



TECH BRIEF

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A STRATEGIC LOOK AT GAPS AND IMPLEMENTATION OPPORTUNITIES FOR HIGH POLYMER MODIFIED ASPHALTS

This Technical Brief presents a gap analysis of high polymer modified asphalt (HP) binders and mixtures in pavement construction, highlighting current limitations and areas for improvement. Implementable actions and lessons learned from State Departments of Transportation (DOTs), along with strategies to enhance the design and implementation of HP binders are identified.

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Introduction

The modification of asphalt binders is not a novel concept and has steadily gained traction over the past several decades. For approximately 50 years, various additives—including polymers, ground tire rubber, chemical modifiers (e.g., acids), and recycled engine oils—have been incorporated into asphalt binders to improve the performance of asphalt mixtures.^(1,2) Several State Departments of Transportation (DOTs) have acknowledged the advantages of polymer-modified asphalt mixtures in mitigating different types of distress caused by traffic loading and environmental conditions in flexible pavements.⁽³⁾ Traditionally, polymer-modified asphalt (PMA) binders have contained polymer contents not exceeding 3.5 percent due to practical challenges related to mixing, storage, and workability. However, advancements in polymer technology have enabled the incorporation of significantly higher polymer contents (approximately 7.5 percent) in asphalt binders, referred to herein as high polymer (HP) binders. These binders exhibit substantially enhanced elasticity that may contribute to addressing certain pavement failure mechanisms of concern to State DOTs.^(4,5) HP binders also offer additional advantages when used in asphalt mixtures subjected to heavy and slow-moving traffic.^(1,3)

The effectiveness of the HP binder 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.⁽⁶⁾ Its inclusion aimed to enhance safety, improve performance, preserve investments, and realize cost savings.



Background

In 2018, a critical review of HP binders and mixtures synthesized findings from both laboratory studies and field projects, demonstrating that increased polymer content enhances rutting resistance, fatigue performance, and long-term durability.⁽¹⁾ The review also examined the structural implications of HP mixtures, suggesting that their improved properties could enable substantial reductions in asphalt layer thickness—by up to 40 percent—without compromising performance.

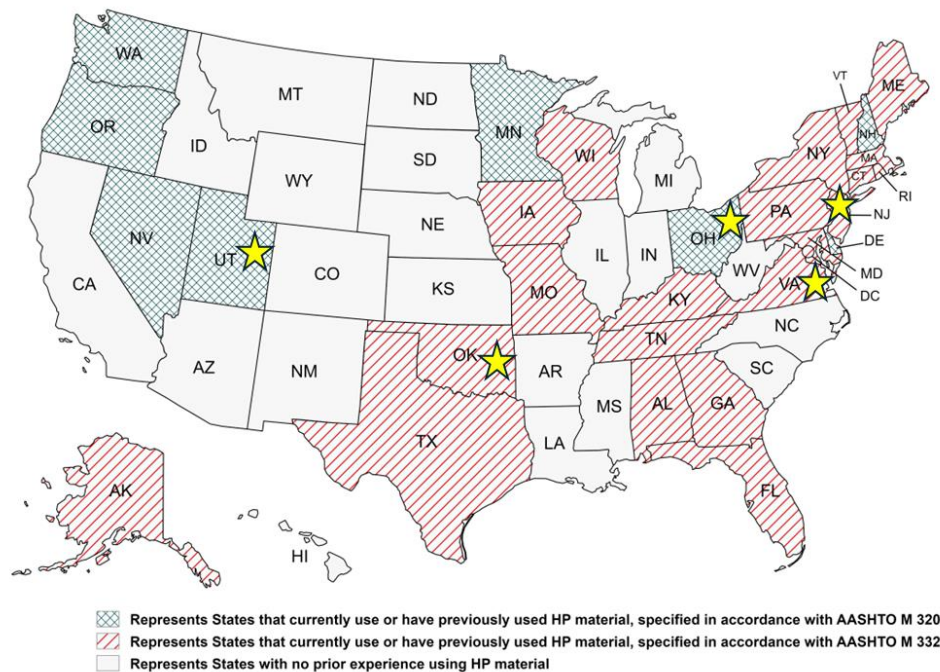
A more recent literature review reaffirmed the benefits of HP binders and mixtures, particularly in enhancing durability and resistance to rutting, cracking (fatigue and reflective), and raveling.^(7,8) HP mixtures have been used in a wide range of pavement applications, including thin overlays, to improve performance and longevity. Structurally, they allow for potential reductions in pavement thickness while maintaining durability and can help mitigate the effects of weaker base or subgrade conditions. In open-graded asphalt mixtures, HP binders were found to enhance durability and reduce raveling, leading to longer-lasting porous pavements.^(8,9) Additionally, HP mixtures can serve as a Stress Absorbing Membrane Interlayer (SAMI), helping to mitigate reflective cracking. Their enhanced performance under high-stress conditions makes them particularly beneficial for intersections, weigh stations, and other high-volume facilities, where increased rutting and fatigue resistance are essential. These advantages make HP binders and mixtures valuable materials for modern pavement engineering, offering both structural and functional improvements across a variety of roadway applications.^(6,10)

