Binder Modified with a Combination of PPA and SBS: The NCAT Test Track Experience

PPA Workshop

April 7, 2009

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Introduction

- National Center for Asphalt Technology (NCAT) Pavement Test Track
  - 309 acre site near Auburn University Auburn Alabama
  - Used and Sponsored by Government Agencies Throughout U.S.
  - Designed to Aid in Research to Extend the Life of Flexible Pavements
  - Provides Opportunity for Sponsors to Answer Questions Through Accelerated Testing

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Test Track Description

- 1.7 mile Closed Loop Facility
  - Consists of Forty-Six 200 ft. Test Sections
  - Each Section Cooperatively Funded
  - Operation and Research Managed by NCAT

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Test Track Design Concept

- Uniform Perpetual Foundation
- Materials and Mix Design Unique to Each Section
- Design Lifetime of 10 Million ESALs
- Design Load Applied Over Two Year Cycle
- Axle Loading Precisely Monitored
- Surface Parameters Measured Weekly

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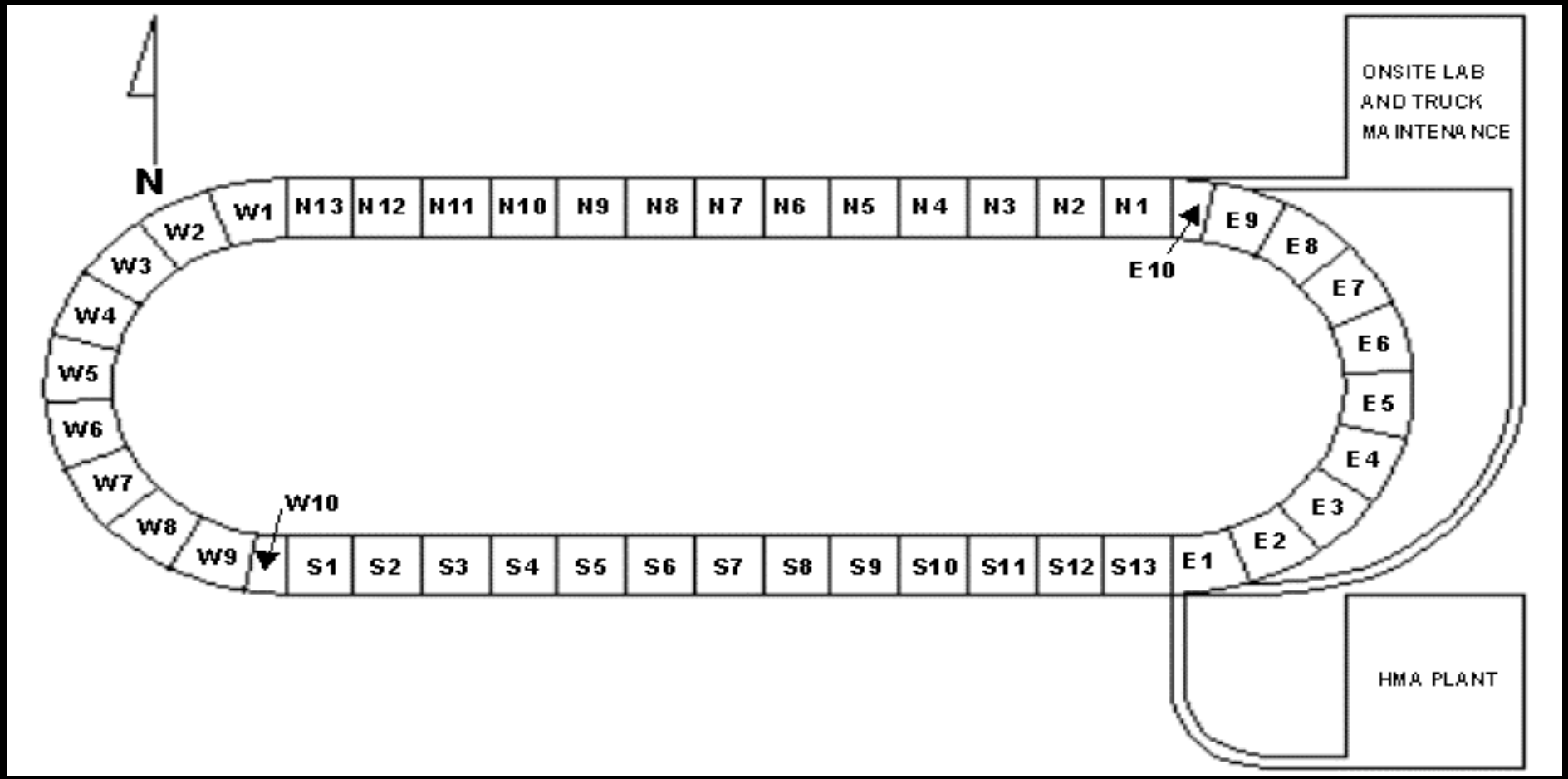
Section Schematic



