

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



Warm Mix Asphalt  
Technical Working Group

May 18<sup>th</sup>, 2010  
NCAT -Auburn, AL



Presented by:

**Professor Walaa S. Mogawer, PE**  
University of Massachusetts Dartmouth  
Highway Sustainability Research Center (HSRC)



# RESEARCH TEAM

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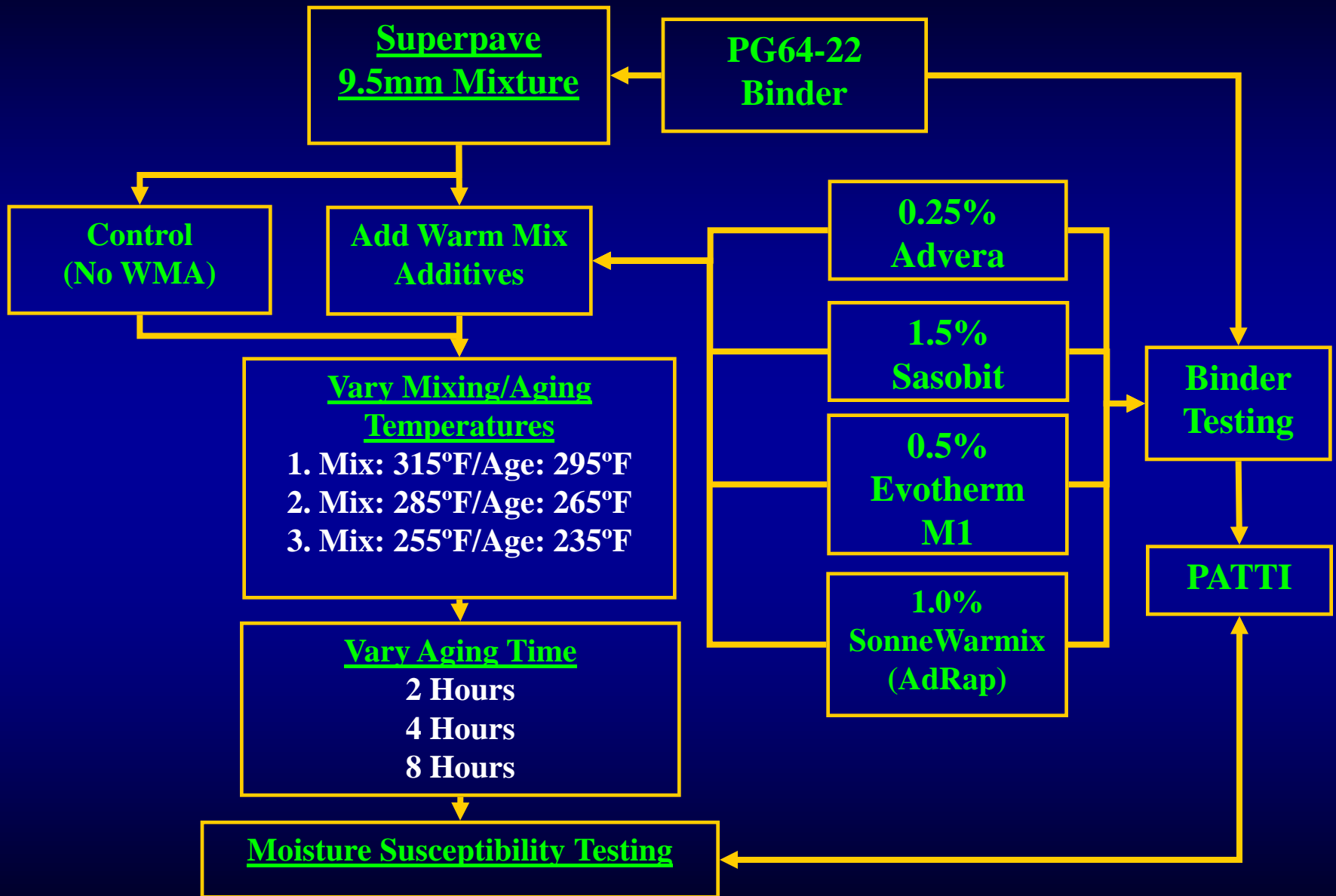


# PROJECT OBJECTIVES

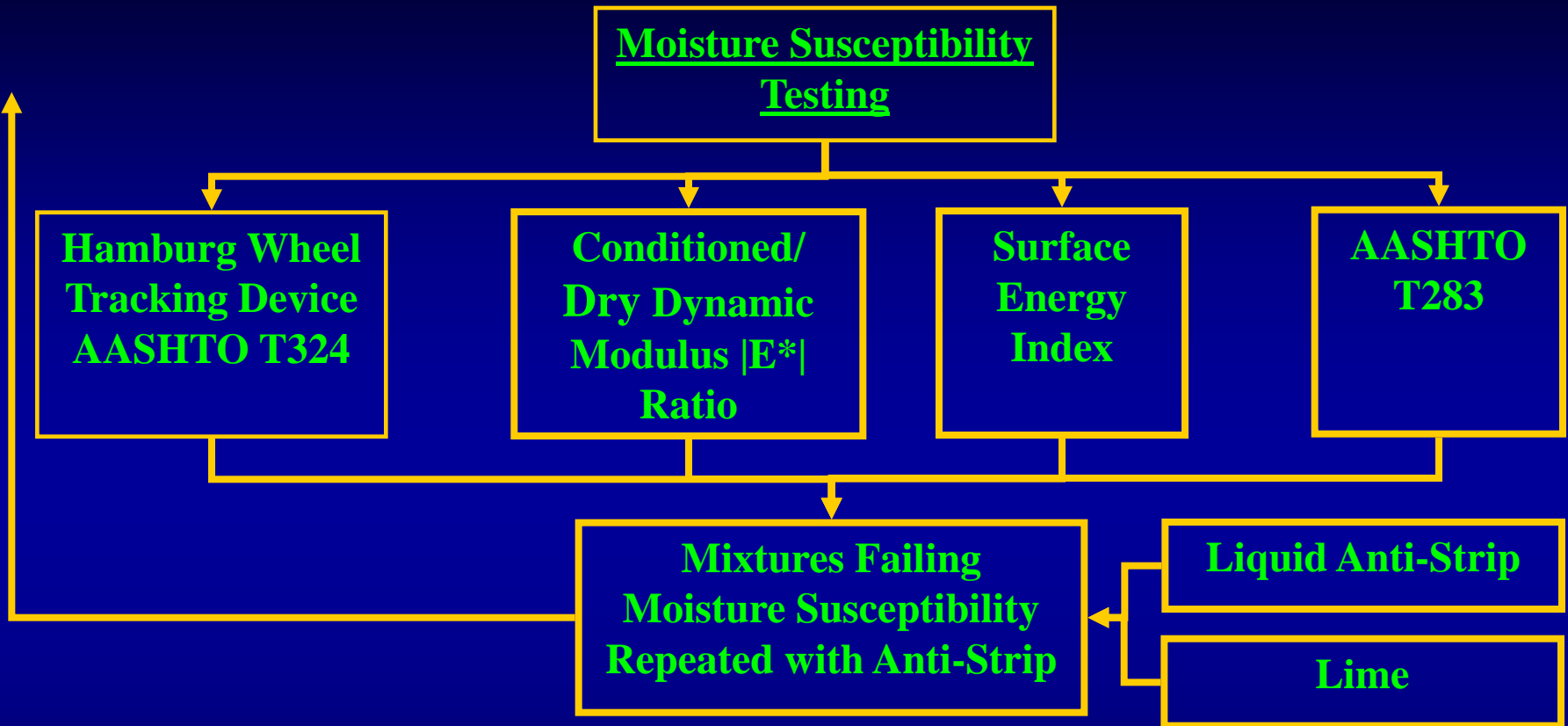
- ➔ Measure the effect of aging time and temperature on the moisture susceptibility of WMA mixtures utilizing:
  - Hamburg Wheel Tracking Device (AASHTO T324)
  - Conditioned/Dry Dynamic Modulus  $|E^*|$  Ratio
  - Adhesive Energy Bond Ratio
  - AASHTO T-283
  
- ➔ Measure the effect of WMA technologies 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%.

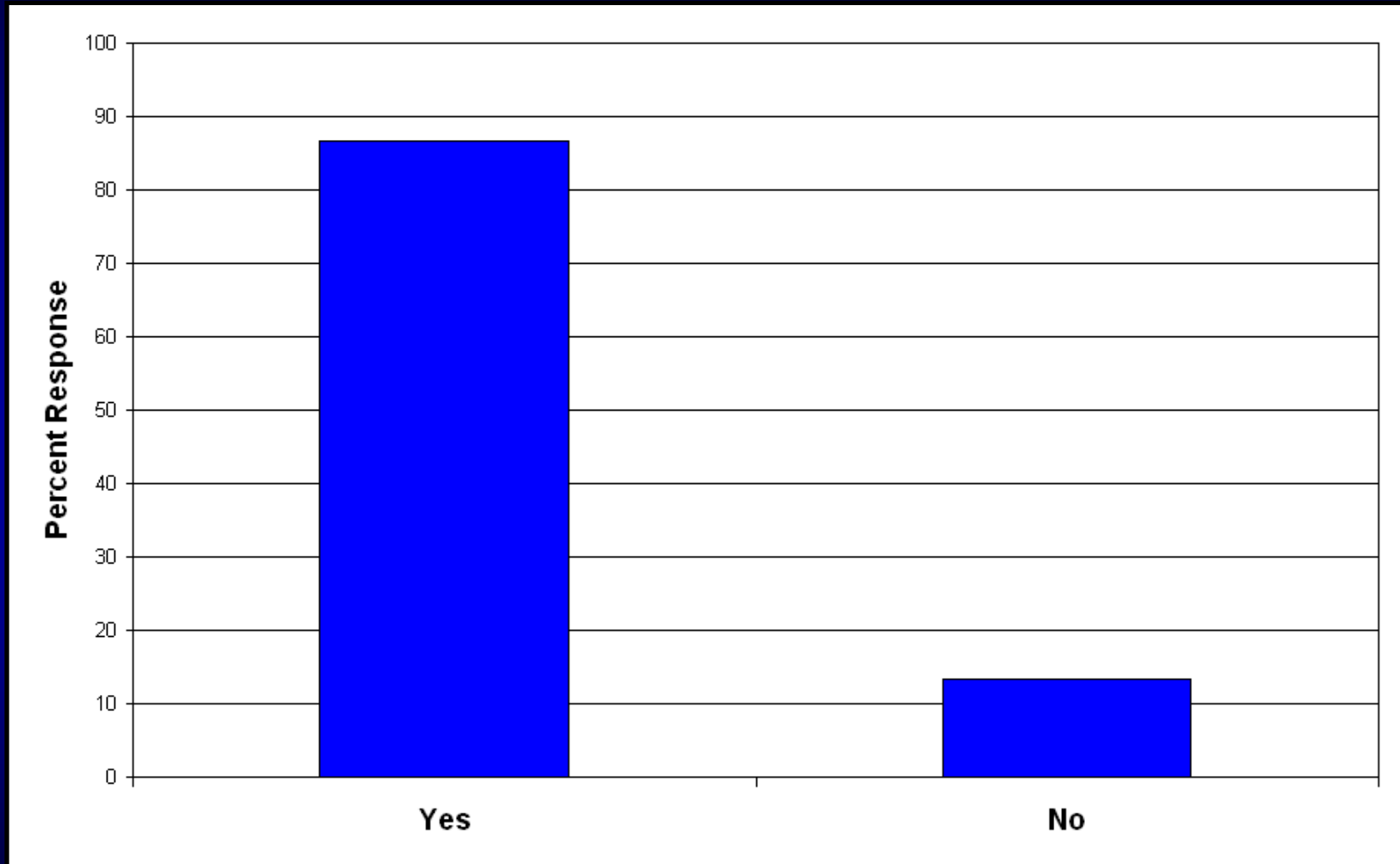


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# HAS WARM MIX ASPHALT BEEN USED IN YOUR STATE?

