Developments in Asphalt Binder Tests and Specifications Resulting from National Research

Mike Anderson, Asphalt Institute

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NJAPA

NCHRP 20-44(19)

- “Implementation of Proposed AASHTO Standards for Asphalt Binders and Mixtures”
- Project Objectives
  - Facilitate actions needed to assure the timely adoption by the AASHTO Committee on Materials and Pavements (COMP) of the proposed AASHTO standards produced in the following NCHRP Projects:
    - **09-52, 09-54**, **09-56A**, **09-59**, **09-60**, and **09-61**
    - others later designated by NCHRP

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Acknowledgments

- National Cooperative Highway Research Program (NCHRP)
  - 20-44(19) Project Panel
    - **Ed Harrigan, NCHRP Program Officer**
    - Roberto Barcena, NCHRP Program Officer
- Research Teams for NCHRP Projects 09-52, 09-54, 09-56A, 09-59, 09-60, and 09-61
- Member Companies of the Asphalt Institute

Disclaimer

This investigation is being sponsored by TRB under the NCHRP Program. Data reported are work in progress. Contents of this research may have not been reviewed by the project panel of NCHRP, nor do they constitute a standard, specification, or regulation.

NCHRP 20-44(19) Research Implementation Team

asphalt institute

National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY


Mike Anderson


Randy West


Mark Buncher


Bob Horan


Danny Gierhart


Jim Musselman


Raquel Moraes


Fan Yin


Pamela Turner

NCHRP 20-44(19) Activities

- Key Tasks
  - Assess the technical basis for any new or revised AASHTO standards proposed in the research projects.
    - Identify gaps in supporting data that must be addressed before adoption.
  - Identify and resolve any conflicts between the requirements of the various standards.
  - Assess the impact of the standard’s adoption on state DOT and industry operations.
  - Provide technical support to COMP during review and balloting.

Tasks 1-4

Table 2. Working Group Assignments for Review of Individual Projects

Project No.	Title	Research Implementation Team Working Group Leaders
09-52	Short-Term Laboratory Conditioning of Asphalt Mixtures	Randy West, Lead Jim Musselman, Support
09-54	Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction	Fan Yin, Lead Raquel Moraes, Support
09-56A	Identifying Influences on and Minimizing the Variability of Ignition Furnace Correction Factors	Danny Gierhart, Lead Bob Horan, Support
09-59	Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance	Mike Anderson, Lead Mark Buncher, Support
09-60	Addressing Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance through Changes in Asphalt Binder Specifications	Mike Anderson, Lead Mark Buncher, Support
09-61	Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures	Raquel Moraes, Lead Pamela Turner, Support

Asphalt Mixtures

- NCHRP 09-52
  - Short-Term Laboratory Conditioning of Asphalt Mixtures
- NCHRP 09-54
  - Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction
- NCHRP 09-56A
  - Identifying Influences on and Minimizing the Variability of Ignition Furnace Correction Factors

Asphalt Binders

- 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 09-52

- Short-Term Laboratory Conditioning of Asphalt Mixtures
  - David Newcomb (PI)
  - Texas A&M University with NCAT and University of California Pavement Research Center
  - Objectives
    - Develop a laboratory short-term aging protocol for loose mix prior to compaction to simulate the aging and asphalt absorption of an asphalt mixture as it is produced in a plant and then loaded into a truck for transport.
    - Develop a laboratory long-term aging protocol to simulate the aging of the asphalt mixture through its initial period of performance.
    - Determine the effects of the following variables on aging: WMA technology, aggregate asphalt absorption, plant temperature, plant type, presence of recycled materials, and asphalt source.

NCHRP 09-52

- Short-Term Laboratory Conditioning of Asphalt Mixtures
  - Key Findings
    - The selected short-term oven aging (STOA) protocols used on LMLC specimens – 2 hours at 135°C (275°F) for HMA and 2 hours at 116°C (240°F) for WMA were able to accurately simulate the amount of aging, and to a lesser extent, absorbed binder that occurs during production at an asphalt plant.
    - The recommended changes to STOA in AASHTO R 30 resulting from this project include:
      - fixing the compaction temperatures at 116°C (240°F) for WMA and at 135°C (275°F) for HMA; and
      - conditioning the sample for 2 hours at the compaction temperature regardless of whether the sample is being prepared for volumetric mix design or performance testing.

NCHRP 09-52

- Short-Term Laboratory Conditioning of Asphalt Mixtures
  - Key Findings
    - Field verification of the proposed changes to the AASHTO R 30 Procedure for laboratory conditioning of asphalt mixtures was conducted in the follow-up NCHRP 09-52A project.
    - The key finding from that work, as reported in NCHRP Report 919, is that the current LTOA procedure in AASHTO R 30 is not realistic simulating only 1-2 years of service.
      - The research suggests replacing the aging of a compacted specimen with aging of loose mix under the same conditions – 5 days at 85°C (185°F) before compaction for performance testing.
      - This level of aging – using loose mix – was expected to simulate 7-10 years in-service (warmer climates) and 12-14 years in-service (colder climates) based on stiffness measurements.

NCHRP 09-54

- Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction
  - Y. Richard Kim (PI)
  - North Carolina State University with Arizona State University and Western Research Institute
  - Objectives
    - Develop a calibrated and validated procedure to simulate the long-term aging of asphalt mixtures for performance testing and prediction.

NCHRP 09-54

- Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction
  - Key Findings
    - The sensitivity of the mechanical properties of asphalt mixtures to asphalt binder oxidation was determined and two reliable chemical and rheological aging index properties (AIPs) were identified to track the oxidation levels of field-aged and laboratory-aged asphalt binders and mixtures.
    - A kinetics-derived climatic aging index (CAI) was developed to prescribe laboratory aging durations to match in-situ aging and predict the evolution of oxidative aging in asphalt pavements. The CAI was simplified and recalibrated using RAP, WMA, and PMA to yield the aging durations as a function of hourly pavement temperature history and depth offering reasonable accuracy to match field aging levels.
    - Preliminary findings from the pavement aging model (PAM) highlight the need to consider both traffic and thermal loading in pavement performance simulations and demonstrate the impact of aging on the deterioration of pavement performance.

