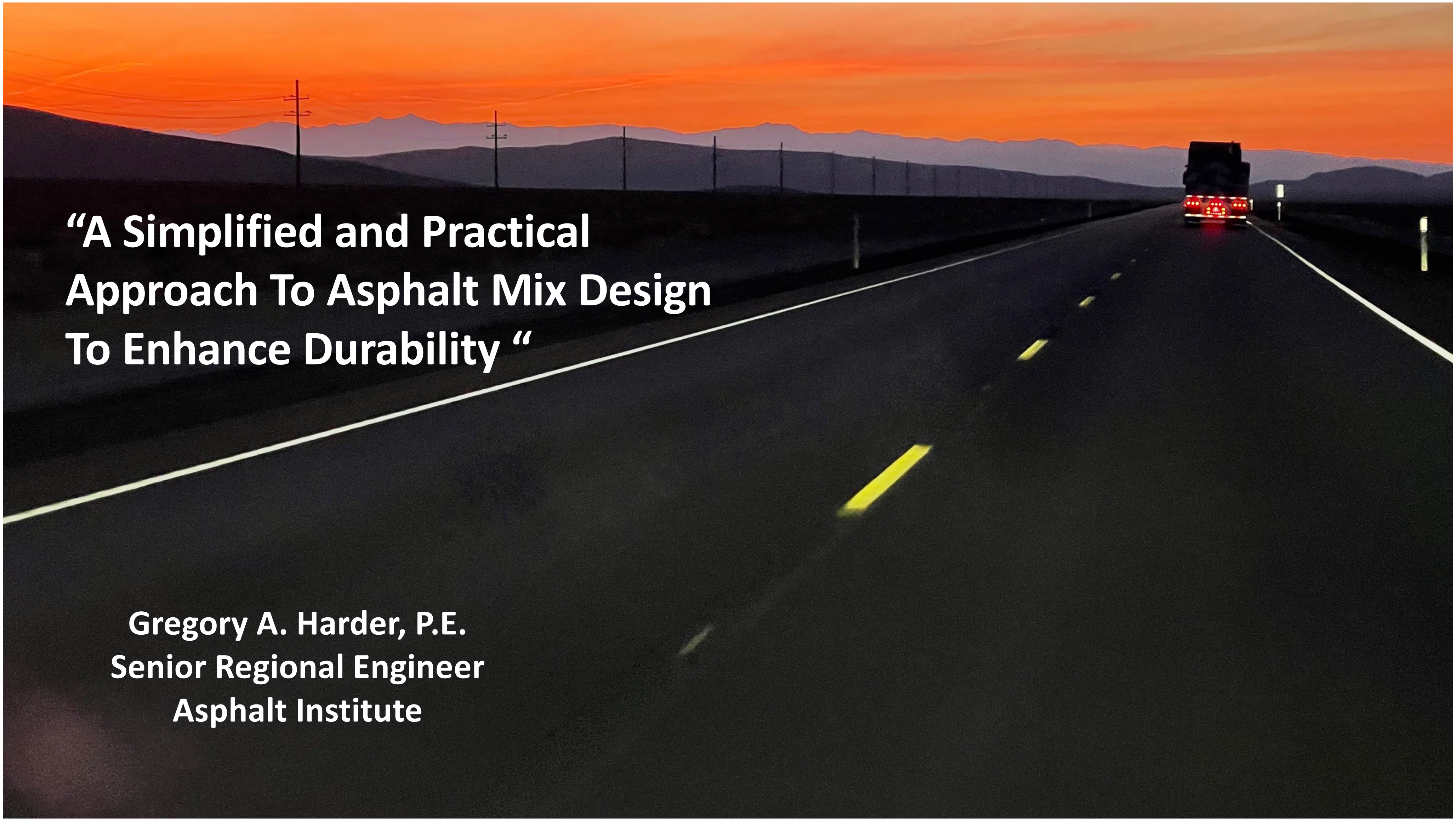
"A Simplified and Practical
Approach To Asphalt Mix Design
To Enhance Durability "
Gregory A. Harder, P.E.
Senior Regional Engineer
Asphalt Institute

Give me a **B** Give me an **M** Give me a **D**

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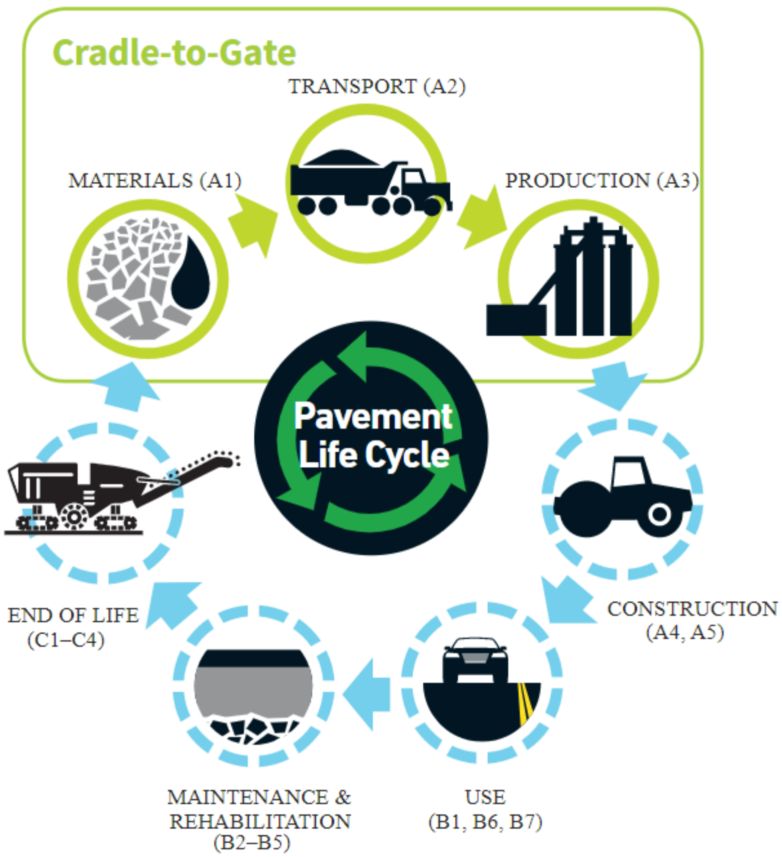
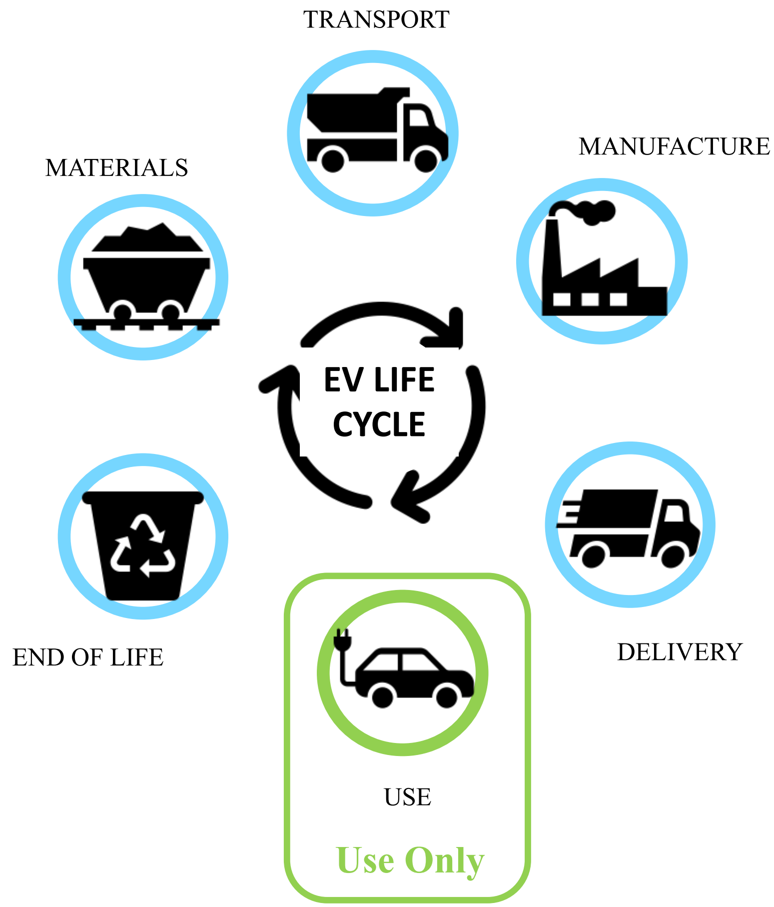
EPD's