The available information on HP mixtures is largely limited to specific field trials conducted in selected States. Additionally, the use of HP binders has been primarily focused on dense- and open-graded asphalt mixtures, with limited application in gap-graded asphalt mixtures such as stone matrix asphalt (SMA). A 2021 study by the Virginia Transportation Research Council (VTRC) indicated that 21 agencies have engaged in or constructed pilot projects involving HP mixtures.⁽¹¹⁾ As part of the FHWA EDC-6 TOPS Program, a case study highlighting Florida’s experience with HP binders and mixtures provided valuable insights into research findings, construction considerations, and cost factors.⁽¹⁰⁾ However, limited information on field performance was provided, and practices from other States that use different raw materials and experience diverse climates were not included.

To address these gaps, a comprehensive analysis of HP binder and mixture usage was conducted. A Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis was carried out to identify critical limitations, knowledge gaps, and implementation challenges. Additionally, lessons learned and implementable actions from selected State DOTs were documented to assist agencies in designing, constructing, and evaluating HP mixtures. To achieve this objective, information was gathered through virtual site visits and other means with five key State DOTs: New Jersey DOT (NJDOT), Ohio DOT, Oklahoma DOT, Utah DOT (UDOT), and Virginia DOT (VDOT). This effort aims to provide transportation agencies with the necessary information to optimize the use of HP binders and mixtures across various paving applications. In the context of this document, “applications” refer to where and how HP binders and mixtures are being used, and “practices” refer to how they are specified, produced, and constructed.

Definitions and Specifications

Virtual site visits with select State DOTs, along with a review of specifications, special provisions, pilot projects, and literature identified 29 State DOTs with experience with HP binders and mixtures, as shown in Figure 1. Eight State DOTs currently use or have previously used HP binders specified in accordance with the American Association of State Highway and Transportation Officials (AASHTO) M 320.⁽¹²⁾ In all cases, an elastic recovery (R_e) requirement of greater than 90 percent, evaluated at the binder performance grade (PG) high temperature (PGHT), is included in accordance with AASHTO T 301 or a state-specific testing method.⁽¹³⁾ Twenty-one State DOTs currently use or have used HP binders specified in accordance with AASHTO M 332.⁽¹⁴⁾ The majority require a maximum non-recoverable creep compliance at 3.2 kPa ($J_{nr, 3.2}$) of 0.1 kPa^{-1} , except for Oklahoma, New York, and Wisconsin, which set the maximum $J_{nr, 3.2}$ at PGHT to 0.5 kPa^{-1} . It is important to note that AASHTO M 320 classifies asphalt binders based on PG using temperature-based criteria focused on rutting and cracking resistance. AASHTO M 332 builds upon AASHTO M 320 by incorporating the Multiple Stress Creep Recovery (MSCR) test, which is particularly useful for evaluating the performance of modified binders under heavy traffic and high stress conditions.



Note 1: States marked with a star indicate virtual site visits.

Note 2: Washington State DOT has switched to AASHTO M 332, but no recent projects or trials involving HP binders have taken place since then.

Figure 1. U.S. map showing States' experience status with HP binders and mixtures.

All states' special provisions and specifications for HP binders emphasize high elasticity and recovery of asphalt binders to ensure superior pavement performance under heavy, stress-concentrated, or slow-moving traffic loads. Some State DOTs, such as Alaska, New Jersey, and Utah, extend these requirements beyond binders by incorporating performance testing on corresponding HP mixtures.



The collected information indicates that States' definition and acceptance of these binders are not strictly based on polymer content but rather on specific binder rheology-related parameters and the performance characteristics of both asphalt binders and mixtures. This reflects a more performance-oriented approach to evaluating HP materials. The following sections highlight the major findings from the virtual site visits with the five key State DOTs. These DOTs were selected based on information gathered from the literature. The selection process considered factors such as the inclusion of HP binders and mixtures in specifications, the annual production volume of HP mixtures, and specific applications employing HP binders.

State Practices

The five visited State DOTs currently specify and permit the use of HP binders and mixtures for standard maintenance and construction projects, each adopting unique requirements and applications. For instance, NJDOT primarily uses HP binders for bridge deck waterproofing surface courses (BDWSC) and ultra-high-performance thin overlays (UHPTO). Additionally, the agency is exploring the use of PG 88-22FR (FR denotes fuel-resistant) and PG 94-22 in chip seal applications to enhance aggregate retention and skid resistance. However, challenges with short-term aging, as these binders do not fully coat the rolling thin film oven (RTFO) jars, have prompted NJDOT to developing new testing specifications for PG 94-22. Notably, NJDOT defines HP binders by rheological performance, not polymer content, in accordance with AASHTO M 332 and AASHTO R 92 standards.^(13,15,16) In comparison, Ohio DOT uses HP mixtures for bridge waterproofing and high-stress locations. HP binders, referred to as PG 88-22M, are pre-blended with polymers like styrene-butadiene-styrene (SBS), styrene-butadiene (SB), or Elvaloy, with no restrictions on polymer content. The binder needs to comply with AASHTO M 320-17 along with additional requirements for elastic recovery, mass change, and separation. Furthermore, rotational viscosity is capped at 3.0 Pa.s, though it may be increased to 10.0 Pa.s if pumpability and workability are maintained.^(17,18)

