TEST TRACK SHOWS OUTSTANDING RESULTS FOR WARM MIX WITH 50% RAP

*Article Courtesy of NCAT. By David H. Timm, Adriana Vargas-Nordcbeck, and J. Richard Willis**

Researchers at the National Center for Asphalt Technology's Test Track have observed excellent results from an experiment pitting conventional pavement mixes against mixes combining recycling and both hot-mix and warm-mix asphalt.

They constructed a control section of conventional hot mix, an experimental section using hot mix with 50% RAP (reclaimed asphalt pavement), and another section using warm mix from a foaming device with 50% RAP. The high-RAP sections had the same total thickness as the control section. In the latest cycle, concluded in September 2011, the high-RAP warm-mix section performed equal to the control.

The attractions of high-RAP and warm mix are compelling for both economic and environmental reasons. Faced with increasing material prices and traffic demands, pavement and materials engineers are constantly searching for innovative approaches to creating high-performing, long-lasting, and, most critically, economical pavement structures.

Use of RAP has been extensive for the past 30 years (McNichol, 2005). However, the amount of RAP allowed in pavement mixtures has been limited by some states due to concerns about the stiffness of the aged binder in the RAP and lack of documentation about long-term performance of high-RAP mixes.

Currently, average RAP contents are about 18%, with 15 states allowing greater than 30% while a few states permit little or no RAP usage (Hansen et al., 2011).

Agencies and industry recognize that increasing average RAP contents up to 25% could cut life-cycle greenhouse gas emissions by 10% (NAPA, 2009). In addition, warm-mix asphalt (WMA) has taken the industry by storm; the tonnage produced in the U.S. more than tripled from 2009 to 2010 (Newcomb, 2011).

Current estimates are a 20% energy reduction when utilizing WMA during production (NAPA, 2009).

Though warm mix and recycling technologies were developed independently, agencies have begun to consider combining them to achieve even greater environmental, performance, and cost benefits. NAPA (2009) estimates that 25% RAP combined with WMA could reduce greenhouse gas emissions by 3 million tons per year.

Achieving even higher RAP percentages could have an even greater impact from sustainability and cost perspectives. In addition, the use of WMA technologies can help improve workability, which is often an issue for high-RAP mixtures.

To explore the use of high RAP and warm mix, these materials became the main focus of a group experiment that began in 2009 at the Test Track. The experiment was sponsored by the Alabama, Florida, North Carolina, South Carolina, and Tennessee Departments of Transportation and the Federal Highway Administration. The study consisted of two sections with 50% RAP that have endured 10 million standard axle loadings, with performance equal to a control section placed at the same time.

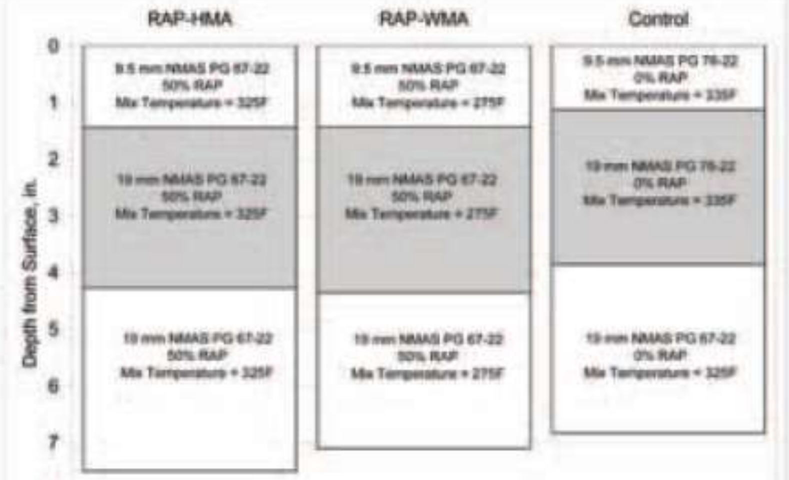

Figure 1. Pavement Materials and Cross Sections

Materials and Cross Sections

Within the experiment, there were three test sections, with each section having a surface, intermediate, and base mixture. The first section was the control; it did not include any RAP and the mixtures were produced as conventional hot mixes. The second test section contained 50% RAP in each layer and the mixes were produced as hot-mix asphalt (RAP-HMA). The third group used the same 50% RAP mixes, but the mixes were produced as WMA using a foaming system (RAP-WMA).

