Delta T_c (ΔT_c) Asphalt Binder Specification Parameter

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Presentation Overview

I. Introduction

II. Background

III. Determination of ΔT_c

IV. Elements Impacting ΔT_c

V. Steps to Implementation of ΔT_c

VI. Alternatives to ΔT_c and Ongoing Research

VII. Status of Implementation of ΔT_c

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Introduction (1 of 4)

- **Objective:** provide knowledge and technical support for responsible deployment of Delta T_c (ΔT_c) as a specification parameter into asphalt binder acceptance specifications.
- **Purpose:** provide preliminary considerations, if a State DOT has pressing needs and wants to proceed with implementation while acknowledging that information on ΔT_c continues to evolve.
- **Federal Highway Administration (FHWA) project: "Deployment and Development of Innovative Asphalt Pavement Technologies. (DDIAPT)"**
    - Tech Brief: Delta T_c Binder Specification Parameter https://www.fhwa.dot.gov/pavement/asphalt/HIF_Delta_Binder_Spec_TchBrf.pdf

Introduction (2 of 4)

- **Delta T_c (ΔT_c) – "Calculated" Asphalt Binder Parameter**
  - Provides Insight Into Relaxation Properties of Asphalt Binders
    - Non-Load Related Cracking
    - Other Age-Related Embrittlement Distresses in Asphalt Pavements
- **ΔT_c - Calculated** using **Bending Beam Rheometer (BBR) Results**
  - Long-Term Aged binder (rolling thin-film oven (RTFO) plus Pressure Aging Vessel (PAV)
  - Recovered Binder from Recycled Asphalt Mixtures (RAP) and Recycled Asphalt Shingles (RAS)

Introduction (3 of 4)

- **Most any type Asphalt Binder can be Evaluated with ΔT_c**
  - Neat Asphalt Binder (asphalt binder with no additives or modifiers), Extracted Binders
  - Asphalt Binders with additives (Anti-Strip, PPA, REOB/VTAE, and Warm-Mix Additives)
  - Modified Asphalt Binders with Polymers or other asphalt additives, (RAP, RAS, or Combinations of RAP and RAS)
- **ΔT_c May Indicate:**
  - Effectiveness of asphalt binder response to aging
  - Effectiveness of additive impact on response of asphalt binder to aging
- **State Departments of Transportation (DOTs) are currently Implementing or Considering Implementation of ΔT_c into Existing Acceptance Specifications**

Introduction (4 of 4)

- **National Level Research Projects are currently Considering ΔT_c in Research**
- **Objective – Promote the "State-of-the-Knowledge" of ΔT_c as a Parameter to Characterize Asphalt Binder Behavior and aid in Affective Deployment as a Specification Parameter**
- **Excerpt and Summary from Asphalt Institute (AI) "State-of-the-Knowledge" Informational Series (IS) 240**

"Use of the Delta Tc Parameter to Characterize Asphalt Binder Behavior" (asphaltinstitute.org)

Background

- **The ΔT_c Parameter Conceptualized during SHRP and later suggested as a performance indicator in the Airfield Asphalt Pavement Technology Program (AAPTP), Project 06-01.**
  - Identify simple asphalt binder and/or asphalt mixture testing to predict imminent durability issues (cracking or raveling).
  - Facilitate timing of asphalt pavement preservation strategies.
- **AAPTP Concluded that ΔT_c could be used as a tool to Predict Ductility and Analyze Durability-Related Properties of Aged Asphalt Pavements.**
- **ΔT_c has Evolved as an Asphalt Binder Parameter that can be used to Evaluate Relaxation Properties of Asphalt Binders.**

Chapter 2 of AI IS 240 provides additional information on the origin of ΔT_c.

Block Cracking

Relaxation Properties of aged Asphalt Binders, Expressed by ΔT_c Values, can Affect Different types of Asphalt Pavement Distresses:

- Non-load related cracking
- Other age-related embrittlement distresses
- Only block cracking is affected directly

Other Cracking Types

Other types of cracking are indirectly affected by ΔT_c:

- **Fatigue**
- **Edge**
- **Longitudinal**
- **Reflective**
- **Transverse**

While ΔT_c may be a contributing factor these types of cracking are predominately caused by other factors

Common Pavement Distresses	Effect of ΔT_c
Block Cracking	Direct
Fatigue Cracking	Indirect
Edge Cracking	Indirect
Longitudinal Cracking	Indirect
Reflection Cracking	Indirect
Transverse Cracking	Indirect
Potholes	Indirect
Raveling	Indirect
Rutting	None
Shoving	None
Bleeding	None

Chapter 5 of AI IS 240 provides additional information on distresses addressed by ΔT_c

