Asphalt Basics:
75 Years of Evolution

Mike Anderson

Asphalt Institute

Acknowledgments

Acknowledgments

asphalt institute

Congratulations to WAPA on 75 Years!

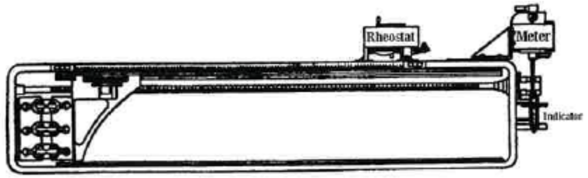
Grading Systems

- Historical
  - Chewing
  - Penetration
    - Developed in early 1900s
    - Consistency Test @ 25°C (77°F)
    - Standard Specification in 1946
  - Viscosity
    - Developed in 1950s
    - Absolute
      - Consistency Test @ 60°C (140°F)
    - Kinematic
      - Consistency Test @ 135°C (275°F)
    - Standard Specification in 1971

SOMETHING TO CHEW ON

EXPLORING THE LEGEND OF THE ASPHALT CHEWING TEST

By Amma Wakefield, P.Eng.



If you have ever attended an asphalt mix design course, you may have heard about the chewing test as one of the first methods of characterizing asphalt cement. You were likely told that the test was conducted exactly as the name suggests.

And, if you sat in a mix design course that I taught, I may have been chewing gum... you know, for effect. So, imagine my surprise when I learned that there was a "chew machine."

Specifically, it was called the Chew Ductility Machine, where a sample of asphalt about one centimeter thick was pulled apart utilizing a gear operated by a handwheel. A motor drive was preferred for better uniformity in the rate of pull, but in both cases, the sample was pulled until breaking, then the distance it stretched before breaking was recorded. The test and machine are referenced in a 1916 manual by Hubbard titled "Laboratory Manual of Bituminous Materials."

Does that mean there was never a test where a person chewed asphalt to determine its quality? Where is the fun in that? Is chewing asphalt a myth?

Well, not so fast... in a 1905 journal "The Modern Asphalt Pavement" by Clifford Richardson, we find a reference to the chewing test that we are more familiar with. Richardson explains that the chewing test was used as a preliminary test for asphalt cement. It involved chewing a small piece of asphalt cement which had been cooled by pouring it into cold water. Don't try this at home kids! But a cooled asphalt cement was placed in the mouth and worked between the teeth.

Through chewing, the asphalt cement rapidly assumes the temperature of the mouth which, for normal body temperature is 98.4°F (36.9°C) and consistent. Richardson explained in the journal that the amount of effort needed to chew the asphalt showed whether it was harder or softer than what experience had taught about a proper consistency in asphalt. An experienced chewer could determine if the asphalt was within four or five points of the desired consistency. One reference stated the chewing test was conducted for 15 minutes!

Another reference in 1911 from the American Society of Municipal Improvement convention mentions the chewing test, where an asphalt consultant J.W. Howard added that the asphalt was of inferior quality "if it becomes like lard or slime."

Who would have thought that there were actually two "chewing" tests, one by mouth and the other by machine? I must confess, I would have been incredibly disappointed if I had learned that chewing asphalt to determine its quality was never really a thing... but 15 minutes though? ▲

Wakefield is an Asphalt Institute Regional Engineer based in Ontario, Canada.

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ASPHALT NEWS

FALL 2019

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And, if you sat in a mix design course that I taught, I may have been chewing gum... you know, for effect. So, imagine my [illegible] a sample of asphalt about one centimeter thick was pulled [illegible] utilizing a gear operated by a handwheel. A [illegible] both cases, the sample was pulled until breaking, then the distance it stretched before breaking was recorded. The test and machine are referenced in a 1916 manual by Hubbard titled "Laboratory Manual of Bituminous Materials."

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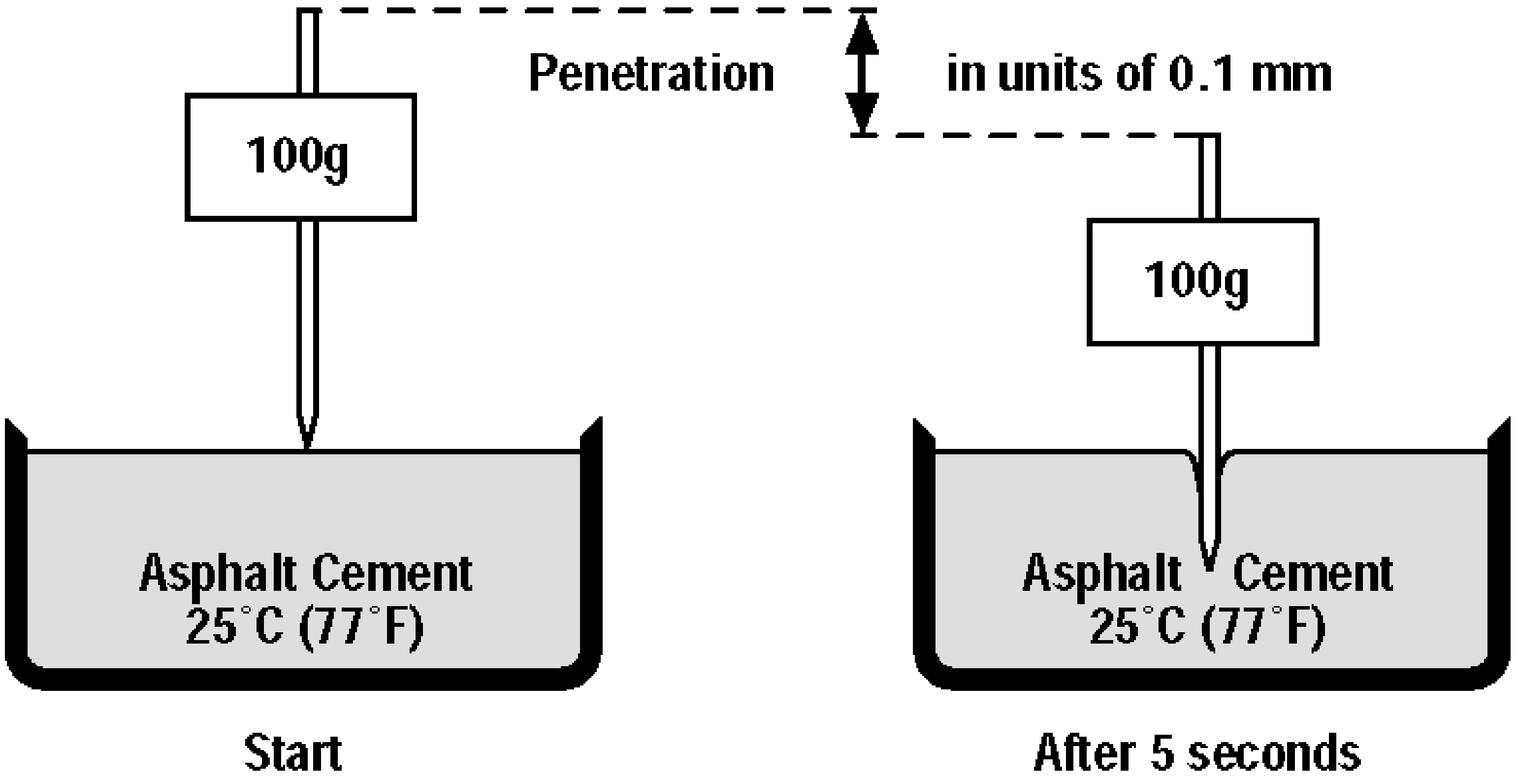
The asphalt was of inferior quality "if it becomes like lard or slime."

Penetration

- Penetration
  - ASTM D5 (AASHTO T49)
    - One of oldest asphalt tests
  - Standard needle allowed to penetrate into sample under specified loading conditions
    - 25°C – 100 grams, 5 seconds
    - 0°C – 200 grams, 60 seconds
    - 46°C – 50 grams, 5 seconds
  - Depth of penetration is recorded in 0.1-mm units (dmm)
  - Three penetration readings per test

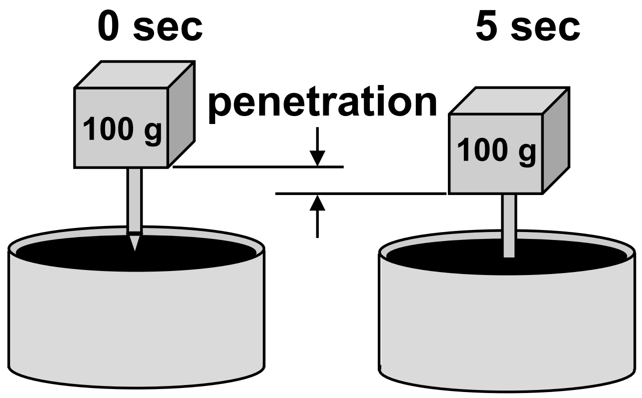
Penetration




"MICROMETER ADJUSTMENT"
PENETROMETER
1/10 Millimeter Divisions

Specifications: Asphalt Cement

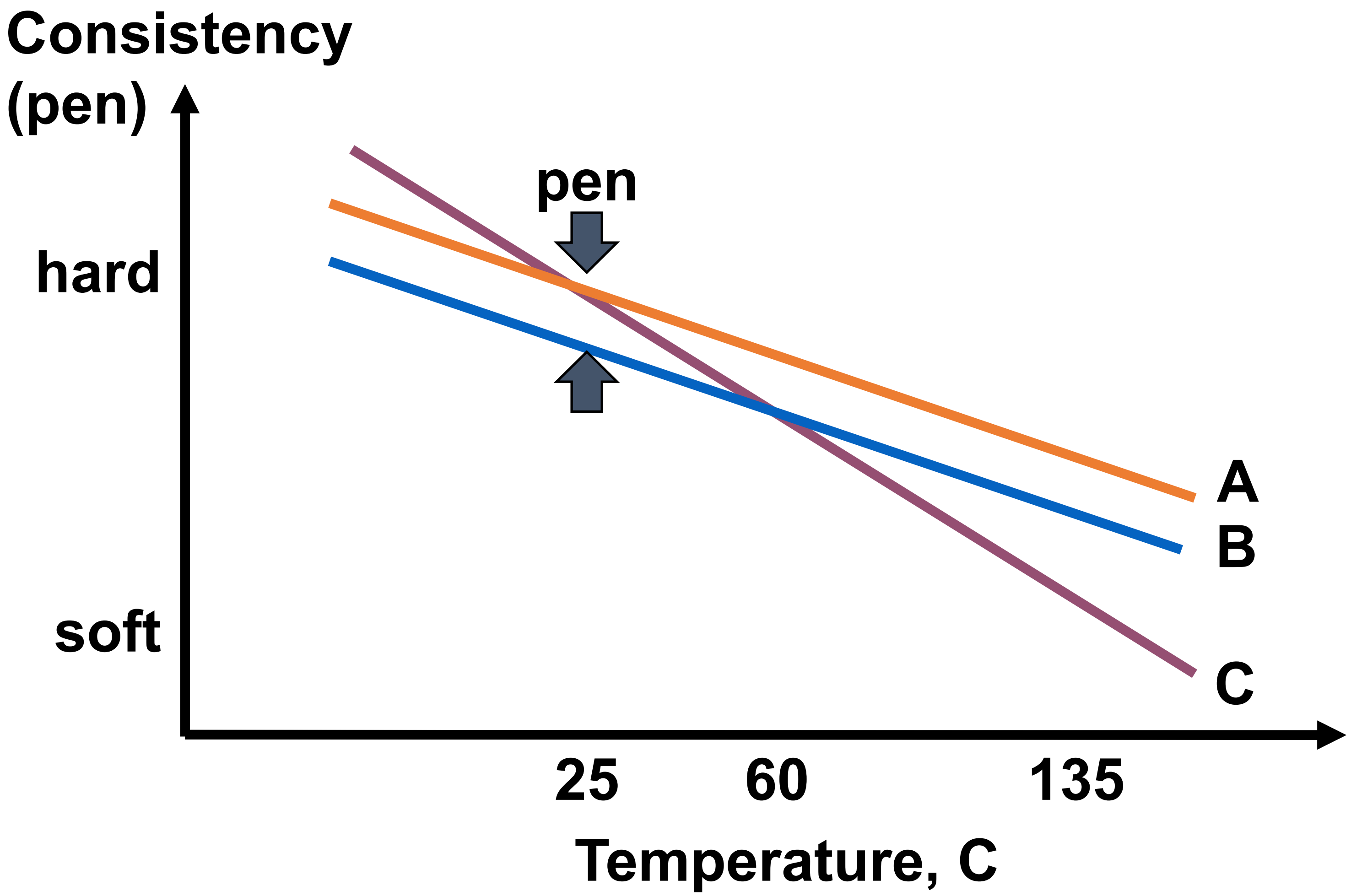
- Penetration Graded Asphalt (PEN)
  - ASTM D946 (AASHTO M20)
  - Grading based on Penetration test at 25°C
    - Standard needle allowed to penetrate into sample under specified loading conditions
      - at 25°C, load of 100 grams is used for 5 seconds
    - Original (unaged) asphalt is tested
    - Empirical test



Penetration Graded Asphalt

Test On Original Asphalt	120-150	85-100
Penetration, 25°C (77°F), dmm	120 min.	85 min.
(100 g - 5 sec)	150 max.	100 max.
Flash Point, COC, °C (°F), min.	219 (425)	232 (450)
Ductility, 25°C (77°F), cm, min.	100	100
Solubility in Trichloroethylene, %min.	99.0	99.0
Tests On Aged Asphalt (TFOT)		
Loss on heating, % maximum	1.3	1.0
Percent of original penetration, min.	46	50
Ductility of residue, cm, minimum	100	75

