High Performance, Highly Modified Asphalt: The Next Generation of Hot Mix Binders

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IH-10, Florida
Comparative Performance Concept

- **HMA, Non-Polymer Modified Asphalt Binder**
- **HMA, Traditional Polymer-Modified Asphalt Binder**
- **HMA, High Performance (HP) Highly Modified Asphalt Binder**

Present Serviceability Index vs. Year
What Is High Performance/Highly Modified Asphalt?

- Highly Modified Asphalt (often called HiMA™ or HPG) is exactly what it says, an asphalt binder with $2-3 \times$ the amount of SBS polymer used to produce grades such as PG76-22.
- The resulting binder contains a dense polymer network that significantly improves mixture performance.
  - Much less sensitive to temperature changes over the range of service temperatures.
  - Much greater resistance to rutting and fatigue cracking.
- SBS polymers are available that allow the use of high polymer content ($\geq 7.5\%$) binders that can be handled at similar temperatures as PG76-22.
- In reality, it is an asphalt-extended polymer binder, rather than a polymer-modified asphalt binder.
SBS in Asphalt Binder (Bitumen)

- SBS polymer absorbs some of the lighter (maltene) fractions of the bitumen
- Expands and forms an elastomeric network in the bitumen that:
  - Provides an elastic response to loading at high service temperatures where unmodified asphalt binders behave as a viscous fluid
  - Improves adhesive and tensile strength
  - Reduces temperature susceptibility
- Strength of the network depends on the polymer content
"S-Curve" - Effect of increasing SBS content

Softening point T R&B [°C] vs SBS Content [%]

- Continuous Bitumen Phase
- Continuous Polymer Phase
- Highly Modified, HP

Examples of grades:
- PG70-22
- PG76-22
- PG76-28
- PG82-22

KRATON
High Performance-Graded Binder - Proposed Specification

Key features:

- Based on AASHTO M332, instead of M320
- Using M320 approach, HPG would grade at PG88-28 or PG94-28
- Uses MSCR, tests RTFO-aged binder at 76°C
- $J_{nr3.2} < 0.10$ kPa\(^{-1}\)
- $R_{3.2} > 90\%$ PAV DSR
- ($G\times\sin\delta$) maximum is 4,000 MPa, which is lower than either AASHTO specification

<table>
<thead>
<tr>
<th>High Performance-Graded (HPG) Binder</th>
<th>HPG</th>
</tr>
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<tr>
<td>Property and Test Method</td>
<td></td>
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<tr>
<td>Original Binder</td>
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<tr>
<td>Flash Point, T&lt;sub&gt;48&lt;/sub&gt;, Min. °C</td>
<td>230</td>
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<tr>
<td>Viscosity, T&lt;sub&gt;316&lt;/sub&gt;, Max. 5.0 Pas, test temperature, °C</td>
<td>135</td>
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<tr>
<td>Separation, ASTM D7173, Dynamic Shear, T&lt;sub&gt;315&lt;/sub&gt;, % G*sinδ Difference, Min. 10%</td>
<td>76</td>
</tr>
<tr>
<td>Polymer Content, Tex 533-D2, Min. %</td>
<td>7.5</td>
</tr>
<tr>
<td>Rolling Thin-Film Oven (Tex 541-C)</td>
<td></td>
</tr>
<tr>
<td>Mass change, Tex 541-C, Max. %</td>
<td>1.0</td>
</tr>
<tr>
<td>Multiple Stress Creep Recovery, T&lt;sub&gt;350&lt;/sub&gt;, Jnr, 3.2 kPa, Max. 0.10 kPa(^{-1}), test temperature, °C</td>
<td>76</td>
</tr>
<tr>
<td>Multiple Stress Creep Recovery, T&lt;sub&gt;350&lt;/sub&gt;, % recovery, 3.2 kPa, Min. 90 %, test temperature, °C</td>
<td>76</td>
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<tr>
<td>Pressure Aging Vessel (PAV) Residue (R 28)</td>
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<tr>
<td>PAV aging temperature, °C</td>
<td>100</td>
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<tr>
<td>Dynamic shear, T&lt;sub&gt;315&lt;/sub&gt; G*sinδ%, Max. 3,000 kPa, Test temperature @ 10 rad/sec, °C</td>
<td>25</td>
</tr>
<tr>
<td>Creep Stiffness, T&lt;sub&gt;313&lt;/sub&gt; @ 60 sec(^{-2}) S, Max. 300 mPas, Min-value, Min. 0.30, Test temperature, °C</td>
<td>-18</td>
</tr>
</tbody>
</table>

