TOPS

Targeted Overlay Pavement Solutions

Highly Modified Asphalt

How-To Document

June 2022

U.S. Department of Transportation
Federal Highway Administration

Every Day Counts
Innovation for a Nation on the Move

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16. Abstract
Highly modified asphalt (HiMA) is an asphalt binder with more than double the amount of polymer modification compared to conventionally modified binders. HiMA binders are used to enhance rutting, cracking, and raveling resistance or as a potential method of reducing pavement thickness. HiMA can be used in various mixtures, ranging from thin overlays to stone matrix asphalt mixtures to open-graded friction courses.

This document provides information to assist agencies, contractors, and material suppliers in adopting and using HiMA. It includes general information on project selection and pavement design, material selection, materials and construction specifications, and materials handling best practices.

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AASTHO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
DOT	Department of Transportation
ESRC	Engineered stress relief course
FHWA	Federal Highway Administration
FDOT	Florida Department of Transportation
HiMA	Highly modified asphalt
HPTO	High-performance thin overlay
ME	Mechanistic empirical
MSCR	Multiple stress creep recovery
NCAT	National Center for Asphalt Technology
NMAS	Nominal maximum aggregate size
PCC	Portland cement concrete
PG	Performance grading
RAP	Reclaimed asphalt pavement
SBS	Styrene-butadiene styrene

INTRODUCTION

A highly modified asphalt (HiMA) is a type of asphalt binder with more than double the amount of polymer modification compared to conventionally modified binders. Mixtures containing HiMA binders have been used in various applications to provide enhanced rutting, cracking, and raveling resistance or potentially to reduce reducing pavement thickness. They are typically used in locations where conventional binder modification is inadequate. The performance of this material makes it a viable potential overlay solution to cost-effectively extend the life of existing pavements.

The Federal Highway Administration (FWHA) developed this how-to document to assist agencies, contractors, and material suppliers with adopting and using this technology. It provides information in the following areas:

- Project selection and pavement design
- Materials selection
- Materials and construction specifications
- Materials handling best practices

One benefit of HiMA mixtures is the relative ease with which their use can be incorporated into asphalt projects. They can be used in various mixtures, ranging from thin overlays to stone matrix asphalt mixtures and open-graded friction courses. Aside from minor changes to binder specifications, mix design, and additional handling characteristics, the impact on an agency's design practices, specifications, and quality control activities is minimal.

Figure 1. Styrene-butadiene styrene polymer pellets. (Source: NCAT)

DEFINITION

Highly modified asphalt (HiMA) mixtures contain asphalt binders that are typically modified with 7 to 8 percent polymer, most commonly styrene-butadiene-styrene (SBS) (Figure 1). This amount of polymer is more than twice what is used in conventional polymer-modified binders (i.e., approximately 3 percent by weight of the binder). The binder-polymer structure of conventionally modified binders consists of an asphalt binder with a dispersed swollen-polymer phase that improves binder properties. By increasing the polymer content, the binder structure changes to a swollen polymer with a dispersed-asphalt phase, making the resultant binder behave more like a rubber compound, enhancing its cracking and rutting resistance (Habbouche et al. 2019) (Figure 2).

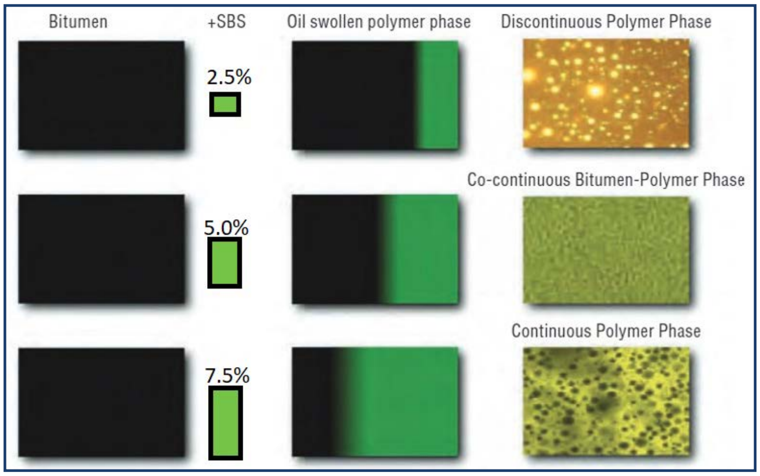

Figure 2. Effect of increasing SBS polymer content on binder/ polymer morphology. (Source: Kraton 2012)

DESIGN

Project Selection Criteria

HiMA mixtures are considered premium mixtures that are more distress-resistant and durable than conventionally modified asphalt mixtures and are typically selected to target specific pavement distress and performance issues. However, if a pavement is exhibiting excessive deflection, as evidenced by a combination of rutting and fatigue cracking, or poor joint load transfer resulting in faulting over 1/4 inch in a jointed concrete pavement, then those structural defects should be corrected before applying the overlay. Preparation such as full-depth reclamation, cracking and seating, or rubblization for reinforced concrete pavements, should be done before adding new material.

