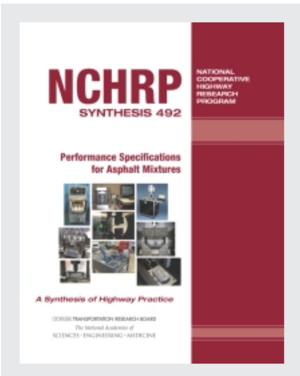

Performance Specifications for Asphalt Mixtures

DETAILS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP SYNTHESIS 492

Performance Specifications for Asphalt Mixtures

A Synthesis of Highway Practice

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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Cover figure: Myriad of asphalt performance tests (*Credit*: Google images).

FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice.*

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

Donna L. Vlasak
Senior Program Officer
Transportation Research Board

This synthesis documents the performance tests used in conjunction with volumetric properties for mixtures. Performance tests are intended to extend service life by guiding material selection (i.e., asphalt binder and aggregate) and proportions (i.e., asphalt content and gradations). The synthesis provides examples of engineering tools used in the development and implementation of performance specifications for asphalt mixtures, examples of the contents of performance-based specifications (PBS) currently used or in development, information on test program implementation and research efforts related to PBS for asphalt mixtures, and the reported benefits and challenges with implementing PBS.

Information for this report was acquired through a literature search, a survey of the use of performance specifications for asphalt mixtures, and seven case examples from six state departments of transportation, and the city of Edmonton, Alberta, Canada.

Leslie Myers McCarthy, Jonathan Callans, and Robert Quigley, Villanova University, Villanova, Pennsylvania, and Sidney V. Scott, III, Hill International, Inc., Philadelphia, Pennsylvania, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

Note: Photographs, figures, and tables in this report may have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at www.trb.org) retains the color versions.

PERFORMANCE SPECIFICATIONS FOR ASPHALT MIXTURES

SUMMARY

Asphalt mixtures are typically designed within a given gradation band to meet a set of volumetric properties at a given laboratory compaction effort. This project will document the state of the practice in performance specifications for asphalt mixtures and their use with traditional volumetric properties. Performance specifications can be performance-related and/or performance-based. Asphalt mixtures include both hot mix asphalt and warm mix asphalt, and are produced at a plant and may include mixtures that have been modified with recycled materials.

Volumetric properties may not provide optimum performance for mixtures that include recycled materials and/or certain types of modifiers. Some agencies have investigated performance specifications for asphalt mixtures. These specifications typically include tests for rutting and cracking. Other agencies are investigating mechanistic properties (i.e., dynamic modulus) in conjunction with implementing mechanistic-empirical pavement design. In addition, certain areas may require performance tests to address specific requirements such as studded tire wear and moisture susceptibility tests.

This synthesis documents the performance tests used in conjunction with volumetric properties for mixtures. Performance tests are intended to extend service life by guiding material selection (i.e., asphalt binder and aggregate) and proportions (i.e., asphalt content and gradations). The results will benefit government agencies, researchers, and the road building industry by providing guidance on making better use of recycled materials, while also providing better performing and more cost-effective asphalt mixtures for specific applications. The synthesis provides examples of engineering tools used in the development and implementation of performance specifications for asphalt mixtures, examples of the contents of performance-based specifications (PBS) currently used or in development, information on test program implementation and research related to PBS for asphalt mixtures, and the reported benefits and challenges with implementing PBS. The findings of this study are intended to provide state departments of transportation (DOTs), Canadian provincial ministries of transportation (MOTs), and local public agencies with useful information on how to more effectively implement performance testing required as part of PBS for asphalt mixtures and on how to better communicate any implementation benefits and challenges to paving industry partners.

The information for this synthesis was gathered through a comprehensive literature review, a survey of DOTs and other transportation agencies, and detailed interviews with multiple organizations in the United States and Canada selected for further study. Forty-six DOTs (45 states and the District of Columbia) responded to the survey, a response rate of 90% (45/50). In addition, responses were received from 10 Canadian provinces and three local agencies. After reviewing documentation in the literature and the detailed survey responses, the city of Edmonton (in Alberta, Canada) along with the states of Florida, Georgia, Louisiana, Maryland, Minnesota, New Jersey, Ohio, Texas, Utah, Virginia, and Wisconsin were selected for further review through interviews. Based on the content analysis of the interviews, six states and Edmonton were fully developed into case examples to display details related to the development and use of PBS, evaluation of performance testing, and implementation efforts

related to PBS conducted by these agencies. The following observations were made based on the agency survey data, detailed interviews, and the literature review.

- The literature review, survey responses, and interviews all indicated that a significant amount of research is underway, both in the United States and abroad, to generate the data and establish the criteria necessary to develop PBS for asphalt mixtures. The results indicated that a small number of DOTs and municipal agencies are currently using performance tests as part of standard mixture acceptance. The survey data indicated that the performance-based properties most commonly used and researched include the measurement of stiffness, thermal cracking, moisture resistance, and fatigue cracking.
- The current state of the practice reported for asphalt pavement mixture design and acceptance is using volumetric properties in conjunction with performance properties. In a few cases, performance tests such as the Asphalt Pavement Analyzer (APA) and Hamburg Wheel Tracking Device (HWTD), which both measure the rutting resistance and resistance to moisture damage, have been incorporated into standard practice, including production acceptance testing at the option of the engineer. It was reported that further research is also underway to address premature fatigue cracking.
- The survey data revealed that the HWTD test, APA test, bending beam rheometer, and flexural beam fatigue test were the most commonly used tests in support of PBS. There were 19 DOTs and three agencies in Canada that reported having the necessary equipment required for the laboratory testing that supports their PBS.
- The most frequently reported reasons for the use of performance specifications for asphalt mixtures were to achieve longer pavement service lives (in terms of resistance to rutting and cracking and other distresses) and to quantify the quality and encourage better construction of flexible pavements.
- The majority of states and Canadian provinces are building flexible pavements from asphalt mixtures produced with recycled materials such as reclaimed asphalt pavement, recycled asphalt shingles, crumb rubber or ground tire rubber, or warm mix additives. Many of these agencies reported that they require different test approaches than those used for traditional hot mix asphalt mixtures as a result of incorporating nontraditional mixture designs.
- A number of agencies have observed that Superpave mix designs may have issues when using recycled materials (e.g., recycled asphalt shingles and crumb rubber). Some of the issues noted by the agencies interviewed included overly dry mixes, increased stiffness, and development of premature cracking. For this reason, some agencies are working toward implementing a balanced mix design process that incorporates performance tests to achieve an optimal balance between rutting resistance and fatigue and thermal cracking resistance.
- Approximately one-third of the state DOTs reported both test time and cost as deciding factors in implementing PBS. The feedback provided through both the detailed survey responses and interviews was that tests need to be straightforward, relatively quick, and easy to perform. Other reasons included for the tests to be accepted by industry and the affordability of the test equipment both to purchase and to run (i.e., minimizing the number of staff and amount of staff time).
- The survey data indicated that few agencies (two state DOTs, two MOTs, and one Canadian city) are currently assessing the costs and benefits of using PBS. However, the data collected indicates momentum in moving forward with performance specifications because 15 state DOTs and one MOT reported that they are planning to assess these factors in the future.
- Substantial research is underway by a number of agencies focused on developing PBS, in conjunction with mechanistic properties, for mix acceptance and production acceptance.

CHAPTER ONE

INTRODUCTION

This chapter introduces background information and highlights the objectives, organization, and key definitions used in the report. The synthesis summarizes a collection of available literature on performance specifications for asphalt mixtures. There was a particular emphasis on reviewing the types of performance testing used to support the specifications related to nontraditional asphalt mixtures that use a variety of production techniques or mixture additives. Transportation agencies were surveyed to determine their current and future use of performance specifications for asphalt mixtures, including the contents and basis for acceptance of asphalt mixtures using performance specifications, test program implementation and research efforts underway, development of contract provisions and pay factors, and the benefits and challenges to implementation. The survey and interview processes used in generating information in the synthesis are also described. The focus of the synthesis was on plant-produced asphalt mixtures and did not consider preservation and maintenance type mixtures; however, if an agency provided information on such mixtures, the comments have been included in the summary response tables.

BACKGROUND

Superpave Mix Design

The Superpave mix design was developed as part of the Strategic Highway Research Program (SHRP) that occurred from 1987 to 1993. The objective was to develop a performance-based asphalt binder specification, a performance-based asphalt mixture specification, and a mix design system. The asphalt binder performance-graded (PG) specification used today is the result of that research.

The attempt to develop a performance-based mix specification was less successful. Although the research program developed performance tests for asphalt mixture and models to predict mixture response (stress, strain, etc.) and to predict mixture performance (rutting, fatigue cracking, thermal cracking) the system ended up being too difficult to implement and was never used by state departments of transportation (DOTs).

The Superpave mixture design system developed during SHRP had three levels of increasing complexity, referred to as Level 1, Level 2, and Level 3 mix design. Performance-based mixture tests were to be used in the Level 2 and Level 3 designs. Originally, Superpave was to be developed solely on performance-based properties. As the SHRP research progressed it became apparent that testing and analysis for the performance predictions would be too complex for many routine projects. Therefore, a simple empirical design method (Level 1) was developed as the base or entry level mix design. After the SHRP initiative, when the performance-based tests and models were not implemented, the base mix design method specified in AASHTO M 323 became known as Superpave (AASHTO 2004). As a result, as implemented Superpave is based on consensus mixture properties such as air voids, voids in mineral aggregate (VMA), etc. The key components of Superpave Level 1 and the decisions made about them are as follows: compaction was to be done with a gyratory compactor; air voids calculated using the theoretical maximum specific gravity and the test specimen's bulk specific gravity; VMA calculated using aggregate bulk specific gravity; voids filled with asphalt (VFA) and aggregate gradation using control points and a restricted zone (that was later removed from the specification); coarse aggregate angularity expressed as crushed faces; and, fine aggregate angularity to control the percentage of natural sand.

Today's mix design technology (Superpave) represents an evolution of ideas that been evaluated through the years. The limitation of Superpave (as well as the previous methods of Marshall and Hveem) is its inability to measure expected performance; specifically, to predict rut resistance, fatigue cracking, low temperature cracking, asphalt binder aging, or resistance to moisture damage. Instead, all three methods use surrogate properties to control performance properties. For example, rutting is controlled by the aggregate properties (e.g., crushed faces on coarse aggregate and fine aggregate angularity on fine aggregate) and the volumetric properties (e.g., air voids and VFA). Fatigue cracking is controlled by the asphalt content, while low temperature cracking is controlled by the low temperature grade of the asphalt binder and the asphalt binder content. The mixture aging is a function of asphalt content, and moisture damage depends on asphalt binder content and the bond strength of asphalt-aggregate interface enhanced by antistrip agents. It is recognized that these are properties of the mix design.

In service, the performance of the mixture is controlled by rutting (influenced by traffic characteristics, high temperature environment, and in-place density); fatigue cracking (controlled by pavement deflection and weather, in as much as it controls deflection); low temperature cracking (induced by weather-related factors such as low temperature and cooling cycles); mixture aging (due to high temperature environment factors such as extreme temperatures and duration of hot weather, and the in-place density); and moisture damage (affected by in-place density and by traffic, in which the load pulses play a role).

Asphalt Mixture Performance Tests

SHRP sought to identify and develop test methods for properties that could be used to predict pavement response and thereby expected pavement performance. In October 1990, a group of senior members from FHWA, state DOTs, and industry made a technology tour of Europe, where they were introduced to mixture performance tests developed at the Laboratoire Centrale des Ponts et Chausees (LCPC). LCPC had developed a wheel-tracking test to measure rutting susceptibility and a trapezoidal fatigue test to measure fatigue cracking potential. These test methods, or similar variants, were suggested for the SHRP program, but were discounted as being nonfundamental.

During the late 1990s and early 2000s, the European Union harmonized specifications for asphalt mixture design. The harmonized specifications (Execution Des Assisses des Chausees Couches de Liaison et Couches de Roulement 2008) adopted a hierarchal approach to mix design, which defined various levels to include:

- Level 0—Aggregate gradation and asphalt content.
- Level 1—Volumetric properties of gyratory compacted plus moisture damage test.
- Level 2—Tests from Level 1 plus wheel tracking rut test.
- Level 3—Tests from Level 2 plus dynamic modulus.
- Level 4—Tests from Level 3 plus fatigue testing.

As Superpave was adopted in North America during the late 1990s and early 2000s there was increasing interest in adoption of tests that were targeted for specific asphalt mixture distresses. During the 1980s, rutting was recognized as a major national issue and the interest in a performance test based on rut testers began to emerge. Moisture damage has remained an issue of great interest in some parts of the country and the confidence in the Tensile Strength Ratio (TSR) test adopted as part of Superpave was low; thus, alternative tests were identified in lieu of TSR.

Following the implementation of Superpave mix design, the occurrence of rutting in asphalt pavements has been significantly less common. More recently cracking, predominantly top-down cracking, has become more common and as a result there has been increased interest in the development and use of cracking tests.

This synthesis seeks to identify performance tests being used by DOTs.

An awareness of materials variability, coupled with advances in testing, increased use of statistical concepts, and improved understanding of materials behavior led researchers to pursue the following complementary lines of inquiry over the past several decades:

- **Performance specifications—**How can we develop and implement more performance-oriented construction specifications that would support the use of acceptance parameters and pay adjustments that are more indicative of how the finished product will perform over time? How can the appropriate warranty period be determined? How can we work with contractors to invest in their product beyond the limits of the contract?
- **Performance-based mixture designs—**How can a performance-based approach to developing and testing mixture designs be incorporated that will provide for satisfactory pavement performance (i.e., optimal balance between rutting and cracking resistance) over a wide range of service conditions and source materials?

The results of such research are being used or piloted by several transportation agencies to improve the long-term performance and cost-effectiveness of their asphalt pavements.

PERFORMANCE SPECIFICATIONS FOR ASPHALT PAVEMENTS

Much of the research related to performance specifications for asphalt pavement has focused on the implementation of pay adjustment systems to address the expected future performance of the in-place pavement. A common payment approach, as incorporated in today's quality assurance (QA) specifications, involves statistically based sampling and testing plans that consider the measured variability of the product to determine pay adjustment factors. A more rational approach, as promoted in performance-related specifications (PRS), uses predictive models to assign pay adjustments based on the difference between the as-designed and as-constructed life-cycle cost of the pavement.

Quality Assurance Specifications

The high construction and materials variability observed in the AASHTO Road Test suggested that the traditional prescriptive specifications used by highway agencies at the time could not adequately control the construction process. This realization led to the development and implementation of so-called QA specifications, which addressed the issues of testing and test variability, sample size, lot size, estimates of the total population, percentage within limits, and pay adjustment factors.

Over time, QA specifications gained widespread acceptance as an improved method for determining the contractor's degree of compliance with specification limits. Various surveys of state DOTs, conducted in 1997, 2000, 2002, and most recently in 2005, have demonstrated the increasing use of QA specifications over the last 20 years. The study by Elmore et al. (1997) included a survey of state DOTs to determine which items are being controlled by these specification types, what parameters are measured, how pay factors are determined, and who conducts the testing (agency or contractor laboratories). All 19 of the responding agencies reported that they use QA specifications for hot mix asphalt (HMA). Nine of the 19 agencies indicated that they have a pay incentive included in the specifications, while 11 have disincentives, clauses that could result in a pay reduction or require rework of the completed pavement. The parameters that were most frequently reported as being used for determining pay factors were asphalt content (by all 11 states with pay factors), in-place density (by 11 states), gradation (by eight states), VMA (by five states), and laboratory-compacted density (by four states).

In a relatively short period, use of QA specifications spread to several other DOTs, as captured in the findings from surveys conducted in 2000 (FHWA 2001) and 2001 (Ksaibati and Butts 2003). In the FHWA survey (2001), many DOTs (including the District of Columbia and Puerto Rico) responded that they either implemented a QA specification (21 states) or were in the process of developing one at that time (14 states). The response rate shifted a year later when the University of Wyoming survey reported that 90% (39 states) of the responding DOTs had implemented a QA specification for asphalt pavement (Ksaibati and Butts 2003).

Research related to QA specifications also focused on identifying the appropriate quality measures on which to base acceptance of the asphalt mixtures and/or in-place pavements. *NCHRP Synthesis 346,* which focused on various QA programs used by state DOTs, provided some insight into the quality measures used for HMA (Hughes 2005). A survey conducted in support of this research found that the measures used in QA testing programs circa 2005 included asphalt content (reportedly used by 40 DOTs), gradation (by 43 DOTs), and compaction (by 28 DOTs). Other reported measures included volumetric properties, ride quality, thickness, and moisture content.

Performance-Related Specifications

Although widely accepted as an improved method for determining compliance with specification limits, QA specifications still did not necessarily address product *performance,* as they were largely based on quality measures that were not directly tied to the performance of the asphalt mixture or the in-place pavement. Moreover, pay factors were often arbitrarily combined into a composite payment factor that did not necessarily relate to the reduced or enhanced value of the as-built pavement.

To address such limitations, research began to focus on the development of enhanced QA specifications, referred to as PRS, which would more directly relate quality measures to long-term performance. PRS are often referred to as the next generation of QA specifications, as they attempt to use predictive models to assign rational pay adjustments based on the difference between the as-designed and as-constructed life-cycle cost of the pavement.

Some of the original research related to the development of a prototype PRS for asphalt mixtures was conducted at the WesTrack site. WesTrack was an experimental test road facility located near Fallon, Nevada, sponsored by FHWA (Epps et al. 2002a, b). The primary project for WesTrack was entitled "Accelerated Field Test of Performance-Related Specifications for Hot-Mix Asphalt Construction," which listed two primary objectives: (1) to provide data to support the continued development of PRS and PRS software for HMA construction by examining how deviations in materials and construction properties (e.g., asphalt content and degree of compaction) affect long-term pavement performance, and (2) to provide field verification of the Superpave mix design procedures developed through the original SHRP Asphalt Research Program. The testing for this project included three experimental variables: asphalt content, air void content, and aggregate gradation. The results, which were summarized in terms of rut depths and percentage of the wheel path areas containing fatigue cracking, were used to develop simple empirical relationships for performance prediction to support a PRS.

Subsequent research to refine PRS models and software led to the development of the Quality-Related Specification Software (QRSS). QRSS is a stand-alone program that calculates the predicted performance of an HMA pavement from the volumetric and materials properties of the as-designed HMA and compares it with that of the as-built pavement calculated from the contractor's lot or sub-lot quality control data. It computes a Predicted Life Difference (PLD) based on fatigue, rutting, and thermal cracking that can be used to reward and/or penalize contractors for their product (Moulthrop and Witczak 2011).

Although PRS have seen only limited use to date potential future enhancements, such as the development and incorporation of more timely and reliable test methods and related criteria—particularly if consistent with the work being performed to advance performance-based mixture designs and mechanistic-empirical pavement structural design—could increase confidence in the predictive capabilities of the underlying performance models and make owners and industry more amendable to wider application of PRS.

PERFORMANCE-BASED MIXTURE DESIGN

For an asphalt mix to perform well in the field it must provide adequate resistance to the various distresses commonly associated with flexible pavement failure such as rutting, fatigue cracking, and thermal cracking. Conventional volumetric mixture design systems, however, provide only limited insight into such behavior, which has driven researchers and practitioners to explore the development of more performance-based mixture designs and related test methods that could be used to optimize the often competing performance needs of a pavement (e.g., adequate resistance to both rutting and cracking) to meet the unique characteristics of a given project or application.

One of the unmet goals of the original SHRP Asphalt Research Program was to develop such a performance-based mixture specification with supporting test methods and equipment. Although the resulting Superpave system led to sweeping changes in the design, selection, testing, and specification of asphalt materials, it still largely relies on surrogate properties and empirical relationships to control the performance of the mixture. To address this limitation, some DOTs have attempted to supplement their conventional volumetric criteria with more performance-based testing conducted to establish the mixture's resistance to common distresses. For example, wheel-tracking tests and the use of stiffer binders have been used to help prevent placement of rut-susceptible mixtures. However, without a timely and reliable method to evaluate fatigue performance, such measures can lead to increases in early cracking, a growing concern given today's increasing use of reclaimed asphalt pavement (RAP), recycled asphalt shingles (RAS), and other nonconventional modified mixtures that are often stiffer than those used in the past.

Performance-based mixture testing would more readily allow for the evaluation and inclusion of such locally available and/or innovative materials for which limited empirical data are available. This is of particular relevance today given recent initiatives to bring more additives to asphalt mixtures in the interest of environmental stewardship and/or fiscal responsibility. A number of additives to asphalt mixtures, such as RAP, RAS, and recycled tires such as ground tire rubber (GTR), have been explored to varying degrees. However, the impact of these additives on the flexible pavement's long-term performance is relatively unknown without extensive field validation.

For example, the use of asphalt roofing shingles in asphalt mixtures may improve the performance of the pavement, due to the increased stiffness compared with standard asphalt mixture designs (Calrecycle 2006). In addition, roofing shingles tend to improve the pavement's resistance to rutting, stability, compaction, rideability and index, and decreases temperature susceptibility. According to Calrecycle (2006), as of July 2006, the following DOTs were reported to permit the use of shingles in asphalt pavement, and to allow a certain percentage of shingles that may replace a portion of aggregate: Georgia (5%, manufacturing scrap only), Maryland (5%, manufacturing scrap only), Michigan and Minnesota (5%, manufacturing scrap only), Missouri (5% max), New Jersey (5%, manufacturing scrap only), North Carolina (5%, manufacturing scrap only), Ohio (allows a certain percentage as listed in specification), and Indiana (5%, manufacturing scrap only). The Calrecycle research also reported that past research conducted by the Florida DOT indicated that shingles can comprise 15% of the aggregate portion and still perform to the levels expected from standard HMA mixtures.

Development and implementation of practical and timely performance tests would allow pavement designers to better understand the expected behavior of these modified asphalt mixtures and allow for the tailoring of specific material requirements (e.g., stiffness, rutting, and cracking properties) to meet the needs of a given project.

SYNTHESIS OBJECTIVE

The objective of this synthesis is to provide state DOTs, Canadian provincial ministries of transportation (MOTs), and other public agencies with information on how to more effectively implement performance specifications and performance testing for asphalt mixtures. The scope of this synthesis focused on performance tests used in conjunction with volumetric properties for specifying both traditional and nontraditional plant-produced asphalt mixtures. Performance tests are intended to provide information to assist in extending service life by guiding material selection (i.e., asphalt binder and aggregate) and proportions (i.e., asphalt content and gradations). The results of this synthesis are intended to benefit government agencies, researchers, and the road-building industry in providing guidance on making better use of recycled materials, while also providing better performing and more cost-effective asphalt mixtures for specific applications. The report will help state and provincial materials engineers, construction, and design engineers, along with other transportation managers to better understand the state of the practice, challenges, and gaps in existing knowledge with respect to performance specifications for asphalt mixtures. Other aspects of this topic that are explored in this study include:

- Agency mix design specifications for plant-produced HMA or warm mix asphalt (WMA);
- Agency use of performance testing and how performance specifications were developed;
- Agency specification criteria (e.g., project selection criteria and testing done internally by agency staff or by external entities);
- QA procedures and supporting information; and
- Performance testing time, equipment availability, and benefit-to-cost analysis.

Various efforts have been made in recent years by some states and other public agencies to address the application of performance testing in making better use of pavement distress prediction models for achieving longer pavement service lives. There is a need to evaluate these efforts and obtain examples of practices that are reported to be effective in order to facilitate the exchange of information and to help other states.

The synthesis also includes suggestions for future research based on existing gaps identified through the literature review, survey, and agency interviews.

STUDY APPROACH

A multifaceted approach was taken to document the various efforts that have been made in recent years by some states and other agencies toward the development and implementation of performance specifications for asphalt mixtures. The approach to this synthesis included a literature review of federal, state, international, and regional research, and a survey of state, provincial, and other transportation agencies. In addition, detailed interviews with state and other agencies were conducted as suggested by the analysis of the survey responses. The following sections provide more detail on each step in the approach.

Literature Review

A number of resources were consulted including the Transport Research International Documentation (TRID), Internet and web searches, FHWA and DOT internal reports, journal publications, conference proceedings, transportation agency specifications and standards, and resources of professional associations. A comprehensive literature review of sources both in the United States and internationally was used to establish current practice and emerging trends related to the use of performance specifications on asphalt paving projects.

Survey of State and Other Transportation Agencies

The survey consisted of 40 questions and was sent to members of the AASHTO Research Advisory Committee with a recommendation for distribution through the DOT research director's office to the DOT materials engineers to complete the survey. The survey was sent to contacts in each of the state DOTs; Washington, D.C.; 11 Canadian MOTs; five ports; three cities; two counties; and two turnpike authorities. Ninety percent (45/50) of all DOTs responded to this synthesis survey. The survey questions and results are included in Appendix A of this report and the full list of respondents is provided in Appendix B. Ten Canadian MOTs, the District of Columbia, two counties, and one city also provided responses to the survey and their responses are indicated separately within the text and in the tables of the appendix. The maps in Figures 1 and 2 show the agencies in the United States and Canada, respectively, that responded to the survey,

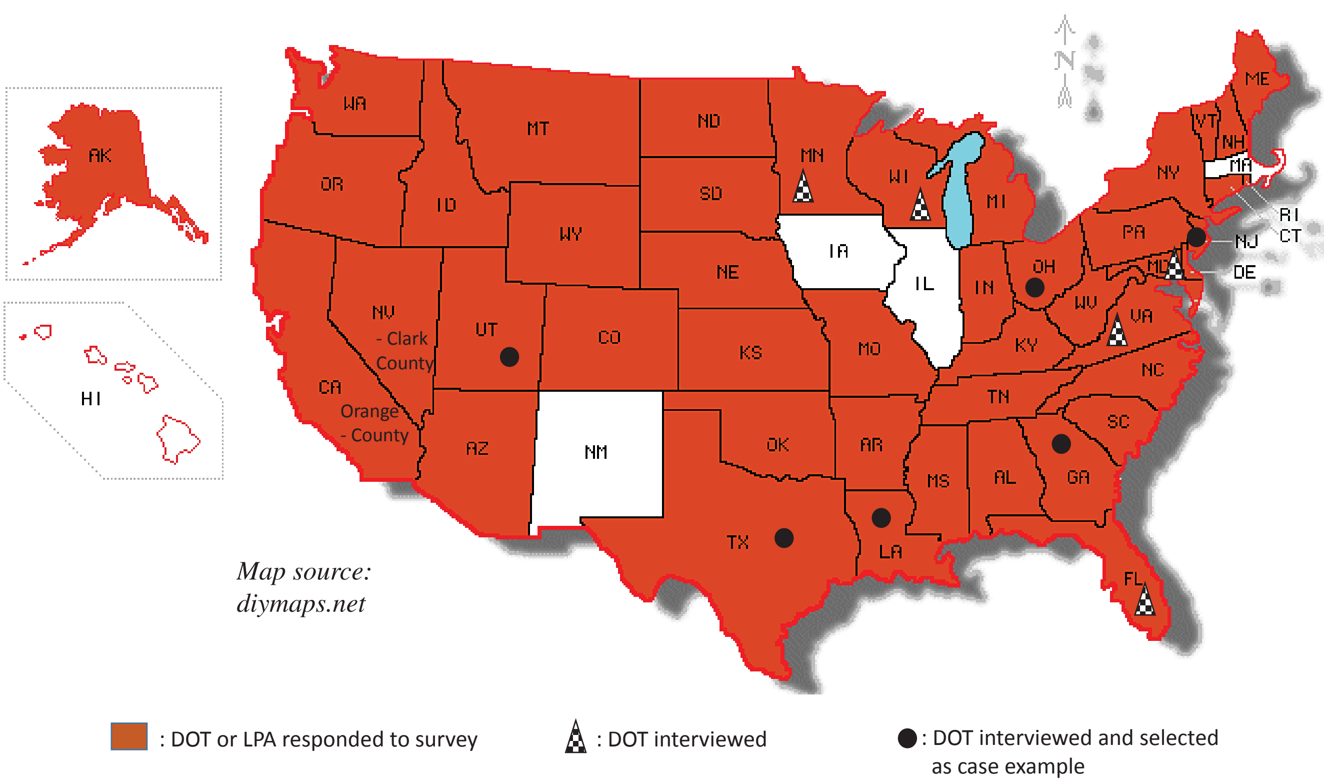


FIGURE 1 Location of U.S. agencies that responded to the survey, were interviewed, and were selected as case example agencies.

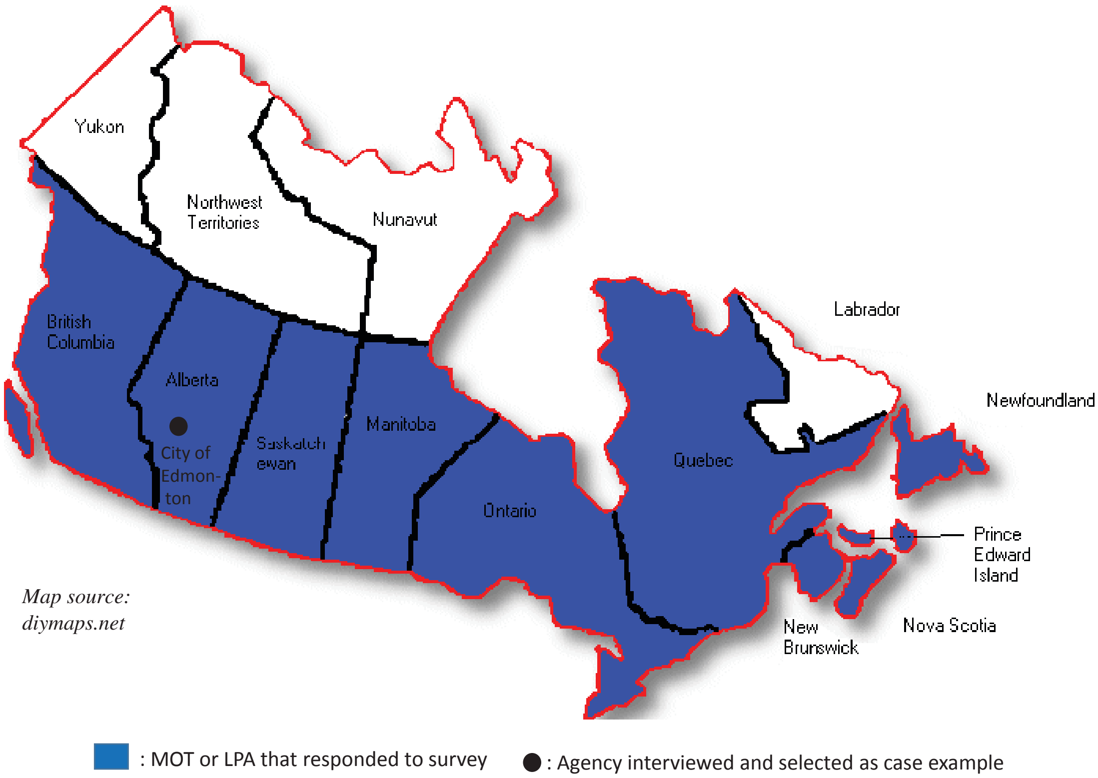


FIGURE 2 Location of Canadian agencies that responded to the survey, were interviewed, and were selected as case example agencies.

specific agencies that were interviewed, and indicates the agencies that were ultimately selected to serve as the case examples, which will be presented in chapter four.

Interviews with Transportation Practitioners in Case Example Agencies

Based on the results of the survey responses, 11 states and one local agency were selected for additional data gathering on practices used related to the use of performance specifications for asphalt paving mixtures. A number of criteria were considered in the selection of these agencies to be interviewed; however, priority was given to agencies that provided detailed responses based on (1) agencies that reported they have substantially moved into the development or use of performance specifications; (2) geographical distribution of states in order to reflect a national perspective and varying climatic conditions; and (3) variety of paving program sizes. It was critical to include agencies in which performance testing has been implemented into specifications for an extended period of time.

At least one representative from each of the organizations was interviewed over the phone or, in some cases, by e-mail, to gather input on issues and practices in their state related to the status of performance specifications and performance testing of asphalt mixtures. A listing and sampling of documents obtained as examples of current practice are included in web-only Appendix D.

REPORT ORGANIZATION

This synthesis report is organized into five chapters. The balance of chapter one presents the report's structure with brief explanations of each chapter's content and defines some of the key terms used throughout the report.

Chapter two describes asphalt performance testing and types of specifications that use the results of performance testing as documented in published literature of federal, state, international, and regional research. Each section of the chapter provides a summary from the literature that focuses on findings related to the types and use of performance specifications for asphalt mixtures, performance tests for asphalt mixtures, pay adjustment factors in performance specifications, and research on the advancement of performance specifications for asphalt mixtures.

Chapter three presents the results from a survey of all state DOTs, provincial MOTs, and other agencies along with the provision of the survey response rates. It provides the state of the practice in many states on the extent to which performance specifications have been developed and implemented. The sections of this chapter are organized to provide a summary of the findings from the survey related to the basis for acceptance of asphalt mixtures using performance specifications, contents of performance specifications for asphalt mixtures, and test program implementation. Another section presents the survey findings related to the development of contract provisions and pay factors for asphalt performance specifications. The chapter closes with a presentation of the benefits and challenges to performance testing of asphalt mixtures, as reported by the transportation agencies. The majority of the information presented in this chapter was obtained through surveys of all 50 states and the District of Columbia, with contributions from personnel in Canadian provincial transportation agencies, one city, and two counties.

Chapter four examines the specific examples of state and local practices related to performance specifications used for the construction of flexible pavements. Detailed interviews were conducted with a number of states and a local agency and these agencies were selected based on their survey responses. The case examples also summarized practices reported in the following key areas: details on the projects that have used performance specifications and outcomes from these projects; post-construction monitoring of projects that used performance specifications; testing protocols; and responsibility for laboratory testing. The majority of the information presented in this chapter was gathered through the detailed interviews with multiple personnel in various agencies or organizations in a number of states and one city that were selected for further study.

Chapter five concludes the synthesis with a summary of findings and suggestions for further study. Key findings are summarized in several areas and the documented practices are drawn from the literature review, results of the state agency survey, and interviews. These chapters are followed by a glossary, a reference section, a bibliography, and four appendices. Appendix A includes a copy of the survey questions along with graphical and tabular presentation of the survey results. Appendix B is a list of the agency survey respondents. Appendix C includes links to resources that were provided by agencies through their survey responses or during the in-depth interviews. Web-only Appendix D presents several sample documents that were offered by agencies as a result of the interviews for sharing as examples.

DEFINITIONS

Key definitions related to specification types and key properties and types of asphalt mixtures, as used in the context of this report, are provided here. Additional terms are defined within the context of their relevant sections. A glossary is also included at the end of the report that further defines acronyms and abbreviations used in the report.

Specification Types

The definitions were adapted, as applicable, from the sixth edition of *TRB Circular E-C173: Glossary of Transportation Construction Quality Assurance Terms* (2013).

End result specifications: Specifications that require the contractor to take complete responsibility for supplying a product or an item of construction. The highway agency's responsibility is to either accept or reject the final product or to apply a pay adjustment commensurate with the degree of compliance with the specifications.

Performance specifications: Specifications that describe how the finished product should perform over time. For highways, performance is typically described in terms of changes in the physical condition of the surface and its response to load, or in terms of the cumulative traffic level that degrades the pavement into a condition that can be defined as failed.

Performance-based specifications: Quality assurance specifications that describe the desired levels of fundamental engineering properties (e.g., resilient modulus, creep properties, and fatigue properties) that are predictors of performance and appear in primary prediction relationships (i.e., models that can be used to predict pavement stress, distress, or performance from combinations of predictors that represent traffic, environmental, roadbed, and structural conditions).

Performance-related specifications: Quality assurance specifications that describe the desired levels of key materials and construction quality characteristics that have been found to correlate with fundamental engineering properties that predict performance. These characteristics [e.g., air voids in asphalt concrete (AC) and compressive strength of portland cement concrete (PCC)] are amenable to acceptance testing at the time of construction.

QA specifications: A combination of end-result specifications and materials and methods specifications. The contractor is responsible for quality control (QC) (process control), and the highway agency is responsible for acceptance of the product.

Types and Properties of Asphalt Mixtures

The following definitions related to key properties and types of asphalt mixtures were adapted primarily from NCHRP or FHWA reports; however, it can be noted that these terms may vary in different states and one must refer to the specific state specifications.

Asphalt mixtures: For the purposes of this synthesis, the term "asphalt mixtures" is intended to represent any HMA or WMA that is produced at the plant. This term includes mixtures that have been modified with the use of recycled materials (e.g., RAP, RAS, crumb rubber from recycled tires or GTR) and other additives. This term does not include maintenance mixtures (e.g., cold mix asphalt and seal coats) or in-place recycled mixtures (e.g., hot-in-place recycled asphalt and cold-in-place recycled asphalt).

Durability: In the context of asphalt pavement, durability is defined is the ability to withstand wear, pressure, damage, or repeated use over a relatively long period, usually several years or more. It is synonymous with longevity and for asphalt pavement can mean a mixture's resistance to raveling, rutting, fatigue and thermal cracking, or moisture damage. Durability also relates to the aging of the asphalt binder over time.

Dynamic modulus $|E^*|$: This is the ratio of stress to strain under vibratory conditions (calculated from data obtained from either free or forced vibration tests, in shear, compression, or elongation). It is a property of viscoelastic materials.

Fatigue: In materials science, fatigue is the weakening of a material caused by repeatedly applied loads. It is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The nominal maximum stress values that cause such damage may be much less than the strength of the material typically quoted as the ultimate tensile stress limit or the yield stress limit. For asphalt pavements, fatigue is manifested by the propagation of cracks in the pavement materials over time.

High RAP asphalt mixtures: NCHRP Report 752: Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content (West et al. 2013) defined high RAP asphalt mixtures to include RAP content that is greater than 25% and may exceed 50%. As a result, this report generally assumes high RAP to be defined as in *NCHRP Report 752;* however, it should be recognized that each individual agency's definition of high RAP may be slightly different in terms of the percentage of RAP content.

Rutting: A rut is a depression worn into a roadway resulting from permanent deformation (strain) in the pavement or subbase material caused by repeated wheel loading. Ruts can also be formed by wear, as from studded snow tires common in cold climate areas.

Stiffness: The stiffness of a material, characterized by the elastic or resilient modulus, is a measure of the extent to which pavement resists deformation in response to an applied force.

Warm mix asphalt: The FHWA Long Term Pavement Performance program has defined warm mix asphalt in their current WMA SPS-10 experiments as asphalt mixtures produced at either 275°F or less or at 30°F below the HMA production temperature. As a result, this report generally assumes WMA to be defined as in the FHWA program; however, it should be recognized that each individual agency or group of agencies (such as in the case of the Northeast Asphalt User-Producer Group), definition of WMA may be slightly different in terms of the percentage of RAP content. More discussion on the definition of WMA can be found in *NCHRP Research Results Digest 374* (2012).

CHAPTER TWO

LITERATURE REVIEW ON PERFORMANCE SPECIFICATIONS FOR ASPHALT MIXTURES

INTRODUCTION

This chapter provides an overview of the specific types of testing used to predict the asphalt mixture performance and on the types of performance specifications used both nationally and internationally for plant-produced asphalt mixtures. The information reported will assist in defining the amount to which performance specifications for asphalt have been developed and implemented. This is accomplished through a review of published literature, university and other research reports, and information publicly available on transportation agency websites.

Pavement performance was defined by Von Quintus (2009) as "changes in the pavement surface condition over time" and pavements that have excellent performance show little surface distress and have a smooth riding surface over the intended design period. Furthermore, an ideal pavement was defined as consisting of a sustained long-lasting structure, having a smooth surface (both at the time of construction and over time), and requiring low levels of maintenance and rehabilitation over time (Von Quintus 2009). This paper presents the ideal asphalt pavement performance characteristics in terms of the pavement smoothness and measurable levels of various distress types including rutting, load-related fatigue cracking, alligator cracking, longitudinal cracking in the wheel path, longitudinal cracking not in the wheel path, and transverse cracking. It also introduced the performance attributes required for designing and constructing long-life flexible pavements.

LITERATURE REVIEW ON PERFORMANCE TESTS FOR ASPHALT MIXTURES

In this section, the test procedures and equipment used for asphalt mixtures are summarized, including information on testing of various types of asphalt mixtures [e.g., WMA and stone matrix asphalt (SMA)] and materials (e.g., binder modifiers, RAS, and RAP). This section also summarizes literature findings related to optimum performance for mixtures with recycled materials, optimum performance for mixtures with modifiers, and performance tests and volumetric properties for asphalt mixtures. A summary of the various tests discussed in this section is presented in Table 1, including associated test methods, applicability, and implementation issues.

The concept of tying mixture parameters to a PRS was first explored in the WesTrack studies in the late 1990s (Epps et al. 1999). Asphalt mixtures included in the WesTrack experiment were tested using the Superpave indirect tensile (IDT) creep and strength test and the thermal stress restrained specimen test (TSRST) to predict the mixture propensity to crack at low temperatures and to fail in fatigue. The fatigue tests were performed on beam specimens from both original and reconstructed sections of the test track, whereas probabilistic empirical performance prediction equations were developed for predicting the future deformation and fatigue cracking of asphalt mixes. The study determined that the most important mix parameter for fatigue cracking is compaction, and as the degree of compaction increased, the fatigue cracking potential significantly decreased. The asphalt content, level of compaction, pavement temperature, and aggregate gradation were all reported to have an impact in predicting each mixture's future rutting performance.

Accelerated Pavement Testing

NCHRP Synthesis Report 433 presented significant findings from full-scale accelerated pavement testing documents and summarized the significant findings from the various experimental activities associated with full-scale accelerated pavement testing programs (JvdM Steyn 2012). The focus was on activities that took place between 2000 and 2011. The report identified that agencies viewed a major benefit of full-scale accelerated pavement testing programs was to assess improved performance modeling and the development of PRS. A number of agencies noted that they were performing benefit–cost ratio evaluations of their full-scale accelerated pavement testing facilities.

Dynamic Modulus

The use of the dynamic modulus as a property for assessing asphalt pavement performance, based on its role in the mechanistic–empirical pavement design method, was studied by Jeong et al. (2015). The research builds on the concept of dynamic modulus potentially being one of the major characteristics in PRS for QA. The study reported that there is currently no feasible method of estimating the mean and variance of the in-place dynamic modulus for the as-built asphalt

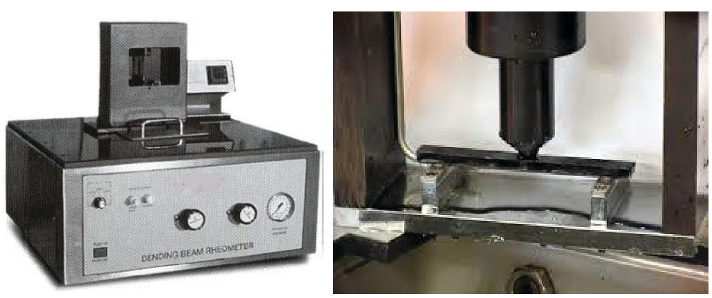
TABLE 1
SUMMARY OF KEY FEATURES OF PERFORMANCE TESTS FOR ASPHALT MIXTURES

PERFORMANCE TESTS FOR ASPHALT MIXTURES

Asphalt Pavement Analyzer

Test Method:	AASHTO TP 63: Determining Rutting Susceptibility of Asphalt Paving Mixtures Using the Asphalt Pavement Analyzer (APA)
Applicability:	The Asphalt Pavement Analyzer (APA) is a second generation device that was originally developed in the mid-1980s as the Georgia Loaded Wheel Tester; a device designed for rut proof testing and field quality control. The APA tracks a loaded aluminum wheel back and forth across a pressurized linear hose over a HMA sample. Although the APA can be used for a number of tests, it is typically used to measure and predict rutting.
Implementation:	➢ Test time: An 8,000 cycle test takes about 8.5 hours (6 hours to preheat the samples plus about 2.5 hours for the 8,000 cycle test and rut measurements). Creation and preparation of the samples can take upwards of several days depending upon conditioning times.

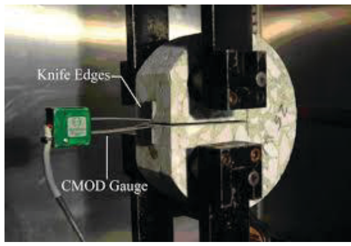
Bending Beam Rheometer

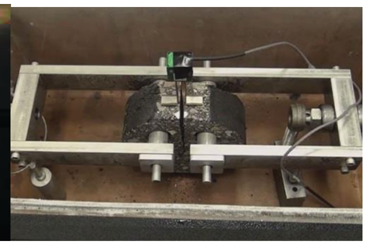


Test Method:	AASHTO T 313: Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR) AASHTO PP 42: Determination of Low-Temperature Performance Grade (PG) of Asphalt Binders for the Superpave PG Binder Specification
Applicability:	Provides a measure of low temperature stiffness and relaxation properties of asphalt binders. These parameters give an indication of an asphalt binder's ability to resist low temperature cracking.
Implementation:	➢ Ease of measurement—most labs not equipped to do this ➢ Time to process test data—slow ➢ Cost of equipment, measurements/tests—Cost ($125–150k) for unit ➢ Technician skills required—medium to high

TABLE 1
(*continued*)

Disc-shaped Compact Tension (DSC) Fracture Energy Test





Test Method:	ASTM D7313-13. Standard Test Method for Determining Fracture Energy of Asphalt–Aggregate Mixtures Using the Disk-Shaped Compact Tension Geometry
Applicability:	Determines the fracture resistance of asphalt–aggregate mixtures. The fracture resistance can help differentiate mixtures whose service life might be compromised by cracking. The test is used to obtain the fracture energy of asphalt mixture lab or field specimens, which can be used in performance-type specifications to control various forms of cracking such as thermal, reflective, and block cracking of pavements surfaced with asphalt concrete.
Implementation:	➢ Similar time and cost to perform other mixture and binder performance tests. Researchers at the University of Illinois have determined the average fabrication time per specimen to be in the 10 to 15 minute range for DC(T) testing, which includes the four saw cuts and two cored holes. This is based on mass production of at least a dozen test specimens. The fabrication of fewer test specimens will lead to a longer per-specimen preparation time. Thus, combined with testing time, each DC(T) test will take approximately 30 minutes of technician time for specimen preparation and testing when larger batches of specimens are tested. Material testing labs are currently charging in the neighborhood of \$200 per test specimen (replicate) for DC(T) testing, and somewhat less for larger quantities of specimens (\$150 per test). ➢ Equipment costs can range from \$10–50K depending on whether a cooling chamber is required.

Dynamic Modulus Test

Test Method:	AASHTO TP 62-07 (2009) Determining Dynamic Modulus of Hot Mix Asphalt (HMA)
Applicability:	Dynamic modulus values measured over a range of temperatures and frequencies of loading can be shifted into a master curve for characterizing asphalt concrete for pavement thickness design and performance analysis. The values of dynamic modulus and phase angle can be used as performance criteria for asphalt concrete mix design.
Implementation:	➢ Equipment cost, manpower, and testing proficiency issues ➢ Specimen preparation and testing time ➢ Determining specification values

(*continued on next page*)

TABLE 1
(*continued*)

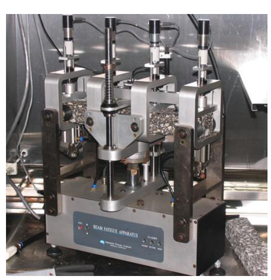
AMPT **Flow Number Testing** 	
Test Method:	AASHTO TP 79-10, Standard Method of Test for Determining the Dynamic Modulus and Flow Number for Hot Mix Asphalt (HMA) Using the Asphalt Mixture Performance Tester (AMPT)
Applicability:	The AMPT is actually a testing machine capable of performing several tests relating to HMA performance. The SPT can perform a flow time test, a flow number test (a repeated load test), and a dynamic modulus test. It can measure fundamental properties related to rutting and cracking susceptibility (Pavement Interactive 2010).
Implementation:	➢ AMPT cost. Manpower and testing proficiency are issues ➢ Specimen preparation and testing time. Further guidance on specimen preparation is needed. The guidance should include details on support equipment requirements and potential sources and best practices for technicians to prepare AMPT specimens (NCAT 2013). ➢ Determining specification values
AMPT **S-VECD**	
Test Method:	AASHTO TP 107-14. This test method covers procedures for preparing and testing asphalt concrete mixtures to determine the damage characteristic curve via direct tension cyclic fatigue tests
Applicability:	Fatigue performance—An advanced testing protocol using the AMPT for the simplified viscoelastic continuum damage (S-VECD) model has been developed in an AASHTO standard. Push-pull cyclical results from the S-VECD testing can be obtained in two days, which is much quicker than traditional beam fatigue testing.
Implementation:	➢ Speed of measurement (i.e., real time)—medium, faster than beam fatigue ➢ Ease of measurement—medium, cutting edge—most labs not equipped to do this ➢ Time to process test data—medium ➢ Cost of equipment, measurements/tests—Cost of AMPT is high but add-on is modest ($12–15K) if added to an existing AMPT used for rutting. ➢ Technician skills required—medium-high ➢ Repeatability and accuracy—to be determined ➢ Standardized measurement (ASTM, AASHTO, agency, etc.)—Yes—AASHTO draft out ➢ Special calibration requirements—Yes
Flexural (Bending) Beam Fatigue 	
Test Method:	AASHTO T 321: Determining the Fatigue Life of Compacted Hot-Mix Asphalt (HMA) Subjected to Repeated Flexural Bending ASTM D7460-10: Standard Test Method for Determining Fatigue Failure of Compacted Asphalt Concrete Subjected to Repeated Flexural Bending

TABLE 1
(*continued*)

Applicability:	The flexural fatigue test is used to characterize the fatigue life of HMA at intermediate pavement operating temperatures. The laboratory fatigue life determined by this standard has been used to estimate the fatigue life of asphalt concrete pavement layers under repeated traffic loading. Although the field performance of asphalt concrete is impacted by many factors (traffic variation, speed, and wander; climate variation; rest periods between loads; aging; etc.), it has been more accurately predicted when laboratory properties are known along with an estimate of the strain level induced at the layer depth by the traffic wheel load traveling over the pavement.
Implementation:	➢ Also called four-point beam bending test, most accepted fatigue test in the United States. It is a standard test method for determining the fatigue life of compacted hot mix asphalt (HMA) subjected to repeated flexural bending. ➢ Testing time is dependent on the strain level chosen for the test. High strain (400–800 microstrain) may be completed in a few hours. Low strain tests (200–400 microstrain) can take several days. Even lower strain levels (50–100 microstrain) can take upwards of a month. Typically 8 to 10 samples are used to develop results for any mix. Hence, it may take several days to several weeks to develop sufficient fatigue data to allow analysis of a given mixture. ➢ It has not been widely implemented by transportation agencies because of two main issues: specimen preparation and testing time. Compared to a cylindrical specimen, it is more expensive and difficult to prepare a beam specimen in the laboratory or extract a beam from a pavement section for testing. In addition, a BBF test can take up to more than 50 days depending on the selected strain level. Thus, it is not used for routine asphalt mix design or quality assurance/quality control (QA/QC) testing, which often requires a quick turnaround.
Hamburg Wheel Tracking Test 	
Test Method:	AASHTO T324, Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Hot-Mix Asphalt (HMA)
Applicability:	Laboratory wheel-tracking devices are used to run simulative tests that measure HMA qualities by rolling a small loaded wheel device repeatedly across a prepared HMA specimen. Performance of the test specimen is then correlated to actual in-service pavement performance. Laboratory wheel-tracking devices can be used to make rutting, fatigue, moisture susceptibility, and stripping predictions. Some of these devices are relatively new and some have been used for upwards of 15 years such as the French Rutting Tester (FRT). The Hamburg Wheel Tracking Device (HWTD), developed in Germany, can be used to evaluate rutting and stripping potential. The HWTD tracks a loaded steel wheel back and forth directly on a HMA sample. Tests are typically conducted on 10.2 x 12.6 x 1.6 inch (260 x 320 x 40 mm) slabs (although the test can be modified to use SGC compacted samples) compacted to 7 percent air voids with a linear kneading compactor. Most commonly, the 1.85 inch (47 mm) wide wheel is tracked across a submerged (underwater) sample for 20,000 cycles (or until 20 mm of deformation occurs) using a 158 pound (705 N) load. Rut depth is measured continuously with a series of LVDTs on the sample. Several modified HWTDs have been produced in the United States with the principal modifications being loading force or wheel type.

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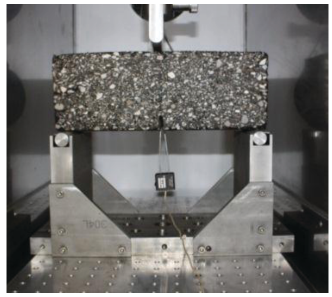
TABLE 1
(*continued*)

Implementation:	➢ Presence of detailed equipment requirements may limit the use of Hamburg test equipment manufactured by other companies. T 324 details specific equipment requirements that appear to be written around the original Hamburg wheel-track equipment available in the United States from Precision Machine & Welding (PMW). There is an initiative to make the standards more generic (to allow use of other company's equipment). ➢ Users must be careful to establish laboratory conditions (e.g., load, number of wheel passes, temperature) that produce consistent and accurate correlations with field performance. ➢ Performance is largely PG driven. The higher the High Temperature Grade, the lower the rut depth. The higher the use of recycled material, the lower the rut depth. ➢ HWTD: encourages high RAP and stiff mixes that will result in increased fatigue and low temp cracking. Need companion test(s) to identify mixes that are overly stiff.
Shear Tester 	
Test Method:	AASHTO T 320: Determining the Permanent Shear Strain and Stiffness of Asphalt Mixtures Using the Superpave Shear Tester (SST)
Applicability:	The Superpave Shear Tester (SST) is used to characterize a HMA mixture's resistance to permanent deformation (rut resistance). This characterization can be used as a performance test for HMA mixtures designed using Superpave mix design or other mix design procedures. The most common SST tests, the repeated shear at constant height (RSCH), and the frequency sweep at constant height (FSCH) tests subject a short HMA cylinder to repeated shear in a pulse manner (RSCH) or a range of loading frequencies (FSCH) in a controlled atmosphere. The SST can measure many parameters but the most typical are permanent shear strain, shear dynamic modulus (|*G**|), phase angle (φ), maximum shear strain, and recovery.
Implementation:	➢ The SST tests are sensitive to sample compaction method. Samples compacted with the SGC (the standard method) tend to exhibit greater resistance to permanent deformation than cores extracted from the field or samples compacted with the rolling wheel compactor. Rolling wheel compacted samples show about the same resistance to permanent deformation as field cores. This is why some researchers advocate the use of the rolling wheel compactor when making SST and other HMA test samples. ➢ Test time is an issue. It takes about 1 week for sample preparation and testing in the SST. About 2 days of this is actual time in the SST.

TABLE 1
(*continued*)

Semicircular Bending Test



Test Method:	Proposed AASHTO Test Method for Determining the Fracture Energy of Asphalt Mixtures Using the Semi Circular Bend Geometry
Applicability:	SCB test is used to obtain the fracture energy of asphalt mixture lab or field specimens, which can be used in performance-type specifications to control various forms of cracking such as thermal, reflective, and block cracking of pavements surfaced with asphalt concrete.
Implementation:	➢ Similar time and cost to perform other mixture and binder performance tests ➢ Good comparisons with more well-known Indirect Tensile Strength (ITS) test ➢ Simpler to perform and quicker than other fatigue cracking tests ➢ Equipment costs can range from \$10–50K depending on whether a cooling chamber is required.

Texas Overlay Test

Test Method:	Tex-248-F, Overlay Test
Applicability:	The overlay test (OT) was developed in the 1970s to test an asphalt mixture's resistance to reflective cracking, but it has also been evaluated to determine the bottom-up fatigue cracking and the thermal reflective cracking resistance of asphalt mixture (Tex-248-F-09). This test method determines the susceptibility of bituminous mixtures to fatigue or reflective cracking. The test is rapid and repeatable, and poor samples fail in minutes. It characterizes both crack initiation and crack propagation properties of asphalt mixtures.
	➢ Advantages are that field cores or gyratory compacted samples can be tested relatively quickly. Tests are rapid and repeatable. ➢ Results found to correlate to flexible and composite pavements ➢ Disadvantages in the sample preparation process (cutting and gluing) ➢ In the current Texas DOT procedure (Tex-248-F), the maximum opening displacement of 0.635 mm (0.025 in.) is deemed too large for testing stiff asphalt mixtures (e.g., with higher RAP and/or RAS contents) and the mixtures of asphalt overlay placed in different climate conditions (i.e., smaller daily temperature variation). The OT is currently conducted at a frequency of 0.1 Hz according to the current procedure, but the OT can be conducted at a higher frequency to reduce testing time. In the current procedure, the failure point is defined as the number of cycles where 93% reduction of the initial peak load occurs. This method of determining the failure point is not consistent with those used in other cracking tests, such as the BBF test in accordance with ASTM D7460 procedure. Thus, additional work is needed to evaluate the maximum opening displacement, test frequency, and method for determining the failure point specified in the current OT procedure (Ma 2014).

pavement; therefore, a methodology of stochastically evaluating the in-place dynamic modulus of the as-built asphalt pavement using a relationship of in-place air voids and a set of single dynamic modulus values measured in the laboratory was presented. The methodology was validated with asphalt mix collected from a construction site and produced a plot to be used for comparing the estimated in-place dynamic modulus and the as-designed asphalt mix as a simple approach to evaluating as-built mix quality. The reported outcome of the methodology established the possibility of incorporating the dynamic modulus into PRS.

Repeated Load Permanent Deformation

A study by Azari (2012) investigated the characterization of asphalt mixtures using an incremental repeated load permanent deformation test. Nine different mixtures from different state DOTs throughout the United States were selected to accurately represent a wide variety of locations, temperatures, mixture types, and traffic loads. Each sample was tested at the same controlled temperature for each test with the same load cycles and stress levels. The temperature was continually increased for each test cycle and the minimum strain rate (MSR) curves were developed to show the resistance of an asphalt mixture to permanent deformation. The MSR curves were generated as a function of temperature * pressure, or TP value, noting that as the TP values increased the MSR value increased exponentially. These charts were used to estimate rut depths by multiplying the given MSR at the given TP value and multiplying the MSR by traffic equivalent single axle loads (ESALs) to obtain the total strain. Once the total strain was found, it was multiplied by pavement thickness to estimate the rut depth. The study reported that with a given TP value for a particular location and traffic pattern, a minimum MSR can be calculated and the mixture can be designed to meet that minimum value. It was reported that a mixture with a lower MSR is more resistant to permanent deformation. In addition, an asphalt mixture with a higher TP value is more resistant to permanent deformation when the MSR is held constant.

Overlay Tester

A report by Zhou et al. (2014) discussed the possible use of the Texas Overlay Tester as an appropriate test for predicting repeated load and cracking in the routine asphalt mixture design process. The report surmised that for standard overlay projects the selection of an appropriate mixture design has been difficult, a result in part of the improvement in a mixture's rutting resistance being offset by a negative impact on its cracking resistance. The Texas Overlay Tester could potentially eliminate the need for these decisions to be made in that it allows for the calculation of certain parameters, depending on location and loading patterns. A number of changes have been made to the original Texas Overlay Tester to modify it for a larger range of pavement samples. Some of the changes include requiring a testing temperature of 77°F (25°C), a loading time of 10 s, a maximum opening size of 0.025 in. (0.625 mm), and a failure point defined as a 93% reduction in load from the maximum load measured at the first cycle. The study proposed that the Texas Overlay Tester can balance the rutting and cracking requirements and would be most effective when combined with the Hamburg Wheel Tracking Device (HWTD) (for evaluating the potential rutting).

Studded Tire Wear Simulator

A study by Wen and Bhusal (2013) investigated various approaches to developing asphalt mixtures that best resist studded tire wear. Studded tires are commonly used in Alaska, Colorado, Idaho, Montana, Nebraska, Oregon, South Dakota, and Washington State and have been reported to cause significant rutting damage. Ruts as deep as 1 in. (25 mm) in 6 years of loading, which exceeds the 0.75 in. (19 mm) maximum allowable rutting in most states, have been observed. In this study, the results of the Studded Tire Wear Simulator (developed in Washington State) are discussed and the sensitive mixture variables were determined to be aggregate type, asphalt binder grade, gradation type, nominal maximum aggregate size, and air void content. The study reported that the benefit of the Studded Tire Wear Simulator is that in addition to measuring studded tire resistance, it also measures standard rutting resistance and standard fatigue cracking resistance of asphalt pavements.

Disc-Shaped Compact Tension

Minnesota Department of Transportation (MnDOT) currently specifies low temperature binder grades to minimize thermal cracking at low winter temperatures (MnDOT 2014). The disc-shaped compact tension test (DCT) was used to simulate the stresses that develop in an asphalt pavement as it shrinks in low temperatures, which was modified from the ASTM D7313 procedure. The DCT measures the fracture energy of a mixture (in J/m^2) by loading a specimen to fracture. The test consists of a disc-shaped test specimen that has a 6-in. (150-mm) diameter and is 2-in. (50-mm) thick, which is placed on the testing apparatus with two holes cut in it for loading locations and a notch cut to initiate the location of cracking. The crack propagation is measured corresponding to the load applied by providing a value in fracture energy at a minimum acceptable value of 0.035 BTU/ft^2 (400 J/m^2). In 2013, five different asphalt pavement projects were tested using the DCT test. If certain specimens did not meet the minimum fracture energy of 0.035 BTU/ft^2 (400 J/m^2), the following recommendations were made to increase fracture resistance: (1) reducing the amount of RAP or RAS in an asphalt mixture; (2) reducing the low-end temperature performance grade, increasing the high-end temperature performance grade; (3) using a smaller nominal aggregate size; (4) increasing binder content; and (5) using harder, crushed quarry rock instead of standard gravel aggregates. The study reported that during the next two upcoming construction seasons that MnDOT plans to finalize implementation of the DCT test.

At present, the MnDOT is in the process of implementing a low-temperature cracking performance specification for asphalt mixtures. The specification utilizes DCT fracture energy as a performance criteria. A pilot implementation was undertaken in 2013 by the use of performance specifications for five construction projects in Minnesota (Johanneck et al. 2015). The implementation required the mix design specimens to be tested as part of mix approval and verification testing conducted on production mix samples. The pilot study helped identify some challenges to full-scale implementation as well as find out certain deviations in DCT fracture energy measurements that can be seen between laboratory-prepared mix design samples and plant-produced production mix. On the basis of the lessons learned through the pilot implementation, current research is underway to modify and finalize the DCT fracture energy performance specifications. MnDOT is presently implementing the use of provisional specifications, intended for use in 2017.

This study also reaffirmed traditional viewpoints on asphalt mix design such as increasing levels of binder content and/or the use of a "colder" performance grade low-temperature binder that is presumed to create a softer mix and result in higher fracture energies. Research is ongoing on the impact of these individual mix design parameters, along with other relevant parameters (VMA, VFA, PG range, percent of recycled materials, etc.) on fracture energy. Furthermore, the pavement sections constructed during the pilot implementation (both with and without adjusted mixes) are being continually observed and their field cracking performance documented to study the effects of fracture energies on cracking performance.

The Chicago Department of Transportation (Chicago DOT) adopted a test procedure, entitled Determining Fracture Energy of Asphalt-Aggregate Mixtures Using the Disk-Shaped Compact Tension Geometry (IDOT 2014), which was modified from the ASTM D7313 procedure. In this method, cores must be taken no less than 12 in. (300 mm) from the edge of the pavement surface and a minimum of three cores must be extracted and tested in the DCT. The specification lists requirements such as compaction, variance, and size of samples, as well as adjusted requirements for non-standard samples such as SMA and other pavement types. The minimum requirements for the mixtures tested in the DCT include: 0.035 BTU/ft^2 (400 J/m^2) for dense-graded asphalt mixtures; 0.031 (350 J/m^2) for low ESAL (i.e., lower heavy vehicle volumes) asphalt mixtures; and, 0.017 (200 J/m^2) for pervious asphalt mixtures. Chicago DOT also requires that all mix designs meet a set of minimum DCT values based on whether the mixture is dense-graded, pervious, or low-volume (low ESAL pavement) when tested using the modified Illinois DOT specification (IDOT 2014). Chicago DOT requires that contractors test all mix designs for DCT compliance, regardless of the agency giving the mix design approval. In addition, the contractor will be required to submit two prepared uncut gyratory specimens 4.75 in. (120 mm) in height for DCT verification testing by the Chicago DOT's QA staff. A portion of the specification used by Chicago DOT is included in web-only Appendix D.

Mixture Types Evaluated with Performance Tests

Reclaimed Asphalt Pavement

A study was conducted in 2013 that served as a synthesis of various types of testing on mixtures designed with RAP using materials from different parts of the United States with different levels of RAP (Marasteanu et al. 2013). In the context of the study, a high RAP content was defined as asphalt mixture produced with more than 25% RAP.

The first experiment was designed to determine an optimal binder content; the results were inconclusive. Dynamic modulus testing was completed to determine critical temperatures; however, the results varied from measured critical temperatures and were also deemed inconclusive. Moisture damage susceptibility was then tested. A large portion of the high RAP content mixes did not meet the 0.80 TSR criteria; therefore, an anti-stripping additive was added in these cases. In all cases, the tensile strength of the RAP mixes exceeded the tensile strength of the virgin mixes. Permanent deformation was evaluated by testing each mix with the confined flow number test. None of the samples exhibited deformation using this method and rutting resistance was determined based on strain instead, which was not affected by the RAP content. Resistance to fatigue cracking was tested with IDT strength tests. The results showed that high RAP mixes had significantly lower fracture energies than the virgin mixes. Fracture energy was improved when a softer grade of virgin binder or a rejuvenating agent was used. Resistance to thermal cracking was tested with both the low temperature Semi-Circular Bend (SCB) test and the Bending Beam Rheometer (BBR) test. Typically, the high RAP content mixes had higher fracture toughness than the virgin mixes but similar, or even lower, fracture energy results. The BBR results showed that mixes containing RAP had higher stiffness and lower m-values, which would result in a higher potential for thermal cracking. The report concluded that based on the critical temperatures, the high RAP content mixes appeared to perform similarly to the mixes produced with virgin aggregates.

Wisconsin DOT created special provisions to establish a procedure for the use of RAP. The testing done on asphalt mixtures is described in detail in the latter half of the special provisions document starting under Section 460.2.8.4.1.4.2, Department (Bureau of Technical Services) Verification Performance Testing Requirements (WisDOT 2014). The appropriate range was determined for the following material parameters: (1) air voids within a range of 2.2% to 4.8%; (2) VMA within ±0.5 of the minimum requirement; and

(3) adequate lift thickness. In Wisconsin, pay factors were primarily determined based on meeting the minimum required density depending on the type of roadway, although other parameters can be considered as well. WisDOT uses ASTM D 7313-07 (ASTM 2013) using the DCT geometry as the standard test method for determining fracture energy of asphalt aggregate mixtures. Random samples are selected for testing and the procedure includes creating a valid test specimen with appropriate material qualities, placing the specimens in a standard freezer for 8 to 12 hours at 10°F (–12°C), and then placing the specimens in a DCT chamber for 1.5 hours at the standard testing temperature, which varies based on the PG binder grade. The minimum allowable fracture energy for all test specimens is 0.035 BTU/ft^2 (400 J/m^2). WisDOT also reported that it uses the AASHTO T 324-11 Hamburg Wheel Track Test (AASHTO 2011) as the standard test for determining allowable rutting levels for HMA. Depending on the asphalt binder grade, a range of 5,000 to 20,000 load passes are completed with a maximum rut depth found to be consistently measuring 0.50 in. (12.5 mm). WisDOT uses the SCB test for the evaluation of crack propagation in asphalt mixtures by computing the critical strain energy rate (J_c) for mixtures containing RAP.

The University of Oklahoma is investigating the fatigue testing of RAP in six different mixes that range in terms of the amount of RAP and the types of binder grades (Zaman 2014). The mixture samples were tested for beam fatigue, IDT strength, dynamic modulus, creep compliance, and resilient modulus. In addition, the Overlay Tester and the SCB test are planned for the study. Following AASHTO TP 107-14 (AASHTO 2014b), the fatigue testing is being conducted three times with each sample, using short, medium, and large failure cycles (i.e., the number of cycles at which the phase angle reaches its peak or the modulus decreases to 10% of the initial modulus, whichever occurs first). Preliminary results were reported and revealed good correlation between the fatigue lives of the binder and the mixture.

High-Performance Thin Overlays

To evaluate the potential for performance-based specifications of high-performance thin asphalt overlay mixtures, Mogawer et al. (2014) investigated the laboratory performance of asphalt mixtures from three state DOTs: Minnesota, New Hampshire and Vermont. These asphalt mixtures were used to develop a pilot specification for pavement overlays. A guide was developed to address reflective cracking, thermal cracking, fatigue cracking, and rutting of asphalt overlay mixtures, and in each of the three pavement mixtures that were tested up to 25% RAP was used in the mix. Criteria were developed for both types of cracking and for rutting. For thermal cracking, it was reported that the mixture must be within ±10°F (6°C) from the low temperature PG of the binder. For other types of cracking, the mixture is expected to exhibit average overlay testing of greater than 300 cycles to failure. For fatigue life, the mixture is intended to meet flexural beam testing of greater than 100,000 cycles. Finally, for rutting the average rut depth for six specimens is intended to be less than 0.16 in. (4 mm) at 8,000 cycles. The study also found that when RAP is included in the asphalt mixtures, it shall exhibit overlay testing cycles to failure within ±10% of those in the control specimens without RAP. Based on the results of laboratory testing and field observations, the pilot specification was slightly refined; however, the impact of RAP on the mixture performance was not determined as part of this study.

Warm Mix Asphalt

In a study by Jones et al. (2010), a series of tests were completed to assess the differences in performance between HMA and WMA when the WMA additive Rediset® WMX was used. The tests were conducted to determine rutting potential, fatigue cracking performance, and moisture sensitivity of both mixture types. The tests conducted included shear testing, fatigue testing, HWTD test, Cantabro test, and TSRST test. It was determined that in the TSRST test, the mixtures with the Rediset WMX additive exhibited significantly better moisture resistance than the control mixes. In each of the other tests, similar results with regard to performance were displayed.

The performance of WMA was assessed in a study by Sargand et al. (2009) in which WMA was constructed outdoors and subjected to standard vehicular loading. There were no obvious visual differences in the WMA compared with HMA after 20 months of service life; therefore, the investigation of WMA was then observed under laboratory conditions in an instrumented section in order to measure the temperature, deflection, subgrade pressure, and longitudinal and transverse strains. There were four different mixes: a control HMA and three WMA manufactured in three different approaches. The laboratory specimens were subjected to rolling wheel loads at temperatures of 40°F, 70°F, and 104°F (4°C, 21°C, and 40°C, respectively). All three of the WMA mixes experienced more initial consolidation than the HMA mix, and the WMA made with emulsion consolidated about twice as much as the other WMA mixes. After initial consolidation, differences in further consolidation were negligible. The transverse and longitudinal strains under falling weight deflectometer (FWD) loading were reported to be consistent among all of the mixes and the study concluded that WMA performed at least as well, if not better, than the HMA mix.

Research conducted on WMA in both the laboratory and field using the HWTD test demonstrated the difference in optimum asphalt content for WMA as compared with that of HMA (Alvarez et al. 2010). The study also used the HWTD test to determine the rutting potential of WMA compared with HMA and found that, if given sufficient time to cure, the WMA can achieve the same strength as the HMA. Other tests were also run to compare the performance of WMA with

HMA: (1) the Texas Overlay Tester was conducted to predict reflective cracking resistance, (2) a dynamic mechanical analysis was completed to observe fatigue cracking resistance, and (3) surface energy measurements were completed for determining moisture susceptibility. The investigation demonstrated that the suite of tests included in the study were effective for describing the fatigue life, rutting resistance, and moisture susceptibility of WMA mixtures.

NCHRP Research Results Digest 374 (2012) provided a recommended testing to define a WMA technology evaluation program that would be compatible with a centralized system of testing, evaluation, and data reporting of engineering materials for the state DOTs, AASHTO National Transportation Product Evaluation Program (NTPEP). The suite of mixture performance tests recommended for the qualification of WMA, as part of the NTPEP program, is shown in Table 2.

Recycled Asphalt Shingles

A study conducted by MnDOT considered the incorporation of RAS in asphalt mixtures of varying composition: (1) a mixture containing 20% RAP, (2) a mixture containing 15% RAP with 5% tear-off shingles, and (3) a mixture containing 15% RAP with 5% manufactured shingles (McGraw et al. 2010). The mixtures were tested in the laboratory to determine stiffness, rutting potential, and moisture sensitivity using dynamic modulus testing, asphalt pavement analyzer, and the Lottman test, respectively. The dynamic modulus testing showed that mixes with tear-off shingles were stiffer than mixes with manufactured waste scrap shingles. At higher temperatures, there was a large stiffness difference between RAP mixes and virgin mixes. The manufactured shingles mix exhibited higher rutting potential than the tear-off shingle mix, and both indicated less rutting potential than virgin mixes. Tear-off shingle mixes were found to be more susceptible to moisture damage than manufactured shingle mixes, with most tear-off shingle mixes failing to meet MnDOT specifications. The results of IDT testing indicated that the tensile strength was not affected by substituting shingles for a percentage of the RAP material.

TABLE 2
SUMMARY OF LABORATORY TESTS: MIXTURE PERFORMANCE

Test	Specification
Mixture design verification with 150-mm diameter	AASHTO T 320
Rutting	AASHTO TP 79, T 324, and T 340
Dynamic modulus	AASHTO TP 79 and PP 61
Compactability	AASHTO R35 draft appendix section 8.3
Durability	AASHTO T 283 and T 324

Source: Marzougui et al. (2012).

Another study by McGraw et al. (2007) investigated the use of both tear-off shingles and manufactured shingles, combined with traditional RAP materials, in both Minnesota and Missouri. Tensile strength tests using the IDT were conducted along with the mixture BBR and direct tension tests on both conventional asphalt produced with virgin binder and on mixtures with various RAS contents. The research results indicated that the addition of shingles lowered the temperature susceptibility to moisture damage of the binders, rendering them stiffer than conventional and RAP-modified binders, at intermediate temperatures more characteristic of fatigue cracking distress.

Asphalt Mixtures Produced with Recycled Tire Rubber

In a study by Bennert et al. (2004), traditional asphalt mixtures were modified using crumb rubber at 20% of the total weight of the asphalt binder. The crumb rubber was blended with the PG64-22 for 1 hour before mixing with the aggregates. Four HMA mixes were used with different PG grades along with one asphalt rubber mix, and the mixtures were analyzed by the following performance tests: (1) APA, (2) repeated load permanent deformation, (3) dynamic modulus, (4) repeated shear, (5) frequency shear, and (6) simple shear test. The simple shear test results indicated that the rubber-modified HMA mixture experienced creep development at lower test temperatures, but limited creep at high temperatures when compared with the standard mix. Frequency shear and simple shear testing revealed that the rubber-modified asphalt mix had significantly lower stiffness at higher loading frequencies, indicating that the mix is less prone to fatigue cracking at lower temperatures. At elevated test temperatures, the rubber-modified asphalt mix had the highest shear modulus, which was found to be indicative of improved rutting resistance. The dynamic modulus testing indicated that by adding crumb rubber to an asphalt mixture both the high temperature and the low temperature grade should be increased. Overall, the performance testing indicated that the rubber-modified asphalt mix will perform well in both temperature extremes along with exhibiting improved fatigue resistance and the potential for longer service lives.

TOOLS FOR DEVELOPMENT AND IMPLEMENTATION OF PERFORMANCE SPECIFICATIONS

In this section, a summary is presented of findings from the literature related to the development and implementation of tools that support the performance specifications for asphalt mixtures.

One of the first efforts to initiate the concept of a PRS for asphalt mixtures was developed by Epps et al. (2002b) as part of the WesTrack project. A Microsoft Windows-based software package, HMA Spec, was developed to generate a construction specification and provide equations that define how pay will be either increased or decreased for meeting, or failing to meet, established performance target values. The software allowed users to input asphalt mixture variables and predicted changes in performance based on adjustments to the inputs. In addition, the software determined how pay is adjusted based on target values selected by the user. The performance prediction models were developed based on data from the WesTrack project, published data, and laboratory-determined data for the specific location in which the asphalt mix was intended to be constructed. Stiffness, permanent deformation, and fatigue cracking were the three primary variables that the software used to predict performance.

The first in a number of national studies in recent years focusing on PRS for asphalt is presented in *NCHRP Research Results Digest 291* (2004). The document presents a summary of the key findings of NCHRP Project 9-15, "Quality Characteristics and Test Methods for Use in Performance-Related Specifications for Hot Mix Asphalt Pavements," which investigated simple and rapid NDT procedures for evaluating the properties of as-constructed HMA pavements by measuring mixture quality characteristics. The study included performance indicators for segregation, initial ride quality, in-place mat density, longitudinal joint density, and in-place permeability. Based on this study, initial specification criteria and threshold values for these five parameters for a PRS are presented and recommendations for further evaluation and validation of these test methods and suggested values are provided.

One of the more recent national efforts for advancing the development and implementation of performance specifications was the development of the Quality Related Specification Software (QRSS) through NCHRP Project 9-22, *A Performance-Related Specification for Hot-Mixed Asphalt* (Fugro Consultants and Arizona State University 2011). Through this effort, a Microsoft Windows-based program entitled QRSS was created that uses the distress performance models, originally developed as part of NCHRP Project 1-37A (Applied Research Associates 2004), to predict how an asphalt mixture will perform over time. The QRSS was created to predict asphalt pavement distresses such as rutting, fatigue cracking, thermal cracking, and rideability based on the International Roughness Index (IRI). The performance measures are a function of air voids, asphalt content, aggregate gradation, volumetric properties, and binder viscosity of the AC layer, among others. In addition, the software takes into account pavement structure, traffic loading, and climate at a given location of interest. The software uses the volumetric and material properties of the as-constructed asphalt pavement to predict future performance by estimating the dynamic modulus of each asphalt layer. The performance results are then compared with the predictions of the as-designed asphalt mixture. These predictions form the basis of a PRS, in which predetermined parameters selected for pay adjustments will not be based strictly on volumetric properties, but on predicted differences in the service lives (or long-term performance) of the flexible pavements. For example, selections for performance indicators in asphalt mixtures include an allowable amount of rutting, thermal cracking, and/or service life, all determined by each individual state DOT.

NCHRP Project 9-22A, *Evaluation of the Quality Related Specification Software* (*QRSS*) *Version 1.0,* was then conducted to beta test the QRSS Version 1.0 through the analysis of samples obtained from multiple paving projects in Texas, Rhode Island, and Utah (Moulthrop et al. 2012). The samples were taken from each project and evaluated for performance, service life, and life expectancy difference between as-designed and as-built pavements. Volumetric-based dynamic modulus values were calculated and compared with the values measured originally in the laboratory and then input to the QRSS. The predicted performance, service life, and life expectancy were determined and compared with outputs from the QRSS through thermal fracture calculations, fatigue cracking, and permanent deformation in the asphalt pavements. The report indicated that the dynamic modulus values measured in the laboratory corresponded well with the dynamic modulus values calculated using the QRSS. It also indicated that when using highly modified asphalt mixtures, the dynamic modulus predictive equation in the QRSS gives less comparable results in terms of rutting predictions. Overall, the research showed that the QRSS accurately predicted life expectancy for each sample.

NCHRP Project 9-22B, *Comparing HMA Dynamic Modulus Measured by Axial Compression and IDT Methods,* studied the impacts of using different asphalt pavement specimens and configurations for distress model predictions from the QRSS Version 1.0 (McCarthy and Bennert 2012). There are various specimen configurations used for dynamic modulus testing along with multiple options for pavement prediction models. Two types of specimens were used for testing: field cores and laboratory compacted. The specimens were tested using different test configurations under the uniaxial compression test and the indirect tension test. The rutting in the asphalt surface layer and asphalt binder layer were predicted, along with bottom-up fatigue cracking in the binder layer. Dynamic modulus values were inputted into three analysis programs: the *Mechanistic Empirical Pavement Design Guide* (*MEPDG*), Arizona State University's SPT program, and QRSS. The types of materials explored in this study included traditional dense-graded asphalt mixtures, SMA, WMA, and a high and low percentage RAP mixture.

A few key conclusions were derived from this study. It was concluded that indirect tension testing is an appropriate alternative to uniaxial compression testing. It was reported that laboratory-compacted samples, plant-compacted samples, and field-compacted samples all displayed similar results in terms of rutting predicted by the various tools, but that the plant-compacted samples produced the most accurate results in terms of predicting the appropriate level of fatigue cracking. The report suggested that it is not necessary to require plant-compacted or field-compacted samples to get accurate pavement performance predictions and that the *MEPDG* software was a relatively appropriate tool for determining the life expectancy of a pavement.

In the 1990s, California DOT (Caltrans) determined that the method and material specifications that were being used at the time were not adequate for producing long-lasting asphalt mixtures, due to variable performance over time (Harvey et al. 2014). In 2000, Caltrans developed the CalME flexible pavement design software (California Department of Transportation 2014), which was calibrated using accelerated pavement testing from numerous locations. Over a period of 10 years of testing and calibration, Caltrans implemented CalME on three northern California Interstate Highway rehabilitation projects. The study reported that material properties in different regions of California are not well established and that testing is required to determine performance metrics for local materials in particular regions. It was determined that pay scale factors be appropriate for each of the different regions of the state, particularly considering the wide range of aggregate bases used that have varying material properties and strengths. The use of repeated load testing was suggested and that different combinations of stiffness and fatigue behavior will allow for mixture designs to be within the acceptable parameters for a certain project. The study recommended that it would be ideal to provide designers with more flexibility and consider alternative combinations to achieve certain asphalt mixture properties.

PAY ADJUSTMENT FACTORS IN PERFORMANCE SPECIFICATIONS

Any information used to set pay adjustment factors for performance-based specifications (PBS) or PRS for asphalt mixtures will be summarized in this section.

NCHRP Research Results Digest 371 reported an evaluation of common approaches for pay adjustment factors for asphalt pavement (Hanna 2013). The most common approaches reported included: engineering-based (complex) methods, empirical methods, and experience-based methods. Engineering-based methods are methods that have been developed based on relationships, and mathematical data and empirical methods are similar but derived from experience rather than engineering principles. Experienced-based methods do not use mathematical principles and do not predict performance; however, the pay factor adjustments are determined based on whether the pavement conforms to certain mix design standards. A survey to state agencies included in the document reported that incentives typically range from 1% to 15%, with the most common incentive reported to be set at 5%, and smoothness is the most frequently used quality measure, followed by the percent within limits associated with performance parameters such as density or air voids. In addition, the survey revealed that most agencies have maximum disincentives and many agencies use a remove-and-replace provision, but only a few agencies use a shutdown provision. The details of triggers for disincentives, remove-and-replace, and shutdown provisions varied among different agencies.

NCHRP Report 704 (Fugro Consultants and Arizona State University 2011) identified that pay factors are a bonus (incentive) or penalty (disincentive) applied to the contract, depending on the predicted service life of as-constructed asphalt mixes. The report listed IRI, rutting, and fatigue cracking as common characteristics used in determining pay factors. Rutting in the surface asphalt layer was considered in the QRSS, based on a database of more than 800 samples under a variety of conditions. An empirical model was developed to predict fatigue cracking, in which more than 7,500 simulations were run to develop a fatigue model. A sample of pay factors determined for IRI are shown in Table 3.

TABLE 3
SAMPLE PAY FACTORS DETERMINED BY THE NCHRP QRSS TOOL

Average IRI for each 0.1 mile of Traffic Lane (In/mile)	Pay Adjustment ($/0.1 mile of Traffic Lane)		
	Schedule 1 (High Traffic Volume)	Schedule 2 (Intermediate Traffic Volume)	Schedule 3 (Low Traffic Volume)
≤ 30	600	600	300
31	580	580	290
32	560	560	280
33	540	540	270
…	…	…	…
74	-180	0	0
75	-200	0	0
76	-220	-20	0
77	-240	-40	0
78	-260	-60	0

Source: Fugro Consultants and Arizona State University (2011).

A study by Monismith et al. (2000) developed performance models that can be used for PRS for flexible pavements based on the results of the WesTrack experiment. The models that were developed account for permanent deformation and fatigue cracking and can be used to develop pay factors that can be used for PRS and HMA pavements. The pay factors consider the quality characteristics of air void content, asphalt content, HMA thickness, and aggregate gradation. The cost model presented considers the present worth of rehabilitation costs due to the as-designed versus as-constructed quality of the pavement.

A study by Epps et al. (2002a,b) used a life-cycle cost model that outputs distresses such as fatigue cracking, rutting, and serviceability loss. The performance inputs were reported to include target pavement thickness, smoothness, asphalt content, air void content, and aggregate gradation among other site factors. An iterative process involving thousands of individual life-cycle cost analyses was conducted to determine the differences between the as-designed and as-constructed asphalt pavement and, depending on values such as the standard deviation and mean of the mixes, pay adjustment factors were determined based on the differences between the performance life predictions.

Weed (2003) proposed a simplified procedure for developing PRS for HMA pavements, which directly considers the effects of as-constructed quality characteristics on expected pavement life-cycle costs in the selection of pay adjustment factors for these quality characteristics. The procedure consisted of using in-place air voids, thickness, and initial smoothness of a constructed flexible pavement as the primary as-constructed quality characteristics that affect pavement performance and expected pavement life. A generic exponential model for computing expected pavement life was developed based on acceptable and unacceptable levels of each quality characteristic. A separate model can then be used to convert expected pavement life to a pay adjustment and pay schedule or incentive/disincentive for the different quality characteristics.

More recent research by Weed (2006) presented a more general model that allows for greater flexibility in developing multicharacteristic relationships. The refined model designated high and low failures as two-sided requirements for parameters, such as high and low limits for air voids in flexible pavements, because conditions considered either too high or too low can negatively affect pavement performance. The model provides a rational approach for tying expected pavement life back to pay adjustments for as-constructed quality.

A study for the Nebraska Department of Roads (Nebraska DOR) investigated the creation of a system intended to assign incentives or disincentives for pavement construction, based on long-term performance characteristics (Peruri 2007). Because the Nebraska DOR already has an incentive program in place, only certain additional characteristics were investigated such as IRI, rutting index, and bleeding (flushing) of paved surface based on data from a number of roadways across the state. These characteristics were suggested for inclusion in the existing pay scale due to their potential to provide better long-term performance predictions than the current approach.

TYPES OF PERFORMANCE SPECIFICATIONS USED NATIONALLY AND INTERNATIONALLY

This subsection summarizes literature related to types of performance specifications for asphalt mixtures documented in the United States and internationally. The information in the following sections was obtained from published literature and is presented in subsections organized by state or country.

Louisiana

The Louisiana Department of Transportation and Development (Louisiana DOTD) published an update on its experience with performance-based and PRS and achieving a balanced asphalt mixture design through the modification of specifications by Cooper et al. (2014a). The research reported that ensuring performance by balancing the amount of rutting and fatigue cracking has been an issue. In 2013, Louisiana DOTD proposed specification modifications for balancing the mixtures, using the testing done on 11 mixtures produced in 2013 to compare with the performance of 40 different mixtures produced in 2006. The testing done on the samples included the HWTD with its loaded wheel test (LWT) and the semicircular bending (SCB) fatigue test.

Michigan

Williams (2004) used characterization of materials, performance testing of asphalt specimens, and statistical analysis in an attempt to develop a performance-based specification for the Michigan DOT. The objectives of the study were to obtain and characterize asphalt field samples throughout Michigan, develop performance testing criteria, and, ultimately, develop field specifications for acceptance. The main reason for the study was to move forward in testing and acceptance procedures and to facilitate the eventual implementation of PRS.

The research divided Michigan into six different regions to address the various climatic properties and levels of material availability, and testing was done on asphalt sampled from each of the six regions. The research primarily used IDT, Superpave shear tester, beam fatigue, uniaxial strain test, and asphalt pavement analyzer (APA). With this information, the accuracy of empirical models used in the past and the effect that asphalt content and air voids have on long-term performance were determined.

New Jersey

Currently, the New Jersey DOT is in the implementation stages of an asphalt mix design and acceptance procedure that includes: (1) performance of volumetric design and allowance for verification by the New Jersey DOT; (2) supplying of materials and asphalt mixes to an external laboratory for performance testing; (3) production of mixes through a plant and paving of test strips offsite; (4) sampling during production and provision of samples to an external laboratory for further performance testing; and (5) sampling and testing every other lot (Bennert et al. 2011). A rutting check, flexural cracking check, and a pavement cracking check are the tests performed by an external laboratory using an APA, a flexural beam fatigue test, and an Overlay Tester, respectively. The APA tests for rutting susceptibility, whereas the flexural beam fatigue test determines the fatigue life of asphalt mixtures. The Overlay Tester was used to simulate horizontal movement at the PCC joint to capture reflective cracking in the asphalt overlay, owing to environmental temperature cycling of the underlying rigid pavement. The type of test used in each case is dependent on whether the mode of cracking is dependent on the flexural properties or the expansive properties of the asphalt pavement.

Currently, there are five different performance-based asphalt mixtures that are required to undergo the testing procedure previously mentioned (Bennert et al. 2014). These mixtures are the high-performance thin overlay (HPTO), binder rich intermediate course (BRIC), bridge deck waterproofing surface course (BDWSC), bottom rich base course (BRBC), and asphalt mixtures containing high percentages of RAP. Each of these asphalt mixtures requires different volumetric properties for acceptance. Although the New Jersey DOT only implemented these performance-based specifications in 2008, field performance has shown that these mixtures are performing exceptionally well, particularly in comparison with previously designed mixtures that were only reaching about half of the expected service life. These performance-based specifications allow for both contractors and engineers to be more accurate in accounting for performance in each of these distress categories.

Virginia

Hughes and Maupin (2000) reported that since the mid-1960s, the Virginia DOT has been working to develop end result specifications, ideally in the form of PRS, where the mixture quality is directly related to performance. The difficulty comes in developing tests for quality characteristics that accurately represent a multitude of different approaches that contractors may have to generate mixture design. The identified AC quality characteristics deemed necessary for predicting future performance in the study were degree of compaction, thickness, smoothness, segregation, strength, and durability. The research proposed required actions to move forward with development such as creating a density specification that measures air voids and implementation of an improved smoothness specification. The report also identified that a test that measures strength accurately be developed along with a measure of durability to address segregation and other durability-related distresses.

International Efforts: Australia

The state of Queensland in Australia developed a technical specification to assist in the construction of dense-graded asphalt layers for heavily trafficked roads (State of Queensland Department of Transport and Main Roads 2013). The specification includes that standard testing shall be done on the asphalt mixtures in order to test their sensitivity to water (Test #Q315) and the compacted density by the amount of air voids at 250 cycles (Test #Q322). Asphalt mixtures intended for use as a binder layer under the surface layer must have a high level of rutting resistance, greater than 12 years of service life, texture depth greater than 0.016 in. (0.4 mm), and an average permeability of less than 15 μm/s. Asphalt mixtures used in structural layers as part of a heavy-duty flexible pavement must have a relatively high level of rutting resistance and an average permeability of less than 15 μm/s.

The specification defines that asphalt mixtures may be comprised of coarse aggregate, fine aggregate, filler, additives, RAP, and/or binder. The maximum RAP content is 15% and RAP may not be used in surface layers. The following performance requirements shall be met:

- The sensitivity to water must be at least 80%;
- Air voids at 250 cycles must be at least 2.5%, 2.6%, or 3.0%, depending on the mix type; and
- The final rut depth shall not exceed 0.16 in. (4 mm).

The specification also requires that asphalt mixtures shall be tested for binder content, gradation, density, binder volume, binder fraction, stability, flow, stiffness, air voids, VMA, voids in the binder, resilient modulus, wheel tracking, and sensitivity to water. During construction, the minimum lift thickness shall be 2 in. (50 mm). The maximum thickness shall be either 2.4 in. (60 mm) or 3.2 in. (80 mm) depending on mixture type. The compaction shall be at least 92.5% or 93%, depending on mixture type.

International Efforts: New Zealand

A performance-based specification was implemented in 2000 in New Zealand for the design, maintenance, and performance requirements for flexible unbound pavement layers for the construction of new pavements and reconstruction of existing pavements (Transit New Zealand 2000). The contractor is responsible for the pavement design, including selection of materials, layer thicknesses, drainage, and the binder type. The contractor is also responsible for maintaining the pavement and seal, including the shape and structural integrity of the pavement, for 12 months after construction. The Compliance Assessment requirements are provided in this document for the following parameters, among others:

- Pavement layer compaction;
- Pavement stiffness (moduli) or strength;
- Surface shape;
- Rut depth;
- Roughness;
- Surface texture (minimum texture depth from "sand patch" test);
- Chip retention;
- Surface waterproofness; and
- Saturation before sealing (i.e., moisture content of pavement surface prior to sealing).

While this specification does provide certain performance parameters for the pavement, it stipulates a 12-month maintenance period and the document noted that the parameters would be analyzed and considered for potential performance specifications for HMA pavements in the future.

International Efforts: South Africa

In 2004, a pavement investigation was completed on the Cape Town International Airport, which combined Marshall mixture design principles with a variety of reliable performance tests and criteria. The outcomes of the airport pavement project were reported to be successful and subsequently led to development of similar approaches for highway pavements (Grobler et al. 2004). In addition to standard volumetric specifications, performance properties have been included for design verification in the asphalt mixture design process in South Africa, such as rutting at 100,000 wheel load applications with the accelerated wheel rut tester and the application of the Council for Scientific and Industrial Research Wheel Tracking Device until the development of rut depths measuring 0.4 in. (10 mm). In addition, Superpave gyratory compaction is now used along with measurement of the average deformation from 2,000 to 3,000 repetitions (tied to traffic levels) in the Dynamic Creep Test. Fatigue resistance was reported to be measured using the four-point Bending Beam Fatigue test, IDT test, and the Repetitive Strain test. The Modified Lottman test and wet Model Mobile Load Simulator test were considered to determine the durability of asphalt mixtures in terms of the amount of stripping of binder.

In addition, Grobler et al. (2004) developed two performance-based parameters: the Comprehensive Rut Resistance Index and the Compaction Effort Index. The Comprehensive Rut Resistance Index is the a function of (1) the Model Mobile Load Simulator rut depths measured at 100,000 load repetitions; (2) number of repetitions of the Council for Scientific and Industrial Research wheel tracking to 0.4 in. (10 mm) rutting; and (3) the percentage of voids in the mix (VIM). The Compaction Effort Index was reported to be a function of (1) the Marshall VIM, (2) filler-to-bitumen ratio, and (3) number of gyrations in the Superpave gyratory compactor that achieve 93% density. It was reported that the intention was to further develop these parameters for use in establishing pay factors.

International Efforts: United Kingdom

The guide or standard most commonly referenced in relation to asphalt mixtures in the United Kingdom is PD 6691 (Mineral Products Association 2009). To meet these standards, the United Kingdom uses "type testing," a method in which the appropriate ingredients are selected for the mixture and a target grading and binder content are selected for the use and application. Whenever performance specifications are used, trial strips are created and tested. These test strips are placed using conventional paving and compaction equipment according to BS 594987, and then tested in accordance with the PD 6691 (which includes volumetric testing on binder content and gradation, as well as other potential performance requirements such as compaction or wheel tracking) and the BS 594987 (which includes a specification for transport, laying and compaction, and type testing protocols) standards.

An article by Ellis et al. (2002) discussed the features of the United Kingdom's performance specifications for surfacing and base layers of pavements. The benefits of using performance specifications for the road user, infrastructure owner, and construction industry in the United Kingdom were discussed. The benefits were listed in the areas of quality (improved safety and travel time, smoother ride and improved pavement performance, and reduced contractual risk), economy (better use of available funds), innovation (new solutions to benefit all stakeholders), and environment (less congestion near work zones, encouragement of sustainable development, and reduced material waste). A PRS for asphalt materials was implemented into the United Kingdom specifications in 1996 and the clause was primarily implemented to: (1) ensure materials reach the standard assumed in the pavement design; (2) allow more scope for contractors to produce the most economic mix design; and (3) ease the introduction of alternative materials into asphalt mixture designs.

RESEARCH ON THE ADVANCEMENT OF PERFORMANCE SPECIFICATIONS FOR ASPHALT MIXTURES

In this section, the past and current research related to the advancement of performance specifications for asphalt mixtures is summarized.

Regional Research

Much of the effort in the initial development of modern-day PRS for asphalt pavements originated with the WesTrack study. In 1999, a forensic review was conducted by Huber and Scherocman to assess why some of the WesTrack test sections did not perform as expected. The underlying significance of this investigation indicated that due to the experimental design and the pavement sections that did not perform as expected, the development of PRS based solely on the WesTrack experiment may not be entirely appropriate.

Williams (2004) researched the use of regression models in order to predict rutting depth based on 10 different HMA material properties designated to be performance-predicting variables. The 10 parameters used to determine future performance included Superpave mixture design level; aggregate gradation; whether or not the asphalt was graded at or above the required performance grade; fine aggregate angularity; complex modulus (to determine susceptibility to rutting); asphalt film thickness; fines-to-binder ratio; asphalt content; and the air voids and VMA of field mixes. In addition, appropriate ranges were determined for each parameter. The findings reported that the three main parameters that can be directly related to rutting and fatigue performance are air void content, asphalt content, and VMA, and reported satisfactory results for predicting fatigue life and rutting potential based on these three parameters.

Dave and Koktan (2011) conducted a study in Minnesota in order to predict the performance of certain asphalt mixtures in that state and determine which mechanical tests were necessary for developing a PRS. One finding of the research identified that the absence of a global performance indicator, or even a few tests that can encompass the overall performance of the asphalt pavement, is a critical issue. The tests reported as having the highest potential for determining performance of asphalt mixtures included indirect tensile tests, fracture energy tests, the Texas Overlay Tester, and the four point bending beam fatigue test. Suggestions were provided for future studies necessary for determining the practicality of a performance test in Minnesota and for determining the feasibility of using performance tests in surrounding states.

Research is currently underway in Louisiana to develop a PBS for asphalt mixtures (Louisiana Transportation Research Center 2011). The report proposed that a minimum of 10 rehabilitation projects with well-known traffic data serve as test locations from which field core samples will be tested with the HWTD loaded wheel test, dynamic modulus test, SCB test, and IDT strength test. The use of a number of nondestructive in situ tests, including the Falling Weight Deflectometer (FWD), Light Weight Falling Deflectometer, and Portable Seismic Pavement Analyzer will be included to test in situ pavements at the 10 locations. The research is intended to provide accurate information about asphalt pavement performance over a number of years, depending on the mixture design.

A study was done by North Carolina State University to develop reliable PRS and considered a fatigue model and a rutting model (Kim 2012). The fatigue model is analyzed using a simplified viscoelastic continuum damage (S-VECD) model, which is a fatigue test dependent on time and temperature, and can determine the effects of aggregate size, asphalt content, PG, and recycled asphalt materials on the fatigue endurance limit of mixtures. Findings from the fatigue model reported that larger aggregate size and the presence of RAP will reduce the endurance limit, while increased asphalt content and PG grades will increase the endurance limit. The rutting model that was analyzed using the triaxial repeated load permanent deformation test indicated that the permanent strain increased both with the number of loading cycles and as the testing temperature was increased.

National Research

FHWA advertised a request for proposal (Solicitation DTFH61-13-R-00030) in 2013 for a project to develop a PRS for pavement construction. The scope of the study planned is to advance the pavement-related portion of the Strategic Highway Research Program (SHRP 2) Report S2-R07-RR-1 (Scott et al. 2014) project, "Performance Specifications for Rapid Renewal," by further developing and demonstrating the products of the two FHWA projects and to fill any remaining gaps such that PRS becomes a viable option for use during pavement construction. SHRP 2 recently wrapped up this project. Specifically for pavement PRS, the R07 report incorporates the work of two ongoing and concurrent research activities funded by the FHWA Turner–Fairbanks Highway Research Center, specifically: (1) DTFH61-08-C-00029 (awarded to Applied Research Associates, Inc., and entitled "Implementation of Jointed Plain Concrete Pavement Performance Related Specification by State Highway Agencies"); and (2) DTFH61-08-H-00005 [awarded to North Carolina State University for "Hot Mix Asphalt (HMA) Performance-Related Specifications Based on Viscoelastoplastic Continuum Damage (VEPCD) Models"].

There are also a number of current research projects funded through NCHRP whose results will impact, to a certain degree, the development of performance-based specifications. A list of some of these projects and a concise description of their scopes are presented in Table 4.

TABLE 4
LIST OF RECENT NCHRP RESEARCH PROJECTS RELATED TO ASPECTS OF PERFORMANCE TESTS

NCHRP Project Number	NCHRP Project Title	Brief Description of Project Scope
9-46	Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content	Develop a mix design and analysis procedure for HMA containing high RAP contents that provide satisfactory long-term performance. Propose changes to existing specifications to account for HMA containing high RAP contents. High RAP content is defined as greater than 25% and may exceed 50%.
9-48	Field versus Laboratory Volumetrics and Mechanical Properties	Determine causes of variability and the precision and bias for volumetric and mechanical properties of dense-graded asphalt mixtures measured within and among these three specimen types: (a) laboratory mixed and compacted, (b) plant mixed and laboratory compacted, and (c) plant mixed and field compacted. Prepare a recommended practice for state DOTs to incorporate these results in specifications and criteria for (a) quality assurance, (b) mix design verification or validation, and (c) structural design and forensic studies.
9-54	Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction	Develop a procedure calibrated and validated with field data to simulate long-term aging of asphalt mixtures for performance testing and prediction to establish a methodology for integrating the effects of long-term aging in Pavement ME Design and other mechanistic design and analysis systems.
9-57	Experimental Design for Field Validation of Laboratory Tests to Assess Cracking Resistance of Asphalt Mixtures	Select candidate laboratory tests for load- and environment-associated cracking applicable for routine use through a literature review and workshop. Develop experimental design for a series of coordinated field experiments to establish, verify, and validate (a) laboratory-to-field relationships for the candidate tests and (b) criteria for assessing the cracking potential of asphalt mixtures.
20-07 Task 361	Hamburg Wheel-Track Test Equipment Requirements and Improvements to AASHTO T 324	Document capabilities of available commercial Hamburg test equipment. Determine Hamburg test equipment capabilities, components, or design features that ensure proper testing and accurate, reproducible results. Provide proposed revisions to AASHTO T 324 to enable the use of a performance-type specification for Hamburg test equipment.

CHAPTER THREE

SURVEY ON USE OF PERFORMANCE SPECIFICATIONS FOR ASPHALT MIXTURES

INTRODUCTION

In this survey, 90% of the state DOTs (45/50) provided input on their use of performance testing and performance specifications for plant-produced asphalt mixtures. The agency survey questions are presented in Appendix A, along with the entire survey response set. The entire list of agency respondents is provided in Appendix B. There were 14 additional respondents, including the District of Columbia DOT, two counties, one city, and 10 Canadian provincial MOTs. Their specific results are referred to in this chapter as other agency responses.

BASIS FOR ACCEPTANCE OF ASPHALT MIXTURES USING PERFORMANCE SPECIFICATIONS

The survey responses to Question 1 showed that the overwhelming majority of respondents reported that in addition to HMA, both WMA [98% of state DOTs (44/45) and 13 other agencies] and asphalt mixtures with RAP [98% of state DOTs (44/45) and 12 other agencies] are used for plant-produced asphalt pavements. The survey results indicated that fewer agencies use asphalt mixtures with RAS [56% of state DOTs (25/45) and three other agencies] and asphalt mixtures with crumb rubber from tires or GTR [36% of state DOTs (16/45) and three other agencies]. Additional mixes used include friction courses that were reported by Arizona DOT and asphalt mixtures with synthetic fibers reported by Pennsylvania DOT. The city of Los Angeles, California, has been designing HMA overlays with 50% RAP and has been collecting data on these high RAP projects. Figure 3 shows the survey responses to Question 1 presented geographically.

