New York State's Balanced Mixture Design (BMD) Research Efforts

Presented By:

Thomas Bennert, Ph.D.
Center for Advanced Infrastructure and Transportation (CAIT)
Rutgers University

Northeast Asphalt Users Producers Group (NEAUPG)
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(Somewhere from my house)

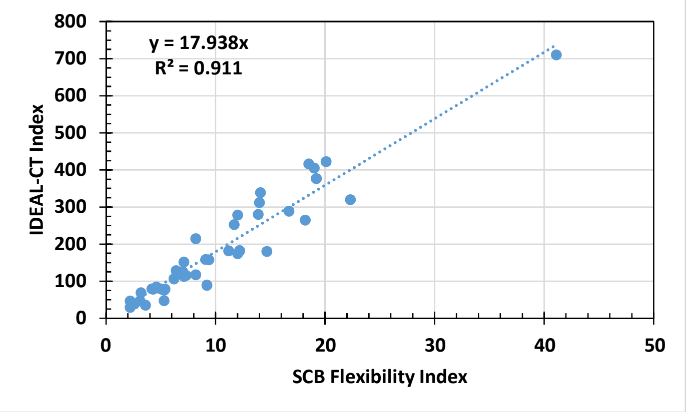
Acknowledgements

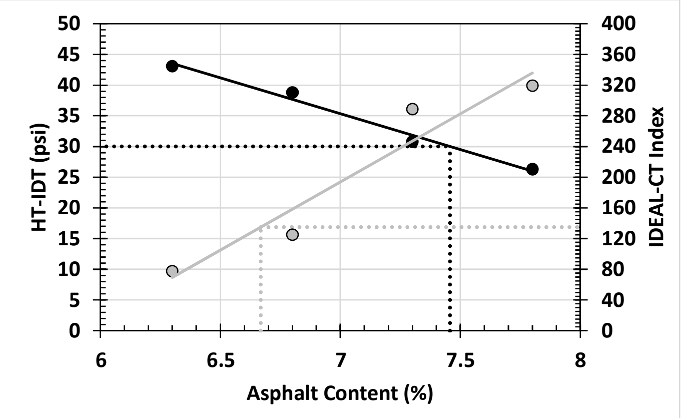
- Zoeb Zavery (Project Manager), NYSDOT
- Ed Wass Jr. and Drew Tulanowski (Mixture Design Verification and Test Specimen Prep)
- Ed Haas (Performance Testing)
- Chris Ericson and Nick Cytowicz (Asphalt Binder Work)

- Majority of work conducted during COVID guidelines at Rutgers University!
  - Over 800 design and volumetric specimens!
  - Over 1000 rutting specimens!
  - Over 1000 fatigue cracking specimens!

Research Goals

- Utilizing different performance tests, evaluate approved NYSDOT asphalt mixtures
  - Determine "limits" of asphalt content for different mixtures based on performance
    - Fatigue performance defining minimum AC%
    - Rutting performance defining maximum AC%
  - Determine "performance based" optimum asphalt content range and compare to volumetric-based asphalt content
  - Evaluate performance criteria for the IDT Test methods
  - Project is for SCOPING – to see where NY mixes are





Methodology

1. Determine raw material properties
    1. Gradation, Gsb, RAP asphalt content and gradation
2. Verify aggregate blends & optimum asphalt content using NYSDOT criteria – adjust asphalt content slightly if needed
3. Produce specimens at -0.5, Opt, +0.5 and +1% optimum asphalt content
    1. Performance samples
    2. Nmax (back-calculated to determine Ndes & Nini)
4. Generate BMD curves to determine optimum range of asphalt content and compare to volumetric
5. Generate database of performance to help establish NYSDOT IDT criteria
    1. Fatigue Cracking: Overlay Tester & SCB FI
    2. Rutting: APA (Rutting at 8,000 cycles) & Hamburg (Rutting at 20,000 cycles)

Mixture Conditioning for Design and Performance Samples

- Design
  - Volumetric conditioning
    - Loose mix conditioning for 2 hours +/- 5 minutes at compaction temperature
  - RAP (Multiple methods in literature how to handle in lab)
    - Heated to same temperature as aggregates (mixing temperature) for 2 hours
    - Added to aggregates in mixing bucket after a five seconds of aggregates mixing dry (before binder added)
    - Based on recommendations from AASHTO R35 – Appendix Section X2.7.2.2
- Performance Specimens
  - Rutting
    - Volumetric Conditioning Only
    - Loose mix conditioning for 2 hours +/- 5 minutes at compaction temperature
  - Fatigue Cracking
    - Volumetric + 4 hours at 135°C (TTI work with MN)
    - Additional conditioning to provide a level of extra aging while still being feasible in a "laboratory workday"