With their higher level of polymer modification, HiMA mixtures also have a higher initial cost than conventional mixtures. However, a cost analysis conducted by the Florida Department of Transportation (FDOT) indicated that projects only required an additional 10 months of life to offset the higher-quality binder costs (Warren 2019). The mixtures can be used as a thin overlay pavement preservation technique, on a milling and resurfacing project, or on new construction.

Common benefits include:

- Improved resistance to rutting in high-stress locations subjected to heavy axle loads and slow-moving traffic, such as truck weigh stations, agricultural inspection stations, and high-volume intersections and interchanges (Fournier 2010).
- Improved resistance to bottom-up fatigue cracking (Timm et al., 2012).
- Mitigated reflective cracking from thermal cracking or thermal expansion joints in portland cement concrete (PCC) pavements (Fournier 2011).
- Reduced raveling in open-graded friction courses (Arambula-Mercado et al. 2019).
- Improved resistance to rutting caused by studded tire wear (Kuennen 2020, Abaza and Dahms 2021).

HiMA overlays can also be used as a viable alternative to PCC pavement reconstruction, as they are known to cost less and take less time to construct. For example, HiMA overlays may be used when PCC rehabilitation, such as rubblization or crack-and-seating, could threaten the integrity of underground utilities in a heavily urbanized area. They can also be used when an asphalt pavement needs additional structural capacity but increasing the overall pavement thickness is not practical. HiMA mixtures can also be a viable option to maintain clearances and curb reveal. A September 2019 FDOT email-based survey of the U.S. States and Canadian provincial agencies collected essential information about HiMA binders and mixtures (Habbouche et al., 2021). Typical application usage as a percentage of total HiMA usage identified in the survey is shown in Figure 3.

Due to the relatively higher cost of the material, the increased stiffness of the asphalt binder, and challenges associated with handwork, FDOT suggests HiMA should not be used for small, low-production areas that need a lot of hand placement. Median openings, turn-outs, and other low-production areas should be paved with conventional asphalt mixtures, unless mitigating factors exist.

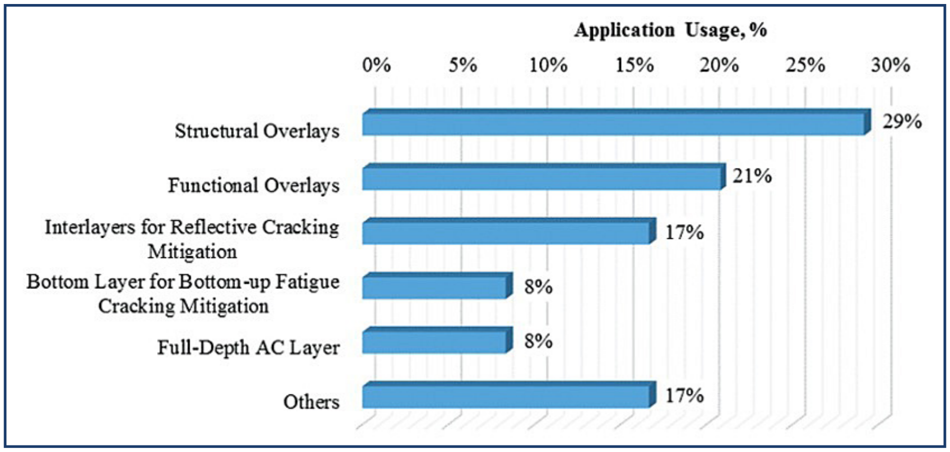

Figure 3. Common HiMA applications. (Source: Habbouche et al. 2021)

Pavement Design Methods

Using a HiMA binder in asphalt mixtures can potentially lead to a higher asphalt pavement mixture structural coefficient and reduced layer thickness for the same design traffic. However, many agencies have adopted a conservative approach and typically assign the same structural layer coefficient as conventional polymer-modified mixtures. A study conducted for FDOT suggested using a structural coefficient of 0.54 for HiMA mixes in Florida based on results from laboratory testing, pavement modeling, and full-scale testing (Habbouche et al., 2019). As a comparison, conventional dense-graded mixtures in Florida use a coefficient of 0.44. This increased value is consistent with the results from research conducted on HiMA test sections at the National Center for Asphalt Technology (NCAT) test track, where three empirical approaches yielded layer coefficients ranging from 0.54 to 0.57.

Overall, HiMA mixtures should be assigned at least the structural layer coefficient equivalent to the one established for conventional polymer-modified mixtures.

In the case of the mechanistic-empirical (ME) design method, material properties are critical inputs to determine the structural contribution of HiMA mixtures. Level 1 inputs rely on testing to determine the material properties of the materials to be used in the design. Test methods can characterize HiMA binders and mixtures for pavement design.

