2023

North Central Peer Exchange on Balanced Mix Design (BMD)

Outcomes Summary

Schaumburg, IL

March 22–23, 2023

U.S. Department of Transportation

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16. Abstract

Seven States from the North Central 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 seven 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 Schaumburg, Illinois. This summary report focuses on agency motivations for considering BMD, the role of sustainability in BMD practice, implementation challenges, 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)		
^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
AV	air voids
BMD	Balanced Mix Design
CAA	coarse aggregate angularity
CAPRI	Consortium for Asphalt Pavement Research and Implementation
DCT	Disc-Shaped Compact Tension Test
DOT	Department of Transportation
ESAL	equivalent single axle load
FAA	fine aggregate angularity
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
IDOT	Illinois DOT
INDOT	Indiana DOT
LTOA	long-term oven aging
MDOT	Michigan DOT
MnDOT	Minnesota DOT
MoDOT	Missouri DOT
NMAS	nominal maximum aggregate size
NCAT	National Center for Asphalt Technology
ODOT	Ohio DOT
PG	Performance Grade
PWL	percent within limits
QA	quality assurance
QC	quality control
RAP	reclaimed asphalt pavement
RAS	reclaimed asphalt shingles
SIP	stripping inflection point
SMA	stone matrix asphalt
TSR	tensile strength ratio
UNR	University of Nevada, Reno
U.S.	United States
VMA	voids in the mineral aggregate
WisDOT	Wisconsin DOT
WMA	warm mix asphalt

INTRODUCTION AND PURPOSE

On March 22–23, 2023, seven States from the North Central 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 seven 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 a pavement structure following BMD emerging practices. The peer exchange was held in Schaumburg, Illinois.

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 the practice.

PEER EXCHANGE GENERAL OVERVIEW

The BMD approaches focus on designing asphalt mixtures for performance and not just meeting specified combined aggregate gradation and volumetric requirements. Association of State Highway and Transportation Officials (AASHTO) PP 105-20 Standard Practice for Balanced Design of Asphalt Mixtures[1,2] 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 AASHTO methods and specifications are not a Federal requirement.
[2]Transportation Research Circular E-C280: Glossary of Terms for Balanced Design of Asphalt Mixtures (2022).

Participants

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

- Illinois Department of Transportation (IDOT).
- Indiana DOT (INDOT).
- Michigan DOT (MDOT).
- Minnesota DOT (MnDOT).
- Missouri DOT (MoDOT)
- Ohio DOT (ODOT).
- Wisconsin DOT (WisDOT).
- FHWA.
- University of Nevada, Reno (UNR).

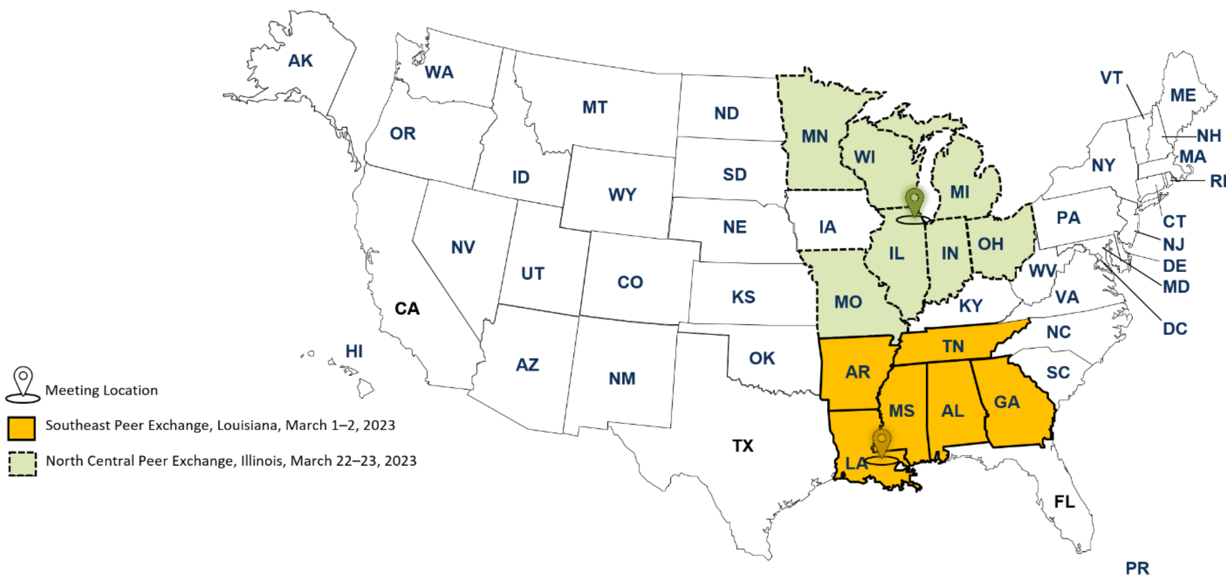

Figure 1. U.S. Map showing participating States in the north central BMD peer exchange.

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 towards implementing BMD within each Agency and needs for moving forward.

Questionnaire

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

Motivations for Considering Moves to BMD Approaches

Superpave[3] volumetric mix design is primarily used for asphalt mixtures. Since its implementation, State DOTs identified asphalt distresses related to the Superpave volumetric design including cracking, raveling, and moisture damage[4], which have become the primary distresses controlling the service lives of asphalt pavements. A common motivation for changing from Superpave volumetric design to BMD is that the traditional volumetric-based mix design procedure without laboratory performance evaluation may not provide optimum performance for asphalt mixtures and lacks opportunities for innovation.