The virgin aggregate used in all three sections was a combination of granite and limestone. Each mixture was designed to 80 gyrations following the Superpave procedure. Within the 50% RAP materials, fractionated RAP was used for the surface (15% fine and 35% coarse RAP) and intermediate/base mixtures (20% fine and 30% coarse RAP).

Figure 1 illustrates the cross sections and as-built thicknesses with nominal maximum aggregate size (NMAS), virgin PG binder grade, and mixing temperature noted for each lift placed. Slight differences in total

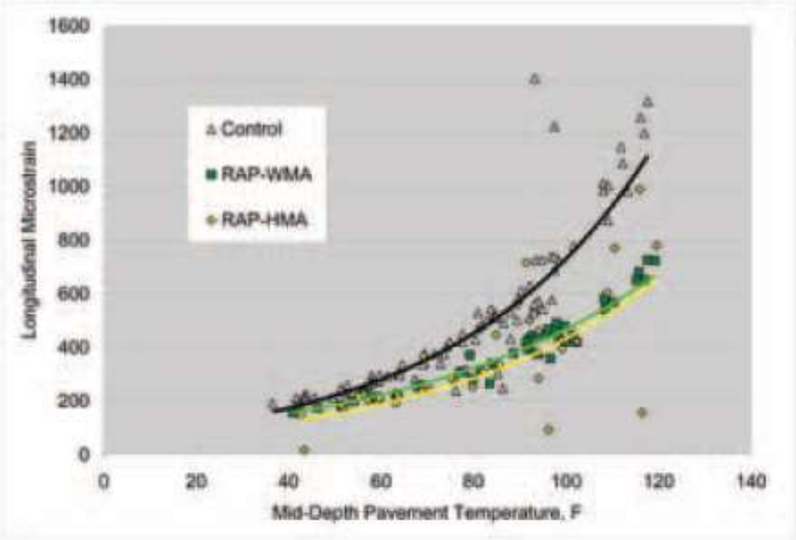

Figure 2. Pavement Response Under Traffic

thickness were noted and adjusted for during data analysis. Each section was placed on the same 6-inch aggregate base and subgrade foundation. Additionally, gauges were installed in each section during construction to measure pavement response under traffic throughout the two-year experiment.

Testing and Evaluation

Construction was completed and the sections were opened to traffic on August 28, 2009. A fleet of five triple-trailer vehicles circled the Test Track 16 hours a day, five days a week for a two-year period to accumulate approximately 10 million standard axle loads. During this time, extensive monitoring using the embedded gauges, pavement deflection testing, and performance monitoring were conducted. Additionally, extensive laboratory testing on each material was conducted to evaluate mechanistic properties and performance characteristics.

Pavement Response Under Traffic

Weekly pavement response measurements were made to determine how much the pavement was deforming under the applied traffic. Figure 2 shows the measured tensile strain in the bottom lift of each section versus measured mid-depth temperature. The control section clearly flexed more than either of the RAP sections.

Though the RAP-WMA fitted curve is slightly higher than the RAP-HMA curve, they were not found to be statistically different so their response could be considered about the same. The differences in the RAP sections compared to the control were much greater at warmer temperatures than cooler. For example, there was approximately a 30% reduction in strain level at 110°F when switching from the control

