Refining Binder Selection to Increase Performance

Mark D Blow, P.E. - Asphalt Institute

NORTH DAKOTA
ASPHALT
CONFERENCE
March 2–3, 2022 ▪ Baymont Inn and Suites Mandan

Superpave Asphalt Binder Specification

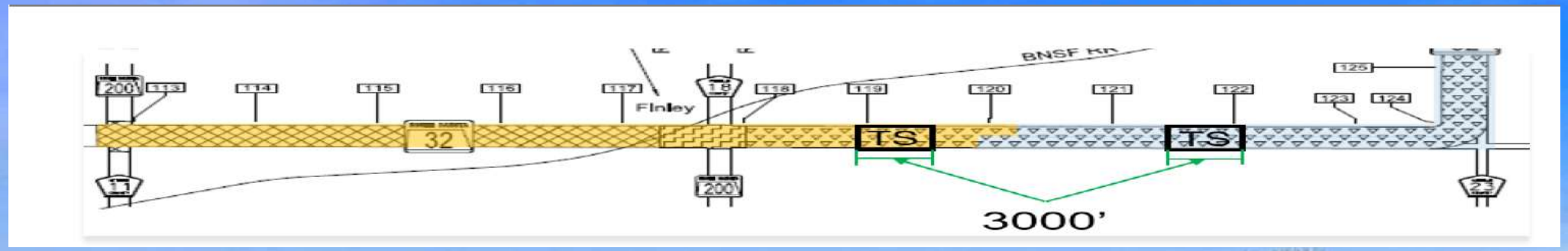
Grading System Based on Climate

PG 58-22

- **Performance Grade**
- **Max pavement design temp**
- **Min pavement design temp**

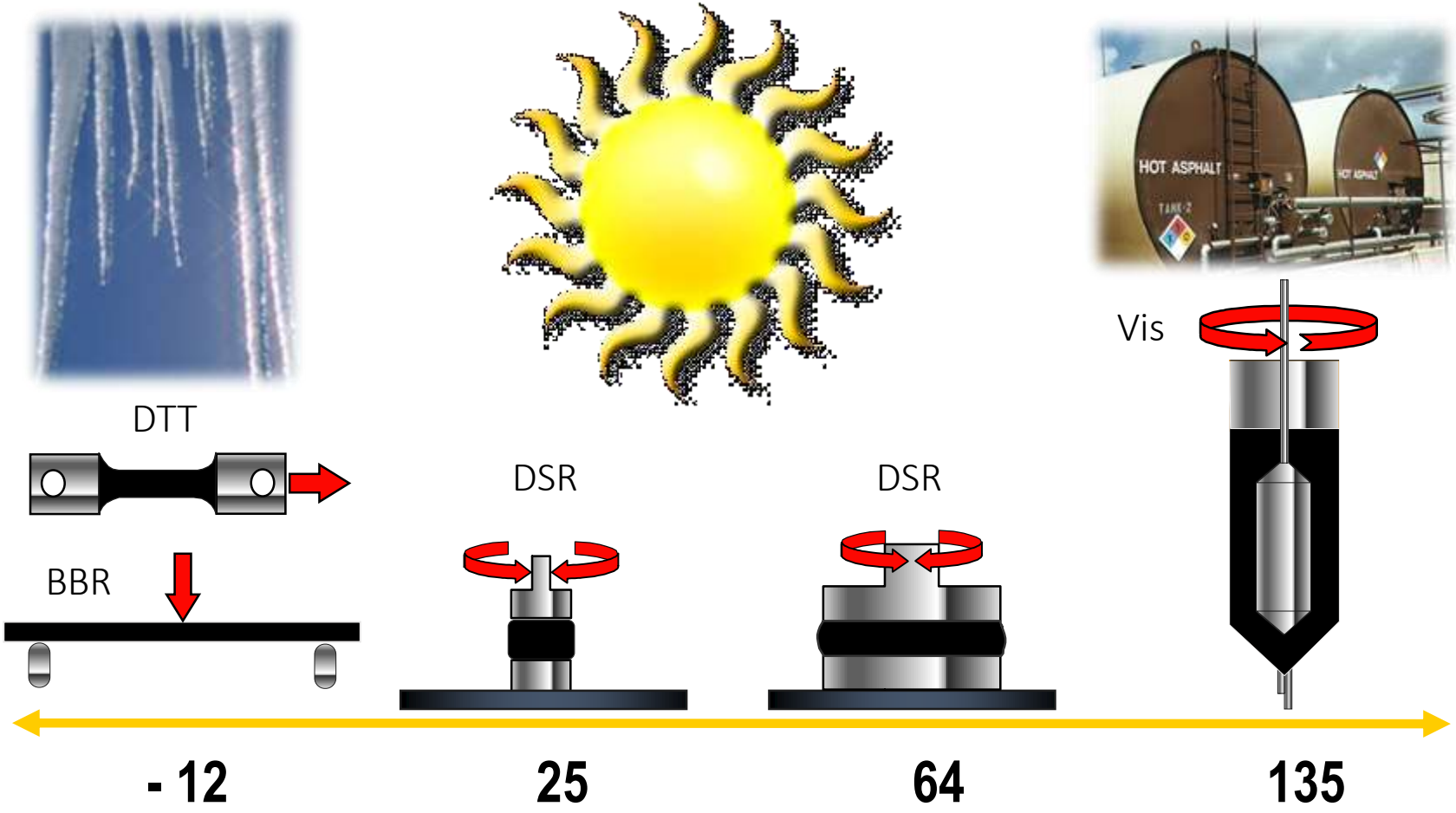
MS-2
Pg. 5 – 2.1.1

Great work at NDDOT



HWY 32 Pavement Test Sections

Testing Temperature



Pavement Temperature, °C

Values for PG 64-22

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Performance Grades (AASHTO M320)

