2024

Accelerated Implementation and Deployment of Pavement Technologies (AIDPT) Pooled Fund Peer Exchange on Balanced Mix Design (BMD)

Outcomes Summary

Auburn, Alabama

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NOTICE

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16. Abstract 15 states across the United States (U.S.) gathered for a peer exchange and discussion on implementation activities to support Balanced Mix Design (BMD). The peer exchange was sponsored by the Federal Highway Administration (FHWA). The 15 States met to discuss state of knowledge, identify successes, current activities and research, and research and implementation gaps pertaining to challenges discussed during previously held regional peer exchanges. The peer exchange was held at National Center for Asphalt Technology (NCAT) in Auburn, Alabama. This summary report focuses on BMD state of knowledge, gaps, and challenges to implementation, performance testing protocols, management challenges, acceptance details, key takeaways, and emerging themes.		

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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LIST OF ABBREVIATIONS AND SYMBOLS

AASHTO: American Association of State Highway and Transportation Officials
AC: Asphalt Content
AIDPT: Accelerated Implementation and Deployment of Technologies Pavement Technologies Program
ALF: Accelerated Load Facility
AMRL: AASHTO Materials Reference Laboratory
AOT: Agency of Transportation
APA: Asphalt Pavement Associations
AQC: Acceptance Quality Control
ARA: Applied Research Associates, Inc.
BMD: Balanced Mix Design
CAPRI: Consortium for Asphalt Pavement Research and Implementation
CBM: Central Bureau of Materials
COAC: Correct Optimum Asphalt Content
COMP: Committee on Materials and Pavements
COV: Coefficient of Variation
CPR: Crack Propagation Rate
CT-Index: Cracking Tolerance Index
DCT: Disc Shaped Compact Tension
DFT: Dynamic Friction Tester
DOT: Department of Transportation
DOTD: Department of Transportation and Development
EPD: Environmental Product Declaration
FAA: Fine Aggregate Angularity
FDR: Full Depth Reclamation
FHWA: Federal Highway Administration
FI: Flexibility Index
FWD: Falling Weight Deflectometer
GHG: Greenhouse Gas
Gmm: Maximum Specific Gravity
Gsb: Bulk Specific Gravity
GWP: Global Warming Potential
HiMA: Highly Modified Asphalt
HMA: Hot Mix Asphalt
HT-ID: High Temperature Indirect Tensile Strength Test
HWTT: Hamburg Wheel Tracking Test
IDEAL-CT: Indirect Tensile Cracking Test
IDEAL-RT: IDEAL Rutting Test
I-FIT: Illinois Flexibility Index Test
J_c: Fracture Mechanics Parameters
JMF: Job Mix Formula
LCA: Life Cycle Analysis
LMLC: Lab Mix Lab Compacted
LTA: Long-Term Aging
LTOA: Long-Term Oven Aging
LTRC: Louisiana Transportation Research Center
LWT: Loaded Wheel Tester
MAP-21: Moving Ahead for Progress in the 21st Century Act
MPL: Material Producer List
ME: Mechanistic-Empirical
MEPDG: Mechanistic-Empirical Pavement Design Guide
MiST: Moisture Induced Stress Tester
MTV: Material Transfer Vehicle
NAPA: National Asphalt Pavement Association
NCAT: National Center for Asphalt Technology
NETC: New England Transportation Consortium
NMAS: Nominal Maximum Aggregate Size
OBC: Optimum Binder Content
OGFC: Open Graded Friction Course
OSU: Oregon State University
OT: Overlay Tester
PCC: Portland Cement Concrete
PG: Performance Grade
PMLC: Plant Mix Lab Compacted
PMS: Pavement Management System
PP: Practice, Provisional Standard
PWL: Percent within Limits
QA: Quality Assurance
QC: Quality Control
RAM: Recycled Asphalt Materials
RAP: Reclaimed Asphalt Pavement
RAS: Reclaimed Asphalt Shingles
RBR: Rapid Bridge Replacement
RTFO: Rolling Thin Film Oven
SAC-A: Surface Aggregate Classification A
SCB: Semicircular Bending Test
SGC: Superpave Gyratory Compactor
SHA: State Highway Administration
SIP: Stripping Inflection Point
SMA: Stone Mastic Asphalt
STOA: Short-Term Oven Aging
TD: Transportation Department
TPF: Transportation Pooled Fund
TRB: Transportation Research Board
TSD: Traffic Speed Deflectometer
TSR: Tensile Strength Ratio
UNR: University of Nevada, Reno
U.S.: United States
VFA: Voids Filled with Asphalt
VMA: Voids in Mineral Aggregate
VTM: Voids in Total Mix
WMA: Warm Mix Asphalt

INTRODUCTION AND PURPOSE

Since 2013, the Accelerated Implementation and Deployment of Technologies Pavement Technologies Program (AIDPT)—in partnership with State Departments of Transportation (DOTs), academia, and industry—has identified asphalt and concrete paving advancements and implemented effective strategies for rapid deployment of new and promising technologies. As part of the AIDPT effort, the Demonstration to Advance New Pavement Technologies Study: Transportation Pooled Fund (TPF)-5(478), was started in 2021. 23 states across the United States (U.S.) are participating in the AIDPT pooled fund project looking at technologies such as asphalt Balanced Mix Design (BMD), resiliency, sustainability, pavement preservation, smoothness, and foundations. On March 12–14, 15 of the 23 states gathered for a peer exchange and discussion on implementation activities to support BMD. The peer exchange was sponsored by the Federal Highway Administration (FHWA). The 15 States met to discuss state of knowledge, identify successes, current activities and research, and research and implementation gaps pertaining to challenges discussed during previously held regional peer exchanges. The peer exchange was held at the National Center for Asphalt Technology (NCAT) in Auburn, Alabama.

This summary report focuses on BMD current state of knowledge, gaps, and major challenges to implementation, the role of agency and stakeholder management in BMD practices, performance testing protocols and validation, acceptance details, and action items for moving forward. All referenced specifications are not Federal requirements unless otherwise noted.

The agenda for the peer exchange was developed based on challenges identified during previous peer exchanges held by FHWA and the University of Nevada, Reno (UNR), as part of their cooperative agreement. Those five previous peer exchanges were held in Schaumberg, IL (2), Salt Lake City, UT, Worcester, MA, and Baton Rouge, LA.

PEER EXCHANGE GENERAL OVERVIEW

The BMD approaches focus on designing asphalt mixtures for performance rather than designing to meet volumetric requirements. The American Association of State Highway and Transportation Officials (AASHTO) Practice, Provisional Standard (PP) 105-20 Standard Practice for Balanced Design of Asphalt Mixtures[1] describes four approaches for a BMD process that are briefly summarized as follows:

- ***Approach A — Volumetric Design with Performance Verification*** consists of using existing volumetric mix design along with additional mechanical tests criteria.
- ***Approach B — Volumetric Design with Performance Optimization*** consists of using existing volumetric mix design to determine a preliminary optimum binder content (OBC) but allows moderate changes in asphalt binder content to meet mechanical tests criteria. This approach is slightly more flexible than Approach A.
- ***Approach C — Performance-Modified Volumetric Design*** allows some of volumetric properties to be relaxed or eliminated as long as the mechanical tests criteria are satisfied. The mechanical test results are used to adjust either the preliminary asphalt binder content or mixture component properties and proportions. This approach is more flexible than Approach A and Approach B.
- ***Approach D — Performance Design*** does not use volumetric properties and relies on the mechanical test results to establish and adjust mixture components and proportions. This is the most flexible approach.

[1]AASHTO PP 105 Standard Practice for Balanced Design of Asphalt Mixtures. AASHTO, Washington, D.C., 2020. Use of this AASHTO specification is not a Federal requirement.

Participants

States represented at the AIDPT BMD peer exchange included (Figure 1):

- Arizona DOT;
- Colorado DOT;
- Connecticut DOT;
- Georgia DOT;
- Hawaii DOT;
- Idaho Transportation Department (TD);
- Illinois DOT (represented by the FHWA Illinois Division office);
- Louisiana Department of Transportation and Development (DOTD);
- Maine DOT;
- Missouri DOT;
- North Dakota DOT;
- Oregon DOT;
- Tennessee DOT;
- Texas DOT; and
- Vermont Agency of Transportation (AOT).

A list of the State participants is provided in Appendix A.

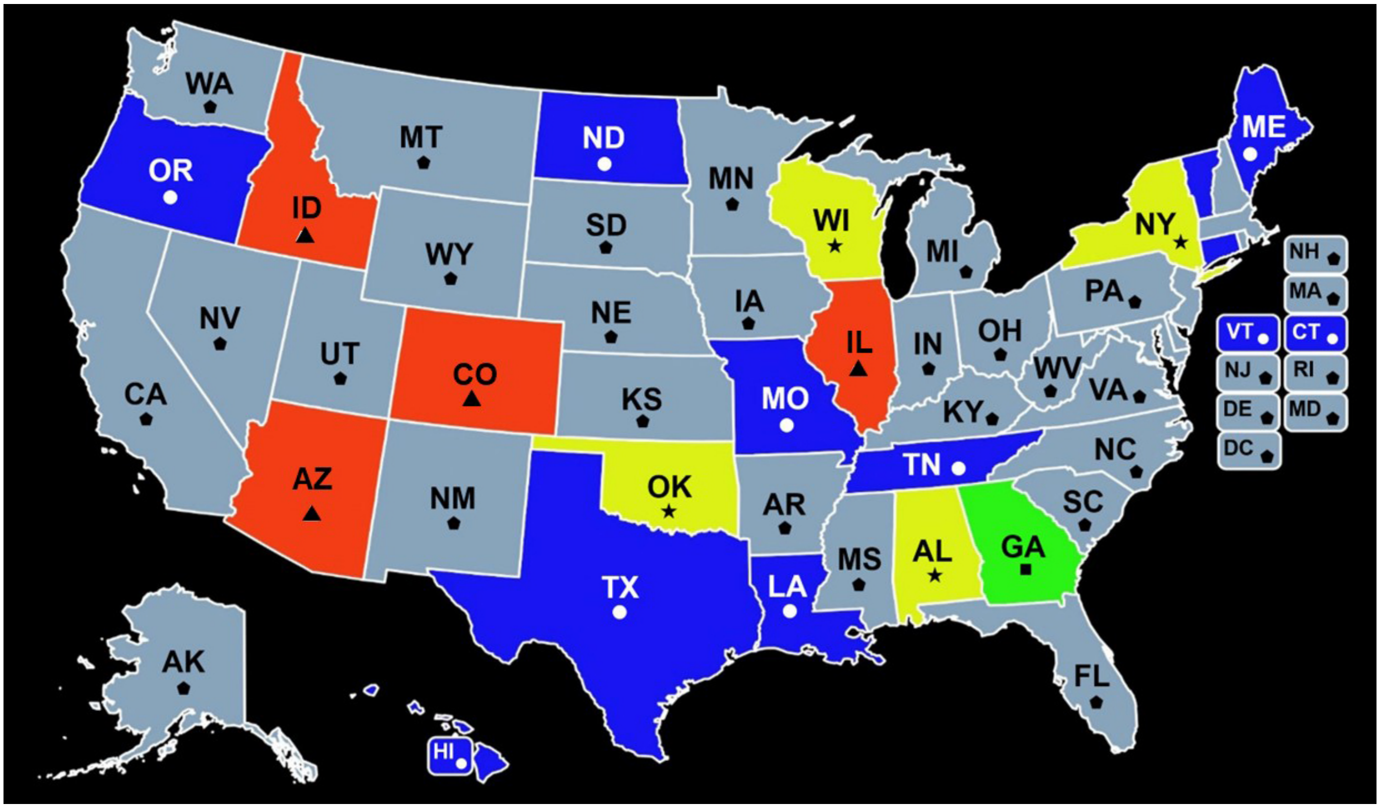

*Figure 1. U.S. Map showing participating States in the AIDPT Pooled Fund BMD peer exchange. (Source: FHWA)**

*Note: AIDPT Pooled Fund BMD Peer Exchange participating states are marked in blue, red, and green. The states marked yellow are included in the AIDPT pooled fund but did not attend the BMD Peer Exchange. Blue marked states chose to focus on the asphalt BMD technology area. The states marked with red are in the AIDPT pooled fund but are participating in a technology other than BMD. Note: AL, NY, OK and WI are participating in the pooled fund in the BMD technology area. Georgia is considering the BMD technology area.

Agenda

Day One of the meeting focused on the BMD current state of practice; pooled fund updates; the NCAT workshop on knowledge, gaps, and challenges to BMD implementation; and the three most common challenges associated with BMD implementation. Day Two focused on group discussions about successes, existing research and research needs of management activities, performance tests, and acceptance details of BMD implementation. The peer exchange was conducted with two participant breakout groups. The report reflects and combines all the responses and feedback shared amongst the groups during the exchange. Future steps towards implementing BMD and needs for moving forward were also discussed. The following items were specifically included in the agenda:

- AIDPT pooled fund background, goals, and objectives.
- BMD current state of practice.
- Overview of common challenges associated with BMD implementation.
- Guidelines and recommendations for field validation tests of BMD.
- BMD performance test specimen fabrication guidelines.
- Different approaches of BMD.
- Challenges and lessons learned.
- Benefits, resources required, risk management, and stakeholder engagement for BMD implementation.
- Next steps toward implementing BMD within each Agency and needs for moving forward.

BACKGROUND AND OBJECTIVES

This in-person BMD peer exchange meeting was organized by FHWA under the Demonstration to Advance New Pavement Technologies Study: TPF-5(478). This pooled fund is part of the AIDPT program initiated by Moving Ahead for Progress in the 21st Century Act (MAP-21) bipartisan legislative bill. The AIDPT program helps participating states with research and implementation of the latest pavement technologies through FHWA and stakeholder collaborations. BMD is one of six technologies under this pooled fund and was included to help interested states at their current stage of BMD implementation to advance to the next stage.

Some states utilized the money with their local university such as Oregon DOT, who is working with Oregon State University (OSU) for its BMD research projects. Louisiana DOTD is closely associated with the Louisiana Transportation Research Center (LTRC) for its BMD research and implementation projects. On the other hand, the funds can also be transferred to another pooled fund of the States's choice. North Dakota DOT is working with the Consortium for Asphalt Pavement Research and Implementation (CAPRI)–another pooled fund–to utilize funds from the AIDPT pooled fund. In fact, the state is constructing its BMD pavement test section by utilizing its BMD pooled fund money through CAPRI. Hawaii DOT will also use the same approach as North Dakota DOT. The allocated funds can also be used to purchase BMD performance testing equipment.

Currently, 23 states are participating in various technologies of the AIDPT pooled fund, and 13 states are involved with the BMD technology. Quarterly progress reports are required from each participating state to update their status on how funds are being used. Resources are also available to help with marketing and advertising the States' activities with BMD implementation.

The real focus of this peer exchange was to share the success of different states, their current activities and research on BMD, and to identify research gaps.

BMD Current State of Practice

Arizona DOT

The State has been conducting some performance testing using the Hamburg Wheel Tracking Test (HWTT), IDEAL Rutting Test (IDEAL-RT), and Indirect Tensile Cracking Test (IDEAL-CT).

Colorado DOT

The State has been researching HWTT and IDEAL-CT using several existing asphalt mixtures.

Connecticut DOT

The legislative body passed a law requiring the use of more recycling in asphalt mixtures. The State started benchmarking IDEAL-RT and IDEAL-CT for its existing asphalt mixtures. Newer asphalt mixtures like Stone Mastic Asphalt (SMA) are being introduced. The State is aiming to conduct a pilot project in 2026.

Georgia DOT

The State is benchmarking IDEAL-CT for mix design. The HWTT has also been implemented for acceptance which led to the elimination of the Tensile Strength Ratio (TSR) test. Early on, when HWTT was implemented, the focus was on having rut resistant asphalt mixtures. This resulted in asphalt mixtures with low Cracking Tolerance Index (CT-Index) values (in the range of 10). Thus, the state has been looking into using IDEAL-CT to improve durability and exploring the need for a moisture sensitivity test beyond just the HWTT. BMD can be a pathway to relax some of the rutting requirements.

Hawaii DOT

The State is still exploring the use of BMD with the aim of introducing new materials and additives into their asphalt mixtures.

Idaho TD

The State is trying to convince management. The State has revised specification this year with no considerations towards BMD. But the ultimate target is approach D. The central lab is equipped to run HWTT and IDEAL-CT. Mix design is required to pass HWTT, although IDEAL-CT is for informational purposes only. All testing is used for information during production.

Illinois DOT

In 2014, the State implemented HWTT. In 2021, it implemented the Illinois Flexibility Index Test (I-FIT) with Short-Term Oven Aging (STOA) and in 2022, it implemented Long-Term Oven Aging (LTOA). The State is currently researching binders with additives/modifiers.

Louisiana DOTD

In 2016, the State implemented BMD for all mixtures using HWTT, and the intermediate temperature Semicircular Bending (SCB) test. It is currently looking into implementing Quality Control (QC) and acceptance. The State is looking forward to moving beyond Approach A.

Maine DOT

Maine has fully implemented HWTT for higher value projects. The state has been investigating the intermediate cracking test IDEAL-CT as the current test of choice to balance cracking and rutting in a BMD framework. Internal management and industry are starting to be supportive of the idea behind BMD and the state now has set up two separate working groups to address the common management and technical challenges. The state is hopeful to have a couple shadow projects in 2024 or shadow/pilot projects no later than 2025.

Missouri DOT

The State has been conducting BMD for a long time with 10-15 pilot projects. The most recent provisional specification is more towards BMD. The State's primary goal is to have full implementation of BMD by summer of 2025. There is some pushback from industry related to the amount of performance testing.

North Dakota DOT

In this state, benchmarking efforts with 20 different projects is the main venture. The State will have a pilot project this summer. All the HWTT and IDEAL-CT equipment is in the central lab. The state is currently using BMD for modified mixtures with Evotherm.

Oregon DOT

The State has conducted benchmarking on production mixes for the past three to four years. IDEAL-CT ranged from 14 to over 100. The State has three research projects with OSU including the implementation plan. It built accelerated pavement test sections and used a BMD approach in five different projects. It is hoping for a pilot project this summer.