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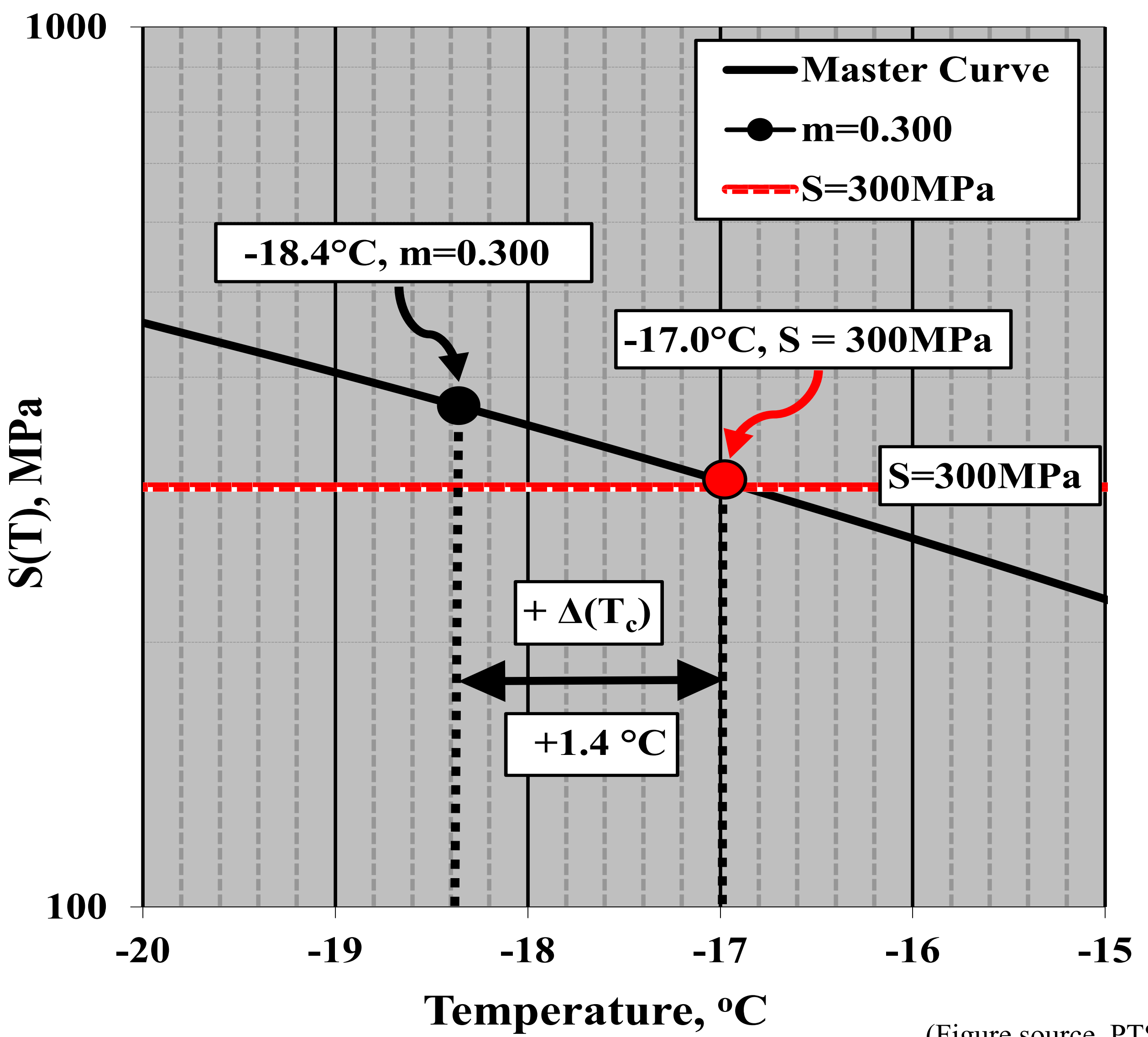
Determination of ΔT_c

Results of Bending Beam Rheometer Test are used to Determine ΔT_c

Critical Temperatures (T_c) are Calculated where AASHTO M 320 and AASHTO M 332 Limits for Creep Stiffness (S) and Creep Rate (m) meet S=300 Mpa and m=0.300

ΔT_c is Calculated by Subtracting the m-critical ($T_{c,m}$) Temp from the S-critical ($T_{c,S}$) Temp

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



(Figure source, PTSi)