High PG	PG 52							PG 58					PG 64						PG 70						PG 76				
Low PG	-10	-16	-22	-28	-34	-40	-46	-16	-22	-28	-34	-40	-10	-16	-22	-28	-34	-40	-10	-16	-22	-28	-34	-40	-10	-16	-22	-28	-34
Original																													
≥230 °C	**Flash Point,** AASHTO T 48																												
≤ 3 Pa-s	**Rotational Viscosity** @ 135° C, AASHTO T 316																												
≥ 1.00 kPa	**DSR G*/sin** δ (Dynamic Shear Rheometer), AASHTO T 315																												
	52							58					64						70						76				
RTFO (Rolling Thin Film Oven), AASHTO T 240																													
≤ 1.00%	**Mass Change**																												
≥ 2.20 kPa	**DSR G*/sin** δ (Dynamic Shear Rheometer), AASHTO T 315																												
	52							58					64						70						76				
PAV (Pressure Aging Vessel), AASHTO R28																													
	90							100					100						100(110)						100(110)				
≤ 5000 kPa	**DSR G*sin** δ (Dynamic Shear Rheometer), AASHTO T 315 **Intermediate Temp. = [(High PG + Low PG)/2] + 4**																												
	25	22	19	16	13	10	7	25	22	19	16	13	31	28	25	22	19	16	34	31	28	25	22	19	37	34	31	28	25
S ≤ 300 MPa m ≥ 0.300	**BBR S (creep stiffness) & m-value** (Bending Beam Rheometer), AASHTO T 313																												
	0	-6	-12	-18	-24	-30	-36	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24

- If BBR m-value ≥ 0.300 and creep stiffness is between 300 and 600, the Direct Tension failure strain requirement of ≥ 1.00% can be used in lieu of the creep stiffness requirement.
- Binder shall be homogeneous, free from water, contain no deleterious materials, be at least 99.0% soluble and contain no particles larger than 250 µm.

AASHTO M320 Specification

Example:

- Toll road
  PG 64-22 ← **90 kph (55 MPH)**
- Toll booth
  PG 70-22 ← **Slow**
- Weigh stations
  PG 76-22 ← **Stopping**

Does PG Grading Predict Performance?

Study of the two mixes with the same aggregate structure, but different binders.

PG 64-22 modified, no rutting

PG 67-22 unmodified, 15mm rut

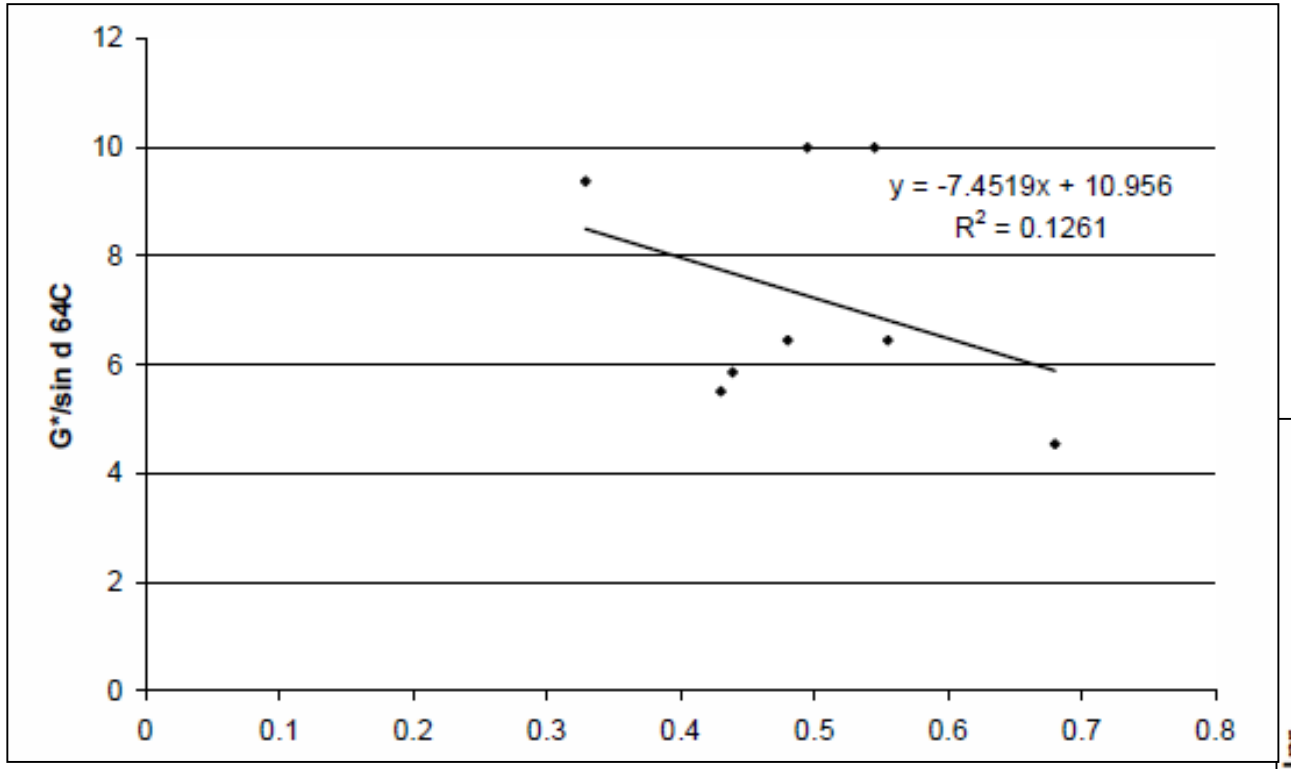
What happened as a result of M 320's inability to fully characterize polymer modified binders?

