University of New Hampshire

Minnesota Asphalt Pavement Association

Balanced Mix Design Approach

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University of New Hampshire

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History of Asphalt Mix Design Process

1890 & 1905
- **Barber Asphalt Paving Company** followed by **New York Testing Company**
- AC: 12-15%, Sand: 70-83%, Pulverized lime carbonite: 5-15%
- Surface sand mix: 100% passing No. 10, 15% passing No. 200, 9 to 14% asphalt

1920 — **Stability**
- **Hubbard Field Method**
- Sand asphalt design, 30 blow; 6" diameter with compression test (performance)

1927 — **Stability + Durability**
- **Francis Hveem (Caltrans)**
- Hveem stabilometer and cohesionmeter; mixes drier relatively; fatigue cracking an issue

1943 — **Stability + Durability**
- **Bruce Marshall, Mississippi Highway Department**
- Standard compaction energy with drop hammer; air voids and VFA, VMA; stability and flow

1993
- **Superpave**
- Level 1 (volumetric); Level 2 and 3 (performance based, but never implemented)

2000s
- **Performance Related Specs, Performance Based Specs, Balanced Mix Design**

Source: https://www.asphaltmagazine.com/history-of-asphalt-mix-design-in-north-america-part-1/

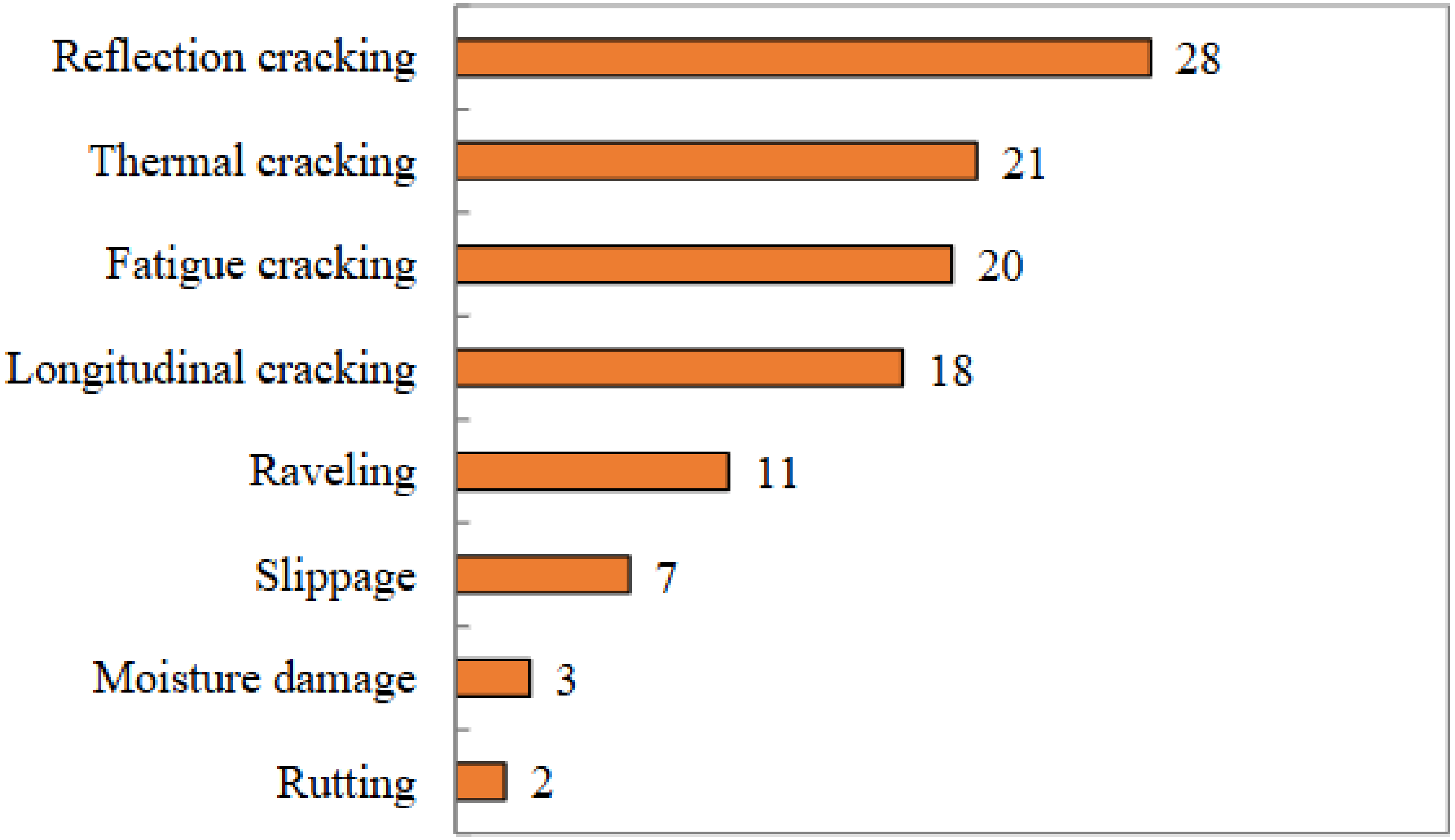
Outline

- Why we need new mix design approach?
- What is balanced mix design?
- Who is implementing BMD?
- BMD Case Studies:
  - Illinois DOT
  - Wisconsin DOT
  - Alabama DOT
  - Virginia DOT
- Critical Considerations and Research Efforts on BMD

Why We Need a New Mix Design Approach?

What Type of Distresses are Occurring Nowadays?

- **51 responses** – 34 US states and 2 Canadian provinces
- Top three:
  1. **Reflection cracking**
  2. **Thermal cracking**
  3. **Fatigue cracking**
- Asphalt community is less concerned about rutting



Source: NCHRP 20-07/Task 406

Current Mix Design Requirements

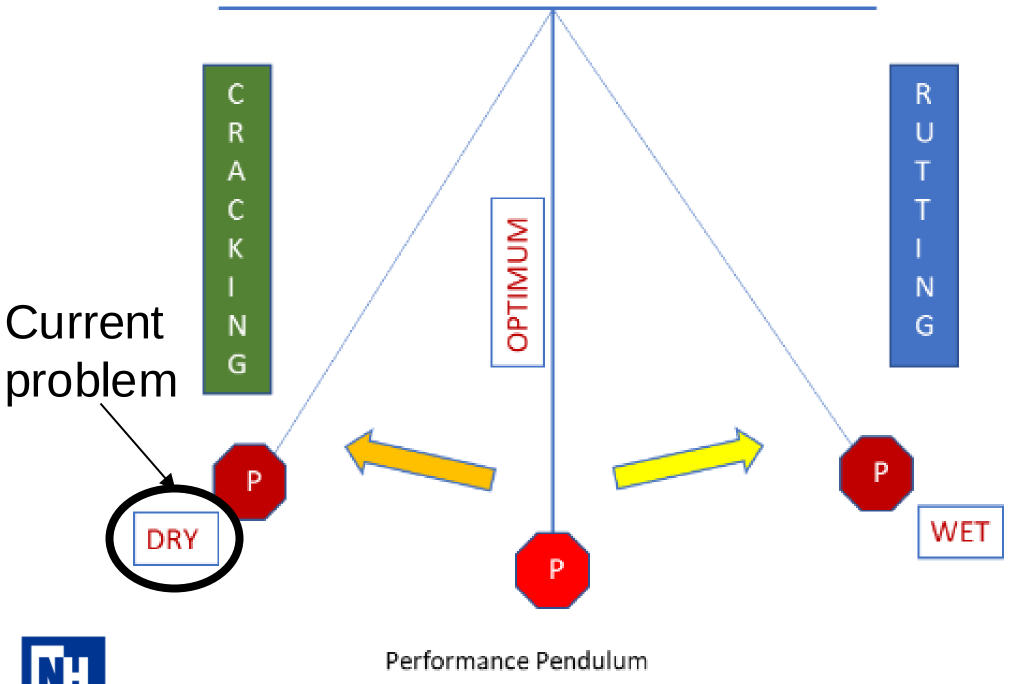
- Problems:
  - Dry mixes (**Cracking**)
  - Volumetric properties (V_a and AFT [V_{be}]) **lacks quality insights** into the binder and mixtures
  - Does not adequately account for **modern materials** like recycled materials, warm-mix additives, polymers, rejuvenators

- Potential Solutions:
  - **Recognize** performance issues related to dry mixes in some areas
  - Increase understanding of the **factors affecting performance**
  - **Design for performance**

What is Balanced Mix Design (BMD)?

BMD – Definition and Advantages

- Asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate, and location within the pavement structure (AASHTO PP 105)



Source: Shane Buchanan

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- Ensure performance

- Enable innovation

- Economic optimization

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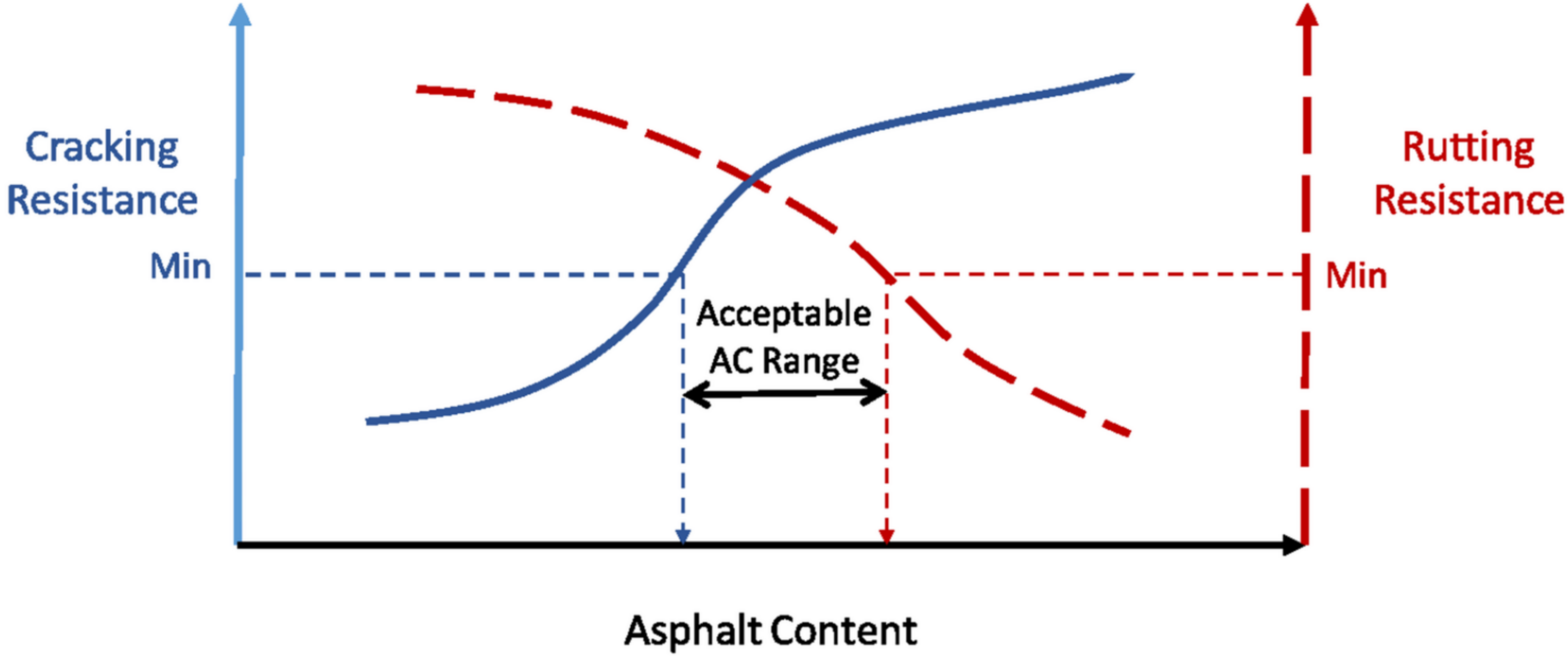
Concept of BMD



- Mix design to balance the major distresses such as rutting and cracking

Source: Newcomb, 2018

BMD Approaches

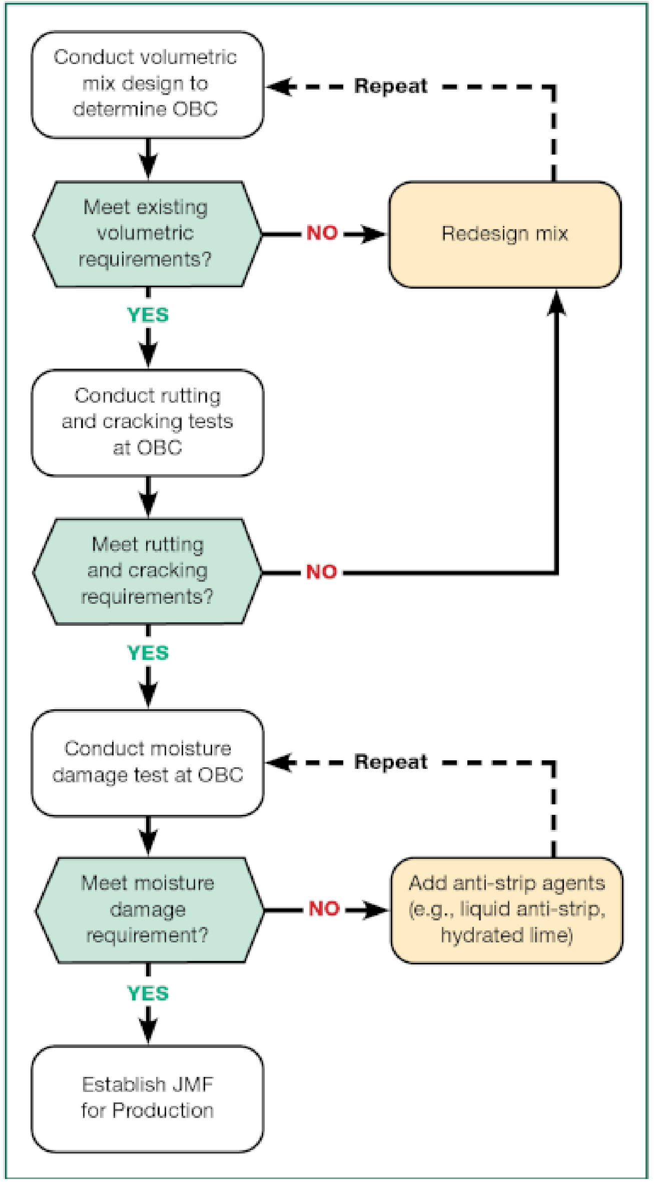
A	B	C	D
Volumetric Design	Initial Volumetrics	Initial Volumetrics	No Volumetric Requirements
Perf. Test Criteria	Perf. Tests @ Vol. Opt. AC ± 0.6%	Perf. Tests @ Adjust %AC & Components	Perf. Tests @ Adjust Proportion and Components
Volumetric Design with Performance **Verification**	Volumetric Design with Performance **Optimization**	**Performance Modified** Volumetric Design	**Performance Design**

