Chip Seals

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Lunch and Learn
Value Management Program, NCDOT
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Outline

- Chip Seal Basics
- Test Specimen Fabrication Methods
- Performance Test Methods
- Desirable Aggregate Characteristics
- Desirable Emulsion Properties
- Performance-Engineered Mix Design
- Optimal Rolling Protocols
- Construction Variability and PRS
- Key Implementation Points

Chip Seals

Definition

- A single layer of asphalt binder (hot applied or emulsion) that is covered by embedded aggregate (one stone thick)
- Also commonly referred to as “seal coat”

Benefits

- Seals the underlying pavement against water intrusion
- Enhance or restore skid resistance
- Enrich the pavement surface to prevent the distresses caused by oxidation.
- Can effectively seal fine cracks unless the cracks are indications of structural distresses
- Low cost
- Fast construction

Chip Seal Power in NC

	2017		2022	
	Chip Seal	**HMA**	**Chip Seal**	**HMA**
Miles Paved	4,479 (50.0%)	4,483 (50.0%)	1,665 (39.0%)	2,622 (61.0%)
Dollars Spent	$61.9 million (16.3%)	$317 million (83.7%)	$25.9 million (10.1%)	$230 million (89.9%)
Dollar per Mile	$13,825	$70,738	$15,563	$87,764

Critical Distresses

- Raveling
  - Loss of aggregate
  - Windshield damage
  - Safety concern

- Bleeding
  - Over application of emulsion
  - Aggregate loss or embedment
  - Safety concern

Chip Seal Types

- Single Seal: Single layer of uniformly graded aggregate on a single layer of binder
- Double Seal: Two consecutive applications of both binder and aggregate
  - The aggregate in the second application is typically about half the nominal size of the first.
- Triple Seal: Three consecutive applications of both binder and aggregate
  - Choke stone is used as the aggregate in the final application.
  - Prevents aggregate particles from dislodging.

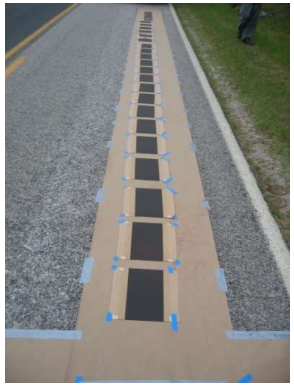
Solutions for Well-Performing Chip Seals

- Quality of materials, design application rates, and construction quality control are all important for well-performing chip seals!
- Need a comprehensive **system** to improve the quality of chip seals
  - Performance specifications for materials
  - Performance-engineered mix design
  - Performance-related specifications for construction quality assurance

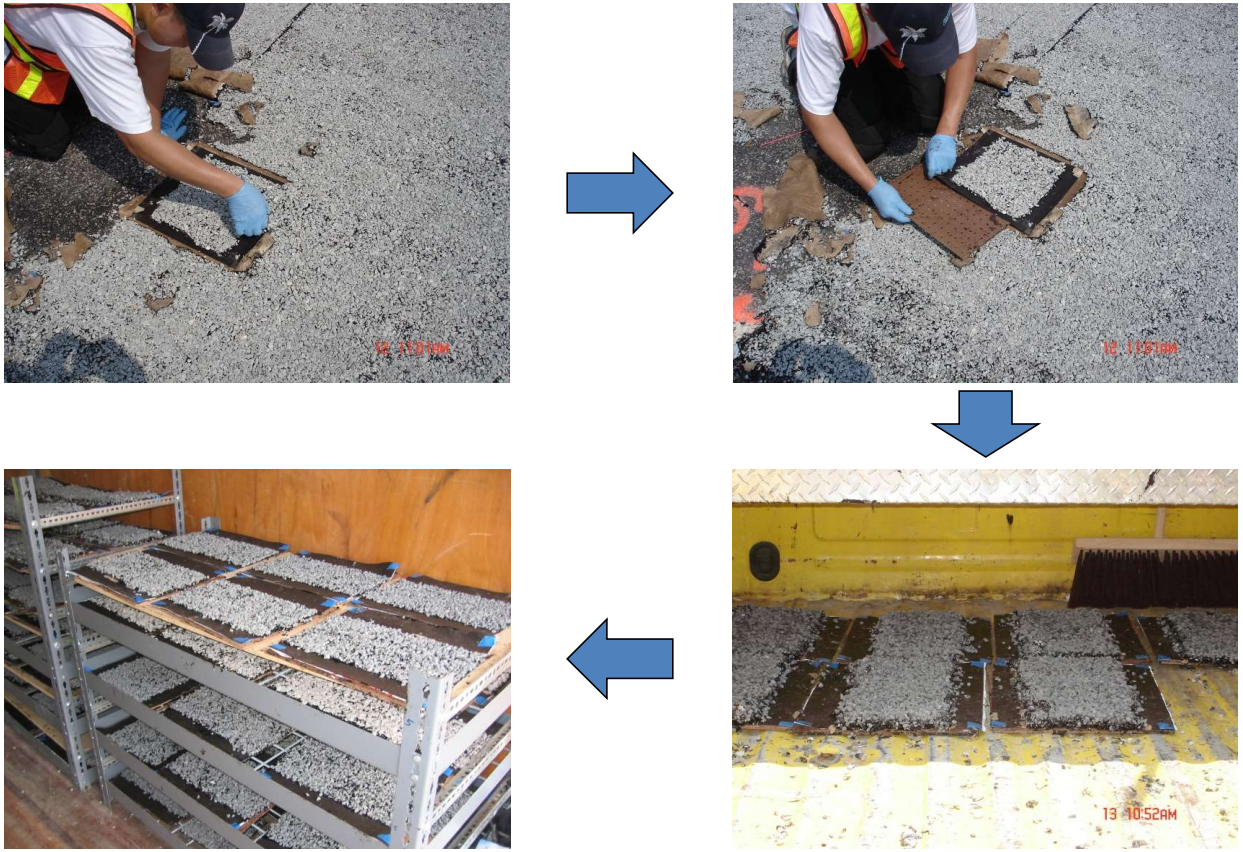
Chip Seal Specimen Fabrication Methods

Laboratory Fabrication Using ChipSS

Field Sampling Procedure

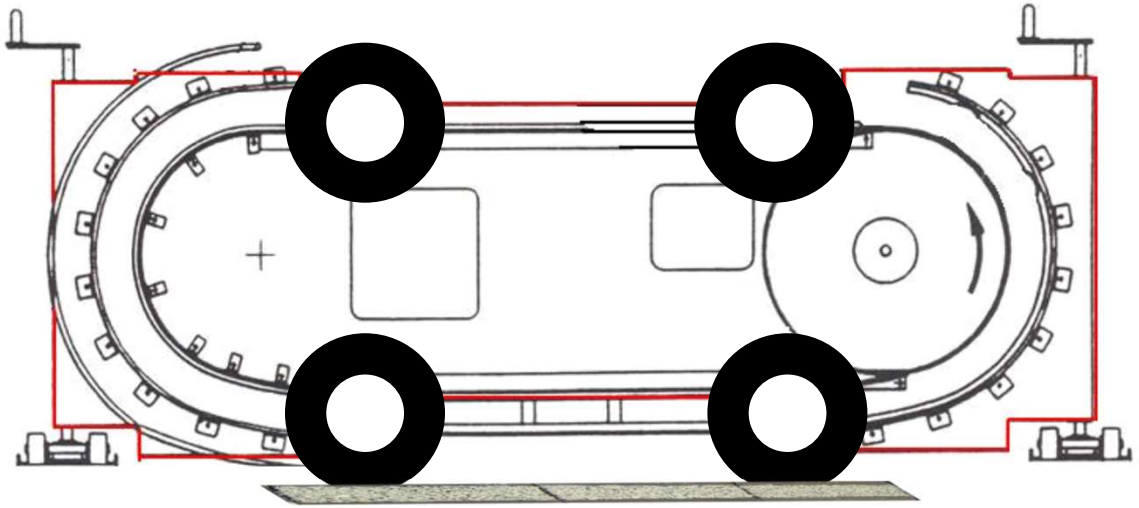


Gathering Samples and Delivery



Chip Seal Performance Test Methods

Third-Scale Model Mobile Loading Simulator (MMLS3)

