Green Sustainable Thin Lift Overlays as a Pavement Preservation Strategy

Northeast Pavement Preservation Partnership Meeting

Boston, MA

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8:30 - 9:00 AM

By:

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Mr. Pat Mitchell - Hudson Liquid Asphalt

Mr. Chris Strack - Sonneborn, Inc.

Overall Scope of Research

Develop Economical & Eco-conscious Mixtures by using High Contents of Sustainable Materials and WMA. Mixtures must Perform Similar to 100% Virgin Material Mixtures.

Recycled Asphalt Shingles

Reclaimed Asphalt Pavement

Scrap Tire Rubber

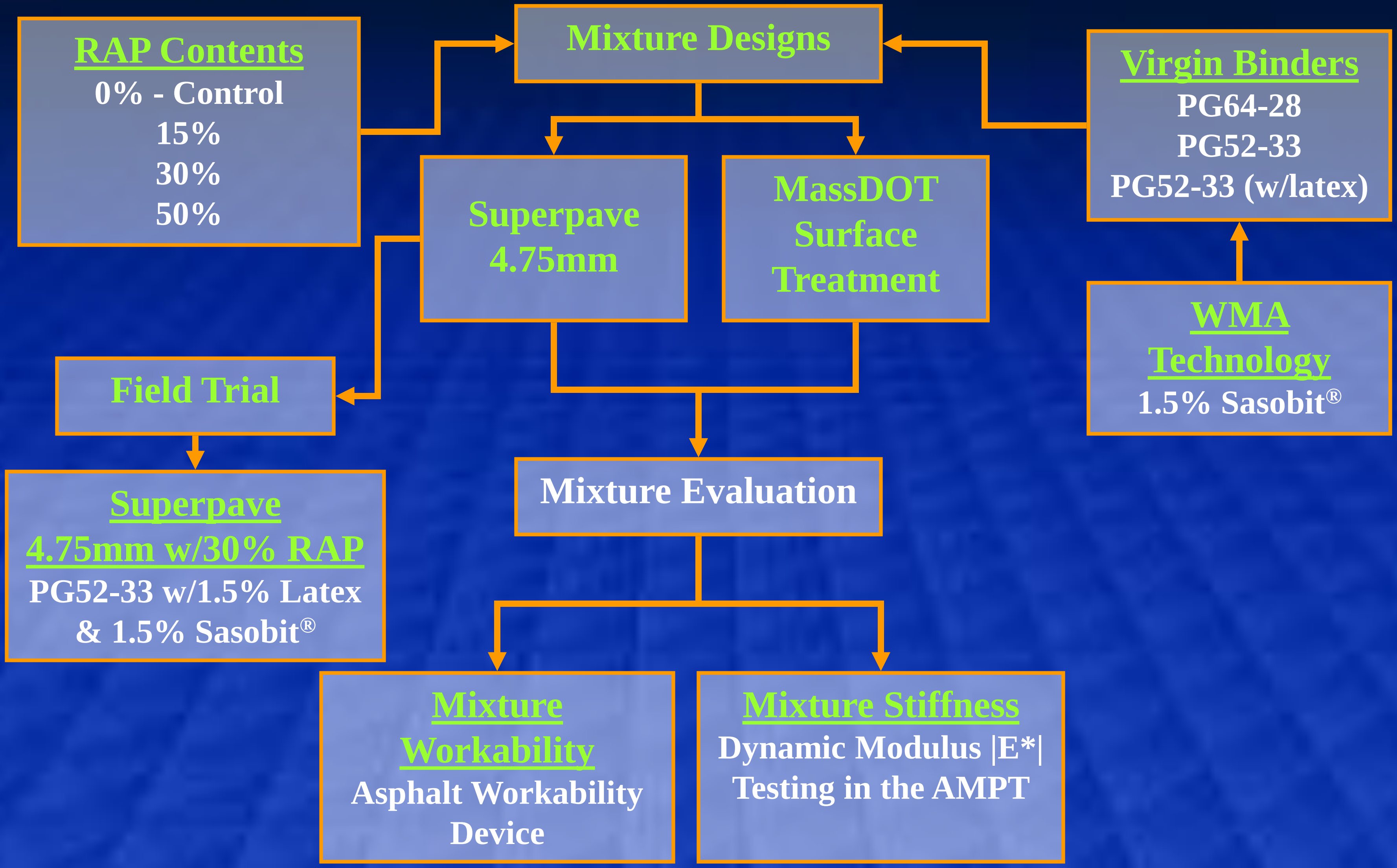
Projects

Year	Mixture Type	Recycled Materials	Binder	WMA
2007 - 2009	Superpave 4.75mm & MassDOT Surface Treatment	0% RAP 15% RAP 30% RAP 50% RAP	PG52-34 PG64-28	Mixtures Included WMA Technology Sasobit
2010 - 2011	Superpave 9.5mm Mixture	0% RAP 40% RAP 5% RAS 35% RAP + 5% RAS	PG52-28	Mixtures Repeated with WMA Technology SonneWarmix
2010 - 2011	12.5mm Asphalt Rubber Gap Graded (ARGG) Mixture	0% RAP 25% RAP 40% RAP	Asphalt Rubber (PG52-28 + 17% Rubber)	Mixtures Repeated with WMA Technology SonneWarmix

Projects

Year	Mixture Type	Recycled Materials	Binder	WMA
2011	Superpave 9.5mm Mixture	0% RAP 40% RAP	PG52-28 PG52-28 + Bio-Binder	Evaluating Bio-Binder as WMA
2011	Superpave 9.5mm Mixture	0% RAP 40% RAP	PG 52-28 PG 64-34 PG 70-22 + 7.5% SBS PG 58-28 + 7.5% SBS 200 PEN + 7.5% SBS	Mixtures Repeated with WMA Technology SonneWarmix

Experimental Plan



Superpave 4.75mm Mix Volumetrics

Volumetric Properties PG64-28 w/1.5% Sasobit®					
	0% RAP	15% RAP	30% RAP	50% RAP	Specification
%Virgin Binder Added	7.0	5.8	4.3	2.3	-
%Extracted Binder	7.0	7.2	6.8	6.4	-
% Air Voids	4.6	4.0	4.0	4.1	4.0%
%VMA	19.5	19.0	17.7	16.5	16-18%
%VFA	76.3	78.7	77.4	75.0	65-78%
Dust-to-Binder Ratio	1.15	1.07	1.36	1.63	0.9-2.0
Volumetric Properties PG52-33 w/1.5% Sasobit®					
%Virgin Binder Added	6.8	5.5	4.0	2.2	-
%Extracted Binder	6.7	6.6	6.4	6.2	-
% Air Voids	4.0	3.7	3.2	4.5	4.0%
%VMA	18.8	16.5	16.0	16.8	16-18%
%VFA	78.7	77.8	80.2	73.3	65-78%
Dust-to-Binder Ratio	1.17	1.27	1.59	1.65	0.9-2.0

Field Trial

- Field trial of Superpave 4.75mm with 30% RAP utilizing the PG52-33 with 1.5% latex and 1.5% Sasobit® binder.
- Mixture placed in one ¾" lift on a 1,100 foot long by 24 foot wide roadway at the town of recycling center.
- Roadway is subject to heavy loading from waste trucks.
- No issues with laydown, compaction, or workability during construction.
- Examined for visual distress in April 2009 and longitudinal and transverse cracking noted.

Main Project Findings

- The stiffness of the mixtures increased as the amount of RAP increased.
- The addition of the RAP caused a reduction in each mixtures workability.
- Mixtures placed at the main field trial, a heavily truck trafficked recycling center, exhibited transverse (thermal) cracking and limited longitudinal cracking isolated to an uphill incline section of the project after 19 months in service.

