# TechBrief

The Asphalt Pavement Technology Program is an integrated national effort to improve the long-term performance and cost effectiveness of asphalt pavements. Managed by the Federal Highway Administration working with State highway agencies, industry and academia, the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement guidelines, methods, procedures, and other tools for use in asphalt pavement materials selection, mix design, testing, construction, and quality control.

Office of Preconstruction, Construction, and Pavements
FHWA-HIF-22-048
Date: April 2022

U.S. Department of Transportation
Federal Highway Administration

# Balanced Asphalt Mix Design: Eight Tasks for Implementation

## Introduction

Balanced Mix Design (BMD) is described as an "asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate, and location within the pavement structure."(1) Goals for implementation of BMD may differ among State Departments of Transportation (DOTs). Initially, some may wish only to add performance tests as part of mix design approval, whereas others may want to replace many existing criteria with new performance test criteria for mix design approval as well as for quality assurance (QA). To learn more regarding the details of BMD and implementation efforts, FHWA conducted virtual site visits between April and September 2020 and interviews of seven early adopter State DOTs, along with material producers, consultants and paving contractors that serviced the agencies. The participating State DOTs were California DOT (Caltrans); Illinois DOT (IDOT); Louisiana DOT and Development (LaDOTD); Maine DOT (MaineDOT); New Jersey DOT (NJDOT); Texas DOT (TxDOT); and Virginia DOT (VDOT).

Successful practices documented from these virtual site visits were collected and synthesized into an overall process of implementing BMD as part of mix design approval and QA. This effort suggested eight major tasks based on concurrent activities (e.g., BMD regional workshops(3), BMD implementation guide(4)). The tasks and the associated subtasks are presented in Table 1. These tasks are meant to summarize the suggested activities that a State DOT may need to undertake to implement a BMD program. Not all tasks may be applied or considered by a State DOT depending on its organizational structure, staffing level, workspace, annual asphalt tonnage, as well as industry experiences and practices. Use of the tasks is not a Federal requirement.

Although there are logical sequences for some of the tasks, there are some cases where tasks may be conducted in parallel or in a different order without any negative consequences. For instance, several activities can occur in multiple inter-related tasks or subtasks. The following sections describe the various tasks for BMD implementation.

**Table 1. Eight Potential Tasks for BMD Implementation.**

| Task | | Sub-Task | Description |
|---|---|---|---|
| **1** | **Motivations and Benefits** | – | – |
| **2** | **Overall Planning** | 2.1 | Identification of Champions |
| | | 2.2 | Establishing a Stakeholders Collaboration |
| | | 2.3 | Doing Homework |
| | | 2.4 | Establishing Goals |
| | | 2.5 | Mapping the Tasks |
| | | 2.6 | Identifying Available External Technical Information and Support |
| | | 2.7 | Developing an Implementation Timeline |
| **3** | **Selecting Performance Tests** | 3.1 | Identifying Primary Modes of Distress |
| | | 3.2 | Identifying and Assessing Performance Test Appropriateness |
| | | 3.3 | Validating the Performance Tests |
| **4** | **Performance Testing Equipment: Acquiring, Managing Resources, Training, and Evaluating** | 4.1 | Acquiring Equipment |
| | | 4.2 | Managing Resources |
| | | 4.3 | Conducting Initial Training |
| | | 4.4 | Evaluating Performance Tests |
| | | 4.5 | Conducting Inter-Laboratory Studies |
| **5** | **Establishing Baseline Data** | 5.1 | Reviewing Historical Data & Information Management System |
| | | 5.2 | Conducting Benchmarking studies |
| | | 5.3 | Conducting Shadow Projects |
| | | 5.4 | Analyzing Production Data |
| | | 5.5 | Determining How to Adjust Asphalt Mixtures Containing Local Materials |
| **6** | **Specifications and Program Development** | 6.1 | Sampling and Testing Plans |
| | | 6.2 | Pay Adjustment Factors (If Part of the Goals) |
| | | 6.3 | Developing Pilot Specifications and Policies |
| | | 6.4 | Conducting Pilot Projects |
| | | 6.5 | Final Analysis and Specification Revisions |
| **7** | **Training, Certifications, and Accreditations** | 7.1 | Developing and/or Updating Training and Certification Programs |
| | | 7.2 | Establishing or Updating Laboratory Accreditation Program Requirements |
| **8** | **Initial Implementation** | – | – |

**– not applicable**

## Task 1: Motivations and Benefits of BMD

The first step for BMD implementation is for stakeholders to understand why a new approach to asphalt mix design and production acceptance may be needed and the associated benefits expected with the change.

