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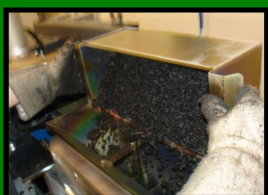
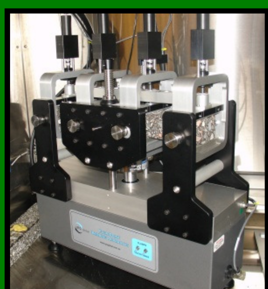
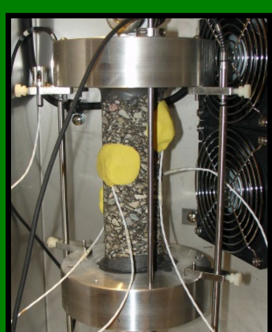
Highway Sustainability Research Center

Innovative Research in Asphalt Pavements







Balancing the Softening Effects of Asphalt Rejuvenators with Polymer Modified Asphalt in High RAP Content Mixtures

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NEAUPG
North East Asphalt User/Producer Group

Portsmouth, NH
October 23rd, 2013 ♦ 4:30PM

Concerns of Using More Recycled Materials

- RAP & RAS binders are aged and much stiffer than virgin binders

- Mixtures incorporating more RAP/RAS may become too stiff and more prone to field failure

- Degree or quality of blending between RAP, RAS, and virgin binder is unknown

Methods of Address Concerns with RAP/RAS Usage

- Use of a softer PG grade binder when RAP contents are ≥ 20% or RAS utilized

- Utilize an asphalt rejuvenator

Concerns with Softer Binder Usage with RAP/RAS

<u>Good Blending</u> - *Mixture is too stiff and compaction inhibited.*

<u>Incomplete Blending</u> - *Mixture effective binder content is low (i.e. RAP/RAS acting as black rock). Incomplete coating of aggregates (increased cracking and moisture damage concerns). Softer binder may dominate performance (rutting concerns).*

Concerns with Asphalt Rejuvenators

- For some state agencies there is a concern that asphalt rejuvenators may increase mixture rutting potential.

- Polymer Modified Asphalt (PMA) binder could be utilized to address the rutting concerns.

- Unknown if rejuvenators continue to soften over time

Project Scope

9.5mm Mixture

Reclaimed Asphalt Pavement

Recycled Asphalt Shingles

9.5mm Wearing Course & Pavement Preservation Strategy Mixture

Asphalt Rejuvenators & Polymer Modified Asphalt (PMA)

Looking to Maximize the Use of Each Recycled Material Individually and Collectively

Project Objectives

1. Design a Superpave 9.5mm mixture with virgin materials. This mixture was designated as the control mixture.

2. Redesign the control mixture using (a) 50 % RAP, (b) 5% PCAS, and (c) 50% RAP + 5% PCAS.

3. Redesign the mixtures with the RAP and/or PCAS after incorporating an asphalt rejuvenator. Five rejuvenators were used in the study.

4. Evaluate the effects of the rejuvenators on the mixture volumetric properties and performance of the mixtures in terms of rutting, moisture damage and cracking (fatigue, low temperature, and reflective cracking).