The survey responses to Question 4 revealed the attributes that are required by the vast majority of DOTs and other agencies before production of asphalt mixtures of all types including aggregate properties such as angularity, abrasion resistance and soundness, asphalt binder properties, laboratory air voids, gradation, asphalt content, VMA, and moisture damage determined by the TSR. The most frequent responses included the use of the APA (reported by five state DOTs and one other agency) and considering voids filled with asphalt VFA (voids filled with asphalt), as reported by four DOTs. Other respondents commented on the consideration of attributes such as permeability, moisture sensitivity, Hveem stability, and/or the dust-to-asphalt cement ratio.

Forty-four percent of state DOTs (20/45) and five other agencies noted in answers to Question 2 that when recycled materials are included in asphalt mixtures, different tests or test approaches are used; a sample of these are highlighted in Table 5. The full set of detailed responses for Question 3 is included in Appendix A.

Pennsylvania DOT reported that its test approach changes when SMA or gap-graded mixtures are used. Kansas DOT mentioned that it will be requiring a HWTD test and a TSRST for mixtures using high RAP percentages in the near future. New York DOT requires the AASHTO T 283 test when certain WMA technologies are used.

The city of Edmonton reported that it makes adjustments to the binder properties and air voids (in percent of the total mix). For mixtures containing RAS, Edmonton requires the voids in the total mix to be reduced by 0.5% of the voids used in the virgin mix.

The responses to Question 7 showed that when using WMA mixtures, Georgia DOT reported that it increases the frequency of samples taken to verify volumetric mix design attributes. Similarly, Pennsylvania DOT increases the frequency of samples tested when using RAP or mixtures with crumb rubber from tires. In response to Question 8, Pennsylvania DOT also reported that it increases the total number of samples taken to verify volumetric mix design attributes when RAP or mixtures with crumb rubber are used. California DOT reported that it increases the total number of samples taken for mixtures containing RAP and RAS.

CONTENTS OF PERFORMANCE SPECIFICATIONS FOR ASPHALT MIXTURES

The survey data from Question 9 showed that the majority of states are either currently using or planning to implement some form of performance specifications, as shown in Table 6.

In this context, performance specifications primarily refer to performance-based attributes used for mix design acceptance and to a lesser extent PRS using volumetric properties with predictive models. The predictive models mentioned by state DOTs and other agencies in responses to Questions 36 and 37 of the survey are presented in Table 7.

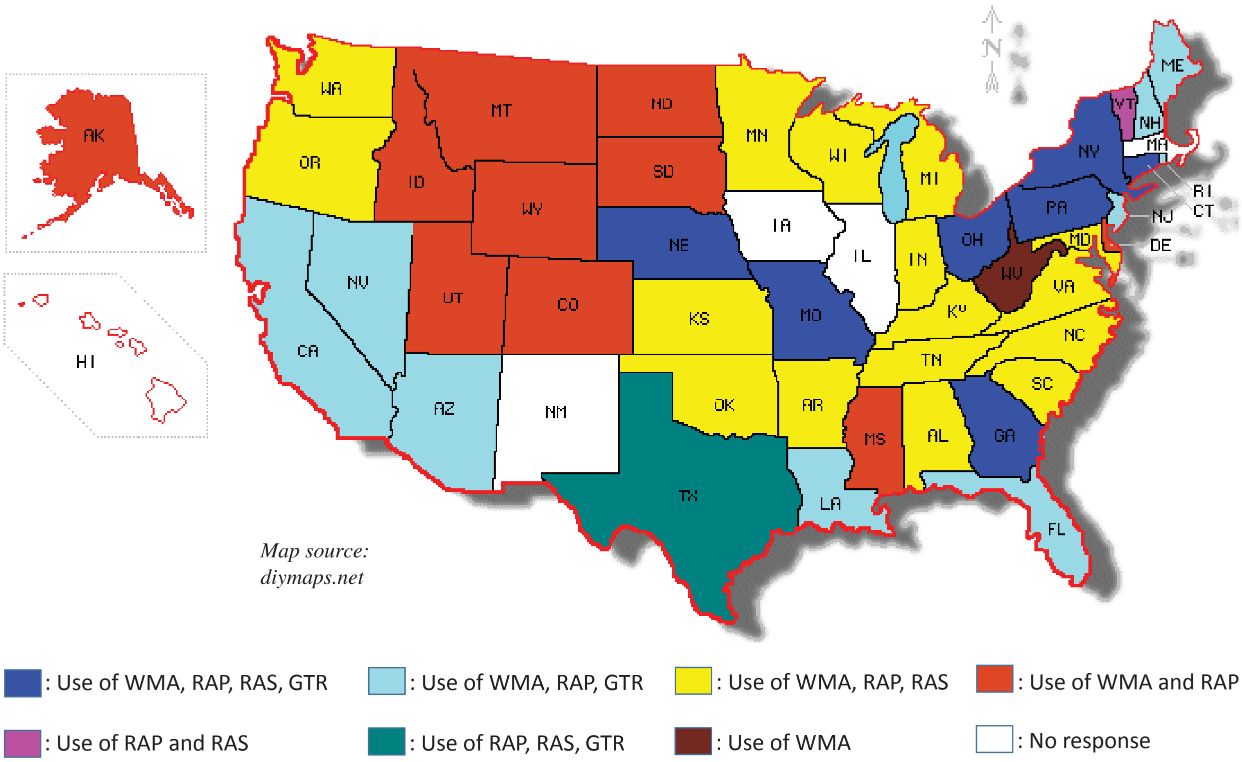


FIGURE 3 Geographic distribution of state DOT responses to Question 1 on the types of asphalt mixtures produced in each state.

There were many reasons reported in Question 10 as to why state DOTs are currently using or planning to use performance specifications for asphalt mixtures, as indicated in Figure 4. Additional responses included quantifying the quality of the end product, as noted by Louisiana DOTD.

In terms of volumetric attributes that are deemed critical to predicting pavement performance in Question 13, 100% of state DOTs that answered this question (44/44) and 13 other agencies reported that density or in-place air voids are one of the most important attributes, followed by asphalt content [82% of state DOTs (36/44) and 11 other agencies], VMA [57% of state DOTs (25/44) and five other agencies], laboratory air voids [55% of state DOTs (24/44) and six other agencies], moisture damage by the TSR [45% of state DOTs (20/44) and nine other agencies], and gradation [39% of state DOTs (17/44) and 10 other agencies]. In other responses to Question 13 regarding performance-based attributes, New Jersey, Ohio, and Georgia DOTs all noted that rutting resistance is considered one of the most important

TABLE 5
SURVEY RESPONSES TO QUESTIONS 2 AND 6 ON TESTS OR TEST APPROACHES FOR RECLAIMED ASPHALT PAVEMENT

Type of Approach	Agency Respondents
Use of Blending Charts	Alberta, California, Kansas, Maryland, Michigan, North Carolina, Ohio
Further Classification of RAP (percentage of RAP, gradation of RAP, etc.)	Delaware, Kansas, Maine, Nova Scotia, Oregon, Québec, Wyoming
Materials Verification (binder content, percent air voids, specific gravity, asphalt content, etc.)	British Columbia, California, Georgia, Idaho, Pennsylvania, Québec, Wyoming
Testing (dynamic modulus, HWTD, Texas Overlay Tester, flexural beam fatigue, etc.)	Kansas, North Carolina, New Jersey, New York, Ohio, South Dakota, Wisconsin

TABLE 6
STATE DOT RESPONSES TO QUESTION 9 ON TYPES OF FACILITIES IN WHICH PERFORMANCE SPECIFICATIONS WERE USED FOR ASPHALT PAVEMENTS

Roadway Type and Use of Performance Specifications	Currently Using Performance Specifications	Planning to Use Performance Specifications	No Plans to Use Performance Specifications
Interstate Pavements	49% (22/45)	18% (8/45)	33% (15/45)
Pavements on Other Arterials (state highway system)	44% (20/45)	22% (10/45)	33% (15/45)
Pavements on Local or County Road System	32% (14/45)	17% (7/45)	46% (21/45)

attributes, whereas fatigue resistance and smoothness were also noted by a few respondents.

Fifty-four percent of state DOTs (21/39) and three other agencies reported in Question 14 that a direct measurement of fatigue is one of the most important performance tests to predict pavement performance, whereas 51% of state DOTs (20/39) and five other agencies reported that a direct measurement of rutting is one of the most important tests. Additional responses included measurement of thermal properties for cracking (five state DOTs), moisture damage or susceptibility testing (two state DOTs), and smoothness or ride quality (two state DOTs).

A number of different approaches or sources were reported to be used as the basis for the development of performance specifications, the majority of which are shown in Table 8 from Question 17.

Additional responses included Ontario MOT's implementation based on lessons learned from warranty contracts and on the review and evaluation of historical performance. Kansas DOT reported its use of the AASHTO TSRST test to aid in the development of performance specifications.

The types of asphalt mixtures for which the performance parameters are used are summarized in Table A15, as reported by the survey respondents in Question 18, and the responses related to fatigue resistance and moisture resistance for the most common asphalt layers (in this case the standard structural lift, standard overlay lift, and high-performance thin

TABLE 7
AGENCY RESPONSES TO QUESTIONS 36 AND 37 RELATED TO THE TYPES OF PREDICTIVE MODELS SUPPORTED BY RESEARCH UNDERWAY

Model Type	Agencies
Simplified Viscoelastic Continuum Damage (S-VECD)	Georgia, Louisiana, Maine, Oklahoma, Virginia
Fracture energy	Colorado, Florida
Predictive models based on fatigue, rutting, or other distress types (e.g., *MEPDG*)	California, city of Edmonton, Florida, Georgia, Louisiana, Nebraska, Québec, South Carolina, South Dakota, Utah, Virginia, Wisconsin
Quality related standard specification	City of Edmonton, Georgia, Louisiana, Maine, Missouri, Pennsylvania, Québec, Saskatchewan
Pavement design optimization based on life-cycle cost analysis	Georgia, Louisiana, Québec, South Carolina, West Virginia

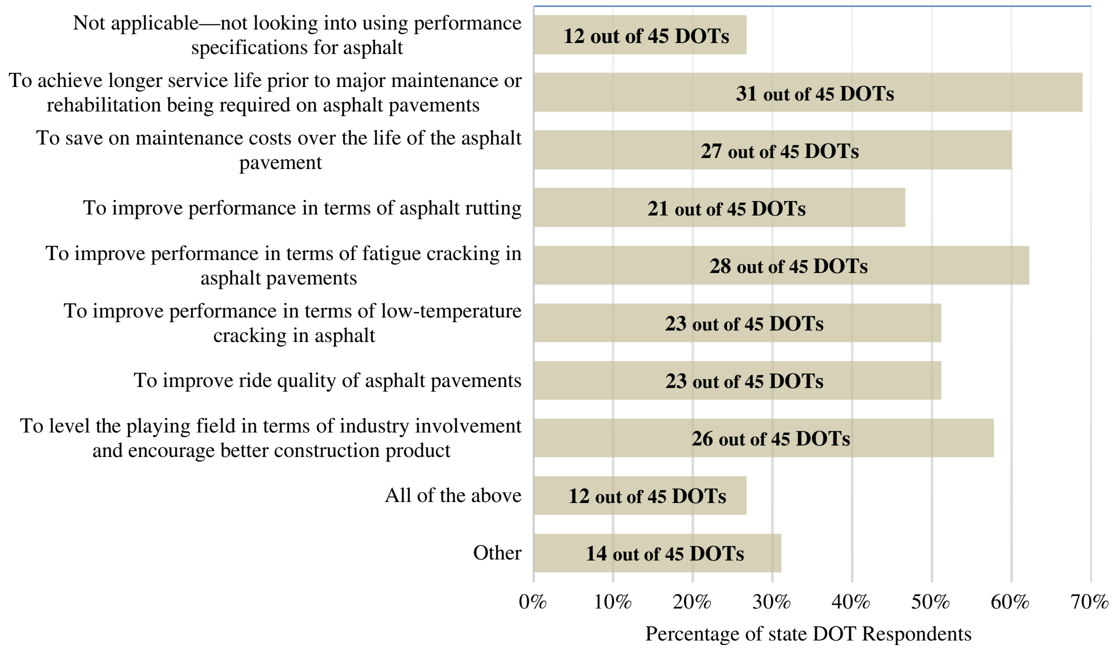


FIGURE 4 Summary of state DOT responses to Question 10 on the reasons to use performance specifications for asphalt mixtures.

overlay) are shown in Figure 5. The city of Edmonton and Ministry of Highways and Infrastructure of Saskatchewan both responded in Question 18 that the fatigue resistance and moisture resistance of standard structural and overlay lifts, and high-performance thin overlays, were key performance parameters. The Nova Scotia Transportation and Infrastructure Renewal, Ontario MOT, and Ministère des Transports du Québec all responded in Question 18 that the moisture resistance of the standard structural and standard overlay lifts was a key performance parameter.

Further analysis of the survey data in Question 19 showed that state DOTs have tested or used performance-based mixture design specifications under the following scenarios or project types, as shown in Figure 6.

Ohio DOT noted in Question 19 that performance-based mixture design specifications could also be considered when high RAP or RAS mixes are being used. Furthermore, Missouri DOT noted that performance-based mixture design specifications would only be considered with more industry acceptance

TABLE 8
STATE DOT RESPONSES TO QUESTION 17 ON THE BASIS FOR IMPLEMENTING PERFORMANCE SPECIFICATIONS

Responses	Fatigue Resistance	Thermal Cracking Resistance	Durability	Moisture Resistance	Stiffness Modulus	Total DOT Responses
Demonstration Project	5	2	3	5	3	6
Pooled Fund Study	1	3	1	1	2	4
Adapted from Another Agency's Specifications	1	1	3	3	0	4
Based on FHWA Research	5	5	3	6	2	10
Based on NCHRP Research	5	5	5	10	3	12
Based on Your Agency's In-House or Sponsored Research	11	10	9	18	6	20

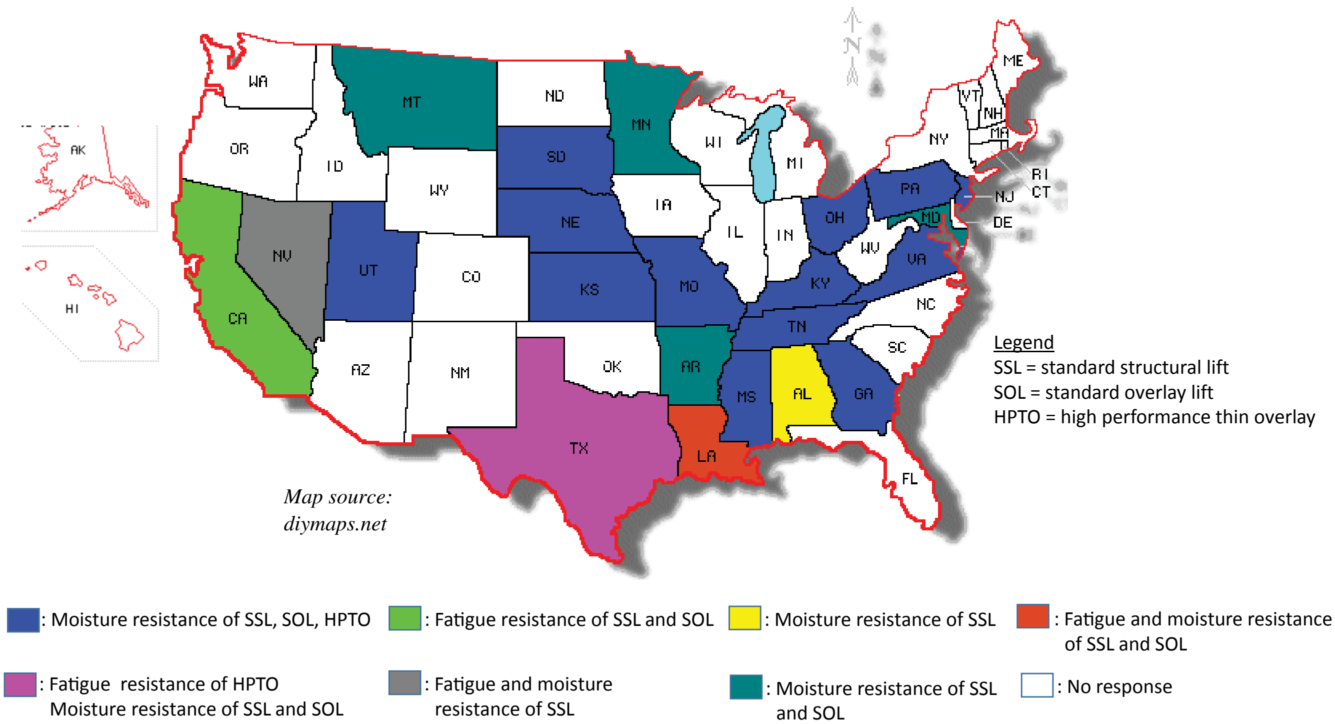


FIGURE 5 State DOT responses to Question 18 on fatigue resistance and moisture resistance performance parameters for the most commonly-reported asphalt surface layer types.

and when test methods are both easy to perform and affordable to operate for the contractor.

The most common tests used to support performance-based mixture designs reported in Question 20 are shown in Table 9.

For the majority of tests performed, the use of an AASHTO or ASTM standard was reported; however, for state DOTs that perform APA testing, seven of the 15 respondents noted that a special agency test method is used in place of an AASHTO or ASTM standard. In addition, Québec MOT reported that it uses the French rutting test in comparison with the APA.

In terms of performance tests used for qualification, quality control, or acceptance the attributes reported in Question 21 included fatigue resistance, stiffness modulus, thermal cracking resistance, durability properties, and moisture resistance. The most common performance tests reported in Question 21 for predicting fatigue resistance included the flexural beam fatigue test (four of 45 state DOTs and two other agencies) and

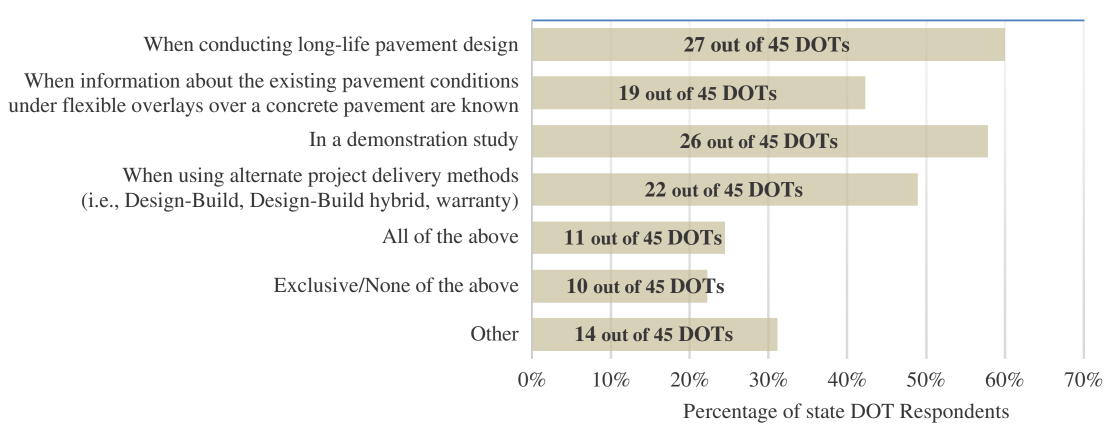


FIGURE 6 Survey state responses to Question 19 on the circumstances for the use of performance-based asphalt mix design specifications.

TABLE 9
AGENCY RESPONSES TO QUESTION 20 ON MOST COMMON PERFORMANCE TESTS FOR PERFORMANCE-BASED DESIGNS

Performance Test Types	Agencies
HWTD Test	California, city of Edmonton, Colorado, Georgia, Kansas, Louisiana, Montana, New York, Pennsylvania, Québec, Saskatchewan, Texas, Utah, Wisconsin
APA Test	Alabama, Arkansas, city of Edmonton, Georgia, Idaho, Mississippi, Nebraska, New Jersey, New York, Ohio, Pennsylvania, Québec, South Carolina, South Dakota, Virginia
Mixture BBR Test	Alabama, city of Edmonton, Colorado, Montana, Nebraska, New Hampshire, Pennsylvania, Québec, Saskatchewan, South Carolina
Flow Number Test Using AMPT	Colorado, New York, Pennsylvania, South Carolina, South Dakota
Dynamic Modulus Test Using AMPT	City of Edmonton, Colorado, New York, Pennsylvania, South Carolina, South Dakota
Flexural Beam Fatigue Test	California, city of Edmonton, New York, Pennsylvania, Québec, Saskatchewan
SCB Test	Louisiana, South Dakota, Wisconsin
RSST Test	California, Pennsylvania, Vermont
DCT Test	Colorado, South Dakota, Wisconsin
Overlay Tester	New Jersey, New York, Texas

the Texas Overlay Tester (three of 45 state DOTs). The most common tests reported for measuring the stiffness modulus included the Dynamic Modulus test in the Asphalt Mixture Performance Test (AMPT) (three of 45 state DOTs and one other agency), the HWTD test (three of 45 state DOTs), and the APA (two of 45 state DOTs). The most common test reported for predicting thermal cracking resistance was the mixture beam bending rheometer (BBR) (five of 45 state DOTs and three other agencies) and the flexural beam fatigue test used by one other agency. The most common tests reported for measuring the durability properties included the HWTD test (six of 45 state DOTs and one other agency) and the APA (five of 45 state DOTs and two other agencies). Québec MOT reported that it also uses the French rutting test for measuring asphalt mixture durability properties. The most common test reported for predicting moisture resistance was the HWTD test (nine of 45 state DOTs and two other agencies).

The survey responses to Question 21 indicated that the HWTD and the APA were the most commonly used performance-based test procedures, with a total of 12 of 45 and 11 of 45 different state DOTs, respectively. One other agency is using the APA for qualification of the mix design, quality control, or acceptance. The city of Edmonton reported that it requires that all SMA mixtures undergo rutting susceptibility testing by the APA procedure during both mixture design and production; however, it does not currently require this testing on all traditional dense-graded mixtures.

The majority of state DOTs (29/44) reported in Question 22 that they currently do not use independent assurance for performance-based tests. A few respondents noted that performance testing is not used for acceptance, but for testing and research purposes only (Florida and Colorado DOTs). The city of Edmonton reported that it operates its own quality assurance (QA) laboratory and Nova Scotia MOT reported that once independent assurance is implemented, the testing would be the responsibility of the contractors.

TEST PROGRAM IMPLEMENTATION

The survey responses to Question 23 indicated that, of the respondents who use performance mixture design specifications, 29% of state DOTs (12/42) and one other agency use shadow performance mix design testing for data collection and use volumetric properties for qualification, quality control (QC), and acceptance. An additional 21% of state DOTs (9/42) and two other agencies are using both volumetric properties and performance design specifications for qualification, QC, and acceptance.

Thirty percent of state DOT respondents (13/43) noted in Question 24 that performance testing is completed by the agency at a state laboratory. Contractor performance testing at a commercial laboratory was reported by 12% of the state DOTs (5/43) and two other agencies. Nine percent of state DOTs (4/43) and one agency reported using a testing consultant at a commercial laboratory. In most cases, it was reported that the agency was running the performance-based tests; however, some agencies are experimenting with having the contractors purchase the equipment and run the tests as part of their QC program. Twenty-three percent of state DOTs (10/43) and four other agencies indicated that the contractor performs testing for QC while the agency performs the testing for verification or acceptance.

Approximately 40% of state DOTs (18/45) and two other agencies indicated in Question 25 that they have the necessary equipment for performance testing, while another 27% (12/45) noted that some limited equipment is available. For example, both Oklahoma and South Carolina DOTs reported they are conducting research on the AMPT and expect delivery of the equipment upon completion of the research. Others, such as Georgia, Missouri, and Pennsylvania DOTs, indicated that they only have some of the equipment presented in the survey.

A number of respondents reported in Question 34 that many different performance parameters have been investigated with sponsored or internal research in the past, as shown in Figure 7. For example, the city of Edmonton reported it is currently evaluating all of its standard asphalt mixtures by comparing their performance characteristics to determine what properties to test. Nova Scotia MOT reported it is researching past performance of rehabilitation treatments based on visual distresses and working to identify which properties to focus on and the availability of tests.

An additional 39% of state DOTs (17/44) and three other agencies noted in Question 33 that they are currently conducting, sponsoring, or planning to conduct or sponsor, research related to performance testing in the future. More detailed information regarding current research, including efforts in Maryland and South Dakota that are assessing the use of models in the AASHTO *MEPDG,* are reported in Question 35 as shown in Table 10.

For example, Rhode Island DOT reported that it is sponsoring research to develop pay adjustment factors for typical AC mixtures used in the state. The pay adjustment factors will be based on pavement life differences predicted using measured material properties and distress models from the QRSS software. The scope of the project includes the evaluation of two typical surface mixtures and a base mixture (that contains between 15% and 25% RAP) for noninterstate highways. The project is intended to produce a spreadsheet-based catalog for predicted pavement service lives that can provide Rhode Island DOT materials and field engineers with the necessary information for assessing the quality of asphalt mixtures produced, and potential pay factor adjustment, in advance of (or early on in) construction.

Oklahoma DOT reported that it does not use comprehensive performance specifications; however, it does conduct certain performance testing on asphalt mixtures. For example, the HWTD rutting test is incorporated into the Oklahoma DOT specifications through agency test method OHD L-55 and the AASHTO T 324 method. In addition, it reported that moisture sensitivity testing is done following the AASHTO T 283 method using one freeze/thaw cycle. Both the rutting and moisture sensitivity tests are required for all asphalt mix designs. Oklahoma DOT reported that it requires the moisture sensitivity testing to be completed every 20,000 tons and the HWTD rutting test to be performed on the same samples for information only within

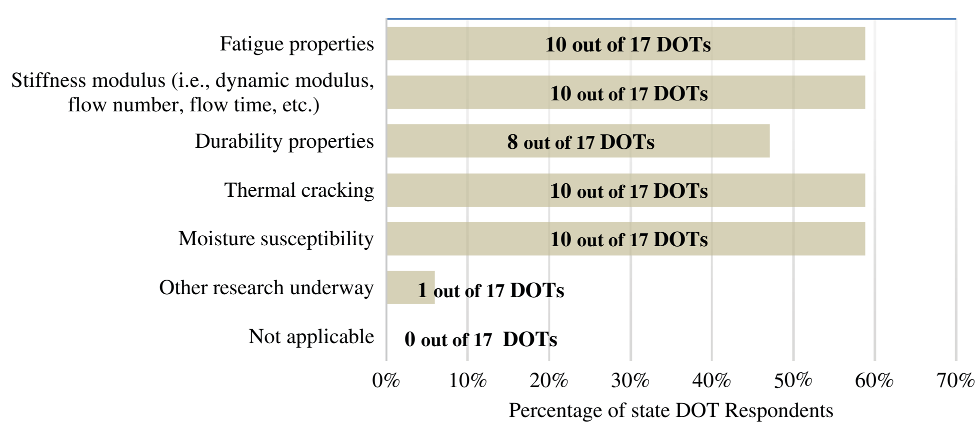


FIGURE 7 Summary of responses to Question 34 on the types of performance testing research for PBS that is conducted or sponsored.

TABLE 10
SAMPLING OF CURRENT AGENCY RESEARCH PROJECTS BEING SPONSORED OR CONDUCTED, AS REPORTED IN QUESTION 35

Agency Respondent	Response
Colorado DOT	Currently performing AMPT and recently began testing for fracture energy using DCT specimens
Georgia DOT	AMPT pooled fund study and has sponsored research regarding moisture susceptibility of asphaltic concrete mixtures and best anti-stripping agents research.
Maine DOT	Performance testing as part of SHRP 2 R07 project
Maryland DOT	AMPT/*MEPDG* pooled fund study investigating integration with *MEPDG* models
Minnesota DOT	AMPT pooled fund study, as well as a 2013 DCT pilot project. DCT implementation is ongoing. Eleven field projects were sampled in 2014 and the round-robin testing for interlaboratory variability is complete. The DCT specification development for 2016 implementation is underway.
Missouri DOT	Performance testing research regarding the semicircular bending test (SCB) and the DCT
Oklahoma DOT	Fatigue testing research
Québec MOT (Canada)	Dynamic modulus research and complex modulus determination for asphalt mixes
South Dakota DOT	*MEPDG* research project on material test characteristics
Utah DOT	BBR beam slivers for low temperature cracking potential of an asphalt mix. SCB test to balance the mix design or get more asphalt binder into the mix, and to predict cracking potential at intermediate temperatures.
Wisconsin DOT	Four high RAP asphalt pavement projects in 2014 with analysis of the mixtures using the DCT, SCB, and HWTD tests as required performance tests.
West Virginia DOT	Beginning some work using the SENB and DENT binder test to correlate with the AMPT and Hamburg tests

the last year. It reported that the University of Oklahoma is currently conducting sponsored research on the fatigue testing of RAP binders and that Oklahoma DOT expects to purchase the equipment necessary to conduct mixture fatigue testing and dynamic modulus testing.

Twenty-three percent of state DOTs (9/39) and two other agencies reported in Question 36 that they pursued predictive models based on rutting, fatigue, or other distress types. A small number of state DOTs and three other agencies have pursued other models, such as the S-VECD model (four of 39 DOTs), QRSS (five of 39 DOTs), or pavement design optimization based on life-cycle cost analysis (four of 39 DOTs).

In addition to the research information presented in Table 10, additional efforts regarding PBS were reported in Question 37. Pennsylvania DOT reported it is optimizing volumetric properties to improve rutting resistance; Florida DOT reported its efforts to find an appropriate fatigue cracking specification; Oklahoma DOT reported on its current research to implement an appropriate fatigue cracking test; and Maine DOT noted its efforts to work with industry to implement performance-based mix designs into standard practice. The city of Edmonton reported that it is in the process of reviewing all of its standard specifications and is including industry partners in the process.

DEVELOPMENT OF CONTRACT PROVISIONS FOR ACCEPTANCE AND PAY FACTORS FOR ASPHALT PERFORMANCE SPECIFICATIONS

Forty-nine percent of state DOTs (22/45) and four other agencies reported in Question 11 that they are currently using performance specifications (although the survey results appeared to indicate that in many cases these are based primarily on volumetric properties) as a basis for acceptance and/or pay factor adjustments. Both Indiana and Maine DOTs reported that they are in the preliminary stages of implementing this effort. Maine DOT noted that the current goal is to first implement the performance-based mix design procedures, then review potential acceptance or pay factor adjustments. Of the 22 states that noted in Question 12 that they are currently using performance specifications, 72% (18/22) and four other agencies indicated that they are using performance specifications as a basis for pay factor adjustments, primarily based on volumetric properties, by utilizing a combined system of both accept/reject and pay adjustments. Only 28% of state DOTs (7/22) reported that they use an accept/reject system only, while another 28% (7/22) use a pay adjustment system only. Indiana DOT and Clark County (Nevada) reported that they are using life-cycle reduction as the basis for pay factor adjustments.

The results from performance testing were reported in Question 15 to have had mixed-use purposes for pay factor adjustments at state DOTs. For example, 29% of state DOTs (12/42) and three other agencies have implemented data (primarily from rutting tests such as the HWTD) from performance testing on pay factors for pavement projects of all roadway classes, and an additional 5% of state DOTs (2/42) and two other agencies are using data from performance testing on pay factors for pavement projects only on interstates. Nineteen percent of state DOTs (8/42) and one other agency indicated that they are planning to implement data from performance testing on future pavement projects. Finally, 55% of state DOTs (23/42) and six other responding agencies indicated they are not planning to use performance test results as an input for pay factor adjustments.

In Question 16, 63% of state DOTs (12/19) and five other agencies that answered this question reported that durability (assumed to mean rutting resistance and resistance to raveling and segregation) and moisture resistance were considered for integration of mixture acceptance and pay factor adjustment. Twelve of 19 state DOTs and three other agencies considered fatigue resistance and stiffness modulus, whereas five of 19 and one other agency considered thermal cracking resistance. In addition, other responses (three of 19 state DOTs) to Question 16 included consideration of rutting resistance.

BENEFITS AND CHALLENGES OF IMPLEMENTATION OF PERFORMANCE SPECIFICATIONS

For 36% of the state DOTs (16/44) the required testing time for many of the performance tests was reported in Question 26 to be a challenge to implementing certain tests, as described in Table 11.

The survey responses to Question 28 reported that cost is a deciding factor in implementing performance testing for 36% of the state DOTs (16/45) and four other agencies. Thirty-one percent of state DOTs (14/45) and four other agencies noted that they plan to assess the relative costs and benefits of implementing performance testing compared with standard volumetric specifications. Of those that indicated that cost was a deciding factor, several different reasons were reported in Question 29 and are shown in Figure 8.

In terms of assessing costs and benefits, nearly all of the 11 state DOTs that responded to Question 31 indicated that HMA (10/11), WMA (9/11), and RAP (10/11) mixes have been included in the assessments. Three other agencies also noted that these mixes are considered. Only 36% of state DOTs (4/11) and two other agencies have considered RAS, while 18% of state DOTs (2/11) have considered asphalt mixes with crumb rubber from tires. New Jersey DOT indicated that they are currently investigating cost and benefit analyses, but that further information is unavailable at this time.

Some of the challenges reported by agencies in Question 38 to implementing performance specifications are shown in Figure 9.

The most common response was associated with the hesitancy in confidently accepting appropriate performance-based test methods, a concern noted by New Jersey, Tennessee, Missouri, and West Virginia DOTs. Utah, Florida, Tennessee, and Missouri DOTs also noted a lack of confidence in full implementation of the available test methods.

TABLE 11
TEST TURNAROUND TIME CHALLENGES IN IMPLEMENTING PERFORMANCE TESTING, AS REPORTED IN QUESTION 27

Reasons Given for Test Turnaround Time as a Deciding Factor	Agency Respondent
Efficiency in meeting deadlines and production goals	Alabama, Florida, Louisiana, Pennsylvania, Utah
Limited resources available and issues with testing procedures	Montana, Nebraska, New Jersey
Avoid delaying the contractor	California, Missouri

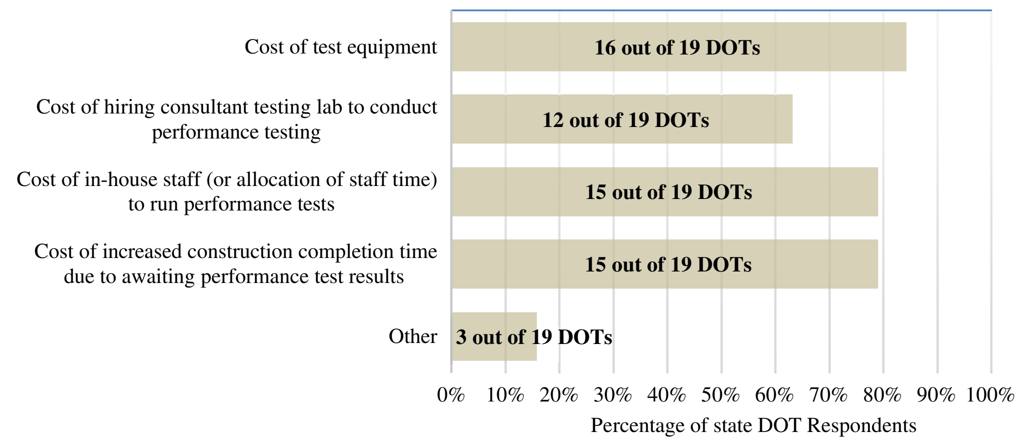


FIGURE 8 Reasons reported in Question 29 on cost as a deciding factor for implementation of PBS.

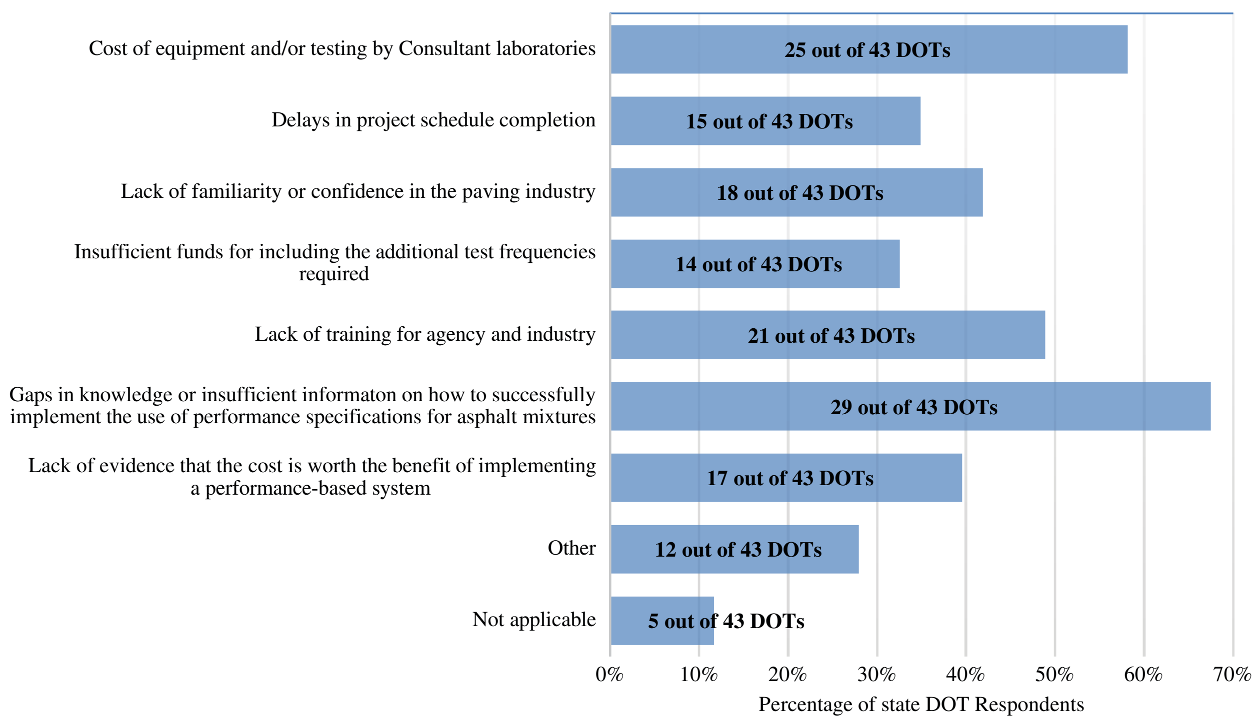


FIGURE 9 Issues reported in Question 38 on the challenges of moving toward using performance specifications for the design and acceptance of asphalt mixtures.

SUMMARY

The survey results indicated that the objectives for using performance specifications generally include longer pavement life (in terms of durability), reduced maintenance, and greater resistance to common pavement distresses. The majority of DOTs and other agencies have integrated recycled asphalt materials into their mixture designs. Many of the DOTs and other agencies surveyed are also implementing PBS using one or more performance tests, or are researching the use of PBS for improved durability primarily through rutting or cracking resistance. The use of recycled materials (i.e., RAP, RAS, and crumb rubber) has affected or altered DOT approaches to mixture design and qualification and some agencies are integrating performance tests into both standard and alternative mixture designs to improve pavement performance. Survey respondents are also researching more advanced mechanistic properties (i.e., AMPT, dynamic modulus) as part of the implementation of mechanistic-empirical pavement design methods. Although PBS has been incorporated as a standard practice in only a small number of agencies, its wider implementation appears to be on the horizon and there are a significant number and variety of research currently underway that address performance testing for mixture design and also for construction acceptance as part of the development of a more advanced mechanistic PBS system for asphalt pavements.

CHAPTER FOUR

CASE EXAMPLES OF PERFORMANCE SPECIFICATIONS FOR ASPHALT MIXTURES

INTRODUCTION

Based on the survey responses, a number of agencies indicated that they are in the process of implementing performance specifications for asphalt mixtures or conducting research with performance tests to support their eventual implementation. As shown previously in Figures 1 and 2, there were 12 agencies that were interviewed to gather more information on their current and planned activities and to present the detailed information in the form of case examples. There were a number of reasons why these agencies were selected to serve as case examples. They represent a geographic distribution to include a wide range of climates and paving program sizes. The responses from the agency survey indicated that Louisiana, New Jersey, and Texas in particular have made considerable advancements in the study of the benefits and challenges of performance testing and performance specifications.

This chapter discusses case examples from six agencies in the United States (Georgia, Louisiana, New Jersey, Ohio, Texas, and Utah DOTs) and one local agency, the city of Edmonton in Alberta in Canada. Their states of practice were captured through interviews with one or multiple members of each of these agencies to determine: (1) how performance specifications for asphalt mixtures were developed and are used, (2) the evaluation of performance testing, and (3) implementation efforts related to performance specifications for asphalt mixtures. Information was also gathered through cursory interviews with five additional state DOTs with experience using performance specifications for mixture design and testing (Florida, Maryland, Minnesota, Virginia, and Wisconsin), which is presented at the conclusion of this chapter.

EDMONTON (ALBERTA, CANADA)

The city of Edmonton in Alberta, Canada, is responsible for 15,000 lane-kilometers (more than 9,000 lane-miles) of paved roads. Edmonton has the only municipal testing laboratory in Canada and the only APA testing equipment in western Canada. The city has the capabilities for classifying the performance of asphalt mixtures using a vast number of tests including: (1) the APA test for the past 12 years; (2) the dynamic modulus test for the past 4 years (using the ASTM procedure with the load frame); (3) the TSR test; (4) the HWTD test; and (5) beam fatigue testing equipment. Edmonton has a minor research program and handles all of the QA testing for any capital construction pavement projects in its jurisdiction. It also does a substantial amount of asphalt mixture performance testing for other municipalities in western Canada, as well as for the Alberta and Saskatchewan MOTs.

Development and Use of Performance-Based Specifications

Edmonton reported that performance testing of each proposed asphalt mixture is conducted before implementation of the mixture in its construction program. The paving contractors are responsible for QC at the plants and the city runs acceptance tests on plant and field samples at its laboratory. The city requires APA testing as part of its AC specification (Section 02065) for acceptance of any asphalt mixtures and is using performance-based mixture design properties for qualification, project QC, and acceptance testing (e.g., dynamic modulus test, flexural beam fatigue test, APA, and HWTD test). The APA is run on the contractor's design mixes at the mix approval phase as well as on plant-sampled mixtures for acceptance.

Edmonton conducts performance tests on both loose mix [i.e., the sample shall be taken at random during paving operations on city projects from a load(s) delivered to the contractor's asphalt plant at least twice each month and the samples are tested by an independent laboratory engaged by the contractor to verify compliance with the specification requirements] as well as core specimens taken from the roadway's post-compacted pavement. For some mixes, performance testing on field cores is used as the acceptance or rejection criteria. For example, this procedure is done on the SMA mixes in which rut resistance is cited as an important criteria for acceptance. It is necessary to meet field core rutting requirements for its SMA mixes and, if the mix fails to meet this requirement, it is rejected and the pavement must be removed and replaced. The 2015 city of

Edmonton specifications for SMA Paving (Section 02067), as well as for Recycled Asphalt Paving (Section 02966) and Superpave Gyratory Compacted (SGC) Hot-Mix Asphalt Paving (Section 02742) are included as sample documents in web-only Appendix D.

Evaluation of Performance Testing

Edmonton has been evaluating the benefits of performance testing (i.e., APA, flexural beam fatigue test, and the TSR for asphalt) for several years. There are 70 asphalt and concrete test sections located around the city that are monitored annually. The field monitoring includes visual inspections, crack evaluations, and deflection testing using the Dynaflect and FWD. The test sections include SMA, Superpave base and surface asphalt mixes, asphalt rubber, ultra-thin whitetopping, conventional concrete pavements, various granular materials, and other technologies used by the city. As an example of field performance validation over time, in 2014 Edmonton allowed the use of Superpave mixtures after a process that included initial mixture laboratory performance testing followed by 7 years of field performance monitoring. All of the mixtures were tested first in the laboratory with the APA, flexural beam fatigue test, and the TSR.

Another example is based on the use of the SMA mixtures on heavy truck traffic routes in Edmonton. In the past, there was one particular signalized intersection with a dense-graded asphalt mixture that rutted to a depth of 1.4 in. (35 mm) annually and where pavement overlays (mill and fill method) were required twice per year. A design SMA mixture was subjected to the full suite of performance tests and the results of the APA test at 126°F (52°C) showed that the mixture failed at 0.5 in. (12.5 mm) of rutting at 35,000 load cycles. A typical Marshall dense-graded surface course mixture used in the city traditionally exhibits 0.3 to 0.4 in. (7 to 10 mm) of rutting at 8,000 load cycles, depending on the mix type. In 2001, the SMA mixture was constructed as the surface mixture over a polymer-modified base layer. The pavement is currently exhibiting 0.3 in. (7 mm) of rutting and has not required any overlay treatments in 14 years, resulting in a significant cost savings for Edmonton for many of its routes traveled by heavy trucks.

In limited instances, the QA data from a project has been used as part of an AASHTOWare Pavement ME Design® analysis to predict the service life for a pavement in which the contractor did not follow the original pavement design. Edmonton has also used the Pavement ME Design software as a tool for dispute resolution with contractors in instances of premature pavement failures, such as in the case of one project in which a binder grade was used that was different than the PG specified in the construction contract. The flexible distress models in the Pavement ME Design predicted that the pavement would exceed the performance criteria threshold sooner than the same pavement with the contract-specified binder type. This approach was used successfully to provide the engineering basis that justified the necessity of removal and replacement action by the contractor.

Implementation Efforts Related to Performance-Based Specifications

The city of Edmonton holds meetings twice each year with the Alberta Roadbuilders and Heavy Construction Association (ARHCA). Edmonton reported that the dedicated meeting dates and in-person communication with the contractors has had a positive effect on the quality of pavements being constructed by the primarily 10 contractors who work to build its roads. One of the meetings is a half-day event that includes 10 members of ARHCA and staff from the city transportation department to review the successes and challenges of the last paving season. The second meeting is a one-day session held in January that focuses on specification changes, construction issues, and rolls out the paving program for the year. In addition, the city runs an annual training session for its project managers and construction inspectors on most effective paving practices. Edmonton is also organizing and delivering a training course in Spring 2015 on most effective paving practices complete with field demonstrations for contractors' crews, paving supervisors, and other staff. The training for the contractors has been done on an as-needed basis; however, Edmonton noted that it may eventually become an annual event.

Edmonton is currently conducting an assessment of the relative costs and benefits of performance testing and the basis of the pay factors used for flexible pavements. The current pay system is close to 20 years old and is based on in situ density, thickness, and binder content pay adjustment factors. However, it is currently reviewing the pay factors to see whether they are still valid and whether the applicability of the factors to performance of asphalt pavements in the field can be validated. Edmonton is also conducting a series of forensic and sensitivity analyses with the AASHTO Pavement ME Design software to review the tolerance level of the pay factors used for disincentives.

GDOT
Georgia Department of Transportation

GEORGIA

Georgia DOT reported that approximately 33% of its annual budget is spent on asphalt pavements. The agency has 14 Bituminous Technical Services Engineers in the districts who approve job mix formula (JMF) designs, inspect large paving projects, and troubleshoot QA problems at contractor plants or on the roadway during placement. Georgia DOT has incorporated performance specifications as a combined system that includes both accept/reject items and pay adjustments. It has established pay tables that are based primarily on gradation, AC content, and in-place air void content, with special pay adjustments applied for projects failing to meet pavement smoothness requirements.

Development and Use of Performance-Based Specifications

Georgia DOT reported asphalt mixture properties determined by performance testing and considered for the integration of mixtures acceptance and pay factor assignment, including durability (in terms of rutting) and moisture resistance. A summary of the tests required for Superpave mixtures is presented in Table 12 and shows there are performance tests used as a standard part of mix design approval and field-produced mix design verification. The Georgia DOT Standard Operating Procedure with the full details regarding performance testing requirements is included in web-only Appendix D. The APA test is used as a standard part of the mix design approval and field-produced mix design verification of all asphalt mixtures. The agency method Georgia Development Test (GDT)-115 is followed for APA testing of asphalt mixtures to determine their rutting susceptibility.

Georgia DOT does not accept plant-produced mixtures on volumetrics and is more concerned with durability, rutting potential, mixture properties (AC content and gradation), and in-place field density. The APA criteria are presented in the laboratory Standard Operating Procedure 2 (Georgia Department of Transportation 2014) and allow an additional ±0.1-in. (2-mm) tolerance for field-produced mix design verification. Any violation of the tolerance means that the mixtures may be subject to removal at the contractor's expense. The agency has different test temperatures based on the mixture location in the pavement's structure. The ¾-in. (19-mm) and 1-in. (25-mm) Superpave mixes are tested at 120°F (49°C) and the ⅜-in. (9.5-mm) and 0.5-in. (12.5-mm) Superpave mixes are tested at 147°F (64°C).

In Georgia, moisture susceptibility testing is of importance because of the stripping potential of aggregates routinely used in asphalt mixtures. The test is done by the Georgia DOT method for comparing the diametral tensile strength of bituminous mixtures on dry and wet specimens (Georgia Department of Transportation 2011), which consists of running a tensile split at a slower rate. The specimen fabrication process is modified from 7.0 ± 1.0% air voids for all asphalt mixtures down to 6.0 ± 1.0% air voids for SMA mixtures. In addition, the special provision requires

TABLE 12
GEORGIA DOT TESTING REQUIREMENTS AND TEST METHODS FOR SUPERPAVE MIXTURES

Test	Test Method
Volumetric Properties	**AASHTO T-312,** "Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of Superpave Gyratory Compactor" AASHTO R 35, "Superpave Volumetric Design for Hot Mix Asphalt (HMA)"
Bulk Density	**AASHTO T-166,** "Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens"
Short Term Aging	**AASHTO R-30,** "Mixture Conditioning of Hot Mix Asphalt (HMA)" Note: The procedure is modified for GDOT mix designs to require only two hours aging.
Maximum Density and Effective Gravity	**AASHTO T-209** "Maximum Specific Gravity of Bituminous Paving Mixtures"
Aggregate Gravities	**AASHTO T-84** "Specific Gravity and Absorption of Fine Aggregate" and **AASHTO T-85,** "Specific Gravity and absorption of Coarse Aggregate" (The designer may obtain coarse aggregate gravities from GDOT or perform this test.)
Moisture Susceptibility	**GDT-66** "Method of Test for Evaluating the Moisture Susceptibility of Bituminous Mixtures by Diametral Tensile Splitting"
Rutting Susceptibility	**GDT-115** "Determining Rutting Susceptibility of Asphalt Paving Mixtures Using the Asphalt Pavement Analyzer (APA)"
Permeability	**GDT-1** Measurement of Water Permeability of Compacted Paving Mixtures

Source: Georgia DOT (2014).

the performance testing using GDT-66 for SMA mixtures as part of its mix design criteria (Georgia Department of Transportation 2013). The rate of stripping of particles is coded according to the degree of stripping (categorized as none, slight, moderate, and severe). The HWTD may also be run for special testing, following the AASHTO T 324 standard for resistance of compacted asphalt mixtures to moisture-induced damage (AASHTO 2014).

Recycled Materials and Nontraditional Mixtures

In Georgia, some different tests or test approaches are required when certain nontraditional mixtures are used. For example, Georgia DOT noted that Abson recovery testing using GDT-119 is conducted on recycled mixtures containing ≥20% RAP for asphalt design approval and QA during production (Georgia Department of Transportation 2014a). The recovered binder is tested to ensure its compliance with the Georgia DOT specified requirements for viscosity of between 6,000 and 16,000 poises.

Georgia DOT allows the use of GTR for mixture modification with the use of the wet or dry method and the test requirements that accompany this use are outlined in its specifications (Georgia Department of Transportation 2012b). It can also be noted that because the dry method does not appear to provide real representative binder modification testing opportunity (i.e., a modified binder cannot be accurately tested at the asphalt plant, as in the case with the wet method), Georgia DOT conducts material usage audits. The audit is performed by acquiring all invoiced GTR quantities dated within the audit time period and comparing with the total asphaltic concrete tonnage produced to ensure that the percentage of GTR approved in the mixture design has been met in the plant-produced mix (from the asphalt drum during production) within ±6% of the required amount of tolerance in the specification. The material audit includes the use of a spreadsheet based on the contractor's invoices and tons of mixture produced compared with the tons of GTR. The materials audit is required throughout the entire mixture production. If there is a trend of violation of the ±6.0% GTR tolerance, a stop-work order is placed on the contractor to address the QC issue at the plant before paving can continue (Georgia Department of Transportation 2014b).

Georgia DOT reported that it has historical and documented issues with stripping of asphalt mixtures owing to certain aggregate types. Therefore, it requires an increased sampling frequency on WMA paving projects in order to conduct moisture susceptibility testing on WMA samples during plant production (Georgia Department of Transportation 2012a). The Georgia DOT Special Provision that deals with WMA is included in web-only Appendix D. There are five asphalt plants in the state that are approved by Georgia DOT to use the foaming system to produce WMA. All WMA designs are verified prior to approval and asphalt plant produced verification samples are tested (using the moisture tensile split test, GDT-66), pulled on the first day of production, and then taken every 5 days or five lots thereafter. The samples are fabricated from nonreheated mix and a number of performance tests are required (Georgia Department of Transportation 2013). The acceptance of the in-place mixes must meet the requirements of the permeability (GDT-1) and rutting susceptibility (GDT-115), and may be subject to fatigue testing using AASHTO T 321 (AASHTO 2003). The Georgia DOT Special Provision that explains the details of the four performance tests is included in web-only Appendix D. Georgia DOT also may verify WMA mix designs (or mix designs incorporating polyphosphoric acid modified binders) using the HWTD according to AASHTO T 324 (AASHTO 2011).

Evaluation of Performance Testing

Georgia DOT has been evaluating the benefits of performance testing (i.e., APA durability, other moisture susceptibility testing) for many years. It reported that some of the attributes considered most important for flexible pavement performance include the resistance to moisture damage, by the agency method, and rutting resistance. As a result, these are the performance-based tests upon which Georgia DOT has concentrated most of its evaluation efforts. Currently, the use of the HWTD test, following the AASHTO T 324 method, is performed on a limited basis. Georgia DOT noted that it has a keen interest in expanding its use of this method and is pursuing a research project to develop Georgia-specific criteria for this test.

Georgia DOT reported that it accepts its asphalt pavements based on mixture control tolerances and in-place air void content. Its plant-produced mix specifications are also validated through field-produced mix design verification that includes complete mixture volumetric testing and permeability, as well as rut susceptibility testing using the APA. Mixture design verification is required for all new mix designs, both at any time a mix adjustment is made in the field and weekly, for all asphalt mixtures placed in interstate pavements. Currently, pay factors are tied directly to mixture control and in-place air void content.

There are two HWTD testers in Georgia at the Georgia DOT Design Laboratory and at one of the Georgia DOT district laboratories. The APA test equipment and the GDT-66 method for moisture susceptibility testing are performed in all Georgia DOT laboratories, as well as in many private consultant and contractor laboratories (Georgia Department of Transportation 2011).

Implementation Efforts Related to Performance-Based Specifications

Georgia DOT is conducting or sponsoring research related to the implementation of performance specifications specifically on the stiffness and moisture resistance properties. For instance, it has participated in the AMPT pooled fund study and sponsored research related to the most effective anti-stripping agents for moisture-susceptible asphalt mixtures. Research is exploring the use of predictive models based on fatigue through the establishment of an S-VECD model and by expanding on the use of aggregate combinations for the dynamic modulus ($|E^*|$) in an attempt to determine a viable fatigue cracking method.

Research

Although Georgia DOT has APA requirements in its current specifications as detailed, it is also reviewing proposals for the generation of state-specific criteria for better predicting the rutting potential of asphalt mixtures. One objective of the research is to develop and propose a HWTD test procedure to be aligned with the Georgia DOT's asphalt materials and mixture design. The research aims to identify the test temperatures and the number of loading (inflection point) of the proposed HWTD process for rutting and stripping performance evaluation. A secondary objective of the research will be to recommend new criteria, vital for evaluating the rut resistance and moisture susceptibility properties of asphalt mixtures by HWTD, such as the maximum allowable rut depth and the maximum number of passes at different temperatures.

The Georgia DOT Pavement Design Unit currently uses life-cycle cost analysis as part of pavement type selection and there is a current research centering on dynamic modulus in preparation for the AASHTOWare Pavement ME Design approach. The primary objectives of the proposed research were reported by Georgia DOT to include:

1. Enhancement of the $|E^*|$ and creep compliance database to include 15 different aggregate sources with PG 64-22, PG 67-22, PG 76-22 PMA, and PG 76-22 PMA with GTR;
2. Recommendation of a test method that predicts realistic strain levels and better fatigue cracking prediction;
3. Comparison of the laboratory and field performance of asphalt mixtures with corrected optimum asphalt content to those using only the optimum asphalt content; and
4. Study of the effects of the nominal maximum aggregate size, aggregate source, binder type, and other mix characteristics on the $|E^*|$, creep compliance, and the long-term performance to propose guidelines for the choice of input data for the AASHTOWare Pavement ME Design software.

Another recent effort underway in Georgia is the comprehensive evaluation of the long-term performance of rubberized pavements (i.e., mixtures containing GTR). This study will evaluate the performance of rubberized porous European mix after 3 and 5 years of service, and SMA pavements after 3 years of service, to determine whether these mixtures perform as well as flexible pavements paved with the polymer-modified asphalt cement, porous European mix, and SMA mixtures. The performance comparison will be conducted by observing results from the Cantabro durability test, weathering test (ASTM 1996), and APA testing of the mixtures included in the study.

LOUISIANA

LDOTD reported that the approval of asphalt mixture designs occurs in the nine LDOTD district offices, and the responsibility to let pavement overlay and road contracts is also at the district level. There are five major asphalt contractors, and 15 to 20 contractors overall, that undertake state paving jobs. All contractor laboratories (in trailers or buildings) must be accredited through the Construction Materials Engineering Council or AASHTO Materials Reference Laboratory. The state listing generally comprises 30 asphalt plants, and most contractors select a fully equipped central location in which to do their initial mix design testing, which does include some performance tests. At this time, the state does not consist of a consultant-based system and, as a result, LDOTD noted that it has been a challenge to implement performance tests such as those conducted with the AMPT equipment owing to the cost and complexity of these tests.

Development and Use of Performance-Based Specifications

Currently, LDOTD Standard Specifications indicate that roadway acceptance testing for asphalt mixtures in Louisiana is limited to density, surface tolerance (i.e., smoothness), and dimensional tolerances (i.e., thickness and width) (Louisiana Department of Transportation and Development 2006). Plant air voids and VFA are used in the acceptance decision with a deduction for air voids outside of available limits. For density testing, three separate cores are taken, per sublot of 1,000 tons, less than 24 hours after placement, and tested by the agency. The contractor is responsible for surface tolerance testing and required to measure the top two lifts of the travel lanes, with the final acceptance based on the measurement of the top lift, as well as to report an average IRI value for the travel lanes. Standard asphalt mixture percent within limit pay adjustment factors for LDOTD are currently based on air voids, roadway density, and IRI, as shown in Tables 13–15.

In the case of SMA mixtures, plant acceptance tests currently include the percentage of added anti-strip, percentage of

TABLE 13
LOUISIANA DOTD PAY ADJUSTMENT SCHEDULE FOR ROADWAY DENSITY OF ASPHALT MIXTURES

Roadway Density PWL	Percent Payment
98-100	105
89-97	100
79-88	98
61-78	90
31-60	80
≤30	50 or Remove[1]

[1]At the option of the Department after investigation.
Source: Louisiana Department of Transportation and Development (2006).

TABLE 14
LOUISIANA DOTD PAY ADJUSTMENT SCHEDULE FOR PLANT ACCEPTANCE OF ASPHALT MIXTURES

Air Voids PWL	Percent Payment
100	103
88-99	100
71-87	98
51-70	90
21-50	80
≤20	50 or Remove[1]

[1]At the option of the Department after investigation.
Source: Louisiana Department of Transportation and Development (2006).

air voids, VMA, and gradation, whereas the roadway acceptance tests include pavement density and surface tolerance (Louisiana Department of Transportation and Development 2006).

LDOTD noted that there have not been many instances of rutting in existing Superpave asphalt pavements, except for some extraneous reasons such as issues at the plant during production, issues in the field during construction, or material problems. Therefore, it indicated that the control of moisture damage and fatigue were performance-based tests the agency considers most important for predicting the pavement performance typical for its roadway system.

Evaluation of Performance Testing

LDOTD is developing specifications that will ultimately use contractor QC tests for acceptance. In the existing specifications, the agency only currently considers volumetric properties; however, it is evaluating test values related to both mixture stripping and rutting to establish a PBS using the loaded wheel tracking test (LWT). The results from the SCB test are planned for use by LDOTD for indicating materials that will or will not perform in the field specifically related to fatigue cracking.

LDOTD has been evaluating the benefits of performance testing for some time and has concentrated primarily on the LWT and SCB tests. A specification is currently in development that will require that asphalt mixtures be tested initially at the contractor's plant in the LWT for rutting and moisture damage, and the SCB test for fatigue. At this time, the new SCB specification is only planned for design purposes as part of the JMF submitted by the contractors. LDOTD will then also take plant samples and the SCB test results will then be verified at the agency district materials laboratories for information purposes.

TABLE 15
LOUISIANA DOTD PAY ADJUSTMENT SCHEDULE FOR MAXIMUM IRI OF ASPHALT MIXTURES IN INCHES PER MILE (mm per km)

Percent of Contract Unit Price (by Sublot)[1]	103%[2]	100%	90%	80%	50% or Remove[3]
Category A All Interstates, Multi-Lift New Construction and Overlays of More than two Lifts	<55 (<870)	<65 (<1030)	65-75 (1030-1180)	NA	>75 (>1180)
Category B One or Two Lift Overlays Over Cold Planed Surfaces, and Two-Lift Overlays Over Existing Surfaces[4]	<65 (<1030)	<75 (<1180)	75-89 (1180-1400)	NA	>89 (>1400)
Category C Single-Lift Overlays Over Existing Surfaces[4]	<75 (<1180)	<85 (<1340)	85-95 (1340-1500)	>95-110 (>1500-1740)	>110 (>1740)
Longitudinal Surface Tolerance Incentive Pay, Final Completion, Average of All Travel Lanes[5]	≤45 (≤710)				

[1]Or portion of sublot placed on the project.
[2]Maximum payment for sublots with exception areas, exclusions or grinding is 100 percent, unless the excluded area is a bridge end.
[3]At the option of the engineer.
[4] Existing surfaces include reconstructed bases without profile grade control.
[5]Only Category A projects are eligible for incentive. However, any grinding except within 300 feet (90 m) of a bridge end will cause the roadway to be ineligible for surface tolerance incentive pay.
Source: Louisiana Department of Transportation and Development (2006).

To generate these initial performance-descriptive values, loose mixture samples were taken from 28 Superpave projects between 1997 and 2002. Gyratory specimens were fabricated and run in the SCB test at the Louisiana Transportation Research Center (LTRC). The mix samples were taken from both wearing and binder courses for both lower-volume and high-volume pavement designs. The results of this investigation provided J_c values, from the SCB test, for both the high- and low-volume roadway mixes to establish minimum design levels of J_c. In the 2015 paving season, two LDOTD districts will use the new specifications in all projects at the mix design phase. An additional 14 projects will be piloted with two in each of the other seven districts.

In a current research study, Research Project 10-4B, "Development of Performance Based Specifications for Louisiana Asphalt Mixtures," the LTRC is evaluating the SCB test on both gyratory produced (plant) and field compacted (roadway) with the ultimate goal of using roadway compacted specimens in the acceptance decision, thus achieving an end result specification. The J_c values determined from SCB tests of these plant and field samples will be correlated to the previous values used to establish design values. A complete copy of LTRC Project Research Capsule 10-4B is included in web-only Appendix D.

Another research project, 11-3B "Testing and Analysis of Loaded Wheel Tester and SCB Properties of Asphaltic Concrete Mixtures," is assessing the adaptation of the SCB test to the Marshall Load frame, which costs approximately $10,000 to make it feasible to incorporate the SCB test in both the contractor and district labs. A complete copy of LTRC Project Research Capsule 11-3B is included in web-only Appendix D.

LDOTD anticipates initiating the LWT test in the plant and the SCB test for design in early 2016. With the successful completion of the 10-4B and 11-3B research projects, the agency hopes to add the SCB test of roadway samples as an acceptance criteria.

Implementation Efforts Related to Performance-Based Specifications

LDOTD reported that it is implementing asphalt performance mix designs by a multifaceted approach that includes: (1) using shadow performance mix design testing for data collection and using standard volumetric properties for mix design; (2) qualification, project QC, and acceptance tests; (3) using performance-based mix design properties and tests to qualify the mix and then using volumetric properties for project QC and production acceptance; and (4) by collecting results from SCB testing at the plant during production for future acceptance testing. The results from these tests will be compared with the proposed SCB (J_c) values from the earlier Superpave mixtures that were monitored.

In addition, the agency has created and conducted training workshops to educate its industry partners on the use of the SCB test and on the forthcoming PBS changes. LDOTD noted that the industry perspective has been that contractors appreciate the need for performance testing to validate the impacts of inputting more RAP and other materials into their mixes.

Since 2008, LDOTD has allowed laboratory blending of crumb rubber that the agency noted had accelerated the interest in getting LWT out to the contractors. In addition, the agency noted that the use of performance testing can support the proposed specification for the use of crumb rubber.

A remaining challenge for LDOTD in implementing performance testing is the desire to run these tests on field samples. The cost of the current SCB test is too prohibitive to be used in all plant and district labs. The agency is therefore looking to modify a Marshall load frame, which loads at a slower rate similar to the Illinois DOT procedure for SCB. This will require a considerable research effort to obtain loose mix and field samples in order to correlate the design J_c with the J_c obtained with the Marshall load frame tester. Once sufficient samples can be obtained for correlation, the SCB test with the Marshall load frame tester could be used for field QC or acceptance testing.

Research

LDOTD reported that a number of research projects are currently underway that relate to the use of performance testing to support the development of PBS. For example, research is planned at the agency and the LTRC that will evaluate the specimen aging process for the SCB test. Another project is exploring the use of the TSRST test to help with the prediction of thermal fracture of Louisiana's asphalt mixtures (Cooper et al. 2014a). The application of the findings of this research could eventually be integrated into a PBS.

Future research reported by LDOTD also includes its involvement in a Pooled Fund Study TPF-5(294) being conducted by the LTRC that will evaluate various fatigue tests, including identifying differences in how the results from these tests differ for mixtures produced with higher RAP or RAS contents. Specifically, one objective of the research project is to establish mechanistic test criteria for achieving durable flexible pavements made from both WMA and HMA mixtures that contain high RAP and/or RAS contents. A second objective is to develop preliminary asphalt mixture specifications that incorporate the resulting mechanistic test criteria to be tested on plant-produced specimens and/or roadway cores, as based on the results of the study. The testing of plant-produced mixtures and roadway cores will facilitate the evaluation of the impacts of higher RAP and/or RAS percentages on the durability of the asphalt mixtures investigated as part of the study.

TABLE 16
KEY FEATURES OF NEW JERSEY DOT PERFORMANCE-BASED SPECIFICATIONS

High RAP Content	Surface Course: Minimum 20% RAP		Base or Intermediate Course: Minimum 30% RAP	
Asphalt Mixture Types Included	Ground tire rubber (GTR), high RAP content, WMA, RAS, crushed recycled container glass, and other additives			
Required Performance Tests for Design, Acceptance, and Pay Adjustments	Rutting	APA testing	AASHTO T 340 test procedure	six specimens
	Moisture susceptibility	TSR test	AASHTO T 283 test procedure	Minimum TSR of 80% in design
	Fatigue and reflective cracking	Overlay Tester	NJDOT B-10 test procedure	three specimens

Source: New Jersey DOT (2007b).

NEW JERSEY

In New Jersey, approximately $300 million of the New Jersey DOT's budget of $2.52 billion is allocated to roadway assets, which consist primarily of paving projects (New Jersey Department of Transportation 2014). In the 2015 work program, New Jersey DOT estimates that approximately 350 lane-miles (563 lane-km) of preventative maintenance paving projects and 600 lane-miles (966 lane-km) will be resurfaced, reconstructed, or rehabilitated. This represents 12% of the total system mainline lane-miles in the state.

New Jersey DOT reported that it has been using PBS for nontraditional specialty asphalt mixes since 2006 and pilot projects were begun in early 2007. The use of PBS mixes has increased since then; however, New Jersey DOT noted that the bulk of its paving projects are for traditional Superpave HMA projects and SMA mixtures. At this time, performance criteria have not yet been developed for these traditional asphalt mixtures (i.e., dense-graded HMA, SMA, and open-graded friction course mixtures).

Development and Use of Performance-Based Specifications

New Jersey DOT noted that it has been incorporating performance specifications through a combined system of both acceptance and rejection of mixtures and pay adjustments. It was reported that the agency aims to have PBS for all asphalt mixtures and that these are currently complete, under development, or will be under development in the near future. Table 16 summarizes some of the key features of the PBS used with recycled or modified mixtures in New Jersey.

A copy of the NJDOT B-10 test procedure for the Overlay Tester (New Jersey Department of Transportation 2007b) is included in web-only Appendix D. Table 17 shows the

TABLE 17
NEW JERSEY DOT PERFORMANCE TESTING REQUIREMENTS AND TEST METHODS FOR DESIGN OF HMA HIGH RAP MIXTURES

Table 902.11.03-2 Performance Testing Requirements for HMA High RAP Design				
	Requirement			
	Surface course		Intermediate course	
Test	PG 64-22	PG 76-22	PG 64-22	PG 76-22
APA at 8,000 loading cycles (AASHTO T 340)	<7 mm	<4 mm	<7 mm	<4 mm
Overlay Tester (NJDOT B-10)	>150 cycles	>175 cycles	>100 cycles	>125 cycles

Source: New Jersey DOT (2007b).

TABLE 18
NEW JERSEY DOT PERFORMANCE TESTING PAY ADJUSTMENTS FOR HMA HIGH RAP MIXTURES

Table 902.11.04-2 Performance Testing Pay Adjustments for HMA High RAP					
	Surface course		Intermediate course		Percent Pay Adjustment
	PG 64-22	PG 76-22	PG 64-22	PG 76-22	
APA at 8,000 loading cycles, mm (AASHTO T 340)	$t^* \le 7$ $7 > t > 10$ $t \ge 10$	$t \le 4$ $4 > t > 7$ $t \ge 7$	$t \le 7$ $7 > t > 10$ $t \ge 10$	$t \le 4$ $4 > t > 7$ $t \ge 7$	0% −1% −5%
Overlay Tester, cycles (NJDOT B-10)	$t \ge 150$ $150 > t > 100$ $t < 100$	$t \ge 175$ $175 > t > 125$ $t \le 125$	$t \ge 100$ $100 > t > 75$ $t \le 75$	$t \ge 125$ $125 > t > 90$ $t \le 90$	0% −1% −5%

*t = depth of rutting in millimeters for the APA, t = number of cycles for the Overlay Tester.
Source: New Jersey DOT (2007a).

details of the criteria that must be met in any asphalt JMF that contains a high percentage of RAP materials.

New Jersey DOT specifications also address performance testing for high RAP mixtures for acceptance and pay adjustment. The contractor must provide five 5-gallon buckets of loose mix to be tested in the APA and Overlay Tester (New Jersey Department of Transportation 2007a). The first sample must be taken during the construction of the test strip and then sampling follows from every lot thereafter. If any samples do not meet the design criteria shown in Table 17, a pay adjustment will be assigned from the criteria shown in Table 18. New Jersey DOT also will assess a pay adjustment, calculated by multiplying the percent pay adjustment by the quantity in the lot and the bid price for the HMA high RAP item, if a lot fails to meet requirements for both the APA and Overlay Tester.

New Jersey DOT also has PBS for its BDWSC pavements, which requires testing in the APA and in flexural beam fatigue. The first sample is taken during the first lot of production and thereafter a sample must be taken every second lot. The performance criteria for this course include a rut depth of less than 0.12 in. (3 mm) in the APA at 8,000 loading cycles and more than 100,000 cycles to failure in the flexural beam fatigue test. Similarly, New Jersey DOT requires performance testing by the APA and flexural beam fatigue of its BRBC pavements. The agency performance specification information is included in Table 19 along with that of the BDWSC.

The performance testing required for BRIC pavements is similar in format to that of the high RAP mixtures and the specification is included in web-only Appendix D. The specification requires that both the APA and Overlay Tester are run for mix design and production performance.

New Jersey DOT specifications require that any asphalt rubber gap-graded course mixtures be performance tested using the TSR with an 80% minimum design requirement. During plant production, sampling is required every 700 tons to verify composition and air voids, while testing for binder draindown, voids in the coarse aggregate of the mix (VCA_{mix}),

TABLE 19
NEW JERSEY DOT PERFORMANCE TESTING REQUIREMENTS FOR VARIOUS SPECIALIZED PAVING MIXTURES

Performance Testing Requirements for Specialized Mixtures		
Test	Requirement for BRBC Mixtures	Requirement for BDWSC Mixtures
Asphalt Pavement Analyzer (AASHTO T 340)	<5 mm at 8,000 loading cycles	<3 mm at 8,000 loading cycles
Flexural Fatigue Life of HMA (AASHTO T 321)	>100,000,000 cycles at 100 microstrains	>100,000 cycles

Source: New Jersey DOT (2007a).

VCA of the aggregates (VCA_{dry}), and the VMA is required every 3,500 tons of produced mix.

Evaluation of Performance Testing

New Jersey DOT has been evaluating the use of performance testing since 2006, and has established criteria for asphalt mixtures accordingly by focusing on fatigue resistance, moisture resistance, and stiffness modulus. In addition, the agency reported that it has done several demonstration projects with performance mixture specifications that used the APA, Overlay Tester, and flexural beam fatigue test equipment. Mixtures such as the HMA with RAP percentages, BRIC, HPTO, and BRBC have been evaluated. The evaluation of these tests has shown that to-date, the plant-produced mixtures have had high potential for longer life. New Jersey DOT noted that thus far, the mixes have been performing very well in the field. It is also using its Pavement Management System to conduct annual field monitoring of the projects and, in one of the projects, the agency has also taken cores and conducted additional visual distress surveys.

Training on the performance tests required in the New Jersey DOT specifications is provided through the New Jersey Society of Asphalt Technologists. Some of the past training sessions included aspects of mixes subject to PBS. The link to the training website is provided in Appendix C.

Implementation Efforts Related to Performance-Based Specifications

New Jersey DOT is planning to invest in testing equipment and training on performance testing of asphalt mixtures of its staff, consultants, and contractor industry members. At this time, only two universities and New Jersey DOT have performance testing capabilities. Currently, there are no in-house testing capabilities at the contractor and private consultant laboratories in the state. There are two New Jersey universities that are equipped with a full range of performance test equipment. However, to make this investment, New Jersey DOT reported that there is a need to first expand the limited staff levels in the Materials Laboratory.

New Jersey DOT noted that it has conducted a basic cost–benefit analysis with Rutgers University that is based on the fatigue laboratory performance tests of plant-produced mixtures. This study has been underway for several years and thus far there have been no failures of the mixtures in the field. The laboratory results showed high potential for good field performance in cracking and the cost–benefit ratio was based on the fatigue test results because rutting is not a common problem for asphalt mixtures in New Jersey. The basic approach to the cost–benefit analysis included testing the standard HMA and the high-performance plant-produced mixtures in the Overlay Tester to measure the properties to predict the number of cycles to failure. An average cost per ton of material was obtained for both a standard HMA mix and six other high-performance mixtures. A performance ratio was also calculated to compare the standard HMA and the high-performance mixtures, and this was used to calculate a benefit–cost ratio. The preliminary results observed by New Jersey DOT were that major benefits are exhibited by mixes with increased binder (i.e., binder rich) in terms of the total cycles to failure in the Overlay Tester.

Research

One research study currently sponsored by New Jersey DOT is investigating the concept of a balanced mixture design that would identify the range of asphalt contents where both rutting and fatigue cracking performance are satisfied and subsequently recommend the appropriate optimum asphalt content. The expected outcome will be to propose performance-based criteria that are sensitive to (1) various traffic levels and (2) location of the mix in the pavement (i.e., surface, intermediate, or base layer) for conventional asphalt mixtures in New Jersey.

Another research study sponsored by New Jersey DOT concerns evaluating how multiple quality characteristics of asphalt mixtures can be incorporated into pay adjustments. It also aims to develop performance-related pay adjustments for use in New Jersey. Construction data and pavement performance data collected from many projects constructed in the state from 1995 through 2005 are being used as part of the study. The study also includes laboratory tests to measure the air voids and permeability of field cores taken at the longitudinal joint. Finally, this research project will propose the minimum bonding strength required to prevent premature slippage cracking or fatigue cracking in flexible pavements.

Another recent research project funded by New Jersey DOT was initiated to support the improvement of pavement service life by performing QA on tack coat bond strength. Because of the large number of both flexible and composite pavements in New Jersey, the agency is concerned with the performance of the quality of bonding between layers because the multiple layers were designed structurally to act as a single layer. The outcomes of the study will be to establish minimum acceptable and desired bond strength values for future projects and to update the New Jersey DOT's tack coat specification by tying it to performance criteria.

OHIO

Several years ago Ohio DOT evaluated PRS for concrete pavements and ran some PCC PRS demonstration projects, but did not pursue a similar path for flexible pavements. Ohio DOT uses the full range of asphalt mix designs including hot and warm mixes, RAP, RAS, and mixes with crumb rubber or rubberized asphalt. The agency considers the volumetric properties used in its current Superpave asphalt specifications (i.e., asphalt content, gradation, air voids, and VMA) to be indirect measures of performance (i.e., durability) in volumetric mix designs. During the design stage as part of RAP binder analysis, if the RAP has gravel in it, Ohio DOT requires a TSR test in addition to the standard volumetric mix properties.

Development and Use of Performance-Based Specifications

Ohio DOT has incorporated APA testing for rutting in the design mix if there is more than 15% fine aggregates (mixes are considered to not meet the angularity requirements in accordance with Ohio DOT specifications). The agency considers rutting and friction in its current mix design process for heavy mixes (i.e., exposed to high traffic volumes). For example, the APA is used solely for Superpave volumetric mixes (heavy mixes). For medium and lighter mixes, Ohio DOT uses the Marshall mixture design approach. The agency also uses the HWTD and TSR tests for measuring the potential for moisture damage. The Ohio DOT district labs generally run the standard extraction tests, gradation testing, and AC content, whereas the Central Office lab includes a gyratory compactor for Superpave and runs the other heavy mix performance tests including APA, TSR, and the Polisher test. The Polisher test is a friction test used to qualify the mix. It uses the British Pendulum Number, in accordance with ASTM E 303, to determine a British Pendulum Number and a degradation curve. It was developed for use in Ohio on selected DOT projects where the aggregate sources are in some cases not suitable for surface mixes. The plan note for the Polisher test, *Polishing and Determining Friction of Gyratory Compacted Asphalt Specimens,* is included in web-only Appendix D together with an Excel™ database of trial projects. Ohio DOT is currently using these performance tests as part of its standard specification requirements for its heavy mixes. In addition, the agency incorporates performance tests for rutting (i.e., the APA test) and flexural beam fatigue (AASHTO T321) in its Supplement Specification 856, Bridge Deck Waterproofing Hot Mix Asphalt Surface Course (WHMA), which is a highly polymer-modified impermeable asphalt surface course specification, as shown in Table 20. The specification is included as a sample document in web-only Appendix D.

Evaluation of Performance Testing

Ohio DOT has conducted or sponsored research on testing related to durability properties, thermal cracking, and moisture susceptibility. For example, it has just completed a research project focused on evaluating WMA with water injection and found that there was not much difference in the amount of aging between WMA and HMA mixes. Also, if using high RAP content, Ohio DOT requires the use of specific performance grade binders. It is about to initiate a research study, "Crack Resistance and Durability of RAS Mixes," and is interested in developing a fatigue test, similar to the Texas Overlay Tester, to adjust the test to be something more easily run by a technician without requiring advanced education or extensive training. The Ohio DOT Office of Research will contract with a local university or other research centers to further research fatigue testing.

TABLE 20
JMF CRITERIA FOR OHIO DOT HMA SURFACE COURSE FOR BRIDGE DECKS

JMF Criteria	Specification
Total Modified Binder, percent, min.	7.25
Gryations, Ndes/ Nmax	50/75
Air Voids, percent	1.5
VMA, percent, min.	15.5
Permeability, ft./day, max. [1]	2.8×10^{-4}
Rutting, mm, max. [2]	4
Flexural Beam Fatigue, cycles, min. [3]	100,000

[1] ASTM D5084 on samples with 2.0 +/- 0.5% percent air voids.
[2] AASHTO T340 (APA) on average of 3 gyratory specimens at 4.0 +/- 0.1% percent air voids at 147°F (64°C)
[3] Only required for steel deck bridges. AASHTO T321 at 1500 microstrains, 10Hz, on average of two samples with 4.0 +/- 1.0% air voids.
Source: Ohio DOT (2013).

Implementation Efforts Related to Performance-Based Specifications

Ohio DOT has recently begun exploring the costs to benefits of performance testing. It reported that more staff is needed to conduct more extensive performance testing. Some level of performance testing has been integrated into Ohio DOT specification requirements for heavy mixes including the APA, HWTD, TSR, and the Polisher. The agency reported that it eventually plans to incorporate a fatigue performance test. It noted some issues that might make it more difficult to immediately shift to the use of a PBS for the design and acceptance of asphalt mixtures. These issues included the lack of familiarity with performance specifications for asphalt mixtures by the local paving industry, gaps in knowledge or information on how to successfully implement performance specifications for asphalt mixtures, and insufficient funds and staffing required to run the additional tests.

TEXAS DEPARTMENT OF TRANSPORTATION

TEXAS

Texas DOT and many other DOTs since the implementation of the original SHRP program (specifically, Superpave for asphalt pavements) have been focusing on performance tests at the mix design stage that more directly measure asphalt pavement performance distresses. Texas DOT has implemented wheel track testing to address rutting, but with the greater use of recycled materials and concerns over premature cracking from the resulting stiffer mixes, the agency has moved toward the development of a performance test for cracking using a balanced mix design procedure for its asphalt performance mixes. This shift included a simple mechanistic-based asphalt overlay design procedure.

The placement of an asphalt overlay is the most common method used by Texas DOT to rehabilitate existing asphalt or concrete pavements. The agency uses the full complement of asphalt mixtures for its plant-produced asphalt pavements including HMA, WMA, RAP, mixes with RAS, and mixes with crumb rubber from recycled tires. Generally, the percentage of RAS materials in the mix is capped (at 5%), but the same approach to qualifying the mixes (i.e., tests, sample size, and frequency) is used for all of these mix types. Selecting the appropriate combination of aggregates and binder types is a difficult balancing process because from Texas DOT's perspective for asphalt mixes to perform well in the field they must have the correct balance of both adequate rutting and cracking resistance. Texas DOT reported that the use of RAP and RAS mixes reduces cost and improves the rutting resistance of HMA pavements; however, using these recycled materials can also result in overly stiff mix designs that are more prone to premature cracking.

Development and Use of Performance-Based Specifications

Texas DOT reported that its objectives for its use of PBS include producing longer service life pavements and improving the performance in terms of rutting resistance, fatigue and low temperature cracking, and ride quality. The agency uses performance tests for virtually all types of projects including flexible pavements on interstates, other arterials on its highway system, and local or county roads.

The current Texas DOT standard specifications asphalt pavement sections, specifically Item 340—Dense-Graded Hot-Mix Asphalt (Small Quantity), and Item 341—Dense-Graded Hot-Mix Asphalt, include the HWTD test for both the mix design qualification and for acceptance, as shown in web-only Appendix D. The HWTD test can be performed at any time during production, but typically one additional field test is performed per project on a pass/fail basis (usually toward the beginning of field production) to ensure that the agency is getting the correct asphalt mixture during production. The HWTD test is used as a direct measurement of rutting and stripping for durability and moisture resistance.

Texas DOT has also incorporated the Texas Overlay Test with selected items in its standard specifications. These specifications include Item 342—Permeable Friction Course, and Item 346—Stone Matrix Asphalt (both included in web-only Appendix D). An early form of the Texas Overlay Test was developed and has been in use since the late 1970s for reflective cracking of asphalt overlays; however, early results also indicated that the Texas Overlay Test had the potential to be used as a tool to screen good from poor crack-resistant mixes. Since 2006, substantial work has been done by Texas Transportation Institute and others to address concerns raised about using the Overlay Test procedure for mix design purposes. The current Texas Overlay Test procedure, Tex-248-F, has been integrated into specific mix designs in conjunction with the HWTD test as noted previously to provide a more balanced approach to controlling both rutting and cracking for specific HMA mix designs.

Evaluation of Performance Testing

Texas DOT, in conjunction with Texas Transportation Institute and other institutions, has conducted various studies on the Texas Overlay Test to address the issue of repeatability of its test results. Because the Texas Overlay Test is a repeated loading test, it tends to have a higher variability than single load tests. Various sensitivity studies were completed on Texas DOT mixes to address factors that affected variability such as asphalt content, performance grade, and test temperature. The agency reported that increasing the asphalt content was observed to significantly improve the cracking resistance. As part of validation efforts, Texas Overlay Test results for different mix types were also compared with field testing performance of pavement sections with different types of cracking, including reflective cracking, fatigue cracking, and low temperature cracking. The results of these studies led Texas DOT to develop specifications that use the HWTD test for standard applications and both the HWTD and Texas Overlay Tester for specific mix design applications.

Implementation Efforts Related to Performance-Based Specifications

Texas DOT has implemented performance testing in its standard specifications for both mix design and production testing. Production testing using the HWTD can occur whenever there is a change in the quality of the mix or areas of rutting are observed. The agency reported that its normal dense-graded mix designs (Items 340 and 341) do not perform well in the Texas Overlay Test (i.e., result in relatively low cycles to failure). For these standard items, Texas DOT reported that it uses the HWTD test, but not the Texas Overlay Test. The permeable friction course (Item 342) and the SMA specification (Item 346) incorporate both the HWTD and the Texas Overlay Test for approval of the job mix formula design and HWTD for production as a pass/fail test.

UTAH

Utah has significant climatic variability from the northern to southern portion of the state, and Utah DOT reported that it has had to adjust its asphalt mix designs to accommodate for the use of recycled materials and to address policy issues with its mix designs. Utah DOT currently uses a standard Superpave HMA volumetric mix design for asphalt pavements with acceptance and pay adjustments based on gradation, AC content, in-place density, and longitudinal joint density (from cores). The agency reported that it also uses the HWTD and TSR tests in its standard mixes for rutting resistance and resistance to moisture damage.

Utah DOT noted that it has stopped paying for binder separately in its contract items, which resulted in contractor mixes with lower AC content for its Superpave mixes. This policy change resulted in what the agency described as dried-out mixes observed to have greater susceptibility to cracking. Utah DOT has reduced the number of gyrations to fewer than 100 in its mix design to address this issue and treats aggregate with hydrated lime for all Superpave mixes. Utah DOT also uses styrene–butadiene–styrene polymer-modified mixes to improve performance and control thermal cracking for RAP mixes. Utah DOT uses up to 25% RAP crumb rubber in the mix for 15%–25% RAP, the agency can bump the PG grade down one level to a softer mix. For RAP mixes with crumb rubber, Utah DOT uses only the wet method (ultimate tensile strength tests on wet specimens); it cannot use the dry method for crumb rubber. It also noted that it does not allow the use of RAS or recycled engine oil due to perceived problems with achieving the appropriate level of mixture stiffness. Utah DOT uses the same design requirements for warm mix.

Development and Use of Performance-Based Specifications

All of Utah DOT current mix designs incorporate the HWTD test for predicting rut resistance; however, the agency reported that it is not satisfied with its mix designs and wants to incorporate a performance test for cracking. The objective is to balance the mix design to provide resistance to rutting and cracking or get more asphalt binder in the mix, based on the use of a SCB test and mixture BBR test for low temperature cracking. The current Utah DOT specification 02741—Hot Mix Asphalt, shown in web-only Appendix D, uses the HWTD test for rutting for all applications. The HWTD test is specified for mix qualification and, if production is suspended, the specifications allow the Utah DOT engineer to conduct additional HWTD testing on production material. Utah DOT binder specification 02745—Asphalt Material Modifies Performance Grade Asphalt Binder (AASHTO M 320) is used for more significant differences in design temperatures where $|G^*|$ for stiffness is broken out separately. This specification is also included in web-only Appendix D. Utah DOT is also currently implementing the AASHTOWare Pavement ME Design approach incorporating mechanistic properties in asphalt mixture design (i.e., use of $|E^*|$ and prediction of strain levels and fatigue cracking).

Evaluation of Performance Testing

Utah DOT noted that it is currently conducting research with the University of Utah on mixture BBR and is developing a provisional standard. A consultant is also researching the SCB test in order to use it for achieving a better balanced mix design for resisting both rutting and cracking resistance and to get proportionally more AC in the mix.

Implementation Efforts Related to Performance-Based Specifications

Utah DOT observed that performance testing is applicable to all mix designs, but is especially relevant for long-life pavement designs and for selected asphalt overlays where underlying PCC pavement conditions are well known. The thinking within Utah DOT is that the use of alternative project delivery in conjunction with good, robust performance tests will allow Utah DOT to scale back its acceptance and reduce the frequency of acceptance testing.

Using the current HWTD test for acceptance has been observed by Utah DOT to be somewhat problematic, due to the test's turnaround time (specifically, the conditioning time) for plant mixes. The agency also reported that there is currently a gap between the specifications and field mix performance regarding mixture acceptance using HWTD test data. The costs of performance testing were also reported to be a challenge. It was noted that the cost and time of BBR testing is not good for a field test, recognizing that the BBR test is currently part of Utah DOT's binder specification. The agency noted that the SCB test has shown better promise as a field test.

FLORIDA

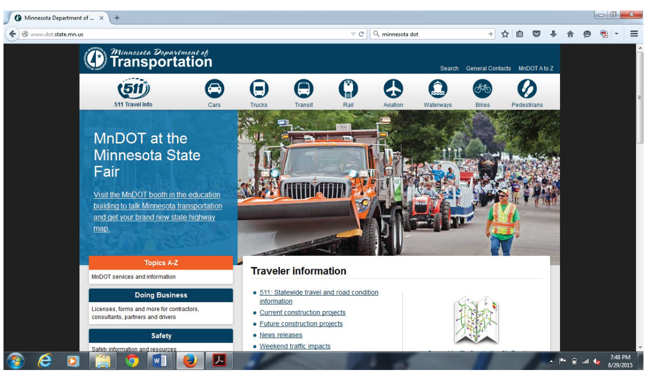
Florida DOT generally uses performance tests for research purposes and also to help establish appropriate specification criteria that will ensure good performance. Performance tests currently being evaluated by Florida DOT include the AMPT for flow number and dynamic modulus; the HWTD and APA tests for rutting; the IDT and Texas Overlay Tester for cracking; and the interlayer bond-strength test for bonding between paved layers. Other research reported by the agency includes the fracture energy test to predict top-down cracking.

In one region of the state, there are a number of farm-to-market roads that were not originally designed with the structural capacity to carry heavy loads. This same region also has had an historical problem with rutting. On these particular asphalt paving projects the APA test is required for all dense-graded mixes.

In general, Florida DOT observed that a challenge to incorporating these performance tests as a basis for PBS is the practicality of using them for routine production testing. Another concern noted by the agency is the lack of familiarity by the contracting industry with the performance tests, thereby making it difficult for them to bid on projects. One idea Florida DOT offered for overcoming this challenge would be to develop and populate a materials database that would provide the contracting industry with a basis for determining what the typical properties of their materials are for use in bidding flexible pavement projects.

MARYLAND

The Maryland State Highway Administration reported that it is participating in a pooled fund research study focused on minimizing the cost of the AMPT equipment to make it more affordable for state officials to complete testing to generate Level 1 materials inputs to the AASHTOWare Pavement ME Design software. The scope of the study was reported to include the AMPT testing of a number of the most common asphalt mixtures used in Maryland for their dynamic modulus. The study is designed to outfit the AMPT to provide a wider range of available data such that the equipment cost will be reduced to a more marketable price, which the agency reported provides the equipment with more versatility for use in the design and construction phases.



MINNESOTA

Minnesota DOT has found that low temperature cracking is the most common pavement distress in its asphalt pavements. Minnesota DOT specifications have to date handled this issue by requiring certain low-temperature grade asphalt binders on all new construction projects over granular base or full-depth reclaimed sections. Although it reduces thermal cracking, a low temperature binder grade does not account for factors such as aggregate types and gradations, recycled materials, or plant and field aging. Minnesota DOT decided that improved testing of asphalt mixtures was necessary to obtain better performance and the DCT was determined to be a good indicator of a pavement's resistance to this type of cracking.

Minnesota DOT subsequently developed a specification provision that includes the DCT test to predict the low temperature cracking potential of asphalt mixtures. The provision requires that the asphalt mix design meet the minimum fracture energy before the mixture is permitted to go to production and placement on the roadway. The sampling required in the provision is per approximately every 2,000 tons of wearing course mixture (i.e., the top 4 in.). The DCT testing will be performed by Minnesota DOT and be used to determine the acceptability of the mixture design. A copy of the Minnesota DCT 2013 Provisional Specification is included in web-only Appendix D.

Minnesota DOT tested the specification on five pilot construction projects across the state, representing differing climatic conditions, construction practices, and asphalt PG binder grades (Van Deusan et al. 2015). The goal of the pilot projects was to implement DCT testing for the mix design and production phases of construction and observe any issues. The testing target was used to verify that mixes met a required fracture energy value of 400 J/m^2. If DCT results did not meet this requirement, mix adjustment recommendations were made by the research team. When recommendations were accepted, test sections with adjusted mix were paved. DCT testing was conducted on both adjusted and unadjusted production mix.

Of the five projects, two passed at mix design and required no mixture adjustments. The remaining three projects did not meet the 400 J/m^2 requirement at mix design and mixture adjustments were made during production. Approximately 9 months after construction, Minnesota DOT conducted distress surveys to gage initial pavement performance after one season of freezing conditions. Results were mixed, with projects constructed with mill and overlay experiencing higher cracking amounts than those with new construction or full-depth reclaimed. This could be attributed to reflective cracking from the pre-existing underlying pavement. A trend of decreasing fracture energy from mix design to production was also observed. Minnesota DOT is conducting a follow-up study (results to be published later in 2015) to compare test results from mix design and production stages to determine the cause of this trend and is also investigating DCT repeatability with four different independent laboratories.

VIRGINIA

Virginia DOT reported that the TSR is also used in its specifications (since at least the 1980s) and that the contractor must run the test and Virginia DOT validates the test results. Typically, verification tests are ideally conducted at the Virginia DOT district laboratories. However, the Virginia DOT's central laboratory has the ability to run tests as well, in the event that the district laboratories are too busy or have specialty testing or forensic investigation needs.

Finally, Virginia DOT uses the Bond test currently in referee-type circumstances (i.e., where the issue goes into a dispute resolution process including the contractor and state highway agency) when there is a question about the tack or bond quality. However, it otherwise is not currently a part of the Virginia DOT's HMA specifications and is only used when the construction process has clearly produced a mixture that is not performing properly. Virginia DOT reported that it is investigating the use of end-result bond strength requirements in any future versions of its asphalt specifications. It also uses IRI testing as part of its performance measures on new asphalt pavements.

WISCONSIN

Wisconsin DOT desired to improve the way that it works with recycled materials in conjunction with industry wanting to find more economical ways to produce mixes. The agency formed a specification development team with the Wisconsin Asphalt Producers Association to pilot the use of mixtures produced with more than 25% recycled materials in HMA and use performance testing to meet baseline performance levels (Paye 2014). Wisconsin DOT requires the use of HWTD for moisture and rutting, and DCT tests for low temperature cracking for mixture acceptance, along with the resultant PG grading. The SCB test for fatigue cracking is required as well, but only for information purposes (still under development). Tests for the HWTD, DCT, and SCB are performed according to the Wisconsin DOT Modified Testing Procedure, whereas testing for the mixture resultant PG grading is according to AASHTO R 29 and M 320. Other standard specification modifications included raising the TSR from 0.70 to 0.75 and lowering target air voids (from 4% to 3.5%). A test strip is required and will only be accepted if the required volumetric, performance, and density results meet the tolerances specified in Special Provisions STH 77 High Recycle asphalt mixtures. Long-term aging (5 days) was required for the DCT and SCB tests.

If the test strip does not meet the tolerances for volumetric, performance, and density per STH 77, the test strip is then considered nonconforming for that mixture type. A second test strip for that mixture type must then be conducted off site. No more on-site test strips for that mixture type will then be allowed, owing to any change in plant or source. Wisconsin DOT will measure HMA test strips by the Lump Sum acceptably completed as passing the required air voids, VMA, density, HWTD, and DCT tests for an on-site test strip only. The agency used the specification on two pilot projects in the 2014 construction season (mill and overlay, and reconstruction) in the lower and upper lifts and planed for a third pilot project for the 2015 season, Some lessons learned were that the long-term aging of DCT and SBC impacted the project mix design timelines and that the use of additives may affect performance. Also, the estimated savings on HMA items varied from 5% to 15% including asphalt binder compared with the standard mix.

SUMMARY

The interviewees from the ten states and one local agency consistently observed the following points:

- The overarching goal of incorporating performance-based tests for mixture designs is to improve the durability and longevity of asphalt pavements.
- Current Superpave volumetric mixture designs have been enhanced or modified with the use of performance testing to improve rutting and cracking resistance and control susceptibility to moisture damage.
- Standard performance testing protocols (e.g., HWTD, APA, and TSR) have been incorporated into agency standard specifications primarily for resistance to rutting and moisture damage for mix design acceptance.
- Greater use of recycled materials (e.g., RAP, RAS, and crumb rubber) combined with reduced AC content have in some cases resulted in stiffer mixes and premature cracking, which has led to research to incorporate standard crack tests (e.g., BBR, SCB, and an overlay test) to find the optimal balance of rutting and cracking resistance in mixture designs.
- The interviewed agencies are moving toward incorporating performance testing for production acceptance (i.e., HWTD is used for production acceptance in standard specifications); however, the barriers to more widespread adoption of performance tests are the cost, manpower, and time required to run the performance tests.

Several of the agencies are advancing mechanistic-empirical design concepts for pavements and evaluating performance tests including the AMPT for flow number and $|E^*|$ as part of the next generation of performance-based mixture designs.

CHAPTER FIVE

CONCLUSIONS

SUMMARY

The results of the extensive review of published literature and the survey responses delivered by 45 state departments of transportation (DOTs), the District of Columbia DOT, 10 Canadian provincial ministries of transportation (MOTs), and three local agencies provided valuable insight into how various agencies are approaching the use of performance specifications for both traditional and nontraditional asphalt mixtures. Case examples were developed with state DOTs in six states and one city in Canada. The information obtained from interviews was used to acquire a more precise idea of the concerns and implementation practices regarding performance testing for the development and use of performance specifications for asphalt mixtures.

CONCLUSIONS

Based on the work carried out in this synthesis the following conclusions can be made:

- The literature review, survey responses, and interviews all indicated that a significant amount of research is underway to generate the data and establish the criteria needed to develop performance-based specifications (PBS) for asphalt mixtures, but that very few agencies are actively using performance tests as part of mixture acceptance at this time. The survey data revealed that the performance-based properties most heavily researched included measurement of the stiffness modulus, thermal cracking and moisture resistance, and fatigue and durability characteristics.
- The current state of the practice reported for asphalt pavement mixture design and acceptance is using volumetric properties in conjunction with performance properties. In a few cases, performance tests such as the Asphalt Pavement Analyzer (APA) and Hamburg Wheel Tracking Device (HWTD), which both measure the rutting resistance and resistance to moisture damage, have been incorporated into standard practice, including production acceptance testing at the option of the engineer. Further research is underway to address premature fatigue cracking.
- The survey data revealed that the HWTD test, APA test, bending beam rheometer, and flexural beam fatigue test were the most commonly used tests in support of PBS. Nineteen DOTs and three agencies in Canada reported that they have the necessary equipment for the laboratory testing that supports their PBS.
- The majority of states and Canadian provinces are building flexible pavements from asphalt mixtures produced with reclaimed asphalt pavement (RAP), recycled asphalt shingle (RAS), or warm mix technologies, and many of the agencies require different test approaches than those used for traditional hot-mix asphalt (HMA) mixtures as a result.
- Approximately 80% of the state DOTs (37/45) require the use of performance tests for predicting moisture damage for initial mixture qualification before production and seven agencies that require APA testing.
- Approximately 27% of the state DOTs (12/45) reported using performance specifications as the basis for mixture acceptance and pay adjustments. However, it can be noted that it is not clear whether all of the agencies are using a PBS.
- The most frequently reported reasons for the use of performance specifications for asphalt mixtures were to achieve longer pavement service lives, in terms of fatigue cracking and other distresses, and to quantify the quality and encourage better construction of flexible pavements.
- The survey data revealed that the HWTD test and the APA test were the most commonly used tests for PBS. Nineteen DOTs and three agencies in Canada reported that they have the necessary equipment required for the laboratory testing that supports their PBS.
- Approximately one-third of the states reported test time and cost as a deciding factor in implementing PBS. The feedback provided through both the detailed survey responses and interviews were that tests need to be straightforward, relatively quick, and easy to perform. Other reasons reported included the need for the tests to be accepted by industry, as well as the affordability of the test equipment both to purchase and to run (i.e., minimizing the amount of staff and staff time).
- From the survey data, it was noted that very few agencies (two state DOTs, two MOTs, and one city in Canada) are currently assessing the costs and benefits of using PBS. However, there appears to be some momentum in moving forward with performance specifications, because 15 state DOTs and one MOT reported that they are planning to assess these factors in the future.

SUGGESTED FUTURE RESEARCH

The results of the synthesis indicate that the primary need for research is to identify more practical and cost-effective performance tests that truly reflect field performance of asphalt mixtures. The challenges most frequently reported to the advancement of performance specifications cited the cost of equipment or testing by private laboratories, insufficient training on performance tests and PBS, and the lack of confidence in test procedures and results. It was repeatedly noted that efforts for technology transfer might be made to assist the industry and agencies in understanding the benefits of added testing, as well as in facilitating agreement between the agencies and industry on which performance tests could be used for mixture acceptance as part of a PBS. Other items related to suggested future research include:

- Guidance to agencies and contractors on how to successfully implement the use of PBS for asphalt mixtures. Of particular interest will be the presentation of this information to both garner buy-in from industry partners and to train the contractors, consultants, and agency staff who will be involved with performance testing. There is a need for research to facilitate the process of the implementation of PBS to identify approaches to the type of training that will be needed and the types of collaborative initiatives for agencies and industry.
- There is a need for more research on the quantification of costs and benefits related to the use of performance specifications. The opportunity for studying this element could be accomplished through the use of PBS as part of projects that use public–private partnerships, warranty, or design-build hybrid contracts. These types of projects would be ideal in that the responsibility for performance is placed on the contractor and this approach could help industry to better engage in the process of implementing PBS.
- The development and use of more practical and economic performance tests that can be applied for field quality control, acceptance, and pay factor adjustment (similar to the initiative underway that was reported by New Jersey DOT) would be an avenue for future research. In this approach, performance tests would be focused on nondestructive testing tailored for production quality control and acceptance, and could be run by industry, that measure performance properties (e.g., intelligent compaction for stiffness or fatigue or continuous deflection devices).
- There are some agencies that reported benefits in researching the use of predictive models [e.g., Simplified Viscoelastic Continuum Design (S-VECD) or other predictive models that target specific distress types, and Quality-Related Specification Software (QRSS)] for the advancement and eventual adoption of PBS. A few states reported exploring the optimization of pavement designs based on life-cycle cost analysis as another area of research to support the future implementation of a PBS for asphalt mixtures.
- Significant advancements in pavement design and pavement distress predictive models have been made in recent years. It is suggested that research be conducted on integrating aspects of the mechanistic empirical pavement models with current and future PBS approaches.
- In addition to the affordability of test equipment and staffing, the amount of mixture sampling, specimen preparation, testing time, and test complexity (in terms of interpreting and reporting results) were mentioned numerous times as being major barriers to the implementation of PBS. Therefore, a suggested area for future efforts is to research the streamlining of the entire performance testing process. This might be accomplished through efforts that include statistical analyses to refine and streamline the required sampling and testing procedures; field studies to validate the results from both laboratory data and predictive models; collaboration with test equipment manufacturers to improve the efficiency, reliability, and affordability of test devices; and coordination with asphalt mixture producers to better tailor the mix approval process to complement a PBS system. Likewise, a national effort to develop consistent and detailed guidance on how to use PBS and the time and effort required to run the supporting performance tests such as the APA, HWTD, and Semi-Circular Bend (in terms of the details of the testing protocols and the various agency or national methods) is needed.

