Evaluating the Effect of Aging Time and Temperature on the Moisture Characteristics of WMA Mixtures

Warm Mix Asphalt Technical Working Group

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NCAT -Auburn, AL

Presented by:

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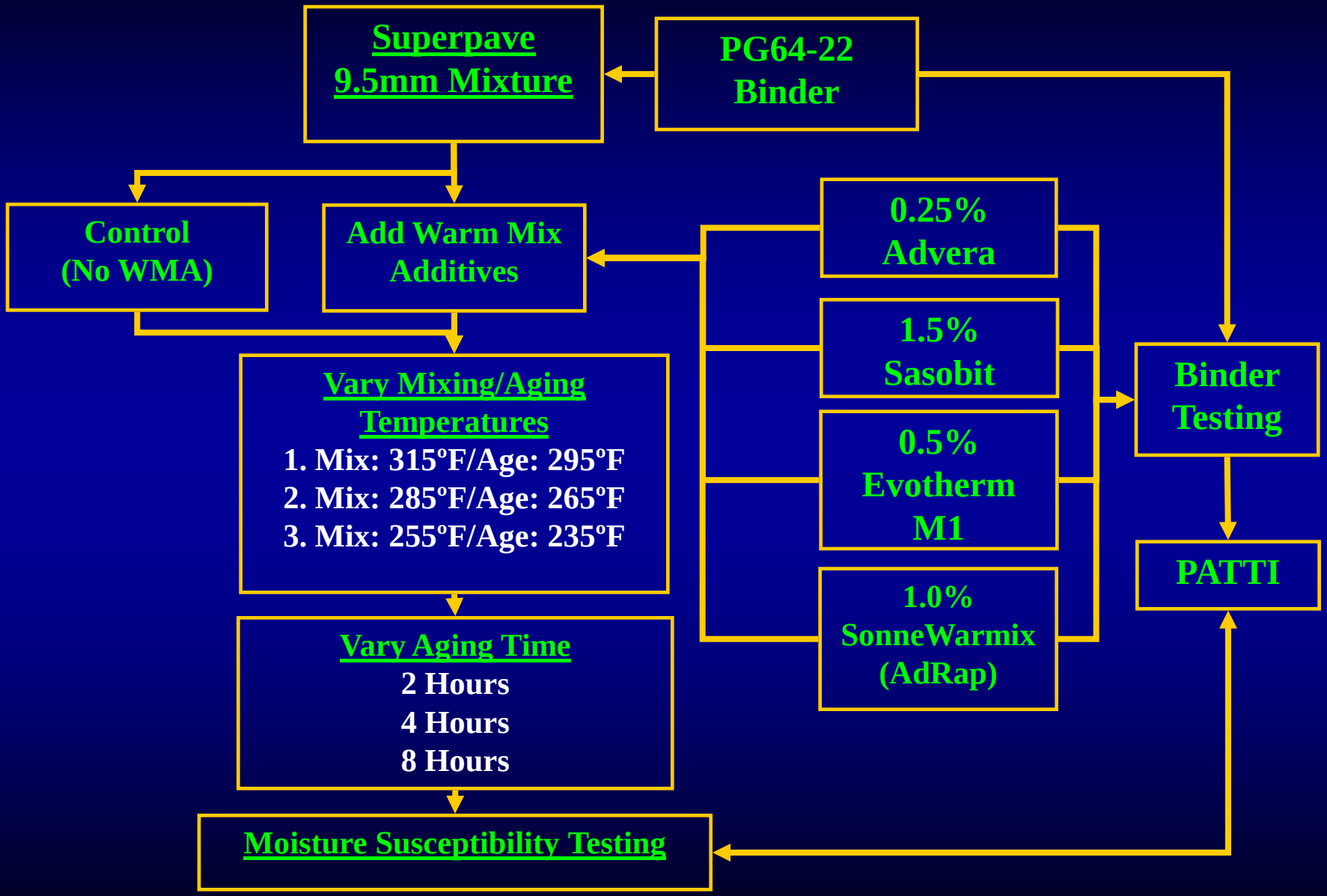
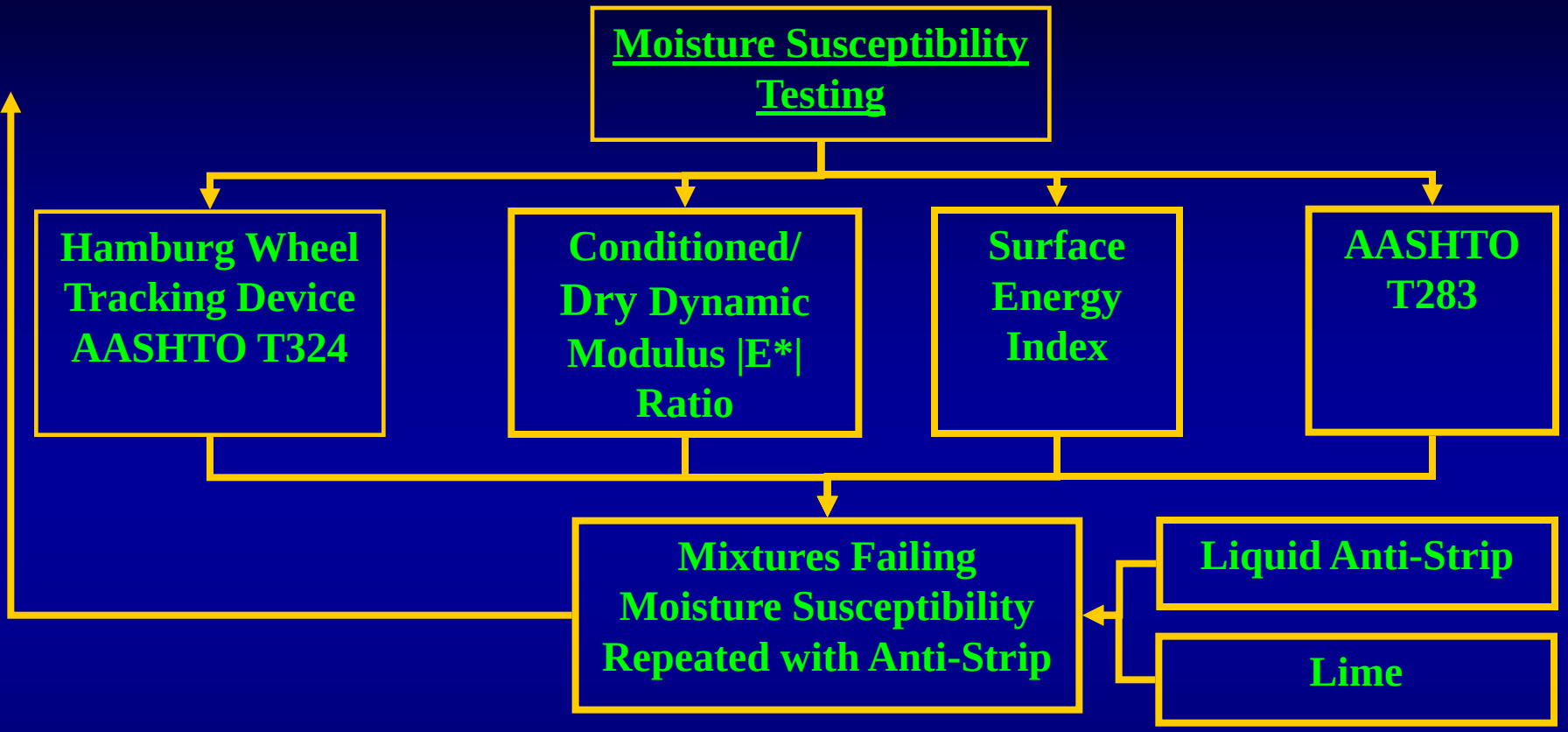
Project Objectives

- Measure the effect of aging time and temperature on the moisture susceptibility of WMA mixtures utilizing:
  - Hamburg Wheel Tracking Device (AASHTO T324)
  - Conditioned/Dry Dynamic Modulus |E*| Ratio
  - Adhesive Energy Bond Ratio
  - AASHTO T-283
- Measure the effect of WMA technologies on the adhesion characteristics of an asphalt binder to aggregate surface utilizing:
  - Modified pull-off test using the Pneumatic Adhesion Tensile Tester (PATTI)

Experimental Plan



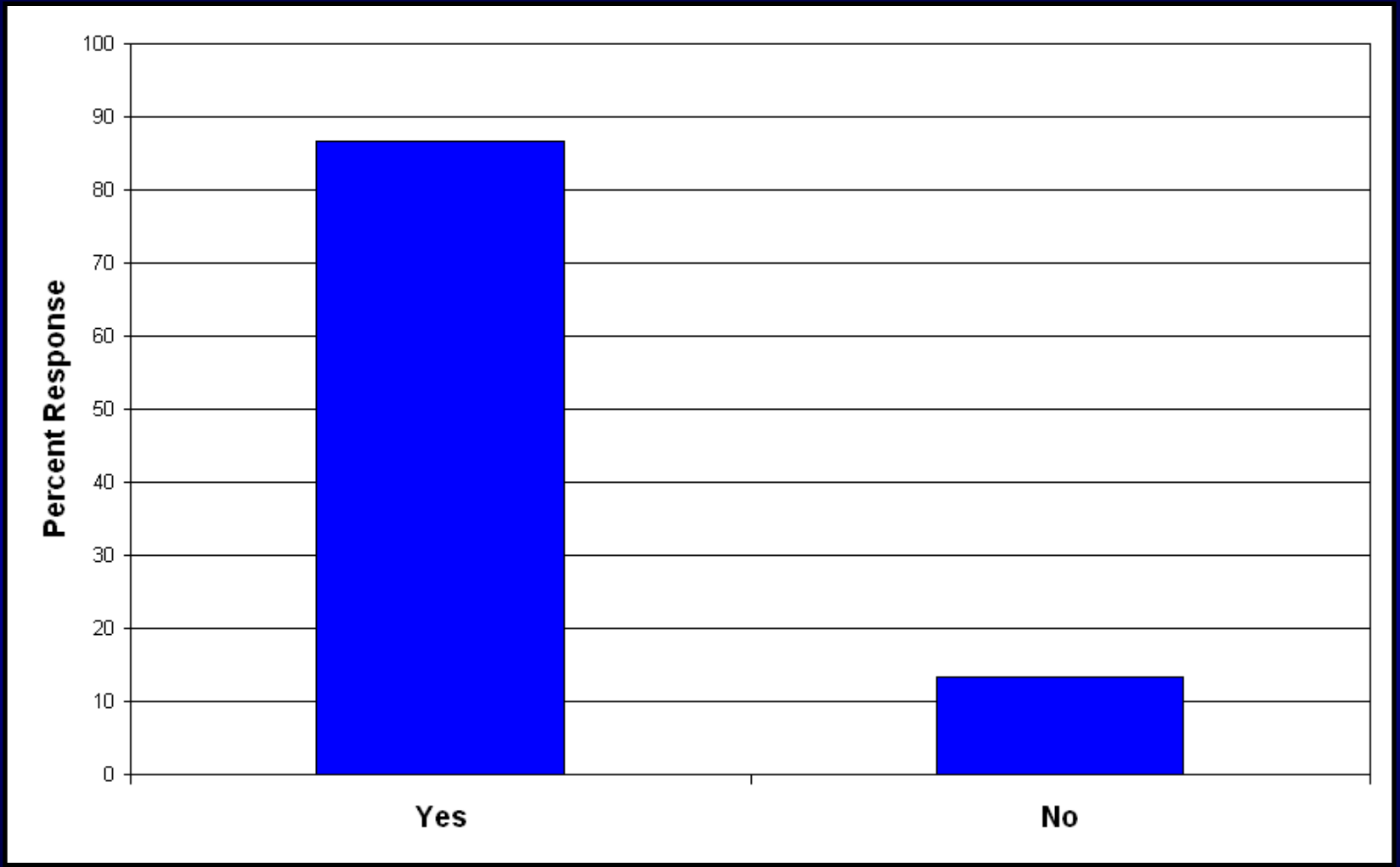
Experimental Plan (cont'd)



