APA rut test** and **HWTT** showed that all LMLC and PMLC had **good resistance** to rutting. In addition, there was no sign for moisture damage for all mixtures tested using HWTT.
- The **APA** and **HWTT** rut depth **increased** with the increase in **binder content** as expected. However, there was a statistically significant difference in the APA rut depth results between mixtures with 5.75% binder content and 4.25% binder content, while the difference in the HWTT results was not statistically significant between 5.75% and 4.25% binder content.

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Evaluation of Rutting Performance and Moisture Susceptibility

- Overall, mixtures prepared with **RAP** tended to have slightly **less rutting** compared to mixtures **without RAP** at the corresponding binder contents, but the difference was not statistically significant.
- The **LCI** showed a better correlation with the APA rut depth ($R^2 = 0.64$).

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Evaluation of Cracking Performance

- The results demonstrated that the **IDTModulus** and **IDTStrength** were able to capture the change in **binder content**, **binder grade**, and **RAP** content. Other indices including **IDEAL-CT** Index, **WeibullCRI**, **CRI**, and **Nflex** factor were sensitive to **binder content** and **RAP** contents from the second source of RAP. Overall, the cracking resistance improved with the increase in binder content as expected. Also, all mixtures prepared at different RAP contents (up to 50%) from the first source of RAP had good resistance to cracking; however, the mixtures prepared with the second source of RAP did not show this trend.

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Evaluation of Cracking Performance

- The results also illustrated that the cracking performance of mixtures prepared with RAP (**up to 50%**) from the second source of RAP can be improved by increasing the binder content. This indicates the importance of the balanced mix design when incorporating RAP materials in asphalt mixtures.

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Implementation

- ITD may consider **implementing and applying a balanced (engineered) mix design** concept for asphalt mixtures prepared with high RAP content to ensure that such mixtures have adequate resistance to cracking and rutting comparable or superior to the control mix. The results of this study showed that adjusting the binder content improved the cracking performance of mixtures prepared with up to 50% RAP.

54

Questions.....

PAVING WITH PLASTIC

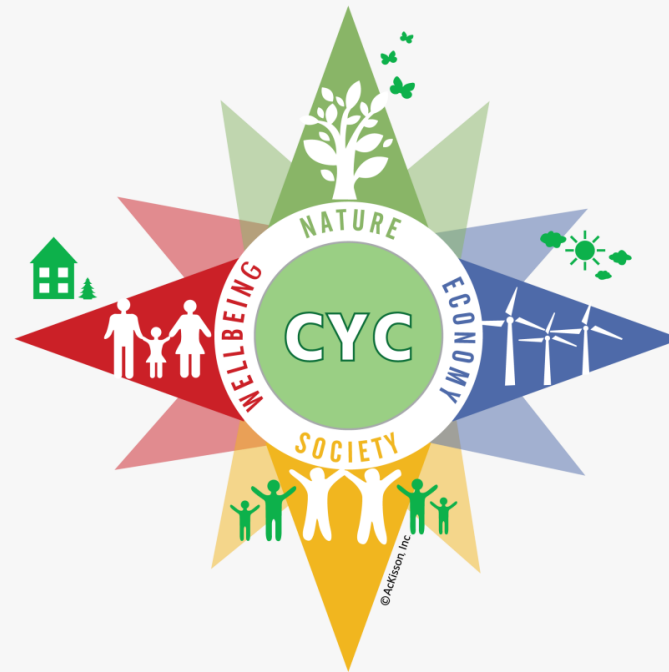


- Trade Association representing asphalt industry

- NAPA's Mission
 - Support
 - Advocate
 - Advance

**What Is
NAPA?**

Sustainability



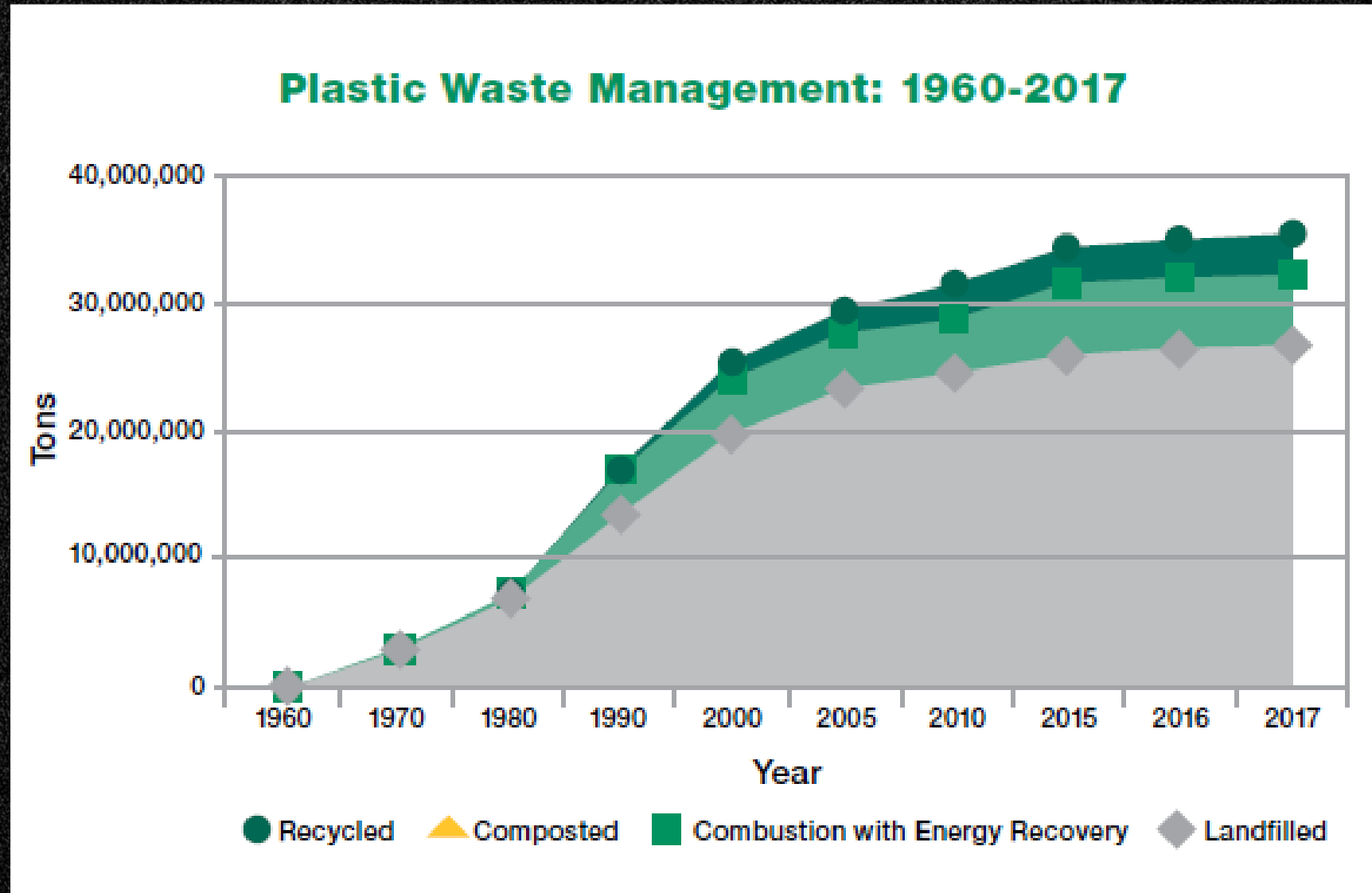


SUSTAINABLE DEVELOPMENT GOALS

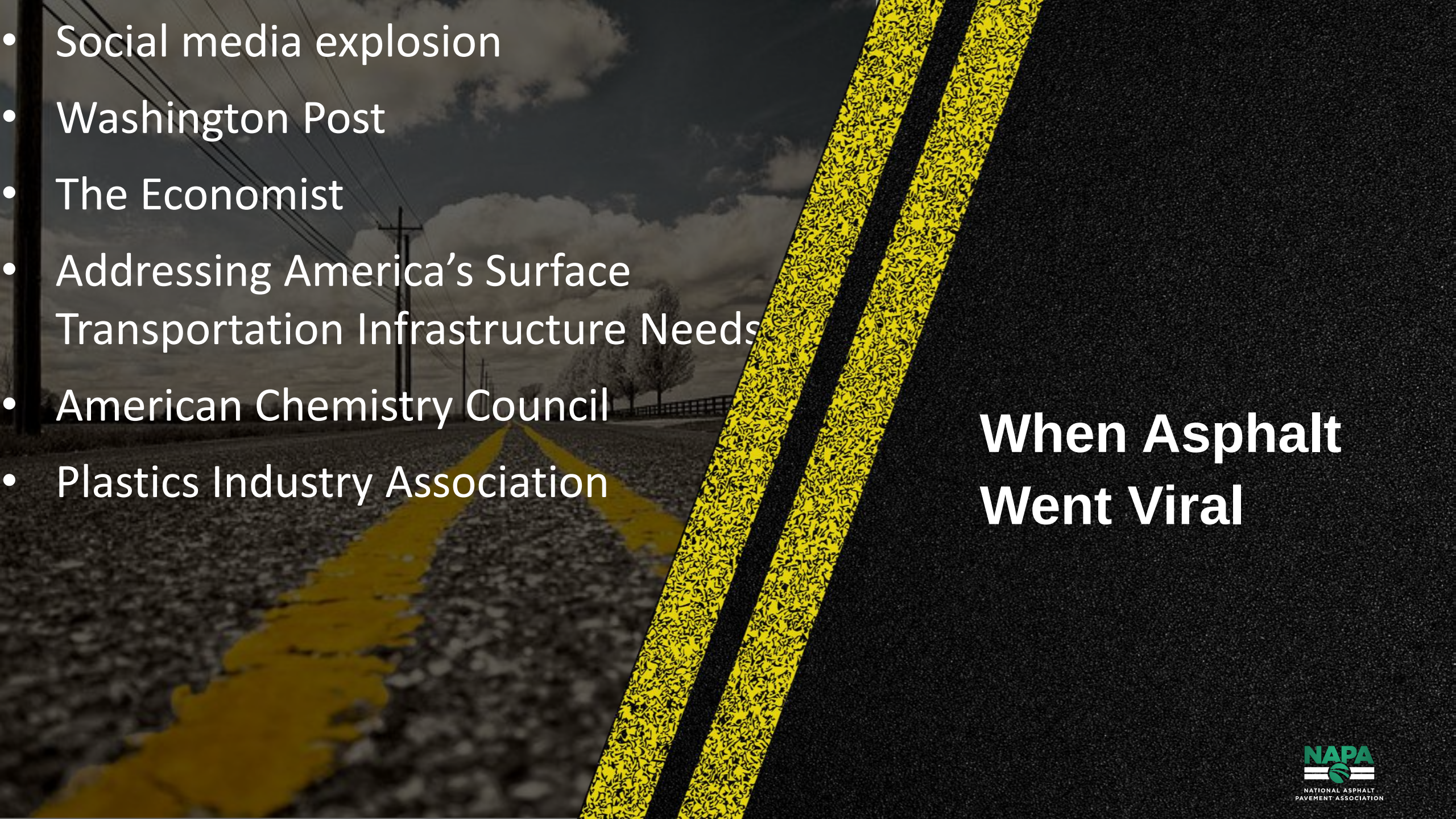
- Three E's
 - Engineering
 - Economics
 - Environment
- FHWA, 2015

FHWA Recycling Policy

Current Status



(EPA, 2020)

- 
- Social media explosion
 - Washington Post
 - The Economist
 - Addressing America's Surface Transportation Infrastructure Needs
 - American Chemistry Council
 - Plastics Industry Association

When Asphalt Went Viral

- 
- Reclaimed asphalt pavement
 - Recycled asphalt shingles
 - Recycled tire rubber
 - Plastics?

**Recycling
Responsibly**

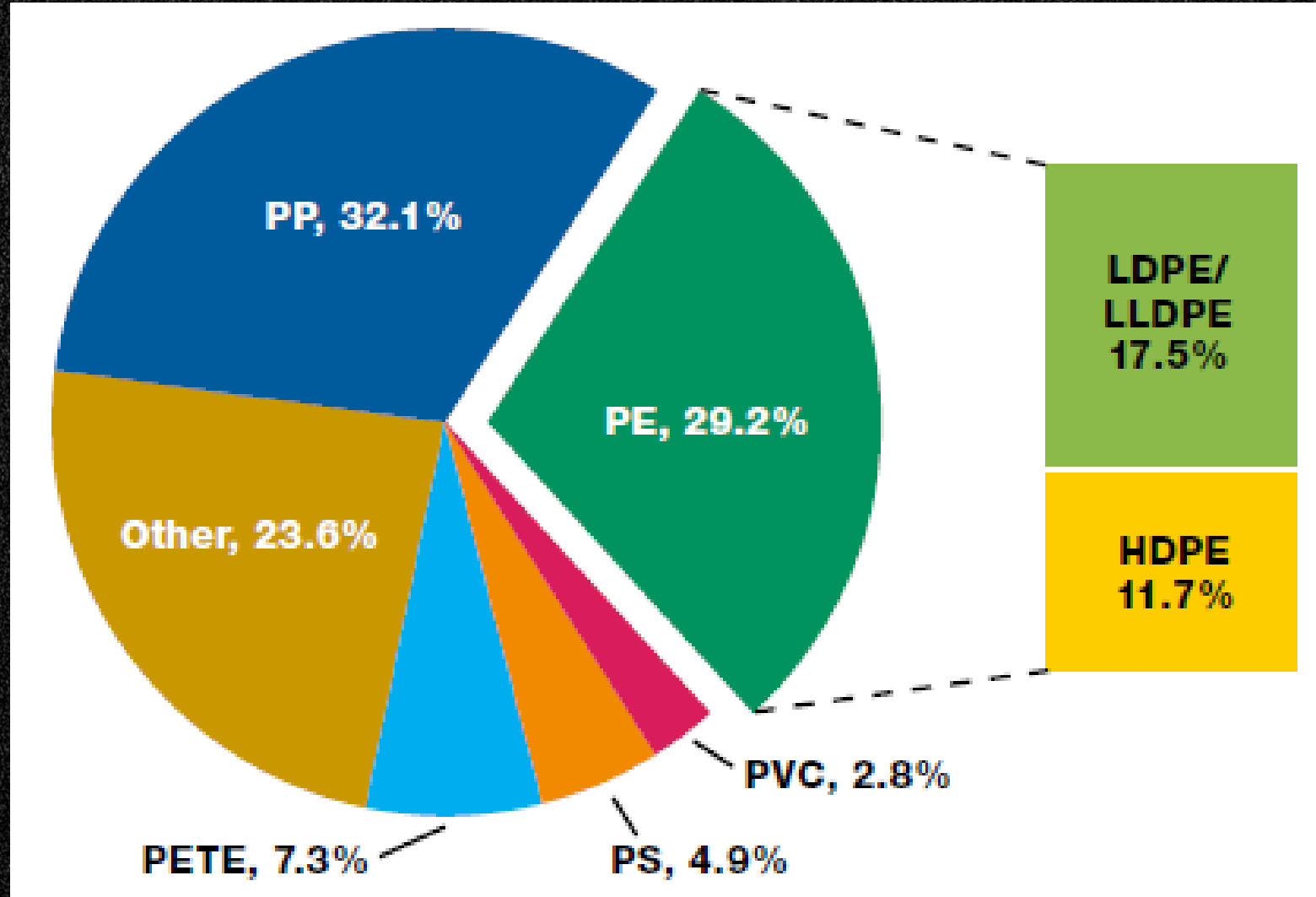
It's Just Plastic, Right...?

Number	Type	Application	Melting Point (F)
1	Polyethylene Terephthalate (PET)	Water Bottles	>482
2	High Density Polyethylene (HDPE)	Plastic bags	266 but can vary
3	Polyvinyl Chloride (PVC)	Pipes	212-500
4	Low Density Polyethylene (LDPE)	Trays	230-248
5	Polypropylene (PP)	Hinges	320-330
6	Polystyrene (PS)	CD Casing	GS at 212
7	Others	Baby bottles	---



NATIONAL ASPHALT
PAVEMENT ASSOCIATION

Plastic Breakdown in MSW

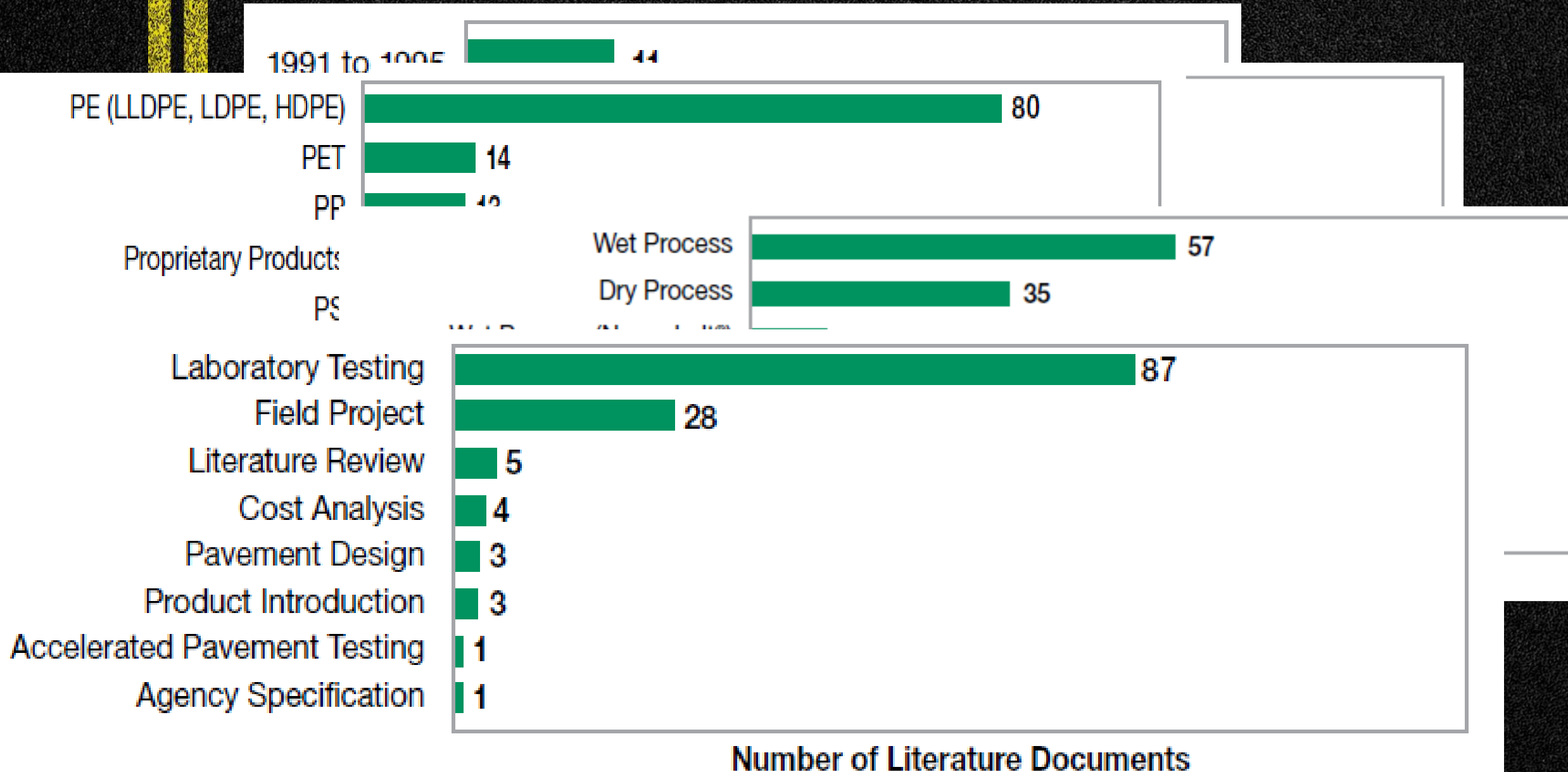


(DuBois, 20202; based on EPA, 2017)

- Plastics Recycling
 - Collection
 - Shredding
 - Washing
 - Decontamination
- Significant investment needed

Plastic Recycling

When In Doubt ... Do A Lit Review



- Wet Process
 - Modification or replacement?
 - 2 – 8% by weight of binder
 - Low melting point needed
- Dry Process
 - Aggregate replacement
 - Mixture modifier
 - Aggregate modifier
 - 0.2 – 1% by agg weight

Wet v Dry

- Binder Performance
 - Plastic stiffens asphalt binder
 - Little data on fatigue
 - Little data on low-temperature
- Phase separation tendencies
 - Additives may help
- PE insoluble in many solvents

Laboratory Binder Testing

- Marshall stability
 - Increased Marshall stability
- Increased stiffness
- Increased rutting resistance
 - Wet – Stiffer binder
 - Dry – Increased agg friction
- Moisture damage
 - Positive or no impact

Laboratory Mixture Characterization

- Most documentation on plant operations relates to Novophalt®
 - High-shear blending unit

Plant Operations

- One study documented construction
 - Difficult to compact
 - Heavy rollers required
- French construction
 - Temperature sensitive, but compaction not an issue

Construction

- Two potential concerns in literature
 - Leaching of toxic components
 - No adverse effects (one study)
- Chlorine-based gases from PVC

Health & Safety

- 
- Environmental Benefits
 - Preservation of resources
 - Reduction of solid waste
 - Emission reduction
 - Environmental Concerns
 - Future recyclability
 - Ongoing work

Environmental

- 200 Field Projects in Literature
 - Improved rutting
 - More cracking
- New field projects
 - India
 - Australia
 - Canada
 - New Zealand
 - And More...

Field Projects

- 
- Sourcing of plastics
 - Methods of incorporation
 - Modifier or replacement
 - Binder characterization
 - Mixture characterization
 - Plant operations
 - Construction
 - H&S
 - Environmental
 - Field performance

Knowledge Gaps

- 
- Patience
 - Partnership
 - Communication

**Moving
Forward**

NAPA - IS-142

RECYCLED PLASTICS IN ASPHALT *PART A:*

State of the Knowledge

Richard Willis, PhD
Fan Yin, PhD, PE
Raquel Moraes, PhD

NAPA - IS-142

RECYCLED PLASTICS IN ASPHALT *PART B:*

Literature Review

Fan Yin, PhD, PE
Raquel Moraes, PhD
Anurag Anand

- NCHRP 9-66
- FHWA Project
- Field Projects
 - California
 - Texas
 - Michigan
 - Wisconsin
 - Pennsylvania
 - More...

**What's
Happening**

THANK YOU!

RWILLIS@ASPHALTPAVEMENT.ORG



Performance-Based Acceptance vs. Performance-Based Design

Idaho Asphalt Conference
October 28, 2021
Dave Johnson, P.E.
Senior Regional Engineer
Asphalt Institute

1

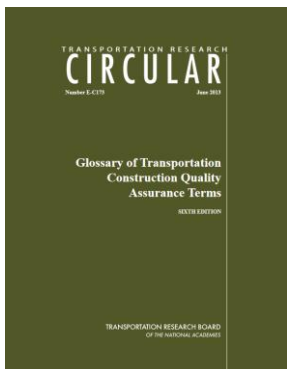
Thank you to NCAT for their willingness to share slides from their
BMD Workshop in my development of this presentation.

2

Performance-Based Acceptance

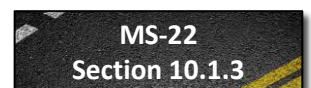
3

Quality Assurance (QA)



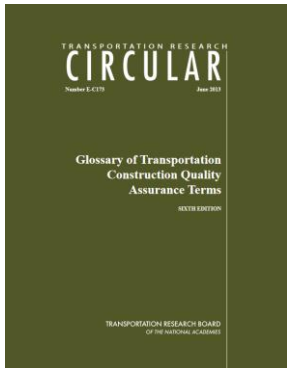
TRB Circular E-C173

“all planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service. QA includes the elements of quality control (QC), acceptance, independent assurance, dispute resolution, laboratory accreditation, and personnel certification.”