2010 - 2011

"Performance Characteristics of Thin Lift Overlay Mixtures Containing High RAP Content, RAS, and Warm Mix Asphalt Technology"

Project Scope

9.5mm Thin Lift Overlay Mixture

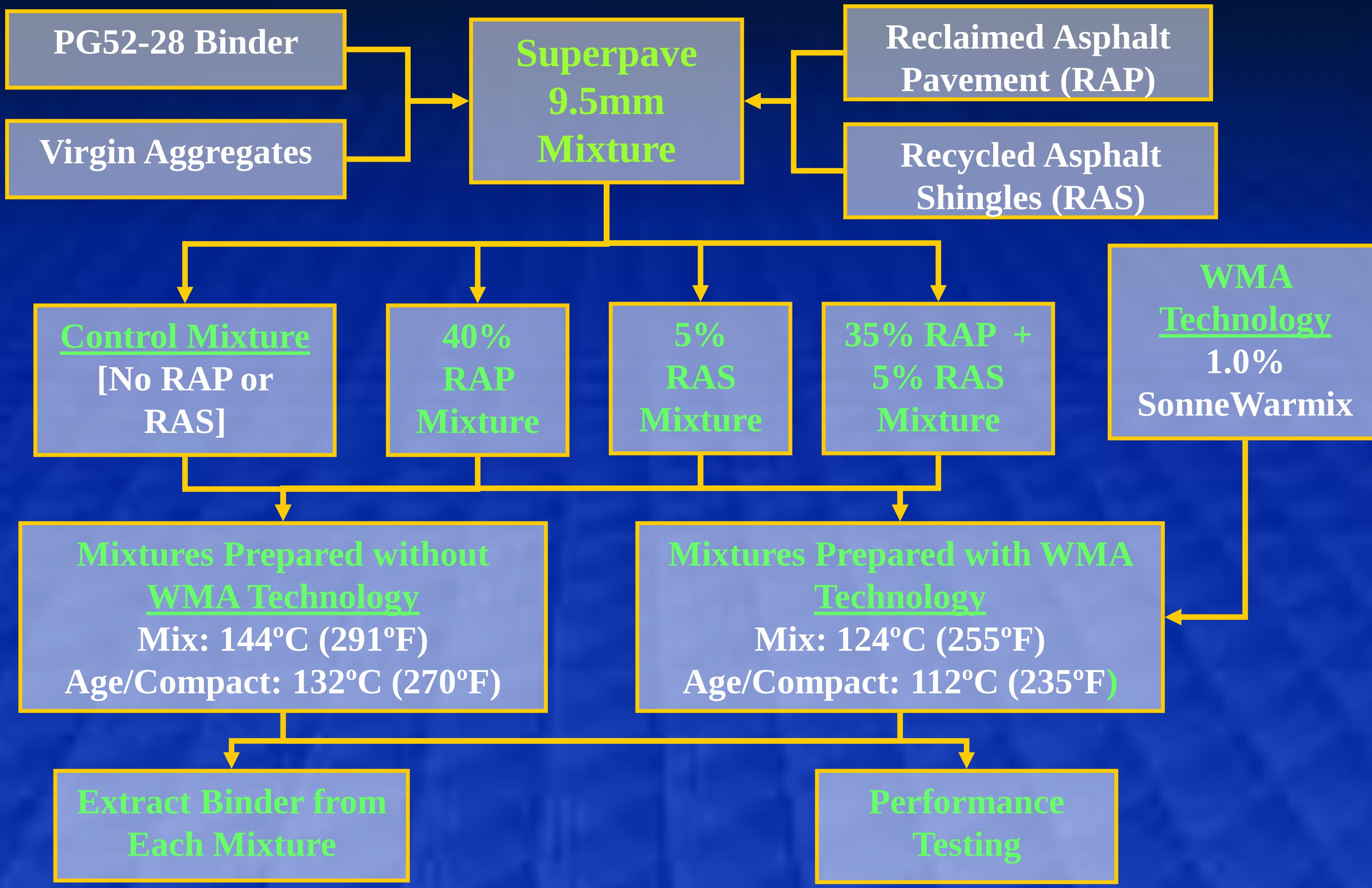
Reclaimed Asphalt Pavement

Recycled Asphalt Shingles (RAS)

Looking at Use of Each Material Both Individually and Collectively

Warm Mix Asphalt Technology

Experimental Plan



Experimental Plan (Cont'd)

Performance Testing

- **<u>Mixture Stiffness</u>**
  Dynamic Modulus |E*| Testing
- **<u>Moisture Susceptibility</u>**
  Hamburg Wheel Tracking Device (HWTD)
- **<u>Reflective Cracking</u>**
  Overlay Tester
- **<u>Low Temperature Cracking</u>**
  Asphalt Concrete Cracking Device (ACCD)

Mixture Volumetrics – Without 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

Performance Testing

- **Testing conducted to determine changes in mixture performance due to incorporation of RAP, RAS and/or the WMA Technology.**

  1. **Stiffness – Dynamic Modulus in AMPT**
  2. **Reflective Cracking – Texas Overlay Tester**
  3. **Low Temperature Cracking – ACCD**
  4. **Moisture Susceptibility/Rutting – HWTD**

Main Project Findings

- 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.

- Reflective cracking results indicated that mixtures incorporating the RAP and/or RAS had reduced reflective cracking resistance as compared to the control.

Main Project Findings

- Low temperature cracking resistance test results indicated that the addition of RAP, RAS and/or WMA technology did not have a negative impact on the low temperature performance of the mixtures.

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

2011

"Performance Characteristics of Asphalt Rubber Mixtures Containing RAP and Warm Mix Asphalt Technology"

Project Scope - Green Design

Warm Mix Asphalt Technology -Wax Based

Reclaimed Asphalt Pavement

12.5mm Asphalt Rubber Mixture

Crumb Rubber from Waste Tires

Experimental Plan

Asphalt Rubber (AR) Binder

12.5mm Asphalt Rubber Mixture

Reclaimed Asphalt Pavement (RAP)

Virgin Aggregates

Mixtures Prepared without <u>WMA Technology</u>
Mix: 177ºC (351ºF)
Age/Compact: 154ºC (309ºF)

Mixtures Prepared with WMA <u>Technology</u>
Mix: 160ºC (320ºF)
Age/Compact: 141ºC (286ºF)

WMA <u>Technology</u>
1.0%
SonneWarmix

<u>Control Mixture</u>
[No RAP]

25% RAP Mixture

40% RAP Mixture

Mixture Testing

Experimental Plan (Cont'd)

Mixture Testing

Performance

- **Mixture Stiffness**
  Dynamic Modulus |E*| Testing
- **Fatigue**
  1. Beam Fatigue
  2. Uniaxial Fatigue
- **Cracking Resistance**
  Overlay Tester
- **Moisture Susceptibility/Rutting**
  Hamburg Wheel Tracking Device (HWTD)

Other

- **Workability**
  UMass Dartmouth Asphalt Workability Device

Mixture Testing

- **Testing conducted to determine changes in mixture performance due to incorporation of Asphalt Rubber binder, RAP and/or the WMA Technology.**

1. **Stiffness – Dynamic Modulus in AMPT**
2. **Fatigue – Beam Fatigue & Uniaxial Fatigue**
3. **Reflective Cracking – Texas Overlay Tester**
4. **Moisture Susceptibility/Rutting – HWTD**
5. **Workability – AWD**




Main Project Findings

- The dynamic modulus and mixture master curve data indicated that addition of 25% and 40% RAP to the control mixture resulted in an increase in mixture stiffness. This stiffness increase was mitigated through the use of the WMA technology and corresponding reduced aging temperatures.

- The push-pull test and beam fatigue test showed similar trends and correspondingly showed good agreement between them. The fatigue life of the mixtures improved as the RAP content increased.

2011

"Performance Characteristics of High RAP Bio-Modified Asphalt Mixtures"

Project Scope – Green Design

9.5mm Thin Lift Overlay Mixture

Reclaimed Asphalt Pavement

Bio - Modified Binder

Experimental Plan

PG52-28 Binder

PG52-28 Binder + 5% Bio-Oil (Bio-Modified Binder)

Superpave 9.5mm Mixture

Virgin Aggregates

Reclaimed Asphalt Pavement (RAP)

Control Mixture [No RAP]

40% RAP Mixture

Control Mixture + Bio-Modified Binder

40% RAP Mixture + Bio-Modified Binder

Testing

Mixture Stiffness
Dynamic Modulus |E*| Testing

Moisture Susceptibility & Rutting
Hamburg Wheel Tracking Device (HWTD)

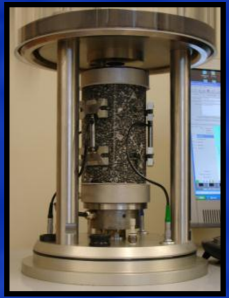
Cracking
Overlay Tester

Workability
UMass Dartmouth Asphalt Workability Device

Performance Testing

- Testing conducted to determine changes in mixture performance due to incorporation of RAP, RAS and/or the WMA Technology.

1. Stiffness – Dynamic Modulus in AMPT
2. Cracking – Texas Overlay Tester
3. Moisture Susceptibility/Rutting – HWTD
4. Workability – AWD




Main Project Findings

- 9.5 mm mixtures incorporating a bio-modified binder with and without 40% RAP were able to be developed to meet Superpave specifications.

- The introduction of the bio-modified binder decreased the mixture stiffness for both the control and 40% RAP mixtures and therefore indicated that the bio-modified binder, at reduced mixing and compaction temperatures, can help reduce the stiffening effects caused by the introduction of high percentages of RAP.

Main Project Findings

- The addition of the bio-modified binder to the mixtures showed improvement in the cracking susceptibility of the control and 40% RAP mixture.

- The HWTD rutting and moisture susceptibility data suggested that the use of a bio-modified binder in conjunction with high percentages of RAP performed similarly or better than a similar mixture fabricated with the virgin binder and better than the control mixture without RAP and virgin binder.