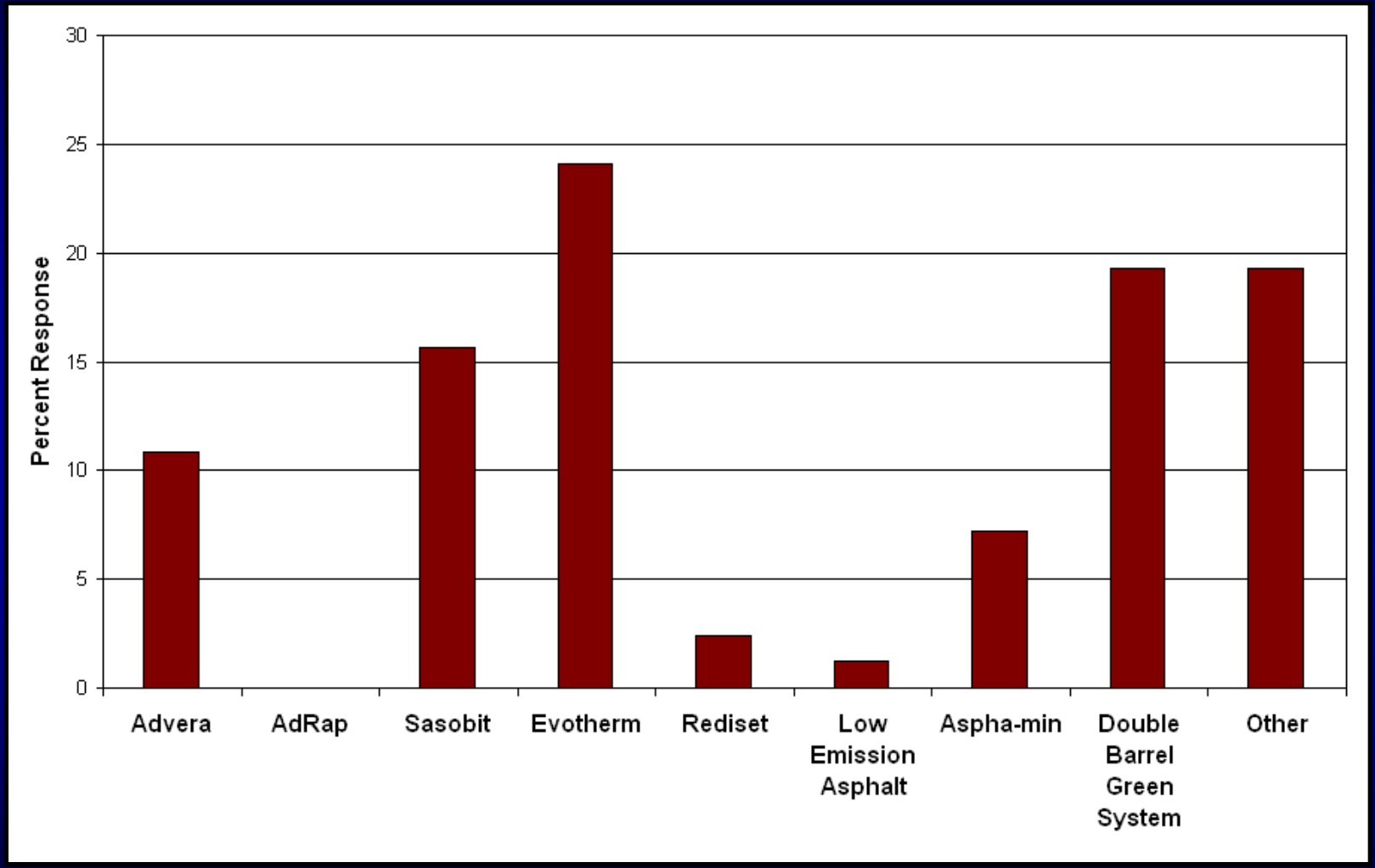
Internet Survey

- Internet based survey developed to:
  - Assess each state's experience with Warm Mix Asphalt
  - Identify conditions leading to WMA mixtures failing moisture susceptibility tests in the laboratory
  - Determine if moisture damage related distresses were observed in the field for any WMA mixtures
- Survey sent to 156 state DOT personnel with at least one representative from each of the 50 states.
- Total survey response was 19.2%.

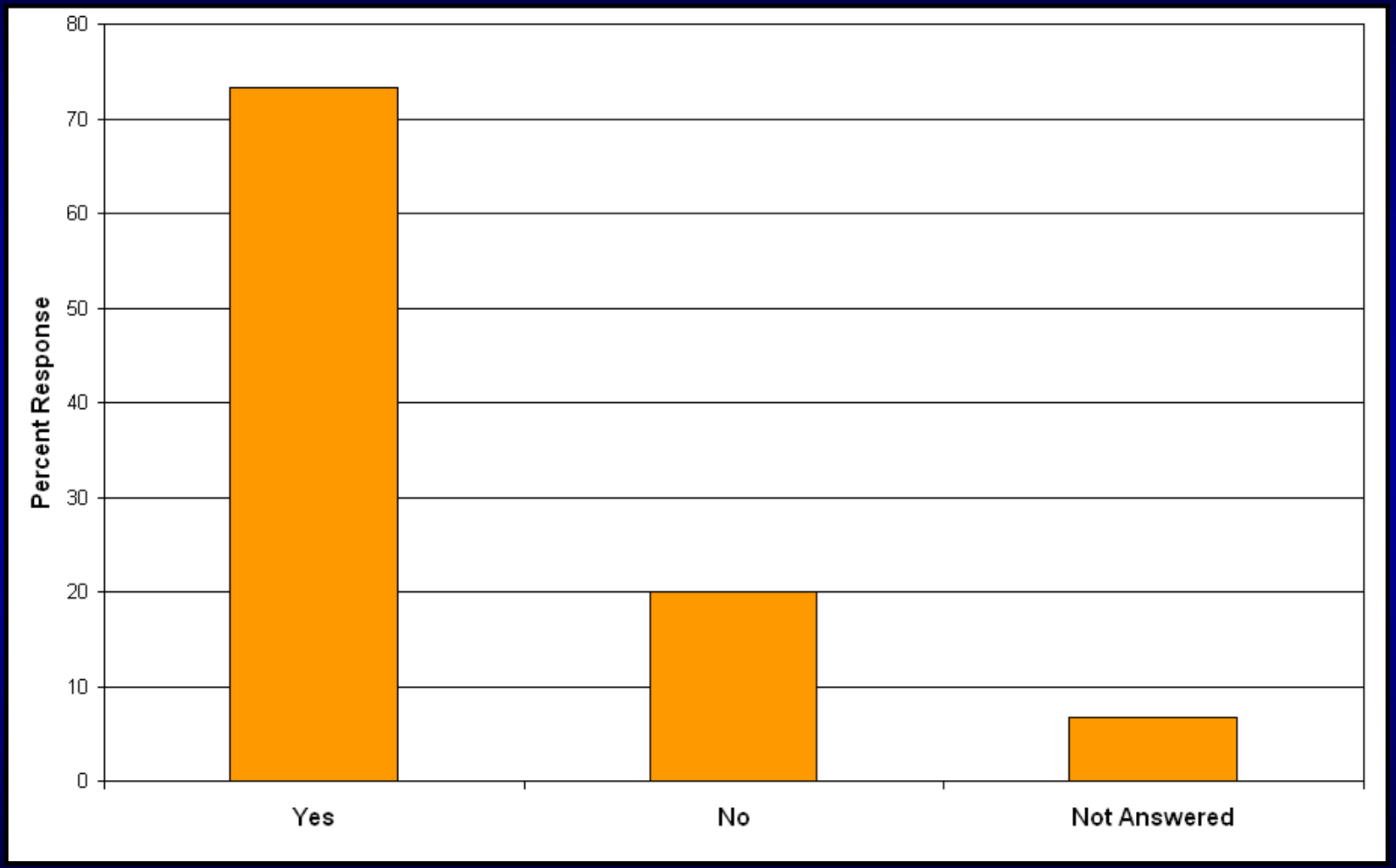
Has Warm Mix Asphalt been used in your state?



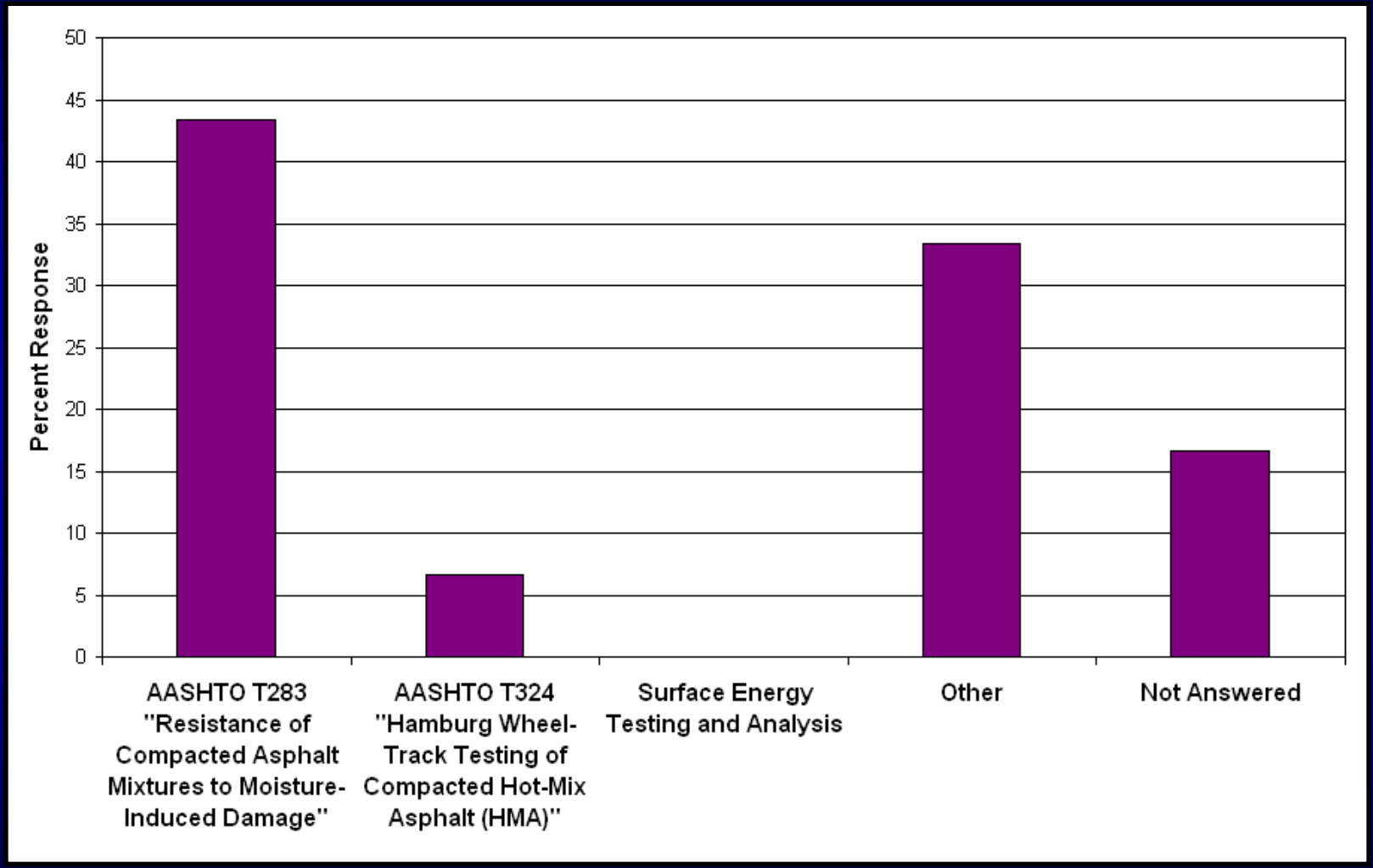
Which WMA Technologies have been used?



