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

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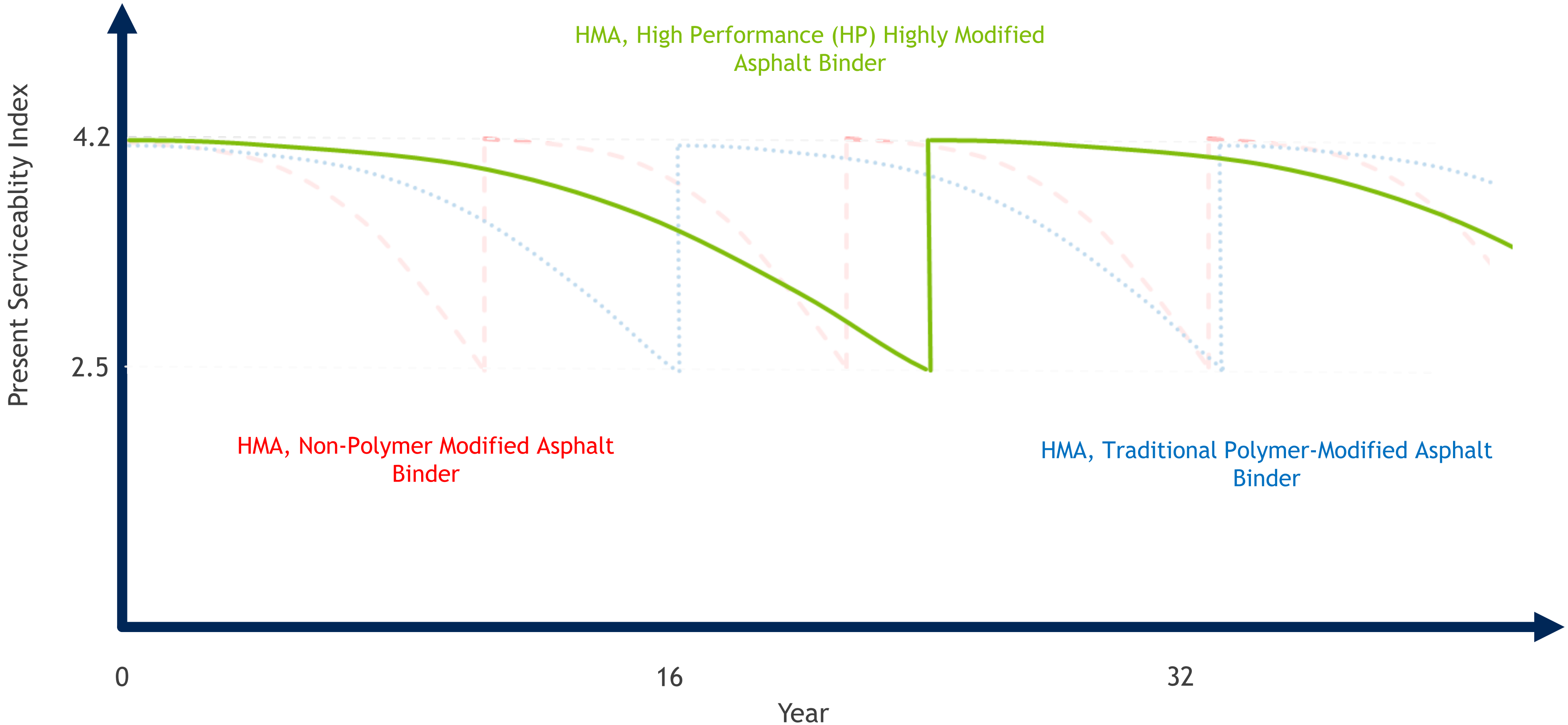
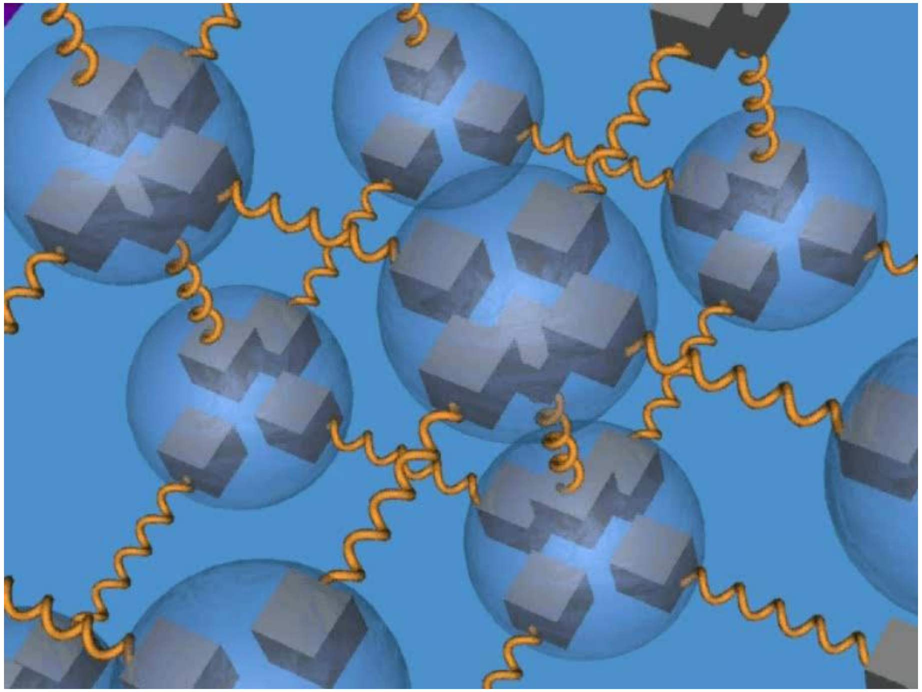
Comparative Performance Concept



What Is High Performance/Highly Modified Asphalt?