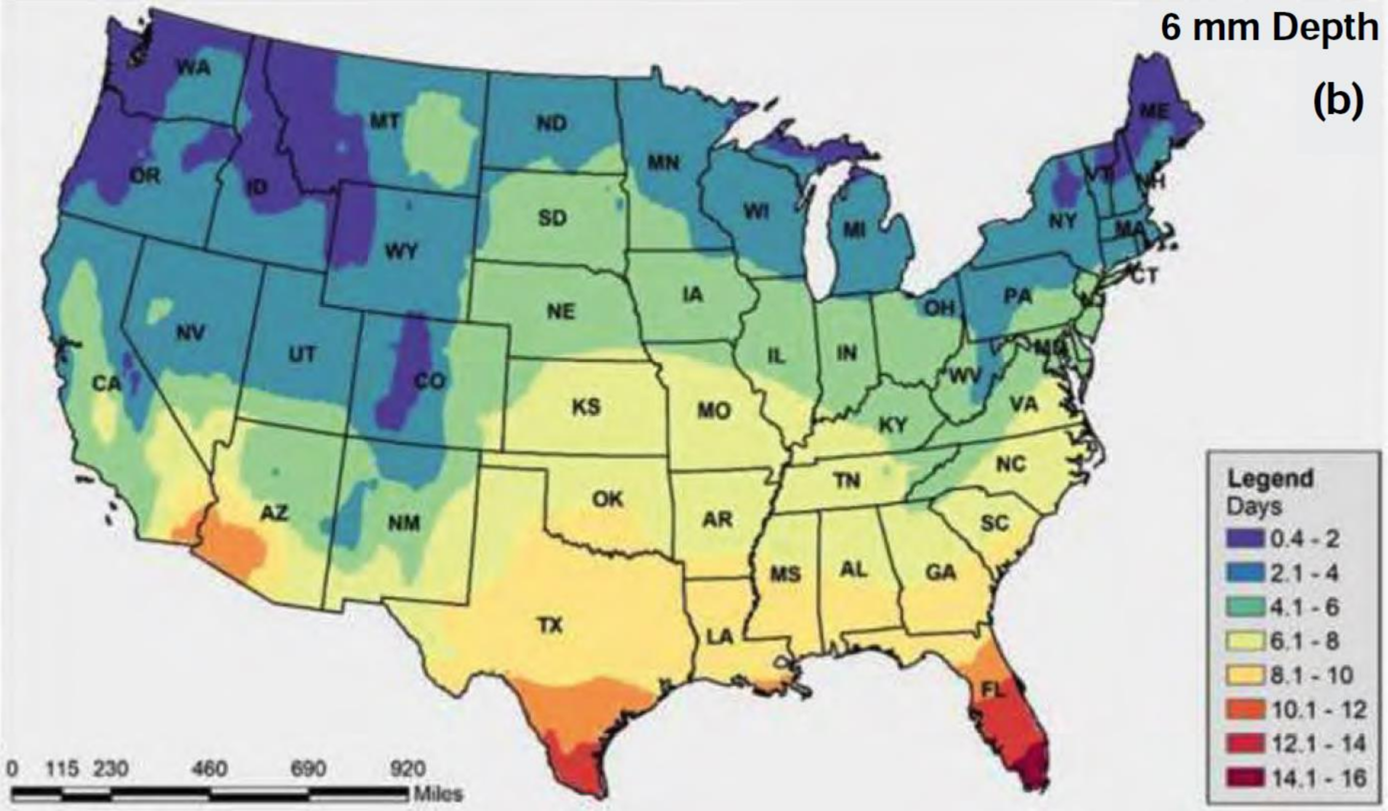
NCHRP 09-54

- Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction
  - Key Findings
    - Loose mixture aging at 95°C was selected as the optimum long-term aging condition for performance testing and prediction of asphalt mixtures.

NCHRP 09-54

- Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction

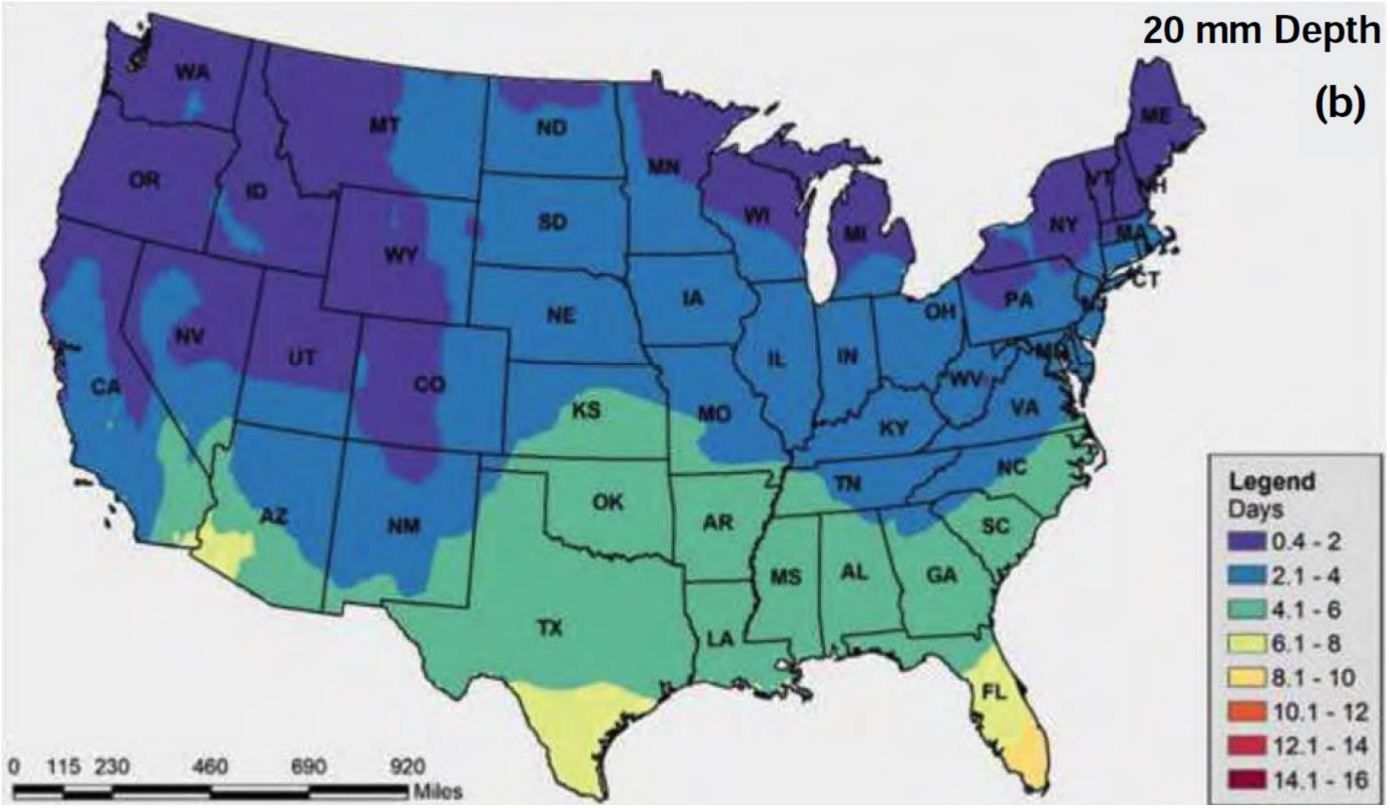
8 Years Aging



NCHRP Report 973, Draft AASHTO Practice for Long-Term Aging

NCHRP 09-54

- Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction



8 Years Aging

NCHRP Report 973, Draft AASHTO Practice for Long-Term Aging

NCHRP 09-56A

- Identifying Influences on and Minimizing the Variability of Ignition Furnace Correction Factors
    - Carolina Rodezno (PI)
    - National Center for Asphalt Technology (NCAT)
    - Objectives
        - determine the variability of asphalt and aggregate correction factors for asphalt mixes containing significant asphalt recycled materials compared to those with virgin binder and aggregate only;
        - further evaluate the effect of reducing the test temperature of AASHTO T 308 method to 800°F; and
        - conduct an interlaboratory study with different mixes to establish a new precision statement for the test procedure.

NCHRP 09-59

Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance
  - Don Christensen (PI, AAT) and Nam Tran (NCAT)
  - Objectives
    - determine asphalt binder properties that are significant indicators of the fatigue performance of asphalt mixtures
    - identify or develop a practical, implementable binder test (or tests) to measure properties that are significant indicators of mixture fatigue performance for use in a performance-related binder purchase specification such as AASHTO M 320 and M 332

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance
  - Key Findings
    - Fatigue life of an asphalt pavement depends upon many factors, but the factors that can be addressed as part of a binder fatigue specification are applied binder strain, binder failure strain and the fatigue exponent.
      - Fatigue life increases with decreasing applied binder strain relative to failure strain and increasing fatigue exponent.
      - Binder failure strain is primarily a function of binder modulus, with failure strain decreasing dramatically with increasing modulus.
      - The fatigue exponent for an asphalt mixture is inversely related to the binder phase angle.

NCHRP 09-59

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      - The fatigue exponent for an asphalt mixture is inversely related to the binder phase angle.

As the binder becomes stiffer (G* increases) fatigue life, or resistance to fatigue damage, decreases

As the binder becomes more brittle (δ decreases) fatigue life, or resistance to fatigue damage, decreases

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance
  - Key Findings
    - A binder's failure strain under fatigue loading and a given set of conditions can be calculated and is called the fatigue strain capacity (FSC).
      - The FSC of a binder is an important factor in determining fatigue performance and is a good basis for a specification test.
      - The current intermediate temperature binder specification parameter, $G^* \sin \delta$ is only moderately correlated to binder FSC.
      - The Glover-Rowe parameter (GRP) correlates much better to FSC and is in fact a good indicator of binder failure strain under a given set of conditions.

