Otta Seals: Design, Construction and Role in a Preventive Maintenance Program

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Iowa State University

Typical Otta Seal Use

- To provide a relatively thick, flexible sealed surface over and unbound structural base layer

Photo: Francis Dayamba Iowa State University

Compared to a chip seal, an Otta seal is:

- Thicker
- More flexible
- Composed of a
  - more graded, dense aggregate, with less restrictive quality requirements:
    - Crushed faces
    - Fines content
    - Possibly hardness
  - Less reactive binder
    - Softer
    - Slower setting

Photo: Charles T. Jahren
Iowa State University

Construction Process

- Construct a structural base layer that can support all traffic loads
- No primer needed
- Heavy Shot of Binder (~0.5 gal/sy)
- Spread a thick layer of Aggregate (~50 lb/sy)
- Considerable Rolling at various times
- Sweeping
- Continued compaction and changes in surface appearance with traffic
- Possible chip, sand or pea rock seal surface

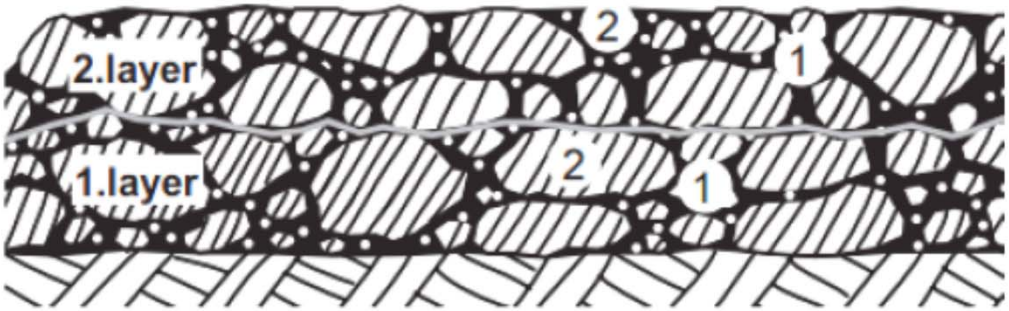
Types of Otta Seal

- Single Otta Seal
- Double Otta Seal
- Possible cover treatments:
  - Chips
  - Pea Rock
  - Sand

Single and double Otta seal

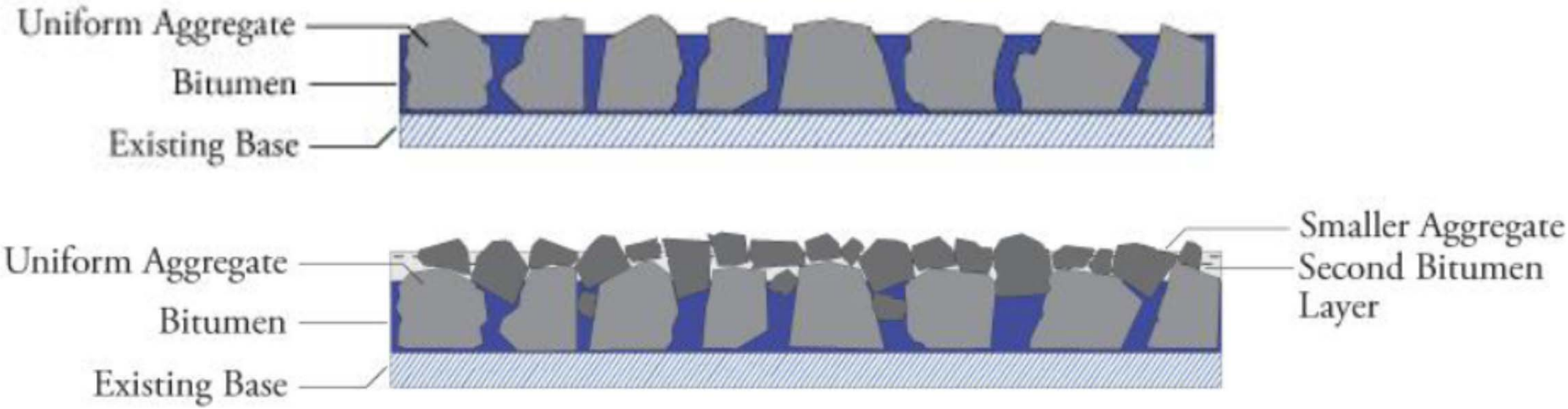
SINGLE OTTA SEAL
No Prime
1 Binder
2 Graded aggregate

DOUBLE OTTA SEAL
No Prime
1 Binder
2 Graded aggregate



Øverby 1999, Norwegian Public Roads Administration

Single and Double Chip Seal



Adapted from ARRB Group 2010

History

- Norwegian Road Research Laboratory
- Elsewhere in Scandinavia
- Southern and Eastern Africa
  - Labor based construction

Photo: Charles T. Jahren
Iowa State University

(Overby 2006)

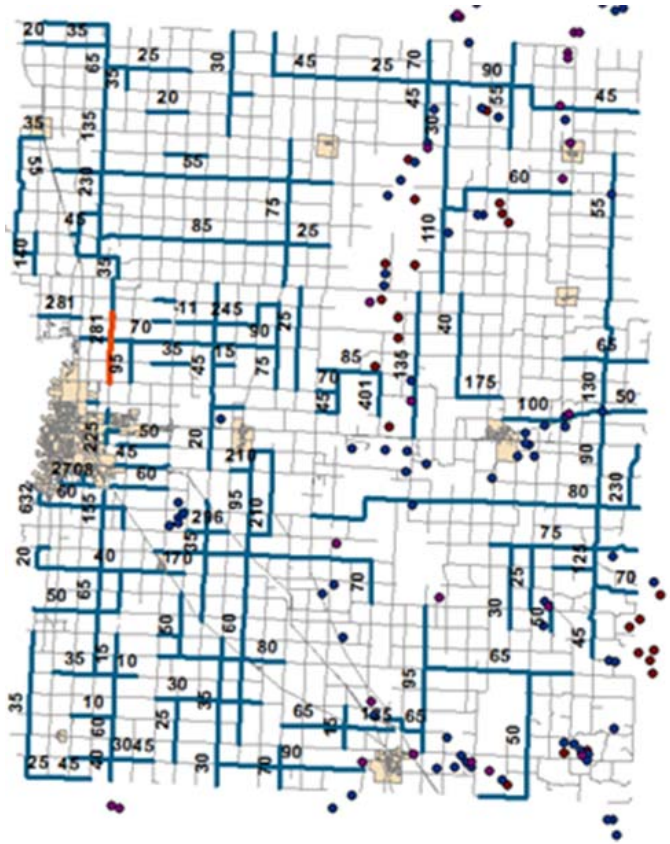
Otta Seal use in Minnesota

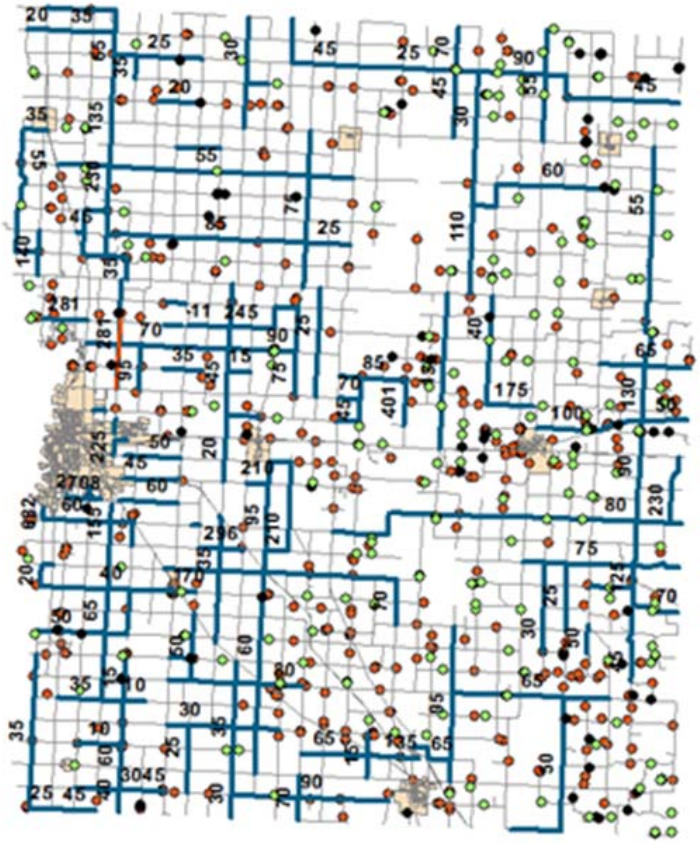
Photos: Charles T. Jahren
Iowa State University

- Low volume unpaved roads where there is a desire for
  - Greater surface stability
  - Lower fugitive dust emissions
- Residential adjacent land use
- Few heavy loads
- Granular subgrade

Gravel Sources and Agricultural Locations in Clay County, MN

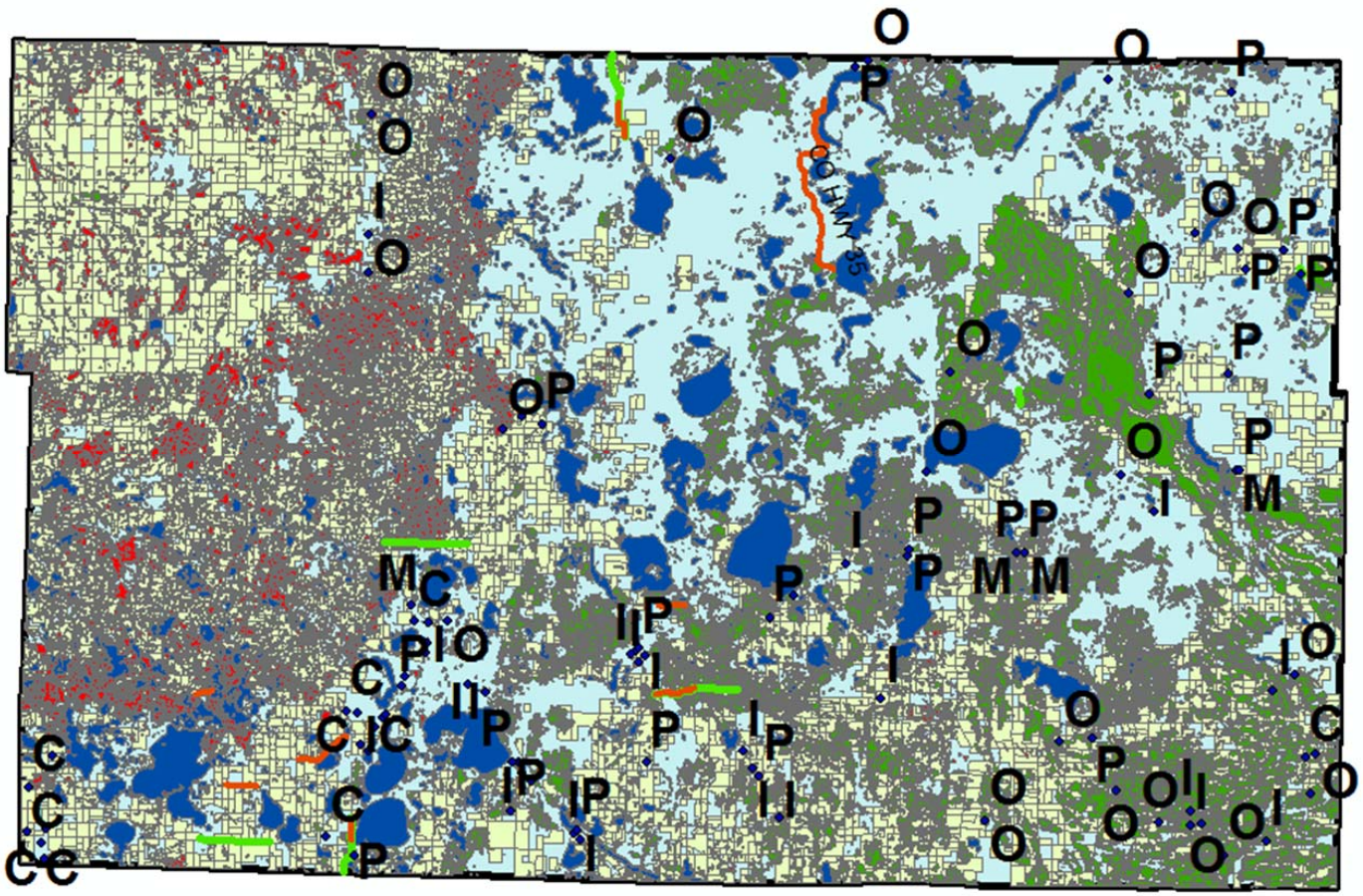
GIS: Francis Dayamba
Iowa State University





Granular Subgrades in Becker County

GIS: Francis Dayamba
Iowa State University



Situations with limited success in MN

- Heavy agricultural or industrial traffic
- Locations where vehicles
  - Stop
  - Start
  - Turn
- Areas with cohesive subgrades

Photo: Charles T. Jahren
Iowa State University

Challenges with Otta seal

Photos: Charles T. Jahren
Iowa State University

Otta Seal Procedure in Becker County, MN

Photos: Becker County, MN

Otta Seal Procedure in Becker County, MN

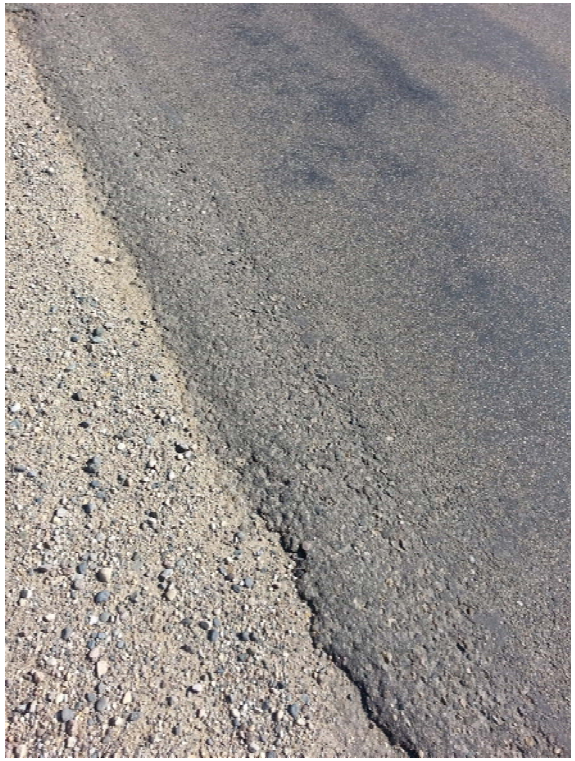
Photos: Becker County, MN

Otta seal with and without seal coat

Photos: Charles T. Jahren
Iowa State University

With and without seal coat surface

Photos: Charles T. Jahren
Iowa State University



Materials from Becker County, MN

- Aggregate source:
  - Gravel
    - Screened
    - Reblended
  - 50 lb/sy
- Binder
  - HFMS-2S
  - 0.50 gal/sy

