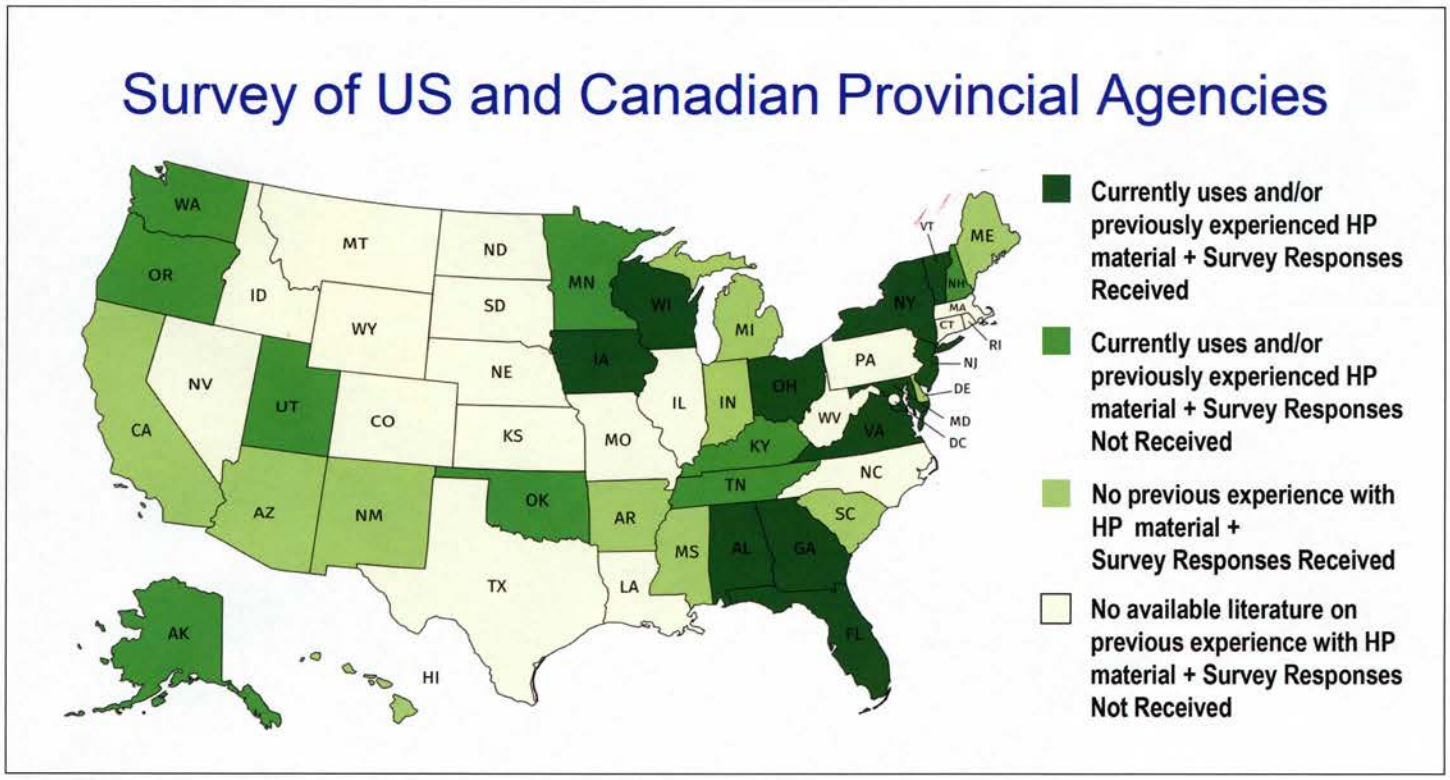

HiMA use from coast-to-coast; U.S. map indicating agencies' experience status with high polymer-modified (HP) asphalt concrete (AC) mixtures (from State of the Practice for High Polymer-Modified Asphalt Binders and Mixtures, Transportation Research Record (TRR) 2021; and Laboratory and Field Performance Evaluation of Pavement Sections With High Polymer-Modified Asphalt Overlays, VTRC 2021

States Balance RAP Content for Successful High Polymer Use

BY TOM KUENNEN

Editor's Note: With the asphalt industry's desire to increase reclaimed asphalt pavement (RAP) use in mix designs, many additive suppliers are offering products to improve and/or restore oxidized binder properties to assist in raising RAP percentages. This article explores the role of high polymer modification in such efforts.

