Progress of Superpave

(Superior Performing Asphalt Pavement)

EVALUATION AND IMPLEMENTATION

Robert N. Jester,
editor

ASTM

STP 1322

STP 1322

Progress of Superpave (Superior Performing Asphalt Pavement): Evaluation and Implementation

Robert N. Jester, editor

ASTM Publication Code Number (PCN):
04-013220-08

ASTM
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

Printed in the U.S.A.

Library of Congress Cataloging-in-Publication Data

Progress of superpave (superior performing asphalt pavement) :
evaluation and implementation / Robert N. Jester, editor.
p. cm.—(STP ; 1322)
"ASTM publication code number (PCN): 04-013220-08."
Includes bibliographical references and index.
ISBN 0-8031-2418-X
1. Pavements, Asphalt—Testing—Congresses. 2. Asphalt
emulsion mixtures—Congresses. 3. Asphalt—Testing—
Congresses. I. Jester, R. N. (Robert N.) II. Series: ASTM special
technical publication ; 1322.
TE266.P76 1997
625.8'5'0287—dc21 97-29520
CIP

Peer Review Policy

Each paper published in this volume was evaluated by two peer reviewers and at least one of the editors. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM Committee on Publications.

To make technical information available as quickly as possible, the peer-reviewed papers in this publication were prepared "camera-ready" as submitted by the authors.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of these peer reviewers. The ASTM Committee on Publications acknowledges with appreciation their dedication and contribution to time and effort on behalf of ASTM.

Printed in Philadelphia, PA
September 1997

Overview

A major result of the research conducted under the Strategic Highway Research Program (SHRP) from 1987 to 1993 was the development of the Superpave (*Su*perior *Per*forming Asphalt *Pave*ments) system for the comprehensive design of asphalt pavements. One-third of the $150 million SHRP research funds were used for the development of performance based asphalt specifications to directly relate laboratory analysis with field performance. The three major components of Superpave are the asphalt binder specification, the mixture design and analysis system, and a computer software system. Included in this performance-based design system is the selection of a performance grade of asphalt binder plus mixture design and analysis to facilitate the selection and combination of binder, aggregate, and, where necessary, modifier to achieve a required level of pavement performance based on traffic, environment (climate), pavement structure, and reliability [*1*,*2*].

Superpave focuses on three types of pavement distress—permanent deformation and fatigue cracking (considered to be load related distress), and low temperature cracking (nonload related distress). Materials selection and mix design also consider the effects of aging and moisture sensitivity on the development of these types of distress [*3*]. The objective of the Superpave mix design system is to define an economical blend of asphalt binder and aggregate that results in a paving mixture having sufficient asphalt for durability, sufficient air voids and voids in the mineral aggregate, sufficient workability, and satisfactory performance characteristics over the service life of the pavement [*4*].

Because of deficiencies in the current system for specifying asphalts, the Superpave binder specification was developed utilizing a new set of test equipment and procedures. It is called a "binder" specification because it is intended for modified as well as unmodified asphalts. The selection of a performance grade (PG) is based on the average seven-day maximum pavement design temperature and the minimum pavement design temperature. A unique feature of the Superpave specification is that the specified criteria remain constant, but the temperature at which the criteria must be met changes for the various PG grades. The tests are performed at temperatures that are encountered by in-service pavements. The test equipment and the purpose of each test is as follows:

Equipment	Purpose
Rolling Thin Film Oven (RTFO) Pressure Aging Vessel (PAV)	simulate binder aging (hardening) characteristics
Dynamic Shear Rheometer (DSR)	measure binder properties at high and intermediate temperatures (performed on original binder, RTFO-aged binder and PAV-aged binder)
Rotational Viscometer	measure binder properties at high temperatures (performed on original binder)
Bending Beam Rheometer (BBR) Direct Tension Tester (DTT)	measure binder properties at low temperatures (performed on PAV-aged binder)

An important aspect of the Superpave binder specification is its reliance on testing asphalt binders in conditions that simulate the three critical stages during the binder's life. Tests performed on the original binder represent the first stage of transport, storage, and handling. Aging of the binder in the rolling thin film oven is used to simulate the effects during mix production and construction. The pressure aging vessel, which follows the rolling thin film oven procedure, is used to simulate years of in-service binder aging in a pavement [*5,6*].