4

Quality Control (QC)

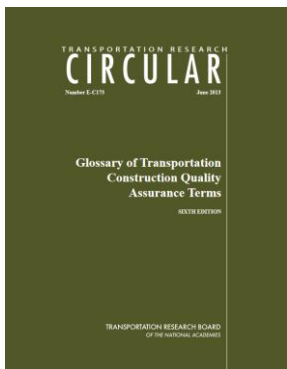


TRB Circular E-C173

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

5

Acceptance



TRB Circular E-C173

*“the process whereby all factors **used by the agency** (i.e. sampling, testing, and inspection) are evaluated to determine the degree of compliance with contract requirements and to determine the corresponding value for a given product.”*

6

Performance Testing in QA

- Performance Tests (PT) should be conducted on plant produced mix and results used in acceptance decisions much like lab compacted air voids are currently used.
- Other pay factors may still include properties such as %AC, in-place density, and joint density (and smoothness for the final layer).
- Need to establish reasonable acceptance limits for PT results considering test precision. Will you use agency results for acceptance or “validated” contractor data?
- Need to establish suitable frequencies of tests.

4

7

Performance Testing in QA

- Timeliness of QA results is critical.
- Most plants produce 200-400 tph. If results take 4 hours to complete the tests, then 800 to 1600 tons of mix have been produced during that time.
- The cost of that mix would be \$50k to \$150k.



5

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Lab Produced vs. Plant Produced Mixtures



- Changes in binder source / properties
- Changes in the aggregate properties
- Breakdown of aggregate through the plant
- Incomplete drying of aggregates
- Variations in baghouse fines return
- Differences in aging and absorption
- Inaccurate plant calibration
- Different laboratory equipment
- Different technicians
- Changes made to mix proportions

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Challenges Associated with Performance-Based Acceptance



- Testing defensibility
 - Timely results
 - Test repeatability
 - Cracking tests
 - Field vs. lab produced specimens
 - Basically, want quick and reliable
- Laboratory setup
 - Do most labs have testing capability?
 - Can the labs handle testing load?

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Performance-Based Design

11

Balance the Mix Design

Strength/
Stability

Smooth Quiet Ride
Skid Resistance

Durability

Rut Resistance

Crack
Resistance

Shoving

Raveling

Flushing
Resistant

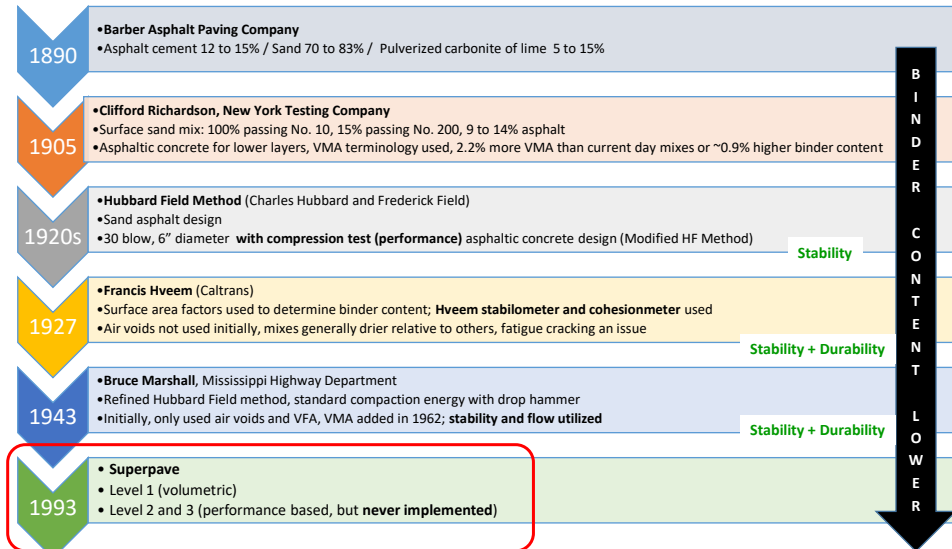
Permeability



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

12

History of Mix Design



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

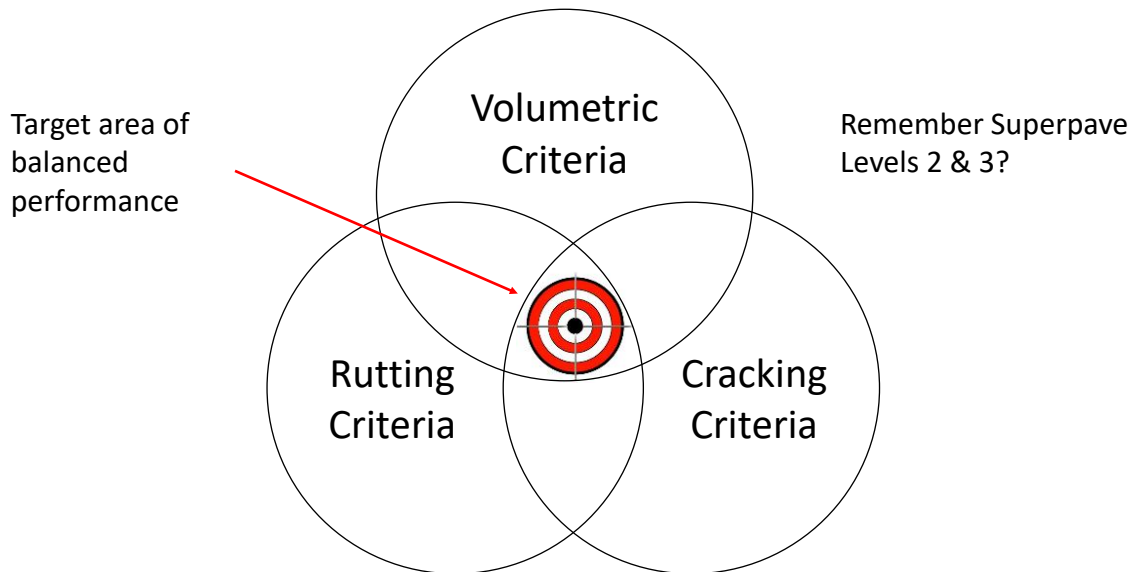
13

What Should Have Happened with Superpave...

- Superpave called for **Level 1, 2, and 3** testing based on traffic load
- **Level 1 (Volumetrics + TSR)** was only for up to around 1 million ESALS
- Level 2 and 3 were to be used for higher traffic loads and included rutting and cracking performance test
- Since we saw such good performance (with materials in 1993-2000), **Levels 2 and 3** were soon forgotten

14

Balanced Mix Design Basic Concept



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Balance Mix Design Drivers

- Rutting?
 - NO
 - Generally not a widespread distress since Superpave implementation
- Cracking?
 - YES
 - Various cracking distresses have increased nationally
- Durability?
 - YES
 - Related to cracking, durability concerns have been noted

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Balanced Mix Design Goals



- Ensure pavement performance
 - Rutting
 - Cracking
 - Durability
- Enable innovation
 - Materials
 - Specifications
- Optimize economics

17

Performance Tests



- Used to assess a mixture's ability to combat or resist specific distresses.
 - Permanent deformation
 - Cracking
 - Reflective
 - Temperature-related
 - Fatigue
 - Moisture damage

18

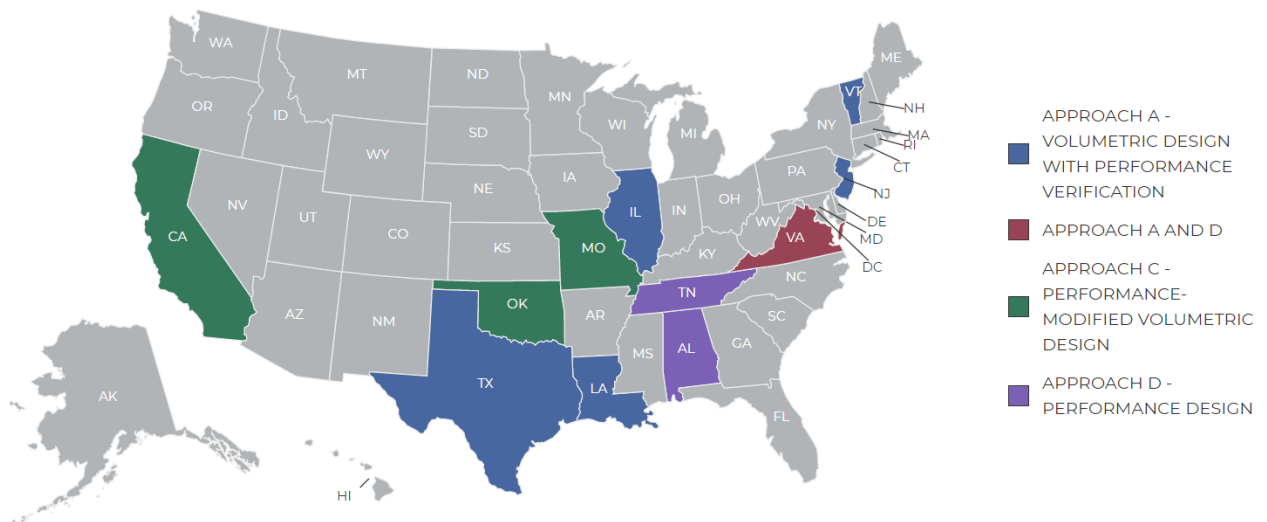
Balance Mix Design Keys



- AASHTO PP 105
 - Four approaches
 - Condition specimens
 - Test for differing distress types
 - Consider
 - Aging
 - Traffic
 - Climate
 - Layer

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Performance Asphalt Design Approach in USA (2021)

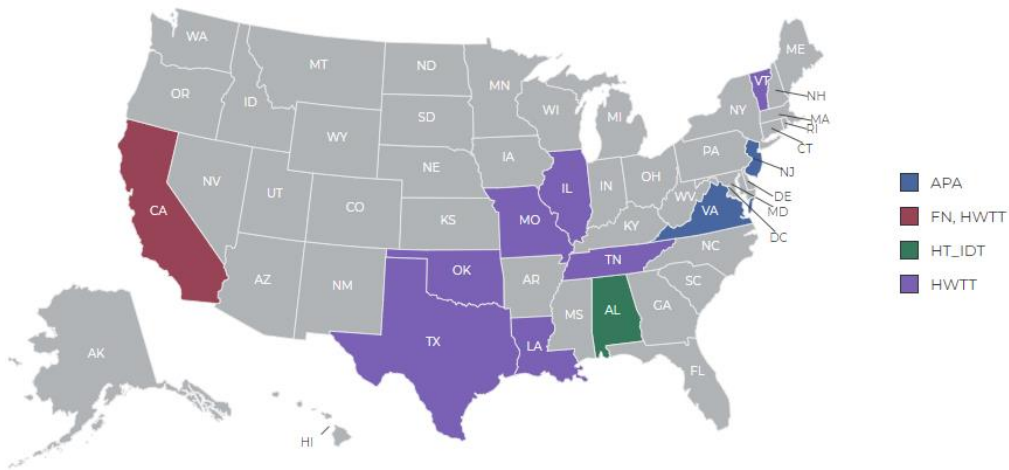


<https://www.asphaltpavement.org/expertise/engineering/resources/bmd-resource-guide/implementation-efforts>

20

Rutting Performance Testing Options

FILTER BY: BMD APPROACH **RUTTING TEST** CRACKING TEST



21

Rutting Performance Testing Options

- Hamburg Wheel Tracking Test
 - Most common choice
 - Used in eight BMD states
 - Generally gaining popularity (BMD and non-BMD states)
- Asphalt Pavement Analyzer
 - Used by two states
 - Generally losing popularity (BMD and non-BMD states)
- Hot Indirect Tension Test
 - Used in Alabama only for BMD

22

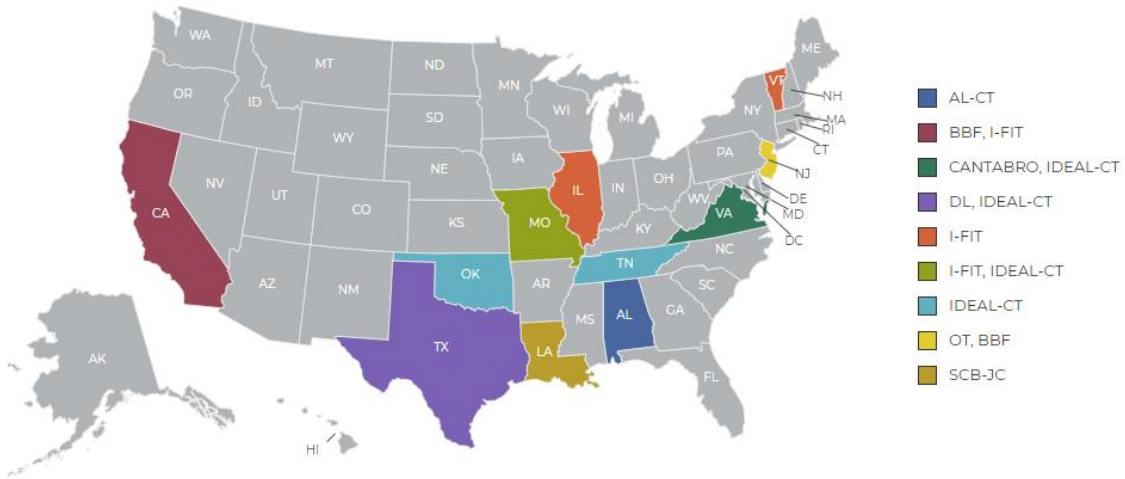
Cracking Performance Testing Options

FILTER BY:

BMD APPROACH

PUTTING TEST

CRACKING TEST



23

Cracking Performance Testing Options

- Eight test procedures currently reported
- Two tests most common
 - I-FIT test
 - IDEAL-CT
- Six states report two cracking tests are required

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Where we are going



- Interest in BMD approaches growing significantly
- Multiple combinations of design approaches and testing requirements being seen
- Likely trends that BMD will instigate (Dave's opinions)
 - Increases in binder contents
 - Mitigates cracking and durability concerns
 - Less reliance on volumetrics
 - Greater reliance on laboratory performance testing during design
 - Innovations
 - Rejuvenators
 - Alternative materials

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Thank You Asphalt Institute Membership



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Questions?



Multiple Stress Creep Recovery (MSCR): State of the Practice

Mike Anderson, Asphalt Institute



University of Idaho (Moscow, Idaho)

October 28, 2021

- Purpose
- Basics
- Test Temperature
- Recovery
- Variability
- Why?

- Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
 - AASHTO T350
 - ASTM D7405
- Uses the concepts of creep and recovery testing to evaluate an asphalt binder's potential for permanent deformation.

- Persistent concern since the inception of the PG Asphalt Binder Specification (AASHTO M320)
 - $G^*/\sin \delta$ may not adequately characterize the performance properties of all modified asphalt binders
 - Testing to determine G^* occurs in the small strain, linear viscoelastic region
 - In the LVE region, the stiffness properties of the base asphalt and modification will dominate the response
 - In the region of higher strain the modification plays a much more significant role
 - High strain region is where damage is expected to occur

- Studies have shown that the MSCR test generates results for modified asphalt binders that better relate the contribution of the asphalt binder to the permanent deformation of the asphalt mixture than the $G^*/\sin \delta$ parameter generated from the DSR using AASHTO T315.
 - Higher strain in the MSCR than in T315

- Studies have shown that the MSCR test generates results for modified asphalt binders that better relate **the contribution of the asphalt binder to the permanent deformation of the asphalt mixture** than the $G^*/\sin \delta$ parameter generated from the DSR using AASHTO T315.
 - Higher strain in the MSCR than in T315
- Meaning?
 - Rutting is dependent on more than the asphalt binder properties

- Purpose

- **Basics**

- Test Temperature

- Recovery

- Variability

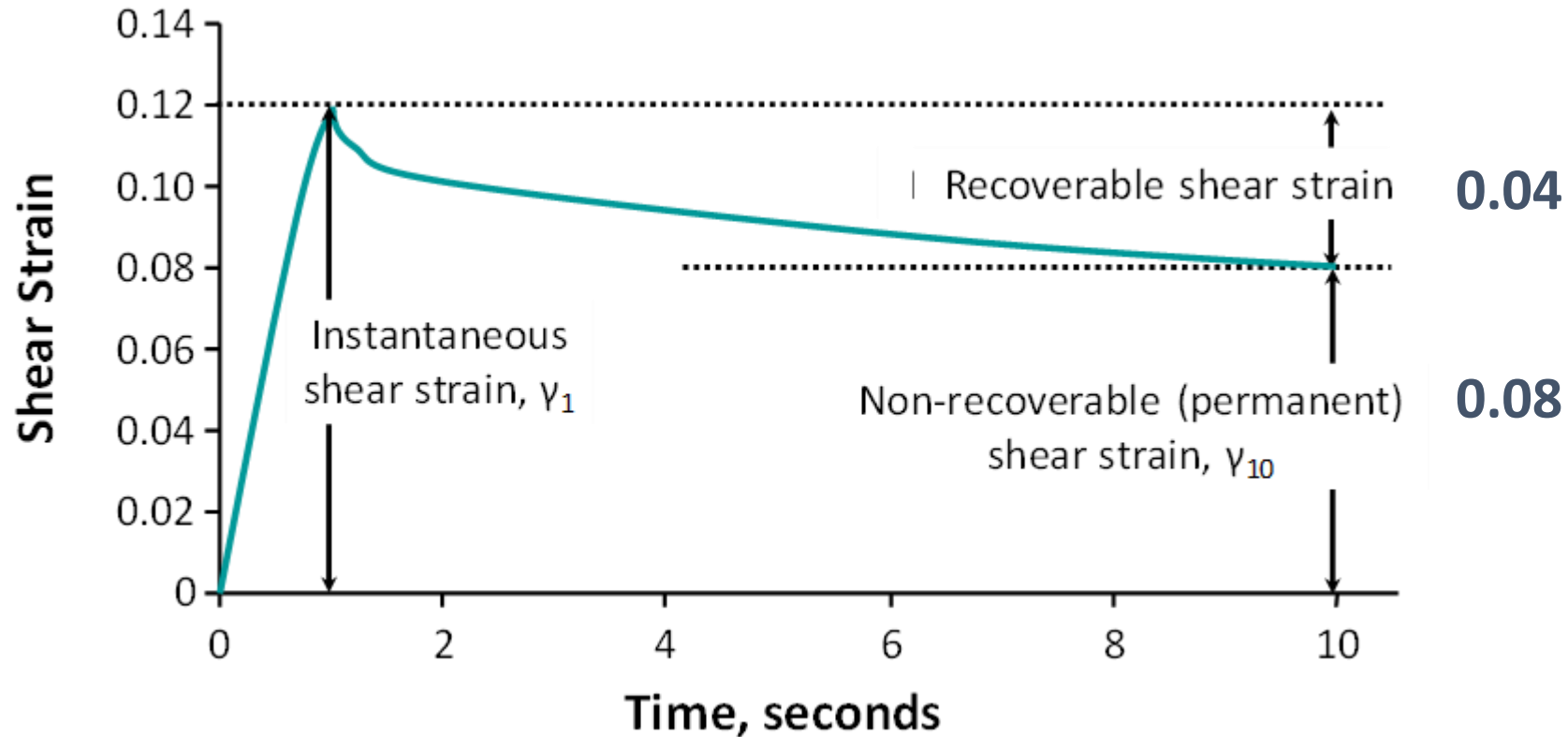
- Why?

Performing the Test (AASHTO T 350)

- Typically performed on RTFO-aged Binder
- Same geometry as T315 testing
 - 25-mm parallel-plate geometry
 - 1-mm gap
- Test Temperature
 - Environmental Temperature
 - Not Grade-Bumped
- 10 cycles per stress level
 - 1-second loading at specified shear stress
 - 0.1 kPa
 - 3.2 kPa
 - 9-second rest period

- Calculate Non-recoverable Creep Compliance (J_{nr})
 - Non-recoverable shear strain divided by applied shear stress
 - “J” = “compliance”
 - “nr” = “non-recoverable”
- Calculate Recovery
 - Difference between strain at end of recovery period and peak strain after creep loading
- Calculate Difference in J_{nr} as a Function of Stress Level

Calculating and Understanding Test Output



Assume $\tau = 0.1$ kPa

$$J_{nr0.1} = \gamma_{nr} / \tau$$

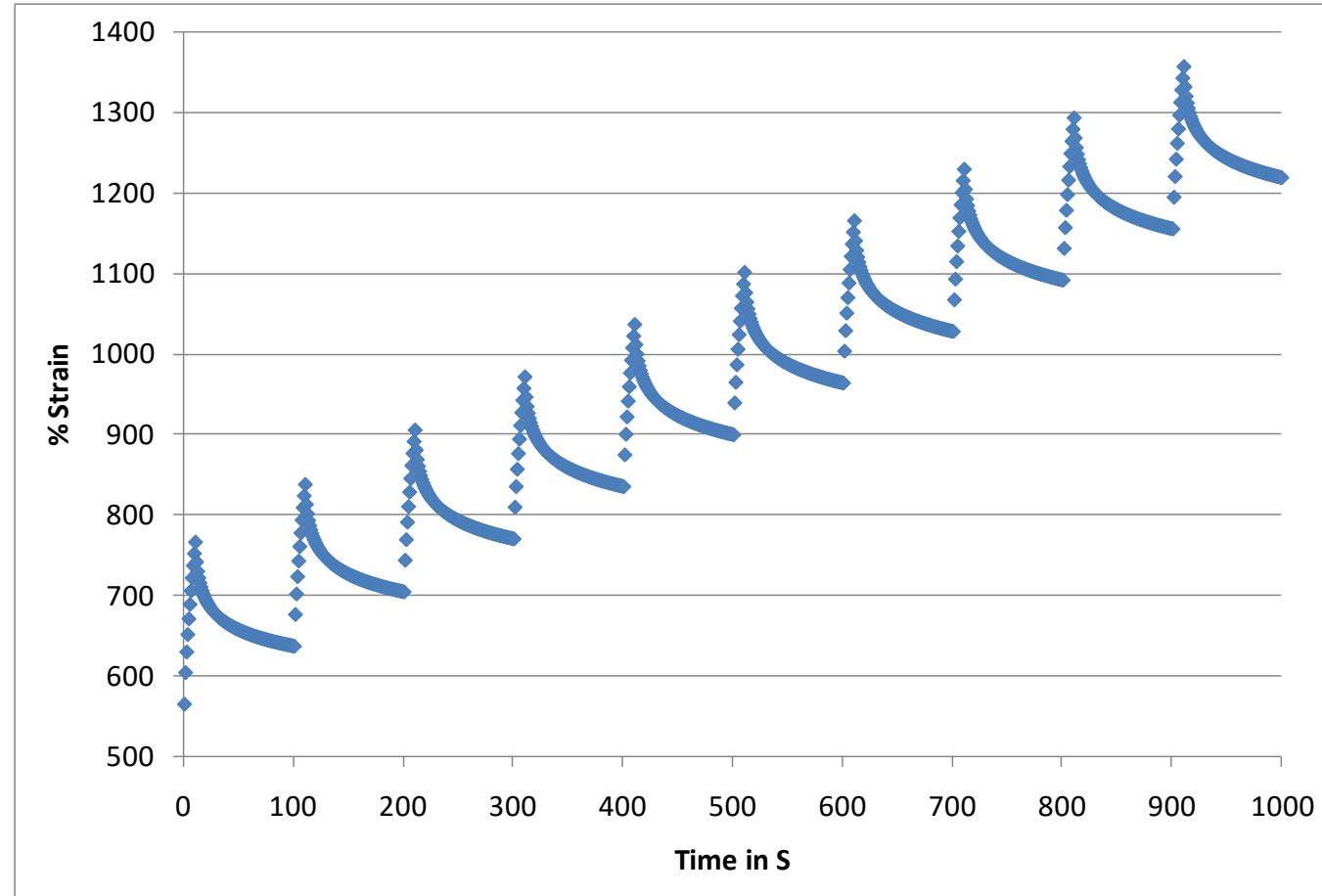
$$J_{nr0.1} = 0.08 / 0.1 \text{ kPa} = 0.8 \text{ kPa}^{-1}$$

Assume $\tau = 0.1$ kPa

$$R_{0.1} = \gamma_r / \gamma_i$$

$$R_{0.1} = 0.04 / 0.12 = 0.33 \text{ or } 33\%$$

Performing the Test – Ten Cycles



- Some notes
 - Test uses high strains
 - Testing of RTFO-aged asphalt binder in T315 with a $G^*/\sin \delta$ value at the specification criterion uses 0.22 kPa shear stress
 - 10% shear strain
 - MSCR testing at 0.1 kPa is less than that strain (still small)
 - MSCR testing at 3.2 kPa is more than 14 times the T315 strain
 - Because of high strain, the sample cannot be re-used
 - Can perform MSCR after T315 but not T315 after MSCR
 - Cannot perform testing at more than one temperature on the same sample

- Operations that are important to the T315 procedure are similarly important to the MSCR procedure
 - temperature verification
 - gap setting
 - trimming
 - equilibrium time to temperature