Cradle-to-Gate
TRANSPORT (A2)
MATERIALS (A1)
PRODUCTION (A3)
Pavement Life Cycle
END OF LIFE (C1–C4)
CONSTRUCTION (A4, A5)
MAINTENANCE & REHABILITATION (B2–B5)
USE (B1, B6, B7)


TRANSPORT
MATERIALS
MANUFACTURE
EV LIFE CYCLE
END OF LIFE
DELIVERY
USE
Use Only

Concerns With Balanced Mix Design (BMD)

- Current tests
  - Not performance tests (FHWA-HIF-19-103)
  - FI vs CT Index
    - FI : fatigue, top down, reflective
    - CT : thermal, reflective
  - What is the distress?
- Lack of long term aging
- Selection of criteria
- Selection of binder content for “balanced mixes”
- Agency expectations

Index Tests

- Work recently done at UNR (Rami Chkaiban)
- 5 different mixes with similar index values
- Additional testing done and run through FlexPave prediction modeling software
- Significantly different performances predicted

UNR Study – Rami Chkaiban

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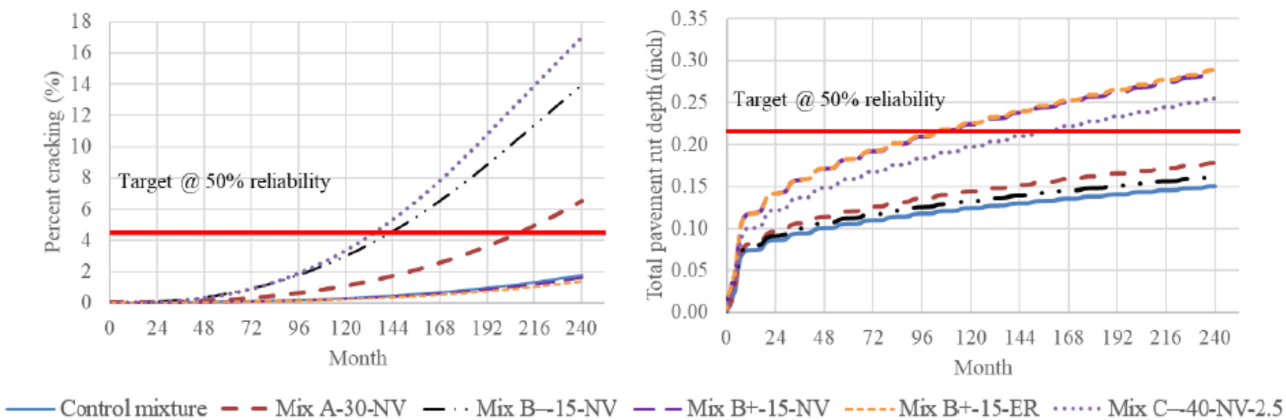
Step 3: BMD influence on predictive pavement performance
(Method 1: Predict pavement performance using default pavement section.)

- FlexPAVE™ 1.1 predictive pavement performance → 8” AC, 8” Base, over Subgrade.



Mixture	Pass/fail target reliability	
	Percent cracking	Total pavement rut depth
Control mixture	Pass	Pass
Mix A-30-NV	Fails at month 209	Pass
Mix B$^-$-15-NV	Fails at month 143	Pass
Mix B$^+$-15-NV	Pass	Fails at month 108
Mix B$^+$-15-ER	Pass	Fails at month 108
Mix C$^-$-40-NV-2.5	Fails at month 135	Fails at month 156

UNR Study – Rami Chkaiban

Step 4: BMD influence on predictive pavement performance
(Conclusions)

- BMD mixtures with similar index-based performance tests parameters ⇒ ≠ predictive pavement performance.

- BMD mixtures with similar index-based performance tests parameters cannot be substituted in pavement design.

- BMD mixtures with similar performance may require different pavement structure ⇒ similar predictive pavement performance.

Aging

- Balanced Mix Design (BMD) process, is an asphalt mixture design process that uses performance tests on appropriately conditioned specimens to address primary modes of distress while taking into consideration asphalt mixture aging, traffic, climate, and location of the mixture within the pavement structure. (FHWA-HIF-19-103)
- How is this being accomplished?

Long Term Oven Aging

With the advancement of Balanced Mixture Design (BMD), laboratory performance tests for asphalt materials are being assessed for their relation to cracking performance in the field. However, most BMD applications do not account for long-term aging. This gap limits the appropriateness of thresholds and the potential of BMD to improve pavement performance as the plethora of additives and reclaimed materials available can behave in drastically different fashions between early, intermediate, and late stages of service. In this study, five mixtures with documented field performance from the Federal Highway Administrations Accelerated Loading Facility were subjected to long-term oven aging (LTOA) protocols. In addition to reheating loose mixtures containing reclaimed asphalt pavement and shingles, the two LTOA methods were 8 h at 135°C and 3 d at 95°C. The objective of this paper is to compare aging approaches, particularly whether equivalence between long-term aged procedures exists, and to highlight the sensitivity (or lack thereof) of common laboratory mixture performance tests. The Indirect Tensile Cracking (IDEAL-CT), Illinois Flexibility Index, Asphalt Mixture Performance Tester cyclic fatigue, and dynamic modulus tests were employed.
The results show a collapse in mixture cracking indices when LTOA is incorporated, raising concerns over BMD implementation using criteria established exclusively with short-term oven aging. Use of |E*|/sin() presented a universal and logic shift in response from the reheated to LTOA state, affirming utility as an aging index. Blending insights can possibly be gleaned from the data, although 95 and 135 LTOA procedures yield mostly equivalent linear viscoelastic and cracking indices.

With the advancement of Balanced Mixture Design (BMD), laboratory performance tests for asphalt materials are being assessed for their relation to cracking performance in the field. However, most BMD applications do not account for long-term aging. This gap limits the appropriateness of thresholds and the potential of BMD to improve pavement performance as the plethora of additives and reclaimed materials available can behave in drastically different fashions between early, intermediate, and late stages of service.

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The results show a collapse in mixture cracking indices when LTOA is incorporated, raising concerns over BMD implementation using criteria established exclusively with short-term oven aging.

TRBAM-22-03912

David J. Mensching, PhD., PE
TFHRC

Selection of Criteria

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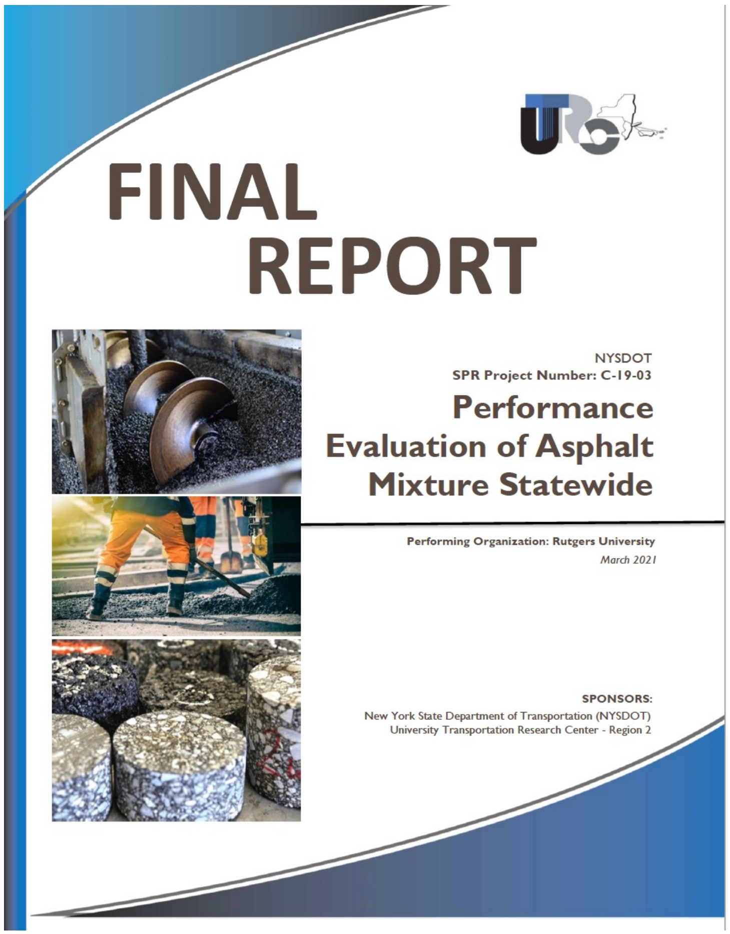
- Should be done based on actual field performance
- Not benchmarking
- VA used mean values
- CT Index
  - NY -135
  - PA – 70-90
  - VA – 70
  - FL – 30
  - OK – 80
  - AL – 55, 83, 110