The Superpave mix design system is based on the volumetric proportioning of asphalt and aggregate materials, and laboratory compaction of trial mixes using the Superpave gyratory compactor. The Superpave gyratory compactor was developed by SHRP researchers to provide a device that could realistically compact mix specimens to densities achieved under actual pavement climate and loading conditions, that is capable of accommodating large aggregates, and could be used as a tool in identifying potential tender mix behavior and other problems associated with compaction. Specimens fabricated with the gyratory compactor are used to determine the volumetric properties (air voids, voids in the mineral aggregate, and voids filled with asphalt) of Superpave mixes. Since the kneading action of the gyratory simulates compaction during construction and subsequent traffic loading better than other methods of laboratory compaction, the Superpave gyratory compactor provides specimens that have been found to be more representative of actual in-service pavements. The design level of compaction for laboratory specimens is based on the environmental conditions and traffic levels expected at the project site. The gyratory compactor, a transportable device, is also suited for quality control/quality assurance since it can be set up at the job site and used to verify that the mixture produced in the plant meets the specifications for the volumetric properties [*7,8*].

Originally, Superpave included three levels of mixture design, designated as Level 1, Level 2, and Level 3, based on traffic loads in terms of Equivalent Single Axle Loads (ESALs) as described:

Level 1	ESALs<10*	Volumetric Design
Level 2	10*<ESALs<10'	Volumetric Design plus Performance Prediction Tests
Level 3	ESALs>10'	Volumetric Design plus Enhanced Performance Prediction Tests

Two devices, the Superpave Shear Tester (SST) and the Indirect Tensile Tester (IDT) were developed to conduct performance based tests used in Level 2 and 3 mix designs. Output from these tests is used as input to performance prediction models in Superpave that estimate actual pavement performance. Indirect tension tests at low temperatures are performed to determine properties required to predict thermal cracking, while shear tests on the SST and indirect tension tests at intermediate temperatures are performed to determine properties required to predict fatigue cracking and permanent deformation. Level 3 involves a considerable amount of sophisticated testing performed on the SST, which can include uniaxial strain test, volumetric test, simple shear test at constant height, frequency sweep test at constant height, and repeated shear test at constant stress ratio, and on the IDT, which can include indirect tensile strength (at intermediate temperature for fatigue cracking), indirect tensile creep (for low temperature cracking) and indirect tensile strength (for low temperature cracking). These tests are typically performed at three temperatures, and a total of 144 tests are required for a full Level 3 mix design with the design mix evaluated at three different binder contents. Only 66 tests are required for a full Level 2 design since testing is performed at fewer temperature levels. The basic philosophical difference is that a Level 3 analysis simulates the actual seasons of the year, while a Level 2 analysis estimates this annual damage by calculating the performance based on precalculated effective temperatures for both permanent deformation and fatigue cracking. The assumption is made with Level 2 that the same amount of pavement distress will occur from 12 months at the effective temperature as in one actual year with individual seasons [*3,7,9*].

The terminology has recently changed such that Level 1 is considered to be the Superpave volumetrix mix design procedures while Levels 2 and 3 are considered to be mix analysis procedures rather than mix design procedures, which are used to predict how well a mix will perform in the field. The Superpave volumetric mix design procedures are used for all Superpave mixes and play a key role in Superpave mix design. The procedures include selecting binders and aggregates that meet the Superpave criteria and using the Superpave gyratory compactor to fabricate test specimens for determining volumetric properties of the mix. The mix analysis procedures provide important additional information for pavements in critical locations that are subjected to high traffic volumes and loads. For these procedures, the test results from the SST and IDT are entered into software models that predict how many ESALs the pavement can carry, or how much time will elapse, before a certain level of rutting, fatigue cracking or low temperature cracking develops [*8,10*]. Using these models, the combined effect of asphalt binders, aggregates, and mixture proportions can be estimated. The models take into account the structure, condition and properties of the existing pavement (if applicable), and the amount of traffic to which the proposed mixture will be subjected over its performance life. The output of the models is millimeters of rutting, percent area of fatigue cracking, and spacing (in meters) of low temperature cracks. By using this approach, the Superpave system joins material properties with pavement structural properties to predict actual pavement performance. If performance levels are determined to be unacceptable, the mixture design may be altered until performance requirements are met [*7*].