Approach - A

*Volumetric Design with Performance **Verification***

- Features:
  - Addition of performance testing to Superpave
  - **Easiest** from an Agency perspective
  - Uses current QCs for acceptance
  - Cost, time, and carbon footprint increase
  - Only option to increase mix VMA (Iterative mix design)
  - Limits RAP and other recycled materials

Most conservative
Lowest innovation potential

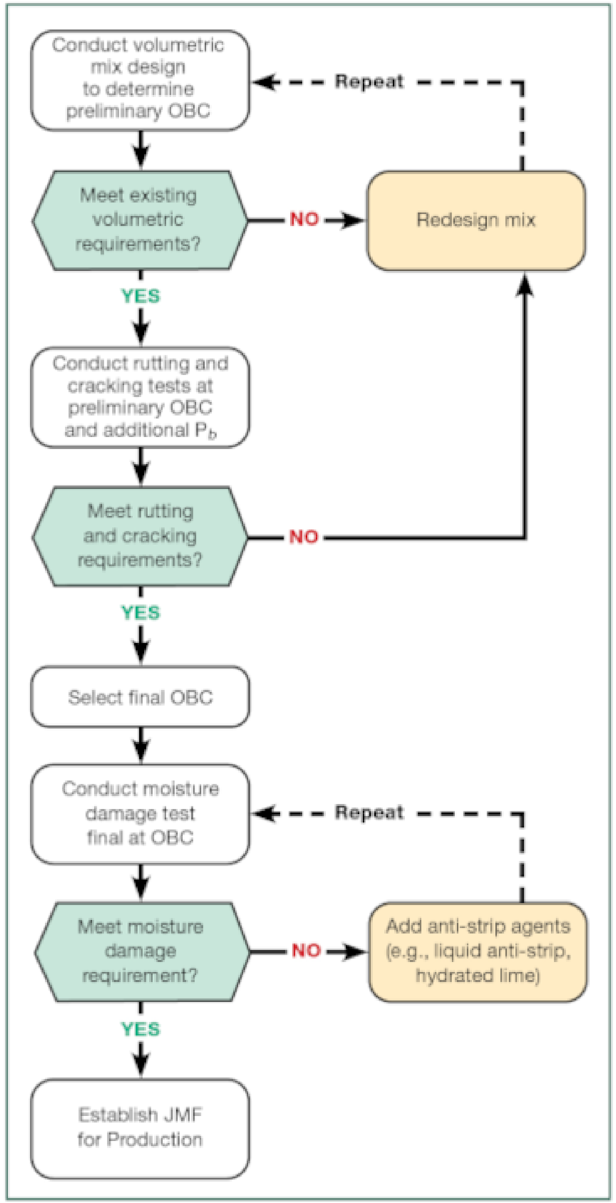


Approach - B

Volumetric Design with Performance ***Optimization***

- Features:
  - Addition of performance test to Superpave
  - **Easy** from an Agency perspective
  - Current QCs can be used for acceptance, with a shift in target air voids
  - Air void and VFA criteria must be relaxed
  - Cost, time, and carbon footprint increase
  - Only binder content can be adjusted Limits RAP and other recycled materials

Slightly more flexible
Limited innovation potential

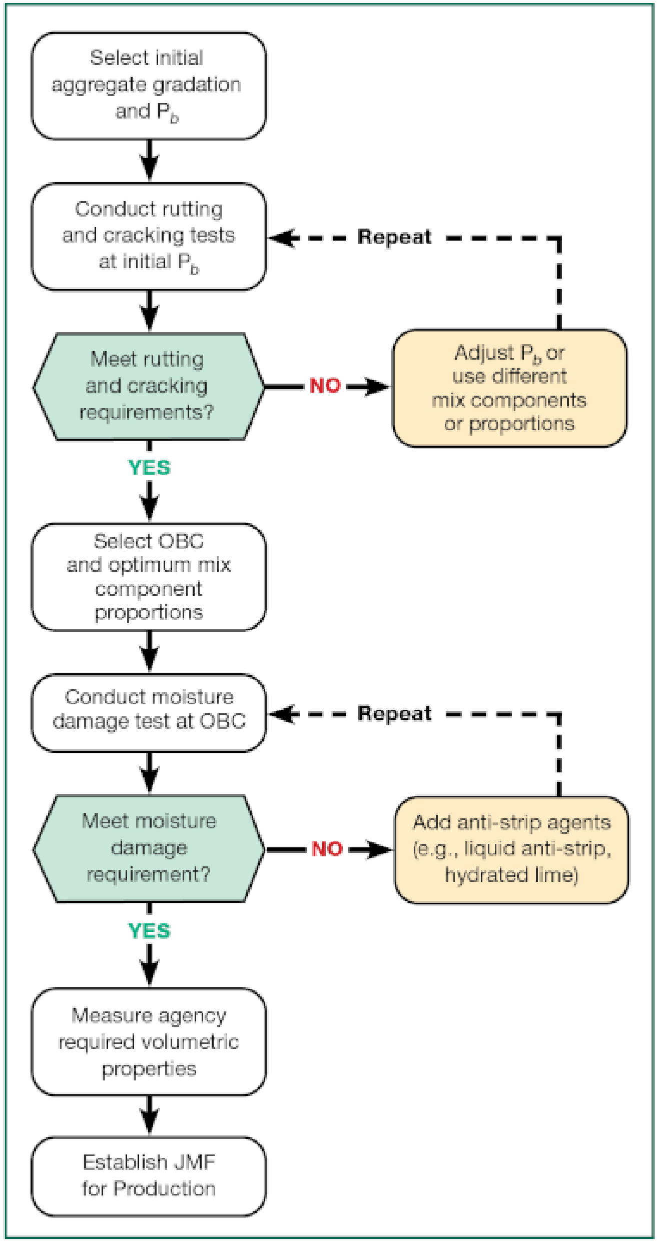


Approach - C

***Performance Modified** Volumetric Design*

- Features:
  - Volumetric criteria can be relaxed or eliminated if performance criteria are satisfied
- Agencies are free to:
  - Utilize a binder grade of their choice and alter the gradation
  - Increase utilization of recycled materials
  - Use other modern-day materials (recycling agents, fibers, innovative materials)

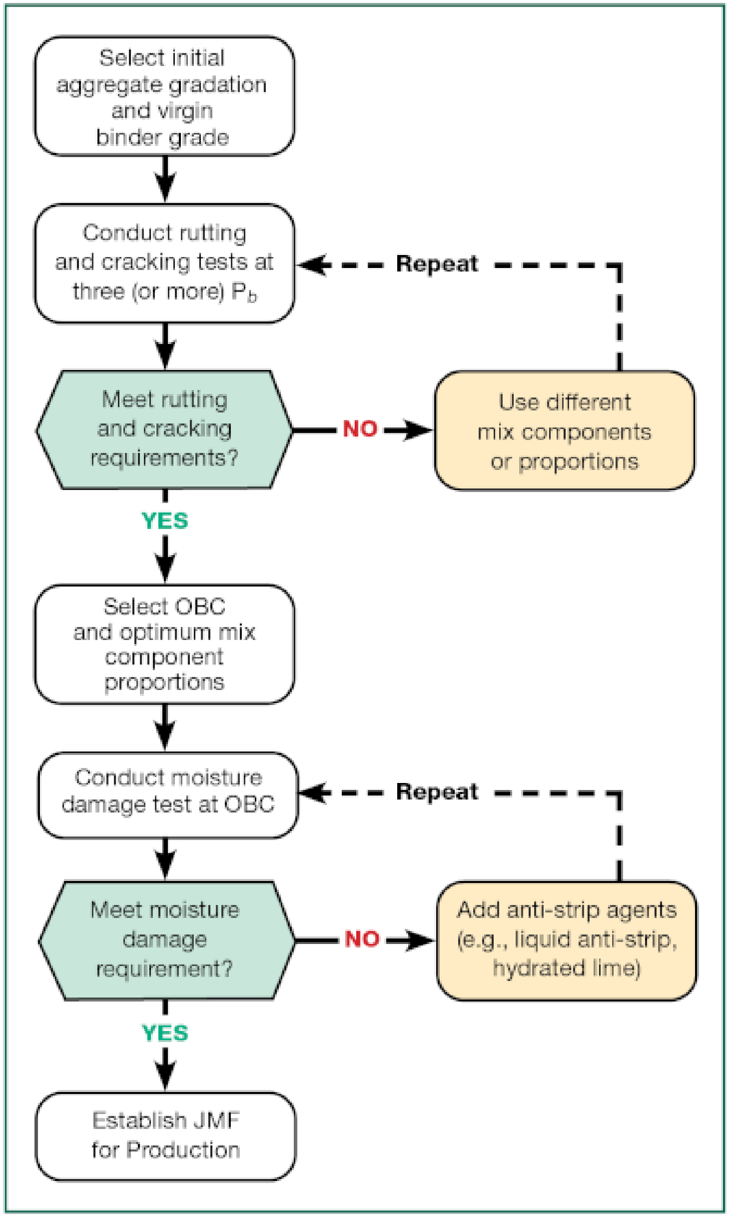
Less conservative
Medium innovation potential



Approach - D
Performance Design

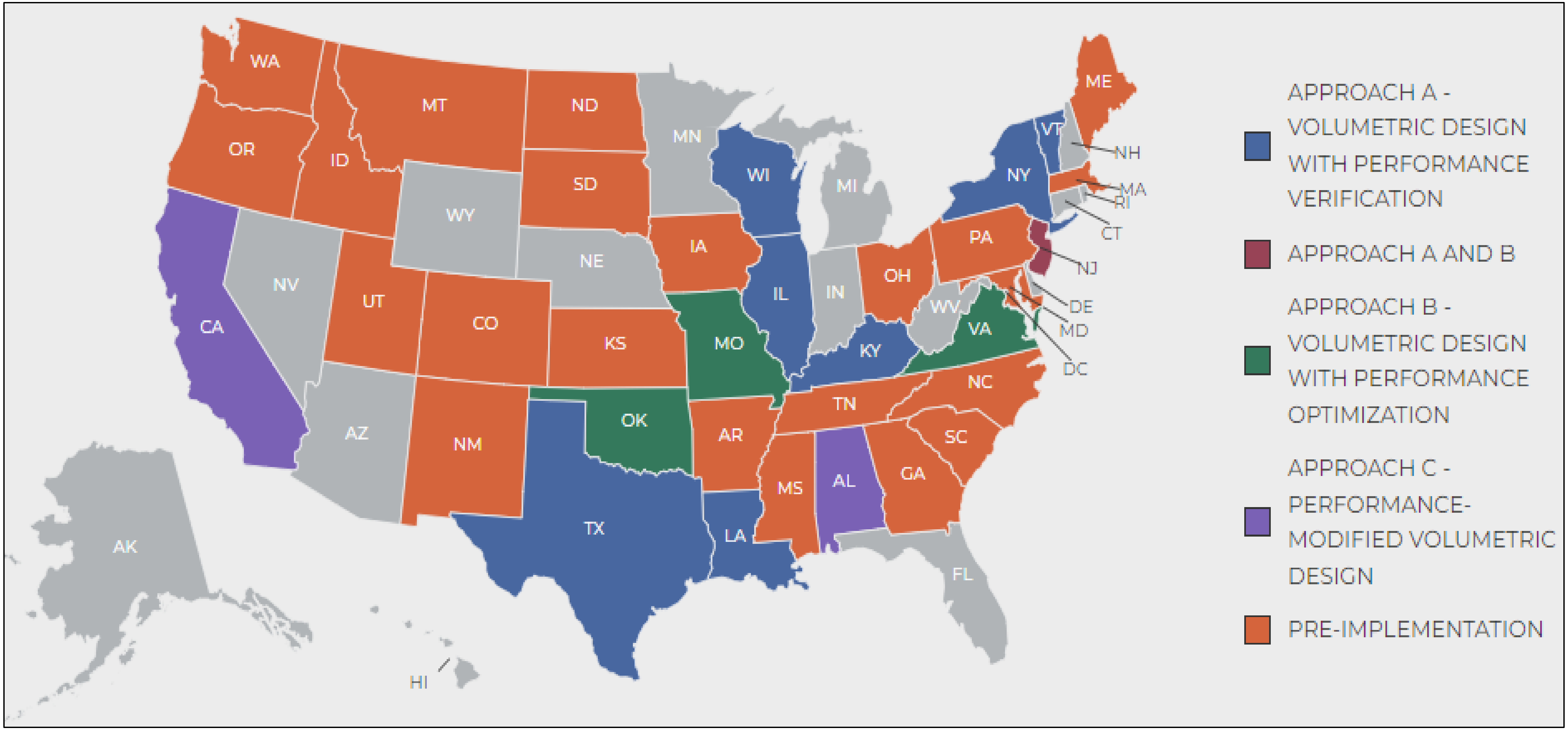
- Features:
  - No criteria for volumetric (serves as a guide)
  - Only the performance criteria must be satisfied
- Agencies are free to:
  - Utilize a binder grade of their choice and alter the gradation
  - Increase utilization of recycled materials
  - Use other modern-day materials (recycling agents, fibers, innovative materials)

