Evaluating Potential Asphalt Binder Specification Recommendations from NCHRP 20-44(19) and BMD Impacts

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DEPARTMENT OF TRANSPORTATION
THE STATE OF NEW JERSEY

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- NJDOT Pavement Design and Management
  - Robert Blight, Nusrat Morshed, Sharad Rana

Motivation & Workplan

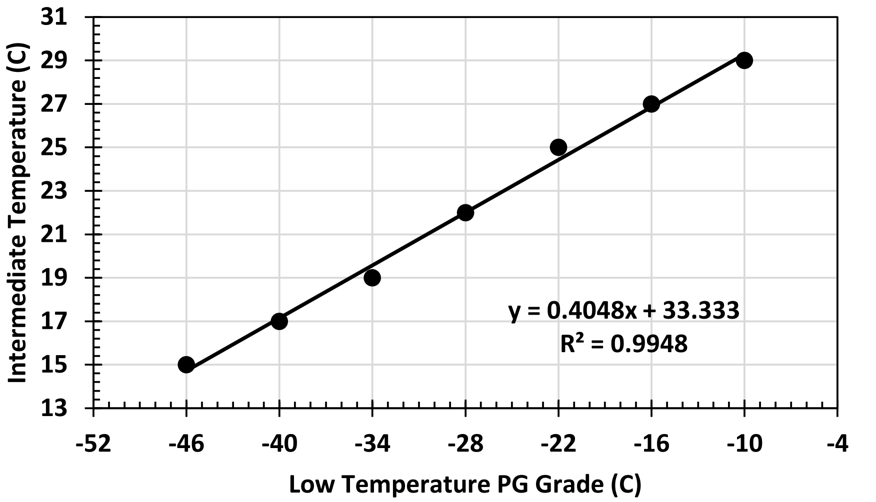
- Evaluate the potential asphalt binder specification changes on NJDOT approved binders
- Evaluate how these properties may change from same suppliers during the year
- Evaluate the impact on Balanced Mixture Design performance testing

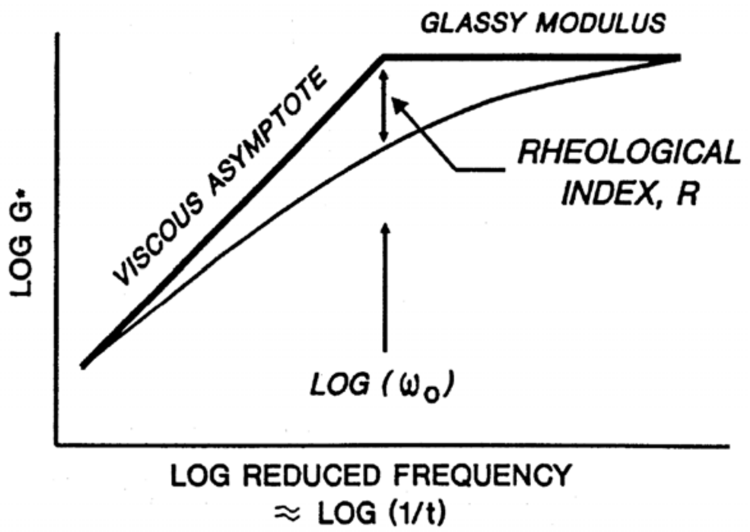
NCHRP 20-44(19)

- Implementation of Proposed AASHTO Standards for Asphalt Binders and Mixtures (Asphalt Institute: Mike Anderson (PI))
  - Try to consolidate NCHRP project deliverables 9-52, 9-54, 9-56A, 9-59, 9-60, 9-61
    - Utilized information for proposed specification improvements
    - Asphalt Mixtures: 9-52, 9-54, 9-56A
    - Asphalt Binders: **<u>9-59</u>, <u>9-60</u>**, 9-61
  - Utilize NJDOT asphalt binder retains from 2021 year for evaluation

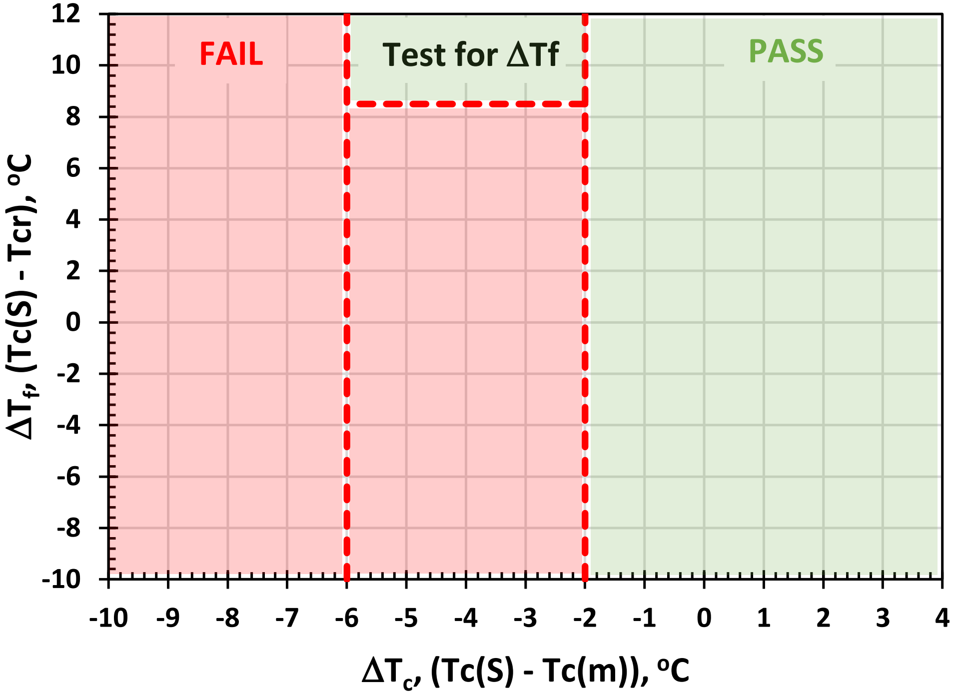
NCHRP 20-44(19) Criteria Evaluated

- Intermediate Temperature Fatigue
  - Glover-Rowe Parameter
    - Tested at regional intermediate temperature *(NCHRP 9-59)* & 10 rad/sec
- Non-Load Associated/Thermal
  - Conventional BBR-based low temp PG grade *(AASHTO M320/R29)*
  - Rheological Index (R-value) based on BBR data
    - Poor field performance found with *(NCHRP 9-59)*
      - High R-values in thin pavements (REOB modified binders)
      - Low R-values in thick pavements
  - Check ΔTc
    - Marginal materials verified with ABCD ΔTf *(NCHRP 9-60)*





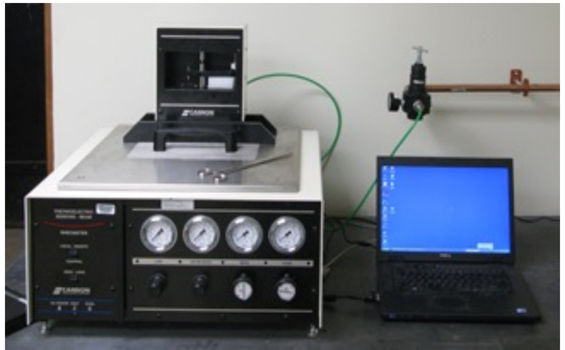
NCHRP 20-44(19) Criteria Evaluated



PAV Aging Temperature (°C)	100						100 (110)					
Dynamic Shear, T315 G*(cos δ)²/sin δ², 10 rad/s, at intermediate temp [a] **> 5,000 kPa** **(>8,000 kPa)**	29	27	25	22	19	17	29	27	25	22	19	17
Creep Stiffness, T313 Stiffness < 300 Mpa m-value > 0.300 at 60 sec & low temp	0	-6	-12	-18	-24	-30	0	-6	-12	-18	-24	-30
Creep Stiffness, T313 R=log(2)log(S/3000)/log(1-m) at 60 sec & low temp min < R < max	**1.50 < R < 2.50** **1.50 < R < 3.20**											
ΔTc Tc,S - Tc,m	≥ -2.0 [b] ≥ -3.0 [c]											
ΔTf [b] Tc,S - Tcr	≥ +8.5 ≥ +4.5											

[a] - Based on low temperature PG requirement of area (NCHRP 9-59)

[b] - Only determine ΔTf when -6 ≤ ΔTc ≤ -2.0; [c] - Only determine ΔTf when -7.0 ≤ ΔTc ≤ -3.0



Binders Evaluated

- NJDOT 2021 Approved Binders and Sources
  - Retains from 2021 paving season
    - 10 “different” PG64E-22
      - 4 refineries with different sampling dates
    - PG64S-22
      - 5 refineries
  - Asphalt binders 20 Hr PAV and 40 Hr PAV
    - 40 Hr PAV used two consecutive 20 Hr conditioning periods

Test Results – How Did We Do?

PG64E-22 Results

				20 Hour PAV									40 Hour PAV								
Supplier	Location	Lot	Date	Intermediate Temperature		Low Temperature PG Grading			Asphalt Binder Cracking Device		BBR R-Value		Intermediate Temperature		Low Temperature PG Grading			Asphalt Binder Cracking Device		BBR R-Value	
				PG Grade	GRP @ 25C	BBR (Stiffness)	BBR (m-value)	ΔTc	Tcr	ΔTf	-22C	-28C	PG Grade	GRP @ 25C	BBR (Stiffness)	BBR (m-value)	ΔTc	Tcr	ΔTf	-22C	-28C
1	B	4	6/21/2021	19.6	1952	-27.9	-27.1	-0.8	-33.6	5.7	2.16	1.99		5602	-26.8	-23.6	-3.2	-32.4	-5.6	2.32	2.05
1	B	6	8/2/2021	19.9	2591.8	-29.2	-27.1	-2.1	-34.7	5.5	2.26	2.12		7143	-27.6	-22.8	-4.8	-31.2	-3.6	2.40	2.16
1	B	9	10/6/2021	20.9	4459.7	-28.0	-25.8	-2.2	-33.1	5.1	2.31	2.07		9503	-26.7	-19.9	-6.8	-31.7	-5.0	2.46	2.22
1	C	11	7/14/2021	24.2	4004.8	-26.1	-25.2	-0.9	-32.4	6.3	2.11	1.94		7919	-25.4	-21.9	-3.5	-28.6	-3.2	2.23	2.07
1	C	14	8/16/2021	21.9	3653.5	-26.6	-24.7	-1.9	-32.3	5.7	2.20	2.04		8369	-25.3	-21.5	-3.8	-30.8	-5.5	2.29	2.05
1	C	17	9/26/2021	20.3	2330.4	-27.9	-26.6	-1.3	-34.8	6.9	2.26	2.01		6732	-26.6	-22.0	-4.6	-31.7	-5.1	2.41	2.10
1	C	23	12/10/2021	21.2	4014.4	-27.4	-24.9	-2.5	-33.4	6.0	2.30	2.12		13788	-25.9	-16.8	-9.1	-29.1	-3.2	2.53	2.23
2		8	8/10/2021	21.8	3424	-27.1	-24.3	-2.8	-31.7	4.6	2.35	2.09		13606	-26.1	-18.6	-7.5	-31.9	-5.8	2.46	2.05
2		10	10/14/2021	23.5	3971	-26.7	-26.0	-0.7	-30.3	3.6	2.17	1.93		12952	-24.9	-19.4	-5.5	-26.1	-1.2	2.28	2.06
3		4	8/24/2021	20.9	3184.5	-29.5	-27.9	-1.6	-35.8	6.3	2.28	2.09		8006	-29.1	-22.7	-6.4	-31.6	-2.5	2.52	2.33