- Most states began requiring additional tests to the ones required in AASHTO M 320
- These mostly empirical tests are commonly referred to as "PG Plus" tests
- These tests are not standard across the states – difficult for suppliers
- Even some of the tests that are the most common, e.g. Elastic Recovery, are not run the same way from state to state

Accelerated Loading Facility (ALF)

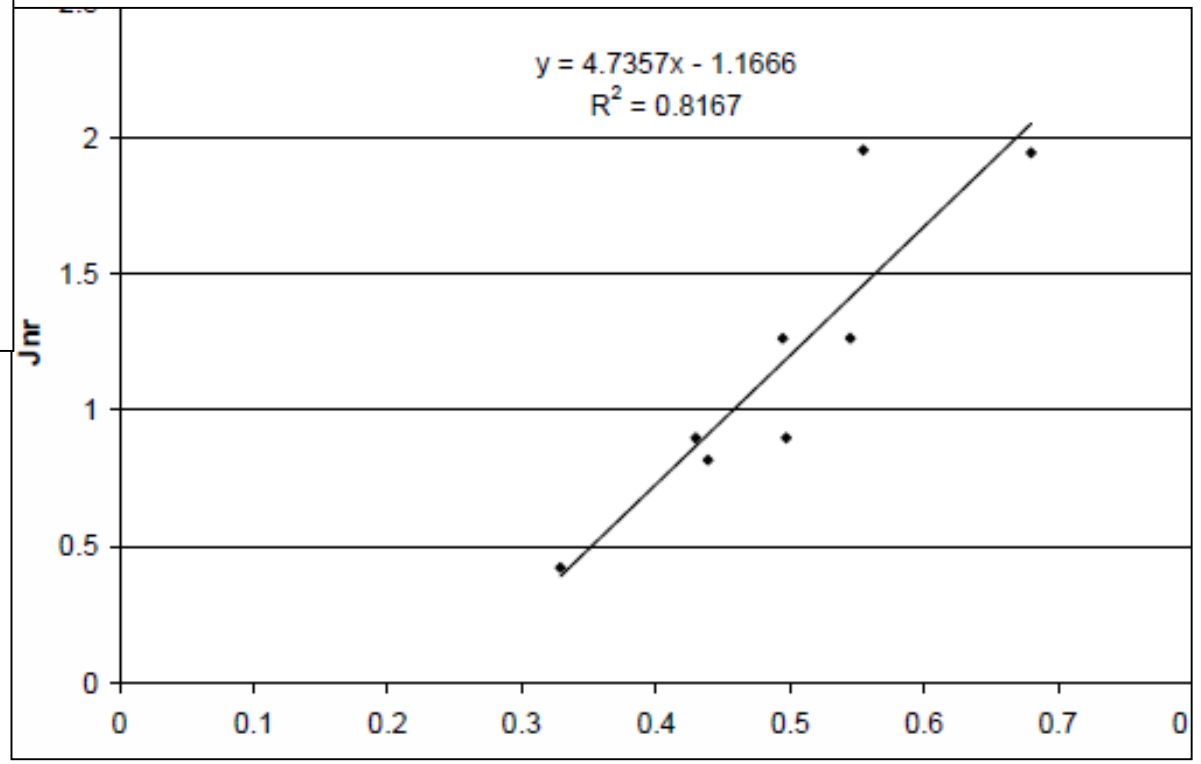
- The pavement was heated to a constant 64°C
- The FHWA ALF uses an 18,000 lbs. single wheel load with no wheel wander
- The speed is 12 MPH
- This is a extreme loading condition far more severe than any actual highway

ALF Loading – M 320 vs. M 332



Traditional M 320
PG Spec
R^2 = 0.13

New M 332
PG Spec
R^2 = 0.82



Multiple Stress Creep Recovery Test

- Performed on RTFO-aged Binder
- Test Temperature
  - Environmental Temperature
  - Not Grade-Bumped
- 10 cycles per stress level
  - 1-second loading at specified shear stress
    - 0.1 kPa
    - 3.2 kPa
  - 9-second rest period

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≤ 4.5 kPa^{-1} ≤ 2.0 kPa^{-1} ≤ 1.0 kPa^{-1} ≤ 0.5 kPa^{-1} (SHVE)	**MSCR $J_{nr,\ 3.2}$** (Multiple Stress Creep-Recovery), AASHTO T 350																												
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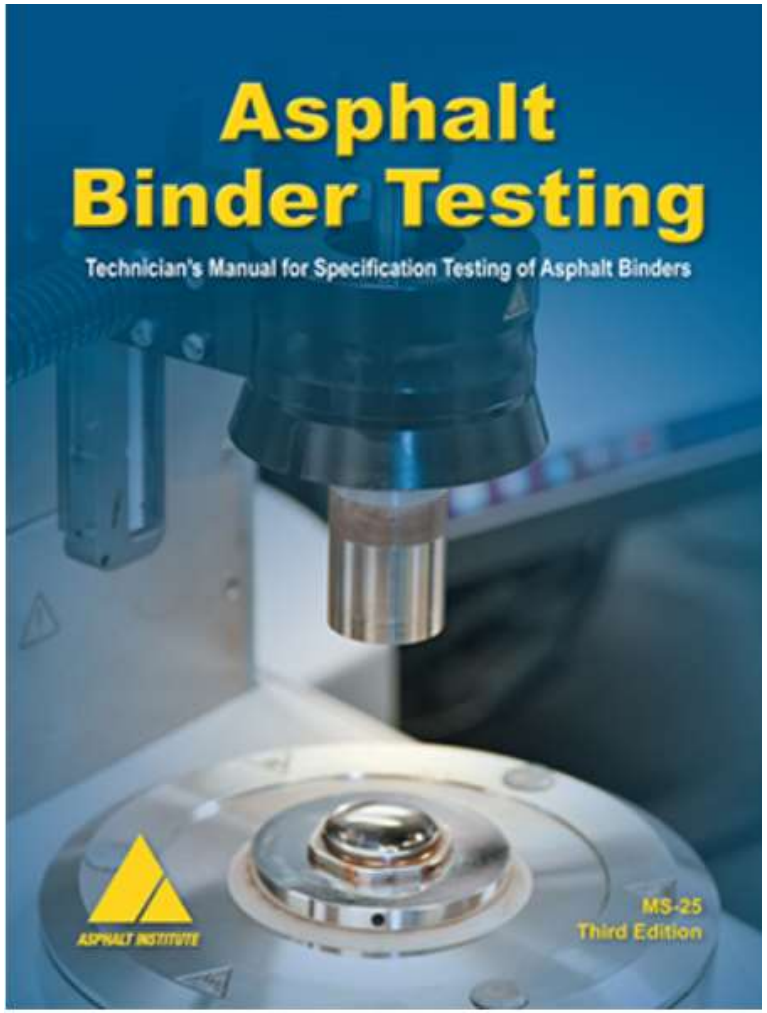
MSCR PG Grading System (AASHTO M 332)

