AWARD NO. 693JJ32350026

Cooperative Agreement
DEVELOPMENT & DEPLOYMENT OF INNOVATIVE ASPHALT PAVEMENT TECHNOLOGIES (DDIAPT2)

Innovative Area: A. Materials
A.3: Other New & Innovative Materials as Agreed Upon
Statement of Work A.3.1: Use of High Polymer Modified Asphalt (HP) Binders and Mixtures Gap Analysis

Memorandum B
Summary of Virtual Site Visit with the Virginia Department of Transportation

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Use of High Polymer Modified Asphalt (HP) Binders and Mixtures Gap Analysis Virtual Site Visit

State:	Virginia	District/Region:	Virginia DOT
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Visit Type:	Asphalt Materials and Pavements	Visit Date:	August 28, 2024
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Location:	Virtual site visit.		
Description of work:	FHWA Development and Deployment of Innovative Asphalt Pavement Technologies (DDIAPT2), Innovation Area: A. Materials; A.3— Other New & Innovative Materials as Agreed Upon; Task A.3.2: Document Case Studies and Practices for Implementation of HP Binders and Mixtures		

☐ PODI

☒ Scheduled/Requested Visit? Activity requested by FHWA

☐ Unscheduled Review?

DISCLAIMER

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Background

Polymer modification of asphalt binders is not a new concept and has become progressively more common over the past several decades. Over the past 50 years, asphalt binders have been modified with various components such as polymers, ground tire rubber, chemicals (e.g., acids), and recycled engine oils to enhance the properties of asphalt mixtures (Habbouche et al., 2020; Habbouche et al., 2021a). Several State departments of transportation (DOTs) have recognized the benefits of polymer-modified asphalt mixtures in resisting multiple modes of load- and climate-induced distress in flexible pavements (Habbouche et al., 2019). The most commonly used polymer-modified asphalt (PMA) binders (referred to herein as PMA binders) have rarely exceeded a polymer content of approximately 3.5% due to practical issues such as mixing, storage, and workability. However, a new polymer structure has allowed for its use in asphalt binders at much higher levels (approximately 7.5%), referred to herein as high polymer (HP) binders. These binders exhibit significantly greater elasticity, which may help mitigate some of the pavement failure modes that concern agencies (Bowers et al., 2017 and 2018).

HP binders offer additional advantages when used in asphalt mixtures subjected to heavy and slow-moving traffic. This application aligns with the Federal Highway Administration (FHWA)'s commitment to advancing resilient and high-performing infrastructure. The effectiveness of this technology was highlighted as a promising tool in the Every Day Counts (EDC)-6: Targeted Overlay Pavement Solutions (TOPS) program toolbox, featured alongside other asphalt overlay products (FHWA, 2021). Its inclusion aimed to enhance safety, improve performance, preserve investments, and realize cost savings. However, available information on mixtures utilizing HP binders (referred to herein as HP mixtures) is limited to specific field trials conducted in selected States. In addition, the use of HP binders has been limited to specific paving applications, primarily focusing on dense and open-graded mixtures, neglecting their use in gap-graded mixtures (e.g., stone matrix asphalt [SMA] mixtures). The development of specifications to characterize HP binders remains State-specific, lacking information related to defining and accepting such specialized binders. Information, lessons learned, and positive practices on the use of recycled materials and additives in HP mixtures are also limited. A recent study from Virginia Transportation Research Council (VTRC) indicated that 21 agencies have engaged in or constructed pilot projects involving HP mixtures (Habbouche et al., 2021b). As part of the FHWA EDC-6 TOPS Program, a case study highlighting Florida's experience with HP binders and mixtures provided helpful insights into research, construction considerations, and cost factors (Vargas et al., 2022). However, limited information on field performance was provided, and possibly missing practices from other States that use different raw materials and experience diverse climates.