Cracking, rutting, and moisture damage were reported as a major concern for participating State DOTs as they considered BMD approaches. To further determine the root of this observation as the motivation for considering implementing BMD, the State participants discussed the type of cracking observed. Thermal or block cracking, fatigue cracking, and reflective cracking were reported by the State participants as common cracking types observed in their asphalt and composite pavements.[4]

State participants discussed how BMD mechanical tests will provide contractors the opportunity to use higher percentages of reclaimed asphalt pavement (RAP) content, relax the requirements for fine aggregate angularity (FAA) and coarse aggregate angularity (CAA), relax/eliminate the tensile strength (TSR) test, while retaining pavement performance. RAP consistency was maintained through the use of fractionated RAP. With such changes/innovations, States can potentially benefit from a reduction in asphalt mixture cost and saving time by excluding the evaluation techniques that are already covered by the BMD tests they are planning to use. State participants also noted that BMD approaches generally enable greater use of local materials than traditional volumetric mix designs, reducing shipping costs and the carbon emissions associated with aggregate and other material transportation. While some of the participating States meet regularly with industry to discuss motivations for moving to BMD, generally these motivations are not formally documented.

Role of Sustainability

State participants discussed how BMD mechanical tests allow to assess the resistance of asphalt

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

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 Illinois, Indiana, Minnesota, and Missouri noted that their State is part of 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:

- 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 may allow agencies to use more local materials reducing carbon emissions of transporting materials. The use of RAP will also decrease the amount of virgin asphalt binder, and such reduction – depending on the RAP binder availability – can significantly reduce the carbon emissions related to the refinement of crude oil. States specifically discussed hauling quality aggregates (i.e., trap rock) from neighboring States for use in stone matrix asphalt (SMA) mixtures and the environmental impact for substituting quality aggregates with local materials.
- BMD may allow for the increased use of RAP without jeopardizing long term performance. One State noted that a high RAP project without BMD (i.e., using volumetric mix design) was experiencing raveling within a few years due to poor mix design.
- States identified difficulties in quantifying sustainability and environmental improvements of BMD. This includes the impact of extended pavement life on life cycle assessment (LCA) calculations, potential delayed maintenance activities, connecting BMD data to asset management practices, standardized data format for analysis and linking data throughout different divisions and districts.
- States highlighted the importance of communicating benefits and success stories of BMD impact on pavement sustainability to better facilitate implementation within other agencies.
- States discussed their asphalt overlay programs for sustainability including lift 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.

- *Existing Guidelines for Validation*. States are familiar with the National Center for Asphalt Technology (NCAT) on-going research task funded by the Consortium for Asphalt Pavement Research and Implementation (CAPRI) to establish BMD validation frameworks.
- *The Enemy is Time*. State participants noted that the sooner agencies start the validation process, the better. Validation takes time and requires industry buy-in. One participant noted that "the best time to begin validation is yesterday, the second best is today, the third best tomorrow."
- *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.
- *Asset Management Frameworks*. Linking data from the mix design stage to the asset management stage of a pavement's life cycle is a key component in BMD validation. This allows BMD champions to provide information to upper management and leadership and present data-driven mix design improvement specifications. States noted that generally divisions may have a plethora of data, but limited information (DRIP–Data Rich, Information Poor).

- **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 with each State, however, there is currently no clear guidance on what the fields should be, and what the preferred structure would be for the database.
  - *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.
  - *Existing templates*. States with existing templates include Wisconsin and Illinois.

- **Variabilities.** Over the course of discussion, variabilities in several procedures were identified. 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?
    - How mechanical test results are affected by the differences in theoretical maximum specific gravity values measured between laboratories?
    - What is the reheating protocol and what adjustments are needed for asphalt mixtures with absorptive aggregates?
    - 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.
    - Only two participating States established a LTOA protocol. The protocol used by IDOT is for compacted semi-circular test specimens aging for 72 hours at 95 degrees C per the Illinois modified AASHTO T 393.[5] The LTOA is only applied for surface asphalt mixtures and on the cracking test specimens. It is conducted on fully prepared semi-circular specimens, as opposed to loose asphalt mixture, to eliminate: (1) any issues with changes in the theoretical maximum specific gravity of an asphalt mixture because of the absorption of asphalt binder by aggregates during the LTOA process before compaction of the loose mixture; and (2) the restart of the LTOA process on loose asphalt mixture should the compacted test specimens from the aged loose mixture fail the specified air voids range. Both situations would reduce laboratory efficiency.
    - The LTOA protocol used by WisDOT consists of 6 hours for loose asphalt mixture at 135 degrees C. This is only applied for the preparation of cracking (or IDEAL-CT) test specimens.
    - Guidance is needed on how to use delta T_c to gauge how aging protocols simulate field aging and what aging protocols get you closer to the critical field aging condition. Delta T_c is a calculated value using results (creep stiffness and creep rate) from the bending beam rheometer test (AASHTO T 313) of asphalt binders.
  - *Asphalt binder sources and additives.* 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. The State participants discussed whether a test like delta T_c for example, is enough to screen asphalt binders and avoid repeating a BMD because of a change in the asphalt binder source.
    - Should additives be allowed at the asphalt plant or terminal?
  - *Production 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.