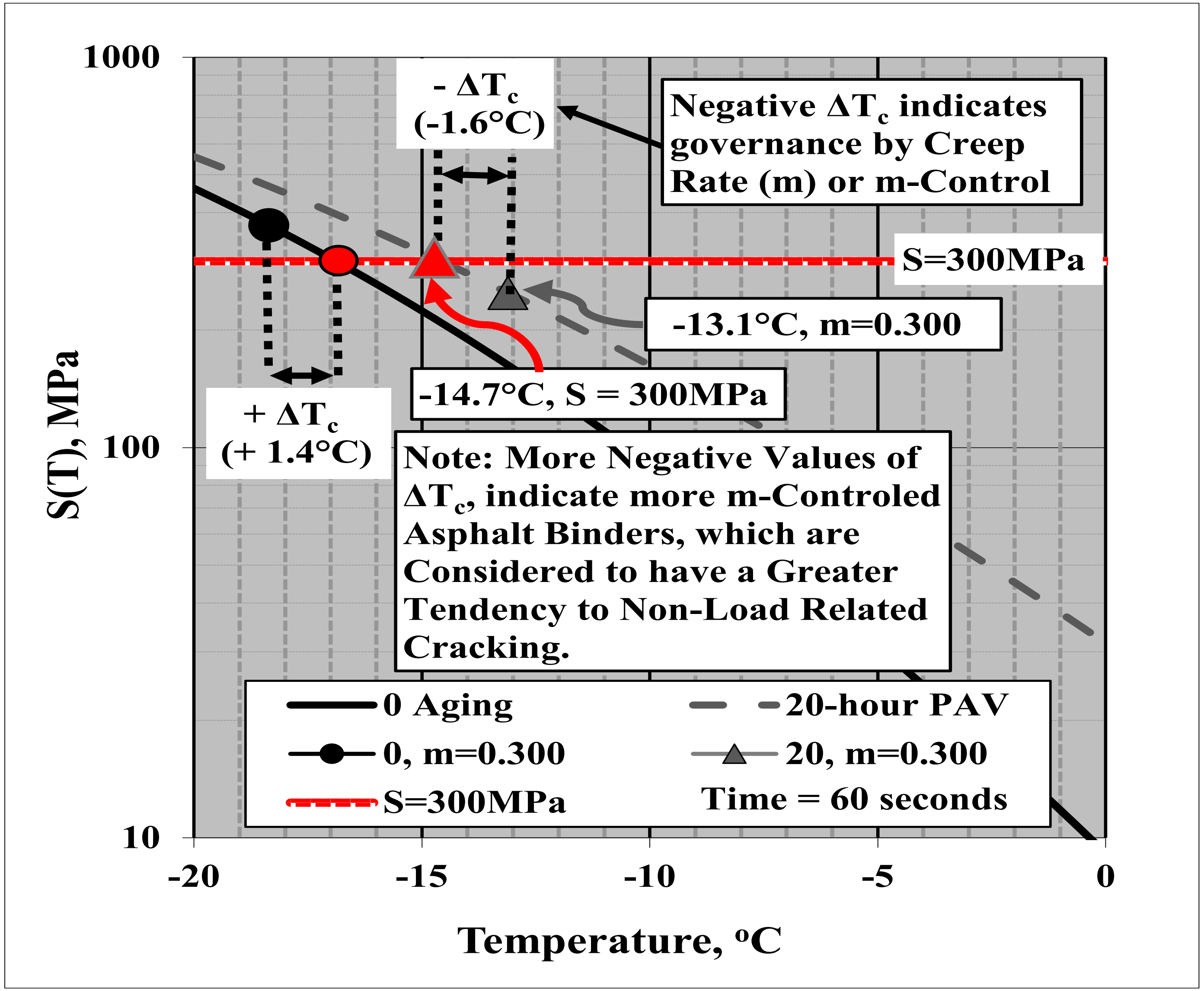
Chapter 3 of AI IS 240 provides additional information on the determination of ΔT_c from BBR

What Does it all Mean? (1 of 2)

A Positive Value of ΔT_c Indicates the Binder is "S-Controlled" (fails S before m).

A Negative Value of ΔT_c Indicates the Binder is "m-Controlled" (fails m before S).

The Magnitue of ΔT_c Indicates the Degree to Which the Binder is Either m-controlled or S-controlled.

