Asphalt Binder Basics
Specifications, History and Future

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Asphalt Binder

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"A dark brown to black cementatious material in which the predominating constituents are bitumens which occur in nature or are obtained in petroleum processing." – ASTM D8

The glue that binds the aggregate together and waterproofs the pavement.

History

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First US hot mix asphalt (HMA) constructed in 1870's

- Pennsylvania Ave.
- Used naturally occurring asphalt from surface of lake on Island of Trinidad

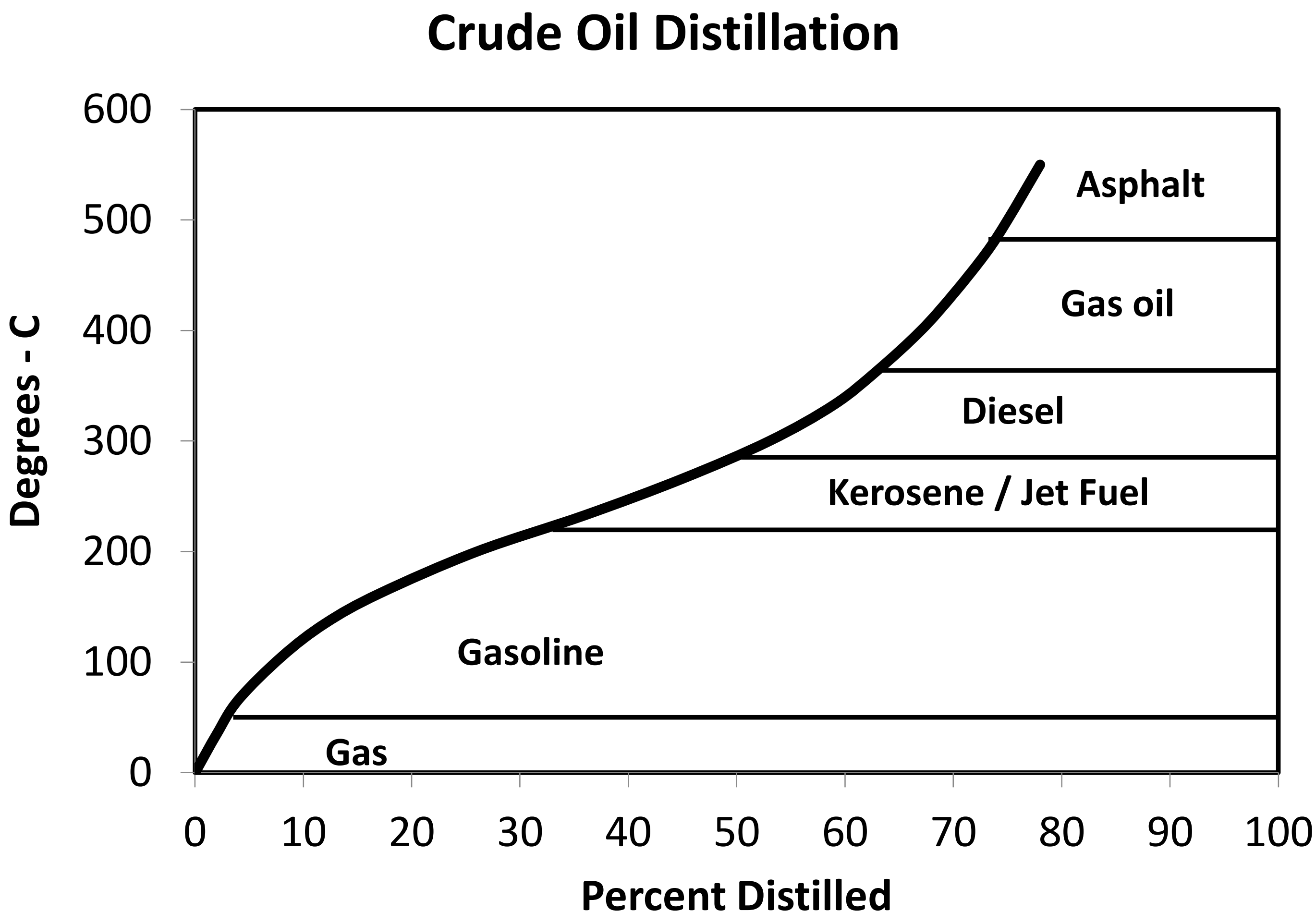
Demand for paved roads exceeded the supply of lake asphalts in late 1800's

Led to use of petroleum asphalts

Petroleum Asphalt

Sweet vs. Sour
Light vs. Heavy

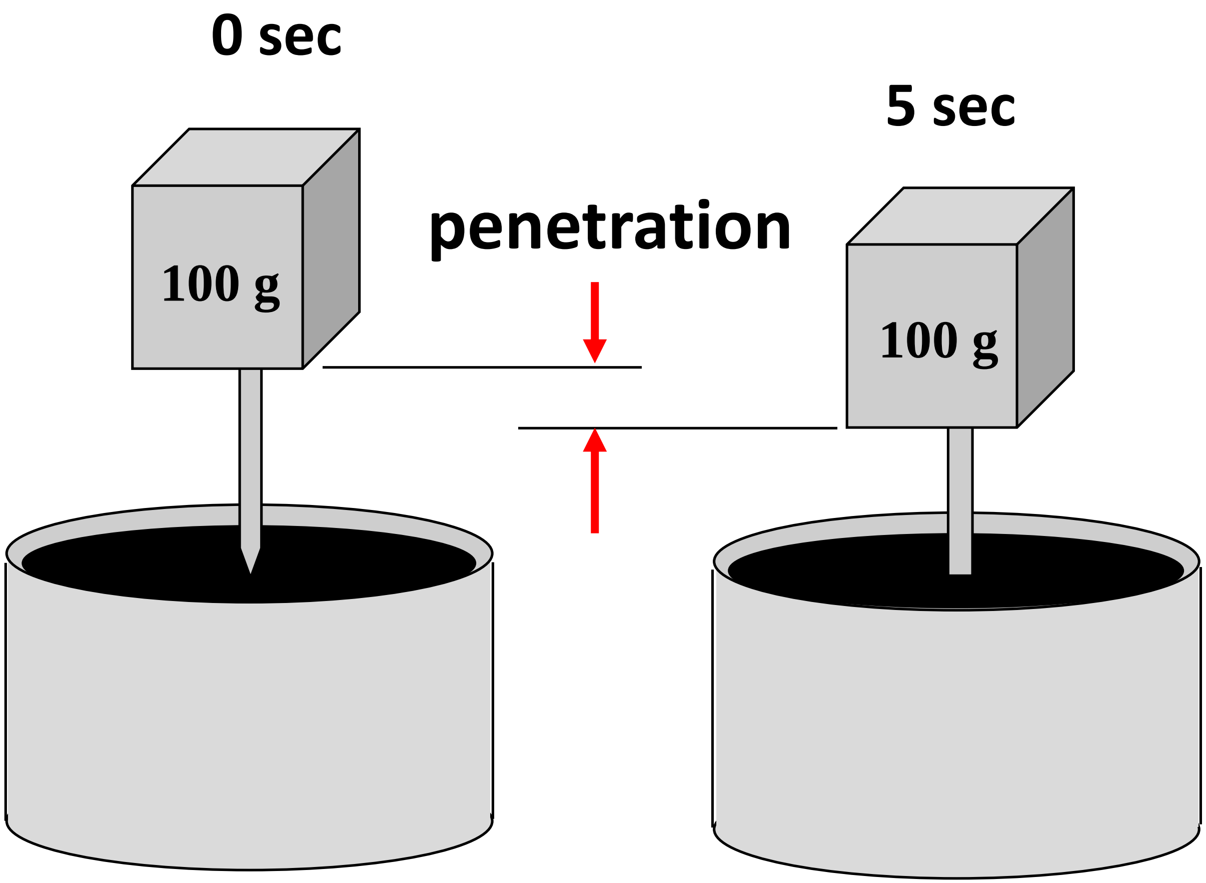
Crude Distillation Temperatures



Historical Grading Systems

- Penetration
  - Developed in early 1900s (first ASTM 1947)
  - Tested @ 25°C (77°F)
- Viscosity
  - Developed in 1950s
  - Absolute Viscosity
    - Tested @ 60°C (140°F)
  - Kinematic Viscosity
    - Tested @ 135°C (275°F)