[5]Use of AASHTO methods and specifications are not a Federal requirement.

- **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 challenge was 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 as part of BMD during production and quality assurance (QA) involves additional resources and staffing. Furthermore, the TSR test has a long turnaround time to get the test results.
  - Some questions arose regarding the use of the HWTT, TSR or both. Further, what should the conditioning be on the specimens that are tested (e.g., Moisture Induced Stress Tester–M.i.S.T.).

- **Communicating BMD Value/Telling the Story/Identifying the "Why?."** Industry and officials within State agencies may need to be convinced of changes in practice. Participants identified that BMD is not out of reach for adoption by industry.
  - *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.
  - *Gaps and Issues.*
    - Agency Benefits of BMD/Relative Benefits of BMD to Other Quality Improvement Efforts. Some of the State participants noted competing priorities within agencies. States are 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.
    - Having the necessary commitment and involvement from industry towards implementation of BMD.

- **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 to relaxing their volumetric requirements in mix designs once enough confidence in BMD tests has been gained. 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. More assistance in the following areas would be helpful for States to implement BMD:
  - Guidance and agency role in advancing from BMD Approach A to Approach D.
  - 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? What should be used for the design gyrations?
        - 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.
        - 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 reported having to repost a State position at least three separate times. Participants also noted competing with industry for the same talent and staff burnout and turnover through long hours and overtime. 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 of existing and intended future practices.

- **Pathway for Field Acceptance and an Acceptable Quality Assurance Program (QAP).** There seems to be a clear desire to move forward to using BMD principles in mix design among the States participating in this north central peer exchange. Challenges to acceptance are further explored below, but include:
    - *Process.* Application in test strips, use for go-no-go, testing frequency, quality measures, use for payment, and establishing thresholds.
    - *Gaps and Issues:*
        - Some of the participating States noted push-back from contractors for moving too quickly on this issue including requiring a variety of mechanical tests. One State noted that industry will adapt to new testing requirements over time as more asphalt mixtures pass BMD test criteria.
        - 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? It was noted that the basic components of a QAP used for acceptance with volumetric properties would also need to apply to one using mixture mechanical testing (e.g., sampling, witnessing, chain of custody, agency verification).
        - Other considerations include interlaboratory studies and restructuring pay for asphalt mixtures. How to effectively implement percent within limits (PWL) for BMD tests? What volumetric properties can be eliminated and replaced with mechanical tests for pay?

- **Other Challenges:**
  - Tests that require 5-8 hours of conditioning or LTOA have proven to be difficult to implement throughout the standard workday given current staff capacity and limited funding to contract out work.
  - Maintaining a constant communication between the various divisions and programs within a State DOT in view of workload levels and priorities.
  - Some of the participating States are still trying to figure out the emerging benefit for investing in or prioritizing the implementing of BMD.

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

- Necessary agency staffing to implement BMD, particularly when there are many competing quality improvement priorities within an agency.
- Document and identify the agency's "why" and relative benefit of BMD including the overall goal and scope for implementation. This is particularly important when there are competing priorities. This includes documenting the improved pavement performance.
- Leverage existing funding sources including FHWA's pooled fund resource.
- Start validation efforts early with a documented plan.
- Where possible, providing training on BMD approaches for staff is a critical implementation step.
- 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 or ID, mixture type, raw material sources, project location, pre-existing pavement condition, lot and sub-lot numbers, BMD test results, etc.).
- Leverage contractors/consultants when State DOT staffing resources are inadequate for testing procedures.
- Track contractors' test results when rolling out BMD testing specifications.

State Program Highlights: Existing Efforts

Illinois:

- *General observations*. Illinois has fully implemented BMD Approach A on all projects. It took IDOT 4 years to fully implement the HWTT for mix design and production. However, the full implementation of the Illinois flexibility index test (I-FIT) took 9 years (includes test development and validation). Test strips are required by IDOT on all projects greater than 3,000 tons. All BMD testing is completed by District laboratories and are the tests of record. The IDOT Central laboratory supports Districts laboratories based on need such as in the case of equipment breakdown. IDOT is still taking cores and conducting distress surveys ever since the construction of the I-FIT pilot projects in 2016. Challenges identified include identifying moving average and individual test limits for mechanical tests and evaluating use of softener modifiers with the new IDOT special provision. Based on IDOT experience, the following observations were made:

  - According to IDOT specifications, the contractor has to compact and submit 160 mm tall gyratory cylinders to the agency for BMD testing. The agency randomly chooses which gyratory cylinders are used for HWTT and I-FIT and saws the gyratory cylinders to the correct test specimen geometry.
  - In general, a mixture that meets the flexibility index (FI) criterion after short-term oven aging (STOA) meets the FI criterion after LTOA.
  - The reduction in FI between STOA and LTOA depends on the asphalt binder type (i.e., polymer-modified versus unmodified) and aggregate mineralogy and absorption. A lesser reduction in FI from short term oven aging to LTOA is generally observed for polymer modified asphalt mixtures.
  - IDOT has over 5,000 I-FIT datasets in their I-FIT database. About 40 percent of the asphalt mixtures placed and tested used polymer-modified asphalt binders.

