



TECH BRIEF

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Balanced Mix Design of Asphalt Mixtures: Challenges & Opportunities

This Technical Brief summarizes key challenges State Departments of Transportation (DOTs) face in adopting Balanced Mix Design (BMD) that are categorized into three focus areas: management (M), technical (T), or overlapping technical-managerial (TM). It also highlights associated opportunities and actionable steps to support effective BMD implementation.

Introduction

As part of the Federal Highway Administration (FHWA) *Development and Deployment of Innovative Asphalt Pavement Technologies* program, six regional peer-to-peer exchanges were conducted (Figure 1).⁽¹⁻⁶⁾ These exchanges facilitated discussions on implementation challenges, emerging themes, and key takeaways related to BMD. The peer-to-peer exchanges covered Southeast, North Central, Northeast, Rocky Mountain West, Midwest, and Mid-Atlantic regions. In addition to these efforts, separate virtual exchanges with Mega-States were held approximately every six months to address unique challenges and share progress specific to larger state agencies. Key objectives included:

- Providing information and effective practices for State DOTs starting or considering the transition to BMD.
- Sharing lessons learned from State DOTs that have pioneered BMD implementation.
- Discussing operational changes and challenges associated with BMD implementation.

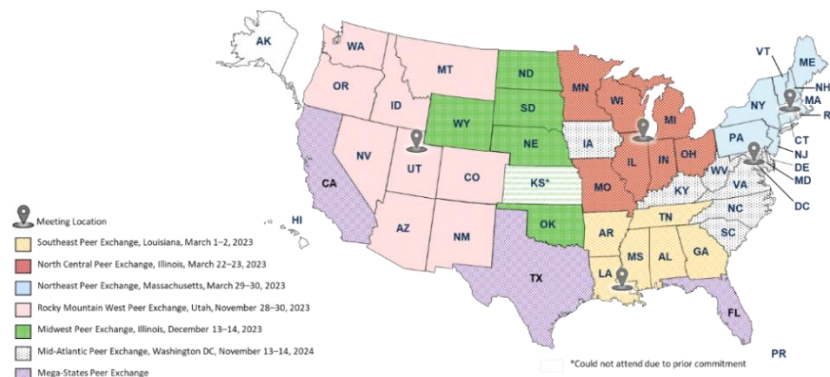


Figure 1. U.S. map of BMD peer-to-peer exchange participants.



Motivations for Moving to BMD

Currently in the U.S., asphalt mix design relies primarily on the Superpave^{1,2,3} volumetric mix design method. While this approach provided a structured mix design framework and led to improved asphalt pavement performance compared to earlier practices, State DOTs have noted performance-related challenges in recent years. As paving materials continue to evolve with the use of innovative and recycled materials, distresses such as cracking, raveling, and moisture damage have become more prevalent. These issues have negatively impacted the service life of some asphalt pavements, prompting interest in more performance-oriented mix design approaches.

A primary motivation for transitioning to BMD is the recognition that traditional volumetric mix design does not always yield optimal asphalt mixture performance. Several State DOTs have reported an increase in various forms of cracking such as reflective, thermal, and fatigue, as well as moisture damage, as major drivers influencing their shift toward BMD.⁽¹⁻⁶⁾ Although rutting is currently not a primary concern by multiple agencies, maintaining rut-resistant mixtures remains a priority. BMD introduces mechanical testing into the mix design process, offering a more robust evaluation of asphalt mixtures to ensure acceptable field performance under various conditions. This approach aims to produce

longer-lasting and better-performing pavements, which in turn lead to cost savings by reducing the frequency of maintenance and rehabilitation activities.

In addition to performance benefits, several State DOTs are also exploring BMD to simplify the mix design process by relaxing some of the volumetric requirements—such as moving from a specified value for air voids to an allowable range for design—while allowing for greater flexibility in material selection. The current volumetric mix design system does not account for the long-term impact of recycled materials and additives. By incorporating mechanical tests, contractors can optimize mix designs and maximize the use of recycled materials without compromising pavement durability. For example, some states are leveraging BMD to evaluate high-RAP (greater than 25%) asphalt mixtures, with early performance data indicating promising results.