Least conservative
Highest innovation potential



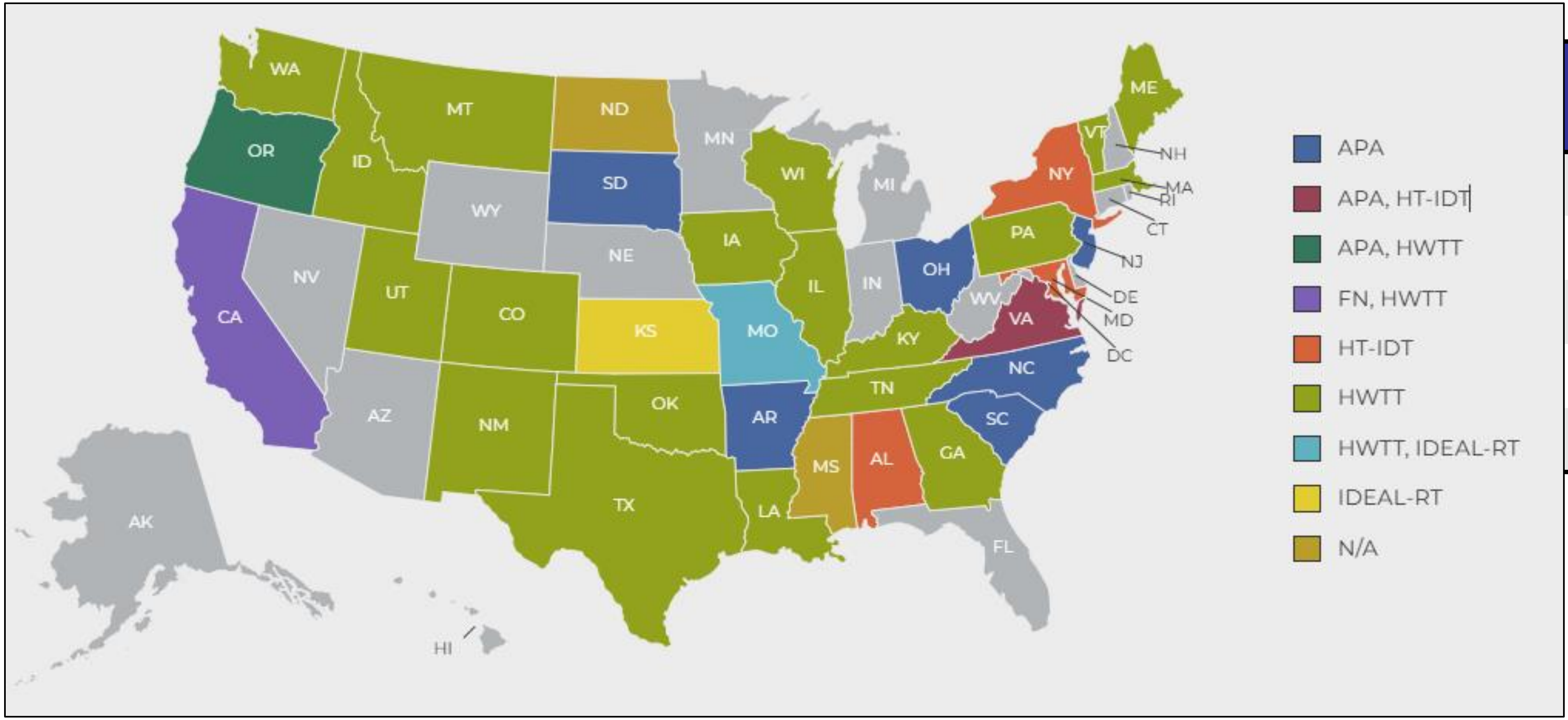
Who is implementing BMD?

BMD Implementation Status – Approaches



Source: NAPA, 2024

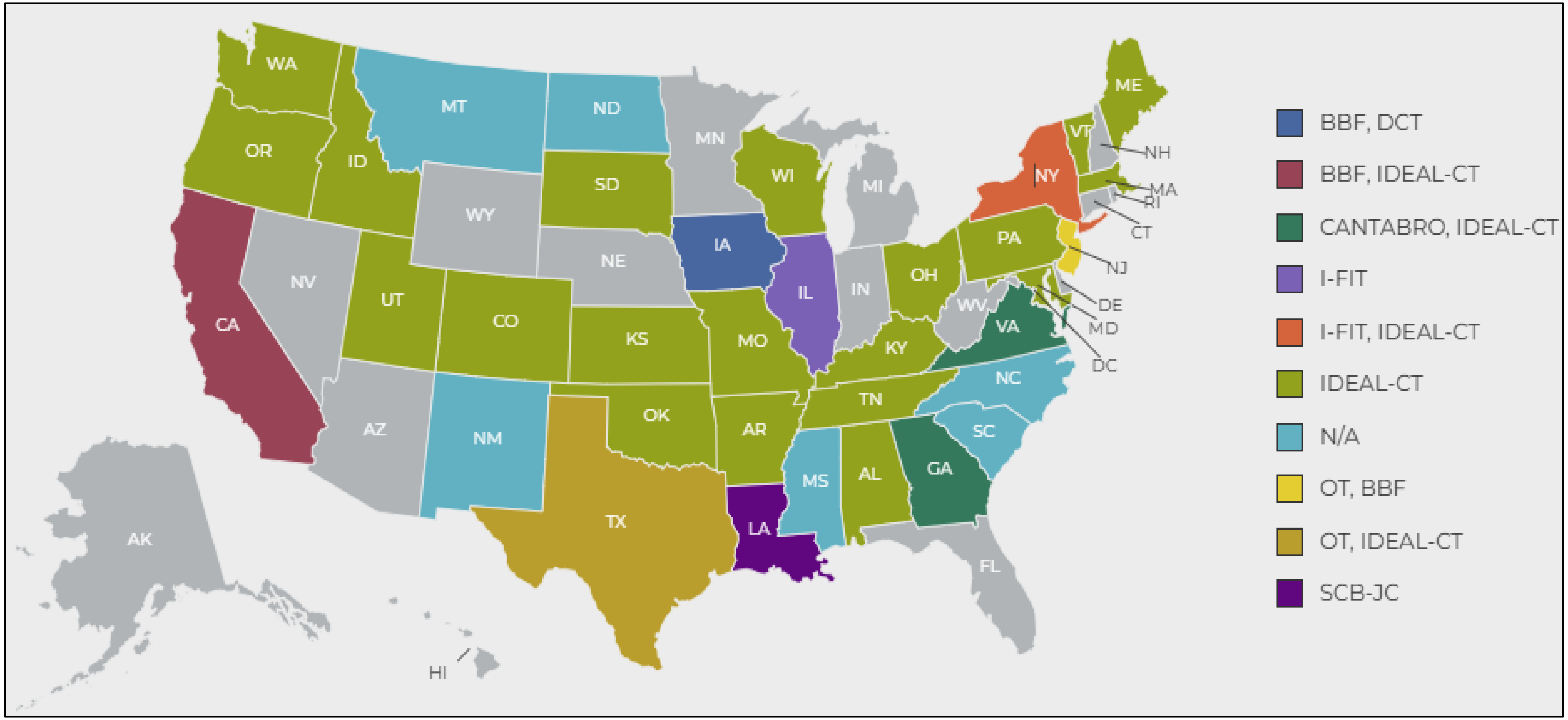
BMD Implementation Status – Rutting Tests



Test	No. of States
HWTT	22
APA	8
HT-IDT	4
FN	1
IDEAL-RT	2

Source: NAPA, 2024

BMD Implementation Status – Cracking Tests



Test	No. of States
IDEAL-CT	25
I-FIT	2
BBF	3
Cantabro	2
OT	2
SCB-J_c	1

Source: NAPA, 2024

BMD Case Studies

Illinois

- Problem Statement:
  - VMD with inadequate cracking resistance

BMD Test Parameter	Average	IDOT BMD Spec. (Average)	Pass/Fail
HWTT Rut Depth at15,000 Passes (mm)	2.0	**≤12.5**	**Pass**
I-FIT FI	5.4	**≥8.0**	**Fail**

- Solution:
  - Using a softer PMA virgin binder (PG 64-34)
    - *IDOT requires **Approach-A***
    - *Softer virgin binder will not affect the volumetrics*
    - *PG 70-28 (PMA) had minimal rutting in HWTT*

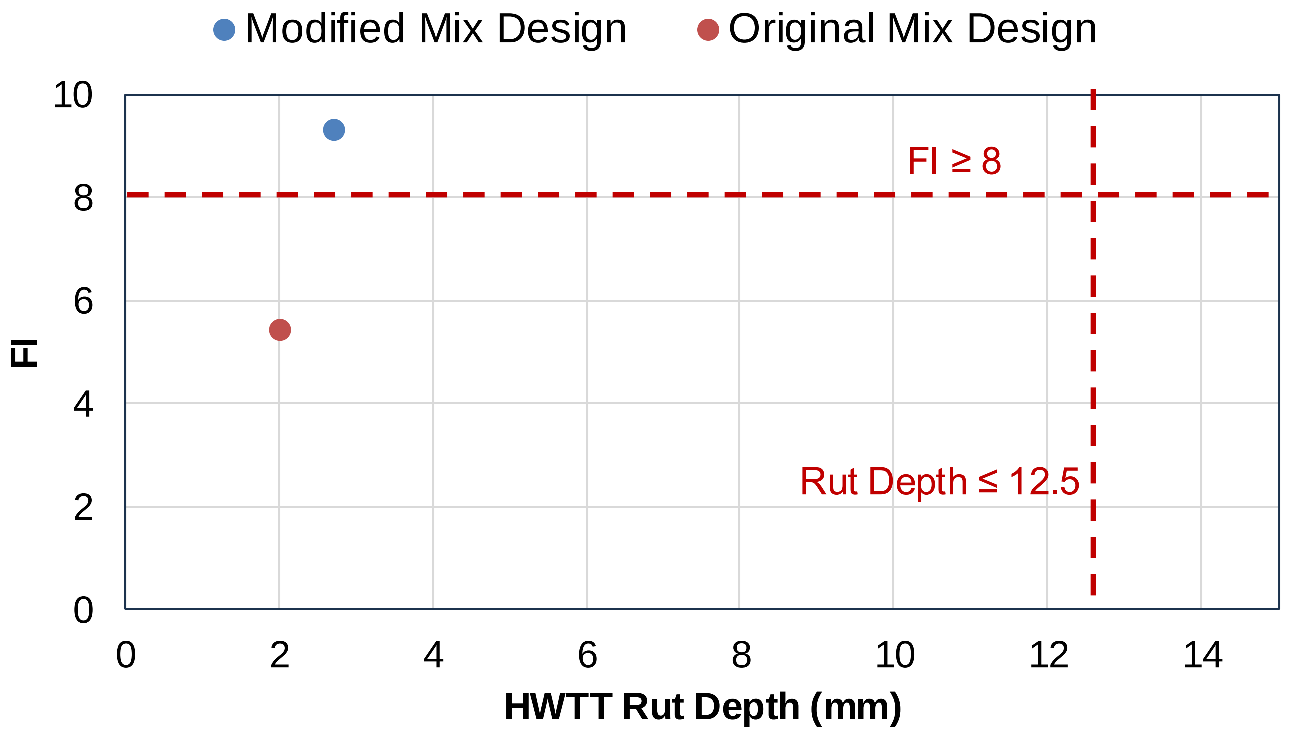
Volumetric **M**ix **D**esign
Polymer **M**odified **A**sphalt
Illinois **D**epartment **O**f **T**ransportation
Hamburg **W**heel **T**racking **T**est

Source: BMD Resource Guide, NAPA 2024

Illinois

BMD Test Parameter	Average	IDOT BMD Spec. (Average)	Pass/Fail
HWTT Rut Depth at15,000 Passes (mm)	2.7	**≤12.5**	**Pass**
I-FIT FI	9.3	**≥8.0**	**Pass**

Performance space diagram →



Source: BMD Resource Guide, NAPA 2024

Wisconsin

- Problem Statement:
  - VMD with inadequate rutting and moisture resistance
  - 6.4% PG 52S-34 OBC (unmodified)

BMD Test Parameter	Average	WisDOT BMD Spec. (Average)	Pass/Fail
HWTT $N_{12.5}$ (passes)	6400	**≥10,000**	**Fail**
HWTT SIP (passes)	4250	**≥8,000**	**Fail**
IDEAL-CT CT_{Index}	60.6	**≥30.0**	**Pass**

- Solution:
  - Using a PMA binder PG 58H-34 and adding a liquid anti-strip additive
    - *WisDOT requires **Approach-A** and LAS additive improves HWTT results*

Volumetric **M**ix **D**esign
Polymer **M**odified **A**sphalt
Wisconsin **D**epartment **O**f **T**ransportation
Hamburg **W**heel **T**racking **T**est

Wisconsin

- LAS Additive

BMD Test Parameter	Average	WisDOT BMD Spec. (Average)	Pass/Fail
HWTT $N_{12.5}$ (passes)	8100	**≥10,000**	**Fail**
HWTT SIP (passes)	5750	**≥8,000**	**Fail**

