2023

Northeast Peer Exchange on Balanced Mix Design (BMD)

Outcomes Summary

Worcester, MA

March 29-30, 2023

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Jason Bittner, Elie Y. Hajj (ORCID: 0000-0001-8568-6360), Timothy B. Aschenbrener (ORCID: 0000-0001-7253-5504), Praveen Gopisetti, Heidi Rockwood</td><td colspan="2">8. Performing Organization Report No.</td></tr>
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Department of Civil and Environmental Engineering
University of Nevada
1664 North Virginia Street
Reno, NV 89557</td><td colspan="2">10. Work Unit No.</td></tr>
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Eight States from the Northeastern 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 eight States met to assess the state-of-practice for the technology, tools, and techniques in designing, verifying, and accepting asphalt mixtures for different layers within the flexible pavement structure, as well as for overlays of different pavements following BMD emerging practices. The peer exchange was held in Worcester, Massachusetts. This summary report focuses on agency motivations for considering BMD, the role of sustainability in BMD practice, implementation challenges, key takeaways, and emerging themes.</td></tr>
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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)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		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)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		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

Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
APA	Asphalt Pavement Analyzer
BMD	Balanced Mix Design
CTDOT	Connecticut DOT
DOT	Department of Transportation
FHWA	Federal Highway Administration
FI	flexibility index
HT-IDT	High Temperature Indirect Tension
HWTT	Hamburg Wheel Tracking Test
I-FIT	Illinois FI test
IDEAL-CT	Indirect Tensile Cracking Test
IDEAL-RT	Ideal Rutting Test
JMF	job mix formula
LCA	life cycle assessment
LTOA	long-term oven aging
MaineDOT	Maine DOT
MassDOT	Massachusetts DOT
NHDOT	New Hampshire DOT
NJDOT	New Jersey DOT
NYSDOT	New York State DOT
OBC	optimum binder content
PennDOT	Pennsylvania DOT
PG	Performance Grade
PMS	pavement management system
QA	quality assurance
QC	quality control
RAP	reclaimed asphalt pavement
RAS	reclaimed asphalt shingles
SIP	stripping inflection point
SMA	stone matrix asphalt
STIC	State Transportation Innovation Council
TSR	tensile strength ratio
UNR	University of Nevada, Reno
U.S.	United States
VTrans	Vermont Agency of Transportation
WMA	warm mix asphalt

INTRODUCTION AND PURPOSE

On March 29–30, 2023, eight States from the Northeastern United States 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 eight States met to assess the state-of-practice for the technology, tools, and techniques in designing, verifying, and accepting asphalt mixtures for different layers within the flexible pavement structure, as well as for overlays of different pavements following BMD emerging practices. The peer exchange was held in Worcester, Massachusetts.

This summary report focuses on agency motivations for considering BMD, the role of sustainability in BMD practice, implementation challenges, key takeaways, and emerging themes. This report will be one of five regional summaries that will contribute to a national perspective on the state of BMD implementation.

PEER EXCHANGE GENERAL OVERVIEW

The BMD approaches focus on designing asphalt mixtures for performance and not just meeting specified recipe and volumetric requirements. Association of State Highway and Transportation Officials (AASHTO) 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. It is the most conservative approach with the lowest innovation potential.
- ***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. While this approach is slightly more flexible than Approach A, it is still considered a conservative approach with limited innovation potential.
- ***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 less conservative than Approach A and Approach B and provides a medium degree of innovation potential.
- ***Approach D — Performance Design*** does not use volumetric properties and relies on the mechanical test results to establish and adjust mixture components and proportions. It is considered the least conservative approach with the highest degree of innovation potential.

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

Participants

States represented at the BMD peer exchange included (Figure 1) (a list of the State participants is provided in Appendix A):

- Connecticut Department of Transportation (CTDOT).
- Maine DOT (MaineDOT).
- Massachusetts DOT (MassDOT).
- New Hampshire DOT (NHDOT).
- New Jersey DOT (NJDOT).
- New York State DOT (NYSDOT).
- Pennsylvania DOT (PennDOT)
- Vermont Agency of Transportation (VTrans)
- FHWA.
- University of Nevada, Reno (UNR).

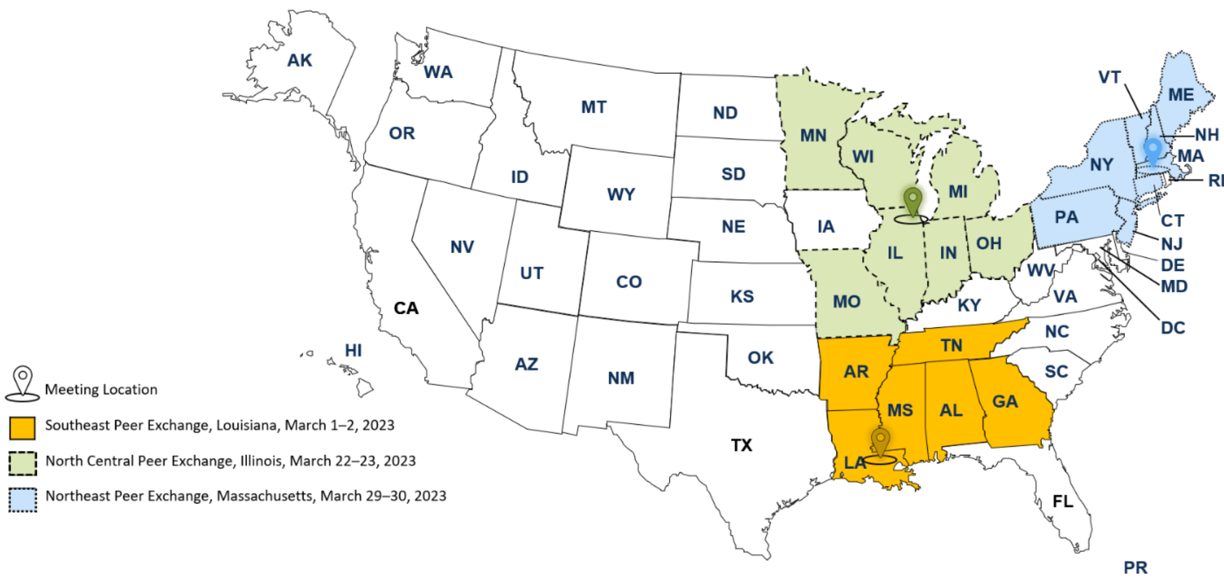

Figure 1. U.S. Map showing participating States in the northeast BMD peer exchange.