A common motivation for change to BMD is that the traditional volumetric-based mix design procedure may not provide optimum performance for asphalt mixtures and lacks opportunites for innovation. Volumetric-based mix designs can result in dry asphalt mixtures and lack the ability to adequately evaluate the impact of many asphalt mixture components or additives such as reclaimed asphalt pavement (RAP), reclaimed asphalt shingles (RAS), warm-mix additives, polymers, recycling agents, and fibers on the performance of asphalt mixtures. Furthermore, a volumetric-based mix design does not provide a performance-optimization process for specific applications that takes into consideration factors other than traffic and climate. Examples include location of the asphalt mixture within the pavement structure (e.g., surface course or intermediate/binder course), special applications (e.g., reflective cracking relief interlayer), and condition of the existing pavement for overlay applications.

Examples of benefits for implementing BMD can be considered by States in support of the need for implementation. Potential benefits include enhancements in the quality of asphalt mixtures (e.g., Caltrans[5], IDOT[6], and MaineDOT[8]); production of cost-effective asphalt mixtures that meet the project performance specifications (TxDOT[10] and VDOT[11]); and overall improvement in the condition of the State DOT pavement network (NJDOT).[9] Other benefits reported by the industry include the opportunity to use innovative asphalt additives, relaxed volumetric properties, and more robust methods for mix design approval and production acceptance.[2] These benefits were not always identified prior to or at the early stages of BMD implementation. Most often they were captured a period of time after implementation, depending on how the BMD specifications evolved along the process.

There are also challenges for implementing BMD regarding resources, research, equipment, and staffing. For example, full implementation could likely take years and BMD performance tests may not be able to fully replace current acceptance testing. There is variability in BMD performance test results that need to be addressed and accounted for. A careful consideration of the potential benefits and challenges for implementation should be performed by State DOTs when embarking on a BMD implementation.

## Task 2: Overall Planning

This task is concerned with the State DOT understanding the overall implementation process, establishing its goals, and determining the resources to achieve those goals.

### *Sub-Task 2.1: Identification of Champions*

Having champions in the State DOT and industry to provide leadership for the various implementation activities and help to resolve technical hurdles are both critical to successfully implementing BMD.[9,16] For a State DOT, this involves continuous communication and internal partnership among various offices, such as materials, pavement design, construction, and pavement management. Other areas critical to implementation include gaining support from industry.

### *Sub-Task 2.2: Establishing a Stakeholders Collaboration*

One key element is the formation of a joint agency, industry, and academia (as appropriate) task force.[11,16] The purpose of the task force should be to provide stakeholder input in the numerous implementation decisions. The task force can be an effective method of assuring that there is continual understanding and support from both industry and agency.

For example, consistent with State law, a State DOT could establish a "BMD Task Force" and a "BMD Technical Subcommittee" to assure proper communication and continuous dialogue with stakeholders and to provide timely and constructive technical input.[16] A "BMD Task Force" would provide periodic status updates for the BMD initiative to executive stakeholders, and a periodic forum for dialogue about progress and key milestones as the effort progresses. On the other hand, a "BMD Technical Subcommittee" role would to provide technical input, and support the development of the BMD specifications, procedures, and training programs.

### *Sub-Task 2.3: Doing Homework (Identifying Issues and Resources, Reviewing Literature)*

This sub-task includes identifying the issues with current asphalt mixtures, identifying the available resources, and reviewing available literature.[1,17,18] This is important for establishing the goals of the BMD program (Sub-Task 2.4) and to ensure that resources and funds availability are not barriers to successful implementation. A State DOT should identify the issues with its current asphalt mixtures and pavement performance and consider how BMD specifications may be able to resolve these issues. Some examples are shown in Table 2.

**Table 2. Examples of Key Issues Being Addressed by State DOTs.**

| State DOT | Issue Addressing |
|---|---|
| Caltrans[5] | Performance of high-traffic asphalt mixtures. |
| IDOT[6], LADOTD[7], VDOT[11] | Performance of asphalt mixtures containing recycled materials. |
| MaineDOT[8] | Premature failure of asphalt mixtures. |
| NJDOT[9] and TxDOT[10] | High-performance and specialty asphalt mixtures. |

It is important for a State DOT to identify available resources that can be devoted to the development and implementation of BMD process. A more detailed analysis can be conducted as described in Task 4.