The primary material property for mechanistic-empirical design is the dynamic modulus (|E*|), which quantifies the modulus of the asphalt mixture over a range of expected temperatures and traffic speeds as a function of loading frequency. Typically, for the same aggregate blend, using a HiMA binder would result in a higher dynamic modulus, translating to extended service life or the possibility of achieving the same performance with a reduced thickness (Tran et al. 2019). Figure 4 shows an example of dynamic modulus master curves for surface mixes placed on

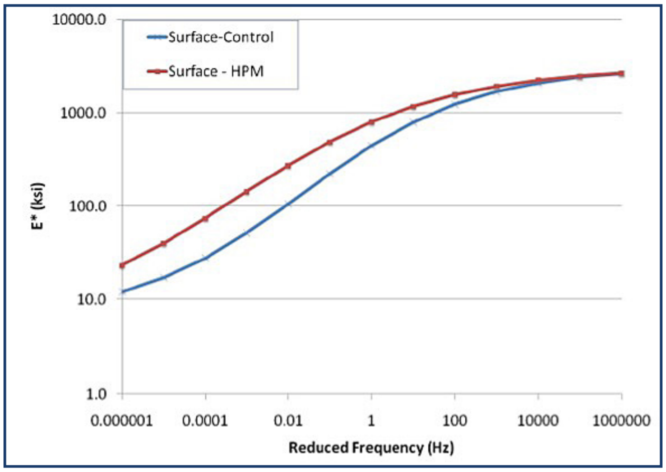

Figure 4. Unconfined dynamic modulus test results from 9.5 mm NMAS mixtures placed at the NCAT test track. (Source: Tran et al. 2019)

test sections at the NCAT test track. The control and high polymer-modified mixtures had similar gradations and volumetric properties, with the main difference being the asphalt binder used.

The primary consideration related to the thickness of functional overlays typically used in maintenance applications is the ability to adequately compact the pavement layer after it is placed to achieve the appropriate density. Thinner pavement layers tend to cool quickly and allow less time for compaction. This cooling, coupled with the increased HiMA binder stiffness, can create significant density challenges for the contractor. FDOTs experience suggests that lift thicknesses of 1.25 inches or greater are sufficient to obtain the desired density if they can accommodate the mixture's nominal maximum aggregate size (NMAS).

MIXTURES AND MATERIALS

The 2019 email survey identified limiting factors of HiMA binders (Figure 5), one of which was the lack of standard specifications (Habbouche et al., 2021). However, incorporating HiMA binders into a specification involves only a few additional considerations compared to the use of conventional polymer-modified binders, most of which pertain to how the material, either the binder or the resulting mixture, must be handled and stored.

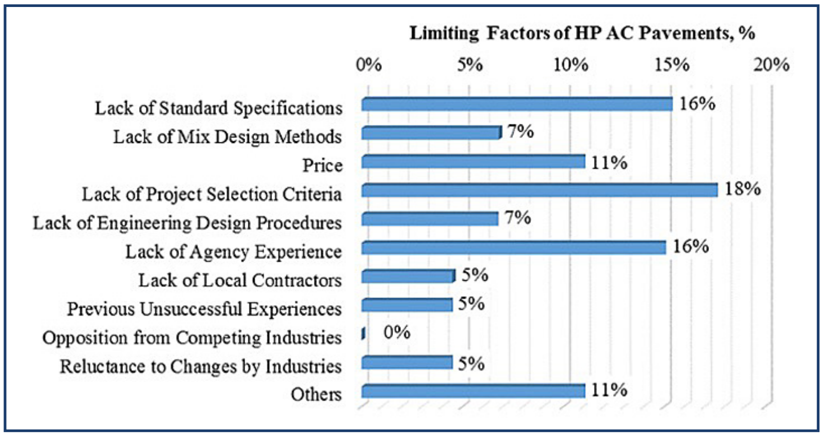

Figure 5. HiMA mixture limiting factors according to survey responses. (Source: Habbouche et al. 2021)

Binder Selection and Specifications

The main difference in materials used in HiMA mixtures is the number of modifiers. While conventional polymer-modified binders contain approximately 2.5 – 3.0 percent polymer by weight of the binder, HiMA binders incorporate a much higher percentage, typically 7 to 8 percent. The polymer most used for modification is styrene-butadiene-styrene (SBS) or styrene-butadiene.

Rather than using a prescriptive method specification and specifying minimum polymer content, some agencies rely on binder performance grade and rheological parameters to define and accept HiMA binders (Habbouche et al., 2021). Specifications for performance grading (PG) can be developed based on AASHTO M 320 S*tandard Specification for Performance-Graded Asphalt Binder*, or AASHTO M 332 *Standard Specification for Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test*. Other properties of interest relate to the high elasticity and recovery expected from high-polymer modification. They can be obtained by conducting AASHTO T 301 *Standard Test Method for Elastic Recovery Test of Asphalt Materials using a Ductilometer* or AASHTO T 350 *Standard Method of Test for MSCR Test of Asphalt Binder Using a Dynamic Shear Rheometer*. AASHTO M 320, AASHTO M 332, AASHTO T 301, and AASHTO T 350 are voluntary specifications and test procedures not required under Federal statute or regulation.