Agenda

Day 1 of the meeting focused on State's existing efforts on BMD while Day 2 focused on future efforts planned on BMD. In particular, the following items were included in the agenda:

- BMD current status.
- BMD goals, scope and approaches.
- Benchmarking studies.
- Validation efforts.
- Role of sustainability.
- Challenges and lessons learned.
- Next steps toward implementing BMD within each Agency and needs for moving forward.

Questionnaire

Three weeks before the FHWA peer exchange meeting, the attendees from the eight participating States were asked to complete a short questionnaire pertaining to their BMD practices. Information was received from a total of eight State DOTs with a summary of the results presented in Appendix B.

Motivations for Considering Moves to BMD Approaches

Superpave[2] volumetric mix design is primarily used for asphalt mixtures. Since its implementation, State DOTs identified asphalt distresses related to the Superpave design including cracking, raveling, and moisture damage[3], which have become the primary distresses controlling the service lives of asphalt pavements. A common motivation for changing from Superpave to BMD is that the traditional volumetric-based mix design procedure may not provide optimum performance for asphalt mixtures and lacks opportunities for innovation.

Reflective cracking, thermal cracking, and moisture damage were reported as a major concern for participating State DOTs as they considered BMD approaches.[3] State participants discussed how BMD mechanical tests will provide contractors the opportunity to use higher percentages of reclaimed asphalt pavement (RAP) content while retaining pavement performance. Concerns with volumetric properties, long-term pavement performance, limitations in available resources, and ability to evaluate and quantify the impact of new materials on asphalt mixture properties are some of the most common reasons mentioned by the participating States for transitioning to BMD procedures. For instance, a State lost one of its major quarries for asphalt mixtures which rises the need to innovate better and evaluate new materials and processes.

Role of Sustainability

State participants discussed how BMD mechanical tests allow to assess the resistance of asphalt mixtures to common distresses and enable mix designers to better utilize sustainable and innovative materials. This use of recycled or other innovative materials can help the States meet low carbon emission targets and meet longer life spans for pavements. State participants from New Jersey and New York noted that their State is part of the FHWA Climate Challenge – Quantifying Emissions of Sustainable Pavements program (https://www.fhwa.dot.gov/infrastructure/climatechallenge/) and aim to identify BMD practices to help support sustainability initiatives. The participants discussed and identified opportunities and areas of exploration for integrating BMD into sustainability that are summarized as follows:

- States discussed three aspects for sustainability that needs to be quantified: environmental impact, better use of local materials and resources, and reduction in pavement maintenance activities.

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[2]Superpave system was implemented by the Strategic Highway Research Program (SHRP), which was a 5-year, $150 million applied research program authorized by the Surface Transportation and Uniform Relocation Act of 1987.

[3]Distress Identification Manual for the Long-Term Pavement Performance Program (Fifth Revised Edition). FHWA-HRT-13-092, FHWA, U.S. Department of Transportation.

- Participants identified that BMD's main impact on sustainability is a potential extension of pavement service life, which reduces the life cycle emissions (and cost) of pavements.
- BMD allows for the optimization of RAP usage without jeopardizing long term performance. States discussed the need to demonstrate the positive impacts for using RAP in asphalt mixtures up to a certain level beyond which RAP starts to negatively impact the sustainability of asphalt pavements.
- States noted the need to quantify sustainability and environmental improvements of BMD. This includes the impact of extended pavement life on life cycle assessment (LCA) calculations and potential delayed maintenance activities.
- States discussed their asphalt overlay programs for sustainability including thickness and life expectancy. States are interested in exploring if BMD can assist in attaining the performance life assumed in structural design.

SUMMARY OF CRITICAL CHALLENGES IN IMPLEMENTING BMD PROCEDURE

State participants identified several specific challenges and themes. Overall challenges included BMD validation, database setup, variabilities, and challenges to full implementation including funding and communicating the benefits of BMD.

- **Identifying a BMD Validation Framework.** Validation of mechanical tests is needed to make sure that test results have a strong relationship to field performance, thus supporting the development of specification criteria for mix design approval and possibly production acceptance. The first step of the validation process is to review and assess the applicability of past studies on relating test results to field performance. Participants identified several questions that require additional consideration.
    - *Framework for Validation*. States raised the need to establish a BMD validation framework with clarifications on the number of validation sites needed for every mechanical test and whether findings from validation efforts of neighboring States with similar climate and materials can be used.
    - *The Enemy is Time*. State participants noted that the sooner agencies start the validation process, the better. States acknowledged that validation takes time and industry buy-in.
    - *Keeping Samples Longer*. Participants highlighted the importance of storing samples longer to allow future data to be collected and analyzed, and to better understand the impacts of proposed changes to mix design.
    - *Field Performance.* The lack of reliable field performance for good and poor performing asphalt mixtures led a State to set BMD tests criteria using predicted asphalt concrete performance life. Another State noted the lack of ability to relate laboratory BMD test results consistently and systematically to field pavement performance.
    - *Barriers.* Identify and overcome the barriers, which include internal resources within the agency, multiple responsibilities, and available funding.

- **Initial Database Setup.** State participants generally noted that there are several data fields that could be useful for reporting and analysis at the completion of testing. These fields should be captured in a common database within each State, however, what those fields are and how the database is structured varied.
    - *Template and format*. State participants noted that additional guidelines, including templates and formatting needs, may be useful for initial database setup.
    - *Laboratory produced versus plant produced data*. Additional data fields should include the source of the samples and other related information (e.g., handling protocols, aging condition, storage time, etc.)
    - *Collect more fields and raw data*. States recommend collecting more fields including raw data, as data that seems irrelevant now, may be useful in the future.
    - *Challenges.* Some of the challenges include effective management of the database and ability to tie materials test results to pavement management system (PMS) and field performance.

- **Variabilities.** Over the course of discussion, several variabilities in materials and test procedures were identified that could impact the ability to obtain consistent test results. There are a number of variabilities that provide some barrier to further implementation of BMD procedures. These variabilities provide some inconsistency in test results and erode confidence among contractors and agencies. State participants identified these common areas where further research and consideration for standardization could be helpful as BMD approaches gain further acceptance:
    - *Sample handling and conditioning protocols*. States reported inconsistency or lack of documented protocols on how to handle asphalt mixtures due to logistic issues, among others. It was understood that greater care and more detailed procedures would be needed for mechanical tests than volumetric properties as the former is significantly more sensitive to sample handling and conditioning. The following questions were raised during the meeting:
        - What is the time period and temperature conditions for handling field-produced asphalt mixtures?
        - What is the protocol for storing materials?
        - What is the reheating protocol?
        - How long after mixing can the specimens be compacted (i.e., lag time)?
        - How long after compaction (i.e., dwell time) can the specimens still be tested and get acceptable results?
    - *Aging Protocols*. Aging protocols vary from agency to agency. The impact of long-term oven aging (LTOA) on the test criteria is still unclear.
        - There is a need for an asphalt mixture aging procedure that can be implemented during production and quality assurance (QA). Having BMD test results within 3 days of production was considered reasonable and acceptable.
        - An extended LTOA duration might not be necessary when a shorter aging duration is an acceptable indicator. A critical aging duration is sufficient to differentiate between good and poor performing asphalt mixtures.
        - Aging effect on BMD test results may be more critical for asphalt mixtures with RAP materials.