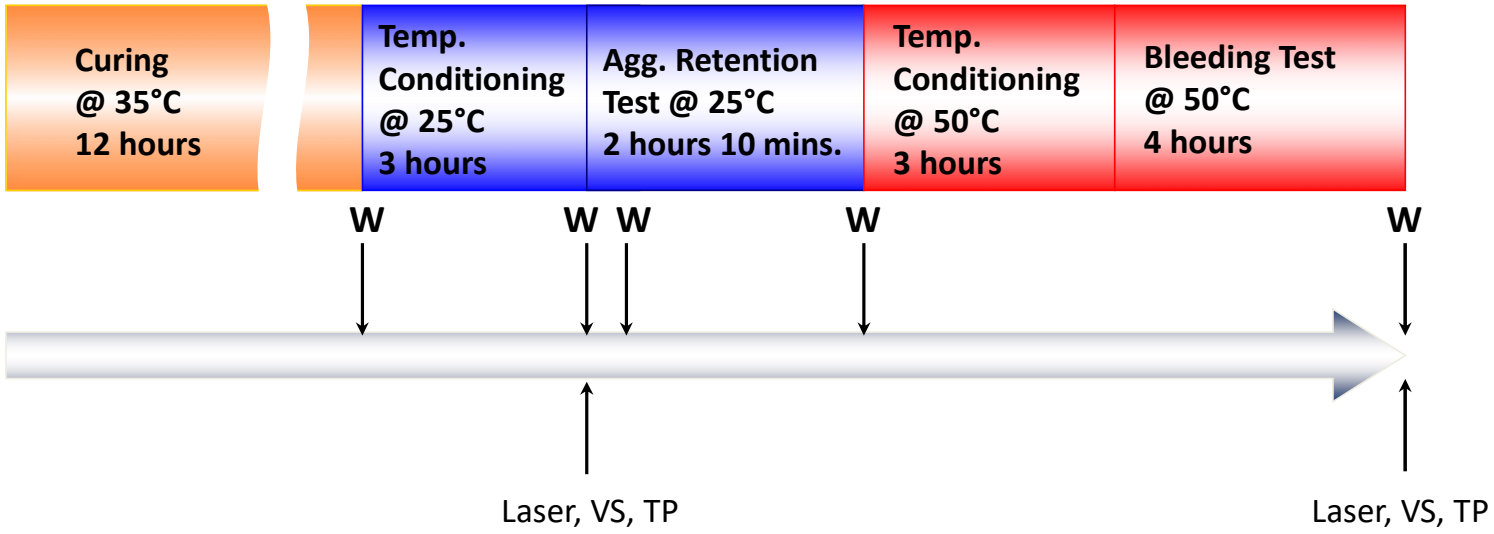


MMLS3 Chip Seal Test Preparation






MMLS3 Test Procedure

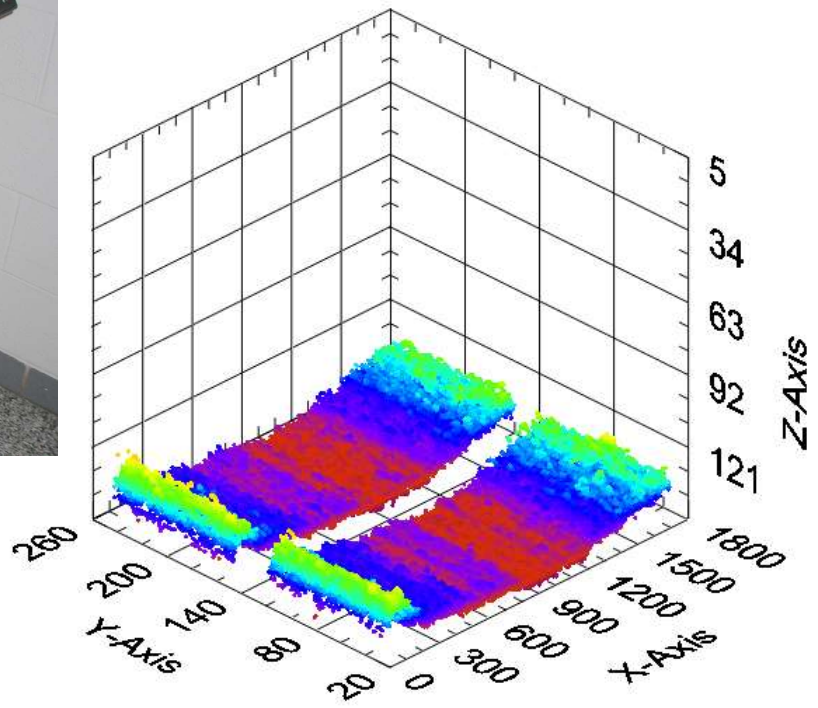


W: Measurement of the Specimen Weight
Laser: Laser Profiler Test
VS: Visual Survey
TP: Transverse Profiling

Sand Patch Test (ASTM E965)

- Spread a predetermined volume of sand into circle on pavement surface
  - Use area of circle and known volume of sand to determine mean texture depth

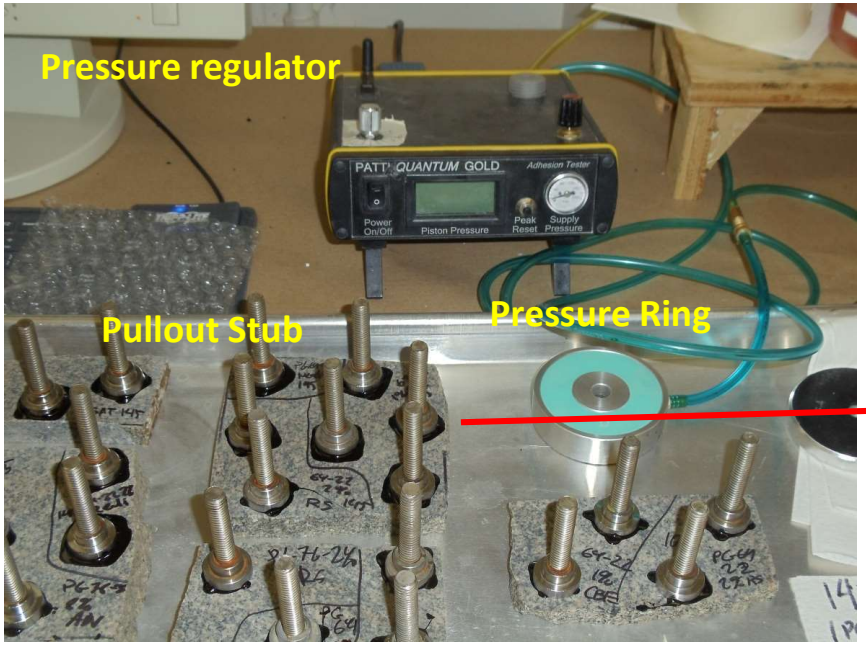
Laser Profiler

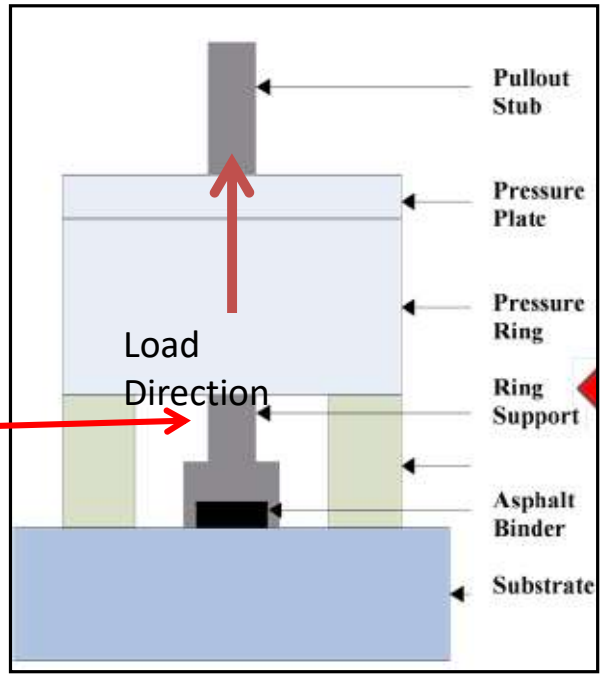


Vialit Test

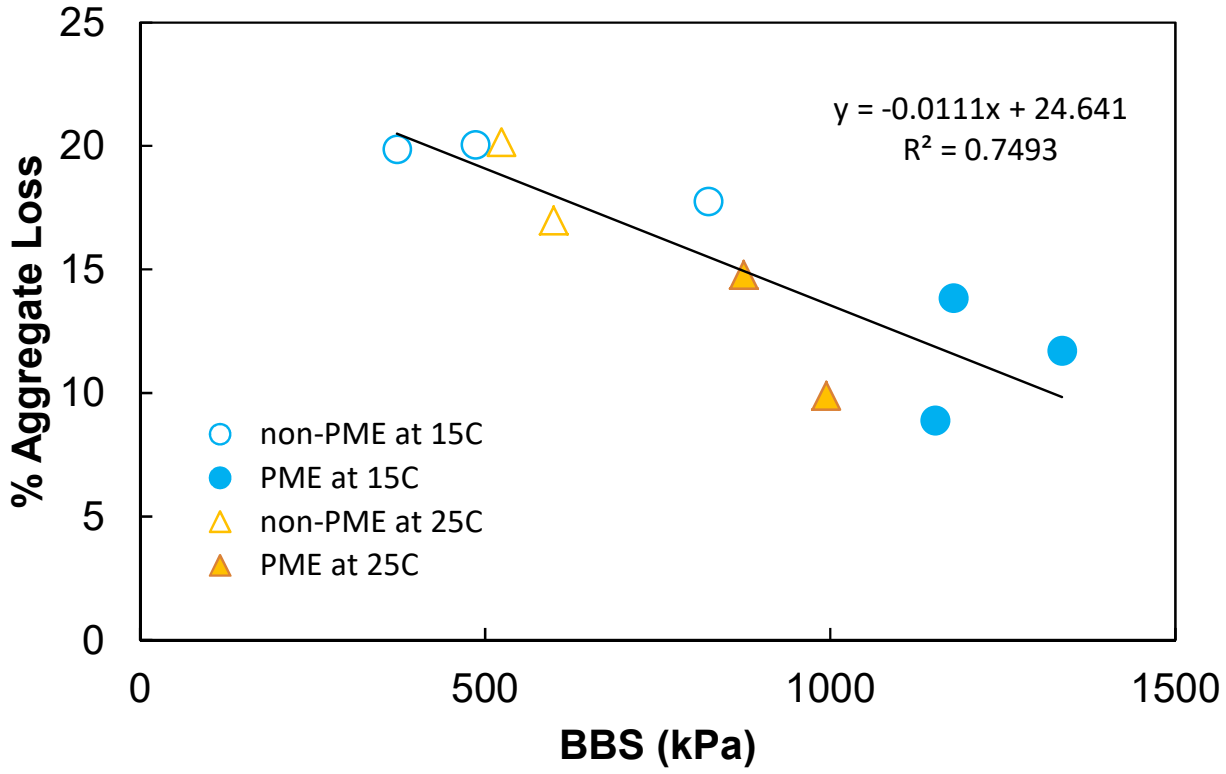
- Curing samples in the oven at 35°C for 24 hours.
- Flip over samples to remove excess aggregate.
- Place samples upside down on a device.
- Drop the ball three times within 10 sec.
- Measure the weight of samples.

