Thin Lift Overlay Research

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Northeast Pavement Preservation Partnership

1st Official Meeting

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Current Thin Lift Projects

1. Design of High Percentage Recycled Asphalt Pavement HMA with Warm Mix Technology for Thin Mix Applications

2. Transportation Pooled Fund Study TPF-5(146)

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Project I:

Design of High Percentage Recycled Asphalt Pavement HMA with Warm Mix Technology for Thin Mix Applications

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Project Description

- Purpose of project was to develop thin lift overlay HMA mix designs to be used for preventive maintenance applications.
- Mixes had a fine aggregate gradation.
- Each mix design incorporated Warm Mix Asphalt (WMA) technology with high percentages of Recycled Asphalt Pavement (RAP).

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Project Objectives

1. **Develop mixes using currently specified mix gradations for thin lift mixes (Superpave and MassHighway) and various Performance Grade (PG) binders used in the Northeast.**

2. **Develop mix designs incorporating WMA technology and varying percentages of RAP. Additionally develop a control mix without RAP.**

3. **Complete development of mix designs in accordance with the Superpave mix design method and the technical guidance provided in the NCHRP Report 452 *"Recommended Use of Reclaimed Asphalt Pavement in the Superpave Mix Design Method: Technician's Manual."***

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Project Objectives (cont'd)

4. Evaluate the performance of the mixes in terms of Dynamic Modulus (E*) at varying temperatures and frequencies using the Simple Performance Test (SPT) device.

5. Develop mix Master Curves based on measured Dynamic Modulus (E*) data for each mix design.

6. Determine the Performance Grade (PG) grade of the extracted and recovered binder for each developed mix.

Project Objectives (cont'd)

8. Develop binder Master Curves for all the mixtures utilizing the binder modulus data (G*) obtained from the Dynamic Shear Rheometer (DSR) and Bending Beam Rheometer (BBR).

9. Evaluate the extent of co-mingling between the RAP binder and added virgin binder via mix and binder Master Curves.

10. Evaluate the workability of each mix.

Methodology

Virgin Aggregates
9.5 mm Crushed Stone
Manufactured Sand
Natural Sand

RAP
4.75 mm NMAS
Fractionated RAP

Virgin Binders
PG64-28
PG58-34
PG52-33
PG52-33 (w/latex)

RAP Percentages
0% 15% 30% 50%

Mix Designs
Superpave 4.75 mm
MassHighway Surface Treatment

Methodology (cont'd)

Mix Designs
Superpave 4.75 mm
MassHighway Surface Treatment

Dynamic Modulus (E*) Testing
Temperatures: 4°C, 20 °C, 40 °C
Frequencies: 0.01 Hz, 0.1Hz, 1Hz, 10Hz (0.01Hz for 40 °C only)

Develop Mix Master Curves
Develop using E* data.

Extraction and Recovery of Binder
AASHTO T319 Rotovap

Determine Performance Grade of Extracted Binder

Develop Binder Master Curves

Workability
Evaluate using prototype device developed by PRISM.

Evaluation of Extent of Co-mingling Between RAP and Virgin Binder

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Materials - RAP

Fractionated 4.75 mm NMAS RAP based on extracted dry aggregate gradation.

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Materials - Aggregates

Virgin Aggregate Stockpiles:

9.5 mm Crushed Stone

Manufactured Sand

Natural Sand

Materials – WMA Technology

Wax Additive WMA Technology (Sasobit®)

Added to Virgin Binder at Dosage Rate of 1.5% of Total Binder in Mix (RAP +Virgin)

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Materials - Binders

Virgin Binders:

PG 64-28

PG 58-34

PG 52-33

PG52-33 (w/ 1.5 %latex)

Note: 1.5% latex added by weight of total binder in selected PG52-33 mixes only.

Superpave 4.75 mm Gradation

Sieve Size	Percent RAP				Target
	0%	15%	30%	50%	
12.5	100	100	100	100	100
9.50	99.2	98.9	99.0	99.0	95-100
4.75	91.9	90.2	90.8	91.2	90-100
2.36	66.3	67.8	67.5	68.5	-
1.18	42.3	46.5	45.7	47.3	30-60
0.60	27.8	31.7	31.5	33.2	-
0.30	17.5	19.1	20.0	21.5	-
0.150	10.3	10.7	12.0	13.3	-
0.075	7.3	6.9	8.0	8.6	6-12

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MHD Surface Treatment Gradation

Sieve Size	Percent RAP				Target
	0%	15%	30%	50%	
12.5	100	100	100	100	100
9.50	99.8	99.9	99.9	99.9	100
4.75	96.5	96.8	97.0	97.2	80-100
2.36	78.1	78.9	78.4	77.1	64-85
1.18	58.5	59.7	58.9	56.7	46-68
0.60	40.2	41.5	41.4	40.4	26-50
0.30	21.0	22.2	23.4	24.6	13-31
0.150	9.2	10.3	12.0	14.2	7-17
0.075	4.5	5.1	6.7	8.8	3-8

Mixing and Compaction Temperatures

Determined from Rotational Viscometer data in accordance with AASHTO T316.

Mixing and compaction temperature range determined as outlined in Asphalt Institute Handbook *"Superpave Level 1 Mix Design."*

Asphalt Binder Type	Mixing Range	Compaction Range
PG 64-28 (1.5% Sasobit)	151-157 °C	141-145 °C
PG 58-34 (1.5% Sasobit)	148-154 °C	136-141 °C
PG 52-33 (1.5% Sasobit)	143-148 °C	132-137 °C
PG 52-33 (1.5% Sasobit & 1.5% Latex)	154-161 °C	141-147 °C

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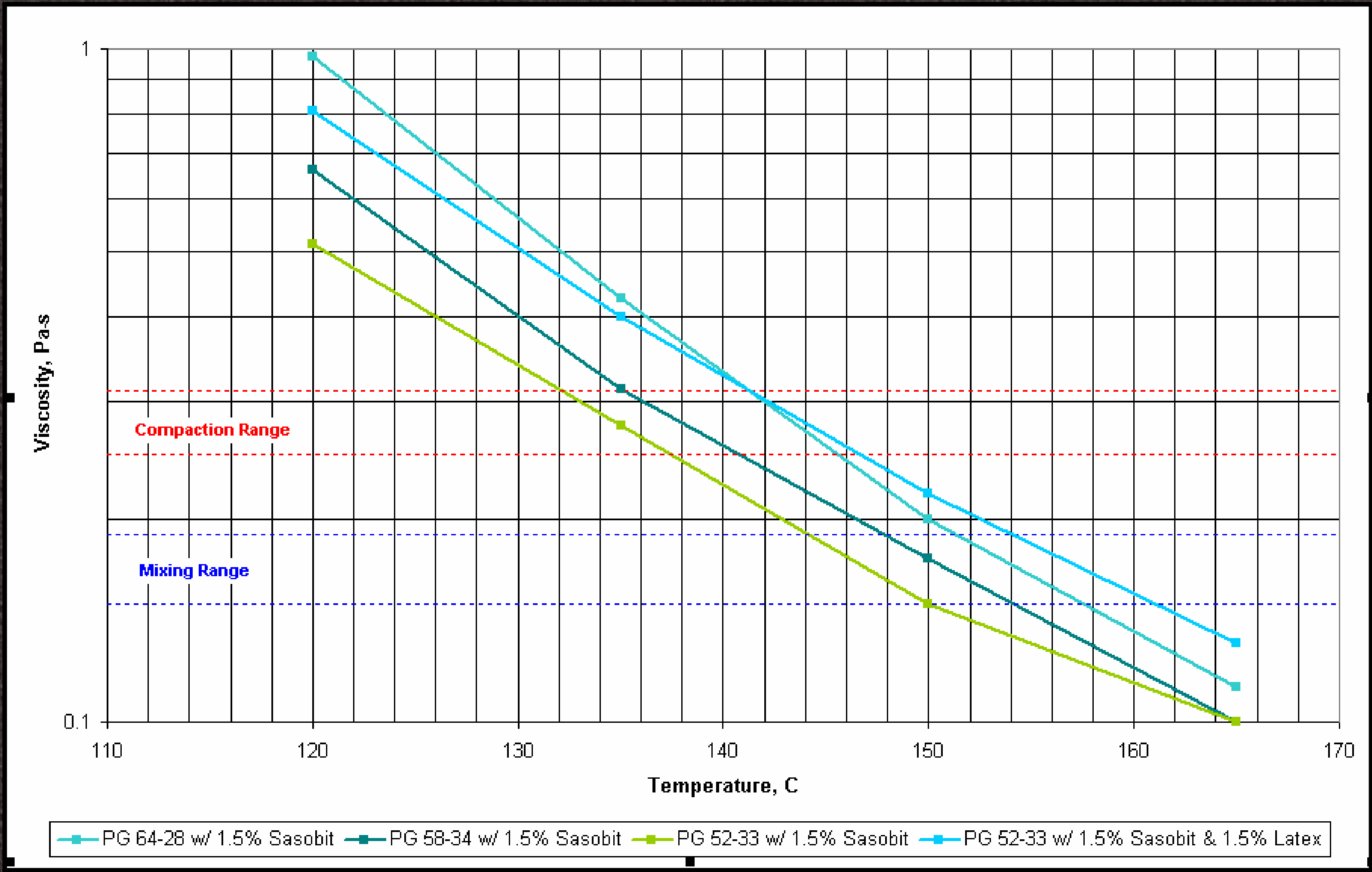
Mixing and Compaction Temperatures