Work is continuing on the evaluation and improvement of Superpave with the ultimate objective of full nationwide implementation. Under an FHWA contract, the University of Maryland was awarded a project to evaluate, validate, and refine the Superpave software and pavement performance models that form the core of the Superpave mix analysis and performance prediction procedures. The objectives of the project are to manage the Superpave performance models, including enhancement of the mix design procedures and development of user guidelines; to provide State highway agencies with the support and assistance necessary to fully begin applying and managing the Superpave system; and to improve all aspects of the Superpave system, with emphasis on evaluation and further development of the pavement performance prediction models. Development of Version 2.0 of the software, a Windows-based version which allows users to design asphalt mixes in conformance with the Superpave volumetric mix design procedures, is currently underway. The ability to accurately predict pavement performance in terms of permanent deformation, fatigue cracking, and thermal cracking is considered to be the only mechanism by which rational binder specifications, fundamental mix design procedures, economic justification for modified asphalt binders, improved structural design, and realistic performance-based quality specifications can be developed [*11*]. This will be a valuable tool in the implementation of Superpave.

As part of the ongoing long-term pavement performance studies, FHWA is coordinating the Specific Pavement Studies Experiment 9 (SPS-9) to validate the Superpave specifications and procedures. SPS-9A will focus on the binder specifications and mix design system, and SPS-98 will focus on pavement structural factors and the reliability of the performance prediction procedures. The SPS-9B study will be coordinated with the Superpave models work being performed under the University of Maryland project [*12*]. Additional experiments are being conducted at WesTrack, a test facility located 100 km southeast of Reno, Nevada, that was built and is being operated by a consortium of seven organizations. One of the objectives of WesTrack is to validate the performance prediction models included in the Superpave mix design and analysis procedures [*13*].

The American Association of State Highway and Transportation Officials has published provisional standards for the Superpave binder and mix test procedures, which allows engineers and technicians to work from a common set of procedures and guidelines for the Superpave tests [*8*]. All States now have the equipment required to test binders for conformance with the Superpave PG binder specification and to fabricate specimens that can be used to determine how well a mix will perform in real-world conditions [*10*].

The five regional User-Producer Groups (North East, North Central, South East, Rocky Mountain, and Pacific Coast) will be a key component in the implementation of the Superpave specifications. Made up of highway agencies and companies that use and produce asphalt binders, the user-producer groups are developing strategies for adopting the Superpave system on a regional basis. Five Superpave Regional Centers have also been established at Pennsylvania State University, Purdue University, Auburn University, University of Nevada-Reno, and University of Texas at Austin. These centers are conducting ruggedness testing for the SST and IDT as well as providing Superpave training on a regional basis, providing problem solving expertise on Superpave technology, and supporting implementation of Superpave by State DOTs and industry in their respective regions [*8*].

The goal is to have the Superpave binder specifications implemented nationwide by 1997 and the Superpave volumetrix mix design procedures, using the Superpave gyratory compactor, implemented by the year 2000. Many States have already constructed Superpave pavements utilizing both the binder specification and the volumetric mix design procedures [*10*]. Before the new specifications, tests and procedures of the Superpave system are adopted as nationwide standards by specifying agencies and industry, a period of trial application and evaluation, and incremental implementation will occur.

The papers in this STP focus on experience to date on the use and applicability of the Superpave system in the design and analysis of binders and asphalt pavements, including both field and laboratory evaluations. Topics covered include:

(1) An evaluation of PBA asphalt grades in terms of SHRP protocols as a first step in Superpave specification implementation in Oregon.
(2) The use of SHRP technology for binders and mix design in the evaluation of five test projects in Arizona.
(3) A laboratory study to determine the applicability of testing using the dynamic shear rheometer to crumb rubber modified asphalt binders and the effect of crumb rubber particle size and concentration on the higher temperature performance grading of rubber modified asphalt binders.
(4) The use of Superpave technology in the mix design for a high-traffic volume intersection near Denver, Colorado.
(5) Field and laboratory evaluation of a test section constructed in California to compare the performance of selected Superpave and Hveem mix designs, to assess the performance of three PG binders, and to relate field performance to the results of repetitive simple shear tests at constant height (RSST-CH).
(6) A study to validate the Superpave binder specification for polymer modified asphalts utilizing test sections constructed in Texas in 1986 containing five different modifiers.
(7) Procedures for selecting the performance grade of virgin asphalt binder under the Superpave PG grading system for use in recycled hot mix asphalt.
(8) An evaluation of the suitability of the Superpave volumetric mix design procedures for a specific type of cold mix.

