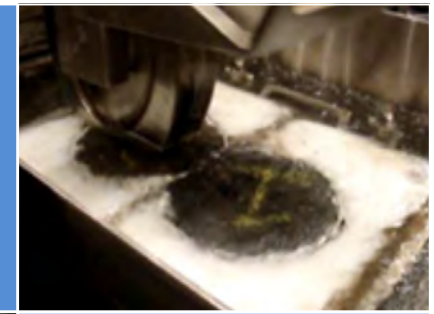
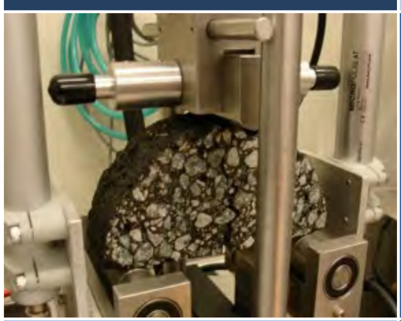


Influence of Production Considerations on Balanced Mixture Designs



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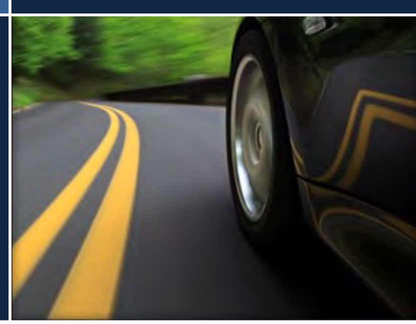
NEAUPG

Wednesday October 17th, 2018



Research Team

Name	Affiliation
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Kevin D. Stuart	Independent Consultant

Background

- Currently, being able to measure or predict mixture performance prior to placement has become essential for many state transportation agencies.

Background
Reasons Why Performance Prediction Needed

1. Incorporation of more recycled materials in mixtures

   Reclaimed asphalt pavement, recycled asphalt shingles, ground tire rubber, etc.

2. Utilization of binders formulated with various modifiers versus conventionally neat asphalt binders

   Re-refined engine oil bottoms, air blown asphalt, rubber, polymers, polyphosphoric acid, etc.

3. Utilization of innovative technologies

   Warm mix asphalt, asphalt rejuvenators, bio-binders, etc.

Background

- State transportation agencies may be approving mixture designs that meet the Superpave volumetric design criteria but may ultimately exhibit subpar performance.

- This has led to a renewed interest using a balanced mixture design (BMD) concept.

Background
FHWA BMD Task Force

- Approach 1

  Volumetric Design with Performance Verification

- Approach 2

  Performance Modified Volumetric Design

- Approach 3

  Performance Design

Background - BMD

- State agencies are using all three approaches and the specific performance testing requirements (tests and associated criterion) vary by individual state.

- Typically state agencies are utilizing a rutting and cracking test for whichever approach they utilize.

Background
Production Considerations & BMD

- What happens to a balanced mixture design during production?

  Binder content, mixture gradations, source of asphalt binders,..... are all dynamic during production. Vary season to season.

- It is currently unknown what happens to the BMD with respect to these types of production considerations.

Study Objective

- Determine the influence of production considerations on mixtures developed using a balanced mixture design approach.

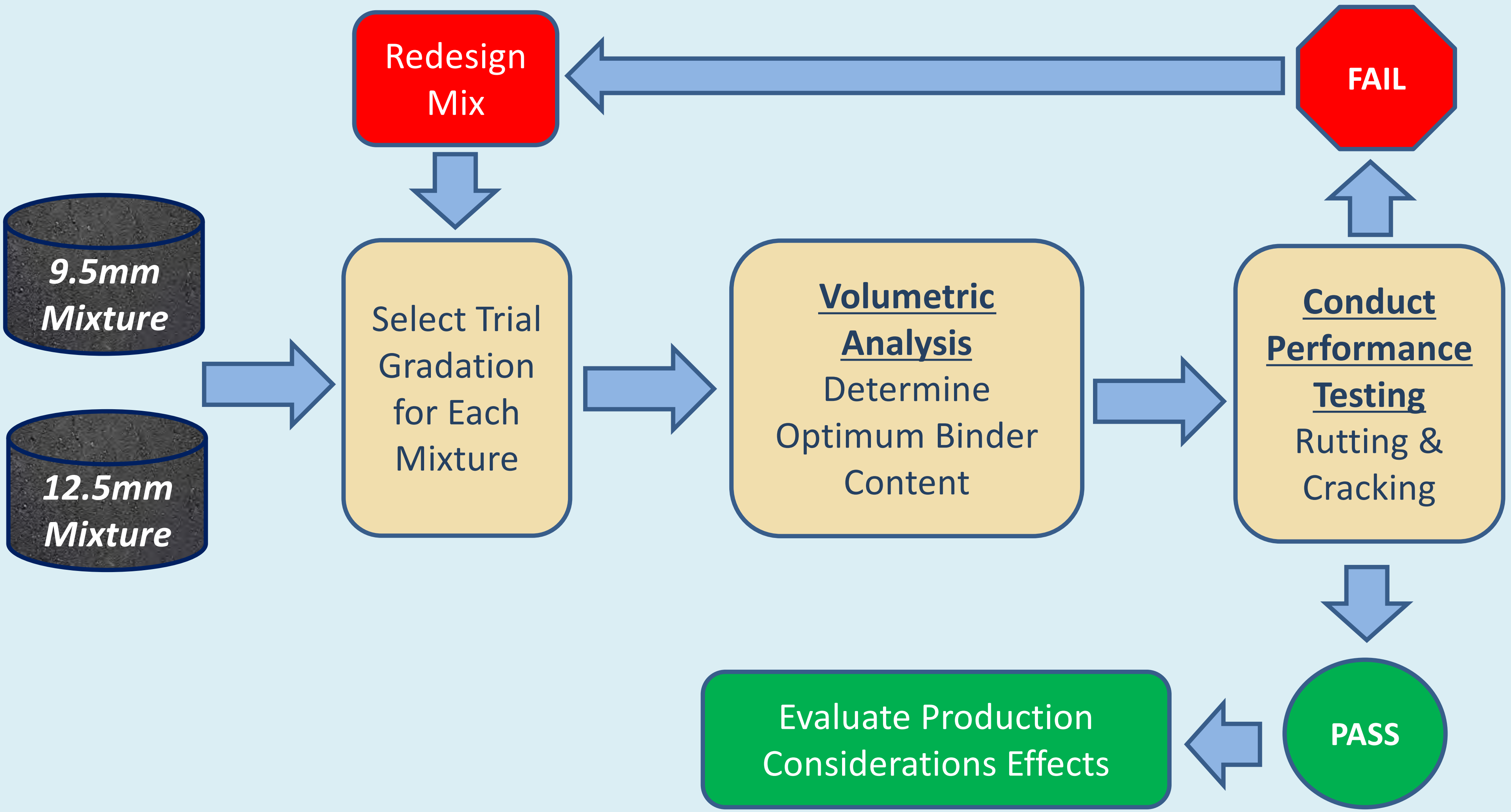
  - Asphalt binder content

  - Percent passing the No. 200 sieve

  - Changes in PG asphalt binder source

Experimental Plan

BMD Approach 1: Volumetric Design with Performance Verification



Experimental Plan

Evaluate Production Considerations Effects

Production Considerations

1. Optimum Asphalt Binder Content +/- Production Tolerance
2. Percent Passing No. 200 +/- Production Tolerance
3. Asphalt Binder Source

Verify Volumetric Properties

Repeat Performance Testing

Evaluate the Magnitude and Significance of Performance Variation Due to Production Considerations

Production Considerations

1. Asphalt Binder Content During Production

MassDOT Quality Assurance specification: ±0.3% of the design optimum.