A State DOT should conduct a critical review of available literature related to BMD and gather information on completed research or undergoing implementation efforts and activities by other State DOTs. This includes reviewing related research projects and findings, specifications and procedures; participating in related workshops; and meeting with other State DOTs to learn about their experience with performance testing. It is also important for a State DOT to understand the factors that drive asphalt mixture performance, including issues with underlying pavement conditions, existing rehabilitation strategies and construction practices that need to be resolved before or concurrent to implementing BMD.

***Sub-Task 2.4: Establishing Goals***

While recognizing the overall benefits from Task 1, a State DOT should establish its goals for its BMD program. Considerations are usually given to a State DOT organizational structure, staffing level, workspace, annual asphalt tonnage, as well as industry experiences and practices (Task 2.3). State DOT goals can focus on the desired improvement of asphalt pavement performance, optimization of recycled materials usage, targeted use of specialty asphalt mixtures for specific pavement applications, improving acceptance practices, or the design and construction of long-lasting asphalt pavements for high investment/high traffic projects.

Since State DOTs have different sizes for their asphalt pavement program, the plan for implementation may consider the following factors. A range of examples of project scope for mix design are shown in Table 3.

- Project investment level (e.g., high investment paving projects).
- Project scope (e.g., full depth reclamation, mill and overlay).
- Highway functional classification (principal arterial, minor arterial, etc.).
- Project traffic level (low, moderate, or high volume).
- Project length and asphalt mixture tonnage.
- Pavement layer (e.g., surface, binder, base course).
- Outcome of a risk-based, cost-benefit analysis for the project; etc.

**Table 3. Examples of BMD Program Scopes Considered by State DOTs.**

| State DOT | Scope of BMD Implementation |
|---|---|
| Caltrans[5] | High-traffic paving projects with more than 100,000 tons of asphalt mixture produced. |
| MaineDOT[8] | Interstate and high investment paving projects. |
| LADOTD[7], IDOT[6], NJDOT[9], and TxDOT[10] | All projects. |
| VDOT[11] | Standard well-graded surface mixtures projects with the intent for all projects to be eventually included. |

***Sub-Task 2.5: Mapping the Tasks***

The major tasks and sub-tasks are described for successful implementation of BMD and the associated performance tests as part of a State DOT's Quality Assurance (QA) program. This document provides many tasks and sub-tasks as an example. A State may find some of these tasks are not applicable for its situation or goals. Further, a State may identify additional tasks or sub-tasks that are necessary.[16,19] It should be noted that the tasks identified in this document may overlap or can be done concurrently. Although a State DOT may have already completed some tasks and sub-tasks, it is important to review earlier tasks to make sure that all issues have been addressed. There is a risk of re-work when tasks are skipped in the name of accelerating implementation.

***Sub-Task 2.6: Identifying Available External Technical Information and Support***

Many State DOTs have internal research underway or have engaged with their universities or other research organizations to provide information to guide decisions related to selection and implementation of performance tests. Thus, a regular review of related information and observations from other State DOTs is needed throughout the BMD implementation process. State DOTs may also reach out to the FHWA Resource Center for technical assistance, training, technology deployment, and interagency coordination.[20] Having periodic peer exchanges can help a State DOT to ensure its BMD implementation program remains viable and productive.

***Sub-Task 2.7: Developing an Implementation Timeline***

Establishing an implementation timeline is important to guide the goals (Sub-Task 2.4) toward successful and timely completion within the available resources (Sub-Task 2.3). The scope (Sub-Task 2.4) plays an important role in the timeline as well. Implementation can be accomplished in phases. For example, a State DOT may create an implementation plan and timeline that provides target dates for major milestones towards BMD implementation (e.g. selection of tests, completion of validation research, pilot projects).[6,11] Although these dates may shift as the process continues, having deadlines helps decision makers prioritize resources to achieve the final goals.

