University of Massachusetts Dartmouth
Highway Sustainability Research Center

Development of Balanced & Eco-Friendly Thin Lift Asphalt Mixtures Incorporating Sustainable Materials

By:

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Project Description

Incorporate one or more of the following materials in a typical thin lift overlay mixture and evaluate the performance of the mixture in terms of stiffness, cracking (reflective, thermal), rutting, moisture damage, and workability:

- High RAP Content
- RAS
- Warm Mix Asphalt (WMA) Technology
- Rejuvenator
- Highly Polymer Modified Asphalt
- Crumb Rubber

Benefits of Balanced & Eco-Friendly Thin Lift Mixtures

Material	Benefit
High RAP content and/or RAS	Recycling Waste Materials + Material Cost Savings
Warm Mix Asphalt Technology	Improves Mixture Workability + Reduces Impact on the Environment
Rejuvenator	Reduces Mixture Stiffness + Aids Blending of Virgin and Recycled Binders
Highly Polymer Modified Asphalt	Balances Softening Effects of Rejuvenators
Crumb Rubber	Recycling Waste Material + Balances Softening Effects of Rejuvenators

Project Scope

Develop Economical & Eco-conscious Mixtures by using a Combination of High Contents of Sustainable Materials, Rejuvenators, Highly Polymer Modified Asphalt, GTR and/or WMA.

Goal is for Mixtures to Perform Similar to 100% Virgin Material Mixtures

Project Scope

Recycled Asphalt Shingles

Reclaimed Asphalt Pavement

Ground Tire Rubber (GTR)

<u>Other Materials:</u>

1. Warm Mix Asphalt Technology
2. Rejuvenators
3. Highly Polymer Modified Asphalt

Project Objectives

- Develop a 9.5mm Superpave thin lift overlay mixture using virgin materials.

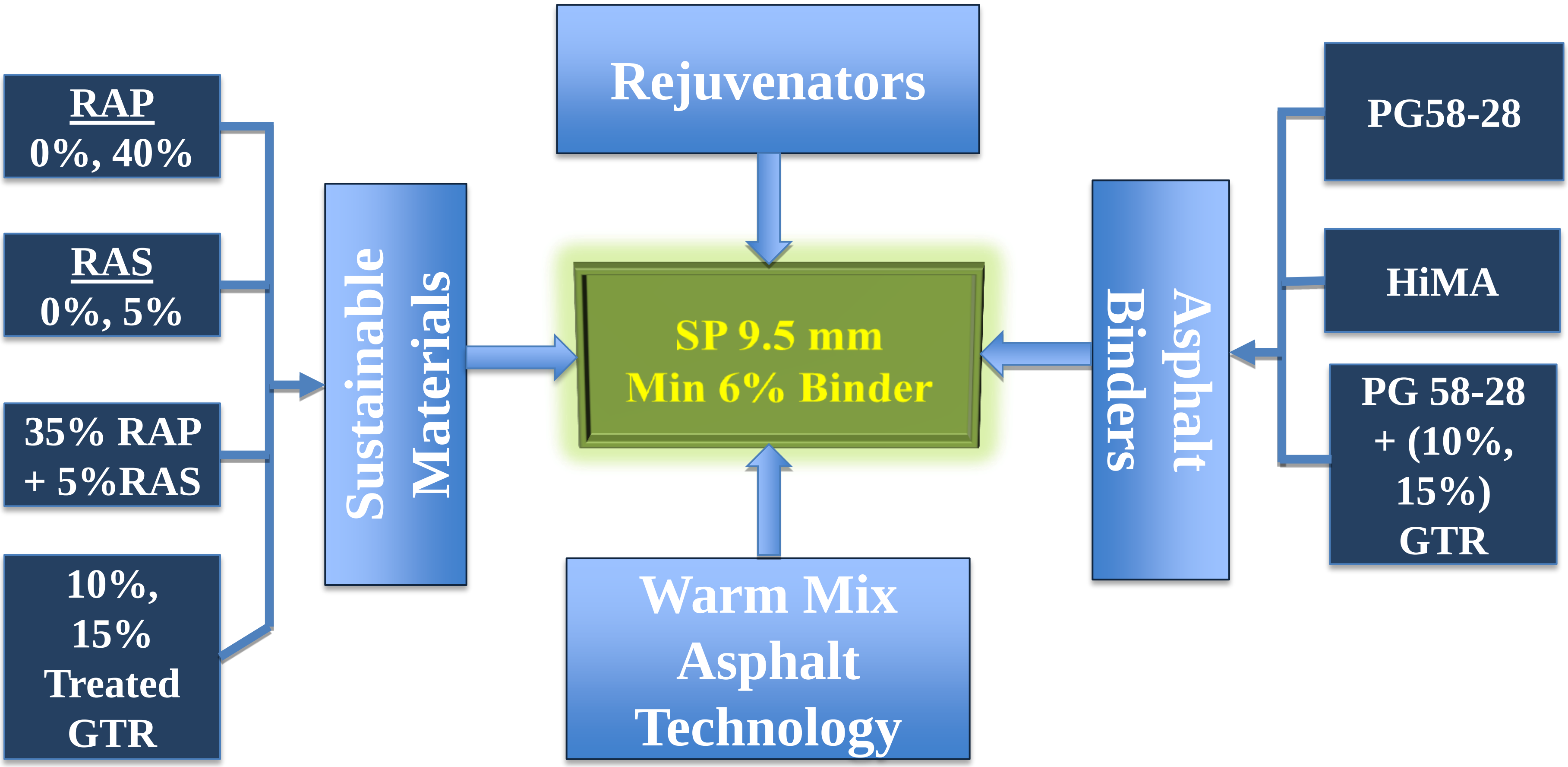
- Develop similar mixtures incorporating a high percentage of RAP, RAS, Ground Tire Rubber (GTR), Treated GTR, Highly Modified Asphalt (HiMA), Rejuvenators, and a WMA technology both individually and also in combination.

- Measure the dynamic modulus of the mixtures as a measure of overall mixture stiffness.

Project Objectives

- Measure the cracking resistance of the mixtures in terms of reflective cracking and thermal cracking.
- Measure the moisture susceptibility and rutting of the mixtures.
- Evaluate the effect of the materials on the workability of the mixtures.
- Evaluate the impact of WMA and rejuvenators on the degree of blending of virgin and aged binders (in-process).

Experimental Plan



Experimental Plan - Mixture Testing

Testing

- **Performance**
  - <u>Cracking Resistance</u>
    - Overlay Tester
    - TSRST
  - <u>Moisture Susceptibility/ Rutting</u>
    - Hamburg Wheel Tracking Device
- <u>Evaluate Degree of Blending</u>
  - Compare Measured E* & Predicted E*
- **Stiffness & Workability**
  - <u>Mixture Stiffness</u>
    - Dynamic Modulus E*
  - <u>Workability</u>
    - Asphalt Workability Device (AWD)

Warm Mix Asphalt Technology

- **Waxed based additive known as SonneWarmix™.**

- **SonneWarmix™ added at a dosage rate of 1.0% by weight of total binder (Virgin +RAP + RAS).**

- **Mixture incorporating the warm mix technology were fabricated with a 35ºF reduction in mixing and compaction temperatures as compared to the mixtures without the technology.**

Rejuvenators

Three rejuvenators have been used in the study:

- **SonnewarmixRJ**
- **SonnewarmixRJT**
- **BituTech RAP**

RAP & RAS

- RAP was obtained from same contractor that supplied the virgin aggregates.
- RAS was provided from a shingle recycling facility in Massachusetts and was pre-consumer material (manufacturer waste).
- RAP average binder content = 5.95% (AASHTO T308 - Ignition)
- RAS average binder content = 17.7% (AASHTO T308 - Ignition)

Mix Design

- Superpave design methodology
- PG 58-28 Control Binder
- Design ESALs = 0.3 to < 3million
- N_{design} = 75 Gyrations
- All mixture gradations designed to be similar to the control mixture without RAP and/or RAS.