% Passing	OS.1
1 in	100
¾ in	100
½ in	84-100
3/8 in	70-98
No. 4	44-70
No. 10	20-48
No. 40	7-25
No. 200	3-10

Case Study Projects

- North Pearl Lake Road
- Pearl Circle
- Airport Road
- CSAH 35
  - Tamarac National Wildlife Refuge

North Pearl Lake Road

Photo: Charles T. Jahren
Iowa State University

North Pearl Lake Road

Photos: Charles T. Jahren
Iowa State University

Pearl Circle

Photos: Charles T. Jahren
Iowa State University

Airport Road

Photos: Charles T. Jahren
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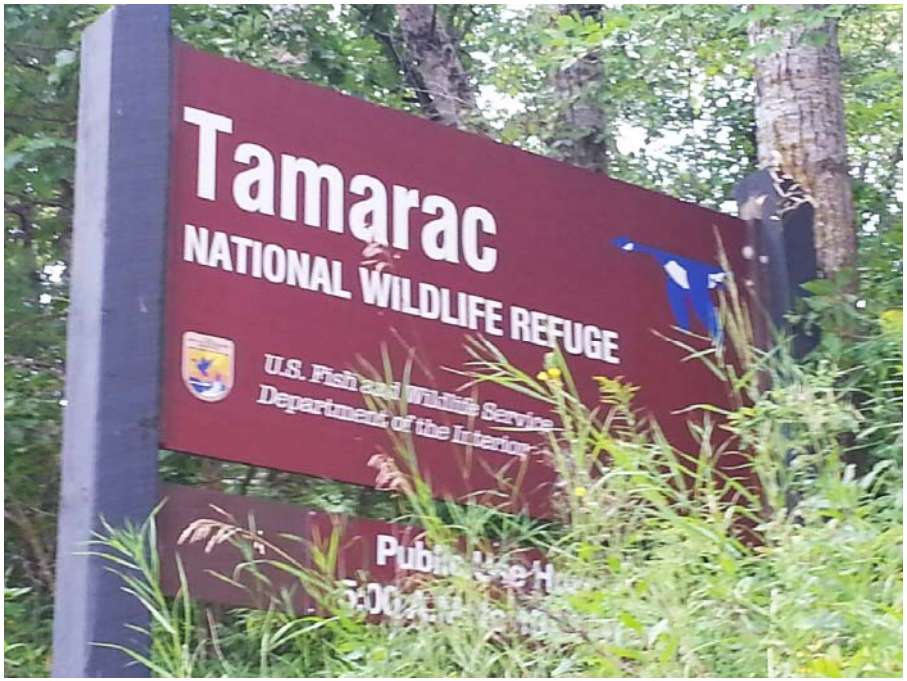
Airport Road

Photos: Charles T. Jahren
Iowa State University

CSAH 35

Photos: Charles T. Jahren
Iowa State University



CSAH 35

Photos: Charles T. Jahren
Iowa State University

Otta Seal and Pavement Preservation

- A tool to preserve network level funding
- Avoid expense of paving certain roads
- Possible use as a holding strategy
- Requires relatively aggressive preventive maintenance for long life
- Can require considerable emergency maintenance in the wrong application

Questions??

Thank You!!!

Performance-Related Specifications for Chip Seals

Y. Richard Kim, Ph.D., P.E., F.ASCE
Jimmy D. Clark Distinguished University Professor
Alumni Association Distinguished Graduate Professor
NC State University

TRB Webinar on Flexible Pavement Preservation

August 18, 2015

Requirements for Well Performing Chip Seals

- Aggregate gradation
- Emulsions
- Aggregate and emulsion application rates
- Construction quality control

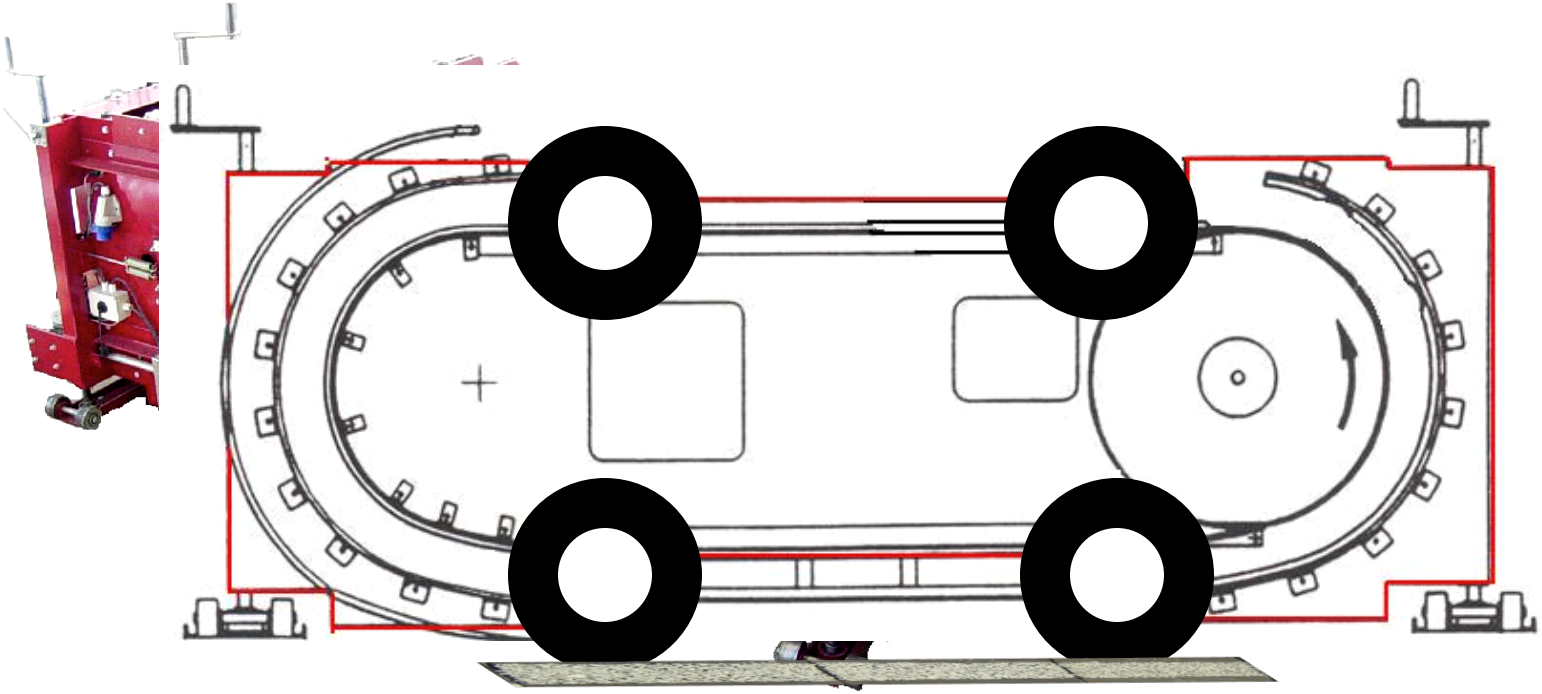
Pavement Preservation Projects at NCSU

- Optimizing Gradations for Surface Treatments – ***Aggregate***
- Quantifying the Benefits of Improved Rolling of Chip Seals – ***Rolling***
- Performance Based Analysis of Polymer Modified Emulsions in Bituminous Surface Treatments – ***Emulsion***
- Development of a New Chip Seal Mix Design Method – ***Mix Design***
- Development of a Field Testing System for Asphalt Surface Treatments – ***Field QC Test***
- Fog Seal Effectiveness for Bituminous Surface Treatments – ***Fog Seal***
- Extending the Use of Chip Seals to High Volume Roads by Using Polymer-Modified Emulsions and Optimized Construction Procedures – ***High Volume Application***
- Field Calibration and Implementation of the Performance-Based Chip Seal Mix Design Method – ***Calibration and Implementation***
- Performance-Related Specifications for Asphaltic Binders Used in Preservation Surface Treatments (NCHRP 09-50) – ***PG Specifications for Emulsion***

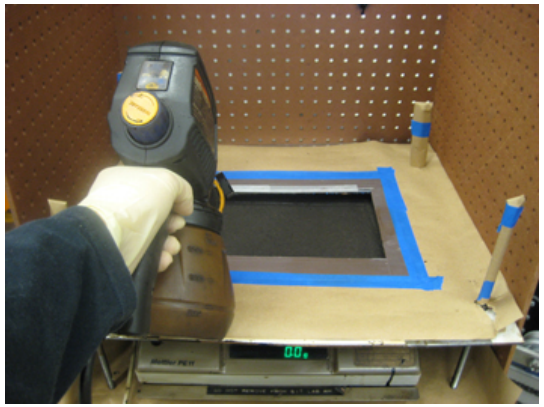
Chip Seal Performance Tests

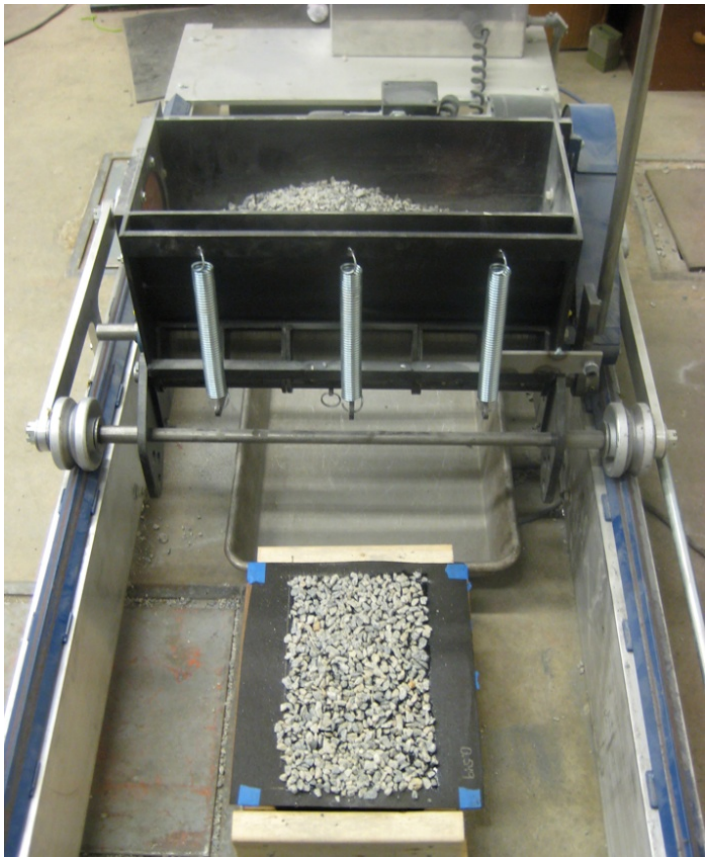
- MMLS3 test
- Vialit test

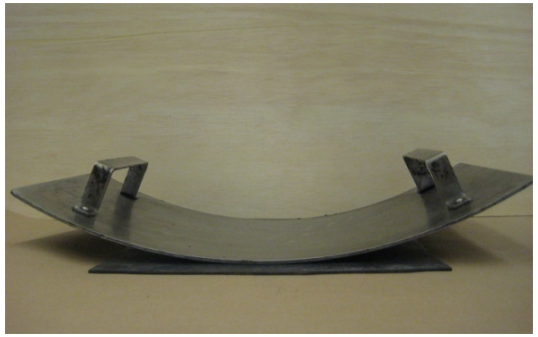
Third Scale Model Mobile Loading Simulator (MMLS3)