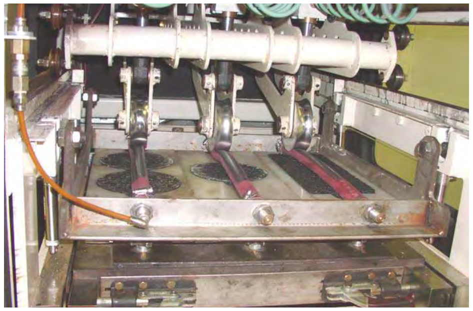
NYSDOT HMA Mixture Verification

- NYSDOT Materials Method 5.16 (2019) used as guidance

Design Criteria/Test Method	Acceptable Tolerance/Variation
Air Voids, V_a (%)	+/- 1.0%
Voids in Mineral Aggregate, VMA (%), for Volumetric Mixes	$VMA_{Table\ 4} - (3.5 - V_{a(lab)})$ when $2.5 \leq V_{a(lab)} \leq 3.5$ $VMA_{Table\ 4} + (V_{a(lab)} - 3.5)$ when $3.5 < V_{a(lab)} \leq 4.5$
Theoretical Maximum Specific Gravity, G_{mm} (g/cm^3)	± 0.019
Bulk Specific Gravity of Compacted HMA Specimen, G_{mb} (g/cm^3)	± 0.028