When using the conventional PG asphalt binder, the parameters evaluated are complex stiffness modulus (G*) and phase angle (ϕ). Agencies that use this approach may specify limiting values for G*sin ϕ or G*/sin ϕ, indicating the binder's susceptibility to cracking and rutting. Other agencies specify a minimum percentage for elastic recovery of the binder measured per AASHTO T 301, which relates to fatigue cracking resistance. Table 1 shows examples of HiMA binder specifications for agencies using the conventional PG system (AASHTO M 320). Note the spread between high- and low-critical temperatures for HiMA binders, also called the useful temperature interval, ranges from 104 to 110 degrees Celsius. Typical polymer-modified binders are generally in the range of 92 to 104 degrees Celsius. This reflects the broader range of HiMA binder serviceability temperatures.

Table 1. Agency specifications and special provisions for HiMA binders based on conventional performance grading (PG) test method.

(Source: AASHTO M 320)

Agency	Performance Grade	Properties
Minnesota	PG 76-34	ER ≥ 90%
New Hampshire	PG 76-34	ER ≥ 90%
Ohio	PG 88-22	ER ≥ 90%
Oregon	PG 76-28	ER ≥ 90%
New York City	PG 76-34	ER ≥ 90%
Utah	PG 76-34	ER ≥ 90%
Vermont	PG 76-34	ER ≥ 90%
Washington	PG 76-34	ER ≥ 90%

The Ohio DOT uses AASHTO M 320 for its HiMA binder specification (referred to as PG 88-22M), which reads as follows. Relevant items are highlighted (Ohio DOT 2018):

702.01 Asphalt Binders.

General. *According to AASHTO M 320-10, Table 1 except as follows. Ensure PG 70-22M, PG 76-22M, PG 88-22M, and PG 64-28 meet the requirements of Table 702.01- 1.*

Table 2. Ohio Material Requirements for PG modified binder.

Test / Requirement	SBR Polymer	SBR Polymer	Pre-Blended	Pre-Blended	Pre-Blended	Pre-Blended	Note
Final PG Binder Grade	70-22M (a, b)	64-28 (b)	64-28 (a)	70-22M (a, k)	70-22M (a, k)	88-22M (a, l, m)	c
Actual Pass Temperatures	Report	Report	Report	Report	Report	Report	i
RTFO Mass Change, percent max.	0.75	0.75	0.75	0.75	0.75	0.75	d
Phase Angle, max.	78	78	78	78	74	74	d
Elastic Recovery, min.	—	—	65	65	75	90	e. d
Toughness, in. lb.	125	105	—	—	—	—	f, d
Tenacity, in. lb.	70	80	—	—	—	—	f, d
Elongation, in. min.	20	20	—	—	—	—	f, d
Ductility, in. min.	28	28	—	—	—	—	j, d
Separation, F max.	10	10	10	10	10	10	g, d
Homogeneity	—	—	—	None	None	None	h, d

a. Pre-blended Binder. Use a base neat asphalt binder that is a -22 grade for 70-22M and 76-22M. Use a base neat asphalt binder that is a -28 grade for 64-28. 64-28 can be neat, PPA modified or modified with SB, SBS or Elvaloy. 64-28 PPA only modified does not have to meet the phase angle or elastic recovery requirements. Ensure SB, SBS or Elvaloy modified 64-28 meets all requirements listed.

b. Post-blended Binder made from neat Supplement 1032 certified or pre-approved standard PG Binder grade and SBR solids amount equal to or above 3.5 percent by weight of total binder to achieve the PG Binder grade. Ensure all listed properties are met.
c. Without Direct Tension, graded with actual pass temperatures.
d. PG Modified Binder.
e. AASHTO T301, 10cm@ 77 °F (25 °C), hold 5 min. before cutting, on RTFO material for SB, SBS, and Elvaloy. Note elongation after one hour to the nearest 0.01 cm and report elastic recovery to nearest 0.1%.
f. ASTM D 5801, 50cm/min @ 77 °F (25 °C).
g. Condition samples according to ASTM D7173. Conduct softening point difference of top and bottom of tube per AASHTO T53. Compatibility of polymer and neat binder is sole responsibility of supplier. Formulate PG Modified Binder to retain dispersion for 3 days minimum.
h. Heat a minimum 400 gram sample at 350 °F (177 °C) for 2.5-3 hours. Pour entire sample over a hot No. 50 (300 µm) sieve at 340 °F (171 °C). Look for retained polymer lumps.
i. Actual high and low temperature achieved by PG Modified Binder beyond required grade, but will not grade out to the next standard PG Binder grade for low temperature.
J. AASHTO T51, @ 39 °F (4 °C), 1 m/min.
k. SB, SBS, Elvaloy or Supplemental Specifications 887 GTR.
I. SB, SBS, Elvaloy.
m. The requirements of 3.0 Pa*s maximum for the rotational viscosity for 88-22M may be waived at the discretion of the Department if the supplier warrants that the asphalt binder can be adequately pumped, mixed, and compacted at or below the temperature requirements in Table 702.00-1. Do not exceed 10.0 Pa*s rotational viscosity using the #27 spindle at time of shipment.