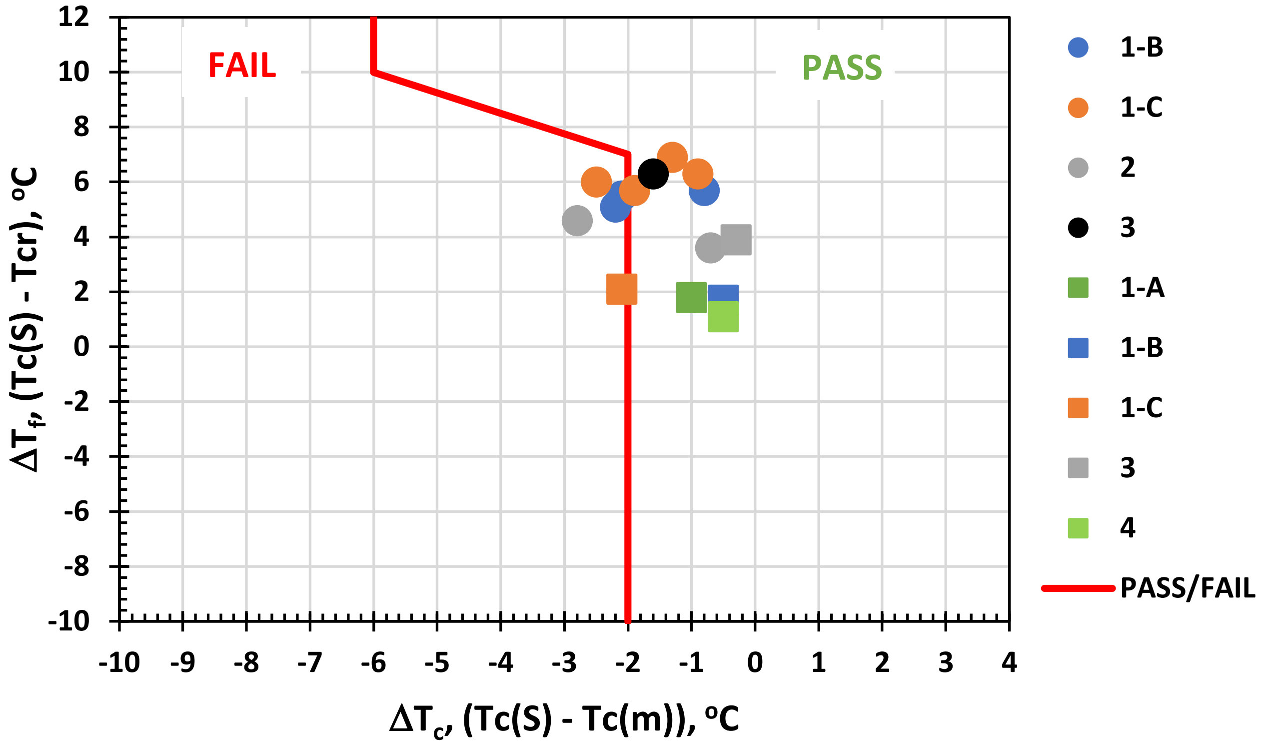
RED indicates failed criteria at that conditioning level

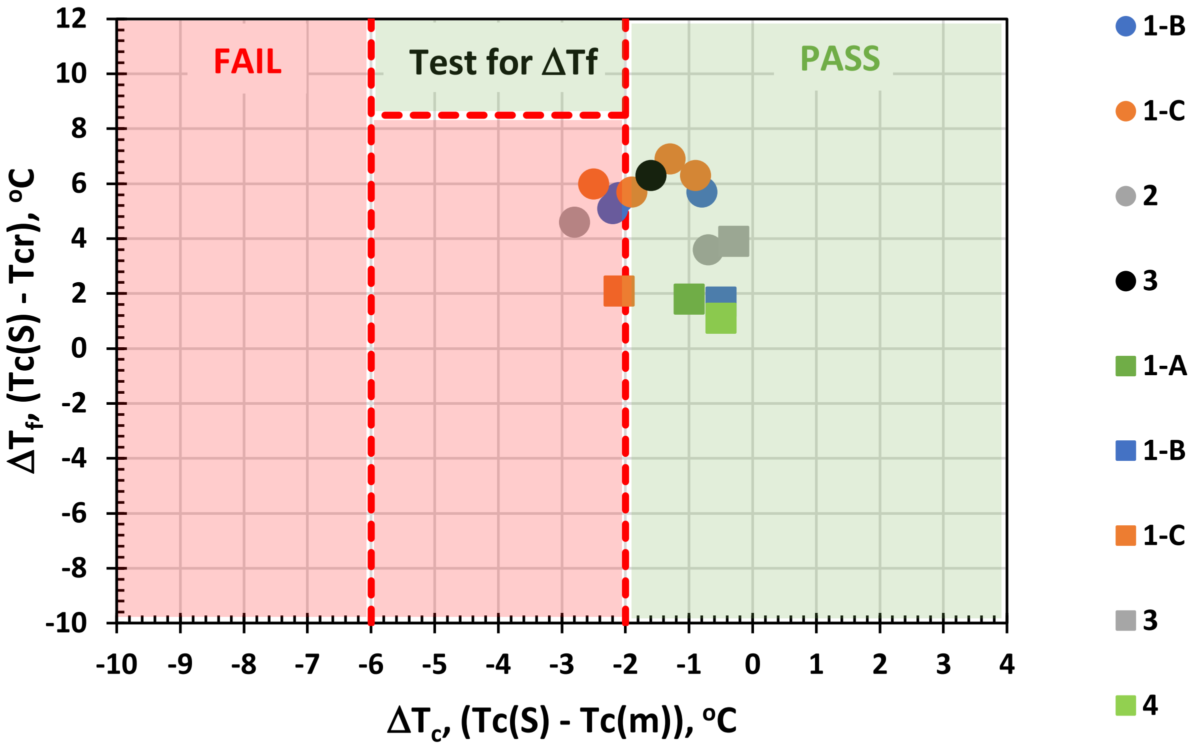
PG64S-22 Results

				20 Hour PAV									40 Hour PAV								
Supplier	Location	Lot	Date	Intermediate Temperature		Low Temperature PG Grading			Asphalt Binder Cracking Device		BBR R-Value		Intermediate Temperature		Low Temperature PG Grading			Asphalt Binder Cracking Device		BBR R-Value	
				PG Grade	GRP @ 25C	BBR (Stiffness)	BBR (m-value)	ΔTc	Tcr	ΔTf	-22C	-28C	PG Grade	GRP @ 25C	BBR (Stiffness)	BBR (m-value)	ΔTc	Tcr	ΔTf	-22C	-28C
1	A	11	10/14/2021	22.6	2874.6	-25.7	-24.7	-1	-27.5	1.8	2.09	1.96		7663	-24.8	-19.1	-5.7	-26.9	-2.1	2.33	2.03
1	B	7	7/20/2021	21.9	2707.3	-27.4	-26.9	-0.5	-29.1	1.7	2.17	1.95		7980	-26.2	-22.1	-4.1	-27.7	-1.5	2.32	2.07
1	C	23	11/15/2021	23.2	4376.8	-26.6	-24.5	-2.1	-28.7	2.1	2.23	2.02		11557	-26.4	-18.5	-7.9	-27.3	-0.9	2.50	2.32
2		8	6/31/21	23.2	2450	-25.9	-25.6	-0.3	-29.8	3.9	2.00	1.94		5859	-25.4	-23.0	-2.4	-28.5	-3.1	2.18	1.99
3		4	4/15/2021	22.4	2728.7	-26.9	-26.4	-0.5	-28	1.1	2.14	1.92		8182	-25.9	-22.4	-3.5	-28.8	-2.9	2.27	2.06

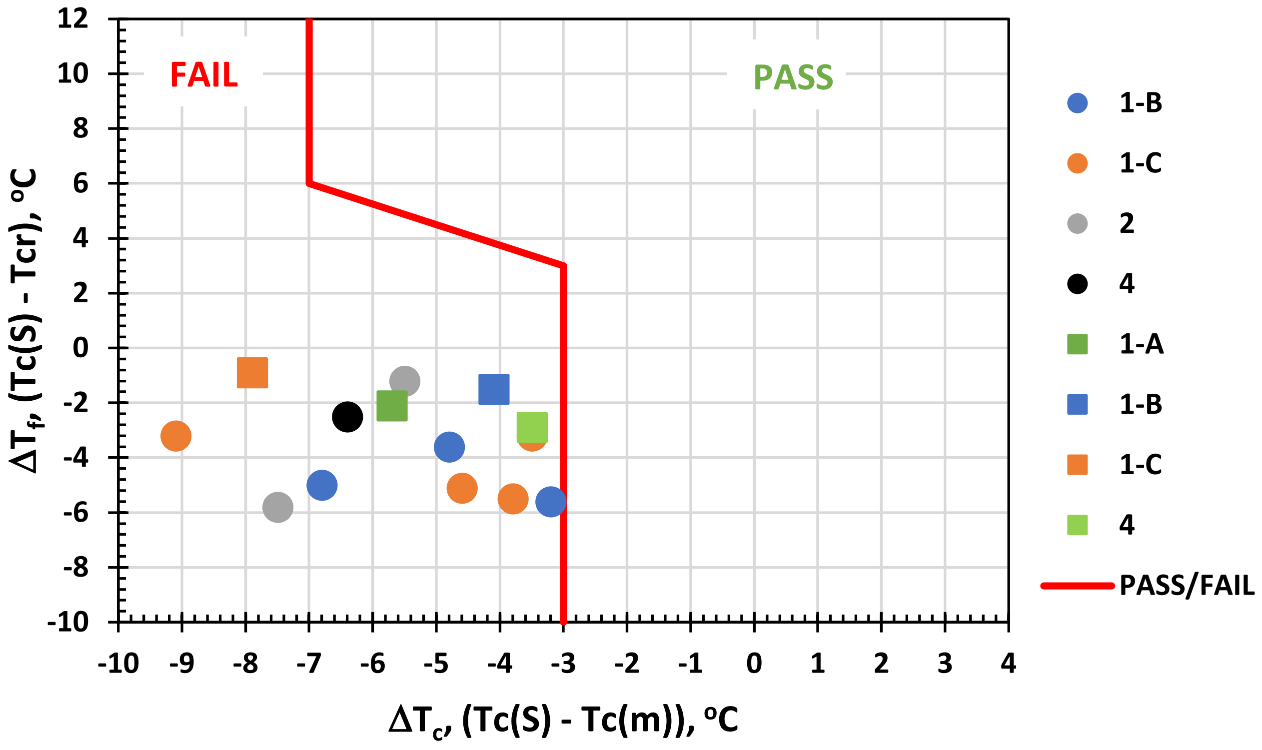
RED indicates failed criteria at that conditioning level