Penetration (1900s)



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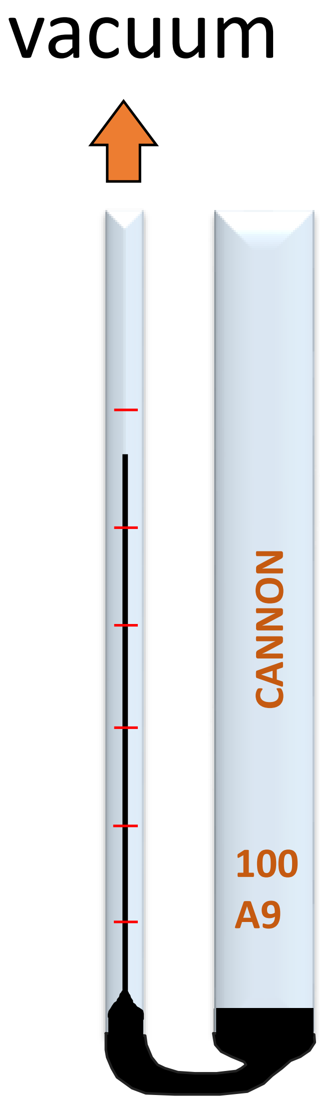
Penetration Specification

Characteristics	AASHTO	ASTM	Penetration Grades				
Penetration, 77°F, 100 g, 5 sec	T49	D5	40 - 50	60 - 70	85 - 100	120 - 150	200 - 300
Visc. @ 275°F Kinematic, Cs Saybolt Furol, SSF	T201	D2170 E102	240 + 120 +	200 + 100 +	170 + 85 +	140 + 70 +	100 + 50 +
Flash Point, °F, Clev Open Cup	T48	D92	450 +	450 +	450 +	425 +	350 +
Thin Film Oven Test Pen on Residue, 77°F, % Orig.	T179 T49	D1754 D5	55 +	52 +	47 +	42 +	37 +
Ductility @ 77°F, cm @ 60°F, cm	T51	D113	100 + ------	100 + ------	100 + ------	60 + ------	------ 60 +
Sol. In Trichloroethylene, %	T44	D2042	99.0 +	99.0 +	99.0 +	99.0 +	99.0 +

General Requirement – The asphalt shall be prepared by the refining of petroleum.
It shall be uniform in character and shall not foam when heated to 350°F

Viscosity (1950s)

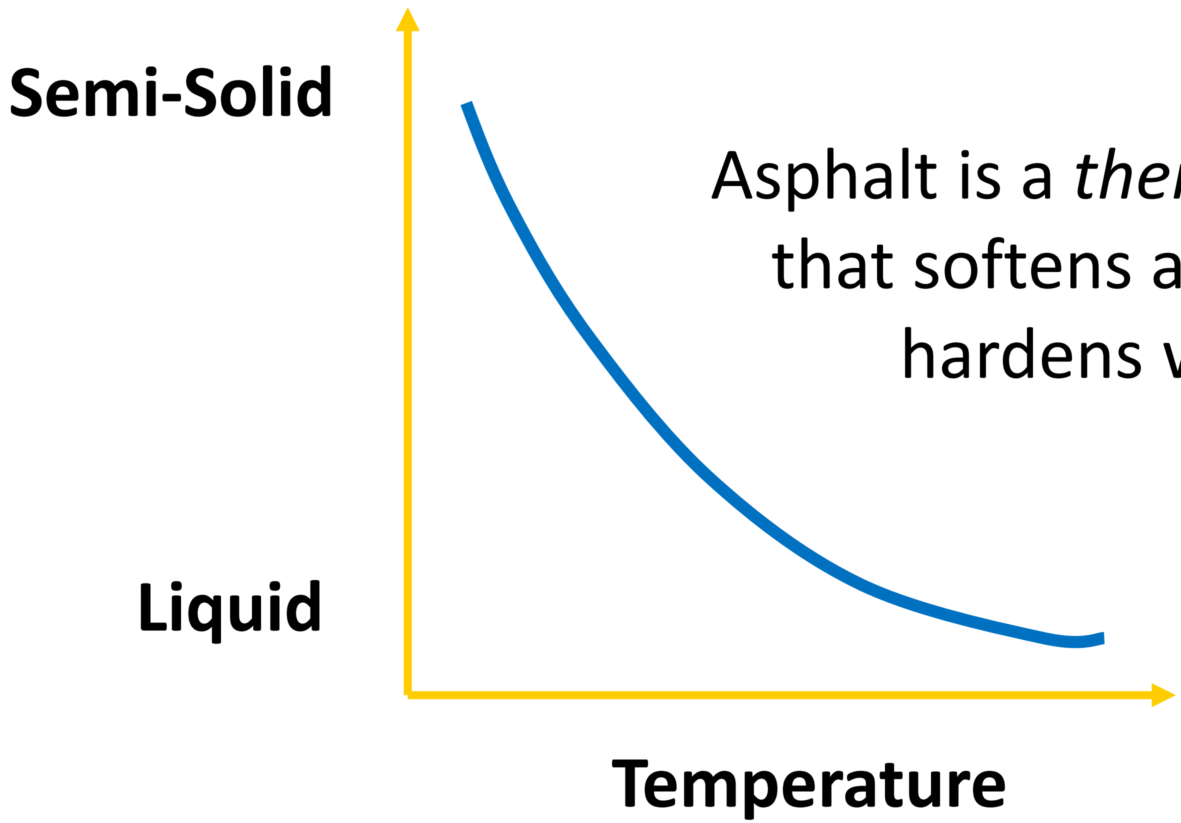


Measure time of flow between lines

Viscosity Specification

Characteristics	Viscosity Grades					
Test	AC-2.5	AC-5	AC-10	AC-20	AC-30	AC-40
Visc. @ 140°F Kinematic, P	250 ± 50	500 ± 100	1000 ± 200	2000 ± 400	3000 ± 600	4000 ± 800
Visc. @ 275°F Kinematic, Cs, Min.	125	175	250	300	350	400
Penetration,77°F, 100 g, 5 sec, Min.	220	140	80	60	50	40
Flash Point, °F, C.O.C., Min.	325	350	425	450	450	450
Sol. In Trichloroethylene, %	T44	99.0 +	99.0 +	99.0 +	99.0 +	99.0 +
Tests on TFOT Residue						
Loss on Heating, %, Max.		1.0	0.5	0.5	0.5	0.5
Visc. @ 140°F Kinematic, P, Max.	1000	2000	4000	8000	12000	16000
Ductility @ 77°F, cm, Min.	100	100	75	50	40	25
Spot Test	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.