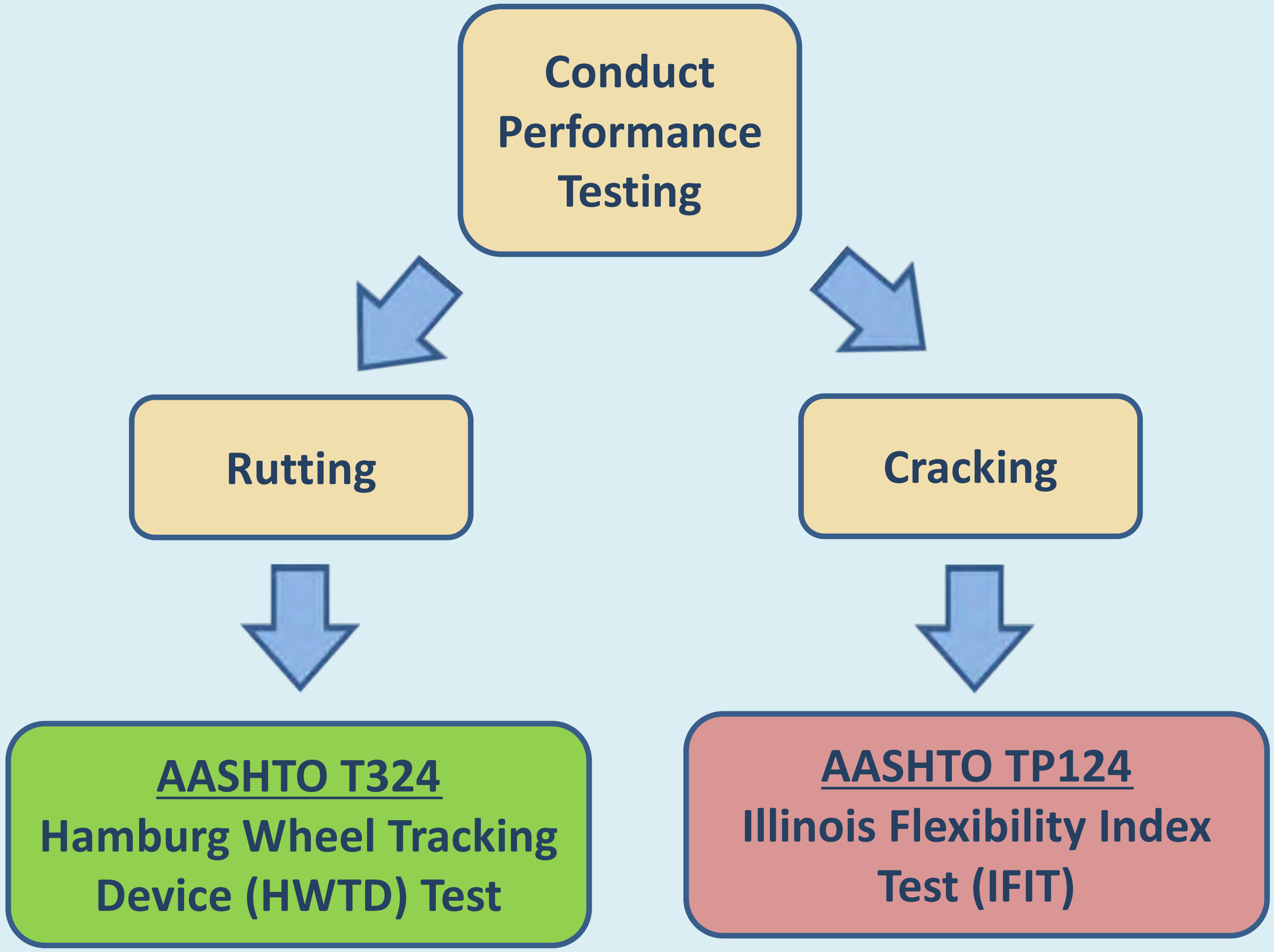
2. Variation of Gradation Passing No. 200 Sieve

MassDOT Quality Assurance specification: ±1.0% of the design Job Mix Formula.

3. Changes in PG Asphalt Binder Source

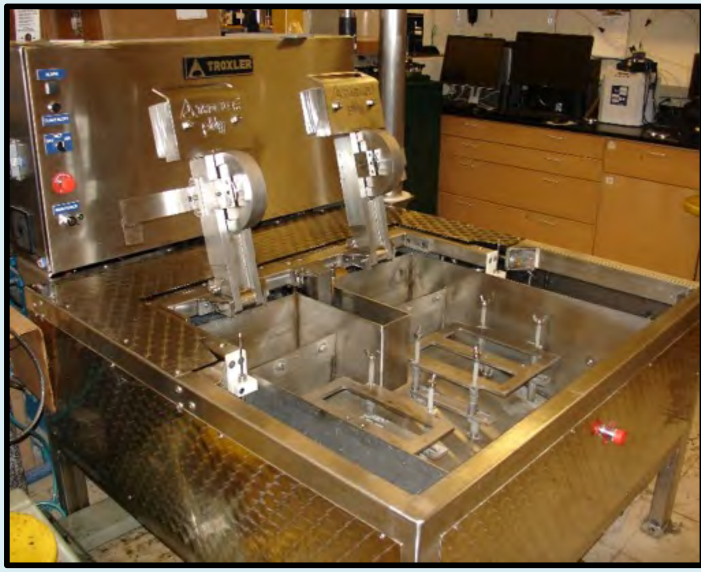
Two different PG64-28 asphalt binders from different sources were utilized, designated as A and B.

Performance Testing Utilized for BMD



Rutting - HWTD

AASHTO T324:Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA)