1. This requirement may be waived at the Department’s discretion if the supplier warrants that the asphalt binder can be adequately pumped, mixed, and compacted at temperatures that meet all applicable safety, environmental, and constructability requirements. Use Spindle 21 when testing for rotational viscosity.
2. Determined as the absolute value of the percent difference in $G\times\sin\delta$ measured on samples taken from the top and bottom: $100\% \times (G\times\sin\delta \text{ (top)} - G\times\sin\delta \text{ (bottom)}) / G\times\sin\delta \text{ (top)}$
3. In Tex 533-C, the SBS peak is changed to 896 cm\(^{-1}\) representing the polyethylene band.
4. Silicone beam molds, as described in AASHTO T313, are acceptable for use.
NCAT’s Test Track—the only high-speed, full-scale accelerated pavement testing facility in the world—is a 1.7-mile oval with experimental sections sponsored by highway agencies and the transportation industry.

Want to get involved? Contact us for information on how to become a sponsor.

About the Test Track

The NCAT Test Track is a national research proving ground for asphalt pavements. Highway agencies and industry sponsors fund research on the 1.7-mile oval in 200-foot test sections. This real-world laboratory allows for cutting-edge experimentation while avoiding the risk of failure on actual roadways. In a step to play a larger role in pavement research, NCAT has also partnered with the Minnesota Department of Transportation’s MnROAD facility to focus on two important national issues that impact each agency: pavement preservation and validation of cracking tests.
Control (S9) and HiMA™(N7) Section Designs, 2009 Construction (NCAT Report 12-08)

- From the report: “workability and compactability were similar to those of a PG 76-22 binder both in the laboratory and in the field”
- Laboratory mix characteristics, field performance were very different.
NCAT Results

- **Laboratory:**
  - Minimal rutting, no moisture damage in Hamburg Wheel Tracking test
  - Fatigue endurance limit 3X higher
  - Less temperature susceptible

- **Field**
  - After 20 million flexible ESAL, about 4 mm rutting with minor superficial cracking
  - Control had bottom-up fatigue cracking
  - No change in ride quality
Additional HiMA™ work at NCAT

- Section N8 (Oklahoma) rehabilitation

- “Green Group” High Modulus Asphalt (EME) study.
  - HiMA mixture, w/35% RAP provided best mechanical properties, performance

- “Cracking Group” - evaluating different laboratory cracking tests vs field performance
  - Promoting top-down cracking, while avoiding traditional, bottom-up fatigue
  - Thin base/binder lifts (4.25 in) for all 6 test sections
  - No bottom-up cracking after 20 million ESAL
  - Section S6 included HiMA wearing course-minimal superficial cracking observed

- Deep (7.5 in), single lift construction
  - 12.5 mm NMS dense-graded mixture, consistent densities achieved
  - No distress, no change in profile after 10 million ESAL
HiMA™ Rehabilitation, Section N8-Performance

- Roughness, rutting stabilized after HPG rehabilitation
- No cracks observed until more than 15 million ESAL
- A resilient alternative for heavy traffic

Figure 4 IRI Evaluation of Oklahoma Perpetual Pavement Sections
Oklahoma I-40, Caddo County

- Before rehab: high severity transverse cracks, rutting, very rough
- Rehabilitation: Feb-Apr 2012
- Practically no distress after 8+ years
- 2020 IRI: 55 in/mi (EB), 53 in/mi (WB)
I-59/20, Tuscaloosa Co., AL MP 62.0-68.4