Some states noted that volumetric-based procedures do not adequately capture the long-term environmental effects, leading to premature failures. Limitations in available resources and funding constraints are also driving agencies to seek innovative solutions for extending pavement service life and optimizing materials use. For example, one state lost a major aggregate source due to quarry depletion, making it essential to develop mix designs that can accommodate alternative materials.

¹Superpave system was developed under the 5-year, \$150 million Strategic Highway Research Program (SHRP) authorized by the Surface Transportation and Uniform Relocation Act of 1987, with \$50 million dedicated to Superpave.

²AASHTO M 323 Standard Specification for Superpave Volumetric Mix Design. American Association of State Highway and Transportation Officials, Washington, D.C.,

2024. Use of this AASHTO specification is not a federal requirement.

³AASHTO R 35 Standard Practice for Superpave Volumetric Design for Asphalt Mixtures. American Association of State Highway and Transportation Officials, Washington, D.C., 2024. Use of this AASHTO practice is not a federal requirement.

The flexibility of BMD encourages the use of locally available and recycled materials supporting cost efficiency. Furthermore, BMD implementation provides opportunities to relax or eliminate certain traditional volumetric requirements, such as fixed design air voids, supporting innovation and mix optimization. A growing consensus among state agencies highlighted the importance of performance-oriented methodologies in ensuring the longevity of asphalt pavements.⁽¹⁻⁶⁾ By adopting BMD, agencies can take a data-driven approach to mix design that balances cost-effectiveness with improved durability under varying traffic and climate conditions.

Key Findings and Opportunities

Key challenges in BMD implementation identified by State DOTs (and similarly faced by contractors) are summarized in Figure 2. These challenges are grouped into three categories: management (M), technical (T), and overlapping technical-managerial (TM). Management challenges include concerns related to organizational strategy and planning, such as stakeholder engagement and change management. Technical challenges focus on laboratory procedures, variability, and integration of BMD into quality assurance. The

combined TM category captures challenges that require both technical expertise and managerial oversight. The reported challenges by states in each region are indicated with a check mark, based on feedback from the regional peer-to-peer exchanges.

Table 1 provides a snapshot of the challenges encountered across the various regions, with check marks indicating which regions identified each specific issue. While the table highlights both common and region-specific concerns, it is important to note that not all challenges were reported across all regions, and not all states within a region necessarily experienced every challenge identified for that region. These insights can inform future implementation strategies, help prioritize areas for support, and encourage collaboration among regions facing similar challenges.

Table 2 through Table 4 summarize the key issues identified by State DOTs, along with corresponding opportunities and denoted actions under each of the three challenge categories. This information aims to support State DOTs and stakeholders in developing effective strategies to adopt BMD, which aligns with state performance goals, available resources, and stakeholder expectations.

