Optimizing the Use of Recycled Asphalt in Minnesota Roads

What Was the Need?
To help reduce the costs and environmental impacts of road construction, MnDOT sometimes uses asphalt mixtures that include a percentage of recycled asphalt pavement recovered from roads and processed for reuse. However, RAP contains fine particles and aged asphalt cement that can cause pavement performance problems, including low-temperature cracking. Consequently, MnDOT currently limits the percentage of RAP used in mixtures based on the percentage of new to existing asphalt cement in the mix. Some Minnesota counties further restrict or prohibit the use of RAP in mixtures used for pavement surface layers or wear courses.

MnDOT and local agencies would like to use as much RAP as possible without compromising mixture specifications or performance. Doing so requires correlating the performance of mixtures to their quantities of RAP and new asphalt cement as well as evaluating how RAP blends with virgin aggregates, which are fresh mixtures of gravel and crushed rock. Researchers were particularly interested in how the recycled binder within RAP is activated during heating so that it coats virgin aggregate and interacts with the new binder added to such mixtures.

What Was Our Goal?
This project aimed to evaluate the performance of high RAP mixtures—those with 30 percent or more RAP—by analyzing RAP pavement performance, observing plant and laboratory RAP-asphalt activation, and evaluating the performance of various RAP mixtures at low temperatures.

What Did We Do?
Researchers analyzed MnDOT pavement performance data to determine the typical performance of asphalt mixtures with varying RAP amounts. Data included asphalt binder performance grade (which indicates the temperature range at which a binder is expected to perform), RAP percentage, transverse crack count and other field observations.

Then they studied RAP-asphalt activation in both a mixing plant and the laboratory to observe how well RAP binder transferred to and coated virgin aggregates. In the plant experiment, different proportions of RAP were blended with virgin aggregate at different temperatures, using no additional liquid asphalt binder. Researchers then attempted to reproduce these results in the laboratory using small batches of similar blends and conducted computer modeling of the resulting data to determine how various mix parameters affected the level of coating.

There was also a laboratory evaluation at low temperatures of eight mixture designs using binders with performance grades of PG 58-28 and PG 58-34, and RAP contents from 0 to 55 percent. Researchers used the indirect tensile test to evaluate both the strength of mixtures and their creep (how a material deforms when subjected to stresses). They also used the semi-circular bend test to evaluate toughness and fracture energy (how well materials resist cracking). Finally, they evaluated the critical temperatures at which mixtures began to perform poorly.
What Did We Learn?

Results showed that for roads built with mixtures containing an average of 20 to 26 percent RAP, using a low PG-34 binder instead of a low PG-28 binder improved transverse cracking by 40 percent per mile and crack spacing by 34 percent. A statistical analysis of data from five counties found cracking performance was most affected by a pavement’s age and the percentage of new asphalt binder in the mixture.

The asphalt activation study during plant mixing found a greater than 50 percent coating of coarse aggregate. For laboratory mixing, there was a less uniform coating and greater abrasion. The factors most influential in getting a complete coating were temperature, mixing time and heating time of RAP. When coating was partial, the percentage of RAP was important in determining the extent of the coating.

Laboratory testing showed that creep stiffness increased with RAP content, with most RAP mixtures being slightly stronger than non-RAP mixtures. The addition of RAP significantly increased the critical temperature for mixtures with PG 58-34 binder, predicting less crack resistance, although researchers found high-RAP mixtures difficult to characterize in this regard. The addition of RAP lowered the fracture energy and increased the fracture toughness of mixtures, with the highest RAP content usually having the most reduced fracture performance, especially at the lowest temperature.

What’s Next?

MnDOT currently has no plans to adjust RAP specifications, but will continue research into maximizing its use, with a focus on using fractionation to achieve higher RAP percentages and the disk-shaped compaction tension test for better characterization of low-temperature cracking. For better low-temperature performance in RAP wear courses, researchers recommend using a low PG-34 binder. For nonwear courses, further research is recommended to establish fracture properties.