Binder Bond Strength (BBS) Test





Vialit Aggregate Loss vs. BBS



Desirable Aggregate Characteristics

Important Aggregate Properties

- Gradation
- Fine Content
- Particle Shape: Flakiness Index
- Abrasion Resistance
- Strength
- Bulk Specific Gravity
- Loose Unit Weight
- Absorption

Material Selection

Aggregate

- Size
  - Establishes the thickness of the chip seal
  - Most agencies use a nominal size that ranges from 3/8 in (9.5 mm) to 1/2 in (12.7 mm)
  - Larger aggregate particle sizes are more durable and less sensitive to variations in binder application rate
  - Larger particles lead to greater noise and windshield damage if dislodged
- Gradation
  - Best to have uniform gradation
  - Limiting dust is critical

Material Selection

Aggregate

- Aggregate shape
  - Angular particles best
  - Rough particles improve bonding
  - Cubical particles desirable because traffic does not have a significant effect on the final orientation of aggregate
- Synthetic aggregate (Lightweight)
  - Produced by heating shale, clay or slate
    - Expands to create a porous, lightweight aggregate.
  - Advantages
    - Low mass, will not break windshields
    - Good skid resistance
    - Tend to have more uniform gradation

Material Selection

Aggregate

- Pre-coated aggregate
  - Only used with hot-applied binder
  - Improves aggregate retention
  - Expedites construction
  - Minimizes dust and moisture issues
  - 0.8 to 2.4 gal/yd^3 binder application rate

Effect of Gradation

MMLS3 Test Results

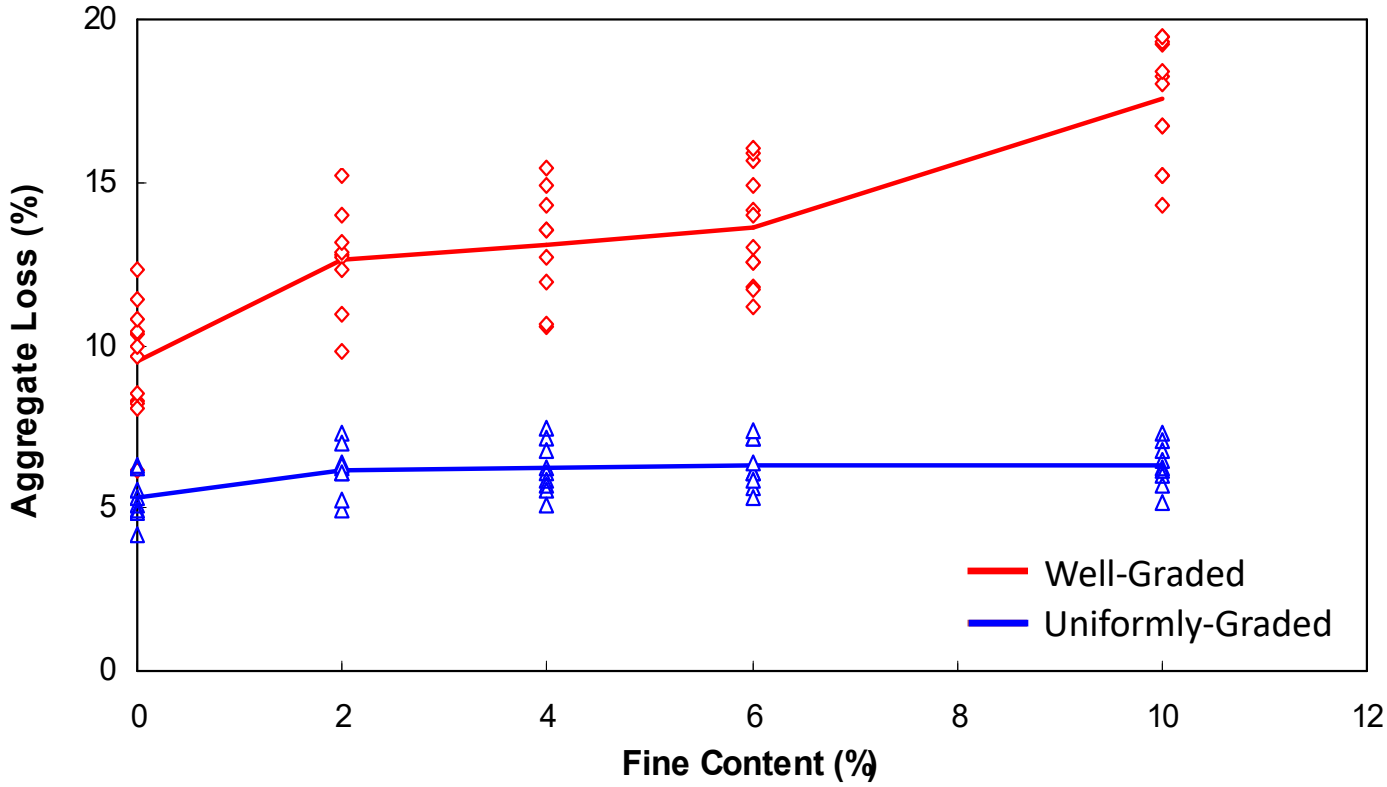
Before Loading	After Agg. Retention Test	After Bleeding Test

Granite 78M with Less Uniform Gradation

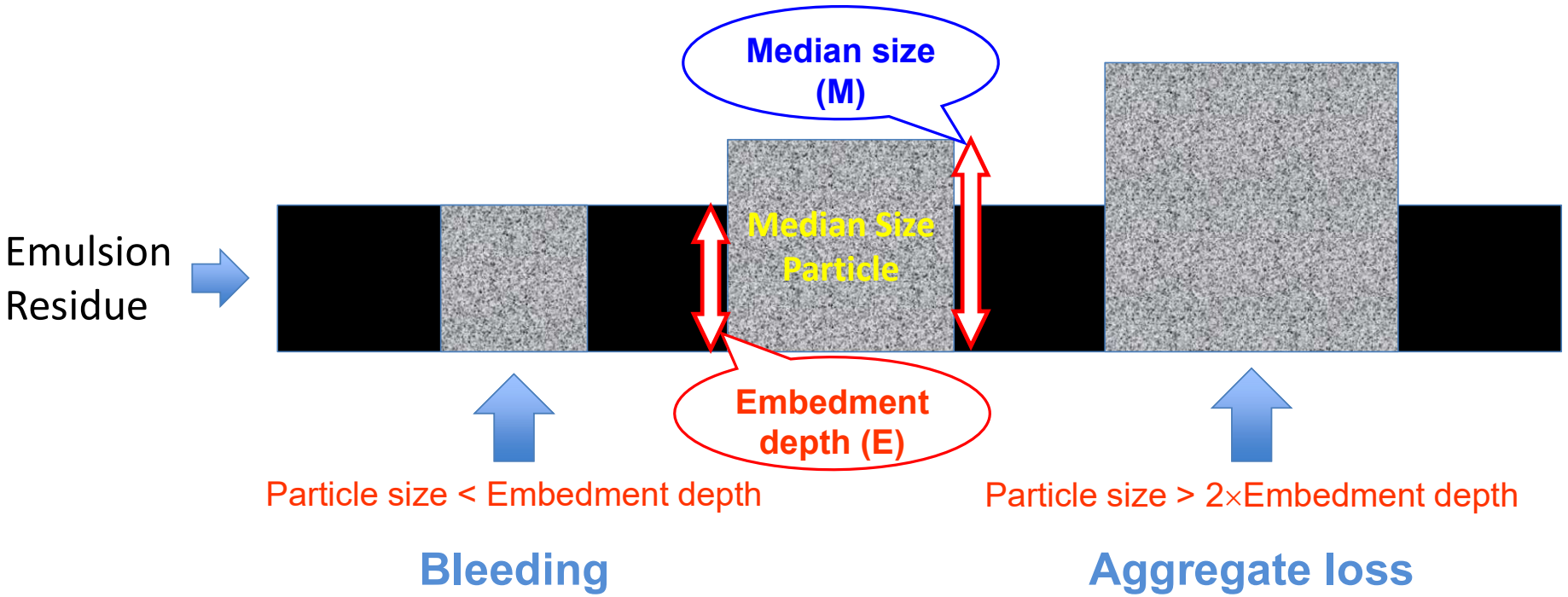
Light-weight 5/16” with More Uniform Gradation