Oklahoma DOT specifies HP binders for rich intermediate layers (RILs) and evaluates them using MSCR test per AASHTO M 332. PG 76E-28 (or PG 88-28) binders must meet $J_{nr, 3.2}$ and elastic recovery requirements while maintaining a flash point above 500°F (260°C). HP binders must also pass separation testing, though viscosity requirements are not enforced. Additionally, a maximum production temperature of 350°F (177°C) is mandated for all PG binders, including HP binders, except those used in warm mix asphalt applications.⁽¹⁹⁾ In comparison, UDOT defines HP binders as those meeting PG 76-34 specifications, with additional performance criteria such as elastic recovery, complex shear modulus (G^*), phase angle, creep stiffness, and critical low-temperature difference (ΔT_c). UDOT does not specify a required polymer content but estimates the HP polymer content to be around 5 to 6 percent. Early projects substituting HP binders into existing mix designs yielded underwhelming results, prompting UDOT to develop a specialized highly modified asphalt mixture (known as HiMod mixture) with tailored specifications.^(20,21)

Finally, VDOT utilizes HP mixtures for select projects annually, defining Type E (HP) mixtures with approximately 7.5 percent polymer modification. HP binders must meet PG 76E-28(HP) specifications, with MSCR $J_{nr, 3.2}$ limited to 0.1 kPa⁻¹ and a minimum percent recovery ($R_{3.2}$) of 90 percent at 3.2 kPa. The binder viscosity is capped at 3.0 Pa.s, though it may be increased to 5.0 Pa.s if workability is maintained. HP mixtures are restricted to a maximum reclaimed asphalt pavement (RAP) content of 15 percent.⁽²²⁾



The special provisions and specifications for the properties of HP binders and mixtures used by the five visited State DOTs are summarized in Table 1. The variations in HP binder specifications highlight each agency’s strategy for balancing binder performance, mix design, and construction challenges, all while ensuring long- term pavement durability.

Table 1. Summary of Agency Special Provisions and Specifications for HP Binders and Mixtures

State	AASHTO Standard	Binder Properties	Mixture Properties
New Jersey	M 332	PG 76E-28	Requirements based on intended application
	T 350	$J_{nr, 3.2} \leq 0.1 \text{ kPa}^{-1}$ & $R_{3.2} \geq 90\%$ at 76°C	
	M 320	PG 94-22	PG 94-22 designed for use in hot-applied chip seals
Ohio	M 320	PG 88-22 (reported as PG 88-22M)	n/a
	T 301	$R_e \geq 90\%$	
Oklahoma	M 332	PG 76E-28	n/a
	T 350	$J_{nr, 3.2} \leq 0.5 \text{ kPa}^{-1}$ & $R_{3.2} \geq 95\%$ at 76°C	
Utah	M 320	PG 76-34	Use of high binder content by requiring high density compaction based on low void mix design for all applications, including both thin and thick asphalt layers.
	T 301	$R_e \geq 90\%$	
	T 313	$\Delta T_c \geq -1.0^\circ\text{C}$	
Virginia	M 332	PG 76E-28	n/a
	T 350	$J_{nr, 3.2} \leq 0.1 \text{ kPa}^{-1}$ & $R_{3.2} \geq 90\%$ at 76°C	

n/a denotes not available.

Usage and Cost

Over the past six years, NJDOT has placed approximately 4.8 million tons of HP asphalt mixtures on State projects, with annual paving programs varying based on project size, available technologies, and scope. HP mixtures cost an average of \$158.27 per ton—about 32 percent higher than conventional PMA mixtures (\$119.86). Despite the increased cost, NJDOT continues to use HP mixtures due to their superior performance benefits, including improved resistance to fatigue and reflective cracking, reduced rutting, and the potential for thinner pavement layers. NJDOT has consistently utilized HP binders and mixtures in various applications, maintaining them as a key component in enhancing pavement performance and durability.

Ohio DOT has utilized HP mixtures since 2014, initially placing them at intersections and bridge decks. The first large-scale application occurred in 2017, with approximately 100,000 tons of HP mixtures produced and placed. Since then, HP mixtures have been specified for high-stress locations, including intersections, bridge decks, and other areas requiring enhanced durability. Over the past decade, Ohio DOT’s annual HP paving program has varied in lane miles based on project size, available technologies, and program scope. The volume of HP mixtures used fluctuates yearly depending on project demands. Cost analysis indicates that HP mixtures typically increase resurfacing project costs by 7 to 10 percent for large-scale applications and 10 to 20 percent for smaller projects due to plant modifications and lower production volumes. However, cost variations depend on project type, tonnage, and plant adjustments, requiring careful comparisons. Despite the



higher costs, Ohio DOT continues to implement HP mixtures for their performance benefits, particularly in high-stress environments. The agency is also exploring additional applications, including full-depth pavement for cost efficiency, perpetual pavements, and thinner overlays for areas with low overhead clearance. Ohio DOT has consistently utilized HP mixtures and has never discontinued their use in pavement projects.