(9) Comparison of the effects of Short-Term Oven Aging and Long-Term Oven Aging on mixtures to the effects of the Rolling Thin Film Oven Test and Pressure Aging Vessel on binders by means of SHRP laboratory tests on recovered and original binders.
(10) A study of pavements constructed in Indiana in 1985 utilizing original binders and mix samples retained at the time of construction plus cores taken after 7 to 8 years of service to compare Superpave PG binder test criteria to actual changes in the properties of the in-service binders.
(11) A study to determine the effects of long-term oven aging of asphalt mixtures on the thermal cracking performance evaluation of mixtures using the Superpave indirect tension test.
(12) A laboratory study to evaluate the Superpave performance prediction models for permanent deformation utilizing three unmodified asphalt binders, one Superpave level 1 mix design, and two aging procedures.
(13) The use of data obtained from the Superpave mix design process for predicting loss or gain in pavement performance life resulting from deviations in asphalt content, aggregate gradation, and compaction during actual construction;
(14) An evaluation of the level of compaction using the SHRP gyratory compactor needed to best simulate field density for various levels of traffic based on testing of mixes using materials from previously constructed Interstate pavements in Arizona.

The editor wishes to thank all those who participated in the symposium and who contributed to this STP. Special thanks to the reviewers of the papers, to ASTM Committee D4 for sponsoring the symposium, and to the ASTM staff for their assistance in preparing for this symposium and in the preparation of this STP.

References

[*1*] Kennedy, T. W., Huber, G. A., Harrigan, E. T., Cominsky, R. J., Hughes, C. S., Von Quintus, H., and Moulthrop, J. S., "Superior Performing Asphalt Pavements (Superpave): The Product of the SHRP Asphalt Research Program," Publication SHRP-A-410, Strategic Highway Research Program, National Research Council, Washington, DC, 1994.
[*2*] "Superpave Level 1 Mix Design," Superpave Series No. 2 (SP-2), Asphalt Institute, Lexington, KY, 1995.
[*3*] Zhang, X. and Huber, G., "Effect of Asphalt Binder on Pavement Performance: An Investigation Using the Superpave Mix Design System," Presented at the 1996 Meeting of the Association of Asphalt Paving Technologists, Baltimore, MD, 18–20 March 1996.
[*4*] Cominsky, R. J., Huber, G. A., Kennedy, T. W., and Anderson, M., "The Superpave Mix Design Manual for New Construction and Overlays," Publication SHRP-A-407, Strategic Highway Research Program, National Research Council, Washington, DC, 1994.
[*5*] "Background of Superpave Asphalt Binder Test Methods," Publication No. FHWA-SA-94-069, Federal Highway Administration, Washington, DC, July 1994.
[*6*] "Performance Graded Asphalt Binder Specification and Testing," Superpave Series No. 1 (SP-1), Asphalt Institute, Lexington, KY, 1994.
[*7*] "Background of Superpave Asphalt Mixture Design and Analysis," Publication No. FHWA-SA-95-003, Federal Highway Administration, Washington, DC, February 1995.
[*8*] "The Superpave System—New Tools for Designing and Building More Durable Asphalt Pavements," Publication Number FHWA-SA-96-010, Federal Highway Administration, Washington, DC.
[*9*] May, R. W. and Killingsworth, B. M., "Superpave Performance Prediction—A First Look at Utility, Sensitivity, and Repeatability," *Journal of the Association of Asphalt Paving Technologists*, Vol. 64, 1995.
[*10*] "FOCUS," Publication Number FHWA-SA-96-017, Federal Highway Administration, Washington, DC, June/July 1996.
[*11*] "Superpave Models," University of Maryland, College Park, MD, Number 1, Summer 1996.