Effect of Gradation on Aggregate Loss

After 13k MMLS3 Cycles

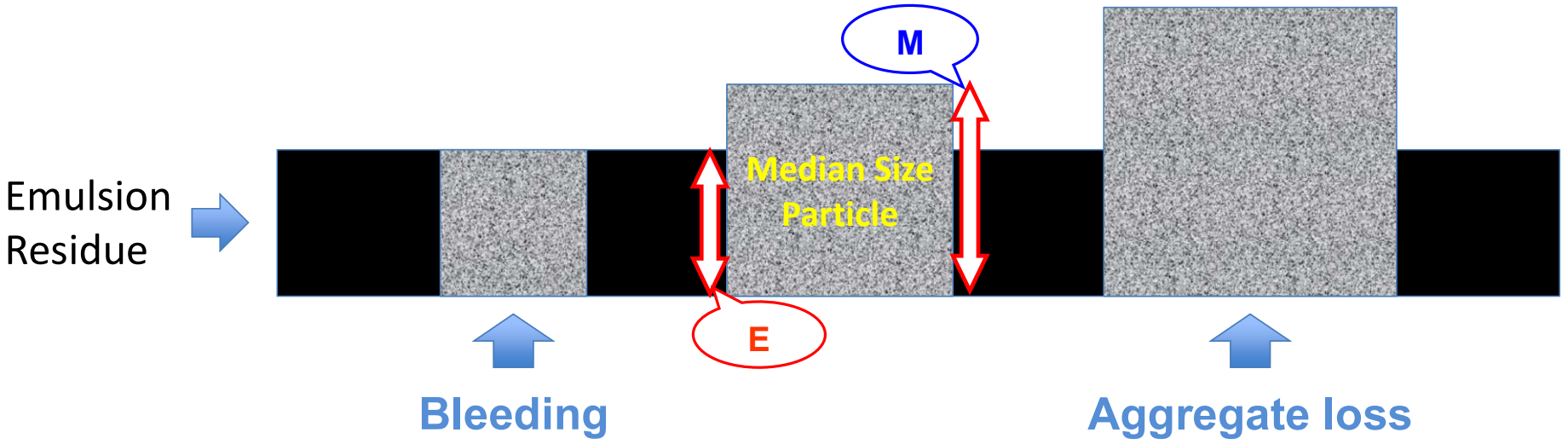


Aggregate Embedment Depth

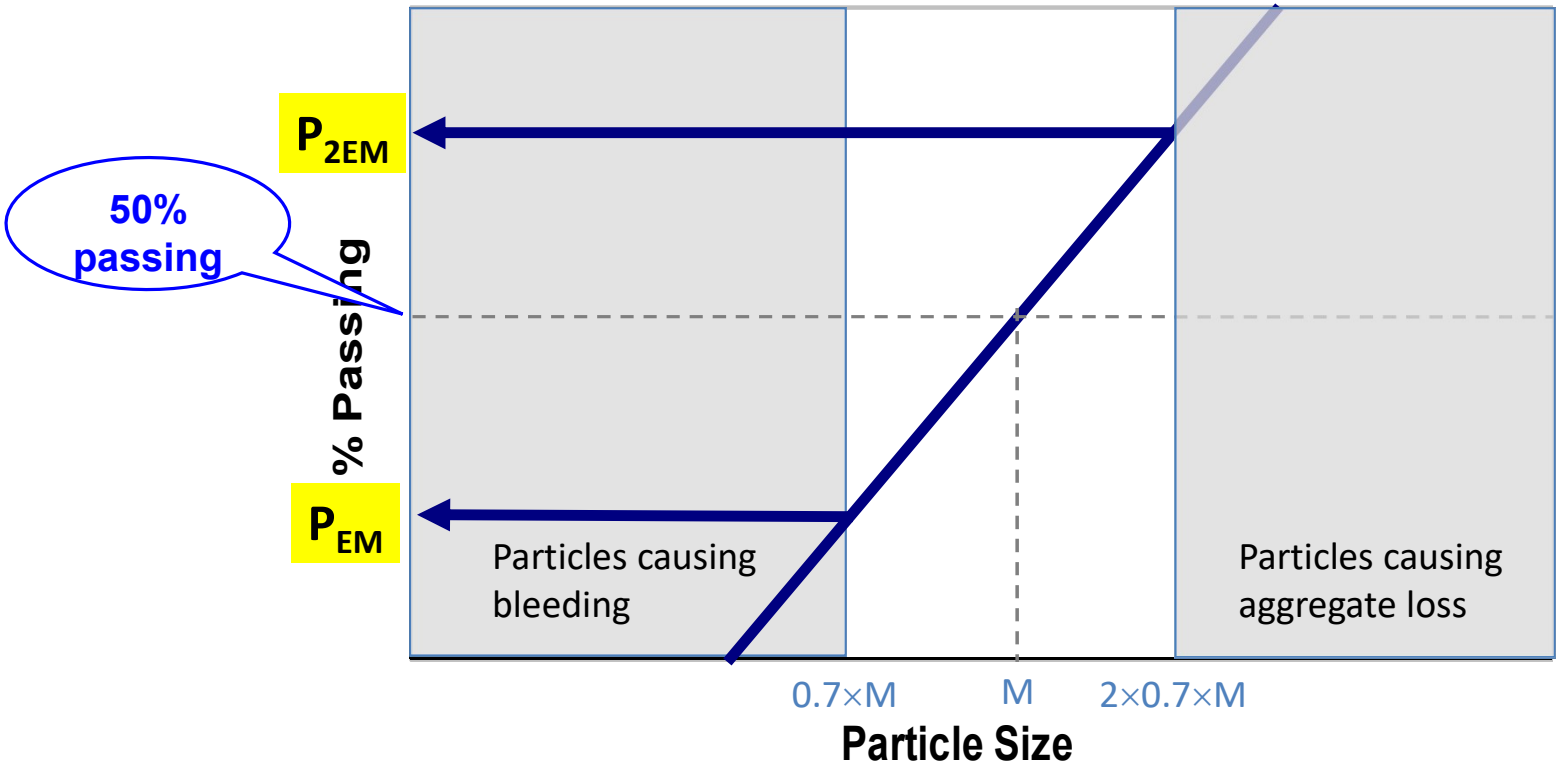


McLeod's Chip Seal Failure Criteria

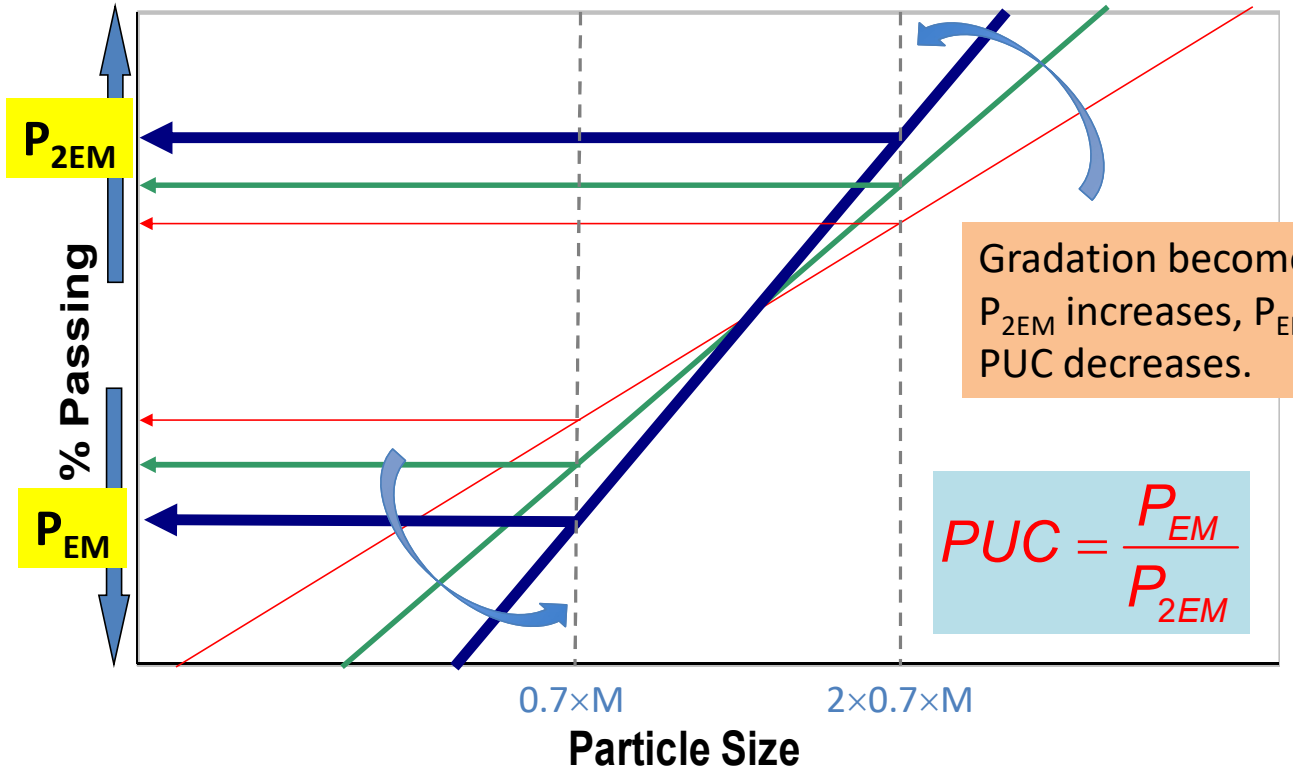
- Optimum embedment depth (E) = Median particle size (M) x (0.65-0.85) = 0.7 x M
- Size of particles that will cause bleeding < Embedment depth = 0.7 x M
- Size of particles that will cause aggregate loss > 2 x Embedment depth = 1.4 x M



