By Paul Fournier
Contributing Author

Highly motivated

Use of binder allows crews to do more with less asphalt

Recent research by the National Center for Asphalt Technology (NCAT) indicates the use of highly polymer-modified asphalt binder (HiMA) in mix design can reduce pavement thickness requirements while matching or exceeding the cracking and rutting resistance of significantly thicker non-HiMA mixes.

Findings from the 2009-11 research cycle at NCAT's Pavement Test Track in Opelika, Ala., show a sponsored pavement section incorporating HiMA binder experienced less than one-third the wheel-path rut depth of the track's control section, which is 20% thicker. Both mixes employed the same Superpave mix design methodology.

In addition, a failed adjoining pavement test section for a different sponsor that was repaired using HiMA technology showed similar results.

A third pavement test section incorporating HiMA binder was constructed at the track for NCAT's 2012-14 research cycle and is currently undergoing heavy truck traffic. A fourth section was installed on a local county road as part of a comprehensive pavement-preservation experiment.

Bigger dose

NCAT's 1.7-mile oval track was designed for accelerated testing of up to 46 individual 200-ft pavement sections in which a design lifetime of pavement damage is compressed into two-year trafficking cycles. Track sections are sponsored by state transportation departments, private industry and others, with NCAT personnel operating and maintaining the track under Assistant Director/Track Manager Dr. Raymond "Buzz" Powell, P.E.

Research cycles take three years, allowing time for construction, two years of truck trafficking, forensics, data analyses and report preparation. Researchers measure and analyze changes to pavement cross sections, including wheel-path rutting caused by continuous heavy truck traffic that imposes 10 million equivalent single-axle loads of 18,000 lb (ESALs) over a two-year period.

NCAT's 2009-11 research cycle began in August 2009 with the reconstruction of 17 test sections. One of the sections, North 7 (N7), incorporates HiMA technology developed by the sponsor, Houston-based Kraton Performance Polymers.

Kraton developed this technology to improve pavement durability and resistance to rutting, shoving and cracking while reducing pavement thickness. HiMA employs significantly higher polymer dosages than those traditionally used in the U.S.

Usually, as polymer content in asphalt binder exceeds 3 to 4%, binder viscosity begins increasing, eventually reaching a point where hot-mix asphalt (HMA) becomes difficult to produce in an asphalt plant. The increased viscosity also reduces workability for paving crews. To address this limitation, Kraton created D0243 copolymer, a modified styrene-butadiene-styrene (SBS) polymer that can be blended with asphalt binder at dosages of 7.5% and higher, gaining the benefits of increased polymer content without substantially increasing binder viscosity.

Thin strength

Section N7 pavement was constructed 5¾ in. thick, with three layers of HMA each containing HiMA binder modified with 7.5% copolymer. The 2¼-in. base layer and 2¼-in. middle layer each contained 19-mm dense mix, and the wearing course was a 9.5-mm dense mix placed 1¼ in. thick. Mix design, design gyrations and other factors were kept the same as the control section to ensure the only variables would be the binder and layer thickness.

The 7-in.-thick control section S9 consisted of three layers—a 3-in. base, 2¾-in. middle course and 1¼-in. wearing course. Top and middle layer binders are conventionally modified with SBS.

Both sections employed identical Superpave design method and aggregate type, but N7's pavement was 18% thinner than S9's pavement and used HiMA binder instead of the SBS-modified PG 76-22 binder used for the control pavement.

Truck trafficking for the 2009-11 cycle concluded on reaching the 10 million ESALs goal in September 2011. Researchers studied accumulated data and arrived at conclusions that were presented at NCAT's Pavement Test Track Conference, held Feb. 28-29, 2012, at Auburn University Hotel and Conference Center.

The findings revealed the average wheel-path rut depth of the N7 HiMA section was less than a third of the control section.

Specifically, Section N7 rut depth was 0.09 in., while S9 rut depth was 0.28 in.

Researchers also reported there were no cracks in either pavement with the completion of 10 million ESALs at the end of the 2009 research cycle. Less than a million ESALs into the next research cycle in fall 2012, several of the 7-in. comparison sections had exhibited small amounts of cracking; however, the thinner HiMA section had still not cracked. Based on preliminary results from weekly roughness and high-speed response measurements, this trend is expected to continue.

Try HiMA instead

Corroborating evidence of HiMA effectiveness was provided by the repair of an adjoining test section on a soft clay subgrade.

Sponsored by the Oklahoma Department of Transportation, Section N8 had failed during the 2006-08 cycle, exhibiting extensive fatigue cracking. The top 5 in. of the 10-in. pavement was milled out and filled with the same mix designs, but the pavement failed again, in just eight months (about a third of the way through the 10 million ESALs research cycle).