Tennessee DOT

The State still heavily utilizes Marshall mix design. It is telling contractors to move into gyratory compacted samples. It is predominantly a Limestone state, with some granite. Different aggregates are present in different parts of the state. It is still in the initial stage of figuring things out.

Texas DOT

The State's efforts with BMD are ongoing and began in 2018 with 33 field test sections constructed from 2019-2022. In 2024, several multi-day shadow projects will be constructed using the BMD approach.

Vermont AOT

Vermont has felt industry and political pressure to incorporate more Recycled Asphalt Materials (RAM) into their mixes since 2008. The state has fully implemented HWTT as the primary rutting and moisture susceptibility test for the majority of Superpave mixtures and is currently looking at the IDEAL-CT as the primary cracking test for BMD. The I-FIT was previously looked at as the primary cracking test from 2017 until 2022, when it was determined that the IDEAL-CT was more conducive for implementation purposes. The State tried Quality Assurance (QA) with HWTT and I-FIT in 2019 and 2020, but this did not work well due to logistics. BMD Approaches C and/or D are the main long-term goals, and their short-term goals involve piloting High Reclaimed Asphalt Pavement (RAP) mixtures and exploring the IDEAL-RT as a "surrogate" for the HWTT to evaluate rutting during QA activities. acceptance

Other States

California, Illinois, Louisiana, Maine, New Jersey, Texas, and Virginia have also been heavily involved in BMD implementation. FHWA interviewed these states and published detailed reports on their BMD related successes and activities. The reports are available on the FHWA cooperative agreement website[2]. Summary reports and tech briefs are also available. As a result, eight tasks for the implementation of BMD were identified and are summarized in the FHWA Tech Brief FHWA-HIF-22-048 (Hajj et al. 2022; Hall, E., Aschenbrener, T., and Nener-Plante, D. 2022. *Balanced Mixture Design: Eight Tasks for Implementation.* FHWA-HIF-22-048. Washington, DC). FHWA has been conducting in-person and virtual workshops to help the states move towards

[2] https://www.fhwa.dot.gov/pavement/asphalt/coopmaterials/

the next tasks in their implementation plans. Five regional peer exchanges have also been completed in 2023 with one more is being planned for the Fall of 2024[3]. These peer exchanges identified several management and technical challenges that served as the basis for the AIDPT BMD peer exchange.

BMD STATE OF KNOWLEDGE, GAPS, AND CHALLENGES TO IMPLEMENTATION

Overview of Common BMD-Related Challenges

Based on the five regional peer exchanges, BMD implementation challenges can be categorized into two categories[4]:

- Management challenges:
  - Change Management;
  - Cost-Benefit Analysis;
  - Specifications and Risk Management;
  - Resource Allocation;
  - Implementation Planning; and
  - Stakeholders Engagement.
- Technical challenges:
  - BMD Tests Validation;
  - Testing Procedures and Protocols;
  - Testing Variabilities;
  - Database Setup;
  - Data Collection, Analysis, and Management;
  - Pathway for Use in Field QA; and
  - Volumetrics Historical Usage.

There are overarching challenges between the two major focus areas:

- Integration with Existing Practices;
- Education, Training, and Skill Development; and
- Information Sharing and Collaboration Among Peers.

The participants in the peer exchange were asked to rank the implementation challenges prior to attending. It was desired to spend more time at the peer exchange focused on most prevalent challenges. The summary of challenges with their ranking is shown below.

[3] https://www.fhwa.dot.gov/pavement/asphalt/coopmaterials/
[4] https://www.fhwa.dot.gov/pavement/asphalt/coopmaterials/HIF_1-pager_Summary_of_Webinar_Series.pdf

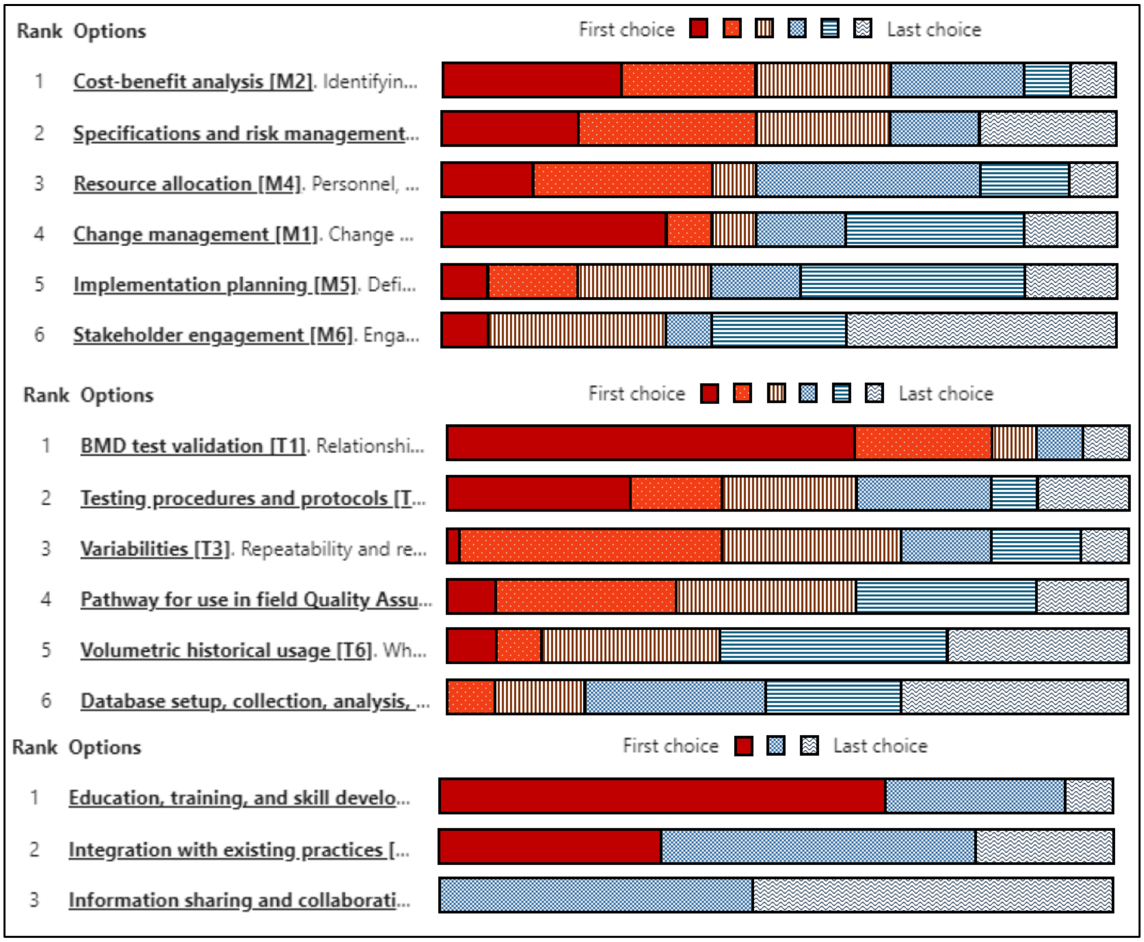

Figure 2. Polling results of ranked implementation challenges from participants prior to attending the AIDPT Pooled Fund BMD peer exchange. (Source: FHWA)

Based on these rankings, the top three challenges were discussed on the first day as a large group. These three challenges included:

- BMD Test Validation;
- Testing Procedures and Protocols; and
- The "Why" and the Benefits.

To start the peer exchange, NCAT staff provided presentations on recent BMD research. The presentations related to: (1) Guidelines and Recommendations for Field Validation, (2) Specimen Fabrication Guide, and (3) Moving from Approach A. Summaries of each of these presentations follow:

Strategies for Field Validation – Presentation by Tom Harman

A study was completed by West et al. develop guidelines and recommendations for field validation of BMD test criteria under CAPRI (West et al. 2024; West, R., Tran, N. Yin, F., Rodenzo, C., and Harman, T. 2024. *Guidelines and Recommendations for Field Validation of Test Criteria for BMD Implementation.* Report Number CAPRI-23.001-R. Auburn, AL.). The guidelines consist of an 11-step process for establishing valid relationships between BMD test results and field pavement performance, and to ensure that appropriate specification criteria are developed. Each step is a chapter in the guideline. Illinois and New Jersey are two of the states who have fully implemented the BMD and did some field validations. Alabama DOT and North

Dakota DOT are in the process of building field test sections. Field validation is important to advance BMD implementation. The 11 steps are described below:

1. Advantages, Disadvantages, and Limitations of Test Section Approaches.
2. Types of Distresses Evaluated in Field Sites.
3. Range of Mixtures and Materials in the Field Validation Effort.
4. Number of Test Sections for a Site.
5. Length of Test Sections.
6. Roadway Geometrics to Avoid.
7. Sampling, Conditioning, and Testing Plan.
8. Pavement Performance Monitoring, Traffic, and Climate Data Collection.
9. Forensic Investigation.
10. Data Analysis and Application of the Results in Specification.
11. Establishing Interim Criteria.

Specimen Fabrication Guide[5] – Presentation by Adam Taylor

Specimen preparation is very important for BMD performance testing variability reduction.

Tools publicly available on the NCAT website are as follows:

- Achieving a target specimen air voids (Videos and Excel Spreadsheets):
    - Air voids tolerance ±0.5% is good.
    - Changing sample height is not good practice.
- Guidance on material handling and aging:
    - Limiting Segregation.
    - Limiting Excess Binder Oxidation.

Limiting segregation and oxidation of mix can help to generate reproducible results. The National Asphalt Pavement Association (NAPA) BMD resource guide is also a valuable tool. AASHTO R47 should be followed to avoid segregation. Having a consistent sample fabrication protocol is key.

Moving from Approach A – Presentation by Randy West

Flexibility with volumetric properties starts with Approach B that allows a change in the asphalt binder content to meet performance test criteria. Approach C allows for a change in asphalt binder content, aggregate properties, asphalt binder type, etc. Approach D solely depends on performance testing. Approach A has been more favorable because of current challenges associated with implementation within a state’s current practices. Approach A provides States with more control about the specified asphalt mixture.

- Flexibility with volumetric properties starts with Approach B that allows a change in the asphalt binder content to meet performance test criteria.

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[5] https://member.asphaltpavement.org/Shop/Product-Catalog/Product-Details?productid=%7BE46B1D15-4A01-EE11-8F6E-00224827B16D%7D

Moore and Taylor, 2023.

Moore, N. and Taylor. A. 2023. *Guide on Asphalt Mixture Specimen Fabrication for BMD Performance Testing*. IS-145. National Asphalt Pavement Association.

- Approach C allows for a change in asphalt binder content, aggregate properties, asphalt binder type, etc.
- Approach D solely depends on performance testing. Approach A has been more favorable because of current challenges associated with implementation within a state's current practices.
- Approach A provides States with more control about the specified asphalt mixture.
- The NAPA website has an interactive map that shows which approaches different states are moving forward with.
- Approach B is a good starting point for states looking to begin BMD implementation as there is more confidence in the performance testing now than ever before.
- IDEAL-RT and High Temperature Indirect Tensile Strength (HT-IDT) are highly correlated, so either could be used for performance testing.
- Both Approach A and Approach B will increase the costs of the agencies because it is the most conservative approach and requires testing to meet both volumetric and performance requirements.
- Moving from volumetrics, Approach A will have room for materials like recycled shingles, fractionated RAP, recycled tire rubber, Warm Mix Asphalt (WMA) additives, rejuvenators, and polymers.
- Gradation and binder content are based on weight and can be a good measurement of acceptance, considering aggregate absorption and/or specific gravity does not vary too much. However, aggregate absorption and/or specific gravity can vary throughout a project. Acceptance quality characteristics based on weight cannot detect these changes. So, it is important to include a volumetric parameter as an acceptance quality characteristic, e.g., Maximum Specific Gravity (Gmm), Voids in Total Mix (VTM), Voids in Mineral Aggregate (VMA). At a minimum a volumetric parameter such as Gmm could be used to trigger more testing if a change is detected.

THREE MOST COMMON CHALLENGES IN IMPLEMENTING BMD PROCEDURE (DAY ONE: ROUND TABLE ONE)

BMD Performance Test Validation

Validation is critical for implementing BMD. Three questions were asked during this discussion:

- Have you completed a validation study?
- Are you currently monitoring or building a validation project?
- Are you curious about how to go by for a validation test?

State DOT-specific responses can be found in Appendix C.

BMD Performance Test Validation Summary

Various DOTs are at different stages when it comes to validating BMD performance tests. Some agencies have performed one or more validation studies, while others are still in the process of selecting projects for validation.

Illinois DOT conducted a validation study incorporating forensic investigation and pilot projects to address premature pavement failure. After implementation of the I-FIT and HWTT, Hot Mix Asphalt (HMA) mixes had not reduced recycling contents on an average basis. Louisiana DOTD utilized SCB for forensic investigation since 2002, refining criteria in 2023. HWTT and SCB testing became mandatory in 2016, showing improvements in block cracking. North Dakota is conducting a validation project focusing on a 15-mile Full Depth Reclamation project with varying Asphalt Content (AC) and intelligent compaction for density control while Oregon DOT is monitoring test section performance. Texas DOT evaluated 33 sections from nine projects, correlating rutting and crack propagation rate with different tests. They are exploring higher RAP percentages and alternative recycled binders, studying production variability with larger test sections.

On the other hand, Missouri DOT is collaborating with the University of Missouri to benchmark criteria and track field performance. Connecticut DOT is in the process of building and combining databases. Georgia DOT faces challenges in manually integrating different databases, and with ongoing management issues related to resources and skillsets. Maine DOT primarily conducts non-reconstruction and overlay work and is yet to perform a validation study with appropriate scoping. Tennessee DOT is seeking benchmarking perspectives on mixes.

Collaboration with universities for performing validations, including inspections and data integration efforts are ongoing across many of these agencies.

Other Key Takeaways

- Benchmarking data is good, but the challenge is how to connect it with field performance and also the time it takes to monitor performance and document differences.
- Pavement management is a network level tool, so caution needs to be taken when assigning to a specific project or when using it for forensic investigation.
- Rather than specifying mixes with certain cracking resistance, adjustments on the different mix components should be targeted.
- Handling of cores is also an issue. Aging and air voids in the core are more scattered than the laboratory specimens. This also varies greatly from index tests to fundamental tests. Cores are mostly used to investigate the current condition of a test section, not for benchmarking or setting criteria.

Performance Testing Procedures and Protocols

Every state is doing BMD sample fabrications and performance testing differently. Unified AASHTO or ASTM standards are necessary. Primary discussion points from this session are provided in Appendix D.

Performance Testing Procedures and Protocols Summary

States expressed challenges pertaining to laboratory accreditation. Georgia DOT's central lab holds AASHTO accreditation, but the six district labs lack accreditation due to management issues like resource constraints and staff turnover. Louisiana DOTD has state-recognized procedures but lacks detailed documentation and as in the case of Georgia, the district labs are not accredited. Missouri DOT seeks to standardize diverse testing procedures as its primary concern.

While discussing long-term aging, Arizona DOT acknowledges the necessity for a uniform aging protocol. Agency practices varied considerably. Illinois DOT's research suggests that three days at 95°C oven aging of fully prepared test specimens is akin to five days at 85°C. Louisiana DOTD considers transitioning from Approach A to LTOA during production and explores scaling factors for aging. Maine DOT considers implementing 20 hours oven aging at 110°C, while Texas DOT currently conducts only short-term aging. Virginia DOT has criteria regarding reheating, and Wisconsin DOT performs BMD cracking tests after six hours at 135°C post-STOA.

Likewise with lag time and dwell time, agency practices varied. Colorado DOT has a lag time of one to two months with a dwell time of approximately three hours. Louisiana DOTD mandates a minimum 24-hour wait time for HWTT based on AASHTO T324, while Missouri DOT requires a 30-minute wait after sampling due to warm mix additives. Oregon DOT lacks a standard practice and tests production mixes after prolonged lab storage. Vermont AOT faces technician shortages, leading to increased lag times.

In response to questions regarding moisture damage, Louisiana DOTD states that they replaced TSR with Loaded Wheel Tester (LWT) due to rain causing significant moisture damage. Discussions are ongoing about reintroducing TSR or conditioning HWTT specimens via Freeze-thaw or Moisture Induced Stress Tester (MiST). Tennessee DOT faces stripping issues with highly absorptive aggregates from west Tennessee. Vermont AOT employs HWTT for rutting and moisture damage but finds the boil test subjective.

Other Key Takeaways

- Georgia hires consultants to overcome shortage in laboratory staff.
- BMD performance testing protocols will not be national but more regional. States can follow the framework from other states, but detailed methodologies of each state can be different.
- Adjustment factors should only be applied to plant mixes.
- Many states are still figuring out testing protocols and standard procedures.
- States need to verify any aging procedures used by contractors.
- Sample fabrication must be standardized. Examples are out there to follow.

Why BMD and the Benefits

The importance and benefits of BMD—more specifically its return of investment, sustainability, and stories and successes—are significant. States are relying on BMD for their specialty mixes. BMD concepts are favorable for higher performing roadways.

Primary discussion points from this session are provided in Appendix E.

Why BMD and the Benefits Summary

In terms of benefits of BMD, both performance and sustainability were themes repeated by many agencies. Connecticut DOT emphasizes sustainability, advocating for top-down messaging to effectively convey the importance. Illinois DOT's 20-25-year-old SMA pavement still performs well, with I-FIT validation efforts completed. Louisiana DOTD shows significant design life increases with Pavement Mechanistic-Empirical (ME) Design software and BMD implementation, alongside no-cost change orders for BMD mixes. Maine DOT will be drafting BMD specifications highlighting sustainability benefits but raises concerns about Environmental Product Declaration's (EPD's) impact. North Dakota DOT benchmarks projects from specific pits, while Oregon DOT and Tennessee DOT foresee BMD enhancing sustainability and reducing costs. Texas DOT sets SCB threshold values and receives industry support for BMD research because BMD can be a way of increasing RAP usage. Vermont AOT echoes other New England state's belief in BMD's sustainability, citing potential aggregate availability challenges.