Penetration Grading



Viscosity

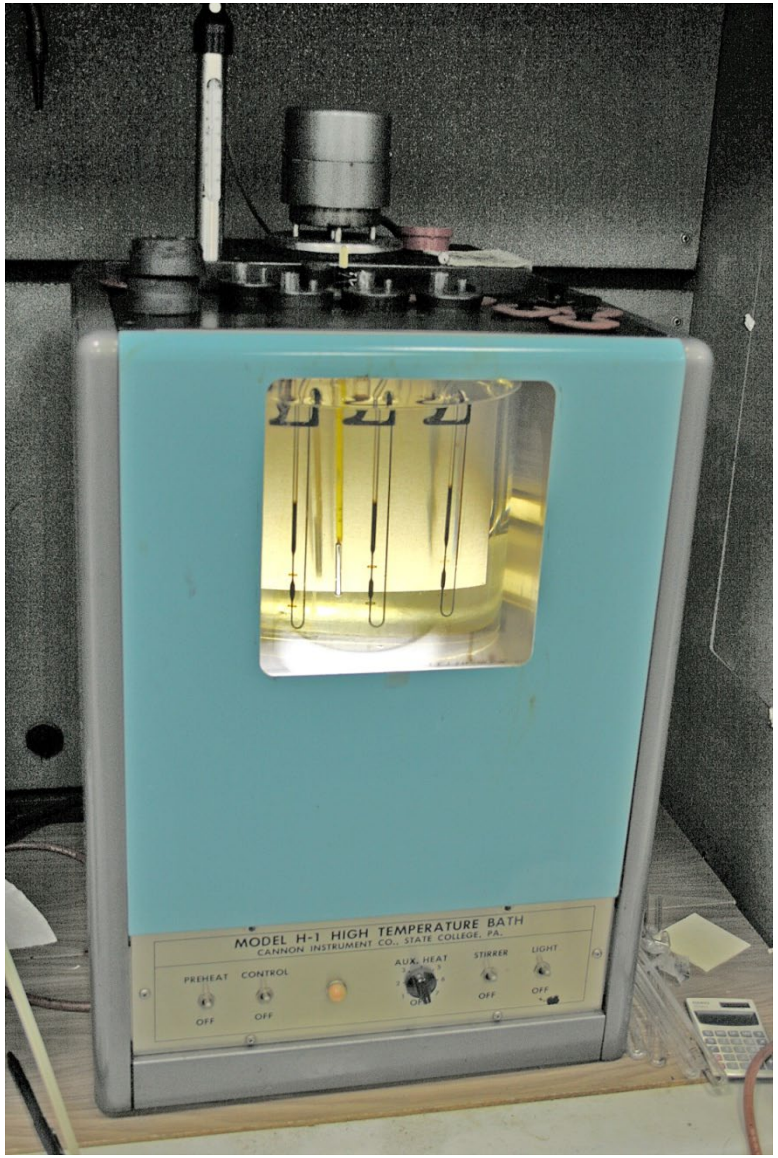
- Absolute Viscosity
  - ASTM D2171 (AASHTO T202)
  - Conducted at 60°C (140°F)
  - Uses partial vacuum to induce flow through capillary tube
- Kinematic Viscosity
  - ASTM D2170 (AASHTO T201)
  - Conducted at 135°C (275°F)
  - Uses gravity to induce flow through capillary tube

Asphalt Cement

- Viscosity Graded Asphalt
  - 60°C (140°F) selected to simulate in-service temperature of asphalt pavements
  - 135°C (275°F) selected to simulate mixing and laydown temperature for HMA

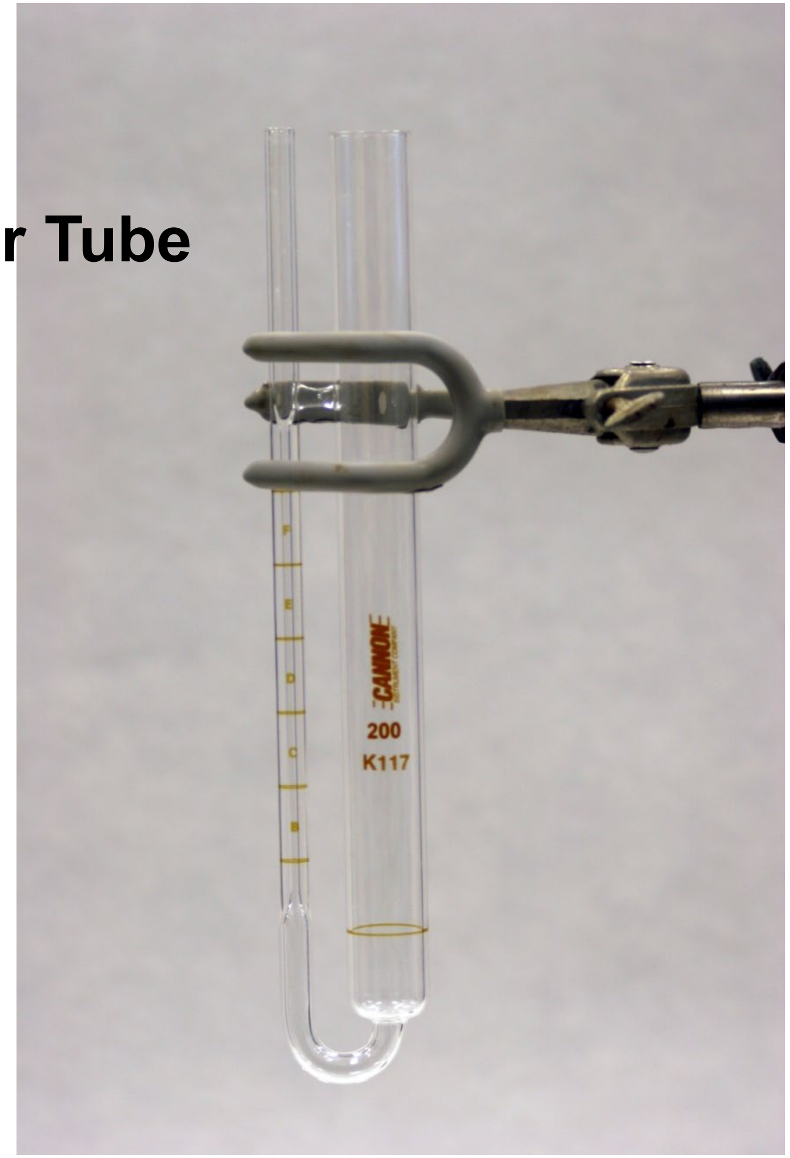
Viscosity


CONSTANT TEMPERATURE BATH
CANNON
Power
Temperature
Temperature Adjust
Preheat
Limit Control


MODEL H-1 HIGH TEMPERATURE BATH
CANNON INSTRUMENT CO., STATE COLLEGE, PA.
PREHEAT
CONTROL
AUX. HEAT
STIRRER
LIGHT

Viscosity

Vacuum Viscometer Tube



Zeitfuchs Cross-Arm Viscometer Tube

Specifications: Asphalt Cement

- Viscosity Graded Asphalt (AC)
  - ASTM D3381 (AASHTO M226)
    - Tables 1 and 2
  - Most commonly used (pre-SHRP) classification system in US
  - Based on Viscosity
    - Measure of the resistance of a material to flow
    - Absolute viscosity at 60°C (140°F)
    - Kinematic viscosity at 135°C (275°F)

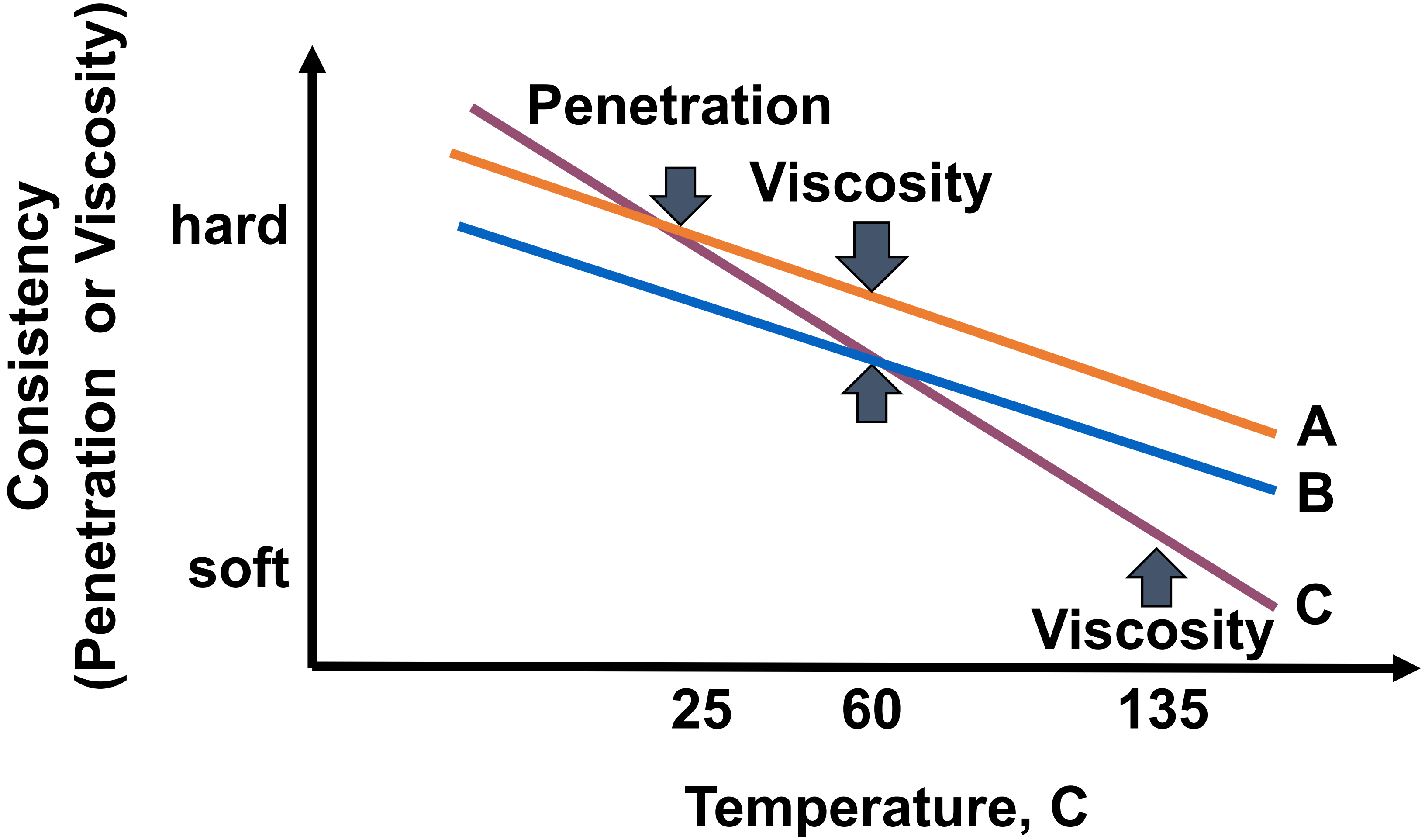
Viscosity Graded Asphalt (AC) Table 1

Test	AC-10	AC-20
Viscosity, 60°C (140°F), poises	1000 ± 200	2000 ± 400
Viscosity, 135°C (275°F), Cs, min.	150	210
Penetration, 25°C (77°F), dmm, min.	70	40
Flash Point, COC, °C (°F), min.	220 (425)	230 (450)
Solubility in Trichloroethylene, % min.	99.0	99.0
Test on residue from TFOT:		
Loss on heating, % max. (optional)		
Viscosity, 60°C (140°F), poises, max.	5000	10000
Ductility, 25°C (77°F), cm, min.	50	20

Viscosity Graded Asphalt (AC) Table 2

Test	AC-10	AC-20
Viscosity, 60°C (140°F), poises	1000 ± 200	2000 ± 400
Viscosity, 135°C (275°F), Cs, min.	250	300
Penetration, 25°C (77°F), dmm, min.	80	60
Flash Point, COC, °C (°F), min.	220 (425)	230 (450)
Solubility in Trichloroethylene, % min.	99.0	99.0
Test on residue from TFOT:		
Loss on heating, % max. (optional)		
Viscosity, 60°C (140°F), poises, max.	5000	10000
Ductility, 25°C (77°F), cm, min.	75	50