- PG 58H-34 PMA binder

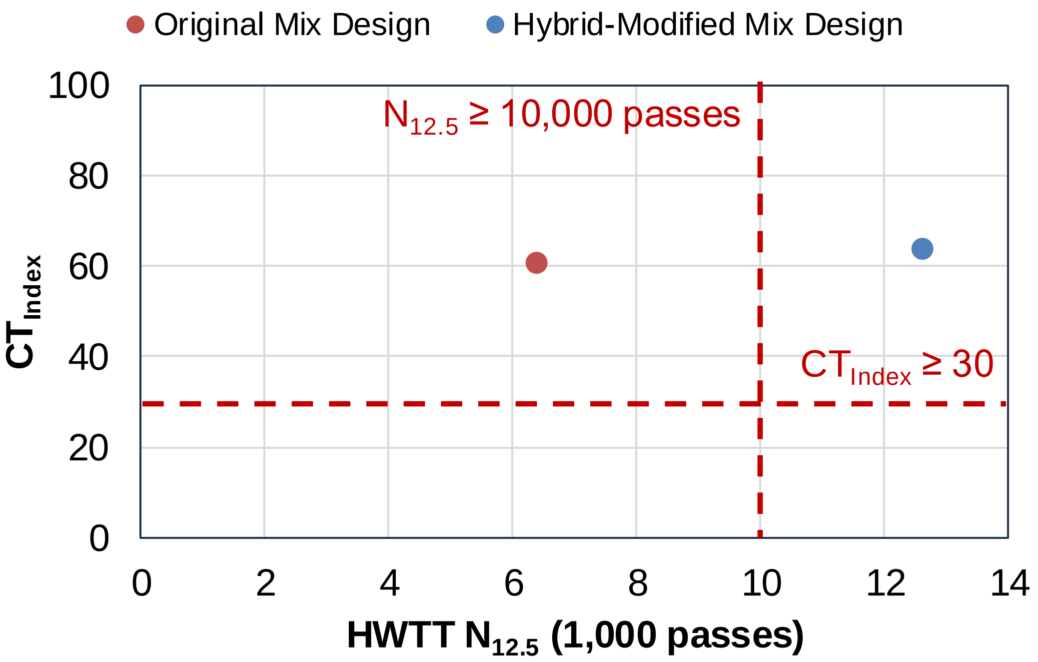
BMD Test Parameter	Average	WisDOT BMD Spec. (Average)	Pass/Fail
HWTT $N_{12.5}$ (passes)	11400	**≥10,000**	**Pass**
HWTT SIP (passes)	8100	**≥8,000**	**Marginal Pass**

- LAS Additive + PG 58H-34 PMA binder (Hybrid)

BMD Test Parameter	Average	WisDOT BMD Spec. (Average)	Pass/Fail
HWTT $N_{12.5}$ (passes)	12600	**≥10,000**	**Pass**
HWTT SIP (passes)	9000	**≥8,000**	**Pass**
IDEAL-CT CT_{Index}	63.6	**≥30.0**	**Pass**

Wisconsin

- Both **mix designs were identical**, except for a PMA binder and a LAS additive
- The **hybrid modification** approach significantly **improved the rutting and moisture resistance** of the original mix design while maintaining cracking resistance
- Higher material cost can be justified from a life-cycle cost perspective



Alabama

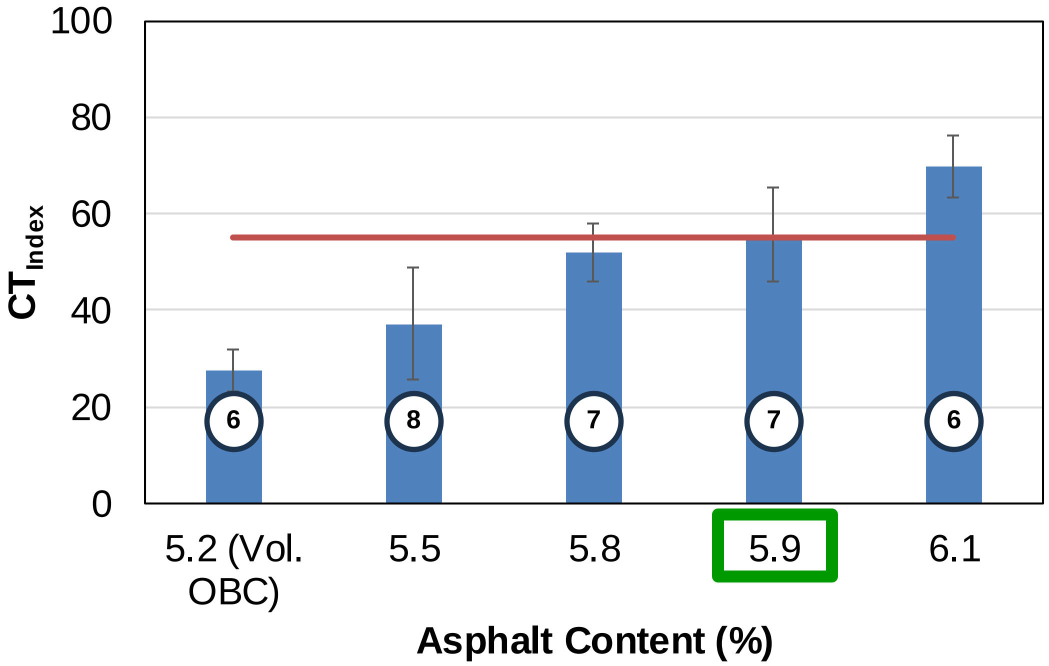
- Problem Statement:
  - VMD with inadequate cracking resistance

BMD Test Parameter	# Replicate	Average	Standard Deviation	ALDOT BMD Spec. (Average)	Pass/Fail
HT-IDT Strength (psi)	3	38.7	3.8	**≥20**	**Pass**
IDEAL-CT CT_{Index}	6	27.6	4.5	**≥55**	**Fail**

- Solution:
  - Modification to meet the ALDOT BMD specs: (**Approach-C/D**)
    1. *Increasing asphalt binder content (Virgin Binder PG 67-22)*
    2. *Using WMA additives to lower mix production temperature and increasing asphalt binder content*

Alabama

1. Increasing asphalt binder content:



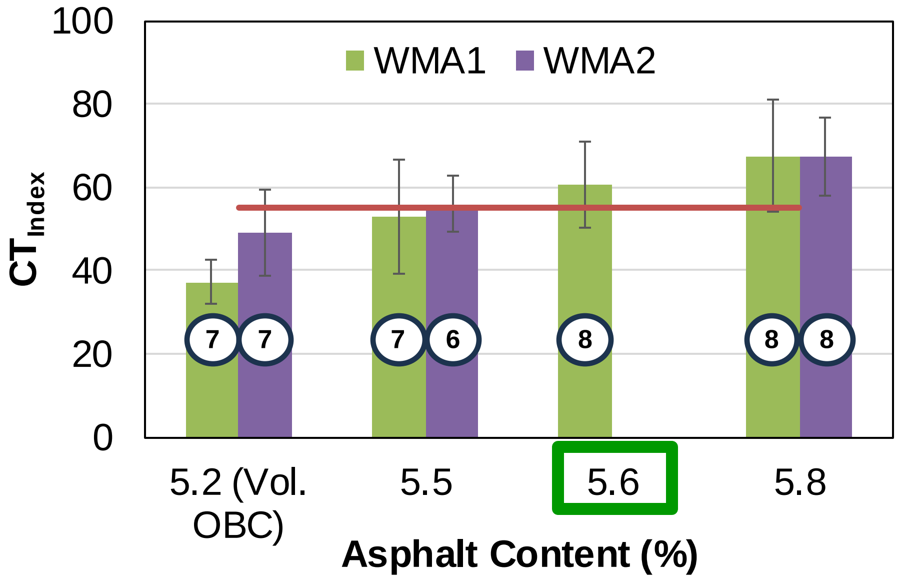
- All the other mix components and **proportions are unchanged**
- **≥6** replicates
- At 5.9% AC, **VMA = 14.5%** and **V_a = 1.8%**

BMD Test Parameter	# Replicate	Average	Standard Deviation	ALDOT BMD Spec. (Average)	Pass/Fail
HT-IDT Strength (psi)	5	27.4	2.7	**≥20**	**Pass**
IDEAL-CT CT_{Index}	7	55.7	9.9	**≥55**	**Pass**

Source: BMD Resource Guide, NAPA 2024

Alabama

2. Using WMA additives and increasing binder content:



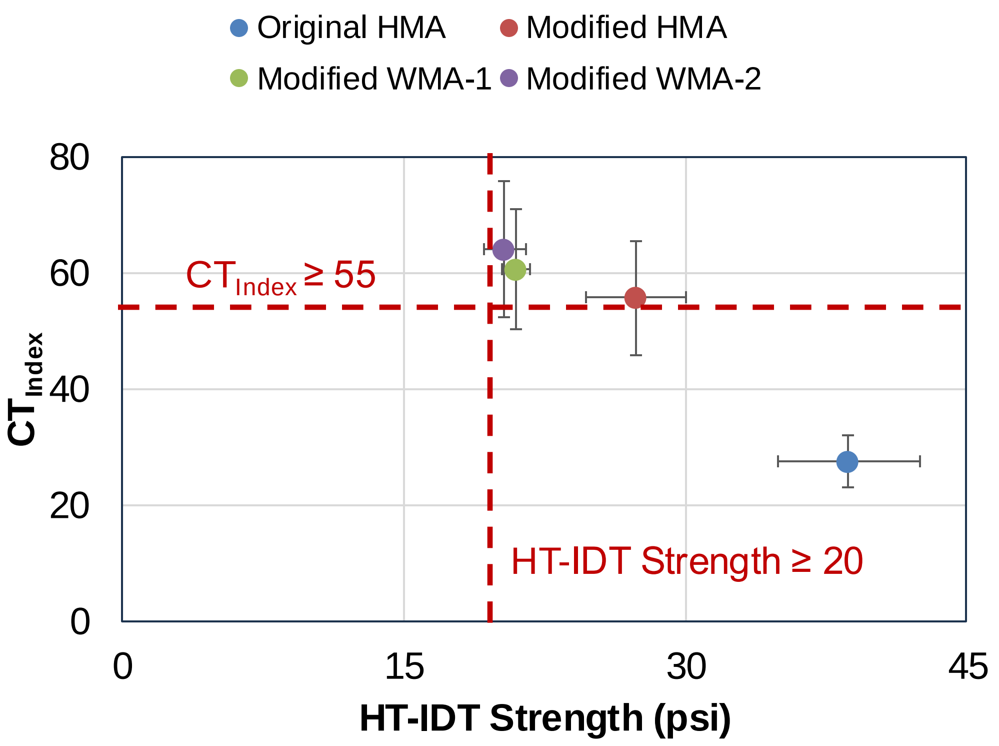
- All the other mix components and **proportions are unchanged**
- **≥6** replicates

Mix Type	BMD Test Parameter	# Replicate	Average	Standard Deviation	ALDOT BMD Spec. (Average)	Pass/Fail
WMA1	HT-IDT Strength (psi)	3	21	0.7	**≥20**	**Pass**
	IDEAL-CT CT_{Index}	8	60.6	10.4	**≥55**	**Pass**
WMA2	HT-IDT Strength (psi)	3	20.4	1.1	**≥20**	**Pass**
	IDEAL-CT CT_{Index}	8	64	11.8	**≥55**	**Pass**

Source: BMD Resource Guide, NAPA 2024

Alabama

Mix Property	Original HMA	Modified HMA	Modified WMA-1	Modified WMA-2
Total Binder Content (%)	5.2	5.9	5.6	5.6
RAP Content (%)	20	20	20	20
Additive	-	-	WMA-1	WMA-2
RAP Binder Replacement (%)	21%	19%	20%	20%
Virgin Binder Content (%)	4.1	4.8	4.5	4.5
Virgin Binder Grade	PG 67-22	PG 67-22	PG 67-22	PG 67-22
Air Voids (%)	3.9	1.8	2.7	2.7
VMA (%)	14.7	14.5	14.5	14.5
VFA (%)	74	87	81	81



Virginia

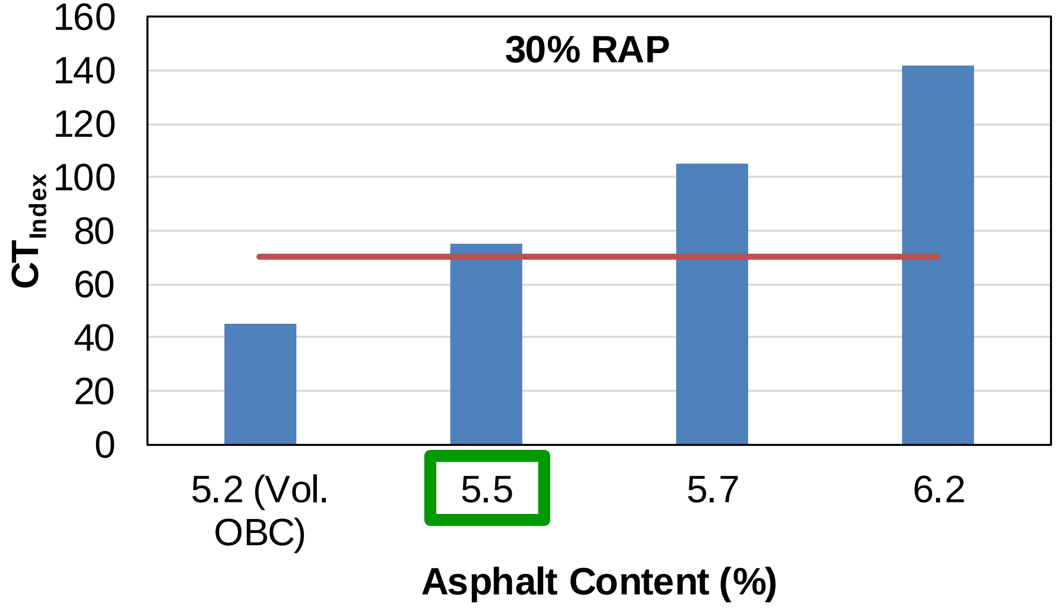
- Problem Statement:
  - – VMD with inadequate cracking resistance

