2023

Southeast Peer Exchange on Balanced Mix Design (BMD)

Outcomes Summary

Baton Rouge, LA

March 1–2, 2023

U.S. Department of Transportation

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16. Abstract

Six States from the Southeastern 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 Baton Rouge, Louisiana. 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

APA	Asphalt Pavement Analyzer
AASHTO	American Association of State Highway and Transportation Officials
ALDOT	Alabama DOT
ARDOT	Arkansas DOT
BMD	Balanced Mix Design
CAPRI	Consortium for Asphalt Pavement Research and Implementation
DOT	Department of Transportation
ESAL	equivalent single axle load
FHWA	Federal Highway Administration
FWD	falling weight deflectometer
GDOT	Georgia DOT
HT-IDT	High Temperature Indirect Tension
HWTT	Hamburg Wheel Tracking Test
IDEAL-CT	Indirect Tensile Cracking Test
IDEAL-RT	Ideal Rutting Test
LaDOTD	Louisiana DOT and Development
LTRC	Louisiana Transportation Research Center
MDOT	Mississippi DOT
NCAT	National Center for Asphalt Technology
PG	Performance Grade
PM	Polymer modified
PMS	pavement management system
PWL	percent within limits
QA	quality assurance
QC	quality control
RAP	reclaimed asphalt pavement
SCB	Semi-Circular Bend
SMA	Stone Matrix Asphalt
TDOT	Tennessee DOT
TSR	tensile strength ratio
TTEC	Transportation Training and Education Center
UNR	University of Nevada, Reno
U.S.	United States
VFA	voids filled with asphalt
WMA	warm mix asphalt

INTRODUCTION AND PURPOSE

On March 1–2, 2023, six States from the Southeastern 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 Baton Rouge, Louisiana.

This summary report focuses on agency motivations for considering BMD, the role of sustainability in BMD practice, implementation challenges, key takeaways, and emerging themes. This report will be one of five regional summaries that will contribute to a national perspective on the state of the practice.

PEER EXCHANGE GENERAL OVERVIEW

The BMD approaches focus on designing asphalt mixtures for performance and not just meeting specified recipe and 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 a BMD process that are briefly summarized as follows:

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

[1]AASHTO PP 105 Standard Practice for Balanced Design of Asphalt Mixtures. American Association of State Highway and Transportation Officials, Washington, D.C., 2020. Use of AASHTO methods and specifications are not a Federal requirement.

Participants

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

- Alabama DOT (ALDOT).
- Arkansas DOT (ARDOT).
- Georgia DOT (GDOT).
- Louisiana DOT and Development (LaDOTD).
- Mississippi DOT (MDOT).
- Tennessee DOT (TDOT).
- FHWA.
- University of Nevada, Reno (UNR).

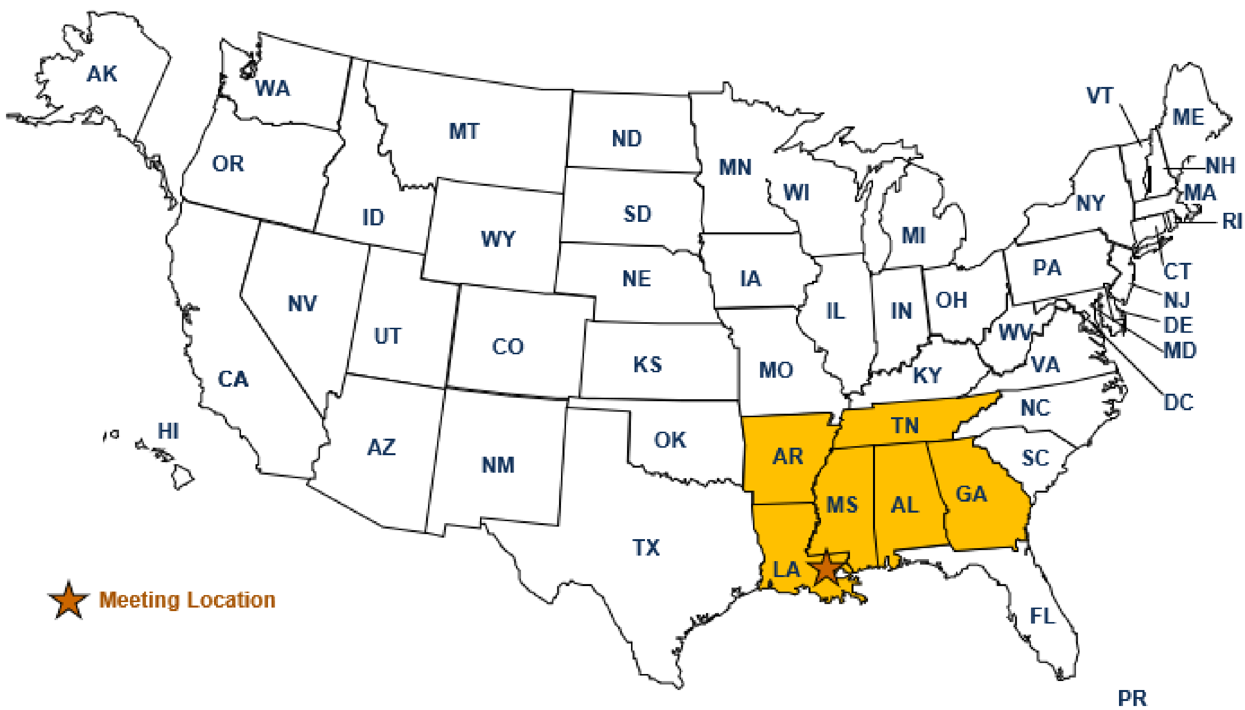

Figure 1. U.S. Map showing participating States in the southeast BMD peer exchange.