- Use and relevance of $J_{nr,Diff}$ as a specification requirement
 - Indicative of stress-sensitive binders
 - Problem for some current formulations
 - Not a problem for the majority of modified binders

- Use and relevance of $J_{nr,Diff}$ as a specification requirement
 - Can be a problem at very low J_{nr} values
 - Small differences can mean big ratios
 - If $J_{nr,3.2} \leq 0.5 \text{ kPa}^{-1}$, then $J_{nr,Diff}$ requirement is waived
 - Small values of J_{nr} should mean reduced contribution to rutting potential
 - Even a big change from 0.1 kPa to 3.2 kPa should not result in a significant increase in rutting potential

Example:

- $J_{nr,0.1} = 0.08 \text{ kPa}^{-1}$
- $J_{nr,3.2} = 0.40 \text{ kPa}^{-1}$
- $J_{nr,Diff} = (0.40 - 0.08) / 0.08 = 0.32/0.08 \times 100\% = 400\%$

- MSCR testing intended for characterizing rutting potential
 - J_{nr} is an indication of the performance-based property of the asphalt binder related to permanent deformation (rutting)
 - Can be conducted at a wide variety of conditions, but
 - Most appropriately conducted at high temperatures on asphalt binder that has been aged to simulate its physical state early in the pavement life after mixing, laydown, and compaction
- Test temperature should always be selected based on actual high pavement temperatures with no grade bumping
 - Regardless of the traffic speed and loading
 - Higher traffic loading can be accounted for by increasing the stiffness (reducing the compliance) required for the asphalt binder at the grade temperature

MTE Rutting Study: WI E10 Fine Mix

PG Grade (M320)	PG Grade (M332)	Test Temp, °C	$J_{nr3.2}$, kPa^{-1}	$R_{3.2}$, %	HWT Rut Depth (10,000 passes), mm
64-22	64S-22	64	3.40	3.4	7.1
70-22	64H-22	64	1.35	4.4	3.6
76-22	64E-22	64	0.24	55.8	1.7
82-22	64E-22	64	0.08	78.5	1.6



Performance Grades (AASHTO M332-20)

The Asphalt Institute
**National
Binder Technician
Certification
PROGRAM**

Performance Grades

High PG	PG 52						PG 58					PG 64					PG 70					PG 76							
Low PG	-10	-16	-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

Original

≥230 °C	Flash Point, AASHTO T 48				
≤ 3 Pa-s	Rotational Viscosity @ 135° C, AASHTO T 316				
≥ 1.00 kPa	S H V E	DSR G*/sin δ (Dynamic Shear Rheometer), AASHTO T 315			
		52	58	64	70

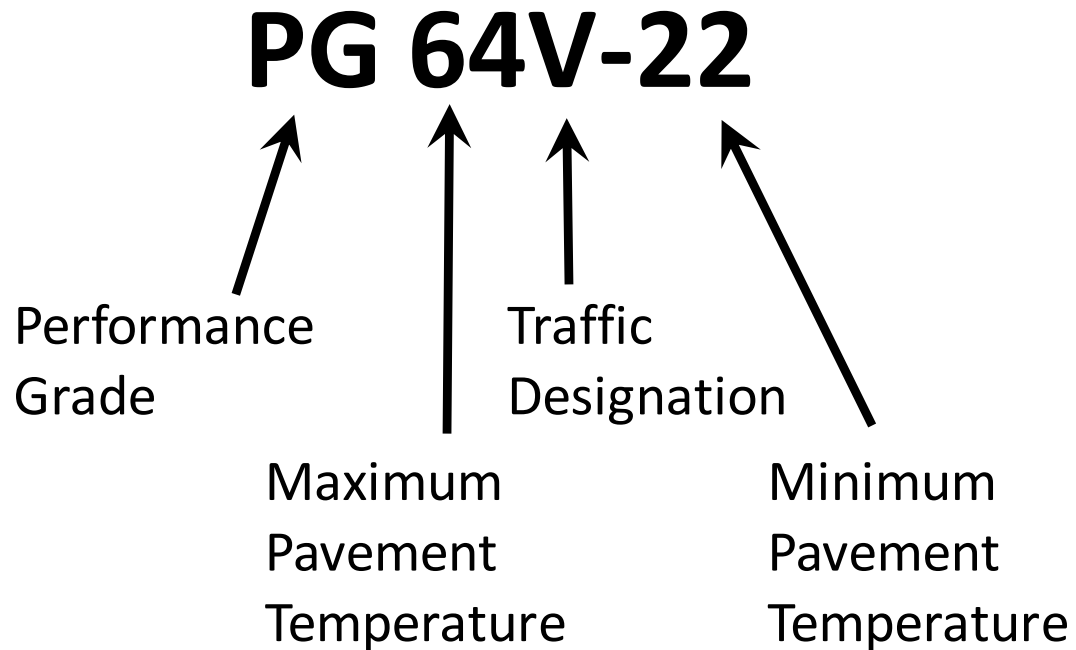
RTFO (Rolling Thin Film Oven), AASHTO T 240

$\leq 1.00\%$	Mass Change					
$\leq 4.5 \text{ kPa}^{-1}$	SHVE	MSCR J_{nr} , 3.2 (Multiple Stress Creep-Recovery), AASHTO T 350				
$\leq 2.0 \text{ kPa}^{-1}$		52	58	64	70	76
$\leq 1.0 \text{ kPa}^{-1}$						
$\leq 0.5 \text{ kPa}^{-1}$						
$\leq 75\%$ <i>See Note Below</i>	SHV	MSCR J_{nr} , Diff (Multiple Stress Creep-Recovery), AASHTO T 350				
		52	58	64	70	76

PAV (Pressure Aging Vessel), AASHTO R28

		90							100							100							100(110)							100(110)						
≤ 5000 kPa	SHVE	DSR $G^*\sin \delta$ (Dynamic Shear Rheometer), AASHTO T 315																																		
≤ 6000 kPa		25	22	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						
$S \leq 300$ MPa		BBR S (creep stiffness) & m-value (Bending Beam Rheometer), AASHTO T 313																																		
$m \geq 0.300$		0	-6	-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

- Binder shall be homogeneous, free from water, contain no deleterious materials, be at least 99.0% soluble and contain no particles larger than 250 μm .
- The $J_{nr,0.1}$ requirement is not applicable for $J_{nr,0.1} \leq 0.5$ kPa⁻¹ at the selected test temperature.



- Expected to perform in an environment where...
 - The maximum pavement temperature is no higher than **64°C**
 - Traffic loading is **very heavy**
 - The minimum pavement temperature is no lower than **-22°C**

- Comparing PG 64V-22 asphalt binder to a PG 64S-22 asphalt binder

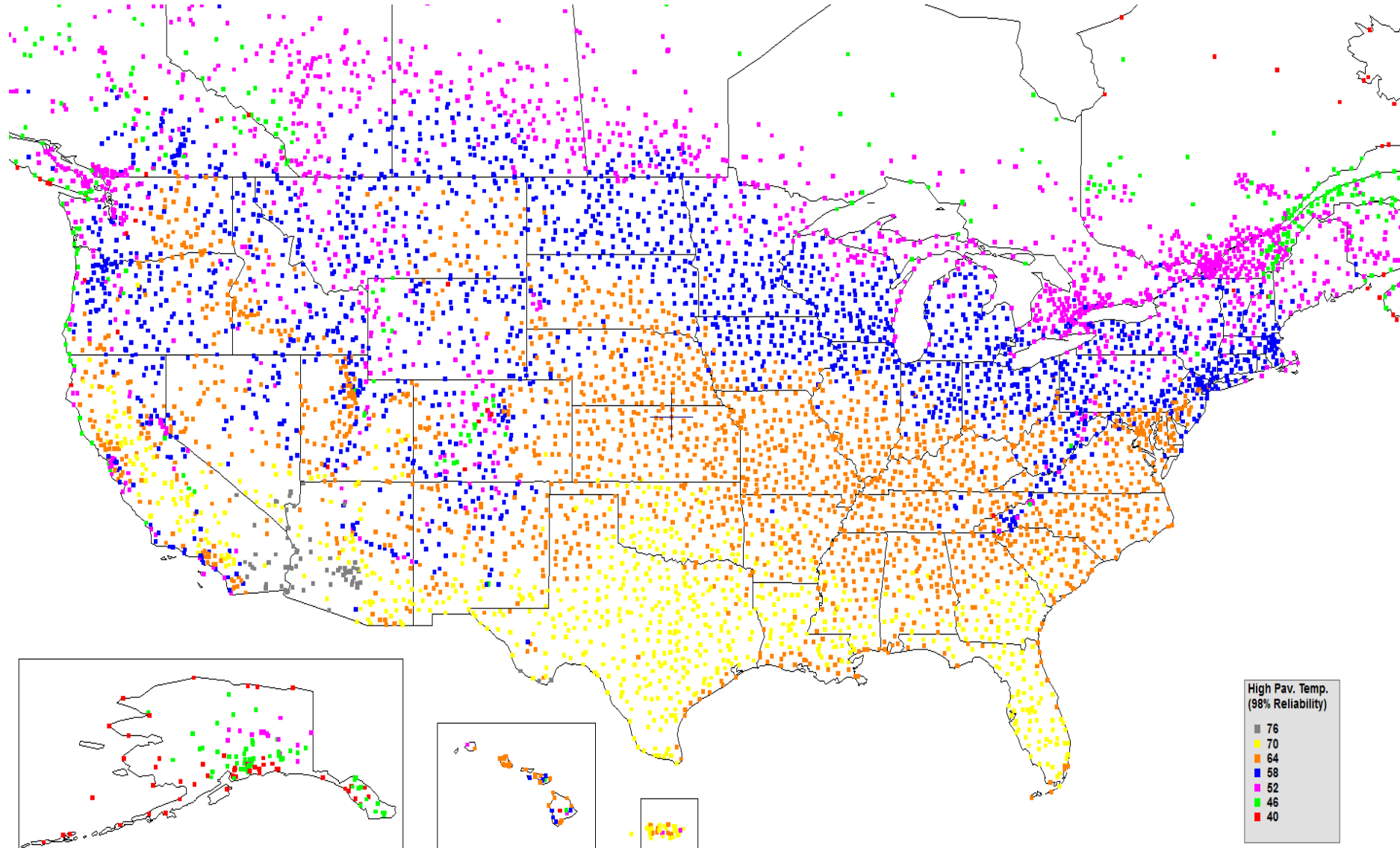
	PG 64V-22	PG 64S-22
ORIGINAL COC Flash Point Rotational Viscosity DSR $G^*/\sin \delta$	$\geq 230^{\circ}\text{C}$ $\leq 3 \text{ Pa}\cdot\text{s}$ $\geq 1.00 \text{ kPa @ } 64^{\circ}\text{C}$	$\geq 230^{\circ}\text{C}$ $\leq 3 \text{ Pa}\cdot\text{s}$ $\geq 1.00 \text{ kPa @ } 64^{\circ}\text{C}$
RTFO Mass Change $J_{\text{nr},3.2}$ $J_{\text{nr},\text{Diff}}$	$\leq 1.00\%$ $\leq 1.0 \text{ kPa}^{-1} \text{ @ } 64^{\circ}\text{C}$ $\leq 75\%$	$\leq 1.00\%$ $\leq 4.5 \text{ kPa}^{-1} \text{ @ } 64^{\circ}\text{C}$ $\leq 75\%$
PAV DSR $G^*\sin \delta$ BBR S BBR m	$\leq 6000 \text{ kPa @ } 25^{\circ}\text{C}$ $\leq 300 \text{ MPa @ } -12^{\circ}\text{C}$ $\geq 0.300 \text{ @ } -12^{\circ}\text{C}$	$\leq 5000 \text{ kPa @ } 25^{\circ}\text{C}$ $\leq 300 \text{ MPa @ } -12^{\circ}\text{C}$ $\geq 0.300 \text{ @ } -12^{\circ}\text{C}$

- Notes on PAV DSR Criterion
 - In M320, intermediate temperature is determined as a function of the high and low temperature grades
 - Grade bumping – i.e. from a PG 64-22 to a PG 76-22 – would increase the intermediate temperature from 25°C to 31°C
 - No grade bumping in M332
 - PG 76-22 equivalent (PG 64V-22 or PG 64E-22) tested at 25°C
 - Higher allowable value of $G^* \sin \delta$ to account for test temperature difference
 - Not intended to disadvantage current-production modified asphalt binders
 - Consider strain tolerance of modified asphalt binders

- Purpose
- Basics
- **Test Temperature**
- Recovery
- Variability
- Why?

- In neat binders a grade bump by temperature will more than double the J_{nr} value
- Some neat binders will maintain their compliance value well beyond the 3.2 kPa stress
- M320 Grade bumping (increasing PG grade temperature) often forced suppliers to use soft base binders and high degree of polymer modification to meet wide temperature ranges and the 2.2 kPa criterion for RTFO $G^*/\sin \delta$

High PG Map (98%) Using LTPPBind 3.1



Test Conditions and Use

- AASHTO M332 Section 4.2 describes the traffic speed and loading conditions
 - Criterion for $J_{nr,3.2}$ is provided for each traffic loading designation

Designation	Traffic (ESAL)	Speed	$J_{nr,3.2}$, kPa ⁻¹
Standard Traffic Loading (S)	$< 10^6$	> 70 km/h (> 43 mph)	≤ 4.5
Heavy Traffic Loading (H)	10^6 to 30^6	> 70 km/h (> 43 mph)	≤ 2.0
	$< 10^6$	20-70 km/h (12-43 mph)	
Very Heavy Traffic Loading (V)	$> 30^6$	> 70 km/h (> 43 mph)	≤ 1.0
	$< 30^6$	< 20 km/h (< 12 mph)	
Extreme Traffic Loading (E)	$> 30^6$	< 20 km/h (< 12 mph)	≤ 0.5

- Purpose
- Basics
- Test Temperature
- **Recovery**
- Variability
- Why?

- Recovery

- In addition to determining J_{nr} the MSCR test can be used to determine the amount of recovery in an asphalt binder during the creep-recovery testing
- MSCR Recovery provides an indication of the elastic response of the asphalt binder
 - A high recovery is an indication that the asphalt binder has a significant elastic component at the test temperature
- Not part of the criteria in AASHTO M323 Table 1
 - Not a true performance requirement

- Use of Recovery- J_{nr} curve for evaluating elastic response
 - D'Angelo Thesis
 - “A minimum MSCR %Recovery of somewhere between 20% and 40% would be a good indication of an effective polymer network in the binder. This range is based on the large increase in %Recovery seen between 2% SBS blend without cross-linker to 2% SBS blend with cross-linker.”
 - “The %Recovery should also be tied to the J_{nr} value for the binder.”
 - “To assure the %Recovery response is primarily from the polymer network and not from just a stiffening of the base binder, the minimum %Recovery should be increased as the J_{nr} value of the binder decreases.”

Recovery as an Indicator of Elastic Response

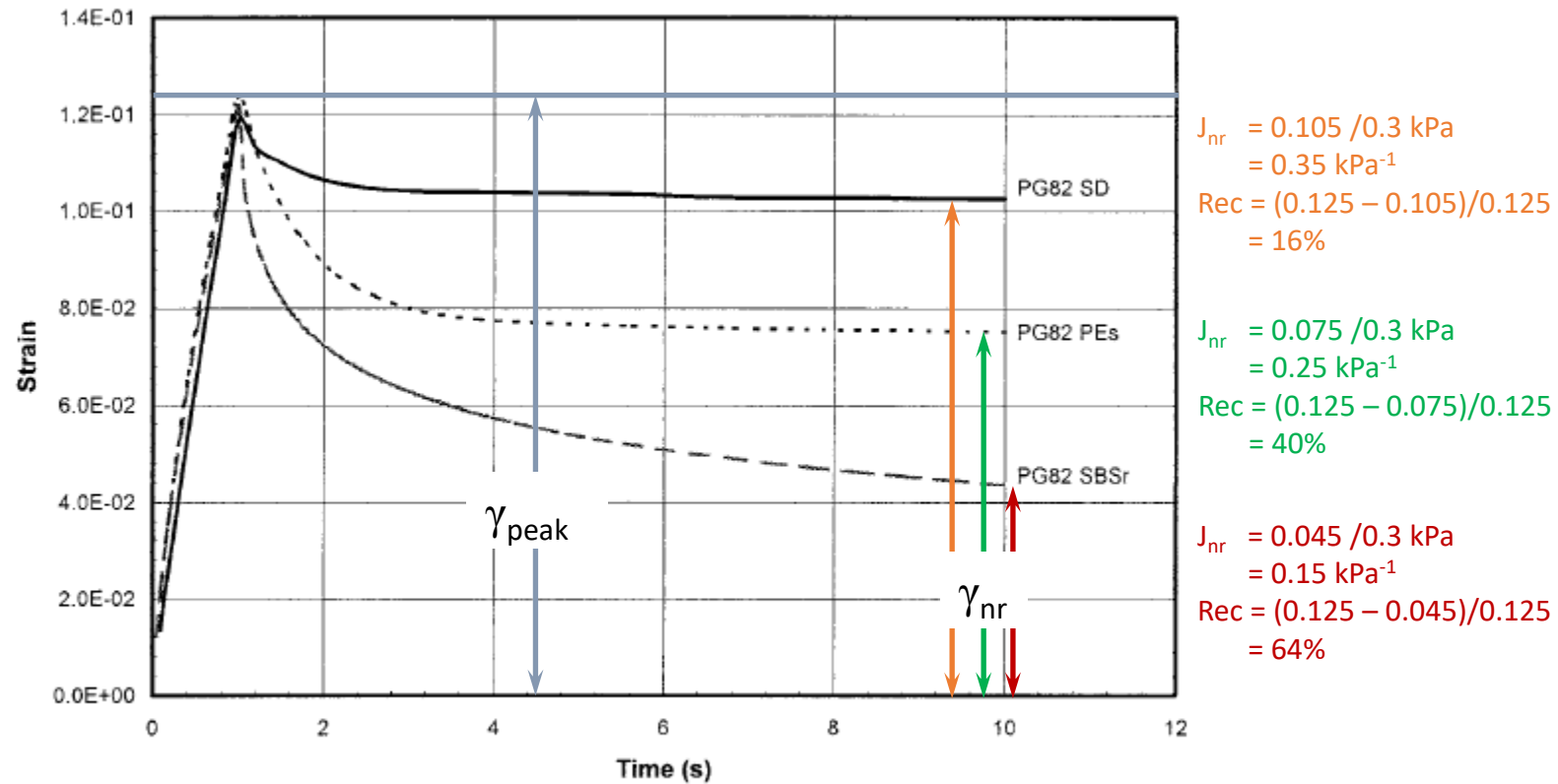
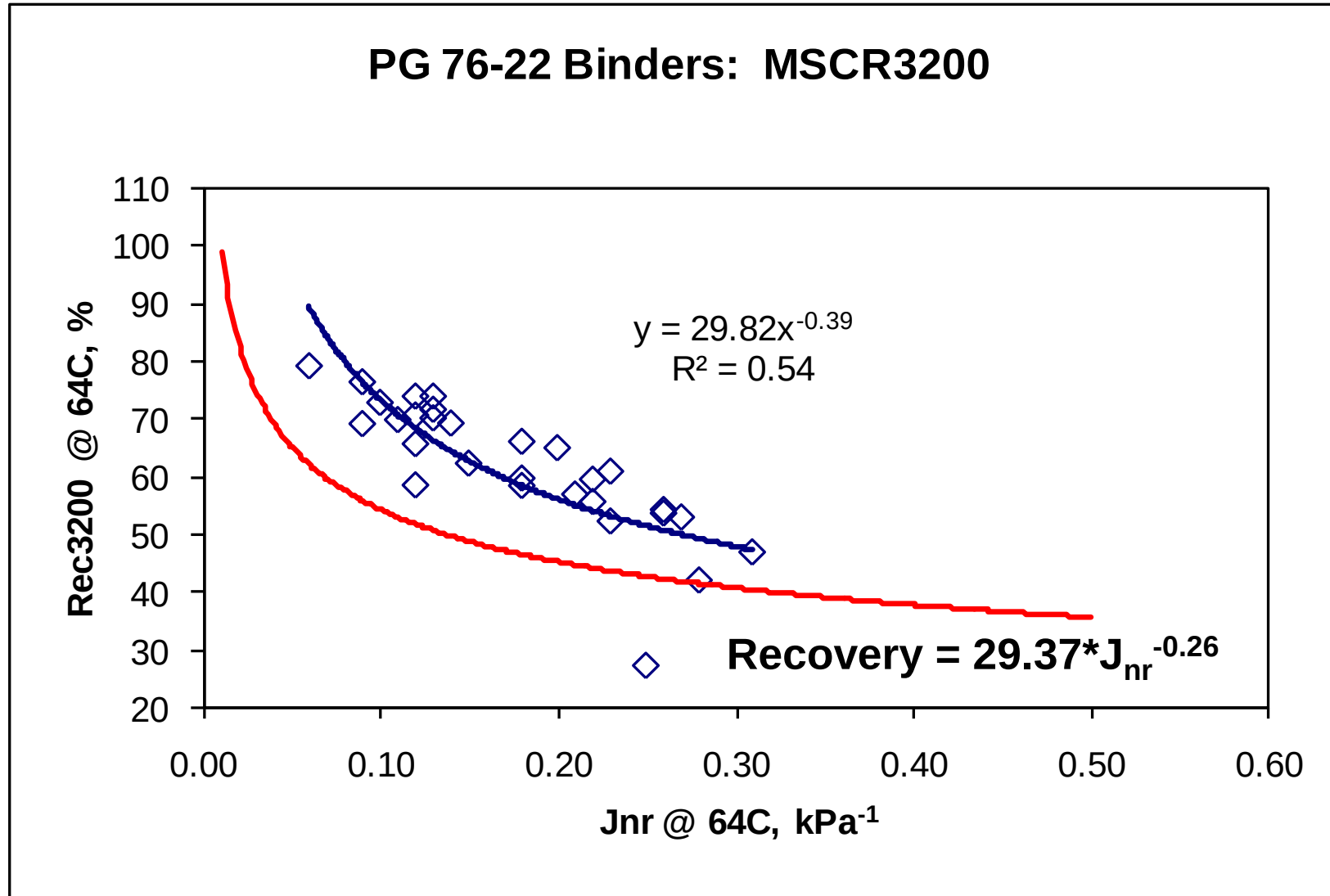


Figure 2.30 Creep and recovery of the first cycle for three PG 82 binders at 1 s loading and 9 s recovery (70°C, 300 Pa).