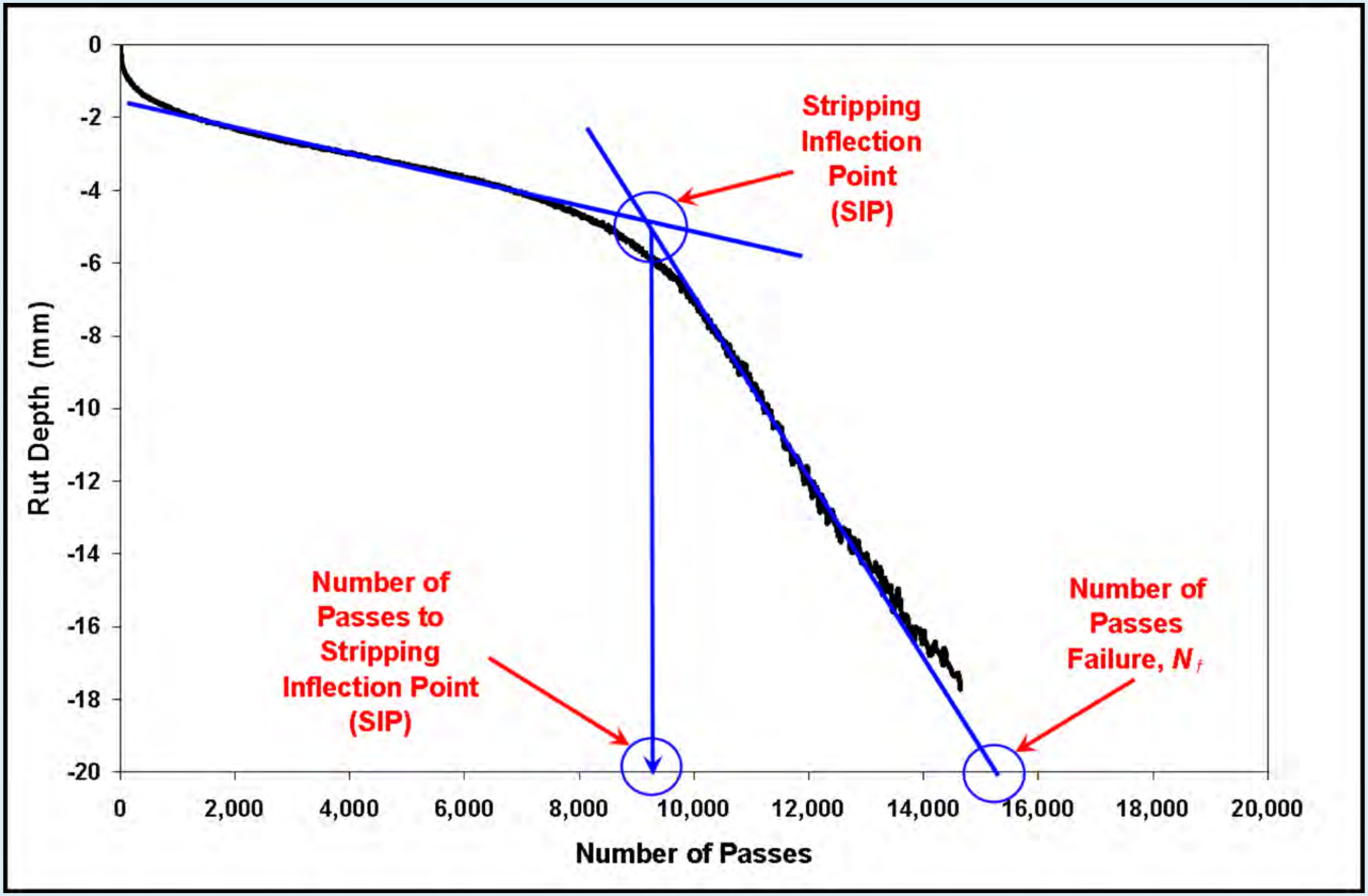


Water at 45ºC (113ºF) • Duration of 20,000 passes • SGC specimens at 7.0±1.0% air voids

MassDOT Pass/Fail Criteria

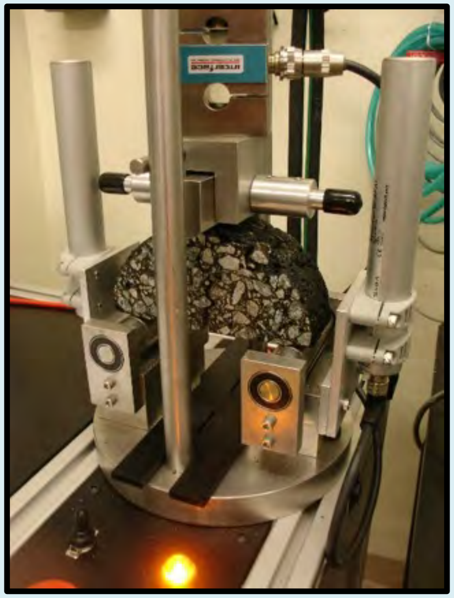
Maximum rut depth of 12.5 mm after 20,000 passes combined with no SIP before 15,000 passes.

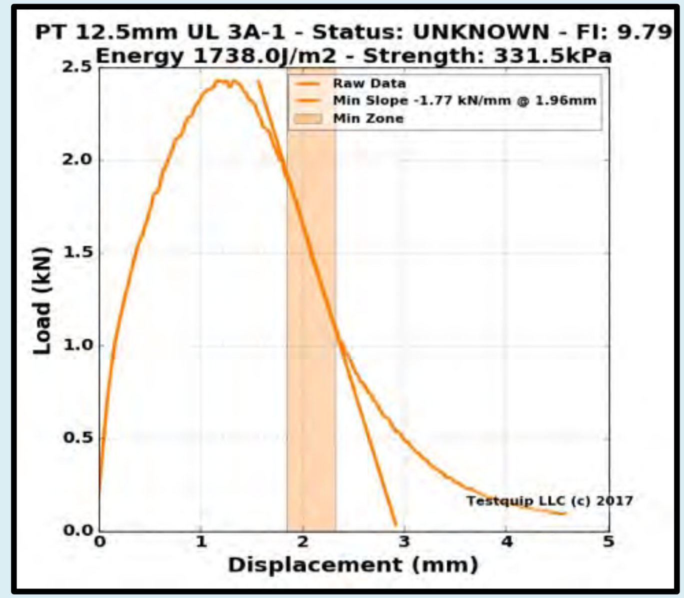
Stripping Inflection Point - HWTD



Cracking – IFIT SCB

AASHTO TP124:Standard Method Of Test For Determining The Fracture Potential Of Asphalt Mixtures Using Semicircular Bend Geometry (SCB) At Intermediate Temperature





Test temperature of 25ºC (77ºF) • Loading rate of 50 mm/min • Test specimens air voids 7.0±1.0%

Preliminary Pass/Fail Criteria

Flexibility Index (FI) of greater than 8.0 has been used as a pass/fail criterion to distinguish between mixtures (Al-Qadi et al., 2015).

BMDs Used in The Study

- 9.5 mm and 12.5 mm mixtures were developed using Approach 1: Volumetric Design with Performance Verification.
- Trial aggregate gradations were developed using existing state approved mixture designs ($N_{design} = 75$).
- Mixtures were developed with the PG64-28 binder from Source A.

BMDs Used in The Study

Sieve Size (mm)	Percent Passing by Weight			
	9.5 mm Mixture	9.5 mm Superpave Specification	12.5 mm Mixture	12.5 mm Superpave Specification
19.0	100	-	100	100 min
12.5	100	100 min	94.0	90-100
9.5	94.0	90-100	86.0	90 max
4.75 (No. 4)	64.0	90 max	61.0	-
2.36 (No. 8)	42.0	32-67	42.0	28-58
1.18 (No. 16)	30.0	-	29.0	-
0.60 (No. 30)	20.0	-	19.0	-
0.30 (No. 50)	13.0	-	13.0	-
0.15 (No. 100)	8.0	-	7.0	-
0.075 (No. 200)	4.2	2-10	4.0	2-10
Optimum Binder Content, %	5.9%	-	5.5%	-

BMDs Results: Volumetric and Performance

Test	Property	9.5 mm Mixture	9.5 mm Superpave Specification	12.5 mm Mixture	12.5 mm Superpave Specification
Volumetric Properties	Air Voids, %	4.1%	4%	4.3%	4%
	Voids in Mineral Aggregate (VMA), %	16.3%	16% min.*	15.5%	15% min.*
	Voids Filled with Asphalt (VFA), %	74.8%	73-76%	72.1%	65-78%
	Dust to Binder Ratio	0.78	0.6-1.2	0.82	0.6-1.2
Rutting	HWTD rutting at 10,000 passes, mm	1.8	-	1.1	-
	HWTD rutting at 20,000 passes, mm	2.9	< 12.5 mm**	1.6	< 12.5 mm**
	HWTD Stripping Inflection Point	NONE	SIP >15,000**	NONE	SIP >15,000**
Cracking	IFIT Flexibility Index (FI)	13.1	>8.0	9.0	>8.0
	IFIT Fracture Energy, J/m^2 (FE)	1,892	-	1,622	-

* MassDOT specifications require a 1% increase in VMA which has been presented.

** MassDOT specification criteria.

Evaluation of Production Considerations

- First, volumetric properties of each mixture were determined with respect to each production consideration.
- The MassDOT specification only requires monitoring of air voids for acceptance testing.
- The mixture air voids must be within ±1.3% of the target of 4%.

