State-of-the-Knowledge Document on Delta T_c

53rd Mid-Atlantic QAW

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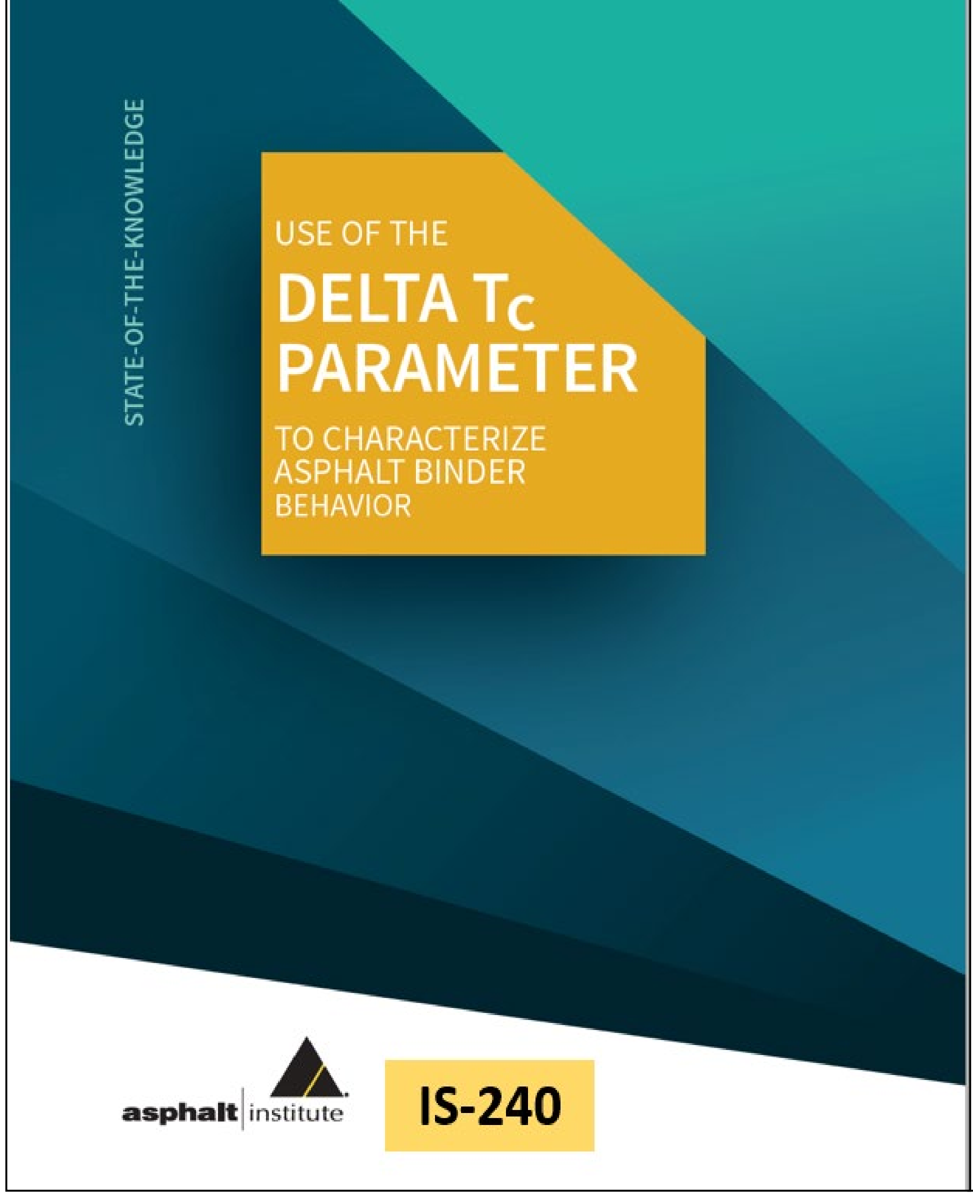
- 11 chapters, 64 pages
- Free download as e-Book on AI’s website (under Engineering)



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http://www.asphaltinstitute.org/engineering/delta-tc-technical-document/

Asphalt Institute Publication

- IS document is a technical “state of the knowledge” document that captures the consensus of the asphalt binder suppliers in the United States on a wide variety of topics related to:
  - Aging/testing
  - Pass/Fail criteria
  - Adoption of ΔT_c in a binder purchase specification
- Not intended to provide guidance
- Asphalt Institute does not take a position on the adoption of ΔT_c in a binder purchase specification