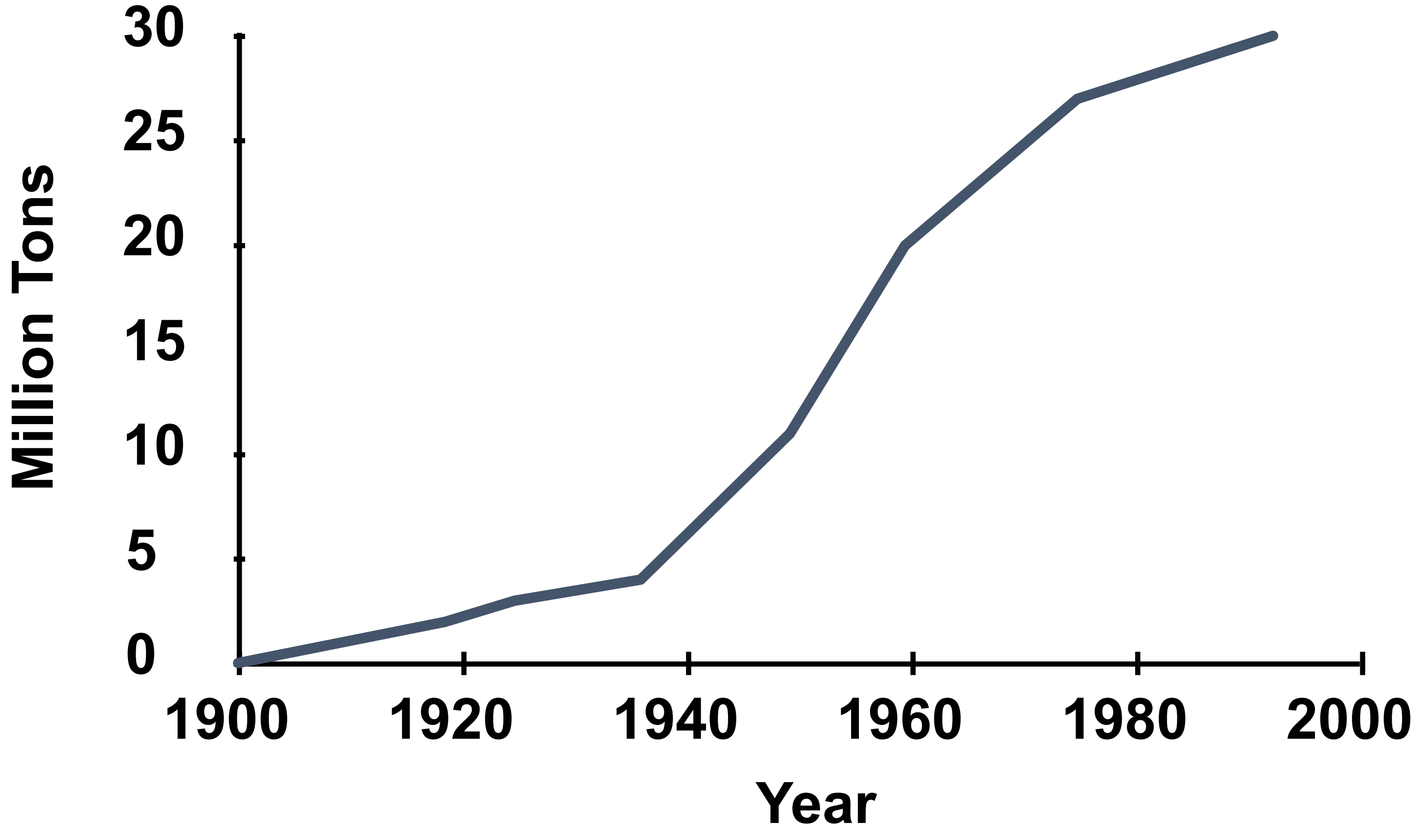
Viscosity Grading



Specifications: Asphalt Cement

- Viscosity Graded After Aging (AR)
  - ASTM D3381 (AASHTO M226) Table 3
  - AR = “Aged Residue”
  - Primarily used in Western US
  - Attempts to identify material characteristics after HMA production and laydown
  - Rolling Thin Film Oven (RTFO)
    - AASHTO T240
    - Simulates aging during mixing in HMA facility

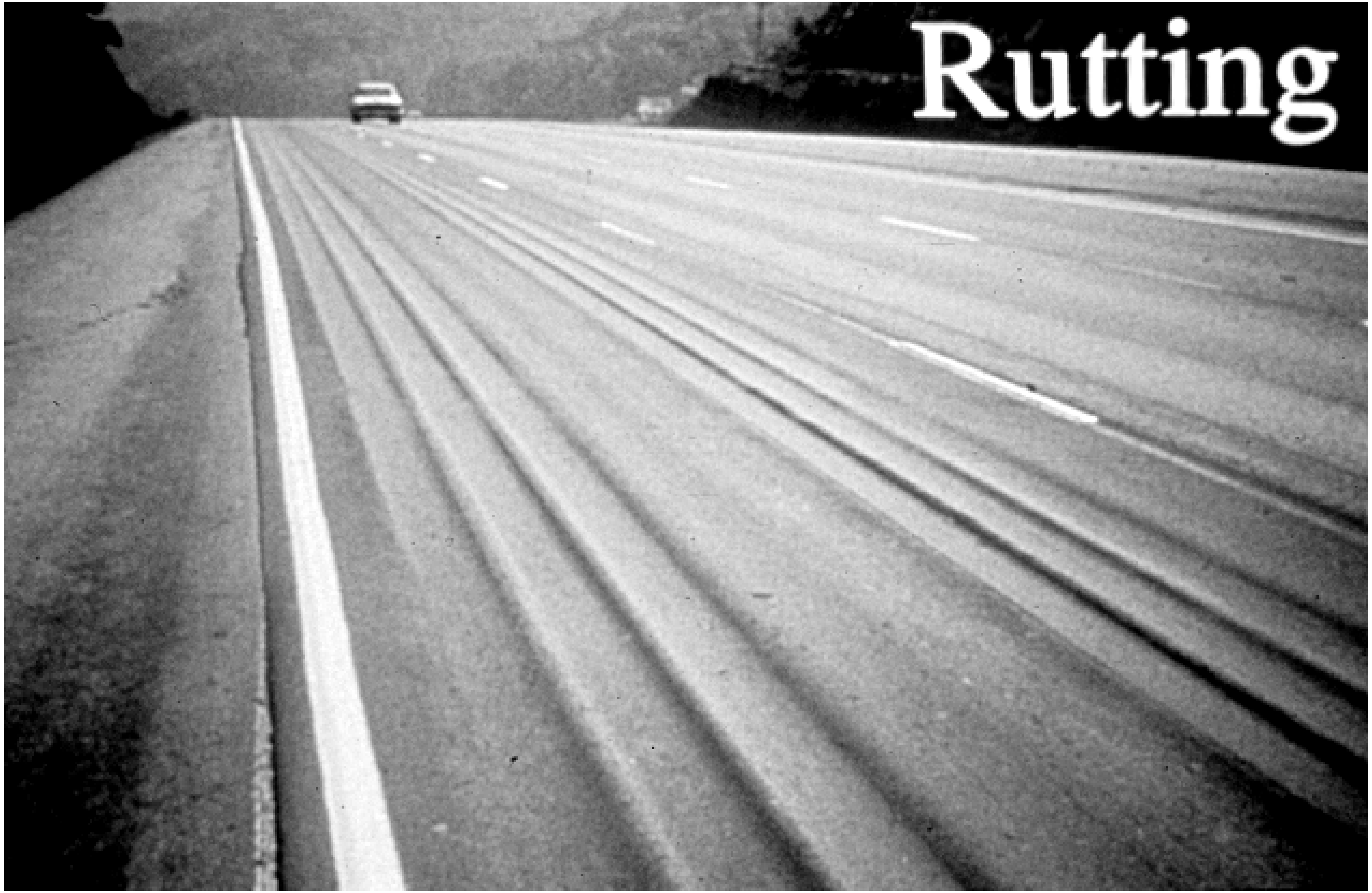
Historical Paving Asphalt Usage in United States



Evolution of Traffic

- Interstate highways - 1956
- AASHO Road Test - 1958-62
  - still widely used for pavement design
  - legal truck load - 73,280 lbs
- Legal load limit to 80,000 lbs - 1982
  - 10% load increase
  - 40-50% greater stress to pavement
- Radial tires, higher contact pressure

Permanent Deformation



SHRP Asphalt Program

- Objective
  - Define chemical and physical characteristics of asphalt and their relationship to performance in pavement systems
- Potential Results
  - Improved design capability and performance prediction
  - Better quality control and better materials
  - Potential savings of $100 million per year

5 projects, 5 years, 230 professional-years

Basics First…

- What do we want from an asphalt binder specification?
  - SHRP-90-007, The SHRP Asphalt Research Program: 1990 Strategic Planning Document
    - The SHRP asphalt program was based on the premise that **asphalt pavement performance is significantly influenced by the properties of the asphalt binder**.
      - The mix designer must select an asphalt binder having properties that meet required minimum performance levels in order for the asphalt pavement to perform as expected for both its present and future environment and traffic loading conditions.

Basics First…

- What do we want from an asphalt binder specification?
  - SHRP-90-007, The SHRP Asphalt Research Program: 1990 Strategic Planning Document
    - The SHRP asphalt program was originally designed to develop specifications that addressed six pavement performance factors: **permanent deformation (rutting)**; **fatigue cracking; low-temperature (thermal) cracking**; moisture sensitivity; aging; and adhesion.
      - Aging was not considered a distress, per se, but was considered important so that the asphalt binder could be tested in a state approximating that which would be attained after a period of time in service.

The SHRP Asphalt Research Program: 1990 Strategic Planning Document

- "…asphalt pavement performance is significantly influenced by the properties of the asphalt binder."
- The researchers used the phrase "significantly influenced" instead of a different phrase such as "a direct result of" in describing the impact of the asphalt binder properties on asphalt pavement performance.
    - With the possible exception of thermal cracking distress, the asphalt binder properties are just part of the story in determining the pavement performance.

Basics First…

- What do we want from an asphalt binder specification?
  - The asphalt binder needs to minimize its contribution to any distress
  - Other factors than asphalt binder properties can lead to distress
    - Aggregate properties
    - Aggregate proportion
    - Volumetric properties
    - Effective asphalt binder content
    - Production in the mixing plant
    - Laydown and compaction
    - Thickness design
    - Drainage

Aging Considerations

- PG binder specification is designed to test materials that are representative of in-service conditions
    - Requires laboratory conditioning procedures to simulate binder conditions immediately after construction and after in-service aging

Short-Term Aging

- RTFO to represent short-term aging
  - Adapted from an existing California method
  - Simulates a batch plant operating at ±150°C
    - Represents a typical condition
    - May not represent drum plants operating at lower temperatures

Long-Term Aging

- PAV to simulate long-term aging
  - Increased temperature and pressure accelerates aging
  - Increased temperature increases the rate of aging
  - Increased pressure makes oxygen available to asphalt cement molecules thereby increasing rate of aging

The Strategic Highway Research Program (SHRP)

- SHRP
  - Established in the 1980s
  - Motivated by what was perceived as declining quality of asphalt cement
- SHRP Products included:
  - PG binder grading system
  - Specifications for aggregate and hot-mix asphalt concrete (HMAC)
  - A new pavement design guide
- PG grading is part of a larger system

SHRP Asphalt Binder Specification

SHRP ASPHALT BINDER SPECIFICATION: DRAFT 1

Property	Asphalt Binder Grade											
	AB 21-20	AB 30-20	AB 40-20	AB 11-10	AB 15-10	AB 20-10	AB 6-5	AB 7.5-5	AB 10-5	AB 3-2.5	AB 4-2.5	AB 5-2.5
Rheology Index*, 0°C (32°F)	2100±210	3000±300	4000±400	1100±110	1500±150	2000±200	600±60	750±75	1000±100	300±30	400±40	500±50
Rheology Index*, 80°C (176°F)	2000±200			1000±100			500±50			250±25		
Nitrogen Factor**	a ± for all grades											
Acid Factor**,max.	b for all grades											
Healing Factor***,min.	c for all grades											
Viscosity, 135°C (275°F), Cs, max.	500 for all grades											
Flash Index, °C (F), min.	232 (450)			219 (425)			177 (350)			163 (325)		

* Related to low temperature cracking and permanent deformation. Test is conducted on aged binders. Binders are aged using low temperature, high oxygen pressure test simulating 5 years of service life.

** Nitrogen factor and acid factor are related to moisture damage and are optional for regions without moisture damage problems or if the asphalt is modified. A surrogate test on the asphalt mixture may be substituted.

