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Sensitivity of Mixture Cracking Performance Tests to Binder Properties and Long-Term Aging

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Abbreviations

- ABR: asphalt blend ratio.
- ALF: accelerated loading facility.
- BMD: balanced mix design.
- CTOD: crack-tip opening displacement.
- CT-Index: cracking test index.
- DENT: double-edged-notched tension test.
- FI: flexibility index.
- ► G_{mm}: theoretical maximum specific gravity.
- HMA: hot-mix asphalt.
- ► IDEAL-CT: indirect tensile asphalt cracking test.
- ▶ I-FIT: Illinois Flexibility Index Test.
- ► ITC: indirect tensile cracking.
- LTA: long-term aging.
- LTOA: long-term oven-aging.

- LVE: linear viscoelastic.
- NCHRP: National Cooperative Highway Research Program.
- ▶ PG: performance grade.
- PMA: polymer-modified asphalt.
- RA: recycling agent.
- RAP: reclaimed asphalt pavement.
- ▶ RAS: reclaimed asphalt shingles.
- RBR: recycled binder ratio.
- Sapp: apparent damage capacity (fatigue index parameter).
- SCB: semicircular bending.
- STA: short-term aging.
- STOA: short-term oven-aging.
- ► TFAAT: thin-film accelerated aging test.
- WMA: warm-mix asphalt.

Outline

- Study objectives.
- ► *"RODEO"* study outline.
- Summary of Phase I and I findings.
- ► Phase III: Validation study.

Objectives

- Highlight the need to consider LTOA for a comprehensive BMD framework.
- Evaluate the sensitivity of various cracking performance tests to LTOA.
- Demonstrate the application of aging duration maps for LTOA at 95 °C for BMD.
- Understand the impact of binder quality and properties on mixture cracking performance indices.



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"RODEO"

A Three-Phase Project



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N_{flex}=N_flex factor.



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Summary of Phase I and I Findings

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FHWA ALF RAP/RAS



Source: FHWA.



Source: FHWA.

NCHRP 09-54 Aging Duration Maps



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ALF Materials

	HMA/WMA Drum Discharge Temperature	149 °C – 160 °C		116 °C – 132 °C		
	Warm-Mix Technology (%)	None		Foam	Chemical	
Recycle Content	0	PG 64-22		N/A	N/A	
	20 ABR RAP ≈ 23 RAP by weight	PG 64-22		PG 64-22	PG 64-22	
	20 ABR RAS ≈ 6 RAS by weight	PG 64-22	PG 58-28	N/A	N/A	
	40 ABR RAP ≈ 44 RAP by weight	PG 64-22	PG 58-28	PG 58-28	PG 58-28	
	N/A = not applicable. Source: FHW					

Accelerated Performance Testing



N_{1st crack}: Number of cycles to first crack.

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Aging Index





All figures source: FHWA.⁽⁵⁾

 E^* = mixture dynamic modulus; δ = mixture phase angle.



800

Lane 6 N_{1st crack}: 122,103 Slope: 0.0075 x N

18

20

x 10000

All figures source: FHWA.⁽⁵⁾

IDEAL-CT Test







All figures source: FHWA.⁽⁵⁾

I-FIT Test







All figures source: FHWA.⁽⁵⁾

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Aging Trends



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Phase III: Validation Study



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Validation Materials

State	Mixture	RBR (RAP) Percent	AC Percent	G _{mm}
Florida	FL 12.5R00	0	5.0	2.541
Montana	MT 9.5R00	0	5.9	2.402
WOILdid	MT 19R00	0	5.0	2.455
	OH 9.5R20	20	6.3	2.423
Ohio	OH 12.5R15	15	5.9	2.475
	OH 19R18	18	5.3	2.452
Vermont	VT 12.5R00	0	5.8	2.478

Source: FHWA.

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LTA Duration

		95 °C	135 °C
State	Mixture	(d)	(h)
Florida	FL12.5R00	7	8
Montana	MT9.5R00	3	8
Montana	MT19R00	3	8
Ohio	OH9.5R20	4	8
Ohio	OH12.5R15	4	8
Ohio	OH19R18	4	8
Vermont	VT12.5R00	3	8



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Source: FHWA.





Source: FHWA.

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ICT (IDEAL-CT) Test Results



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SCB (I-FIT) Test Results



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Uniaxial Cyclic Fatigue Results



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Extracted Binders: DENT Results



Summary of Findings

- ► Phase III results confirmed Phases I and II findings.
- Aging Index could be based on some LVE parameters.
- ► DENT (CTOD) results correlated well with I-FIT (FI).
 - Both test methods are based on fracture mechanics fundamentals.
 - CT-Index correlated with CTOD as well.
 - I-FIT, IDEAL-CT, and DENT were conducted at 25 °C, while uniaxial fatigue testing temperature is a function of climatic PG.
- More work is needed to integrate LTA in a comprehensive BMD framework.

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