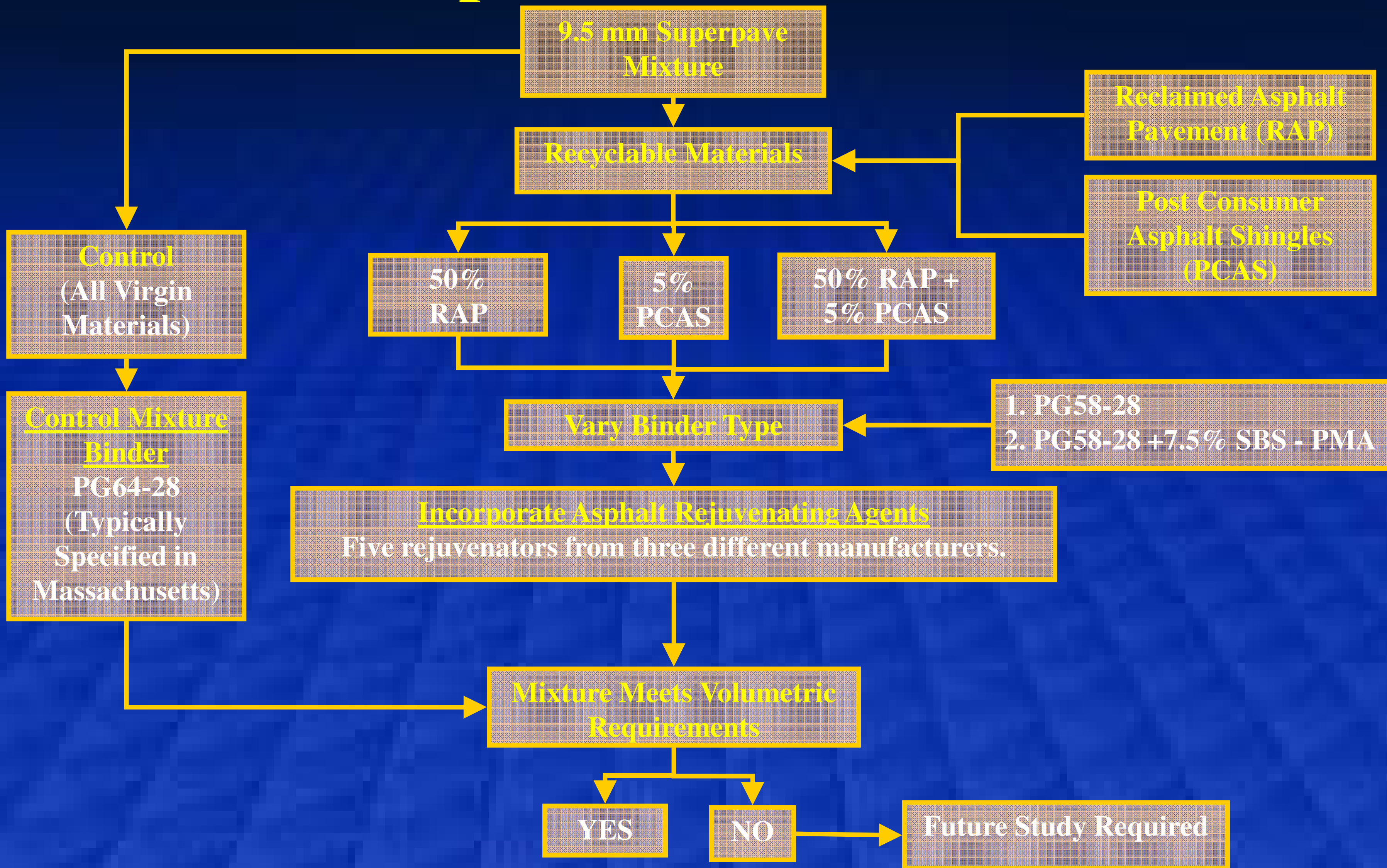
Project Objectives

5. Determine the effect of the rejuvenators on the blending between the RAP and/or PCAS binder and virgin binders using Atomic Force Microscopy (AFM).

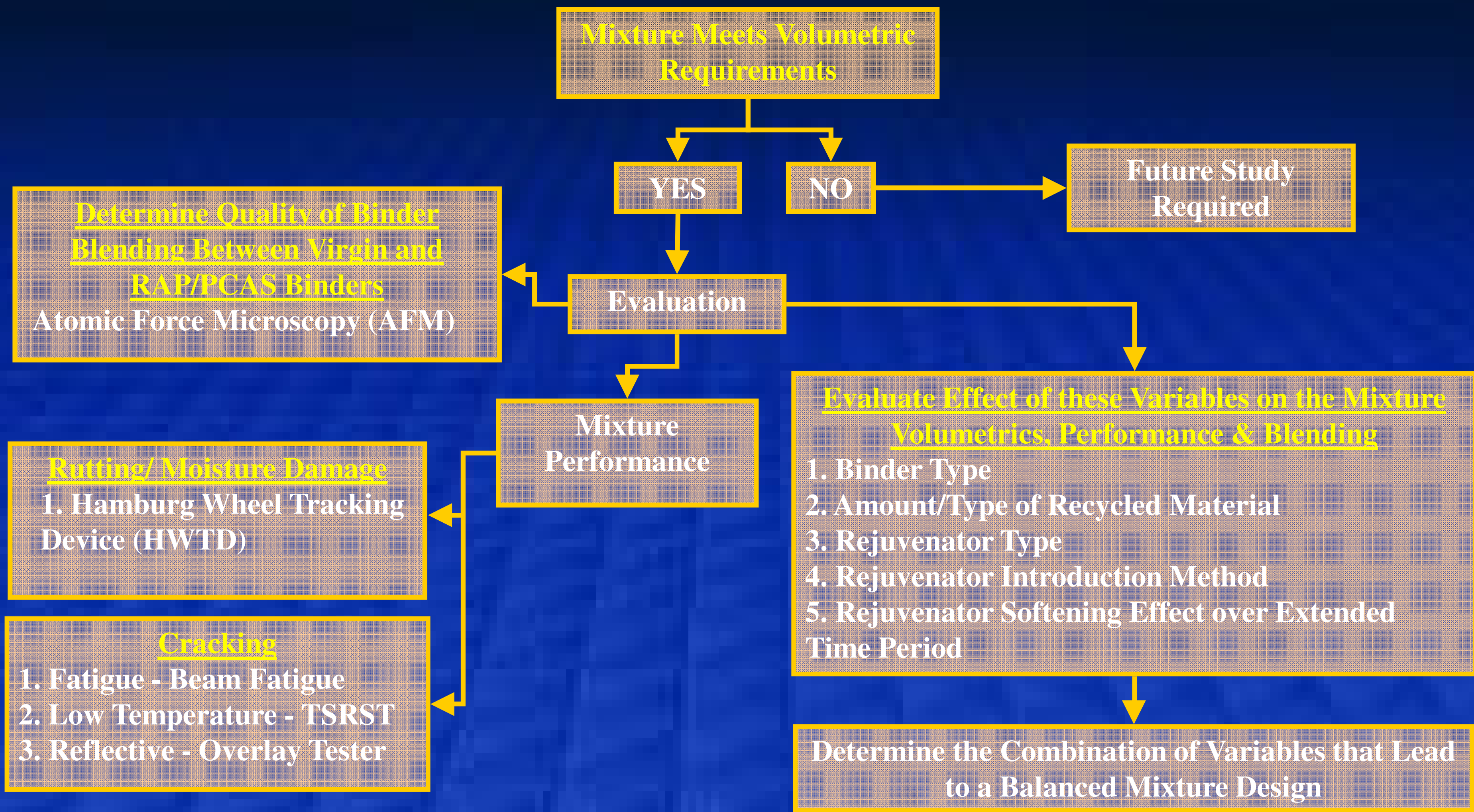
6. Determine if asphalt rejuvenators continue to soften the mixture over an extended period of time.