Performance Uniformity Coefficient



Performance Uniformity Coefficient



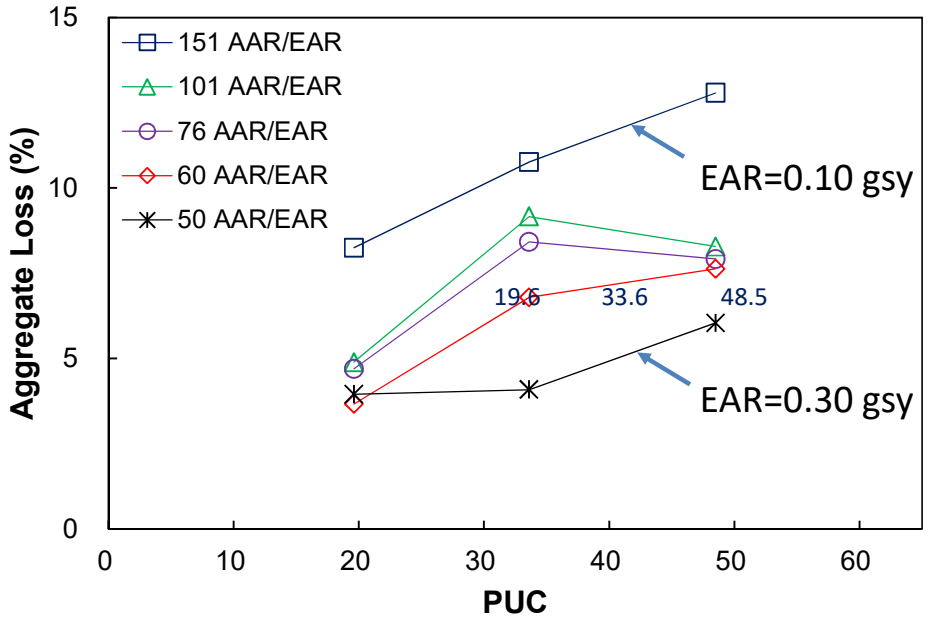
Gradation becomes more uniform, P_{2EM} increases, P_{EM} decreases, and PUC decreases.

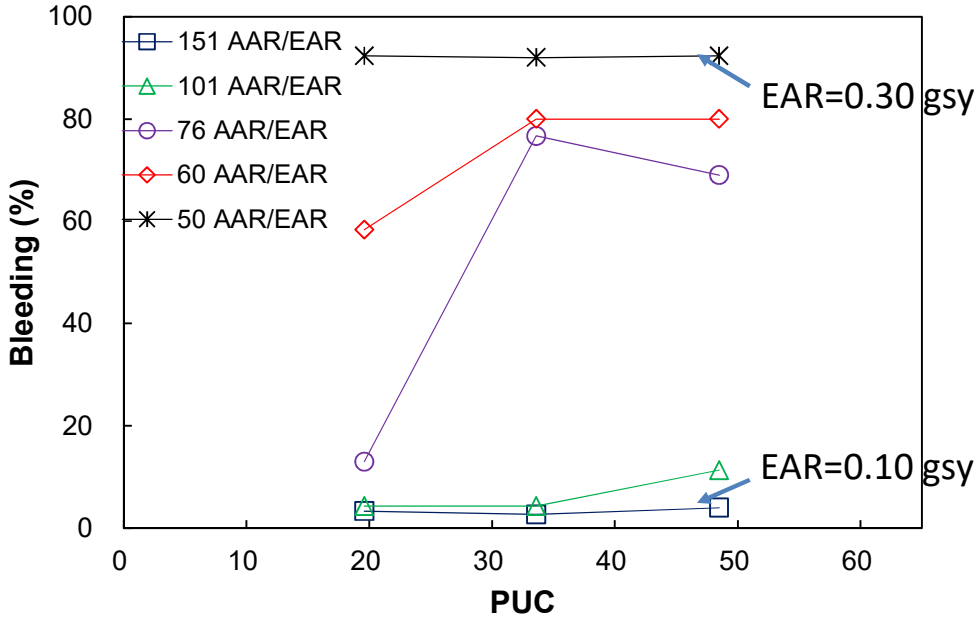
$$PUC = \frac{P_{EM}}{P_{2EM}}$$

A lower PUC yields less bleeding and less aggregate loss.

Effect of PUC on Chip Seal Performance

Granite 78M Aggregate





- Aggregate Application Rate (AAR) = 15.1 lb/yd^2
- Emulsion Application Rate (EAR) = 0.10, 0.15, 0.20, 0.25, and 0.30 gal/yd^2

Desirable Emulsion Properties

Material Selection

Emulsion

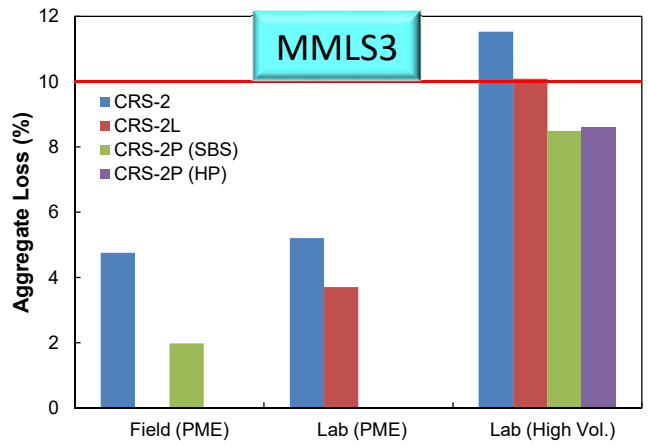
- Important considerations
  - Set rate – Rapid Setting
  - Charge selected based on aggregate type
    - Cationic emulsions generally outperform anionic emulsions because they are less sensitive to weather, inherently have antistripping qualities, and are electrostatically compatible with more types of aggregate.
  - Most often high viscosity (2) – CRS-2
  - Often contain modification – CRS-2L or CRS-2P

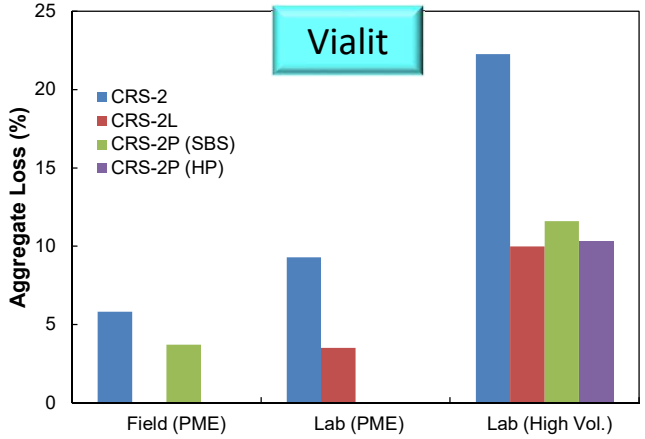
Material Selection

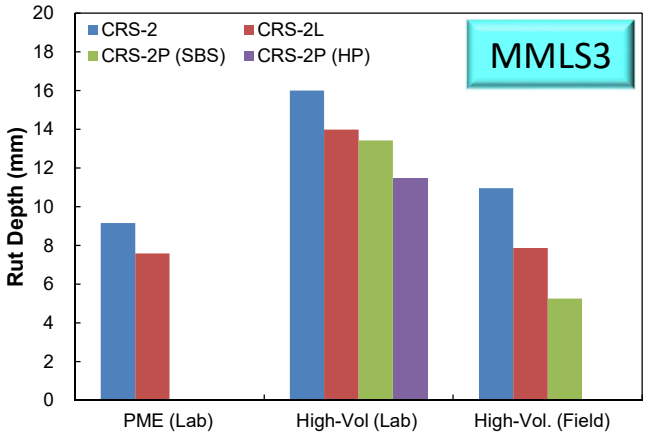
Emulsion

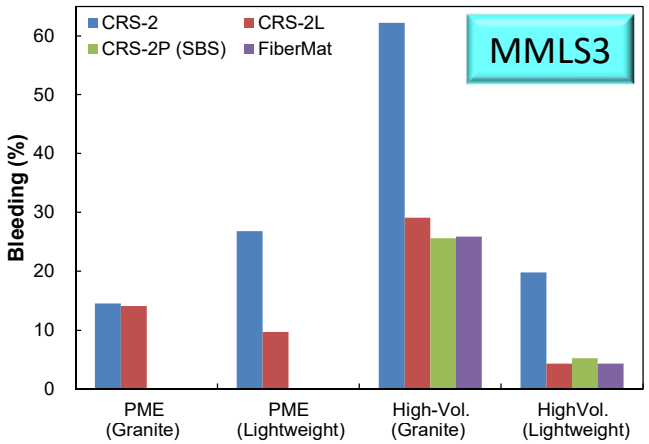
- High float emulsions (HF)
  - Pass “float test”
  - Prevents flowing at high temperatures
  - Allow for a thicker residual asphalt film on the aggregate
  - Can be used with “dirty” aggregate (up to 5% fines)