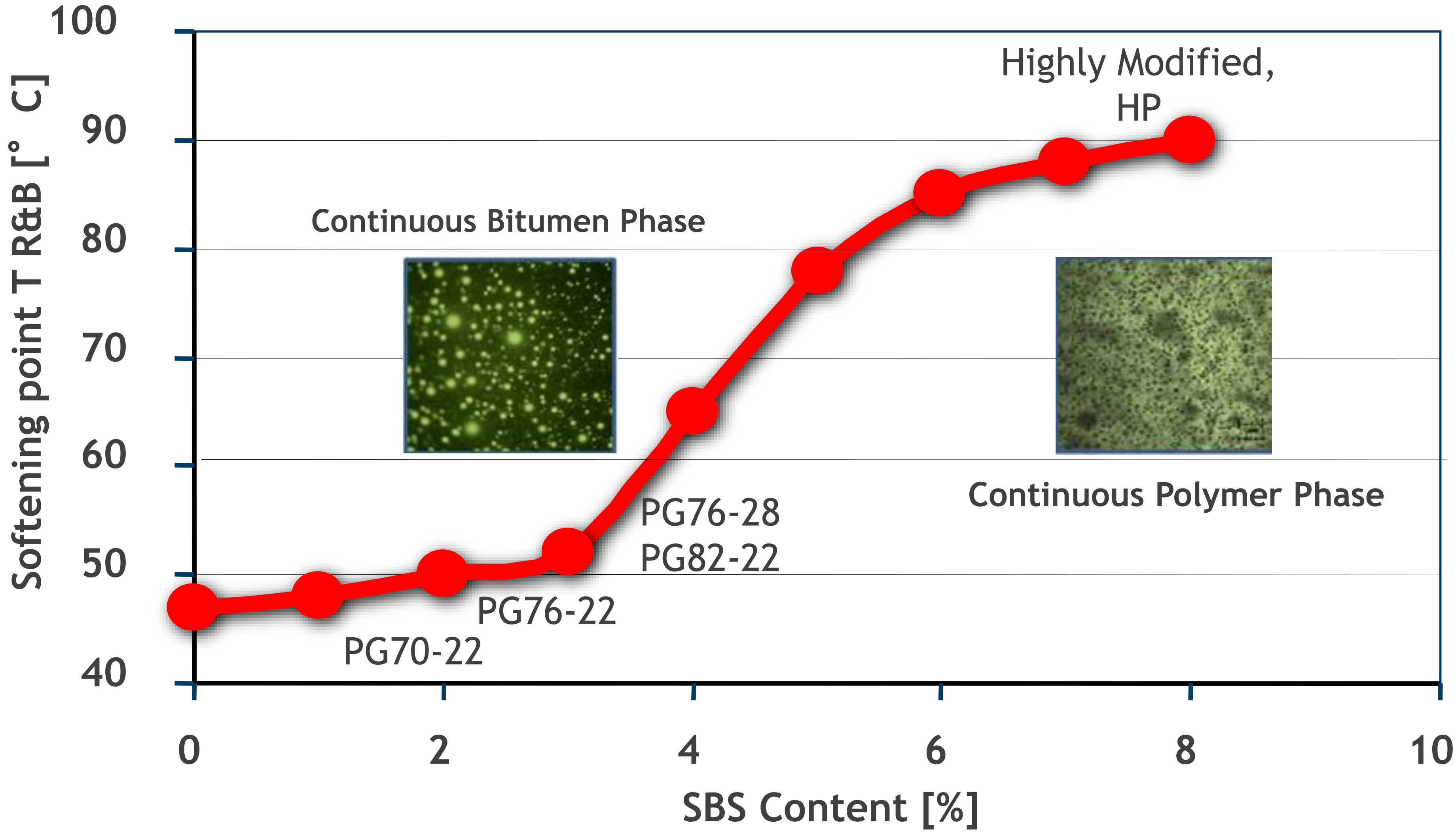
- Highly Modified Asphalt (often called HiMA™ or HPG) is exactly what it says, an asphalt binder with **2-3 X** the amount of SBS polymer used to produce grades such as PG76-22
- The resulting binder contains a dense polymer network that significantly improves mixture performance
  - Much less sensitive 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 (≥ 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



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*sinδ) maximum is 4,000 MPa, which is ***lower*** than either AASHTO specification