Other Key Takeaways

- BMD can allow for the use of some local marginal aggregates (less trucking), which would benefit EPD. Transportation distance and binder content are big contributors to Global Warming Potential (GWP) from a materials standpoint (moisture content of stockpile is another aspect).
- BMD can serve as a performance guardrail and incorporate newer tools. Life Cycle Analysis (LCA) of BMD sections can be the next step.
- Developing a one-pager titled "why BMD and the benefits" can be helpful in the long run. NCAT data examples and LTRC sustainability studies can also be included.

- From an agency point of view, the benefit of BMD would be improved field performance. From a contractor's perspective, the benefit of BMD would be the increased use of RAP, reduced cost, etc.
- There is a concern that BMD may affect friction.
- Just looking at the cradle to gate will not provide the full picture. Full LCA is needed (from cradle to grave).

ROLE OF MANAGEMENT IN BMD IMPLEMENTATION (DAY TWO: ROUND TABLE TWO)

In this session, cost benefit analysis, management issues, resources and equipment issues, stakeholder involvement, specifications and risk management, and implementation plans were discussed. This was accomplished with two, smaller breakout groups.

Primary discussion points from this session are provided in Appendix F.

Role of Management Summary

Management support for BMD varies, with some proactive and others less engaged. Arizona DOT faces no upper management resistance to BMD and plans an FHWA workshop inviting industry partners. Colorado DOT's regional heads show some resistance, with ongoing benchmarking and concerns about variability. Connecticut DOT sees limited resistance, implementing BMD for specific mixes to maintain control and aiming for Approach D eventually. Georgia DOT navigates policy changes slowly, noting benefits and challenges with BMD implementation. Idaho TD struggles to convince contractors. Louisiana DOTD reports minimal cost increases with BMD and increased RAP usage. Maine DOT grapples with cost challenges and consultant fees. Missouri DOT focuses on performance but faces equipment and staffing hurdles. North Dakota DOT tackles equipment costs and phased implementation challenges. Oregon DOT and Tennessee DOT report industry alignment and benefits with BMD, while Texas DOT emphasizes industry support and extensive BMD testing. Vermont AOT seeks cost savings and management engagement, exploring RAP mix reductions.

Key Takeaways

Management Support

Support from management can be divided into three categories: disengaged to no support, have some support, and progressive management. Overall, there is mixed support for BMD from agency management. Some of management is progressive and proactive, while others take a backseat. Some states have strong agency involvement, while in others, contractors are stronger than the agencies.

Needs

Needs are as follows: specifications development for pilot projects, sample preparation standards, NAPA guidelines as source guides, more funding opportunities like leverage exiting pooled funds, short-term research, more staff and resources for the agencies, multiple levels of training starting at the technician level, training on how to talk to decision makers, examples of states with long-term or detailed BMD implementation plans, a top-down push on BMD through leaders on AASHTO, work with the BMD Implementation Working Group, resources to document benefits, an explanation of variability from an educational standpoint, coordination with the industry, case studies from successful states like New Jersey, and training videos.

Why BMD is Needed

Higher RAP content in the mix, chances of using innovative materials (fibers and polymers), and increased density.

PERFORMANCE TESTING DETAILS (DAY TWO: ROUND TABLE THREE)

Aging, sample preparation, dwell and lag time were discussed. This was accomplished with two, smaller breakout groups.

Primary discussion points from this session are provided in Appendix G.

Performance Testing Details Summary

Each DOT grapples with different issues, such as variability in testing results, concerns over aging protocols, and the need for integrated data management systems. For instance, Arizona DOT expresses concern over variabilities in BMD testing, particularly in AC, RAP, and binder type. Colorado DOT is addressing variabilities in BMD testing and focusing on setting benchmarks. Connecticut DOT faces challenges with variable IDEAL-CT numbers and aging issues. Georgia DOT addresses consistency issues between regional and central labs. Hawaii DOT is initiating BMD implementation. Idaho TD focuses on integrated data systems. Illinois DOT discusses testing protocols and historical data utilization. Louisiana DOTD validates Fracture Mechanics Parameters (J_c) for Superpave Gyratory Compactor (SGC) specimens and utilizes LaPAVE for data management, while Maine DOT navigates storage conditions and silo time limitations. Missouri DOT relies on contractors for proper testing procedures, while North Dakota DOT encounters challenges in consistent BMD testing. Oregon DOT focuses on establishing test protocols for IDEAL-CT, and Tennessee DOT works on handling plant-produced mixes. Texas DOT faces variability issues in BMD testing and struggles with data integration, and Vermont AOT identifies test protocol challenges and emphasizes the need for a scaling factor for aging. These summaries reflect the diverse efforts and hurdles encountered by state DOTs as they navigate the complexities of implementing BMD testing protocols to enhance pavement performance and durability.

Key Takeaways

Aging

During the AASHTO Committee on Materials and Pavements (COMP) task group meeting, a LTOA standard was put together that was separate from AASHTO R30. The approach was to provide multiple methods for LTOA in the AASHTO standard practice. Method A is aging of compacted specimens within five days at 85°C; Method B is loose mix aging at 85°C (duration depends on the layer in pavement structure); Method C consists of loose mix aging at 95°C (duration is not dictated); Method D is loose mix aging at 100-125°C (the exact temperature within this range depends on the climate and age to be represented); Method E is loose mix aging at 135°C (six hours in the northern part and eight hours in the southern part of the country). This standard is to be balloted by COMP soon. It is important because there is no LTOA protocol for most of the states, but states recognize that it is important and want to have something realistic that fits the testing schedule.

Lag and Dwell Time

CAPRI will conduct an expanded lab lag-dwell times experiment with other labs to replicate the experiments, with the same experimental plan for FHWA/NCAT. CAPRI needs different provisions for short-term and long-term aging. This would be valuable as no uniform protocols exist. This will offer a different perspective on how to handle lag-dwell times.

Performance Test Validation and Setting Criteria

There is a need for a raw data standard for individual performance tests that is independent of the equipment and software version. Exponential value needs to be nationally calibrated. An appendix of the raw data structure would be good.

Sampling and Handling

Some protocols are needed. Proper direction is needed on specimen preparation (i.e. what can be standardized and what cannot). Training on why each step in the sample preparation matters is important. Sample size, container, boxes, etc. need to be standardized. Sample reheating protocols are needed. What to do while sampling from plant storage silos should also be clear. AASHTO Technical Training Solutions can be one avenue.

Database

Linking to a different database is a key concern, how to break down different data silos. State examples are needed for linking BMD data, Falling Weight Deflectometer (FWD) data, core photo, Pavement Management System (PMS), etc. Multiple data containers talk with each other. Standard format is needed for raw data files.

ACCEPTANCE DETAILS (DAY TWO: ROUND TABLE FOUR)

This is more information about implementation during production. This was accomplished with two, smaller breakout groups.

Primary discussion points from this session are provided in Appendix H.

BMD Acceptance Summary

Most DOTs continue to evolve in terms of their practices for using BMD testing for acceptance criteria. They are early in their BMD implementation process and are striving to find a balance between volumetric and BMD criteria. DOTs are also grappling with the issue of production testing for BMD and are currently limiting BMD to mix design testing only. Many are also relaxing some prescriptive criteria in their current specifications. For example, Arizona DOT is considering relaxing lab-measured air voids and RAP content limitations. They reference specifications from other states and find a five-day turnaround time acceptable. Colorado DOT suggests leaving out RAP content limitations and relaxing lime content criteria. They use warm mix additives and fibers in asphalt mix. Connecticut DOT faces time constraints with performance testing and suggests loosening aggregate and RAP content criteria. Georgia DOT performs performance testing for mix design but not on production samples and is aiming for Approach C. Hawaii DOT seeks example specifications for setting acceptance criteria and plans to include BMD in their specifications. Idaho TD aims for Approach D but starts with Approach A and requires performance testing during mix design and production. Illinois DOT has requirements for BMD testing during mix design and beginning production but not for acceptance or pay factors. Illinois DOT allowed increases in the amount of recycled asphalt binder from fractionated RAP and Reclaimed Asphalt Shingles (RAS). Louisiana DOTD is transitioning from Approach A to performance testing during production, using SCB and IDEAL-CT tests with scaling factors for aging. Maine DOT plans to start with Approach A and B, eventually moving to Approach C, and is considering loosening Fine Aggregate Granularity (FAA) requirements. Missouri DOT follows Approach B, pays for volumetrics, and proposes reducing testing frequency for volumetrics. North Dakota DOT aims for Approach B, considering FAA issues and starting with mix design verification with BMD tests. Oregon DOT needs more resources to establish BMD acceptance criteria and uses traditional gradation and Percent within Limits (PWL) pay system. Tennessee DOT considers their status as Approach B but loosened RAS and RAP requirements for some projects. Texas DOT wants to incorporate more RAP in mixes, pays based on air voids and mat density for BMD sections, and aims to build robust BMD specifications. Vermont AOT currently follows Approach A but considers Approach C or D for the long term, discussing eliminating 80 gyration mixes.

Key Takeaways

Role of Volumetric Properties

Relaxing some volumetric properties such as air voids, aggregate consensus properties, and limitation on RAP. Increasing the use of RAP and RAS. Recycling content can be relaxed. Eliminating hydrated lime. Using more plastics. Using new and innovative materials.

Acceptance Details

BMD tests are primarily done for mix design and no performance tests are currently being conducted for acceptance. BMD tests are performed during production and if the test passes, the states offer incentives. Otherwise, they rely on traditional Acceptance Quality Controls (AQCs). Some states are checking BMD criteria at test strip. Also, there are incentives for traditional AQCs, but you must pass the BMD tests. The state agencies need to determine the right amount of time to turn acceptance around and where is the line for rejection. They also need to establish the difference between the tests performed for the purpose of mix design and the purpose of acceptance because that will drive what to test at each stage. Need to establish what the options are to bring BMD into acceptance. Go/no go with cease in production can be difficult.

Needs

There needs to be a better understanding of BMD approaches and what it will take to move forward. There needs to be more staff to conduct the tests. There is a need for more information on incentives within lot variability of production, and sensitivity of induvial mix designs to AC. Example specifications are needed. More pilot projects are needed. A synthesis of current practices is needed.

NEXT STEPS TOWARDS IMPLEMENTING BMD: SUMMARY OF TAKEAWAYS AND ACTION ITEMS

Key Takeaways and Action Items

Arizona DOT

Key Takeaway

Will pay better attention to procedures from specimen preparation to testing. Will follow the specification. Will invite FHWA to conduct BMD workshop.

Action Item

Continue conversation with the industry. Will try to sell the idea for Approach B. Invite FHWA to conduct BMD workshop.

Colorado DOT

Key Takeaway

Will place more importance on sample fabrication. The state has been doing Plant Mix Lab Compacted (PMLC). It will be good to also include Lab Mix Lab Compacted (LMLC) to see how the tests go.

Action Item

Validation of tests. The agency has four years of data collected. Now it's time to go back and check performance against CT-Index numbers.

Connecticut DOT

Key Takeaway

The agency hosts regularly scheduled meetings with industry. Engages industry about what the 2026 pilot project would look like and received some feedback.

Action Item

Come up with a BMD implementation plan and document some steps. Reach out to industry and get their feedback.

Georgia DOT

Key Takeaway

Validation of BMD performance tests.

Action Item

Start a pilot project on BMD. Start collecting data.

Hawaii DOT

Key Takeaway

Stakeholders' engagement and pilot projects are necessary.

Action Item

Put a BMD implementation plan on paper. Conduct benchmarking studies.

Idaho TD

Key Takeaway

Time to gather BMD test results and compare with field performance data.

Action Item

The agency will start developing its own specification for BMD and look for a pilot project.

Illinois DOT

Key Takeaway

The agency has no immediate plans to look for ways to increase random performance testing outside of design and start of production.

Action Item

The agency does a good job of collecting test data and needs to continue correlating the test data with field performance data.

Louisiana DOTD

Key Takeaway

What other states are doing with BMD proved helpful along with the feedback on Louisiana's process. The agency is continuing with research to ultimately move to Approach C or D.

Action Item

The agency is currently using incentive programs in specification to encourage contractors to run the performance test during production, and to decide whether they want to be a part of the program. New specifications are likely to come out next year with the new administration. This offers an opportunity to suggest changes. A major action item is to bring back the knowledge to the contractor's association and state. Then, confirm the direction with the new administration and provide a path to get there by incentivizing production testing.

Maine DOT

Key Takeaway

Long-term oven aging will be executable within standard working days (20 hours at 110°C). That will also minimize oven use. Concerned about the performance of mixture after it has aged in a silo.

Action Item

Needs to document the status of the state within the eight tasks. Working closely with the industry.

Missouri DOT

Key Takeaway

Will look at different options of LTOA. Comparing test results and field performance. Establishing a formal way to evaluate the project performance.

Action Item

The agency is moving from Approach B to C/D, but that will take some time. Will look into starting a pilot project.

North Dakota DOT

Key Takeaway

Uses BMD performance tests to push other things such as high RAP content.

Action Item

Test strip is starting in the summer and shadow projects are down the line. Needs to get in writing specification of the sampling, handling, and aging protocols including lag-dwell times.

Oregon DOT

Key Takeaway

The state has been focusing on mix design but needs to keep acceptance in mind also. There is no unique way to implement BMD. Lessons are learned from other states.

Action Item

The agency will begin the development of an Implementation plan. Will look for a pilot project and start developing specifications.

Tennessee DOT

Key Takeaway

Will look at other approaches of aging. Is currently looking at five days, but that is not practical.

Action Item

Connecting a different database.

Texas DOT

Key Takeaway

Acceptance criteria. The agency still has volumetrics in place and at some point, needs to start relaxing or eliminating. Therefore, the agency needs to look into what needs to be changed.

Action Item

The agency will establish different criteria to reduce variabilities from performance tests. Will look at how to analyze data from pilot projects.

Vermont AOT

Key Takeaway

Aggregate consensus properties could potentially be relaxed. Will try to move to Approach C/D. Anti-stripping requirements could also be relaxed. Power BI seems attractive for data management and as a tool for both validation and evaluating LTOA protocols. Membership in CAPRI is worth considering.

Action Item

The agency will devise a validation plan. Need to investigate projects from 2019 and 2020 to investigate their performance for validation and/or determining LTOA protocols. Will determine candidate BMD projects for the 2025 paving season.

Action Items Summary

Each participating DOT is actively engaged in various initiatives to advance BMD implementation, addressing specific challenges and priorities within their respective regions. These DOTs outlined their strategies and actions regarding BMD implementation. The key takeaways and action items from each DOT are shown below relative to the eight tasks for the implementation of BMD (Hajj et al. 2022; Hall, E., Aschenbrener, T., and Nener-Plante, D. 2022. *Balanced Mixture Design: Eight Tasks for Implementation.)* It is worth noting that not all tasks may be applied or considered. Some tasks may be conducted in parallel or in a different order without any negative consequences.

- Sub-Task 2.2 – Establishing Stakeholder Partnership: Arizona, Connecticut, Hawaii, Louisiana, and Maine.
- Sub-Task 2.7 – Developing an Implementation Timeline: Connecticut, Hawaii, Maine, and Oregon.
- Sub-Task 3.3 – Validating the Performance Test: Colorado, Georgia, Idaho, and Vermont.
- Sub-Task 4.4 – Evaluating Performance Tests (with clear and specific test methods): Arizona, Colorado, North Dakota, Maine, Tennessee, Texas, and Vermont.
- Sub-Task 5.2 – Conducting Benchmarking Studies: Hawaii.
- Sub-Task 5.4 – Analyzing Production Data (Reviewing Historical Data and Information Management System): Tennessee and Vermont.
- Sub-Task 6.3 – Developing Pilot Specifications and Policies: Idaho, Louisiana, and Texas.
- Sub-Task 6.4 – Conducting Pilot Projects: Connecticut, Idaho, Missouri, Oregon, and Vermont.
- Task 8 – Initial Implementation: Illinois, Louisiana, Missouri, Texas, and Vermont.

When reaching Task 8, the effort is not completed. It should be noted that several DOTs that have reached significant levels of implementation towards Task 8, are revisiting past components on their BMD specification.

Primarily, they are looking to transition to an Approach that relaxes some DOT requirements and shifts more responsibility to the contractor, e.g., shifting from Approach A to Approach C or D.

PEER EXCHANGE SUMMARY

As part of the AIDPT Demonstration to Advance New Pavement Technologies Study: TPF-5(478), 15 state DOTs met at the NCAT in Auburn, Alabama, to discuss state of knowledge, identify successes, current activities and research, and research and implementation gaps pertaining to BMD challenges discussed during previously held regional peer exchanges.

Various DOTs are at different stages when it comes to validating BMD performance tests. Some agencies have performed one or more validation studies, while others are still in the process of selecting projects for validation. Acceptance of BMD tests primarily occurs during mix design, with some DOTs offering incentives for passing tests during production. Challenges include determining acceptance criteria and turnaround times. Needs include a better understanding of BMD approaches, more staff, incentive information, example specifications, and pilot projects.

Action items across DOTs include advocating for BMD approaches, hosting workshops, and engaging with industry partners. Overall, DOTs are actively engaged in various initiatives to advance BMD implementation, addressing challenges and priorities within their regions. These actions include validation studies, database integration, stakeholder engagement, and adjusting acceptance criteria. Collaboration with industry partners and universities is crucial for success.