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RAP Mixing Temperature

- **RAP was heated to different mixing temperature.**
- **RAP mixing temperature was 110°C (230 °F) as outlined in NCHRP Report 452 *"Recommended Use of Reclaimed Asphalt Pavement in the Superpave Mix Design Method: Technician's Manual."***

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Volumetrics - PG52-33

	Superpave 4.75 mm				Superpave Specification Target
RAP Added, %	0%	15%	30%	50%	-
AC (oven), %	6.7	6.6	6.4	6.0	-
Added AC, %	6.8	5.5	4.0	2.0	-
Air Voids, %	4.0	3.7	3.2	2.7	4.0
VMA, %	18.8	16.5	16.0	15.4	16-18
VFA, %	78.7	77.8	80.2	82.6	65-78
Dust to Binder Ratio	1.17	1.27	1.59	1.60	0.9-2.0

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Volumetrics - PG52-33 (cont'd)

	MHD Surface Treatment				MassHighway Specification Target
RAP Added, %	0%	15%	30%	50%	-
AC (oven), %	7.8	7.6	6.9	6.0	7.0-8.0
Added AC, %	8.0	6.5	4.5	2.0	-
Air Voids, %	6.1	5.5	5.3	4.9	-
VMA, %	22.6	21.1	19.4	18.1	-
VFA, %	73.1	74.1	72.7	72.8	-
Dust to Binder Ratio	0.61	0.74	1.09	1.53	-

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Volumetrics - PG52-33 with Latex

	Superpave 4.75 mm 1.5% Latex	Superpave Specification Target
RAP Added, %	30%	-
AC (oven), %	6.3	-
Added AC, %	3.7	-
Air Voids, %	4.4	4
VMA, %	17.5	16-18
VFA, %	74.9	65-78
Dust to Binder Ratio	1.55	0.9-2.0

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Volumetrics - PG64-28

	Superpave 4.75 mm				Superpave Specification Target
RAP Added, %	0%	15%	30%	50%	-
AC (oven), %	7.0	7.2	6.8	6.4	-
Added AC, %	7.0	5.8	4.3	2.3	-
Air Voids, %	4.6	4.0	4.0	4.1	4.0
VMA, %	19.4	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

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Volumetrics - PG64-28 (cont'd)

	MHD Surface Treatment				MassHighway Specification Target
RAP Added, %	0%	15%	30%	50%	-
AC (oven), %	8.0	7.8	7.0	6.3	7.0-8.0
Added AC, %	8.0	6.5	4.5	2.0	-
Air Voids, %	5.5	6.0	5.7	5.6	-
VMA, %	22.1	21.9	19.9	17.8	-
VFA, %	75.4	72.6	71.4	68.5	-
Dust to Binder Ratio	0.60	0.71	1.06	1.64	-

Volumetrics - PG58-34

	Superpave 4.75 mm				Superpave Specification Target
RAP Added, %	0%	15%	30%	50%	-
AC (oven), %	6.7	6.6	6.4	6.0	-
Added AC, %	6.8	5.5	4.0	2.0	-
Air Voids, %	4.1	3.6	3.8	3.8	4.0
VMA, %	19.0	17.6	17.0	15.9	16-18
VFA, %	78.5	80.5	77.9	76.1	65-78
Dust to Binder Ratio	1.16	1.15	1.44	1.69	0.9-2.0

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Volumetrics - PG58-34 (cont'd)

	MHD Surface Treatment				MassHighway Specification Target
RAP Added, %	0%	15%	30%	50%	-
AC (oven), %	7.8	7.6	6.9	6.0	7.0-8.0
Added AC, %	8	6.5	4.5	2.0	-
Air Voids, %	5.4	6.3	5.9	5.6	-
VMA, %	21.9	21.6	19.8	17.8	-
VFA, %	75.2	71.0	70.1	68.4	-
Dust to Binder Ratio	0.62	0.62	1.10	1.67	-

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Comparison of RAP Mixes to Control

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Binder Extraction & Recovery

Extractions performed in accordance with AASHTO T319 (Rotovap).

Binder Extraction & Recovery (cont'd)

Preliminary Test Results:

RAP binder has a grade of PG94-XX.

Future Extraction, Recovery and PG Grading Tests:

Perform replicate testing on RAP stockpile.

Perform testing on each mix developed (control and varying percentages of RAP).

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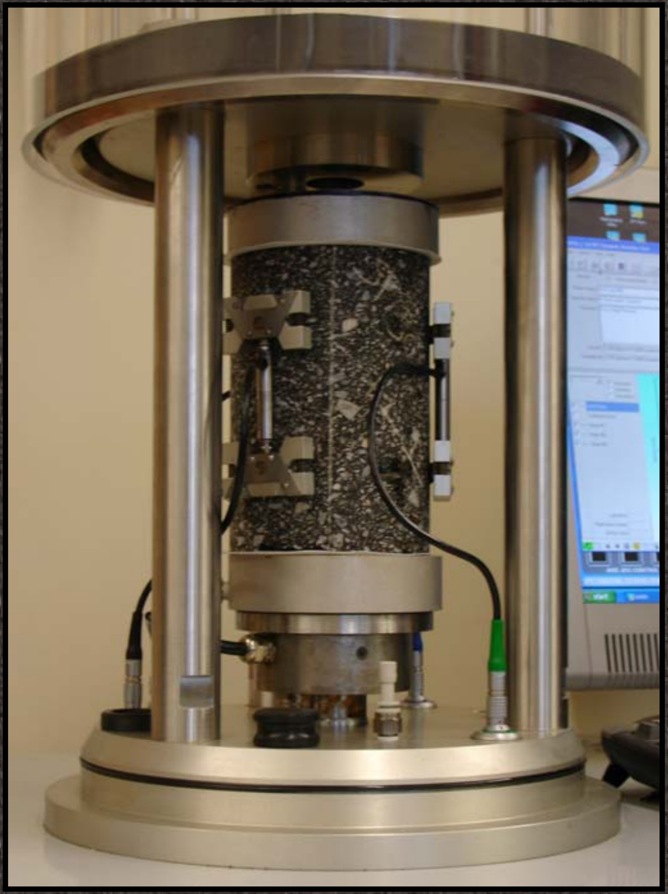
Dynamic Modulus (E*) Testing