  - *Asphalt binder sources.* Most participating States allow contractors to change asphalt binder sources from mix design to production or during production provided the performance grade (PG) remains unchanged. Although volumetric properties are generally not sensitive to the changes in asphalt binder source, asphalt mixture mechanical tests can be. For example, two asphalt binders from different suppliers may impact the BMD cracking test results even when both binders meet the PG specified for the project. The State participants discussed the need for an asphalt binder test to screen asphalt binders and avoid repeating a BMD because of a change in the asphalt binder source.
  - P*roduction versus mix design.*
    - Variability during production at the asphalt mixture plant remains an issue for BMD testing.
    - Laboratory test results from mix design can differ substantially from the test results on plant-produced material.
    - How to determine the optimum lot size for BMD tests while taking into consideration the variability in test results.

- **Stripping and Moisture Damage.** Moisture damage ranges in severity from raveling to stripping of an asphalt mixture. Participating States are generally satisfied with their current testing and process to identify if a mixture is moisture susceptible. However, the following challenges were raised by the States:
  - Four of the participating States use the tensile strength ratio (TSR) while others use the Hamburg Wheel Tracking Test (HWTT) to evaluate the moisture damage of asphalt mixtures at the mix design stage and some at the start of production. The States noted that implementation of any of the moisture damage tests part of BMD during production and quality assurance (QA) involves additional resources and staffing. TSR test has a long turnaround time to get the test results and HWTT may not be practical to use during production. A couple of States noted their interest in the use of hydrostatic pore pressure to evaluate the moisture susceptibility of asphalt mixtures.
  - Some States raised a concern about the TSR not being a good parameter to properly identify asphalt mixtures prone to moisture damage. Some States are exploring the use of HWTT as a substitute for the TSR.
  - Some States raised the concern of using the HWTT to evaluate asphalt mixtures for both rutting resistance and moisture susceptibility at the same time. Furthermore, a more granular approach is needed for analyzing HWTT test results from the left and right wheels rather than only focusing on the average of the results from the two wheels. For example, how to best interpret test results when asphalt mixtures under one wheel exhibit a stripping infliction point (SIP) while the other side does not and yet both sides meet the rut depth criteria.
  - A State noted that the difference in test results among asphalt mixtures with satisfactory rut depths can be large. Furthermore, asphalt mixtures can exhibit a counterintuitive behavior.

- **Communicating BMD Value/Telling the Story/Identifying the "Why?"** Industry and officials within State agencies may need to be convinced of changes in practice. The States need to identify and "document" the need for BMD and the primary goal, determine the scope, develop a plan for phased implementation and how can BMD address the agency priorities. Additional

- *Process.* Communicating the importance of BMD to industry and leadership are critical for further adoption. Messaging may include that BMD gives contractors a flexibility in the mix design and materials selection. States need to identify and document the "why" and the "goal" of their BMD approach. Several benefits were noted by most of the participants but the primary reason to consider BMD is to improve asphalt pavement performance and this can be accomplished through BMD by eliminating poor performing mixtures.
  - State participants noted the need to initiate discussions with upper management and industry about the level of changes and efforts that may be needed for adapting to BMD.
- *Gaps and Issues.*
  - Having agency benefits or relative benefits from BMD implementation identified. A State participant noted competing priorities within the agency. A State can be considering multiple initiatives around asphalt to solve a variety of issues and therefore need to rank BMD on its level of importance given constrained resources.
  - Ability to evaluate urgency needs in-time and identify available alternative solutions. State participants raised the concern with limited availability of existing materials and suggested use of more recycled materials.
  - Having the necessary commitment and involvement from industry toward implementation of BMD.
  - Hesitation from the upper management at the State DOT to introduce something new like BMD that may potentially increase the cost.

- **Adapting Mix Designs for New Materials.** Participants discussed the need to consider performance of asphalt mixtures based on innovation. New additives and materials need to be tested for their impact on the mechanical properties of asphalt mixtures. If new materials result in asphalt mixtures that do not meet volumetric properties (or even if they do), the volumetric mix design system is not sufficient to assess how the additives affect the mechanical properties and different standards need to be considered such as BMD.

- **Volumetric Properties Historical Usage**. During the discussion, States indicated they are open for relaxing their volumetric requirements in mix designs once enough confidence in BMD tests has been gained. In particular, a State noted that relaxing of its volumetric requirements should not happen before confirming the correlation of the BMD test results to field pavement performance. For the most part, there have been a lot of identified shortcomings with relying heavily on volumetric properties when they fail to properly capture changes in asphalt mixture components and proportions. By stepping away from volumetric properties to test asphalt mixture performance would give contractors the ability to have greater access to more resources and responsible use of materials. More assistance in the following areas would be helpful for States to implement BMD:
  - Relaxing volumetric properties including which criteria, how much, and the role they play in QA. Questions remain:

        - Are mechanical tests run through BMD enough to control consistency without volumetric properties? What other parameters can be used to control consistency?
        - Will industry and leadership feel enough confidence using tests in lieu of volumetric properties given current testing technology and practices?
    - Gaps and Next Steps.
        - Messaging takes time.
        - Stakeholder engagement needed.
        - Correlation of BMD test results to field pavement performance.
        - Focus on shadow and pilot projects.

- **Adequate Resources, Staffing, and Training.** State participants noted the difficulty of implementing new practices without necessary staff and budget. One participant noted the struggle to find qualified quality control (QC) technicians during the night shift in particular. Identified needs to address this issue include:
    - *Process.*
        - Training, education, and new qualifications for staff may be needed.
        - Consider formal training workshops on new procedures.

    - *Gaps and Issues*
        - More training and staffing are needed with the implementation of BMD.
        - More documentation is needed with the implementation of BMD, including existing and intended future practices.
        - Getting contractors on board with purchasing BMD test equipment for their laboratories.