APPENDIX A: PARTICIPANTS LIST

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APPENDIX B:
PEER EXCHANGE MEETING AGENDA

TUESDAY MORNING, MARCH 12, 2024; NCAT WORKSHOP	
TIME (CDT)	**SESSION**
8:00-8:15 AM	**Check In** (morning session in large classroom)
8:15-8:45 AM	**Welcome/Introductions** • Pooled Fund Opening Remarks – FHWA • Participant Self-Introductions • Housekeeping (overview of agenda, breakout groups, plan for lunch, facility details etc.)
8:45-9:00 AM	**Peer Exchange Meeting Primary Focus (Tim Aschenbrener, FHWA)** • Background, Goals, and Objectives • BMD Current State of Practice and Updates
9:00-12:00 PM	**NCAT Workshop: BMD State of Knowledge, Gaps, and Challenges to Implementation** • Overview of Common Challenges (Derek Nener-Plante, FHWA) • CAPRI, Guidelines, and Recommendations for Field Validation of Test Criteria for BMD Implementation (Tom Harman, NCAT) • Specimen Fabrication Guide (Adam Taylor, NCAT) • A Case Against Approach A (Randy West, NCAT)
TUESDAY AFTERNOON, MARCH 12, 2024: PEER EXCHANGE	
TIME (CDT)	**SESSION**
12:00-1:00 PM	Lunch
1:00-4:15 PM	**Group Discussion/Round Table #1: BMD Pooled Fund Activities** • Summary presentation from “cheat sheets” on the overview of each state’s status. • 3, 1-hour focused and open discussions on each of the 3 most common challenges based on the advanced polling.
2:30-2:45 PM	BREAK
4:15-4:30 PM	**Wrap-Up and Review Day 2 Agenda**

WEDNESDAY, MARCH 13, 2024: PEER EXCHANGE	
TIME (CDT)	**SESSION**
8:00-8:15 AM	**Opening Remarks** (morning sessions in 2 breakout rooms) • For each "Group Discussion/Round Table" select one or two bullets to describe a success, existing research, or needed research.
8:15-9:45 AM	**Group Discussion/Round Table #2: Management Future Direction: Successes, Existing Research or Activities, Needed Research** • Why go to BMD? (e.g., Cost and Environmental Benefits) • Resources (e.g., Personnel, Equipment, Funding) • Implementation Plan • Specifications and Risk Management • Stakeholder Engagement
9:45-10:05 AM	**BREAK**
10:05-12:00 PM	**Group Discussion/Round Table #3: Testing Details Future Direction: Successes, Existing Research or Activities, Needed Research** • Test Protocols (e.g., Aging, Sampling-Handling, Lag-Dwell, etc.) • Test Validation • Setting Criteria • Database
12:00-1:00 PM	**Lunch on your own** (return to 2 breakout rooms)
1:00-2:30 PM	**Group Discussion/Round Table #4: Acceptance Details Future Direction: Successes, Existing Research or Activities, Needed Research** • Role of Volumetric Properties • What Can You Relax? (e.g., Volumetric Properties, Aggregate Properties) • Acceptance Methodologies • Project Selection / Implementation Strategies
2:30-3:00 PM	**BREAK** (after break, go to large classroom)
3:00-3:30 PM	**Report Outs from Each Breakout Group from Round Tables #2, #3, and #4**
3:30-4:15 PM	**Summary: Next Steps towards Implementing BMD within each Agency and Needs for Moving Forward** • Each State can provide at least one action item and one take-away from peer exchange
4:15-4:30 PM	**Wrap-Up Feedback and Test Track Tour Logistics**

THURSDAY, MARCH 14, 2024: NCAT TEST TRACK/LAB TOUR	
TIME (CDT)	**SESSION**
8:00-11:00 AM	**NCAT Test Track/Lab Tour**
11:00-11:30 PM	**Adjourn – Thank You and Safe Travels**

APPENDIX C:
BMD PERFORMANCE TEST VALIDATION ROUNDTABLE DISCUSSION

Validation is critical for implementing BMD. Three questions were asked during this discussion:

- Have you completed a validation study?
- Are you currently monitoring or building a validation project?
- Are you curious about how to go by for a validation test?

Have you completed a validation study?

Illinois DOT

The validation study was based on forensic investigation and pilot projects monitoring. After the implementation of the HWTT, many HMA mixes utilized increased recycled content. Additionally, there was legislative action to use RAS in HMA mixes. Premature cracking of many HMA pavements led to the development of I-FIT. Pavement cores were collected and tested from a range of good to poor performing pavements. Pavements showed cracking when the Flexibility Index (FI) was below 4.0. Also had research field projects with up to 60% binder replacement. Afterwards, used asphalt mixtures from FHWA Accelerated Load Facility (ALF) sections to establish the FI criteria, a min of 8.0 for typical dense-graded asphalt mixtures. The criteria were supported by a University of Illinois research study which focused on reflective cracking.

Louisiana DOTD

Fortunately, SCB has been used for forensic investigation early on (from 2002) which led to the inclusion in BMD. Since the test was used for a while, it helped in validating the test. Field projects with sections constructed with varying technologies (shadow testing) were used. Data had been collected from Lab, plant, and field. In 2014, the agency had as-produced data and compared it to the performance data PMS. In 2023, the agency completed a project to revalidate the SCB test criteria (refine criteria). Validation was not planned but sufficient data was there to do the work. From 2016 specifications, HWTT and SCB testing have become mandatory. Some issues have also emerged. For instance, HWTT rutting went up (from 2-3 mm to 6 mm) with the implementation of SCB but showed improvements in block cracking that sometimes showed up in the first year. The majority of block cracking showed up in two to three years, especially in rural areas. Most of the block cracking was eliminated after the implementation of 2016 specifications. Immediate improvements have been observed. The current concern is whether what was designed is being produced in the plant. AC also went up 0.2-0.3% but most of the improvements are in Voids Filled with Asphalt (VFA) from 68 to 72-73. The PMS had a combined index that had to be separated into a rutting and a cracking index. Threshold values were established. The pavement sections used were mostly mill and fill, with some full milling. Binder courses were all the same and technologies varied in wearing course. Some of the sections had WMA, and some had rubbers. Rural areas (full depth) mostly showed block cracking (some bottom-up cracking), while in Urban areas (mostly 3-to-4-inch mill and fill) top-down cracking was predominant.

Missouri DOT

The agency is working with the University of Missouri to benchmark the criteria. The university performed some testing. Pavements were identified and initial test criteria were established. Benchmarking effort is ongoing. The agency knows where the mixes are placed but needs to work on how to track field performance with mix. Missouri keeps test results in AASHTOWare Project but no tie to PMS at the moment.

Are you currently monitoring or building a validation project?

Connecticut DOT

The agency hired a young engineer that built and combined databases (materials, pavement management) using Microsoft Power BI (can pull from AASHTOWare, PDF, etc.).

North Dakota DOT

The ongoing validation project is a 15-miles long project close to the central office, so monitoring was easier. It is a Full Depth Reclamation (FDR) with cement treatment. The project will have eight test sections with four inches of asphalt, with the bottom two inches remaining the same. Each test section is two miles. Two sections with RAP and all the rest with varying AC based on testing. North Dakota used Performance Grade (PG) 58S-28 for a long time and is now exploring the use of PG 58H-34. The intelligent compaction system was used to ensure density. The biggest issue was finding the right project. Thermal cracking is what drives performance and doing a mill and overlay was not viable, so reconstruction was necessary. Aware of integrating the data and working on it. Does not have a material database.

Oregon DOT

The agency is tracking the performance of their eligible test sections.

Texas DOT

Texas did validation on projects that are two to four years old with differing weather conditions and geography. In total, there are 33 test sections from nine projects, and most are mill and inlay. But Texas does have control sections within each project. The agency is using Texas Overlay Tester (OT) and HWTT but running IDEAL-CT and RT in the background. Universities in Texas conduct additional inspections on a regular basis. From current data, there is better correlation between field performance and IDEAL-RT and IDEAL-CT as opposed to HWTT and OT. Of the 33 test sections, no test sections failed the HWTT and only one section failed the OT Crack Propagation Rate (CPR) threshold. Four mixtures failed the IDEAL-RT threshold and 10 mixtures failed the IDEAL-CT, with several starting to show early life rutting and cracking distress. Texas is now looking at increasing RAP to 40% and is looking at different recycled binder availability, plastic products, etc. Texas is also using larger sections to look at production variability (three days production).

Are you curious about how to go by for a validation study?

Georgia DOT

Needs to manually tie the different databases together. Management issues like resources and skillset persists. Working with AASHTOWare Project.

Maine DOT

Most of the road work in Maine is not full construction but validation guides commonly state the need for the validation to be performed on a full construction project. Maine needs validation sections that are applicable to the scopes of work where BMD will likely be used.

Tennessee DOT

The agency has been approached by contractors, but the mixes being used are not the ones that necessarily having issues. The CT-Index of those mixes is around 80. Tennessee is looking for a benchmarking perspective. The Pavement evaluation team marks pavement sections to follow up on for field condition. Pavement system data is stored by 0.1 mile. Needs to ask for the data from the control team. The issue is that the database is handled by a separate Pavement team.

APPENDIX D: PERFORMANCE TESTING PROCEDURES AND PROTOCOLS ROUNDTABLE DISCUSSION

What States Think About Overall BMD Testing Standard and Protocols

Georgia DOT

The State's central lab has AASHTO accreditation. The biggest disconnection is the six district labs that do not hold any accreditation. This falls under management issues; the resources are not there and even when resources exist, loss of experienced staff is common without handling training and responsibilities. Procedures are written but trained people are not there.

Louisiana DOTD

The agency has state recognized test procedures and standardized sampling from truck, splitting, and short- and long-term aging procedures for SCB. However, it does not have specific documentations of detailed protocols. The central lab and LTRC are AASHTO Materials Reference Laboratory (AMRL) accredited, but none of the district labs have accreditation.

Missouri DOT

The biggest concern of the agency is how to standardize different testing procedures.

Long Term Aging Procedure

Arizona DOT

The agency feels the need for a uniform aging protocol. The framework should stay the same, but the details can be altered if necessary.

Illinois DOT

Illinois conducted a research project and found that three days at 95°C oven aging on fully prepared test specimens is similar to five days at 85°C oven aging. The resulting specifications require LTOA PMLC production specimens to have a minimum FI of 4.0, with LMLC mix design samples to have a minimum FI of 5.0. Please note that there are additional criteria for 4.75 mm Nominal Maximum Aggregate Size (NMAS) and SMA mixtures.

Louisiana DOTD

The agency's long-term aging practice is five days at 85°C. The contractor produces eight SGC samples, and the State selects, cuts, and runs the LTOA. The State is ready to move away from approach A but needs to settle on LTOA during production. It is also looking to apply a scaling factor, such as original binder properties that can be multiplied with 2.2 to get Rolling Thin Film Oven (RTFO) aging. The agency is looking for a reduction in SCB J_c using a scaling factor that would be applied for production. It is also looking for IDEAL-CT as a surrogate test for production. LTRC is running cracking tests from no aging to different levels of aging. They can limit the silos time to more than five hours. Aging adjustment factors may be based on initial production lot. The state needs more mixtures testing. The state thinks the scaling factor is necessary to convince industry to go along with the concept of long-term aging.

Maine DOT

The New England states BMD working group concluded that 20-hour oven aging at 110°C is implementable but are also interested in long term aging protocols that use the same temperature for splitting, compacting, and conditioning that can be completed within a standard workday. From a production standpoint the long-term aging procedure needs to be completed within a standard workday or will need to be long enough to go into the next workday. Working with other Northeast States to investigate a regional procedure that will work for most states.

Tennessee DOT

The State has allotted four hours for cracking tests but not committed in writing.

Texas DOT

Currently, the State only has short-term aging.

Virginia DOT

The State has different criteria for reheating or no reheating at all.

Wisconsin DOT

The State's long-term aging procedure is six hours at 135°C, after STOA for BMD cracking tests.

Controlling Dwell or Lag Time

Colorado DOT

The State's lag time is typically one to two months. Dwell time is approximately three hours.

Louisiana DOTD

The State has a minimum time of 24 hours (based on AASHTO T324) for HWTT but no maximum time. Looking at dwell time, the sample properties did not change between two weeks. Outside that time, it does change properties.

Missouri DOT

In the State's updated provisional specifications, the wait time is 30 minutes once sampled (due to warm mix additive to stabilize). Then, once the temperature is right, testing can start. No reheating is allowed in the specification. Everything is done hot.

Oregon DOT

The State has no standard practice. It has been testing production mixes that have been sitting in the lab for a while.

Vermont AOT

The State does not have a standard practice, primarily due to lab and field technician staff availability being a concern and the need to "balance" investigative testing and regular acceptance testing/business practices. Due to an increase in sampling at the paver for acceptance testing instead of at the plant, there have been more acceptance samples coming into the lab for testing and processing, which has resulted in an increase in lag time for BMD testing of production split samples. Dwell time, on the other hand, has gone down given that paving activities are only allowed from May through November annually.

Moisture Damage (Concern for Almost All States)

Louisiana DOTD

The State got rid of TSR when it implemented the LWT. There is a lot of rain, so moisture damage is a huge problem. The most recent discussion is on bringing back TSR or conditioning HWTT specimens using Freeze-thaw or MiST.

Tennessee DOT

Highly absorptive aggregates from west Tennessee are prone to stripping.

Vermont AOT

The State uses HWTT for both rutting and moisture damage after it was found via New England Transportation Consortium (NETC) Project 15-3 that the TSR test wasn't representative of moisture damage in New England climatic conditions. However, moisture damage remains a concern with higher amounts of RAP and there is interest in bringing back the TSR test. The State also requires the Texas boil test (ASTM D3625) to be performed for mix design qualification and weekly during plant production, but this test can be very subjective and dependent on technician judgment.

APPENDIX E: WHY BMD AND THE BENEFITS ROUNDTABLE DISCUSSION

Benefits of BMD

Connecticut DOT

Sustainability is a focus in this State. If the message is conveyed from top management to the bottom, that will be more effective than a bottom-up approach. Aggregate availability is an issue.

Illinois DOT

The State has a SMA pavement that is 20 to 25 years old and still performing well and is maintaining very good I-FIT values. Illinois DOT has a large database of HWTT/I-FIT results and continues to monitor HMA pavement performance.

Louisiana DOTD

Sections have not failed yet. The agency started a project in 2019. 10 roadways of pre-implementation and 10 roadways of post-implementation with level one dynamic modulus data have ran using Pavement ME Design software. The roadways showed a 35% increase in design pavement life. Cracking life increased by four to six years. The State is allowing contractors to do a no-cost change order for BMD mixes. There is an increase of material cost though, but it is negligible. Louisiana already went through local calibration of Pavement ME. The final report is to be published within the next couple months. LTRC also presented a study at the Transportation Research Board (TRB) conference that looked at the impact on EPDs with BMD and the use of recycled materials. Even 50% of RAP showed less Greenhouse Gas (GHG) emissions, without compromising performance. The agency is using BMD as a tool to keep industry on board. It is partnering with industry on BMD to help reduce and assess the risk.

Maine DOT

The agency has benchmarked many mixes. The agency sees BMD as a way to get improved performance and as a risk mitigation tool for innovative materials and more sustainable processes. There is a concern that EPD implementation may negatively affect long term performance in its current state and cradle to gate limitation. The agency would be interested in seeing draft specification examples to use as a starting point while drafting its own BMD specifications.

North Dakota DOT

The agency is benchmarking some projects coming out of certain pits.

Oregon DOT

The State has concerns about EPD implementation and increased asphalt in BMD.

Tennessee DOT

For this agency, BMD mixes can bump RAP usage, which can minimize trucking for shipping virgin aggregates and therefore save cost.

Texas DOT

The agency came up with threshold values for OT. It is receiving good support from industry regarding BMD implementation efforts. Currently, the agency is in the research and field validation phase and considering revising the current threshold values with a special specifications revision. BMD can be a way of increasing

RAP usage; Texas bumped it from 30-40%. Surface Aggregate Classification A (SAC-A) has also become favorable with a BMD approach.

Vermont AOT

Like other New England states, Vermont believes BMD can bring sustainability and resiliency while also serving as a “backstop” for potential issues with recycled materials. Aggregate availability has not yet become a serious issue but is expected to be.

APPENDIX F:
ROLE OF MANAGEMENT IN BMD IMPLEMENTATION ROUNDTABLE DISCUSSION

Role of Management

Arizona DOT

Arizona has no resistance for BMD from upper management. The State is planning a FHWA BMD workshop and will invite all industry partners. It seems BMD is more accepted by young and new generation contractors. Industry believes that BMD implementation will give them more control. For informational purposes only, the agency is currently testing different mixes across the state, including SMA mixes, following some of the parameters established on the BMD framework. The vision is to test every mix with BMD. For pay factor, Arizona still sticks with their old PWL.

Colorado DOT

Regional heads of the agency are somewhat resistant to BMD. The agency is still in the benchmarking stage. The State has an issue of variability. IDEAL-CT values are from 20 to 2000. Manpower is also an issue—only two people are responsible for BMD-related tests.

Connecticut DOT

Not a lot of resistance in Connecticut. BMD has an avenue within the agency. The agency is implementing BMD for certain types of mixes only, as the agency wants full control. It is still using old PWL for pay factors and wants to move away from this. But BMD tests are time consuming. From 2019, Connecticut stopped taking samples from plants and started taking from projects for QC/QA and acceptance. They want to trust the contractor and stop micromanaging. Connecticut wants to implement approach D eventually, but they started with A, just to let things flow internally. Maybe approach B or C will be used in the near future. It wants a win-win situation for everyone. Contractors do not want to let go of any control. The State is aiming for a BMD pilot project by 2026. Variability in the BMD performance tests is a concern.

Georgia DOT

The State has a good working relationship with management. But policy changes are moving slowly. There is some agency resistance and asking to fit volumetrics. Industry aim is to protect the industry. With the introduction of RAP, the agency started seeing reflective cracking within six months. That is when upper management decided to take action. They found a workability/Compactability improvement with the introduction of neat binder into the mix, and they relaxed VFA criteria. Correct Optimum Asphalt Content (COAC) has led the way to the BMD Approach B or C. HWTT is used for Rutting and moisture, and COAC is a surrogate for cracking. The agency has been doing benchmarking. There are also some resource issues (equipment, staff, training, frequency). The agency tried I-FIT and SCB and the technicians did not like it. IDEAL-CT is easier to operate, understand, and implement.

Idaho TD

The agency is struggling to convince contractors that BMD is the way to go. Contractors are opposed to the change. Used to allow 30% RAP and now, maximum 17% is allowed as RAP. This can help in pushing BMD. Currently, the agency runs HWTT and CT (for info only) during mix design. During production, it also runs HWTT and CT for informational purposes only. Does not have adequate state resources to run the HWTT and

CT, even if they are for solely informational purposes. Has the equipment in one lab and is trying to get two other labs set up. Some of the labs had to be remodeled. Funding is not the biggest challenge though.