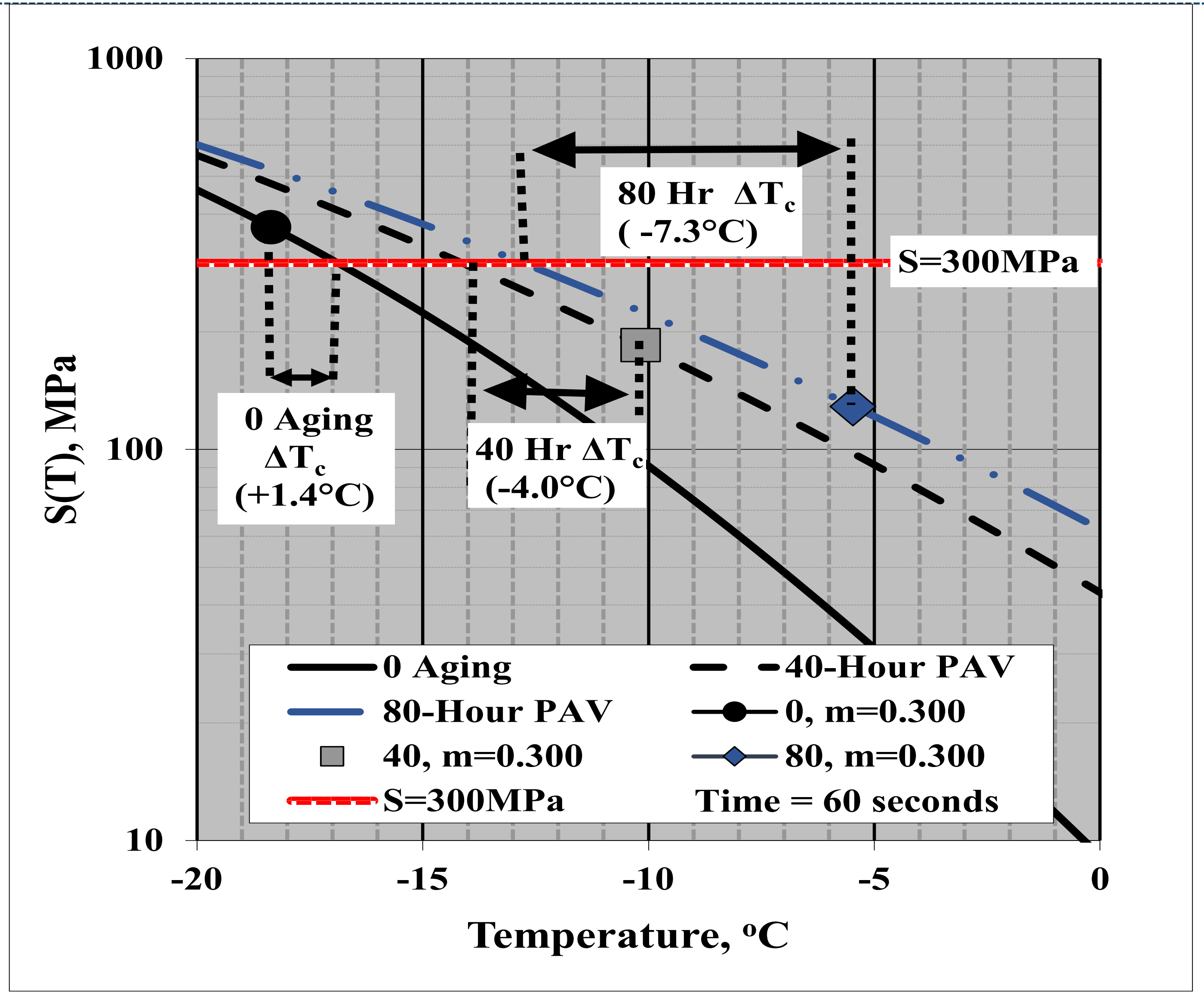


(Figure source, PTSi)

What Does it all Mean? (2 of 2)

The Magnitue of ΔT_c Indicates the Degree to Which the Binder is Either m-controlled or S-controlled.

More Negative Values of ΔT_c , more m-Controlled Asphalt Binders, are Considered to have a Greater Tendency to Non-Load Related Cracking

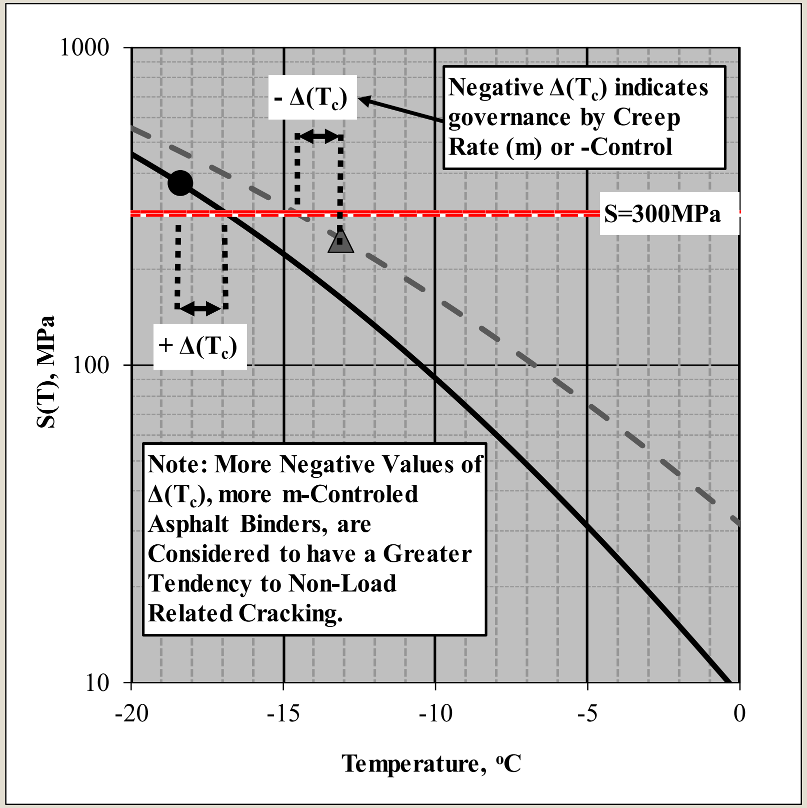


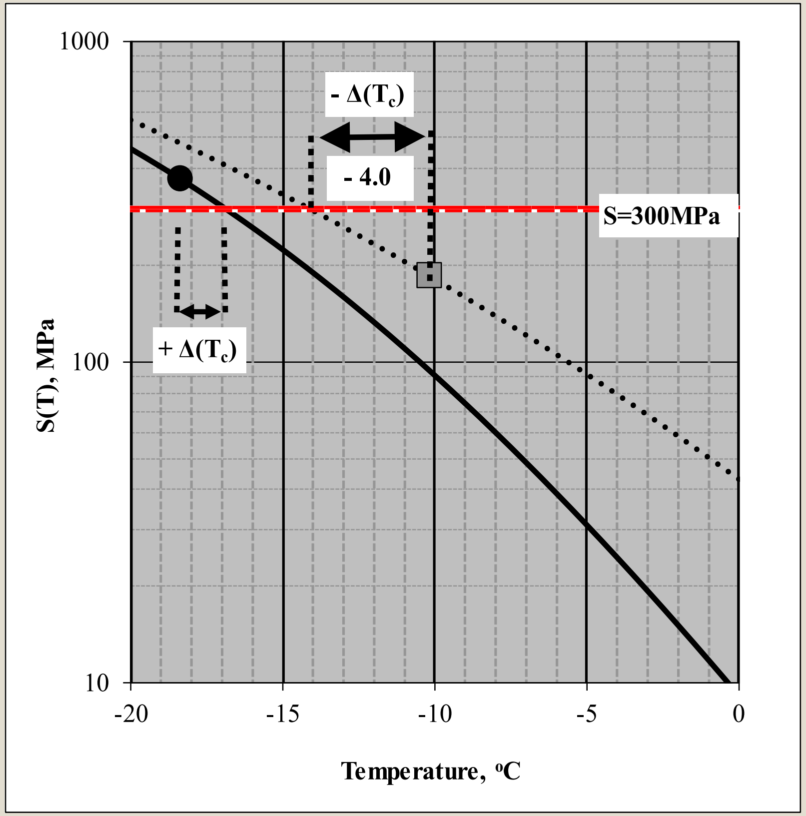
(Figure source, PTSi)