7. Determine if a PMA can control the softening effect of an asphalt rejuvenator in these types of mixtures without degrading the cracking performance.

Experimental Plan



Experimental Plan



Binders

➔PG64-28 utilized for control all virgin material mixtures. Mixing :161-165ºC (322-329ºF), Compaction: 153-157ºC (322-329ºF).

➔PG58-28 utilized for RAP and/or PCAS mixtures. Mixing: 150ºC (300ºF), Compaction: 138ºC (280ºF).

➔PMA binder was created by adding 7.5% SBS polymer from Kraton Polymers U.S. LLC to the PG58-28 binder. Mixing: 166ºC (331ºF), Compaction: 149ºC (300ºF).

Aggregates, RAP & PCAS

- ➔ Virgin aggregates (9.5mm aggregate and stone dust) and RAP obtained from same contractor.
- ➔ RAS was provided by a local company. All RAS utilized was post-consumer (tear-offs).
- ➔ RAP & PCAS air dried until constant mass achieved.
- ➔ RAP and RAS binder was extracted/recovered and graded. RAP binder was a PG82-16 (82.0-21.8). RAS binder was not able to be graded as PG requirements were not met at 130°C (high end) and 0°C (low end).

Mixture Design

- The same gradation maintained for all mixtures regardless of RAP and/or PCAS content.
- Mixture gradation met the requirements of a Superpave 9.5mm and Ohio DOT Item 424 "Fine Graded Polymer Modified Asphalt Concrete Type B" also known as Smoothseal Type B.

Mixture Design

Sieve Size	Sieve Size (mm)	Target Gradation for All Mixtures	Superpave 9.5mm Specification	Ohio Smoothseal Type B
3/4"	19.0 mm	100	-	-
1/2"	12.5 mm	100	100 min	100
3/8"	9.5 mm	98.0	90-100	95-100
No. 4	4.75 mm	85.0	90 max	85-95
No. 8	2.36 mm	58.0	32-67	53-63
No. 16	1.18 mm	42.0	-	37-47
No. 30	0.600 mm	27.0	-	25-35
No. 50	0.300 mm	15.0	-	9-19
No. 100	0.150 mm	9.0	-	-
No. 200	0.075 mm	6.0	2-10	3-8
Binder Content, %=		6.5%	-	6.4% min.

Mixture Design

- Design ESALs = 0.3 to < 3 million
- N_{design} = 75 gyration
- RAP added to top of heated aggregate for two hours prior to mixing.
- PCAS added to top of heated aggregate for 5 minutes prior to mixing.
- Rejuvenators added to pool of heated binder immediately prior to mixing.

Asphalt Rejuvenators

- Rejuvenators were selected based of previous use in pavement preservation activities or due to the fact they were based on green chemistry technology.

- Rejuvenators were obtained from: Holly Frontier Corporation, Warner Babcock Institute for Green Chemistry, and Sonneborn LLC.

Asphalt Rejuvenator Selection

- Performance grading of the binders was completed to determine the asphalt rejuvenator's impact on the PG grade as compared to the control PG64-28 binder.
- The goal was to maintain the PG64-28 performance grade of the mixture blended binder.

Performance Grading (PG) Results

Binder	Continuous High Grade, ºC	Continuous Low Grade, ºC	PG Grade
Control PG64-28	68.08	-30.00	64-28
PG58-28	60.63	-33.91	58-28
Extracted and Recovered RAP Binder	82.01	-21.79	82-16
Mixture Blended Binders			
50% RAP + NO REJ	71.81	-26.70	70-22
50% RAP + REJ A	64.80	-30.96	64-28
50% RAP + REJ B	64.80	-30.10	64-28
50% RAP + REJ C	67.00	-31.10	64-28
50% RAP + REJ D	68.00	-30.00	64-28
50% RAP + REJ E	61.07	-27.74	58-22
50% RAP + REJ F	65.10	-32.87	64-28
50% RAP + REJ G	61.77	-31.30	58-28
50% RAP + REJ H	64.80	-33.96	64-28
50% RAP + REJ I	66.52	-29.74	64-28