The "Development and Deployment of Innovative Asphalt Pavement Technologies" program, referred to herein as the Asphalt | Innovate | Enlighten | Implement (AIEI) Program, is a five-year cooperative agreement with FHWA (9/23–9/28). The purpose of this program is to address the ongoing challenges faced by the transportation community to adopt new technologies and reduce the time to implement them in business practices, specifications, and construction methods relating design, production, testing, control, construction, and investigation of asphalt pavements. This project also supports the overall goals of advancing 21st-century solutions and improving performance and safety to keep America moving forward. Multiple efforts were undertaken as part of Year 1 of this effort. Among these, the effort entitled "Use of High Polymer Modified Asphalt (HP) Binders and Mixtures – Gap Analysis", was undertaken (SOW A.3.1).

Objective

The overarching objective of this effort is to facilitate and conduct a comprehensive gap analysis on the use of HP binders and mixtures and identify critical limitations, gaps, and needs through Strengths-Weaknesses-Opportunities-Threats (S.W.O.T) analysis. In addition to addressing these limitations, the scope includes identifying and putting forth effective practices and lessons learned by DOTs. This will provide DOTs with valuable information for designing, constructing, and accepting HP binders and mixtures, and will complement the work completed under the FHWA EDC-6: TOPS program. To accomplish this objective, information was collected through virtual site visits and other means with five key agencies. The Virginia Department of Transportation (VDOT) graciously agreed to host a virtual site visit.

Scope and Outcomes

The scope of each virtual site visit included:

- Watching a short pre-recorded kick-off webinar that expanded on the objectives of the effort.
- Completing a comprehensive data-gathering form developed by the Team, which consisted of 30 questions divided into nine modules.
- Attending a 2-hour meeting to discuss the agency's responses and address any additional follow-up questions or requests for information.

The outcomes of each virtual site visit included a summary of meeting notes, the recorded virtual site visit with the agency, and a brief summary memorandum to each FHWA Division Office and the agencies visited, outlining the observations and any recommendations identified.

This document serves as the brief summary memorandum on the observations and findings identified through the VDOT virtual site visit.

Practice and Usage

VDOT currently specifies and permits the use of HP mixtures for standard maintenance and construction projects. While not many projects are selected each year, a few are implemented annually. VDOT defines Type E (HP) asphalt mixtures as mixtures incorporating a neat asphalt material with a high polymer modification (approximately 7.5%), complying with AASHTO M 332 for performance grade (PG) 76E-28(HP) [PG 76E-28(HP)]. An exception to this specification is that the Multiple Stress Creep and Recovery (MSCR) test specifies a maximum non-recoverable creep compliance $J_{nr3.2}$ value of 0.1 kPa^{-1} when tested according to AASHTO T 350. In addition, the minimum MSCR percent recovery at 3.2 kPa is specified to be 90%. The MSCR test for $J_{nr3.2}$ and percent recovery is conducted at 76°C. The viscosity of the binder is specified to be less than or equal to 3.0 Pa-s, although the Engineer may allow an increase to 5.0 Pa-s if the binder supplier and contractor agree that the binder remains suitably workable. HP mixtures are limited to a maximum of 15% reclaimed asphalt pavement (RAP) material by total weight of mixture.

VDOT has been using HP mixtures for over five years, with initial applications dating back to 2014. In that year, researchers at VTRC initiated a study to evaluate the differences in constructability, laboratory performance, and initial field performance between asphalt mixtures produced with HP binders and those produced with conventional PMA binders (Bowers et al., 2018). This study involved the construction of a trial project comparing an asphalt surface mixture (SM) containing an HP binder with one containing a

PMA binder as a control. The two mixtures were used in a resurfacing project on a milled surface in a subdivision in Northern Virginia (NOVA).

The asphalt SM with the HP binder was found to be constructible without significant changes to paving operations. Furthermore, laboratory testing demonstrated that its performance was equivalent to or better than that of the control mixture. These promising results supported a broader field investigation into the use of HP binders in asphalt overlays, particularly as a reflective crack mitigation technique or as a tool for enhanced crack resistance on high-volume facilities (Bowers et al., 2018). This established their primary application in structural and functional overlays. Since 2015, HP asphalt overlays have been used in several locations across Virginia, particularly on jointed concrete pavements (JCPs) and cracked asphalt pavements. Moreover, HP mixtures have also been utilized in new construction projects, including the widening of I-64 in the Hampton Roads District.