Oklahoma DOT has implemented HP mixtures in structural overlays, as interlayers to mitigate reflective cracking, and in bottom layers to prevent bottom-up fatigue cracking. Over the past five years, Oklahoma DOT has placed approximately 307,887 tons of HP mixtures, covering more than 110 miles of paving—an average of 22 miles per year. HP mixtures have accounted for roughly 1.6 percent of Oklahoma DOT’s total annual paving program by tonnage. The annual HP paving program has varied considerably in lane miles and tonnage based on project size, availability of alternative technologies, and program scope. Cost analysis indicates that HP mixtures result in a 21 to 31 percent increase in cost compared to conventional PMA mixtures. However, these costs fluctuate depending on project type, tonnage, plant adjustments, location, and bidding conditions, requiring careful comparisons using projects of similar scope. Despite higher initial costs, Oklahoma DOT continues to use HP mixtures due to their performance benefits, particularly in mitigating bottom-up fatigue cracking, reflective cracking, and rutting. Oklahoma DOT is also exploring the potential for using HP mixtures to design thinner pavement sections for enhanced cost efficiency.

UDOT has been utilizing HP binders and HiMod mixtures for over nine years, with initial projects dating back to 2015-2016. Early applications involved direct substitution of PG 76-34 binders into existing PG 64-34 mix designs, maintaining the same asphalt content. In 2021, the Wendover Port of Entry project marked the first instance of a HiMod mixture being specifically designed for PG 76-34 binders, featuring low air void designs and high in-place densities, which have since been integrated into UDOT’s specifications. HiMod mixtures are used across multiple applications, including structural and functional overlays of varying thicknesses (1.5, 2.0, and 3.0 inches), with the 1.5-inch overlay playing a key role in UDOT’s preservation program. Additionally, HiMod mixtures are proposed as interlayers to mitigate reflective cracking, particularly for Portland cement concrete pavement (PCCP) rehabilitation, and are considered an alternative to SMA in certain cases. They have also been effectively used in thick asphalt layers (5–6 inches) and new construction projects, demonstrating their structural resilience.^(23,24) One notable project involves rehabilitating old PCCP on Interstate 215 by overlaying a rubblized concrete layer with a HiMod mixture, potentially avoiding full pavement replacement and saving approximately \$40 million. HiMod mixtures have also been used for bridge deck overlays, where achieving 97 percent density is a critical performance criterion. To enhance durability, a minimum binder content of 6.0 percent or higher is required based on the combined bulk specific gravity (G_{sb}) of the aggregate.

Since 2021, UDOT has placed approximately 27,595 tons of HiMod mixtures, with about 525,000 tons (600 lane miles) scheduled for bidding in 2024, extending into 2025. Usage has increased as confidence in the technology has grown. The cost per ton for HiMod mixtures falls between



traditional hot-mix asphalt (HMA) and SMA mixtures. Costs fluctuate based on location, trucking distances, plant adjustments, and the bidding process, requiring careful project comparisons. UDOT continues to use HiMod mixtures to prevent rutting, mitigate fatigue and reflective cracking, and enhance long-term pavement performance. The agency has considered but not implemented the use of HP binders in open-graded friction courses (OGFC).

Since 2014, VDOT has used approximately 94,293 tons of HP mixtures on State projects, representing less than 1.0 percent of the total paving program. The annual usage of HP mixtures has varied considerably based on project size, availability of alternative technologies, and overall program scope. Cost data indicates that HP mixtures typically result in a 23 to 40 percent cost increase for large resurfacing projects ($\geq 8,000$ tons) compared to conventional PMA mixtures. For smaller projects ($< 8,000$ tons), cost increases range from 13 to 87 percent, driven by factors similar to those observed in other states, including plant modifications, lower production volumes, and limited contractor participation. Given these variations, cost comparisons should be made cautiously, ensuring projects of similar scope are used for evaluation. Despite higher costs, VDOT continues to utilize HP mixtures for their performance benefits, particularly in mitigating reflective cracking on jointed concrete pavements (JCPs) and enhancing crack resistance on high-volume roadways. HP mixtures are primarily used to prevent top-down fatigue cracking, address reflective cracking in asphalt overlays over JCP, and support research initiatives. VDOT is also considering their use in new interstate construction projects. VDOT has consistently used HP mixtures without any reported discontinuation.

