2023

Midwest Peer Exchange on Balanced Mix Design (BMD)

Outcomes Summary

Schaumburg, IL

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16. Abstract

Six States from the Midwest 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 six 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

Table of Contents

List of Figures

LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
APA	Asphalt Pavement Analyzer
BMD	Balanced Mix Design
DCT	Disk Shaped Compact Tension
DOT	Department of Transportation
EPD	Environmental Product Declaration
FHWA	Federal Highway Administration
FI	flexibility index
GHG	greenhouse gas
HWTT	Hamburg Wheel Tracking Test
IDEAL-CT	Indirect Tensile Cracking Test
IDEAL-RT	Ideal Rutting Test
IDOT	Illinois DOT
IRA	Inflation Reduction Act
LTOA	long-term oven aging
NDDOT	North Dakota DOT
NDOT	Nebraska DOT
NMAS	nominal maximum aggregate size
OBC	optimum binder content
ODOT	Oklahoma DOT
PG	Performance Grade
PMS	pavement management system
QA	quality assurance
RAP	reclaimed asphalt pavement
RAS	reclaimed asphalt shingles
SDDOT	South Dakota DOT
SMA	stone matrix asphalt
STOA	short-term oven aging
TSR	tensile strength ratio
U.S.	United States
WMA	warm mix asphalt
WYDOT	Wyoming DOT

INTRODUCTION AND PURPOSE

On December 12–13, 2023, six States from the Midwestern United States (U.S.) gathered for a peer exchange on implementation activities to support Balanced Mix Design (BMD). The peer exchange was sponsored by the Federal Highway Administration (FHWA). The six 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 advancing BMD into practice, the role of sustainability in BMD, implementation challenges, key takeaways, and emerging themes. It should be noted that all referenced specifications are not federal requirements unless otherwise noted.

PEER EXCHANGE GENERAL OVERVIEW

BMD focuses on designing asphalt mixtures to meet performance requirements rather than just 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 BMD, summarized as follows:

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

Participants

States represented at the BMD peer exchange included (Figure 1) (individual participants are provided in Appendix A):

- Illinois Department of Transportation (IDOT)
- Nebraska DOT (NDOT)
- North Dakota DOT (NDDOT)

[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.

- Oklahoma DOT (ODOT)
- South Dakota DOT (SDDOT)
- Wyoming DOT (WYDOT)

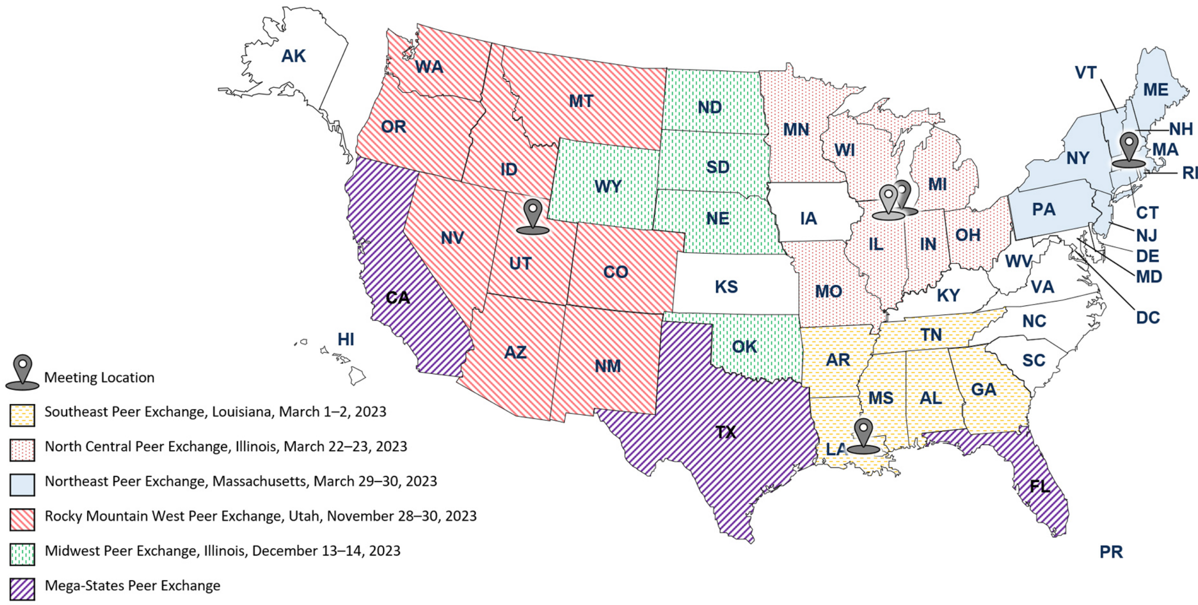

Figure 1. U.S. Map showing participating States in the Midwestern BMD Peer Exchange.