Illinois DOT

The implementation of BMD in Illinois involved extensive research and much coordination with Illinois DOT leadership, the Illinois DOT Districts and industry. The HWTT was implemented in 2014 and was modeled on the method used in Texas. Research and development of the I-FIT began in 2013 with implementation in 2021 for short-term aging and 2022 for long-term aging. Illinois has fully implemented BMD. In terms of lessons learned from the process, it takes time to move from development of a test/analysis procedure through the implementation of a specification. It took approximately nine years to fully implement I-FIT. It is important to complete the potential tasks listed in the FHWA BMD framework either internally or through external research efforts with university partners. Further, it is important to test materials in design and production. The mixture properties in production will not match the design in most cases so it is imperative to conduct performance tests in the production phase. Finally, communication with test device manufacturers, HMA producers, and Districts is important. The DOT needed to work with manufacturers to identify what is feasible in terms of specimen dimension tolerances. This communication helped identify what is needed in terms of sawing equipment. The DOT needed to communicate what mixture variables significantly affect performance properties to HMA producers. This information needed to be provided at meetings and conferences as much as possible. Finally, communication with District laboratories was needed to identify what the labs were seeing with day-to-day testing and test turnaround time.

Louisiana DOTD

The agency experiences a minimal cost increase. BMD allowed additional 5% of RAP in the surface mix (Total 15 to 20%). The state is using polymer-modified binders. SMA was $115-$120/ton pre-pandemic and is now $170/ton (aggregates and hauling the biggest cost). The agency has been using SMA for a long time. Then, the industry started to push back against using SMA with the new administration. The agency implemented LWT for the moisture susceptibility test. Before implementing LWT, it had Open Graded Friction Course (OGFC) issues with compatibility. LWT has the ability to screen out compatibility problems. Louisiana implemented BMD for all travel lane mixtures at one time. Pilot studies (three of the contractors bought LWT for the sake of compatibility testing) for LWT are also ongoing. For cracking, the agency needs districts to be equipped for acceptance testing. The agency worked with FHWA to purchase a HWTT for implementation. The district purchased their equipment through acquisition money. Thin overlay testing in the HWTT did not do well when using full specimen. In the field it did great. In the lab, it should be done as an overlay for HWTT.

Maine DOT

The cost aspect is a challenge. Management is asking to showcase how to decrease costs and the use of higher binder percentage or Highly modified asphalt (HiMA) is not helping with up-front cost reduction. Initial cost is the key from the current management perspective. There is a perception of a cost increase with BMD. Therefore, there is pressure to improve performance, without an increase in cost. The agency feels that the cost of using consultants is increasing significantly compared to in-house costs.

Missouri DOT

Prior to BMD, Missouri always allowed RAP, but dry pavements were not lasting. Performance became key. The agency has progressive management. The challenge is how to slow down. The agency has the provision of contractors who make the pills for QC and acceptance and send samples to the state central lab for testing.

Moving forward, the State has plans to purchase equipment for districts to accelerate turnaround time. Samples are still made in the field in the contractor's lab (tried to send samples in boxes to the lab and variability was high). Conducting CT and RT. HWTT is in the mix design stage. Missouri has a lot of county roads. The focus is on the high traffic roads, not on lower risk and lower traffic roads.

North Dakota DOT

Equipment cost is an issue. Contractors from Minnesota are using advanced technologies which may not be true for local contractors. Another concern is how to handle production-related issues. The agency will try to solve the hurdle of equipment and staffing once benchmarking is completed. There are no stationary plants, only mobile ones. Mobile plants can only handle 25-30% RAP. While benchmarking, the agency sampled everything. But starting implementation would be a more phased approach. The agency is close to finding the threshold. HWTT is a harsh test that may not be seen on low traffic roads. Balancing resources is necessary. The State is implementing an ultra-thin binder wearing course and implemented a ¾ inch layer that's been successful in the field.

Oregon DOT

Management is helpful in implementing BMD. Contractors are also familiar with BMD, as they have seen it for quite a few years. They are very familiar with sample preparation. The Asphalt Pavement Association (APA) and paving companies are also in good standing with the agency. Therefore, industry is aligned. The agency's maintenance budget is stretched thin, so it had to secure an emergency maintenance budget. It is also buying BMD performance test equipment. Oregon uses AC and gradation PWL for pay factors. BMD tests are done for verification only.

Tennessee DOT

Minimum AC is 5.7%. The agency Cap RAP at lower content. RAP is generally PG 70 for the higher temperature side. Benefits can be seen on the recycled side. Requires compatibility tests for anti-strip additives.

Texas DOT

Industry likes the BMD concept. Although the agency is performing the BMD tests in addition to its current practices, the additional BMD tests are being performed only by Texas DOT's Materials and Tests Division central laboratory or by universities. Moving forward, more district laboratories will be equipped with OT, IDEAL-CT, and IDEAL-RT equipment. By September 2024, Texas DOT will have an established OT certification program as well as a Material Producer List (MPL) for approved OT machines. Laboratories on the MPL will help support Texas DOT's central laboratory with BMD testing demand. Everyone in Texas is on board with BMD and there seems to be no pushback. There is a BMD working group within industry that meets regularly with Texas DOT, contractors, suppliers, and universities. Industry is aware of the ongoing research and the upcoming specification change. Industry has a good presence and provides feedback during the Texas DOT quarterly meetings. The agency is proceeding with the HWTT and OT. IDEAL-CT is also getting collected in addition to OT. Similarly, IDEAL-RT is also getting collected in addition to HWTT. Texas now has 33 test sections that it has designed with BMD for over four years. Best practices and observations for BMD are followed.

Vermont AOT

Upper management is concerned about cost. Bid results for a High RAP pilot project advertised weeks before the peer exchange demonstrated a cost savings of $5 per ton. Management has not been too engaged with BMD, but they have been supportive regarding equipment purchases and haven't explicitly expressed skepticism;

more engagement by upper management would be helpful given other pavement-related challenges in the state. There is a working group set up every winter during their collaboration meetings with Industry, and until very recently, there was some skepticism on the Industry side about implementing BMD. For benchmarking purposes, it has sampled everything. But for implementation, it will be a management decision for scope. The agency is looking for opportunities to do research and work with CAPRI.

APPENDIX G: PERFORMANCE TESTING DETAILS ROUNDTABLE DISCUSSION

Performance Testing Details

Arizona DOT

Arizona is concerned that variabilities in BMD testing will force it to lower the benchmark. Data sources need to be made available. Regarding performance testing, the agency thinks some limits should be placed on reheating samples or a time limit should be set on performing a test after receiving a sample.

Colorado DOT

Colorado sees variabilities in BMD testing with changing AC, RAP, gradation, binder type, etc. It is now testing samples and working on setting up some benchmarks. Lab produced mixes give more accurate results. Filed mixes show variabilities, but the time required to bring them in may be an issue.

Connecticut DOT

Connecticut is facing issues with variable IDEAL-CT numbers. It is conducting some mix designs verification with BMD. The agency thinks the collection place of material (plant or job site) is also a cause of variability. Data accumulation needs to be done. The agency also thinks aging is an issue.

Georgia DOT

Georgia has an issue with consistency between regional and central labs. It moved to 10-to-20 pound. boxes and must combine boxes for at least coarser mixes. Not supposed to reheat material more than once. The agency's protocol is documented. Still, some technicians put all the boxes in the oven all at once. The agency had to train technicians on how to plan for reheating and testing. The agency does not use LTOA, only STOA. The agency uses worksheets and SharePoint for data storage. Data is stored in a unified filing system.

Hawaii DOT

The agency is only initiating BMD and is concerned about the timeline for different tests and Implementation. It is still in the paperwork stage.

Idaho TD

The agency does not use LTOA, only STOA. It uses the AASHTOWare Project mainly for change orders and invoices. Central labs use spreadsheets. The agency collects profile data using a different system. Idaho TD also started collecting Traffic Speed Deflectometer (TSD) data (mileposts, linear referencing, TSD different referencing). Have different silos of data. Using part of the AIPDT pooled fund, Idaho is trying to create an integrated database for materials and PMS.

Illinois DOT

Testing protocols are discussed with stakeholders. The agency has detailed procedures on specimen fabrication. Illinois DOT does annual round robin testing for volumetrics, HWTT and I-FIT variables. Illinois has a large amount of historical data from across the state with testing equipment in each District lab. This data helped to establish confidence in tests.

Louisiana DOTD

The agency is validating J_c for SGC specimens from contactor. Specimens are cut and aged by state. It relies on contractors to gather the correct sampling for maintaining consistency. Long-term aging can mask the effect of short-term aging. There was a learning curve for cutting notch, and as a result, extensive training was required for personnel. LTRC developed a model for verification and validation that takes QC parameters and runs them through the model to get a J_c with R^2 above 0.8. QC data (gradation, AC, P_{be}, RAP content) was used to predict J_c. Pulled plant mix from sublots, run unaged and aged and check against the model. Option Two establishes J_c during design and IDEAL-CT during design, and uses unaged CT as indicator if something changed. The agency is not comfortable with IDEAL-CT as a design parameter (during mix design) since it does not pick up polymer and density. It is okay as a surrogate test for acceptance. The agency also has an in-house database system LaPAVE. This is a mix design and cracking tests database for AC, Portland Cement Concrete (PCC), Soils. Tied to lab mix design and Job Mix Formula (JMF), for BMD tests specimens. For the HWTT, laboratory technicians upload raw data, and the system does the calculation. For J_c they upload load vs deflection data. Production data such as lot/sublots and in place density are also tied in. QC data is also incorporated. Also links to headlight. Headlight talks to LaPAVE to fill in nondestructive tabs. The database has not been around as long as the tests were performed. LaPAVE does not interact with PMS.

Maine DOT

The agency wants CAPRI to be involved with the active discussion on sampling and handling. Storage conditions also vary. Specification limit is set to the maximum 36 hours within a silo. Producers fill silos early in the morning since they observed increased consistency. Needs to have a maximum silo time in specification. The agency has a lot of data on plant mix that has been cooled and reheated. It requires plant verification at the beginning of the year for new designs or designs that had control issues the previous year. It needs a clearer definition on the reheating temperature and time. Options are elevated temperature during the day or 20 hours at 110°C. It considers the limitations of the oven in the labs. It is preferred to put the sample in a heated oven. Gmm variation has been noticed with time/absorption. Lab operating time needs to be considered for LTOA. Planning is needed for start time to avoid overtime, weekends, and holidays.

Missouri DOT

The agency is counting on contractors to realize that better results are achieved when things are done right. Specification is there for testing mix design with IDEAL-CT at critically aged condition. HWTT and RT are also performed at the lab. For field samples, just CT and RT are performed. Sampling is done at the plant. Contractors sample and make the pills without any long-term aging. They observed a difference in the test results between the ones done first and the ones done later. Usually, five IDEAL-CT replicates are run, and the high and low are discarded to reduce variability. The agency uses critical aging for mix design. It makes sure aging protocol for mix design can be used for verification. The agency uses AASHTOWare Project for post construction and material side data storage. The AASHTOWare Asset initiative may be helpful. The agency does not have something that ties the condition of pavements to mix designs.

North Dakota DOT

The agency is not consistent in conducting BMD performance tests. Some tests are conducted in one to two weeks, while others are being performed currently using last year’s sampled mixes. The agency has a written procedure for sampling materials. Testing during production is challenging because of increased silo time. The agency does not use LTOA, only STOA. The agency uses Excel spreadsheets for data storage. It has data files online for construction records. The agency created an importer to import excel data from individual files to a master excel.

Oregon DOT

The agency needs to establish test protocols for IDEAL-CT. Central lab is doing mix design verification. They are also working on building a database and trying to combine PMS data, distress data, information from cores, etc. Currently, the agency is storing everything within spreadsheets. It is also concerned about long term aging protocols.

Tennessee DOT

The agency needs to figure out how to handle plant-produced mixes.

Texas DOT

The agency has been testing both OT and IDEAL-CT for cracking performance. A CT-Index of 80 has been used as the threshold since the beginning of the BMD effort. Good correlation has been observed between field performance and IDEAL-CT results. However, for superpave mixes tested as of last year, approximately 30% passed the CT-Index threshold of 80. As a result, the agency is considering slightly decreasing the threshold although Texas is comfortable with its current passing limits. Thus far, premature cracking has been observed when CT-Index values are approximately 40 or less. Therefore, there is potential to effectively lower the CT-Index threshold. In the early stages of the BMD effort, variability in the CT-Index values was observed for the same mix types. As a result, production will be monitored for three consecutive days in the upcoming BMD projects. Extensive testing has been done on the BMD pilot projects. Texas has a lot of data, but linking all the data together is challenging. However, the ongoing efforts will ultimately serve to update the agency's BMD special specification.

Vermont AOT

The agency thinks that besides validation, test protocols are the biggest hurdles. For example, there is a written procedure for sampling materials out in the field. The agency implemented training for field sampling and, this year, will have regional rodeos to train construction field staff. For BMD, the agency does not use LTOA currently, only STOA and has guidance available for Industry and their own internal procedures. The state would strongly support a scaling factor for aging if it is generated with high confidence, otherwise 20 hours at 110°C would be the favored LTOA protocol from a lab operations perspective. In the laboratory as previously noted, lag time has gone up, but dwell time has decreased.

APPENDIX H:
BMD ACCEPTANCE DETAILS ROUNDTABLE DISCUSSION

BMD Acceptance Details

Arizona DOT

Arizona may consider relaxing lab measured air voids as a criterion. With the introduction of BMD, at some point the agency may explore the increase of RAP content in the mixes. The Agency is currently referencing specifications from other states for BMD. Arizona thinks a five-day turnaround time on test results is good.

Colorado DOT

Limitation on RAP content can be left out as an acceptance criterion. Lime content can also be relaxed. Instead, warm mix additives like Evotherm or antistripping agents can be used. Colorado also uses fibers in their asphalt mix. The state is also referencing specifications from other states for BMD.

Connecticut DOT

The agency is concerned about the time required for performance testing. Aggregate consensus properties and RAP content can be loosened from acceptance criterion, although contractors may not agree to that. Connecticut does not have many natural aggregates. The agency believes volumetrics criterion can be relaxed to move away from Approach A.

Georgia DOT

Georgia is doing performance testing for mix design but not on production samples. There is a correction factor for RAP mixes and no correction for virgin mixes. But there are limited mixes with virgin binder. The agency uses gradation and AC for acceptance and process control along with field density. The agency is shooting for Approach C. A framework is required to move from traditional methods to Approach C. The agency is thinking of relaxing air voids and taking a closer look at consensus properties.

Hawaii DOT

Example specifications will be helpful in setting acceptance criteria. The agency wants to include BMD in its specifications.

Idaho TD

The ultimate goal for the agency is Approach D, but is starting with Approach A. The challenge is to get performance testing done (HWTT and IDEAL-CT) with current capacity. Having a trial project would help. Currently the agency requires the contactors to pass HWTT during mix design. It also requires them to run HWTT during production for information purposes only. BMD tests for mix design and during production are tracked closely and periodic performance tests are conducted to ensure everything is in order. (uses current AQCs and periodic testing for BMD tests). If the first performance test fails, the contractor needs to follow up with a second test. If the second test fails, again, the contractor needs to propose changes. No paving is allowed until correcting the issue.

Illinois DOT

Acceptance is based upon Department test results for volumetrics and density. BMD performance tests (HWTT and I-FIT) are required for mix designs and start of HMA production. Increases in the amount of recycled asphalt binder from fractionated RAP and RAS are allowed.

Louisiana DOTD

Louisiana has been using approach A for a long time and wants to begin evaluating performance tests during production. Performance tests used during production will be one notch SCB and IDEAL-CT with scaling factors used for aging. Next steps need to be discussed before moving from approach A to B, C or D. The agency is looking for ways to decrease EPD. Contractors are on a two-year cycle for mix design. 70% of designs are coming up for requalification. LTRC is struggling since it is a research lab and not a production lab. The agency is almost to the point of verifying and accepting mixes during production, and it will involve the central and district labs in SCB testing. The agency depends on mat density PWL and smoothness. There is no room to relax during production. It runs acceptance tests during production, but they are not used for paying. The agency has QC requirements (performance tests are run during production by the contractor and inspector. Louisiana DOTD does not necessarily have to be present when these QC tests are performed). Part of the development of LaPAVE is to have a secure system where contractors can upload their data for review by the state. Original plan was using the contractor data for pay along with state verification of the data using LaPAVE. Contractors did not agree on statistics/validation.

Maine DOT

The agency is moving forward with a plan. It plans to start with Approach A and B, and ideally will move to Approach C. The agency keeps source qualities for aggregates and binders, and is not likely to remove or reduce initially, but will loosen up design limitations (e.g., reduce FAA requirements, relax air void levels). It may loosen up aggregates FAA. In production, the agency has target tolerances on volumetric properties. Properties that are within the minimum failing specification will be observed to see whether criteria can be revised or loosened up. The agency intends to use HWTT in design and IDEAL-RT in production. Initial investigation has shown that IDEAL-RT is a good surrogate to HWTT if materials are adequate. The agency sticks with traditional AQCs and collects performance data for information purposes. What is an acceptable tolerance to balance the risk, is the main question now. The agency has an acceptable AC tolerance range in terms of BMD tests that can be used during production. It is still conducting BMD tests for information purposes only. The agency is considering what upper and lower tolerances can be loosened and accept BMD tests. Maine has a strong acceptance program PWL. How to deal with failing results is also a concern. More things will fall under QC than on acceptance. Maine does PWL with incentives. An idea was proposed of a pay incentive where one doesn’t meet BMD test criteria, then one won’t receive incentives. One needs to pass the BMD tests during production to be eligible for incentives. Maine contractors want test results in 48 hours.

Missouri DOT

Missouri is following approach B. It allows a range in air voids. It continues to pay for volumetrics. It has added incentives for IDEAL-CT as long as they pass rutting criteria. PWL on density, air void, %AC. Still keeping the TSR test. With BMD, TSR is just a qualifier (previously was part of PWL). The agency sets target air void during mix design and that becomes the acceptance. The agency proposed an idea for the next construction cycle. The idea is to reduce frequency of testing (from 3000 tons to 6000 tons) for volumetrics. For example, BMD tests have to be performed every 3000 tons and volumetrics every 6000 tons. All material sampling is now performed at the plant and not in the field behind the paver. The Pavement Thermal Profiler is used in the field for acceptance and incentives. Material Transfer Vehicle (MTV) is incidental (not a separate pay item).