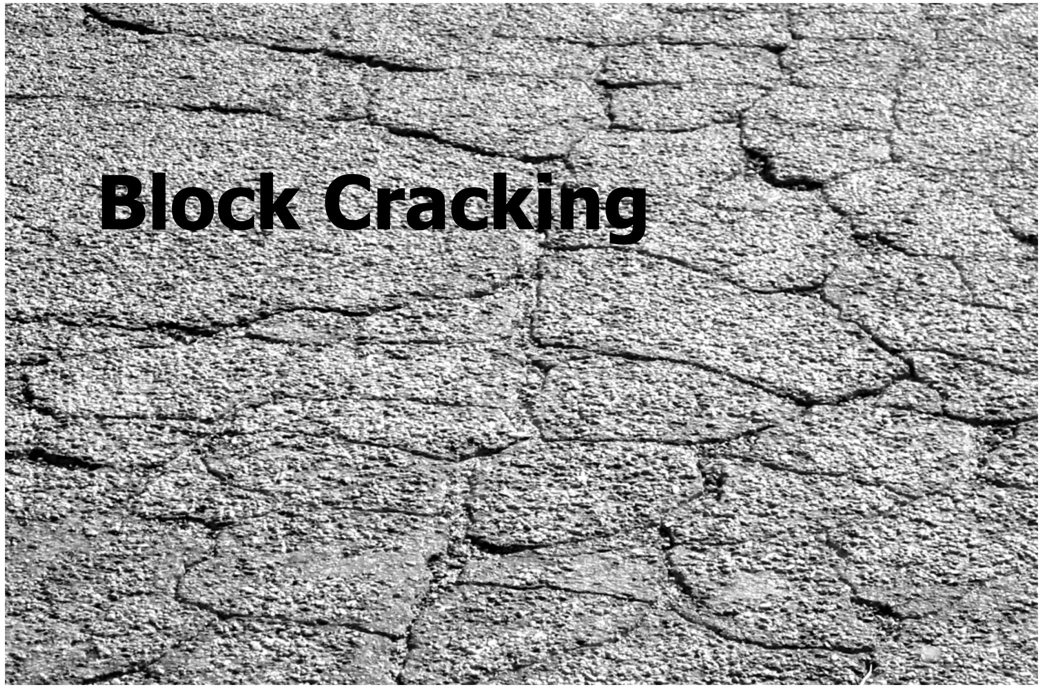
Document Background and Purpose

- AI TAC decided in April 2019 to develop this document
- Why
  - More and more agencies looking to implement ΔTc in binder purchase spec
  - Relevant info on ΔTc was scattered
  - Difficult to sort through relevant sources
- Need
  - Single, comprehensive, up-to-date reference
  - Focal point for dialog to those wanting a better understanding of ΔTc and its relevance in characterizing binder behavior

Delta Tc Background

What is ΔTc?

- Asphalt durability parameter derived from low temp BBR test and results (S and m)
- Provides insight into binder relaxation properties that contribute to non-load related cracking and other age-related embrittlement distresses



What is ΔTc?

- Conceptualized by Anderson, et al. in Journal AAPT, Vol. 80, 2011
  - FAA sponsored study, AAPTP 06-01 Techniques for Prevention and Remediation of Non-Load-Related Distresses on HMA Airport Pavements
  - Intended as a <u>forensic analysis</u> of existing airfield pavements
  - Aimed at timing of preventive maintenance
- Since 2011 gained interest as <u>specification</u> parameter by DOT’s

AAPTP 06-01 Research Objectives

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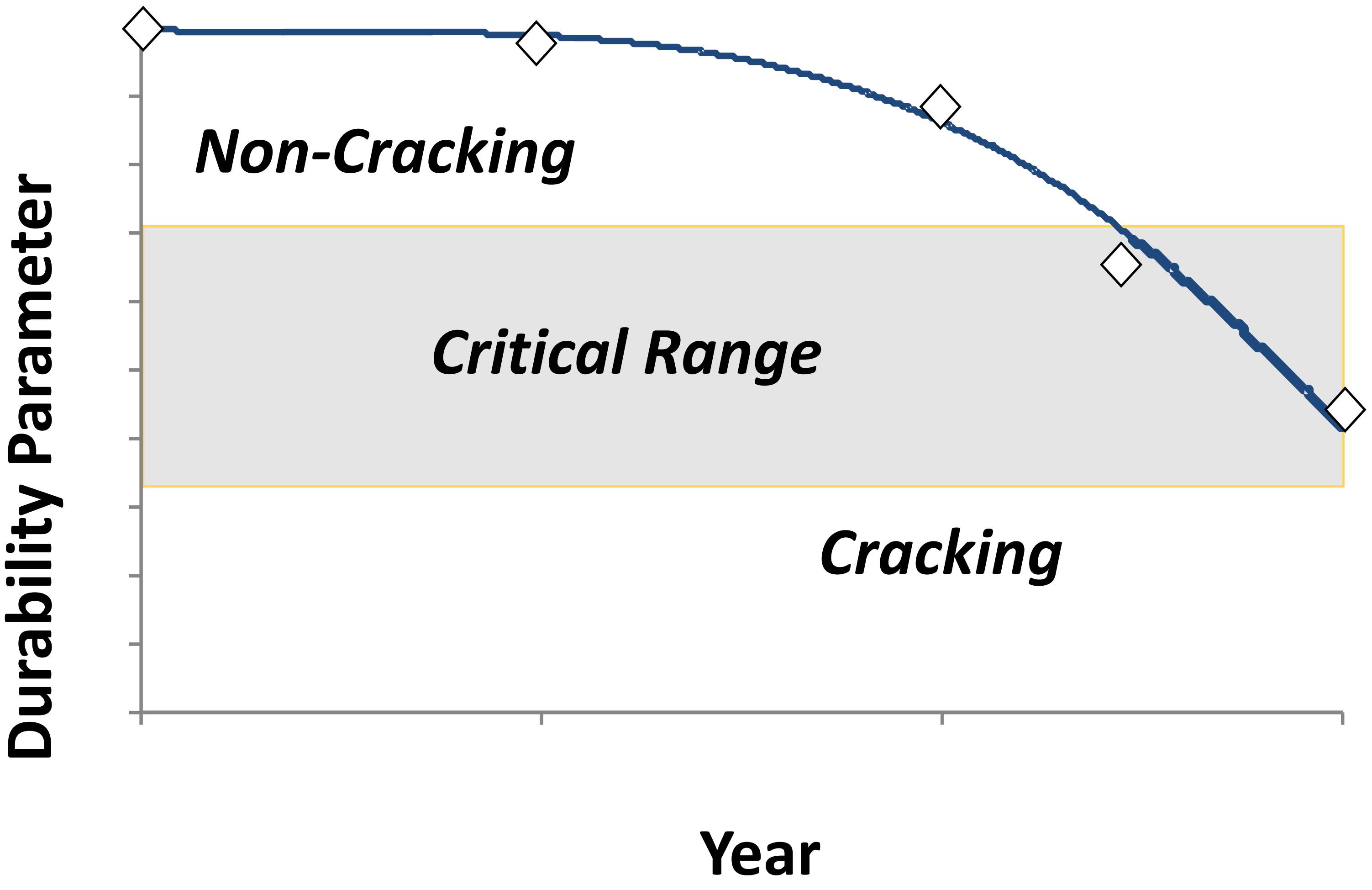
- Objectives
  - Develop a practical guide identifying means to prevent and mitigate cracking caused by environmental effects.
  - Develop one or more test procedures that could be used by a pavement manager to determine when preventative maintenance is needed to prevent the development of cracking (specifically block cracking).