Agenda

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

- BMD 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 peer exchange, the attendees from the six participating States were asked to complete a short questionnaire pertaining to their BMD practices. Information was received from all six State DOTs with a summary of the results presented in Appendix B.

Motivations for Considering Moves to BMD Approaches

In the U.S., the Superpave[2] volumetric mix design is primarily used for asphalt mix design. Since its implementation in the late 1990's and early 2000's, State DOTs have identified performance challenges related to the Superpave 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 or block cracking, and moisture damage were reported as a major concern for participating State DOTs as they considered BMD approaches.[3] A key benefit sited by multiple states was the potential to see longer lasting and better performing pavement while reducing costs. This included a focus on increased and premature cracking in pavements. Furthermore, some States noted that they would like to simplify mix design process through BMD implementation. Some State participants discussed how BMD mechanical tests will provide contractors the opportunity to use higher percentages of reclaimed asphalt pavement (RAP) while retaining pavement performance and actively pursuing increased use of RAP within the coming years. Further identified motives for moving to BMD approaches included pavement performance in harsh or extreme winters.

Role of Sustainability

State participants discussed how BMD mechanical tests assess the resistance of asphalt mixtures to common distresses and enable mix designers to better utilize more 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, North Dakota, and Oklahoma 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 as follows:

- State participants identified that BMD's main impact on sustainability is a potential extension of pavement service life, which reduces the life cycle greenhouse gas (GHG) emissions (and cost) of pavements. The goal is to utilize BMD for the optimization of RAP usage without jeopardizing long-term performance.
- One State participant noted that their State has been using high RAP asphalt mixtures since 2008 and has been satisfied with the performance of their pavements. This has led to significant cost savings. However, it was also noted that the State had to implement

[2]Superpave system was developed under 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. $50 million of the SHRP effort was dedicated to Superpave.
[3]Distress Identification Manual for the Long-Term Pavement Performance Program (Fifth Revised Edition). FHWA-HRT-13-092, FHWA, U.S. Department of Transportation.

several changes to their volumetric mix design method and acceptance program to ensure satisfactory performance with the high RAP asphalt mixtures.

- One State noted that in a particular district, virgin asphalt mixtures will typically have higher asphalt binder content. If pavement life is extended, the life cycle greenhouse gas emissions of the pavement should offset higher upfront emissions due to the higher asphalt binder used.
- One State noted a challenge with implementing cradle-to-gate life cycle policies for asphalt pavements, emphasizing the need for a cradle-to-grave approach to fully capture the extension in pavement life.
- States discussed their progress towards implementing Environmental Product Declarations (EPD). Some contractors are beginning to establish their EPDs for their asphalt mixtures. This prompted contractors to ask some States to allow the use of warm mix asphalt (WMA) additives. BMD can potentially allow states to explore the use of different additives and materials that can have a positive impact on sustainability.
- States also discussed the cost-saving benefits of using recycled materials such as RAP and reclaimed asphalt shingles (RAS), as well as the potential additional funding opportunities by incorporating sustainability into a pavement program. The performance of high RAP asphalt mixtures was also discussed. States discussed the lower embodied carbon targets in the Inflation Reduction Act (IRA) and the long-term usefulness of BMD.

SUMMARY OF CRITICAL CHALLENGES IN IMPLEMENTING BMD

State participants identified several specific challenges and themes. Overall challenges included BMD validation, database setup, variabilities, and barriers 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 relating test results to field performance. State participants identified several questions that require additional consideration.
    - *Getting Started*. Few States that participated in the midwestern peer exchange had a documented plan for BMD Test Validation at this point. Further challenges included having a plan for monitoring and documenting pavement performance, including the assignment of responsibilities.
    - *Testing Procedures and Protocols.* Few State participants had established BMD testing procedures and protocols. Some questioned the intent of asphalt mixture aging in regions with colder climates. Further challenges in testing included resources for equipment maintenance and reference specimens for verification and calibration.
    - *Barriers.* Identify and overcome the barriers, which include internal resources within the agency, multiple responsibilities, and available funding. Challenges also include broader industry acceptance. A state noted their unique challenges with BMD test validation effort due to the use of portable asphalt plants that make it hard to change materials on the fly, the limited time available for conducting

multiple mix designs and testing (e.g., crushing and mix design happen just weeks before paving), and their short construction season. This will limit the State choices for the type of asphalt mixtures and changes to be made on a BMD test validation project.