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PPA/SBS Modified Binders

- Pre-SuperPave SBS Modified Asphalt
- Post-SuperPave SBS Modified Asphalt

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PPA/SBS Modified Binders

PG Grade Achieved	76-22	76-22	76-22	76-22
PPA %	0	0.2	0.4	0.6
Polymer %	4.25	3.75	2.9	2.6
Brookfield Vis.@ 135	2350	2030	1510	1360
ODSR	1.557	1.524	1.366	1.42
Phase Angle	68.7	68.6	78.3	79.4
Wt. Loss	0.012	-0.024	0.23	0.008
RDSR	2.472	2.802	2.281	2.58
PDSR	1424	2038	1804	1934
BBR S Value	138	150	163	172
BBR M Value	0.320	0.310	0.311	0.306
Elastic Recovery	80.00%	77.50%	69.00%	64.00%

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PPA/SBS Binders for NPTT-2000

- NCAT – No Specific Objective for Binder or Binder Supplier
- Single Source Binder Supplier PG67-22 and PG76-22
- Binder Supplier Selected Binder Formulation
  - Performance
  - Economics
  - Results of Mississippi I-55 Field Trial
  - Current Products Marketed

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PPA/SBS Binder for NPTT-2000

- **2000 Test Track Formulation**
  - SuperPave™ PG76-22
    - Venezuelan Crude Source
    - 3.5 Weight Percent SBS Block Co-Polymer
    - 0.25 Weight Percent Polyphosphoric Acid (105)
    - 0.05 Weight Percent Amine Anti-Stripping Agent

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PPA/SBS Binder for 2000 Test Track (PG76-22)

Test	Result	Specification
Original DSR @ 76 °C, G*/Sinδ (kPA)	1.231	1.00 kPa Min.
RTFO DSR @ 76°C, G*/Sinδ (kPa)	2.487	2.20 kPa Min.
PAV DSR @ 25°C, G*Sinδ (kPa)	3363	5000 kPa Max.
PAV DSR @ 31°C, G*Sinδ (kPa)	1544	5000 kPa Max.
Stiffness @ -12°C, S (MPa)	165	300 Mpa Max.
Slope @ -12°, m	0.311	0.300 Min.
Viscosity @ 135° (Pa•Sec)	1.516	3 Pa•Sec
Force Ductility Ratio, Original @ 4°C	0.5364	0.3 Min.
Elastic Recovery, RTFO @ 25°C (%)	83	60 Min.