TPF-5(153) Research Objectives

- TPF-5(153) Optimal Timing of Preventive Maintenance for Addressing Environmental Aging in Hot-Mix Asphalt Pavements
  - MN, MD, OH, TX, WI, LRRB
- Primary Objective
  - to develop and validate technology that can be used by highway agencies to determine the proper timing of preventive maintenance in order to mitigate damage caused by asphalt aging

Concept



Non-Cracking
Critical Range
Cracking
Durability Parameter
Year

General Concept

- In-service aging leads to oxidation and loss of flexibility at intermediate and low temperatures
  - Block-cracking
    - when environmental (non-load) conditions create thermal stresses that cause strain in the asphalt mixture that exceeds the failure strain

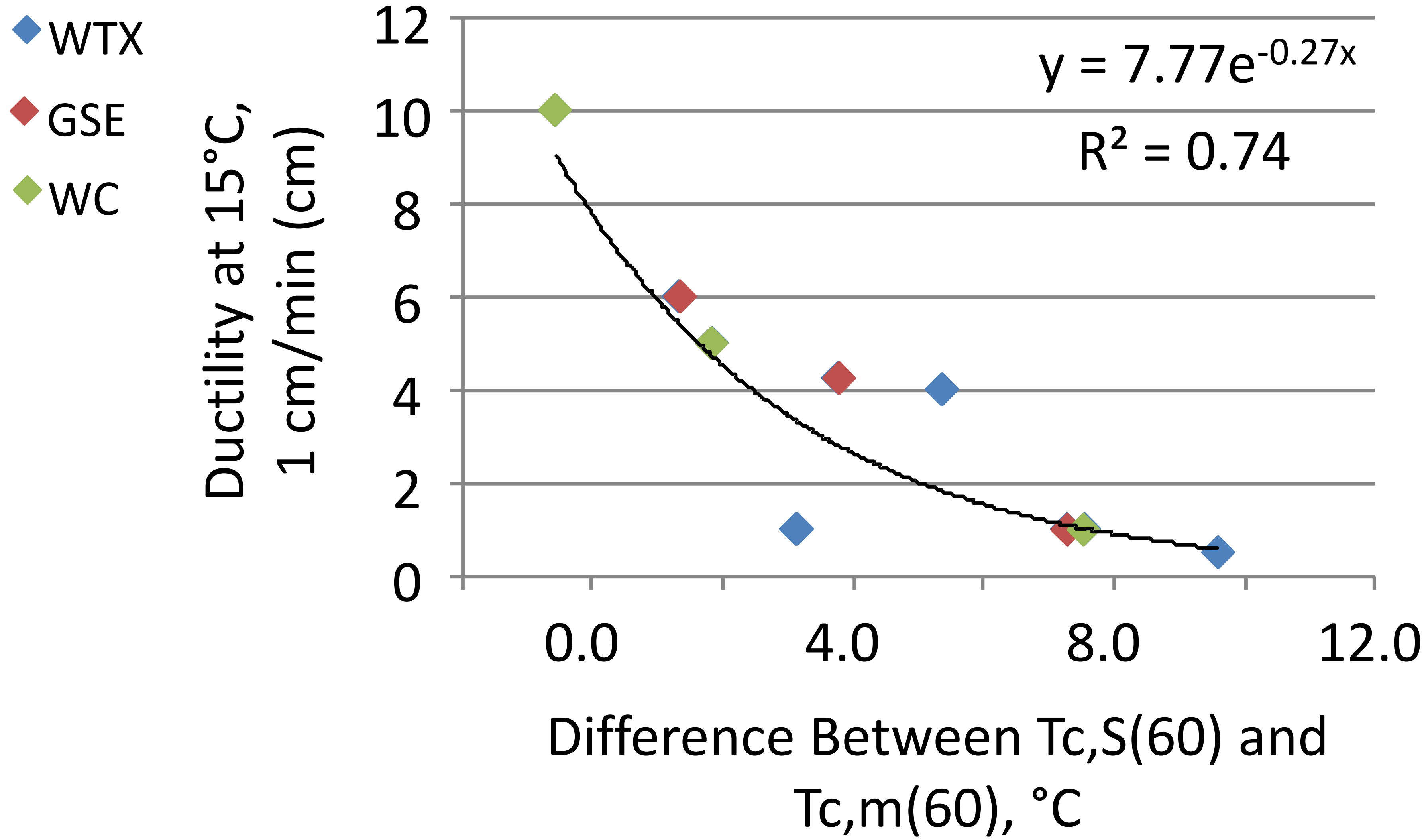
General Concept

- In-service aging leads to oxidation and loss of flexibility at intermediate and low temperatures
  - Preventing or mitigating distress
    - identify a property of the asphalt binder or mixture that sufficiently correlates with its flexibility
    - provide a procedure to monitor when flexibility reaches a state where corrective action is needed

Asphalt Oxidation

- Physical Changes – Ductility
  - Block cracking severity related to ductility at 60°F (15°C) – Kandhal (1977)
    - “Low-Temperature Ductility in Relation to Pavement Performance”, ASTM STP 628, 1977
  - Loss of surface fines as ductility = 10 cm
  - Surface cracking when ductility = 5 cm
  - Serious surface cracking when ductility < 3 cm

Relationship between ΔT_c and Ductility



Delta Tc
What is it and How is it Determined?