In summary, the five visited State DOTs have consistently adopted HP binders and mixtures for their enhanced performance in addressing common pavement distresses, particularly in high-stress or high-risk locations. Despite the reported higher initial costs, these State DOTs continue to use HP mixtures because of the long-term performance benefits they offer. Among these benefits is the potential for thinner pavement layers, which can contribute to cost savings over time while maintaining or even improving pavement performance. It should be noted that the five State DOTs reported no information on life cycle costs or benefit-cost ratios for HP mixtures. HP mixtures have proven to be particularly effective in critical infrastructure projects where pavement longevity and resilience are paramount. The cost of HP mixtures can vary depending on factors such as project size, production volumes, and plant modifications. Smaller projects, in particular, tend to incur higher costs due to limited production capacity and the need for adjustments in mix design. However, the agencies remain committed to using HP mixtures because of their proven durability, their ability to extend pavement life, reduce maintenance requirements, and improve overall pavement quality. HP mixtures are no longer restricted to specific applications but are now used across a variety of pavement challenges.

Mix Design and Performance

NJDOT employs a structured approach to BDWSC and UHPTO mix designs, prioritizing volumetric properties before performance testing. These mixtures use 50 design gyrations with lower design air voids and higher voids in mineral aggregate (VMA), but no RAP is permitted.⁽¹⁶⁾



Structural credit for these mixtures remain aligned with conventional mixtures. NJDOT integrates performance testing, including flexural bending beam fatigue (for BDWSC mixtures) and Texas overlay testing (for UHPTO mixtures) for cracking assessment, and the asphalt pavement analyzer (APA) test (for both BDWSC and UHPTO mixtures) for rutting assessment. They also attempt to address compaction challenges in HP mixtures caused by rapid cooling during mix design.⁽²⁵⁾ Wet paving conditions have resulted in blistering issues. NJDOT has also explored hot-applied chip seals using HP binders to improve aggregate retention and skid resistance.

Ohio DOT uses the Superpave mix design for HP mixtures and does not provide additional structural credit beyond that of conventional mixtures. Moreover, RAP usage in HP mixtures remains consistent with that in conventional mixtures. While standard preparation and compaction practices are maintained, the structural benefits of HP binders are being explored in a perpetual pavement study. The agency is also investigating HP mixtures as interlayers as well as the use of Balanced Mix Design (BMD) but has no plans to increase RAP content. Long-term performance data are still being collected to assess cost-effectiveness.

Oklahoma DOT designs RIL mixtures using Superpave with a 9.5mm gradation, targeting 3.0 percent air voids and a minimum 5.5 percent asphalt content. No RAP is allowed, and rutting resistance is tested via the Hamburg Wheel-Track Test (HWTT). Oklahoma DOT follows its established surface preparation and paving practices and does not assign structural credit for HP mixtures. No blistering has been reported in these mixtures, and no additional performance testing is required during production.

UDOT employs a modified Superpave approach for HiMod mixtures, reducing air voids to 1.0 percent for 50 gyrations and increasing VMA and voids filled with asphalt (VFA). A maximum of 15% RAP is permitted in the mixture. HiMod mixtures undergo HWTT and fatigue testing. Structural coefficients are being evaluated in an upcoming study of instrumented pavement sections. No substantial construction changes have been noted, and the mixtures have performed well even under challenging climatic conditions in Utah.

VDOT uses Superpave for HP mixtures with standard volumetric requirements. A maximum of 15 percent RAP is permitted, and no performance testing is required. HP mixtures are mainly used in mill-and-fill maintenance activities, with no assigned structural credit. HP binders undergo testing during mix design and production, ensuring consistency in performance.

Challenges and Limitations

The use of HP binders in asphalt mixtures has been reported across several States, with varying challenges and limitations impacting their broader adoption. In New Jersey, the high initial cost of HP mixtures remains an important barrier, compounded by a lack of industry experience and limited contractor availability for specialized work. Previous unsuccessful experiences, such as a bridge deck mixture failure, have contributed to hesitancy. Similarly, Oklahoma faces high costs and the absence of project selection criteria, along with concerns about constructability and the risk of rutting in mixtures with high binder content. Contractor familiarity with HP mixtures is not widespread, although some divisions have had more success due to contractor experience.



Ohio's adoption of HP binders is hindered by high costs and concerns about the capability of local asphalt terminals to sustain supply demands. A survey conducted by Ohio DOT revealed that binder suppliers are cautious about producing specialty binders like PG 88-22M, given production risks and limited demand. Additionally, the cost-effectiveness of HP mixtures is questioned, as suppliers argue that the long-term durability may not justify the considerable upfront cost.

In Utah, although the initial reluctance of the industry to adopt HiMod mixtures was noted, contractors have since adapted, finding them cost-effective and viable, particularly compared to traditional SMA mixtures. HiMod mixtures also allow for incorporation of RAP, improving the resource responsible use of recycled materials.

In Virginia, the lack of engineering design procedures and project selection criteria presents challenges, alongside opposition from competing industries and supply chain disruptions affecting the necessary polymers for HP binders. These factors, combined with limited production and concerns over material variability, further complicate the widespread adoption of HP mixtures.

Overall, while HP binders show substantial potential in improving pavement durability, the high initial costs, supply chain limitations, and technical challenges remain key factors that need to be addressed for more widespread use. Despite these barriers, States continue to explore their use, recognizing the long-term performance benefits.