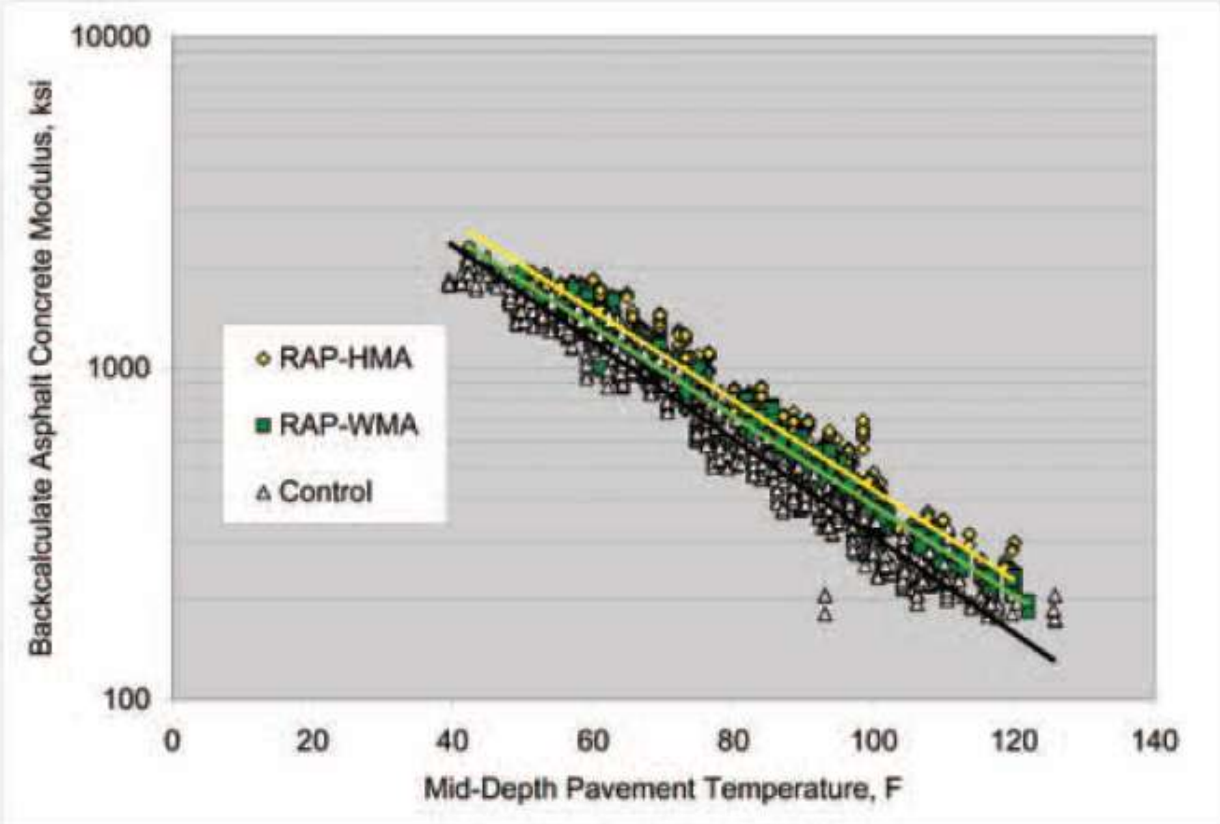

Figure 3. In-Place Material Properties

to the RAP sections. Conversely, at 50°F and below, there were no statistical differences between any of the sections.

Through the end of the 2009-11 research cycle, no cracking had been observed on any of the sections. Therefore, at this point, they could be judged to have equivalent cracking performance based on field data. However, some estimates regarding future cracking performance can be made using the field-measured strain from Figure 2 combined with laboratory beam fatigue testing conducted on each base mixture.

The reason the RAP sections have good cracking performance on the Test Track can be explained by the laboratory fatigue testing. The higher-stiffness RAP mixtures resulted in lower measured strains in the field compared to the conventional hot mix. Fatigue testing of higher-stiffness RAP mixtures at these lower strain levels results in a longer fatigue life in the laboratory.

Deflection Testing and Material Properties

During the test cycle, each section was subjected to deflection testing using a falling-weight deflectometer (FWD) several times per month. These deflections were used to find the in-place stiffness properties of each section using back-calculation. Figure 3 summarizes the in-place stiffness versus temperature. The fitted curves on each set of points shows, as expected, that the control section was softest, followed by the RAP-WMA section, with the RAP-HMA section the stiffest. Though there is scatter within the data, which might lead one to believe that they are similar, they are actually statistically significant, with the greater differences noted at the highest temperatures. For example, at 110°F, the RAP-WMA section was approximately 26% stiffer than the control while the RAP-HMA section was nearly 41% stiffer than the control. The increased stiffness contributed to the lower measured strain levels shown in Figure 2.

Performance

Each section was inspected on a weekly basis over the two-year traffic cycle. At the conclusion of traffic in September 2011, no cracking had been observed on any of the sections. Minor amounts of rutting were observed, with the control section having approximately 5 mm while both RAP sections were around 2.5 mm. The slightly better rutting performance could be attributed to the increased stiffness of the materials as noted above.

Moving Forward

After the first 10 million standard load applications, the 50% RAP sections have proven themselves to reduce strain levels through increased stiffness with the same total thickness as the control section. These differences are more pronounced at higher temperatures. Since no cracking and a very minor amount of rutting have been observed to this point, the plan is to continue traffic on these sections into the 2012 Test Track research cycle to more fully evaluate the sections. However, at this point, one cannot overlook the sustainability benefits in the short term by utilizing 50% RAP combined with WMA to achieve equivalent or better performance than through conventional materials.

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