- **Pathway for Quality Assurance (QA) and Field Acceptance.** There seems to be a clear desire to move forward to using BMD principles in mix design among the States participating in this northeastern peer exchange. Challenges to acceptance are further explored below, but include:
    - *Gaps and Issues:*
        - Asphalt mixtures are generally optimized for projects built under low-bid contracts and not necessarily for performance. How contractors can use BMD to produce cost-effective asphalt mixtures meeting BMD test criteria while still being competitive.
        - Who should be sampling asphalt mixtures? Where does the responsibility lie for preparing samples and specimens? What processes are in place to retain and ensure sample security? Who should be responsible for conducting mechanical tests?
        - How to overcome industry concerns with the acceptance side of the BMD process?
        - How to handle acceptance not only using plant-produced asphalt mixtures but based on field core samples?
        - What is the sensitivity of the BMD tests to changes in asphalt mixtures components and proportions?
        - Other considerations include interlaboratory studies and restructuring pay for asphalt mixtures.

- **Regional Collaboration Opportunities.** State participants discussed and expressed interest in initiating regional collaboration to support the implementation of BMD. States can reduce research and development duplication by collaborating and pooling resources. For example, participating States can work together to decide on handling, conditioning and long-term aging procedures given their geographical proximity and resemblances for climate and materials. This could help in accelerating the implementation of BMD by providing consistency among the States, whenever possible. States noted the need for coordinating such opportunities, identifying topics for discussion, and exploring available funds.

- **Other Challenges:**
  - Maintaining a constant communication between the various divisions and programs within a State DOT in view of workload levels and priorities.
  - Coming to a consensus on different aspects of BMD whether internally between the various divisions and programs of a State DOT or externally with the industry.
  - Figuring out the emerging benefit for investing in or prioritizing the implementation of BMD for some of the participating States.
  - Having limited number of contractors typically bidding for asphalt pavement projects can impact the implementation of BMD and the pace of change according to some of the participating States.
  - Availability of multiple cracking tests without clear knowledge of the assumptions, bases, and differences among them led some of the participating States to be hesitant in selecting a BMD test for implementation.
  - Relying on local or regional interlaboratory (i.e., round robin) studies in order to make sure accurate results are being produced when a there is no proficiency sample program in place for BMD tests. This can be further challenging when there are only a handful of laboratories equipped with BMD tests in the region.

SUMMARY OF TAKEAWAYS

(Refer to Appendix B–Survey Responses for Additional Information on Current State Practices) Participants were asked to identify their primary lessons and outcomes from participating in the peer exchange. This section provides existing efforts, future roadmaps, and State level lessons learned from the peer exchange to highlight items that various DOTs found valuable and important for their future implementation efforts.

Overall Key Takeaways

- Start by developing a plan for implementation of BMD to avoid missteps and minimize mistakes that could have been avoided in the first place.
- Identify staffing need to implement BMD, particularly when there are many competing quality improvement priorities within an agency. Consideration of current staffing resources and additional workload for implementing BMD.
- Document and identify the agency's "why" and relative benefit of BMD. This is particularly important for the development of BMD goals and scope and when there are competing priorities.
- Leverage existing funding sources including FHWA's pooled fund resource.

- Start validation efforts early with a documented plan.
- Where possible, provide staff training on BMD approaches and implementation methods.
- Identify ways to partner with industry during implementation to ensure buy-in.
- Leverage existing experiences and resources from peer agencies.
- Having and inspiring confidence in moving away from volumetric properties to BMD tests is critical for BMD implementation.
- Incorporate as many data fields and raw data in the BMD database to tie to construction and asset management data (e.g., mix design info, mixture type, raw material sources, project location, pre-existing pavement condition, lot and sub-lot numbers, BMD test results, field performance, etc.).
- Opportunities for regional collaboration to accelerate the implementation of BMD. This includes sharing experiences, creating and providing access to a shared database, unifying handling, reheating, conditioning and aging procedures, etc.
- Recognize that implementation of BMD will take time and might face setbacks during the process.

State Program Highlights: Existing Efforts

Connecticut:

- *General observations*. CTDOT is in the initial planning stages and exploring ways to implement BMD given a relatively open timeline.
    - CTDOT currently uses the Superpave mix design method and is not doing any BMD asphalt mixtures. All of its Superpave asphalt mixtures are designed to a single level of design gyrations.
    - CTDOT is building a database of Asphalt Pavement Analyzer (APA), HWTT, and Indirect Tensile Cracking Test (IDEAL-CT) results by benchmarking field-produced asphalt mixtures from select random projects.
    - No validation efforts have been completed yet. The plan is to be able to use the benchmarking test results to validate the APA, HWTT, and IDEAL-CT.
- *Roadmap.* No formal plan has been developed. CTDOT is planning to use pooled funds to obtain equipment and select a test that can be used during production along with the mix design phase. CTDOT is working on identifying and communicating internally and externally why BMD is important and why the State should adopt this new practice.
- *Lessons Learned.* The current plan is to take the implementation steps very slow similar to how Superpave was implemented. The agency is facing two opposite situations where smaller producers having implemented great QC systems and are great with innovation while large producers not showing any interest in BMD. Asphalt mixture is optimized to win the project and not performance as a result of the current low-bidding process. Imposing pay adjustments for the asphalt mixture did not help overcome the low-bid environment.

Maine:

- *General observations*. MaineDOT believes that BMD has a great opportunity to allow innovation with less prescriptive specifications. However, there is a need for agencies to find opportunities to assume some perceived up-front risk to be able to prove out the BMD concept in real-world applications.

    - MaineDOT selected BMD tests criteria based on existing research studies and specifications from other State DOTs. A preliminary relationship to field performance was confirmed for the HWTT with a forensic study of poorly performing asphalt pavements and a regional research project using Maine's asphalt mixtures.
    - HWTT specifications is only on high traffic asphalt mixtures and scope does not cover all asphalt mix designs.
    - MaineDOT noted the need to confirm the relationship of BMD test results for laboratory produced laboratory compacted, field produced laboratory compacted, and field produced field compacted (i.e., cores) asphalt mixtures in order to have confidence in BMD tests.
- *Roadmap.* No formal plan has been developed. MaineDOT envisions the implementation of a tiered approach from approach A through Approach C in order to build understanding of the BMD tests with industry partners (Note that contractors perform the mix designs for the State). This will give time for contractors to get the testing equipment and for MaineDOT to gain confidence in the shift from volumetric to performance design. Over time confidence in the BMD test results and their correlation to field asphalt pavement performance could enable eventual shift to Approach D.
    - Initially, implement BMD on priority 1 or 2, high investment projects with a vision to implement for all asphalt mixtures in the future.
    - MaineDOT benchmarking effort includes all asphalt mix designs over the span of one year as well as many other randomly selected mix designs over several years. This is done to ensure test results cover all mix design variations independent of targeting specific design variables.
    - The large database of BMD test results collected over the course of several years comprises: 1,500 HWTT results; 3,200 IDEAL-CT results; 1,600 Ideal Rutting Test (IDEAL-RT) results, 350 High Temperature Indirect Tension (HT-IDT) strength tests; and 2,000 AMPT cyclic fatigue and stress sweep rutting tests for over 100 asphalt mixtures. Statistical assessment of the benchmark data will be performed to determine significant variables.
- *Lessons Learned.* There is a hesitation from the upper management toward conducting 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 the State can 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 to offset the addition of BMD limits and see if the perceived cost increase is validated by industry bids. Elevated bids have impeded opportunities to innovate.
    - AMPT cyclic fatigue and stress sweep rutting tests are very time consuming (takes a week to get test results).
    - Fear that the focus is too much on the BMD tests for pay and lose sight of production control in terms of consistent production, raw materials, and plant operations.