Laboratory Chip Seal Specimen Fabrication Using ChipSS





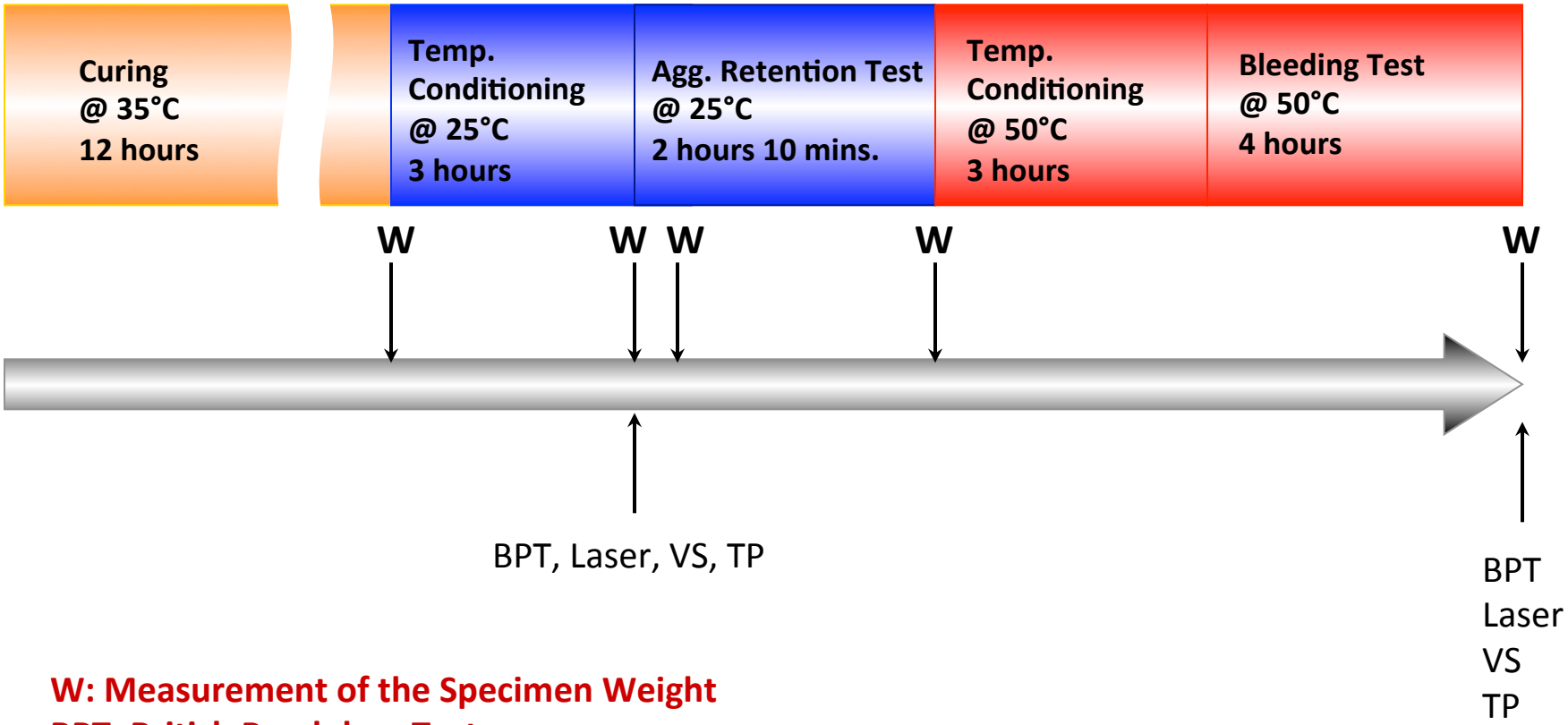


MMLS3 Test Preparation

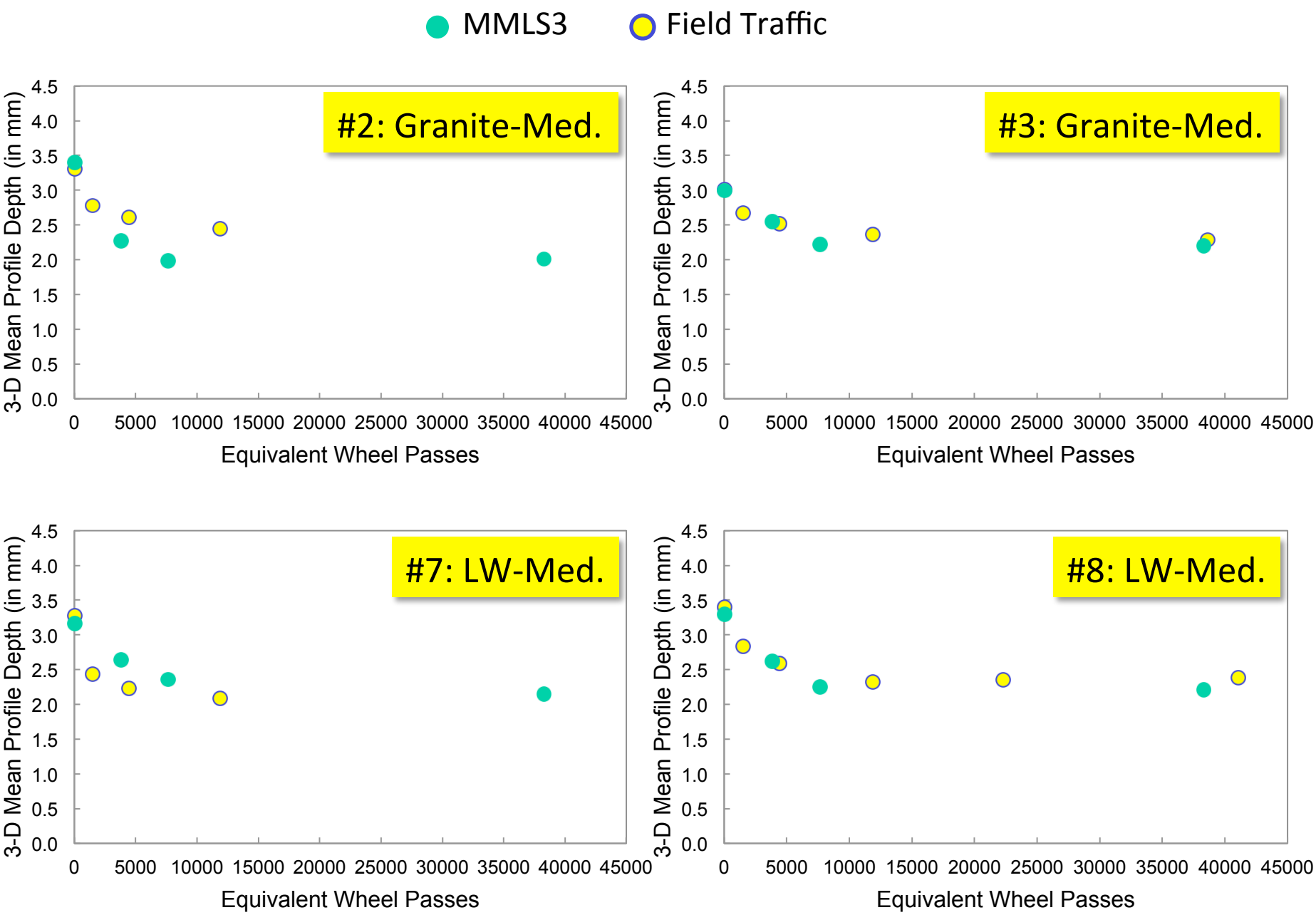





MMLS3 Test Procedure



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

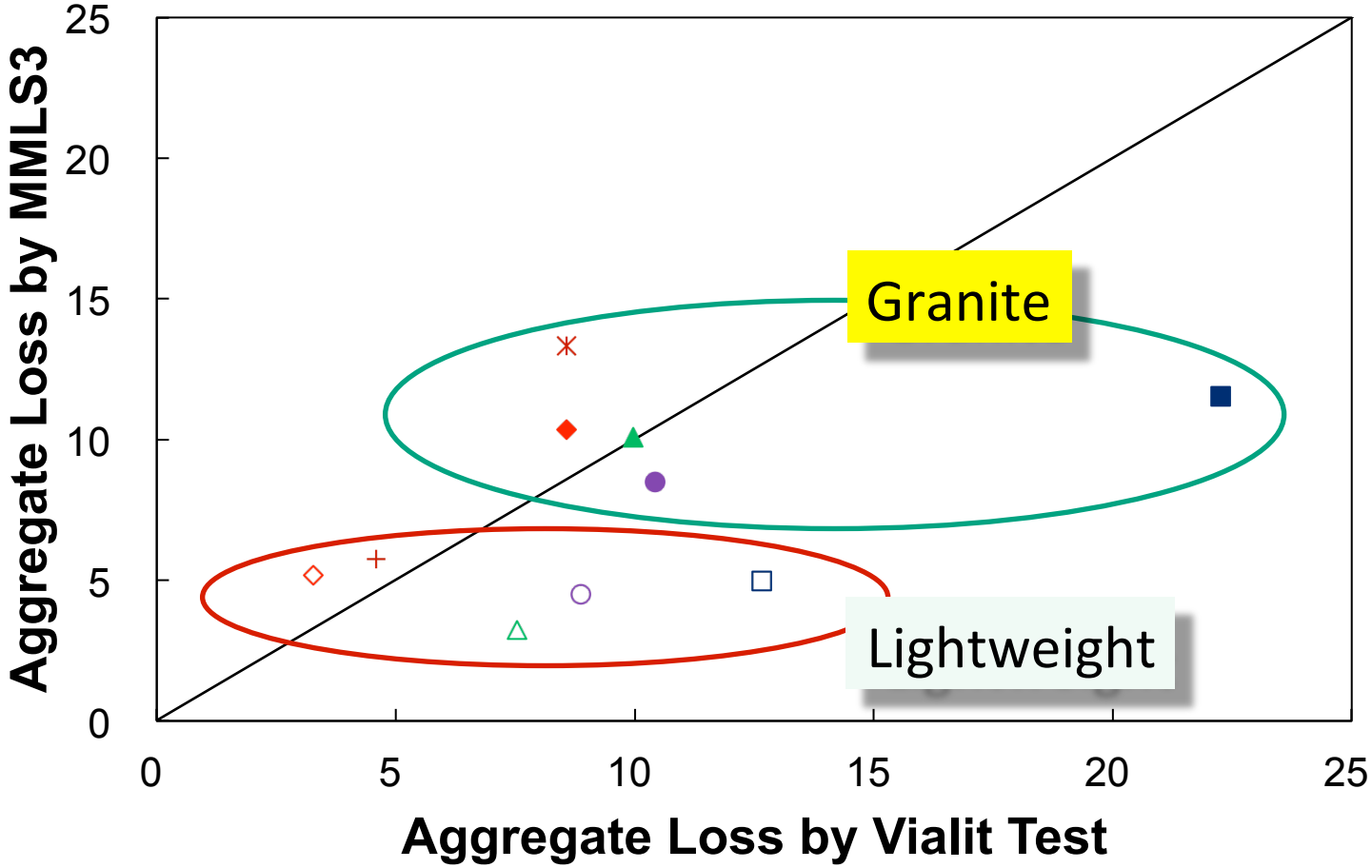

MMLS3
Field Traffic
#2: Granite-Med.
#3: Granite-Med.
#7: LW-Med.
#8: LW-Med.
3-D Mean Profile Depth (in mm)
Equivalent Wheel Passes
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
0
5000
10000
15000
20000
25000
30000
35000
40000
45000