## Task 3: Selecting Performance Tests

For each type of asphalt pavement distress, there are several possible mixture performance tests that can be considered for use in asphalt mix design and production acceptance. The selection of performance tests can draw upon information in the new AASHTO provisional standards[21,22] for BMD (which are voluntary and non-mandatory standards), the final report from the National Cooperative Highway Research Program (NCHRP) 20-07/Task 406, the report by Hajj et al. (2019) titled Index-Based Tests for Performance Engineered Mixture Designs for Asphalt Pavements, and the National Asphalt Pavement Association's (NAPA's) Balanced Mix Design Resource Guide.[1,2,18,21,22]

### *Sub-Task 3.1: Identifying Primary Modes of Distress*

This task and sub-task begins with a detailed analysis to determine how the issues can be addressed. It is important for a State DOT to specifically identify the primary asphalt pavement modes of distress (e.g., bottom-up fatigue cracking, reflection cracking, rutting, moisture damage, friction loss) to be considered in the BMD process.(18,23) Consideration should be given to the intended application (e.g., new construction, major rehabilitation, mill and overlay), to the mix design, and to information regarding commonly-observed field distresses. A State DOT can use its pavement management system data in addition to field site visits to identify critical distresses and performance periods.

### *Sub-Task 3.2: Identifying and Assessing Performance Tests Appropriateness*

In this sub-task, a State DOT identifies candidate performance tests to assess resistance to the primary modes of distress determined in Sub-Task 3.1.(16,18,24) There can be more than one type of distress with each having more than one type of candidate performance tests.

A State DOT in partnership with industry can assess the overall appropriateness of each of the candidate performance tests for routine use in a BMD process based on the agency's needs, capabilities, resources, etc. Consideration can be given to the available resources while considering sample preparation, specimen conditioning and testing, training needs and applicability, equipment cost, repeatability, material sensitivity, and field validation, not provided in order of priority. Additional potential considerations can be given to the differences in test results between laboratory and plant-produced asphalt mixtures, and the laboratory aging and conditioning protocols for asphalt mixtures prior to performance testing.

The most important factors should be identified by each State depending on the goals, experience with a given test(s), and the stage of the implementation program. For example, the top three factors for NJDOT in selecting performance tests for mix design when first implementing BMD around 2006 were field validation, repeatability, and specimen conditioning/testing time.(9) At its current stage of the implementation, NJDOT is particularly interested in effective and practical test methods for routine usage during production with results that can be tied to a pay factor for acceptance of asphalt mixtures.(9)

A State DOT may elect to conduct specific studies to establish new or modify existing performance tests. This includes the development of a new standard test method or the use of an existing test method and modifying it as needed. For example, IDOT supported the research and other activities associated with the development of the Illinois Flexibility Index test (I-FIT) to address observed brittleness of some Illinois mixtures containing RAP and RAS.(6) On the other hand, NJDOT supported the research and other activities associated with the use and modification (as needed) of the existing Overlay Test (OT) and Flexural Beam Fatigue (FBF) in specialty asphalt mixtures to address related pavement distresses.(9)

The outcome of this sub-task is the selection of the most promising performance tests for each of the targeted modes of distress. Another factor to consider is the benchmarking study of typical asphalt mixtures (Sub-Task 5.2).

### *Sub-Task 3.3: Validating the Performance Tests*

A critical step in selecting appropriate mixture performance tests is to make sure that the test results have a strong relationship to field performance, thus supporting the development of specification criteria for mix design approval and possibly production acceptance .(16,24–28) The criteria can be established from data sets from a series of tasks that may include: Sub-Tasks 3.3, 4.5, 5.2, 5.4, and 6.5.

The first step is to review and assess the validity and applicability of past studies on relating test results to field performance. If deemed necessary, planning needs to be done for conducting additional field validation efforts of performance tests under state-specific conditions. Additional field validation can be very time consuming and may take many years so starting the planning process early is important.

One method to establish laboratory-to-field correlations is by building a group of field test sections in which the only variable among the sections is mixture properties for a single layer. All other variables such as underlying support conditions, traffic, layer thickness, and age need to be consistent among the test sections so that field performance differences are not confounded by those factors. Each group of test sections should be built to target a specific type of distress (e.g., reflection cracking, thermal cracking, moisture damage, rutting). The asphalt mixtures can be tested using all of the candidate methods being considered for BMD. Five to ten test sections per group is desirable to develop good laboratory-to-field relationships and include sections with a wide range of expected resistance to the distress of interest. Lessons learned from the Long-Term Pavement Performance (LTPP) Specific Pavement Studies (SPS) experiments are useful in planning field validation experiments.

Accelerated loading facilities, heavy vehicle simulators, test tracks, and similar facilities can be used for field validation, but there are noteworthy limitations with these experiments. The wheel speeds at some of these facilities are much slower than typical highway traffic. Thus, knowing that asphalt mixtures' response to traffic loads is rate-dependent; the results of the test sections may provide a useful ranking of performance, but they may not be appropriate for use in setting criteria for the performance tests. Other issues with these facilities are temperature control and aging. Typically, experiments using these loading facilities are conducted at a specific temperature and do not simulate the effects of daily and seasonal temperature changes on performance. Aging of the test sections occurs over time, so an experiment that loads one test section at a time over a period of a few years is confounded by different degrees of aging.