[*12*] "FOCUS," Publication Number FHWA-SA-95-014, Federal Highway Administration, Washington, DC, November 1995.
[*13*] "FOCUS," Publication Number FHWA-SA-96-020, Federal Highway Administration, Washington, DC, September 1996.

Robert N. Jester
Eastern Federal Lands Highway Division,
Federal Highway Administration,
Sterling, Virginia;
symposium chairman and editor.

Contents

Rita B. Leahy,[1] Scott B. Cramer,[2] and Gary O. Thompson[3]

OREGON'S SUPERPAVE IMPLEMENTATION

REFERENCE: Leahy, R.B., Cramer, S.B., and Thompson, G.O., "**Oregon's Superpave Implementation,**" Progress of Superpave (Superior Performing Asphalt Pavement): Evaluation and Implementation, ASTM STP 1322, R. N. Jester, Ed., American Society for Testing and Materials, 1997.

ABSTRACT: Oregon Department of Transportation (ODOT) has specified performance-based asphalts (PBAs) since 1991. Developed by the Pacific Coast Conference on Asphalt Specifications (PCCAS) in 1990, the PBA concept uses conventional test methods for classification and facilitates binder selection based on climatic conditions. The Conference plan was to use the PBA concept and conventional tests as an interim approach which would eventually be replaced with the Strategic Highway Research Program performance grade (SHRP-PG) specification and supporting tests. As a first step in the SHRP implementation/validation effort ODOT has evaluated its commonly used PBA grades in terms of the SHRP (now called Superpave) protocols. The limited binder evaluation to date suggests the following equivalencies:

Binder Classification	
PCCAS - PBA	SHRP/Superpave - PG
PBA-2	PG 64-16,22,28
PBA-3	PG 58-34 or 64-28
PBA-5	PG 64-22
PBA-6	PG 64-34

Using the Superpave weather database, nomographs were developed to illustrate the recommended binder grades. Because of Oregon's climatic diversity, as many as 14 binder grades could be used. Practical constraints and realistic measures such as state-maintained road-miles associated with the various PG binders, however, suggest that 4 PG binders may suffice. Additionally, preliminary economic analysis suggests that implementation of the PG system could provide substantial

---

[1]Associate Professor, Oregon State University, Corvallis, OR 97331.

[2]Graduate Research Assistant, Oregon State University, Corvallis, OR 97331.

[3]Pavement Materials Engineer, Oregon Department of Transportation, Salem, OR 97310.

savings. Because of Oregon's extensive use of open-graded friction courses, additional work must be done to determine what effects, if any, the PG classification might have on this mix type in terms of field performance.

KEYWORDS: Strategic Highway Research Program, SHRP, Superpave, asphalt, binder, specification, classification, implementation, performance-based asphalt, performance grade.

INTRODUCTION

PBA Background

Developed by the Pacific Coast Conference on Asphalt Specifications (PCCAS) in 1990, the PBA system is intended to facilitate binder selection without compromising performance. The climatic conditions used in the PBA system are as shown in Table 1. (In general, PBA grade is inversely proportional to temperature susceptibility, i.e., properties of PBA-2 are more sensitive to temperature than are properties of PBA-6.

TABLE 1--Climatic Conditions for PBAs

	Highest Mean Monthly Air Temperature		
Lowest Recorded Air Temperature	below 32°C	above 32°C	above 38°C
above -23°C	Moderate PBA-1	Hot PBA-4	Very Hot PBA-7
above -29°C	Moderate/Cold PBA-2	Hot/Cold PBA-5	
below -29°C	Moderate/Very Cold PBA-3	Hot/Very Cold PBA-6	

Binder performance addresses the following: temperature susceptibility (including thermal cracking, rutting, tenderness, mix production and placement); short- and long-term aging; purity; safety; and mix properties (adhesion, permanent deformation and fatigue cracking). Conventional tests initially used for classification included penetration, viscosity and ductility on both original and rolling thin film oven (RTFO) aged binders. It was the Conference plan to use the PBA concept and conventional tests as an interim approach which would eventually be replaced with the Strategic Highway Research Program performance grade (SHRP-PG) specification and supporting tests. As evidence of its evolutionary nature, the current PBA specification does integrate some aspects of the Superpave technology, e.g., pressure aging vessel for conditioning; and rheological parameters such as shear modulus (G^*) and phase angle (δ).