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.
- **Fast and simple!**

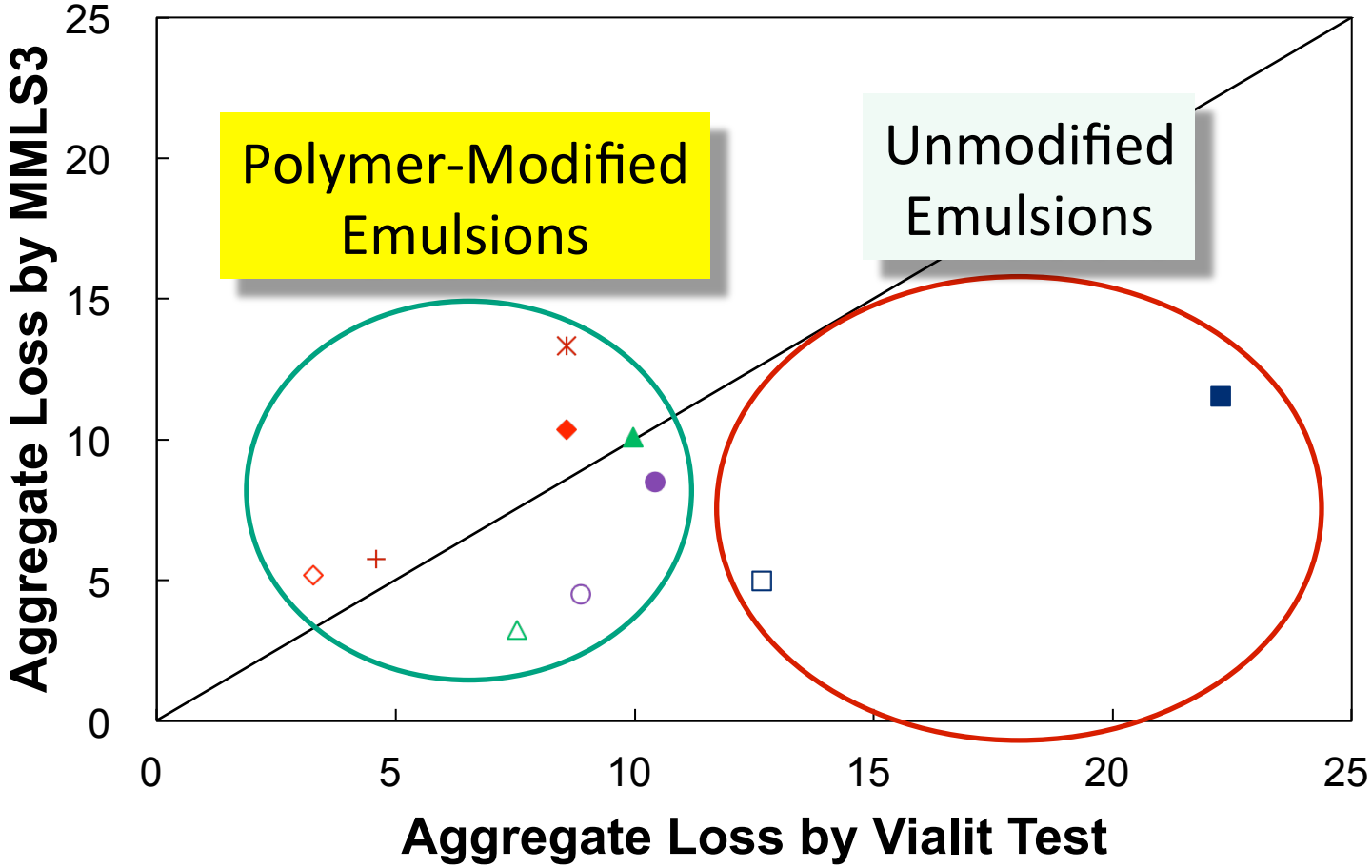
MMLS3 vs. Vialit

Aggregate Evaluation



MMLS3 vs. Vialit

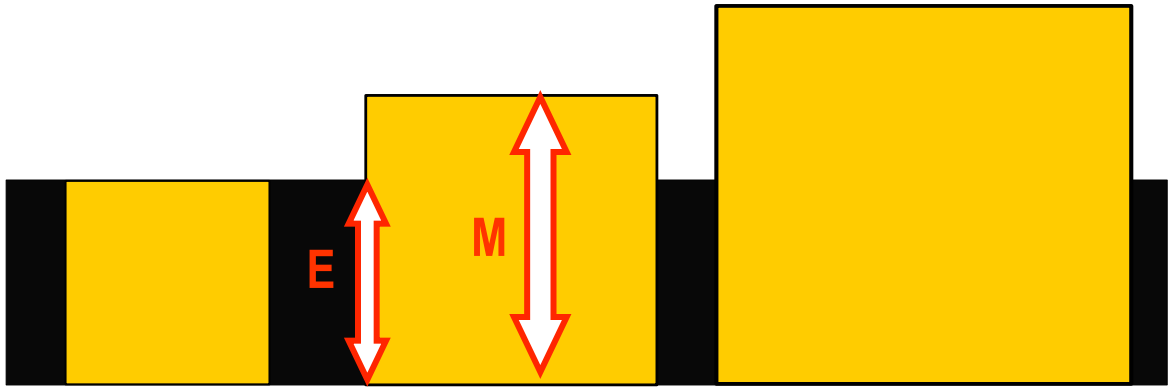
Binder Evaluation



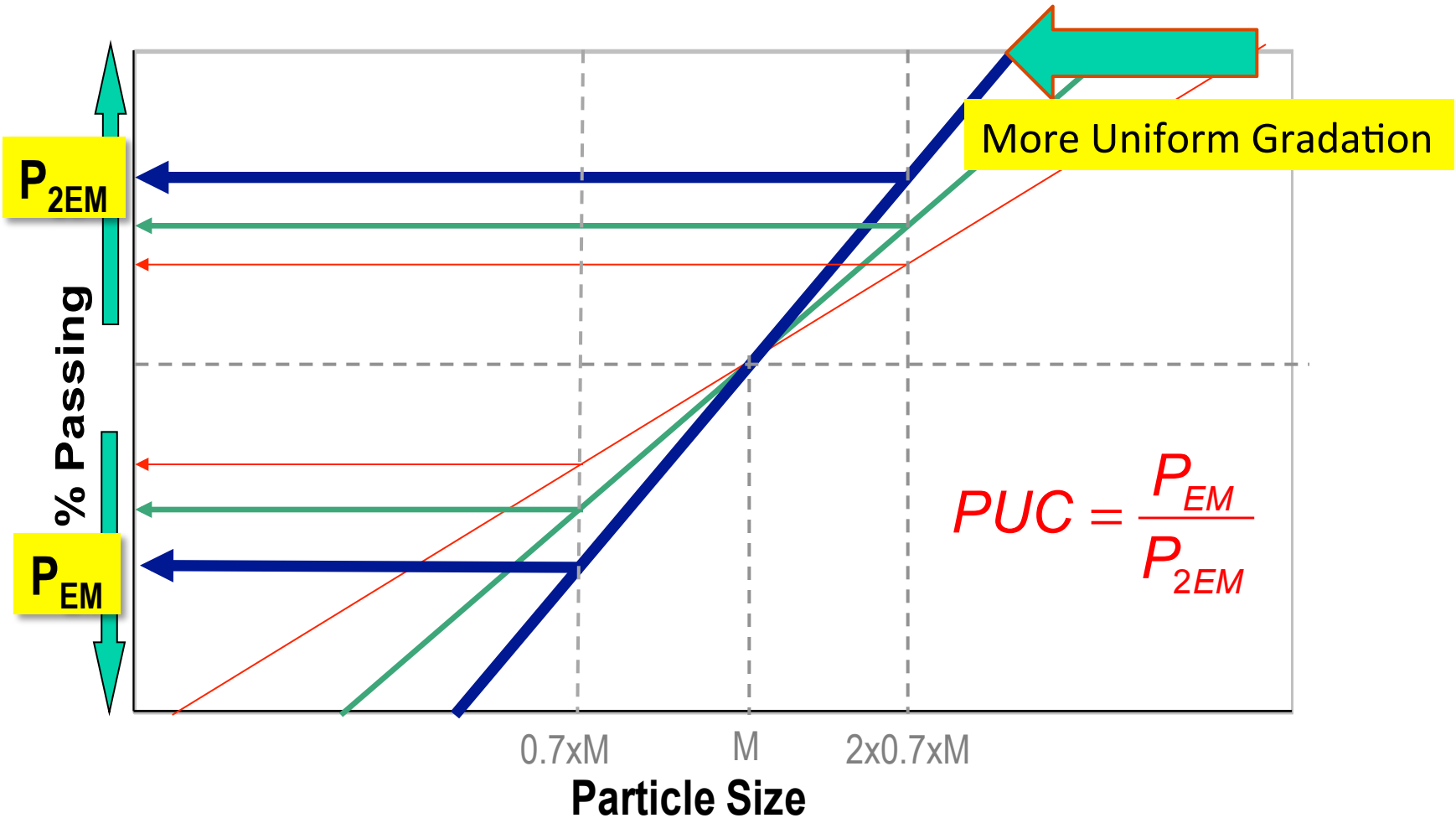
PERFORMANCE-RELATED UNIFORMITY COEFFICIENT (PUC) FOR AGGREGATE GRADATION

McLeod's Failure Criteria

- Embedment depth (E)
  - ✓ E = Median particle size (M) x (0.65~0.85)
- Bleeding
  - ✓ Particle size < Embedment depth = 0.7 x M
- Aggregate loss
  - ✓ Particle size > 2 x Embedment depth = 1.4 x M



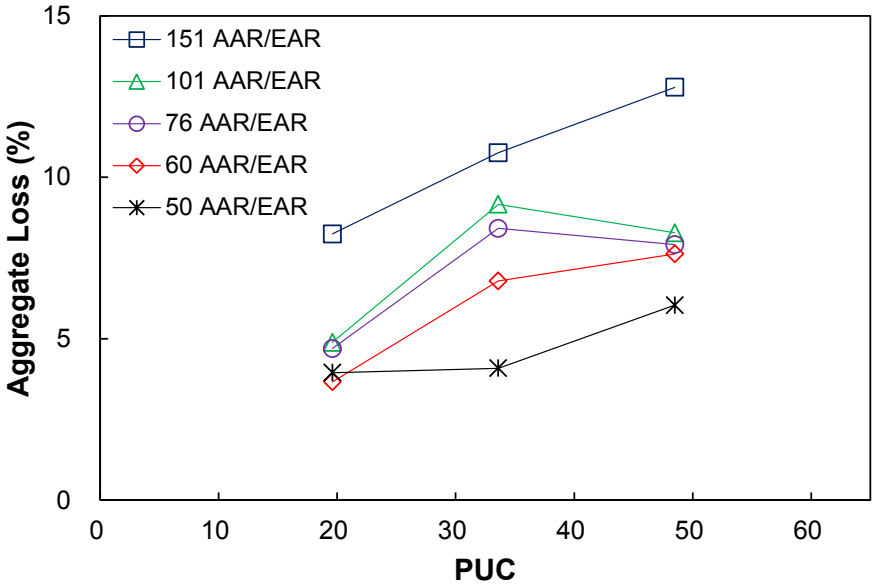
Effect of Gradation on Performance

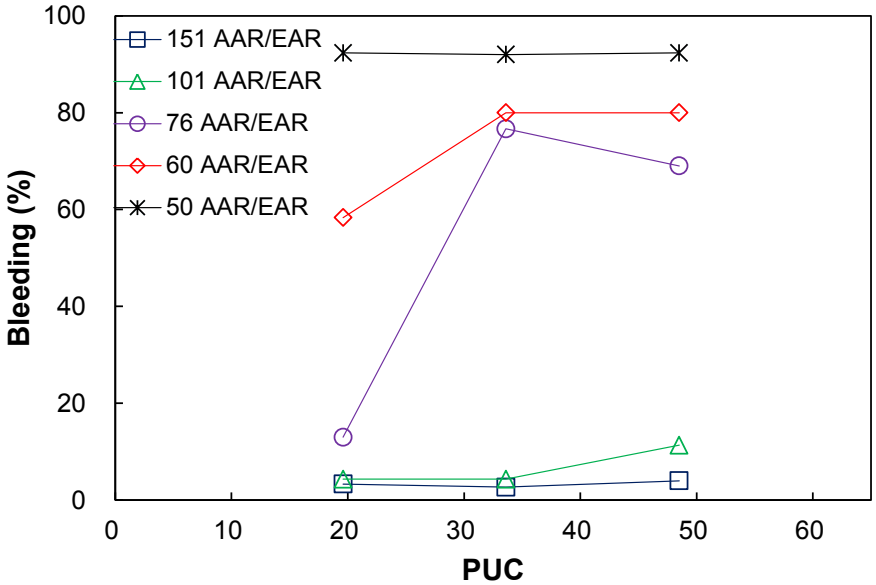


- A more uniform gradation (i.e., lower PUC) yields less bleeding and less aggregate loss.

Effect of PUC on Performance

Granite 78M



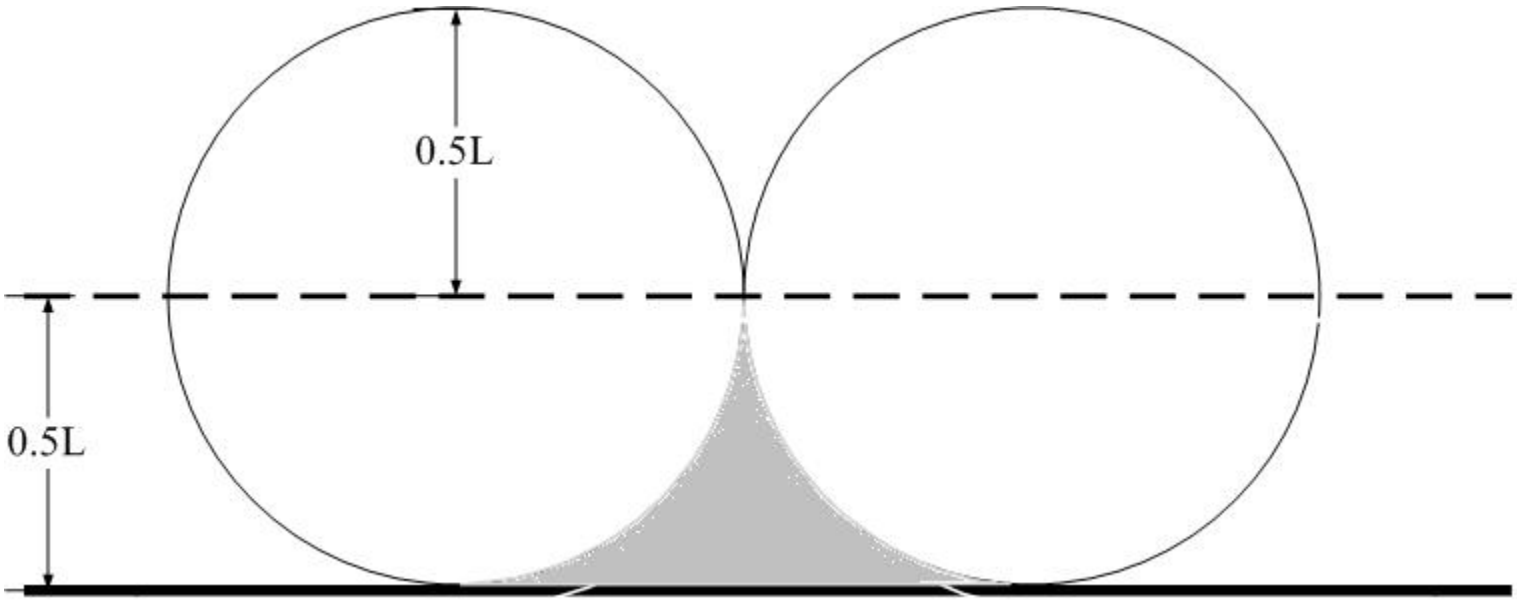


- Application Rate
  - AAR: 15.1 lb/yd^2
  - EARs: 0.10, 0.15, 0.20, 0.25, and 0.30 gal/yd^2

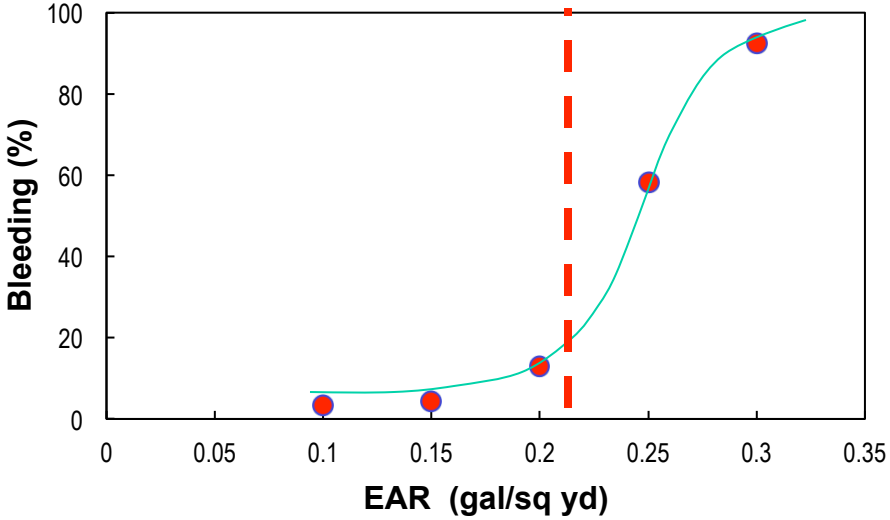
PERFORMANCE-RELATED MIX DESIGN

50% Initial Embedment Concept

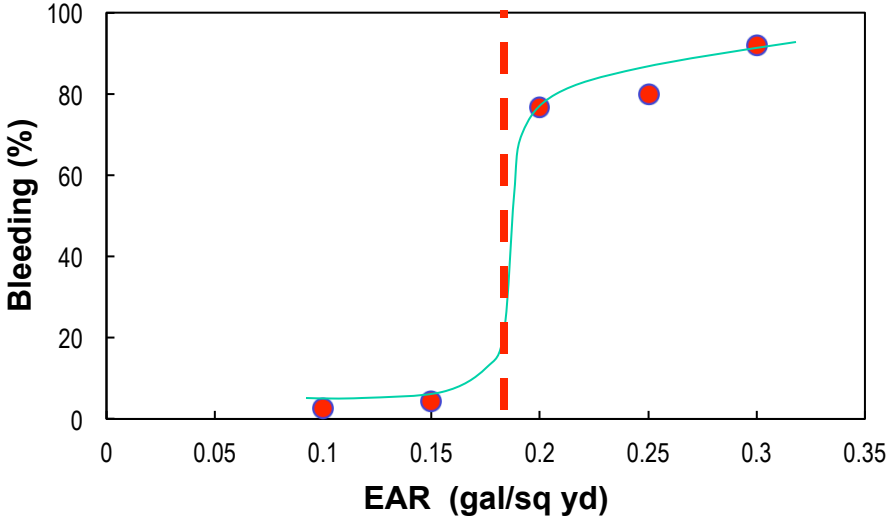
- Design to fill up subsurface voids (grey)
- Subsurface voids account for ~50% embedment