High Performance-Graded (HPG) Binder

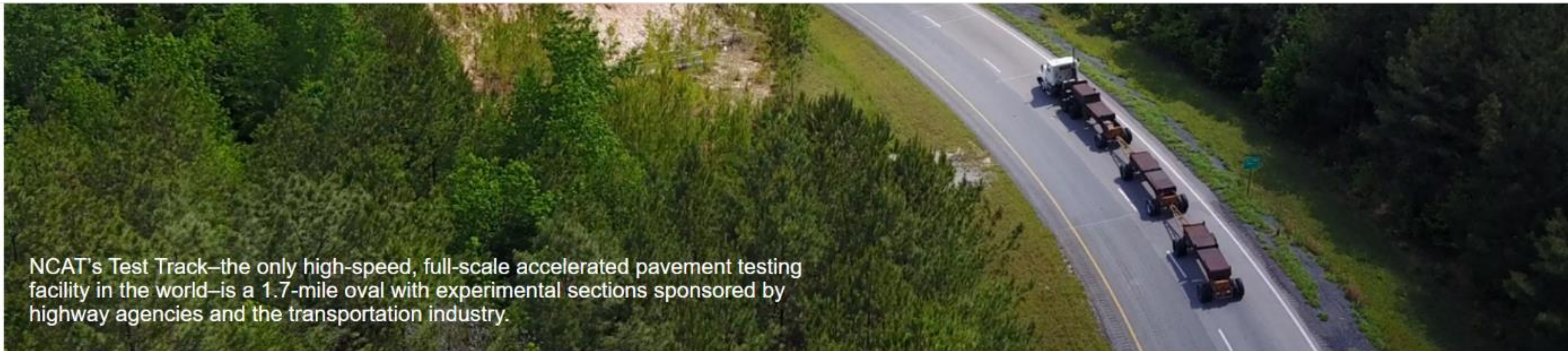
Property and Test Method	HPG
Original Binder	
Flash Point, T 48, Min. °C	230
Viscosity, T316, Max. 5.0 Pa-s, test temperature, °C[1]	135
Separation, ASTM D7173, Dynamic Shear, T315, % G*/sinδ Difference[2], Max. 10%, temperature, °C	76
Polymer Content, Tex-533-C[2], Min. %	7.5
Rolling Thin-Film Oven (Tex-541-C)	
Mass change, Tex-541-C, Max. %	1.0
Multiple Stress Creep Recovery, T350, Jnr, 3.2kPa, Max. 0.10 kPa-1, test temperature, °C	76
Multiple Stress Creep Recovery, T350, % recovery, 3.2kPa, Min. 90.0%, test temperature, °C	76
Pressure Aging Vessel (PAV) Residue (R 28)	
PAV aging temperature, °C	100
Dynamic shear, T315 G*sin(δ), Max. 3,000kPa Test temperature @ 10 rad/sec., °C	25
Creep Stiffness, T313 @ 60 sec[3] S, Max. 300mPa, m-value, Min. 0.30, Test temperature, °C	-18

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*/sinδ measured on samples taken from the top and bottom: 100*(G*/sinδ (top) - G*/sinδ (bottom))/ G*/sinδ (top)
3. In Tex-533-C, the SBS peak is changed to 699cm^{-1}, representing the polystyrene band.
4. Silicone beam molds, as described in AASHTO T313, are acceptable for use.

NCAT Test Track

National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY

About NCAT | Test Track | Pavement Preservation | Education & Training | Our Research



