NCHRP 9-55: Recycled Asphalt Shingles in Asphalt Mixtures with Warm Mix Asphalt Technologies

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Existing Field Projects

Location	Date Const.	RAS% RAP%	Mix Variables
US 287 Fort Worth, TX	Oct. 2012	5% 15%	HMA
			WMA (chem.)
FM 973 Austin, TX	Dec. 2011 Jan. 2012	3% 15%	HMA sect. 3
			WMA (chem.) sect. 9
		5%, 0%	HMA sect. 4
		3%, 15%	HMA w/ PG 58-28, sect. 6
I-88, IL Tollway Aurora, IL	Jun.-Aug. 2012	5% 13%	WMA (chem.), two agg. types

Existing Field Projects - Performance

Location	Mix Variables	Age	Field Performance
US 287 Fort Worth, TX	HMA	37 mos.	Low-severity transverse cracking (reflective)
	WMA (chem.)	37 mos.	Low-severity transverse cracking (reflective) Low-severity longitudinal (edge) cracking
FM 973 Austin, TX	HMA PG 64-22 15% RAP-3% RAS	47 mos.	Low-severity transverse cracking Low-severity block cracking
	WMA (chem.)	47 mos.	Low-severity longitudinal cracking
	HMA PG 64-22 0% RAP-5% RAS	47 mos.	Low-severity longitudinal cracking
	HMA w/ PG 58-28	47 mos.	Low and medium-severity longitudinal cracking Low-severity transverse cracking
I-88, IL Tollway Aurora, IL	WMA (chem.), two agg. types	46 mos.	Low, medium and high-severity transverse cracking (mostly reflective)

New Field Projects

Location	Date Const.	RAS % RAP %	Mix Test Sections	Prod. Temp.
SR 96 Larsen, WI	Sept. 2013	3% PC 14%	HMA	324
			Rediset	317
			Zycotherm	321
US 84 Enterprise AL	June 2014	5% PC 15%	HMA, low Va	351
			HMA, adjusted Va	350
			WMA (foam), low Va	312
			WMA (foam), adjusted Va	304
Union Valley Rd. Oak Ridge, TN	Oct. 2014	3% PC 10%	HMA	315
			WMA (chem.)	267
SR 58 Wilson, NC	June 2015	5% 20%	HMA w/ PCRAS	305
			WMA (chem.) w/ PCRAS	277
			HMA w/ MWRAS	297
			WMA (chem.) w/ MWRAS	276
SR 39 LaPorte, IN	Oct. 2015	2% MW 15%	HMA	318
			WMA (foam)	303

New Field Projects - Performance

Location	Mix Variables	Age	Field Performance
SR 96 Larson, WI	Control, Rediset, Zycotherm	24 mos.	Minor reflection cracking over unrubblized PCCP
US 84, Enterprise, AL	HMA & WMA – low Va HMA & WMA – adj. Va	29mos.	Low-severity transverse cracking.
Union Valley Rd. Oak Ridge, TN	WMA & HMA	25 mos.	Low-severity transverse cracking. No other distresses
SR 58 Wilson, NC	HMA & WMA w/ PCRAS, HMA & WMA w/ MSRAS	14 mos.	Low-severity transverse cracking. No other distresses
SR 39 LaPorte, IN	WMA & HMA	16 mos.	No cracking or other distresses

Laboratory Testing

- Recovered Binder: PG, ΔTc, MSCR, LAS
- Plant mix, Lab Compacted (reheated)
  - Stiffness: E* (confined)
  - Rutting: FN and HWTT
  - Cracking: BBF. ER, OT, IFIT, SCB-Jc, IDT Creep
- Lab Mix, Lab Compacted
  - mix design verification

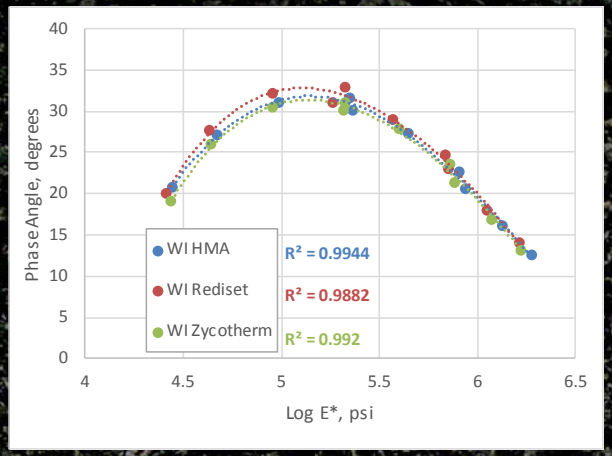
Location	RAS % RAP %	Mix Test Sections	%Vbe	ΔTc	OT >300
SR 96 Larsen, WI	3% PC 14%	HMA	11.4	-3.5	241
		Rediset	10.8	-3.8	285
		Zycotherm	11.6	-5.0	436
US 84 Enterprise AL	5% PC 15%	HMA, low Va	11.1	-7.7	19
		WMA, low Va	12.2	-8.1	214
		HMA, adj. Va	10.3	-10.8	24
		WMA, adj. Va	10.8	-8.6	44
Union Valley Rd. Oak Ridge, TN	3% PC 10%	HMA	9.9	-11.7	226
		WMA (chem.)	11.2	-5.5	807
SR 58 Wilson, NC	5% 20%	HMA w/ MWRAS	10.1	-2.7	125
		WMA (chem.) w MWRAS	10.9	-2.0	619
		HMA w/ PCRAS	11.6	-3.2	215
		WMA (chem.) w/ PCRAS	11.4	-2.9	333
SR 39 LaPorte, IN	2% MW 15%	HMA	9.3	-5.6	109
		WMA (foam)	9.7	-6.1	158