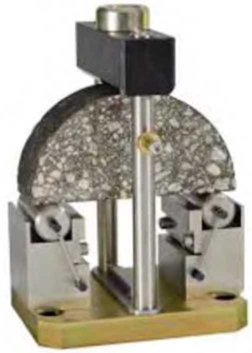
Test Procedures Used in Research Study

RUTTING EVALUATION

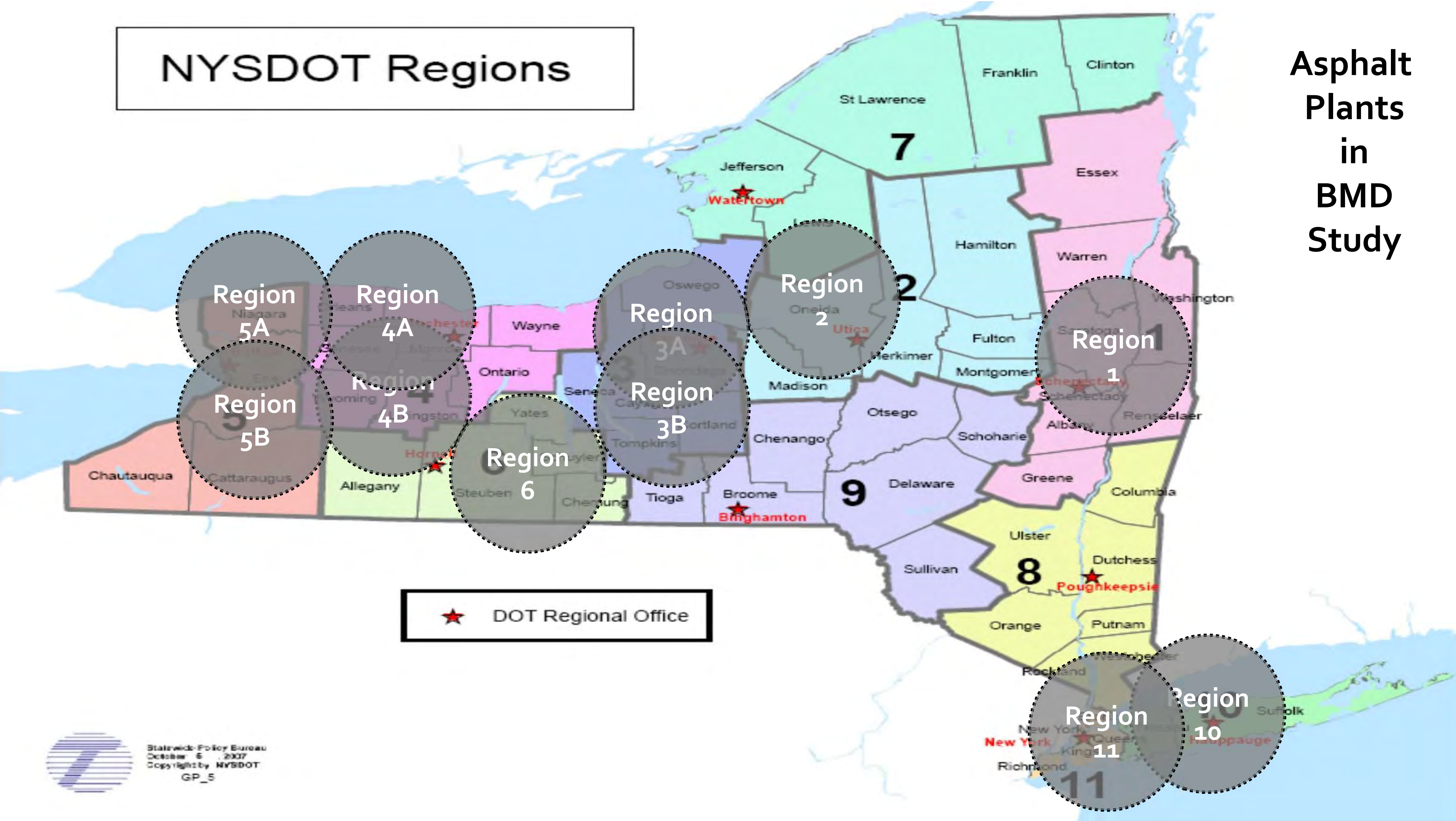


FATIGUE CRACKING EVALUATION





Asphalt Plants in BMD Study



Mixture Verification

Mixture Verification

- After gradations and gravities were determined for each aggregate and RAP source, mixes blended as per JMF
  - RAP had binder recovered for accurate AC%
  - RAP aggregate gravities conducted on recovered aggregates after ignition
  - Modifications were made to blend percentages if gradations off by +/- 4%
    - +/- 2% for No. 200
    - RAP content (by mix weight) always remained constant for JMF
- Optimum asphalt content verified using volumetrics
  - If not met, asphalt content modified to meet final volumetrics

Example of Volumetric Verification

- Volumetrics compared to original design as first step to verify mix
- Example shows good agreement between JMF volumetrics and those of reconstructed mix

Standard Method of Test for

Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens

AASHTO Designation: T 166-12

Standard Method of Test for

Percent Air Voids in Compacted Dense and Open Asphalt Mixtures

AASHTO Designation: T 269-11[1]
ASTM Designation: D 3203-05

Project ID: NYSDOT BMD
Technician: Drew
Date: 4/10/2020

Mix Type: 75 Gyr Design Verification, 9.5mm NMAS
Supplier Mix #7
Gsb: 2.619
% Fines: 5.9

Core ID	AC %	Bulk Specific Gravity	Max. Specific	Air Voids (%)	VMA (%)	VFA (%)	#200/Pbe	%Gmm @ Ninitial	%Gmm @ Ndesign
JMF	6.1	2.350	2.435	3.5	16.20	78.4	0.89	85.8	
Spec		+/- 0.028	+/- 0.019	2.5 to 4.5	> 15.0	60 to 80	0.8 to 1.6	< 89.0	96.5
1	6.1	2.329	2.444	4.7	16.5	71.5	1.13	85.5	95.3
2	6.1	2.335	2.444	4.5	16.3	72.6	1.13	85.7	95.5
3	6.1	2.342	2.444	4.2	16.0	74.0	1.13	86.2	95.8
Average	6.1	2.335	2.444	4.4	16.3	72.7	1.13	85.8	95.6
Table 1 - Verification		2.322	2.416		Minimum				
Requirements		2.378	2.454		15.9				

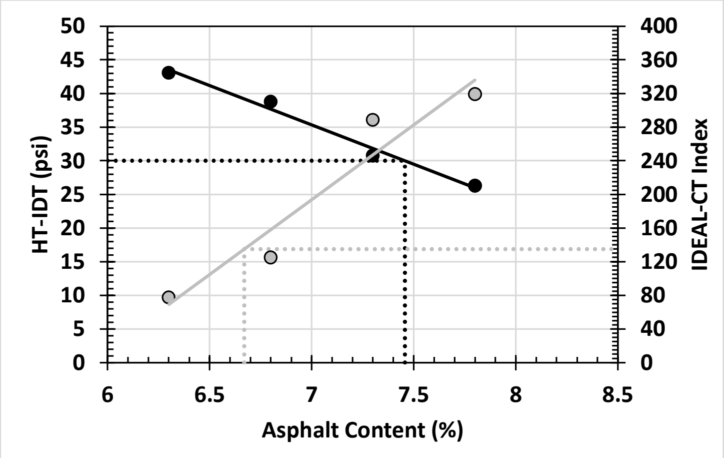
Performance Testing

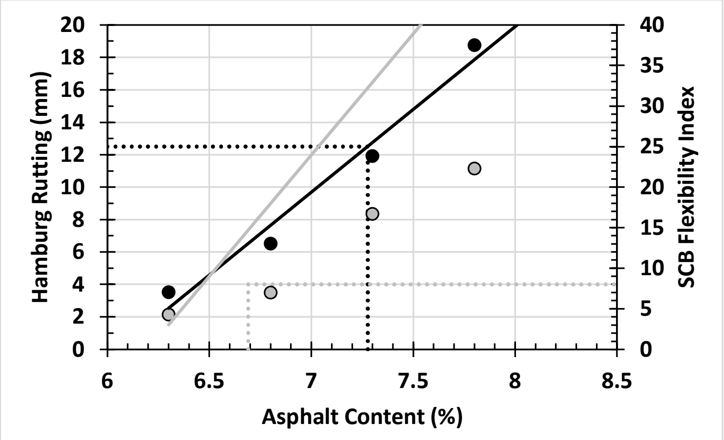
Performance Testing

- Final test specimens were compacted between 5.5 to 6.5% air voids to mirror typical field densities
  - Asphalt Content: -0.5, Opt, +0.5, and +1.0%
- Performance Specimens
  - Rutting
    - Asphalt Pavement Analyzer (AASHTO T340) @ 64C
    - Hamburg Wheel Tracking (AASHTO T324) @ 50C
    - High Temperature IDT (NCHRP 9-33) @ 44C
  - Fatigue Cracking
    - SCB Flexibility Index (AASHTO TP124) @ 25C
    - IDEAL-CT Index (ASTM D8225) @ 25C
    - Overlay Tester (NJDOT B-10) @ 25C

