

## Balanced Mix Design- A 1-Year Reality Check on Quality Control Testing and State DOT Adoption

### Introduction

Balanced Mix Design (BMD) has emerged as a critical advancement beyond the traditional volumetric methods of pavement evaluation. Volumetric design methods do not adequately capture in-service pavement performance under varying traffic and environmental conditions, and mixtures meeting volumetric requirements may still experience premature cracking or rutting. These limitations have become more pronounced with the increased use of modified and recycled materials. In response, many state highway agencies are actively evaluating BMD implementation through research, benchmarking, and pilot projects. This direction aligns with the Federal Highway Administration's (FHWA) Performance Engineered Pavements (PEP) vision, which emphasizes long-term pavement performance through the integration of structural design, Performance Engineered Mixture Design, quality assurance, and performance-based acceptance, with BMD and performance-related specifications serving as central components for asphalt pavements.

Despite substantial progress, a broadly accepted and practical BMD framework is still evolving, and implementation challenges persist across design and production workflows. Performance thresholds and sensitivity evaluation are often based on limited datasets, which can restrict broader applicability. Additional challenges also arise in integrating performance testing into plant production QA/QC, particularly for cracking resistance, which typically requires long-term aging protocols that are difficult to accommodate within production timelines. Accordingly, a comprehensive synthesis of recent literature, current DOT practices, and ongoing/ completed BMD research is needed to identify implementation variability and unresolved gaps in practice.

### Objective

The objectives of this study were to synthesize BMD implementation and related research in the southeastern U.S. region on essential topics within the BMD framework through a comprehensive review of ongoing and completed studies on BMD procedures. The research team also conducted a two-round survey of current BMD practices to document the implementation status of participating states, analyze commonalities in project scopes and methodologies across the region, and identify discrepancies that may affect regional implementation and practice. Additionally, survey feedback was analyzed to synthesize common findings, conclusions, and recommendations across studies and to identify further research needs to support more effective implementation.

### Scope

This study focused on BMD-related research and implementation status, with an emphasis on the southeastern U.S. region and supporting consideration of relevant national efforts for context and benchmarking. The study covered targeted BMD synthesis topics across the mix design-to-production pathway, including performance

### Principal Investigators

Baoshan Huang, Ph.D., P.E.  
Kai Huang, Ph.D.  
865-789-5532

### LTRC Contact

Tyson Rupnow, Ph.D., P.E.  
225-767-9124

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Research Center



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tests, sample conditioning and aging practices, QA/QC testing, performance criteria/thresholds, testing frequency, data management, key implementation challenges in design and production, and agency adoption. The work consisted of a literature/document review and agency/stakeholder information gathering through a two-round survey process, and these efforts were compiled into an implementation-oriented synthesis report.

## Methodology

This synthesis was executed through several coordinated tasks designed to evaluate BMD research and implementation and develop actionable recommendations. A comprehensive literature review was first conducted to identify more than 170 ongoing and completed BMD-related studies and refine the targeted synthesis topics. A first round survey was then developed and distributed to state agencies nationwide to document current BMD practices, including performance testing, conditioning and aging, QA/QC approaches, performance thresholds, data management, and implementation challenges. The responses were analyzed to identify commonalities, discrepancies, recurring themes, effective practices, and preliminary findings. Based on the first round survey results, a second round survey was developed and administered to state agencies in the southeastern U.S. to detail key findings and clarify remaining gaps, particularly in testing methods, sample conditioning, data management, QA/QC, and the roadmap of implementation. Findings from the literature review and both rounds of surveys were then synthesized to document state implementation statuses, compare practices across agencies, and identify consistent conclusions, state-specific considerations, and future research needs.

## Conclusions

The synthesis of BMD studies found substantial progress in performance-based mixture design across state highway agencies, but also highlighted overlapping research efforts, regional inconsistencies, and implementation bottlenecks that continue to limit broad adoption. Survey results and regional discussions confirm that BMD activities are widespread, yet implementation remains highly variable across agencies in terms of test selection, specification establishment, and readiness for deployment. Current practice continues to focus primarily on cracking and rutting performance, while QA/QC implementation remains constrained by operational feasibility, aging requirements, laboratory capacity, and unresolved

variability-to-specification translation. Overall, the findings show that broader and more effective BMD implementation will require not only continued technical refinement (e.g., performance criteria, aging protocols, and field validation), but also stronger institutional readiness, clearer specification frameworks, and coordinated regional/national efforts to support practical, performance-linked adoption.

## Recommendations

It is recommended that regional and national BMD implementation efforts prioritize the harmonization of core performance testing protocols, variability-aware QA/QC frameworks, and practical aging procedures, particularly for production-feasible application of long-term aging methods. Coordinated actions should include regional benchmarking databases, inter-laboratory proficiency programs, standardized sample handling/reheating procedures, and phased/tiered implementation pathways that align technical rigor with operational feasibility. The findings also support the development of clearer decision frameworks for RAP/RAS, modifiers, and additives; stronger linkage of BMD test results to mechanistic pavement design and PMS-based field validation; and greater incorporation of surface functionality measures where appropriate. Overall, broader BMD adoption will depend on coordinated, data-driven, and variability-aware implementation strategies that improve consistency and support technically defensible, performance-linked specifications across agencies.