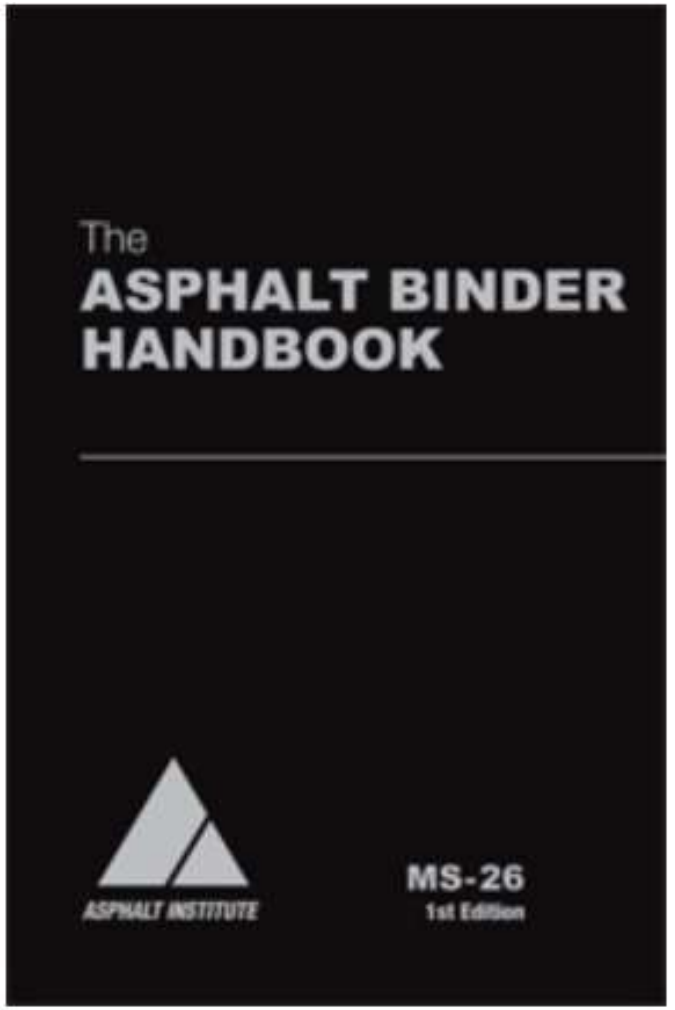
- Environmental grade plus traffic level designation; i.e. PG 64E-22
  - Four traffic levels
    - S = Standard: < 10 million ESALs and standard traffic loading
    - H = Heavy: 10 – 30 million ESALs or slow moving traffic loading
    - V = Very Heavy: > 30 million ESALs or standing traffic loading
    - E = Extra Heavy: > 30 million ESALs and standing traffic loading

Note: MSCR system replaces grade bumping.

For More Binder Information



MS-25



MS-26

Is a PG a Modified Binder?

Effect of Loading Rate

Reliability

"Rule of 92"

PG 64 - 34 => 64 - - 34 = 98

Probably modified

Depends on asphalt source

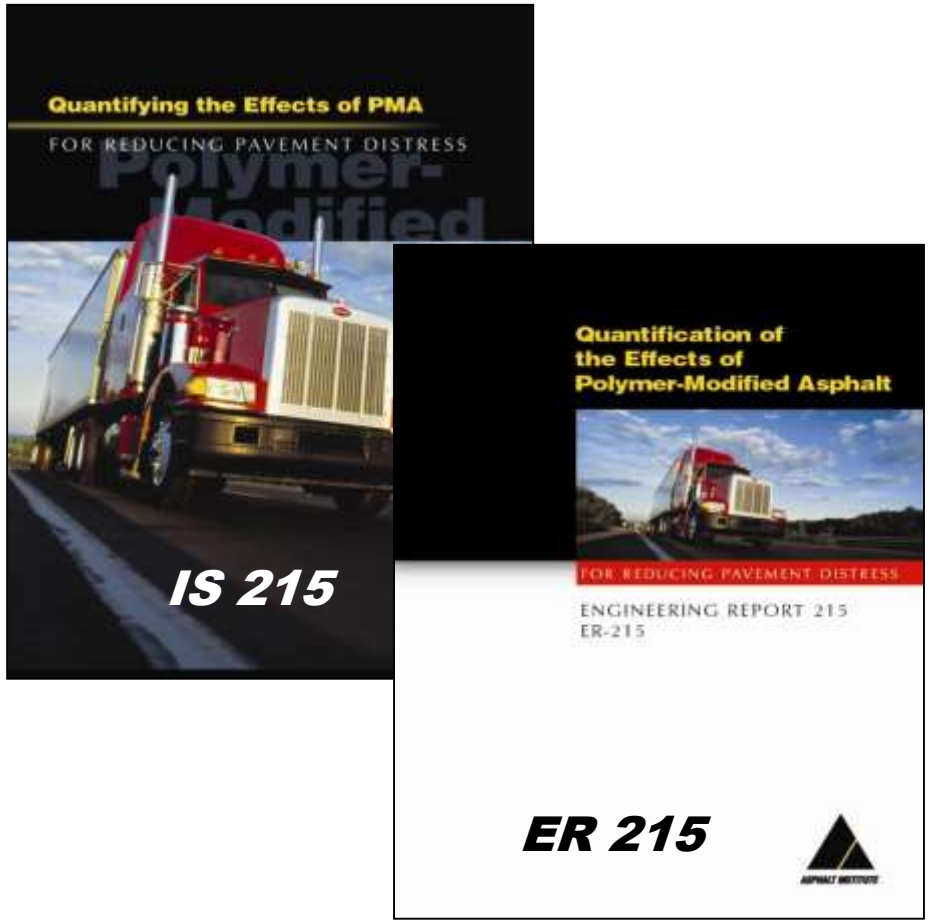
Rounding

Effect of Traffic

What are we looking for- Price or Performance?

LTPP Studies

Quantifying the Effects of PMA for Reducing Pavement Distress



This study (published in Feb 2005) used national field data to determine enhanced service life of pavements containing polymer modified binders versus conventional binders. The data is from a variety of climates and traffic volumes within North America.