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PPA/SBS Binders for 2003 Test Track

- NCAT – No Specific Objective for Binder or Binder Supplier
- Sponsors Recommended Binder and Binder Supplier
- Primary Binder Supplier Selected Binder Formulation PG70 and PG76-22
  - Performance
  - Economics
  - Results of Mississippi I-55 Field Trial
  - Current Products Marketed

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PPA/SBS Binder for 2003 Test Track (PG76-22)

- **2003 Test Track Formulation**
  (Identical to 2000 formulation)
  - SuperPave™ PG76-22
    - Venezuelan Crude Source
    - 3.5 Weight Percent SBS Block Co-Polymer
    - 0.25 Weight Percent Polyphosphoric Acid (105)
    - 0.05 Weight Percent Amine Anti-Stripping Agent

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PPA/SBS Binder for 2003 Test Track (PG76-22)

Test	Result	Specification
Original DSR @ 76 °C, G*/Sinδ (kPA)	1.458	1.00 kPa Min.
RTFO DSR @ 76°C, G*/Sinδ (kPa)	2.248	2.20 kPa Min.
PAV DSR @ 25°C, G*Sinδ (kPa)	3813	5000 kPa Max.
PAV DSR @ 31°C, G*Sinδ (kPa)	1815	5000 kPa Max.
Stiffness @ -12°C, S (MPa)	155	300 Mpa Max.
Slope @ -12°, m	0.31	0.300 Min.
Viscosity @ 135° (Pa•Sec)	1.4	3 Pa•Sec
Force Ductility Ratio, Original @ 4°C	0.5087	0.3 Min
Elastic Recovery, RTFO @ 25°C (%)	81	60 Min

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PPA/SBS Binder for 2003 Test Track (PG70-22)

- **2003 Test Track Formulation**
  - SuperPave™ PG70-22
    - Venezuelan Crude Source
    - 1.4 Weight Percent SBS Block Co-Polymer
    - 0.25 Weight Percent Polyphosphoric Acid (105)
    - 0.05 Weight Percent Amine Anti-Stripping Agent

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PPA/SBS Binder for 2003 Test Track (PG70-22)

Test	Result	Specification
Original DSR @ 70 °C, G*/Sinδ (kPA)	1.517	1.00 kPa Min.
RTFO DSR @ 70°C, G*/Sinδ (kPa)	2.905	2.20 kPa Min.
PAV DSR @ 25°C, G*Sinδ (kPa)	3880	5000 kPa Max.
PAV DSR @ 28°C, G*Sinδ (kPa)	2997	5000 kPa Max.
Stiffness @ -12°C, S (MPa)	183	300 Mpa Max.
Slope @ -12°, m	0.338	0.300 Min.
Viscosity @ 135° (Pa•Sec)	0.738	3 Pa•Sec
Force Ductility, Original @ 4°C (kg)	1.838	0.23 Min
Elastic Recovery, RTFO @ 25°C (%)	65	40 Min

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Construction of 2000 Test Track

- Ten Sponsoring Entities
  - Nine State DOTs
  - Federal Highway Administration
- Designed to Suit All Sponsor Experimental Needs
- Underlying Pavement Structure Identical in Every Section
- Common Interest
  - Effect of Gradations (ARZ and BRZ)
  - Effect PG on Rutting Performance

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Construction of 2000 Test Track

- Two States- Effect of Mix Design Methodology on Rutting Performance
- Two States- Compare Gravel to Stone Mixes
- One State- Compare Different NMAS

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Construction of 2000 Test Track

- Eighteen Sections Contained PPA/SBS Modified PG76-22
- Various Aggregates
  - Limestone
  - Slag
  - Gravel
  - Granite
  - Marble Schist
  - Combinations of the Above

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Construction of 2000 Test Track

- Moisture Sensitivity not Specific Area of Interest
  - All Sections With the Exception of N11 and N12 Contained Liquid Amine Anti-Stripping
  - Some Sections Contained both Liquid Amine Anti-Stripping Agent and Hydrated Lime
  - Sections N11 and N12 Contained Only Hydrated Lime

Construction of 2003 Test Track

- Eleven Sponsoring Entities
  - Ten State DOTs
  - Federal Highway Administration
- Sponsors of 2000 Test Track Were Allowed to Leave Sections to Extended Traffic
- Rutting Expected to be Minimal in Sections left to Traffic

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Construction of 2003 Test Track

