Case Study: Long-term Performance of SMA Pavements in Washington State

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Outline

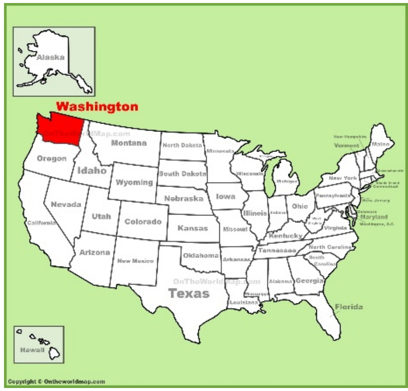
- Introduction
- Project Information
- Research Scope
- Results of SMA and HMA Comparison
  - Field Performance
  - Field Cores Mixture Properties
  - Extracted Binder Properties
- Conclusions and Future Study

Introduction

- SMA is widely used in northern and central Europe for over 25 years.
- In U.S., some studies in MD and GA showed: SMA performs well against rutting and roughness for periods exceeding 10 years.
  - ✓ Stone to stone contact
  - ✓ High asphalt content; Polymer modified binder
- National specifications: AASHTO R46, AASHTO M325
- State's good experience is critical for successful implementation of SMA.
- WA's experience (not so good at the beginning):
  - ✓ 1999: SR 524 mix design construction issue
  - ✓ 2000: I-90 inadequate control over mix production

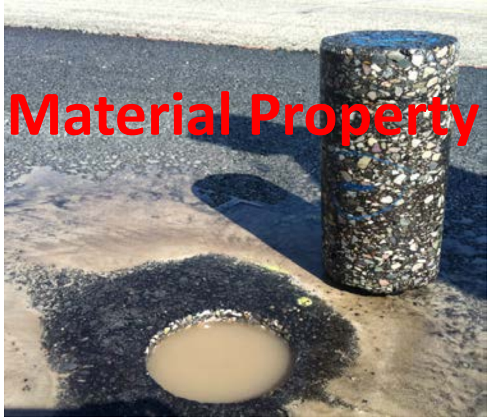
Project Information

- Eastern Washington: dry-freeze
- I-90: from SR 21 to Ritzville; AADT- 38,300; paved in 2001
- SMA: 12.5-mm NMAS, PG 76-28
- HMA: 12.5-mm NMAS, PG 64-28
- Both on WB lanes, overlay thickness 63.5 mm



Research Objective

- Investigate the long-term performance of SMA pavement as compared to control HMA pavement

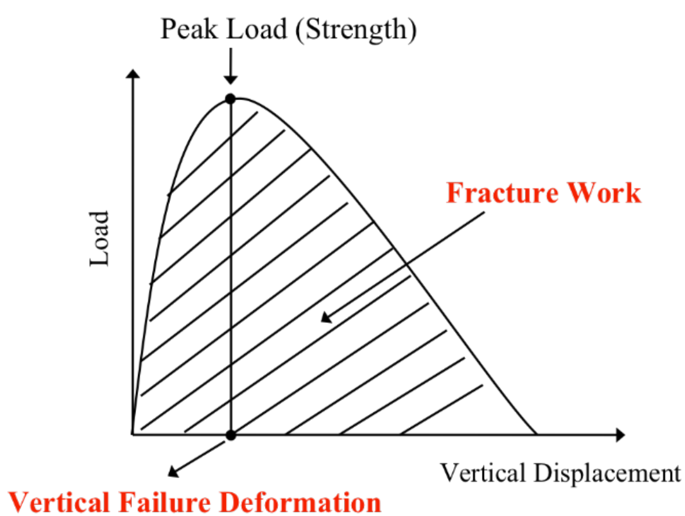


- WSPMS
  - Pavement structural condition (PSC): cracking
  - Pavement rutting condition (PRC): rutting
  - Pavement profile condition (PCC): roughness
- Field inspection

- Field cores
  - Mixtures testing
- Binder extraction
- Aggregate gradation
- Binder Recovery
  - Binder testing

