Performance Based Specification for High RAP Mixes in Cold Climates

Andrew Hanz – MTE Services Inc.
Ervin Dukatz – Mathy Construction
Gerald Reinke – MTE Services Inc.

Northeast Asphalt User Producer Group Meeting
October 21, 2015

Acknowledgements

- MTE Staff
  - Steve Engber, Doug Herlitzka, Alex Engstler
- WisDOT High RAM Committee
  - Chaired by Barry Paye, WisDOT and Deb Schwerman, WAPA

WisDOT High Recycle Pilot Program

- Proposed to WisDOT management by industry in winter of 2013.
  - Pavement Sustainability
  - Economic Benefits
- Specification was developed for 2014 construction season and modified for 2015.
  - Includes performance tests and mix design changes.
- 4 projects let. Two were constructed in 2014, two in 2015.

High RAM SPV Mix Design Changes

Maximum % Binder Replacement (PBR)

Material	Lower Lift	Upper Lift*
RAS	25	20
RAM (max 5% RAS by wt. of agg.)	50	40

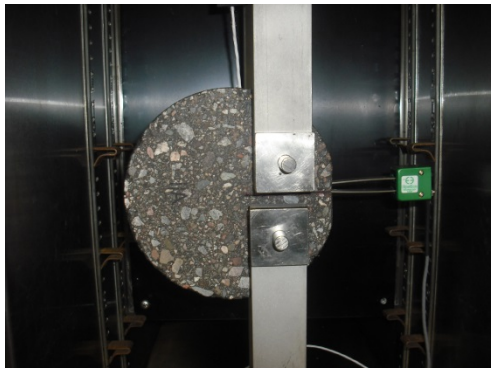
* Reduce upper and lower plan PG grade by one grade for PBR >25% (i.e. PG 58-28 becomes PG 52-34)

Mix Design and QC

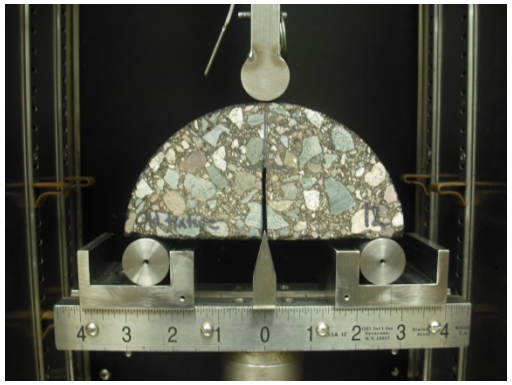
- Design Air Voids decreased from 4.0% to 3.5%
- TSR increased from 0.70 to 0.75
- Increase maximum Dust to Binder Ratio to 1.6
- Add daily monitoring of asphalt content via extraction.

WisDOT SPV - Selected Performance Tests

Thermal Cracking
DC(t)



Fatigue
Semi-Circular Bend



Rutting
Hamburg

LT (-18 or -24°C) IT (25°C) HT (50°C)

Long Term Aging – AASHTO R30 (5 days at 85°C)

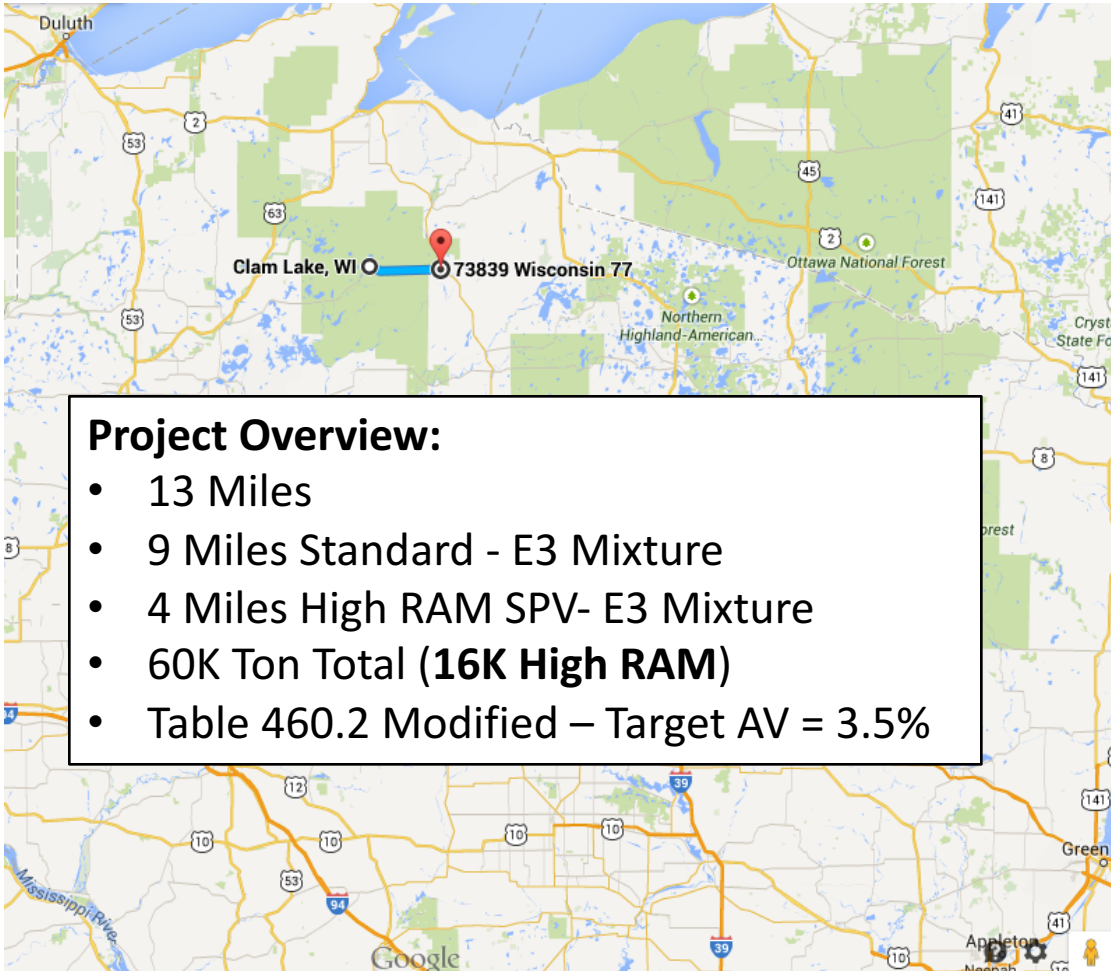
- SCB and DCT
- Recovered binder grade and ΔTc

Testing Requirements

- Timing of submittals
  - Preliminary: Mix Design and Test Strip
  - Construction: 1st 600 ton and every 10k ton after.
- Logistical Challenges
  - Agency approval of mix design and test strip results required.
  - Minimum time lag between test strip and construction ~ 10 days.

STH 77 Project Overview

- Design High PBR Mixes Using RAP
- Meet or exceed performance of standard mix
- Meet performance testing requirements for rutting, fatigue, and thermal cracking.



Pavement Section Details

Location: Ashland County - Clam Lake to STH 13

- Standard Mix ~ 9.5 miles
  - 3” pavement depth
  - 1.25” Leveling Layer 12.5mm E3 PG 58-34
  - 1.75” Upper Layer 12.5mm E3 PG 58-34
- High Recycle Length – 4.08 miles (West End)
  - 4” total pavement depth
  - 2.25” Lower Layer 19mm E3 High Recycle
  - 1.75” Upper Layer 12.5mm E3 High Recycle
- Constructed in August/Sept of 2014.

Approach to Project

Materials Selection and Mix Design

1. Characterize RAP	• Obtain millings from project. • Extract/RAM binder and determine true PG.
2. Determine Binder Properties	• Apply Blending Charts: Target PG 58-34. • Virgin Grade Binder: PG 52-40, -40 grade made with bio-derived oil.
3. Volumetric Mix Design	• Same process as conventional mix design. • Target AV is 3.5% for high RAM.

Approach to Project

Performance Testing

4. Verify Binder Properties

- In mix design compact pill to 6.5% AV
- 5 Days Aging at 85°C, extract and recover binder.
- Target is PG 58-34, ΔTc > -5.0°C