IS-215 Survey Data

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Table 1. Summary of Reasons Why Agencies Use PMA Mixtures

Reason for Using PMA Mix	Rutting	Thermal Cracking	Fatigue Cracking	Stripping, Moisture Damage	Durability	Raveling	Tenderness
Primary	58%	21%	0%	0%	0%	0%	0%
Secondary	37%	47%	0%	21%	47%	11%	11%
Total	95%	68%	0%	21%	47%	11%	11%

IS-215 Rut Depth Data

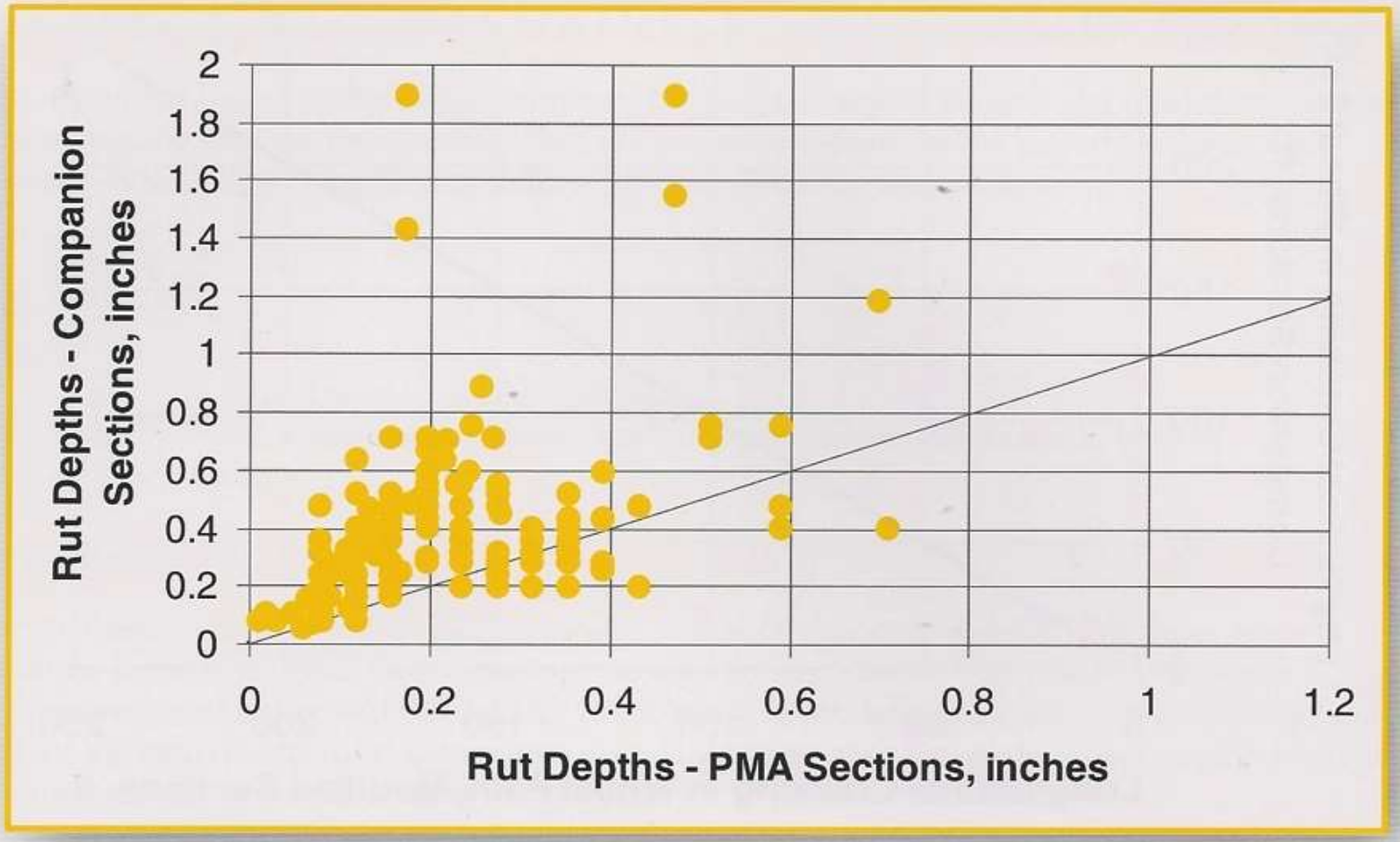


Figure 1 Graphical comparison of the rut depths measured on sections with PMA and the companion sections — those without PMA mixtures.