North Dakota DOT

The agency uses regressed air voids. It classifies mixes by FAA. The State gives bituminous recommendations. The agency is aiming for Approach B. FAA value of 45 mixes results in excess waste. Uses 75 gyrations for everything. There is a lot of waste and major efforts are needed to get FAA of 45. Approach B checks design sensitivity to binder content. Needs more than just passing at OBC if volumetrics will continue to be used as AQCs with low frequency of BMD tests. The agency started with mix design verification with BMD performance tests on a test strip before considering for the production stage.

Oregon DOT

The agency feels the need for more resources to establish a BMD acceptance criterion. Currently, they are using traditional gradation and the PWL pay system. Flat and elongated particles can be loosened as an acceptance criterion. Pilot projects are needed to move forward with establishing acceptance criteria. The agency is referencing specifications from other states while working with BMD.

Tennessee DOT

The agency considered its status as Approach B. But the projects are associated with Approach C because the agency loosened its requirements on RAS and RAP content on these projects. RAP is restrictive in the state now (low). The state has a 65 gyrations specification. Volumetrics are checked on the trial batch, and then during production, gradation and AC content are also checked.

Texas DOT

Sample processing time is an issue. The agency's central laboratory performs IDEAL-CT only for informational purposes on standard construction projects in an effort to build a database. The contractor needs to submit HWTT results for their mixes, which need to be performed by Texas DOT or an approved HWTT machine on the agency's MPL. The agency requires passing HWTT results on mix designs and verifies passing results on trial batches. The agency wants to incorporate more RAP in its mixes and does not want to compromise the quality of pavements. The BMD approach is a potential method of allowing higher RAP contents than those currently on the specifications. For their BMD sections, Texas is still paying based on lab molded density and in-place air voids with the current BMD special specification. The agency will continue to look into changing the acceptance criteria, but in the meantime will keep the traditional acceptance criteria and start off with considering reduced samples per lot. Texas has been working to build robust BMD specifications. Texas is allowed a 10-day turnaround time for testing all samples, but typically accomplishes this before the 10-day timeframe.

Vermont AOT

The agency currently follows Approach A in general. On pilot projects in 2019 and 2020, the HWTT and I-FIT were specified for both mix design qualification and for QA testing. If these BMD tests were failing for QA, corrective actions were needed by the producer, and if the errors were not solved, the State could rescind the mix design. However, the agency was unable to rescind any designs because by the time the test results were available, the projects had already been completed. For the long term, the agency is looking into Approach C and/or D. It sees a possibility of air voids being eliminated and being replaced with binder content or pay adjustments with performance test results. This summer, drafting of Approach C or D specification will start. The agency is also having an internal discussion to eliminate 80 gyration mixes entirely (addressing workability concerns).

APPENDIX I:
BMD CURRENT PRACTICE "CHEAT SHEETS"

BMD Current Practice

Table 1: What is the current implementation status of BMD?

Agency	Response
Alabama DOT	Research studies, initial planning.
Arizona DOT	Still thinking/exploring.
Colorado DOT	Shadow projects, initial planning.
Connecticut DOT	Research studies, initial planning.
Georgia DOT	Georgia DOT has already changed its mix design procedures to allow for more asphalt cement in the mix, and in doing so, has relaxed some of the volumetric requirements of Superpave mix design. It is now developing Special Provision specifications for some pilot BMD projects.
Idaho TD	Shadow projects, research studies, initial planning. Still thinking/exploring. Other: Mix designs are required to meet rutting/stripping thresholds. IDEAL-CT is run for information only.
Illinois DOT	Fully implemented.
Louisiana DOTD/LTRC	Fully implemented.
Maine DOT	Shadow projects (existing project using conventional acceptance tests; additional samples for mechanical testing obtained during the course of the project; mechanical test results are for informational purposes only), research studies, initial planning.
Mississippi DOT	Research studies, initial planning. Still thinking/exploring. Cataloging current SuperPave mix designs.
Missouri DOT	Pilot projects (typical bidding-contracting process with the new QA requirements applied; mechanical testing required as part of mix design and acceptance).
Montana DOT	Research studies, initial planning.
New York State DOT	Pilot projects (typical bidding-contracting process with the new QA requirements applied; mechanical testing required as part of mix design and acceptance).
North Dakota DOT	Shadow projects, research studies, initial planning.
Oklahoma DOT	Pilot projects, research studies.
Oregon DOT	Pilot projects, shadow projects, research studies.
Pennsylvania DOT	Shadow projects (existing project using conventional acceptance tests; additional samples for mechanical testing obtained during the course of the project; mechanical test results are for informational purposes only), research studies, initial planning.
Tennessee DOT	Pilot projects, shadow projects, research studies.
Texas DOT	Developing pilot specifications and policies, conducting shadow projects, reviewing historical data and information management system, conducting inter-laboratory studies, validating the performance tests.
Vermont AOT	Pilot projects (typical bidding-contracting process with the new QA requirements applied; mechanical testing required as part of mix design and acceptance), shadow projects (existing project using conventional acceptance tests; additional samples for mechanical testing obtained during the course of the project; mechanical test results are for informational purposes only), research studies.

Table 2: What is the project scope of BMD?

Agency	Response
Alabama DOT	Too early in the process to say.
Arizona DOT	All projects.
Colorado DOT	All projects.
Connecticut DOT	Other: Probably take a system approach. Apply to Superpave mix design.
Georgia DOT	Just pilot projects for now.
Idaho TD	All projects. Other: Unsure. Likely roadways with moderate to high traffic. Currently, all mix designs are being tested for both cracking (informational) and stripping/rutting (acceptance).
Illinois DOT	All projects.
Louisiana DOTD/LTRC	All projects.
Maine DOT	Other: Initially priority 1 or 2, high investment. Future all standard specification mix designs.
Mississippi DOT	All projects.
Missouri DOT	Projects with high asphalt tonnage.
Montana DOT	All projects.
New York State DOT	All projects. Other: Planned project scope would be all permanent top course paving.
North Dakota DOT	All projects, Projects with high asphalt tonnage.
Oklahoma DOT	All projects.
Oregon DOT	Projects with high asphalt tonnage.
Pennsylvania DOT	Other: Wearing courses.
Tennessee DOT	Unknown at this time.
Texas DOT	All projects, surface Superpave mixtures
Vermont AOT	All projects.

Table 3: Which BMD approaches are being considered by your State DOT?

Agency	Response
Alabama DOT	Approach A.
Arizona DOT	Approach A.
Colorado DOT	Approaches A and B.
Connecticut DOT	Undecided. Probably Approach A or B.
Georgia DOT	Approach C.
Idaho TD	Approach D.
Illinois DOT	Approach A.
Louisiana DOTD/LTRC	Approach A.
Maine DOT	Contractors perform the mix designs. We will most likely have to implement in a tiered approach from Approach A through C in order to build understanding of the tests with our industry partners. This will give us time for contractors to get the testing equipment and for the department to gain confidence in the shift from volumetric to performance design. Over time, confidence in the test methods correlation to field performance could enable an eventual shift to Approach D.
Mississippi DOT	Unsure.
Missouri DOT	Approach B.
Montana DOT	Approaches B, C, and D.
New York State DOT	Approaches A and C.
North Dakota DOT	Approach B.
Ohio DOT	Approach A. Would be interested in B and C (not clear the difference between the two) to allow adjusting.
Oklahoma DOT	Approaches B and D.
Oregon DOT	Approaches B and C.
Pennsylvania DOT	Approach A.
Tennessee DOT	Approach D.
Texas DOT	Approaches B and C.
Vermont AOT	Approaches A, B, and C.

Benchmarking Studies

Table 4: Were any benchmarking studies conducted during the BMD implementation process?

Agency	Response
Alabama DOT	A benchmarking study is planned for next year.
Arizona DOT	Ongoing.
Colorado DOT	Ongoing.
Connecticut DOT	Yes.
Georgia DOT	Yes.
Idaho TD	Yes.
Illinois DOT	Yes.
Louisiana DOTD/LTRC	Yes.
Maine DOT	Yes.
Mississippi DOT	Ongoing.
Missouri DOT	Yes.
Montana DOT	Ongoing.
New York State DOT	Ongoing.
North Dakota DOT	Yes.
Ohio DOT	Yes.
Oklahoma DOT	Ongoing.
Oregon DOT	Ongoing.
Pennsylvania DOT	Yes.
Tennessee DOT	Ongoing.
Texas DOT	Yes
Utah DOT	Yes.
Vermont AOT	Ongoing.

Table 5: Who is responsible for the conduct of benchmarking mechanical tests?

Agency	Response
Alabama DOT	Designated third-party lab.
Arizona DOT	State DOT lab.
Colorado DOT	State DOT lab (with the assistance of NCAT).
Connecticut DOT	Designated third-party lab.
Georgia DOT	NCAT.
Idaho TD	State DOT lab, designated third-party lab, contractors.
Illinois DOT	Mix type, NMAS, binder PG grade, percent asphalt and percent virgin asphalt, polymer modified or neat binder, ABR, (F)RAP and/or RAS, VMA, air voids, etc.
Louisiana DOTD/LTRC	LTRC.
Maine DOT	State DOT lab. Contractors should also bench mark their materials so they are aware of any discrepancies between State and contractor results.
Mississippi DOT	State DOT lab.
Missouri DOT	State DOT lab, designated third-party lab.
Montana DOT	State DOT lab.
New York State DOT	State DOT lab, designated third-party lab, asphalt producer lab.
North Dakota DOT	State DOT lab.
Oklahoma DOT	State DOT lab, OSU.
Oregon DOT	State DOT lab.
Pennsylvania DOT	Other.
Tennessee DOT	State DOT lab, designated third-party lab.
Texas DOT	Texas DOT Materials & Tests Division.
Vermont AOT	State DOT lab.

Table 6: What factors are included in the benchmarking study (e.g., mixture type, NMAS, binder type)? Please note if impacts of mix design and production variables on test results are being analyzed.

Agency	Response
Alabama DOT	Alabama will analyze the test section with different cracking and rutting test targets. The contractor will be free to use their own means to stay within those target ranges. The Analysis will be done by NCAT.
Arizona DOT	Comparing different cracking test. Testing different mixtures with IDEAL-CT.
Colorado DOT	Binder type and supplier, mix type (NMAS, gyrations), % RAP, % AC, % Voids, and % VMA are factors. Currently no analysis of production variability's impact on the results, but Colorado has multiple production samples from the same mix, so it may be something it can look at in the future.
Connecticut DOT	N/A.
Georgia DOT	This was a research project conducted by NCAT that involved the collection of asphalt plant production mixtures to be used in a benchmarking study prior to Georgia DOT implementing IDEAL-CT. There was hope to determine a valid minimum CT-Index requirement with a Contractor Mix Design Approval request. More than 45 mixtures samples representing seven different mix types currently specified by Georgia DOT were sampled and specimens were fabricated for the purpose of determining the rutting and cracking resistance of mixtures being used in the state of Georgia. Also, results were analyzed to determine how the implemented changes in COAC ratio—from 100:0 to 75:25, and then to 60:40—affected the cracking and rutting resistance of recycled asphalt mixtures. In addition, the cracking and rutting test results of the recycled mixtures were also compared with those of the respective virgin asphalt mixtures for reference. Results were then analyzed to propose CT-Index thresholds for future implementation in Georgia DOT specifications, for asphalt mix design implementation in Georgia DOT specifications, and for asphalt mix design.
Idaho TD	All mixes are currently being tested during design by the mix design lab. Idaho TD has been gathering and conducting some mix performance testing for information during production since 2020 (due to staffing and resource limitations, this has been challenging).
Illinois DOT	Factors include mix type, NMAS, binder PG grade, percent asphalt and percent virgin asphalt, polymer modified or neat binder, ABR, (F)RAP and/or RAS, VMA, air voids, etc.
Louisiana DOTD/LTRC	A benchmarking study was conducted involving historic data collected through research and comparing to measured cracking and rutting field measurements. Pilot projects were also implemented.
Maine DOT	Maine's benchmarking effort has included all asphalt mixture designs over the span of one year. Maine has also included many other randomly selected designs over several years to ensure we have values that cover all design variations that are independent of targeting specific design variables. Statistical assessment of the benchmark data will be performed to determine significant variables.
Mississippi DOT	Is still in the process of gathering data from all mix designs.
Missouri DOT	All SuperPave and SMA Mix Design Types meet Missouri DOT specifications – Include Mix Type, NMAS – ½" or 3/8", PG 64-22 (S, H, and V) contract grade binder types.
Montana DOT	Is still sorting through benchmarking study factors but are trying to include as much data as possible to identify any trends that may be evident.
New York State DOT	The following factors are being captured to help with asphalt mixture benchmarking: Mixture Type, NMAS, binder PG, binder content, gradation. All

Agency	Response
	factors are recorded during mixture design. When appropriate, producers are required to keep all listed factors consistent across production within production tolerances.
North Dakota DOT	FAA grade, RAP content, binder grade.
Oklahoma DOT	Mix Type, NMAS, binder PG and source, RAP content, and RAP BR are all factors.
Oregon DOT	Oregon has been running IDEAL-CT and HWTT on much of its mixtures. It categorizes by gyrations, NMAS, and binder type. It hasn't really been running comparisons between mix design and production results.
Pennsylvania DOT	JMF: NMAS, Pb, Ndesign, PG of Virgin Binder added to JMF. Final PG of JMF, Rapid Bridge Replacement (RBR), %RAP, %RAS, Gmm, Bulk Specific Gravity (Gsb), VMA, TSR, Gradation Data, Type of Anti-Strip, Dosage of Anti-Strip. HWTT: Number of passes at Max Impression, Number of Passes at 12.55mm Rut Depth, Rut depth at 10,000 passes, Test Temperature, Specimen 1 Air Void Content, Specimen 2 Air Void Content, Creep Slope, Strip Slope, Streep / Creep Ratio. CT-Index: Specimen Thickness, Specimen Diameter, Post-Peak Displacement at 75% of Peak Load, Post Peak Slope at 75% Peak Load, Test Temp, Failure Energy, Work of Failure, Cracking Index, Air Voids, TSR, Coefficient of Variation (COV).
Tennessee DOT	Currently the agency is benchmarking its most commonly used dense mix classification (Tennessee DOT – D). It is looking at all 3 common grades of binder. Its focus so far has been on design. As a historical Marshall Mix Design state, Tennessee is currently evaluating ways to run BMD style testing utilizing the existing Marshall infrastructure. An initial study was conducted by Dr. Ben Bowers at Auburn University. The agency is continuing that study in our own lab and in a partner study through the University of Tennessee with Dr. Baoshaun Huang.
Texas DOT	Mix type, aggregate type, asphalt source, AC, asphalt PG, additives. The impacts of mix design and production variables on test results vary. Higher ACs generally improve cracking performance test results, polymer modified asphalt generally improves cracking and rutting performance test results, aggregate type and source effects rutting/moisture susceptibility tests, etc.
Vermont AOT	Mix Type, NMAS, Binder Grade, Modifier, binder content, RAP content, and Binder source are all factors.

Validation Studies

Table 7: Was validation of performance tests completed to assure that mechanical test results have a strong relationship to field performance?

Agency	Response
Arizona DOT	Ongoing.
Colorado DOT	Yes.
Connecticut DOT	Ongoing.
Idaho TD	Ongoing.
Illinois DOT	Yes.
Maine DOT	Maine DOT based its selection of performance tests criteria on existing research studies and specifications from other State Highway Administrations (SHAs). A preliminary relationship to field performance was confirmed for the HWTT with a forensic study of failed pavements and a regional research project using Maine's asphalt mixtures.
Missouri DOT	Ongoing.
Montana DOT	Haven't gotten that far, but that is the plan.
Nebraska DOT	Ongoing.
Nevada DOT	Ongoing.
New Hampshire DOT	No.
New Jersey DOT	Yes.
New Mexico DOT	N/A.
New York State DOT	Ongoing.
North Dakota DOT	Ongoing.
Oklahoma DOT	Ongoing.
Oregon DOT	Ongoing.
Pennsylvania DOT	Ongoing.
Texas DOT	Yes. Continued testing and analysis is on-going
Vermont AOT	Ongoing.

Table 8: What is the source of field performance data used for validation process?

Agency	Response
Alabama DOT	Test-track.
Arizona DOT	Pilot projects, other.
Colorado DOT	PMS, accelerated load facility, test track, research test sections.
Connecticut DOT	PMS, research test sections.
Georgia DOT	Will use the pilot projects for this.
Idaho TD	PMS, research test sections.
Illinois DOT	Accelerated load facility, pilot projects, research test sections.
Louisiana DOTD/LTRC	PMS, research test sections.
Maine DOT	PMS.
Mississippi DOT	None performed yet.
Missouri DOT	PMS, research study conducted.
Montana DOT	PMS, pilot projects, research test sections. As mentioned, Montana is not that far yet, but these are the intended sources of field performance data.
New York State DOT	PMS, accelerated load facility, test track, pilot projects.
North Dakota DOT	Research test sections.
Oklahoma DOT	PMS, accelerated load facility, pilot projects.
Oregon DOT	Accelerated load facility, pilot projects.
Pennsylvania DOT	PMS, pilot projects.
Tennessee DOT	Test track, research test sections.
Texas DOT	Closely monitored research field test sections. Nine field projects with 33 unique mixtures have been constructed across the state of Texas with different materials/climates/traffic. The projects have been monitored annually from construction for one to five years with field surveys and performance testing of cores. Additional BMD pilot field projects are under construction or in the planning stage for 2024 construction.
Vermont AOT	PMS, pilot projects.

Application of BMD

Table 9: What is the scope or applicability of BMD tests?