- **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, and storage time).
  - *Data Collection*. States suggest expanding data collecting to include additional raw and field data (pre, during, and post-construction of BMD mixtures). This stems from the understanding that data currently seemed irrelevant may be useful and valuable in the future.
  - *Challenges.* A couple of State participants have not yet started benchmarking for asphalt mixtures. A couple more have only started benchmarking in the past few years. One State participant noted a desire to learn and apply lessons learned from neighboring States. Database setup and implementation vary widely across State participants. An additional challenge raised by several state participants is the effective management of the database and ability to tie materials test results to field performance.

- **Sources of Variabilities.** Over the course of discussion, several variabilities in materials and test procedures were identified that could impact the implementation of BMD. There are a number of variabilities that create some inconsistency in test results and erode confidence among contractors and agencies.
  - *Sample handling and conditioning protocols*. States reported inconsistency or a lack of documented protocols on how to handle asphalt mixtures due to logistic issues and practices, 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. One State is currently experiencing BMD testing of asphalt mixtures “randomly” sampled from asphalt plants (i.e., representative samples) during production. These BMD tests on representative samples lack data related to volumetrics, asphalt binder content, or gradation. Failures identified through BMD testing are communicated to contractors to encourage improvements. The variability in the BMD test results for the representative samples will be compared to that from verification testing.
  - *Aging Protocols*. Aging protocols vary from agency to agency and were raised as a key issue within variabilities. The impact of aging requirements given colder climates remains unclear.
    - There is a need for an asphalt mixture aging procedure that can be implemented during production and quality assurance (QA).

    - One State noted that asphalt mixture aging is still a significant factor to consider with BMD tests, especially given the ongoing challenges during production with long and variable transportation time between job sites and laboratories. The handling and conditioning methods still need to be defined and implemented.
    - The aging effect on BMD test results may be more critical for asphalt mixtures with RAP materials.
    - Questions were raised during the discussion regarding the influence of short-term oven aging (STOA) versus long-term oven aging (LTOA) on BMD test results and asphalt mixture performance. Similar concerns were raised about lag time (i.e., how long after mixing can the specimens be compacted) and dwell time (i.e., how long after compaction can the specimens still be tested and get acceptable results). One State participant expressed the desire to establish and implement an LTOA procedure to reduce cracking distresses.
  - *Asphalt binder sources.* A variety of States discussed exploring different asphalt binders to achieve performance grade (PG). 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.
  - 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 often differ 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:
  - One of the State participants use the Hamburg Wheel Tracking Test (HWTT), while the others use the tensile strength ratio (TSR) (AASHTO T 283) or a modified version of TSR to evaluate the moisture damage of asphalt mixtures at the mix design stage. Some States use HWTT only for rutting tests or are in the process of purchasing or implementing HWTT. The States noted that implementation of any of the moisture damage tests part of BMD during production and acceptance involves additional resources and staffing.

- **Communicating BMD Value/Telling the Story/Identifying the "Why?"** Industry and officials within State agencies may need to be convinced of the need for a change 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.
  - *Process.* Communicating the importance of BMD to industry and leadership is critical for further adoption. Messaging may include that BMD gives contractors

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 including an improvement of asphalt pavement performance, better ability to use local materials, reduce pavement cracking potential, and produce more sustainable and cost-effective asphalt mixtures.

  - *Gaps and Issues.*
    - Having difficulties in hiring and attracting personnel in general, and in providing necessary certifications and training for technicians involved in testing.
    - Having the necessary commitment and involvement from industry toward implementation of BMD.

- **Volumetric Properties Historical Usage**. During the discussion, States indicated they can see the benefits of implementing BMD, but need to gain contractor and industry buy-in before relaxing volumetric requirements in mix designs. 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 quality control and acceptance. Questions remain:
    - Are BMD mechanical tests enough to control consistency without volumetric properties? What other parameters can be used to control consistency?
    - Will industry and leadership confidently believe using mechanical mixture performance 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 benchmarking procedures.