Massachusetts:

- *General observations*. MassDOT is currently collecting test results on shadow projects. Additional samples for mechanical testing are obtained during the course of the project and mechanical test results are used for informational purposes only. Benchmarking tests are being conducted by a designated third-party laboratory.

  - MassDOT has been using HWTT for mix design approval for the past 10 years.
  - The State requires mechanical tests for specialty asphalt mixtures such as bridge overlay mixtures, high performance surface courses, and stone matrix asphalt (SMA).
  - MassDOT has not seen significant rutting problems with its asphalt mixtures.
  - MassDOT requires warm mix asphalt (WMA) technology to be used on all asphalt mixtures to promote its GreenDOT initiative. It has also allowed them to extend the paving season. Contractors are encouraged but not required to lower production temperatures.
  - MassDOT is concerned about the observed variability in BMD cracking tests that undermines the confidence in BMD.
  - MassDOT settled for now on 20 hours aging at 110°C for LTOA of loose asphalt mixtures for BMD cracking test.
- *Roadmap.* The plan is to implement BMD Approach A or B for all projects at the mix design stage, for initial verification (test strip or trial plant batch), and for acceptance as a go/no-go during production.
- *Lessons Learned.* Organizing materials database has been a struggle and needs help in linking the asphalt mixture design data with the construction QA data and the field performance data.
  - Determining pass/fail criteria for BMD tests is difficult without enough testing and the ability to tie test results to field performance. Pavement performance predictions are being used in the interim to establish cracking test criteria.

New Hampshire:

- *General observations*. NHDOT sees value in BMD but a bit skeptical when looking into implementation. May begin with a lower level of implementation with existing staffing level. Funding is available to buy IDEAL-CT and IDEAL-RT equipment. NHDOT is curious about the variability in BMD test results due to asphalt mixture variables including varying asphalt binder sources.
- *Roadmap.* No formal plan has been developed. Considering IDEAL-CT as it is most commonly accepted in Northeastern States. Considering Approach A for pilot projects and Approach B for State Transportation Innovation Council (STIC) research projects. NHDOT envisions BMD implementation at the mix design stage only.
  - Internal discussion led to agree on the value of conducting benchmarking studies that will comprises asphalt mixtures with different asphalt binder grades and sources, asphalt mixture types, mixture proportions and components, and aggregate sources. The intent is toward isolating variability between BMD test results.
  - Have a conceptual plan for shadow projects for IDEAL-CT and IDEAL-RT. NHDOT doesn't see any value of conducting shadow projects on low volume traffic projects.
  - Focus is on plant inspection and consistency of the asphalt mixture produced.
  - NHDOT has been doing AMPT cyclic fatigue and stress sweep rutting tests for several years and likes the idea of performance-related specifications but has not seen a realistic way to implement.

- *Lessons Learned.* The current plan is to take the implementation steps very slow. Research findings were not conclusive when asphalt mix design and production variables are not controlled.
    - Many variables are used in shadow project and major concern is with variability when comparing test results from multiple shadow projects.

New Jersey:

- *General observations*. NJDOT has fully implemented BMD for specialty asphalt mixtures. The NJDOT's BMD for designing asphalt mixtures and approving job mix formulas (JMFs) follows a combination of Approach A and Approach B. NJDOT approach is to ensure proper performance from the specialty asphalt mixtures without abandoning the traditional volumetric properties for mix design, test strip at the beginning of production, and QA. Round robin studies for the various BMD tests were conducted to determine within and between laboratory variability.
- *Roadmap.* No formal plan has been developed. The overall goal is to achieve better performing asphalt pavements. Priority is to provide the opportunity to use more RAP in asphalt mixtures without jeopardizing performance. Effort is being focused on finding surrogate BMD tests that will provide quicker turnaround of test results for QA. Currently exploring the use of HT-IDT and IDEAL-CT.
- *Lessons Learned.*
    - Need for BMD mechanical tests that allows asphalt mixture suppliers to conduct their own QC testing at a lower cost.
    - Need for a greater frequency of sampling for BMD mechanical tests (Currently NJDOT samples every 3,500 tons). More variability has been observed in BMD samples, and identifying frequency of testing and lot size has been a major challenge in the implementation of BMD.
    - Need to have consistency in sampling and testing of asphalt mixtures for BMD.
    - Need to hire additional inspectors at the asphalt plants and need to provide additional training to inspectors.

New York State:

- *General observations.* NYSDOT has been benchmarking asphalt mixtures. The following factors are being captured: asphalt mixture type, asphalt binder PG, asphalt binder content, and gradation. During mix design all factors are recorded. Asphalt mixture producers are required to keep all listed factors consistent across production within production tolerances, whenever appropriate.
    - NYSDOT has 36 projects so far with approved volumetric-based asphalt mixtures that were confirmed passing BMD test criteria.
    - The BMD tests database includes around 500 individual test results for each of the IDEAL-CT and HT-IDT.
- *Roadmap.* Interested in full implementation of BMD to all projects with a focus on Approach A and Approach B. NYSDOT has been communicating and working with industry partners (producers, regional materials/ construction, academia, etc.) to achieve a version of BMD implementation that is feasible. NYSDOT has supported multiple accelerated loading research efforts, and multiple asphalt mixture BMD efforts to establish State-wide test criteria.

