BY DAVID JONES
CONTRIBUTING AUTHOR

Mild behavior

California tests the performance of warm-mix asphalt

Interest in warm-mix asphalt (WMA) technologies is on the rise as efforts to "green" the country's roadways increase.

However, before road authorities in most U.S. states will embrace WMA, they need data showing that it provides performance equal to or better than conventional hot-mix asphalt (HMA) and that potential problems related to lower-temperature compaction and moisture sensitivity will not hinder their efforts to use more environmentally friendly materials and techniques.

In 2007, the California Department of Transportation (Caltrans) tapped the University of California Pavement Research Center (UCPRC) as a partner in initiating a wide-ranging research study into the use of WMA in the state. The study's primary objective was to gather the data needed to answer the key issue about the relative performances of various WMA technologies and HMA, and as the project proceeded, it was expected to provide insight into any possible compaction and moisture-related problems.

With these questions in mind and working with Caltrans, WMA technology providers and asphalt and paving contractors, the UCPRC prepared a research work plan with a phased approach that would combine accelerated pavement testing (to address longer-term pavement performance questions), laboratory testing and field experiments on in-service pavements. The phased approach would give the study team the flexibility to adjust the plan as their research identified specific needs and priorities for the later phases. Designed as it was, the research would partly address the lack of data on longer-term performance of WMA, providing road authorities with some confidence to implement the technology on higher traffic volume roads.

20 in truck years

As the main study was formulated, researchers identified WMA's potential for early rutting as their primary concern; this concern arose from the knowledge that the lower temperatures used to produce and compact WMA would result in less binder aging and potentially a lower mix stiffness, while historically, compacting at lower temperatures usually results in higher air void contents and lower densities. To address this, an accelerated pavement test, using the Caltrans Heavy Vehicle Simulator (HVS) was designed.

The HVS is a mobile accelerated pavement-testing machine that is used to understand pavement behavior by applying controlled loads under controlled pavement and environmental conditions. In 1995 Caltrans purchased two of the machines, which are operated by the UCPRC team and have been used to assess a wide range of pavement design issues in the state. As much as 20 years of truck traffic can be simulated in a three-month test, thereby lowering the risk and accelerating the implementation of new or improved technologies on high-traffic roads.

In this study, the performance of three WMA technologies—Advera, Evotherm DAT and Sasobit (supplied by the PQ Corp., MeadWestvaco and Sasol Wax North America, respectively)—would be compared against an HMA control on a special test track built at the Graniterock Co.'s A.R. Wilson Quarry near Aromas, Calif.

The test track was constructed in September 2007, using asphalt from the commercial asphalt mix plant at the quarry. Test sections were built according to a standard mix design used for projects in the vicinity of the asphalt plant, without adjustments to accommodate the additives. Target production temperatures for the control mix were set at 310°F and at 250°F for the warm mixes.

Degrees of warm

After allowing the pavement test track to cure for six weeks, researchers turned to the investigation of early rutting development by beginning the first phase of HVS testing in October 2007 and ending it in April 2008.

The development of rutting in a pavement occurs in stages, the first of which is called the "embedment phase" where a rut develops relatively quickly and then slows down or stabilizes before it enters its next phase. The study's main interest in this first phase of HVS testing focused on the early rutting performance of the various mixes at elevated temperatures (pavement temperature of 122°F at 2 in.), using the maximum legal truck load.

Meanwhile, the researchers conducted a concurrent laboratory study comprising a series of tests on specimens sawed or cored from the test track to determine whether California's current laboratory performance tests were appropriate for assessing WMA and to identify priorities for future phases of the study.

Lab work included shearing tests to assess rutting performance (a short-term performance issue), moisture sensitivity tests (typically a medium-term performance issue) and fatigue cracking tests (to assess long-term performance). Altogether, they carried out a total of 144 shear tests (using different temperature and stress configurations), 384 fatigue tests (with varied temperature, strain and moisture conditions), 16 Hamburg Wheel Track moisture sensitivity tests and 56 retained tensile strength moisture sensitivity tests.

