



Project Summary Report 0-1872-S

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Project 0-1872: Evaluate Non-Specification Properties for
Performance Graded Asphalts Which May Affect Performance

Authors: Charles J. Glover and Richard R. Davison

A New Method for Assessing Asphalt Binder Performance Durability

This project was designed to answer questions about the adequacy of Superpave specifications and in particular to find a specification superior to the $G \cdot \sin \delta$ function, which does not satisfactorily predict fatigue cracking. Also, there has been an ongoing concern that the pressure aging vessel (PAV) does not accurately simulate hardening of asphalts in pavements. Finally, with the increasing use of modifiers there is concern about the applicability of Superpave specifications to these materials, and also about the effect of modifiers on water susceptibility.

We addressed all of these questions in this project with emphasis on developing a new long-term performance test that would use new aging conditions and a new measurement, still based on the dynamic shear rheometer (DSR) instrument, that would relate to excessive oxidative hardening and subsequent fatigue. The literature contains data that indicate ductility measured at lower temperatures ranging from 10 to 15 °C (50 to 59 °F) correlates well

with the conditions of old roadways, so a correlation was desired between ductility and DSR measurements. Field verification was an important part of this project.

What We Did...

This comprehensive project was directed at developing an improved method of screening asphalt binders for long-term pavement performance, and it included studies of aged binders recovered from pavements. This work involved a new look at:

- asphalt binder oxidation methods and their effects on binders (including polymer modified binders);
- the effect of binder aging on Superpave performance properties, especially low-temperature bending beam rheometer (BBR) S and m values; and
- studies of the role of other properties important to durability that are not included in Superpave.

The work culminated in a new binder aging and testing protocol for predicting the long-term performance of

asphalt binders in pavements. Specifically, this work included:

- investigations to develop an appropriate DSR function that relates to long-term binder durability in pavements and that can be readily measured with existing DSR equipment;
- fundamental studies of asphalt oxidation, especially of the effect of oxygen pressure on asphalt hardening rates, important for understanding the suitability of accelerated aging procedures such as the PAV;
- studies of the suitability of the PAV as a conditioning procedure for assessing long-term binder durability;
- studies of the effect of PAV aging on low-temperature asphalt properties;
- extensive studies of accelerated aging methods to determine an appropriate procedure for conditioning asphalt that has the combined objectives of accurately representing long-term pavement aging while at the same time being capable of being performed in a reasonable length of time;



- investigations of the impact of polymer modifiers on binder properties, on binder durability, and on water susceptibility; and
- studies of binders recovered from pavement cores to test conclusions about binder properties and performance and to calibrate laboratory aging rates to field aging rates.

What We Found...

A New DSR Function for Predicting Age-Related Failure

Literature studies show a strong correlation between asphalt ductility and pavement performance, especially fatigue cracking. In this project, we have discovered a new dynamic shear rheometer function that correlates very well with ductility for unmodified binders.

The DSR function is measured at 44.7 °C (112 °F) and 10 rad/s, providing a method that is easily accessible to standard Superpave laboratory rheological equipment and methods and appears to be an excellent function for tracking pavement aging.

For modified asphalts, the DSR-ductility results were complex. Generally for a given value of the DSR function, the ductility was better than indicated by the DSR function correlation for unmodified asphalts. Larger amounts of modifier produced increasing values of ductility for a given function value. This enhancement was very asphalt dependent, however, so no general correlation could be found.

For modified asphalts, force-ductility measurements showed that modifiers change the extensional behavior of binders by providing flow stability and, in some cases, by increasing the failure stress of the binder. These effects can result in much improved binder ductility for unaged or lightly aged binders.

As modified binders oxidize, the asphalt hardens and the improvement to ductility imparted by modifiers decreases. After enough aging, the improvement is gone and modified binders perform no better than their aged unmodified counterparts. Nevertheless, modifiers appear to provide added life to binders. A critical question remains as to whether the life extension is cost-effective, and an answer will rely on the actual amount of life extension and the cost of the modification.

Ductility and aging results indicate that polymer modifiers generally improve asphalt hardening rates, but the amount of improvement is modifier and asphalt dependent. Styrene butadiene styrene (SBS) or styrene butadiene rubber (SBR) at small concentrations (1 percent) do not have much beneficial effect on binder hardening.

Even though a ductility-DSR correlation does not seem to exist for modified binders, a direct tension-ductility correlation does. This correlation may allow using the Superpave direct tension instrument in lieu of ductility measurements, which, although not as convenient as DSR, is much more convenient than using only ductility.

A New Aging Procedure

A new aging procedure uses the PAV apparatus but is modified by taking advantage of the higher average aging rate when the asphalt is aged in thinner films. This change, combined with a somewhat longer aging time, results in more extended binder aging and thus a more rigorous test of durability than the standard PAV method. At the same time, the resulting rankings for aged binders are more representative of rankings that are

obtained from aging near pavement conditions.

Tests measured low-temperature properties, BBR S and m and direct tension failure strain, for asphalts aged in the standard PAV procedure and in the environmental room, both after rolling thin film oven test (RTFOT) aging. The properties for PAV-aged asphalts agreed remarkably well with the properties obtained after 38 days in the environmental room, although longer times in the PAV did not correlate as well with any specific longer time in the environmental room.