- *Roadmap.* IDOT is currently examining the role that volumetric properties play and how they interact with BMD especially for QA. The State does not anticipate a change from BMD Approach A in the near term. IDOT is looking to increase testing frequency by shifting from a single test in production to moving averages for mechanical tests to better evaluate situational failures. IDOT currently requires HWTT and I-FIT at the start of production only. IDOT is interested in Superpave 5 and its impact on BMD.
  - A test strip is conducted the first day of production. IDOT requires the contractor to sample the asphalt mixture and have 48 hours to submit compacted gyratory cylinders to the district laboratory for HWTT and I-FIT testing.
  - If failing BMD test criteria are observed during production, the contractor needs to make necessary adjustments to the asphalt mixture to get passing test results. If the asphalt mixture fails twice in a row, production is stopped and will only resume after having passing BMD test results.
- *Lessons Learned.* IDOT highlighted the importance of database management, staffing and resources, and training. This includes:
  - Tying more information and data fields to materials testing database early on in the BMD process.
  - Having staff and resources dedicated to implement BMD is critical. Given limited agency staffing, the importance of having and leveraging different consultants and contractors from industry to run BMD tests and validation was noted.
  - Having continuous training and improvement: IDOT teaches fabrication process as part of training classes.

Indiana:

- *General observations*. While existing projects still use conventional acceptance tests, INDOT has undertaken shadow projects, research studies, and benchmarking studies. The current focus is on collecting mechanical test results for informational purpose only. The

agency currently uses HWTT and the indirect tensile cracking test (known as IDEAL-CT) with a 4-hour aging protocol. Rutting problems are not prevalent throughout the State. Industry is interested in moving away from volumetrics. The State has formed a subcommittee for communication and implementation purposes.
    - QA procedures are implemented by the State to provide inspection of the contractor's processes. Field samples are taken for both quality control (QC) and acceptance. The contractor's QC data is reviewed by INDOT. No split samples of asphalt mixture between contractor and agency are currently being used for acceptance. Nevertheless, a split sample of asphalt mixture is used for BMD testing. INDOT compacts the specimens for mechanical testing.
- *Roadmap.* Interested in exploring the use of BMD for areas beyond current specifications, such as increased amounts of RAP, and other materials that may benefit performance. Planning on incorporating BMD as part of climate challenge and to encourage use of higher RAP. Looking at creating a framework or documented timeline. Planned 2024 BMD pavements using high RAP and rejuvenator sections, and warm mix asphalt (WMA) sections as part of FHWA climate challenge.
- *Lessons Learned.* INDOT highlighted the importance of starting validation early and collecting as much data as soon as possible. Seeing a greater focus on strategic planning and timeline, sample preparation and handling procedures, staff training, and sample consistency. Crucial for implementation purposes is to identify the value of implementing BMD as well as identifying and communicating the "Why."

Michigan:

- *General observations*. MDOT is exploring ways to implement BMD given a relatively open timeline. The State has a blank canvas as it concerns BMD implementation and is therefore open to different approaches and implementation methods and timelines. MDOT currently uses the air voids (AV) regression approach. This led to an increase in asphalt binder content (about 0.3 to 0.4 percent), which is supposed to help with the asphalt mixture's resistance to cracking. Hold up is cost of equipment and lack of push from industry to implement BMD. The challenge is to how to communicate the value of BMD when having implemented regressed AV approach.
- Commonly, seeing thermal, reflection, and longitudinal cracking throughout the State. Not seeing a general industry push for implementation of BMD.
- *Roadmap.* Identifying champions locally to create buy-in at higher levels. Re-examining timeline of BMD implementation based on new expectations. Expecting to apply to all projects in the distant future and focus is on Approach A or Approach B.
- *Lessons Learned.* MDOT highlighted the importance of inspiring confidence in contractors and leadership to use rutting and cracking mechanical tests in lieu of volumetric properties. The importance of networking and using expertise of regional peers to understand implementation timelines, hurdles, and concerns was also noted. A challenge being faced by MDOT is the high staff turnover rate.

Minnesota:

- *General observations*. MnDOT is actively exploring approaches and implementation with a greater focus on interstates. Highlighted challenges include finding qualified workforce while adding new procedures to existing volumetric approval processes. Currently uses

HWTT for rutting and moisture damage and exploring Disc-Shaped Compact Tension Test (DCT) and IDEAL-CT for cracking tests.

- *Roadmap.* MnDOT is working on communicating why BMD is important and why the State should adopt this new practice.
- *Lessons Learned.* MnDOT highlighted the importance of data gathering as it concerns mechanical testing, which can be developed into information to persuade decision makers. Furthermore, the importance of networking and leveraging peer agencies in implementing new processes was discussed. MnDOT sees the need to bridge the gap between research and practice. Finally, the agency is working to ensure that contractors' performance during construction gets tracked to see how the pavements perform. Further, the importance of test validation given level of confidence with test methods was highlighted.