IS-215 Fatigue Cracking Data

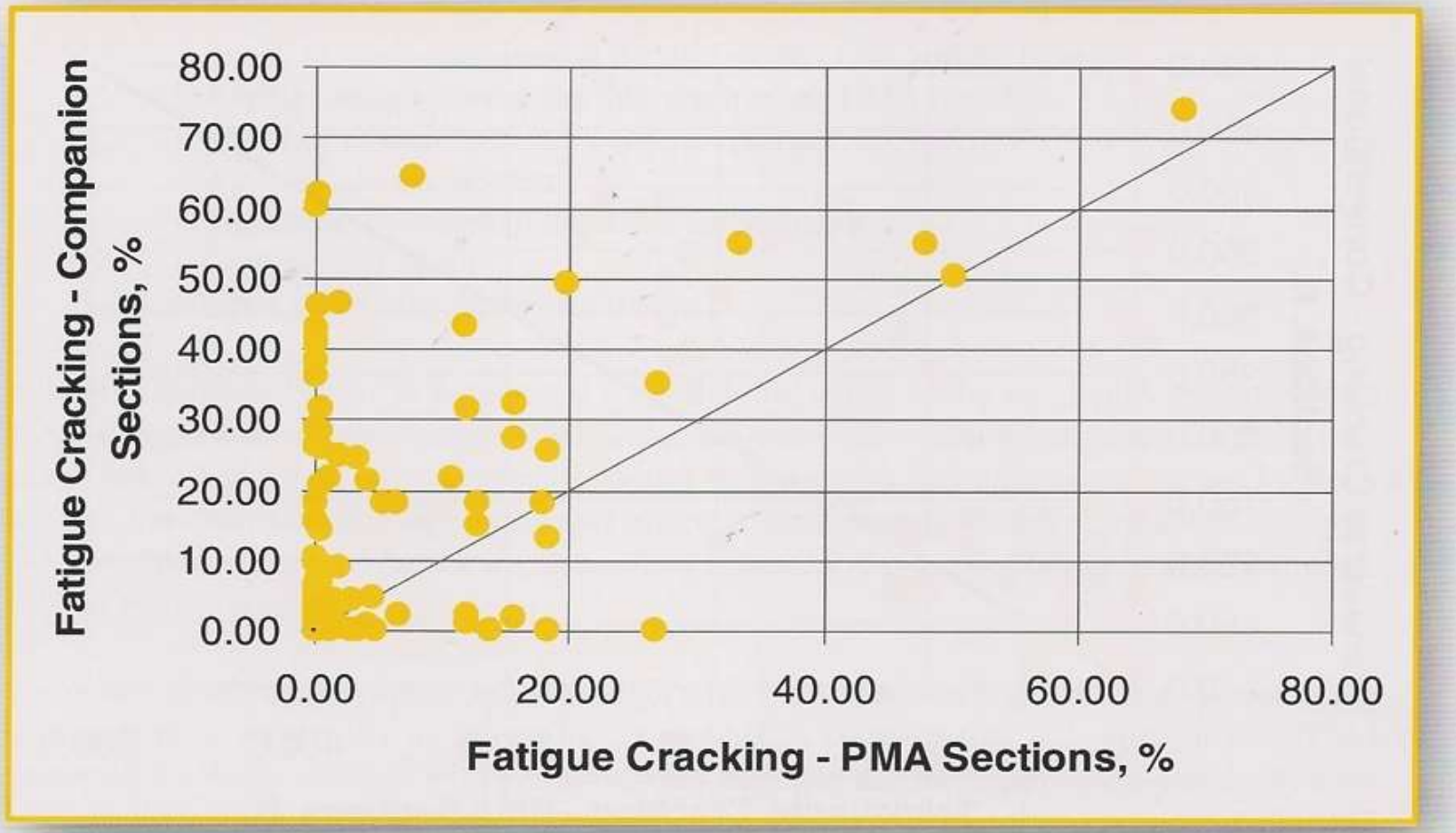


Figure 2 Graphical comparison of the fatigue cracking measured in percent wheel path area on sections with PMA and the companion sections — those without PMA mixtures.

IS-215 Thermal Cracking Data

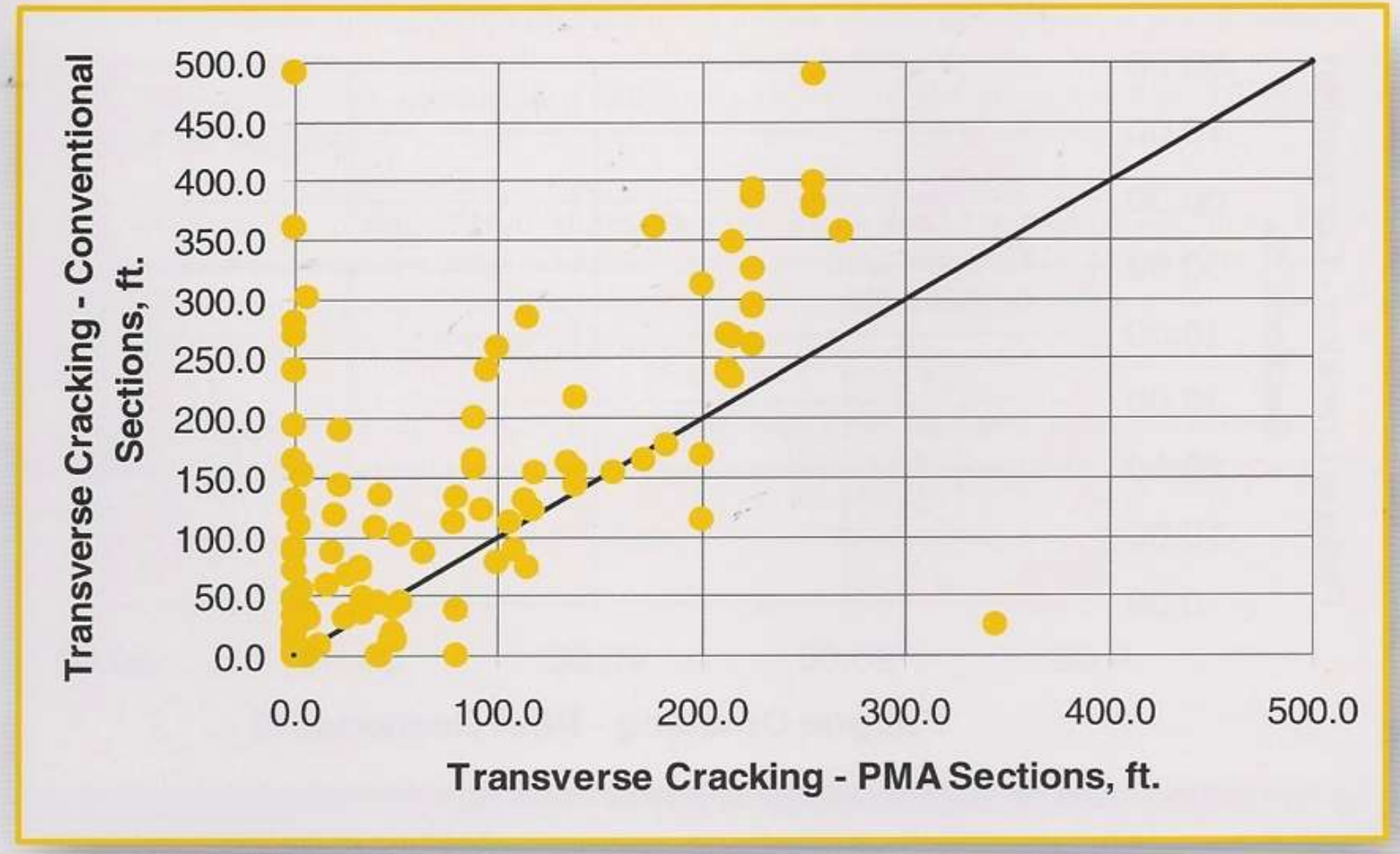


Figure 4 Graphical comparison of the length of transverse cracks measured on sections with PMA and the companion sections — those without PMA mixtures.