Some examples from other States are shown in Table 4. It should be noted that a State DOT may elect to use more than one field validation method.

**Table 4. Examples of Additional Field Validations Conducted by State DOTs.**

| State DOT | BMD Field Validation |
|---|---|
| TxDOT[10] | National Center for Asphalt Technology (NCAT) Test Track and evaluation of field projects. |
| IDOT[6] and LADOTD[7] | Evaluation of field projects. |
| NJDOT[9] | Pavement Management System data. |
| VDOT[11] | Heavy vehicle simulator. |

## Task 4: Performance Testing Equipment: Acquiring, Managing Resources, Training, and Evaluating

This task involves acquiring needed equipment, managing available resources, conducting initial training, evaluating performance tests, and conducting inter-laboratory studies (ILS).

### *Sub-Task 4.1: Acquiring Equipment*

State DOTs and contractors need equipment to conduct the selected performance tests, including the necessary equipment for sample preparation, aging/conditioning, and fabrication (e.g., table saws, conditioning chambers, water baths, aging ovens). This involves purchasing new equipment or modification of existing equipment.[5–11]

***Sub-Task 4.2: Managing Resources***

Additional effort may be needed to rearrange existing workspaces or to create new areas in laboratories to accommodate and install equipment. For example, a few IDOT District laboratories had to rearrange workspace to improve efficiency.[6] In the case of MaineDOT, resources were allocated to convert a stairwell into a room to house new equipment, and convert a janitor's closet into a space for coring and sawing specimens.[8]

***Sub-Task 4.3: Conducting Initial Training***

As new performance tests are adopted, the technicians conducting the tests need to have a basic understanding of the test methods and equipment. This includes understanding sample handling protocols in addition to data analysis and interpretation.

***Sub-Task 4.4: Evaluating Performance Tests***

Besides the factors considered in Sub-Task 3.2, and prior to conducting inter-laboratory studies, other test considerations need to be evaluated for how the performance test can be put into routine practice. Research needs may be identified and conducted in order to complete missing and incomplete information of the potential candidate test methods. Examples of additional considerations for performance testing evaluation include:

- Developing a new standard test method (e.g., IDOT[6], LADOTD[7], TxDOT[10]) or using an existing test method and modifying it as needed (Caltrans[5], MaineDOT[8], NJDOT[9], VDOT[11]).
- Establishing test methods with clear and specific details on: associated calculation and analysis methods and techniques, standardized reporting of test results and parameters, as well as database attributes for the stored raw/primary test data. For example, MaineDOT[8] realized the importance of robust standard test methods to minimize test result differences due to different equipment manufacturers. In some cases, a standardized program or worksheet is developed to ensure that results are calculated/analyzed in a consistent manner.
- Establishing proper sample handling, fabrication, and preparation procedures reduces the variability of test results due to differences between laboratory to laboratory.[30–33]
- Understanding differences between laboratory and plant-produced asphalt mixtures. Recognizing differences between asphalt mixtures fabricated in the laboratory and produced through an asphalt plant is needed to understand how to incorporate performance testing in QA production testing.
- Establishing laboratory aging and conditioning protocols for asphalt mixtures prior to performance testing. This involves the selection of short- and long-term aging protocols for some performance tests. The aging protocol may differ for laboratory- and plant-produced mixtures as well as surface mixtures and mixtures used in underlying layers.

***Sub-Task 4.5: Conducting Inter-Laboratory Studies (ILS)***

One of the factors in selecting the appropriate performance test (Task 3.2) is test precision. For most of the performance tests, there is limited information on the repeatability (within-laboratory variability) of the test. A test with poor precision may not be able to discern high-performing mixtures from low-performing mixtures. A ruggedness study, conducted in accordance with ASTM E1169[34] (a voluntary and non-mandatory standard), is often an important step in the development of a test to improve its variability. However, understanding the variability of a test is not just an important factor in the selection of a test, it is also important in setting appropriate specification criteria and verification procedures.

## Task 5: Establishing Baseline Data

Establishing baseline data is critical for the development of performance test criteria and related specifications. When using baseline data, both State DOT and industry gain confidence that the preliminary test criteria used for asphalt mix design and/or production acceptance are appropriately set. Ultimately, the test criteria can be established from data sets from a series of tasks that may include: Sub-Tasks 3.3, 4.5, 5.2, 5.4, and 6.5.