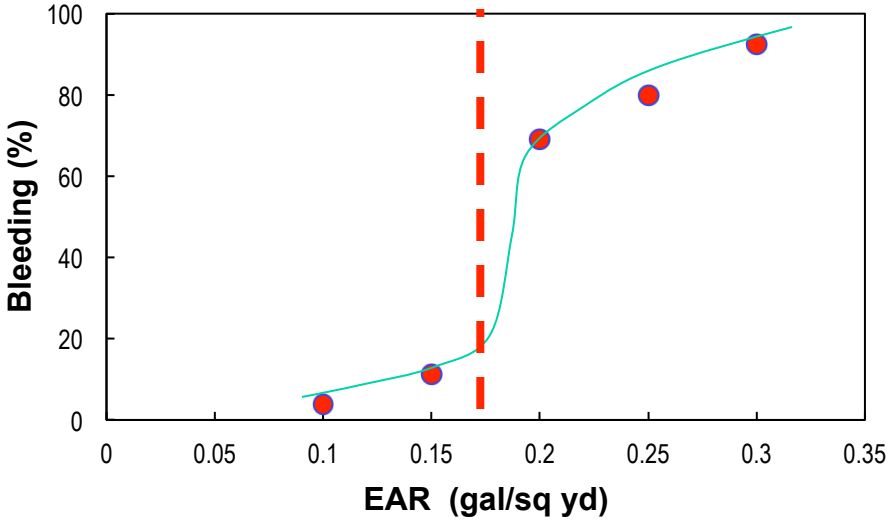
Gradation A



Gradation B

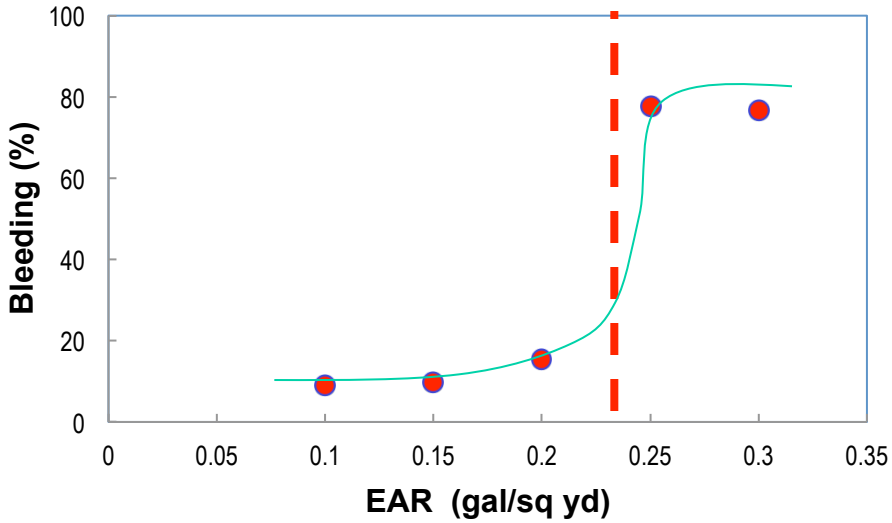


Granite 78M

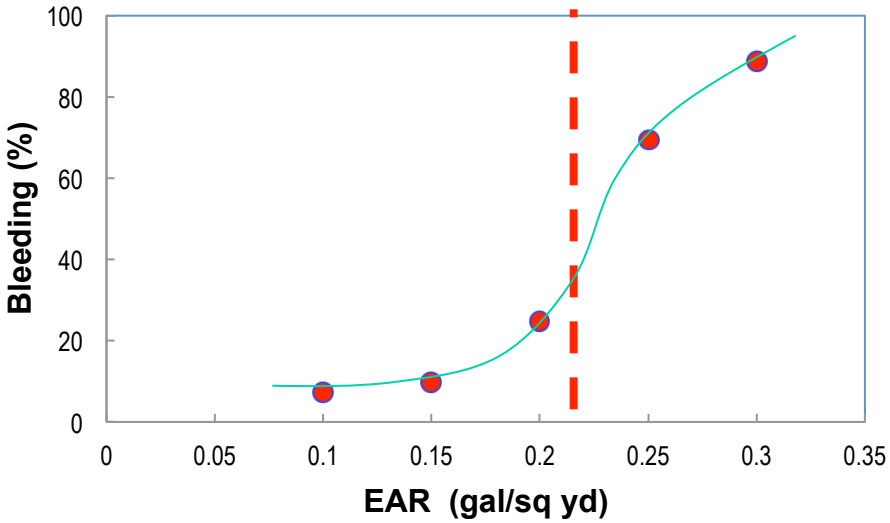


Gradation C

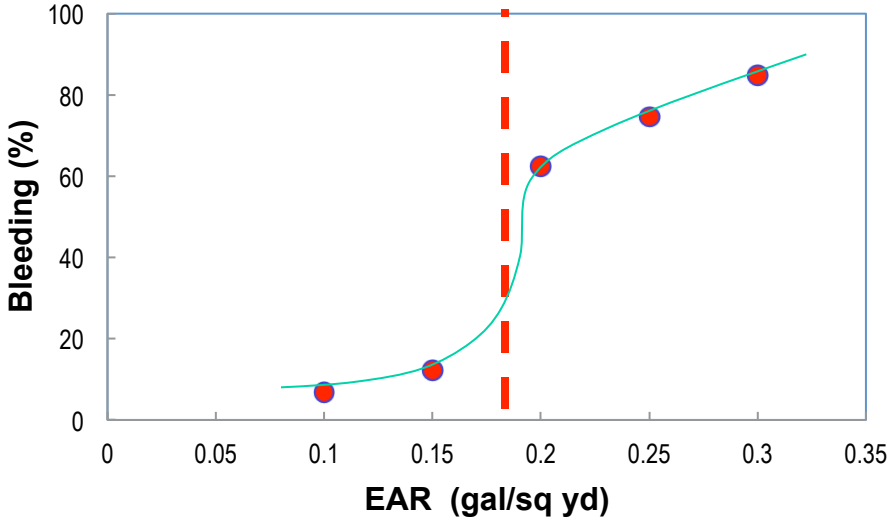
Gradation A



Gradation B



Light-weight



Gradation C

Rate Determination

- Modified board test for AAR
- Laser profilometer to determine the volume of subsurface voids and EAR

EMULSION PRS

Source: NCHRP Project 09-50

Emulsion PRS Framework

- Materials are considered in two phases:
  - Fresh emulsion
  - Residue
- Propose test methods to address specific, common distresses in field
- Retain designation for emulsifier type and set rate
- Replace 1 vs. 2 viscosity designation with Performance Grade (PG)

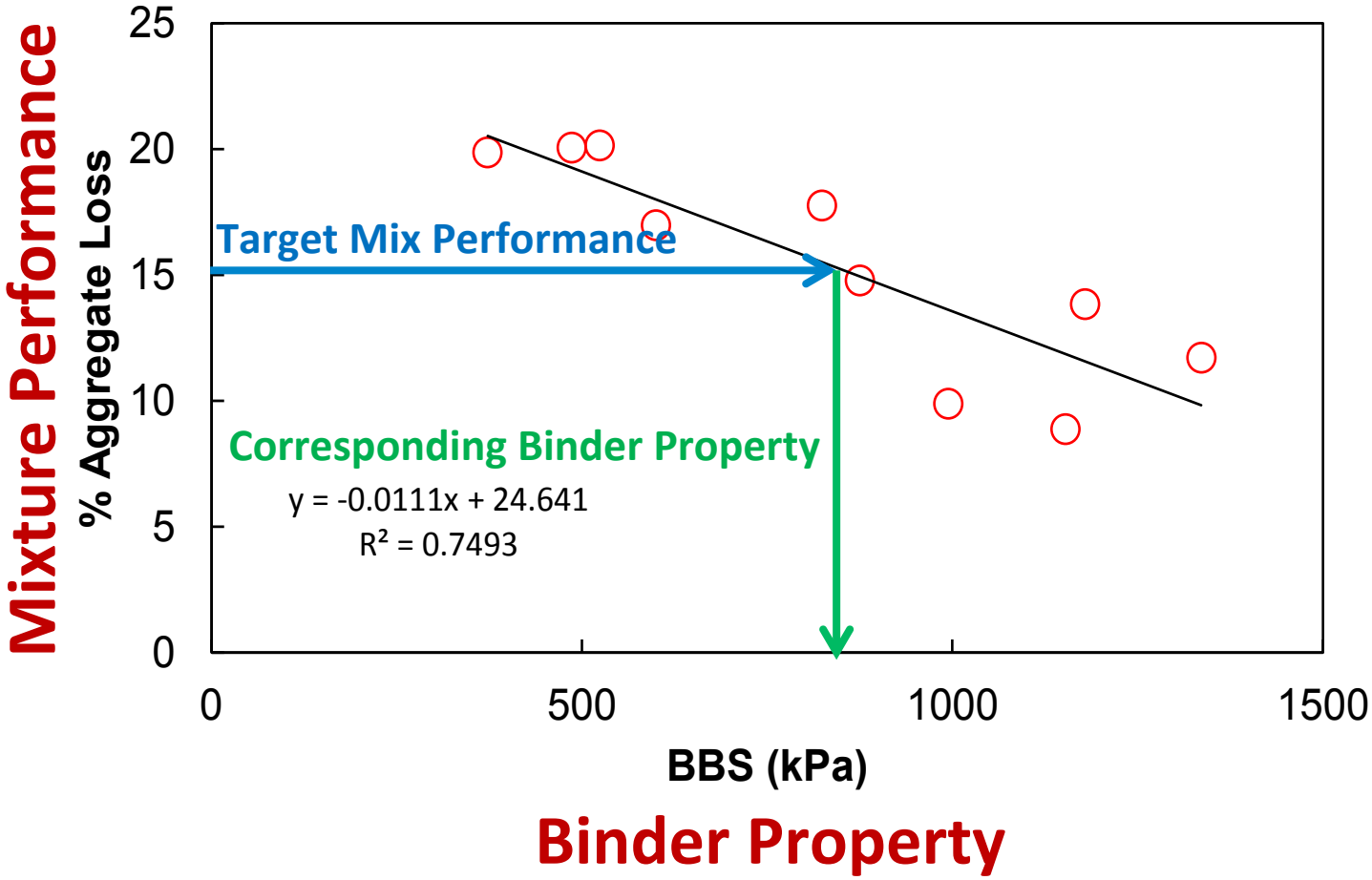
Source: NCHRP Project 09-50

Emulsion PRS Framework – Cont'd

- Introduce climatic considerations that are consistent with current binder PG spec
  - Test temperatures selected based on climate
    - ✓ Spec limits independent of test temperature
- Introduce traffic considerations by including different spec limits based on traffic designation
  - Low –> 0-500 AADT
  - Medium –> 501-2500 AADT
  - High –> Above 2500 AADT
- E.g., CRS-PG64-22M

Source: NCHRP Project 09-50

Underlying Concept for the PRS



Source: NCHRP Project 09-50

Final Emulsion Materials List

Chip Seal

- C-CRS-2 (A)
- C-CRS-2P (A)
- C-HFRS-2P (A)
- C-CRS-1-(B)
- C-CRS-1H-(B)
- C-RS-1-(B)
- C-CRS-2P/L (C)
- C-HFRS-2 (C)
- C-CRS-2 (E)
- C-CRS-2P (E)
- C-CRS-2P-HP(E)
- C-CRS-2 (F)
- C-CRS-2L (F)
- C-CRS-2 (NC)
- C-CRS-2L (NC)
- PP-C-CRS-2 (A)
- PP-C-HFRS-2 (C)
- PP- C-CRS-2P (E)

No. of Emulsions: 18

Microsurfacing

- M-CSS-1H (A)
- M-CSS-1H (B)
- M-CSS-1H (C)
- M-CSS-1HP (C)
- M-CSS-1HP (D)
- M-CQS-1H (E)
- M-CQS-1HP (E)
- M-CSS-1HL (F)
- M-CSS-1H (F)
- M-CSS-1HL-NC (field)
- PP-M-CSS-1H (F)
- PP-M-CSS-1HP (D)
- PP-M-CSS-1H (B)
- PP- M-CQS-1HP (E)