Agenda

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

- BMD current status.
- BMD goals, scope and approaches.
- Benchmarking studies.
- Validation efforts.
- Role of sustainability.
- Challenges and lessons learned.
- Next steps towards implementing BMD within each Agency and needs for moving forward.

Questionnaire

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

Motivations for Considering Moves to BMD Approaches

Superpave[2] volumetric mix design is primarily used for asphalt mixtures. Since its implementation, State DOTs identified asphalt distresses related to the Superpave design including cracking and raveling[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.

Cracking was reported as a major concern for participating State DOTs as they considered BMD approaches. To further determine the root of this observation as the motivation for considering implementing BMD, the State participants discussed the type of cracking observed, and their processes involved in evaluating the condition of the existing pavement layer, assessing the type and extent of existing cracks, and selecting milling depth. Reflective cracking was consistently reported by the State participants as the predominate cracking type observed in their asphalt pavements, followed by block cracking and top-down (longitudinal) cracking.[3] States mostly use their pavement management system (PMS) data to identify distresses, often supported by field cores; though the number of cores sampled have been reduced over the years due to limitations in available resources. Only one of the six State DOTs noted the use of the falling weight deflectometer (FWD) device on high profile projects to confirm the observations from the PMS data. While several factors influence the milling depth, very often it has been driven by the available funds.

Role of Sustainability

State participants discussed how BMD mechanical tests allow to assess the resistance of asphalt mixtures to common distresses and enable mix designers to better utilize sustainable and innovative materials. This use of recycled or other innovative materials can help the States meet low carbon emission targets and meet longer life spans for pavements. State participants from Alabama, Mississippi, and Louisiana noted that their State is part of FHWA Climate Challenge – Quantifying Emissions of Sustainable Pavements program (https://www.fhwa.dot.gov/infrastructure/climatechallenge/) and aim to identify BMD practices to help support sustainability initiatives. Other key observations from individual participating

[2]Superpave system was implemented by the Strategic Highway Research Program (SHRP) which was a 5-year, $150 million applied research program authorized by the Surface Transportation and Uniform Relocation Act of 1987.

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

States for BMD's integration into sustainability discussions included:

- Demonstrating that ride quality (i.e., smoothness) can be retained over a longer period with asphalt mixtures designed using the BMD approach when compared to traditional volumetric mix designs.
- Documenting the improvement in in-place density with the BMD mixtures coupled with the use of warm mix asphalt (WMA) technologies and percent within limits (PWL) specifications.
- Demonstrating the responsible use of reclaimed asphalt pavement (RAP) with BMD without jeopardizing performance. Requiring fractionation and screening of RAP material reduced the RAP pile variability.
- Having mechanical tests and protocols in place help assist in determining new materials' effect on asphalt mixture properties and pavement performance that can be tied back to sustainability.
- Establishing the influence of asphalt binder source on BMD test results and the environment.

SUMMARY OF CRITICAL CHALLENGES IN IMPLEMENTING BMD PROCEDURE

State participants identified several specific challenges and themes. Overall challenges included standardization, database and data collection questions, variabilities, and challenges to full implementation including funding and communicating the benefits of BMD.

- **Identifying a BMD Validation Framework.** Validation of mechanical tests is needed to make sure that test results have a strong relationship to field performance, thus supporting the development of specification criteria for mix design approval and possibly production acceptance. The first step of the validation process is to review and assess the applicability of past studies on relating test results to field performance. Participants identified several questions that require additional consideration.
  - How to standardize validation efforts and what needs to be considered?
    - The National Center for Asphalt Technology (NCAT) has an on-going research task funded by the Consortium for Asphalt Pavement Research and Implementation (CAPRI) to establish a BMD validation framework.
  - How to use validation efforts to set initial BMD criteria?
  - How to ensure BMD criteria are defensible?
  - How to balance setting the initial criteria versus adjusting criteria in the future as more experience is gained?
  - How to handle pay in specifications?

- **Initial Database Setup.** State participants generally noted that there are several data fields that could be useful for reporting and analysis at the completion of testing. These fields should be captured in a common database with each State, however, there is currently no clear guidance on what the fields should be and what the preferred structure would be for the database.
  - An approach that could provide some crucial next steps to support implementation would be to determine a common structure and consistent fields, perhaps even

including example databases to be shared in the community of practitioners.
  - NCAT will get permission to share a database example for what they have been using in research for a couple States.