    - Completed multiple pilot projects on asphalt mixtures containing fiber, high RAP, plastics, and rejuvenators. Findings showed that they either perform well or poorly. Regional labs are performing IDEAL-CT tests on cores.
- *Lessons Learned.* Unsure how reliable the PMS data is for establishing cracking test criteria given how cracking data is reported. One of the challenges that NYSDOT is facing is the evaluation period for field projects. There are less than 40 projects in service that have all BMD mechanical testing completed. All of these projects have been in-service less than 5 years and most of them less than 3 years. Ideally, these projects would all have 10 years of service in order to use field performance for establishing tests criteria. Accelerated loading facilities have assisted in some of this effort; however, the State does not have a representative number of asphalt mixtures evaluated in this manner or necessarily in representative climates.

Pennsylvania:

- *General observations.* Currently three design levels for 50, 75 and 100 gyrations are being used and contractors are being allowed to list multiple asphalt binder sources. Mix designs are approved by district engineer and not centrally.
    - In 2022, started with 50 gyrations surface levels and planning to test all gyration levels next year. In 2023, contractors are required to use a third-party laboratory to conduct HWTT and IDEAL-CT.
    - Industry raised concerns related to the acceptance of BMD, which has been the biggest challenge in QA. In-place density is still thought to be critical to include in acceptance.
    - Recycling agents with high RAP asphalt mixtures are not allowed by PennDOT and BMD can help to assess any of their potential benefits.
- *Roadmap.* No formal plan has been developed but interested in the implementation of Approach A for BMD at the mix design stage. In early stages to identify the thresholds. A research project is in-progress to identify gaps and help understand what other States are doing overall and come up with meaningful threshold values.
    - Collecting benchmarking data from HWTT and IDEAL-CT from contractors.
    - Shadow projects: currently no specifications require BMD testing.
- *Lessons Learned.* A better detailed approach for the analysis of the HWTT results under the loaded wheels is needed. An additional concern has been noted on the variability between the different devices for a given test.

Vermont:

- *General observations.* VTrans identified moisture damage and cracking as being the major distresses to address with BMD. Concerns were raised with the TSR ability to capture moisture susceptible asphalt mixtures. Vtrans is interested in moving to HWTT if proven to be a reliable test. However, realizing how impractical is to use HWTT during production, VTrans is interested in an aggregate property that can be related to the moisture susceptibility of an asphalt mixture. The observed stripping problem in asphalt mixtures can be due to the usage of natural sand.
- *Roadmap.* No formal plan has been developed. Vtrans is interested in implementing BMD Approach A for all of its asphalt mixtures. The intent is to develop a BMD program that includes mix design, initial verification, and go/no-go criteria for

acceptance. VTrans will need to determine if asphalt mix designs should be allowed to carry over to subsequent years as is in the current practice. VTrans has been conducting benchmarking testing for about 70 asphalt mixtures a year.

  - VTrans is concerned about industry exposure and experience in BMD. VTrans does not want to eliminate potential bidders on construction projects by outpacing the industries adoption of BMD.
  - The plan is to phase in implementation by starting with relatively lenient test criteria and move toward more stringent criteria with time.

- *Lessons Learned.*
  - Initially, the Illinois Flexibility Index test (I-FIT) was selected for cracking. Benchmarking testing of asphalt mixtures revealed a high variability in the I-FIT test results. Accordingly, VTrans decided to drop out the I-FIT and move forward with the IDEAL-CT.
  - Very limited information or standards are available on sample handling, reheating, and conditioning which led to the loss of significant data. This forces the State to develop its own procedures and protocols which require time and effort.
  - VTrans found itself relaxing the testing for certain volumetric properties of field-produced loose asphalt mixtures due to staff shortage. Consideration should have been given to staff availability and the effort needed to collect samples and process the BMD testing. Staff had to dedicate extra time for BMD related work.
  - Due to limitations in State staffing and resources, there is a significant lag time between the sampling and testing of field-produced asphalt mixtures. Samples taken in early summer have been sitting in cardboard boxes and have not been tested yet, contributing to the variability in test results.

APPENDICES

Appendix A: Participants List

Northeast Peer Exchange on
Balanced Mix Design
Worcester, MA 01605
March 29–30, 2023

Participant List

State/Organization	Participant Name	Email
CT	David Howley	david.howley@ct.gov
CT	Shawn Greenlaw	shawn.greenlaw@ct.gov
MA	Mark Brum	Mark.Brum@dot.state.ma.us
MA	Edmund Naras	Edmund.Naras@dot.state.ma.us
MA	James Pierce	James.Pierce@dot.state.ma.us
ME	Richard Bradbury	richard.bradbury@maine.gov
ME	Casey Nash	casey.b.nash@maine.gov
ME	Nico Trebouet	nicolas.trebouet@maine.gov
NH	Joseph Blair	Joseph.R.Blair@dot.nh.gov
NH	Matthew Courser	matthew.courser@dot.nh.gov
NJ	Mark Gillece	mark.gillece@dot.nj.gov
NY	Michael Heim	Michael.Heim@dot.ny.gov
PA	Cenk Sengoz	csengoz@pa.gov
VT	Ian Anderson	ian.anderson@vermont.gov
VT	Aaron Schwartz	Aaron.Schwartz@vermont.gov
FHWA	Marco Rocha	marco.rocha@dot.gov
FHWA	Derek Nener-Plante	derek.nenerplante@dot.gov
FHWA	Tim Aschenbrener	timothy.aschenbrener@dot.gov

Appendix B: Questionnaire

FHWA Northeast Peer Exchange

PRE-MEETING SURVEY

Three weeks before the FHWA peer exchange meeting, attendees were asked to complete a short survey pertaining to their agency's BMD practices. The intent of the survey was to stimulate thoughts in preparation for the meeting and to generate information to help guide the meeting discussions. Responses were received from a total of 8 agencies with a summary of the results presented below.

Respondent Information

Name	Email	Affiliation
David Howley	david.howley@ct.gov	Connecticut DOT
Rick Bradbury Casey Nash	richard.bradbury@maine.gov casey.b.nash@maine.gov	Maine DOT
Mark Brum	Mark.Brum@dot.state.ma.us	Massachusetts DOT
Joseph Blair	Joseph.R.Blair@dot.nh.gov	New Hampshire DOT
Mark Gillece	mark.gillece@dot.nj.gov	New Jersey DOT
Michael Heim	Michael.Heim@dot.ny.gov	New York State DOT
Jay Sengoz	csengoz@pa.gov	Pennsylvania DOT
Ian Anderson	ian.anderson@vermont.gov	Vermont Agency of Transportation

