Effect of Rejuvenator on HMA Mixtures with High RAP and RAS Contents

RESEARCH SYNOPSIS 12-05

National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY

Problem Statement

The use of recycled materials in hot-mix asphalt (HMA) mixtures reduces costs for producers and highway agencies as well as reduces the environmental impact associated with the extraction, transportation and processing of virgin materials. However, most highway agencies currently allow only low percentages of reclaimed asphalt pavement (RAP) – less than 25 percent by weight of aggregate – and/or up to 5 percent reclaimed asphalt shingles (RAS). The reason is that recycled binders are less strain-tolerant and may be more susceptible to cracking in certain applications.

Agencies are concerned that the use of high RAP/RAS mixtures may adversely affect performance of asphalt pavements, ultimately resulting in higher pavement maintenance and rehabilitation costs. Using a recycling agent, or rejuvenator, is one possible approach to offsetting the higher binder stiffness and improving cracking resistance of a mixture when high RAP/RAS contents are used.

Objective

The objective of this study was to evaluate the effect of using a rejuvenator pre-blended with a virgin asphalt binder on laboratory-measured performance properties of recycled binders and HMA mixtures with high RAP and RAS contents. A cost comparison of HMA mixtures with RAP and/or RAS was also conducted.

Description of Study

Three 9.5-mm mix designs were used in this study: a virgin (control) mix design, a 50 percent RAP mix design and a 20 percent RAP plus 5 percent RAS mix design. The virgin binder used in the mix designs was a PG 67-22. For each mix, 0.5 percent liquid anti-strip (by weight of the virgin binder) manufactured by ArrMaz Custom Chemicals was added to the virgin binder before mixing. The rejuvenator selected for this study was Cyclogen®L, which does not contain asphalt binder.

A total of five mixtures were evaluated in this study: the control, 50 percent RAP, and 20 percent RAP plus 5 percent RAS mixes described above, as well as a 50 percent RAP mix with rejuvenator and a 20 percent RAP plus 5 percent RAS mix with rejuvenator.

Plan for Binder Testing

Testing of virgin and recycled asphalt binders was conducted in two steps. The first step was to determine 1) the effect of the rejuvenator on the performance properties of the recycled binders extracted from RAP and RAS, and 2) the optimum amount of rejuvenator required to restore the performance properties of the recycled binders to meet the requirements for a PG 67-22 (the grade of the virgin binder used in the mix designs).

The second step was to determine the properties of the blends of the recycled binders, virgin binder and rejuvenator. The rejuvenator was mixed with the virgin binder at the optimum rejuvenator dosage rate determined in step one. Then, the blend was mixed with the binders extracted from RAP and RAS based on the amount of each binder determined in the 50 percent RAP and 20 percent RAP plus 5 percent RAS mix designs. This testing was necessary to determine the true grade of each blend and to ensure there were no compatibility issues.

Plan for Mixture Testing

Due to the time-dependent diffusion process of the rejuvenators, asphalt mixtures were tested in both short- and long-term aged conditions in accordance with AASHTO R 30. The short- and long-term properties were used to evaluate the mixture resistance to permanent deformation and cracking, respectively.

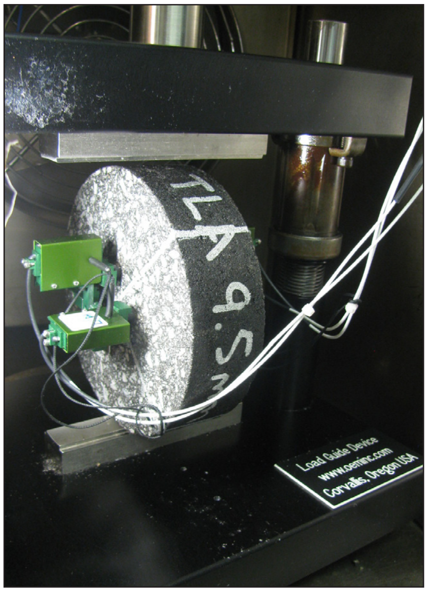

Figure 1 Indirect tension testing to determine critical low-temperature cracking properties of mixtures.

Moisture damage susceptibility of each mixture was evaluated through the tensile strength ratio (TSR) test. The dynamic modulus (E*) and Asphalt Pavement Analyzer (APA) tests were conducted on the short-term aged specimens to determine the short-term aged stiffness and evaluate mix resistance to permanent deformation.