BMD Test Parameter	Average	VDOT BMD Spec. (Average)	Pass/Fail
APA Rut Depth (mm)	2.7	**≤8.0**	**Pass**
IDEAL-CT CT_{Index}	45	**≥70**	**Fail**
Cantabro Mass Loss (%)	5.2	**≤7.5**	**Pass**

- Solution:
  - – Modification to meet the VDOT BMD specs: (**Approach-C**)
    1. *Increasing asphalt binder content (Virgin Binder PG 64-22)*
    2. *Increasing RAP content, adding a recycling agent, and increasing asphalt binder content*

Virginia

1. Increasing asphalt binder content:



- 9.5 mm NMAS surface mix
- All the other mix components and **proportions are unchanged**
- At 5.5% AC, **VMA = 16.2%** and **V_a = 2.9%** instead of 16.3% and 4% respectively at 5.2% AC originally

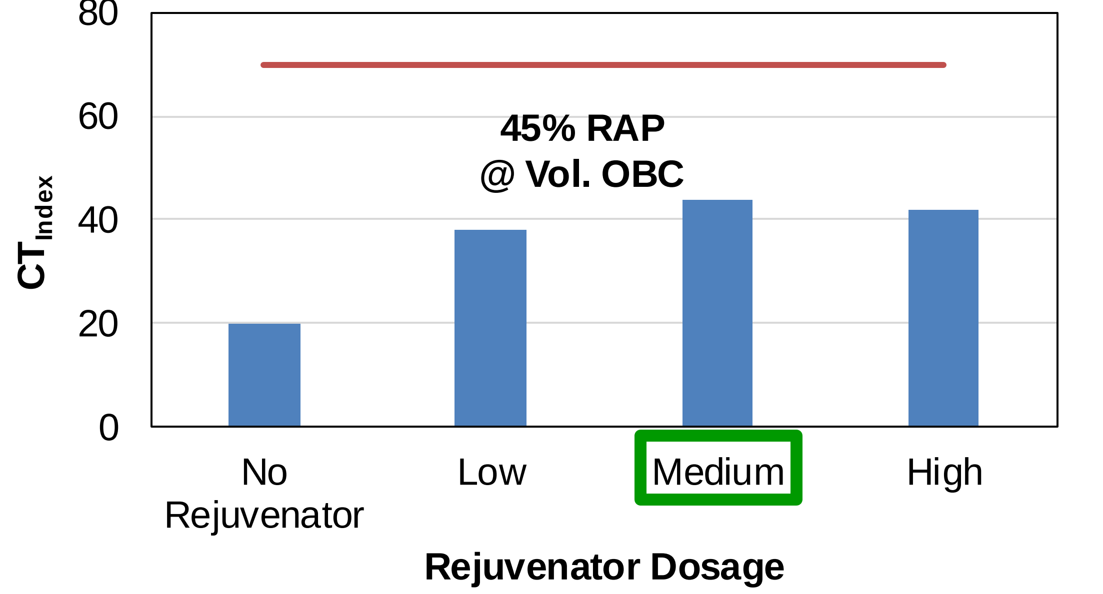
BMD Test Parameter	Average	VDOT BMD Spec. (Average)	Pass/Fail
APA Rut Depth (mm)	3.3	**≤8.0**	**Pass**
IDEAL-CT CT_{Index}	75	**≥70**	**Pass**
Cantabro Mass Loss (%)	4.7	**≤7.5**	**Pass**

Source: BMD Resource Guide, NAPA 2024

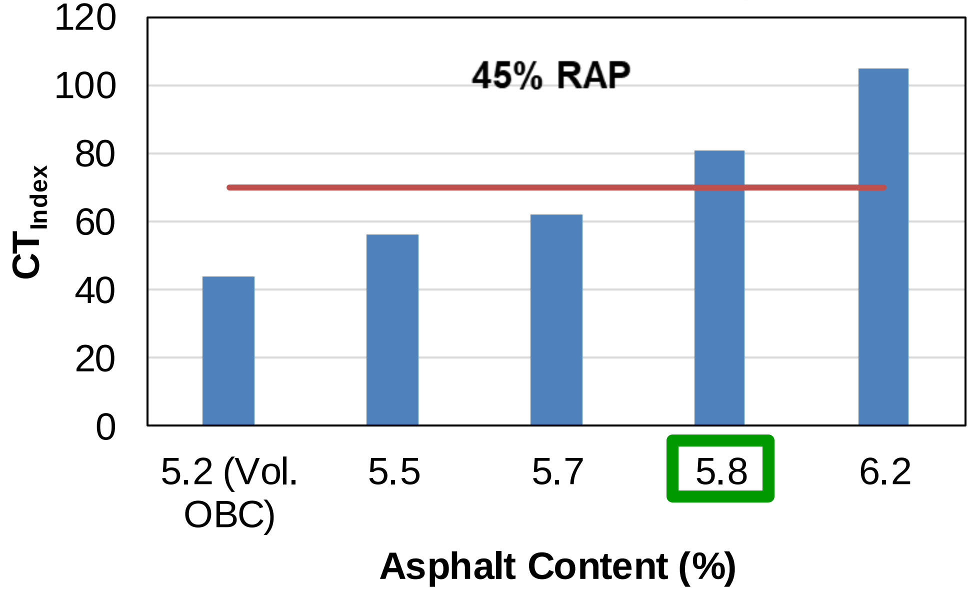
Virginia

2. Increasing RAP and binder content + adding recycling agent

Recycling Agent Dosage Impact



Binder Content Impact

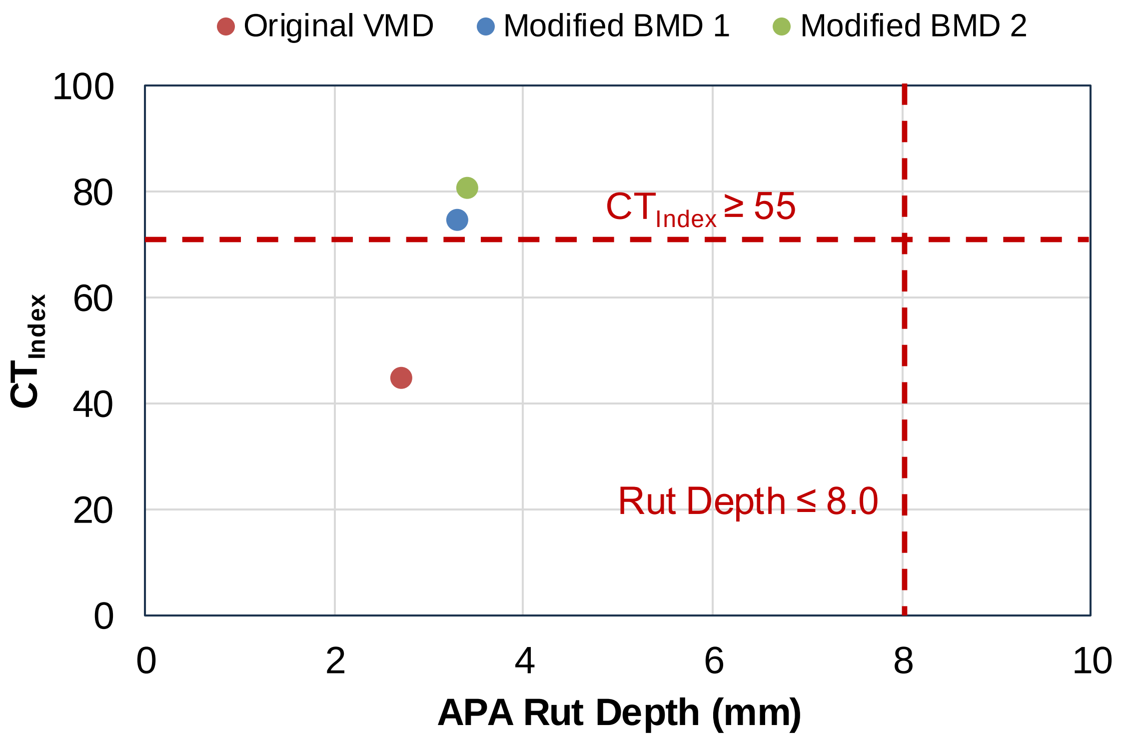


BMD Test Parameter	Average	VDOT BMD Spec. (Average)	Pass/Fail
APA Rut Depth (mm)	3.3	**≤8.0**	**Pass**
IDEAL-CT CT_{Index}	75	**≥70**	**Pass**
Cantabro Mass Loss (%)	4.7	**≤7.5**	**Pass**

Source: BMD Resource Guide, NAPA 2024

Virginia

Mix Property	Original VMD	Modified BMD 1	Modified BMD 2
Total Binder Content (%)	5.2	5.5	5.8
RAP Content (%)	30	30	45
Additive	-	-	Recycling Agent
RAP Binder Replacement (%)	24	24	38
Virgin Binder Content (%)	3.9	4.2	3.6
Virgin Binder Grade	PG 64-22	PG 64-22	PG 64-22
Air Voids (%)	4	2.9	2.3
VMA (%)	16.3	16.2	16.5
VFA (%)	75.5	82.1	86.1



Critical Considerations and Research Efforts on BMD

Critical Considerations to BMD

Material Screening and Selection

- Materials (RAP, RAs, and binders) should be carefully screened and selected to ensure their **compatibility** and **pavement longevity**

Test Simplification and Efficiency

- Test methods should be **flexible, simple, and accommodating to location** and production variables
- Should be validated: Specimen and pavement scale

QA Process

- **Quick access to performance properties** is crucial for allowing contractors to adjust production variables without delays

Examples of On-going Research Efforts to Support BMD Implementation

- BMD development for airfield asphalt mixtures
- Practicality improvements for Illinois Flexibility Index (I-FIT) test
- Development of Simplified Wedge Splitting Test (SWST)

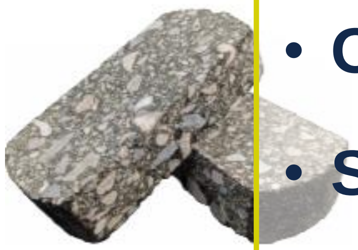
BMD Application for Airfield Asphalt Pavement

Objectives:

- Introduce cracking test(s) that measure fundamental properties
  - Rapid, low-cost, minimal training, and easy to incorporate in QC/QA
  - Consider crack initiation and propagation
- Correlate the recommended test(s) to pavement performance at:
  - National Airport Pavement Test Facility (NAPTF)
  - National Airport Pavement and Materials Research Center (NAPMRC)

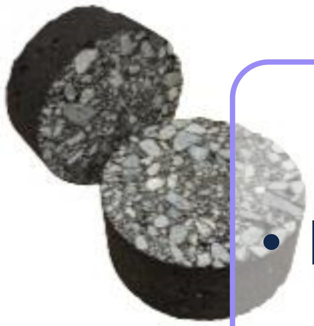
AIRPORT ASPHALT PAVEMENT TECHNOLOGY PROGRAM (AAPTP)

Cracking Test Evaluation



Fatigue
- Overlay
- SCB-F

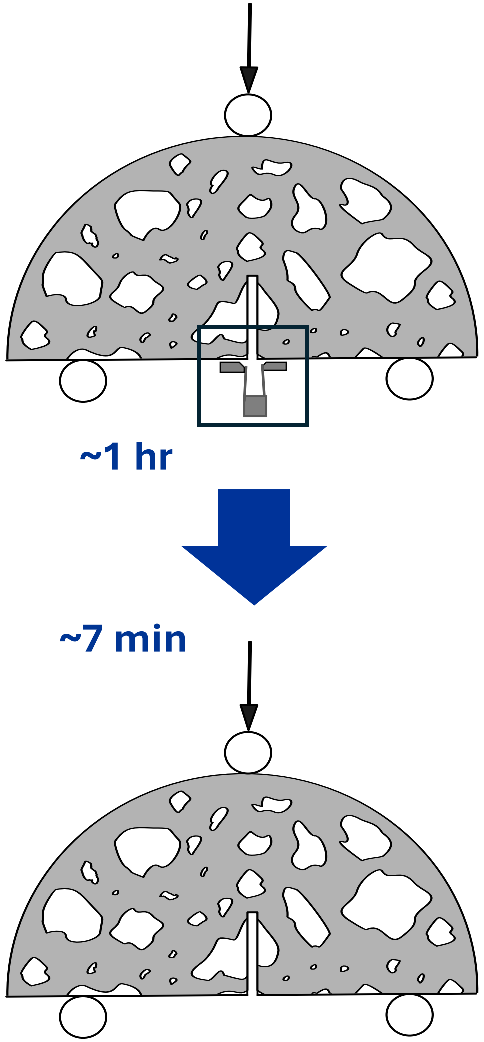
Low Temp
- DCT
- LT-SCB



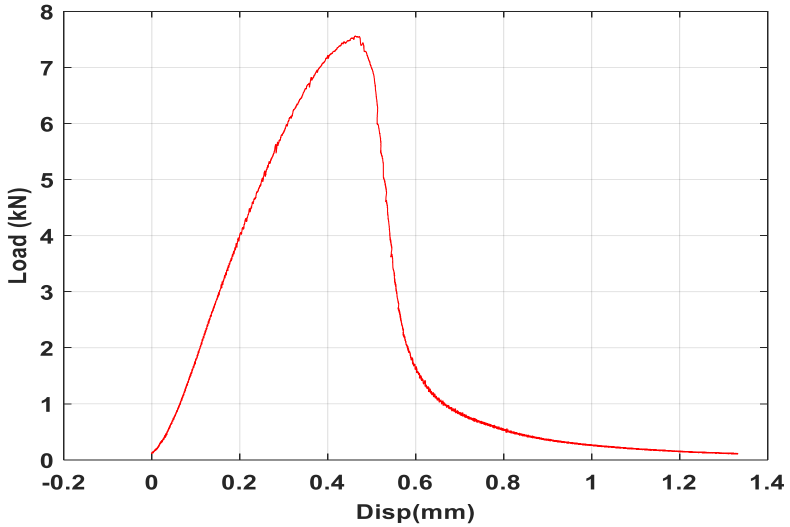
Strength
- E*
- IDEAL CT

Room Temp
- I-FIT
- Shear

Low-Temperature SCB Test Simplification (ongoing)



