Validation of Performance-Related Specification of High RAP Content Surface Mixtures Placed on High Volume Roads

NEAUPG

North East Asphalt User Producer Group (NEAUPG) 2024

Springfield, MA ✦ October 16th, 2024

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Outline

1. Background
2. Objectives
3. Methodology
4. Results
5. Conclusions

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Background

- MassDOT's current specifications only allow up to 15% RAP in its top surface asphalt mixture layer.

- Based on a 2020 MassDOT funded study entitled *Influence of Reclaimed Asphalt Pavement (RAP) Source and Virgin Binder Source on RAP Specifications and Balanced Mix Design* the following was concluded:

  - The RAP content could be increased over the 15% maximum based on the properties of the RAP, which depends on its source.

  - For the same RAP content, RAP source has a significant effect on the cracking resistance of asphalt mixtures.

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Background

- MassDOT approved demonstration projects using high RAP surface asphalt mixtures with RAP contents between 25% and 30% for high volume interstate projects to pilot the production, placement, and variability of high RAP content surface mixtures.

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Objectives

1. Document variability in virgin binder, RAP, and mixtures properties across different production seasons.

2. Characterize the impact of virgin binder and RAP properties on mixture performance.

3. Evaluate the influence of material variations during production on the balanced performance of mixtures across different seasons.

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Experimental Plan

Project #1 (25% RAP)

9.5mm Mixture

1. Laboratory Trial Mix Formula (LTMF)
2. October 2021 (10/21)
3. November 2021 (11/21)
4. June 2022 (06/22)
5. May 2023 (05/23)

Project #2 (28% RAP)

12.5mm Mixture

1. Laboratory Trial Mix Formula (LTMF)
2. October 2022 (10/22)
3. June 2023 (06/23)
4. August 2023 (08/23)

Obtain LTMF and Materials from the Production Facility at Different Dates/Seasons

Materials

1. Virgin Asphalt Binder
2. Reclaimed Asphalt Pavements (RAP)
3. Plant Produced Asphalt Mixtures

Extract & Recover Asphalt Binder

1. RAP
2. Plant Produced Asphalt Mixture

Determine the Asphalt Binder Performance Grade (PG)

1. Virgin Binder
2. Recovered RAP Binder
3. Recovered Asphalt Mixture Binder

Characterize the Plant Produced Asphalt Mixtures and RAP Stockpile Properties

1. Asphalt Content
2. Aggregate Gradation

Conduct Mixture Performance Evaluation Testing

Rutting & Moisture Susceptibility

Hamburg Wheel Tracking Test (HWTT)

Intermediate Temperature Cracking

1. Illinois Flexibility Index Test (I-FIT)
2. Indirect Tensile Asphalt Cracking Test (IDEAL)

Low-Temperature Cracking

Thermal Stress Restrained Specimen Test (TSRST)

Asphalt Binder Test Results - Virgin Binders

Project #1 (25% RAP)		
Sample Date	**Binder PG**	**Average ΔT_C**
LTMF	PG64(64E) -34	+0.8
10/21	PG70(64E) -28	-0.3
11/21	PG64(64E) -34	+0.7
06/22	PG70(64E) -34	+0.3
05/23	PG64(64E) -34	+0.5

Project #2 (28% RAP)		
Sample Date	**Binder PG**	**Average ΔT_C**
LTMF	PG70(64E) -34	+0.1
10/22	PG70(64E) -34	+0.3
06/23*	PG64(64V) -28	+0.5
08/23	PG64(64V) -34	+0.7

** Virgin binder 64E-28 with recycling agent*

The final blended binder grade (RAP and virgin) in the mixture should be a PG64E-28.

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Asphalt Binder Test Results - RAP Binders

Project #1 (25% RAP)		
Sample Date	**Binder PG**	**Average ΔT_C**
LTMF	PG88-16	-2.9
10/21	PG88-16	-2.8
11/21	PG82-22	-2.3
06/22	PG82-22	-1.1
05/23	PG88-16	-3.4

Project #2 (28% RAP)		
Sample Date	**Binder PG**	**Average ΔT_C**
LTMF	PG88-16	-1.6
10/22	PG88-16	-1.9
06/23	PG88-16	0.0
08/23	PG88-16	-0.7

- For Project #1, the RAP binder high- and low-temperature grades changed by one grade from LTMF to production in some instances.
- This highlights the need to verify the RAP stockpile properties during production.