Missouri:

- *General observations.* MoDOT started benchmarking in 2018 with HWTT and I-FIT using plant-produced asphalt mixtures. The benchmarking study included about 200 asphalt mixtures over a 3-year period. MoDOT is currently undergoing pilot projects using a typical bidding-contract process with new QA requirements. Currently, asphalt mixture samples for BMD testing are collected at the plant and compacted by the contractor. The compacted samples are submitted to and tested by MoDOT. Concerns remain with controlling the variability of the CT-Index and limited staff and contractor experience throughout the state with tests. Challenges include:
    - Assigning representative weight factors for BMD test results to be used for asphalt mixture pay factors. What BMD tests and weight factors should be used along other volumetric properties to decide contractor pay bonus or deduction? Should the same weight factor be used for cracking and rutting tests?
    - Reducing variabilities in mechanical test results.
    - Finding time and resources to sample and fabricate multiple QA samples.
- *Roadmap.* Intends to explore opportunities to acquire equipment as part of a pooled fund and do more research to identify internal gaps towards implementing BMD including training. Looking to implement a long-term aging component as part of the BMD cracking test based on existing models from participants. Aiming to continue the BMD implementation as part of pay factors but still believe that certain volumetric properties are important for assuring consistency of asphalt mixtures during production. MoDOT is exploring the use of high temperature indirect tension (HT-IDT) strength test for rutting.
- *Lessons Learned.* MoDOT identified that implementation differs across States and approaches, the transition from purely volumetric to BMD can and should be different across States to allow for individual agency and state-wide circumstances. The required frequency of testing under BMD can prove challenging at the beginning of the implementation cycle, as different tests require time and capabilities. Through pilot projects, MoDOT found that it was over testing asphalt mixtures. Identified frequency of testing as the biggest hurdle in implementing BMD.

Ohio:

- *General observations.* ODOT is open to different approaches and implementing BMD. The State currently uses Marshall and Superpave mix design methods and is typically a high usage of RAP. The State is in the initial planning phase having run pilot projects and shadow projects using IDEAL-CT as well as benchmarking studies. ODOT used IDEAL-CT for informational purposes only in 2022 on medium and heavy traffic mixtures. ODOT is observing differences in pavement life based on districts. Challenges remain primarily around staffing and resources to implement any of the BMD approaches.
    - ODOT observed large differences in IDEAL-CT test results when theoretical maximum specific gravity measurements differed between contractor and agency laboratories. Differences as high as 100 points in the CT-index were observed.
- *Roadmap:* Planning for implementing BMD Approach A for all projects eventually but first implementation steps will likely start with heavy traffic projects. Plan to use HWTT with stripping inflection point (SIP) and IDEAL-CT for mix design and removing TSR.
- *Lessons Learned:* ODOT highlighted the importance of being flexible in the approach towards initial and full BMD implementation and allowing timelines to expand as necessary to incorporate new implementation practices. ODOT is looking at a revised implementation expectation of 8–10 years based on what was heard from the peer States at the meeting. ODOT also noted the importance of understanding and documenting the value of BMD especially as a form of change management in the strategic planning and visioning stage.

Wisconsin:

- *General observations.* WisDOT has settled on using HWTT and IDEAL-CT for BMD. Since 2021, WisDOT had 4 pilot projects for BMD with special provision with test criteria for HWTT including SIP as well as CT-Index (min of 30 after LTOA). All these projects required designing asphalt mixtures using Approach A. Since 2020, WisDOT has been testing plant-produced asphalt mixtures for informational purposes only. Challenges include resources and investment, especially when rolling up from central design testing to statewide regional testing. The State experiences a lot of staff turnover from both contractor and agency side necessitating a continuous education of new staff. Another challenge is the difference in the HWTT results between contractor and agency.
- *Roadmap:* WisDOT is looking to implement Approach C on all projects with high asphalt tonnage. Prior to the implementation, the State's plan is to have pilot projects within each of WisDOT's regions. These projects will have short test sections, and Approach C will be used for the design of asphalt mixtures used for paving the test sections. WisDOT is planning on doing round robin testing in the future and ways to minimize variability in BMD test results. Looking to possibly using HT-IDT or ideal rutting test (IDEAL-RT) during production for acceptance after correlating with HWTT. The intention for using these rapid tests is to decrease the testing time. WisDOT will continue to look into refining the BMD test criteria to incorporate traffic level besides the PG of the asphalt binder.

- *Lessons Learned:* WisDOT highlighted the importance of data management and validation frameworks, especially as it concerns asset management.
    - WisDOT recommends that agencies incorporate as many data fields as possible when initializing BMD databases as its useful to track a plethora of items and visualize performance based on a variety of features, including geology, equipment used, and field location to track back performance.
    - Validation frameworks should include asset management frameworks – linking up data is a challenge that needs to be overcome to present information to decision makers and upper management. A good validation method and framework is key to this approach.
    - WisDOT needs not to accelerate the implementation process but rather take the time to develop and documents a strategic plan with short and long-term goals.

APPENDICES

Appendix A: Participants List

North Central Peer Exchange on
Balanced Mix Design
Schaumburg, IL 60195
March 22–23, 2023

Participant List

State/Organization	Participant Name	Email
IL	Brian Pfeifer	Brian.Pfeifer@illinois.gov
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FHWA	Tim Aschenbrener	timothy.aschenbrener@dot.gov
FHWA	Tom Duncan	Thomas.L.Duncan@dot.gov

Appendix B: Questionnaire

FHWA North Central 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 seven agencies with a summary of the results presented below.