2010 - 2011

“Performance and Workability Characteristics of High Performance Thin Lift Overlays Incorporating High RAP Content and Warm Mix Asphalt Technology”

HPThinOL

- High Performance Thin Asphalt Overlays (HPThinOL) are defined as having a thickness of one inch or less and are used in applications requiring higher levels of rutting and fatigue resistance.

- HPThinOL are used as a pavement preservation strategy and are placed on pavements that have remaining structural capacity that is expected to outlive the pavement preservation strategy.

- Current specifications for HPThinOL generally require a Polymer Modified Asphalt (PMA).

- Sustainable HPThinOL incorporate high RAP content (40%), a WMA technology, and PMA binders.

Project Scope

9.5mm Thin Lift Overlay Mixture

Reclaimed Asphalt Pavement

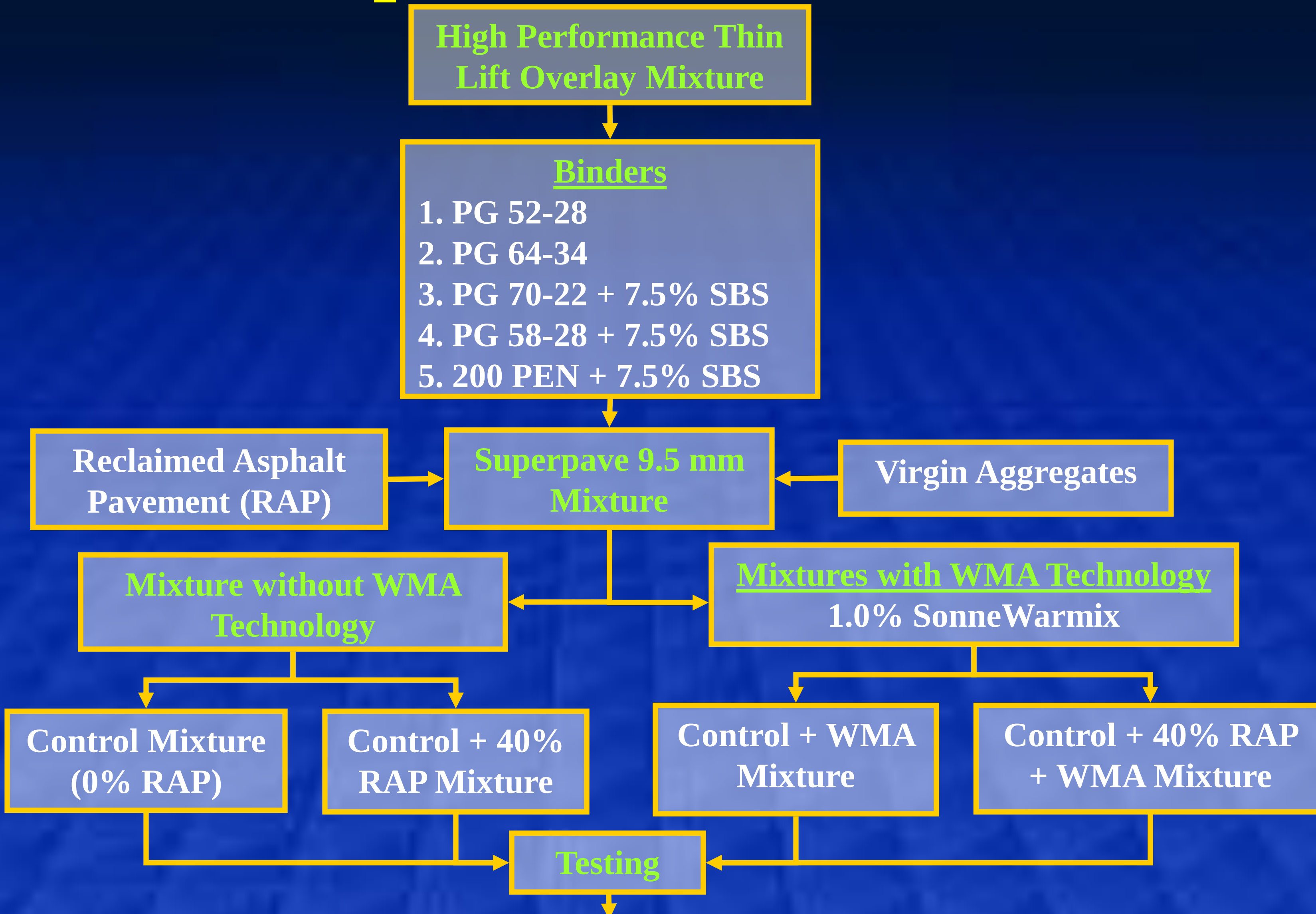
Polymer Modified Asphalt (PMA)

Warm Mix Asphalt Technology

Project Objectives

- **Measure the effect of RAP, WMA technology, and PMA binders on the dynamic modulus (stiffness) of the mixtures.**
- **Measure the reflective cracking resistance of the mixtures using the Texas Overlay tester.**
- **Measure the moisture susceptibility and rutting resistance of the mixtures using the Hamburg Wheel Tracking Device (HWTD).**
- **Evaluate the effect of high RAP content, WMA, and PMA on the workability of the HPThinOL mixtures.**

Experimental Plan



Experimental Plan

- **Testing**
  - **Performance**
    - **Reflective Cracking**: Overlay Tester
    - **Moisture Susceptibility/ Rutting**: Hamburg Wheel Tracking Device
  - **Stiffness & Workability**
    - **Mixture Stiffness**: Dynamic Modulus | E* |
    - **Workability**: Asphalt Workability Device (AWD)

Control Binder

- The control binder was a PG52-28 unmodified conventional binder.
- Softest grade available that met the low temperature requirement of a PGXX-28 binder that is typically specified in the Northeast.
- Based on the viscosity of the binder, the mixture mixing temperature was 144ºC (291ºF) and the compaction temperature was 132ºC (270ºF).

PMA Binders

- A PG64-34 obtained from Road Science, LLC. Based on the manufacturers recommendations the mixture mixing temperature was 154ºC (309ºF) and the compaction temperature was 143ºC (289ºF).

- The three remaining polymer modified binders were obtained from Kraton Polymers U.S. LLC: PG70-22 + 7.5% SBS, PG58-28 + 7.5% SBS and 200 PEN +7.5% SBS.

- The base binders for the three Kraton binders were selected in order to meet the potential existing pavement conditions where the HPThinOL would be placed. For pavement with high severity distresses, the softest binder would be used.

PMA Binders

- Based on the manufacturers recommendations, the mixture mixing temperature was 166ºC (331ºF) and the compaction temperature was 149ºC (300ºF) for all three of these binders.

Warm Mix Asphalt Technology

- Waxed based additive known as SonneWarmix™.
- Previously utilized in numerous field projects in Massachusetts and other New England states.
- SonneWarmix™ added at a dosage rate of 1.0% by weight of total binder (Virgin +RAP).
- Mixtures incorporating the warm mix technology were fabricated with a reduction in mixing and compaction temperatures as compared to the mixtures without the technology.

WMA Temperature Selection

- **The reduced WMA temperatures were selected based on the workability of the mixtures. The workability test will be described later.**
- **The workability (torque) values will increase as the temperature drops. The temperature at which the rate of increase changed was used as an estimate for the aging temperatures.**
- **The mixing temperature was selected at a range of 10 - 20 °C higher than the aging temperature.**

Mixing & Compaction Temperatures

	Without WMA Technology		With WMA Technology	
Binder	Mixing	Compaction	Mixing	Compaction
PG52-28	144ºC (291ºF)	132ºC (270ºF)	124ºC (255ºF)	113ºC (235ºF)
PG64-34	154ºC (309ºF)	143ºC (289ºF)	138ºC (280ºF)	127ºC (261ºF)
PG70-22 + 7.5% SBS	166ºC (331ºF)	149ºC (300ºF)	144ºC (291ºF)	127ºC (261ºF)
PG58-28 + 7.5% SBS	166ºC (331ºF)	149ºC (300ºF)	144ºC (291ºF)	127ºC (261ºF)
200 PEN +7.5% SBS	166ºC (331ºF)	149ºC (300ºF)	144ºC (291ºF)	127ºC (261ºF)

RAP

- RAP was obtained from same contractor that supplied the virgin aggregates.
- RAP average binder content = 5.26% (AASHTO T308 - Ignition)

Aggregate & RAP Properties

Sieve Size	9.5mm	Natural Sand	Stone Sand	Stone Dust	RAP
19.0 mm	100	100	100	100	100
12.5 mm	99.4	100	100	100	100
9.5 mm	93.8	100	10	100	99.8
4.75 mm	29.7	99.7	99.8	99.7	74.3
2.36 mm	5.2	98.3	83.7	83.7	56.5
1.18 mm	2.8	93.3	54.3	57.1	43.2
0.600 mm	2.3	73.3	33.8	38.6	31.9
0.300 mm	2.1	29.7	19.0	24.9	20.5
0.150 mm	1.8	4.8	9.4	15.9	12.5
0.075 mm	1.5	0.9	4.3	10.9	8.5
Bulk Specific Gravity	2.642	2.624	2.644	2.629	2.638
Absorption, %	0.43	0.45	0.53	0.60	0.76

Mixture Gradations

Sieve Size	Control	40% RAP	9.5 mm Superpave Specification
19.0 mm	100	100.0	-
12.5 mm	99.7	99.8	100 min.
9.5 mm	97.1	97.7	90-100
4.75 mm	66.8	64.6	90 max.
2.36 mm	47.8	44.8	32-67
1.18 mm	33.5	31.7	-
0.600 mm	23.0	21.9	-
0.300 mm	13.3	12.9	-
0.150 mm	7.1	6.7	-
0.075 mm	4.4	4.4	2-10

For the 40% RAP mixtures the virgin binder replaced with recycled binder was 35.1%.