Performance Grading (PG) Results

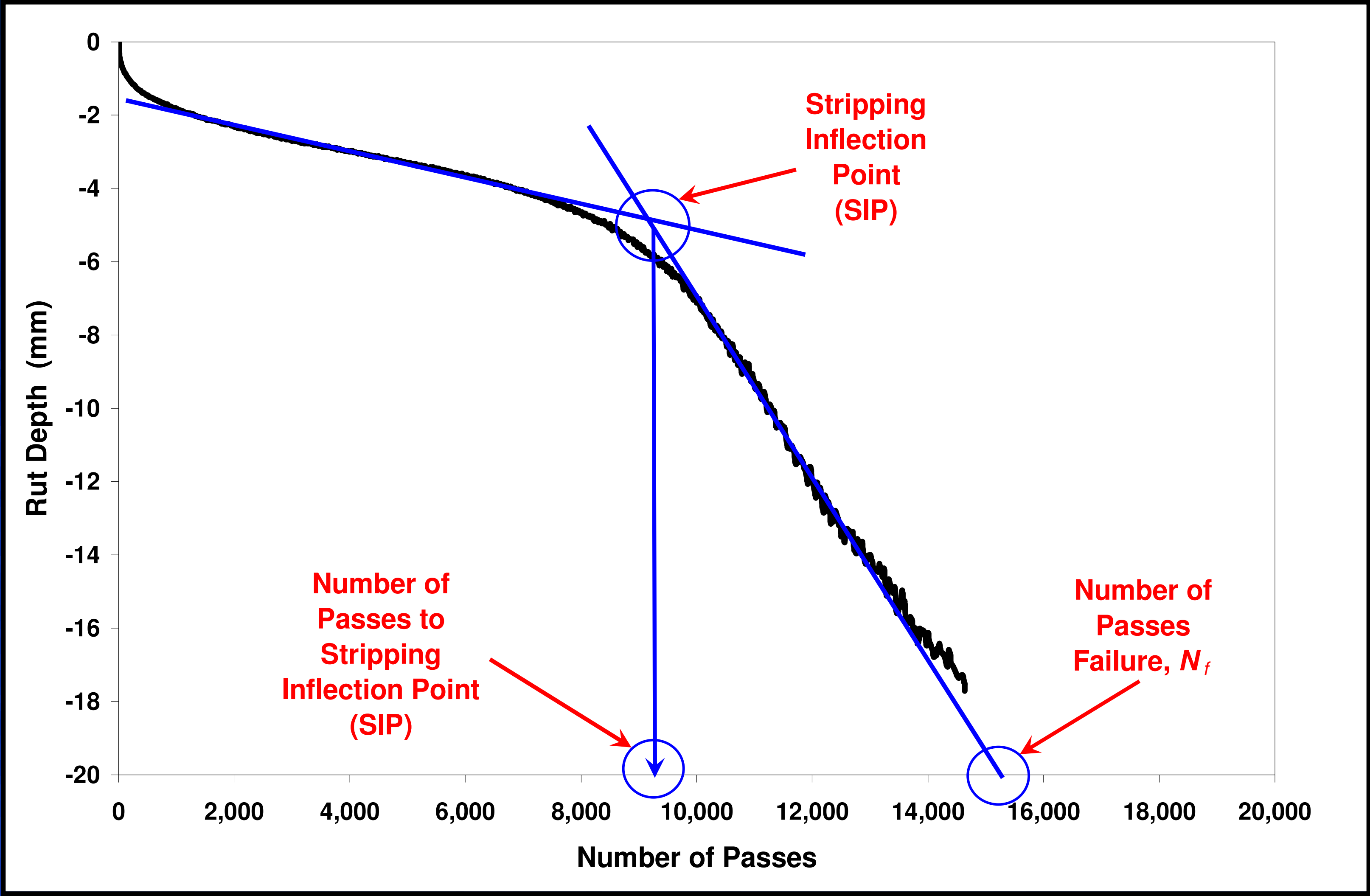
- Holly Frontier rejuvenators B & C were selected because they maintained the continuous high PG grade near the control PG 64-28 while simultaneously maximizing the continuous low PG grade.
- Warner Babcock rejuvenators F & H were selected because they maintained the PG64-28 of the control binder.
- Sonneborn LLC rejuvenator I was selected because it showed acceptable binder testing results and it was from a different manufacturer.

Mixture Performance Testing

Rutting/Moisture Susceptibility - Hamburg Wheel Tracking Device (HWTD)

- HWTD testing conducted in accordance with AASHTO T324
- Water temperature of 50ºC (122ºF)
- Test duration of 20,000 cycles

Stripping Inflection Point (SIP)



Rutting/Moisture Susceptibility – HWTD Results

Mixture	Stripping Inflection Point	Rut Depth at 10,000 Passes (mm)	Rut Depth at 20,000 Passes (mm)
Control PG64-28	NONE	0.76	1.39
50% RAP NO REJ	NONE	1.09	1.80
50% RAP + REJ B	17,400	1.25	3.31
50% RAP + REJ C	14,500	1.46	12.76
50% RAP + REJ F	11,800	2.73	18.48
50% RAP + REJ H	10,600	4.14	20.09
50% RAP + REJ I	12,900	1.92	16.70
50% RAP + REJ B + Polymer	NONE	0.40	0.50
50% RAP + REJ C + Polymer	NONE	0.41	0.52
50% RAP + REJ F + Polymer	NONE	0.50	0.66
50% RAP + REJ H + Polymer	NONE	0.48	0.67
50% RAP + REJ I+ Polymer	NONE	0.51	0.68