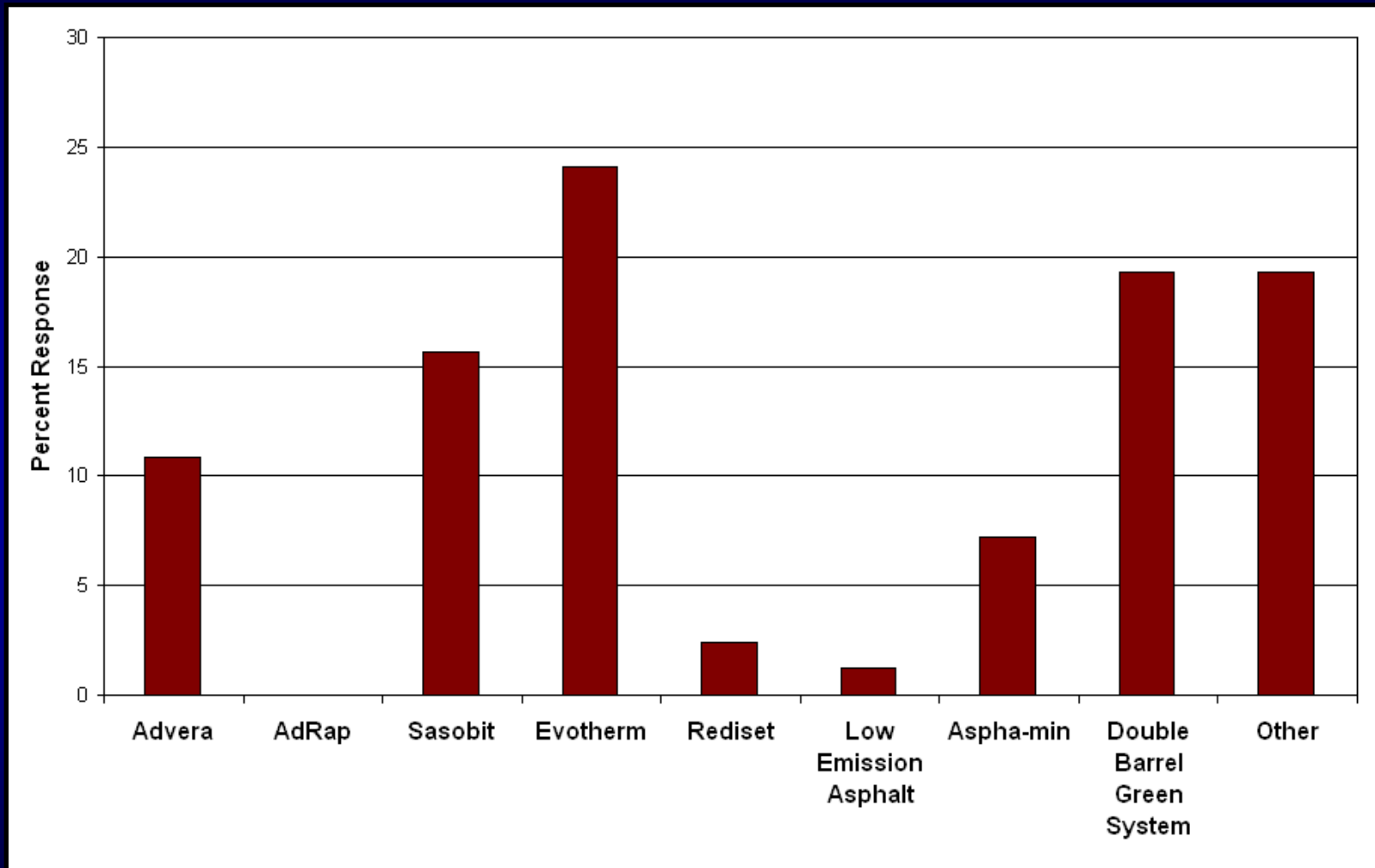


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# WHICH WMA TECHNOLOGIES HAVE BEEN USED?



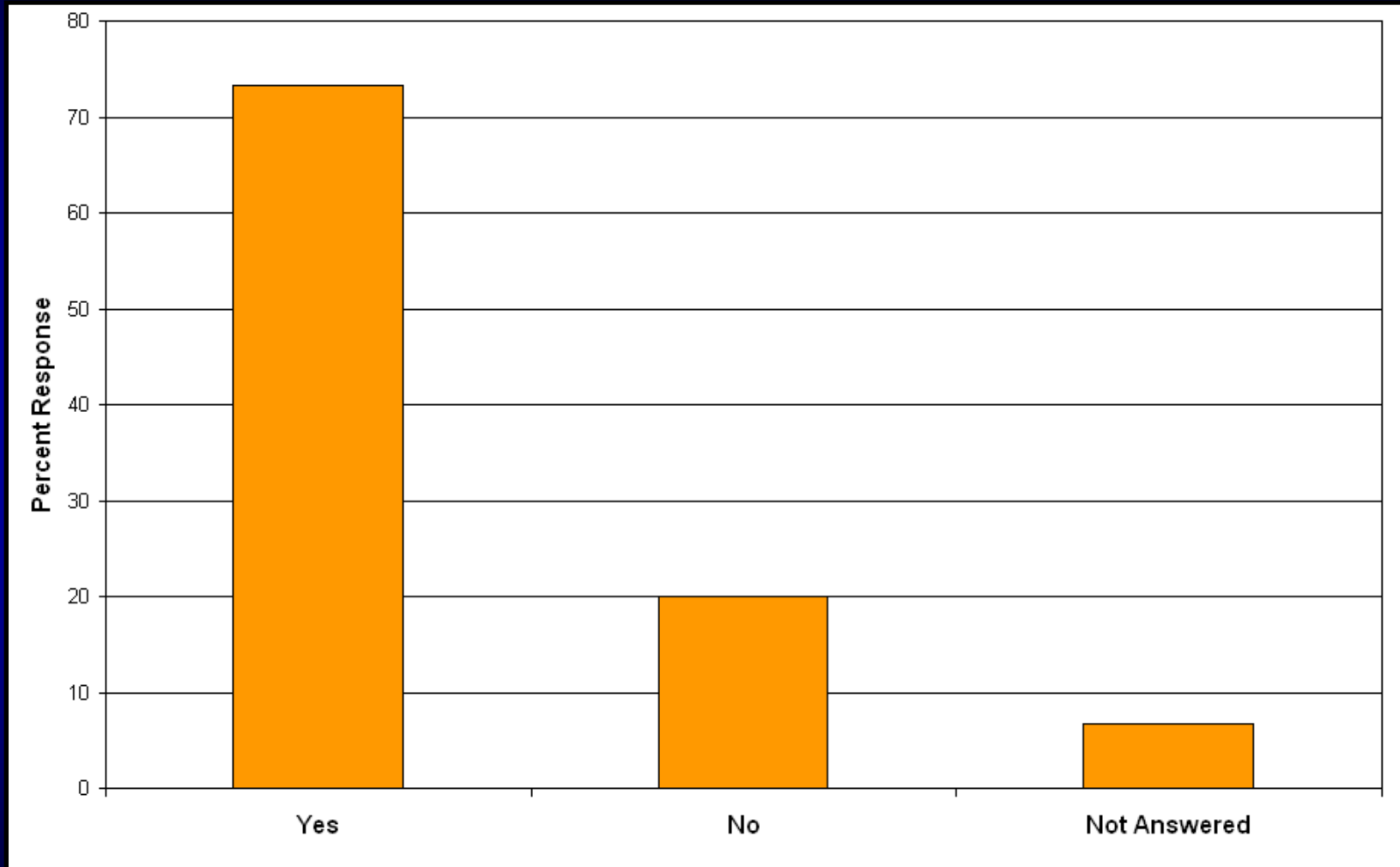
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# DO YOU HAVE A MOISTURE DAMAGE TEST REQUIREMENT FOR MIXTURES INCORPORATING WMA TECHNOLOGIES?