Production Considerations: Effects on the BMDs Volumterics

Mixture	Production Consideration		Average Air Voids, % Binder Source A	Average Air Voids, % Binder Source B
9.5 mm	Asphalt Binder Content During Production	Binder Lower Limit (-0.3%)	5.0	4.0
		Optimum Binder Content	4.1	3.2
		Binder Upper Limit (+0.3%)	2.9	2.4*
	Variation of Gradation Passing No. 200 Sieve	-1% No. 200	3.6	4.2
		Design No. 200	4.1	3.2
		+1% No. 200	3.1	3.4
12.5 mm	Asphalt Binder Content During Production	Binder Lower Limit (-0.3%)	5.1	4.6
		Optimum Binder Content	4.3	4.1
		Binder Upper Limit (+0.3%)	3.6	3.0
	Variation of Gradation Passing No. 200 Sieve	-1% No. 200	3.7	3.9
		Design No. 200	4.2	4.1
		+1% No. 200	3.1	3.6

*** Average mixture air voids outside of 4 ± 1.3% production tolerance.**

Production Considerations: Asphalt Binder Content

- Per MassDOT specification, the binder content tolerance during production should be within ±0.3% optimum determined during the mixture design.

- Specimens of each mixture were fabricated at the lower limit (-0.3%) and upper limit (+0.3%) binder contents and tested for their performance (rutting & cracking).

Rutting Results: Asphalt Binder Content

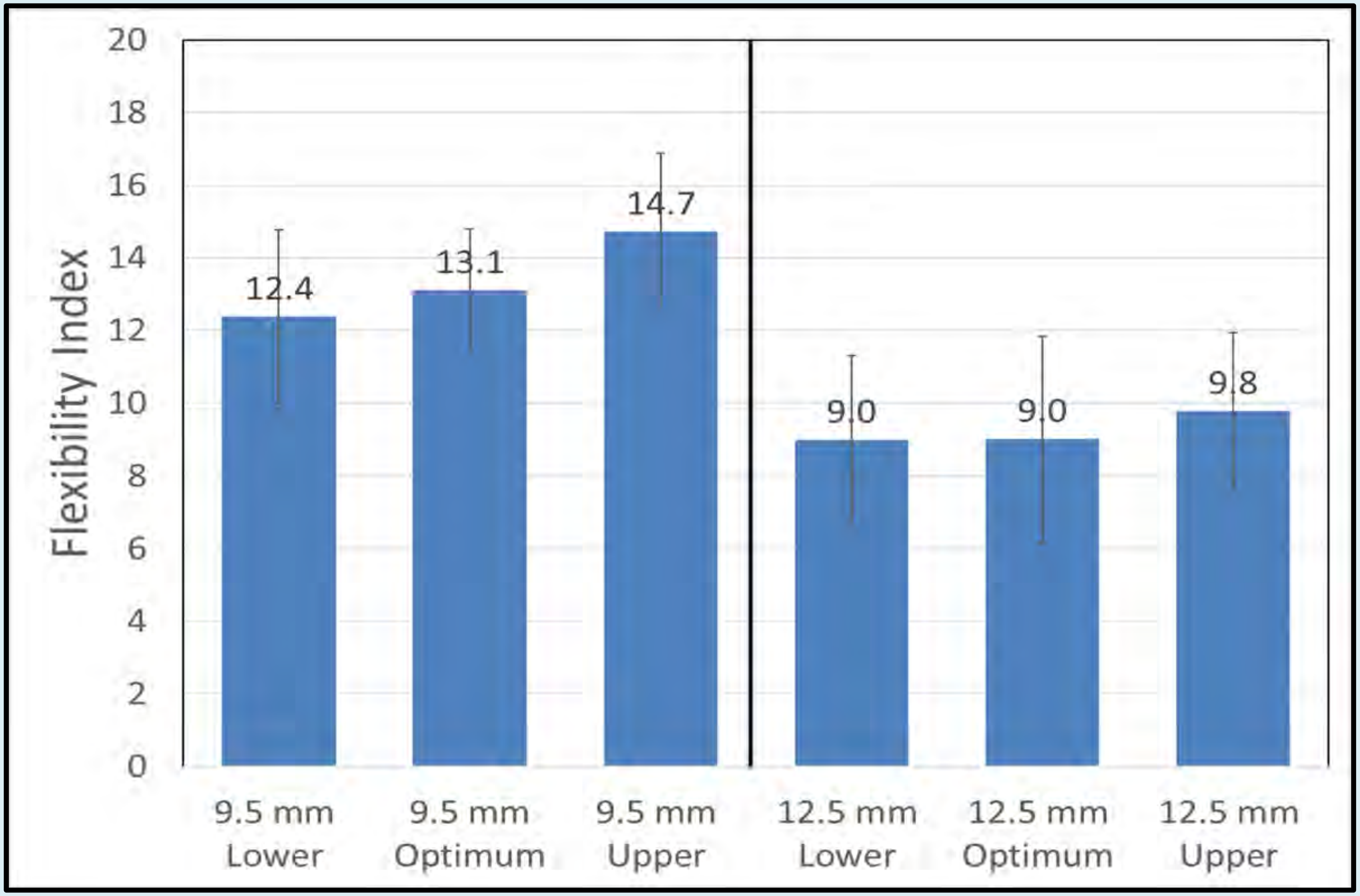
Mixture	Rutting at 10,000 passes, mm	Rutting at 20,000 passes, mm	HWTD Stripping Inflection Point
9.5 mm Binder Lower Limit (-0.3%)	2.8	3.5	NONE
9.5 mm Optimum Binder Content	1.8	2.9	NONE
9.5 mm Binder Upper Limit (+0.3%)	4.1	8.4	10,400*
12.5 mm Binder Lower Limit (-0.3%)	2.3	2.7	NONE
12.5 mm Optimum Binder Content	1.1	1.6	NONE
12.5 mm Binder Upper Limit (+0.3%)	3.3	3.7	NONE

Note: All mixtures prepared with Binder Source A.