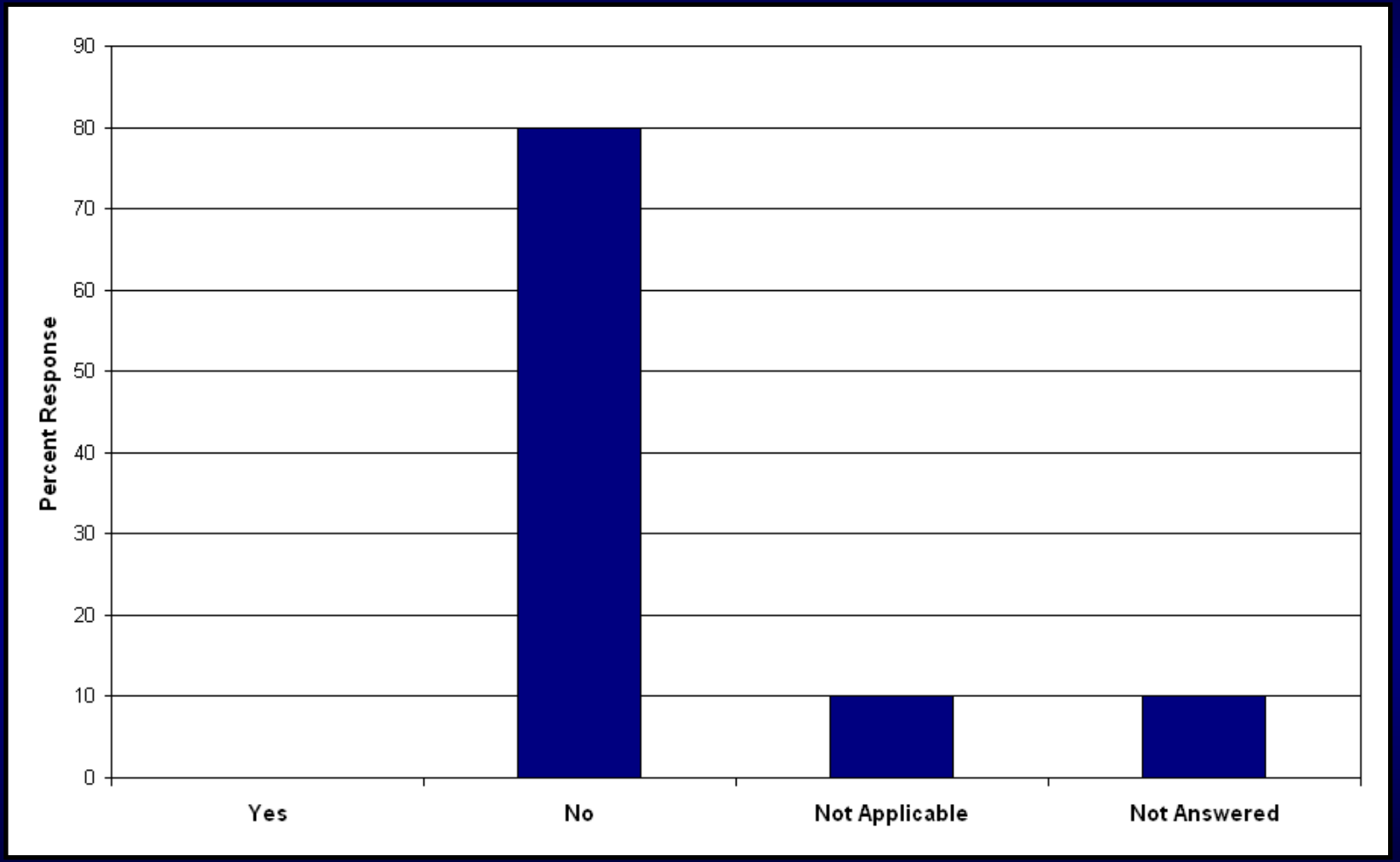
Do you have a moisture damage test requirement for mixtures incorporating WMA technologies?



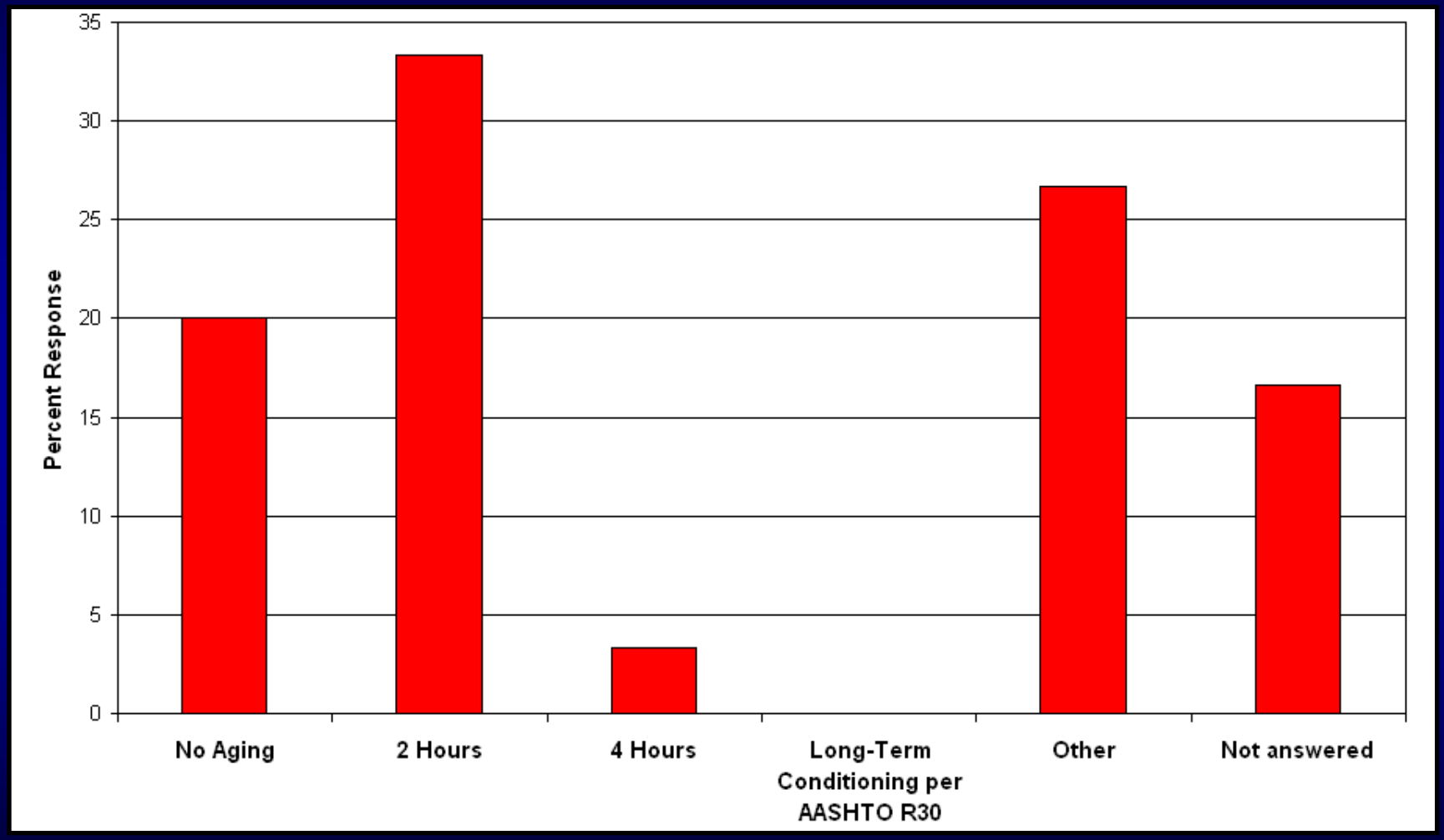
Which specific moisture damage test is utilized for WMA mixtures?



Has your state/agency observed any moisture damage related field distress in WMA mixtures?



Does your state/agency have a requirement for how long a WMA mixture is aged (conditioned) prior to compaction in the LAB?



Mixture Design

Superpave Mixture Design

- A 9.5mm mixture was developed in accordance with Superpave specifications as outlined in AASHTO R35.
- Design ESALs = 3 to <30 million (N_{des} =100).
- Mixtures developed with PG64-22 binder.
- Optimum binder content = 6.2%

9.5mm Mixture Design

Sieve Size	9.5 mm JMF	Specification
19.0 mm	100	-
12.5 mm	100	100 min.
9.5 mm	98.6	90-100
4.75 mm	69.1	90 max.
2.36 mm	44.0	32-67
1.18 mm	29.8	-
600 µm	20.5	-
300 µm	13.5	-
150 µm	8.4	-
75 µm	5.5	2-10

9.5mm Mixture Design

	9.5mm Mix Design	Specification
Percent Binder	6.2%	-
% Air Voids	4.0	4.0
%VMA	16.8	15.0 min.
%VFA	77.2	73-76
Dust-to-Binder Ratio	0.7	0.6-1.2

Binder Information

PG64-22

- **Mixing Temperature Range:**
  165-161ºC (329-322ºF)

- **Compaction Temperature Range:**
  156-152ºC (313-306ºF)

WMA Additive Technologies

Technology	Dose
Advera	0.25% by weight of mixture
Sasobit	1.5% by weight of binder
Evotherm M1	0.5% by weight of binder
AD-RAP 390 (SonneWarmix)	1.0% by weight of binder

Note: All additives introduced to the heated binder/aggregates immediately before mixing the specimen.

Anti-strip

- Two different anti-stripping agents (liquid anti-strip and lime) were used for mixtures failing the HWTD test.
- Liquid anti-strip (ArrMaz Ad-Here XL900) was added at a dose of 0.5% by weight of binder.
- Lime was added dry at a rate of 1.0% by weight of batched aggregate.
- Adding lime dry to the aggregate required a new mixture design which yielded an optimum binder content of 6.0% for the lime mixtures (vs. 6.2% for all other mixtures).

Moisture Susceptibility Testing

Hamburg Wheel Tracking Device (HWTD)

HWTD Testing

- Moisture susceptibility testing conducted using the Hamburg Wheel Tracking Device (HWTD).
- Testing performed in accordance with AASHTO T324 *"Hamburg Wheel-Track Testing of Compacted Hot-Mix Asphalt (HMA)."*
- Water temperature of 50ºC (122ºF) during testing
- 30 min soak time at 50ºC prior to testing
- Test conducted for 20,000 cycles or until specimens exhibited high amounts of rutting.

HWTD Testing

- Data analyzed to determine the Stripping Inflection Point (SIP).
- SIP gives an indication of the onset of moisture damage (stripping).
- Specimen air voids at 7.0 2.0%.

Stripping Inflection Point (SIP)