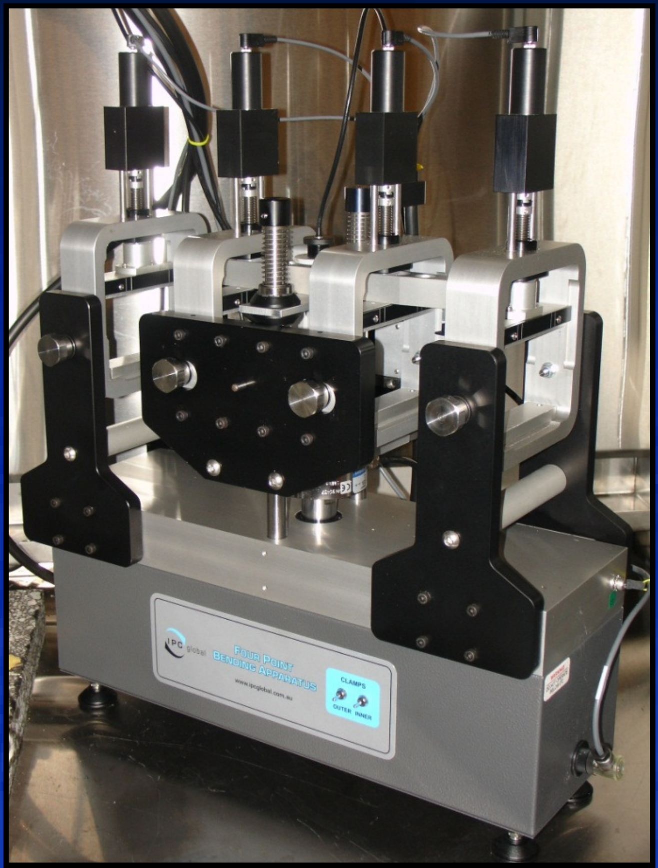
HWTD Conclusions

- The control mixture, had minimal rutting at the 10,000 and 20,000 passes and had no inflection point. The same was true for 50% RAP mixture with the softer binder.

- When rejuvenators were used, the rutting of the 50% RAP mixture increased relative to the control mixture. Furthermore, all rejuvenators caused the 50% RAP mixture to exhibit an inflection point.

- The use of a PMA did remedy the rutting and moisture damage susceptibility of the mixtures with rejuvenators.