Agency	Response
Alabama DOT	Mix design. To be determined.
Arizona DOT	Mix design, initial verification, acceptance (go/no-go), acceptance (pay factor).
Colorado DOT	Mix design, acceptance (go/no-go), acceptance (pay factor).
Connecticut DOT	Undecided. Most likely start with mix design.
Georgia DOT	Mix design, acceptance (go/no-go).
Idaho TD	Mix design, initial verification. Initial verification for information only. Production for information only. Both have been limited by staffing and resources. The agency would like to pilot a drafted go/no-go specification in the next year.
Illinois DOT	Mix design, initial verification (test trip or trial plant batch), acceptance (go/no-go).
Louisiana DOTD/LTRC	Mix design, initial verification (test trip or trial plant batch), acceptance (go/no-go).
Maine DOT	Mix design, initial verification (test trip or trial plant batch).
Mississippi DOT	Mix design, initial verification (test trip or trial plant batch), acceptance (go/no-go). Still in planning phase.
Missouri DOT	Mix design, acceptance (pay factor).
Montana DOT	Mix design, initial verification, acceptance (go/no-go), acceptance (pay factor).
New York State DOT	Mix design, acceptance (go/no-go).
North Dakota DOT	Mix design, initial verification.
Oklahoma DOT	Mix design.
Oregon DOT	Mix design, initial verification.
Pennsylvania DOT	Mix design.
Tennessee DOT	Mix design, acceptance (go/no-go).
Texas DOT	Mix design, evaluating potential acceptance criteria.
Vermont AOT	Mix design.

General Opinions

Table 10: What are your overall comments or concerns related to the BMD process?

Agency	Response
Alabama DOT	BMD Test results have greater variability than volumetric test results; tests are slower than volumetrics, which leads to slower information for QC/QA purposes.
Arizona DOT	There are too many cracking tests to choose from to not have standard procedure specifications. There is still quite a bit of variation in testing results and how these results will be compared and evaluated.
Colorado DOT	The wide variety of tests, specifications, and methods used by states to define a “balanced” mix design makes it very difficult to implement at the DOT level. There are so many different research efforts that are ongoing, some with significant overlap. It seems like there should be an almost Superpave level of national coordination for the implementation of BMD, but currently each state is left to determine the best course of action on its own.
Connecticut DOT	N/A.
Georgia DOT	Georgia DOT is in the initial phase of establishing specifications for the letting of BMD pilot projects. With that said, since Georgia DOT revised its mix design process of limiting the RAP AC credited binder contribution, it has seen vast improvements in its asphaltic concrete mixtures that incorporate RAP. As mentioned earlier, because Georgia is adding additional virgin binder, it has had to lax the requirements for volumetric requirements such as VFA, VMA and VTM. It should be noted that Georgia DOT has never used volumetric criteria for acceptance.
Idaho TD	I think BMD is much needed to replace/augment the current Superpave methodology. The biggest hurdles currently are staffing, curing protocols, and tying the test results to long-term performance.
Illinois DOT	In Illinois, the test of record is the Dept. test. The Contractor fabricates and compacts 160 mm tall gyratory cylinders from lab-produced mix for design or plant-produced mix during production and submits to the Dept. to be tested. The Dept. “randomly” chooses which cylinders are for HWTT and which are to be tested using the I-FIT procedure. The Dept. cuts 62 mm HWTT specimens and 50 mm test specimens for I-FIT (short-term aged and long-term aged) and tests. The Contractor also fabricates and submits 95 mm tall gyratory cylinders to the Dept. to test for tensile strength and TSR evaluation. The Dept. purchased ten of the same HWTT machines from a manufacturer and ten of the same I-FIT machines from a manufacturer. This allows the Illinois DOT District labs to complete testing. This helps improve comparability and reduce variability since the Dept. test is the test of record. The Central Bureau of Materials (CBM) also purchased equipment to calibrate the Dept’s. I-FIT machines to improve confidence in the correctness of the Dept’s. I-FIT test results. The load cell equipment is also calibrated annually to ensure its accuracy. I-FIT Long-Term Aging (LTA) is only required on surface mixes since they are exposed to aging conditions more extensively than the binder (or lower support) layers. The LTA procedure is conducted on fully prepared semi-circular specimens, as opposed to loose mix, to eliminate (1) any issues with Gmm

Agency	Response
	changes because of the absorption during the aging process before compaction of the loose mix, and (2) if air void range failures occurred on the aged loose mix test specimens, causing the aging process to be restarted prior to compaction. Both situations would reduce lab efficiency.
Louisiana DOTD/LTRC	Louisiana DOTD is encouraged by the direction the quality of the asphalt mixtures in this state has progressed to, post BMD implementation. There were certainly growing pains and learning opportunities along the way. The ability to add more RAP and encourage contractor innovation have been two strong benefits.
Maine DOT	BMD has a great opportunity to allow innovation with less prescriptive specifications, but agencies need to find opportunities to assume some perceived up-front risk to be able to prove the BMD concept in real-world applications. There needs to be confirmed relationships between lab and field produced asphalt mixtures in order to have confidence in lab performance tests on laboratory batched mixtures relating to lab tests on field produced mixtures and field compacted mixtures. A lot of work related to cracking tests in BMD stops short of relating plant produced field compacted specimens (cores) to laboratory batched lab compacted specimens that are produced during mix design. Maine is also concerned with its lack of ability to relate laboratory test results to field performance consistently and systematically. An additional concern is the impact of factors outside the producer’s control, such as binder source. Some research is showing a significant impact in cracking test results between binders from different suppliers even when both meet the PG grade.
Mississippi DOT	Mississippi is curious about the correlation of HWTT/APA and HT-IDT/IDEAL-RT since requiring a HWTT or APA test during production is not feasible. The agency is interested to know how high RAP contents can go when switching to BMD. Can the same principles of BMD work for SMA?
Missouri DOT	Controlling the variability of the CT-Index Test. Warm Mix Additives and Rejuvenators affecting initial CT-Index results. Large Asphalt tonnage representing few BMD test results.
Montana DOT	The agency’s only real concern at this point is the test for cracking that it chose, IDEAL-CT, may not yield consistent results. Montana went with that test because of its simplicity and technician familiarity with equipment, since its similar to the Marshall test apparatus. However, the results it is seeing are not consistent, so identifying trends to set specification limits has been elusive so far. Its hope has always been to correlate HWTT and Disc Shaped Compact Tension (DCT) to IDEAL-RT and IDEAL-CT, respectively, so the quicker test could be used for QA purposes in the field, with the more complex and longer-term tests used for initial mix design verification. So far, the rutting correlation appears to have potential, not so sure for the cracking correlation.
New York State DOT	New York’s concerns with the BMD design implementation are currently centered around full implementation and determination of appropriate volumetric concessions. The agency has spoken to and worked with industry partners (Producers, Asphalt Institute, Regional Materials/Construction, Academia) to get to a version of implementation that is feasible. It has supported multiple accelerated loading research efforts, and multiple mixture balancing efforts to determine our State-wide criteria.

Agency	Response
North Dakota DOT	North Dakota has learned a lot about its aggregate sources by running HWTT during its Benchmarking efforts and has made some adjustments to current projects based on these results. One Adjustment was to add a liquid anti-strip to a project by change order that showed moisture susceptibility.
Oklahoma DOT	Determine testing frequency during production. Assessing RAP quality, variability, and accessibility. Determine variability of IDEAL-CT.
Oregon DOT	Thinks that once a long-term laboratory aging process is standardized, it will make comparison between Agencies much easier to do. Believes AASHTO is working on this. Everyone wants the same thing – to pay for good mix, and screen out bad mix.
Pennsylvania DOT	At this time, BMD Should be used for design purposes only to avoid bad mixes and improve existing mixes. Using BMD for acceptance has several challenges. (Who will perform the test? What will be the acceptance criteria? Etc.) Variability is a concern. Aging: Samples need to be tested right away but this may not always be the case. At the TRB, Dr. Tom Bennert indicated that not all the binders were the same: PG 64S-22 binder produced by two different companies may not perform the same even though both are called the same binder. Should we investigate the crude sources and create tiers (good binder vs. better binder)? Aggregate Source and Types: Different aggregate sources and types will probably perform differently. We have 11 districts in PA and BMD thresholds should be defined regionally. For HWTT, the reporting of only the Average Rut Depth may be misleading due to the high difference in rut depth between left and right tracks in some cases. For example, Pennsylvania had a sample where left track rutted 4.20 mm, but the right track rutted 9.97 mm. The average is 7.09mm. Only looking at the average will probably give a false sense of expected performance. There needs to be a process to identify outliers when the delta between the left and right track is high. A conservative approach is to consider the worst-case data (e.g. 9.97 mm) to be on the safe side.
Tennessee DOT	It seems that there are quite a few benefits to be gained here, but the amount of unknowns make taking even the smallest first step difficult. The agency is excited for the possibility it has in being able to improve performance and innovate with new pavements. However, the scope of the change is overwhelming and processing how that effects mix design, production, and acceptance for a whole state DOT and contractors is massive and is going to take a long time.
Texas DOT	Long-term effect of utilizing more RAP in mixtures. Since we do not have an LTA protocol, we do not predict cracking on later years in the pavement's design life. Mixes pass the cracking and rutting criteria upfront, but unsure if there will be a long-term implication of using more RAP. We will not know this until BMD pavements reach the end of their life. Is adding additional recycle materials going to accelerate oxidation rates that are not being accounted for with current testing?

Agency	Response
	Committing full confidence in the cracking and rutting tests that are selected. If in the future, it is determined that there were issues with the tests, then the entire BMD approach and process are compromised.
Vermont AOT	Vermont intends to develop a program to include Mix Design, initial verification, and go/no-go criteria, as well as determine if mix designs should be allowed to carry over to subsequent years (as is current practice). The timeliness of testing is a major concern as the agency considers implementation of the HWT. Aging is another concern as it considers that BMD can be used as a tool to evaluate things like high RAP, Recycling Agents, binder modifiers, etc. Does the initial performance and aged performance match with the field performance? Variability of each test, and the applicability of them in QA, including the ability to do QC, and its relationship to the Acceptance testing result is also a concern.

Table 11: What are some of the major challenges your DOT is facing?

Agency	Response
Alabama DOT	Joint durability, OGFC longevity and durability.
Arizona DOT	Educating the local contractors, not having standard specifications, too many tests and equipment to choose from. Standardization of test procedure. Training technicians. Money for new equipment. How do you prove that BMD mix will last longer? Not having enough money to monitor test sections. How do you validate BMD design to field performance? Can you design BMD with Mechanistic-Empirical Pavement Design Guide (MEPDG)?
Colorado DOT	Figuring out where to set the IDEAL-CT results criteria for different mixes. How to determine what to specify to ensure adequate cracking resistance. Determining an oven aging process for IDEAL-CT samples that reflects field aging, while still being reasonable enough to implement in the lab for production samples. Finding a rutting test with good performance correlation that can be run on samples during production. HWTT is currently being used to evaluate rutting susceptibility but is primarily a stripping test and will be difficult to run in field labs during production.
Connecticut DOT	Money for test equipment and deciding which tests to pursue. The agency is now enrolled in a pooled fund which will help with equipment procurement.
Georgia DOT	Seeking partnership and collaboration from local asphalt industry in the future for full implementation of BMD.
Idaho TD	Resources to take the next steps have been a big challenge. Another is general buy-in by parts of industry and parts of Idaho TD. We would like to move forward with some pilot projects in the next year utilizing Approach D design methodology and go/no-go during test strip based on mechanical tests with a fingerprint of volumetrics to use for mix acceptance during production.
Illinois DOT	Moving average and individual test limits for performance tests. Increasing performance test sampling frequency if moving average limits used. Evaluating use of softener modifiers (rejuvenators) with new Illinois DOT special provision.
Louisiana DOTD/LTRC	Long-term aging protocol to move towards production acceptance.
Maine DOT	Hesitation towards even putting out pilot projects due to the current elevated prices for asphalt mixtures and the perception that adding more, or different criteria will increase costs. It would be ideal if Maine could put out some option bids on low-risk routes where the BMD option would allow the loosening/removal of certain volumetric mix design and consensus quality criteria (Approach D). This would be done to offset the addition of BMD limits and to see if the perceived cost increase is validated by industry bids. Elevated bids have impeded opportunities to innovate. A general lack of good process control during mix production will make it even more challenging to maintain compliance with BMD mechanical test properties.
Mississippi DOT	State-wide training that would be required to teach technicians how to use the BMD testing equipment. Personnel issues as well. We are trying to keep the current employees we have.
Missouri DOT	Moving away from volumetrics and using BMD test results. Figuring out mix consistency parameters and pay factors for contractor and agency comfort. Time and Resources of sampling and fabricating multiple QC/QA samples for testing both Volumetrics and Performance test specimens.

Agency	Response
	Discrepancies between Volumetrics parameters and Performance results. Which parameters should control on actual quality?
New York State DOT	One of the challenges that this department is facing is the evaluation period for these projects. It has less than 40 projects in service that have all performance testing done in-specification. Of these projects, all of them have been in-service for less than 5 years and most of them less than 3. Ideally, these projects would all have 10 years of service. Accelerated loading facilities have assisted in some of this. However, the agency does not have a representative number of mixes evaluated in this manner or necessarily in representative climates.
North Dakota DOT	North Dakkota contractors use portable plants that move from one project to the next. Mix designs are created only a couple weeks before the project and then verified by North Dakota DOT. This short time frame will make implementing BMD more difficult.
Oklahoma DOT	Workforce. Training and buy-in from residencies.
Oregon DOT	Statewide funding for pavement is down and projected to go considerably lower in the coming years.
Pennsylvania DOT	Not all producers have equipment to perform BMD. Some smaller companies expressed concerns that purchasing equipment for BMD is a significant financial burden. There needs to be a contingency plan in place when BMD equipment fails. BMD reports should be standardized. Different companies and different lab reports are different. Format is different, terminology is different, some reports do not have the JMF information at all, etc. A technician certification program needs to be established to train technicians on performance testing.
Tennessee DOT	Tennessee never adopted Superpave mix design, so its testing inventory is still mostly Marshall. Tennessee is attempting to find a way to make that work. If not, then the cost to each contractor will be pretty high to make the switch. Tennessee is also a state with primarily limestone aggregates. It has always managed friction by utilizing a minimum silicious aggregate requirement. In a BMD world, specs like that are mostly meant to go away which leaves Tennessee in a tough spot with safety. It is working on some level of testing using the Dynamic Friction Tester (DFT) to try for design acceptance. The agency's lab is somewhat skeptical due to the size of the slab required for that test though. If it is unable to spec friction through a performance style test, it will probably end up sticking with a prescriptive polish resistant minimum which will severely limit the ability to use higher RAP contents. In an effort to encourage contractors to not bid AC contents low, Tennessee's bid structure for bidding AC is set to a minimum amount for each mix type and then the state pays the contractor for whatever extra binder based on the actual approved JMF at the market price as a price adjustment. This has worked very well in keeping mix designs from being a race to the bottom in binder content. However, in the first attempt at a truly BMD bid mix, this became quite a hurdle. Leaving this in place subsidizes higher AC contents at the expense of more innovative procedures, so Tennessee successfully argued to have it removed. However, contractors are not used carrying this risk and finding it put on them in BMD is yet another issue to resolve in implementing BMD.
Texas DOT	No major challenges in current stage. Extreme coordination and level of material testing in the allotted timeframes are issues that require a very large effort.

Agency	Response
Vermont AOT	Staffing to be able to collect samples and process the performance testing materials. Overall workload of materials staff to dedicate time to BMD related work. Industry exposure and experience in BMD. Vermont doesn't want to eliminate potential bidders on construction projects by outpacing the industries adoption of BMD. Not having full AASHTO standards to reference on the process for reheating samples to conduct Performance testing. Not having widely accepted guidelines on sample aging, testing condition, specimen prep, etc., leaves Vermont with having to develop them on its own, and prove their validity before implementing.

BMD Performance Tests

Table 12: Primary modes of distress?

Agency	Response
Alabama DOT	Rutting, fatigue cracking.
Arizona DOT	Rutting, fatigue cracking, thermal or block cracking, reflective cracking, moisture damage.
Colorado DOT	Fatigue cracking, thermal or block cracking, reflective cracking.
Connecticut DOT	Fatigue cracking, reflective cracking, moisture damage.
Georgia DOT	Reflective cracking, moisture damage.
Idaho TD	Rutting, fatigue cracking, reflective cracking, moisture damage.
Illinois DOT	Rutting, fatigue cracking, thermal or block cracking, reflective cracking, moisture damage, friction characteristics.
Louisiana DOTD/LTRC	Rutting, fatigue cracking, reflective cracking, moisture damage.
Maine DOT	Rutting, reflective cracking, moisture damage. Intermediate temperature cracking susceptibility. General cracking.
Minnesota DOT	Thermal or block cracking, reflective cracking.
Mississippi DOT	Fatigue cracking, reflective cracking.
Missouri DOT	Rutting, thermal or block cracking, moisture damage.
New York State DOT	Fatigue cracking, thermal or block cracking, reflective cracking.
North Dakota DOT	Rutting, thermal or block cracking, moisture damage.
Oklahoma DOT	Fatigue cracking, reflective cracking.
Oregon DOT	Fatigue cracking, thermal or block cracking, reflective cracking.
Pennsylvania DOT	Rutting, fatigue cracking, moisture damage.
Tennessee DOT	Rutting, fatigue cracking, friction characteristics.
Texas DOT	Rutting, fatigue cracking, reflective cracking, skid resistance.
Vermont AOT	Rutting, fatigue cracking, moisture damage.

Summary of Agency Experiences with Mechanical Testing

Table 13: Alabama DOT

Item	Rutting	Cracking	Durability/Moisture Damage	Other Distress
Standard Test Method	HWTT, HT-IDT.	IDEAL-CT.	TSR, HWTT.	N/A.
Test Criteria (if available)	• HWTT is currently used for approval of SMA an ESAL Range E dense grade mix designs. • HWTT: Mixes with 67-22 Binder < 10mm at 10,000 cycles. Mixes with 76-22 binder < 10mm rutting at 20,000 passes. • HT-IDT proposed for future BMD design and acceptance.	To be determined proposed criteria: • ESAL Range A/B 50. • ESAL Range C/D 75. • ESAL Range E 100.	• TSR : 0.80. • HWTT: Mixes with 67-22 Binder < 10mm at 10,000 cycles. Mixes with 76-22 binder < 10mm rutting at 20,000 passes.	N/A.
Laboratory Aging protocol or simulation	HWTT, HT-IDT, AASHTO R30 2 hour	AASHTO R 30 2 hour	N/A.	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	We do not currently use a rut test for acceptance.	We do not currently use a cracking test for acceptance.	TSR is used for both.	N/A.