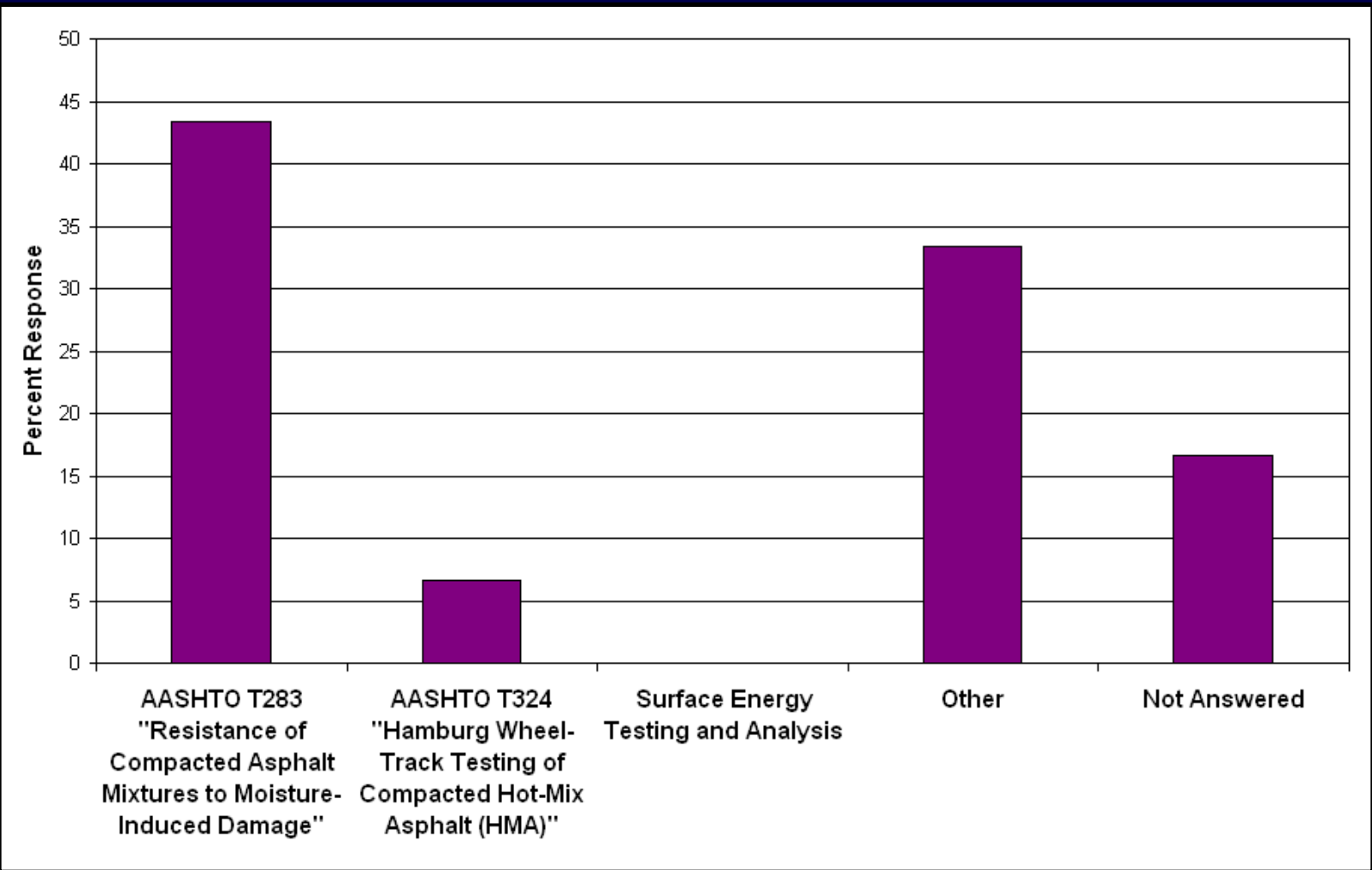


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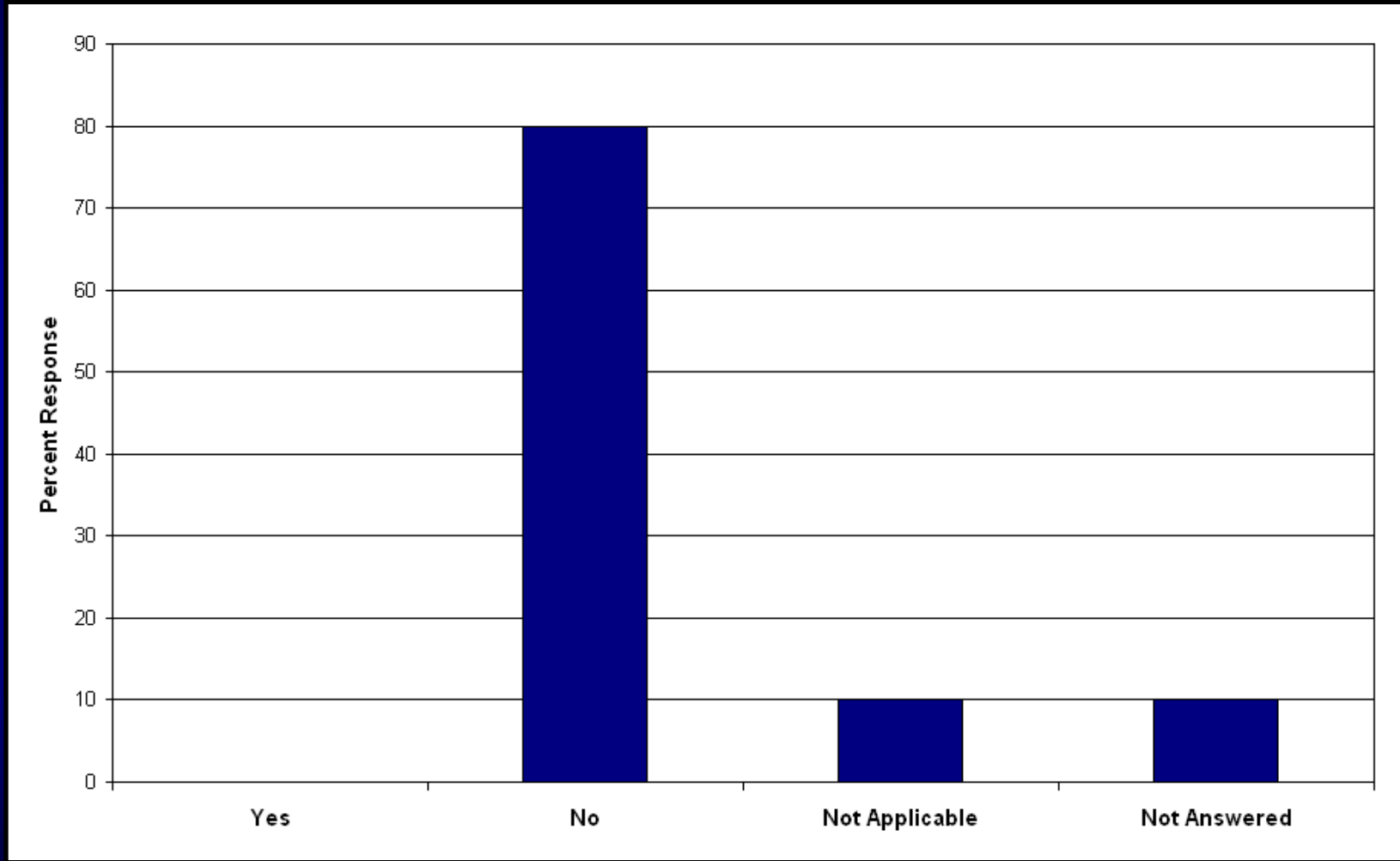
# WHICH SPECIFIC MOISTURE DAMAGE TEST IS UTILIZED FOR WMA MIXTURES?



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# HAS YOUR STATE/AGENCY OBSERVED ANY MOISTURE DAMAGE RELATED FIELD DISTRESS IN WMA MIXTURES?

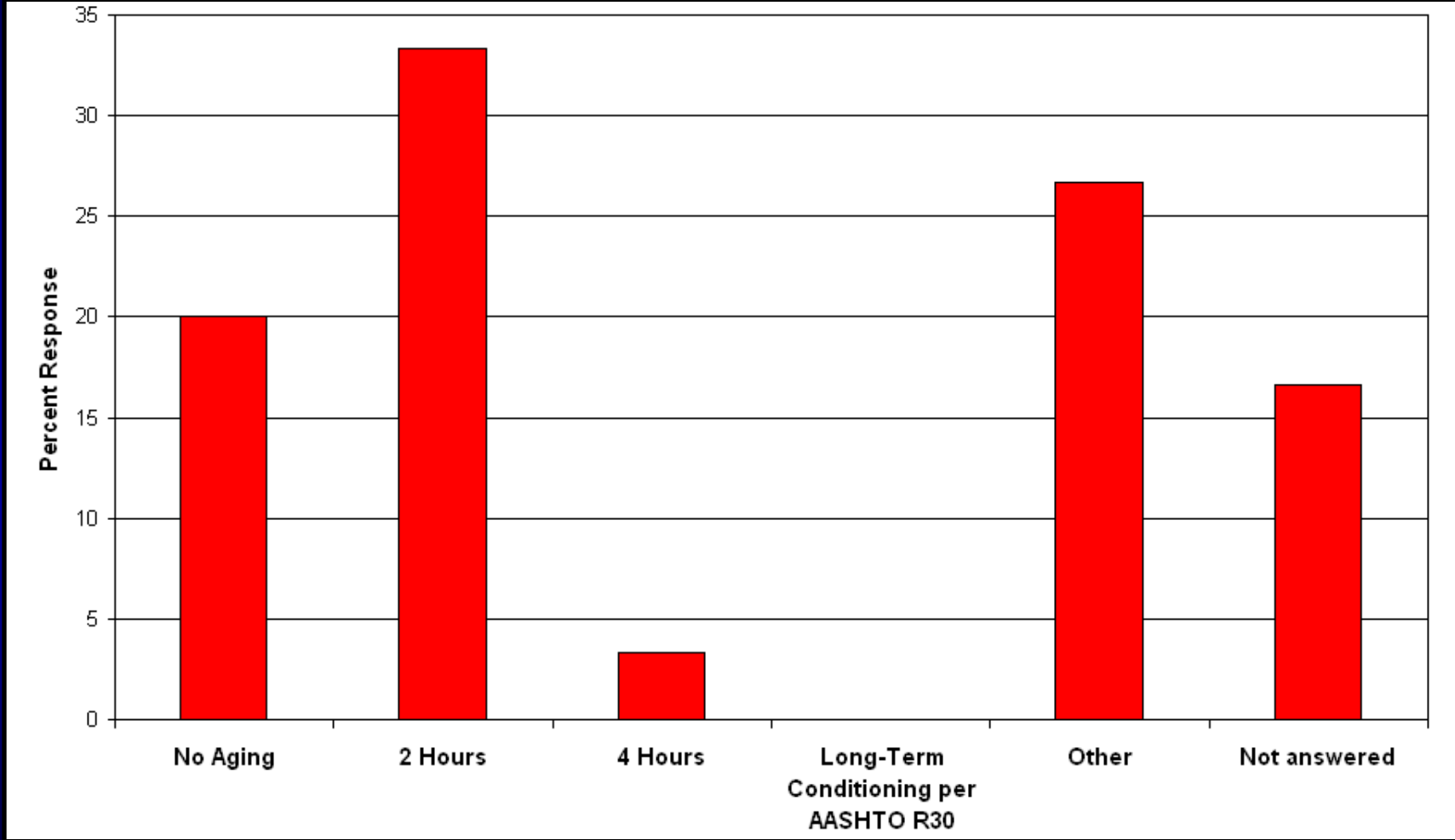


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# DOES YOUR STATE/AGENCY HAVE A REQUIREMENT FOR HOW LONG A WMA MIXTURE IS AGED (CONDITIONED) PRIOR TO COMPACTION IN THE LAB?



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# MIXTURE DESIGN



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# **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%**



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# 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



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# 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



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# BINDER INFORMATION

## PG64-22

- ⇒ Mixing Temperature Range:  
165-161°C (329-322°F)
- ⇒ Compaction Temperature Range:  
156-152°C (313-306°F)



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# WMA ADDITIVE TECHNOLOGIES

Technology	Dose
Advera	0.25% by weight of <u>mixture</u>
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



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# HAMBURG WHEEL TRACKING DEVICE (HWTD)



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# 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 50°C (122°F) during testing**
- **30 min soak time at 50°C 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%.



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# STRIPPING INFLECTION POINT (SIP)

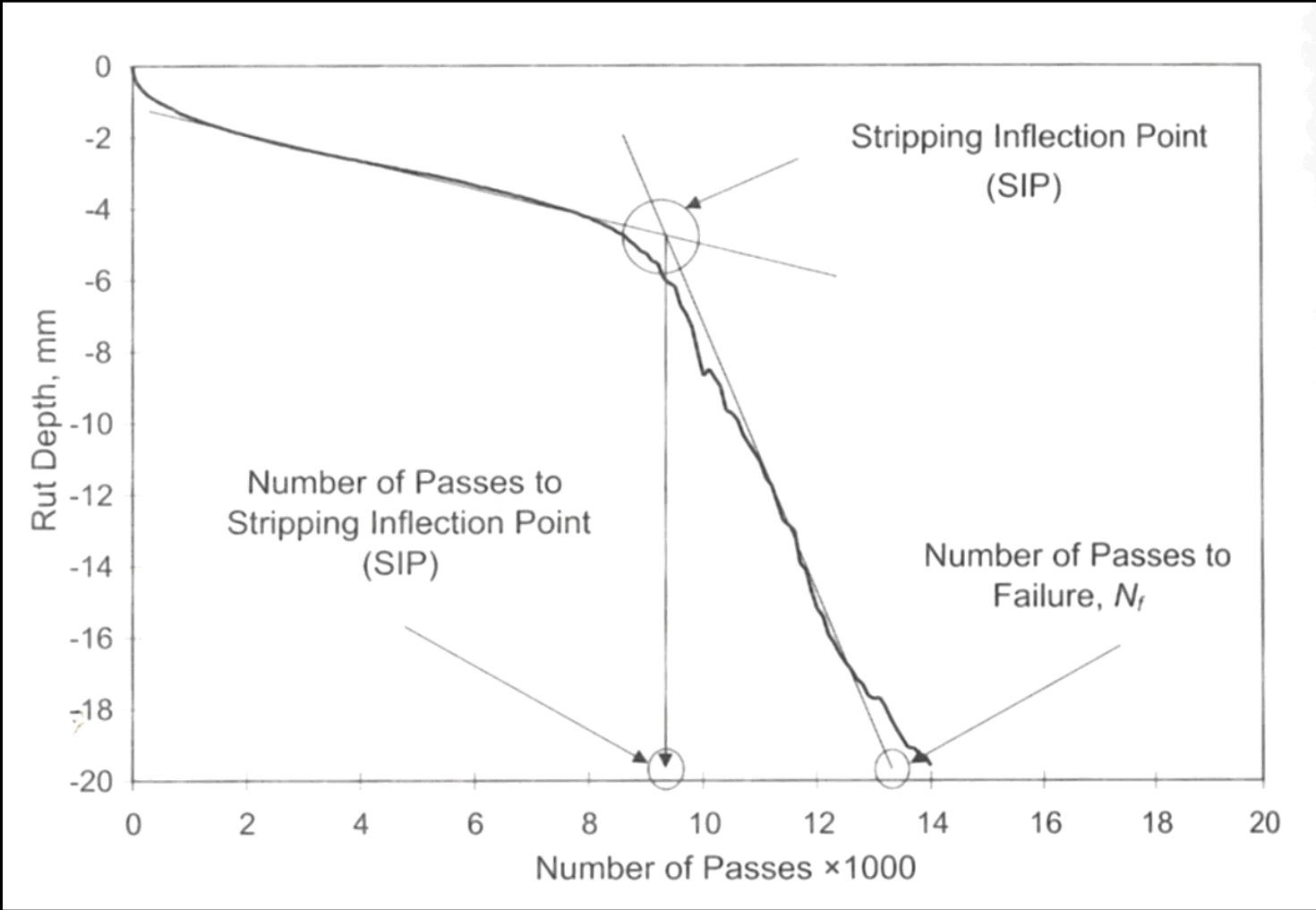


Diagram from AASHTO T324 “Hamburg Wheel-Track Testing of Compacted Hot-Mix Asphalt (HMA)” 2006.