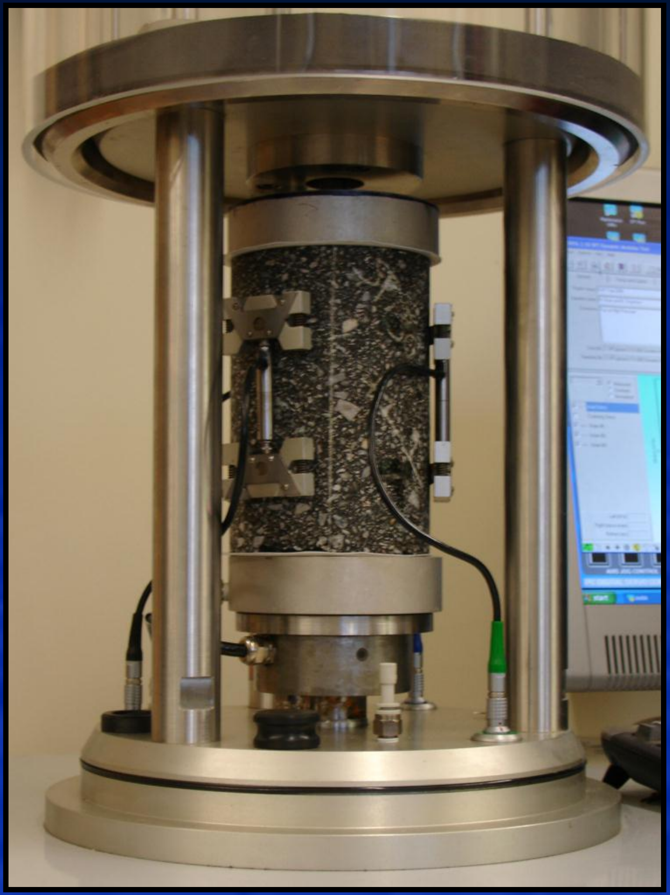
Mixture Volumetric Properties

	Control Mixtures					
Properties	PG52-28 Control Binder	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	PG52-28 Control Binder	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 Volumetric Properties

	Control + 40% RAP Mixtures					
Properties	PG52-28 Control Binder	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	PG52-28 Control Binder	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 Stiffness - Dynamic Modulus



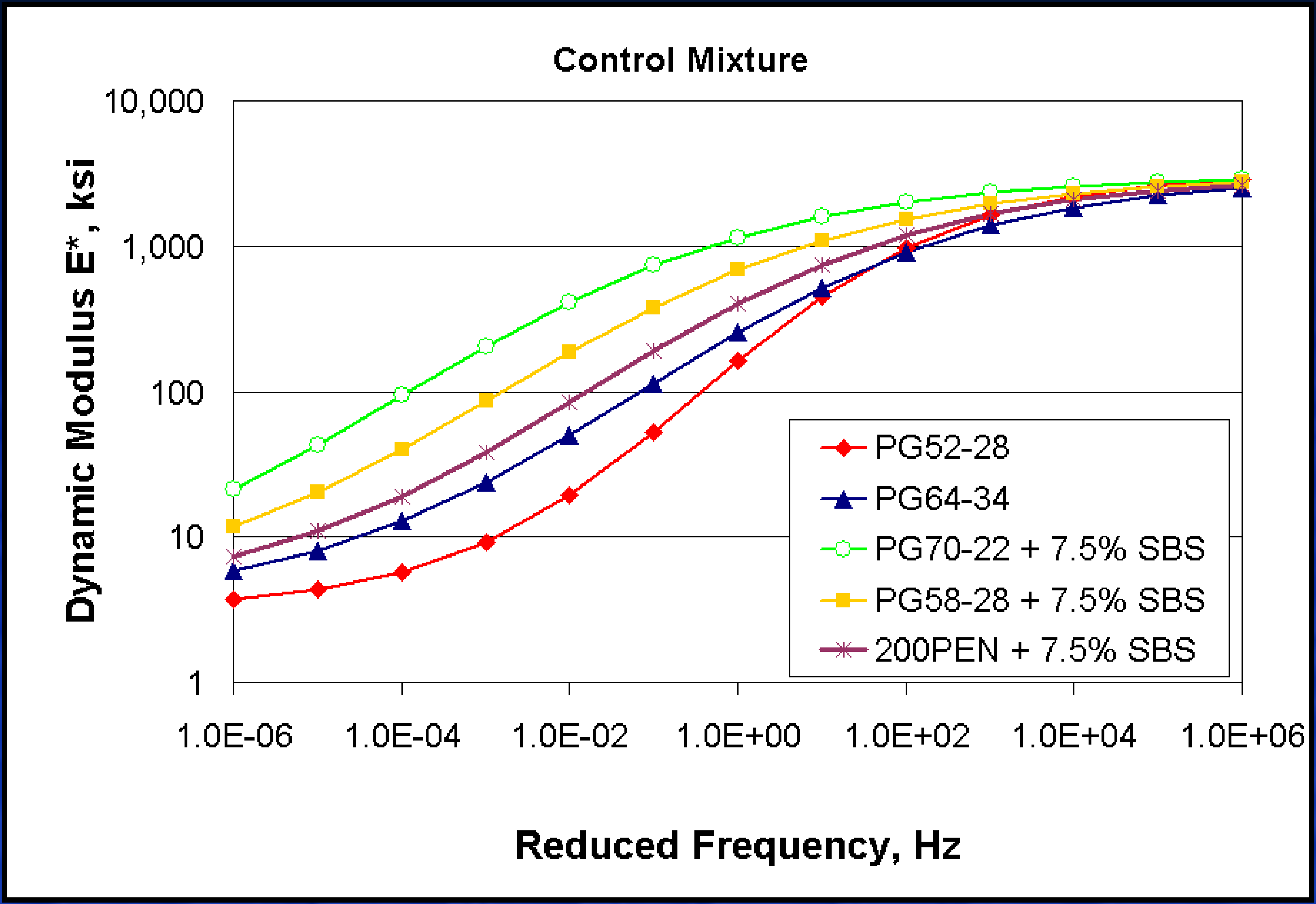
Asphalt Mixture Performance Tester (AMPT)

Conducted to determine changes in mixture stiffness due to the incorporation of a PMA binder, RAP and/or the WMA technology.