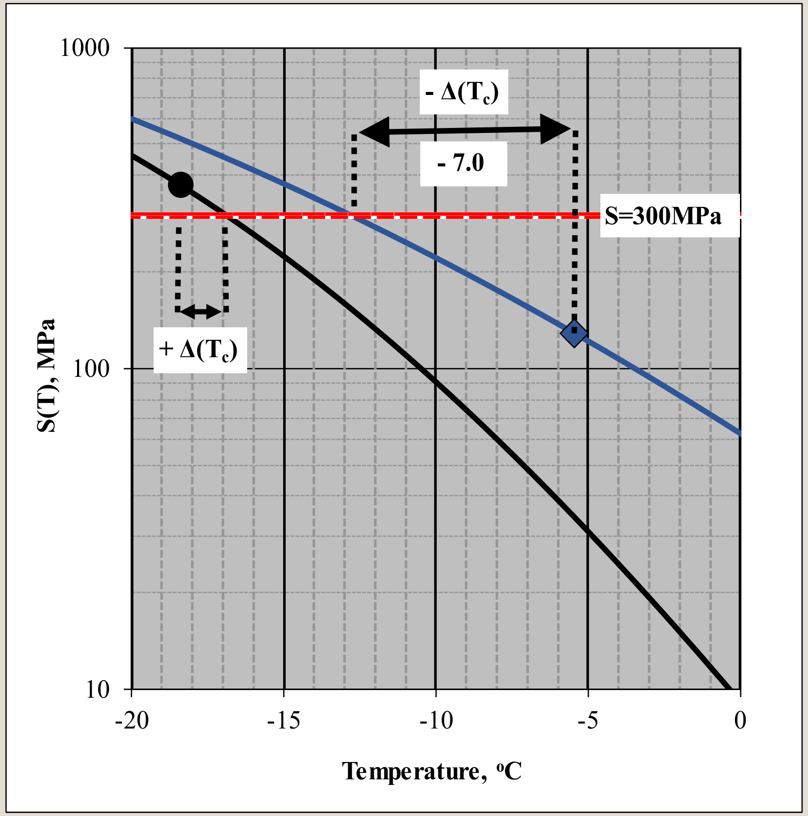
Asphalt Binder Aging Impact on ΔT_c

- Asphalt Binder Response to **Aging** is the Primary Element Effecting $\Delta T_{c.}$
- Laboratory **Aging** is Key to Evaluation of Asphalt Binder Durability and the Effect of ΔT_c on Pavement Durability.
  - As **Aging** Increases the Trend of ΔT_c is to become more Negative.
  - Extended PAV Aging Causes Asphalt Binders to become more m-Controlled (thus more negative values of ΔT_c)
- **How Much Laboratory Aging** is Needed to Adequately Evaluate ΔT_c.
- **No Simple Answer** to the Degree of Laboratory Aging Needed?

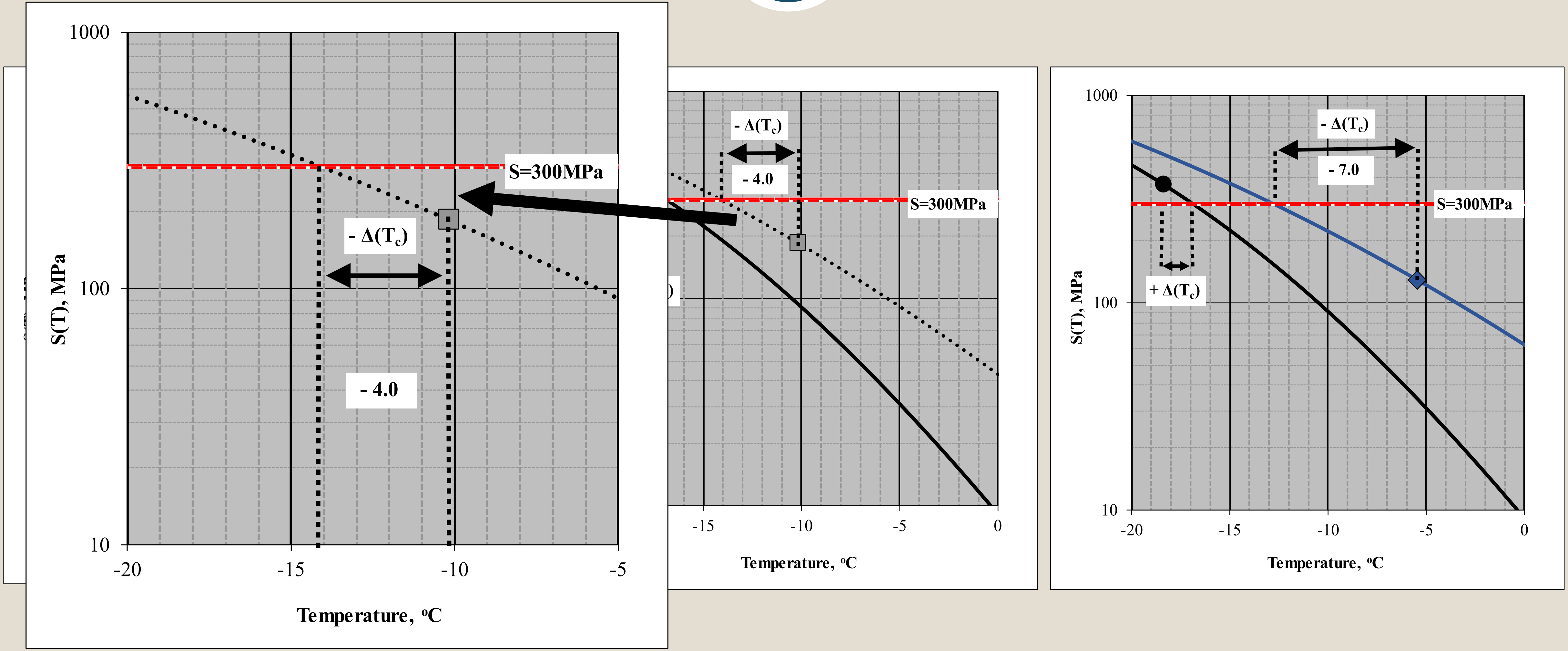
Laboratory Aging 20, 40, and 80 PAV Hours (1 of 2)