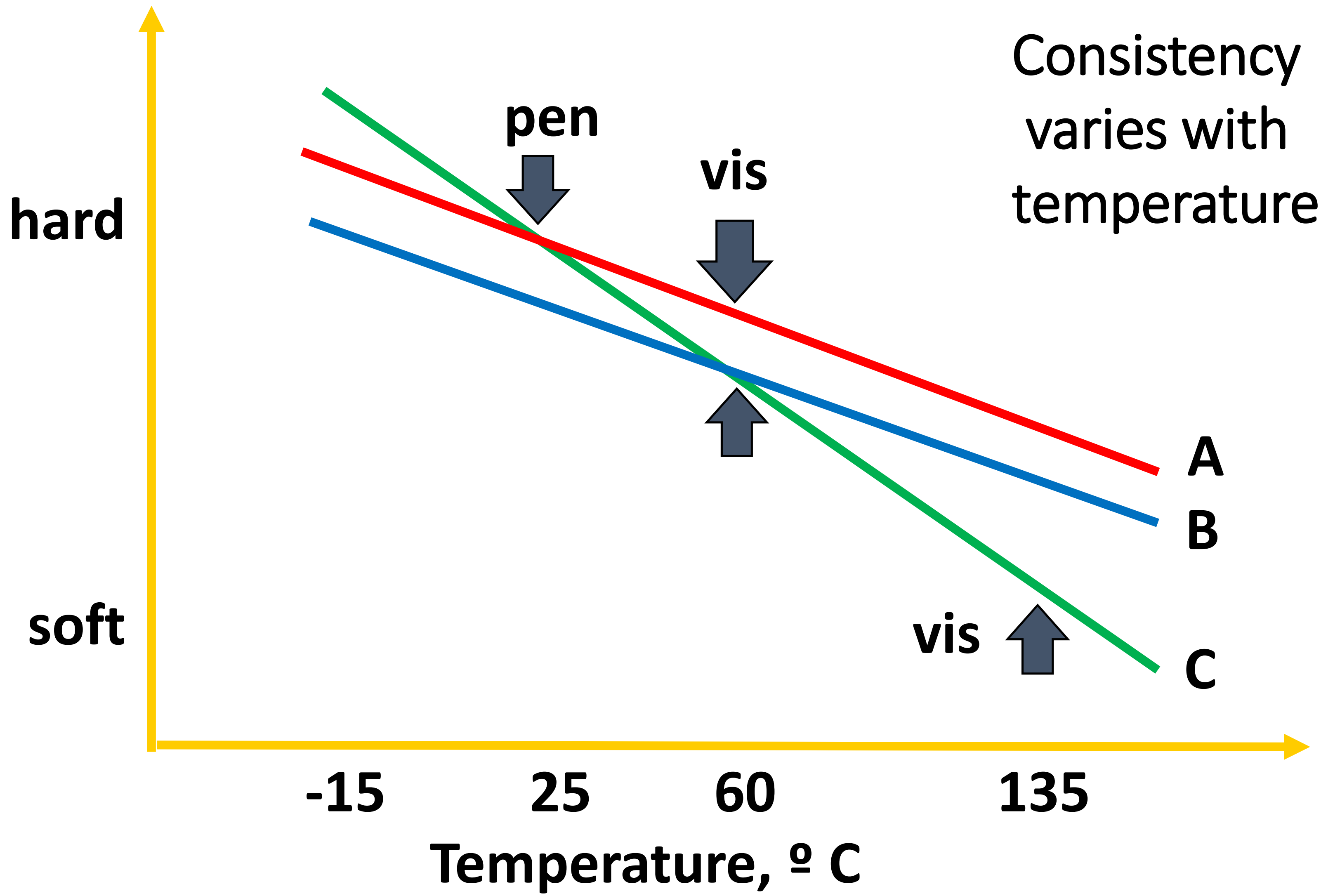
Asphalt Binder Properties



Asphalt is a *thermoplastic* material that softens as it is heated and hardens when cooled.

MS-2
Section 2.1.1

Historic Specifications - Shortcomings



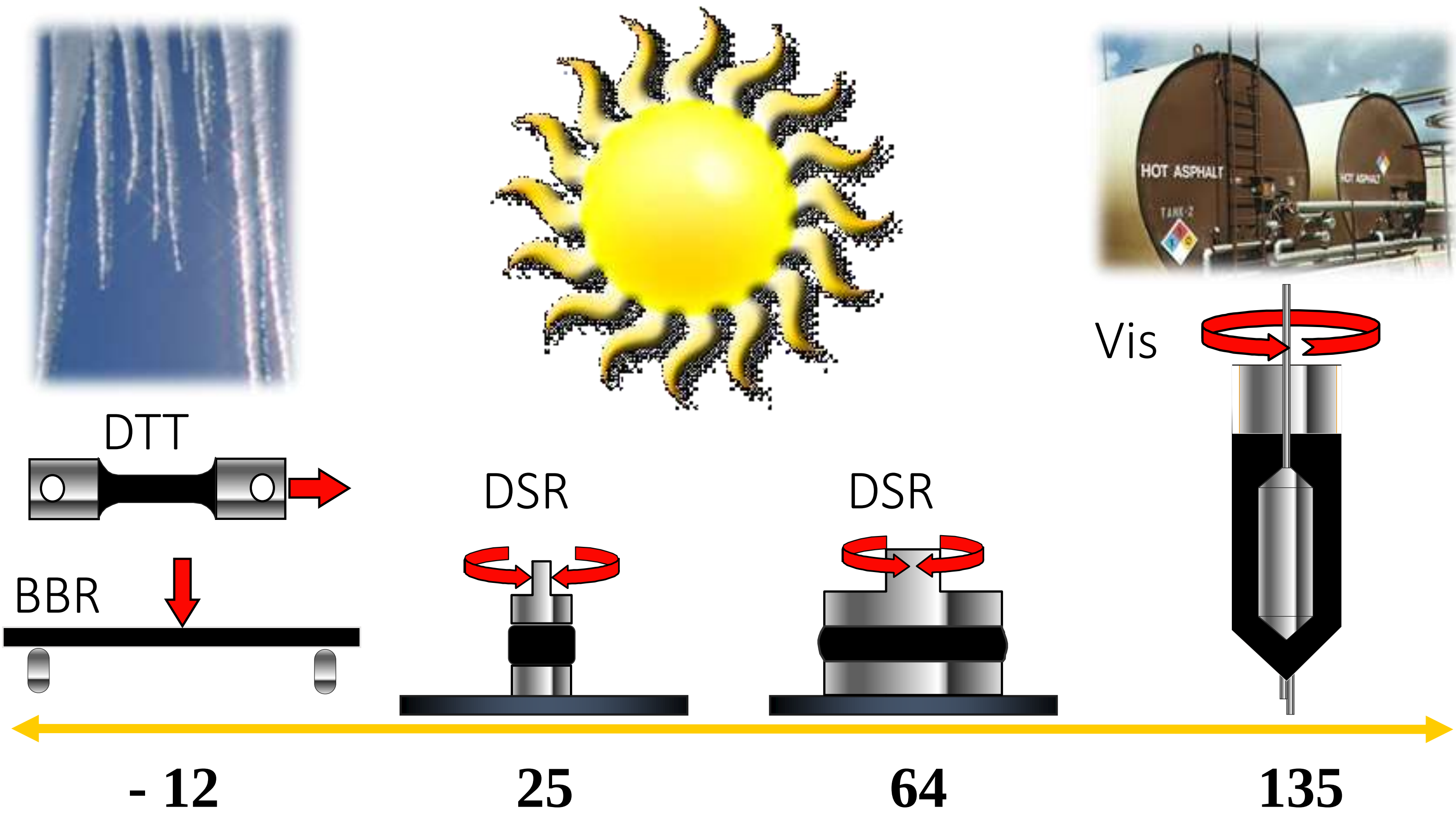
Grading System Based on Climate

PG 58-22

- **Performance Grade** → PG
- **Average 7-day max pavement design temp** → 58
- **Min pavement design temp** → -22