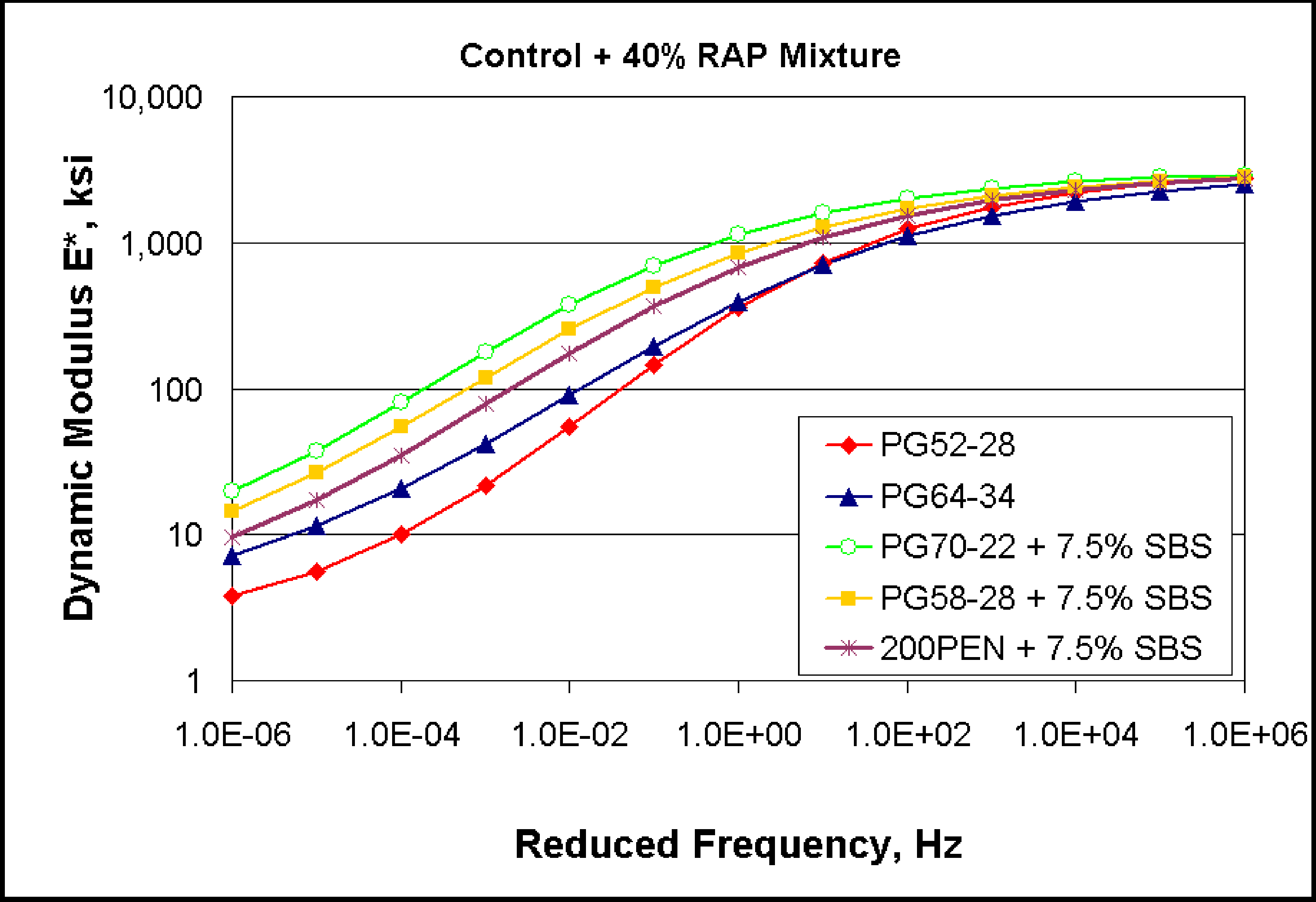
Temperature	Frequency
4°C	10 Hz, 1Hz, 0.1Hz
20°C	10 Hz, 1Hz, 0.1Hz
35°C*	10 Hz, 1Hz, 0.1Hz, 0.01Hz

*35ºC for PG52-28, 40ºC for PG64-34 & 45ºC for remaining PMA binders.