Mixture Gradations

Sieve Size	Control	40% RAP	5% RAS	35% RAP + 5% RAS	9.5 mm Superpave Specification
19.0mm	100	100	100	100	-
12.5 mm	99.7	99.8	100	100	100 min.
9.5 mm	97.1	97.8	97.4	98.1	90-100
4.75 mm	66.8	64.5	66.2	66.5	90 max.
2.36 mm	47.8	45.3	45.8	46.6	32-67
1.18 mm	33.5	32.6	33.2	33.9	-
0.600 mm	23.0	22.9	23.4	23.9	-
0.300 mm	13.3	13.6	13.9	14.4	-
0.150 mm	7.1	7.1	7.6	7.5	-
0.075 mm	4.4	4.7	4.6	5.1	2-10

Mixture Volumetrics - w/o WMA Technology

Properties	Control	40% RAP	5% RAS	35% RAP + 5% RAS	9.5 mm Superpave Specification
Total Binder Content, %	6.0	6.0	6.0	6.0	-
Virgin Binder Added, %	6.0	3.6	5.1	3.0	-
Air Voids,%	3.9	4.2	3.7	4.2	4.0%
VMA, %	16.2	16.1	16.0	15.9	15% min.
VFA, %	76.3	73.8	76.8	73.8	65-78
Dust to Binder Ratio	0.82	0.89	0.86	1.01	0.6 -1.2

Mixture Volumetrics - with WMA Technology

Properties	Control + 1% WMA	40% RAP + 1% WMA	5% RAS + 1% WMA	35% RAP + 5% RAS + 1% WMA	9.5 mm Superpave Specification
Total Binder Content, %	6.0	6.0	6.0	6.0	-
Virgin Binder Added, %	6.0	3.6	5.1	3.0	-
Air Voids,%	3.9	3.8	4.4	4.7	4.0%
VMA, %	16.7	15.7	16.8	16.4	15% min.
VFA, %	76.9	75.7	74.2	71.6	65-78
Dust to Binder Ratio	0.78	0.90	0.84	1.00	0.6 -1.2

Mixture Volumetrics - Control + HiMA with & w/o WMA

	Control Mixtures					
Properties	PG58-28	PG64-34	PG70-22 + 7.5 SBS	PG58-28 + 7.5% SBS	200PEN + 7.5% SBS	9.5 mm Superpave Specification
Air Voids,%	3.9	3.1	3.3	2.1	2.3	4.0%
VMA, %	16.2	16.0	16.0	15.1	15.3	15% min.
VFA, %	76.3	80.7	79.4	85.9	85.1	65-78
	Control + 1% WMA Mixtures					
Properties	PG58-28	PG64-34	PG70-22 + 7.5 SBS	PG58-28 + 7.5% SBS	200PEN + 7.5% SBS	9.5 mm Superpave Specification
Air Voids,%	3.9	2.6	3.3	3.0	2.5	4.0%
VMA, %	16.7	15.6	16.1	15.9	15.7	15% min.
VFA, %	76.9	83.4	79.4	81.4	84.2	65-78

Mixture Volumetrics - 40% RAP + HiMA with & w/o WMA

	Control + 40% RAP Mixtures					
Properties	PG58-28	PG64-34	PG70-22 + 7.5 SBS	PG58-28 + 7.5% SBS	200PEN + 7.5% SBS	9.5 mm Superpave Specification
Air Voids,%	4.2	3.1	3.1	2.9	3.3	4.0%
VMA, %	16.1	15.5	15.4	15.1	15.7	15% min.
VFA, %	73.8	80.1	80.0	80.6	79.1	65-78
	Control + 40% RAP + 1% WMA Mixtures					
Properties	PG58-28	PG64-34	PG70-22 + 7.5 SBS	PG58-28 + 7.5% SBS	200PEN + 7.5% SBS	9.5 mm Superpave Specification
Air Voids,%	3.8	3.6	3.9	3.1	3.2	4.0%
VMA, %	15.7	16.1	16.0	15.4	15.5	15% min.
VFA, %	75.7	77.6	75.9	80.2	79.4	65-78

Mixture Volumetrics - 40% RAP + Rejuvenators

Properties	40% RAP + Sonne RJ	40% RAP + Sonne RJT	40% RAP + Bitutech	9.5 mm Superpave Specification
Total Binder Content, %	6.0	6.0	6.0	-
Virgin Binder Added, %	3.84	3.84	3.84	-
Air Voids,%	3.7	3.6	4.1	4.0%
VMA, %	16.6	16.2	16.6	15% min.
VFA, %	77.7	77.8	75.3	65-78
Dust to Binder Ratio	0.75	0.75	0.75	0.6 -1.2

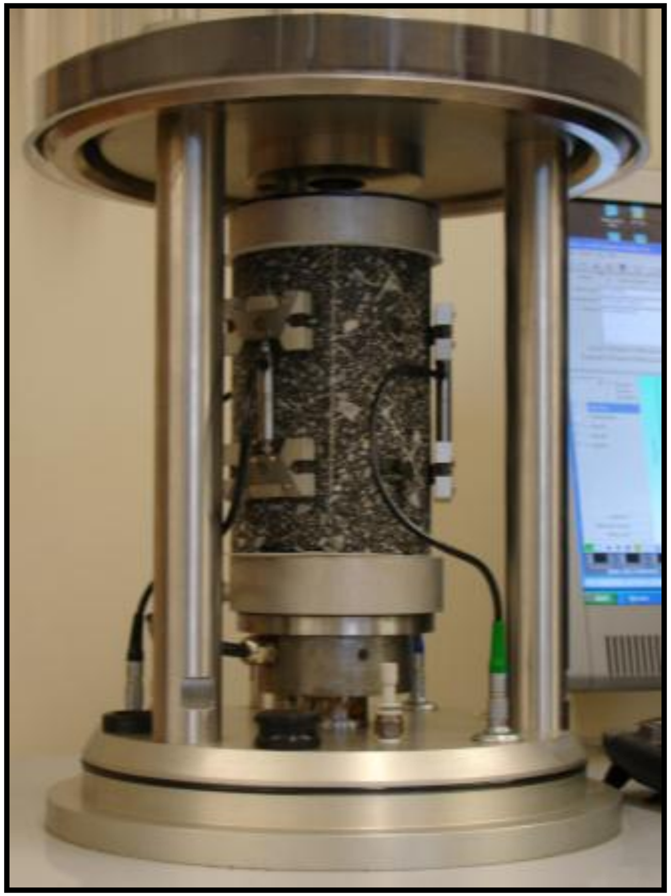
Mixture Volumetrics - Control with GTR

Properties	58-28	58-28 + 10% Untreated Rubber	58-28 + 15% Untreated Rubber	58-28 + 10% Treated Rubber	58-28 + 15% Treated Rubber	9.5 mm Superpave Spec.
Total Binder Content, %	6.0	6.0	6.0	6.0	6.0	-
Virgin Binder Added, %	6.0	6.0	6.0	6.0	6.0	-
Air Voids,%	3.5	4.3	4.3	4.6	4.7	4.0%
VMA, %	16.2	16.5	16.4	16.8	16.9	15% min.
VFA, %	78.4	73.9	73.8	72.6	72.2	65-78
Dust to Binder Ratio	0.75	0.77	0.78	0.77	0.77	0.6 -1.2

Mixture Volumetrics - 40% RAP with GTR

Properties	58-28	58-28 + 10% Untreated Rubber	58-28 + 15% Untreated Rubber	58-28 + 10% Treated Rubber	58-28 + 15% Treated Rubber	9.5 mm Superpave Spec.
Total Binder Content, %	6.0	6.0	6.0	6.0	6.0	-
Virgin Binder Added, %	3.84	3.84	3.84	3.84	3.84	-
Air Voids,%	4.3	4.6	4.4	4.9	4.8	4.0%
VMA, %	16.7	16.7	16.5	17.3	16.9	15% min.
VFA, %	74.3	72.5	73.3	71.7	71.6	65-78
Dust to Binder Ratio	0.76	0.78	0.78	0.75	0.77	0.6 -1.2