- Twenty-Three of the Existing Sections were left to Extended Traffic
  - Nine Sections Left to Extended Traffic Utilized PPA/SBS Modified PG76-22
- Twenty-Two New Sections Built
  - Nine Sections Reconstructed or Partially Reconstructed Using PPA/SBS Modified Binder
  - Six PG76-22 and Three PG70-22

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Construction of 2003 Test Track (22 New Sections)

- New Sponsor Sections Designed to Suit All Sponsor Experimental Needs
- Underlying Pavement Structure Identical in Every Section as with 2000 Test Track
- Objective – Evaluate Potential to Predict Performance

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Construction of 2003 Test Track (22 New Sections)

- Sponsors Supplied Variety of Aggregates
- Sponsors Relied on Various Sources of Binder
- In Sections Discussed, PG76 and PG70 Supplied by Single Source
- All Newly Constructed Sections Contained Liquid Amine Anti-Strip

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Construction of 2003 Test Track (22 New Sections)

- Eight Sections were Utilized for a Structural Experiment – Did not Contain PPA/SBS Modified Binder
- Fourteen New Sections were Shallow Mill and Inlay for Rutting Study
- Nine Inlay Sections Contained PPA/SBS Modified Binder

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Weather

Year	Average High Temperature °C (°F)	Est. Avg High Pavement Temp 25.4 mm Depth	Lowest Temperature °C (°F)	Total Annual Rainfall cm (inches)
NPTT-2000				
2000	38.6 (101.4)	62.7°C (144.8°F)	-5.6 (22)	96.39 (37.95)
2001	34.2 (93.6)	59.3°C (138.7°F)	-9.4 (15)	120.93 (47.61)
2002	34.6 (94.2)	59.6°C (139.3°F)	-8.3 (17)	98.86 (38.92)
NPTT-2003				
2003	32.9 (91.3)	58.3°C (136.9°F)	-11.1 (12)	121.54 (47.85)
2004	36.4 (97.6)	61.0°C (141.8°F)	-6.1 (21)	132.33 (52.10)
2005	34.8 (94.6)	59.8°C (139.6°F)	-6.7 (20)	126.16 (49.67)
* Montgomery Annual Temperature and Percipitation				
Montgomery Historical Data:				
Average High Air Temperature 35.9°C (96.6°F) Standard Deveation 1.5				
Maximum High Temperture 38.7°C (101.7°F)				
Average Low Air Temperature -9.6°C (14.7°F) Standard Deveation 3.3				
Maximum Low Temperature -5.0°C (23.0°F)				
Minimum Low Temperature -18°C (-0.4°F)				

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PERMANENT DEFORMATION

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Permanent Deformation
2000 Test Track

PPA/SBS Modified Binders		
Section	NPTT-2000 Rut Depth mm (inch)	NPTT-2003 Rut Depth mm (inch)
N1	1.90 (0.004)	Replaced
N2	2.15 (0.085)	Replaced
N9	0.70 (0.028)	Replaced
N10	0.65 (0.026)	Replaced
N11	1.65 (0.065)	2.02 (0.080)
N12	2.50 (0.098)	3.10 (0.122)
N13	4.95 (0.195)	Replaced
S1	1.80 (0.071)	Replaced
S2	0.60 (0.024)	1.15 (0.045)
S3	0.60 (0.024)	1.07 (0.042)
S4	0.70 (0.028)	Replaced
S5	0.60 (0.024)	Replaced
S8	1.60 (0.063)	2.00 (0.079)
S11	2.35 (0.093)	3.10 (0.122)