  Flexibility Index FI
  - NY - 8
  - NH - 10
  - IL – 8-16 ; 5-10
  - MO – 2-6
  - CA - 3
- Some mixes might get worse



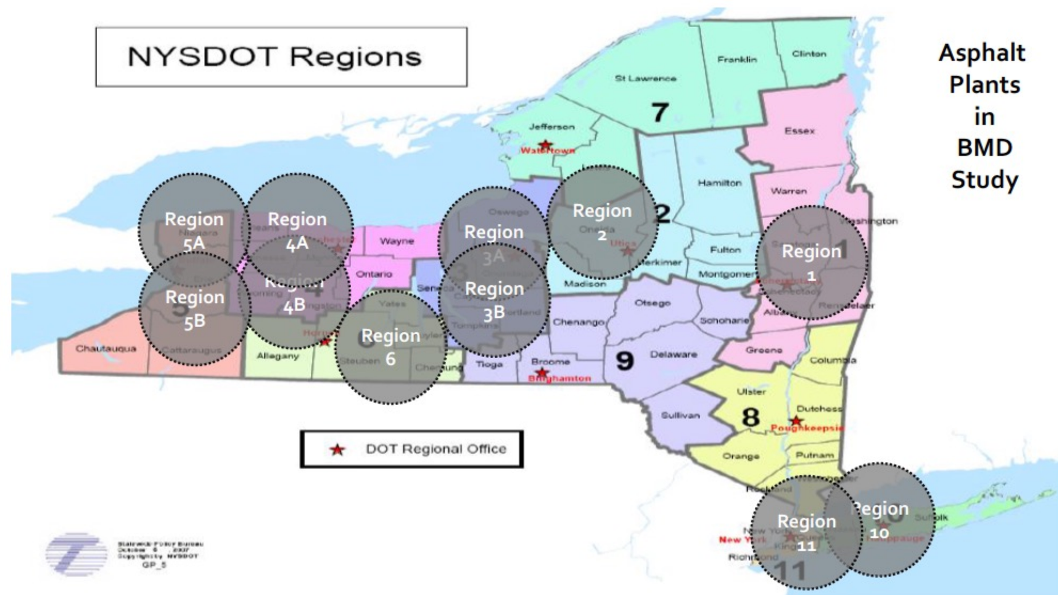


Figure 6 – Regional Locations of Asphalt Mixtures Evaluated in NYSDOT BMD Study

Asphalt Plants in BMD Study

Balanced Mix Design Results

- Comparing Volumetric vs Performance Optimum AC%
  - Performance Minimum AC% is defined as average minimum asphalt content to achieve fatigue cracking performance
- For the 11 mixes tested;
  - 5 of 11 mixes were shown to be "Balanced"
  - 6 of 11 mixes were not "Balanced" or under-asphalted
  - <u>ALL mixes met the rutting requirements</u>

Mix Type	Minimum Asphalt Content (%)		Vol. vs Perform.
	Performance	Volumetric	
Mix #1	6.59	6.8	0.21
Mix #2	5.57	6.1	0.53
Mix #3	6.67	6.8	0.13
Mix #4	6.36	6.8	0.44
Mix #5	6.54	6.2	-0.34
Mix #6	5.91	5.5	-0.41
Mix #7	6.50	6.1	-0.40
Mix #8	7.81	7.0	-0.81
Mix #9	6.38	6.3	-0.08
Mix #10	6.39	6.0	-0.39
Mix #11	6.63	6.7	0.07

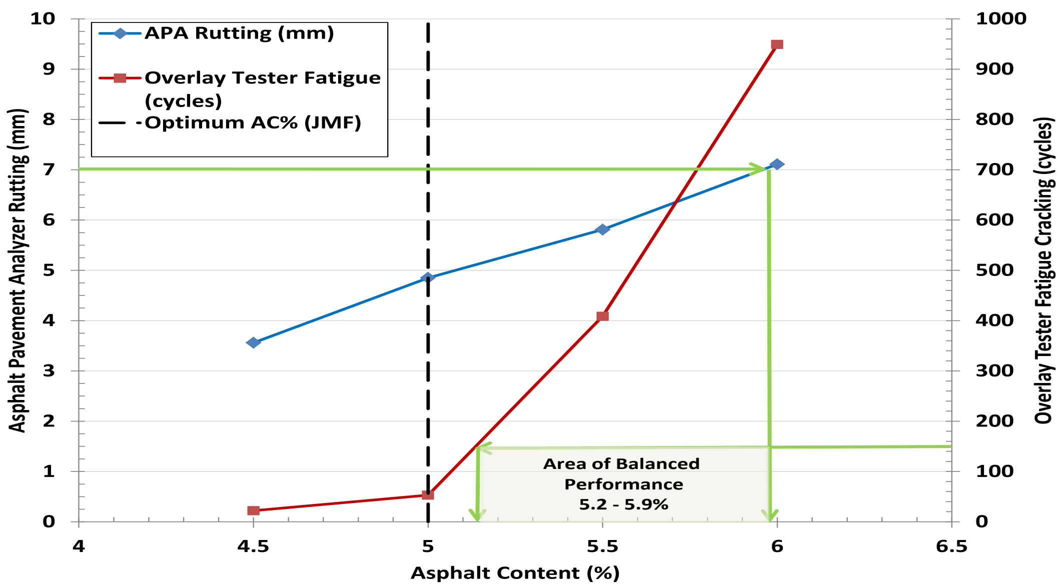
Condition	Standard Deviation (1s)[a]	Acceptable Range of Two Test Results (d2s)[a]
Single-operator precision		
Asphalt content (%)	0.069	0.196
Multilaboratory precision		
Asphalt content (%)	0.117	0.330

[a] These values represent the 1s and d2s limits described in ASTM C670.