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance
  - Recommendations
    - The current intermediate binder specification parameter, G*sin δ, should be replaced by the Glover-Rowe parameter (GRP) determined at a frequency of 10 rad/s. The maximum allowable value for GRP after 20-hour PAV aging should be 5,000 kPa.
    - $GRP = G^*(\cos \delta)^2 / (\sin \delta)$

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance
  - Key Findings
    - Laboratory testing conducted suggests that binder R-value is a good predictor of overall fatigue strain capacity.
    - At a given modulus level, binders with lower R-values will exhibit higher failure strains than binders with high R-values – such as those that have been heavily oxidized.
    - Although the SDENT test is also a reasonable indicator of inherent fatigue strain capacity, the correlation is not as good as for R-value.
      - Considering the difficulty and cost of implementing a specification which includes the SDENT test, this procedure cannot be recommended based on research conducted as part of NCHRP 9-59.

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance
  - Recommendations
    - The binder fatigue specification should include an allowable range for the Christensen-Anderson R-value of from 1.5 to 2.5, after 20-hour PAV aging.
    - The R-value should be calculated using the following equation:

$$R = log(2)\frac{log(S/3{,}000)}{log(1-m)}$$

Where

R = Christensen-Anderson R (rheologic index)

S = BBR creep stiffness at 60 seconds, MPa

m = BBR m-value at 60 seconds

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance

Project :	sga	Target Temp (°C) :	-18.0	Conf Test (GPa) :	221
Operator :	mrp	Min. Temp (°C) :	-18.0	Conf Date :	05/20/2016
Specimen :	NC-B-1	Max. Temp (°C) :	-17.9	Force Const (mN/bit) :	0.15
Test Time :	04:36:30 PM	Temp Cal Date :	05/20/2016	Defl Const (μm/bit) :	0.139
Test Date :	05/20/2016	Soak Time (min) :	60.0	Cmpl (μm/N) :	6.25
File Name :	16052005	Beam Width (mm) :	12.70	Cal Date :	05/19/2016
BBR ID :	3474	Thickness (mm) :	6.35	Software Version :	BBRw 1.24

t Time (s)	P Force (mN)	d Deflection (mm)	Measured Stiffness (MPa)	Estimated Stiffness (MPa)	Difference (%)	m-value	R-value
8.0	978	0.228	346	346	0.000	0.282	1.96
15.0	977	0.273	289	288	-0.346	0.306	1.93
30.0	976	0.341	231	231	0.000	0.332	1.91
60.0	976	0.433	182	182	0.000	0.357	1.91
120.0	975	0.560	140	141	0.714	0.383	1.91
240.0	974	0.734	107	107	0.000	0.409	1.91

A = 2.76 B = -0.205 C = -0.0428 R^2 = 0.999988

Force (t=0.0s) = 36 mN Deflection (t=0.0s) = 0.000 mm
Force (t=0.5s) = 955 mN Deflection (t=0.5s) = 0.113 mm

Max Force Deviation (t=0.5 - 5.0s) = -20, +4 mN
Max Force Deviation (t=5.0 - 240.0s) = -3, +4 mN

Average Force (t=0.5 - 240.0s) = 975 mN
Maximum Force (t=0.5 - 240.0s) = 979 mN
Minimum Force (t=0.5 - 240.0s) = 955 mN

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance
  - Recommendations
    - The current intermediate test temperatures in AASHTO M 320 and M 332 should be replaced by temperatures based on the low PG of the asphalt binder instead of the current temperatures which use the average of the High and Low PG temperatures plus 4°C.

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance
  - Recommendations

Low PG	Intermediate Test Temperature, °C
-10	29
-16	27
-22	25
-28	22
-34	19

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance
  - Expected Impacts
    - GRP is determined using T 315 on PAV-aged material at the same loading frequency (10 rad/s). No (or minimal) impact on lab operations expected.
    - One significant change could be the test temperature used by the technician for grade verification. The change to a single temperature based on the low PG of the asphalt binder means that a simplified chart can be used for determining intermediate test temperature.
      - If a user agency is using grade bumping in AASHTO M 320 for modified asphalt binders and not basing the intermediate test temperature on the base, unmodified asphalt binder grade, then the recommended change may result in testing being conducted at a lower intermediate temperature. This could have an impact on the ability of the modified asphalt binder to meet the specification value.

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance
  - Expected Impacts
    - The impact of the change to GRP will more significantly affect asphalt binders with lower phase angles, causing them to fail the specification criterion that they may have previously passed.

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance
  - Expected Impacts
    - Most PG 52 grades would be tested at temperature **6°C warmer** than current practice
    - Most PG 58 grades would be tested at temperature **3°C warmer** than current practice
    - Most PG 64 grades would be tested at the **same temperature** as current practice
    - Most PG 70 grades would be tested at temperatures **3-5°C colder** than current practice
    - Most PG 76 grades would be tested at temperatures **6-7°C colder** than current practice

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance
  - Expected Impacts

G* (kPa)/δ (degrees)	GRP, kPa			G*sin δ, kPa		
	8000	7000	6000	8000	7000	6000
40	7303	6391	5478	5142	4500	3857
42	6603	5777	4952	5353	4684	4015
45	5657	4950	4243	5657	4950	4243
47	5088	4452	3816	5851	5119	4388
50	4315	3776	3236	6128	5362	4596

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance
  - Expected Impacts
    - The estimated impact on lab operations should be very low as the principal findings from the research include:
      - calculating a new parameter from the standard AASHTO T 315 (DSR) test for use in M 320 and M 332;
      - calculating a new parameter from the standard AASHTO T 313 (BBR) test for use in M 320 and M 332;
      - changing the intermediate test temperature in for use in M 320 and M 332 for PAV DSR testing; and
      - incorporating new specification criteria for BBR testing.

Asphalt Binder Specification Objectives

- NCHRP 09-59 Objectives
  - determine asphalt binder properties that are significant indicators of the **fatigue** performance of asphalt mixtures
  - identify or develop a practical, implementable binder test (or tests) to measure properties that are significant indicators of mixture fatigue performance for use in a performance-related binder purchase specification such as AASHTO M 320 and M 332
- NCHRP 09-60 Objectives
  - propose changes to the current performance-graded (PG) asphalt binder specifications, tests, and practices to remedy gaps and shortcomings related to the premature loss of asphalt pavement **durability in the form of cracking and raveling**.

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 δ** (Ferry 1980)."

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

2. Two main types of failure during service life were encountered on the project. The most prevalent was fatigue cracking as displayed by wheel track "alligator" type cracking. The other was a large block type cracking together with pitting and raveling. This was most prevalent in the passing lane. The amount of fatigue type cracking appears to be related to the consistency of the recovered asphalt as measured by penetration and viscosity. The other form of cracking appears to be related to the gain in shear susceptibility during weathering. This is also indicated by a marked drop in ductility during service life. This form of cracking, as found on this test project appears to be the same as that encountered by P. C. Doyle, reference (4), on other test roads.

- Fatigue Cracking
  - Related to recovered asphalt binder consistency (i.e., stiffness)
- Block Cracking with Raveling
  - Weathering characterized by drop in ductility (i.e., viscoelastic behavior)

Zube and Skog:
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on the project. The most prevalent was f displayed
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the same a ntered by P. C. Doyle, reference (4), on other
test roads.

Current PG Specification (AASHTO M 320 and M 332)

- Fatigue Cracking **G*sin δ**
  - Related to recovered asphalt binder consistency (i.e., stiffness)
- Block Cracking with Raveling **n/a**
  - Weathering characterized by drop in ductility (i.e., viscoelastic behavior)

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Revised PG Specification
(AASHTO M 320 and M 332)

- Fatigue Cracking **GRP**
  - Related to recovered asphalt binder consistency (i.e., stiffness)
- Block Cracking with Raveling **R-value**
  - Weathering characterized by drop in ductility (i.e., viscoelastic behavior)