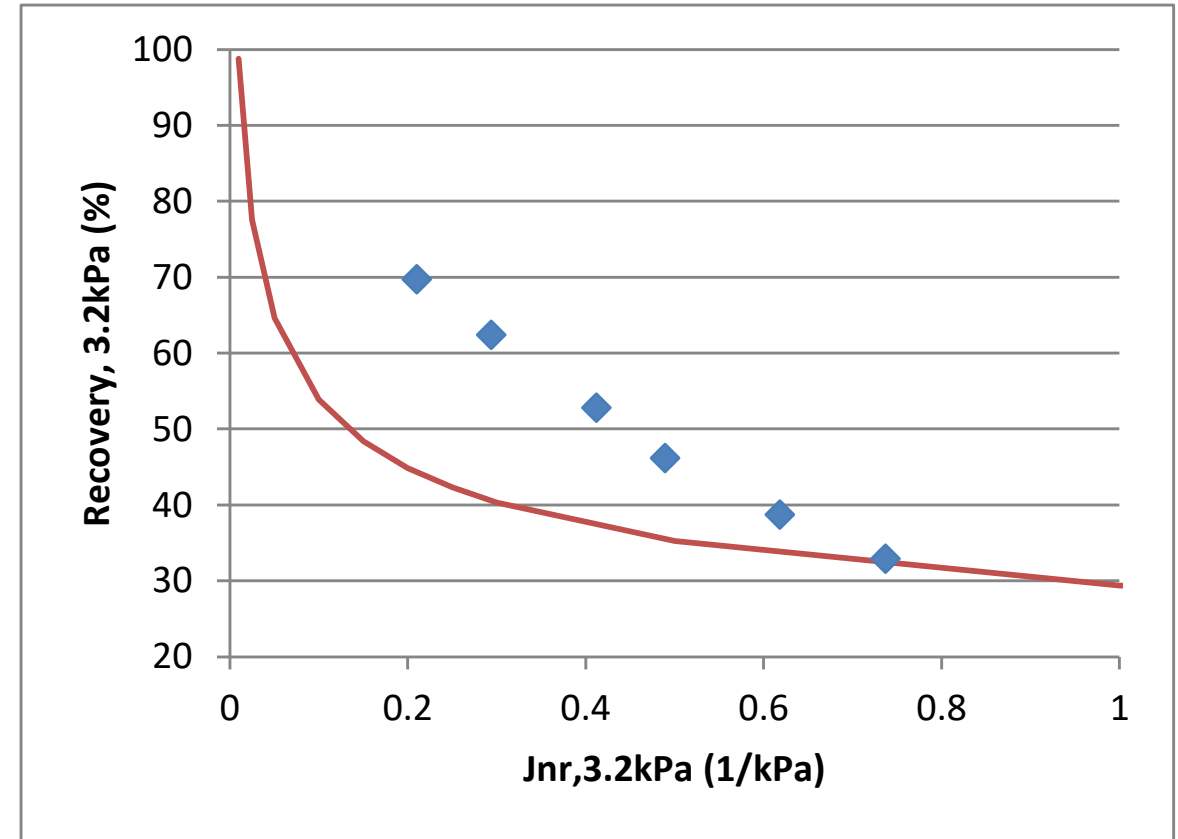
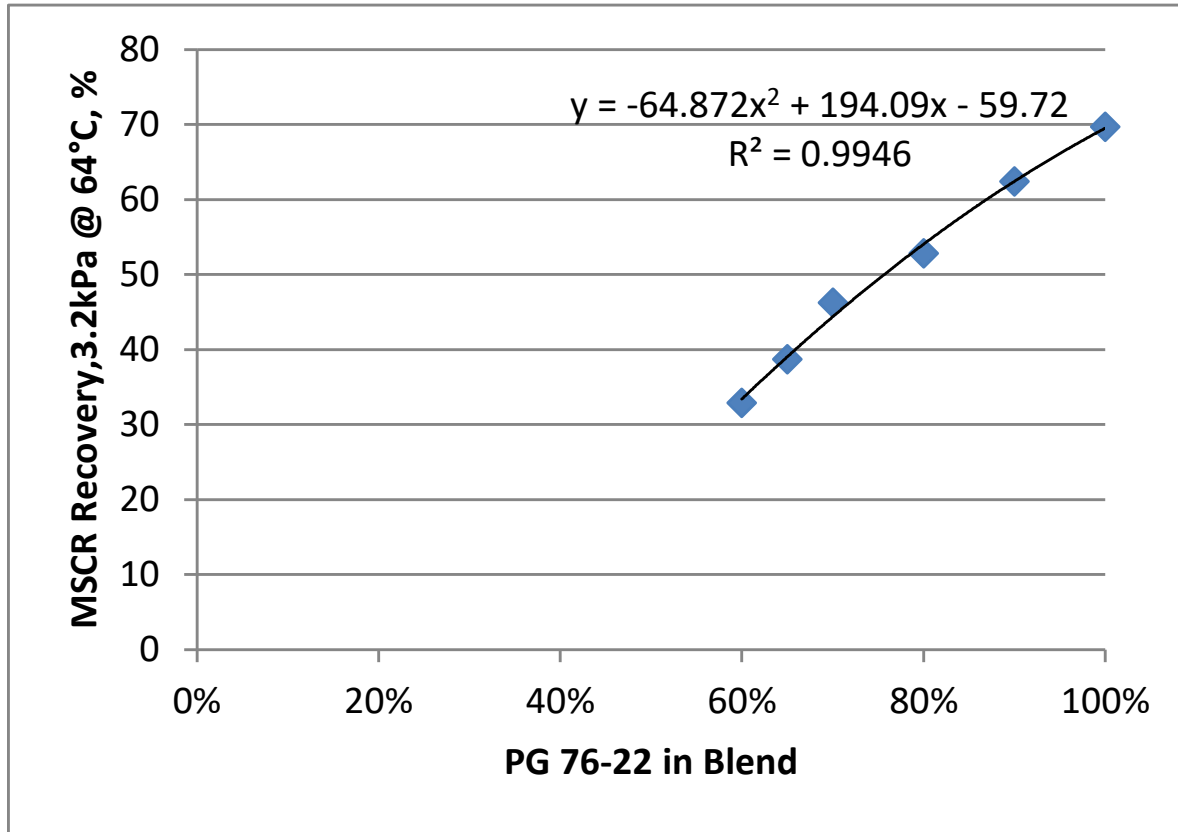
Excerpt from NCHRP Report 459, *Characterization of Modified Asphalt Binders in Superpave Mix Design*

Recovery as an Indicator of Elastic Response



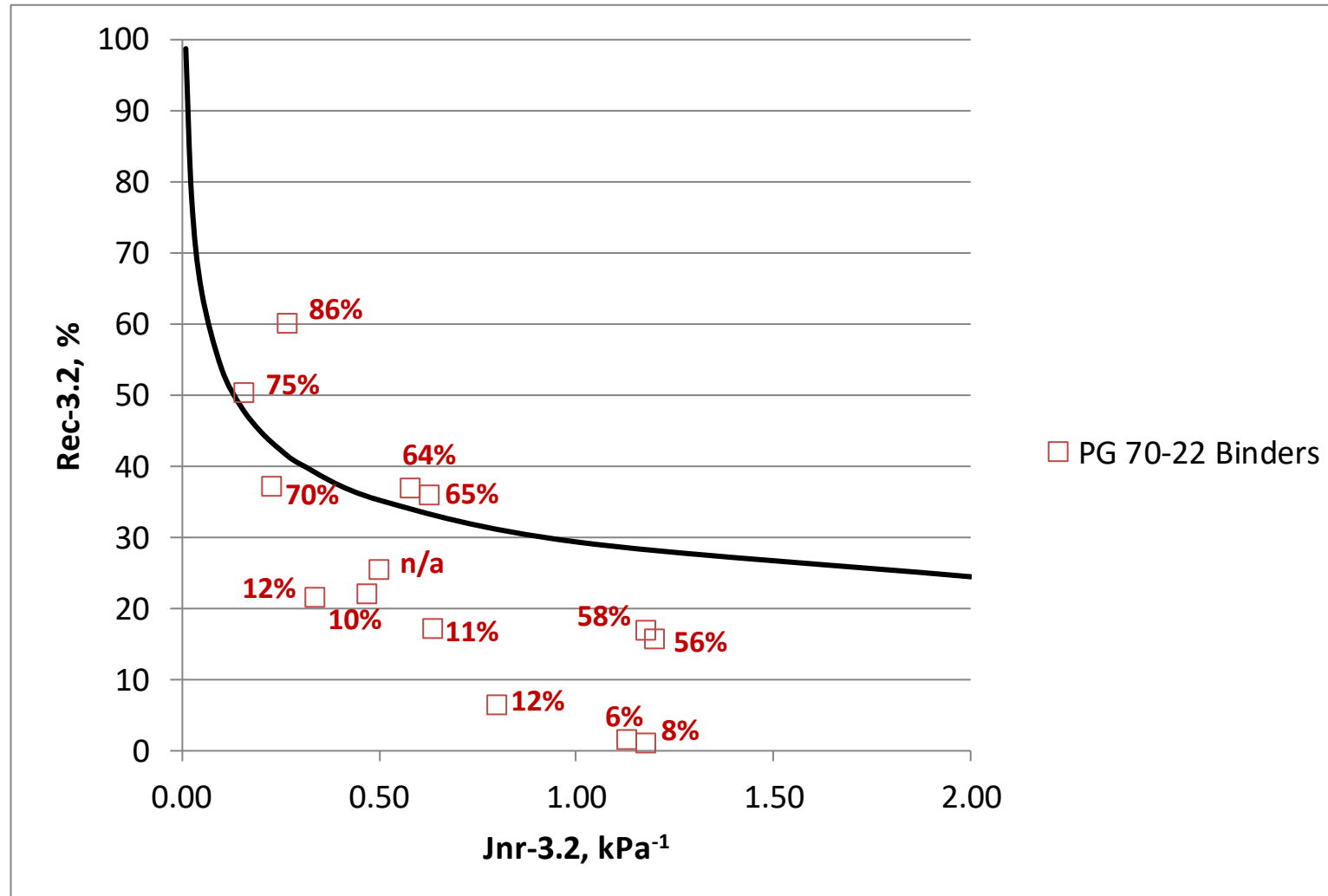
Implementation of the MSCR Test and Specification

- Use of Recovery- J_{nr} curve for evaluating elastic response



Implementation of the MSCR Test and Specification

- Use of Recovery- J_{nr} curve for evaluating elastic response



Standard Practice for

**Evaluating the Elastic Behavior of
Asphalt Binders Using the Multiple
Stress Creep Recovery (MSCR)
Test**

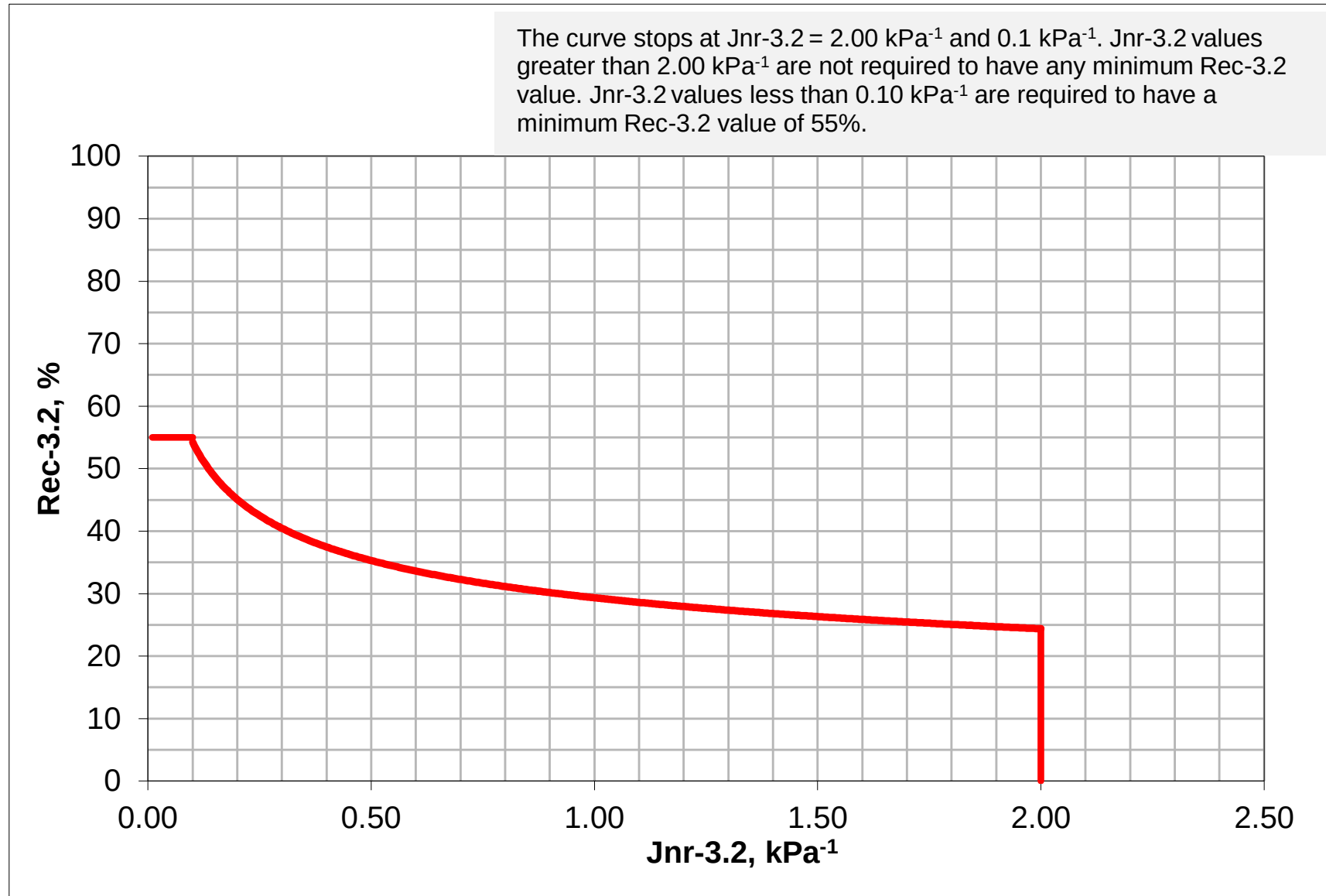
AASHTO Designation: R 92-18



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

- Why Have a Separate Practice?
 - M320 and M332 are Performance-Based Specifications
 - No “PG Plus” tests, like ER, are included in M320
 - In M332 the parameter related to performance is Jnr
 - MSCR Recovery is like ER in that it identifies elastic response of modified asphalt binders

AASHTO MSCR Recovery Practice



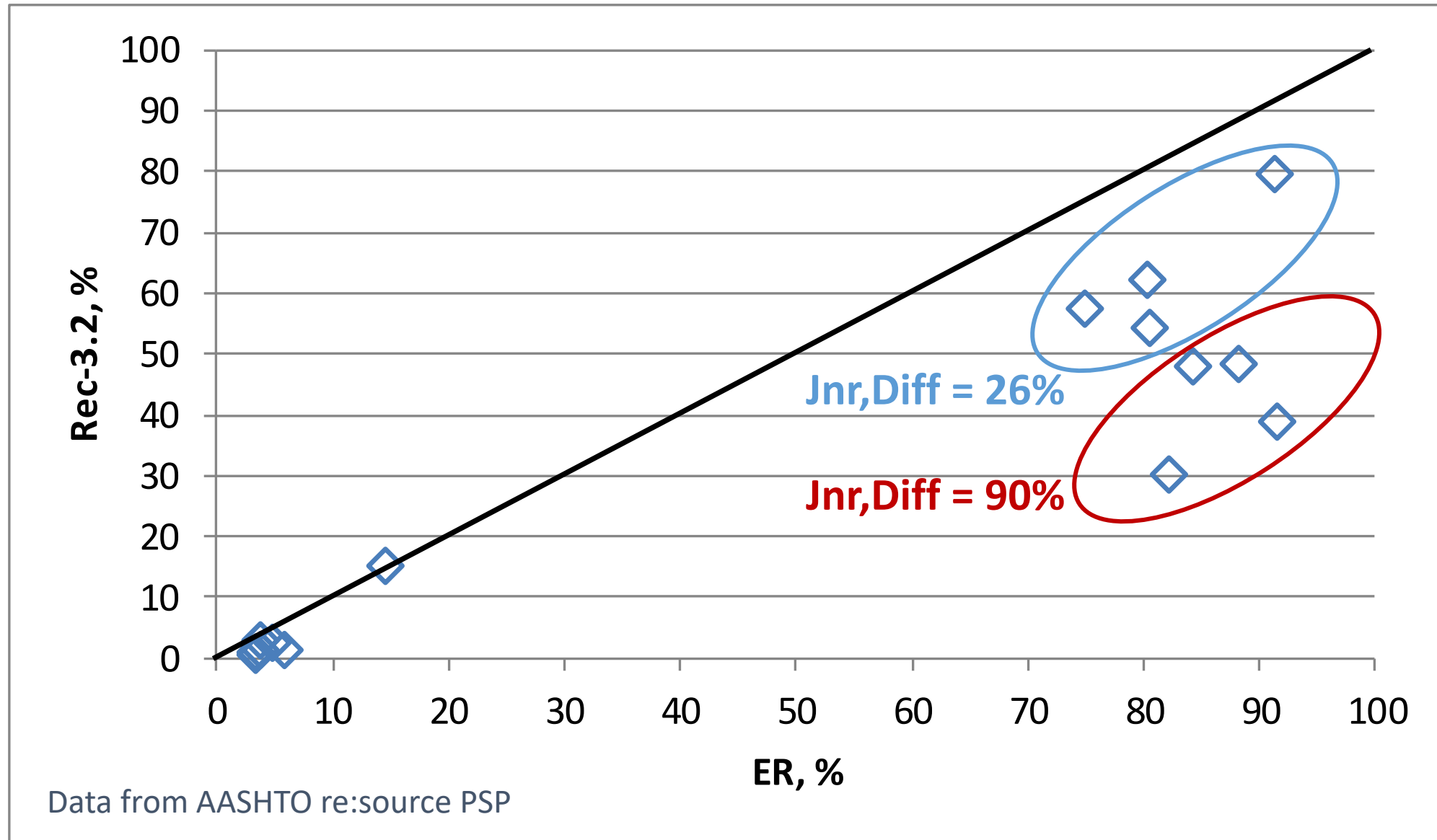
- Notes on Use of MSCR Recovery
 - Curve developed for modified asphalt binders in production at the time
 - Many PG 76-22 asphalt binders and those modified with similar levels of polymer
 - Favors networked modification
 - Curve stops at 0.1 kPa^{-1} and 2.0 kPa^{-1}
 - $J_{nr,3.2}$ values above 2.0 kPa^{-1} would be classified as an **S** grade at the test temperature used and would not normally be a modified asphalt binder
 - $J_{nr,3.2}$ values below 0.1 kPa^{-1} would be classified as an **E** (Extreme) grade at the test temperature used
 - The $R_{3.2}$ value is sufficiently high (55%) that it would be extremely unlikely that any unmodified asphalt binder could have a Recovery exceeding the minimum

- Notes on Use of MSCR Recovery
 - High temperature binder specification parameter from M332 is $J_{nr,3.2}$
 - If the asphalt binder meets the appropriate $J_{nr,3.2}$ criterion, then it should be expected that the binder will minimize its contribution to permanent deformation (rutting) of the asphalt mixture.

- Notes on Use of MSCR Recovery

- If a user wants to validate that an asphalt binder has been polymer-modified, specifically modified with an elastomer, then adding the appropriate MSCR Recovery ($R_{3.2}$) value as a minimum requirement is an option
 - MSCR Recovery could replace other PG Plus tests that are intended to have a similar purpose
 - e.g., Elastic Recovery, Force Ductility, and Toughness and Tenacity
 - Strong correlations should not be expected when conducting comparative testing between MSCR Recovery and other PG Plus tests
 - Purposes may be similar, but test conditions are sufficiently different

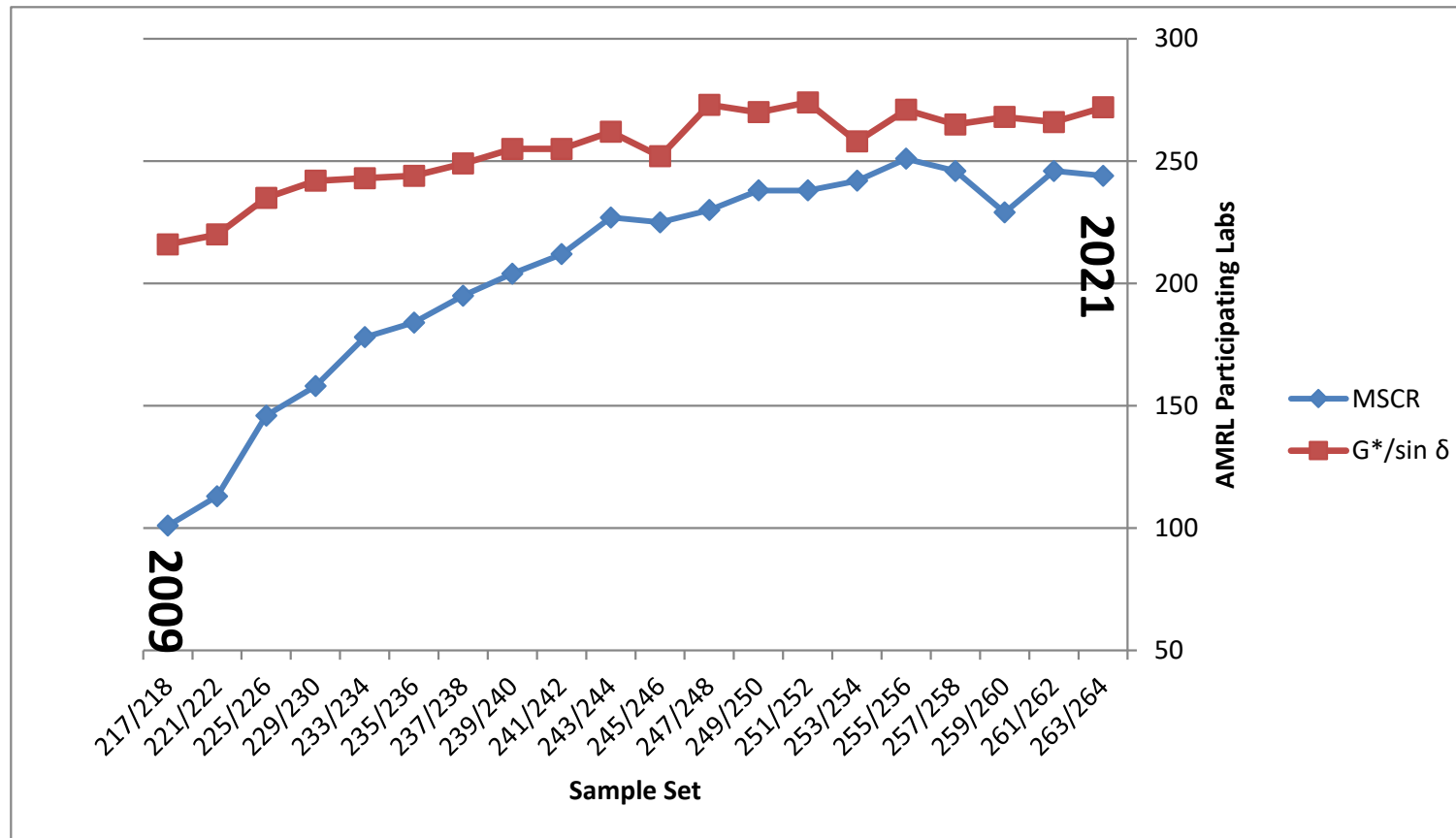
Implementation of the MSCR Test and Specification



- Purpose
- Basics
- Test Temperature
- Recovery
- **Variability**
- Why?