- Protocols
  - Specimen = ~~24.7 mm~~ 50 mm
  - Test Temp = ~~PGL~~ True PGL(E) + 10° C
  - Control = ~~CMOD~~ LLD
  - Rate = ~~0.03~~ 0.15 mm/min

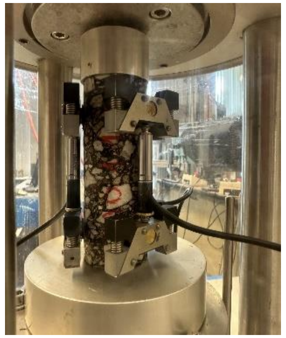


Examples of On-going Research Efforts to Support BMD Implementation

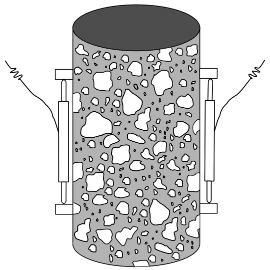
- BMD development for airfield asphalt mixtures
- **Practicality improvements for Illinois Flexibility Index test (I-FIT)**
- Development of Simplified Wedge Splitting Test (SWST)

Test Temperature and Test Simplification for Illinois Flexibility Index Test (I-FIT) (AASHTO T-393)

- **AASHTO T-393 uses single test temperature for all mixtures (25 °C)**
- **It needs ability to carefully control specimen temperature**



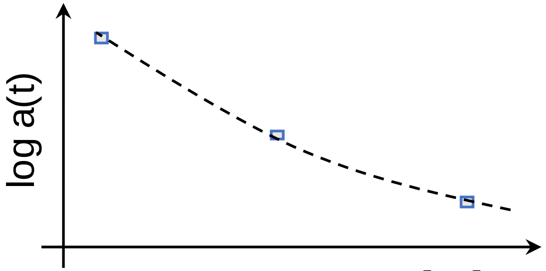
AASHTO T 342



Complex modulus (small size samples)
- 2.9, 18 and 30°C
- 0.1, 0.5, 1, 5, 10 and 25 Hz

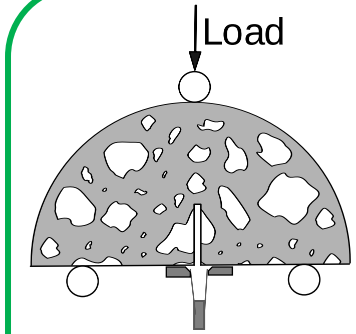
Asphalt mixtures

Mix-1	Mix-2
Mix-3	Mix-4



TTSP

Five loading rate and temperature combinations



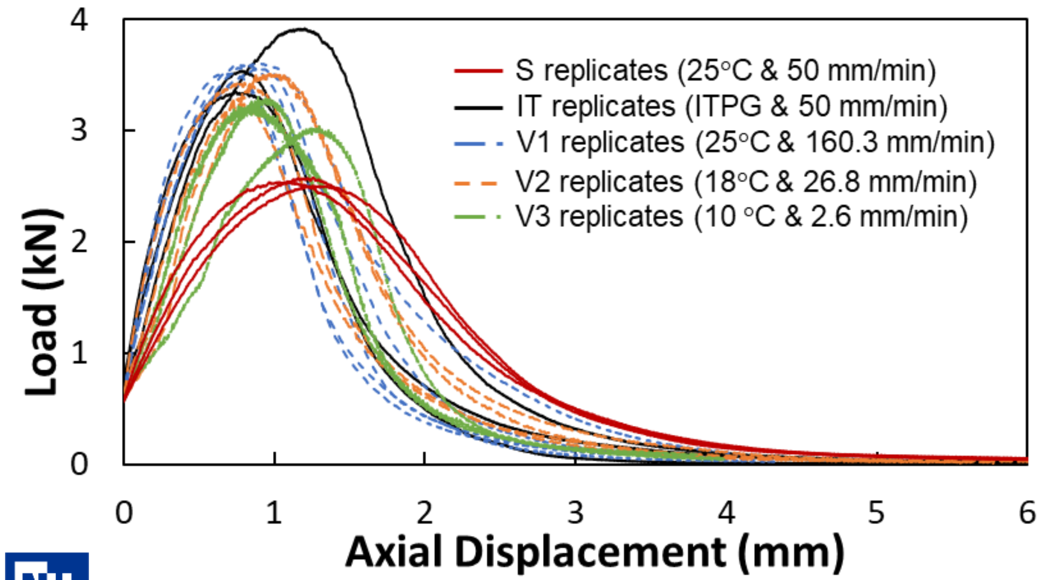
SCB test

- Peak load (PL)
- FI
- RDCI
- Post-peak slope (m)
- FE_{LLD}
- FE_{CMOD}

AASHTO T 393

I-FIT Test Conditions: Summary and Results

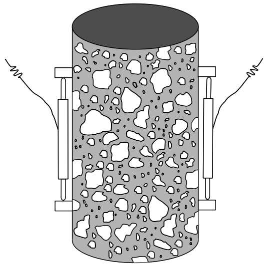
Variation	Mix-1		Mix-2		Mix-3		Mix-4	
	T (°C)	LLD (mm/min)	T (°C)	LLD (mm/min)	T (°C)	LLD (mm/min)	T (°C)	LLD (mm/min)
Standard (S)	25.0	50.0	25.0	50.0	25.0	50.0	25.0	50.0
ITPG scenario (IT)	20.4	50.0	30.0	50.0	29.8	50.0	28.1	50.0
Variation-1 (V1)	25.0	160.3	25.0	14.5	25.0	14.9	25.0	22.5
Variation-2 (V2)	18.0	26.8	18.0	2.1	18.0	2.0	18.0	3.0
Variation-3 (V3)	**10.0**	**2.6**	34.0	127.3	34.0	127.0	**34.0**	**213.2**



Study Outcomes:

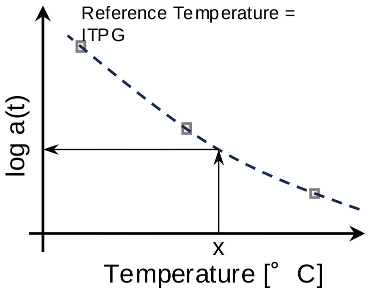
- Test temperature should be related to required PG grade for the pavement (based on pavement location and depth within pavement)
- Test can be run at room temperatures without temperature conditioning and loading rate is adjusted based on temperature

Implementation Procedures for Agencies



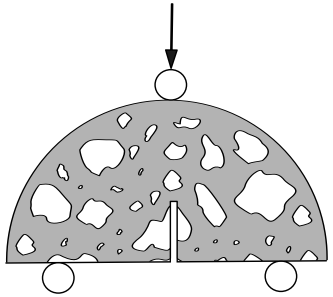
Step-1 (Complex Modulus Test)

Perform the complex modulus test with test range covering the ITPG of the binder.



Step-2 (Shift Factor Calculation)

Determine the shift factor [a(t)] for the target SCB test temperature [x] from the master curve at ITPG as a reference temperature (based on complex modulus test results).



Step-3 (SCB Test)

Determine the adjusted loading rate required for target SCB test temperature [x]

[i.e. $\frac{Standard\ loading\ rate}{Shift\ factor} = \frac{50}{[a(t)]}$ mm/min].

Region specific tables can be prepared having temperature and loading rate

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Application of time-temperature superposition principle for cracking characterization of asphalt mixtures using semi-circular bend test

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A R T I C L E I N F O

Keywords:
Time-temperature superposition principle
Reclaimed asphalt pavement
Cracking characterization
Flexibility index
Balanced mix design

A B S T R A C T

In recent decades, numerous laboratory tests have been developed to characterize the cracking performance of asphalt mixtures. Among these, the semi-circular bend (SCB)-based Illinois flexibility index test (I-FIT) (AASHTO T 393) has emerged as a favored method due to its straightforward specimen preparation and better sensitivity to mixture variables. However, the cracking susceptibility of asphalt mixtures is significantly influenced by temperature and loading rate, leading to a discrepancy in performance between standard test conditions and real-world scenarios. To address this challenge, this study explores the applicability of the time-temperature superposition principle (TTSP) for the SCB test. The study evaluates four mixtures incorporating reclaimed asphalt pavement (RAP) and/or reclaimed asphalt shingles (RAS) across various loading rates and temperature combinations. Findings suggest that TTSP can be applied to the SCB test without significantly impacting cracking performance indices such as flexibility index and post-peak slope. Furthermore, the study also demonstrates that TTSP can be applied in the crack propagation phase during the post-peak domain of the mixtures. The findings of the study will allow laboratories to develop more flexible testing plans without compromising the accuracy and reliability of performance parameters by adjusting the loading rate corresponding to the test temperature and vice versa. Consequently, this approach can potentially make a balanced mix design (BMD) practice more implementable.

1. Introduction

The semi-circular bend (SCB) test has been developed to measure the fracture properties of asphalt mixtures, particularly in the domain of low and intermediate temperatures as illustrated in Fig. 1a. The SCB test is widely used for both asphalt mixture design and quality control due to its straightforward specimen preparation procedure and equipment availability in laboratories. Its practicality and relatively quick testing time are a few of the reasons why it is widely used by agencies and contractors. It is extensively employed to evaluate the effects of fibers [1] and recycled materials, such as reclaimed asphalt pavement (RAP) [2,3], reclaimed asphalt shingles (RAS) [4,5], and crumb rubber [6,7] on mixture performance. Additionally, the notched SCB specimens can potentially be used to predict indirect tensile strength in the low-temperature domain [8,9].

The test results, i.e., the load vs. load-line displacement (LLD) curve (Fig. 1b), can be used to evaluate several parameters, including peak load or strength, flexibility index (FI), pre-peak fracture energy, post-peak slope, fracture energy (FE), and rate-dependent cracking index (RDCI). These parameters are crucial for assessing the cracking resistance of asphalt materials under standard testing conditions (displacement rate and test temperature) [10]. Additionally, the cracking performance of the mixtures can be evaluated using the load vs. crack mouth opening displacement (CMOD) curve if CMOD is measured

Abbreviations: BMD, balanced mix design; CMOD, crack mouth opening displacement; COV, coefficient of variation; FE, fracture energy; FI, flexibility index; HMA, hot mix asphalt; HTPG, high-temperature performance grade; IDEAL-CT, indirect tensile asphalt cracking test; I-FIT, Illinois flexibility index test; ITPG, intermediate temperature performance grade; LLD, load-line displacement; LTPG, low-temperature performance grade; LVE, linear viscoelastic; MEPDG, mechanistic-empirical pavement design guide; NMAS, nominal maximum aggregate size; PG, performance grade; PRI, performance ranking index; RAP, reclaimed asphalt pavement; RAS, reclaimed asphalt shingles; RDCI, rate-dependent cracking index; RLPD, repeated load permanent deformation; S, standard scenario; SCB, semi-circular bend; TTSP, time-temperature superposition principle; V1, variation-1; V2, variation-2; V3, variation-3; WLF, Williams-Landel-Ferry.

