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Listen Up! Challenges for Asphalt Balanced Mixture Design Implementation and How the Research Community Can Help

NATIONAL ACADEMIES *Sciences Engineering Medicine*

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Introduction

The design of asphalt mixtures for use in infrastructure applications is a topic that has generated significant research and focus over recent years. The Superpave (SUperior PERforming Asphalt PAVEments) method was developed because of the Strategic Highway Research Program where the performance of asphalt mixtures was studied under different traffic and environmental conditions. The Superpave mix design method used today relies heavily upon volumetric properties to ensure adequate performance of asphalt mixtures to the many distresses experienced in the field. Recent advancements in mechanical testing of asphalt mixtures, often referred to as 'performance tests,' brought to the asphalt community the concept of balanced mix design (BMD) and the use of these tests to augment or go beyond volumetric design.

BMD represents a pivotal shift in asphalt mix design methodologies, promising enhanced pavement performance and potential for innovation by contractors to meet the performance need. However, its integration into existing practices poses multifaceted challenges for agencies, consultants, and contractors alike. The E-Circular delves into some of these challenges from varied perspectives, offering insights gleaned from experiences across different sectors of the asphalt community. This document represents the summary of a session titled "Balanced Mix Design Implementation Challenges and Tools" delivered at the 102nd Annual Meeting of the Transportation Research Board in Washington, DC, in 2023. The session was organized and sponsored by the Standing Committee on Production and Use of Asphalt. During the session, representatives from an agency, a consultant, and a contractor provided insights to the audience on the biggest challenges they face for BMD implementation. This document presents a summary of those perspectives so that the research community can better understand the critical areas for which stakeholders require answers to advance the implementation of BMD into their existing system.

The agency perspective underscores the need for a gradual, partnership-driven approach to BMD implementation, emphasizing the challenges of selecting performance tests and navigating limited regional testing capacities. From the consultant's viewpoint, the spectrum of approaches adopted by agencies and the confidence in testing repeatability are highlighted, alongside the burgeoning opportunities for innovation in materials. The contractor's perspective delves into the intricacies of material selections and design considerations, advocating for enhanced research efforts and collaboration to streamline operations and validate specifications.

Collectively, these perspectives highlight the multifaceted challenges inherent in BMD implementation and underscore the importance of collaboration, innovation, and practical research in overcoming them. The asphalt community is grappling with the task of integrating a change as wide-ranging as BMD into their everyday practices. While challenges are common, from testing complexities to material selections, collaboration emerges as the need for success. By fostering partnerships, embracing innovation, and advancing research, the industry can overcome these obstacles and pave the way for resilient, sustainable, and high-performing asphalt pavements.

PUBLISHER'S NOTE

CHALLENGES FOR BALANCED MIX DESIGN IMPLEMENTATION

An Agency's Perspective

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INTRODUCTION

This article summarizes several challenges that agencies may face in trying to implement BMD testing into their existing asphalt Superpave mix design process. Unlike other changes that agencies implement, BMD involves physical testing and processes that require capital investment and a steep learning curve for the agency and asphalt producers. Therefore, the implementation of BMD for asphalt should be approached incrementally and in partnership with asphalt producers.

BALANCED MIX DESIGN IMPLEMENTATION CHALLENGES

New Test Challenges

Agencies need to select the performance tests that will provide the optimum balance between asphalt rutting and cracking while keeping in mind that no test has a perfect record for rejecting all failing materials or accepting all passing materials. Moreover, agencies need to consider the additional time needed to perform BMD testing and the implications of the extended duration for mix design acceptance may have on contracts with restricted time for performing work.

An agency that has previously implemented a rutting test, such as the Texas Department of Transportation adoption of the Hamburg wheel track test (HWTT), is in a much better position to implement BMD compared to agencies without such experience. For a state agency that has never required BMD performance-related testing, the number of regional laboratories capable of conducting the required testing may be very limited. In Pennsylvania, which has not required BMD performance-related testing, the level of regional testing capacity became apparent during several pilot project efforts. There was therefore a need to partner with asphalt industry and committing to follow a plan for benchmarking and phased implementation of BMD over a defined timeframe.