NCHRP 09-59

- Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance

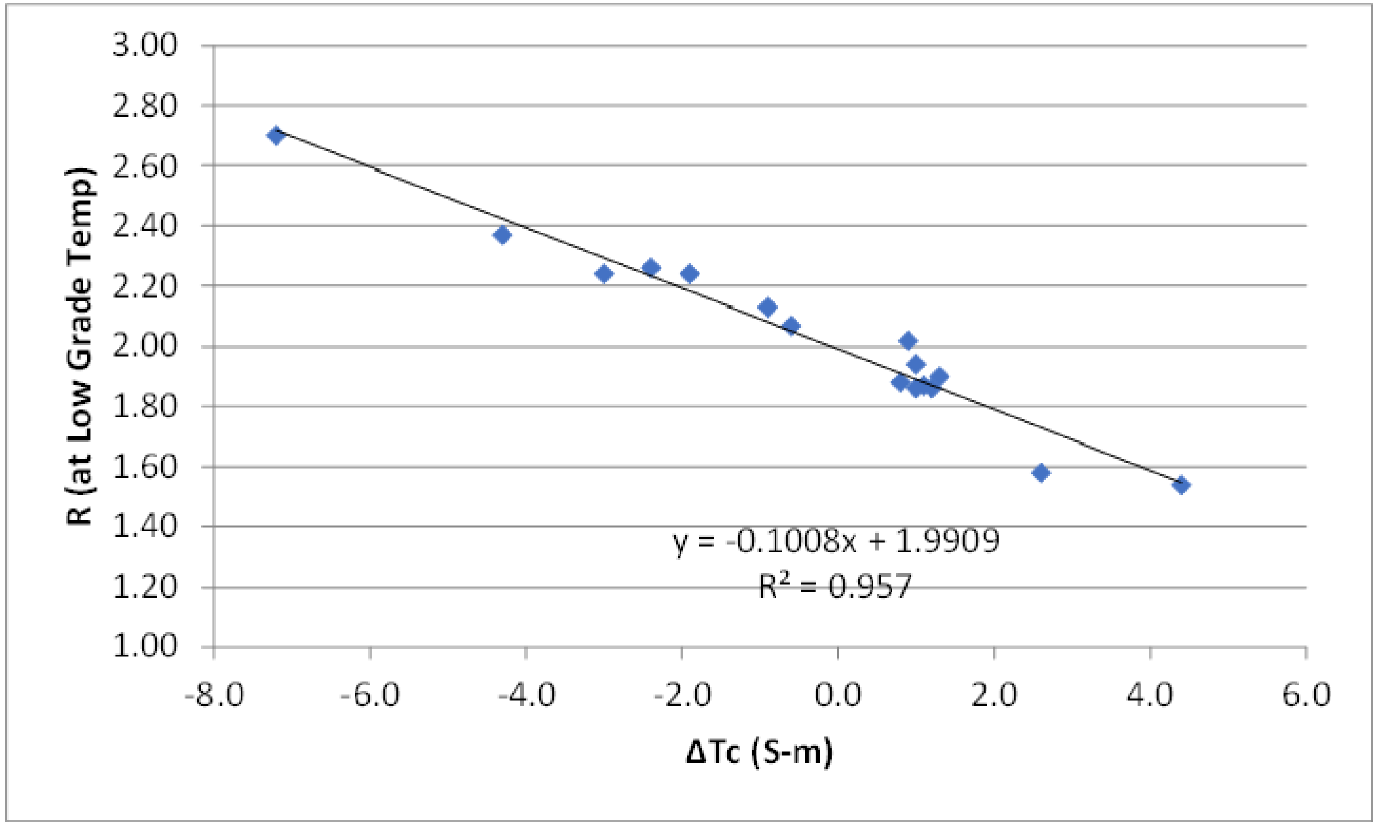


FIGURE 3. Relationship Between R Value and ΔT_c for Selected Unmodified Asphalt Binders

NCHRP 09-60

Addressing Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance through Changes in Asphalt Binder Specifications

NCHRP 09-60

- Addressing Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance through Changes in Asphalt Binder Specifications
  - Jean-Pascal Planche (PI, WRI), Michael D. Elwardany (WRI), Donald Christensen (AAT), Gayle King (Consultant), Carolina Rodezno (NCAT),and Snehalata Huzurbazar (Consultant/Statistician)
  - Objectives
    - propose changes to the current performance-graded (PG) asphalt binder specifications, tests, and practices to remedy gaps and shortcomings related to the premature loss of asphalt pavement durability in the form of cracking and raveling.

NCHRP 09-60

- Addressing Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance through Changes in Asphalt Binder Specifications
  - Key Findings
    - Recommend adding ΔT_c to AASHTO M 320 and M 332 as a specification parameter.
      - Relates to the relaxation properties of unmodified binders and generally relates to the colloidal structure of the asphalt binder.
    - The use of ΔT_c alone can underestimate the performance of some complex binders such as polymer modified asphalt (PMA) binders
      - Due to an inability to capture failure properties outside the linear viscoelastic (LVE) domain such as strength/strain tolerance of PMAs.

NCHRP 09-60

- Addressing Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance through Changes in Asphalt Binder Specifications
  - Key Findings
    - To capture strength/strain tolerance, it is recommended to use the Asphalt Binder Cracking Device (ABCD) to determine the critical cracking temperature, T_{cr}
      - AASHTO T 387, Determining the Cracking Temperature of Asphalt Binder Using the Asphalt Binder Cracking Device (ABCD)
    - T_{cr} is used with the temperature at which BBR Stiffness at 60 seconds of loading is equal to the specification value of 300 MPa ($T_{c,S}$)

NCHRP 09-60

- Addressing Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance through Changes in Asphalt Binder Specifications
  - Key Findings
    - A new parameter, ΔT_f is determined as the difference between $T_{c,S}$ and T_{cr}
      - Higher values of ΔT_f are associated with better asphalt binder strength/strain tolerance relative to its stiffness.

NCHRP 09-60

- Addressing Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance through Changes in Asphalt Binder Specifications
  - Key Findings
    - New revised specification:
      - Uses standard RTFO/PAV20 aging
      - Uses BBR data to determine $T_{c,S}$, $T_{c,m}$ and ΔT_c.
      - Uses ABCD to calculate T_{cr}

NCHRP 09-60

- Addressing Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance through Changes in Asphalt Binder Specifications
  - Key Findings
    - If ΔT_c values are less than -6°C, then the asphalt binder fails to meet the specification.
    - If ΔT_c values are greater than -2°C, then the asphalt binder meets the specification.
    - If ΔT_c values are less than or equal to -2°C and greater than or equal to -6°C, then the ABCD test is used to determine T_{cr} and, subsequently, ΔT_f.
      - In this instance, the ΔT_f must be greater than a specified value from 7 to 10°C as a function of the ΔT_c value to meet the specification.

NCHRP 09-60

- ABCD
  - AASHTO T 387
  - Summary of Method
    - Asphalt binder is heated and poured into silicone mold with strain gauge
    - Sample is cooled at a constant rate
      - From 20°C to 0°C in 30 minutes
      - From 0°C to cracking temperature at a rate of 20°C/hr
    - Sample cracks when jump in strain appears
      - T_{cr} is temperature at which that jump occurs

NCHRP 09-60

- ABCD

Figure 2: ABCD setup: Temperature Chamber; Filled & Empty Ring (King, 2007).