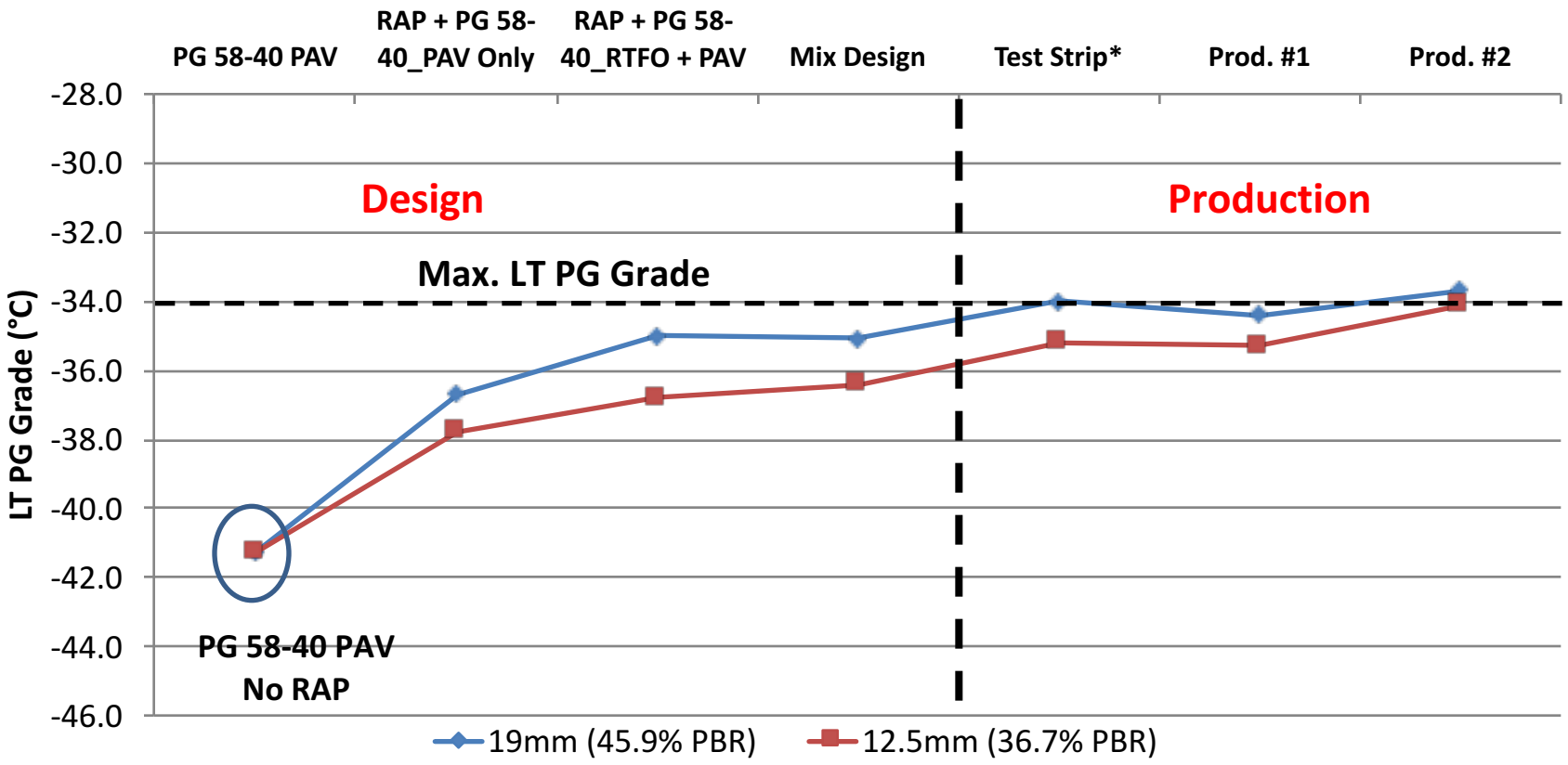
5. Evaluate Hamburg

- Base Binder (Plan) = PG 52-40, also SPV air voids result in higher total binder content.
- Modify binder to PG 58-40 to improve Hamburg results.

6. Cracking Resistance

- 5 Days Aging at 85°C – Compacted Mixture
- Mixture: SCB @ 25°C, DCT @ -24°C, Fracture Energy > 400 J/m^2

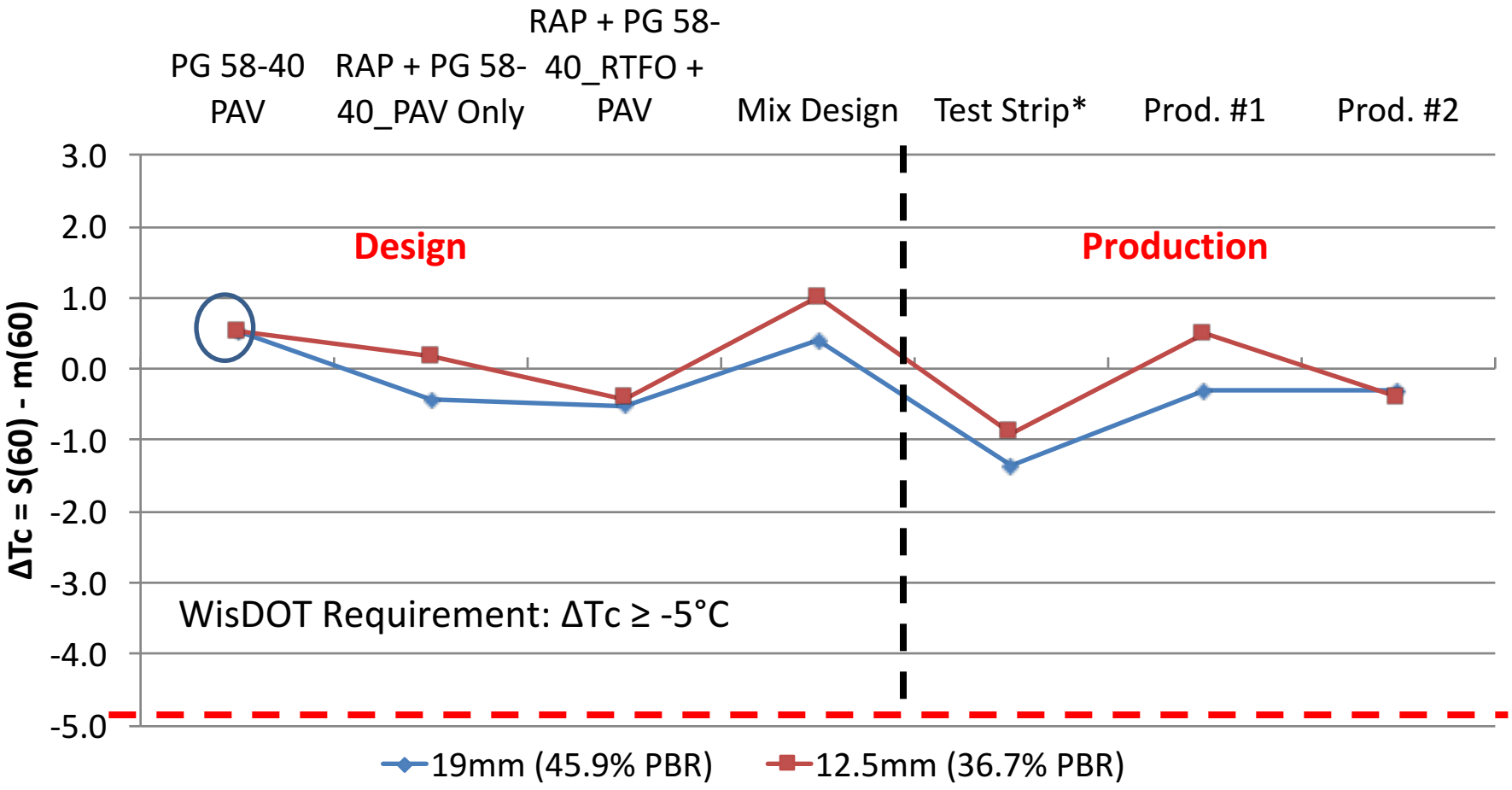
Results – Recovered LT PG



Lab Blends for Initial Formulation

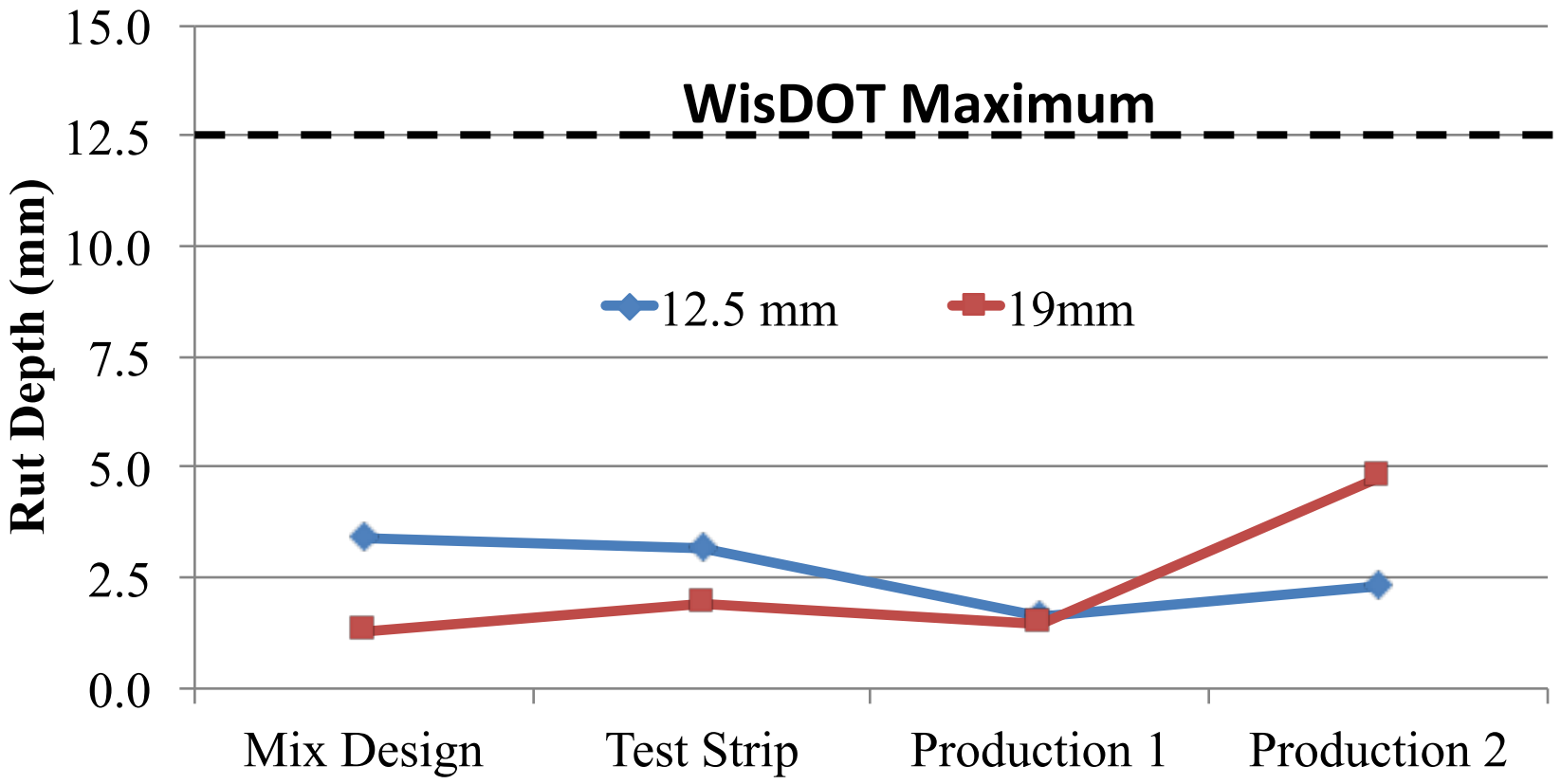
- 19.0mm: 60% PG 58-40 + 40% RAP from STH 77
- 12.5mm: 70% PG 58-40 + 30% RAP from STH 77