Mixture Stiffness - Dynamic Modulus



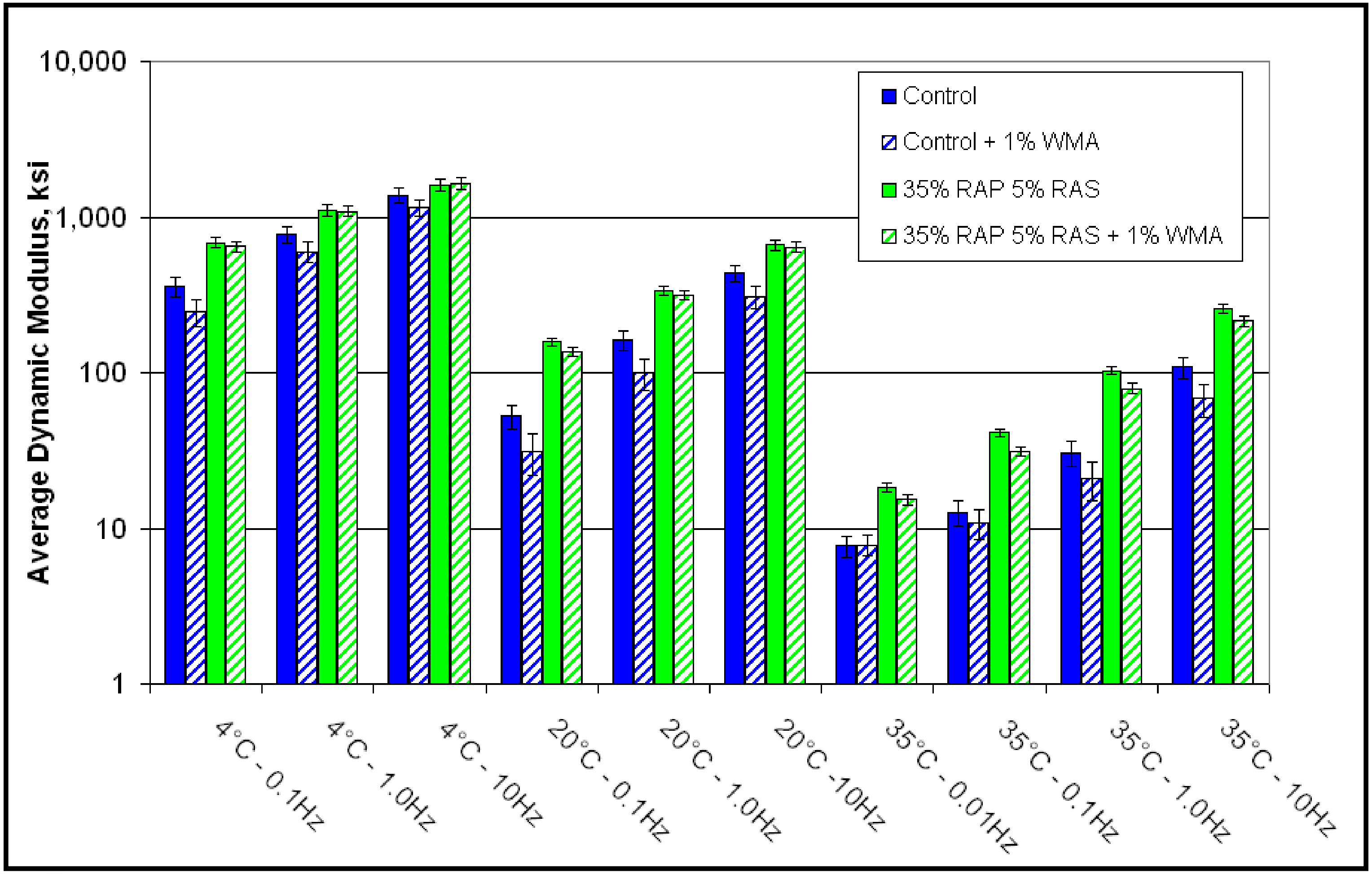
Asphalt Mixture Performance Tester

Conducted to determine changes in mixture stiffness due to the incorporation of RAP or RAS, HiMA, GTR, Rejuvenator and/or the WMA technology.

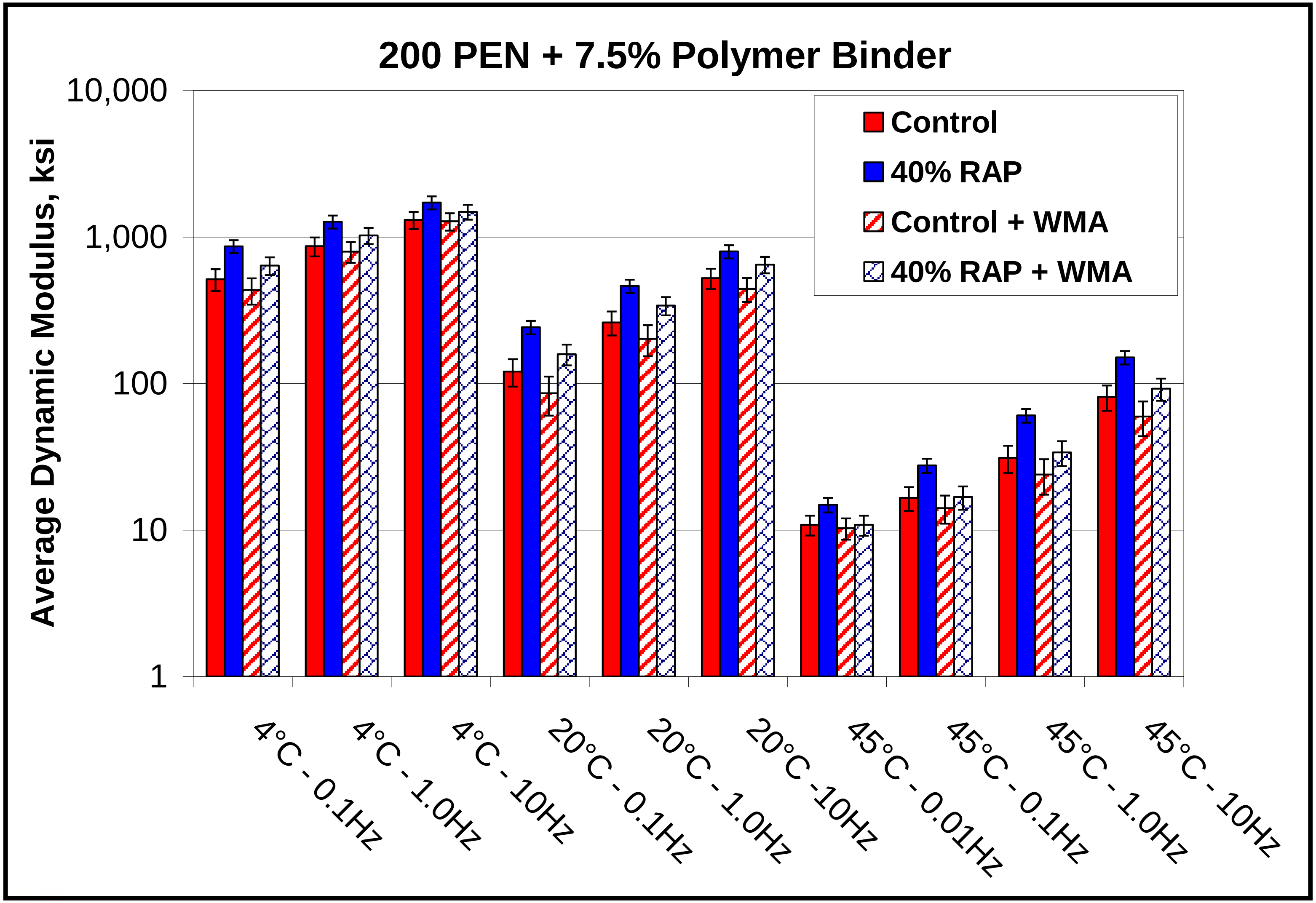
Temperature	Frequency
4°C	10 Hz, 1Hz, 0.1Hz
20°C	10 Hz, 1Hz, 0.1Hz
35°C*	10 Hz, 1Hz, 0.1Hz, 0.01Hz