Fatigue – Four Point Bending Beam

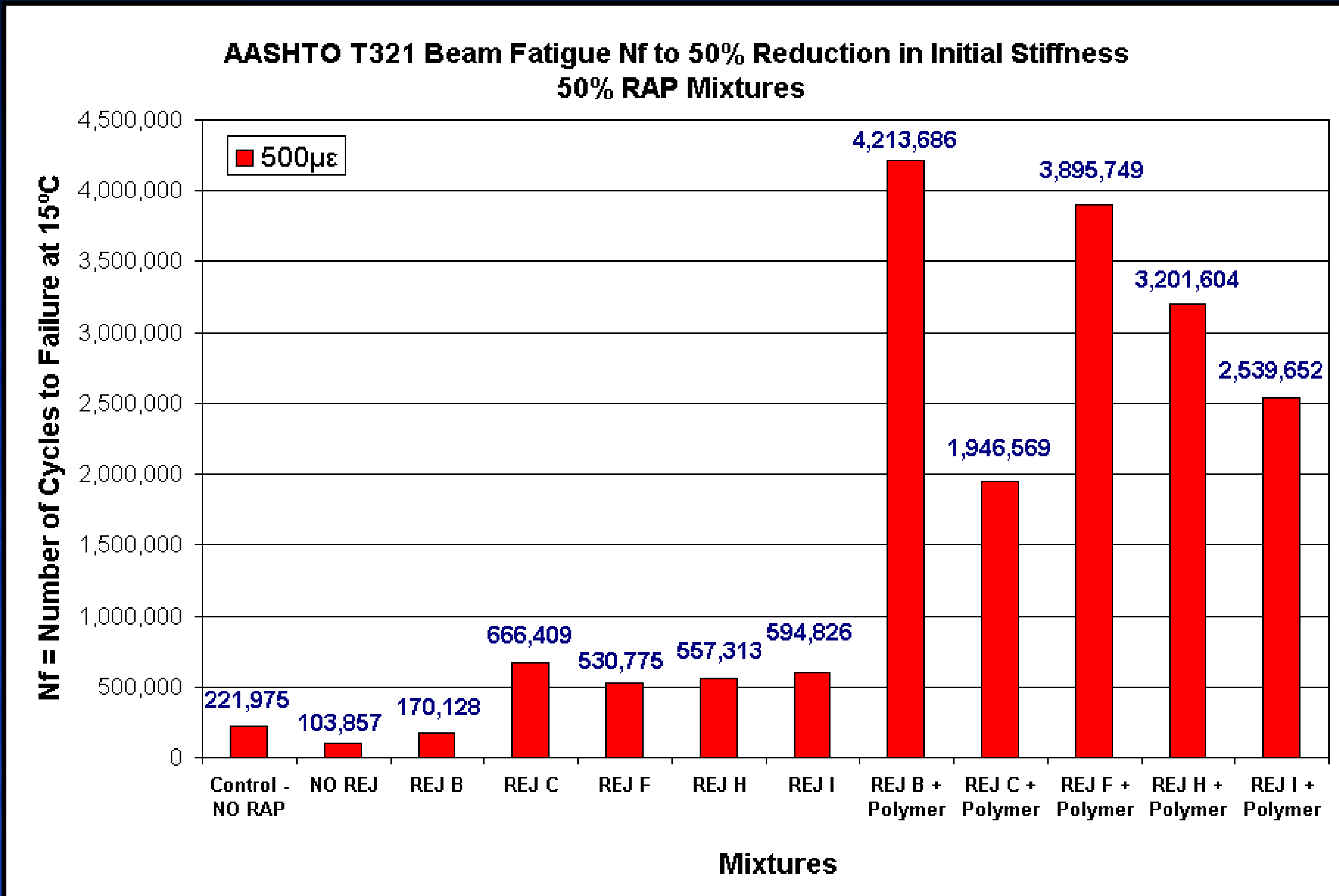


Testing in Accordance with AASHTO T321

- Specimens were fabricated at a target air void level of 7.0 ± 1.0%
- Testing conducted in strain control mode
- Loading Frequency = 10Hz
- Sinusoidal Wave Form
- Failure Criteria = 50% reduction in initial stiffness per AASHTO T321 method

Temperature	Strain Levels
15°C (59°F)	300με, 500με, 700με & 900με

Beam Fatigue Results



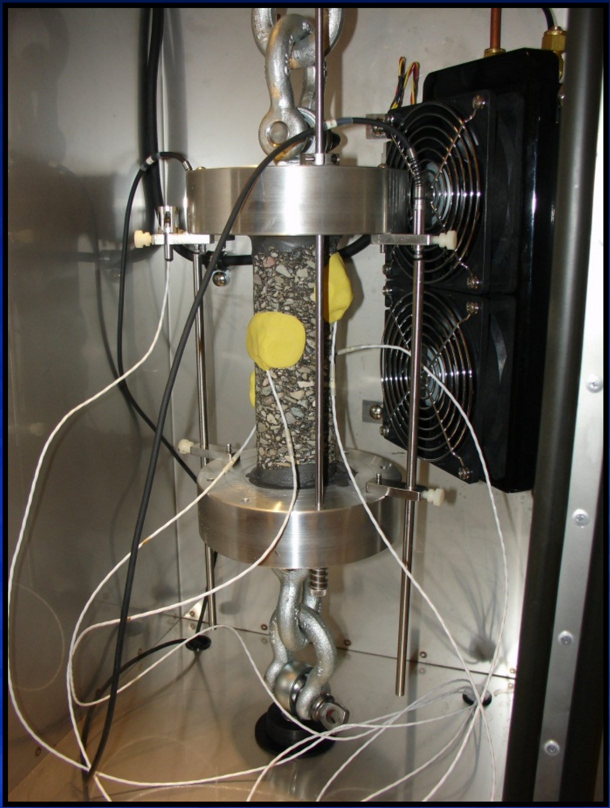
Beam Fatigue Conclusions

- The 50% RAP mixture with the softer binder and no rejuvenator showed reduced fatigue performance at the 500 $\mu\varepsilon$ strain level as compared to the control mixture.

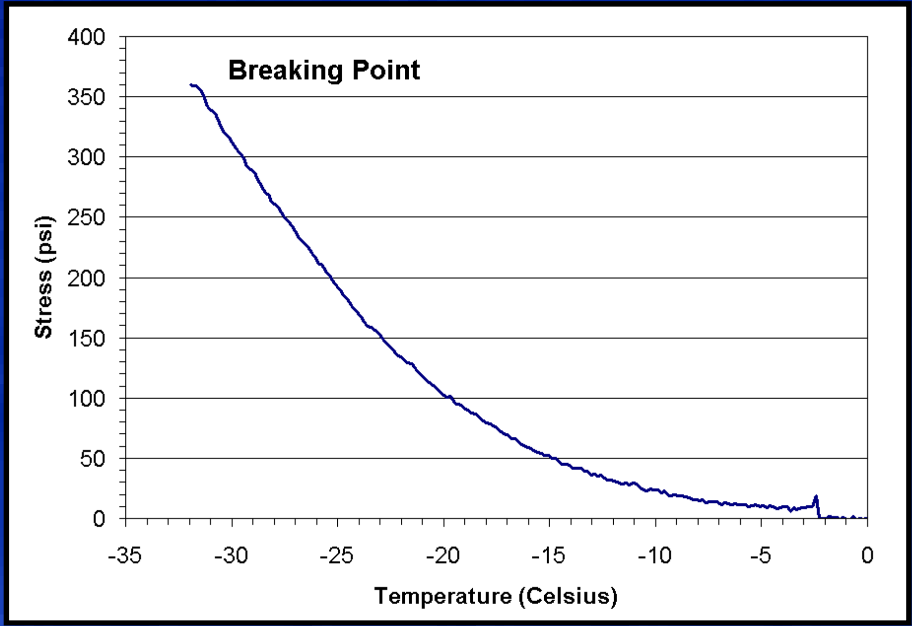
- Generally, by incorporating the rejuvenators, the fatigue performance of the 50% RAP mixture improved relative to the control mixture (except for REJ B -500 $\mu\varepsilon$)

- PMA improved the fatigue life of the 50% RAP mixture with rejuvenators to a level much higher than the control mixture and much higher than the mixture with the incorporation of rejuvenators alone.