An agency must be cognizant of the substantial capital investment for industry partners to implement BMD requiring the agency commitment with firm and reasonable timeline to incentivize industry to acquire equipment and train technicians to perform the new tests.

Infrastructure Challenges

If agencies are committed to implementing BMD testing for asphalt mix designs, there needs to be an assessment of the capacity of available regional private laboratories to conduct BMD testing. Pilot projects can be used to assess the regional testing capacity by monitoring the challenges that industry partners encounter to access qualified BMD testing services.

During Pennsylvania's pilot projects, industry partners had difficulty finding testing services as some research laboratories decided to limit the amount of private testing offered due to their focus on research related activities. This limitation has led to progressive industry partners making the decision to acquire the equipment and train their technicians to perform the necessary BMD tests.

Personnel Challenges

The pilot project process has also highlighted the need to perform a benchmarking testing program to provide both, the agency and industry partner personnel, with the opportunity to thoroughly evaluate BMD testing methods and results.

Asphalt Producer Support

It is essential that the agency engage their local industry partner organizations in the planning for implementation of BMD. This engagement does not mean that the agency needs to seek full approval on all aspects of BMD implementation. However, including the concerns of industry partners can improve and make the implementation process much more smoothly.

Actionable Specification Limits

Agencies need to establish specification limits for the mix design process and, if desired, for the quality control (QC) and acceptance limits. Any limits set should be reasonable and achievable. It is suggested to complete a benchmarking study that considers currently approved mix designs to select specification limits. These BMD test limits should aim to improve asphalt mix design toward better cracking and rutting performance without imposing unreasonable increases in asphalt mixture costs.

It is suggested that agencies initially concentrate on the mix design process because the BMD test results on plant-produced asphalt mixtures may be unreliable because of several factors (sampling methods, conditioning procedures, test variability, etc.). There is currently a potential for contractors to be penalized because materials that pass other tests fail in the BMD tests.

Phased Approach to Benchmark Testing and Final Implementation

Because several states have never required a test for rutting or cracking performance evaluation, there is a lack of qualified laboratories that are currently capable of performing BMD testing. Additionally, many commercial laboratories (including smaller asphalt producer laboratories) are hesitant to acquire equipment and train personnel to perform needed testing without certain ongoing requirements. A commitment from agencies to adopt specific testing methods and a phased-in approach are generally needed to allow businesses to make the decision to acquire equipment and give the time needed for testing laboratories to become proficient in testing.

SUMMARY

A comprehensive asphalt mix design benchmarking process is key to both developing the needed testing infrastructure and gathering the data agencies need to set reasonable, meaningful, and achievable, BMD testing limits for final implementation of BMD. Agencies also need to familiarize themselves and get comfortable with the BMD testing process and structure the administrative aspects to align with their specific asphalt acceptance specification process. A comprehensive benchmarking process gives both the time and data needed for industry and agency to work out small and large issues related to making BMD testing part of the mix design and acceptance process for asphalt pavements.

A Consultant's Perspective

SCOTT QUIRE
Bluegrass Testing Company

INTRODUCTION

The concept of BMD is being introduced by agencies around the country and challenges to address are being quickly realized. The BMD process is utilizing mechanical tests that are to be correlated to observed field performance. This article summarizes the present concerns of a consultant performing BMD of asphalt mixtures and some of the challenges being addressed.