MassDOT Pass/Fail Criteria

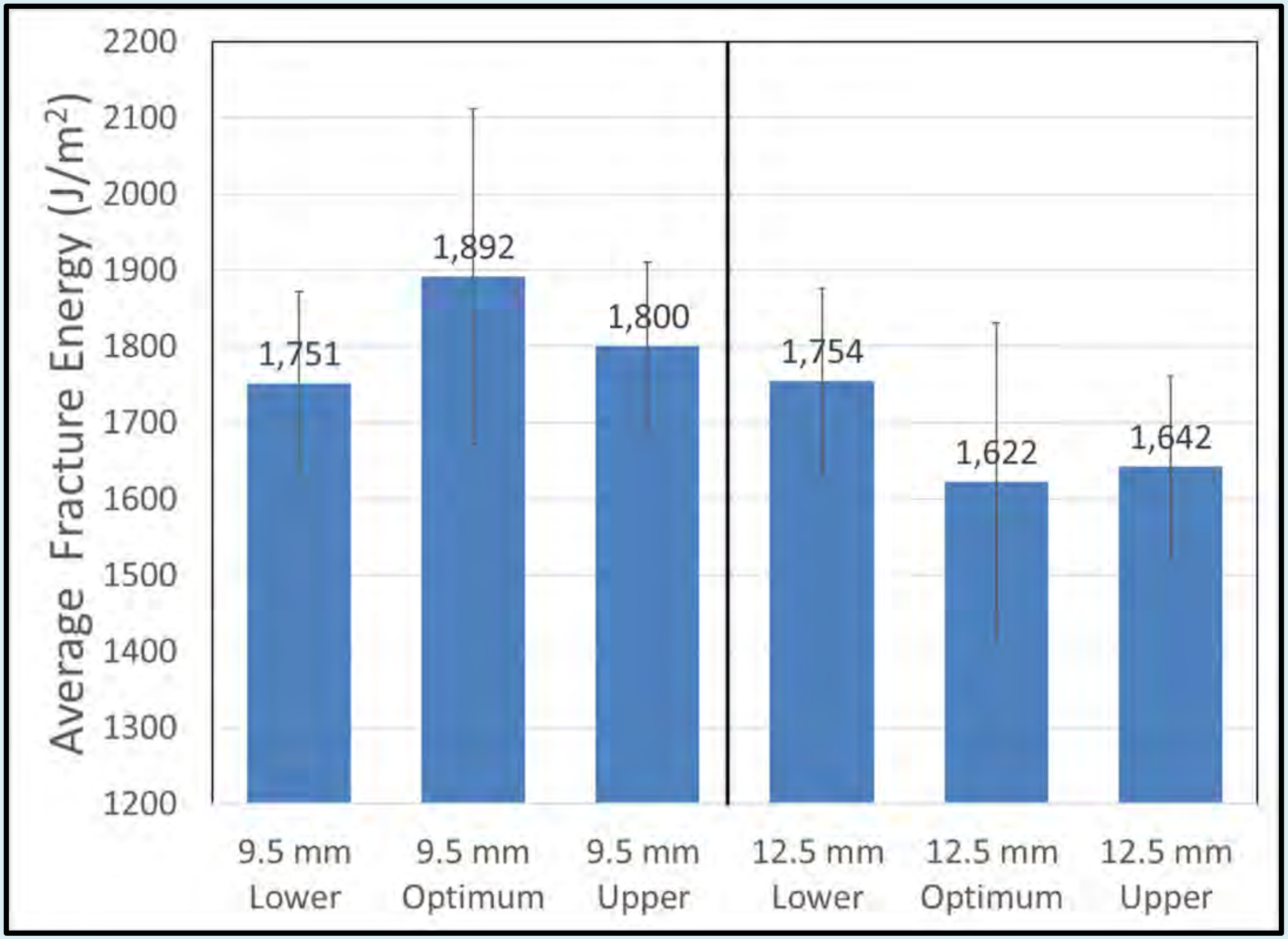
Maximum rut depth of 12.5 mm after 20,000 passes combined with no SIP before 15,000 passes.

Cracking Results: Asphalt Binder Content



Note: All mixtures prepared with Binder Source A.

Cracking Results: Asphalt Binder Content



Note: All mixtures prepared with Binder Source A.

Discussion: Asphalt Binder Content

- The 9.5 mm mixture at the upper limit binder content (+0.3%) was no longer balanced. The MassDOT specification requirements for SIP was not met.

- Generally, all other mixtures provided acceptable rutting and cracking performance in reference to the performance criteria.

Production Considerations: Variation of Gradation Passing No. 200 Sieve

- Per MassDOT specification, the variation of the gradation passing the No. 200 sieve during production should be within ±1.0% of the design percentage determined during the mixture design

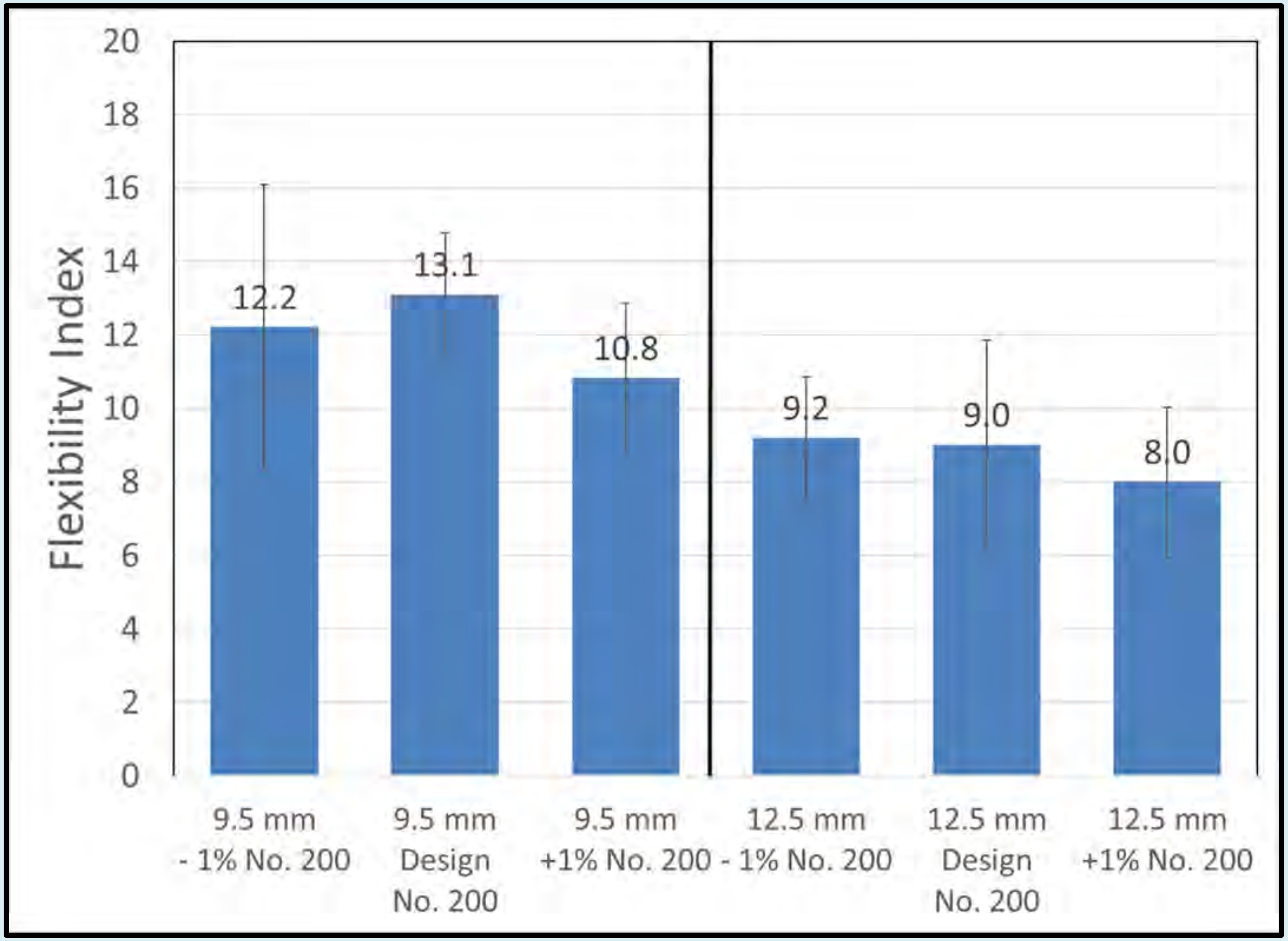
- Specimens of each mixture were fabricated at the lower limit (-1.0%) and upper limit (+1.0%) percent passing the No. 200 and tested for their performance (rutting & cracking).

