Designing Superpave Mixes with Locally Reclaimed Asphalt Pavement

North Central States Jointly Fund Study

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States in the North Central region of the United States quickly adopted Superpave® starting in 1993. At that time, however, the Superpave specifications did not provide guidance on the use of reclaimed asphalt pavement (RAP) in hot-mix asphalt (HMA). States therefore were reluctant to specify RAP in HMA pavements, although most previously had recycled RAP into new HMA pavements. As a result, RAP use decreased, despite the environmental and economic benefits.

Problem

The Superpave specifications initially did not address how to incorporate RAP into the mix design, despite reports of good performance with RAP. As Superpave became the predominant means for designing and analyzing asphalt mixtures, guidelines for RAP use were developed under National Cooperative Highway Research Program (NCHRP) Project 9-12, Incorporation of Reclaimed Asphalt Pavement in the Superpave System, completed in March 2000 by the North Central Superpave Center (NCSC) and the Asphalt Institute (*1*–*3*).

The study led to changes in three specifications adopted by the American Association of State Highway and Transportation Officials, allowing the incorporation of RAP into Superpave mixtures. But NCHRP Project 9-12 did not include materials common to the North Central United States. Therefore seven states in the region—Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, and Wisconsin—jointly funded a concurrent regional project at the

NCSC to study typical regional materials and higher RAP contents (*4*).

Solution

The study expanded the NCHRP project research by investigating materials common to the North Central region, as well as the use of a higher RAP content. Researchers compared the mixture properties of different proportions of RAP and virgin materials. Indiana, Michigan, and Missouri each provided one plant-produced mixture with RAP for study, along with the component raw materials—RAP, virgin binder, and virgin aggregate.

Laboratory Tests

The plant-produced mix from each source was recreated in the laboratory with the same RAP content. A comparison of the plant and lab-produced mixes verified that the lab procedures had produced realistic mixtures.

In addition, the raw materials were combined in the lab to produce mixtures with no RAP and with a content of up to 50 percent RAP. Binder and mixture tests were performed following the protocols established in the NCHRP project. The mixtures with different RAP contents were compared for recovered binder stiffness and creep, as well as for mixture stiffness and permanent strain.

In the laboratory, binder properties were determined for

- Unaged, original binders;
- Binders aged in a rolling thin-film oven (RTFO), to simulate the binder aging or hardening that occurs when a mixture is produced in a hot-mix plant; and
- Binders aged by the RTFO and a pressure-aging vessel (PAV), to simulate in-service binder aging.

The properties were measured in terms of critical temperatures—that is, the temperatures at which the binders just met the specification limits. The temperatures also were determined for virgin binders with no RAP; for binders extracted and recovered from RAP, or 100 percent RAP; and for binders recovered from mixes with specific percentages of RAP.

Results

The study results showed that acceptable Superpave mixtures could be designed with as much as 40 percent to 50 percent RAP, although the gradation and aggregate quality may limit the amount of RAP that can be used. The addition of 20 percent to 25 percent RAP significantly stiffened the binder and mixture; with higher RAP contents, the mixture stiffness increased and the permanent strain decreased.