CHALLENGES ENCOUNTERED IN PERFORMING BALANCED MIX DESIGN

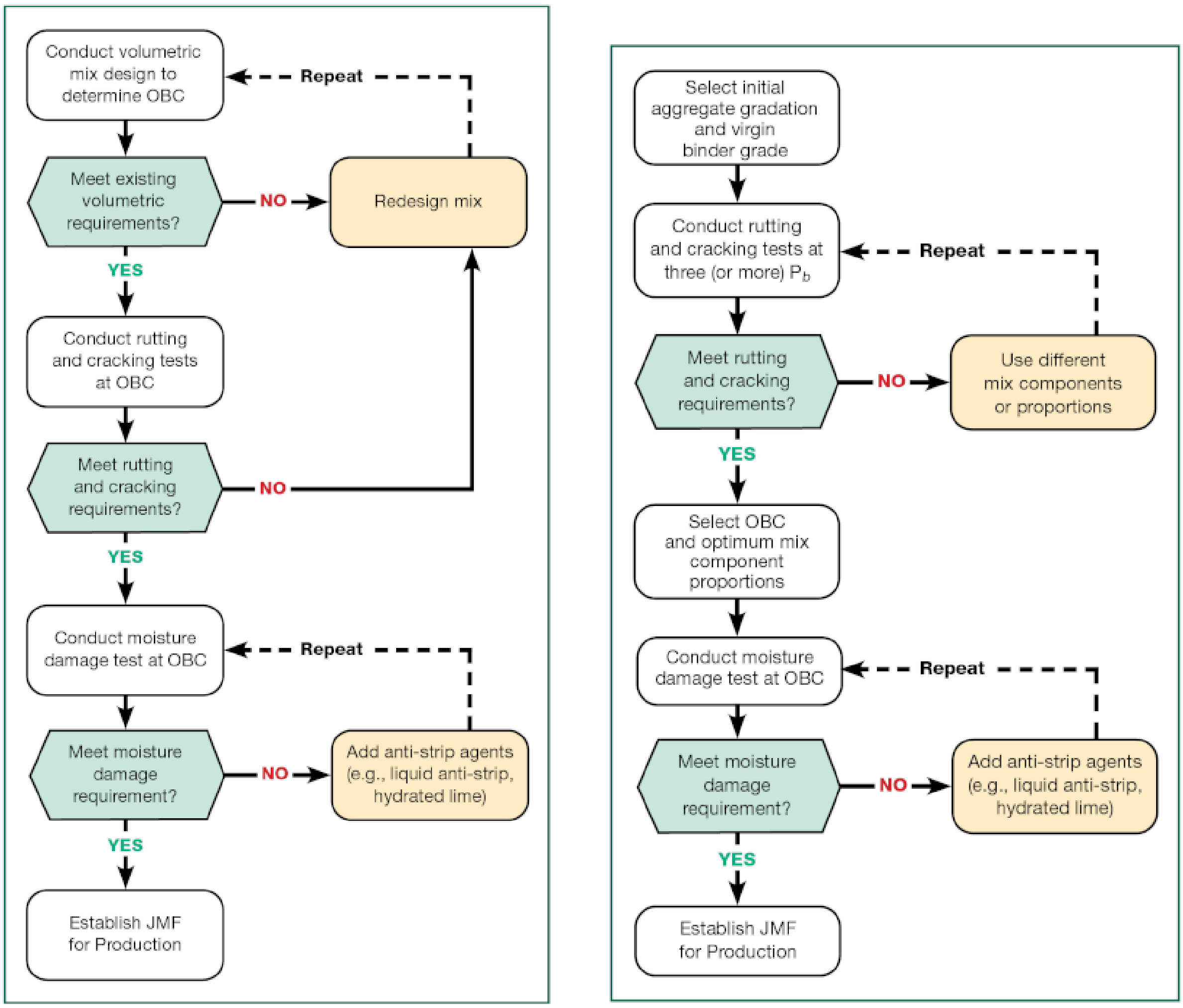
As a consultant involved in performing balanced asphalt mixtures across the United States, some of the challenges encountered include:

- Agency approach to BMD (Approach A → Approach D).
  - Approach A leads to restrictions to innovation and a prescriptive method specification.
- Aging protocols.
  - Short-term aging versus critical aging conditions.
- Repeatability of the test results.
- With innovative BMD approaches, there is an opportunity to:
  - Utilize increased reclaimed asphalt pavement (RAP) content.
  - Utilize supplemental products such as ground tire rubber (GTR), aramid fibers, etc.