Rutting Results: Variation of No. 200 Sieve

Mixture	Rutting at 10,000 passes, mm	Rutting at 20,000 passes, mm	HWTD Stripping Inflection Point
9.5 mm -1% No. 200	1.2	1.7	NONE
9.5 mm Design No. 200	1.8	2.9	NONE
9.5 mm +1% No. 200	3.4	4.0	NONE
12.5 mm -1% No. 200	1.6	2.0	NONE
12.5 mm Design No. 200	1.1	1.6	NONE
12.5 mm +1% No. 200	3.1	4.0	NONE

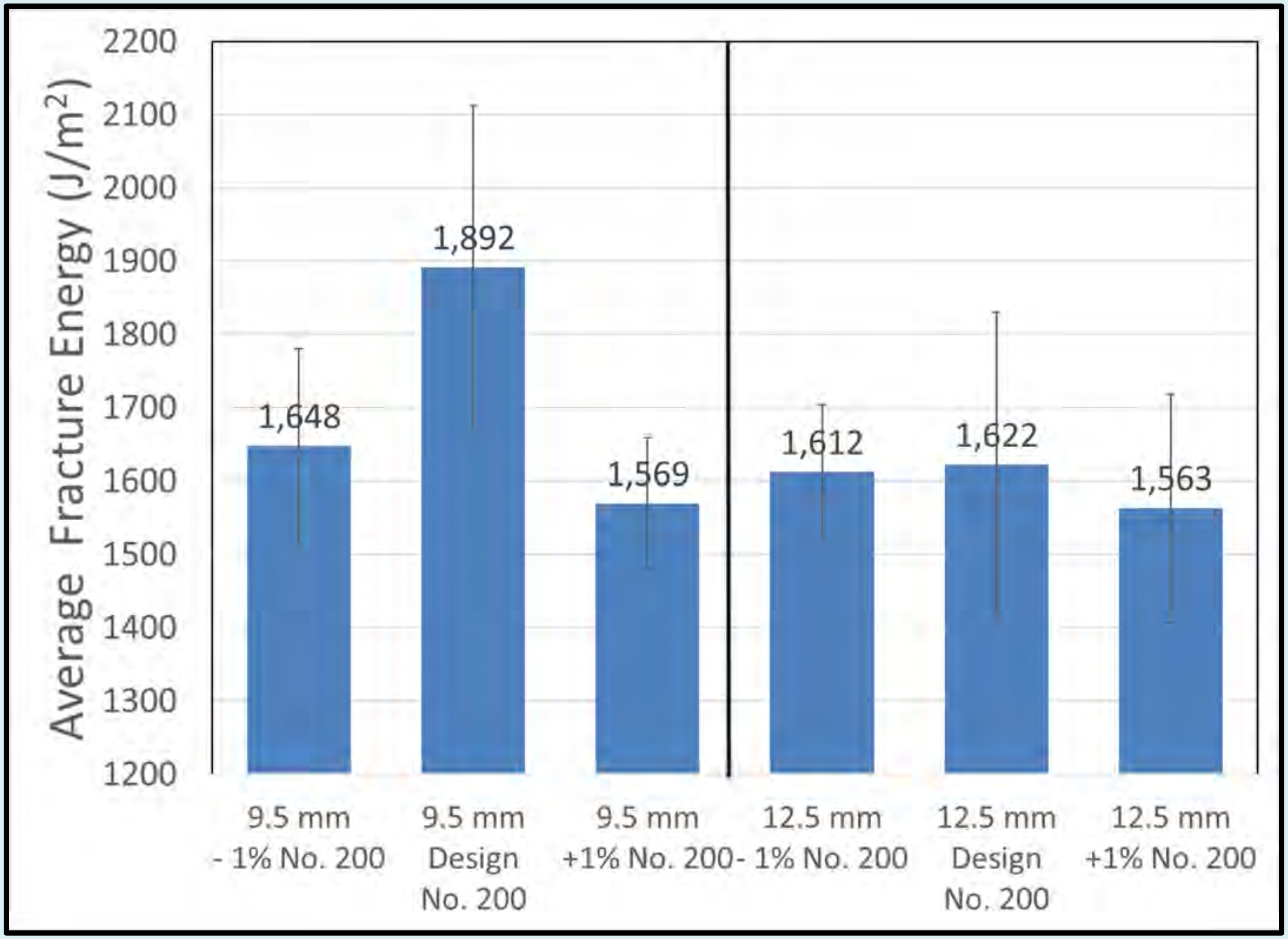
Note: All mixtures prepared with Binder Source A.

Cracking Results: Variation of No. 200 Sieve



Note: All mixtures prepared with Binder Source A.

Cracking Results: Variation of No. 200 Sieve



Note: All mixtures prepared with Binder Source A.

Discussion: Variation of No. 200 Sieve

- Generally, all mixtures provided acceptable rutting and cracking performance using the selected tests.

- This indicated that the mixtures remained balanced with respect to variation of the gradation passing the No. 200 sieve.

Production Considerations: Asphalt Binder Source

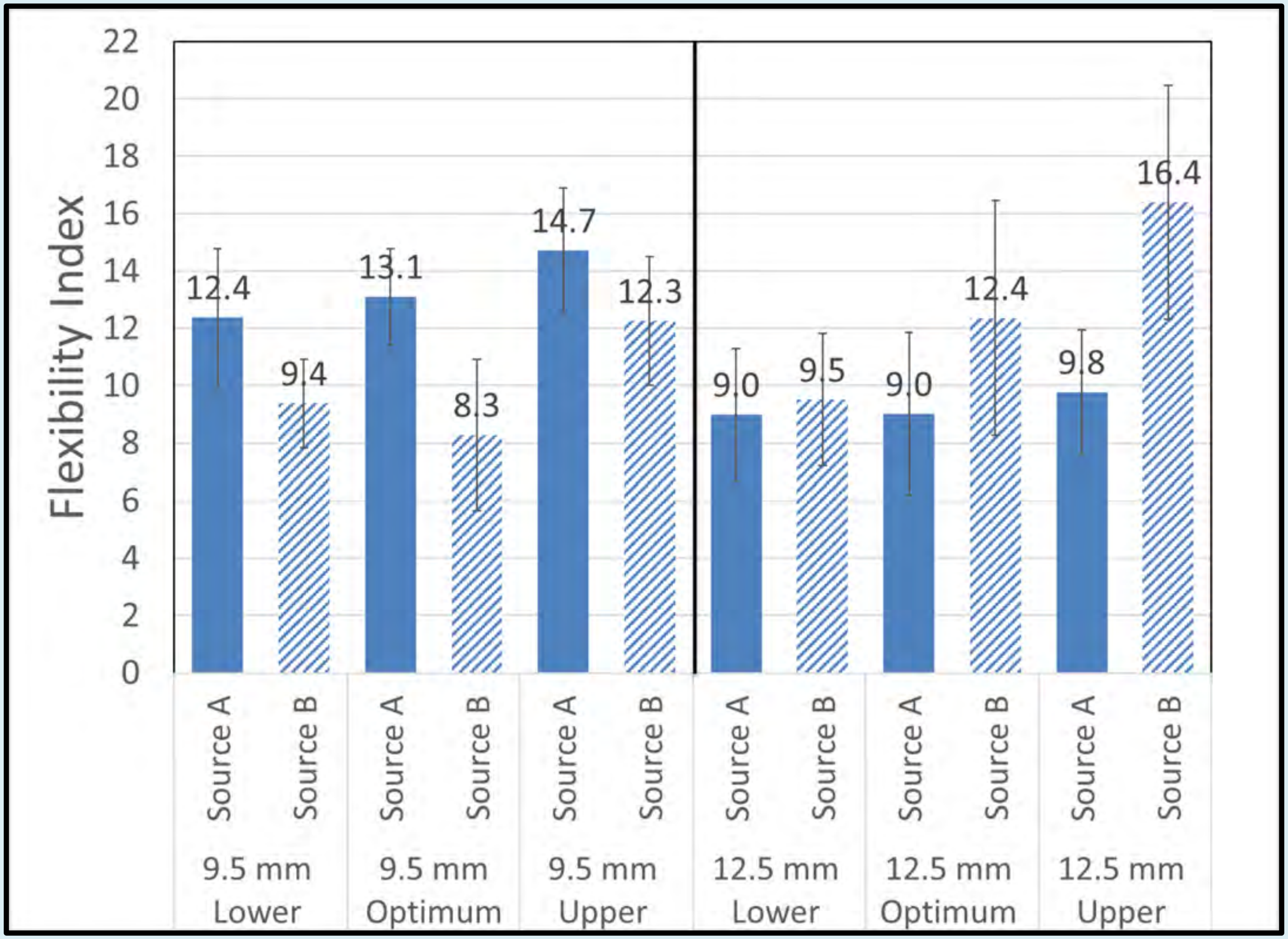
- The potential performance differences in the balance mixture designs were evaluated using two similarly graded PG binders from different sources.
- This shows the impact of changing binder source during production.
- All production consideration effects were re-evaluated using Binder Source B.