Temperature	Frequency
4°C	10 Hz, 1Hz, 0.1Hz
20°C	10 Hz, 1Hz, 0.1Hz
40°C	10 Hz, 1Hz, 0.1Hz, 0.01Hz



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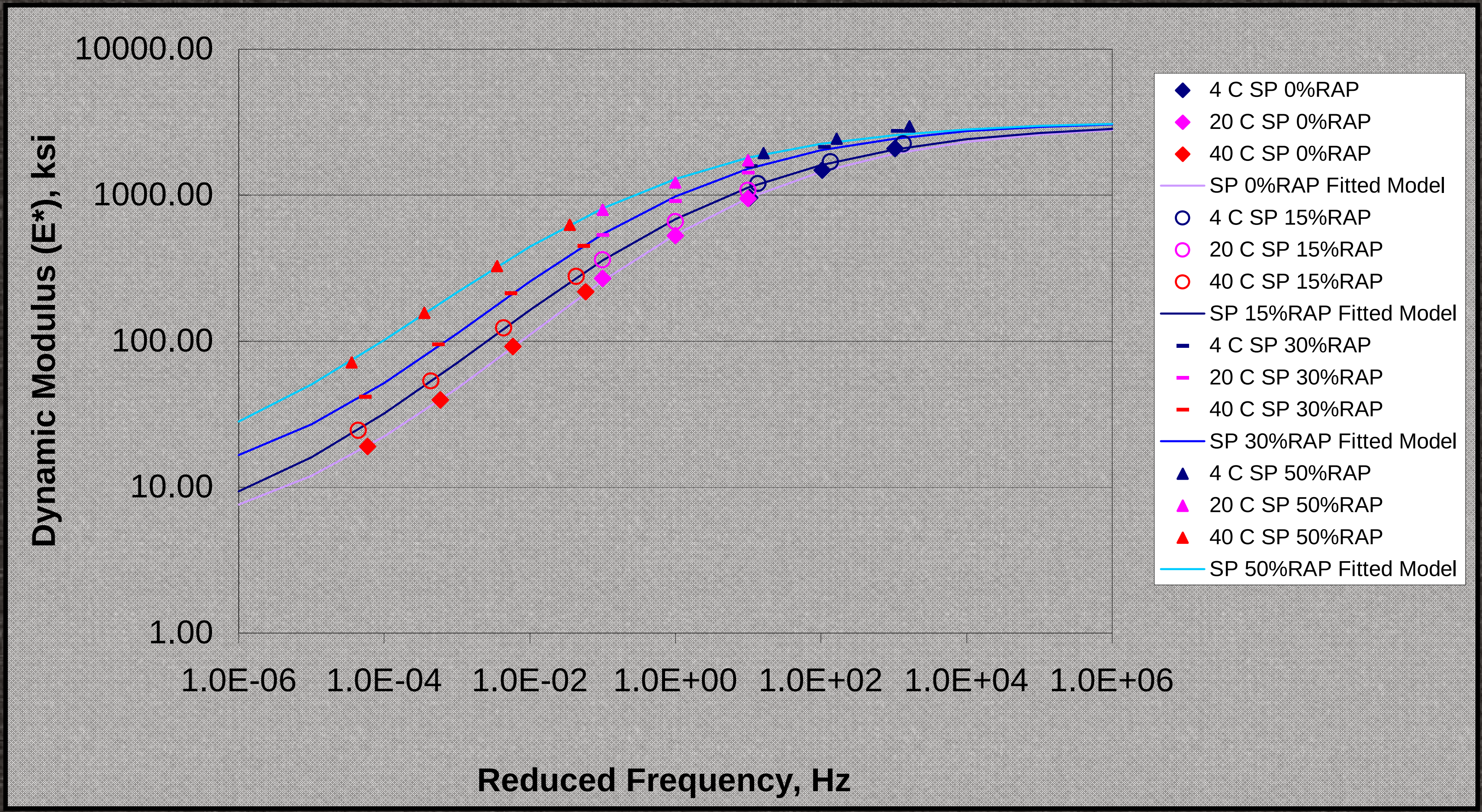
Mix Master Curve Development

Dynamic Modulus (E*) data measured in the Simple Performance Test (SPT) device utilized to develop mix Master Curve.

Master Curve provides and indication of the performance of each mix at different temperatures and loading frequencies.

Comparison of mix Master Curves provides a measure to evaluate the performance of one mix versus another.

Master Curve PG64-28 Superpave Mixes



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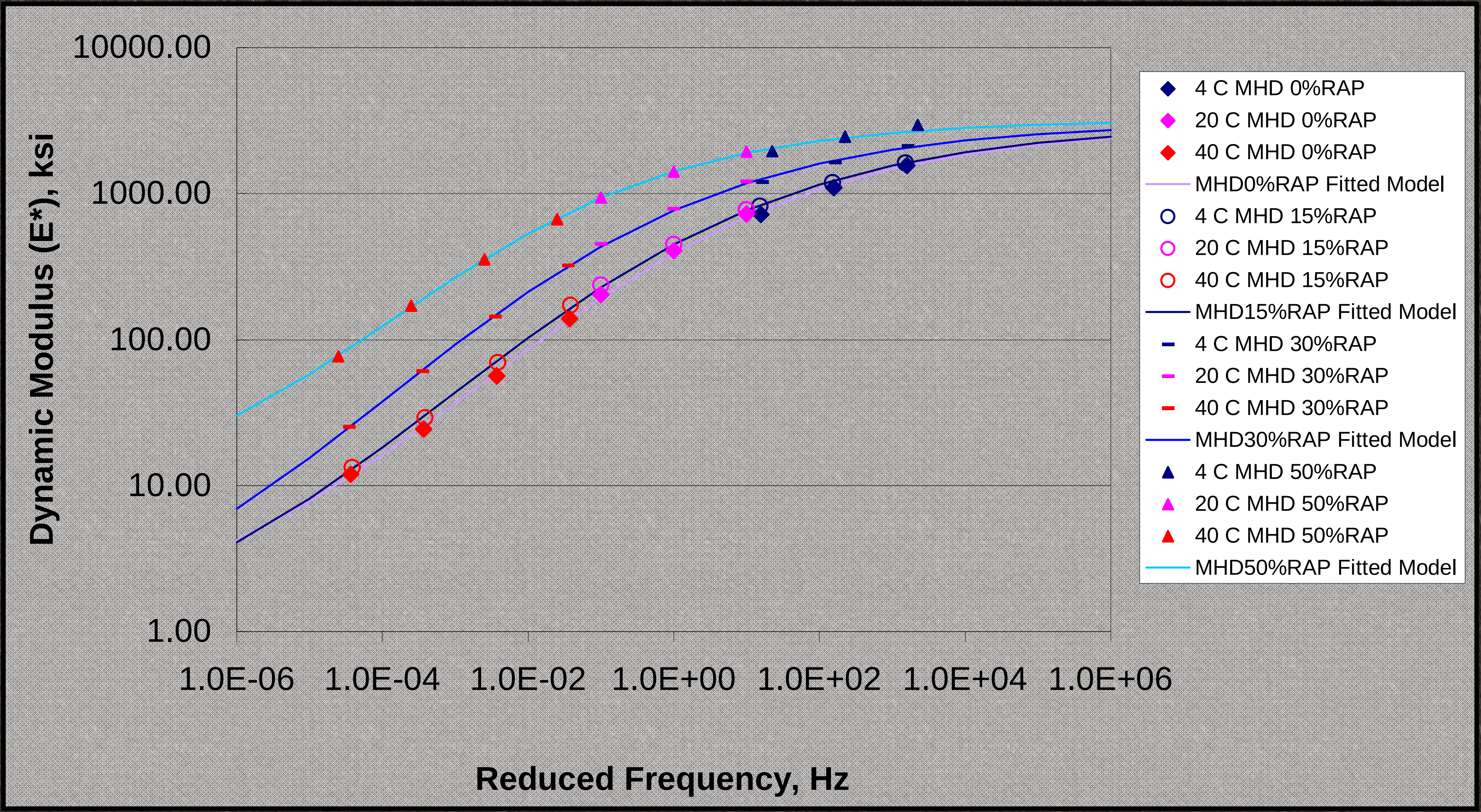
Master Curve PG64-28 MassHighway Mixes