Effect of Polymer Modification of Emulsion



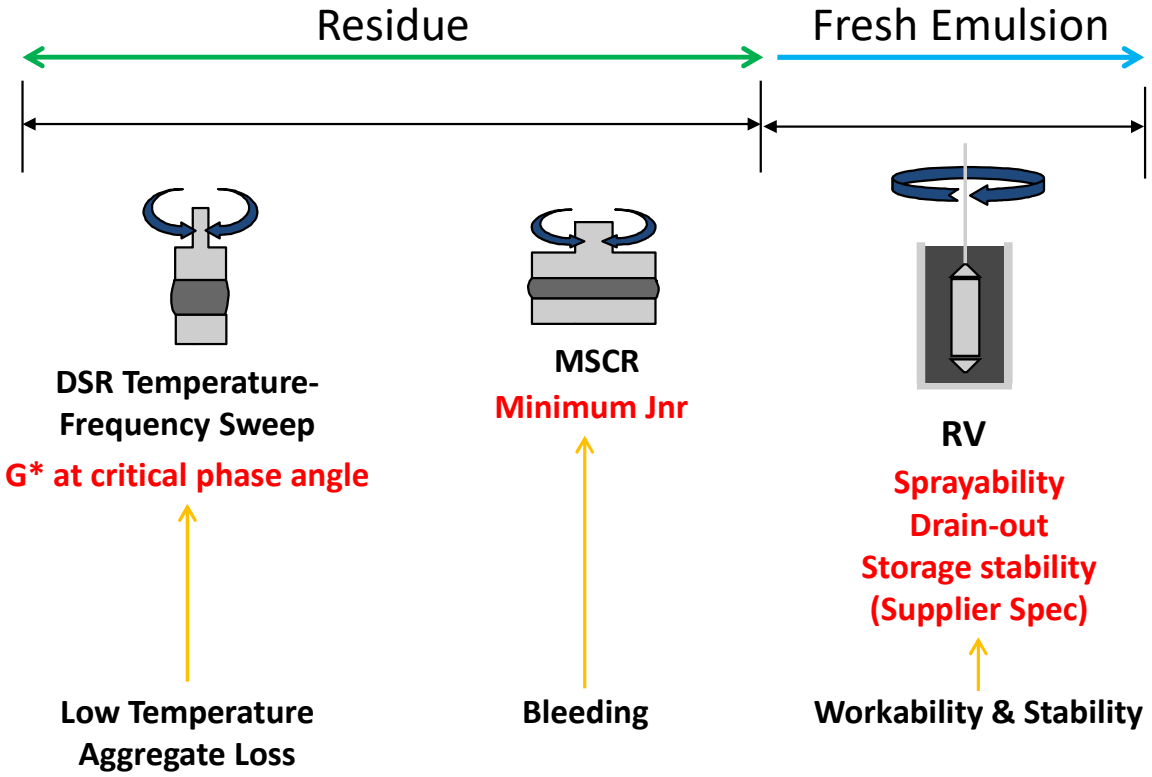






Emulsion PG Tests for Chip Seal Emulsions

Developed under NCHRP 9-50 (Kim, Adams, Castorena, Illias)



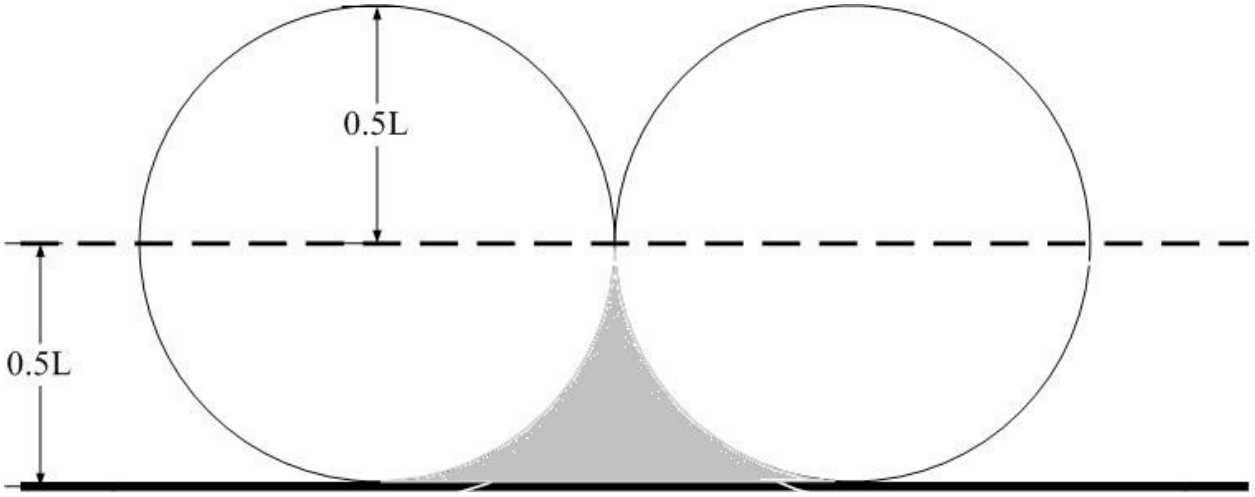
EPG Limit Summary

Material	PG Test	Performance Parameter	Traffic Level	Test Temp. Range	EPG Limit
Fresh Emulsion	RV	Separation Ratio	N/A	60°C	0.5 to 1.5
		Stability Ratio			Maximum 2
		Sprayability			Maximum 400 cP
		Drainout			Minimum 50 cP
Emulsion Residue	DSR MSCR	Maximum *Jnr* @ 3.2 kPa	Low	High	< 8 kPa^{-1}
			Med		< 5.5 kPa^{-1}
			High		< 3.5 kPa^{-1}
	DSR Frequency Sweep	Maximum |G*| @δc	Low	5°C and 15°C	< 30 MPa
			Med		< 20 MPa
			High		< 10 MPa

Performance-Engineered Mix Design

50% Initial Embedment Concept

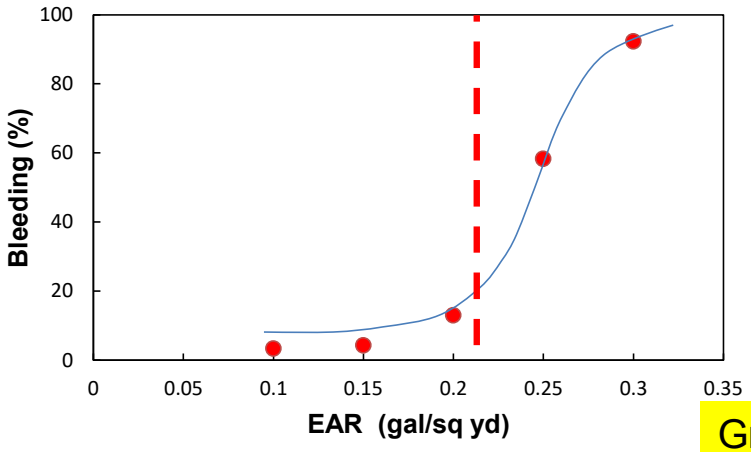
- Design to fill up subsurface voids (grey area)
- Subsurface voids account for ~50% embedment
- Traffic densification causes the embedment depth to increase to about 70%.