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

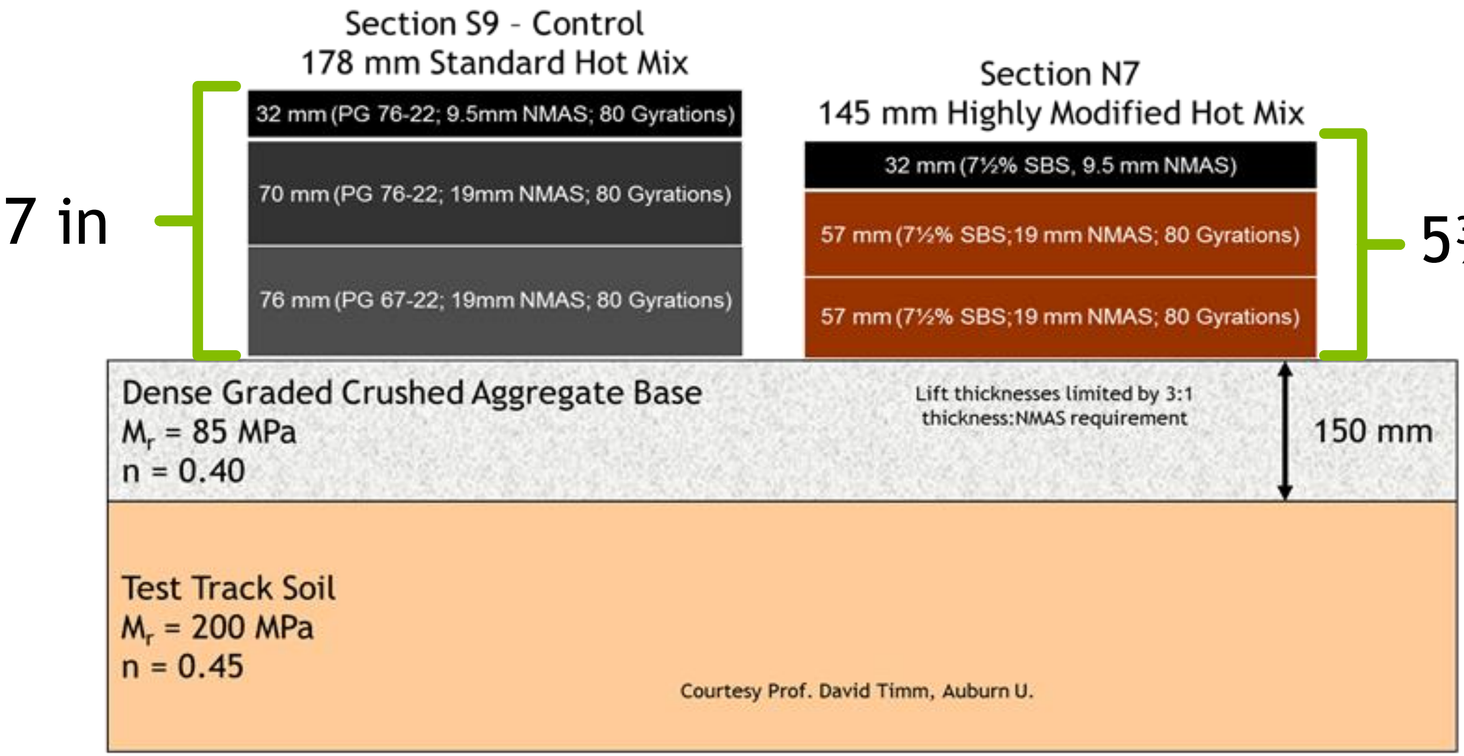
GET IN TOUCH

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.