Balanced Mix Design Work

- For graphical presentation, test methods were grouped to determine "balanced" conditions
  - APA and Overlay Tester
  - Hamburg and SCB Flexibility Index
  - HT-IDT and IDEAL-CT Index
- For each mix;
  - Minimum asphalt content = average of fatigue tests
  - Maximum asphalt content = average of rutting tests
  - BMD Range = Maximum - Minimum





Final Performance Criteria for NYSDOT BMD

- Initial criteria determined based on previous NYSDOT research studies

Rutting		Fatigue Cracking	
APA	< 4.0 mm @ 8,000 cycles	Overlay Tester	> 250 cycles
Hamburg	< 12.5 mm @ 20,000 cycles	SCB Flexibility Index	> 8.0
IDT Strength	?	IDEAL-CT Index	?

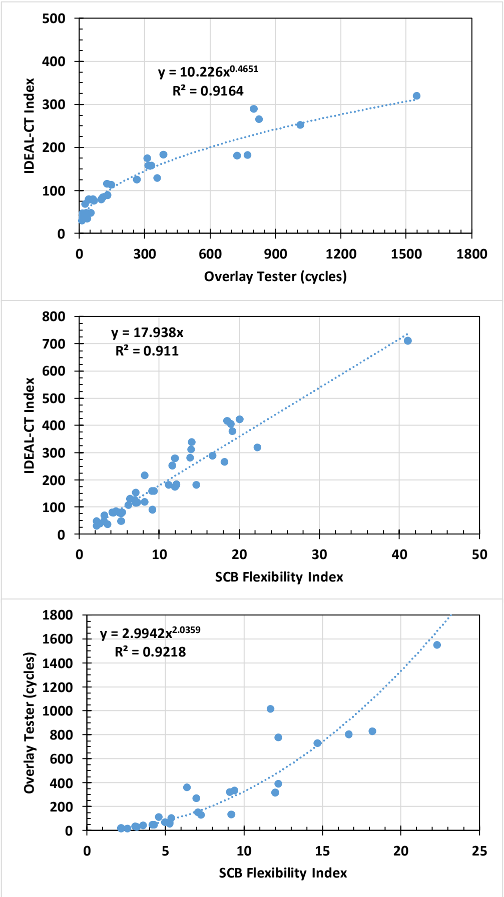
IDT Performance Criteria

- Minimal experience with IDT performance testing in NY
- Used existing “accepted” criteria for different test methods to calibrate IDT performance criteria
  - Fatigue: OT and SCB FI
  - Rutting: APA and Hamburg

NY Performance Database – Fatigue Cracking

- Total of 11 different mixtures provided 44 data sets for comparison of NYSDOT asphalt mixes
- Averaging regressions used to determine "equivalent" IDT parameters
  - Example:
    - SCB FI of 8.0 = IDEAL-CT of 134
      Overlay Tester of 250 = IDEAL-CT of 144
      Average = 138

	IDEAL-CT	OT	SCB FI
Mix #1	38.1	17	2.6
	78.5	102	5.4
	157.8	318	9.1
	182.3	387	12.2
Mix #2	46.3	18	2.2
	79.3	65	5
	115.2	130	7.3
	252.2	1015	11.7
Mix #3	47.1	34	3.1
	84.0	109	4.6
	113.1	149	7.1
	180.1	726	14.7
Mix #4	34.9	39	3.6
	79	46	4.2
	128.2	360	6.4
	181.2	774	12.2
Mix #5	29	14	2.2
	68.3	28	3.2
	75.7	69	5.3
	173.8	314	12
Mix #6	47.1	56	5.3
	89.1	132	9.2
	157.3	332	9.4
	264.8	827	18.2
Mix #7	77.7	45	4.3
	125.1	266	7
	288.7	801	16.7
	319.3	1550	22.3
Mix #8	181.5		11.2
	280		13.9
	376.8		19.2
	710.3		41.1
Mix #9	118.1		7.1
	214.7		8.2
	311.5		14
	422.1		20.1
Mix #10	78		5.1
	151		7.1
	278.1		12
	405		19
Mix #11	105.9		6.2
	117.4		8.2
	338.3		14.1
	415.5		18.5



Final Performance Criteria for NYSDOT BMD

Rutting		Fatigue Cracking	
APA	< 4.0 mm @ 8,000 cycles	Overlay Tester	> 250 cycles
Hamburg	< 12.5 mm @ 20,000 cycles	SCB Flexibility Index	> 8.0
IDT Strength	> 30 psi @ 44°C	IDEAL-CT Index	> 135