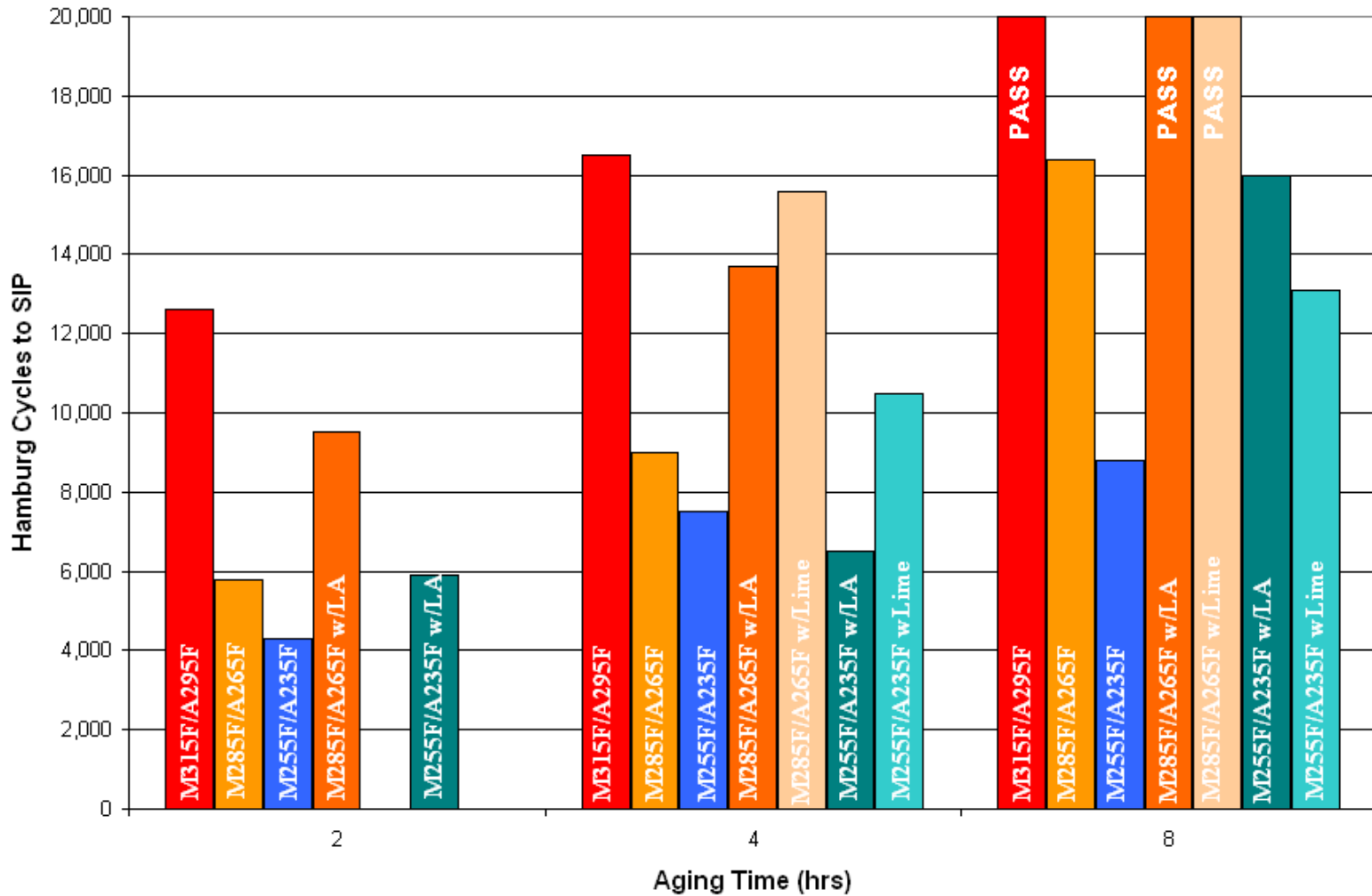
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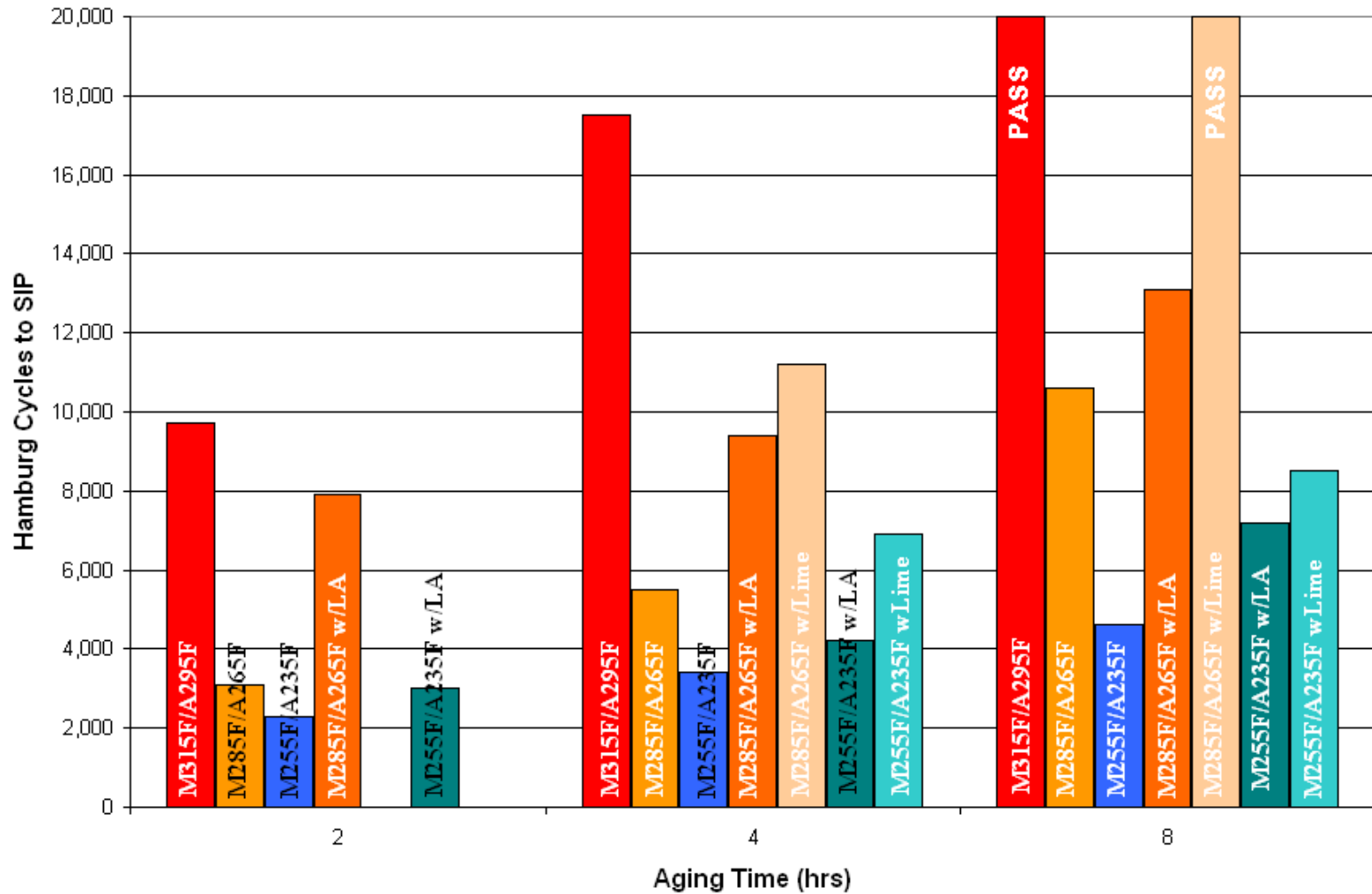
# HWTD RESULTS - CONTROL