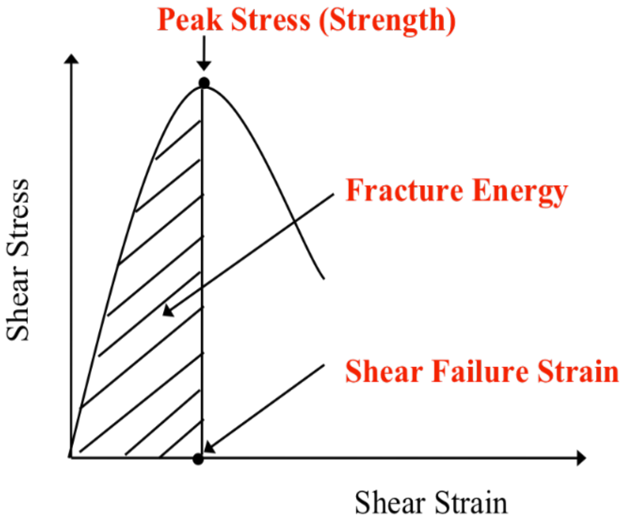
Material Characterization: Mixture

Mixture Test	IDT Dynamic Modulus/Creep Compliance	Fatigue- IDT Fracture at Room Temp	Thermal Cracking- IDT Fracture at Low Temp	Studded Tire Wear Test
Testing Conditions	Temp.: -20, -10, 0, 10, 20, 30ºC; Frequency: 20, 10, 5, 1, 0.1, 0.01 Hz Duration: 100 seconds	Temp.: 20ºC Loading rate: 50.8 mm/min	Temp.: -10ºC Loading rate: 2.54 mm/min	Temp.: room Pressure: 690 kPa Speed: 140 rpm Duration: 2 min
Material Properties	Dynamic modulus; Creep compliance	IDT strength; Fracture work density; Horizontal failure strain	IDT strength; Fracture work density	Mass loss
References /Standards	Wen et al. 2002	Shen et al. 2017; AASHTO T322	Shen et al. 2017; AASHTO T322	Wen and Wu 2015



Material Characterization: Asphalt Binder

Binder Test	Performance Grading (PG)	Rutting: MSCR	Fatigue: Monotonic at Room Temp	Thermal Cracking: Monotonic at Low Temp
Testing Conditions	Different temp depending on the test (DSR, BBR)	Stress: 0.1, 3.2 kPa Temp.:	Temp.: 20ºC Shear rate: 0.3 s^{-1}	Temp.: 5ºC Shear strain rate: 0.01 s^{-1}
Material Properties	PG; BBR stiffness; m-value	$Jnr_{0.1}$, $Jnr_{3.2}$; $R_{0.1}$, $R_{3.2}$	Maximum stress; Fracture energy; Failure strain	Maximum stress; Fracture energy; Failure strain
References/Standards	AASHTO MP1/T240/T313	AASHTO T350	Shen et al. 2017	Wu 2017; Shen et al. 2017



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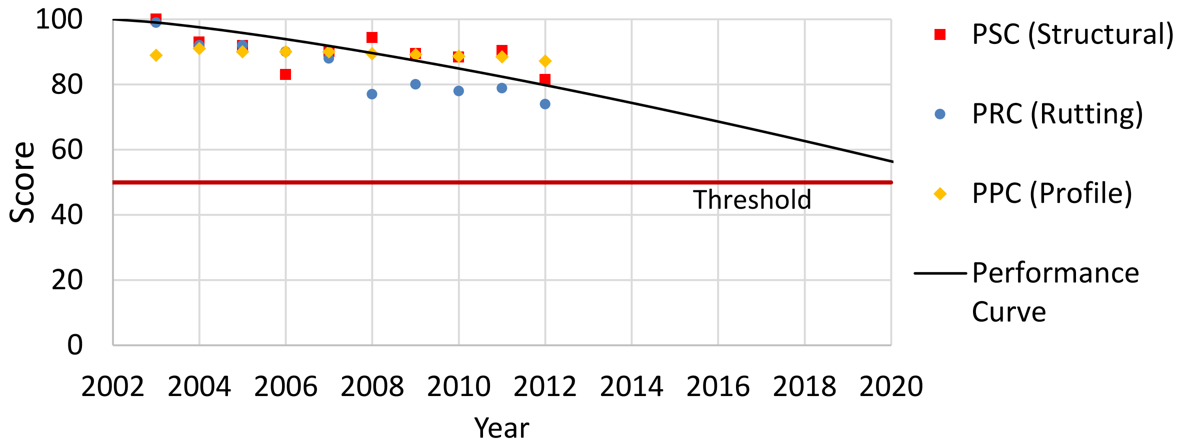
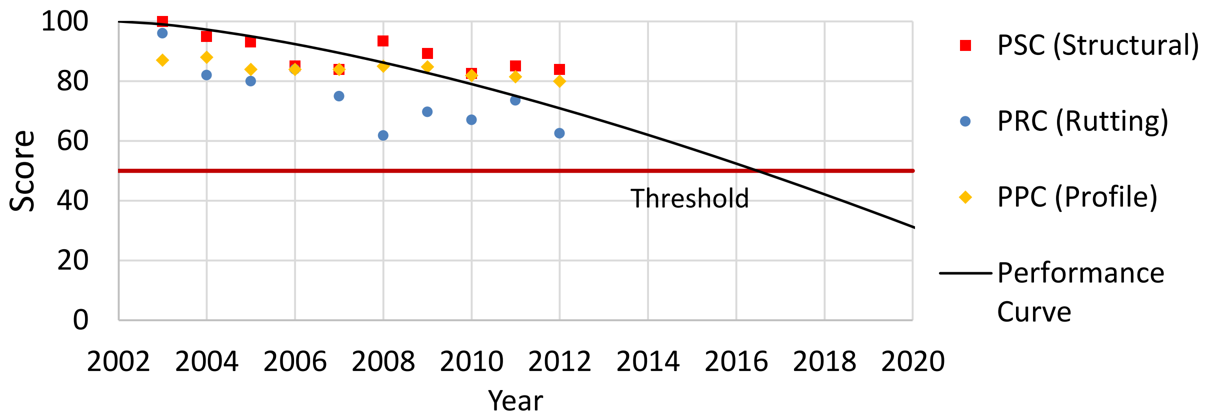
Field Performance