ODOT Binder Use

As shown in Figure 1, ODOT typically specifies PBA-2 and PBA-3 west and east of the Cascades, respectively, for dense-graded mixes; and PBA-5 and PBA-6 west and east of the Cascades, respectively, for open-graded mixes. In 1993 the average bid price for PBA-3/6 was approximately $75/ton more than PBA-2/5. Clearly, if PBA-2/5 were used in only a few projects east of the Cascades, the savings would be substantial. Using the Superpave weather database and statistical reliability concepts, ODOT is optimistic that the SHRP-PG system may help to refine binder selection and enhance field performance.

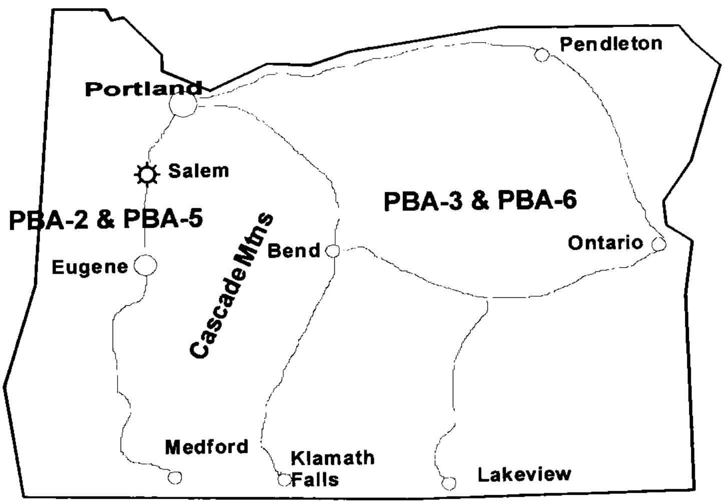

FIG 1--Binders Currently Specified by Oregon DOT

BINDER IMPLEMENTATION

ODOT's approach to implementation involved three key steps: classification of its commonly used PBA grades in terms of the Superpave PG system; review of the Superpave weather database to determine binder needs; and development of guidelines for anticipated binder use.

Binder Testing

As noted previously, binders typically used by ODOT include PBA-2, 3, 5, and 6. Fourteen binders (PBA-2, 3, 5, and 6) from six sources (i.e., suppliers) were classified in accordance with AASHTO PP6 [1].

Review of Weather Database

Data from Oregon's 175 weather stations were used to determine the recommended binder grade at several levels of reliability. For the low temperature binder grade, both algorithms were considered: the "original" which assumes that air temperature is equal to pavement surface temperature; and the Canadian algorithm which converts air temperature to pavement surface temperature as shown below [2]:

$$T_{surf} = 0.859 \times T_a + 1.7 \qquad (1)$$

where

T_{surf} = pavement surface, °C, and

T_a = air temperature, °C.

Guidelines for Anticipated Use

Several maps were developed to illustrate the high and low temperature binder grades needed at 50 percent and 98 percent levels of reliability. These were refined in lieu of practical constraints, i.e., likely binder sources and number of state-maintained road-miles associated with a particular binder grade, to yield tentative guidelines for anticipated binder use.

RESULTS AND DISCUSSION

Binder Testing

As noted previously, 14 binders from six sources/suppliers were classified in accordance with AASHTO PP6. Intermediate and high temperature testing (to determine shear modulus (G*) and phase angle (δ)) was completed with three dynamic shear rheometers (DSR), all of which were made by Bohlin: two were model DSR-2 and one was model CS-50. The intermediate and high temperature testing was conducted in three different laboratories by three different operators. Low temperature testing was done with the ATS bending beam rheometer (BBR). Shown in Table 2 is a summary of the classification results. Differences in classification are shown by the shaded cells. Although there were three cases in which test results yielded different high temperature grades, one can more easily see the variability of the test results in Figures 2 and 3. Coefficients of variability ranged from 3% to 34% and 8% to 37% for the unaged and aged binders, respectively. As extensive round robin test data are not readily available, or widely distributed, the authors are uncertain as to the significance of this variability. Typical test results for BBR stiffness and m-value at -18°C are shown in Figures 4 and 5. These results (ie, Figures 4 and 5) suggest that BBR stiffness and m-value may be more effective for discriminating among asphalts. As can be seen in Figures 4 and 5, PBA-2 and PBA-5 had similar stiffnesses and m-values, as did PBA-3 and PBA-6.