Research Efforts

In New Jersey, while there are no dedicated laboratory or field studies specifically on HP mixtures, several pilot projects are underway. These include a UHPTO project on Interstate 295 and a Route 42 project involving HP mixtures. Additionally, a new chip seal product using PG 94-22 binder is being tested during the 2025 construction season. These projects are focused on evaluating the performance and benefits of HP binder and mixtures in practical applications. Meanwhile, Ohio DOT has sponsored two key research efforts on HP binders and mixtures. The first study evaluated various asphalt layer thicknesses and concluded that sections with HP mixtures showed improved performance, meeting perpetual pavement criteria and demonstrating better resistance to rutting.^(26,27) The second project, focusing also on perpetual pavement in Ohio, highlighted that HP mixtures could increase pavement lifespan by 25 percent, though they come with a 10 to 20 percent increase in costs.⁽²⁸⁾ As a result, further research was recommended to explore the use of high RAP content.

Oklahoma DOT has not commissioned any research on HP mixtures but has sponsored a test section at the National Center for Asphalt Technology (NCAT) Test Track. The rehabilitation of this section using HP binder provided valuable insights into how HP materials can improve rut resistance and crack mitigation, especially in areas with weak subgrades. Similarly, UDOT has not yet conducted research on HiMod mixtures other than work done in and through their central laboratory, though a report will be produced for a 2025 Interstate 215 project. Complementary laboratory fatigue testing has shown that HiMod mixtures perform better than conventional mixtures in terms of fatigue resistance. This is attributed to the higher binder content and the stability provided by the HP binder.

Finally, Virginia's research includes two major studies on HP binders and mixtures. The first study investigated their use for reflective crack mitigation on JCPs, finding that HP mixtures could enhance crack resistance and could be applied without major construction issues.^(4,5) The second study further



evaluated the use of HP mixtures in overlays and found they outperformed conventional PMA mixtures, with HP overlays extending pavement life by approximately 34 percent.⁽²⁾

These findings across various States demonstrate the potential of HP mixtures to enhance pavement durability, resistance to cracking and rutting, and overall lifespan, although cost considerations and further research with recycled materials are crucial to optimize their use.

Implementation Efforts

The implementation of HP binders and mixtures across various states has been gradual and shaped by practical experiences, pilot projects, and evolving strategies. In New Jersey, the adoption of HP binders has been driven more by performance goals rather than a specific implementation plan. Pilot projects have been conducted, including those featuring PG 88-22 chip seal and UHPTO mixtures, though no control sections with conventional mixtures were included for comparison. Ohio DOT adoption of HP binders began as a competitive alternative for bridge deck waterproofing and expanded to high-stress areas. Key lessons from Ohio DOT's implementation include balancing material costs and anticipated plant upgrades. In Oklahoma, HP binders were introduced following early failures at the NCAT test track, leading to the adoption of HP mixtures for pavement rehabilitation. Oklahoma DOT gradually expanded their use, with full implementation occurring after positive evaluations of test sections. Utah DOT's use of HiMod mixtures began in 2015 and has steadily grown, with statewide implementation achieved by 2024. The mixtures have been applied in a variety of regional contexts, including bridge decks, thin and thick-lift overlays, and PCCP overlays. Virginia's implementation began with a focus on mitigating reflective cracking, using pilot projects to introduce HP binders and mixtures into the state's practices. Despite challenges, including project delays and concerns over maximum temperature thresholds, VDOT has integrated HP mixtures into its standard paving operations.

Across these States, the adoption of HP mixtures has been characterized by a mix of experimentation, learning from peer States, and addressing challenges as they arise, ultimately demonstrating the potential of these mixtures to improve pavement durability, resistance to cracking, and overall performance.

Key Insights and Opportunities

The implementation of HP binders and mixtures across multiple States has led to key lessons that shape their continued use. In New Jersey, the primary lesson learned is the necessity of modifying acceptance testing to account for the higher viscosity of HP binders, as traditional tests may not sufficiently capture their performance characteristics. Ohio DOT has found that HP mixtures do not require special handling or placement techniques compared to conventional PMA mixtures, but supplier certification and approval processes remain critical for maintaining quality. Oklahoma DOT identified the importance of allowing adequate cooling time when placing a RIL over concrete to prevent thermal issues that can cause pavement failures. Utah DOT's experience underscores the need to adjust mix designs to lower voids and increase density requirements to maximize the benefits of HP binders. For UDOT, the increased binder content permitted by the specification when using PG 76-34 has proven to be a critical factor in achieving successful performance. Similarly, VDOT has emphasized the importance of adhering to supplier recommendations for storage and handling, as well as assessing plant capabilities before implementing HP binder use.



Despite these insights, challenges remain in adopting and optimizing HP binders and mixtures. NJDOT has encountered industry hesitancy regarding pavement preservation efforts using HP binders, further complicated by the material's higher viscosity, which presents difficulties in production and application. In Ohio, the true characterization of HP mixtures' resistance to additional loading while preventing cracking remains a challenge, impacting their use in structural designs. Oklahoma DOT faces issues with the short shelf life of HP binders, leading to potential disruptions in production due to settlement, cooling, and clogged storage systems. A key lesson learned by UDOT came from its first PG 76-34 project in 2015, where binder gelling occurred partially due to the lack of rotational viscosity requirement (3.0 Pa.s) needed for pumpability. This experience highlighted the importance of maintaining critical workability criteria in specifications. Additionally, UDOT learned not to mandate a specific polymer type or content, instead allowing suppliers the flexibility to formulate binders that meet the required specification. VDOT has experienced cost-related challenges due to initial supply limitations, as well as concerns over the influence of storage conditions and weather on binder performance.