Mixture Low Temperature Cracking - TSRST



- Cooling Rate of -10ºC/hour
- Testing in accordance with AASHTO TP10-93



TSRST Results

Mixture	TSRST Specimen Temperature at Failure, ºC
Control PG64-28	-22.2
50% RAP NO REJ	-20.7
50% RAP + REJ B	-24.9
50% RAP + REJ C	-27.8
50% RAP + REJ F	-27.0
50% RAP + REJ H	-28.8
50% RAP + REJ I	-27.5
50% RAP + REJ B + Polymer	-25.9
50% RAP + REJ C + Polymer	-22.5
50% RAP + REJ F + Polymer	-26.4
50% RAP + REJ H + Polymer	-29.0
50% RAP + REJ I + Polymer	-26.7

TSRST Conclusions

- Adding the rejuvenators to the 50% RAP mixture improved its cracking temperature relative to the control mixture and the mixture prepared with a softer binder.
- The data indicated that the PMA marginally altered the low temperature improvement of the 50% RAP mixture with the rejuvenators relative to the control mixture.

Reflective Cracking - Overlay Tester

- Test Temperature = 15ºC (59ºF)
- Test Termination at 2,000 cycles or 93% Load reduction
- Testing in accordance with Tex-248-F

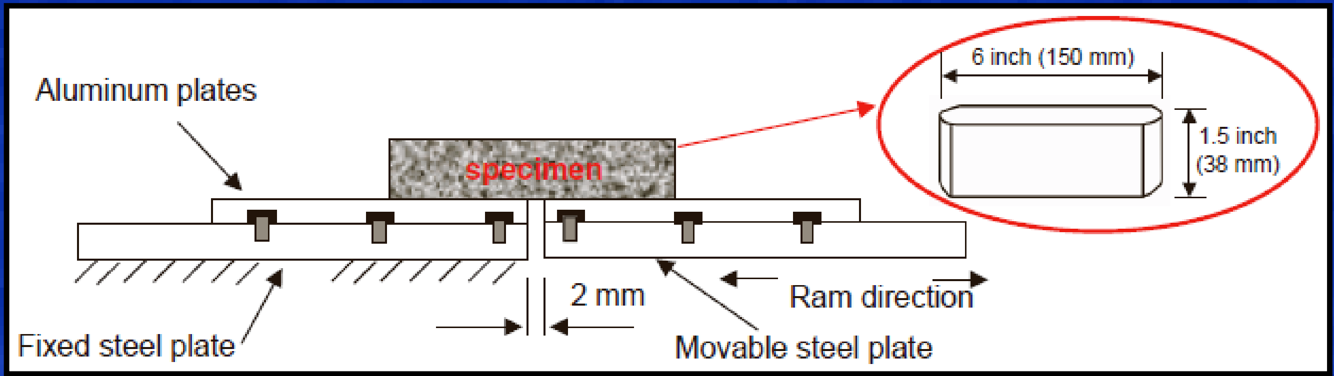
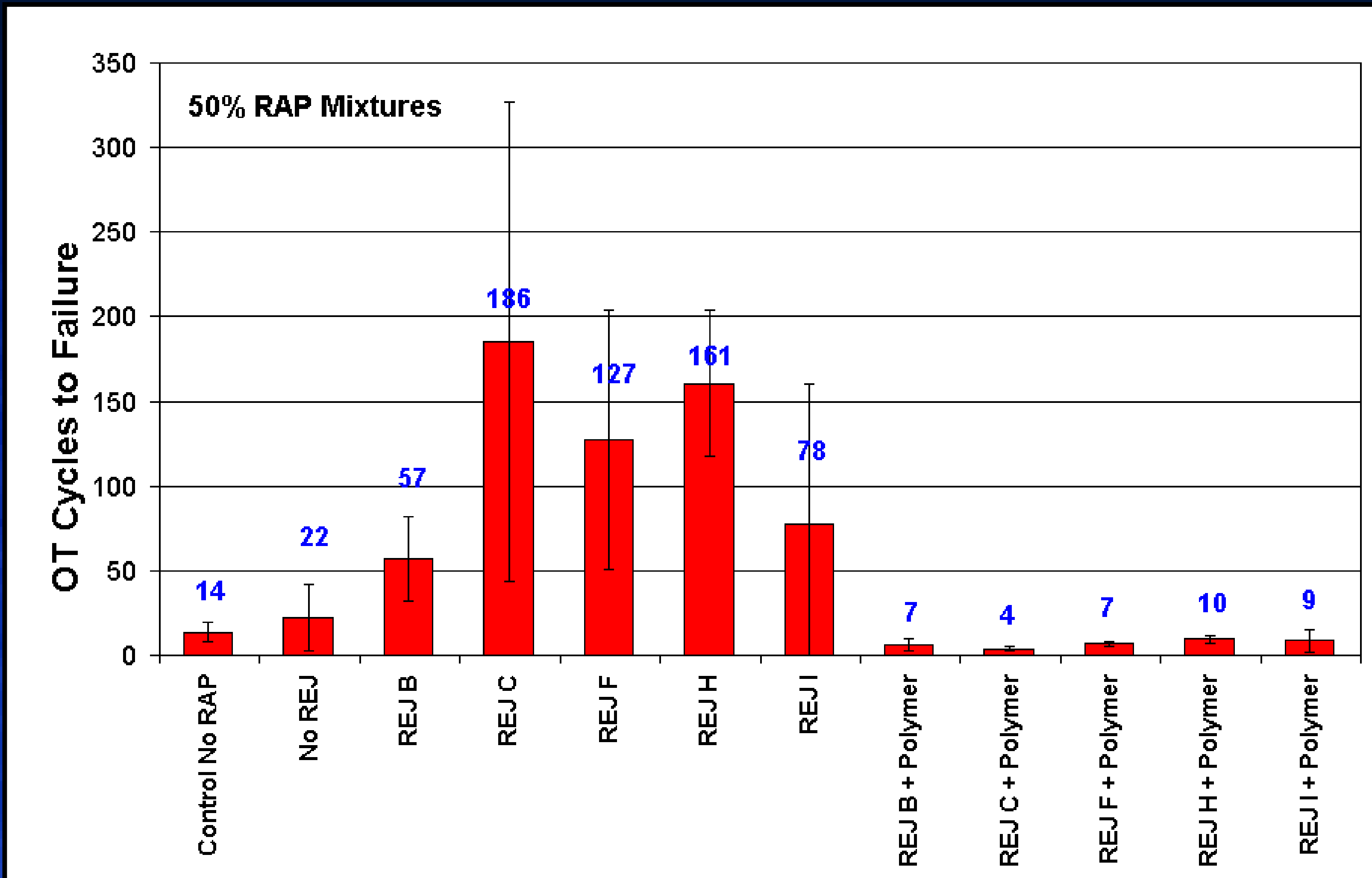