9.5mm SP CONTROL Mixtures

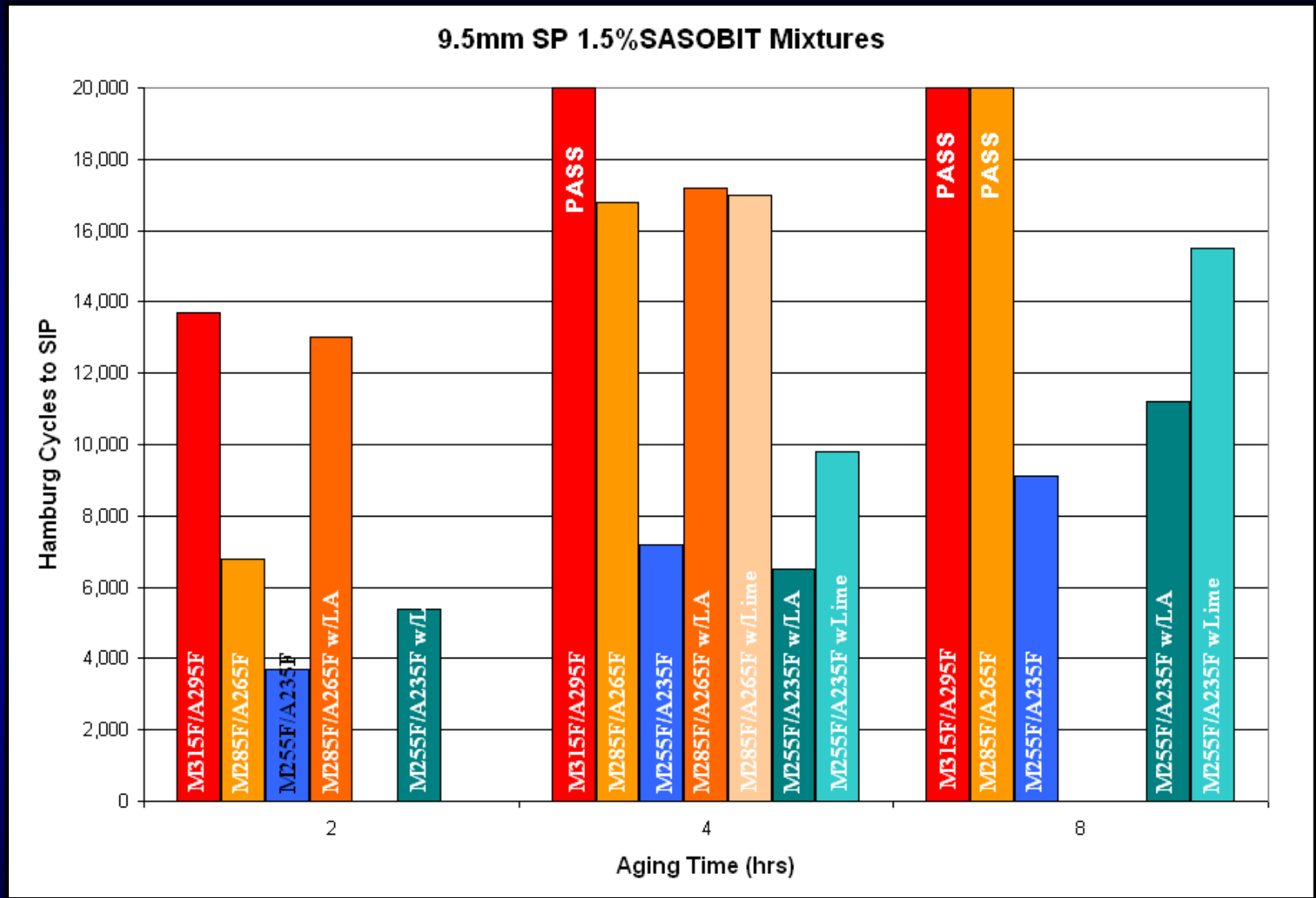


# HWTD RESULTS - ADVERA

9.5mm SP 0.25% ADVERA Mixtures



# HWTD RESULTS - SASOBIT



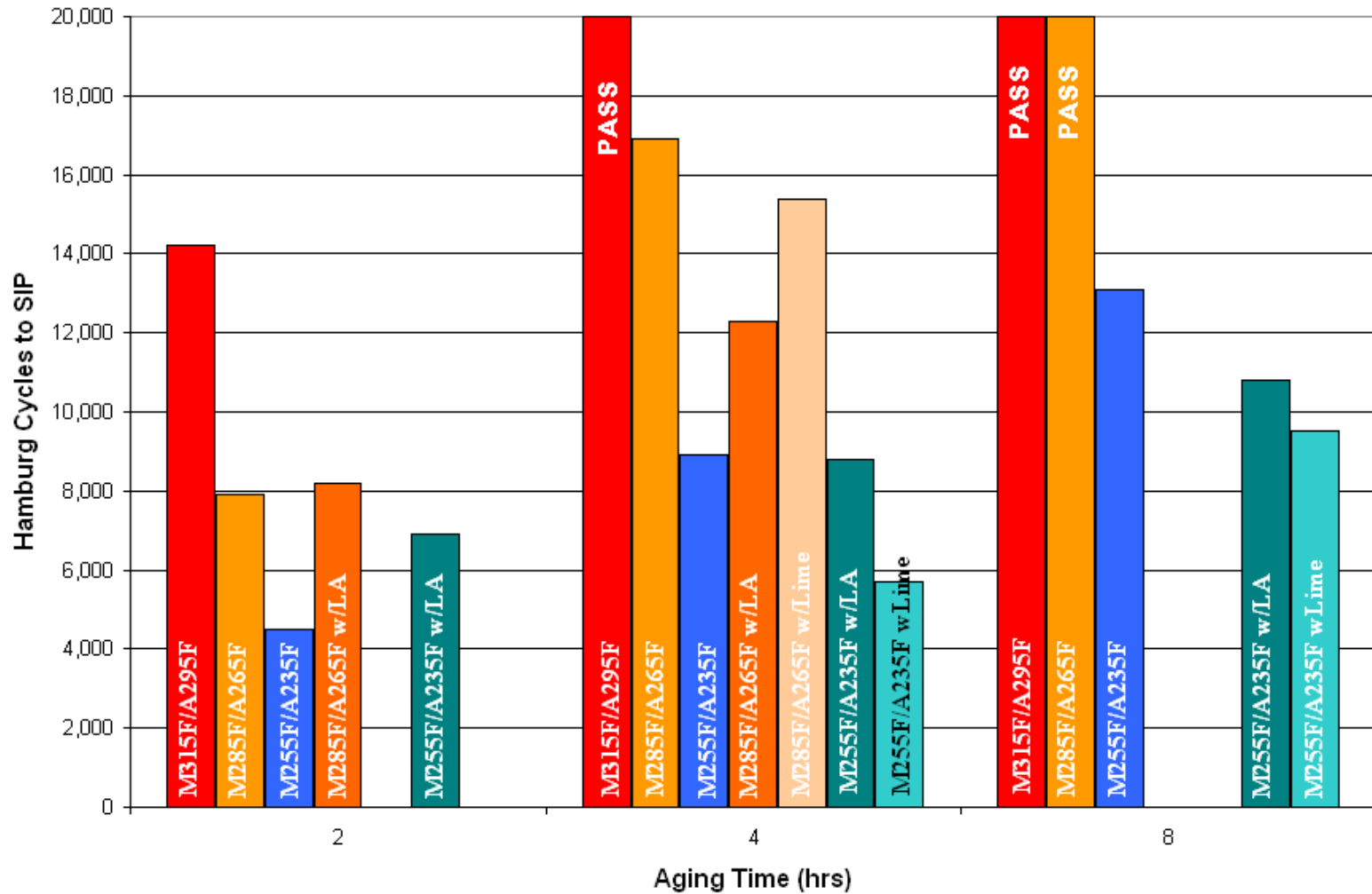
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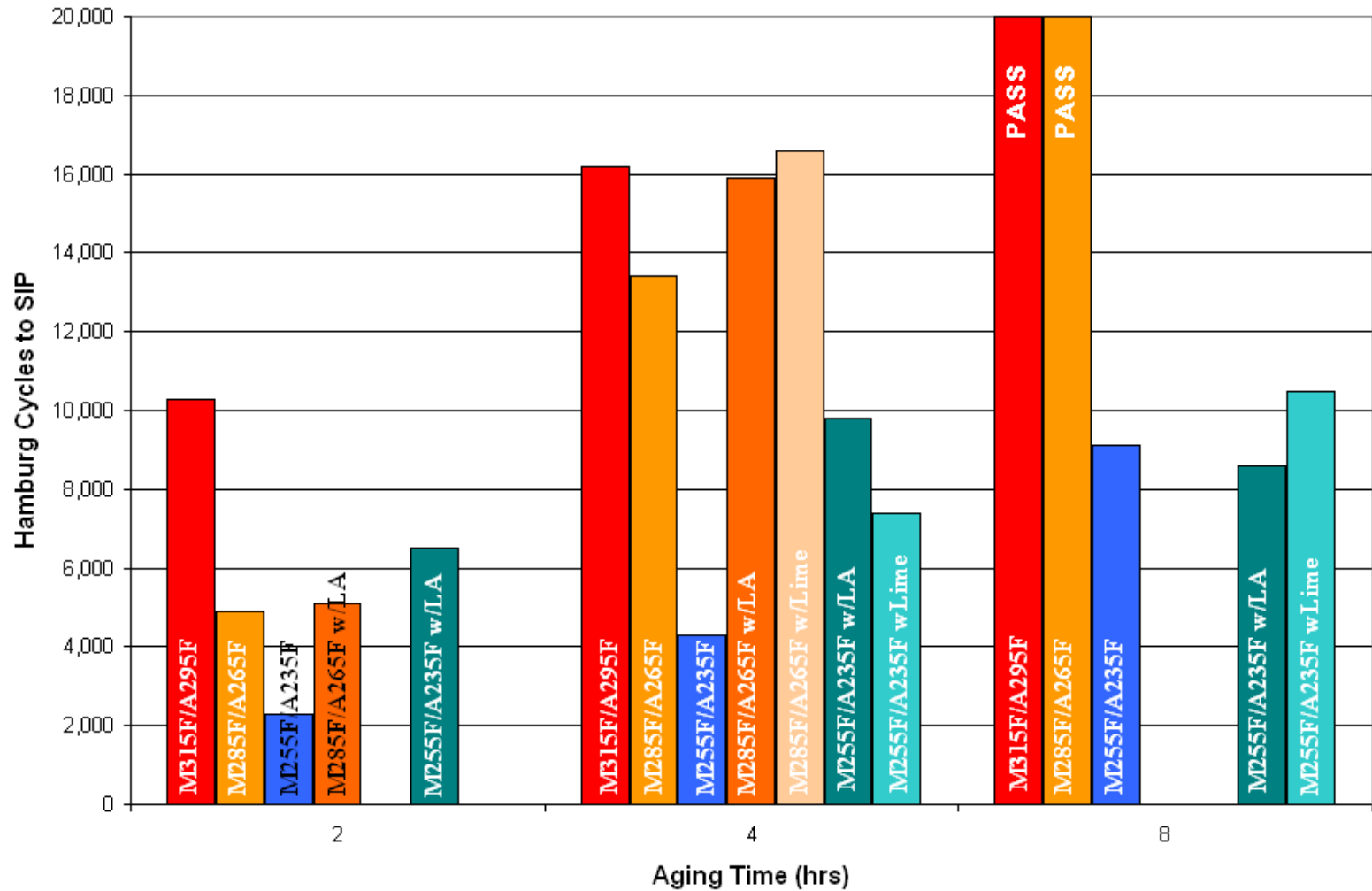
# HWTD RESULTS - EVOTHERM

9.5mm SP 0.5%Evotherm Mixtures



# HWTD RESULTS - AD-RAP

9.5mm SP 1.0% AD-RAP 390 Mixtures



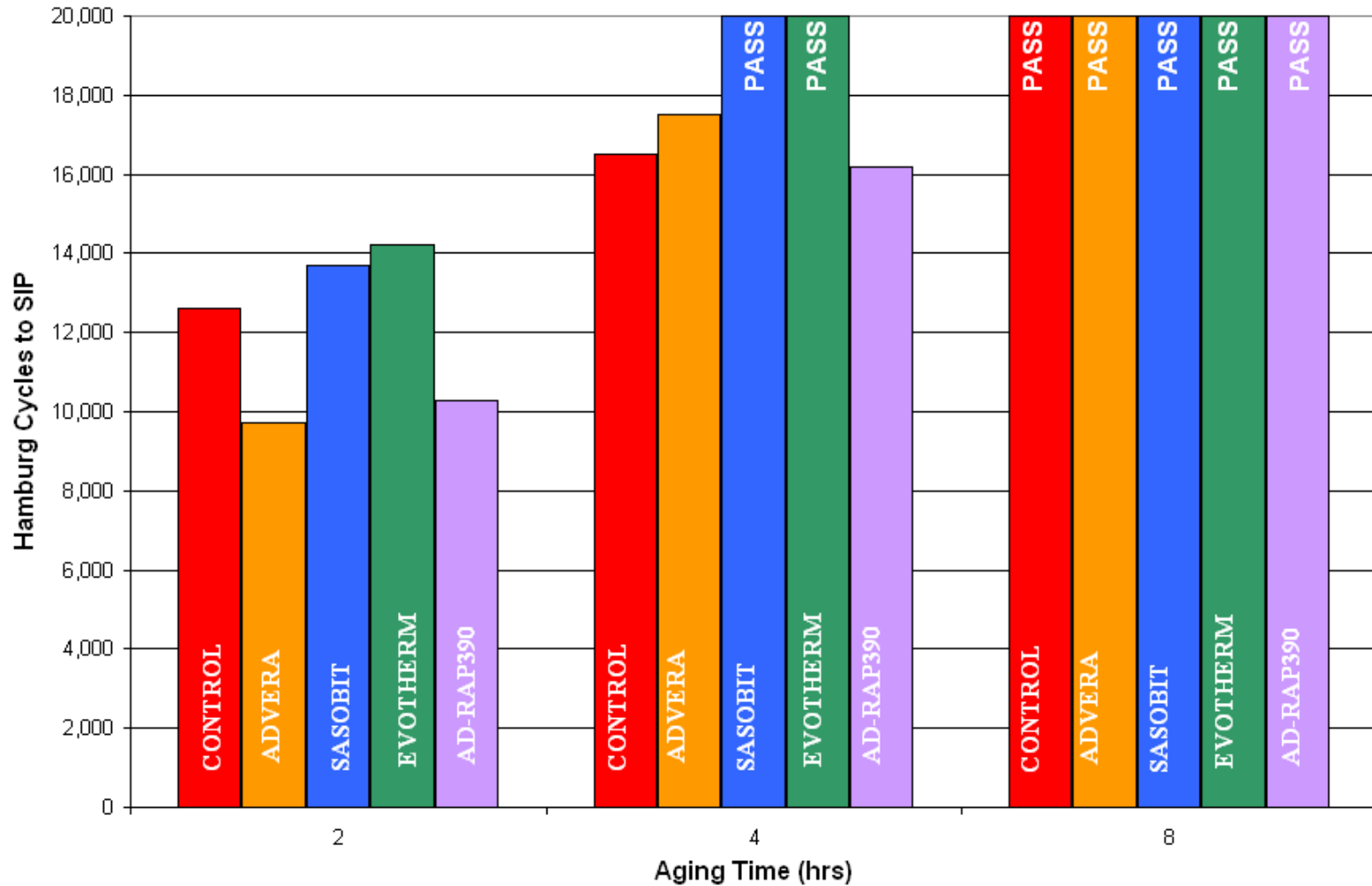
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# HWTD RESULTS - M315F/A295F

9.5mm SP Mixtures - Mixed 315F (157C)/Aged 295F (146C)