Balanced Mix Design (BMD) Results

BMD Analysis – Mix #4 (PG64V-22, 10% RAP)

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

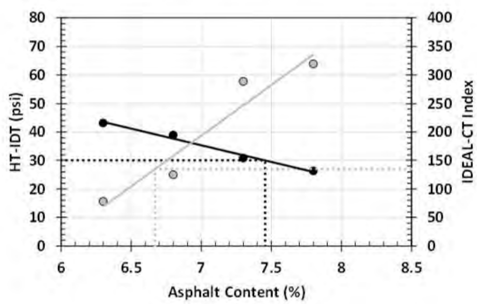
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: Mix #4 **Design Traffic Level:** > 0.3
Supplier: N.A. **Asphalt Binder Grade:** PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: HT-IDT **Criteria:** > 30 psi
Fatigue Cracking Test: IDEAL-CT **Criteria:** > 135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): **6.67**
Maximum Asphalt Content (%): **7.46**
Volumetric Asphalt Content (%): **6.8**

BALANCED

RAPL is accredited by AASHTO's AMRL Program

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

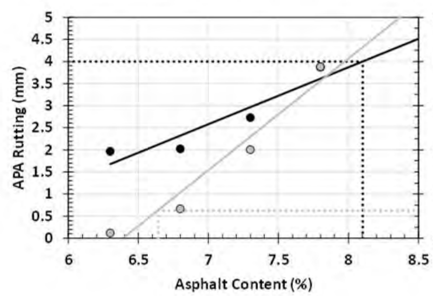
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: Mix #4 **Design Traffic Level:** > 0.3
Supplier: N.A. **Asphalt Binder Grade:** PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: APA **Criteria:** < 4 mm
Fatigue Cracking Test: Overlay Tester **Criteria:** > 250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): **6.64**
Maximum Asphalt Content (%): **8.10**
Volumetric Asphalt Content (%): **6.8**

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Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

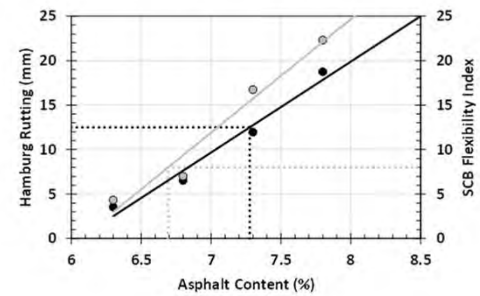
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: Mix #4 **Design Traffic Level:** > 0.3
Supplier: N.A. **Asphalt Binder Grade:** PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: Hamburg Wheel Tracking **Criteria:** < 12.5 mm
Fatigue Cracking Test: SCB Flexibility Index **Criteria:** > 8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): **6.69**
Maximum Asphalt Content (%): **7.28**
Volumetric Asphalt Content (%): **6.8**

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BMD Analysis – Mix #8 (PG64V-22, 15% RAP)

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

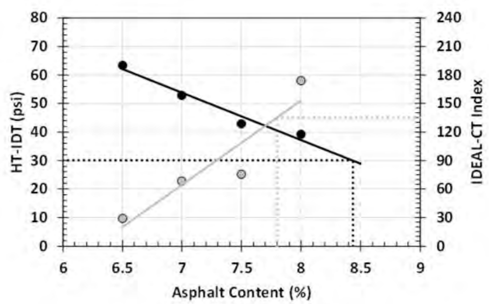
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: Mix #8
Supplier: N.A.
Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: HT-IDT — **Criteria:** > 30 psi
Fatigue Cracking Test: IDEAL-CT — **Criteria:** > 135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): 7.80
Maximum Asphalt Content (%): 8.43
Volumetric Asphalt Content (%): 7

NOT BALANCED

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Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

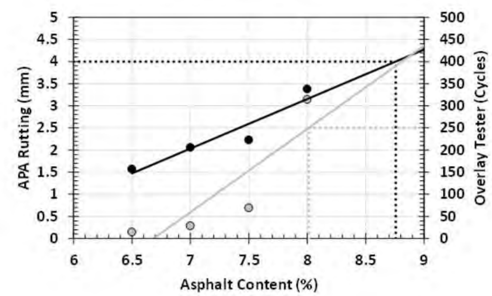
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: Mix #8
Supplier: N.A.
Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: APA — **Criteria:** < 4 mm
Fatigue Cracking Test: Overlay Tester — **Criteria:** > 250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): 8.01
Maximum Asphalt Content (%): 8.76
Volumetric Asphalt Content (%): 7

NOT BALANCED

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Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