High polymer-modified asphalt (HP) mixes are being adopted by state departments of transportation (DOTs) across the United States, but the DOTs differ on the percentage of reclaimed asphalt pavement (RAP) that they will use with confidence in those mixes.

Polymer modifiers can improve the performance of asphalt pavements. While modification of liquid asphalt binders with polymers has been shown to improve resistance to cracking, rutting and raveling of pavements, there is a practical limit to conventional polymer concentration.

Typically, as polymer concentration exceeds 3%, the viscosity of the binder increases such that the mix becomes more difficult to produce in the plant and less workable for the paving crew. However, Kraton™ D0243, which is a styrene-butadiene-styrene (SBS) product manufactured by Kraton Performance Polymers Inc., Houston, has been used in larger percent applications than conventional polymer modifiers.

This material is labeled HiMA* (for Highly Modified Asphalt), or generically HP for high polymer, and is designed to provide enhanced durability. It is provided as a terminal blend with asphalt binder that may contain up to 7.5% SBS polymer. In addition to enhanced crack- and rut-resistance, HP mixes permit durable thinner lifts, counterbalancing the increased cost of the modifier.

As a result, DOTs are looking closely at the characteristics of mix designs containing HiMA, in particular the percentages of RAP, with a goal of optimizing design for durability and crack resistance, while not overly diluting the HiMA binder content with residual asphalt binder from the RAP.

COAST-TO-COAST EXPERIENCE

Referring to HiMA as HP for high-polymer, Virginia DOT has used HP extensively. Its research arm, the Virginia Transportation Research Council (VTRC), last year released a survey of HP use by other states and Canadian provinces (State of the Practice for High Polymer-Modified Asphalt Binders and Mixtures, 2021).

"In general, HP AC mixtures have been used in a wide range of applications, ranging from full-depth AC, to thin AC overlays under heavy traffic on interstates and slow-braking loads at intersections," the authors wrote (see sidebar).

"No major field-related construction issues in relation to mixing temperatures and in-place compaction of HP AC mixtures were reported by agencies; standard construction practices and equipment were adequate," they wrote. But HP is a different animal, they said, adding "the majority of SBS polymers used to produce HP asphalt binders have a different chemical structure than those used to produce conventional PMA asphalt binders."

Yet with HP mixes, states are keeping their standard practices, they found. "No changes to current routine practices were identified by agencies as part of their quality control and quality assurance program with regard to placing HP AC mixtures," they wrote. "No practices or enforcements of specific safety, health, or environmental restrictions were identified by agencies with regard to using HP asphalt binders in AC mixtures."

The inventory of liquid asphalt used and HP mixtures produced should be tracked on a daily basis to make sure the HP asphalt binder is not stored longer than its recommended shelf life, and warm mix additives can be used to attempt to increase the workability of produced HP AC mixtures, they concluded.

VIRGINIA CHOOSES HP MIXES

The Commonwealth of Virginia owns most of the pavements in the state, so is burdened with maintaining 5,000 lane miles of interstate highway, and another 22,000 lane miles of primary-level highways, said Jhony Habbouche, Ph.D., P.E., research scientist, VTRC, VDOT. Much of these highways are asphalt-over-concrete, and the commonwealth has been at war against reflective cracking of concrete joints, more so than fatigue cracking or bottom-up cracking.

"Reflective cracking, coming from the joint, is the major driver for VTRC and VDOT to explore more innovative technologies and alternatives in order to prevent or reduce such type of cracking in AC overlays," Habbouche said. "We aim to totally stop reflective cracking, but this will never happen. Therefore, we try to delay it as long as we can. VDOT explored and is still exploring numerous treatment strategies to mitigate reflective cracking. This includes saw and seal, in-place recycling, crack-relief mechanism (e.g., fabric pavement interlayers, chip seals), fracture slab processes, and asphalt mixes with expected higher cracking resistance. The use of high polymer-modified HP AC mixes has been one of many promising alternatives being considered in Virginia."

Due to its cost, Virginia uses HP only in surface mixes, as they are most vulnerable to reflective cracking. "For us in Virginia, it would not be cost-effective to go HP on a full AC depth," Habbouche said. "We have good mixes that perform well, so really HP is used more on jobs with jointed concrete pavement where we have major issues with cracks reflecting through."