Rutting Results: Asphalt Binder Source

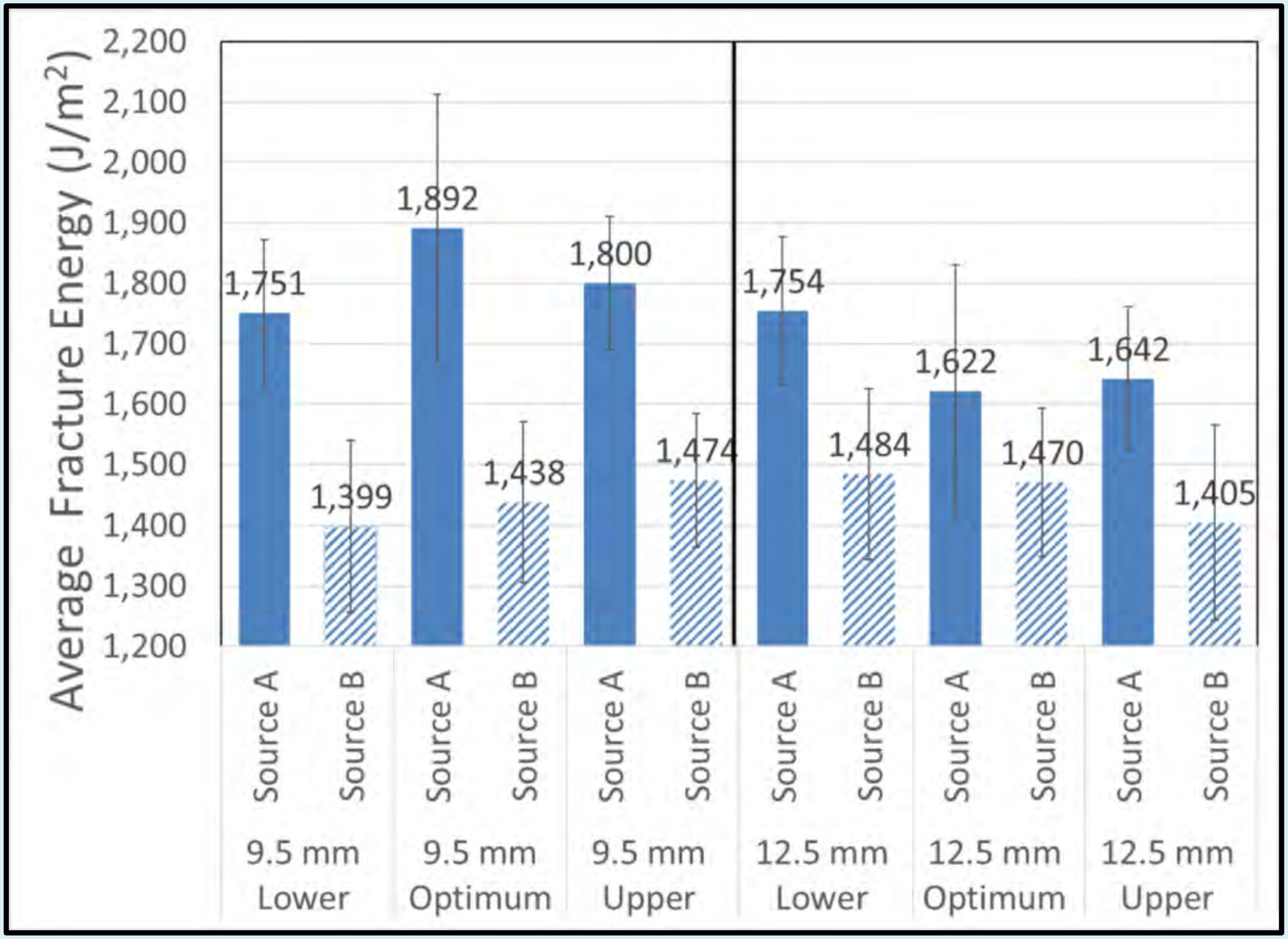
Mixture	Binder Source	Rutting at 10,000 passes, mm	Rutting at 20,000 passes, mm	HWTD SIP
9.5 mm Binder Lower Limit (-0.3%)	Source A	2.8	3.5	NONE
	Source B	1.5	1.9	NONE
9.5 mm Optimum Binder Content	Source A	1.8	2.9	NONE
	Source B	2.4	3.1	NONE
9.5 mm Binder Upper Limit (+0.3%)	Source A	4.1	8.4	10,400
	Source B*	3.3	4.5	NONE
12.5 mm Binder Lower Limit (-0.3%)	Source A	2.3	2.7	NONE
	Source B	2.8	3.7	NONE
12.5 mm Optimum Binder Content	Source A	1.1	1.6	NONE
	Source B	1.5	2.0	NONE
12.5 mm Binder Upper Limit (+0.3%)	Source A	3.3	3.7	NONE
	Source B	3.1	5.2	NONE
9.5 mm -1% No. 200	Source A	1.2	1.7	NONE
	Source B	2.3	3.0	NONE
9.5 mm Design No. 200	Source A	1.8	2.9	NONE
	Source B	2.4	3.1	NONE
9.5 mm +1% No. 200	Source A	3.4	4.0	NONE
	Source B	1.4	1.9	NONE
12.5 mm -1% No. 200	Source A	1.6	2.0	NONE
	Source B	1.7	2.7	NONE
12.5 mm Design No. 200	Source A	1.1	1.6	NONE
	Source B	1.5	2.0	NONE
12.5 mm +1% No. 200	Source A	3.1	4.0	NONE
	Source B	2.5	3.6	NONE

* Mixture failed volumetric requirement for air voids.