Summary of Expected Increase in Service Life, Years, Based on M-E Damage Based Analysis

Assumptions: Unmodified sections designed for 20 yr. life. Also, PMA in top 4 inches.

Site Factor	Condition Description		Added Life
Foundation	Non-expansive, coarse soils		5-10
	Expansive and plastic soils (PI>35)		2-5
	Frost Susceptible in cold climate		2-5
Water Table & Drainage	Deep		5-10
	Shallow; adequate		5-8
	Shallow; inadequate		0-2
Existing Pavement Condition	HMA	Good	5-10
		Poor-extensive cracking	1-3
	PCC	Good	3-6
		Poor-faulting & cracking	0-2

Continued:
Summary of Expected Increase in Service Life, Yrs

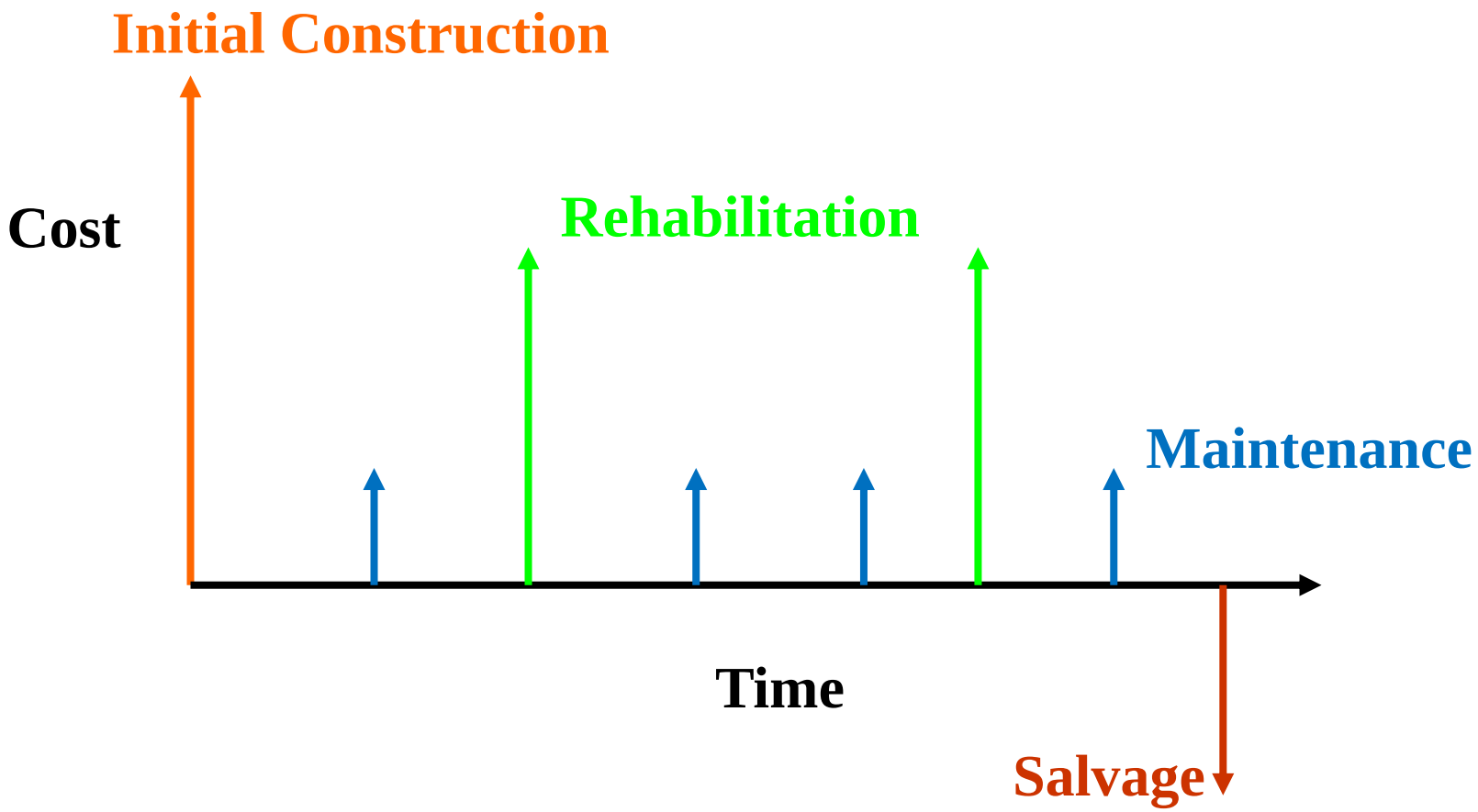
Assumptions: Unmodified sections designed for 20 yr. life. Also, PMA in top 4 inches.

Site Factor	Condition Description		Added Life
Climate; Temp. Fluctuations	Hot	Hot Extremes	5-10
	Mild		2-5
	Cold	Cold Extremes	3-6
Traffic, Truck Volumes	Low	Intersections	5-10
		Thoroughfares	3-6
		Heavy Loads	5-10
	Moderate		5-10
	High		5-10

Is this reliable info?

- Yes, the information, analysis and results are accurate …..
- These projects were part of SHRP's LTPP program
- They were well designed and well built
- It shows what we can achieve when we do things right.

We make a lot of assumptions in our business



PMS is critical

We need to:

- Have accurate condition ratings
- Account for pavement materials
- Have uniform construction processes

Another Way?

Is there another way to analyze value?

I believe there is.

When was the last time you painted your house or fence?

What do binders cost?

2020 NDDOT Ave. Unit Bid Prices

Description		Unit	Total Quantity	Average Bid Price
PG 58S-28	Asphalt Binder	Ton	40,033	$448.80
PG 58H-28	Asphalt Binder	Ton	23,178	$502.93
PG 58S-34	Asphalt Binder	Ton	2,439	$508.54
PG 58H-34	Asphalt Binder	Ton	667	$506.00
PG 58E-34	Asphalt Binder	Ton	329	$812.98

Highest to Lowest Difference = $59.74 or $364.18 per binder ton?
@ 6% Binder = $3.58 / ton of mix for 58S-34

Simple County overlay

10 mile overlay, No milling

Original Contract Amount	$ 1,500,814.57
1,575.5 contract binder Tons @ $462.07/ton	$ 727,991.29
1,575.5 Tons X $59.74 per ton increase	$ $94,120.37
Increase in Project Cost	6.27%

Years needed to recover additional 6.3% expenditure		
10 year assumed life	7.5	months
20 year assumed life	15.1	months

Complicated Interstate overlay

20 + mile overlay, extensive traffic control, underdrains, etc.