- **Variabilities.** Over the course of discussion, variabilities in several procedures were identified. There are a number of variabilities that provide some barrier to further implementation of BMD procedures. These variabilities provide some inconsistency in test results and erode confidence among contractors and agencies. State participants identified these common areas where further research and consideration for standardization could be helpful as BMD approaches gain further acceptance:
  - *Sample handling and conditioning protocols*. States reported inconsistency or lack of documented protocols on how to handle asphalt mixtures due to logistic issues, among others. It was understood that greater care and more detailed procedures would be needed for mechanical tests than volumetric properties as the former is significantly more sensitive to sample handling and conditioning. The following questions were raised during the meeting:
    - What is the time period and temperature conditions for handling field-produced asphalt mixtures?
    - What is the protocol for storing materials?
    - How long after compaction can the specimens still be tested and get acceptable results?
    - How will this impact technicians time and standard operating procedures including number of available ovens and water baths at the proper temperatures?
  - *Aging protocols*.
    - Short-term aging protocols vary from agency to agency.
    - No participating States except LaDOTD have established a long-term aging protocol. The protocol used by LaDOTD is for compacted specimen aging for 5 days at 85 degree C per AASHTO R 30.[4]
    - Guidance is needed on how to use delta Tc (and possibly other aging indices) to gauge how an aging protocol simulate field aging and what aging protocol gets you closer to the critical field aging condition. Delta Tc is a calculated value using results (creep stiffness and creep rate) from the bending beam rheometer test (AASHTO T 313) of asphalt binders.
    - One State suggested the importance of keeping asphalt binder specifications, particularly with short-term aged asphalt mixture samples.
  - *Asphalt binder sources.* Most participating States allow contractors to change asphalt binder sources from mix design to production or during production provided the PG grade remains unchanged. Additionally, the asphalt binder may come from the same supplier, but the supplier's product can be refined by changing crude sources. Although volumetric properties are generally not sensitive to the changes in asphalt binder source, asphalt mixture mechanical tests can be.
    - Three States out of the six experienced the impact of changes in asphalt binder source on BMD test results.
    - A State observed variabilities in the Indirect Tensile Cracking Test (IDEAL-

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

CT) ranging from 20–30 percent due to changes in asphalt binder source.
    - Another State observed the impact of changing asphalt binder type and source on Hamburg Wheel Tracking Test (HWTT) and Semi-Circular Bend (SCB) test results.
  - *Production versus mix design.*
    - Variability during production at the asphalt mixture plant remains an issue for BMD testing.
    - Laboratory test results from mix design can differ substantially from the test results on plant-produced material.
  - *Production lots*.
    - Different batches of the same asphalt mixture may perform differently based on the controls used during production for temperature, moisture content, and similar characteristics. The variabilities in production lots make it difficult to replicate certain results across an entire project.

- **Stripping and Moisture Damage.** Moisture damage ranges in severity from raveling to stripping of an asphalt mixture. Some States are satisfied with their current testing and process to identify if a mixture is moisture susceptible. However, other States identified a need to improve the ability to identify moisture susceptible mixtures.
  - Some States reported some concerns with being able to identify asphalt mixtures that would be susceptible to stripping and moisture damage with existing BMD tests.
  - Most participating States allow the use of liquid anti-strip. Some allow liquid anti-strip to be added at the asphalt binder terminal or at the asphalt plant. Some concerns were raised by a State about pre-blending asphalt binders with a liquid anti-strip at the terminal (e.g., no sufficient amount of liquid anti-strip is added to modify the asphalt binder, thermal instability as a result of storing the liquid anti-strip modified asphalt binder hot for extended period).
  - States questioned the appropriate liquid anti-strip dosage and quality.

- **Communicating BMD Value/Common Terminology.** A State noted that BMD might not be as big of a change as some industry members conceive for asphalt mix designs.
  - Contractor concerns over acceptance and quality control (QC) need a formal strategy and marketing plan to adopt changes.

- **Adapting Mix Designs for New Materials.** Participants discussed the need to consider performance of asphalt mixtures based on innovation. New additives and materials need to be tested for their impact on the mechanical properties of asphalt mixtures. If new materials result in asphalt mixtures that do not meet volumetric properties (or even if they do), the volumetric mix design system is not sufficient to assess how the additives affect the mechanical properties and different standards need to be considered such as BMD.
  - Without QA process, how to trust innovation/additives during mix design?

- **Volumetric Properties Historical Usage**. During the discussion, States indicated they are open for relaxing their volumetric requirements in mix designs once enough confidence in BMD tests has been gained. For the most part, there have been a lot of identified shortcomings with relying heavily on volumetric properties when they fail to properly capture changes in asphalt mixture components and proportions.

    - Which volumetric properties should have criteria relaxed?
    - How much should the criteria be relaxed?

- **Funding/Staffing (training).** State participants highlighted the need for BMD training. Testing capacity and funding for test equipment also could be a financial barrier for some of the participating States.
    - A more formal training on new procedures is needed if moving toward using mechanical tests for acceptance during production, as well as an opportunity to discuss with their contractor community.
    - Participating States indicated they would need additional support if Approach D is to be considered including how to handle technician certifications.

- **Pathway for Quality Assurance (QA) and Field Acceptance.** There seems to be a clear desire to move forward to using BMD principles in mix design among the States participating in this southeast peer exchange. Challenges to acceptance are further explored below, but include:
    - Using BMD for acceptance will require more training and staffing.
    - Where should the testing be done, e.g., central laboratory, district laboratory?
    - Who should do the testing, e.g., State, consultant?
    - Pay based on BMD tests and bonuses are based on volumetric properties.
    - Consider restructuring pay for asphalt mixtures.

- **Other Challenges:**
    - Some additional items that were discussed included uncertainty if all BMD tests are reliable. Some States reported limited trust in some test's ability to screen poor performing asphalt mixtures. Confidence in testing is needed to rely on BMD tests to ensure performance.
    - Contractor's issues with equipment availability and malfunctioning test equipment that could delay work or cause schedule concerns.

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.