AASHTO T 387

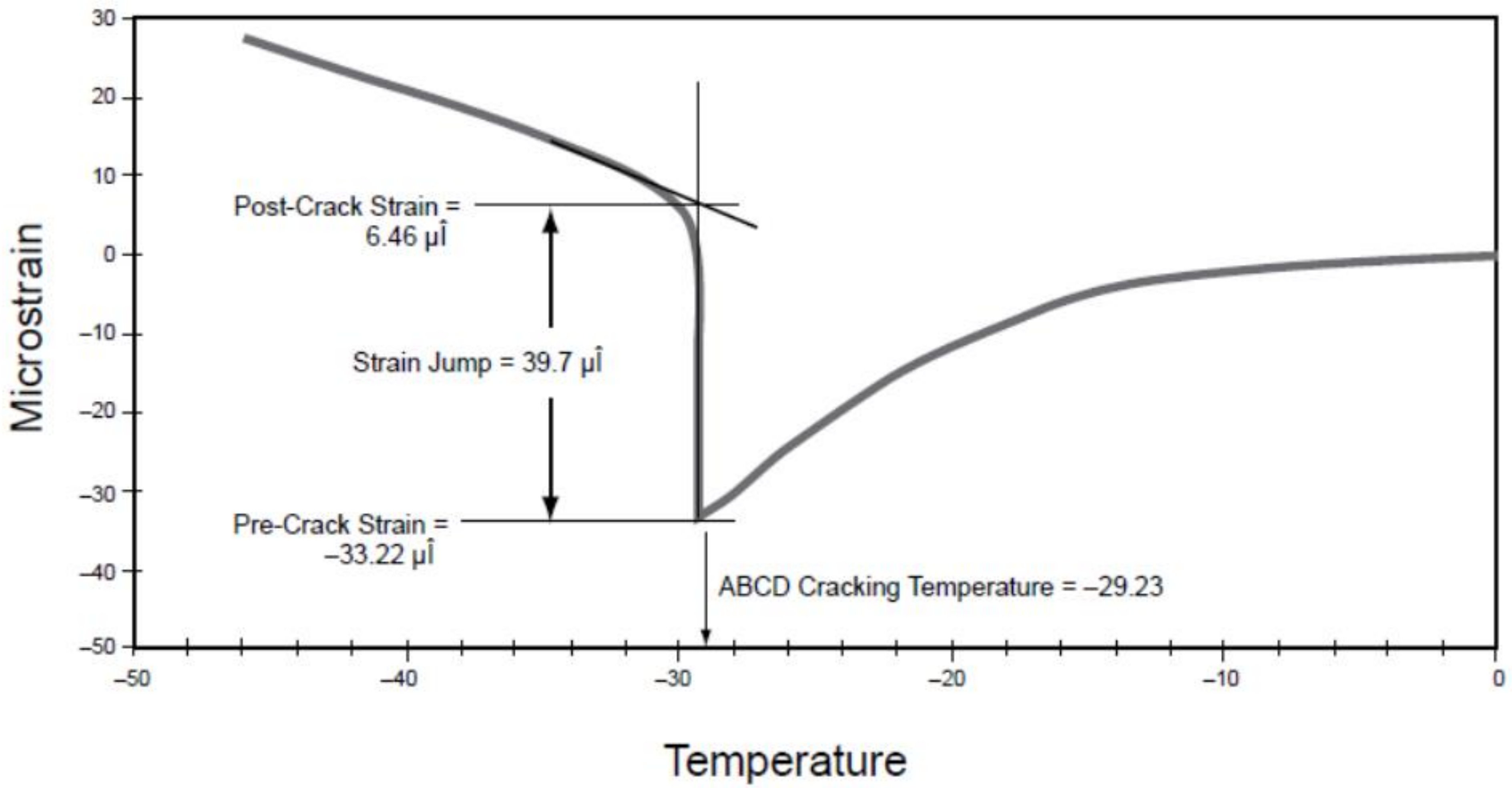


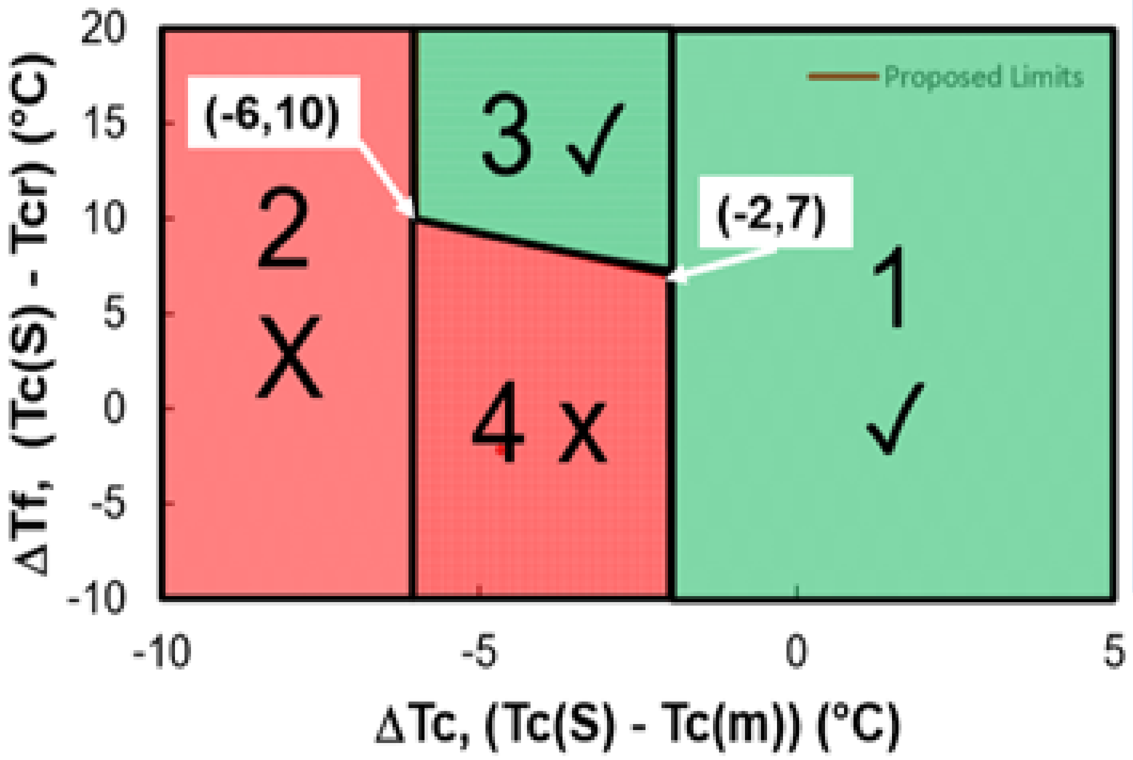
Figure 6—Typical ABCD Test Results: Strain versus Temperature

NCHRP 09-60

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

NCHRP 09-60

- Addressing Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance through Changes in Asphalt Binder Specifications
  - Expected Impacts
    - The determination of ΔT_c requires testing at two or more BBR temperatures. This may be an operational challenge for user agencies who are most often just verifying the grade of the asphalt binder.

NCHRP 09-60

- Addressing Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance through Changes in Asphalt Binder Specifications
  - Expected Impacts
    - The determination of ΔT_f requires the use of the ABCD test to first determine T_{cr}.
    - The ABCD equipment is not widely available commercially at this time.
    - Estimated equipment cost is likely to be in the range of $40,000 to $50,000.

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- Addressing Impacts of Changes in Asphalt Binder Formulation and Manufacture on Pavement Performance through Changes in Asphalt Binder Specifications
  - Expected Impacts
    - The use of the ABCD test with BBR testing means that 1-2 additional pans of PAV-aged asphalt binder may be needed.

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- Expected Impacts
  - The use of ΔT_f in the manner proposed – as an additional test when routine testing indicates that the specification is not met – is similar to the way in which the Direct Tension test can be used in AASHTO M 320 Table 1.
  - Footnote g in AASHTO M 320 Table 1:
    - "If the creep stiffness is below 300 MPa the direct tension test is not required. If the creep stiffness is between 300 and 600 MPa, the direct tension failure strain requirement can be used in lieu of the creep stiffness requirement. The m-value requirement must be satisfied in both cases."

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- Expected Impacts
  - AASHTO M 320 Footnote g was rarely employed for a few reasons:
    1. The Direct Tension test was cumbersome to execute properly and had higher-than-desirable variability.
    2. The condition where m-value met the requirement, but S failed the requirement only occurred for S-controlled asphalt binders (positive ΔT_c values). Asphalt binders supplied for conformance to AASHTO M 320 were more often m-controlled (negative ΔT_c values).
    3. Asphalt binders that failed the maximum 300 MPa requirement at a given temperature it still could be sold as an asphalt binder with a higher low temperature PG.
       - In other words, if the sample failed S at -18°C but passed m-value, rather than running the Direct Tension test and possibly selling the asphalt binder as a PG xx-28, it could just be sold as a PG xx-22. In some cases, the additional testing might be beneficial, but often it was just avoided.

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- Expected Impacts
  - AASHTO M 320 Footnote g was rarely employed for a few reasons:
    - Although Reason (1) is likely still a fair statement for the ABCD test, Reasons (2) and (3) are different.
      - The use of ΔT_c as a criterion means that the specification is identifying m-controlled asphalt binders, which are more common.
      - ΔT_c is a temperature-independent parameter – meaning that there is no recourse to sell an asphalt binder with a failing ΔT_c value as a different grade.