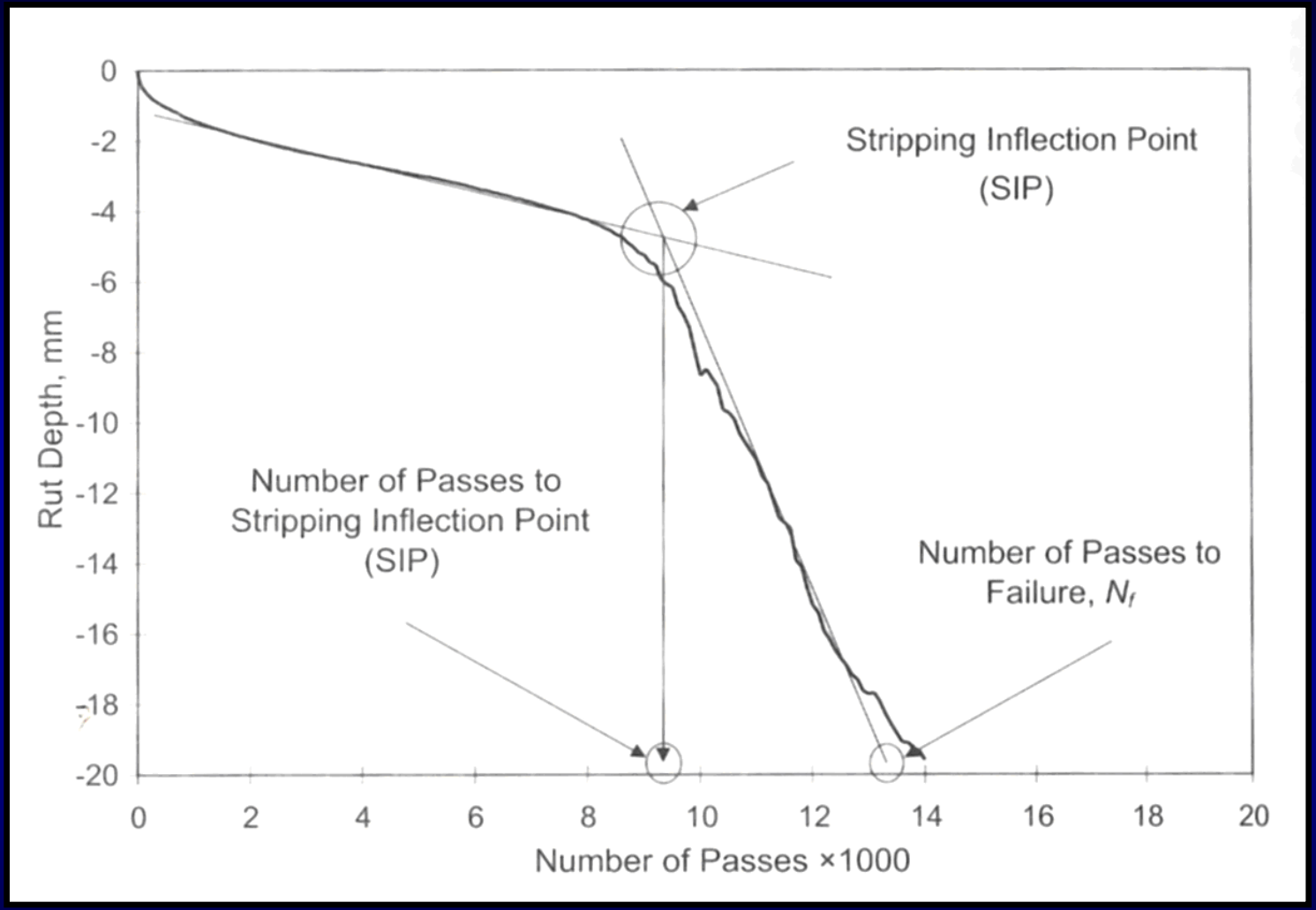
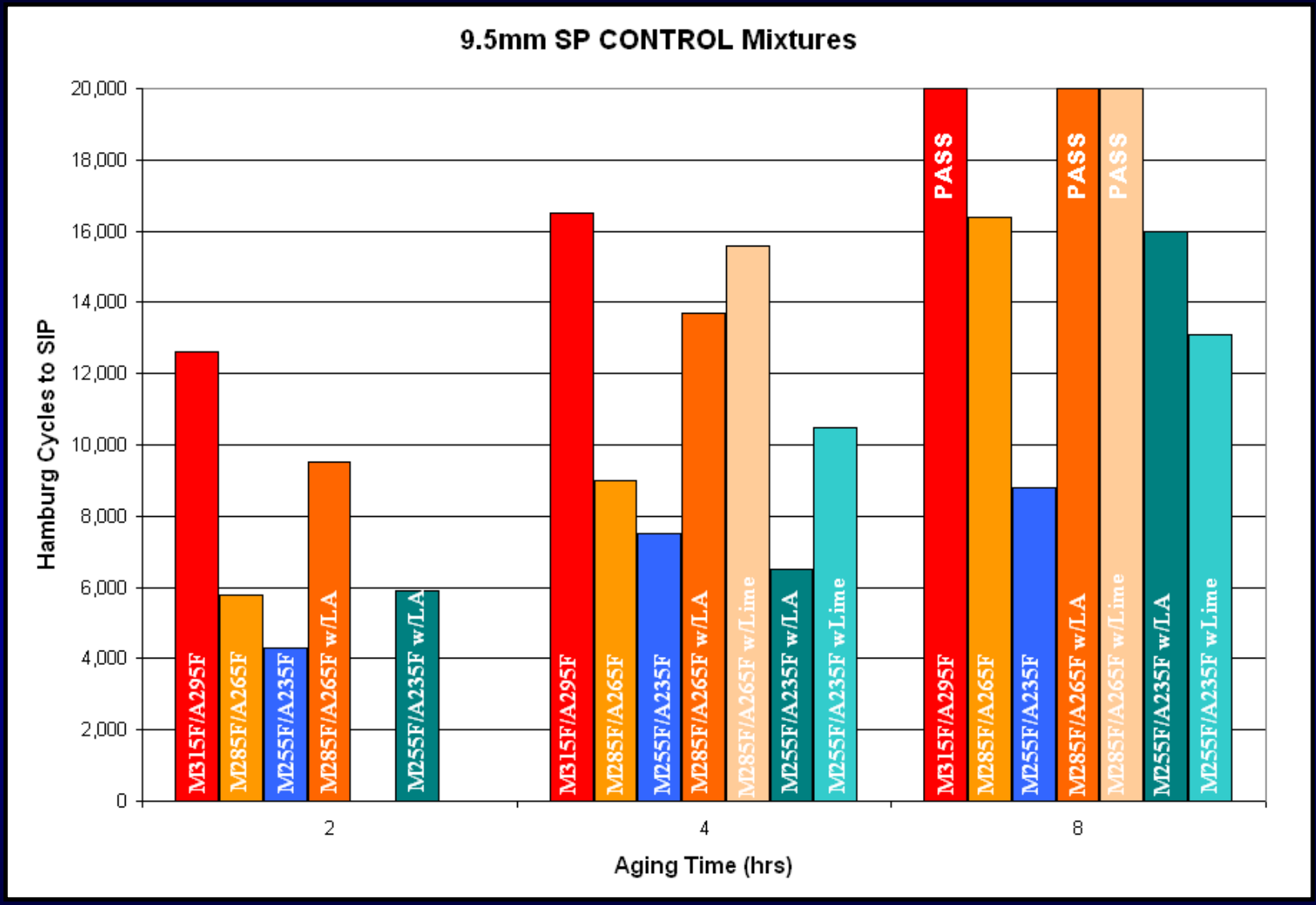
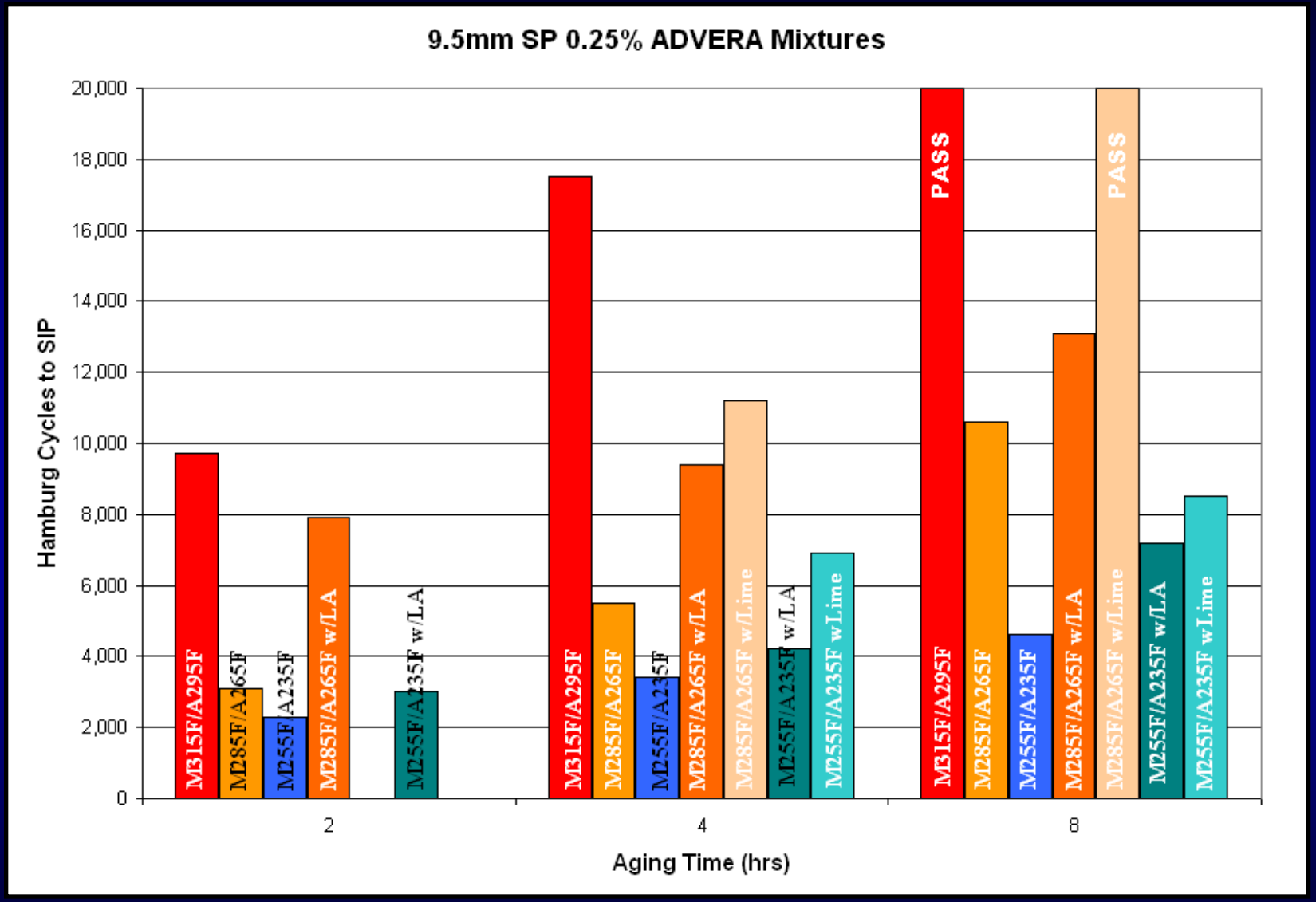


Diagram from AASHTO T324 "Hamburg Wheel-Track Testing of Compacted Hot-Mix Asphalt (HMA)" 2006.