***35°C or 40°C Based on Type of Binder Used.**

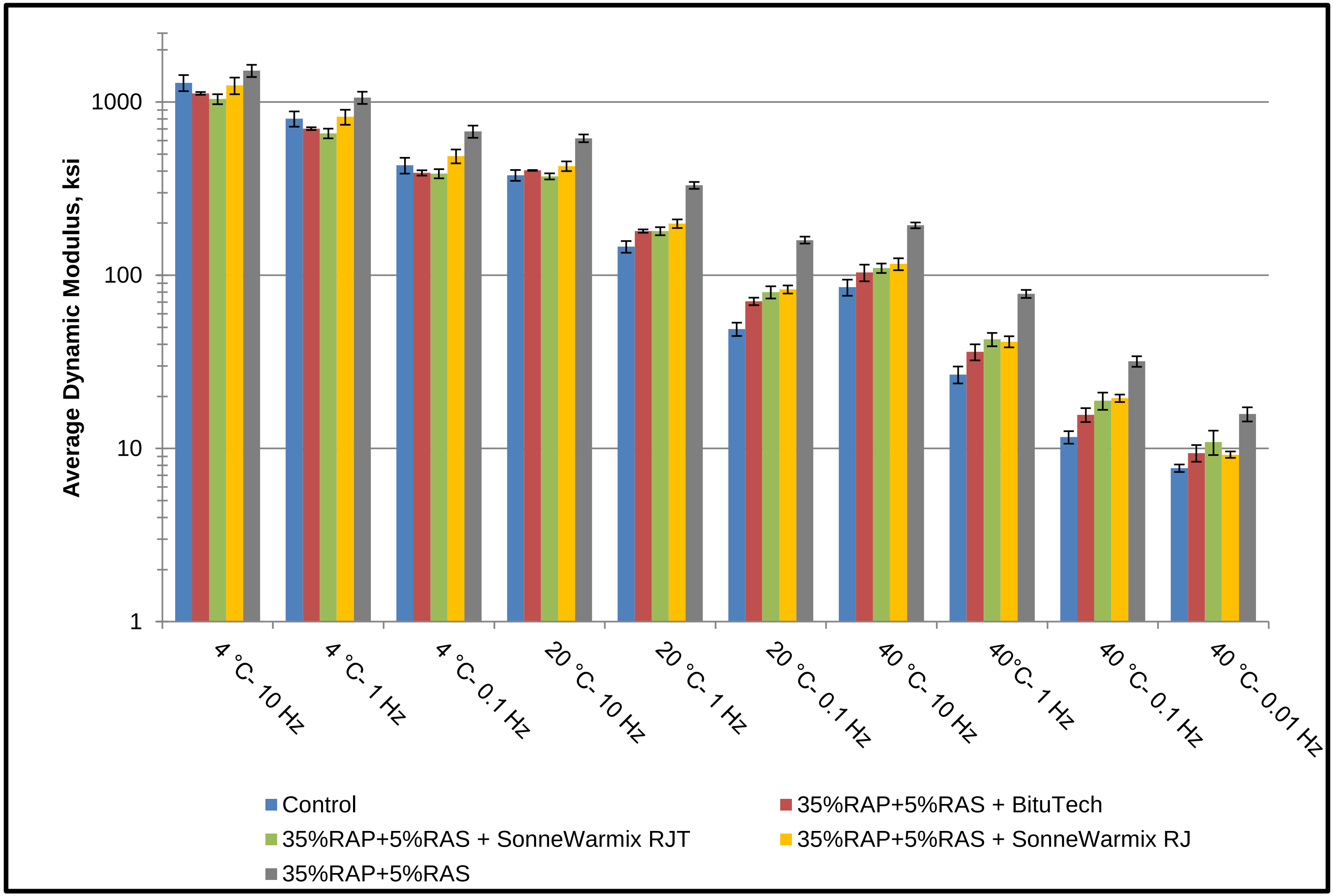
|E*| Data -
Control & 35% RAP + 5% RAS



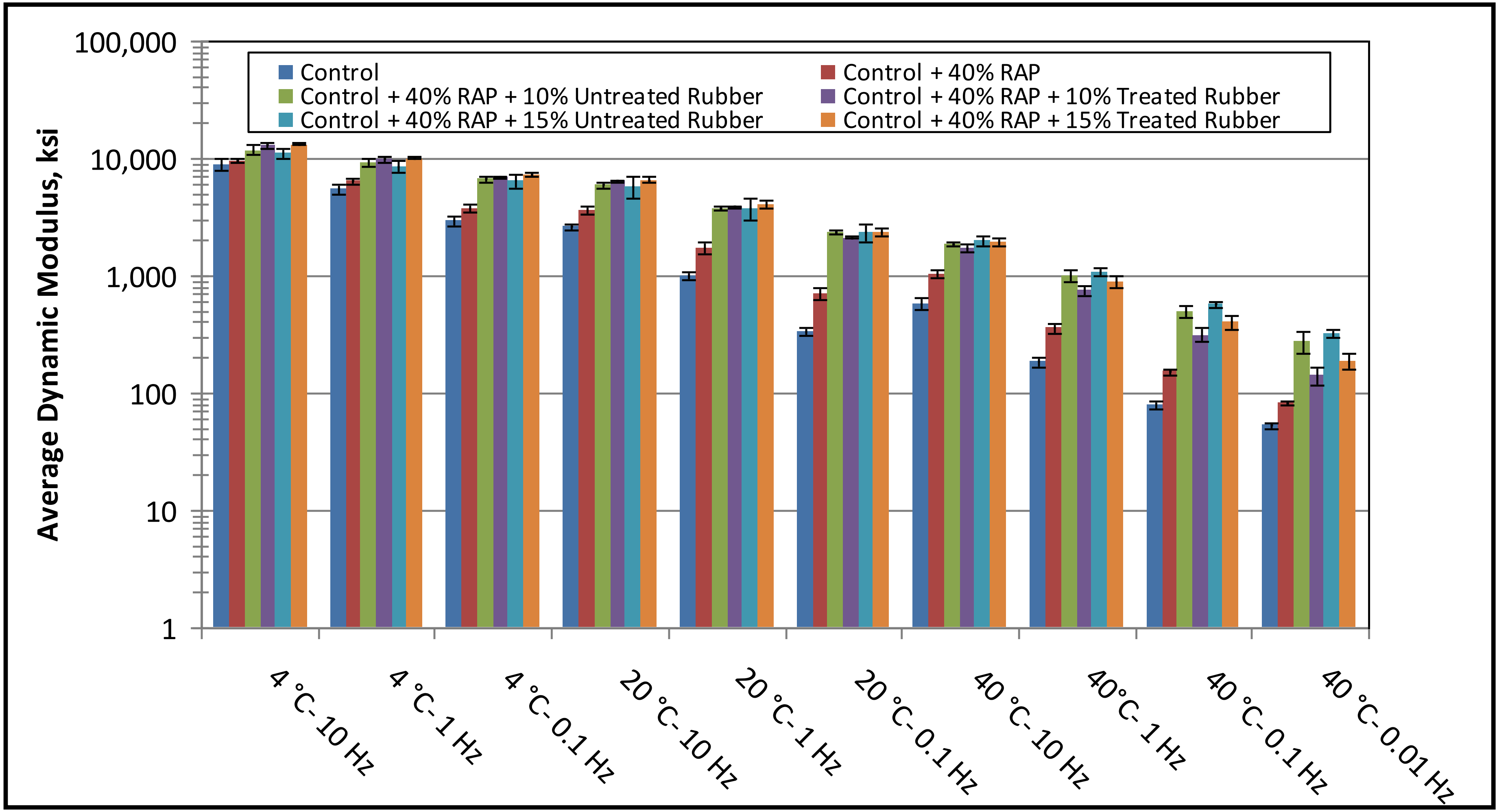
|E*| Data – HiMA 200 PEN + 7.5% SBS



|E*| Data - 35% RAP + 5% RAS + Rejuvenators



|E*| Data - 40% RAP + GTR / Treated GTR



Reflective Cracking - Overlay Tester

Test Temperature = 15ºC (59ºF)

Test Termination at 1,200 cycles or 93% Load reduction

Testing in accordance with Tex-248-F

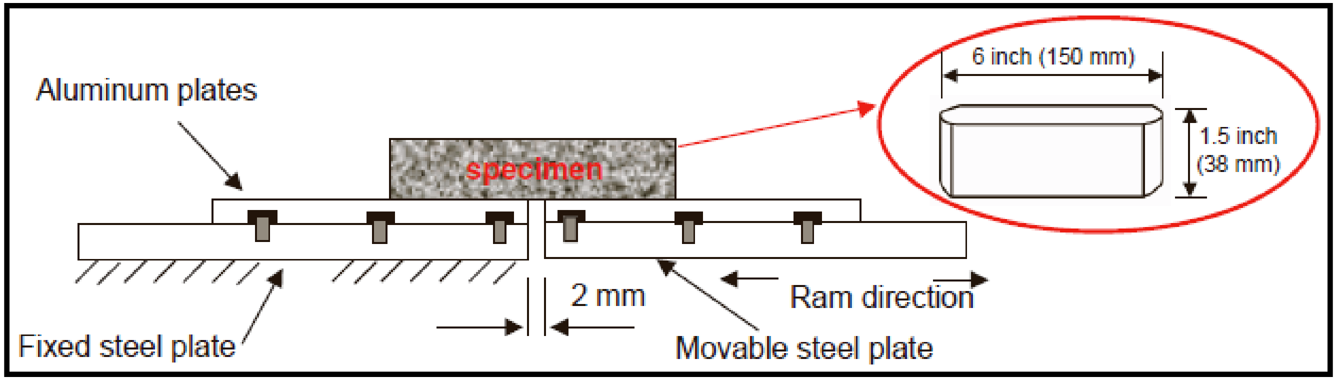


Diagram from: Zhou et al. "Overlay Tester: Simple Performance Test for Fatigue Cracking" Transportation Research Record: Journal of the Transportation Research Board, No. 2001, Transportation Research Board of the National Academies, Washington, D.C., 2007, pp. 1–8.

