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Project Summary Report 0-1710-S
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Project 0-1710: Superpave Binder Tests for Surface Treatment Binders

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PROJECT SUMMARY REPORT

Development and Initial Validation of a Surface Performance-Graded Binder Specification

Presently, surface treatment design and material selection are based on experience and traditional specifications, which are not performance-based measures and sometimes result in inadequate performance. Though a Superpave performance-graded (PG) binder specification does exist for hot-mix asphalt concrete (HMAC) binders, this specification cannot be applied to surface treatment binders because of differences in design and construction methods, structural functions and response behavior, distress types, and environmental exposure.

Therefore, in 2000 the Texas Department of Transportation (TxDOT) initiated a research project to develop a performance-based specification for surface treatment binders. This project developed and initially validated a new surface performance-graded (SPG) specification for surface treatment binders. Recommendations toward further validation and improving the specification were also made.

What We Did...

Information Search and Review

Researchers completed a literature search and review and conducted an extensive survey to:

- review the PG specification for HMAC binders;
- obtain general definitions of surface treatments and their primary purposes, uses, and benefits;
- obtain information on current design procedures, construction methods, and materials and required properties including selection criteria for surface treatments;
- identify common surface treatment distresses and their causes, including those directly related to binder properties (aggregate loss and bleeding); and
- identify commonly used materials for surface treatments and determine qualitative performance ratings of these materials in different Texas climates and traffic conditions.

Development of the SPG Specification

Researchers designed and completed an extensive laboratory testing program, analyzed the test results, and developed the SPG specification including the associated grade selection process. The laboratory testing program included commonly used binders, investigation and analysis of emulsion recovery processes, and standard and modified PG binder testing.

Differences between standard and modified PG testing used for the SPG specification included:

- High and low pavement temperatures were calculated at the surface to reflect critical conditions for surface treatment performance.
- Narrower temperature increments of 3 °C were utilized.
- Binder SPG properties were determined on unaged and pressure aging vessel (PAV) aged material to represent the critical first year of surface treatment performance.
- Rotational viscometer tests were conducted at multiple temperatures to obtain spraying temperatures.
- Dynamic shear rheometer (DSR) testing was performed only on unaged binder to reflect critical conditions for newly constructed surface treatments.
- For low-temperature testing after PAV aging, the stiffness was measured at the fastest loading time possible (8 seconds) using bending beam rheometer (BBR) equipment to simulate critical traffic loading conditions. The actual test temperature was used to determine the low-temperature SPG grade.

To develop the SPG specification, researchers analyzed measured binder properties from extensive laboratory testing in conjunction with performance ratings and corresponding surface pavement temperatures calculated using the Strategic Highway Research Program (SHRP) temperature models and the LTPPBind V2.1 database.

To further validate specification threshold values, researchers utilized more theoretical approaches with the Upper Bound Theorem (UBT) and RHEA rheological software analysis. For SPG grade selection, pavement surface temperatures are the primary determinant.

Initial Validation of the SPG Specification

The scope of this initial validation project assumed that design and construction were adequate. For initial validation of the SPG specification, researchers completed:

- highway section (HS) identification including project data collection,
- laboratory testing including field binder sampling and SPG grading,
- field performance monitoring, and
- data analysis including a comparison of SPG binder grades and actual field performance.

Project information from 45 randomly selected HSs from the 2001 and 2002 TxDOT district surface treatment programs provided the basis for validation. Data were collected for factors that affected surface treatment performance including binders (types and associated suppliers), aggregates (types, gradations, and coating), environmental conditions, and traffic. Environmental conditions in terms of high and low pavement surface temperatures were obtained from the LTPPBind V2.1 database from weather stations closest to the selected HSs at 98 percent reliability. All selected HSs were single surface treatments and utilized seven different binders. Most of these materials were sampled onsite for laboratory testing and SPG grading.

Thereafter, a one-year performance monitoring period of the selected HSs was conducted. A visual survey of three inspections (i.e., just after construction, after summer, and after winter) per HS with field measurements supplemented by consecutive digital images of distresses was conducted to ensure that each HS was subjected to at least a complete seasonal cycle. Predominant surface treatment distresses (aggregate loss and bleeding) associated with inappropriate material selection were monitored on each HS. The surface condition index (SCI) criterion was used for performance evaluation and rating of the HSs using an arbitrarily selected threshold of 70 percent between passing (adequate performance) and failing (inadequate performance).

What We Found…

Compared to hot oven, rotovap, hot plate, and distillation processes; the stirred can method yielded better results for emulsion recovery in terms of residue quantity, minimization of asphalt oxidation, maximization of water removal, and optimization of the recovery process time (170 minutes). This method was used throughout the project.

Based on Fourier-transform infrared (FTIR) spectroscopy analysis, PAV aging is equivalent to one year of environmental exposure for surface treatments.