*** Related to fatigue cracking.

PG Asphalt Binders

Performance Grades

Original

- ≥230 °C — **Flash Point**
- ≤ 3 Pa-s @ 135 °C — **Rotational Viscosity**
- ≥ 1.00 kPa — **DSR G*/sin δ** (Dynamic Shear Rheometer)

(Rolling Thin Film Oven) RTFO, Mass Change ≤ 1.00%

- ≥ 2.20 kPa — **DSR G*/sin δ** (Dynamic Shear Rheometer)

(Pressure Aging Vessel) PAV

- 20 hours, 2.10 MPa
- ≤ 5000 kPa — **DSR G*sin δ** (Dynamic Shear Rheometer) Intermediate Temp. = [(Max. + Min.)/2] + 4
- S ≤ 300 MPa, m ≥ 0.300 — **BBR S (creep stiffness) & m-value** (Bending Beam Rheometer)
- ε_f ≥ 1.00% — **DTT** (Direct Tension Tester)

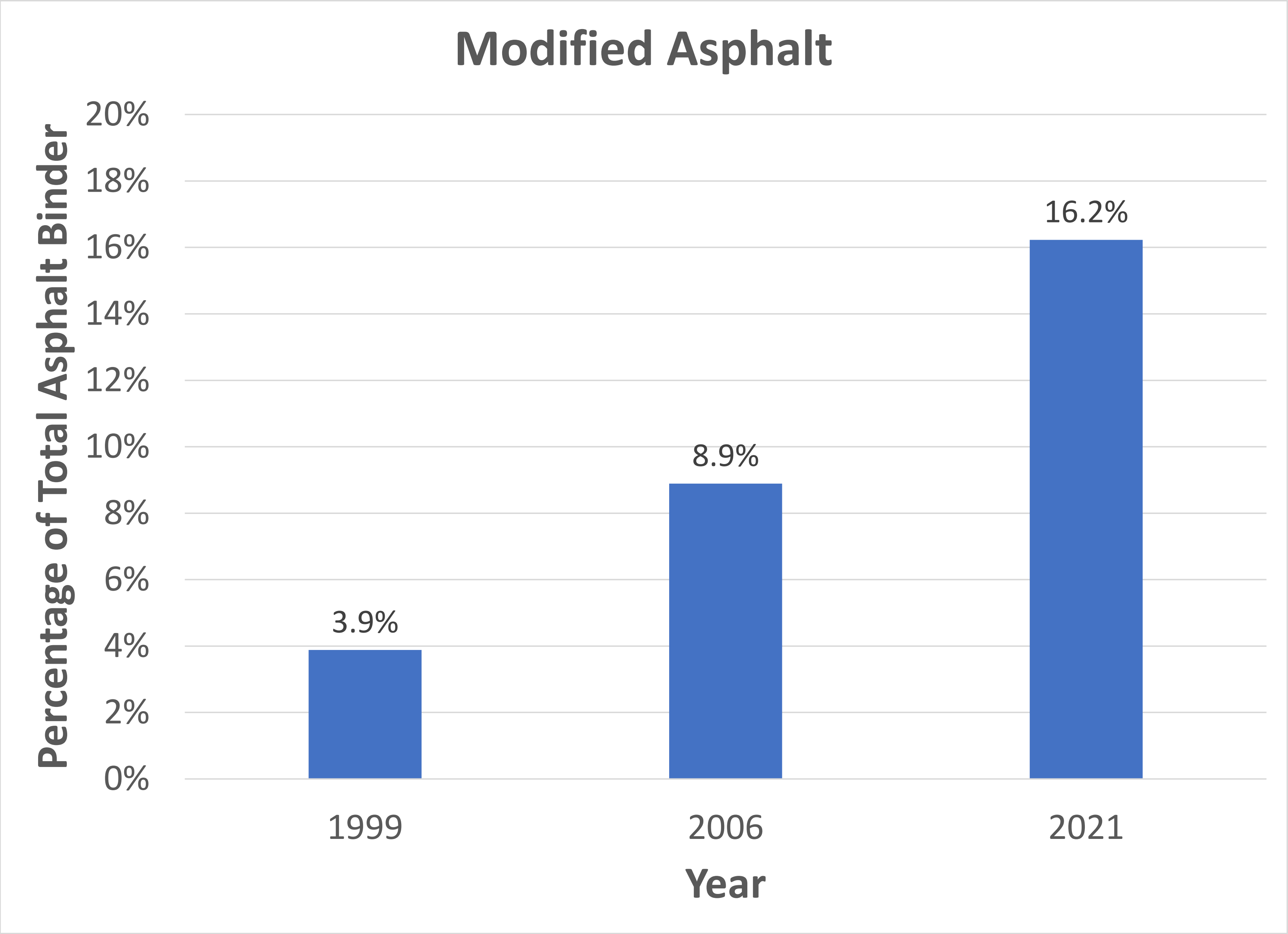
Max. Design Temp.	PG 46			PG 52						
Min. Design Temp.	-34	-40	-46	-10	-16	-22	-28	-34	-40	-46
Original ≥ 1.00 kPa DSR G*/sin δ	46			52						
RTFO ≥ 2.20 kPa DSR G*/sin δ	46			52						
PAV 20 hours, 2.10 MPa	90			90						
≤ 5000 kPa DSR G*sin δ	10	7	4	25	22	19	16	13	10	7
S ≤ 300 MPa, m ≥ 0.300 BBR	-24	-30	-36	0	-6	-12	-18	-24	-30	-36
ε_f ≥ 1.00% DTT	-24	-30	-36	0	-6	-12	-18	-24	-30	-36

Max. Design Temp.	PG 58					PG 64					
Min. Design Temp.	-16	-22	-28	-34	-40	-10	-16	-22	-28	-34	-40
Original ≥ 1.00 kPa DSR G*/sin δ	58					64					
RTFO ≥ 2.20 kPa DSR G*/sin δ	58					64					
PAV 20 hours, 2.10 MPa	100					100					
≤ 5000 kPa DSR G*sin δ	25	22	19	16	13	31	28	25	22	19	16
S ≤ 300 MPa, m ≥ 0.300 BBR	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30
ε_f ≥ 1.00% DTT	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30

Max. Design Temp.	PG 70						PG 76					PG 82				
Min. Design Temp.	-10	-16	-22	-28	-34	-40	-10	-16	-22	-28	-34	-10	-16	-22	-28	-34
Original ≥ 1.00 kPa DSR G*/sin δ	70						76					82				
RTFO ≥ 2.20 kPa DSR G*/sin δ	70						76					82				
PAV 20 hours, 2.10 MPa	100(110)						100(110)					100(110)				
≤ 5000 kPa DSR G*sin δ	34	31	28	25	22	19	37	34	31	28	25	40	37	34	31	28
S ≤ 300 MPa, m ≥ 0.300 BBR	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	0	-6	-12	-18	-24
ε_f ≥ 1.00% DTT	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	0	-6	-12	-18	-24

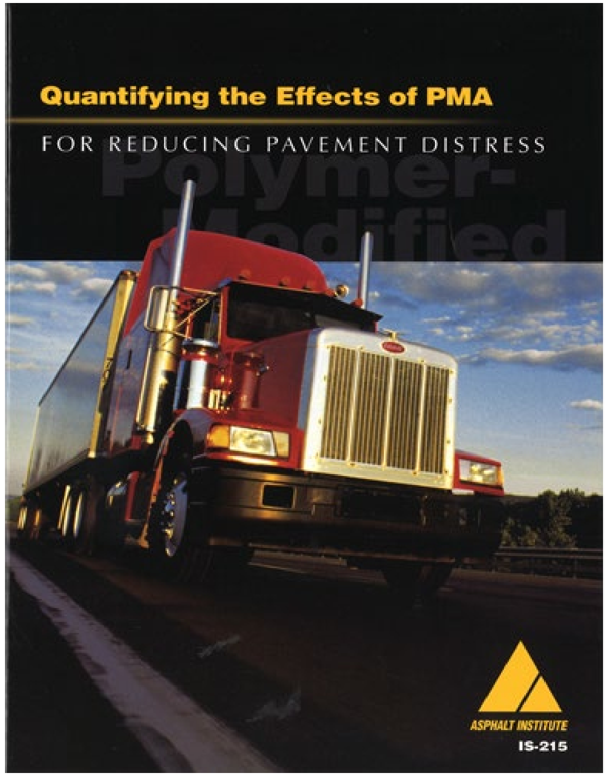
If BBR m-value ≥ 0.300 and creep stiffness is between 300 and 600, the Direct Tension failure strain requirement can be used in lieu of the creep stiffness requirement.

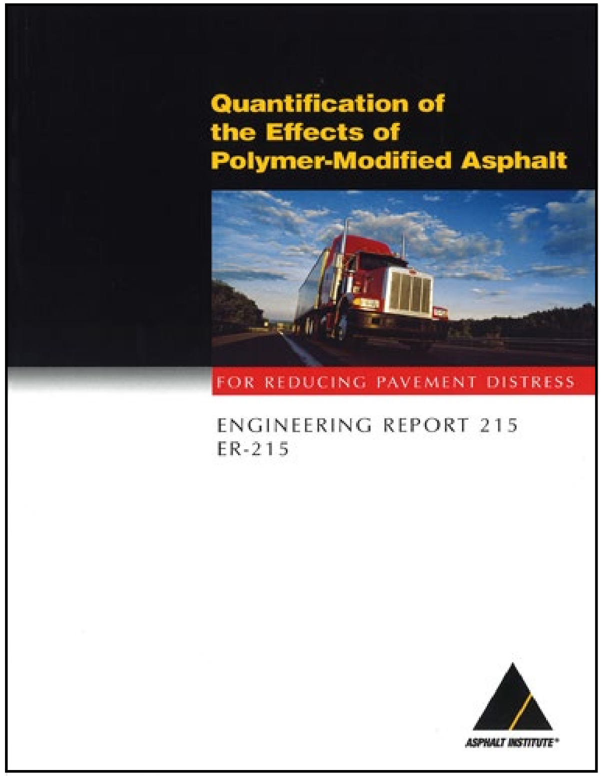
Modified Asphalt Usage



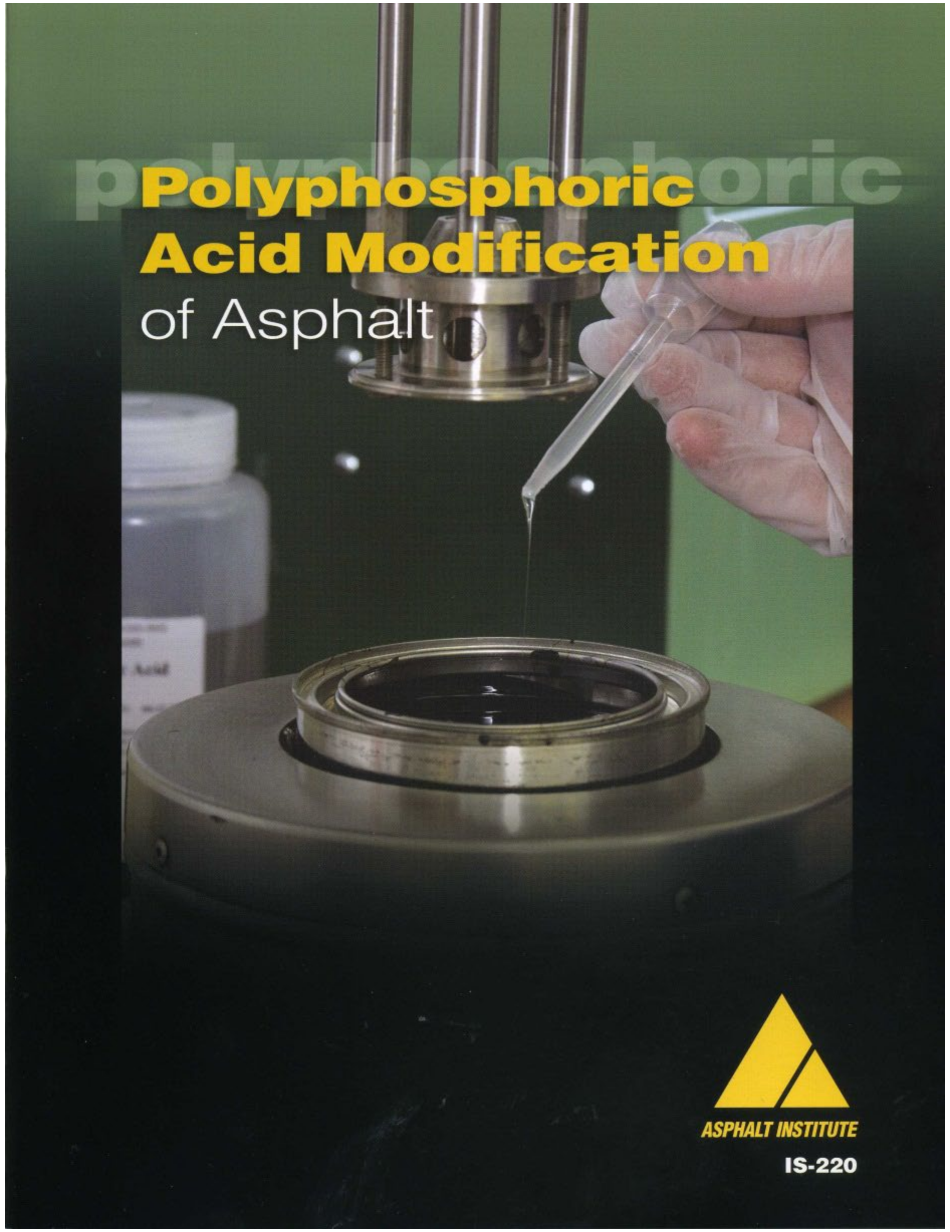
Quantifying the Effects of Polymer Modification

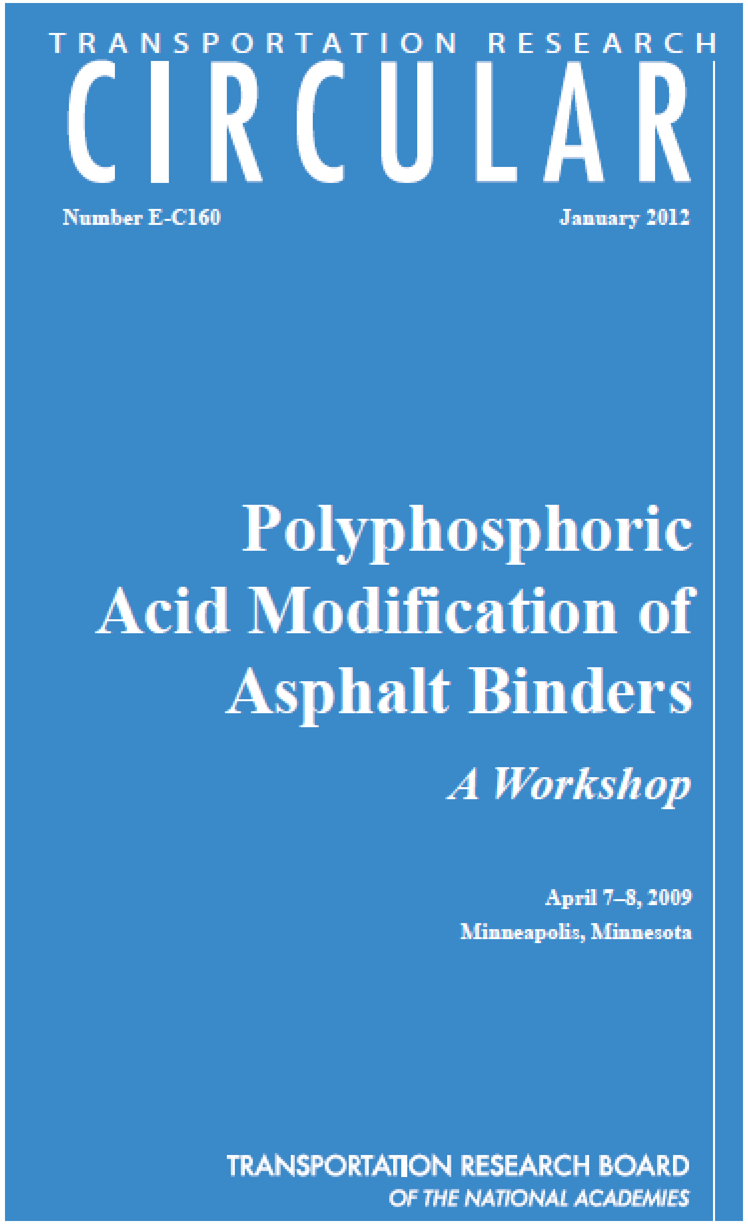
- Report on 2005 study
- “The use of PMA definitely extends the service life of flexible pavements and HMA overlays.”
    - Harold Von Quintus (ARA) – Principal Investigator