Currently, Virginia applications treat HP-modified mixes the same as its standard polymer-modified mixes. But it's taken the further step of using HP to bolster its stone matrix asphalt (SMA) mixes. Given their premium aggregates, higher asphalt binder content, and load of polymer modifier and fibers, inexperienced contractors may find SMA mixes difficult to place. But in 2014 and 2015, Virginia's contractors rose to the occasion.

"Virginia was one of the first states to deal with HP SMA and I want to give credit to our very talented asphalt contractors in Virginia," Habbouche said. "The first time they placed an SMA with an HP, it was difficult, whether in producing, transporting or compacting the mix. Virginia contractors can now produce, transport and compact any HP SMA mix like they would in any unmodified mix."

HP base course containing 35% RAP is placed at the NCAT test track by East Alabama Paving. *Photo courtesy of NCAT*

These HP SMA overlays—like nearly all Virginia mixes with modified asphalt binders—contain 15% RAP, and Habbouche has not seen any problems with combining RAP with HiMA. "We haven't seen any incompatibilities at the moment, but we're taking baby steps," he said. "We are allowing up to 15% RAP, because we've had good experience when allowing up to 15% RAP in a regular polymer modified mix, our reference point."

QUELL REFLECTIVE CRACKING

Most of Virginia's initial placements of HP or HiMA mixes have been in the Northern Virginia suburbs of Washington D.C., said David P. Shiells, P.E., Northern Virginia district materials engineer with VDOT.

"Northern Virginia is one of the busiest districts in the Commonwealth," Shiells said. "We have a significant amount of the statewide construction and maintenance work, so we need to keep up with technological advances. In fact, we were the first Virginia district to try high polymer asphalt back in 2014."

Even though the first placement of HP mix was a trial with a Superpave 9.5 mm mix in a subdivision, Shiells never lost sight of the primary application: interstate highways.

"We started small because we did not know how this material was going to perform and whether it was going to be difficult to place," he said. "Obviously, the main focus was on interstate pavements where we have a lot of reflective cracking from transverse joints in the underlying concrete. We were hoping that the HP mix would reduce the severity of the reflective cracking."

In 2015, the following year, VDOT placed a HiMA on nine miles north- and southbound I-95 in Prince William County. "We used the high polymer binder in a Superpave 12.5 mm surface mix, placed 2 inches thick," Shiells said. "That's typically what we use on our interstates in a mill-and-resurface project. We simply replaced the regular PG76-22 binder with a terminal blend high polymer binder." This mix also contained 15% RAP. Since then, the Northern Virginia district pioneered, and has also been successfully placing, HP SMA on the interstates.

"Trying to patch reflective cracks is time-consuming and expensive," Shiells said. "Milling down to the concrete is difficult because we can only get a deep patch across one or two lanes at a time. We have to mill out one or two lanes, place and compact the patch material in lifts, and

In Utah, a 6-inch-thick lift of HP-modified mix containing 15% RAP is placed at Wendover truck weigh station in summer 2021. *Photo courtesy of the Asphalt Institute*

then repeat the process on the remaining lanes. We have a very limited window for lane closures, which are typically limited to between 10 p.m. and 5 a.m., so if we can do a regular 2-inch mill and resurface, it limits the amount of disruption that we cause to the traveling public and improves cost effectiveness," Shiells added. All this supports HP mixes instead of deep concrete repairs.

BASES AT NCAT

HP mixes have been studied for over a decade at the National Center for Asphalt Technology (NCAT) at Auburn University. At NCAT, HiMA modifier was used in its test track sections during its 2009-2012 research cycle. There, the manufacturer's Section N7 and Oklahoma DOT's Section N8—repaired with HiMA—performed so well that the Oklahoma DOT decided to use HiMA on I-40 west of Oklahoma City, where it's intended to resist rutting and reflective cracking.

This project was built in 2012 and continues to provide excellent performance. According to pavement management system data available on Oklahoma DOT's website, in 2021 this section of highway has minimal cracking or rutting and has excellent ride quality (IRI < 50 inches/mile). NCAT's test track also has been studying use of RAP with HP mixes via its 2012 Green Group and 2015 Cracking Group experiments.

"We started with HiMA modified binder back in 2009, when we did a full depth structural section as well as a mill/inlay using virgin mixes that performed in an outstanding manner," said Dr. Buzz Powell, P.E., NCAT associate director and research professor. Later, in the 2012 track cycle, NCAT had a centerpiece group experiment it called the Green Group, using mixes not unlike those in many state DOTs, with RAP in the base, intermediate and surface courses.