Figure 6. Dynamic shear rheometer used for the MSCR test. (Source: Asphalt Testing Solutions)

Since the test methods outlined in AASHTO M 320 were developed for unmodified binders, the MSCR test was later developed to better characterize a wider variety of asphalt binders, including polymer-modified binders. The MSCR test uses the Dynamic Shear Rheometer (Figure 6) to determine the non-recoverable creep compliance (J_{nr}) and the average percent recovery (R) of the binder. The J_{nr} parameter at 3.2 kPa determines the resistance of the binder to permanent deformation, while the percent recovery ($R_{3.2}$) indicates the presence of polymer and the quality of blending. Table 2 provides examples of HiMA binder specifications for agencies that have adopted the MSCR method of binder classification as specified in AASHTO M 332. The “E” grade designation stands for extremely heavy traffic, indicating a highly rut-resistant material at the expected pavement temperature for the regional climate.

Table 3. Agency specifications and special provisions for HiMA binders based on MSCR tests. (Source: AASHTO M 332)

Agency	Performance Grade	Properties
Alabama	PG 76E-22	R3.2 ≥ 90%
Alaska	PG 64E-40	Jnr, 3.2 ≤ 0.1 kPa-1 and R3.2 ≥ 95% at 64°C
Florida	PG 76E-22	Jnr, 3.2 ≤ 0.1 kPa-1 and R3.2 ≥ 90% at 76°C
Georgia	PG 76E-22	Jnr, 3.2 ≤ 0.1 kPa-1 and R3.2 ≥ 90% at 76°C
Iowa	PG 64E-34	R3.2 ≥ 90% at 64°C
Kentucky	PG 76E-22	R3.2 ≥ 90% at 76°C
Missouri	PG 76E-22	Jnr, 3.2 ≤ 0.1 kPa-1 and R3.2 ≥ 90% at 76°C
New Jersey	PG 64E-22	Jnr, 3.2 ≤ 0.3-0.5 kPa-1 at 64°C
New York	PG 76E-28	Jnr, 3.2 ≤ 0.5 kPa-1 and R3.2 ≥ 55% at 76°C
Oklahoma	PG 76E-28	R3.2 ≥ 95% at 76°C
Tennessee	PG 76E-28	Jnr, 3.2 ≤ 0.1 kPa-1 and R3.2 ≥ 90% at 76°C
Virginia	PG 76E-28	Jnr, 3.2 ≤ 0.1 kPa-1 and R3.2 ≥ 90% at 76°C
Wisconsin	PG 58E-34	Jnr, 3.2 ≤ 0.5 kPa-1 and R3.2 ≥ 75% at 58°C

The Virginia DOT uses AASHTO M 332 for its HiMA binder specification, referred to as high polymer. It reads as follows (Virginia DOT 2020):

> ***210.02—Materials***
>
> ***(e) Asphalt Binders*** *shall conform to AASHTO M 332 Table 1. High-polymer binder shall consist of mixes incorporating a neat asphalt material with a high-polymer modification (approximately 7.5 percent) complying with AASHTO M 332 for PG 76E-28 (HP), except that the MSCR shall have a Jnr3.2 maximum value of 0.1 kPa*$^{-1}$ *when tested according to AASHTO T350. The minimum MSCR percent recovery at 3.2 kPa shall be 90 percent. The MSCR test for Jnr and percent recovery shall be run at 76 degrees Celsius. The viscosity shall be less than or equal to 3.0 Pa-s. However, the engineer may increase the viscosity limit to 5.0 Pa-s if the binder supplier and contractor agree the binder is suitably workable.*

Aggregate Selection

Aggregate selection and the corresponding specifications for HiMA mixtures do not involve any special considerations. However, it is important to note that HiMA mixtures are considered premium mixtures typically used in high-stress applications, and the aggregate used needs to reflect that level of quality. Although some agencies have opted not to allow reclaimed asphalt pavement (RAP) in HiMA mixes, those restrictions primarily aim to maximize the benefits of the premium binder or not dilute the polymer with RAP binder. While the inclusion of RAP may result in decreased cracking resistance (Roque et al. 2020), it has been used successfully in several projects.

The selection of the NMAS should follow the same NMAS to lift thickness ratio used for other mixtures. The gradation of the aggregate blend may follow the same agency specifications as non-HiMA mixtures. Overlay applications have been placed in lifts as thin as 0.75 inches, although thicknesses of at least 1.25 inches are more commonly used. As described previously, thinner layers cool quicker, so consideration should be given during project design to use a lift thickness that will allow for better compaction. Several demonstration projects report using Superpave 9.5 mm NMAS mixtures in thin 1-inch overlays without any difficulties meeting the State-required compaction specification (Fournier 2011, Fournier and Clark 2012, Fournier 2012).

Figure 7. HiMA high-performance thin overlay (HPTO) mixture. (Source: T. Walbeck)

Mix Design

When designing HiMA mixtures, there are no significant changes to conventional design methodologies. Mixture design may be conducted using the same method the agency typically uses for conventional mixtures. HiMA binders may be used in mixtures with different aggregate gradations (dense-graded, open-graded, gap-graded/stone matrix asphalt) depending on their intended use. The material supplier should recommend the mixing and compaction temperatures, but typically they will be higher than conventionally modified binders. During the design process, mixture conditioning should be conducted according to AASHTO R 30, based on the established compaction temperature of the mixture. It is important to note that with a combination of absorptive aggregates and higher mixing and compaction temperatures, the amount of absorbed binder may be slightly higher when compared to a conventionally modified binder. AASHTO R 30 is a voluntary specification and is not required under Federal statute or regulation.