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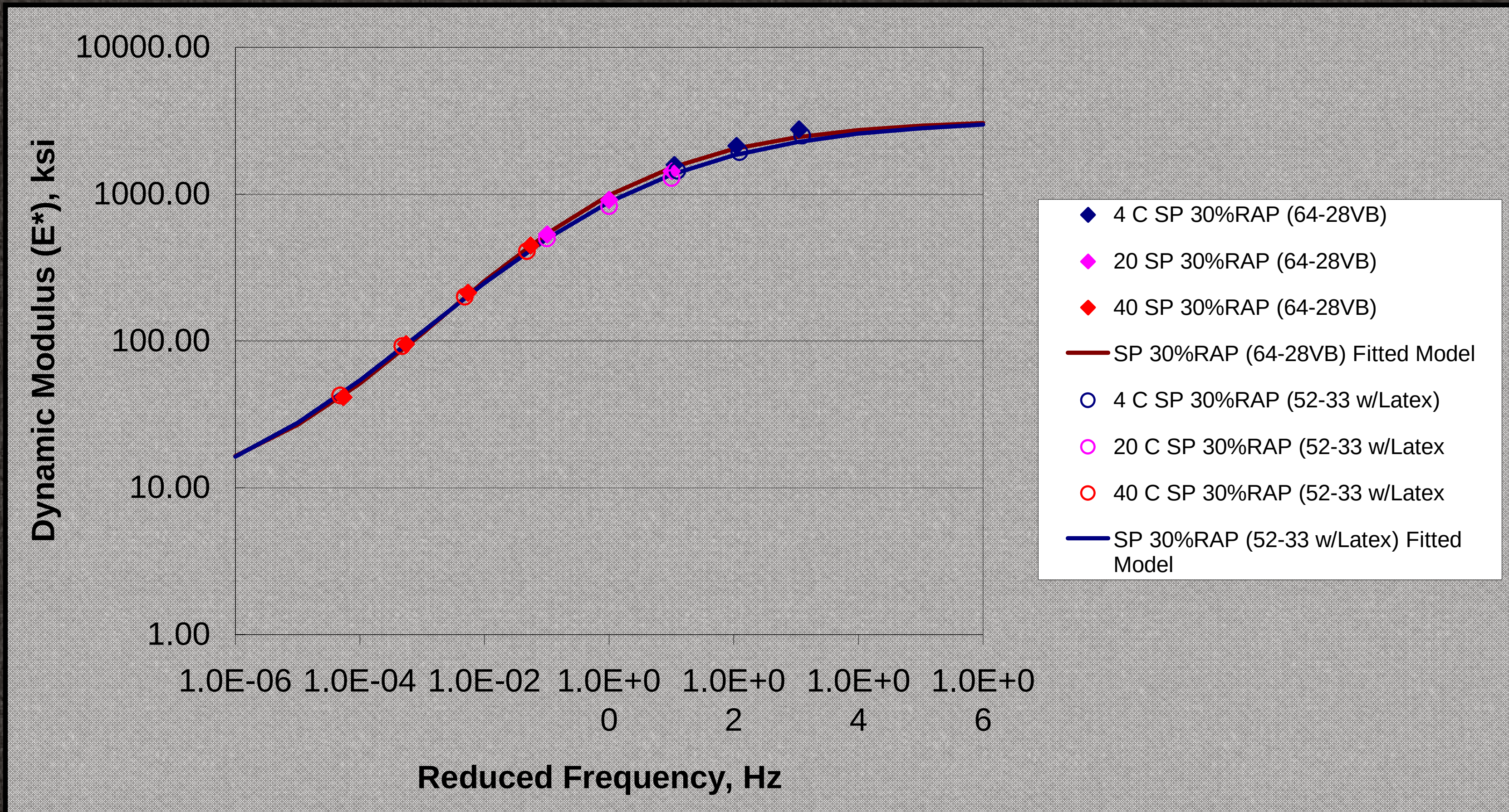
Master Curve Comparison Superpave With 30% RAP



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Binder Master Curve Testing

Complex Shear Modulus (G*) testing of extracted binder from mixes:

DSR testing at low and intermediate temperatures and at varying frequencies.

BBR testing at low temperatures and at varying frequencies.

Binder Master Curve Development

Separate binder Master Curves developed from:

1. **G* data from extracted binder testing.**
2. **G* back calculated using Hirsch model from E* data.**

Comparison of these two Master Curves gives an indication of the extent of co-mingling of the binder in the RAP and the virgin binder.

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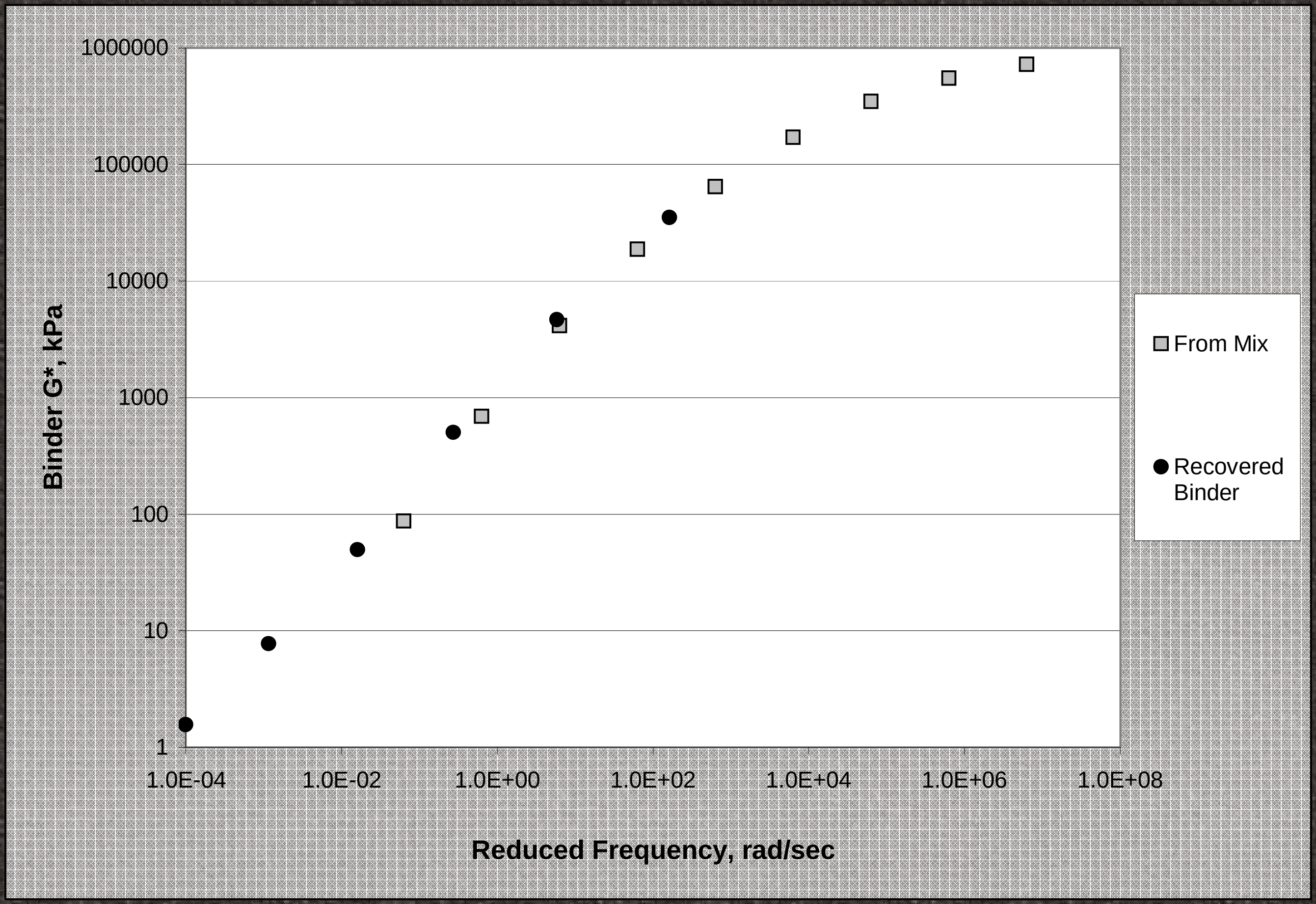
Binder Master Curve Example of Good Co-Mingling