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Asphalt Binder Test Results - Mixture Binders

Project #1 (25% RAP)		
Sample Date	**Binder PG**	**Average ΔT_C**
LTMF	PG76(64E) -28	-1.1
10/21	PG70(64V) -28	-1.0
11/21	PG70(64E) -28	-2.2
06/22	PG70(64V) -22	-2.4
05/23	PG70(64V) -28	1.2

Project #2 (28% RAP)		
Sample Date	**Binder PG**	**Average ΔT_C**
LTMF	PG88(64E) -22	-3.5
10/22	PG82(64E) -22	-1.0
06/23	PG82(64E) -22	-1.3
08/23	PG76(64V) -28	+0.2

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Asphalt Binder Test Results - Mixture Binders

- Not all extracted and recovered mixture binders met the MassDOT specified criteria of a PG64E-28.
- For Project #1 most of the extracted and recovered mixture binders met the MassDOT low-temperature PG grade criterion of -28ºC. The exception was the 06/22 mixture.
- For Project #2, most of the binders did not meet the MassDOT low-temperature PG grade criterion. Only the binder extracted and recovered from the 05/23 mixture was -28ºC.
- The ΔT_c results of the extracted and recovered mixture binders indicated a promising resistance to non-load associated cracking as all binders had ΔT_c values higher than the suggested threshold of warmer than -5.0°C

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RAP Aggregate Gradation & Binder Content Results

Project #1 (25% RAP)								
	LTMF	**10/21**	**11/21**	**06/22**	**05/23**		**Standard Deviation**	**Suggested NCHRP 752 Standard Deviation Limits**
19 mm (3/4")	100	100	100	100	100		0	< 5.0
12.5 mm (3/4")	98.1	97.3	98.5	97.6	98.8		0.63	< 5.0
9.5 mm (3/4")	92.4	90.6	90.8	88.2	93.4		1.9	< 5.0
4.75 mm (No. 4)	69.7	71.9	63.5	61.2	73.7		5.4 F	< 5.0
2.36 mm (No. 8)	51.9	57.0	46.1	44.2	57.4		6.05 F	< 5.0
1.18 mm (No. 16)	39.0	44.0	33.8	32.7	44.1		5.41 F	< 5.0
0.6 mm (No. 30)	28.4	32.1	24.5	24.1	32.4		3.99	< 5.0
0.3 mm (No. 50)	18.8	21.7	16.7	17.1	21.8		2.46	< 5.0
0.15 mm (No. 100)	11.7	13.5	10.3	11.0	13.5		1.44	< 5.0
0.075 mm (No. 200)	7.5	8.7	6.5	7.1	8.5		0.93	< 1.5
Binder Content, %	4.88	5.37	5.15	5.00	5.46		0.24	< 0.5

Note: F= Standard deviation of measurements outside suggested NCHRP 752 limits

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RAP Aggregate Gradation & Binder Content Results

Project #2 (28% RAP)							
	LTMF	**10/22**	**06/23**	**08/23**		**Standard Deviation**	**Suggested NCHRP 752 Standard Deviation Limits**
19 mm (3/4")	100.0	100.0	100.0	100.0		0	< 5.0
12.5 mm (3/4")	98.5	98.5	99.0	99.0		0.28	< 5.0
9.5 mm (3/4")	93.4	94.4	95.4	93.1		1.06	< 5.0
4.75 mm (No. 4)	65.7	71.1	70.8	73.3		3.22	< 5.0
2.36 mm (No. 8)	45.4	53.4	50.1	56.0		4.56	< 5.0
1.18 mm (No. 16)	33.3	41.4	37.7	40.9		3.74	< 5.0
0.6 mm (No. 30)	24.8	31.3	28.9	29.5		2.76	< 5.0
0.3 mm (No. 50)	17.8	22.2	21.3	20.9		1.95	< 5.0
0.15 mm (No. 100)	11.6	15.0	14.9	14.1		1.56	< 5.0
0.075 mm (No. 200)	7.7	10.7	10.7	9.5		1.41	< 1.5
Binder Content, %	6.08	6.16	6.06	6.04		0.05	< 0.5