Key findings and observations from mix production and construction included:

- A minimal number of modifications to the asphalt plant were needed to accommodate the warm-mix additives;
- No problems were noted with producing the asphalt mixes at the lower temperatures. The target mix production temperatures (i.e., 310°F and 250°F) were achieved;
- Although a PG 64-16 asphalt binder was specified in the work plan, subsequent tests by the Federal Highway Administration indicated that the binder was rated as PG 64-22. However, this was not expected to affect the outcome of the experiment. After mixing Sasobit into the binder, the PG grading changed from PG 64-22 to PG 70-22. The addition of Advera and Evotherm did not alter the PG grade;
- The control, Advera and Evotherm mixes met the project mix design requirements. However, the binder content of the Sasobit mix was below the target binder content because of a binder feed problem at the asphalt plant. This was accounted for when interpreting the HVS and laboratory test results;
- Although the moisture content of the mixes with additives were notably higher than those in the control mix (which indicates that potentially less moisture will evaporate from aggregates at lower production temperatures), all the mixes were well within the minimum Caltrans-specified moisture content level;
- Construction procedures and final pavement quality did not appear to be influenced by the lower construction temperatures. The Advera mix showed no evidence of tenderness, and acceptable compaction was achieved. Some tenderness was noted on the Evotherm and Sasobit sections resulting in shearing under the rollers at various stages of breakdown and/or rubber-tired rolling, indicating that the compaction temperatures were still higher than optimal. No problems were observed after final rolling at lower temperatures. Optimal compaction temperatures are likely to differ among the different warm-mix technologies;
- Some haze/smoke was evident on the control mix during transfer of the mix from the truck to the paver. No haze or smoke was observed on the mixes with additives;
- Interviews with the paving crew after construction revealed that improved working conditions were seen as a big advantage. While they experienced no problems with construction at the lower temperatures, tenderness on the Evotherm and Sasobit sections was not considered as being significantly different from that experienced with conventional mixes during normal construction activities;
- Although temperatures at the beginning of compaction on the warm-mix sections were considerably lower than the Caltrans-specified limits, the temperatures recorded

Lab work included shearing tests to assess rutting performance, moisture sensitivity tests and fatigue cracking tests.

on completion of compaction were within limits, indicating that the rate of temperature loss in the mixes with additives was lower than that on the control mix, as expected;

- Based on density measurements taken during and after construction, it was concluded that adequate compaction can be achieved on warm mixes at the lower temperatures; and
- Skid-resistance measurements using the standard Caltrans method indicated that the warm-mix additives tested do not influence the skid resistance of an asphalt mix.

HVS trafficking on each of the four sections revealed that the duration of the embedment phases (high early-rutting phase of a typical two-phase rutting process) on the Advera and Evotherm sections were similar to that of the control. However, the rut depths at the end of the embedment phases on these two sections were slightly higher than the control, which was attributed to less oxidation of the binder during mix production at lower temperatures.

After the embedment phase, rutting behavior of the warm-mix sections followed trends similar to the control. The performance of the Sasobit section could not be directly compared with the other three sections given that the binder content of the mix was lower.

Laboratory test results indicated that use of the warm-mix technologies assessed in this study did not significantly influence the performance of the asphalt concrete in terms of rutting and fatigue when compared with control specimens produced and compacted at conventional HMA temperatures.

Performance of the Advera and Evotherm mixes was essentially the same as the control, while the Sasobit performed slightly better in the rutting tests and slightly worse in the fatigue cracking tests as a result of the lower binder content.

Moisture sensitivity testing indicated that all the mixes tested, including the HMA control, were potentially susceptible to moisture damage. There was, however, no difference in the level of moisture sensitivity between the control mix and mixes with warm-mix additives. Significantly, the compatibility of the laboratory rutting test results with HVS test results indicated that they are appropriate measures of expected field performance.

Another round

Encouraged by the results and the data amassed in the first part of this study, Caltrans requested a second round of HVS tests for a deeper assessment of the potentially troublesome issue of the mixes' moisture sensitivity. New HVS test track sections were prepared by presoaking with water for 14 days (holes were drilled around the outside of the section to the bottom of the first lift of asphalt).

The same HVS testing program used for the Phase 1 HVS testing was repeated on these new sections while a constant flow of water across the surface and the drilled holes was maintained. The water was heated to 122°F to keep the pavement surface from cooling. After this round of testing was completed, no moisture-related damage was observed on any of the sections despite the aggressive testing program. In fact, observers found that all the sections actually withstood more HVS repetitions in reaching the failure criterion (a ½-in. rut) set for the experiment in the second phase of testing compared to the first phase. (This extra rut resistance was attributed to oxidation of the binder in the 12 months after construction.)

Using the results gathered from these two phases of HVS and lab testing and from pilot studies in various locations around the state, Caltrans and industry representatives are formulating a process for approving the use of WMA technologies and revising specifications to allow the use of WMA on projects statewide. Meanwhile, the Caltrans/UCPRC partnership is planning a third phase of field HVS and laboratory testing that will assess use of warm-mix technologies with rubberized HMA.

Jones is the project scientist and principal investigator at the University of California-Davis.