- Extensive longitudinal cracking
  - About 1/3 of cracks extended beyond the top 4 inches of pavement
  - Deflection (FWD) analysis suggested the need for additional pavement thickness
- Numerous bridges within project limits complicated things
  - Very costly to raise bridges to allow for additional structure
  - Estimated almost $8.7 million just to raise bridge surfaces
Alabama I-59/20 Rehabilitation

Pavement Layers

1. 12.5 mm Max Aggregate Size
   SMA (Thickness = 2.25 inches)
   Used PG 76-22 Binder

2. 12.5 mm Max Aggregate Size
   HiMA Designed to 4% V_4 (Thickness = 1.5 inches)

3. 25 mm Max Aggregate Size
   HiMA Designed to 4% V_4 (Thickness = 3 inches)

4. 12.5 mm Max Aggregate Size
   HiMA Designed to 2% V_4 (Thickness = 1.5 inches)

From Braden Smith (Hunt Refining) at 2018 SEAUPG Meeting
Resurfacing/Thin Overlays

- Dense-graded HMA
  - More resistant to rutting, cracking, spalling, studded-tire wear
    - New York City, 1st Ave
    - Florida (US 90, US 41)
    - Anchorage, AK

- Open-Graded/Permeable Friction Courses
  - Extend the life of open-graded friction courses by 50% (TTI-led study for Florida DOT)
  - Provide OGFC/PFC mixtures that are much more resistant to raveling and cracking than when using other binders such as PG76-22 and asphalt-rubber (NCHRP 877, performed by NCAT)
Manhattan, 1st Avenue

- Used NJDOT “High Performance, Thin Overlay” as a guide specification
- Trial project in 2012, performance convinced NYCDOT to overlay 53 blocks on 1st Ave in 2013
- 1½ inches, placed over repaired JRCP, geotextile
- TR News Article, May/June 2019 issue (http://www.trb.org/Publications/Blurbs/179900.aspx)
- In “good” condition, according to NYCDOT website
Florida-US 90 @ I-10 (Midway), Westbound Lanes

- Extends from a Pilot station south (east) of I-10, through the interchange to beyond the entrance to a Flying J truck stop
- Channelized truck traffic, stopping and turning into truck stop
- Planned to reconstruct with concrete pavement, but milled and replaced 2.5 inches of HMA using HP binder as a trial/stopgap measure
US 90 @ I-10, Midway

Looking east at turning traffic

Stop bar at traffic signal
FDOT Rutting Measurements, US 90

US 90 High Polymer Test Section Rut Data

- Conventional Mix (2014 PCS)
- High Polymer Binder Mix (2019 PCS)

Rut Depth (inches)

US 90 Gadsden County Westbound Outside Travel Lane (MP 11.482 - 12.458)
Test section at ALF site at State Materials Office in Gainesville

Additional trial projects in FL Panhandle where rutting had been a problem

July 2017-adopted “High Polymer” binder grade as part of FDOT Standard Specifications, replacing PG82-22

Research projects at UNR and TTI to evaluate AASHTO layer coefficient and OGFC performance

Observed improvements in rutting and reflection crack performance compared to PG76-22 in overlay of JCP in Tampa (US 41)
PFC/OGFC

- Water flows in and through the layer, improving wet weather driving conditions
- For high speed traffic, porous layer greatly reduces air pumping and sound generated at the tire/pavement interface
- Shown to reduce TSS in storm water by 90% compared to surfaces with sheet flow, BMP for highway runoff water quality in Edwards recharge zone
Other States

- Alaska: mixtures using highly modified asphalt binder (PG64E-40) are shown to be more resistant to studded tire wear and are used where this has been an historical problem, especially around Anchorage
- New Jersey: bridge deck waterproofing surface course, binder-rich intermediate course mixtures
- Virginia: SMA and dense-graded mixtures, especially in overlays of jointed concrete on Interstate highways
High Performance/Highly Modified Asphalt Binders: Best Uses