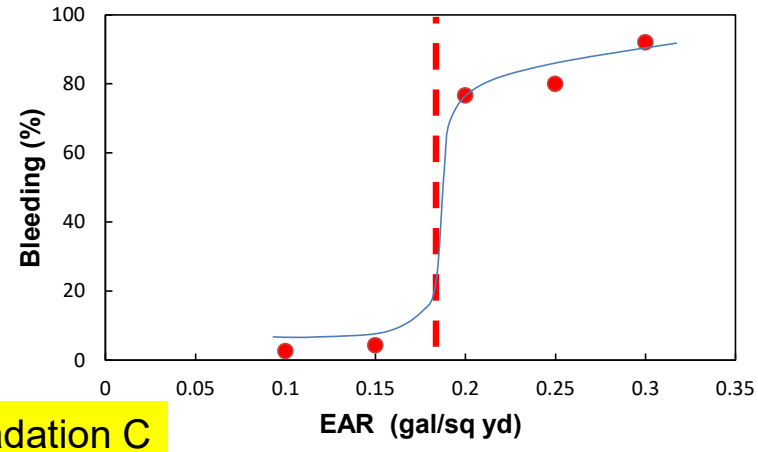
Recommended Mix Design Procedure

- Determine Design Aggregate Application Rate
  - Modified Board Test (305 mm by 508 mm board)
- Determine Design Emulsion Application Rate
  - Laser scan of Modified Board Test
  - Volumetric calculations
  - Adjust for existing surface absorption
  - Adjust for aggregate absorption
  - Consider penetration adjustment based on surface hardness
    - Penetration Ball Test (New Zealand 2005)
  - Consider steep grade adjustment (experience based)

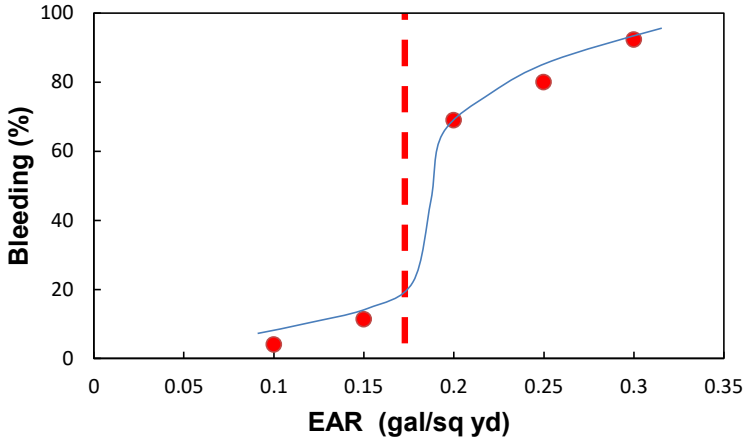
Gradation A



Gradation B



Gradation C



Granite 78M

Optimum EAR from PEMD

Optimal Rolling Protocols

Roller Types Used

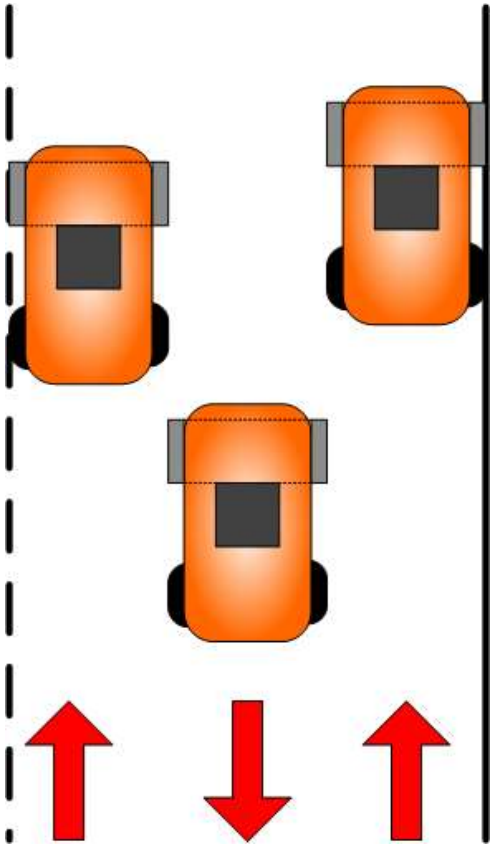
Steel Wheel Roller

Pneumatic Tire Roller

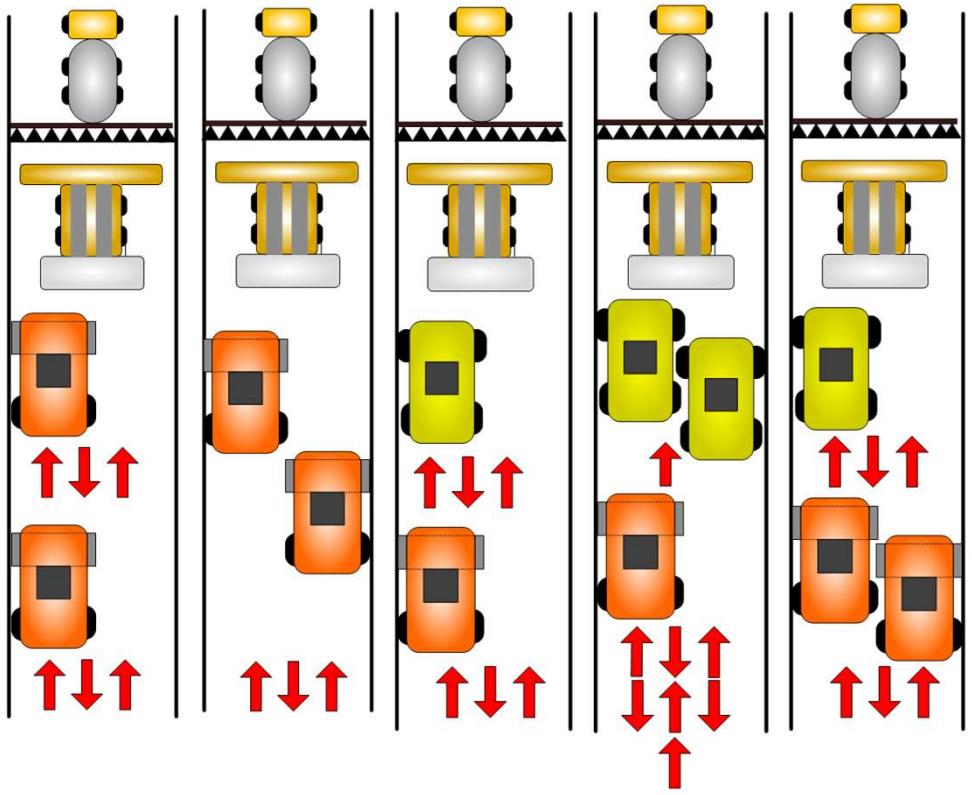
Combination Roller

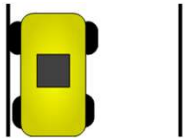
Coverage vs. Pass

- Number of coverages = Number of roller passes on the *same* location
- 3 passes in zigzag pattern = 1 coverage

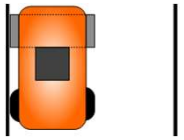


Rolling Pattern Study





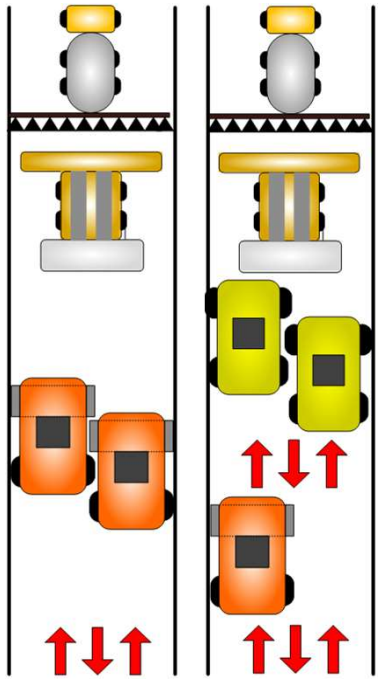
Pneumatic Tire Roller



Combination Roller

Optimal Rolling Protocols

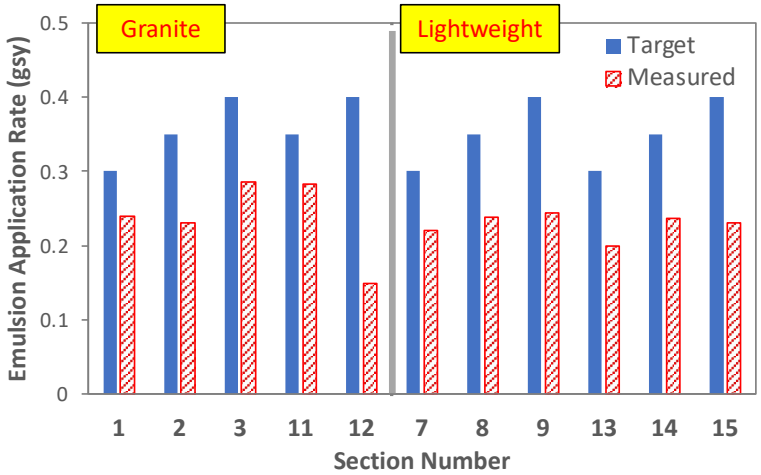
- Pneumatic tire roller and combination roller recommended
- Optimal number of rolling coverages of three
- No rolling required for the bottom layer of triple seal
- Recommended rolling protocols
  - Two roller case: Two combination rollers side-by-side
  - Three roller case: Two pneumatic tire rollers side-by-side followed by one combination roller