Note: F= Standard deviation of measurements outside suggested NCHRP 752 limits

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Mixture Property Test Results

Project #1 (25% RAP)									
	LTMF	**10/21**	**11/21**	**06/22**	**05/23**		**9.5 mm Superpave Specification**	**Lower Engineering Limit (LEL)**	**Upper Engineering Limit (UEL)**
19 mm (3/4")	100	100	100	100	100		100	100	100
12.5 mm (3/4")	100	98.2 F	98.9 F	99.5 F	99.9 F		100 min	100	100
9.5 mm (3/4")	94.0	92.6	93.3	95.2	96.4		90-100	90	100
4.75 mm (No. 4)	62.0	59.8	59.1	68.2 F	66		90 max	56	68
2.36 mm (No. 8)	40.0	39.7	39.1	47.3 F	43.1		32-67	35	45
1.18 mm (No. 16)	29.0	27.1	26.8	31.6	29		-	26	32
0.6 mm (No. 30)	20.0	18.4	18.5	21.2	19.5		-	17	23
0.3 mm (No. 50)	13.0	12.2	12.6	12.8	12.6		-	10	16
0.15 mm (No. 100)	8.0	7.6	8	7.6	7.4		-	6	10
0.075 mm (No. 200)	4.0	4.6	5.3	4.3	4.6		2-10	2.5	5.5
Binder Content, %	5.60	5.74	5.91	6.1 F	5.60		-	5.2	6.0
G_{mm}	2.471	2.474	2.473	2.501*	2.471		-	-	-

F= Outside MassDOT acceptance limit

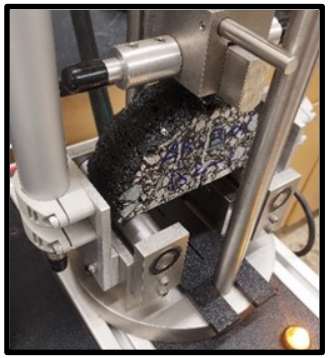
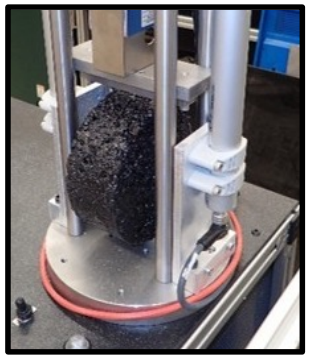
* Significantly different G_{mm} compared to the LTMF.

Mixture Property Test Results

Project #2 (28% RAP)								
	LTMF	**10/22**	**06/23**	**08/23**		**12.5 mm Superpave Specification**	**Lower Engineering Limit (LEL)**	**Upper Engineering Limit (UEL)**
19 mm (3/4")	100	100	100	100		100	100	100
12.5 mm (3/4")	95.0	93.1	97.4	96.8		90-100	89	100
9.5 mm (3/4")	81.0	78.6	85.5	81.0		90 max	75	87
4.75 mm (No. 4)	51.0	47.7	53.8	49.9		-	45	57
2.36 mm (No. 8)	34.0	32.6	33.8	32.7		28-58	29	40
1.18 mm (No. 16)	26.0	24.2	24.2	23.8		-	23	29
0.6 mm (No. 30)	19.0	18.6	18.5	18.0		-	17	23
0.3 mm (No. 50)	14.0	14.2	14.3	13.7		-	11	17
0.15 mm (No. 100)	8.0	9.2	9.7	9.1		-	6	10
0.075 mm (No. 200)	4.3	5.6	5.9 F	5.5		2-10	2.8	5.8
Binder Content, %	5.20	5.26	5.60	5.20		-	4.8	5.6
G_{mm}	2.473	2.478	2.479	2.479		-	-	-