Implementable practices have emerged to mitigate some of these challenges and enhance the use of HP binders. In New Jersey, controlling the daily amount of binder used in production has helped minimize logistical issues and has contributed to more uniform mixtures. Ohio DOT has demonstrated that HP mixtures effectively mitigate instability in high-stress areas and outperform standard mixtures in rutting, cracking, and mass loss resistance. In Oklahoma, managing binder deliveries to align with daily production needs has been a proactive approach to addressing storage concerns. UDOT has benefited from close collaboration with its State asphalt pavement association during the implementation and outreach efforts. The use of material transfer vehicles (MTVs) and adequate trucking played a key role in improving smoothness for both thin and thick asphalt lifts. VDOT has highlighted the critical role of communication between suppliers, contractors, and State officials in ensuring smooth project execution and resolving potential issues early.

Despite these advancements, notable gaps remain in fully integrating HP binders and mixtures into pavement practices. NJDOT still lacks a comprehensive understanding of how traditional PG binder tests should be adapted for HP binders, indicating a need for further research in this area. The state is exploring how HP mixtures can extend pavement lifespan and reduce the frequency of rehabilitation and reconstruction efforts. Ohio DOT has yet to incorporate HP binder properties into structural pavement design methodologies and refine mix designs for BMD approaches. Oklahoma DOT has limited exploration into improving HP binder shelf life or optimizing storage conditions.

UDOT faces logistical concerns regarding hopper sizes for trucking thicker lifts, while long-term performance data for HiMod mixtures is still pending. UDOT is monitoring ongoing projects to compare the long-term performance of HiMod mixtures with traditional HMA and SMA mixtures, considering both cost efficiency and performance benefits. The agency is particularly interested in recyclability, aiming to assess how HiMod binders interact with RAP stockpiles and whether they can contribute to improved paving practices. Contractors have noted that HiMod thick lifts are more difficult to saw, often causing blades to overheat and wear out up faster. However, they also express a preference for HiMod due to its smooth flow through the paver, reduced paver cleanup compared to SMA, and ease of compaction with less effort.



VDOT has highlighted the absence of life-cycle cost analyses (LCCA) to quantify the economic benefits of HP binders and the need for additional verification tools for polymer contents like the Fourier-transform infrared spectroscopy (FTIR). Establishing State specifications for HP mixtures within the evolving BMD framework remains an ongoing challenge that necessitates continued research and development.

Key Strategies for Appropriate Implementation

Figure 2 presents the findings from the SWOT analysis on HP binders and mixtures, based on the information compiled in this effort and the discussions with select State DOTs through virtual site visits. The analysis highlights strengths that support implementation, weaknesses that can be addressed through training and specification refinement, and opportunities for accelerating adoption through research and funding initiatives. It also identifies threats, such as supply chain constraints and funding limitations, which can be mitigated through proactive management and policy advocacy. By leveraging strengths and addressing challenges, stakeholders can support the adoption of HP materials in pavement infrastructure.

Implementing HP binders and mixtures involves careful planning and strategies to ensure optimal performance, cost-efficiency, and long-term pavement durability. Agencies new to HP binders or those seeking to refine their specifications can benefit from a variety of approaches, based on the experiences of peer State DOTs. One key strategy is the adoption of performance-based specifications, as opposed to relying solely on polymer content limits. This flexible approach encourages innovation and cost-effective sourcing while ensuring the performance of HP binders. By focusing on performance metrics like MSCR, elastic recovery, and phase angle, State DOTs can better assess binder suitability and performance under varying conditions.

The application-specific selection of HP mixtures is another important consideration. States like NJDOT, Ohio DOT, Oklahoma DOT, and VDOT have tailored HP mixtures to specific pavement distress mechanisms. By identifying local pavement distress patterns and selecting the appropriate HP mixture, State DOTs can address specific performance challenges, improving both durability and cost-effectiveness. It is important to note that HP mixtures are not intended to compensate for structurally deficient pavement layers or inappropriate maintenance strategies. Their use should be considered within a broader, performance-based pavement design and preservation framework.

Cost considerations are also crucial, as HP mixtures tend to have higher initial costs compared to conventional materials. Despite these costs, the long-term performance benefits, including reduced maintenance needs and extended pavement life, may justify the investment. A comprehensive evaluation of cost trade-offs, including reductions in maintenance frequency and life-cycle costs, can help State DOTs make informed decisions about HP binder use.

Binder testing and specification refinements are ongoing processes for many State DOTs. Establishing a feedback loop between research, laboratory testing, and field performance allows State DOTs to continually improve and adapt specifications to meet emerging challenges and technologies.