Laboratory Aging 20, 40, and 80 PAV Hours (2 of 2)



Elements Impacting ΔT_c

- Asphalt Binder Response to **Aging**, **Aging**, and **Aging**.
- Effects of Additives on Asphalt Binder Properties and Aging Response
  - Reclaimed Asphalt Pavement (RAP).
  - Recycled Asphalt Shingles (RAS).
  - Re-refined Engine Oil Bottoms (REOB).
  - Elastomeric Polymer Modification.
  - Combined Effects.
- Air Rectified Asphalt Binders (Air Blown)

Impact of RAP on ΔT_c

As asphalt binder aging plays the primary role in ΔT_c performance, it is somewhat apparent the impact addition of age hardened Reclaimed Asphalt Pavement (RAP) binders will have on ΔT_c performance.

Effect of Recycled Asphalt Pavement on ΔT_c				
Asphalt Binder Blend	No RAP	10 Percent	20 Percent	40 Percent
PG52-34 Plus RAP A	2.2	0.2	0.1	0.7
PG64-22 Plus RAP A	-1.9	-2.7	-2.8	-4.4
PG52-34 Plus RAP B	2.2	0.4	-1.0	-2.8
PG64-22 Plus RAP B	-1.9	-3.4	-5.1	-4.8
PG52-34 Plus RAP C	2.2	-0.1	-0.7	-0.8
PG64-22 Plus RAP C	-1.9	-2.8	-3.1	-1.7

Data Source NCHRP Web Document 30 Project 09-12 October 2000

Impact of RAS on ΔT_c

Recycled Asphalt Shingles (RAS) asphalt binder is highly oxidized and very stiff. RAS, is expected to impact ΔT_c performance to a higher degree than RAP asphalt binder.

Calculation of the ΔT_c of RAS asphalt binder not as straight forward as with RAP asphalt binder due to difficulty of BBR analysis.

Estimated ΔT_c of Recycled Asphalt Shingle Binder			
RAS Source	**T_c High**	**T_c Low**	**ΔT_c**
New Hampshire	163.0	12.0	-33.0
Oregon	152.0	14.0	-37.0
Texas	122.0	-7.0	-23.0
Wisconsin	146.0	16.0	-40.0
Wisconsin	146.0	6.0	-31.0

Data Source AI IS 240

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Implementation of the ΔT_c Parameter (1 of 2)

- **Familiarize with ΔT_c.** AI IS-240 is a great starting point.
- **ΔT_c** parameter primarily intended to address durability related distresses.
- More negative values may have indirect impact on other forms of cracking.
- Clearly understand the performance challenge to be addressed.
- **ΔT_c** more than a number, it is not a panacea that cures all cracking issues.
    - Laboratory evaluation of existing pavements may be necessary.
    - **Alternative** approaches to **ΔT_c** may prove **more appropriate?**

Implementation of the ΔT_c Parameter (2 of 2)

AI IS 240 suggests a five step systematic approach to implementation:

1. Clearly **identify the problem** ΔT_c is intended to address.
2. Determine whether ΔT_c is the **most favorable alternative**.
3. **Select aging method** to ensure ΔT_c measurements are representative.
4. **Evaluate existing pavements** that exhibit diverse cracking behavior.
5. **Evaluate ΔT_c results** obtained to **determine** simulative **aging protocol**.

Work together regionally to facilitate uniform transition for the asphalt industry.