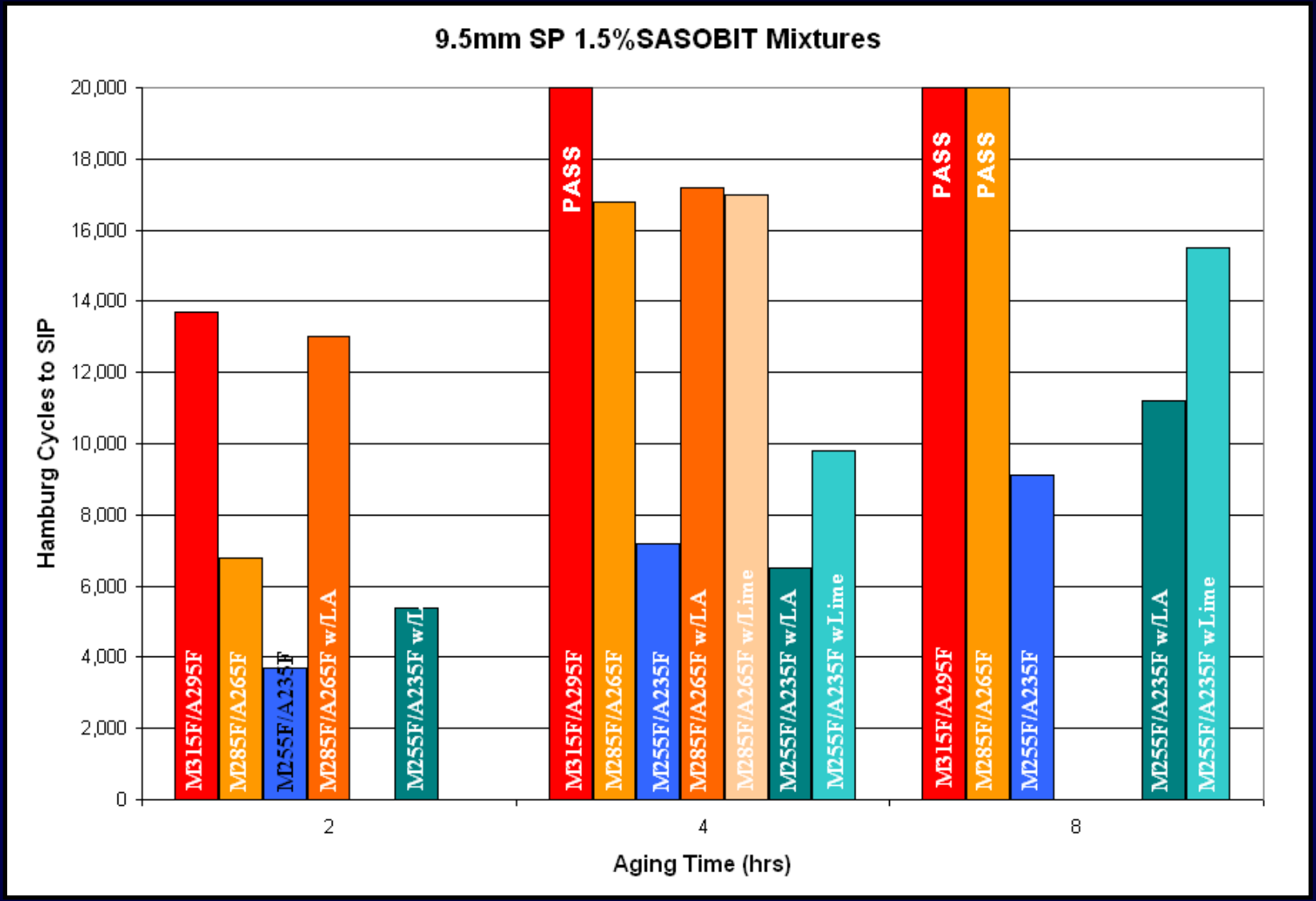
HWTD Results - Control



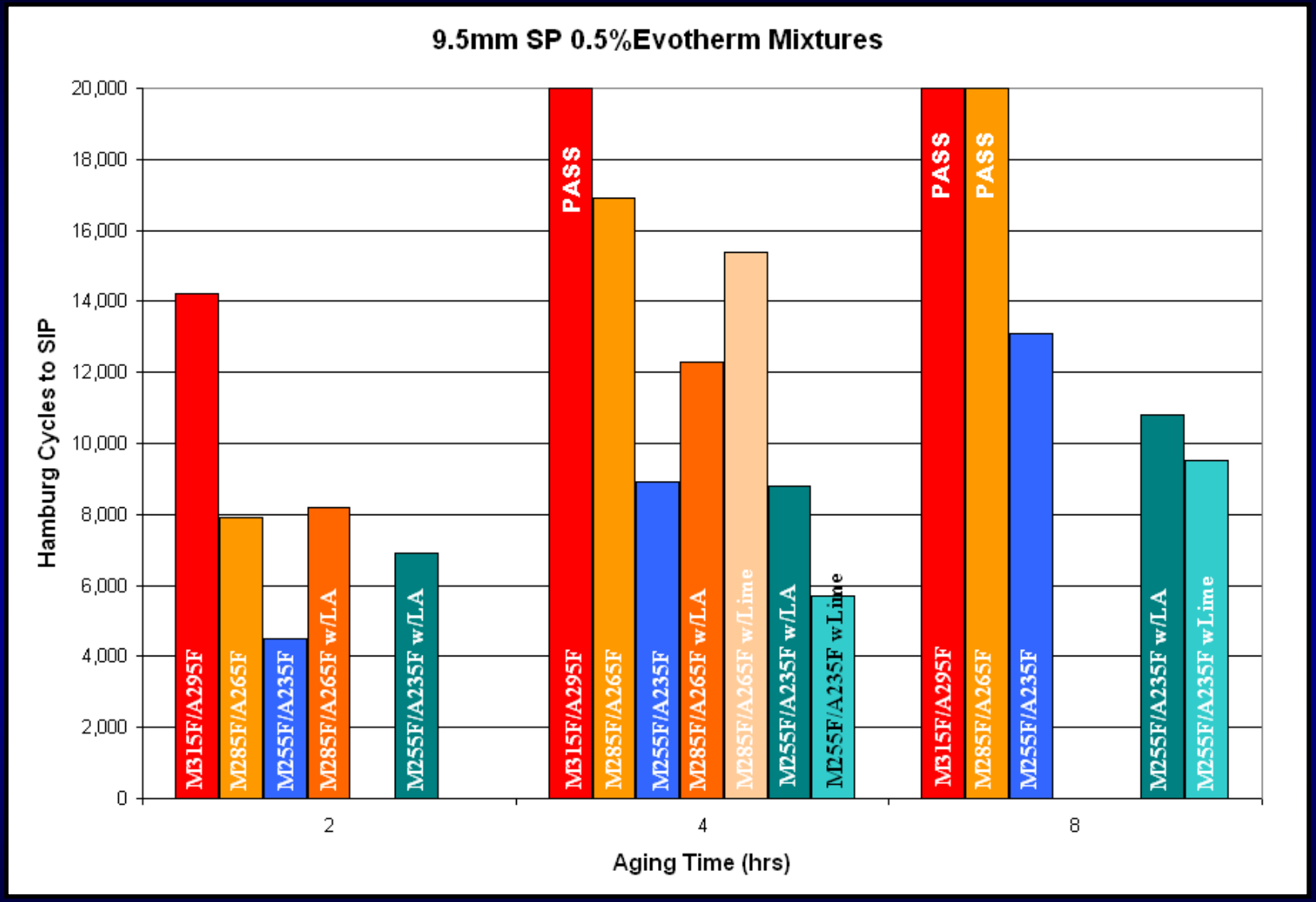
HWTD Results - Advera



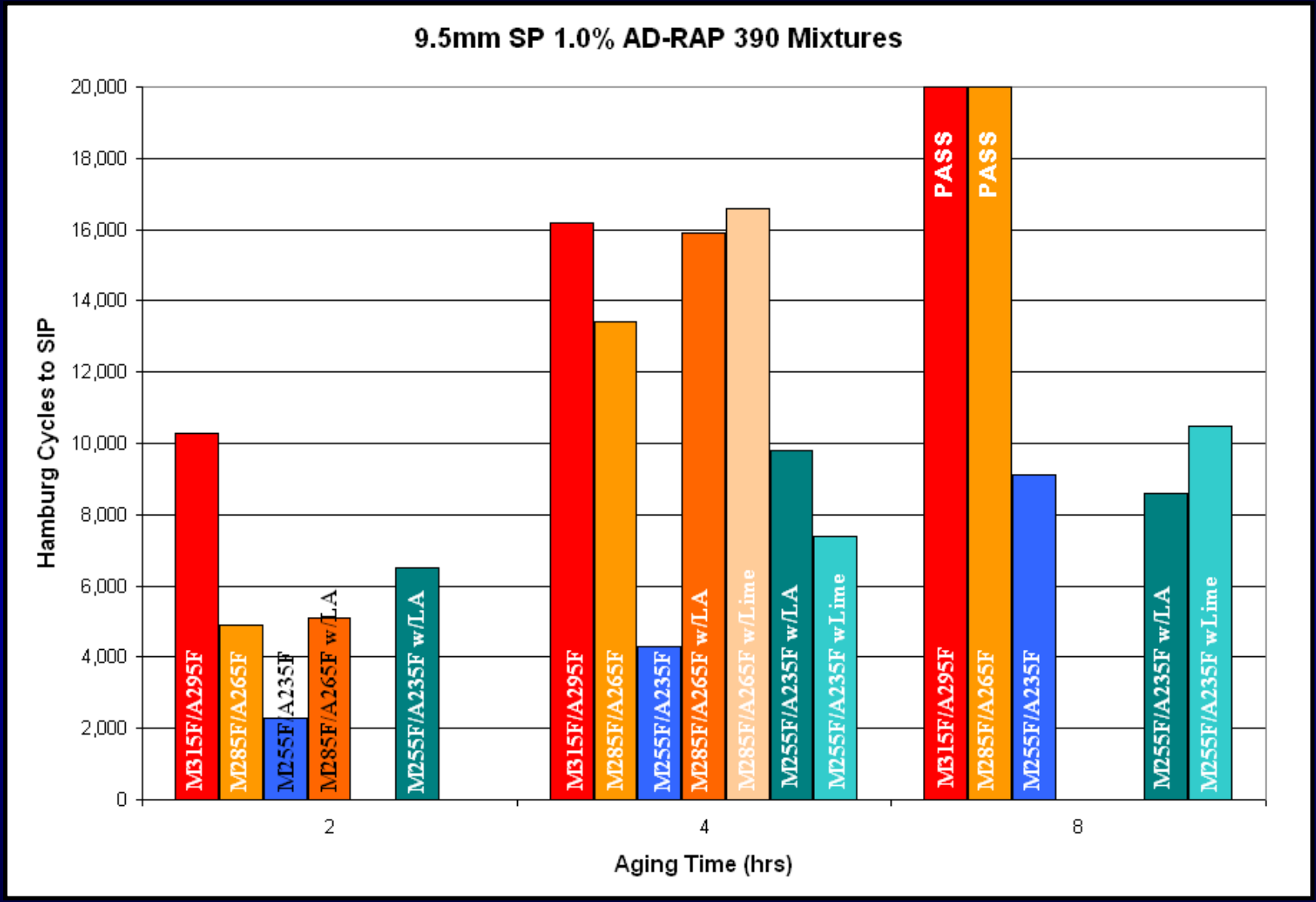
HWTD Results - Sasobit



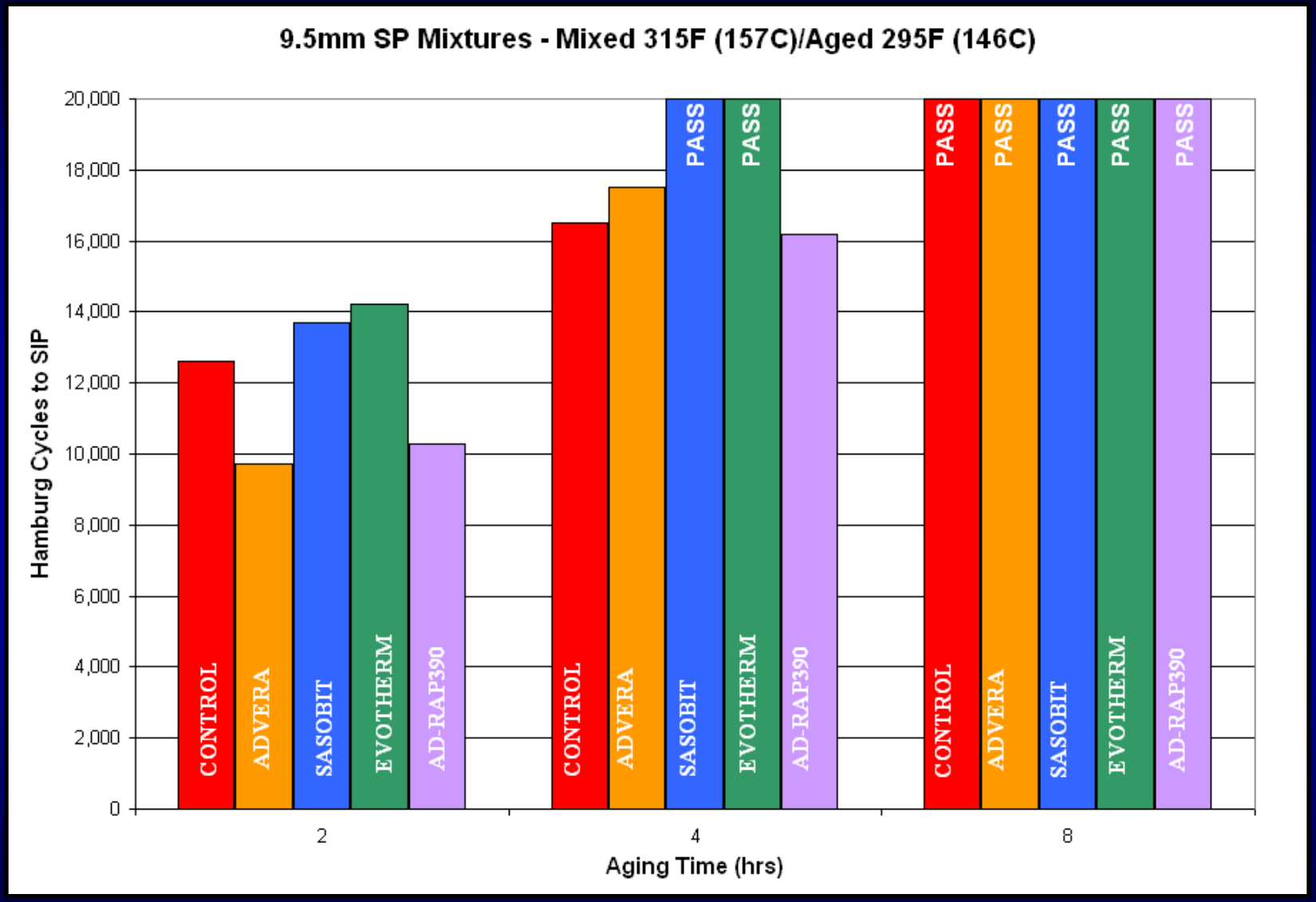
HWTD Results - Evotherm



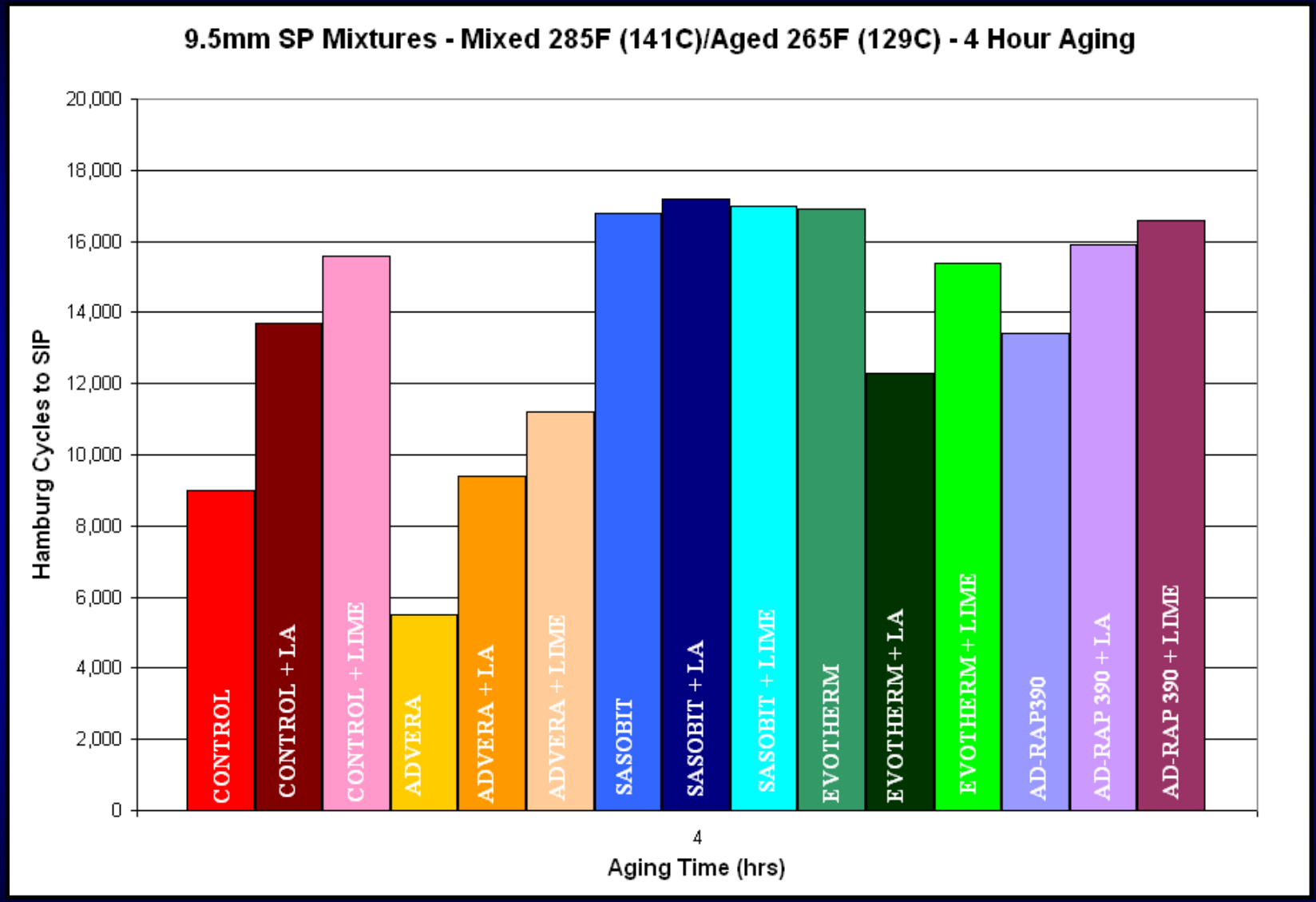
HWTD Results - AD-RAP



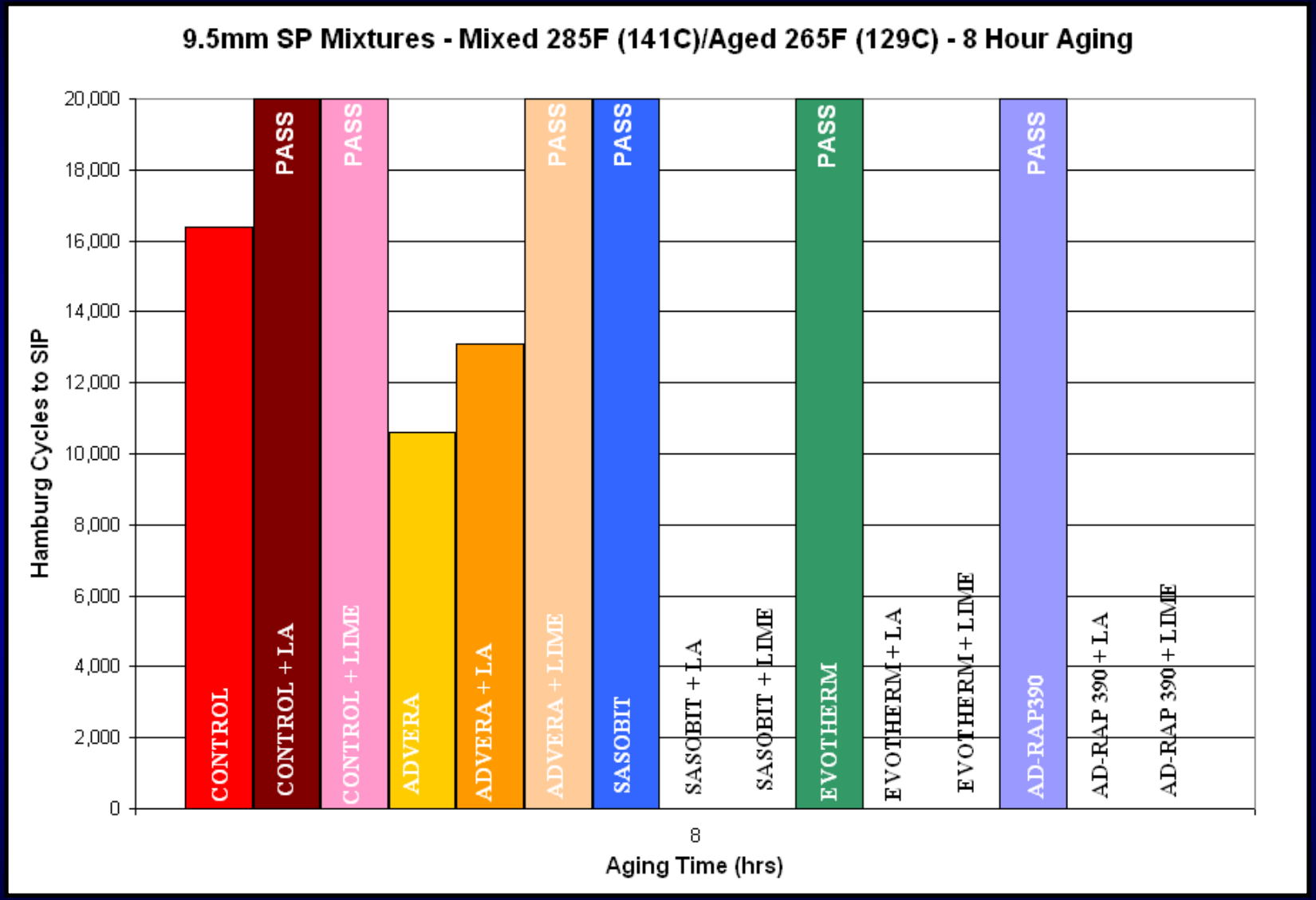
HWTD Results - M315F/A295F



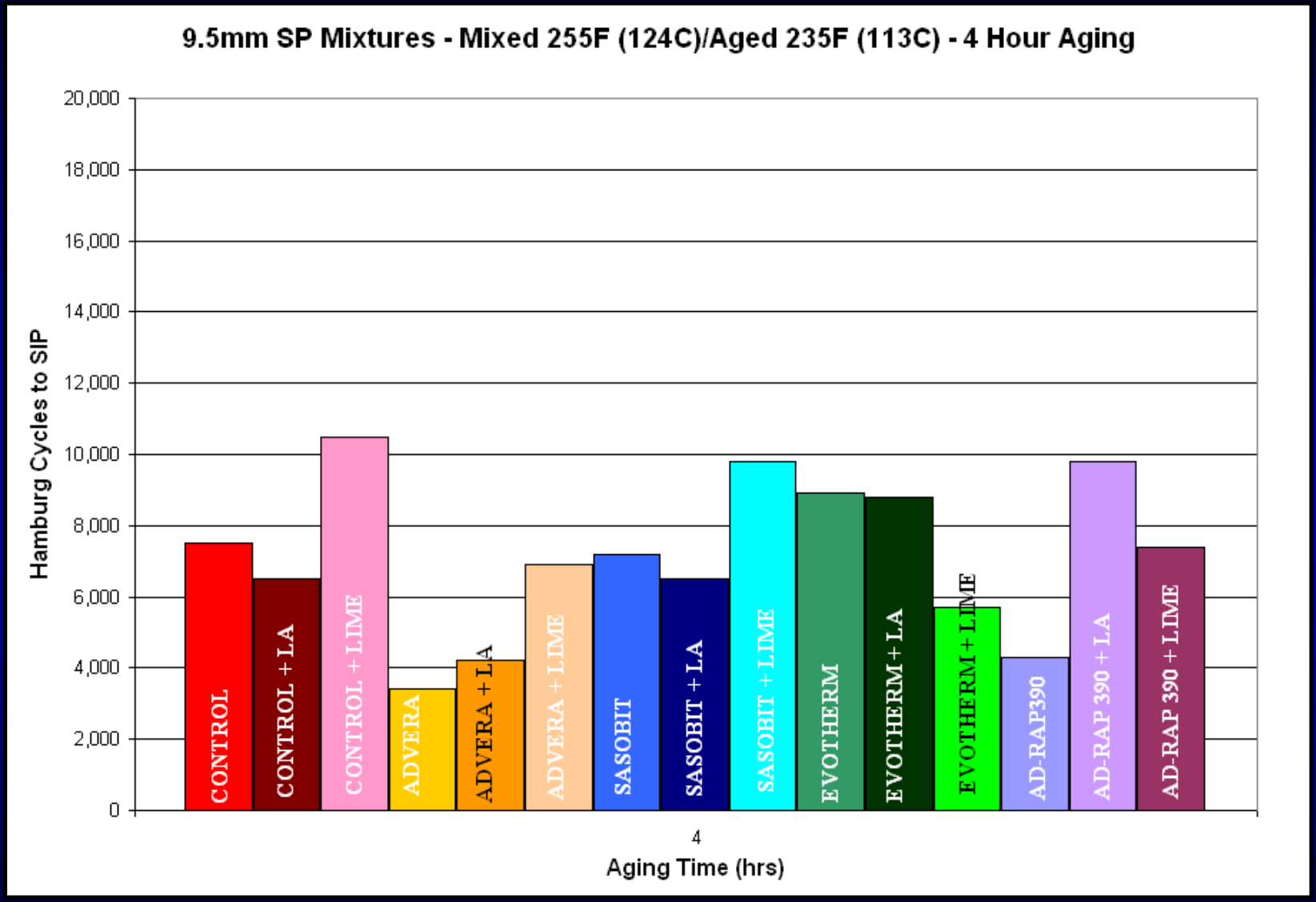
HWTD - M285F/A265F 4HRS



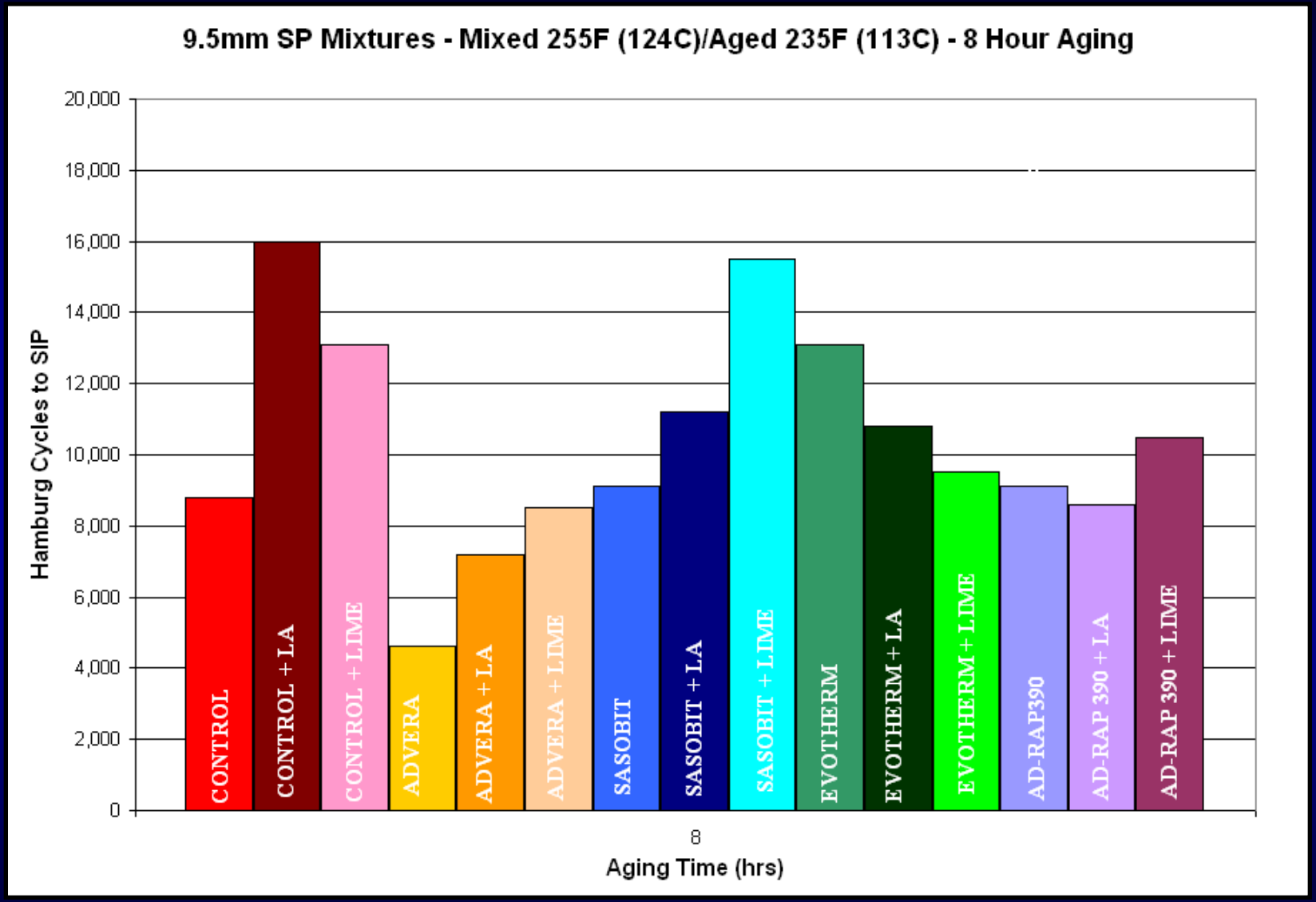
HWTD - M285F/A265F 8HRS



HWTD - M255F/A235F 4HRS



HWTD - M255F/A235F 8HRS



4 Hour Aging HWTD - Results

	Aging Temperature								
	No LA			With LA			With Lime		
Mix Type	295 F	265 F	235 F	295 F	265 F	235 F	295 F	265 F	235 F
Control	16,500	9,000	7,500	NT	13,700	6,500	NT	15,600	10,500
Advera	17,500	5,500	3,400	NT	9,400	4,200	NT	11,200	6,900
Sasobit	20,000	16,800	7,200	NT	17,200	6,500	NT	17,000	9,800
Evotherm	20,000	16,900	8,900	NT	12,300	8,800	NT	15,400	5,700
AD-RAP	16,200	13,400	4,300	NT	15,900	9,800	NT	16,600	7,400

NT = Not Tested

8 Hour Aging HWTD - Results

	Aging Temperature								
	No LA			With LA			With Lime		