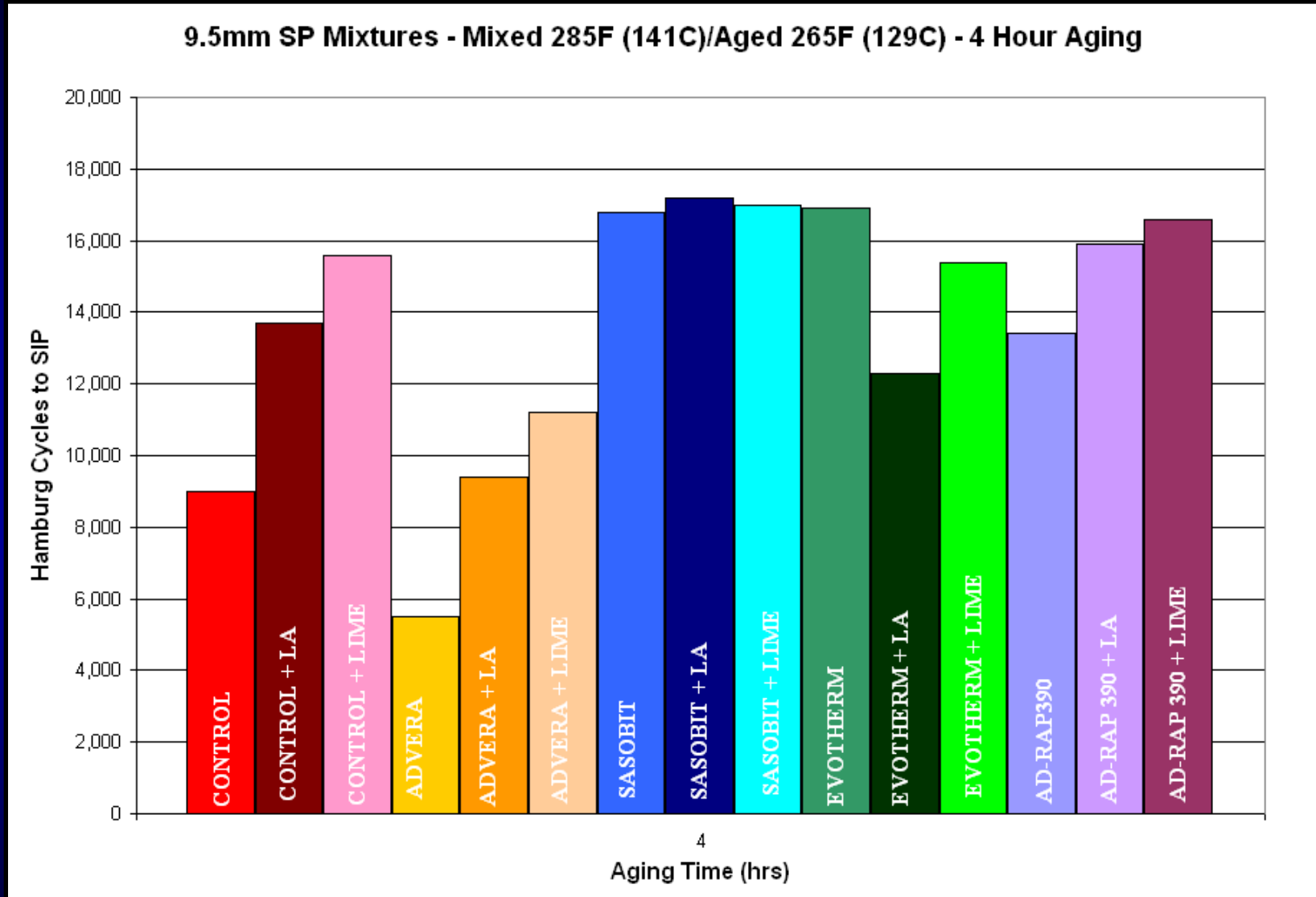


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# HWTD - M285F / A265F 4HRS



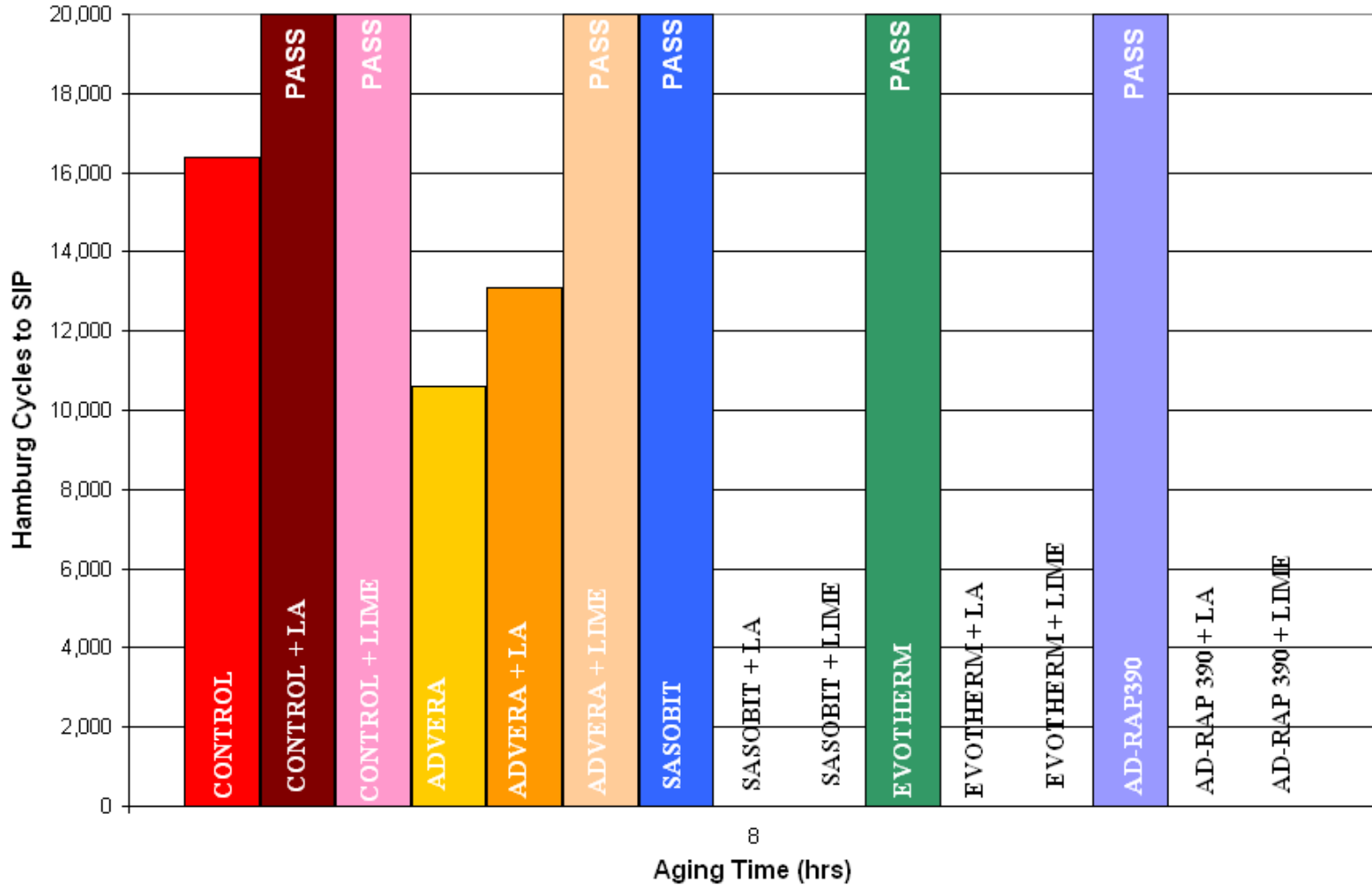
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# HWTD - M285F / A265F 8HRS

9.5mm SP Mixtures - Mixed 285F (141C)/Aged 265F (129C) - 8 Hour Aging



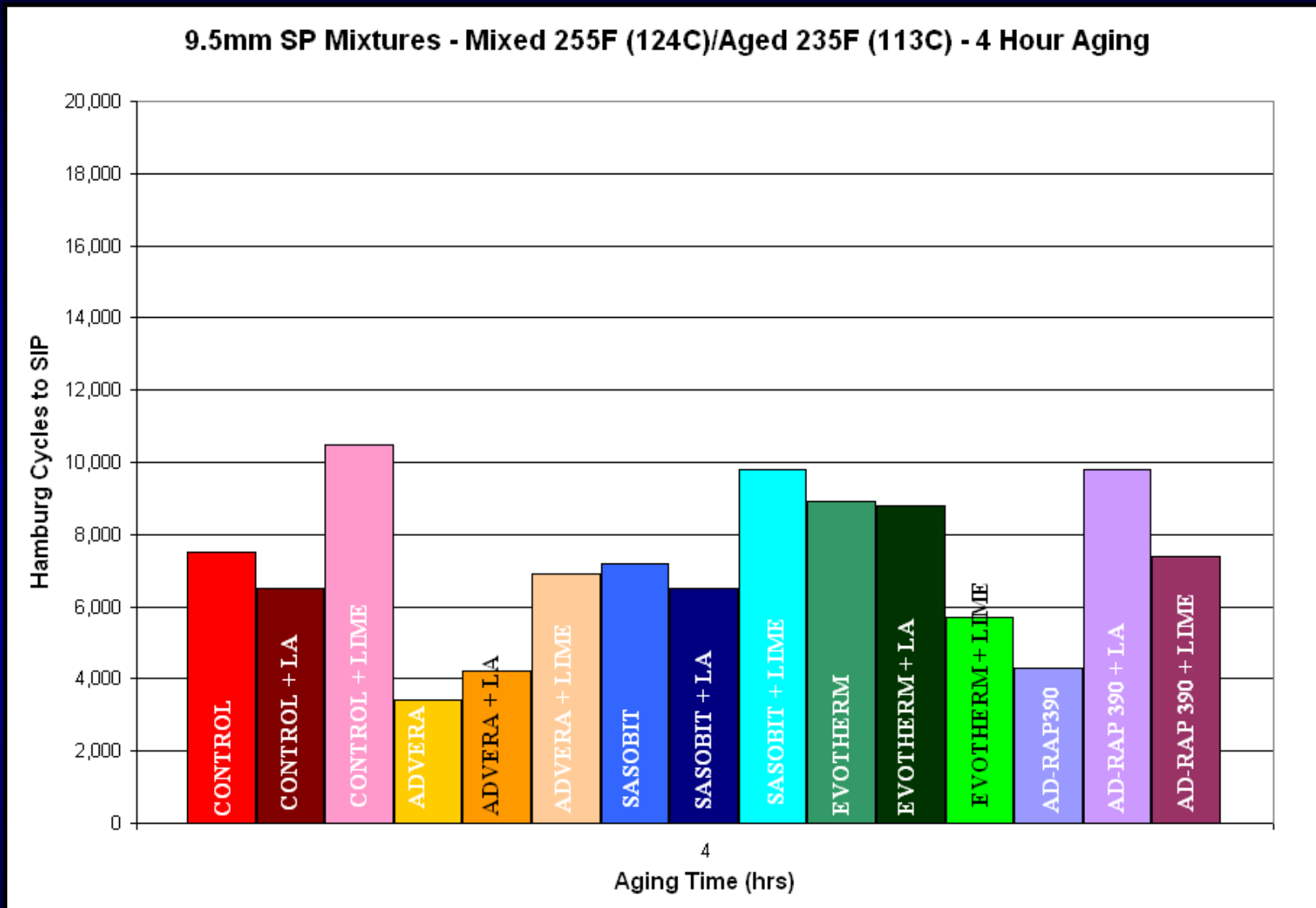
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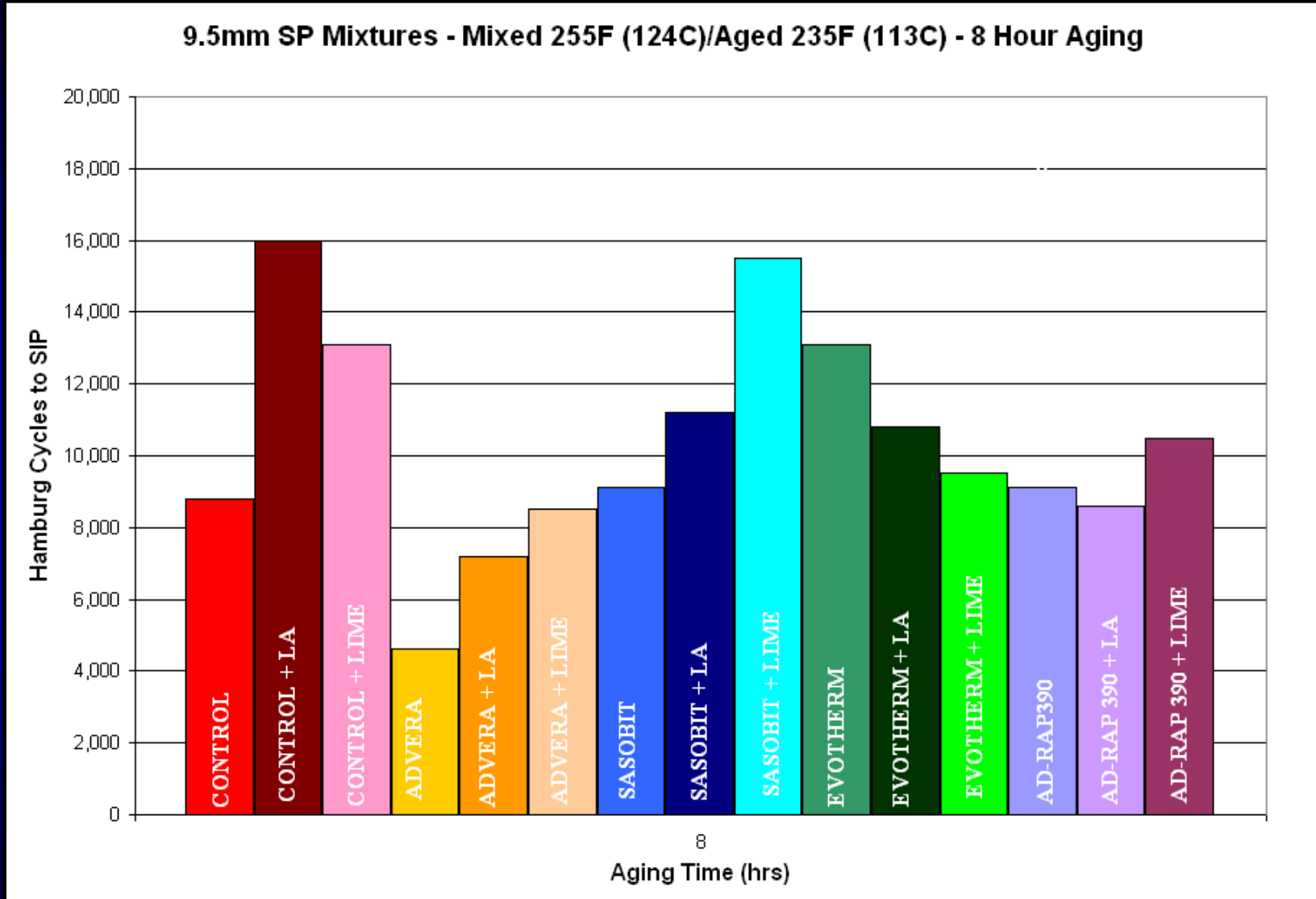