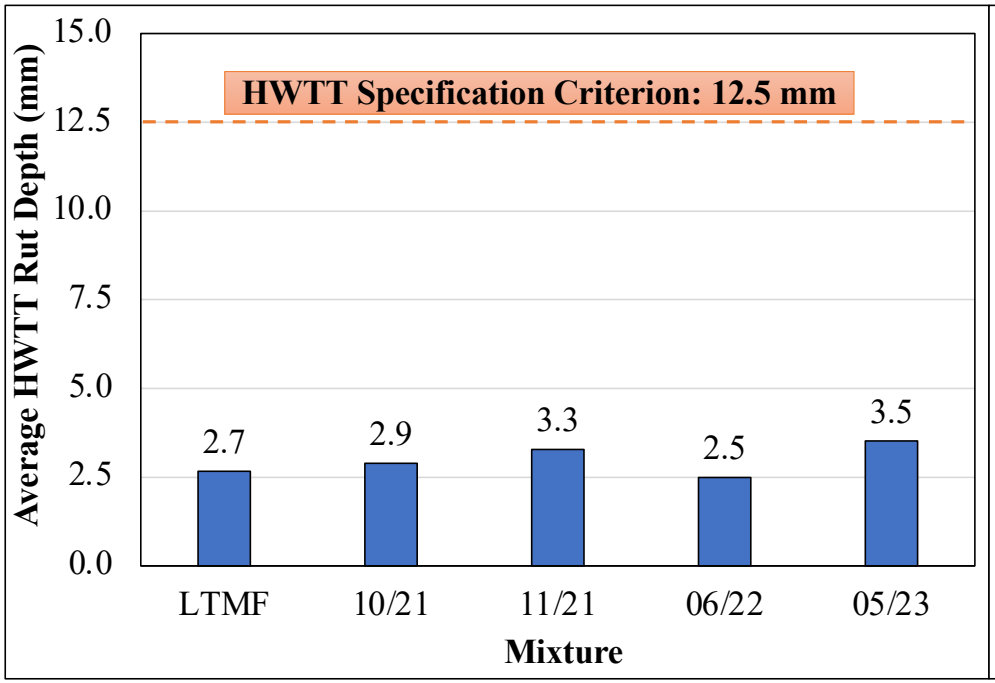
F= Outside MassDOT acceptance limit

Mixture Performance Evaluation

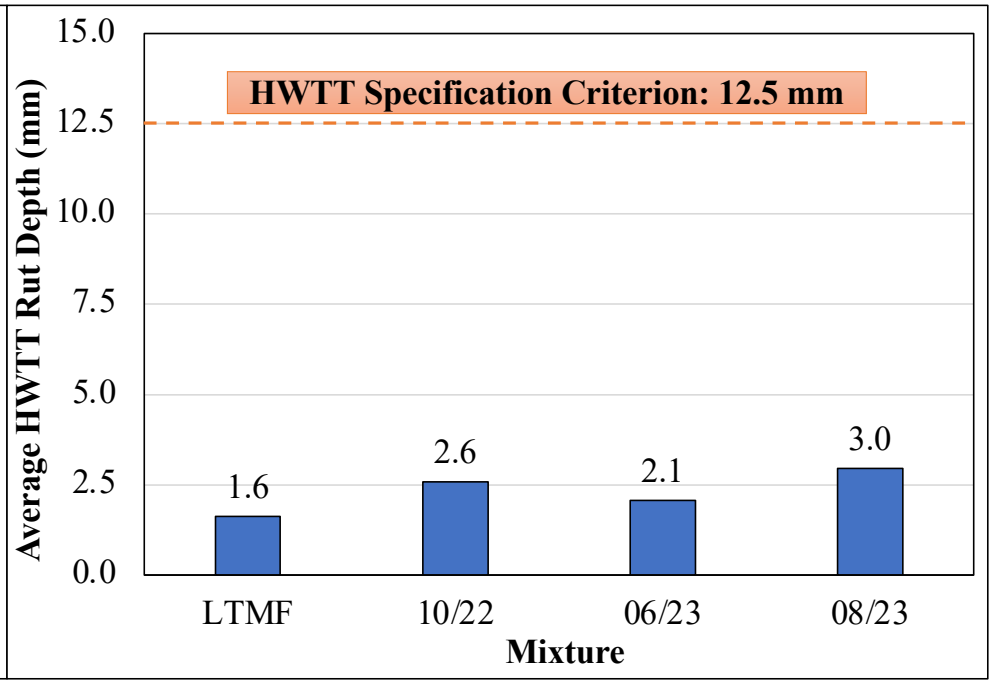
	Rutting & Moisture Susceptibility	Intermediate Temperature Cracking Tests		Low Temperature Cracking
Test	HWTT 	I-FIT 	IDEAL-CT 	TSRST 
Specification	AASHTO T 324	AASHTO T 393	ASTM D 8225	AASHTO TP 10-93
Test Temperature	45°C	25°C	25°C	n/a