State Program Highlights: Existing Efforts

Alabama:

- *General observations*. Current standard practice is a dense-graded Superpave mix design where traditional volumetric properties are used for asphalt mix design approval. Acceptance is based on volumetric properties and ride quality.
    - Currently using HWTT for high equivalent single axle load (ESAL) and Stone Matrix Asphalt (SMA) mixtures. State is pleased with the test for mix design but test is not fast enough for being adopted during acceptance. Thus, looking for the

use of High Temperature Indirect Tension (HT-IDT) test for rutting along with the IDEAL-CT for cracking.
    - State received mixed reactions for the test selections from stakeholders ranging between very supportive to very discouraging.
    - About 240 asphalt mixtures were tested over two years including high ESAL and SMA mixtures. Contractors were asked to submit compacted specimens for BMD testing by the State. One of the lessons learned was the need for clear instructions on how to handle and short-term age asphalt mixtures before compacting and submitting to the State.
- *Roadmap.* No formal plan has been developed but planning to prepare a detailed Gantt chart. State is planning for a validation project in 2024.
- *Lessons Learned.* ALDOT highlighted the importance of formalizing processes, data collection and data standardization, education and collaboration. This included:
    - Formalizing a BMD approach including planning with tasks and timelines and adopting a BMD task force to engage specific areas, associations, and industries.
    - Making a data wish list to be collected as part of the validation projects.
    - Informing and educating area personnel as the BMD concept may be new to project engineers and lab personnel.
    - The importance of greater collaboration between States including results of current practices.
    - Though moisture damage is not believed to be a problem, it is worth a closer look as part of the validation projects.

Arkansas:

- *General observations*. Currently Superpave mix design is used with Asphalt Pavement Analyzer (APA) required for all mixtures. The State has not observed any rutting issues. All tests are conducted in central laboratory.
    - There is a plan for 350 asphalt mixtures to be tested in one year. Plans for BMD demonstration with the use of a hybrid technique: shadow with a pilot project test section. This allows for evaluating the BMD specifications.
    - A wide range of CT-index values is observed between 10 to 150. RAP is allowed up to 30 percent by the State but in most cases a 15 percent RAP is being used to avoid meeting the blending chart requirements applied to higher RAP quantities. SMA mixes are not used in the State.
- *Roadmap.* No formal plan has been developed. The current goal is to complete two projects in summer 2023 to implement BMD and monitor field performance to verify the recommendations for CT-index from research (a minimum of 50 CT-index after 4 hrs of short-term aging of loose mixture at 275degree F). This effort is being championed by the new division head.
- *Lessons Learned.* ARDOT stressed the importance of focusing on test type selection, validation, and aging. Future consideration may include more robust test sections and validation projects beyond a single case; using HT-IDT as a surrogate for APA; and keeping in communication with laboratories about storing and aging (possibly developing standard protocols for handling, storing, and aging in the future).

Georgia:

- *General observations*. Agency have been using HWTT for a while as a rutting test along with the tensile strength ratio (TSR) in accordance with AASHTO T 283 for moisture susceptibility.

    - A benchmarking study was conducted that included 45 plant-produced asphalt mixtures representing seven mixture types. A special provision for BMD is drafted for pilot projects. Besides the HWTT and IDEAL-CT, a permeability test and Cantabro test are included.
    - Recognizing the benefits of using RAP to conserve natural resources, GDOT allows up to 40 percent of fractionated RAP with 30 percent being the typical usage. In order to ensure performance a 60:40 Corrected Optimum Asphalt Content (COAC) is adopted (i.e., 60 percent RAP binder contribution). This practice was confirmed with the benchmarking study that showed improved cracking for the tested asphalt mixtures without jeopardizing rutting.
- *Roadmap.* Drafted a BMD special provision. In the process of getting pilot projects approved for 2023 paving season in different parts of the State. The plan is to have collaboration with the industry.
- *Lessons Learned.* Georgia focused on getting validation effort done at a specified time and it is important to continue test and implement BMD after pilot projects to keep momentum on these initiatives moving. The need to evaluate the asphalt mixture aging procedure was identified.

Louisiana:

- *General observations*. Implemented major specifications revision in 2016 where volumetric property requirements were adjusted and BMD rutting and cracking tests were implemented for all asphalt mixtures. The implementation was done in phases, with the HWTT being implemented first to get contractors familiar with the process and how to compact samples to achieve target air voids. In 2014, pilot projects were completed with SCB test before implementation in 2016.
    - BMD tests play a major role during production: run HWTT for verification every 10,000 or 20,000 tons of asphalt mixture, and results are used as stop or go during production.
    - The major changes to the volumetric properties are: target air voids level of 3.5±0.5 percent; minimum voids in mineral aggregates (VMA) reduced by 0.5 percent; and minimum voids filled with asphalt (VFA) increased to 72 percent. The State would like to relax volumetric properties and allow for innovation.
    - Polymer modified (PM) asphalt binder is mandated, though for low traffic (<3,500 average daily traffic), HWTT and SCB generally pass without the PM binder, and contractor was allowed binder substitution.
- *Roadmap.* Looking at aging protocol to shorten the test time and establish new thresholds so the test is applicable during production. LaDOTD has been satisfied with SCB implementation that screened out mixtures which had compatibility issues when using various type of additives (e.g., polymer, RAP, binder performance grade).
- *Lessons Learned.* Louisiana identified the need for more specific, location-based analysis including the desire to develop a gaps and needs analysis for implementing BMD at a State level. They also focused on the importance of communication and cooperation between other States in the region and noted that state-specific issues impact

implementation of BMD. For instance, Louisiana is predominantly more industry forward and any implementation of BMD needs to take that into account.