SMA Performance



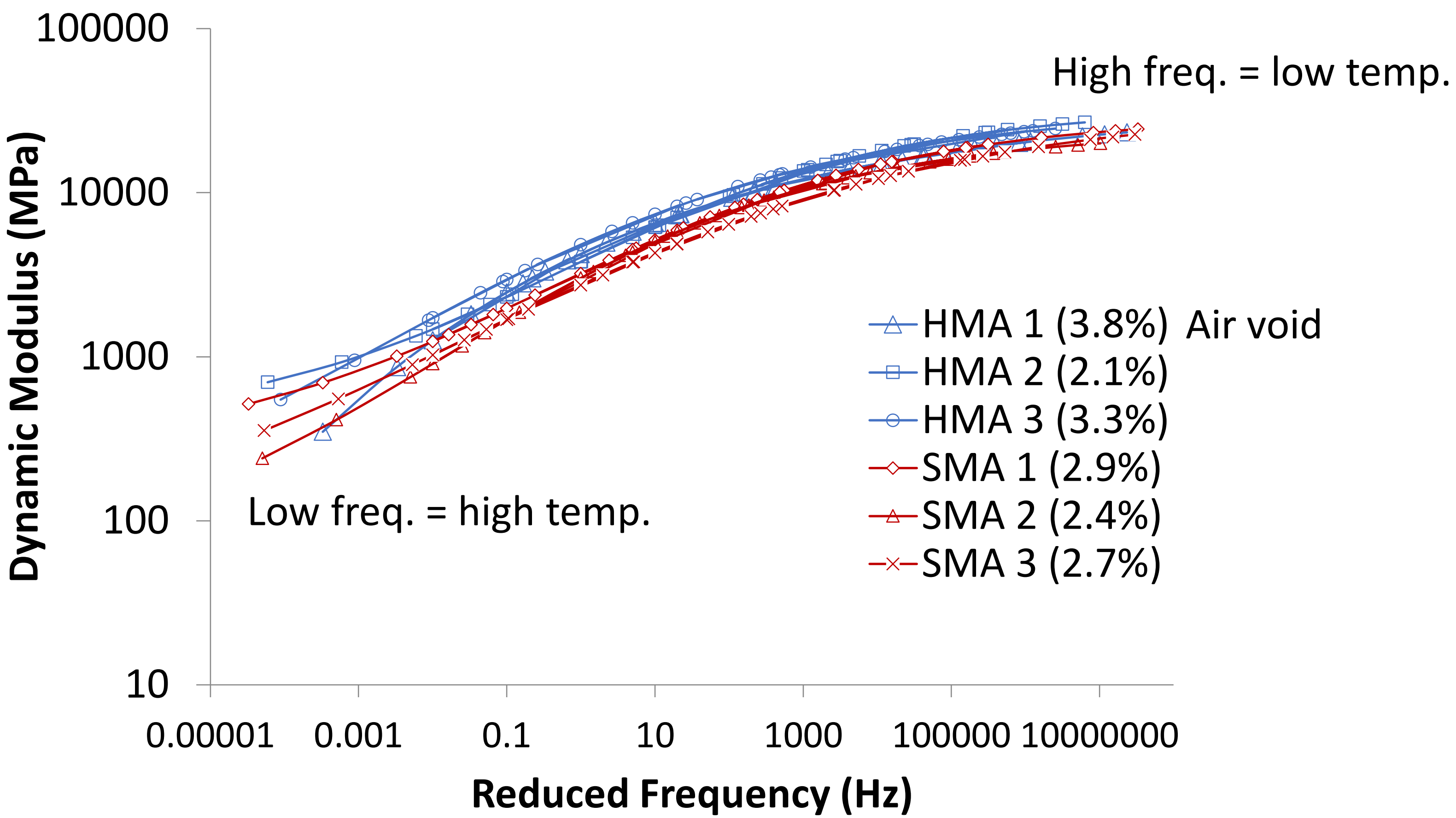
HMA Performance
(Note: HMA was patched in 2008)