Courtesy of Tom Bennert

Selection of Binder Content

- Who determines the binder content?
  - Minimize cracking (high end of the range)
  - Middle of the BMD range (*truly balanced*)
  - Minimize rutting (low end of the range)

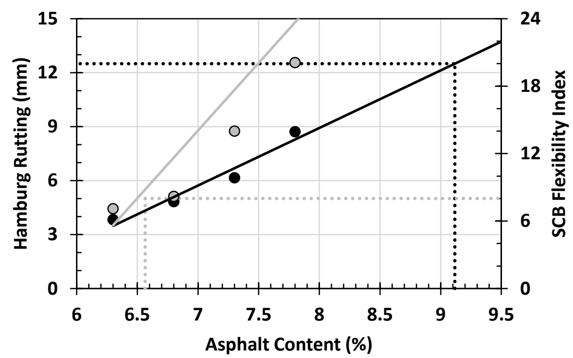


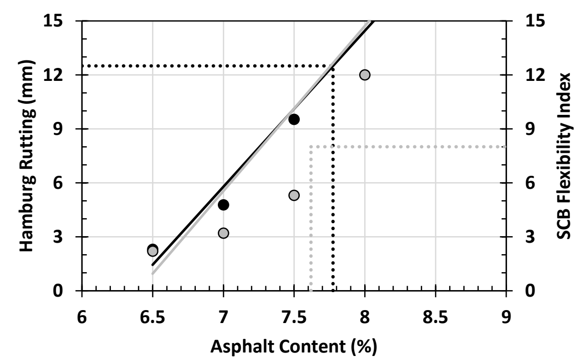
Criteria was selected based on **VIRGIN** mixes

Courtesy of Tom Bennert

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	BMD AC% Range	Vol. vs Perform.	RAP Content (%)	Low Temp PG of RAP	Binder Grade
Mix #1	1.2	0.21	20	-16.4	PG64V-22
Mix #2	2.7	0.53	15	-17.3	PG64V-22
Mix #3	0.9	0.13	15	-17.8	PG64V-22
Mix #4	2.8	0.44	10	-20.3	PG64V-22
Mix #5	2.1	-0.34	20	-18.6	PG64V-22
Mix #6	4.7	-0.41	20	-16.7	PG64V-22
Mix #7	3.3	-0.40	15	-11.2	PG64V-22
Mix #8	0.5	-0.81	15	-14.6	PG64V-22
Mix #9	1.6	-0.08	20	-15.7	PG64V-22
Mix #10	6.5	-0.39	20	-16.5	PG64E-22
Mix #11	3.6	0.07	20	-17	PG64E-22

Courtesy of Tom Bennert

Agency Expectations

- This is not the holy grail
- Improved performance is not guaranteed with BMD
- FHWA Mission Statement:

> *"The Path Forward for Asphalt Pavement Performance will guide FHWA Pavement & Materials engineers in focusing their efforts to increase asphalt pavement performance by fostering science surrounding data-driven approaches to asphalt pavement across its life cycle in order to improve sustainability, including mobility, economy, and safety. This Path Forward will guide FHWA as we assist stakeholders in the implementation of BMD and performance testing tools to attain incremental improvements in mixture durability, cost effective designs, and innovation."*

Acknowledgement

WHRP
Wisconsin Highway Research Program

WISCONSIN DEPARTMENT OF TRANSPORTATION

- Project 0092-14-06 Critical Factors Affecting Asphalt Durability
  - Evaluate changes to the composition of asphalt mixtures that WisDOT should consider to improve durability
    - Resistance to load associated cracking
    - Resistance to aging

http://wisconsindot.gov/documents2/research/14-06-revised-final-report.pdf

Advanced Asphalt Technologies, LLC
"Engineering Services for the Asphalt Industry"

Improving Durability

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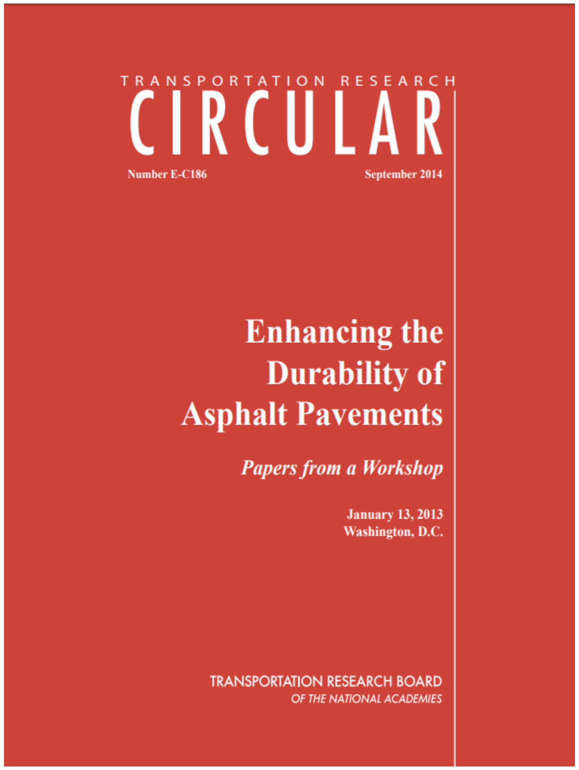
- Increase Effective Volume of Binder
- Use Polymer Modification
- Use Softer Grade of Binder
- Place Limits on Recycled Binder Effectiveness



http://onlinepubs.trb.org/onlinepubs/circulars/ec186.pdf

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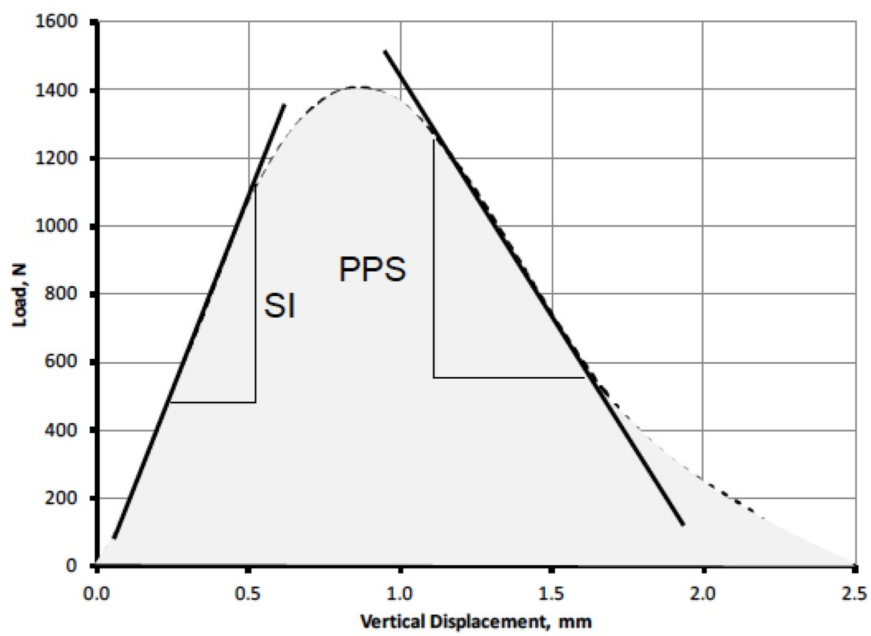
Illinois SCB (Flexibility Index)



FI = Energy/Post Peak Slope
Resistance to cracking
increases with increasing FI

Advanced Asphalt Technologies, LLC
Engineering Services for the Asphalt Industry"

Example Design Specification

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Effective RAP Binder Ratio	Minimum Design VBE, vol %							
	58-28 S	58-28 H	58-28 V	58-28 E	58-34 S	58-34 H	58-34 V	58-34 E
0.00	10.0	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
>0.00 ≤0.05	10.4	10.2	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
>0.05 ≤0.10	10.7	10.5	10.1	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
>0.10 ≤0.15	11.1	10.9	10.4	**10.0**	**10.0**	**10.0**	**10.0**	**10.0**
>0.15 ≤0.20	11.5	11.3	10.8	10.2	10.1	**10.0**	**10.0**	**10.0**
>0.20 ≤0.25	11.9	11.7	11.2	10.6	10.4	10.2	**10.0**	**10.0**
>0.25 ≤0.30	12.2	12.0	11.5	11.0	10.8	10.6	10.1	**10.0**
>0.30 ≤0.35	Low Temperature Grade Controls				11.2	11.0	10.5	**10.0**
>0.35 ≤0.40					11.5	11.3	10.9	10.3
>0.40 ≤0.45					11.9	11.7	11.2	10.6
>0.45 ≤0.50					12.3	12.1	11.6	11.0