KNOWLEDGE GAPS

The following section outlines some knowledge gaps that stemmed from the agency survey and interviews. Based on this work, the following activities are suggested to address knowledge gaps identified as part of this study:

- There is little guidance that exists on how to proceed with PBS, both in terms of any quantitative data being collected (or statistical analyses being conducted) and in terms of the availability of tests that address the primary pavement distresses being observed by a particular agency. The agencies observed that the primary benefits of using performance specifications are typically noted on roadways with higher impacts, and that the cost of implementing PBS may not justify the means (benefits) in places that consist primarily of lower volume roads. It appears that this is an area of opportunity for future data collection and should consider the existence of adequate staff resources and available data, as well as define the applicability of PBS for each locale or roadway network. In addition, the use of available simple screening test information (e.g., data from Cantabro testing) and from results of full-scale accelerated pavement test facilities could be considered for integration with PBS.

- Some agencies reported that they are initiating the process of having contractors purchase the equipment and run the tests as part of their quality control program. This process would benefit by agencies working with industry to incorporate some of the most promising performance-based tests. It was noted in multiple survey responses and interviews that any future development of PBS mixture design specifications should consider the cost and availability of the performance tests, and that the relationship to actual field performance must be determined, prior to full implementation.
- There appears to be confusion with the interpretation of terms commonly associated with performance specifications and the true practical differences between PBS, performance-related specifications, and other types of specifications. It is suggested that more widespread efforts be made to familiarize both the agencies and industry with the terms and associated components of the various specification types. A 2014 workshop conducted by FHWA on performance-related specifications would be a suitable model for future dissemination of this type of information on performance specifications.
- One gap in knowledge is that various agencies define asphalt mixtures such as warm mix asphalt and those designated as having a high RAP component differently. In addition, the variability during the production and construction of asphalt mixtures also varies from agency to agency. For the implementation of performance specifications to be more comprehensive, a national effort to consistently define these parameters and terms would be beneficial.
- Another need is to more fully understand the extent of international experience with performance specifications, and primarily PBS, outside of North America. It is suggested that such efforts seek to more fully research the use of PBS internationally and to better engage practitioners in other parts of the world to identify benefits, costs, and experiential information on this topic.

GLOSSARY

AASHO	American Association of State Highway Officials
AC	Asphalt concrete
AMPT	Asphalt Mixture Performance Tester
AMRL	AASHTO Materials Reference Laboratory
APA	Asphalt Pavement Analyzer test equipment
ARHCA	Alberta Roadbuilders and Heavy Construction Association
BBR	Bending beam rheometer
BDWSC	Bridge deck waterproof surface course
BRBC	Bottom rich base course
BRIC	Binder rich intermediate course
DCT	Disc-shaped compact tension (fracture energy test)
DOT	Department of transportation (state highway agency)
$\|E^*\|$	Dynamic modulus of asphalt mixtures
ESAL	Equivalent single axle load
FAA	Fine aggregate angularity
FWD	Falling Weight Deflectometer
$\|G^*\|$	Complex Shear Modulus of Bituminous Mixtures
GTR	Ground tire rubber
HMA	Hot mix asphalt
HPTO	High performance thin overlay
HWTD	Hamburg Wheel Tracking Device
IDT	Indirect Tension Test
IRI	International Roughness Index
JMF	Job mix formula
LWT	Loaded wheel tracking test
MOT	Ministry of transportation (Canada)
MSR	Minimum Strain Rate
PBS	Performance-based specifications
PCC	Portland cement concrete
PEM	Porous European mix
PG	Performance Grade of a Superpave Asphalt Binder
PRS	Performance-related specifications
QA	Quality assurance
QC	Quality control
RA	Reclaimed asphalt pavement
RAS	Recycled asphalt shingles
SBS	Styrene–butadiene–styrene
SCB	Semi-circular Bend Test
SHRP	Strategic Highway Research Program
SMA	Stone matrix asphalt
S-VECD	Simplified Viscoelastic Continuum Damage
TRLPD	Triaxial Repeated Load Permanent Deformation
TSR	Tensile Strength Ratio
TSRST	Thermal Stress Restrained Specimen Test
VCA	Voids in the coarse aggregate
VFA	Voids filled with asphalt
VIM	Voids in the mix
VMA	Voids in the mineral aggregate
WMA	Warm mix asphalt

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This research report summarizes the first phase of a study to determine the effect of crumb rubber modifiers on asphalt binders. Research was conducted on aging properties, thermal properties, and long-term storage properties, as well as information on classification using SHRP specifications.

Brunette, B. and J. Lundy, "Use and Effects of Studded Tires on Oregon Pavements," *Transportation Research Record 1536,* Transportation Research Board, National Research Council, Washington, D.C., 1996, pp. 64–72 [Online]. Available: http://preservingoregonsroads.org/wp-content/uploads/2012/03/UseEffects.pdf [accessed Mar. 27, 2015].

This report is a follow up to a study conducted in 1974 regarding studded pavement tires and their effect on pavements in Oregon. Rutting information, studded tire traffic information, and additional pavement damage were analyzed in an effort to better understand the effect that studded tires have and possible options to improve pavement performance in the future.

Buttlar, W. and M. Harrell, "Development of End-Result and Performance-Related Specifications for Asphalt Pavement Construction in Illinois," *1998 Transportation Conference Proceedings,* 1998, pp. 195–202 [Online]. Available: http://www.ctre.iastate.edu/pubs/crossroads/195development.pdf [accessed Feb. 20, 2015].

This report details the effort in Illinois to move toward performance-related specifications, The Illinois Department of Transportation established an incremental process to gradually move from end result specifications to PRS. The study identified that the development of relationships between the design of asphalt mixtures and the performance of asphalt mixtures is critical. These relationships were recommended for monitoring over the longer term and compared with scientific data in order that they may be modified and improved as the PRS is perfected. To do so, a pilot study began in Illinois in 1996 and has been monitored annually for the measurement of rut depth, roughness, effective layer moduli, distress mapping, and serviceability data to develop relationships between as-designed sections of pavements and the performance of those roadway sections.

Cosentino, P., *Developing Specifications for Using Recycled Asphalt Pavement as Base, Subbase or General Fill Materials,* Report BB-892, Florida Department of Transportation, Tallahassee, Mar. 2001 [Online]. Available: http://www.dot.state.fl.us/Research-Center/Completed_Proj/Summary_SMO/FDOT_BB892.pdf [accessed Feb. 20, 2015].

This research report details a study for the Florida Department of Transportation regarding the use of recycled (or reclaimed) asphalt pavement as a fill material, which has not been a typical approach in the past. The study looked into the strength properties of RAP and the long-term storage properties at elevated temperatures.

Evans, L., K. Smith, N. Gharaibeh, and M. Darter, *Development and Implementation of a Performance-Related Specification for SR 9a, Florida: Final Report,* FHWA-HIF-09-016, Federal Highway Administration, Washington, D.C., Nov. 2008 [Online]. Available: http://www.fhwa.dot.gov/pavement/concrete/pubs/hif09016/hif09016.pdf [accessed Feb. 20, 2015].

This document summarizes a study to evaluate a performance specification for jointed plain concrete pavement in Florida. The performance characteristics looked into were thickness, strength, and smoothness. Pay curves were also developed.

Eurobitume, "Position Paper: Performance Related Specifications for Bituminous Binders," Eurobitume, Brussels, Belgium, Jan. 2012 [Online]. Available: http://www.eurobitume.eu/system/files/PRS-PositionPaper-January2012.pdf [accessed Mar. 27, 2015].

This paper provides a general outline of the industry's status regarding bituminous binder specifications. In addition, recommendations for future research and directions that the industry needs to head regarding binder specifications are discussed.

Federal Highway Administration (FHWA), *Reclaimed Asphalt Pavement in Asphalt Mixtures: State of the Practice,* FHWA-HRT-11-021, FHWA, Washington, D.C., April 2011 [Online]. Available: http://www.fhwa.dot.gov/publications/research/infrastructure/pavements/11021/002.cfm [accessed Mar. 14, 2015].

This is a report from FHWA detailing the state of the practice of using reclaimed asphalt pavements in asphalt mixtures. The report looks at seven surveys conducted between 2007 and 2009 regarding the use of RAP and compiles the data to present it in a way that summarizes RAP usage in the United States and Canada.

Jacobs Engineering, London-wide Asphalt Specification: Guidance on the Selection and Recommendations for the Use of Road Surfacing Materials, London Technical Advisors Group and Transport for London, Sept. 2009 [Online]. Available: http://www.londoncouncils.gov.uk/London%20Councils/LondonAsphaltSpecificationRevision.pdf [accessed Mar. 27, 2015].

Performance parameters are outlined for hot rolled asphalt mixtures in London, which only includes minor details for the Marshall Stability test.

Jensen, W. and M. Abdelrahman, *Crumb Rubber in Performance-Graded Asphalt Binder,* SPR-01 (05) P585, Nebraska Department of Roads, Grand Island, Nov. 2006 [Online]. Available: http://nlcs1.nlc.state.ne.us/epubs/r6000/b016.0112-2006.pdf [accessed Feb. 22, 2015].

This report by the University of Nebraska studies the effects of adding crumb rubber to asphalt binders. Performance, stability, and workability are analyzed with varying time and temperature considerations.

Miller, J., A. Simpson, and D. Andrei, D., *Performance-Based Specifications for HMA Pavements on Airfields,* AAPTP Project 06-03, MACTEC Engineering and Consulting, Beltsville, Md., Sept. 2009 [Online]. Available: http://www.aaptp.us/Report.Final.06-03.pdf [accessed Mar. 27, 2015].

This study outlines performance-based specifications for HMA mixtures for airfield pavements by discussing the material characteristics of HMA that play into performance, as well as the desired performance standards that should be met. In addition, the use of empirical models as compared with mechanistic-empirical models used to analyze pavement performance is discussed.

New Jersey Department of Transportation (NJDOT), *Acceptance of Surface Course Rideability,* Section 406.13, NJDOT, N.J., 2004 [Online]. Available: http://radio-weblogs.com/0132378/stories/2003/12/02/njdot SpecificationsSection406SuperpaveHma.html [accessed April 22, 2015].

This is a ride quality specification for HMA pavements in New Jersey, based on the International Roughness Index, which best correlates to user perception of ride quality, as opposed to the Profilograph Index or Rolling Straightedge. The key feature of this specification is that the incentive and disincentive pay adjustments for the various levels of ride quality were set based on expected pavement life (and associated cost of reconstruction) for those various levels of initial ride quality. This specification is a true performance specification, as it pertains to ride quality, in that the pay adjustments for initial measure ride quality are based on expected performance of the pavement.

Ohio Department of Transportation, *Introduction to Asphalt Pavement Design and Specifications,* Flexible Pavements of Ohio, Columbus [Online]. Available: http://www.flexiblepavements.org/files/events/conferences/3-%20IntroDesign.pdf [accessed Mar. 27, 2015].

This is a presentation by the Ohio DOT about the general use of flexible pavements. The function of flexible pavements, as well as design and construction goals, is discussed.

Recommended Guide Specifications for Long Life Pavement Alternatives Using Existing Pavements, SHRP 2 R23 Guide Specifications, June 2013 [Online]. Available: http://www.pavementrenewal.org/docs/GuideSpecifications.pdf [accessed Mar. 14, 2015].

This document takes a state-of-the-practice type of approach in summarizing the specifications used by various DOTs for existing pavements. Elements that could be added or elements that might provide supplemental help to organizations dealing with pavements are also included. In addition, guide specifications not included in the AASHTO Guide Specifications are discussed, such as stone matrix asphalt, open-graded friction course, rubbilization of PCC, and saw, crack, and seat.

Rosales-Herrera, V. I., J. A. Prozzi, and J. Prozzi, *Mixture Design and Performance-Based Specifications for Cold Patching Mixtures,* FHWA/TX-08/0-4872-2, Center for Transportation Research at the University of Texas at Austin, 2007 [Online]. Available: http://www.prolinecoldasphalt.com/ProLine%20Presentation.pdf [accessed Mar. 27, 2015].

This is a presentation that highlights the mixture designs and performance specifications for cold patching mixtures sponsored by the Texas DOT. Six different materials were reviewed for use in cold patching and were tested for workability, stability, and cohesion on top of visual field inspections.

Washington State Department of Transportation (WSDOT), *Pavements and Studded Tire Damage,* Washington State Department of Transportation State Materials Laboratory, Seattle, Mar. 2006 [Online]. Available: http://www.wsdot.wa.gov/NR/rdonlyres/098E61DC-AD06-486D-AFA2-808207BCEE7E/0/PavementsStuddedTires.pdf [accessed Mar. 27, 2015].

This document investigated the status of studded tire damage to hot mix asphalt pavements in the state of Washington. A number of different types of roadways were investigated and used to demonstrate what studded tire damage looks like and how it affects the roadways and the users. The report concluded that technology is continually being developed to allow vehicles to drive over roadways and continually measure pavement damage.

Weed, R. and K. Tabrizi, *Conceptual Framework for Pavement Smoothness Specification,* Paper No. 05-0922, CD ROM, 84th Annual Meeting of the Transportation Research Board, Washington, D.C., Jan. 2005, 26 pp.

This paper presents the framework for the New Jersey IRI Ride Quality Specification for HMA pavements and highlights the idea that pavements initially built smoother will outlast pavements with higher IRI values. It discusses the concept of relating expected pavement life to the initial percent defective pavement in terms of initial ride quality. Once the expected pavement life (based on ride quality) is known, specific dollar values can be assigned to the as-constructed ride quality based on the anticipated cost of future rehabilitation and reconstruction. The paper draws values of improvement in expected pavement life from FHWA studies that have correlated pavement life to initial smoothness.

APPENDIX A

Survey Questions and Results

Question 1: Which types of asphalt mixtures does your agency currently use for plant-produced asphalt pavements?

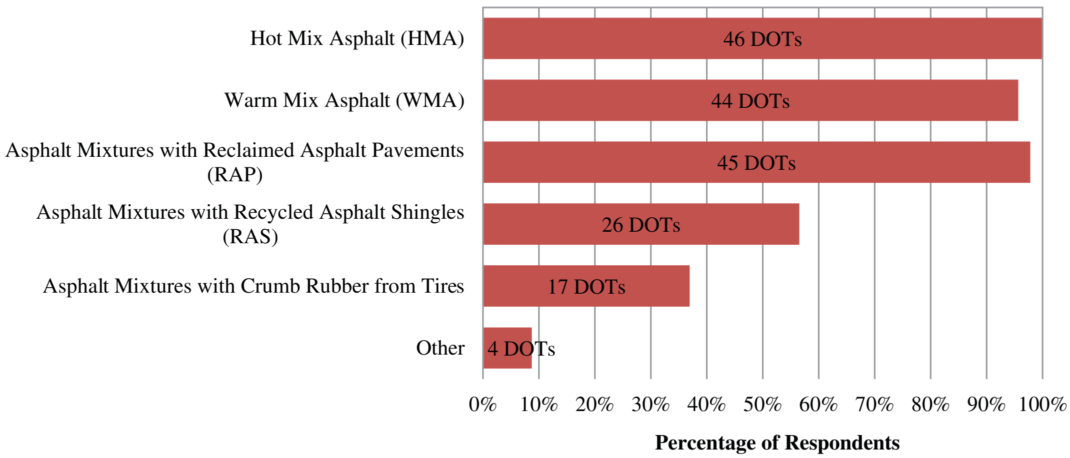

FIGURE A1 Survey response to Question 1: "Which types of asphalt mixtures does your agency currently use for plant-produced asphalt pavements?"

TABLE A1
ADDITIONAL RESPONSES TO QUESTION 1: "WHICH TYPES OF ASPHALT MIXTURES DOES YOUR AGENCY CURRENTLY USE FOR PLANT-PRODUCED ASPHALT PAVEMENTS?"

Respondent	Response Comments
Arizona	Friction courses
Clark County, NV	Terminal blend
Kentucky	RAP and RAS combined
Michigan	We have a recycled tire permissive specification but not specifically crumb rubber
Pennsylvania	Asphalt mixtures with both RAP and RAS. Asphalt mixtures with synthetic fibers

Question 2: Does your agency require different tests or approaches when recycled materials are incorporated into the asphalt mixture?

TABLE A2
SURVEY RESPONSE TO QUESTION 2: "DOES YOUR AGENCY REQUIRE DIFFERENT TESTS OR APPROACHES WHEN RECYCLED MATERIALS ARE INCORPORATED INTO THE ASPHALT MIXTURE?"

Response Type	Response Rate
Yes	44%
No	52%
Other	4%
Number of Total Responses	46
Respondent	**Response Comments**
Michigan	Blending charts for RAP and RAS
New York	Only when using RAS or high RAP (>20%) in trial projects

Question 3: Please provide some details on the different tests or test approaches required when recycled materials are used in an asphalt mixture.

TABLE A3
SURVEY RESPONSE TO QUESTION 3: "PLEASE PROVIDE SOME DETAILS ON THE DIFFERENT TESTS OR TEST APPROACHES REQUIRED WHEN RECYCLED MATERIALS ARE USED IN AN ASPHALT MIXTURE"

Respondent	Response Comments
Alberta, Canada	With RAP >20% we require rheology blending procedures as outlined in Appendix X1 of AASTHO M323.
Arizona	RAP Binder Correction Factor Ignition Furnace Correction Solvent Extraction Ignition Furnace Calibration
Arkansas	We require a temperature viscosity curve for the blend of reclaimed and virgin binder for all mixes using RAP except on PG 64-22 mixes with less than 15% RAP.
British Columbia, Canada	For RAP: Typical, MC; AC; Gradation; Percent Fracture; and Specific Gravity of coarse and fine. When requested Deval, Standard for uncompacted void content ASTM C1252; and % of flat and elongated (Superpave mixes); and AC Rheology Testing
California	For "high" RAP mixtures, we require blending chart of recovered binder and virgin binder during mix designs, fractionating (using 3/8 sieve) RAP pile, and additional QC and QA testing of the RAP pile during production.
Delaware	DelDOT's asphalt calculator must be used to determine allowable RAP/RAS percentages. This is a binder replacement program.
Georgia	We conduct Abson recovery testing on the recycled mixture for asphalt design approval and quality assurance during production. We conduct testing on the recovered binder to make sure it complies with our specified requirements for viscosity of 6,000–16,000 poises. We also conduct material usage audits when crumb rubber is used via the dry method.
Indiana	RAP A/C Content, gradation, PG Grade, Aggregate Properties: LA Wear, Idaho Degradation, Fracture Face, and Sand Equivalent
Kansas	High RAP—KDOT determines RAP grading, which is included in contract for blending chart use. Hamburg required on some projects to confirm potential for rutting.
Maine	We perform tests on the RAP (grad. and % binder) to classify the RAP, which determines the maximum allowable RAP % in the mix, based on P200 and % binder variability.
Maryland	Depending on the asphalt blend ratio, blending charts may be required to determine if a binder bump is required.
Michigan	We require blending charts for higher replacement levels of binder by use of RAP and or RAS.
New Jersey	For high RAP mixtures (surface course min. % RAP 20% or greater and intermediate/base course 30% min and greater) NJDOT requires APA rut test (4 mm max.) and Overlay Test (100 cycles min.).
New York	For RAS and high RAP (>20%) trials—during the mix design we require: Dynamic Modulus and Flow Number—AASHTO TP 79 Flexural Beam Fatigue—AASHTO T 321 Overlay Tester—TXDOT TX 248F.
North Carolina	When percentage is 30% or greater recycled content by weight of mix, additional testing is required (dynamic modulus or PG blending charts).
Nova Scotia, Canada	Contractor to determine the binder contribution from the RAP source utilized for the project (asphalt binder content test on RAP).
Ohio	During the design stage, we require RAP binder analysis done with a blending chart (we use viscosities). If the RAP has gravel in it, we require a TSR (AASHTO T283) on mix as well.
Oklahoma	RAP Pb at design requires chemical extraction to adjust ignition oven correction factor; 75%–85% of ignition results for RAS is the chemical extraction Pb.
Oregon	Must determine binder content of recycled material and use Oregon DOT procedure to determine specific gravity of recycled material
Pennsylvania	Asphalt mixtures with high RAP or both RAP and RAS require additional evaluation of the asphalt binder for selection of the virgin binder grade. Asphalt mixtures with crumb rubber require additional and different tests due to high crumb rubber contents and blending of crumb rubber with the asphalt binder at the asphalt mixture plant.
Québec, Canada	Characterization of the recycled materials (binder content, density, granularity, etc.)
South Dakota	Extractions PG grading recovered binder evaluating DCT and SCB
Vermont	PG verification
Washington	For mixtures >20% RAP or any quantity of RAS we require binder extraction, recovery, and blending.
Wisconsin	Pilot Project Phase—Above 25% binder replacement requires Hamburg Wheel, Disc Shaped Compaction Test, and Semi-Circular Bend Performance Testing
Wyoming	Asphalt content and gradation of the RAP

Question 4: What attributes are typically required for initial qualification of the asphalt mixtures, prior to production?

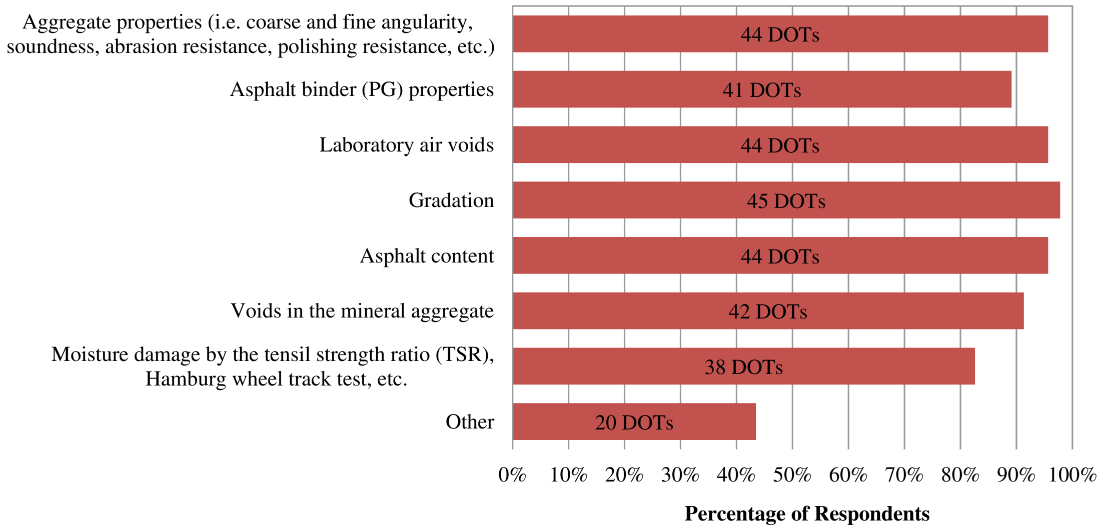

FIGURE A2 Survey response to Question 4: "What attributes are typically required for initial qualification of the asphalt mixtures, prior to production?"

TABLE A4
SURVEY RESPONSE TO QUESTION 4: "WHAT ATTRIBUTES ARE TYPICALLY REQUIRED FOR INITIAL QUALIFICATION OF THE ASPHALT MIXTURES, PRIOR TO PRODUCTION?"

Respondent	Response Comments
Alberta, Canada	All of the above is required as part of a Lab mix design submission, but not for plant produced mix.
Arizona	IMC
Arkansas	Moisture sensitivity test and APA rutting test
Clark County, Nevada	Surface Area (SA) Local Requirement, for arterial, APA
Florida	Do not do tests when a contractor uses approved mix design (after the initial verification)
Georgia	VFA, Dust Ratio, APA. Aggregate Testing is part of the Qualified Products List approval.
Kansas	TSRST
Manitoba, Canada	Stability, flow
Maine	F/Beff; VFB
Minnesota	Asphalt film thickness
Missouri	Ensure the correct PG binder, specified in the contract, is being utilized in the proposed JMF.
Montana	VFA, D/P, DSR
New Hampshire	T 283
Nevada	Hveem stability
North Carolina	Dust/AC ratio, range of allowable VFA
Nova Scotia, Canada	Film thickness (calculation only)
Oregon	Asphalt Pavement Analyzer
Pennsylvania	Aggregate absorptions, combined aggregate Gsb
South Carolina	APA
South Dakota	APA test

Question 5: Do these attributes (from the previous question) change, or are they combined differently, based on the type of asphalt mixture (e.g., HMA, WMA, mixtures with RAP, RAS, or crumb rubber, etc.)?

TABLE A5
SURVEY RESPONSE TO QUESTION 5: "DO THESE ATTRIBUTES (FROM THE PREVIOUS QUESTION) CHANGE, OR ARE THEY COMBINED DIFFERENTLY, BASED ON THE TYPE OF ASPHALT MIXTURE (e.g., HMA, WMA, mixtures with RAP, RAS, or crumb rubber, etc.)?"

Response Type	Response Rate
Yes	20%
No	80%
Number of Total Responses	46

Question 6: If yes, how are the number or types of required attributes being varied, and for which asphalt mixture types? Please provide a brief description or a link to this information on your agency's website.

TABLE A6
SURVEY RESPONSE TO QUESTION 6: "IF YES, HOW IS THE NUMBER OR TYPES OF REQUIRED ATTRIBUTES BEING VARIED, AND FOR WHICH ASPHALT MIXTURE TYPES? PLEASE PROVIDE A BRIEF DESCRIPTION OR A LINK TO THIS INFORMATION ON YOUR AGENCY'S WEBSITE"

Respondent	Response Comments
California	RHMA (gap-graded gradation with wet process asphalt rubber binder) 1. VMA range increased to 18%–23%; 2. There is a minimum binder content of 7.5%; 3. Gradation (from dense to gap grading); 4. Asphalt rubber binder testing (as opposed to PG testing); 5. gyration number and pressure adjusted to accommodate RHMA
Clark County, Nevada	Binder content, rut requirements, surface area require
Georgia	Abson recovery testing is conducted for compliance with specifications for all mixtures containing 20% or greater recycled asphalt materials or if recycled shingles are included in a mixture prior to mix design approval
Kansas	We will be requiring Hamburg and TSRST using high RAP and a rejuvenator on a project in 2015.
Missouri	The PG binder required changes as the amount of RAP and RAS is increased. Over a certain amount either a softer binder is required or a blend chart is needed, depending on the amount of replacement. This is being applied to all non-Superpave mix designs. RAP is now allowed in SMA mixes; shingles only allowed in Superpave mixes with PG 62-24 oil.
New Brunswick, Canada	AC binder is a variable. Base Course and Seal Course each have their own void criteria
New Jersey	Here is a link to HMA specs: http://www.state.nj.us/transportation/eng/specs/2007/spec900.shtm#s902. Here is a link to the SI documents for projects: http://state.nj.us/transportation/eng/specs/ The 900 section of the SI has other HMA spec. mixture requirements.
New York	TSR—AASHTO T283 performed during the mix design on certain mixtures when there is a heightened concern for moisture damage. Examples—certain aggregates, certain WMA technologies, past in-place performance of similar mix designs, etc.
Orange County, California	When using ARHM, we use a gap-graded aggregate. We also check the gradation of the crumb rubber itself.
Pennsylvania	Attributes do not change with dense-graded Superpave mixtures, but do change with SMA or gap-graded mixtures or thin HMA overlays.

Question 7: Is a change required by your agency's performance specifications, in terms of the sampling frequency of the volumetric mix design attributes, depending on the type of asphalt mixture?

TABLE A7
SURVEY RESPONSE TO QUESTION 7: "IS A CHANGE REQUIRED BY YOUR AGENCY'S PERFORMANCE SPECIFICATIONS, IN TERMS OF THE SAMPLING FREQUENCY OF THE VOLUMETRIC MIX DESIGN ATTRIBUTES, DEPENDING ON THE TYPE OF ASPHALT MIXTURE?"

Sample Type vs. Frequency Change	Increased Frequency	No Change in Frequency	Number of Total Responses
Warm Mix Asphalt	98%	2%	45
Asphalt Mixtures with Reclaimed Asphalt Pavements (RAP)	98%	2%	44
Asphalt Mixtures with Recycled Asphalt Shingles (RAS)	100%	0%	33
Asphalt Mixtures with Crumb Rubber from Tires	96%	4%	27
Asphalt Mixtures with both RAP and RAS	100%	0%	1

Respondent	**Response Comments**
Georgia	Increased frequency for WMA
Pennsylvania	Increased frequency for mixtures with RAP, mixtures with crumb rubber from tires, and mixtures with both RAP and RAS.

Question 8: Is a change required by your agency's performance specifications, in terms of the number of samples for confirming the volumetric mix design attributes, depending on the type of asphalt mixture?

TABLE A8
SURVEY RESPONSE TO QUESTION 8: "IS A CHANGE REQUIRED BY YOUR AGENCY'S PERFORMANCE SPECIFICATIONS, IN TERMS OF THE NUMBER OF SAMPLES FOR CONFIRMING THE VOLUMETRIC MIX DESIGN ATTRIBUTES, DEPENDING ON THE TYPE OF ASPHALT MIXTURE?"

Sample Type vs. Sampling Change	No Change in Samples Taken	More Samples Taken	Number of Total Responses
Warm Mix Asphalt	100%	0%	43
Asphalt Mixtures with Reclaimed Asphalt Pavements (RAP)	95%	5%	43
Asphalt Mixtures with Recycled Asphalt Shingles (RAS)	97%	3%	31
Asphalt Mixtures with Crumb Rubber from Tires	96%	4%	26
Asphalt Mixtures with both RAP and RAS	100%	0%	1

Respondent	**Response Comments**
California	More samples taken for mixtures with RAP and mixtures with RAS
Pennsylvania	More samples taken for mixtures with RAP, mixtures with crumb rubber from tires, and mixtures with both RAP and RAS

Question 9: What is the status in your agency with regards to performance specifications for the design and acceptance of asphalt mixtures? Note: definitions for performance-based specifications (e.g., attributes primarily used for mix design acceptance) or performance-related specifications (e.g., predictive models using in situ air voids, asphalt content, binder viscosity, etc.) for asphalt mixture design would both apply for this question.

TABLE A9
SURVEY RESPONSE TO QUESTION 9: "WHAT IS THE STATUS IN YOUR AGENCY WITH REGARDS TO PERFORMANCE SPECIFICATIONS FOR THE DESIGN AND ACCEPTANCE OF ASPHALT MIXTURES? NOTE: DEFINITIONS FOR PERFORMANCE-BASED SPECIFICATIONS (e.g., attributes primarily used for mix design acceptance) OR PERFORMANCE-RELATED SPECIFICATIONS (e.g., predictive models using in situ air voids, asphalt content, binder viscosity, etc.) FOR ASPHALT MIXTURE DESIGN WOULD BOTH APPLY FOR THIS QUESTION?"

Roadway Type and Use of Performance Specifications	Currently Using Performance Specifications	Planning to Use Performance Specifications	No Plans to Use Performance Specifications	Number of Total Responses
Interstate pavements	49%	18%	33%	45
Pavements on other arterials (state highway system)	44%	22%	33%	45
Pavements on local or county road system	33%	17%	50%	45

Question 10: Why is your agency looking at using performance specifications for asphalt mixtures?

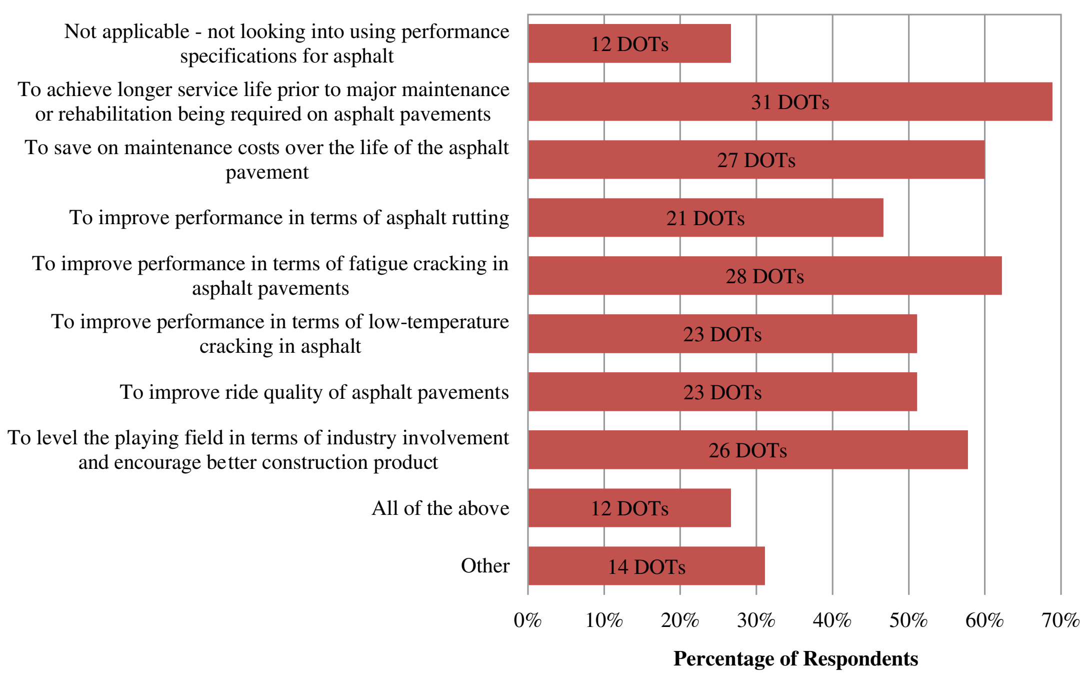

FIGURE A3 Survey response to Question 10: "Why is your agency looking at using performance specifications for asphalt mixtures?"

TABLE A10
SURVEY RESPONSE TO QUESTION 10: "WHY IS YOUR AGENCY LOOKING AT USING PERFORMANCE SPECIFICATIONS FOR ASPHALT MIXTURES?"

Respondent	Response Comments
Colorado	Currently ONLY using performance-related specifications; i.e., AC content, Voids, etc. Hamburg Wheel Tracker and AMPT are test for information only.
Louisiana	Quantify quality of end product

Question 11: Is your agency incorporating performance specifications as a basis for mixture acceptance and/or pay factor adjustments?

TABLE A11
SURVEY RESPONSE TO QUESTION 11: "IS YOUR AGENCY INCORPORATING PERFORMANCE SPECIFICATIONS AS A BASIS FOR MIXTURE ACCEPTANCE AND/OR PAY FACTOR ADJUSTMENTS?"

Response Type	Response Rate
Yes	49%
No	44%
Other	7%
Number of Total Responses	45
Respondent	**Response Comments**
Alberta, Canada	Price adjustments based on pavement compaction, aggregate gradation, and asphalt content
Indiana	Planning on doing this
Louisiana	Hamburg QC; SCB design; potential pay adjustments
Maine	Our first goal is to implement performance-based mix design; then possibly use for acceptance during construction.

Question 12: How is your agency incorporating performance specifications as a basis for mixture acceptance and/or pay factor adjustments?

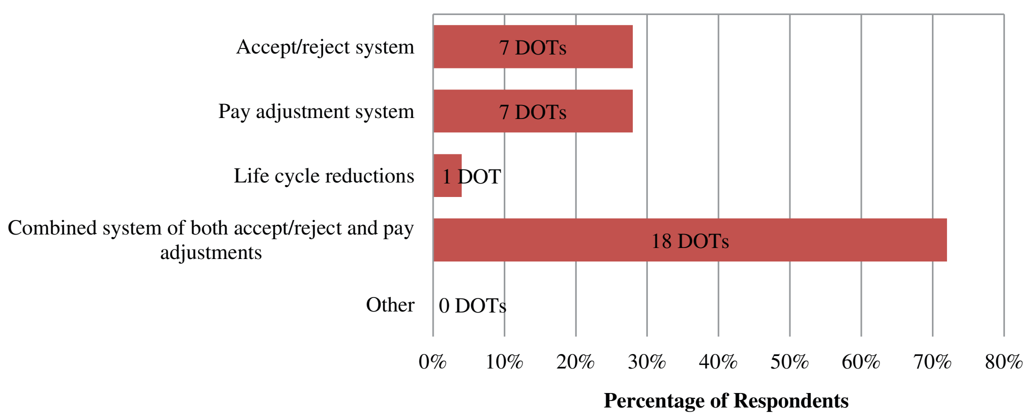

FIGURE A4 Survey response to Question 12: "How is your agency incorporating performance specifications as a basis for mixture acceptance and/or pay factor adjustments?"

Question 13: Which attributes does your agency consider most important for pavement performance?

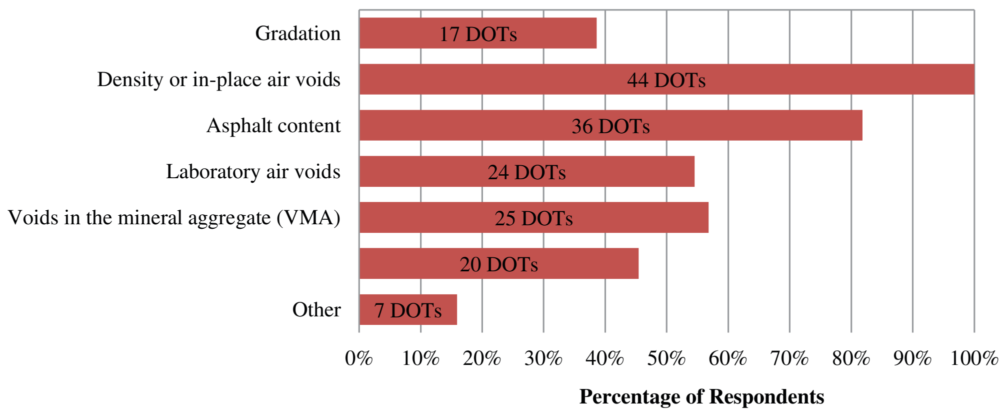

FIGURE A5 Survey response to Question 13: "Which attributes does your agency consider most important for pavement performance?"

TABLE A12
SURVEY RESPONSE TO QUESTION 13: "WHICH ATTRIBUTES DOES YOUR AGENCY CONSIDER MOST IMPORTANT FOR PAVEMENT PERFORMANCE?"

Respondent	Response Comments
Clark County, Nevada	Arterial APA
Georgia	We consider rutting resistance and VMA important and do have VMA requirements for mix design approval, but do not use VMA for production acceptance.
Louisiana	In-place density considered primary
Maine	Smoothness
Minnesota	Asphalt film thickness
New Jersey	Ride quality, fatigue resistance, rut resistance
Ohio	Friction and rutting
Oklahoma	Mix design fatigue test at some point in future
Orange County, California	s-value

Question 14: Which performance-based tests does your agency consider most important for predicting the pavement performance typical for your roadways?

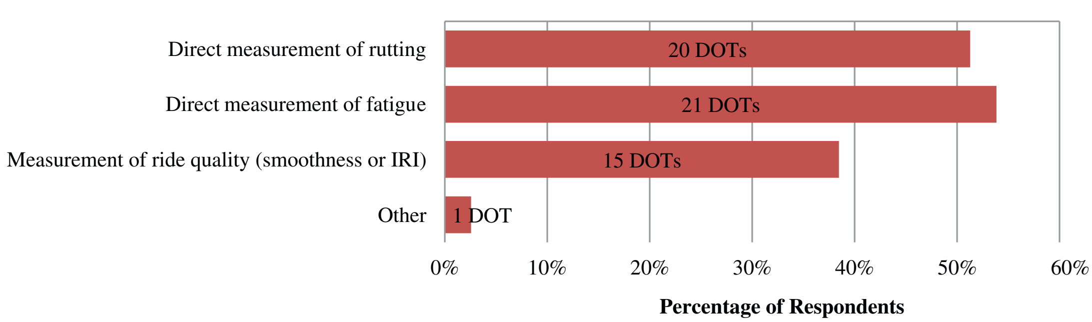

FIGURE A6 Survey response to Question 14: "Which performance-based tests does your agency consider most important for predicting the pavement performance typical for your roadways?"

TABLE A13
ADDITIONAL COMMENTS PROVIDED IN RESPONSE TO QUESTION 14: "WHICH PERFORMANCE-BASED TESTS DOES YOUR AGENCY CONSIDER MOST IMPORTANT FOR PREDICTING THE PAVEMENT PERFORMANCE TYPICAL FOR YOUR ROADWAYS?"

Respondent	Response Comments
Arkansas	Sometimes the APA is run
Clark County, Nevada	Arterial and collector = APA
Colorado	Test data from AMPT (resilient modulus, flow number, etc.)
Connecticut	Raveling and segregation
Georgia	Moisture susceptibility testing
Kansas	Low temperature cracking
Louisiana	Hamburg; SCB
Minnesota	Thermal cracking
Montana	Hamburg, in place voids
Nebraska	Cracking
Nevada	IRI
Orange County, California	Stability value
Pennsylvania	With concern that mixtures do not contain sufficient asphalt for durability, we are looking at rutting tests to add additional asphalt above optimum without increasing rutting significantly. Also, some form of cracking test would also be beneficial for previous issue and with issue of asphalt mixtures with high reclaimed binder ratios.
Washington, D.C.	Rutting and cracking

Question 15: How has your agency used results from performance testing in establishing pay factors for asphalt pavements? Note: Performance testing relates laboratory mixture design to actual field performance by characterizing the main HMA performance parameters and how the parameters change throughout the service life of the pavement.

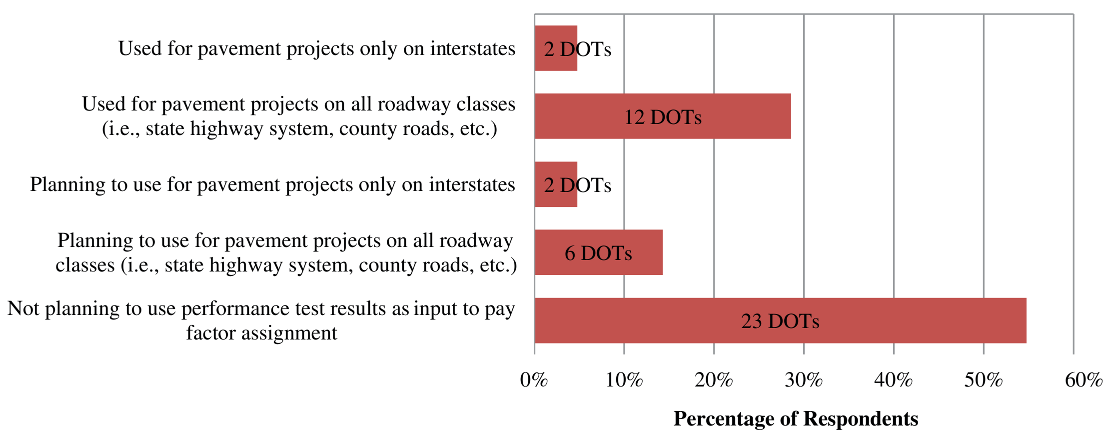

FIGURE A7 Survey response to Question 15: "How has your agency used results from performance testing in establishing pay factors for asphalt pavements? Note: Performance testing relates laboratory mixture design to actual field performance by characterizing the main HMA performance parameters and how the parameters change throughout the service life of the pavement."

Question 16: What specific asphalt mixture performance properties were used or considered for the integration of mixture acceptance and pay factor assignment?

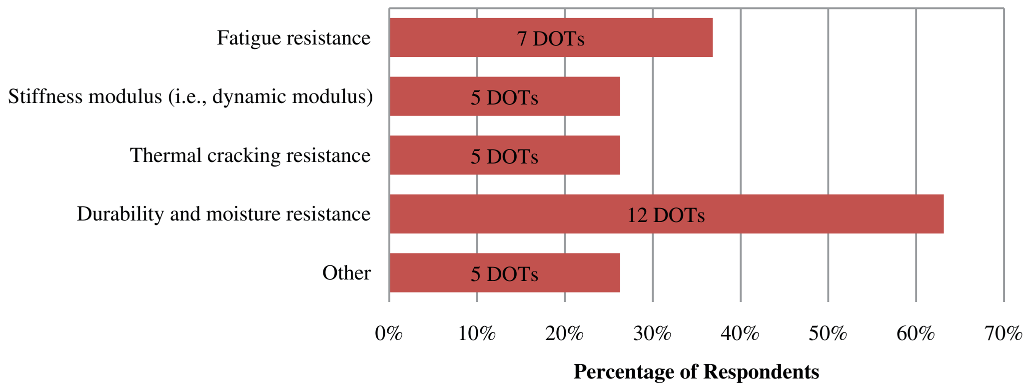

FIGURE A8 Survey response to Question 16: "What specific asphalt mixture performance properties were used or considered for the integration of mixture acceptance and pay factor assignment?"

Question 17: Please describe your agency's efforts related to the development of performance specifications for asphalt mixtures.

TABLE A14
SURVEY RESPONSE TO QUESTION 17: "PLEASE DESCRIBE YOUR AGENCY'S EFFORTS RELATED TO THE DEVELOPMENT OF PERFORMANCE SPECIFICATIONS FOR ASPHALT MIXTURES"

	Fatigue Resistance	Thermal Cracking Resistance	Durability	Moisture Resistance	Stiffness Modulus	Number of Total Responses
Demonstration project	5	2	3	5	3	6
Pooled fund study	1	3	1	1	2	4
Adapted from sister agency specifications	1	1	3	3	0	4
Based on FHWA research	5	5	3	6	2	10
Based on NCHRP research	5	5	5	10	3	12
Based on your agency's in-house or sponsored research	11	10	9	18	6	20

Respondent	Response Comments
Kansas	AASHTO TSRST test for thermal cracking resistance
Ontario	Fatigue resistance, thermal cracking resistance, durability, and moisture resistance all based on lessons learned from warranty contracts and review and evaluation of historical pavement performance.
South Carolina	OGFC durability concerns warranty? 3–5 years for durability.

Question 18: For which types of asphalt mixtures does your agency use the following performance parameters?

TABLE A15
SURVEY RESPONSE TO QUESTION 18: "FOR WHICH TYPES OF ASPHALT MIXTURES DOES YOUR AGENCY USE THE FOLLOWING PERFORMANCE PARAMETERS?"

	Fatigue Resistance	Thermal Cracking Resistance	Durability	Moisture Resistance	Stiffness Modulus	Number of Total Responses
Standard structural lift	3	4	6	22	1	23
Standard overlay lift	2	3	8	20	0	22
High performance thin overlays	1	1	6	13	1	16
Binder rich intermediate course	2	0	0	4	1	5
Bridge deck surface course	2	0	1	5	1	5
Bottom rich base course	3	0	0	6	2	7

Respondent	Response Comments
Alabama	Fatigue resistance for standard structural SMA mixes
Alaska	Any asphalt mixture in pavement design for fatigue resistance
Colorado	Not currently used
Kansas	AASHTO TSRST test for thermal cracking resistance
New Jersey	Moisture resistance for Asphalt Rubber Gap Graded Course

Question 19: Under which circumstances would your agency elect to or propose to use performance-based asphalt mix design specifications?

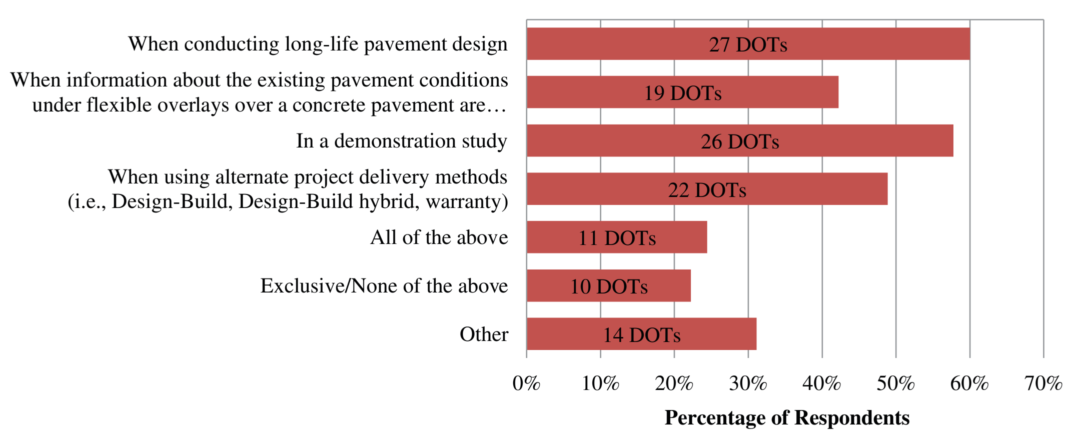

FIGURE A9 Survey response to Question 19: "Under which circumstances would your agency elect to or propose to use performance-based asphalt mix design specifications?"

TABLE A16
SURVEY RESPONSE TO QUESTION 19: "UNDER WHICH CIRCUMSTANCES WOULD YOUR AGENCY ELECT TO OR PROPOSE TO USE PERFORMANCE-BASED ASPHALT MIX DESIGN SPECIFICATIONS?"

Respondent	Response Comments
Colorado	Performance-based specifications not currently used
New Brunswick, Canada	Not being considered
Missouri	When the appropriate tests are selected along with the required limits for achieving satisfactory field performance. Tests need to be straightforward, easy to perform, and affordable for contractors to purchase and perform. Also, need industry acceptance.
Ohio	RAS and/or high RAP mixes.

Question 20: What tests do you use for performance-based mixture designs?

TABLE A17
SURVEY RESPONSE TO QUESTION 20: "WHAT TESTS DO YOU USE FOR PERFORMANCE-BASED MIXTURE DESIGNS?"

	AASHTO or ASTM Standard	Agency Test Method	Other Test Method	Number of Total Responses
Repeated Simple Shear Test (RSST)	3	0	0	3
Flexural Beam Fatigue Test	3	0	0	3
Hamburg Wheel Track Device (HWTD) Test	8	4	0	12
Asphalt Pavement Analyzer (APA)	7	7	0	14
Dynamic Modulus Test in the Asphalt Mixture Performance Tester (AMPT)	5	0	0	5
Flow Number Test Using AMPT	5	0	0	5
Flow Time Test Using AMPT	2	0	0	2
Semicircular Bending (SCB) Test	3	1	0	3
Bending Beam Rheometer (BBR) Test	7	0	0	7
Disc-shaped Compact Tension (DCT) Fracture Energy Test	3	0	0	3
Texas Overlay Tester	0	1	2	3

Respondent	Response Comments
Georgia	Agency test method for Moisture Susceptibility Testing
Kansas	AASHTO or ASTM standard for TSRST
Minnesota	Agency test method for DCT (working towards future implementation)
Nebraska	We are currently doing research with Nebraska materials and looking at Flow Time and Flow Number
Ohio	Agency test method for The Polisher
Québec	Agency test method for dynamic modulus test
	Agency test method for French Rutting Test (in comparison with APA)
Virginia	AASHTO or ASTM Standard for TSR
	Agency test method for Bond Test

Question 21: If you are using performance-based mix design properties for qualification of the mix design or QC and acceptance, which performance properties and tests are used?

TABLE A18
SURVEY RESPONSE TO QUESTION 21: "IF YOU ARE USING PERFORMANCE-BASED MIX DESIGN PROPERTIES FOR QUALIFICATION OF THE MIX DESIGN OR QC AND ACCEPTANCE, WHICH PERFORMANCE PROPERTIES AND TESTS ARE USED?"

	Fatigue resistance		Stiffness modulus (e.g. [E*], flow number, etc.)		Thermal cracking resistance		Durability properties		Moisture resistance		Other		Total	
Repeated simple shear test (RSST)	1	100%	0	0%	0	0%	1	100%	0	0%	0	0%	1	100%
Flexural beam fatigue test	4	100%	1	25%	0	0%	1	25%	0	0%	0	0%	4	100%
Hamburg wheel track test	1	8.3%	3	25%	0	0%	6	50%	9	75%	3	25%	12	100%
Asphalt pavement analyzer (APA)	1	9.1%	2	18.2%	0	0%	5	45%	0	0%	5	45.5%	11	100%
Dynamic modulus test in the Asphalt Mixture Performance Tester (AMPT)	0	0%	3	75%	0	0%	1	25%	0	0%	1	25%	4	100%
Flow Number test using AMPT	0	0%	1	25%	0	0%	1	25%	0	0%	2	50%	4	100%
Flow Time test using AMPT	0	0%	1	50%	0	0%	0	0%	0	0%	1	50%	2	100%
Semicircular bending (SCB) test	2	100%	0	0%	1	50%	1	50%	0	0%	0	0%	2	100%
Bending beam rheometer (BBR) test	1	20%	1	20%	5	100%	0	0%	0	0%	0	0%	5	100%
Disc-shaped compact tension (DCT) fracture energy test	1	50%	0	0%	2	100%	0	0%	0	0%	0	0%	2	100%
Texas Overlay Test	3	100%	0	0%	0	0%	0	0%	0	0%	0	0%	3	100%
Dynamic modulus test	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	100%
E* from AMTP for high end designs in future, T283 common.	1	100%	0	0%	0	0%	0	0%	0	0%	0	0%	1	100%
Future fatigue method from a research project to be determined.	1	100%	0	0%	0	0%	0	0%	0	0%	0	0%	1	100%
TSRST	0	0%	0	0%	1	100%	0	0%	0	0%	0	0%	1	100%
French rutting test	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	100%
The Polisher	0	0%	0	0%	0	0%	1	100%	0	0%	0	0%	1	100%
We perform APA for internal data only	0	0%	0	0%	0	0%	1	100%	0	0%	0	0%	1	100%
AASHTO t283	0	0%	0	0%	0	0%	0	0%	1	100%	0	0%	1	100%
TSR	0	0%	0	0%	0	0%	0	0%	1	100%	0	0%	1	100%
We perform T283 for moisture sensitivity	0	0%	0	0%	0	0%	0	0%	1	100%	0	0%	1	100%
Bond Test	0	0%	0	0%	0	0%	0	0%	0	0%	1	100%	1	100%
not using any, so N/A	0	0%	0	0%	0	0%	0	0%	0	0%	1	100%	1	100%

Question 22: Does your agency use Independent Assurance (IA) for performance-based tests of asphalt mixtures?

TABLE A19
SURVEY RESPONSE TO QUESTION 22: "DOES YOUR AGENCY USE INDEPENDENT ASSURANCE (IA) FOR PERFORMANCE-BASED TESTS OF ASPHALT MIXTURES?"

Response Type	Response Rate
Yes	16%
No	66%
Other	18%
Number of Total Responses	44
Respondent	**Response Comments**
Colorado	Tests are for information only
Connecticut	IA on performance-related tests
Florida	Performance-based tests are used for research purpose only
Georgia	We do comparison testing though no longer called IA. We now do a system based IA
Louisiana	Researching, in future
Nova Scotia, Canada	When implemented, the testing would be the responsibility of the contract or to provide the information specified.

Question 23: How are you implementing asphalt performance mix designs in your agency specifications?

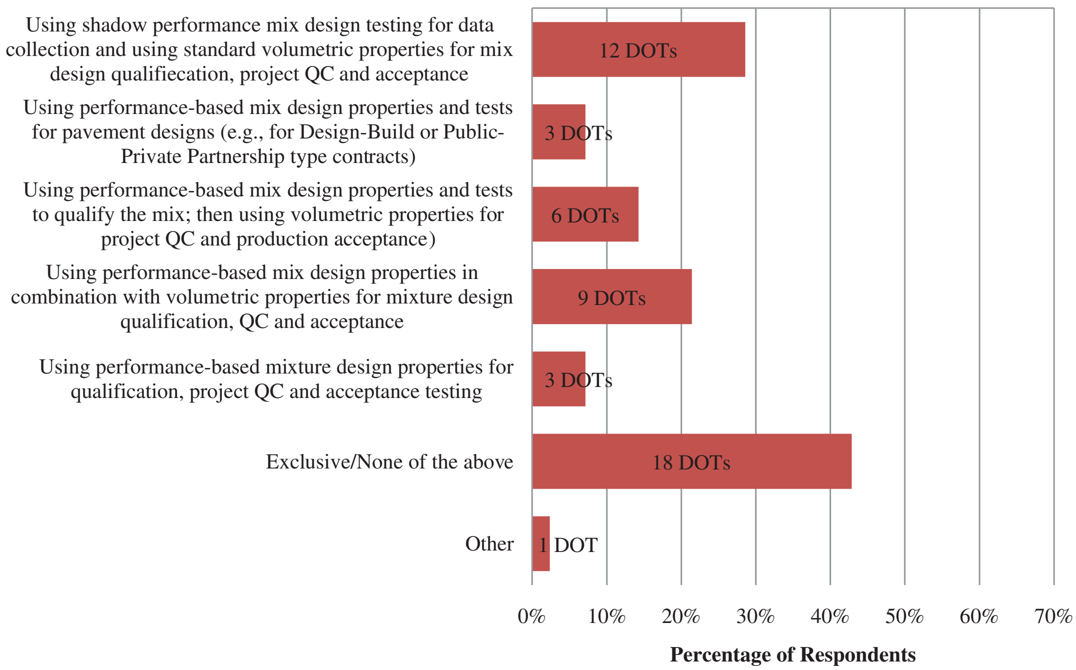

FIGURE A10 Survey response to Question 23: "How are you implementing asphalt performance mix designs in your agency specifications?"

TABLE A20
SURVEY RESPONSE TO QUESTION 23: "HOW ARE YOU IMPLEMENTING ASPHALT PERFORMANCE MIX DESIGNS IN YOUR AGENCY SPECIFICATIONS?"

Respondent	Response Comments
Louisiana	Collecting SCB results in design for future acceptance testing

Question 24: As part of your agency's QA plan for the use of asphalt performance-based mix designs, who is responsible for performance testing?

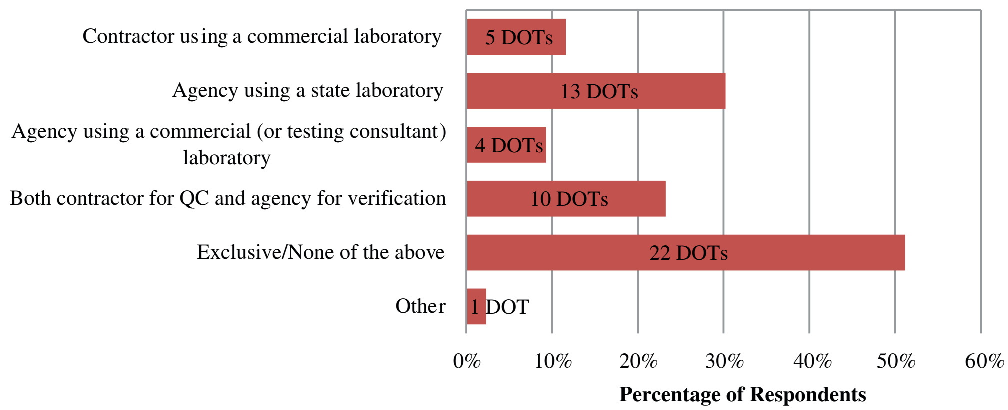

FIGURE A11 Survey response to Question 24: "As part of your agency's QA plan for the use of asphalt performance-based mix designs, who is responsible for performance testing?"

TABLE A21
SURVEY RESPONSE TO QUESTION 24: "AS PART OF YOUR AGENCY'S QA PLAN FOR THE USE OF ASPHALT PERFORMANCE-BASED MIX DESIGNS, WHO IS RESPONSIBLE FOR PERFORMANCE TESTING?"

Respondent	Response Comments
Orange County, California	County laboratory
Pennsylvania	Above selection is currently being done on a very limited number of mix designs that are of particular concern during mix design review.

Question 25: Does your agency currently have the equipment required for performance-based mix design testing?

TABLE A22
SURVEY RESPONSE TO QUESTION 25: "DOES YOUR AGENCY CURRENTLY HAVE THE EQUIPMENT REQUIRED FOR PERFORMANCE-BASED MIX DESIGN TESTING?"

Response Type	Response Rate
Yes	40%
No	22%
Pending (ordered equipment, not yet received)	2%
Not applicable	9%
Other	27%
Number of Total Responses	45
Respondent	**Response Comments**
Alabama	Only APA, TSR, and BBR
Georgia	We have some of the testing equipment detailed in this survey.
Kansas	KDOT-TSRST/KSU-Hamburger
Missouri	MoDOT has an APA for rut testing, but currently we do not have any equipment for determining the cracking potential of asphalt mixtures such as SCB and DCT.
Montana	For limited tests we now require. Considering acquiring additional equipment to expand use of performance-based testing.
New York	NYSDOT has an improperly working AMPT (Interlaken)
Ohio	Fatigue through research
Oklahoma	AMPT and fatigue equipment delivered at end of research
Oregon	Some test
Pennsylvania	Yes, we have an APA, Jr (APA and Hamburg) and we have an AMPT
South Carolina	AMPT—research ongoing

Question 26: Has the testing time (and the level of effort required for analyzing test results) been a deciding factor in whether to implement performance-based specifications on a project?

TABLE A23
SURVEY RESPONSE TO QUESTION 26: "HAS THE TESTING TIME (AND THE LEVEL OF EFFORT REQUIRED FOR ANALYZING TEST RESULTS) BEEN A DECIDING FACTOR IN WHETHER TO IMPLEMENT PERFORMANCE-BASED SPECIFICATIONS ON A PROJECT?"

Response Type	Response Rate
Yes	36%
No	30%
Not applicable	30%
Other	5%
Number of Total Responses	44
Respondent	**Response Comments**
Nebraska	Geographical locations for timeliness of reporting results
New Hampshire	Have not evaluated at this time

Question 27: Please provide some details on the reasons why test turnaround time has been a deciding factor.

TABLE A24
SURVEY RESPONSE TO QUESTION 27: "PLEASE PROVIDE SOME DETAILS ON THE REASONS WHY TEST TURNAROUND TIME HAS BEEN A DECIDING FACTOR"

Respondent	Response Comments
Alabama	We approved mix designs quite frequently. We would be greatly affected by increasing testing/review time.
California	Contractor may have to perform multiple mix design/testing before arriving to an approved mix.
Florida	One of factors. We need to approve the mix designs on time. For production level, it is a day-to-day job.
Kentucky	Specimen fabrication and testing time take too long for AMPT testing.
Louisiana	Performance test should be easy to conduct, in a timely manner, and easy to interpret and report. To minimize risk and enable plant adjustments when changes are recognized.
Maine	The additional test time for AMPT specimen fabrication and testing is a barrier.
Minnesota	Lead time between the bid and project startup; must be adequate if mix design changes are required.
Missouri	According to the MoDOT specifications, if the laboratory that designed the asphalt mixtures participates in the AASHTO proficiency sample program for the required tests and has achieved a score of 3 or better, we have 7 days to review the mix design. MoDOT's philosophy is to review and approve mix designs as quickly as possible so we do not delay the contractor in completing the project. Also, have concerns about the level of effort going to be required for performance-based mix design evaluations.
Montana	Limited resources (FTE), production flow
Nebraska	Not just the remote locations in Nebraska, but we are talking an entire new testing and acceptance protocol.
New Jersey	Rutgers Asphalt Pavement Lab (RAPL) has performed all of NJDOT's mixture performance testing up to this point in time. RAPL is a very busy research lab and turnaround time is sometimes an issue. To fully implement performance-based QA for all mixes it would take a substantial increase in state resources. The state has been struggling with budgetary issues and an increase for additional funding in-house to accomplish this is a difficult sell in the current climate.
Pennsylvania	Sometimes due to short time between asphalt mixture producer submitting mix designs for review and when it is actually needed for project construction. Greater than 10,000 asphalt mixture designs submitted by our asphalt mixture producers statewide (different aggregate combinations, different ESAL ranges, different aggregate skid resistance level—PennDOT has five aggregate skid levels).
Tennessee	Specimen preparation times for AMPT and fatigue-based tests are too long for production-level testing.
Utah	Project work requires we meet time deadlines

Question 28: Has cost been a deciding factor in whether to implement performance-based specifications on a project?

TABLE A25
SURVEY RESPONSE TO QUESTION 28: "HAS COST BEEN A DECIDING FACTOR IN WHETHER TO IMPLEMENT PERFORMANCE-BASED SPECIFICATIONS ON A PROJECT?"

Response Type	Response Rate
Yes	36%
No	31%
Not applicable	24%
Other	9%
Number of Total Responses	45
Respondent	**Response Comments**
Florida	Could be
Nebraska	Somewhat, but more implementation issues

Question 29: What are some of the reasons that cost has become a deciding factor for your agency for implementing performance-based specifications?

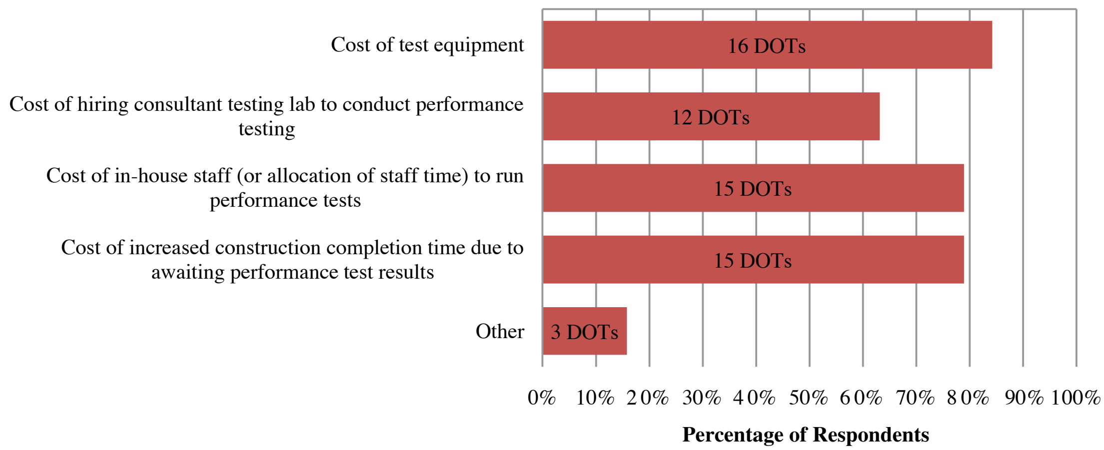

FIGURE A12 Survey response to Question 29: "What are some of the reasons that cost has become a deciding factor for your agency for implementing performance-based specifications?"

Question 30: Has your agency assessed the relative costs and benefits of using performance-based mix design specifications, as compared to the approaches your agency currently uses for the acceptance of mix designs?

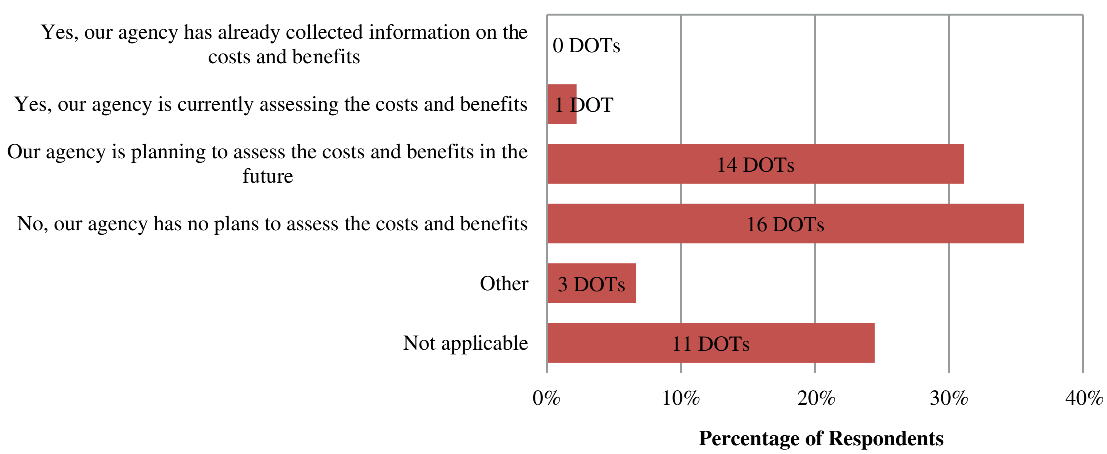

FIGURE A13 Survey response to Question 30: "Has your agency assessed the relative costs and benefits of using performance-based mix design specifications, as compared to the approaches your agency currently uses for the acceptance of mix designs?"

TABLE A26
SURVEY RESPONSE TO QUESTION 30: "HAS YOUR AGENCY ASSESSED THE RELATIVE COSTS AND BENEFITS OF USING PERFORMANCE-BASED MIX DESIGN SPECIFICATIONS, AS COMPARED TO THE APPROACHES YOUR AGENCY CURRENTLY USES FOR THE ACCEPTANCE OF MIX DESIGNS?"

Respondent	Response Comments
Manitoba, Canada	We conducted an environmental scan on Canada (cost only) method-based vs. performance specs.
Nebraska	We have some ideas of the costs of the equipment, but the time to train, certify, and look at true performance-related acceptance parameters takes each agency quite a while to measure say a laboratory flexing test for cracking and then compare to actual field performance.
Ohio	No, keeping options open
Pennsylvania	I believe any performance-based mix design specifications will need to consider cost and availability of the performance-based testing since this will likely fall on the asphalt mixture producers.

Question 31: Which types of asphalt mixtures have been included in the assessments of the relative cost and benefits of moving to a performance-based mix design approach?

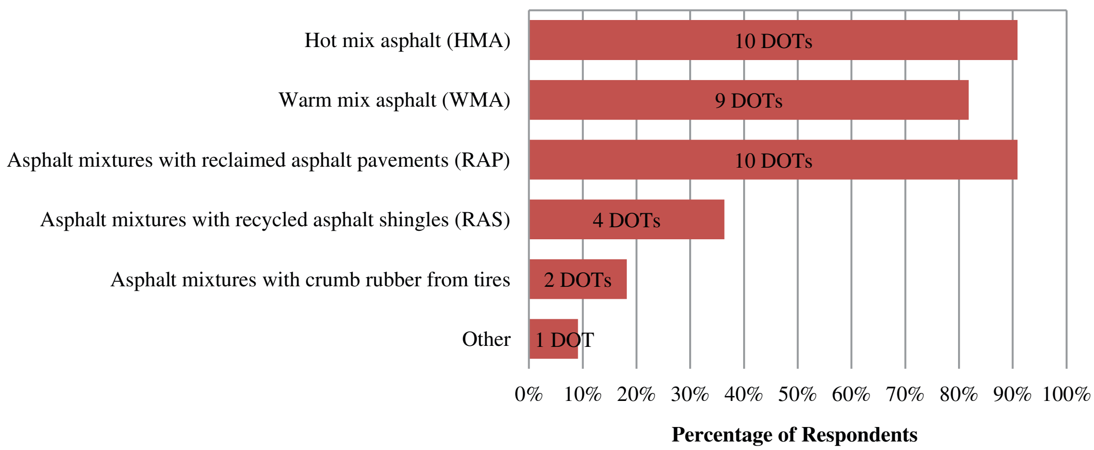

FIGURE A14 Survey response to Question 31: "Which types of asphalt mixtures have been included in the assessments of the relative cost and benefits of moving to a performance-based mix design approach?"

Question 32: Please provide a link to any published costs and benefits documents that support the implementation of performance-based specifications by your organization.

TABLE A27
SURVEY RESPONSE TO QUESTION 32: "PLEASE PROVIDE A LINK TO ANY PUBLISHED COSTS AND BENEFITS DOCUMENTS THAT SUPPORT THE IMPLEMENTATION OF PERFORMANCE-BASED SPECIFICATIONS BY YOUR ORGANIZATION"

Respondent	Response Comments
Louisiana	Mostly concerned with capitalization of equipment

Question 33: Is your agency conducting or sponsoring, or planning to conduct or sponsor, any research related to demonstrating or implementing other potential performance tests in specifications for asphalt mixtures?

TABLE A28
SURVEY RESPONSE TO QUESTION 33: "IS YOUR AGENCY CONDUCTING OR SPONSORING, OR PLANNING TO CONDUCT OR SPONSOR, ANY RESEARCH RELATED TO DEMONSTRATING OR IMPLEMENTING OTHER POTENTIAL PERFORMANCE TESTS IN SPECIFICATIONS FOR ASPHALT MIXTURES?"

Response Type	**Response Rate**
Yes	39%
No	61%
Number of Total Responses	44

Question 34: Which types of research on testing for performance-based properties have your agency conducted or sponsored?

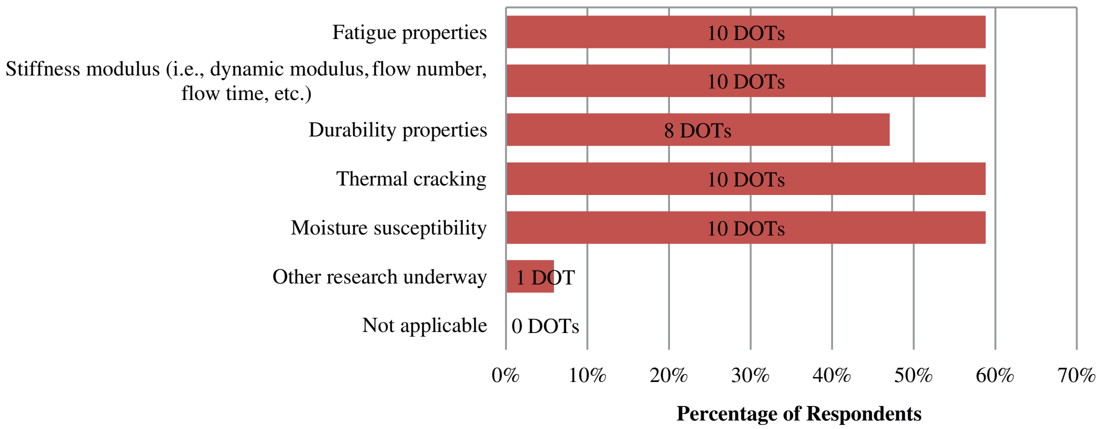

FIGURE A15 Survey response to Question 34: "Which types of research on testing for performance-based properties have your agency conducted or sponsored?"

TABLE A29
SURVEY RESPONSE TO QUESTION 34: "WHICH TYPES OF RESEARCH ON TESTING FOR PERFORMANCE-BASED PROPERTIES HAVE YOUR AGENCY CONDUCTED OR SPONSORED?"

Respondent	**Response Comments**
Nebraska	SCB testing is being used in several of our research projects.
Nova Scotia, Canada	Past performance of rehabilitation treatments based on visual distresses.

Question 35: Please provide some information on the research underway at your agency related to performance testing for asphalt performance-based specifications.

TABLE A30
SURVEY RESPONSE TO QUESTION 35: "PLEASE PROVIDE SOME INFORMATION ON THE RESEARCH UNDERWAY AT YOUR AGENCY RELATED TO PERFORMANCE TESTING FOR ASPHALT PERFORMANCE-BASED SPECIFICATIONS"

Respondent	Response Comments
Colorado	Currently performing AMPT Testing for E*, flow number, etc. Recently began testing for fracture energy using DCT specimens—all performance testing at this time is for information only, and used for pavement design decisions.
Georgia	GDOT has participated in the AMPT-pooled fund study. GDOT has sponsored moisture susceptibility of asphaltic concrete mixtures and best anti-stripping agents research
Kansas	Project by project: attempting to assess predictability of lab testing vs. field performance
Maine	We are conducting performance testing as part of SHRP2 R07 project.
Maryland	MEPD-G/AMPT pooled fund study
Minnesota	Pooled fund study. 2013 DCT pilot project.
Missouri	Currently looking at the semicircular bending test (SCB) and the disc-shaped compact tensile test (DST) for evaluating mixes using RAP and RAS. Have seen an increase in cracking in our pavements using recycled materials. Wanting to determine which test correlates to field performance, that is easy to conduct, and is economical to buy and operate.
Nebraska	All of our research can be supplied to you upon request via jodi.gibson@nebraska.gov
North Carolina	Two ongoing research projects with NC State University (Dr. Richard Kim and Dr. Akhtar Tayebali)
Nova Scotia, Canada	Currently in discussion as to what properties to focus on and what tests are available.
Oklahoma	ODOT FFY 2015 SP&R Item Number 2243 "Recommended Fatigue Test for ODOT"
Québec, Canada	Many research and tests for dynamic modulus
South Dakota	MEPDG research project on material test characteristics
Utah	BBR Beam Slivers for low temperature cracking potential of an asphalt mix. Research between UDOT and the University of Utah in process. SCB test to balance the mix design or get more asphalt binder into the mix. Also to predict cracking potential at intermediate temperatures. Research started between UDOT and a consultant.
Wisconsin	Four pilot projects constructed/will be constructed in 2014 and 2015
West Virginia	We are beginning some work using the SENB and DENT binder test to correlate with the AMPT and Hamburg tests.

Question 36: Which types of efforts related to asphalt performance specifications have your agency pursued?

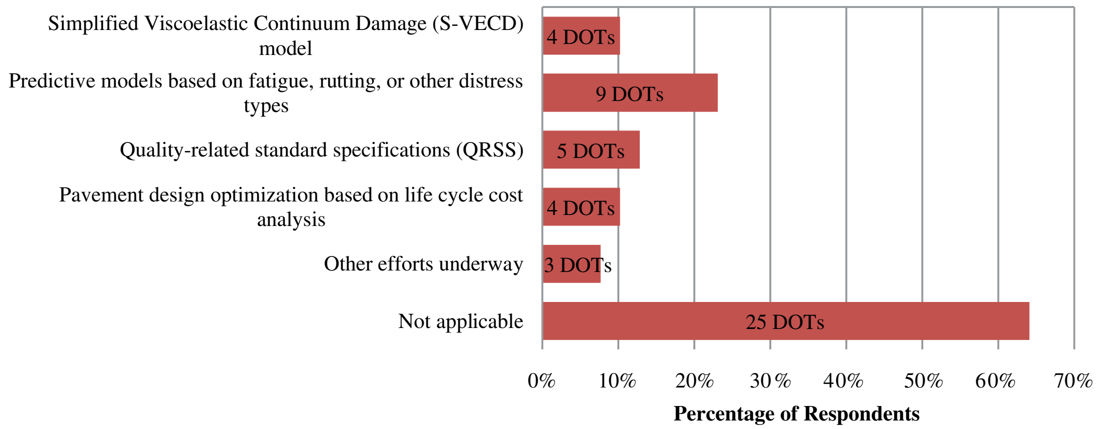

FIGURE A16 Survey response to Question 36: "Which types of efforts related to asphalt performance specifications have your agency pursued?"

TABLE A31
SURVEY RESPONSE TO QUESTION 36: "WHICH TYPES OF EFFORTS RELATED TO ASPHALT PERFORMANCE SPECIFICATIONS HAVE YOUR AGENCY PURSUED?"

Respondent	Response Comments
Florida	Whatever approach is effective in terms of cost, benefit, and accuracy.
Oklahoma	We have looked at the S-VECD and others for our fatigue research project.

Question 37: Please provide some information on the efforts underway at your agency related to performance-based specifications for asphalt.

TABLE A32
SURVEY RESPONSE TO QUESTION 37: "PLEASE PROVIDE SOME INFORMATION ON THE EFFORTS UNDERWAY AT YOUR AGENCY RELATED TO PERFORMANCE-BASED SPECIFICATIONS FOR ASPHALT"

Respondent	Response Comments
Florida	We have been looking for many cracking tests throughout the states, but most of them are complicated, time-consuming, and results could be varied a lot especially for the cracking test.
Georgia	GDOT is currently reviewing research proposals involving the S-VECD. We have APA requirements in our current specifications, but are reviewing research proposals for Georgia specific criteria for Hamburg Wheel Tracking Device. Our Pavement Design Unit uses life-cycle cost analysis as part of pavement type selection.
Maine	We are conducting performance testing as part of SHRP2 R07 project. We are also working with industry to implement performance-based mix designs.
Oklahoma	Specifications for a fatigue test method, if one is not standardized already, would be suggested at the end of our fatigue research.
Pennsylvania	Looking at optimizing the asphalt content of asphalt mixtures through either minimum asphalt contents based on mixture and aggregate volumetrics and also looking at rut resistance testing of asphalt mixtures with above optimum asphalt contents to try and increase durability of asphalt mixtures without significantly increasing rutting of asphalt wearing coarse layers.
Québec, Canada	Complex modulus determination of asphalt mixes at the Ministere des Transports du Québec—2010
Virginia	Currently the only parameters that could be considered performance-based are requirements for TSR and APA for mix design acceptance and bond strength testing for non-tracking tack coat materials. VDOT would like to move to using more performance-based testing but still has a long way to go before that is achieved.

Question 38: What are some of the issues that make it challenging for your agency to shift to the use of performance specifications for the design and acceptance of asphalt mixtures?

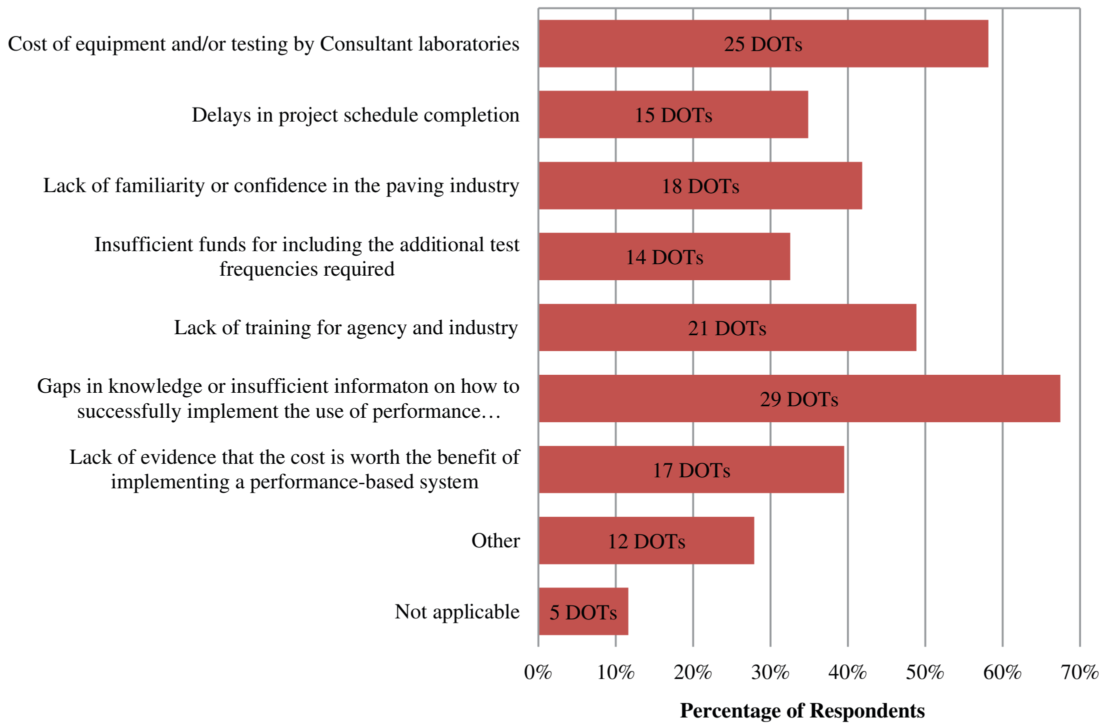

FIGURE A17 Survey response to Question 38: "What are some of the issues that make it challenging for your agency to shift to the use of performance specifications for the design and acceptance of asphalt mixtures?"

TABLE A33
SURVEY RESPONSE TO QUESTION 38: "WHAT ARE SOME OF THE ISSUES THAT MAKE IT CHALLENGING FOR YOUR AGENCY TO SHIFT TO THE USE OF PERFORMANCE SPECIFICATIONS FOR THE DESIGN AND ACCEPTANCE OF ASPHALT MIXTURES?"

Respondent	Response Comments
Florida	How reliable the performance test is, especially for cracking
Kansas	Solid info on how to proceed
Kentucky	Lack of personnel
Louisiana	Tech transfer to agency and industry to understand the benefits of adding requirements
Missouri	Lack of industry agreement on which tests to utilize for acceptance
New Jersey	Industry resistance
Ohio	Staff
Oklahoma	Design is our primary focus for now
Tennessee	Lack of confidence in the available test methods or test turnaround times too long
West Virginia	Strong political paving industry, we need their buy in…
Wyoming	Wyoming has many low volume roads where benefit of using performance-based specs would not be worth the cost.

Question 39: Please share a copy of your agency's performance specifications for asphalt pavements and/or mixture types by providing the weblinks in the following comment boxes.

Information shown in Appendix D

APPENDIX B

List of Agency Respondents

State Departments of Transportation
Alabama
Alaska
Arizona
Arkansas
California
Colorado
Connecticut
Delaware
District of Columbia
Florida
Georgia
Idaho
Indiana
Kansas
Kentucky
Louisiana
Maine
Maryland
Michigan
Minnesota
Mississippi
Missouri
Montana
Nebraska
Nevada
New Hampshire
New Jersey
New York
North Carolina
North Dakota
Ohio
Oklahoma
Oregon
Pennsylvania
Rhode Island
South Carolina
South Dakota
Tennessee
Texas
Utah
Vermont
Virginia
Washington
West Virginia
Wisconsin
Wyoming

Canadian Ministries of Transportation
Alberta
British Columbia
Manitoba
New Brunswick
Newfoundland
Nova Scotia
Ontario
Prince Edward Island
Québec
Saskatchewan

Local Public Agencies
City of Edmonton, Alberta
Clark County, Nevada
County of Orange, California

APPENDIX C

Links to Resources Identified in Survey and Interviews

TABLE C1
QUESTION 39: PLEASE SHARE A COPY OF YOUR AGENCY'S PERFORMANCE SPECIFICATIONS FOR ASPHALT PAVEMENTS AND/OR MIXTURE TYPES BY PROVIDING THE WEBLINKS IN THE FOLLOWING COMMENT BOXES

Respondent	Title	Link	Additional Notes
Alabama	Standard Specifications for Highway Construction	http://www.dot.state.al.us/conweb/doc/Specifications/2012%20DRAFT%20Standard%20Specs.pdf	SMA and Standard Structural (all layers)
	Rutting Susceptibility Determination of Asphalt Paving Mixtures Using the Asphalt Pavement Analyzer	http://www.dot.state.al.us/mtweb/Testing/testing_manual/doc/pro/ALDOT401.pdf	SMA
	Resistance of Compacted Hot-Mix Asphalt to Moisture Induced Damage	http://www.dot.state.al.us/mtweb/Testing/testing_manual/doc/pro/ALDOT361.pdf	All
California	Materials Information: Long Life Pavement Considerations: Summary of Coring Data	http://www.dot.ca.gov/hq/esc/oe/project_ads_addenda/02/02-3E7504/	15% and 25% RAP Long Life HMA
City of Edmonton, Alberta, Canada	Roadways: Design Standards Construction Specifications	http://www.edmonton.ca/city_government/documents/RoadsTraffic/Volume_2_-_Roadways_May_2012.pdf	Paving specification section
Colorado	Business Center: Section 100 Revisions	www.codot.gov/business/designsupport/construction-specifications/2011-Specs/standard-special-provisions/section-100-revisions	All HMA and WMA
	Business Center: Sections 200–500 Revisions	www.codot.gov/business/designsupport/construction-specifications/2011-Specs/standard-special-provisions/sections-200-500-revisions	All HMA and WMA
	Business Center: 2011 Specifications Book	www.codot.gov/business/designsupport/construction-specifications/2011-Specs/2011-specs-book	General specification link
Georgia	Design Manuals	http://www.dot.ga.gov/doingbusiness/PoliciesManuals/roads/Pages/default.aspx	
Louisiana	Standard Specifications	wwwsp.dotd.la.gov/Inside_LaDOTD/Divisions/Engineering/Standard_Specifications	

TABLE C1
(*continued*)

Respondent	Title	Link	Additional Notes
Michigan	Special Provision for Superpave Hot Mix Asphalt Percent Within Limits (PWL)	http://mdotcf.state.mi.us/public/dessssp/spss_source/12SP-501U-03.pdf	Superpave asphalt
	Special Provision for Materials and Workmanship Pavement Warranty	http://mdotcf.state.mi.us/public/dessssp/spss_source/12SP500(A)v2.pdf	Warranty boiler plate asphalt
	Special Provision for Warranty Work Requirements for New/Reconstructed Hot Mix Asphalt Pavement on Unbounded or Stabilized Base	http://mdotcf.state.mi.us/public/dessssp/spss_source/12SP501(N)v1.pdf	Reconstruct warranty asphalt
Missouri	Asphaltic Concrete Pavement	www.modot.org/business/standards_and_specs/Sec0403.pdf	Superpave: SP048, SP035, SP125, SP190, and SP250 as well as SMA mixes for heavy traffic
	Plant Mix Bituminous Base and Pavement	www.modot.org/business/standards_and_specs/Sec0401.pdf	Plant mix bituminous pavement and plant mix bituminous base, BP-1, BP-2, BP-3, and BB for medium traffic
	Plant Mix Bituminous Surface Leveling	www.modot.org/business/standards_and_specs/Sec0402.pdf	Plant mix bituminous surface leveling: SL, for low traffic
Nova Scotia, Canada	Standard Specification for Highway Construction and Maintenance	http://www.novascotia.ca/tran/publications/standard.pdf	Division 4, Section 19, all flexible pavements
New Jersey	Hot Mix Asphalt Specification	http://www.state.nj.us/transportation/eng/specs/2007/spec900.shtm#s902	
	SI document for projects:	http://www.state.nj.us/transportation/eng/specs/	The 900 section of the SI has other HMA specification mixture requirements
	New Jersey Society of Asphalt Technologists	http://www.njsat.org/	Training on PBS and performance testing is provided to industry, consultants, and New Jersey DOT through NJSAT
Nevada	Standard Specifications and Plans for Road and Bridge Construction	http://www.nevadadot.com/About_NDOT/NDOT_Divisions/Engineering/Specifications/Standard_Specifications_and_Plans_for_Road_and_Bridge_Construction.aspx	

(*continued on next page*)

TABLE C1
(*continued*)

Respondent	Title	Link	Additional Notes
Ohio	ODOT Proposal Notes, Supplemental Specifications, and Supplements	http://www.dot.state.oh.us/Divisions/ConstructionMgt/OnlineDocs/Pages/ProposalNotesSupplementalSpecificationsandSupplements.aspx	See sections 300 and 400 in spec book, Supplements and Supplemental Specifications have other mixes and agency procedures
	Continuing Investigation of Polishing and Friction Characteristics of Limestone Aggregates in Ohio	http://www.dot.state.oh.us/Divisions/Planning/SPR/Research/reportsandplans/Reports/2009/Pavement/134219_FR.pdf	FHWA Report No. FHWA/OH-2009/10, September 2009
Oklahoma	Oklahoma Department of Transportation Specifications	http://www.odot.org/c_manuals/specbook/oe_ss_2009.pdf	Standard Specs. Section 411 and 708 mostly
	2009 Special Provisions	http://www.odot.org/c_manuals/specprov2009/index.php	708-26 – Superpave mostly
Pennsylvania	Publication 408 Design Specifications	ftp://ftp.dot.state.pa.us/public/bureaus/design/Pub408/pdf%20for%20printing%202011%208/Pub_408_2011_8.pdf	Superpave HMA and WMA, SMA
Québec, Canada	Québec Publications	http://www2.publicationsduQuébec.gouv.qc.ca/transports/html/7c4.html	
	Québec Publications	http://www3.publicationsduQuébec.gouv.qc.ca/produits/ouvrage_routier/documents/document9.fr.html	
Texas	Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges	ftp://ftp.dot.state.tx.us/pub/txdot-info/des/spec-book-1114.pdf	Items 340, 341, 342, 346, 347, and 348
Utah	2012 Individual Specifications	02741 HMA Spec: http://www.udot.utah.gov/main/f?p=100:pg:0:::1:T,V:3694,	Hot mix asphalt (allows warm mix and RAP)
Virginia	Division II—Materials: Special Provision Copied Notes, Special Provision and Supplemental Specifications	http://www.virginiadot.org/business/resources/const/07RevDiv_II.pdf	Asphalt concrete (SS21112), Stone matrix asphalt (SS24807), thin hot mix overlays
	Division III—Roadway Construction – Special Provision Copied Notes, Special Provision and Supplemental Specifications	http://www.virginiadot.org/business/resources/const/07RevDiv_III.pdf	Nontracking Tack Coat (S310AM3) and overlays
Wisconsin	Special Provisions STH 77 high recycled asphalt materials (RAM)	http://wisconsindot.gov/hcciDocs/bid-let/2014/20140408/addenda/031-soi.pdf	Describes High Recycle HMA mixture design, providing, and maintaining a quality management program for High Recycle HMA mixtures, and constructing High Recycle HMA pavement. Applies also to High Recycle HMA and High Recycle WMA.

APPENDIX D

Sample Documents Related to Performance Testing as Part of Specifications for Asphalt Mixtures (electronic format only, available online)

City of Chicago DOT

Standard Method of Test for Determining Fracture Energy of Asphalt-Aggregate Mixtures Using the Disk-Shaped Compact Tension Geometry [Modified Illinois Modified Test Procedure (IDOT District 1 / CDOT / OMP)]: not available in online format

City of Edmonton

Construction Specifications Section 02966: Recycled Asphalt Paving:
http://www.edmonton.ca/city_government/documents/Volume_2_-_Roadways.pdf#search=Construction%20Specifications%20Section%2002966:%20Recycled%20Asphalt%20Paving (Page 162)

Construction Specifications Section 02067: Stone Mastic Asphalt Concrete:
http://www.edmonton.ca/city_government/documents/Volume_2_-_Roadways.pdf#search=Construction%20Specifications%20Section%2002966:%20Recycled%20Asphalt%20Paving (Page 37)

Construction Specifications Section 02742: SGC Hot-Mix Asphalt Paving:
http://www.edmonton.ca/city_government/documents/Volume_2_-_Roadways.pdf#search=Construction%20Specifications%20Section%2002966:%20Recycled%20Asphalt%20Paving (Page 98)

Georgia DOT

Standard Operating Procedure (SOP) 2 Control of Superpave Bituminous Mixture Designs: not available in online format

Special Provision Section 410—Warm Mix Asphaltic Concrete Construction: not available in online format

Special Provision Section 828—Hot Mix Asphaltic Concrete Mixtures: not available in online format

Louisiana DOTD

LTRC Research Project Capsule 10-4B – Development of Performance Based Specifications for Louisiana Asphalt Mixtures: https://www.ltrc.lsu.edu/pdf/2011/capsule_10_4B.pdf

LTRC Research Project Capsule 11-3B – Testing and Analysis of LWT and SCB Properties of Asphaltic Concrete Mixtures: https://www.ltrc.lsu.edu/pdf/2011/capsule_11_3B.pdf

Minnesota DOT

MnDOT 2013 Disk-shaped Compact Tension Test (DCT) Provision:
http://www.dot.state.mn.us/research/RFP/2014proposals/summaries/Disc-ShapedTest.pdf

New Jersey DOT

NJDOT B-10 – Overlay Test for Determining Crack Resistance of HMA:
http://www.nj.gov/transportation/eng/specs/2007/pdf/njdotb10.pdf

Section 401 – Hot Mix Asphalt (HMA) Courses:
http://www.state.nj.us/transportation/eng/specs/2007/spec400.shtm#s401

Ohio DOT

Plan Note: Polishing and Determining Friction of Gyratory Compacted Asphalt Specimens: not available in online format

Polisher Trial Projects British Pendulum Number Results Contractor Name and Date (Excel Spreadsheet): not available in online format

Supplement Specification 856, Bridge Deck Waterproofing, Hot Mix Asphalt Surface Course:
http://www.dot.state.oh.us/Divisions/ConstructionMgt/Specification%20Files/856_04182014_for_2013.pdf

Texas DOT

Item 340 Dense-Graded Hot-Mix Asphalt (Small Quantity): ftp://ftp.dot.state.tx.us/pub/txdot-info/des/spec-book-1114.pdf (Page 214)

Item 341 Dense-Graded Hot-Mix Asphalt: ftp://ftp.dot.state.tx.us/pub/txdot-info/des/spec-book-1114.pdf (Page 230)

Item 342 Permeable Friction Course: ftp://ftp.dot.state.tx.us/pub/txdot-info/des/spec-book-1114.pdf (Page 258)

Item 346 Stone-Matrix Asphalt: ftp://ftp.dot.state.tx.us/pub/txdot-info/des/spec-book-1114.pdf (Page 302)

Utah DOT

Section 02741 Hot Mix Asphalt (HMA): www.udot.utah.gov/main/uconowner.gf?n=7591302386285401

Section 02745 Asphalt Material: www.udot.utah.gov/main/uconowner.gf?n=7591510482297218

Illinois Modified Test Procedure
(IDOT District 1 / CDOT / OMP)

Effective Date: September 20th, 2014

Standard Method of Test
For
Determining Fracture Energy of Asphalt-Aggregate Mixtures Using the Disk-Shaped Compact Tension Geometry

Reference ASTM D 7313-07

ASTM Section	***Illinois Modification***
4.1	Replace the second sentence with the following: The test method is valid for specimens that are tested at -12°C ± 0.5°C.
4.1	New paragraph: Two specimens are required for a valid test. The average of the two specimens will determine if the material is acceptable. If the variance between two gyratory produced specimens exceeds 75 J/m2 or the variance between two core produced specimens exceeds 100 J/m2, then a third specimen shall be tested to determine if the one test is an outlier. An average of two qualifying tests will be used if one test is determined to be an outlier. Otherwise, an average of three values will be used.
6.1	Replace with the following: Test specimens shall be produced or procured according to the following requirements. Cores: 1. Cores shall be sampled from the pavement at the same offset. The edge of the core must be 12" minimum from edge of pavement. Sample a minimum of three cores for DCT. All cores shall be cut to produce a specimen of 150mm (+/- 2 mm) in diameter. 2. *Investigative Cores:* Sample three additional cores. Two cores shall be tested for Gmb and used in the DCT. And the two additional cores shall be tested for Gmm to determine the in-place air voids, using ASTM D2726. 3. *Production Cores:* Use the Gmm from the Design, the day's production, or the five day running average. 4. If a core is greater than 50mm, cut excess thickness from the top and bottom of the core. If there is only enough room to cut from one edge, cut from the top of the core. 5. For cores that are less than 50mm, use the correction factor to determine the J/m^2 based on the actual thickness. Production or Design Material: 1. All samples shall be compacted using a gyratory compactor to 7.0% ± 0.5 Air Voids with the following exceptions: SMA, CDOT LC and All Other (IDOT Standard Specification 1030.01) samples shall be compacted to 6.0% ± 0.5 Air Voids. Sample shall be prepared at height of 120mm or greater.

	2. Two DCT samples shall be cut from the same gyratory specimen.
6.2	Add the following: Test specimens shall be fabricated in accordance with the dimensions shown in Fig. 3.
7.1	Replace with the following: *Conditioning* – The specimens shall be placed in a standard freezer for a minimum of 8 hours and a maximum of 12 hours at a temperature within -12°C ±5°C. Alternatively, temperature condition the specimens until such time as the internal temperature of a control specimen (placed in freezer at same time/condition as test specimens) is at a constant temperature of -12°C±5°C and maintains that temperature range for 0.5 hours.. After the initial conditioning, the specimen shall be placed into the DCT chamber for 1 hour ±0.5 hours at the standard testing temperature of -12°C±5°C.

1. GENERAL

1.1 SECTION INCLUDES

1.1.1 Reclaiming existing asphalt pavement.

1.1.2 The design and production of recycled asphalt hot-mix.

1.1.3 Placing recycled asphalt hot-mix.

1.2 RELATED SECTIONS

1.2.1 Section 02066 SGC Hot-Mix Asphalt Concrete

1.2.2 Section 02742 SGC Hot-Mix Asphalt Paving

1.2.3 Section 02961 Pavement Cold Milling

1.3 QUALITY ASSURANCE

To Section 02066 – SGC Hot-Mix Asphalt Concrete.

2. PRODUCTS

2.1 MATERIALS

2.1.1 **Reclaimed Asphalt Pavement (RAP);** Rap is salvaged, milled, pulverized, broken, or crushed asphalt pavement removed from an existing pavement.

2.1.2 **Recycled Asphalt Shingles (RAS)**: pre-consumer or post consumer shingles that have been processed, sized, and are ready for incorporation into a hot mix Asphalt mixture.

2.1.3 **Virgin Aggregate:** new aggregate to Section 02066 – SGC Hot-Mix Asphalt Concrete.

2.1.4 **Aggregate in Recycled Asphalt Mix:** to Section 02066 – SGC Hot-Mix Asphalt Concrete modified as follows:

Mix Type:	20mm - B	10mm - HT	10mm - LT
Designation 1 class:	20	10.0	10.0
Sieve Size (μm)	**Total % Passing by Mass**		
160	9-16	7 – 16	8 – 16
80	4-9	4 - 9	4 - 9

2.1.5 **Asphalt Cement:** The extracted blended asphalt cement shall meet the PG requirements as detailed in 02066 – SGC Hot-Mix Asphalt Concrete.

2.2 MIX DESIGN AND PROPORTIONING

2.2.1 Submit a recycled asphalt mix design to Section 02066 – SGC Hot-Mix Asphalt Concrete for the specified mix type based on the following maximum RAP, RAS, or combination of RAP and RAS content:

Mix type:	20mm - B	10mm - HT	10mm - LT
Maximum RAP content if only using RAP in the mix (% by mass of total mix)	25	10	20
Maximum RAS content if only using RAS in the mix (% by mass of total mix)	3	3	3
Maximum RAP and RAS content if using both RAP and RAS in the mix, subject to the above noted individual maximums (% by mass of total mix)	25	10	20

2.2.2 Determine asphalt content and gradation of the RAS material for mixture design purposes in accordance with AASHTO T-164, Method A or B and AASHTO T-30. Calculate and ensure the ratio of the virgin binder to total binder is greater than 80% in surface mixtures and 75% in non-surface mixtures. "Surface" mixtures are defined as mixtures that will be final lifts or riding surfaces of a pavement structure. "Non-Surface" mixtures are defined as mixtures that will be intermediate or base layers in a pavement structure.

2.2.3 RAS shall contain no more that 0.5% by total cumulative weight of extraneous waste materials including but not limited to, metals, glass, paper, rubber, wood nails, plastics, soil, brick tars, and other contaminating substances. This percentage shall be determined on material retained on the 5.000mm sieve

2.2.4 RAS shall be free from asbestos fibers.

2.2.5 The Contractor shall, with the mix design, furnish PG test results from the virgin binder, the binder extracted from the individual RAP or RAS materials and PG test results indicating that the binder in the mix resulting from the blending of the RAP, RAS, or RAP and RAS materials meets the grade specified in the contract.

2.3 ASPHALT PLANT

2.3.1 In addition to the requirements of Section 02066 – SGC Hot-Mix Asphalt Concrete, the mixing plant shall be capable of receiving and mixing the proportions of RAP, RAS, virgin aggregate and asphalt cement as designed.

2.3.2 The mixing plant shall be capable of thorough degradation and heating of RAP and RAS particles and blending with virgin aggregate and asphalt cement to produce a homogeneous mix at the point of discharge.

2.4 EQUIPMENT

2.4.1 **Cold Planer:** to Section 02961 - Pavement Cold Milling.

2.4.2 **Haul Vehicle:** capable of receiving milled material directly from the cold planer and hauling directly to a stockpile.

2.4.3 **Weigh Scale:** shall meet the following requirements:

2.4.3.1 Inspected and certified by Weights and Measures Inspection Services of Canada Consumer and Corporate Affairs as often as directed by the Engineer, with the inspection certificate exhibited as required.