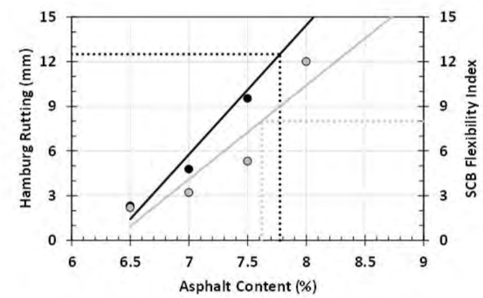
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: Mix #8
Supplier: N.A.
Design Traffic Level: > 0.3
Asphalt Binder Grade: PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: Hamburg Wheel Tracking — **Criteria:** < 12.5 mm
Fatigue Cracking Test: SCB Flexibility Index — **Criteria:** > 8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): 7.62
Maximum Asphalt Content (%): 7.78
Volumetric Asphalt Content (%): 7.0

NOT BALANCED

AAP AASHTO R18

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BMD Analysis – Mix #9 (PG64V-22, 20% RAP)

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

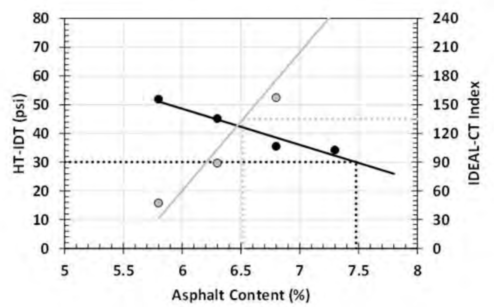
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: Mix #9 **Design Traffic Level:** >0.3
Supplier: N.A. **Asphalt Binder Grade:** PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: HT-IDT **Criteria:** > 30 psi
Fatigue Cracking Test: IDEAL-CT **Criteria:** > 135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): **6.52** **NOT BALANCED**
Maximum Asphalt Content (%): **7.48**
Volumetric Asphalt Content (%): **6.3**

AASHTO R18
RAPL is accredited by AASHTO's AMRL Program

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

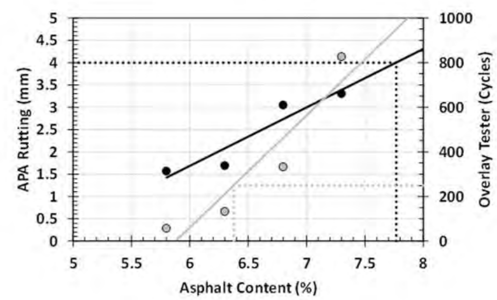
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: Mix #9 **Design Traffic Level:** >0.3
Supplier: N.A. **Asphalt Binder Grade:** PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: APA **Criteria:** < 4 mm
Fatigue Cracking Test: Overlay Tester **Criteria:** > 250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): **6.38** **NOT BALANCED**
Maximum Asphalt Content (%): **7.48**
Volumetric Asphalt Content (%): **6.3**

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Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

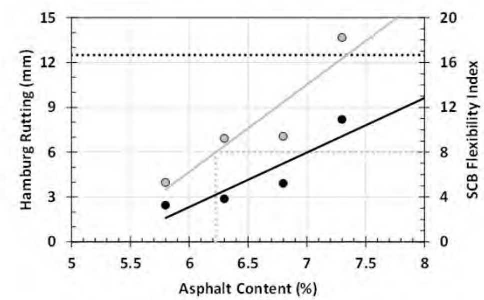
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: Mix #9 **Design Traffic Level:** >0.3
Supplier: N.A. **Asphalt Binder Grade:** PG64V-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: Hamburg Wheel Tracking **Criteria:** < 12.5 mm
Fatigue Cracking Test: SCB Flexibility Index **Criteria:** > 8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): **6.23** **BALANCED**
Maximum Asphalt Content (%): **8.79**
Volumetric Asphalt Content (%): **6.3**

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BMD Analysis – Mix #10 (PG64E-22, 20% RAP)

Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

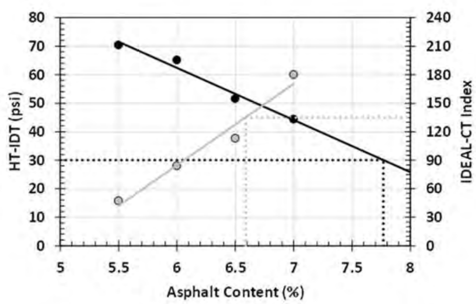
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: Mix #10 **Design Traffic Level:** > 0.3
Supplier: N.A. **Asphalt Binder Grade:** PG64E-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: HT-IDT **Criteria:** > 30 psi
Fatigue Cracking Test: IDEAL-CT **Criteria:** > 135

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): 6.59
Maximum Asphalt Content (%): 7.77
Volumetric Asphalt Content (%): 6.0

NOT BALANCED

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Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

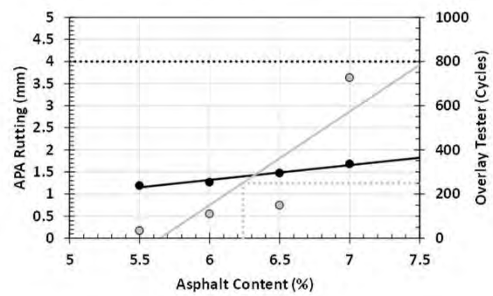
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: Mix #10 **Design Traffic Level:** > 0.3
Supplier: N.A. **Asphalt Binder Grade:** PG64E-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: APA **Criteria:** < 4 mm
Fatigue Cracking Test: Overlay Tester **Criteria:** > 250 cycles