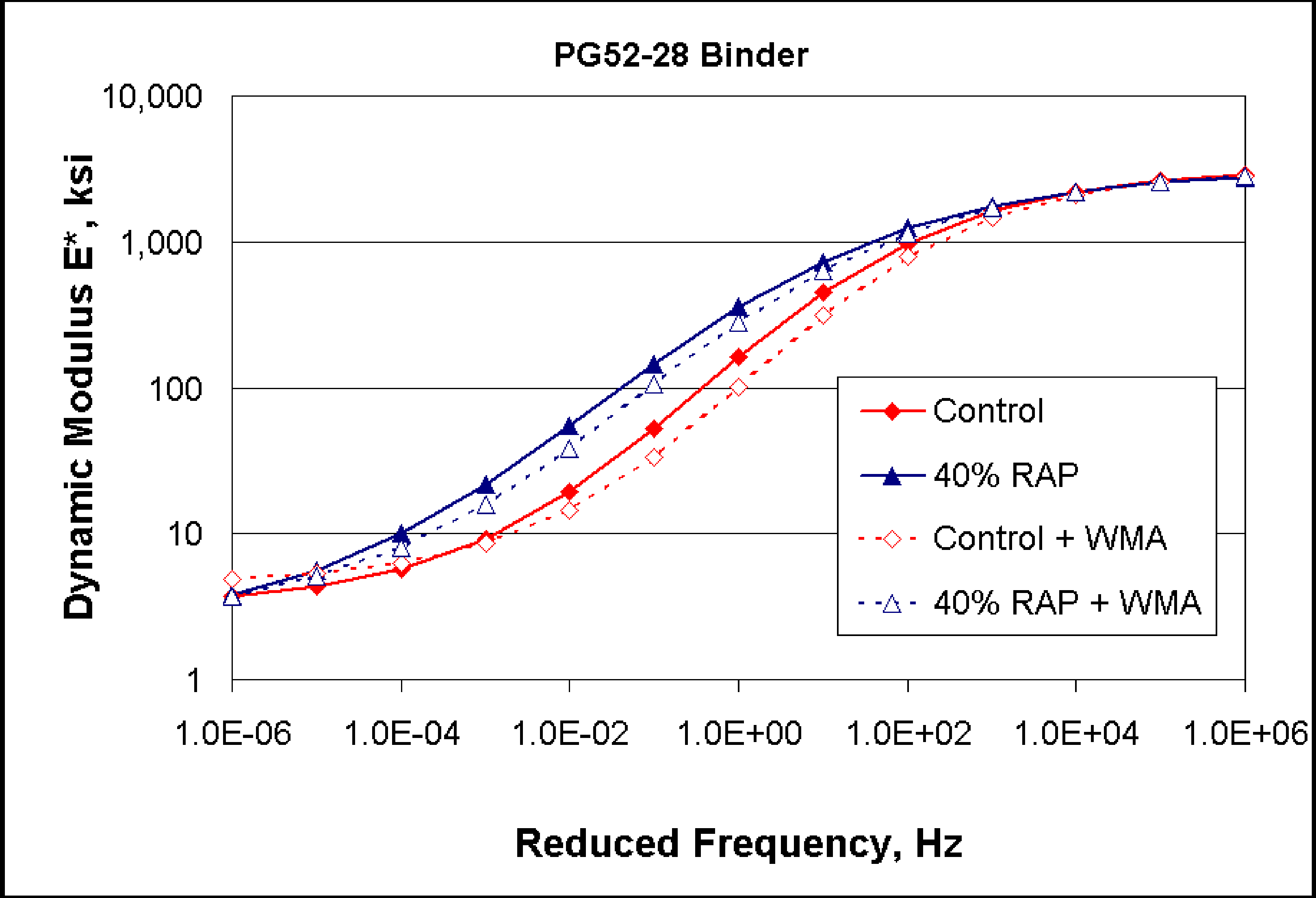
Dynamic Modulus Master Curve



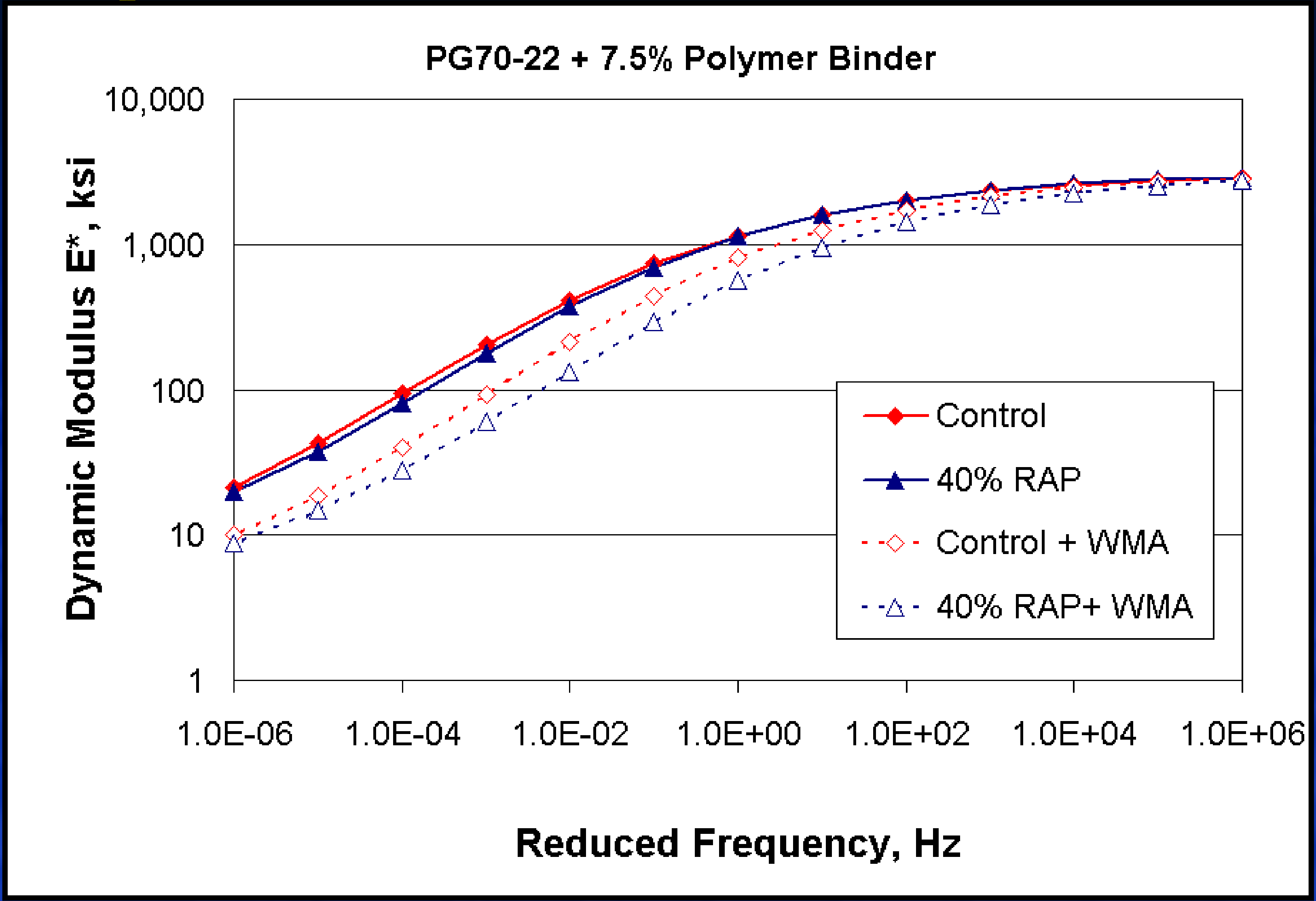
Dynamic Modulus Master Curve



Dynamic Modulus Master Curve



Dynamic Modulus Master Curve



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

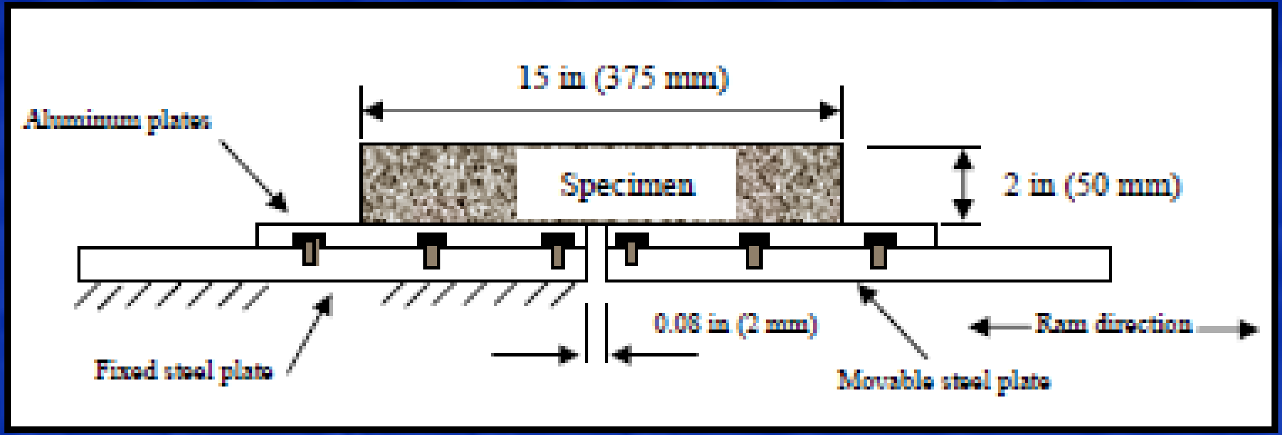


Diagram from: Zhou and Scullion "Overlay Tester: A Rapid Performance Related Crack Resistance Test" Report No. FHWA/TX-05/0-4467-2 (2005).

Overlay Tester Results – NO WMA

Mixture	Binder	Average Overlay Test (OT) Cycles to Failure
Control	PG52-28	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	PG52-28	3
	PG64-34	195
	PG70-22 + 7.5% SBS	3
	PG58-28 + 7.5% SBS	4
	200 PEN + 7.5% SBS	104

Overlay Tester Results - WMA

Mixture	Binder	Average Overlay Test (OT) Cycles to Failure
Control + WMA	PG52-28	936
	PG64-34	1200
	PG70-22 + 7.5% SBS	8
	PG58-28 + 7.5% SBS	156
	200 PEN + 7.5% SBS	1200
40% RAP + WMA	PG52-28	143
	PG64-34	453
	PG70-22 + 7.5% SBS	425
	PG58-28 + 7.5% SBS	12
	200 PEN + 7.5% SBS	439

Overlay Tester - Conclusions

- The addition of 40% RAP to the control mixture reduced the reflective cracking resistance of the mixture regardless of type the binder utilized.
- The use of the WMA technology could improve the reflective cracking resistance as compared to the control.
- The use of a polymer modified binder may improve the reflective cracking resistance of the mixture.

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

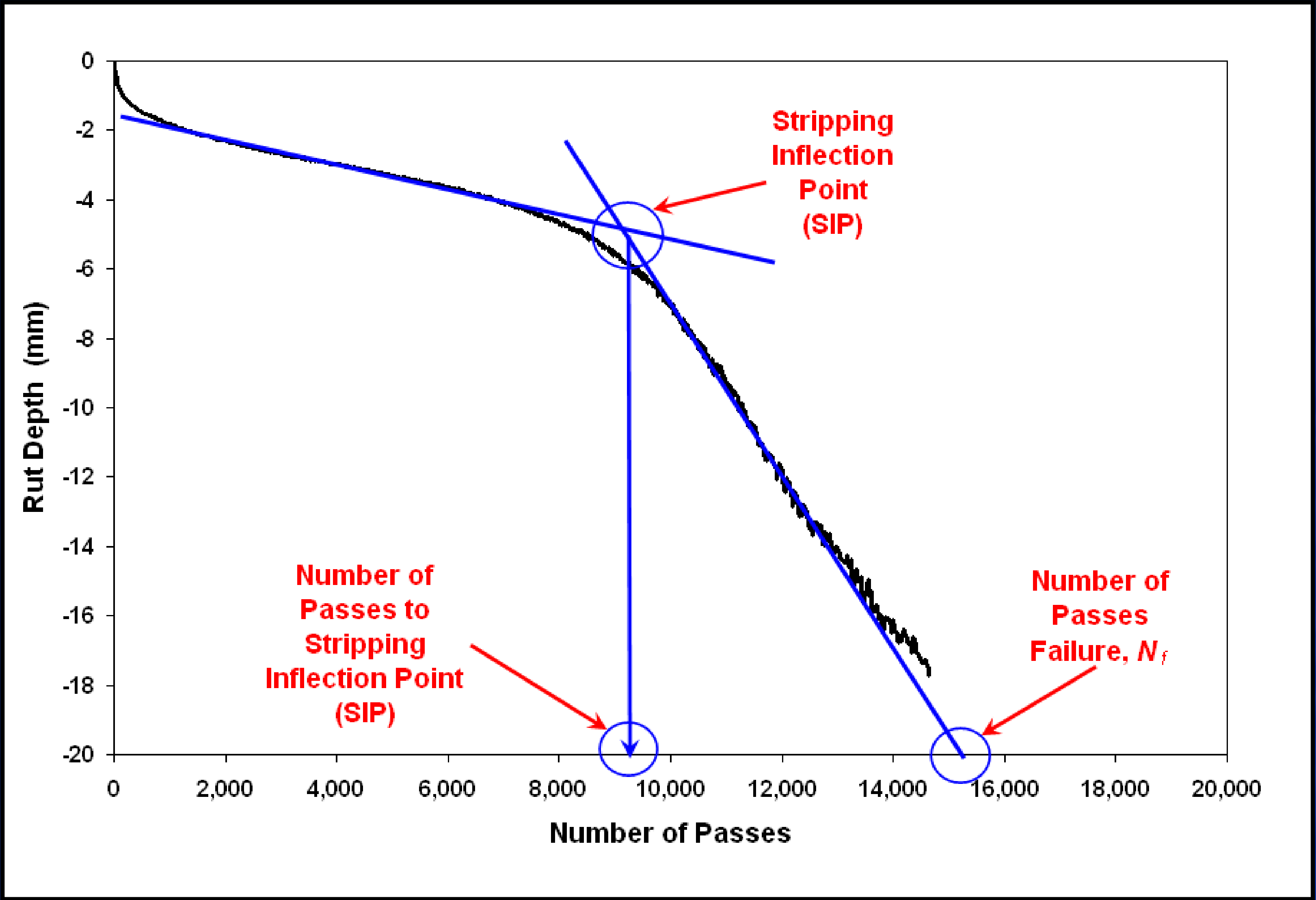
- HWTD testing conducted in accordance with AASHTO T324

- Water temperature of 40ºC (104ºF) during testing for control PG52-28 binder

- Water temperature of 50ºC (122ºF) during testing for PMA binder mixtures

- Test duration of 20,000 cycles

Stripping Inflection Point (SIP)



HWTD Test Results - NO WMA

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	MRD>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 testing conducted at 40°C for mixtures fabricated with this binder.
MRD>20mm = Testing did not reach specified cycles due to the maximum rut depth exceeding 20 mm.