http://eng.auburn.edu/research/centers/ncat/testtrack/index.html

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

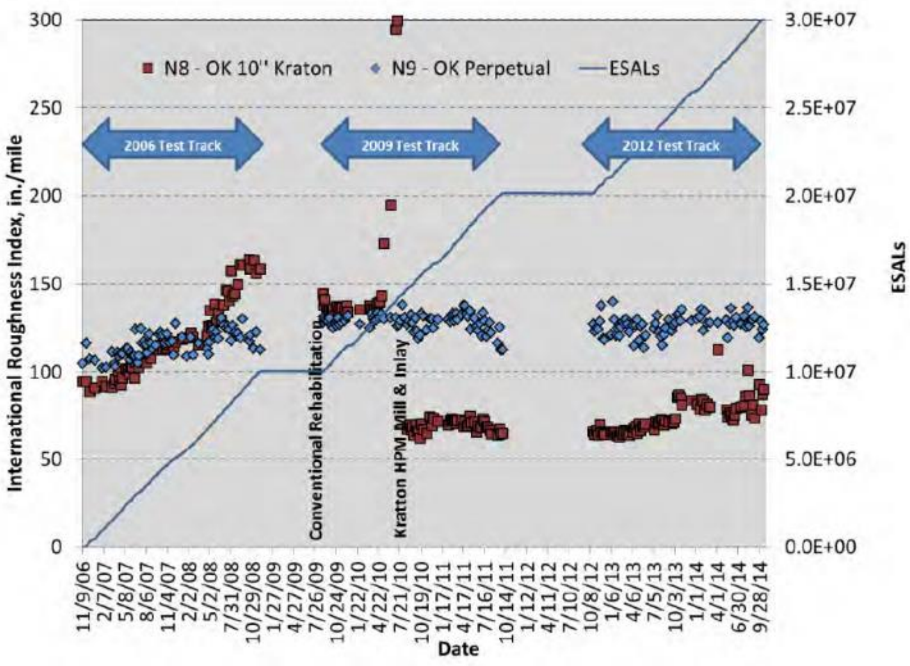


Figure 4 IRI Evaluation of Oklahoma Perpetual Pavement Sections

Section N8, Before 2nd Rehabilitation

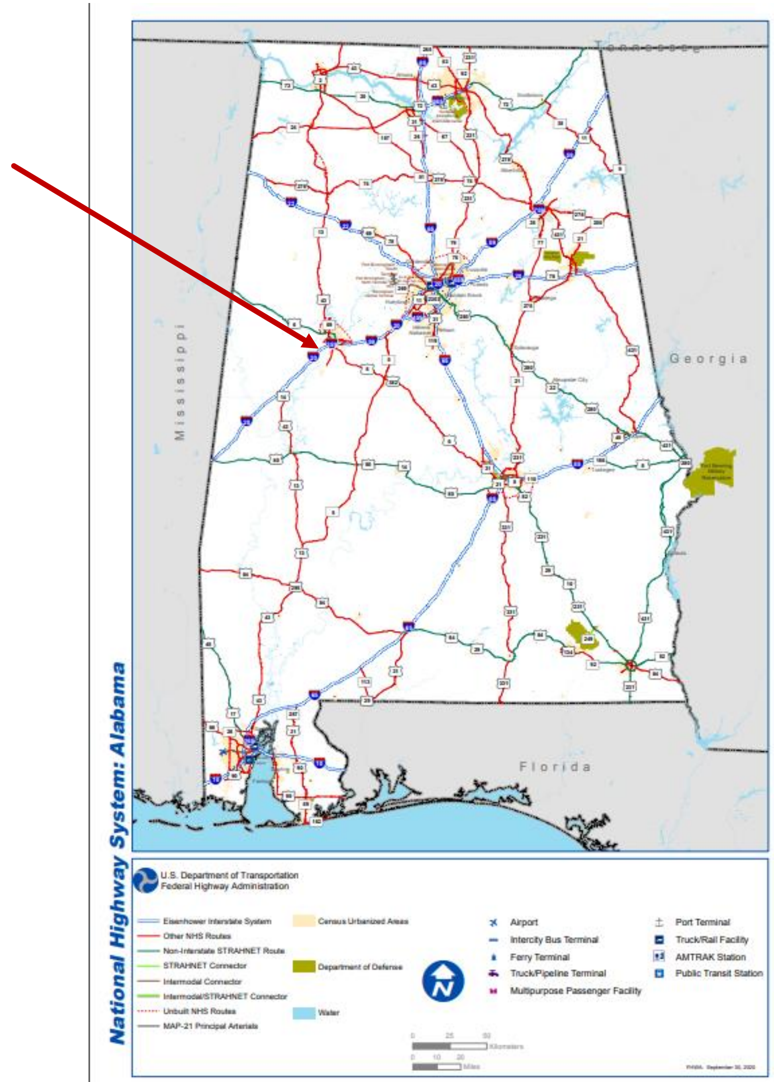
- Roughness, rutting stabilized after HPG rehabilitation
- No cracks observed until more than 15 million ESAL
- A resilient alternative for heavy traffic

Oklahoma I-40, Caddo County

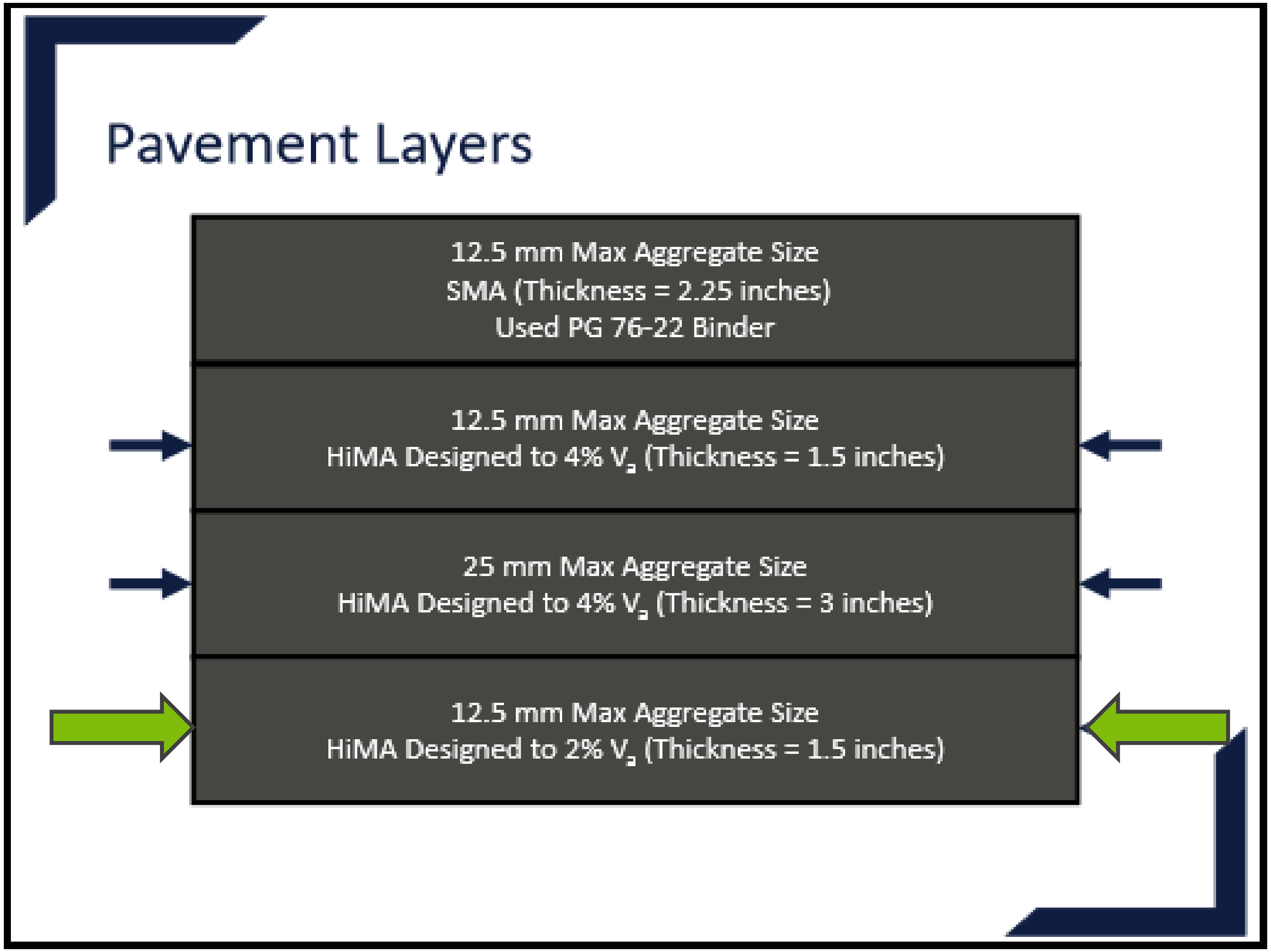
- Before rehab: high severity transverse cracks, rutting, very rough
- Rehabilitation: Feb-Apr 2012
- Practically no distress after 8+ years
- 2020 IRI: 55 in/mi (EB), 53 in/mi (WB)