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): 6.24
Maximum Asphalt Content (%): 13.99
Volumetric Asphalt Content (%): 6

NOT BALANCED

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Standard Specification for
Balanced Mix Design

AASHTO Designation: M XXX-XX

AASHTO

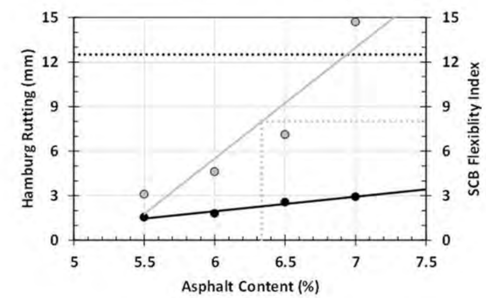
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Region: Mix #10 **Design Traffic Level:** > 0.3
Supplier: N.A. **Asphalt Binder Grade:** PG64E-22

PERFORMANCE TESTS AND CRITERIA

Rutting Test: Hamburg Wheel Tracking **Criteria:** < 12.5 mm
Fatigue Cracking Test: SCB Flexibility Index **Criteria:** > 8

PERFORMANCE TEST RESULTS



Minimum Asphalt Content (%): 6.33
Maximum Asphalt Content (%): 16.77
Volumetric Asphalt Content (%): 6.0

NOT BALANCED

RAPL is accredited by AASHTO's AMRL Program

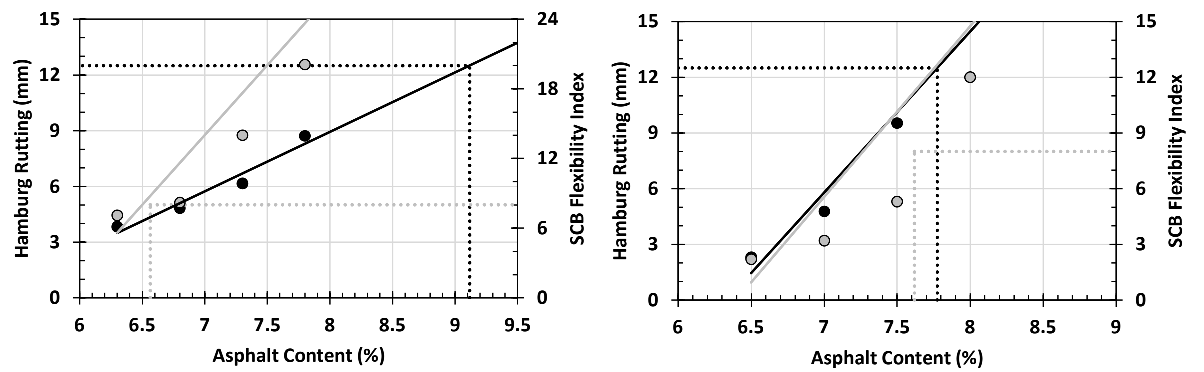
Balanced Mix Design Results

- Based on lab "verified" determined Optimum AC%
  - Optimum AC% is defined as average minimum asphalt content to achieve fatigue cracking performance
- For the 11 mixes tested;
  - 4 of 11 mixes were shown to be "Balanced"
  - 2 of 11 mixes had exactly minimum AC%
  - 5 of 11 mixes were not "Balanced" – under asphalted
  - ALL mixes met the rutting requirements

Mix Type	Minimum Asphalt Content (%)		Vol. vs
	Performance	Volumetric	Perform.
Mix #1	6.6	6.8	0.2
Mix #2	5.6	6.1	0.5
Mix #3	6.5	6.8	0.3
Mix #4	6.7	6.8	0.1
Mix #5	6.5	6.2	-0.3
Mix #6	5.9	5.5	-0.4
Mix #7	6.5	6.1	-0.4
Mix #8	7.8	7.0	-0.8
Mix #9	6.3	6.3	0.0
Mix #10	6.4	6.0	-0.4
Mix #11	6.7	6.7	0.0

Balanced Mix Design Results

- Another factor to consider is not just minimum asphalt content, but the “range” within a BMD
- Narrow ranges would make mixture difficult to produce within tolerances
  - Most mixes resulted in an average BMD range that could be achievable during production
    - Including a tolerance for AC%



Mix Type	Vol. vs Perform.	BMD AC% Range	RAP Content (%)	Binder Grade
Mix #1	0.2	1.2	20	PG64V-22
Mix #2	0.5	2.7	15	PG64V-22
Mix #3	0.3	2.4	15	PG64V-22
Mix #4	0.1	1.0	10	PG64V-22
Mix #5	-0.3	2.1	20	PG64V-22
Mix #6	-0.4	4.7	20	PG64V-22
Mix #7	-0.4	3.4	15	PG64V-22
Mix #8	-0.8	0.5	15	PG64V-22
Mix #9	0.0	1.7	20	PG64V-22
Mix #10	-0.4	6.5	20	PG64E-22
Mix #11	0.0	3.6	20	PG64E-22