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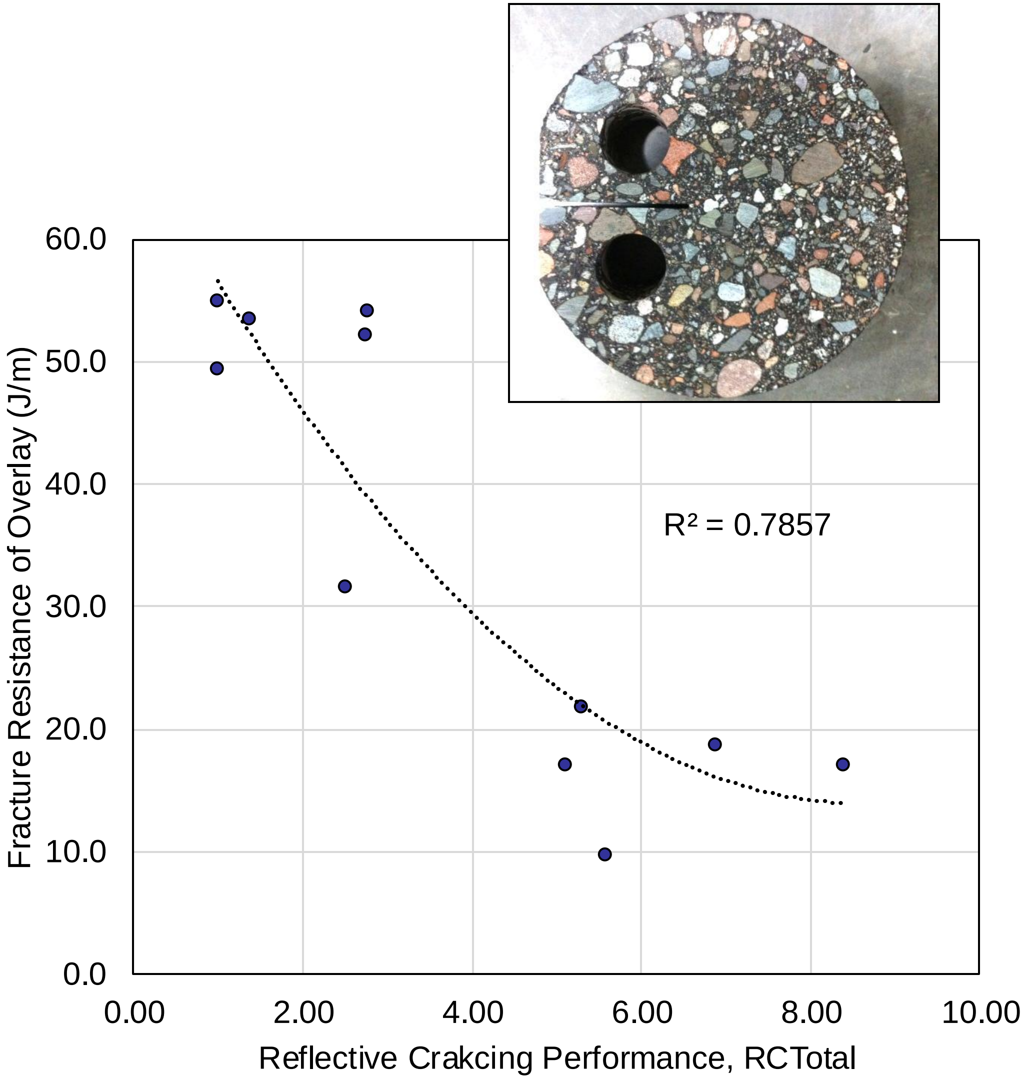
More Details

Examples of On-going Research Efforts to Support BMD Implementation

- BMD development for airfield asphalt mixtures
- Practicality improvements for Illinois Flexibility Index (I-FIT) test
- **Development of Simplified Wedge Splitting Test (SWST)**
  - **Acknowledgements: Shongtao Dai and Joseph Voels (MnDOT)**

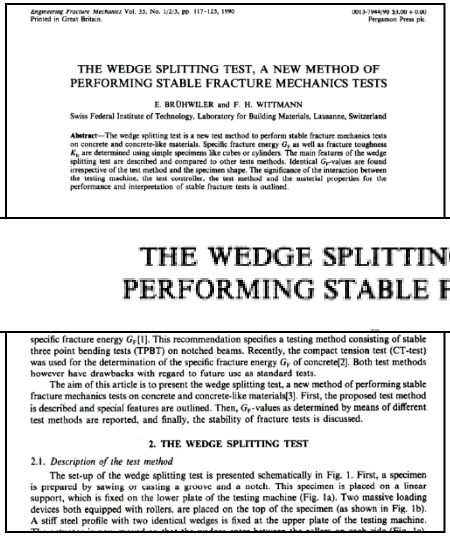
Simplified Wedge Splitting Test (SWST): Motivation

- DCT has shown to correlate very well with transverse cracking performance of asphalt mixtures in Minnesota
  - Fracture energy (G_f) as well as post-peak indices have been assessed in past and will get more comprehensive assessment under a new MnDOT/LRRB effort.
  - A massive database of results exist for MN mixes tested using DCT
- DCT is a complex test: specimen fabrication, specimen conditioning, testing
- DCT cannot be used as a routine test within a QA process for asphalt mixtures



How to combine simplicity and existing knowledge?

- DCT:
  - Complex specimen geometry → Needs significant operator training
  - Takes too long to get results → Not good for process control
- DCT + CT-Index → Simplified Wedge Splitting Test (SWST)
- SWST is not an entirely new concept



Engineering Fracture Mechanics Vol. 35, No. 1/2/3, pp. 117–125, 1990 Printed in Great Britain. 0013-7944/90 $3.00 + 0.00 Pergamon Press plc

THE WEDGE SPLITTING TEST, A NEW METHOD OF PERFORMING STABLE FRACTURE MECHANICS TESTS

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Abstract—The wedge splitting test is a new test method to perform stable fracture mechanics tests on concrete and concrete-like materials. Specific fracture energy G_F as well as fracture toughness K_Ic are determined using simple specimens like cubes or cylinders. The main features of the wedge splitting test are described and compared to other tests methods. Identical G_F-values are found irrespective of the test method and the specimen shape. The significance of the interaction between the testing machine, the test controller, the test method and the material properties for the performance and interpretation of stable fracture tests is outlined.

specific fracture energy G_F[1]. This recommendation specifies a testing method consisting of stable three point bending tests (TPBT) on notched beams. Recently, the compact tension test (CT-test) was used for the determination of the specific fracture energy G_F of concrete[2]. Both test methods however have drawbacks with regard to future use as standard tests.

The aim of this article is to present the wedge splitting test, a new method of performing stable fracture mechanics tests on concrete and concrete-like materials[3]. First, the proposed test method is described and special features are outlined. Then, G_F-values as determined by means of different test methods are reported, and finally, the stability of fracture tests is discussed.

2. THE WEDGE SPLITTING TEST

2.1. *Description of the test method*

The set-up of the wedge splitting test is presented schematically in Fig. 1. First, a specimen is prepared by sawing or casting a groove and a notch. This specimen is placed on a linear support, which is fixed on the lower plate of the testing machine (Fig. 1a). Two massive loading devices both equipped with rollers, are placed on the top of the specimen (as shown in Fig. 1b). A stiff steel profile with two identical wedges is fixed at the upper plate of the testing machine.

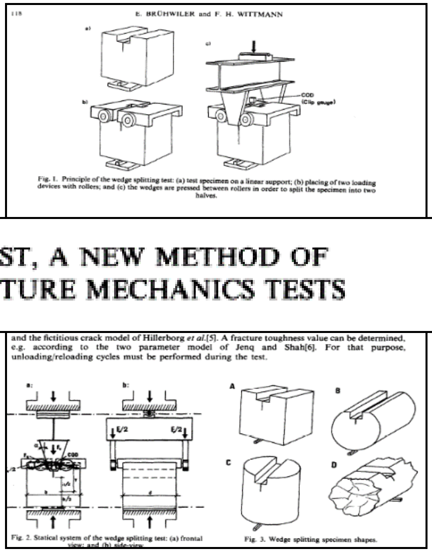

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Fig. 1. Principle of the wedge splitting test: (a) test specimen on a linear support; (b) placing of two loading devices with rollers; and (c) the wedges are pressed between rollers in order to split the specimen into two halves.

and the fictitious crack model of Hillerborg et al.[5]. A fracture toughness value can be determined, e.g. according to the two parameter model of Jenq and Shah[6]. For that purpose, unloading/reloading cycles must be performed during the test.

Fig. 2. Statical system of the wedge splitting test: (a) frontal view; and (b) side-view.

Fig. 3. Wedge splitting specimen shapes.

THE WEDGE SPLITTING TEST, A NEW METHOD OF PERFORMING STABLE FRACTURE MECHANICS TESTS

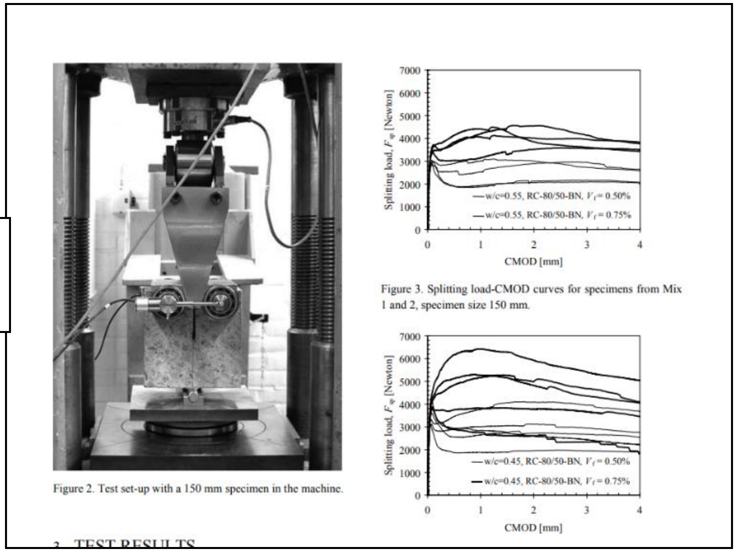
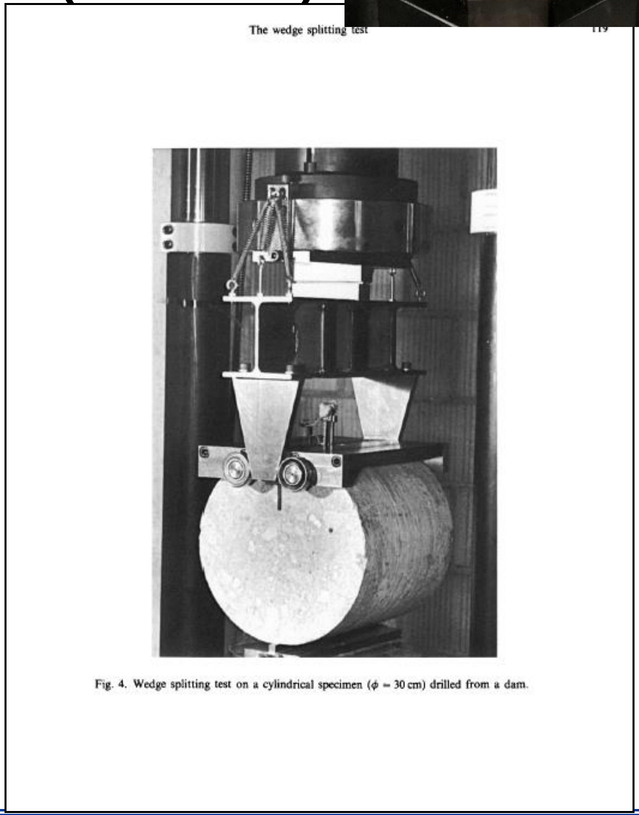


Figure 2. Test set-up with a 150 mm specimen in the machine.

Figure 3. Splitting load-CMOD curves for specimens from Mix 1 and 2, specimen size 150 mm.

3. TEST RESULTS



The wedge splitting test 119

Fig. 4. Wedge splitting test on a cylindrical specimen (ϕ = 30 cm) drilled from a dam.

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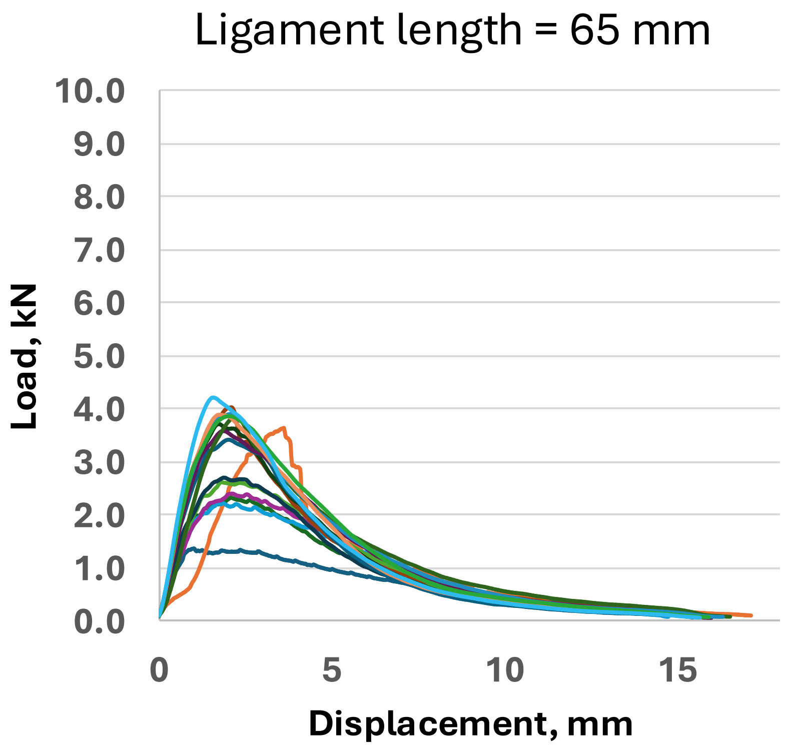
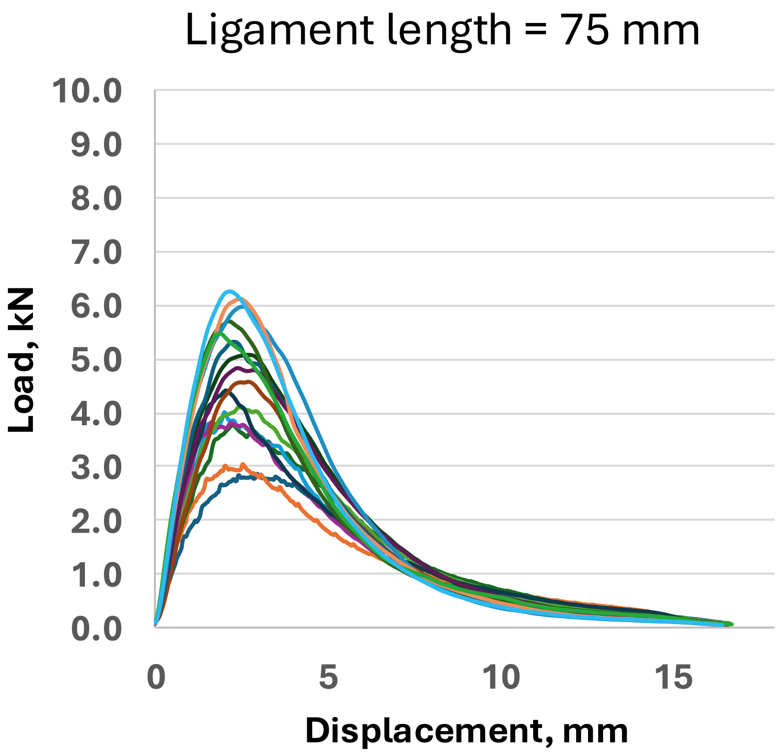
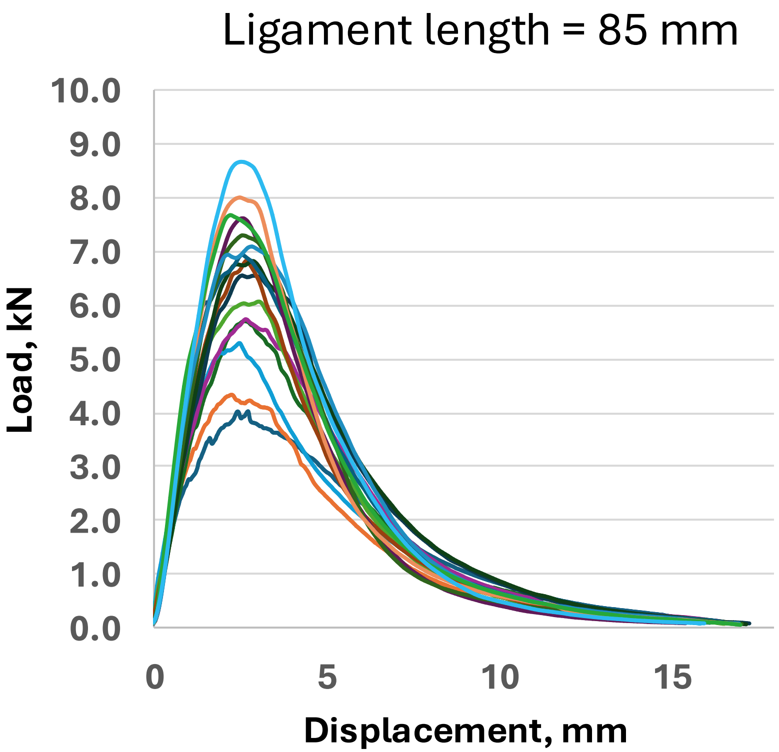
MnDOT Testing using SWST