Results – Recovered Binder ΔTc



Mix Performance Results

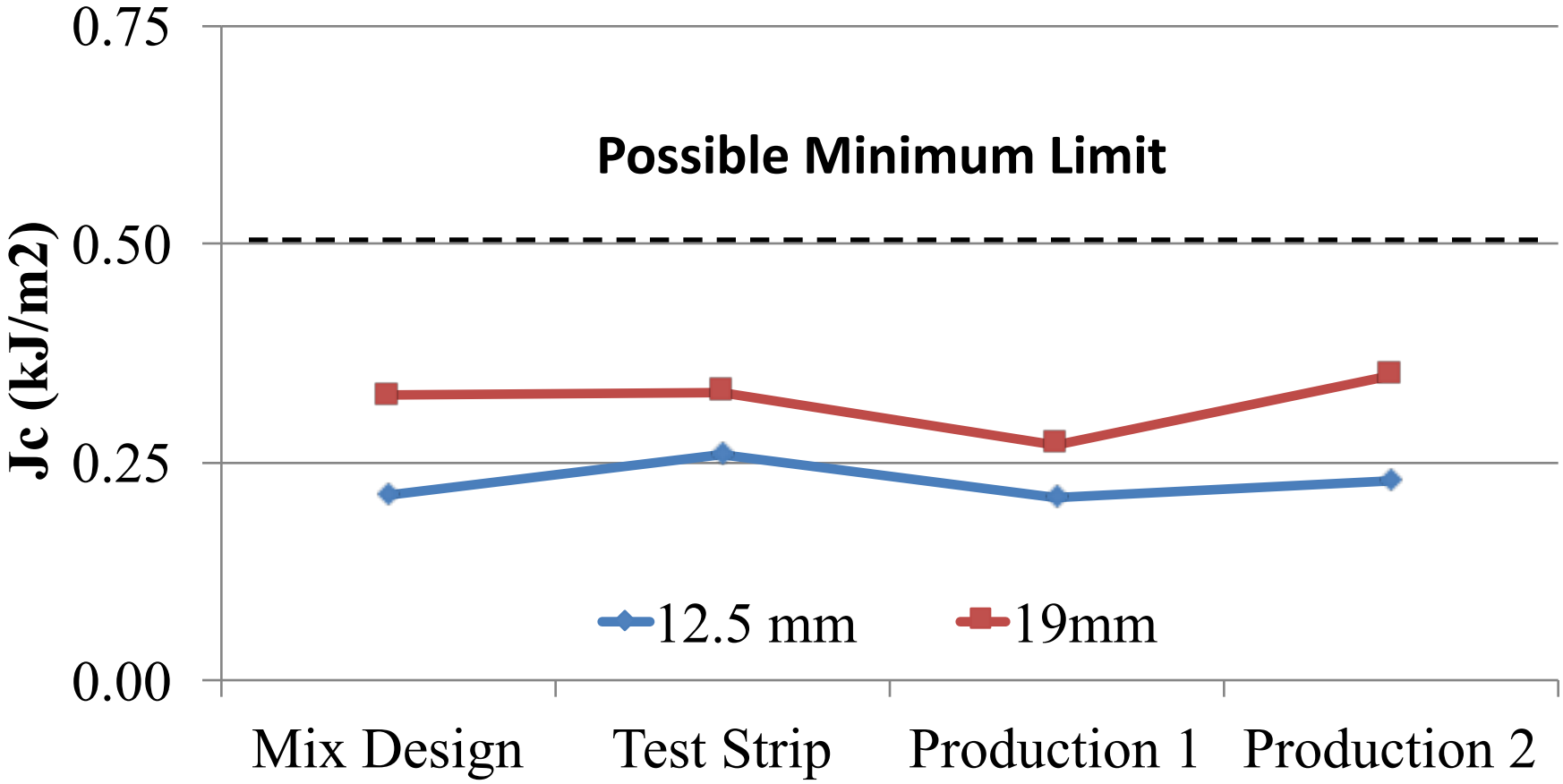
Hamburg at 50°C



Rut Depth at 5000 passes.

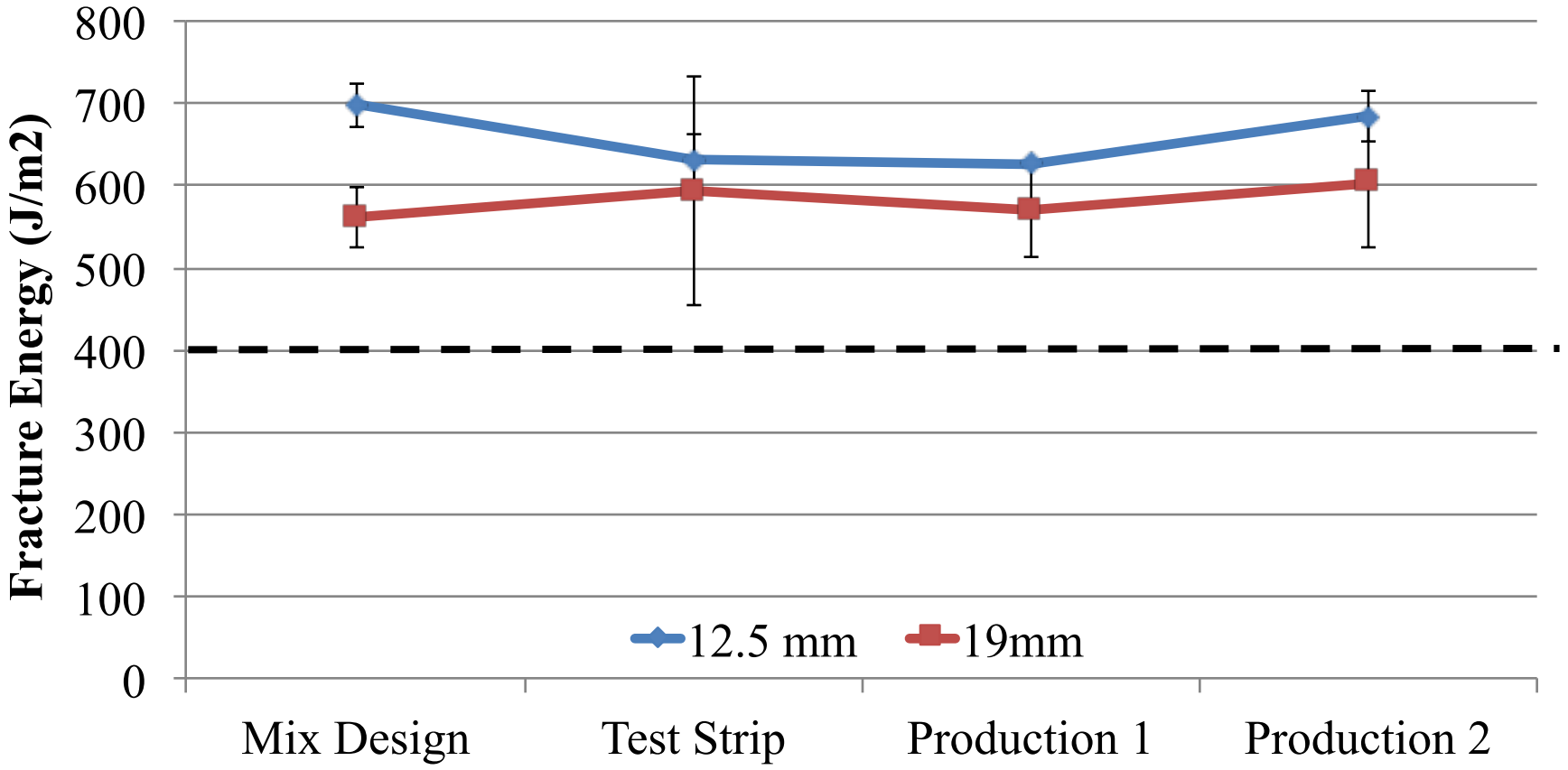
Mix Performance Results

SCB @ 25°C



Mix Performance Results

DCT @ -24°C

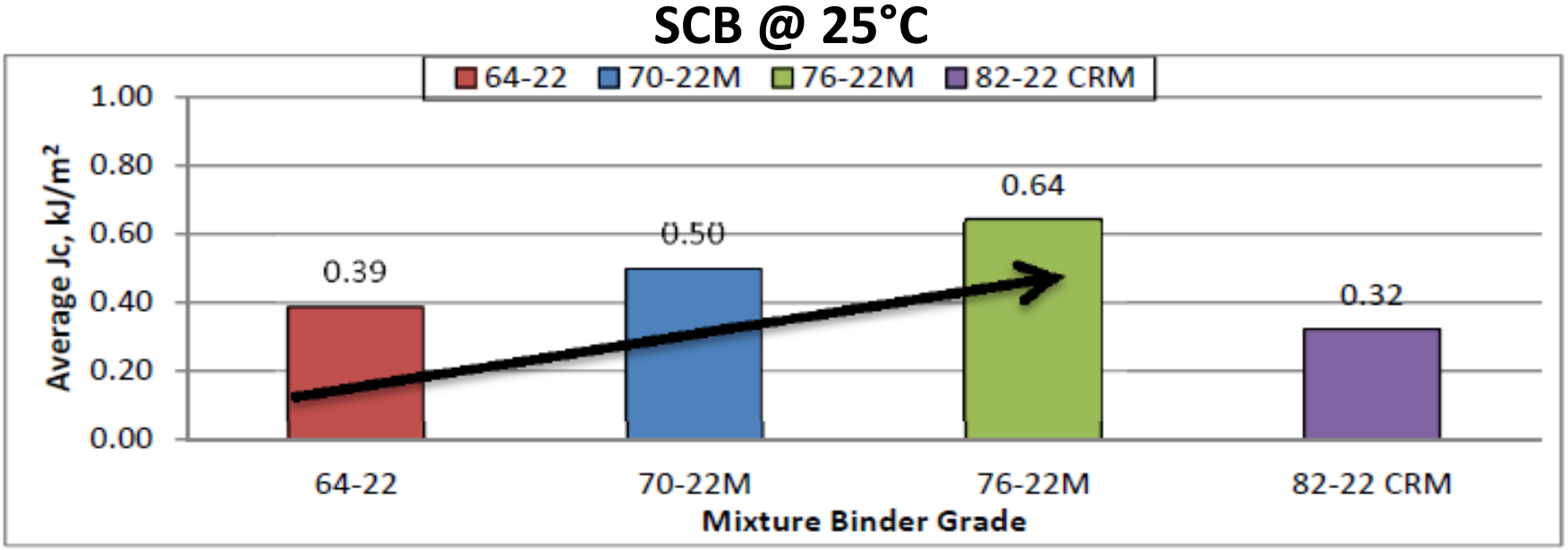


Points for Discussion

1. SCB Test Temperature Selection
   - Constant or based on climate?
2. Alternative Long Term Aging Methods
   - Loose mix aging at 12 to 24 hrs.
3. Comparison to the Control
   - Focus on recovered binder properties and cracking tests.