# HWTD - M255F / A235F 4HRS



# HWTD - M255F / A235F 8HRS



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# 4 HOUR AGING HWTD - RESULTS

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

NT = Not Tested



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# 8 HOUR AGING HWTD - RESULTS

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

NT = Not Tested



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# PROPOSED AGING TRIAL

Performed on Advera & SonneWarmix Mixtures - No Anti-Strip

## Day 1

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



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# PROPOSED AGING TRIAL - RESULTS

	M315°F/ A295°F	M285°F/ A265°F	M255°F/ A235°F	Proposed Aging
Control	16,500	9,000	7,500	Not Tested
Advera	17,500	5,500	3,400	4,000
SonneWarmmix	16,200	13,400	4,300	4,200

Comparison of 4 hour aging HWTD SIP.



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# ASPHALT BINDER MOISTURE SENSITIVITY TESTING

## BITUMEN BOND STRENGTH (BBS) TEST

University of Wisconsin Madison

Professor Hussain Bahia, Ph.D.

Enad Mahmoud, Ph.D.



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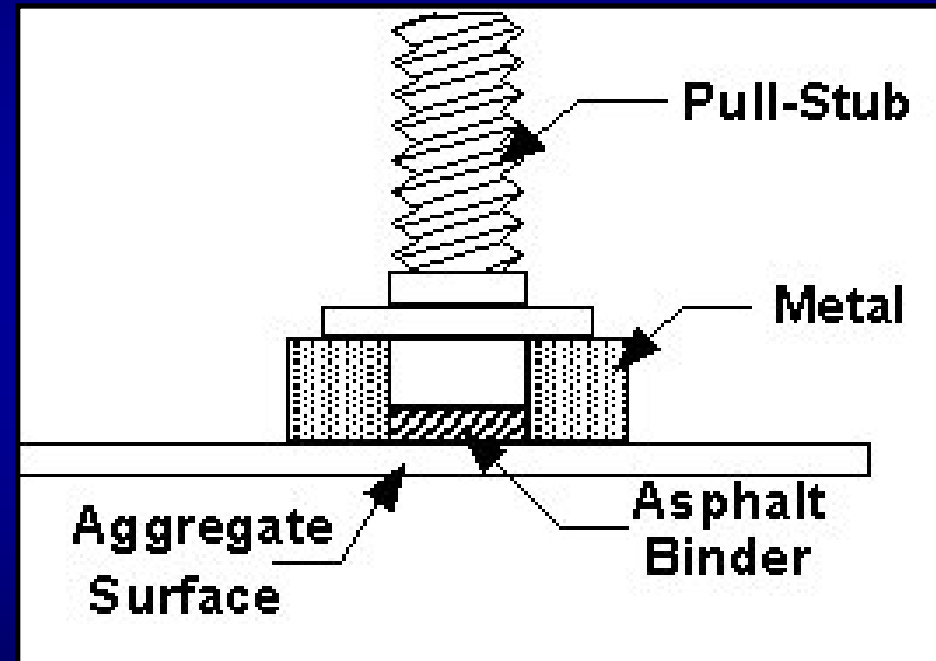
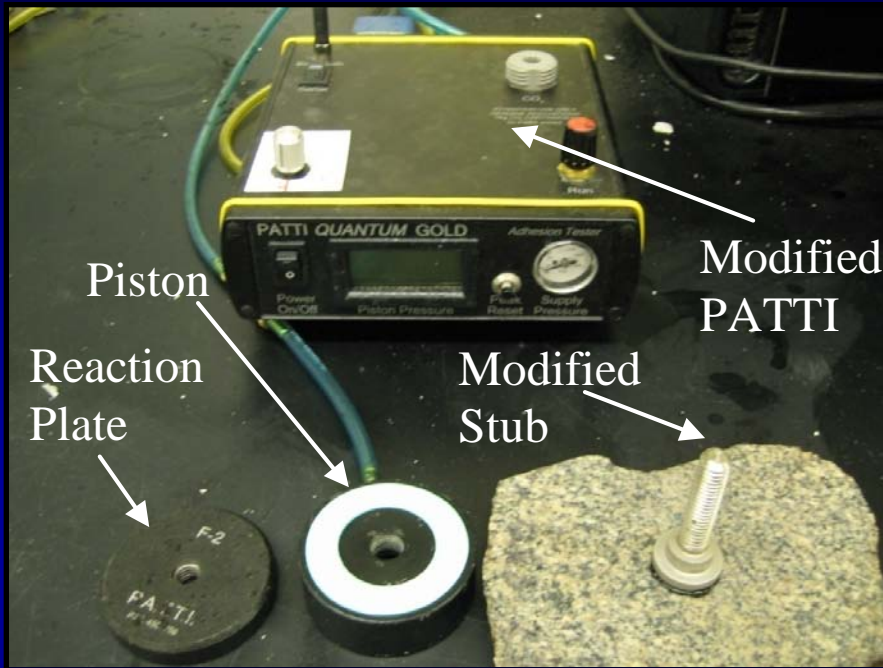


# **BITUMEN BOND STRENGTH (BBS) TEST**

- ➔ **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>

# BITUMEN BOND STRENGTH (BBS) TEST

- ➔ Upward force is applied by the PATTI to the binder specimen through 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 20°C (68°F).

Each binder was tested “WET” after 24 hours of moisture conditioning at 40°C (104°F).

A limestone aggregate plate was used for each test.

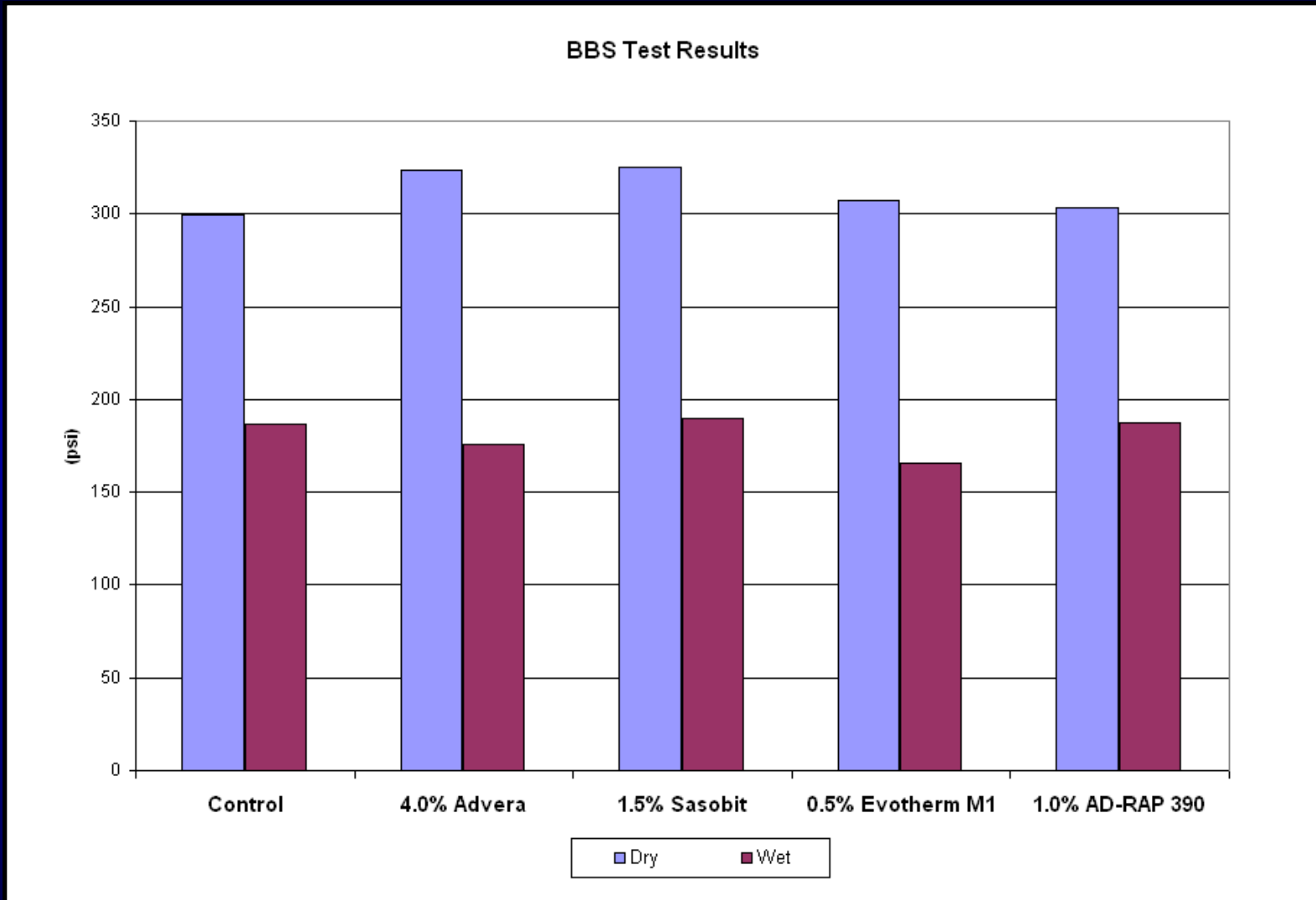


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# BBS TEST RESULTS



# 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.



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# 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.**