- Tougher, more durable wearing courses
  - Permeable Friction Courses, Thin Overlay Mixtures, SMA
- Upper lifts for pavements where 20 year design ESAL > 10 million
  - Perpetual pavements
- Deep rehabilitation due to overloads (oilfield, bus pads)
  - Ability to get in, get out, stay out in challenging construction and loading conditions
- Resilient pavement structures
- Low voids bridge deck surfaces
Optimized Mix Design

- Should prioritize meeting performance criteria, instead of mixture volumetric properties
  - Volumetric properties are important for production QC
- Performance-related testing, potential HP criteria (dense-graded mixtures):
  - Rutting/stripping: HWT < 6 mm
  - Cracking:
    - Overlay test: Critical Fracture Energy ≥ 1.5 in-lb/in
    - Crack Progression Rate ≤ 0.35
- General-allow HMA producers latitude in binder selection
  - For example, could using HP binders allow the greater use of RAP or natural sand while still meeting performance criteria?
  - NJDOT does this for their high performance, thin overlay and bridge deck surfacing specifications
Example - TxDOT Item 341, Type C

Increase binder content, resistance to cracking without rutting
LCCA-Agency Costs: 3.5% discount rate, 40 year analysis period

<table>
<thead>
<tr>
<th>Roadway Classification</th>
<th>NPV-Agency Costs, $ X 1000/mile</th>
<th>HP Binder, ΔHMA, Cost/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PG76-22</td>
<td>$15.00</td>
</tr>
<tr>
<td>Rural Arterial</td>
<td>$4,146.95</td>
<td>$3,905.00</td>
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<tr>
<td>Urban Arterial</td>
<td>$6,796.58</td>
<td>$6,550.95</td>
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<tr>
<td>Limited Access</td>
<td>$8,058.65</td>
<td>$7,662.99</td>
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</tbody>
</table>

- Estimated net present value for project types assuming different asphalt mixture cost differences (per short ton) of hot mix asphalt
  - Accounted for difference in project costs assuming different mixture cost differentials
  - Typical difference: $15-25/ton depending on mix type
- HP mixture is cost-effective due to increase in service life
FHWA “Every Day Counts” Initiative

- Targeted Overlay Pavement Solutions
- Solutions for integrating innovative overlay procedures into practices that can improve performance, lessen traffic impacts, and reduce the cost of pavement ownership.
- Approximately half of all infrastructure dollars are invested in pavements, and more than half of that investment is in overlays. By enhancing overlay performance, State and local highway agencies can maximize this investment and help ensure safer, longer-lasting roadways for the traveling public.

State of the Practice

Recent improvements to design methods, interlayer technology, slab geometry, and concrete mixtures have broadened concrete overlay surface treatment applicability, reliability, sustainability, and cost-effectiveness. A joint effort by Georgia, Iowa, Kansas, Michigan, Minnesota, Missouri, North Carolina, and Oklahoma resulted in the development of an improved design procedure for jointed unbonded concrete overlays on either concrete or composite pavements.

For asphalt overlays, several State departments of transportation (DOTs) have adopted SMA due to increased service life and performance. The Maryland, Alabama, and Utah DOTs each used over 1 million tons of SMA during a 5-year period. DOTs in Florida, Georgia, New Jersey, New York City, Tennessee, and Virginia found highly modified asphalt in thin overlays is more resistant to reflective cracking. It has increased pavement life by two to four times for DOTs in Alabama and Oklahoma.
FOR WHAT’S COMING?

Paving

We bring you the best pavement experience through cutting-edge bitumen modification, pavement design and construction support for a range of paving applications.

Did you know that Kraton:
- Invented the SBS polymers
- Pioneered SBS bitumen modification
- Has over 40 years of experience implementing SBS in paving applications
- Authored numerous patents related to styrenic block copolymer technologies
- Continuously innovates expanding the technology portfolio
- Reaches Americas, Asia, Africa, Australia and Europe

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