Review of Weather Database

Based on weather station data, numerous maps were developed to illustrate the binders needed as a function of level of reliability. Shown in Figures 6 and 7 are the PG binders needed based on the original and Canadian low temperature algorithms. At the 98 percent level of reliability high temperature grades ranged from 46 to 64, whereas low temperature grades ranged from -40 to -10. Because of the environmental diversity, 13 or 14 binder grades could be specified as shown in the Table 3.

Guidelines for Anticipated Use

Shown in Table 4 and Figure 8 are the PG binders likely to be specified. Realistic constraints such as readily available binder sources and state-maintained road-miles associated with a particular binder grade were important factors into the decision-making process. Furthermore, flexible pavements in the central and eastern portions of

TABLE 2--Summary of Superpave PG Classification

Binder Source	PBA Grade	Superpave PG Classification			
		High Temp Grade			Low Temp Grade
		Bohlin DSR-2	Bohlin CS-50	Bohlin DSR-2	
A	2	64	64	64	-28
B	2	64	58	64	-16
C	3	58	58	64	-34
A	3	64	58	58	-34
D	3	64	64	64	-28
C	5	64	64	70	-22
A	5	64	64	64	-22
E	5	64	64	64	-22
F	5	64	64	64	-22
C	6	64	64	64	-34
A	6	64	64	64	-34
E	6	64	64	64	-34
B	6	58	58	58	-28
F	6	64	64	64	-34

TABLE 3--SHRP Binders Needed Based on Weather Station Data

SHRP PG Binders Needed 98% Level of Reliability Original Algorithm	64-40 64-34 64-28 64-22	58-40 58-34 58-28 58-22 58-16	52-22 52-16	46-16 46-10
SHRP PG Binders Needed 98% Level of Reliability Canadian Algorithm	64-34 64-28 64-22 64-16 64-10	58-34 58-28 58-22 58-16 58-10	52-16 52-10	46-16 46-10

the state, where the lowest temperatures are recorded, typically use cold-mix. Shown in Figure 9 is the distribution of approximate number of state-maintained road-miles associated with a particular binder grade. Binder grades shown are those associated with a 98% level of reliability and the original low temperature algorithm. As evident from