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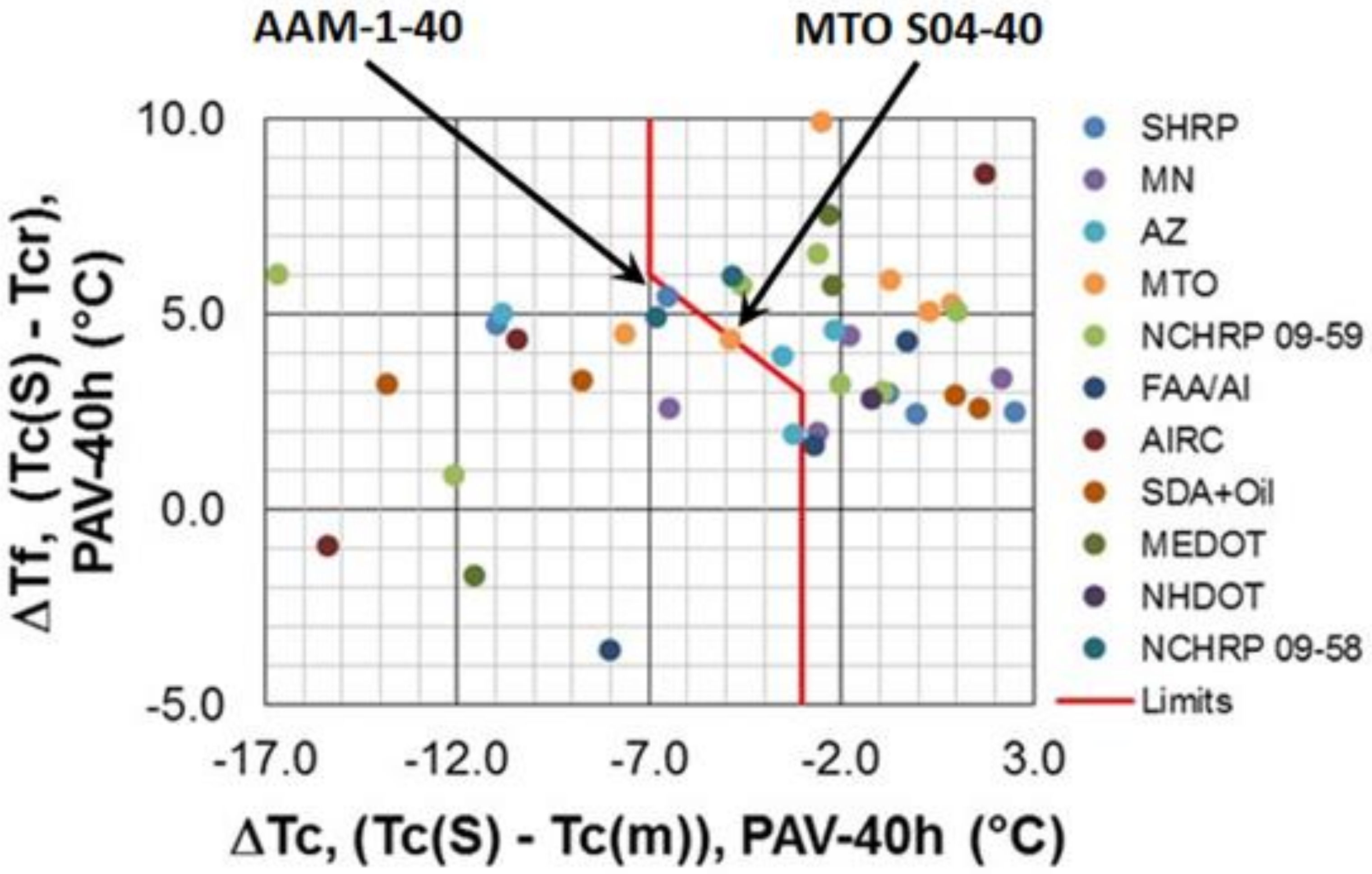
- Expected Impacts



NCHRP 09-59 and 09-60 (PAV20)

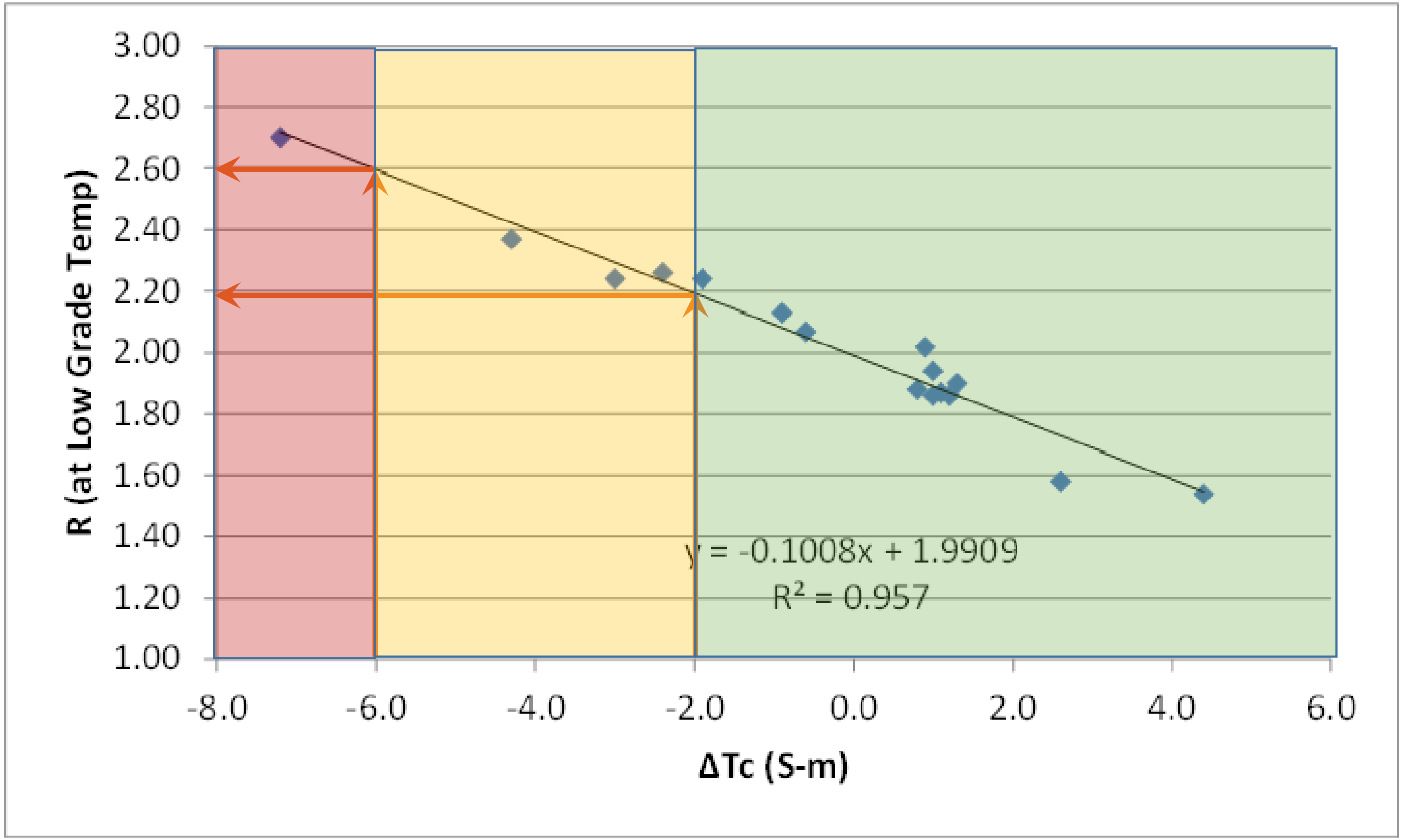


FIGURE 3. Relationship Between R Value and ΔT_c for Selected Unmodified Asphalt Binders

NCHRP 09-59 and 09-60 (PAV20)