Non-PPA/SBS Modified Binders		
Section	NPTT-2000 Rut Depth mm (inch)	NPTT-2003 Rut Depth mm (inch)
N3	7.35 (0.289)	Replaced
N4	5.40 (0.213)	Replaced
N5	8.05 (0.317)	Replaced
N6	4.40 (0.173)	Replaced
N7*	2.30 (0.091)	Replaced
N8*	1.35 (0.053)	Replaced
S6	2.10 (0.083)	3.64 (0.143)
S7	3.55 (0.140)	4.31 (0.170)
S9	2.75 (0.108)	3.35 (0.132)
S10	4.50 (0.177)	5.10 (0.201)
S12**	2.80 (0.110)	3.90 (0.154)
S13**	2.30 (0.091)	3.44 (0.135)
* SBR Modified Binders		
** SB Modified Binders		

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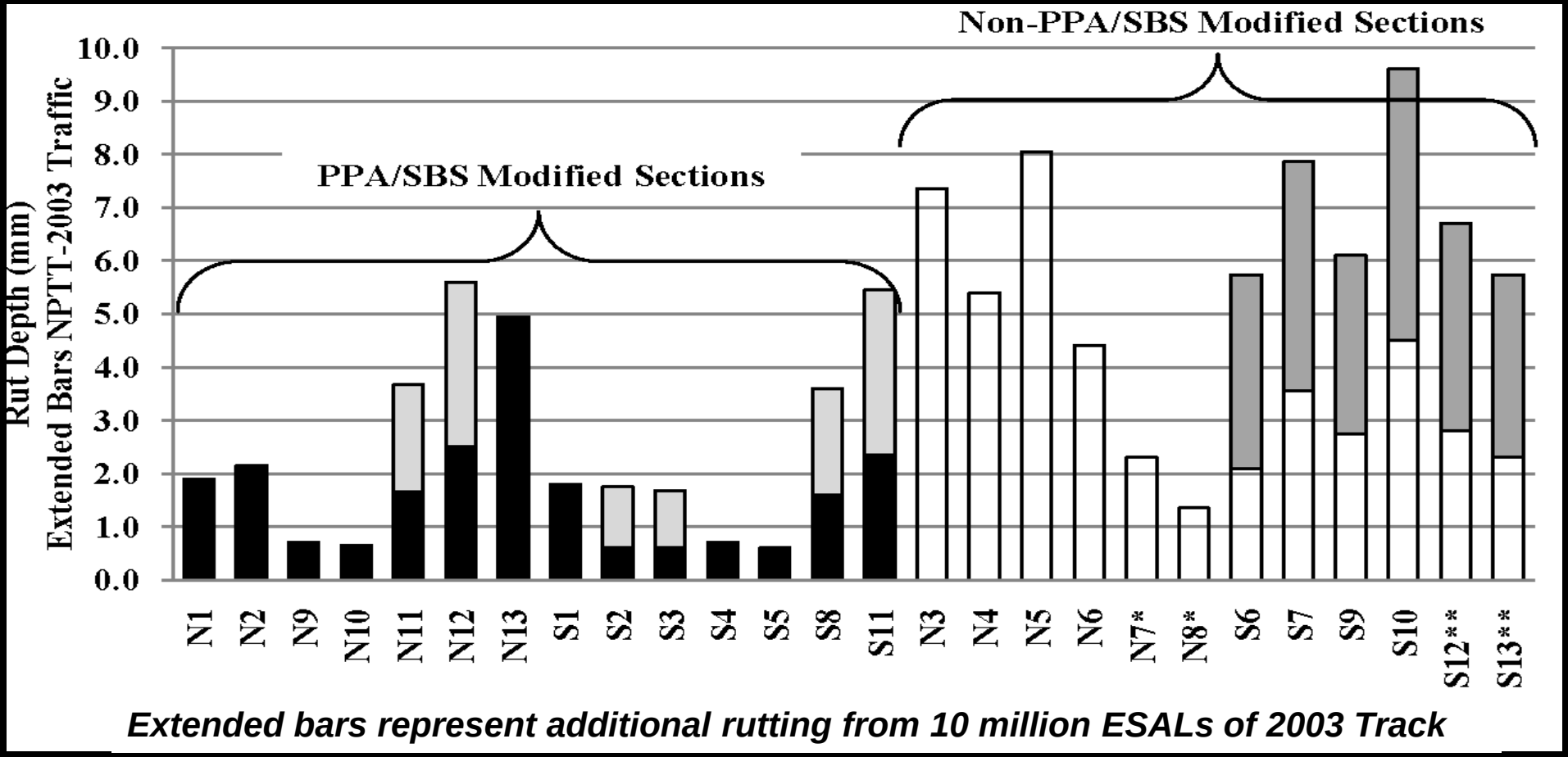
Permanent Deformation 2000/2003 Test Tracks