Location	RAS % RAP %	Mix Test Sections	%Vbe	ΔTc	ER >1.3
SR 96 Larsen, WI	3% PC 14%	HMA	11.4	-3.5	3.2
		Rediset	10.8	-3.8	3.7
		Zycotherm	11.6	-5.0	2.8
US 84 Enterprise AL	5% PC 15%	HMA, low Va	11.1	-7.7	1.7
		WMA, low Va	12.2	-8.1	1.9
		HMA, adj. Va	10.3	-10.8	0.6
		WMA, adj. Va	10.8	-8.6	2.0
Union Valley Rd. Oak Ridge, TN	3% PC 10%	HMA	9.9	-11.7	4.5
		WMA (chem.)	11.2	-5.5	3.1
SR 58 Wilson, NC	5% 20%	HMA w/ MWRAS	10.1	-2.7	0.3
		WMA (chem.) w MWRAS	10.9	-2.0	2.1
		HMA w/ PCRAS	11.6	-3.2	3.9
		WMA (chem.) w/ PCRAS	11.4	-2.9	2.4
SR 39 LaPorte, IN	2% MW 15%	HMA	9.3	-5.6	2.1
		WMA (foam)	9.7	-6.1	2.3

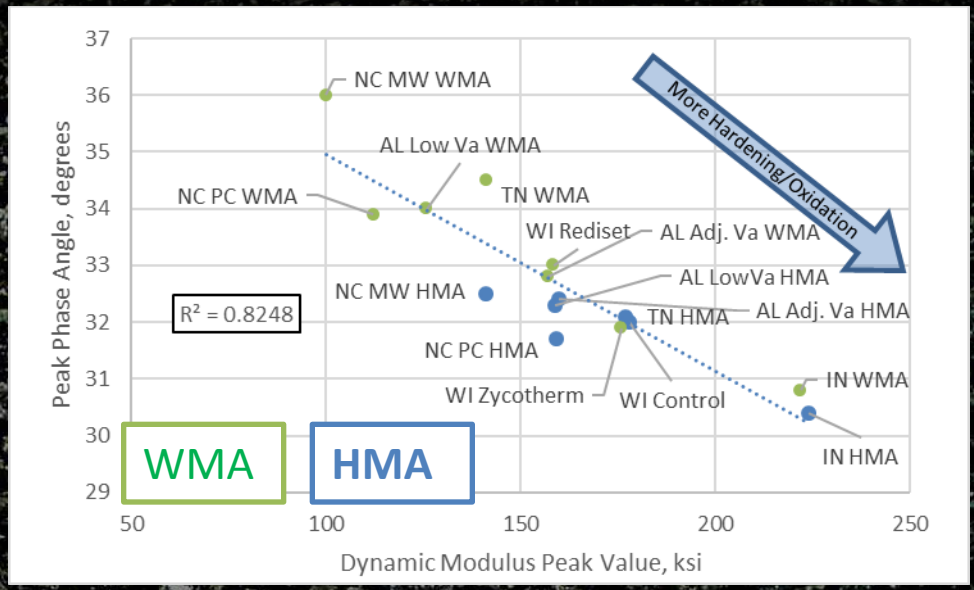
Location	RAS % RAP %	Mix Test Sections	%Vbe	ΔTc	SCB-Jc >0.5
SR 96 Larsen, WI	3% PC 14%	HMA	11.4	-3.5	0.37
		Rediset	10.8	-3.8	0.41
		Zycotherm	11.6	-5.0	0.36
US 84 Enterprise AL	5% PC 15%	HMA, low Va	11.1	-7.7	0.41
		WMA, low Va	12.2	-8.1	0.68
		HMA, adj. Va	10.3	-10.8	0.47
		WMA, adj. Va	10.8	-8.6	0.65
Union Valley Rd. Oak Ridge, TN	3% PC 10%	HMA	9.9	-11.7	0.64
		WMA (chem.)	11.2	-5.5	0.64
SR 58 Wilson, NC	5% 20%	HMA w/ MWRAS	10.1	-2.7	0.32
		WMA (chem.) w MWRAS	10.9	-2.0	0.38
		HMA w/ PCRAS	11.6	-3.2	0.57
		WMA (chem.) w/ PCRAS	11.4	-2.9	0.40
SR 39 LaPorte, IN	2% MW 15%	HMA	9.3	-5.6	0.50
		WMA (foam)	9.7	-6.1	0.55