MS-2 Section 2.1.1

Testing Temperature – Climate based

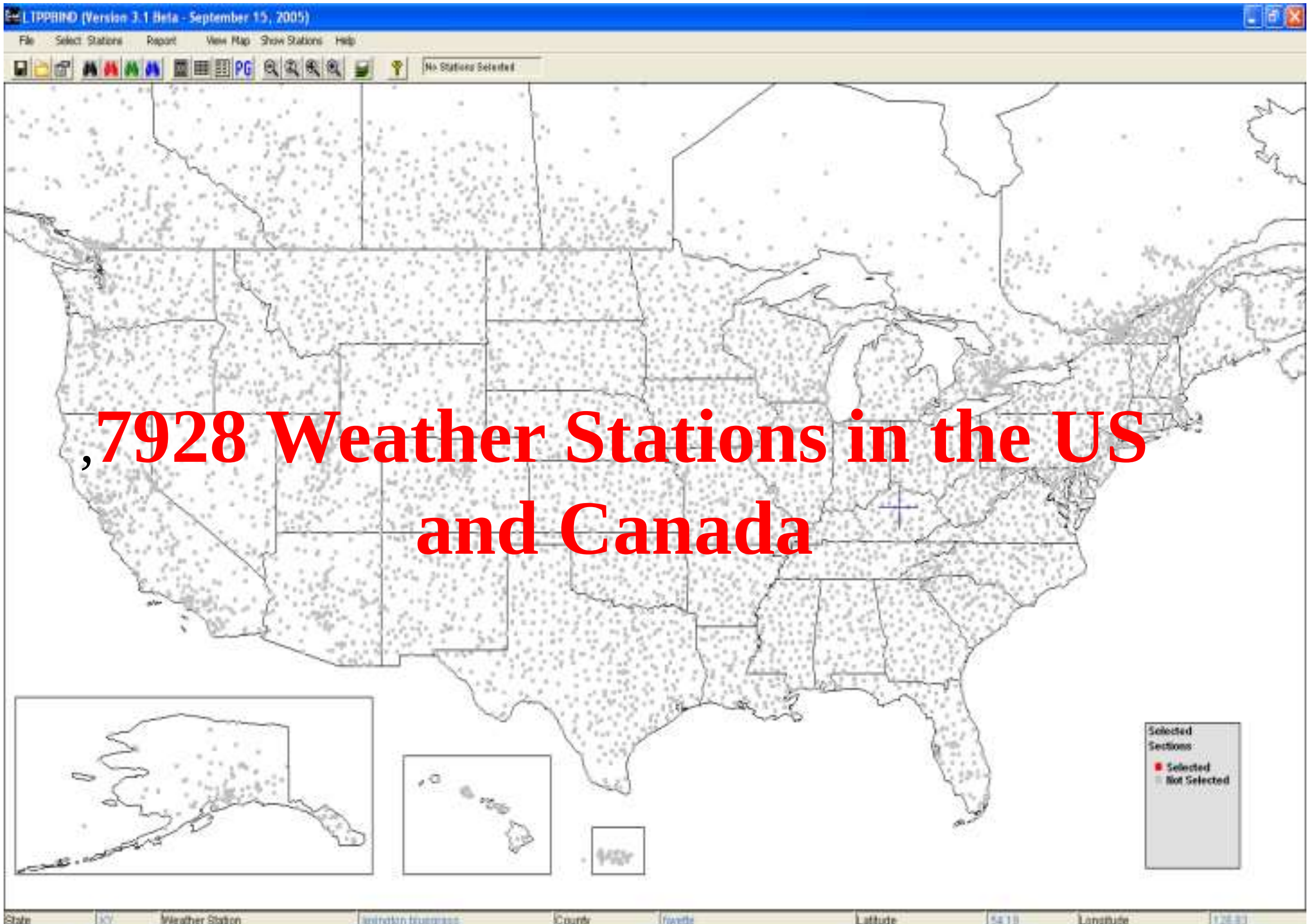


Pavement Temperature, °C

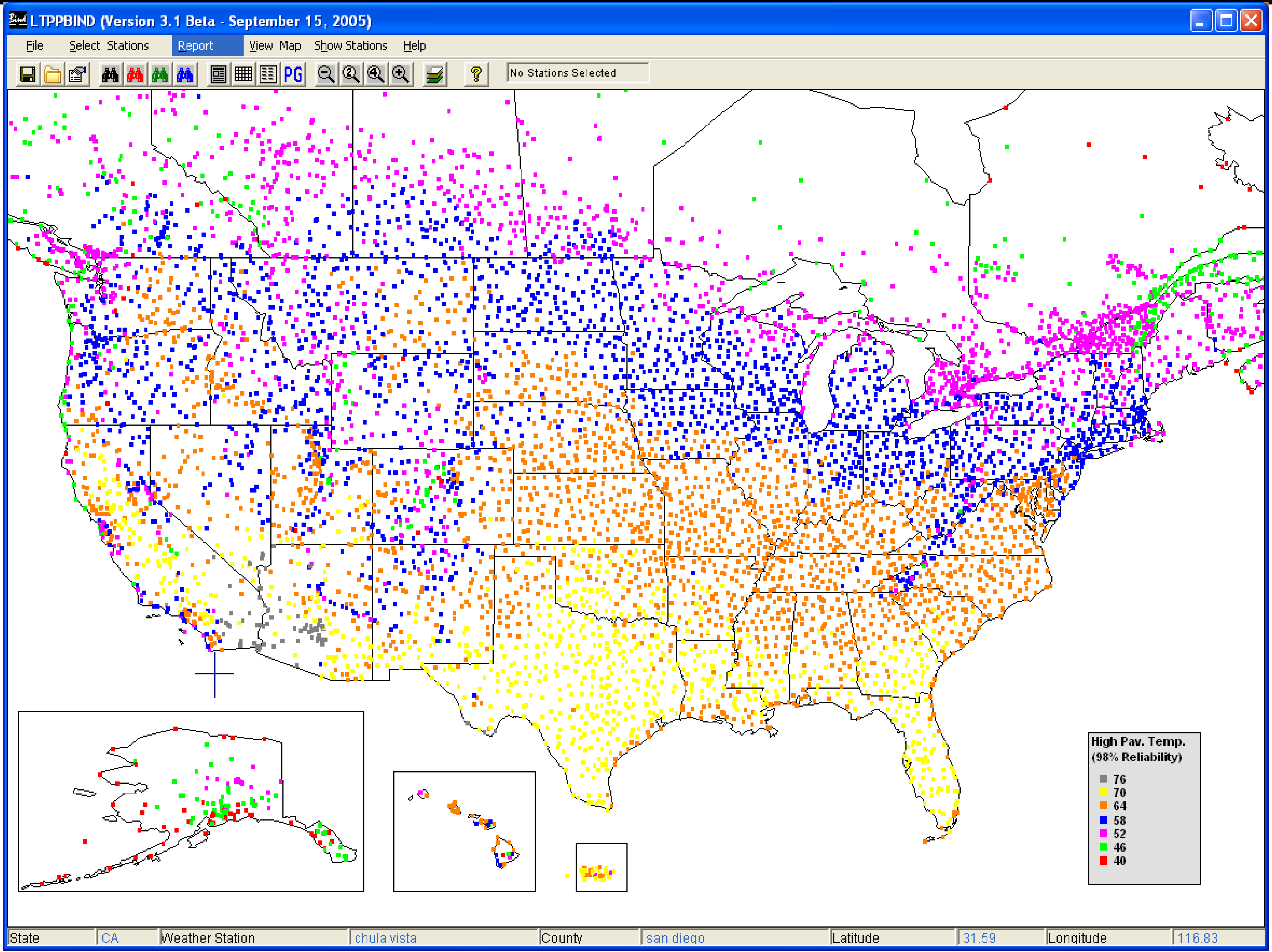