NCAT suggested that Oklahoma officials try reconstructing the top 5¾ in. of N8 using the HiMA design that had been used on N7. They agreed to do so but downsized the base course aggregate to a 9.5-mm mix to mitigate reflective cracking from the remaining damaged pavement. Additionally, the binder content in the base was increased in a rich bottom approach.

On Aug. 17, 2010, crews removed the top 5¾ in. of existing N8 pavement and replaced this with HiMA mix. Truck traffic resumed immediately, and NCAT instruments continued collecting data.

When truck trafficking concluded in September 2011, the average rut depth

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Design questions to be addressed

Kraton's chief asphalt chemist, Dr. Bob Kluttz, said empirical data obtained from the NCAT Pavement Test Track will be helpful in addressing important questions about designing pavements using such advanced materials as highly modified asphalt binders.

"How do we design pavements with these materials? How thick do we need to design HiMA pavements to be perpetual? In rehabilitation and overlay, how thick does the HiMA structure need to be to prevent damage to the substructure? These are some of the issues we are investigating," said Kluttz.

In his work on pavement design, Kluttz is focusing on calibrating HiMA characteristics with parameters employed by design methodologies of the American Association of State Highway & Transportation Officials (AASHTO). At present, Albuquerque-based Applied Research Associates has been developing DARWin-ME software, which updates and supports AASHTO's Mechanistic-Empirical Pavement Design Guide, Interim Edition: A Manual of Practice.

AASHTO's design guide aims to identify physical causes of pavement stress (the mechanistic element) and calibrate them with observed pavement performance (the empirical element). But there is a problem in matching HiMA characteristics with this methodology, said Kluttz.

"AASHTO and MEPDG/DARWin ME use layered elastic damage models that are largely empirical. For example, the design models for DARWin-ME were based on fits to some 8,000 data points of actual field performance of unmodified asphalt, so fatigue and rutting behavior are determined by asphalt modulus and pavement design. When we introduce a different type of binder such as HiMA that has exceptional fatigue resistance and resilience, there is no standard input to address these characteristics," he said.

To address this issue, Kraton researchers are adjusting HiMA calibration factors for use in DARWin-ME and also are adjusting structural numbers employed in the original AASHTO 93 (DARWin 3.1) methodology. For DARWin-ME this involves inputting fatigue endurance limits ascertained by such tests on HiMA specimens as four-point bending beam or Asphalt Mixture Performance Tester (AMPT) push-pull testing. In addition, they are investigating the use of technology developed as part of a National Cooperative Highway Research Program (NCHRP) project using data from the AMPT flow number test to adjust rutting calibration factors.

"We have used this methodology for pavement designs in Brazil and hope to do the same for projects in the U.S. in the coming year," Kluttz concluded.

of repaired Section N8 was 0.11 in., compared with the 0.19-in. rut depth of the perpetual control section. Moreover, there was no surface cracking. The HiMA rehabilitation had survived approximately 30% more traffic than the initial stone-matrix asphalt (SMA) over dense-graded Superpave mill and fill, with no indication that distresses were pending in either surface performance measurements or high-speed pavement response. This trend is expected to continue in the 2012 research cycle.

Three DOTs are sponsoring four sections as a Green Group, which will compare the performance and structural responses of four test sections that combine high-recycled-content mixtures with perpetual pavement design principles.

Turning green

Kraton and Oklahoma are continuing their sponsorship of the N7 and N8 sections, respectively. In addition, the DOTs of Alabama, North Carolina and South Carolina are sponsoring four sections as a "Green Group" in partnership with the Alabama Department of Environmental Management (ADEM).

The Green Group will compare the performance and structural responses of four test sections that combine high-recycled-content mixtures with perpetual pavement design principles, with a goal of reducing initial pavement costs and extending pavement lives. All were produced using warm-mix asphalt (WMA) technologies.

The control section incorporated 20% reclaimed asphalt pavement (RAP) in the surface layer and 35% RAP in the intermediate and base layers.

A second section has an SMA surface layer containing 25% RAP, an intermediate layer with 50% RAP and a base layer containing 35% RAP and HiMA.

The third section has an SMA surface with 5% post-consumer shingles and no added fibers. The intermediate layer contains RAP and recycled shingles to achieve 50% recycled binder content, while the base layer contains 25% RAP and a PG 76-22 binder in a rich bottom design.

For the fourth section, the surface layer consists of SMA with ground tire rubber (GTR) and no added fibers. The intermediate layer has 35% RAP and GTR-modified binder, and the base layer comprises an "Arizona" gap-graded asphalt-rubber mix with 20% GTR.

In commenting on the experiment, Powell said, "State DOTs want to consider materials that will reduce the cost of pavement construction, but they need to implement changes in a way that does not negatively impact pavement life. Ideally, we need to reduce the cost of construction while we lengthen pavement life. The track is a tool that allows them to do that." **AT**

Fournier is a free-lance writer based in Nashua, N.H.

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