BMD Current Practice	
What is the current implementation status of BMD?	
Agency	**Response**
Connecticut	Research Studies Initial Planning
Maine	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
Massachusetts	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
New Hampshire	Pilot projects (Typical bidding-contracting process with the new Quality Assurance requirements applied. Mechanical testing required as part of mix design & acceptance) Research studies Initial Planning Still thinking/exploring
New Jersey	Fully implemented Pilot projects (Typical bidding-contracting process with the new Quality Assurance requirements applied. Mechanical testing required as part of mix design & acceptance) Still thinking/exploring
New York State	Pilot projects (Typical bidding-contracting process with the new Quality Assurance requirements applied. Mechanical testing required as part of mix design & acceptance)
Pennsylvania	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
Vermont	Pilot projects (Typical bidding-contracting process with the new Quality Assurance requirements applied. Mechanical testing required as part of mix design & 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

What is the project scope for BMD?	
Agency	**Response**
Connecticut	Other: Probably take a system approach. Apply to Superpave mix design.
Maine	Other: Initially priority 1 or 2, high investment. Future all standard specification mix designs.
Massachusetts	All projects Interstates Projects with high asphalt tonnage
New Hampshire	Other: Pilot BMD specs for 1 SMA project in 2024 paving season at mix design acceptance stage based on contractor results; BMD STIC research for 2 mix types (1 is SMA) w/ testing performed by NHDOT
New Jersey	Other: Projects using Specialty Mixes
New York	All projects Other: Planned project scope would be all permanent top course paving
Pennsylvania	Other: Wearing courses
Vermont	All projects

Which BMD approaches are being considered by your State DOT?	
Agency	**Response**
Connecticut	Other: Undecided. Probably A or B.
Maine	Other: 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 eventual shift to approach D
Massachusetts	Approach A - Volumetric Design with Performance Verification Approach B - Volumetric Design with Performance Optimization
New Hampshire	Approach A - Volumetric Design with Performance Verification Approach B - Volumetric Design with Performance Optimization Other: Approach A for Pilot Projects and Approach B for STIC research project
New Jersey	Approach A - Volumetric Design with Performance Verification Approach B - Volumetric Design with Performance Optimization
New York	Approach A - Volumetric Design with Performance Verification Approach C - Performance-Modified Volumetric Design
Pennsylvania	Approach A - Volumetric Design with Performance Verification
Vermont	Approach A - Volumetric Design with Performance Verification Approach B - Volumetric Design with Performance Optimization Approach C - Performance-Modified Volumetric Design

Benchmarking Studies

Were any benchmarking studies conducted during the BMD implementation process?	
Agency	**Response**
Connecticut	Yes.
Maine	Yes.
Massachusetts	Yes.
New Hampshire	Other: Intended as part as BMD STIC Research effort
New Jersey	Yes.
New York	Yes. Ongoing.
Pennsylvania	Yes.
Vermont	Yes. Ongoing.

Who is responsible for the conduct of benchmarking mechanical tests?	
Agency	**Response**
Connecticut	Designated third-party lab
Maine	State DOT Lab Other: Contractor's should also bench mark their materials so they are aware of any discrepancies between State and contractor results.
Massachusetts	Designated third-party lab
New Hampshire	State DOT Lab
New Jersey	State DOT Lab Designated third-party lab
New York	State DOT Lab Designated third-party lab Other: Asphalt Producer Lab
Pennsylvania	Other
Vermont	State DOT Lab

What factors are included in the benchmarking study? (mixture type, NMAS, binder type). Please note if impacts of mix design and production variables on test results are being analyzed?	
Agency	**Response**
Maine	Our benchmarking effort has included all asphalt mixture designs over the span of one year as well as many other randomly selected designs over several years to ensure we have values that cover all design variations independent of targeting specific design variables. Statistical assessment of the benchmark data will be performed to determine significant variables.
Massachusetts	We used Superpave 12.5 mm mixtures designed using a PG 64S-28
New Hampshire	Binder grade, Binder source (noted), Mix type, NMAS, Mix ingredients proportions of volumetric design, and aggregate source. Intent is toward isolating variability between BMD test results.
New Jersey	Mixture type and NMAS
New York	The following factors are being captured to help with asphalt mixture benchmarking: Mixture Type, NMAS, binder performance grade, binder content, gradation. During mixture design all factors are recorded. Producers are required to keep all listed factors consistent across production within production tolerances, when appropriate.
Pennsylvania	JMF: NMAS, Pb, Ndesign, PG of Virgin Binder added to JMF. Final PG of JMF, RBR, %RAP, %RAS, Gmm, Gsb, VMA, TSR, Gradation Data, Type of Anti-Strip, Dosage of Anti-Strip Hamburg: 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, COV
Vermont	Mix Type, NMAS, Binder Grade, Modifier, binder content, RAP content, Binder source.

Validation Studies

Was validation of performance tests completed to assure that mechanical test results have a strong relationship to field performance?	
Agency	**Response**
Connecticut	Ongoing.
Maine	Other: MaineDOT based its selection of performance tests criteria on existing research studies and specifications from other 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
Massachusetts	Yes.
New Hampshire	No.
New Jersey	Yes.
New York	Yes. Ongoing.
Pennsylvania	Ongoing.
Vermont	Yes. Ongoing.

What is the source of field performance data used for validation process?	
Agency	**Response**
Connecticut	Pavement management system Research test sections
Maine	Pavement management system
Massachusetts	Other: Predictive Materials
New Hampshire	Pilot projects
New Jersey	Research test sections
New York	Pavement management system Accelerated load facility Test track Pilot projects
Pennsylvania	Pavement management system Pilot projects
Vermont	Pavement management system Pilot projects

Application of BMD

What is the scope or applicability of BMD tests?	
Agency	**Response**
Connecticut	Other: Undecided. Most likely start with mix design.
Maine	Mix design Initial verification (test trip or trial plant batch)
Massachusetts	Mix design Initial verification (test trip or trial plant batch) Acceptance (go/no-go)
New Hampshire	Mix design
New Jersey	Mix design Initial verification (test trip or trial plant batch) Acceptance (pay factor)
New York	Mix design Acceptance (go/no-go)
Pennsylvania	Mix design
Vermont	Mix design