Trial Section 1 – RAP Binder Contribution

October 2012- After one year

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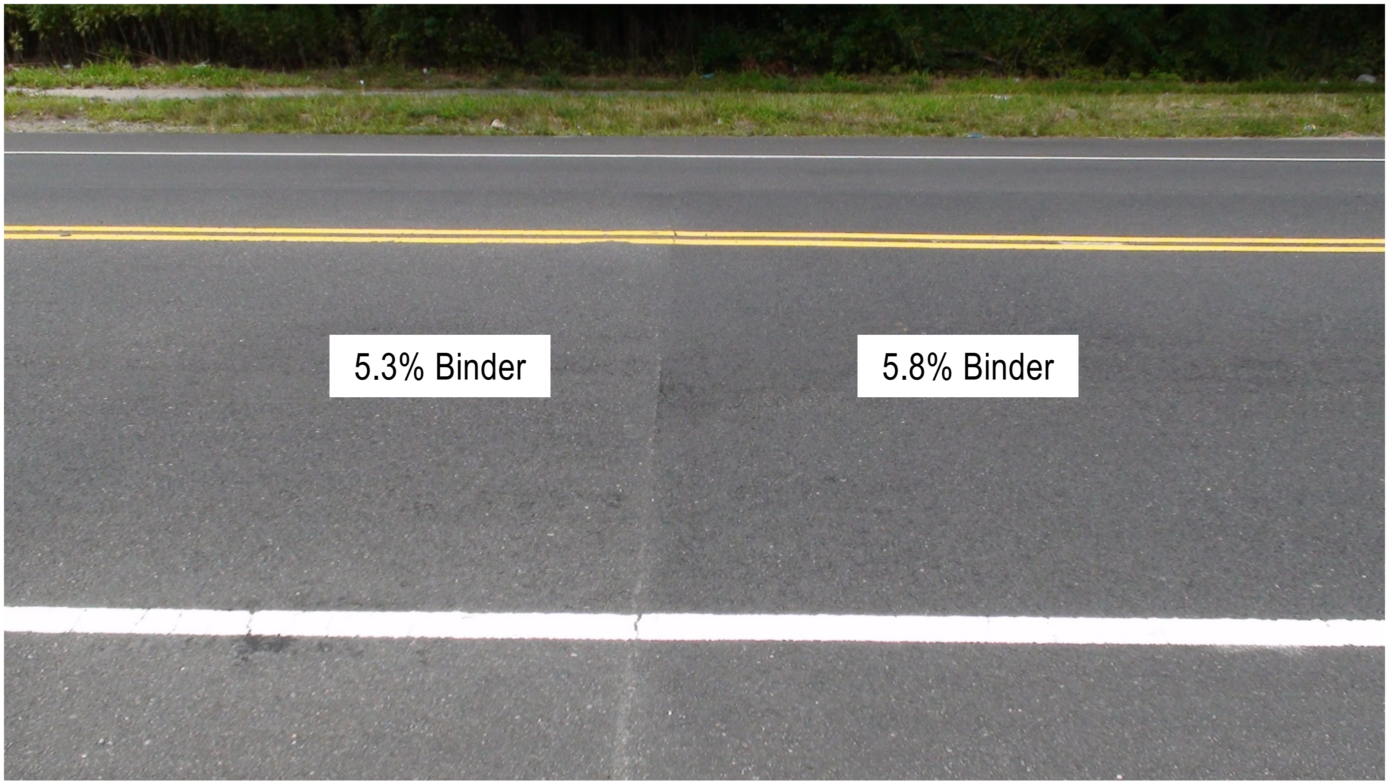

NEW YORK STATE

Research Approach

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RAP Design

- Volumetric Design – Perform rutting index test at DBC, -0.5, +0.5, and +1.0

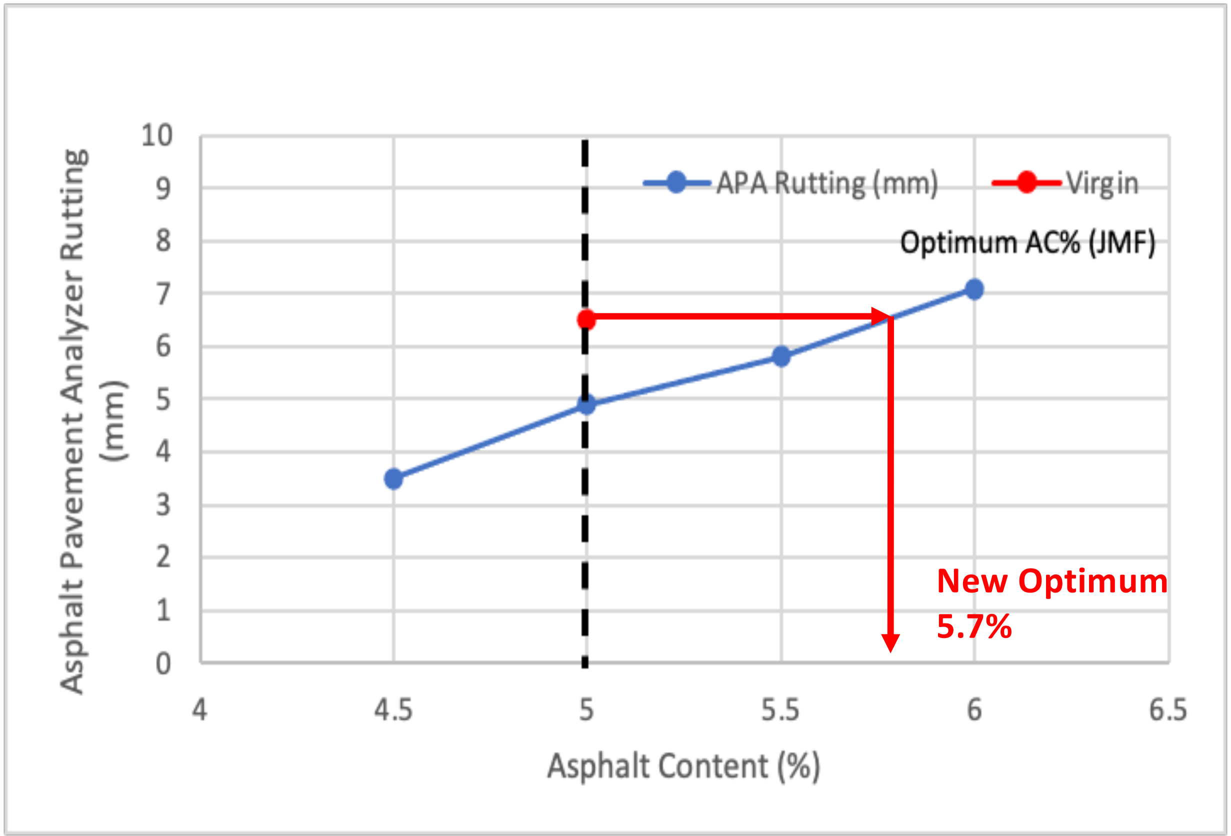
Virgin Specimen

- Batch out DBC samples – recover RAP aggregate – add to virgin aggregate and mix with virgin binder to DBC – perform rutting index test