- **Adequate Resources, Staffing, and Training.** State participants noted the difficulty of implementing new practices without the necessary staff and budget. Several States noted that they only had limited staff resources and highlighted the importance of meeting the timing requirements for testing within the short seasons. States also emphasized the necessity of retaining staff with the expertise and their availability to perform the BMD related tests. 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. One State noted that one technician runs all BMD tests.
    - Getting contractors on board with purchasing BMD test equipment for their

laboratories.
    - States highlighted the need for increased cooperation/collaboration between field and office staff such as for the acquisition of extra sampling materials.
    - Further identified issues include wage rates for staff, staff rotation, hiring, and retaining talent.

- **Pathway for Quality Assurance (QA) including Field Acceptance and Quality Control.** There seems to be a clear desire to move forward to using BMD principles in mix design among the States participating in this Midwestern Peer Exchange. Challenges to acceptance are further explored below, but include:
  - *Gaps and Issues:*
    - Asphalt mixtures are generally designed for the lowest cost under low-bid contracts and not necessarily for performance. How can contractors use BMD to produce cost-effective asphalt mixtures meeting BMD test criteria while still being competitive?.
    - Who should be sampling asphalt mixtures for acceptance? 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?
    - Other considerations include interlaboratory studies and restructuring pay for asphalt mixtures. For example, one state noted that they pay for asphalt binder separately, which has made it easier to increase asphalt binder content to ensure acceptable mixture durability and resistance to cracking.

- **Regional Collaboration Opportunities.** State participants discussed and expressed interest in regional collaboration to support the implementation of BMD. At a minimum States can exchange databases and share insights regarding challenges faced and ways to overcome them.

- **Other Challenges:**
  - The role of aging and lag and dwell time in pavement performance was a key issue highlighted among the State participants.
  - Implementation planning was a key identified issue including the lack of overall plan or path with milestones, issues with messaging and motivation, and understanding other needed efforts to successfully implement BMD.
  - Stakeholder engagement is needed including a continuation of conversation with industry and coordination with contractors to see what they can change and achieve.
  - Other challenges include questions on what asphalt mixture factors to consider in BMD test sections due to limitations with logistics and practice.
  - Limitations of BMD implementation without broader acceptance from industry.
  - Relying on local or regional interlaboratory (i.e., round robin) studies 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.
- The need for research and collaboration on lag and dwell times and their impact on BMD test results.
- 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.
- 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.
- 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. One State participant noted that, while the path to BMD implementation is a big lift, the potential benefits are similarly immense.

State Program Highlights: Existing Efforts

Illinois:

- *General observations*. IDOT has fully implemented BMD Approach A on all projects. IDOT noted that the State had implemented BMD in stages. 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 conducted benchmarking studies during the BMD implementation process, which included a variety of factors such as mix type, nominal maximum aggregate size (NMAS), asphalt binder PG, asphalt binder replacement percentage from RAP, fractionated RAP, and/or RAS, among others.
    - Validation of I-FIT performance test has been completed by IDOT.
    - IDOT District 1 attended a previous BMD peer exchange (i.e., north central peer exchange) and as a result started testing of asphalt mixtures "randomly" sampled (i.e., representative) from the plant during production. Overall, IDOT District 1

    observed a decrease in the passing rate of the BMD test results for the "randomly" sampled asphalt mixtures. IDOT will continue to research its current BMD testing approach during production and implement any necessary improvements.
  - IDOT identified certain challenges including establishing a moving average and individual test limits for BMD tests, increasing performance test sampling frequency if moving average limits used, and evaluating the use of softener modifiers with the new IDOT special provision.
- *Roadmap.* IDOT is a lead state in implementing BMD. IDOT would like to conduct more BMD testing on a "random" basis within District 1 (northeastern Illinois including Chicago). The State is exploring the possibility of expanding testing on representative samples within the constraints of the current resources. IDOT is also examining ways to handle volumetric requirements during mix design and acceptance. IDOT is reviewing and analyzing condition rating survey data for pilot projects conducted in 2016.
- *Lessons Learned.* IDOT highlighted the importance of regional collaboration when implementing BMD. As more states begin to use BMD, buy-in from industry and contractors will become easier.