Field Inspection

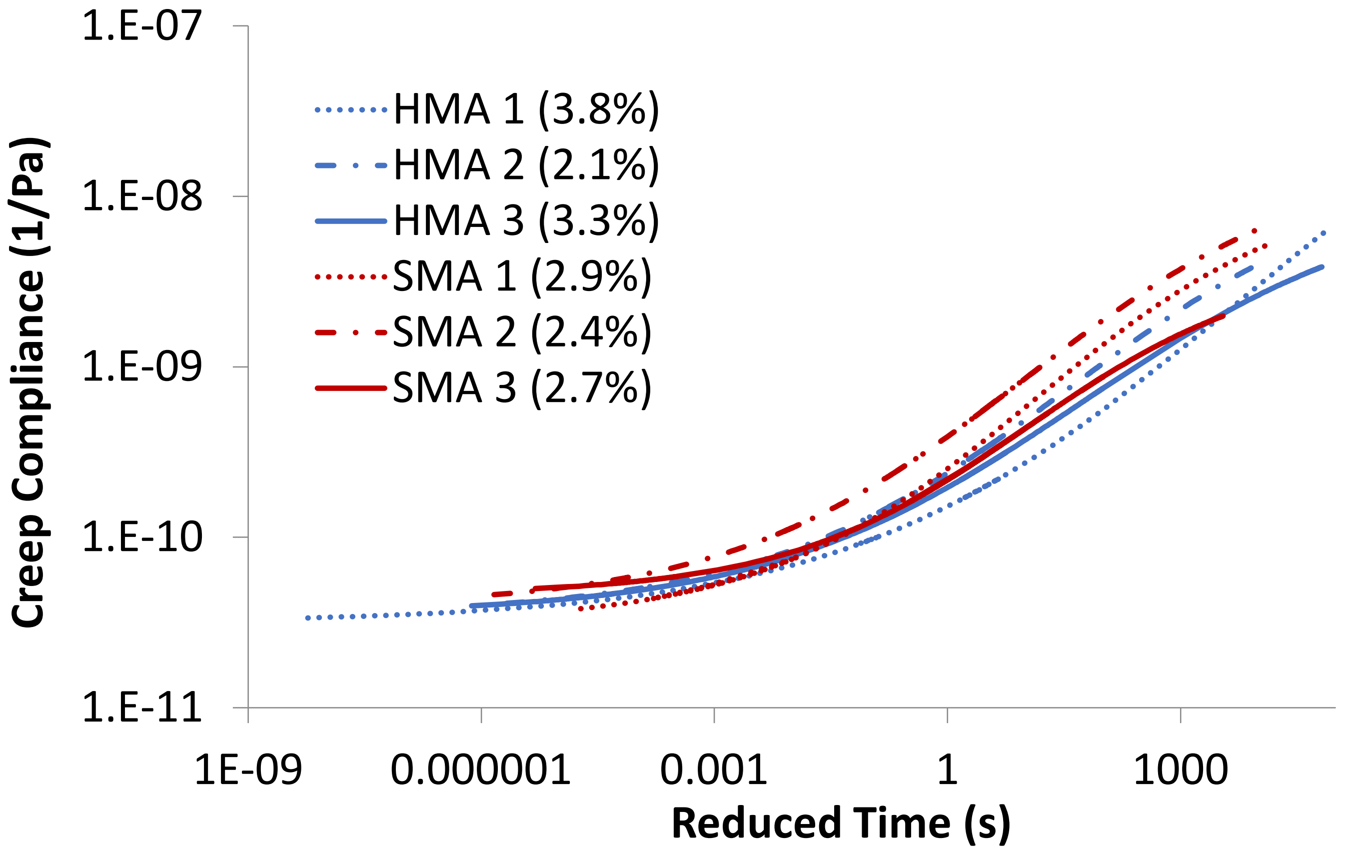
Section	Cracking	Rutting	Rut Depth, mm
HMA	74	61	7.1
SMA	80	88	5.8