The PAV can be eliminated and BBR determinations estimated after RTFOT aging (or an alternative hot-mix aging procedure) only, based on values of $G^*/\sin \delta$ at 58 °C (136 °F). The amount of error introduced by this estimation procedure appears to be acceptable.

From age hardening results at a variety of conditions of temperature and pressure, a number of comparisons can be made. Especially notable are that 122 days at 60 °C (140 °F), 1 atm air corresponds to 32 hours at 90 °C (194 °F), 20 atm air and 377 hours at 88 °C (190 °F), 1 atm air, all after RTFOT aging. All of these tests were in 0.86 mm (0.034 in) thick films.

Water susceptibility results determined for several asphalts with and without modifiers indicated that the modifiers did not greatly affect the water susceptibility.

A New Trial Specification

The DSR function was coupled with the new aging procedure in a tentative specification that should guard against failure caused by premature asphalt hardening and consequent fatigue cracking. This method appears to be a good predictor of asphalt resistance to



failure due to oxidative hardening. The method is not effective for modified asphalts. But an alternative direct tension procedure for modified materials shows promise.

New Pavement Aging Results

There is some evidence that seal coats may penetrate below the surface of a pavement, even in dense-graded mixes, under the right conditions. Many of the pavements that were tested failed to provide definitive determinations of a critical value of the binder DSR function or of pavement binder aging rates because binder stiffening over time showed anomalous trends. These observed anomalies (reversals in stiffening) could be explained by seal coat penetration, if it occurred to a significant degree.

If, in fact, seal coats are able to penetrate into the pavement, then they may provide a significant opportunity to rejuvenate pavements in place. For those pavements where the binder stiffening anomalies may be explained by seal coat penetration, the supposed rejuvenation reversed approximately 10 to 15 years of pavement aging. Other pavement data suggest that a specially designed seal coat may be able to halt pavement aging.

Pavements can oxidize at surprisingly uniform rates with depth, even for dense-graded mixes.

Brittle binders can be better tolerated in stiff pavement systems. Thus, an appropriate limiting DSR function value depends on the stiffness of the pavement system.

The Superpave RTFOT plus PAV procedure ages binders at Texas conditions to a level that is approximately equal to hot-mix aging plus four years on the road,

based on SH 21 data. This is not a very severe level of aging in the context of pavement life.

One month of aging in the 60 °C (140 °F) environmental room was equivalent to approximately 15 months on SH 21 after the initial jump passed. This calibration will vary with climate, binder composition, and air voids.

On SH 21, aggregate altered neither the oxidation hardening susceptibility nor the path followed on the G' versus η'/G' map, compared to laboratory aging of the neat binder. This comparison suggests that aggregates do not have a large impact on asphalt oxidation reactions.

The Researchers Recommend...

For TxDOT Evaluation or Implementation

TxDOT laboratories should begin evaluating the proposed long-term durability specification procedure to gain familiarity with it and with the performance of different asphalts, preliminary to implementation. The test calls for RTFOT or equivalent aging followed by aging in the PAV apparatus at 90 °C (194 °C) and 20 atm air but in thin 0.86 mm (0.034 in) films and for an extended time of 32 hours. This level of aging is about three times more severe than the Superpave PAV procedure provides. This procedure is followed by DSR function measurement to determine the asphalt's remaining flexibility after the extended aging.

The use of penetrating seal coats to rejuvenate underlying pavement should be evaluated. Rejuvenating seal coats should use materials that are specially designed to produce

a more ductile and slower aging binder in the pavement.

Falling weight deflectometer (FWD) measurements together with measurements of binder ductility (through the DSR function) should be implemented as a method for evaluating remaining pavement life and scheduling seal coats to rejuvenate the underlying pavement and to halt or drastically slow further hardening. A combination of a low-stiffness pavement and a brittle binder leads to cracking failure.

TxDOT laboratories should evaluate the abbreviated procedure to determine low-temperature Superpave properties immediately after the hot-mix aging test, in lieu of PAV conditioning.

Further Study

Further study is recommended in the following areas:

- the use of seal coats designed specifically to halt oxidation of the underlying pavement;
- development of a method for determining binder stiffness in mixtures and in pavement cores, as a means of assessing remaining life, especially important for modified materials for which extraction and recovery is unproven;
- polymer modification to understand the cause of the benefit degradation that occurs due to aging and whether this can be improved by adjusting asphalt composition;
- the effect of asphalt composition on polymer benefit;
- the effect of modifier on binder failure stress; and
- the use of direct tension measurements to characterize polymer ductility and thus durability.



For More Details...

The research is documented in Report 1872-1, *Development of a New Method for Assessing Asphalt Binder Performance Durability*.

Research Supervisor: Charles J. Glover, Ph.D., P.E., (979) 845-3389, c-glover@tamu.edu

TxDOT Project Director: Jerry Peterson, Construction Division, (512) 506-5821, gpeters@mailgw.dot.state.tx.us

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

To obtain copies of reports, contact Nancy Pippin, Texas Transportation Institute, TTI Communications, at (979) 458-0481 or n-pippin@ttimail.tamu.edu. See our online catalog at <http://tti.tamu.edu>.

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Texas Transportation Institute/TTI Communications
The Texas A&M University System
3135 TAMU
College Station, TX 77843-3135