I-59/20, Tuscaloosa Co., AL MP 62.0-68.4

- Opened in 1970, rehabilitated in 1983, 1990 and 2001
- 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



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

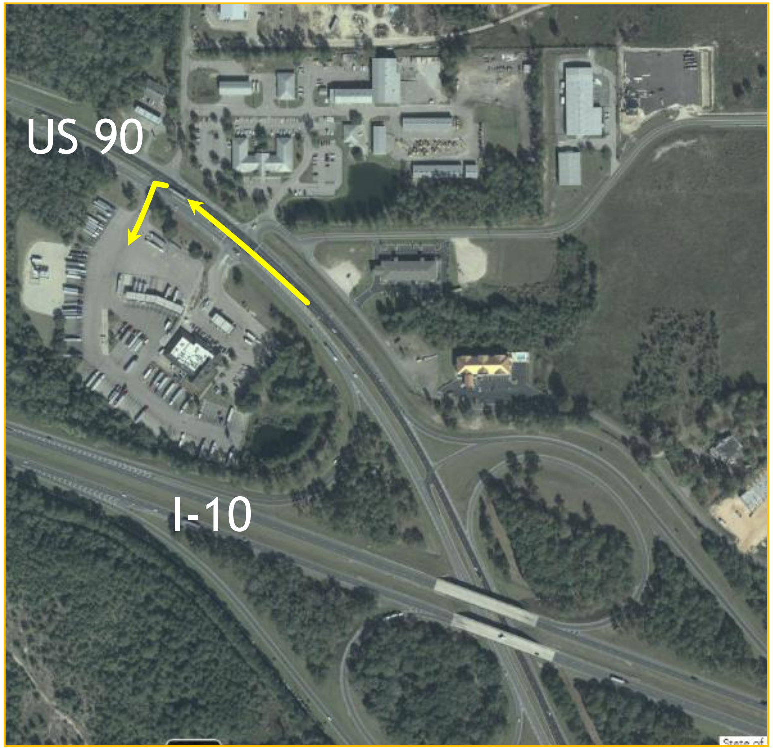
1st Ave, 2013

1st Ave, 2019

- 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

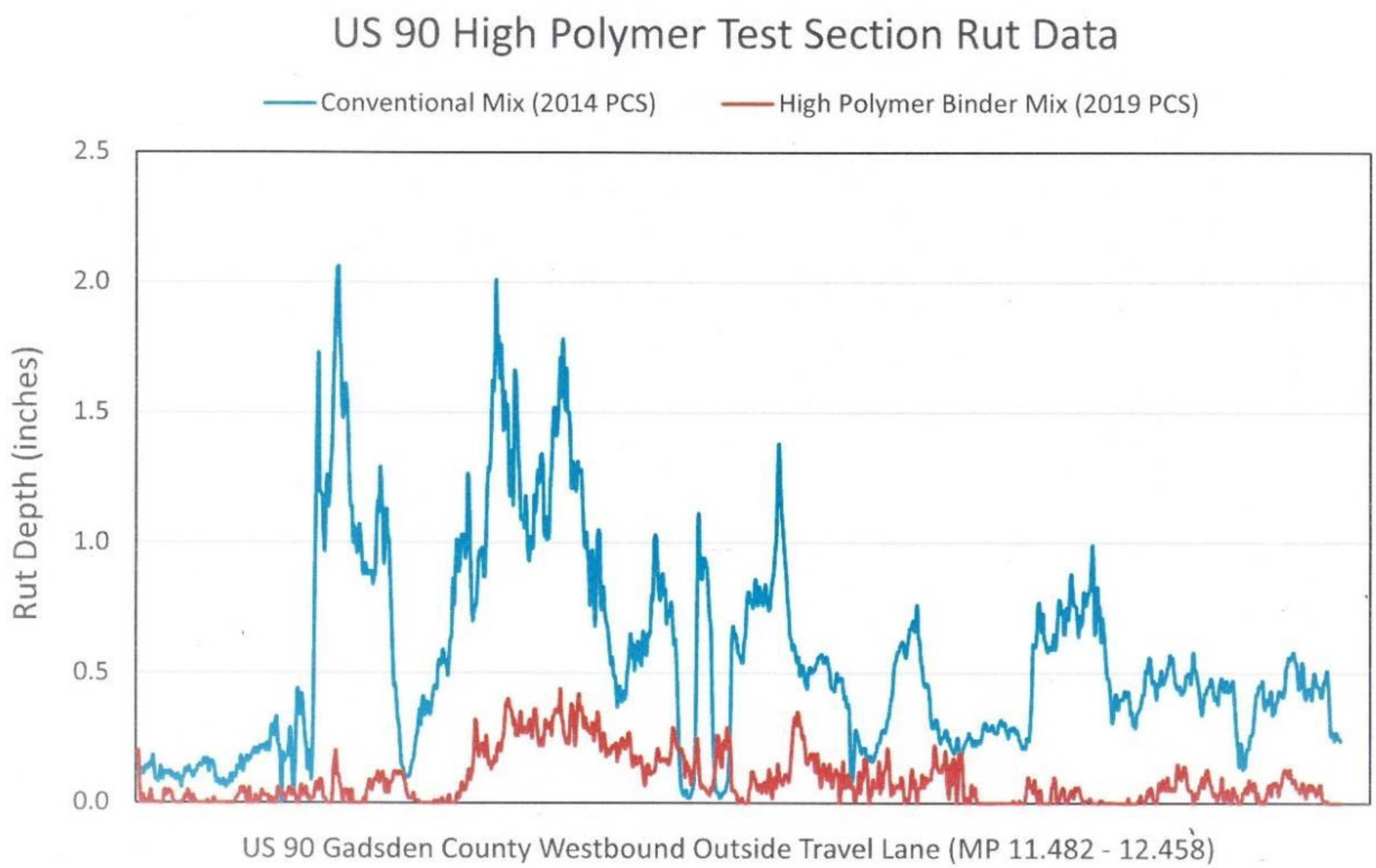


US 90 @ I-10, Midway

Looking east at turning traffic

Stop bar at traffic signal

FDOT Rutting Measurements, US 90



Florida DOT

- Test section at ALF site at State Materials Office in Gainesville