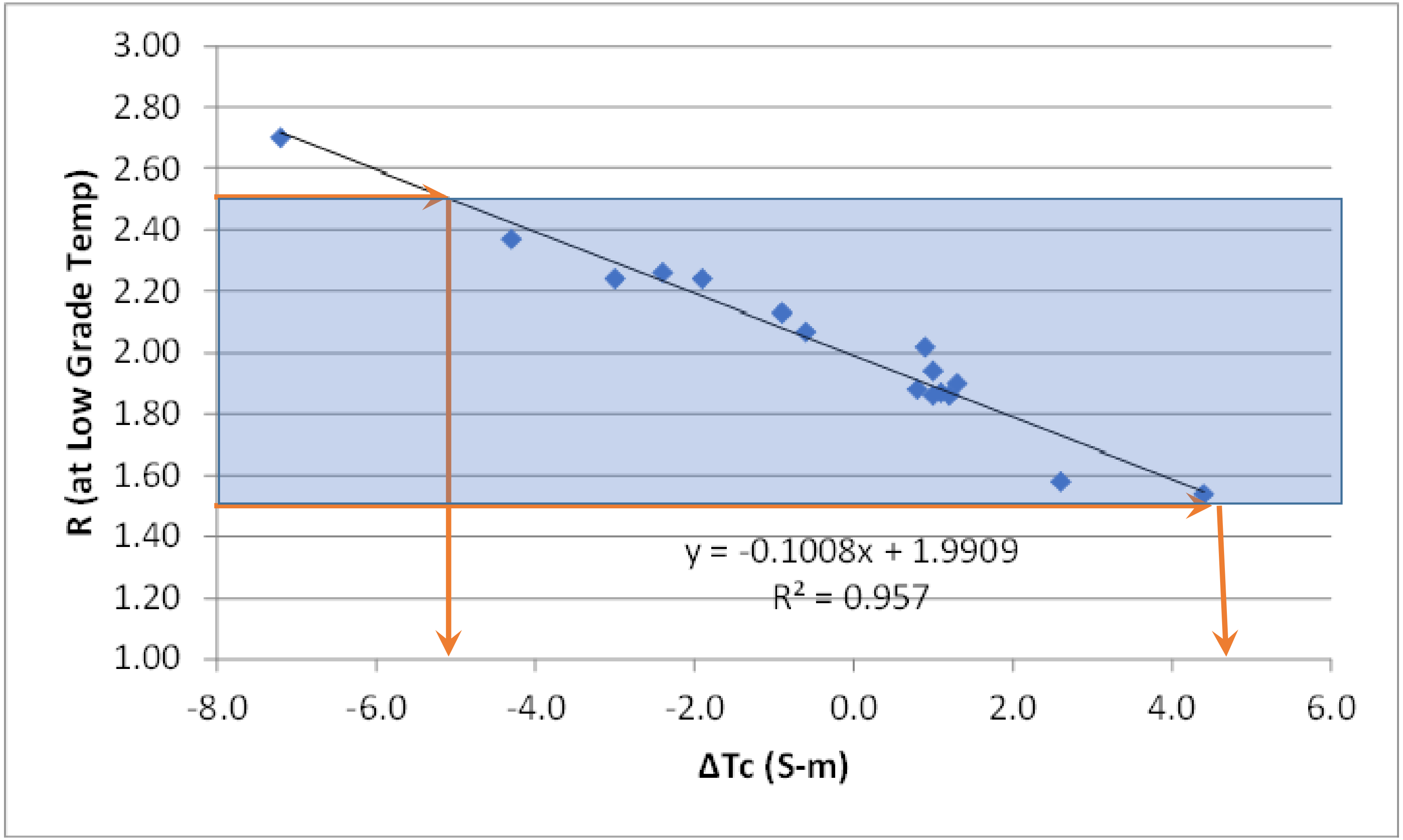


FIGURE 3. Relationship Between R Value and ΔT_c for Selected Unmodified Asphalt Binders

NCHRP 09-59 and 09-60 (PAV20)

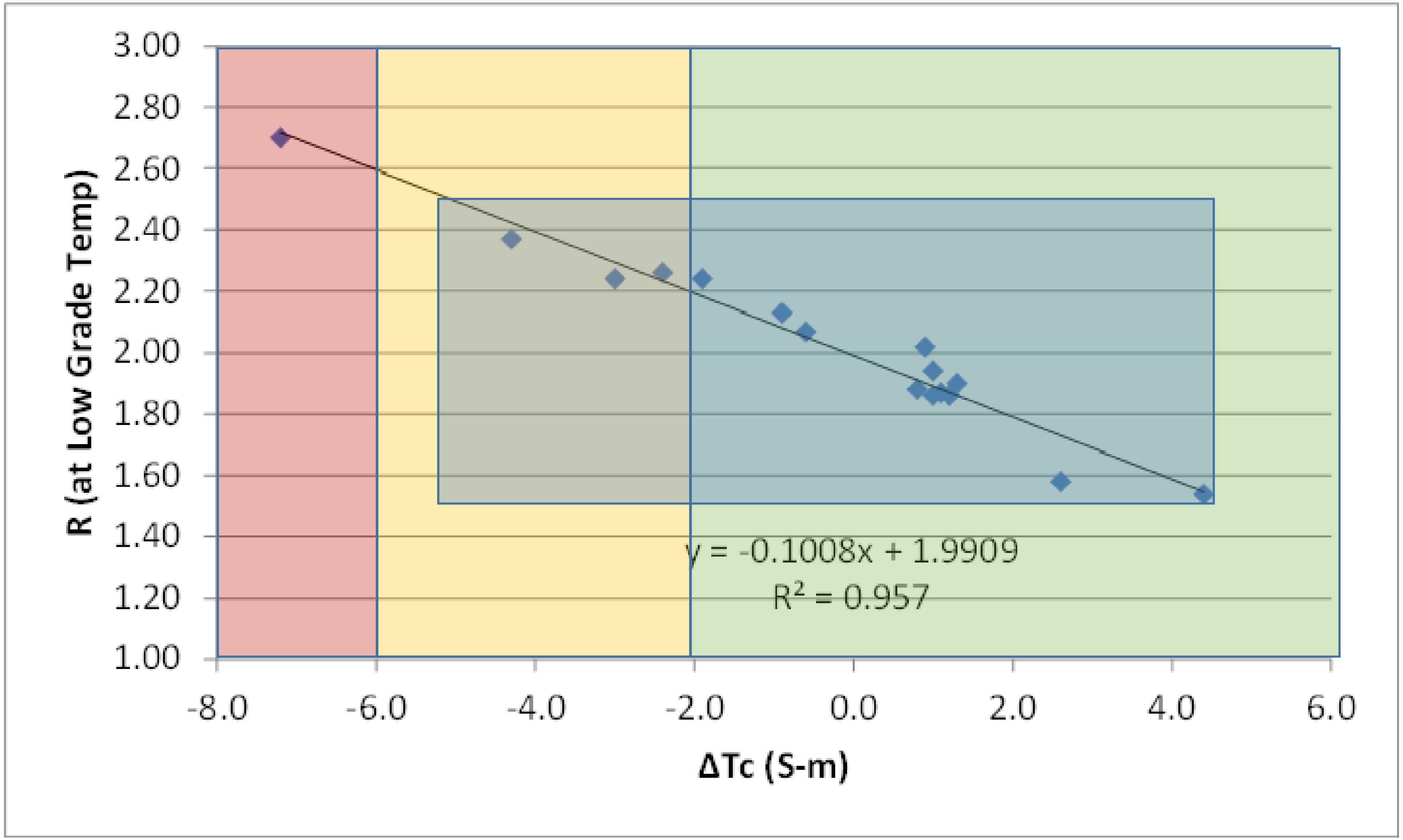


FIGURE 3. Relationship Between R Value and ΔT_c for Selected Unmodified Asphalt Binders

NCHRP 09-61

Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures

NCHRP 09-61

- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Ramon Bonaquist (PI, AAT), Jeramie J. Adams (WRI), and David A. Anderson (Consultant)
  - Objectives
    - develop practical laboratory aging methods to accurately simulate the short-term (from production to placement) and long-term (in-service) aging of asphalt binders.
    - determine the relationship between different methods of laboratory aging of asphalt binders and the actual aging that occurs during mixture production, transport, and placement as well as during the service life of the pavement structure.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Key Findings
    - The recommendation for short-term conditioning of asphalt binders is to continue to use AASHTO T 240
    - Although the film thickness and its renewal during the test depend on the consistency of the asphalt binder, properties of residue from AASHTO T 240 agree reasonably well with the properties of asphalt binder recovered from mixtures which were short-term conditioned in accordance with the recommendations from NCHRP 09-52