Extended bars represent additional rutting from 10 million ESALs of 2003 Track

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Permanent Deformation 2000 Test Track

- Rutting Considered to be Minimal to None in all Sections
- PPA/SBS Sections
  - Minimum of 0.6 mm (0.02 inch)
  - Maximum of 4.95 mm (0.19 inch)
- Unmodified PG67-22 Sections
  - Minimum of 2.1 mm (0.08 inch)
  - Maximum of 8.1 mm (0.32 inch)

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Permanent Deformation
2003 Test Track

PPA/SBS Modified Binders	
Section	NPTT-2003 Rut Depth mm (inch)
N9*	3.79 (0.149)
N10*	4.84 (0.191)
N13	3.29 (0.130)
S1	2.92 (0.115)
S4	2.14 (0.084)
S5	2.58 (0.102)
Rutting Study Sections	
* PG 70-22 Sections	

Non-PPA/SBS Modified Binders	
Section	NPTT-2003 Rut Depth mm (inch)
N1	Fatigue Failure
N2	Fatigue Failure
N3	3.21 (0.126)
N4	2.56 (0.101)
N5	3.06 (0.120)
N6	5.01 (0.197)
N7	3.98 (0.157)
N8	2.38 (0.093)
Structural Study Sections	

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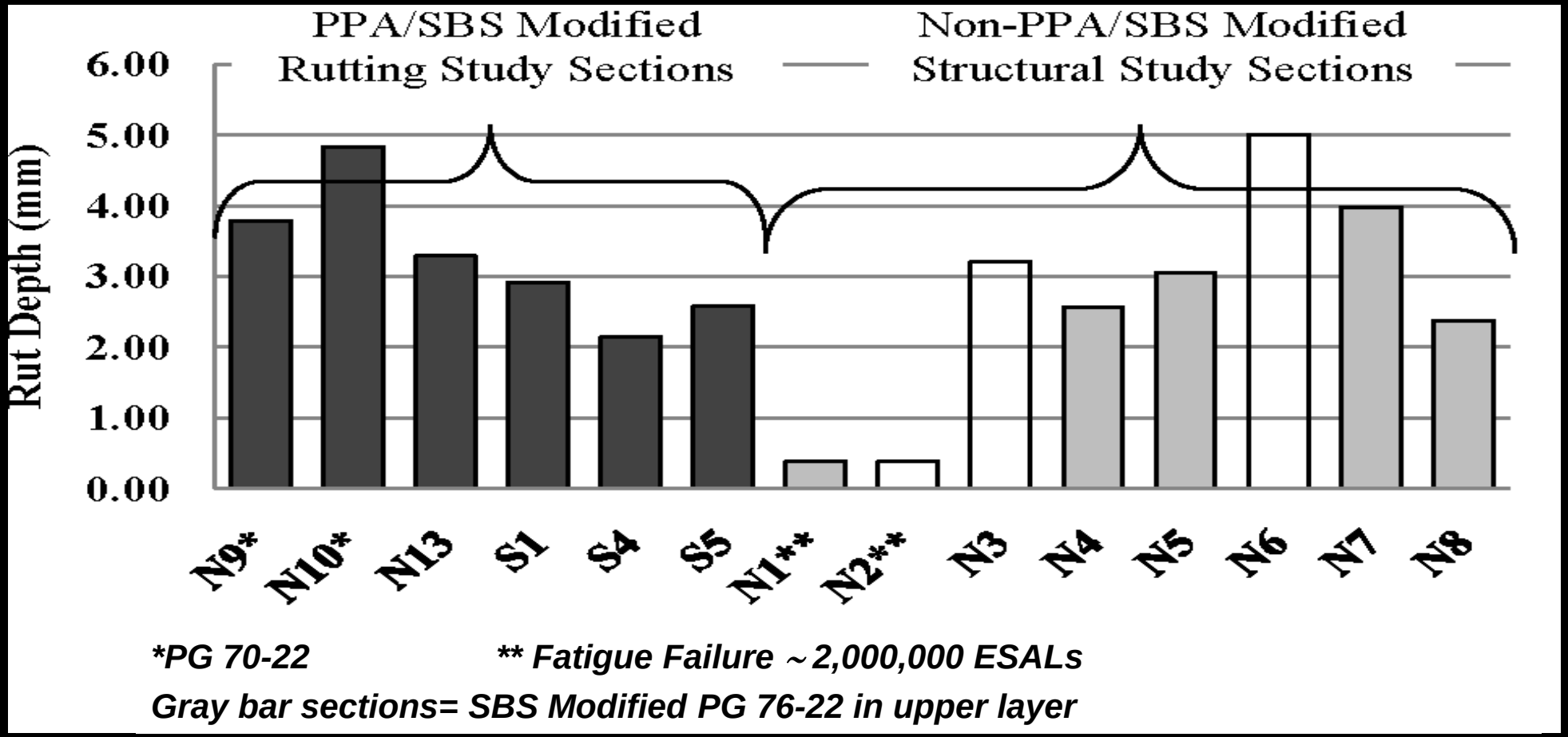
Permanent Deformation
2003 Test Track