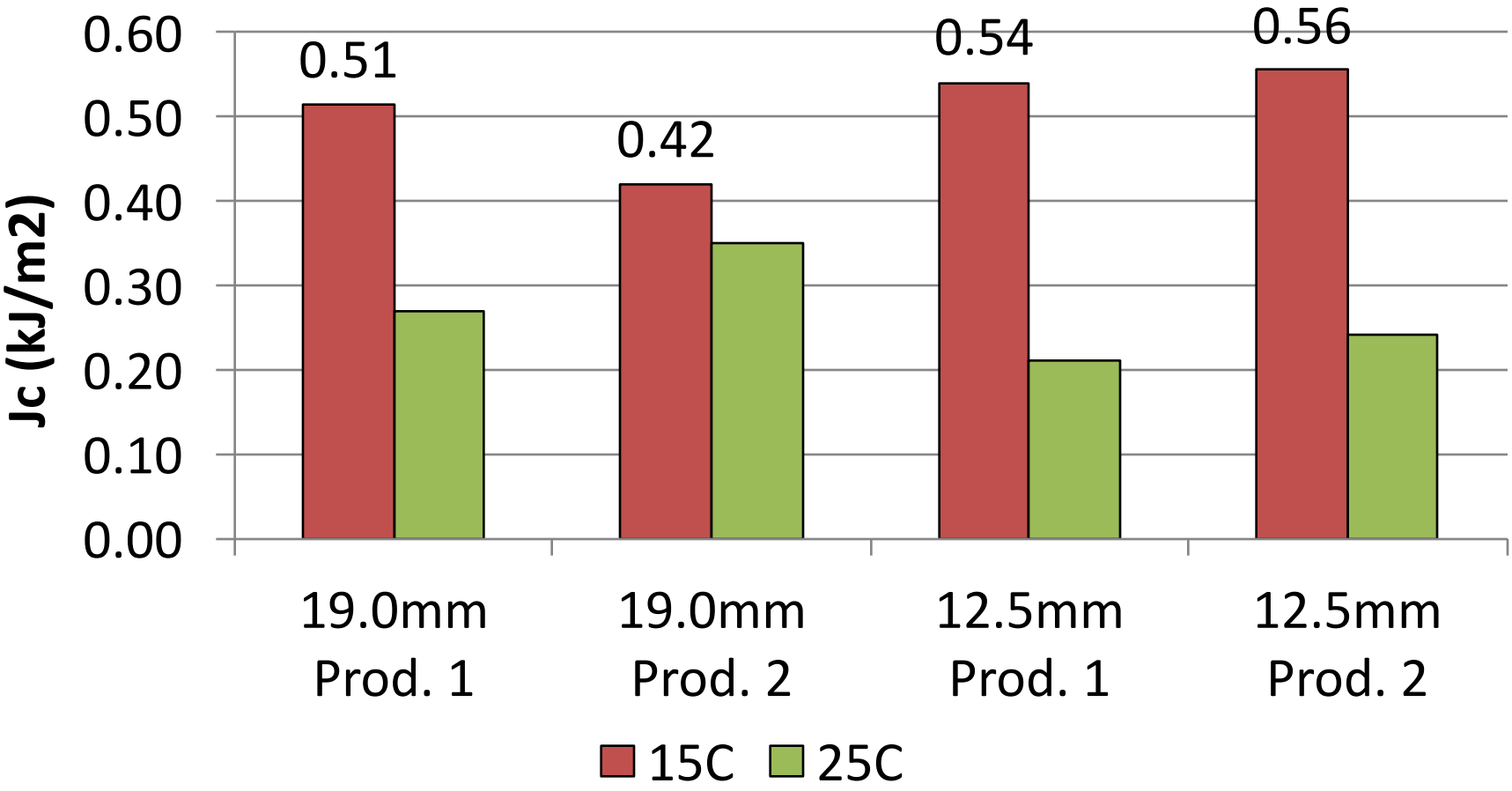
SCB Test Temperature Selection

LSU Research Report 11-3B



- IT PG of asphalt used in the study ranges from 25°C to 34°C.
- Recommends Jc > 0.5 kJ/m^2 for PG 76 and lower.
- Limit established based on relation to field performance.

WisDOT Pilot Project Results
15°C vs. 25°C



SCB Temperature Selection

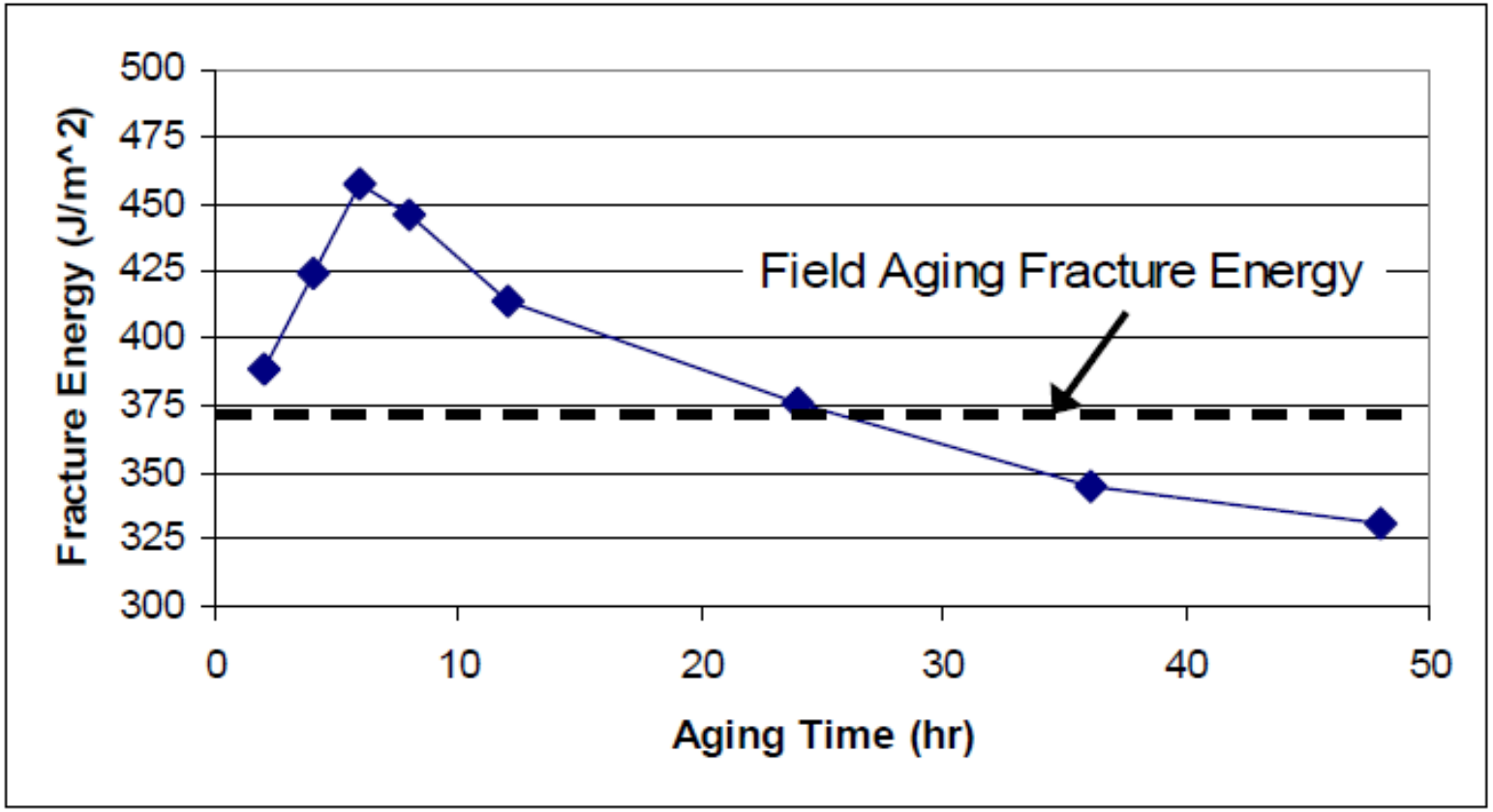
- When test temperature was adjusted to 15°C for WisDOT mixes, Jc values were consistent with LSU recommendations.
- **Recommendation**
  - Select SCB test temperature based on climate using LTTP Bind and calculation for intermediate temperature PG.
- For Wisconsin
  - Northern half is a PG 58-34: SCB temp = 16°C
  - Southern half is a PG 58-28: SCB temp = 19°C

Mixture Long Term Aging

- Issues with AASHTO R30 (5 days @ 85°C)
  - Aging gradient with depth in sample.
  - Sample dimensions change due to creep.
  - Time requirements, particularly when applied to a construction project.
- Proposed alternative:
  - Loose mix aging at 135°C for 12 to 24 hours.
  - Based on AAPT paper by Braham (2009) and further work by Phil Blankenship at AI.

Loose Mix Aging at 135°C

Effect of Aging Time on DCT

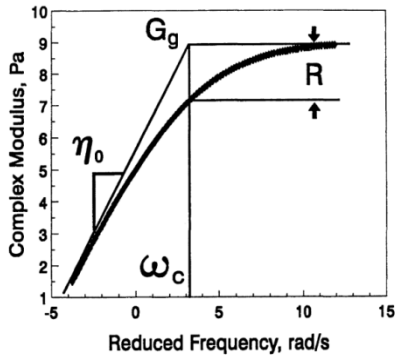


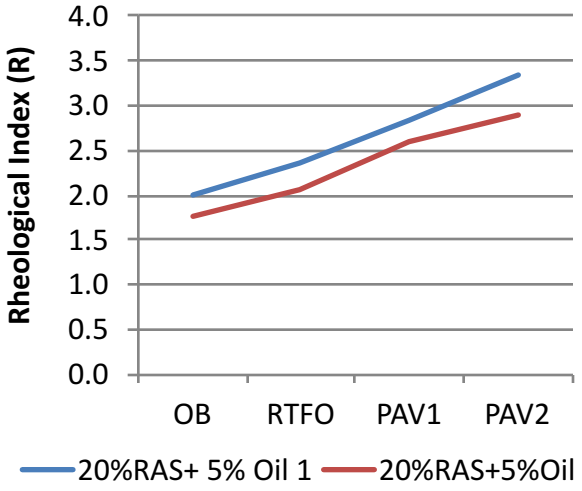
Braham, Buttlar, Clyne, "The Effect of Laboratory Aging on Hot Mix Asphalt Fracture Energy." AAPT 2009.