Dynamic Modulus



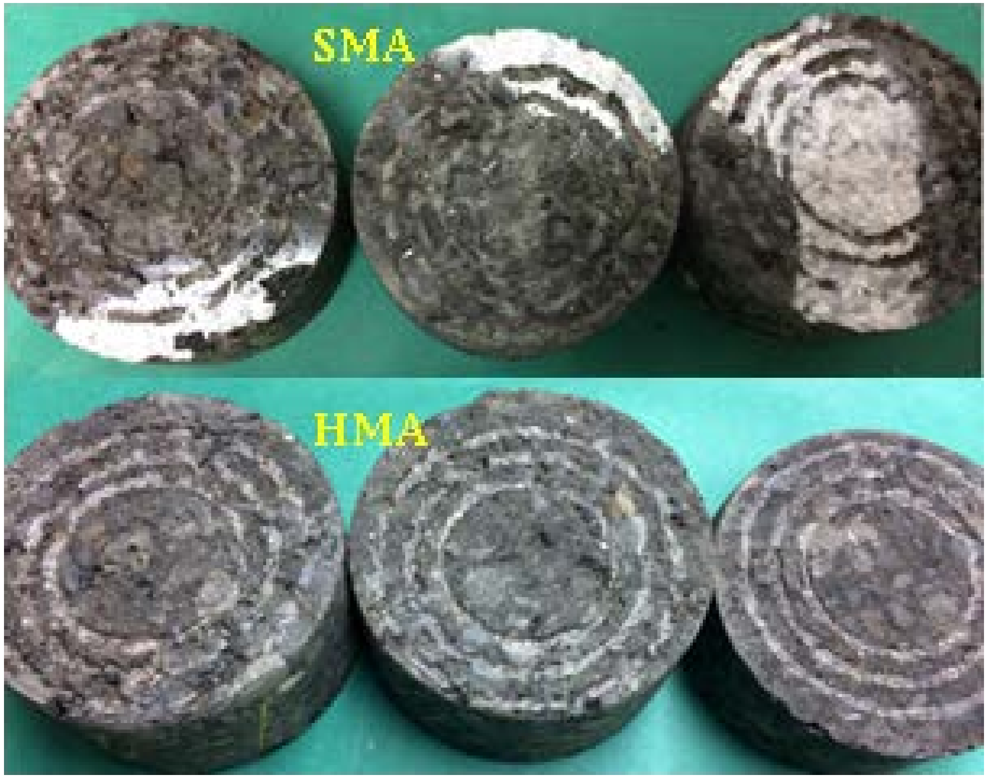
- Overall, HMA E* 20% higher than SMA E*.
- SMA is more flexible than HMA.

Creep Compliance



- Overall, HMA shows lower creep compliance than SMA.
- SMA gives a better ability to relax stress, and thus better thermal cracking resistance.

Studded Tire Wear Test Result

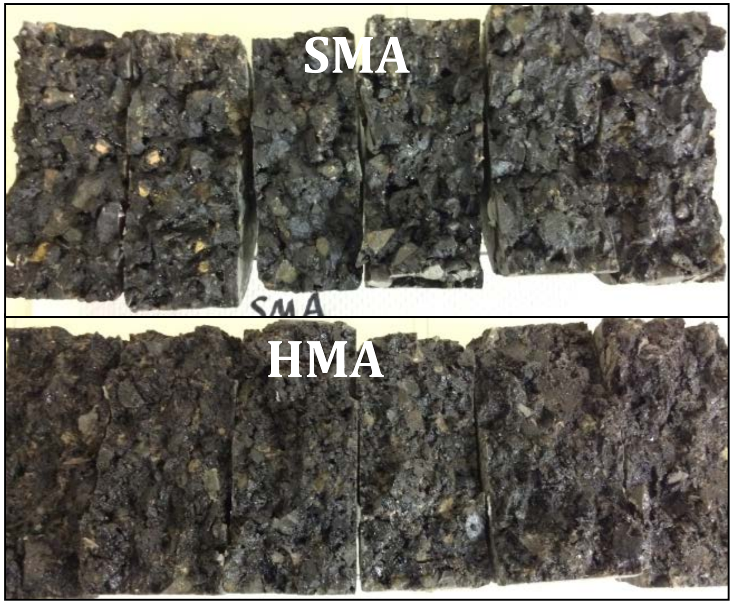


- No significant difference in mass loss
- Comparable wear resistance

	Average Mass Loss, g	Standard Deviation, g	P-value
11 HMA specimens	2.7	1.46	*0.73 > α=0.05*
12 SMA specimens	3.3	0.75	

