TEXAS TRANSPORTATION INSTITUTE
THE TEXAS A&M UNIVERSITY SYSTEM

Project Summary Report 1460-S
Project 0-1460: Research Support for the Addition of Tire Rubber in Asphalt

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PROJECT SUMMARY REPORT

High-Cure Crumb Rubber Modified Asphalt for Dense-Graded Mixes

The Texas Department of Transportation (TxDOT) uses tire rubber in asphalt pavements in a variety of ways, some of which require special design or construction practices. These include immediate use after blending to avoid rubber settling, or use in open- or gap-graded mixes to avoid compaction problems. Use in dense-graded mixes, however, has not been adopted, due to historical problems. Through this research, we have developed a method for using recycled tire rubber in standard dense-graded mixes to achieve improved pavement performance, but without special design or handling requirements.

Asphalt is a complex mixture of materials—the bottoms product of the crude oil barrel. As such, it consists of a wide variety of chemical compounds, whose interactions define its physical properties and durability and, consequently, its performance in pavements.

Ideal performance demands the following:

- the pavement binder and mix must be capable of placement and compaction to provide an even and strong ride surface and appropriate mix density (air voids);
- the binder, together with the mix design, must be able to withstand loading to prevent permanent deformation (wheel path rutting);
- the binder must be able to withstand low temperatures and the resulting thermal stresses that develop as the pavement shrinks;
- the binder must be able to withstand repeated loading and unloading without exhibiting fatigue failure (cracking); and
- the binder must be able to sustain these performance criteria over an extended period of time, meaning that it either must resist oxidative aging or have a limited response to it.

Trials show that incorporating ground tire rubber in asphalt improves low-temperature cracking resistance and binder durability. But using the material as traditional low-cure asphalt rubber (defined by American Society for Testing and Materials [ASTM] to be at least 15 percent rubber in the binder) has its challenges: performance has been inconsistent, and most of the successful applications have been in open- or gap-graded mixes, which can be very costly due to the large amount of rubber in the binder and binder in the mix.

There is a key question to using ground tire rubber in asphalt by any method. Is the inevitable additional binder cost, which translates into a higher mix cost, warranted by the amount of enhanced performance which is obtained? Answering this question requires a comprehensive study of using ground tire rubber, the properties of the modified binder, and a life-cycle cost analysis for competing treatment methods.

What We Did . . .

In response to these issues of economically improving binders with ground tire rubber, we conducted an extensive study of methods for using ground tire rubber in asphalt binders with emphasis on dense-graded mixes. Topics studied included production methods, issues related to performance properties of asphalt and rubber blends, durability to oxidative aging, placement of field trials, and economic evaluations.

Production Methods

We found that the biggest drawbacks to achieving an asphalt-rubber blend suitable for dense-graded mixes were the heterogeneity of the sample and the high viscosity at hot mix conditions. Consequently, a large effort focused on evaluating rubber curing in asphaltic materials. Parameters studied were asphalt composition, curing shear rate and type of mixer, curing temperature, curing time, rubber content, rubber particle size, and rubber type.

Specifically, the curing studies investigated the comparative effectiveness of low-, intermediate-, and high-cure methods. Basically, the low-cure process is that which is used to produce asphalt rubber as defined by ASTM. Intermediate- and high-cure methods increase the temperature, shear, and time of cure to obtain a more homogeneous blend. We studied air oxidation while curing as a means of increasing the extent of the cure and decreasing the cure time, and to determine its effects on the resulting binder properties.

Performance Properties

A detailed study of specification properties determined the effect of cure conditions on performance grade properties. We evaluated blend settling stability, important to storage and processing, and the effect of an asphalt's Corbett composition on High-Cure Crumb Rubber Modified Asphalt (HC-CRMA) performance grade and settling. Finally, we reviewed industrial production issues such as high-temperature viscosity, settling stability, and tracking curing to meet these properties.

Long-Term Durability

We conducted a significant study of oxidation of base asphalt binders and rubber-cured materials. The bulk of this study aged materials at 60 °C (140 °F) and atmospheric air because the high-pressure, high-temperature Pressure Aging Vessel (PAV) is flawed for accurate comparisons of different materials. Studies were made in low-, intermediate-, and high-cure blends and included hardening rates, oxidation activation energies, and the relation between oxidation level and hardening.