Binder Evaluation for High RAM Mixes

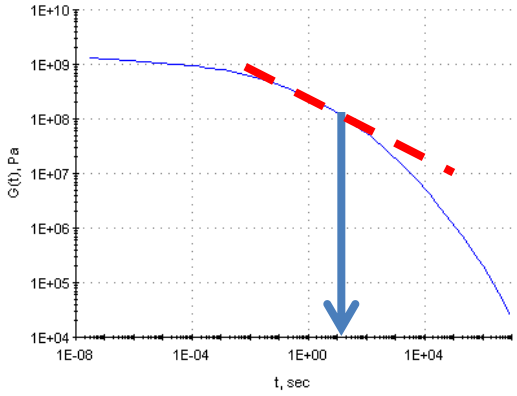
Direct Measurement – 4mm PP

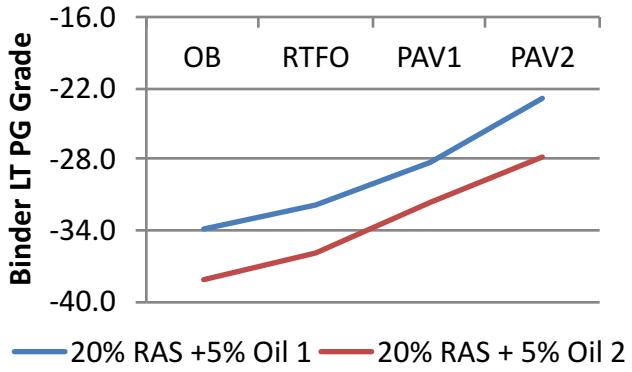
Effect of Aging





PG Grading



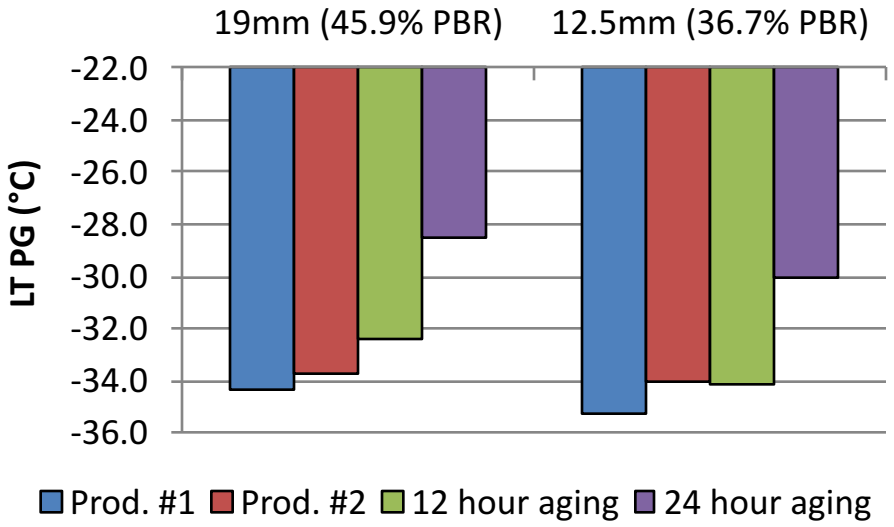


1. Anderson, et al., "Binder Characterization and Evaluation – Volume 3: Physical Characterization." SHRP A-369 Report, National Research Council, 1994.
2. Farrar, Sui, et al. 4 mm Plate Development – TRB 2011, 2012, Eurobitume 2012 and others.

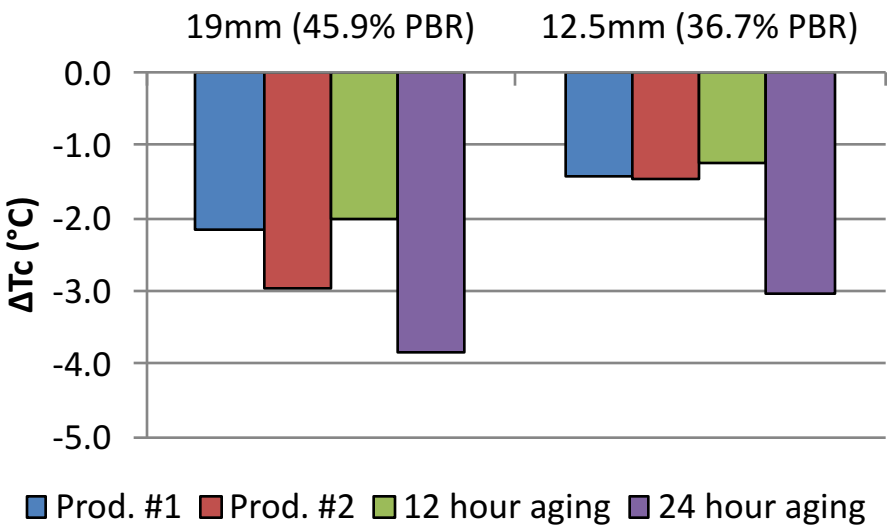
Evaluation of Loose Mix Aging

Binder Properties

LT PG Grade



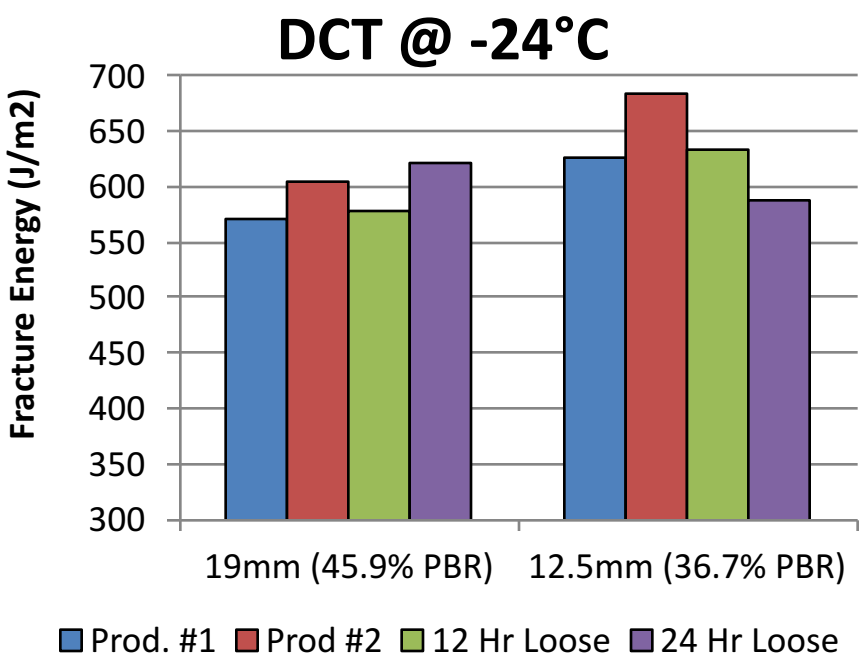
ΔTc

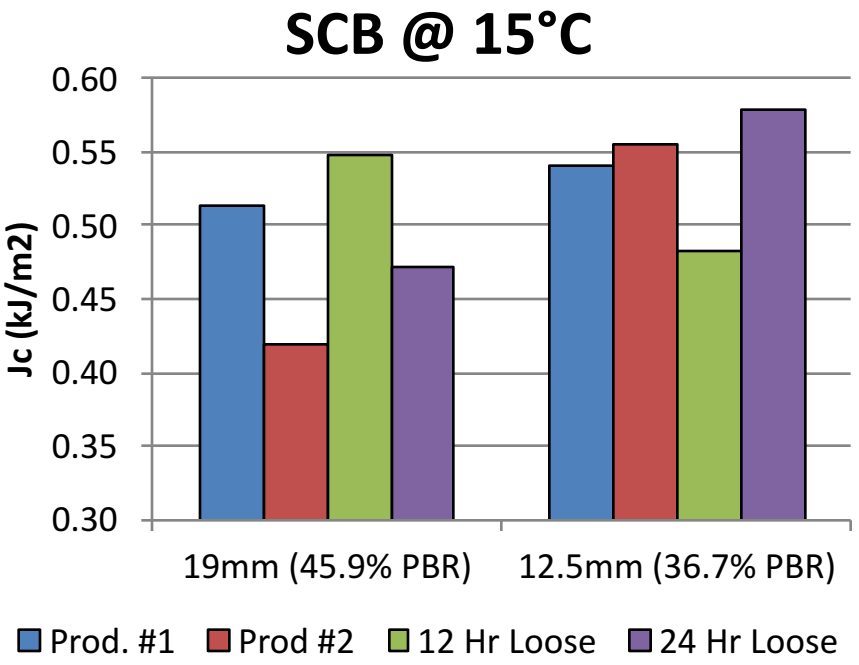


- Production Samples were aged for 5 days at 85°C. All binders extracted with toluene and recovered with Roto Vap.
- Low temperature properties estimated using 4mm DSR.
- 12 hour loose mix aging correlates well with 5 day aging procedure.