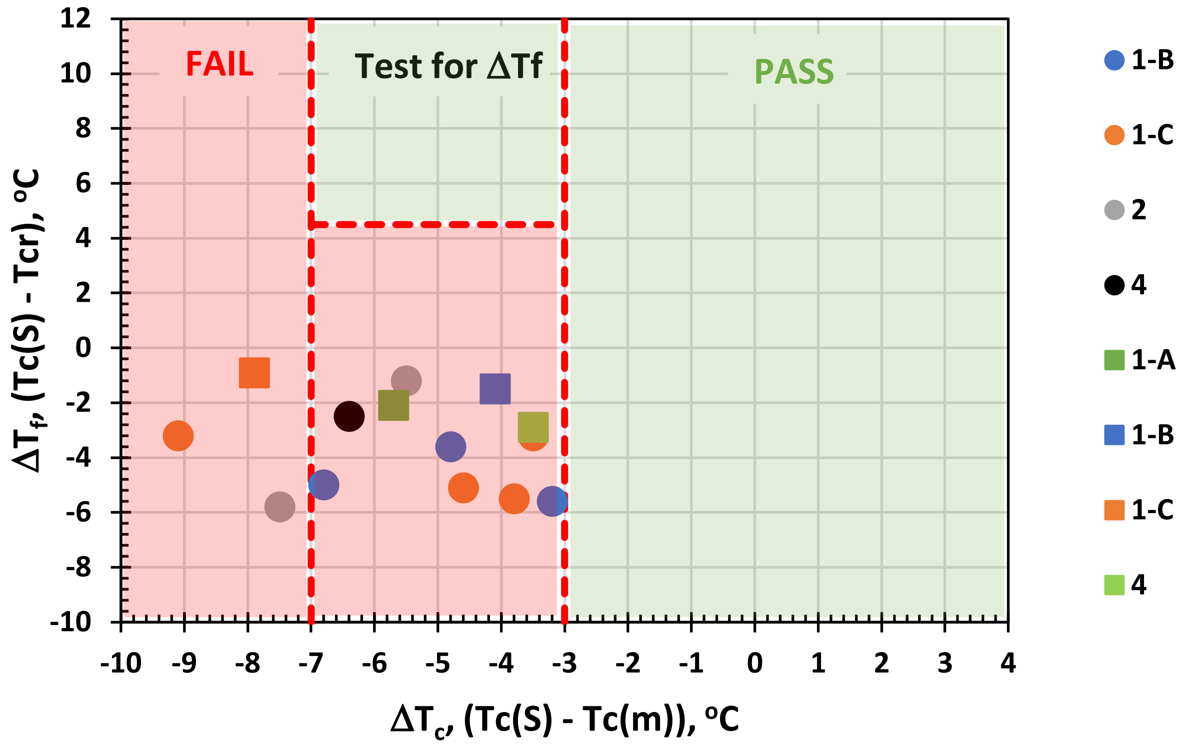
NCHRP 9-60/20-44(19) Approach – 20 Hr PAV





NCHRP 9-60/20-44(19) Approach – 40 Hr PAV





General Summary from Proposed NCHRP20-44(19)

20 HR PAV CONDITIONED

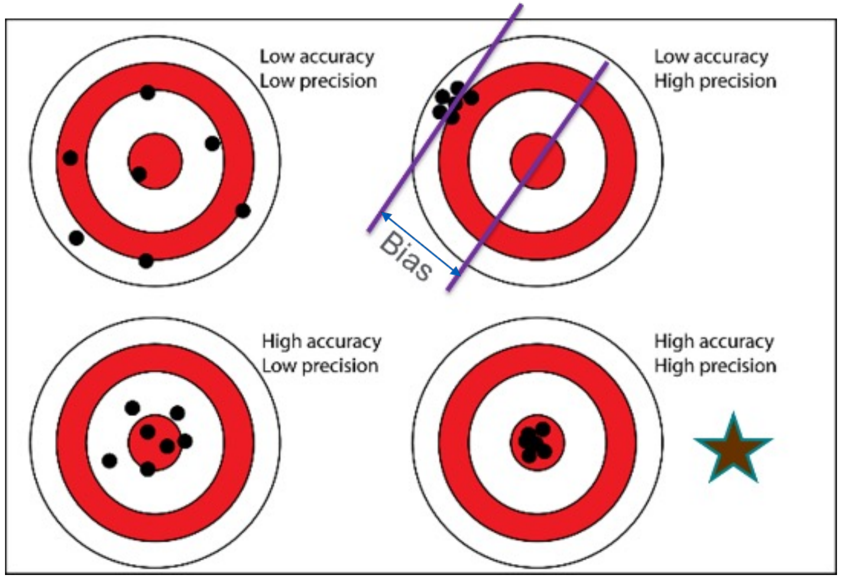
- No failures for Glover-Rowe
- No failures for BBR R-value range @ -22C
- 5 failures for ΔTc
  - All 5 failed ΔTf check
    - 4 PG64E-22; 1 PG64S-22

40 HR PAV CONDITIONED

- 8 failures for Glover-Rowe
- No failures for BBR R-value range @ -22C
- 14 failures for ΔTc
  - All 14 failed ΔTf check
  - Binders failing at 20 hr PAV also failed at 40 hr PAV
  - Only 1 binder sample passed

Criteria Selection?

- Results brings up a few questions
  - How does repeatability impact criteria?
  - Are the current criteria appropriate?
  - Does the criteria reflect mixture/pavement performance?



Mike Worden (2008)

Repeatability of ΔTc

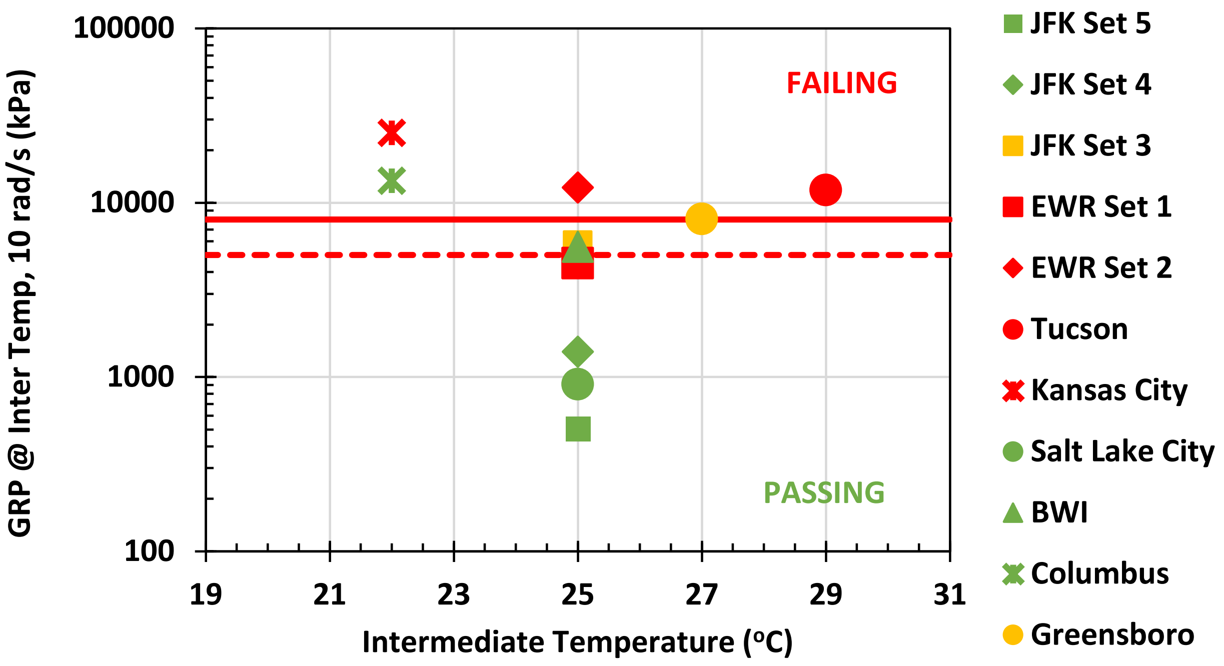
Study	Binder Type	ΔTc (°C)		Aging Method
		Average	2ds [1]	
Illinois DOT [2]	PG58-28	-3.9	2.8	40 Hr PAV [3]
	PG64-22	-6.5	2.6	
NEAUPG [4]	PG58-28	0.4	1.6	20 Hr PAV
		-3.0	3.3	40 Hr PAV (20 Hr + 20 Hr)
		-2.5	2.0	40 Hr PAV
	PG76-22 (PG64E-22)	-0.6	1.1	20 Hr PAV
		-3.5	2.9	40 Hr PAV (20 Hr + 20 Hr)
		-3.2	1.2	40 Hr PAV

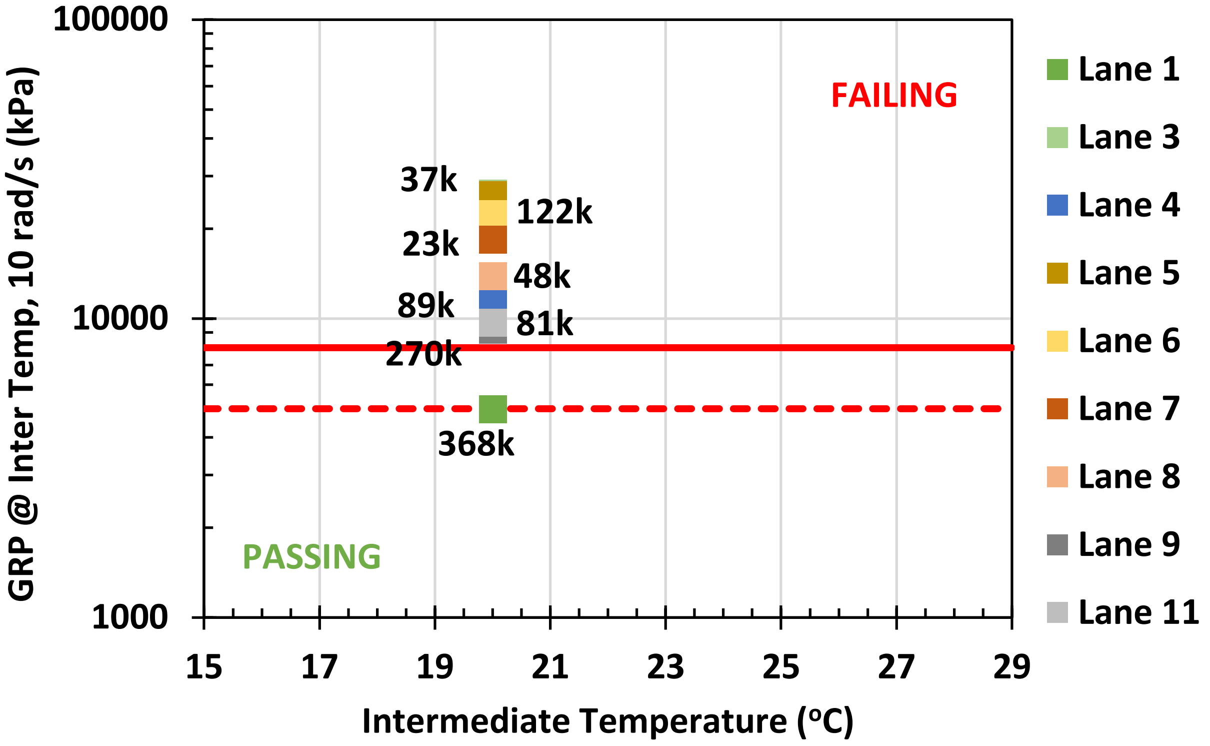
[1] 2ds is the allowable range of two results for multiple labs
[2] Study conducted by Asphalt Institute under Mike Anderson (2021)
[3] Not known how 40 Hrs were achieved in PAV
[4] Study conducted by Greg Harder (2019) under Northeast Asphalt User Producer Group (NEAUPG) Asphalt Binder Technical Group

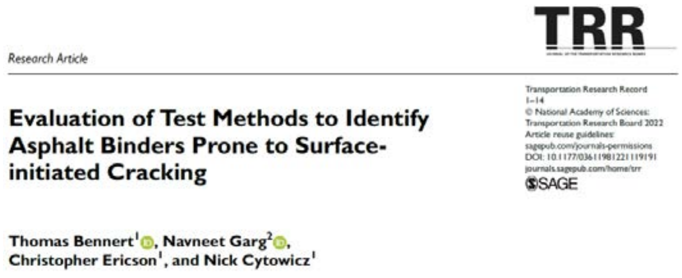
	20 Hr	40 HR
Ave 2ds	1.35	2.47

NCHRP 20-44(19): Criteria vs Performance

Field: G-R Intermediate Temp Criteria?