VDOT has used approximately 94,293 tons of HP mixtures on State projects since 2014. This constitutes less than 1.0% of the overall paving program. Over the past decade, VDOT's annual HP paving program has varied significantly in lane miles and tonnage, depending on project size, the availability of alternative technologies, and the scope of the program. Table 1 provides a detailed breakdown of the approximate annual tonnage of HP mixtures placed by VDOT. The volume of HP mixtures used fluctuated based on the specific demands of each year's program and the number of projects undertaken.

In terms of cost, Table 1 also summarizes the approximate price per ton of HP mixtures and the corresponding price difference compared to conventional PMA mixtures. Overall, HP mixtures typically resulted in a 23% to 40% cost increase for large tonnage resurfacing projects (≥ 8,000 tons) compared to conventional PMA mixtures. For smaller projects (< 8,000 tons), the cost increase ranged from 13% to 87%, largely due to factors such as plant modifications, smaller production volumes, and limited availability of contractors bidding on the projects. It is important to note that cost data can vary significantly depending on factors such as project type, tonnage, plant adjustments, project location, and the bidding process. Therefore, comparisons are to be made cautiously, ensuring that projects of similar scope are used to assess the price differential properly.

Table 1. VDOT Estimates of Annual Tonnage and Approximate Prices of HP Mixtures Used.

Year	Approximate quantity of HP mixtures placed (tons)	Approximate price for HP mixtures placed ($ per ton)	Approximate difference in price from conventional PMA mixtures ($ per ton)
2015	6,627	135.00	+53.00
2015	31,622	100.00	+19.00
2015	6,627	135.00	+63.00
2017	3,297	110.00	+24.00
2017	1,126	121.00	+36.00
2020	6,504	127.00	+15.00
2020	11,819	130.00	+37.00
2020	31,815	141.50	+31.50
2023	1,483	155.00	+18.00

VDOT = Virginia Department of Transportation; HP = high polymer-modified asphalt; PMA = conventional polymer-modified asphalt.

Despite the higher costs, VDOT continues to use HP mixtures due to their performance benefits, particularly in mitigating reflective cracking on JCPs or when deemed appropriate as a tool for increased crack resistance on higher-volume facilities.

VDOT primarily uses HP mixtures to prevent top-down fatigue cracking, to mitigate reflective cracking—particularly those induced by JCPs covered with asphalt overlays—and for research purposes. The agency is also exploring other potential applications, including their use in new construction on Interstate projects. VDOT has reported that it has never discontinued the use of HP mixtures at any time.

Specifications

As mentioned previously, VDOT refers to HP binders as PG 76E-28(HP), with specific thresholds for non-recoverable creep compliance (maximum 0.1 kPa^{-1}) and percent recovery at 3.2 kPa (minimum 90%) at 76°C. HP binders can be used in dense-graded SM or gap-graded asphalt mixtures (SMA) in Virginia. SM-HP are designed to achieve 3.5% air voids content using 50 gyrations, while SMA-HP are designed for 4.0% air voids using 75 gyrations (VDOT, 2020). Regardless of the mixture type, HP mixtures are limited to a maximum of 15% RAP material by total weight of the mixture. Currently, no performance testing is specified for HP mixtures beyond volumetric properties, regardless of the mixture type.

The quality of supplied HP binders is generally verified to meet specification requirements both at the terminal and the plant. At the terminal, testing is performed on each lot or batch of HP binder, with VDOT aiming to sample and test before the binder is shipped to the asphalt plant. At the plant, testing is conducted on at least one sample per lot or batch of binder. If the binder does not meet HP specifications, production is put on hold until the required HP properties are achieved.

Regarding the acceptance process, VDOT accepts HP binders on a lot or batch basis, which results in more frequent testing compared to typical binders used in conventional projects within the Commonwealth. Although VDOT does not specify a maximum storage time for HP binders, the agency has emphasized to contractors the importance of planning, schedule lookaheads, and weather considerations due to the shorter shelf-life of this type of binder.