Mississippi:

- *General observations.* Evaluating the HWTT, APA, IDEAL-CT, IDEAL-RT (Ideal Rutting Test), HT-IDT, Cantabro test for all asphalt mixtures as part of a research effort. All specimen fabrication is conducted in house to have a better control of variability. MDOT has been cataloging asphalt mixtures for about 18 months and an average CT-Index is found around 70.
    - Research project is used to help in BMD tests selection. The RTrack has been identified as a promising test and working on developing a specification for the test. Cantabro is also being implemented on compacted samples during production.
- *Roadmap:* No official validation project on the horizon. Still waiting to decide which BMD tests to use.
- *Lessons Learned:* At this point in implementing BMD practices, Mississippi stressed the importance of thinking on a project-based level while moving towards programmatic implementation. The State is continuing to focus on shadow projects with some validation to establish minimum test criteria, developing aging protocols, and implementing a dedicated BMD task force.

Tennessee:

- *General observations.* State uses Marshall mix design. Cracking has started to become an issue. Looking to adopt IDEAL-CT and HWTT. CT-Index observed rages from a value of 10 to 150+, however lower values are observed for certain areas of the State (i.e., aggregate sources).
    - On-going research studies on BMD looking into IDEAL-CT using 4-inch diameter specimens compacted using Marshall hammer.
- *Roadmap:* No official plan. Completed few pilot projects.
- *Lessons Learned:* Continued efforts towards BMD adoption as a long-term implementation strategy are crucial. Tennessee noted that aggregate issues were arising based on geographies throughout the State and expressed a desire to formulate a dedicated task force, to create more engagement and buy-in from the asphalt community and to perform a validation study and create a formalized lessons learned document at this stage.

APPENDICES

Appendix A: Participants List

Southeast Peer Exchange on
Balanced Mix Design
Baton Rouge, LA 70808
March 1-2, 2023

Participant List

State/Organization	Participant Name	Email
AL	Zane Hartzog	hartzogz@dot.state.al.us
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FHWA	Tim Aschenbrener	timothy.aschenbrener@dot.gov

Appendix B: Questionnaire

FHWA Southeast Peer Exchange

PRE-MEETING SURVEY

Three weeks before the FHWA peer exchange meeting, attendees were asked to complete a short survey pertaining to their agency's BMD practices. The intent of the survey was to stimulate thoughts in preparation for the meeting and to generate information to help guide the meeting discussions. Responses were received from a total of 6 agencies with a summary of the results presented below.

Respondent Information

Name	Affiliation
Zane Hartzog	Alabama DOT
Jared Johnson	Arkansas DOT
Josh Bragg	Georgia DOT
Samuel Cooper III	LADOTD/LTRC
Cass Coon	Mississippi DOT
Matthew Chandler	Tennessee DOT

BMD Current Practice

What is the current implementation status of BMD?

Agency	Response
Alabama DOT	Research studies, Initial planning
Arkansas DOT	Pilot projects, Shadow projects, Research studies
Georgia DOT	GDOT has already changed its mix design procedures to allow for more asphalt cement in the mix and in doing so has relaxed some of the volumetric requirements of Superpave mix design. We are now developing Special Provision specifications for some pilot BMD projects.
LADOTD/LTRC	Fully Implemented
Mississippi DOT	Research studies, Initial planning, Still thinking/exploring, cataloging current Superpave mix designs.
Tennessee DOT	Pilot projects, Shadow projects, Research studies

What is the project scope for BMD?

Agency	Response
Alabama DOT	Too early in the process to say
Arkansas DOT	Projects with high asphalt tonnage
Georgia DOT	Just pilot projects for now
LADOTD/LTRC	All projects
Mississippi DOT	All projects
Tennessee DOT	Unknown at this time

Which BMD approaches are being considered by your State DOT?	
Agency	**Response**
Alabama DOT	Approach A
Arkansas DOT	Approach C and D (Using a hybrid C and D approach)
Georgia DOT	Approach C
LADOTD/LTRC	Approach A
Mississippi DOT	Unsure
Tennessee DOT	Approach D

Benchmarking Studies

Were any benchmarking studies conducted during the BMD implementation process?	
Agency	**Response**
Alabama DOT	We have a benchmarking study planned for next year
Arkansas DOT	Ongoing
Georgia DOT	Yes
LADOTD/LTRC	Yes
Mississippi DOT	On-going
Tennessee DOT	On-going

Who is responsible for the conduct of benchmarking mechanical tests?	
Agency	**Response**
Alabama DOT	Designated third-party lab
Arkansas DOT	State DOT Lab, Designated third-party lab
Georgia DOT	National Center for Asphalt Technology
LADOTD/LTRC	LTRC Research
Mississippi DOT	State DOT Lab
Tennessee DOT	State DOT Lab, Designated third-party 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**
Alabama DOT	We will analyze test section with different cracking and rutting test targets. The contractor will be free to use their own means to stay within those target ranges. The Analysis will be done by NCAT.
Arkansas DOT	Mix type, binder grade, design gyrations; Impacts will be analyzed at the end of the benchmarking process
Georgia DOT	This was a research project conducted by the National Center for Asphalt Technology that involved the collection of asphalt plant production mixtures to be used in a benchmarking study prior to GDOT implementing IDEAL CT. It was hoped to determine a valid minimum CT Index requirement with Contractor Mix Design Approval request. More than 45 mixtures samples representing seven different mix types currently specified by GDOT were sampled and specimens were fabricated for the purpose of determining the rutting and cracking resistance of mixtures being used in the state of Georgia. Also of interest, results were analyzed to determine how the implemented changes in COAC ratio, from 100:0 to 75:25 and then to 60:40, affected the cracking and rutting resistance of recycled asphalt mixtures. In addition, the cracking and rutting test results of the recycled mixtures were also compared with those of the respective virgin asphalt mixtures for reference. Results were then analyzed to propose CTindex thresholds for future implementation in GDOT specifications for asphalt mix design implementation in GDOT specifications for asphalt mix design
LADOTD/LTRC	Benchmarking study was conducted involving historic data collected through research and comparing to measured cracking and rutting field measurements. Pilot projects were also implemented.
Mississippi DOT	Still in the process of gathering data from all mix designs.
Tennessee DOT	Currently we are benchmarking our most commonly used dense mix classification (TDOT – D). We are looking at all 3 common grades of binder. Our focus so far has been on design. As a historical Marshall Mix Design state we are Currently evaluating ways to run BMD style testing utilizing the existing Marshall infrastructure. An initial study was Conducted by Dr Ben Bowers at Auburn. We are continuing that study in our own lab and in a partner study through the University of Tennessee with Dr Baoshaun Huang.