IDT Test Results

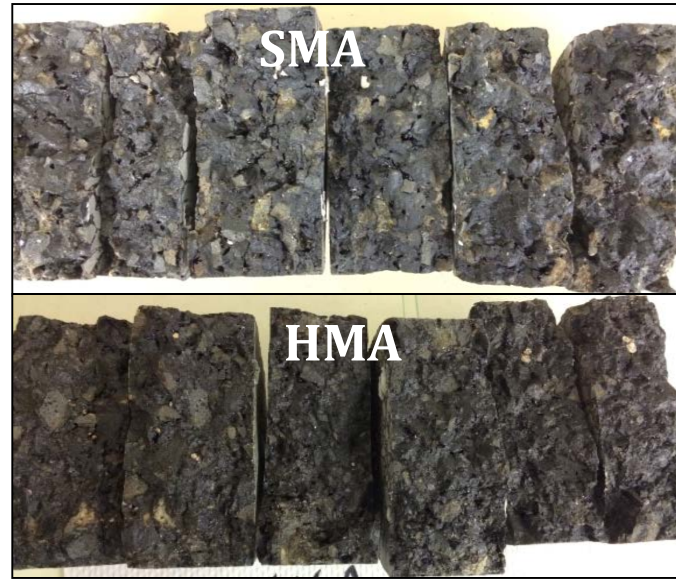
20°C



SMA: Cohesive failure

HMA: Aggregate fracture

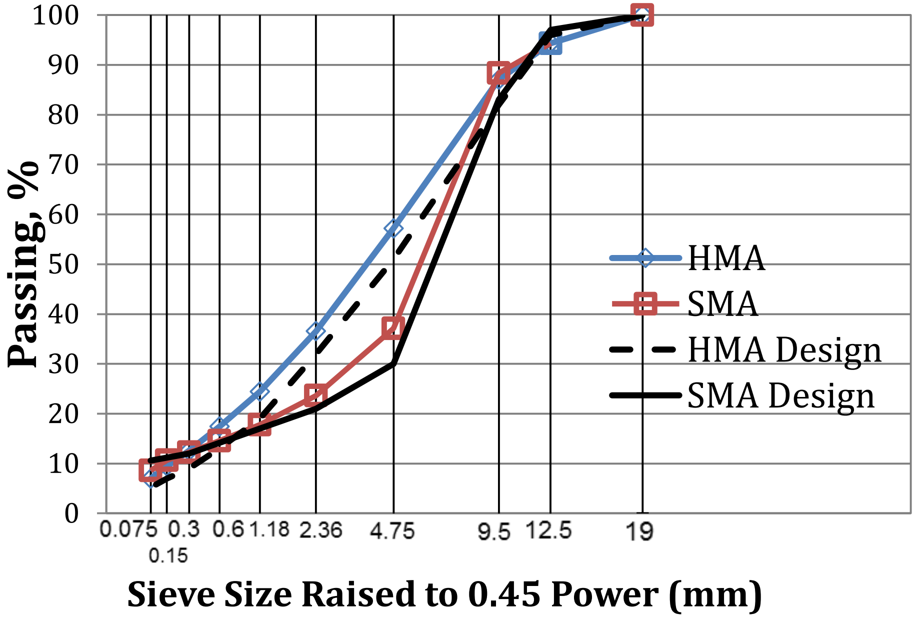
-10°C

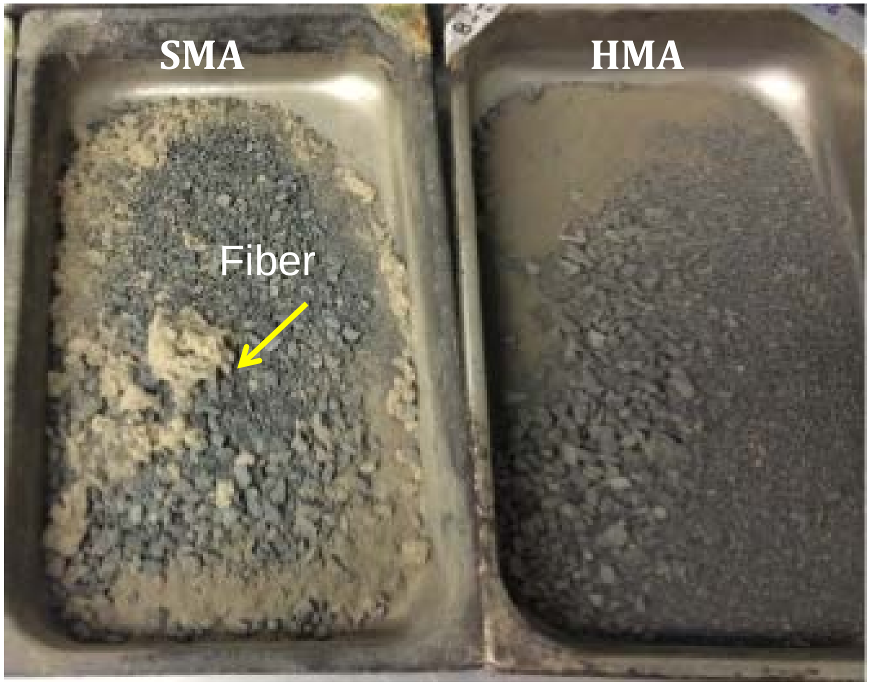


Test Condition	Parameters	HMA Mean	HMA σ	SMA Mean	SMA σ	HMA – SMA, %
20° C	IDT Strength, kPa	2992.3	297.2	2581.4	74.5	15.9
	Fracture Work Density, kPa	148.9	24.8	220.6	2.8	-32.5
	Horizontal Failure Strain	0.0060	0.0004	0.0096	0.0014	-37.5
-10° C	IDT Strength, kPa	4465.0	369.6	4397.5	188.2	1.5
	Fracture Work Density, kPa	82.0	11.0	120.0	9.0	-31.6

- SMA performs better than HMA for bottom-up and top-down cracking resistance, as well as thermal cracking resistance.