Overlay Test – RAP/RAS/WMA Results

Mixture	Average OT Cycles to Failure
Control	1,004
40% RAP	3
5% RAS	308
35% RAP + 5% RAS	22
Control + 1% WMA	936
40% RAP + 1% WMA	143
5% RAS + 1% WMA	297
35% RAP + 5% RAS + 1% WMA	63

Overlay Test – HiMA Results

Mixture	Binder	Average Overlay Test (OT) Cycles to Failure
Control	PG58-28	1,004
	PG64-34	1200
	PG70-22 + 7.5% SBS	2
	PG58-28 + 7.5% SBS	38
	200 PEN + 7.5% SBS	387
40% RAP	PG58-28	3
	PG64-34	195
	PG70-22 + 7.5% SBS	3
	PG58-28 + 7.5% SBS	4
	200 PEN + 7.5% SBS	104

Overlay Test – Rejuvenator Results

Mixture	Rejuvenator	Average Overlay Test (OT) Cycles to Failure
40% RAP	NONE	260
	BituTech	1300
	SonneWarmixRJT	1060
	SonneWarmixRJ	440
35% RAP + 5% RAS	NONE	120
	BituTech	360
	SonneWarmixRJT	300
	SonneWarmixRJ	240
5% RAS	NONE	360
	BituTech	1020
	SonneWarmixRJT	700
	SonneWarmixRJ	480

Overlay Test – GTR Results

Mixture	GTR	Average Overlay Test (OT) Cycles to Failure
Control	None	1004
	10% Untreated	53
	15% Untreated	28
	10% Treated	13
	15% Treated	28
40% RAP	None	37
	10% Untreated	8
	15% Untreated	4
	10% Treated	4
	15% Treated	5

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

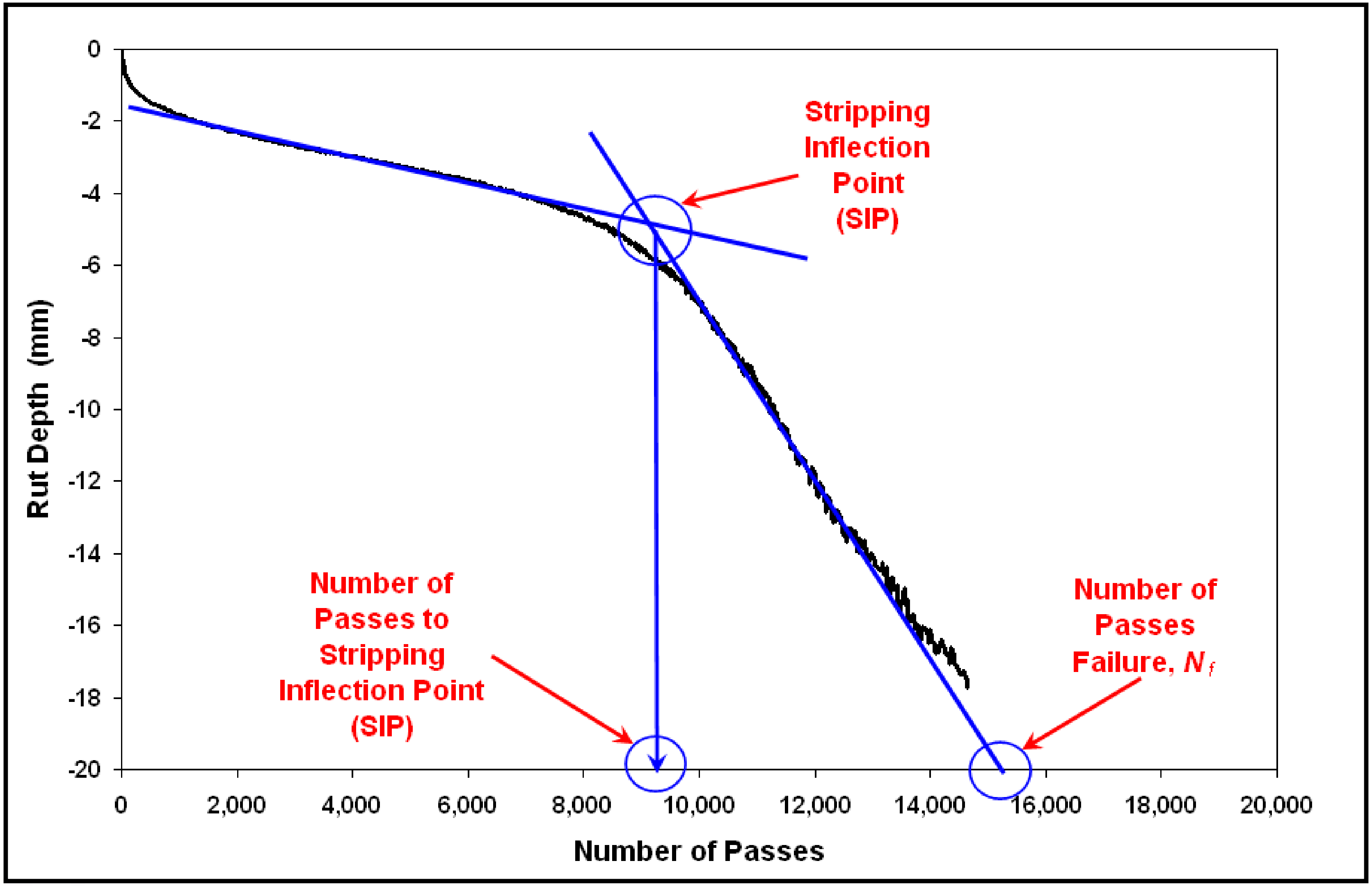
HWTD testing conducted in accordance with AASHTO T324

Water temperature of 40ºC (104ºF) during testing for control PG58-28 binder

Water temperature of 50ºC (122ºF) during testing for HiMA binder & GTR mixtures

Test duration of 20,000 cycles

Stripping Inflection Point (SIP)



HWTD Test – RAP/RAS/WMA Results

Mixture	Stripping Inflection Point
Control	16,800
40% RAP	NONE
5% RAS	NONE
35% RAP + 5% RAS	NONE
Control + 1% WMA	6,200
40% RAP + 1% WMA	NONE
5% RAS + 1% WMA	9,800
35% RAP + 5% RAS + 1% WMA	NONE

HWTD Test – HiMA Results

Mixture	Binder	Stripping Inflection Point	Avg. Rut 10,000 Cycles (mm)	Avg. Rut 20,000 Cycles (mm)
Control	PG52-28*	16,800	0.7	0.9
	PG64-34	10,500	2.7	>20mm
	PG70-22 + 7.5% SBS	NONE	0.4	0.5
	PG58-28 + 7.5% SBS	NONE	0.8	1.0
	200 PEN + 7.5% SBS	17,500	1.4	2.9
40% RAP	PG52-28*	NONE	1.6	5.2
	PG64-34	NONE	1.6	2.5
	PG70-22 + 7.5% SBS	NONE	0.6	0.7
	PG58-28 + 7.5% SBS	NONE	0.8	1.0
	200 PEN + 7.5% SBS	NONE	1.0	1.2

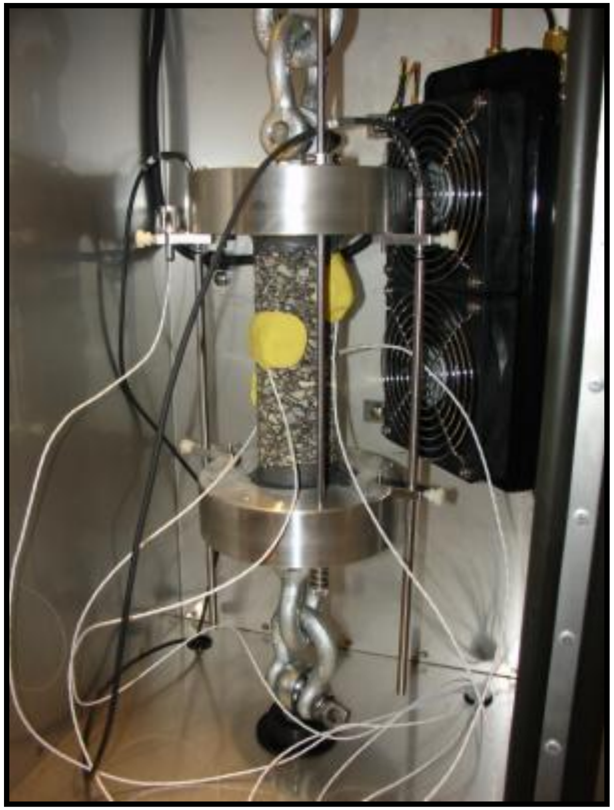
HWTD Test – Rejuvenator Results

Mixture	Rejuvenator	Stripping Inflection Point	Avg. Rut 10,000 Cycles (mm)	Avg. Rut 20,000 Cycles (mm)
40% RAP	NONE	NONE	1.37	2.79
	BituTech	12,270	6.25	>20mm
	SonneWarmixRJT	11,550	3.45	>20mm
	SonneWarmixRJ	10,550	4.73	>20mm
35% RAP + 5% RAS	NONE	NONE	0.80	1.03
	BituTech	NONE	1.58	3.29
	SonneWarmixRJT	NONE	1.80	3.74
	SonneWarmixRJ	NONE	1.51	2.85
5% RAS	NONE	8,230	7.27	>20mm
	BituTech	7,210	11.43	>20mm
	SonneWarmixRJT	5,190	16.90	>20mm
	SonneWarmixRJ	6,690	12.53	>20mm