In terms of quality control programs or practices specifically implemented for HP projects, no changes have been reported, regardless of the mixture type being produced and placed (SM versus SMA). For acceptance, VDOT employs practices similar to those used for conventional mixtures.

VDOT does not currently have specific project selection criteria for the use of HP binders and mixtures. However, if there is interest in using HP mixtures from various districts, VDOT recommends their use on high-profile projects. These are typically characterized by high traffic volumes, frequent resurfacing needs, or locations in densely populated areas, given the high cost of HP paving materials, especially when used with SMA.

Mixture Design and Performance

As mentioned previously, VDOT uses the Superpave mix design methodology for SM and SMA mixtures containing HP binders. Compared to standard mix designs for PMA mixtures, VDOT has reported no deviations from typical practices. In all cases, SM-E (E denotes extremely heavy traffic and requires the use of PG 64E-22 asphalt binder) and SM-HP mixtures are designed to achieve 3.5% air voids content using 50 gyrations, while SMA-E and SMA-HP mixtures are designed for 4.0% air voids using 75 gyrations (VDOT, 2020). Regardless of the mixture type, HP mixtures are limited to a maximum of 15%

RAP material by total weight of the mixture. VDOT has emphasized that HP binders must be tested at the mix design stage, as well as before and during production. Currently, no performance testing beyond volumetric properties is specified for HP mixtures, regardless of the mixture type.

VDOT does not currently assign any additional structural credit for HP mixtures. The majority of HP mixtures are used in maintenance projects, where mill-and-fill operations are typically performed. For new construction, VDOT employs the AASHTOWare® Pavement ME software for design; however, the software has not yet been calibrated to account for the use of SM-HP and SMA-HP mixtures.

VDOT has reported no differences in surface preparation when placing HP asphalt mixtures compared to traditional mixtures. However, VDOT encourages concrete patching when HP mixtures are placed on top of concrete pavements. In addition, VDOT does not have a specific policy for addressing joints in JCPs. VDOT also does not impose an upper limit on the mixing or production temperature of HP mixtures but recommends following the guidance provided by the HP binder supplier and polymer manufacturer.

According to a previous survey conducted with Virginia contractors experienced in producing and placing HP mixtures, no changes from routine established practices were reported in relation to surface preparation or paving operations. However, contractors noted that additional compaction effort might be needed when using the same paving equipment as for conventional mixtures. Based on their experience, contractors in Virginia recommend running unmodified mixtures through the paver before placing HP mixtures to preheat the equipment and minimize sticking. Minimizing wait times at the job site for loaded trucks is critical, as HP mixtures tend to cool and stiffen more quickly than conventional mixtures (Habbouche et al., 2021).

VDOT reported no immediate need for additional performance metrics but noted that testing for permeability has been considered, although it is not currently a requirement for SMA mixes.

Restrictions and Limitations

VDOT reported no special practices or enforcement of specific safety or health restrictions when using HP binders in asphalt mixtures. In cases where specific practices are warranted, these are typically based on the recommendations of binder suppliers and polymer manufacturers.

However, several factors have been identified as potential limitations to the broader use of HP binders, mixtures, and pavements in Virginia. These include high costs, as presented in Table 1; the lack of project selection criteria; the absence of engineering design procedures (e.g., no additional performance testing and no methodology to quantify the additional structural benefits of using HP mixtures); opposition from competing industries (such as those advocating for the use of crumb rubber or fibers); and resistance to change within the industry.

Another concern highlighted by VDOT involves supply chain disruptions affecting the polymers required to produce HP binders that meet VDOT requirements and specifications. It can be noted that the SBS polymer used to produce HP binders is significantly different from the one used in conventional PMA binders (Habbouche et al., 2021b and 2021c). In Virginia, HP binders have been supplied by three binder suppliers, with the majority being provided by one supplier from a single terminal. Due to the low tonnage and limited information, VDOT could not confirm whether the use of various HP binder supplied by different producers would lead to any changes in material properties and/or paving operations.