Mixture Rutting and Moisture Susceptibility Results

Project#1 (25% RAP)



Project#2 (28% RAP)



- All mixtures met the MassDOT specification criteria. Rutting and moisture damage were not issues for these mixtures.

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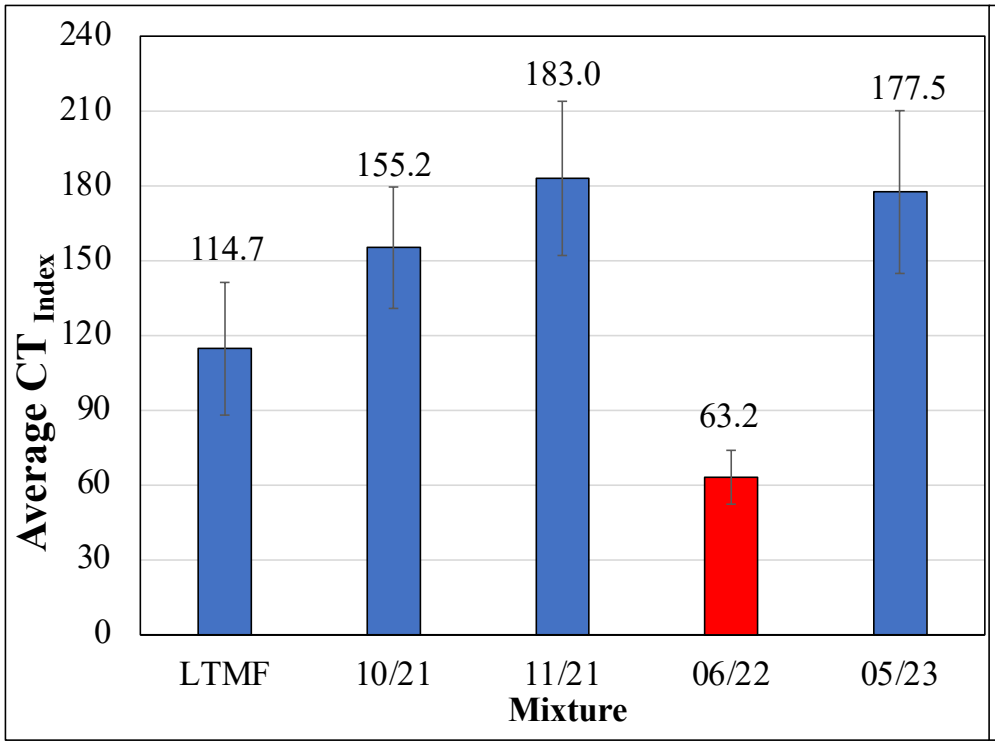
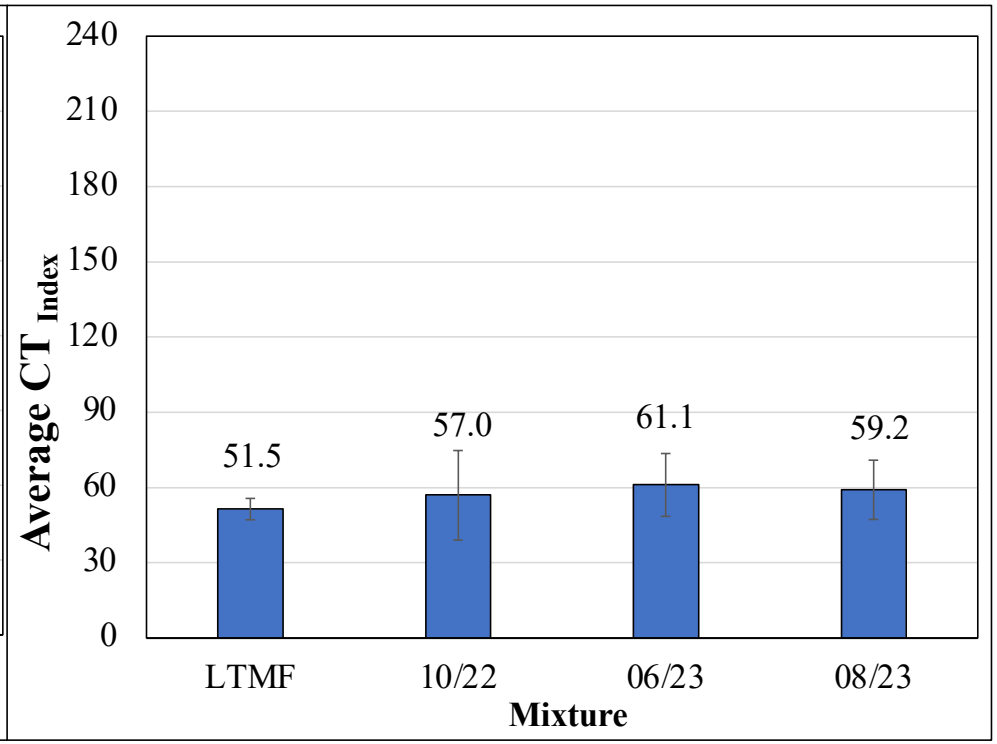
Mixture Intermediate Temperature Cracking Results