- Different notch depths and loading rates (to compensate for test temperatures)







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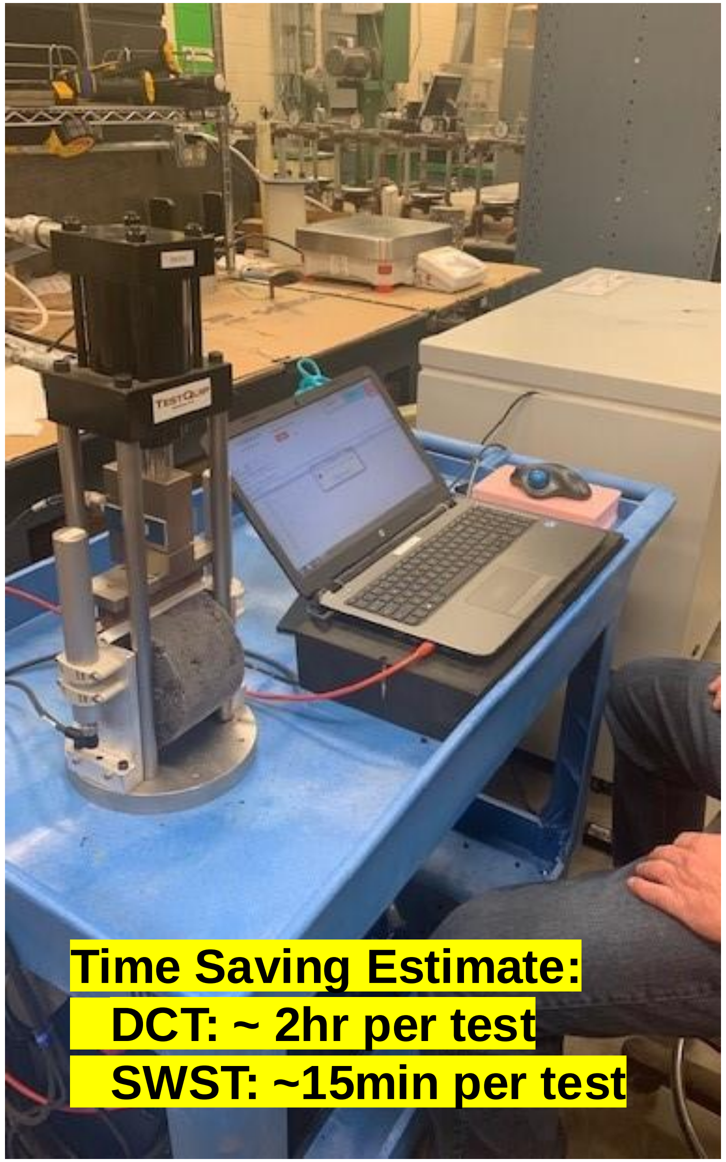
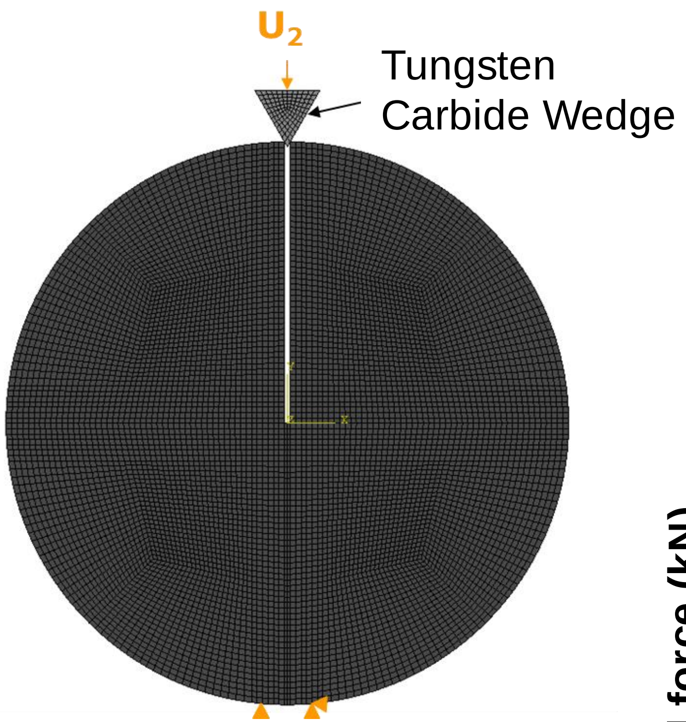
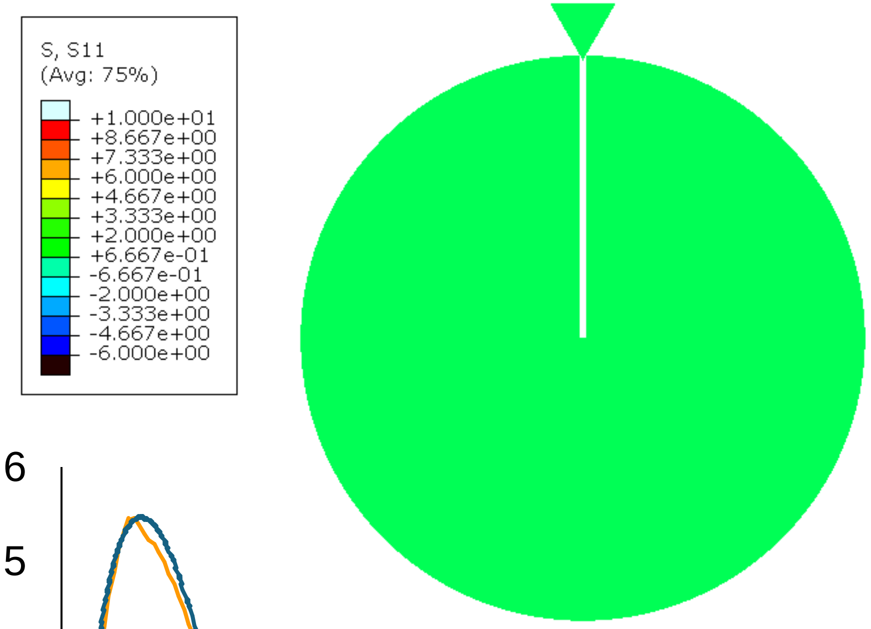
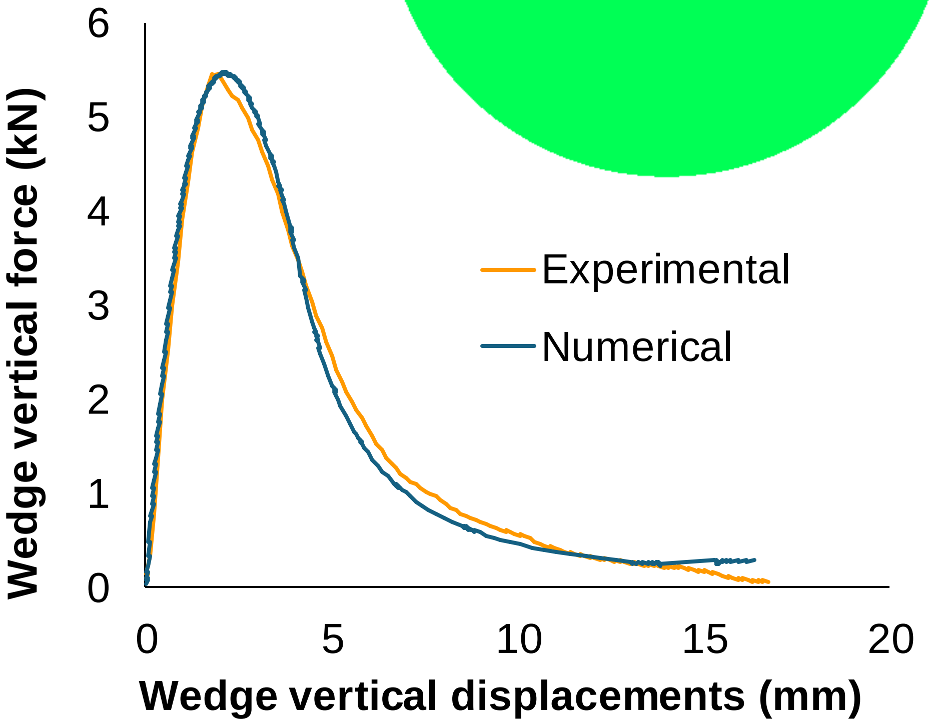
SWST Trials and Modelling



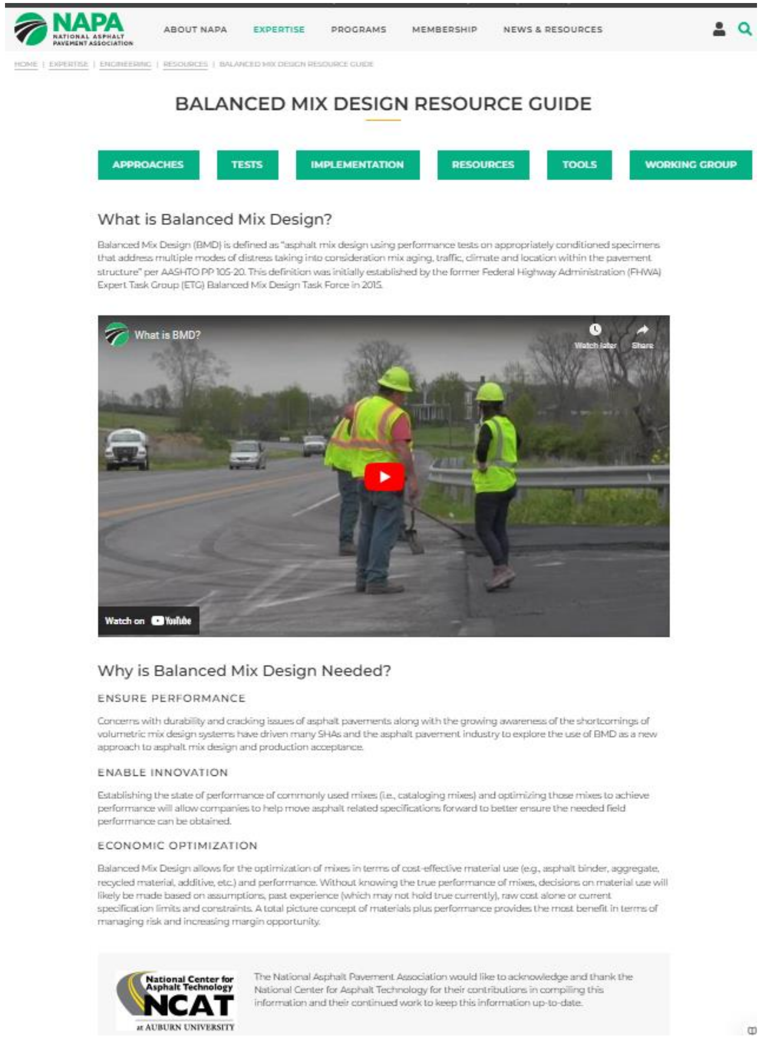
Time Saving Estimate:
DCT: ~ 2hr per test
SWST: ~15min per test







BMD Resources



- NAPA-IS 143 BMD Resource Guide 2021
- NCHRP 20-07 Task 406 BMD Framework Final Report
- NCHRP Synthesis 552 Practices for Fabricating Asphalt Specimens for Performance Testing in Laboratories
- Technical Report: Positive Practices, Lessons Learned, and Challenges When Implementing Balanced Design of Asphalt Mixtures: Site Visits (WRSC-TR-22-11)
- Technical Report: Index-based tests for performance-engineered mixture designs for asphalt pavements (FHWA-HIF-19-103)
- BMD Case Studies

BMD IMPLEMENTATION WORKING GROUP

Thank you for your attention!

Questions and Comments?

University of New Hampshire