No. of Emulsions: 13

Spray Seal

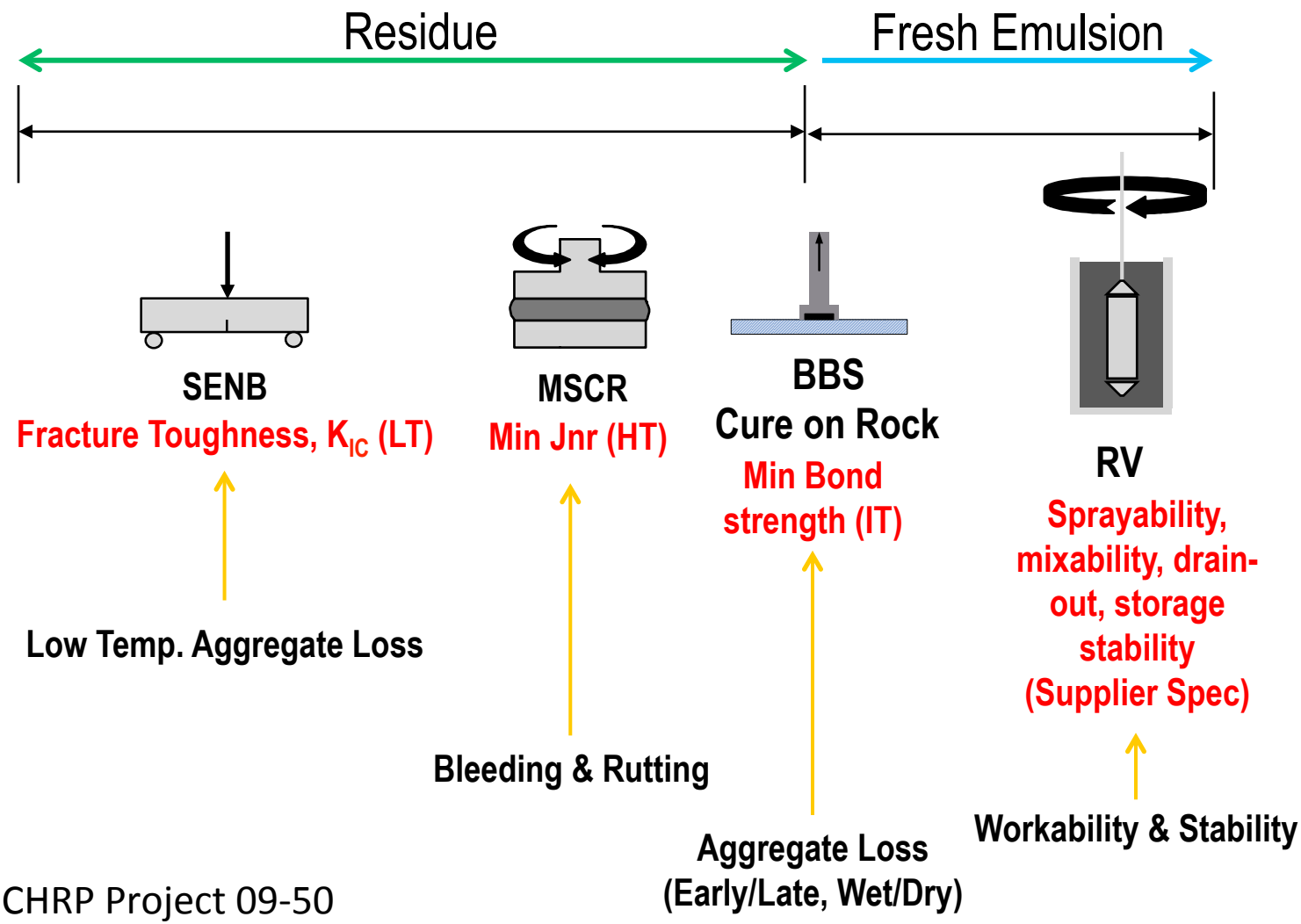
- F-CRS-2 (A)
- F-SS-1 (B)
- F-CSS-1 (B)
- F-Revive (E)
- F-SS-1H (E)
- F-CSS-1H (E)
- PP-F-CSS-1 (B)
- PP-F-CSS-1H (E)

No. of Emulsions: 8

Source: NCHRP Project 09-50

Proposed Specification Tests for Emulsions

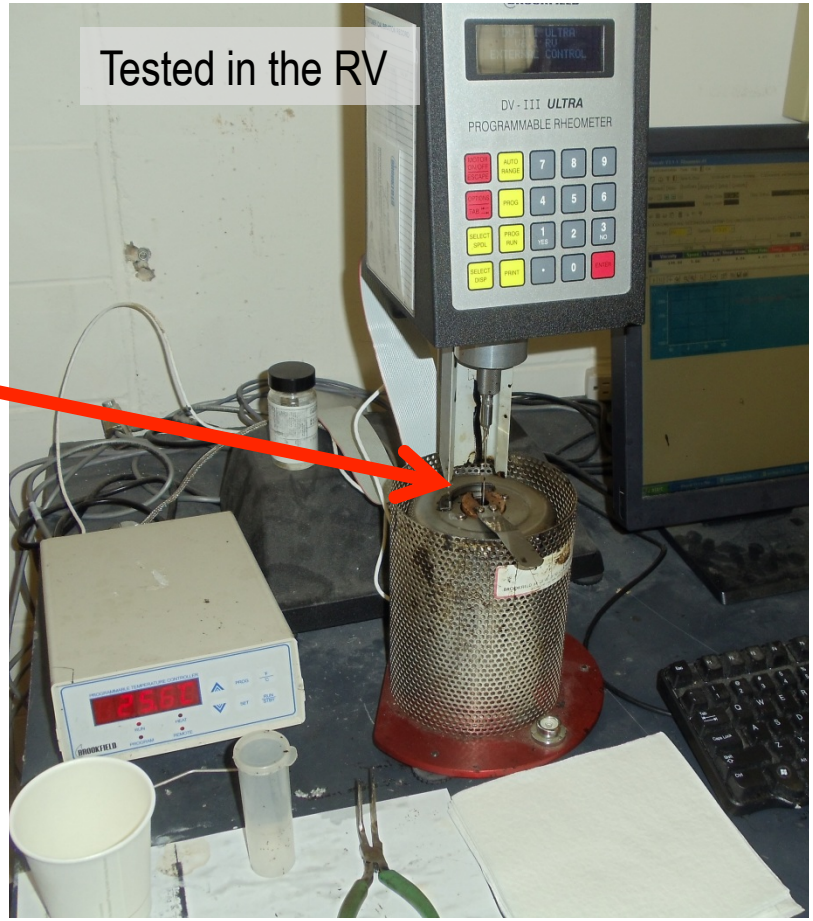
Chip Seals



Source: NCHRP Project 09-50

Storage Stability

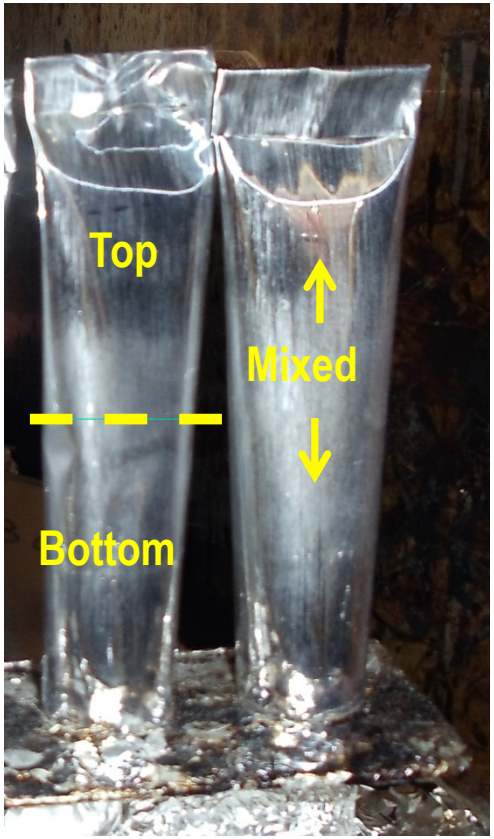
Fresh Emulsion



Source: NCHRP Project 09-50

Storage Stability

Fresh Emulsion

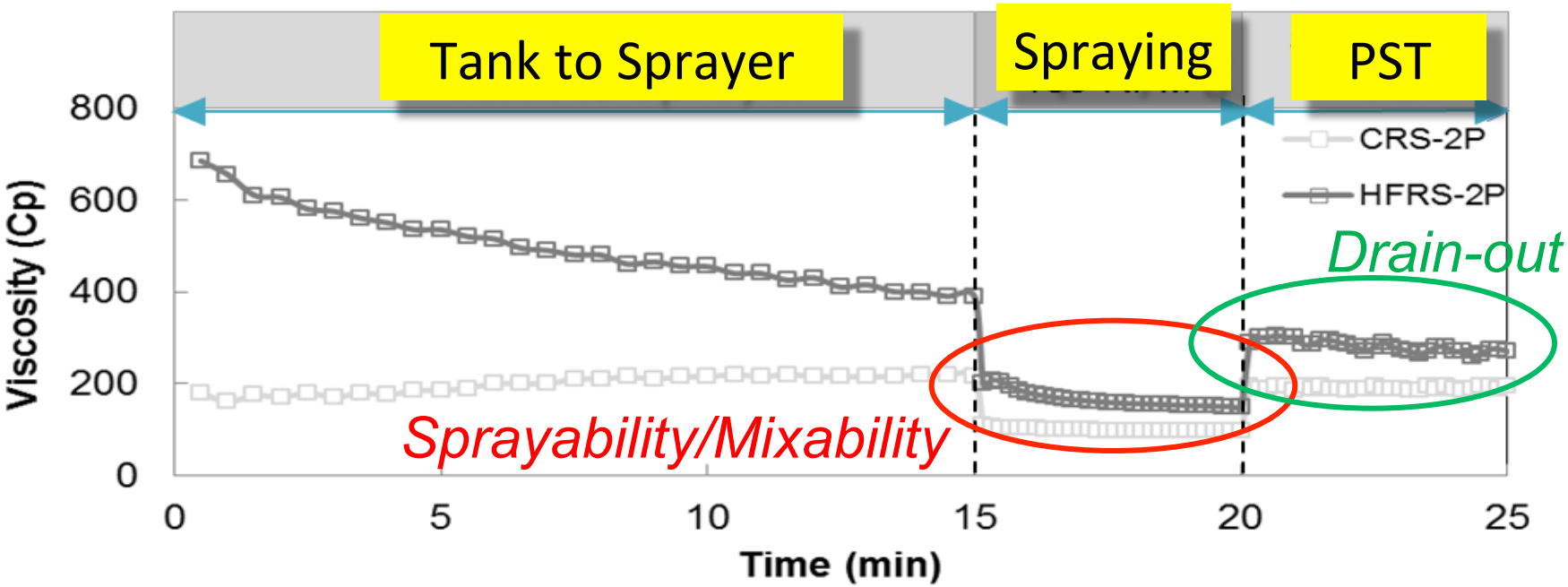


- Rotational Viscometer to measure:
  - Separation Ratio (Rs): η_{Top}/η_{Bottom}
    - ✓ Stability under sedimentation, creaming
  - Stability Ratio (Rd): $\eta_{Mixed}/\eta_{Reference}$
    - ✓ Potential for flocculation, coagulation

Source: NCHRP Project 09-50

Workability
Fresh Emulsion

- Rotational Viscometer
  - 3-step-shear test: Vary the shear rate to simulate spraying and drain-out potential

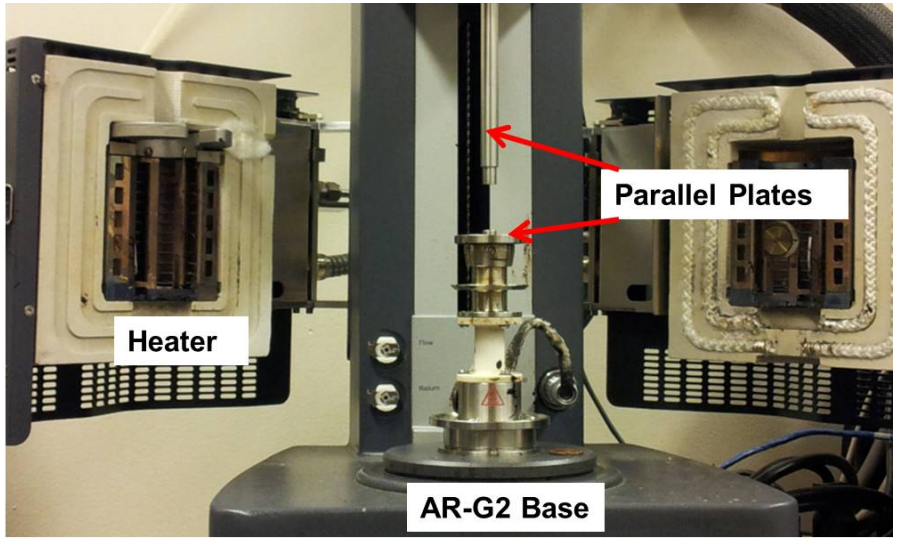


Source: NCHRP Project 09-50

Stiffness and Stress Relaxation

Residue

- Dynamic Shear Rheometer (DSR)
  - High temperature: Jnr from Multiple Stress Creep and Recovery (MSCR) test (25 mm plate)