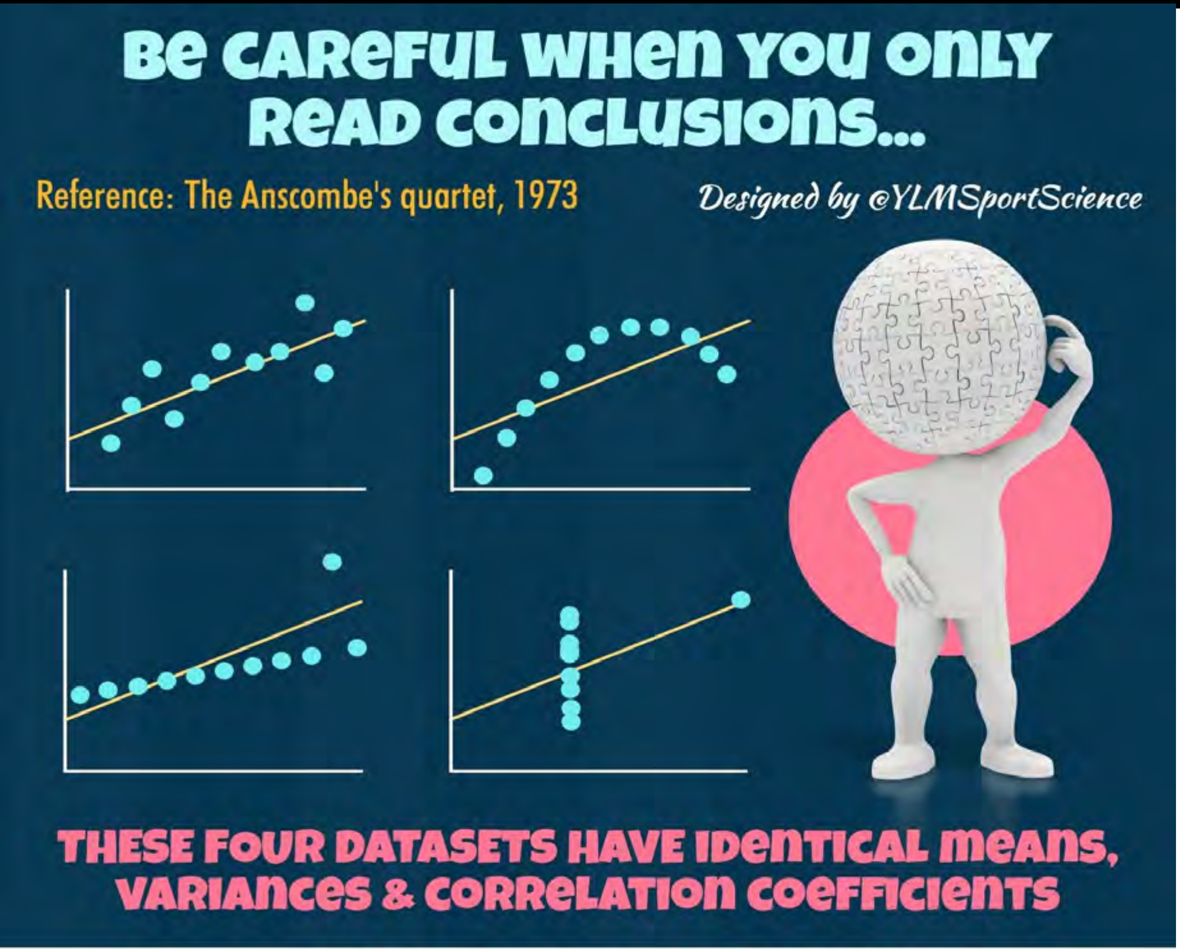
Summary and Conclusions

- NYSDOT investing in understanding BMD concepts and inclusion of performance testing to validate mix design
- Mixtures selected in study showed varying levels of rutting and fatigue performance
  - 5 of 11 PASSED BMD criteria; 4 of 11 FAILED BMD criteria
  - 2 of 11 had exact minimum AC% to meet fatigue
  - ALL mixes met rutting requirements!
- Majority of mixtures showed a BMD range that would allow for production and still maintain production tolerances

Summary and Conclusions

- Some questions that still need to be determined to move forward
  - Selection of BMD optimum asphalt content
    - Fatigue minimum + production tolerance?
    - Middle of BMD range?
  - Implementation of aging protocols?
    - Method should consider required time to reduce time delays
  - Quality control testing?
    - Implement different test methods for design and then QC testing?
    - What to do with failing results? Pay adjustments?
    - Timing of testing (how soon after specimen production)?
  - Educating regions and industry on proper testing and analysis procedures

Thank you for your time!
Questions?



Thomas Bennert, Ph.D.
Rutgers University
609-213-3312
bennert@soe.rutgers.edu