Values for PG 64-22

LTPPBIND Software

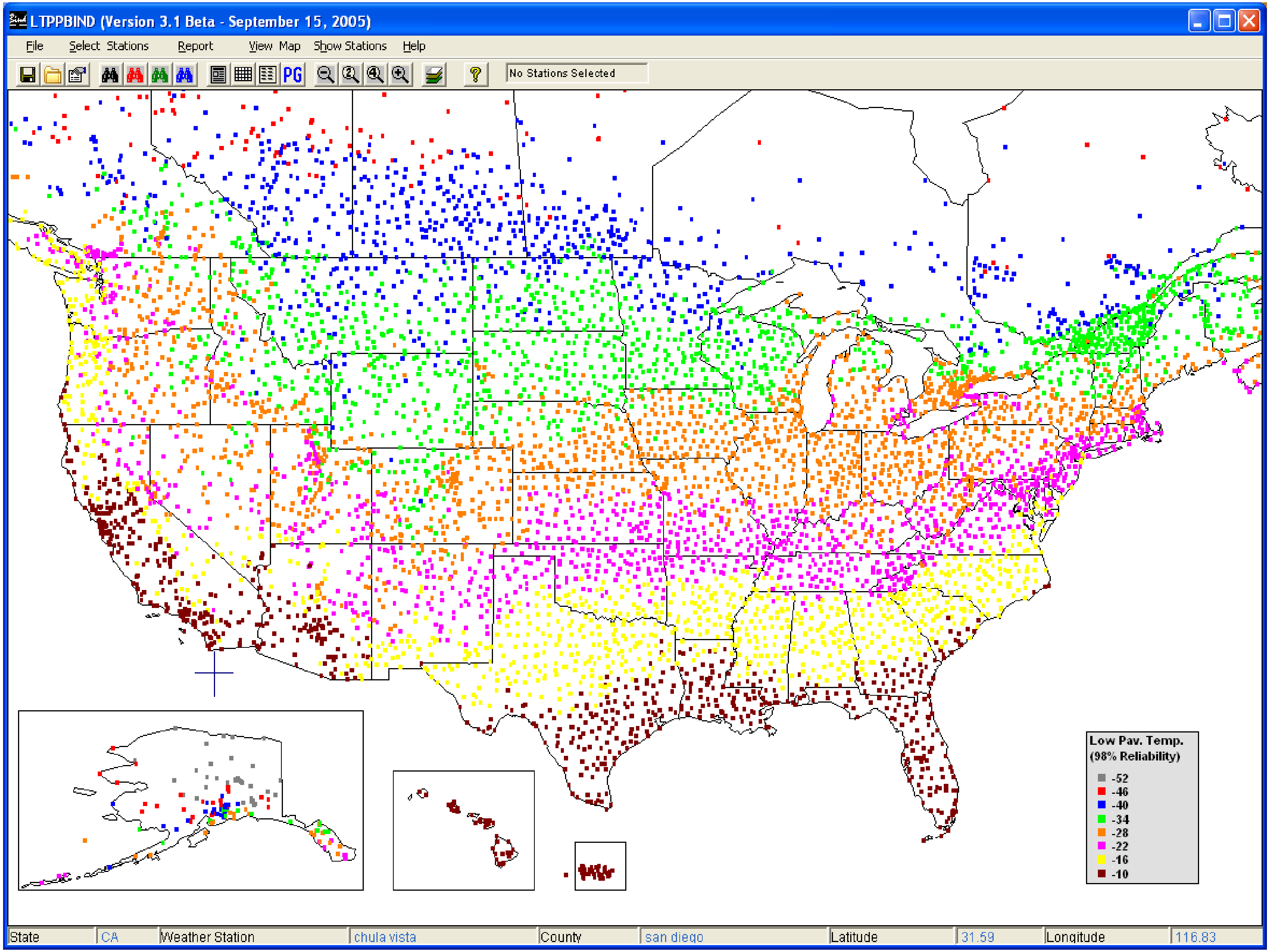
http://www.fhwa.dot.gov/PAVEMENT/ltpp/ltppbind.cfm