HWTD Test Results - WMA

Mixture	Binder	Stripping Inflection Point	Avg. Rut 10,000 Cycles (mm)	Avg. Rut 20,000 Cycles (mm)
Control + WMA	PG52-28*	6,200	MRD>20mm	MRD>20mm
	PG64-34	6,500	MRD>20mm	MRD>20mm
	PG70-22 + 7.5% SBS	NONE	1.0	1.3
	PG58-28 + 7.5% SBS	15,000	1.7	9.2
	200 PEN + 7.5% SBS	4,500	MRD>20mm	MRD>20mm
40% RAP + WMA	PG52-28*	NONE	0.9	1.4
	PG64-34	13,000	2.1	12.4
	PG70-22 + 7.5% SBS	NONE	0.5	0.7
	PG58-28 + 7.5% SBS	NONE	1.0	1.5
	200 PEN + 7.5% SBS	16,750	1.5	3.1

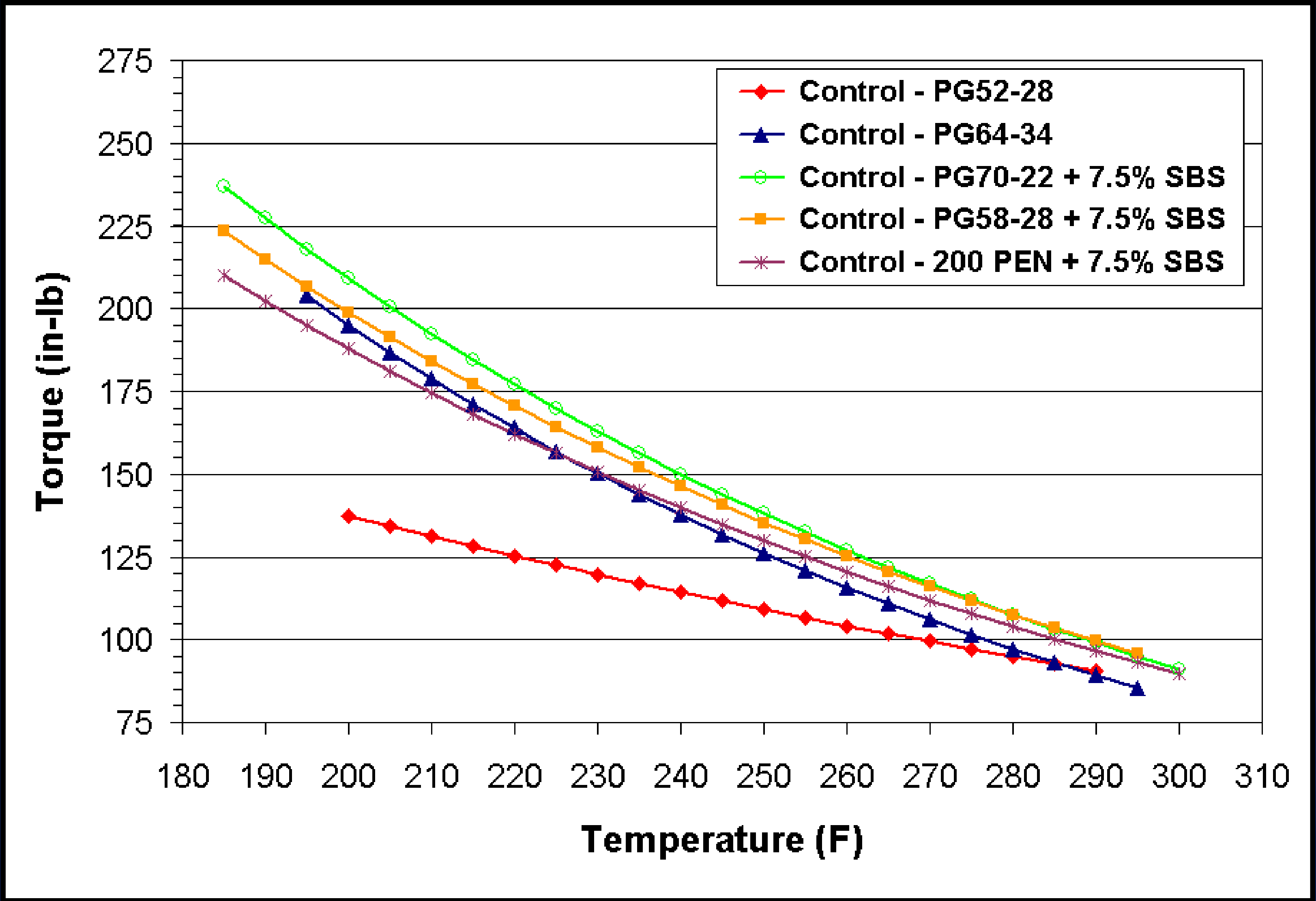
* = HWTD testing conducted at 40°C for mixtures fabricated with this binder.
MRD>20mm = Testing did not reach specified cycles due to the maximum rut depth exceeding 20 mm.