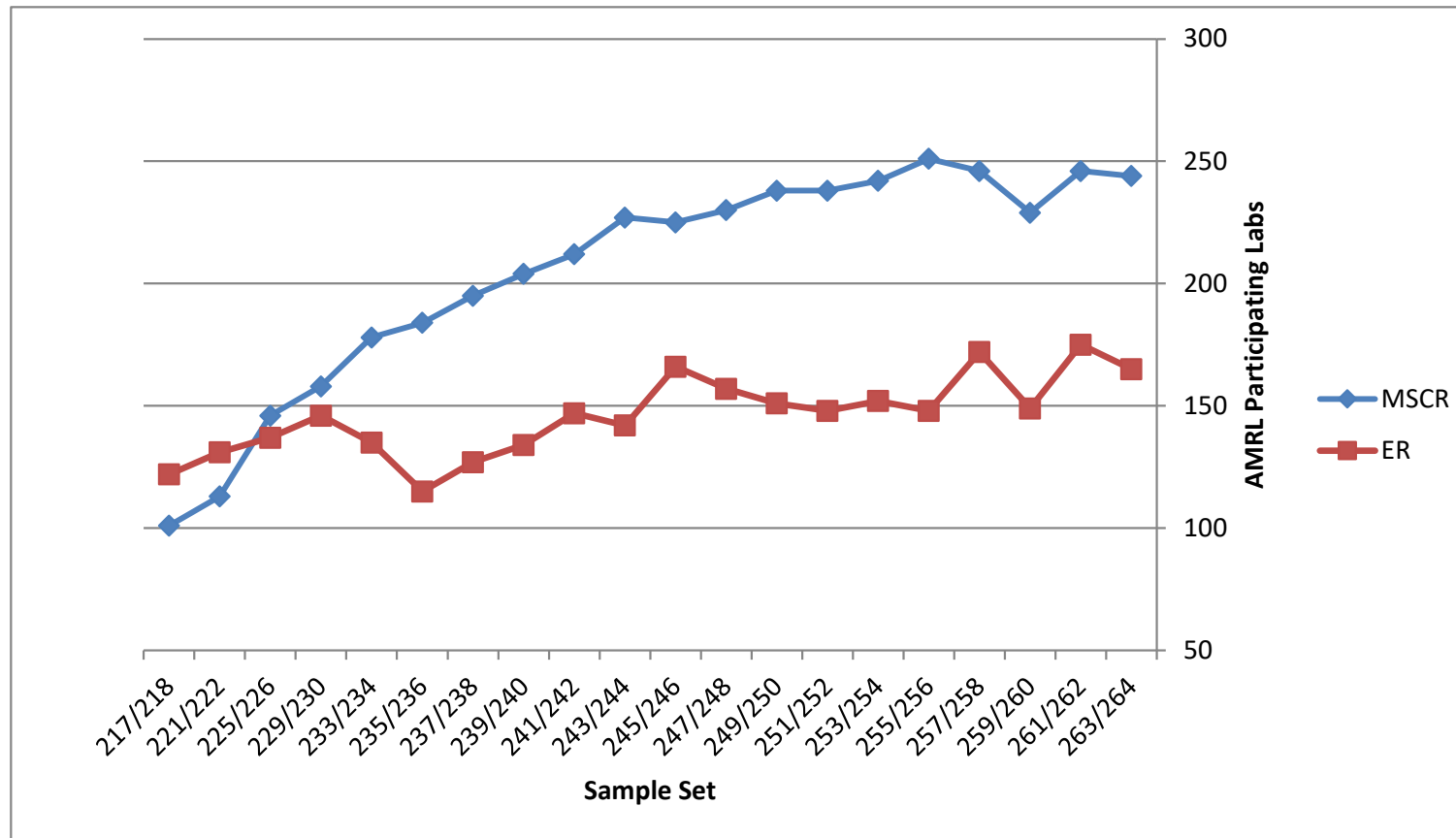
Implementation of the MSCR Test and Specification

- Number of Participating Labs
 - AASHTO re:source PSP



Implementation of the MSCR Test and Specification

- Number of Participating Labs
 - AASHTO re:source PSP



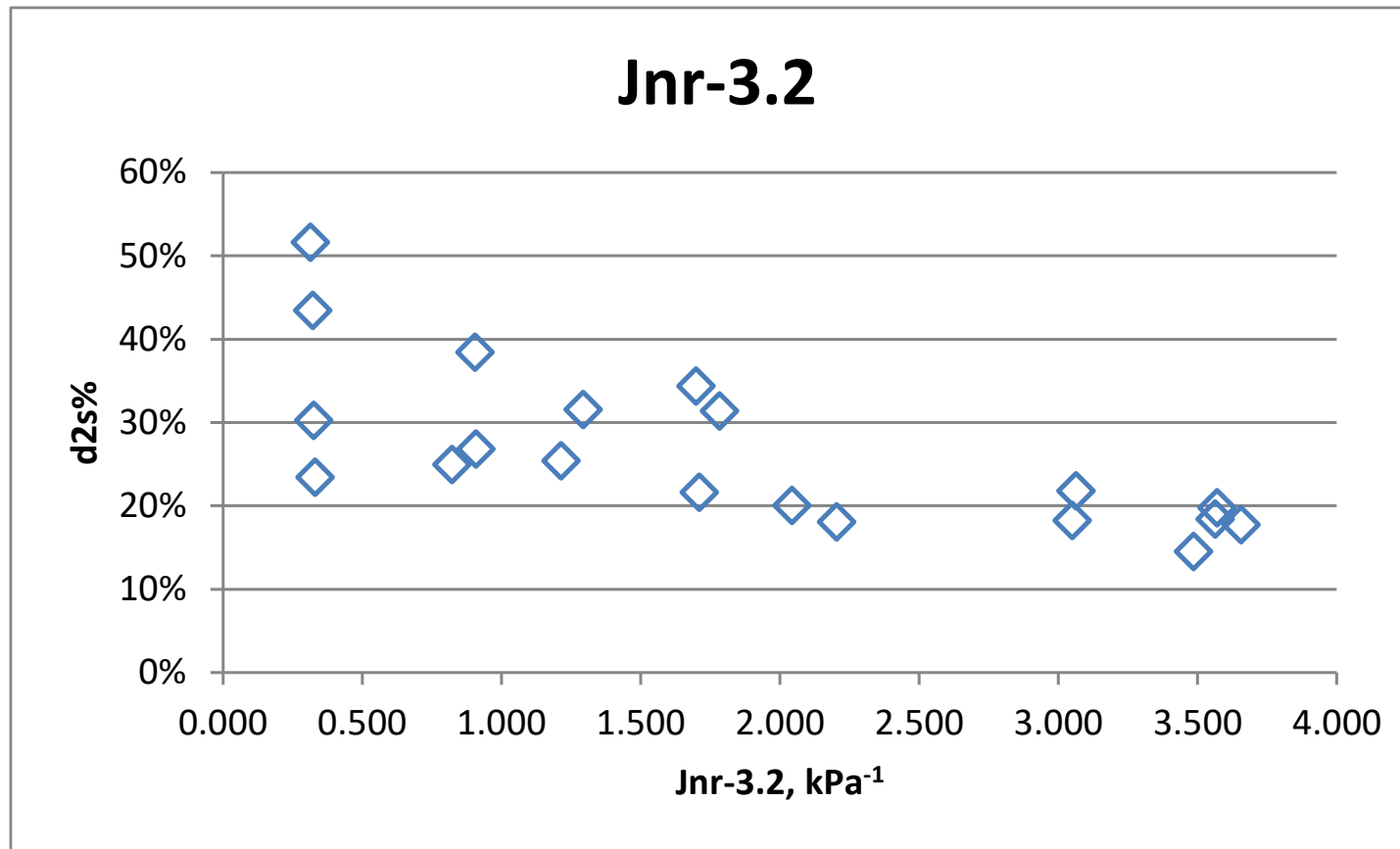
Implementation of the MSCR Test and Specification

- Variability of MSCR test
 - AI-Coordinated ILS
 - d2s% shown for between lab (reproducibility)

ILS	Multi-Lab Rec-3.2	Multi-Lab Jnr-3.2
ETG 2009	18.1%	22.0-42.6%
NEAUPG 2010	18.7%	33.7%
SEAUPG 2011	9.8%	28.0%
NEAUPG 2012	7.6%	33.0%
PCCAS 2013	13.8%	36.8%

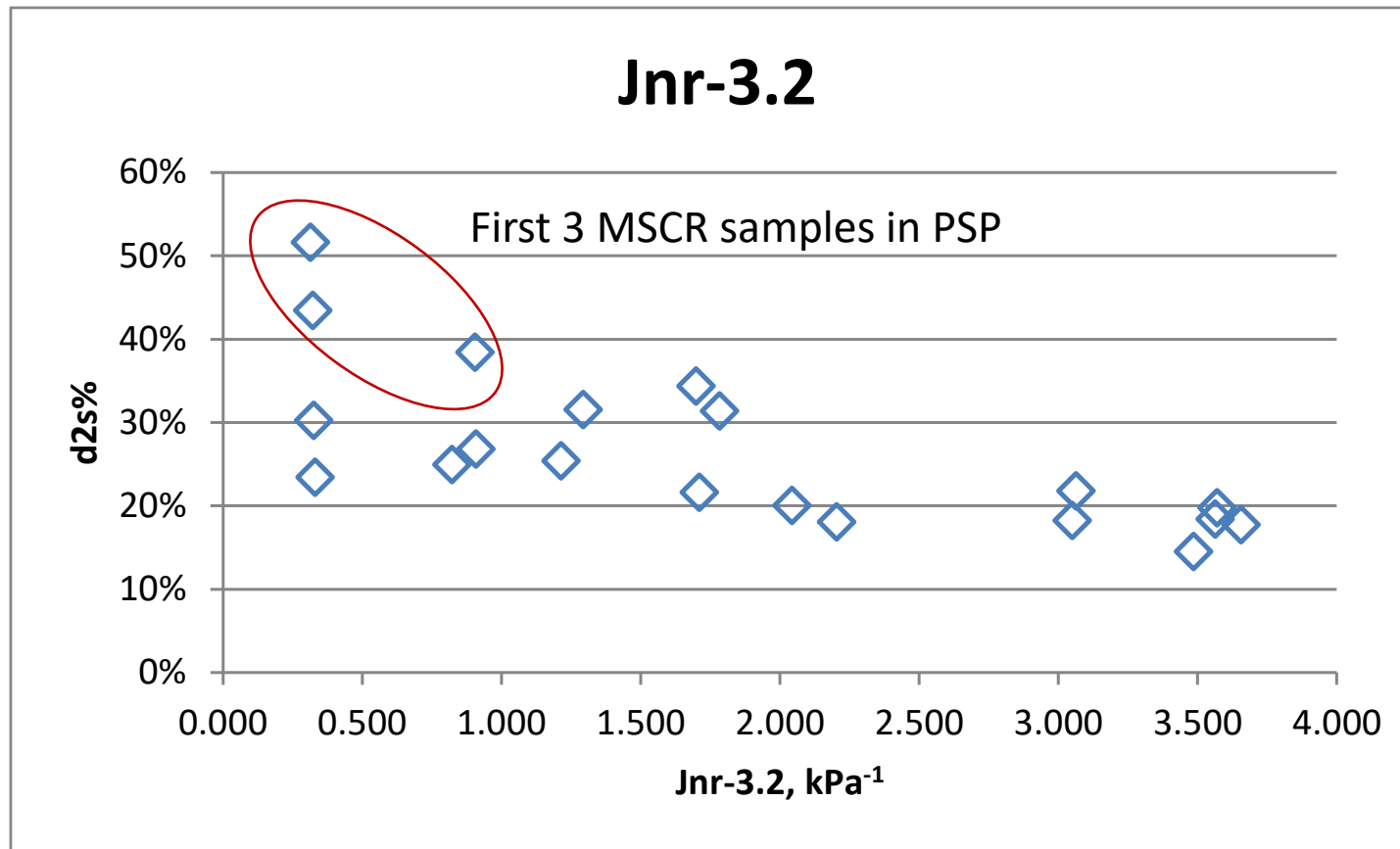
Implementation of the MSCR Test and Specification

- Variability of MSCR test
 - AASHTO re:source PSP



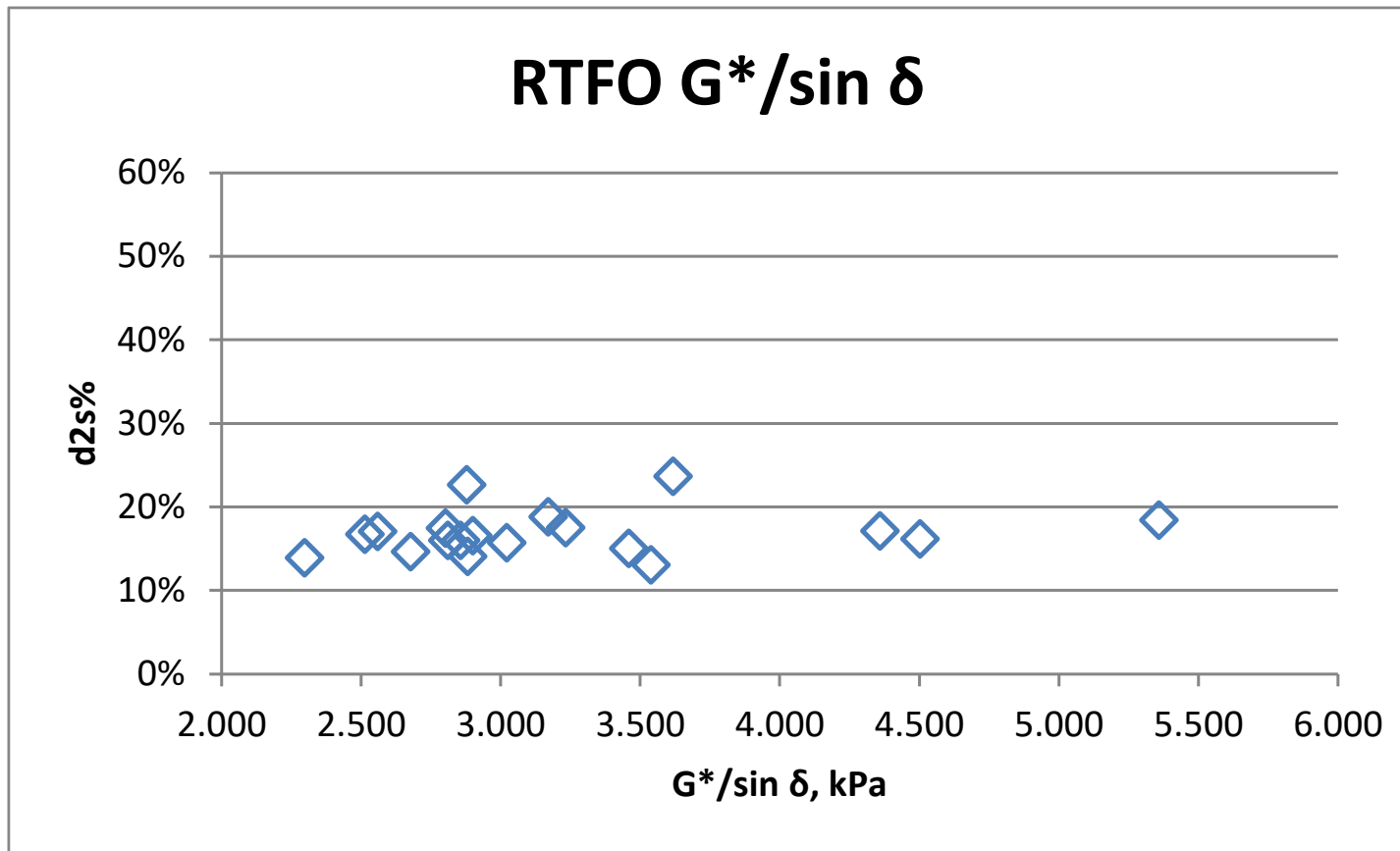
Implementation of the MSCR Test and Specification

- Variability of MSCR test
 - AASHTO re:source PSP



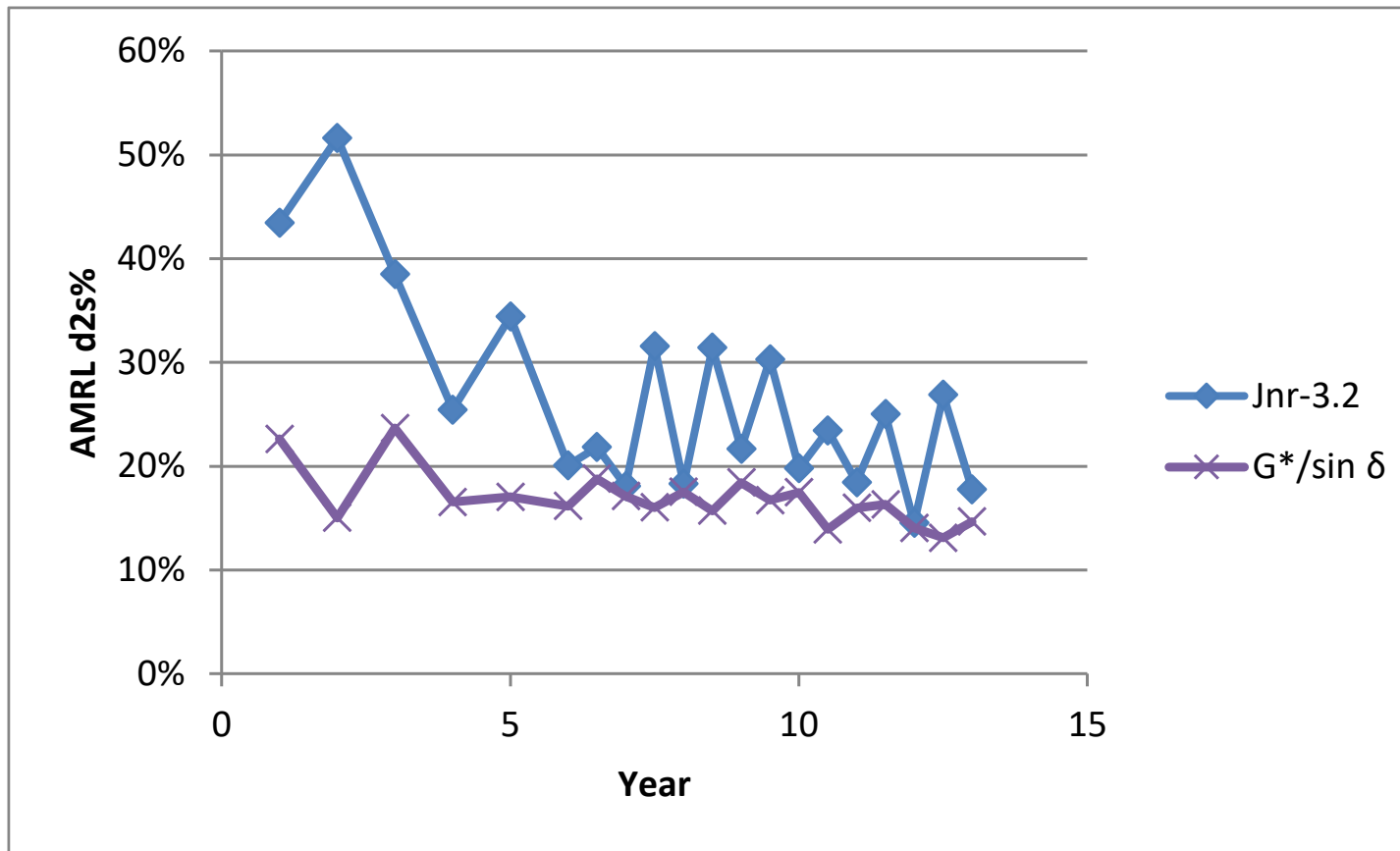
Implementation of the MSCR Test and Specification

- Variability of MSCR test
 - AASHTO re:source PSP



Implementation of the MSCR Test and Specification

- Variability of MSCR test
 - AASHTO re:source PSP

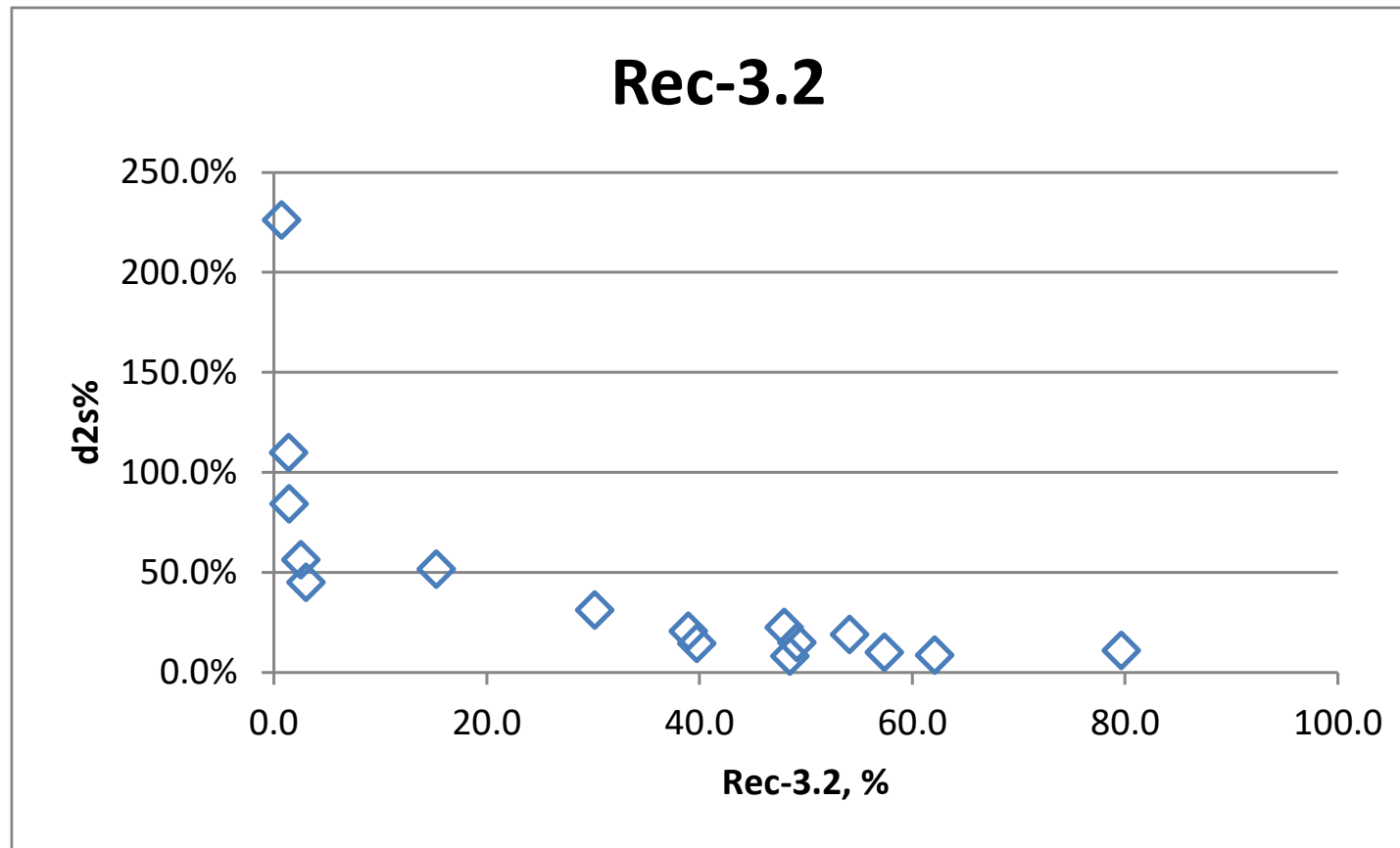


- AASHTO re:source has been analyzing data from the MSCR test in the Proficiency Sample Programs (PSP) since 2009
 - Since 2009, the average $J_{nr3.2}$ values for the samples have been in the range of 0.327 to 3.657 kPa⁻¹
 - For these 17 samples, the corresponding multi-laboratory d2s% values have been in the range of 14.5% to 34.4%, with an average value of 23.5%
 - Over the same time frame the multi-laboratory d2s% values for the RTFO $G^*/\sin \delta$ parameter (AASHTO T315) have been in the range of 13.1% to 18.8%, with an average value of 16.2%

- AASHTO re:source has been analyzing data from the MSCR test in the Proficiency Sample Programs (PSP) since 2009
 - Since 2009, eight of the asphalt binders appeared to be modified with average $R_{3.2}$ values for the samples in the range of 30.1% to 62.1%
 - For these eight samples, the corresponding multi-laboratory d2s% values have been in the range of 8.2% to 31.1%, with an average value of 16.2%

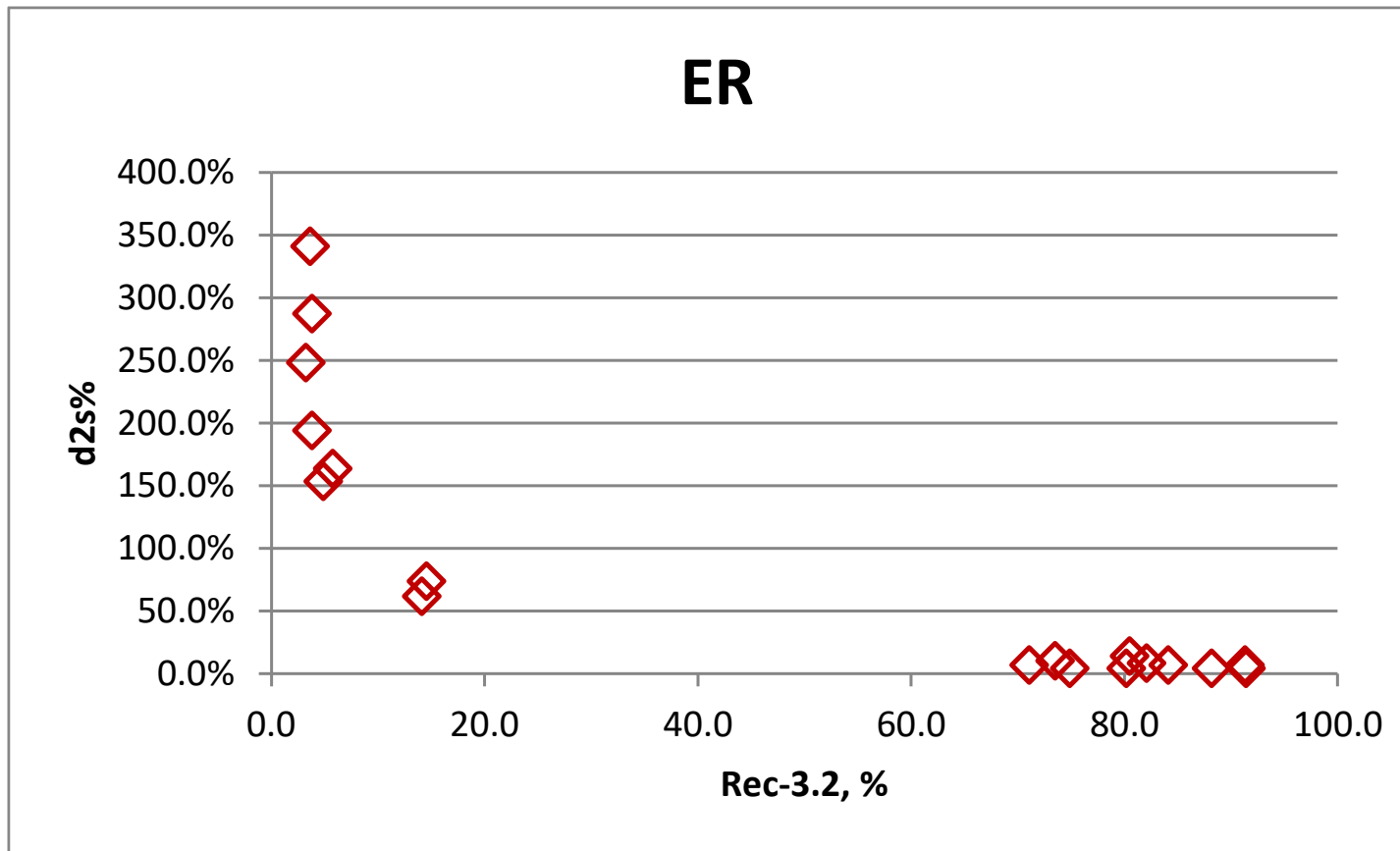
Implementation of the MSCR Test and Specification