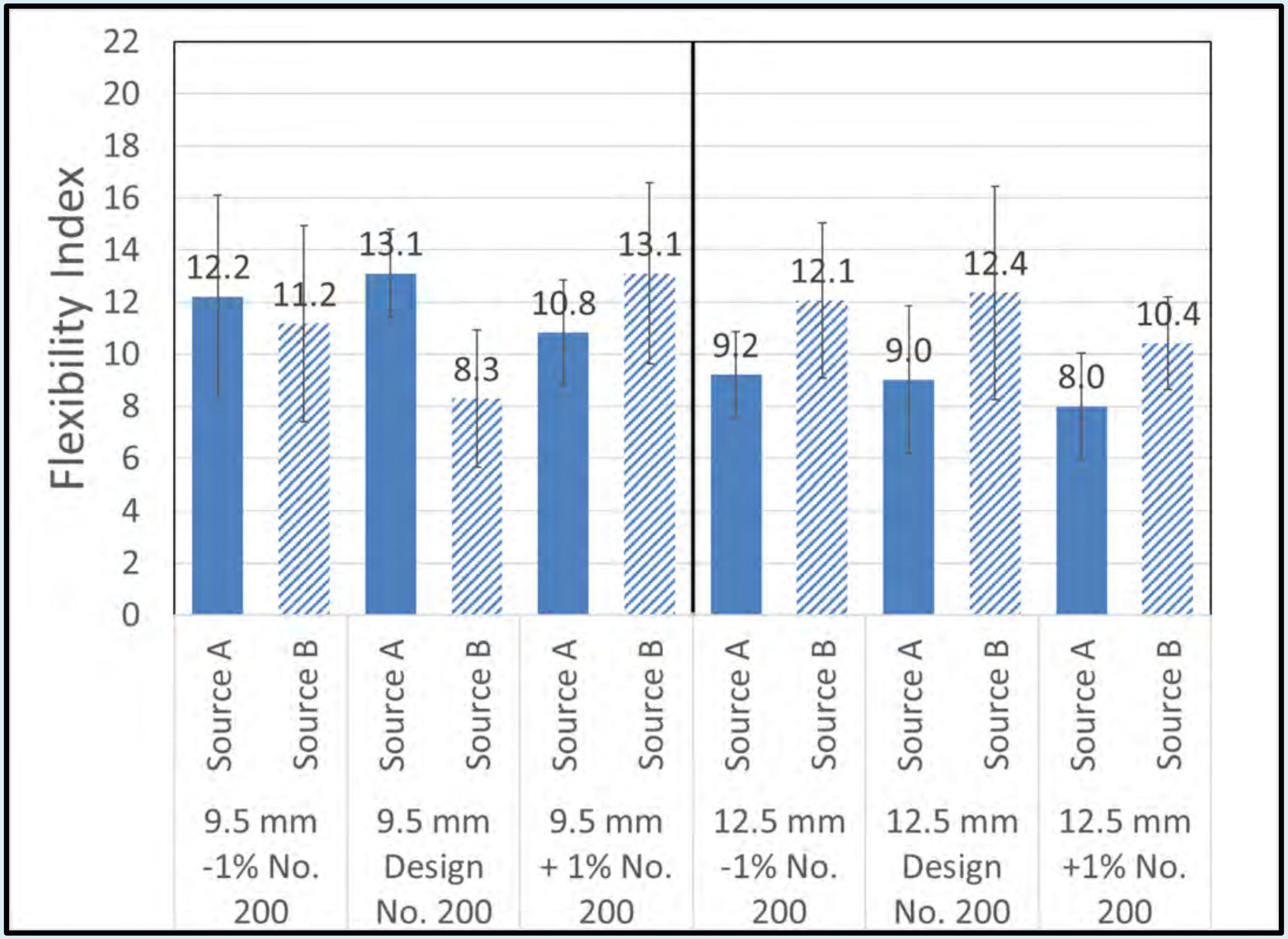
Cracking Results: Binder Source & Binder Content



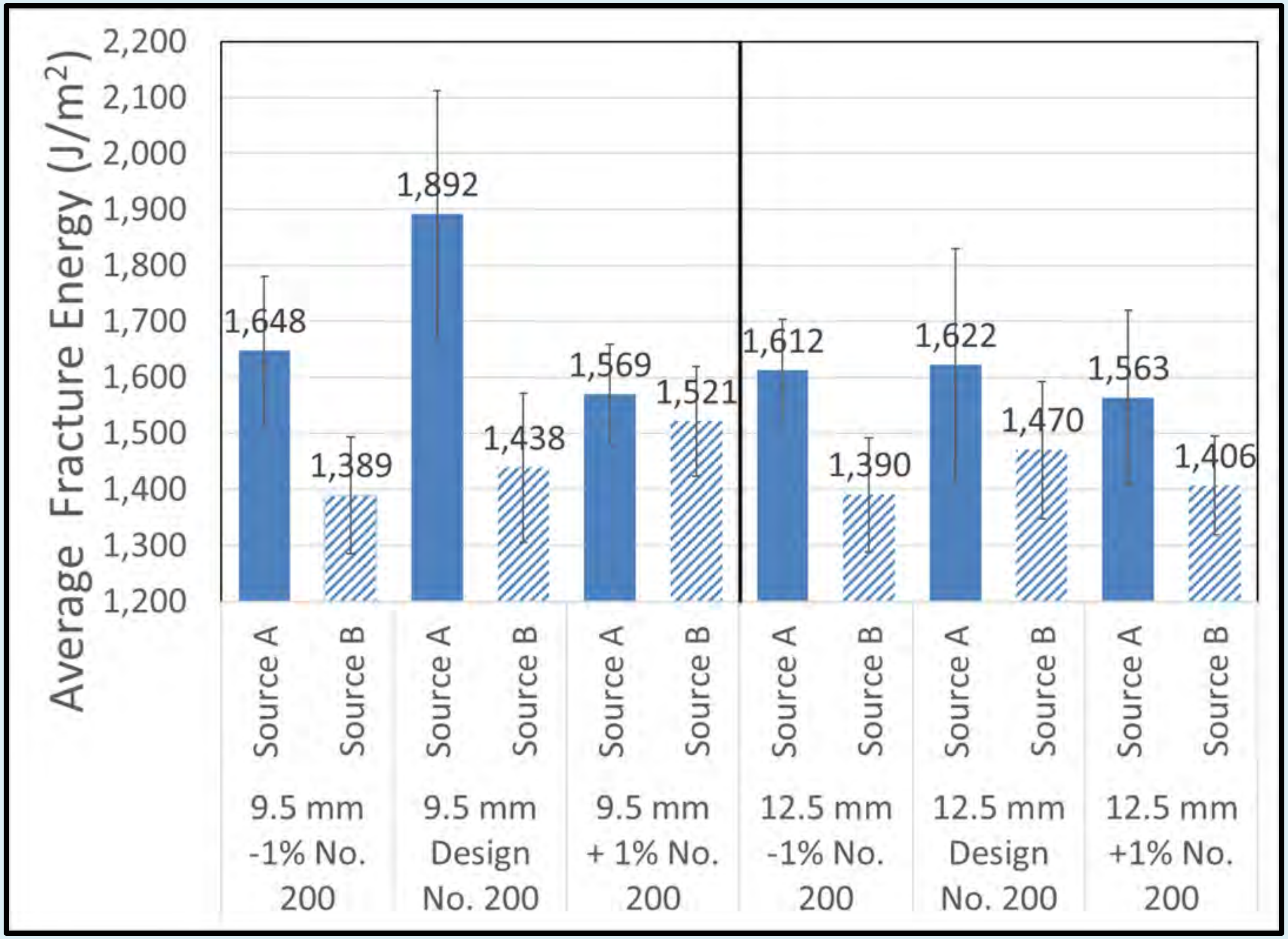
Cracking Results: Binder Source & Binder Content



Cracking Results: Binder Source & No. 200



Cracking Results: Binder Source & No. 200



Discussion: Asphalt Binder Source

- Generally, all mixtures provided acceptable rutting (except one) and cracking performance using the selected tests and criteria.
- This indicated that mixtures remained balanced with respect to asphalt binder source.
- Rutting data did not give an indication that asphalt binder source had a major impact on performance.

Discussion: Asphalt Binder Source

- Changing the binder content or the binder source can have a significant effect on the FI values, however, they all passed.

- No criterion is currently available for the FE values obtained from IFIT test, however the trend was clear. Mixtures fabricated with asphalt binder Source B consistently exhibited lower FE values as compared to those fabricated with asphalt binder Source A.

Discussion: Asphalt Binder Source

- In terms of a balanced mixture design, if FE was utilized as the pass/fail criteria of the cracking test, it would be possible that many of the mixtures fabricated with asphalt binder Source B may fail.

- The FE results suggest that it is conceptually possible to effectively unbalance the mixture design by simply changing the source of asphalt binder.

- This shows the importance of selecting appropriate performance tests and criteria for balanced mixture designs that correlate to field performance.

Conclusions

- This study underscores the importance of understanding the effect of production considerations and compensating for them when developing mixtures using the balanced mixture design concept.

Thank you!