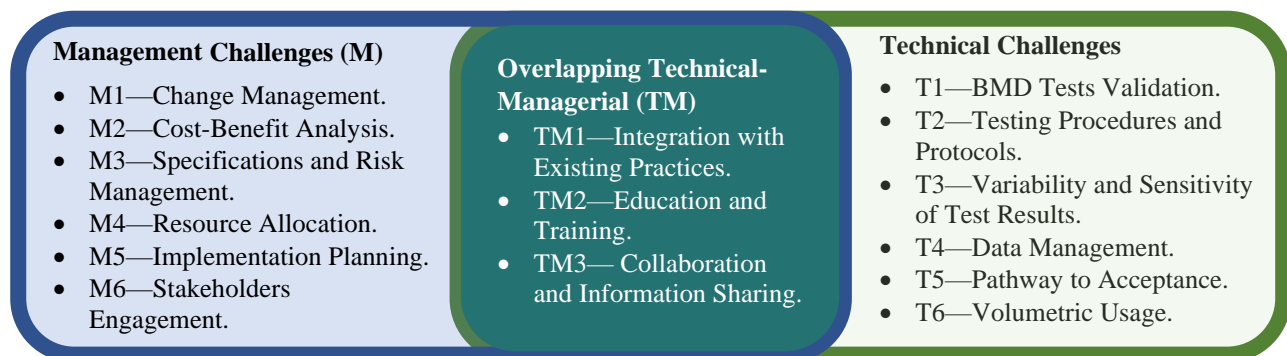


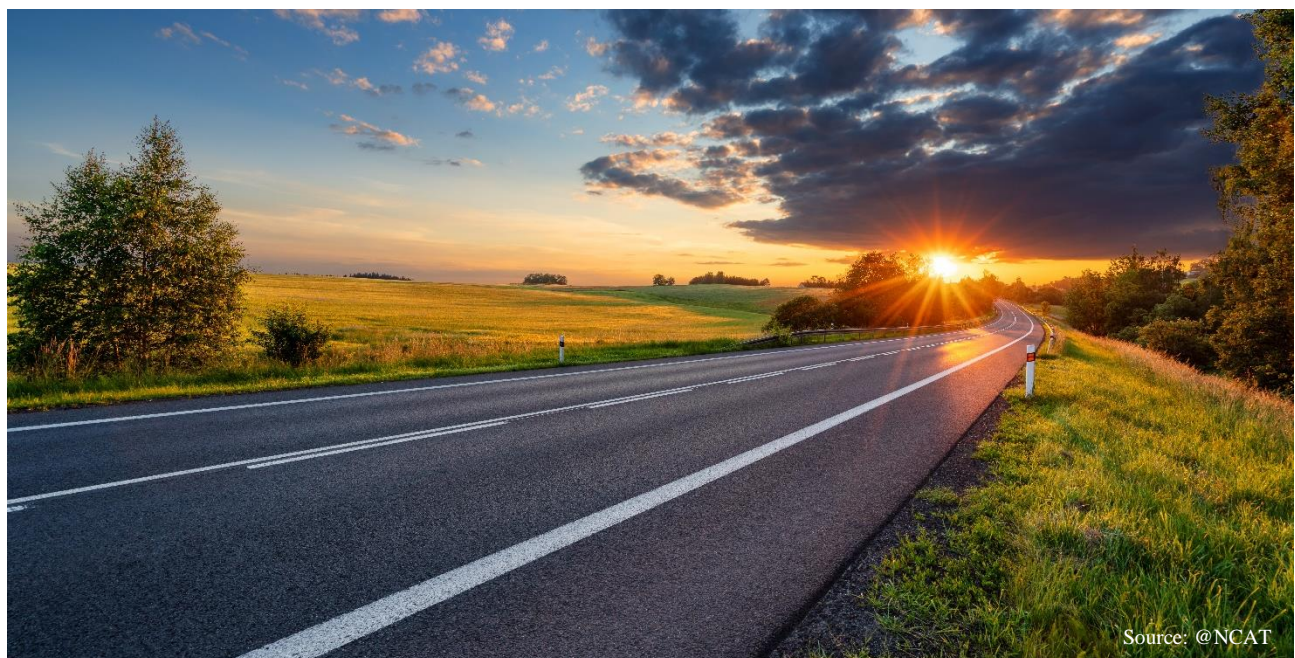
Figure 2. Challenges identified from peer-to-peer exchanges: Management, Technical, and Overlapping Technical-Managerial.



Table 1. Regional BMD Implementation Challenges by Category

Challenges	South-east	North Central	North-east	Rocky Mountain	Mid-west	Mid Atlantic
Management (M)						
M1—Change Management	✓	✓	✓	✓	✓	✓
M2—Cost-Benefit Analysis	–	–	✓	–	–	✓
M3—Specifications and Risk Management	–	–	✓	–	–	–
M4—Resource Allocation	✓	✓	✓	✓	✓	✓
M5—Implementation Planning	–	–	–	–	✓	✓
M6—Stakeholders Engagement	–	✓	✓	✓	✓	✓
Technical (T)						
T1—BMD Tests Validation	✓	✓	✓	✓	✓	✓
T2—Testing Procedures and Protocols	✓	✓	✓	✓	✓	✓
T3—Variability and Sensitivity of Test Results	✓	✓	✓	✓	✓	✓
T4—Data Management	✓	✓	✓	✓	✓	✓
T5—Pathway to Acceptance	✓	✓	✓	✓	✓	✓
T6—Volumetric Usage	✓	✓	✓	✓	✓	✓
Overlapping Technical-Managerial (TM)						
TM1—Integration with Existing Practices	✓	–	–	–	✓	–
TM2—Education & Training	✓	✓	✓	✓	✓	✓
TM3—Collaboration and Information Sharing	–	✓	✓	✓	✓	–

–not identified.