- Variability of MSCR test
 - AASHTO re:source PSP



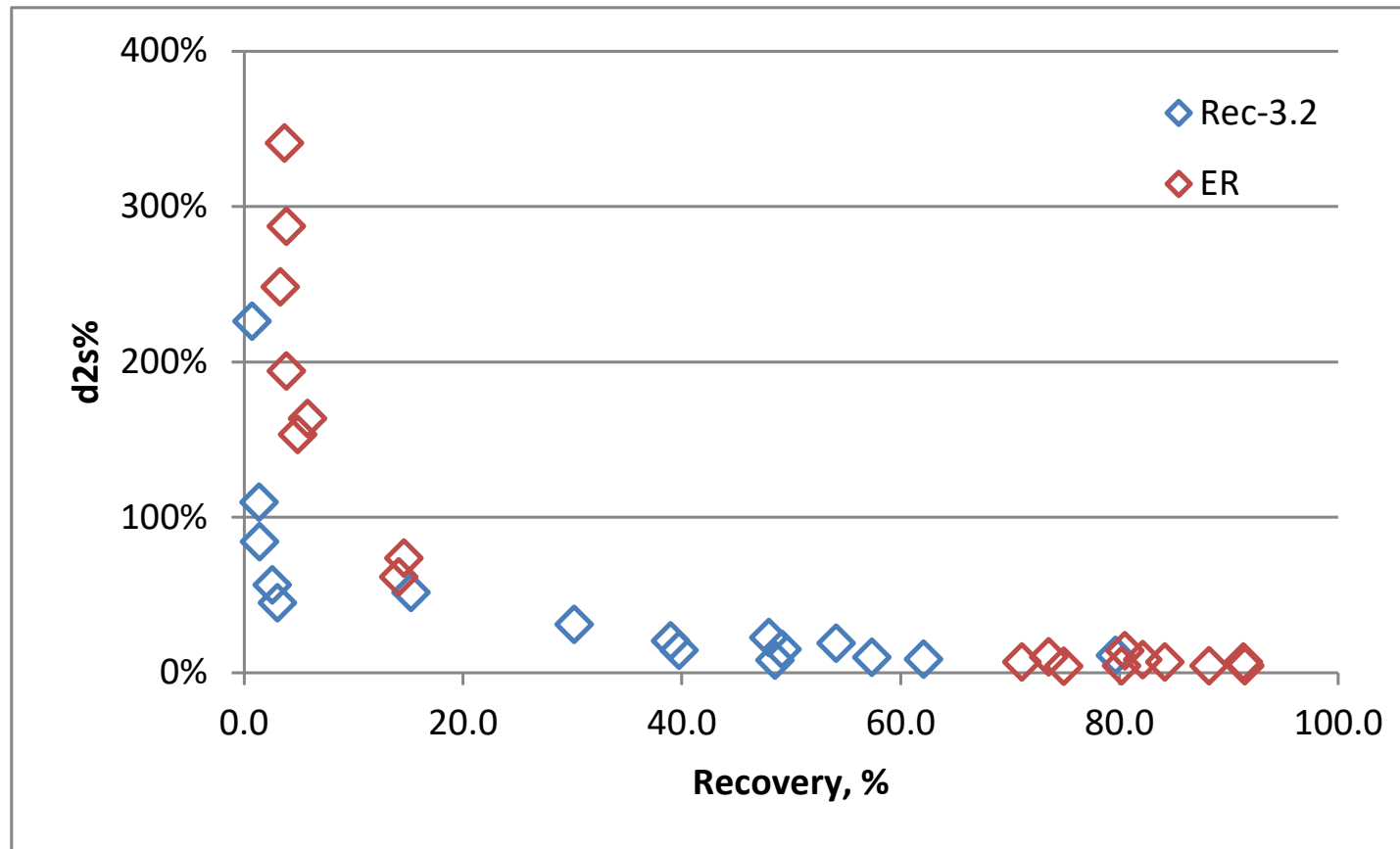
Implementation of the MSCR Test and Specification

- Variability of ER test
 - AASHTO re:source PSP



Implementation of the MSCR Test and Specification

- Variability of ER and MSCR Recovery tests
 - AASHTO re:source PSP



- Variability of MSCR test
 - PCCAS ILS (2013)

Table 20: Estimated Repeatability and Reproducibility from ILS

<i>Test</i>	<i>Acceptable Range of Two Test Results (d2s%)</i> <i>2013 PCCAS ILS</i>	
	<i>Single Operator Precision</i>	<i>Multilaboratory Precision</i>
Elastic Recovery (RTFO) at 25°C	5.6%	9.2%
R&B Softening Point	2.8%	7.7%
Ductility (Original) at 4°C	17.9%	75.0%
Ductility (RTFO) at 4°C	19.5%	95.1%
Toughness at 25°C	15.3%	29.1%
Tenacity at 25°C	17.9%	30.0%

MSCR Rec-3.2

8.0%

17.3%

Implementation of the MSCR Test and Specification

- Variability of MSCR test
 - AASHTO T 350-19

	Single Operator (Repeatability)		Multilaboratory (Reproducibility)	
	Coefficient of Variation (1s%)	Acceptable Range of Two Results (d2s%)	Coefficient of Variation (1s%)	Acceptable Range of Two Results (d2s%)
$R_{0.1}$ (%)	1.6	4.4	4.8	13.5
$R_{3.2}$ (%)	1.9	5.5	4.5	12.7
$J_{nr0.1}$ (kPa ⁻¹)	4.4	12.5	11.7	33.1
$J_{nr3.2}$ (kPa ⁻¹)	4.7	13.2	10.8	30.7

Precision estimates based on analysis of data from 4 pairs of AASHTO re:source proficiency samples representing 149-225 labs. Four modified asphalt binder grades – PG 58-28, PG 70-28, PG 76-22, and PG 82-22 – were used as samples in the analysis. Average range of values is as shown:

$R_{0.1}$:	54.6% to 71.6%	$R_{3.2}$:	30.0% to 48.5%
$J_{nr0.1}$:	0.62 kPa ⁻¹ to 1.02 kPa ⁻¹	$J_{nr3.2}$:	1.22 kPa ⁻¹ to 1.79 kPa ⁻¹

Implementation of the MSCR Test and Specification

- Variability of MSCR test
 - AASHTO T 350-19

	Single Operator (Repeatability)		Multilaboratory (Reproducibility)	
	Coefficient of Variation (1s%)	Acceptable Range of Two Results (d2s%)	Coefficient of Variation (1s%)	Acceptable Range of Two Results (d2s%)
$R_{0.1}$ (%)	1.6	4.4	4.8	13.5
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$J_{nr0.1}$ (kPa ⁻¹)	4.4	12.5	11.7	33.1
$J_{nr3.2}$ (kPa ⁻¹)	4.7	13.2	10.8	30.7
$G^*/\sin \delta$ (kPa), RTFO	2.5	7.2	5.9	16.8

Implementation of the MSCR Test and Specification

- Variability of MSCR test
 - AASHTO T 350-19

	Single Operator (Repeatability)		Multilaboratory (Reproducibility)	
	Coefficient of Variation (1s%)	Acceptable Range of Two Results (d2s%)	Coefficient of Variation (1s%)	Acceptable Range of Two Results (d2s%)
$R_{0.1}$ (%)	1.6	4.4	4.8	13.5
$R_{3.2}$ (%)	1.9	5.5	4.5	12.7
$J_{nr0.1}$ (kPa ⁻¹)	4.4	12.5	11.7	33.1
$J_{nr3.2}$ (kPa ⁻¹)	4.7	13.2	10.8	30.7
$J_{nr3.2}$ (kPa ⁻¹) Unmod.	8 samples from PSP (2009-2021)		6.6	18.6
G*/sin δ (kPa), RTFO	2.5	7.2	5.9	16.8

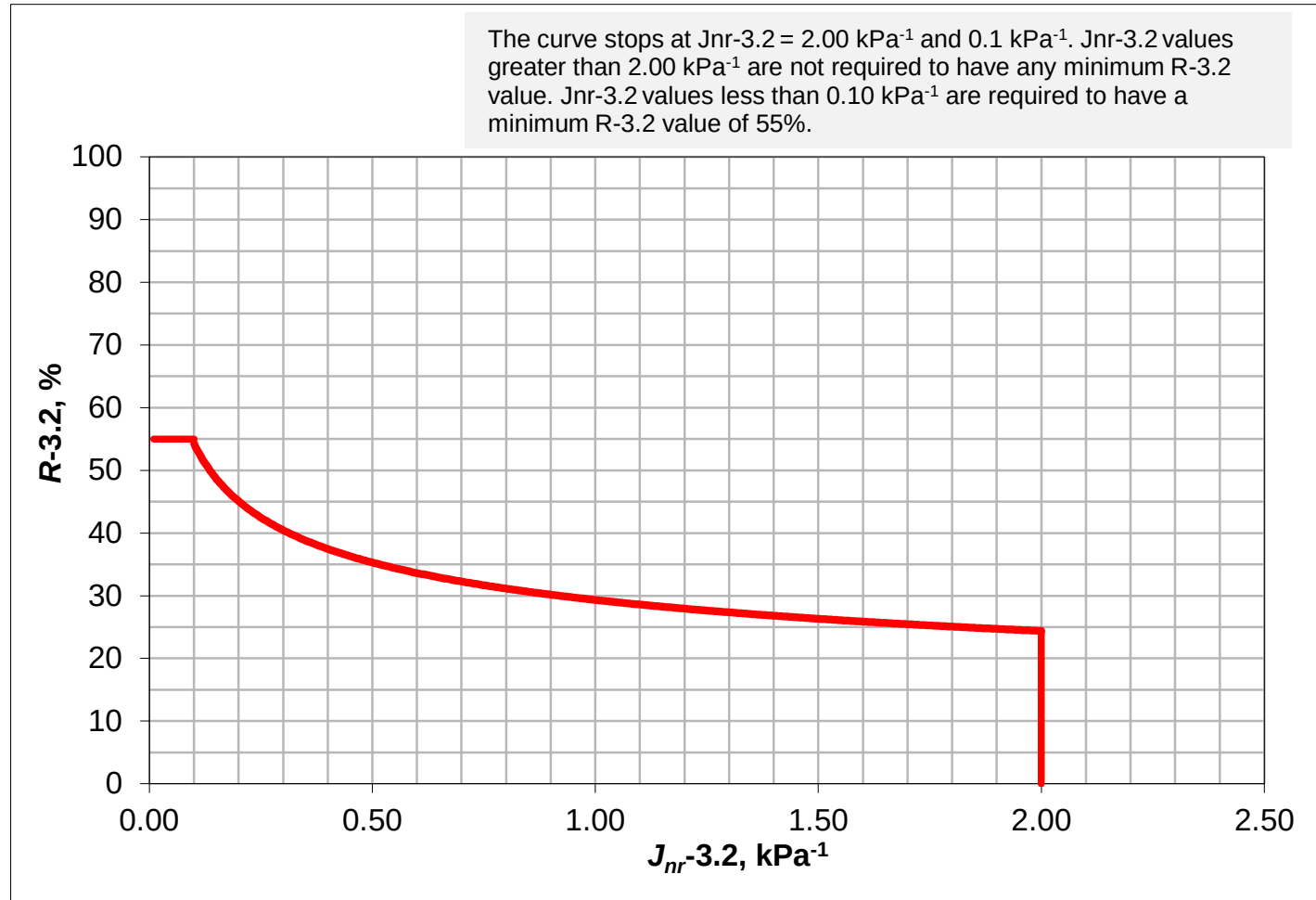
Implementation of the MSCR Test and Specification

- Variability of MSCR test
 - AASHTO T 350-19

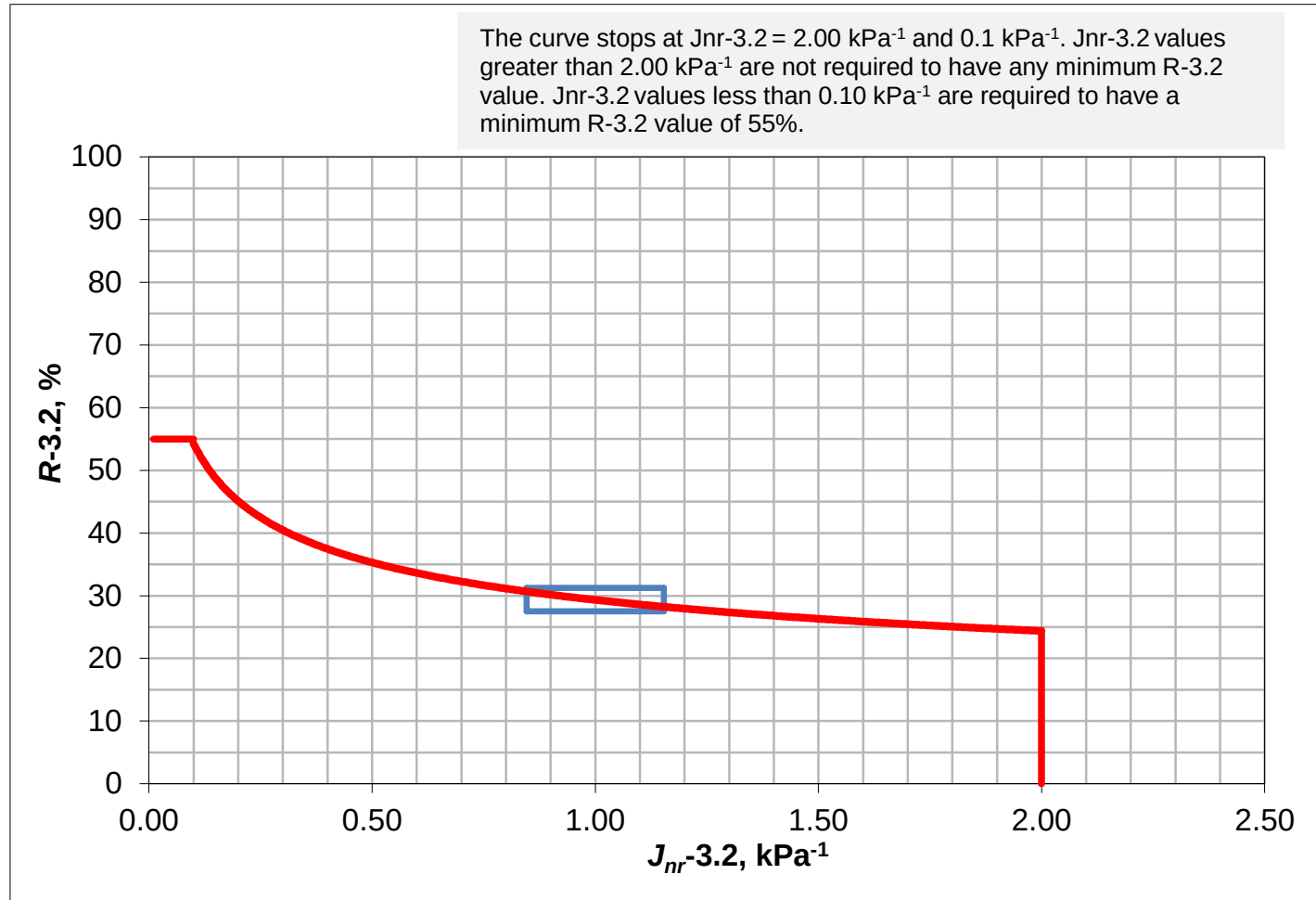
	Single Operator (Repeatability)		Multilaboratory (Reproducibility)	
	Coefficient of Variation (1s%)	Acceptable Range of Two Results (d2s%)	Coefficient of Variation (1s%)	Acceptable Range of Two Results (d2s%)
$R_{0.1}$ (%)	1.6	4.4	4.8	13.5
$R_{3.2}$ (%)	1.9	5.5	4.5	12.7
$J_{nr0.1}$ (kPa ⁻¹)	4.4	12.5	11.7	33.1
$J_{nr3.2}$ (kPa ⁻¹)	4.7	13.2	10.8	30.7
$J_{nr3.2}$ (kPa ⁻¹) Unmod.	8 samples from PSP (2009-2021)		6.6	18.6
$G^*/\sin \delta$ (kPa), RTFO	2.5	7.2	5.9	16.8

- Acceptable range of results for two labs
 - At specification value of 2.00 kPa⁻¹
 - $J_{nr3.2}$ range = 0.62 kPa⁻¹
 - At specification value of 1.00 kPa⁻¹
 - $J_{nr3.2}$ range = 0.31 kPa⁻¹
 - At specification value of 0.5 kPa⁻¹
 - $J_{nr3.2}$ range = 0.16 kPa⁻¹
 - At specification value of 2.20 kPa
 - $G^*/\sin \delta$ range = 0.37 kPa

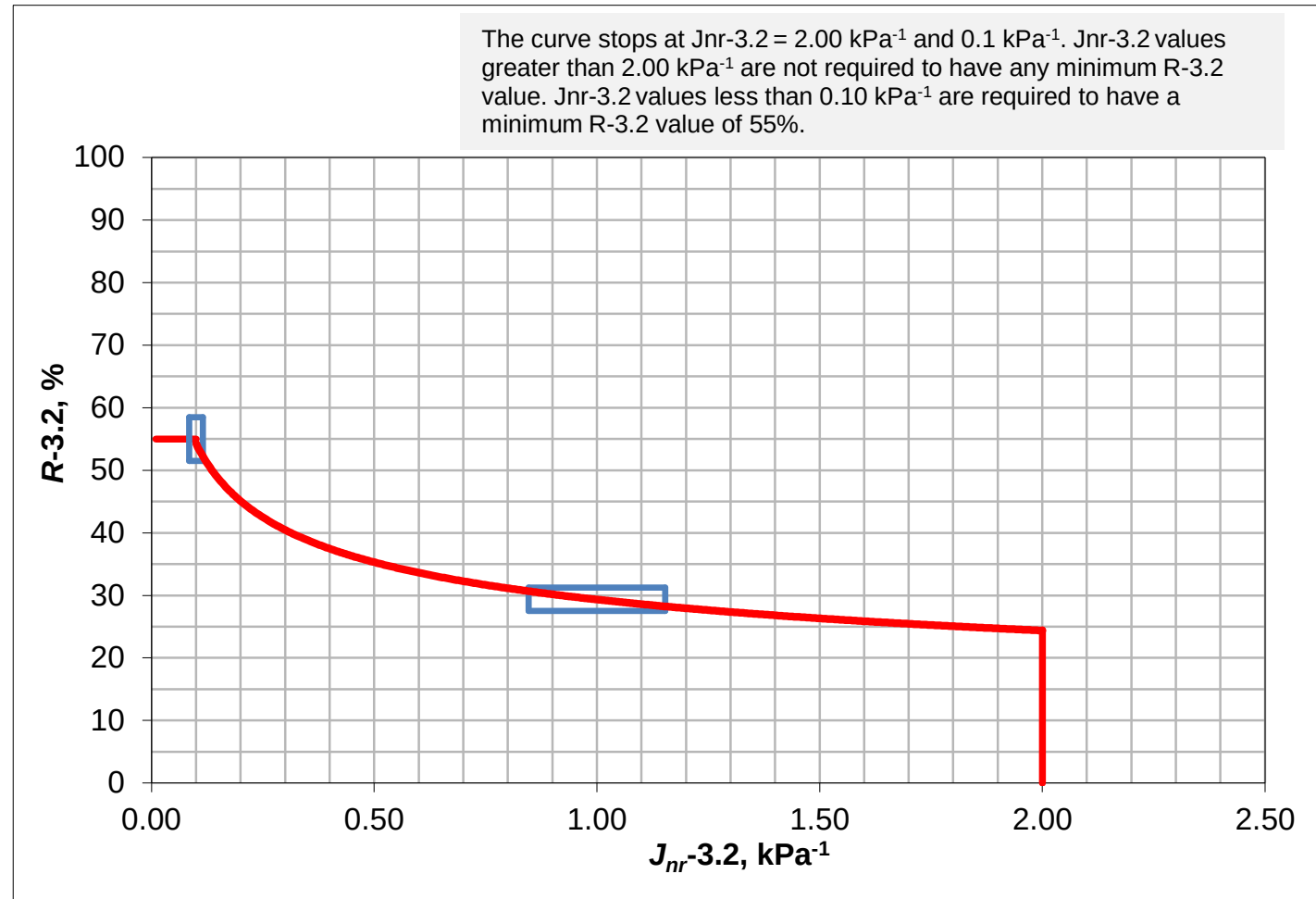
Evaluating Elastic Behavior



Evaluating Elastic Behavior: Variability



Evaluating Elastic Behavior: Variability



- Purpose
- Basics
- Test Temperature
- Recovery
- Variability
- **Why?**

Multiple Stress Creep and Recovery (MSCR) Implementation and Transition



PREPARED BY:

GAYLON L. BAUMGARDNER, PH.D.
CO-PRINCIPAL INVESTIGATOR

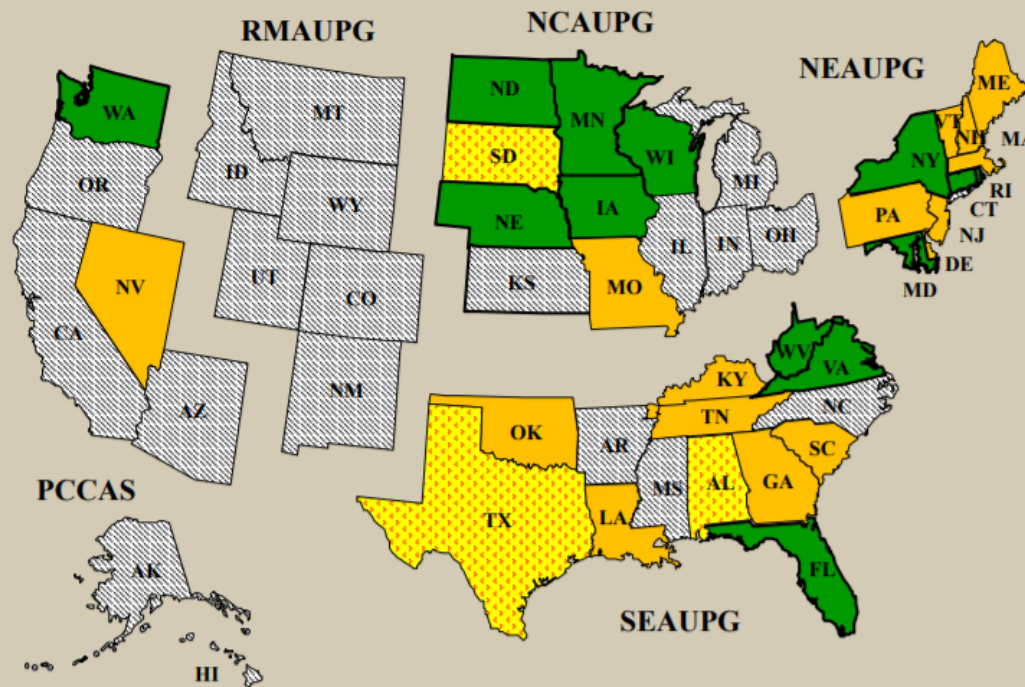
FEDERAL HIGHWAY ADMINISTRATION (FHWA)
“DEVELOPMENT AND DEPLOYMENT OF INNOVATIVE ASPHALT PAVEMENT
TECHNOLOGIES” COOP AGREEMENT WITH UNIVERSITY OF NEVADA, RENO

PRESENTED BY:

GAYLON L. BAUMGARDNER, PH.D. & JOHN A. D'ANGELO, PH.D.