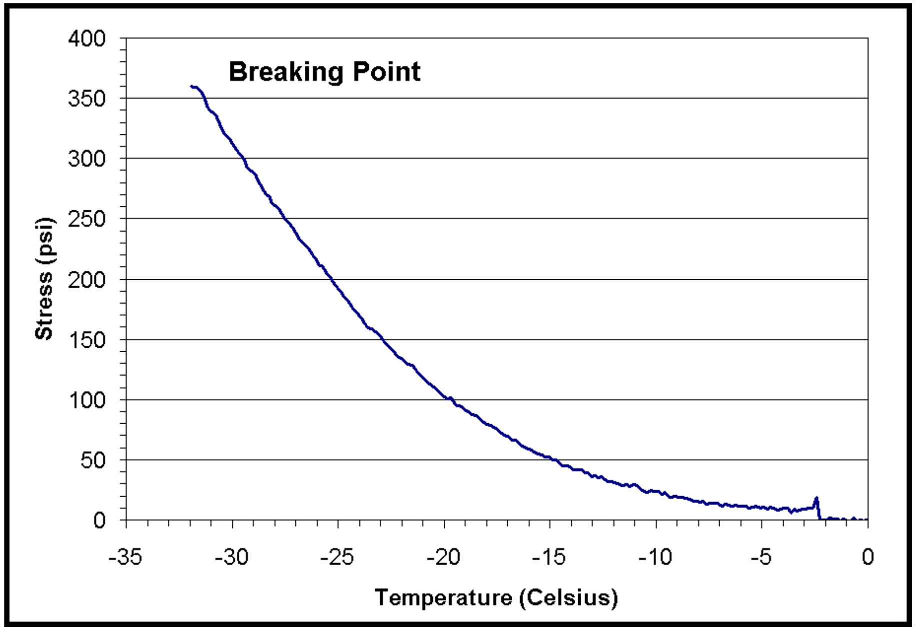
HWTD Test – GTR Results

Mixture	GTR	Avg. Rut 20,000 Cycles (mm)
Control	10% Untreated	1.74
	15% Untreated	0.90
	10% Treated	4.63
	15% Treated	8.63
40% RAP	10% Untreated	0.74
	15% Untreated	0.34
	10% Treated	1.02
	15% Treated	1.64

Mixture Low Temperature Cracking - TSRST



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



TSRST – Rejuvenator Results

Mixture	Rejuvenator	Average Low Cracking Temperature, °C
40% RAP	NONE	-23.5
	BituTech	-27.4
	SonneWarmixRJT	-27.1
	SonneWarmixRJ	-27.4
35% RAP + 5% RAS	NONE	-23.3
	BituTech	-25.3
	SonneWarmixRJT	-27.9
	SonneWarmixRJ	-27.3
5% RAS	NONE	-23.4
	BituTech	-24.5
	SonneWarmixRJT	-26.3
	SonneWarmixRJ	-26.2

TSRST – GTR Results

Mixture	GTR	Average Low Cracking Temperature, °C
Control	NONE	-24.3
	10% Untreated	-28.5
	15% Untreated	-31.0
	10% Treated	-24.7
	15% Treated	-27.3
40% RAP	NONE	-18.3
	10% Untreated	-21.5
	15% Untreated	-20.2
	10% Treated	-22.1
	15% Treated	-25.3