Mix Type	295 F	265 F	235 F	295 F	265 F	235 F	295 F	265 F	235 F
Control	20,000	16,400	8,800	NT	20,000	16,000	NT	20,000	13,100
Advera	20,000	10,600	4,600	NT	13,100	7,200	NT	20,000	8,500
Sasobit	20,000	20,000	9,100	NT	NT	11,200	NT	NT	15,500
Evotherm	20,000	20,000	13,100	NT	NT	10,800	NT	NT	9,500
AD-RAP	20,000	20,000	9,100	NT	NT	8,600	NT	NT	10,500

NT = Not Tested

Proposed Aging Trial

Performed on Advera & SonneWarmix Mixtures - No Anti-Strip

Day 1

- Mixtures mixed at 255ºF (124ºC)
- Loose mixture aged 4 hours at 235ºF (113ºC)
- Loose mixture compacted in SGC
- Specimens allowed to cool at room temperature for 6 hours
- Specimens aged at 140ºF (60ºC) for 14 hours

Day 2

- Specimens allowed to cool to room temperature
- Specimens cut for HWTD testing
- Specimen volumetric properties measured

Day 3

- Specimens tested in the HWTD

Proposed Aging Trial - Results

	M315ºF/ A295ºF	M285ºF/ A265ºF	M255ºF/ A235ºF	Proposed Aging
Control	16,500	9,000	7,500	Not Tested
Advera	17,500	5,500	3,400	4,000
SonneWarmix	16,200	13,400	4,300	4,200

Comparison of 4 hour aging HWTD SIP.

Asphalt Binder Moisture Sensitivity Testing