What is Delta Tc (ΔTc)

- **Delta Tc** (ΔTc) is a parameter that provides insight into the relaxation properties of an asphalt binder which can contribute to non-load related cracking or other age-related embrittlement distresses in an asphalt pavement.
- It is a calculated value using the results (S and m) from the BBR test.
- It is intended to be used on binder that has been short and long-term aged (RTFO plus PAV)
- Can also be used on binder recovered from asphalt pavements

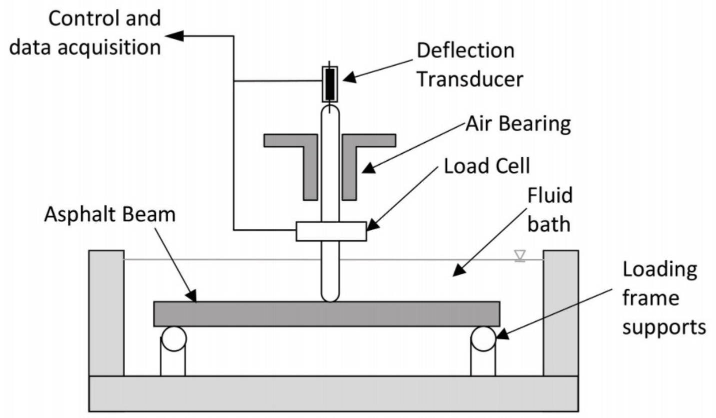
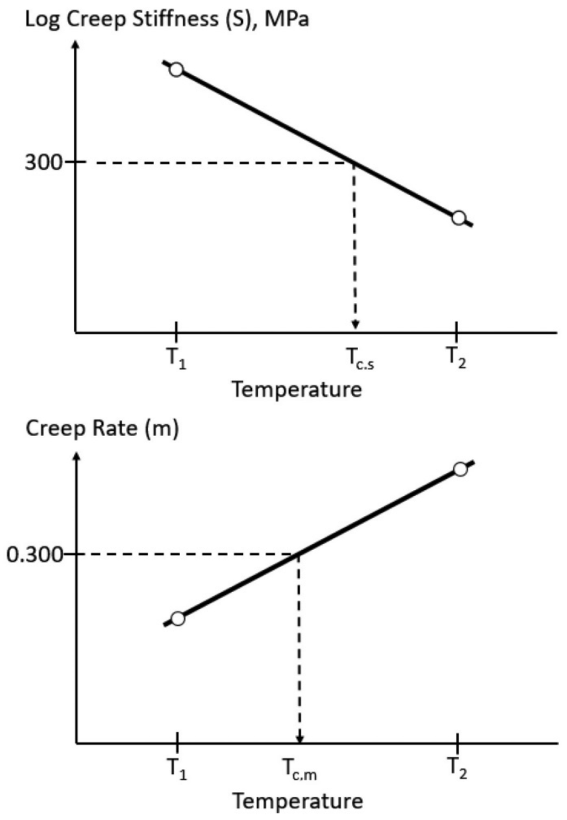


Figure 8. Simple Schematic of BBR Test Apparatus

What is Delta Tc (ΔT_c)?

- Delta Tc (ΔT_c) is the difference between the critical low temperatures of the asphalt binder, determined using the Bending Beam Rheometer (BBR), where the stiffness (S) at 60 seconds of loading time is exactly equal to the specification value of 300 MPa and the m-value (m) at 60 seconds of loading time is exactly equal to the specification value of 0.300.



What Does ΔT_c Represent?

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- ΔT_c represents the relationship between stiffness and relaxation
  - As aging occurs, S increases and m decreases
  - Similar response at intermediate temperatures for G* (increases) and δ (decreases)
  - Balance between change in stiffness and proportion of viscous and elastic properties

Determining ΔT_c

- Calculate the value of ΔT_c :