Mixture Workability Evaluation

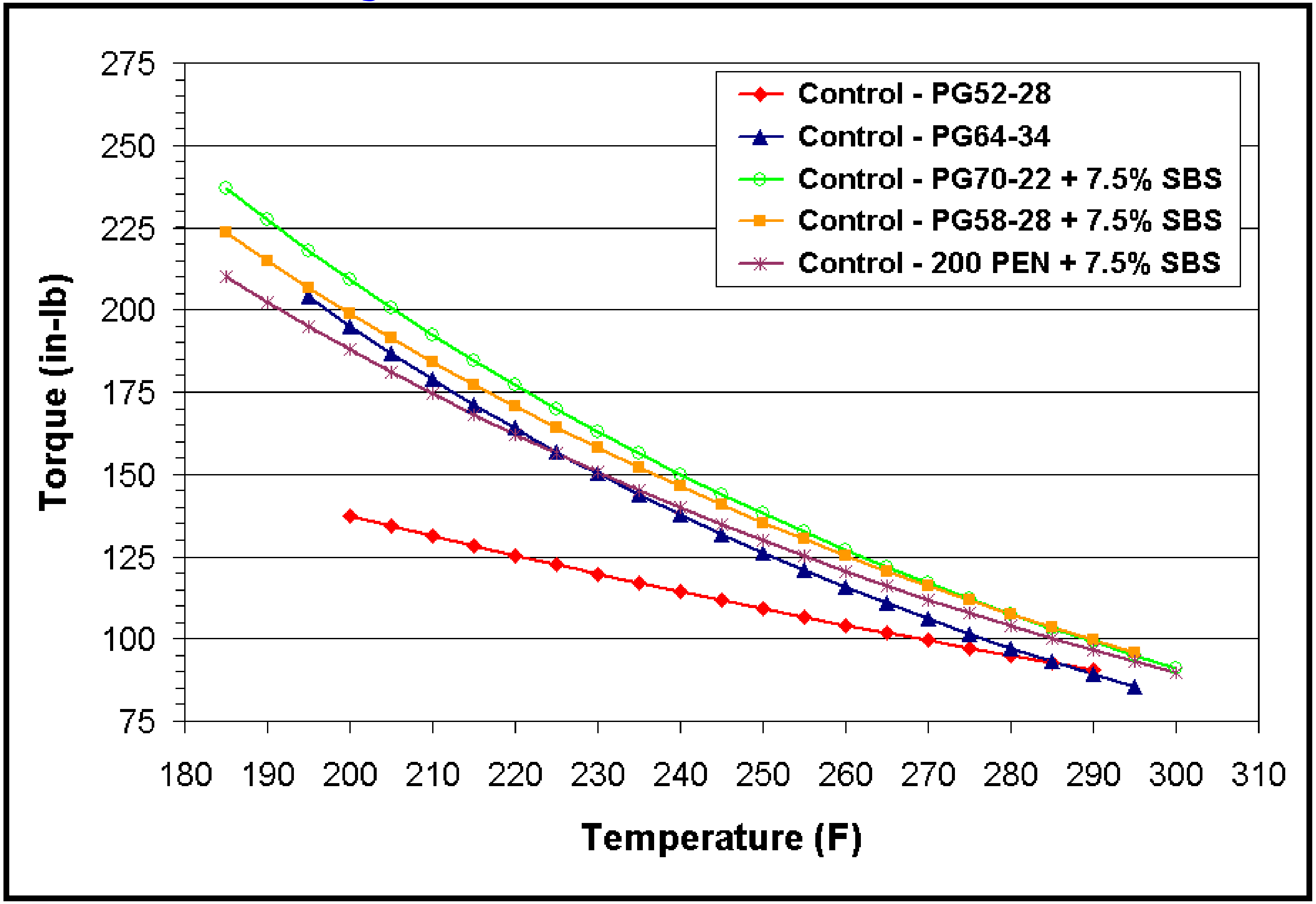
UMass Dartmouth AWD

AWD Paddle Configuration

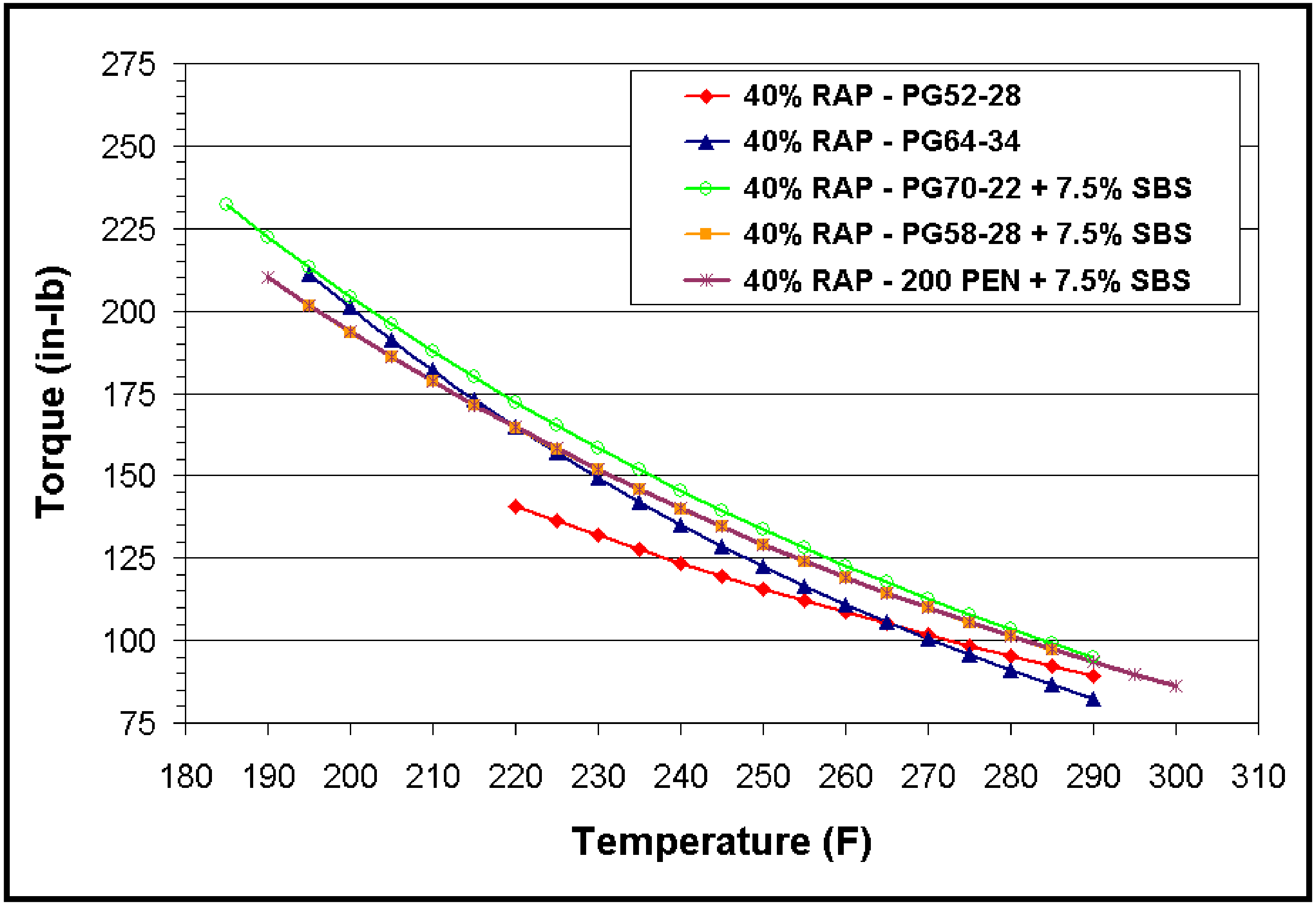
Mixture Workability Evaluation

- Conducted on selected mixtures.
- The AWD operates on the torque measurement principles that have been previously established.
- Mixtures exhibiting higher torque values at the same temperature are considered less workable.