PG 70-22* * Fatigue Failure ~2,000,000 ESALs*

Gray bar sections= SBS Modified PG 76-22 in upper layer

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Permanent Deformation 2003 Test Track

- Rutting in all Tangent Sections of 2003 Test Track Considered to be Minimal at 2-5 mm
- Average Accumulated Rut Depth of Sections Containing PPA/SBS Modified Binders was a low of 2.14 mm (0.084 inch) PG76 to a High of 4.48 mm (0.191 inch) PG70

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Permanent Deformation 2003 Test Track

- Sections Using Conventional SBS Modified Binders Exhibited More Rutting than PPA/SBS Modified Sections
- SuperPave™ Grade Bumping Proved Beneficial in Reduction of Permanent Deformation
- PG76 < PG70 < PG67

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FATIGUE

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Fatigue
2000 Test Track

- Fatigue Cracking Observed in Four Test Sections of 2000 Test Track.
  - All Fatigue Cracked Sections were Polymer Modified
  - Only One Section Contained PPA/SBS Modified Binder
  - PPA/SBS Modified Section Left to 20M ESALs of Traffic
  - All Gravel BRZ Mix (Least Rutting) Stiff-Low Binder Content (Top Down 50-100mm)

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Fatigue
2003 Test Track

- Fatigue Cracking Observed in Three Test Sections
- All Sections Within the Eight Structural Sections
- None of the Fatigue Cracked Sections Contained PPA/SBS Modified Binder
- Two Sections Contained SBS Modified Binder

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Moisture Damage

- Average Annual Rainfall in Excess of 40 inches
- Some Aggregates in Construction of Both Research Cycles Susceptible to Moisture Damage
- Moisture Damage was not a Mode of Failure Identified in Either Research Cycle
- In Top Down Cracked Sections Moisture Damage was not Apparent

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Conclusion

- Effect of PPA on Binder and Pavement Performance Extremely Studied/Documented
- Use of PPA Debated /Banned without Just Cause
- Research from NCAT Test Track Provided Information in Six Years that Would Normally Take about 20 Years
- NCAT Pavement Test Track Provided Comprehensive Performance Evaluation of PPA/SBS Modified Binders

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Questions?

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