Original Contract Amount	$ 22,565,024.00
12,976.4 contract binder Tons @ $425.78/ton	$ 5,525,138.00
12,976.4 Tons X $59.74 per ton increase	$ 775,210.14
Increase in Project Cost	3.44%

Years needed to recover additional 3.44% expenditure		
10 year assumed life	4	months
20 year assumed life	8	months

Small Town Urban / Grading

1 mile 3-Lane, grading, C&G, sidewalks, lighting and new asphalt surface

Original Contract Amount	$3,521,707.00
9518.5 Ton recycled mix bid @ 4.7% binder	
447.7 contract binder Tons @ $730.00/ton	$326,821.00
571.1 (6%) virgin binder Tons X $789.74 per ton	$451,020.51
Project Binder cost increase	$124,199.51
Increase in Project Cost	3.52%

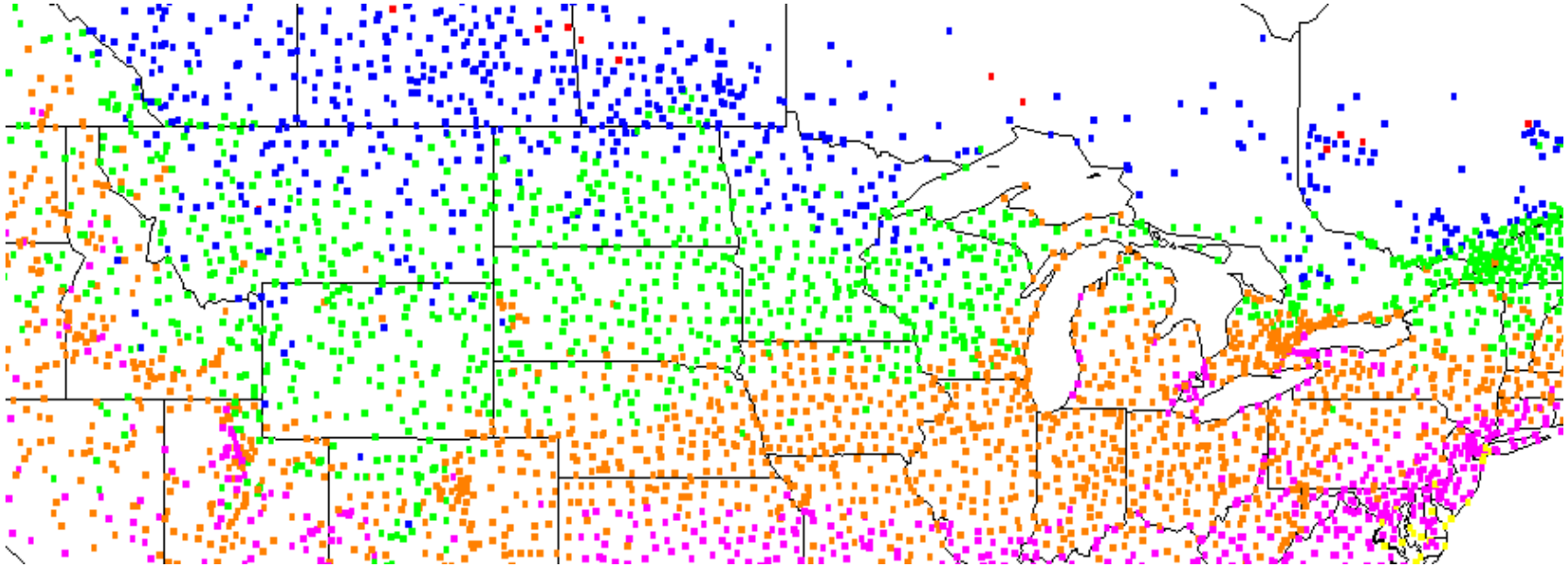
Years needed to recover additional 3.52% expenditure		
10 year assumed life	4.2	months
20 year assumed life	8.4	months

In Conclusion

A few parting thoughts on increasing pavement performance

New Construction

- Use the proper -xx binders to prevent thermal cracking!
- 25 year old SHRP recommendation.



LTPPBind v3.1
https://infopave.fhwa.dot.gov/Page/Index/LTPP_BIND

On overlays

Consider higher performance binders on overlays

- Reduced rutting
- Reduced cracking
- Better crack seal performance
- Maintain existing crack resistance

  Example - Do not place an overlay with -22 binder on a pavement built with a -34 binder.

Better Joint Performance

Interstate Saw and Seal

- Orig. 1962 PCC
- 1999 - 3” HMA
- 2004 – 1.5” SMA
  - ✓PG 70-28
- 2004 – Saw/Seal
- 2009 – Sealed secondary cracks
- Photo taken in 2018

Consider reducing the # of grades

2020 NDDOT Ave. Unit Bid Prices

430	5803	PG 58S-28 ASPHALT CEMENT	46,033.00	$20,659,811.90	$448.80	TON
430	5806	PG 58H-28 ASPHALT CEMENT	23,178.80	$11,657,341.53	$502.93	TON
430	5815	PG 58S-34 ASPHALT CEMENT	2,439.03	$1,240,338.00	$508.54	TON
430	5818	PG 58H-34 ASPHALT CEMENT	8,987.50	$4,547,712.50	$506.00	TON
430	5824	PG 58E-34 ASPHALT CEMENT	667.00	$542,258.75	$812.98	TON
430	5828	PG 58-28 ASPHALT CEMENT	329.00	$172,725.00	$525.00	TON

2020 SDDOT Ave. Unit Bid Prices

320E0005	PG 58-34 Asphalt Binder	Ton	42,859.80	23,960,780.48	559.05
320E0007	PG 64-28 Asphalt Binder	Ton	871.50	579,453.00	664.89
320E0008	PG 64-34 Asphalt Binder	Ton	28,463.80	17,062,417.81	599.44

Thank you

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