To determine the long-term properties, the test specimens cored/cut from the gyratory specimens were long-term aged in an oven at 85˚C for 120 hours according to AASHTO R 30. Four tests were then performed: E* to determine stiffness of the mixture, indirect tensile

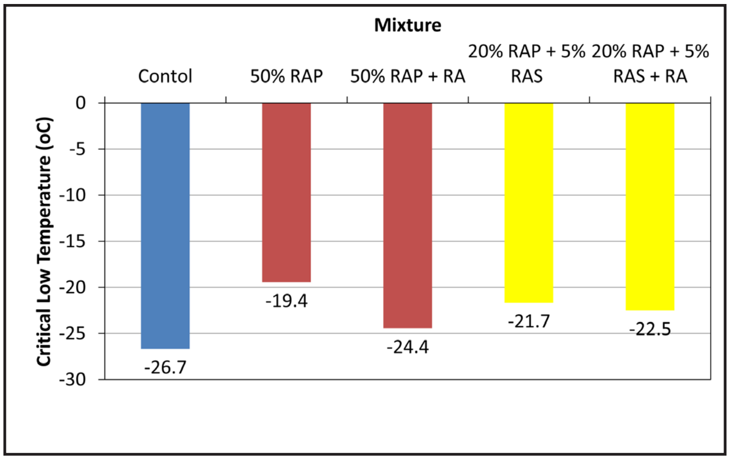

Figure 2 Critical low temperatures of mixtures.

(IDT) to determine the critical low-temperature cracking properties, and energy ratio (ER) and overlay tester (OT) to determine the mixture's resistance to cracking at intermediate temperatures.

Conclusions

This study evaluated the effect of a rejuvenator on the performance properties of recycled binders and mixtures with high RAP and RAS contents. The following conclusions were made based on the results:

1) The desired amount of rejuvenator was determined based on a linear relationship between the rejuvenator content and critical low temperature of the blend of recycled binder and rejuvenator. In this study, an optimum rejuvenator content of 12 percent by the total weight of recycled binders was selected to restore the performance properties of the recycled binders to meet the requirements for a PG 67-22 (the performance grade of the virgin binder).
2) The rejuvenator content of 12 percent restored the critical low temperature of 1) the 50 percent RAP and virgin binder blend from -18.2 to -21.2 and 2) the 20 percent RAP plus 5 percent RAS and virgin binder from -19.4 and -21.3. However, these blends narrowly failed the low critical temperature requirement for a PG 67-22.
3) The virgin binder and the 20 percent RAP plus 5 percent RAS blend with rejuvenator had the greatest resistance to fatigue cracking, followed by the 50 percent RAP blend with rejuvenator and the 20 percent RAP plus 5 percent RAS blend without rejuvenator.
4) Tensile strength ratio values for all mixtures were equal or greater than the commonly accepted failure threshold of 0.8. Using rejuvenator in the RAP/RAS mixtures improved the TSR values.
5) After both long- and short-term aging of two sets of specimens from each mixture, the two mixtures with rejuvenator appeared to age faster than the other mixtures. The use of rejuvenator decreased the stiffness of these mixtures based on dynamic modulus testing; however, these mixtures were still stiffer than the virgin mix in both long- and short-term aged conditions.
6) Using rejuvenator improved all four fracture properties — fracture energy (FE), dissipated creep strain energy at failure ($DCSE_f$), minimum dissipated creep strain energy (DCSEmin) and energy ratio (ER) — for the 50 percent RAP mix, and improved the FE, $DCSE_f$ and DCSEmin of the 20 percent RAP plus 5 percent RAS mix. All the mixes except the 50 percent RAP mix without rejuvenator met the proposed minimum $DCSE_f$ and ER requirements.
7) The control mixture exhibited the lowest critical failure temperature (-27.7˚C), followed by the 50 percent RAP mixture with rejuvenator, the 20 percent RAP plus 5 percent RAS mix with rejuvenator and then the 20 percent RAP plus 5 percent RAS mix without rejuvenator. Mixtures with a lower critical failure temperature are likely to have a better resistance to low-temperature cracking.
8) Using the overlay test (OT) test procedure, the virgin control mix was found to have the highest average number of cycles to failure, which was statistically different from those of the recycled mixes. Among the recycled mixtures, the 20 percent RAP plus 5 percent RAS with rejuvenator had the highest average number of cycles to failure, followed by the 50 percent RAP mix with rejuvenator, the 20 percent RAP plus 5 percent RAS mix, and the 50 percent RAP mix. However, the differences in the number of cycles to failure among the recycled mixes were not statistically significant.
9) All the mixtures exhibited APA manual rut depths less than 5.5 mm. Thus, all five mixtures would be expected to have good rutting resistance in the field.
10) Based on a cost comparison, using 50 percent RAP mix, 50 percent RAP mix with rejuvenator, 20 percent RAP plus 5 percent RAS mix or 20 percent RAP plus 5 percent RAS mix with rejuvenator can result in significant cost savings: about 36, 29, 21 and 16 percent, respectively, compared to the cost per ton of virgin mix.

Recommendations for Implementation

The use of rejuvenator in recycled mixtures appears to improve the cracking resistance of these mixtures without adversely affecting their resistance to moisture damage and permanent deformation. It is recommended that the rejuvenator, which should be pre-blended with the virgin binder, be used to improve cracking resistance of asphalt mixtures with high RAP and RAS contents. However, further research is needed to evaluate other rejuvenators and the use of rejuvenators in asphalt mixtures with tear-off RAS.

Acknowledgements and Disclaimer

This study was sponsored by the Alabama Department of Transportation. This research synopsis provides a brief summary of the study's final publication. This document is for general guidance and reference purposes only. NCAT, Auburn University, and the listed sponsoring agencies assume no liability for the contents or their use.