Aggregate Gradation Test Result





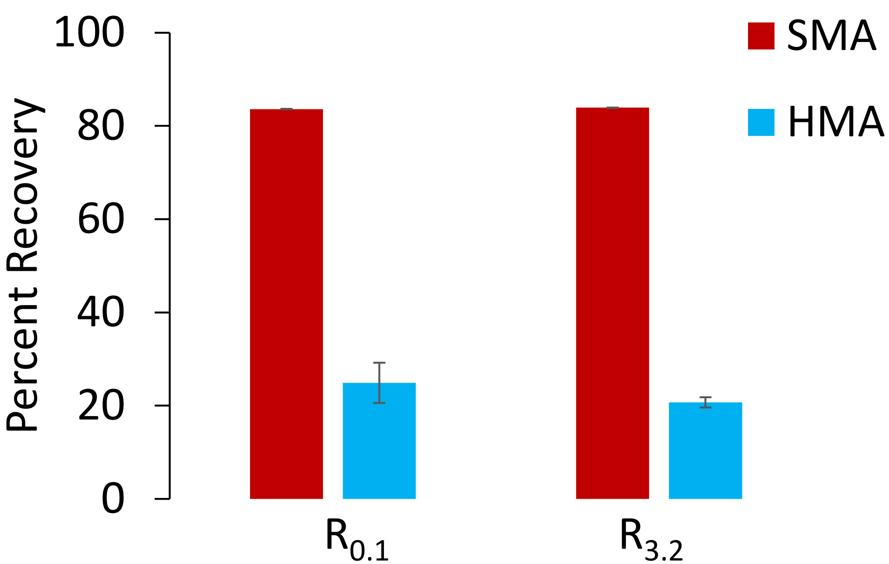
	In-place Measured Asphalt Content, %	Designed Asphalt Content, %
SMA	6.8	6.8
HMA	5.6	5.44

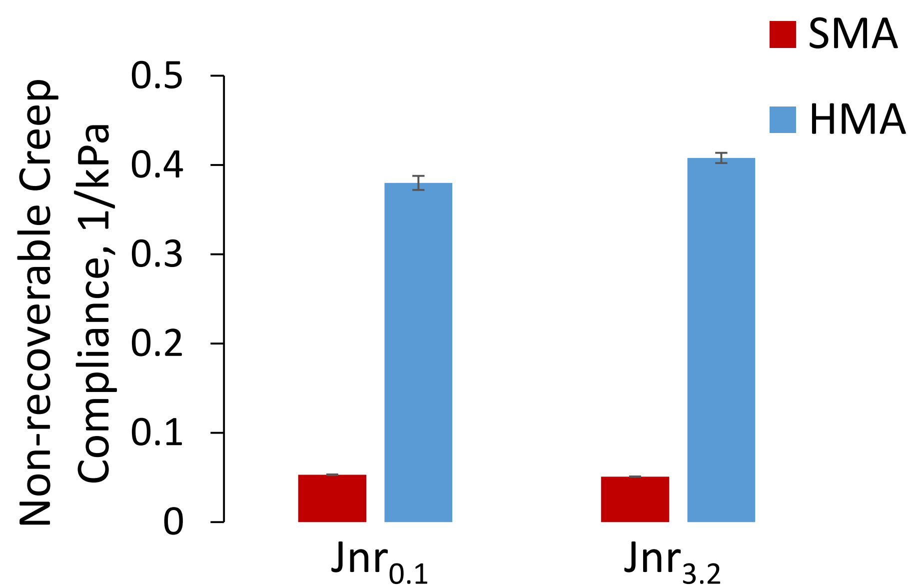
Binder PG Test Results

	Original PG	Measured True PG	PG
HMA	64-28	73.3-24.4	70-22
SMA	76-28	81.8-29.3	76-28

- SMA slows down oxidation possibly due to a thicker asphalt film.