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# ACKNOWLEDGEMENTS

**Mike Nichols – Aggregate Industries**

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**Neil Miller - PQ Corporation**

**Chris Strack – Sonneborn, Inc.**

**Pat Mitchell – Hudson Liquid Asphalts**

**Tejash Ghandi - MeadWestvaco Corp**

**John Shaw - Sasol Wax**



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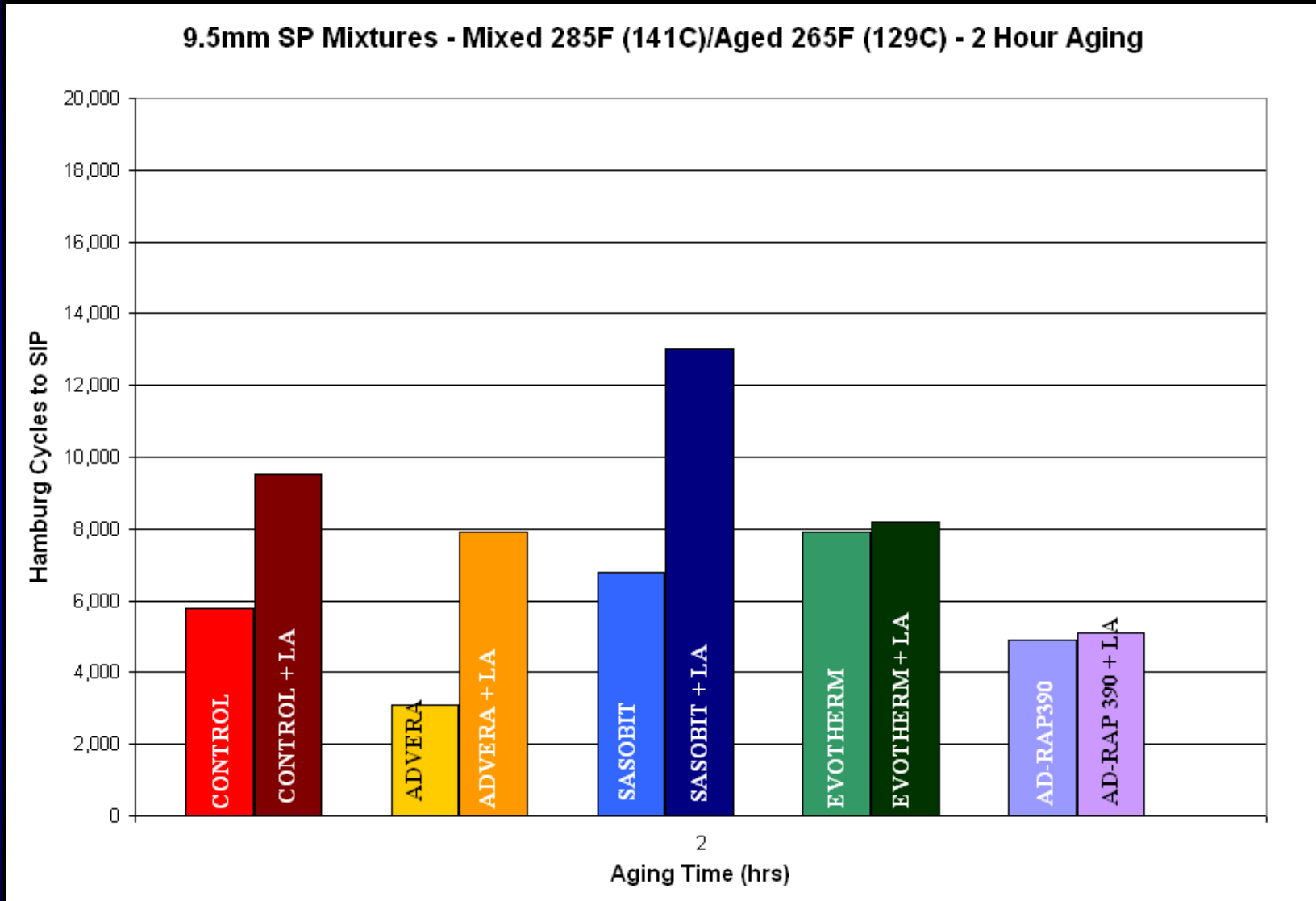
**THANK YOU!**



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# HWTD - M285F / A265F 2HRS

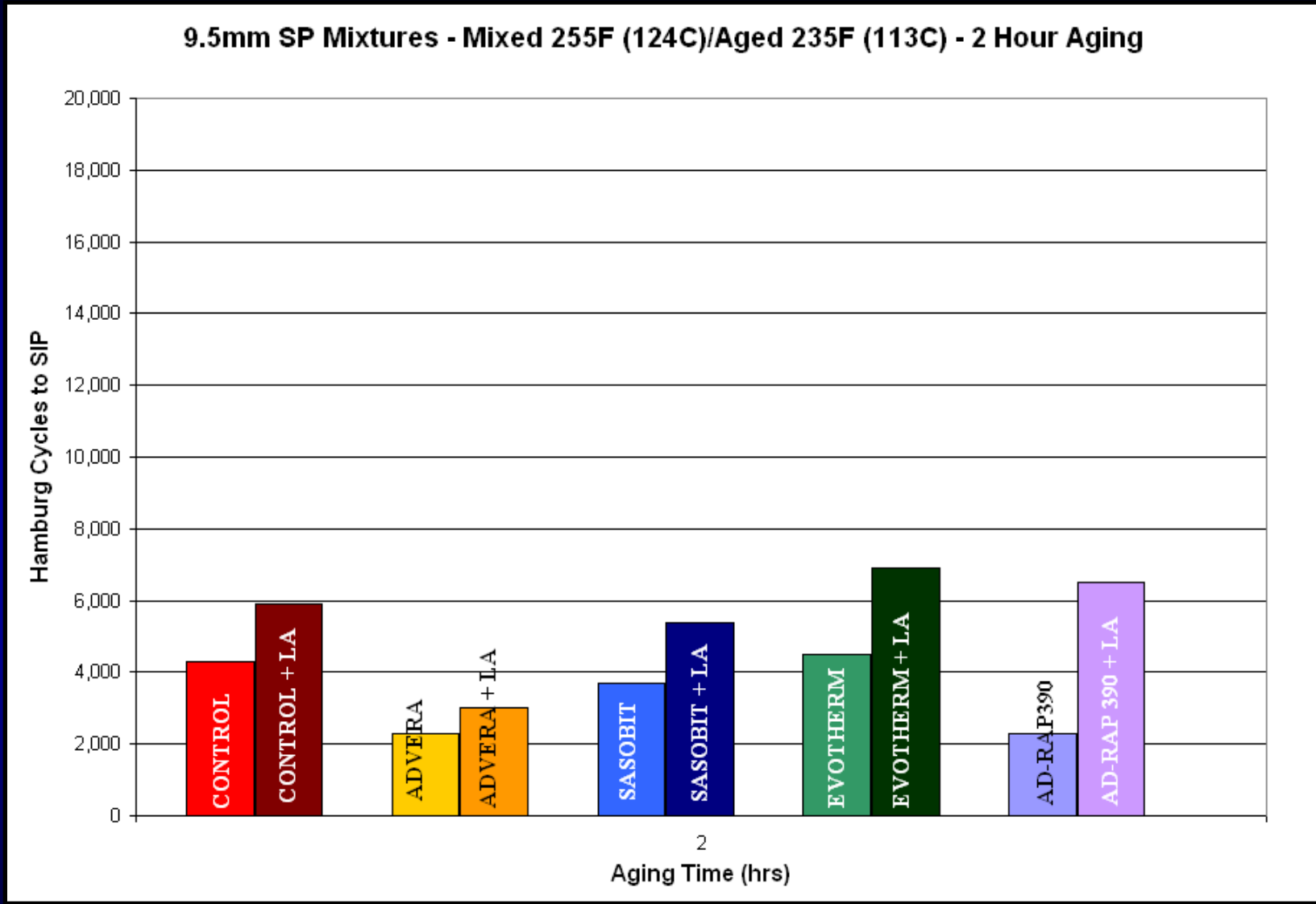


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# HWTD - M255F / A235F 2HRS



# 2 HOUR AGING HWTD - RESULTS

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

NT = Not Tested



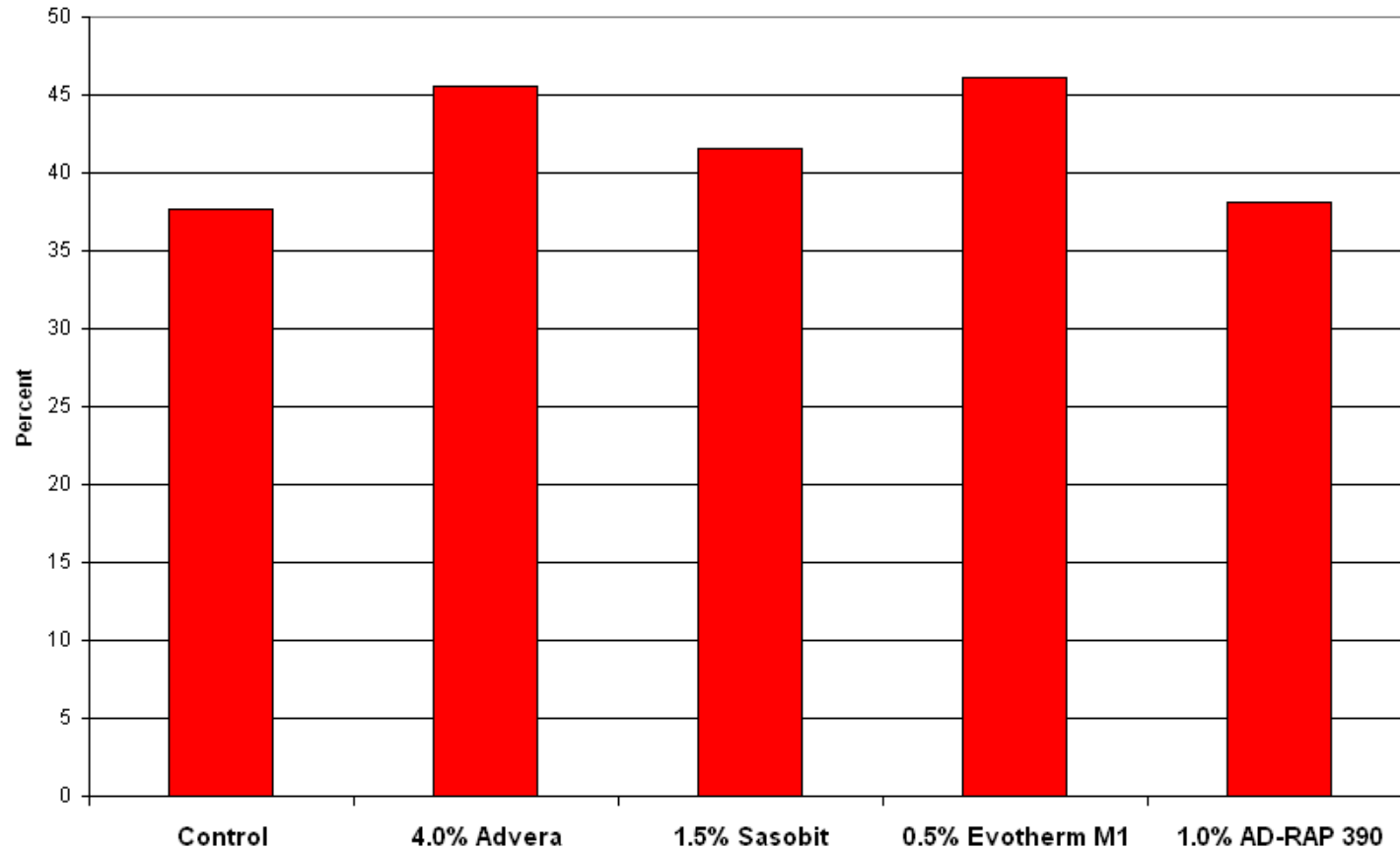
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# BBS TEST RESULTS

BBS Test Results - % Drop from Dry to Wet Condition



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