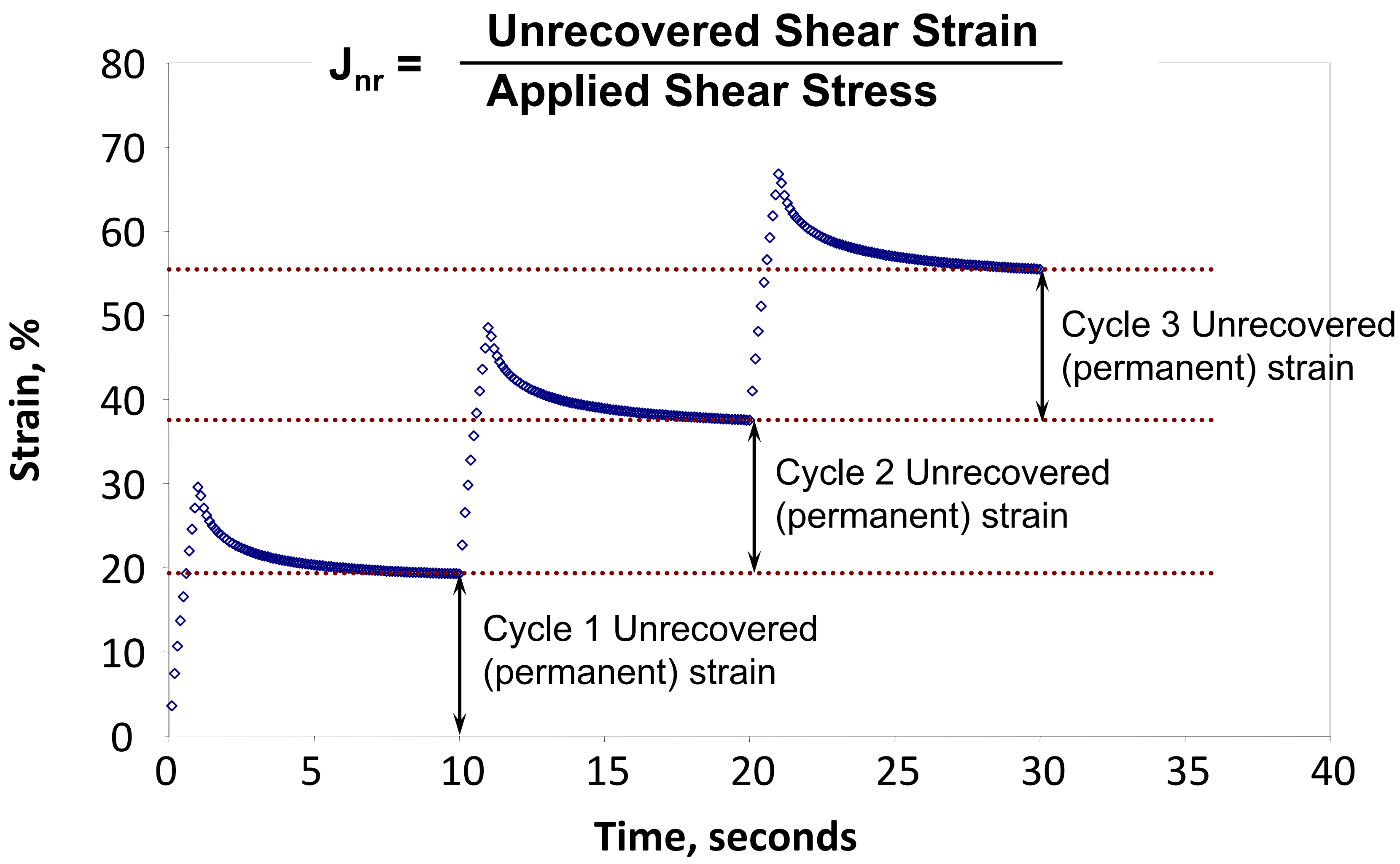


PPA

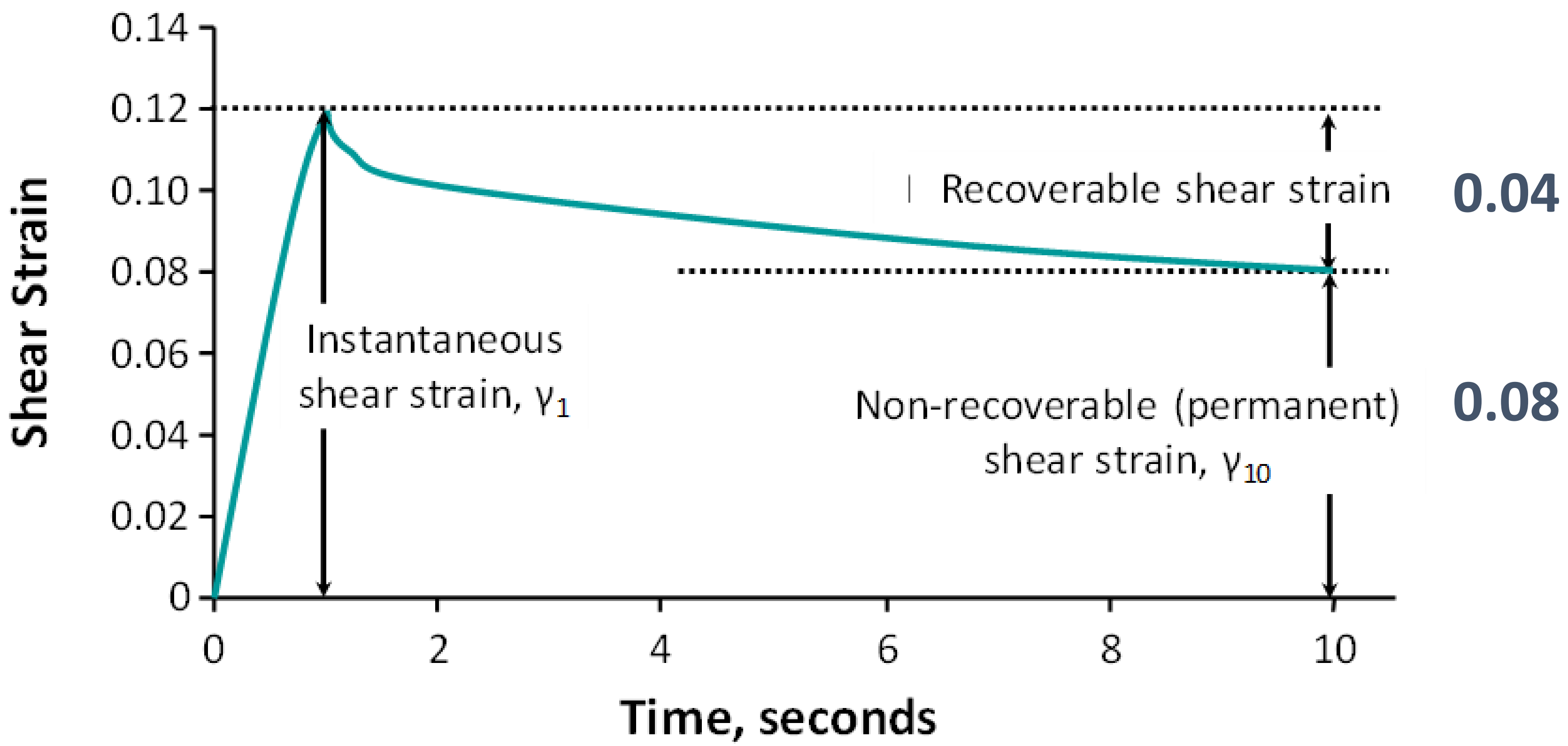

Polyphosphoric
Acid Modification
of Asphalt
ASPHALT INSTITUTE
IS-220


TRANSPORTATION RESEARCH
CIRCULAR
Number E-C160
January 2012
Polyphosphoric
Acid Modification of
Asphalt Binders
A Workshop
April 7–8, 2009
Minneapolis, Minnesota
TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

MSCR – Non-Recoverable Compliance (J_{nr})



MSCR: Calculating and Understanding Test Output



Assume τ = 0.1 kPa

$J_{nr0.1} = \gamma_{nr}/\tau$

$J_{nr0.1} = 0.08/0.1\ \text{kPa} = 0.8\ \text{kPa}^{-1}$

Assume τ = 0.1 kPa

$R_{0.1} = \gamma_r / \gamma_i$

$R_{0.1} = 0.04/0.12 = 0.33$ or 33%

Addressing Asphalt Binder Contribution to Rutting: MSCR

Standard Method of Test for

Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

AASHTO Designation: T 350-19 (2023)[1]

AASHTO

Technically Revised: 2019 | Reviewed but Not Updated: 2023 | Editorially Revised: 2021

Technical Subcommittee: 2b, Liquid Asphalt

1. SCOPE

1.1. This test method covers the determination of percent recovery and nonrecoverable creep compliance of asphalt binders by means of the Multiple Stress Creep Recovery (MSCR) test. The MSCR test is conducted using the Dynamic Shear Rheometer (DSR) at a specified temperature. It is intended for use with residue from T 240 (Rolling Thin-Film Oven Test (RTFOT)).

1.2. The percent recovery value is intended to provide a means for determining the elastic response and stress dependence of polymer modified and unmodified asphalt binders.

MSCR Specification

ASPHALT ACADEMY

Performance Grades (AASHTO M332-20)

The Asphalt Institute
National Binder Technician Certification
PROGRAM

Performance Grades

High PG	PG 52	PG 58	PG 64	PG 70	PG 76
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% *See Note Below* (S H V)	**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 V E)	**DSR G*sin δ** (Dynamic Shear Rheometer), AASHTO T 315				
S ≤ 300 MPa m ≥ 0.300	**BBR S (creep stiffness) & m-value** (Bending Beam Rheometer), AASHTO T 313				

PG 52:

Low PG	-10	-16	-22	-28	-34	-40	-46
DSR G*sin δ	25	22	19	16	13	10	7
BBR S & m-value	0	-6	-12	-18	-24	-30	-36

PG 58:

Low PG	-16	-22	-28	-34	-40
DSR G*sin δ	25	22	19	16	13
BBR S & m-value	-6	-12	-18	-24	-30

PG 64:

Low PG	-10	-16	-22	-28	-34	-40
DSR G*sin δ	31	28	25	22	19	16
BBR S & m-value	0	-6	-12	-18	-24	-30

PG 70:

Low PG	-10	-16	-22	-28	-34	-40
DSR G*sin δ	34	31	28	25	22	19
BBR S & m-value	0	-6	-12	-18	-24	-30

PG 76:

Low PG	-10	-16	-22	-28	-34
DSR G*sin δ	37	34	31	28	25
BBR S & m-value	0	-6	-12	-18	-24

- 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.
- The J_{nrDiff} requirement is not applicable for $J_{nr3.2}$ ≤ 0.5 kPa^{-1} at the selected test temperature.

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Implementation of the MSCR Test and Specification

TechBrief

The Asphalt Pavement Technology Program is an integrated, national effort to improve the long-term performance and cost effectiveness of asphalt pavements. Managed by the Federal Highway Administration through partnerships with State highway agencies, Industry and academia the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement guidelines, methods, procedures and other tools for use in asphalt pavement materials selection, mixture design, testing, construction and quality control.

U.S. Department of Transportation
Federal Highway Administration

Office of Pavement Technology

FHWA-HIF-11-038

April 2011

THE MULTIPLE STRESS CREEP RECOVERY (MSCR) PROCEDURE

This Technical Brief provides an overview of the intent of the Superpave MSCR procedure to evaluate asphalt binder and its relation to asphalt pavement performance.