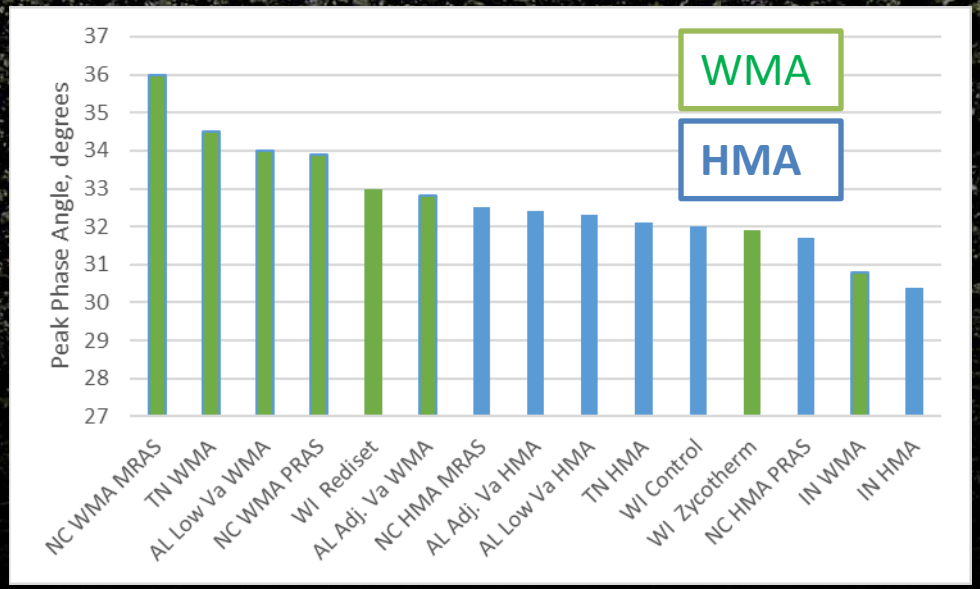
Location	RAS % RAP %	Mix Test Sections	%Vbe	ΔTc	IFIT >8.0
SR 96 Larsen, WI	3% PC 14%	HMA	11.4	-3.5	3.3
		Rediset	10.8	-3.8	5.8
		Zycotherm	11.6	-5.0	2.9
US 84 Enterprise AL	5% PC 15%	HMA, low Va	11.1	-7.7	0.7
		WMA, low Va	12.2	-8.1	2.9
		HMA, adj. Va	10.3	-10.8	0.2
		WMA, adj. Va	10.8	-8.6	1.0
Union Valley Rd. Oak Ridge, TN	3% PC 10%	HMA	9.9	-11.7	3.3
		WMA (chem.)	11.2	-5.5	4.9
SR 58 Wilson, NC	5% 20%	HMA w/ MWRAS	10.1	-2.7	1.8
		WMA (chem.) w MWRAS	10.9	-2.0	7.3
		HMA w/ PCRAS	11.6	-3.2	3.7
		WMA (chem.) w/ PCRAS	11.4	-2.9	4.7
SR 39 LaPorte, IN	2% MW 15%	HMA	9.3	-5.6	1.1
		WMA (foam)	9.7	-6.1	1.7

E* Parameters as Cracking Indicators



Black Space Diagram





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PRELIMINARY FINDINGS

- Production and Construction of RAS Mixtures
- Mix Design Verification
- Short Term Field Performance
- Performance Tests Results

Production and Construction of RAS Mixtures

- Lower mix production temperatures associated with WMA did not cause plant issues or construction problems for any of the project sites evaluated in this study.
- Similar roller patterns resulted in statistically equivalent as-constructed densities for WMA mixes compared to the corresponding HMA

Short Term Field Performance

- All projects had less than 5 mm rutting after 2-3 years.
- No project had any evidence of moisture damage.
- Reflection cracking was the most common cracking distress.
- All test sections had similar surface texture depths.
- The use of WMA did not appear to effect density changes under traffic compared to HMA. Density did change over time for most projects.

Mix Design Verification

- Slight differences in the optimum asphalt content were found for all mixtures. The tendency was for verified mixtures to have higher asphalt contents.
- Critical properties such as the specific gravity of the aggregate tended to have higher verified values (RAS G_{sb} between lab variability).

Performance Tests

- WMA mixtures tend to have lower E* values than those of corresponding HMA mixtures in most cases.
- Fn and HWT results indicate WMA mixtures are more susceptible to rutting, but still met suggested criteria.
- Most WMA mixtures were slightly more resistant to cracking (OT, IFIT, ER and Jc).

Performance Tests

- Analysis of IDT creep compliance & strength tests indicate WMA mixtures generally have a small improvement in low temperature cracking.
- E* parameters generally agree with results obtained from laboratory performance tests. Thus, providing an additional tool to evaluate cracking susceptibility.

In General

- WMA mixtures had better lab results for cracking resistance and were slightly more susceptible to rutting.
- All field sections are performing well which makes it challenging to validate performance test criteria.
- Long term monitoring of field sections is recommended.