Validation Studies

Was validation of performance tests completed to assure that mechanical test results have a strong relationship to field performance?	
Agency	**Response**
Alabama DOT	On-going
Arkansas DOT	On-going
Georgia DOT	Yes
LADOTD/LTRC	Yes
Mississippi DOT	Not yet
Tennessee DOT	On-going

What is the source of field performance data used for validation process?	
Agency	**Response**
Alabama DOT	Test-track
Arkansas DOT	Pilot projects; Getting benchmark values for all approved mix designs currently in use
Georgia DOT	We will use the pilot projects for this
LADOTD/LTRC	Pavement management system, Research test sections
Mississippi DOT	None performed yet
Tennessee DOT	Test track, Research test sections

Application of BMD

What is the scope or applicability of BMD tests?	
Agency	**Response**
Alabama DOT	Mix design, To be determined
Arkansas DOT	Mix design, Initial verification (test trip or trial plant batch)
Georgia DOT	Mix design, Acceptance (go/no-go)
LADOTD/LTRC	Mix design, Initial verification (test trip or trial plant batch), Acceptance (go/no-go)
Mississippi DOT	Mix design, Initial verification (test trip or trial plant batch), Acceptance (go/no-go), Still in planning phase
Tennessee DOT	Mix design, Acceptance (go/no-go)

General opinions	
What are your overall comments or concerns related to the BMD process?	
Agency	**Response**
Alabama DOT	BMD Test results have greater variability than volumetric test results; Tests are slower than volumetrics, which leads to slower information for QC/QA purposes
Arkansas DOT	Need to determine our minimum benchmark for IDEAL-CT Index (crack test), Best ways to gauge field performance of a BMD mix vs a standard Superpave mix
Georgia DOT	GDOT is just in the initial phase of establishing specifications for the letting of BMD pilot projects. With that said, since GDOT revised its mix design process of limiting the RAP AC credited binder contribution, we have seen vast improvement in our asphaltic concrete mixtures incorporating RAP. As mentioned earlier, because we are adding additional virgin binder, we have had to lax the requirements for such volumetric requirements as VFA, VMA and VTM. It should be noted, that GDOT has never used volumetric criteria for acceptance.
LADOTD/LTRC	LADOTD is encouraged by the direction the quality of the asphalt mixtures in this state has progressed post BMD implementation. There were certainly growing pains and learning opportunities along the way. The ability to add more RAP and encourage contractor innovation have been two strong benefits.
Mississippi DOT	I am curious about the correlation of Hamburg/APA and Hot-IDT/IDEAL-RT since requiring a Hamburg or APA test during production is not feasible. Interested to know how high RAP contents can go when switching to BMD. Can the same principles of BMD work for SMA?
Tennessee DOT	It seems that there are quite a few benefits to be gained here but the amount of unknowns make taking even the smallest first step difficult. I'm excited for the possibility we have in being able to improve performance and innovate with new pavements. However, the scope of the change is overwhelming and processing how that effects mix design, production, acceptance for a whole state DOT and contractors is massive and is going to take a long time.

What are some of the major challenges your DOT is facing?	
Agency	**Response**
Alabama DOT	Joint durability, OGFC Longevity and durability
Arkansas DOT	How to encourage BMD participation and how to pay for it fairly, How to specify BMD in a way that we get improved mixes rather than just our current mixes that may happen to pass our criteria
Georgia DOT	To seek partnership and collaboration from local asphalt industry in the future for full implementation of BMD.
LADOTD/LTRC	Long term aging protocol to move towards production acceptance.
Mississippi DOT	State-wide training that would be required to teach technicians how to use the BMD testing equipment. Personnel issues as well. We are trying to keep the current employees we have.
Tennessee DOT	We never adopted Superpave mix design so our testing inventory is still mostly Marshall. We are attempting to find a way to make that work. If not, then the cost to each contractor will be pretty high to make the switch We are also a state with primarily limestone aggregates. We've always managed friction utilizing a minimum silicious aggregate requirement. In a BMD world specs like that are mostly meant to go away which leaves us in a tough spot with safety. We are working on some level of testing using the DFT to try for design acceptance. Our lab is somewhat skeptical due to the size of the slab required for that test though. If we are unable to spec friction through a performance style test we will probably end up sticking with a prescriptive polish resistant minimum which will severely limit the ability to use higher RAP contents. In an effort to encourage contractors to not bid AC contents low, our bid structure for bidding AC is set to a minimum amount for each mix type and then the state pays the contractor for whatever extra binder based on the actual approved JMF at the market price as a price adjustment. This has worked very well in keeping mix designs from being a race to the bottom in binder content. However, in our first attempt at a truly BMD bid mix this became quite a hurdle. Leaving this in place subsidizes higher AC contents at the expense of more innovative procedures, so we successfully argued to have it removed. However, contractors are not used carrying this risk and finding it put on them in BMD is yet another issue to resolve in implementing BMD