Alternatives to the ΔT_c Parameter (1 of 3)

- Cracking - predominant distress affecting pavement durability.
- ΔT_c is just one of several alternatives available to address age-related embrittlement by specification means. Early on other alternatives were suggested as well:
  - Glover-Rowe (GR) Parameter
  - Rheological Index (R)
  - Cross-Over Modulus
  - Limiting (minimum) S-value

Alternatives to the ΔT_c Parameter (2 of 3)

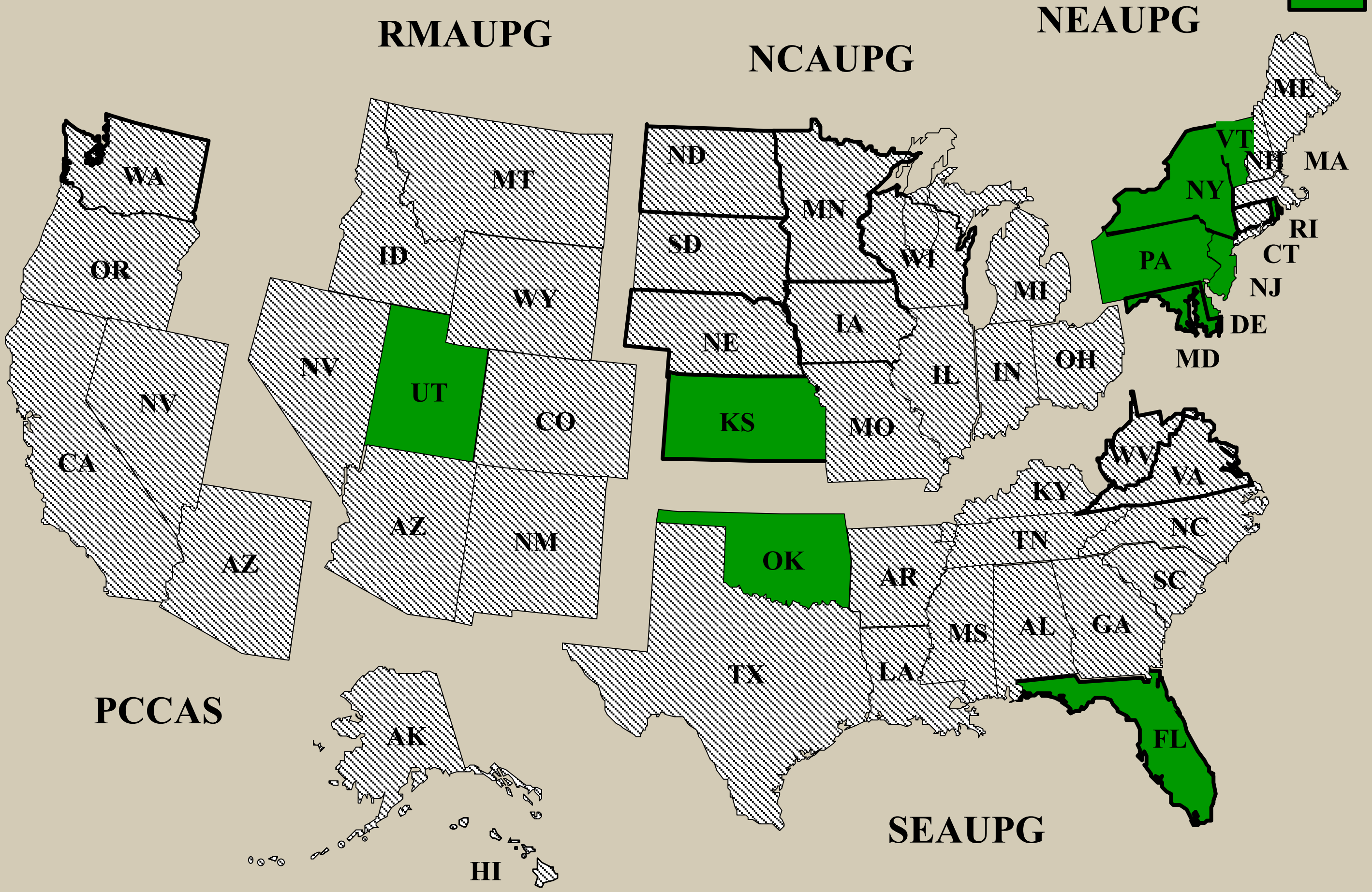
- More recently, other alternatives have been proposed:
- Some research indicates that ΔT_c may be more effective at identifying deleterious affects of additives in asphalt binder than as a predictor of asphalt binder cracking or durability.
  - Propose minimum S-value for a given m-value.
  - Suggest variable S-value minimums applied to variable m-values for specific values of ΔT_c.
  - e.g., If ΔT_c = -8 then the specification limit would be a minimum S-value of 125 MPa, with an allowable increase of the minimum S-value to 150 MPa for m-values greater than 0.32.

Alternatives to the ΔT_c Parameter (3 of 3)

- National Cooperative Highway Research Program (NCHRP) Project 9-60:
- A ΔT_f parameter would become an optional specification parameter, as was the case with the direct tension test. The ΔT_f parameter incorporates a binder fracture test using the Asphalt Binder Cracking Device (ABCD).
- Uses results from ΔT_c and ΔT_f after 20-hour PAV aging.
  - ΔT_c uses standard BBR results to calculate $T_{c,S} - T_{c,m} = \Delta T_c$.
  - ΔT_c threshold is set at -2 for warning and -6 for failure.
  - If, ΔT_c fails these limits then, ΔT_f is employed, where: $\Delta T_f = \text{ABCD } T_{c,f} - \text{BBR } T_{c,S,}$

- **Chapter 7 of AI IS 240 provides additional information on alternatives to ΔT_c**