Binder Content Selection

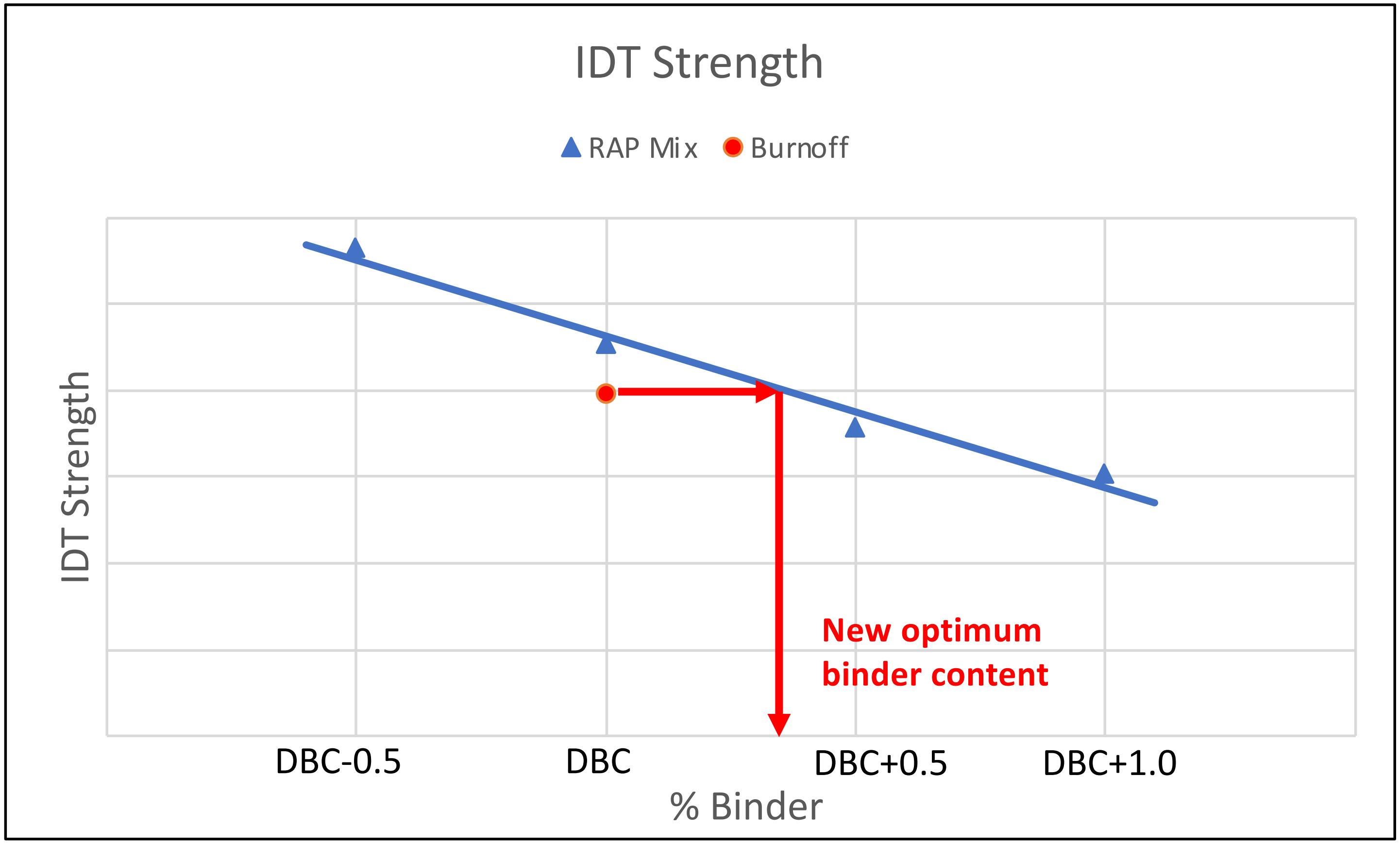
- Choose optimum binder content for the RAP mixture that corresponds to the rutting value for the virgin specimen

Concept



Asphalt Pavement Analyzer Rutting (mm)
10
9
8
7
6
5
4
3
2
1
0
4
4.5
5
5.5
6
6.5
Asphalt Content (%)
APA Rutting (mm)
Virgin
Optimum AC% (JMF)
New Optimum
5.7%

In This Study



Materials

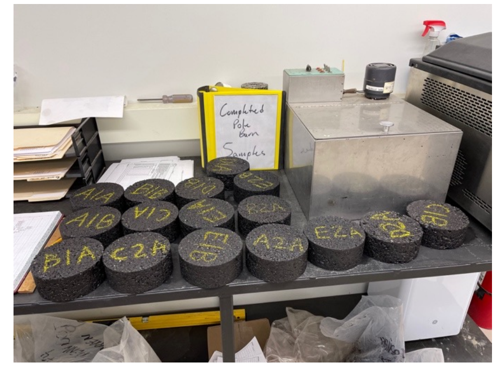
- 5 different mixes (all different geologies)
- NY (gravel, limestone, granite), NJ (basalt), PA (gneiss)
- 9.5mm and 12.5mm NMAS
- A simple interim approach in lieu of BMD
- Addresses concerns

Table 2. Asphalt Mixture Properties

Sieve Size (mm)	% Passing				
	Mix A	**Mix B**	**Mix C**	**Mix D**	**Mix E**
Producer	Polkville Stone	Pallette Stone	Jointa Lime Co.	Stavola	Hanson
Location	Polkville, NY	Saratoga, NY	Newburg, NY	Bound Brook,	Glen Mills, PA
NMAS	9.5	9.5	12.5	12.5	9.5
19.0	100	100	100	100	100
12.5	100	99	100	93.6	100
9.5	100	93	87	80	98
No. 4	73	56	54	45.2	63
No. 8	45	34	39	31.3	34
No. 16	30	22	27	24.8	23
No. 30	21	15	18	19.4	17
No. 50	14	9	12	11.2	13
No. 100	9	6	8	6.4	8
No. 200	7	5	4.9	5.1	4.6
PG Grade	PG 64V-22	PG 64V-22	PG 64V-22	PG 64S-22	PG 64S-22
RAP %	10%	20%	20%	15%	15%
Binder %	6.9	6	5.5	5.2	5.6
Air Voids %	3.5	3.8	3.6	4.0	4.1
VMA %	16.8	16.6	14.3	15.8	16.4
VFA %	76.8	77.3	75.2	74.7	7.5
Gmm	2.409	2.519	2.452	2.628	2.607
Gsb	2.596	2.733	2.609	2.840	2.825

Note: Gmm is the Theoretical Maximum Relative Density of the mix, Gsb is the bulk specific gravity of the aggregate, NMAS is Nominal Maximum Aggregate Size, RAP is Reclaimed Asphalt Pavement, VFA is Voids Filled with Asphalt, and VMA is Voids in the Mineral Aggregate.

Phase 1



- Determine if recovery method has effect on index values
- Develop virgin mixes based on composite gradation from each JMF
- Created RAP by adding asphalt then loose mix aging 5 days@95C
- 3 mixes for each aggregate source
  - Virgin
  - Virgin with recovered agg from ignition oven
  - Virgin with recovered agg from solvent extraction
- 30% recovered agg
- Used HT IDT strength - 7% voids, 44C, 64S-22