Table 14: Arizona DOT

Item	Rutting	Cracking	Durability/Moisture Damage	Other Distress
Standard Test Method	HWTT.	IDEAL-CT.	IMC.	N/A.
Test Criteria (if available)	AASHTO T324.	ASTM Standard D8225.	Arizona test method 802.	N/A.
Laboratory Aging protocol or simulation	2-hour.	2-hour.	2-hour.	N/A.
Well-defined lag time and dwell time? **Yes or No (if Yes, please provide details on your process)**	Lag Time = Can range anywhere between a few days and a few weeks. Dwell Time = Usually 1-2 days after specimens are compacted the tests are conducted.	Lag Time = Can range anywhere between a few days and a few weeks. Dwell Time = Usually 1-2 days after specimens are compacted the tests are conducted.	N/A.	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	N/A.	N/A.	N/A.	N/A.

Table 15: Colorado DOT

Item	Rutting	Cracking	Durability/Moisture Damage	Other Distress
Standard Test Method	HWTT.	IDEAL-CT.	HWTT.	N/A.
Test Criteria (if available)	Max of 4mm after 10,000 passes.	Still determining.	Max of 4mm after 10,000 passes.	N/A.
Laboratory Aging protocol or simulation	No.	No, but investigating options.	No.	N/A.
Well-defined lag time and dwell time? **Yes or No (if Yes, please provide details on your process)**	No.	No.	No.	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	N/A.	N/A.	N/A.	N/A.

Georgia DOT

Performance Tests

Permeability Test

Ensure Superpave and Stone Matrix mix designs include testing according to GDT 1 ("Measurement of Water Permeability of Compacted Asphalt Paving Mixtures"). Ensure specimen air voids for this test are 6.0 ±1.0 %. The average permeability of three specimens may not exceed 3.60 ft per day (125 $\times 10^{-5}$cm per sec).

Moisture Susceptibility Test

For all mixtures using approved Liquid Anti-Stripping Additive meeting the requirements of Section 831 in lieu of hydrated lime, fabricate and test specimens in accordance with AASHTO T283. When required by the Office of Materials and Testing due to visible signs of stripping in any laboratory fabricated or plant produced asphaltic concrete mixtures, AASHTO T283 shall be performed for continued validation of the mix design.

Ensure specimen air voids for this test are 7.0 ±1.0% for all mixes excluding Stone Matrix mixes. Ensure specimen air voids for this test are 6.0 ± 1.0% for Stone Matrix mixes. For all mix types, the minimum tensile splitting ratio is 0.80, except a tensile splitting ratio of no less than 0.70 may be acceptable if all individual strength values exceed 100 psi (690 kPa). Ensure individual splitting strength of the three conditioned and three controlled samples are not less than 60 psi (415 kPa). Ensure retention of coating as determined by GDT 56 is not less than 95%.

HWTT for Rutting and Moisture Susceptibility Test

Ensure mix designs of all mix types except Open-graded Surface Mixes (OGFC and PEM), and Open-graded Crack Relief Interlayer (OGI) mix, include testing in accordance with AASHTO T 324. Ensure specimen air voids for this test are 7.0 ± 1.0% for all mix types, other than SMA mixes and at a testing temperature of 50°C (122°F). Ensure specimen air voids for this test are 6.0 ±1.0 % for SMA mixtures and at a testing temperature of 50°C (122°F). Use the testing and acceptance criteria established in Table 16.

Table 16: HWTT and Acceptance Criteria

Binder PG	Mix Type	Number of Passes	Maximum Rut Depth	Minimum SIP
PG 64-22 and PG 67-22	4.75 mm, 9.5 mm SP Type I, and 9.5-mm SP Type II.	15,000.	≤ 12.5 mm.	> 15,000 Passes.
PG 64-22 and PG 67-22	12.5 mm SP, 19 mm SP and 25 mm SP.	20,000.	≤ 12.5 mm.	> 20,000 Passes.
PG 76-22	All Mix types.	20,000.	≤ 12.5 mm.	> 20,000 Passes.

Tested specimens shall be inspected for any visible signs of stripping. Any mix design's tested specimens that fail to maintain 95% of asphalt cement coating, as described in GDT 56 section D.2.d, will be required to meet specified requirements for AASHTO T283 as detailed in 828.2.B.2.b. Failure to conform to specified maximum rutting tolerance or minimum Stripping Inflection Point (SIP) will result in non-approval of the submitted mix design.

Fatigue Testing

The Department may verify dense-graded mix designs by fatigue testing according to AASHTO T 321 or another procedure approved by the Department.

Abrasion Loss of Asphaltic Mixture Testing

The Department will evaluate Open-graded Friction Course, Porous European Mix, SMA, and when required, Superpave Mix Types in accordance with AASHTO T401. In accordance with AASHTO T 312, compact OGFC and PEM specimens using the SGC to a specimen height of 115 ± 5 mm and specimen air void content range specified in Sub-section 828.2.01.A. Specimen air voids for the SMA specimens shall be 6.0 % ± 1.0 % with a specimen height of 115 ± 5 mm. Specimen air voids for all Superpave Mix Types specimens, when required, shall be 7.0 % ± 1.0 % with a specimen height of 115 ± 5 mm. Bulk Specific Gravity of the compacted open-graded mixtures shall be determined using the Corelok vacuum-sealing device in accordance with AASHTO T 331. Individual specimens and average of three specimens for OGFC, PEM, SMA, and when required Superpave Mix Types shall comply with mix design and acceptance criteria established in Table 17. for Interstate pavements. For all other uses, Abrasion Loss results shall be reported in mix design approval submissions for all OGFC, PEM, and SMA Mix Types.

Table 17: Abrasion Loss Performance Testing and Acceptance Criteria

Asphaltic Concrete Mix Type	Mix Design and QA Maximum Abrasion Loss Percent
All Superpave Mix Types Used on Interstate Mainline or Ramps	10.
All SMA Mix Types	10.
All Open-graded Mix Types	20.

IDEAL-CT

Ensure mix designs of all mix types except Open-graded Surface Mixes (OGFC and PEM), and Open-graded Crack Relief Interlayer (OGI) mix, include testing in accordance with ASTM D8225. Ensure individual and average of three (3) specimens CT-Index results are included with mix design approval submission. The mix design laboratory shall fabricate and submit IDEAL-CT specimens with all asphaltic concrete mix design approval request to the Asphalt Mix Design Unit at the Office of Materials and Testing. All IDEAL-CT specimens shall comply with specified minimum CT-Index requirements established in Table 18.

Table 18: IDEAL-CT Performance Testing and Acceptance Criteria

Design Roadway Classification	Asphaltic Concrete Mix Type	Mix Design and QA Minimum CT-Index
State Routes (Non-controlled access) <10,000 ADT	4.75 mm and All Superpave Mix Types.	≥ 50.
State Routes (Non-controlled access) ≥10,000 ADT	All Superpave Mix Types.	≥ 70.
Interstates and Controlled Access State Routes	All Superpave Mix Types.	≥ 100.
Interstates and Controlled Access State Routes	All SMA Mix Types.	≥ 150.

Table 19: Idaho TD				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	AASHTO T 324.	ASTM D8225.	AASHTO T 324.	N/A.
Test Criteria (if available)	<10.0 mm @ 15,000.	> 80 (information only at this time).	No SIP @ 15,000.	N/A.
Laboratory Aging protocol or simulation	AASHTO R 30.	AASHTO R 30.	AASHTO R 30.	N/A.
Well-defined lag time and dwell time? **Yes or No (if Yes please provide details on your process)**	No.	No.	No.	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	Yes.	Yes.	Yes.	N/A.

Table 20: Illinois DOT

Item	Rutting	Cracking	Durability/Moisture Damage	Other Distress
Standard Test Method	IL-modified AASHTO T-324 HWTT.	IL-modified AASHTO T-393 I-FIT.	IL-modified AASHTO T-283 Tensile Strength and TSR.	N/A.
Test Criteria (if available)	≤ 12.5mm of Rut Depth at a Minimum number of Wheel Passes based on PG Asphalt Grade and Mix Type if 4.75mm NMAS.	Short Term Aged (STA) FI ≥8.0; LTA criteria for Design of 5.0 and 4.0 for Production Mix. FI of 16.0 for SMA (10.0 for LTA SMA) and 12.0 for 4.75 mix. LTA criteria only for surface mixtures.	TSR ≥ 0.85 (150mm dia. specimens). Minimum Conditioned Strength of 60 psi for non-polymer mixes and 80 psi for polymer modified mixes [minimum of 70 psi for PG 64-28 or lower (softer) asphalt binders].	N/A.
Laboratory Aging protocol or simulation	Yes, if WMA produced at temps. 275 +/- 5°F or less, loose mix aged at 270 +/- 5°F for 2 hours prior to compaction.	Semi-circular Test Specimens Aged in 95˚C Oven for 72 hours, then tested according to IL Mod AASHTO T 393.	None, other than 60˚C (140˚F) water bath conditioning in AASHTO T283.	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	Yes.	Yes.	Yes.	N/A.

Table 21: Louisiana DOTD/LTRC

Item	Rutting	Cracking	Durability/Moisture Damage	Other Distress
Standard Test Method	AASHTO T324.	ASTM D8044.	AASHTO T324.	N/A.
Test Criteria (if available)	• Level 2: (high traffic) <6 mm @ 20,000 passes. • Level 1: (low traffic) <10mm @ 20,000 passes.	• Level 2: (high traffic) J_c>0.6 kJ/m^2. • Level 1: (low traffic) J_c>0.5 kJ/m^2.	No SIP.	N/A.
Laboratory Aging protocol or simulation	AASHTO R30 – Short Term Aging.	AASHTO R30 – Long Term Aging 5 days – 85°C.	AASHTO R30 –Short Term Aging.	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	N/A. Must pass prior to production. Verified during production.	N/A. Must pass prior to production.	N/A. Must pass prior to production. Verified during production.	N/A.

Table 22: Maine DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	AASHTO T 324 – 22 (Implemented); ASTM D8360-22 (Investigating).	ASTM D8225-19 (Investigating).	AASHTO T 324 – 22 (Implemented).	N/A.
Test Criteria (if available)	Rut Depth < 12.5 mm at 20,000 passes. # Passes ≥ 20000: • 45C for 64-28. • 48C for 64E. • 50 C for asphalt rubber or 70E.	Preliminary criteria of CTI ≤ 150 on reheated plant produced or 2hr aged lab-batched material.	SIP ≥15,000 passes: • 45C for 64-28. • 48C for 64E. • 50 C for asphalt rubber or 70E.	N/A.
Laboratory Aging protocol or simulation	Lab produced (rarely used): Short-term conditioning procedure in R 30 (135°C for 2 hours).	Short-term conditioning procedure R 30 (135°C for 2 hours). Considering long term/critical aging options.	Lab produced (rarely used): Short-term conditioning procedure in R 30 (135°C for 2 hours).	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	Primarily just design approval.	Not implemented but unlikely for acceptance.	Primarily just design approval.	N/A.

Table 23: Mississippi DOT

Item	Rutting	Cracking	Durability/Moisture Damage	Other Distress
Standard Test Method	Looking at APA and HWTT; IDEAL-RT and HT-IDT possible.	IDEAL-CT.	HWTT and Cantabro.	N/A.
Test Criteria (if available)	N/A.	N/A.	N/A.	N/A.
Laboratory Aging protocol or simulation	Short term aging (2 hours).	Short term aging (2 hours).	Short term aging (2 hours).	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	IDEAL-RT or HT-IDT for production. Some combination of the 4 for mix design.	IDEAL-CT for both.	Both for mix design and possibly cantabro for production.	N/A.

Table 24: Missouri DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	HWTT.	CT-Index.	TSR.	N/A.
Test Criteria (if available)	Max. 0.5" Rutting @ # Passes correlating to Binder Type.	> 100 – 3% Bonus. Minimum = 45. < 45 – 3% Deduct.	• ≥90% – 3% Bonus. • 75-89% –100% Pay. • 70-74% – 2% Deduct. • 65-69% – 3% Deduct. • <65% Remove.	N/A.
Laboratory Aging protocol or simulation	2-hour Lab Aging.	2-hour Lab Aging.	AASHTO T283 – Cooled to room temperature and reheated for 2 hours.	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	Yes.	Yes.	Yes.	N/A.

Table 25: New York State DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	High Temperature Indirect Tensile Strength (ASTM D6931-17, NCHRP 9-33), IDEAL-RT (In Evaluation), HWTT (In Evaluation).	SCB I-FIT Test (AASHTO T393-21), IDEAL-CT (ASTM D8225-19).	TSR (AASHTO T283).	N/A.
Test Criteria (if available)	30 pounds per square inch; no criteria set; 20,000 passes.	FI of 8; index value of 135.	Greater than 80%.	N/A.
Laboratory Aging protocol or simulation	• Lab Mixed: 4 hours aging at compaction temperature. • Plant Mixed: No additional aging.	• Lab Mixed: 4 hours aging at compaction temperature. • Plant Mixed: No additional aging.	None.	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	Yes.	Yes.	Yes.	N/A.

Table 26: North Dakota DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	HWTT.	IDEAL-CT, DCT.	HWTT.	N/A.
Test Criteria (if available)	>10,000 passes, Water 46 C.	Not established.	>8000 passes, Water 46 C.	N/A.
Laboratory Aging protocol or simulation	N/A.	4 hours at 135 C.	N/A.	N/A.
Well-defined lag time and dwell time? **Yes or No (if Yes, please provide details on your process)**	N/A.	N/A.	N/A.	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	N/A.	N/A.	N/A.	N/A.

Table 27: Oklahoma DOT

Item	Rutting	Cracking	Durability/Moisture Damage	Other Distress
Standard Test Method	HWTT.	IDEAL-CT.	TSR.	N/A.
Test Criteria (if available)	12.5 mm max, 10, 15 or 20K passes depending on PG grade.	CT-Index: 100 Surface, 60 Intermediate.	.80 Design / .75 Field.	N/A.
Laboratory Aging protocol or simulation	AASHTO R30 – 2-hour aging.	4-hour aging.	2-hour aging.	N/A.
Well-defined lag time and dwell time? **Yes or No (if Yes, please provide details on your process)**	No.	No.	No.	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	No, only run for mix design acceptance.	No, only for mix design acceptance, will evaluate field testing with 2024 implementation projects.	Yes.	N/A.

Table 28: Oregon DOT

Item	Rutting	Cracking	Durability/Moisture Damage	Other Distress
Standard Test Method	HWTT.	IDEAL-CT.	Modified Lottman/HWTT.	N/A.
Test Criteria (if available)	7 mm @ 20,000 passes at 50C.	Not chosen.	80 TSR mix design. No inflection point at 15,000 passes.	N/A.
Laboratory Aging protocol or simulation	R30 short term only.	Long term 24 hours at 95C.	N/A.	N/A.
Well-defined lag time and dwell time? **Yes or No (if Yes, please provide details on your process)**	No.	No.	No.	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	N/A.	N/A.	N/A.	N/A.

Table 29: Pennsylvania DOT

Item	Rutting	Cracking	Durability/Moisture Damage	Other Distress
Standard Test Method	HWTT.	CT-Index.	TSR.	N/A.
Test Criteria (if available)	N/A.	N/A.	N/A.	N/A.
Laboratory Aging protocol or simulation	N/A.	N/A.	N/A.	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	Yes.	Yes.	Yes.	N/A.

Table 30: Tennessee DOT

Item	Rutting	Cracking	Durability/Moisture Damage	Other Distress
Standard Test Method	HWTT.	IDEAL-CT.	HWTT.	DFT?
Test Criteria (if available)	<12mm rutting @ 50C. Min passes req'd changes by road AADT (10/15/20k).	< min 50/75/100 Depending on road AADT. Considering a peak load requirement.	SIP may occur but only beyond 10k passes, all roads.	Research underway. Most likely some level of friction achieved at a design polishing with a 3WP.
Laboratory Aging protocol or simulation	R30, 2-hour.	R30, 4-hour.	R30, 2-hour.	TBD, some level of 3WP.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	Probably No. Evaluating for a quick test for acceptance.	Yes (probably).	Probably no. TSR.	No.

Table 31: Texas DOT

Item	Rutting	Cracking	Durability/Moisture Damage	Other Distress
Standard Test Method	HWTT, IDEAL-RT.	Texas OT, IDEAL-CT.	N/A.	N/A.
Test Criteria (if available)	• HWTT, Max 12.5mm rut: ○ @ 10,000 for PG 64. ○ @ 15,000 for PG 70. ○ @ 20,000 for PG 76. • IDEAL-RT: ○ 60 for PG 64 or lower. ○ 65 for PG 70. ○ 75 for PG 75 or higher.	• Texas OT: ○ CFE > 1. ○ CPR < 0.45. • IDEAL-CT: ○ 80 for PG -22 or higher. ○ 100 for PG -28 or lower.	N/A.	N/A.
Laboratory Aging protocol or simulation	2 hours short term oven aging at compaction temperature.	2 hours short term oven aging at compaction temperature.	N/A.	N/A.
Same test used during mix design and acceptance? (if applicable) Yes or No (if No please specify test)	Yes.	Yes.	N/A.	N/A.

Table 32: Vermont AOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	HWTT.	IDEAL-CT.	HWTT.	N/A.
Test Criteria (if available)	0.5” at 20000 passes (going into effect ~2024).	No Criteria, data reporting only.	SIP at 15000 (going into effect ~2024).	N/A.
Laboratory Aging protocol or simulation	R30.	R30.	R30.	N/A.
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No, please specify test)**	No, Mix Design only, we are not considering it for acceptance testing program wide.	No, Mix Design only, we are not considering it for acceptance testing program wide.	No, Mix Design only, we are not considering it for acceptance testing program wide.	N/A.