BMD Performance Tests

Primary modes of distress	
Agency	**Response**
Alabama DOT	Rutting, Fatigue cracking
Arkansas DOT	Fatigue cracking, Reflective cracking
Georgia DOT	Reflective cracking, Moisture damage
LADOTD/LTRC	Rutting, Fatigue cracking, Reflective cracking, Moisture damage
Mississippi DOT	Fatigue cracking, Reflective cracking
Tennessee DOT	Rutting, Fatigue cracking, Friction Characteristics

Summary of Agency Experiences with Mechanical Testing				
Alabama DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	Hamburg HT-IDT	IDEAL-CT	TSR Hamburg	–
Test Criteria (if available)	Hamburg is currently used for approval of SMA an ESAL Range E dense grade mix designs Hamburg: Mixes with 67-22 Binder < 10mm at 10,000 cycles Mixes with 76-22 binder < 10mm rutting at 20,000 passes HT-IDT proposed for future BMD design and acceptance	To be determined proposed criteria: ESAL Range A/B 50 ESAL Range C/D 75 ESAL Range E 100	TSR : 0.80 Hamburg: Mixes with 67-22 Binder < 10mm at 10,000 cycles Mixes with 76-22 binder < 10mm rutting at 20,000 passes	–
Laboratory Aging protocol or simulation	Hamburg None HT-IDT AASHTO R30 2 hour	AASHTO R 30 2 hour	None	–
Same test used during mix design and acceptance? (if applicable) Yes or No (if No please specify test)	We do not currently use a rut test for acceptance.	We do not currently use a cacking test for acceptance	TSR is used for both	–

–not applicable or data not available.

Arkansas DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	Asphalt Pavement Analyzer	IDEAL-CT (ASTM D8225)	Retained Stability (Modified T245)	–
Test Criteria (if available)	Two 150mm by 75mm specimens; 100 psi hose pressure; 8000 cycles	Per ASTM D8225	6in breaking head; 140F water bath for 24hrs	–
Laboratory Aging protocol or simulation	AASHTO R30 Short Term Aging - 2 hours at compaction temp	AASHTO R30 Short Term Aging – 4hr at 135C	No aging	–
Same test used during mix design and acceptance? (if applicable) Yes or No (if No please specify test)	Rutting not tested during acceptance	Will be included in verification process for information only at this time Included in QA testing for information only at this time	Used for mix verification during first 90 days of production	–

–not applicable or data not available.

LADOTD/LTRC				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	AASHTO T324	ASTM D8044	AASHTO T324	–
Test Criteria (if available)	Level 2: (high traffic) <6mm @ 20,000 passes Level 1: (low traffic) <10mm @ 20,000 passes	Level 2: (high traffic) Jc>0.6 kJ/m^2 Level 1: (low traffic) Jc>0.5 kJ/m^2	No stripping inflection point	–
Laboratory Aging protocol or simulation	AASHTO R30 – Short Term Aging	AASHTO R30 – Long Term Aging 5 days – 85°C	AASHTO R30 –Short Term Aging	–
Same test used during mix design and acceptance? (if applicable) Yes or No (if No please specify test)	NA Must pass prior to production. Verified during production.	NA Must pass prior to production.	NA Must pass prior to production. Verified during production	–

–not applicable or data not available.

Mississippi DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	Looking at APA and Hamburg; IDEAL-RT and Hot IDT possible	IDEAL-CT	Hamburg and Cantabro	–
Test Criteria (if available)				–
Laboratory Aging protocol or simulation	Short term aging (2 hours)	Short term aging (2 hours)	Short term aging (2 hours)	–
Same test used during mix design and acceptance? (if applicable) Yes or No (if No please specify test)	IDEAL-RT or Hot IDT for production; Some combination of the 4 for mix design	IDEAL-CT for both	Both for mix design and possibly Cantabro for production	–

–not applicable or data not available.

Tennessee DOT				
Item	**Rutting**	**Cracking**	**Durability/Moisture Damage**	**Other Distress**
Standard Test Method	HWTT	Ideal CT	HWTT	DFT?
Test Criteria (if available)	<12mm rutting @ 50C Min passes req'd changes by road AADT. (10/15/20k)	< min 50/75/100 Depending on road AADT. Considering a peak load requirement	SIP may occur but only beyond 10k passes, all roads	Research underway. Most likely some level of friction achieved at a design polishing with a 3WP.
Laboratory Aging protocol or simulation	R30, 2hrs	R30, 4hrs	R30, 2hr	TBD, some level of 3WP
Same test used during mix design and acceptance? (if applicable) Yes or No (if No please specify test)	Probably No Evaluating for a quick test for acceptance	Yes (probably)	Probably no TSR	No

Georgia DOT

Performance Test:

Permeability test: Ensure Superpave and Stone Matrix mix designs include testing according to GDT 1 ("Measurement of Water Permeability of Compacted Asphalt Paving Mixtures"). Ensure specimen air voids for this test are 6.0 ±1.0 percent. The average permeability of three specimens may not exceed 3.60 ft per day (125 ×10−5cm per sec).