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NCHRP
Research Report 973

National Cooperative Highway Research Program

Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction
PHASE III RESULTS

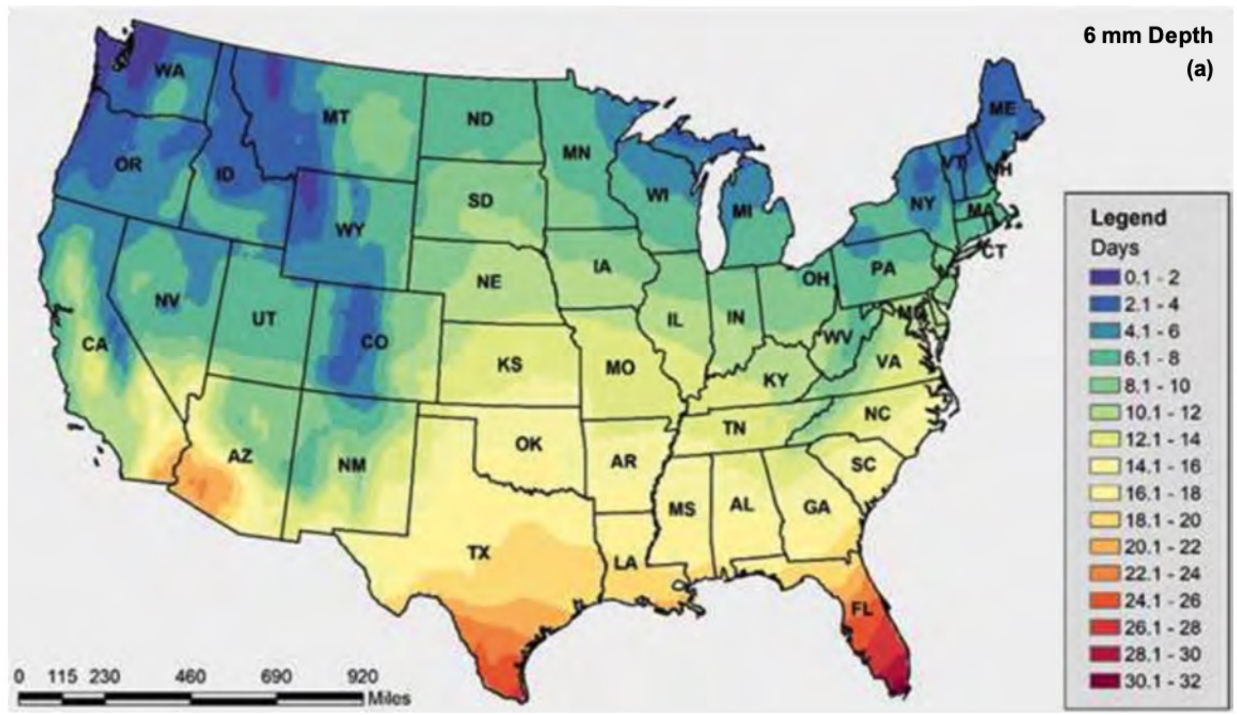
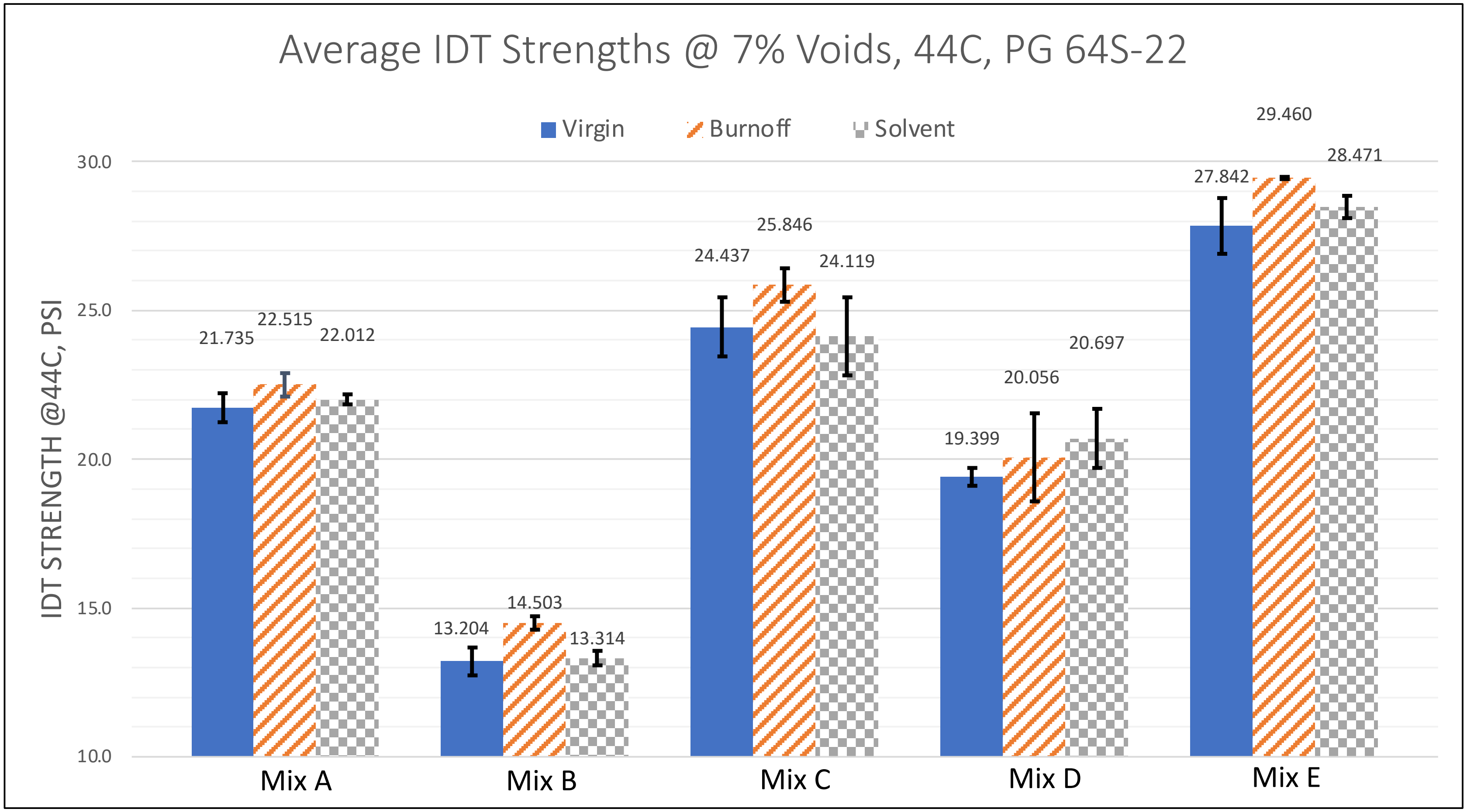


Figure 14. Required oven aging durations at 95C to match 16 years of field aging for depths of 6 mm

Phase 1 Results



Phase 1 Results

- Performed an ANOVA and t-Test
- ANOVA showed no significant differences in the three average values for mixes A, C, D, and E
  - B results were statistically different
- t-Test showed similar results when comparing virgin/burnoff; virgin/solvent; and burnoff/solvent
  - No statistical difference except for mix B
    - Virgin vs burnoff
    - Burnoff vs solvent
    - Virgin vs solvent were statistically the same