Since the binders are stiffer than neat binders, HiMA mixtures may be more resistant to compaction in the gyratory compaction mold, resulting in a slightly higher binder content to meet the design target air voids (Tran et al., 2019). The higher binder contents in HiMA mixtures can improve overall fatigue and low-temperature cracking resistance without compromising rutting performance (Kwon et al. 2018), which is a desirable characteristic as more agencies transition to balanced mix design and performance testing.

There are very few differences between HiMA mixtures and conventionally modified mixtures regarding additives such as mineral filler, hydrated lime, or fibers. Warm-mix asphalt additives are frequently used with HiMA mixtures, but primarily as a compaction aid or antistripping additive rather than to reduce production and placement temperatures.

Performance Testing

Laboratory performance testing of HiMA mixtures may be conducted using the same tests available for non-HiMA mixtures. Properties of interest generally relate to the mixture's resistance to rutting, fatigue, and thermal cracking. As part of a demonstration project led by state highway agencies in the Northeast Pavement Preservation Partnership, a pilot performance-based specification was developed for high-performance thin overlays utilizing a HiMA binder. Table 3 shows the laboratory mixture performance criteria outlined in this specification (Mogawer et al., 2014). While the tests and criteria were selected for a specific application of HiMA mixtures, similar tests may be used in other instances to verify the enhanced performance expected when using high-polymer modification.

Table 4. Overview of NPPP pilot specification for HPTO utilizing HiMA binder.
(Source: Mogawer et al. 2014)

Mixtures without RAP		
Property	**Device/Test**	**Criteria**
Thermal cracking temperature of mixture	TSRST: AASHTO TP 10-93	± 6°C from the low-temperature PG of the binder (minimum of 3 test specimens per mixture)
Cracking	OT: Texas DOT Test Designation Tex-248-F	Mixtures shall exhibit average OT cycles to failure (93% load reduction) ≥ 300
Fatigue life	Flexural beam: AASHTO T 321	≥ 100,000 cycles
Rutting	APA: AASHTO TP 63 at the PG high temperature for the project location	The average rut depth for 6 specimens is ≤ 4 mm at 8,000 loading cycles
Added Requirement for Mixtures with RAP		
Property	**Device/Test**	**Criteria**
Cracking	OT: Texas DOT Test Designation Tex-248-F	Mixtures containing RAP shall exhibit overage OT cycles to failure (93% load reduction) within ± 10% of the OT cycles to failure of control specimens without RAP (minimum of 3 test specimens per mixture)

* The tests and criteria included in the table are voluntary and not required by Federal statute or regulation.

According to the specification, the strain level should equal the strain in the existing asphalt pavement layer or, as an alternative, use a 750 microstrain level with PG 76-34 and a 500 microstrain level with a PG 82-28.

CONSTRUCTION SPECIFICATIONS

Production

In general, producing HiMA mixtures is not significantly different from making mixtures with conventionally modified binders. While storage and handling of HiMA binders typically follow the same construction practices as conventional polymer-modified binders, some differences should be addressed by the contractor. The most critical issues when using HiMA binders are length of storage time and temperature.

Storage and Transportation

Due to their short period of readiness for placement, HiMA binders should not be stored for more than 3 days to 1 week, depending on the source. Ideally, HiMA binders should be used immediately and not stored at all. If storage is required, follow supplier instructions regarding maximum temperatures, storage time, circulation, and agitation requirements that may be specific to the product (Warren 2019). During this time, binder samples may be obtained and tested to ensure the product maintains its properties. Some agencies require maximum polymer separation as determined with ASTM D7173.[1] Basic on-site testing can include penetration

[1] Use of ASTM D7173 is not a Federal requirement.

at 25 degrees Celsius, softening point, and viscosity at 160 degrees Celsius.

In general, HiMA binders should not exceed 320 degrees Fahrenheit during storage. Overheating HiMA binders increases viscosity. The polymer will continue to crosslink, affecting the workability of the mixture. If storage is required, the temperature should be reduced, and mixing/agitation may need to be performed periodically or as the supplier recommends (AMAP 2015).

Figure 8. Asphalt binder storage tanks. (Source: CRH Americas Materials)

If tank storage leads to an issue, such as weather, project delays, etc., or if there are issues with surplus HiMA material, contractors should have other options available. These alternatives, which can help minimize overall project costs, could be as simple as using the HiMA binder in a non-HiMA mixture (Warren 2019). Whatever alternative the contractor chooses will need to be approved by the agency and may involve additional sampling and testing. While HiMA mixtures can be stored for short periods, it is not recommended they be stored overnight. Storage should be in properly heated and insulated silos (AMAP 2015).