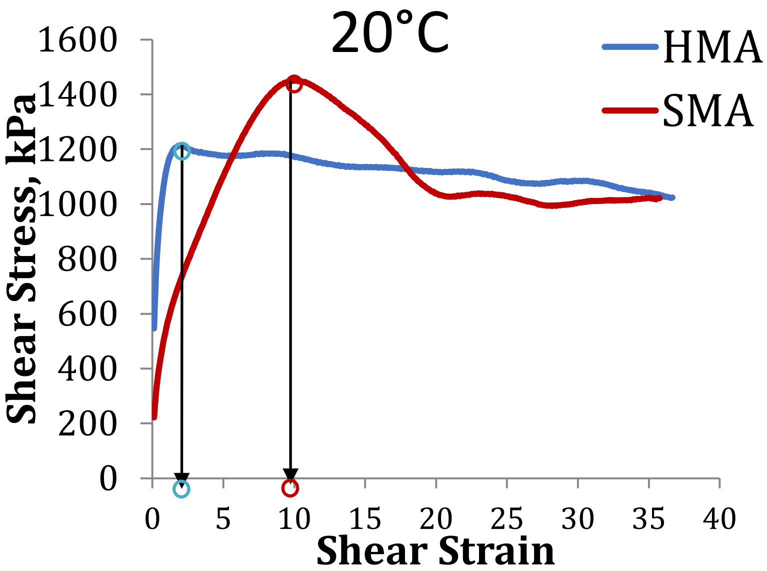
Binder MSCR Test Results

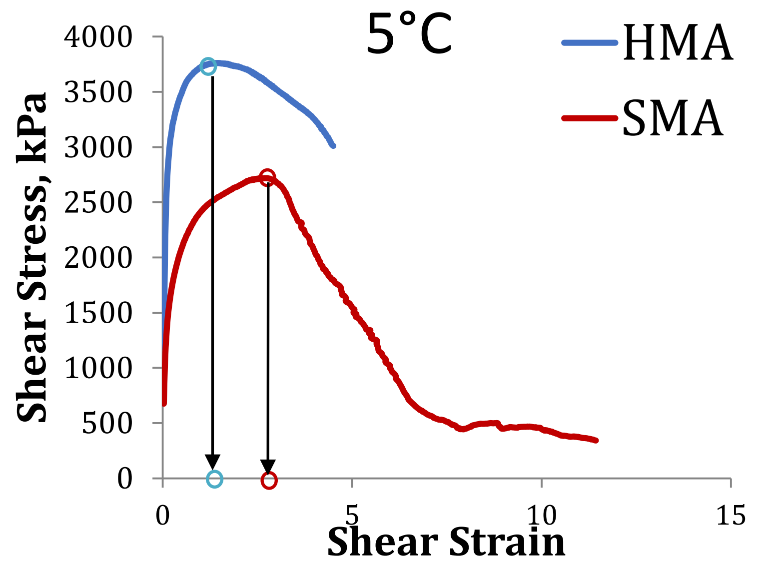




- SMA binder shows better resistance to rutting.

DSR Monotonic Fracture Test Result





Binder	SMA	HMA	SMA – HMA, %
Shear Strength, kPa	1446	1256	15
Fracture Energy, kPa	10495	1930	444
Failure Strain	10	2	443

Binder	SMA	HMA	SMA – HMA, %
Shear Strength, kPa	2410	4144	-42
Fracture Energy, kPa	5275	5082	4
Failure Strain	3	1	85

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Conclusions

- SMA pavement exhibited better long-term field performance than HMA control pavement.
- Field SMA field cores indicated:
  - ✓ Lower E* and higher creep compliance
  - ✓ Better resistance to rutting
  - ✓ Comparable resistance to studded tire wear
  - ✓ Better resistance to bottom-up and top-down fatigue cracking
  - ✓ Better thermal cracking resistance
- Field-extracted SMA binder indicated:
  - ✓ Slower oxidation rate due to a thicker film thickness
  - ✓ Better rutting resistance
  - ✓ Better fatigue and thermal cracking resistance

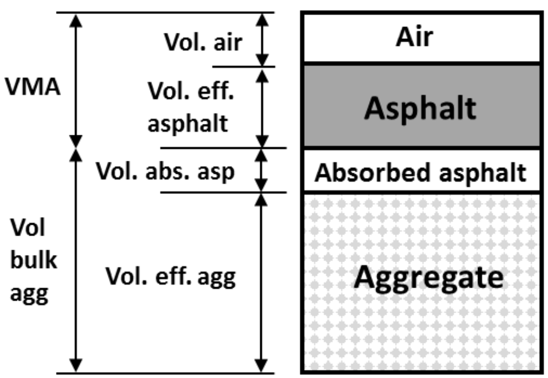
Future Study: Balanced Mix Concept for SMA

(Credit: Mr. David Lippert)

Balanced Mix Design Concept for SMA

Low Temperature Cracking | Fatigue/Block/Other Forms of Cracking | Permanent Deformation

-40°C | -20°C | 20°C | 40°C



SuperpaveTM Volumertics

+

Cracking: I-FIT Test

+

Rutting: Hamburg

(Credit: Dr. Imad Al-Qadi)


Material Production
Design
Surface Course
Base Course
Subbase Course
Construction
Use
Preservation, Maintenance, & Rehabilitation
End-of-life
Environmental
Social
Economic
SMA Pavement with Sustainability Considerations

Future Study

- Include more case studies with varying traffic, environmental and other factors to draw relatively conclusive decisions.
- Further evaluation on the effects of aggregate gradation and binder PG on the difference performance.

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Thank You!
Any questions?

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