Agency Approach to Balanced Mix Design

Agencies across the United States are in varying states of implementing the concept of BMD. The BMD process outlined in AASHTO PP-105 Standard Practice for Balanced Design of Asphalt Mixtures varies from the most conservative Approach A (Volumetric Design with Performance Verification) to the most innovative Approach D (Performance Design) (Figure 1). The most encountered approach is Approach A, where agencies integrate performance testing for cracking and rutting susceptibility into their existing volumetric mix design system. This integration may lead to "specification creep," as additional test requirements to address cracking and rutting resistance are included to the most typical volumetric requirements. If either of the performance tests were to fail the test criteria, the need to re-initiate the entire mix design process is faced.

If Approach D is selected by an agency this allows the greatest opportunity for innovative approaches to the components used in the mix design process. The opportunities to innovate will offer the chance to go beyond the limits of prescriptive method specifications most typically used by agencies to control some performance concerns. The benefit of performance testing verification lies in addressing agencies' concerns regarding adequate mixture performance. However, it presents a challenge to mix designers regarding where to start. Experienced mix designers can leverage previous successful mix design efforts as a starting point, while less experienced mix designers will find greater challenges. Thus, having guidelines to support the mix design process would be highly beneficial.



(a) **(b)**

FIGURE 1 Graphical illustrations of BMD: (*a*) Approach A; and (*b*) Approach D [National Asphalt Pavement Association (NAPA) BMD Resource Guide, 2024].

Aging Protocols

The short-term aging method that is referenced by many of the performance tests is found in AASHTO R 30 Standard Practice for Mixture Conditioning of Hot-Mix Asphalt. In the most recent version of AASHTO R 30, the conditioning time for for mechanical testing was reduced from 4 to 2 h (AASHTO R 30-22, Section 7.1.3, Note 4). This change is expected to result, for example, in an increase in cracking resistance indicated by a higher CT index value and a decrease in rutting resistance reflected by a higher HWTT rut depth. Thus, an agency that had already intiated the process of establishing baseline data for their performance tests using the previous 4-h mechanical aging method will find their data skewed. This necessitates either re-initiating data collection and discarding previous performance test data or continuing with the 4-h aging condition.

The critical aging (or long-term aging) is recognized to better identify the needed laboratory aging to correlate with observed in-service pavement cracking. However, there is a need for a consensus agreement on a uniform, critical aging condition. Different approaches to critical aging exist, and it would be beneficial for the research community to collaborate and establish a uniformly accepted standard.

Repeatability of the Test Results

Recent studies have shown that the repeatability of some of the more accepted performance test methods have some rather large, recognized repeatability concerns (Figure 2). The need for a better technician training program should provide the opportunity to reduce this test variability.

For Original Untrimmed Data

Single-Operator Precision—The single-operator coefficient of variation was 18.3%. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ from each other by more than 51.1%[A] of their average.

Multi-Laboratory Precision—The multi-laboratory coefficient of variation was 21.3%. Therefore, results of two properly conducted tests by two different laboratories on specimens of the same material are not expected to differ from each other by more than 59.7%[A] of their average.

[A]These numbers represent the difference limits in percent (d2s%) as described in Practice ASTM C670.

Note X—These precision statements are based on an interlaboratory study that involved 14 laboratories (16 data sets), two materials with CT index values ranging from 44 to 162, and five replicate tests per operator.

FIGURE 2 Example of findings for precision estimates for CT Index (Habbouche et al., 2022).