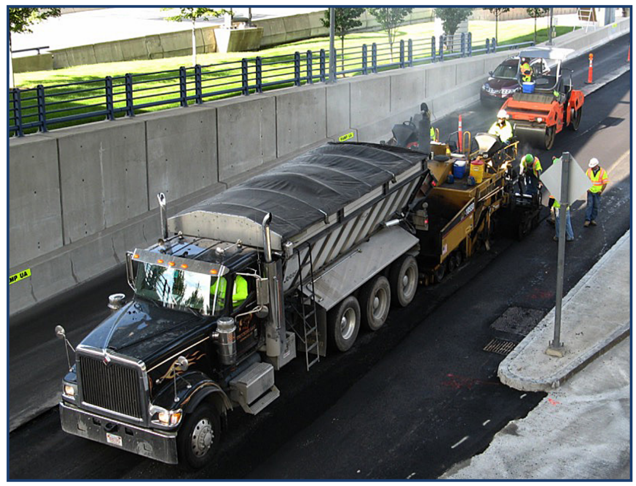

Figure 9. Mixture transport with properly tarped loads. (Source: CRH Americas Materials)

Maintaining proper temperature during mix production is key. The ideal mixing temperature is mix dependent but generally falls within 320 to 330 degrees Fahrenheit. While starting the production process at a slightly higher temperature may help with the initial heating of the plant components, silos, trucks, material transfer vehicles, and pavers, it is important to note that excessive temperatures can potentially damage the binder and hurt constructibility and performance (AMAP 2015).

The same construction practices used for conventional polymer-modified mixes should be followed when transporting HiMA mixtures. Loads should be covered with tarps overlapping the sides and securely fastened to prevent significant decreases in temperature (AMAP 2015). Depending on the length of haul, truck beds may need to be partially insulated (fronts and bottoms). In cooler climates and during longer hauls, truck beds may need to be fully insulated (all four sides and bottoms).

Surface Preparation

Surface preparation before placement of HiMA mixtures should follow the same construction practices as other mixtures. Milling may be performed, if necessary, to achieve a specified thickness or to eliminate surface distresses, especially minor rutting.

A tack coat should be applied to ensure proper bonding to the underlying surface. Selection of the tack coat material is usually made in accordance with the agency's standard specifications. Due to the premium nature of the mixture, several agencies require a reduced-tracking tack material to ensure an adequate bond with the underlying layer. However, it is important to ensure the tack coat material and the HiMA binder are compatible. One HiMA demonstration project reported the presence of clumps of tack material on the surface, usually caused by pickup on the haul truck tires when using a latex-modified tack coat (Fournier 2012).

Placement

Successful placement of HiMA mixtures largely depends on maintaining a continuous paving operation. It is essential the plant production rate, the number of trucks used, paver speed, and compaction operations are all correctly balanced to avoid having trucks waiting for extended periods or rollers being left behind by the paver. Material transfer devices are frequently used to help establish this continuous paving process. The mixture temperature behind the screed should be approximately 300 degrees Fahrenheit, and the breakdown rollers should be kept close to the paver. HiMA mixtures are stiffer mixes that are sometimes placed much thinner, causing them to cool quicker than conventional polymer-modified mixes. Compaction should be completed promptly to achieve the target density while the mat is still above the cessation temperature of 175 to 180 degrees Fahrenheit where no additional increase in density is possible. In addition, due to this increased stiffness, handwork can be more difficult and should be minimized (AMAP 2015). In general, no special compaction equipment is needed, but it still may be necessary to adjust rolling patterns to achieve density. The pattern should be closely monitored and maintained to ensure consistency.

Acceptance

The same quality characteristics and test methods used for conventional polymer-modified mixtures may be used for acceptance and quality control of HiMA mixtures. This can include binder content, gradation, volumetrics, roadway density, and smoothness. If binder samples are taken for acceptance, the specifications outlined in AASHTO M 320 or 332 should typically apply. While generally not used for approval, samples may also be tested using Fourier Transform Infrared Spectroscopy to determine the approximate polymer content once a baseline measurement is established.

Figure 10. HiMA mixture paving operation on US-202 in Rochester, NH. (Source: Klutz)

CONSTRUCTION AND MAINTENANCE PRACTICES

The following sections include some known potential issues with HPTO (and thin lift pavements in general) and troubleshooting information.

Quality Control at Plant

The binder viscosity should be monitored daily to ensure no HiMA binder degradation has occurred during handling and storage. A common method used is AASHTO T 316.

Storage

Use HiMA binders in the shortest possible time after delivery. If storage is required, the temperature should be monitored, and the material circulated or agitated as recommended by the supplier. Avoid multiple heating and cooling cycles.

Quality control staff should frequently monitor the binder temperature while in storage and the length of time it has been stored. Storage temperatures generally should not exceed 320 degrees Fahrenheit, and many suppliers recommend even lower storage temperatures. A 24-hour temperature recording device that provides a permanent record, such as a printed graph, is one tool that may help quality control staff monitor and manage the binder temperature.

Mixing the HiMA binder with other binders (particularly unmodified binders) should be avoided as it will degrade the quality of the binder, potentially failing to meet specifications. Using dedicated storage tanks for HiMA binders can help prevent contamination. If a dedicated tank is not available, the tank should be completely emptied before use. In addition, HiMA binders from different suppliers should not be mixed, as different polymer and cross-linking technologies may not be compatible and may cause the polymer to separate.