Nebraska:

- *General observations*. Nebraska is in the initial planning stages and exploring ways to implement BMD with a flexible timeline. So far NDOT has conducted shadow projects and research studies and is focused on using the Indirect Tensile Cracking Test (IDEAL-CT) and the Ideal Rutting Test (IDEAL-RT). This is to complement the use of PG58-34 asphalt binder in mix designs that is anticipated to have a positive impact on asphalt mixture performance.
  - NDOT has currently not determined an approach to implement BMD. However, NDOT has been conducting internal BMD testing to explore ways to improve the durability of asphalt mixtures.
  - NDOT uses a high percentage of RAP in its asphalt mixtures. Extreme cold weather is a factor in asphalt mix design considerations.
- *Roadmap.* NDOT is planning for intense data gathering related to BMD and to continue benchmarking testing. The plan is to continue monitoring the pavement performance for comparison with laboratory test results. The findings from the benchmarking may be used to establish a minimum asphalt binder content per mix design procedure. NDOT will continue to partner with the University of Nebraska to run BMD tests and does not foresee allowing contractors to fulfill this requirement in the near future. NDOT has not yet determined an Approach for BMD but is establishing and refining existing protocols for sampling, testing, and aging including lag and dwell times.
- *Lessons Learned.* NDOT is working on establishing a LTOA procedure for cracking knowing that aging can have a significant impact on the performance and durability of high RAP asphalt mixtures. Takeaways include collaborating with other State DOTs in the Midwest to understand where NDOT lies on implementation in relation to other peer states, make future connections for continued discussion, and answer technical questions including lag and dwell times, as well as specimen aging protocols.

North Dakota:

- *General observations*. NDDOT is in the initial planning stages of BMD implementation. Current volumetric mix design done by contractors with district coordinators completing

verification.
  - Modified their mix design a few years ago to regressed air voids methods and purchased HWTT. Currently uses HWTT, IDEAL-CT, and Disk Shaped Compact Tension (DCT) for high, intermediate, and low temperatures.
- *Roadmap.* NDDOT is looking at conducting a validation project in 2024, followed by the implementation of shadow projects in 2025 and pilot specifications in 2026. The BMD validation project is anticipated to have eight test sections, each spanning 2 miles in length. Given the challenges faced by NDDOT related to portable asphalt plants, aggregate source, and construction season, the following factors are being considered: different asphalt binder grades, asphalt binder contents, and RAP contents.
  - NDDOT currently has one technician running all BMD tests. This may need to expand during BMD implementation.
  - NDDOT contractors use portable plants that move from one project to the next – mix designs are created only few weeks before the project and then verified by NDDOT. This short time frame for the conduct of mix design makes BMD implementation more challenging (not enough time for multiple mix designs and testing).
  - NDDOT has not yet evaluated the impact of lag and dwell times and is assessing what to consider between STOA and LTOA.
- *Lessons Learned.* The plan is to use BMD for all projects including those with high asphalt tonnage. During benchmarking efforts, the HWTT results led to adjustments to asphalt mixtures on some projects. For instance, a liquid antistrip was added to an asphalt mixture on a project that showed moisture susceptibility. NDDOT appreciated the lead that IDOT has taken in BMD implementation.
  - NDDOT met with Wisconsin and Montana DOT in part to understand and mitigate impacts of cold weather on mix design and changed HWTT temperature from 50°C to 46°C.
  - NDDOT is currently looking at establishing a LTOA procedure for cracking.

Oklahoma:

- *General observations*. ODOT is currently conducting pilot projects and research studies with the intent to apply BMD to all projects.
  - Decided to hire a consultant to help with pilot project implementation.
  - Started with an STOA at 2 hours of aging. Eventually moved to 4 hours of aging in the laboratory that was found to better replicate the aging condition of reheated plant-produced asphalt mixtures.
- *Roadmap.* Developed a four-phase implementation plan for BMD. Phase 1 involves introducing the concept; Phase 2 focuses in proof of concept (2022 pilot projects); Phase 3 (started in 2023) includes ongoing benchmarking with 165 asphalt mixtures being tested while tracking dwell time; and Phase 4 entails implementation with testing during production. ODOT intends to start Phase 4 implementation in 2024.
  - ODOT expressed concerns over staffing issues and resources in implementation.
  - Currently, ODOT does not allow RAP in surface mixes, but is looking to allow up to 25% RAP in surface mixes with BMD. Unfortunately, RAP quality available in the state is poor.

- *Lessons Learned*. ODOT highlighted that ambitious goals related to BMD may be achievable given regional coordination. ODOT is planning to meet internally with various involved entities and will provide an emphasis on training, and testing procedures and protocols.