- Additional trial projects in FL Panhandle where rutting had been a problema
- 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

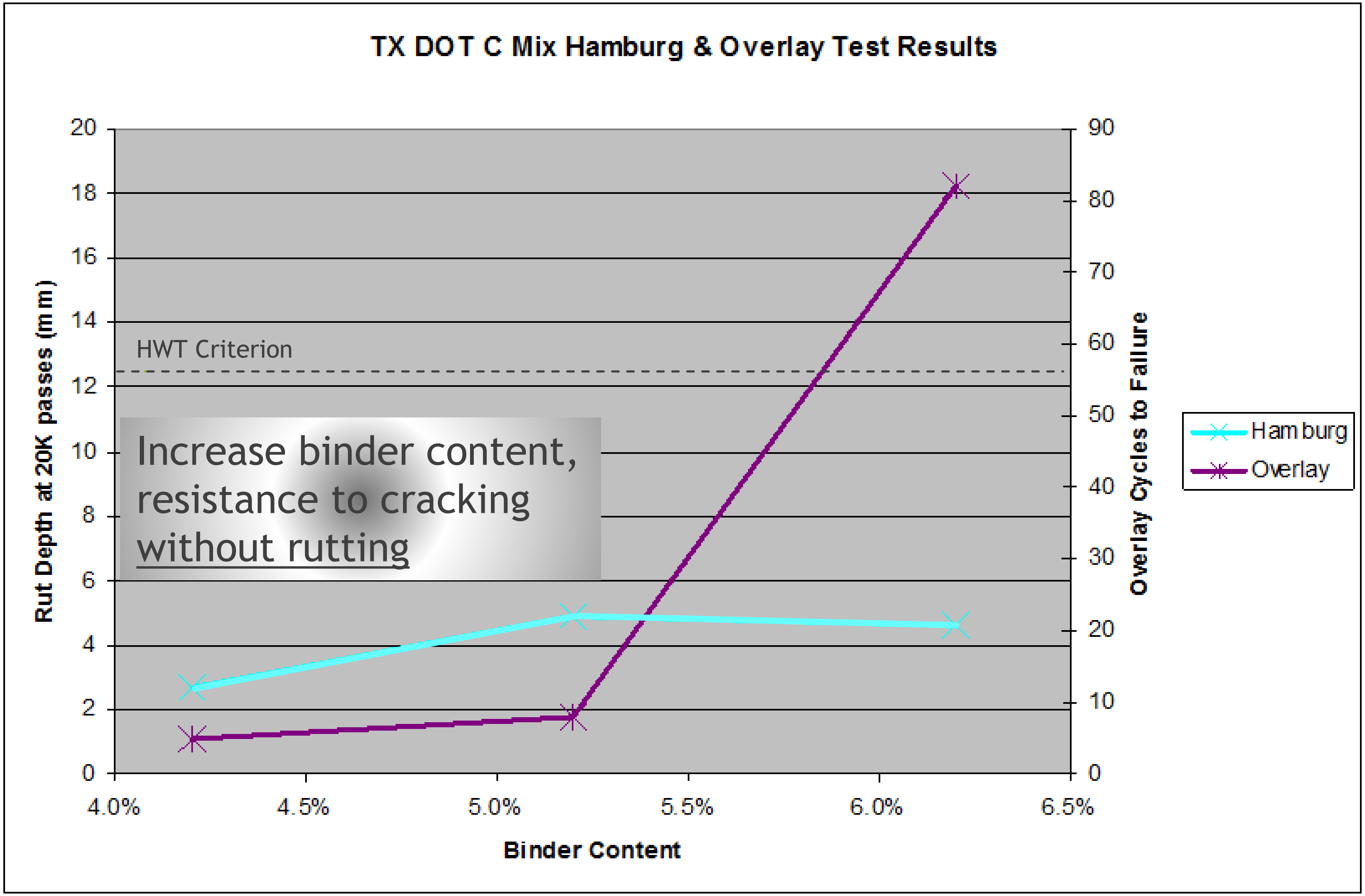
- Tougher, more durable wearing courses
  - Permeable Friction Courses, Thin Overlay Mixtures, SMA
- Upper lifts for pavements where 20 year design ESAL > 10 million
  - Perpetual pavements
- Deep rehabilitation due to overloads (oilfield, bus pads)
  - Ability to get in, get out, stay out in challenging 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