TRR

Research Article

Evaluation of Test Methods to Identify Asphalt Binders Prone to Surface-initiated Cracking

Transportation Research Record
1–14
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DOI: 10.1177/03611981221119191
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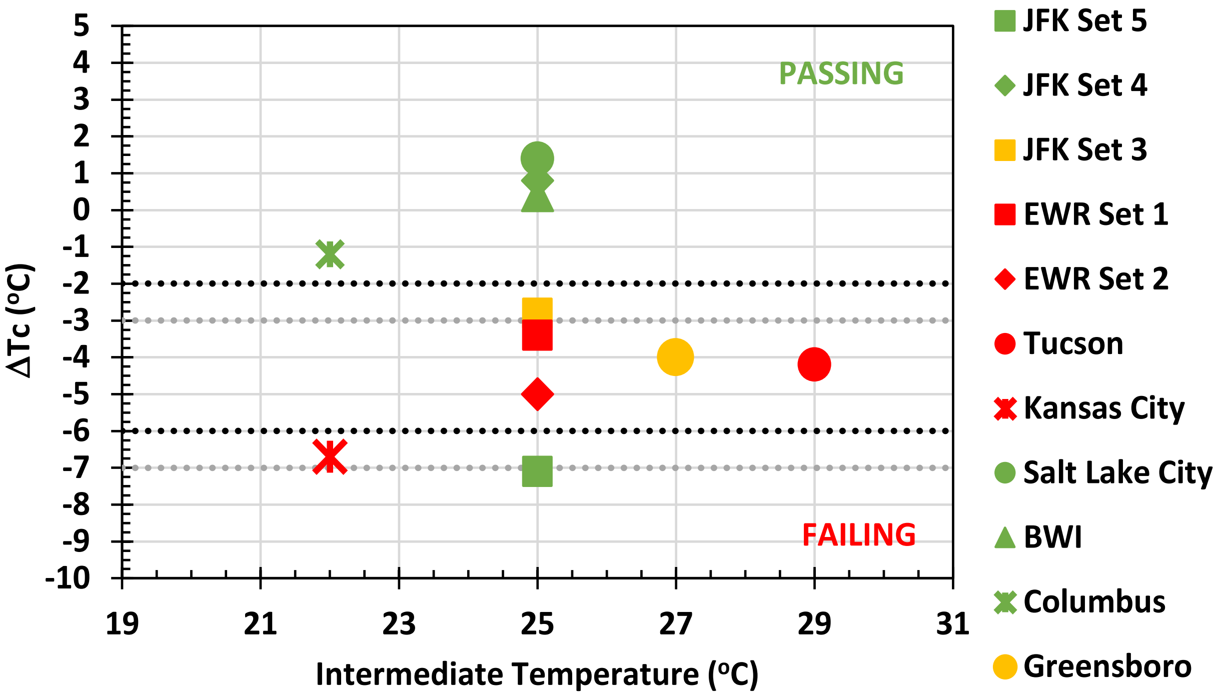
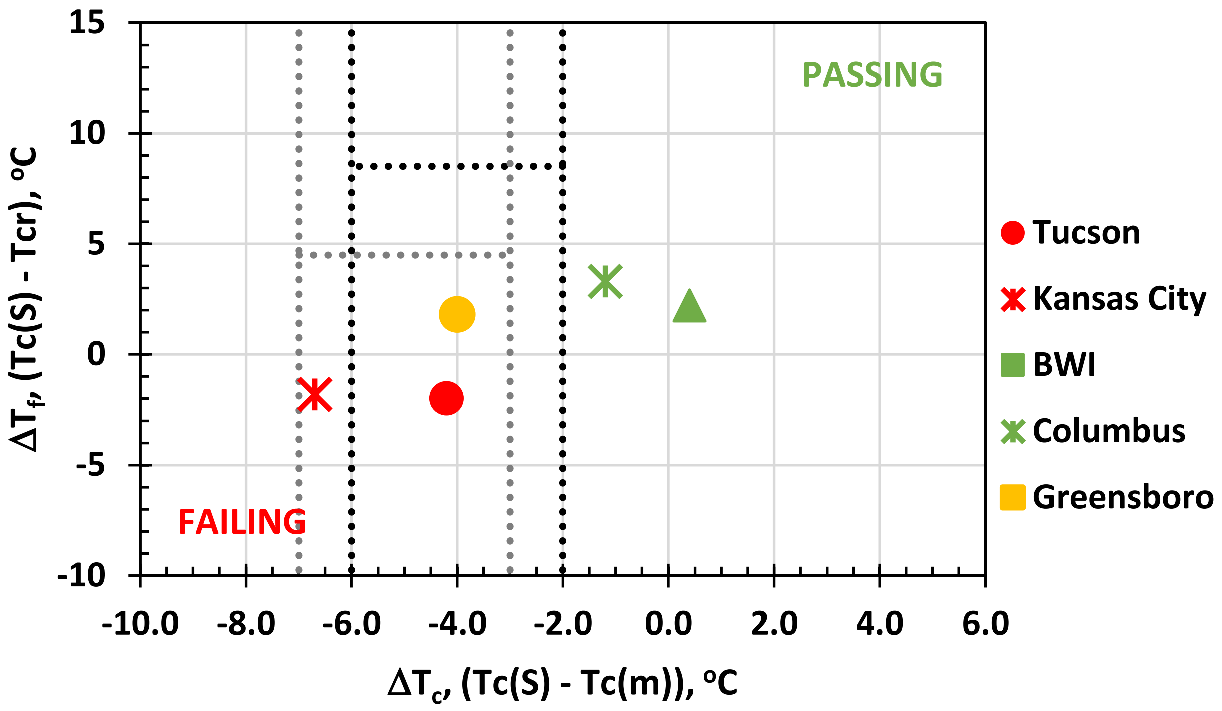
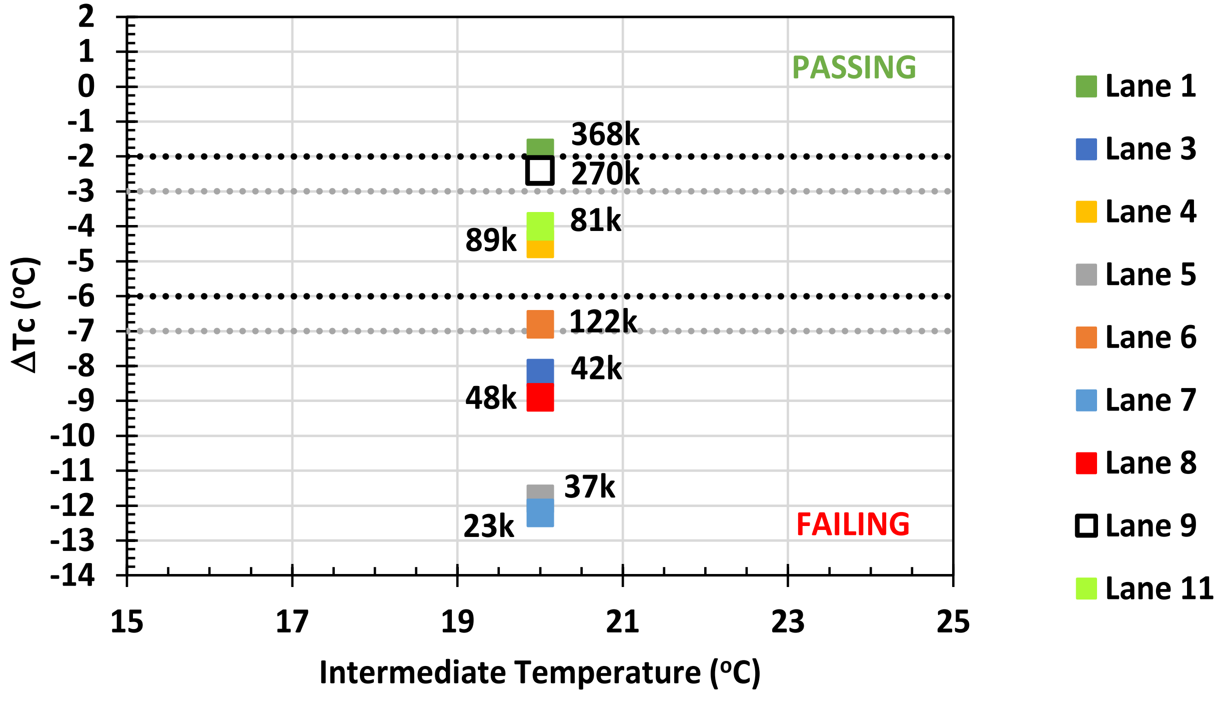
Thomas Bennert[1], Navneet Garg[2], Christopher Ericson[1], and Nick Cytowicz[1]

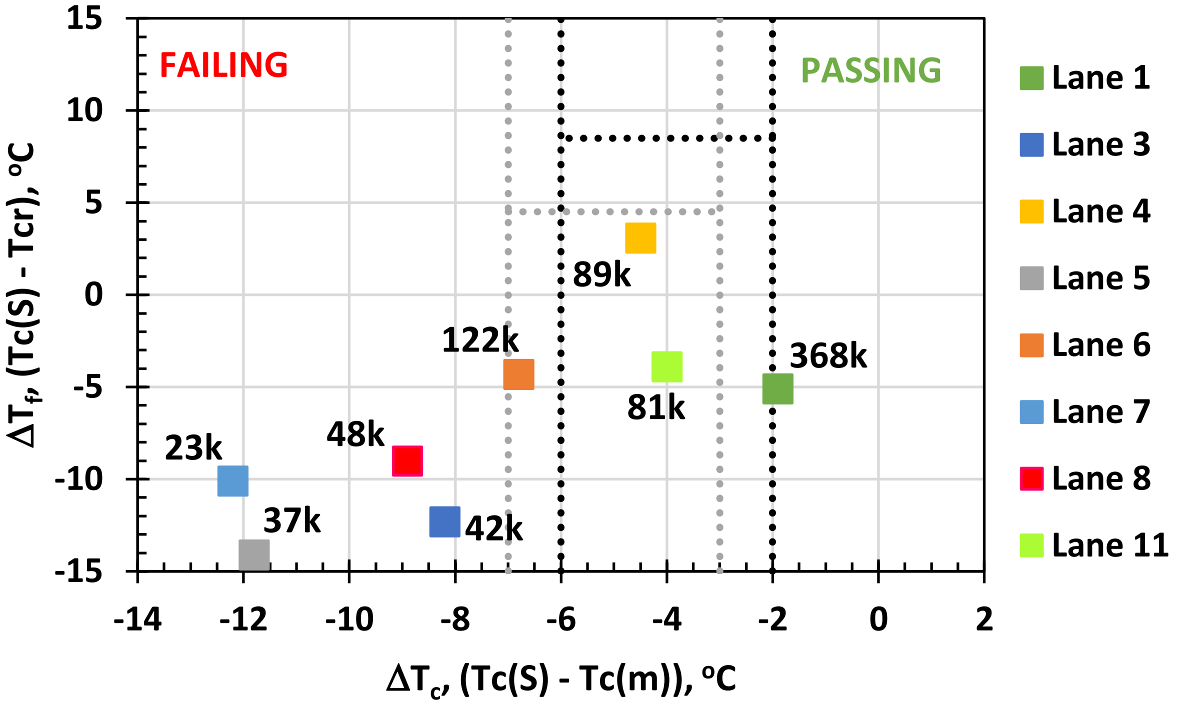
Field: ΔTc Criteria?