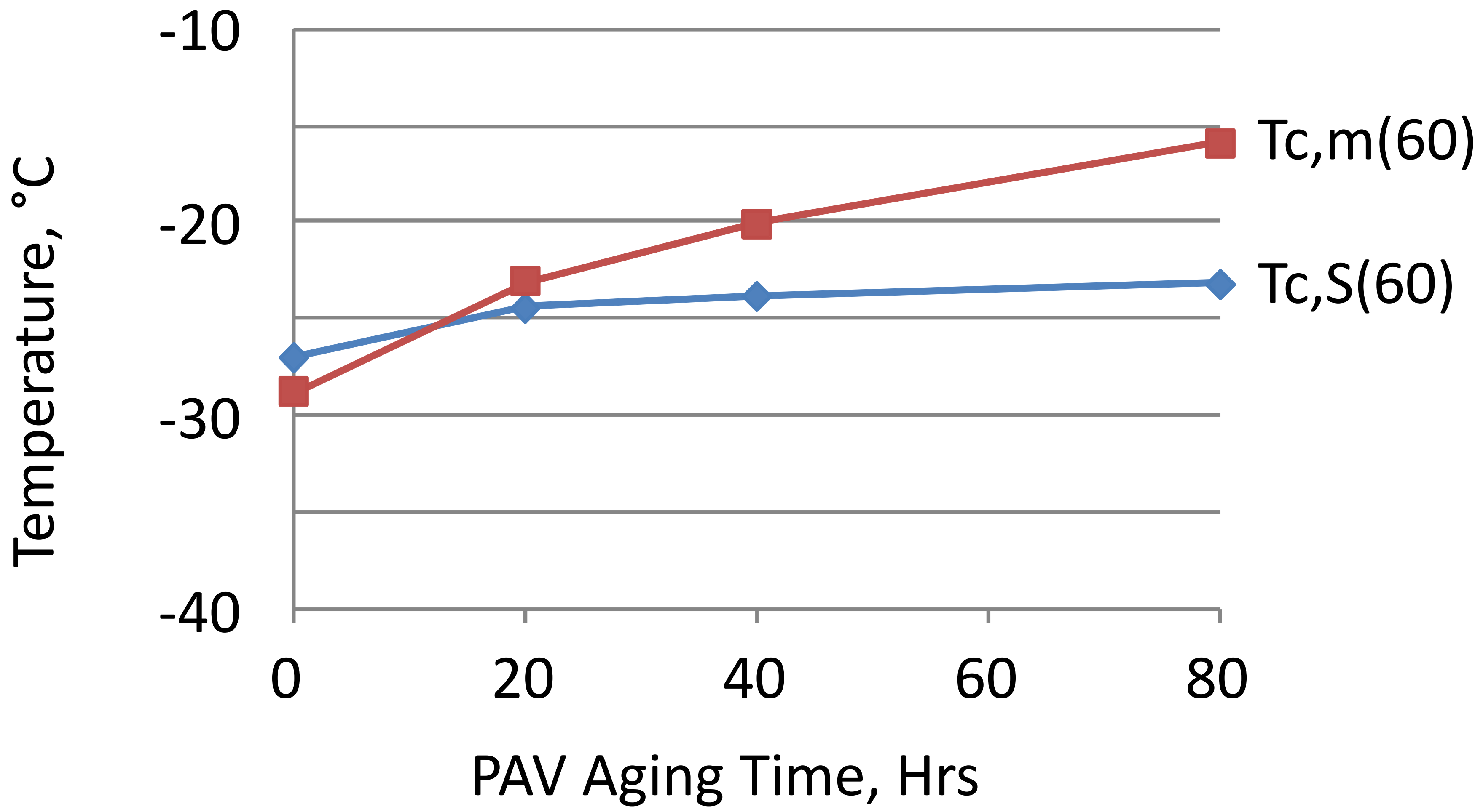
$$\Delta T_c = T_{c,S} - T_{c,m}$$

- Positive values of ΔT_c indicate an S-controlled asphalt binder
- Negative values of ΔT_c indicate an m-controlled asphalt binder

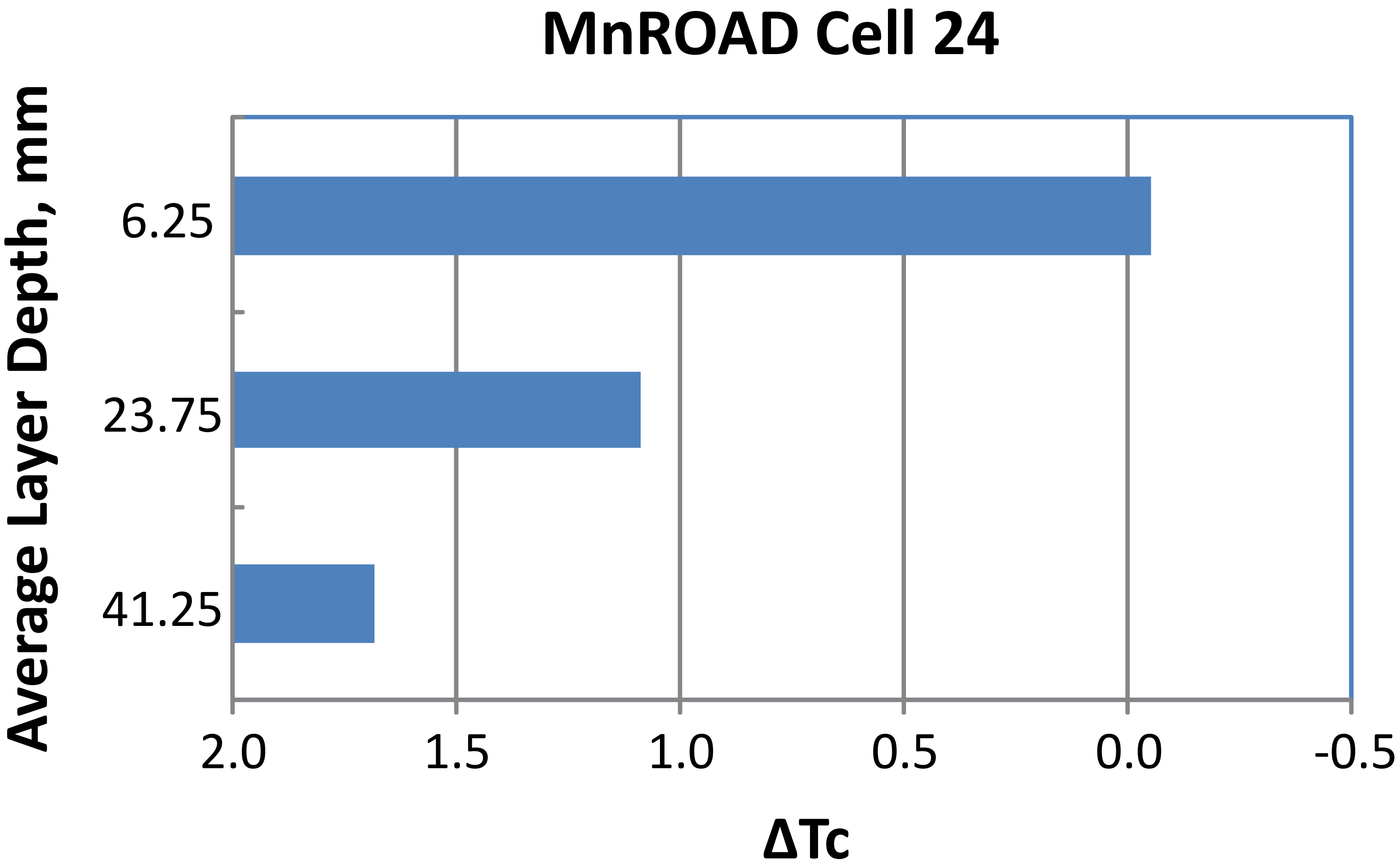
Relaxation

- **ΔTc is related to the relaxation properties of a binder. What is relaxation and how does binder relaxation properties relate to mixture performance?**
  - Asphalt exhibits a bit of viscous behavior, even at low temperatures when its behavior is mostly considered elastic.
  - Therefore, when thermal stresses build up as a pavement gets colder, the asphalt binder will gradually experience viscous flow and the stresses will greatly reduce.
    - This reduction of stresses over time is what is known as relaxation.
    - In general, as a binder ages, its relaxation properties are diminished.
    - An asphalt pavement that has a binder with good relaxation properties will be less likely to have durability-related cracking than a pavement containing a binder with poor relaxation properties.