Workability Evaluation

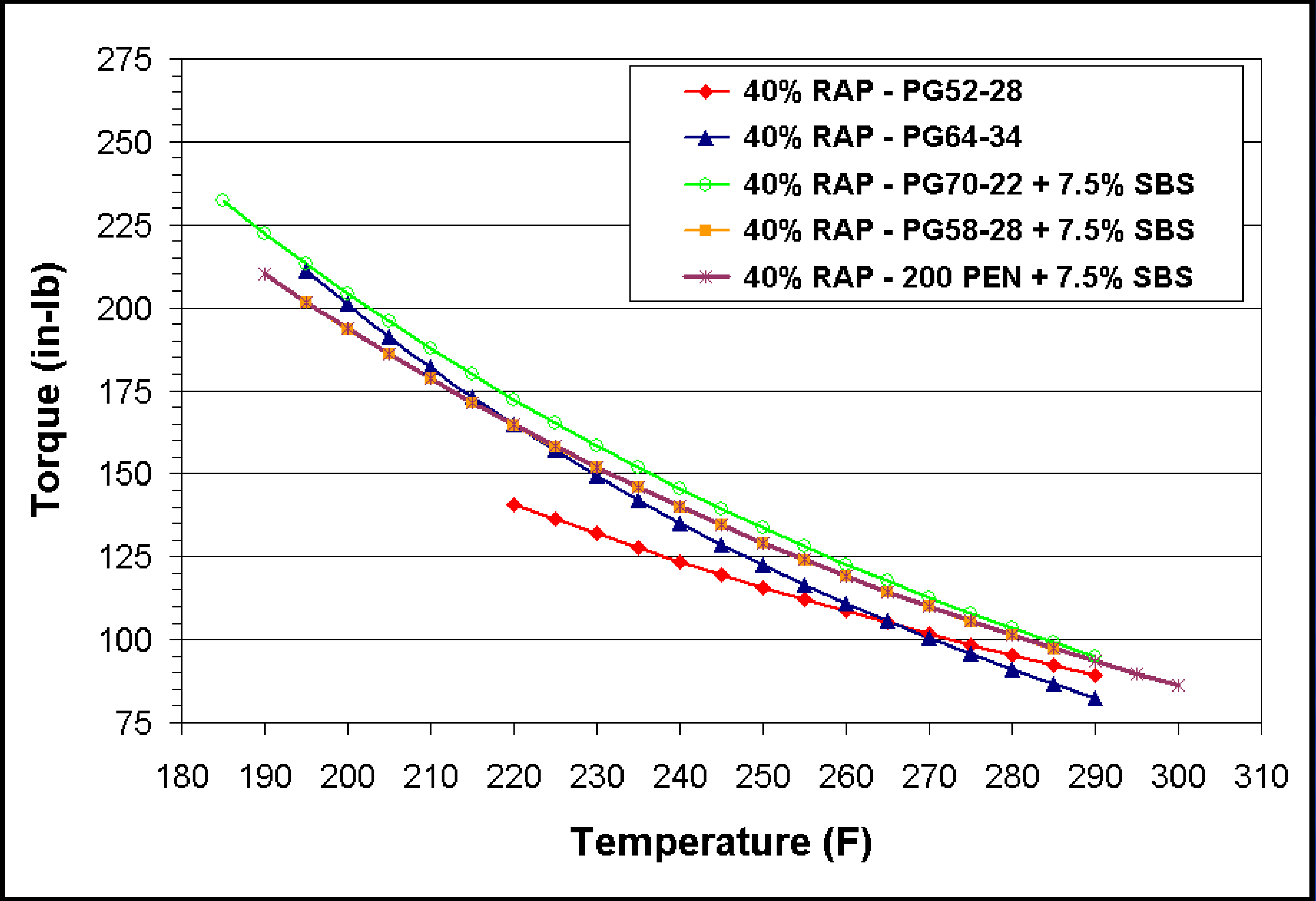
UMass Dartmouth AWD

AWD Paddle Configuration

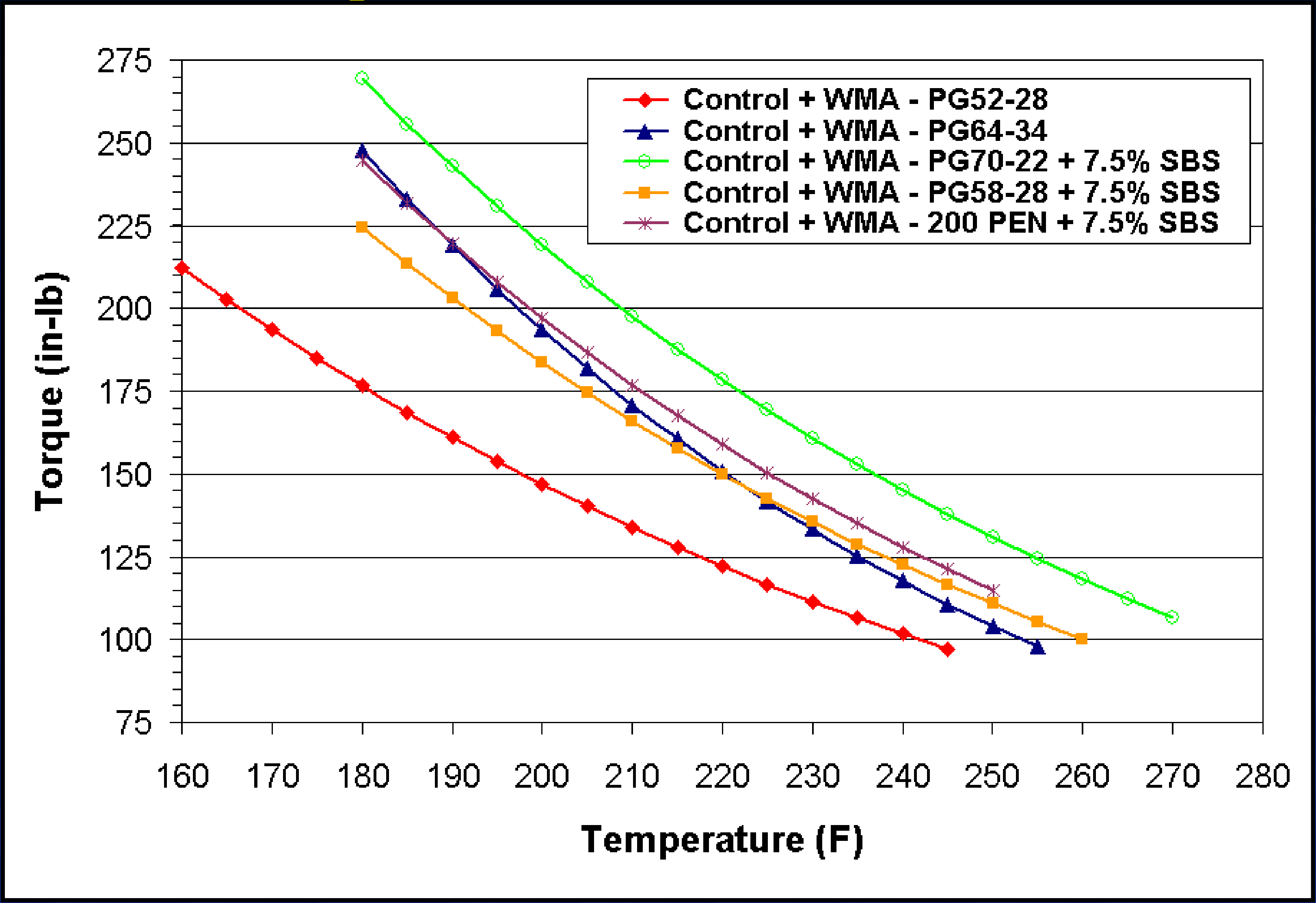
Workability Results - Control



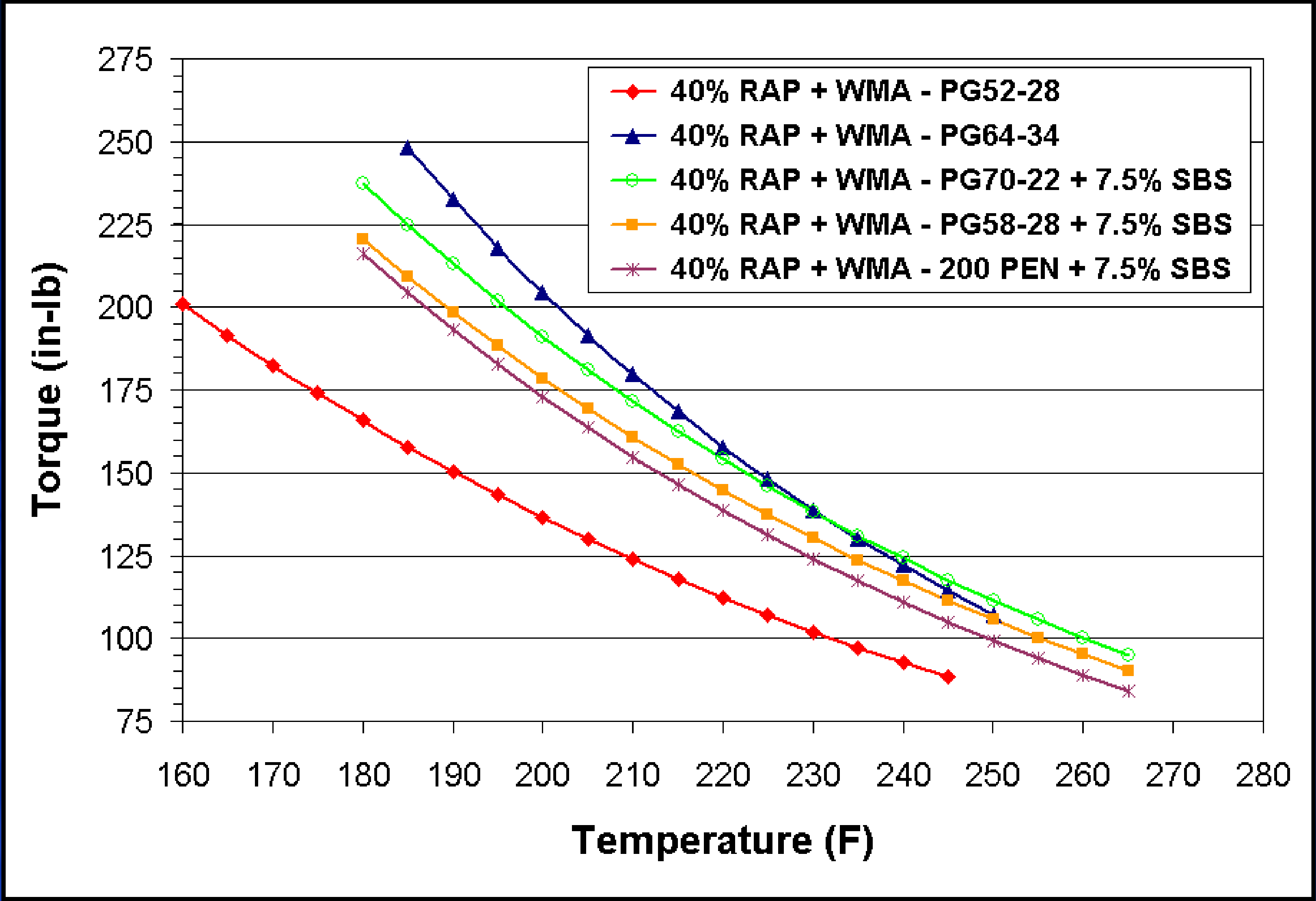
Workability Results – 40% RAP



Workability Results – Control + WMA



Workability Results - 40% RAP + WMA



Overall Project Conclusions

- Control mixtures incorporating only PMA showed increased stiffness as compared to the control mixtures. The higher stiffness mixtures may be more susceptible to cracking if placed over a pavement that will be exposed to high amount of deflections.

- The addition of 40% RAP to the control mixture increased the mixture stiffness as compared to the control mixture without RAP for all binder types, although the magnitude of the increase in stiffness was small for some PMA binder tested.

- WMA can be utilized to reduce the mixture stiffness for these HPThinOL mixtures which may lead to enhanced workability and performance characteristics.

Overall Project Conclusions

- The use of a WMA technology could improve the reflective cracking resistance of HPThinOL that is designed with PMA and incorporates high RAP contents. This may be a result of the technology itself or the associated reducing mixing and aging temperatures.

- The use of a polymer modified binder and/or the addition of RAP may improve the moisture susceptibility and rutting characteristics of the mixture. The use of the WMA technology in combination with the PMA and/or RAP may result in reduced mixture moisture susceptibility and rutting performance.

Overall Project Conclusions

- The addition of 40% RAP did not significantly decrease the mixture workability of the PMA mixtures, 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 mixtures tested and may be attributed to the reduced mixing and compaction temperatures utilized for these type of mixtures.

Thank You!