From Advanced Asphalt Testing LLC, "Evaluation of Hot-Mix Asphalt Mixture Containing Recycled or Waste Product Materials Using Performance Testing" (2005)

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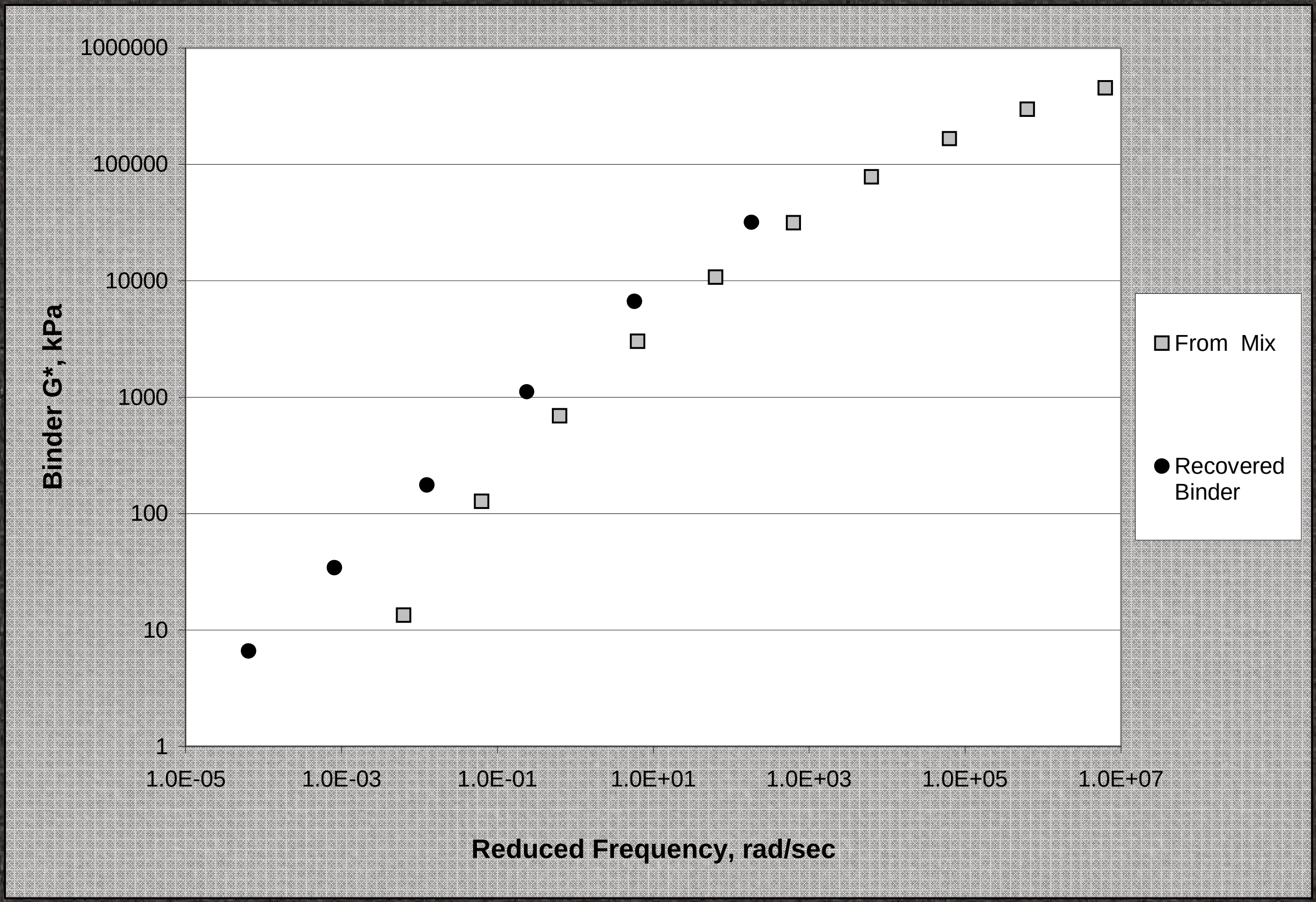
Binder Master Curve Example of Poor Co-Mingling



From Advanced Asphalt Testing LLC, "Evaluation of Hot-Mix Asphalt Mixture Containing Recycled or Waste Product Materials Using Performance Testing" (2005)

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Workability

Good workability is significant to these mixes due to the high stiffness of the binder in the RAP and the amount of RAP being used in each mix.

Workability evaluation of each mix will be conducted using prototype device designed and built by UMass Dartmouth. This device is being patented.

Workability prototype is complete. Data for these RAP mixes is expected to be collected and compiled in 2008.

Conclusions

Thin lift mixes with up to 50% RAP were developed using typical binders used in the Northeast.

Volumetric testing showed that some of the mixes with RAP met all volumetric criteria. However, other mixes tested showed small variations in the VMA and VFA outside the acceptable range suggested by Superpave.

Conclusions (cont'd)

Preliminary Master Curves developed suggested that the Superpave 4.75 mm mixes with PG64-28 and RAP might perform as well as the control mix without RAP at high, intermediate, and low temperatures. Further testing needs to be conducted to verify that this applies to all mixes, RAP contents and binder types.

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Project II:

Transportation Pooled Fund Study TPF-5(146)

Evaluation of Modified Performance Grade Binders in Thin Lift Maintenance Mixes, Surface Mix, and a Reflective Crack Relief Layer Mix.

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Participating States

Massachusetts

New York

New Jersey

New Hampshire

Connecticut

Rhode Island

Project Objectives

Develop thin lift HMA mixes for maintenance and rehabilitation purposes using different modified binders typically specified in the Northeast.

Develop a Reflective Crack Relief Layer (RCRL) mix.

Evaluate the performance of these mixes.