2.4.3.2 Of sufficient size and capacity for weighing any haul vehicle in one operation with all wheels on the platform.

2.4.3.3 Scale house to be provided complete with furnishings, subject to the approval of the Engineer..

2.4.4 **Mechanical Sweeper:** capable of removing loose material and debris from the milled surface

2.4.5 **Asphalt Shingle Grinder**: capable of receiving and processing asphalt shingles meeting the end product size requirements listed.

3. EXECUTION

3.1 RECLAIMING ASPHALT PAVEMENT

3.1.1 **Cold Milling:** Mill the designated pavement with a cold planer to Section 02961 - Pavement Cold Milling, supplemented as follows:

3.1.1.1 Sweeping before Milling: Before milling, sweep the pavement surface with a mechanical sweeper to remove debris and dirt accumulations that may contaminate the millings.

3.1.1.2 Operate the planer in a manner that will minimize tearing and breaking of the underlying and adjacent pavement.

3.1.1.3 Water Use: Carefully control the amount of water used in milling. Moisture in the RAP is of critical importance during hot-mix production.

3.1.1.4 Load milled material directly from the planer into the haul vehicle.

3.1.1.5 Sweeping after Milling: Immediately sweep the milled surface clean with a mechanical sweeper following the planer by not more than 100 m.

3.1.1.6 Milling Stop Line: Terminate milling at a uniform line across the roadway at the end of a working day. Provide a transition in the road surface profile at a slope of not more than 25 mm/m.

3.1.1.7 Rain: Suspend the milling operation in the event of rain or other inclement weather. Fill the milled area with a paving mix if the potential to pond water exists. Remove the temporary cover before resuming milling operations.

3.1.1.8 Traffic Hazard: Promptly repair, to the Engineer's satisfaction, any distress in the newly milled surface which could become a hazard to vehicular traffic.

3.1.1.9 Minimize contamination of the RAP with granular, clay and other deleterious materials at all times.

3.1.2 **Stockpiling RAP**

The RAP becomes the Contractor's property after removal from the jobsite, unless otherwise stated in the Special Provisions of the contract. The Contractor is responsible for stockpiling RAP in accordance with the following guidelines.

3.1.2.1 Drainage: Choose a site that has positive surface drainage away from the base of the stockpile.

3.1.2.2 Stockpile Base: Must have adequate strength to support the anticipated volume of RAP in the stockpile.

3.1.2.3 Particle Sizes: RAP being stockpiled shall meet the following gradation, or must be crushed to obtain the required gradation.

Sieve Size (mm)	Total % Passing by Mass
125	100
80	99 - 100
40	95 - 100

3.1.2.4 Ensure that the RAP is not disturbed after stockpiling. The RAP shall remain loose and uncompacted. No equipment shall be permitted to operate on the stockpile.

3.2 Recycled Asphalt Shingles (RAS)

3.2.1 RAS Production

Process the RAS by ambient grinding or granulating to meet the requirements in the following table when tested in accordance with AASHTO T27 (prior to extraction process)

Sieve Size (μm)	Total % Passing by Mass
10 000	100
5 000	70.0 - 95.0
160	15.0 Max.
80	7.0 Max.

3.2.2 Stockpiling RAS:

The Contractor is responsible for stockpiling RAS in accordance with the following guidelines.

3.2.2.1 Drainage: Choose a site that has positive surface drainage away from the base of the stockpile.

3.2.2.2 Stockpile Base: Must have adequate strength to support the anticipated volume of RAS in the stockpile

3.2.2.3 Ensure that the RAS is not disturbed after stockpiling. The RAS shall remain loose and uncompacted. No equipment shall be permitted to operate on the stockpile.

- The Contractor may uniformly blend sand or fine aggregate with RAS in stockpiles if needed to keep the processed material workable. The sand or fine aggregate added must be considered in the final gradation of the new HMA.
- Use RAS that is sufficiently dry to be- free flowing and to prevent foaming when blended with the hot binder.

3.2.3 If the Contractor elects to use RAS, the following additional conditions shall apply:

3.2.3.1 The Contractor shall have an approved Quality Control Plan (QCP) that details how the RAS will be processed and controlled. When the Contractor intends to use RAS from a RAS Supplier, that supplier's QCP shall be submitted by the Contractor. The QCP shall be submitted with the Contractor's HMA mix design and shall address the following:

3.2.3.1.1 RAS Processing Techniques. This requires a schematic diagram and narrative that explains the processing (grinding, screening, and rejecting) and stockpile operation for this specific project. Hand sorting of deleterious material prior to grinding is required. In addition, this plan must address the control of agglomeration and moisture.

3.2.3.1.2 Determination and Control of RAS Asphalt Binder Content (AASHTO T-164, Method A or B): Frequency: 1/200 tonnes of processed RAS material (minimum five tests).

3.2.3.1.3 Control of RAS Gradation (CP31 or AASHTO T-30): Frequency: 1/200 tonnes of processed RAS material (minimum three tests)

3.2.3.1.4 Asbestos content of RAS: Frequency: 1/1000 tonnes of processed RAS material (minimum three tests)

3.2.3.1.5 Moisture content of RAS: Frequency: 1/day

3.2.3.1.6 Deleterious Material: Frequency: 1/1000 tonnes of RAS material (minimum three tests)

3.3 PRODUCTION OF RECYCLED ASPHALT MIX

3.3.1 Production: Produce recycled asphalt mixture in accordance with the approved mix design and to Section 02066 – SGC Hot-Mix Asphalt Concrete.

3.4 PAVING

3.4.1 Paving Operation: to Section 02742 – SGC Hot-Mix Asphalt Paving.

3.4.2 Substitute Mix: Provide at least 24 hours notice to the Engineer if recycled asphalt hot-mix cannot be produced as intended.

3.4.3 Tolerances: to Section 02742 – SGC Hot-Mix Asphalt Paving.

END OF SECTION

1. GENERAL

1.1 SECTION INCLUDES

1.1.1 Production of a hot mixture of asphalt binder and aggregate for paving.

1.1.2 Requirements for mix design, quality control, and quality assurance.

1.2 RELATED SECTION

1.2.1 Section 02060 – Aggregate

1.2.2 Section 02743 – Stone Mastic Asphalt Paving

1.3 DEFINITIONS

1.3.1 **SGC Specimens**: Test specimens prepared using the SHRP Gyratory Compactor (SGC) at the specified number of N_{Design} gyrations of 100.

1.4 SUBMITTALS

1.4.1 Submittal of Asphalt Cement Data

1.4.1.1 Submit certified test results in writing with the mix design that the asphalt cement complies with the specifications. This certification shall include, but not be limited to:

- Name of the Supplier
- Source(s) of the Base Asphalt Cement(s)
- Type and Source(s) of admixture(s)
- Proportions of materials
- Laboratory test results of the Asphalt Cement
- Certification statement that the Asphalt Cement complies with the requirements of this specification.

Certification shall be submitted (1) for a binder used in the design of a job mix formula as part of a submittal, and, (2) during the life of an approved job mix formula.

1.4.2 Mix Design

1.4.2.1 Submit a mix design carried out by an independent laboratory to the Engineering Services Section at least 10 days before the start of any SMA production, and for each subsequent change in supplier or source of materials. No hot-mix production can proceed until the applicable mix design and job-mix formula is approved by the Engineer.

1.4.2.2 Submit all SMA mix design characteristics, including graphs used in arriving at the final mix design; the bulk specific gravity of individual aggregates and the combined aggregates; individual aggregate and mineral filler gradations and combined aggregate gradations: the graph of maximum specific gravity versus asphalt content; Blends and Job Mix Formula; the asphalt absorption of the combined aggregates and the Tensile Strength Ratio (TSR) as well as results of Asphalt Pavement Analyzer (APA) testing.

1.4.2.3 Submit, with the mix design, six 4-litre containers of PMA asphalt binder, and a sufficient quantity of each aggregate component to result in a 100-kg sample of combined aggregate at the design proportions.

1.4.3 Plant Scale Certificate

Provide a copy of the plant scale certificates to the Engineering Services Section at least 10 days prior to any SMA production.

1.4.4 Job Mix Formula

1.4.4.1 Submit with the SMA Mix design the proportions of materials and plant settings to include the following.

For Batch Plant:

- Sieve analysis of combined aggregate in the mix.
- Sieve analysis of aggregate in each bin separation to be used.
- Mass of material from each bin for each batch of mix.
- Mass of asphalt binder in each batch.
- Mixing temperature of asphalt binder determined from its temperature-viscosity curve, or as recommended by the manufacturer.

For Continuous or Drum-Mix Plant:

- Sieve analysis of each aggregate and mineral filler.
- Sieve analysis of combined aggregate in the mix.
- Mass of asphalt binder per tonne of mix.
- Mixing temperature of asphalt binder determined from its temperature-viscosity curve, or as recommended by the manufacturer.
- Settings of aggregate and asphalt binder feed systems (blend).

1.4.5 Quality Control Plan

Before beginning hot-mix production, submit a quality control plan to the Engineering Services Section including the following recommended tests and frequency. Submit test results daily to the Engineer for review.

Tests:
2 Superpave Gyratory Compactor (SGC) per test
Asphalt binder content
Air voids
Voids in the mineral aggregate (VMA)
Voids filled with asphalt binder
Moisture content of the mix
Gradation of the mix
Plant discharge temperature
Asphalt storage temperature

Frequency: A minimum of 2 tests per day of production.

1.4.6 Aggregates

1.4.6.1 **For Aggregate supplied by the Contractor**: Submit abrasion, soundness, flat and elongated, detrimental matter and clay content test results for each aggregate source. Submit results of sieve analysis to ASTM C136, and crushed face count at the following frequencies:

- For a stockpile existing at the time of contract award: a minimum of one sieve test and one crushed face count per 1 000 tonnes of aggregate. In addition, submit the average gradation of an entire stockpile when submitting a mix design using aggregate from the stockpile.
- For aggregate stockpiled during the contract: a minimum of one sieve test and one crushed face count per 1 500 tonnes of aggregate, or each day's production, whichever is less.

1.4.6.2 Submit results to the Engineering Services Section within 24 hours of testing. Do not use aggregate until test results have been reviewed and accepted by the Engineer.

1.4.6.3 **For Aggregate Supplied by the City of Edmonton**: If the aggregate is supplied by the City of Edmonton the aggregate will be available for pick-up from one of the City of Edmonton rubble recycling locations as set forth in the contract documents. The Contractor will supply the loader required to load the aggregate. However, the Contractor may choose to have the SMA material hauled directly to a stockpile location of his choice. The material haul date will be stipulated in the contract documents. The Contractor shall bid accordingly. The City of Edmonton is responsible for the quality assurance testing of the aggregate in stockpile and will provide the results of all QA testing to the successful contractor. It is the contractor's responsibility to confirm the gradation of the stockpile materials to be used; the City of Edmonton will make the stockpile available to the contractor to verify the gradation of the materials.

1.5 QUALITY ASSURANCE

1.5.1 Inspection and Testing

In addition to field inspections by the Engineer, the quality assurance laboratory will conduct plant inspection and materials sampling and testing described in the following paragraphs.

1.5.2 Asphalt Concrete Plant

Inspections will be conducted at least once a week during production to check plant calibrations, plant operation, production settings, temperatures, and materials handling. Samples of materials and mixture will be taken and tested.

1.5.3 Asphalt Cement

Quality assurance sampling and testing of the Asphalt Cement shall be performed by the contractor, at no cost to the, City of Edmonton, to verify compliance to the specification. A sample shall be taken at random during paving operations on City of Edmonton projects from a load(s) delivered to the contractor's asphalt plant at least twice a month or as directed by the Engineer. The sample shall be tested by an independent laboratory engaged by the Contractor to verify compliance with the specification requirements as stated in Section 2.1.1. Test results shall be reported in writing to the, Engineering Services Section of Transportation Services, City of Edmonton by the Contractor. Non-complying test results will be reported to the Engineering Services Section within 24 hours of completion of the test(s). Compliant sample test results shall be submitted in writing to the Engineering Services Section, no later than 10 working days after the date of sampling.

1.5.3.1 A test report shall include, but not be limited to, (1) report date, (2) date of sampling, (3) bill of lading number of load sampled, (4) destination of load, (5) report of test results, (6) standard test identifications, (7) specification requirements, (8) statement of compliance, and certification signature. Failure to comply with quality assurance testing may result in rejection of either the binder, and/or the job mix formula, and/or the associated job mix placed on a project.

1.5.3.2 If non-complying material is identified, the paving program may be suspended for 24 hours, as directed by the Engineer, during which time the Contractor and the Engineer will meet to determine the impact of the non-compliance, and specify the necessary remedial action to be taken by the Contractor. Remedial action shall be either acceptance, or acceptance at a pay adjustment, or removal and replacement at no cost to the City of Edmonton. The paving program may continue upon written authorization by the Engineer.

1.5.3.3 Production binder identified to be in non-compliance shall not be shipped to a project. Asphalt concrete batched and placed with non-complying binder shall be removed and replaced, as directed by the Engineer with complying material by the Contractor at no cost to the City of Edmonton.

1.5.3.4 Binder substitution in an authorized job mix formula shall not be allowed, without prior approval of the Engineer.

1.5.3.5 Actual asphalt cement content, in which unit price adjustments will be based on, is defined as the amount of asphalt cement in the mix as determined through the Quality Assurance testing program.

1.5.4 Production Mix Analysis

Full SGC testing will be conducted at a minimum frequency of one test, with two SGC specimens per test, for each 500 tonnes of hot-mix, or a day's production, whichever is less. Determine the asphalt cement content and the Maximum Theoretical Density (MTD) of SMA at a minimum frequency of one test for every 250 tonnes of hot-mix produced, or a day's production, whichever is less

1.5.5 Job Mix Formula

The quality assurance laboratory will test a trial batch of the job-mix formula to verify the mix design. The mix design and job-mix formula will not be approved until successful results are obtained.

1.5.6 Aggregate Gradation Tolerance

The variation from the approved job-mix aggregate gradation shall not exceed the following limits:

	% Passing by Mass	
Sieve Size (μm)	Individual Sample	Average of Last 3 Samples
5 000	± 3.0	± 3.0
1 250	± 3.0	± 2.5
630	± 3.0	± 2.0
315	± 3.0	± 2.0
160	-1.0 to +3.0	-1.0 to +2.0
80	-1.0 to +2.5	-0.5 to +1.0

1.5.7 Asphalt Content Tolerance

The allowable variation from the approved design asphalt content shall be ± 0.2% by mass of mix.

1.5.8 Air Void Tolerance

The allowable variation from the design air voids in the mix shall be ± 0.5%.

1.5.9 Mixing Temperature Tolerance

The allowable variation from the design mixing temperature shall be ± 9°C.

2. PRODUCTS

2.1 MATERIALS

2.1.1 **Polymer Modified Asphalt Cement:** to AASHTO M320, Table 2 (included in this specification as Table 02067.1), grade PMA PG 76-28, PG 70-28, or as otherwise set forth in the contract documents. For the Polymer Modified PG 76-28 and PG 70-28 Straight asphalt cement shall be modified with SB-type copolymers to reach the specified performance grade. No other modifiers are allowed unless approved in writing by the City of Edmonton

2.1.2 **Aggregates:** to section - 02060 – Aggregates and as shown below.

2.1.2.1 The Stone Mastic combined aggregate gradation requirements, including the required mineral filler shall be as follows:

Sieve Size (μm)	Percent Passing by Mass
20 000	minimum 100
16 000	97 - 100
12 500	88 - 100
10 000	30 - 80
6 300	22 - 45
5 000	20 - 35
2 500	16 - 26
1 250	14 - 22
630	13 - 20
315	12 - 18
160	10 - 16
80	10 - 14

2.1.2.2 Additional Stone Mastic aggregate properties shall be as follows:

Coarse Aggregate Physical Properties:

Property	Test Method	Requirement
LA Abrasion, % loss Grading B for plus 10 mm material Grading C for minus 10mm material	AASHTO T 96/ ASTM C131	22% Maximum
Flat & Elongated, % 3:1 5:1	ASTM D 4791	20% maximum. 5% Maximum
Absorption, %	AASHTO T 85	2% Maximum.
Soundness (5 Cycles), % Sodium sulfate Magnesium Sulfate	AASHTO T 104	15% Maximum 20% Maximum
Detrimental Matter, %	Alberta Infrastructure TLT 107	2% Maximum
Crushed Face Count, % One Face Two Faces	ASTM D 5821	100% with at least 1 100% with at least 2

Fine Aggregate Physical Properties:

Property	Test Method	Requirement
Soundness (5 Cycles), % Sodium sulfate Magnesium Sulfate	AASHTO T 104	15% Maximum 20% Maximum

Angularity, %	AASHTO TP 33	45% Minimum
Liquid Limit, %	AASHTO T 89	25% Maximum
Plasticity Index	AASHTO T 90	Non-Plastic

2.1.2.3 Fine Aggregate: that fraction of the total aggregate passing the 5 000 μm sieve. Fine aggregate shall contain 100% manufactured or crushed fines

2.1.3 Mineral Filler: The mineral filler should consist of Limestone dust or approved alternate meeting the requirements of AASHTO M-17 or ASTM D242. Filler should be free from organic impurities and the portion passing the 80 μm sieve size shall have a Plasticity Index of zero.

The mineral filler shall meet the following gradation requirements:

Sieve size (μm)	Percent Passing (by Mass)
600	100
300	92-100
80	60-100

2.1.3 Stabilizing Agent: Cellulose fibers shall be added at a rate of approximately 0.3 percent by total mass of mix in order to prevent draindown. The exact cellulose fibre addition rate to be determined by the SMA mix design.

The cellulose fibers shall meet the following requirements:

Property*	Requirement
Sieve Analysis: **Method A – Alpine Sieve Analysis** Fiber Length Passing 0.150 mm **Method B – Mesh Screen Analysis** Fiber Length Passing 0.850 mm Passing 0.425 mm Passing 0.160 mm	 6 mm Maximum 70 +/- 10 % 6 mm Maximum 85 +/- 10 % 65 +/- 10 % 30 +/- 10%
Ash Content	18 +/- 5% non-volatiles
pH	7.5 +/- 1.0
Oil Absorption	5.0 +/- 1.0 times fiber mass
Moisture Content	Less than 5% (by mass)

*Note: Test methods in accordance with those outlined in : Fiber Length "Designing Stone Matrix Asphalt Mixtures Volume IV – Mixture Design Method, Construction Guidelines and Quality Control Procedures" report dated July, 1998 and prepared by the National Center for Asphalt Technology (NCAT).

2.2 EQUIPMENT

2.2.1 Asphalt Plant

2.2.1.1 Asphalt Mixing Plant: conforming to ASTM D995, capable of consistently producing a homogeneous mixture in which all aggregate particles are uniformly and thoroughly coated with asphalt, and meeting the following supplementary requirements:

2.2.1.2 Provide free and safe access for the Engineer to verify proportions, settings, and temperatures, and to take samples of asphalt, aggregate and mixture.

2.2.1.3 All asphalt-paving plants are required to be operated in accordance with the Alberta Environmental Protection Code of Practice. All contractors operating asphalt plants shall provide proof of registration with Alberta Environmental Protection and agree that the asphalt plant shall be operated in accordance with the Code of Practice.

2.3 MIX DESIGN

2.3.1 The SMA Mix design shall be performed by an independent laboratory according to the procedures outlined in NCHRP Report 425 "Designing Stone Matrix Asphalt Mixtures for Rut Resistant Pavements – Part 2 Mixture Design Methods, Construction Guidelines and Quality Control/Quality Assurance Procedures" subject to the following parameters:

Selected Parameters	**Requirement**
Superpave Gyratory Compactor Design (100 Gyrations)	
Air Voids, %	3.5% +/- 0.5%
VMA, %	17 Minimum
VCA_{mix}, %	Less than VCA_{dry}
Tensile Strength Ratio % (AASHTO T283)	75 Minimum
Draindown @ production temperature, %	0.3 Maximum

2.3.1.1 **Rutting Susceptibility Testing**: SMA shall be subjected to the Asphalt Pavement Analyzer (APA) procedure during the mix design process and will be subjected to testing during actual production of the mixture, as deemed necessary by the Engineer. APA testing will be carried out by the City of Edmonton Quality Assurance laboratory or conversely the contractor may use an independent laboratory to perform APA testing. The APA device must meet the requirements of AASHTO TP63-03 and must be equipped with an automatic rut measurement system. The APA device must be calibrated at least once per year according to the procedures in the test method. In addition, the load cell used for checking wheel loads shall be calibrated at least once per year. Each test shall have 6 cylindrical samples fabricated and tested with the interior temperature of the APA set at 52° C. The downward force shall be set at 45 Kg and the hoses shall be pressurized to 689 kPa. Each specimen shall be compacted so that 7+/- 0.5 percent air voids are achieved. The APA rut test results shall be provided to the nearest 0.1 mm. The average rut depth for the specimens tested shall not exceed 5.0mm.

2.3.2 Modifications to the Stone Mastic mix design procedure or criteria are as follows:

- Metric sieves in accordance with CGSB Specification 8-GP-2M shall be used in place of the sieves specified in the Asphalt Institute Manual.
- PG Asphalt Cement content shall be reported based on the total mass of the mix
- Fine aggregate angularity criteria shall be as defined in 2.1.2.2.
- The Alberta Transportation and Utilities ATT and TLT test procedures shall be used to determine fine aggregate angularity.

2.3.3 Job-Mix Formula

Do not make changes to the approved job-mix formula without written approval from the Engineer. Display the currently approved job-mix formula in clear sight of the plant operator.

3. EXECUTION

3.1 PRODUCTION OF MIX

3.1.1 Good Practice Guide

Refer to the Quality Improvement Series 122 "Designing and Constructing SMA Mixtures – State of the Art Practice" as published by The National Asphalt Pavement Association (NAPA), for guidance in good practices of handling materials and hot-mix production insofar as consistent with this Section.

3.1.2 Production Rate

Produce hot-mix at a rate compatible with the rate of placement and compaction on the job.

3.2 Aggregate in Stockpile

3.2.1 Stockpile aggregate in horizontal lifts. Stacking conveyors are not allowed for stockpiling. Draw aggregate from stockpile in a manner that mixes the full depth of stockpile face.

3.2.2 When it is necessary to blend aggregates from one or more sources to produce the combined gradation, stockpile each source or size of aggregate individually. Do not blend aggregates in a stockpile.

3.2.3 If one or more of the mix properties are not met, the Engineer will order suspension of mix production until the Contractor has demonstrated to the Engineer's satisfaction that corrective measures have been taken to produce a mix that meets the requirements of this section.

END OF SECTION

Table 02067.1: AASHTO M320 Table 2

Table 2—Performance-Graded Asphalt Binder Specification

Performance Grade	PG 46			PG 52							PG 58					PG 64					
	34	40	46	10	16	22	28	34	40	46	16	22	28	34	40	10	16	22	28	34	40
Average 7-day max pavement design temperature, °C[a]	<46			<52							<58					<64					
Min pavement design temperature, °C[a]	>-34	>-40	>-46	>-10	>-16	>-22	>-28	>-34	>-40	>-46	>-16	>-22	>-28	>-34	>-40	>-10	>-16	>-22	>-28	>-34	>-40
Original Binder																					
Flash point temp, T 48, min °C	230																				
Viscosity, T 316:[b] max 3 Pa·s, test temp, °C	135																				
Dynamic shear, T 315:[c] $G^*/\sin\delta^d$, min 1.00 kPa test temp @ 10 rad/s, °C	46			52							58					64					
Rolling Thin-Film Oven Residue (T 240)																					
Mass change,[e] max, percent	1.00																				
Dynamic shear, T 315: $G^*/\sin\delta^d$, min 2.20 kPa test temp @ 10 rad/s, °C	46			52							58					64					
Pressurized Aging Vessel Residue (R 28)																					
PAV aging temperature, °C[f]	90			90							100					100					
Dynamic shear, T 315: $G^* \sin\delta^d$, max 5000 kPa test temp @ 10 rad/s, °C	10	7	4	25	22	19	16	13	10	7	25	22	19	16	13	31	28	25	22	19	16
Critical low cracking temp, R 49:[g] Critical cracking temp determined by R 49, test temp, °C	−24	−30	−36	0	−6	−12	−18	−24	−30	−36	−6	−12	−18	−24	−30	0	−6	−12	−18	−24	−30

[a] Pavement temperatures are estimated from air temperatures using an algorithm contained in the LTPP Bind program, may be provided by the specifying agency, or by following the procedures as outlined in M 323 and R 35.
[b] This requirement may be waived at the discretion of the specifying agency if the supplier warrants that the asphalt binder can be adequately pumped and mixed at temperatures that meet all applicable safety standards.
[c] For quality control of unmodified asphalt binder production, measurement of the viscosity of the original asphalt binder may be used to supplement dynamic shear measurements of $G^*/\sin\delta$ at test temperatures where the asphalt is a Newtonian fluid.
[d] $G^*/\sin\delta$ = high temperature stiffness and $G^* \sin\delta$ = intermediate temperature stiffness.
[e] The mass change shall be less than 1.00 percent for either a positive (mass gain) or a negative (mass loss) change.
[f] The PAV aging temperature is based on simulated climatic conditions and is one of three temperatures, 90°C, 100°C, or 110°C. Normally the PAV aging temperature is 100°C for PG 58-xx and above. However, in desert climates, the PAV aging temperature for PG 70-xx and above may be specified as 110°C.
[g] For verification of grade, at a minimum perform T 313 at the test temperature and at the test temperature minus 6°C and T 314 at the test temperature. Testing at additional temperatures for T 313 may be necessary if 300 MPa is not bracketed at the initial two test temperatures. Compare the failure stress from T 314 to the calculated induced thermal stress as per R 49. If the failure stress exceeds the induced thermal stress, the asphalt binder is deemed a "PASS" at the specification temperature.

Table 02067.1: AASHTO M320 Table 2 (continued)

Table 2—Performance-Graded Asphalt Binder Specification *(Continued)*

Performance Grade	PG 70						PG 76					PG 82				
	10	16	22	28	34	40	10	16	22	28	34	10	16	22	28	34
Average 7-day max pavement design temperature, °C[a]	<70						<76					<82				
Min pavement design temperature, °C[a]	>-10	>-16	>-22	>-28	>-34	>-40	>-10	>-16	>-22	>-28	>-34	>-10	>-16	>-22	>-28	>-34
Original Binder																
Flash point temp, T 48, min °C	230															
Viscosity, T 316:[b] max 3 Pa·s, test temp, °C	135															
Dynamic shear, T 315:[c] G*/sinδ[d], min 1.00 kPa test temp @ 10 rad/s, °C	70						76					82				
Rolling Thin-Film Oven Residue (T 240)																
Mass change,[e] max, percent	1.00															
Dynamic shear, T 315: G*/sinδ[d], min 2.20 kPa test temp @ 10 rad/s, °C	70						76					82				
Pressurized Aging Vessel Residue (R 28)																
PAV aging temperature, °C[f]	100 (110)						100 (110)					100 (110)				
Dynamic shear, T 315: G* sinδ[d], max 5000 kPa test temp @ 10 rad/s, °C	34	31	28	25	22	19	37	34	31	28	25	40	37	34	31	28
Critical low cracking temp, R 49:[g] Critical cracking temp determined by R 49, test temp, °C	0	−6	−12	−18	−24	−30	0	−6	−12	−18	−24	0	−6	−12	−18	−24

[a] Pavement temperatures are estimated from air temperatures using an algorithm contained in the LTPP Bind program, may be provided by the specifying agency, or by following the procedures as outlined in M 323 and R 35.
[b] This requirement may be waived at the discretion of the specifying agency if the supplier warrants that the asphalt binder can be adequately pumped and mixed at temperatures that meet all applicable safety standards.
[c] For quality control of unmodified asphalt binder production, measurement of the viscosity of the original asphalt binder may be used to supplement dynamic shear measurements of G*/sinδ at test temperatures where the asphalt is a Newtonian fluid.
[d] G*/sinδ = high temperature stiffness and G* sinδ = intermediate temperature stiffness.
[e] The mass change shall be less than 1.00 percent for either a positive (mass gain) or a negative (mass loss) change.
[f] The PAV aging temperature is based on simulated climatic conditions and is one of three temperatures 90°C, 100°C, or 110°C. Normally the PAV aging temperature is 100°C for PG 58-xx and above. However, in desert climates, the PAV aging temperature for PG 70-xx and above may be specified as 110°C.
[g] For verification of grade, at a minimum perform T 313 at the test temperature and at the test temperature minus 6°C and T 314 at the test temperature. Testing at additional temperatures for T 313 may be necessary if 300 MPa is not bracketed at the initial two test temperatures. Compare the failure stress from T 314 to the calculated induced thermal stress as per R 49. If the failure stress exceeds the induced thermal stress, the asphalt binder is deemed a "PASS" at the specification temperature.

1. GENERAL

1.1 SECTION INCLUDES

1.1.1 Supply and placement of SGC hot-mix asphalt concrete for roadway paving.

1.2 RELATED SECTIONS

1.2.1 Section 02066 – SGC Hot-Mix Asphalt Concrete

1.2.2 Section 02961 - Pavement Cold Milling

1.2.3 Section 02963 - Liquid Asphalt Coats

1.3 DEFINITIONS

1.3.1 **ESS**: The Engineering Services Section, Transportation Services of the City of Edmonton (City).

1.3.2 **Overlay:** paving over an existing pavement for rehabilitation purposes and not as part of staged paving.

1.3.3 **Staged Paving:** paving where a lift or lifts that form part of the total pavement structure are deferred to a future date.

1.3.4 **SGC Density:** the Superpave Gyratory Compactor (SGC) shall be used to prepare laboratory formed specimens at Ndesign of either 75 or 100 gyrations. The SGC formed specimens shall be used for the determination of volumetric properties on a field produced SGC hot-mix as outlined in the Asphalt Institute SP-2 Manual.

1.4 QUALITY ASSURANCE

1.4.1 Thickness Cores

ESS will:

1.4.1.1 Take a minimum of one core per 1,000 m^2 of SGC hot-mix asphalt pavement and determine the thickness of the mat, for each stage of paving.

1.4.1.2 A thickness deficiency at the completion of the first stage of paving may be accepted by the City provided the deficiency is less than 12mm and the deficient thickness can be included in the subsequent stage of paving.

1.4.1.3 If the initial core thickness is deficient at the completion of the final lift of paving, that initial thickness is discarded, and 3 new cores will be taken within 10 m of the original core location at a minimum spacing of 2.5 m between cores. The average thickness of the 3 new cores represents that area.

1.4.2 Asphalt Cement Content and Density Specimen Sampling and Testing

ESS will:

1.4.2.1 Determine the Maximum Theoretical Density (MTD) and asphalt cement content of the SGC hot-mix at a minimum frequency of one test for every 250 tonnes of SGC hot-mix produced, or a day's production, whichever is less.

1.4.2.2 Obtain one core from compacted mat placed from same load of SGC hot-mix from which SGC specimens were obtained, or from suspect compacted mat, and test for density. Where specified in the special provisions of the contract obtain a second core from the compacted mat for rut testing in the Asphalt Pavement Analyzer (APA).

1.4.2.3 Obtain one core from compacted mat representing 1,000 m^2 and test for density.

1.4.2.4 Basis of Acceptance: SGC hot-mix pavement compaction will be accepted based on the ratio (in percent) of the core density to the MTD. If cores were taken from a mat where no MTD are available, acceptance will be based on the ratio of core density to the average MTD for that day's production.

1.4.2.5 Representative Cores: A single core is initially taken representing the quantity of SGC hot-mix in not more than 1,000 m^2 of mat, with a minimum of one core taken from a day's production. If the initial core density is below specified, that initial density is discarded, and 3 new cores will be taken within 10 m of the original core location at a minimum spacing of 2.5 m between cores. The average density of the 3 new cores represents that area.

1.4.3 Rutting Susceptibility Specimen Sampling and Testing (Where Specified)

ESS will:

1.4.3.1 Where specified determine the rutting susceptibility of laboratory SGC hot-mix specimens at a minimum frequency of one test for every 5,000 tonnes of SGC hot-mix produced, for an individual project by subjecting the SGC hot-mix specimens to the APA procedure. The APA device will meet the requirements of AASHTO TP63-03 and is equipped with an automatic rut measurement system. The APA device will be calibrated at least once per year according to the procedures in the test method. In addition, the load cell used for checking wheel loads will be calibrated at least once per year. Each test shall have 6 cylindrical samples fabricated and tested with the interior temperature of the APA set at 52°C. The downward force shall be set at 45 Kg and the hoses shall be pressurized to 689 kPa. Each specimen shall be compacted so that 7.0+/-0.5 percent air voids are achieved. The APA rut test results shall be provided to the nearest 0.1 mm

1.4.3.2 Where specified, determine the rutting susceptibility of SGC hot-mix field core specimens taken at the location of the SGC hot-mix samples by subjecting the field core specimens to the APA procedure as described in the above section. The average rut depth for the specimens tested shall not exceed the specified APA requirements for the mix type. If the initial APA rutting is above specified, that initial APA result is discarded, and 6 new cores will be taken within 10 m of the original core location at a minimum spacing of 2.5 m between cores. The average APA result of the 6 new cores will be taken as to represent that area.

1.4.4 Tensile Strength Ratio (TSR) Specimen Sampling and Testing (Capital Program)

ESS will:

1.4.4.1 Determine the TSR of SGC hot-mix field samples at a minimum frequency of one test for every 5,000 tonnes of SGC hot-mix produced, for an individual project, in accordance with AASHTO T283, including the optional freeze-thaw cycle.

2. PRODUCTS

2.1 MATERIALS

2.1.1 SGC Hot-Mix Asphalt Concrete

To Section 02066 – SGC Hot-Mix Asphalt Concrete.

2.1.2 Tack Coat

To Section 02963 - Liquid Asphalt Coats

2.2 EQUIPMENT

2.2.1 Trucks for Transporting Mix:

Trucks shall be compatible with size and capacity of the paver; with clean, tight, smooth-sided boxes equipped with waterproof tarpaulins of sufficient size to securely cover all material when boxes are fully loaded. The side of the truck box shall have a 12-mm diameter hole 300 mm from bottom for checking mix temperature. Use only approved release agents, such as water based liquid soap, dry soap powder or approved material and drain all excess release agents from truck beds prior to loading SGC hot-mix. Petroleum derivatives are not permitted as release agents.

2.2.2 Paver

Pavers shall be self-propelled; with automatic screed controls to maintain grade from a reference string line or ski and to control crossfall, smoothness and joint matching; with vibratory screed equipped with vibratory extensions and augers capable of uniformly spreading the mixture to specified widths and depths without segregation or tearing. Follow the manufacturer's recommended operating procedures.

2.2.3 Rollers

Shall be self-propelled, reversible; static, oscillating or vibratory steel-drum or pneumatic-tired rollers; with wetting and scraping devices to prevent adhesion of mix to drums or tires (petroleum derivatives are not permitted for cleaning); capable of attaining required density and smoothness; and pneumatic-tired rollers to be equipped with wind skirts. Follow the manufacturer's recommended operating procedures.

2.2.4 Hand Tools

Rakes, lutes, tampers, straightedges, levels, and other hand tools as necessary to complete the work shall be available.

3. EXECUTION

3.1 GOOD PAVING PRACTICE

Production, Placement, Compaction and Quality Assurance of the SGC hot-mix mix should be pursuant to the requirements of TB-1 "Hot Mix Asphalt Materials, Mixture Design and Construction" as prepared by the National Centre for Asphalt Technology (NCAT) and published by the National Asphalt Pavement Association (NAPA), for guidance in good practices of handling materials and hot-mix production insofar as consistent with this Section.

3.1.1 Refer to the latest edition of the "*Construction of Hot Mix Asphalt Pavements"*, Asphalt Institute Manual Series No. 22 (MS-22), for guidance in good paving practice insofar as consistent with this Section.

3.1.2 Provide an experienced foreman who shall be in full time attendance on the paving site to take charge of the entire paving operation from transporting of the mix to final rolling.

3.2 PREPARATION

3.2.1 The Engineer will inspect the existing pavement, base, or subbase before SGC hot-mix paving. The Contractor shall repair imperfections and clean up as directed by the Engineer. Surface shall be true to line and grade within tolerance, firm, dry, and free of loose and deleterious material.

3.2.2 For new construction or as directed by the Engineer all Catch basins, manholes, water valves, and other fixtures shall be brought to proper grade before final lift paving. Provide temporary protection where necessary until completion of paving. If catch basins, manholes, water valves, and other fixtures are not raised prior to final lift paving as required and are required to be raised subsequent to final lift paving a $2,000.00 penalty per occurrence, as documented by the Engineer, will be assessed.

3.2.3 Multiple Lift Paving

Apply tack coat to the previous lift before placing a lift, unless permitted otherwise by the Engineer. Clean the exposed surface before tacking.

3.2.4 Preparation for Overlay or for Succeeding Stage Paving

3.2.4.1 Sweeping and Cleaning: Sweep the existing pavement surface with an approved mechanical sweeper. Remove all residual debris and accumulations of deleterious material.

3.2.4.2 Surface Milling: If specified, grind the existing surface to specified depth according to Section 02961 – Pavement Cold Milling

3.2.4.3 Tack Coat: When the existing surface has passed inspection by the Engineer, apply tack coat to Section 02963 - Liquid Asphalt Coats.

3.2.4.4 Apply tack coat to surfaces intended to be in contact with SGC hot-mix, including the sides of gutters, catch basins, manholes, and other concrete and metal fixtures. Before placing SGC hot-mix, let tack coat completely cure and have tacked surfaces inspected by the Engineer

3.2.4.5 Asphalt Levelling Course: The Engineer will designate those areas having 20 mm or greater depressions for levelling course application. Spread the levelling course of SGC hot-mix with a paver one lift at a time, not exceeding 60 mm compacted thickness, and compact to required density.

3.3 WEATHER LIMITATIONS

- No paving is permitted when rain or snow is imminent, or when the surface or base to be paved is wet, icy, snow-covered, or frozen, unless waived by the Engineer.

- No paving is permitted when air temperature and wind speed conditions are below the applicable mat curve in Chart 02742.1, unless waived by the Engineer.

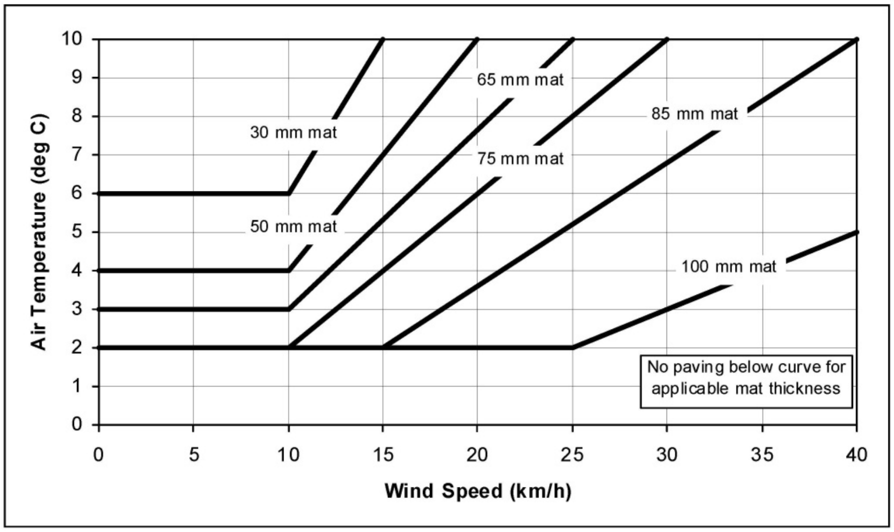

CHART 02742.1: AIR TEMPERATURE AND WIND LIMITATIONS ON PAVING

3.4 TRANSPORTATION OF SGC HOT-MIX

3.4.1 Transport the SGC hot-mix in approved trucks with protective covers properly secured to the sides and back of truck box so that no funnelling air movement develops under the cover during hauling.

3.4.2 Before loading with SGC hot-mix, thoroughly clean the box of any accumulation of asphaltic material. Lubricate inside surfaces with a light coating of soap, detergent solution or an approved release agent. Petroleum derivatives are not permitted.

3.4.3 Maintain trucks clean of mud and other material that could contaminate the paving area.

3.4.4 Discharge SGC hot-mix into the paver hopper without spilling and without the truck box bearing down on the hopper.

3.4.5 If the unit for payment is tonnes, no payment will be made for SGC hot-mix tonnage unless the Engineer is provided with a copy of the corresponding asphalt mix load ticket immediately upon arrival at the site.

3.5 SPREADING

3.5.1 Placing the SGC hot-mix shall be a continuous operation with the paver moving at a uniform speed compatible with the rate of compaction rolling and SGC hot-mix mix delivery.

3.5.2 Spreading of Mix

3.5.2.1 Ensure that mix compaction temperature meets the asphalt cement manufacturer's requirements, as measured in the mat, immediately behind the paver.

3.5.2.2 Spread the SGC hot-mix uniformly in one or more lifts, or as directed by the Engineer, to depths sufficient to obtain a minimum compacted thickness of 30 mm for 10mm–LT and 10mm–HT mixes and 45 mm for 20mm-B mixes and a maximum compacted thickness of 75 mm for 10mm–LT and 10mm–HT mixes and 100 mm for 20mm-B mixes.

3.5.2.3 Excess SGC hot-mix is to be wasted. Do not pick up any SGC hot-mix materials that has been placed through a paver and put back into the paver hopper. Placing of any excess paver laid SGC hot-mix back into the paver hopper will be assessed a $500.00 penalty per occurrence, as documented by the Engineer.

3.5.3 Segregation

3.5.3.1 If segregation of mix material occurs, the Engineer will immediately suspend spreading until the cause is determined and corrected.

3.5.3.2 Prior to roller compaction, remove fat spots, sandy accumulations, high and low spots, and other irregularities and repair with SGC hot-mix. Scratch surface with rake tines to ensure bonding of added mix. Do not spread loose SGC hot-mix that has been raked off onto the mat.

3.6 HAND SPREADING

3.6.1 Hand spread SGC hot-mix in small areas not accessible to paver, and where permitted by the Engineer.

3.6.2 Do not broadcast SGC hot-mix. Hand place mix carefully to avoid the segregation of coarse and fine aggregate. Use lutes and rakes to thoroughly loosen and uniformly distribute the SGC hot-mix. Remove lumps that do not break down readily.

3.6.3 Heat hand tools to prevent asphalt sticking. Do not overheat tools to prevent damaging of the SGC hot-mix.

3.6.4 Before rolling, check surface with template or straightedge, and correct irregularities.

3.7 COMPACTION

3.7.1 Compact the SGC hot-mix mat with rollers in good working order and operated by competent operators. Use the number, type, and mass of rollers required to obtain the required compaction within the available compaction time and compatible with the rate of SGC hot-mix placement.

3.7.2 Develop and follow the best pattern of rolling to obtain the uniform compaction across the mat including joints and edges without degrading the aggregate through over compaction. Indicate the rolling pattern to the Engineer when requested.

3.7.3 Perform compaction rolling with rollers following the paver as closely as possible, until required density is obtained. Perform finish rolling to eliminate equipment marks and to create a surface with a uniform tightly knit texture.

3.7.4 Complete final rolling before the mat surface temperature reaches 40°C as determined with an infrared thermometer.

3.7.5 For small areas inaccessible to rollers, use an approved vibratory plate compactor or hand tamper to thoroughly compact the SGC hot-mix.

3.7.6 If compaction or finish rolling difficulties occur, suspend paving operations, redesign the mix and obtain Engineer's approval of a trial batch before resuming paving.

3.8 JOINTS

3.8.1 Transverse Joint

3.8.1.1 Plan length of spread to provide for a minimum 1 m offset of transverse joints in successive lifts and adjacent mats.

3.8.1.2 Transverse joints shall be straight, have a vertical face painted with tack coat before placement of the adjacent mat, be thoroughly compacted, and meet surface tolerances.

3.8.2 Longitudinal Joint

3.8.2.1 Location: Plan mat limits to ensure that surface longitudinal joints will be offset not more than 150 mm from the centre of a proposed pavement marking line between travel lanes. If permitted by the Engineer, the joint may be located at the centre of a travel lane.

3.8.2.2 Plan width of spread to provide for a minimum 150 mm offset (in a dovetail pattern) of longitudinal joints in successive lifts.

3.8.2.3 Create a longitudinal joint while the temperature at the edge of the first of two adjacent mats is above 80°C. Allow an overlap of 25 to 50 mm between mats. This may be accomplished by multiple pavers in staggered formation, or by limiting paver advance.

3.8.2.4 Do not roll the 150 mm wide strip along edge of first mat until the adjacent mat is placed. Roll the joined mat immediately to insure bonding while the mix at the joint is about 80°C.

3.8.2.5 If a hot longitudinal joint as described in 3.8.2.3 cannot be created, then carefully roll the edge of the first mat, form or cut a clean vertical face 150 mm back from the mat edge and to the full depth of the mat, and paint with tack coat before placing the adjacent mat.

3.8.2.6 Should the longitudinal joint treatment indicated in 3.8.2.5 not be performed where required, the area of asphalt pavement will be assessed a pay factor of 95 percent. This pay factor will be applied to the price of the total quantity of asphalt placed in the mat area

3.8.2.7 The finished longitudinal joint shall be thoroughly compacted and shall meet surface tolerances.

3.9 MIX PRODUCTION AND PAVING TOLERANCES

3.9.1 Aggregate Gradation Tolerance

The variation from the approved job-mix aggregate gradation shall not exceed the following limits:

Sieve Size (μm)	% Passing by Mass	
	Individual Sample	Average of Last 3 Samples
20 000	± 2.0	± 1.0
16 000	± 3.0	± 1.0
12 500	± 4.0	± 2.0
10 000	± 5.0	± 3.0
8 000	± 4.0	± 3.0
6 300	± 4.0	± 3.0
5 000	± 3.0	± 3.0
1 250	± 3.0	± 2.5
630	± 3.0	± 2.0
315	± 3.0	± 2.0
160	-3.0 to +1.0	-2.0 to +1.0
80	-2.5 to +1.0	-1.0 to +0.5

3.9.2 **Asphalt Content Field Mix Tolerance**: Allowable variation from approved design asphalt content shall be ±0.3 percent by mass of mix.

3.9.3 **Tolerance for Air Voids in Field Mix**:

Mix Type:	10mm - HT	10mm - LT	20mm - B
Air Voids, %:	4.0 ± 0.5	3.0 ± 0.5	3.5 ± 0.5

3.9.4 **Minimum Film Thickness in Field Mix**:

Mix Type:	10mm - HT	10mm - LT	20mm - B
Min Film Thickness, μm:	7.5 min.	7.5 min.	6.5 min.

3.9.5 **Voids Filled in field Mix:**

Mix Type:	10mm - HT	10mm - LT	20mm - B
Voids Filled, %:	70 - 80	73 - 85	65 - 75

3.9.6 Mixing Temperature Tolerance

The allowable variation from the design mixing temperature shall be ± 10°C.

3.9.7 3.9.7 Mixture Handling Tolerance

In accordance with Section 3.5.2.3; $500.00 penalty per documented occurrence.

3.9.8 Smoothness Tolerances

Maximum variation under 3 m straightedge as follows:

3.9.8.1 Longitudinal (in the direction of travel): 3 mm.
Transverse (across the direction of travel): 6 mm.
(straight crossfall)

3.9.8.2 Grade: ±6 mm maximum variation from designated grade elevations.

3.9.8.3 Texture: Finished surface shall be free of visible signs of poor workmanship such as, but not limited to:

- Segregation, as demonstrated through sandy spots or excessively open spots (areas of water bleeding from the mat),
- Areas exhibiting excess or insufficient asphalt cement, as demonstrate through fat spots or open textured spots,
- Improper matching of longitudinal and transverse joints,
- Dimpling, roller marks, cracking, or tearing.

If surface and grade tolerances are exceeded, or if surface texture is not met, grind down and resurface defective areas as directed by the Engineer.

3.9.9 Thickness Tolerance

3.9.9.1 Deficient Thickness: If average core thickness is deficient that area of asphalt pavement will be assessed a pay factor according to Table 02742.1 to be applied to the price of the quantity of SGC hot-mix in that mat area.

3.9.9.2 Excess Thickness: Asphalt pavement with excess thickness may be accepted with no extra payment, if surface and grade tolerances and texture are met.

TABLE 02742.1 ASPHALT THICKNESS PAY FACTORS

THICKNESS DEFICIENCY (%)	PAY FACTOR (%)
10.0	100.0
11.0	97.0
12.0	93.7
13.0	90.0
14.0	85.5
15.0	80.5
16.0	75.0
17.0	68.0
18.0	60.0
19.0	50.0
Over 19.0 %	Grind and Resurface

3.9.10 Density Tolerance

3.9.10.1 Required Density: Each mat of hot-mix placed shall be compacted to the following minimum density (Percent of Maximum Theoretical Density (MTD)) for the type of paving, or as indicated in the contract Special Provisions.

Minimum Density	Type of Paving
94%	All stages in staged paving for freeways, arterials, industrial/commercial roadways and residential collector roadways, and residential local roadways including FAC Overlays
93%	Alley paving.
93%	Rehabilitation overlay
93%	Asphalt walk/bikeway.

3.9.10.2 Deficient Density: If the average core density is below specified, the represented area of mat may be accepted subject to a pay factor according to Table 02742.2 to be applied to the price of the quantity of SGC hot-mix in that mat area.

TABLE 02742.2 ASPHALT DENSITY PAY FACTORS

Percentage of MTD 94% MTD Required	Pay Factor (%)	Percentage of MTD 93% MTD Required	Pay Factor (%)
94.0	100.0	93.0	100.0
93.9	99.9	92.9	98.4
93.8	99.8	92.8	96.8
93.7	99.6	92.7	95.2
93.6	99.4	92.6	93.9
93.5	99.1	92.5	92.0
93.4	98.7	92.4	90.4
93.3	98.3	92.3	88.8
93.2	97.8	92.2	87.3
93.1	97.2	92.1	85.7
93.0	96.5	92.0	84.1
92.9	95.8	91.9	82.5
92.8	95.0	91.8	80.9
92.7	94.2	91.7	79.3
92.6	93.3	91.6	77.7
92.5	92.3	Less than 91.5	Grind and Resurface
92.4	91.1		
92.3	89.8		
92.2	88.5		
92.1	87.1		
92.0	85.5		
91.9	83.8		
91.8	82.0		
91.7	80.0		
91.6	77.7		
Less than 91.5	Grind and Resurface		

3.9.11 APA Tolerance (Where Required)

3.9.11.1 Maximum APA rutting: If average core APA rutting is above 5.0 mm for 10mm-HT and 20mm–B and 7.0 mm for 10mm-LT, that area of asphalt pavement will be assessed a pay factor according to Table 02742.3 to be applied to the price of the quantity of SGC hot-mix in that mat area.

TABLE 02742.3 APA RUTTING PAY FACTORS

10mm - HT & 20mm - B, APA RUTTING MEASUREMENT (mm)	10 mm - LT, APA RUTTING MEASUREMENT (mm)	PAY FACTOR (%)
5.0	7.0	100.0
5.2	7.2	95.0
5.4	7.4	90.0
5.6	7.6	85.0
5.8	7.8	80.0
6.0	8.0	75.0
6.2	8.2	70.0
6.4	8.4	65.0
6.6	8.6	60.0
6.8	8.8	55.0
Over 7.0 mm	Over 9.0 mm	Grind and Resurface

3.9.12 Asphalt Cement Content Tolerance

3.9.12.1 The allowable variation from the approved design asphalt content shall be ± 0.30 Percent by mass of mix.

3.9.12.2 Deficient Asphalt Cement Content: If the asphalt cement content, as determined by ESS indicates low or high asphalt cement content, the represented area of mat may be accepted subject to a pay factor according to Table 02742.4 and is to be applied to the unit price of the 250 tonnes or equivalent area of hot-mix in the mat.

TABLE 02742.4 ASPHALT CEMENT CONTENT PAY FACTOR

ESS Asphalt Cement Content (%)	PAY FACTOR (%)
± 0.00 – 0.30	100.0
± 0.31 - 0.35	94.0
± 0.36 – 0.40	90.0
± 0.41 – 0.45	86.0
± 0.46 –0.50	78.0
± 0.51	Grind and Resurface

3.9.12.3 Asphalt Cement Content Appeal Mechanism (Capital Projects)

In the event of a Deficient Asphalt Cement Content result the following Asphalt Cement Content Appeal Mechanism will be allowed by the City of Edmonton:

3.9.12.3.1 The original core location shall be confirmed by the ESS;

3.9.12.3.2 The ESS will then re-core for determination of asphalt cement content. The re-coring (which may require multiple cores to obtain the required quantity of materials for a re-test) will be taken from the mat representing the original test within 10 meters on either side of the original test location. Only a single test is required for verification process. All core holes to be filled with hot-mix asphalt, by the Contractor, to the satisfaction of the Engineer.

3.9.12.3.3 The asphalt cement content test result from the re-core will supersede the original QA result**.**

3.9.12.3.4 If the asphalt cement content of the re-core is within the penalty range the penalty will be calculated in accordance with TABLE 02741.3 ASPHALT CEMENT PAY FACTORS for the quantity of asphalt represented by the test. No further re-coring is allowed.

3.9.12.3.5 If the asphalt cement content of the re-core is in the "remove and replace" range, additional cores will be taken at equal distances on either side of the original core and tested for asphalt cement content. This process is to be repeated until locations on either side of the re-core identify asphalt within specification. The spacing is at the discretion of the contractor.

3.9.12.3.6 Once the area of asphalt to be removed and replaced" is identified, the area inclusive of the last core used to delineate the deficient area shall be removed and replaced to the satisfaction of the Engineer.

3.9.12.4 Asphalt Cement Content Appeal Mechanism (Private Development):

In the event of a Deficient Asphalt Cement Content result the following Asphalt Cement Content Appeal Mechanism will be allowed by the City of Edmonton and shall be paid for by the Contractor:

3.9.12.4.1 The original core location shall be confirmed by Engineer, the Quality Assurance agency and the City Inspector;

3.9.12.4.2 The Contractor will then be allowed to re-core for determination of asphalt cement content. The re-coring (which may require multiple cores to obtain the required quantity of materials for a re-test) will be taken from the mat representing the original test within 10 meters on either side of the original test location. Only a single test is required for verification process. All core holes to be filled with hot-mix asphalt, by the contractor, to the satisfaction of the Engineer.

3.9.12.4.3 The asphalt cement content test result from the re-core, along with the original test result, shall be submitted to the City of Edmonton for review. The result from the asphalt cement content test from the re-core will supersede the original QA result**.**

3.9.12.4.4 If the asphalt cement content of the re-core is within the penalty range the penalty will be calculated in accordance with TABLE 02741.3 ASPHALT CEMENT PAY FACTORS for the quantity of asphalt represented by the test. No further re-coring is allowed.

3.9.12.4.5 If the asphalt cement content of the re-core is in the "remove and replace" range, additional cores will be taken at equal distances on either side of the original core and tested for asphalt cement content. This process is to be repeated until locations on either side of the re-core identify asphalt within specification. The spacing is at the discretion of the contractor.

3.9.12.4.6 Once the area of asphalt to be removed and replaced" is identified, the area inclusive of the last core used to delineate the deficient area shall be removed and replaced to the satisfaction of the Engineer.

3.9.13 TSR Tolerance

3.9.13.1 Deficient TSR (Capitol Program): If the TSR result, as determined by ESS, of field samples is below 80.0 percent (for laboratory prepared samples of field mix), the following actions will be taken by ESS:

- First occurrence; the contractor will receive a warning letter from the ESS indicating the deficient TSR value.
- Second consecutive occurrence; In the event of a second consecutive low TSR value below 80.0 percent the contractor will have their production suspended until it can provide acceptable TSR test results to the ESS. During this period of time the Contractor, the Engineer, and ESS will meet to determine the impact of the non-compliance, and specify the necessary remedial action to be taken by the Contractor. Remedial action shall be either acceptance, acceptance at a pay adjustment as detailed in the following table 02742.5, or removal and replacement at no cost to the City. If suspended, the paving program shall only continue upon approval by ESS.

TABLE 02742.5 TSR PAY FACTORS

Percentage of TSR	Pay Factor (%)
80.0 or higher	100.0
78.0 to 79.9	99.0
76.0 to 77.9	97.0
74.0 to 75.9	95.0
72.0 to 73.9	92.0
70.0 to 71.9	89.0
68.0 to 69.9	85.0
66.0 to 67.9	81.0
64.0 to 65.9	76.0
62.0 to 63.9	71.0
60.0 to 61.9	65.0
Less than 59.9	Grind and resurface

3.10 CLEANUP

3.10.1 Leave site clean and free of debris and surplus materials.

3.10.2 Opening to Traffic: Open new SGC hot-mix pavement to traffic when the surface has cooled to ambient temperature or when authorized by the Engineer. Remove barricades and signs when no longer needed.

END OF SECTION

Laboratory SOP 2 Issued November, 1996
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Georgia Department of Transportation
Office of Materials and Testing

Standard Operating Procedure (SOP) 2
Control of Superpave Bituminous Mixture Designs

I. General

Monitoring the quality of Bituminous Mixtures used on Georgia Department of Transportation work is a responsibility of the Bituminous Construction Branch of the Office of Materials and Testing. This branch is under the direction of the State Bituminous Construction Engineer. The Bituminous Construction Branch comprises the Asphalt Design Unit, the Bituminous Control Unit, and the Bituminous Technical Services Unit.

The Asphalt Design Unit performs, verifies, and recommends approval of designs for Superpave mixtures, Open-Graded Friction Course (OGFC), Porous European Mix (PEM) mixtures, Stone Matrix Asphalt (SMA), slurry seals, sand-bituminous bases, micro-surfacing, and other asphalt mixtures as assigned.

The Asphalt Design Engineer oversees design activities statewide, including designs and verifications performed by the Office of Materials and Testing and Branch Laboratories. The Asphalt Design Engineer reviews and recommends approval of designs made in commercial laboratories which have been certified in accordance with SOP 36. Designs submitted by certified laboratories shall be prepared, verified and approved in accordance with this Standard Operating Procedure. The Asphalt Design Engineer forwards acceptable designs to the State Bituminous Construction Engineer with recommendation for approval or approval for provisional use, as appropriate. Once approved, a design shall be published and transmitted to the certified laboratory which performed the design. Designs found to be incorrect or deficient shall be referred back to the designer within two weeks of receipt . Designers may resubmit their designs for approval when appropriate changes or corrections have been made. The State Bituminous Construction Engineer may make field adjustments of the Job Mix formula and may require field verification of mix designs, as discussed below.

II. Approval Process

A. Governing Documents

Commercial laboratories wishing to perform mix designs for use in GDOT projects shall comply with SOP 36, *Certification of Laboratory and Personnel for the Design of Asphaltic Concrete Mixtures.*

All mix designs shall meet current contract specifications and shall be prepared in accordance with applicable standard methods, described below. Mix designs from commercial laboratories shall be approved only for work covered under state funded contracts, and designs for mix types and levels not specified for state work are not eligible for approval.

Aggregates used in Asphaltic Concrete mixes must meet the requirements of Sections 800 and 802 of the Specifications. Asphalt Cement used in the mixture shall meet the requirements of Section 820 for Superpave Asphalt Binder. All designs for publication must meet the requirements of Section 828, "Hot Mix Asphaltic Concrete Mixtures". All ingredients of asphalt mixtures shall be from sources approved by the Department. Approved aggregate sources, except proprietary RAP stockpiles and sand pits, are listed in Qualified Products Lists 1 and 2. Other approved sources are listed in their respective Qualified Products Lists.

Mix designs must be submitted using the GDOT approved mix design software. Completed design studies shall be submitted to the Asphalt Design Engineer by letter request, including the technician's certification required under SOP 36. The letter request should also identify any entity, other than the firm which produced the design, which is authorized to use it. Other required information is as follows:

1. Types and sources of aggregate ingredients
2. Asphalt binder grade and source
3. Gyratory compaction sheets
4. Results of ignition calibration tests, including worksheet and print-out
5. Test results required for the Superpave mix design study
6. RAP stockpile number, if RAP is included
7. Results of permeability test plus sample, as required

Test results for the mix design study shall be entered into the GDOT Mix Design Software and submitted as an Asphaltic Concrete Mix Design Report. Mix designs shall be approved which are correct and complete and which conform to the design criteria set forth in Section 828 of the Specifications.

Approved asphalt mix designs shall be identified by a mix identification number which will identify the designer, aggregate sources, mix type, and design level.

B. Verification of Designs

Mix designs shall be verified by the Office of Materials and Testing at a minimum frequency of ten percent of the designs submitted by each certified laboratory, or at the discretion of the State Bituminous Construction Engineer. These verifications shall be performed by a GDOT laboratory designated by the Asphalt Design Engineer. A verification will consist of replicating all or part of the design test procedures, as the Asphalt Design Engineer may require. Samples shall be tested at the asphalt and air void contents required for certain design tests or at optimum asphalt content, as appropriate. Sufficient quantities of stockpile samples shall be retained for at least two weeks after submittal of a design, or until approval of design is granted, whichever comes first. Results of the verification must match the design results within the tolerances below. In addition, when design volumetrics are verified by gyrating a full set of new samples, the resulting VMA and VFA must also fall within the tolerances specified in Section 828.

Test	Verification Tolerance
G_{mb} - AASHTO T-166	±0.03
G_{se} - AASHTO T-209 and T-308	±0.03
% VTM - AASHTO T-312	4% ± 1.0%
% G_{mm} @ N_{ini} - AASHTO T-312	± 1.0%
% G_{mm} @ N_{des} - AASHTO T-312	± 1.0%
VMA - AASHTO R 35	- 0.5% to +0.8%
VFA - AASHTO R 35	± 5%
Dust/AC Ratio - AASHTO T-312	± 0.2
Gradation:	
Upper Control Sieve - % Passing	± 3.5 %
No. 8 (2.36 mm) Sieve – % Passing	± 2.5 %
No 200 (75 µm) Sieve –% Passing	± 1.6 %
LWT - GDT-115	±2.0 mm, but not to exceed design limit
Retained Tensile Strength - GDT- 66	(average of three) ± 10 % must also meet design minima for strength and % retained
Calibration Factor for ignition tests	± 0.12 %

Where G_{mb} is the bulk specific gravity of the mix, G_{se} is the effective specific gravity of the aggregate, and N_{ini} and N_{des} are the numbers of initial gyrations and design gyrations, respectively. VTM and VMA are the percent air voids and percent voids in the mineral aggregate, respectively, and VFA is percent voids filled with asphalt. LWT refers to the loaded wheel test result using the Asphalt Pavement Analyzer (APA).

In applying the tolerances above for percent of G_{mm} at N_{ini} and percent of G_{mm} at N_{des}, the G_{mm} shall be re-calculated using the G_{se} determined in the verification.

If the verification result does not match the design values within the above tolerances, an investigation shall be initiated by the State Bituminous Construction Engineer. The investigation may include a review of design procedures and equipment calibrations as well as the results of a field verification. If the cause for the discrepancy cannot be resolved, approval of the design may be withdrawn.

C. Field Verification

All mix designs shall be subject to one or more field verifications during production at the discretion of the State Bituminous Construction Engineer. Verification shall consist of replicating certain mix design tests on samples of the mixture delivered to a state project, normally when the design is first used and subsequently in some cases, at the discretion of the State Bituminous Construction Engineer. Field verification tests shall normally include AASHTO T-209, AASHTO T-166, and AASHTO T-312 to verify design volumetrics and may include , GDT 115, GDT-66, and other tests as the State Bituminous Construction Engineer may require. A field verification shall be acceptable when results fall within the tolerances in the table below. Designs which fail field verification shall be invalid unless an approved revision is made to correct the deficiency, or unless it is shown that the production sample was deficient and that the deficiency has been corrected.

Test	Field Verification Tolerance
G_{mb} - AASHTO T-166	± 0.03
G_{se} - AASHTO T-209 (and GDT-125)	±0.03
GDT-66	not to exceed specified design limits
Design Volumetrics - AASHTO R 35:	
VMA	not to exceed specified design limits
VTM (air voids) @ optimum AC	not to exceed specified design limits

D. Continuity and Cancellation of Mix Designs

An approved and field verified mix design may be used from project to project as long as the design meets current specifications, provided that satisfactory performance of the mixture is obtained, that the properties of the mixture remain consistent with the design values, and that no significant change occurs in the properties or approval status of the ingredients. The State Bituminous Construction Engineer may withdraw approval of a mix design on the basis of unsatisfactory or erratic test results, poor performance of the mixture in place, or evidence that the properties of the mixture differ substantially from the properties predicted in the design. In the case of RAP mixtures, approval will be withdrawn if the RAP stockpile is depleted or if the average gradation of the RAP, based on five random samples, varies to the extent that the combined gradation of the design is altered by more than one-half the mixture control tolerance.

E. Ownership, Use, and Disclosure of Mix Designs

Mix designs shall be made available only to the designer and to users authorized by the designer. Mix designs are considered to be proprietary information. They are not subject to public disclosure under the Georgia Open Records Act by virtue of O.C.G.A. 50-18-72(b)(1), which protects the confidentiality of trade secrets obtained from a business entity that are confidential and required to be submitted to a government agency.

III. Design Process

The object of an Asphaltic Concrete Design is to produce a combination of the proposed ingredients that will perform satisfactorily throughout the design life of the pavement. Such a mixture must contain sufficient asphalt cement to provide a thick film and limited air voids so the mix can resist stripping and weathering due to intrusion of water and air. The mix must also be stable enough to resist permanent deformation, flushing, excessive densification, and loss of friction properties. The volumetric design process is complicated by the facts that asphalt is thermoplastic and that specific elevated temperatures must be maintained in the design work. Superpave Mixtures are to be designed in accordance with AASHTO R 35 except as altered by Georgia Department of Transportation's specifications including but not limited to SOPs, GDTs and GSPs. ,Many design details are difficult to remember; therefore a ready reference entitled "Asphalt Hot Mix Design Reference Guide" can be found in Appendix A.

A. Sampling and Grading

Sampling of aggregates proposed for use in bituminous mix designs may be initiated by the Contractor, commercial laboratory, or materials supplier. The requesting party should submit the samples to the design laboratory. Materials sampled for design work must be representative of quarry production intended for use on the project. The average ingredient characteristics should be represented in the design. The designer shall resolve any discrepancies in the ingredient properties before beginning any design work.

Each aggregate sample submitted for design is initially dried, and sieve analysis is performed to determine its gradation. Grading of coarse aggregate samples is done using the appropriate sieves for the specific mix type involved. These sieve sizes can be found in Section 828 of the Specifications. In addition, appropriate "breaker" sieves must be used to prevent overloading the sieves. Each ingredient shall be batched individually. Bulk batching of aggregates is prohibited.

Aggregate used for batching Superpave specimens is not separated below the No. 8 (2.36 mm) sieve, with the exception that a washed gradation is performed on minus 2.36 mm portion by washing over the No 200 (75 μm) sieve.

If the coarse or fine aggregate is excessively dusty, soft, easily broken, or shows other signs of potential problems, the Asphalt Design Engineer should be consulted for investigation of the source, stockpiles, and operations. The Revised decision in such matters will rest with the State Materials and Research Engineer.

Once the appropriate blend, meeting requirements established in Section 828 and Appendix B, has been established, batches of Superpave design specimens to determine optimum asphalt content shall be prepared to produce a compacted Superpave specimen 115.0 ± 5.0 mm high and 150 mm in diameter for density testing. The height of test samples should be 95.0 ± 5.0 mm for tensile splitting specimens and 75.0 ± 1.0 mm for loaded wheel test specimens. Designers should ensure that all samples, including those for gradation and specific gravities, will meet the minimum sample size requirements for their respective tests.

B. Preparing Superpave Specimens

1. Asphalt Cement

   Samples shall be heated to the appropriate temperature for the asphalt binder being used. Temperatures for preparing Superpave specimens are based on the viscosity of the asphalt cement involved. These values are very important; they can be found in the Asphalt Mixture Control Temperature Chart which is available from the Asphalt Design Engineer.

2. Short term Aging

   The short term aging procedure applies to laboratory-prepared loose mix only. The laboratory aging process is necessary to simulate mixture aging during typical plant production and placement. All samples for testing shall be aged by placing the mixture in a pan and spreading it to an even thickness of approximately 55 ± 5 lbs/yd^2 (30 ± 2 kg/m^2) immediately after sample mixing. Place the mixture and pan in a forced draft oven for 2 hours at compaction temperature.

C. Superpave Gyratory Compactor

A gyratory compactor meeting the requirements of AASHTO T-312 shall be used to compact density specimens for testing. The gyratory compactor may also be used for preparing samples for performance testing as detailed in Section 828. The gyratory compactor shall be calibrated and the operation of the data acquisition device shall be checked based on the interval established in AASHTO R18. The compaction pressure should be checked and set to the proper value; 600 ± 18 kPa, and the rate of revolution should be set at 30 gyrations per minute. The internal angle is to be set at 1.16 ±

0.02 degrees. It is recommended that the calibration be done for the internal angle using the Dynamic Angle Validator (DAV) if different brands or models of the gyratory compactor are being used.

Samples shall be gyrated to the number specified for the N_{des} level required in Section 828.

D. Testing Superpave Specimens

All testing shall be in accordance with the appropriate AASHTO or GDT procedure, as follows:

Test	Test Method
Volumetric Properties	**AASHTO T-312,** "Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of Superpave Gyratory Compactor" AASHTO R 35, "Superpave Volumetric Design for Hot Mix Asphalt (HMA)
Bulk Density	**AASHTO T-166,** "Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens"
Short Term Aging	**AASHTO R-30,** "Mixture Conditioning of Hot Mix Asphalt (HMA)" Note: The procedure is modified for GDOT mix designs to require only two hours aging.
Maximum Density and Effective gravity	**AASHTO T-209** "Maximum Specific Gravity of Bituminous Paving Mixtures"
Aggregate Gravities	**AASHTO T-84** "Specific Gravity and Absorption of Fine Aggregate" and **AASHTO T-85,** "Specific Gravity and absorption of Coarse Aggregate" (The designer may obtain coarse aggregate gravities from GDOT or perform this test.)
Moisture Susceptibility	**GDT-66** "Method of Test for Evaluating the Moisture Susceptibility of Bituminous Mixtures by Diametral Tensile Splitting"
Rutting Susceptibility	**GDT-115** "Determining Rutting Susceptibility of Asphalt Paving Mixtures Using the Asphalt Pavement Analyzer (APA)"
Permeability	**GDT-1** Measurement of Water Permeability of Compacted Paving Mixtures

Use the design calculations as outlined in AASHTO R 35 and T-312. However, replace G_{sb} with G_{se} when calculating VMA. When designing a Superpave mix containing RAP materials, the effective specific gravity (G_{se}) of the RAP shall be used in place of the bulk specific gravity (G_{sb}) in determining the combined aggregate bulk specific gravity for the blend. A method of calculating batch weights for RAP mixes is presented in Appendix C. Additionally, when designing Superpave mixtures containing RAP and/or RAS; a Corrected Optimum AC Content (COAC) is to be calculated and used as detailed in Appendix D.

E. Moisture Susceptibility

Moisture susceptibility will be determined by the tensile splitting method according to GDT 66. For these tests, the specimens will be fabricated at optimum asphalt cement content. All mixtures containing RAP and/or RAS; will be fabricated at the corrected optimum asphalt cement content **(COAC)**. The compactive effort for the specimens is to be reduced such that the air voids fall in a range required in Section 828. Specimens prepared for this test will include hydrated lime, or anti-stripping additive, or both, as specified for the ingredients proposed. For gyratory specimens that fail moisture susceptibility, Marshall specimens (4 inch) may be substituted.

F. Rutting Susceptibility Testing

Results of tests with the Asphalt Pavement Analyzer shall be provided for all Superpave mixtures. The rutting susceptibility test will be conducted according to GDT-115. For these tests, the specimens will be fabricated at optimum asphalt cement content. All mixtures containing RAP and/or RAS; shall be fabricated at the corrected optimum asphalt cement content **(COAC)**. Three beam specimens or six gyratory specimens should be tested for each mix design. If the average rut depth for the three specimens exceeds specified limits, the asphaltic concrete mixture shall not be used in the work. The compactive effort for the specimens is reduced such that the air voids fall in a range required in Section 828. Test temperature for this test shall be 149 °F (64 °C), except for 19 mm and 25 mm Superpave mixes, for which it shall be 120 °F (49 °C).

G. Fatigue Testing

The Office of Materials and Testing may conduct a fatigue test on any Superpave asphalt mixture design or Superpave asphalt mixture used in construction to determine acceptability of the materials. The test shall be performed according to test procedure AASHTO T 321, or other procedure approved by the Office of Materials and Testing. All mixtures containing RAP and/or RAS; shall be fabricated at the corrected optimum asphalt cement content **(COAC)**.

H. Calibration Factor for Ignition Test

The designer shall, as part of the design process, perform calibration tests for use when testing the mixture in the ignition furnace, according to GDT 125. All results, including the worksheet and the print-out from the ignition furnace, shall be submitted with the design study and request for approval. All mixtures containing RAP and/or RAS shall be fabricated at the corrected optimum asphalt cement content (COAC).

Verification. The approved calibration factor shall remain in use unless, in the judgment of the State Bituminous Construction Engineer, the accuracy of the testing technique, calibration, or apparatus is found to be invalid or unreliable.

The contractor shall provide samples of the mix ingredients to the Department for verification of the CF on request. On receiving evidence that invalid or unreliable test results have been obtained, the State Bituminous Construction Engineer may suspend use of the ignition test on the mixture being produced until a correct calibration is obtained and until all other discrepancies involving calibration, apparatus and technique have been resolved. Where an incorrect CF has been applied in acceptance testing, results shall be corrected by applying a valid CF.

When a Job Mix Formula is submitted for approval prior to beginning production, the calibration factor of the mixture shall be included in the submittal. (This shall apply in all cases, regardless of the test method to be used for quality control testing.)

IV. Changes in Established Design Procedures, Criteria, or Mix Requirements

Changes in established procedures, criteria, and mix requirements are the prerogative of the State Materials and Research Engineer. Specifications, procedures, and other changes may apply to all bituminous mixtures, or only to a particular mixture. Any certified laboratory designing mixes for use in GDOT work will be placed on a list to receive information on revisions pertaining to bituminous mix design specifications and procedures.

V. Revisions of Approved Designs

Generally, when a particular ingredient of a mix design becomes unavailable, the contractor must provide a different design in order to continue work on a project. While the contractor is always responsible for the supply of materials, it is recognized that certain aggregate sizes may become unavailable due to unforeseeable causes. Often this interrupts paving work in progress, causing inconvenience to the public. In some instances, it may be possible to substitute one coarse aggregate ingredient for a similar material from a different source without affecting the quality of the mixture. In these cases only, the laboratory which designed the mix may submit a design revision for consideration. Design revisions will be subject to the following conditions:

A. Actual Shortage Required

The revision must be necessitated by an actual shortage, sufficient to delay work in progress, of a coarse aggregate ingredient of an approved design.

B. Similar Substitute Ingredient

The substitute ingredient must be similar to the replaced ingredient in mineralogy, particle size and shape, specific gravity, and abrasion resistance.

C. Revised Design Support Requirements

The proposed revised design shall be supported by volumetric tests on a minimum of two pairs of specimens, at asphalt content checkpoints above and below the optimum asphalt content of the original design. The State Bituminous Construction Engineer may require verification of previous tests for susceptibility to rutting, fatigue, and moisture when these properties of the design are marginal.

State Materials Engineer

Director of Construction

Appendix A

Hot Mix Asphalt Design Reference Guide

(Note: Preparation and Testing requires the use of metric units only)

Sequence No.	Description
1	Dry incoming aggregate as described in AASHTO: T 27-93.
2	Grade aggregates as described in AASHTO: T 27-93. Use Gilson shaker and shake at least 10 minutes.
3	Calculate gradation of each aggregate type. Carry calculations to the nearest 0.1%. Compare to source average values and consider plant breakdown.
4	Calculate blend, keeping within control limits. Use AASHTO R 35 as a reference.
5	Batch aggregates as described in AASHTO 312 and AASHTO R 35. The design specimens must be 115 ± 5 mm high (95 mm for moisture susceptibility and 75 mm for LWT). Thoroughly mix the minus 2.36 mm aggregate during batching. Sample weights for AASHTO T-209 (maximum theoretical specific gravity) and gradation must be 2000 grams, except samples for 25 mm mixtures, which shall weigh at least 2500 g.
6	Heat the pans of aggregate to temperature specified on Mixing and Compaction Temperature Control Chart for the source of asphalt cement being used.
7	Heat the asphalt cement to temperature specified on Mixing and Compaction Temperature Control Chart for the source of asphalt cement being used. Heat only a half day's run. Never overheat or reheat AC.
8	Add and mix RAP material, if required, with the hot aggregates. Mix only until the RAP material is blended with the aggregate.
9	Add and mix hydrated lime. Add 1.0% by weight of the aggregate for virgin mixes or as calculated in Appendix C for RAP mixes. Add hydrated lime to the heated aggregate and mix until the aggregate is coated with lime.
10	Mix the heated AC and aggregate in a preheated bowl. The temperature at the time of mixing is very important. Care should be exercised to thoroughly coat the aggregate with AC.
11	When sample has been thoroughly mixed, place the mixture in a pan and spread it uniformly to approximately55 ± 5 lbs/yd^2 (30 ± 2 kg/m^2). Place the mixture and pan in a forced draft oven for 2 hours at the upper limit of the compaction temperature range. All samples for testing (with the exception of moisture susceptibility samples) shall be aged.
12	At least 30 minutes before compaction of the first specimen, place the compaction molds and base plates in an oven at compaction temperature.
13	At the end of the aging process, remove a mold and base plate from the oven. Assemble base plate and mold. Place a paper disk on top of the base plate. Place the aged mixture in the mold (do not spade). Be extremely careful to keep segregation to a minimum when transferring the sample to the heated mold. Place a paper disk on top of the sample.
14	Compact specimen using the Superpave Gyratory Compactor in accordance with AASHTO 312.
15	Remove the mold containing the compacted specimen from the compactor and extrude the specimen from the mold. A short cooling period is allowable to facilitate specimen removal to minimize sample damage. Remove the paper disks from the top and bottom of the specimen. Place the specimen on a flat, well supported surface where it will not be disturbed during cooling. A fan can be used to accelerate cooling, if necessary. Repeat this procedure for each specimen.
16	Determine G_{mb} in accordance with AASHTO T-166. Use balance accurate to 1.0 g. Be sure the water is clean and at correct temperature. Beware of specimens that release excessive bubbles when submerged. Such samples may prove misleading density values. Be sure the basket and suspension wire do not contact anything.

Appendix B

Ensure that Superpave Asphalt Concrete Mixtures Designs meet the following mix design limits:

Sieve Size	Design Gradation Limits, Percent Passing				
	9.5 mm Superpave Type I	9.5 mm Superpave Type II	12.5 mm Superpave	19 mm Superpave	25 mm Superpave
1½ in (37.5 mm)					100*
1- in (25.0 mm)			100*	100*	90-100
3/4 in (19.0 mm)	100*	100*	98-100****	90-100	55-89** (85 – 89)[1]
1/2 in (12.5 mm)	98-100****	98-100****	90-100	60-89*** (85 – 89)[1]	50-70
3/8 in (9.5 mm)	90-100	90-100	70-89 (85 – 89)[1]	55-75	
No. 4 (4.75 mm) s	65-85	55-75			
No. 8 (2.36 mm)	48-55	42-47	38-46 (42 – 45)[1]	32-36 (33 – 35)[1]	30-36 (33 – 35)[1]
No. 200 (75 μm)	5.0-7.0 (5.5 – 6.5)[1]	5.0-7.0 (5.5 – 6.5)[1]	4.5-7.0 (5.0 – 6.0)[1]	4.0-6.0 (4.5 – 5.2)[1]	3.5-6.0 (4.5 – 5.2)[1]
Range for % AC (Note 4)	5.4-7.25	5.25-7.00	5.00-6.25	4.25-5.50	4.00-5.25

Note 1 details the desired Mix Design combined gradation for each referenced sieve

Appendix C

Method of Calculating Batch Weights for Mix Designs With Recycled Asphalt

PURPOSE: To calculate the weights of reclaimed asphalt pavement (RAP), virgin aggregate, and liquid asphalt cement (AC) for preparing volumetric samples of asphalt mixtures.

Example calculations are for an aggregate batch weight of 4800 g. Assume mix will contain 30% RAP and RAP contains 6.3% AC by extraction. For this example, assume one point of the design will use 5.5% total AC.

1. Total weight of mix = $\frac{\text{Agg. Wt.}}{100 - \%\ AC}$

   Example: $\frac{4800g}{100\% - 5.5\%} = 5079g$

2. Grams of RAP to batch = (Total Wt of mix)(% RAP)

   Example: (5079)(30%) = 1524 grams RAP

3. (2)(% AC in RAP) = Grams of old AC from RAP

   Example: (1524 grams)(6.4%) = 97.5 grams old AC

4. (1) – Agg. Wt. – (3) = Grams of new AC to add

   Example: 5079 – 4800 –97.5 = 181.5 grams of new AC to add

5. (2) – (3) = Grams of aggregate in RAP

   Example: 1524 – 97.5 = 1426.5 grams

6. % Aggregate contributed by RAP = $\frac{(5)}{\text{Agg. Batch}}$

   Example: $\frac{1426.5}{4800}$ = 29.7% total aggregate from RAP

7. % lime in mix = [100% - (6)][1.0 %] + [(6)][0.5%]

   Example: (1.0%)(100% – 29.7%) + (0.5%)(29.7%) = 0.9 % Lime

   NOTE: This step assumes 50% of RAP will have fractured faces which need to be treated with hydrated lime.

Standard Operating Procedure (SOP) 2

8. % Aggregate available for other sizes = 100 – (6) – (7)

   Example: 100 – 29.7 – 0.9 = 69.4% available for virgin aggregate

9. Calculate Blend

   Example: For this example, assume the following blend will be used:

   29.7% - RAP aggregate
   20.0% - 89 stone
   25.0% - 810 screenings
   24.4% - 777 (manufactured sand)
   0.9% - hydrated lime
   100% - Total aggregate

10. Calculate Batch Weights

    Batch wt. of virgin agg. = agg. batch wt. times % of blend

RAP	= (2)	= 1524 grams	
#89	= 4800 X 20%	= 960	
#810	= 4800 X 25%	= 1200	
#777	= 4800 X 24.4%	= 1171	
Lime	= 4800 X 0.9%	= 43	
New AC (for 5.5%)	= (4)	= 181.5	
Total Wt.		= 5,079.5 grams	(Differs from (1) above due to round-off error.)

NOTE: As the total weight for each point of the design changes (Step 1), the grams of RAP to batch up in Step 2 will also change slightly, as will the available aggregate in Step 8. Therefore, use the AC content nearest the anticipated optimum (usually the third point of the design) as the value to use in Step 1 and on which the blend percentages and batch weights are to be calculated.

Steps 1 through 4 should be repeated for each point in the design to determine the amount of new AC.

NOTE: Use the extracted gradation (or gradation after burning in the ignition oven) of the RAP to calculate the mix blends; use the gradation of the RAP "as is" (from the Gilson shaker) to determine individual sizes for the batch weight. (See pages 1 and 3 of the design software.)

Appendix D

Method of Calculating Credited Asphalt Cement Content for Corrected Optimum AC Content for Asphaltic Concrete Mixtures Incorporating Reclaimed Asphalt Pavement (RAP) or Post-Consumer Recycled Asphalt Shingles (RAS)

Purpose: To calculate the Credited AC Content (**CAC**) and Not Credited AC Content (**NCAC**) to be used to determine the Corrected Optimum AC Content **COAC** of Asphaltic Concrete Mixtures incorporating RAP and/or Recycled Asphalt Shingles (RAS) for all mixtures. The **CAC** and **NCAC** shall be used to determine the amount of additional new AC required to be added to an Asphaltic Concrete Mix Design's Original Optimum AC Content (**OOAC** as determined in AASHTO R 35-09 Section 10.5 at VTM = 4.0% air voids. **OOAC must meet the requirements of Section 828.2.03.A.** The **CAC** and **NCAC** shall be calculated using an applied factor as follows: **CAC** shall be calculated using a factor of 0.75 while the **NCAC** is equivalent to 0.25 where 1.0 – 0.75 equals 0.25.

The **COAC,** as determined using this procedure, shall be used in fabricating samples for all performance tests established in Section 828.2.B.2. Additionally, the **COAC** is to be listed on the Mix Design Summary Sheet **(as a note)** and used for JMF purposes.

Example calculations detailed are for a 12.5 mm Superpave Mix Type. Assume mix will contain 25% RAP and RAP contains 5.75% AC (RAP Stockpile Specific) determined using GDT-83 or GDT-125. For this example, assume the **OOAC**, as determined in AASHTO R 35-09 Section 10.5 is 5.10% total AC.

12.5 mm Superpave Mix with 5.10% **OOAC** (AASHTO R 35-09 Section 10.5 @ VTM 4% Air Voids). RAP = 25 % with 5.75% AC in RAP

1. Using Standard Mix Design Procedure RAP contributes 5.75 % x 0.25 = 1.44 % AC to the blended total AC of mix
2. Using factor to calculate **CAC** = 1.44 % x 0.75 = 1.08% AC
3. Using factor to calculate **NCAC** = 1.44 % - 1.08 % = 0.36 % AC
4. Add the 0.36 % **NCAC** to 5.10 % **OOAC** = 5.46 %
5. The **COAC** = 5.46 %
6. 5.46 % **COAC** shall be used for specimen fabrication for all performance test required in Section 828.2.B.2
7. **COAC** of 5.46 % will be listed as Corrected Optimum on Mix Design Summary Sheet as a note at the bottom.

Note: All Required Performance Test as specified in Section 828.2.B.2 shall be conducted at the Corrected Optimum AC Content (COAC). Mix Design Summary Sheet will list the COAC as the Corrected Optimum AC Content.

Revised: September 19, 2011
Revised: October 23, 2012

DEPARTMENT OF TRANSPORTATION
STATE OF GEORGIA

SPECIAL PROVISION

Section 410—Warm Mix Asphaltic Concrete Construction

410.1 General Description

This work includes constructing one or more courses of plant produced Warm Mix Asphaltic Concrete on the prepared foundation or existing roadway surface. The mixture shall conform to the lines, grades, thicknesses, typical sections and cross sections shown on the Plans or established by the Engineer.

This section includes the requirements for all warm mix asphaltic concrete mixtures regardless of the gradation of the aggregates, type and amount of bituminous material, or pavement use. Follow the requirements in Section 400 and Section 402 for production and placement, materials, equipment, and acceptance plans except as noted or modified in this Specification.

Work will be accepted on a lot-to-lot basis according to the requirements of this Section, Section 400 and Section 106.

410.1.01 Definitions

Warm Mix Asphalt: a term used to describe the lower production, placement and compaction temperatures required in conjunction with the application of one of several approved warm mix asphalt technologies.

General Provisions 101 through 150

410.1.02 Related References

A. Standard Specifications

Section 400—Hot Mix Asphaltic Concrete Construction

Section 402—Hot Mix Recycled Asphaltic Concrete

B. Referenced Documents

SOP 40

SOP 43

QPL 89

410.1.03 Submittals

Add the following in addition to the requirements established in Section 400 and Section 402:

A. Paving Plan

Before starting warm mix asphaltic concrete construction, submit a written paving plan to the Engineer for approval. Include the following in the paving plan:

- Proposed starting date and location of test section, when required
- Type of warm mix asphaltic concrete technology to be used.
- Location of plant(s)
- Rate and temperature of warm mix production
- Average haul distance(s)
- Number of haul trucks
- Paver speed feet (meter)/minute for each placement operation
- Mat width for each placement operation
- Number and type of rollers for each placement operation

- Sketch of the typical section showing the paving sequence for each placement operation
- Electronic controls used for each placement operation
- Temporary pavement marking plan

If staged construction is designated in the Plans or contract, provide a paving plan for each construction stage.

If segregation is detected, submit a written plan of measures and actions to prevent segregation. Work will not continue until the plan is submitted to and approved by the Department.

B. Job Mix Formula

After the Contract has been awarded, submit to the Engineer a written job mix formula proposed for each mixture type to be used based on an approved mix design. Furnish the following information for each mix:

- Specific project for which the mixture will be used
- Source and description of the materials to be used
- Mixture I.D. Number
- Proportions of the raw materials to be combined in the paving mixture
    - Include proportion of Warm Mix Asphaltic Concrete Additive blended with asphalt cement
- Single percentage of the combined mineral aggregates passing each specified sieve
- Single percentage of asphalt by weight of the total mix to be incorporated in the completed mixture
- Single temperature at which to discharge the mixture from the plant
- Theoretical specific gravity of the mixture at the designated asphalt content
- Name of the person or agency responsible for quality control of the mixture during production

Do the following to have the formulas approved in accordance with SOP 40 "Approval of Contractor Job Mix Formulas" and to ensure quality:

1. Submit proposed job mix formulas for review at least two weeks before beginning the mixing operations.
2. Do not start warm mix asphaltic concrete work until the Engineer has approved a job mix formula for the mixture to be used. No mixture will be accepted until the Engineer has given approval.
3. Provide mix designs for all Superpave and 4.75 mm mixes to be used. The Department will provide mix design results for other mixes to be used.
4. After a job mix formula has been approved, assume responsibility for the quality control of the mixtures supplied to the Department according to Subsection 106.01, "Source of Supply and Quantity of Materials."

C. Quality Control Program

Submit a Quality Control Plan to the Office of Materials for approval. The Quality Control Program will be included as part of the certification in the annual plant inspection report.

410.2 Materials

Follow requirements established in Section 400and Section 402 for production and placement, materials, equipment, acceptance plans and adjustments except as noted or modified in this Specification.

Produce Warm Mix Asphaltic Concrete in an asphalt plant equipped with an approved water injection foaming system - documented on QPL 45 or use an approved terminally blended chemical additive listed on QPL 89. Either approved method must provide mix production temperatures that are at least 30 F° less than the JMF temperature in the Asphalt Cement Mixture Control Temperature Chart for PG Binder published by the Office of Materials.

Ensure materials comply with the specifications listed in Section 400.2 Table 1.

410.3 Construction Requirements

Follow requirements established in Section 400and Section 402 for production and placement, materials, equipment, acceptance plans and adjustments except as noted or modified in this Specification.

410.3. 01 Personnel

General Provisions 101 through 150.

410.3.02 Equipment

Asphaltic concrete plants - producing mix for Department use are governed by Quality Assurance for Hot Mix Asphaltic Concrete Plants in Georgia, Laboratory Standard Operating Procedure No. 27.

Add the following in addition to the equipment requirements established in Section 400 and Section 402:

A. Additional Requirements for Observing Composition of Warm Mix Asphaltic Concrete Mixtures

1. Modification of plant equipment

   Modify the asphalt plant as required by the manufacturer to introduce the warm mix asphaltic concrete technology.

   Modifications may include:

   a. Approved asphalt binder water injection foaming systems.
      - Ensure any additive other than potable water is approved prior to use in the water injection system.
      - Ensure the water injection equipment is tied into the computer in the asphalt plant control room so the metering of the injected water can be continuously monitored by the plant operator.
      - Ensure the injection system is interlocked so variable water injection is automatically controlled by the plant production rate. Do not allow the water injection system to exceed 2.0% water by weight of asphalt cement for normal production rates. When approved by the Office of Materials, the water injection system may be increased to a maximum of 2.5% water by weight of asphalt cement for Warm Mix Asphaltic Concrete production rates $\leq$ 150 tons per hour or when producing approved Warm Mix Asphaltic Concrete mixes containing > 30 % RAP or as recommended by the water injection systems' manufacturer.
      - Ensure the water injection rate cannot be manually overridden by the plant operator once established and approved in the plant's computer.
      - Ensure the water injection system is interlocked with the plant controls to interrupt mixture when a control or equipment failure in the injection system occurs.
      - Ensure the water injects into the asphalt cement flow before the asphalt cement makes contact with the aggregate in the drum. Do not allow water to mix with the aggregate prior to the asphalt cement spray.
      - Ensure the water injection equipment includes water storage and a pump control interlocked with the injection computer controls.
      - Ensure the water flow alarm is installed in the plant control room to alert a shortage in the water storage tank or any other disruption in the water flow equipment.
      - Provide an asphalt cement sampling valve at the water injection equipment to sample the asphalt cement prior to the spray system.

   b. Additional AC tank for approved terminally blended additive modified asphalt cement.
      - Ensure the approved warm mix asphaltic concrete additive has been pre-blended at the asphalt terminal and is documented on the Bill of Lading (BOL) coming from the approved asphalt supplier. Ensure the percent of approved warm mix asphaltic concrete additive added to the asphalt cement is printed on the BOL. The warm mix asphalt concrete additive modified asphalt cement shall be stored in a separate AC tank without any cross contamination from pre-existing virgin asphalt cement.

410.3.05 Construction

Follow requirements established in Section 400 and Section 402 for production and placement, materials, equipment, - acceptance plans and adjustments except as noted or modified in this Specification.

1. **Additional Requirements for Mixture control of warm mix asphaltic concrete**

   Compose warm mix asphaltic concrete from a uniform mixture of aggregates, bituminous material, and if required, hydrated lime, mineral filler, or other approved additive.

   Make the constituents proportional to produce mixtures meeting the requirements in Section 828. The general composition limits prescribed are extreme ranges within which the job mix formula must be established. Base mixtures on a design analysis meeting the requirements in Section 828. Specific mix designs incorporating warm mix asphaltic concrete terminally blended additives are required for each mix type. Include the dosage rate of approved terminally blended Warm Mix Asphaltic Concrete additive in proportion to the asphalt cement in each mix design. When producing warm mix asphaltic concrete using an approved water injection foaming system at the asphalt plant, standard approved mix designs may be used.

When producing warm mix asphaltic concrete:

- Use an approved water injection foaming system at the asphalt plant documented on QPL 45 "Georgia's List of Approved Hot Mix Asphalt Plants"
- Use an approved terminal blended warm mix asphaltic concrete additive listed on QPL 89 "Approved Warm Mix Asphaltic Concrete Additives"

Other warm mix asphaltic concrete terminally blended additives and unapproved water injection foaming systems may be approved for use on a project basis under the following conditions:

- Prior to commencement of the work, construct a 500 ton test section for evaluation for compliance with all specified requirements established in this Section, Section 400and Section 828.
- Work shall be halted and the contractor shall submit a written plan of action detailing what steps will be taken to meet specifications if any of these requirements are not met in the test section. If approved by the Engineer, the contractor will construct another 500 ton test section. The contractor shall not be allowed to start continual mix placement until an acceptable test section including mix design verification of the plant produced mix is obtained. For non-let Warm Mix Asphaltic Concrete projects, the contractor may elect to continue mix placement using conventional Hot Mix Asphaltic Concrete while the test section mix design verification is being conducted.
- The Department shall have ten (10) business days to complete the mix design verification of plant produced mix. Once the Department's mix design verification of plant produced mix has been completed and the test section has been approved by the Engineer, placement of the warm mix asphaltic concrete may continue provided all specified requirements are maintained.

Ensure during mixture placement, the material conforms to the requirements established in Section 400.3.05.F.

Ensure the field performance of the in-place mixtures meet the requirements of Section 828.2.B for Permeability, Moisture Susceptibility, Rutting Susceptibility and Fatigue. In-place mix may be evaluated for compliance with Subsection 828.2.B at the discretion of the State Bituminous Construction Engineer under the following conditions:

- Deviates greater than 10 percent on gradation for mixture control sieves from the approved Job Mix Formula based on Acceptance or Independent Samples.
- Deviates greater than 0.7 percent in asphalt cement content from the approved Job Mix Formula based on Acceptance or Independent Samples.
- The calculated mean pavement air voids result in an adjusted pay factor less than 0.80 or any single sub lot result in mean pavement air voids exceeding 10.5 percent.

Remove and replace any material determined to not meet the requirements established in Section 828.2.B at the Contractor's expense. Mix produced not using an approved mix design and job mix formula is subject to removal and replacement at the contractor's expensed upon the recommendation of the Office of Materials.

If control test results show the characteristic tested do not conform to the job mix formula control tolerances given in Section 828, take immediate action to ensure the quality control methods are effective.

Control the materials to ensure extreme variations do not occur. Maintain the gradation within the composition limits in Section 828.

410.3.06 Quality Acceptance

A. Additional Acceptance Plans for Gradation and Asphalt Cement Content for Warm Mix Asphaltic Concrete

Add the following in addition to the requirements established in Section 400and Section 402:

1. For approved water injection foaming systems, two weeks prior to starting production, provide a quality control plan documenting the manufacturer's recommended water injection target rate for the foaming system which includes acceptable variations for production using their system. The quality control plan shall include a target mixture production temperature for the asphalt plant meeting the specified production temperature that is at least 30 F° less than the JMF temperature in the Asphalt Cement Mixture Control Temperature Chart for PG Binder published by the Office of Materials.
2. For approved warm mix asphaltic concrete terminally blended additives, two weeks prior to starting production, provide a quality control plan documenting the manufacturer's recommendation for mixture production using their additive. The quality control plan shall include a target mixture production temperature for the asphalt plant meeting

the specified production temperature that is at least 30 F° less than the JMF temperature in the Asphalt Cement Mixture Control Temperature Chart for PG Binder published by the Office of Materials.

B. Additional Sampling, Testing, and Inspection Requirements for Warm Mix Asphaltic Concrete.

1. In addition to all standard sampling, testing and inspection requirements established in Section 400, Section 402 and Section 828, the following requirements are also established:
   - Provide fabricated samples for testing in accordance with GDT 66 during the first day of mixture production and then at least once every 5 days or 5 Lots thereafter. These samples are to be fabricated during mixture production and not from reheated material. The samples fabricated by the Contractor are to be submitted to the District laboratory for testing. A new approved mix design will be required for any warm mix asphaltic concrete failing to meet the requirements established in Section 828.
   - Ensure laboratory compaction temperature ranges are included in the quality control plan and are used when formulating samples for mixture testing.
   - Ensure all mixture samples obtained for material acceptance for asphalt cement content are dried to constant weight prior to performing GDT 125.

410.3.07 Contractor Warranty and Maintenance

Follow requirements established in Section 400and Section 402 for production and placement, materials, equipment, acceptance plans and adjustments except as noted or modified in this Specification.

410.4 Measurement

Follow requirements established in Section 400and Section 402 for production and placement, materials, equipment, acceptance plans and adjustments except as noted or modified in this Specification.

410.5 Payment

Warm mix asphaltic concrete of the various types is paid for at the Contract Unit Price per ton (megagram) or per square yard (meter). Payment is full compensation for furnishing and placing materials including asphalt cement, hydrated lime when required, approved additives, and for cleaning and repairing, preparing surfaces, hauling, mixing, spreading, rolling, and performing other operations to complete the Contract Item.

Payment will be made under:

Item No. 410	Warm Mix asphaltic concrete _________mm Recycled Superpave, group-blend, including bituminous materials and hydrated lime	Per ton (megagram)
Item No. 410	Warm Mix asphaltic concrete ___ mm Recycled Superpave, group-blend, including polymer-modified bituminous materials and hydrated lime	Per ton (megagram)
Item No. 410	Warm Mix asphaltic concrete _________mm Recycled Superpave, Type__, group-blend, including bituminous materials and hydrated lime	Per ton (megagram)
Item No. 410	Warm Mix asphaltic concrete _________mm Recycled mix, group-blend, including bituminous materials and hydrated lime	Per ton (megagram)
Item No. 410	Recycled Warm Mix asphaltic concrete patching including bituminous materials and hydrated lime	Per ton (megagram)
Item No. 410	Recycled Warm Mix asphaltic concrete leveling including bituminous materials and hydrated lime	Per ton (megagram)

410.5.01 Adjustments

A. **Follow** requirements established in Section 400 for production and placement, materials, equipment, acceptance plans and adjustments except as noted or modified in this Specification.

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Revised: November 16, 2012
Revised: June 25, 2013

DEPARTMENT OF TRANSPORTATION
STATE OF GEORGIA

SPECIAL PROVISION

Section 828—Hot Mix Asphaltic Concrete Mixtures

Delete Section 828 and substitute the following:

828.1 General Description

This specification includes the requirements for hot mix asphaltic concrete mixtures, including:

- Open-graded surface mixtures (OGFC and PEM)
- Stone Matrix Asphalt mixtures (SMA)
- Superpave mixtures
- Fine-graded (4.75 mm) mixtures

828.1.01 Definitions

The Nominal Maximum Sieve Size is one standard sieve size larger than the first sieve to retain more than ten percent of the aggregate, per AASHTO R35. Mixture types in this section are identified according to Nominal Maximum Sieve Size.

828.1.02 Related References

A. Standard Specifications

Section 400-Hot Mix Asphaltic Concrete Construction

Section 800–Coarse Aggregate

Section 802–Aggregates for Asphaltic Concrete

Section 819–Fiber Stabilizing Additives

Section 820–Asphalt Cement

Section 831–Admixtures

Section 882–Lime

Section 883–Mineral Filler

B. Referenced Documents

AASHTO R30

AASHTO R35

AASHTO T 321

AASHTO T 112

AASHTO T 209

AASHTO T 305

AASHTO T 312

AASHTO T 245

AASHTO T 340

SOP-36

SOP-2

GDT 1

GDT 56

GDT 63

GDT 66

GDT 114

GDT 115

GDT 123

QPL 1

QPL 2

QPL 7

QPL 26

QPL 41

QPL 77

QPL 81

828.2 Materials

A. Requirements

Use approved hot mix asphalt concrete mixtures that meet the following requirements:

1. Produce each asphalt mixture according to a Department approved Job Mix Formula and Asphalt Mix Design, see Subsection 400.1 for submittal and approval of Job Mix Formulas.
2. Ensure individual acceptance test results meet the Mixture Control Tolerances specified in the appropriate table below, Subsections 828.2.01 through 828.2.04.
3. Ensure the Engineer approves all materials used to prepare and place the mixtures before incorporating them into the Work. Use only the ingredients listed in the approved Asphalt Mix Design and Job Mix Formula. For virgin aggregates use sources meeting the requirements of Section 802 and are listed in QPL 1 or QPL 2; for mixes in which local sand is permitted, use the approved sand source identified in the mix design. For mixtures containing Reclaimed Asphalt Pavement (RAP), use only RAP from the approved stockpile identified in the mix design. Use asphalt cement meeting the requirements of Section 820, from a source listed in QPL 7.
4. Obtain approved SMA mix designs, Superpave mix designs and 4.75 mm mix designs from a mix design laboratory certified by the Department. Obtain approved mix designs for types PEM and OGFC mixtures from the Department's Office of Materials, which produces and furnishes these mix designs.
5. Ensure all SMA mix designs are designed in accordance with GDT-123 ("Determining the Design Proportions of Stone Matrix Asphalt Mixtures"). Ensure SMA mix designs are verified and approved by the Department prior to use. Ensure Superpave and 4.75 mm mix designs are designed in accordance with SOP-2 ("Control of Superpave Bituminous Mixture Designs") and are approved by the Department as provided therein. Ensure these mixes are designed by a laboratory and technician certified in accordance with SOP-36, ("Certification of Laboratories and Personnel for Design of SMA and Superpave Asphalt Mixtures").
6. Use only mixtures composed of the aggregate groups and blends indicated in the Proposal and Plans by their pay item designations, defined as follows:

Pay Item Designation	Allowable Aggregate Groups
Group I or II	Group I, Group II, or Blend I
Group II only	Group II only
Blend I	Either 100% Group II material or a blend of Group I and Group II. Do not use Group I material for more than 60%, by weight, of the total aggregate nor

	more than 50%, by weight, of the coarse aggregate fraction.