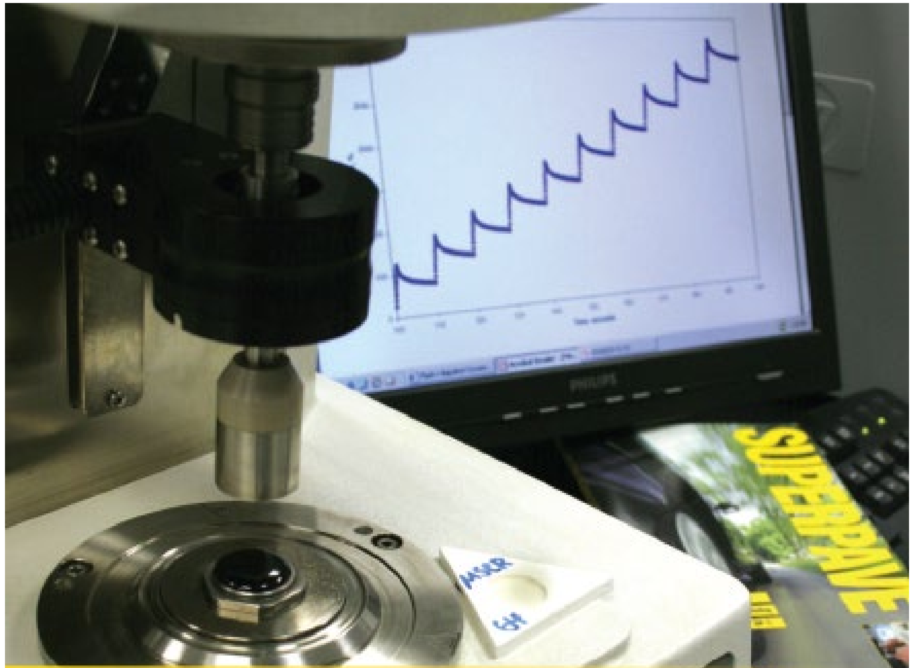
Rationale for MSCR Procedure

The Multiple Stress Creep Recovery (MSCR) test is the latest improvement to the Superpave Performance Graded (PG) Asphalt Binder specification. This new test and specification – listed as AASHTO TP70 and AASHTO MP19 – provide the user with a new high temperature binder specification that more accurately indicates the rutting performance of the asphalt binder and is blind to modification. A major benefit of the new MSCR test is that it eliminates the need to run tests such as elastic recovery, toughness and tenacity, and force ductility, procedures designed specifically to indicate polymer modification of asphalt binders. A single MSCR test can provide information on both performance and formulation of the asphalt binder.

Overview

So what exactly is the MSCR test? The MSCR test uses the well-established creep and recovery test concept to evaluate the binder's potential for permanent deformation. Using the Dynamic Shear Rheometer (DSR), the same piece of equipment used today in the existing PG specification, a one-second creep load is applied to the asphalt binder sample. After the 1-second load is removed, the sample is allowed to recover for 9 seconds. Figure 1 shows typical data for a polymer modified binder. The test is started with the application of a low stress (0.1 kPa) for 10 creep/recovery cycles then the stress in increased to 3.2 kPa and repeated for an additional 10 cycles.

The material response in the MSCR test is significantly different than the response in the existing PG tests. In the PG system, the high



Asphalt Institute Guidance Document

Implementation of the Multiple Stress Creep Recovery Test and Specification

The purpose of this document is to provide guidance to the asphalt industry, users and producers, regarding the implementation of the new high temperature binder test and specification using the Multiple Stress Creep Recovery (MSCR) test. The MSCR test replaces the existing AASHTO M320 Dynamic Shear Rheometer (DSR) test used for characterizing the high temperature performance properties of an asphalt binder after short-term aging. It is the Asphalt Institute's opinion that the MSCR test and specification represent a technical advancement over the current PG specification that will allow for better characterization of the high temperature performance-related properties of an asphalt binder.

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Multiple Stress Creep Recovery (MSCR) Test

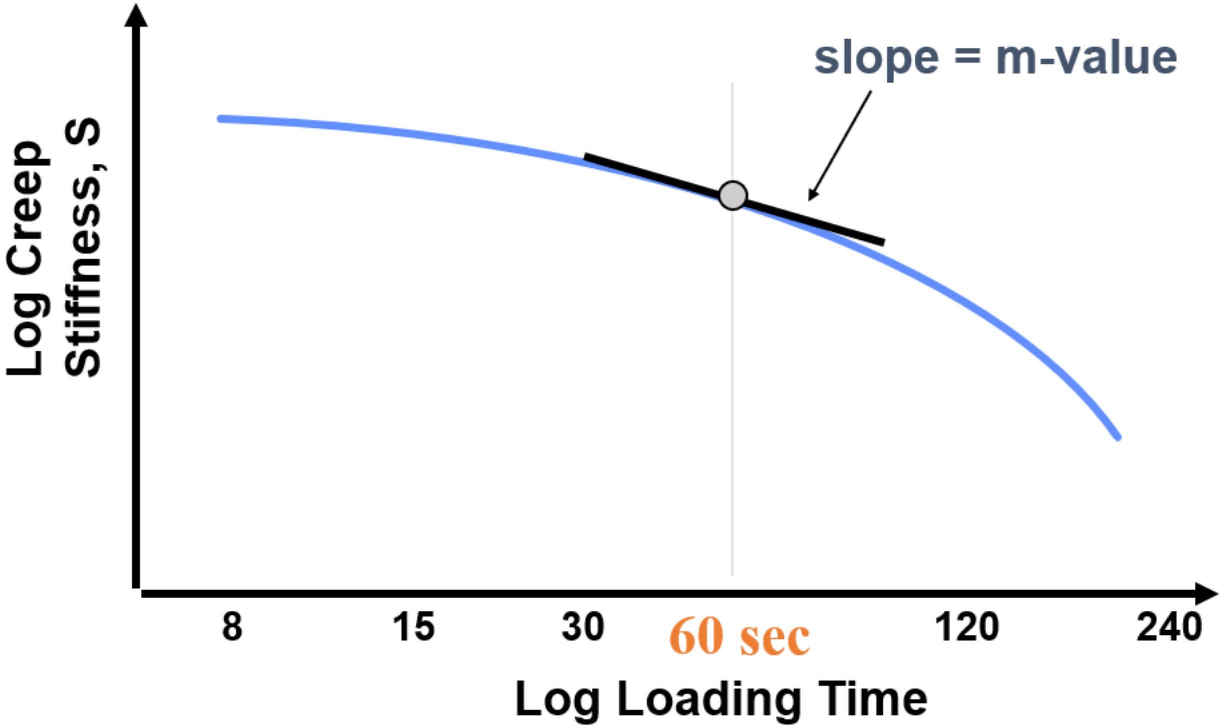
- 2010
  - “It is the Asphalt Institute’s opinion that the MSCR test and specification represent a technical advancement over the current PG specification that will allow for better characterization of the high temperature performance-related properties of an asphalt binder.”

MSCR: Calculating and Understanding Test Output

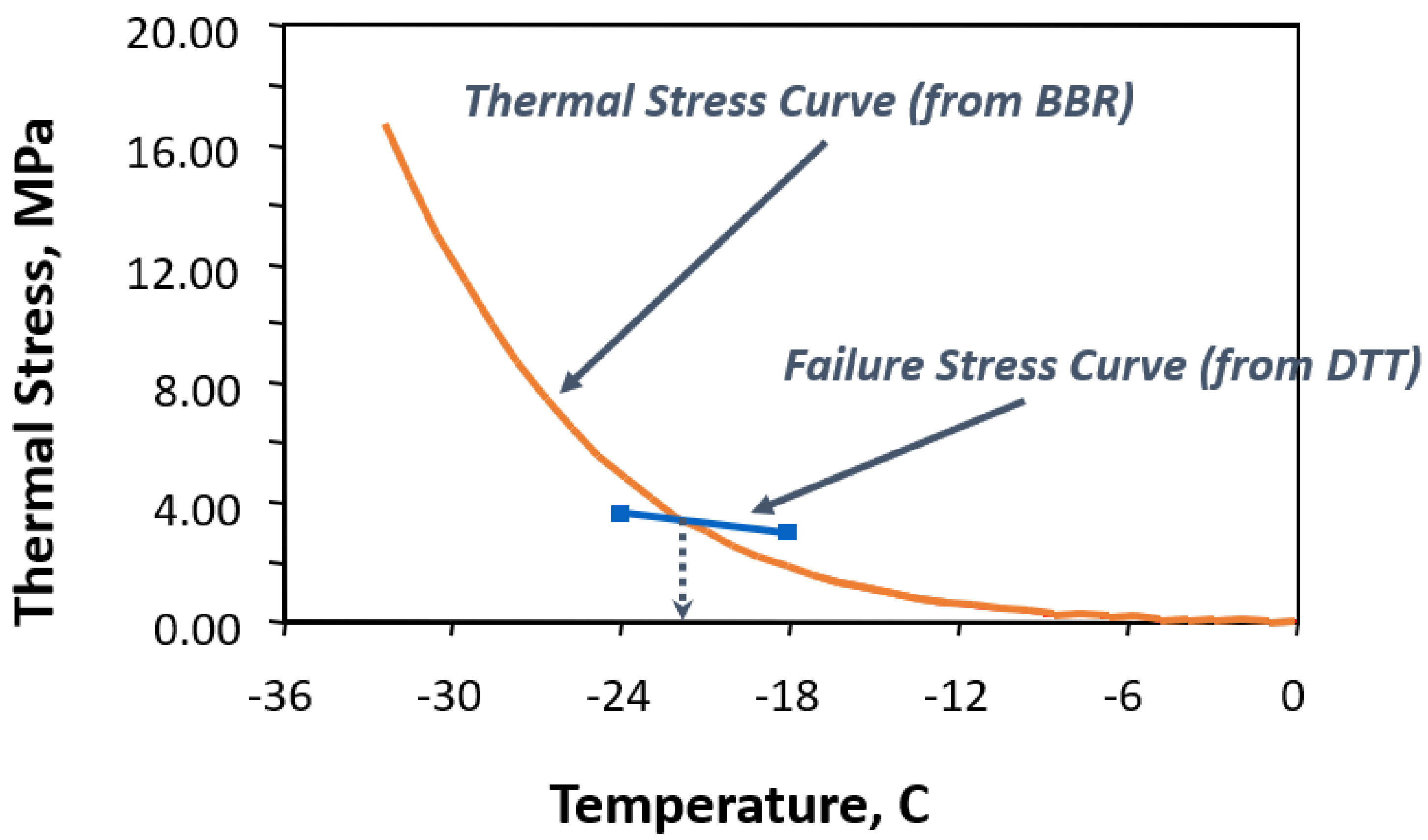
- MTE Rutting Study: WI E10 Fine Mix

PG Grade (M320)	PG Grade (M332)	Test Temp, °C	$J_{nr3.2}$, kPa^{-1}	$R_{3.2}$, %	HWT Rut Depth (10,000 passes), mm
70-22	n/a	75	5.74	0.5	13.2
64-22	64S-22	64	3.40	3.4	7.1
70-22	70S-22	70	2.92	1.5	5.1
70-22	64H-22	64	1.35	4.4	3.6
76-22	64E-22	64	0.24	55.8	1.7
82-22	64E-22	64	0.08	78.5	1.6

Low Temperature Behavior of Asphalt Binders



Low Temperature Behavior of Asphalt Binders



Low Temperature Cracking in Mix Design

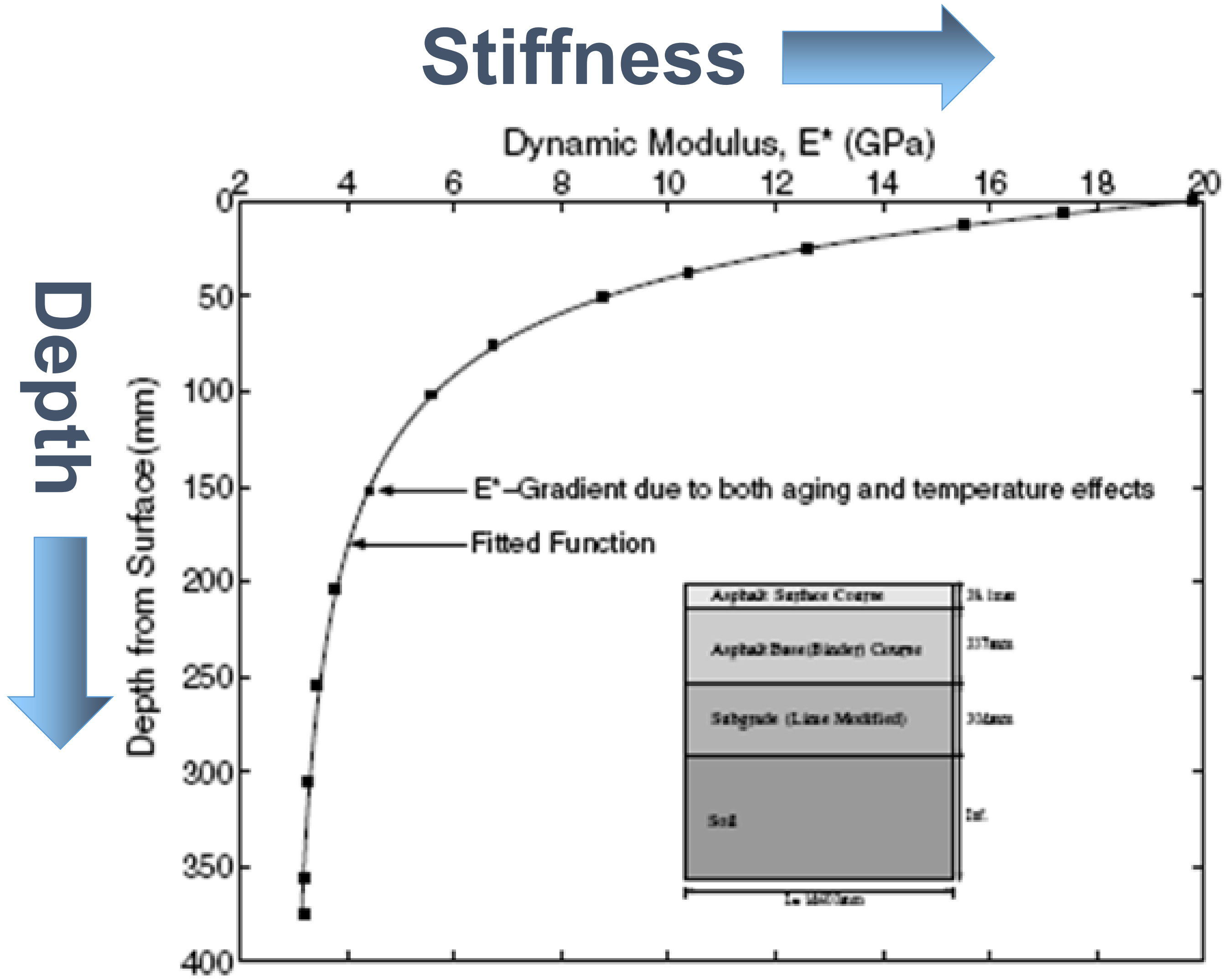
- Recommended Tests and Conditions
  - NCHRP Report 673
    - Research also has shown that thermal cracking performance of asphalt mixtures is most strongly affected by the asphalt binder properties.
      - As long as the asphalt binder that is used in the mixture has the appropriate low temperature properties for the expected use, the expectation for conventional asphalt mixtures will be that they will have adequate laboratory thermal cracking performance.