Project#1 (25% RAP)

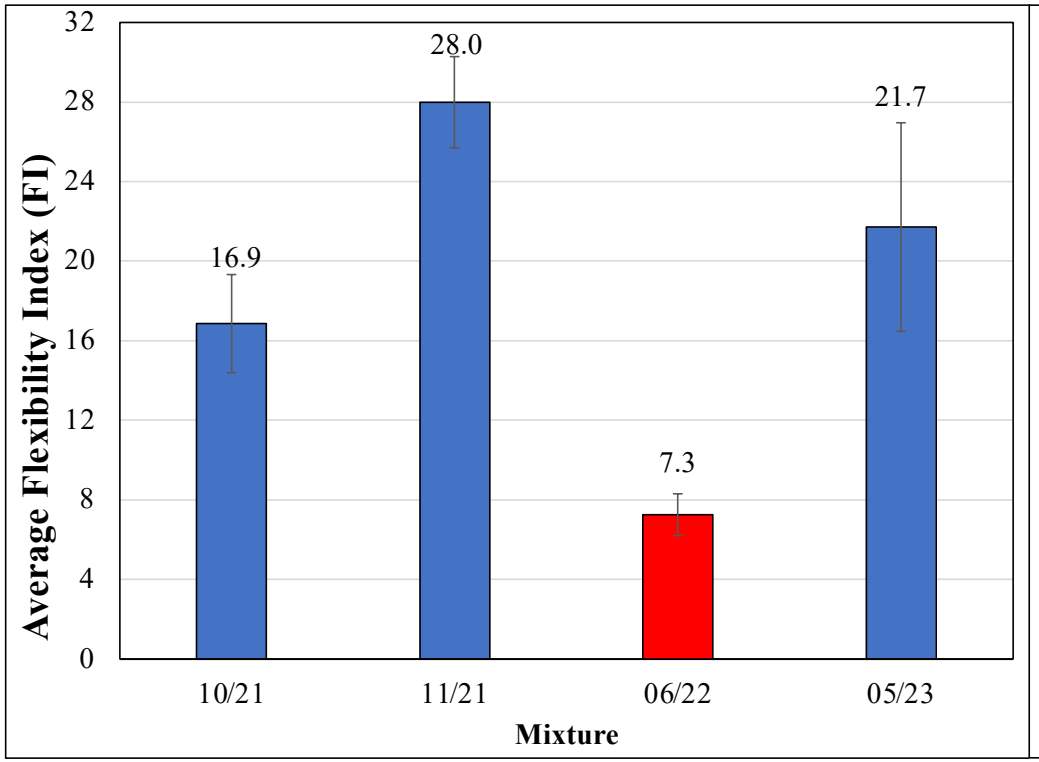


Project#2 (28% RAP)