High Temperature Grades



Low Temperature Grades



PG Binder Selection - Topeka, KS

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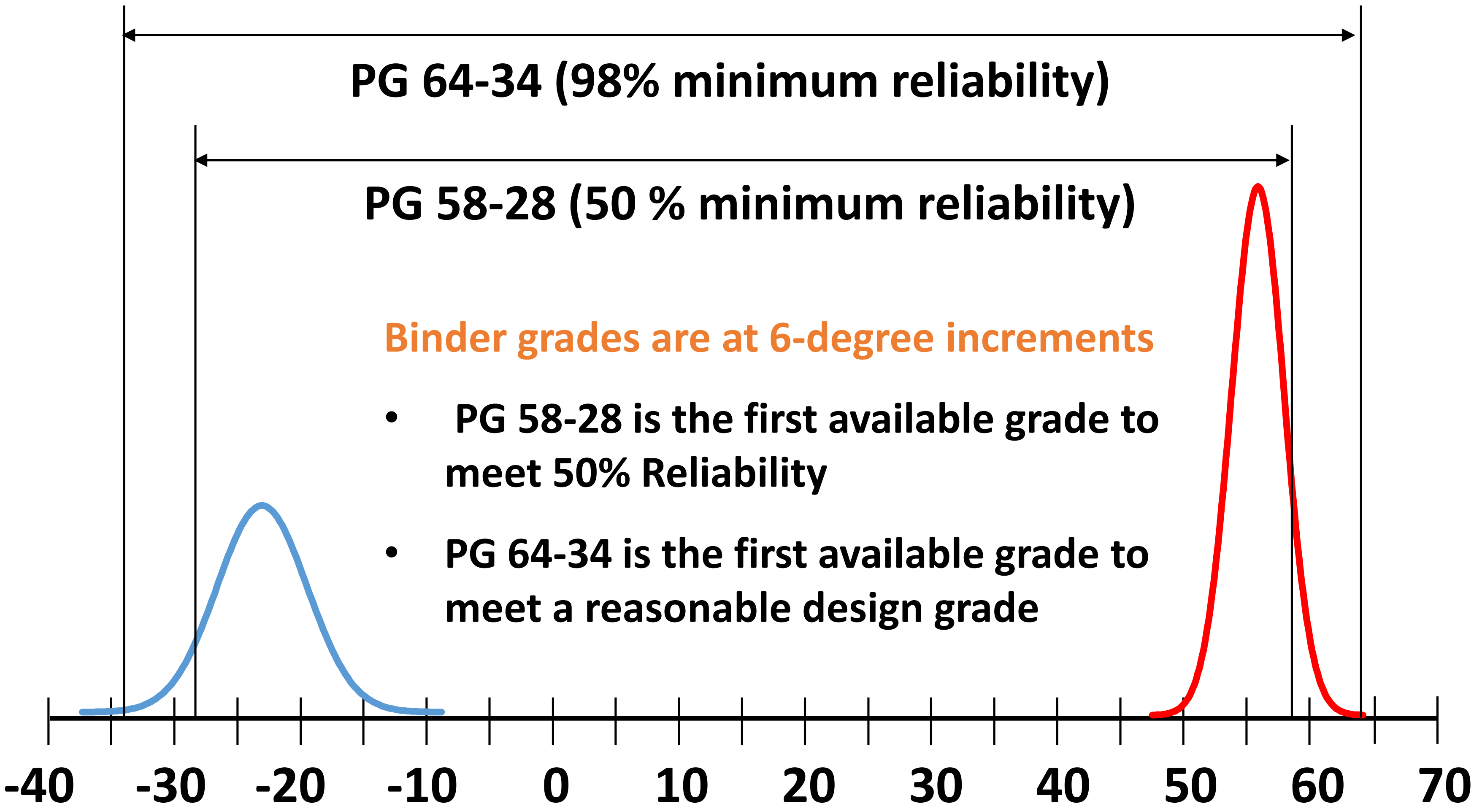
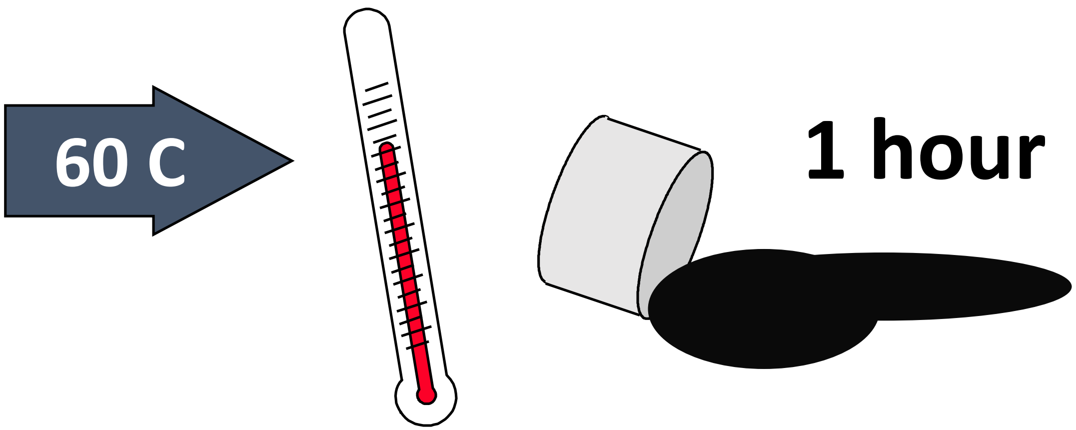
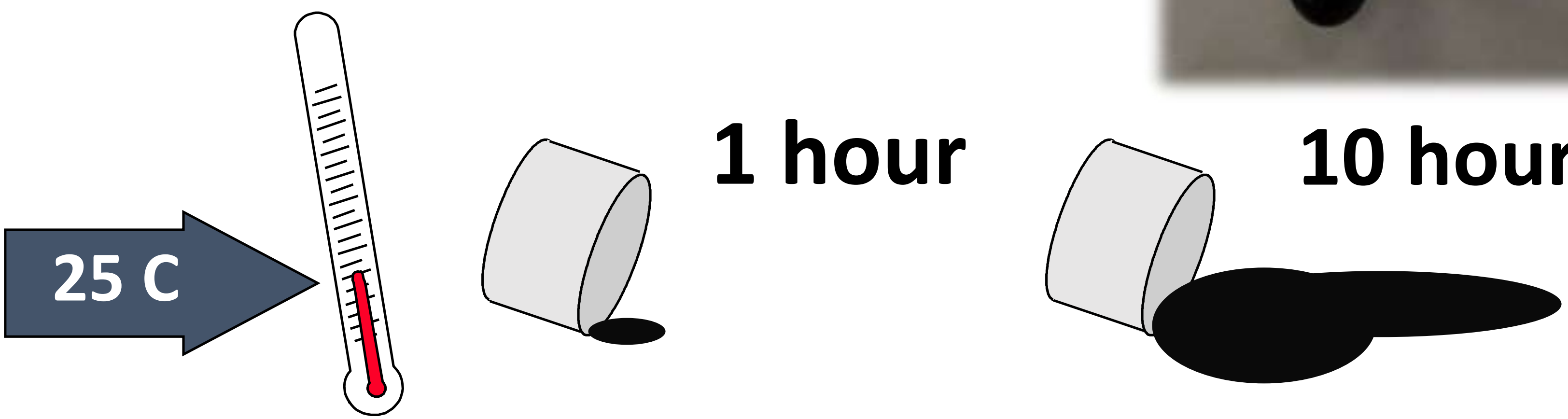


Asphalt Flow Behavior

Time & Temperature Dependent





Effect of Loading Rate on Binder Selection

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Example:

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

Effect of Traffic Amount on Binder Selection

- 10 to 30 million ESALs
  - Consider increasing one high temperature grade
- > 30 million ESALs
  - Increase one high temperature grade
- Newer recommendations are based on more gradual bumping in LTPPBind version 3.0+

Performance Grades

Max. Design Temp.	PG 46			PG 52							PG 58					PG 64						PG 70						PG 76					PG 82				
Min. Design Temp.	-34	-40	-46	-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	-10	-16	-22	-28	-34
Original																																					
≥230 °C	**Flash Point**																																				
≤ 3 Pa-s @ 135 °C	**Rotational Viscosity**																																				
≥ 1.00 kPa	**DSR G*/sin δ** (Dynamic Shear Rheometer)																																				
	46			52							58					64						70						76					82				
(Rolling Thin Film Oven) RTFO, Mass Change ≤ 1.00%																																					
≥ 2.20 kPa	**DSR G*/sin δ** (Dynamic Shear Rheometer)																																				
	46			52							58					64						70						76					82				
(Pressure Aging Vessel) PAV																																					
20 hours, 2.10 MPa	90			90							100					100						100(110)						100(110)					100(110)				
≤ 5000 kPa	**DSR G*sin δ** (Dynamic Shear Rheometer) Intermediate Temp. = [(Max. + Min.)/2] + 4																																				
	10	7	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	40	37	34	31	28
S ≤ 300 MPa m ≥ 0.300	**BBR S (creep stiffness) & m-value** (Bending Beam Rheometer)																																				
	-24	-30	-36	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	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 can be used in lieu of the creep stiffness requirement.																																					
ε_f ≥ 1.00%	**DTT** (Direct Tension Tester)																																				
	-24	-30	-36	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	0	-6	-12	-18	-24

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Is a PG a Modified Binder?

