Summary of Findings for Section N7 at the NCAT Pavement Test Track:
Surface Paving with 35% RAP Content and Delta S

Dr. Nam Tran, Assistant Director and the Principal Investigator for the North 7 Section at the NCAT Test Track
January 8, 2020
Evaluation of High RAP Mixture with Delta S Rejuvenator on the NCAT Pavement Test Track

It is a common practice among producers to use recycled asphalt pavement (RAP) as a component in new asphalt mixtures. Most state highway agencies allow up to 25% RAP to be used in their asphalt mixtures with the nationally average RAP content being 20.1% in 2017 (1). The amount of RAP allowed in asphalt mixtures has not increased over the years likely due to concerns that using higher proportions of RAP could result in asphalt mixtures that are prone to cracking and/or other durability issues.

Several methods have been investigated to reduce the potential effect of RAP binder on the field performance of asphalt mixtures. One of the methods is to use rejuvenators to restore some rheological properties of oxidized asphalt binders in RAP mixtures. These rejuvenators can be petroleum-based or bio-based materials that have been formulated to restore the balance of maltenes that were lost or transformed to asphaltenes in the oxidized RAP binder.

Delta S is a bio-based, commercially available rejuvenator developed by Collaborative Aggregates for use in recycled asphalt mixtures. This rejuvenator was used to produce an asphalt mixture with recycled materials placed in the surface layer of Section N7 for field performance evaluation on the NCAT Pavement Test Track since 2015. The field performance of the surface mix in Section N7 is being compared with that of the surface mix in Section N1, which is the control section for the ongoing Cracking Group experiment.

Experimental Plan

The two surface mixtures were designed to meet the volumetric requirements specified in AASHTO M323 with a design compaction effort ($N_{des}$) of 80 gyrations. The base and binder asphalt layers in the two sections consisted of the same highly polymer-modified (HiMA) asphalt mixture, which was designed to be resistant to fatigue cracking so that all cracking would occur in the surface layer. The aggregate base consisted of a 6-inch crushed granite layer. The subgrade at the Test Track is classified as an A-4 material according to the AASHTO soil classification system.

The surface layer of Section N1 was built using a 9.5 mm NMAS mixture with 20% RAP and a PG 67-22 virgin binder to represent a typical asphalt mixture being used in the United States. This mixture was selected as the control mixture for the Cracking Group experiment, which has been carried out at the NCAT Pavement Test Track since 2015.

The surface layer of Section N7 was built with a 35% RAP surface mixture. The construction of this section was part of a study sponsored by Collaborative Aggregates to evaluate the effectiveness of Delta S on the field performance. To produce the N7 surface mixture, Delta S was in-line injected into the PG 67-22 binder supply at a target rate of 5% by weight of RAP binder. To give the Delta S rejuvenator time to interact with the aged binder in the RAP, the mixture was stored in a silo for two hours before being transported to the Test Track for paving in Section N7.

The field performance of the two surface mixtures is evaluated based on weekly measurements of ride quality, rutting, and cracking. In addition, samples of plant mix were taken during construction of the two surface mixtures and tested in the laboratory to determine their stiffness, rutting, and cracking resistance.
Field Performance

At the end of the 2015 research cycle (from 2015 through 2018), the two surface mixtures in Sections N1 and N7 showed good ride quality and rutting performance. The area of cracking observed in the surface mixture of Section N7 was higher than that of the surface mixture in Section N1, but the cracks were very tight (less than 1 mm wide) near-surface cracks. Both sections (N1 and N7) were kept in place for continuing traffic for another research cycle to allow for a thorough field performance evaluation.

Figures 1 and 2 show the field performance of Sections N1 and N7, respectively, for the first half of the 2018 research cycle (starting in 2018). The area of cracking stayed the same at approximately 10 percent of the lane area for Section N1 while it slowly increased from around 20 percent to approximately 25 percent of the lane area for Section N7 in the first half of the research cycle (approximately 5 million ESALs). The cracks observed in Section N7 were still very tight as shown in Figure 3. In some areas, the cracks became connected, and some fines could be seen along some of the connected cracks (Figure 3b). To further evaluate the cracks observed in Section N7, field cores were extracted from the areas with the connected cracks. As shown in Figure 3c, these cracks appeared to develop from the bottom of Section N7 and propagate to the surface, affecting the performance of the surface layer in this study.

The average rut depths measured in both sections were still below 5.0 mm, indicating good rutting performance. Both sections showed good ride quality (IRI) and similar increasing trends in macrotexture.
Figure 1. Field Performance of Section N1 as of January 8, 2020
Figure 2. Field Performance of Section N7 as of January 8, 2020
Figure 3. Section N7 as of January 8, 2020 ((a) Hairline Cracks in the Wheel Paths, (b) Closeup of Hairline Cracks, (c) Field Core Confirming Bottom-Up Cracking)

Laboratory versus Field Cracking Performance

Table 1 summarizes the laboratory test results performed on the plant mixtures and their extracted binders for comparing with the field cracking measurements. The overlay test (OT) was conducted in accordance with the Tex-248F and NCAT-modified procedures while the Illinois Flexibility Index Test (I-FIT) was done following the AASHTO TP 124-16 procedure. Both tests have been used to evaluate the cracking resistance of asphalt mixtures (2-5). While the average test results shown in Table 1 were different for the Texas OT and I-FIT tests, they were statistically similar (same letter) when considering the variability of the test results. The NCAT-OT test results were statistically different, and they appeared to agree with the trends shown in the field cracking measurements with Section N7 having a larger area of cracking, which included both top-down and bottom up fatigue cracking observed in this section.

Table 1. Laboratory and Field Cracking Performance

<table>
<thead>
<tr>
<th>Mixture</th>
<th>$\Delta T_c$</th>
<th>Texas OT (Nf)</th>
<th>NCAT-OT (Nf)</th>
<th>I-FIT (Fl)</th>
<th>Avg. Field Cracking (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1 20% RAP</td>
<td>-9.4</td>
<td>25 (A)</td>
<td>556 (A)</td>
<td>3.58 (A)</td>
<td>11</td>
</tr>
<tr>
<td>N7 35% RAP + Delta S</td>
<td>-10.1</td>
<td>10 (A)</td>
<td>73 (B)</td>
<td>3.43 (A)</td>
<td>26</td>
</tr>
</tbody>
</table>

*Letters next to Texas OT, NCAT-OT, and I-FIT results represent groupings from statistical analysis.*
Summary
The two surface mixes showed good rutting and smoothness measurements and similar increasing trends in macrotexture in the first half of the 2018 research cycle (approximately 5 million ESALs). While the cracking performance for Section N1 stayed the same in the first 5 million ESALs, the area of cracking increased from around 20 percent to approximately 25 percent of the lane area for Section N7. Connected cracks were observed in some locations within Section N7, and the cores extracted from these areas showed these cracks initiated from the bottom layer and propagated to the top, affecting the cracking performance of the surface layer. The cracks in Section N7 were still tight, but some fines could be observed along some of the cracks. Thus, it is important to monitor the performance of Section N7 in the early spring as cracking may increase significantly due to cool temperatures. Finally, the field cracking performance appeared to agree with the laboratory cracking test results, especially those from the NCAT-modified OT test procedure.

References