Linear coefficient of thermal expansion for asphalt binder is on average about 17 times greater than the coefficient of thermal expansion for aggregate

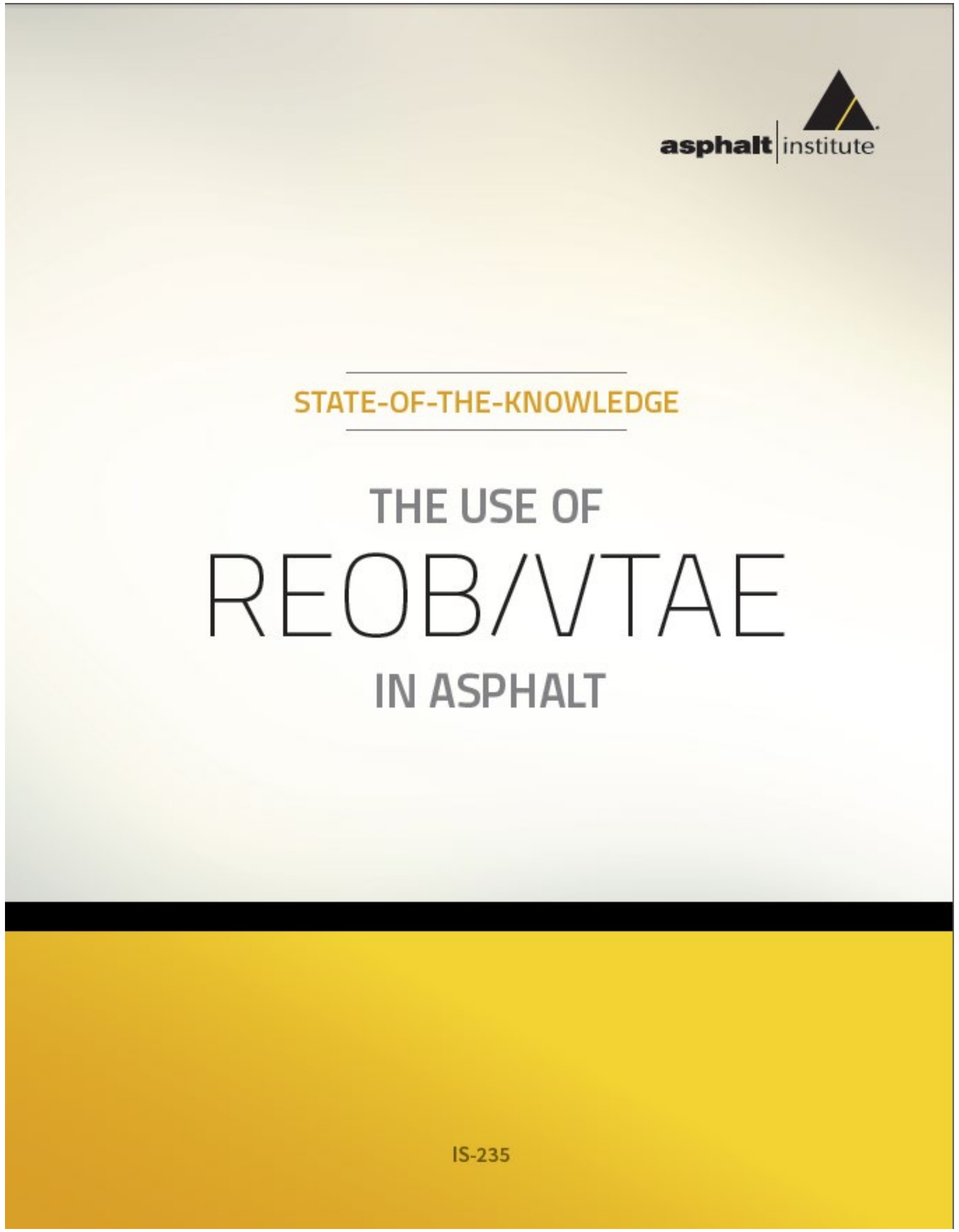
How Asphalt Pavements Behave with Aging

- Durability Cracks
  - Mixture is brittle
  - Random, wandering cracking
  - Longitudinal
- Depends on…
  - Asphalt binder (some)
  - Mineral aggregate (little)
  - Volumetric proportioning (some)

Witczak and Mirza: Global Aging Model (1995)



REOB/VTAE



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Observations, conclusions and recommendations provided in IS-235 are based on the review of information as of the end of 2015. The 89-page document starts with a 2-page Executive Summary.

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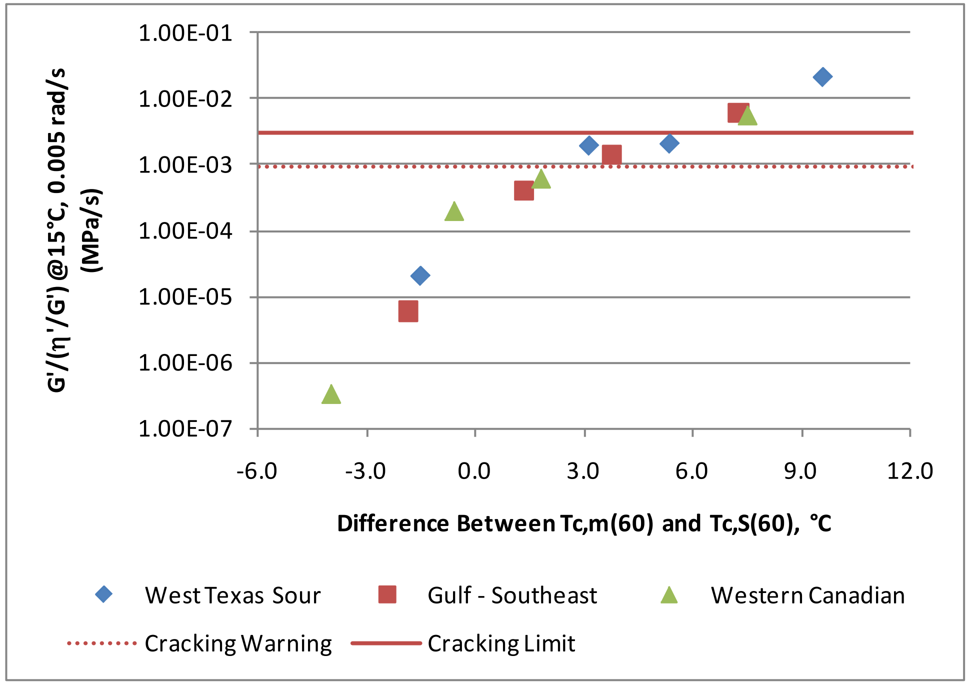
The Use of REOB/VTAE in Asphalt

Delta Tc



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State-of-the-Knowledge: Use of the Delta T_c Parameter to Characterize Asphalt Binder Behavior

Asphalt Institute Technical Advisory Committee

ISBN: 978-1-934154-77-9

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Asphalt Binders: Improved Aging and Characterization of Asphalt Binder Fatigue and Durability

- NCHRP 09-59
  - Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance
- NCHRP 09-60
  - Addressing Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance through Changes in Asphalt Binder Specifications
- NCHRP 09-61
  - Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures

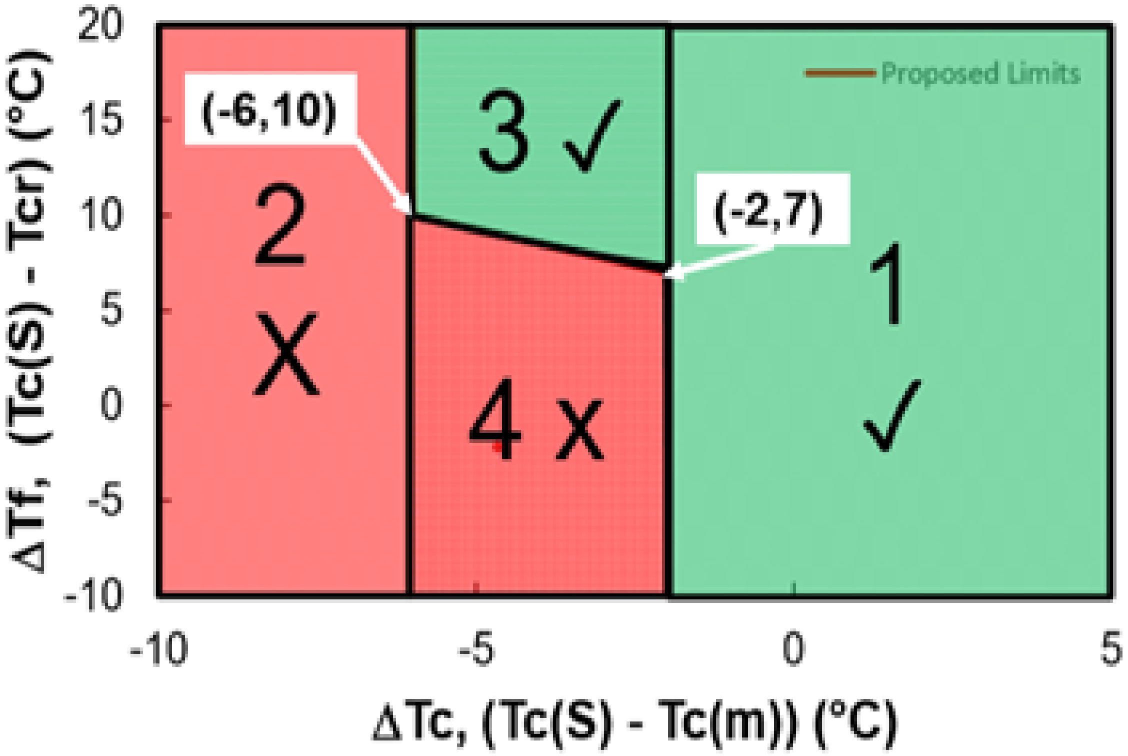
NCHRP 09-60

Western Research INSTITUTE

Summary on Proposed Specs Based on ABCD & BBR

Testing

- RTFO+PAV20
- LPG: BBR test + ABCD test only for critical binders
- 3 PAV pans are sufficient for both BBR & ABCD Tests



Proposed specifications framework

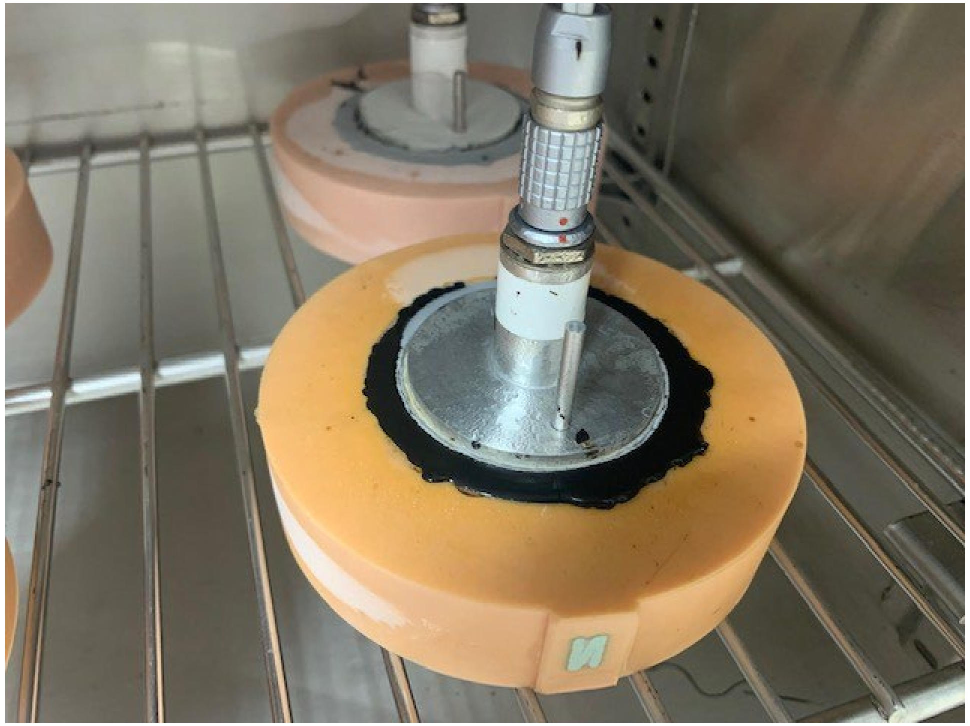
- Addition to current Climate-based PG
- Universal - blind
- BBR alone when