Workability and constructability concerns may also be addressed by adjusting viscosity limits or production temperatures, as seen with Ohio DOT and Oklahoma DOT. Ensuring proper mix design requirements for density and binder content, as done by UDOT and VDOT, helps balance binder



stiffness with workability, ensuring effective field placement and maintaining high performance standards. Additionally, agencies may consider expanding the applications of HP mixtures. Some States are testing HP mixtures beyond their initial uses, such as NJDOT’s exploration of chip seals and Ohio DOT’s interest in full-depth and perpetual pavement applications. Pilot projects can provide valuable data to assess whether HP mixtures can offer enhanced performance in additional applications and justify the associated costs.

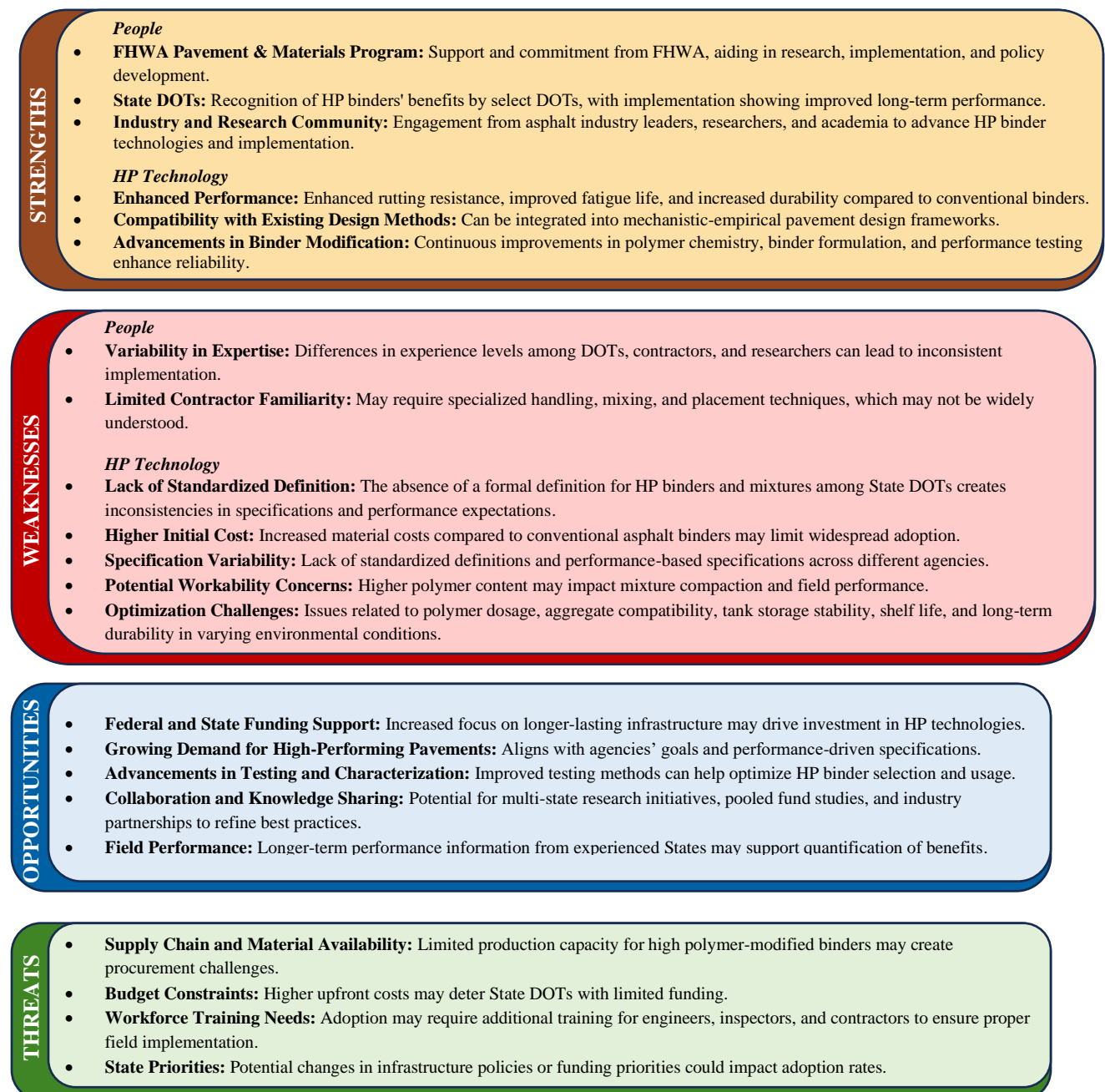


Figure 2. SWOT analysis for HP technology.



Finally, project-specific cost evaluations can be conducted to account for variations in tonnage, plant modifications, location, and bidding conditions. Developing a robust cost-comparison framework ensures that HP binder use aligns with project budgets and feasibility, promoting the efficient allocation of resources.

By integrating these strategies, State DOTs can effectively implement HP binders and mixtures, balancing performance and cost to achieve long-lasting and durable asphalt pavements.

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