Evaluation of Loose Mix Aging

Mixture Cracking Performance

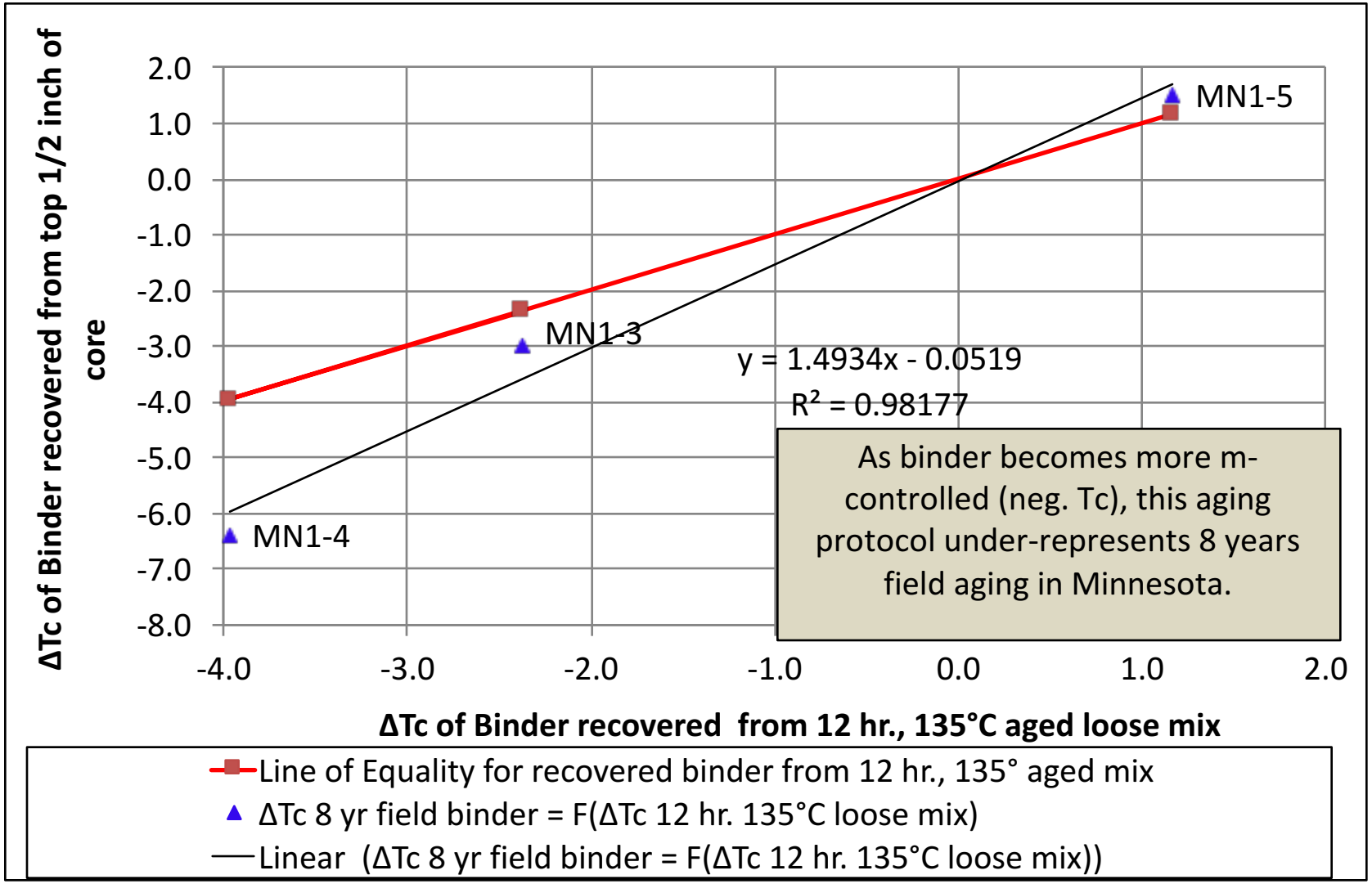




- Performance is similar for 5 day aged production samples and 12 hr loose mix aged samples.
- Effect of 24 hour aging not as severe for mixture performance, particularly in DCT test.

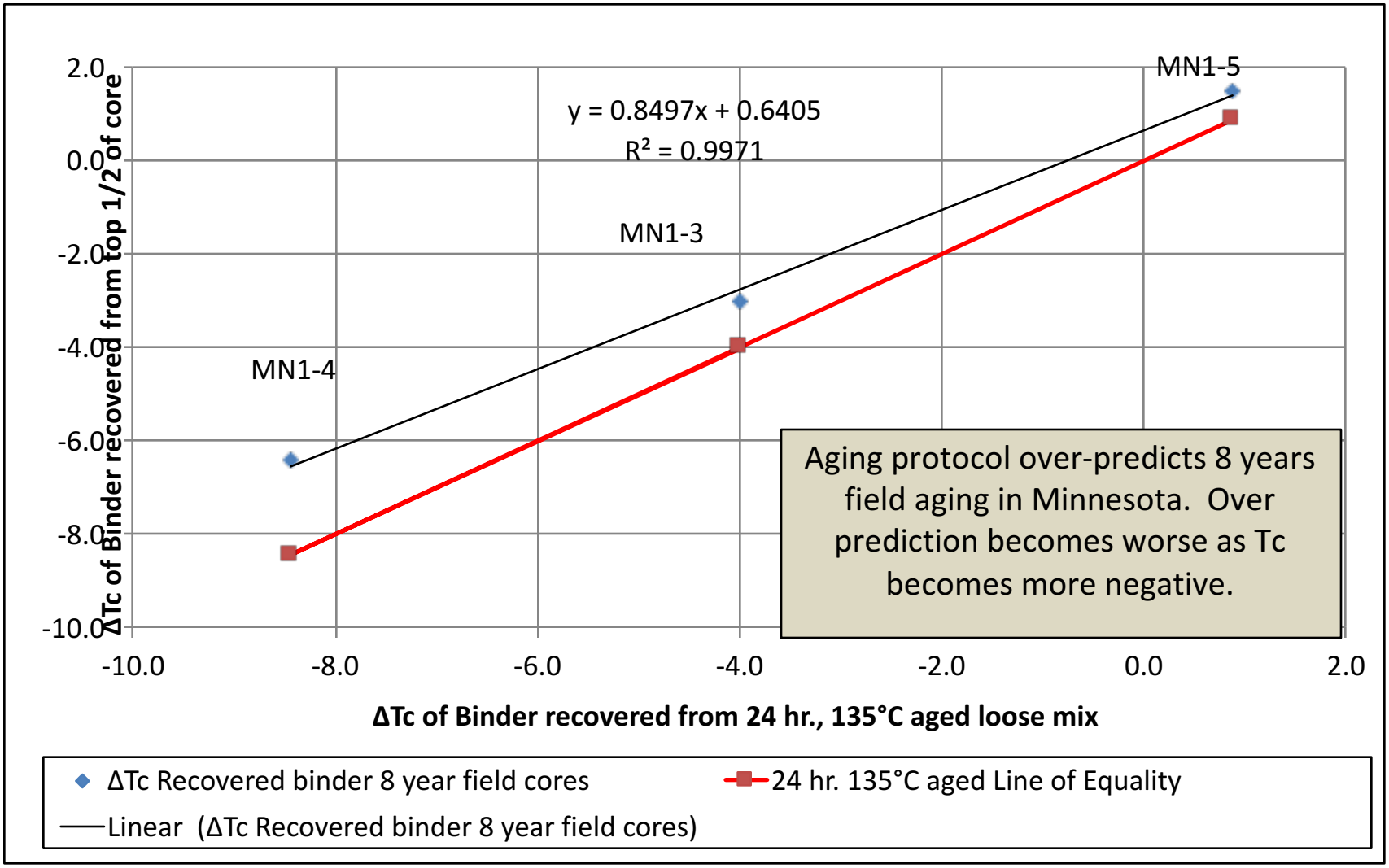
Laboratory vs. Field Aging, (Reinke, 2015 ETG)

12 Hr. Loose Mix @ 135°C



Laboratory vs. Field Aging (Reinke, 2015 ETG)

24 Hr. Loose Mix @ 135°C



Mixture Long Term Aging

- Loose mix aging at reduced times is a viable alternative to compacted sample aging.
- Mixture fracture tests, particularly the DCT showed less sensitivity to aging than recovered binder properties.
- **Recommendation**
  - Adopt 12 hrs. loose mix aging at 135°C as an alternative method for AASHTO R30.
  - Continue research on relating properties of field mixes to distress.

WisDOT High RAM SPV

Sample Conditioning Protocol

Step	Test Procedure	Conditioning	Reference
1)	Mix Design/Volumetrics	2 hrs ± 5 min @ Compaction Temp	AASHTO R30, Section 7.1
2)	**Hamburg**		
	lab-mixed	4 hrs ± 5 min @ 135 ± 3C	AASHTO R30, Section 7.2
	plant produced	min. reheat time to reach Compaction Temp	
	DCT and SCB		
	lab-mixed	Step 1 PLUS 12 hrs ± 30 min @ 135 ± 3C	WisDOT-Modified AASHTO R30, SPV Section 7.2
	plant produced	12 hrs ± 30 min @ 135 ± 3C	

12 hour loose mix aging protocol selected as an accelerated aging method based on comparison with 5 day compacted sample aging at 85°C

Comparison to Control Mix

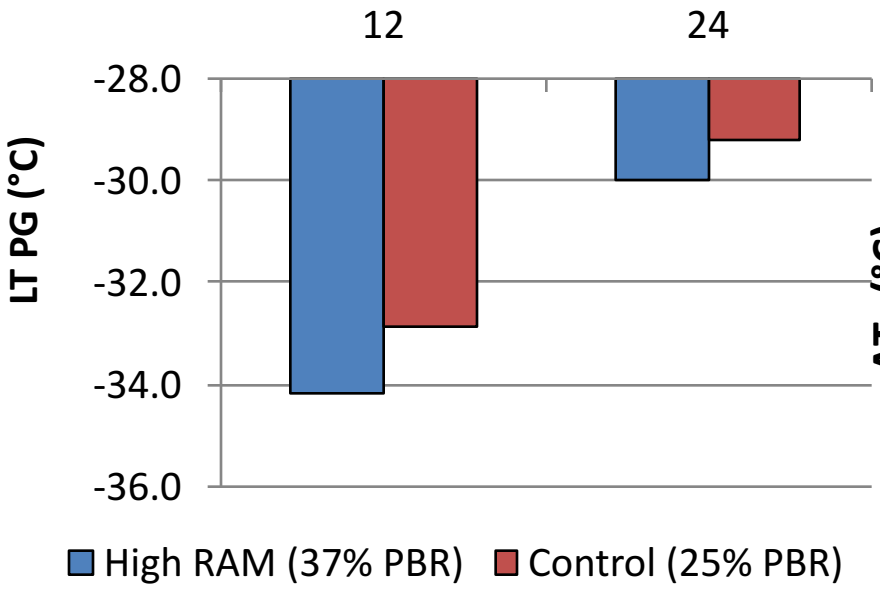
- At a minimum our expectation was that the high RAM mix would perform as well as conventional mixes placed in WI.
- Primary distress in WI is cracking, comparison will focus on
  - Recovered binder grading
  - SCB and DCT testing
  - Sensitivity to aging