### *Sub-Task 5.1: Reviewing Historical Data & Information Management System*

The first step for establishing baseline data is for a State DOT to leverage its previous experiences with performance testing of asphalt mixtures.[23,39] This involves extracting any historical test data for asphalt mixtures and its associated field pavement performance from the State DOT information management system. Analysis of historical data would allow a State DOT to explore and identify the applicability and/or validity of a performance test(s) for use in a BMD process. This also helps a State DOT to identify needed changes to existing test methods. Having valid historical data can help establish performance test criteria.

### *Sub-Task 5.2: Conducting Benchmarking Studies*

A State DOT can collaborate with industry to benchmark existing asphalt mix designs using the performance tests selected in Task 3.[40] The goal of benchmarking is to determine how existing mixtures perform using the selected tests. Important considerations for benchmarking include:

- Selecting mixtures with known field performance when available.
- Including asphalt mixtures from all of the State's mix categories as well as mixtures with different asphalt binder grades, aggregate types, recycled materials contents, and other mixture components and proportions.
- Including two parts, with one focused on mix design approval using laboratory-mixed, laboratory-compacted (LMLC) specimens, while the other would be focused on testing of plant-mixed, laboratory-compacted (PMLC) specimens.
- Using a standardized step-by-step sample fabrication procedure to all participating laboratories for the sake of consistency, because sample fabrication has a significant impact on mixture performance test results (developed in Sub-Task 4.4).
- Consolidating all performance testing at the State DOT laboratory or a designated third-party laboratory to eliminate between-laboratory variability in the test results.
- Developing and analyzing a database of performance test results to determine the impact of mix design and production variables on the performance test results, and more importantly, to help in the process of establishing preliminary specification criteria (including test criteria) for use on pilot projects (Task 6).
- Evaluating several of the most promising performance tests in order to determine which test provides rational results and would be implementable.

It is important to keep in mind the differences between the concept of performance test validation and benchmarking. Table 5 compares these two common terms used in BMD.

**Table 5. Validation of Performance Testing Versus Benchmarking of Existng Asphalt Mixtures[1].**

| Activitiy | Primary Goal |
|---|---|
| Validation of Performance Testing | To ensure that performance test results have a strong relationship to field performance. |
| Benchmarking of Asphalt Mixtures | To determine how existing asphalt mix designs perform using the selected performance tests. |

### *Sub-Task 5.3: Conducting Shadow Projects*

To familiarize agency and contractor staff with the selected performance tests, shadow projects should be considered. A shadow project consists of identifying an existing project that uses conventional acceptance tests and obtains additional samples during the course of the project for performance testing. The performance test results are for informational purposes only as there are no changes to either the contract or the specifications for the project. The performance testing are performed by the State DOT at either its central or district laboratory, but also can be performed by the contractor for quality control purposes. At the completion of the project, the data from this additional testing is shared and discussed with the contractor as well as project personnel. The three goals of the shadow projects are: (1) to better familiarize both State DOT and contractor personnel with the selected tests; (2) to add to the database of test results from the benchmarking studies (Sub-Task 5.2); and (3) to gather information on typical production variability. A project selection process is needed on how best to select shadow projects, including recommended number of projects and samples, and means of assuring that the testing is properly conducted.

### *Sub-Task 5.4: Analyzing Production Data*

As mentioned above, one of the reasons for conducting shadow projects (Sub-Task 5.3) is to collect data on production variability of the performance test results. Since the tests may be new, there may be limited data from other agencies with which to compare. The variability of the performance test results can be compared to the variability of the traditional acceptance quality characteristics (AQCs). Analysis of the variability may provide motivation to further explore partitioning the total variability into the three components (testing variability, sampling variability, and materials variability) so that subsequent efforts can appropriately focus on improving the component(s) with the highest impact.