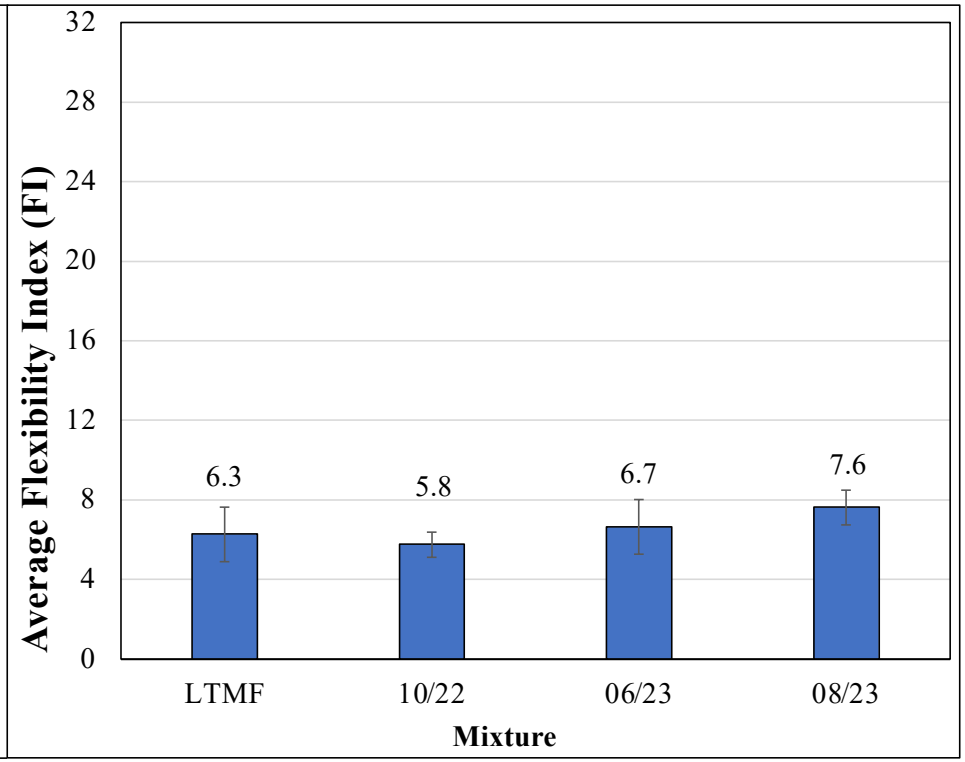


Mixture Intermediate Temperature Cracking Results

Project#1 (25% RAP)