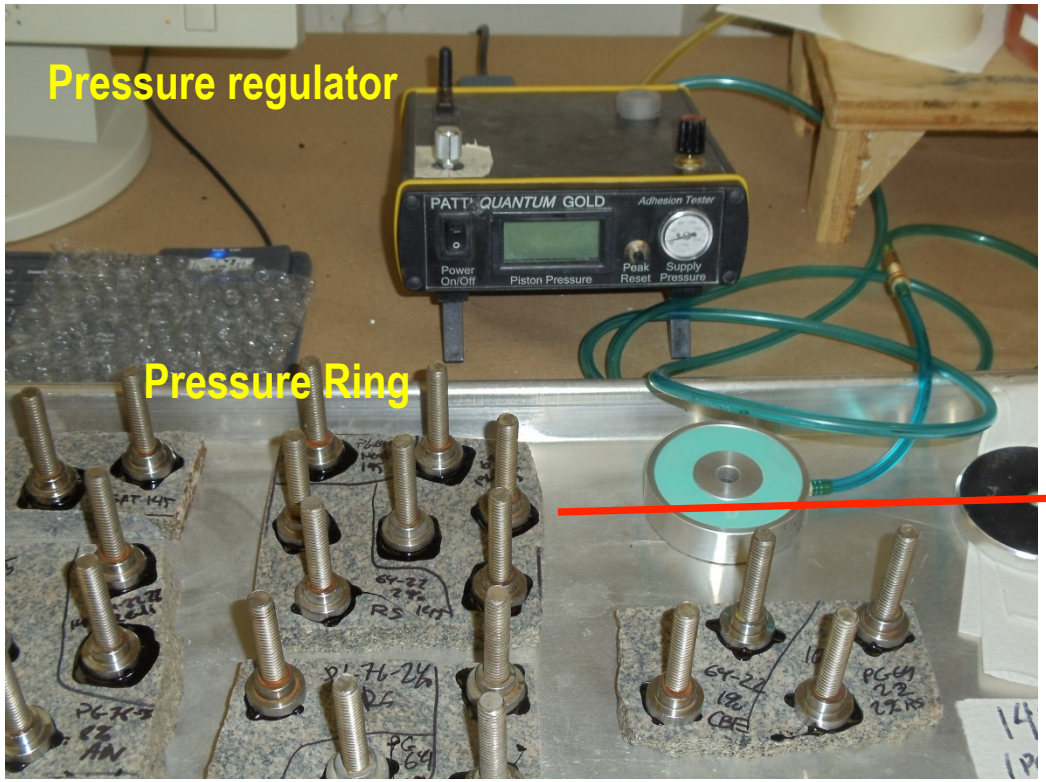


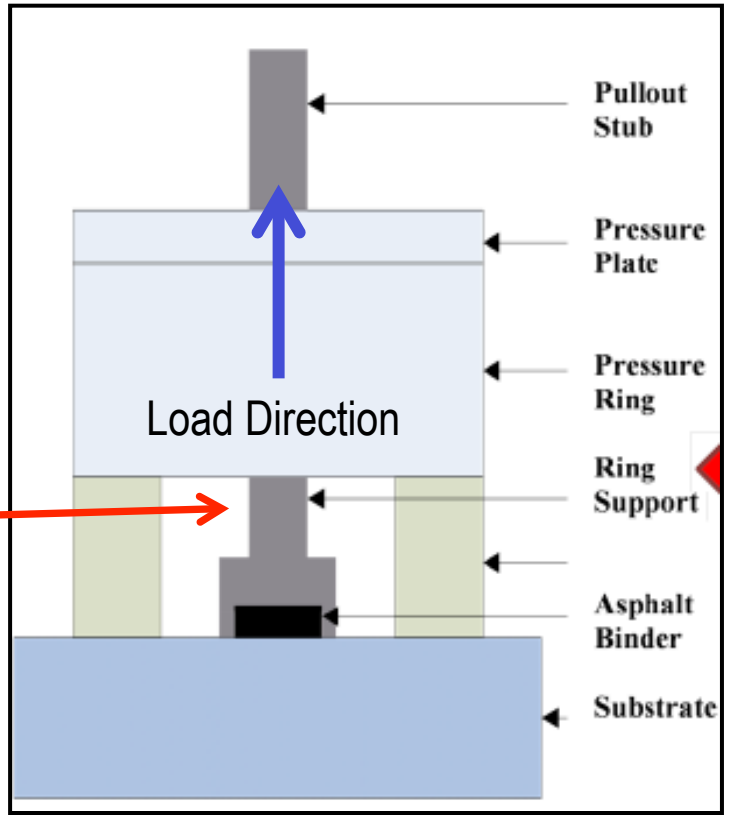
Source: NCHRP Project 09-50

Resistance to Raveling

Residue

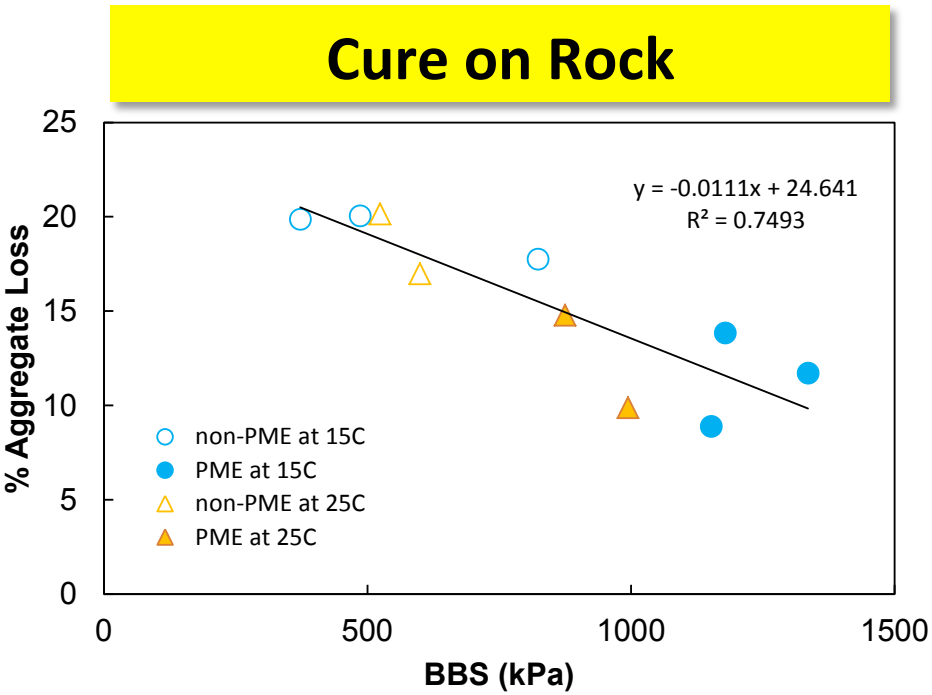
- Bitumen Bond Strength (BBS) Test

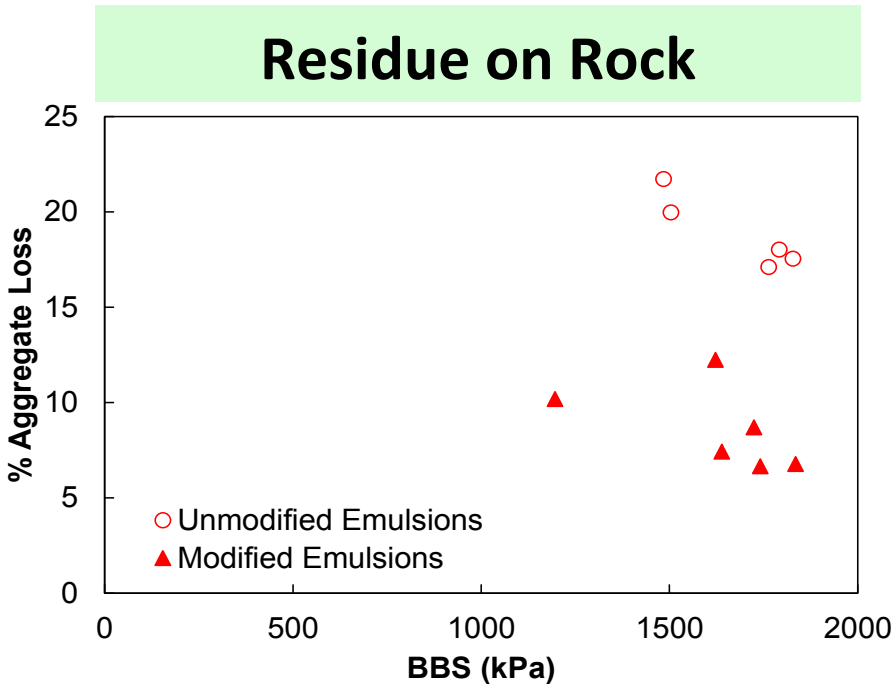




Source: NCHRP Project 09-50

Sample Preparation for BBS Test

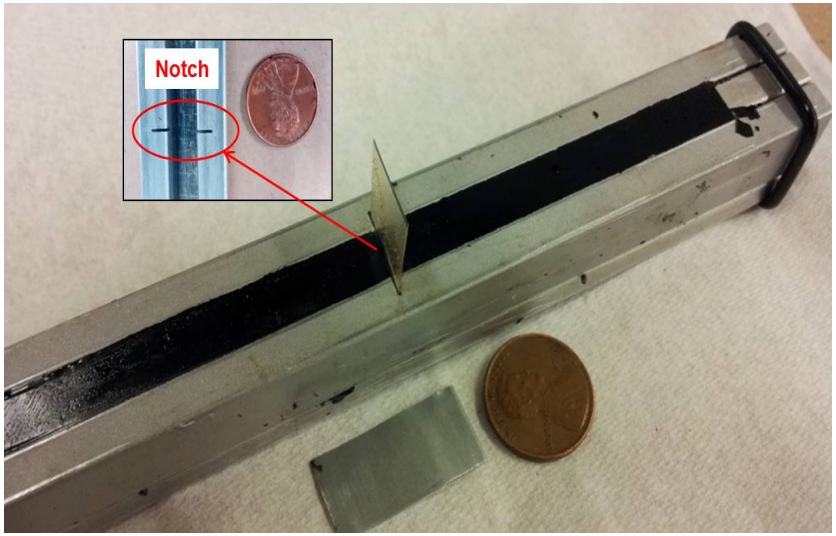


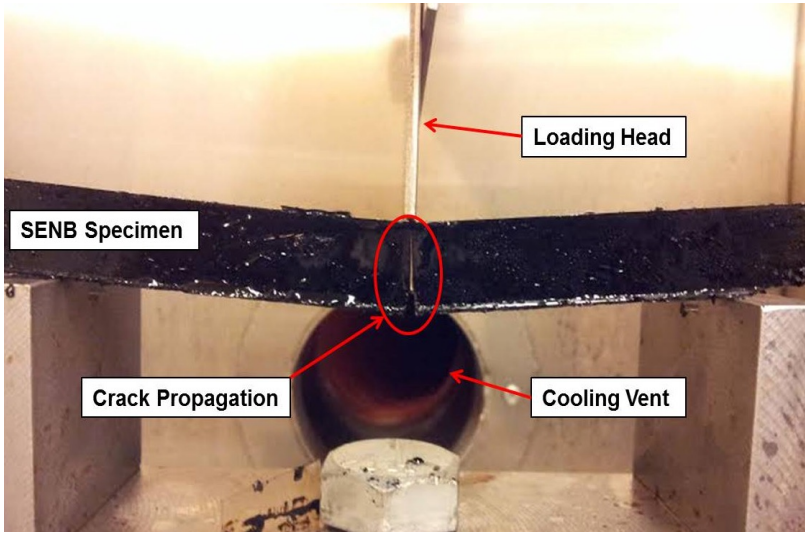


Source: NCHRP Project 09-50

Low Temperature Agg. Loss

- Single Edge Notched Beam (SENB) Test
  - Fracture toughness (K_{IC}) measured at **0.1 mm/s loading rate** at the low temperature grade