South Dakota:

- *General observations*. SDDOT is considering options to implement BMD and is specifically looking at BMD for projects with high asphalt tonnage.
    - SDDOT implemented acceptance for asphalt mixtures in the late 90s and currently verifies asphalt mixtures in the Central Laboratory. SDDOT has been specifying the Asphalt Pavement Analyzer (APA) for rutting for over 15 years (criteria varies based on the traffic level).
    - The use of 40% RAP is specified in some shoulder asphalt mixtures.
- *Roadmap.* Looking into IDEAL-CT for cracking. SDDOT is focused on establishing key benchmarking testing protocols to build their database.
- *Lessons Learned.* The current plan is to proceed with the BMD implementation tasks gradually. Research findings were not conclusive when asphalt mix design and production variables are not controlled.
    - Many variables are used in shadow projects and major concern is with variability when comparing test results from multiple shadow projects.
    - SDDOT is focused on establishing a benchmark target, communicating with industry to keep them engaged, and found the discussions on lag and dwell times to be insightful.

Wyoming:

- *General observations*. WYDOT is still exploring opportunities for BMD implementation and has had no implementation activities of BMD yet. WYDOT implemented volumetric specifications seven years ago and is still in provisions.
    - Purchased load frame to benchmark cracking (IDEAL-CT) and rutting (IDEAL-RT) data.
    - As budgets allow, WYDOT will purchase HWTT to replace existing HWTT to evaluate rutting.
- *Roadmap.* No formal plan has been developed. The overall goal is to gain industry buy-in through AGC subcommittees and workshops.
- WYDOT is focused on benchmarking IDEAL-CT cracking values for construction mix designs.
    - WYDOT will first implement Approach A on heavy traffic interstates in order to familiarize both WYDOT and industry with BMD.
- *Lessons Learned.*
    - WYDOT highlighted the importance of building a small team to establish baseline data (e.g., benchmarking testing) to present to stakeholders. The baseline data will compare existing asphalt mixtures against BMD test criteria to illustrate the importance of shifting towards BMD.

APPENDICES

Appendix A: Participants List

Midwest Peer Exchange on
Balanced Mix Design
Schaumburg, IL 60915
December 12–13, 2023

Participant List

State/Organization	Participant Name	Email
IL	Kevin Finn	kevin.finn@illinois.gov
IL	Stephen Jones	stephen.m.jones@illinois.gov
IL	Mike Schilke	michael.schilke@illinois.gov
IL	Brian Pfeifer	brian.pfeifer@illinois.gov
IL	Brian Hill	Brian.Hill@illinois.gov
NE	Robert Rea	robert.rea@nebraska.gov
ND	Tyler Wollmuth	twollmuth@nd.gov
OK	David Vivanco	dvivanco@odot.org
SD	Shea Lemmel	Shea.Lemmel@state.sd.us
WY	Wes Bybee	wesley.bybee@wyo.gov
FHWA	Dennis Dvorak	dennis.dvorak@dot.gov
FHWA	Derek Nener-Plante	derek.nenerplante@dot.gov
FHWA	Tim Aschenbrener	timothy.aschenbrener@dot.gov

Appendix B: Questionnaire

FHWA Midwestern States Peer Exchange

PRE-MEETING DATA SUMMARY

Prior to 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 6 agencies with a summary of the results presented below.

Respondent Information

Name	Affiliation	Email
Tom Zehr & Brian Hill	Illinois DOT	Thomas.Zehr@illinois.gov; Brian.Hill@illinois.gov
Robert Rea	Nebraska DOT	Robert.Rea@nebraska.gov
Tyler Wollmuth	North Dakota DOT	twollmuth@nd.gov
David Vivanco	Oklahoma DOT	DVivanco@odot.org
Shea Lemmel	South Dakota DOT	Shea.Lemmel@state.sd.us
Wes Bybee	Wyoming DOT	wesley.bybee@wyo.gov

BMD Current Practice

What is the current implementation status of BMD?

Agency	Response
Illinois DOT	Fully implemented.
Nebraska DOT	Shadow projects, Research Studies.
North Dakota DOT	Shadow projects, Research studies, Initial planning.
Oklahoma DOT	Pilot projects, Research studies.
South Dakota DOT	Still thinking/exploring.
Wyoming DOT	Still thinking/exploring.