Moisture Susceptibility test: For all mixtures using approved Liquid Anti-Stripping Additive meeting the requirements of Section 831 in lieu of hydrated lime, fabricate and test specimens in accordance with AASHTO T283. When required by the Office of Materials and Testing due to visible signs of stripping in any laboratory fabricated or plant produced asphaltic concrete mixtures, AASHTO T283 shall be performed for continued validation of the mix design.

Ensure specimen air voids for this test are 7.0 ±1.0 percent for all mixes excluding Stone Matrix mixes. Ensure specimen air voids for this test are 6.0 ± 1.0 percent for Stone Matrix mixes. For all mix types, the minimum tensile splitting ratio is 0.80, except a tensile splitting ratio of no less than 0.70 may be acceptable if all individual strength values exceed 100 psi (690 kPa). Ensure individual splitting strength of the three conditioned and three controlled samples are not less than 60 psi (415 kPa). Ensure retention of coating as determined by GDT 56 is not less than 95 percent.

Hamburg Wheel-Tracking Test for rutting and moisture susceptibility test: Ensure mix designs of all mix types except Open-graded Surface Mixes (OGFC and PEM), and Open-graded Crack Relief Interlayer (OGI) mix, include testing in accordance with AASHTO T 324. Ensure specimen air voids for this test are 7.0 ± 1.0 percent for all mix types, other than SMA mixes and at a testing temperature of 50°C (122°F). Ensure specimen air voids for this test are 6.0 ±1.0 percent for SMA mixtures and at a testing temperature of 50°C (122°F). Use the testing and acceptance criteria established in Table 3.

TABLE 3 – HAMBURG WHEEL TRACKING DEVICE TESTING AND ACCEPTANCE CRITERIA

Binder Performance Grade (PG)	Mix Type	Number of Passes	Maximum Rut Depth	Minimum Stripping Inflection Point
PG 64-22 and PG 67-22	4.75 mm, 9.5 mm SP Type I, and 9.5-mm SP Type II	15,000	≤ 12.5 mm	> 15,000 Passes
PG 64-22 and PG 67-22	12.5 mm SP, 19 mm SP and 25 mm SP	20,000	≤ 12.5 mm	> 20,000 Passes
PG 76-22	All Mix types	20,000	≤ 12.5 mm	> 20,000 Passes

Tested specimens shall be inspected for any visible signs of stripping and any mix design's tested specimens that fail to maintain 95 percent of asphalt cement coating, as described in GDT 56 section D.2.d, will be required to meet specified requirements for AASHTO T 283 as detailed in 828.2.B.2.b. Failure to conform to specified maximum rutting tolerance or minimum stripping inflection point (SIP) will result in non-approval of the submitted mix design.

Fatigue testing: The Department may verify dense-graded mix designs by fatigue testing according to AASHTO T 321 or other procedure approved by the Department.

Abrasion Loss of Asphaltic Mixture Testing: The Department will evaluate Open-graded Friction Course, Porous

European Mix, SMA, and when required, Superpave Mix Types in accordance with AASHTO T401. In accordance with AASHTO T 312, compact OGFC and PEM specimens using the Superpave Gyrator Compactor to a specimen height of 115 ± 5 mm and specimen air void content range specified in Sub-section 828.2.01.A. Specimen air voids for the SMA specimens shall be 6.0 percent ± 1.0 percent with a specimen height of 115 ± 5 mm. Specimen air voids for all Superpave Mix Types specimens, when required, shall be 7.0 percent ± 1.0 percent with a specimen height of 115 ± 5 mm. Bulk Specific Gravity of the compacted open-graded mixtures shall be determined using Corelok vacuum-sealing device in accordance with AASHTO T 331. Individual specimen and average of three specimens for OGFC, PEM, SMA, and when required Superpave Mix Types shall comply with mix design and acceptance criteria established in Table 4. for Interstate pavements. For all other uses, Abrasion Loss results shall be reported in mix design approval submissions for all OGFC, PEM, and SMA Mix Types.

TABLE 4 –ABRASION LOSS PERFORMANCE TESTING AND ACCEPTANCE CRITERIA

Asphaltic Concrete Mix Type	Mix Design and Quality Acceptance Maximum Abrasion Loss Percent
All Superpave Mix Types Used on Interstate Mainline or Ramps	10
All SMA Mix Types	10
All Open-graded Mix Types	20

Indirect Tensile Asphalt Cracking Test (IDEAL-CT): Ensure mix designs of all mix types except Open-graded Surface Mixes (OGFC and PEM), and Open-graded Crack Relief Interlayer (OGI) mix, include testing in accordance with ASTM D8225. Ensure individual and average of three (3) specimens CT Index results are included with mix design approval submission. The mix design laboratory shall fabricate and submit IDEAL CT specimens with all asphaltic concrete mix design approval request to the Asphalt Mix Design Unit at the Office of Materials and Testing. All IDEAL CT specimens shall comply with specified minimum CT Index requirements established in Table 5.

TABLE 5 – IDEAL-CT PERFORMANCE TESTING AND ACCEPTANCE CRITERIA

Design Roadway Classification	Asphaltic Concrete Mix Type	Mix Design and Quality Acceptance Minimum CT Index
State Routes (Non-controlled access) <10,000 ADT	4.75 mm and All Superpave Mix Types	≥ 50
State Routes (Non-controlled access) ≥10,000 ADT	All Superpave Mix Types	≥ 70
Interstates and Controlled Access State Routes	All Superpave Mix Types	≥ 100
Interstates and Controlled Access State Routes	All SMA Mix Types	≥ 150