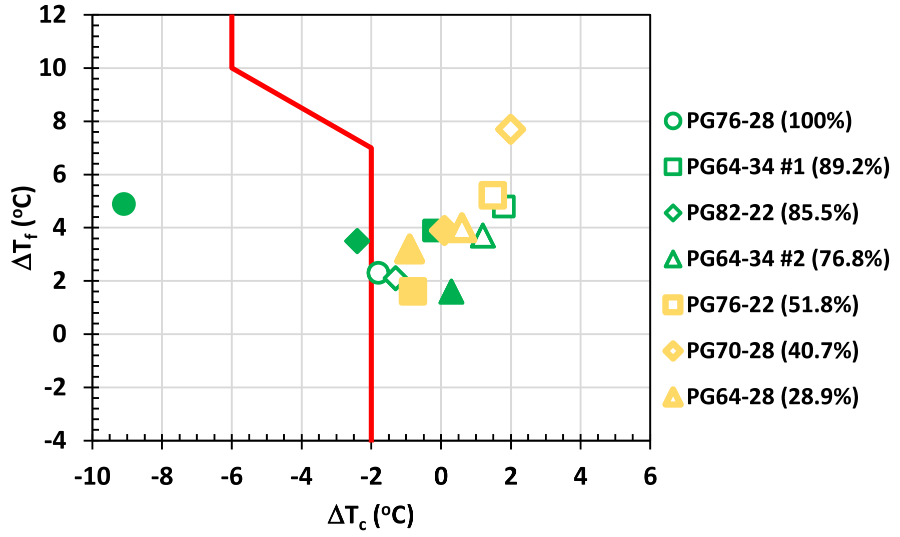
Field: ΔTc Criteria?

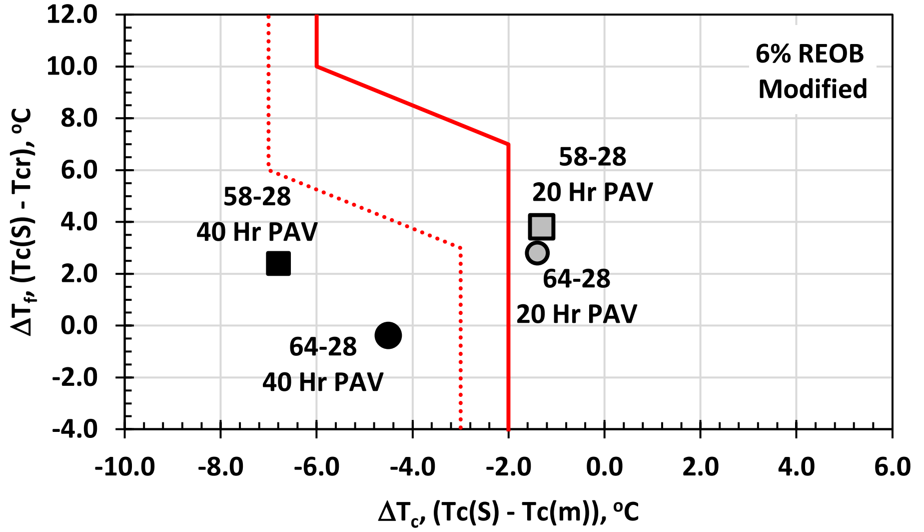




NCHRP 20-44(19) Criteria

- Overall, understanding first try, initial proposed criteria for Glover-Rowe and ΔTc seem appropriate for 20 Hr PAV
- ABCD & ΔTf parameter helps to differentiate but is it needed?
  - High PMA binders?
  - Equipment cost ≈ $50k
    - Can state agency justify if only used for small amount of testing?
    - Parameters related to other conventional tests?
- Concerned regarding 40 hr PAV criteria, especially for ΔTc
  - Repeatability of measurements
  - Too restrictive?