Field Implementation

Field trials of HC-CRMAmaterials used in dense-graded mixes implemented and evaluated the laboratory studies described above. Test sections using several levels of rubber content were placed to test all aspects of field implementation: industrial curing, settling during transport, hot-mix processing, pavement placement, and pavement durability.

Economic Evaluation

This project also included an economic analysis of asphalt-rubber materials. A capitalized cost method assessed several scenarios, some of which were: high-cure with a range of rubber content used in dense-graded mixes; high-cure using a premium performance base asphalt cement; and low-cure, high rubber content, high binder content gap- or open-graded mixes (traditional asphalt rubber).

What We Found . . .

Production Methods

1. A high-cure crumb rubber modified asphalt (HC-CRMA) binder suitable for use in dense-graded mixes can be produced through a combination of high temperature and high shear. Milder conditions of shear and temperature may do little more than swell the rubber particles as they absorb compounds from the asphalt.

2. Production in the presence of oxygen can enhance the breakdown of rubber and the curing process. As with curing in the absence of oxygen, higher temperature, higher shear, and finer initial mesh rubber all decrease the time needed to achieve a high cure. As with any oxidation process using an organic material, safety precautions must be observed and temperatures and air flow must not exceed a safe level.

3. Either curing method (with or without oxidation) produces a material with excellent settling stability and a high-temperature (135 °C, 275 °F) viscosity that meets the SuperPave specification of less than 3 Pa • s (30 poise).

Performance Properties

4. CRMA and HC-CRMAmaterials show enhanced Superpave performance grades over the base asphalt.

Curing at relatively low temperatures and low shear rates leads to a moderate interaction of the rubber material with the asphalt and a PG span which is widened considerably by improvements at both high- and low-temperature ends. However, many low-cure materials do not meet the optional maximum high-temperature viscosity of 3 Pa • s (30 poise) at 135 °C (275 °F) and a settling test for storage stability. Curing with higher shear mixing and a higher temperature breaks down the rubber particles sufficiently to give lower viscosities at hot-mix installation and at rutting conditions, to the point of meeting the high-temperature viscosity criterion, while retaining significant performance grade enhancements. Materials produced at the highest level of curing widen the PG span only incrementally when using a continuous grading, or single degree increment basis, but do not always yield improvement on a specification basis.

Curing in the presence of oxygen results in more rapid digestion of the rubber and oxidation of the base asphalt material to a higher viscosity. These two effects together can result in a significantly wider PG span, increasing the upper grade by up to three grades, while the rubber serves to hold the low-temperature grade or at least limit its loss. Temperatures and air flow must not exceed safe levels.

5. Three concerns associated with industrial preparation of HC-CRMA materials were resolved. The optional high-temperature viscosity specification (HTV) is achieved; the Texas Settling Test for storage stability of the binder is met if the curing process is carried far enough; and a dynamic shear rheometer at reduced gap settings gives a sensitive and efficient measure of the extent of cure.

Long-Term Durability

6. The incorporation of rubber in asphalt binders provides enhanced aging characteristics. Low-cure blends have very low hardening rates and decreased hardening in response to a given amount of oxidation. High-cure blends exhibit excellent aging characteristics, equal to or better than those of the low-cure materials. Aging can be retarded further by utilizing low-asphaltene source binders, although this probably would adversely affect the material's rutting resistance.

7. For rubber-modified materials, the use of a high-temperature, high-pressure aging procedure to simulate long-term aging (e.g., as in the Superpave protocol) is not reliable; we recommend aging at 60 °C, 1 atm air to assess aging in CRMAor HC-CRMA materials. Drawing conclusions from aging at PAV test conditions on road aging is problematic for conventional asphalt binders but is even worse for crumb rubber modified materials.

Field Implementation

8. HC-CRMAbinders can be used successfully in the field in dense-graded mixes with no mix design adjustments and can have improved Superpave performance grades and, especially, improved oxidative hardening characteristics. Binders ranging from 8.0 to 17.6 percent rubber were used in dense-graded type C and D mixes having just under 5 percent

binder, the same level as the non-rubber control AC. The CRMA binders were processed in the hot-mix plant at nominal conditions and with no complications, pavement compaction proceeded nominally, and performance grades of the CRMAmaterials were improved over those of the base asphalt by one grade on the high end and up to one grade on the low end. Furthermore, high-temperature (135 °C, 275 °F) viscosities met the optional limit of 3 Pa • s (30 poise), even for the highest rubber content binder. Laboratory data for the test section materials suggest that the durability to summertime oxidation will be significantly increased over the durability of the control material.