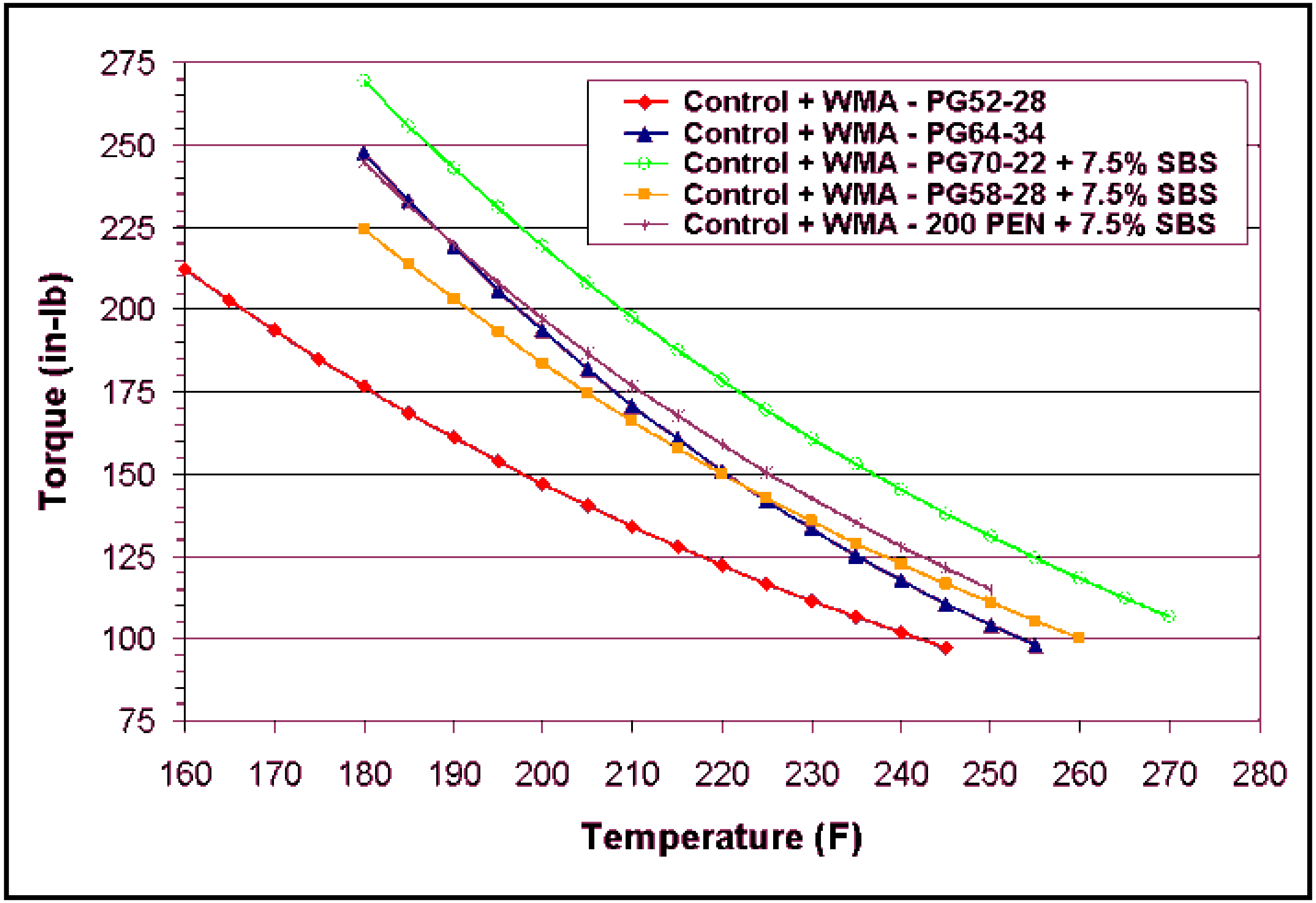
Workability Results – HiMA Control



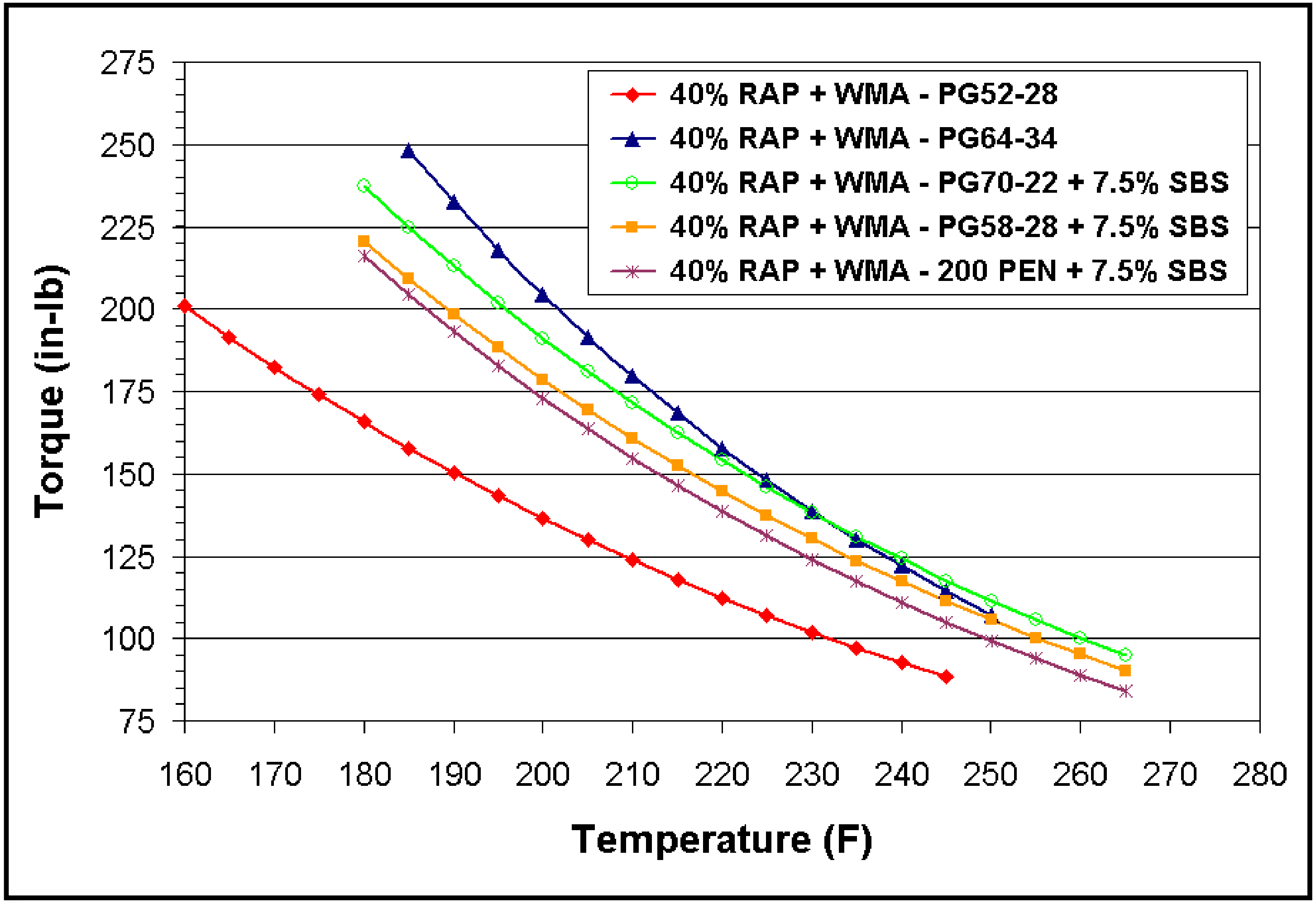
Workability Results – HiMA 40% RAP



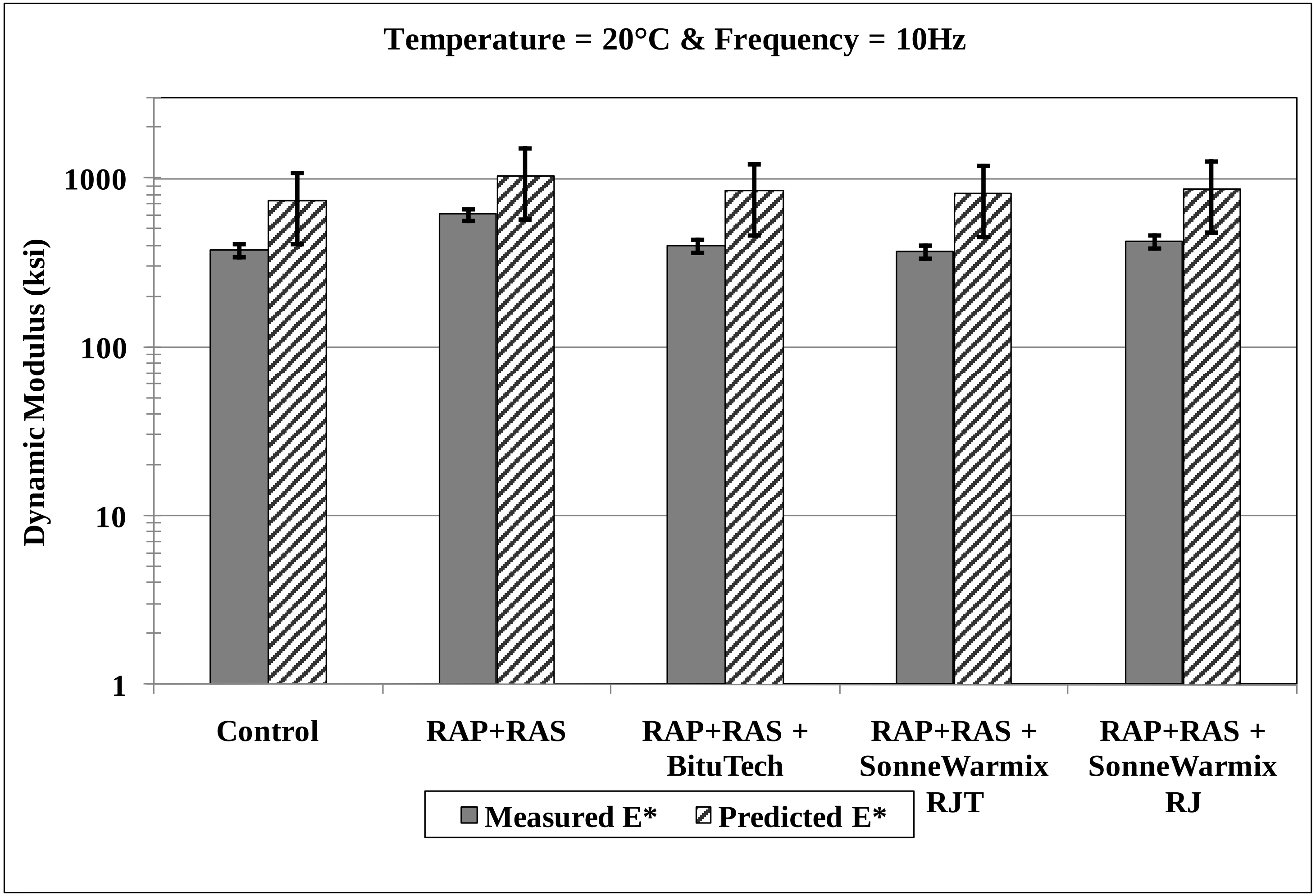
Workability Results – HiMA Control + WMA



Workability Results – HiMA 40% RAP + WMA



Degree of Blending – 20°C , 10Hz



Conclusions

- Dynamic modulus testing indicated that the incorporation of high RAP content and/or RAS caused an increase in the stiffness of the mixtures.

- Mixtures incorporating the WMA technology showed generally lower dynamic modulus values than the mixture without the technology.

Conclusions

- Mixtures incorporating HiMA showed increased stiffness as compared to the control mixtures.

- The incorporation of RAP, GTR, and Treated GTR increased the stiffness of the mixes.

- The rejuvenators did soften the resultant binder of the 40% RAP mixture.

Conclusions

- Reflective cracking results obtained from the Overlay Test indicated that mixtures incorporating the RAP and/or RAS had reduced reflective cracking resistance as compared to the control.
- The use of a WMA technology and/or rejuvenator could improve the reflective cracking resistance the mixtures designed with HiMA.
- The data suggested that RAP and GTR made the mixtures more susceptible to reflective cracking.

Conclusions

- Moisture susceptibility results indicated, for the majority, that the mixtures incorporating RAP and/or RAS had improved moisture susceptibility relative to the control mixtures.

- RAP, GTR and Treated GTR significantly improved resistance of the mixtures against rutting and moisture.

- The rejuvenators increased the rutting and moisture susceptibility of the 40% RAP and 5% RAS mixtures.

Conclusions

- TSRST test results suggested that incorporation of GTR and Treated GTR reduced the low temperature cracking potential of the mixtures.

- The TSRST data showed that the rejuvenators helped mitigate the reduction in the low temperature cracking of the mixtures due to the incorporation of RAP and RAS.

Conclusions

- The addition of 40% RAP did not significantly decrease the mixture workability of the mixtures with HiMA, whereas the workability of the control binder mixtures was reduced.
- The introduction of the WMA technology to the mixtures did marginally improve the workability of all HiMA mixtures tested.

Conclusions

- The use of high RAP content, RAS, WMA technology, rejuvenators, polymer modified asphalt, and GTR used in any combination in asphalt mixtures must be evaluated carefully. In order to be truly balanced, the mixture should be designed to perform acceptably in terms of cracking, rutting, moisture damage, and workability.

Ongoing & Future Work

- Complete mixture workability evaluations.
- Conduct fatigue cracking evaluations using the Flexural Beam Fatigue Setup (AASHTO T321).
- Evaluate the effect of different WMA types and dosages on mixture performance.
- Evaluate the use of rejuvenators in combination with polymer modified asphalt and/or GTR.

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THANK YOU!