What is the project scope for BMD?

Agency	Response
Illinois DOT	All projects.
Nebraska DOT	All projects.
North Dakota DOT	All projects, Projects with high asphalt tonnage.
Oklahoma DOT	All projects.
South Dakota DOT	Projects with high asphalt tonnage.
Wyoming DOT	All projects, Other: Still thinking/exploring.

Which BMD approaches are being considered by your State DOT?	
Agency	**Response**
Illinois DOT	Approach A.
Nebraska DOT	Other: Have not determined approach.
North Dakota DOT	Approach B.
Oklahoma DOT	Approach B, Approach D.
South Dakota DOT	Approach A.
Wyoming DOT	Approach A, Approach B.

Benchmarking Studies

Were any benchmarking studies conducted during the BMD implementation process?	
Agency	**Response**
Illinois DOT	Yes.
Nebraska DOT	Yes, On-going.
North Dakota DOT	Yes.
Oklahoma DOT	Yes, On-going.
South Dakota DOT	On-going.
Wyoming DOT	Other: N/A – No implementation as of yet.

Who is responsible for the conduct of benchmarking mechanical tests?	
Agency	**Response**
Illinois DOT	State DOT Lab, Other-University of Illinois at Urbana-Champaign.
Nebraska DOT	State DOT Lab, Other-University of Nebraska.
North Dakota DOT	State DOT Lab.
Oklahoma DOT	State DOT Lab, Other-Oklahoma State University.
South Dakota DOT	State DOT Lab.
Wyoming DOT	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**
Illinois DOT	Mix type, NMAS, binder PG grade, percent asphalt and percent virgin asphalt, polymer modified or neat binder, ABR, (F)RAP and/or RAS, VMA, air voids, etc.
Nebraska DOT	Only mix type, NMAS, binder type, consensus properties.
North Dakota DOT	FAA Grade, RAP content, binder grade.
Oklahoma DOT	Mix Type, NMAS, Binder PG Grade and Source, RAP content, RAP BR.
South Dakota DOT	SDDOT recently purchased a new load frame with the capability of performing cracking tests. We will be starting to gather results from various mixes. Plan on testing mixes with different binder grades and suppliers, with and without RAP, different mix types.
Wyoming DOT	WYDOT will analyze based upon mixture volumetric properties, RAP BR, and binder grade.

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.
Nebraska DOT	On-going.
North Dakota DOT	On-going.
Oklahoma DOT	On-going.
South Dakota DOT	On-going.
Wyoming DOT	Other: N/A – No implementation as of yet.

What is the source of field performance data used for validation process?	
Agency	**Response**
Illinois DOT	Accelerated load facility, Pilot projects, Research test sections.
Nebraska DOT	Pavement management system, Research test sections.
North Dakota DOT	Research test sections.
Oklahoma DOT	Pavement management system, Accelerated load facility, Pilot projects.
South Dakota DOT	Pavement management system.
Wyoming DOT	Pavement management system and pilot projects.

Application of BMD	
What is the scope or applicability of BMD tests?	
Agency	**Response**
Illinois DOT	Mix design, Initial verification, Acceptance.
Nebraska DOT	Mix design, Initial verification.
North Dakota DOT	Mix design, Initial verification.
Oklahoma DOT	Mix design.
South Dakota DOT	Mix design.
Wyoming 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 HWTT specimens and 50mm test specimens for I-FIT (STOA and LTOA) 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 HWTT 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.
Nebraska DOT	Just setting up the aging parameters and testing procedures and looking at repeatability.
North Dakota DOT	We have learned a lot about our aggregate sources by running the Hamburg wheel tracker during our Benchmarking efforts and have made some adjustments to current projects based on these results. One Adjustment was to add a liquid antistrip to a project by change order that showed moisture susceptibility.

Oklahoma DOT	Determine testing frequency during production. Assessing RAP quality, variability, and accessibility. Determine variability of IDEAL-CT
South Dakota DOT	Long-term aging and correlation to field performance. Variability of cracking test results. We have used the Asphalt Pavement Analyzer (APA) for rutting for many years. We will be receiving an APA Junior that will be capable of performing the Hamburg Wheel Tracking Test. SDDOT has a separate bid item for the PG Binder. Rutting and moisture damage issues are very minimal.
Wyoming DOT	N/A.