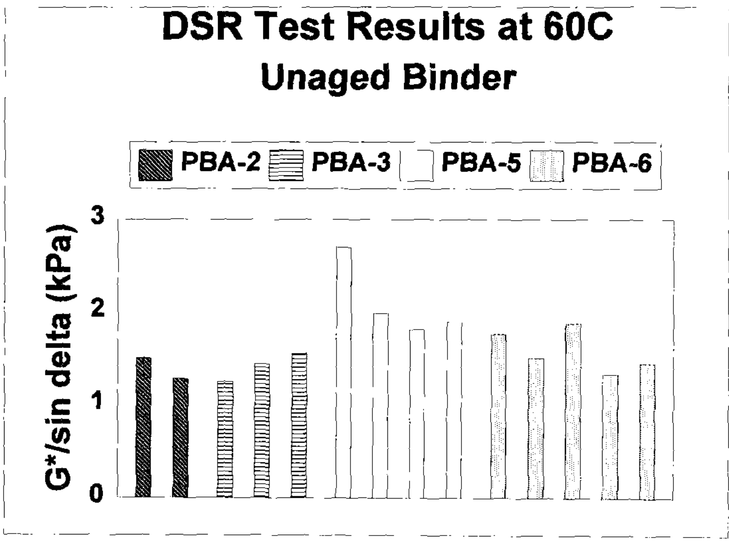

FIG 2--DSR Test Results on Unaged Binder

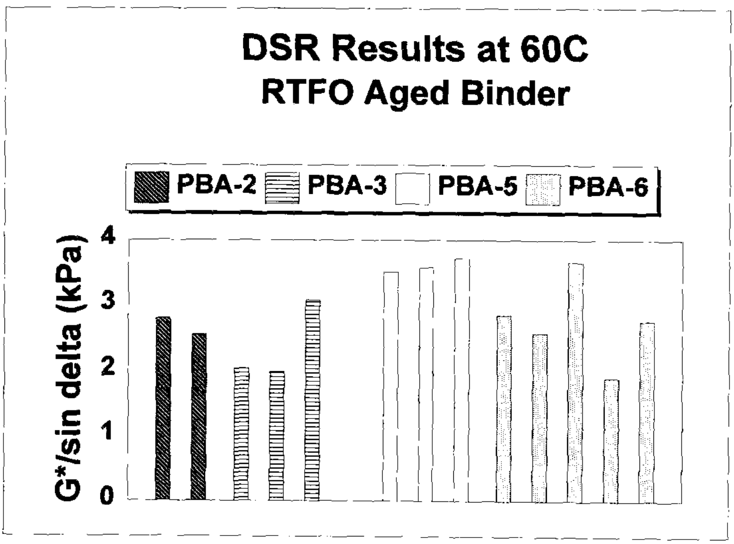

FIG 3--DSR Test Results on RTFO Aged Binder

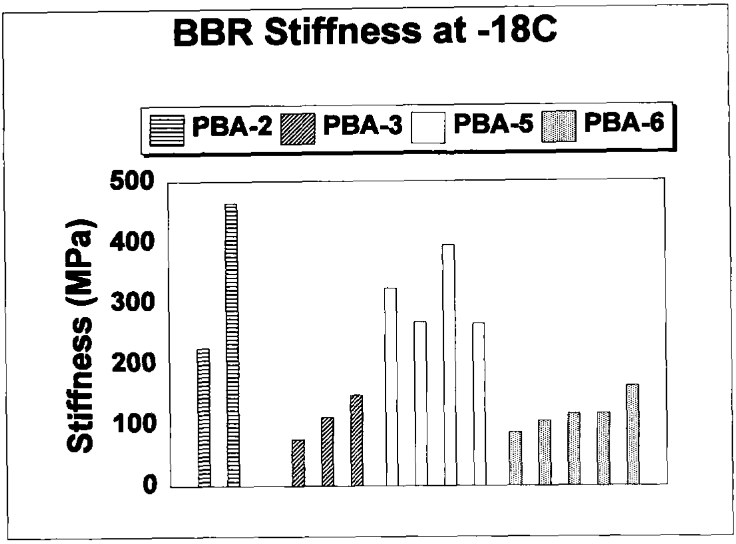

FIG 4--BBR Stiffness at -18°C

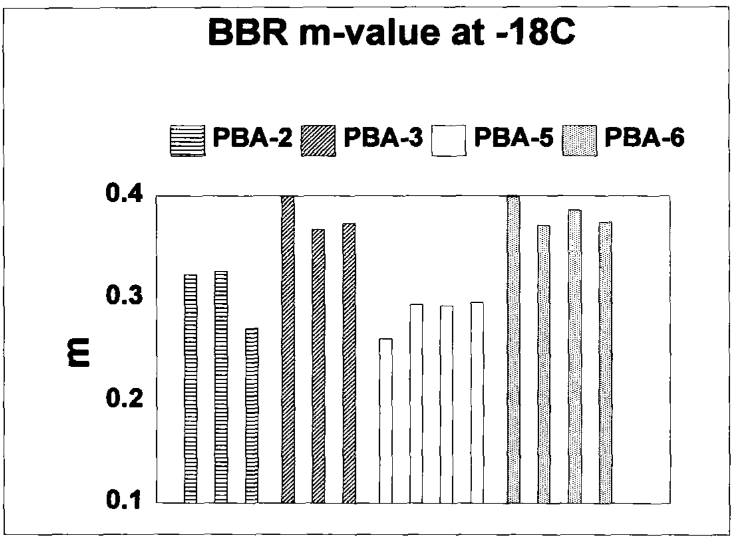

FIG 5--BBR m-value at -18°C