Bitumen Bond Strength (BBS) Test

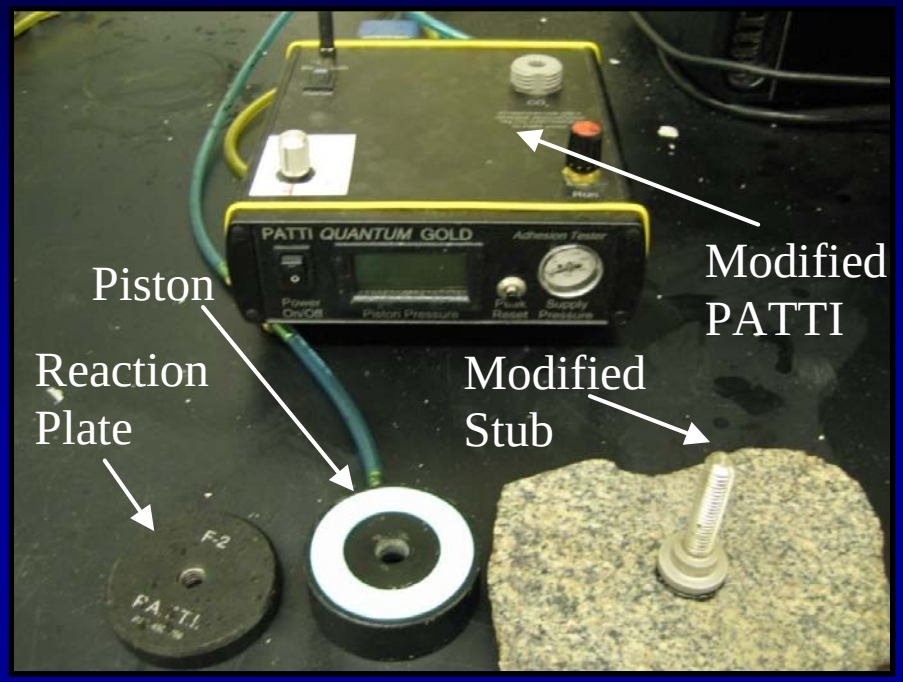
University of Wisconsin Madison
Professor Hussain Bahia, Ph.D.
Enad Mahmoud, Ph.D.

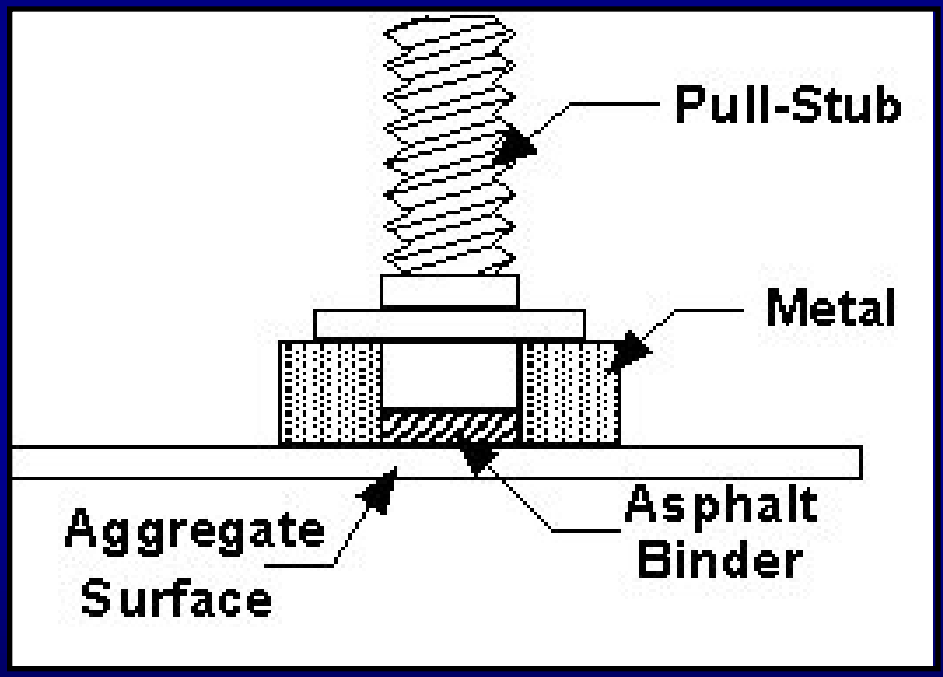
WMA TWG Meeting – May 18th 2010
NCAT - Auburn, AL

Bitumen Bond Strength (BBS) Test

- Testing conducted by University of Wisconsin-Madison using the using the Pneumatic Adhesion Tensile Tester (PATTI).
- PATTI is used to evaluate adhesive failures at the binder-aggregate interface and cohesive failures of the binder.
- Procedure originally developed by Youtcheff and Aurilio. Modified procedure includes changes to the pull-out stub and a different surface (aggregate plate).

BBS Testing - PATTI





Picture Courtesy: Enad Mahmoud, Ph.D.- University of Wisconsin-Madison
Figure Courtesy: http://www.engr.wisc.edu/centers/wsmtl/WSMTL-WEB-pg02J-NEWS-Kanitpong.htm

$POTS = (P \times Ag) - C$
A_{ps}

Bitumen Bond Strength (BBS) Test

- Upward force is applied by the PATTI to the binder specimen though the pull-out stub. The maximum pressure (failure pressure) is recorded.

- Pull-Off Tensile Strength (POTS) is then calculated.