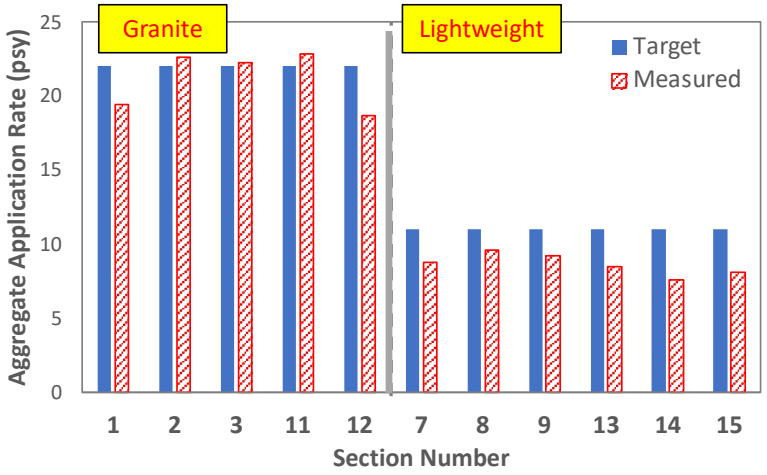


Construction Variability of Chip Seals

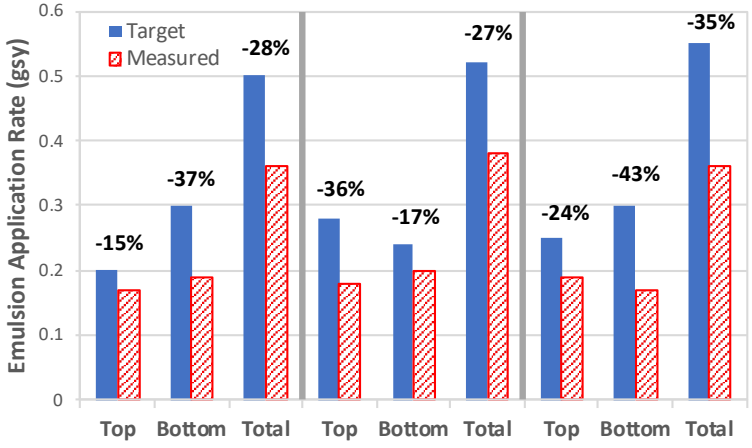
Field Material Rate Variability

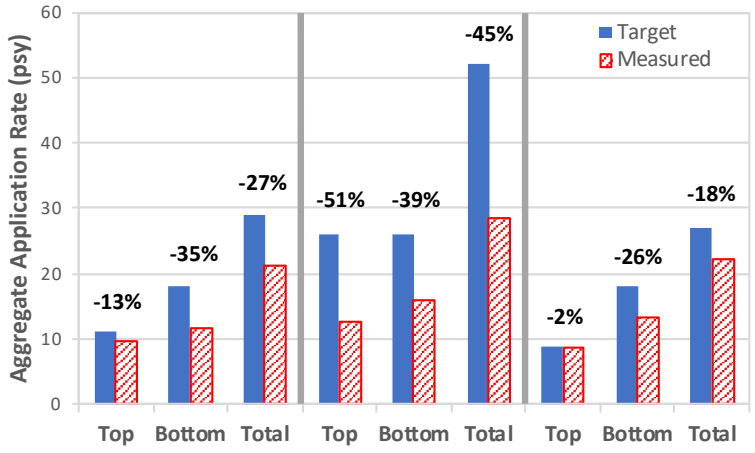
By NCDOT (2008)



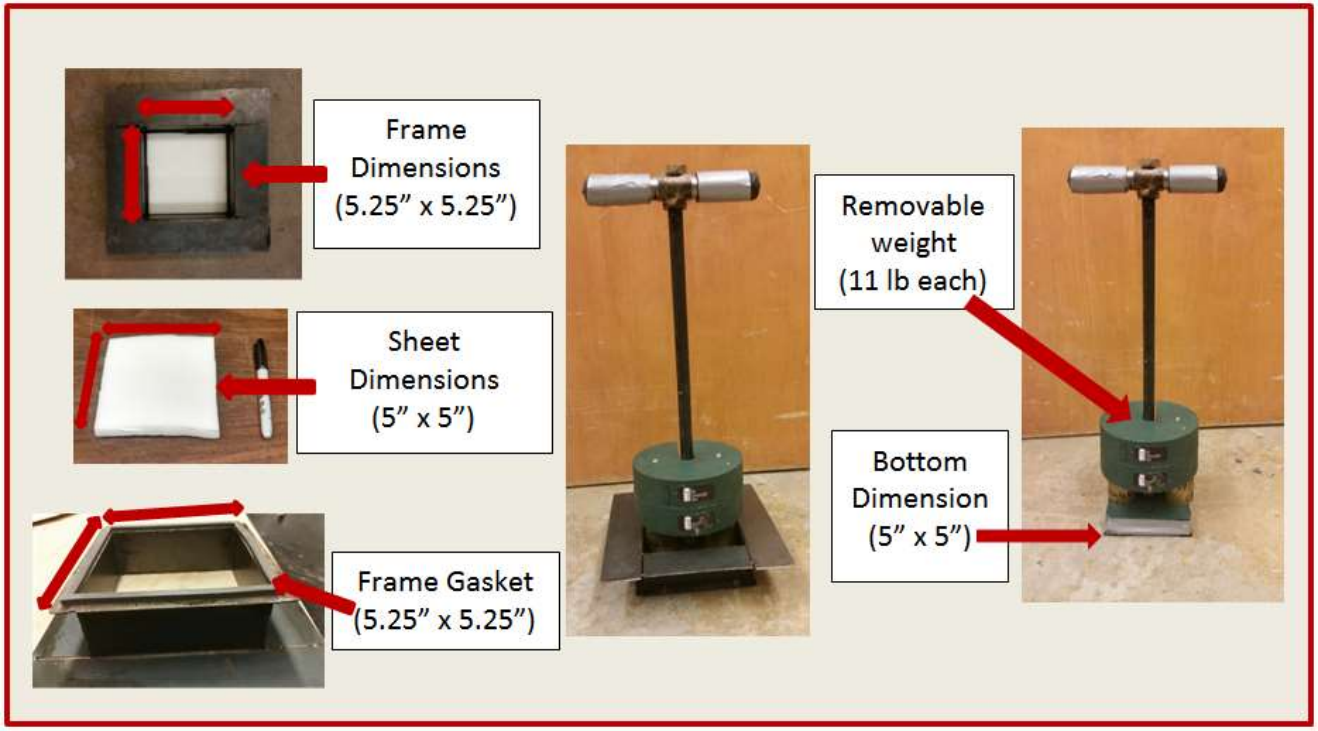


By Contractors (2016)





Tack Lifter


Frame Dimensions (5.25" x 5.25")
Sheet Dimensions (5" x 5")
Frame Gasket (5.25" x 5.25")
Removable weight (11 lb each)
Bottom Dimension (5" x 5")

Performance-Related QA Specifications

PRS for Chip Seals (NCHRP 10-82A)

Acceptance Quality Characteristics	Related Performance Measure	Proposed Test Method	Test Parameter
Emulsion-Aggregate Adhesive Strength	Aggregate Loss	Vialit Test (Lab)	% Aggregate Loss
Gradation	Aggregate Loss	Gradation Analysis of Vialit Samples (Lab)	Performance Uniformity Coefficient
Emulsion Application Rate	Aggregate Loss and Bleeding	Tack Lifter or Ignition Oven on Vialit Samples	% Difference from Target EAR
Aggregate Application Rate	Aggregate Loss and Bleeding	Ignition Oven on Vialit Samples	% Difference from Target AAR

Key Implementation Points

Aggregate

- Importance of uniform gradation (PUC as the specification)
- Fine content less than 1.5%

Emulsion

- Use of polymer modified emulsion strongly recommended
  - Excellent aggregate retention, bleeding, rutting, and low temperature performance of polymer-modified chip seals
  - Faster curing behavior with better long term adhesion strength

Key Implementation Points – Cont'd

Rolling

- Pneumatic tire roller and combination roller recommended
- Optimal number of rolling coverages of three
- No rolling required for the bottom layer of triple seal
- Recommended rolling protocols:
  - Two roller case: Two combination rollers side-by-side
  - Three roller case: Two pneumatic tire rollers side-by-side followed by one combination roller

Key Implementation Points – Cont'd

Mix Design

- Aggregate application rate (AAR) from the modified board test (305 mm by 508 mm board) – minimum three replicates
  - Traffic whip off factor
  - Wet aggregate
- Laser profiler to determine emulsion application rate (EAR) using the 50% initial embedment depth
  - Aggregate absorption
  - Absorption into existing pavement surface

Key Implementation Points – Cont'd

Specifications

- Emulsion PG specifications for chip seals, microsurfacings, and fog seals (NCHRP 09-50)
  - Rotational viscometer and DSR
- Performance-Related Specification for chip seals

Key Implementation Points – Cont'd

Construction

- Significant variability in AAR and EAR even with pre-construction calibration
- Chip seal construction best practices document
- Chip seal certification and QC/QA program

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Thank you!

Questions?