Representative temperatures in Texas and corresponding qualitative performance ratings were used to establish the following threshold values for properties required to determine a binder SPG grade:

- spraying temperatures corresponding to binder viscosities between 0.10 and 0.15 Pa·s with a maximum temperature of 180 °C to prevent alteration of binder and modifiers;
- an initial G*/Sin δ limit of 0.75 kPa to preclude aggregate loss and minimize bleeding at high temperatures due to low shear resistance and the inability of the binder to hold the aggregate in place under traffic forces; and
- flexural stiffness and m-values (slope of log stiffness-log time plot) measured in the modified BBR test procedure of 500 MPa and 0.24, respectively, to preclude aggregate loss at low temperatures when the binder stiffness is high, causing fracture under traffic loading.

The proposed SPG specification was initially validated by comparing laboratory-measured SPG binder grades to actual observed field performance of 45 randomly selected HSs. There was a good correlation for 78 percent of the HSs. However, laboratory and field performance results for 22 percent of the HSs did not correlate, mostly for AC15-5TR and AC5-2% latex binders. Researchers attributed these discrepancies to the SPG limits and grading criteria; poor material quality; and design, construction, quality control, and traffic factors.

In the final proposed SPG specification (Table 1), the following modifications were made based on the initial validation study:

- an increased spraying viscosity-temperature limit of 205 °C to include some additional modified binders,
- a decreased G*/Sin δ high temperature threshold value of 0.65 kPa to include binders that were insignificantly below 0.75 kPa with adequate field performance, and
- an increased temperature grade increment of 6 °C for the lower temperature limit to ensure a consistent change in reliability at both high and low design temperatures.

Eight standardized binder SPG grades were established for Texas conditions at 98 percent reliability.

Table 1. The Final Proposed SPG Specification.

	Performance Grade											
	SPG 58				SPG 61				SPG 64			
	-10	-16	-22	-28	-10	-16	-22	-28	-10	-16	-22	-28
Average 7-Day Maximum Surface Pavement Design Temperature, °C	<58				<61				<64			
Minimum Surface Pavement Design Temperature, °C	>-10	>-16	>-22	>-28	>-10	>-16	>-22	>-28	>-10	>-16	>-22	>-28
Original Binder												
Viscosity ASTM D 4402 Maximum: 0.15 Pa·s Minimum: 0.10 Pa·s Test Temperature, °C	≤205				≤205				≤205			
Dynamic Shear, AASHTO TP5 $\frac{G^*}{\sin\delta}$, Minimum: 0.65 kPa Test Temperature @10 rad/s, °C	58				61				64			
Pressure Aging Vessel (PAV) Residue (AASHTO PP1)												
PAV Aging Temperature, °C	90				100				100			
Creep Stiffness, AASHTO TP1 S, Maximum: 500 MPa m-value, Minimum: 0.240 Test Temperature @ 8s, °C	-10	-16	-22	-28	-10	-16	-22	-28	-10	-16	-22	-28

*The above table presents only three SPG grades as an example, but the grades are unlimited and can be extended in both directions of the temperature spectrum using 3 and 6 °C increments.

Application of the SPG specification does not necessarily guarantee satisfactory surface treatment performance. Design, aggregates, construction, and quality control also play a significant role.

The Researchers Recommend...

As a result of the project, researchers recommend that:

- TxDOT implement the proposed SPG specification (Table 1) as a relatively cost-effective method for selecting binders to ensure adequate surface treatment performance and
- engineers recognize that binder selection must be coupled with additional specifications to ensure that design, aggregates, construction, and quality control contribute to adequate surface treatment performance.

Researchers recommend further research in the following areas:

- further validation, possibly with controlled test sections or pilot implementation projects to address some of the deficiencies and failures associated with the proposed SPG specification;
- development of new and simpler testing equipment and a methodology to characterize the binder low-temperature properties;
- further testing and SPG grading of AC5-2% latex materials and others not considered in the development and/or initial validation of the specification to establish SPG grades for these materials and to identify possible revised SPG threshold values;
- exploration of the possibilities of directly incorporating traffic and loading conditions into the binder SPG grade selection process; and
- performance monitoring for more than one year to capture the full effect of traffic, environmental conditions, and aging of the binder.

For More Details...

The research is documented in:

Research Report 1710-1: *A Performance-Graded Binder Specification for Surface Treatments*

Research Report 0-1710-2: *A Surface Performance-Graded (SPG) Specification for Surface Treatment Binders: Development and Initial Validation*

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TxDOT Implementation Status—February 2005

The new surface performance-graded binder specifications will require additional validation before statewide implementation. A future implementation project is being planned to complete the field validation.

For more information, contact Dr. German Claros, P.E., Research and Technology Implementation Office, (512) 465-7403, gclaros@dot.state.tx.us.

YOUR INVOLVEMENT IS WELCOME!

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