Opportunities for Innovation and Related Issues

As agencies move forward with the implementation of BMD concepts and gain confidence in the BMD tests and their criteria to achieve better-performing asphalt pavements, the opportunity to innovate with BMD Approach D will gain greater acceptance. The innovation in materials and the opportunity to use BMD performance testing to instill confidence among agencies would allow:

- Greater utilization of RAP; and
- Use of additives: recycling agents, GTR, aramid fibers, etc.

Greater Utilization of RAP

The increased usage of RAP that can be validated by the use of BMD performance tests comes with some recognized factors to address:

- RAP aggregate.
  - Grading consistency.
  - Aggregate concerns.
    - Durability.
    - Effect on polish resistant aggregate requirements.
    - Angularity.
- RAP binder.
  - Binder performance grading (e.g., PG 88-16 versus PG 100-4).
  - Very stiff RAP binder necessitating the need for:
    - Softer binder grades (e.g., PG 58-28, PG 52-34).
    - Recycling agents.
  - Elastic binder properties
    - 10- to 15-year-old pavements previously placed with polymer-modified asphalt binder now turned into RAP.
    - Recovered asphalt binder showing high percent recovery using the multiple stress creep recovery test (AASHTO T 350).
- Benefit or recognition of the RAP impact on BMD performance tests.

SUMMARY

There are several concerns, challenges, and opportunities for those tasked with developing BMD and collaborating with agencies to determine implementation strategies. As time allows for greater experience to help validate the BMD test limits, there is an opportunity to transition from BMD Approach A to Approach D. This transition provides an opportunity for innovation that the asphalt production industry looks forward to.

A Contractor's Perspective

CHENG LING
Pike Industries, Inc., A CRH Company

INTRODUCTION

This article summarizes the challenges for BMD implementation lying ahead from a contractor's perspective according to the recent experience in Vermont since BMD implementation by the Vermont Agency of Transportation (VTrans) in 2019. The challenges and gaps in material selections, mix design, and production, along with discussions of research needs to address these gaps are presented.

BACKGROUND

The implementation of BMD has been considered or initiated in many states across the country. The current implementation status following different approaches can be found in Figure 3 according to the NAPA BMD Resource Guide (2024). Among the three northern New England states that Pike Industries, Inc., (referred to as Pike) operates in, Vermont is in the process of implementation with Approach A (volumetric design with performance verification); Maine is evaluating various BMD tests and planning for implementation; and New Hampshire is also considering the initial investigation and evaluation of BMD tests and specifications.