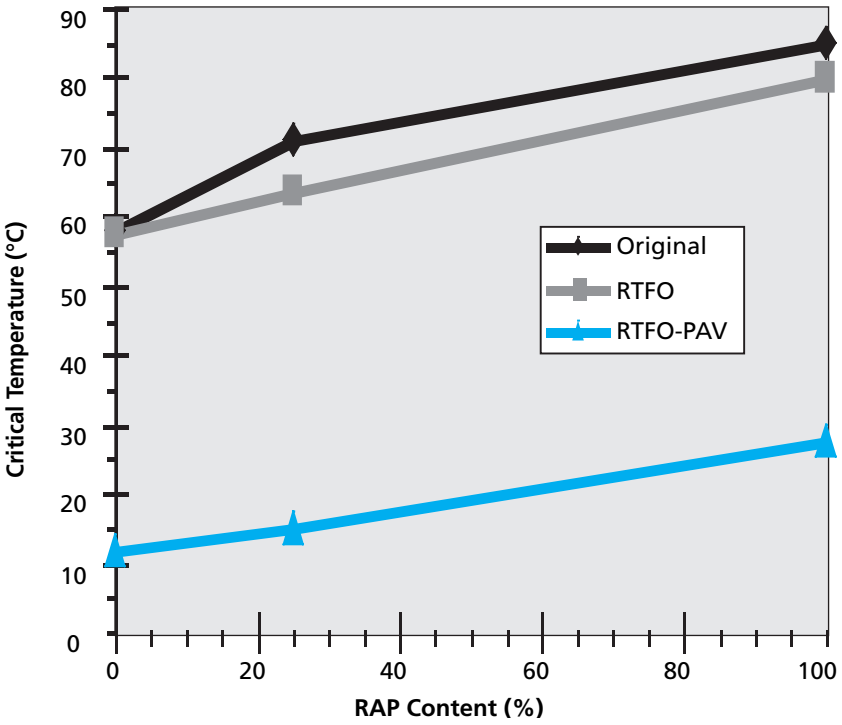

FIGURE 1 Measured binder properties can be predicted with linear blending charts.

The study also confirmed the finding from NCHRP Project 9-12 that blending the hardened RAP binder and the virgin binder could be charted as an approximately linear relation. Figure 1 charts binder properties versus RAP content for the study. The properties of the virgin and recovered RAP binders are those shown for 0 percent and 100 percent RAP, respectively.

Linear blending charts were constructed to predict the properties of binders incorporating various percentages of RAP by connecting the virgin and RAP binder properties with a straight line. The properties of a binder blended with RAP can be estimated by where the connecting line crosses the RAP content.

The data for the actual recovered, blended binder properties for 25 percent RAP in the RTFO and RTFO-PAV conditions fall on the straight lines connecting the RAP and virgin binder properties. This confirms that the linear blending charts are appropriate for predicting blended binder properties.

As expected, however, linear blending did not occur in the unaged condition. In this instance, the RAP binder was tested as if it were unaged—that is, as if it had not gone through the hot-mix plant—although it was aged material. The blend of RAP and

virgin binder also included some aged material. When the RAP binder and the blended binder were tested as if they were unaged, the critical temperatures were somewhat overestimated, as indicated by the deviation from the straight-line relationship.

These results support a tiered approach to RAP use. Low amounts of RAP can be used without adjusting the virgin binder grade, but larger amounts of RAP call for a softer binder to counteract the stiffening effects of the oxidized RAP binder.

The results agreed with the NCHRP 9-12 findings, suggesting that states in the North Central region could implement the results and recommendations of the national study with confidence.

Application

States in the North Central region report that, in general, RAP use is returning to the levels common before Superpave. Indiana and Kansas use as much RAP as before, with typical contents around 15 percent to 25 percent.

Use is increasing in Iowa as contractors adjust to gyratory mix designs for roads with lower traffic volume. RAP content is typically 10 percent to 15 percent, but some mixes have included 26 percent.

Illinois RAP use ranges from 0 to 50 percent, depending on the application. The Nebraska Department of Roads reports that about 90 percent of the mixes used in the state contain between 5 percent and 50 percent RAP.

Wisconsin reuses 100 percent of the material milled up in the state, with RAP contents of up to 35 percent in the lower pavement layers and up to 20 percent in the upper layers. Missouri was not a major recycling state before the implementation of Superpave, but now allows the use of up to 15 percent RAP in mixes for low-volume roadways.

The Indiana material tested in this study has been placed on a Specific Pavement Studies test site of the Long-Term Pavement Performance Program for 12-year monitoring and evaluation.

Benefits

As a sponsoring state, Indiana conducted a cost–benefit analysis of the research project as part of an independent review of the cost-effectiveness of the DOT's research program. The findings are documented in a report posted on the web, which also details the assumptions.[1]

Because the costs of this project were shared with six other states, Indiana DOT contributed only $15,000—one-seventh of the study cost of $105,000. According to the conservative estimate of the cost-effectiveness review, Indiana DOT's savings in materials were nearly $330,000 per year when adding only 5 percent RAP to more than 5 million tons of base and intermediate mixes—although RAP contents of 15 percent to 20 percent are more typical. The review did not assess the environmental benefits of reusing RAP.

The study yielded a conservative benefit-to-cost ratio of 220:1 for Indiana in material cost savings alone; the six other states that shared in funding the study may accrue similar or even higher benefit-to-cost ratios. This regional study allowed states to pool resources and to leverage funding to investigate a common concern effectively and economically.

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Suggestions for "Research Pays Off" topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (telephone 202-334-2952, e-mail gjayaprakash@nas.edu).

[1]http://rebar.ecn.purdue.edu/jtrp/Benefit03/2003%20Programs/SPR2143_RAP.pdf