BBR: Gulf-Southeast (GSE)



ΔT_c is an Indicator of Oxidative Aging



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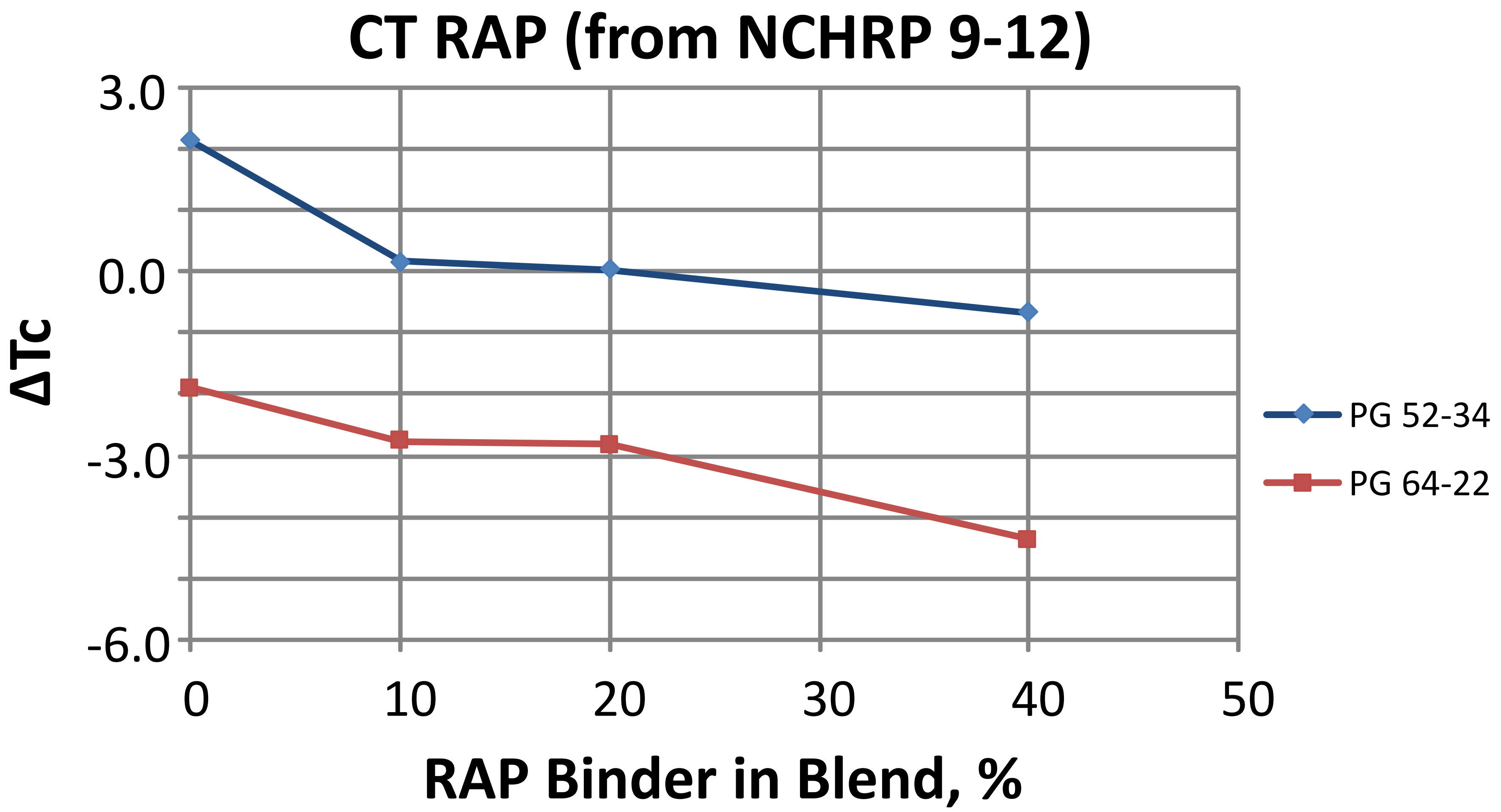

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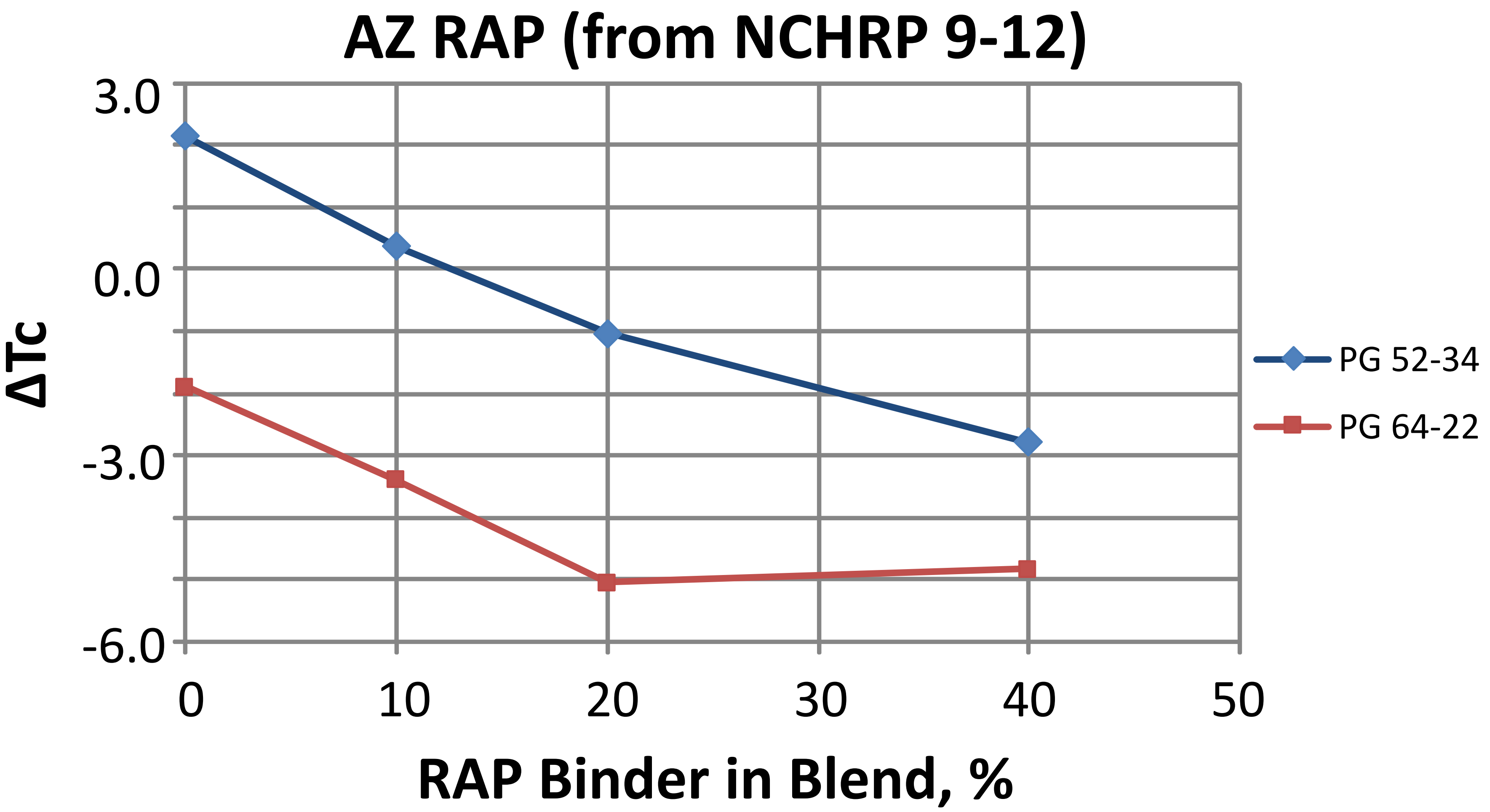