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Effect of Loading Rate

Reliability

"Rule of 92"

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

Probably modified

Depends on asphalt source

Rounding

Effect of Traffic

MSCR Implementation

The use of polymer modified binders has grown tremendously over the past several years

However, the most widely used binder specification in the U.S., AASHTO M320, was based on a study of neat (unmodified) binders, and may not properly characterize polymer modified binders

Does PG Grading Predict Performance?

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

PG 63-22 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?

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- 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

ER Information and Test Time

- The Elastic Recovery Test is an excellent tool to establish the *presence* of polymer modification.
  - It takes about 4 hours to prepare and test samples for this information.
- However, it is a poor tool to evaluate the rutting *performance* of polymer-modified binders.
- The MSCR test can use the same sample already being run in the DSR to give more information in a few extra minutes.

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

ALF Loading

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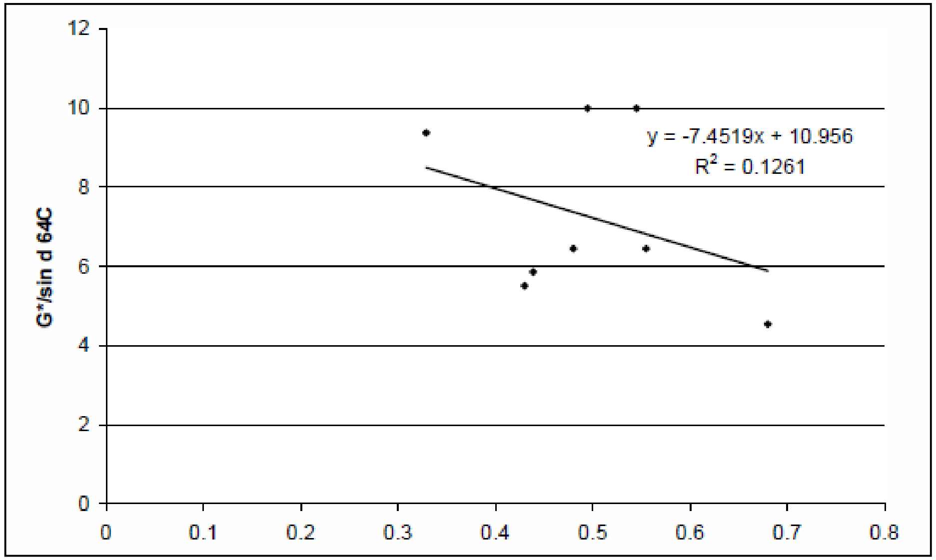
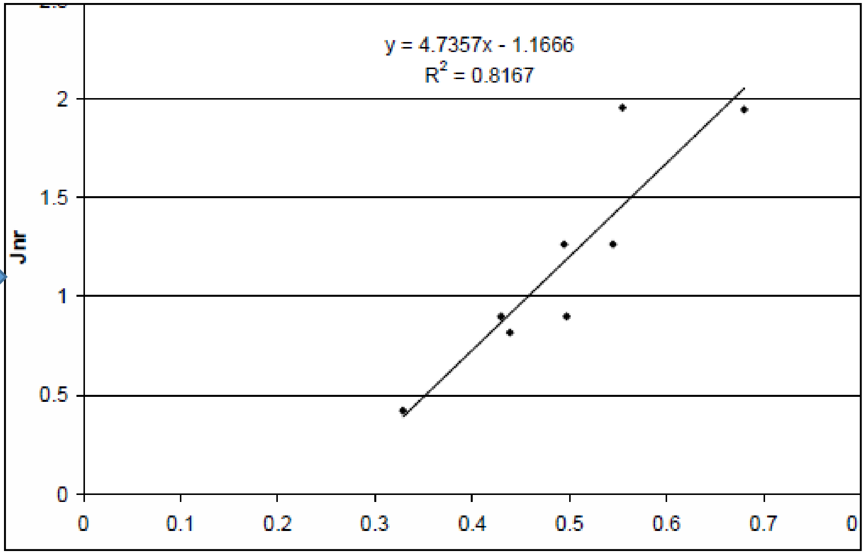
- The pavement was heated to a constant 64°C.
- The FHWA ALF uses an 18,000 lb. single wheel load with no wheel wander.
- The speed is 12 MPH.
- This is a extreme loading condition far more severe than any actual highway.

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



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The Asphalt Institute
National Binder Technician Certification PROGRAM

Performance Grades (AASHTO M332)

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 (S H V E)	**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**																												
≤ 4.5 kPa^{-1} S ≤ 2.0 kPa^{-1} H ≤ 1.0 kPa^{-1} V ≤ 0.5 kPa^{-1} E	**MSCR $J_{nr,\ 3.2}$** (Multiple Stress Creep-Recovery), AASHTO T 350																												
	52							58					64						70						76				
≤ 75% (S H V E)	**MSCR $J_{nr,\ Diff}$** (Multiple Stress Creep-Recovery), AASHTO T 350																												
	52							58					64						70						76				
PAV (Pressure Aging Vessel), AASHTO R28																													
	90							100					100						100(110)						100(110)				
≤ 5000 kPa S ≤ 6000 kPa H ≤ 6000 kPa V ≤ 6000 kPa E	**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.