Respondent Information

Name	Email	Affiliation
Tom Zehr	Thomas.Zehr@illinois.gov	Illinois DOT
Brian Hill	Brian.Hill@illinois.gov	Illinois DOT
Nathan Awwad	nawwad@indot.in.gov	Indiana DOT
Michelle Miller	millerm81@michigan.gov	Michigan DOT
Greg Johnson	gregory.d.johnson@state.mn.us	Minnesota DOT
Jason Blomberg	Jason.Blomberg@modot.mo.gov	Missouri DOT
Eric Biehl	eric.biehl@dot.ohio.gov	Ohio DOT
Ali Arabzadeh	ali.arabzadeh@dot.wi.gov	Wisconsin DOT

BMD Current Practice

What is the current implementation status of BMD?

Agency	Response
Illinois DOT	Fully implemented.
Indiana 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
Michigan DOT	Initial Planning. Still thinking/exploring.
Minnesota DOT	Still thinking/exploring.
Missouri DOT	Pilot projects (Typical bidding-contracting process with the new Quality Assurance requirements applied. Mechanical testing required as part of mix design & acceptance).
Ohio DOT	Pilot projects (Typical bidding-contracting process with the new Quality Assurance requirements applied. Mechanical testing required as part of mix design & acceptance). Initial Planning. Still thinking/exploring. Other: Shadow Projects for mix design acceptance only for IDEAL-CT, we do have about 10 projects that have minimum for IDEAL-CT. We also have sold two BMD, but they're special higher high RAP mixes.
Wisconsin DOT	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. Other: Mechanical testing for mix design and conventional for acceptance.

What is the project scope for BMD?	
Agency	**Response**
Illinois DOT	All projects.
Indiana DOT	All projects.
Michigan DOT	Interstates. Projects with high asphalt tonnage.
Minnesota DOT	Interstates.
Missouri DOT	Projects with high asphalt tonnage.
Ohio DOT	Other: Not sure. Heavy traffic is probably the preference but planning for all.
Wisconsin DOT	Projects with high asphalt tonnage (more than 10,000 tons).

Which BMD approaches are being considered by your State DOT?	
Agency	**Response**
Illinois DOT	Approach A - Volumetric Design with Performance Verification.
Indiana DOT	Approach A - Volumetric Design with Performance Verification. Approach B - Volumetric Design with Performance Optimization.
Michigan DOT	Approach A - Volumetric Design with Performance Verification.
Minnesota DOT	Approach A - Volumetric Design with Performance Verification.
Missouri DOT	Approach B - Volumetric Design with Performance Optimization.
Ohio DOT	Approach A - Volumetric Design with Performance Verification. Other: A for now. Would be interested in B and C (not clear the difference between the two) to allow adjusting.
Wisconsin DOT	Approach C - Volumetric Design with Performance Verification.

Benchmarking Studies

Were any benchmarking studies conducted during the BMD implementation process?	
Agency	**Response**
Illinois DOT	Yes.
Indiana DOT	On-going.
Michigan DOT	Other: Unknown.
Minnesota DOT	Other: We have researched DCT in the past.
Missouri DOT	Yes.
Ohio DOT	Yes.
Wisconsin DOT	Yes.; On-going.

Who is responsible for the conduct of benchmarking mechanical tests?	
Agency	**Response**
Illinois DOT	State DOT Lab; Other: University of Illinois at Urbana-Champaign.
Indiana DOT	State DOT Lab.
Michigan DOT	Not available.
Minnesota DOT	State DOT Lab.
Missouri DOT	State DOT Lab; Designated third-party lab.
Ohio DOT	Other: Researcher.
Wisconsin DOT	State DOT Lab; Other: Contractors split samples with DOT.

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**
Illinois DOT	Mix type, nominal maximum aggregate size (NMAS), binder PG grade, percent asphalt and percent virgin asphalt, polymer modified or neat binder, asphalt binder replacement (ABR), (F)RAP and/or RAS, voids in the mineral aggregate (VMA), air voids, etc.
Indiana DOT	Not available.
Michigan DOT	Not available.
Minnesota DOT	Traffic levels, AC binder grades, air voids.
Missouri DOT	All Superpave and SMA Mix Design Types meeting MoDOT specifications – Include Mix Type, NMAS – ½” or 3/8”, PG 64-22 (S, H, and V) contract grade binder types.
Ohio DOT	There was a matrix to determine various variables in mixes (RAP % and aggregate geology to name a few) and various mix types to cover as much as we could in the research project. Around 80-85 mixes were tested, this was done through a research project, and was mainly on mix design mixes. They did look at mix design and plant production some and there were differences.
Wisconsin DOT	Mixture type (LT, MT, HT and SMA), NMAS (No. 1–6 mixes), and binder type (AASHTO M 332) are among the factors that are included. We are investigating the differences between mix design and production results as well as the interlaboratory variability. Based on a recent study conducted through Wisconsin Highway Research Program (WHRP) (1), it was recommended that WisDOT continue using its current specifications with the regressed air voids approach for the design of low-traffic mixtures. For medium-traffic, high-traffic and stone matrix asphalt (SMA) mixtures, the researchers recommended the BMD approach referred to as performance-modified volumetric mix design and provided preliminary criteria of the HWTT, IDEAL-CT, and DCT. In the special provision (SPV) that we have prepared for our BMD pilot projects, we have required the contractors to meet the requirements made for the number of passes to failure and stripping inflection point when the mixes are tested using a HWTT device to ensure resistance to rutting. Also, to make sure that the mixes are resistant to cracking, the mentioned SPV requires the mixes to have a minimum cracking tolerance index when tested using IDEAL-CT. The mentioned requirements need to be met during the mix design process. West, R., Yin, F., Rodezno, C., & Taylor, A. (2021). *Balanced Mixture Design Implementation Support* (No. WHRP 0092-20-04). Wisconsin. Dept. of Transportation. Research and Library Unit.