"We had 35% RAP bottom and the middle layers, and 20% RAP in the surface," Powell said. "We used this as the control section because those are pretty common numbers for state DOTs to use 35% RAP below the surface and 20% RAP surface."

One section, S5, had an HP base mix containing 35% RAP and neat binder intermediate lift with 50% RAP. This high-RAP focus section, part of the Green Group, was rebuilt in 2013 due to bond failure between the base and intermediate layers. In the successful rebuild, a heavier tack coat was used, but no changes were made to the original mix design for the HiMA base mix. The rebuilt section S5 supported more ESALs than any other section in the experiment.

NCAT's 2015 Cracking Group experiment relied on HP base and binder courses to preclude potential bottom-up cracking that could interfere with the study of surface cracking.

"We wanted all the cracking to be surface cracking," Powell said, "so we built bottom layers and middle layers using HiMA and containing 17% RAP as an experimental control, and then placed a variety of different types of mixes on the surface that we evaluated in the laboratory. Pavement thickness was intentionally thin in order to produce higher deflections. We used the HP binder to make sure that we didn't have any distresses down below the surface, that all the distresses that we saw would be in the surface layer. The HP lower pavement layers performed exactly the way we hoped they would, and we were able to isolate the cracking just to the surface layer in every test section."

For this work the HP-modified base and intermediate layers were 2 ¼ inches thick, each containing 17% RAP, and the virgin various surface layers were 1 ½ inches thick.

UTAH'S THICK LIFT

In a summer 2021 application, Utah DOT skipped using HP-modified pavement layers in favor of a deep, HP-modified 6-inch-thick pavement placed at a truck weigh station subject to rutting. This HP mix contained 15% RAP.

Previously Utah DOT had lab-tested, using the Hamburg, incrementally richer dosages of HiMA binder in a typical Utah 12.5 mm Superpave mixture, up to 6.8% binder, which closed air voids. The same slabs were tested a second time with an additional 20-pound load and still passed the 10-mm requirement.

Encouraged by these laboratory results, Utah placed two HiMA sections on state routes, in which the HP binder was substituted for conventional binder with no other changes. This led to placement of the 6-inch HP lift at the weigh station, where truck queues might require costly Portland cement concrete pavements on approaches. Evotherm** modifier was added as a compaction aid.

Why such a thick lift? "The quality of the pavement is better because we have better compaction numbers," said Howard J. Anderson, P.E., state asphalt engineer, Materials Division, Utah DOT. "We don't need a tack coat and we can build the pavement faster with less testing.

"That's because we are so far past the danger area of density that we feel that we can reduce coring in the future, as the normal UDOT spec is at least 93.5% compaction," Anderson said. "We don't want anything that has 8% or more voids. And if everything that we're putting down is so far above that, then our risk for density is much less and our quality is much higher."

The lift was placed 7 ½ inches deep and compacted to 6 inches, where Utah achieved 97% compaction for the full depth. "I could have put down 8 or 9 inches of this mix, and I wanted to, but the region cut us back because we normally have asphalt projects up to 6 inches in depth," Anderson said. "We could do that because with the compaction aid it's lubricated enough to get density we want. That's a target density of 96% for the top 3 inches, with lower limit to 94%."

While this HP mix contained 15% RAP, Anderson felt he could go higher, up to 25%, as long as the total binder content was high enough to provide the lubrication for thick lift compaction and the mix passed the Hamburg rut test, but for this application they wanted to be conservative as higher RAP amounts might complicate compaction.

The original mix design called for 5.6% total binder, but in Anderson's opinion was not enough to facilitate the kind of lubrication that would

Florida DOT fights rutting at agricultural inspection stations with HP asphalt mixes. *Photo courtesy of University of Florida*

meet his requirements for voids filled with asphalt. "Because we know that we're not sensitive to being over-asphalted, we moved it up to a total of 6% binder," Anderson said. "At that level, we had 1% voids at 50 gyrations, we just had enough to facilitate the compaction, and it turns out it wasn't too much. Based on our lab tests, we could have used 6.5% and still not be in a rutting situation.