Chris Kufner, MnDOT

Metro District Pavement & Materials Engineer

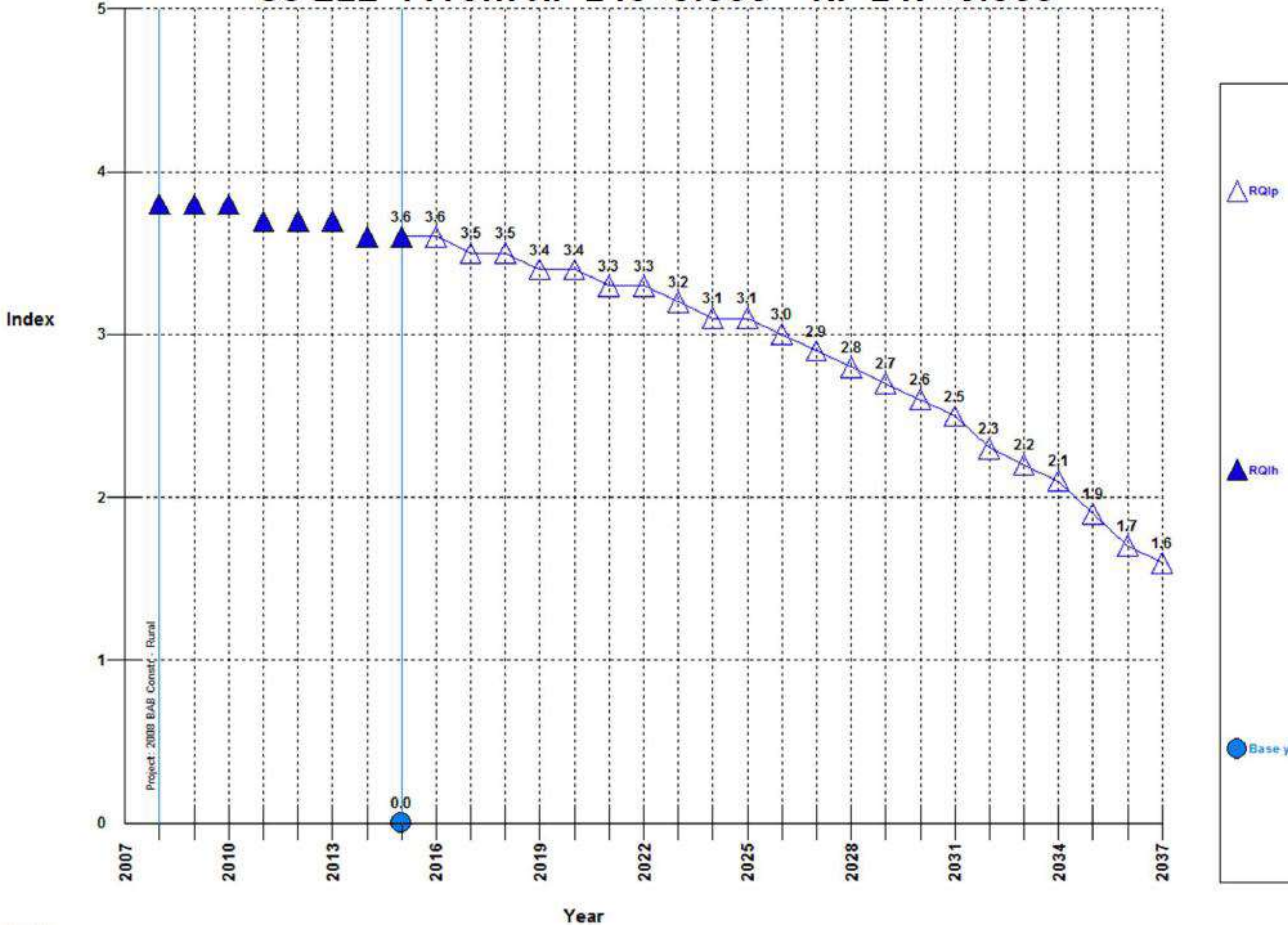
Performance of US 212 SMA

- >10 million ESALs → Concrete Pavement
- <10 million ESALs → LCCA → Alternate Bid

- Majority of project was > 10 million, but
- Westerly 2.7 miles < 10 million ESALs

- Alternate Bid:
  - Bituminous option: 9" Bit (top 2" is SMA)
  - Concrete option: 10" Concrete
    - BOTH: 6" Aggregate Base over 24" Sel Granular over 24" compaction subcut.

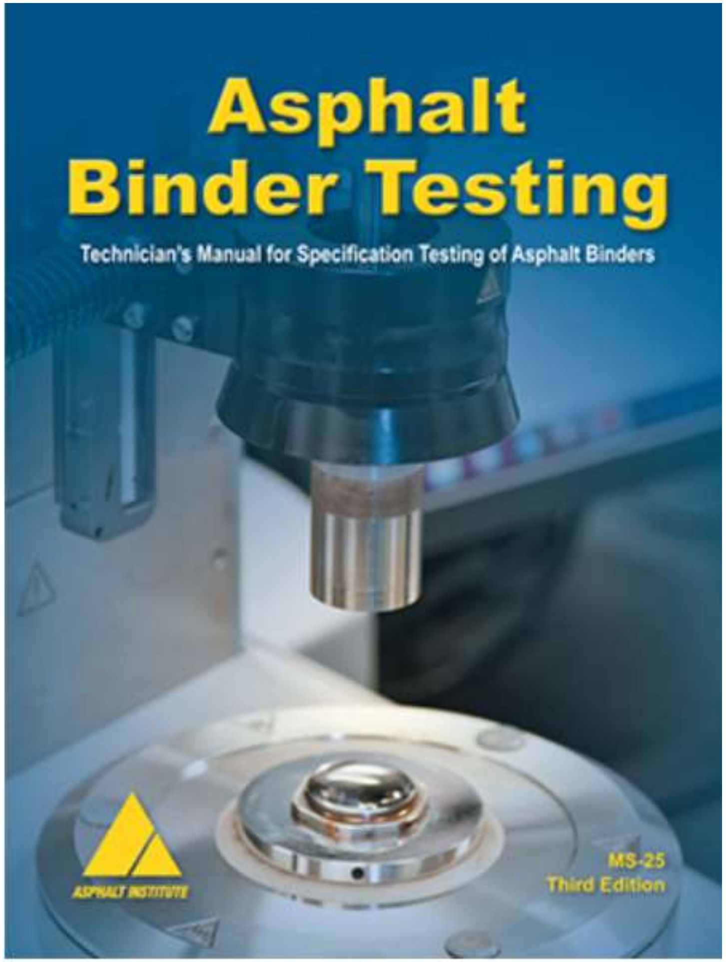
US 212- I From RP 146+0.000 – RP 147+0.000



Performance of US 212 SMA

ONE THERMAL CRACK IN 2.7 MILES

For More Binder Information



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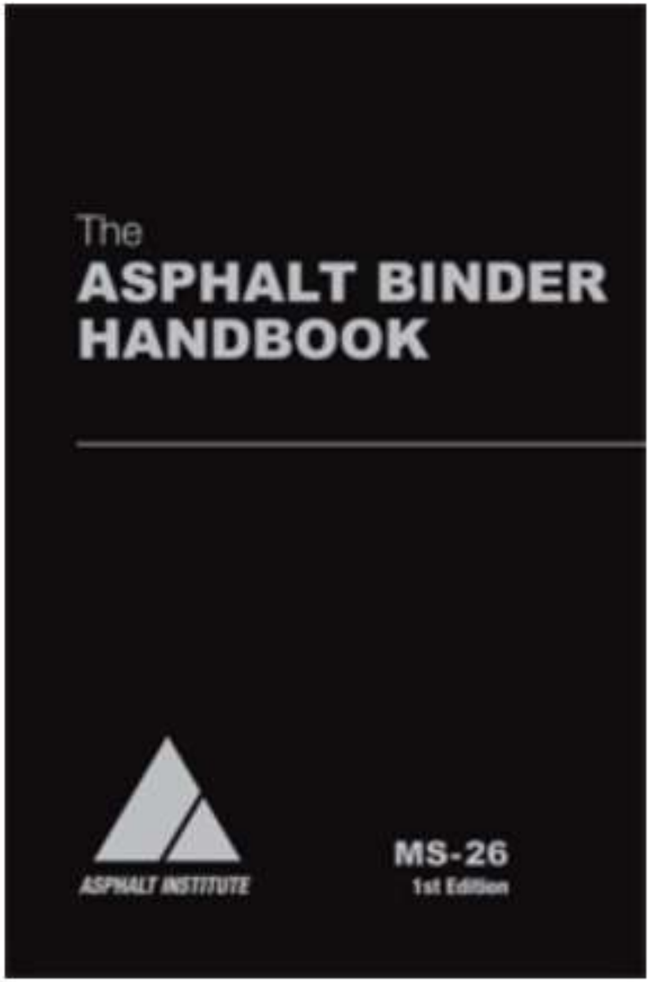

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