Mixture Production

It is important to maintain proper temperatures during mix production and not overheat the HiMA binder. Overheating the binder is counterproductive and will increase its viscosity rather than decrease it. To ensure proper flow in the binder supply line, the in-line pipe diameters at the plant should be checked before the delivery of HiMA binders begins. If needed, larger pipe diameters may be used (Habbouche et al., 2021).

An unmodified binder may be circulated before start-up and then switched to a HiMA binder during production to avoid buildup in the pumping system. Similarly, after shutdown at the end of the shift, an unmodified binder may be circulated through the pump to remove any residual HiMA binder. For mix production, if a temperature loss during the initial production run is a concern, one option is to start the production operations with an unmodified mix to preheat the plant components, especially the slat conveyor and storage silos. The startup mix can then be shipped to another project or recycled to the RAP stockpile before HiMA production begins.

Placement

There are no equipment modifications necessary to place HiMA mixtures. As stated previously, using a material transfer device is suggested to help ensure a continuous paving operation. Another effective practice is to balance the production rates, including mixing at the plant, hauling, lay down, and compaction, to avoid paver speed changes, interruptions, and long stops during the paving operation. Where possible, HiMA mixtures should not be placed in areas of low production and handwork areas unless necessary.

Paving HiMA mixtures at night can also be accomplished with minimal changes to the paving operations. In general, it is suggested that the minimum ambient air temperature be 50 degrees Fahrenheit. It is also important not to let the mixture cool excessively (typically < 25 degrees Fahrenheit) before compaction begins. Once again, coordination is important to keep the breakdown roller close to the paver and ensure a continuous and consistent compaction process.

The number and types of rollers used may vary, but in general, no significant modifications are needed. The same rolling pattern as conventional polymer-modified mixtures may be used, with adjustments made as necessary. The compaction operation needs to be continually monitored to ensure the rolling pattern is consistently followed, and density is being properly achieved.

On HiMA projects, pneumatic-tired rollers have been used successfully, but as with conventional mixes, the key is to ensure that the tires are hot before compacting the mat. However, if excessive pickup becomes a problem, pneumatic-tired rollers may need to be removed from the rolling train. Also, a good practice is to use newer, unblemished steel-wheel rollers, both vibratory and static. Older rollers, especially those used to compact aggregate bases that are rusted and pitted, will not have a uniform film of water across the drum surfaces. This may cause the mix to stick and build upon the drum. A possible solution is to use liquid dishwashing soap in the water supply tank on the steel-wheel rollers. Cleanup of the paving equipment should be performed immediately after completion of the paving operation while the residual mixture is still warm and workable.

SUMMARY

HiMA mixtures have been used in various applications to provide enhanced rutting, cracking, and raveling resistance or as a potential method of reducing pavement thickness. They can be used as a thin overlay pavement preservation technique; on a milling and resurfacing project; or on new construction. The performance of this material makes it a viable potential overlay solution to cost-effectively extend the life of existing pavements.

Key takeaways include the following:

- HiMA mixtures can be incorporated into asphalt projects with minimal changes to design practices, specifications, and construction practices.
- When designing the pavement thickness, HiMA mixtures should be assigned at least the structural layer coefficient equivalent to the one established for conventional polymer-modified mixtures, up to a maximum of 0.54. For ME designs, HiMA binders will have a higher dynamic modulus, which can be used to extend the pavement's service life or achieve the same performance with a reduced thickness.
- For functional overlays, the minimum thickness typically specified for a HiMA mixture is 1.25 inches and generally follows the same NMAS to lift thickness ratio used for other mixtures. However, it is important to note that specifying thinner lifts allows less time for compaction, which could adversely impact pavement density and overall performance.

- Aggregate and mix design specifications generally remain the same as conventionally modified mixtures used in similar traffic and loading situations.
- Performance tests are a viable mechanism to evaluate the potential benefits of HiMA mixtures.
- Consistent communication is essential to a successful project. This includes communications between the agency and contractor and between the contractor and binder supplier.
- Producing HiMA mixtures is not significantly different from producing mixtures with conventionally modified binders. The most important issues when using HiMA binders are the length of storage and temperature.
- HiMA binders should not be stored for an extended period (no more than 3 days to one week, depending on the source). If storage is required, the temperature should be reduced, and mixing/agitation should be performed periodically or as recommended by the supplier.
- Storage temperatures of HiMA binders should typically not exceed 320 degrees Fahrenheit.
- Successful placement of HiMA mixtures depends on maintaining a continuous paving operation, with a good balance between plant production, trucking, paver speeds, and rollers. Material transfer devices are recommended.
- During paving operations, the temperature of the mixture behind the screed should be approximately 300 degrees Fahrenheit and the breakdown rollers should be kept as close to the paver as practical. In general, no special compaction equipment is needed.
- Optimal density may be obtained by adjusting the rolling patterns.
- The compaction operation should be continually monitored to ensure the rolling pattern is consistent and proper density is achieved.

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