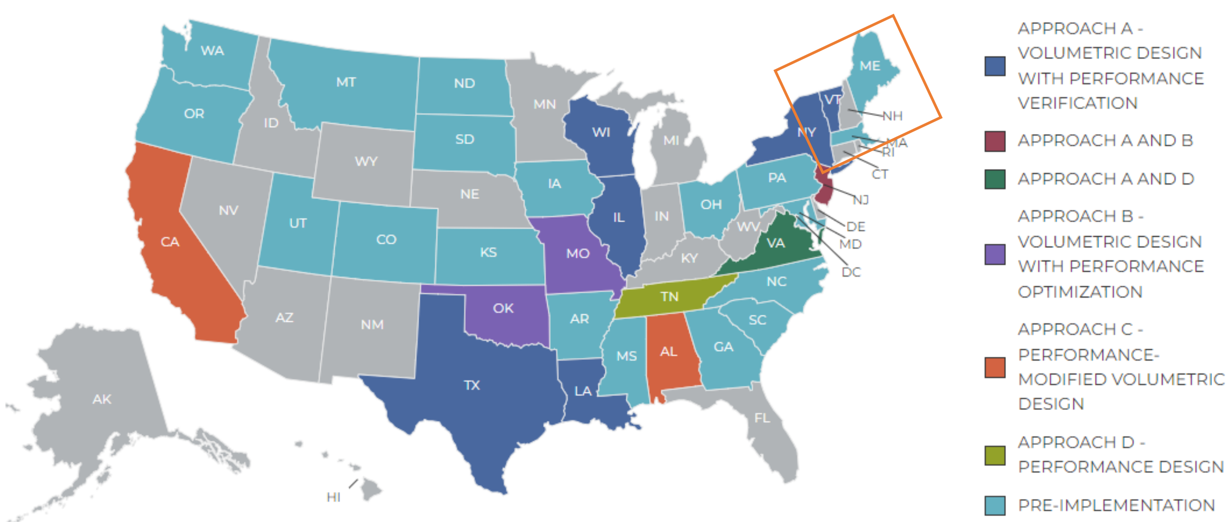


FIGURE 3 BMD implementation status (NAPA BMD Resource Guide, 2024).

The implementation process in Vermont started in 2019. The general special provisions and project special provisions were both issued by VTrans in 2019, and the new specification book with the incorporation of BMD was released in summer 2023, which won't take effect until the 2024 paving season. Three BMD pilot projects have been constructed with the performance testing requirements in both design and acceptance. The specification limits in the special provisions which only applied to Type IVS [nominal maximum aggregate size (NMAS) of 9.5 mm] mix are listed as follows.

- For the HWTT run at 45°C (AASHTO T 324), a maximum of 10 mm for the rut depth at 20,000 passes and a minimum of 15,000 passes for the stripping inflection point were required.
- For I-FIT test at 25°C (AASHTO T 393), a minimum of 10.0 units were required.
- Both HWTT and I-FIT specification limits applied to the short-term oven-aged mix following AASHTO R 30 during the laboratory design, as well as reheated plant-produced asphalt mixture.
- A minimum of 60% quality level was specified during the percent within limit calculations.

Note that HWTT and I-FIT have been required by VTrans in the mix design submittal starting in 2020, and I-FIT will be replaced by IDEAL-CT with the projects under the new specification book in 2024.

Pike has started the BMD evaluation process concurrently with VTrans since 2019. Various laboratory test equipment has been acquired, and training has been provided for QC technicians designated to perform the mixture performance tests. Pike has also been proactively working/collaborating with VTrans on several research and implementation efforts associated with BMD (e.g., round robin studies, long-term aging protocols). While Pike has gone through the BMD implementation process, it realized that there are certain constraints on the contractor side which could affect implementation, including equipment purchase; staffing, training, and certification; specifications that may constrain innovations; communications between agency and contractor; and challenges in working with multiple agencies, specifications, and tests. It is critical that these constraints be properly addressed through the partnership between agency and industry along with the support from the research community in order to ensure the smooth implementation of BMD.

CHALLENGES IN MATERIAL SELECTIONS

BMD is a different design theory (performance-related) than Superpave volumetric design, which requires us to have a deep understanding of the materials and what impact each of the mixture ingredients may have on the asphalt mixture performance. Challenges and gaps exist during the material selections when considering and selecting the asphalt binder, aggregate, recycled materials, and additives that are included in the asphalt mixtures.

Asphalt binder supply has been and will remain volatile in coming years. There's a need to better understand the impact of asphalt binder supply source on the mixture performance. BMD test results could be influenced by changing asphalt binder supplies, which has been found and validated by many researchers and practitioners. Figure 4 shows how the three different asphalt