LCCA-Agency Costs: 3.5% discount rate, 40 year analysis period

	NPV-Agency Costs, $ X 1000/mile		
Roadway Classification	PG76-22	HP Binder, ΔHMA, Cost/ton	
		$15.00	$25.00
Rural Arterial	$4,146.95	$3,905.00	$4,007.68
Urban Arterial	$6,796.58	$6,550.95	$6,677.15
Limited Access	$8,058.65	$7,662.99	$7,869.77

- 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

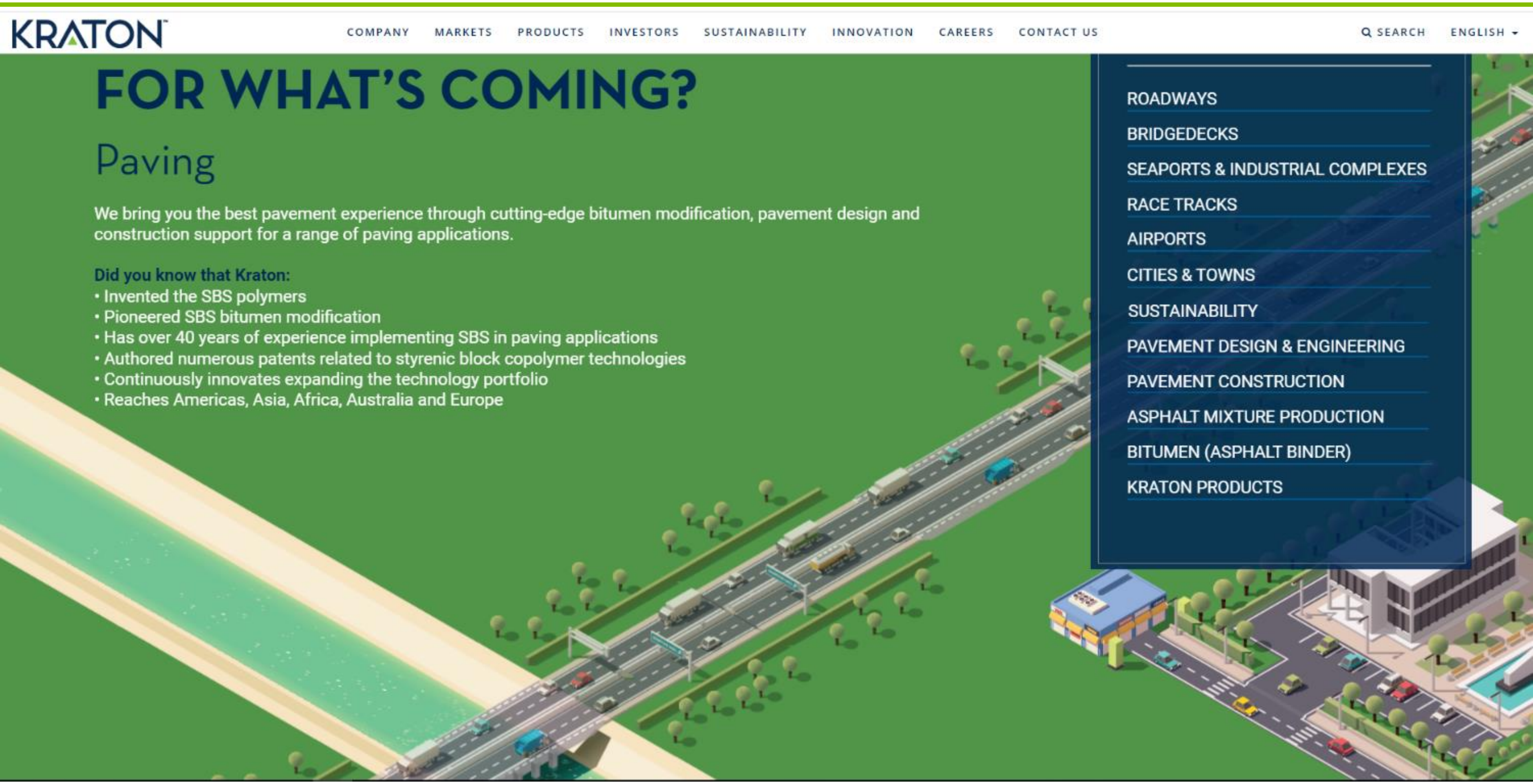
- Targeted Overlay Pavement Solutions
- Solutions for integrating innovative overlay procedures into practices that can improve performance, lessen traffic impacts, and reduce the cost of pavement ownership.
- Approximately half of all infrastructure dollars are invested in pavements, and more than half 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.

https://kraton.com/products/paving/pavingsbs.php



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