ΔTc > -2°C (Accepted)
ΔTc <-6°C (Rejected)

- BBR & ABCD for

-6°C<ΔTc <-2°C
ΔTf min = 7°C at -2°C
ΔTf min = 10°C at -6°C

AASHTO T 387



Photos taken at Ohio DOT Office of Materials Management

AASHTO T 387

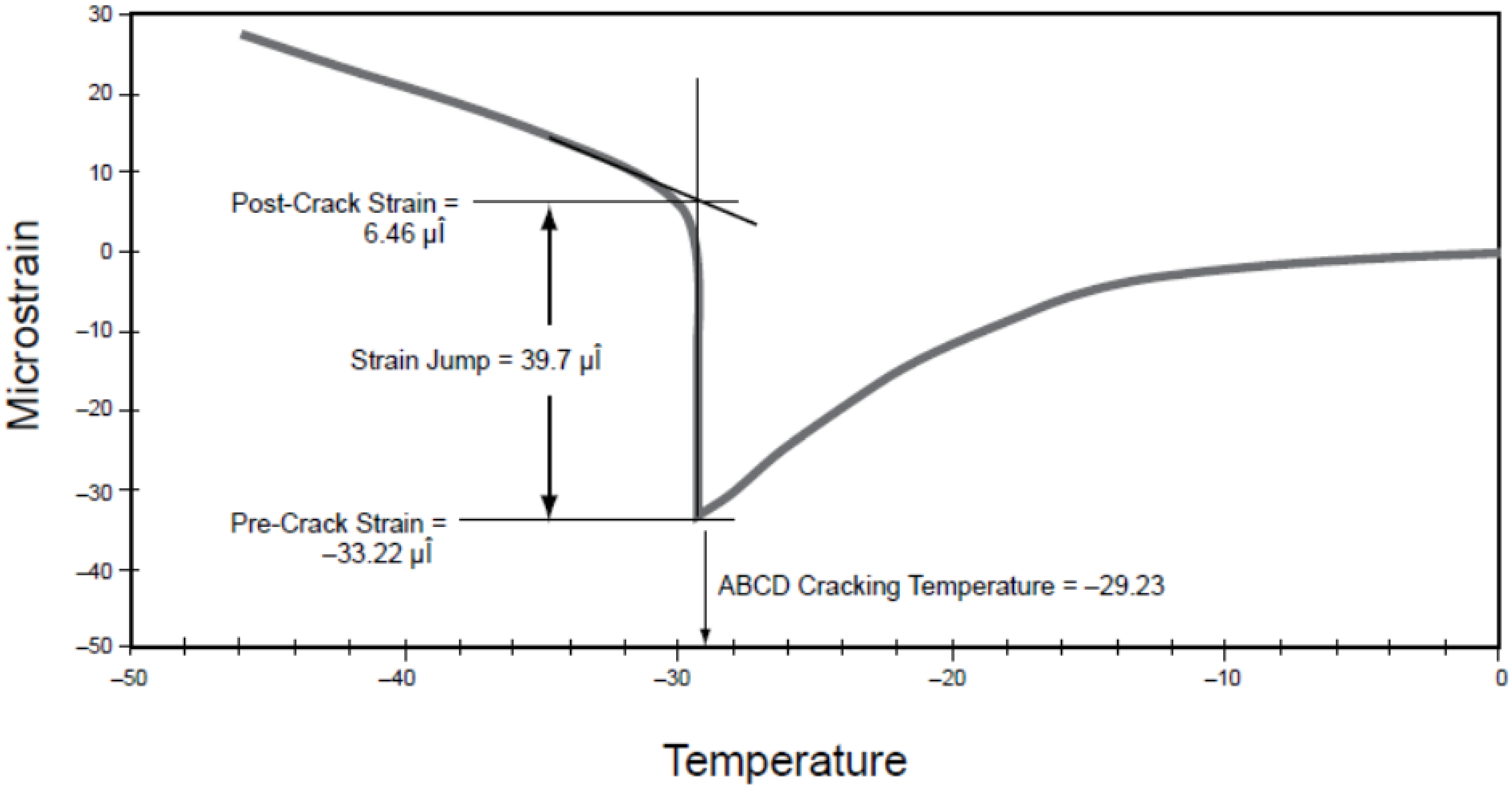


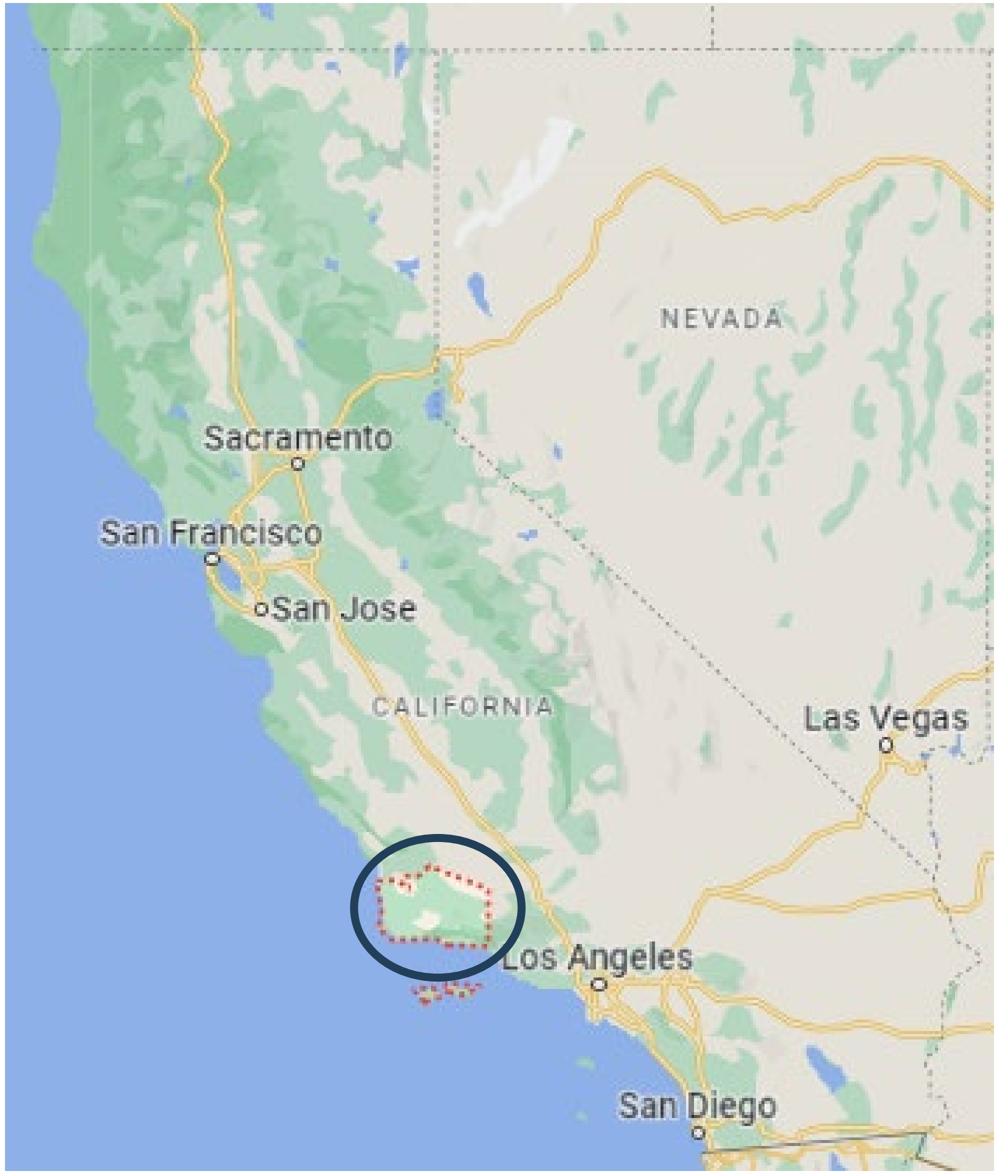
Figure 6—Typical ABCD Test Results: Strain versus Temperature

Zube and Skog:
"Final Report on the Zaca-Wigmore Asphalt Test Road"

- 1969 AAPT Paper
- Relevance to PG Specification
  - From SHRP Report A-367 (Pages 36-37):
    - "At the suggestion of the A-003A researchers, and in light of an **evaluation of the fatigue performance in field trials such as Zaca-Wigmore** (figure 2.22), the fatigue criterion was changed to reflect the energy dissipated per load cycle. Dissipated energy in a dynamic shear test is appropriately **calculated as $G^*\sin\delta$** (Ferry 1980)."

Zube and Skog:
"Final Report on the Zaca-Wigmore Asphalt Test Road"

- Two main types of failure during service life were encountered on the project
  - Fatigue Cracking
    - Most prevalent
    - Related to recovered asphalt binder consistency (i.e., stiffness)
  - Block Cracking with Raveling
    - Most prevalent in the passing lane
    - Gain in shear susceptibility during weathering
    - Drop in ductility (i.e., viscoelastic behavior) during service life



Lessons from the Zaca-Wigmore Asphalt Test Road

Specification	Fatigue Cracking	Block Cracking (Durability)
Current (M 320 and M 332)	G*sin δ	n/a
Research (M 320 and M 332)	GRP ($G^*\cos^2\delta/\sin\delta$)	R-value **or** ΔT_c **or** δ at $G^*_{critical}$

Developments in Asphalt Binder Tests and Specifications Resulting from National Research

- **NCHRP 09-59**
  - Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance

    - Recommend Glover-Rowe Parameter (GRP) on PAV-aged Asphalt Binder instead of $G^*\sin\delta$
      - $G^*\cos^2\delta/\sin\delta \leq 5000$ kPa at 10 rad/s and intermediate temperature
    - Recommend R-value calculated from BBR data as additional parameter for durability
      - $1.50 \leq R \leq 2.50$
    - Recommend intermediate temperatures to be based only on low temperature grade rather than as a function of high and low temperatures

Developments in Asphalt Binder Tests and Specifications Resulting from National Research

- **NCHRP 09-60**
  - Addressing Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance through Changes in Asphalt Binder Specifications

- Recommend using ΔT_c as added parameter for durability, relaxation
  - ΔT_c minimum of -6°C
    - ΔT_c < -2°C requires passing value of ΔT_f to qualify
    - Similar to Footnote g in AASHTO M 320 Table 1
  - ΔT_f determined using T_{cr} from ABCD and $T_{c,S}$ from BBR

Developments in Asphalt Binder Tests and Specifications Resulting from National Research

- **NCHRP 09-61**
  - Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures

    - No change in RTFO procedure
      - Note elevation change in new version of AASHTO T 240
    - No change in PAV procedure for standard long-term aging
    - If considering extended aging (to simulate 40-hour PAV), use…
      - Thinner film in PAV pan (12.5 grams)
      - 20 hours, 2.1 MPa air pressure
      - Revised temperature based on average of 98% high and low PG
        - 5°C increments

Conceptual PG Asphalt Binder Specification (Standard PAV)

Performance Grade:	PG 64						PG 70					
	–10	–16	–22	–28	–34	–40	–10	–16	–22	–28	–34	–40
Average 7-day max pavement design temp, °C[a]	<64						<70					
Design low pavement temperature, °C[a]	>–10	>–16	>–22	>–28	>–34	>–40	>–10	>–16	>–22	>–28	>–34	>–40
Tests on Residue from Pressure Aging Vessel (R 28)												
PAV aging temperature, °C[f]	100						100 (110)					
Dynamic shear, T 315: $G^* (\cos \delta)^2 / \sin \delta$,[d] maximum value 5,000 kPa, at 10 rad/s and test temperature, °C[g,h]	29	27	25	22	19	17	29	27	25	22	19	17
Creep stiffness, T 313:[f] Stiffness, maximum value 300 Mpa m-value, minimum value 0.30, at 60 sec and test temperature, °C	0	–6	–12	–18	–24	–30	0	–6	–12	–18	–24	–30
Creep stiffness, T313: R=log(2) log(S/3,000)/log(1-m) at 60 sec and specified test temperature minimum / maximum	1.50/2.50											
ΔT_c $T_{c,S} - T_{c,m}$	≥ -2.0[m]											
ΔT_f[m] $T_{c,S} - T_{cr}$	$\Delta T_{f,min} = \frac{22 - 3 * \Delta T_c}{4}$											

[m] If ΔT_c is greater than or equal to -2.0 then the determination of ΔT_f is not required. If ΔT_c is between -2.0 and -6.0 then ΔT_f may be determined. In that case, if ΔT_f exceeds the minimum value the sample is considered to meet the ΔT_c requirement.

Final Thoughts

- We continue to improve our knowledge and understanding how asphalt materials behave
  - Use of advanced testing and analysis
  - Artificial intelligence/machine learning can help
- Asphalt binders will continue to evolve
  - New sources, blends, processes, modification
- Tests and specifications will continue to evolve and need to be performance-based
  - Should not need to prohibit any product ***if*** specification is performance-based
- No national specification until ~75 years ago
  - Penetration spec was 25 years old when a new system (viscosity) came along
  - Viscosity spec was 22 years old when a new system (PG) came along
  - PG is 30 years old currently – some updating may be required

Thanks!

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