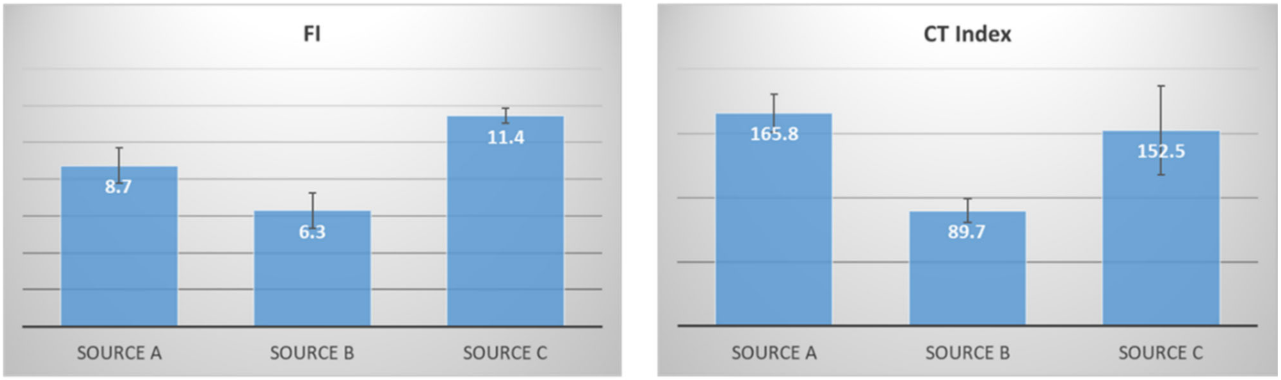


FIGURE 4 Impact of asphalt binder supply source on BMD cracking tests for data provided by Pike (NAPA Webinar, 2021).

binder sources can affect the cracking test results of the mixtures with the same design. For asphalt mixture producers and contractors, an asphalt binder screening tool would be very helpful during the material selection stage to identify the favorable asphalt binder source on the market.

Another area for focus is understanding the impact of aggregate source and quality on BMD. As the aggregate source or type matters, so does the compatibility between the asphalt binder and aggregate depending on the physical and chemical properties at the binder-aggregate interface. One of the challenges is to have a better understanding of these during the BMD evaluation. Specifically, the following questions need to be investigated and addressed:

- What aggregate fundamental properties are critical in BMD?
- How can asphalt binder-aggregate compatibility be checked quickly?

In addition to the asphalt binder and aggregate, more research is needed to advance the use of recycled asphalt materials in the mixtures. Increased efforts are desired to further increase the RAP usage to greater than 40% in the mixture to reduce the consumption of virgin binder and aggregate and reduce the carbon footprint associated with the production of these raw materials. According to a recent webinar hosted by NAPA (2022), each 1% increase in RAP utilization would reduce about 0.35 kg of CO^{2}_{e} per mix ton. If this 1% increase was to be pushed to all the asphalt mixtures produced annually across the United States, the reduction of greenhouse gas (GHG) emission is almost equivalent to that of 30,000 gasoline-powered passenger vehicles driven for 1 year.

Moreover, research on integration of recycled binder availability into the volumetric design and BMD is necessary. A better understanding of the recycled binder activation through the rejuvenation process is needed to maximize the recycled binder availability in the asphalt mixture. This is even more important with the reclaimed asphalt shingle (RAS), as RAS binder is more severely aged and much stiffer than RAP binder. Also important is advancing and implementing other asphalt recycling technologies such as cold central plant recycling, cold in-place recycling, and full-depth reclamation, with collaborative efforts from research studies to support the specification development.

In addition, it is time to revisit the asphalt mixture specifications that limit the RAP use. The research community could help by providing education for owners, especially in assisting the local agencies known for using low amount of recycled material to understand these technologies, the value of recycling, and the positive environmental impact they could bring to the planet.

On the additive side, it has been a challenge to fully understand the compatibility among various additives, binder, aggregate and recycled materials. It is desired to have a screening tool developed for agencies and contractors on the selection of the right additives (e.g., recycling agents) for a specific mix. It is also important to continue to research and advance the temperature reduction technologies (warm-mix asphalt, half-warm-mix asphalt, cold-mix asphalt) to reduce the direct emissions out of the manufacturing facilities and field construction. Besides, research is needed to better understand the use of other recycled materials as shown in Figure 5 (e.g., tires, glasses, plastics) in asphalt pavements to protect the environment as well as find innovative ways to improve the performance of asphalt pavements.