### *Sub-Task 5.5: Determining How to Adjust Asphalt Mixtures Containing Local Materials*

For each performance test, research studies may need to be conducted to evaluate sensitivity to asphalt mixture component properties or proportions (e.g., aggregates, asphalt binders, recycled materials, additives), volumetric parameters (e.g., air voids, VMA), and aging.[41–43]

## Task 6: Specifications and Program Development

A State DOT should develop preliminary mix design and/or acceptance criteria for use in developing specifications prior to the pilot projects. A State DOT may use the information gathered from the field validation experiments (Sub-Task 3.3), variability studies (Sub-Task 4.5), and established baseline data (Task 5) to establish performance test criteria.[17] Furthermore, information from the State DOT's existing QA program can be used to select the appropriate quality measures, AQCs, and preliminary AQC specification limits for each test method. In this task, risk analyses can also be used to evaluate the preliminary acceptance criteria. In addition, the information from the aforementioned tasks can also be used to select appropriate quality characteristics for quality control.

Based on the goals set by a State DOT (Sub-Task 2.4), there are a number of options of how acceptance and quality control testing can be handled for acceptance during mixture production. Examples are shown in Table 6. Both NJDOT and TxDOT are exploring the use of surrogate test(s) for acceptance during production with correlation to asphalt mix design performance test(s).[9,10] The benefits for using surrogate performance tests include: minimal investments by both the State DOT and industry; more tests can be completed within normal working hours; and reduced overall need for staffing and quick turnaround time on test results. However, surrogate tests for acceptance may require correlation/calibration with more fundamental performance tests to ensure that they provide robust evaluation of mixture performance properties. These benefits may vary largely depending on which surrogate performance test is selected.

**Table 6. State DOT Examples for Asphalt Mixture Acceptance during Production.[5–11]**

| State DOT | Acceptance |
|---|---|
| Caltrans[5], LADOTD[7], VDOT[11] | Volumetric properties with performance tests for information. |
| NJDOT[9], TxDOT[10] | Surrogate performance tests correlated to mix design approval tests. |
| IDOT[6], NJDOT[9], and MaineDOT[8] | Actual performance tests (same used during mix design). |
| NJDOT[9] | Performance tests with pay adjustment factors. |

### *Sub-Task 6.1: Sampling & Testing Plans*

A State DOT should develop sampling and testing plans for using performance tests in a QA program. Consideration may be given to identifying sampling location and methods, and specifying appropriate lot and sublot sizes, including how the choice of lot and sublot sizes impacts the reliability of acceptance decisions.[44,45] Often the decision of sublot size, and therefore the sampling frequency, is based on logistical factors that affect the time needed to obtain results for each test. This includes the verification of the key properties of the asphalt mix design at the start of production and the possible use of surrogate tests or screening tests in the QA program. This sub-task would need to meet the requirements of 23 CFR 637.207 Subpart B Quality Assurance Program, including independent sampling for validating contractor data and independent assurance.[46]

### *Sub-Task 6.2: Pay Adjustment Factors (If Part of the Goals)*

The goal of a performance specification is to link the design and acceptance characteristics of materials and construction to the expected performance of the pavement. Some State DOTs may decide to develop a pay schedule that relates AQCs to the expected life of the pavement layer. The selected AQCs may include some traditional asphalt mixture properties as well as results of performance tests or surrogate tests. To be effective, pay adjustments should be set to encourage the contractor to produce the materials as consistently as possible and be realistically achievable based on production variability data determined during pilot projects. The rationale for the pay adjustment schedule should be documented and supported, if desired by the State DOT. With limitedexperience in this area, this could be an opportunity for future research.

### *Sub-Task 6.3: Developing Pilot Specifications and Policies*

A State DOT should develop related specifications and revise other elements of its QA program for use in upcoming pilot projects (Sub-Task 6.4). This includes a compilation of the required acceptance tests, quality measures, AQCs, specification limits, sampling and testing frequencies, QC requirements, methods of validating contractor QC data (if contractor data is used for acceptance), and payment determination. In addition, a State DOT should address potential revisions to its independent assurance program, technician certification, laboratory qualification, and materials testing dispute resolution. These revised documents are to be used for pilot projects.

### *Sub-Task 6.4: Conducting Pilot Projects*

Pilot projects are used to evaluate the new QA program requirements under actual contractual conditions. Unlike shadow projects, pilot projects go through the typical bidding-contracting process with the new QA requirements applied, including performance testing required as part of asphalt mix design and acceptance. The number of pilot projects should be determined by the State DOTs. Pilot projects would include meetings with the BMD Technical Support Staff and pre-bid conferences to discuss the new requirements, along with discussions on how to address problems that may occur during construction. The just-in-time training can be conducted by individuals who were involved with performance testing that was conducted previously, in order to utilize lessons learned and hands-on experience as the additional technicians are trained.