Source: NCHRP Project 09-50

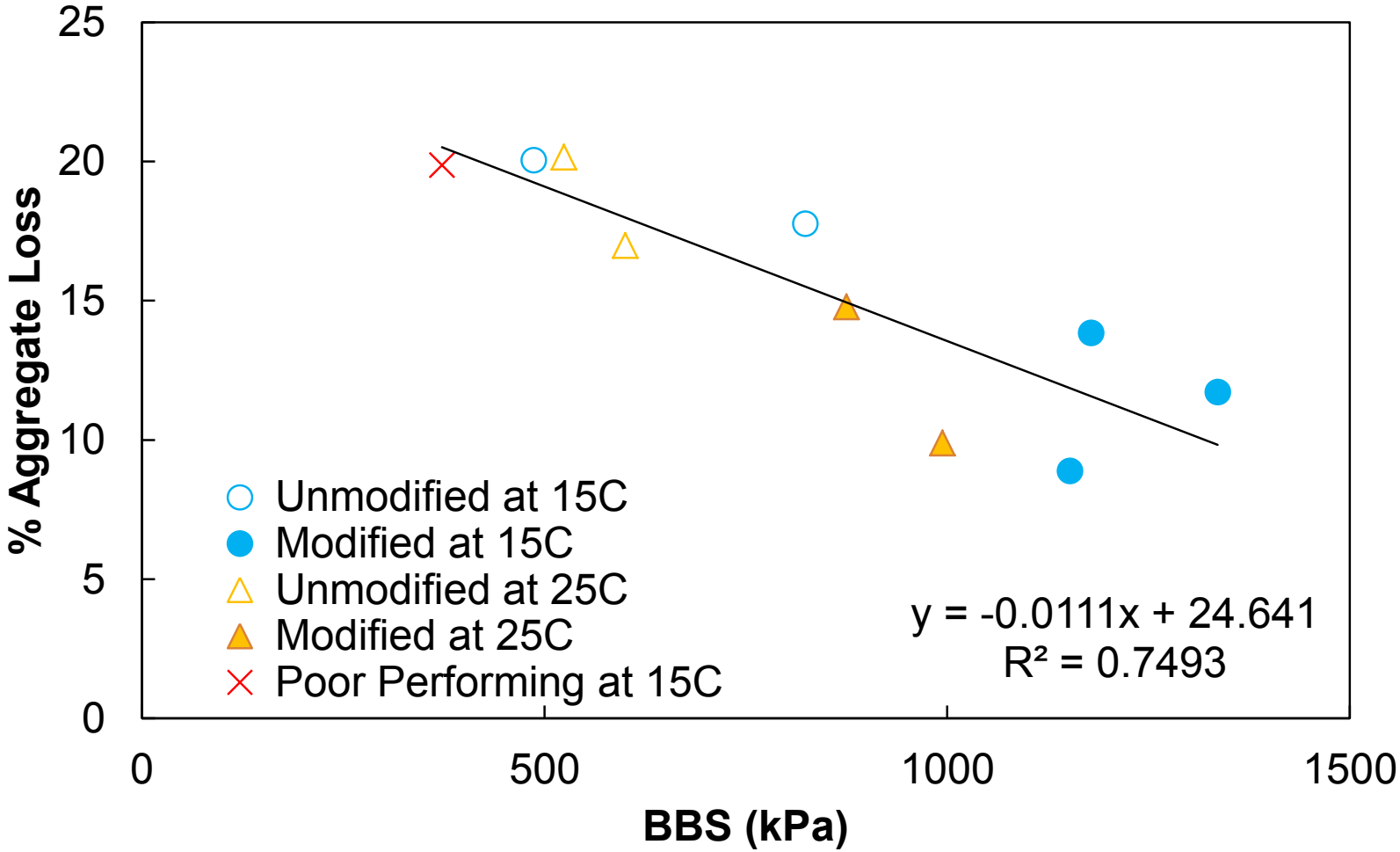
Specification Development

Raveling Performance at Intermediate Temperature

Source: NCHRP Project 09-50

Vialit Aggregate Loss vs. BBS

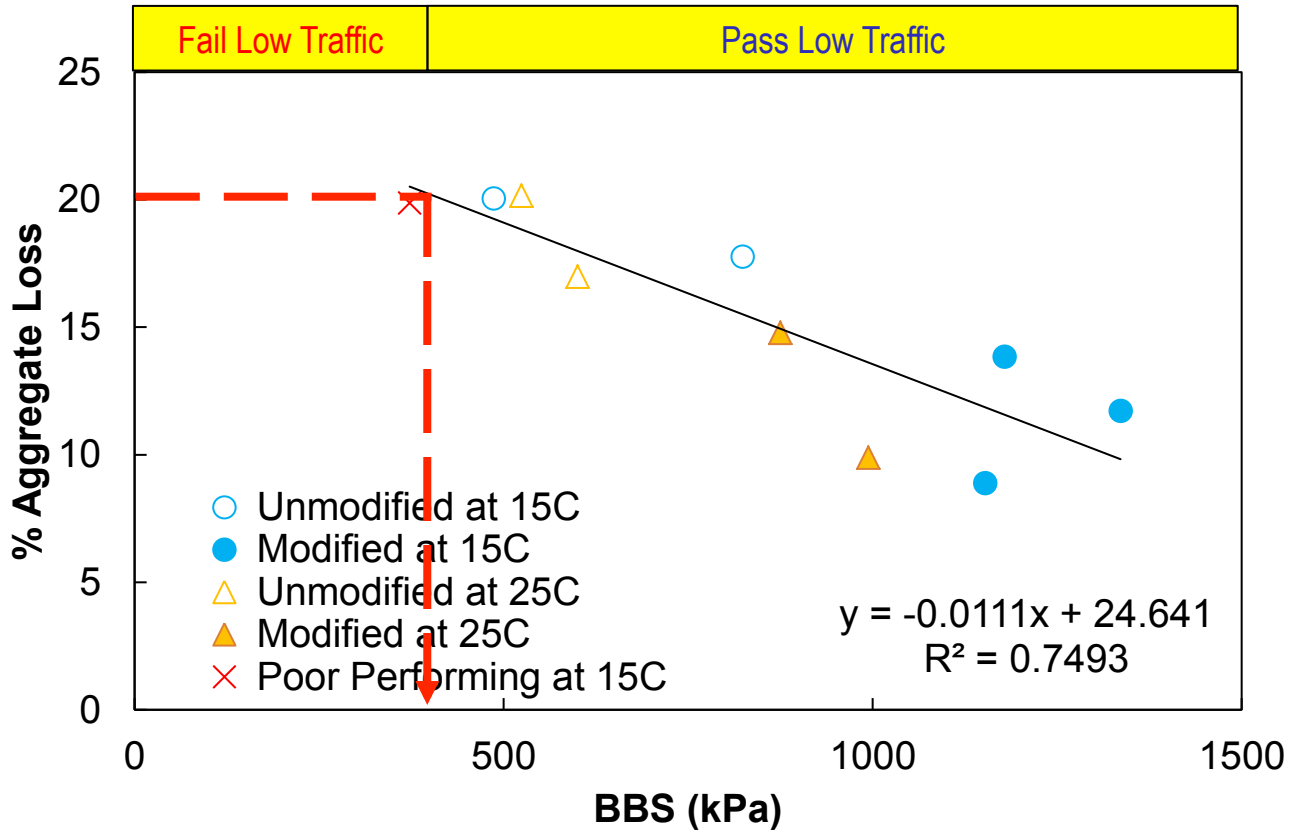
20 Hours Curing on Rock



Source: NCHRP Project 09-50

BBS vs. Aggregate Loss

Determination of Low Traffic Bond Strength Limit

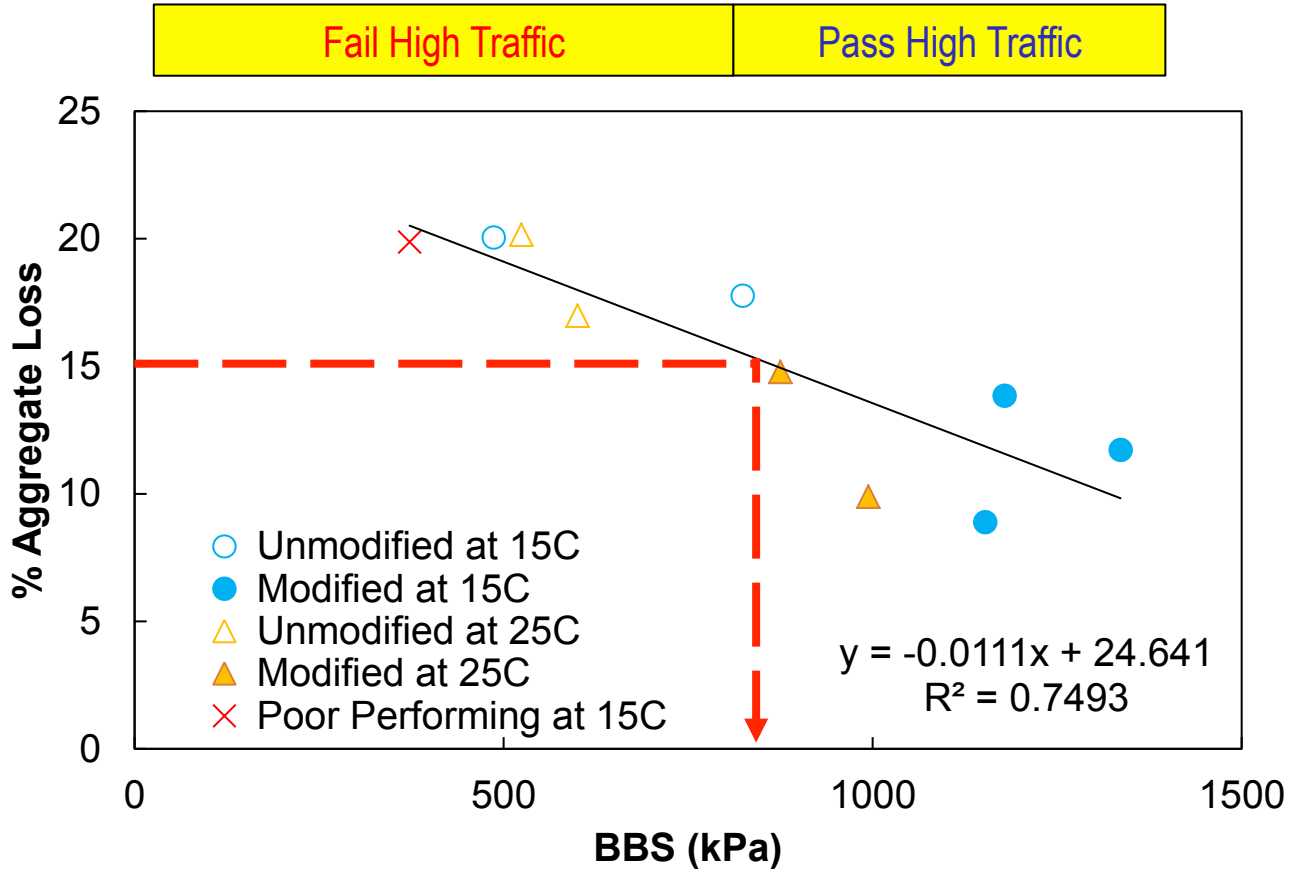


- Low traffic limit determined using 20% Vialit aggregate loss criterion => Min. Bond Strength = 400 kPa

Source: NCHRP Project 09-50

BBS vs. Aggregate Loss

Determination of High Traffic Bond Strength Limit

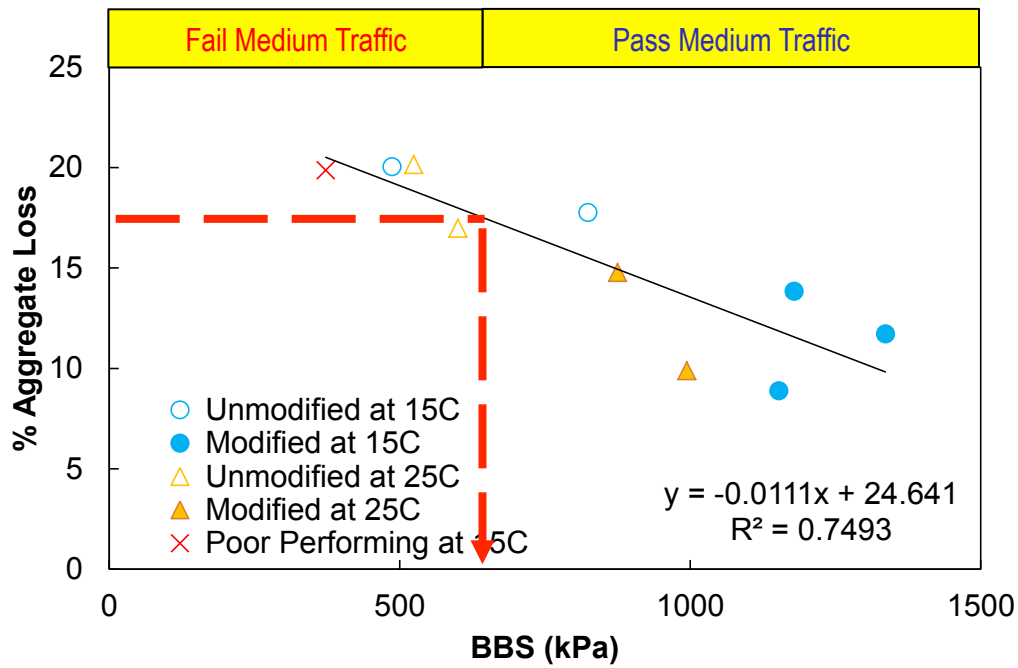


- Modified emulsions have proven to perform well in high traffic conditions.
- High traffic bond strength limit at 15% aggregate loss delineates between modified/unmodified binders => Min. Bond Strength = 800 kPa

Source: NCHRP Project 09-50

BBS vs. Aggregate Loss

Determination of Medium Traffic Bond Strength Limit



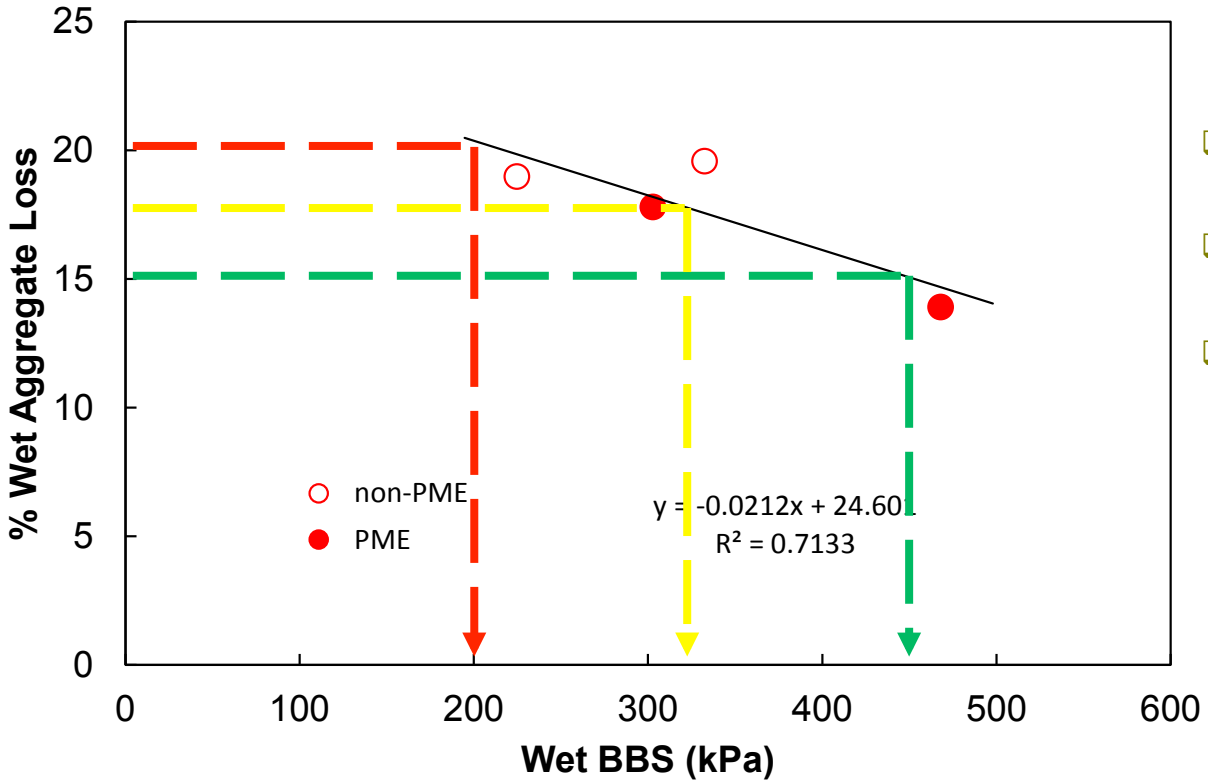
Specification Limit Summary

- **Low**: AADT < 500
  - Min. Bond Strength = 400 kPa
- **Medium**: 500 < AADT < 2500
  - Min. Bond Strength = 600 kPa
- **High**: AADT > 2500
  - Min. Bond Strength = 800 kPa

- Medium traffic limit based on average of high and low limits => Min. Bond Strength = 600 kPa

Source: NCHRP Project 09-50

Wet Raveling Specification Limit



Traffic Classes

- **Low Traffic**: AADT < 500
  - Min. Bond Strength = 200 kPa
- **Medium Traffic**: 500<AADT<2500
  - Min. Bond Strength = 325 kPa
- **High Traffic**: AADT > 2500
  - Min. Bond Strength = 450 kPa

Source: NCHRP Project 09-50

Proposed Fresh Emulsion Specification

Performance Parameter	Temperature (°C)	Specified Limit
Separation Ratio	60	0.5 to 1.5
Stability Ratio		Maximum 2
Sprayability		Maximum 400 cP
Drainout		Minimum 50 cP

Source: NCHRP Project 09-50

Proposed Chip Seal Emulsion Specification

Distress Type	Temperature Range	Performance Parameter	Traffic Level	Specified Limit
Bleeding	High	MSCR Jnr	Low	Max Jnr: 8
			Medium	Max Jnr: 5.25
			High	Max Jnr: 3.25
Late Raveling	Intermediate	Bond Strength	Low	Min. Bond Strength: 400
			Medium	Min. Bond Strength: 600
			High	Min. Bond Strength: 800
Early Raveling	Intermediate	Bond Strength	Low	Min. Bond Strength: 200
			Medium	Min. Bond Strength: 250
			High	Min. Bond Strength: 300
Wet Raveling	Intermediate	Wet Bond Strength	Low	Min. Bond Strength: 200
			Medium	Min. Bond Strength: 325
			High	Min. Bond Strength: 450
Low Temperature Raveling	Low	Fracture Toughness, K_{IC}	N/A	Min K_{IC}: 1 MPa$\sqrt{mm}$

Source: NCHRP Project 09-50

Well-Performing Chip Seals

- **Performance-related** Uniformity Coefficient (PUC) for aggregate gradation
- **Performance-related** specifications for emulsions
- **Performance-related** mix design for AAR and EAR

Thank you!