Source: @NCAT



Table 2. Management Challenges, Opportunities, and Actions for Advancing BMD Implementation

Sub-Category	Challenge	Opportunity	Action
M1— Change Management	Resistance to replacing traditional specifications with BMD due to unclear goals and priorities.	Alignment of BMD with performance goals through clear communication and understanding across various stakeholders.	<ul style="list-style-type: none"> • Identify internal champions to foster culture shift. • Document and share BMD goals and scope. • Emphasize improving asphalt mixture performance. • Align with State internal priorities
M2— Cost-Benefit Analysis	Limited business case for BMD investments.	Demonstration of lifecycle cost savings and performance gains to decision-makers and stakeholders.	<ul style="list-style-type: none"> • Develop a comprehensive business case outlining costs and benefits. • Highlight performance improvements and collaboration on risk management between agency and contractor. • Address executive-level and contractor concerns. • Conduct and document case studies. • Perform life cycle cost analysis (LCCA) comparisons.
M3— Specifications and Risk Management	Uncertainty around acceptance of BMD mixtures, recycled material usage, and associated budget risks.	Co-development of adaptable performance specifications aligned with BMD, while managing performance risks.	<ul style="list-style-type: none"> • Collaborate nationally to standardize specifications and reduce risk. • Address recycled materials within BMD context. • Establish action plans for addressing failing BMD test results during production to minimize budget impacts.
M4— Resource Allocation	Limited funding, personnel, or equipment for implementation.	Resource planning to justify investments and support sustainable BMD adoption.	<ul style="list-style-type: none"> • Phase investment plans by initially targeting the most commonly used or specialty asphalt mixtures. • Seek pooled-fund partnerships. • Find and develop a qualified workforce. • Assess equipment needs (e.g., ovens, baths) and identify staffing requirements. • Secure funding for pilot and full-scale deployment.
M5— Implementation Planning	Lack of formalized plan for BMD rollout.	Structured implementation into manageable, trackable tasks for streamlined adoption.	<ul style="list-style-type: none"> • Develop a BMD implementation plan with clear tasks and milestones. • Assign responsible parties for each milestone. • Manage complexity using dedicated planning tools.
M6— Stakeholders Engagement	Uneven buy-in across stakeholders	Early engagement and improved communication to unify support for better implementation.	<ul style="list-style-type: none"> • Establish an agency–industry task force. • Organize stakeholder forums, feedback loops, and workshops. • Tailor outreach to small and large contractors, highlighting mutual benefits.



Table 3. Technical Challenges, Opportunities, and Actions for Advancing BMD Implementation