General opinions	
What are your overall comments or concerns related to the BMD process?	
Agency	**Response**
Maine	Balanced Mix Design has 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 out the BMD concept in real-world applications. There needs to be confirmed relationships between lab and field produced asphalt mixtures 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. I am also concerned with our lack of ability to relate laboratory test results consistently and systematically to field performance. 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.
Massachusetts	1. It's been a challenge to select the right test. We were hesitant to select a crack test because it seems that there is a new test that comes out every few years. We first were thinking FIT and now have selected IDEAL-CT. 2. Determining pass/fail criteria is difficult without enough testing. We decided to take the results from our research study and have a one-year phase in period where we will require testing but for information only. 3. Once we have a good handle of the testing and its ability to predict performance, we would consider allowing the contractor to have more flexibility with design if they meet minimum performance criteria. 4. To start we are using predictive models to come up with the pass/fail criteria for the IDEAL-CT. 5. At this point we settled on 20 hrs aging at 110°C for long-term aging. 6. Variability in the cracking tests remains a concern and undermines confidence in BMD. 7. Most of the testing was performed on conventional unmodified binders, yet most of the surface courses now being specified are PMA. We are unsure how this should impact the IDEAL-CT testing.
New Jersey	NJDOT approach is to ensure that we are getting Performance from the Specialty Mixes without abandoning the traditional Volumetric tests for Mix Design, Test Strip, and Acceptance.
New York	Our concerns with the BMD design implementation are currently centered around full implementation and determination of appropriate volumetric concessions. We have spoken to and worked with industry partners (Producers, Asphalt Institute, Regional Materials/Construction, Academia) to get to a version of implementation that is feasible. We have supported multiple accelerated loading research efforts, and multiple mixture balancing efforts to determine our State-wide criteria.

General opinions	
Pennsylvania	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 it may not always be the case. At the TRB, Dr. Tom Bennert indicated that not all the binders were the same: PG64S-22 binder produced by 2 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 Hamburg, the reporting of only the Average Rut Depth may be misleading due to the high difference in rut depth between left and right tracks for some cases. For example, we 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.
Vermont	We intend 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 we consider implementation of the HWT. Aging is another concern as we consider 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.

What are some of the major challenges your DOT is facing?	
Agency	**Response**
Connecticut	Money for test equipment and deciding which tests to pursue. Now enrolled in a pooled fund which will help with equipment procurement.
Maine	Hesitation toward 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 we 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) to offset the addition of BMD limits and 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.
Massachusetts	1. Getting contractors on board with purchasing the equipment for their labs. 2. Long term aging protocols to get a better understanding of cracking. 3. Understanding how much variability we should expect with each test. How does asphalt binder effect the results? 4. Without a proficiency sample program for these tests we have to rely on local or regional round robins in order to make sure we are getting accurate results. This is challenging when there are only a handful of devices in the region.
New Hampshire	Learning curve, variability of test results due to binder source, staff limitations
New Jersey	• Need Performance Testing that allows Suppliers to do their own Quality Control testing at a lower cost • Need quicker turnaround on Acceptance Testing • Need greater frequency of sampling for Performance Testing (Currently NJDOT samples every 3,500 tons) • Need more inspectors at plants, more training of inspectors
New York	One of the challenges that our department is facing is the evaluation period for these projects. We have less than 40 projects in service that have all performance testing done in-specification. Of these projects, all of them have been in-service 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, we do not have a representative number of mixes evaluated in this manner or necessarily in representative climates.
Pennsylvania	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.

What are some of the major challenges your DOT is facing?	
Vermont	• 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, we don't want to eliminate potential bidders on construction projects by outpacing the industries adoption of BMD. • Not having protocols to reference on the process for reheating samples to conduct Performance testing. Not having a consensus on sample aging protocols, testing condition, specimen preparation, etc., leaves us having to develop them on our own, and prove their validity before implementing.

BMD Performance Tests

Primary modes of distress	
Agency	**Response**
Connecticut	Fatigue Cracking Reflective Cracking Moisture Damage
Maine	Rutting Reflective Cracking Moisture Damage Other: Intermediate temperature cracking susceptibility. General cracking.
Massachusetts	Rutting Fatigue cracking Moisture damage
New Hampshire	Rutting Thermal or block cracking
New Jersey	Rutting Fatigue cracking Reflective cracking Moisture damage
New York	Fatigue cracking Thermal or block cracking Reflective cracking
Pennsylvania	Rutting Fatigue cracking Moisture damage
Vermont	Rutting Fatigue cracking Moisture damage

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)	–
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	–
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)	–
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.	–

–not applicable or data not available.

Massachusetts DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	HWTT AASHTO T 324	IDEAL-CT ASTM D 8225	HWTT AASHTO T 324	–
Test Criteria (if available)	a maximum rut depth of 12.5 mm after 20,000 passes combined with no SIP before 15,000 passes	≥ 90	a maximum rut depth of 12.5 mm after 20,000 passes combined with no SIP before 15,000 passes	–
Laboratory Aging protocol or simulation	loose mixture is to be conditioned in accordance with AASHTO R 30 Short term aging protocol	20 Hrs at 100 °C	loose mixture is to be conditioned in accordance with AASHTO R 30 Short term aging protocol	–
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No please specify test)**	Yes	Yes	Yes	–

–not applicable or data not available.

New Hampshire DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	IDEAL-RT (STIC research) and HWT (SMA Pilot)	IDEAL-CT (STIC research & SMA Pilot)	–	Tensile strength Ratio (TSR)
Test Criteria (if available)	SMA Pilot: HWT: Average rut depth, mm (inches) 10.0 (0.40) maximum at 20,000 cycles (SIP), passes 15,000 min	SMA Pilot: 175 minimum	–	TSR>0.8, 7% AV ± 0.5%
Laboratory Aging protocol or simulation	–	–	–	–
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No please specify test)**	Mix Design only, not for acceptance	Mix Design only, not for acceptance	–	Mix Design only, not for acceptance

–not applicable or data not available.

New Jersey DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	APA	Overlay	TSR	–
Test Criteria (if available)	Varies by mix	Varies by mix	Varies by mix	–
Laboratory Aging protocol or simulation	Short-term conditioning in accordance with AASHTO R30	Short-term conditioning in accordance with AASHTO R30	Short-term conditioning in accordance with AASHTO R30	–
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No please specify test)**	Yes	Yes	Test only used during Mix Design	–

–not applicable or data not available.

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) Hamburg Wheel Tracker (In Evaluation)	Semicircular Bending IFIT Test (AASHTO T393-21) IDEAL CT (ASTM D8225-19)	Tensile Strength Ratio (AASHTO T283)	–
Test Criteria (if available)	30 pounds per square inch No criteria set 20,000 passes	Flexibility Index of 8 Index value of 135	Greater than 80%	–
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	–
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No please specify test)**	Yes	Yes	Yes	–

–not applicable or data not available.

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

–not applicable or data not available.

Vermont Agency of Transportation				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	HWT	IDEAL-CT	HWT	–
Test Criteria (if available)	½” at 20000 passes (going into effect ~2024)	No Criteria, data reporting only	stripping inflection point at 15000 (going into effect ~2024)	–
Laboratory Aging protocol or simulation	R30	R30	R30	–
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.	–

–not applicable or data not available.