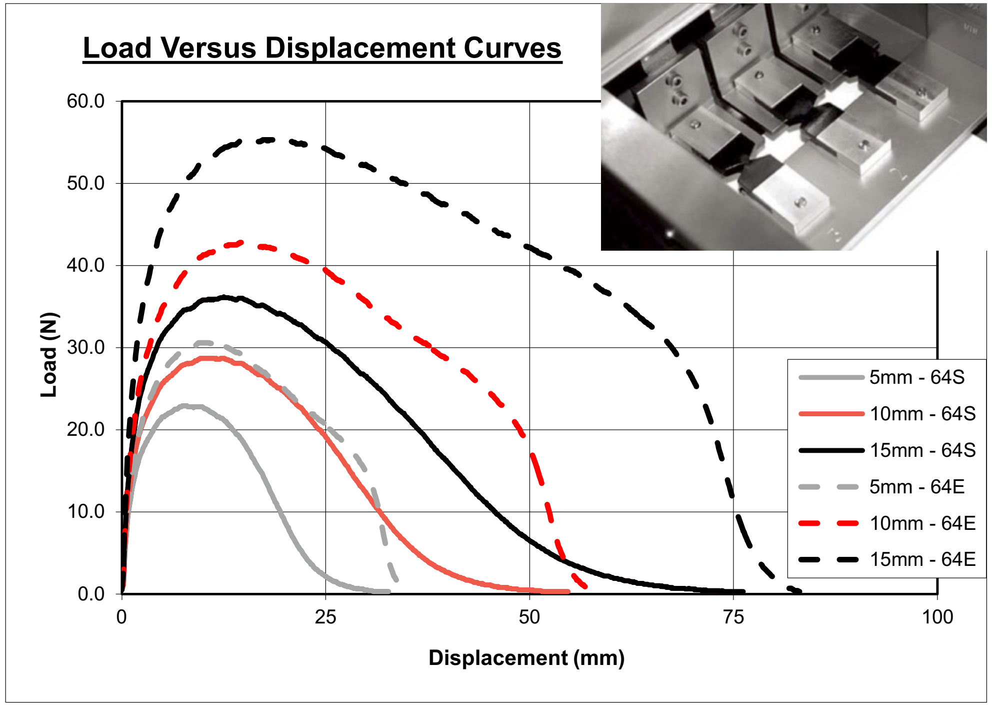




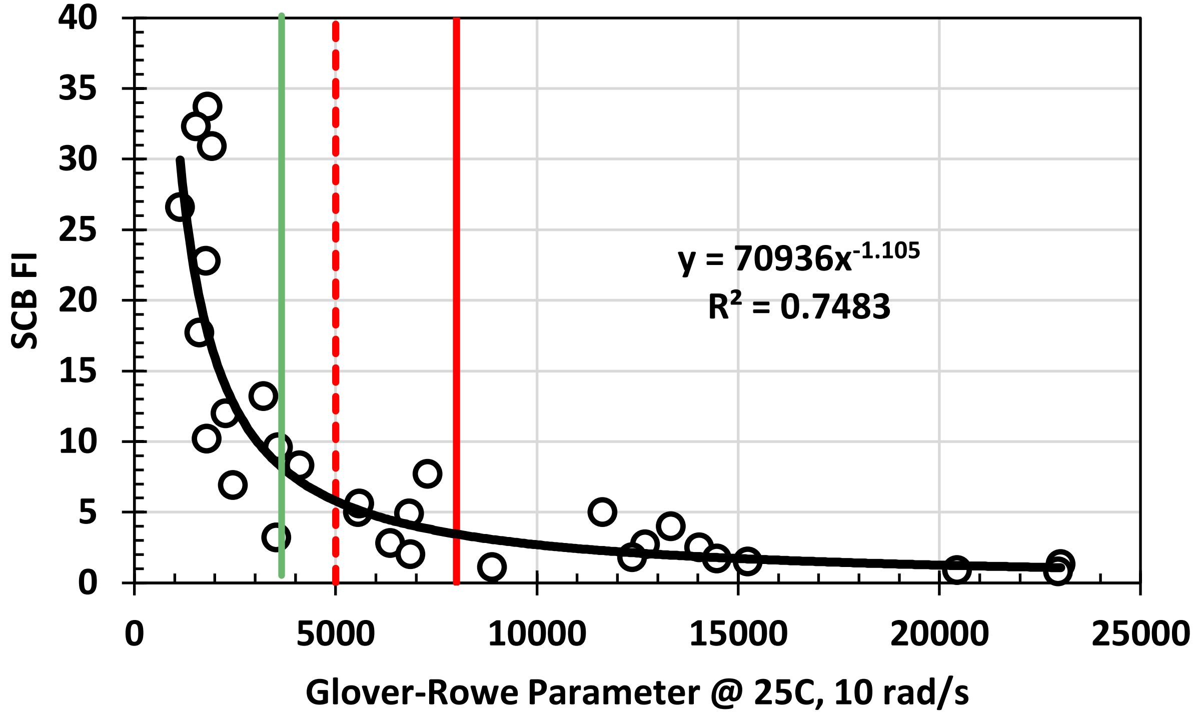
Impact on Balanced Mixture Design

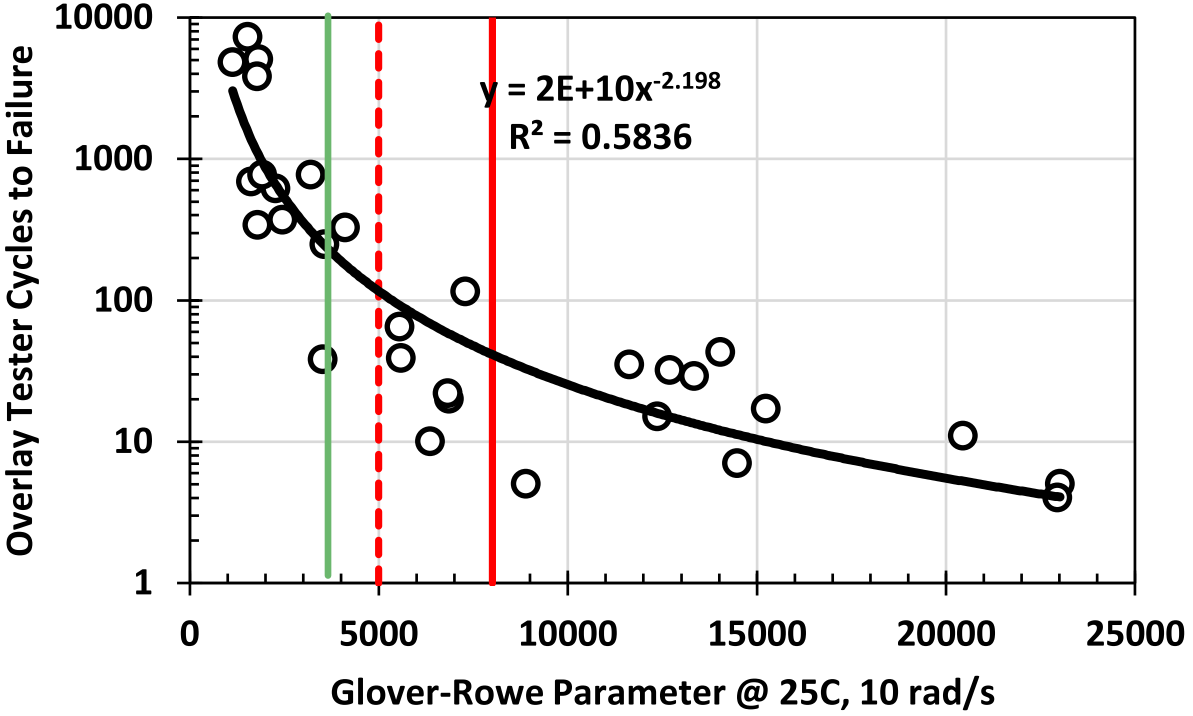
Impact of Binders on BMD

- As agencies move toward BMD, important for mix suppliers to understand impact of binders
  - Improve mix performance with improved binder performance?
  - Impact of supplier?
  - Contamination?
  - Volumetrics?
- As agencies move toward BMD, important for liquid suppliers to understand impact of binders
  - Variability from Lot to Lot?
  - Source change?



GRP Intermediate Temp Criteria vs Mixture Testing

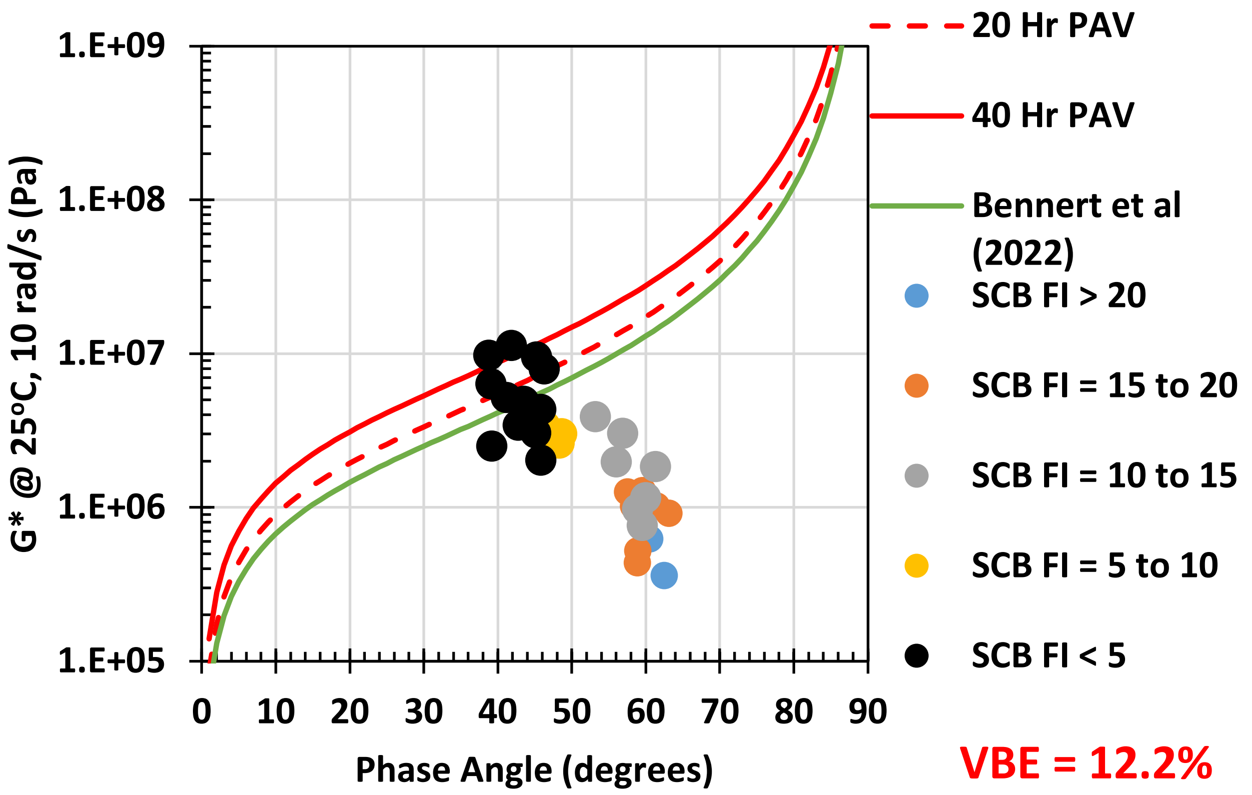




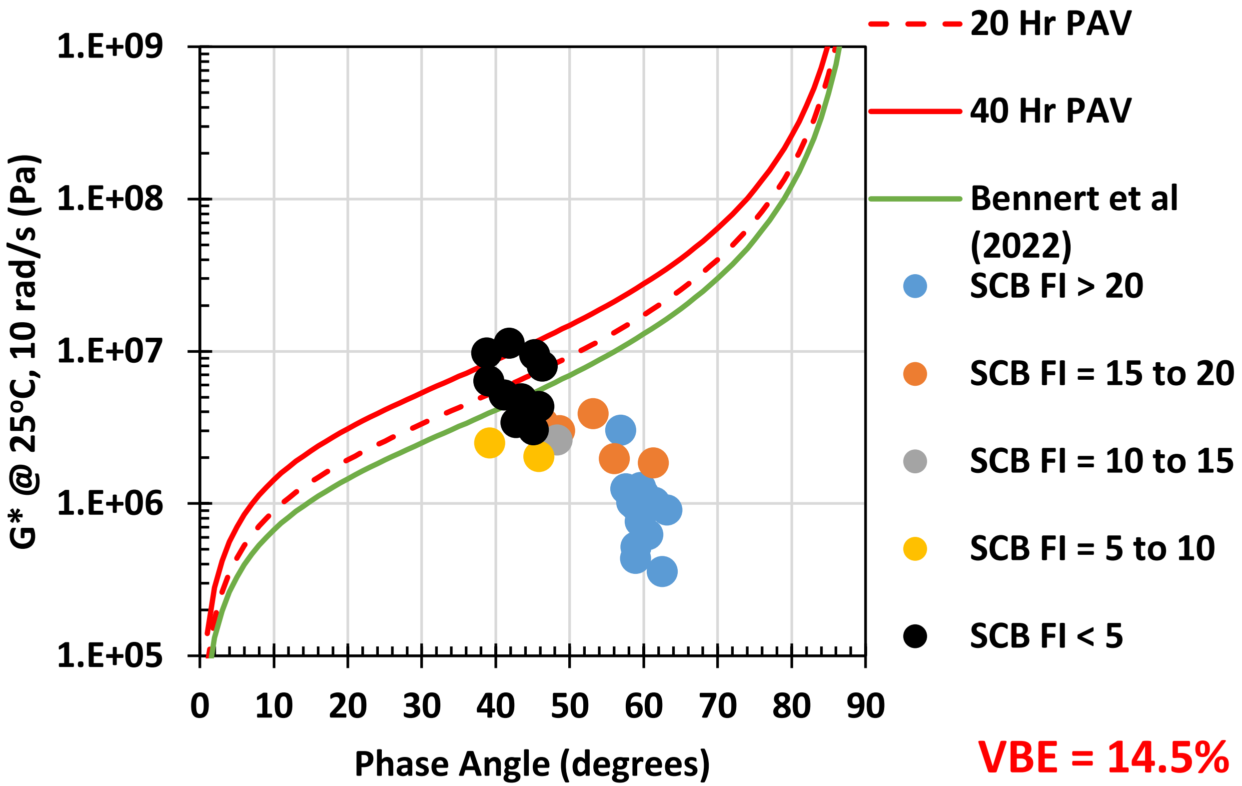
GRP @ 25C (kPa)	SCB FI @ 25C	OT Cycles @ 25C
3750	8.0	279
5000	5.8	148
8000	3.5	53

SCB FI vs Binder (GRP) vs Volumetrics

- Good binders provide good performance – poor binders result in poor performance
- Improved volumetrics can help moderate binder perform better!



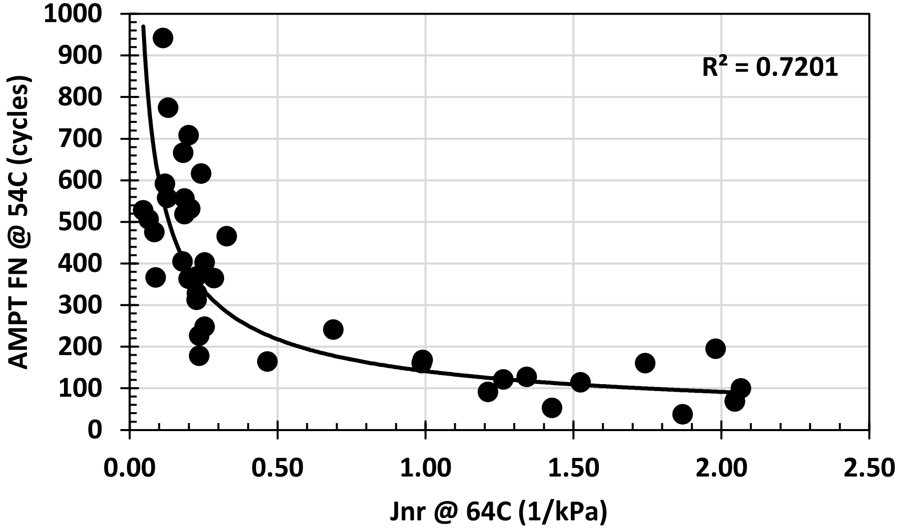
VBE = 12.2%

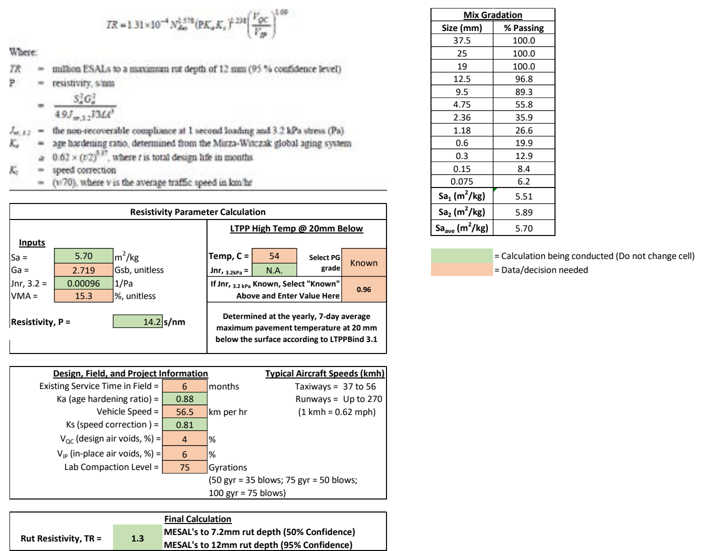


VBE = 14.5%

Impact on Rutting Performance

- Rutting performance dominated by non-recoverable creep compliance (Jnr)
  - Used Resistivity model developed by Don Christensen to compare 2021 NJDOT retains
  - Predicts MESAL's to reach a predicted rut depth
    - Differences in refineries
    - Differences in sampling date





$$TR = 1.31 \times 10^{-4} N_{des}^{1.578} (PK_a K_s)^{1.238} \left(\frac{V_{QC}}{V_{IP}}\right)^{1.00}$$