CHALLENGES IN DESIGN AND PRODUCTION

Several challenges in BMD implementation have been identified or foreseen during the design and production of asphalt mixture, including but not limited to the following:

- Understand the BMD impacts on mixture composition change. While agency sets the specifications, both agency and contractor need to understand the impact of BMD specification on the potential mixture change. For contractors, guidance for asphalt mixture adjustments is needed if the mixture fails the specification.
- Select short-term and long-term aging protocols for asphalt mixtures in BMD and understand their impacts on operations.
- Understand the interchangeability/correlations between BMD tests and between different aging conditions.
- Relax volumetric requirements to encourage innovations. More laboratory research and field studies are needed to support the industry moving from Approach A toward Approach D.
- Validate the specification thresholds and tolerances in mix design and production. Studies to verify the correlation between laboratory test results and field performance are needed as is understanding the differences between design and production and the extent to whether they are related to aging condition, production variation, or aggregate–binder–RAP source.

FIGURE 5 Various recycled materials.

- Incorporate BMD tests into the current quality assurance (QA) practices. A better understanding of the production variation and its impact on BMD in QA is necessary. On the pay factor determination, research and data support from the lab-to-field correlation are critical to quantify the impact of BMD test results on the asphalt pavement service life.
- Conduct routine inter-laboratory evaluation with assistance from the research community to support a statewide or regional proficiency sample testing program.
- Educate owners and producers–contractors on the use and acceptance of BMD. NAPA has recently developed BMD agency and industry business cases for the promoting the use of BMD (NAPA, Balanced Mix Design: Industry Business Case). Assistance would be helpful in disseminating educational materials and providing support to local implementations.

SUMMARY OF CHALLENGES

BMD represents a major shift in the way asphalt mixtures are specified, designed, and accepted if successfully and responsibly implemented. BMD can potentially provide several impactful benefits to stakeholders but there are some significant challenges that must be addressed. This E-Circular, which summarizes a lectern session from the 103rd Annual Meeting of the Transportation Research Board (2024), has presented multiple viewpoints as to these major challenges. It is important to collect and understand the challenges for all affected stakeholders to facilitate the responsible implementation of BMD. It is also important for the research community, who is the primary audience for the lectern session and this document, to understand these challenges as they continue to advance the latest in BMD innovation.

Some of the major challenges identified by the different perspectives included:

- **Resources.** The ability to obtain equipment, qualified personnel, and the time to manage the implementation of BMD initially and then when BMD is in practice.
- **Resistance to Change.** There is a struggle to convince stakeholders the benefit of changing to a BMD approach and why to dedicate the resources to it.
- **Validation.** The effectiveness of the BMD approach will largely rest on having rational, defendable, and actionable criteria and specification limits. The effort needed to generate these criteria is significant when resources are tough to obtain.
- **Variabilities.** The larger variability associated with the BMD tests are challenging to all parties and can erode confidence in the values. These variabilities are seen in laboratory procedures, specimen fabrication, different equipment, and other facets.
- **Aging.** Many acknowledge the importance of the asphalt mixtures resistance to aging and how it impacts cracking. There are many challenges in how agencies and their stakeholders are evaluating the different aging procedures as there are tradeoffs between accuracy and practicality for implementation.
- **BMD Approaches.** The major benefit to BMD in addition to improved performance is to allow flexibility to mix designers to innovate beyond where they may be allowed in current specifications. The full benefits of BMD may not be realized without moving to other approaches beyond Approach A and relaxing current requirements. At the same

time there is risk and challenges in determining what properties and specifications to relax from an agency point of view.

It is critical that future research and work in BMD address these challenges to help practitioners advance implementation efforts. By understanding the challenges that face all parties, the asphalt community can collaboratively work together to advance BMD as the latest evolution in asphalt materials.

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