### *Sub-Task 6.5: Final Analysis and Specification Revisions*

Under this sub-task, a State DOT conducts a comprehensive review of the specifications as well as any other necessary changes to its QA program based upon the lessons learned from the pilot projects. Data collected as part of the pilot projects are analyzed and specifications are modified accordingly. In addition, any systemic problems that were encountered during the projects should be addressed. This is also a good time to review the performance of field validation test sections, shadow projects, and other sources of information outside of the State and consider adjustments to the preliminary specification criteria. Specification revisions and any necessary changes should be completed prior to initial implementation.

## Task 7: Training, Certifications, and Accreditations

### *Sub-Task 7.1: Developing and/or Updating Training and Certification Programs*

Following the completion of the pilot projects and prior to initial implementation, a State DOT would formalize the changes to its existing technician certification and qualification programs, and determine how training could be provided for personnel already qualified for the previously used acceptance tests.[47,48]

In addition to using formalized training and certification programs, a State DOT can also use workshops to provide training on mixture performance testing for mix design approval and production acceptance. Course manuals designed for understanding the testing requirements of a State DOT can be prepared and provided to participants. The course manuals need to be updated regularly and may include detailed descriptions and photos of test methods, including equipment, sampling, specimen preparation, test procedure, etc.[6,10] Having instructional videos highlighting the details for sample preparation, specimen fabrication, testing, and data analysis have also been found to be extremely helpful for technicians and other personnel involved in the implementation process of the performance tests.[6,7,10] State DOTs should indetify the staff that need training and the types of training needed. Depending on the staff roles, different training may be needed for laboratory test procedure or data analysis and interpretation. Offering one-on-one support and training was also found to be an effective tool.

### *Sub-Task 7.2: Updating Laboratory Qualification and Accreditation Program Requirements*

Since many of the asphalt tests used in performance testing are relatively new, accreditation standards may not exist. While most of the cracking and rutting tests have standard test procedures, many are still in the provisional stage. A State DOT should add the performance testing to its program. Until performance tests are included in its approved accreditation program, a State DOT should qualify laboratories conducting performance testing. The State's qualfication process should include equipment checks to its routine checklist for district/region, area, contractor, consultant, and other laboratories for conducting the tests in the BMD program. A State DOT can use critical equipment/calibration checks to assist in updating its inspections by adding these test procedures.

A State DOT could also establish and implement a statewide proficiency testing program for all technicians involved in performance testing of asphalt mixtures for design and acceptance.[5–7,10] This involves technicians fabricating and testing specimens and reporting test results for analysis. A proficiency testing program ensures that technicians are properly performing the tests in accordance with applicable standard methods. A proficiency testing program provide useful updates to repeatability and reproducibility data, and also identify which laboratories may have results that are significantly different from the overall population of results. Such laboratories would need to carefully review its procedures for sample preparation and conducting the test.

### Task 8: Initial Implementation

Prior to implementation, the State DOT should communicate the changes and new requirements to both industry and agency personnel. This technology transfer can be done through the use of webinars, face-to-face meetings, and workshops. It can also be supported by having "implementation teams" that can help both contractors, consultants, and State DOT personnel address problems, interpret specification requirements, etc. It is important to integrate a feedback loop into the process to ensure and encourage communication and regular feedback from the various stakeholders, and to help identify areas for future adjustment and improvement.

The scope for project selection may need to be developed prior to implementation of BMD and specifications. The scope should tie to the target goals for the BMD program and can consider the project investment level, the rehabilitation type, the project highway functional classification and traffic level, the project length and asphalt tonnage, the pavement layer, etc. The scope for project selection should be regularly evaluated and updated based on the feedback loop and consider available resources within a State DOT.

## Summary

Several suggested tasks and sub-tasks for the implementation of BMD are presented. Each State is likely to start at a different task (e.g., starting from scratch, already implemented one performance test, etc.) and end at a different task (e.g., mix design only, acceptance, performance prediction, etc.). With varying goals and differences in available resources for implementation (e.g., time, funding, academia support, etc.), each State is also likely to take a different path from start to end. This information is provided to assist State DOTs in the efforts to plan for a successful implementation of BMD into their asphalt pavement program.

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# Balanced Mixture Design: Eight Tasks for Implementation

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**Distribution** — This Technical Brief is being distributed according to a standard distribution. Direct distribution is being made to the Divisions and Resource Center.

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**Key Words** — asphalt mix design, balanced mix design, asphalt mixture performance testing, performance engineered pavements, implementation.

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April 2022 FHWA-HIF-22-048