Where:

TR = million ESALs to a maximum rut depth of 12 mm (95 % confidence level)

P = resistivity, s/nm

$= \frac{S_a^2 G_a^2}{4.9 J_{nr,3.2} VMA^3}$

$J_{nr,3.2}$ = the non-recoverable compliance at 1 second loading and 3.2 kPa stress (Pa)

K_a = age hardening ratio, determined from the Mirza-Witczak global aging system

$= 0.62 \times (t/2)^{0.37}$, where t is total design life in months

K_s = speed correction

= (v/70), where v is the average traffic speed in km/hr

Resistivity Parameter Calculation

Inputs

Sa =	5.70	m^2/kg
Ga =	2.719	Gsb, unitless
Jnr, 3.2 =	0.00096	1/Pa
VMA =	15.3	%, unitless
Resistivity, P =	14.2	**s/nm**

LTPP High Temp @ 20mm Below

Temp, C =	54	**Select PG grade**	Known
Jnr, $_{3.2kPa}$ =	N.A.		
If Jnr, $_{3.2\ kPa}$ Known, Select "Known" Above and Enter Value Here			**0.96**

Determined at the yearly, 7-day average maximum pavement temperature at 20 mm below the surface according to LTPPBind 3.1

Design, Field, and Project Information

Existing Service Time in Field =	6	months
Ka (age hardening ratio) =	0.88	
Vehicle Speed =	56.5	km per hr
Ks (speed correction) =	0.81	
V_{QC} (design air voids, %) =	4	%
V_{IP} (in-place air voids, %) =	6	%
Lab Compaction Level =	75	Gyrations (50 gyr = 35 blows; 75 gyr = 50 blows; 100 gyr = 75 blows)

Typical Aircraft Speeds (kmh)

Taxiways = 37 to 56
Runways = Up to 270
(1 kmh = 0.62 mph)

Final Calculation

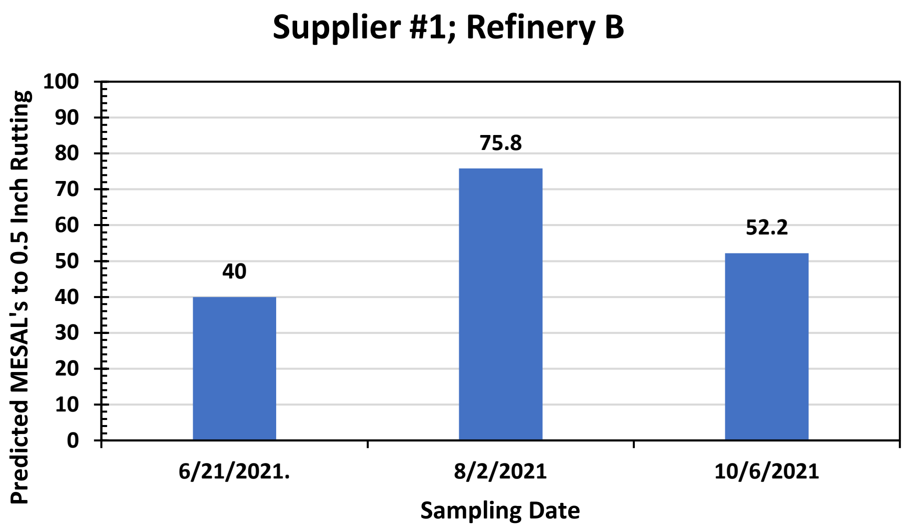
Rut Resistivity, TR =	**1.3**	**MESAL's to 7.2mm rut depth (50% Confidence)**
		MESAL's to 12mm rut depth (95% Confidence)

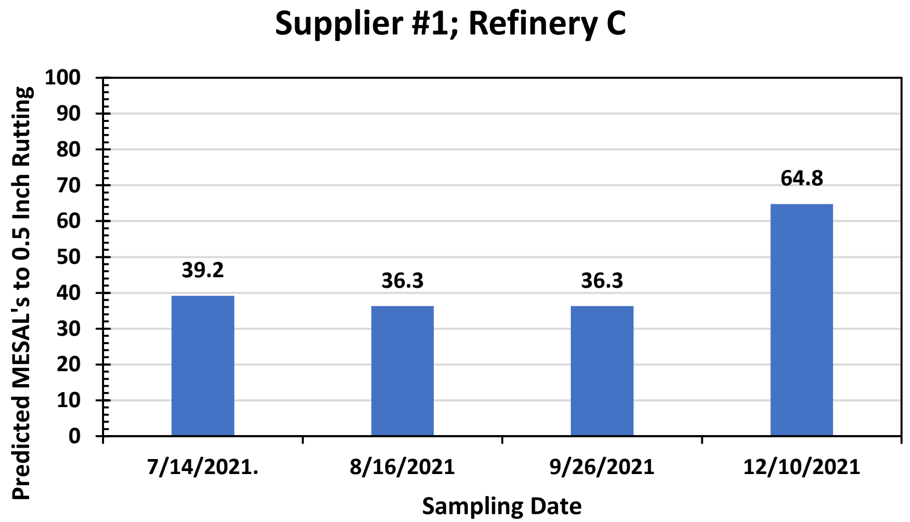
Mix Gradation

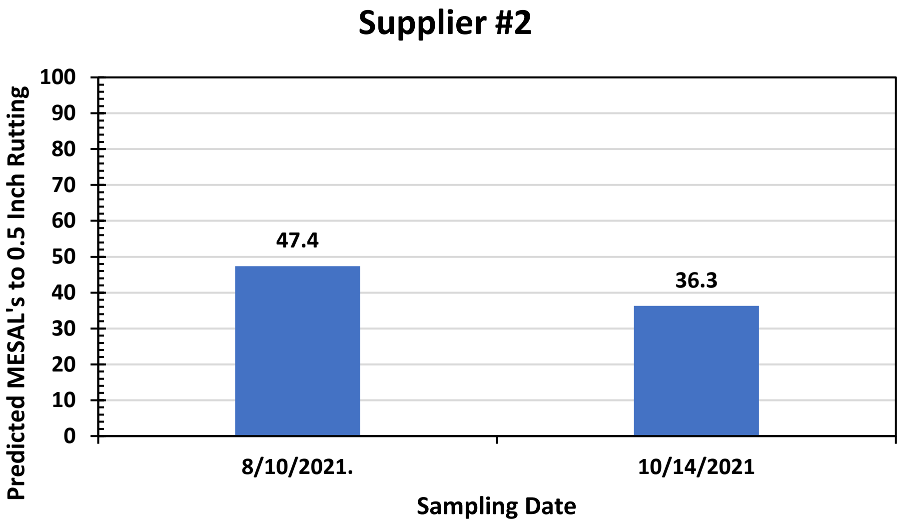
Size (mm)	% Passing
37.5	100.0
25	100.0
19	100.0
12.5	96.8
9.5	89.3
4.75	55.8
2.36	35.9
1.18	26.6
0.6	19.9
0.3	12.9
0.15	8.4
0.075	6.2
Sa_1 (m^2/kg)	5.51
Sa_2 (m^2/kg)	5.89
Sa_{ave} (m^2/kg)	5.70

= Calculation being conducted (Do not change cell)
= Data/decision needed

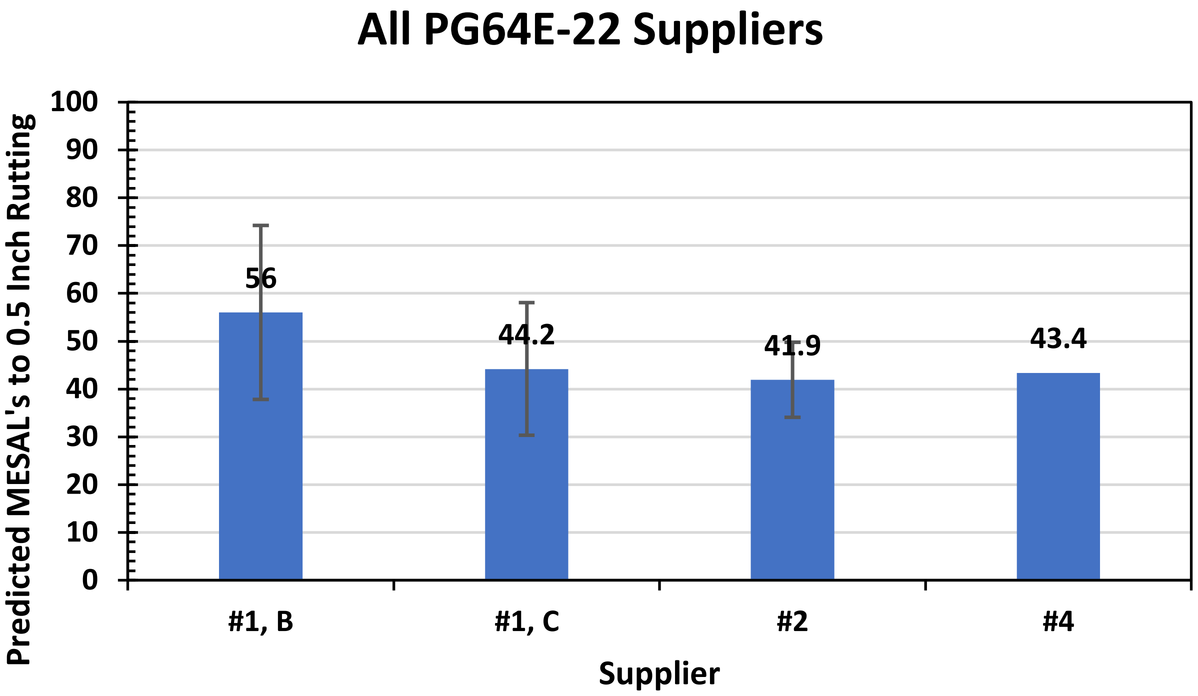
Impact on Rutting Performance (Sampling Date) – PG64E