Can ΔTc be used to predict cracking?

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- ΔTc is thought to be directly related to block cracking.
  - However, fatigue, edge, longitudinal, reflection, and transverse cracking may indirectly be related to ΔTc of the binder.
    - These distress types are typically caused by other factors, yet ΔTc can play a supporting role in their development.

ΔT_c Potential Issues

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- BBR Limitations
  - Often cannot interpolate $T_{c,m}$ for highly negative values of ΔT_c
    - Stiffness is too low at temperatures where m-value approaches 0.300
    - Concerns about excess deflection
    - RAP/RAS
  - Polymer Modified Asphalt Binders
    - Have a higher elastic component at a given stiffness due to the polymer
    - Result is lower (more negative) values of ΔT_c

Steps to Consider Before Implementation

- **What are some things that an agency should consider before implementing ΔTc in a purchase specification?**
  - A brief summary of these steps is described in the "Considerations for Implementation of ΔTc as a Specification Parameter" section of the document
  - When implementing important specification changes, AI encourages agencies to work together regionally (such as in User-Producer Groups) to facilitate uniform transition for the asphalt industry.

Step #1: Identify issues to be solved

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- **Clearly identify the pavement performance challenge that ΔTc is intended to solve**
  - Without this clear statement of purpose, it is possible that a specification change will not mitigate the intended problem.
  - ΔTc is primarily aimed at asphalt pavement distress that is related to a lack of durability exhibited by asphalt binders. The most prominent distress that ΔTc targets is block cracking of aged asphalt pavements, which was the damage for which ΔTc was originally developed to predict.

Step #2: Is ΔTc is the best parameter?

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- **Determine whether ΔTc is the best parameter to solve the problem identified in the first step**
  - Determination of ΔTc potentially has an onerous effect on laboratory workflow.

Step #3: Determine amount of aging needed

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- **Consider what form of laboratory aging needs to be used to simulate pavement aging so that ΔTc measurements are made on representative samples**
  - This step, along with Step #4, ensures that the ΔTc specification is relevant
  - To accomplish this, a variety of PG binders should be laboratory aged, typically using variations on AASHTO R28
  - At present, 20- and 40-hours of pressure aging are most commonly used for ΔTc determinations

Step #4: Sample existing asphalt pavement

- **Sample existing asphalt pavements, preferably in service for at least five years, and measure ΔTc on in-situ materials**
  - Asphalt pavements exhibiting poor performance clearly due to asphalt durability as well as good-performing pavements should be sampled in the form of cores
  - Because aging occurs most rapidly in the materials most exposed to the elements, asphalt binder from the top ½-inch (12.5 mm) of the core should be extracted and recovered for determination of ΔTc
    - This is considered a conservative approach in determining ΔTc because it represents a worst case for aging

Step #4: Sample existing asphalt pavement (cont.)

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- **Sample existing asphalt pavements, preferably in service for at least five years, and measure ΔTc on in-situ materials (continued)**
  - However, if in the first step it is decided that ΔTc needs to target the asphalt binder contribution to load-associated damage, it might be desirable to evaluate ΔTc for lower asphalt layers
  - When extracting/recovering asphalt materials, consideration should be given to using toluene as it is accepted as a standard solvent that is well-suited for the evaluation of polymer-modified asphalt binders

Step #5: Determine aging protocol

- **Evaluate the ΔTc test results obtained in the previous step to arrive at the aging protocol necessary to simulate the ΔTc values obtained in service**
  - Laboratory aging data from step three (laboratory aging required to simulate in-service pavement aging) be employed for this purpose.
  - The last step is to conduct a discriminate analysis to arrive at ΔTc value that distinguishes between good and poor pavement performance

Step #6: Evaluate data to determine ΔTc criteria

- **Conduct a discriminant analysis to arrive at a ΔTc value that distinguishes between good and poor pavement performance with respect to age-related embrittlement or other distress type under consideration**

How variable is ΔTc (NEAUPG Study)?