7. For patching or leveling use Group I, Group II, or Blend I. Mix types for patching and leveling are specified in Subsection 400.3.03.B.
8. Include lime (hydrated lime) from an approved source and meeting the requirements of Section 882 in all paving courses except as otherwise provided in the Contract. For a list of approved sources of lime, see QPL 41.
   a. Add lime to each mixture at the rate prescribed in the approved mix design.
   b. Ensure mix designs using only virgin aggregate include lime at a minimum rate of 1.00 % of the total dry aggregate weight. Ensure mix designs using RAP include lime at a minimum rate equal to 1.00 % of the virgin aggregate fraction plus 0.50 % of the aggregate in the RAP fraction.
   c. Add more lime or add lime plus an approved Heat-Stable Anti-Stripping Additive meeting the requirements of Section 831, if necessary to meet requirements for mixture properties, and pursuant to an approved mix design. However, the Department will not make additional payment for these materials. For a list of sources of Heat-Stable Anti-Stripping Additives, see QPL 26.
   d. Where specifically allowed in the contract on LARP, airport, and parking lot projects, an approved Heat-Stable Anti-Stripping Additive meeting the requirements of Section 831 may be substituted for hydrated lime. Ensure the mix gradation is adjusted to replace the lime with an equivalent volume of fines passing the 0.075 mm sieve. Add Heat-Stable Anti-stripping Additive at a minimum rate of 0.5 percent of the asphalt cement portion.
9. Use performance grade PG 64-22 or PG 67-22 asphalt cement in all mix designs and mixtures except as follows:
   a. The State Materials Engineer will determine the performance grade to be used, based on Table 2 – Binders Selection Guideline for Reclaimed Asphalt Pavement (RAP) Mixtures, AASHTO M323 and laboratory testing results as required in Section 828.2.B for mixtures containing ≥ 25% equivalent binder replacement for RAP/RAS mixtures.
   b. Use only grade PG 76-22, excluding shoulder construction in the following mixes: all SMA, 12.5 mm PEM, 9.5 mm and 12.5 mm OGFC, 12.5 mm Superpave, on projects with ADT greater than 25,000; and in all mixtures for which polymer-modified asphalt is specified in the pay item.
10. Use of local sand is restricted as follows:
    a. Do not place mixtures containing local sand on the traveled way of the mainline or ramps of the Interstate System. Mixtures with local sand may be used for shoulder construction on these facilities.
    b. Ensure local sand will not constitute more than 20 % of the total aggregate weight of any mix design or production mix.
    c. Subject to the above limits, 19 mm, 12.5 mm, and 9.5 mm Superpave mix designs and 4.75 mm mix designs containing local sand may be used on projects with a current ADT not exceeding 2,000.
    d. 25 mm Superpave mix designs containing not more than 20 % local sand may be used on all facilities except the main line and ramps of the Interstate System.
    e. Obtain local sand for use in asphalt mixtures from a source approved by the Department.
    f. Approval of local sand sources: The Department will sample, test, and approve sources of local sand. Ensure local sand contains no more than 7.0 % clay by weight and is free of foreign substances, roots, twigs, and other organic matter. Ensure sand is free of clay lumps, as determined by AASHTO T 112, and has a sand equivalent value exceeding 25%, as determined by GDT 63.

B. Fabrication

1. Design procedures: For all Superpave and 4.75 mm mixes, ensure conformance with the Superpave System for Volumetric Design (AASHTO T 312 and AASHTO R30), as adapted in SOP-2. Ensure Superpave mixes are designed at a design gyration number (N_{des}) of 65 gyrations and initial gyration number (N_{ini}) of 6 gyrations. Ensure 4.75 mm mixes, (N_{des}) are designed at 50 gyrations, and (N_{ini}) at 6 gyrations. Open-graded mix designs will be designed by the Department in accordance with GDT 114. In all cases, the procedure for measuring Maximum Specific Gravity (G_{mm}) is AASHTO T 209. In addition to gradation and volumetric analysis, ensure mix designs include the following performance tests, as applicable.
2. Performance Test:
   a. 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 %. The average permeability of three specimens may not exceed 3.60 ft per day (125 $\times 10^{-5}$cm per sec).

b. Moisture susceptibility test: Ensure mix designs of all types except open-graded surface mixes include testing for moisture susceptibility according to GDT 66. Ensure specimen air voids for this test are 7.0 ±1.0% for all mixes excluding Stone Matrix mixes. Ensure specimen air voids for this test are 6.0 ± 1.0% for Stone Matrix mixes. 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 average splitting strength of the three conditioned and three controlled samples are not less than 60 psi (415 kPa) for either group. Ensure retention of coating as determined by GDT 56 is not less than 95%.

c. Rutting susceptibility test: Ensure mix designs of all types except Open-graded Surface Mixes (OGFC and PEM), and mixtures designed exclusively for trench widening include testing according to GDT 115 or AASHTO T 340. Design limits for this test are as follows: Ensure specimen air voids for this test are 5.0 ± 1.0% for all mix types incorporating ≥ 15 percent RAP, excluding SMA mixtures. Ensure specimen air voids for this test are 6.0 ± 1.0% for all mix types incorporating < 15 percent RAP, excluding SMA mixtures. Ensure specimen air voids for this test are 6.0 ± 1% for all SMA mixtures. Ensure testing temperature is 64°C (147°F) for all mix types except 19 mm and 25 mm Superpave mixes, which are to be tested at 49°C (120°F). Ensure maximum deformation is 5.0 mm for all mixes except 4.75 mm mix, 9.5 mm Types I and II Superpave mixes. Ensure maximum deformation for the 9.5 mm Type II Superpave mix is 6.0 mm at 64°C (147°F) and 8.0 mm at 64°C (147°F) for the 4.75 mm and 9.5 mm Type I Superpave mix.

d. 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.

e. Hamburg Wheel-Tracking Test: The Department may verify Warm Mix Asphalt dense-graded mix designs or mix designs incorporating Polyphosphoric Acid (PPA) modified binders by Hamburg Wheel-tracking testing according to AASHTO T 324.

C. Acceptance

See Subsection 106.03 and Section 400. Ensure individual test results meet the Mixture Control Tolerances listed in Subsections 828.2, 828.2.01 ,828.2.02, 828.2.03, or 828.2.04, whichever applies with the following exception. Ensure field verification results for rutting susceptibility tests performed on laboratory fabricated and/or roadway cores obtained from asphalt plant produced mixtures meet specified requirements with a tolerance of +2.0 mm.

D. Materials Warranty

See General Provisions 101 through 150.

828.2.01 Open-Graded Surface Mixtures

A. Requirements

Produce the mixture according to an approved mix design and Job Mix Formula. Ensure Open-Graded Surface Mixtures meet the following mixture control tolerances and mix design criteria:

Sieve Size	Mixture Control Tolerance, %	Design Gradation Limits, % Passing		
		9.5 mm OGFC	12.5 mm OGFC	12.5 mm PEM
3/4 in (19 mm) sieve	±0.0		100*	100*
1/2 in (12.5 mm) sieve	±6.1	100*	85-100	80-100
3/8 in (9.5 mm) sieve	±5.6	85-100	55-75	35-60
No. 4 (4.75 mm) sieve	±5.7	20-40	15-25	10-25
No. 8 (2.36 mm) sieve	±4.6	5-10	5-10	5-10
No. 200 (75 µm) sieve	±2.0	2-4	2-4	1-4
Range for % AC	±0.4	6.0-7.25	5.75-7.25	5.5-7.0
Class of stone (Section 800)		"A" only	"A" only	"A" only
Drain-down (AASHTO T305), %		<0.3	<0.3	<0.3

* Mixture control tolerance is not applicable to this sieve for this mix.

1. In 12.5 mm and 9.5 mm OGFC and 12.5 mm PEM mixes, use only PG 76-22 asphalt cement (specified in Section 820).

2. Ensure all OGFC and PEM mixes include a stabilizing fiber of the type (cellulose or mineral) specified in the mix design and meeting the requirements of Section 819. Ensure the dosage rate is as specified in the mix design and sufficient to prevent drain-down exceeding the above tolerance.

B. Fabrication

See Section 400.

828.2.02 Stone Matrix Asphalt Mixtures

A. Requirements

Produce the mixture according to an approved mix design and Job Mix Formula. Ensure Stone Matrix Asphalt mixtures meet the following mixture control tolerances and mix design criteria:

Sieve Size	Mixture Control Tolerance	Design Gradation Limits, Percent Passing		
		9.5 mm SMA	12.5 mm SMA	19 mm SMA
1- in (25 mm) sieve	±0.0			100*
3/4 in (19 mm) sieve	±7.0	100*	100*	90-100
1/2 in (12.5 mm) sieve	±6.1	98-100**	85-100	44-70
3/8 in (9.5 mm) sieve	±5.6	70-100	50-75	25-60
No. 4 (4.75 mm) sieve	±5.7	28-50	20-28	20-28
No. 8 (2.36) mm sieve	±4.6	15-30	16-24	15-22
No. 50 (300 μm) sieve	±3.8	10-17	10-20	10-20
No. 200 (75 μm) sieve	±2.0	8-13	8-12	8-12
Range for % AC (Note 1)	±0.4 (Note 2)	6.0-7.5	5.8-7.5	5.5-7.5
Design optimum air voids (%)		3.5 ±0.5	3.5 ±0.5	3.5 ±0.5
% aggregate voids filled with AC (VFA)		70-90	70-90	70-90
Tensile splitting ratio after freeze-thaw cycle GDT-66		80%	80%	80%
Drain-down (AASHTO T305), %		<0.3	<0.3	<0.3

*Mixture control tolerance is not applicable to this sieve for this mix.

**Mixture control tolerance is ± 2.0% for this sieve for 9.5 mm SMA mixes placed at spread rates greater than 135 lb/yd^2. For 9.5 mm SMA mixes placed at spread rates of 135 lb/yd^2 or less, 100 % passing is required on this sieve.

Note 1: Range for % AC is Original Optimum AC (OOAC) at 35 gyrations (Gyratory compactor) or 50 blows (Marshall compactor) prior to Corrected Optimum AC (COAC) calculation detailed in GDT 123 (Appendix A)

Note 2: Quality Acceptance Test Results for AC content that deviate > ± 0.3% from the approved Job Mix Formula (JMF) consistently over three lots may subject the mix to a revised AC content on project JMF at the discretion of the State Materials Engineer based on statistical trend.

1. Ensure SMA mixtures are compacted at 35 gyrations with the Superpave Gyratory compactor or 50 blows with the Marshall compactor.
2. Ensure SMA mixtures contain mineral filler and fiber stabilizing additives and meet the following requirements:
   a. Asphalt cement grade PG-76-22 (specified in Section 820) is required in all SMA mixtures.
   b. Aggregates for SMA meet the requirements of Subsection 802.2.02.A.3.
   c. Use the approved mineral filler specified in the mix design and meeting the requirements of Section 883 Approved sources of mineral filler are listed in QPL 81.

Use the approved Fiber Stabilizing Additive of the type (cellulose or mineral) specified in the mix design and meeting the requirements of Section 819. Approved sources of Fiber Stabilizing Additive are listed in QPL 77. The dosage rate will be as specified in the mix design and sufficient to prevent drain-down exceeding the above tolerance.

B. Fabrication

See Section 400.

828.2.03 Superpave Asphalt Concrete Mixtures

A. Requirements for Superpave Mixtures (except Parking Lot Mixtures)

Produce the mixture according to an approved mix design and Job Mix Formula. Ensure Superpave Asphalt Concrete mixtures meet the following mixture control tolerances and mix design limits:

1. Gradation limits for Superpave mixtures are as follows:

Sieve Size	Mixture Control Tolerance	Design Gradation Limits, Percent Passing				
		9.5 mm Superpave Type I	9.5 mm Superpave Type II	12.5 mm Superpave (Note 1)	19 mm Superpave	25 mm Superpave
1½ in (37.5 mm)						100*
1- in (25.0 mm)	± 8.0			100*	100*	90-100
3/4 in (19.0 mm)	±8.0**	100*	100*	98-100****	90-100	55-89**
1/2 in (12.5 mm)	±6.0***	98-100****	98-100****	90-100	60-89***	50-70
3/8 in (9.5 mm)	±5.6	90-100	90-100	70-89	55-75	
No. 4 (4.75 mm) s	±5.6	65-85	55-75			
No. 8 (2.36 mm)	±4.6	48-55	42-47	38-46	32-36	30-36
No. 200 (75 μm)	±2.0	5.0-7.0	5.0-7.0	4.5-7.0	4.0-6.0	3.5-6.0
Range for % AC (Note 3)	± 0.4 (Note 2)	5.50-7.25	5.25-7.00	5.00-6.25	4.25-5.50	4.00-5.25

* Mixture control tolerance is not applicable to this sieve for this mix.

** Ensure mixture control tolerance is within ± 10.0% for this sieve for 25 mm Superpave.

***Ensure mixture control tolerance is within ± 8.0% for this sieve for 19 mm Superpave.

***Ensure mixture control tolerance is within ± 2.0% for this sieve for 12.5 mm and 9.5 mm mixes.

Note 1: Use PG 76-22 in 12.5 mm Superpave, excluding shoulder construction, on all projects with ADT greater than 25,000 as detailed in the Contract Pay Item.

Note 2: Quality Acceptance Test Results for AC content deviating > ± 0.3 % from the approved Job Mix Formula (JMF) consistently over three Lots may subject the mix to a revised AC content on the project JMF at the discretion of the State Materials Engineer based on statistical trend.

Note 3: Range for % AC is Original Optimum AC (OOAC) at 65 gyrations prior to the Corrected Optimum AC (COAC) calculation detailed in SOP 2 (Appendix D).

2. Volumetric limits are as follows:

Design Parameter	Mix Type	Limits
% of Max. Specific Gravity (Gmm) at design gyrations, (Ndes)	All	96%
% Gmm at the initial number of gyrations, Ni	All	91.5% maximum
% voids filled with asphalt (VFA) at Ndes	9.5 mm Type I	Min. 72; Max. 80
	9.5 Type II and 12.5 mm	Min. 72; Max. 76
	19 mm	Min. 71; Max 76
	25 mm	Min. 69; Max 76
Fines to effective asphalt binder ratio (F/Pbe)	9.5 mm Type I	0.6 to 1.4
	All other types	0.8 to 1.6
Minimum Film Thickness (microns)*	All	> 7.00
Minimum % Voids in Mineral Aggregate (VMA) Note: VMA shall be calculated using the effective specific gravity of the aggregate (Gse). See SOP-2SP.	25 mm	13.0
	19 mm	14.0
	12.5 mm	15.0
	9.5 Type I	16.0
	9.5 Type II	16.0

*Superpave Mixtures approved prior to January 31, 2012, may be adjusted to meet Minimum Film Thickness requirements by the State Materials Engineer.

B. Requirements for Superpave Parking Lot Mixes (NOT FOR STANDARD HIGHWAY/STREET PAVING)

1. Surface Layers for parking facilities:

Sieve Size	Mixture Control Tolerance	Design Gradation Limits, Percent Passing		
		4.75 mm Mix	9.5 mm Superpave Type I	9.5 mm Superpave Type II
1- in (25.0 mm) sieve	± 8.0			
3/4 in (19.0 mm) sieve	±8.0**		100*	100*
1/2 in (12.5 mm) sieve	±6.0	100*	98-100****	98-100****
3/8 in (9.5 mm) sieve	±5.6	90-100	90-100	90-100
No. 4 (4.75 mm) sieve	±5.6	75-95	65-85	55-75
No. 8 (2.36 mm) sieve	±4.6	60-65	48-55	42-47
No. 50 (300 μm) sieve	+3.8	20-50		
No. 200 (75 μm) sieve	±2.0	4-12	5.0-7.0	5.0-7.0
Range for Total AC	+ 0.4	6.00 - 7.50	5.50 - 7.25	5.25 - 7.00

* Mixture control tolerance is not applicable to this sieve for this mix.

****Ensure mixture control tolerance is within ± 2.0% for this sieve for 12.5 mm and 9.5 mm mixes.

2. Subsurface Layers for parking facilities:

Sieve Size	Mixture Control	Design Gradation Limits, Percent Passing	

	Tolerance	12.5 mm Superpave	19 mm Superpave	25 mm Superpave
				100*
1- in (25.0 mm) sieve	± 8.0	100*	100*	90-100
3/4 in (19.0 mm) sieve	±8.0**	98-100****	90-100	55-89**
1/2 in (12.5 mm) sieve	±6.0***	90-100	60-89***	50-70
3/8 in (9.5 mm) sieve	±5.6	70-89	55-75	
No. 8 (2.36 mm) sieve	±4.6	38-46	32-36	30-36
No. 200 (75 µm) sieve	±2.0	4.5-7.0	4.0-6.0	3.5-6.0
Range for Total AC	+ 0.4	5.00 - 6.25	4.25 - 5.50	4.00 - 5.25

*Mixture control tolerance is not applicable to this sieve for this mix.

**Ensure mixture control tolerance is within ±10.0% for this sieve for 25 mm Superpave mixes.

*** Ensure mixture control tolerance is within ±8.0% for this sieve for 19 mm Superpave mixes.

****Ensure mixture control tolerance is within ±2.0% for this sieve for 12.5 mm and 9.5 mm Superpave mixes.

3. Volumetric limits for parking facilities are as follows:

Design Parameter	Mix Type	Limits
% of Max. Specific Gravity (Gmm) at design gyrations, Ndes)	All	96%
% Gmm at the initial number of gyrations, Ni	All	91.5 % maximum
% voids filled with asphalt (VFA) at Ndes	9.5 mm Type I	Min. 72; Max. 80
	9.5 Type II and 12.5 mm	Min. 72; Max. 78
	19 and 25 mm	Min. 71; Max 76
Fines to effective asphalt binder ration (F/Pbe)	9.5 mm Type I	0.6 to 1.4
	All other types	0.8 to 1.6
Minimum Film Thickness (microns)*	4.75 mm	> 6.00
	All other types	> 7.00
Minimum % Voids in Mineral Aggregate (VMA)	25 mm	13.0
	19 mm	14.0
Note: VMA shall be calculated using the effective specific gravity of the aggregate (Gse). See SOP-2	12.5 mm	15.0
	9.5 mm Types I, II	16.0

* Mixtures approved prior to January 31, 2012, may be adjusted to meet Minimum Film Thickness requirements by the State Materials Engineer.

C. Fabrication

See Section 400.

828.2.04 Fine-Graded Mixtures

A. Requirements

Produce the mixture according to an approved mix design and Job Mix Formula. Ensure ~~that~~ fine-graded mixtures meet the following mixture control tolerances and design limits:

ASPHALTIC CONCRETE - 4.75 mm Mix

Sieve Size	Mixture Control Tolerance	Design Gradation Limits, % passing
1/2 in (12.5 mm) sieve*	±0.0	100*
3/8 in (9.5 mm) sieve	±5.6	90-100
No. 4 (4.75 mm) sieve	±5.7	75-95
No. 8 (2.36 mm) sieve	±4.6	60-65
No. 50 (300 µm) sieve	±3.8	20-50
No. 200 (75 µm) sieve	±2.0	4-12
Range for % AC	±0.4	6.00 – 7.50
Design optimum air voids (%)		4.0 – 7.0
% Aggregate voids filled with AC		60 - 80
Minimum Film Thickness (microns)**		> 6.00

* Mixture control tolerance is not applicable to this sieve for this mix.

** 4.75 mm Mixtures approved prior to January 31, 2012, may be adjusted to meet Minimum Film Thickness requirements by the State Materials Engineer.

B. Fabrication

See Section 400.

C. Acceptance

See Subsection 106.3 and Section 400. Ensure individual test results meet the Mixture Control Tolerances listed in Subsections 828.2, 828.2.01, 828.2.02, 828.2.03, 828.2.04, whichever applies.

D. Materials Warranty

See General Provisions 101 through 150.

RESEARCH
PROJECT CAPSULE

December 2011

[10 4]

TECHNOLOGY TRANSFER PROGRAM

Development of Performance Based Specifications for Louisiana Asphalt Mixtures

JUST THE FACTS:

Start Date:
April 1, 2011

Duration:
36 months

End Date:
March 31, 2014

Funding:
SPR

Principal Investigator:
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Louisiana Transportation Research Center
4101 Gourrier Ave
Baton Rouge, LA 70808

Sponsored jointly by the Louisiana Department of Transportation and Development and Louisiana State University

POINTS OF INTEREST:

Problem Addressed / Objective of Research / Mehodology Used Implementation Potential

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PROBLEM

Currently, Louisiana's quality control/quality assurance (QC/QA) practice for asphalt mixture in pavement construction is based on controlling volumetric properties of mixtures and compacted asphalt mixture layers. Parameters such as gradation, asphalt cement content, air voids, voids filled with asphalt, pavement density, and surface smoothness are included. In fact, this practice is common in many other state highway agencies in the US. While the QC/QA specifications have served highway agencies well to judge if the produced asphalt mixtures are acceptable compared to the initial designs, those volumetric control parameters are found to be insufficient to ensure the long term performance of the asphalt pavements since these parameters are not direct predictors of pavement performance. In addition, with the availability of alternative paving materials being proposed to enhance the sustainability of pavements, such as reclaimed asphalt pavement (RAP), crumb rubber modified asphalt recycled asphalt shingles (RAS), and warm-mix asphalt (WMA) mixtures, there is a pressing need for highway agencies to examine alternative pavement quality control systems. A performance based specification (PBS), which relies on fundamental mechanical properties of asphalt mixtures as performance predictors of pavements, is a promising candidate to replace current QC/QA specifications.

Therefore, it is proposed herein to investigate the feasibility and applicability of key PBS principles such as the utilization of in-situ nondestructive testing (NDT) devices and subsequent use of the NDT measures in performance prediction models that will examine if the produced mixture will meet the performance target parameters at the end of its designed service life. Through this research, it will be ultimately sought to develop a framework for the implementation of the PBS for the Louisiana Department of Transportation and Development (LADOTD) for asphalt pavement construction.

OBJECTIVE

The ultimate goal of the proposed research is to develop a framework for the implementation of a PBS for new and rehabilitated asphalt pavements. Specific objectives of the study include: identifying state-of-the-practice of PBS employed in highway agencies, evaluating the applicability of key PBS principles to LA pavements, developing a tailored PBS for LADOTD, and developing a framework of the PBS implementation in Louisiana.

METHODOLOGY

To achieve the objectives of this study, a minimum of 10 rehabilitation projects throughout the state with known traffic data and a good plant record of mixture consistency will be selected. Field core samples, known as plant-produced field-compacted (PF) will be tested at a minimum for the loaded wheel tracking (LWT) test, dynamic modulus test, semi-circular bend (SCB) test, and indirect tensile strength (ITS) test. In addition, a suite of NDT in-situ tests that includes the falling weight deflectometer (FWD), light falling weight deflectometer (LFWD), and portable seismic pavement analyzer (PSPA) will be conducted at corresponding locations where PF samples are taken for comparisons with laboratory test results. Furthermore, density will be measured in the field and in the laboratory.

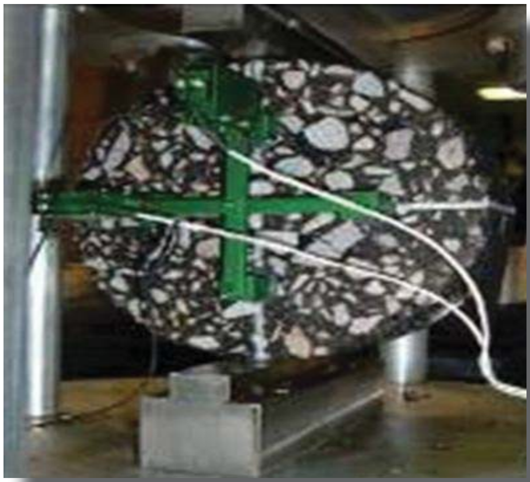
In addition to the aforementioned rehabilitation projects, it is anticipated that three new field projects from a proposed companion LTRC study titled *Test and Analysis of LWT and SCB of Asphalt Concrete Mixtures* will provide plant-produced laboratory-compacted (PL) and PF (plant produced field compacted samples) for collecting additional test results. The same suite of tests will be performed on these samples as the one to be performed on the samples obtained from the rehabilitation projects.

The proposed research study will be conducted according to the following tasks:

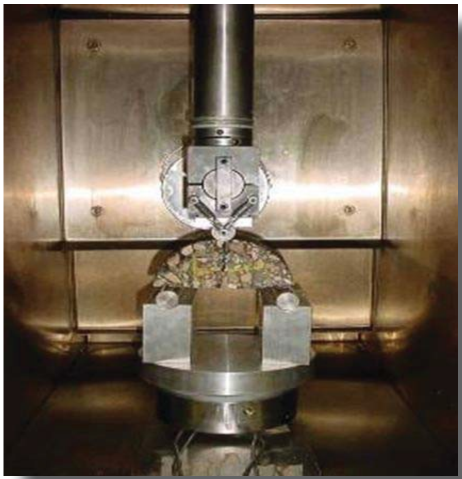
- Task 1 – Conducting a Literature Review
- Task 2 – Identifying Field Projects and Preparing Samples
- Task 3 – Conducting Laboratory and Field Experiments
- Task 4 – Performing Data Analyses
- Task 5 – Developing a Prototype PBS
- Task 6 – Preparing a Draft Project Report

IMPLEMENTATION POTENTIAL

It is anticipated that results from this study will provide guidelines for the implementation of mechanical tests for QC/QA of asphalt mixture in lieu of the current physical and volumetric properties.



Indirect tensile dynamic modulus test set up



Semi circular bend test set up

Loaded wheel tracking test set up

For more information about LTRC's research program, please visit our Web site at www.ltrc.lsu.edu.

RESEARCH PROJECT CAPSULE [11-3B]

June 2011

TECHNOLOGY TRANSFER PROGRAM

Testing and Analysis of LWT and SCB Properties of Asphaltic Concrete Mixtures

JUST THE FACTS:

Start Date:
April 1, 2011

Duration:
24 months

End Date:
March 31, 2013

Funding:
SPR: TT-Fed/TT-Reg

Principal Investigator:
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Louisiana Transportation Research Center
4101 Gourrier Ave
Baton Rouge, LA 70808

Sponsored jointly by the Louisiana Department of Transportation and Development and Louisiana State University

POINTS OF INTEREST:

Problem Addressed / Objective of Research / Mehodology Used Implementation Potential

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PROBLEM

Currently, Louisiana's Quality Control and Quality Assurance (QC/QA) practice for asphalt mixtures in pavement construction is mainly based on controlling properties of plant-produced mixtures that include gradation and asphalt content, air voids, moisture susceptibility tests (Modified Lottman) and roadway parameters, such as pavement density. These controlling properties have served Louisiana well, yet with growing interest in considering alternative paving materials such as rubber modified asphalts, reclaimed asphalt pavement (RAP), recycled shingles, and the warm-mix asphalt (WMA) technologies, there is a pressing need to implement mechanical tests on samples representing plant produced mixtures or roadway core samples that will screen materials prone to rutting, cracking, and alternative moisture damage indicators.

The Louisiana Transportation Research Center (LTRC) has been conducting loaded wheel tracker (LWT) and semi-circular bend (SCB) tests for several years for forensic investigation and research purposes only. Furthermore, Texas has adopted the LWT for design approval and plant produced mixtures. Louisiana has recommended a 6-mm maximum rut depth for design of asphalt mixtures and Texas has adopted a 12-mm maximum rut depth requirement for 10,000, 15,000, and 20,000 passes depending on PG grade of asphalt binder. Testing of cores and plant produced mixtures using local materials is needed to verify these LWT parameters in Louisiana.

Recently, the Louisiana Department of Transportation and Development (DOTD) has planned to introduce LWT (rutting) and SCB (cracking) specification limits that are reasonable and practical, considering the commonly used construction materials and projected traffic in the state of Louisiana. Consequently, a statewide testing scheme is planned to generate a wide spread LWT and SCB database.

OBJECTIVE

The objective of this research is to implement the loaded wheel tracker and to evaluate a simplified semi-circular bend test as an end result parameter for testing asphaltic concrete mixtures. The research will focus on testing both plant produced loose mixtures and roadway cores.

METHODOLOGY

The proposed research study will be conducted according to the following tasks:

- **Task 1** – Conducting Literature Review
- **Task 2** – Developing a Simplified SCB Test Apparatus (Modify Marshall Load Frame)
- **Task 3** – Identifying Field Projects and Field Sampling
- **Task 4** – Laboratory Testing
- **Task 5** – Data Analyses
- **Task 6** – Developing of End Result Specifications
- **Task 7** – Preparing a Project Report

SCB testing apparatus

SCB test setup

IMPLEMENTATION POTENTIAL

A system to conduct mechanical property test to determine the predicted performance of asphalt mixtures has been a need for more than 100 years. It is believed that the LWT and SCB tests will provide end results that can be used to predict this performance. LTRC began using the LWT device as a research tool before 2000. The device has also been used in Louisiana as a forensics investigative tool, providing a good predictor of pavement performance. Texas DOT adopted the use of the LWT device in their mix designs and mixture production in 2004. The outcome of this study will allow Louisiana to require the use of the LWT for quality acceptance as part of the Standard Specifications.

LTRC has been using the SCB test device as a research tool since 2004. It too has been used in several research projects as a predictor of pavement performance of asphalt mixtures. The ability to adapt this device to a commonly used Marshall Load frame device will provide another tool for quality acceptance. However, minor training will be necessary for the entire asphalt materials community.

LWT test

For more information about LTRC's research program, please visit our Web site at www.ltrc.lsu.edu.

Minnesota Department of Transportation

Disk-shaped Compact Tension Test (DCT) Provision

Description
The DCT (disk-shaped compact tension test) predicts low temperature cracking potential of asphalt mixtures. This provision requires the mix design, for approximately 2,000 tons of wearing course mixture (top 4 inches), meet minimum fracture energy before the mixture is allowed to be produced and placed on the roadway. Disk Shaped Compact Tension Testing (DCT) will be performed by MnDOT and used to determine the acceptability of the mixture design.

Mix Design
The following requirements are added to 2360.2.E.5:

DCT Sample

At least 14 calendar days before actual production, submit briquettes to the District Materials Laboratory for fracture energy testing. Submit briquettes for each mixture type.

Use the same asphalt grade as specified in the contract provisions to batch material at the design proportions including optimum asphalt. RAP source must be from the project. Use a cure time of 2 h ±15 minutes at 290 °F [144 °C] following Laboratory Manual Method 1813.

Compact and submit briquettes in accordance with Table DCT-1:

Table DCT-1
Mixture Sample Requirements

Item	Gyratory Design
Number of compacted briquettes*	4
Compacted briquette air void content	6.5 % – 7.5 %
* 6 in [150 mm] dia. specimens at 95mm ± 5mm ht.	

Fracture Energy Requirements

Department or another approved Department Laboratory will test the compacted samples according to ASTM D7313-08 to determine the average fracture energy of the submitted mix design. In addition to the requirements of 2360.2 E5 the mixture design must also meet the minimum fracture energy for the specified traffic level as shown in Table DCT-2.

Table DCT-2
Average Minimum Fracture Energy Requirements

Traffic Level	Fracture Energy
2 - 4	400 J/m^2
5	460 J/m^2

Redesign the mixture and re-submit samples for evaluation if the submitted sample does not meet the average minimum fracture energy. Methods that have been used to increase fracture energy include:

- Selecting an asphalt binder that has a lower low end temperature grade than the specified grade (PG xx-34 instead of PG xx-28).

- Selecting an asphalt binder that has a higher high end temperature grade than the specified grade (PG 64-xx instead of PG 58-xx).
- Using a modified asphalt binder instead of an unmodified asphalt binder.
    i. Elastomeric polymers (SBS or Elvaloy) perform slightly better than polyphosphoric acid, mineral filler, and other binder modifiers.
- Using a harder crushed quarry rock instead of limestone or gravel aggregates.
- Increasing the binder content of the mixture.
- Reducing the amount of recycled materials (RAP or shingles).
- Using a smaller nominal aggregate size.

Production Samples

Take one sample per mix type per day for Department evaluation of fracture energy. Sample size is 90lbs (40kg) or 4 full 6x12” cylinder molds. On the sample identification card include: Project No., date, mixture designation code, MDR number, and test number (DCT-XX). Results from production testing will be used for information only.

NJDOT B-10 – OVERLAY TEST FOR DETERMINING CRACK RESISTANCE OF HMA

A. Scope. This test method is used to determine the susceptibility of HMA specimens to fatigue or reflective cracking. This test method measures the number of cycles to failure.

B. Apparatus. Use the following apparatus:

1. Overlay Tester. An electro-hydraulic system that applies repeated direct tension loads to specimens. The machine features two blocks, one is fixed and the other slides horizontally. The device automatically measures and records a time history of load versus displacement every 0.1 sec at a selected test temperature.

   The sliding block applies tension in a cyclic triangular waveform to a constant maximum displacement of 0.06 cm (0.025 in.). This sliding block reaches the maximum displacement and then returns to its initial position in 10 sec. (one cycle).

2. Temperature Control System. The temperature chamber must be capable of controlling the test temperature with a range of 32 to 95 °F (0 to 35 °C).
3. Measurement System. Fully automated data acquisition and test control system. Load, displacement, and temperature are simultaneously recorded every 0.1 sec.
4. Linear Variable Differential Transducer (LVDT). Used to measure the horizontal displacement of the specimen (+/- 0.25 in.). Refer to manufacturer for equipment accuracy for LVDT.
5. Electronic Load Cell. Used to measure the load resulting from the displacement (5000 lb capacity). Refer to manufacturer for equipment accuracy for load cell.
6. Specimen Mounting System. Used two stainless steel base plates to restrict shifting of the specimen during testing. The mounting jig holds the two stainless steel base plates for specimen preparation.
7. Cutting Template.
8. Two Part Epoxy. Two part epoxy with a minimum 24 hour tensile strength of 600 psi (4.1 MPa) and 24 hour shear strength of 2,000 psi (13.8 MPa).
9. 10 lb weight (4.5 kg). Used to place on top of specimens while being glued to specimen platens.
10. ¼ inch Width Adhesive Tape. Placed over gap in plates to prevent the epoxy from bonding the plates together.
11. Paint or Permanent Marker. Used to outline specimens on platens for placement of epoxy.
12. 3/8-in. Socket Drive Handle with a 3-in. (7.6 cm) extension.

C. Procedure. Perform the following steps:

1. Sample Preparation.

a. Laboratory Molded Specimens - Use cylindrical specimens that have been compacted using the gyratory compactor (AASHTO T 312). Specimen diameter must be 6 inches (150 mm) and a specimen height must be 4.5 inches +/- 0.2 inches (115 +/- 5 mm).

Note 1 - Experience has shown that molded laboratory specimens of a known density usually result in a greater density (or lower air voids) after being trimmed. Therefore, it is recommended that the laboratory technician produce molded specimens with an air void level slightly higher than the targeted trimmed specimen. Determine the density of the final trimmed specimen in accordance with AASHTO T 166.

b. Core Specimens – Specimen diameter must be 6 inches +/- 0.1 inch (150 mm +/- 2 mm). Determine the density of the final trimmed specimen in accordance with AASHTO T166.

2. Trimming of Cylindrical Specimen. Before starting, refer to the sawing device manufacturer's instructions for cutting specimens.

a. Place the cutting template on the top surface of the laboratory molded specimen or roadway core. Trace the location of the first two cuts by drawing lines using paint or a permanent maker along the sides of the cutting template.

b. Trim the specimen ends by cutting the specimen perpendicular to the top surface following the traced lines. Discard specimen ends.

c. Trim off the top and bottom of the specimen to produce a sample with a height of (1.5 inches +/- 0.02 inches (38 mm +/- 0.5 mm).

d. Measure the density of the trimmed specimen in accordance with AASHTO T 166. If the specimen does not meet the density requirement as specified for performance testing for the mix being tested, then discard it and prepare a new specimen.

e. Air dry the trimmed specimen to constant mass, where constant mass is defined as the weight of the trimmed specimen not changing by more than 0.05% in a 2 hour interval.

3. Mounting Trimmed Specimen to Base Plates (Platens).

a. Mount and secure the base plates (platens) to the mounting jig. Cut a piece of adhesive tape approximately 4.0 inches (102 mm) in length. Center and place the piece of tape over the gap between the base plates.

b. Prepare the epoxy following manufacturer's instructions.

c. Cover a majority of the base plates (platens) with epoxy, including the tape. Glue the trimmed specimen to the base plates.

d. Place a 10 lb (4.5 kg) weight on top of the glued specimen to ensure full contact of the trimmed specimen to the base plates. Allow the epoxy to cure for the time recommended by the manufacturer. Remove the weight from the specimen after the epoxy has cured.

e. Turn over the glued specimen so the bottom of the base plates faces upward. Using a hacksaw, cut a notch through the epoxy which can be seen through the gap in the base plates. The notch should be cut as evenly as possible and should just begin to reach the specimen underneath the epoxy. Great care should be taken not to cut more than 1/16 inch (1.58 mm) into the specimen.

f. Place the test sample assembly in the Overlay Tester's environmental chamber for a minimum of 1 hour before testing.

4. Start Testing Device. Please refer to manufacturer's equipment manual prior to operating equipment.

a. Turn on the Overlay Tester. Turn on the computer and wait to ensure communication between the computer and the Overlay Tester occurs.

b. Turn on the hydraulic pump using the Overlay Tester's software. Allow the pump to warm up for a minimum of 20 minutes.

c. Turn the machine to load control mode to mount the sample assembly.

5. Mounting Specimen Assembly to Testing Device. Enter the required test information into the Overlay Tester software for the specimen to be tested.

a. Mount the specimen assembly onto the machine according to the manufacturer's instructions and the following procedural steps.

1. Clean the bottom of the base plates and the top of the testing machine blocks before placing the specimen assembly into the blocks. If all four surfaces are not clean, damage may occur to the machine, the specimen, or the base plates when tightening the base plates.
2. Apply 15 lb-in of torque for each screw when fastening the base plates to the machine.

6. Testing Specimen.

a. Perform testing at a constant temperature recommended by the New Jersey Department of Transportation for the mixture in question. This is typically either 59 °F (15 °C) or 77 °F (25 °C).

Note 3 – Ensure the trimmed specimen has also reached the constant temperature required.

b. Start the test by enabling the start button on the computer control program. Perform testing until a 93% reduction or more of the maximum load measured from the first opening cycle occurs. If 93% is not reached, run the test until a minimum of 1,200 cycles.

c. After the test is complete, remove the specimen assembly from the Overlay Tester machine blocks.

D. Report. Include the following items in the report:

1. Date and time molded or cored.
2. NJDOT mixture identification.
3. Trimmed specimen density.
4. Starting Load.
5. Final Load.
6. Percent decline (or reduction) in Load.
7. Number of cycles until failure.
8. Test Temperature

SECTION 401 – HOT MIX ASPHALT (HMA) COURSES

ADD THE FOLLOWING TO 401.01:

401.01 DESCRIPTION

This Section also describes the requirements for constructing a Hot Mix Asphalt (HMA) course with required minimum amounts of Reclaimed Asphalt Pavement (RAP).

ADD THE FOLLOWING TO 401.02.01:

401.02.01 Materials

Hot Mix Asphalt HIGH RAP 902.11

ADD THE FOLLOWING SUBSECTION TO 401.03:

401.03.07Hot Mix Asphalt (HMA) HIGH RAP

A. Paving Plan. At least 20 days before beginning placing the HMA HIGH RAP, submit a detailed plan of operation as specified in 401.03.03.A to the RE for approval. Include in the paving plan a proposed location for the test strip. Submit for Department approval a plan of the location for the HMA HIGH RAP on the project.

B. Weather Limitations. Place HMA HIGH RAP according to the weather limitations in 401.03.03.B.

C. Test Strip. Construct a test strip as specified in 401.03.03.C.

D. Transportation and Delivery of HMA. Deliver HMA HIGH RAP as specified in 401.03.03.D.

E. Spreading and Grading. Spread and grade HMA HIGH RAP as specified in 401.03.03.E. Record the laydown temperature (temperature immediately behind the paver) at least once per hour during paving. Submit the temperatures to the RE and to the HMA Plant producing the HMA HIGH RAP.

F. Compacting. Compact HMA HIGH RAP as specified in 401.03.03.F.

G. Opening to Traffic. Follow the requirements of 401.03.03.G for opening HMA HIGH RAP to traffic.

H. Air Void Requirements. Ensure that the HMA HIGH RAP is compacted to meet the air void requirements as specified in 401.03.03.H.

I. Thickness Requirements. Ensure that the HMA HIGH RAP is paved to meet the thickness requirements as specified in 401.03.03.I.

J. Ride Quality Requirements. Ensure that the HMA HIGH RAP is paved to meet the ride quality requirements as specified in 401.03.03.J

ADD THE FOLLOWING TO 401.04:

401.04 MEASUREMENT AND PAYMENT

The Department will measure and make payment for Items as follows:

Item	*Pay Unit*
HOT MIX ASPHALT ___ ___ ___ SURFACE COURSE HIGH RAP	TON
HOT MIX ASPHALT ___ ___ ___ INTERMEDIATE COURSE HIGH RAP	TON
HOT MIX ASPHALT ___ ___ ___ BASE COURSE HIGH RAP	TON

ADD THE FOLLOWING TO 902:

902.11 HOT MIX ASPHALT HIGH RAP

902.11.01 Mix Designations

The requirements for specific HMA mixtures with required minimum amounts of RAP are identified by the abbreviated fields in the Item description as defined as follows:

HOT MIX ASPHALT 12.5H64 SURFACE COURSE HIGH RAP

1. "HOT MIX ASPHALT" "Hot Mix Asphalt" is located in the first field in the Item description for the purpose of identifying the mixture requirements.
2. "12.5" The second field in the Item description designates the nominal maximum size aggregate (in millimeters) for the job mix formula (sizes are 4.75, 9.5, 12.5, 19, 25, and 37.5 mm).
3. "H" The third field in the Item description designates the design compaction level for the job mix formula based on traffic forecasts as listed in Table 902.02.03-2 (levels are L=low, M=medium, and H=high).
4. "64" The fourth field in the Item description normally designates the high temperature (in °C) of the performance-graded binder (options are 64, 70, and 76 °C). In the High RAP mixes this field will designate the mix performance requirements.
5. "SURFACE COURSE" The last field in the Item description designates the intended use and location within the pavement structure (options are surface, intermediate, or base course).
6. "HIGH RAP" This additional field designates that there will be a minimum percentage of RAP required for the mixture in 902.11.02.

902.11.02 Composition of Mixture

Provide materials as specified:

Aggregates for Hot Mix Asphalt..901.05

Use a virgin asphalt binder that will result in a mix that meets the performance requirements specified in Table 902.11.03-2. Ensure that the virgin asphalt binder meets the requirements of 902.01.01 except the performance grade. Use a performance grade of asphalt binder as determined by the mix design and mix performance testing. Submit a certificate of analysis (COA) showing the PG continuous grading (AASHTO R 29) for the asphalt binder used in the mix design.

For quality assurance testing of the asphalt binder, the ME may sample the asphalt binder during production of the mix and compare the results with the COA submitted at the time of mix design. To analyze the binder the ME will test the binder at the nearest standard PG temperature then compare the results with the COA. If the high and low temperature test results are within 25% of the results from the same temperature on the COA, then the ME will consider the asphalt binder comparable to the binder used during mix design.

Mix HMA HIGH RAP in a plant that is listed on the QPL for HMA Plants and conforms to the requirements for HMA Plants as specified in 1009.01.

Composition of the mixture for HMA HIGH RAP surface course is coarse aggregate, fine aggregate, asphalt binder, and a minimum of 20 percent Reclaimed Asphalt Pavement (RAP), and may also include mineral filler, asphalt rejuvenator and Warm Mix Asphalt (WMA) additives or processes as specified in 902.01.05. When WMA is used it must meet the requirements as specified in 902.10. Ensure that the finished mix does not contain more than a total of 1 percent by weight contamination from Crushed Recycled Container Glass (CRCG).

The composition of the mixture for HMA HIGH RAP base or intermediate course is coarse aggregate, fine aggregate, asphalt binder, and a minimum of 30 percent Reclaimed Asphalt Pavement (RAP), and may also include mineral filler, up to 10 percent of additional recycled materials, asphalt rejuvenator, and Warm Mix Asphalt (WMA) additives or processes as specified in 902.01.05. When WMA is used it must meet the requirements as specified in 902.10. The recycled materials may consist of a combination of RAP, CRCG, Ground Bituminous Shingle Material (GBSM), and RPCSA, with the following individual limits:

Table 902.11.02-1 Use of Recycled Materials in Base or Intermediate Course

Recycled Material	Minimum Percentage	Maximum Percentage
RAP	30	
CRCG		10
GBSM		5
RPCSA		20

Combine the aggregates to ensure that the resulting mixture meets the grading requirements specified in Table 902.02.03-1. In determining the percentage of aggregates of the various sizes necessary to meet gradation requirements, exclude the asphalt binder.

Ensure that the combined coarse aggregate, when tested according to ASTM D 4791, has less than 10 percent flat and elongated pieces retained on the No. 4 sieve and larger. Measure aggregate using the ratio of 5:1, comparing the length (longest dimension) to the thickness (smallest dimension) of the aggregate particles.

Ensure that the combined fine aggregate in the mixture conforms to the requirements specified in Table 902.02.02-2. Ensure that the material passing the No. 40 sieve is non-plastic when tested according to AASHTO T 90.

902.11.03 Mix Design

At least 45 days before initial production, submit a job mix formula for the HMA HIGH RAP on forms supplied by the Department, to include a statement naming the source of each component and a report showing that the results meet the criteria specified in Tables 902.02.03-1 and 902.11.03-1.

Include in the mix design the following based on the weight of the total mixture:

1. Percentage of RAP or GBSM.
2. Percentage of asphalt binder in the RAP or GBSM.
3. Percentage of new asphalt binder.
4. Total percentage of asphalt binder.
5. Percentage of each type of virgin aggregate.

Table 902.11.03-1HMA HIGH RAP Requirements for Design

Compaction Levels	Required Density (% of Theoretical Max. Specific Gravity)		Voids in Mineral Aggregate (VMA)[2], % (minimum) — Nominal Max. Aggregate Size, mm					Voids Filled With Asphalt (VFA) %	Dust-to-Binder Ratio
	@N_{des}[1]	@N_{max}	25.0	19.0	12.5	9.5	4.75		
L	96.0	≤ 98.0	13.0	14.0	15.0	16.0	17.0	70 - 85	0.6 - 1.2
M	96.0	≤ 98.0	13.0	14.0	15.0	16.0	17.0	65 - 85	0.6 - 1.2

1. As determined from the values for the maximum specific gravity of the mix and the bulk specific gravity of the compacted mixture. Maximum specific gravity of the mix is determined according to AASHTO T 209. Bulk specific gravity of the compacted mixture is determined according to AASHTO T 166. For verification, specimens must be between 95.0 and 97.0 percent of maximum specific gravity at N_{des}.
2. For calculation of VMA, use bulk specific gravity of the combined aggregate include aggregate extracted from the RAP.

The job mix formula for the HMA HIGH RAP mixture establishes the percentage of dry weight of aggregate, including the aggregate from the RAP, passing each required sieve size and an optimum percentage of asphalt binder based upon the weight of the total mix. Determine the optimum percentage of asphalt binder according to AASHTO R 35 and M 323 with an N_{des} as required in Table 902.02.03-2. Before maximum specific gravity testing or compaction of specimens, condition the mix for 2 hours according to the requirements for conditioning for volumetric mix design in AASHTO R 30, Section 7.1. If the absorption of the combined aggregate is more than 1.5 percent according to AASHTO T 84 and T 85, ensure that the mix is short term conditioned for 4 hours according to AASHTO R 30, Section 7.2 prior to compaction of specimens (AASHTO T 312) and determination of maximum specific gravity (AASHTO T 209). Ensure that the job mix formula is within the master range specified in Table 902.02.03-1.

Ensure that the job mix formula provides a mixture that meets a minimum tensile strength ratio (TSR) of 80% when prepared according to AASHTO T 312 and tested according to AASHTO T 283. Submit the TSR results with the mix design.

Determine the correction factor of the mix including the RAP by using extracted aggregate from the RAP in the proposed proportions when testing is done to determine the correction factor as specified in AASHTO T 308. Use extracted aggregate from the RAP in determining the bulk specific gravity of the aggregate blend for the mix design.

For each mix design, submit with the mix design forms 3 gyratory specimens and 1 loose sample corresponding to the composition of the JMF. Ensure that the samples include the percentage of RAP that is being proposed for the mix. The ME will use these to verify the properties of the JMF. Compact the specimens to the design number of gyrations (N_{des}). For the mix design to be acceptable, all gyratory specimens must comply with the requirements specified in Tables 902.02.03-1 and 902.11.03-1. The ME reserves the right to be present at the time the gyratory specimens are molded.

In addition, submit nine gyratory specimens and five 5-gallon buckets of loose mix to the ME. The ME will use these additional samples for performance testing of the HMA HIGH RAP mix. The ME reserves the right to be present at the time of molding the gyratory specimens. Ensure that the additional gyratory specimens are compacted according to AASHTO T 312, are 77 mm high, and have an air void content of 6.5 ± 0.5 percent. The ME will test six (6) specimens using an Asphalt Pavement Analyzer (APA) according to AASHTO T 340 at 64ºC, 100 psi hose pressure, and 100 lb. wheel load. The ME will use the remaining three (3) specimens to test using an Overlay Tester (NJDOT B-10) at 25°C and a joint opening of 0.025 inch.

The ME will approve the JMF if the results meet the criteria in Table 902.11.03-2.

Table 902.11.03-2 Performance Testing Requirements for HMA HIGH RAP Design

Test	Requirement			
	Surface Course		Intermediate Course	
	PG 64-22	PG 76-22	PG 64-22	PG 76-22
APA @ 8,000 loading cycles (AASHTO T 340)	< 7 mm	< 4 mm	< 7 mm	< 4 mm
Overlay Tester (NJDOT B-10)	> 150 cycles	> 175 cycles	> 100 cycles	> 125 cycles

If the JMF does not meet the APA and Overlay Tester criteria, redesign the HMA HIGH RAP mix and submit for retesting. The JMF for the HMA HIGH RAP mixture is in effect until modification is approved by the ME.

When unsatisfactory results for any specified characteristic of the work make it necessary, the Contractor may establish a new JMF for approval. In such instances, if corrective action is not taken, the ME may require an appropriate adjustment to the JMF.

Should a change in sources be made or any changes in the properties of materials occur, the ME will require that a new JMF be established and approved before production can continue.

902.11.04 Sampling and Testing

A. General Acceptance Requirements. The RE or ME may reject and require disposal of any batch or shipment that is rendered unfit for its intended use due to contamination, segregation, improper temperature, lumps of cold material, or incomplete coating of the aggregate. For other than improper temperature, visual inspection of the material by the RE or ME is considered sufficient grounds for such rejection.

Ensure that the temperature of the mix at discharge from the plant or storage silo meets the recommendation of the supplier of the asphalt binder, supplier of the asphalt modifier and WMA manufacturer. For HMA, do not allow the mixture temperature to exceed 330°F at discharge from the plant. For WMA, do not allow the mixture temperature to exceed 300°F at discharge from the plant.

Combine and mix the aggregates and asphalt binder to ensure that at least 95 percent of the coarse aggregate particles are entirely coated with asphalt binder as determined according to AASHTO T 195. If the ME determines that there is an on-going problem with coating, the ME may obtain random samples from 5 trucks and will determine the adequacy of the mixing on the average of particle counts made on these 5 test portions. If the requirement for 95 percent coating is not met on each sample, modify plant operations, as necessary, to obtain the required degree of coating.

B. Sampling. The ME will take 5 stratified random samples of HMA HIGH RAP for volumetric acceptance testing from each lot of approximately 3500 tons of a mix. When a lot of HMA HIGH RAP is less than 3500 tons, the ME will take samples at random for each mix at the rate of one sample for each 700 tons. The ME will perform sampling according to AASHTO T 168, NJDOT B-2, or ASTM D 3665.

Use a portion of the samples taken for volumetric acceptance testing for composition testing.

C. Quality Control Testing. The HMA HIGH RAP producer shall provide a quality control (QC) technician who is certified by the Society of Asphalt Technologists of New Jersey as an Asphalt Technologist, Level 2. The QC technician may substitute equivalent technician certification by the Mid-Atlantic Region Technician Certification Program (MARTCP). Ensure that the QC technician is present during periods of mix production for the sole purpose of quality control testing and to assist the ME. The ME will not perform the quality control testing or other routine test functions in the absence of, or instead of, the QC technician.

The QC technician shall perform sampling and testing according to the approved quality control plan, to keep the mix within the limits specified for the mix being produced. The QC technician may use acceptance test results or perform additional testing as necessary to control the mix.

To determine the composition, perform ignition oven testing according to AASHTO T 308.

For each acceptance test, perform maximum specific gravity testing according to AASHTO T 209 on a test portion of the sample taken by the ME. Sample and test coarse aggregate, fine aggregate, mineral filler, and RAP according to the approved quality control plan for the plant.

Ensure that the supplier has in operation an ongoing daily quality control program to evaluate the RAP. As a minimum, this program shall consist of the following:

1. An evaluation performed to ensure that the material conforms to 901.05.04 and compares favorably with the design submittal.
2. An evaluation of the RAP material performed using a solvent or an ignition oven to qualitatively evaluate the aggregate components to determine conformance to 901.05.
3. Quality control reports as directed by the ME.

D. Acceptance Testing and Requirements. The ME will determine volumetric properties at N_{des} for acceptance from samples taken, compacted, and tested at the HMA plant. The ME will compact HMA HIGH RAP to the number of design gyrations (N_{des}) specified in Table 902.02.03-2, using equipment according to AASHTO T 312. The ME will determine bulk specific gravity of the compacted sample according to AASHTO T 166. The ME will use the most current QC maximum specific gravity test result in calculating the volumetric properties of the HMA HIGH RAP.

The ME will determine the dust-to-binder ratio from the composition results as tested by the QC technician.

Ensure that the HMA HIGH RAP mixture conforms to the requirements specified in Table 902.11.04-1, and to the gradation requirements in Table 902.02.03-1. If 2 samples in a lot fail to conform to the gradation or volumetric requirements, immediately initiate corrective action.

The ME will test a minimum of 1 sample per lot for moisture, basing moisture determinations on the weight loss of an approximately 1600-gram sample of mixture heated for 1 hour in an oven at 280 ± 5°F. Ensure that the moisture content of the mixture at discharge from the plant does not exceed 1.0 percent.

Table 902.11.04-1 HMA HIGH RAP Requirements for Control							
Compaction Levels	Required Density (% of Theoretical Max. Specific Gravity)	Voids in Mineral Aggregate (VMA), % (minimum)					Dust-to-Binder Ratio
		Nominal Max. Aggregate Size, mm					
	@Ndes[1]	25.0	19.0	12.5	9.5	4.75	
L, M	95.0 – 98.5	13.0	14.0	15.0	16.0	17.0	0.6 - 1.3

1. As determined from the values for the maximum specific gravity of the mix and the bulk specific gravity of the compacted mixture. Maximum specific gravity of the mix is determined according to AASHTO T 209. Bulk specific gravity of the compacted mixture is determined according to AASHTO T 166.

E. **Performance Testing for HMA HIGH RAP.** Provide five (5) 5-gallon buckets of loose mix to the ME for testing in the Asphalt Pavement Analyzer (APA) and the Overlay Tester device. Ensure that the first sample is taken during the construction of the test strip as specified in 401.03.07.C.Thereafter, sample every lot or as directed by the ME. If a sample does not meet the design criteria for performance testing as specified in Table 902.11.03-2, the Department will assess a pay adjustment as specified in Table 902.11.04-2. If a lot fails to meet requirements for both APA and Overlay Tester, the Department will assess pay adjustments for both parameters. The Department will calculate the pay adjustment by multiplying the percent pay adjustment (PPA) by the quantity in the lot and the bid price for the HMA High RAP item.

Table 902.11.04-2 Performance Testing Pay Adjustments for HMA HIGH RAP					
	Surface Course		Intermediate Course		PPA
	PG 64-22	PG 76-22	PG 64-22	PG 76-22	
APA @ 8,000 loading cycles, mm (AASHTO T 340)	$t \leq 7$ $7 > t > 10$ $t \geq 10$	$t \leq 4$ $4 > t > 7$ $t \geq 7$	$t \leq 7$ $7 > t > 10$ $t \geq 10$	$t \leq 4$ $4 > t > 7$ $t \geq 7$	0 – 1 – 5
Overlay Tester, cycles (NJDOT B-10)	$t \geq 150$ $150 > t > 100$ $t \leq 100$	$t \geq 175$ $175 > t > 125$ $t \leq 125$	$t \geq 100$ $100 > t > 75$ $t \leq 75$	$t \geq 125$ $125 > t > 90$ $t \leq 90$	0 – 1 – 5

Plan Note: Polishing and Determining Friction of Gyratory Compacted Asphalt Specimens

On this project conduct laboratory polishing and friction measurement of the surface course asphalt mixture as described below. Conduct polishing and friction testing on the surface course mix design approval submittal samples and QC six inch diameter gyratory samples. For mix design approval submit two polished gyratory specimens with BPN friction measurements (per ASTM E 303) and two unpolished specimens with the submittal packet to the Laboratory. Submit tabular BPN vs time values for a friction degradation curve in electronic Excel format. For QC conduct polishing and BPN friction measurement on two polished gyratory specimens, one chosen randomly by the Contractor from the second day of production and one chosen randomly by the District from remaining surface course production. Submit tested QC samples and data to the Laboratory. Submit tabular BPN vs time values for a friction degradation curve in electronic Excel format with identification of the project and JMF. Use the Excel file layout available from FPO or the ODOT OMM lab. Note on the Excel file any notes of value such as if new or used polishing disc was used. Submit electronic TE-199s representing asphalt mix used for preparing the polished gyratory samples.

POLISHING AND DETERMINING FRICTION NUMBER OF GYRATORY COMPACTED SPECIMENS

Asphalt Polishing Machine Requirements
Asphalt Polishing Machine Operation
British Pendulum Testing for Determining British Pendulum Number
Laboratory Test Procedure for Friction Degradation Curve

Asphalt Polishing Machine Requirements. The Polisher is a laboratory accelerated polishing device to polish the cross sectional surface of a gyratory compacted asphalt mixture sample using a rotating rubber disc at a constant rotating speed and under constant vertical force. Ensure that the polishing machine meets the following requirements:

1. Hold a gyratory compacted asphalt mixture sample in place while it is being subjected to rotational polishing action on the cross sectional surface of the sample by a rubber polishing disc.

2. Accommodate a gyratory compacted sample size of 6 in (15.2 cm) diameter by 6 in (15.24 cm) height or 6 in (15.24 cm) diameter by 4 in (10.2 cm) height.

3. Maintain flat contact between the rubber polishing disc and the asphalt mixture sample cross sectional surface during the entire duration of polishing action .

4. Maintain a constant vertical force of 290 lb (131.5 kg) during polishing.

5. Maintain a constant rotational speed of the rubber polishing disc at 30 rpm.

6. Maintain constant water flow of 100 ml (3.38 oz) per minute onto the contact interface between the sample top surface and bottom surface of rubber disc during polishing. Provide an easily seen flow meter.

7. Automatic timer to shut off rubber polishing disc rotation at every one hour interval.

8. The rubber polishing disc is made of 90 Durometer SBR rubber.

Asphalt Polishing Machine Operation. The Polisher must be operated in accordance with the operator manual instructions. However, certain potential problems should be watched for.

1) The water flow rate is critical for maximizing the life of the rubber pad, but too much water will stop the wearing process on the aggregate. If the flow rate is set while the machine is stopped expect some flow rate change during operation. Set the flow rate to achieve the required flow rate of 100ml/minute during polisher operation. Experience will determine the best setting to start with to achieve the correct flow rate.
2) Some mix types with high friction aggregate like slag or crushed gravel will wear polishing discs quickly. If wear is excessive bits of rubber can clog the disc water flow channels. As needed, remove the pad or otherwise verify channels are clear for flow of water.
3) Even wear on the polishing disc is desired. Uneven wear with greater disc degradation towards the outside of the disc indicates uneven water flow.
4) Multiple discs may be necessary to complete a full cycle of polishing depending on aggregate type.
5) Evenly worn discs may be re-used.

British Pendulum Testing for Determining British Pendulum Number. Test samples with a calibrated British Pendulum Tester in accordance with ASTM E 303 to determine a British Pendulum Number (BPN). Record the final reading as the BPN for the asphalt mixture. Measure four BPN numbers and average for each test.

Laboratory Test Procedure for Friction Degradation Curve The Friction Degradation Curve is a curve obtained from tests using the Polisher. It is a curve showing the BPN values, measured by the British Pendulum Tester in accordance with ASTM E 303, versus polishing time at one hour intervals until reaching the 8-hour duration.

Two gyratory compacted samples prepared in accordance with the JMF are required. The procedure consists of the following steps.

Step 1: Measure the initial BPN of sample cross sectional surface using the British Pendulum Tester and record it as BPN_0 at time t_0.

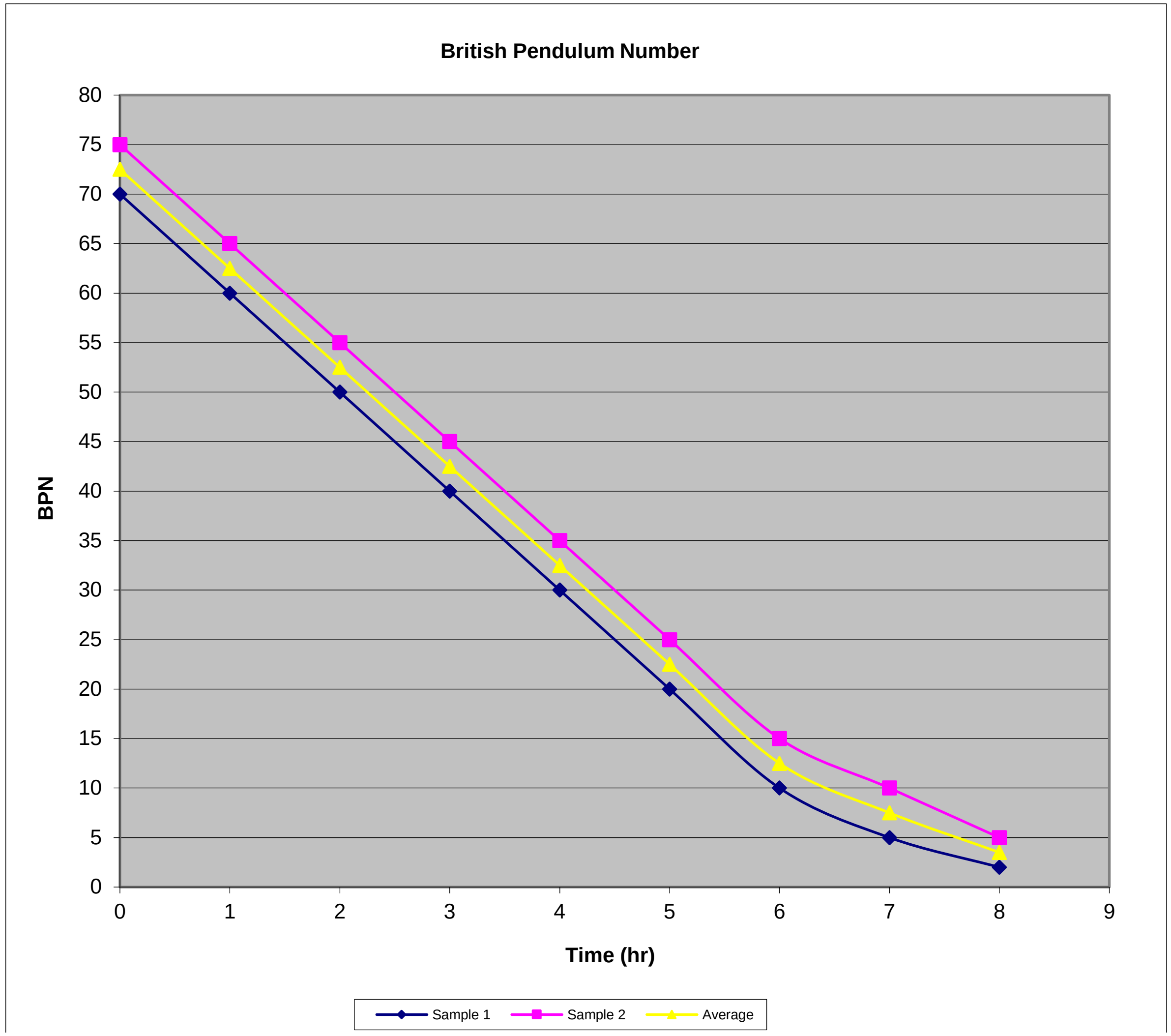
Step 2: Subject sample to one hour polishing in the Polisher.

Step 3: Measure the friction value using the British Pendulum Tester and record it as BPN at t, where t indicates accumulated polishing duration.

Repeat Step 2 and Step 3 for the next one-hour polishing and measurement, until a total of 8 hours polishing duration is complete.

Date	
Contractor Name	
JMF	
Project No.	
Mix type	442E00200 ASPHALT CONCRETE SURFACE COURSE, 9.5 MM, TYPE A (446)
Sample 1 Date/ time	
Sample 2 Date/ time	

	BPN Number		
Time (hr)	Sample 1	Sample 2	Average
0	70	75	73
1	60	65	63
2	50	55	53
3	40	45	43
4	30	35	33
5	20	25	23
6	10	15	13
7	5	10	8
8	2	5	4



Mix type
424E10000 FINE GRADED POLYMER ASPHALT CONCRETE, TYPE A
424E12000 FINE GRADED POLYMER ASPHALT CONCRETE, TYPE B
424E12001 FINE GRADED POLYMER ASPHALT CONCRETE, TYPE B, AS PER PLAN
424E12011 FINE GRADED POLYMER ASPHALT CONCRETE, TYPE B, WITH
424E99000 SPECIAL - FLEXIBLE PAVEMENT
442E00200 ASPHALT CONCRETE SURFACE COURSE, 9.5 MM, TYPE A (446)
442E00201 ASPHALT CONCRETE SURFACE COURSE, 9.5 MM, TYPE A (446), AS
442E00300 ASPHALT CONCRETE SURFACE COURSE, 9.5 MM, TYPE B (446)
442E00301 ASPHALT CONCRETE SURFACE COURSE, 9.5 MM, TYPE B (446), AS
442E10000 ASPHALT CONCRETE SURFACE COURSE, 12.5MM, TYPE A (446)
442E10001 ASPHALT CONCRETE SURFACE COURSE, 12.5 MM, TYPE A (446),
442E10002 ASPHALT CONCRETE SURFACE COURSE, 12.5MM, TYPE A (446) WITH
442E10003 ASPHALT CONCRETE SURFACE COURSE, 12.5MM, TYPE A (446) WITH
442E10050 ASPHALT CONCRETE SURFACE COURSE, 12.5MM, TYPE B (446)
442E10051 ASPHALT CONCRETE SURFACE COURSE, 12.5 MM, TYPE B (446),
442E10060 ASPHALT CONCRETE SURFACE COURSE, 12.5MM, TYPE B (446) WITH
442E10061 ASPHALT CONCRETE SURFACE COURSE, 12.5MM, TYPE B (446) WITH
442E10100 ASPHALT CONCRETE INTERMEDIATE COURSE, 19MM, TYPE A (446)
442E10101 ASPHALT CONCRETE INTERMEDIATE COURSE, 19 MM, TYPE A (446),
442E10150 ASPHALT CONCRETE INTERMEDIATE COURSE, 19MM, TYPE B (446)
442E10151 ASPHALT CONCRETE INTERMEDIATE COURSE, 19 MM, TYPE B (446),
442E10500 ASPHALT CONCRETE SURFACE COURSE, 9.5 MM, TYPE A (448)
442E10501 ASPHALT CONCRETE SURFACE COURSE, 9.5 MM, TYPE A (448), AS
442E10503 ASPHALT CONCRETE SURFACE COURSE, 9.5 MM, TYPE A (446)
442E10510 ASPHALT CONCRETE SURFACE COURSE, 9.5MM, TYPE A (448)
442E10511 ASPHALT CONCRETE SURFACE COURSE, 9.5MM, TYPE A (448)
442E10600 ASPHALT CONCRETE SURFACE COURSE, 9.5 MM, TYPE B (448)
442E10601 ASPHALT CONCRETE SURFACE COURSE, 9.5 MM, TYPE B (448), AS
442E20000 ASPHALT CONCRETE SURFACE COURSE, 12.5MM, TYPE A (448)
442E20001 ASPHALT CONCRETE SURFACE COURSE, 12.5 MM, TYPE A (448), AS
442E20010 ASPHALT CONCRETE SURFACE COURSE, 12.5MM, TYPE A (448)
442E20050 ASPHALT CONCRETE SURFACE COURSE, 12.5MM, TYPE B (448)
442E20051 ASPHALT CONCRETE SURFACE COURSE, 12.5 MM, TYPE B (448), AS

STATE OF OHIO
DEPARTMENT OF TRANSPORTATION

SUPPLEMENT SPECIFICATION 856

Bridge Deck Waterproofing
Hot Mix Asphalt Surface Course

October 18, 2013

856.01 Description

The requirements of C&MS 401, 442, 448 and 702.01 apply except as modified below. Bridge Deck Waterproofing Hot Mix Asphalt Surface Course (WHMA) is a highly polymer modified impermeable asphalt. In conjunction with preparation and sealing as described below the WHMA is designed to be a low maintenance waterproof wearing course system for bridge decks.

856.02 Materials

Aggregate: Do not use aggregate restricted as “SR or SRH” per 703.01.

RAP and RAS: Do not use any reclaimed asphalt pavement or reclaimed asphalt shingles.

Modified Asphalt Binder: Use a Supplement 1032 certified PG 88-22M binder meeting 702.01 requirements or provide an approved Thermoplastic Polymeric Asphalt Modifier (TPAM) added as a dry ingredient at the asphalt mix plant. Compose the TPAM modified binder with a minimum 2.25% TPAM modifier (by weight of mix) and minimum 5.00% (by weight of mix) neat Supplement 1032 certified PG 64-22 binder. Provide to the Engineer a signed certification statement from the thermoplastic polymeric asphalt (TPAM) supplier that the below modified binder properties are met. In addition, provide test data meeting the following properties from tests on modified binder that uses the PG 64-22 binder to be used on the project.

> **TPAM modified binder -** Meet PG 88-22 and Elastic recovery (ER) of 90.0 percent minimum using the ER procedure in 702.01 for PG 88-22M. (May exceed high temperature grade but do not exceed low temperature grade.)

Mix Design: Compose a Job Mix Formula (JMF) for the WHMA to meet the following properties. Submit a proposed JMF to the Laboratory for approval a minimum of two weeks before placement. If TPAM is used provide a mix design from the TPAM supplier meeting the following properties and submit using the ODOT JMF submittal packet. Ensure the JMF meets the gradation requirements for a 9.5mm mix in Table 442.02-2. Do not use any Warm Mix Asphalt method unless a component of the TPAM product.

JMF Criteria	Specification
Total Modified Binder, percent, min.	7.25
Gryations, Ndes/ Nmax	50/75
Air Voids, percent	1.5
VMA, percent, min.	15.5
Permeability, ft./day, max. [1]	2.8×10^{-4}
Rutting, mm, max. [2]	4
Flexural Beam Fatigue, cycles, min. [3]	100,000

[1] ASTM D5084 on samples with 2.0 +/- 0.5% percent air voids.
[2] AASHTO T340 (APA) on average of 3 gyratory specimens at 4.0 +/- 0.1% percent air voids at 147°F (64°C)
[3] Only required for steel deck bridges. AASHTO T321 at 1500 microstrains, 10Hz, on average of two samples with 4.0 +/- 1.0% air voids.

Edge and Joint Sealant
Meet ASTM D6690 Type 4. Submit a signed certification statement and test data to the Engineer and Laboratory representing the supplied batch. Supply a minimum 10 pound unheated sample taken at the project to the Laboratory.

Tack Coat
Use tack coat meeting 702.13. Do not dilute tack coat material. A neat PG64-22 binder may be substituted for the above 702.13 tack. When TPAM is used a special tack coat may be required by the manufacturer of the TPAM modifier.

856.03 Asphalt Plant Requirements
Do not use the Warm Mix Asphalt method with this item. For TPAM mixing do not use parallel flow drum plants. For TPAM mixing in batch plants dry mix for 10 seconds and then add the asphalt binder and wet mix for 80 seconds.

856.04 Construction
The Department will schedule a preconstruction meeting at least two weeks prior to the project start to discuss production and placement considerations of the WHMA. When producing asphalt mix using TPAM ensure a technical representative of the TPAM supplier is present at the meeting and during initial construction.

Ensure the existing pavement surface temperature is 50°F (10°C) and rising for placement of the WHMA. Ensure WHMA arrives at the paver above 330°F (166 °C) unless otherwise directed by the binder or TPAM supplier. Never exceed 370°F. Do not use rubber tire rollers. Use double drum steel rollers in static mode. Do not release the pavement to traffic until the temperature of the mat has dropped below 140ºF (60°C).

Quality Control
Conduct density gauge quality control testing on the asphalt mat according to Supplement 1055 except as follows. Do not calculate the Minimum Density Target from cores per Supplement 1055. The Minimum Density Target (lb/ft^3) will be calculated by taking 96 percent of the Theoretical Density (lb/ft^3) at

optimum binder content from the approved mix design. If a density gauge has a known correction factor apply this factor. If the correction factor is unknown use a factor of zero. Ensure only density gauge(s) corrected for the project are used on the project. If the Minimum Density Target is not achieved adjust rolling and re-measure in the same location immediately. If the Minimum Density Target cannot be achieved at this location stop placement and determine a plan of correction satisfactory to the Engineer. If the Minimum Density Target is achieved take readings every 20-50 feet depending on deck length. Do not apply the pay deductions of Table 1055.04-2.

Edge and Joint Sealant
Apply sealant 0.10 to 0.15 inch thick on all vertical surfaces in contact with WHMA and 2 to 4 inches wide on adjacent horizontal surfaces before and after WHMA placement. Vertical surfaces include curbs, parapet walls, headers, drains, scuppers, and joints as well as transverse and longitudinal joints in the WHMA. Do not apply a band more than 2 inches wide to the horizontal surface of WHMA transverse and longitudinal joints.

Tack Coat
Apply at a rate of 0.10 to 0.15 gallon per square yard. Ensure 100 percent of the existing surface is covered.

856.05 Production Quality Control
Modify the Air Voids specification limits of Table 441.10-1 to be 0.5% to 2.5%.

856.06 Payment
The Department will consider the unit bid price per cubic yard to include all labor, materials and equipment necessary to complete the work.

Designer Notes:

1) Do not use waterproofing fabric or similar under this waterproofing overlay.
2) Ensure project completion date is prior to November 1.

The WHMA is not intended to accommodate structural movements at the expansion joint locations. Provide a method for structural expansion separately

Item 340
Dense-Graded Hot-Mix Asphalt (Small Quantity)

1. DESCRIPTION

Construct a hot-mix asphalt (HMA) pavement layer composed of a compacted, dense-graded mixture of aggregate and asphalt binder mixed hot in a mixing plant. This specification is intended for small quantity (SQ) HMA projects, typically under 5,000 tons total production.

2. MATERIALS

Furnish uncontaminated materials of uniform quality that meet the requirements of the plans and specifications.

Notify the Engineer of all material sources and before changing any material source or formulation. The Engineer will verify that the specification requirements are met when the Contractor makes a source or formulation change, and may require a new laboratory mixture design, trial batch, or both. The Engineer may sample and test project materials at any time during the project to verify specification compliance in accordance with Item 6, "Control of Materials."

2.1. **Aggregate**. Furnish aggregates from sources that conform to the requirements shown in Table 1 and as specified in this Section. Aggregate requirements in this Section, including those shown in Table 1, may be modified or eliminated when shown on the plans. Additional aggregate requirements may be specified when shown on the plans. Provide aggregate stockpiles that meet the definitions in this Section for coarse, intermediate, or fine aggregate. Aggregate from reclaimed asphalt pavement (RAP) is not required to meet Table 1 requirements unless otherwise shown on the plans. Supply aggregates that meet the definitions in Tex-100-E for crushed gravel or crushed stone. The Engineer will designate the plant or the quarry as the sampling location. Provide samples from materials produced for the project. The Engineer will establish the Surface Aggregate Classification (SAC) and perform Los Angeles abrasion, magnesium sulfate soundness, and Micro-Deval tests. Perform all other aggregate quality tests listed in Table 1. Document all test results on the mixture design report. The Engineer may perform tests on independent or split samples to verify Contractor test results. Stockpile aggregates for each source and type separately. Determine aggregate gradations for mixture design and production testing based on the washed sieve analysis given in Tex-200-F, Part II.

2.1.1. **Coarse Aggregate**. Coarse aggregate stockpiles must have no more than 20% material passing the No. 8 sieve. Aggregates from sources listed in the Department's *Bituminous Rated Source Quality Catalog* (BRSQC) are preapproved for use. Use only the rated values for hot-mix listed in the BRSQC. Rated values for surface treatment (ST) do not apply to coarse aggregate sources used in hot-mix asphalt.

For sources not listed on the Department's BRSQC:

- build an individual stockpile for each material;
- request the Department test the stockpile for specification compliance; and
- once approved, do not add material to the stockpile unless otherwise approved.

Provide aggregate from non-listed sources only when tested by the Engineer and approved before use. Allow 30 calendar days for the Engineer to sample, test, and report results for non-listed sources.

Provide coarse aggregate with at least the minimum SAC shown on the plans. SAC requirements only apply to aggregates used on the surface of travel lanes. SAC requirements apply to aggregates used on surfaces other than travel lanes when shown on the plans. The SAC for sources on the Department's *Aggregate Quality Monitoring Program* (AQMP) (Tex-499-A) is listed in the BRSQC.

2.1.1.1. **Blending Class A and Class B Aggregates**. Class B aggregate meeting all other requirements in Table 1 may be blended with a Class A aggregate to meet requirements for Class A materials. Ensure that at least 50% by weight, or volume if required, of the material retained on the No. 4 sieve comes from the Class A aggregate source when blending Class A and B aggregates to meet a Class A requirement. Blend by volume if the bulk specific gravities of the Class A and B aggregates differ by more than 0.300. Coarse aggregate from RAP and Recycled Asphalt Shingles (RAS) will be considered as Class B aggregate for blending purposes.

The Engineer may perform tests at any time during production, when the Contractor blends Class A and B aggregates to meet a Class A requirement, to ensure that at least 50% by weight, or volume if required, of the material retained on the No. 4 sieve comes from the Class A aggregate source. The Engineer will use the Department's mix design Excel template, when electing to verify conformance, to calculate the percent of Class A aggregate retained on the No. 4 sieve by inputting the bin percentages shown from readouts in the control room at the time of production and stockpile gradations measured at the time of production. The Engineer may determine the gradations based on either washed or dry sieve analysis from samples obtained from individual aggregate cold feed bins or aggregate stockpiles. The Engineer may perform spot checks using the gradations supplied by the Contractor on the mixture design report as an input for the Excel template; however, a failing spot check will require confirmation with a stockpile gradation determined by the Engineer.

2.1.2. **Intermediate Aggregate**. Aggregates not meeting the definition of coarse or fine aggregate will be defined as intermediate aggregate. Supply intermediate aggregates, when used, that are free from organic impurities.

The Engineer may test the intermediate aggregate in accordance with Tex-408-A to verify the material is free from organic impurities. Supply intermediate aggregate from coarse aggregate sources, when used, that meet the requirements shown in Table 1 unless otherwise approved.

Test the stockpile if 10% or more of the stockpile is retained on the No. 4 sieve, and verify that it meets the requirements in Table 1 for crushed face count (Tex-460-A) and flat and elongated particles (Tex-280-F).

2.1.3. **Fine Aggregate**. Fine aggregates consist of manufactured sands, screenings, and field sands. Fine aggregate stockpiles must meet the gradation requirements in Table 2. Supply fine aggregates that are free from organic impurities. The Engineer may test the fine aggregate in accordance with Tex-408-A to verify the material is free from organic impurities. No more than 15% of the total aggregate may be field sand or other uncrushed fine aggregate. Use fine aggregate, with the exception of field sand, from coarse aggregate sources that meet the requirements shown in Table 1 unless otherwise approved.

Test the stockpile if 10% or more of the stockpile is retained on the No. 4 sieve, and verify that it meets the requirements in Table 1 for crushed face count (Tex-460-A) and flat and elongated particles (Tex-280-F).

Table 1
Aggregate Quality Requirements

Property	Test Method	Requirement
Coarse Aggregate		
SAC	Tex-499-A (AQMP)	As shown on the plans
Deleterious material, %, Max	Tex-217-F, Part I	1.5
Decantation, %, Max	Tex-217-F, Part II	1.5
Micro-Deval abrasion, %	Tex-461-A	Note[1]
Los Angeles abrasion, %, Max	Tex-410-A	40
Magnesium sulfate soundness, 5 cycles, %, Max	Tex-411-A	30
Crushed face count,[2] %, Min	Tex-460-A, Part I	85
Flat and elongated particles @ 5:1, %, Max	Tex-280-F	10
Fine Aggregate		
Linear shrinkage, %, Max	Tex-107-E	3
Combined Aggregate[3]		
Sand equivalent, %, Min	Tex-203-F	45

1. Not used for acceptance purposes. Optional test used by the Engineer as an indicator of the need for further investigation.
2. Only applies to crushed gravel.
3. Aggregates, without mineral filler, RAP, RAS, or additives, combined as used in the job-mix formula (JMF).

Table 2
Gradation Requirements for Fine Aggregate

Sieve Size	% Passing by Weight or Volume
3/8"	100
#8	70–100
#200	0–30

2.2. **Mineral Filler**. Mineral filler consists of finely divided mineral matter such as agricultural lime, crusher fines, hydrated lime, or fly ash. Mineral filler is allowed unless otherwise shown on the plans. Use no more than 2% hydrated lime or fly ash unless otherwise shown on the plans. Use no more than 1% hydrated lime if a substitute binder is used unless otherwise shown on the plans or allowed. Test all mineral fillers except hydrated lime and fly ash in accordance with Tex-107-E to ensure specification compliance. The plans may require or disallow specific mineral fillers. Provide mineral filler, when used, that:

- is sufficiently dry, free-flowing, and free from clumps and foreign matter as determined by the Engineer;
- does not exceed 3% linear shrinkage when tested in accordance with Tex-107-E; and
- meets the gradation requirements in Table 3.

Table 3
Gradation Requirements for Mineral Filler

Sieve Size	% Passing by Weight or Volume
#8	100
#200	55–100

2.3. **Baghouse Fines**. Fines collected by the baghouse or other dust-collecting equipment may be reintroduced into the mixing drum.

2.4. **Asphalt Binder**. Furnish the type and grade of performance-graded (PG) asphalt specified on the plans.

2.5. **Tack Coat**. Furnish CSS-1H, SS-1H, or a PG binder with a minimum high-temperature grade of PG 58 for tack coat binder in accordance with Item 300, "Asphalts, Oils, and Emulsions." Specialized or preferred tack coat materials may be allowed or required when shown on the plans. Do not dilute emulsified asphalts at the terminal, in the field, or at any other location before use.

The Engineer will obtain at least one sample of the tack coat binder per project in accordance with Tex-500-C, Part III, and test it to verify compliance with Item 300, "Asphalts, Oils, and Emulsions." The Engineer will obtain the sample from the asphalt distributor immediately before use.

2.6. **Additives**. Use the type and rate of additive specified when shown on the plans. Additives that facilitate mixing, compaction, or improve the quality of the mixture are allowed when approved. Provide the Engineer with documentation, such as the bill of lading, showing the quantity of additives used in the project unless otherwise directed.

2.6.1. **Lime and Liquid Antistripping Agent**. When lime or a liquid antistripping agent is used, add in accordance with Item 301, "Asphalt Antistripping Agents." Do not add lime directly into the mixing drum of any plant where lime is removed through the exhaust stream unless the plant has a baghouse or dust collection system that reintroduces the lime into the drum.

2.6.2. **Warm Mix Asphalt (WMA)**. Warm Mix Asphalt (WMA) is defined as HMA that is produced within a target temperature discharge range of 215°F and 275°F using approved WMA additives or processes from the Department's MPL.

WMA is allowed for use on all projects and is required when shown on the plans. When WMA is required, the maximum placement or target discharge temperature for WMA will be set at a value below 275°F.

Department-approved WMA additives or processes may be used to facilitate mixing and compaction of HMA produced at target discharge temperatures above 275°F; however, such mixtures will not be defined as WMA.

2.7. **Recycled Materials**. Use of RAP and RAS is permitted unless otherwise shown on the plans. Do not exceed the maximum allowable percentages of RAP and RAS shown in Table 4. The allowable percentages shown in Table 4 may be decreased or increased when shown on the plans. Determine asphalt binder content and gradation of the RAP and RAS stockpiles for mixture design purposes in accordance with Tex-236-F. The Engineer may verify the asphalt binder content of the stockpiles at any time during production. Perform other tests on RAP and RAS when shown on the plans. Asphalt binder from RAP and RAS is designated as recycled asphalt binder. Calculate and ensure that the ratio of the recycled asphalt binder to total binder does not exceed the percentages shown in Table 5 during mixture design and HMA production when RAP or RAS is used. Use a separate cold feed bin for each stockpile of RAP and RAS during HMA production.

Surface, intermediate, and base mixes referenced in Tables 4 and 5 are defined as follows:

- **Surface**. The final HMA lift placed at or near the top of the pavement structure;
- **Intermediate**. Mixtures placed below an HMA surface mix and less than or equal to 8.0 in. from the riding surface; and
- **Base**. Mixtures placed greater than 8.0 in. from the riding surface.

2.7.1. **RAP**. RAP is salvaged, milled, pulverized, broken, or crushed asphalt pavement. Crush or break RAP so that 100% of the particles pass the 2 in. sieve. Fractionated RAP is defined as 2 or more RAP stockpiles, divided into coarse and fine fractions.

Use of Contractor-owned RAP, including HMA plant waste, is permitted unless otherwise shown on the plans. Department-owned RAP stockpiles are available for the Contractor's use when the stockpile locations are shown on the plans. If Department-owned RAP is available for the Contractor's use, the Contractor may use Contractor-owned fractionated RAP and replace it with an equal quantity of Department-owned RAP. This allowance does not apply to a Contractor using unfractionated RAP. Department-owned RAP generated through required work on the Contract is available for the Contractor's use when shown on the plans. Perform any necessary tests to ensure Contractor- or Department-owned RAP is appropriate for use. The Department will not perform any tests or assume any liability for the quality of the Department-owned RAP unless otherwise shown on the plans. The Contractor will retain ownership of RAP generated on the project when shown on the plans.

The coarse RAP stockpile will contain only material retained by processing over a 3/8-in. or 1/2-in. screen unless otherwise approved. The fine RAP stockpile will contain only material passing the 3/8-in. or 1/2-in. screen unless otherwise approved. The Engineer may allow the Contractor to use an alternate to the 3/8-in. or 1/2-in. screen to fractionate the RAP. The maximum percentages of fractionated RAP may be comprised of coarse or fine fractionated RAP or the combination of both coarse and fine fractionated RAP.

Do not use Department- or Contractor-owned RAP contaminated with dirt or other objectionable materials. Do not use Department- or Contractor-owned RAP if the decantation value exceeds 5% and the plasticity index is greater than 8. Test the stockpiled RAP for decantation in accordance with Tex-406-A, Part I. Determine the plasticity index in accordance with Tex-106-E if the decantation value exceeds 5%. The decantation and plasticity index requirements do not apply to RAP samples with asphalt removed by extraction or ignition.

Do not intermingle Contractor-owned RAP stockpiles with Department-owned RAP stockpiles. Remove unused Contractor-owned RAP material from the project site upon completion of the project. Return unused Department-owned RAP to the designated stockpile location.

Table 4
Maximum Allowable Amounts of RAP[1]

Maximum Allowable Fractionated RAP[2] (%)			Maximum Allowable Unfractionated RAP[3] (%)		
Surface	Intermediate	Base	Surface	Intermediate	Base
20.0	30.0	40.0	10.0	10.0	10.0

1. Must also meet the recycled binder to total binder ratio shown in Table 5.
2. Up to 5% RAS may be used separately or as a replacement for fractionated RAP.
3. Unfractionated RAP may not be combined with fractionated RAP or RAS.

2.7.2. **RAS**. Use of post-manufactured RAS or post-consumer RAS (tear-offs) is permitted unless otherwise shown on the plans. Up to 5% RAS may be used separately or as a replacement for fractionated RAP in accordance with Table 4 and Table 5. RAS is defined as processed asphalt shingle material from manufacturing of asphalt roofing shingles or from re-roofing residential structures. Post-manufactured RAS is processed manufacturer's shingle scrap by-product. Post-consumer RAS is processed shingle scrap removed from residential structures. Comply with all regulatory requirements stipulated for RAS by the TCEQ. RAS may be used separately or in conjunction with RAP.

Process the RAS by ambient grinding or granulating such that 100% of the particles pass the 3/8 in. sieve when tested in accordance with Tex-200-F, Part I. Perform a sieve analysis on processed RAS material before extraction (or ignition) of the asphalt binder.

Add sand meeting the requirements of Table 1 and Table 2 or fine RAP to RAS stockpiles if needed to keep the processed material workable. Any stockpile that contains RAS will be considered a RAS stockpile and be limited to no more than 5.0% of the HMA mixture in accordance with Table 4.

Certify compliance of the RAS with DMS-11000, "Evaluating and Using Nonhazardous Recyclable Materials Guidelines." Treat RAS as an established nonhazardous recyclable material if it has not come into contact with any hazardous materials. Use RAS from shingle sources on the Department's MPL. Remove substantially all materials before use that are not part of the shingle, such as wood, paper, metal, plastic, and felt paper. Determine the deleterious content of RAS material for mixture design purposes in accordance with Tex-217-F, Part III. Do not use RAS if deleterious materials are more than 0.5% of the stockpiled RAS unless otherwise approved. Submit a sample for approval before submitting the mixture design. The Department will perform the testing for deleterious material of RAS to determine specification compliance.

2.8. **Substitute Binders**. Unless otherwise shown on the plans, the Contractor may use a substitute PG binder listed in Table 5 instead of the PG binder originally specified, if the substitute PG binder and mixture made with the substitute PG binder meet the following:

- the substitute binder meets the specification requirements for the substitute binder grade in accordance with Section 300.2.10., "Performance-Graded Binders"; and
- the mixture has less than 10.0 mm of rutting on the Hamburg Wheel test (Tex-242-F) after the number of passes required for the originally specified binder. Use of substitute PG binders may only be allowed at the discretion of the Engineer if the Hamburg Wheel test results are between 10.0 mm and 12.5 mm.

Table 5
Allowable Substitute PG Binders and Maximum Recycled Binder Ratios

Originally Specified PG Binder	Allowable Substitute PG Binder	Maximum Ratio of Recycled Binder[1] to Total Binder (%)		
		Surface	Intermediate	Base
HMA				
76-22[2]	70-22 or 64-22	20.0	20.0	20.0
	70-28 or 64-28	30.0	35.0	40.0
70-22[2]	64-22	20.0	20.0	20.0
	64-28 or 58-28	30.0	35.0	40.0
64-22[2]	58-28	30.0	35.0	40.0
76-28[2]	70-28 or 64-28	20.0	20.0	20.0
	64-34	30.0	35.0	40.0
70-28[2]	64-28 or 58-28	20.0	20.0	20.0
	64-34 or 58-34	30.0	35.0	40.0
64-28[2]	58-28	20.0	20.0	20.0
	58-34	30.0	35.0	40.0
WMA[3]				
76-22[2]	70-22 or 64-22	30.0	35.0	40.0
70-22[2]	64-22 or 58-28	30.0	35.0	40.0
64-22[4]	58-28	30.0	35.0	40.0
76-28[2]	70-28 or 64-28	30.0	35.0	40.0
70-28[2]	64-28 or 58-28	30.0	35.0	40.0
64-28[4]	58-28	30.0	35.0	40.0

1. Combined recycled binder from RAP and RAS.
2. Use no more than 20.0% recycled binder when using this originally specified PG binder.
3. WMA as defined in Section 340.2.6.2., "Warm Mix Asphalt (WMA)."
4. When used with WMA, this originally specified PG binder is allowed for use at the maximum recycled binder ratios shown in this table.

3. EQUIPMENT

Provide required or necessary equipment in accordance with Item 320, "Equipment for Asphalt Concrete Pavement."

4. CONSTRUCTION

Produce, haul, place, and compact the specified paving mixture. In addition to tests required by the specification, Contractors may perform other QC tests as deemed necessary. At any time during the project, the Engineer may perform production and placement tests as deemed necessary in accordance with Item 5, "Control of the Work." Schedule and participate in a pre-paving meeting with the Engineer on or before the first day of paving unless otherwise directed.

4.1. **Certification**. Personnel certified by the Department-approved hot-mix asphalt certification program must conduct all mixture designs, sampling, and testing in accordance with Table 6. Supply the Engineer with a list of certified personnel and copies of their current certificates before beginning production and when personnel changes are made. Provide a mixture design developed and signed by a Level 2 certified specialist.

Table 6
Test Methods, Test Responsibility, and Minimum Certification Levels

Test Description	Test Method	Contractor	Engineer	Level[1]
1. Aggregate and Recycled Material Testing				
Sampling	Tex-221-F	✓	✓	1A
Dry sieve	Tex-200-F, Part I	✓	✓	1A
Washed sieve	Tex-200-F, Part II	✓	✓	1A
Deleterious material	Tex-217-F, Parts I & III	✓	✓	1A
Decantation	Tex-217-F, Part II	✓	✓	1A
Los Angeles abrasion	Tex-410-A		✓	TxDOT
Magnesium sulfate soundness	Tex-411-A		✓	TxDOT
Micro-Deval abrasion	Tex-461-A		✓	2
Crushed face count	Tex-460-A	✓	✓	2
Flat and elongated particles	Tex-280-F	✓	✓	2
Linear shrinkage	Tex-107-E	✓	✓	2
Sand equivalent	Tex-203-F	✓	✓	2
Organic impurities	Tex-408-A	✓	✓	2
2. Asphalt Binder & Tack Coat Sampling				
Asphalt binder sampling	Tex-500-C, Part II	✓	✓	1A/1B
Tack coat sampling	Tex-500-C, Part III	✓	✓	1A/1B
3. Mix Design & Verification				
Design and JMF changes	Tex-204-F	✓	✓	2
Mixing	Tex-205-F	✓	✓	2
Molding (TGC)	Tex-206-F	✓	✓	1A
Molding (SGC)	Tex-241-F	✓	✓	1A
Laboratory-molded density	Tex-207-F	✓	✓	1A
VMA[2] (calculation only)	Tex-204-F	✓	✓	2
Rice gravity	Tex-227-F	✓	✓	1A
Ignition oven correction factors[3]	Tex-236-F	✓	✓	2
Indirect tensile strength	Tex-226-F	✓	✓	2
Hamburg Wheel test	Tex-242-F	✓	✓	2
Boil test	Tex-530-C	✓	✓	1A
4. Production Testing				
Mixture sampling	Tex-222-F	✓	✓	1A
Molding (TGC)	Tex-206-F		✓	1A
Molding (SGC)	Tex-241-F		✓	1A
Laboratory-molded density	Tex-207-F		✓	1A
VMA[2] (calculation only)	Tex-204-F		✓	1A
Rice gravity	Tex-227-F		✓	1A
Gradation & asphalt binder content[3]	Tex-236-F		✓	1A
Moisture content	Tex-212-F		✓	1A
Hamburg Wheel test	Tex-242-F		✓	2
Boil test	Tex-530-C		✓	1A
5. Placement Testing				
Trimming roadway cores	Tex-207-F	✓	✓	1A/1B
In-place air voids	Tex-207-F		✓	1A/1B
Establish rolling pattern	Tex-207-F	✓		1B
Ride quality measurement	Tex-1001-S	✓	✓	Note[4]

1. Level 1A, 1B, and 2 are certification levels provided by the Hot Mix Asphalt Center certification program.
2. Voids in mineral aggregates.
3. Refer to Section 340.4.8.3., "Production Testing," for exceptions to using an ignition oven.
4. Profiler and operator are required to be certified at the Texas A&M Transportation Institute facility when Surface Test Type B is specified.

4.2. **Reporting, Testing, and Responsibilities**. Use Department-provided Excel templates to record and calculate all test data pertaining to the mixture design. The Engineer will use Department Excel templates for any production and placement testing. Obtain the latest version of the Excel templates at http://www.txdot.gov/inside-txdot/forms-publications/consultants-contractors/forms/site-manager.html or from the Engineer.

The maximum allowable time for the Engineer to exchange test data with the Contractor is as given in Table 7 unless otherwise approved. The Engineer will immediately report to the Contractor any test result that requires suspension of production or placement or that fails to meet the specification requirements.

Subsequent mix placed after test results are available to the Contractor, which require suspension of operations, may be considered unauthorized work. Unauthorized work will be accepted or rejected at the discretion of the Engineer in accordance with Article 5.3., "Conformity with Plans, Specifications, and Special Provisions."

Table 7
Reporting Schedule

Description	Reported By	Reported To	To Be Reported Within
Production Testing			
Gradation	Engineer	Contractor	1 working day of completion of the test
Asphalt binder content			
Laboratory-molded density			
VMA (calculation)			
Hamburg Wheel test			
Moisture content			
Boil test			
Binder tests			
Placement Testing			
In-place air voids	Engineer	Contractor	1 working day of completion of the test[1]

1. 2 days are allowed if cores cannot be dried to constant weight within 1 day.

4.3. **Mixture Design**.

4.3.1. **Design Requirements**. The Contractor may design the mixture using a Texas Gyratory Compactor (TGC) or a Superpave Gyratory Compactor (SGC) unless otherwise shown on the plans. Use the typical weight design example given in Tex-204-F, Part I, when using a TGC. Use the Superpave mixture design procedure given in Tex-204-F, Part IV, when using a SGC. Design the mixture to meet the requirements listed in Tables 1, 2, 3, 4, 5, 8, 9, and 10.

4.3.1.1. **Target Laboratory-Molded Density When The TGC Is Used**. Design the mixture at a 96.5% target laboratory-molded density. Increase the target laboratory-molded density to 97.0% or 97.5% at the Contractor's discretion or when shown on the plans or specification.

4.3.1.2. **Design Number of Gyrations (Ndesign) When The SGC Is Used**. Design the mixture at 50 gyrations (Ndesign). Use a target laboratory-molded density of 96.0% to design the mixture; however, adjustments can be made to the Ndesign value as noted in Table 9. The Ndesign level may be reduced to no less than 35 gyrations at the Contractor's discretion.

Use an approved laboratory from the Department's MPL to perform the Hamburg Wheel test in accordance with Tex-242-F, and provide results with the mixture design, or provide the laboratory mixture and request that the Department perform the Hamburg Wheel test. The Engineer will be allowed 10 working days to provide the Contractor with Hamburg Wheel test results on the laboratory mixture design.

The Engineer will provide the mixture design when shown on the plans. The Contractor may submit a new mixture design at any time during the project. The Engineer will verify and approve all mixture designs (JMF1) before the Contractor can begin production.

Provide the Engineer with a mixture design report using the Department-provided Excel template. Include the following items in the report:

- the combined aggregate gradation, source, specific gravity, and percent of each material used;
- asphalt binder content and aggregate gradation of RAP and RAS stockpiles;
- the target laboratory-molded density (or Ndesign level when using the SGC);

- results of all applicable tests;
- the mixing and molding temperatures;
- the signature of the Level 2 person or persons that performed the design;
- the date the mixture design was performed; and
- a unique identification number for the mixture design.

Table 8
Master Gradation Limits (% Passing by Weight or Volume) and VMA Requirements

Sieve Size	A Coarse Base	B Fine Base	C Coarse Surface	D Fine Surface	F Fine Mixture
2"	100.0[1]	–	–	–	–
1-1/2"	98.0–100.0	100.0[1]	–	–	–
1"	78.0–94.0	98.0–100.0	100.0[1]	–	–
3/4"	64.0–85.0	84.0–98.0	95.0–100.0	100.0[1]	–
1/2"	50.0–70.0	–	–	98.0–100.0	100.0[1]
3/8"	–	60.0–80.0	70.0–85.0	85.0–100.0	98.0–100.0
#4	30.0–50.0	40.0–60.0	43.0–63.0	50.0–70.0	70.0–90.0
#8	22.0–36.0	29.0–43.0	32.0–44.0	35.0–46.0	38.0–48.0
#30	8.0–23.0	13.0–28.0	14.0–28.0	15.0–29.0	12.0–27.0
#50	3.0–19.0	6.0–20.0	7.0–21.0	7.0–20.0	6.0–19.0
#200	2.0–7.0	2.0–7.0	2.0–7.0	2.0–7.0	2.0–7.0
Design VMA, % Minimum					
–	12.0	13.0	14.0	15.0	16.0
Production (Plant-Produced) VMA, % Minimum					
–	11.5	12.5	13.5	14.5	15.5

1. Defined as maximum sieve size. No tolerance allowed.

Table 9
Laboratory Mixture Design Properties

Mixture Property	Test Method	Requirement
Target laboratory-molded density, % (TGC)	Tex-207-F	96.5[1]
Design gyrations (Ndesign for SGC)	Tex-241-F	50[2]
Indirect tensile strength (dry), psi	Tex-226-F	85–200[3]
Boil test[4]	Tex-530-C	–

1. Increase to 97.0% or 97.5% at the Contractor's discretion or when shown on the plans or specification.
2. Adjust within a range of 35–100 gyrations when shown on the plans or specification or when mutually agreed between the Engineer and Contractor.
3. The Engineer may allow the IDT strength to exceed 200 psi if the corresponding Hamburg Wheel rut depth is greater than 3.0 mm and less than 12.5 mm.
4. Used to establish baseline for comparison to production results. May be waived when approved.

Table 10
Hamburg Wheel Test Requirements

High-Temperature Binder Grade	Test Method	Minimum # of Passes[1] @ 12.5 mm[2] Rut Depth, Tested @ 50°C
PG 64 or lower	Tex-242-F	10,000
PG 70		15,000
PG 76 or higher		20,000

1. May be decreased or waived when shown on the plans.
2. When the rut depth at the required minimum number of passes is less than 3 mm, the Engineer may require the Contractor to increase the target laboratory-molded density (TGC) by 0.5% to no more than 97.5% or lower the Ndesign level (SGC) to no less than 35 gyrations.

4.3.2. **Job-Mix Formula Approval.** The job-mix formula (JMF) is the combined aggregate gradation, target laboratory-molded density (or Ndesign level), and target asphalt percentage used to establish target values for hot-mix production. JMF1 is the original laboratory mixture design used to produce the trial batch. When WMA is used, JMF1 may be designed and submitted to the Engineer without including the WMA additive. When WMA is used, document the additive or process used and recommended rate on the JMF1 submittal. Furnish a mix design report (JMF1) with representative samples of all component materials and request approval to produce the trial batch. Provide approximately 10,000 g of the design mixture and request that the Department perform the Hamburg Wheel test if opting to have the Department perform the test. The Engineer will verify JMF1 based on plant-produced mixture from the trial batch unless otherwise determined. The Engineer may accept an existing mixture design previously used on a Department project and may waive the trial batch to verify JMF1. Provide split samples of the mixtures and blank samples used to determine the ignition oven correction factors. The Engineer will determine the aggregate and asphalt correction factors from the ignition oven used for production testing in accordance with Tex-236-F.

The Engineer will use a TGC calibrated in accordance with Tex-914-K in molding production samples. Provide an SGC at the Engineer's field laboratory for use in molding production samples if the SGC is used to design the mix.

The Engineer may perform Tex-530-C and retain the tested sample for comparison purposes during production. The Engineer may waive the requirement for the boil test.

4.3.3. **JMF Adjustments**. If JMF adjustments are necessary to achieve the specified requirements, the adjusted JMF must:

- be provided to the Engineer in writing before the start of a new lot;
- be numbered in sequence to the previous JMF;
- meet the mixture requirements in Table 4 and Table 5;
- meet the master gradation limits shown in Table 8; and
- be within the operational tolerances of the current JMF listed in Table 11.

The Engineer may adjust the asphalt binder content to maintain desirable laboratory density near the optimum value while achieving other mix requirements.