Research Projects

In terms of research efforts, the research division of VDOT, VTRC, has completed two studies focused on HP binders and mixtures. The first study, titled *Evaluation of Highly Polymer-Modified Asphalt Mixtures: Phase I* (VTRC Report 18-R14), was published in 2018 (Bowers et al., 2018). Reflective cracking in asphalt overlays on JCP has been a long-standing concern for VDOT. While there are various methods to delay crack propagation through asphalt overlays, these often require specialized equipment, unique mix designs, or specific additives. The emergence of HP binders offers a new potential solution, where the use of HP binder in the asphalt mixture alone can help mitigate cracks. Before using HP binder asphalt mixtures on a jointed concrete overlay project, VDOT conducted a trial to assess the constructability and laboratory performance of mixtures incorporating this binder. The trial compared an asphalt SM with HP binder to a standard unmodified SM (control) in a mill and resurfacing project in a NOVA subdivision. The HP binder mixture was found to be constructible without significant changes to paving operations, and its laboratory performance was similar to or exceeded that of the control mixture. The promising results supported further investigation into the use of HP binders as a crack mitigation technique in asphalt mixtures over jointed concrete, or as a means to enhance crack resistance. The study suggested that VDOT consider using asphalt mixtures with HP binders as a crack resistance tool when deemed appropriate by decision makers, such as the district materials engineer. It also recommended that VTRC and VDOT districts concerned with reflective cracking in asphalt overlays explore the potential of HP mixtures as a reflective crack mitigation layer.

The second project, titled *Laboratory and Field Performance Evaluation of Pavement Sections with High Polymer-Modified Asphalt Overlays* (VTRC Report 21-R16), was completed and published in 2021 (Habbouche et al., 2021a). Since the initial section was constructed in 2014, HP overlays have been applied at several locations over existing JCPs and cracked asphalt pavements in an effort to mitigate reflective cracking. The aim of the second project was to further evaluate the feasibility of using HP mixtures in Virginia as a technique for reflective crack mitigation or as a means of enhancing crack resistance on higher-traffic facilities. The study also provided insights into the state of the practice and lessons learned from the use of HP mixtures in both the United States and Canada. In general, HP mixtures have been used in various applications, particularly in areas with heavy traffic on interstates and slow-braking loads at intersections. No significant field-related construction issues were reported regarding mixing temperatures or in-place compaction of HP mixtures, and standard construction practices and equipment were used. Key lessons learned emphasized the importance of good communication between the polymer/binder supplier and the contractor, as well as the value of solid planning prior to the work. The performance of conventional PMA and HP field-produced mixtures was evaluated in the laboratory for durability and resistance to rutting and cracking. Based on the mixtures tested, HP mixtures outperformed PMA mixtures, regardless of the mixture type (SM vs. SMA). In addition, SMA mixtures showed better performance compared to SMs, regardless of the binder type (PMA or HP). Overall, SMA-HP mixtures exhibited the most promising performance among all the evaluated mixtures. Distress survey data collected from VDOT's Pavement Management System for HP field sections were compared with data from control PMA sections. The HP sections showed the most promising performance five years after construction (2015-2020), regardless of traffic levels or pre-existing pavement conditions. While none of the evaluated mixtures (HP or PMA) fully eliminated reflective cracking, the HP mixtures demonstrated a noticeable improvement. Performance evaluations using network-level pavement management data were conducted to estimate the life expectancy of HP asphalt overlays. On average, PMA overlays had a predicted service life of 6.2 years, while HP overlays had a predicted service life of 8.3 years, representing a 34% extension in performance life with HP modification. The study recommended ongoing assessment of the as-constructed properties of future HP projects to build a comprehensive materials characterization database. Furthermore, it was suggested that the performance of existing and future HP sections is to be continuously monitored. This will help refine service life prediction models and assess the cost-effectiveness of using HP mixtures as more data becomes available over time. Finally, the study recommended investigating the use of a balanced mix design approach to further enhance the durability and longevity of PMA and HP mixtures in Virginia.