Validation Studies	
Was validation of performance tests completed to assure that mechanical test results have a strong relationship to field performance?	
Agency	**Response**
Illinois DOT	Yes.
Indiana DOT	No.
Michigan DOT	Yes.
Minnesota DOT	Other: Unsure at this point.
Missouri DOT	Yes; On-going.
Ohio DOT	Other: Not really. IDEAL-CT compared closely with I-FIT, which has ties to field performance per numerous studies.
Wisconsin DOT	Yes-BMD NCAT-MnRoad Cracking Pooled Fund. On-going- BMD Test Sections.

What is the source of field performance data used for validation process?	
Agency	**Response**
Illinois DOT	Accelerated load facility; Pilot projects; Research test sections.
Indiana DOT	Not available.
Michigan DOT	Not available.
Minnesota DOT	Pilot projects; Research test sections.
Missouri DOT	Pavement management system. Other: Research Study Conducted.
Ohio DOT	Other: We used 80% passing in our benchmark study that had zero to do with field performance other than we have decent field performance now.
Wisconsin DOT	Pavement management system; Test track – MNROAD – NCAT; Research Test Sections.

Application of BMD	
What is the scope or applicability of BMD tests?	
Agency	**Response**
Illinois DOT	Mix design; Initial verification (test trip or trial plant batch); Acceptance (go/no-go).
Indiana DOT	Mix design.
Michigan DOT	Mix design; Initial verification (test trip or trial plant batch).
Minnesota DOT	Mix design; Acceptance (go/no-go).
Missouri DOT	Mix design; Acceptance (pay factor).
Ohio DOT	Other: Not there yet.
Wisconsin DOT	Mix design.

General opinions	
What are your overall comments or concerns related to the BMD process?	
Agency	**Response**
Illinois DOT	• In Illinois, the test of record is the Dept. test. The Contractor fabricates and compacts 160mm 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 Hamburg testing and which are to be tested using the I-FIT procedure. The Dept. cuts 62mm Hamburg test specimens and 50mm test specimens for I-FIT (short term aged and long term aged) and tests. The Contractor also fabricates and submits 95mm tall gyratory cylinders to the Dept. to test for tensile strength and TSR evaluation. • The Dept. purchased 10 of the same Hamburg Wheel machines from a manufacturer and 10 of the same I-FIT machines from a manufacturer. This allows the IDOT 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 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.
Indiana DOT	We are still struggling to find a need that BMD addresses. So far, it appears to be more complicated than necessary and adds more burden to the current mix design approval and/or acceptance processes. However, we are still interested in exploring the use of BMD for areas that are currently "beyond" our specs, such as increased amounts of RAP, and other materials that may benefit performance but we currently have a hard time specifying, such as fibers. Our biggest concerns are that it appears the current performance tests are highly variable, and much is still unknown about the connection to long term performance.
Michigan DOT	Not available.
Minnesota DOT	Not available.
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.
Ohio DOT	I like BMD for several reasons as it opens up the door to more innovated technologies (various additives), more RAP, and a way to validate what's being produced. For BMD to really work, the DOT needs to have a good means of validating mix designs and testing during QA, especially as you step away from Approach A and closer to Approach D. This requires the DOT to be staffed, which lies one of the biggest issues. I also think that to move to Approach D that you need to have a good correlation to field performance. I also wonder if criterial based on Approach A would necessarily align with what the criteria for Approach D should be. That is, is Approach A limiting what we could see since you're locked in to an air void requirement.
Wisconsin DOT	Interlaboratory variability between labs has been the main concern. In some cases, IDEAL – CT tends to underestimate the influence of polymers. If BMD is going to be incorporated into the QA process, a different rutting test should be selected. If not, HWTT should only be expected in design. The best QA tests can be run frequently. Our plan is to fully adopt the "Approach C" or volumetric-based design with performance verification. After gaining Confident and obtaining good results, our next plan will be relaxing the FAA and CAA and/or relaxing or eliminating TSR.

What are some of the major challenges your DOT is facing?	
Agency	**Response**
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 IDOT special provision.
Indiana DOT	Not available.
Michigan DOT	Not available.
Minnesota DOT	Our challenges are workmanship, trucking, having enough workforce, and having qualified people that also have experience/knowledge.
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. Discrepancies between Volumetrics parameters and Performance results- Which parameters should control on actual quality?
Ohio DOT	Staffing to be able to implement this. Me, myself, and I are trying to do this and 100 other different things.
Wisconsin DOT	The contractors tend to decrease the aggregates percentage passing No. 8 sieve, as it causes the mixtures to become coarser and more prone to water permeably/durability. Taking the leap from central design testing to statewide regional testing is going to be a big leap. Defining when WisDOT needs to invest resources to get all the regions equipped is important. Once WisDOT decides to include performance tests at the production level, the level of investment will need to increase by 6 times. This is competing with other priorities within the DOT such as AASHTOWare Materials implementation, increased project funding, and FHWA priorities.