U.S. Status of Implementation/Transition

25

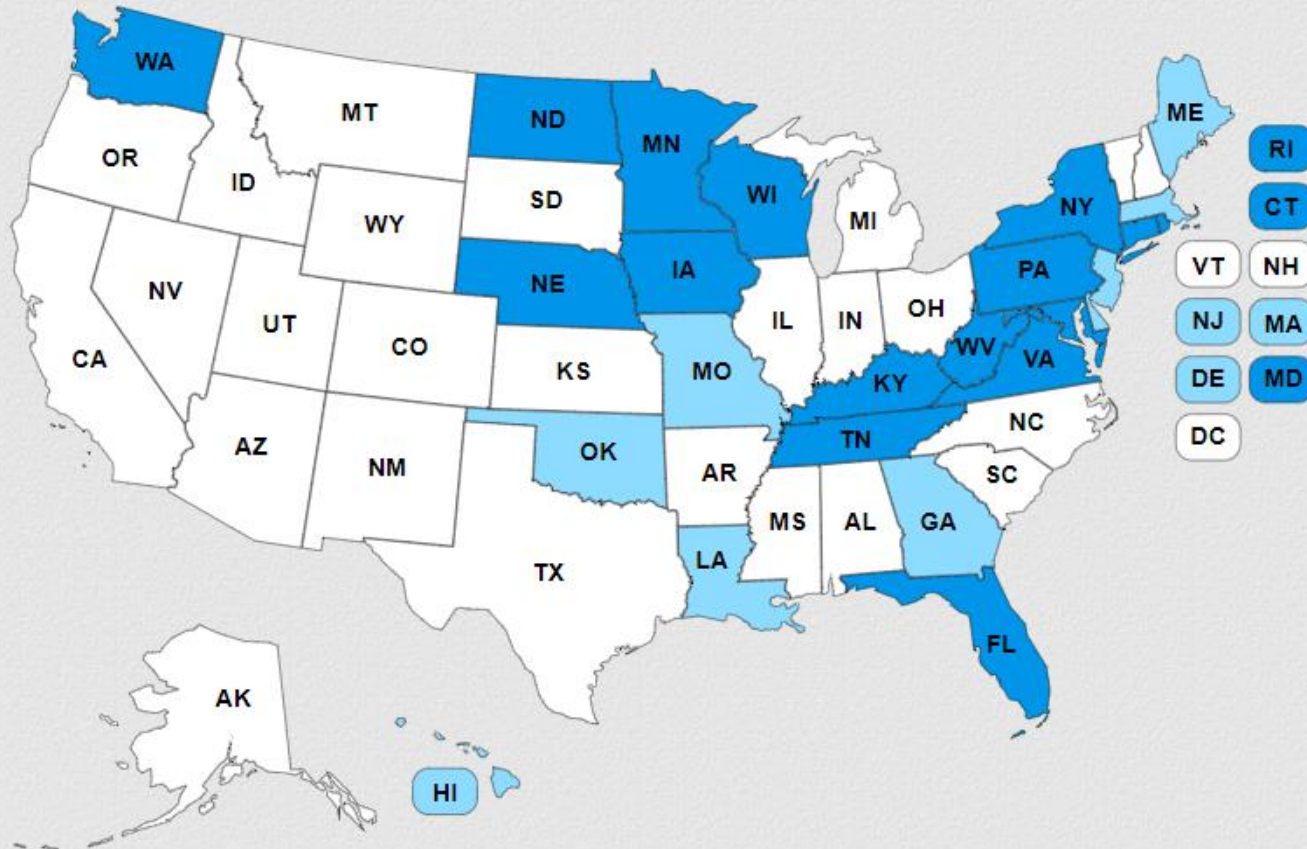


- 13 States Using M332
 - CT, FL, IA, MD, MN, NE, ND, NY, RI, VA, WA, WI, WV
- 15 States Using M332 for PMB only.
 - DE, GA, KY, LA, MA, ME, MO, NH, NJ, NV, OK, PA, SC, TN, VT
- 3 States Using M320 with M332 % recovery as a Plus test.
 - AL, SD, TX
- 19 States Using M320 and other Plus tests.
 - AK, AR, AZ, CA, CO, HI, ID, IL, IN, KS, MI, MS, MT, NC, NM, OH, OR, UT, WY

A Decade of MSCR Implementation

Current Status of MSCR Implementation in US

All State Specification Summaries are in Adobe PDF format



☐ M320 Specifications

- Standard Specification for Performance-Graded Asphalt Binder
- Includes States still using M320
- Includes States that use MSCR Recovery only as a PG-Plus test

☒ M320 / M332 Specifications

- States that specify M332 for some grades and M320 for other grades
- Includes States that allow a substitution of M332 for M320 grades

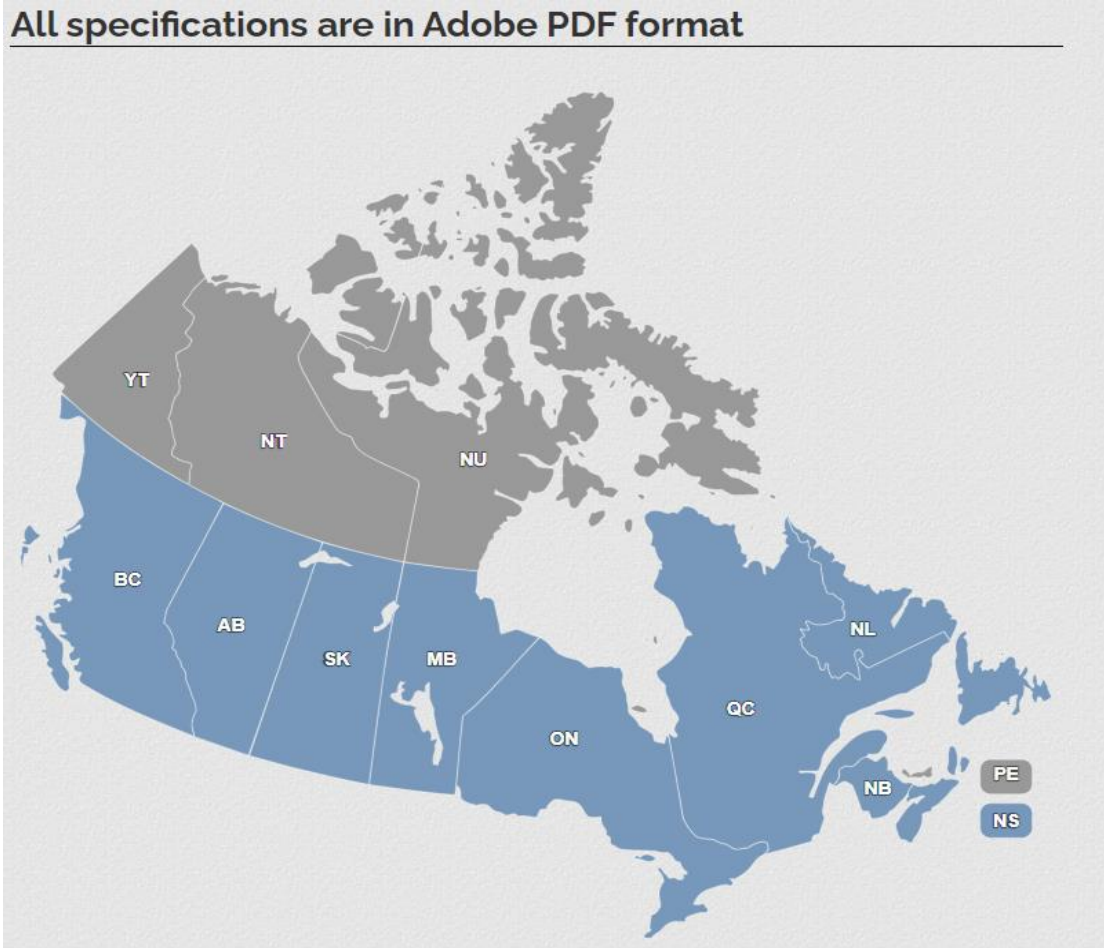
☒ M332 Specifications

- Standard Specification for Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) test
- Includes States that have adopted M332 for all grades
- Includes States that have adopted M332 for all grades, but retain the M320 nomenclature

A Decade of MSCR Implementation

Current Status of MSCR Implementation in Canada

All specifications are in Adobe PDF format



- AASHTO M 320
 - Alberta
 - New Brunswick
 - Nova Scotia
 - New Foundland/Labrador
- AASHTO M 320 with MSCR %Recovery
 - British Columbia
 - Manitoba
 - Ontario
- AASHTO M 332
 - Quebec

- United States
 - 25 of 50 states have implemented MSCR for all grades or some grades
 - A number of states use AASHTO M320 but also use MSCR %Recovery
 - Many DOTs have been doing M332 (MSCR) testing to gain knowledge
- Canada
 - 1 province has adopted MSCR (AASHTO M332)
 - 3 provinces use M320 but also use MSCR %Recovery

- Why Use the MSCR Test and Spec?
 - Non-recoverable creep compliance (J_{nr}) is better correlated with pavement rutting than $G^*/\sin \delta$
 - The high temperature parameter is truer to the intent of the PG specification, that it be blind to method of modification

- Why Use the MSCR Test and Spec?
 - MSCR Recovery can be used to identify elastomeric modification, thereby eliminating the need for many PG-Plus tests like Elastic Recovery
 - Much quicker test
 - Not directly tied to performance

Thanks!

GLOBAL MEMBERS



REGULAR MEMBERS



ASSOCIATE MEMBERS



CANADIAN MEMBERS



INTERNATIONAL MEMBERS



COMMERCIAL MEMBERS



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LOW VOLUME ROADS - BALANCING LIMITED FUNDING WITH PAVEMENT REHABILITATION NEEDS

David Jones, PhD

University of California Pavement Research Center, Davis, California

**61st Annual Idaho Asphalt Conference
Moscow ID, October 28, 2021**



1



2

Overview

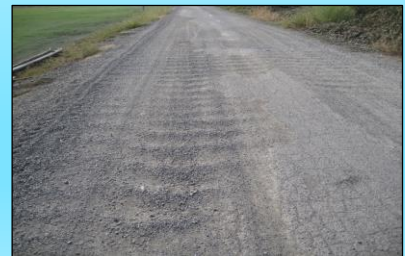
- Introduction
- Road investigation
- Improvement strategies
- Conclusions



3

Introduction

- Defining “low-volume”
- The US road network (*2019 FHWA Highway Stats, excluding privately owned*):
 - 4.125 million miles
 - 3.407 million miles categorized as minor arterial, minor collector, or local
 - i.e., lower volume roads
 - 1.219 million miles are unpaved
 - Unpaved road network is growing due to “unpaving”, both intentional and passive



4

Introduction

- Problems with managing low volume roads
 - Money, money, money
 - Spending priorities based on traffic, not on all the strategic values (food, raw materials, energy)
 - Expertise, skills, and risk of innovation
 - Understanding evolution of the road
 - Inappropriate strategy choices
 - Lack of maintenance (worst-first funding model)
 - Inappropriate specifications and poor enforcement of them
- This all equals more miles than money to maintain them
- So what can we do?



5

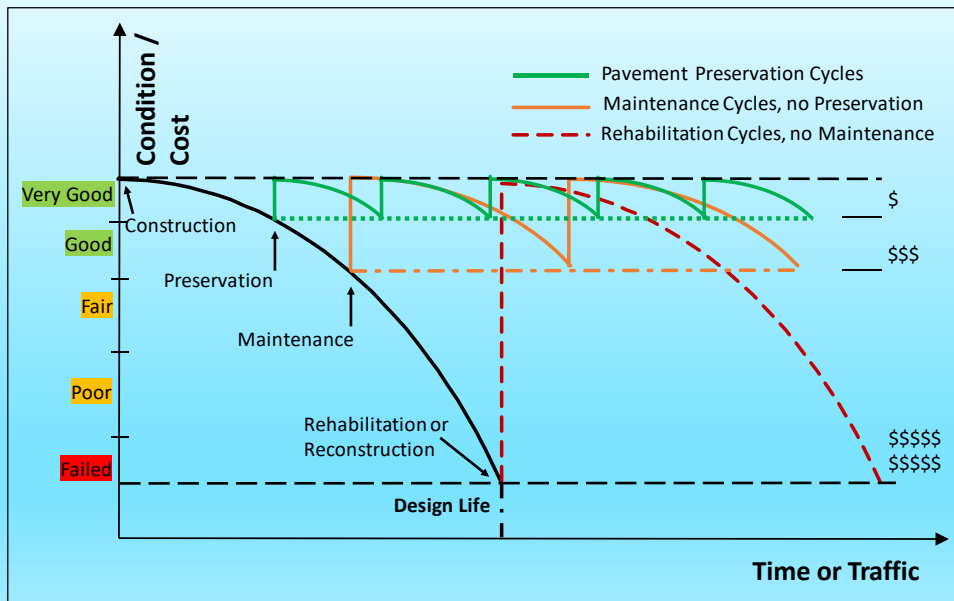
Introduction

- Start with answering the following:
 1. What have we got?
 - Site investigation
 - Budget
 2. What do we want?
 - Expectations
 3. What can we afford?
 - Reality
 4. How can we innovate to stretch budgets?
- Choose a strategy that balances rehabilitation/reconstruction with preservation/maintenance
 - Keep good roads good, invest savings in new improvements
 - Worst-first approach is not a good strategy!



6

Introduction



7

10 Steps to Making a Good LVR Decision

1. Investigate
2. Analyze
3. Identify sustainable options
4. Ask others
5. Narrow the choices
6. Review pros and cons of each
7. Choose an option
8. Prepare to defend the choice
9. Do it
10. Preserve/maintain it



8

Overview

- Introduction
- Road investigation
- Improvement strategies
- Conclusions



9

Investigation

- Key part of the process. Don't skip it!
- Provides information on the existing pavement structure and why it looks like it does
- Findings are used to determine an appropriate strategy
- Costs are negligible
- It's not rocket science, just rocks, a bit of science, and lot's of common sense!



10

Investigation Steps

- Separate training presentation module!
- Desktop study
 - Review all available information
- Walk the road
 - Cause of distresses, drainage, safety issues
- DCP testing
 - Existing structure and subgrade conditions
- Material sampling
 - What can be reused, what is needed
- Laboratory testing
 - Gradation and plasticity
- Develop options based on results



Courtesy, K Skorseth

11

Overview

- Introduction
- Road investigation
- Improvement strategies
- Conclusions



12

Improvement Strategies

- Suggestions focus on constrained budgets for severely distressed roads
- Paved roads
 - Conventional overlay (often too late)
 - In-place recycling with no additive
 - In-place recycling with additive
 - Convert to engineered unpaved
- Unpaved roads
 - Upgrade to engineered unpaved
 - Weatherproof with surface treatment (chip seal, etc.)



13

Strategies for Low-Volume Paved Roads

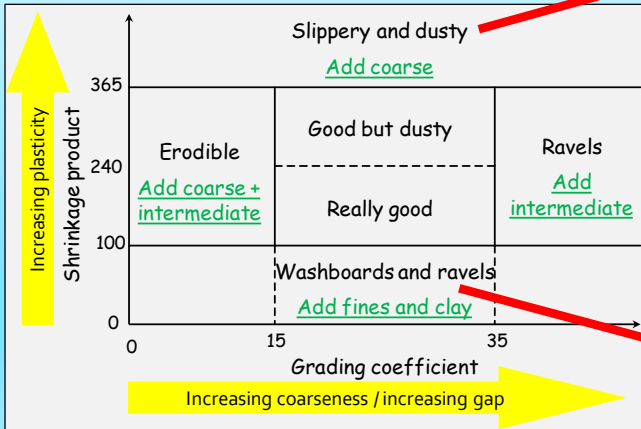
- Limited age-related distresses
 - Preservation/maintenance treatment (microsurfacing, chip seal, rubberized chip seal, cape seal, overlay, geosynthetic + surface treatment, etc.)
 - Fix causes of problems (often water)
- AADT < 150 with severe distresses
 - Consider converting/upgrading to an engineered unpaved road
 - Performance spec plus chemical treatment (balanced mix design)
 - Can be surfaced when funds permit
 - Guidance available



14

Performance Spec (Balanced Mix Design)

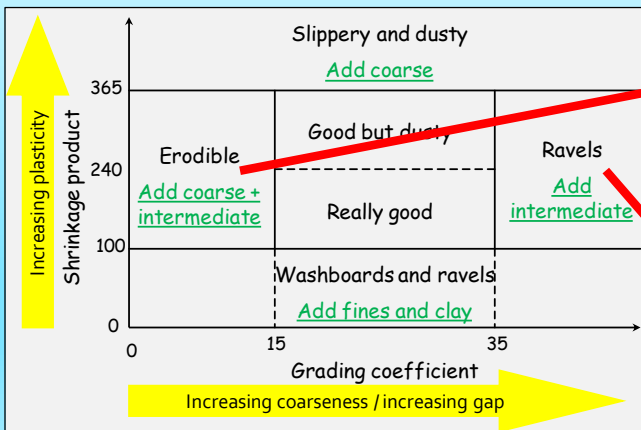
- Check against specification and/or use performance prediction chart



15

Performance Spec (Balanced Mix Design)

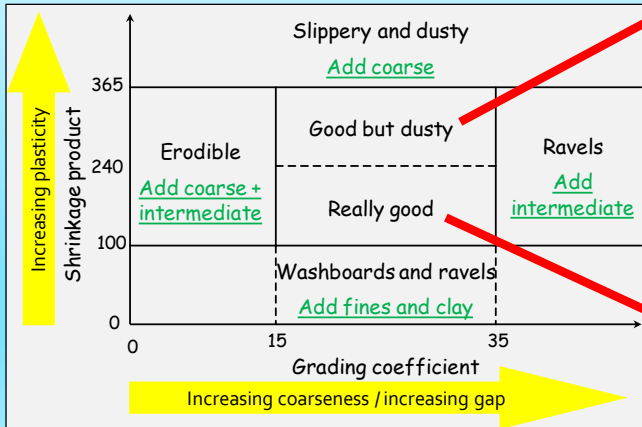
- Check against specification and/or use performance prediction chart



16

Performance Spec (Balanced Mix Design)

- Check against specification and/or use performance prediction chart



17

www.ucprc.ucdavis.edu/dustcontrol

UNPAVED ROAD CHEMICAL TREATMENT SELECTION TOOL

UCPRC City and County Pavement Improvement Center

Home Instructions Treatment Selection Results Interpretation About

WELCOME TO THE UCPRC'S UNPAVED ROAD CHEMICAL SELECTION TOOL SITE

There are millions of kilometers/miles of unpaved roads around the world managed by numerous authorities, land owners, and public and private organizations. Common to all of these roads are unacceptable levels of dust, poor riding quality and/or impassability in wet weather, and expensive maintenance and gravel replacement activities. Over the last 100+ years, a range of different chemical treatments have been developed to overcome these issues. Most of these are proprietary, which can complicate selection of an appropriate treatment for a specific set of conditions. There is also no single product that will solve all problems under all conditions.

A procedure has therefore been developed to guide practitioners in the selection of an appropriate treatment. This procedure, based on the 1999 US Forest Service Guide (*Dust Palliative Selection and Application Guide*), and updated with new research and experience, factors traffic, climate, material properties, and road geometry into the most appropriate treatment selections for a given set of input values. The procedure is based on the philosophy of using chemical treatments to keep good roads in good condition, rather than attempting to use chemical treatments to "fix" bad roads. This unpaved road chemical treatment selection tool and information related to it is fully described in the UCPRC guideline entitled "Guidelines for the Selection, Specification and Application of Chemical Dust Control and Stabilization Treatments on Unpaved Roads." This web-based chemical treatment selection tool can be considered as a companion to the guideline.

Loss of fines (as dust) on an untreated road

The photo on the left shows loss of fines on an untreated road while the photo on the right shows the results of applying a fines preservation treatment.

Stable fines preservation on a treated road

Disclaimer

This unpaved road chemical treatment selection procedure has been developed to guide selection of an appropriate treatment. It is based on the experience of practitioners and documented field experiment results. It is a guide only and does not replace engineering practice and judgment. Before initiating a treatment program, users should check actual performance for their particular materials and conditions with appropriate laboratory performance tests and/or short field experiments and/or seek guidance from other experienced practitioners and treatment suppliers. The University of California does not endorse the use of any specific product for dust control and stabilization of unpaved roads. In no event shall the University of California be liable to any party for direct, indirect, special, incidental, or consequential damages, including lost profits, arising out of the use of this system, even if the University of California has been advised of the possibility of such damage. The University of California specifically disclaims any warranties, including, but not limited to, the implied warranties of merchantability, fitness for a particular purpose and noninfringement.

Accept

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Lakes Highway District, ID

- 2012 FHWA Scan Tour
- Systematic upgrade of network over a period of years
 - Preserve existing, use savings to upgrade next on the list
- Costs (2012)
 - Untreated average maintenance cost
 - Annual \$12,500/mile
 - Treated average maintenance cost
 - Year 1 - \$6,400/mile
 - Subsequent years - \$4,650/mile
 - Rate of gravel loss reduced by >50%



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Strategies for Low-Volume Paved Roads

- AADT > 150 with severe distresses, limited trucks (<100k ESALs)
 - Usually too late for overlay, and reconstruction cost is prohibitive
 - Consider full-depth, in-place recycling (FDR) with no additive
 - Select recycle depth to achieve blend of existing materials to achieve good gradation
 - Add supplemental RAP if needed
 - Cover with appropriate surface treatment
 - Guidance is available



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FDR-N (pulverization)



21

FDR-N (pulverization)



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Strategies for Low-Volume Paved Roads

- AADT > 150 with severe distresses, trucks (>100k ESALs)
 - Consider full-depth, in-place recycling with appropriate additive
 - Select recycle depth to achieve blend of existing materials to achieve good gradation (10 to 12 in.)
 - Add supplemental RAP if needed to increase structural capacity and/or improve drainage
 - Select additive based on material properties
 - Engineered materials (RAP and AB): emulsified or foamed asphalt
 - Marginal materials: cementitious
 - Cover with appropriate surface treatment or thin overlay



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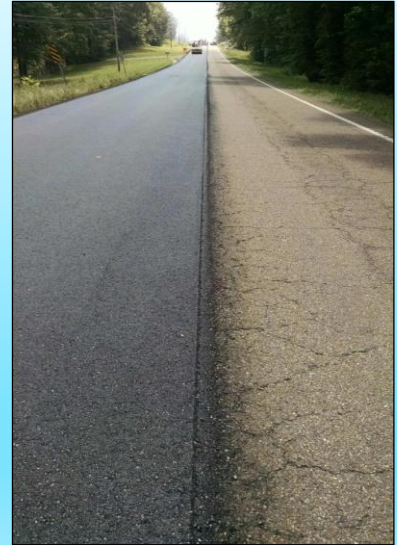
FDR-FA



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Key Recycling Construction Steps

- Use an experienced contractor with agency oversight
- Know what you are recycling
 - LVRs are inherently variable
- Monitor all activities including recycled material
- Compact to refusal density (breakover)
- Clear/improve drains
- Fog seal prior to trafficking
- Surface as soon as feasible, with a tack coat
- Enforce QC/QA of surface placement
 - For every 1% air-voids above spec = 1 year less fatigue cracking life
- Preserve/maintain



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Do Recycled Pavements Last?



- FDR-FA constructed in 2002
 - 10 in. FDR-FA with 2.5 in. overlay
 - 6,000 AADT, 20% trucks
- Designed as 5-yr maintenance intervention
- RHMA-O in 2014
- No distress in 2020
- So yes!

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Do Recycled Pavements Last?



- FDR-FA tests
 - 10 in. FDR-FA with 2 in. overlay
 - Trafficked with HVS 24/7
 - Controlled temperature and water addition
- 34 million ESALs, 50% applied at 2.5x legal axle load limit
- No cracks, 0.25 in. rut
- So, yes!

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Overview

- Introduction
- Road investigation
- Improvement strategies
- Conclusions



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Conclusions

- Low-volume roads are managed with very constrained budgets
- There are many proven innovative ways to do a good job with less funds
- What ever you think of, someone has probably tried it already. Find out
- Preserve/maintain what you have; use savings to rehabilitate next priority
 - Worst-first is not an effective use of funds
- Recycling existing materials in-place is often the most cost-effective and sustainable option



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Why Recycle?