Table 11
Operational Tolerances

Description	Test Method	Allowable Difference Between Trial Batch and JMF1 Target	Allowable Difference from Current JMF Target
Individual % retained for #8 sieve and larger	Tex-200-F or Tex-236-F	Must be within master grading limits in Table 8	±5.0[1,2]
Individual % retained for sieves smaller than #8 and larger than #200			±3.0[1,2]
% passing the #200 sieve			±2.0[1,2]
Asphalt binder content, %	Tex-236-F	±0.5	±0.3[2]
Laboratory-molded density, %	Tex-207-F	±1.0	±1.0
VMA, %, min	Tex-204-F	Note[3]	Note[3]

1. When within these tolerances, mixture production gradations may fall outside the master grading limits; however, the % passing the #200 will be considered out of tolerance when outside the master grading limits.
2. Only applies to mixture produced for Lot 1 and higher.
3. Mixture is required to meet Table 8 requirements.

4.4. **Production Operations**. Perform a new trial batch when the plant or plant location is changed. Take corrective action and receive approval to proceed after any production suspension for noncompliance to the specification. Submit a new mix design and perform a new trial batch when the asphalt binder content of:

- any RAP stockpile used in the mix is more than 0.5% higher than the value shown on the mixture design report; or
- RAS stockpile used in the mix is more than 2.0% higher than the value shown on the mixture design report.

4.4.1. **Storage and Heating of Materials**. Do not heat the asphalt binder above the temperatures specified in Item 300, "Asphalts, Oils, and Emulsions," or outside the manufacturer's recommended values. Provide the Engineer with daily records of asphalt binder and hot-mix asphalt discharge temperatures (in legible and discernible increments) in accordance with Item 320, “Equipment for Asphalt Concrete Pavement,” unless otherwise directed. Do not store mixture for a period long enough to affect the quality of the mixture, nor in any case longer than 12 hr. unless otherwise approved.

4.4.2. **Mixing and Discharge of Materials**. Notify the Engineer of the target discharge temperature and produce the mixture within 25°F of the target. Monitor the temperature of the material in the truck before shipping to ensure that it does not exceed 350°F (or 275°F for WMA) and is not lower than 215°F. The Department will not pay for or allow placement of any mixture produced above 350°F.

Produce WMA within the target discharge temperature range of 215°F and 275°F when WMA is required. Take corrective action any time the discharge temperature of the WMA exceeds the target discharge range. The Engineer may suspend production operations if the Contractor’s corrective action is not successful at controlling the production temperature within the target discharge range. Note that when WMA is produced, it may be necessary to adjust burners to ensure complete combustion such that no burner fuel residue remains in the mixture.

Control the mixing time and temperature so that substantially all moisture is removed from the mixture before discharging from the plant. The Engineer may determine the moisture content by oven-drying in accordance with Tex-212-F, Part II, and verify that the mixture contains no more than 0.2% of moisture by weight. The Engineer will obtain the sample immediately after discharging the mixture into the truck, and will perform the test promptly.

4.5. **Hauling Operations**. Clean all truck beds before use to ensure that mixture is not contaminated. Use a release agent shown on the Department’s MPL to coat the inside bed of the truck when necessary.

Use equipment for hauling as defined in Section 340.4.6.3.2., “Hauling Equipment.” Use other hauling equipment only when allowed.

4.6. **Placement Operations**. Collect haul tickets from each load of mixture delivered to the project and provide the Department’s copy to the Engineer approximately every hour, or as directed. Use a hand-held thermal camera or infrared thermometer to measure and record the internal temperature of the mixture as discharged from the truck or Material Transfer Device (MTD) before or as the mix enters the paver and an approximate station number or GPS coordinates on each ticket unless otherwise directed. Calculate the daily yield and cumulative yield for the specified lift and provide to the Engineer at the end of paving operations for each day unless otherwise directed. The Engineer may suspend production if the Contractor fails to produce and provide haul tickets and yield calculations by the end of paving operations for each day.

Prepare the surface by removing raised pavement markers and objectionable material such as moisture, dirt, sand, leaves, and other loose impediments from the surface before placing mixture. Remove vegetation from pavement edges. Place the mixture to meet the typical section requirements and produce a smooth, finished surface with a uniform appearance and texture. Offset longitudinal joints of successive courses of hot-mix by at least 6 in. Place mixture so that longitudinal joints on the surface course coincide with lane lines, or as directed. Ensure that all finished surfaces will drain properly.

Place the mixture at the rate or thickness shown on the plans. The Engineer will use the guidelines in Table 12 to determine the compacted lift thickness of each layer when multiple lifts are required. The thickness determined is based on the rate of 110 lb./sq. yd. for each inch of pavement unless otherwise shown on the plans.

Table 12
Compacted Lift Thickness and Required Core Height

Mixture Type	Compacted Lift Thickness Guidelines		Minimum Untrimmed Core Height (in.) Eligible for Testing
	Minimum (in.)	Maximum (in.)	
A	3.00	6.00	2.00
B	2.50	5.00	1.75
C	2.00	4.00	1.50
D	1.50	3.00	1.25
F	1.25	2.50	1.25

4.6.1. **Weather Conditions**. Place mixture when the roadway surface temperature is at or above 60°F unless otherwise approved. Measure the roadway surface temperature with a hand-held thermal camera or infrared thermometer. The Engineer may allow mixture placement to begin before the roadway surface reaches the required temperature if conditions are such that the roadway surface will reach the required temperature within 2 hr. of beginning placement operations. Place mixtures only when weather conditions and moisture conditions of the roadway surface are suitable as determined by the Engineer. The Engineer may restrict the Contractor from paving if the ambient temperature is likely to drop below 32°F within 12 hr. of paving.

4.6.2. **Tack Coat**. Clean the surface before placing the tack coat. The Engineer will set the rate between 0.04 and 0.10 gal. of residual asphalt per square yard of surface area. Apply a uniform tack coat at the specified rate unless otherwise directed. Apply the tack coat in a uniform manner to avoid streaks and other irregular patterns. Apply a thin, uniform tack coat to all contact surfaces of curbs, structures, and all joints. Allow adequate time for emulsion to break completely before placing any material. Prevent splattering of tack coat when placed adjacent to curb, gutter, and structures. Roll the tack coat with a pneumatic-tire roller to remove streaks and other irregular patterns when directed.

4.6.3. **Lay-Down Operations**.

4.6.3.1. **Windrow Operations**. Operate windrow pickup equipment so that when hot-mix is placed in windrows substantially all the mixture deposited on the roadbed is picked up and loaded into the paver.

4.6.3.2. **Hauling Equipment**. Use belly dumps, live bottom, or end dump trucks to haul and transfer mixture; however, with exception of paving miscellaneous areas, end dump trucks are only allowed when used in conjunction with an MTD with remixing capability unless otherwise allowed.

4.6.3.3. **Screed Heaters**. Turn off screed heaters, to prevent overheating of the mat, if the paver stops for more than 5 min.

4.7. **Compaction**. Compact the pavement uniformly to contain between 3.8% and 8.5% in-place air voids.

Furnish the type, size, and number of rollers required for compaction as approved. Use a pneumatic-tire roller to seal the surface unless excessive pickup of fines occurs. Use additional rollers as required to remove any roller marks. Use only water or an approved release agent on rollers, tamps, and other compaction equipment unless otherwise directed.

Use the control strip method shown in Tex-207-F, Part IV, on the first day of production to establish the rolling pattern that will produce the desired in-place air voids unless otherwise directed.

Use tamps to thoroughly compact the edges of the pavement along curbs, headers, and similar structures and in locations that will not allow thorough compaction with rollers. The Engineer may require rolling with a trench roller on widened areas, in trenches, and in other limited areas.

Complete all compaction operations before the pavement temperature drops below 160°F unless otherwise allowed. The Engineer may allow compaction with a light finish roller operated in static mode for pavement temperatures below 160°F.

Allow the compacted pavement to cool to 160°F or lower before opening to traffic unless otherwise directed. Sprinkle the finished mat with water or limewater, when directed, to expedite opening the roadway to traffic.

4.8. **Production Acceptance**.

4.8.1. **Production Lot**. Each day of production is defined as a production lot. Lots will be sequentially numbered and correspond to each new day of production. Note that lots are not subdivided into sublots for this specification.

4.8.2. **Production Sampling**.

4.8.2.1. **Mixture Sampling**. The Engineer may obtain mixture samples in accordance with Tex-222-F at any time during production.

4.8.2.2. **Asphalt Binder Sampling**. The Engineer may obtain or require the Contractor to obtain 1 qt. samples of the asphalt binder at any time during production from a port located immediately upstream from the mixing drum or pug mill in accordance with Tex-500-C, Part II. The Engineer may test any of the asphalt binder samples to verify compliance with Item 300, "Asphalts, Oils, and Emulsions."

4.8.3. **Production Testing**. The Engineer will test at the frequency listed in the Department's *Guide Schedule of Sampling and Testing* and this specification. The Engineer may suspend production if production tests do not meet specifications or are not within operational tolerances listed in Table 11. Take immediate corrective action if the Engineer's laboratory-molded density on any sample is less than 95.0% or greater than 98.0%, to bring the mixture within these tolerances. The Engineer may suspend operations if the Contractor's corrective actions do not produce acceptable results. The Engineer will allow production to resume when the proposed corrective action is likely to yield acceptable results.

The Engineer may use alternate methods for determining the asphalt binder content and aggregate gradation if the aggregate mineralogy is such that Tex-236-F does not yield reliable results. Use the applicable test procedure if an alternate test method is selected.

Table 13
Production and Placement Testing

Description	Test Method
Individual % retained for #8 sieve and larger	Tex-200-F or Tex-236-F
Individual % retained for sieves smaller than #8 and larger than #200	
% passing the #200 sieve	
Laboratory-molded density	Tex-207-F
Laboratory-molded bulk specific gravity	
In-Place air voids	
VMA	Tex-204-F
Moisture content	Tex-212-F, Part II
Theoretical maximum specific (Rice) gravity	Tex-227-F
Asphalt binder content	Tex-236-F
Hamburg Wheel test	Tex-242-F
Recycled Asphalt Shingles (RAS)[1]	Tex-217-F, Part III
Asphalt binder sampling and testing	Tex-500-C
Tack coat sampling and testing	Tex-500-C, Part III
Boil test	Tex-530-C

1. Testing performed by the Construction Division or designated laboratory.

4.8.3.1. **Voids in Mineral Aggregates (VMA)**. The Engineer may determine the VMA for any production lot. Take immediate corrective action if the VMA value for any lot is less than the minimum VMA requirement for production listed in Table 8. Suspend production and shipment of the mixture if the Engineer's VMA result is more than 0.5% below the minimum VMA requirement for production listed in Table 8. In addition to suspending production, the Engineer may require removal and replacement or may allow the lot to be left in place without payment.

4.8.3.2. **Hamburg Wheel Test**. The Engineer may perform a Hamburg Wheel test at any time during production, including when the boil test indicates a change in quality from the materials submitted for JMF1. In addition to testing production samples, the Engineer may obtain cores and perform Hamburg Wheel tests on any areas of the roadway where rutting is observed. Suspend production until further Hamburg Wheel tests meet the specified values when the production or core samples fail the Hamburg Wheel test criteria in Table 10. Core samples, if taken, will be obtained from the center of the finished mat or other areas excluding the vehicle wheel paths. The Engineer may require up to the entire lot of any mixture failing the Hamburg Wheel test to be removed and replaced at the Contractor's expense.

If the Department's or Department-approved laboratory's Hamburg Wheel test results in a "remove and replace" condition, the Contractor may request that the Department confirm the results by re-testing the failing material. The Construction Division will perform the Hamburg Wheel tests and determine the final disposition of the material in question based on the Department's test results.

4.8.4. **Individual Loads of Hot-Mix**. The Engineer can reject individual truckloads of hot-mix. When a load of hot-mix is rejected for reasons other than temperature, contamination, or excessive uncoated particles, the Contractor may request that the rejected load be tested. Make this request within 4 hr. of rejection. The Engineer will sample and test the mixture. If test results are within the operational tolerances shown in Table 11, payment will be made for the load. If test results are not within operational tolerances, no payment will be made for the load.

4.9. **Placement Acceptance**.

4.9.1. **Placement Lot**. A placement lot is defined as the area placed during a production lot (one day's production). Placement lot numbers will correspond with production lot numbers.

4.9.2. **Miscellaneous Areas**. Miscellaneous areas include areas that typically involve significant handwork or discontinuous paving operations, such as temporary detours, driveways, mailbox turnouts, crossovers, gores, spot level-up areas, and other similar areas. Miscellaneous areas also include level-ups and thin overlays when the layer thickness specified on the plans is less than the minimum untrimmed core height eligible for testing shown in Table 12. The specified layer thickness is based on the rate of 110 lb./sq. yd. for each inch of pavement unless another rate is shown on the plans. Compact miscellaneous areas in accordance with Section 340.4.7., "Compaction." Miscellaneous areas are not subject to in-place air void determination except for temporary detours when shown on the plans.

4.9.3. **Placement Sampling**. Provide the equipment and means to obtain and trim roadway cores on site. On site is defined as in close proximity to where the cores are taken. Obtain the cores within one working day of the time the placement lot is completed unless otherwise approved. Obtain two 6-in. diameter cores side-by-side at each location selected by the Engineer for in-place air void determination unless otherwise shown on the plans. For Type D and Type F mixtures, 4-in. diameter cores are allowed. Mark the cores for identification, measure and record the untrimmed core height, and provide the information to the Engineer. The Engineer will witness the coring operation and measurement of the core thickness.

Visually inspect each core and verify that the current paving layer is bonded to the underlying layer. Take corrective action if an adequate bond does not exist between the current and underlying layer to ensure that an adequate bond will be achieved during subsequent placement operations.

Trim the cores immediately after obtaining the cores from the roadway in accordance with Tex-207-F if the core heights meet the minimum untrimmed value listed in Table 12. Trim the cores on site in the presence of the Engineer. Use a permanent marker or paint pen to record the date and lot number on each core as well as the designation as Core A or B. The Engineer may require additional information to be marked on the core and may choose to sign or initial the core. The Engineer will take custody of the cores immediately after they are trimmed and will retain custody of the cores until the Department's testing is completed. Before turning the trimmed cores over to the Engineer, the Contractor may wrap the trimmed cores or secure them in a manner that will reduce the risk of possible damage occurring during transport by the Engineer. After testing, the Engineer will return the cores to the Contractor.

The Engineer may have the cores transported back to the Department's laboratory at the HMA plant via the Contractor's haul truck or other designated vehicle. In such cases where the cores will be out of the Engineer's possession during transport, the Engineer will use Department-provided security bags and the Roadway Core Custody protocol located at http://www.txdot.gov/business/specifications.htm to provide a secure means and process that protects the integrity of the cores during transport.

Instead of the Contractor trimming the cores on site immediately after coring, the Engineer and the Contractor may mutually agree to have the trimming operations performed at an alternate location such as a field laboratory or other similar location. In such cases, the Engineer will take possession of the cores immediately after they are obtained from the roadway and will retain custody of the cores until testing is completed. Either the Department or Contractor representative may perform trimming of the cores. The Engineer will witness all trimming operations in cases where the Contractor representative performs the trimming operation.

Dry the core holes and tack the sides and bottom immediately after obtaining the cores. Fill the hole with the same type of mixture and properly compact the mixture. Repair core holes with other methods when approved.

4.9.4. **Placement Testing**. The Engineer may measure in-place air voids at any time during the project to verify specification compliance.

4.9.4.1. **In-Place Air Voids**. The Engineer will measure in-place air voids in accordance with Tex-207-F and Tex-227-F. Cores not meeting the height requirements in Table 12 will not be tested. Before drying to a constant weight, cores may be pre-dried using a Corelok or similar vacuum device to remove excess moisture. The Engineer will use the corresponding theoretical maximum specific gravity to determine the air void content of each core. The Engineer will use the average air void content of the 2 cores to determine the in-place air voids at the selected location.

The Engineer will use the vacuum method to seal the core if required by Tex-207-F. The Engineer will use the test results from the unsealed core if the sealed core yields a higher specific gravity than the unsealed core. After determining the in-place air void content, the Engineer will return the cores and provide test results to the Contractor.

Take immediate corrective action when the in-place air voids exceed the range of 3.8% and 8.5% to bring the operation within these tolerances. The Engineer may suspend operations or require removal and replacement if the in-place air voids are less than 2.7% or greater than 9.9%. The Engineer will allow paving to resume when the proposed corrective action is likely to yield between 3.8% and 8.5% in-place air voids. Areas defined in Section 340.9.2., "Miscellaneous Areas," are not subject to in-place air void determination.

4.9.5. **Irregularities**. Identify and correct irregularities including segregation, rutting, raveling, flushing, fat spots, mat slippage, irregular color, irregular texture, roller marks, tears, gouges, streaks, uncoated aggregate particles, or broken aggregate particles. The Engineer may also identify irregularities, and in such cases, the Engineer will promptly notify the Contractor. If the Engineer determines that the irregularity will adversely affect pavement performance, the Engineer may require the Contractor to remove and replace (at the Contractor's expense) areas of the pavement that contain irregularities and areas where the mixture does not bond to the existing pavement. If irregularities are detected, the Engineer may require the Contractor to immediately suspend operations or may allow the Contractor to continue operations for no more than one day while the Contractor is taking appropriate corrective action.

4.9.6. **Ride Quality**. Use Surface Test Type A to evaluate ride quality in accordance with Item 585, "Ride Quality for Pavement Surfaces," unless otherwise shown on the plans.

5. MEASUREMENT

Hot mix will be measured by the ton of composite hot-mix, which includes asphalt, aggregate, and additives. Measure the weight on scales in accordance with Item 520, "Weighing and Measuring Equipment."

6. PAYMENT

The work performed and materials furnished in accordance with this Item and measured as provided under Section 340.5., “Measurement,” will be paid for at the unit bid price for “Dense Graded Hot-Mix Asphalt (SQ)” of the mixture type, SAC, and binder specified. These prices are full compensation for surface preparation, materials including tack coat, placement, equipment, labor, tools, and incidentals.

Trial batches will not be paid for unless they are included in pavement work approved by the Department.

Pay adjustment for ride quality, if applicable, will be determined in accordance with Item 585, “Ride Quality for Pavement Surfaces.”

Item 341

Dense-Graded Hot-Mix Asphalt

1. DESCRIPTION

Construct a hot-mix asphalt (HMA) pavement layer composed of a compacted, dense-graded mixture of aggregate and asphalt binder mixed hot in a mixing plant. Pay adjustments will apply to HMA placed under this specification unless the HMA is deemed exempt in accordance with Section 341.4.9.4., "Exempt Production."

2. MATERIALS

Furnish uncontaminated materials of uniform quality that meet the requirements of the plans and specifications.

Notify the Engineer of all material sources and before changing any material source or formulation. The Engineer will verify that the specification requirements are met when the Contractor makes a source or formulation change, and may require a new laboratory mixture design, trial batch, or both. The Engineer may sample and test project materials at any time during the project to verify specification compliance in accordance with Item 6, "Control of Materials."

2.1. **Aggregate**. Furnish aggregates from sources that conform to the requirements shown in Table 1 and as specified in this Section. Aggregate requirements in this Section, including those shown in Table 1, may be modified or eliminated when shown on the plans. Additional aggregate requirements may be specified when shown on the plans. Provide aggregate stockpiles that meet the definitions in this Section for coarse, intermediate, or fine aggregate. Aggregate from reclaimed asphalt pavement (RAP) is not required to meet Table 1 requirements unless otherwise shown on the plans. Supply aggregates that meet the definitions in Tex-100-E for crushed gravel or crushed stone. The Engineer will designate the plant or the quarry as the sampling location. Provide samples from materials produced for the project. The Engineer will establish the Surface Aggregate Classification (SAC) and perform Los Angeles abrasion, magnesium sulfate soundness, and Micro-Deval tests. Perform all other aggregate quality tests listed in Table 1. Document all test results on the mixture design report. The Engineer may perform tests on independent or split samples to verify Contractor test results. Stockpile aggregates for each source and type separately. Determine aggregate gradations for mixture design and production testing based on the washed sieve analysis given in Tex-200-F, Part II.

2.1.1. **Coarse Aggregate**. Coarse aggregate stockpiles must have no more than 20% material passing the No. 8 sieve. Aggregates from sources listed in the Department's *Bituminous Rated Source Quality Catalog* (BRSQC) are preapproved for use. Use only the rated values for hot-mix listed in the BRSQC. Rated values for surface treatment (ST) do not apply to coarse aggregate sources used in hot-mix asphalt.

For sources not listed on the Department's BRSQC:

- build an individual stockpile for each material;
- request the Department test the stockpile for specification compliance; and
- once approved, do not add material to the stockpile unless otherwise approved.

Provide aggregate from non-listed sources only when tested by the Engineer and approved before use. Allow 30 calendar days for the Engineer to sample, test, and report results for non-listed sources.

Provide coarse aggregate with at least the minimum SAC shown on the plans. SAC requirements only apply to aggregates used on the surface of travel lanes. SAC requirements apply to aggregates used on surfaces other than travel lanes when shown on the plans. The SAC for sources on the Department's *Aggregate Quality Monitoring Program* (AQMP) (Tex-499-A) is listed in the BRSQC.

2.1.1.1. **Blending Class A and Class B Aggregates**. Class B aggregate meeting all other requirements in Table 1 may be blended with a Class A aggregate to meet requirements for Class A materials. Ensure that at least 50% by weight, or volume if required, of the material retained on the No. 4 sieve comes from the Class A aggregate source when blending Class A and B aggregates to meet a Class A requirement. Blend by volume if the bulk specific gravities of the Class A and B aggregates differ by more than 0.300. Coarse aggregate from RAP and Recycled Asphalt Shingles (RAS) will be considered as Class B aggregate for blending purposes.

The Engineer may perform tests at any time during production, when the Contractor blends Class A and B aggregates to meet a Class A requirement, to ensure that at least 50% by weight, or volume if required, of the material retained on the No. 4 sieve comes from the Class A aggregate source. The Engineer will use the Department's mix design Excel template, when electing to verify conformance, to calculate the percent of Class A aggregate retained on the No. 4 sieve by inputting the bin percentages shown from readouts in the control room at the time of production and stockpile gradations measured at the time of production. The Engineer may determine the gradations based on either washed or dry sieve analysis from samples obtained from individual aggregate cold feed bins or aggregate stockpiles. The Engineer may perform spot checks using the gradations supplied by the Contractor on the mixture design report as an input for the Excel template; however, a failing spot check will require confirmation with a stockpile gradation determined by the Engineer.

2.1.1.2. **Micro-Deval Abrasion**. The Engineer will perform a minimum of one Micro-Deval abrasion test in accordance with Tex-461-A for each coarse aggregate source used in the mixture design that has a Rated Source Soundness Magnesium (RSSM) loss value greater than 15 as listed in the BRSQC. The Engineer will perform testing before the start of production and may perform additional testing at any time during production. The Engineer may obtain the coarse aggregate samples from each coarse aggregate source or may require the Contractor to obtain the samples. The Engineer may waive all Micro-Deval testing based on a satisfactory test history of the same aggregate source.

The Engineer will estimate the magnesium sulfate soundness loss for each coarse aggregate source, when tested, using the following formula:

$$Mg_{est.} = (RSSM)(MD_{act.}/RSMD)$$

where:
$Mg_{est.}$ = magnesium sulfate soundness loss
$MD_{act.}$ = actual Micro-Deval percent loss
$RSMD$ = Rated Source Micro-Deval

When the estimated magnesium sulfate soundness loss is greater than the maximum magnesium sulfate soundness loss specified, the coarse aggregate source will not be allowed for use unless otherwise approved. The Engineer will consult the Geotechnical, Soils, and Aggregates Branch of the Construction Division, and additional testing may be required before granting approval.

2.1.2. **Intermediate Aggregate**. Aggregates not meeting the definition of coarse or fine aggregate will be defined as intermediate aggregate. Supply intermediate aggregates, when used, that are free from organic impurities. The Engineer may test the intermediate aggregate in accordance with Tex-408-A to verify the material is free from organic impurities. Supply intermediate aggregate from coarse aggregate sources, when used, that meet the requirements shown in Table 1 unless otherwise approved.

Test the stockpile if 10% or more of the stockpile is retained on the No. 4 sieve, and verify that it meets the requirements in Table 1 for crushed face count (Tex-460-A) and flat and elongated particles (Tex-280-F).

2.1.3. **Fine Aggregate**. Fine aggregates consist of manufactured sands, screenings, and field sands. Fine aggregate stockpiles must meet the gradation requirements in Table 2. Supply fine aggregates that are free from organic impurities. The Engineer may test the fine aggregate in accordance with Tex-408-A to verify the material is free from organic impurities. No more than 15% of the total aggregate may be field sand or other uncrushed fine aggregate. Use fine aggregate, with the exception of field sand, from coarse aggregate sources that meet the requirements shown in Table 1 unless otherwise approved.

Test the stockpile if 10% or more of the stockpile is retained on the No. 4 sieve and verify that it meets the requirements in Table 1 for crushed face count (Tex-460-A) and flat and elongated particles (Tex-280-F).

Table 1
Aggregate Quality Requirements

Property	Test Method	Requirement
Coarse Aggregate		
SAC	Tex-499-A (AQMP)	As shown on the plans
Deleterious material, %, Max	Tex-217-F, Part I	1.5
Decantation, %, Max	Tex-217-F, Part II	1.5
Micro-Deval abrasion, %	Tex-461-A	Note[1]
Los Angeles abrasion, %, Max	Tex-410-A	40
Magnesium sulfate soundness, 5 cycles, %, Max	Tex-411-A	30
Crushed face count,[2] %, Min	Tex-460-A, Part I	85
Flat and elongated particles @ 5:1, %, Max	Tex-280-F	10
Fine Aggregate		
Linear shrinkage, %, Max	Tex-107-E	3
Combined Aggregate[3]		
Sand equivalent, %, Min	Tex-203-F	45

1. Used to estimate the magnesium sulfate soundness loss in accordance with Section 341.2.1.1.2., “Micro-Deval Abrasion.”
2. Only applies to crushed gravel.
3. Aggregates, without mineral filler, RAP, RAS, or additives, combined as used in the job-mix formula (JMF).

Table 2
Gradation Requirements for Fine Aggregate

Sieve Size	% Passing by Weight or Volume
3/8"	100
#8	70–100
#200	0–30

2.2. **Mineral Filler**. Mineral filler consists of finely divided mineral matter such as agricultural lime, crusher fines, hydrated lime, or fly ash. Mineral filler is allowed unless otherwise shown on the plans. Use no more than 2% hydrated lime or fly ash unless otherwise shown on the plans. Use no more than 1% hydrated lime if a substitute binder is used unless otherwise shown on the plans or allowed. Test all mineral fillers except hydrated lime and fly ash in accordance with Tex-107-E to ensure specification compliance. The plans may require or disallow specific mineral fillers. Provide mineral filler, when used, that:

- is sufficiently dry, free-flowing, and free from clumps and foreign matter as determined by the Engineer;
- does not exceed 3% linear shrinkage when tested in accordance with Tex-107-E; and
- meets the gradation requirements in Table 3.

Table 3
Gradation Requirements for Mineral Filler

Sieve Size	% Passing by Weight or Volume
#8	100
#200	55–100

2.3. **Baghouse Fines**. Fines collected by the baghouse or other dust-collecting equipment may be reintroduced into the mixing drum.

2.4. **Asphalt Binder**. Furnish the type and grade of performance-graded (PG) asphalt specified on the plans.

2.5. **Tack Coat**. Furnish CSS-1H, SS-1H, or a PG binder with a minimum high-temperature grade of PG 58 for tack coat binder in accordance with Item 300, “Asphalts, Oils, and Emulsions.” Specialized or preferred tack coat materials may be allowed or required when shown on the plans. Do not dilute emulsified asphalts at the terminal, in the field, or at any other location before use.

The Engineer will obtain at least one sample of the tack coat binder per project in accordance with Tex-500-C, Part III, and test it to verify compliance with Item 300, “Asphalts, Oils, and Emulsions.” The Engineer will obtain the sample from the asphalt distributor immediately before use.

2.6. **Additives**. Use the type and rate of additive specified when shown on the plans. Additives that facilitate mixing, compaction, or improve the quality of the mixture are allowed when approved. Provide the Engineer with documentation such as the bill of lading showing the quantity of additives used in the project unless otherwise directed.

2.6.1. **Lime and Liquid Antistripping Agent**. When lime or a liquid antistripping agent is used, add in accordance with Item 301, “Asphalt Antistripping Agents.” Do not add lime directly into the mixing drum of any plant where lime is removed through the exhaust stream unless the plant has a baghouse or dust collection system that reintroduces the lime into the drum.

2.6.2. **Warm Mix Asphalt (WMA)**. Warm Mix Asphalt (WMA) is defined as HMA that is produced within a target temperature discharge range of 215°F and 275°F using approved WMA additives or processes from the Department’s MPL.

WMA is allowed for use on all projects and is required when shown on the plans. When WMA is required, the maximum placement or target discharge temperature for WMA will be set at a value below 275°F.

Department-approved WMA additives or processes may be used to facilitate mixing and compaction of HMA produced at target discharge temperatures above 275°F; however, such mixtures will not be defined as WMA.

2.7. **Recycled Materials**. Use of RAP and RAS is permitted unless otherwise shown on the plans. Do not exceed the maximum allowable percentages of RAP and RAS shown in Table 4. The allowable percentages shown in Table 4 may be decreased or increased when shown on the plans. Determine asphalt binder content and gradation of the RAP and RAS stockpiles for mixture design purposes in accordance with Tex-236-F. The Engineer may verify the asphalt binder content of the stockpiles at any time during production. Perform other tests on RAP and RAS when shown on the plans. Asphalt binder from RAP and RAS is designated as recycled asphalt binder. Calculate and ensure that the ratio of the recycled asphalt binder to total binder does not exceed the percentages shown in Table 5 during mixture design and HMA production when RAP or RAS is used. Use a separate cold feed bin for each stockpile of RAP and RAS during HMA production.

Surface, intermediate, and base mixes referenced in Tables 4 and 5 are defined as follows:

- **Surface**. The final HMA lift placed at or near the top of the pavement structure;
- **Intermediate**. Mixtures placed below an HMA surface mix and less than or equal to 8.0 in. from the riding surface; and
- **Base**. Mixtures placed greater than 8.0 in. from the riding surface.

2.7.1. **RAP**. RAP is salvaged, milled, pulverized, broken, or crushed asphalt pavement. Crush or break RAP so that 100% of the particles pass the 2 in. sieve. Fractionated RAP is defined as 2 or more RAP stockpiles, divided into coarse and fine fractions.

Use of Contractor-owned RAP including HMA plant waste is permitted unless otherwise shown on the plans. Department-owned RAP stockpiles are available for the Contractor’s use when the stockpile locations are shown on the plans. If Department-owned RAP is available for the Contractor’s use, the Contractor may use Contractor-owned fractionated RAP and replace it with an equal quantity of Department-owned RAP. This allowance does not apply to a Contractor using unfractionated RAP. Department-owned RAP generated through required work on the Contract is available for the Contractor’s use when shown on the plans.

Perform any necessary tests to ensure Contractor- or Department-owned RAP is appropriate for use. The Department will not perform any tests or assume any liability for the quality of the Department-owned RAP unless otherwise shown on the plans. The Contractor will retain ownership of RAP generated on the project when shown on the plans.

The coarse RAP stockpile will contain only material retained by processing over a 3/8-in. or 1/2-in. screen unless otherwise approved. The fine RAP stockpile will contain only material passing the 3/8-in. or 1/2-in. screen unless otherwise approved. The Engineer may allow the Contractor to use an alternate to the 3/8-in. or 1/2-in. screen to fractionate the RAP. The maximum percentages of fractionated RAP may be comprised of coarse or fine fractionated RAP or the combination of both coarse and fine fractionated RAP.

Do not use Department- or Contractor-owned RAP contaminated with dirt or other objectionable materials. Do not use Department- or Contractor-owned RAP if the decantation value exceeds 5% and the plasticity index is greater than 8. Test the stockpiled RAP for decantation in accordance with Tex-406-A, Part I. Determine the plasticity index in accordance with Tex-106-E if the decantation value exceeds 5%. The decantation and plasticity index requirements do not apply to RAP samples with asphalt removed by extraction or ignition.

Do not intermingle Contractor-owned RAP stockpiles with Department-owned RAP stockpiles. Remove unused Contractor-owned RAP material from the project site upon completion of the project. Return unused Department-owned RAP to the designated stockpile location.

Table 4
Maximum Allowable Amounts of RAP[1]

Maximum Allowable Fractionated RAP[2] (%)			Maximum Allowable Unfractionated RAP[3] (%)		
Surface	Intermediate	Base	Surface	Intermediate	Base
20.0	30.0	40.0	10.0	10.0	10.0

1. Must also meet the recycled binder to total binder ratio shown in Table 5.
2. Up to 5% RAS may be used separately or as a replacement for fractionated RAP.
3. Unfractionated RAP may not be combined with fractionated RAP or RAS.

2.7.2. **RAS**. Use of post-manufactured RAS or post-consumer RAS (tear-offs) is permitted unless otherwise shown on the plans. Up to 5% RAS may be used separately or as a replacement for fractionated RAP in accordance with Table 4 and Table 5. RAS is defined as processed asphalt shingle material from manufacturing of asphalt roofing shingles or from re-roofing residential structures. Post-manufactured RAS is processed manufacturer's shingle scrap by-product. Post-consumer RAS is processed shingle scrap removed from residential structures. Comply with all regulatory requirements stipulated for RAS by the TCEQ. RAS may be used separately or in conjunction with RAP.

Process the RAS by ambient grinding or granulating such that 100% of the particles pass the 3/8 in. sieve when tested in accordance with Tex-200-F, Part I. Perform a sieve analysis on processed RAS material before extraction (or ignition) of the asphalt binder.

Add sand meeting the requirements of Table 1 and Table 2 or fine RAP to RAS stockpiles if needed to keep the processed material workable. Any stockpile that contains RAS will be considered a RAS stockpile and be limited to no more than 5.0% of the HMA mixture in accordance with Table 4.

Certify compliance of the RAS with DMS-11000, "Evaluating and Using Nonhazardous Recyclable Materials Guidelines." Treat RAS as an established nonhazardous recyclable material if it has not come into contact with any hazardous materials. Use RAS from shingle sources on the Department's MPL. Remove substantially all materials before use that are not part of the shingle, such as wood, paper, metal, plastic, and felt paper. Determine the deleterious content of RAS material for mixture design purposes in accordance with Tex-217-F, Part III. Do not use RAS if deleterious materials are more than 0.5% of the stockpiled RAS unless otherwise approved. Submit a sample for approval before submitting the mixture design. The Department will perform the testing for deleterious material of RAS to determine specification compliance.

2.8. **Substitute Binders**. Unless otherwise shown on the plans, the Contractor may use a substitute PG binder listed in Table 5 instead of the PG binder originally specified, if the substitute PG binder and mixture made with the substitute PG binder meet the following:

- the substitute binder meets the specification requirements for the substitute binder grade in accordance with Section 300.2.10., "Performance-Graded Binders"; and
- the mixture has less than 10.0 mm of rutting on the Hamburg Wheel test (Tex-242-F) after the number of passes required for the originally specified binder. Use of substitute PG binders may only be allowed at the discretion of the Engineer if the Hamburg Wheel test results are between 10.0 mm and 12.5 mm.

Table 5
Allowable Substitute PG Binders and Maximum Recycled Binder Ratios

Originally Specified PG Binder	Allowable Substitute PG Binder	Maximum Ratio of Recycled Binder[1] to Total Binder (%)		
		Surface	Intermediate	Base
HMA				
76-22[2]	70-22 or 64-22	20.0	20.0	20.0
	70-28 or 64-28	30.0	35.0	40.0
70-22[2]	64-22	20.0	20.0	20.0
	64-28 or 58-28	30.0	35.0	40.0
64-22[2]	58-28	30.0	35.0	40.0
76-28[2]	70-28 or 64-28	20.0	20.0	20.0
	64-34	30.0	35.0	40.0
70-28[2]	64-28 or 58-28	20.0	20.0	20.0
	64-34 or 58-34	30.0	35.0	40.0
64-28[2]	58-28	20.0	20.0	20.0
	58-34	30.0	35.0	40.0
WMA[3]				
76-22[2]	70-22 or 64-22	30.0	35.0	40.0
70-22[2]	64-22 or 58-28	30.0	35.0	40.0
64-22[4]	58-28	30.0	35.0	40.0
76-28[2]	70-28 or 64-28	30.0	35.0	40.0
70-28[2]	64-28 or 58-28	30.0	35.0	40.0
64-28[4]	58-28	30.0	35.0	40.0

1. Combined recycled binder from RAP and RAS.
2. Use no more than 20.0% recycled binder when using this originally specified PG binder.
3. WMA as defined in Section 341.2.6.2., "Warm Mix Asphalt (WMA)."
4. When used with WMA, this originally specified PG binder is allowed for use at the maximum recycled binder ratios shown in this table.

3. EQUIPMENT

Provide required or necessary equipment in accordance with Item 320, "Equipment for Asphalt Concrete Pavement."

4. CONSTRUCTION

Produce, haul, place, and compact the specified paving mixture. In addition to tests required by the specification, Contractors may perform other QC tests as deemed necessary. At any time during the project, the Engineer may perform production and placement tests as deemed necessary in accordance with Item 5, "Control of the Work." Schedule and participate in a mandatory pre-paving meeting with the Engineer on or before the first day of paving unless otherwise shown on the plans.

4.1. **Certification**. Personnel certified by the Department-approved hot-mix asphalt certification program must conduct all mixture designs, sampling, and testing in accordance with Table 6. Supply the Engineer with a list of certified personnel and copies of their current certificates before beginning production and when personnel changes are made. Provide a mixture design developed and signed by a Level 2 certified specialist. Provide Level 1A certified specialists at the plant during production operations. Provide Level 1B certified specialists to conduct placement tests.

Table 6
Test Methods, Test Responsibility, and Minimum Certification Levels

Test Description	Test Method	Contractor	Engineer	Level[1]
1. Aggregate and Recycled Material Testing				
Sampling	Tex-221-F	✓	✓	1A
Dry sieve	Tex-200-F, Part I	✓	✓	1A
Washed sieve	Tex-200-F, Part II	✓	✓	1A
Deleterious material	Tex-217-F, Parts I & III	✓	✓	1A
Decantation	Tex-217-F, Part II	✓	✓	1A
Los Angeles abrasion	Tex-410-A		✓	TxDOT
Magnesium sulfate soundness	Tex-411-A		✓	TxDOT
Micro-Deval abrasion	Tex-461-A		✓	2
Crushed face count	Tex-460-A	✓	✓	2
Flat and elongated particles	Tex-280-F	✓	✓	2
Linear shrinkage	Tex-107-E	✓	✓	2
Sand equivalent	Tex-203-F	✓	✓	2
Organic impurities	Tex-408-A	✓	✓	2
2. Asphalt Binder & Tack Coat Sampling				
Asphalt binder sampling	Tex-500-C, Part II	✓	✓	1A/1B
Tack coat sampling	Tex-500-C, Part III	✓	✓	1A/1B
3. Mix Design & Verification				
Design and JMF changes	Tex-204-F	✓	✓	2
Mixing	Tex-205-F	✓	✓	2
Molding (TGC)	Tex-206-F	✓	✓	1A
Molding (SGC)	Tex-241-F	✓	✓	1A
Laboratory-molded density	Tex-207-F	✓	✓	1A
VMA[2] (calculation only)	Tex-204-F	✓	✓	2
Rice gravity	Tex-227-F	✓	✓	1A
Ignition oven correction factors[3]	Tex-236-F	✓	✓	2
Indirect tensile strength	Tex-226-F	✓	✓	2
Hamburg Wheel test	Tex-242-F	✓	✓	2
Boil test	Tex-530-C	✓	✓	1A
4. Production Testing				
Selecting production random numbers	Tex-225-F, Part I		✓	1A
Mixture sampling	Tex-222-F	✓	✓	1A
Molding (TGC)	Tex-206-F	✓	✓	1A
Molding (SGC)	Tex-241-F	✓	✓	1A
Laboratory-molded density	Tex-207-F	✓	✓	1A
VMA[2] (calculation only)	Tex-204-F	✓	✓	1A
Rice gravity	Tex-227-F	✓	✓	1A
Gradation & asphalt binder content[3]	Tex-236-F	✓	✓	1A
Control charts	Tex-233-F	✓	✓	1A
Moisture content	Tex-212-F	✓	✓	1A
Hamburg Wheel test	Tex-242-F	✓	✓	2
Micro-Deval abrasion	Tex-461-A		✓	2
Boil test	Tex-530-C	✓	✓	1A
Abson recovery	Tex-211-F		✓	TxDOT
Overlay test	Tex-248-F		✓	TxDOT
Cantabro loss	Tex-245-F		✓	2
5. Placement Testing				
Selecting placement random numbers	Tex-225-F, Part II		✓	1A/1B
Trimming roadway cores	Tex-207-F	✓	✓	1A/1B
In-place air voids	Tex-207-F	✓	✓	1A/1B
Establish rolling pattern	Tex-207-F	✓		1B
Control charts	Tex-233-F	✓	✓	1A
Ride quality measurement	Tex-1001-S	✓	✓	Note[4]
Segregation (density profile)	Tex-207-F, Part V	✓	✓	1B
Longitudinal joint density	Tex-207-F, Part VII	✓	✓	1B
Thermal profile	Tex-244-F	✓	✓	1B

1. Level 1A, 1B, and 2 are certification levels provided by the Hot Mix Asphalt Center certification program.
2. Voids in mineral aggregates.
3. Refer to Section 341.4.9.2.3., “Production Testing,” for exceptions to using an ignition oven.
4. Profiler and operator are required to be certified at the Texas A&M Transportation Institute facility when Surface Test Type B is specified.

4.2. **Reporting and Responsibilities**. Use Department-provided Excel templates to record and calculate all test data, including mixture design, production and placement QC/QA, control charts, thermal profiles, segregation density profiles, and longitudinal joint density. Obtain the latest version of the Excel templates at http://www.txdot.gov/inside-txdot/forms-publications/consultants-contractors/forms/site-manager.html or from the Engineer. The Engineer and the Contractor will provide any available test results to the other party when requested. The maximum allowable time for the Contractor and Engineer to exchange test data is as given in Table 7 unless otherwise approved. The Engineer and the Contractor will immediately report to the other party any test result that requires suspension of production or placement, a payment penalty, or that fails to meet the specification requirements. Record and submit all test results and pertinent information on Department-provided Excel templates to the Engineer electronically by means of a portable USB flash drive, compact disc, or via email.

Subsequent sublots placed after test results are available to the Contractor, which require suspension of operations, may be considered unauthorized work. Unauthorized work will be accepted or rejected at the discretion of the Engineer in accordance with Article 5.3., "Conformity with Plans, Specifications, and Special Provisions."

Table 7
Reporting Schedule

Description	Reported By	Reported To	To Be Reported Within
Production Quality Control			
Gradation[1]	Contractor	Engineer	1 working day of completion of the sublot
Asphalt binder content[1]			
Laboratory-molded density[2]			
Moisture content[3]			
Boil test[3]			
Production Quality Assurance			
Gradation[3]	Engineer	Contractor	1 working day of completion of the sublot
Asphalt binder content[3]			
Laboratory-molded density[1]			
Hamburg Wheel test[2]			
Boil test[3]			
Binder tests[2]			
Placement Quality Control			
In-place air voids[2]	Contractor	Engineer	1 working day of completion of the lot
Segregation[1]			
Longitudinal joint density[1]			
Thermal profile[1]			
Placement Quality Assurance			
In-place air voids[1]	Engineer	Contractor	1 working day of receipt of the trimmed cores for in-place air voids[4]
Segregation[2]			
Longitudinal joint density[2]			
Thermal profile[2]			
Aging ratio[2]			
Pay adjustment summary	Engineer	Contractor	2 working days of performing all required tests and receiving Contractor test data

1. These tests are required on every sublot.
2. Optional test. To be reported as soon as results become available.
3. To be performed at the frequency specified on the plans.
4. 2 days are allowed if cores cannot be dried to constant weight within 1 day.

The Engineer will use the Department-provided Excel template to calculate all pay adjustment factors for the lot. Sublot samples may be discarded after the Engineer and Contractor sign off on the pay adjustment summary documentation for the lot.

Use the procedures described in Tex-233-F to plot the results of all quality control (QC) and quality assurance (QA) testing. Update the control charts as soon as test results for each sublot become available. Make the control charts readily accessible at the field laboratory. The Engineer may suspend production for failure to update control charts.

4.3. **Quality Control Plan (QCP)**. Develop and follow the QCP in detail. Obtain approval for changes to the QCP made during the project. The Engineer may suspend operations if the Contractor fails to comply with the QCP.

Submit a written QCP before the mandatory pre-paving meeting. Receive approval of the QCP before beginning production. Include the following items in the QCP:

4.3.1. **Project Personnel**. For project personnel, include:

- a list of individuals responsible for QC with authority to take corrective action;
- current contact information for each individual listed; and
- current copies of certification documents for individuals performing specified QC functions.

4.3.2. **Material Delivery and Storage**. For material delivery and storage, include:

- the sequence of material processing, delivery, and minimum quantities to assure continuous plant operations;
- aggregate stockpiling procedures to avoid contamination and segregation;
- frequency, type, and timing of aggregate stockpile testing to assure conformance of material requirements before mixture production; and
- procedure for monitoring the quality and variability of asphalt binder.

4.3.3. **Production**. For production, include:

- loader operation procedures to avoid contamination in cold bins;
- procedures for calibrating and controlling cold feeds;
- procedures to eliminate debris or oversized material;
- procedures for adding and verifying rates of each applicable mixture component (e.g., aggregate, asphalt binder, RAP, RAS, lime, liquid antistrip, WMA);
- procedures for reporting job control test results; and
- procedures to avoid segregation and drain-down in the silo.

4.3.4. **Loading and Transporting**. For loading and transporting, include:

- type and application method for release agents; and
- truck loading procedures to avoid segregation.

4.3.5. **Placement and Compaction**. For placement and compaction, include:

- proposed agenda for mandatory pre-paving meeting, including date and location;
- proposed paving plan (e.g., paving widths, joint offsets, and lift thicknesses);
- type and application method for release agents in the paver and on rollers, shovels, lutes, and other utensils;
- procedures for the transfer of mixture into the paver, while avoiding segregation and preventing material spillage;
- process to balance production, delivery, paving, and compaction to achieve continuous placement operations and good ride quality;
- paver operations (e.g., operation of wings, height of mixture in auger chamber) to avoid physical and thermal segregation and other surface irregularities; and
- procedures to construct quality longitudinal and transverse joints.

4.4. **Mixture Design**.

4.4.1. **Design Requirements.** The Contractor may design the mixture using a Texas Gyratory Compactor (TGC) or a Superpave Gyratory Compactor (SGC) unless otherwise shown on the plans. Use the typical weight design example given in Tex-204-F, Part I, when using a TGC. Use the Superpave mixture design procedure given in Tex-204-F, Part IV, when using a SGC. Design the mixture to meet the requirements listed in Tables 1, 2, 3, 4, 5, 8, 9, and 10.

4.4.1.1. **Target Laboratory-Molded Density When The TGC Is Used**. Design the mixture at a 96.5% target laboratory-molded density. Increase the target laboratory-molded density to 97.0% or 97.5% at the Contractor's discretion or when shown on the plans or specification.

4.4.1.2. **Design Number of Gyrations (Ndesign) When The SGC Is Used**. Design the mixture at 50 gyrations (Ndesign). Use a target laboratory-molded density of 96.0% to design the mixture; however, adjustments can be made to the Ndesign value as noted in Table 9. The Ndesign level may be reduced to no less than 35 gyrations at the Contractor's discretion.

Use an approved laboratory from the Department's MPL to perform the Hamburg Wheel test, and provide results with the mixture design, or provide the laboratory mixture and request that the Department perform the Hamburg Wheel test. The Engineer will be allowed 10 working days to provide the Contractor with Hamburg Wheel test results on the laboratory mixture design.

The Engineer will provide the mixture design when shown on the plans. The Contractor may submit a new mixture design at any time during the project. The Engineer will verify and approve all mixture designs (JMF1) before the Contractor can begin production.

Provide the Engineer with a mixture design report using the Department-provided Excel template. Include the following items in the report:

- the combined aggregate gradation, source, specific gravity, and percent of each material used;
- asphalt binder content and aggregate gradation of RAP and RAS stockpiles;
- the target laboratory-molded density (or Ndesign level when using the SGC);
- results of all applicable tests;
- the mixing and molding temperatures;
- the signature of the Level 2 person or persons that performed the design;
- the date the mixture design was performed; and
- a unique identification number for the mixture design.

Table 8
Master Gradation Limits (% Passing by Weight or Volume) and VMA Requirements

Sieve Size	A Coarse Base	B Fine Base	C Coarse Surface	D Fine Surface	F Fine Mixture
2"	100.0[1]	–	–	–	–
1-1/2"	98.0–100.0	100.0[1]	–	–	–
1"	78.0–94.0	98.0–100.0	100.0[1]	–	–
3/4"	64.0–85.0	84.0–98.0	95.0–100.0	100.0[1]	–
1/2"	50.0–70.0	–	–	98.0–100.0	100.0[1]
3/8"	–	60.0–80.0	70.0–85.0	85.0–100.0	98.0–100.0
#4	30.0–50.0	40.0–60.0	43.0–63.0	50.0–70.0	70.0–90.0
#8	22.0–36.0	29.0–43.0	32.0–44.0	35.0–46.0	38.0–48.0
#30	8.0–23.0	13.0–28.0	14.0–28.0	15.0–29.0	12.0–27.0
#50	3.0–19.0	6.0–20.0	7.0–21.0	7.0–20.0	6.0–19.0
#200	2.0–7.0	2.0–7.0	2.0–7.0	2.0–7.0	2.0–7.0
Design VMA, % Minimum					
–	12.0	13.0	14.0	15.0	16.0
Production (Plant-Produced) VMA, % Minimum					
–	11.5	12.5	13.5	14.5	15.5

1. Defined as maximum sieve size. No tolerance allowed.

Table 9
Laboratory Mixture Design Properties

Mixture Property	Test Method	Requirement
Target laboratory-molded density, % (TGC)	Tex-207-F	96.5[1]
Design gyrations (Ndesign for SGC)	Tex-241-F	50[2]
Indirect tensile strength (dry), psi	Tex-226-F	85–200[3]
Boil test[4]	Tex-530-C	–

1. Increase to 97.0% or 97.5% at the Contractor's discretion or when shown on the plans or specification.
2. Adjust within a range of 35–100 gyrations when shown on the plans or specification or when mutually agreed between the Engineer and Contractor.
3. The Engineer may allow the IDT strength to exceed 200 psi if the corresponding Hamburg Wheel rut depth is greater than 3.0 mm and less than 12.5 mm.
4. Used to establish baseline for comparison to production results. May be waived when approved.

Table 10
Hamburg Wheel Test Requirements

High-Temperature Binder Grade	Test Method	Minimum # of Passes[1] @ 12.5 mm[2] Rut Depth, Tested @ 50°C
PG 64 or lower	Tex-242-F	10,000
PG 70		15,000
PG 76 or higher		20,000

1. May be decreased or waived when shown on the plans.
2. When the rut depth at the required minimum number of passes is less than 3 mm, the Engineer may require the Contractor to increase the target laboratory-molded density (TGC) by 0.5% to no more than 97.5% or lower the Ndesign level (SGC) to no less than 35 gyrations.

4.4.2. **Job-Mix Formula Approval**. The job-mix formula (JMF) is the combined aggregate gradation, target laboratory-molded density (or Ndesign level), and target asphalt percentage used to establish target values for hot-mix production. JMF1 is the original laboratory mixture design used to produce the trial batch. When WMA is used, JMF1 may be designed and submitted to the Engineer without including the WMA additive. When WMA is used, document the additive or process used and recommended rate on the JMF1 submittal. The Engineer and the Contractor will verify JMF1 based on plant-produced mixture from the trial batch unless otherwise approved. The Engineer may accept an existing mixture design previously used on a Department project and may waive the trial batch to verify JMF1. The Department may require the Contractor to reimburse the Department for verification tests if more than 2 trial batches per design are required.

4.4.2.1. **Contractor's Responsibilities**.

4.4.2.1.1. **Providing Gyratory Compactor**. Use a TGC calibrated in accordance with Tex-914-K when electing or required to design the mixture in accordance with Tex-204-F, Part I, for molding production samples. Furnish an SGC calibrated in accordance with Tex-241-F when electing or required to design the mixture in accordance with Tex-204-F, Part IV, for molding production samples. Locate the SGC, if used, at the Engineer's field laboratory and make the SGC available to the Engineer for use in molding production samples.

4.4.2.1.2. **Gyratory Compactor Correlation Factors**. Use Tex-206-F, Part II, to perform a gyratory compactor correlation when the Engineer uses a different gyratory compactor. Apply the correlation factor to all subsequent production test results.

4.4.2.1.3. **Submitting JMF1**. Furnish a mix design report (JMF1) with representative samples of all component materials and request approval to produce the trial batch. Provide approximately 10,000 g of the design mixture if opting to have the Department perform the Hamburg Wheel test on the laboratory mixture, and request that the Department perform the test.

4.4.2.1.4. **Supplying Aggregates**. Provide approximately 40 lb. of each aggregate stockpile unless otherwise directed.

4.4.2.1.5. **Supplying Asphalt**. Provide at least 1 gal. of the asphalt material and sufficient quantities of any additives proposed for use.

4.4.2.1.6. **Ignition Oven Correction Factors**. Determine the aggregate and asphalt correction factors from the ignition oven in accordance with Tex-236-F. Provide the Engineer with split samples of the mixtures before the trial batch production, including all additives (except water), and blank samples used to determine the correction factors for the ignition oven used for QA testing during production. Correction factors established from a previously approved mixture design may be used for the current mixture design if the mixture design and ignition oven are the same as previously used, unless otherwise directed.

4.4.2.1.7. **Boil Test.** Perform the test and retain the tested sample from Tex-530-C until completion of the project or as directed. Use this sample for comparison purposes during production. The Engineer may waive the requirement for the boil test.

4.4.2.1.8. **Trial Batch Production**. Provide a plant-produced trial batch upon receiving conditional approval of JMF1 and authorization to produce a trial batch, including the WMA additive or process if applicable, for verification testing of JMF1 and development of JMF2. Produce a trial batch mixture that meets the requirements in Table 4, Table 5, and Table 11. The Engineer may accept test results from recent production of the same mixture instead of a new trial batch.

4.4.2.1.9. **Trial Batch Production Equipment**. Use only equipment and materials proposed for use on the project to produce the trial batch.

4.4.2.1.10. **Trial Batch Quantity**. Produce enough quantity of the trial batch to ensure that the mixture meets the specification requirements.

4.4.2.1.11. **Number of Trial Batches**. Produce trial batches as necessary to obtain a mixture that meets the specification requirements.

4.4.2.1.12. **Trial Batch Sampling**. Obtain a representative sample of the trial batch and split it into 3 equal portions in accordance with Tex-222-F. Label these portions as “Contractor,” “Engineer,” and “Referee.” Deliver samples to the appropriate laboratory as directed.

4.4.2.1.13. **Trial Batch Testing**. Test the trial batch to ensure the mixture produced using the proposed JMF1 meets the mixture requirements in Table 11. Ensure the trial batch mixture is also in compliance with the Hamburg Wheel requirement in Table 10. Use a Department-approved laboratory to perform the Hamburg Wheel test on the trial batch mixture or request that the Department perform the Hamburg Wheel test. The Engineer will be allowed 10 working days to provide the Contractor with Hamburg Wheel test results on the trial batch. Provide the Engineer with a copy of the trial batch test results.

4.4.2.1.14. **Development of JMF2**. Evaluate the trial batch test results after the Engineer grants full approval of JMF1 based on results from the trial batch, determine the optimum mixture proportions, and submit as JMF2. Adjust the asphalt binder content or gradation to achieve the specified target laboratory-molded density. The asphalt binder content established for JMF2 is not required to be within any tolerance of the optimum asphalt binder content established for JMF1; however, mixture produced using JMF2 must meet the voids in mineral aggregates (VMA) requirements for production shown in Table 8. If the optimum asphalt binder content for JMF2 is more than 0.5% lower than the optimum asphalt binder content for JMF1, the Engineer may perform or require the Contractor to perform Tex-226-F on Lot 1 production to confirm the indirect tensile strength does not exceed 200 psi. Verify that JMF2 meets the mixture requirements in Table 5.

4.4.2.1.15. **Mixture Production**. Use JMF2 to produce Lot 1 as described in Section 341.4.9.3.1.1., “Lot 1 Placement,” after receiving approval for JMF2 and a passing result from the Department’s or a Department-approved laboratory’s Hamburg Wheel test on the trial batch. If desired, proceed to Lot 1 production, once JMF2 is approved, at the Contractor’s risk without receiving the results from the Department’s Hamburg Wheel test on the trial batch.

Notify the Engineer if electing to proceed without Hamburg Wheel test results from the trial batch. Note that the Engineer may require up to the entire sublot of any mixture failing the Hamburg Wheel test to be removed and replaced at the Contractor's expense.

4.4.2.1.16. **Development of JMF3**. Evaluate the test results from Lot 1, determine the optimum mixture proportions, and submit as JMF3 for use in Lot 2.

4.4.2.1.17. **JMF Adjustments**. If JMF adjustments are necessary to achieve the specified requirements, make the adjustments before beginning a new lot. The adjusted JMF must:

- be provided to the Engineer in writing before the start of a new lot;
- be numbered in sequence to the previous JMF;
- meet the mixture requirements in Table 4 and Table 5;
- meet the master gradation limits shown in Table 8; and
- be within the operational tolerances of JMF2 listed in Table 11.

4.4.2.1.18. **Requesting Referee Testing**. Use referee testing, if needed, in accordance with Section 341.4.9.1., "Referee Testing," to resolve testing differences with the Engineer.

Table 11
Operational Tolerances

Description	Test Method	Allowable Difference Between Trial Batch and JMF1 Target	Allowable Difference from Current JMF Target	Allowable Difference between Contractor and Engineer[1]
Individual % retained for #8 sieve and larger	Tex-200-F or Tex-236-F	Must be Within Master Grading Limits in Table 8	±5.0[2,3]	±5.0
Individual % retained for sieves smaller than #8 and larger than #200			±3.0[2,3]	±3.0
% passing the #200 sieve			±2.0[2,3]	±1.6
Asphalt binder content, %	Tex-236-F	±0.5	±0.3[3]	±0.3
Laboratory-molded density, %	Tex-207-F	±1.0	±1.0	±1.0
In-place air voids, %		N/A	N/A	±1.0
Laboratory-molded bulk specific gravity		N/A	N/A	±0.020
VMA, %, min	Tex-204-F	Note[4]	Note[4]	N/A
Theoretical maximum specific (Rice) gravity	Tex-227-F	N/A	N/A	±0.020

1. Contractor may request referee testing only when values exceed these tolerances.
2. When within these tolerances, mixture production gradations may fall outside the master grading limits; however, the % passing the #200 will be considered out of tolerance when outside the master grading limits.
3. Only applies to mixture produced for Lot 1 and higher.
4. Test and verify that Table 8 requirements are met.

4.4.2.2. **Engineer's Responsibilities**.

4.4.2.2.1. **Gyratory Compactor**. For mixtures designed in accordance with Tex-204-F, Part I, the Engineer will use a Department TGC, calibrated in accordance with Tex-914-K, to mold samples for trial batch and production testing. The Engineer will make the Department TGC and the Department field laboratory available to the Contractor for molding verification samples, if requested by the Contractor.

For mixtures designed in accordance with Tex-204-F, Part IV, the Engineer will use a Department SGC, calibrated in accordance with Tex-241-F, to mold samples for laboratory mixture design verification. For molding trial batch and production specimens, the Engineer will use the Contractor-provided SGC at the field laboratory or provide and use a Department SGC at an alternate location. The Engineer will make the Contractor-provided SGC in the Department field laboratory available to the Contractor for molding verification samples.

4.4.2.2.2. **Conditional Approval of JMF1 and Authorizing Trial Batch**. The Engineer will review and verify conformance of the following information within 2 working days of receipt:

- the Contractor's mix design report (JMF1);
- the Contractor-provided Hamburg Wheel test results;

- all required materials including aggregates, asphalt, additives, and recycled materials; and
- the mixture specifications.

The Engineer will grant the Contractor conditional approval of JMF1 if the information provided on the paper copy of JMF1 indicates that the Contractor's mixture design meets the specifications. When the Contractor does not provide Hamburg Wheel test results with laboratory mixture design, 10 working days are allowed for conditional approval of JMF1. The Engineer will base full approval of JMF1 on the test results on mixture from the trial batch.

Unless waived, the Engineer will determine the Micro-Deval abrasion loss in accordance with Section 341.2.1.1.2., "Micro-Deval Abrasion." If the Engineer's test results are pending after 2 working days, conditional approval of JMF1 will still be granted within 2 working days of receiving JMF1. When the Engineer's test results become available, they will be used for specification compliance.

After conditionally approving JMF1, including either Contractor- or Department-supplied Hamburg Wheel test results, the Contractor is authorized to produce a trial batch.

4.4.2.2.3. **Hamburg Wheel Testing of JMF1**. If the Contractor requests the option to have the Department perform the Hamburg Wheel test on the laboratory mixture, the Engineer will mold samples in accordance with Tex-242-F to verify compliance with the Hamburg Wheel test requirement in Table 10.

4.4.2.2.4. **Ignition Oven Correction Factors**. The Engineer will use the split samples provided by the Contractor to determine the aggregate and asphalt correction factors for the ignition oven used for QA testing during production in accordance with Tex-236-F.

4.4.2.2.5. **Testing the Trial Batch**. Within 1 full working day, the Engineer will sample and test the trial batch to ensure that the mixture meets the requirements in Table 11. If the Contractor requests the option to have the Department perform the Hamburg Wheel test on the trial batch mixture, the Engineer will mold samples in accordance with Tex-242-F to verify compliance with the Hamburg Wheel test requirement in Table 10.

The Engineer will have the option to perform the following tests on the trial batch:

- Tex-226-F, to verify that the indirect tensile strength meets the requirement shown in Table 9; and
- Tex-530-C, to retain and use for comparison purposes during production.

4.4.2.2.6. **Full Approval of JMF1**. The Engineer will grant full approval of JMF1 and authorize the Contractor to proceed with developing JMF2 if the Engineer's results for the trial batch meet the requirements in Table 11. The Engineer will notify the Contractor that an additional trial batch is required if the trial batch does not meet these requirements.

4.4.2.2.7. **Approval of JMF2**. The Engineer will approve JMF2 within one working day if the mixture meets the requirements in Table 5 and the gradation meets the master grading limits shown in Table 8. The asphalt binder content established for JMF2 is not required to be within any tolerance of the optimum asphalt binder content established for JMF1; however, mixture produced using JMF2 must meet the VMA requirements shown in Table 8. If the optimum asphalt binder content for JMF2 is more than 0.5% lower than the optimum asphalt binder content for JMF1, the Engineer may perform or require the Contractor to perform Tex-226-F on Lot 1 production to confirm the indirect tensile strength does not exceed 200 psi.

4.4.2.2.8. **Approval of Lot 1 Production**. The Engineer will authorize the Contractor to proceed with Lot 1 production (using JMF2) as soon as a passing result is achieved from the Department's or a Department-approved laboratory's Hamburg Wheel test on the trial batch. The Contractor may proceed at its own risk with Lot 1 production without the results from the Hamburg Wheel test on the trial batch.

If the Department's or Department-approved laboratory's sample from the trial batch fails the Hamburg Wheel test, the Engineer will suspend production until further Hamburg Wheel tests meet the specified values. The Engineer may require up to the entire sublot of any mixture failing the Hamburg Wheel test be removed and replaced at the Contractor's expense.

4.4.2.2.9. **Approval of JMF3 and Subsequent JMF Changes**. JMF3 and subsequent JMF changes are approved if they meet the mixture requirements shown in Table 4, Table 5, and the master grading limits shown in Table 8, and are within the operational tolerances of JMF2 shown in Table 11.

4.5. **Production Operations**. Perform a new trial batch when the plant or plant location is changed. Take corrective action and receive approval to proceed after any production suspension for noncompliance to the specification. Submit a new mix design and perform a new trial batch when the asphalt binder content of:

- any RAP stockpile used in the mix is more than 0.5% higher than the value shown on the mixture design report; or
- RAS stockpile used in the mix is more than 2.0% higher than the value shown on the mixture design report.

4.5.1. **Storage and Heating of Materials**. Do not heat the asphalt binder above the temperatures specified in Item 300, "Asphalts, Oils, and Emulsions," or outside the manufacturer's recommended values. Provide the Engineer with daily records of asphalt binder and hot-mix asphalt discharge temperatures (in legible and discernible increments) in accordance with Item 320, "Equipment for Asphalt Concrete Pavement," unless otherwise directed. Do not store mixture for a period long enough to affect the quality of the mixture, nor in any case longer than 12 hr. unless otherwise approved.

4.5.2. **Mixing and Discharge of Materials**. Notify the Engineer of the target discharge temperature and produce the mixture within 25°F of the target. Monitor the temperature of the material in the truck before shipping to ensure that it does not exceed 350°F (or 275°F for WMA) and is not lower than 215°F. The Department will not pay for or allow placement of any mixture produced above 350°F.

Produce WMA within the target discharge temperature range of 215°F and 275°F when WMA is required. Take corrective action any time the discharge temperature of the WMA exceeds the target discharge range. The Engineer may suspend production operations if the Contractor's corrective action is not successful at controlling the production temperature within the target discharge range. Note that when WMA is produced, it may be necessary to adjust burners to ensure complete combustion such that no burner fuel residue remains in the mixture.

Control the mixing time and temperature so that substantially all moisture is removed from the mixture before discharging from the plant. Determine the moisture content, if requested, by oven-drying in accordance with Tex-212-F, Part II, and verify that the mixture contains no more than 0.2% of moisture by weight. Obtain the sample immediately after discharging the mixture into the truck, and perform the test promptly.

4.6. **Hauling Operations**. Clean all truck beds before use to ensure that mixture is not contaminated. Use a release agent shown on the Department's MPL to coat the inside bed of the truck when necessary.

Use equipment for hauling as defined in Section 341.4.7.3.3., "Hauling Equipment." Use other hauling equipment only when allowed.

4.7. **Placement Operations**. Collect haul tickets from each load of mixture delivered to the project and provide the Department's copy to the Engineer approximately every hour, or as directed. Use a hand-held thermal camera or infrared thermometer, when a thermal imaging system is not used, to measure and record the internal temperature of the mixture as discharged from the truck or Material Transfer Device (MTD) before or as the mix enters the paver and an approximate station number or GPS coordinates on each ticket. Calculate the daily yield and cumulative yield for the specified lift and provide to the Engineer at the end of paving operations for each day unless otherwise directed. The Engineer may suspend production if the Contractor fails to produce and provide haul tickets and yield calculations by the end of paving operations for each day.

Prepare the surface by removing raised pavement markers and objectionable material such as moisture, dirt, sand, leaves, and other loose impediments from the surface before placing mixture. Remove vegetation from pavement edges. Place the mixture to meet the typical section requirements and produce a smooth, finished surface with a uniform appearance and texture. Offset longitudinal joints of successive courses of hot-mix by at least 6 in. Place mixture so that longitudinal joints on the surface course coincide with lane lines, or as directed. Ensure that all finished surfaces will drain properly. Place the mixture at the rate or thickness shown on the plans. The Engineer will use the guidelines in Table 12 to determine the compacted lift thickness of each layer when multiple lifts are required. The thickness determined is based on the rate of 110 lb./sq. yd. for each inch of pavement unless otherwise shown on the plans.

Table 12
Compacted Lift Thickness and Required Core Height

Mixture Type	Compacted Lift Thickness Guidelines		Minimum Untrimmed Core Height (in.) Eligible for Testing
	Minimum (in.)	Maximum (in.)	
A	3.00	6.00	2.00
B	2.50	5.00	1.75
C	2.00	4.00	1.50
D	1.50	3.00	1.25
F	1.25	2.50	1.25

4.7.1. **Weather Conditions**.

4.7.1.1. **When Using a Thermal Imaging System**. The Contractor may pave any time the roadway is dry and the roadway surface temperature is at least 32°F; however, the Engineer may restrict the Contractor from paving surface mixtures if the ambient temperature is likely to drop below 32°F within 12 hr. of paving. Provide output data from the thermal imaging system to demonstrate to the Engineer that no recurring severe thermal segregation exists in accordance with Section 341.4.7.3.1.2., "Thermal Imaging System."

4.7.1.2. **When Not Using a Thermal Imaging System**. Place mixture when the roadway surface temperature is at or above the temperatures listed in Table 13 unless otherwise approved or as shown on the plans. Measure the roadway surface temperature with a hand-held thermal camera or infrared thermometer. The Engineer may allow mixture placement to begin before the roadway surface reaches the required temperature if conditions are such that the roadway surface will reach the required temperature within 2 hr. of beginning placement operations. Place mixtures only when weather conditions and moisture conditions of the roadway surface are suitable as determined by the Engineer. The Engineer may restrict the Contractor from paving if the ambient temperature is likely to drop below 32°F within 12 hr. of paving.

Table 13
Minimum Pavement Surface Temperatures

Originally Specified High Temperature Binder Grade	Minimum Pavement Surface Temperatures (°F)	
	Subsurface Layers or Night Paving Operations	Surface Layers Placed in Daylight Operations
PG 64 or lower	45	50
PG 70	55[1]	60[1]
PG 76 or higher	60[1]	60[1]

1. Contractors may pave at temperatures 10°F lower than these values when utilizing a paving process including WMA or equipment that eliminates thermal segregation. In such cases, use a hand-held thermal camera operated in accordance with Tex-244-F to demonstrate to the satisfaction of the Engineer that the uncompacted mat has no more than 10°F of thermal segregation.

4.7.2. **Tack Coat**. Clean the surface before placing the tack coat. The Engineer will set the rate between 0.04 and 0.10 gal. of residual asphalt per square yard of surface area. Apply a uniform tack coat at the specified rate unless otherwise directed. Apply the tack coat in a uniform manner to avoid streaks and other irregular patterns. Apply a thin, uniform tack coat to all contact surfaces of curbs, structures, and all joints. Allow adequate time for emulsion to break completely before placing any material. Prevent splattering of tack coat when placed adjacent to curb, gutter, and structures. Roll the tack coat with a pneumatic-tire roller to remove streaks and other irregular patterns when directed.

4.7.3. **Lay-Down Operations**.

4.7.3.1. **Thermal Profile**. Use a hand-held thermal camera or a thermal imaging system to obtain a continuous thermal profile in accordance with Tex-244-F. Thermal profiles are not applicable in areas described in Section 341.4.9.3.1.4., "Miscellaneous Areas."

4.7.3.1.1. **Thermal Segregation**.

4.7.3.1.1.1. **Moderate**. Any areas that have a temperature differential greater than 25°F, but not exceeding 50°F, are deemed as having moderate thermal segregation.

4.7.3.1.1.2. **Severe**. Any areas that have a temperature differential greater than 50°F are deemed as having severe thermal segregation.

4.7.3.1.2. **Thermal Imaging System**. Review the output results when a thermal imaging system is used, and provide the automated report described in Tex-244-F to the Engineer daily unless otherwise directed. Modify the paving process as necessary to eliminate any recurring (moderate or severe) thermal segregation identified by the thermal imaging system. The Engineer may suspend paving operations if the Contractor cannot successfully modify the paving process to eliminate recurring severe thermal segregation. Density profiles are not required and not applicable when using a thermal imaging system. Provide the Engineer with electronic copies of all daily data files that can be used with the thermal imaging system software to generate temperature profile plots upon completion of the project or as requested by the Engineer.

4.7.3.1.3. **Thermal Camera**. Take immediate corrective action to eliminate recurring moderate thermal segregation when a hand-held thermal camera is used. Evaluate areas with moderate thermal segregation by performing density profiles in accordance with Section 341.4.9.3.3.2., "Segregation (Density Profile)." Provide the Engineer with the thermal profile of every sublot within one working day of the completion of each lot. Report the results of each thermal profile in accordance with Section 341.4.2., "Reporting and Responsibilities." The Engineer will use a hand-held thermal camera to obtain a thermal profile at least once per project. No production or placement bonus will be paid for any sublot that contains severe thermal segregation. Suspend operations and take immediate corrective action to eliminate severe thermal segregation unless otherwise directed. Resume operations when the Engineer determines that subsequent production will meet the requirements of this Section. Evaluate areas with severe thermal segregation by performing density profiles in accordance with Section 341.4.9.3.3.2., "Segregation (Density Profile)." Remove and replace the material in any areas that have both severe thermal segregation and a failing result for Segregation (Density Profile) unless otherwise directed. The sublot in question may receive a production and placement bonus if applicable when the defective material is successfully removed and replaced.

4.7.3.2. **Windrow Operations**. Operate windrow pickup equipment so that when hot-mix is placed in windrows, substantially all the mixture deposited on the roadbed is picked up and loaded into the paver.

4.7.3.3. **Hauling Equipment**. Use belly dumps, live bottom, or end dump trucks to haul and transfer mixture; however, with exception of paving miscellaneous areas, end dump trucks are only allowed when used in conjunction with an MTD with remixing capability or when a thermal imaging system is used unless otherwise allowed.

4.7.3.4. **Screed Heaters**. Turn off screed heaters to prevent overheating of the mat if the paver stops for more than 5 min. The Engineer may evaluate the suspect area in accordance with Section 341.4.9.3.3.4., "Recovered Asphalt Dynamic Shear Rheometer (DSR)," if the screed heater remains on for more than 5 min. while the paver is stopped.

4.8. **Compaction**. Compact the pavement uniformly to contain between 3.8% and 8.5% in-place air voids. Take immediate corrective action to bring the operation within 3.8% and 8.5% when the in-place air voids exceed the range of these tolerances. The Engineer will allow paving to resume when the proposed corrective action is likely to yield between 3.8% and 8.5% in-place air voids.

Obtain cores in areas placed under Exempt Production, as directed, at locations determined by the Engineer. The Engineer may test these cores and suspend operations or require removal and replacement if the in-place air voids are less than 2.7% or more than 9.9%. Areas defined in Section 341.4.9.3.1.4., "Miscellaneous Areas," are not subject to in-place air void determination.

Furnish the type, size, and number of rollers required for compaction as approved. Use a pneumatic-tire roller to seal the surface unless excessive pickup of fines occurs. Use additional rollers as required to remove any roller marks. Use only water or an approved release agent on rollers, tamps, and other compaction equipment unless otherwise directed.

Use the control strip method shown in Tex-207-F, Part IV, on the first day of production to establish the rolling pattern that will produce the desired in-place air voids unless otherwise directed.

Use tamps to thoroughly compact the edges of the pavement along curbs, headers, and similar structures and in locations that will not allow thorough compaction with rollers. The Engineer may require rolling with a trench roller on widened areas, in trenches, and in other limited areas.

Complete all compaction operations before the pavement temperature drops below 160°F unless otherwise allowed. The Engineer may allow compaction with a light finish roller operated in static mode for pavement temperatures below 160°F.

Allow the compacted pavement to cool to 160°F or lower before opening to traffic unless otherwise directed. Sprinkle the finished mat with water or limewater, when directed, to expedite opening the roadway to traffic.

4.9. **Acceptance Plan**. Pay adjustments for the material will be in accordance with Section 341.6., "Payment."

Sample and test the hot-mix on a lot and sublot basis. Suspend production until test results or other information indicates to the satisfaction of the Engineer that the next material produced or placed will result in pay factors of at least 1.000, if the production pay factor given in Section 341.6.1., "Production Pay Adjustment Factors," for 2 consecutive lots or the placement pay factor given in Section 341.6.2., "Placement Pay Adjustment Factors," for 2 consecutive lots is below 1.000.

4.9.1. **Referee Testing**. The Construction Division is the referee laboratory. The Contractor may request referee testing if a "remove and replace" condition is determined based on the Engineer's test results, or if the differences between Contractor and Engineer test results exceed the maximum allowable difference shown in Table 11 and the differences cannot be resolved. The Contractor may also request referee testing if the Engineer's test results require suspension of production and the Contractor's test results are within specification limits. Make the request within 5 working days after receiving test results and cores from the Engineer. Referee tests will be performed only on the sublot in question and only for the particular tests in question. Allow 10 working days from the time the referee laboratory receives the samples for test results to be reported. The Department may require the Contractor to reimburse the Department for referee tests if more than 3 referee tests per project are required and the Engineer's test results are closer to the referee test results than the Contractor's test results.

The Construction Division will determine the laboratory-molded density based on the molded specific gravity and the maximum theoretical specific gravity of the referee sample. The in-place air voids will be determined based on the bulk specific gravity of the cores, as determined by the referee laboratory and the Engineer's average maximum theoretical specific gravity for the lot. With the exception of "remove and replace" conditions, referee test results are final and will establish pay adjustment factors for the sublot in question. The Contractor may decline referee testing and accept the Engineer's test results when the placement pay adjustment factor for any sublot results in a "remove and replace" condition. Placement sublots subject to be removed and replaced will be further evaluated in accordance with Section 341.6.2.2., "Placement Sublots Subject to Removal and Replacement."

4.9.2. **Production Acceptance**.

4.9.2.1. **Production Lot**. A production lot consists of 4 equal sublots. The default quantity for Lot 1 is 1,000 tons; however, when requested by the Contractor, the Engineer may increase the quantity for Lot 1 to no more than 4,000 tons. The Engineer will select subsequent lot sizes based on the anticipated daily production such that approximately 3 to 4 sublots are produced each day. The lot size will be between 1,000 tons and 4,000 tons. The Engineer may change the lot size before the Contractor begins any lot.

If the optimum asphalt binder content for JMF2 is more than 0.5% lower than the optimum asphalt binder content for JMF1, the Engineer may perform or require the Contractor to perform Tex-226-F on Lot 1 to confirm the indirect tensile strength does not exceed 200 psi. Take corrective action to bring the mixture within specification compliance if the indirect tensile strength exceeds 200 psi unless otherwise directed.

4.9.2.1.1. **Incomplete Production Lots**. If a lot is begun but cannot be completed, such as on the last day of production or in other circumstances deemed appropriate, the Engineer may close the lot. Adjust the payment for the incomplete lot in accordance with Section 341.6.1., "Production Pay Adjustment Factors." Close all lots within 5 working days unless otherwise allowed.

4.9.2.2. **Production Sampling**.

4.9.2.2.1. **Mixture Sampling**. Obtain hot-mix samples from trucks at the plant in accordance with Tex-222-F. The sampler will split each sample into 3 equal portions in accordance with Tex-200-F and label these portions as "Contractor," "Engineer," and "Referee." The Engineer will perform or witness the sample splitting and take immediate possession of the samples labeled "Engineer" and "Referee." The Engineer will maintain the custody of the samples labeled "Engineer" and "Referee" until the Department's testing is completed.

4.9.2.2.1.1. **Random Sample**. At the beginning of the project, the Engineer will select random numbers for all production sublots. Determine sample locations in accordance with Tex-225-F. Take one sample for each sublot at the randomly selected location. The Engineer will perform or witness the sampling of production sublots.

4.9.2.2.1.2. **Blind Sample**. For one sublot per lot, the Engineer will obtain and test a "blind" sample instead of the random sample collected by the Contractor. Test either the "blind" or the random sample; however, referee testing (if applicable) will be based on a comparison of results from the "blind" sample. The location of the Engineer's "blind" sample will not be disclosed to the Contractor. The Engineer's "blind" sample may be randomly selected in accordance with Tex-225-F for any sublot or selected at the discretion of the Engineer. The Engineer will use the Contractor's split sample for sublots not sampled by the Engineer.

4.9.2.2.2. **Informational Cantabro and Overlay Testing**. When requested or shown on the plans, select one random sublot from Lot 2 or higher for Cantabro and Overlay testing during the first week of production. Obtain and provide the Engineer with approximately 90 lb. (40 kg) of mixture in sealed containers, boxes, or bags labeled with the Control-Section-Job (CSJ), mixture type, lot, and sublot number. The Engineer will ship the mixture to the Construction Division for Cantabro and Overlay testing. Results from these tests will not be used for specification compliance.

4.9.2.2.3. **Asphalt Binder Sampling**. Obtain a 1-qt. sample of the asphalt binder for each lot of mixture produced. Obtain the sample at approximately the same time the mixture random sample is obtained. Sample from a port located immediately upstream from the mixing drum or pug mill in accordance with Tex-500-C, Part II. Label the can with the corresponding lot and sublot numbers and deliver the sample to the Engineer. The Engineer may also obtain independent samples. If obtaining an independent asphalt binder sample, the Engineer will split a sample of the asphalt binder with the Contractor. The Engineer will test at least one asphalt binder sample per project to verify compliance with Item 300, "Asphalts, Oils, and Emulsions."

4.9.2.3. **Production Testing**. The Contractor and Engineer must perform production tests in accordance with Table 14. The Contractor has the option to verify the Engineer's test results on split samples provided by the Engineer. Determine compliance with operational tolerances listed in Table 11 for all sublots.

Take immediate corrective action if the Engineer's laboratory-molded density on any sublot is less than 95.0% or greater than 98.0% to bring the mixture within these tolerances. The Engineer may suspend operations if the Contractor's corrective actions do not produce acceptable results. The Engineer will allow production to resume when the proposed corrective action is likely to yield acceptable results.

The Engineer may allow alternate methods for determining the asphalt binder content and aggregate gradation if the aggregate mineralogy is such that Tex-236-F does not yield reliable results. Provide evidence that results from Tex-236-F are not reliable before requesting permission to use an alternate method unless otherwise directed. Use the applicable test procedure as directed if an alternate test method is allowed.

Table 14
Production and Placement Testing Frequency

Description	Test Method	Minimum Contractor Testing Frequency	Minimum Engineer Testing Frequency
Individual % retained for #8 sieve and larger	Tex-200-F or Tex-236-F	1 per sublot	1 per 12 sublots[1]
Individual % retained for sieves smaller than #8 and larger than #200			
% passing the #200 sieve			
Laboratory-molded density	Tex-207-F	N/A	1 per sublot[1]
Laboratory-molded bulk specific gravity			
In-place air voids			
VMA	Tex-204-F		
Segregation (density profile)[2]	Tex-207-F, Part V	1 per sublot	1 per project
Longitudinal joint density	Tex-207-F, Part VII		
Moisture content	Tex-212-F, Part II	When directed	
Theoretical maximum specific (Rice) gravity	Tex-227-F	N/A	1 per sublot[1]
Asphalt binder content	Tex-236-F	1 per sublot	1 per lot[1]
Hamburg Wheel test	Tex-242-F	N/A	1 per project
Recycled Asphalt Shingles (RAS)[3]	Tex-217-F, Part III	N/A	
Thermal profile[2]	Tex-244-F	1 per sublot	
Asphalt binder sampling and testing	Tex-500-C	1 per lot (sample only)	
Tack coat sampling and testing	Tex-500-C, Part III	N/A	
Boil test[4]	Tex-530-C	1 per lot	
Cantabro loss[5]	Tex-245-F	1 per project (sample only)	
Overlay test[5]	Tex-248-F		

1. For production defined in Section 341.4.9.4., "Exempt Production," the Engineer will test one per day if 100 tons or more are produced. For Exempt Production, no testing is required when less than 100 tons are produced.
2. Not required when a thermal imaging system is used.
3. Testing performed by the Construction Division or designated laboratory.
4. The Engineer may reduce or waive the sampling and testing requirements based on a satisfactory test history.
5. Testing performed by the Construction Division and for informational purposes only.

4.9.2.4. **Operational Tolerances**. Control the production process within the operational tolerances listed in Table 11. When production is suspended, the Engineer will allow production to resume when test results or other information indicates the next mixture produced will be within the operational tolerances.

4.9.2.4.1. **Gradation**. Suspend operation and take corrective action if any aggregate is retained on the maximum sieve size shown in Table 8. A sublot is defined as out of tolerance if either the Engineer's or the Contractor's test results are out of operational tolerance. Suspend production when test results for gradation exceed the operational tolerances for 3 consecutive sublots on the same sieve or 4 consecutive sublots on any sieve unless otherwise directed. The consecutive sublots may be from more than one lot.

4.9.2.4.2. **Asphalt Binder Content**. A sublot is defined as out of operational tolerance if either the Engineer's or the Contractor's test results exceed the values listed in Table 11. No production or placement bonus will be paid for any sublot that is out of operational tolerance for asphalt binder content. Suspend production and shipment of the mixture if the Engineer's or the Contractor's asphalt binder content deviates from the current JMF by more than 0.5% for any sublot.

4.9.2.4.3. **Voids in Mineral Aggregates (VMA)**. The Engineer will determine the VMA for every sublot. For sublots when the Engineer does not determine asphalt binder content, the Engineer will use the asphalt binder content results from QC testing performed by the Contractor to determine VMA.

Take immediate corrective action if the VMA value for any sublot is less than the minimum VMA requirement for production listed in Table 8. Suspend production and shipment of the mixture if the Engineer's VMA results on 2 consecutive sublots are below the minimum VMA requirement for production listed in Table 8. No production or placement bonus will be paid for any sublot that does not meet the minimum VMA requirement for production listed in Table 8 based on the Engineer's VMA determination.

Suspend production and shipment of the mixture if the Engineer's VMA result is more than 0.5% below the minimum VMA requirement for production listed in Table 8. In addition to suspending production, the Engineer may require removal and replacement or may allow the sublot to be left in place without payment.

4.9.2.4.4. **Hamburg Wheel Test**. The Engineer may perform a Hamburg Wheel test at any time during production, including when the boil test indicates a change in quality from the materials submitted for JMF1. In addition to testing production samples, the Engineer may obtain cores and perform Hamburg Wheel tests on any areas of the roadway where rutting is observed. Suspend production until further Hamburg Wheel tests meet the specified values when the production or core samples fail the Hamburg Wheel test criteria in Table 10. Core samples, if taken, will be obtained from the center of the finished mat or other areas excluding the vehicle wheel paths. The Engineer may require up to the entire sublot of any mixture failing the Hamburg Wheel test to be removed and replaced at the Contractor's expense.

If the Department's or Department approved laboratory's Hamburg Wheel test results in a "remove and replace" condition, the Contractor may request that the Department confirm the results by re-testing the failing material. The Construction Division will perform the Hamburg Wheel tests and determine the final disposition of the material in question based on the Department's test results.

4.9.2.5. **Individual Loads of Hot-Mix**. The Engineer can reject individual truckloads of hot-mix. When a load of hot-mix is rejected for reasons other than temperature, contamination, or excessive uncoated particles, the Contractor may request that the rejected load be tested. Make this request within 4 hr. of rejection. The Engineer will sample and test the mixture. If test results are within the operational tolerances shown in Table 11, payment will be made for the load. If test results are not within operational tolerances, no payment will be made for the load.

4.9.3. **Placement Acceptance**.

4.9.3.1. **Placement Lot**. A placement lot consists of 4 placement sublots. A placement sublot consists of the area placed during a production sublot.

4.9.3.1.1. **Lot 1 Placement**. Placement bonuses for Lot 1 will be in accordance with Section 341.6.2., "Placement Pay Adjustment Factors"; however, no placement penalty will be assessed for any sublot placed in Lot 1 when the in-place air voids are greater than or equal to 2.7% and less than or equal to 9.9%. Remove and replace any sublot with in-place air voids less than 2.7% or greater than 9.9%.

4.9.3.1.2. **Incomplete Placement Lots**. An incomplete placement lot consists of the area placed as described in Section 341.4.9.2.1.1., "Incomplete Production Lots," excluding areas defined in Section 341.4.9.3.1.4., "Miscellaneous Areas." Placement sampling is required if the random sample plan for production resulted in a sample being obtained from an incomplete production sublot.

4.9.3.1.3. **Shoulders, Ramps, Etc**. Shoulders, ramps, intersections, acceleration lanes, deceleration lanes, and turn lanes are subject to in-place air void determination and pay adjustments unless designated on the plans as not eligible for in-place air void determination. Intersections may be considered miscellaneous areas when determined by the Engineer.

4.9.3.1.4. **Miscellaneous Areas**. Miscellaneous areas include areas that typically involve significant handwork or discontinuous paving operations, such as temporary detours, driveways, mailbox turnouts, crossovers, gores, spot level-up areas, and other similar areas. Temporary detours are subject to in-place air void determination when shown on the plans. Miscellaneous areas also include level-ups and thin overlays when the layer thickness specified on the plans is less than the minimum untrimmed core height eligible for testing shown in Table 12. The specified layer thickness is based on the rate of 110 lb./sq. yd. for each inch of pavement unless another rate is shown on the plans. When "level up" is listed as part of the item bid description code, a pay adjustment factor of 1.000 will be assigned for all placement sublots as described in Section 341.6, "Payment." Miscellaneous areas are not eligible for random placement sampling locations. Compact miscellaneous areas in accordance with Section 341.4.8., "Compaction." Miscellaneous areas are not subject to in-place air void determination, thermal profiles testing, segregation (density profiles), or longitudinal joint density evaluations.

4.9.3.2. **Placement Sampling**. The Engineer will select random numbers for all placement sublots at the beginning of the project. The Engineer will provide the Contractor with the placement random numbers immediately after the sublot is completed. Mark the roadway location at the completion of each sublot and record the station number. Determine one random sample location for each placement sublot in accordance with Tex-225-F. Adjust the random sample location by no more than necessary to achieve a 2-ft. clearance if the location is within 2 ft. of a joint or pavement edge.

Shoulders, ramps, intersections, acceleration lanes, deceleration lanes, and turn lanes are always eligible for selection as a random sample location; however, if a random sample location falls on one of these areas and the area is designated on the plans as not subject to in-place air void determination, cores will not be taken for the sublot and a 1.000 pay factor will be assigned to that sublot.

Provide the equipment and means to obtain and trim roadway cores on site. On-site is defined as in close proximity to where the cores are taken. Obtain the cores within one working day of the time the placement sublot is completed unless otherwise approved. Obtain two 6-in. diameter cores side-by-side from within 1 ft. of the random location provided for the placement sublot. For Type D and Type F mixtures, 4-in. diameter cores are allowed. Mark the cores for identification, measure and record the untrimmed core height, and provide the information to the Engineer. The Engineer will witness the coring operation and measurement of the core thickness. Visually inspect each core and verify that the current paving layer is bonded to the underlying layer. Take corrective action if an adequate bond does not exist between the current and underlying layer to ensure that an adequate bond will be achieved during subsequent placement operations.

Trim the cores immediately after obtaining the cores from the roadway in accordance with Tex-207-F if the core heights meet the minimum untrimmed value listed in Table 12. Trim the cores on site in the presence of the Engineer. Use a permanent marker or paint pen to record the lot and sublot numbers on each core as well as the designation as Core A or B. The Engineer may require additional information to be marked on the core and may choose to sign or initial the core. The Engineer will take custody of the cores immediately after they are trimmed and will retain custody of the cores until the Department's testing is completed. Before turning the trimmed cores over to the Engineer, the Contractor may wrap the trimmed cores or secure them in a manner that will reduce the risk of possible damage occurring during transport by the Engineer. After testing, the Engineer will return the cores to the Contractor.

The Engineer may have the cores transported back to the Department's laboratory at the HMA plant via the Contractor's haul truck or other designated vehicle. In such cases where the cores will be out of the Engineer's possession during transport, the Engineer will use Department-provided security bags and the Roadway Core Custody protocol located at http://www.txdot.gov/business/specifications.htm to provide a secure means and process that protects the integrity of the cores during transport.

Decide whether to include the pair of cores in the air void determination for that sublot if the core height before trimming is less than the minimum untrimmed value shown in Table 12. Trim the cores as described above before delivering to the Engineer if electing to have the cores included in the air void determination. Deliver untrimmed cores to the Engineer and inform the Engineer of the decision to not have the cores included in air void determination if electing to not have the cores included in air void determination. The placement pay factor for the sublot will be 1.000 if cores will not be included in air void determination.

Instead of the Contractor trimming the cores on site immediately after coring, the Engineer and the Contractor may mutually agree to have the trimming operations performed at an alternate location such as a field laboratory or other similar location. In such cases, the Engineer will take possession of the cores immediately after they are obtained from the roadway and will retain custody of the cores until testing is completed. Either the Department or Contractor representative may perform trimming of the cores. The Engineer will witness all trimming operations in cases where the Contractor representative performs the trimming operation.

Dry the core holes and tack the sides and bottom immediately after obtaining the cores. Fill the hole with the same type of mixture and properly compact the mixture. Repair core holes with other methods when approved.

4.9.3.3. **Placement Testing**. Perform placement tests in accordance with Table 14. After the Engineer returns the cores, the Contractor may test the cores to verify the Engineer's test results for in-place air voids. The allowable differences between the Contractor's and Engineer's test results are listed in Table 11.

4.9.3.3.1. **In-Place Air Voids**. The Engineer will measure in-place air voids in accordance with Tex-207-F and Tex-227-F. Before drying to a constant weight, cores may be pre-dried using a Corelok or similar vacuum device to remove excess moisture. The Engineer will average the values obtained for all sublots in the production lot to determine the theoretical maximum specific gravity. The Engineer will use the average air void content for in-place air voids.

The Engineer will use the vacuum method to seal the core if required by Tex-207-F. The Engineer will use the test results from the unsealed core to determine the placement pay adjustment factor if the sealed core yields a higher specific gravity than the unsealed core. After determining the in-place air void content, the Engineer will return the cores and provide test results to the Contractor.

4.9.3.3.2. **Segregation (Density Profile)**. Test for segregation using density profiles in accordance with Tex-207-F, Part V. Density profiles are not required and are not applicable when using a thermal imaging system. Density profiles are not applicable in areas described in Section 341.4.9.3.1.4., "Miscellaneous Areas."

Perform a density profile every time the paver stops for more than 60 sec. on areas that are identified by either the Contractor or the Engineer as having thermal segregation and on any visibly segregated areas unless otherwise approved. Perform a minimum of one profile per sublot if the paver does not stop for more than 60 sec. and there are no visibly segregated areas or areas that are identified as having thermal segregation.

Provide the Engineer with the density profile of every sublot in the lot within one working day of the completion of each lot. Report the results of each density profile in accordance with Section 341.4.2., "Reporting and Responsibilities."

The density profile is considered failing if it exceeds the tolerances in Table 15. No production or placement bonus will be paid for any sublot that contains a failing density profile. When a hand-held thermal camera is used instead of a thermal imaging system, the Engineer will measure the density profile at least once per project. The Engineer's density profile results will be used when available. The Engineer may require the Contractor to remove and replace the area in question if the area fails the density profile and has surface irregularities as defined in Section 341.4.9.3.3.5., "Irregularities." The sublot in question may receive a production and placement bonus if applicable when the defective material is successfully removed and replaced.

Investigate density profile failures and take corrective actions during production and placement to eliminate the segregation. Suspend production if 2 consecutive density profiles fail unless otherwise approved. Resume production after the Engineer approves changes to production or placement methods.

Table 15
Segregation (Density Profile) Acceptance Criteria

Mixture Type	Maximum Allowable Density Range (Highest to Lowest)	Maximum Allowable Density Range (Average to Lowest)
Type A & Type B	8.0 pcf	5.0 pcf
Type C, Type D & Type F	6.0 pcf	3.0 pcf

4.9.3.3.3. **Longitudinal Joint Density**.

4.9.3.3.3.1. **Informational Tests**. Perform joint density evaluations while establishing the rolling pattern and verify that the joint density is no more than 3.0 pcf below the density taken at or near the center of the mat. Adjust the rolling pattern, if needed, to achieve the desired joint density. Perform additional joint density evaluations, at least once per sublot, unless otherwise directed.

4.9.3.3.3.2. **Record Tests**. Perform a joint density evaluation for each sublot at each pavement edge that is or will become a longitudinal joint. Joint density evaluations are not applicable in areas described in Section 341.4.9.3.1.4., "Miscellaneous Areas." Determine the joint density in accordance with Tex-207-F, Part VII. Record the joint density information and submit results on Department forms to the Engineer. The evaluation is considered failing if the joint density is more than 3.0 pcf below the density taken at the core random sample location and the correlated joint density is less than 90.0%. The Engineer will make independent joint density verification at least once per project and may make independent joint density verifications at the random sample locations. The Engineer's joint density test results will be used when available.

Provide the Engineer with the joint density of every sublot in the lot within one working day of the completion of each lot. Report the results of each joint density in accordance with Section 341.4.2., "Reporting and Responsibilities."

Investigate joint density failures and take corrective actions during production and placement to improve the joint density. Suspend production if the evaluations on 2 consecutive sublots fail unless otherwise approved. Resume production after the Engineer approves changes to production or placement methods.

4.9.3.3.4. **Recovered Asphalt Dynamic Shear Rheometer (DSR)**. The Engineer may take production samples or cores from suspect areas of the project to determine recovered asphalt properties. Asphalt binders with an aging ratio greater than 3.5 do not meet the requirements for recovered asphalt properties and may be deemed defective when tested and evaluated by the Construction Division. The aging ratio is the DSR value of the extracted binder divided by the DSR value of the original unaged binder. Obtain DSR values in accordance with AASHTO T 315 at the specified high temperature performance grade of the asphalt. The Engineer may require removal and replacement of the defective material at the Contractor's expense. The asphalt binder will be recovered for testing from production samples or cores in accordance with Tex-211-F.

4.9.3.3.5. **Irregularities**. Identify and correct irregularities including segregation, rutting, raveling, flushing, fat spots, mat slippage, irregular color, irregular texture, roller marks, tears, gouges, streaks, uncoated aggregate particles, or broken aggregate particles. The Engineer may also identify irregularities, and in such cases, the Engineer will promptly notify the Contractor. If the Engineer determines that the irregularity will adversely affect pavement performance, the Engineer may require the Contractor to remove and replace (at the Contractor's expense) areas of the pavement that contain irregularities and areas where the mixture does not bond to the existing pavement.

If irregularities are detected, the Engineer may require the Contractor to immediately suspend operations or may allow the Contractor to continue operations for no more than one day while the Contractor is taking appropriate corrective action.

4.9.4. **Exempt Production**. The Engineer may deem the mixture as exempt production for the following conditions:

- anticipated daily production is less than 1,000 tons;
- total production for the project is less than 5,000 tons;
- when mutually agreed between the Engineer and the Contractor; or
- when shown on the plans.

For exempt production, the Contractor is relieved of all production and placement sampling and testing requirements, and the production and placement pay factors are 1.000. All other specification requirements apply, and the Engineer will perform acceptance tests for production and placement listed in Table 14 when 100 tons or more per day are produced.

For exempt production:

- produce, haul, place, and compact the mixture in compliance with the specification and as directed;
- control mixture production to yield a laboratory-molded density that is within ±1.0% of the target laboratory-molded density as tested by the Engineer;
- compact the mixture in accordance with Section 341.4.8., "Compaction"; and

- when a thermal imaging system is not used, the Engineer may perform segregation (density profiles) and thermal profiles in accordance with the specification.

4.9.5. **Ride Quality**. Measure ride quality in accordance with Item 585, “Ride Quality for Pavement Surfaces,” unless otherwise shown on the plans.

5. MEASUREMENT

Hot mix will be measured by the ton of composite hot-mix, which includes asphalt, aggregate, and additives. Measure the weight on scales in accordance with Item 520, “Weighing and Measuring Equipment.”

6. PAYMENT

The work performed and materials furnished in accordance with this Item and measured as provided under Section 341.5., “Measurement,” will be paid for at the unit bid price for “Dense Graded Hot-Mix Asphalt” of the mixture type, SAC, and binder specified. These prices are full compensation for surface preparation, materials including tack coat, placement, equipment, labor, tools, and incidentals.

Pay adjustments for bonuses and penalties will be applied as determined in this Item; however, a pay adjustment factor of 1.000 will be assigned for all placement sublots for “level ups” only when “level up” is listed as part of the item bid description code. A pay adjustment factor of 1.000 will be assigned to all production and placement sublots when “exempt” is listed as part of the item bid description code.

Payment for each sublot, including applicable pay adjustment bonuses, will only be paid for sublots when the Contractor supplies the Engineer with the required documentation for production and placement QC/QA, thermal profiles, segregation density profiles, and longitudinal joint densities in accordance with Section 341.4.2., “Reporting and Responsibilities.” When a thermal imaging system is used, documentation is not required for thermal profiles or segregation density profiles on individual sublots; however, the thermal imaging system automated reports described in Tex-244-F are required.

Trial batches will not be paid for unless they are included in pavement work approved by the Department.

Pay adjustment for ride quality will be determined in accordance with Item 585, “Ride Quality for Pavement Surfaces.”

6.1. **Production Pay Adjustment Factors**. The production pay adjustment factor is based on the laboratory-molded density using the Engineer’s test results. A pay adjustment factor will be determined from Table 16 for each sublot using the deviation from the target laboratory-molded density defined in Table 9. The production pay adjustment factor for completed lots will be the average of the pay adjustment factors for the 4 sublots sampled within that lot.

Table 16
Production Pay Adjustment Factors for Laboratory-Molded Density[1]

Absolute Deviation from Target Laboratory-Molded Density	Production Pay Adjustment Factor (Target Laboratory-Molded Density)
0.0	1.050
0.1	1.050
0.2	1.050
0.3	1.044
0.4	1.038
0.5	1.031
0.6	1.025
0.7	1.019
0.8	1.013
0.9	1.006
1.0	1.000
1.1	0.965
1.2	0.930
1.3	0.895
1.4	0.860
1.5	0.825
1.6	0.790
1.7	0.755
1.8	0.720
> 1.8	Remove and replace

1. If the Engineer's laboratory-molded density on any sublot is less than 95.0% or greater than 98.0%, take immediate corrective action to bring the mixture within these tolerances. The Engineer may suspend operations if the Contractor's corrective actions do not produce acceptable results. The Engineer will allow production to resume when the proposed corrective action is likely to yield acceptable results.

6.1.1. **Payment for Incomplete Production Lots**. Production pay adjustments for incomplete lots, described under Section 341.4.9.2.1.1., "Incomplete Production Lots," will be calculated using the average production pay factors from all sublots sampled. A production pay factor of 1.000 will be assigned to any lot when the random sampling plan did not result in collection of any samples.

6.1.2. **Production Sublots Subject to Removal and Replacement**. If after referee testing, the laboratory-molded density for any sublot results in a "remove and replace" condition as listed in Table 16, the Engineer may require removal and replacement or may allow the sublot to be left in place without payment. The Engineer may also accept the sublot in accordance with Section 5.3.1., "Acceptance of Defective or Unauthorized Work." Replacement material meeting the requirements of this Item will be paid for in accordance with this Section.

6.2. **Placement Pay Adjustment Factors**. The placement pay adjustment factor is based on in-place air voids using the Engineer's test results. A pay adjustment factor will be determined from Table 17 for each sublot that requires in-place air void measurement. A placement pay adjustment factor of 1.000 will be assigned to the entire sublot when the random sample location falls in an area designated on the plans as not subject to in-place air void determination. A placement pay adjustment factor of 1.000 will be assigned to quantities placed in areas described in Section 341.4.9.3.1.4., "Miscellaneous Areas." The placement pay adjustment factor for completed lots will be the average of the placement pay adjustment factors for up to 4 sublots within that lot.