Methodology

Literature Review

Modified Binders
5 Different Types

Aggregates
Gravel Source
Crushed Source

Binder Testing
Performance Grade
Elastic Recovery
Multi-Stress Creep Recovery

Mix Designs
4.75 mm Superpave
9.5 mm Superpave
RCRL

Mix Performance Testing
Dynamic Modulus (E*)
Accelerated Pavement Testing

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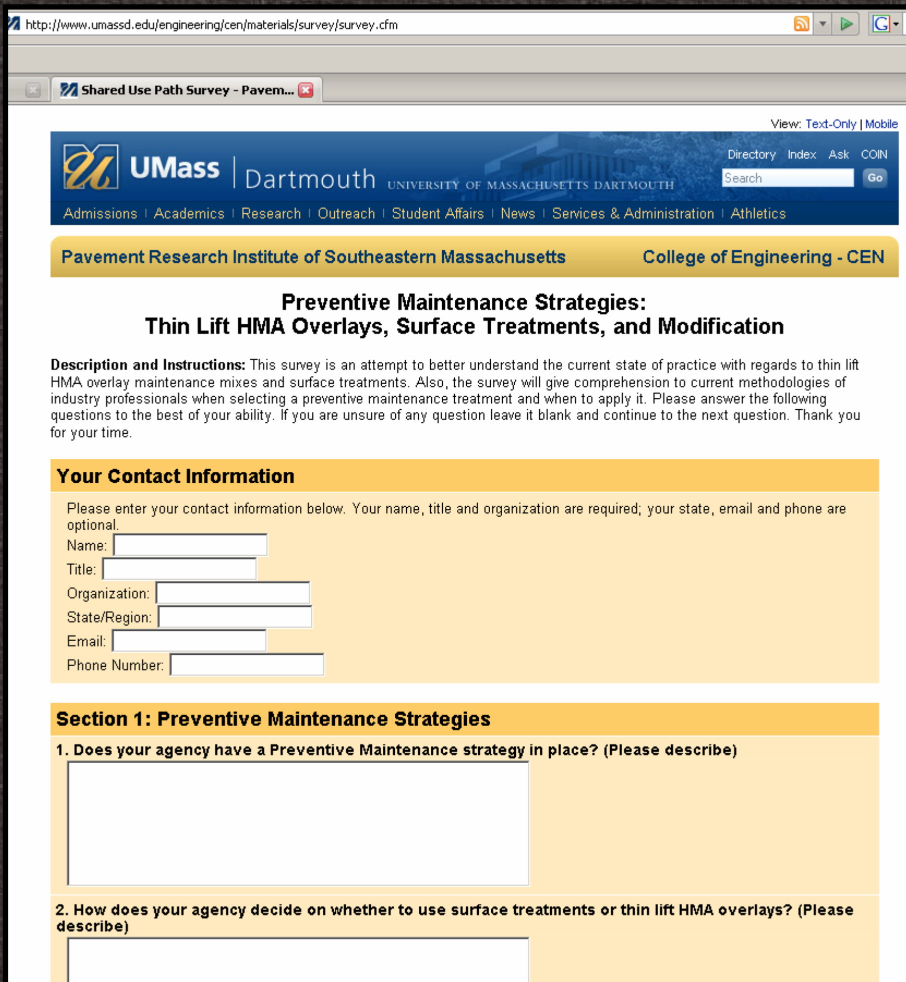
Literature Review

- Review development of maintenance and rehabilitation mixes prepared with polymer modified binders using Superpave design methodology.
- Review differences between different types of polymer modifiers.
- Conduct survey to quantify State DOT experiences with using PMA in thin lift maintenance or rehabilitation mixes.
- Review of design and test methods for PMA mixes as well as methods for placement.

SURVEY


http://www.umassd.edu/engineering/cen/materials/survey/survey.cfm

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Preventive Maintenance Strategies:
Thin Lift HMA Overlays, Surface Treatments, and Modification

Description and Instructions: This survey is an attempt to better understand the current state of practice with regards to thin lift HMA overlay maintenance mixes and surface treatments. Also, the survey will give comprehension to current methodologies of industry professionals when selecting a preventive maintenance treatment and when to apply it. Please answer the following questions to the best of your ability. If you are unsure of any question leave it blank and continue to the next question. Thank you for your time.

Your Contact Information

Please enter your contact information below. Your name, title and organization are required; your state, email and phone are optional.

Name:
Title:
Organization:
State/Region:
Email:
Phone Number:

Section 1: Preventive Maintenance Strategies

1. Does your agency have a Preventive Maintenance strategy in place? (Please describe)

2. How does your agency decide on whether to use surface treatments or thin lift HMA overlays? (Please describe)

Internet (web) based survey.

Attempted to solicit responses from over 100 Federal, State, and select Local agency representatives.

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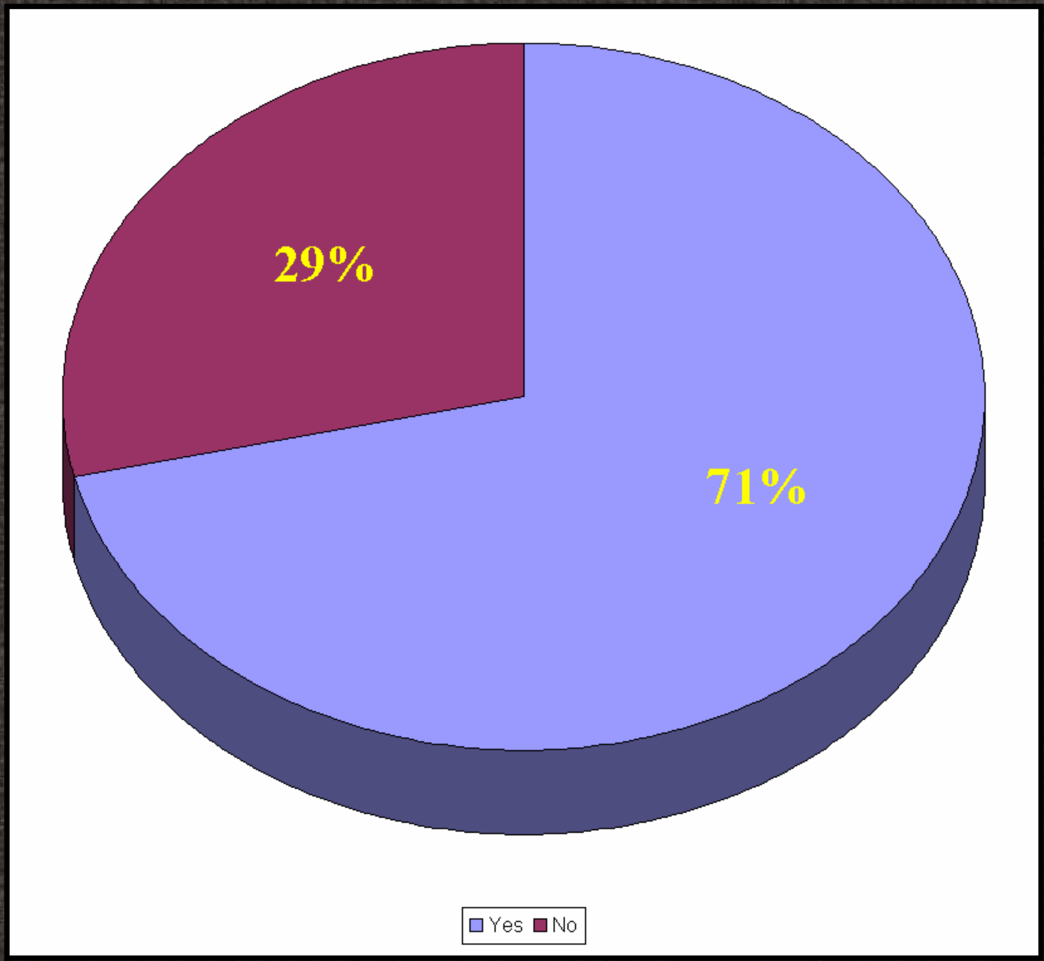
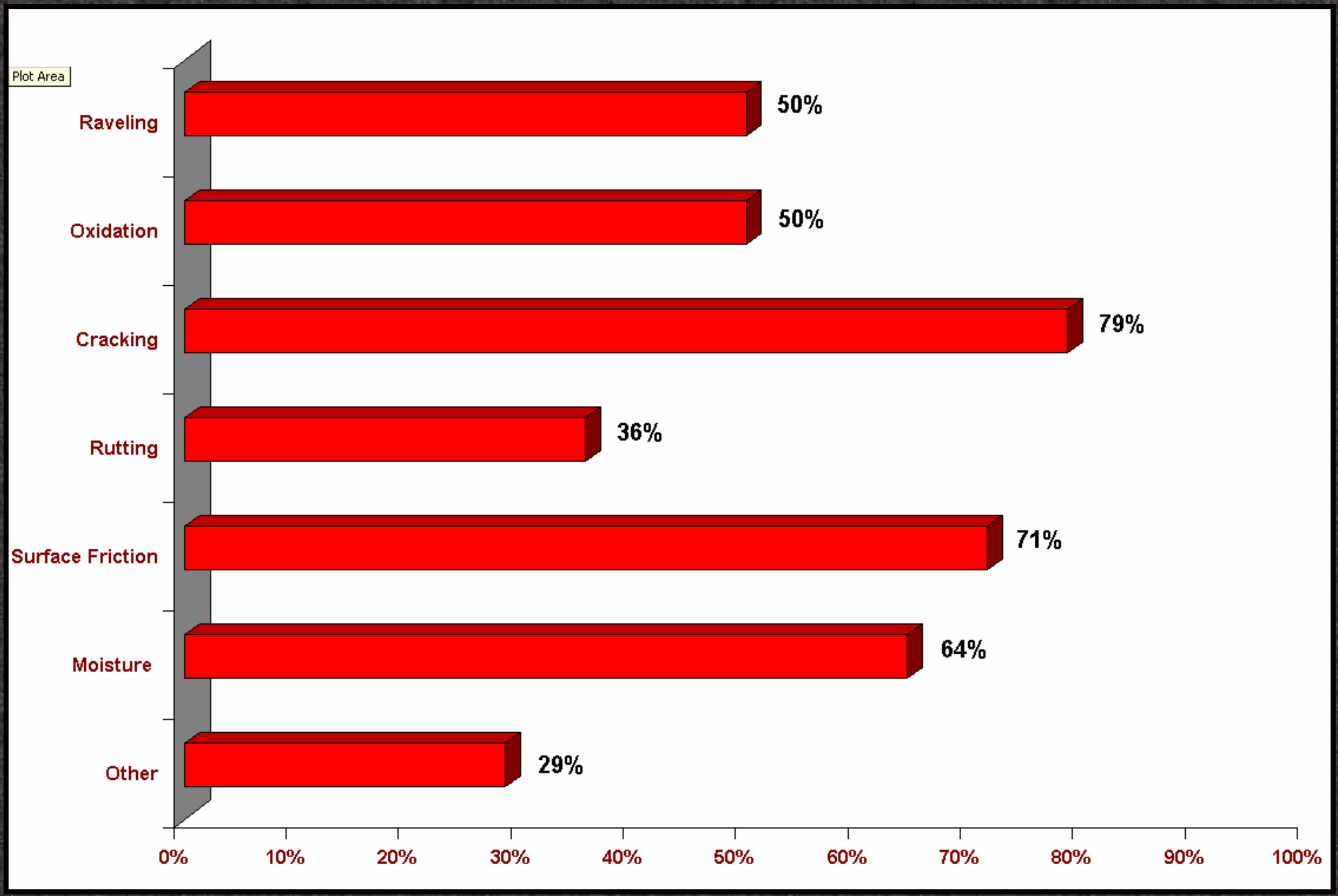
Preliminary Survey Results