"The high mod permits the higher percent, and it permits it without rutting," Anderson added. "It's a very different feel as you get used to this material, compared to a conventional mix. And it goes against what you're used to. It goes against the normal rules. You're closing down air voids and you're putting yourself in what would normally be a rutting situation; but because the glue is that good, instead of putting you into a rutting situation, it's just giving you an even stronger pavement."

After more than five months of tremendous truck traffic at the I-80 port of entry, the pavement has not budged or flushed, and the performance is outstanding, Anderson said.

FLORIDA: HP, BUT NO RAP

HiMA is the Sunshine State's premium binder to address severe rutting, bottom-up fatigue (alligator) cracking, and raveling (in OGFC mixtures).

Florida DOT uses it to enhance mixes and refers to it as a high polymer (HP) binder. Since 2015, the state's completed 39 projects with high polymer binder and placed over 522,000 tons of high polymer mix.

According to public information, HP binder replaced PG82-22 in FDOT's July 2017 spec book. However, it imposes limitations on its use. It must use SBS or SB polymer only, with no polyphosphoric acid. In particular, no RAP is permitted in HP mixtures, while up to 20% RAP is allowed in conventional polymer modified mixes.

Only 0.3% of FDOT's system is deficient due to rutting; however, rutting is a significant safety concern as traffic is increasing and rutting is occurring at agricultural inspection stations, truck weigh stations and at urban interchanges, where HP mixes are an alternative to placement of more expensive PCC slabs.

FDOT determined there is roughly a 20% increase in structural capacity for high polymer binder mixtures compared to asphalt mixtures containing PG76-22 binder.

Its performance with respect to both rutting and cracking is increased, the state said. Recently the DOT learned through research that it improves the durability or raveling resistance of OGFCs.

Despite the fact that Florida DOT uses HP mixes successfully, it does not allow use of RAP in HP/HiMA mixes. Considering HP mixes are more costly, the state doesn't want to run the risk of the residual binder on the RAP diluting the effectiveness of the HiMA binder, which is delivered as a terminal blend in an exact dosage.

The February 2020 technical paper, "Enhanced Characterization of RAP for Cracking Performance," University of Florida Department of Civil and Coastal Engineering, described research into allowed amounts of RAP in conventional polymer modified and HP mixes. It stated:

- Characterizing RAP binder stiffness and RAP fineness is required to increase the current maximum RAP content (20%) in polymer modified asphalt (PMA) mixtures.
- The specific maximum RAP limits based on RAP binder stiffness and RAP fineness, proposed in the study, may be used to successfully introduce up to 40 percent RAP in PMA mixtures, and
- Incorporation of 20 percent RAP in HP mixtures would sacrifice the premium benefits of HP binder. AP

** HiMA is either a trademark or registered trademark of Kraton Corporation or its subsidiaries or affiliates, in one or more, but not all countries.*
*** Evotherm is a trademark of Ingevity LLC, North Charleston, South Carolina.*

LEARN MORE

Much more information on HiMA and its performance with RAP in the field and the lab is available from research reports referenced in this article. Please visit these sites to download the reports:

Laboratory and Field Performance Evaluation of Pavement Sections With High Polymer-Modified Asphalt Overlays, by Jhony Habbouche, Ph.D., P.E., Ilker Boz, Ph.D., and Brian K. Diefenderfer, Ph.D., P.E., VRTC (2019)

http://vtrc.virginiadot.org/PubDetails.aspx?id=298387

State of the Practice for High Polymer-Modified Asphalt Binders and Mixtures, by Jhony Habbouche, Ilker Boz, Brian K. Diefenderfer, VRTC; Bryan C. Smith, Virginia DOT; and Sayed Hamidullah Adel, Engineering Systems and Environment, University of Virginia (2021)

https://www.researchgate.net/publication/349441542_State_of_the_Practice_for_High_Polymer-Modified_Asphalt_Binders_and_Mixtures

Periodic reports on track activity at NCAT involving HP mixes may be viewed here:

https://eng.auburn.edu/research/centers/ncat/files/technical-reports/rep16-04.pdf

https://eng.auburn.edu/research/centers/ncat/files/technical-reports/rep18-04.pdf

https://eng.auburn.edu/research/centers/ncat/files/technical-reports/rep21-03.pdf

Enhanced Characterization of RAP for Cracking Performance by Dr. Reynaldo Roque, P.E., Bongsuk Park, Dr. Jian Zou and George Lopp, University of Florida Department of Civil and Coastal Engineering

https://rosap.ntl.bts.gov/view/dot/50034