Table 17
Placement Pay Adjustment Factors for In-Place Air Voids

In-Place Air Voids	Placement Pay Adjustment Factor	In-Place Air Voids	Placement Pay Adjustment Factor
< 2.7	Remove and Replace	6.4	1.042
2.7	0.710	6.5	1.040
2.8	0.740	6.6	1.038
2.9	0.770	6.7	1.036
3.0	0.800	6.8	1.034
3.1	0.830	6.9	1.032
3.2	0.860	7.0	1.030
3.3	0.890	7.1	1.028
3.4	0.920	7.2	1.026
3.5	0.950	7.3	1.024
3.6	0.980	7.4	1.022
3.7	0.998	7.5	1.020
3.8	1.002	7.6	1.018
3.9	1.006	7.7	1.016
4.0	1.010	7.8	1.014
4.1	1.014	7.9	1.012
4.2	1.018	8.0	1.010
4.3	1.022	8.1	1.008
4.4	1.026	8.2	1.006
4.5	1.030	8.3	1.004
4.6	1.034	8.4	1.002
4.7	1.038	8.5	1.000
4.8	1.042	8.6	0.998
4.9	1.046	8.7	0.996
5.0	1.050	8.8	0.994
5.1	1.050	8.9	0.992
5.2	1.050	9.0	0.990
5.3	1.050	9.1	0.960
5.4	1.050	9.2	0.930
5.5	1.050	9.3	0.900
5.6	1.050	9.4	0.870
5.7	1.050	9.5	0.840
5.8	1.050	9.6	0.810
5.9	1.050	9.7	0.780
6.0	1.050	9.8	0.750
6.1	1.048	9.9	0.720
6.2	1.046	> 9.9	Remove and Replace
6.3	1.044		

6.2.1. **Payment for Incomplete Placement Lots**. Pay adjustments for incomplete placement lots described under Section 341.4.9.3.1.2., "Incomplete Placement Lots," will be calculated using the average of the placement pay factors from all sublots sampled and sublots where the random location falls in an area designated on the plans as not eligible for in-place air void determination. A placement pay adjustment factor of 1.000 will be assigned to any lot when the random sampling plan did not result in collection of any samples.

6.2.2. **Placement Sublots Subject to Removal and Replacement**. If after referee testing, the placement pay adjustment factor for any sublot results in a "remove and replace" condition as listed in Table 17, the Engineer will choose the location of 2 cores to be taken within 3 ft. of the original failing core location. The Contractor will obtain the cores in the presence of the Engineer. The Engineer will take immediate possession of the untrimmed cores and submit the untrimmed cores to the Construction Division, where they will be trimmed if necessary and tested for bulk specific gravity within 10 working days of receipt.

The average bulk specific gravity of the cores will be divided by the Engineer's average maximum theoretical specific gravity for that lot to determine the new pay adjustment factor of the sublot in question. If the new pay adjustment factor is 0.700 or greater, the new pay adjustment factor will apply to that sublot. If the new pay adjustment factor is less than 0.700, no payment will be made for the sublot. Remove and replace the failing sublot, or the Engineer may allow the sublot to be left in place without payment. The Engineer may also accept the sublot in accordance with Section 5.3.1., “Acceptance of Defective or Unauthorized Work.” Replacement material meeting the requirements of this Item will be paid for in accordance with this Section.

6.3. **Total Adjusted Pay Calculation**. Total adjusted pay (TAP) will be based on the applicable pay adjustment factors for production and placement for each lot.

$TAP = (A+B)/2$

where:
A = Bid price × production lot quantity × average pay adjustment factor for the production lot
B = Bid price × placement lot quantity × average pay adjustment factor for the placement lot + (bid price × quantity placed in miscellaneous areas × 1.000)

Production lot quantity = Quantity actually placed - quantity left in place without payment

Placement lot quantity = Quantity actually placed - quantity left in place without payment - quantity placed in miscellaneous areas

Item 342
Permeable Friction Course (PFC)

1. DESCRIPTION

Construct a hot-mix asphalt (HMA) surface course composed of a compacted permeable mixture of aggregate, asphalt binder, and additives mixed hot in a mixing plant.

2. MATERIALS

Furnish uncontaminated materials of uniform quality that meet the requirements of the plans and specifications.

Notify the Engineer of all material sources and before changing any material source or formulation. The Engineer will verify that the specification requirements are met when the Contractor makes a source or formulation change, and may require a new laboratory mixture design, trial batch, or both. The Engineer may sample and test project materials at any time during the project to verify specification compliance in accordance with Item 6, "Control of Materials."

2.1. **Aggregate**. Furnish aggregates from sources that conform to the requirements shown in Table 1 and as specified in this Section. Aggregate requirements in this Section, including those shown in Table 1, may be modified or eliminated when shown on the plans. Additional aggregate requirements may be specified when shown on the plans. Provide aggregate stockpiles that meet the definitions in this Section for coarse aggregate. Do not use intermediate or fine aggregate in PFC mixtures. Aggregate from reclaimed asphalt pavement (RAP) is not required to meet Table 1 requirements unless otherwise shown on the plans. Supply aggregates that meet the definitions in Tex-100-E for crushed gravel or crushed stone. The Engineer will designate the plant or the quarry as the sampling location. Provide samples from materials produced for the project. The Engineer will establish the Surface Aggregate Classification (SAC) and perform Los Angeles abrasion, magnesium sulfate soundness, and Micro-Deval tests. Perform all other aggregate quality tests listed in Table 1. Document all test results on the mixture design report. The Engineer may perform tests on independent or split samples to verify Contractor test results. Stockpile aggregates for each source and type separately. Determine aggregate gradations for mixture design and production testing based on the washed sieve analysis given in Tex-200-F, Part II.

2.1.1. **Coarse Aggregate**. Coarse aggregate stockpiles must have no more than 20% material passing the No. 8 sieve. Aggregates from sources listed in the Department's *Bituminous Rated Source Quality Catalog* (BRSQC) are preapproved for use. Use only the rated values for hot-mix listed in the BRSQC. Rated values for surface treatment (ST) do not apply to coarse aggregate sources used in hot-mix asphalt.

For sources not listed on the Department's BRSQC:

- build an individual stockpile for each material;
- request the Department test the stockpile for specification compliance; and
- once approved, do not add material to the stockpile unless otherwise approved.

Provide aggregate from non-listed sources only when tested by the Engineer and approved before use. Allow 30 calendar days for the Engineer to sample, test, and report results for non-listed sources.

Provide coarse aggregate with at least the minimum SAC shown on the plans. SAC requirements only apply to aggregates used on the surface of travel lanes. SAC requirements apply to aggregates used on surfaces other than travel lanes when shown on the plans. The SAC for sources on the Department's *Aggregate Quality Monitoring Program* (AQMP) (Tex-499-A) is listed in the BRSQC.

2.1.1.1. **Blending Class A and Class B Aggregates**. Class B aggregate meeting all other requirements in Table 1 may be blended with a Class A aggregate to meet requirements for Class A materials; however, Class B virgin (non-recycled) aggregate may be disallowed when shown on the plans. Ensure that at least 50% by weight, or volume if required, of the material retained on the No. 4 sieve comes from the Class A aggregate source when blending Class A and B aggregates to meet a Class A requirement. Blend by volume if the bulk specific gravities of the Class A and B aggregates differ by more than 0.300. Coarse aggregate from RAP and Recycled Asphalt Shingles (RAS) will be considered as Class B aggregate for blending purposes.

The Engineer may perform tests at any time during production, when the Contractor blends Class A and B aggregates to meet a Class A requirement, to ensure that at least 50% by weight, or volume if required, of the material retained on the No. 4 sieve comes from the Class A aggregate source. The Engineer will use the Department's mix design Excel template, when electing to verify conformance, to calculate the percent of Class A aggregate retained on the No. 4 sieve by inputting the bin percentages shown from readouts in the control room at the time of production and stockpile gradations measured at the time of production. The Engineer may determine the gradations based on either washed or dry sieve analysis from samples obtained from individual aggregate cold feed bins or aggregate stockpiles. The Engineer may perform spot checks using the gradations supplied by the Contractor on the mixture design report as an input for the Excel template; however, a failing spot check will require confirmation with a stockpile gradation determined by the Engineer.

2.1.1.2. **Micro-Deval Abrasion**. The Engineer will perform a minimum of one Micro-Deval abrasion test in accordance with Tex-461-A for each coarse aggregate source used in the mixture design that has a Rated Source Soundness Magnesium (RSSM) loss value greater than 15 as listed in the BRSQC. The Engineer will perform testing before the start of production and may perform additional testing at any time during production. The Engineer may obtain the coarse aggregate samples from each coarse aggregate source or may require the Contractor to obtain the samples. The Engineer may waive all Micro-Deval testing based on a satisfactory test history of the same aggregate source.

The Engineer will estimate the magnesium sulfate soundness loss for each coarse aggregate source, when tested, using the following formula:

$$Mg_{est.} = (RSSM)(MD_{act.}/RSMD)$$

where:
$Mg_{est.}$ = magnesium sulfate soundness loss
$MD_{act.}$ = actual Micro-Deval percent loss
$RSMD$ = Rated Source Micro-Deval

When the estimated magnesium sulfate soundness loss is greater than the maximum magnesium sulfate soundness loss specified, the coarse aggregate source will not be allowed for use unless otherwise approved. The Engineer will consult the Geotechnical, Soils, and Aggregates Branch of the Construction Division, and additional testing may be required before granting approval.

Table 1
Coarse Aggregate Quality Requirements

Property	Test Method	Requirement
SAC	Tex-499-A (AQMP)	As shown on the plans
Deleterious material, %, Max	Tex-217-F, Part I	1.0
Decantation, %, Max	Tex-217-F, Part II	1.5
Micro-Deval abrasion, %	Tex-461-A	Note[1]
Los Angeles abrasion, %, Max	Tex-410-A	30
Magnesium sulfate soundness, 5 cycles, %, Max	Tex-411-A	20
Crushed face count,[2] %, Min	Tex-460-A, Part I	95
Flat and elongated particles @ 5:1, %, Max	Tex-280-F	10

1. Used to estimate the magnesium sulfate soundness loss in accordance with Section 342.2.1.1.2., "Micro-Deval Abrasion."
2. Only applies to crushed gravel.

2.2. **Baghouse Fines**. Fines collected by the baghouse or other dust-collecting equipment may be reintroduced into the mixing drum.

2.3. **Asphalt Binder**. Furnish the type and grade of binder specified on the plans that meets the requirements of Item 300, "Asphalts, Oils, and Emulsions."

2.3.1. **Performance-Graded (PG) Binder**. Provide an asphalt binder with a high-temperature grade of PG 76 and low-temperature grade as shown on the plans in accordance with Section 300.2.10., "Performance-Graded Binders," when PG binder is specified.

2.3.2. **Asphalt-Rubber (A-R) Binder**. Provide A-R binder that meets the Type I or Type II requirements of Section 300.2.9., "Asphalt-Rubber Binders," when A-R is specified unless otherwise shown on the plans. Use at least 15.0% by weight of Crumb Rubber Modifier (CRM) that meets the Grade B or Grade C requirements of Section 300.2.7., "Crumb Rubber Modifier," unless otherwise shown on the plans. Provide the Engineer the A-R binder blend design with the mix design (JMF1) submittal. Provide the Engineer with documentation such as the bill of lading showing the quantity of CRM used in the project unless otherwise directed.

2.4. **Tack Coat**. Furnish CSS-1H, SS-1H, or a PG binder with a minimum high-temperature grade of PG 58 for tack coat binder in accordance with Item 300, "Asphalts, Oils, and Emulsions." Specialized or preferred tack coat materials may be allowed or required when shown on the plans. Do not dilute emulsified asphalts at the terminal, in the field, or at any other location before use.

The Engineer will obtain at least one sample of the tack coat binder per project in accordance with Tex-500-C, Part III, and test it to verify compliance with Item 300, "Asphalts, Oils, and Emulsions." The Engineer will obtain the sample from the asphalt distributor immediately before use.

2.5. **Additives**. Use the type and rate of additive specified when shown on the plans. Additives that facilitate mixing, compaction, or improve the quality of the mixture are allowed when approved. Provide the Engineer with documentation such as the bill of lading showing the quantity of additives used in the project unless otherwise directed.

2.5.1. **Fibers**. Provide cellulose or mineral fibers when PG binder is specified. Do not use fibers when A-R binder is specified. Submit written certification to the Engineer that the fibers proposed for use meet the requirements of DMS-9204, "Fiber Additives for Bituminous Mixtures." Fibers may be pre-blended into the binder at the asphalt supply terminal unless otherwise shown on the plans.

When at least 3% RAS is used in the mixture, the Contractor may reduce the amount of fibers as specified in Table 4, Note 3.

2.5.2. **Lime Mineral Filler**. Add lime as mineral filler at a rate of 1.0% by weight of the total dry aggregate in accordance with Item 301, "Asphalt Antistripping Agents," unless otherwise shown on the plans or waived by the Engineer based on Hamburg Wheel test results. Do not add lime directly into the mixing drum of any plant where lime is removed through the exhaust stream unless the plant has a baghouse or dust collection system that reintroduces the lime into the drum.

2.5.3. **Lime and Liquid Antistripping Agent**. When lime or a liquid antistripping agent is used, add in accordance with Item 301, "Asphalt Antistripping Agents." Do not add lime directly into the mixing drum of any plant where lime is removed through the exhaust stream unless the plant has a baghouse or dust collection system that reintroduces the lime into the drum. When the plans require lime to be added as an antistripping agent, lime added as mineral filler will count towards the total quantity of lime specified.

2.5.4. **Warm Mix Asphalt (WMA**). Warm Mix Asphalt (WMA) is defined as HMA that is produced within a target temperature discharge range of 215°F and 275°F using approved WMA additives or processes from the Department's MPL.

WMA is allowed for use on all projects and is required when shown on the plans. When WMA is required, the maximum placement or target discharge temperature for WMA will be set at a value below 275°F.

Department-approved WMA additives or processes may be used to facilitate mixing and compaction of HMA produced at target discharge temperatures above 275°F; however, such mixtures will not be defined as WMA.

2.6. **Recycled Materials**. Use of RAP and RAS is permitted unless otherwise shown on the plans. Do not exceed the maximum allowable percentages of RAP and RAS shown in Table 2. The allowable percentages shown in Table 2 may be decreased or increased when shown on the plans. Determine asphalt binder content and gradation of the RAP and RAS stockpiles for mixture design purposes in accordance with Tex-236-F. The Engineer may verify the asphalt binder content of the stockpiles at any time during production. Perform other tests on RAP and RAS when shown on the plans. Asphalt binder from RAP and RAS is designated as recycled asphalt binder. Calculate and ensure that the ratio of the recycled asphalt binder to total binder does not exceed the percentages shown in Table 2 during mixture design and HMA production when RAP or RAS is used. Use a separate cold feed bin for each stockpile of RAP and RAS during HMA production.

2.6.1. **RAP**. RAP is salvaged, milled, pulverized, broken, or crushed asphalt pavement. Crush or break RAP so that 100% of the particles pass the 2 in. sieve. Fractionated RAP is defined as 2 or more RAP stockpiles, divided into coarse and fine fractions.

Use of Contractor-owned RAP, including HMA plant waste, is permitted unless otherwise shown on the plans. Department-owned RAP stockpiles are available for the Contractor's use when the stockpile locations are shown on the plans. If Department-owned RAP is available for the Contractor's use, the Contractor may use Contractor-owned fractionated RAP and replace it with an equal quantity of Department-owned RAP. Unfractionated RAP is not allowed in PFC mixtures. Department-owned RAP generated through required work on the Contract is available for the Contractor's use when shown on the plans. Perform any necessary tests to ensure Contractor- or Department-owned RAP is appropriate for use. The Department will not perform any tests or assume any liability for the quality of the Department-owned RAP unless otherwise shown on the plans. The Contractor will retain ownership of RAP generated on the project when shown on the plans.

The coarse RAP stockpile will contain only material retained by processing over a 3/8-in. or 1/2-in. screen unless otherwise approved. Fine RAP is not allowed in PFC mixtures. The Engineer may allow the Contractor to use an alternate to the 3/8-in. or 1/2-in. screen to fractionate the RAP.

Do not use Department- or Contractor-owned RAP contaminated with dirt or other objectionable materials.

Do not intermingle Contractor-owned RAP stockpiles with Department-owned RAP stockpiles. Remove unused Contractor-owned RAP material from the project site upon completion of the project. Return unused Department-owned RAP to the designated stockpile location.

2.6.2. **RAS**. Use of post-manufactured RAS or post-consumer RAS (tear-offs) is permitted unless otherwise shown on the plans. RAS is defined as processed asphalt shingle material from manufacturing of asphalt roofing shingles or from re-roofing residential structures. Post-manufactured RAS is processed manufacturer's shingle scrap by-product. Post-consumer RAS is processed shingle scrap removed from residential structures. Comply with all regulatory requirements stipulated for RAS by the TCEQ. RAS may be used separately or in conjunction with RAP.

Process the RAS by ambient grinding or granulating such that 100% of the particles pass the 3/8 in. sieve when tested in accordance with Tex-200-F, Part I. Perform a sieve analysis on processed RAS material before extraction (or ignition) of the asphalt binder.

Any stockpile that contains RAS will be considered a RAS stockpile and be limited to no more than 5.0% of the HMA mixture in accordance with Table 2.

Certify compliance of the RAS with DMS-11000, "Evaluating and Using Nonhazardous Recyclable Materials Guidelines." Treat RAS as an established nonhazardous recyclable material if it has not come into contact with any hazardous materials. Use RAS from shingle sources on the Department's MPL. Remove substantially all materials before use that are not part of the shingle, such as wood, paper, metal, plastic, and felt paper. Determine the deleterious content of RAS material for mixture design purposes in accordance with Tex-217-F, Part III. Do not use RAS if deleterious materials are more than 0.5% of the stockpiled RAS unless otherwise approved. Submit a sample for approval before submitting the mixture design. The Department will perform the testing for deleterious material of RAS to determine specification compliance.

Table 2
Maximum Allowable Amounts of Recycled Binder, RAP, and RAS

Maximum Ratio of Recycled Binder to Total Binder[1] (%)	Maximum Allowable Recycled Material[2] (%)	
	Fractionated RAP[3]	RAS[4]
15.0	10.0	5.0

1. Combined recycled binder from fractionated RAP and RAS.
2. Unfractionated RAP is not allowed in PFC mixtures.
3. May replace up to 5% fractionated RAP with RAS.
4. May be used separately or as a replacement for no more than 5% of the allowable fractionated RAP.

3. EQUIPMENT

Provide required or necessary equipment in accordance with Item 320, "Equipment for Asphalt Concrete Pavement." When A-R binder is specified, equip the hot-mix plant with an in-line viscosity-measuring device located between the blending unit and the mixing drum. Provide a means to calibrate the asphalt mass flow meter on-site when a meter is used.

4. CONSTRUCTION

Produce, haul, place, and compact the specified paving mixture. In addition to tests required by the specification, Contractors may perform other QC tests as deemed necessary. At any time during the project, the Engineer may perform production and placement tests as deemed necessary in accordance with Item 5, "Control of the Work." Schedule and participate in a mandatory pre-paving meeting with the Engineer on or before the first day of paving unless otherwise shown on the plans.

4.1. **Certification**. Personnel certified by the Department-approved hot-mix asphalt certification program must conduct all mixture designs, sampling, and testing in accordance with Table 3. Supply the Engineer with a list of certified personnel and copies of their current certificates before beginning production and when personnel changes are made. Provide a mixture design developed and signed by a Level 2 certified specialist. Provide Level 1A certified specialists at the plant during production operations. Provide Level 1B certified specialists to conduct placement tests.

Table 3
Test Methods, Test Responsibility, and Minimum Certification Levels

Test Description	Test Method	Contractor	Engineer	Level[1]
1. Aggregate and Recycled Material Testing				
Sampling	Tex-221-F	✓	✓	1A
Dry sieve	Tex-200-F, Part I	✓	✓	1A
Washed sieve	Tex-200-F, Part II	✓	✓	1A
Deleterious material	Tex-217-F, Parts I & III	✓	✓	1A
Decantation	Tex-217-F, Part II	✓	✓	1A
Los Angeles abrasion	Tex-410-A		✓	TxDOT
Magnesium sulfate soundness	Tex-411-A		✓	TxDOT
Micro-Deval abrasion	Tex-461-A		✓	2
Crushed face count	Tex-460-A	✓	✓	2
Flat and elongated particles	Tex-280-F	✓	✓	2
2. Asphalt Binder & Tack Coat Sampling				
Asphalt binder sampling	Tex-500-C, Part II	✓	✓	1A/1B
Tack coat sampling	Tex-500-C, Part III	✓	✓	1A/1B
3. Mix Design & Verification				
Design and JMF changes	Tex-204-F	✓	✓	2
Mixing	Tex-205-F	✓	✓	2
Molding (SGC)	Tex-241-F	✓	✓	1A
Laboratory-molded density	Tex-207-F	✓	✓	1A
Rice gravity	Tex-227-F	✓	✓	1A
Ignition oven correction factors[2]	Tex-236-F	✓	✓	2
Drain-down	Tex-235-F	✓	✓	1A
Hamburg Wheel test	Tex-242-F	✓	✓	2
Overlay test	Tex-248-F		✓	TxDOT
Boil test	Tex-530-C	✓	✓	1A
Cantabro loss	Tex-245-F	✓	✓	2
4. Production Testing				
Control charts	Tex-233-F	✓	✓	1A
Mixture sampling	Tex-222-F	✓	✓	1A
Gradation & asphalt binder content[2]	Tex-236-F	✓	✓	1A
Moisture content	Tex-212-F	✓	✓	1A
Micro-Deval abrasion	Tex-461-A		✓	2
Drain-down	Tex-235-F	✓	✓	1A
Boil test	Tex-530-C	✓	✓	1A
Abson recovery	Tex-211-F		✓	TxDOT
5. Placement Testing				
Control charts	Tex-233-F	✓	✓	1A
Ride quality measurement	Tex-1001-S	✓	✓	Note[3]
Thermal profile	Tex-244-F	✓	✓	1B
Permeability	Tex-246-F	✓	✓	1B

1. Level 1A, 1B, and 2 are certification levels provided by the Hot Mix Asphalt Center certification program.
2. Refer to Section 342.4.5., "Production Operations," for exceptions to using an ignition oven.
3. Profiler and operator are required to be certified at the Texas A&M Transportation Institute facility when Surface Test Type B is specified.

4.2. **Reporting and Responsibilities**. Use Department-provided Excel templates to record and calculate all test data, including mixture design, production and placement tests, control charts, and thermal profiles. Obtain the latest version of the Excel templates at http://www.txdot.gov/inside-txdot/forms-publications/consultants-contractors/forms/site-manager.html or from the Engineer. The Engineer and the Contractor will provide any available test results to the other party when requested. The Engineer and the Contractor will immediately report to the other party any test result that requires suspension of production or placement or that fails to meet the specification requirements. Record and submit all test results and pertinent information on Department-provided Excel templates to the Engineer electronically by means of a portable USB flash drive, compact disc, or via email.

Subsequent sublots placed after test results are available to the Contractor, which require suspension of operations, may be considered unauthorized work. Unauthorized work will be accepted or rejected at the discretion of the Engineer in accordance with Article 5.3., “Conformity with Plans, Specifications, and Special Provisions.”

Use the procedures described in Tex-233-F to plot the results of all production and placement testing, when directed. Update the control charts as soon as test results for each sublot become available. Make the control charts readily accessible at the field laboratory. The Engineer may suspend production for failure to update control charts.

4.3. **Quality Control Plan (QCP**). Develop and follow the QCP in detail. Obtain approval for changes to the QCP made during the project. The Engineer may suspend operations if the Contractor fails to comply with the QCP.

Submit a written QCP before the mandatory pre-paving meeting when directed. Receive approval of the QCP before beginning production. Include the following items in the QCP:

4.3.1. **Project Personnel**. For project personnel, include:

- a list of individuals responsible for QC with authority to take corrective action;
- current contact information for each individual listed; and
- current copies of certification documents for individuals performing specified QC functions.

4.3.2. **Material Delivery and Storage**. For material delivery and storage, include:

- the sequence of material processing, delivery, and minimum quantities to assure continuous plant operations;
- aggregate stockpiling procedures to avoid contamination and segregation;
- frequency, type, and timing of aggregate stockpile testing to assure conformance of material requirements before mixture production; and
- procedure for monitoring the quality and variability of asphalt binder.

4.3.3. **Production**. For production, include:

- loader operation procedures to avoid contamination in cold bins;
- procedures for calibrating and controlling cold feeds;
- procedures to eliminate debris or oversized material;
- procedures for adding and verifying rates of each applicable mixture component (e.g., aggregate, asphalt binder, RAP, RAS, lime, liquid antistrip, WMA, fibers);
- procedures for reporting job control test results; and
- procedures to avoid segregation and drain-down in the silo.

4.3.4. **Loading and Transporting**. For loading and transporting, include:

- type and application method for release agents; and
- truck loading procedures to avoid segregation.

4.3.5. **Placement and Compaction**. For placement and compaction, include:

- proposed agenda for mandatory pre-paving meeting, including date and location;
- proposed paving plan (e.g., paving widths, joint offsets, and lift thicknesses);
- type and application method for release agents in the paver and on rollers, shovels, lutes, and other utensils;
- procedures for the transfer of mixture into the paver, while avoiding segregation and preventing material spillage;
- process to balance production, delivery, paving, and compaction to achieve continuous placement operations and good ride quality;

- paver operations (e.g., operation of wings, height of mixture in auger chamber) to avoid physical and thermal segregation and other surface irregularities; and
- procedures to construct quality longitudinal and transverse joints.

4.4. **Mixture Design**.

4.4.1. **Design Requirements**. Use the PFC design procedure given in Tex-204-F, Part V, unless otherwise shown on the plans. Design the mixture to meet the requirements listed in Tables 1, 2, and 4. Use a Superpave Gyratory Compactor (SGC) at 50 gyrations as the design number of gyrations (Ndesign).

The Engineer will provide the mixture design when shown on the plans. The Contractor may submit a new mixture design at any time during the project. The Engineer will verify and approve all mixture designs (JMF1) before the Contractor can begin production.

Provide the Engineer with a mixture design report using the Department-provided Excel template. Include the following items in the report:

- the combined aggregate gradation, source, specific gravity, and percent of each material used;
- asphalt binder content and aggregate gradation of RAP and RAS stockpiles;
- results of all applicable tests;
- the mixing and molding temperatures;
- the signature of the Level 2 person or persons that performed the design;
- the date the mixture design was performed; and
- a unique identification number for the mixture design.

Table 4
Master Gradation Limits (% Passing by Weight or Volume) and Laboratory Mixture Design Properties

Sieve Size	PG 76 Mixtures		A-R Mixtures		Test Procedure
	Fine (PFC-F)	Coarse (PFC-C)	Fine (PFCR-F)	Coarse (PFCR-C)	
3/4"	–	100.0[1]	100.0[1]	100.0[1]	Tex-200-F
1/2"	100.0[1]	80.0-100.0	95.0-100.0	80.0-100.0	
3/8"	95.0-100.0	35.0-60.0	50.0-80.0	35.0-60.0	
#4	20.0-55.0	1.0-20.0	0.0-8.0	0.0-20.0	
#8	1.0-10.0	1.0-10.0	0.0-4.0	0.0-10.0	
#200	1.0-4.0	1.0-4.0	0.0-4.0	0.0-4.0	
Mixture Properties					
Asphalt binder content, %	6.0-7.0	6.0-7.0	8.0-10.0	7.0-9.0	–
Design gyrations (Ndesign)	50	50	50	50	Tex-241-F
Lab-molded density, %	78.0 Max	82.0 Max	82.0 Max	82.0 Max	Tex-207-F
Hamburg Wheel test,[2] passes at 12.5 mm rut depth	10,000 Min[3]	Note[2]	Note[2]	Note[2]	Tex-242-F
Overlay tester,[2] number of cycles	200 Min	Note[2]	Note[2]	Note[2]	Tex-248-F
Drain-down, %	0.10 Max	0.10 Max	0.10 Max	0.10 Max	Tex-235-F
Fiber content, % by wt. of total PG 76 mixture	0.20[4]-0.50	0.20[4]-0.50	–	–	Calculated
Lime content, % by wt. of total aggregate	1.0[5]	1.0[5]	1.0[5]	1.0[5]	Calculated
CRM content, % by wt. of A-R binder	–	–	15.0 Min	15.0 Min	Calculated
Boil test[6]	–	–	–	–	Tex-530-C
Cantabro loss, %	20.0 Max	20.0 Max	20.0 Max	20.0 Max	Tex-245-F

1. Defined as maximum sieve size. No tolerance allowed.
2. Mold test specimens to Ndesign at the optimum asphalt binder content (JMF1). Perform the test for informational purposes only when no minimum number is specified.
3. May be decreased when approved.
4. The Contractor may reduce the amount of fibers to no less than 0.10%, provided the mixture meets the drain-down requirement, when at least 3% RAS is used in the mixture.
5. Unless otherwise shown on the plans or waived by the Engineer based on Hamburg Wheel results.
6. Used to establish baseline for comparison to production results. May be waived when approved.

4.4.2. **Job-Mix Formula Approval**. The job-mix formula (JMF) is the combined aggregate gradation, Ndesign level, and target asphalt percentage used to establish target values for hot-mix production. JMF1 is the original laboratory mixture design used to produce the trial batch. When WMA is used, JMF1 may be designed and submitted to the Engineer without including the WMA additive. When WMA is used, document the additive or process used and recommended rate on the JMF1 submittal. The Engineer and the Contractor will verify JMF1 based on plant-produced mixture from the trial batch unless otherwise approved. The Engineer may accept an existing mixture design previously used on a Department project and may waive the trial batch to verify JMF1. The Department may require the Contractor to reimburse the Department for verification tests if more than 2 trial batches per design are required.

4.4.2.1. **Contractor's Responsibilities**.

4.4.2.1.1. **Gyratory Compactor.** Furnish an SGC calibrated in accordance with Tex-241-F for molding production samples. Locate the SGC at the Engineer's field laboratory and make the SGC available to the Engineer for use in molding production samples.

4.4.2.1.2. **Gyratory Compactor Correlation Factors**. Use Tex-206-F, Part II, to perform a gyratory compactor correlation when the Engineer uses a different SGC. Apply the correlation factor to all subsequent production test results.

4.4.2.1.3. **Hamburg and Overlay Testing.** Use an approved laboratory from the Department's MPL to perform the Hamburg Wheel test and provide results with the mixture design, or provide 10,000 g of the laboratory mixture and request that the Department perform the Hamburg Wheel test.

Provide 25,000 g of the laboratory mixture and request that the Department perform the Overlay test.

The Engineer will be allowed 10 working days to provide the Contractor with Hamburg Wheel and Overlay test results on the laboratory mixture design.

4.4.2.1.4. **Submitting JMF1**. Furnish a mix design report (JMF1) including Hamburg and Overlay results. Provide representative samples of all component materials and request approval to produce the trial batch.

4.4.2.1.5. **Supplying Aggregates**. Provide approximately 40 lb. of each aggregate stockpile unless otherwise directed.

4.4.2.1.6. **Supplying Asphalt**. Provide at least 1 gal. of the asphalt material and sufficient quantities of any additives proposed for use.

4.4.2.1.7. **Ignition Oven Correction Factors**. Determine the aggregate and asphalt correction factors from the ignition oven in accordance with Tex-236-F. Note that the asphalt content correction factor takes into account the percent fibers in the mixture so that the fibers are excluded from the binder content determination. Provide the Engineer with split samples of the mixtures before the trial batch production, including all additives (except water), and blank samples used to determine the correction factors for the ignition oven used for quality assurance (QA) testing during production. Correction factors established from a previously approved mixture design may be used for the current mixture design if the mixture design and ignition oven are the same as previously used unless otherwise directed.

4.4.2.1.8. **Boil Test**. Perform the test and retain the tested sample from Tex-530-C until completion of the project or as directed. Use this sample for comparison purposes during production. The Engineer may waive the requirement for the boil test. Add lime or liquid antistripping agent, as directed, if signs of stripping exist.

4.4.2.1.9. **Trial Batch Production**. Provide a plant-produced trial batch upon receiving conditional approval of JMF1 and authorization to produce a trial batch including the WMA additive or process, if applicable, for verification testing of JMF1 and development of JMF2. Produce a trial batch mixture that meets the requirements in Table 2 and Table 5. The Engineer may accept test results from recent production of the same mixture instead of a new trial batch.

4.4.2.1.10. **Trial Batch Production Equipment**. Use only equipment and materials proposed for use on the project to produce the trial batch. Provide documentation to verify the calibration or accuracy of the asphalt mass flow meter to measure the binder content. Verify that asphalt mass flow meter meets the requirements of 0.4% accuracy, when required, in accordance with Item 520, "Weighing and Measuring Equipment." The Engineer may require that the accuracy of the mass flow meter be verified based on quantities used.

4.4.2.1.11. **Trial Batch Quantity**. Produce enough quantity of the trial batch to ensure that the mixture meets the specification requirements.

4.4.2.1.12. **Number of Trial Batches**. Produce trial batches as necessary to obtain a mixture that meets the specification requirements.

4.4.2.1.13. **Trial Batch Sampling**. Obtain a representative sample of the trial batch and split it into 3 equal portions in accordance with Tex-222-F. Label these portions as "Contractor," "Engineer," and "Referee." Deliver samples to the appropriate laboratory as directed.

4.4.2.1.14. **Trial Batch Testing**. Test the trial batch to ensure the mixture produced using the proposed JMF1 meets the mixture requirements in Table 5. Provide the Engineer with a copy of the trial batch test results.

4.4.2.1.15. **Development of JMF2**. Evaluate the trial batch test results, determine the target mixture proportions, and submit as JMF2 after the Engineer grants full approval of JMF1 based on results from the trial batch. Verify that JMF2 meets the mixture requirements in Table 2.

4.4.2.1.16. **Mixture Production**. Use JMF2 to produce Lot 1 after receiving approval for JMF2.

4.4.2.1.17. **Development of JMF3**. Evaluate the test results from Lot 1, determine the optimum mixture proportions, and submit as JMF3 for use in Lot 2.

4.4.2.1.18. **JMF Adjustments**. If JMF adjustments are necessary to achieve the specified requirements, make the adjustments before beginning a new lot. The adjusted JMF must:

- be provided to the Engineer in writing before the start of a new lot;
- be numbered in sequence to the previous JMF;
- meet the mixture requirements in Table 2;
- meet the master gradation and binder content limits shown in Table 4; and
- be within the operational tolerances of JMF2 listed in Table 5.

4.4.2.1.19. **Requesting Referee Testing**. Use referee testing, if needed, in accordance with Section 342.4.9.1., "Referee Testing," to resolve testing differences with the Engineer.

Table 5
Testing Frequency and Mixture Production Tolerances

Test Description	Test Method	Minimum Contractor Testing Frequency	Minimum Engineer Testing Frequency	Operational Tolerance from Current JMF
Individual % retained for sieve sized larger than #200	Tex-200-F	1 per sublot	1 per 12 sublots	±5.0[1]
% passing the #200 sieve				±2.0[1]
Laboratory-molded density, %	Tex-207-F, Part VIII	1 per sublot	1 per lot	Table 4
Asphalt binder content, %	Tex-236-F[2]	1 per sublot	1 per lot[3]	±0.3[4]
Drain-down, %	Tex-235-F	1 per sublot	1 per 12 sublots	Table 4
Boil test[5]	Tex-530-C	1 per project	1 per project	N/A
Cantabro loss, %	Tex-245-F	1 per project (sample only)	1 per project	Table 4
Asphalt binder sampling	Tex-500-C	1 per lot (sample only)	1 per project	N/A
Tack coat sampling and testing	Tex-500-C, Part III	N/A	1 per project	N/A
Thermal profile	Tex-244-F	1 per sublot	Optional	N/A

1. Only applies to mixture produced for Lot 1 and higher. Aggregate gradation is not allowed to be outside the limits shown in Table 4.
2. Ensure the binder content determination excludes fibers. Add the recycled binder content to the flow meter readout when the asphalt mass flow meter is used to determine binder content.
3. May be obtained from asphalt mass flow meter readouts.
4. Binder content is not allowed to be outside the limits shown in Table 4.
5. The Engineer may reduce or waive the sampling and testing requirements based on a satisfactory test history.

4.4.2.2. **Engineer's Responsibilities**.

4.4.2.2.1. **Gyratory Compactor.** The Engineer will use a Department SGC calibrated in accordance with Tex-241-F to mold samples for laboratory mixture design verification. For molding trial batch and production specimens, the Engineer will use the Contractor-provided SGC at the field laboratory or provide and use a Department SGC at an alternate location. The Engineer will make the Contractor-provided SGC in the Department field laboratory available to the Contractor for molding verification samples.

4.4.2.2.2. **Hamburg Wheel and Overlay Testing**. At the Contractor's request, the Department will perform the Hamburg Wheel test on the laboratory mixture in accordance with Tex-242-F to verify compliance with the Hamburg Wheel test requirement in Table 4. The Department will perform the Overlay test in accordance with Tex-248-F to verify compliance with the Overlay test requirements in Table 4. The Engineer will be allowed 10 working days to provide the Contractor with Hamburg Wheel and Overlay test results on the laboratory mixture design.

4.4.2.2.3. **Conditional Approval of JMF1 and Authorizing Trial Batch**. The Engineer will review the Contractor's mix design report and verify specification conformance of the mixture and component materials. The Engineer will grant conditional approval of JMF1 within 2 working days of receiving the complete mixture design report (JMF1) and all required materials.

Unless waived, the Engineer will determine the Micro-Deval abrasion loss in accordance with Section 342.2.1.1.2., "Micro-Deval Abrasion." If the Engineer's test results are pending after 2 working days, conditional approval of JMF1 will still be granted within 2 working days of receiving JMF1. When the Engineer's test results become available, they will be used for specification compliance.

The Contractor is authorized to produce a trial batch after the Engineer grants conditional approval of JMF1.

4.4.2.2.4. **Ignition Oven Correction Factors**. The Engineer will use the split samples provided by the Contractor to determine the aggregate and asphalt correction factors for the ignition oven used for QA testing during production in accordance with Tex-236-F. The Engineer will verify that the asphalt content correction factor takes into account the percent fibers in the mixture so that the fibers are excluded from the binder content determination.

4.4.2.2.5. **Testing the Trial Batch**. Within 1 full working day, the Engineer will sample and test the trial batch to ensure that the mixture meets the requirements in Table 5.

The Engineer will have the option to perform the following tests on the trial batch:

- Tex-235-F, to verify that drain-down meets the requirements shown in Table 4;
- Tex-530-C, to retain and use for comparison purposes during production; and
- Tex-245-F, to verify the Cantabro loss meets the requirement shown in Table 4.

4.4.2.2.6. **Full Approval of JMF1**. The Engineer will grant full approval of JMF1 and authorize the Contractor to proceed with developing JMF2 if the Engineer's results for the trial batch meet the requirements in Table 5.

The Engineer will notify the Contractor that an additional trial batch is required if the trial batch does not meet these requirements.

4.4.2.2.7. **Approval of JMF2**. The Engineer will approve JMF2 within one working day if the mixture meets the requirements in Table 2 as well as the master grading limits and binder content shown in Table 4.

4.4.2.2.8. **Approval of Lot 1 Production**. The Engineer will authorize the Contractor to proceed with Lot 1 production (using JMF2).

4.4.2.2.9. **Approval of JMF3 and Subsequent JMF Changes**. JMF3 and subsequent JMF changes are approved if they meet the mixture requirements shown in Table 2 and the master grading and binder content limits shown in Table 4, and are within the operational tolerances of JMF2 shown in Table 5.

4.4.2.2.10. **Binder Content Adjustments**. For JMF2 and above, the Engineer may require the Contractor to adjust the target binder content by no more than 0.3% from the current JMF.

4.5. **Production Operations**. Perform a new trial batch when the plant or plant location is changed. Perform QC at the frequency and within the tolerances listed in Table 5. Take corrective action and receive approval to proceed after any production suspension for noncompliance to the specification. Submit a new mix design and perform a new trial batch when the asphalt binder content of:

- any RAP stockpile used in the mix is more than 0.5% higher than the value shown on the mixture design report; or
- RAS stockpile used in the mix is more than 2.0% higher than the value shown on the mixture design report.

At any time during production, the Engineer may require the Contractor to verify the following based on quantities used:

- lime content (within ±0.1% of JMF), when PG binder is specified;
- fiber content (within ±0.03% of JMF), when PG binder is specified; and
- CRM content (within ±1.5% of JMF), when A-R binder is specified.

Maintain the in-line measuring device when A-R binder is specified to verify the A-R binder viscosity between 2,500 and 4,000 centipoise at 350°F unless otherwise approved. Record A-R binder viscosity at least once per hour and provide the Engineer with a daily summary unless otherwise directed.

If the aggregate mineralogy is such that Tex-236-F does not yield reliable results, the Engineer may allow alternate methods for determining the asphalt content and aggregate gradation. The Engineer will require the Contractor to provide evidence that results from Tex-236-F are not reliable before permitting an alternate method unless otherwise allowed. Use the applicable test procedure as directed if an alternate test method is allowed.

4.5.1. **Storage and Heating of Materials**. Do not heat the asphalt binder above the temperatures specified in Item 300, "Asphalts, Oils, and Emulsions," or outside the manufacturer's recommended values. Provide the Engineer with daily records of asphalt binder and hot-mix asphalt discharge temperatures (in legible and discernible increments) in accordance with Item 320, "Equipment for Asphalt Concrete Pavement," unless otherwise directed. Do not store mixture for a period long enough to affect the quality of the mixture, nor in any case longer than 12 hr. unless otherwise approved.

4.5.2. **Mixing and Discharge of Materials**. Notify the Engineer of the target discharge temperature and produce the mixture within 25°F of the target. Monitor the temperature of the material in the truck before shipping to ensure that it does not exceed 350°F (or 275°F for WMA) and is not lower than 215°F. The Department will not pay for or allow placement of any mixture produced above 350°F.

Produce WMA within the target discharge temperature range of 215°F and 275°F when WMA is required. Take corrective action any time the discharge temperature of the WMA exceeds the target discharge range. The Engineer may suspend production operations if the Contractor's corrective action is not successful at controlling the production temperature within the target discharge range. Note that when WMA is produced, it may be necessary to adjust burners to ensure complete combustion such that no burner fuel residue remains in the mixture.

Control the mixing time and temperature so that substantially all moisture is removed from the mixture before discharging from the plant. Determine the moisture content, if requested, by oven-drying in accordance with Tex-212-F, Part II, and verify that the mixture contains no more than 0.2% of moisture by weight. Obtain the sample immediately after discharging the mixture into the truck, and perform the test promptly.

4.6. **Hauling Operations**. Clean all truck beds before use to ensure that mixture is not contaminated. Use a release agent, when necessary, shown on the Department's MPL to coat the inside bed of the truck.

Use equipment for hauling as defined in Section 342.4.7.3.3., "Hauling Equipment." Use other hauling equipment only when allowed.

4.7. **Placement Operations**. Collect haul tickets from each load of mixture delivered to the project and provide the Department's copy to the Engineer approximately every hour or as directed. Use a hand-held thermal camera or infrared thermometer, when a thermal imaging system is not used, to measure and record the internal temperature of the mixture as discharged from the truck or Material Transfer Device (MTD) before or as the mix enters the paver and an approximate station number or GPS coordinates on each ticket. Calculate the daily yield and cumulative yield for the specified lift and provide to the Engineer at the end of paving operations for each day unless otherwise directed. The Engineer may suspend production if the Contractor fails to produce and provide haul tickets and yield calculations by the end of paving operations for each day.

Prepare the surface by removing raised pavement markers and objectionable material such as moisture, dirt, sand, leaves, and other loose impediments from the surface before placing mixture. Remove vegetation from pavement edges. Place the mixture to meet the typical section requirements and produce a smooth, finished surface with a uniform appearance and texture. Offset longitudinal joints of successive courses of hot-mix by at least 6 in. Place mixture so that longitudinal joints on the surface course coincide with lane lines, or as directed. Ensure that all finished surfaces will drain properly.

4.7.1. **Weather Conditions**.

4.7.1.1. **When Using a Thermal Imaging System**. The Contractor may pave any time the roadway is dry and the roadway surface temperature is at least 50°F; however, the Engineer may restrict the Contractor from paving if the ambient temperature is likely to drop below 32°F within 12 hr. of paving. Provide output data from the thermal imaging system to demonstrate to the Engineer that no recurring severe thermal segregation exists in accordance with Section 342.4.7.3.1.2., "Thermal Imaging System."

4.7.1.2. **When Not Using a Thermal Imaging System**. Place mixture when the roadway surface temperature is at or above 70°F unless otherwise approved or as shown on the plans. Measure the roadway surface temperature with a hand-held thermal camera or infrared thermometer. The Engineer may allow mixture placement to begin before the roadway surface reaches the required temperature if conditions are such that the roadway surface will reach the required temperature within 2 hr. of beginning placement operations. Place mixtures only when weather conditions and moisture conditions of the roadway surface are suitable as determined by the Engineer. The Engineer may restrict the Contractor from paving if the ambient temperature is likely to drop below 32°F within 12 hr. of paving.

4.7.2. **Tack Coat**. Clean the surface before placing the tack coat. The Engineer will set the rate between 0.04 and 0.10 gal. of residual asphalt per square yard of surface area. Apply a uniform tack coat at the specified rate unless otherwise directed. Apply the tack coat in a uniform manner to avoid streaks and other irregular patterns. Apply a thin, uniform tack coat to all contact surfaces of curbs, structures, and all joints. Allow adequate time for emulsion to break completely before placing any material. Prevent splattering of tack coat when placed adjacent to curb, gutter, and structures. Roll the tack coat with a pneumatic-tire roller to remove streaks and other irregular patterns when directed.

4.7.3. **Lay-Down Operations**.

4.7.3.1. **Thermal Profile**. Use a hand-held thermal camera or a thermal imaging system to obtain a continuous thermal profile in accordance with Tex-244-F. Thermal profiles are not applicable in areas described in Section 342.4.9.4., "Miscellaneous Areas."

4.7.3.1.1. **Thermal Segregation**.

4.7.3.1.1.1. **Moderate**. Any areas that have a temperature differential greater than 25°F, but not exceeding 50°F, are deemed as having moderate thermal segregation.

4.7.3.1.1.2. **Severe**. Any areas that have a temperature differential greater than 50°F are deemed as having severe thermal segregation.

4.7.3.1.2. **Thermal Imaging System**. Review the output results when a thermal imaging system is used, and provide the automated report described in Tex-244-F to the Engineer daily unless otherwise directed. Modify the paving process as necessary to eliminate any recurring (moderate or severe) thermal segregation identified by the thermal imaging system. The Engineer may suspend paving operations if the Contractor cannot successfully modify the paving process to eliminate recurring severe thermal segregation. Provide the Engineer with electronic copies of all daily data files that can be used with the thermal imaging system software to generate temperature profile plots upon completion of the project or as requested by the Engineer.

4.7.3.1.3. **Thermal Camera**. Take immediate corrective action to eliminate recurring moderate thermal segregation when a hand-held thermal camera is used. Provide the Engineer with the thermal profile of every sublot within one working day of the completion of each lot. Report the results of each thermal profile in accordance with Section 342.4.2., "Reporting and Responsibilities." The Engineer will use a hand-held thermal camera to obtain a thermal profile at least once per project. Suspend operations and take immediate corrective action to eliminate severe thermal segregation unless otherwise directed. Resume operations when the Engineer determines that subsequent production will meet the requirements of this Section.

4.7.3.2. **Windrow Operations**. Operate windrow pickup equipment so that when hot-mix is placed in windrows, substantially all the mixture deposited on the roadbed is picked up and loaded into the paver.

4.7.3.3. **Hauling Equipment**. Use belly dumps, live bottom, or end dump trucks to haul and transfer mixture; however, with exception of paving miscellaneous areas, end dump trucks are only allowed when used in conjunction with an MTD with remixing capability or when a thermal imaging system is used unless otherwise allowed.

4.7.3.4. **Screed Heaters**. Turn off screed heaters to prevent overheating of the mat if the paver stops for more than 5 min. The Engineer may evaluate the suspect area in accordance with Section 342.4.9.5., "Recovered Asphalt Dynamic Shear Rheometer (DSR)," if the screed heater remains on for more than 5 min. while the paver is stopped.

4.8. **Compaction**. Roll the freshly placed PFC with a steel-wheeled roller, operated in static mode, to seat the mixture without excessive breakage of the aggregate and to provide a smooth surface and uniform texture. Do not use pneumatic rollers. Moisten the roller drums thoroughly with a soap and water solution to prevent adhesion. Use only water or an approved release agent on rollers, tamps, and other compaction equipment unless otherwise directed.

The Engineer may use or require the Contractor to use Tex-246-F to test and verify that the compacted mixture has adequate permeability. Adjust the mixture design or construction methods if the compacted mixture does not exhibit adequate permeability.

Complete all compaction operations before the pavement temperature drops below 160°F unless otherwise allowed. The Engineer may allow compaction with a light finish roller operated in static mode for pavement temperatures below 160°F.

Allow the compacted pavement to cool to 160°F or lower before opening to traffic unless otherwise directed. Sprinkle the finished mat with water or limewater, when directed, to expedite opening the roadway to traffic.

4.9. **Acceptance Plan**. Sample and test the hot-mix on a lot and sublot basis. A production lot consists of 4 equal sublots. Lot 1 will be 2,000 tons. The Engineer will select subsequent lot sizes based on the anticipated daily production. The lot size will be between 2,000 and 4,000 tons. The Engineer may change the lot size before the Contractor begins any lot.

4.9.1. **Referee Testing**. The Construction Division is the referee laboratory. The Contractor may request referee testing if the differences between Contractor and Engineer test results exceed the operational tolerances shown in Table 5 and the differences cannot be resolved. The Contractor may also request referee testing if the Engineer's test results require suspension of production and the Contractor's test results are within specification limits. Make the request within 5 working days after receiving test results and cores from the Engineer. Referee tests will be performed only on the sublot in question and only for the particular tests in question. Allow 10 working days from the time the referee laboratory receives the samples for test results to be reported. The Department may require the Contractor to reimburse the Department for referee tests if more than 3 referee tests per project are required and the Engineer's test results are closer to the referee test results than the Contractor's test results.

4.9.2. **Asphalt Binder Sampling**. Obtain a 1 qt. (1 gal. for A-R binder) sample of the asphalt binder for each lot of mixture produced. Obtain the sample at approximately the same time the mixture random sample is obtained. Sample from a port located immediately upstream from the mixing drum or pug mill in accordance with Tex-500-C, Part II. Label the can with the corresponding lot and sublot numbers and deliver the sample to the Engineer. The Engineer may also obtain independent samples. If obtaining an independent asphalt binder sample, the Engineer will split a sample of the asphalt binder with the Contractor. The Engineer will test at least one asphalt binder sample per project to verify compliance with Item 300, "Asphalts, Oils, and Emulsions."

4.9.3. **Operational Tolerances**. Control the production process within the operational tolerances listed in Table 5. Suspend production and placement operations when production or placement test results exceed the tolerances listed in Table 5 unless otherwise allowed. When production is suspended, the Engineer will allow production to resume when test results or other information indicates the next mixture produced will be within the operational tolerances.

4.9.4. **Miscellaneous Areas**. Miscellaneous areas include areas that typically involve significant handwork or discontinuous paving operations such as driveways, mailbox turnouts, crossovers, gores, spot level-up areas, and other similar areas. The specified layer thickness is based on the rate of 90 lb./sq. yd. for each inch of pavement unless another rate is shown on the plans. Miscellaneous areas are not subject to thermal profiles testing.

4.9.5. **Recovered Asphalt Dynamic Shear Rheometer (DSR)**. The Engineer may take production samples or cores from suspect areas of the project to determine recovered asphalt properties. Asphalt binders with an aging ratio greater than 3.5 do not meet the requirements for recovered asphalt properties and may be deemed defective when tested and evaluated by the Construction Division. The aging ratio is the DSR value of the extracted binder divided by the DSR value of the original unaged binder. Obtain DSR values in accordance with AASHTO T 315 at the specified high temperature performance grade of the asphalt. The Engineer may require removal and replacement of the defective material at the Contractor's expense. The asphalt binder will be recovered for testing from production samples or cores in accordance with Tex-211-F.

4.9.6. **Irregularities**. Identify and correct irregularities, including segregation, rutting, raveling, flushing, fat spots, mat slippage, irregular color, irregular texture, roller marks, tears, gouges, streaks, uncoated aggregate particles, or broken aggregate particles. The Engineer may also identify irregularities, and in such cases, the Engineer will promptly notify the Contractor. If the Engineer determines that the irregularity will adversely affect pavement performance, the Engineer may require the Contractor to remove and replace (at the Contractor's expense) areas of the pavement that contain irregularities and areas where the mixture does not bond to the existing pavement. If irregularities are detected, the Engineer may require the Contractor to immediately suspend operations or may allow the Contractor to continue operations for no more than one day while the Contractor is taking appropriate corrective action.

4.9.7. **Ride Quality**. Measure ride quality in accordance with Item 585, "Ride Quality for Pavement Surfaces," unless otherwise shown on the plans.

5. MEASUREMENT

PFC will be measured by the ton of composite PFC. The composite PFC is defined as the asphalt, aggregate, and additives. The weights of asphalt and aggregate will be calculated based on the measured weight of PFC and the target percentage of asphalt and aggregate. Measure the weight on scales in accordance with Item 520, "Weighing and Measuring Equipment."

5.1. **Asphalt**. The asphalt weight in tons will be determined from the total weight of PFC. Measured asphalt percentage will be obtained using Tex-236-F or asphalt mass flow meter readings for PG 76 mixtures, as determined by the Engineer. Measured asphalt percentage will be obtained using asphalt mass flow meter readings for A-R mixtures. Provide the Engineer with a daily summary of the asphalt mass flow meter readings for A-R mixtures unless otherwise directed. Add the recycled binder content to the flow meter readings when calculating asphalt quantities.

5.1.1. **Target Percentage**. The JMF target asphalt percentage will be used to calculate the weight of asphalt binder unless the measured asphalt binder percentage is more than 0.3 percentage points below the JMF target asphalt percentage or less than the minimum percentage specified in Table 4. Volumetric meter readings will be adjusted to 140°F and converted to weight.

5.1.2. **Measured Percentage**. The averaged measured asphalt percentage from each sublot will be used for payment for that lot's production when the measured percentage for any sublot is more than 0.3 percentage points below the JMF target asphalt percentage or less than the minimum percentage specified in Table 4.

5.2. **Aggregate**. The aggregate weight in tons will be determined from the total weight of PFC less the weight of the asphalt.

6. PAYMENT

The work performed and materials furnished in accordance with this Item and measured as provided under Article 342.5., "Measurement," will be paid for at the unit bid price for "PFC (Asphalt)" of the binder specified and for "PFC (Aggregate)" of the grade and SAC specified. These prices are full compensation for surface preparation, materials including tack coat, placement, equipment, labor, tools, and incidentals.

Trial batches will not be paid for unless they are included in pavement work approved by the Department.

Pay adjustment for ride quality will be determined in accordance with Item 585, "Ride Quality for Pavement Surfaces."

Item 346
Stone-Matrix Asphalt

Texas Department of Transportation

1. DESCRIPTION

Construct a hot-mix asphalt (HMA) pavement layer composed of compacted stone-matrix asphalt (SMA) or stone-matrix asphalt rubber (SMAR) mixture of aggregate, asphalt binder, and additives mixed hot in a mixing plant. Pay adjustments will apply to HMA placed under this specification unless the HMA is deemed exempt in accordance with Section 346.4.9.4., "Exempt Production."

2. MATERIALS

Furnish uncontaminated materials of uniform quality that meet the requirements of the plans and specifications.

Notify the Engineer of all material sources and before changing any material source or formulation. The Engineer will verify that the specification requirements are met when the Contractor makes a source or formulation change, and may require a new laboratory mixture design, trial batch, or both. The Engineer may sample and test project materials at any time during the project to verify specification compliance in accordance with Item 6, "Control of Materials."

2.1. **Aggregate**. Furnish aggregates from sources that conform to the requirements shown in Table 1 and as specified in this Section. Aggregate requirements in this Section, including those shown in Table 1, may be modified or eliminated when shown on the plans. Additional aggregate requirements may be specified when shown on the plans. Provide aggregate stockpiles that meet the definitions in this Section for coarse, intermediate, or fine aggregate. Aggregate from reclaimed asphalt pavement (RAP) is not required to meet Table 1 requirements unless otherwise shown on the plans. Supply aggregates that meet the definitions in Tex-100-E for crushed gravel or crushed stone. The Engineer will designate the plant or the quarry as the sampling location. Provide samples from materials produced for the project. The Engineer will establish the Surface Aggregate Classification (SAC) and perform Los Angeles abrasion, magnesium sulfate soundness, and Micro-Deval tests. Perform all other aggregate quality tests listed in Table 1. Document all test results on the mixture design report. The Engineer may perform tests on independent or split samples to verify Contractor test results. Stockpile aggregates for each source and type separately. Determine aggregate gradations for mixture design and production testing based on the washed sieve analysis given in Tex-200-F, Part II.

2.1.1. **Coarse Aggregate**. Coarse aggregate stockpiles must have no more than 20% material passing the No. 8 sieve. Aggregates from sources listed in the Department's *Bituminous Rated Source Quality Catalog* (BRSQC) are preapproved for use. Use only the rated values for hot-mix listed in the BRSQC. Rated values for surface treatment (ST) do not apply to coarse aggregate sources used in hot-mix asphalt.

For sources not listed on the Department's BRSQC:

- build an individual stockpile for each material;
- request the Department test the stockpile for specification compliance; and
- once approved, do not add material to the stockpile unless otherwise approved.

Provide aggregate from non-listed sources only when tested by the Engineer and approved before use. Allow 30 calendar days for the Engineer to sample, test, and report results for non-listed sources.

Provide coarse aggregate with at least the minimum SAC shown on the plans. SAC requirements only apply to aggregates used on the surface of travel lanes. SAC requirements apply to aggregates used on surfaces other than travel lanes when shown on the plans. The SAC for sources on the Department's *Aggregate Quality Monitoring Program* (AQMP) (Tex-499-A) is listed in the BRSQC.

2.1.1.1. **Blending Class A and Class B Aggregates**. Class B aggregate meeting all other requirements in Table 1 may be blended with a Class A aggregate to meet requirements for Class A materials; however, Class B virgin (non-recycled) aggregate may be disallowed when shown on the plans. Ensure that at least 50% by weight, or volume if required, of the material retained on the No. 4 sieve comes from the Class A aggregate source when blending Class A and B aggregates to meet a Class A requirement. Blend by volume if the bulk specific gravities of the Class A and B aggregates differ by more than 0.300. Coarse aggregate from RAP and Recycled Asphalt Shingles (RAS) will be considered as Class B aggregate for blending purposes.

The Engineer may perform tests at any time during production, when the Contractor blends Class A and B aggregates to meet a Class A requirement, to ensure that at least 50% by weight, or volume if required, of the material retained on the No. 4 sieve comes from the Class A aggregate source. The Engineer will use the Department's mix design Excel template, when electing to verify conformance, to calculate the percent of Class A aggregate retained on the No. 4 sieve by inputting the bin percentages shown from readouts in the control room at the time of production and stockpile gradations measured at the time of production. The Engineer may determine the gradations based on either washed or dry sieve analysis from samples obtained from individual aggregate cold feed bins or aggregate stockpiles. The Engineer may perform spot checks using the gradations supplied by the Contractor on the mixture design report as an input for the Excel template; however, a failing spot check will require confirmation with a stockpile gradation determined by the Engineer.

2.1.1.2. **Micro-Deval Abrasion**. The Engineer will perform a minimum of one Micro-Deval abrasion test in accordance with Tex-461-A for each coarse aggregate source used in the mixture design that has a Rated Source Soundness Magnesium (RSSM) loss value greater than 15 as listed in the BRSQC. The Engineer will perform testing before the start of production and may perform additional testing at any time during production. The Engineer may obtain the coarse aggregate samples from each coarse aggregate source or may require the Contractor to obtain the samples. The Engineer may waive all Micro-Deval testing based on a satisfactory test history of the same aggregate source.

The Engineer will estimate the magnesium sulfate soundness loss for each coarse aggregate source, when tested, using the following formula:

$$Mg_{est.} = (RSSM)(MD_{act.}/RSMD)$$

where:
$Mg_{est.}$ = magnesium sulfate soundness loss
$MD_{act.}$ = actual Micro-Deval percent loss
$RSMD$ = Rated Source Micro-Deval

When the estimated magnesium sulfate soundness loss is greater than the maximum magnesium sulfate soundness loss specified, the coarse aggregate source will not be allowed for use unless otherwise approved. The Engineer will consult the Geotechnical, Soils, and Aggregates Branch of the Construction Division and additional testing may be required before granting approval.

2.1.2. **Intermediate Aggregate**. Aggregates not meeting the definition of coarse or fine aggregate will be defined as intermediate aggregate. Supply intermediate aggregates, when used, that are free from organic impurities. The Engineer may test the intermediate aggregate in accordance with Tex-408-A to verify the material is free from organic impurities. Supply intermediate aggregate from coarse aggregate sources, when used, that meet the requirements shown in Table 1 unless otherwise approved.

Test the stockpile if 10% or more of the stockpile is retained on the No. 4 sieve, and verify that it meets the requirements in Table 1 for crushed face count (Tex-460-A) and flat and elongated particles (Tex-280-F).

2.1.3. **Fine Aggregate**. Fine aggregates consist of manufactured sands, screenings, and field sands. Fine aggregate stockpiles must meet the gradation requirements in Table 2. Supply fine aggregates that are free from organic impurities. The Engineer may test the fine aggregate in accordance with Tex-408-A to verify the material is free from organic impurities. No more than 15% of the total aggregate may be field sand or other uncrushed fine aggregate. Use fine aggregate, with the exception of field sand, from coarse aggregate sources that meet the requirements shown in Table 1 unless otherwise approved.

Test the stockpile if 10% or more of the stockpile is retained on the No. 4 sieve and verify that it meets the requirements in Table 1 for crushed face count (Tex-460-A) and flat and elongated particles (Tex-280-F).

Table 1
Aggregate Quality Requirements

Property	Test Method	Requirement
Coarse Aggregate		
SAC	Tex-499-A (AQMP)	As shown on the plans
Deleterious material, %, Max	Tex-217-F, Part I	1.0
Decantation, %, Max	Tex-217-F, Part II	1.5
Micro-Deval abrasion, %	Tex-461-A	Note[1]
Los Angeles abrasion, %, Max	Tex-410-A	30
Magnesium sulfate soundness, 5 cycles, %, Max	Tex-411-A	20
Crushed face count,[2] %, Min	Tex-460-A, Part I	95
Flat and elongated particles @ 5:1, %, Max	Tex-280-F	10
Fine Aggregate		
Linear shrinkage, %, Max	Tex-107-E	3
Combined Aggregate[3]		
Sand equivalent, %, Min	Tex-203-F	45

1. Used to estimate the magnesium sulfate soundness loss in accordance with Section 346.2.1.1.2., “Micro-Deval Abrasion.”
2. Only applies to crushed gravel.
3. Aggregates, without mineral filler, RAP, RAS, or additives, combined as used in the job-mix formula (JMF).

Table 2
Gradation Requirements for Fine Aggregate

Sieve Size	% Passing by Weight or Volume
3/8-in.	100
#8	70–100
#200	0–30

2.2. **Mineral Filler**. Mineral filler consists of finely divided mineral matter such as agricultural lime, crusher fines, hydrated lime, or fly ash. Mineral filler is allowed unless otherwise shown on the plans. Use no more than 2% hydrated lime unless otherwise shown on the plans. Use no more than 5% fly ash unless otherwise shown on the plans. Test all mineral fillers except hydrated lime and fly ash in accordance with Tex-107-E to ensure specification compliance. The plans may require or disallow specific mineral fillers. Provide mineral filler, when used, that:

- is sufficiently dry, free-flowing, and free from clumps and foreign matter as determined by the Engineer;
- does not exceed 3% linear shrinkage when tested in accordance with Tex-107-E; and
- meets the gradation requirements in Table 3.

Table 3
Gradation Requirements for Mineral Filler

Sieve Size	% Passing by Weight or Volume
#8	100
#200	55–100

2.3. **Baghouse Fines**. Fines collected by the baghouse or other dust-collecting equipment may be reintroduced into the mixing drum.

2.4. **Asphalt Binder**. Furnish the type and grade of binder specified on the plans that meets the requirements of Item 300, “Asphalts, Oils, and Emulsions.”

2.4.1. **Performance-Graded (PG) Binder**. When SMA is specified, provide an asphalt binder with a high-temperature grade of PG 76 and low-temperature grade as shown on the plans in accordance with Section 300.2.10., "Performance-Graded Binders."

2.4.2. **Asphalt-Rubber (A-R) Binder**. When SMAR is specified, provide A-R binder that meets the Type I or Type II requirements of Section 300.2.9., "Asphalt-Rubber Binders," unless otherwise shown on the plans. Use at least 15.0% by weight of Crumb Rubber Modifier (CRM) that meets the Grade B or Grade C requirements of Section 300.2.7., "Crumb Rubber Modifier," unless otherwise shown on the plans. Provide the Engineer the A-R binder blend design with the mix design (JMF1) submittal. Provide the Engineer with documentation such as the bill of lading showing the quantity of CRM used in the project unless otherwise directed.

2.5. **Tack Coat**. Furnish CSS-1H, SS-1H, or a PG binder with a minimum high-temperature grade of PG 58 for tack coat binder in accordance with Item 300, "Asphalts, Oils, and Emulsions." Specialized or preferred tack coat materials may be allowed or required when shown on the plans. Do not dilute emulsified asphalts at the terminal, in the field, or at any other location before use.

The Engineer will obtain at least one sample of the tack coat binder per project in accordance with Tex-500-C, Part III, and test it to verify compliance with Item 300, "Asphalts, Oils, and Emulsions." The Engineer will obtain the sample from the asphalt distributor immediately before use.

2.6. **Additives**. Use the type and rate of additive specified when shown on the plans. Additives that facilitate mixing, compaction, or improve the quality of the mixture are allowed when approved. Provide the Engineer with documentation such as the bill of lading showing the quantity of additives used in the project unless otherwise directed.

2.6.1. **Fibers**. Provide cellulose or mineral fibers when PG binder is specified. Submit written certification to the Engineer that the fibers proposed for use meet the requirements of DMS-9204, "Fiber Additives for Bituminous Mixtures." Fibers may be pre-blended into the binder at the asphalt supply terminal unless otherwise shown on the plans.

When at least 3% RAS is used in the mixture, the Contractor may reduce the amount of fibers as specified in Note 2 of Table 8.

2.6.2. **Lime and Liquid Antistripping Agent**. When lime or a liquid antistripping agent is used, add in accordance with Item 301, "Asphalt Antistripping Agents." Do not add lime directly into the mixing drum of any plant where lime is removed through the exhaust stream unless the plant has a baghouse or dust collection system that reintroduces the lime into the drum.

2.6.3. **Warm Mix Asphalt (WMA)**. Warm Mix Asphalt (WMA) is defined as HMA that is produced within a target temperature discharge range of 215°F and 275°F using approved WMA additives or processes from the Department's MPL.

WMA is allowed for use on all projects and is required when shown on the plans. When WMA is required, the maximum placement or target discharge temperature for WMA will be set at a value below 275°F.

Department-approved WMA additives or processes may be used to facilitate mixing and compaction of HMA produced at target discharge temperatures above 275°F; however, such mixtures will not be defined as WMA.

2.7. **Recycled Materials**. Use of RAP and RAS is permitted unless otherwise shown on the plans. Do not exceed the maximum allowable percentages of RAP and RAS shown in Table 4. The allowable percentages shown in Table 4 may be decreased or increased when shown on the plans. Determine asphalt binder content and gradation of the RAP and RAS stockpiles for mixture design purposes in accordance with Tex-236-F. The Engineer may verify the asphalt binder content of the stockpiles at any time during production. Perform other tests on RAP and RAS when shown on the plans. Asphalt binder from RAP and RAS is designated as recycled asphalt binder. Calculate and ensure that the ratio of the recycled asphalt binder to total binder does not exceed the percentages shown in Table 4 during mixture design and HMA production when RAP or RAS is used. Use a separate cold feed bin for each stockpile of RAP and RAS during HMA production.

Surface and non-surface mixes referenced in Table 4 are defined as follows:

- **Surface**. The final HMA lift placed at or near the top of the pavement structure; and
- **Non-Surface**. Mixtures placed below an HMA surface mix.

2.7.1. **RAP**. RAP is salvaged, milled, pulverized, broken, or crushed asphalt pavement. Crush or break RAP so that 100% of the particles pass the 2 in. sieve. Fractionated RAP is defined as 2 or more RAP stockpiles, divided into coarse and fine fractions.

Use of Contractor-owned RAP including HMA plant waste is permitted unless otherwise shown on the plans. Department-owned RAP stockpiles are available for the Contractor's use when the stockpile locations are shown on the plans. If Department-owned RAP is available for the Contractor's use, the Contractor may use Contractor-owned fractionated RAP and replace it with an equal quantity of Department-owned RAP. Unfractionated RAP is not allowed in SMA and SMAR mixtures. Department-owned RAP generated through required work on the Contract is available for the Contractor's use when shown on the plans. Perform any necessary tests to ensure Contractor- or Department-owned RAP is appropriate for use. The Department will not perform any tests or assume any liability for the quality of the Department-owned RAP unless otherwise shown on the plans. The Contractor will retain ownership of RAP generated on the project when shown on the plans.

The coarse RAP stockpile will contain only material retained by processing over a 3/8-in. or 1/2-in. screen unless otherwise approved. The fine RAP stockpile will contain only material passing the 3/8-in. or 1/2-in. screen unless otherwise approved. The Engineer may allow the Contractor to use an alternate to the 3/8-in. or 1/2-in. screen to fractionate the RAP. The maximum percentages of fractionated RAP may be comprised of coarse or fine fractionated RAP or the combination of both coarse and fine fractionated RAP.

Do not use Department- or Contractor-owned RAP contaminated with dirt or other objectionable materials. Do not use Department- or Contractor-owned RAP if the decantation value exceeds 5% and the plasticity index is greater than 8. Test the stockpiled RAP for decantation in accordance with Tex-406-A, Part I. Determine the plasticity index in accordance with Tex-106-E if the decantation value exceeds 5%. The decantation and plasticity index requirements do not apply to RAP samples with asphalt removed by extraction or ignition.

Do not intermingle Contractor-owned RAP stockpiles with Department-owned RAP stockpiles. Remove unused Contractor-owned RAP material from the project site upon completion of the project. Return unused Department-owned RAP to the designated stockpile location.

2.7.2. **RAS**. Use of post-manufactured RAS or post-consumer RAS (tear-offs) is permitted unless otherwise shown on the plans. RAS is defined as processed asphalt shingle material from manufacturing of asphalt roofing shingles or from re-roofing residential structures. Post-manufactured RAS is processed manufacturer's shingle scrap by-product. Post-consumer RAS is processed shingle scrap removed from residential structures. Comply with all regulatory requirements stipulated for RAS by the TCEQ. RAS may be used separately or in conjunction with RAP.

Process the RAS by ambient grinding or granulating such that 100% of the particles pass the 3/8 in. sieve when tested in accordance with Tex-200-F, Part I. Perform a sieve analysis on processed RAS material before extraction (or ignition) of the asphalt binder.

Add sand meeting the requirements of Table 1 and Table 2 or fine RAP to RAS stockpiles if needed to keep the processed material workable. Any stockpile that contains RAS will be considered a RAS stockpile and be limited to no more than 5.0% of the HMA mixture in accordance with Table 4.

Certify compliance of the RAS with DMS-11000, "Evaluating and Using Nonhazardous Recyclable Materials Guidelines." Treat RAS as an established nonhazardous recyclable material if it has not come into contact with any hazardous materials. Use RAS from shingle sources on the Department's MPL. Remove substantially all materials before use that are not part of the shingle, such as wood, paper, metal, plastic, and felt paper. Determine the deleterious content of RAS material for mixture design purposes in accordance with Tex-217-F, Part III. Do not use RAS if deleterious materials are more than 0.5% of the stockpiled RAS unless otherwise approved. Submit a sample for approval before submitting the mixture design. The Department will perform the testing for deleterious material of RAS to determine specification compliance.

Table 4
Maximum Allowable Amounts of Recycled Binder, RAP, and RAS

Mixture Description & Location	Maximum Ratio of Recycled Binder to Total Binder[1] (%)	Maximum Allowable Recycled Material[2] (%)	
		Fractionated RAP[3]	RAS[4]
Surface	15.0	15.0	5.0
Non-Surface	20.0	20.0	5.0

1. Combined recycled binder from fractionated RAP and RAS.
2. Unfractionated RAP is not allowed in SMA or SMAR mixtures.
3. May replace up to 5% fractionated RAP with RAS.
4. May be used separately or as a replacement for no more than 5% of the allowable fractionated RAP.

3. EQUIPMENT

Provide required or necessary equipment in accordance with Item 320, "Equipment for Asphalt Concrete Pavement." When A-R binder is specified, equip the hot-mix plant with an in-line viscosity-measuring device located between the blending unit and the mixing drum. Provide a means to calibrate the asphalt mass flow meter on-site when a meter is used.

4. CONSTRUCTION

Produce, haul, place, and compact the specified paving mixture. In addition to tests required by the specification, Contractors may perform other QC tests as deemed necessary. At any time during the project, the Engineer may perform production and placement tests as deemed necessary in accordance with Item 5, "Control of the Work." Schedule and participate in a mandatory pre-paving meeting with the Engineer on or before the first day of paving unless otherwise shown on the plans.

4.1. **Certification**. Personnel certified by the Department-approved hot-mix asphalt certification program must conduct all mixture designs, sampling, and testing in accordance with Table 5. Supply the Engineer with a list of certified personnel and copies of their current certificates before beginning production and when personnel changes are made. Provide a mixture design developed and signed by a Level 2 certified specialist. Provide Level 1A certified specialists at the plant during production operations. Provide Level 1B certified specialists to conduct placement tests.

Table 5
Test Methods, Test Responsibility, and Minimum Certification Levels

Test Description	Test Method	Contractor	Engineer	Level[1]
1. Aggregate and Recycled Material Testing				
Sampling	Tex-221-F	✓	✓	1A
Dry sieve	Tex-200-F, Part I	✓	✓	1A
Washed sieve	Tex-200-F, Part II	✓	✓	1A
Deleterious material	Tex-217-F, Parts I & III	✓	✓	1A
Decantation	Tex-217-F, Part II	✓	✓	1A
Los Angeles abrasion	Tex-410-A		✓	TxDOT
Magnesium sulfate soundness	Tex-411-A		✓	TxDOT
Micro-Deval abrasion	Tex-461-A		✓	2
Crushed face count	Tex-460-A	✓	✓	2
Flat and elongated particles	Tex-280-F	✓	✓	2
Linear shrinkage	Tex-107-E	✓	✓	2
Sand equivalent	Tex-203-F	✓	✓	2
Organic impurities	Tex-408-A	✓	✓	2
2. Asphalt Binder & Tack Coat Sampling				
Asphalt binder sampling	Tex-500-C, Part II	✓	✓	1A/1B
Tack coat sampling	Tex-500-C, Part III	✓	✓	1A/1B
3. Mix Design & Verification				
Design and JMF changes	Tex-204-F	✓	✓	2
Mixing	Tex-205-F	✓	✓	2
Molding (SGC)	Tex-241-F	✓	✓	1A
Laboratory-molded density	Tex-207-F	✓	✓	1A
VMA[2] (calculation only)	Tex-204-F	✓	✓	2
Rice gravity	Tex-227-F	✓	✓	1A
Ignition oven correction factors[3]	Tex-236-F	✓	✓	2
Drain-down	Tex-235-F	✓	✓	1A
Hamburg Wheel test	Tex-242-F	✓	✓	2
Overlay test	Tex-248-F		✓	TxDOT
Boil test	Tex-530-C	✓	✓	1A
4. Production Testing				
Selecting production random numbers	Tex-225-F, Part I		✓	1A
Mixture sampling	Tex-222-F	✓	✓	1A
Molding (SGC)	Tex-241-F	✓	✓	1A
Laboratory-molded density	Tex-207-F	✓	✓	1A
VMA[2] (calculation only)	Tex-204-F	✓	✓	1A
Rice gravity	Tex-227-F	✓	✓	1A
Gradation & asphalt binder content[3]	Tex-236-F	✓	✓	1A
Control charts	Tex-233-F	✓	✓	1A
Moisture content	Tex-212-F	✓	✓	1A
Hamburg Wheel test	Tex-242-F	✓	✓	2
Micro-Deval abrasion	Tex-461-A		✓	2
Drain-down	Tex-235-F	✓	✓	1A
Boil test	Tex-530-C	✓	✓	1A
Abson recovery	Tex-211-F		✓	TxDOT
Overlay test	Tex-248-F		✓	TxDOT
Cantabro loss	Tex-245-F		✓	2
5. Placement Testing				
Selecting placement random numbers	Tex-225-F, Part II		✓	1A/1B
Trimming roadway cores	Tex-207-F	✓	✓	1A/1B
In-place air voids	Tex-207-F	✓	✓	1A/1B
Establish rolling pattern	Tex-207-F	✓	✓	1B
Control charts	Tex-233-F	✓	✓	1A
Ride quality measurement	Tex-1001-S	✓	✓	Note[4]
Segregation (density profile)	Tex-207-F, Part V	✓	✓	1B
Longitudinal joint density	Tex-207-F, Part VII	✓	✓	1B
Thermal profile	Tex-244-F	✓	✓	1B

1. Level 1A, 1B, and 2 are certification levels provided by the Hot Mix Asphalt Center certification program.
2. Voids in mineral aggregates.
3. Refer to Section 346.4.9.2.3., "Production Testing," for exceptions to using an ignition oven.
4. Profiler and operator are required to be certified at the Texas A&M Transportation Institute facility when Surface Test Type B is specified.

4.2. **Reporting and Responsibilities**. Use Department-provided Excel templates to record and calculate all test data, including mixture design, production and placement QC/QA, control charts, thermal profiles, segregation density profiles, and longitudinal joint density. Obtain the latest version of the Excel templates at http://www.txdot.gov/inside-txdot/forms-publications/consultants-contractors/forms/site-manager.html or from the Engineer. The Engineer and the Contractor will provide any available test results to the other party when requested. The maximum allowable time for the Contractor and Engineer to exchange test data is as given in Table 6 unless otherwise approved. The Engineer and the Contractor will immediately report to the other party any test result that requires suspension of production or placement, a payment penalty, or that fails to meet the specification requirements. Record and submit all test results and pertinent information on Department-provided Excel templates to the Engineer electronically by means of a portable USB flash drive, compact disc, or via email.

Subsequent sublots placed after test results are available to the Contractor, which require suspension of operations, may be considered unauthorized work. Unauthorized work will be accepted or rejected at the discretion of the Engineer in accordance with Article 5.3., "Conformity with Plans, Specifications, and Special Provisions."

Table 6
Reporting Schedule

Description	Reported By	Reported To	To Be Reported Within
Production Quality Control			
Gradation[1]	Contractor	Engineer	1 working day of completion of the sublot
Asphalt binder content[1]			
Laboratory-molded density[2]			
Moisture content[3]			
Boil test[3]			
Production Quality Assurance			
Gradation[3]	Engineer	Contractor	1 working day of completion of the sublot
Asphalt binder content[3]			
Laboratory-molded density[1]			
Hamburg Wheel test[2]			
Boil test[3]			
Binder tests[2]			
Placement Quality Control			
In-place air voids[2]	Contractor	Engineer	1 working day of completion of the lot
Segregation[1]			
Longitudinal joint density[1]			
Thermal profile[1]			
Placement Quality Assurance			
In-place air voids[1]	Engineer	Contractor	1 working day of receipt of the trimmed cores for in-place air voids[4]
Segregation[2]			
Longitudinal joint density[2]			
Thermal profile[2]			
Aging ratio[2]			
Pay adjustment summary	Engineer	Contractor	2 working days of performing all required tests and receiving Contractor test data

1. These tests are required on every sublot.
2. Optional test. To be reported as soon as results become available.
3. To be performed at the frequency specified on the plans.
4. 2 days are allowed if cores cannot be dried to constant weight within 1 day.

The Engineer will use the Department-provided Excel template to calculate all pay adjustment factors for the lot. Sublot samples may be discarded after the Engineer and Contractor sign off on the pay adjustment summary documentation for the lot.

Use the procedures described in Tex-233-F to plot the results of all quality control (QC) and quality assurance (QA) testing. Update the control charts as soon as test results for each sublot become available. Make the control charts readily accessible at the field laboratory. The Engineer may suspend production for failure to update control charts.

4.3. **Quality Control Plan (QCP)**. Develop and follow the QCP in detail. Obtain approval for changes to the QCP made during the project. The Engineer may suspend operations if the Contractor fails to comply with the QCP.

Submit a written QCP before the mandatory pre-paving meeting. Receive approval of the QCP before beginning production. Include the following items in the QCP:

4.3.1. **Project Personnel**. For project personnel, include:

- a list of individuals responsible for QC with authority to take corrective action;
- current contact information for each individual listed; and
- current copies of certification documents for individuals performing specified QC functions.

4.3.2. **Material Delivery and Storage**. For material delivery and storage, include:

- the sequence of material processing, delivery, and minimum quantities to assure continuous plant operations;
- aggregate stockpiling procedures to avoid contamination and segregation;
- frequency, type, and timing of aggregate stockpile testing to assure conformance of material requirements before mixture production; and
- procedure for monitoring the quality and variability of asphalt binder.

4.3.3. **Production**. For production, include:

- loader operation procedures to avoid contamination in cold bins;
- procedures for calibrating and controlling cold feeds;
- procedures to eliminate debris or oversized material;
- procedures for adding and verifying rates of each applicable mixture component (e.g., aggregate, asphalt binder, RAP, RAS, lime, liquid antistrip, WMA, fibers);
- procedures for reporting job control test results; and
- procedures to avoid segregation and drain-down in the silo.

4.3.4. **Loading and Transporting**. For loading and transporting, include:

- type and application method for release agents; and
- truck loading procedures to avoid segregation.

4.3.5. **Placement and Compaction**. For placement and compaction, include:

- proposed agenda for mandatory pre-paving meeting, including date and location;
- proposed paving plan (e.g., paving widths, joint offsets, and lift thicknesses);
- type and application method for release agents in the paver and on rollers, shovels, lutes, and other utensils;
- procedures for the transfer of mixture into the paver while avoiding segregation and preventing material spillage;
- process to balance production, delivery, paving, and compaction to achieve continuous placement operations and good ride quality;
- paver operations (e.g., operation of wings, height of mixture in auger chamber) to avoid physical and thermal segregation and other surface irregularities; and
- procedures to construct quality longitudinal and transverse joints.

4.4. **Mixture Design**.

4.4.1. **Design Requirements.** Use the SMA or SMAR design procedure given in Tex-204-F, Part VI or Part VII unless otherwise shown on the plans. Design the mixture to meet the requirements listed in Tables 1, 2, 3, 4, 7, 8, and 9.

Design SMA or SMAR mixtures using a Superpave Gyratory Compactor (SGC) at 50 gyrations as the design number of gyrations (Ndesign). The Ndesign level may be reduced to no less than 35 gyrations at the Contractor's discretion.

Use an approved laboratory from the Department's MPL to perform the Hamburg Wheel test, and provide results with the mixture design, or provide the laboratory mixture and request that the Department perform the Hamburg Wheel test. Provide laboratory mixture and request that the Department perform the Overlay test. The Engineer will be allowed 10 working days to provide the Contractor with Hamburg Wheel and Overlay test results on the laboratory mixture design.

The Engineer will provide the mixture design when shown on the plans. The Contractor may submit a new mixture design at any time during the project. The Engineer will verify and approve all mixture designs (JMF1) before the Contractor can begin production.

Provide the Engineer with a mixture design report using the Department-provided Excel template. Include the following items in the report:

- the combined aggregate gradation, source, specific gravity, and percent of each material used;
- asphalt binder content and aggregate gradation of RAP and RAS stockpiles;
- the Ndesign level used;
- results of all applicable tests;
- the mixing and molding temperatures;
- the signature of the Level 2 person or persons that performed the design;
- the date the mixture design was performed; and
- a unique identification number for the mixture design.

Table 7
Master Gradation Limits (% Passing by Weight or Volume) and VMA Requirements

Sieve Size	SMA-C Coarse	SMA-D Medium	SMA-F Fine	SMAR-C Coarse	SMAR-F Fine
3/4-in.	100.0[1]	100.0[1]	–	100.0[1]	–
1/2-in.	80.0–90.0	85.0–99.0	100.0[1]	72.0–85.0	100.0[1]
3/8-in.	25.0–60.0	50.0–75.0	70.0–100.0	50.0–70.0	95.0–100.0
#4	20.0–28.0	20.0–32.0	30.0–60.0	30.0–45.0	40.0–50.0
#8	14.0–20.0	16.0–28.0	20.0–40.0	17.0–27.0	17.0–27.0
#16	8.0–20.0	8.0–28.0	6.0–30.0	12.0–22.0	12.0–22.0
#30	8.0–20.0	8.0–28.0	6.0–30.0	8.0–20.0	8.0–20.0
#50	8.0–20.0	8.0–28.0	6.0–30.0	6.0–15.0	6.0–15.0
#200	8.0–12.0	8.0–12.0	4.0–12.0	5.0–9.0	5.0–9.0
Design VMA, % Min					
	17.5	17.5	17.5	19.0	19.0
Production (Plant-Produced) VMA, % Min					
	17.0	17.0	17.0	18.5	18.5

1. Defined as maximum sieve size. No tolerance allowed.

Table 8
Laboratory Mixture Design Properties

Mixture Property	SMA Mixtures	SMAR Mixtures	Test Procedure
Design gyrations, (Ndesign)[1]	50	50	Tex-241-F
Target laboratory-molded density, %	96.0	96.0	Tex-207-F
Asphalt binder content, %	6.0-7.0	7.0-10.0	–
Drain-down, %	0.10 Max	0.10 Max	Tex-235-F
Fiber content, % by wt. of total mixture	0.20[2]-0.50	–	Calculated
CRM content, % by wt. of A-R binder	–	15.0 Min	Calculated
Hamburg Wheel test,[3] rut depth @ 20,000 passes tested @ 50°C, mm	12.5 Max	12.5 Max	Tex-242-F
Overlay test, number of cycles	200 Min	200 Min	Tex-248-F
Boil test[4]	–	–	Tex-530-C

1. Adjust within a range of 35–100 gyrations when shown on the plans or specification or when mutually agreed between the Engineer and Contractor.
2. When at least 3% RAS is used in the mixture, the Contractor may reduce the amount of fibers to no less than 0.10% provided the mixture meets the drain-down requirement.
3. For SMAR mixes, the number of passes required for the Hamburg Wheel test may be decreased. Other tests may be required for SMAR mixes instead of, or in addition to, the Hamburg Wheel test when shown on the plans.
4. Used to establish baseline for comparison to production results. May be waived when approved.

4.4.2. **Job-Mix Formula Approval**. The job-mix formula (JMF) is the combined aggregate gradation, Ndesign level, and target asphalt percentage used to establish target values for hot-mix production. JMF1 is the original laboratory mixture design used to produce the trial batch. When WMA is used, JMF1 may be designed and submitted to the Engineer without including the WMA additive. When WMA is used, document the additive or process used and recommended rate on the JMF1 submittal. The Engineer and the Contractor will verify JMF1 based on plant-produced mixture from the trial batch unless otherwise approved. The Engineer may accept an existing mixture design previously used on a Department project and may waive the trial batch to verify JMF1. The Department may require the Contractor to reimburse the Department for verification tests if more than 2 trial batches per design are required.

4.4.2.1. **Contractor's Responsibilities**.

4.4.2.1.1. **Providing Superpave Gyratory Compactor**. Furnish an SGC calibrated in accordance with Tex-241-F for molding production samples. Locate the SGC at the Engineer's field laboratory and make the SGC available to the Engineer for use in molding production samples.

4.4.2.1.2. **Gyratory Compactor Correlation Factors**. Use Tex-206-F, Part II, to perform a gyratory compactor correlation when the Engineer uses a different SGC. Apply the correlation factor to all subsequent production test results.

4.4.2.1.3. **Submitting JMF1**. Furnish a mix design report (JMF1) with representative samples of all component materials and request approval to produce the trial batch. Provide approximately 25,000 g of the laboratory mixture and request the Department perform the Overlay test. Provide an additional 10,000 g of the design mixture if opting to have the Department perform the Hamburg Wheel test on the laboratory mixture, and request that the Department perform the test.

4.4.2.1.4. **Supplying Aggregates**. Provide approximately 40 lb. of each aggregate stockpile unless otherwise directed.

4.4.2.1.5. **Supplying Asphalt**. Provide at least 1 gal. of the asphalt material and sufficient quantities of any additives proposed for use.

4.4.2.1.6. **Ignition Oven Correction Factors**. Determine the aggregate and asphalt correction factors from the ignition oven in accordance with Tex-236-F. Note that the asphalt content correction factor takes into account the percent fibers in the mixture so that the fibers are excluded from the binder content determination. Provide the Engineer with split samples of the mixtures, before the trial batch production, including all additives (except water), and blank samples used to determine the correction factors for the ignition oven used for QA testing during production. Correction factors established from a previously approved mixture design may be used for the current mixture design, if the mixture design and ignition oven are the same as previously used unless otherwise directed.

4.4.2.1.7. **Boil Test.** Perform the test and retain the tested sample from Tex-530-C until completion of the project or as directed. Use this sample for comparison purposes during production. The Engineer may waive the requirement for the boil test.

4.4.2.1.8. **Trial Batch Production**. Provide a plant-produced trial batch upon receiving conditional approval of JMF1 and authorization to produce a trial batch, including the WMA additive or process if applicable, for verification testing of JMF1 and development of JMF2. Produce a trial batch mixture that meets the requirements in Table 4 and Table 9. The Engineer may accept test results from recent production of the same mixture instead of a new trial batch.

4.4.2.1.9. **Trial Batch Production Equipment**. Use only equipment and materials proposed for use on the project to produce the trial batch. Provide documentation to verify the calibration or accuracy of the asphalt mass flow meter to measure the binder content. Verify that asphalt mass flow meter meets the requirements of 0.4% accuracy, when required, in accordance with Item 520, "Weighing and Measuring Equipment." The Engineer may require that the accuracy of the mass flow meter be verified based on quantities used.

4.4.2.1.10. **Trial Batch Quantity**. Produce enough quantity of the trial batch to ensure that the mixture meets the specification requirements.

4.4.2.1.11. **Number of Trial Batches**. Produce trial batches as necessary to obtain a mixture that meets the specification requirements.

4.4.2.1.12. **Trial Batch Sampling**. Obtain a representative sample of the trial batch and split it into 3 equal portions in accordance with Tex-222-F. Label these portions as "Contractor," "Engineer," and "Referee." Deliver samples to the appropriate laboratory as directed.

4.4.2.1.13. **Trial Batch Testing**. Test the trial batch to ensure the mixture produced using the proposed JMF1 meets the mixture requirements in Table 9. Ensure the trial batch mixture is also in compliance with the Hamburg Wheel requirement in Table 8. Use a Department-approved laboratory to perform the Hamburg Wheel test on the trial batch mixture or request that the Department perform the Hamburg Wheel test. The Engineer will be allowed 10 working days to provide the Contractor with Hamburg Wheel test results on the trial batch. Provide the Engineer with a copy of the trial batch test results.

4.4.2.1.14. **Development of JMF2**. Evaluate the trial batch test results after the Engineer grants full approval of JMF1 based on results from the trial batch, determine the optimum mixture proportions, and submit as JMF2. Adjust the asphalt binder content or gradation to achieve the specified target laboratory-molded density. The asphalt binder content established for JMF2 is not required to be within any tolerance of the optimum asphalt binder content established for JMF1; however, mixture produced using JMF2 must meet the voids in mineral aggregates (VMA) requirements for production shown in Table 7. If the optimum asphalt binder content for JMF2 is more than 0.5% lower than the optimum asphalt binder content for JMF1, the Engineer may perform Tex-248-F on Lot 1 to confirm the mixture meets the Overlay test requirement of 200 cycles. Verify that JMF2 meets the mixture requirements in Table 4.

4.4.2.1.15. **Mixture Production**. Use JMF2 to produce Lot 1 as described in Section 346.4.9.3.1.1., "Lot 1 Placement," after receiving approval for JMF2 and a passing result from the Department's or a Department-approved laboratory's Hamburg Wheel test on the trial batch. If desired, proceed to Lot 1 production, once JMF2 is approved, at the Contractor's risk without receiving the results from the Department's Hamburg Wheel test on the trial batch.

Notify the Engineer if electing to proceed without Hamburg Wheel test results from the trial batch. Note that the Engineer may require up to the entire sublot of any mixture failing the Hamburg Wheel test be removed and replaced at the Contractor's expense.

4.4.2.1.16. **Development of JMF3**. Evaluate the test results from Lot 1, determine the optimum mixture proportions, and submit as JMF3 for use in Lot 2.

4.4.2.1.17. **JMF Adjustments**. If JMF adjustments are necessary to achieve the specified requirements, make the adjustments before beginning a new lot. The adjusted JMF must:

- be provided to the Engineer in writing before the start of a new lot;
- be numbered in sequence to the previous JMF;
- meet the mixture requirements in Table 4;
- meet the master gradation limits shown in Table 7; and
- be within the operational tolerances of JMF2 listed in Table 9.

4.4.2.1.18. **Requesting Referee Testing**. Use referee testing, if needed, in accordance with Section 346.4.9.1., "Referee Testing," to resolve testing differences with the Engineer.

Table 9
Operational Tolerances

Description	Test Method	Allowable Difference Between Trial Batch and JMF1 Target	Allowable Difference from Current JMF Target	Allowable Difference between Contractor and Engineer[1]
Individual % retained for #8 sieve and larger	Tex-200-F or Tex-236-F	Must be within Master Grading Limits in Table 7	±5.0[2,3]	±5.0
Individual % retained for sieves smaller than #8 and larger than #200			±3.0[2,3]	±3.0
% passing the #200 sieve			±2.0[2,3]	±1.6
Asphalt binder content, %	Tex-236-F[4]	±0.5	±0.3[3]	±0.3
Laboratory-molded density, %	Tex-207-F	±1.0	±1.0	±0.5
In-place air voids, %		N/A	N/A	±1.0
Laboratory-molded bulk specific gravity		N/A	N/A	±0.020
VMA, % Min	Tex-204-F	Note[5]	Note[5]	N/A
Theoretical maximum specific (Rice) gravity	Tex-227-F	N/A	N/A	±0.020
Drain-down	Tex-235-F	Note[6]	Note[6]	Note[6]

1. Contractor may request referee testing only when values exceed these tolerances.
2. When within these tolerances, mixture production gradations may fall outside the master grading limits; however, the % passing the #200 will be considered out of tolerance when outside the master grading limits.
3. Only applies to mixture produced for Lot 1 and higher.
4. Ensure the asphalt binder content determination excludes fibers. Add the recycled binder content to the flow meter readout when the asphalt mass flow meter is used to determine binder content.
5. Test and verify that Table 7 requirements are met for VMA.
6. Test and verify that Table 8 requirements are met for drain-down.

4.4.2.2. **Engineer's Responsibilities**.

4.4.2.2.1. **Gyratory Compactor**. The Engineer will use a Department SGC, calibrated in accordance with Tex-241-F, to mold samples for laboratory mixture design verification. For molding trial batch and production specimens, the Engineer will use the Contractor-provided SGC at the field laboratory or provide and use a Department SGC at an alternate location. The Engineer will make the Contractor-provided SGC in the Department field laboratory available to the Contractor for molding verification samples.

4.4.2.2.2. **Conditional Approval of JMF1 and Authorizing Trial Batch**. The Engineer will review and verify conformance of the following information within 2 working days of receipt:

- the Contractor's mix design report (JMF1);
- the Department-provided Overlay test results;
- the Contractor-provided Hamburg Wheel test results;
- all required materials including aggregates, asphalt, additives, and recycled materials; and
- the mixture specifications.

The Engineer will grant the Contractor conditional approval of JMF1 if the information provided on the paper copy of JMF1 indicates that the Contractor's mixture design meets the specifications. When the Contractor does not provide Hamburg Wheel test results with laboratory mixture design, 10 working days are allowed for conditional approval of JMF1. The Engineer will base full approval of JMF1 on the test results on mixture from the trial batch.

Unless waived, the Engineer will determine the Micro-Deval abrasion loss in accordance with Section 346.2.1.1.2., "Micro-Deval Abrasion." If the Engineer's test results are pending after 2 working days, conditional approval of JMF1 will still be granted within 2 working days of receiving JMF1. When the Engineer's test results become available, they will be used for specification compliance.

After conditionally approving JMF1, including either Contractor- or Department-supplied Hamburg Wheel test results, the Contractor is authorized to produce a trial batch.

4.4.2.2.3. **Hamburg Wheel and Overlay Testing of JMF1**. If the Contractor requests the option to have the Department perform the Hamburg Wheel test on the laboratory mixture, the Engineer will mold samples in accordance with Tex-242-F to verify compliance with the Hamburg Wheel test requirement in Table 8. The Engineer will perform the Overlay test. The Engineer will mold samples in accordance with Tex-248-F to verify compliance with the Overlay test requirements in Table 8.

4.4.2.2.4. **Ignition Oven Correction Factors**. The Engineer will use the split samples provided by the Contractor to determine the aggregate and asphalt correction factors for the ignition oven used for QA testing during production in accordance with Tex-236-F. The Engineer will verify that the asphalt content correction factor takes into account the percent fibers in the mixture so that the fibers are excluded from the binder content determination.

4.4.2.2.5. **Testing the Trial Batch**. Within 1 full working day, the Engineer will sample and test the trial batch to ensure that the mixture meets the requirements in Table 9. If the Contractor requests the option to have the Department perform the Hamburg Wheel test on the trial batch mixture, the Engineer will mold samples in accordance with Tex-242-F to verify compliance with the Hamburg Wheel test requirement in Table 8.

The Engineer will have the option to perform the following tests on the trial batch:

- Tex-248-F to confirm the mixture meets the Overlay test requirement of 200 cycles; and
- Tex-530-C, to retain and use for comparison purposes during production.

4.4.2.2.6. **Full Approval of JMF1**. The Engineer will grant full approval of JMF1 and authorize the Contractor to proceed with developing JMF2 if the Engineer's results for the trial batch meet the requirements in Table 9. The Engineer will notify the Contractor that an additional trial batch is required if the trial batch does not meet these requirements.

4.4.2.2.7. **Approval of JMF2**.The Engineer will approve JMF2 within one working day if the mixture meets the requirements in Table 4 and the gradation meets the master grading limits shown in Table 7. The asphalt binder content established for JMF2 is not required to be within any tolerance of the optimum asphalt binder content established for JMF1; however, mixture produced using JMF2 must meet the VMA requirements shown in Table 7. If the optimum asphalt binder content for JMF2 is more than 0.5% lower than the optimum asphalt binder content for JMF1, the Engineer may perform Tex-248-F on Lot 1 to confirm the mixture meets the Overlay test requirement of 200 cycles.

4.4.2.2.8. **Approval of Lot 1 Production**. The Engineer will authorize the Contractor to proceed with Lot 1 production (using JMF2) as soon as a passing result is achieved from the Department's or a Department-approved laboratory's Hamburg Wheel test on the trial batch. The Contractor may proceed at its own risk with Lot 1 production without the results from the Hamburg Wheel test on the trial batch.

If the Department's or Department-approved laboratory's sample from the trial batch fails the Hamburg Wheel test, the Engineer will suspend production until further Hamburg Wheel tests meet the specified values. The Engineer may require up to the entire sublot of any mixture failing the Hamburg Wheel test be removed and replaced at the Contractor's expense.

4.4.2.2.9. **Approval of JMF3 and Subsequent JMF Changes**. JMF3 and subsequent JMF changes are approved if they meet the mixture requirements shown in Table 4, the master grading limits shown in Table 7, and are within the operational tolerances of JMF2 shown in Table 9.

4.5. **Production Operations**. Perform a new trial batch when the plant or plant location is changed. Take corrective action and receive approval to proceed after any production suspension for noncompliance to the specification. Submit a new mix design and perform a new trial batch when the asphalt binder content of:

- any RAP stockpile used in the mix is more than 0.5% higher than the value shown on the mixture design report; or
- RAS stockpile used in the mix is more than 2.0% higher than the value shown on the mixture design report.

4.5.1. **Storage and Heating of Materials**. Do not heat the asphalt binder above the temperatures specified in Item 300, "Asphalts, Oils, and Emulsions," or outside the manufacturer's recommended values. Provide the Engineer with daily records of asphalt binder and hot-mix asphalt discharge temperatures (in legible and discernible increments) in accordance with Item 320, "Equipment for Asphalt Concrete Pavement," unless otherwise directed. Do not store mixture for a period long enough to affect the quality of the mixture, nor in any case longer than 12 hr. unless otherwise approved.

4.5.2. **Mixing and Discharge of Materials**. Notify the Engineer of the target discharge temperature and produce the mixture within 25°F of the target. Monitor the temperature of the material in the truck before shipping to ensure that it does not exceed 350°F (or 275°F for WMA) and is not lower than 215°F. The Department will not pay for or allow placement of any mixture produced above 350°F.

Produce WMA within the target discharge temperature range of 215°F and 275°F when WMA is required. Take corrective action any time the discharge temperature of the WMA exceeds the target discharge range. The Engineer may suspend production operations if the Contractor's corrective action is not successful at controlling the production temperature within the target discharge range. Note that when WMA is produced, it may be necessary to adjust burners to ensure complete combustion such that no burner fuel residue remains in the mixture.

Control the mixing time and temperature so that substantially all moisture is removed from the mixture before discharging from the plant. Determine the moisture content, if requested, by oven-drying in accordance with Tex-212-F, Part II, and verify that the mixture contains no more than 0.2% of moisture by weight. Obtain the sample immediately after discharging the mixture into the truck, and perform the test promptly.

4.6. **Hauling Operations**. Clean all truck beds before use to ensure that mixture is not contaminated. Use a release agent shown on the Department's MPL to coat the inside bed of the truck when necessary.

Use equipment for hauling as defined in Section 346.4.7.3.3., "Hauling Equipment." Use other hauling equipment only when allowed.

4.7. **Placement Operations**. Collect haul tickets from each load of mixture delivered to the project and provide the Department's copy to the Engineer approximately every hour or as directed. Use a hand-held thermal camera or infrared thermometer, when a thermal imaging system is not used, to measure and record the internal temperature of the mixture as discharged from the truck or Material Transfer Device (MTD) before or as the mix enters the paver and an approximate station number or GPS coordinates on each ticket. Calculate the daily yield and cumulative yield for the specified lift and provide to the Engineer at the end of paving operations for each day unless otherwise directed. The Engineer may suspend production if the Contractor fails to produce and provide haul tickets and yield calculations by the end of paving operations for each day.

Prepare the surface by removing raised pavement markers and objectionable material such as moisture, dirt, sand, leaves, and other loose impediments from the surface before placing mixture. Remove vegetation from pavement edges. Place the mixture to meet the typical section requirements and produce a smooth, finished surface with a uniform appearance and texture. Offset longitudinal joints of successive courses of hot-mix by at least 6 in. Place mixture so that longitudinal joints on the surface course coincide with lane lines, or as directed. Ensure that all finished surfaces will drain properly. Place the mixture at the rate or thickness shown on the plans. The Engineer will use the guidelines in Table 10 to determine the compacted lift thickness of each layer when multiple lifts are required. The thickness determined is based on the rate of 110 lb./sq. yd. for each inch of pavement unless otherwise shown on the plans.

Table 10
Compacted Lift Thickness and Required Core Height

Mixture Type	Compacted Lift Thickness Guidelines		Minimum Untrimmed Core Height (in.) Eligible for Testing
	Minimum (in.)	Maximum (in.)	
SMA-C	2.25	4.00	2.00
SMA-D	1.50	3.00	1.25
SMA-F	1.00	2.00	1.25
SMAR-C	2.00	4.00	1.75
SMAR-F	1.50	3.00	1.25

4.7.1. **Weather Conditions**.

4.7.1.1. **When Using a Thermal Imaging System**. The Contractor may pave any time the roadway is dry and the roadway surface temperature is at least 50°F; however, the Engineer may restrict the Contractor from paving surface mixtures if the ambient temperature is likely to drop below 32°F within 12 hr. of paving. Provide output data from the thermal imaging system to demonstrate to the Engineer that no recurring severe thermal segregation exists in accordance with Section 346.4.7.3.1.2., “Thermal Imaging System.”