Does your agency use or specify any thin lift HMA overlay maintenance mixes?



Preliminary Survey Results

What distresses does your agency hope to resolve using thin lift HMA overlay mixes?



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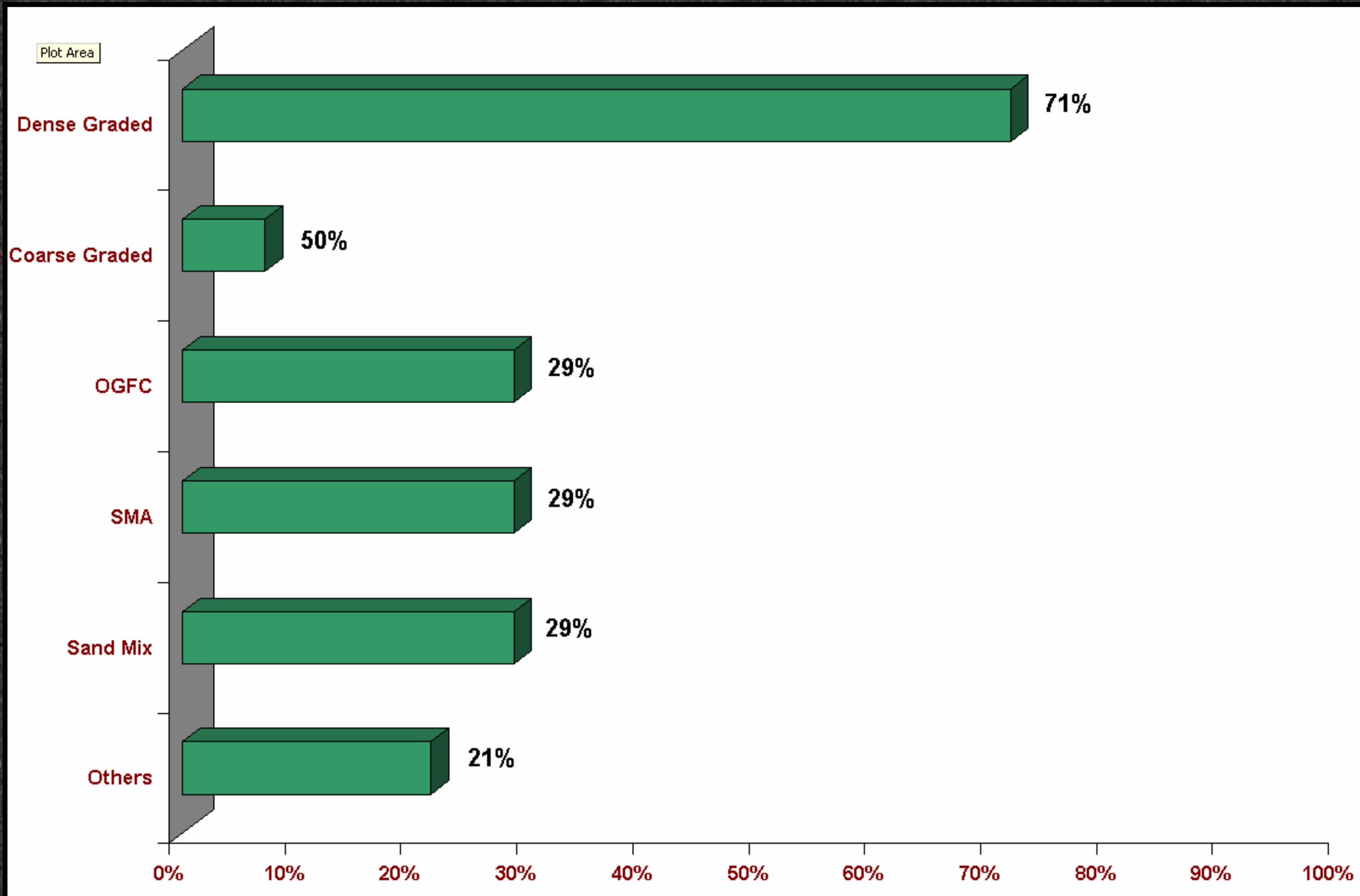
Preliminary Survey Results

What types of thin mixes does your agency use?