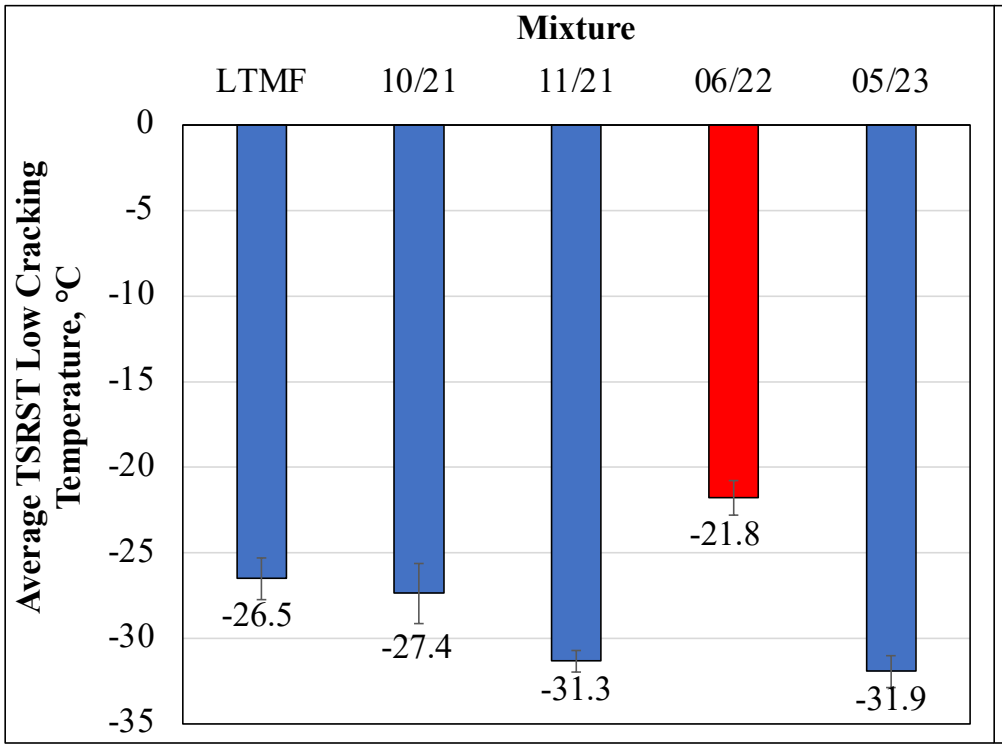


Project#2 (28% RAP)

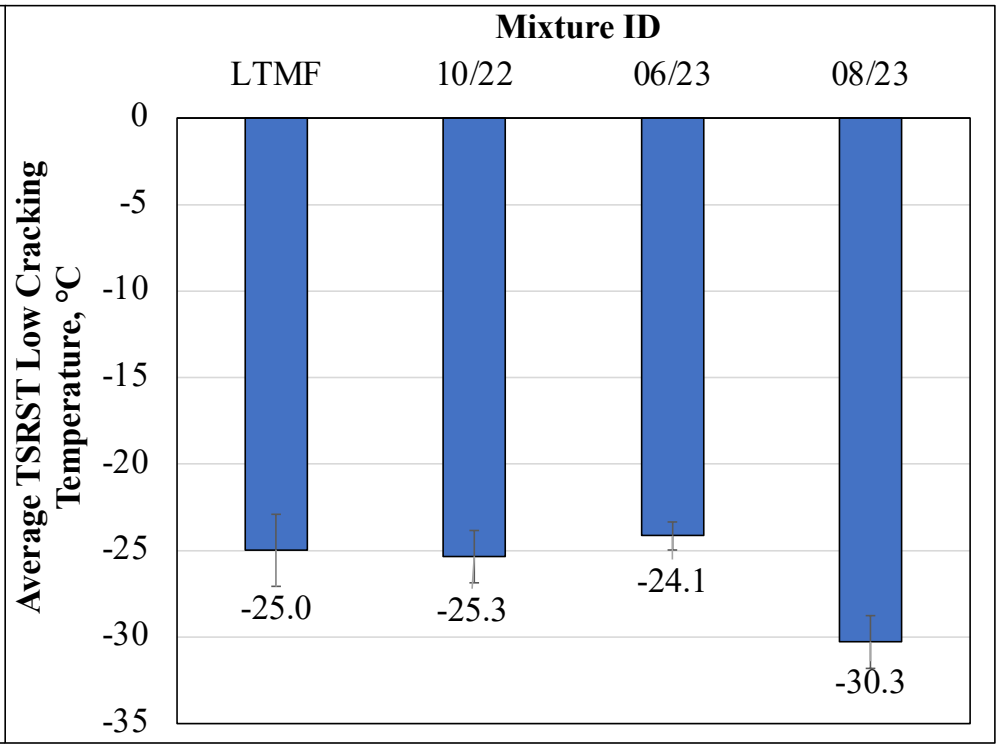


Mixture Low-Temperature Cracking Results

Project#1 (25% RAP)



Project#2 (28% RAP)



Conclusions

- Asphalt mixtures with high RAP content can be produced and provide acceptable balanced performance for rutting, intermediate- and low-temperature cracking resistance.

- Material characteristics should be rigorously validated during production to ensure the approved mixture design is maintained.

- Testing during production will allow for adjustments to the mixture if the material properties change significantly, thereby ensuring the mixture remains balanced.

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Thank you