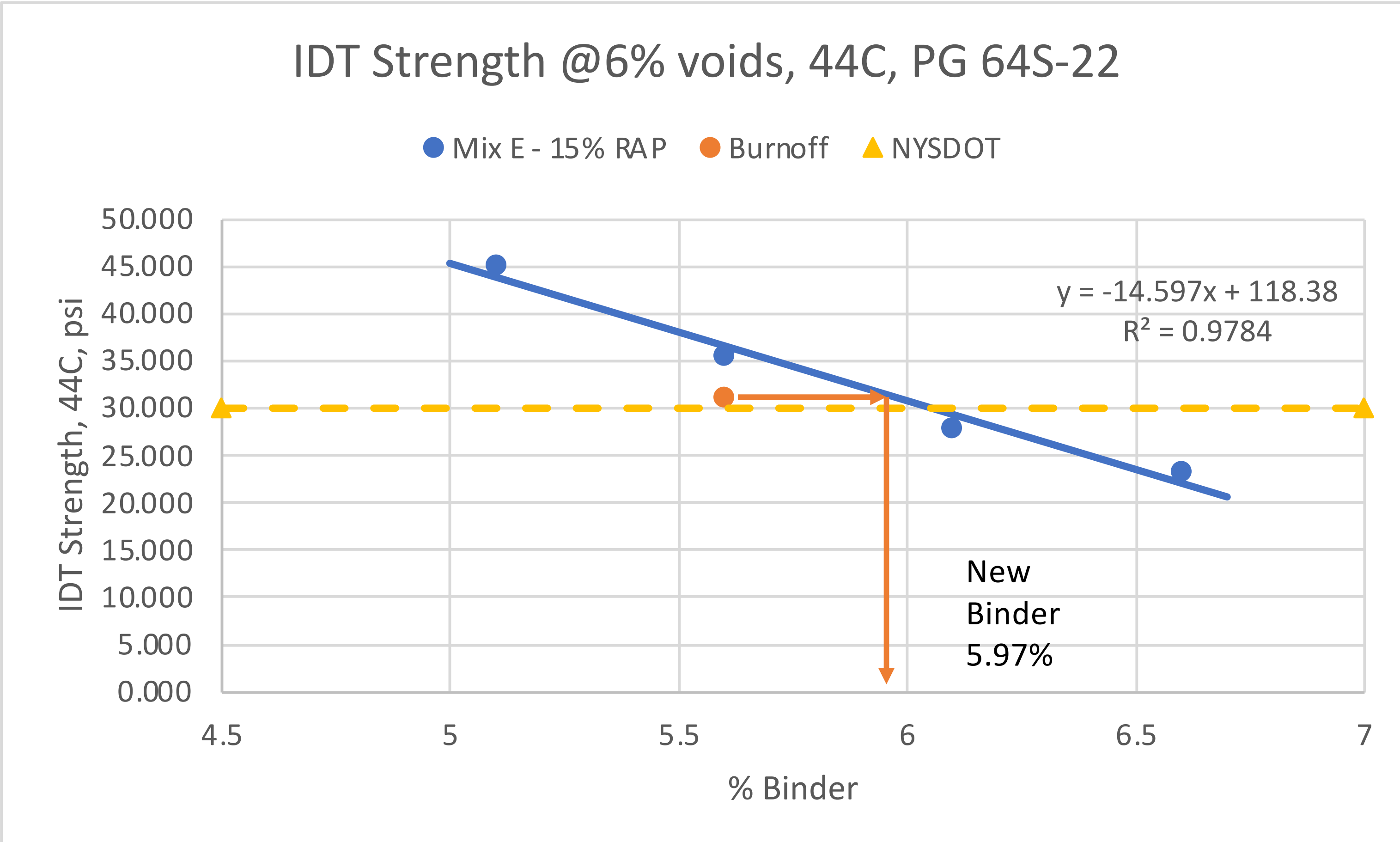
Phase 2

- Perform HT IDT testing @6.0% +/- 0.5% voids at 44C
  - DBC, DBC-0.5%, +0.5%, and +1.0%
- Use PG binder from JMF (PG 64V-22, PG 64S-22)
- Use both extraction methods for virgin mixes
- Determine new optimum binder content

Results – Mix E

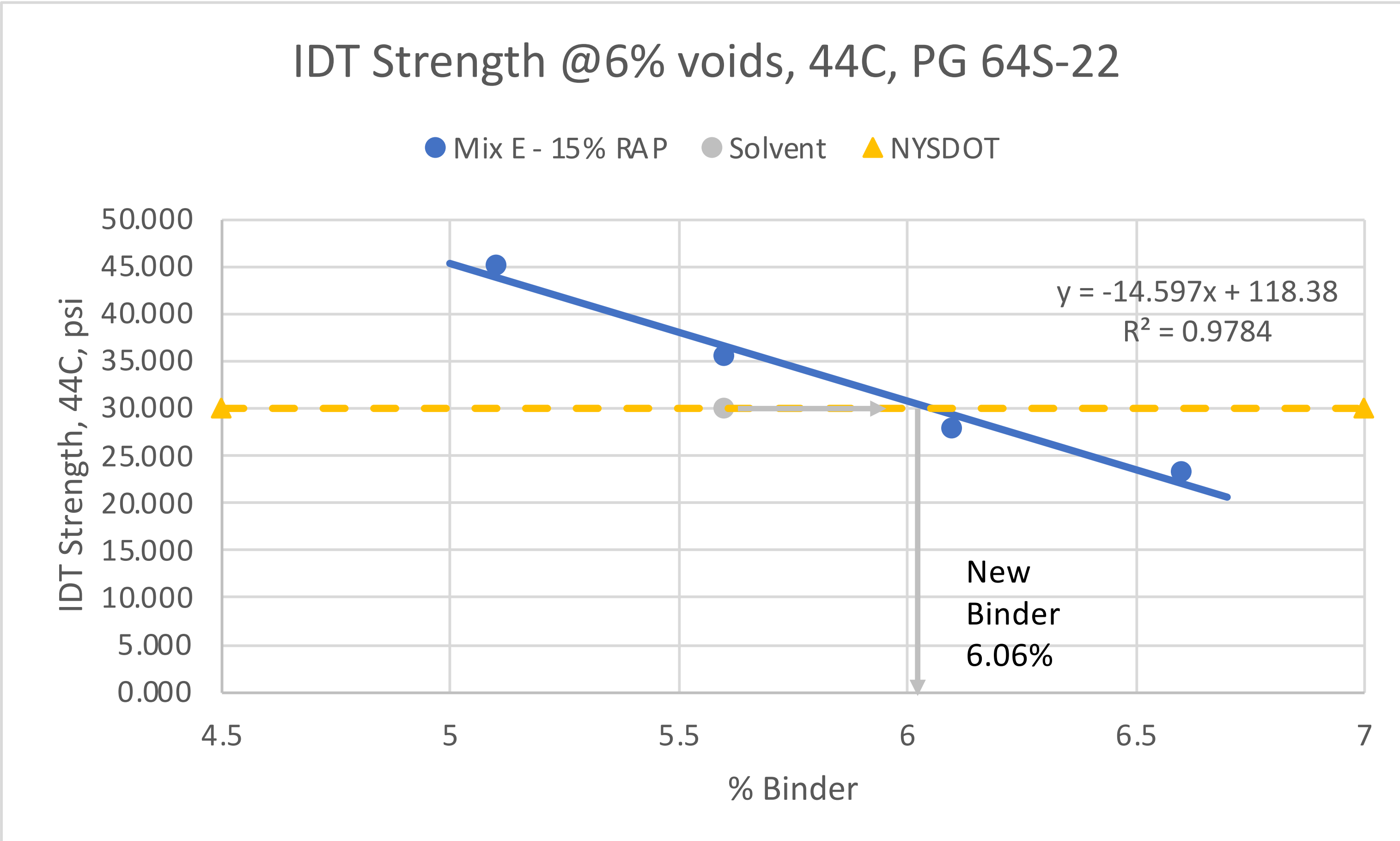
MIX STRENGTH IN PSI						
MIX ID		SAMPLE				
		1	2	3	4	AVG
ERN-5.1		44.599	47.896	42.968	44.951	45.104
ERN-5.6		35.489	36.896	34.900	34.954	35.560
ERB-5.6		32.273	33.126	29.918	29.613	31.233
ERS-5.6		29.552	31.082	29.850	29.485	29.992
ERN-6.1		27.989	29.011	27.672	27.332	28.001
ERN-6.6		23.142	23.488	23.643	22.905	23.295

Phase 2



IDT Strength @6% voids, 44C, PG 64S-22
Mix E - 15% RAP
Burnoff
NYSDOT
y = -14.597x + 118.38
R² = 0.9784
New
Binder
5.97%
IDT Strength, 44C, psi
% Binder
50.000
45.000
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.000
0.000
4.5
5
5.5
6
6.5
7

Phase 2


IDT Strength @6% voids, 44C, PG 64S-22
Mix E - 15% RAP
Solvent
NYSDOT
y = -14.597x + 118.38
R² = 0.9784
New
Binder
6.06%
IDT Strength, 44C, psi
50.000
45.000
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.000
0.000
4.5
5
5.5
6
6.5
7
% Binder

New Binder Contents

	Recovery Method	JMF Binder Content, %	New Binder Content, %	Change
Mix A	Burn	6.9	7.12	0.22
	Solvent		7.26	0.14
Mix B	Burn	6.0	6.12	0.12
	Solvent		6.27	0.27
Mix C	Burn	5.5	5.89	0.39
	Solvent		5.95	0.45
Mix D	Burn	5.2	5.93	0.73
	Solvent		5.93	0.73
Mix E	Burn	5.6	5.97	0.37
	Solvent		6.06	0.46

Mix E

		HWT		CT Index
% Binder	Avg. # of Passes to 12.5mm	Avg. # of Passes to Fail @25mm	Avg. # of Passes to SIP	Avg. CT Index
5.6	**10043**	**12274**	**9124**	**112.0**
6	**8115**	**10451**	**6967**	**152.7**

Concerns With BMD

- Current tests
  - Not performance tests (FHWA-HIF-19-103)
  - FI vs CT Index
    - FI : fatigue, top down, reflective
    - CT : thermal, reflective
  - What is the distress?
- Lack of long term aging
- Selection of criteria
- Selection of binder content for “balanced mixes”
- Agency expectations

Future Work

- Future work may include:
  - Same approach using HWT and/or APA
  - Check each mix for compliance to current (proposed) DOT BMD criteria

Thank you

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Questions?

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Fax: 315-238-7000

Email: gharder@asphaltinstitute.org

In Loving Memory of

Gregory M. Harder

December 12, 2002

December 21, 2022

#LLGH