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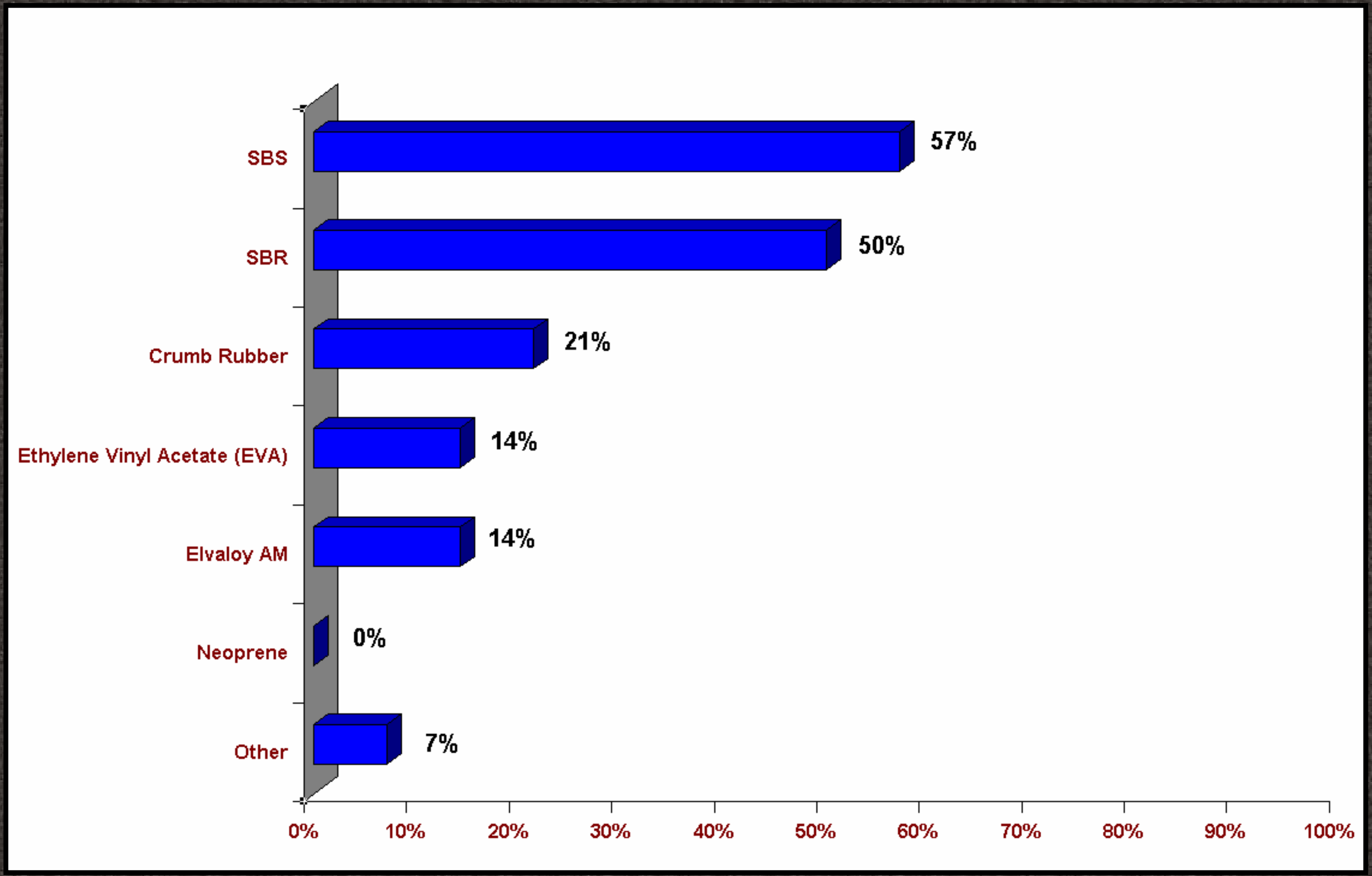
Preliminary Survey Results

What polymers does your agency use for thin lift HMA overlays?



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Binders

1. PG 64-28 without modification (Control)
2. PG 64-28 Poly-Phosphoric Acid (PPA) Modified
3. PG 64-28 SBR (Styrene-Butadiene Rubber) Latex Modified
4. PG 76-22 SBS (Styrene-Butadiene-Styrene) Modified
5. PG 76-34 Chemically Modified Crumb Rubber
6. PG 64-34 SBS (Styrene-Butadiene-Styrene) Modified

Aggregates

Crushed Stone Source – Wrentham, Massachusetts

9.5mm Crushed Stone	Washed Sand
Natural Sand	Fines
Dust	

Gravel Stone Source – Farmington, New Hampshire

9.5mm Gravel Stone	Grits
Washed Sand	Fines
Dust	

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Mix Designs

	PG64-28 Neat	PG 64-28 PPA	PG64-28 SBR (Latex)	PG 76-22 SBS	PG 76-34 CMCR	PG 64-34 SBS
SP 4.75 mm – Crushed Stone Source	✓	✓	✓	✓	✓	✓
SP 9.5 mm – Gravel Stone Source	✓	✓	✓	✓	✓	✓
SP 9.5 mm – Crushed Stone Source	✓	✓	✓	✓	✓	✓
SP 9.5 mm – Gravel Stone Source	✓	✓	✓	✓	✓	✓
RCRL				✓	✓	

SP = Superpave RCRL = Reflective Crack Relief Layer

Binder Testing

Verification of Performance Grade (PG) of each binder in accordance with AASHTO and Superpave specifications.

Determine elastic recovery of each binder per AASHTO T301.

Perform Multi-Stress Creep Recovery Test (MSCRT) on each binder.

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Performance Testing

Thin Lift Mixes:

Dynamic Modulus (E*)

Accelerated Pavement Testing

Beam Fatigue

RCRL:

Accelerated Pavement Testing

Beam Fatigue

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Dynamic Modulus Testing

Temperature	Frequency
4°C	10 Hz, 1Hz, 0.1Hz
20°C	10 Hz, 1Hz, 0.1Hz
40°C	10 Hz, 1Hz, 0.1Hz, 0.01Hz

Simple Performance Test Device

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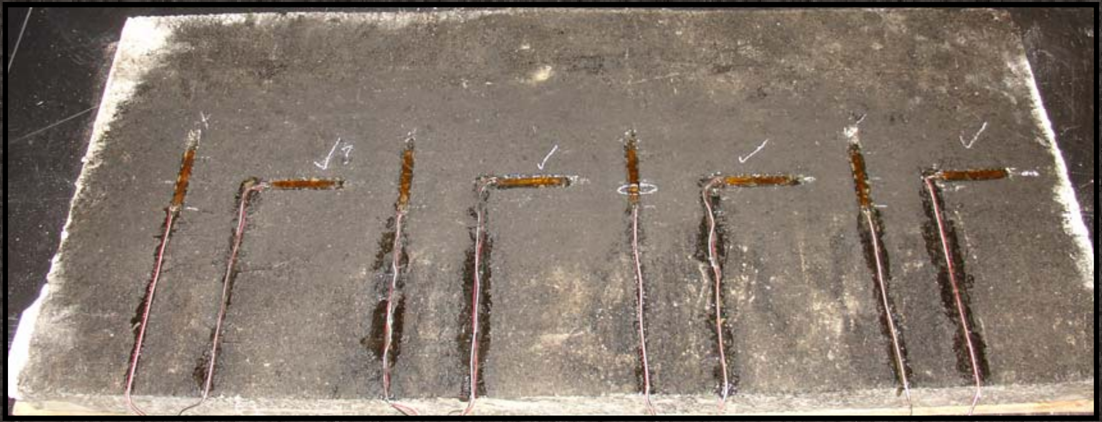
Accelerated Pavement Testing



Model Mobile Load Simulator (MMLS3)

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Thank You!

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