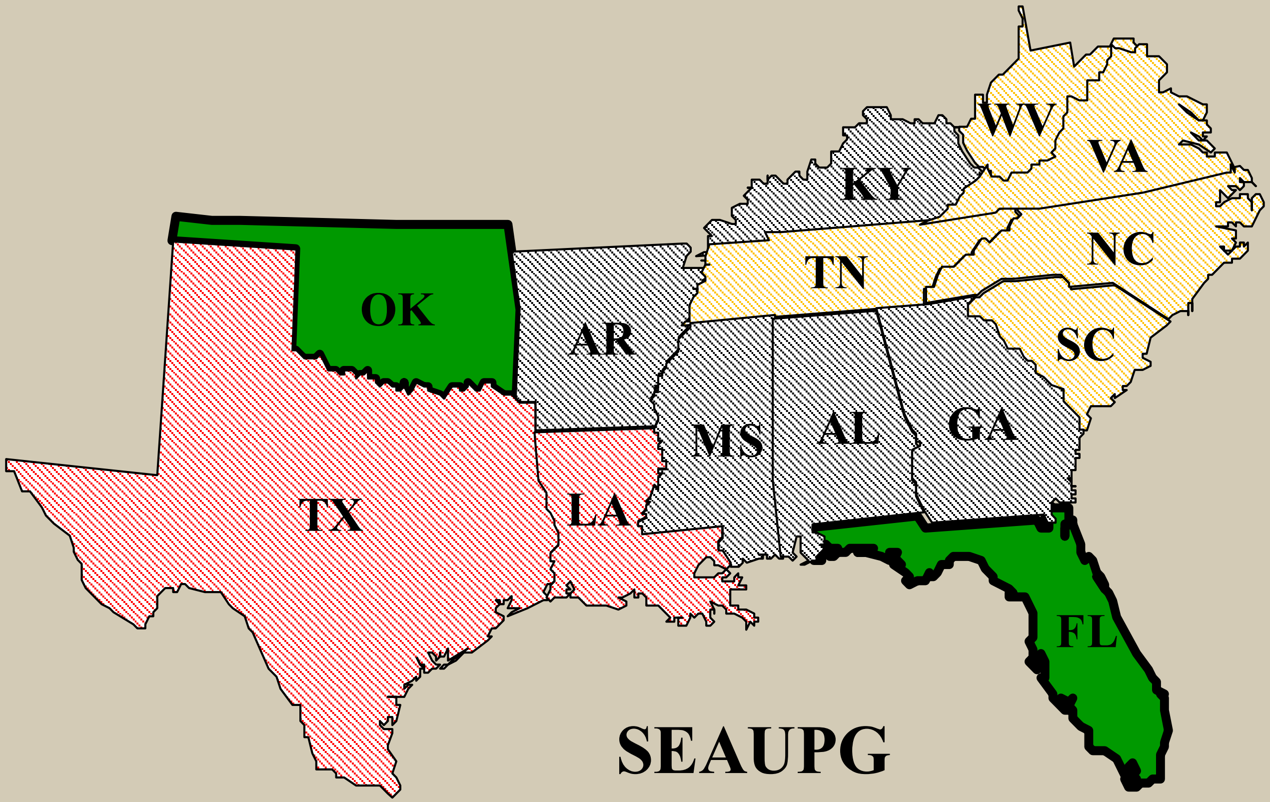
Status of Implementation of ΔT_c



10 States Specifying ΔT_c

- DE, 40 Hr PAV $\Delta T_c \geq -5.0$°C
- FL, 20 Hr PAV $\Delta T_c \geq -5.0$°C
- KS, 40 Hr PAV $\Delta T_c \geq -5.0$°C
- MD, 40 Hr PAV $\Delta T_c \geq -5.0$°C
- NJ, 40 Hr PAV $\Delta T_c \geq -5.0$°C
- NY, 40 Hr PAV $\Delta T_c \geq -5.0$°C
- OK, 20 Hr PAV $\Delta T_c \geq -6.0$°C
- PA, 40 Hr PAV $\Delta T_c \geq -5.0$°C
- UT, 20 Hr PAV $\Delta T_c \geq -2.0$°C
- VT, 40 Hr PAV $\Delta T_c \geq -5.0$°C

Status of Implementation of ΔT_c in the SEAUPG Region



- 2 States Specifying ΔT_c
  - FL, 20 Hr PAV $\Delta T_c \geq -5.0°C$
  - OK, 20 Hr PAV $\Delta T_c \geq -6.0°C$
- 2 States Looking at 4mm DSR
  - LA
  - TX, also looking at limiting BBR values
- 5 States monitoring or report only
  - NC, SC, TN, VA, WV
- 5 States not currently using ΔT_c
  - KY, AL, AR, GA, MS

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Summary (1 of 2)

- Brief review of ΔT_c as a parameter to characterize asphalt binder behavior.
- Information Relies on AI IS-240:

  Use of the Delta Tc Parameter to Characterize Asphalt Binder Behavior

- Objective is to provided knowledge to promote responsible deployment of ΔT_c as an asphalt binder purchase specification parameter.
- Presented a brief description of ΔT_c how it is determined, and relevance in characterizing the behavior of asphalt binders.

Summary (2 of 2)

- Brief discussed elements impacting the ΔT_c parameter.
- Discussed possible steps to implementation of the ΔT_c parameter.
- Discussed possible alternatives to implementation of the ΔT_c parameter.
- Presented a brief overview of the current state of implementation of the ΔT_c parameter in the SEAUPG states.

Thank You.