BBS Test

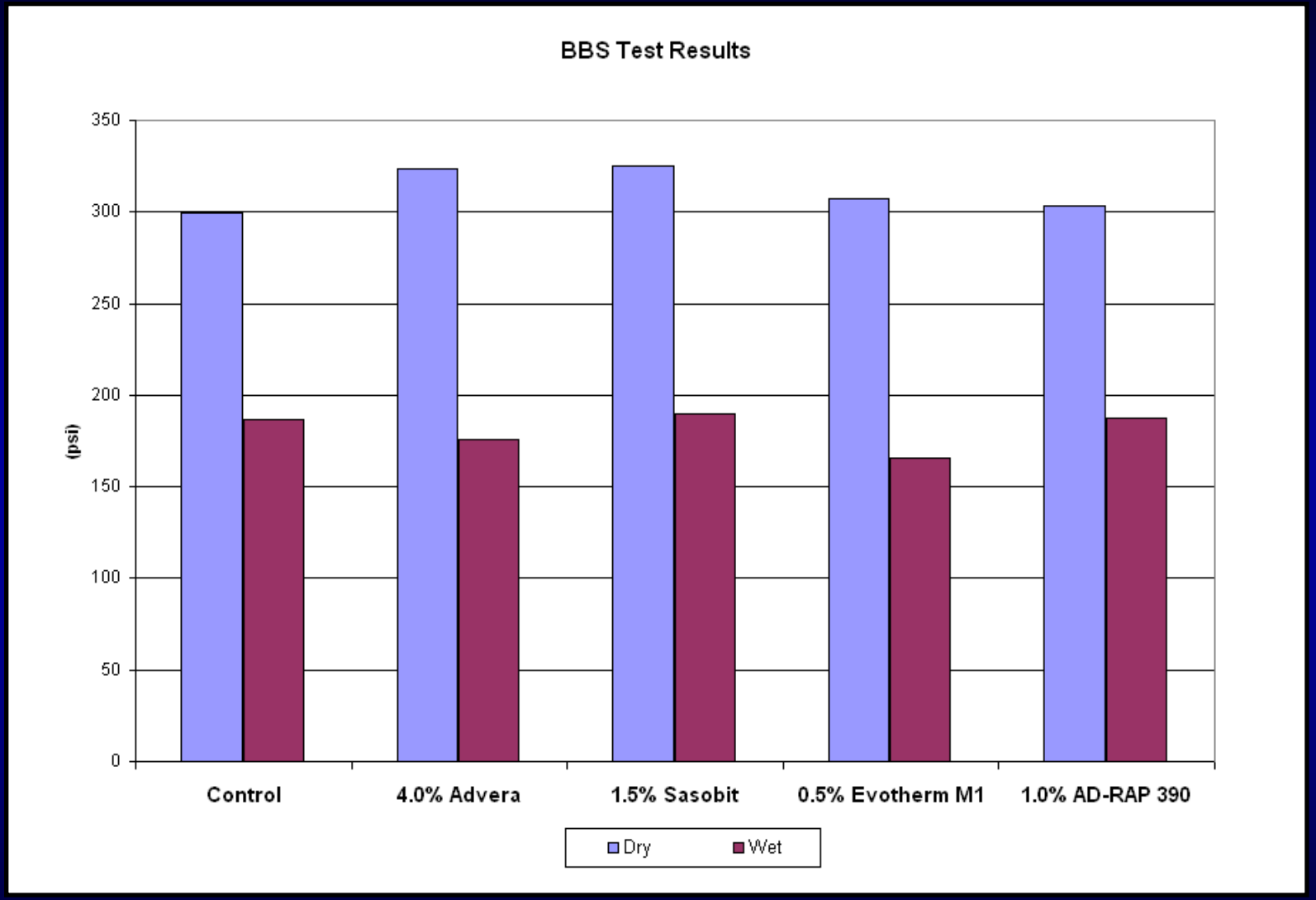
- **Binders tested for this project:**
  - **PG64-22 [Control]**
  - **PG64-22 + 4.0% Advera (0.25% by weight of mix)**
  - **PG64-22 + 1.5% Sasobit**
  - **PG64-22 + 0.5% Evotherm M1**
  - **PG64-22 + 1.0% AD-RAP 390**

- **Each binder was tested "DRY" at 20ºC (68ºF).**

- **Each binder was tested "WET" after 24 hours of moisture conditioning at 40ºC (104ºF).**

- **A limestone aggregate plate was used for each test.**

BBS Test Results



Moisture Susceptibility Tests - Ongoing

- **Conditioned/ Dry Dynamic Modulus |E*| Ratio**
  Comparing dry dynamic modulus to moisture conditioned dynamic modulus to give an indication of moisture susceptibility of mixtures.

- **Adhesive Energy Bond Ratio [Surface Energy]**
  Fine portion of the mix is being tested by Texas A&M University.

Conclusions

- Internet survey of state DOTs indicated that there have been no cases of Warm Mix Asphalt mixtures exhibiting moisture damage related distress in the field.
- Internet survey showed that most state DOTs have moisture susceptibility test requirement for warm mixes.
- The main moisture susceptibility tests being utilized by state DOTs are: AASHTO T283 (TSR) , ASTM D4867 (TSR), AASHTO T324 (Hamburg), modified TSR tests, and AASHTO T165 (Immersion Compression Test).

Conclusions

- HWTD testing indicated WMA mixtures are sensitive to aging temperature and aging time.
- WMA mixtures tested in this study had the best moisture damage performance when aged for 8 hrs at high temperatures.

Acknowledgements

Mike Nichols – Aggregate Industries

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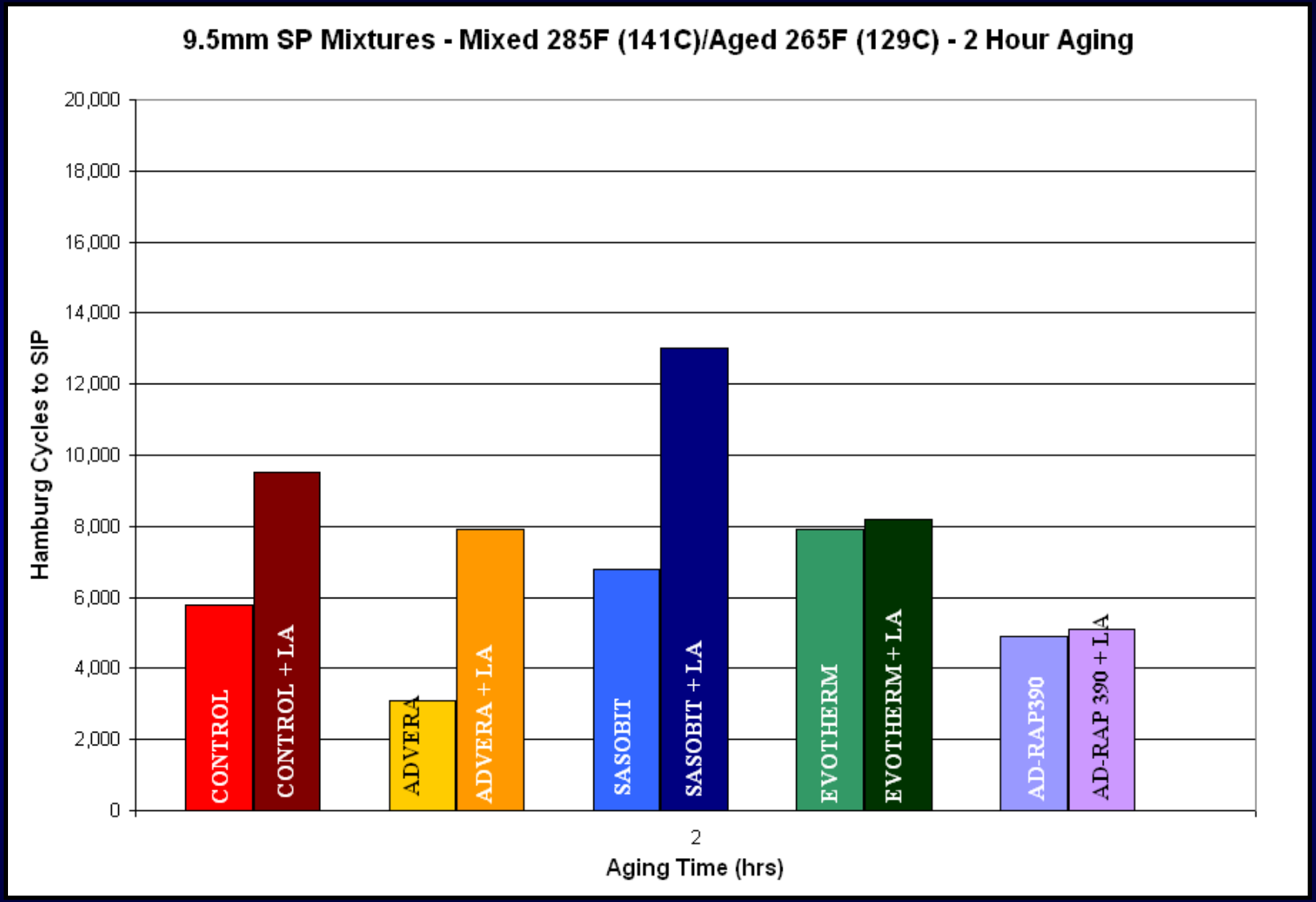
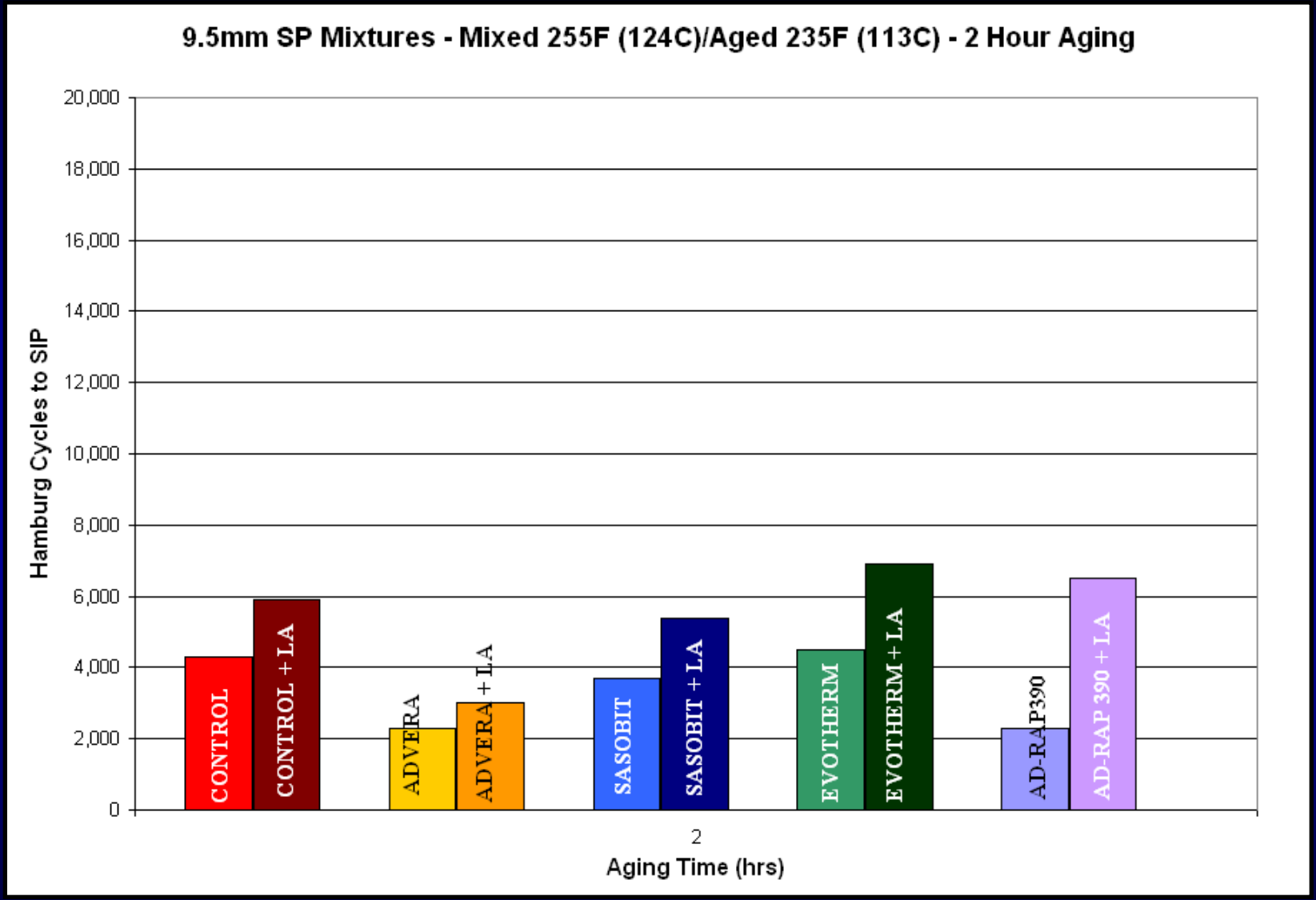
John Shaw - Sasol Wax

Thank you!

HWTD - M285F/A265F 2HRS



HWTD - M255F/A235F 2HRS



2 Hour Aging HWTD - Results

	Aging Temperature								
	No LA			With LA			With Lime		
Mix Type	295 F	265 F	235 F	295 F	265 F	235 F	295 F	265 F	235 F
Control	12,600	5,800	4,300	NT	9,500	5,900	NT	NT	NT
Advera	9,700	3,100	2,300	NT	7,900	3,000	NT	NT	NT
Sasobit	13,700	6,800	3,700	NT	13,000	3,700	NT	NT	NT
Evotherm	14,200	7,900	4,500	NT	8,200	4,500	NT	NT	NT
AD-RAP	10,300	4,900	2,300	NT	5,100	2,300	NT	NT	NT

NT = Not Tested

BBS Test Results