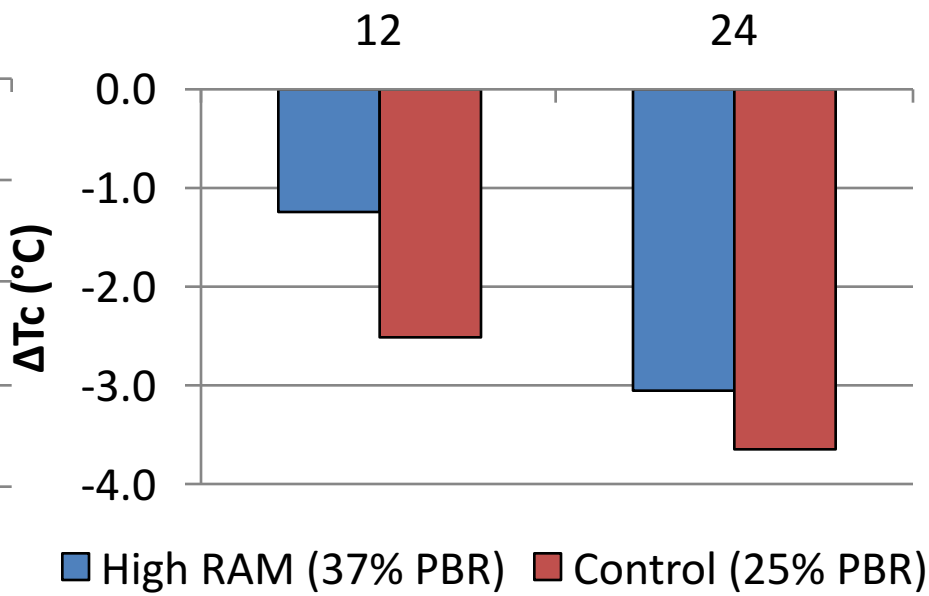
Comparison of Mix Designs

Property	Control Mix – 12.5mm	High RAM 12.5mm
% Binder Replacement	24.5%	36.7%
Design Air Void	4.0%	3.5%
VMA	15.1%	14.9%
Vbe	11.1%	11.4%
Dust to Binder Ratio	0.90	1.0
Asphalt Binder Grade	PG 58-34	PG 58-40
MSCR Jnr 3.2 kPa @ 58C	3.0	1.1
MSCR %R 3.2 kPa @ 58°C	0	43.5%

Binder Properties

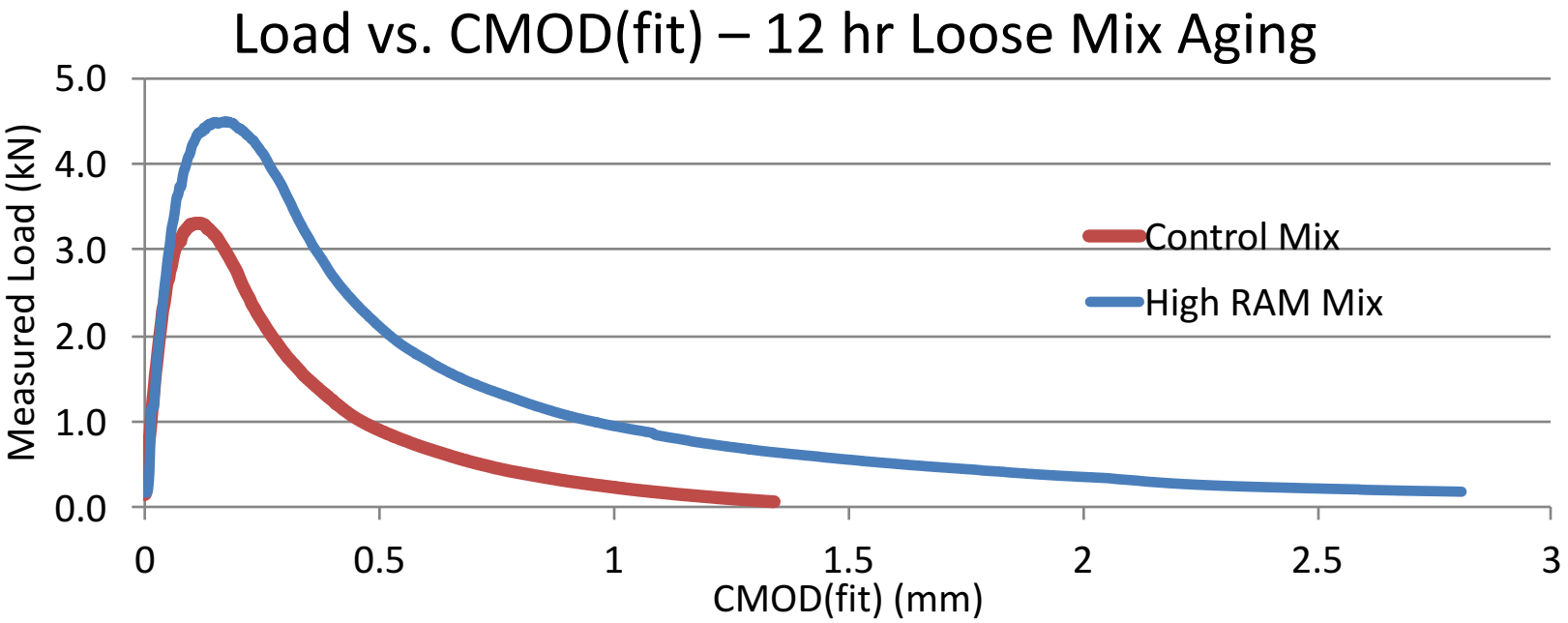
Binder recovered from mixes subjected to loose mix aging at 135°C





- High RAM mix is softer after 12 hours loose mix aging, mixes behave the same at 24 hour aging.

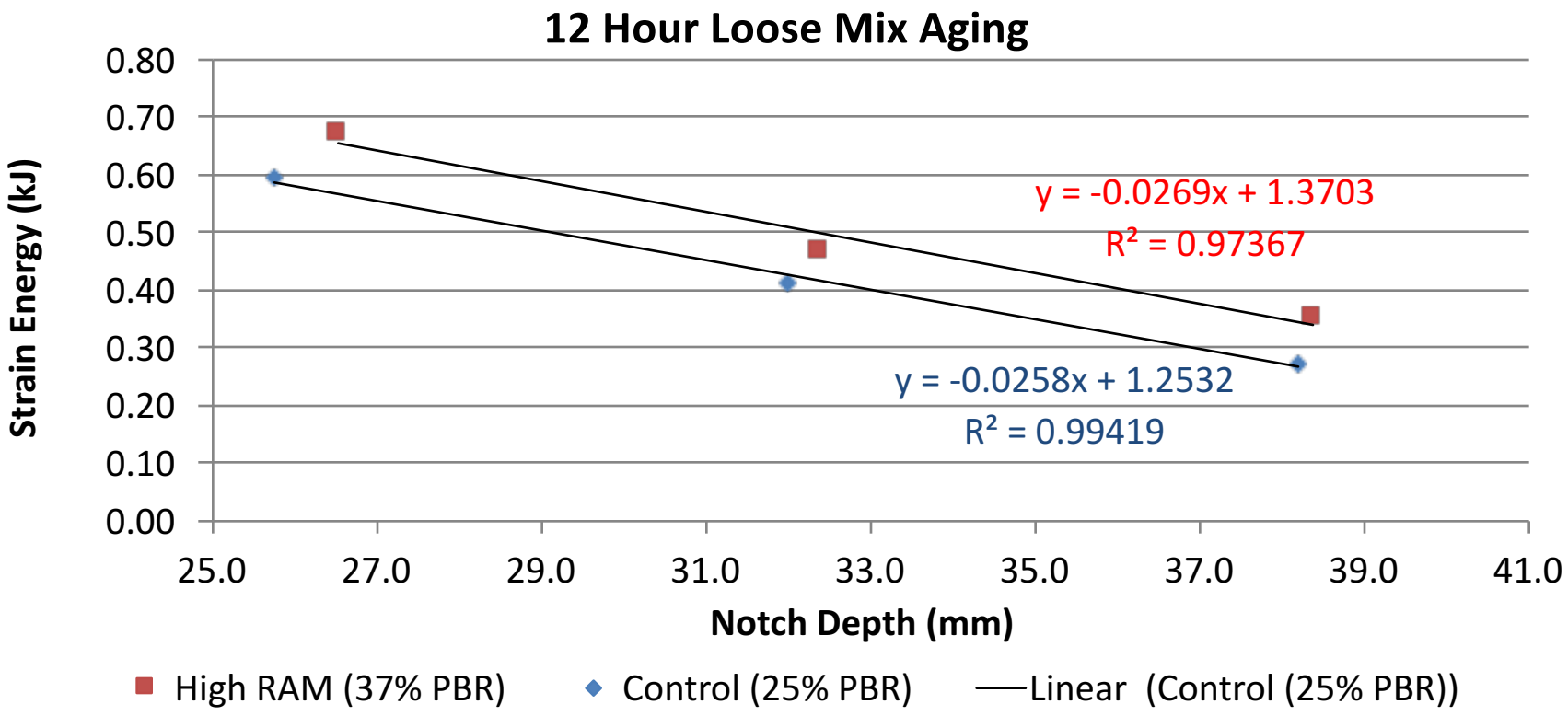
DCT Results @ -24C



Mix	Gf: 12 Hr Loose Mix Aging (J/m2)		Gf: 24 Hour Loose Mix Aging (J/m2)	
High RAM	634.3	70.8	587.5	127.9
Control	296.1	20.4	360.4	5.0