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Key Findings
    - A survey of agency technicians resulted in a report that approximately 4% of asphalt binders creep from the container during AASHTO T 240.
      - Binder loss issue was reported for both neat and modified asphalt binders.
      - Some states report no loss, while neighboring states report high percentages.
      - Appears that equipment and technique need evaluation rather than a wholesale replacement of AASHTO T 240.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Key Findings
    - The recommendation for long-term conditioning of asphalt binders is that changing the operating parameters of the PAV (AASHTO R 28) can produce residue that reasonably simulates near-surface aging after 10 years in-service.
    - Changes will generally require thinner films and high temperatures in the PAV.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Key Findings
    - Use PAV procedure with the standard 20-hr aging at 2.1 MPa pressure but only 12.5 grams of asphalt binder in the pan (instead of 50 grams)
      - Calibrated results to the properties of recovered asphalt binders from 26 LTPP pavement sections where original binder and cores from 8 to 16 years in-service were available.
      - The findings of that calibration indicate that the PAV temperature to use depends on the average of the 98 percent reliability high and low pavement temperature from LTPPBind3.1.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Key Findings
    - The researchers recognized two main problems with implementing the change in PAV conditions (temperature and film thickness).
      - PAV pan must be very level to maintain even film thickness
        - Level within about 0.00045 mm/mm.
        - Very difficult to achieve with current PAV designs.
        - Will be necessary to have PAVs with automatic leveling control.
      - When using the recommended temperatures in a sensitivity study, it was found that some modified binders do not completely cover the pan.
        - A levelling step at a higher temperature under inert atmosphere needs to be added.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Key Findings
    - Residue from static conditioning of 12.5 g of binder in a PAV pan in an oven also reasonably reproduced the properties of binder recovered from short-term conditioned loose mix.
      - Possible that the same equipment can be used for short- and long-term conditioning.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Key Findings
    - Using the same film thickness and pans for short- and long-term conditioning offers the potential to simplify laboratory conditioning.
      - Short-term condition the binder in the PAV in the pans used for the long-term procedure at low-pressure at 163 °C.
        - Conditioning the thin film under a low pressure above atmospheric would eliminate the laboratory elevation effect that is known to be an issue with AASHTO T 240.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Key Findings
    - Upon completion of the short-term conditioning, one pan would be removed, cooled, weighed for mass change determination, and the residue tested for high pavement temperature rheological properties.
    - The temperature would be reduced to the long-term conditioning temperature, the pressure increased to 2.1 MPa, and the binder further conditioned for 20 hours.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Key Findings
    - Combined short- and long-term conditioning
      - removes the viscosity-dependent film renewal associated with AASHTO T 240
      - removes the laboratory elevation effect associated with AASHTO T 240
      - eliminates binder transfer loss between short- and long-term conditioning
      - improves the uniformity of the thin film for the subsequent long-term conditioning due to the higher temperature used for the short-term conditioning.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Key Findings
    - Combined short- and long-term conditioning
      - Not recommended as an AASHTO standard until there is prototype equipment available.
        - Prototype equipment should have:
          - a level pan system (current ovens used for short-term conditioning have shelves that warp as the oven heats, so leveling the pan is very difficult)
          - accurate temperature control from 80 to 170°C
          - accurate pressure control at both low pressure and 2.1 MPa
          - the potential ability to introduce air and an inert gas depending on how well modified binders level at 163°C.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
    - Recommendations
        - Continue to use RTFO for short-term aging of asphalt binders
        - If 20-hour PAV is to be used then no changes recommended
        - If longer aging simulation is required then instead of 40-hour PAV using 50 grams of asphalt binder at 90, 100, or 110°C use 20-hour PAV with 12.5 grams of asphalt binder at varying temperature based on high and low pavement temperature.

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TABLE 4. NCHRP 09-61 Draft Final Report: Recommended 12.5 g, 20-hr PAV Conditioning Temperatures for Performance Grading

Average of 98 % Reliability High and Low Pavement Temp., °C	Calculated PAV Temp., ºC	Recommended PAV Temp., ºC	% of LTPPBind 3.1 Stations	PG Grade Based on Environment
-6[1]	84.4	85	1	PG 40-52; PG 46-52; PG 40-46
-3[1]	86.6			
0[1]	88.9	90	4	PG 52-52; PG 46-46; PG 40-40; PG 46-40; PG 52-46; PG 40-34
3	91.1			
6	93.4	95	20	PG 58-46; PG 52-40; PG 46-34; PG 40-28 PG 58-40; PG 52-34; PG 46-28; PG 40-22
9	95.7			
12	97.9	100	41	PG 64-40; PG 58-34; PG 52-28; PG 46-22; PG 40-16 PG 64-34; PG 58-28: PG 52-22; PG 46-16; PG 40-10 PG 64-28; PG 58-22; PG 52-16; PG 46-10
15	100.2			
18	102.5			
21	104.8	105	20	PG 70-28; PG 64-22; PG 58-16; PG 52-10 PG 70-22; PG 64-16; PG 58-10
24	107.1			
27	109.3	110	13	PG 70-16; PG 64-10; PG 70-10
30	111.6			
33[1]	115.0	115	1	PG 76-10

[1] Outside range of data used in calibration.
Gray shaded cells indicate standard PAV aging temperatures per *AASHTO M 320* and *M 332*.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Expected Impacts
    - No impact on lab operations for agency and industry labs for short-term aging
      - Continue to use RTFO procedure
      - Labs that experience asphalt binder loss during the conduct of AASHTO T 240 may need to consider changes in technique and/or training to minimize the occurrence of binder loss during the procedure.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Expected Impacts
    - Depending on level of long-term aging desired, the procedure using the PAV (AASHTO R 28) could have a greater impact on lab operations.
      - The use of extended aging (40 hours in the standard PAV) impacts operations by requiring twice as long before aged residue can be obtained for intermediate and low temperature asphalt binder properties.
      - The reduction in film thickness in the pans from 3.1 millimeters (50 grams of asphalt binder) to 0.8 millimeters (12.5 grams of asphalt binder) allows the conditioning to be conducted using the standard time (20 hours) while still producing residue that has the same properties as the extended aging time (40 hours). This significantly improves lab operations.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Expected Impacts
    - The challenge with using thinner films is maintaining a consistent film thickness.
      - Requires very level pans that are not warped.
      - Operationally could pose a significant challenge for labs to routinely ensure levelness.
      - An extra levelling step conducted at a higher temperature under inert atmosphere may be needed for some modified asphalt binders.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Expected Impacts
    - The last recommended change was to use a varying PAV temperature as a function of the high and low PG temperature of the asphalt binder.
    - The recommended temperatures are 85-115°C in 5°C increments based on the asphalt binder PG.

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- Short- and Long-Term Binder Aging Methods to Accurately Reflect Aging in Asphalt Mixtures
  - Expected Impacts
    - This change may have some impact on operations.
      - In current practice, a PG 58-28 asphalt binder sample could be subjected to long-term conditioning in the same PAV run as a PG 64-22 asphalt binder since both would be conditioned at 100°C. In the proposed practice, a PG 58-28 would be conditioned at 100°C, but a PG 64-22 asphalt binder would be conditioned at 105°C.
      - Could need additional PAV equipment to accommodate the increased operating temperatures.
      - Education needed to understood the appropriate temperature for conditioning.

Future Performance-Graded Asphalt Binder Specifications

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:[i] 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] $T_{c,S} - T_{cr}$	≥ +8.5											

[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.

Conceptual PG Asphalt Binder Specification (Longer 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]	110	105		100			110		105		100	
Dynamic shear, T 315: $G^* (\cos \delta)^2 / \sin \delta$,[d] maximum value 8,000 kPa, at 10 rad/s and test temperature, °C[e,h]	29	27	25	22	19	17	29	27	25	22	19	17
Creep stiffness, T 313:[i] 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	1.50/3.20											
ΔT_c $T_{c,S} - T_{c,m}$	≥ -3.0[m]											
ΔT_f[m] $T_{c,S} - T_{cr}$	≥ +4.5											

[m] If ΔT_c is greater than or equal to -3.0 then the determination of ΔT_f is not required. If ΔT_c is between -3.0 and -7.0 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.

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
    - 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
      - No change for PG 58-28 and PG 64-22 grades

- **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

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

- **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

asphalt institute

- Questions or Comments?

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