Sub-Category	Challenge	Opportunity	Action
T1— BMD Tests Validation	Lack of a standard validation framework and timely data collection; need for linking laboratory BMD test results with field performance.	Validation, using multiple approaches, builds credibility and confidence in BMD tests and their criteria.	<ul style="list-style-type: none"> • Create a standardized test validation framework. • Conduct validation experiments and leverage peer knowledge on validation practices • Monitor in-service performance of asphalt mixtures and refine BMD test criteria. • Collect and store field samples for future testing.
T2— Testing Procedures and Protocols	Inconsistent or lack of sample handling, aging, and conditioning methods including lag and dwell times.	Standardization improves test repeatability by greater focus on consistent specimen fabrication and provides tailored testing conditions for climate-specific cracking types.	<ul style="list-style-type: none"> • Develop protocols for handling, short-term and long-term aging, and conditioning of asphalt mixtures for BMD testing. • Assess the need for multiple tests to address different cracking types and varying climatic zones.
T3— Variability and Sensitivity of Test Results	Variability in BMD test results across laboratories and mixture types. Sensitivity of test results due to factors like changes in binder source, gradation, and production conditions.	Reducing variability increases confidence in test results, enabling greater trust in mixture performance and supporting innovation.	<ul style="list-style-type: none"> • Conduct inter-laboratory and sensitivity studies to assess variability of and improve consistency in BMD test results. • Quantify variability between laboratory and plant-produced asphalt mixtures. • Identify and raise awareness of production factors that may influence BMD test results. • Offer technical training to stakeholders. • Consider the number of replicates.
T4— Data Management	Fragmented or incomplete data for mix design, BMD tests, acceptance, and performance tracking.	Data can inform decision-making and specifications.	<ul style="list-style-type: none"> • Create a centralized and structured database template. • Build or adopt templates to link mix design results with field performance. • Incorporate many data fields with raw data.
T5— Pathway to Acceptance	No defined process for integrating BMD test results in acceptance or payment.	Acceptance based on performance ensures quality and expected value while maintaining in-place density and smoothness.	<ul style="list-style-type: none"> • Adopt mix design verification protocols using verification lots, test strips, or batch mixtures at the start of production. • Implement go/no-go BMD test criteria. • Define lot and subplot sizes, along with sampling frequency while considering testing time and variability. • Establish payment structures closely aligned with validated BMD tests that reliably reflect field performance and account for production variability to enable justified performance-oriented incentives or penalties. • Address sampling responsibilities and lag/dwell time impact on dispute resolution.*
T6— Volumetric Usage	Uncertainty about retaining or relaxing traditional volumetric specification criteria.	Advance specifications while balancing innovation and risk. BMD tests may replace some volumetric properties.	<ul style="list-style-type: none"> • Determine which volumetric and aggregate properties can be relaxed or eliminated. • Transition towards performance-oriented quality measures, such as percent within limits.

*Lag time = duration between asphalt mixture sampling and specimen compaction; Dwell time = duration between specimen compaction and mechanical testing.



Table 4. Overlapping Technical-Managerial Challenges, Opportunities, and Actions for Advancing BMD Implementation

Sub-Category	Challenge	Opportunity	Action
TM1— Integration with Existing Practices	Lack of integration of BMD into existing workflows and specifications, coupled with technical and operational disconnects between key agency groups/divisions (e.g., materials, construction, pavement management).	Compatibility of BMD with existing workflows and specifications, streamlined testing procedures, and improved coordination across agency groups for effective adoption.	<ul style="list-style-type: none"> • Adapt workflows and specifications to integrate BMD. • Define roles and responsibilities across agency groups, consultants, and contractors. • Establish clear communication channels to ensure seamless coordination.
TM2— Education & Training	Limited formal training on BMD test methods and data interpretation, leading to skill gaps in BMD implementation and analysis.	Training programs and workshops on BMD test methods and data interpretation, developing skilled staff for continued implementation.	<ul style="list-style-type: none"> • Collaborate with universities and industry partners to develop hands-on BMD training modules. • Develop and deliver BMD certification programs. • Include test method demonstrations, data analysis, and interpretation exercises in the training. • Plan for continuous training of new staff to address high turnover.
TM3— Collaboration and Information Sharing	Lack of cross-agency collaboration and knowledge sharing, with agencies working in isolation.	Increased cross-agency collaboration, pooling resources, and expertise to accelerate shared learning and adoption.	<ul style="list-style-type: none"> • Facilitate regional working groups and roundtables for cross-agency collaboration. • Share specifications, lessons learned, and templates across agencies. • Seek industry feedback to align with effective practices. • Bridge gap between research and practice.





State Participants Key Takeaways

State participants collectively acknowledged that BMD implementation is a multifaceted process necessitating clear direction, appropriate resources, and cross-functional collaboration. A recurring theme was the importance of developing a structured implementation plan early in the process to streamline steps and manage expectations. Several State DOTs noted that documenting their specific motivations or the “why” behind adopting BMD was instrumental in setting goals and aligning internal and external stakeholders.