BMD Performance Tests

Primary modes of distress	
Agency	**Response**
Illinois DOT	Rutting, Fatigue cracking, Thermal or block cracking, Reflective cracking, Moisture damage, Friction characteristics.
Indiana DOT	Fatigue cracking, Reflective cracking.
Michigan DOT	Thermal or block cracking; Reflective cracking.
Minnesota DOT	Thermal or block cracking; Reflective cracking.
Missouri DOT	Rutting, Thermal or block cracking; Moisture damage.
Ohio DOT	Fatigue cracking; Thermal or block cracking; Reflective cracking; Moisture damage.
Wisconsin DOT	Rutting; Fatigue cracking; Thermal or block cracking; Moisture damage.

Summary of Agency Experiences with Mechanical Testing				
Illinois DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	IL-modified AASHTO T 324 Hamburg	IL-modified AASHTO T 393 I-FIT	IL-modified AASHTO T 283 Tensile Strength & TSR	–
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) Flexibility Index ≥ 8.0; Long-Term Aged (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 (150 mm 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)	–
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 IL-modified AASHTO T 283 No freeze/thaw cycle(s) and No Saran Wrap and Plastic Bag	–
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.

Indiana DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	Hamburg AASHTO T 324	IDEAL-CT ASTM D8225	Cantaboro AASHTO TP 108 TSR, AASHTO T 283	–
Test Criteria (if available)	N/A	N/A	N/A 80% min for HMA 70% min for SMA	–
Laboratory Aging protocol or simulation	AASHTO R 30, except 4 hr conditioning.	AASHTO R 30, except 4 hr conditioning.	AASHTO R 30, except 4 hr conditioning.	–
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No please specify test)**	–	–	–	–

–not applicable or data not available.

Michigan DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	–	–	TSR.	–
Test Criteria (if available)	–	–	80% minimum.	–
Laboratory Aging protocol or simulation	–	–	Short term aging, freeze-thaw cycle.	–
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No please specify test)**	–	–	No, not needed for acceptance.	–

–not applicable or data not available.

Minnesota DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	Hamburg	DCT/IDEAL	Hamburg	–
Test Criteria (if available)	Depending on traffic level of mix specified	Depending on traffic level of mix specified	Depending on traffic level of mix specified	–
Laboratory Aging protocol or simulation	2 hour?	2 hour?	2 hour?	–
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No please specify test)**	Mix Design Only	Mix Design Only	Mix Design Only	–

–not applicable or data not available.

Missouri DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	Hamburg	CT-Index	TSR	–
Test Criteria (if available)	Max. ½" 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	–
Laboratory Aging protocol or simulation	2-hour Lab Aging	2-hour Lab Aging	AASHTO T 283 – Cooled to room temperature and reheated for 2 hours	–
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.

Ohio DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	Currently APA (Supplement 1057: AASHTO T 340 slightly modified), but research project kicking off soon to look at HWTT and a rutting rapid test for QC.	IDEAL-CT (Supplement 1033; ASTM D8225-19 modified)	Currently TSR (Supplement 1051; T 283 modified), but research project looking at HWTT.	–
Test Criteria (if available)	Criteria is conflicting, however, only required on heavy traffic mixes when more than 15% of fine agg. doesn't meet the min FAA of 44. Most designers design for 15% max therefore the test is rarely used. Less than 5.0 mm for PG 58-28 and PG 64-22 mixes tested at 120 deg F and less than 3.0 mm for all other mixes tested at 130 deg F.	Proposed minimums: Surface mixes: Min of 80 12.5 mm Intermediate: Min of 70 Other intermediates and base: Min of 60	All heavy traffic mixes (Superpave): Min of 0.80 Other mixes (containing gravel): Min of 0.70. This is changing as we're requiring antistrip and the min would change to 0.80.	–
Laboratory Aging protocol or simulation	AASHTO R 30 for STOA for 4 hours at 275 deg F for mix design acceptance.	AASHTO R 30 for STOA for 4 hours at 275 deg F for mix design acceptance. Plant mix: Allow to col then reheat at compaction temperature for 2.5 to 3 hours prior to compaction.	Loose mix aged for 4 hours at 275 deg F. Then heat loose mix to required compaction temp before compaction.	–
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No please specify test)**	Yes, currently. We are looking at research to find a quicker test.	The plan is to use the same test, but we currently haven't used the test in mix design yet. We also need to reevaluate plant produced materials and how we would accept them (reheat mix, heat up procedure, etc.)	–	–

–not applicable or data not available.

Wisconsin DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	HWTT	IDEAL-CT test	HWTT	–
Test Criteria (if available)	The minimum number of passes to failure (or rut depth of 12.5 mm) depending on the binder designation, e.g., S (10,000 passes), H (15,000 passes), V (20,000 passes), and E (20,000 passes). In addition, the minimum number of passes to reach SIP is 8,000.	Minimum CT-Index values of 30 and 80 for dense-graded and SMA mixtures, respectively.	The minimum number of passes to reach SIP is 8,000.	–
Laboratory Aging protocol or simulation	Short time aging of 4 hours for lab mixed and none for plant mixed	6 hours long-term aging.	Short time aging of 4 hours for lab mixed and none for plant mixed	–
Same test used during mix design and acceptance? (if applicable) **Yes or No (if No please specify test)**	Yes	–	–	–

–not applicable or data not available.