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
Nebraska DOT	None at this time, more to come as we get further along into this testing.
North Dakota DOT	ND contractors use portable plants that move from one project to the next. Mix designs are created only a couple weeks before the project and then verified by NDDOT. This short time frame will make implementing BMD more Difficult.
Oklahoma DOT	Workforce. Training and buy-in from residencies.
South Dakota DOT	Added time for mix design verification. Equipment and test procedure training. What cracking test and specification limits to use?
Wyoming DOT	Cost to implement (initial equipment purchase). Staffing / personnel to implement the program.

BMD Performance Tests

Primary modes of distress	
Agency	**Response**
Illinois DOT	Rutting, Fatigue cracking, Thermal or block cracking, Reflective cracking, Moisture damage, Friction characteristics.
Nebraska DOT	Fatigue cracking, Thermal or block cracking, Reflective cracking.
North Dakota DOT	Rutting, Thermal or block cracking, Moisture damage.
Oklahoma DOT	Fatigue cracking, Reflective cracking.
South Dakota DOT	Thermal or block cracking, Reflective cracking.
Wyoming DOT	Thermal or block cracking, Reflective cracking.

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 (FI) ≥8.0; Long-Term Aged (LTA) criteria for Design of 5.0 and 4.0 for Production Mix. FI of 16.0 for stone matrix asphalt (SMA) (10.0 for LTA SMA) and 12.0 for 4.75 mix. LTA criteria only for surface mixtures.	TSR ≥ 0.85 (150mm dia. specimens). Minimum Conditioned Strength of 60 psi for non-polymer mixes and 80 psi for polymer modified mixes (minimum of 70 psi for PG 64-28 or lower (softer) asphalt binders)	–
Laboratory Aging protocol or simulation	Yes, if WMA produced at temps. 275 +/- 5°F or less, loose mix aged at 270 +/- 5°F for 2 hours prior to compaction	Semi-circular Test Specimens Aged in 95°C Oven for 72 hours, then tested according to IL Mod AASHTO T 393	None, other than 60°C (140°F) water bath conditioning in AASHTO T283 No Freeze/Thaw Cycle and No Saran Wrap and Plastic Bag	–
Well-defined lag time and dwell time? Yes or No (if Yes please provide details on your process)	–	No. However for all tests, IDOT recommends re-heating the mix a minimal number of times, conduct same times and procedures when multiple labs are trying to compare, and to compact and test as soon as possible after mix is produced. IDOT evaluated time between compaction & testing for I-FIT several years ago & decided 3 weeks was practical max. time (although not specified).	–	–
Same test used during mix design and acceptance? (if applicable) Yes or No (if No please specify test)	Yes	Yes	Yes	–

–not applicable or not available

Nebraska DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	IDEAL-RT	IDEAL-CT	T 283	–
Test Criteria (if available)	–	–	–	–
Laboratory Aging protocol or simulation	NCAT Protocol	–	–	–
Well-defined lag time and dwell time? Yes or No (if Yes please provide details on your process)	Still Determining	–	–	–
Same test used during mix design and acceptance? (if applicable) Yes or No (if No please specify test)	–	–	–	–

–not applicable or not available

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

–not applicable or not available

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

–not applicable or not available

South Dakota DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	T 340	N/A (looking at IDEAL-CT test)	SD309 (T 245 / D4867)	–
Test Criteria (if available)	APA Max. Rutting (mm): 5 – 8 depending on the type of mix (run @ high PG binder temp)	–	TSR = 80% minimum (70% min. for Class G mixes)	–
Laboratory Aging protocol or simulation	No	–	Compaction temp for 2 hours prior to compaction (1 hour for field samples).	–
Well-defined lag time and dwell time? Yes or No (if Yes please provide details on your process)	No	–	No	–
Same test used during mix design and acceptance? (if applicable) Yes or No (if No please specify test)	Mix Design Only	–	Mix Design Only – waived if 1.00% hydrated lime is added.	–

–not applicable or not available

Wyoming DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	HWTT & IDEAL-RT	ASTM D8225 (IDEAL-CT)	AASHTO T 283 (TSR)	–
Test Criteria (if available)	–	TBD	75% minimum TSR	–
Laboratory Aging protocol or simulation	–	–	Yes	–
Well-defined lag time and dwell time? Yes or No (if Yes please provide details on your process)	–	–	Yes as per T283	–
Same test used during mix design and acceptance? (if applicable) Yes or No (if No please specify test)	–	–	Yes	–

–not applicable or not available