Cost and Benefits

VDOT reported no information on life cycle costs or benefit-cost ratios for HP mixtures. As previously mentioned, HP mixtures were associated with a 23% to 40% cost increase for large-tonnage resurfacing projects compared to conventional PMA mixtures. For smaller projects, the cost increase ranged from 13% to 87%, primarily due to factors such as plant modifications, smaller production volumes, and the limited availability of contractors bidding on these projects. Furthermore, VDOT is awaiting the construction of additional HP pavement sections and the collection of more data to conduct a comprehensive life-cycle cost analysis.

Implementation Plan

The implementation of HP binders and mixtures in Virginia has evolved over time, driven initially by the need to mitigate reflective cracking on JCPs. However, there was no formalized plan to implement HP binders and mixtures across the Commonwealth. Instead, the introduction of these materials began with pilot projects, such as the 2014 project on Summerwood Circle in NOVA, which compared an HP mixture to an unmodified asphalt mixture.

The use of HP mixtures was not permitted statewide from the outset. Projects utilizing HP binders were initially treated as research efforts unless explicitly included as bid items, at which point they were considered implemented. Since 2014, Virginia has aimed to construct at least one HP project per year, though some years saw multiple projects, while others had none. Over time, HP mixtures have been incorporated as a standard tool in the state's paving practices, signifying full implementation.

Several insights and lessons were gained during this process. Successes often stemmed from strong communication and collaboration with additive and binder manufacturers, ensuring their involvement throughout the process. Modifications to project schedules for trial sections were critical to preventing waste of HP binders, especially given the material's sensitivity to timing. One significant challenge occurred when a hurricane impacted a project progress, resulting in a binder that did not meet HP specifications; this required a price adjustment to the contract.

Despite these successes, certain challenges remain. For instance, the absence of a maximum temperature cutoff for HP mixtures, with recommendations based solely on suppliers' guidelines, has led to hesitancy among some district material engineers, particularly regarding the potential for burning fibers in SMA mixes. Addressing these concerns through continued communication, education, and collaboration will be key to further enhancing the use of HP mixtures in Virginia.

While HP mixtures are now a viable tool in Virginia's pavement toolbox, their implementation journey reflects a combination of trial, adaptation, and lessons learned from both successes and challenges.

Additional Information

The implementation and use of HP binders and mixtures in Virginia have provided valuable lessons, while also revealing several challenges, positive practices, and gaps that require attention. One of the key lessons learned has been the importance of adhering to binder suppliers' recommendations regarding storage time and weather considerations, which can significantly impact material performance. In addition, it became clear that not all asphalt plants are equipped to handle HP binders effectively, underscoring the need for careful assessment of plant capabilities before implementation.

Challenges have been multifaceted, with price being a significant factor, particularly during the early stages when there were limited suppliers capable of providing HP binders to Virginia. Other issues include concerns related to storage shelf life and the influence of weather on binder performance, which require careful planning and monitoring.

Despite these challenges, positive practices have emerged that contribute to successful outcomes. Communication among all parties involved—suppliers, contractors, and state officials—has proven essential in ensuring smooth project execution and addressing potential issues proactively.

However, several gaps remain that hinder the broader adoption and optimization of HP binders and mixtures. A notable gap is the lack of comprehensive performance comparisons and cost-benefit analyses, particularly in terms of life-cycle cost analysis, which limits the ability to fully quantify the value of this technology. There is also a need to ensure that the asphalt mixture consistently meets expected properties and that the HP binder is being used as intended. The application of Fourier-transform infrared spectroscopy (FTIR) as a verification tool has been identified as an area needing further exploration.

In addition, the transition toward balanced mix design presents challenges, as there is currently no established specification for E or HP mixtures. Addressing these gaps will be critical to advancing the effective and efficient use of HP binders and mixtures in the Commonwealth, providing greater confidence in their performance and cost-effectiveness over the pavement's life cycle.

Finally, VDOT is not currently considering an increase in the RAP content for SM and SMA mixtures when incorporating HP binders.

Acknowledgement

The team greatly appreciates the time, effort, and information provided by VDOT staff. This concludes the summary of the virtual visit with VDOT.

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