July 1998 placement of overlay on FM 2818.

Economic Evaluation

9. Capitalized cost analysis is appropriate for analyzing competing technologies with different life expectancies, installed repeated times and at different installed costs. The method determines the present value of an installation now plus repeated installations at the end of each life cycle plus yearly maintenance.

10. Comparisons of several cases show that the life-cycle cost of HC-CRMAmaterials compares very favorably to that of conventional asphalt binders. A high-cure crumb rubber binder at 16 percent rubber in a dense-graded mix would need to last just 16 percent longer than the comparable conventional mix in order to have an equal capitalized cost, the break-even point. At the same time, oxidative hardening rates at road aging conditions are reduced some 50 percent or more by the high-cure rubber. Consequently, achieving the required extended life is believed to be well within reach for dense-graded mixes, even for a high rubber content binder.

11. Capitalized cost analysis shows that high rubber-content binders, high binder mixes (traditional Asphalt Rubber) require a significantly longer life extension for economic payout. At 18 percent rubber in the binder and 9 percent binder in the mix, a life extension of the order of 60 percent (over a conventional asphalt binder dense-graded mix of the same thickness) is required. With 6 percent binder in the mix instead of the 9 percent, the required life extension is reduced to 33 percent, still more than twice that required to break even with the HC-CRMA.

12. The key issue to economic payout is the actual life extension provided by the binder. To establish this enhancement definitively will take continued monitoring of test pavements such as those placed in this project.

The Researchers Recommend . . .

1. Continue to track existing test sections. This is important in obtaining long-term performance data, thereby establishing more precise economic evaluations of the method.

2. Consider the use of HC-CRMAin standard mixes as an alternative to special tire rubber mix designs currently used in some applications.

3. Test high-cure materials in test sections in other locations having greater extremes of temperature, and perhaps together with other technology such as stress absorbing membrane innerlayers (SAMI), to test performance in colder climates and in reflection cracking situations.

4. Further verify the use of rheometer gap versus phase angle as a measure of curing. These relations should be compared to other measures of curing. The rheometer gap is a rapid method for tracking field curing of these materials.

5. Investigate curing of rubber at high-temperature and high-shear conditions in a low-viscosity flux and then add a high-viscosity material to achieve the desired top performance grade. This approach is expected to give a good grade, good settling properties, and good hardening properties.

6. Investigate air curing of rubber in low-viscosity flux materials, followed by the addition of higher-viscosity material to obtain grade. Air curing in a light material will not cause as much hardening as in normal asphalt materials.

7. Further investigate the relation of asphalt composition to rubber curing. Recommendations 5 and 6 are based on composition studies. However, these effects are not completely understood and still deserve additional investigation.

8. Further investigate the interaction of air-blown asphalts and rubber during curing.

For More Details . . .

The research is documented in report FHWA/TX-00/1460-1, *A Comprehensive Laboratory and Field Study of High-Cure Crumb-Rubber Modified Asphalt Materials*, Department of Energy reports DOE/AL/99567-1, *Development of Asphalts and Pavements Using Recycled Tire Rubber: Phase I Technical Feasibility Technical Progress Report* and DOE/AL/99567-2, *Development of Asphalts and Pavements Using Recycled Tire Rubber: Phase I Technical Feasibility Final Report*.

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TxDOT Implementation Status
March 2001

Implementation of Project 0-1460 was approved on November 18, 1999. This IPR covers the cost differential for the construction of three sections in the Houston District. The total project length was 10,300 feet and was located at FM 1266 in Galveston County. The construction was completed in June 2000, and the project engineer was Jose Ramirez. A type D mix was used with 12, 8, and 0 percent of crumb rubber. The Odessa District is also using crumb rubber in several projects as part of their rehabilitation program.

The Research and Technology Implementation Office (RTI) would consider supporting additional projects constructed using crumb rubber. If you are interested, please contact RTI at the following address.

Contact: Dr. German Claros, P.E., RTI, (512) 467-3881, gclaros@dot.state.tx.us

YOUR INVOLVEMENT IS WELCOME!

DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the U.S. Department of Transportation, Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. Trade names are used solely for information and not for product endorsement. The engineer in charge of this project was Charles James Glover, Ph.D., P.E. (Texas, 48732).