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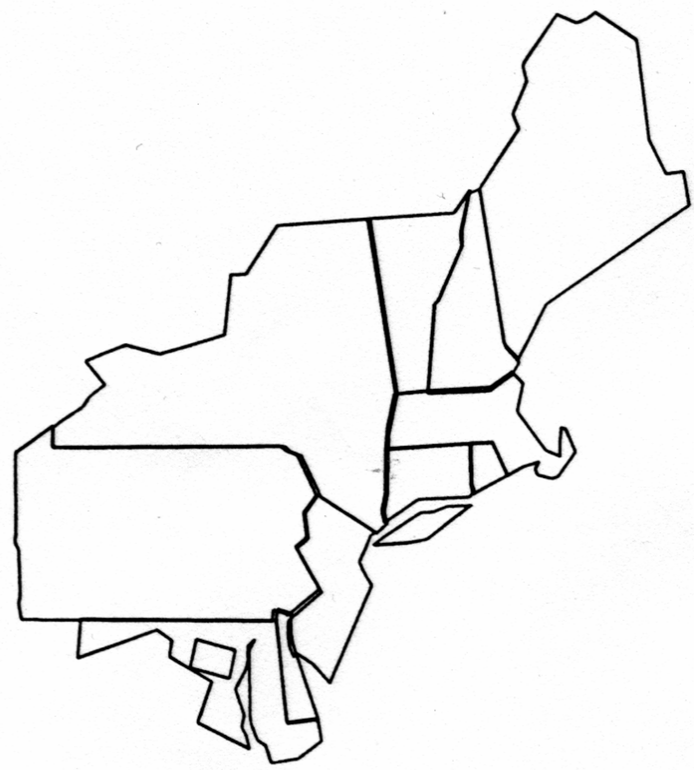
- Phase 1 - 23 labs (10 suppliers, 9 DOT's, FHWA, 3 Universities)
- Two binders
  - Binder A – PG 58S-28
  - Binder B – PG 64E-22
- Four Aging Conditions:
  - Method A – Standard 20-hour PAV
  - Method B – 20+20-hour PAV
  - Method C – 20+4+20-hour PAV
  - Method D – 40-hour PAV



How variable is ΔTc (NEAUPG Study) ?

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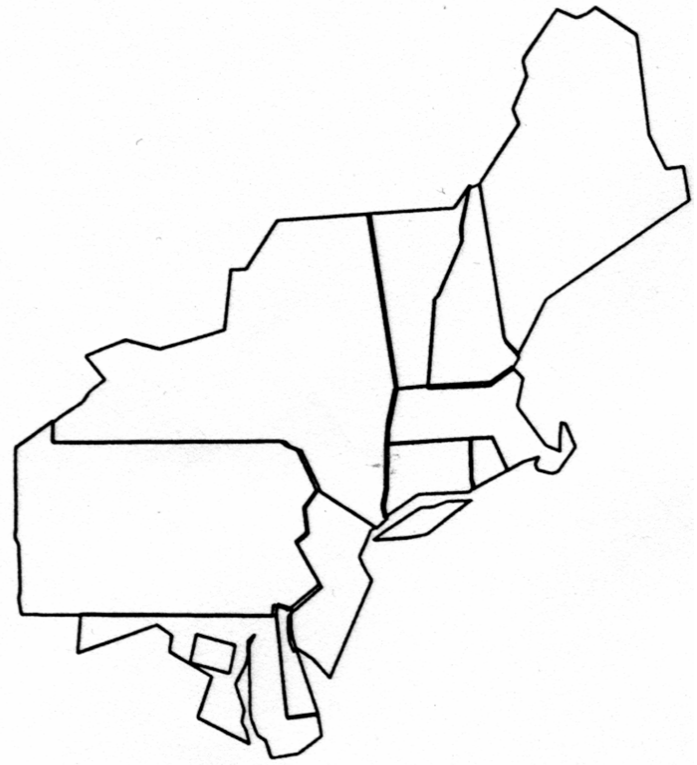
- Phase 2 - 23 labs (11 suppliers, 9 DOT's, FHWA, 2 Universities)
- One engineered binder
  - Binder A – PG 64S-22
- Four Aging Conditions:
  - Method A – Standard 20-hour PAV
  - Method B – 20+20-hour PAV
  - Method C – 20+4+20-hour PAV
  - Method D – 40-hour PAV
  - ***Method E – Standard 20-hour PAV w/12.5 grams per pan***



How variable is ΔTc ?

Table 2. Northeast Asphalt User Producer Group Extended Laboratory Aging Study (7)

BBR Property	PG 58S-28				
	Method A	**Method B**	**Method C**	**Method D**	**Method E**
Avg m-value @ -18°C	0.322	0.286	0.285	0.285	-
Avg stiffness @ -18°C	243	283	280	278	-
Avg m-value @ -24°C	0.261	0.242	0.235	0.241	-
Avg stiffness @ -24°C	494	530	531	541	-
Avg ΔT_C, °C	+0.3	-3.2	-2.6	-2.6	-
	PG 64E-22				
Avg m-value @ -12°C	0.347	0.307	0.306	0.304	-
Avg stiffness @ -12°C	157	195	191	197	-
Avg m-value @ -18°C	0.287	0.264	0.258	0.258	-
Avg stiffness @ -18°C	327	363	361	383	-
Avg ΔT_C, °C	-0.5	-3.5	-3.6	-3.2	-
	PG 64S-22[A]				
Avg m-value @ -12°C	0.318	0.305	0.293	0.302	0.299
Avg stiffness @ -12°C	103	71	82	77	79
Avg m-value @ -18°C	0.278	0.271	0.262	0.273	0.268
Avg stiffness @ -18°C	197	135	146	139	142
Avg ΔT_C, °C	-7.4	-13.1	-15.1	-14.3	-15.0

[A] test temperatures for Methods B, C, D, and E were -6 and -12°C

Are agencies using ΔTc in their specifications?

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- At the time this document was developed, ten agencies in North America had or soon will adopt ΔTc as a specification parameter in some manner
  - There is about an even split between agencies using 20- and 40-hour PAV aging protocols
  - Most (but not all) agencies have adopted a minimum limit for ΔTc of -5.0°C. The basis for that specification value is the AAPTP research mentioned earlier

Summary

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- ΔT_c can be easily calculated using standard BBR test data
  - Depending on lab and practices, 1-2 additional BBR tests at different temperatures may be needed
- ΔT_c appears to be an indicator of oxidative aging and loss of relaxation properties
  - Related to intermediate, durability cracking even though the tests are performed at low temperatures
  - Greater aging results in lower (more negative) values of ΔT_c

Summary

- Variability of ΔT_c appears reasonable, as it is a product of BBR testing
  - Consider variability if establishing guidance for use
- Asphalt binders with very negative values of ΔT_c may be more difficult to test in the BBR
  - RAS binders
- Caution when using ΔT_c with polymer modified asphalt binders
  - Higher elastic component may make ΔT_c more negative

Thanks!

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