Staffing emerged as a critical consideration, particularly for State DOTs managing multiple competing initiatives. State participants recommended early identification of resource gaps and the integration of BMD training into workforce development programs. Another key area of focus was fostering collaboration with industry to gain buy-in, particularly from contractors and consultants whose support is crucial for successful implementation.

Peer exchange participants also highlighted the importance of starting validation efforts early in the implementation process, leveraging existing funding, and learning from the experiences of other DOTs.^(7,8) Several State DOTs are exploring opportunities for regional collaboration to harmonize laboratory practices, data systems, and asphalt mixture handling procedures (e.g., storage, reheating). Additionally, there was a strong consensus that transitioning from volumetric to performance-related specifications will require confidence-building through education, transparent communication, and ongoing monitoring. The following summarizes the overall key takeaways:

- **Start with a plan:** Establish a detailed BMD implementation roadmap early to minimize missteps and avoid preventable mistakes.
- **Define the “why”:** Clearly document the agency’s purpose and anticipated benefits of BMD to align goals, scope, and priorities.
- **Identify champions:** Designate agency and industry champions to advocate, troubleshoot, and lead the BMD transition.
- **Account for staffing needs:** Assess current resources and workload impacts; plan staffing accordingly, especially with competing priorities.
- **Invest in training:** Provide consistent staff training on BMD principles, procedures, and implementation strategies.
- **Start validation early:** Once initial overall planning is complete and BMD tests to address observed distresses have been identified, begin validation with a well-documented plan to build confidence in BMD test results and refine implementation.
- **Transition mindset:** Inspire confidence in moving from traditional volumetric properties to performance-oriented BMD testing.
- **Collaborate with industry:** Engage contractors and consultants early to ensure buy-in, especially when internal resources are limited.
- **Leverage peer resources:** Use experiences, tools, and templates from other DOTs to guide implementation and avoid redundant work.



- **Utilize existing funding:** Take advantage of existing funding sources to support implementation activities.
- **Build strong data systems:** Incorporate detailed data (mix design, raw materials, location, field performance, etc.) into BMD databases to support asset management and construction linkage.
- **Encourage regional collaboration:** Share databases, standardize laboratory practices (handling, aging, reheating), and exchange lessons learned.
- **Plan for setbacks:** Understand BMD implementation is a long-term process that may face challenges but yields significant long-term benefits.

Summary

This Tech Brief summarizes the findings from six regional peer-to-peer exchanges focusing on the implementation of BMD for asphalt mixtures. The exchanges brought together State DOTs to share and discuss their experiences, challenges, and key takeaways in transitioning to BMD.

The primary motivation for considering BMD stems from the limitations of the current Superpave volumetric mix design method in consistently producing long-lasting and durable asphalt mixtures. BMD offers a performance-oriented approach that incorporates mechanical testing to improve asphalt pavement longevity while allowing for greater flexibility in material selection.

The peer-to-peer exchanges identified key challenges across management, technical, and overlapping technical-managerial areas. These challenges were summarized by regional areas. It is important to note that not all State DOTs

are encountering all these challenges. Management challenges included change management, cost-benefit analysis, specification and risk management, resource allocation, implementation planning, and stakeholder engagement. Technical challenges revolved around BMD test validation, testing procedures and protocols, variabilities in test results, data management, establishing a pathway to quality assurance, and the role of volumetric usage. Overlapping challenges involved integrating BMD with existing practices, education and training, and fostering collaboration and information sharing.

Despite these challenges, the participating State DOTs highlighted significant opportunities and potential actions for successful BMD implementation. Key takeaways emphasized the importance of starting with a detailed implementation plan, clearly defining the agency's motivations for adopting BMD, identifying champions for advocacy, accounting for staffing needs and investing in training, initiating validation efforts early, transitioning the mindset towards performance-oriented testing, fostering collaboration with industry, leveraging peer resources, building robust data systems, encouraging regional collaboration, and understanding that BMD implementation is a long-term process with substantial long-term benefits. Overall, the exchanges underscored the need for a structured, collaborative, and well-resourced approach to successfully integrate BMD into asphalt mix design, verification, and acceptance.



Source: @Elie Hajj



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