4.7.1.2. **When Not Using a Thermal Imaging System**. Place mixture when the roadway surface temperature is at or above 70°F unless otherwise approved or as shown on the plans. Measure the roadway surface temperature with a hand-held thermal camera or infrared thermometer. The Engineer may allow mixture placement to begin before the roadway surface reaches the required temperature if conditions are such that the roadway surface will reach the required temperature within 2 hr. of beginning placement operations. Place mixtures only when weather conditions and moisture conditions of the roadway surface are suitable as determined by the Engineer. The Engineer may restrict the Contractor from paving if the ambient temperature is likely to drop below 32°F within 12 hr. of paving.

4.7.2. **Tack Coat**. Clean the surface before placing the tack coat. The Engineer will set the rate between 0.04 and 0.10 gal. of residual asphalt per square yard of surface area. Apply a uniform tack coat at the specified rate unless otherwise directed. Apply the tack coat in a uniform manner to avoid streaks and other irregular patterns. Apply a thin, uniform tack coat to all contact surfaces of curbs, structures, and all joints. Allow adequate time for emulsion to break completely before placing any material. Prevent splattering of tack coat when placed adjacent to curb, gutter, and structures. Roll the tack coat with a pneumatic-tire roller to remove streaks and other irregular patterns when directed.

4.7.3. **Lay-Down Operations**.

4.7.3.1. **Thermal Profile**. Use a hand-held thermal camera or a thermal imaging system to obtain a continuous thermal profile in accordance with Tex-244-F. Thermal profiles are not applicable in areas described in Section 346.4.9.3.1.4., “Miscellaneous Areas.”

4.7.3.1.1. **Thermal Segregation**.

4.7.3.1.1.1. **Moderate**. Any areas that have a temperature differential greater than 25°F, but not exceeding 50°F, are deemed as having moderate thermal segregation.

4.7.3.1.1.2. **Severe**. Any areas that have a temperature differential greater than 50°F are deemed as having severe thermal segregation.

4.7.3.1.2. **Thermal Imaging System**. Review the output results when a thermal imaging system is used, and provide the automated report described in Tex-244-F to the Engineer daily unless otherwise directed. Modify the paving process as necessary to eliminate any recurring (moderate or severe) thermal segregation identified by the thermal imaging system. The Engineer may suspend paving operations if the Contractor cannot successfully modify the paving process to eliminate recurring severe thermal segregation. Density profiles are not required and not applicable when using a thermal imaging system. Provide the Engineer with electronic copies of all daily data files that can be used with the thermal imaging system software to generate temperature profile plots upon completion of the project or as requested by the Engineer.

4.7.3.1.3. **Thermal Camera**. Take immediate corrective action to eliminate recurring moderate thermal segregation when a hand-held thermal camera is used. Evaluate areas with moderate thermal segregation by performing density profiles in accordance with Section 346.4.9.3.3.2., “Segregation (Density Profile).” Provide the Engineer with the thermal profile of every sublot within one working day of the completion of each lot. Report the results of each thermal profile in accordance with Section 346.4.2., “Reporting and Responsibilities.” The Engineer will use a hand-held thermal camera to obtain a thermal profile at least once per project. No production or placement bonus will be paid for any sublot that contains severe thermal segregation. Suspend operations and take immediate corrective action to eliminate severe thermal segregation unless otherwise directed. Resume operations when the Engineer determines that subsequent production will meet the requirements of this Section. Evaluate areas with severe thermal segregation by performing density profiles in accordance with Section 346.4.9.3.3.2., “Segregation (Density Profile).” Remove and replace the material in any areas that have both severe thermal segregation and a failing result for Segregation (Density Profile) unless otherwise directed. The sublot in question may receive a production and placement bonus if applicable when the defective material is successfully removed and replaced.

4.7.3.2. **Windrow Operations**. Operate windrow pickup equipment so that when hot-mix is placed in windrows, substantially all the mixture deposited on the roadbed is picked up and loaded into the paver.

4.7.3.3. **Hauling Equipment**. Use belly dumps, live bottom, or end dump trucks to haul and transfer mixture; however, with exception of paving miscellaneous areas, end dump trucks are only allowed when used in conjunction with an MTD with remixing capability or when a thermal imaging system is used unless otherwise allowed.

4.7.3.4. **Screed Heaters**. Turn off screed heaters to prevent overheating of the mat if the paver stops for more than 5 min. The Engineer may evaluate the suspect area in accordance with Section 346.4.9.3.3.4., “Recovered Asphalt Dynamic Shear Rheometer (DSR),” if the screed heater remains on for more than 5 min. while the paver is stopped.

4.8. **Compaction**. Compact the pavement uniformly to contain between 3.7% and 7.0% in-place air voids. Take immediate corrective action to bring the operation within 3.7% and 7.0% when the in-place air voids exceed the range of these tolerances. The Engineer will allow paving to resume when the proposed corrective action is likely to yield between 3.8% and 8.5% in-place air voids.

Obtain cores in areas placed under Exempt Production, as directed, at locations determined by the Engineer. The Engineer may test these cores and suspend operations or require removal and replacement if the in-place air voids are less than 2.7% or more than 8.0%. Areas defined in Section 346.4.9.3.1.4., “Miscellaneous Areas,” are not subject to in-place air void determination.

Furnish the type, size, and number of rollers required for compaction as approved. Use a pneumatic-tire roller to seal the surface unless excessive pickup of fines occurs. Use additional rollers as required to remove any roller marks. Use only water or an approved release agent on rollers, tamps, and other compaction equipment unless otherwise directed.

Use the control strip method shown in Tex-207-F, Part IV, on the first day of production to establish the rolling pattern that will produce the desired in-place air voids unless otherwise directed.

Use tamps to thoroughly compact the edges of the pavement along curbs, headers, and similar structures and in locations that will not allow thorough compaction with rollers. The Engineer may require rolling with a trench roller on widened areas, in trenches, and in other limited areas.

Complete all compaction operations before the pavement temperature drops below 160°F unless otherwise allowed. The Engineer may allow compaction with a light finish roller operated in static mode for pavement temperatures below 160°F.

Allow the compacted pavement to cool to 160°F or lower before opening to traffic unless otherwise directed. Sprinkle the finished mat with water or limewater, when directed, to expedite opening the roadway to traffic.

4.9. **Acceptance Plan**. Pay adjustments for the material will be in accordance with Section 346.6., “Payment.”

Sample and test the hot-mix on a lot and sublot basis. Suspend production until test results or other information indicates to the satisfaction of the Engineer that the next material produced or placed will result in pay factors of at least 1.000 if the production pay factor given in Section 346.6.1., “Production Pay Adjustment Factors,” for 2 consecutive lots or the placement pay factor given in Section 346.6.2., “Placement Pay Adjustment Factors,” for 2 consecutive lots is below 1.000.

4.9.1. **Referee Testing**. The Construction Division is the referee laboratory. The Contractor may request referee testing if a “remove and replace” condition is determined based on the Engineer’s test results, or if the differences between Contractor and Engineer test results exceed the maximum allowable difference shown in Table 9 and the differences cannot be resolved. The Contractor may also request referee testing if the Engineer’s test results require suspension of production and the Contractor’s test results are within specification limits. Make the request within 5 working days after receiving test results and cores from the Engineer. Referee tests will be performed only on the sublot in question and only for the particular tests in question. Allow 10 working days from the time the referee laboratory receives the samples for test results to be reported. The Department may require the Contractor to reimburse the Department for referee tests if more than 3 referee tests per project are required and the Engineer’s test results are closer to the referee test results than the Contractor’s test results.

The Construction Division will determine the laboratory-molded density based on the molded specific gravity and the maximum theoretical specific gravity of the referee sample. The in-place air voids will be determined based on the bulk specific gravity of the cores, as determined by the referee laboratory, and the Engineer’s average maximum theoretical specific gravity for the lot. With the exception of remove and replace conditions, referee test results are final and will establish pay adjustment factors for the sublot in question. The Contractor may decline referee testing and accept the Engineer’s test results when the placement pay adjustment factor for any sublot results in a “remove and replace” condition. Placement sublots subject to be removed and replaced will be further evaluated in accordance with Section 346.6.2.2., “Placement Sublots Subject to Removal and Replacement.”

4.9.2. **Production Acceptance**.

4.9.2.1. **Production Lot**. A production lot consists of 4 equal sublots. The default quantity for Lot 1 is 1,000 tons; however, when requested by the Contractor, the Engineer may increase the quantity for Lot 1 to no more than 4,000 tons. The Engineer will select subsequent lot sizes based on the anticipated daily production such that approximately 3 to 4 sublots are produced each day. The lot size will be between 1,000 tons and 4,000 tons. The Engineer may change the lot size before the Contractor begins any lot.

If the optimum asphalt binder content for JMF2 is more than 0.5% lower than the optimum asphalt content for JMF1, the Engineer may perform Tex-248-F on Lot 1 to confirm the mixture meets the Overlay test requirement of 200 cycles.

4.9.2.1.1. **Incomplete Production Lots**. If a lot is begun but cannot be completed, such as on the last day of production or in other circumstances deemed appropriate, the Engineer may close the lot. Adjust the payment for the incomplete lot in accordance with Section 346.6.1., “Production Pay Adjustment Factors.” Close all lots within 5 working days, unless otherwise allowed.

4.9.2.2. **Production Sampling**.

4.9.2.2.1. **Mixture Sampling**. Obtain hot-mix samples from trucks at the plant in accordance with Tex-222-F. The sampler will split each sample into 3 equal portions in accordance with Tex-200-F and label these portions as "Contractor," "Engineer," and "Referee." The Engineer will perform or witness the sample splitting and take immediate possession of the samples labeled "Engineer" and "Referee." The Engineer will maintain the custody of the samples labeled "Engineer" and "Referee" until the Department's testing is completed.

4.9.2.2.1.1. **Random Sample**. At the beginning of the project, the Engineer will select random numbers for all production sublots. Determine sample locations in accordance with Tex-225-F. Take one sample for each sublot at the randomly selected location. The Engineer will perform or witness the sampling of production sublots.

4.9.2.2.1.2. **Blind Sample**. For one sublot per lot, the Engineer will obtain and test a "blind" sample instead of the random sample collected by the Contractor. Test either the "blind" or the random sample; however, referee testing (if applicable) will be based on a comparison of results from the "blind" sample. The location of the Engineer's "blind" sample will not be disclosed to the Contractor. The Engineer's "blind" sample may be randomly selected in accordance with Tex-225-F for any sublot or selected at the discretion of the Engineer. The Engineer will use the Contractor's split sample for sublots not sampled by the Engineer.

4.9.2.2.2. **Informational Cantabro Testing**. Select one random sublot from Lot 2 or higher for Cantabro testing during the first week of production. Obtain and provide the Engineer with approximately 40 lb. (18 kg) of mixture in sealed containers, boxes, or bags labeled with CSJ, mixture type, lot, and sublot number. The Engineer will ship the mixture to the Construction Division for testing. Results from this production test will not be used for specification compliance.

4.9.2.2.3. **Asphalt Binder Sampling**. Obtain a 1-qt. (1-gal. for A-R binder) sample of the asphalt binder for each lot of mixture produced. Obtain the sample at approximately the same time the mixture random sample is obtained. Sample from a port located immediately upstream from the mixing drum or pug mill in accordance with Tex-500-C, Part II. Label the can with the corresponding lot and sublot numbers and deliver the sample to the Engineer. The Engineer may also obtain independent samples. If obtaining an independent asphalt binder sample, the Engineer will split a sample of the asphalt binder with the Contractor. The Engineer will test at least one asphalt binder sample per project to verify compliance with Item 300, "Asphalts, Oils, and Emulsions."

4.9.2.3. **Production Testing**. The Contractor and Engineer must perform production tests in accordance with Table 11. The Contractor has the option to verify the Engineer's test results on split samples provided by the Engineer. Determine compliance with operational tolerances listed in Table 9 for all sublots.

Take immediate corrective action if the Engineer's laboratory-molded density on any sublot is less than 95.0% or greater than 97.0% to bring the mixture within these tolerances. The Engineer may suspend operations if the Contractor's corrective actions do not produce acceptable results. The Engineer will allow production to resume when the proposed corrective action is likely to yield acceptable results.

At any time during production the Engineer may require the Contractor to verify the following based on quantities used:

- lime content (within ±0.1% of JMF), when PG binder is specified;
- fiber content (within ±0.03% of JMF), when PG binder is specified; and
- CRM content (within ±1.5% of JMF), when A-R binder is specified.

Maintain the in-line measuring device to verify the A-R binder viscosity between 2,500 and 4,000 centipoise at 350°F when A-R binder is specified unless otherwise approved. Record A-R binder viscosity at least once an hour and provide the Engineer with a daily summary unless otherwise directed.

The Engineer may allow alternate methods for determining the asphalt binder content and aggregate gradation if the aggregate mineralogy is such that Tex-236-F does not yield reliable results. Provide evidence that results from Tex-236-F are not reliable before requesting permission to use an alternate method unless otherwise directed. Use the applicable test procedure as directed if an alternate test method is allowed.

Table 11
Production and Placement Testing Frequency

Description	Test Method	Minimum Contractor Testing Frequency	Minimum Engineer Testing Frequency
Individual % retained for #8 sieve and larger	Tex-200-F or Tex-236-F	1 per sublot	1 per 12 sublots[1]
Individual % retained for sieves smaller than #8 and larger than #200			
% passing the #200 sieve			
Laboratory-molded density	Tex-207-F	N/A	1 per sublot[1]
Laboratory-molded bulk specific gravity			
In-place air voids			
VMA	Tex-204-F		
Segregation (density profile)[2]	Tex-207-F, Part V	1 per sublot	1 per project
Longitudinal joint density	Tex-207-F, Part VII		
Moisture content	Tex-212-F, Part II	When directed	
Theoretical maximum specific (Rice) gravity	Tex-227-F	N/A	1 per sublot[1]
Drain-down	Tex-235-F	1 per sublot	1 per 12[1] sublots
Asphalt binder content	Tex-236-F		1 per lot[1]
Hamburg Wheel test	Tex-242-F	N/A	1 per project
Recycled Asphalt Shingles (RAS)[3]	Tex-217-F, Part III	N/A	
Thermal profile[2]	Tex-244-F	1 per sublot	
Asphalt binder sampling and testing	Tex-500-C	1 per lot (sample only)	
Tack coat sampling and testing	Tex-500-C, Part III	N/A	
Boil test[4]	Tex-530-C	1 per lot	
Cantabro Test[5]	Tex-245-F	1 per project (sample only)	

1. For production defined in Section 346.4.9.4., "Exempt Production," the Engineer will test one per day if 100 tons or more are produced. For Exempt Production, no testing is required when less than 100 tons are produced.
2. Not required when a thermal imaging system is used.
3. Testing performed by the Construction Division or designated laboratory.
4. The Engineer may reduce or waive the sampling and testing requirements based on a satisfactory test history.
5. Testing performed by the Construction Division and for informational purposes only.

4.9.2.4. **Operational Tolerances**. Control the production process within the operational tolerances listed in Table 9. When production is suspended, the Engineer will allow production to resume when test results or other information indicates the next mixture produced will be within the operational tolerances.

4.9.2.4.1. **Gradation**. Suspend operation and take corrective action if any aggregate is retained on the maximum sieve size shown in Table 7. A sublot is defined as out of tolerance if either the Engineer's or the Contractor's test results are out of operational tolerance. Suspend production when test results for gradation exceed the operational tolerances for 3 consecutive sublots on the same sieve or 4 consecutive sublots on any sieve unless otherwise directed. The consecutive sublots may be from more than one lot.

4.9.2.4.2. **Asphalt Binder Content**. A sublot is defined as out of operational tolerance if either the Engineer's or the Contractor's test results exceed the values listed in Table 9. No production or placement bonus will be paid for any sublot that is out of operational tolerance for asphalt binder content. Suspend production and shipment of the mixture if the Engineer's or the Contractor's asphalt binder content deviates from the current JMF by more than 0.5% for any sublot.

4.9.2.4.3. **Voids in Mineral Aggregates (VMA)**. The Engineer will determine the VMA for every sublot. For sublots when the Engineer does not determine asphalt binder content, the Engineer will use the asphalt binder content results from QC testing performed by the Contractor to determine VMA.

Take immediate corrective action if the VMA value for any sublot is less than the minimum VMA requirement for production listed in Table 7. Suspend production and shipment of the mixture if the Engineer's VMA results on 2 consecutive sublots are below the minimum VMA requirement for production listed in Table 7. No production or placement bonus will be paid for any sublot that does not meet the minimum VMA requirement for production listed in Table 7 based on the Engineer's VMA determination.

Suspend production and shipment of the mixture if the Engineer's VMA result is more than 0.5% below the minimum VMA requirement for production listed in Table 7. In addition to suspending production, the Engineer may require removal and replacement or may allow the sublot to be left in place without payment.

4.9.2.4.4. **Fibers**. Suspend production and shipment of the mixture if fiber content varies from the design target value by more than 10% on 2 consecutive tests.

4.9.2.4.5. **Hamburg Wheel Test**. The Engineer may perform a Hamburg Wheel test at any time during production including when the boil test indicates a change in quality from the materials submitted for JMF1. In addition to testing production samples, the Engineer may obtain cores and perform Hamburg Wheel tests on any areas of the roadway where rutting is observed. Suspend production until further Hamburg Wheel tests meet the specified values when the production or core samples fail the Hamburg Wheel test criteria in Table 8. Core samples, if taken, will be obtained from the center of the finished mat or other areas excluding the vehicle wheel paths. The Engineer may require up to the entire sublot of any mixture failing the Hamburg Wheel test to be removed and replaced at the Contractor's expense.

If the Department's or Department-approved laboratory's Hamburg Wheel test results in a "remove and replace" condition, the Contractor may request that the Department confirm the results by re-testing the failing material. The Construction Division will perform the Hamburg Wheel tests and determine the final disposition of the material in question based on the Department's test results.

4.9.2.5. **Individual Loads of Hot-Mix**. The Engineer can reject individual truckloads of hot-mix. When a load of hot-mix is rejected for reasons other than temperature, contamination, or excessive uncoated particles, the Contractor may request that the rejected load be tested. Make this request within 4 hr. of rejection. The Engineer will sample and test the mixture. If test results are within the operational tolerances shown in Table 9, payment will be made for the load. If test results are not within operational tolerances, no payment will be made for the load.

4.9.3. **Placement Acceptance**.

4.9.3.1. **Placement Lot**. A placement lot consists of 4 placement sublots. A placement sublot consists of the area placed during a production sublot.

4.9.3.1.1. **Lot 1 Placement**. Placement bonuses for Lot 1 will be in accordance with Section 346.6.2., "Placement Pay Adjustment Factors"; however, no placement penalty will be assessed for any sublot placed in Lot 1, when the in-place air voids are greater than or equal to 2.7% and less than or equal to 8.0%. Remove and replace any sublot with in-place air voids less than 2.7% or greater than 8.0%.

4.9.3.1.2. **Incomplete Placement Lots**. An incomplete placement lot consists of the area placed as described in Section 346.4.9.2.1.1., "Incomplete Production Lots," excluding areas defined in Section 346.4.9.3.1.4., "Miscellaneous Areas." Placement sampling is required if the random sample plan for production resulted in a sample being obtained from an incomplete production sublot.

4.9.3.1.3. **Shoulders, Ramps, Etc**. Shoulders, ramps, intersections, acceleration lanes, deceleration lanes, and turn lanes are subject to in-place air void determination and pay adjustments unless designated on the plans as not eligible for in-place air void determination. Intersections may be considered miscellaneous areas when determined by the Engineer.

4.9.3.1.4. **Miscellaneous Areas**. Miscellaneous areas include areas that typically involve significant handwork or discontinuous paving operations, such as driveways, mailbox turnouts, crossovers, gores, spot level-up areas, and other similar areas. Temporary detours are subject to in-place air void determination when shown on the plans. Miscellaneous areas also include level-ups and thin overlays when the layer thickness specified on the plans is less than the minimum untrimmed core height eligible for testing shown in Table 10. The specified layer thickness is based on the rate of 110 lb./sq. yd. for each inch of pavement unless another rate is shown on the plans. When "level up" is listed as part of the item bid description code, a pay adjustment factor of 1.000 will be assigned for all placement sublots as described in Section 341.6, "Payment." Miscellaneous areas are not eligible for random placement sampling locations. Compact miscellaneous areas in accordance with Section 346.4.8., "Compaction." Miscellaneous areas are not subject to in-place air void determination, thermal profiles testing, segregation (density profiles), or longitudinal joint density evaluations.

4.9.3.2. **Placement Sampling**. The Engineer will select random numbers for all placement sublots at the beginning of the project. The Engineer will provide the Contractor with the placement random numbers immediately after the sublot is completed. Mark the roadway location at the completion of each sublot and record the station number. Determine one random sample location for each placement sublot in accordance with Tex-225-F. Adjust the random sample location by no more than necessary to achieve a 2-ft. clearance if the location is within 2 ft. of a joint or pavement edge.

Shoulders, ramps, intersections, acceleration lanes, deceleration lanes, and turn lanes are always eligible for selection as a random sample location; however, if a random sample location falls on one of these areas and the area is designated on the plans as not subject to in-place air void determination, cores will not be taken for the sublot and a 1.000 pay factor will be assigned to that sublot.

Provide the equipment and means to obtain and trim roadway cores on-site. On-site is defined as in close proximity to where the cores are taken. Obtain the cores within one working day of the time the placement sublot is completed unless otherwise approved. Obtain two 6-in. diameter cores side-by-side from within 1 ft. of the random location provided for the placement sublot. Mark the cores for identification, measure and record the untrimmed core height, and provide the information to the Engineer. The Engineer will witness the coring operation and measurement of the core thickness. Visually inspect each core and verify that the current paving layer is bonded to the underlying layer. Take corrective action if an adequate bond does not exist between the current and underlying layer to ensure that an adequate bond will be achieved during subsequent placement operations.

Trim the cores immediately after obtaining the cores from the roadway in accordance with Tex-207-F if the core heights meet the minimum untrimmed value listed in Table 10. Trim the cores on-site in the presence of the Engineer. Use a permanent marker or paint pen to record the lot and sublot numbers on each core as well as the designation as Core A or B. The Engineer may require additional information to be marked on the core and may choose to sign or initial the core. The Engineer will take custody of the cores immediately after they are trimmed and will retain custody of the cores until the Department's testing is completed. Before turning the trimmed cores over to the Engineer, the Contractor may wrap the trimmed cores or secure them in a manner that will reduce the risk of possible damage occurring during transport by the Engineer. After testing, the Engineer will return the cores to the Contractor.

The Engineer may have the cores transported back to the Department's laboratory at the HMA plant via the Contractor's haul truck or other designated vehicle. In such cases where the cores will be out of the Engineer's possession during transport, the Engineer will use Department-provided security bags and the Roadway Core Custody protocol located at http://www.txdot.gov/business/specifications.htm to provide a secure means and process that protects the integrity of the cores during transport.

Decide whether to include the pair of cores in the air void determination for that sublot if the core height before trimming is less than the minimum untrimmed value shown in Table 10. Trim the cores as described above before delivering to the Engineer if electing to have the cores included in the air void determination. Deliver untrimmed cores to the Engineer and inform the Engineer of the decision to not have the cores included in air void determination if electing to not have the cores included in air void determination. The placement pay factor for the sublot will be 1.000 if cores will not be included in air void determination.

Instead of the Contractor trimming the cores on-site immediately after coring, the Engineer and the Contractor may mutually agree to have the trimming operations performed at an alternate location such as a field laboratory or other similar location. In such cases, the Engineer will take possession of the cores immediately after they are obtained from the roadway and will retain custody of the cores until testing is completed. Either the Department or Contractor representative may perform trimming of the cores. The Engineer will witness all trimming operations in cases where the Contractor representative performs the trimming operation.

Dry the core holes and tack the sides and bottom immediately after obtaining the cores. Fill the hole with the same type of mixture and properly compact the mixture. Repair core holes with other methods when approved.

4.9.3.3. **Placement Testing.** Perform placement tests in accordance with Table 11. After the Engineer returns the cores, the Contractor may test the cores to verify the Engineer's test results for in-place air voids. The allowable differences between the Contractor's and Engineer's test results are listed in Table 9.

4.9.3.3.1. **In-Place Air Voids**. The Engineer will measure in-place air voids in accordance with Tex-207-F and Tex-227-F. Before drying to a constant weight, cores may be pre-dried using a Corelok or similar vacuum device to remove excess moisture. The Engineer will average the values obtained for all sublots in the production lot to determine the theoretical maximum specific gravity. The Engineer will use the average air void content for in-place air voids.

The Engineer will use the vacuum method to seal the core if required by Tex-207-F. The Engineer will use the test results from the unsealed core to determine the placement pay adjustment factor if the sealed core yields a higher specific gravity than the unsealed core. After determining the in-place air void content, the Engineer will return the cores and provide test results to the Contractor.

4.9.3.3.2. **Segregation (Density Profile)**. Test for segregation using density profiles in accordance with Tex-207-F, Part V. Density profiles are not required and are not applicable when using a thermal imaging system. Density profiles are not applicable in areas described in Section 346.4.9.3.1.4., "Miscellaneous Areas."

Perform a density profile every time the paver stops for more than 60 sec. on areas that are identified by either the Contractor or the Engineer as having thermal segregation and on any visibly segregated areas unless otherwise approved. Perform a minimum of one profile per sublot if the paver does not stop for more than 60 sec. and there are no visibly segregated areas or areas that are identified as having thermal segregation.

Provide the Engineer with the density profile of every sublot in the lot within one working day of the completion of each lot. Report the results of each density profile in accordance with Section 346.4.2., "Reporting and Responsibilities."

The density profile is considered failing if it exceeds the tolerances in Table 12. No production or placement bonus will be paid for any sublot that contains a failing density profile. When a hand-held thermal camera is used instead of a thermal imaging system, the Engineer will measure the density profile at least once per project. The Engineer's density profile results will be used when available. The Engineer may require the Contractor to remove and replace the area in question if the area fails the density profile and has surface irregularities as defined in Section 346.4.9.3.3.5., "Irregularities." The sublot in question may receive a production and placement bonus if applicable when the defective material is successfully removed and replaced.

Investigate density profile failures and take corrective actions during production and placement to eliminate the segregation. Suspend production if 2 consecutive density profiles fail unless otherwise approved. Resume production after the Engineer approves changes to production or placement methods.

Table 12
Segregation (Density Profile) Acceptance Criteria

Mixture Type	Maximum Allowable Density Range (Highest to Lowest)	Maximum Allowable Density Range (Average to Lowest)
SMA-C & SMAR-C	8.0 pcf	5.0 pcf
SMA-D, SMA-F & SMAR-F	6.0 pcf	3.0 pcf

4.9.3.3.3. **Longitudinal Joint Density**.

4.9.3.3.3.1. **Informational Tests**. Perform joint density evaluations while establishing the rolling pattern, and verify that the joint density is no more than 3.0 pcf below the density taken at or near the center of the mat. Adjust the rolling pattern, if needed, to achieve the desired joint density. Perform additional joint density evaluations at least once per sublot unless otherwise directed.

4.9.3.3.3.2. **Record Tests**. Perform a joint density evaluation for each sublot at each pavement edge that is or will become a longitudinal joint. Joint density evaluations are not applicable in areas described in Section 346.4.9.3.1.4., "Miscellaneous Areas." Determine the joint density in accordance with Tex-207-F, Part VII. Record the joint density information and submit results on Department forms to the Engineer. The evaluation is considered failing if the joint density is more than 3.0 pcf below the density taken at the core random sample location and the correlated joint density is less than 90.0%. The Engineer will make independent joint density verification at least once per project and may make independent joint density verifications at the random sample locations. The Engineer's joint density test results will be used when available.

Provide the Engineer with the joint density of every sublot in the lot within one working day of the completion of each lot. Report the results of each joint density in accordance with Section 346.4.2., "Reporting and Responsibilities."

Investigate joint density failures and take corrective actions during production and placement to improve the joint density. Suspend production if the evaluations on 2 consecutive sublots fail unless otherwise approved. Resume production after the Engineer approves changes to production or placement methods.

4.9.3.3.4. **Recovered Asphalt Dynamic Shear Rheometer (DSR)**. The Engineer may take production samples or cores from suspect areas of the project to determine recovered asphalt properties. Asphalt binders with an aging ratio greater than 3.5 do not meet the requirements for recovered asphalt properties and may be deemed defective when tested and evaluated by the Construction Division. The aging ratio is the DSR value of the extracted binder divided by the DSR value of the original unaged binder. Obtain DSR values in accordance with AASHTO T 315 at the specified high temperature PG of the asphalt. The Engineer may require removal and replacement of the defective material at the Contractor's expense. The asphalt binder will be recovered for testing from production samples or cores in accordance with Tex-211-F.

4.9.3.3.5. **Irregularities**. Identify and correct irregularities including segregation, rutting, raveling, flushing, fat spots, mat slippage, irregular color, irregular texture, roller marks, tears, gouges, streaks, uncoated aggregate particles, or broken aggregate particles. The Engineer may also identify irregularities, and in such cases, the Engineer will promptly notify the Contractor. If the Engineer determines that the irregularity will adversely affect pavement performance, the Engineer may require the Contractor to remove and replace (at the Contractor's expense) areas of the pavement that contain irregularities and areas where the mixture does not bond to the existing pavement. If irregularities are detected, the Engineer may require the Contractor to immediately suspend operations or may allow the Contractor to continue operations for no more than one day while the Contractor is taking appropriate corrective action.

4.9.4. **Exempt Production**. When the anticipated daily production is less than 1,000 tons, the total production for the project is less than 5,000 tons, or when mutually agreed between the Engineer and the Contractor, the Engineer may deem the mixture as exempt production. Production may also be exempt when shown on the plans.

For exempt production, the Contractor is relieved of all production and placement sampling and testing requirements and the production and placement pay factors are 1.000. All other specification requirements apply and the Engineer will perform acceptance tests for production and placement listed in Table 14 when 100 tons or more per day are produced.

For exempt production:

- produce, haul, place, and compact the mixture in compliance with the specification and as directed;
- control mixture production to yield a laboratory-molded density that is within ±1.0% of the target laboratory-molded density as tested by the Engineer;
- compact the mixture in accordance with Section 346.4.8., "Compaction," and
- when a thermal imaging system is not used, the Engineer may perform segregation (density profiles) and thermal profiles in accordance with the specification.

4.9.5. **Ride Quality**. Measure ride quality in accordance with Item 585, "Ride Quality for Pavement Surfaces," unless otherwise shown on the plans.

5. MEASUREMENT

Hot mix will be measured by the ton of composite hot-mix. The composite hot-mix is the asphalt, aggregate, and additives. Measure the weight on scales in accordance with Item 520, "Weighing and Measuring Equipment." Provide the Engineer with a daily summary of the asphalt mass flow meter readings for SMAR mixtures unless otherwise directed.

6. PAYMENT

The work performed and materials furnished in accordance with this Item and measured as provided under Article 346.5., "Measurement," will be paid for at the unit bid price for "Stone Matrix Asphalt" of the mixture type, SAC, and binder specified. These prices are full compensation for surface preparation, materials including tack coat, placement, equipment, labor, tools, and incidentals.

Pay adjustments for bonuses and penalties will be applied as determined in this Item; however, a pay adjustment factor of 1.000 will be assigned for all placement sublots for "level ups" only when "level up" is listed as part of the item bid description code. A pay adjustment factor of 1.000 will be assigned to all production and placement sublots when "exempt" is listed as part of the item bid description code.

Payment for each sublot, including applicable pay adjustment bonuses, will only be paid for sublots when the Contractor supplies the Engineer with the required documentation for production and placement QC/QA, thermal profiles, segregation density profiles, and longitudinal joint densities in accordance with Section 346.4.2., "Reporting and Responsibilities." When a thermal imaging system is used, documentation is not required for thermal profiles or segregation density profiles on individual sublots; however, the thermal imaging system automated reports described in Tex-244-F are required.

Trial batches will not be paid for unless they are included in pavement work approved by the Department.

Pay adjustment for ride quality will be determined in accordance with Item 585, "Ride Quality for Pavement Surfaces."

6.1. **Production Pay Adjustment Factors**. The production pay adjustment factor is based on the laboratory-molded density using the Engineer's test results. A pay adjustment factor will be determined from Table 13 for each sublot using the deviation from the target laboratory-molded density defined in Table 8. The production pay adjustment factor for completed lots will be the average of the pay adjustment factors for the 4 sublots sampled within that lot.

Table 13
Production Pay Adjustment Factors for Laboratory-Molded Density[1]

Absolute Deviation from Target Laboratory-Molded Density	Production Pay Adjustment Factor (Target Laboratory-Molded Density)
0.0	1.100
0.1	1.100
0.2	1.100
0.3	1.086
0.4	1.075
0.5	1.063
0.6	1.050
0.7	1.038
0.8	1.025
0.9	1.013
1.0	1.000
1.1	0.900
1.2	0.800
1.3	0.700
> 1.3	Remove and replace

1. If the Engineer's laboratory-molded density on any sublot is less than 95.0% or greater than 97.0%, take immediate corrective action to bring the mixture within these tolerances. The Engineer may suspend operations if the Contractor's corrective actions do not produce acceptable results. The Engineer will allow production to resume when the proposed corrective action is likely to yield acceptable results.

6.1.1. **Payment for Incomplete Production Lots**. Production pay adjustments for incomplete lots, described under Section 346.4.9.2.1.1., "Incomplete Production Lots," will be calculated using the average production pay factors from all sublots sampled. A production pay factor of 1.000 will be assigned to any lot when the random sampling plan did not result in collection of any samples.

6.1.2. **Production Sublots Subject to Removal and Replacement**. If after referee testing, the laboratory-molded density for any sublot results in a "remove and replace" condition as listed in Table 13, the Engineer may require removal and replacement or may allow the sublot to be left in place without payment. The Engineer may also accept the sublot in accordance with Section 5.3.1., "Acceptance of Defective or Unauthorized Work." Replacement material meeting the requirements of this Item will be paid for in accordance with this Section.

6.2. **Placement Pay Adjustment Factors**. The placement pay adjustment factor is based on in-place air voids using the Engineer's test results. A pay adjustment factor will be determined from Table 14 for each sublot that requires in-place air void measurement. A placement pay adjustment factor of 1.000 will be assigned to the entire sublot when the random sample location falls in an area designated on the plans as not subject to in-place air void determination. A placement pay adjustment factor of 1.000 will be assigned to quantities placed in areas described in Section 346.4.9.3.1.4., "Miscellaneous Areas." The placement pay adjustment factor for completed lots will be the average of the placement pay adjustment factors for up to 4 sublots within that lot.

Table 14
Placement Pay Adjustment Factors for In-Place Air Voids

In-Place Air Voids	Placement Pay Adjustment Factor	In-Place Air Voids	Placement Pay Adjustment Factor
< 2.7	Remove and Replace	5.4	1.080
2.7	0.710	5.5	1.075
2.8	0.740	5.6	1.070
2.9	0.770	5.7	1.065
3.0	0.800	5.8	1.060
3.1	0.830	5.9	1.055
3.2	0.860	6.0	1.050
3.3	0.890	6.1	1.045
3.4	0.920	6.2	1.040
3.5	0.950	6.3	1.035
3.6	0.980	6.4	1.030
3.7	1.010	6.5	1.025
3.8	1.040	6.6	1.020
3.9	1.070	6.7	1.015
4.0	1.100	6.8	1.010
4.1	1.100	6.9	1.005
4.2	1.100	7.0	1.000
4.3	1.100	7.1	0.970
4.4	1.100	7.2	0.940
4.5	1.100	7.3	0.910
4.6	1.100	7.4	0.880
4.7	1.100	7.5	0.850
4.8	1.100	7.6	0.820
4.9	1.100	7.7	0.790
5.0	1.100	7.8	0.760
5.1	1.095	7.9	0.730
5.2	1.090	8.0	0.700
5.3	1.085	> 8.0	Remove and Replace

6.2.1. **Payment for Incomplete Placement Lots**. Pay adjustments for incomplete placement lots described under Section 346.4.9.3.1.2., "Incomplete Placement Lots," will be calculated using the average of the placement pay factors from all sublots sampled and sublots where the random location falls in an area designated on the plans as not eligible for in-place air void determination. A placement pay adjustment factor of 1.000 will be assigned to any lot when the random sampling plan did not result in collection of any samples.

6.2.2. **Placement Sublots Subject to Removal and Replacement**. If after referee testing, the placement pay adjustment factor for any sublot results in a "remove and replace" condition as listed in Table 14, the Engineer will choose the location of 2 cores to be taken within 3 ft. of the original failing core location. The Contractor will obtain the cores in the presence of the Engineer. The Engineer will take immediate possession of the untrimmed cores and submit the untrimmed cores to the Construction Division, where they will be trimmed if necessary and tested for bulk specific gravity within 10 working days of receipt. The average bulk specific gravity of the cores will be divided by the Engineer's average maximum theoretical specific gravity for that lot to determine the new pay adjustment factor of the sublot in question. If the new pay adjustment factor is 0.700 or greater, the new pay adjustment factor will apply to that sublot. If the new pay adjustment factor is less than 0.700, no payment will be made for the sublot. Remove and replace the failing sublot, or the Engineer may allow the sublot to be left in place without payment. The Engineer may also accept the sublot in accordance with Section 5.3.1., "Acceptance of Defective or Unauthorized Work." Replacement material meeting the requirements of this Item will be paid for in accordance with this Section.

6.3. **Total Adjusted Pay Calculation.** Total adjusted pay (TAP) will be based on the applicable pay adjustment factors for production and placement for each lot.

$$TAP = (A+B)/2$$

where:
A = Bid price × production lot quantity × average pay adjustment factor for the production lot
B = Bid price × placement lot quantity × average pay adjustment factor for the placement lot + (bid price × quantity placed in miscellaneous areas × 1.000)

Production lot quantity = Quantity actually placed - quantity left in place without payment

Placement lot quantity = Quantity actually placed - quantity left in place without payment - quantity placed in miscellaneous areas

SECTION 02741

HOT MIX ASPHALT (HMA)

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Products and procedures for placing and compacting a surface course of one or more layers of HMA comprised of aggregate, asphalt binder, hydrated lime, and other additives.

B. Option to incorporate Reclaimed Asphalt Pavement (RAP) materials into HMA pavement.

1.2 RELATED SECTIONS

A. Section 01452: Pavement Smoothness

B. Section 01456: Materials Dispute Resolution

C. Section 02742S: Project Specific Surfacing Requirements

D. Section 02745: Asphalt Material

E. Section 02746: Hydrated Lime

F. Section 02748: Prime Coat/Tack Coat

1.3 REFERENCES

A. AASHTO M 323: Superpave Volumetric Mix Design

B. AASHTO R 35: Superpave Volumetric Design for Hot-Mix Asphalt (HMA)

C. AASHTO T 19: Bulk Density (“Unit Weight”) and Voids in Aggregate

D. AASHTO T 89: Determining the Liquid Limit of Soils

E. AASHTO T 90: Determining the Plastic Limit and Plasticity Index of Soils

F. AASHTO T 96: Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

G. AASHTO T 104: Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate

H. AASHTO T 112: Clay Lumps and Friable Particles in Aggregate

I. AASHTO T 176: Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

J. AASHTO T 195: Determining Degree of Particle Coating of Asphalt Mixtures

K. AASHTO T 209: Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt (HMA)

L. AASHTO T 255: Total Evaporable Moisture Content of Aggregate by Drying

M. AASHTO T 304: Uncompacted Void Content of Fine Aggregate

N. AASHTO T 335: Determining the Percentage of Fracture in Coarse Aggregate

O. UDOT Materials Manual of Instruction

P. UDOT Minimum Sampling and Testing Requirements

Q. UDOT Quality Management Plans

1.4 DEFINITIONS

A. Lot – The number of tons of HMA placed in a Production Day.

B. Minor Target Change – A change from the verified mix design gradation target on a maximum of two sieves with the following limitations.
   1. The maximum allowable change in the target gradation on the #8 or any coarser sieve is limited to 3 percent passing per sieve.
   2. The maximum allowable change in the target gradation on the #16 or #50 sieves is 2 percent passing per sieve.
   3. The maximum allowable change in the target gradation on the #200 sieve is 0.5 percent passing.
   4. No target change may violate the mix design requirements in this section.

C. Production Day – A 24 hour period in which HMA is being placed.

D. RAP – Recycled Asphalt Pavement. Crushed or milled asphalt materials that have been removed from pavements. Aggregates contained in these materials are required to meet Table 5 except sand equivalent.

E. Thin Overlay Pavement – An overlay where the sum of the thickness of the HMA lifts is less than two inches.

1.5 SUBMITTALS

A. Mix design at least 10 working days before paving according to the UDOT Materials Manual of Instruction 960.

B. Verification that hydrated lime meets the requirements of Section 02746.

C. Verification that asphalt binder meets the requirements of Section 02745.

D. Changes in job mix design
   1. Submit a written request for any proposed change in the job-mix gradation.
      a. Allow at least 12 hours for approval before incorporating a minor target change into production.
      b. Allow at least six working days for verification and approval of any other change.
   2. Include documentation supporting correlation between suggested target changes and mix design volumetric requirements. Department acceptance test results or Contractor QC test data or both are acceptable.
   3. Submit samples according to the UDOT Materials Manual of Instruction 960 for a volumetric mix design verification for anything other than approved minor target changes. This includes changes in the aggregate source, asphalt binder source, or asphalt binder grade.

E. Corrective action plan according to this Section, articles 3.3 paragraph B and 3.4 paragraph A4b.

1.6 ACCEPTANCE

A. Acceptance sampling and testing of material is according to UDOT Minimum Sampling and Testing Requirements.

B. Gradation and asphalt binder content
   1. The Engineer evaluates a lot on the test results of four samples with the following exceptions:

a. Compute incentive/disincentive using the test results from three samples if only three samples can be taken for the production day.
b. Combine test results with the next day of production if at least three random samples cannot be taken. Take one sample for each 500 tons, or portion thereof, from the following day's production.
c. Add the lot to the previous day's production for the final day's production if three random samples cannot be taken.
d. The lot may be increased to include up to three production days when agreed upon in advance by both the Contractor and the Engineer when less than 900 tons are anticipated per production day.

2. Evaluate the lot using the number of tests "n" in Table 3.
3. The Engineer informs the Contractor of the time and place of sampling not more than 15 minutes before sampling.

C. Density and Thickness

1. Contractor obtains cores within two contract days after the pavement is placed. Refer to UDOT Materials Manual of Instruction 984.
    a. The Engineer marks coring location for in-place density and joint density cores.
    b. Move transversely to a point 1 ft from the edge of the pavement for in-place density if the random location for coring falls within 1 ft of the edge of the overall pavement section (outer part of shoulders).
    c. Fill core holes with HMA or high AC content cold mix and compact.
    d. The Department witnesses the coring operation, takes possession of the cores immediately, and begins testing the cores within 24 hours for density acceptance.
2. Density Requirements
    a. The target for in-place density is 93.5 percent of Theoretical Maximum Specific Gravity except for thin overlay pavements.
    b. The target for in-place density is 92.5 percent of Theoretical Maximum Specific Gravity for Thin overlay pavement projects.
    c. Use the average of the Theoretical Maximum Specific Gravity tests for each lot.
    d. Acceptance for in-place density may be based on establishing a rolling pattern for items such as bridge decks, utility work, traffic signals, detours, lane leveling, driveways, other handwork, or small projects with plan quantities less than 500 tons.

3. Thickness Requirements
   a. The Department accepts a lot for thickness when:
      1) The average thickness is not more than ½ inch greater or ¼ inch less than the total design thickness specified.
      2) No individual sublot shows a deficient thickness of more than ⅜ inch.
   b. Excess Thickness – The Engineer may allow excess thickness to remain in place or may order its removal.
      1) The Department pays for 50 percent of the mix for material in excess of the +½ inch tolerance when excess thickness is allowed to remain in place.
   c. Deficient Thickness – Place additional material where lots or sublots are deficient in thickness.
      1) The Department pays for material necessary to reach specified thickness.
      2) The Department pays for 50 percent of the mix for additional material over specified thickness necessary to achieve minimum lift thickness.
      3) Minimum compacted lift is 3 times the nominal maximum aggregate size.
   d. Thickness tolerances established above do not apply to leveling courses. Check final surfaces in stage construction.
   e. Thickness acceptance for thin overlay pavement consists of checking thickness regularly with a depth probe during placement and taking corrective action as necessary.

D. The Department applies Incentives/Disincentives for Gradation/Asphalt Content, In-Place Density, and Longitudinal Joint Density. The Engineer computes Incentive/Disincentive for each lot. Refer to Section 01452 for smoothness requirements.
   1. Compute incentive/disincentive for Gradation/Asphalt Binder and In-place Density according to Table 1.
   2. Base the incentive/disincentive on Percent within Limit (PT) computation using Tables 2, 3, and 4.
   3. Use lowest single value combined for gradation (each of the sieves) and asphalt binder content for calculating the gradation/asphalt binder content incentive/disincentive.
   4. Use Tables 2, 3, and 4 to determine PT for in-place density.
   5. Meet PT of 88 or greater for in-place density or the Department does not pay incentives on gradation/asphalt binder content.
   6. Incentive for Joint Density is $0.20 per linear foot of longitudinal joint for each lift when the average of all joint densities is above 91 percent of Theoretical Maximum Specific Gravity for the lot.

7. The following work is not eligible for incentive:
   a. Items such as utility work, traffic signals, detours, lane leveling, and driveways.
   b. Small projects with plan quantities of HMA less than 500 tons.
8. The Department will reject the lot if the PT is less than 60 percent.

E. The Department rejects lots:
   1. If the PT for any individual measurement listed in Table 2 is less than 60 percent.
   2. The Engineer may accept a reject lot. Refer to Section 01456.
      a. A $25 per ton price reduction will be assessed.
      b. The lot will not be eligible for any incentive.

F. The Engineer may elect to accept material on visual inspection for work such as utility work, traffic signals, detours, lane leveling, and driveways, other hand work, or small projects with plan quantities less than 500 tons.
   1. Lots accepted on visual inspection are not eligible for Incentive/Disincentive.
   2. The Engineer reserves the option of conducting any acceptance tests necessary to determine that the material and workmanship meets the project requirements.
   3. Acceptance for density may be based on establishing and maintaining a roller pattern to obtain maximum density without over-stressing the pavement.

Table 1

Incentive/Disincentive for Gradation, Asphalt Binder Content, and Density	
PT Based on Min. Four Samples	**Incentive/Disincentive (Dollars/Ton)**
> 99	1.50
96-99	1.00
92-95	0.60
88-91	0.00
84-87	-0.26
80-83	-0.60
76-79	-0.93
72-75	-1.27
68-71	-1.60
64-67	-1.93
60-63	-2.27
<60	Reject

Table 2

Upper and Lower Limit Determination	
Parameter	**UL and LL**
¾ inch sieve for 1 inch HMA ½ inch sieve for ¾ inch HMA ⅜ inch sieve for ½ inch HMA No. 4 sieve for ⅜ inch HMA	Target Value ± 6.0%
No. 8 sieve	Target Value ± 5.0%
No.50 sieve	Target Value ± 3.0%
No. 200 sieve	Target Value ± 2.0%
Asphalt Binder Content	Target Value ± 0.35%
Density	Lower Limit Target Value - 2.0% Upper Limit Target Value + 3.0%

Table 3

Quality Index Values for Estimating Percent Within Limits										
PU/PL	**n=3**	**n=4**	**n=5**	**n=6**	**n=7**	**n=8**	**n=10**	**n=12**	**n=15**	**n=20**
100	1.16	1.50	1.75	1.91	2.06	2.15	2.29	2.35	2.47	2.56
99	1.16	1.47	1.68	1.79	1.89	1.95	2.04	2.09	2.14	2.19
98	1.15	1.44	1.61	1.70	1.77	1.80	1.86	1.89	1.93	1.97
97	1.15	1.41	1.55	1.62	1.67	1.69	1.74	1.77	1.80	1.82
96	1.15	1.38	1.49	1.55	1.59	1.61	1.64	1.66	1.69	1.70
95	1.14	1.35	1.45	1.49	1.52	1.54	1.56	1.57	1.59	1.61
94	1.13	1.32	1.40	1.44	1.46	1.47	1.49	1.50	1.51	1.53
93	1.12	1.29	1.36	1.38	1.40	1.41	1.43	1.43	1.44	1.46
92	1.11	1.26	1.31	1.33	1.35	1.36	1.37	1.37	1.38	1.39
91	1.10	1.23	1.27	1.29	1.30	1.31	1.32	1.32	1.32	1.33
90	1.09	1.20	1.23	1.24	1.25	1.25	1.26	1.26	1.27	1.27
89	1.08	1.17	1.20	1.21	1.21	1.21	1.21	1.21	1.22	1.22
88	1.07	1.14	1.16	1.17	1.17	1.17	1.17	1.17	1.17	1.17
87	1.06	1.11	1.12.	1.12	1.12	1.13	1.13	1.13	1.13	1.13
86	1.05	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
85	1.03	1.05	1.05	1.05	1.05	1.04	1.04	1.04	1.04	1.04
84	1.02	1.02	1.02	1.01	1.01	1.01	1.00	1.00	1.00	1.00
83	1.00	0.99	0.98	0.97	0.97	0.96	0.96	0.96	0.96	0.96
82	0.98	0.96	0.95	0.94	0.94	0.93	0.93	0.92	0.92	0.92
81	0.96	0.93	0.92	0.91	0.90	0.90	0.89	0.89	0.89	0.88
80	0.94	0.90	0.88	0.87	0.86	0.86	0.85	0.85	0.85	0.85
79	0.92	0.87	0.85	0.84	0.83	0.83	0.82	0.82	0.82	0.81
78	0.89	0.84	0.82	0.81	0.80	0.79	0.79	0.78	0.78	0.78
77	0.87	0.81	0.79	.0.78	0.77	0.76	0.76	0.75	0.75	0.75
76	0.84	0.78	0.76	0.75	0.74	0.73	0.72	0.72	0.72	0.72
75	0.82	0.75	0.73	0.72	0.71	0.70	0.69	0.69	0.69	0.68
74	0.79	0.72	0.70	0.68	0.67	0.67	0.66	0.66	0.66	0.65
73	0.77	0.69	0.67	0.65	0.64	0.64	0.62	0.62	0.62	0.62
72	0.74	0.66	0.64	0.62	0.61	0.61	0.60	0.59	0.59	0.59
71	0.71	0.63	0.60	0.59	0.58	0.58	0.57	0.56	0.56	0.56
70	0.68	0.60	0.58	0.56	0.55	0.55	0.54	0.54	0.54	0.53
69	0.65	0.57	0.55	0.54	0.53	0.52	0.51	0.51	0.51	0.50
68	0.62	0.54	0.52	0.51	0.50	0.50	0.48	0.48	0.48	0.48
67	0.59	0.51	0.49	0.48	0.47	0.47	0.46	0.45	0.45	0.45
66	0.56	0.48	0.46	0.45	0.44	0.44	0.43	0.42	0.42	0.42
65	0.53	0.45	0.43	0.42	0.41	0.41	0.40	0.40	0.40	0.39
64	0.49	0.42	0.40	0.39	0.38	0.38	0.37	0.37	0.37	0.37
63	0.46	0.39	0.37	0.36	0.35	0.35	0.35	0.34	0.34	0.34
62	0.43	0.36	0.34	0.33	0.33	0.33	0.32	0.31	0.31	0.31
61	0.39	0.33	0.31	0.30	0.30	0.30	0.29	0.29	0.29	0.28
60	0.36	0.30	0.28	0.27	0.26	0.26	0.25	0.25	0.25	0.25
<60	≤ 0.35	≤ 0.29	≤ 0.27	≤ 0.26	≤ 0.25	≤ 0.25	≤ 0.24	≤ 0.24	≤ 0.24	≤ 0.24

Enter table in the appropriate “number of tests” column and round down to the nearest value.

Table 4

Definitions, Abbreviations, and Formulas for Acceptance	
Term	**Explanation**
Target Value (TV)	The target values for gradation and asphalt binder content are given in the Contractor's volumetric mix design. See this Section, article 1.6 for density target values.
Average (AVE)	The sum of the lot's test results for a measured characteristic divided by the number of test results–the arithmetic mean.
Sample Standard Deviations	The square root of the value formed by summing the squared difference between the individual test results of a measured characteristic and AVE, divided by the number of test results minus one.
Upper Limit (UL)	The value above the TV of each measured characteristic that defines the upper limit of acceptable production. (Table 2)
Lower Limit (LL)	The value below the TV of each measured characteristic that defines the lower limit of acceptable production (Table 2)
Upper Quality Index (QU)	QU = (UL - AVE)/s
Lower Quality Index (QL)	QL = (AVE - LL)/s
Percentage of Lot Within UL (PU)	Determined by entering Table 3 with QU.
Percentage of Lot Within LL (PL)	Determined by entering Table 3 with QL.
Total Percentage of Lot Within UL and LL (PT)	PT = (PU + PL) – 100
Incentive/Disincentive	Determined by entering Table 1 with PT or PL.

All values for AVE, s, QU, and QL will be calculated to at least four decimal places and carried through all further calculations. Rounding to lower accuracy is not allowed.

1.7 DISPUTE RESOLUTION

A. Refer to Section 01456 when disputing the validity of the Department's acceptance tests.

B. The option to dispute the validity of the Department's test results is waived if the paired "t" testing described in this Section, article 3.4 is not performed.

PART 2 PRODUCTS

2.1 ASPHALT BINDER

A. Project Specific Surfacing Requirements – Refer to Section 02742S.

B. Asphalt Material – Refer to Section 02745.

2.2 AGGREGATE

A. Crusher processed virgin aggregate material consisting of crushed stone, gravel, or slag.

B. Refer to Table 5 to determine the suitability of the aggregate.
   1. Coarse aggregates
      a. Retained on No. 4 sieve
   2. Fine aggregates
      a. Clean, hard grained, and angular
      b. Passing the No. 4 sieve

Table 5

Aggregate Properties – HMA

Test Method	Test No.	75 Design Gyrations and Greater	Less Than 75 Design Gyrations
One Fractured Face	AASHTO T 335	95% minimum	85% min (1 inch and ¾ inch) 90% min (½ inch and ⅜ inch)
Two Fractured Face	AASHTO T 335	90% minimum	80% min (1 inch and ¾ inch) 90% min (½ inch and ⅜ inch)
Fine Aggregate Angularity	AASHTO T 304	45 minimum	45 minimum
Flakiness Index	UDOT MOI 933 (Based on ⅜ inch sieve and above)	17% maximum	17% maximum
L.A. Wear	AASHTO T 96	35% maximum	40% maximum
Sand Equivalent	AASHTO T 176 (Pre-wet method)	60 minimum	45 minimum
Plasticity Index	AASHTO T 89 and T 90	0	0
Unit Weight	AASHTO T 19	minimum 75 lb/cu ft	minimum 75 lb/cu ft
Soundness (sodium sulfate)	AASHTO T 104	16% maximum loss with five cycles	16% maximum loss with five cycles
Clay Lumps and Friable Particles	AASHTO T 112	2% maximum	2% maximum
Natural Fines	N/A	0%	10% maximum

C. Meet gradation requirements in Table 6.

Table 6

Aggregate Gradations (Percent Passing by Dry Weight of Aggregate)					
Sieve Size		**1 inch**	**¾ inch**	**½ inch**	**⅜ inch**
Control Sieves	**1½ inch**	100.0			
	1 inch	90.0 - 100.0	100.0		
	¾ inch	<90	90.0 - 100.0	100.0	
	½ inch		<90	90.0 – 100.0	100.0
	⅜ inch			<90	90.0 - 100.0
	No. 4				< 90
	No. 8	19.0 - 45.0	23.0 - 49.0	28.0 - 58.0	32.0 - 67.0
	No. 200	1.0 - 7.0	2.0 - 8.0	2.0 – 10.0	2.0 – 10.0

2.3 HYDRATED LIME

A. Meet the requirements of Section 02746.

2.4 RECLAIMED ASPHALT PAVEMENT (RAP) (OPTIONAL)

A. Do not adjust the asphalt binder grade when RAP content is not more than 15 percent by total weight of the hot mix and RAP asphalt binder content is not more than 15 percent of the total asphalt binder content by weight.

B. Adjust asphalt binder grade according to AASHTO M 323 when RAP asphalt binder content is between 15 to 25 percent of the asphalt binder weight.

1. Select one grade softer than the grade specified. Do not select any grades lower than PG XX-34.
2. Provide test reports indicating that the PG grade and quantity of the recovered asphalt binder is consistent throughout the stockpile.
3. Limit RAP to 25 percent of the total weight of the hot mix and RAP binder to 25 percent of the total binder.

C. RAP aggregate is required to meet Table 5 with exception of Sand Equivalent. Refer to AASHTO T 176.

2.5 WARM MIX

A. Meet all design requirements of Hot Mix Asphalt.

2.6 VOLUMETRIC DESIGN

A. Perform Superpave Volumetric Mix Design according to UDOT Materials Manual of Instruction 960 and the following:
   1. Incorporate hydrated lime into all designs. Refer to Section 02746.
   2. Comply with Table 7 and Table 8.

B. The Department Region Materials Lab verifies the Volumetric Mix Design. Refer to the UDOT Materials Manual of Instruction 960.
   1. Do not begin paving until verification is complete.
   2. The Resident Engineer and Region Materials Engineer will provide written verification of the field volumetric mix design.

C. Mix Design Changes
   1. The Department may allow up to two minor target changes per project without penalty to contractor. The Department charges $1,000 for each additional minor target change.
   2. The Department allows up to two volumetric mix design verifications, (including field verifications), per project. The Department charges $3,000 for each additional laboratory or field verification required. This includes all laboratory or field volumetric mix design verifications required due to contractor initiated target changes.
   3. The Resident Engineer and Region Materials Engineer will review each change and provide written notice of approval or rejection of each mix design change.

Table 7

Volumetric Design Gyrations				
20 Years Design ESALS (Million)	**Compaction Parameters**			**Voids Filled with Asphalt (VFA) (%)**
	$N_{initial}$ /% of G_{mm}*	**N_{design} /% of G_{mm}***	**N_{max} /% of G_{mm}***	
0.3	6/≤ 91.5	50/ 96.5	75/≤ 98	70 - 80 **
0.3 to <3	7/≤ 90.5	75/ 96.5	115/≤ 98	70 – 80
3 to < 30	8/≤ 89	100/ 96.5	160/≤ 98	70 – 80
≥ 30	9/≤ 89	125/ 96.5	205/≤ 98	70 – 80

* G_{mm}: Theoretical maximum specific gravity of mix. Refer to AASHTO T 209.
** 67 percent specified lower limit VFA for 1-inch nominal maximum size mixture.

Table 8

Volumetric Design Requirements	
HMA design mixing and compaction temperatures	Provided by the Engineer
Dust Proportion Range	0.6 - 1.40
Voids in Mineral Aggregate (VMA) at N_{design} AASHTO R 35.9.2 using G_{sb} at SSD. Equation based on percent of total mix.	12.5% - 13.5% for 1 inch 13.5% - 14.5% for ¾ inch 14.5% - 15.5% for ½ inch 15.5% - 16.5% for ⅜ inch
Hamburg Wheel Tracker UDOT MOI 990	75 Design Gyrations and Greater Maximum 10 mm impression at 20,000 passes. Less than 75 Design Gyrations Maximum 10 mm impression at 10,000 passes

2.7 PRIME COAT/TACK COAT

A. Refer to Section 02748.

PART 3 EXECUTION

3.1 HMA

A. Dry aggregate to an average moisture content of not more than 0.2 percent by weight.
   1. May be verified by AASHTO T 255.
   2. Adjust burners to avoid damage or soot contamination of the aggregate.

B. Treat aggregate with hydrated lime. Refer to Section 02746.
   1. Method A or B
   2. The Department applies a deduction for mix produced by a non-certified supplier to cover the costs of inspection. The deduction is applied according to the UDOT Quality Management Plan 514 Hot-Mix Asphalt.

C. Coat with asphalt binder 100 percent of the particles passing and 98 percent of the particles retained on the No. 4 sieve.
   1. May be verified by AASHTO T 195.
   2. Discontinue operation and make necessary corrections if material is not properly coated.

D. Maintain temperature of the HMA between the limits identified on the Volumetric Mix Design Verification Letter for mixing and compacting.
   1. The Department rejects materials heated over the identified limits.
   2. Remove all material rejected by the Department for overheating.

3.2 HMA PLANT

A. Provide
   1. Positive means to determine the moisture content of aggregate.
   2. Positive means to sample all material components.
   3. Sensors to measure the temperature of the HMA at discharge.
   4. The ability to maintain mix discharge temperature according to the mix design.

B. Asphalt Binder Storage Tanks
   1. Provide a positive means for separating and identifying asphalt grades when multiple products are used in mix production.
   2. Provide a positive means of sampling the asphalt binder. Accept a common sampling point where multiple products are used in mix production.

3.3 CEASE PRODUCTION

A. Cease production when any two out of three consecutive lots meet one of the following criteria:
   1. A net disincentive
   2. Air voids at N_{des} averaged for each lot are less than 2.5 or greater than 4.75 percent
   3. VMA at N_{des} averaged for each lot are not within Target Value ± 1.25 percent

B. Submit a corrective action plan to the Engineer before production continues indicating the changes in production procedures that will be implemented to correct the deficiencies. Address the specific issues contributing to the cease production directive. The Engineer must approve the revised plan before production continues.

C. The Engineer may require a new mix design.

D. The Engineer may require Hamburg Wheel-Track testing for up to 5 lots after the cease production order.
   1. Sample to be taken randomly from behind the paver for up to 5 lots after the cease production order.
   2. Failure to meet the requirements of Table 8 results in rejection of the lot.

3.4 LABORATORY CORRELATION

A. Perform split-sample, paired *t*-testing with the Department based on project quality control testing using Department LQP qualified lab.
   1. Perform split-sample, paired *t* analysis on all mix acceptance tests and tests related to volumetric properties.
   2. Perform paired *t* analysis as defined in the UDOT Materials Manual of Instruction, Appendix C.
   3. Continue paired *t*-testing until at least two consecutive production days meet $\alpha = 0.05$ for a two tailed distribution.
   4. Resolve discrepancies in lab results within the first five production days.
      a. Cease production if two consecutive days in the first five days cannot be achieved.
      b. Submit a corrective action plan to the Engineer before production continues indicating the changes in procedures that will be implemented to correct the deficiencies. Both Contractor and Department labs must make paired *t* test results available within 24 hours of sampling.

3.5 SURFACE PREPARATION

A. Locate, reference, and protect all utility covers, monuments, curb and gutter, and other components affected by the paving operations.

B. Remove all moisture, dirt, sand, leaves, and other objectionable material from the prepared surface before placing the tack coat and mix.

C. Complete spot leveling before placing pavement courses.
   1. Place, spread, and compact leveling mix on portions of the existing surface.
   2. Fill and compact any localized potholes more than 1 inch deep.
   3. Allow compacted mix to cool sufficiently to below 150 degrees F to provide a stable structural platform before placing additional lifts of HMA.

D. Apply tack coat to all paved surfaces before applying a leveling course or pavement lift as required in Section 02748.

E. Allow sufficient cure time for prime coat/tack coat before placing HMA.

3.6 SURFACE PLACEMENT

A. Provide a compactable sloped edge adjacent to the next lane to be paved when full-width or Echelon paving is impractical and more than one pass is required.
   1. Coat edge with tack coat according to Section 02748 at a residual rate of 0.05 gal/yd^2.
   2. Echelon paving is the preferred method for constructing a longitudinal joint.
   3. Refer to Section 01554 and DD and TC Series Standard Drawings for pavement edge slope required to safely maintain traffic.

B. Adjust the production of the mixing plant and material delivery until a steady paver speed is maintained.

C. Offset longitudinal joints 6 to 12 inches in succeeding courses.
   1. Place top course joint within 1 ft of the centerline or lane line.
   2. Tack the longitudinal edge before placing the adjacent pass if the previous pass has cooled below 175 degrees F.

D. Offset transverse construction joints at least 6 ft longitudinally.

E. Do not allow construction vehicles, general traffic, or rollers to pass over the uncompacted end or edge of freshly placed mix until the mat temperature drops to a point where damage or differential compaction will not occur.

F. Taper the end of a course subjected to traffic at approximately 50:1 (horizontal to vertical).
   1. Remove the portion of the pass that contains the tapered end before placing fresh mix.
   2. Tack the contact surfaces before fresh mix is placed against the compacted mix.

G. Use a motor grader, spreader box, or other approved spreading methods for projects under 180 yd^2, irregular areas, or for miscellaneous construction such as detours, sidewalks, and leveling courses.

3.7 COMPACTION

A. Use a small compactor or vibratory roller at structures in addition to normal rolling.

B. Operate in a transverse direction next to the back wall and approach slab.

3.8 LIMITATIONS

A. Do not place on frozen base or during adverse climatic conditions such as precipitation or when roadway surface is icy or wet.

B. Use a release agent that does not dissolve asphalt and is acceptable to the Engineer for all equipment and hand tools used to mix, haul, and place the HMA.

C. Place between April 15, and October 15, and when the air temperature in the shade and the roadway surface temperature are above 50 degrees F.
   1. The Department determines and provides written approval if it is acceptable to place outside the above limits.

END OF SECTION

SECTION 02745

ASPHALT MATERIAL

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Asphalt materials

1.2 RELATED SECTIONS Not Used

1.3 REFERENCES

A. AASHTO M 81: Cutback Asphalt (Rapid-Curing Type)

B. AASHTO M 82: Cutback Asphalt (Medium-Curing Type)

C. AASHTO M 140: Emulsified Asphalt

D. AASHTO M 208: Cationic Emulsified Asphalt

E. AASHTO M 226: Viscosity Graded Asphalt Cement

F. AASHTO M 282: Joint Sealants, Hot-Poured, Elastomeric-Type, for Portland Cement Concrete Pavements

G. AASHTO M 320: Performance Graded Asphalt Binder

H. AASHTO R 28: Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)

I. AASHTO T 44: Solubility of Bituminous Materials

J. AASHTO T 48: Flash and Fire Points by Cleveland Open Cup

K. AASHTO T 49: Penetration of Bituminous Materials

L. AASHTO T 50: Float Test for Bituminous Materials

M. AASHTO T 51: Ductility of Bituminous Materials

N. AASHTO T 59: Emulsified Asphalt

O. AASHTO T 201: Kinematic Viscosity of Asphalts (Bitumens)

P. AASHTO T 228: Specific Gravity of Semi-Solid Asphalt Materials

Q. AASHTO T 240: Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)

R. AASHTO T 300: Force Ductility of Asphalt Materials

S. AASHTO T 301: Elastic Recovery Test of Asphalt Materials by Means of a Ductilometer

T. AASHTO T 313: Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)

U. AASHTO T 314: Determining the Fracture Properties of Asphalt Binder in Direct Tension

V. AASHTO T 315: Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

W. AASHTO T 316: Viscosity Determination of Asphalt Binder Using Rotational Viscometer

X. ASTM D 2006: Method for Characteristic Groups in Rubber Extender and Processing Oils by the Precipitation Method.

Y. ASTM D 2007: Characteristic Groups in Rubber Extender and Processing Oils and Other Petroleum Derived Oils by the Clay Gel Absorption Chromatographic Method

Z. ASTM D 2026: Cutback Asphalt (Slow Curing Type)

AA. ASTM D 4402: Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer

BB. ASTM D 5329: Sealants and Fillers, Hot-Applied, For Joints and Cracks in Asphaltic and Portland Cement Concrete Pavements

CC. ASTM D 5801: Toughness and Tenacity of Bituminous Materials

DD. California Test Methods

EE. UDOT Materials Manual of Instruction

FF. UDOT Minimum Sampling and Testing Requirements

GG. UDOT Quality Management Plan

1.4 DEFINITIONS Not Used

1.5 SUBMITTALS

A. A vendor-prepared bill of lading showing the following information for each material shipment:
   1. Type and grade of material
   2. Type and amount of additives used, if applicable
   3. Destination
   4. Consignee's name
   5. Date of Shipment
   6. Railroad car or truck identification
   7. Project number
   8. Loading temperature
   9. Net weight in tons or net gallons corrected to 60 degrees F, when requested
   10. Specific gravity
   11. Bill of lading number
   12. Manufacturer of asphalt material

1.6 ACCEPTANCE

A. Acceptance sampling and testing of material is according to UDOT Minimum Sampling and Testing Requirements.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Each shipment of asphalt material must:
   1. Be uniform in appearance and consistency.
   2. Show no foaming when heated to the specified loading temperature.

B. Do not supply shipments contaminated with other asphalt types or grades than those specified.

1.8 GRADE OF MATERIAL

A. The Engineer determines the grade of material to be used based on the supply source designated by the Contractor when the bid proposal lists more than one grade of asphalt material.

1.9 PAYMENT PROCEDURES

A. Price adjustments for asphalt binder and liquid asphalt including chip-seal emulsions and cut-backs.
   1. Department procedures governs price adjustments made where asphalt material does not conform to the specifications.
      a. The Engineer may order the removal of any or all the defective asphalt material if the price adjustment exceeds 30 percent.
      b. The pay factor for such material is 0.50 when allowed to remain in place.

B. Price adjustments for Performance Graded Asphalt Binder (PGAB)
   1. Department PGAB management plan governs price reductions or removal of material where the binder does not meet the specifications.

PART 2 PRODUCTS

2.1 PERFORMANCE GRADED ASPHALT BINDER (PGAB)

A. Supply PGABs under the Approved Supplier Certification (ASC) System. Refer to the UDOT Quality Management Plan Section 509, Asphalt Binder.

B. Refer to AASHTO M 320 for all PGABs having algebraic differences less than 92 degrees between the high and low design temperatures.

C. Refer to AASHTO M 320 modified by Tables 1, 2, 3, 4, 5, 6, 7, and 8 for all PGABs having algebraic differences equal to or greater than 92 degrees between the high and low design temperatures.

Table 1

PG58-34		
Original Binder		
Dynamic Shear Rheometer, AASHTO T 315	@ 58° C, G*, kPa	1.30 Min.
	@ 58° C, phase angle, degrees	74.0 Max.
Rotational Viscometer, AASHTO T 316	@ 135° C, Pa.s	3 Max.
Flash Point, AASHTO T 48	°C	260 Min.
RTFO Residue, AASHTO T 240		
Dynamic Shear Rheometer, AASHTO T 315	@ 58° C, G*/sinδ, kPa	2.20 Min.
Elastic Recovery, AASHTO T 301 mod (a)	%	65 Min.
PAV Residue, 20 hours, 2.10 MPa, 100° C, AASHTO R 28		
Dynamic Shear Rheometer, AASHTO T 315	@ 16° C, kPa	5,000 Max.
Bending Beam Rheometer, AASHTO T 313	@ -24° C, S, MPa	300 Max.
	@ -24° C, m-value	0.300 Min.
Direct Tension Test, AASHTO T 314	@ -24° C, Failure Strain, %	1.5 Min.
	@ -24° C, Failure Stress (b), MPa	4.0 Min.

(a) Modify paragraph 4.5 as follows: Stop the ductilometer after 20 cm has been reached and within 2 seconds. Sever the specimen at its center with a pair of scissors.
(b) No allowances will be given for passing at a colder grade.

Table 2

PG64-28		
Original Binder		
Dynamic Shear Rheometer, AASHTO T 315	@ 64° C, G*, kPa	1.30 Min.
	@ 64° C, phase angle, degrees	74.0 Max.
Rotational Viscometer, AASHTO T 316	@ 135° C, Pa.s	3 Max.
Flash Point, AASHTO T 48	°C	260 Min.
RTFO Residue, AASHTO T 240		
Dynamic Shear Rheometer, AASHTO T 315	@ 64° C, G*/sinδ, kPa	2.20 Min.
Elastic Recovery, AASHTO T 301 mod (a)	%	65 Min.
PAV Residue, 20 hours, 2.10 MPa, 100 °C, AASHTO R 28		
Dynamic Shear Rheometer, AASHTO T 315	@ 22° C, kPa	5,000 Max.
Bending Beam Rheometer, AASHTO T 313	@ -18° C, S, MPa	300 Max.
	@ -18° C, m-value	0.300 Min.
Direct Tension Test, AASHTO T 314	@ -18° C, Failure Strain, %	1.5 Min.
	@ -18° C, Failure Stress (b), MPa	4.0 Min.

(a) Modify paragraph 4.5 as follows: Stop the ductilometer after 20 cm has been reached and within 2 seconds. Sever the specimen at its center with a pair of scissors.
(b) No allowances will be given for passing at a colder grade.

Table 3

PG64-34		
Original Binder		
Dynamic Shear Rheometer, AASHTO T 315	@ 64° C, G*, kPa	1.30 Min.
	@ 64° C, phase angle, degrees	71.0 Max.
Rotational Viscometer, AASHTO T 316	@ 135° C, Pa.s	3 Max.
Flash Point, AASHTO T 48	°C	260 Min.
RTFO Residue, AASHTO T-240		
Dynamic Shear Rheometer, AASHTO T 315	@ 64° C, G*/sinδ, kPa	2.20 Min.
Elastic Recovery, AASHTO T 301 mod (a)	%	70 Min.
PAV Residue, 20 hours, 2.10 MPa, 100 °C, AASHTO R 28		
Dynamic Shear Rheometer, AASHTO T 315	@ 19° C, kPa	5,000 Max.
Bending Beam Rheometer, AASHTO T 313	@ -24° C, S, MPa	300 Max.
	@ -24° C, m-value	0.300 Min.
Direct Tension Test, AASHTO T 314	@ -24° C, Failure Strain, %	1.5 Min.
	@ -24° C, Failure Stress (b), MPa	4.0 Min.

(a) Modify paragraph 4.5 as follows: Stop the ductilometer after 20 cm has been reached and within 2 seconds. Sever the specimen at its center with a pair of scissors.
(b) No allowances will be given for passing at a colder grade.

Table 4

PG70-22		
Original Binder		
Dynamic Shear Rheometer, AASHTO T 315	@ 70° C, G*, kPa	1.30 Min.
	@ 70° C, phase angle, degrees	74.0 Max.
Rotational Viscometer, AASHTO T 316	@ 135° C, Pa.s	3 Max.
Flash Point, AASHTO T 48	°C	260 Min.
RTFO Residue, AASHTO T 240		
Dynamic Shear Rheometer, AASHTO T 315	@70°C, G*/sinδ, kPa	2.20 Min.
Elastic Recovery, AASHTO T 301 mod (a)	%	65 Min.
PAV Residue, 20 hours, 2.10 MPa, 100 °C, AASHTO R 28		
Dynamic Shear Rheometer, AASHTO T 315	@ 28° C, kPa	5,000 Max.
Bending Beam Rheometer, AASHTO T 313	@ -12° C, S, MPa	300 Max.
	@ -12° C, m-value	0.300 Min.
Direct Tension Test, AASHTO T 314	@ -12° C, Failure Strain, %	1.5 Min.
	@ -12° C, Failure Stress (b), MPa	4.0 Min.

(a) Modify paragraph 4.5 as follows: Stop the ductilometer after 20 cm has been reached and within 2 seconds. Sever the specimen at its center with a pair of scissors.
(b) No allowances will be given for passing at a colder grade.

Table 5

PG70-28		
Original Binder		
Dynamic Shear Rheometer, AASHTO T 315	@ 70° C, G*, kPa	1.30 Min.
	@ 70° C, phase angle, degrees	71.0 Max.
Rotational Viscometer, AASHTO T 316	@ 135° C, Pa.s	3 Max.
Flash Point, AASHTO T 48	°C	260 Min.
RTFO Residue, AASHTO T 240		
Dynamic Shear Rheometer, AASHTO T 315	@ 70° C, G*/sinδ, kPa	2.20 Min.
Elastic Recovery, AASHTO T 301 mod (a)	%	70 Min.
PAV Residue, 20 hours, 2.10 MPa, 100 °C, AASHTO R 28		
Dynamic Shear Rheometer, AASHTO T 315	@ 25° C, kPa	5,000 Max.
Bending Beam Rheometer, AASHTO T 313	@ -18° C, S, MPa	300 Max.
	@ -18° C, m-value	0.300 Min.
Direct Tension Test, AASHTO T 314	@ -18° C, Failure Strain, %	1.5 Min.
	@ -18° C, Failure Stress (b), MPa	4.0 Min.

(a) Modify paragraph 4.5 as follows: Stop the ductilometer after 20 cm has been reached and within 2 seconds. Sever the specimen at its center with a pair of scissors.
(b) No allowances will be given for passing at a colder grade.

Table 6

PG70-34		
Original Binder		
Dynamic Shear Rheometer, AASHTO T 315	@ 70° C, G*, kPa	1.30 Min.
	@ 70° C, phase angle, degrees	71.0 Max.
Rotational Viscometer, AASHTO T 316	@ 135 °C, Pa.s	3 Max.
Flash Point, AASHTO T 48	°C	260 Min.
RTFO Residue, AASHTO T 240		
Dynamic Shear Rheometer, AASHTO T 315	@ 70° C, G*/sinδ, kPa	2.20 Min.
Elastic Recovery, AASHTO T 301 mod (a)	%	75 Min.
PAV Residue, 20 hours, 2.10 MPa, 100 °C, AASHTO R 28		
Dynamic Shear Rheometer, AASHTO T 315	@ 22° C, kPa	5,000 Max.
Bending Beam Rheometer, AASHTO T 313	@ -24° C, S, MPa	300 Max.
	@ -24° C, m-value	0.300 Min.
Direct Tension Test, AASHTO T 314	@ -24° C, Failure Strain, %	1.5 Min.
	@ -24° C, Failure Stress (b), MPa	4.0 Min.

(a) Modify paragraph 4.5 as follows: Stop the ductilometer after 20 cm has been reached and within 2 seconds. Sever the specimen at its center with a pair of scissors.
(b) No allowances will be given for passing at a colder grade.

Table 7

PG76-22		
Original Binder		
Dynamic Shear Rheometer, AASHTO T 315	@ 76° C, G*, kPa	1.30 Min.
	@ 76° C, phase angle, degrees	71.0 Max.
Rotational Viscometer, AASHTO T 316	@ 135° C, Pa.s	3 Max.
Flash Point, AASHTO T 48	°C	260 Min.
RTFO Residue, AASHTO T 240		
Dynamic Shear Rheometer, AASHTO T 315	@ 76° C, G*/sinδ, kPa	2.20 Min.
Elastic Recovery, AASHTO T 301 mod (a)	%	70 Min.
PAV Residue, 20 hours, 2.10 MPa, 100 °C, AASHTO R 28		
Dynamic Shear Rheometer, AASHTO T 315	@ 31°C, kPa	5,000 Max.
Bending Beam Rheometer, AASHTO T 313	@ -12° C, S, MPa	300 Max.
	@ -12° C, m-value	0.300 Min.
Direct Tension Test, AASHTO T 314	@ -12° C, Failure Strain, %	1.5 Min.
	@ -12° C, Failure Stress (b), MPa	4.0 Min.

(a) Modify paragraph 4.5 as follows: Stop the ductilometer after 20 cm has been reached and within 2 seconds. Sever the specimen at its center with a pair of scissors.
(b) No allowances will be given for passing at a colder grade.

Table 8

PG76-28		
Original Binder		
Dynamic Shear Rheometer, AASHTO T 315	@ 76° C, G*, kPa	1.30 Min.
	@ 76° C, phase angle, degrees	71. 0 Max.
Rotational Viscometer, AASHTO T 316	@ 135° C, Pa.s	3 Max.
Flash Point, AASHTO T 48	°C	260 Min.
RTFO Residue, AASHTO T 240		
Dynamic Shear Rheometer, AASHTO T 315	@ 76° C, G*/sinδ, kPa	2.20 Min.
Elastic Recovery, AASHTO T 301 mod (a)	%	75 Min.
PAV Residue, 20 hours, 2.10 MPa, 100 °C, AASHTO R 28		
Dynamic Shear Rheometer, AASHTO T 315	@ 28° C, kPa	5,000 Max.
Bending Beam Rheometer, AASHTO T 313	@ -18° C, S, MPa	300 Max.
	@ -18° C, m-value	0.300 Min.
Direct Tension Test, AASHTO T 314	@ -18° C, Failure Strain, %	1.5 Min.
	@ -18° C, Failure Stress (b), MPa	4.0 Min.

(a) Modify paragraph 4.5 as follows: Stop the ductilometer after 20 cm has been reached and within 2 seconds. Sever the specimen at its center with a pair of scissors.
(b) No allowances will be given for passing at a colder grade.

2.2 ASPHALTIC CEMENT, LIQUID ASPHALTS, AND REJUVENATING AGENTS

A. Refer to AASHTO M 226, Table 2 with the following modifications:
   1. Delete and replace ductility at 77 degrees F (25 degrees C) with ductility at 39.2 degrees F (4 degrees C) using the values specified below.

AC - 2.5	AC - 5	AC - 10	AC - 20
50+	25+	15+	5+

B. Cationic and Anionic Emulsified Asphalt
   1. All standard Slow Setting (SS, CSS), Quick Setting (QS, CQS) Medium Setting (MS, CMS), and Rapid Setting (RS, CRS) grades including all High-Float designations (HF).
   2. Supply under the Approved Supplier Certification System (ASC).
   3. Refer to and meet AASHTO M 208 and M 140.

C. Meet the requirements of one of these tables:
   1. Table 9 – Cationic Rapid Setting Emulsified Polymerized Asphalt (CRS-2P)
   2. Table 10 – Latex Modified Cationic Rapid Setting Emulsified Asphalt (LMCRS-2)
   3. Table 11 – Cationic Medium Setting Emulsified Asphalt (CMS-2S)
   4. Table 12 – High Float Medium Setting Emulsified Asphalt (HFMS-2)
   5. Table 13 – High Float Medium Setting Emulsified Polymerized Asphalt (HFMS-2P)
   6. Table 14 – High Float Medium Setting Emulsified Polymerized Asphalt (HFMS-2SP)
   7. Table 15 – High Float Rapid Setting Emulsified Polymerized Asphalt (HFRS-2P).
   8. Table 16 – Setting Cationic Rapid Emulsified Asphalt (CRS-2A, B)

D. Curing Cut-Back Asphalt
   1. Refer to specification ASTM D 2026 for slow curing (SC).
   2. Refer to specification AASHTO M 82 for medium curing (MC).
   3. Refer to specification AASHTO M 81 for rapid curing (RC).

E. Meet the requirements for Emulsified Asphalt Pavement Rejuvenating Agent:
   1. Table 17 – Type A
   2. Table 18 – Type B
   3. Table 19 – Type B Modified
   4. Table 20 – Type C
   5. Table 21 – Type D

Table 9

Cationic Rapid Setting Emulsified Polymerized Asphalt (CRS-2P)			
Tests	**Test Method**	**Min.**	**Max.**
Emulsion			
Viscosity , SF, 140º F (60º C), s (Project-site Acceptance/Rejection Limits)	AASHTO T 59	100	400
Settlement (a) 5 days, percent	AASHTO T 59		5
Storage Stability Test (b) 1 d, 24 h, percent	AASHTO T 59		
Demulsibility (c) 35 ml, 0.8% sodium dioctyl Sulfosucinate, percent	AASHTO T 59	40	
Particle Charge Test	AASHTO T 59	Positive	
Sieve Test, percent	AASHTO T 59		0.10
Distillation			
Oil distillate, by volume of emulsion, percent			0
Residue (d), percent		68	
Residue from Distillation Test			
Penetration, 77º F (25º C), 100 g, 5 s, dmm	AASHTO T 49	80	150
Ductility, 39.2º F (4º C), 5 cm/min, cm Toughness, lb-in Tenacity, lb-in	AASHTO T 51 ASTM D 5801 ASTM D 5801	35 75 50	
Solubility in trichloroethylene, percent	AASHTO T 44	97.5	

The test requirement for settlement may be waived when the emulsified asphalt is used in less than five days or the purchaser may require that the settlement test be run from the time the sample is received until it is used, if the elapsed time is less than five days.

(b) The 24-hour (1-day) storage stability test may be used instead of the five day settlement test.

(c) The demulsibility test is made within 30 days from date of shipment.

(d) Distillation is determined by AASHTO T 59 with modifications to include a 350 ± 5º F (177 ± 3º C) maximum temperature to be held for 15 minutes.

Modify the asphalt cement before emulsification.

Table 10

Latex Modified Cationic Rapid Setting Emulsified Asphalt (LMCRS-2)			
Tests	**Test Method**	**Min.**	**Max.**
Emulsion			
Viscosity, SF, 122º F (50º C), s (Project Site Acceptance/Rejection Limits)	AASHTO T 59	140	400
Settlement (a) 5 days, percent	AASHTO T 59		5
Storage Stability Test (b) 1 d, 24 h, percent	AASHTO T 59		1
Demulsibility (c) 35 ml, 0.8% sodium Dioctyl Sulfosucinate, percent	AASHTO T 59	40	
Particle Charge Test	AASHTO T 59	Positive	
Sieve Test, percent	AASHTO T 59		0.3
Distillation			
Oil distillate, by volume of emulsion, percent			0
Residue (d), percent		65	
Residue from Distillation Test			
Penetration, 77º F (25º C), 100 g, 5 s, dmm	AASHTO T 49	40	200
Torsional Recovery (e)		18	

(a) The test requirement for settlement may be waived when the emulsified asphalt is used in less than a five-day time; or the purchaser may require that the settlement test be run from the time the sample is received until it is used, if the elapsed time is less than 5 days.
(b) May use the 24-hour (1-day) storage stability test instead of the five-day settlement test.
(c) Make the demulsibility test within 30 days from date of shipment.
(d) Determine distillation by AASHTO T 59, with modifications to include a 350 ± 5ºF (177±3ºC) maximum temperature to be held for 15 minutes.
(e) CA 332 (California Test Method)

Co-mill latex and asphalt during emulsification

Table 11

Cationic Medium Setting Emulsified Asphalt (CMS-2S)		
Tests	**Test Method**	**Specification**
Emulsion		
Viscosity, SF, 122º F (50º C), s	AASHTO T 59	50 - 450
Percent residue	AASHTO T 59	60 min
Storage Stability Test, 1d, 24h, percent	AASHTO T 59	1 max
Sieve, percent	AASHTO T 59	0.10 max
Particle charge	AASHTO T 59	Positive
Oil Distillate, percent by volume of emulsion	AASHTO T 59	5-15
Residue		
Penetration, 77º F (25º C), 100g, 5 sec, dmm	AASHTO T 59	100-250
Solubility, percent	AASHTO T 59	97.5 min.

Table 12

High Float Medium Setting Emulsified Asphalt (HFMS-2)			
Tests	**Test Method**	**Min.**	**Max.**
Emulsion			
Viscosity, SF, 122° F (50° C), s (Project Site Acceptance/Rejection Limits	AASHTO T 59	70	300
Storage Stability Test, 1d, 24 h, percent	AASHTO T 59		1.0
Sieve Test , percent	AASHTO T 59		0.1
Distillation	AASHTO T 59		
Oil Distillate, by volume of emulsion, percent	AASHTO T 59	NA	NA
Residue, percent	AASHTO T 59	65	
Residue from Distillation Test			
Penetration, 77° F (25° C), 100g, 5 s, dmm	AASHTO T 49	50	200
Float Test, 140° F (60° C), s	AASHTO T 50	1,200	
Solubility in Trichloroethylene, percent	AASHTO T 44	97.5	
Ductility, 77° F (25° C) 5cm/min, cm	AASHTO T 51	40	

Table 13

High Float Medium Setting Emulsified Polymerized Asphalt (HFMS-2P) (a)			
Tests	**Test method**	**Min.**	**Max.**
Emulsion			
Viscosity, SF, 122º F (50º C), s (Project Site Acceptance/Rejection Limits)	AASHTO T 59	100	450
Storage Stability Test, 1 d, 24 h, percent	AASHTO T 59		1.0
Sieve Test, percent	AASHTO T 59		0.1
Distillation			
Oil distillate, by volume of emulsion, percent	AASHTO T 59		7
Residue (b), percent	AASHTO T 59	65	
Residue from Distillation Test			
Penetration, 77º F (25º C), 100 g, 5 s, dmm	AASHTO T 49	70	300
Float Test, 140º F (60º C), s	AASHTO T 50	1,200	
Solubility in trichloroethylene, percent	AASHTO T 44	97.5	
Elastic Recovery, 77º F (25º C), percent	AASHTO T 301	50	

(a) Supply an HFMS-2P (anionic, polymerized, high-float) as an emulsified blend of polymerized asphalt cement, water, and emulsifiers. Polymerize the asphalt cement with at least 3.0% polymer by weight of the asphalt cement before emulsification. The emulsion must be smooth and homogeneous throughout with no white, milky separation, pumpable, and suitable for application through a distributor after standing undisturbed for at least 24 hours.

(b) Determine the distillation by AASHTO T 59, with modifications to include a 350 ± 5º F (177 ± 3º C) maximum temperature to be held for 15 minutes.

Table 14

High Float Medium Setting Emulsified Polymerized Asphalt (HFMS-2SP) (a)			
Tests	**Test method**	**Min.**	**Max.**
Emulsion			
Viscosity, SF, 122º F (50º C), s (Project Site Acceptance/Rejection Limits)	AASHTO T 59	50	450
Storage Stability Test, 1 d, 24 h, percent	AASHTO T 59		1
Sieve Test, percent	AASHTO T 59		0.1
Distillation			
Oil distillate, by volume of emulsion, percent	AASHTO T 59		7
Residue (b), percent	AASHTO T 59	65	
Residue from Distillation Test			
Penetration, 77º F (25º C), 100 g, 5 s, dmm	AASHTO T 49	150	300(c)
Float Test, 140ºF (60ºC), s	AASHTO T 50	1200	
Solubility in trichloroethylene, percent	AASHTO T 44	97.5	
Elongation Recovery(d), 77º F (25º C), percent	AASHTO T 301	50	

(a) Supply an HFMS-2SP (anionic, polymerized, high-float) as an emulsified blend of polymerized asphalt cement, water, and emulsifiers. Polymerize the asphalt cement with at least 3.0% polymer by weight of the asphalt cement before emulsification. The emulsion must be smooth and homogeneous throughout with no white, milky separation, pumpable, and suitable for application through a distributor after standing undisturbed for at least 24 hours.

(b) Determine the distillation by AASHTO T 59, with modifications to include a 350 ± 5º F (177 ± 3º C) maximum temperature to be held for 15 minutes.

(c) Emulsified Asphalt (HFMS-2SP) with a residual penetration greater than 300 dmm may be used with Cold Bituminous Pavement (Recycle) to address problems with cool weather or extremely aged existing pavement when approved by the Engineer.

(d) Report only when penetration is greater than 300 dmm.

Table 15

High Float Rapid Setting Emulsified Polymerized Asphalt (HFRS-2P) (a)			
Tests	**Test method**	**Min.**	**Max.**
Emulsion			
Viscosity, SF @ 122º F (50º C), s (Project Site Acceptance/Rejection Limits)	AASHTO T 59	50	450
Storage Stability Test (b) 1 d, 24 h, percent	AASHTO T 59		1
Demulsibility 0.02 N Ca Cl_2, percent	AASHTO T 59	40	
Sieve Test, percent	AASHTO T 59		0.1
Distillation			
Oil distillate, by volume of emulsion, percent	AASHTO T 59		3
Residue (b), percent	AASHTO T 59	65	
Residue from Distillation Test			
Penetration, 77º F (25º C), 100 g, 5 s, dmm	AASHTO T 49	70	150
Float Test, 140º F (60º C), s	AASHTO T 50	1,200	
Solubility in trichloroethylene, percent	AASHTO T 44	97.5	
Elastic Recovery, 77º F (25º C), percent	AASHTO T 301	58	

(a) Supply an HFMS-2SP (anionic, polymerized, high-float) as an emulsified blend of polymerized asphalt cement, water, and emulsifiers. Polymerize the asphalt cement with at least 3.0% polymer by weight of the asphalt cement before emulsification. The emulsion must be smooth and homogeneous throughout with no white, milky separation, pumpable, and suitable for application through a distributor after standing undisturbed for at least 24 hours.

(b) Determine the distillation by AASHTO T 59, with modifications to include a 350 ± 5ºF (177±3ºC) maximum temperature to be held for 15 minutes.

Table 16

Cationic Rapid Setting Emulsified Asphalt (CRS-2A,B)			
Tests	**Test Method**	**Min**	**Max**
Emulsion			
Viscosity, SF, 122º F (50º C), s (Project Site Rejection/Acceptance Limits)	AASHTO T 59	140	400
Storage stability test, 24 h, percent	AASHTO T 59		1
Demulsibility, 35 mL 0.8 percent Sodium Dioctyl Sulfosucinate, percent	AASHTO T 59	40	
Particle charge test	AASHTO T 59	Positive	
Sieve test, percent	AASHTO T 59		0.10
Distillation			
Oil distillate, by volume of emulsion, percent	AASHTO T 59		0
Residue, percent	AASHTO T 59	65	

Use PG58-22 and PG64-22 as base asphalt cement for CRS-2A, B, respectively. Specification for high temperature performance – original and RTFO G*/sinδ within 3º C of grade.

Table 17

Emulsified Type A Asphalt Pavement Rejuvenating Agent Concentrate			
Property	**Test Method**	**Limits**	
Viscosity, SF, 77º F (25º C), s	AASHTO T 59	15 Min	40 Max
Residue , percent W (a)	AASHTO T 59	60 Min.	65 Max.
Miscibility Test (b)	AASHTO T 59	No Coagulation	
Sieve Test, percent W (c)	AASHTO T 59	0.20 Max.	
5-day Settlement, percent W	AASHTO T 59	5.0 Max.	
Particle Charge	AASHTO T 59	Positive	
Light Transmittance , %	UDOT MOI 8-973	30 Max.	
Cement Mixing	AASHTO T 59	2 Max.	
Residue from Distillation (a)			
Viscosity, 140º F (60º C), mm^2/s	ASTM D 4402	150 - 300	
Flash Point, COC, º F (º C)	AASHTO T 48	385 Min.	
Asphaltenes, percent W	ASTM D 2006	0.4 Min.	0.75 Max.
Maltene Distribution Ratio $(PC + A_1)/(S + A_2)$ (d)	ASTM D 2006	0.3 Min.	0.6 Max
Saturated Hydrocarbons, S (d)	ASTM D 2006	21 Min.	28 Max.
PC/S Ratio (d)	ASTM D 2006	1.5 Min.	

(a) AASHTO T 59, Evaporation Test, modified as follows: Heat a 50 gram sample to 300ºF until foaming ceases, then cool immediately and calculate results.

(b) AASHTO T 59, modified as follows: Use a 0.02 Normal Calcium Chloride solution in place of distilled water.

(c) AASHTO T 59, modified as follows: Use distilled water in place of a two percent sodium oleate solution.

(d) Chemical composition by ASTM Method D-2006-70:
PC= Polar Compounds, A_1 = First Acidaffins
A_2 = Second Acidaffins, S = Saturated Hydrocarbons

Table 18

Emulsified Type B Asphalt Pavement Rejuvenating Agent Concentrate		
Tests	**Test Method**	**Limits**
Viscosity, SF, 77º F (25º C), s	AASHTO T 59	25 - 150
Residue, percent W	AASHTO T 59 (mod) (a)	62 Min.
Sieve Test, percent W	AASHTO T 59	0.10 Max.
5-day Settlement	AASHTO T 59	5.0 Max.
Particle Charge	AASHTO T 59	Positive
Pumping Stability (b)		Pass
Residue from Distillation (a)		
Viscosity @ 140º F (60º C), mm^2/s	AASHTO T 201	2,500 - 7,500
Solubility in 1,1,1 Trichloroethylene, percent	AASHTO T 44	98 Min.
Flash Point, COC	AASHTO T 48	204º C, Min.
Asphaltenes, percent W	ASTM D 2007	15 Max.
Saturates, percent W	ASTM D 2007	30 Max.
Aromatics, percent W	ASTM D 2007	25 Min.
Polar Compounds, percent W	ASTM D 2007	25 Min.

(a) Determine the distillation by AASHTO T 59 with modifications to include a 300 ± 5º F (149 ± 3º C) maximum temperature to be held for 15 minutes.

(b) Test pumping stability by pumping 475 ml of Type B diluted 1 part concentrate to 1 part water, at 77º F (25º C) through a ¼ inch gear pump operating at 1750 rpm for 10 minutes with no significant separation or coagulation in pumped material.

Type B – an emulsified blend of lube oil or lube oil extract and petroleum asphalt.

Table 19

Emulsified Type B Modified Asphalt Pavement Rejuvenating Agent Concentrate

Property	Test Method	Limits
Viscosity, SF, 77º F (25º C), s	AASHTO T 59	50 - 200
Residue(a), percent W	AASHTO T 59	62 Min.
Sieve Test, percent W	AASHTO T 59	0.20 Max.
5-day Settlement, percent W	AASHTO T 59	5.0 Max.
Particle Charge	AASHTO T 59	Positive
Pumping Stability (b)		Pass
Residue from Distillation (a)		
Viscosity (c) 275º F (135º C), cP	ASTM D 4402	150 - 300
Penetration, 77º F (25º C), dmm	AASHTO T 49	180 Min.
Solubility in 1,1,1 Trichloroethylene, percent	AASHTO T 44	98 Min.
Flash Point, COC, º F (º C)	AASHTO T 48	400(204) Min.
Asphaltenes, percent W	ASTM D 2007	20 - 40
Saturates, percent % W	ASTM D 2007	20 Max.
Polar Compounds, percent W	ASTM D 2007	25 Min.
Aromatics, percent W	ASTM D 2007	20 Min.
PC/S Ratio	ASTM D 2007	1.5 Min.

(a) Determine the distillation by AASHTO T 59 with modifications to include a 300±5ºF (149 ± 3º C) maximum temperature to be held for 15 minutes.

(b) Pumping stability is tested by pumping 475 ml of Type B diluted 1 part concentrate to 1 part water, at 77º F (25º C) through a ¼ inch gear pump operating at 1750 rpm for 10 minutes with no significant separation or coagulation in pumped material.

(c) Brookfield Thermocel Apparatus-LV model. ≥ 50 rpm with a #21 spindle, 7.1 g residue, at > 10 torque

As required by the Asphalt Emulsion Quality Management Plan, UDOT Minimum Sampling and Testing Requirements, Section 508) the supplier certifies that the base stock contains at least 15% by weight of Gilsonite Ore. Use the HCL precipitation method as a qualitative test to detect the presence of Gilsonite.

Table 20

Emulsified Type C Asphalt Pavement Rejuvenating Agent Concentrate		
Property	**Test Method**	**Limits**
Viscosity, SF, 77º F (25º C), s	AASHTO T 59	10 - 100
Residue (a), percent W (Type C supplied ready to use 1:1 or 2:1.	AASHTO T 59	30 Min. 1:1 40 Min. 2:1
Sieve Test, percent W (b)		0.10 Max.
5-day Settlement, percent W	AASHTO T 59	5.0 Max.
Particle Charge	AASHTO T 59	Positive
pH (May be used if particle charge test is inconclusive)		2.0 - 7.0
Pumping Stability (c)		Pass
Tests of Residue from Distillation (a)		
Viscosity, 275º F (135º C), mm^2/s	AASHTO T 201	475 - 1,500
Solubility in 1,1,1 Trichloroethylene, percent	AASHTO T 44	97.5 Min.
RTFO mass loss, percent W	AASHTO T 240	2.5 Max.
Specific Gravity	AASHTO T 228	0.98 Min.
Flash Point, COC	AASHTO T 48	232º C, Min.
Asphaltenes, percent W	ASTM D 2007	25 Min., 45 Max.
Saturates, percent W	ASTM D 2007	10 Max.
Polar Compounds, percent W	ASTM D 2007	30 Min.
Aromatics, percent W	ASTM D 2007	15 Min.

(a) Determine the distillation by AASHTO T 59 with modifications to include a 300 ± 5º F (149 ± 3º C) maximum temperature to be held for 15 minutes.
(b) Test method identical to AASHTO T 59 except that distilled water is used in place of 2% sodium oleate solution.
(c) Test pumping stability by pumping 475 ml of Type diluted 1 part concentrate to 1 part water, at 77º F (25º C) through a ¼ inch gear pump operating at 1750 rpm for 10 minutes with no significant separation or coagulation in pumped material.

As required by the Asphalt Emulsion Quality Management Plan, UDOT Minimum Sampling and Testing Requirements, Section 508), the supplier certifies that the base stock contains at least 10% by weight of Gilsonite ore. Use the HCL precipitation method as a qualitative test to detect the presence of Gilsonite.

Table 21

Emulsified Type D Asphalt Pavement Rejuvenating Agent Concentrate		
Property	**Test Method**	**Limits**
Viscosity, SF, 77º F (25º C), s	AASHTO T 59	30 - 90
Residue, (b) percent W	AASHTO T 59	65
Sieve Test, percent W	AASHTO T 59	0.10 Max.
pH		2.0 - 5.0
Residue from Distillation (b)		
Viscosity, 140º F (60º C), cm^2/s	AASHTO T 201	300 - 1200
Viscosity, 275º F (135º C), mm^2/s	AASHTO T 201	300 Min.
Modified Torsional Recovery (a) percent	CA 332 (Mod)	40 Min.
Toughness, 77º F (25º C), in-lb	ASTM D 5801	8 Min.
Tenacity, 77º F (25º C), in-lb	ASTM D 5801	5.3 Min.
Asphaltenes, percent W	ASTM D 2007	16 Max.
Saturates, percent W	ASTM D 2007	20 Max.

(a) Torsional recovery measurement to include first 30 seconds.
(b) Determine the distillation by AASHTO T 59 with modifications to include a 300 ± 5º F (149 ± 3º C) maximum temperature to be held for 15 minutes.

2.3 HOT-POUR CRACK SEALANT FOR BITUMINOUS CONCRETE

A. Combine a homogenous blend of materials to produce a sealant according to properties and tests in Table 22.

B. Packaging and Marking – Supply sealant pre-blended, pre-reacted, and pre-packaged in lined boxes weighing no more than 30 lb.
   1. Use a dissolvable lining that will completely melt and become part of the sealant upon subsequent re-melting.
   2. Deliver the sealant in the manufacturer's original sealed container. Clearly mark each container with the manufacturer's name, trade name of sealant, batch or lot number, and recommended safe heating and application temperatures.

Table 22

Hot-Pour Bituminous Concrete Crack Sealant			
Application Properties			
Workability	Pour readily and penetrate 0.25 inch and wider cracks for the entire application temperature range recommended by the manufacturer.		
Curing	No tracking caused by normal traffic after 45 minutes from application.		
Asphalt Compatibility ASTM D 5329, Section 14.	No failure in adhesion. No formation of an oily ooze at the interface between the sealant and the bituminous concrete or softening or other harmful effects on the bituminous concrete.		
Material Handling	Follow the manufacturer's safe heating and application temperatures.		
Test Method	**Property**	**Minimum**	**Maximum**
AASHTO T 51	Ductility, modified, 1cm/min, 39.2º F (4º C), cm	30	
UDOT method 967	Cold Temperature Flexibility	no cracks	
AASHTO T 300 (a)	Force-Ductility, lb force		4
ASTM D 5329	Flow 140ºF (60º C), 5 hrs 75º angle, mm		3
AASHTO M 282 (b)	Tensile-Adhesion, modified	300%	
AASHTO T 228	Specific Gravity, 60º F (15.6º C)		1.140
ASTM D 5329	Cone Penetration, 77º F (25º C), 150 g, 5 sec., dmm		90
ASTM D 5329	Resilience, 77º F (25º C), 20 sec., percent	30	
ASTM D 4402	Viscosity, 380ºF (193.3ºC), SC4-27 spindle, 20 rpm, Cp		2,500
ASTM D 5329	Bond, Non-Immersed as specified in AASHTO M 282		Pass

(a) Maximum of 4 lb force during the specified elongation of 30 cm @ 1 cm/min, 39.2º F (4º C).

(b) Delete Bond, Non-Immersed modification in AASHTO M 282. Perform tensile-adhesion test according to ASTM D 5329.

PART 3 EXECUTION Not Used

END OF SECTION

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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