SCB Results at 15°C

12 Hour Loose Mix Aging

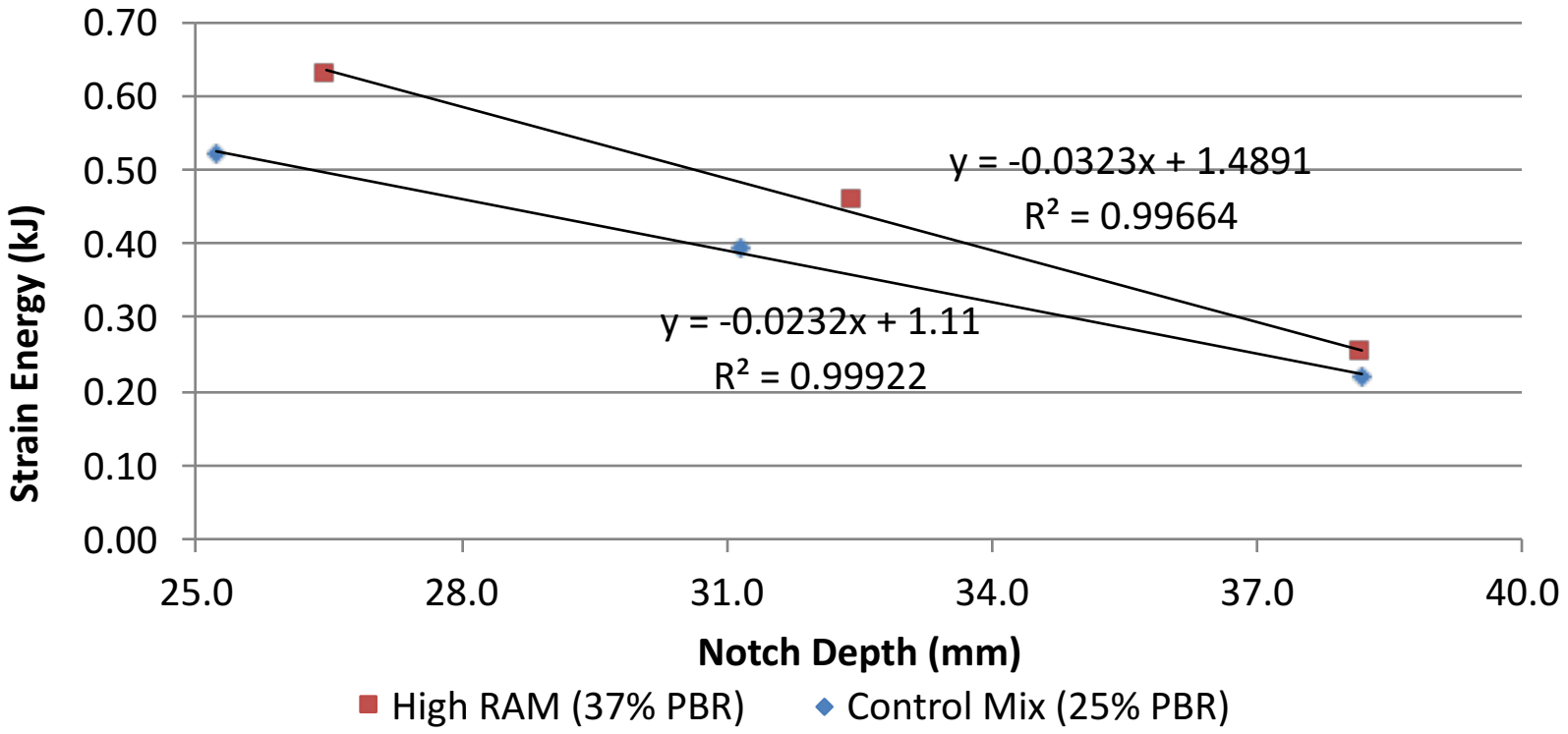


Jc High RAM Mix = 0.48 kJ/m^2

Jc Control Mix = 0.45 kJ/m^2

SCB Results at 15°C

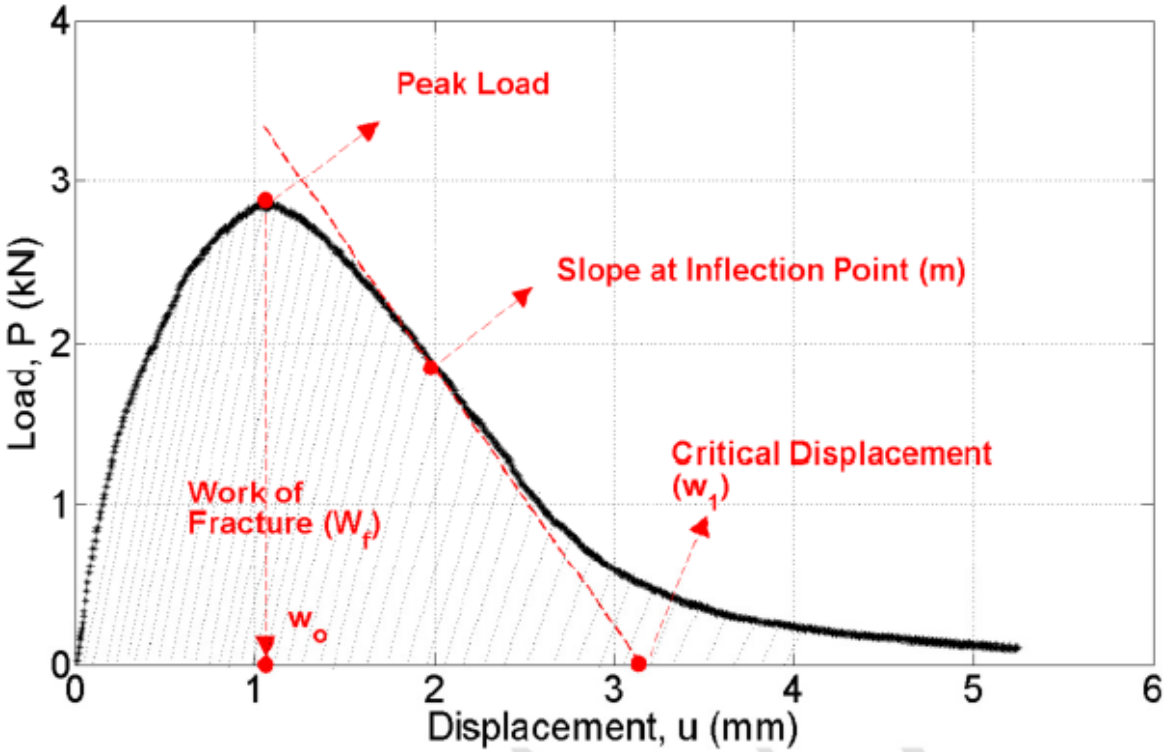
24 hour Loose Mix Aging



Jc High RAM Mix = 0.58 kJ/m^2

Jc Control Mix = 0.40 kJ/m^2

SCB Post Peak Behavior



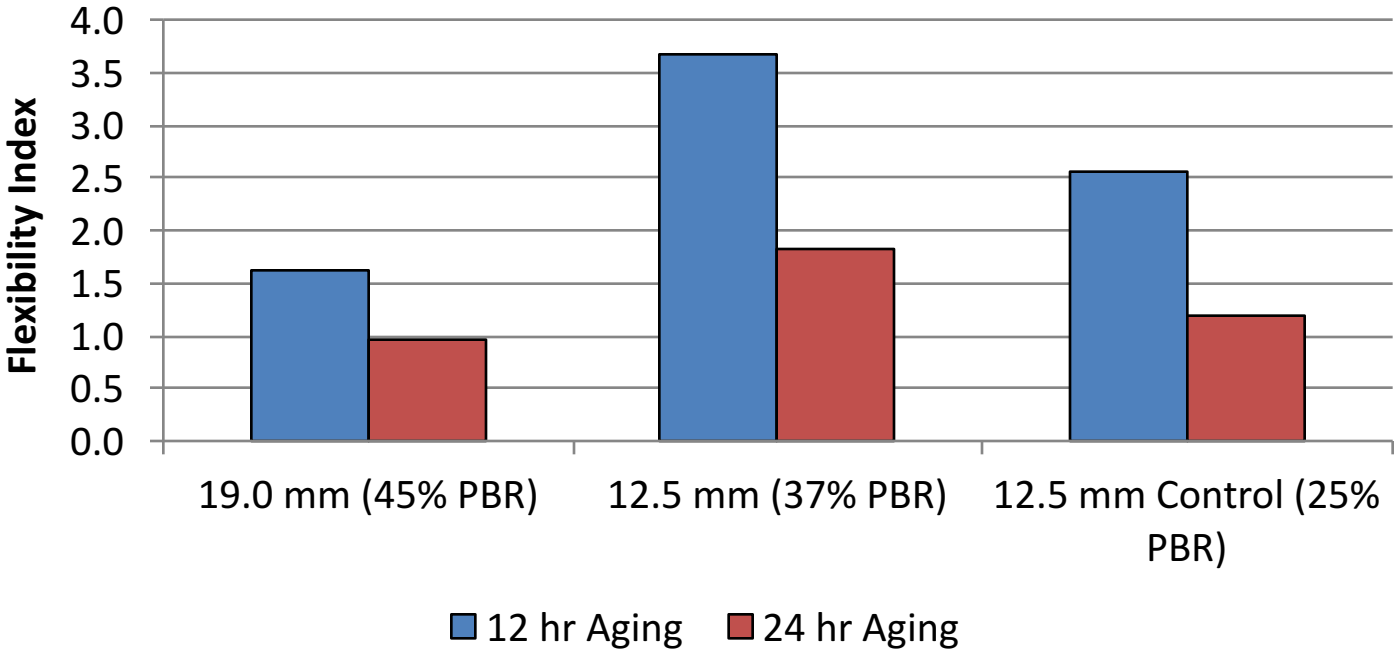
$$FI = \frac{G_f}{|m|} \times A$$

A = 0.01

Al-Qadi – Presentation at April 2015 ETG meeting Fall River and draft AASHTO TP

- Analysis method presented by UIUC was applied to the existing SCB test data set.
- Main differences between SCB procedures are test temperature (15°C vs. 25°C), loading rate (0.5 mm/min vs. 50 mm/min) and notch depth (25mm vs. 15mm).

Flexibility Index – Effects of Mix Design and Aging



- Flexibility Index discriminates between mixtures and the effects of aging.
- For 12.5mm mix, high RAM performs better than control for both aging conditions. Possibly due to presence of polymer and use of bio oil.
- Subsequent work at MTE has implemented the formal UIUC draft AASHTO procedure.

STH 77 Observations After 1 Yr.

- High RAM Section was 4 miles long.
- Control is 9 miles.
- Overall pavement is performing well.

- Very few transverse cracks.
- Small crack width
- No difference in performance between sections.

Summary

- Goal to meet or exceed the performance properties of the control mix was achieved.
- Contributing factors to performance improvements for high RAM mix.
  - Higher effective binder content/lower air voids.
  - Benefits of modification from polymer and bio-derived oil.
- Effect of aging on mixture cracking tests needs further investigation.

Next Steps

- WisDOT High RAM Committee will review performance testing provision after 2015 construction season.
- Continue standardization and evaluation of the SCB test. ***ASTM WK 48574***
- Continue investigation of post-peak behavior in SCB evaluation (UIUC method).
- Fall 2015 – Survey and coring of STH 77 to capture field performance after 1 year in service.

Thank You

Andrew Hanz, Ph.D.
Technical Director
MTE Services Inc.
608-779-6352 (office)
608-780-2509 (mobile)
andrew.hanz@mteservices.com