Diagram from: Zhou et al. "Overlay Tester: Simple Performance Test for Fatigue Cracking" Transportation Research Record: Journal of the Transportation Research Board, No. 2001, Transportation Research Board of the National Academies, Washington, D.C., 2007, pp. 1–8.

Overlay Tester Results



Overlay Tester Conclusions

- The results illustrated that the selected rejuvenators improved the resistance to reflective cracking for the 50% RAP mixture relative to the control mixture.

- The use of the PMA did not increase the number of cycles to failure in the OT as it did in the beam fatigue tests.

Softening Effect of Rejuvenators over Extended Time Period

- Initial specimens were compacted and subsequently tested in the HWTD within three days.

- Extended time specimens were stored unwrapped for approximately three months and then tested in the HWTD. The storage temperature was approximately 25°C.

- All testing parameters in the HWTD were consistent with the initial performance evaluations conducted in the HWTD that were discussed previously.

Softening Effect of Rejuvenators over Extended Time Period

Mixture	Stripping Inflection Point	Rut Depth at 10,000 Passes (mm)	Rut Depth at 20,000 Passes (mm)
50% RAP + REJ B (4hr Aging)	17,400	1.25	3.31
50% RAP + REJ B (3 Month)	16,700	1.40	5.03
50% RAP + REJ C (4hr Aging)	14,500	1.46	12.76
50% RAP + REJ C (3 Month)	16,700	1.72	10.78
50% RAP + REJ F (4hr Aging)	11,800	2.73	18.48
50% RAP + REJ F (3 Month)	12,700	2.65	16.68
50% RAP + REJ H (4hr Aging)	10,600	4.14	20.09
50% RAP + REJ H (3 Month)	14,300	2.14	14.42
50% RAP + REJ I (4hr Aging)	12,900	1.92	16.70
50% RAP + REJ I (3 Month)	10,700	3.32	20.07

Softening Effect of Rejuvenators over Extended Time Period

- **Overall the data indicated that the rejuvenators did not continue to soften over an extended period of time.**
- **This finding requires further investigation with extended aging times and at higher temperatures.**

Conclusions

- PMA was able to remedy the rutting and stripping of the 50% RAP mixtures with rejuvenator.

- The addition of the PMA binder improved the fatigue life of the 50% RAP mixture with rejuvenators to a level much higher than the control mixture and much higher than the mixture with the rejuvenator alone.

Conclusions

- The HWTD data indicated that the asphalt rejuvenators used in this study did not soften or very marginally softened the mixtures over the extended period of aging time. This finding requires further investigation with extended aging times and at higher temperatures.

Acknowledgements

The following people have been instrumental in completing the research presented here:

Mr. Ed Naras – MassDOT

Mr. Alexander J. Austerman, PE – UMass HSRC

Dr. Munir Nazzal – Ohio University

Dr. John Warner – Warner Babcock Institute for Green Chemistry

Mr. Patrick Gribbin – Holly Frontier Corporation

Mr. Chris Strack – Sonneborn LLC

Dr. Robert Kluttz – Kraton Polymers US LLC

Thank You!