- ✓ Proven technology backed up by research
- ✓ More sustainable if designed & built correctly
- ✓ Uses all existing, paid for materials
- ✓ Requires limited new materials
- ✓ Minimizes trucking operations
- ✓ Shorter construction time, less traffic disruption
- ✓ Cost effective / lower life-cycle cost
- ✓ Removes distresses instead of covering them
- ✓ Strategies available for most pavement problems
- ✓ Selected strategies enhance structural capacity
- ✓ Extended pavement life
- ✓ Recycled roads can be recycled again
- ✓ Specifications are in place in most states
- ✓ Experienced contractors in most states

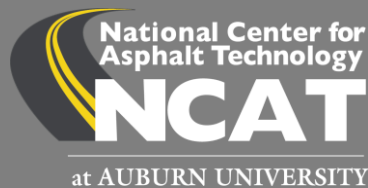


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djjones@ucdavis.edu



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HMA Preservation: Seal Coat and Micro Surfacing

Adriana Vargas, PhD

1

Background

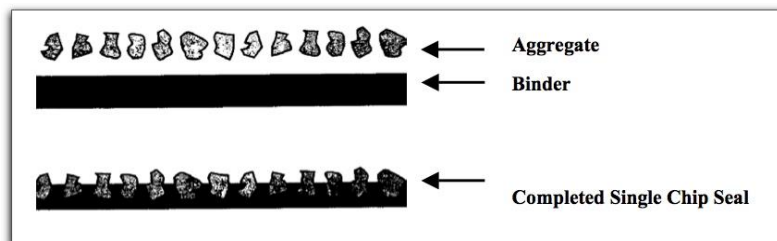
- Seal coats and micro surfaces are some of the most popular treatments
- Relatively inexpensive
- Can be very effective
- Cost-effectiveness is maximized with proper treatment selection



2

Seal Coat

- Application of asphalt binder (hot or emulsion) immediately followed by application of an aggregate
- Seal is then rolled to sit the aggregate in the binder
- “Chip seal”



Caltrans, 2008



3

Seal Coat



4

Seal Coat



- Cracking
- Weathering
- Raveling
- Friction



- Loose chips
- Noise
- Weather limitations



5

Micro Surfacing

- Mixture of polymer modified emulsified asphalt, dense-graded crushed fine aggregate, mineral filler, break control additives and water
- High performance enhanced slurry seal
- Allows for quick return to traffic (~ 1 hour)



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Micro Surfacing



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Micro Surfacing



- Weathering
- Raveling
- Friction
- Rutting
- Irregular profile



- Special equipment
- Cost



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What to Expect

- SHRP 2 Report S2-R26-RR-2 (2011)

Treatment	Expected Performance	
	Treatment Life (yr)	Pavement Life Extension (yr)
Microsurfacing		
Single course	3–6	3–5
Double course	4–7	4–6
Chip seal		
Single course	3–7	5–6
Double course	5–10	8–10



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LESSONS LEARNED FROM NCAT-MnROAD RESEARCH



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TPF-5(375)



TRANSPORTATION POOLED FUND PROGRAM

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[Home](#) > [Study Detail View](#)

Study Detail View

National Partnership to Determine the Life Extending Benefit Curves of Pavement Preservation Techniques (MnROAD/NCAT Joint Study – Phase II)

General Information

Study Number: TPF-5(375) [View Commitment Details](#)

Status: Cleared by FHWA

Contract/Other Number:

Lead Agency: Minnesota Department of Transportation

Est. Completion Date: Dec 30, 2023

Last Updated: Jan 31, 2019

Contract Start Date: Jan 1, 2019

Contract End Date:

Solicitation Number: 1461

Partners: AL, AR, CO, FHWA, FP2, GDOT, IL, KS, KY, MDOT SHA, MI, MN, MO, MS, NC, NY, OK, PA, SC, TN, TX, WI, WV

Related Study Number(s): 1459 - ACCELERATED PERFORMANCE TESTING ON THE 2018

Contact Information:

Lead Agency Contact(s):

Ben Worel
ben.worel@state.mn.us
Phone: 7633812130

FHWA Technical Liaison(s):

Jack Jernigan
Jack.Jernigan@dot.gov
Phone: 202-493-3363

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Sponsors



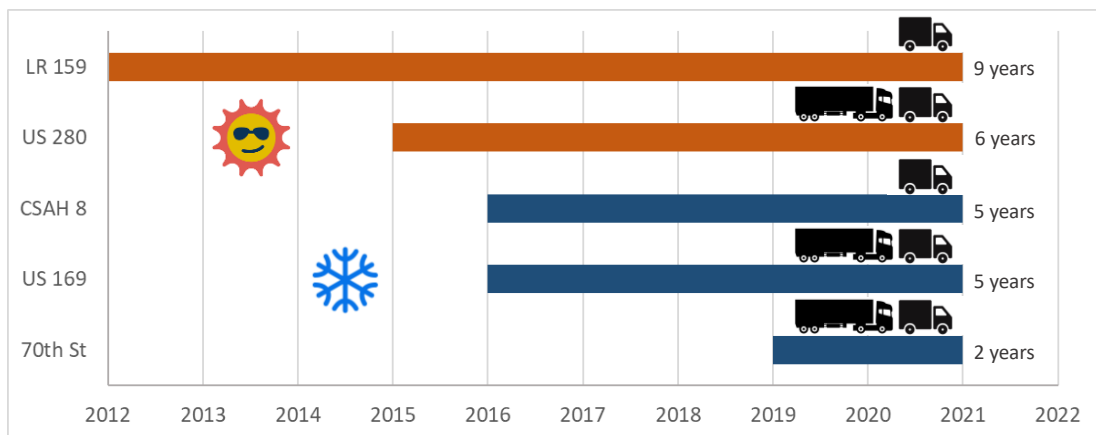
12

PG Study Sections



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Time in Service



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PG Study Sections

CHIP SEALS

- Single layer
- Double layer
- Triple layer
- Single layers with crack sealing
- Fibermat
- Scrub seals*

MICRO SURFACES

- Single layer
- Double layer
- Single layers with crack sealing
- Fibers
- HiMA



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Fibermat Chip Seal



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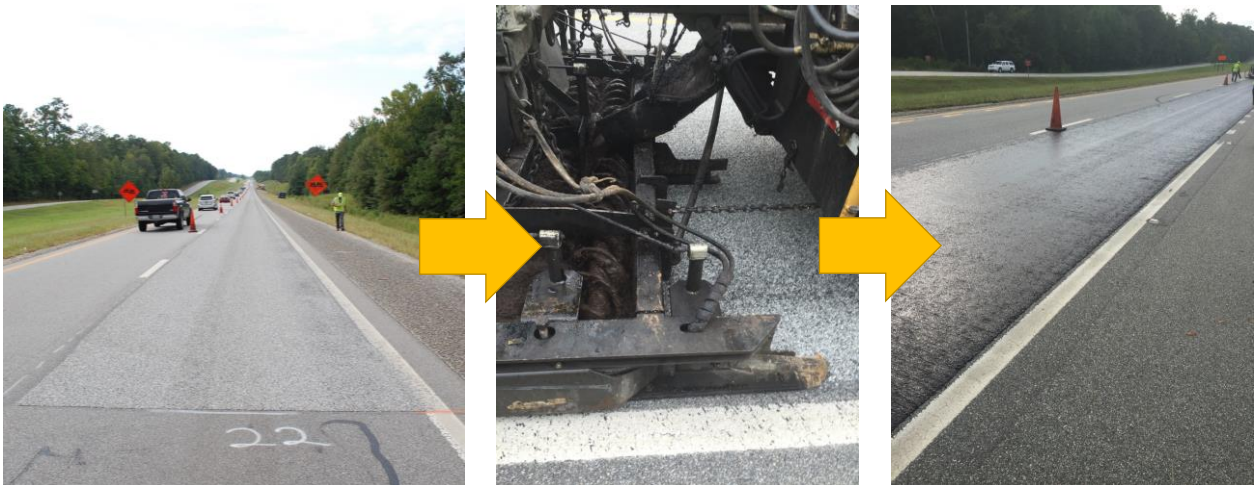
Scrub Seal



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Cape Seals

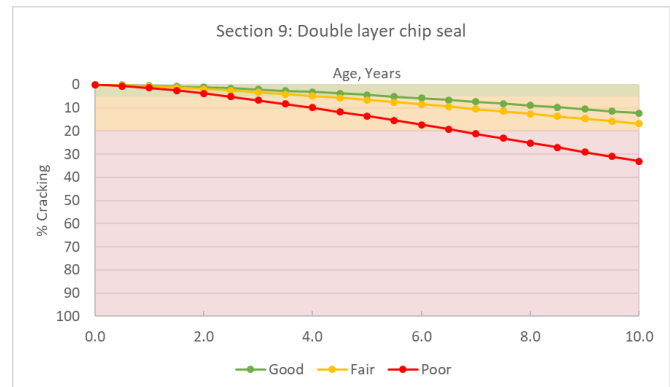


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What We've Learned

- Target GOOD pavements
- There's always *some* benefit even if pavement is in poor condition
 - Not cost-effective



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What We've Learned

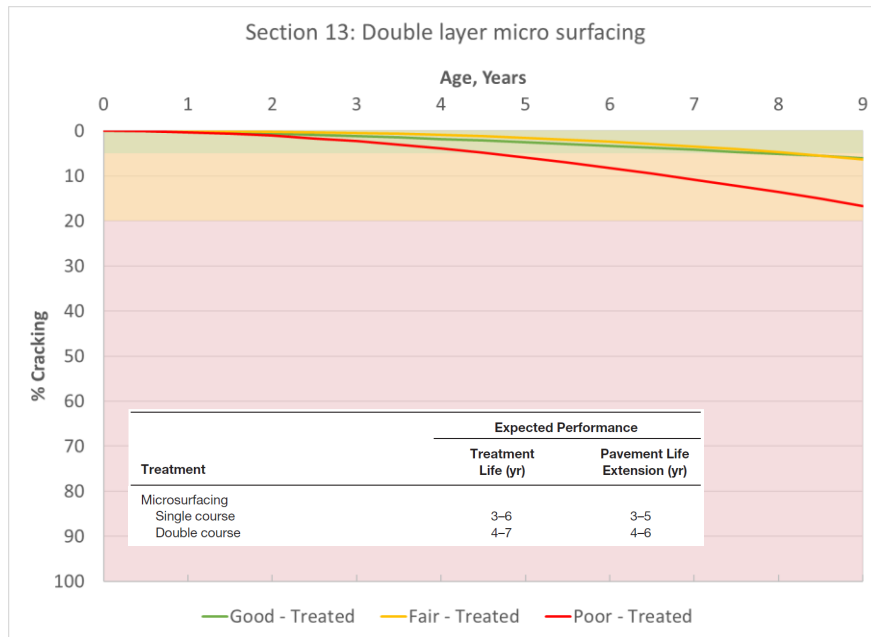
- Life extension may be higher than typically reported
 - Good materials
 - Good designs
 - Good treatment selection
 - Good construction



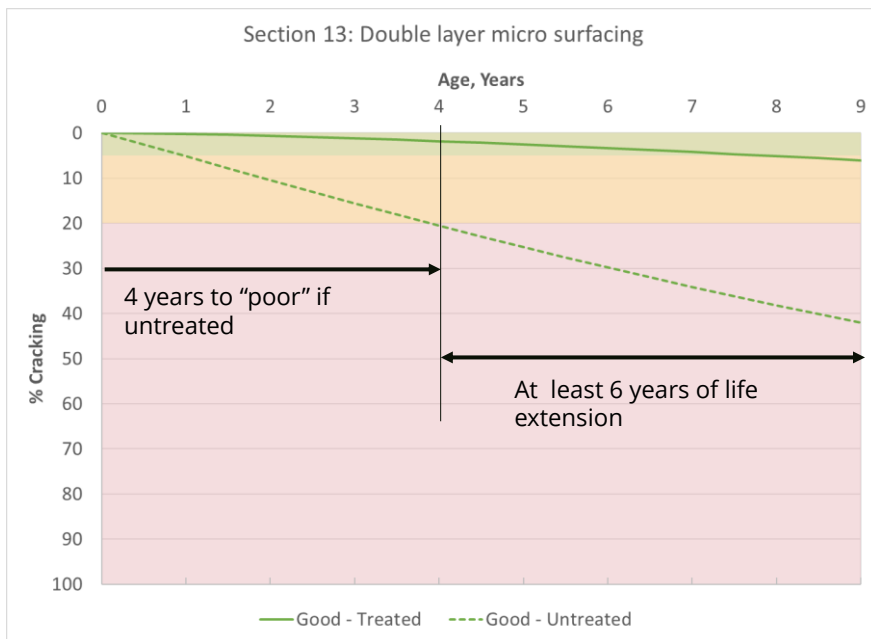
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22



At year 9,
treated
pavement is
barely
transitioning to
"fair" condition

What We've Learned

- The more you do, the more you get
 - Multiple layers
 - Crack sealing
 - Treatment combinations (Cape seals)



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UNTREATED



SINGLE LAYER CHIP SEAL



SINGLE LAYER CHIP SEAL
+ CRACK SEAL



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SCRUB SEAL



FIBERMAT CHIP SEAL

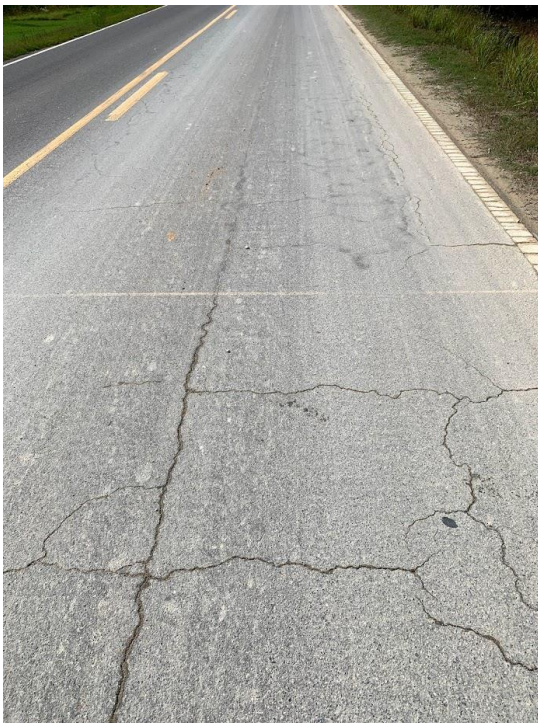


DOUBLE LAYER CHIP SEAL



TRIPLE LAYER CHIP SEAL

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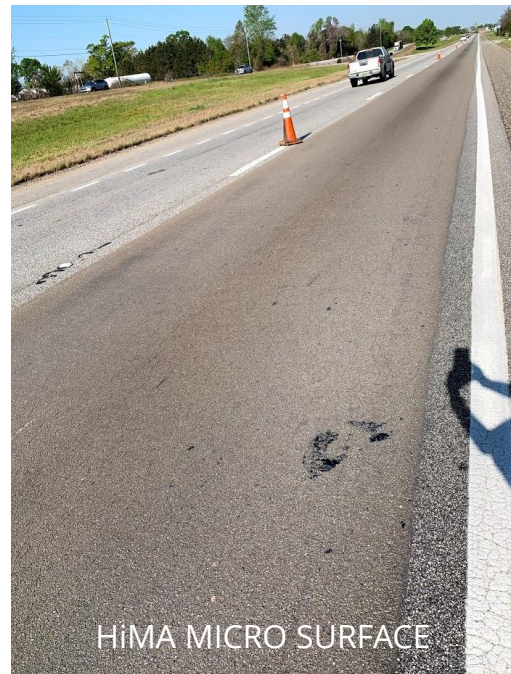
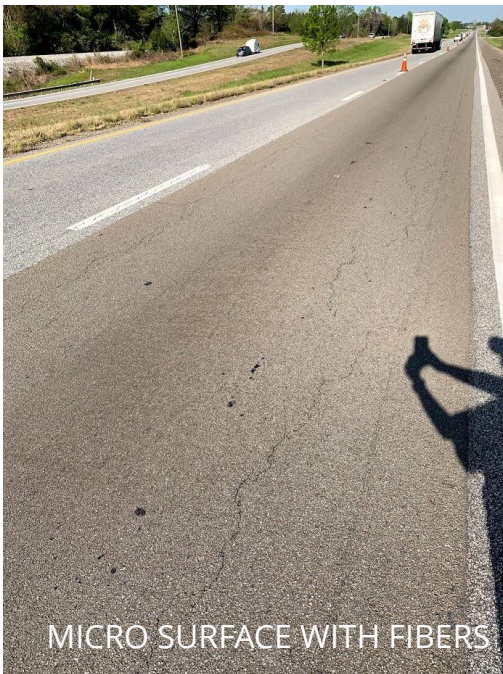
SINGLE MICRO SURFACE
WITH CRACK SEALING

SINGLE MICRO SURFACE

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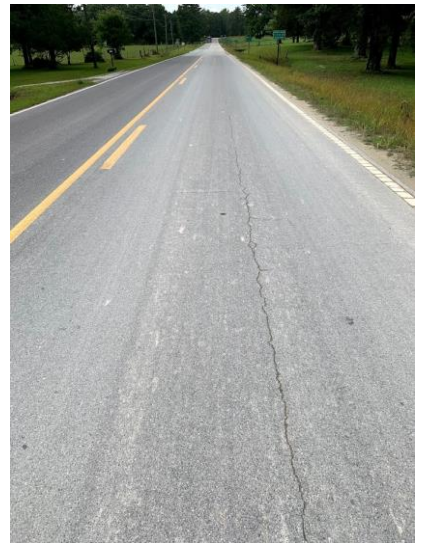
CAPE SEAL



SCRUB CAPE SEAL



FIBERMAT CAPE SEAL



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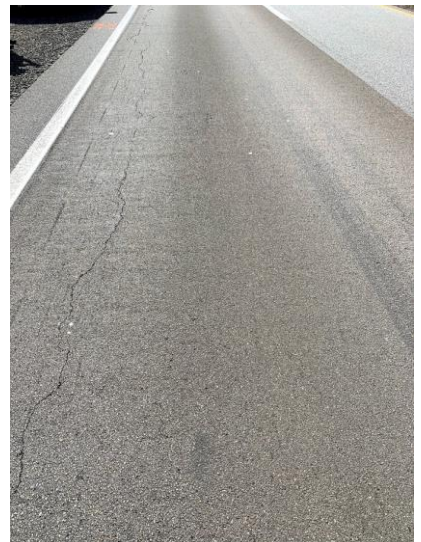
CAPE SEAL



SCRUB CAPE SEAL



FIBERMAT CAPE SEAL



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What We've Learned

- Treatments can work under different conditions
 - Don't immediately rule out based on traffic or climate

BUT...

- Be cautious



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SINGLE CHIP SEALS

Observations:

- Good to fair cracking performance
- Roughness in Northern sections is higher, related to thermal cracking
- Chip loss in Northern sections as a result of snow plowing

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FIBERMAT CHIP SEALS

Observations:

- Better cracking performance compared to single chip seals
- Better chip retention

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CHIP SEAL



FIBERMAT CHIP SEAL



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CHIP SEAL



FIBERMAT CHIP SEAL



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LOW TRAFFIC



HIGH TRAFFIC

**TRIPLE CHIP SEALS****Observations:**

- Good cracking performance
- Bleeding, especially in high traffic sections – may require action if friction is affected

NORTH

SOUTH



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What We've Learned

- Cracking reduction is most notable benefit
 - Easy to see
 - It is not the only parameter
- What are you targeting?



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Time to 20% Cracking – Lee Road 159

Treatment	Poor	Fair	Good
Single chip seal	4.4	7.7	7.7
Single chip seal + crack seal	7.3	7.3	8.6
Double chip seal	6.7	9+	9+
Triple chip seal	9+	9+	9+
Fibermat chip seal	7.0	8.7	9+
Scrub seal	9+	9+	9+



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% Crack Reduction at Year 9 – Lee Road 159

Treatment	Poor	Fair	Good
Single chip seal	14	20	19
Single chip seal + crack seal	20	31	17
Double chip seal	38	46	35
Triple chip seal	56	54	39
Fibermat chip seal	41	39	30
Scrub seal	55	46	32



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Time to 20% Cracking – Lee Road 159

Treatment	Poor	Fair	Good
Single micro surface	1.7	4.5	5.0
Single micro + crack seal	4.6	6.1	5.1
Double micro surface	9+	9+	9+
Cape seal	9+	9+	9+
Fibermat cape seal	9+	9+	9+
Scrub cape seal	9+	9+	9+



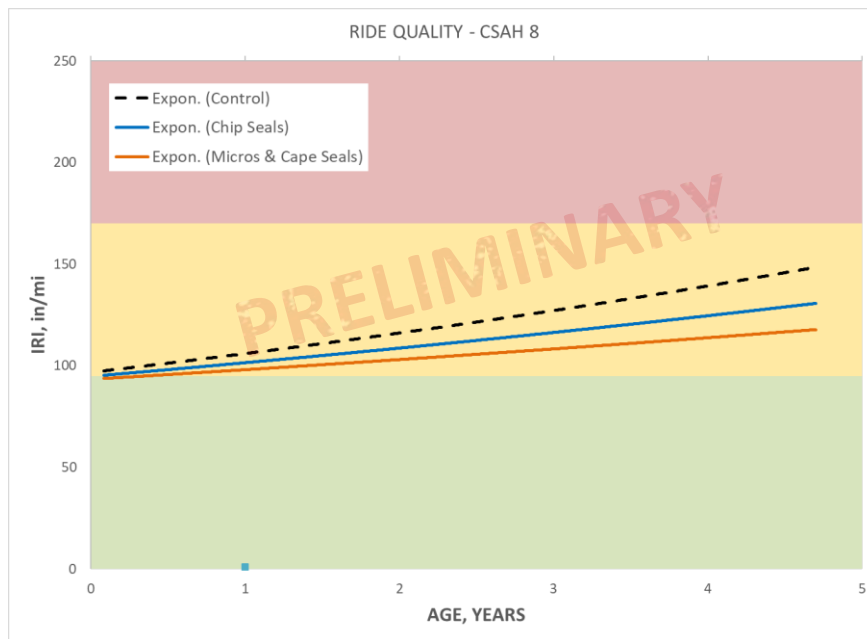
40

% Crack Reduction at Year 9 – Lee Road 159

Treatment	Poor	Fair	Good
Single micro surface	6	18	11
Single micro + crack seal	31	27	2
Double micro surface	59	55	40
Cape seal	61	56	40
Fibermat cape seal	72	64	43
Scrub cape seal	68	56	40



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Summary

- Chip seals and micro surfacing extend pavement life
 - Combinations = added benefits
- Some treatments within same category have similar performance
 - Unit costs for each agency will determine cost-effectiveness
- No major issues in any location
 - Adjust to your particular conditions



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Summary

- More information: www.ncat.us

The screenshot shows the NCAT website with the following elements:

- Header:** NCAT logo (National Center for Asphalt Technology at AUBURN UNIVERSITY) on the left. Navigation links: About NCAT, Test Track, Pavement Preservation (highlighted with a yellow circle), Education & Training, Our Research, and search/social media icons.
- Test Track Section:** A sidebar on the left lists: Pavement Preservation (highlighted), Construction Data, Observed Performance, Sponsors (2012-2020), and Pavement Preservation Group Study Resources.
- Main Content Area:**

Pavement Preservation

The [Moving Ahead for Progress in the 21st Century Act \(MAP-21\)](#) defines pavement preservation as programs and activities employing a network level, long-term strategy that enhances pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety, and meet road user expectations.

When the right treatment is applied to the right road at the right time, roads can be kept in good condition instead of performing costly rehabilitation and reconstruction alternatives later in the pavement's life when the structure has deteriorated.

Pavement Preservation Group Study

The pavement preservation group study is quantifying the life-extending and condition-improving benefits of different pavement preservation treatments and treatment combinations on low-volume and high-volume roadways in both northern and southern climates. By determining the field performance of treatments applied at various stages of pavement life and decay, historically broad performance expectations for various preservation options will be discretely quantified to allow agencies to make objective decisions regarding treatment selection. A second focus of the study is to develop specifications and recommended guidelines for quality assurance testing and inspection of pavement preservation treatments.

Southern Test Locations

Below the text are three small images showing different roadways and landscapes.

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Thank you!

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