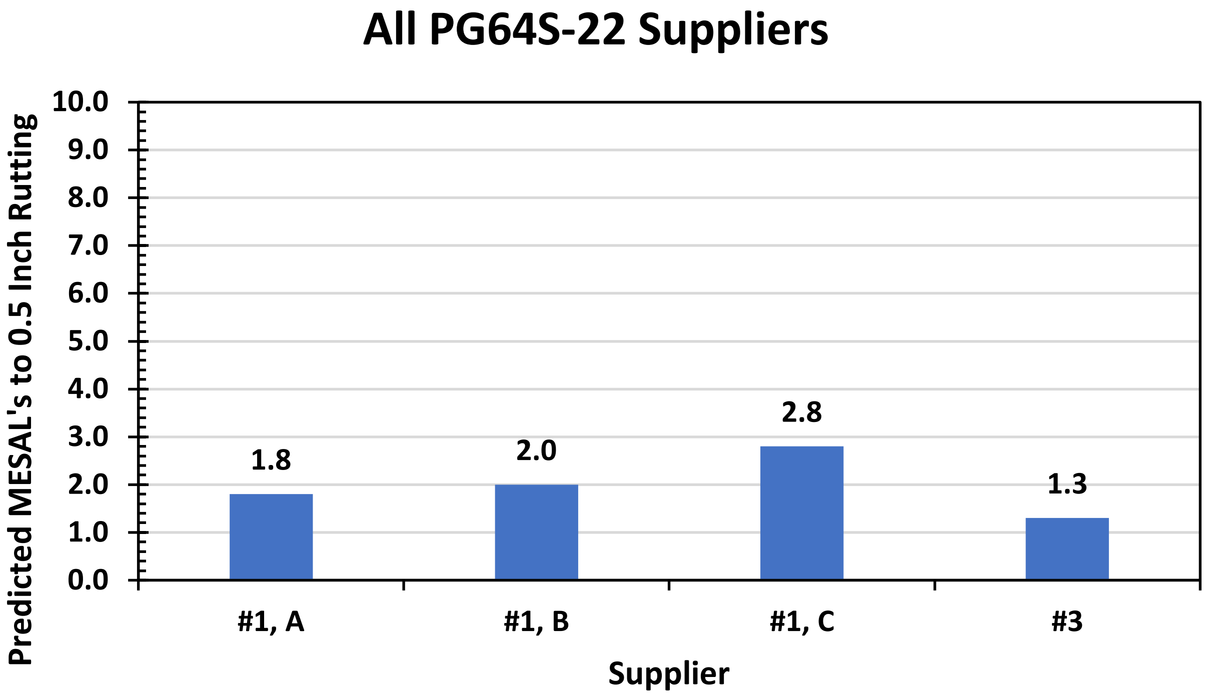






Impact on Rutting Performance – All Suppliers & Binders





Final Thoughts

Final Thoughts and Conclusions

- Both GRP and ΔTc show relationship to cracking performance and recommended for states to adopt
  - Proposed criteria appear "close"
- Inclusion of ABCD & ΔTf still debatable
  - Good research tool for fracture, but will it pick up PMA the poor ΔTc
    - Perhaps revising threshold is needed
- Concern regarding 40 hr PAV criteria
  - Repeatability of ΔTc measurements comes into play
- Supplier variability needs to be understood by mix suppliers
  - Can not design on edge of BMD criteria
- Engineered binders will help BMD, but volumetrics will still play a significant role, especially on the cracking side!

As Ted Lasso reminded us..
"Be curious, not judgmental…"

Thank you for your time!

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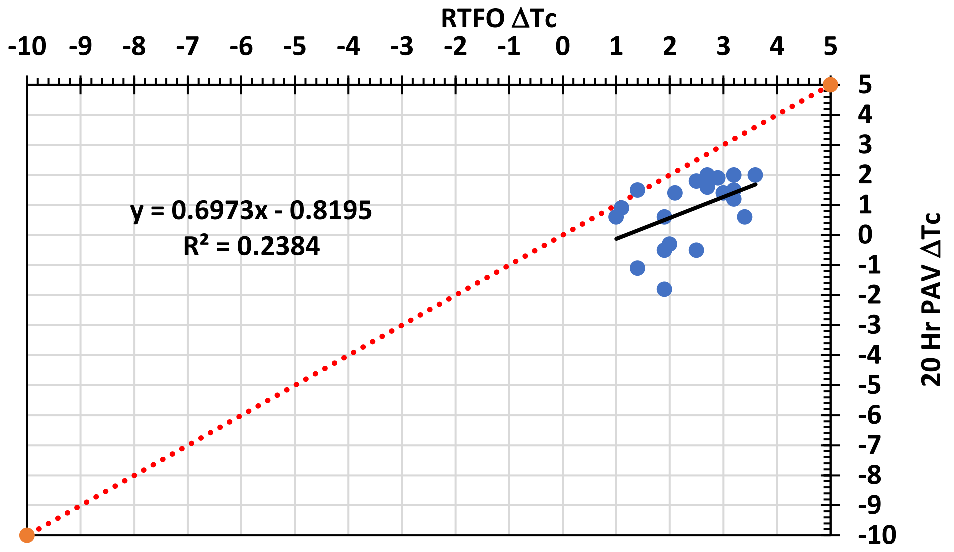
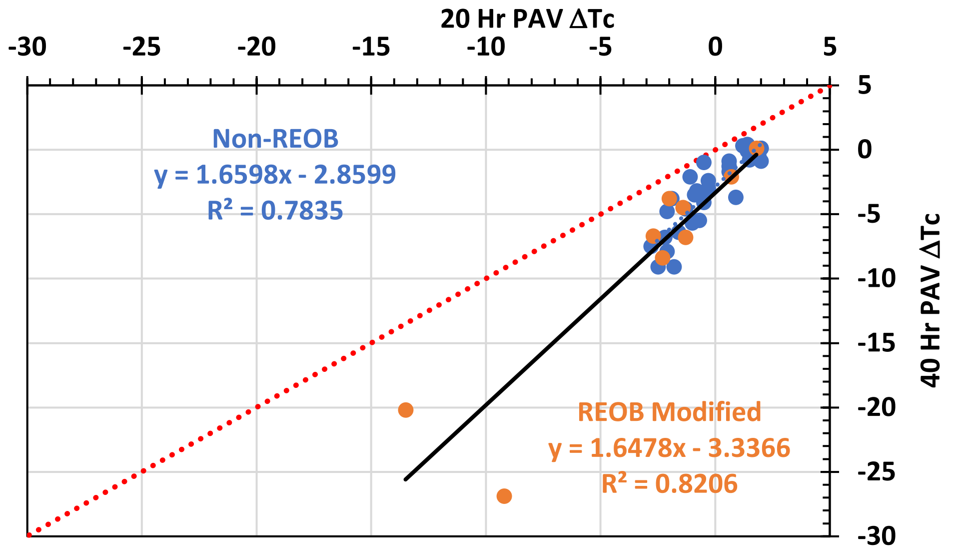
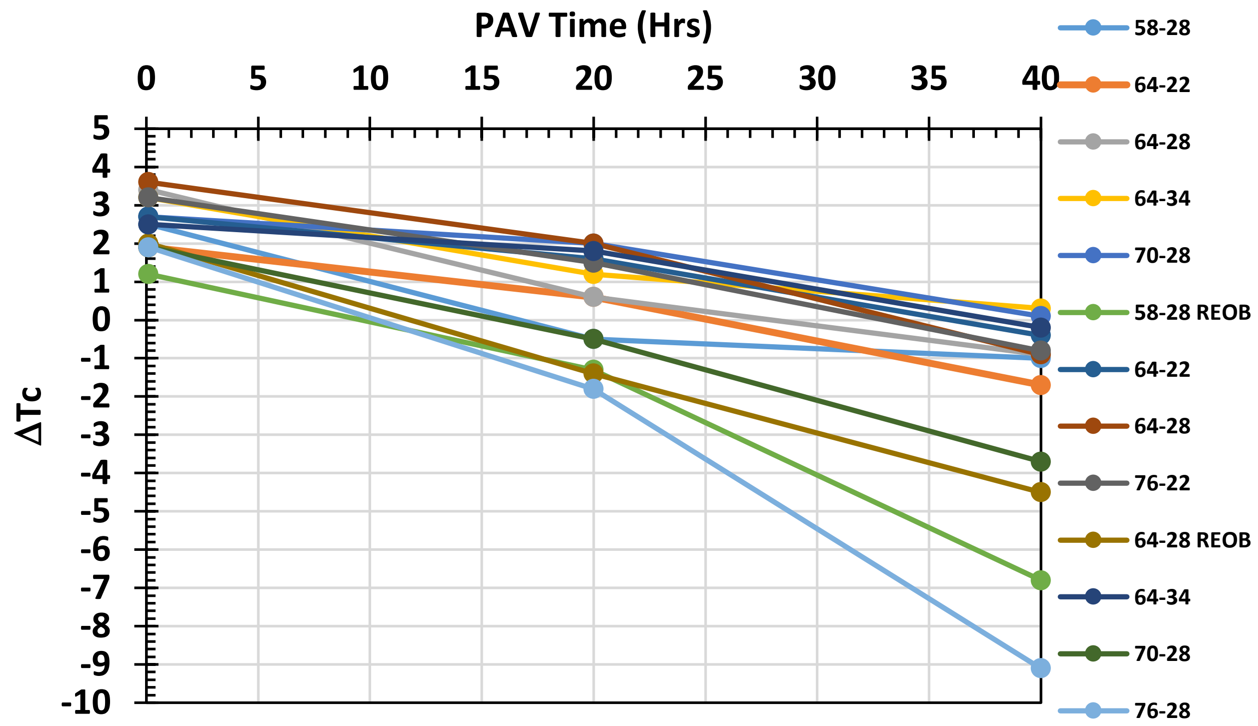
General Summary from Proposed NCHRP20-44(19)

- At 20 hour PAV
  - No failures for Glover-Rowe
  - No failures for BBR R-value range @ -22C
  - 5 failures for ΔTc
    - All 5 failed ΔTf check
- At 40 hour
  - 8 failures for Glover-Rowe
  - No failures for BBR R-value range @ -22C
  - 14 failures for ΔTc
    - All 14 failed ΔTf check
    - Binders failing at 20 hr PAV also failed at 40 hr PAV

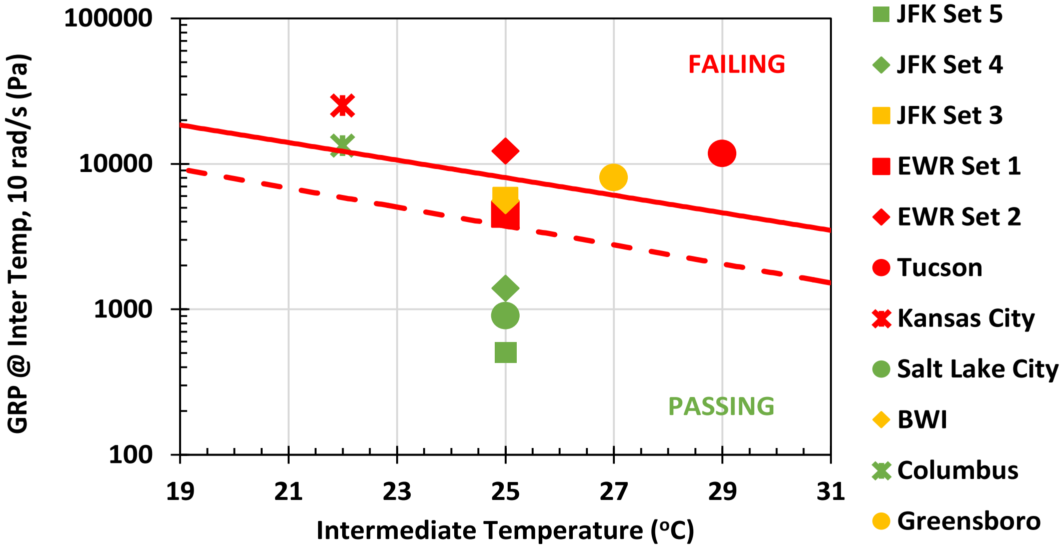
ΔTc Criteria – 20 Hr vs 40 Hr

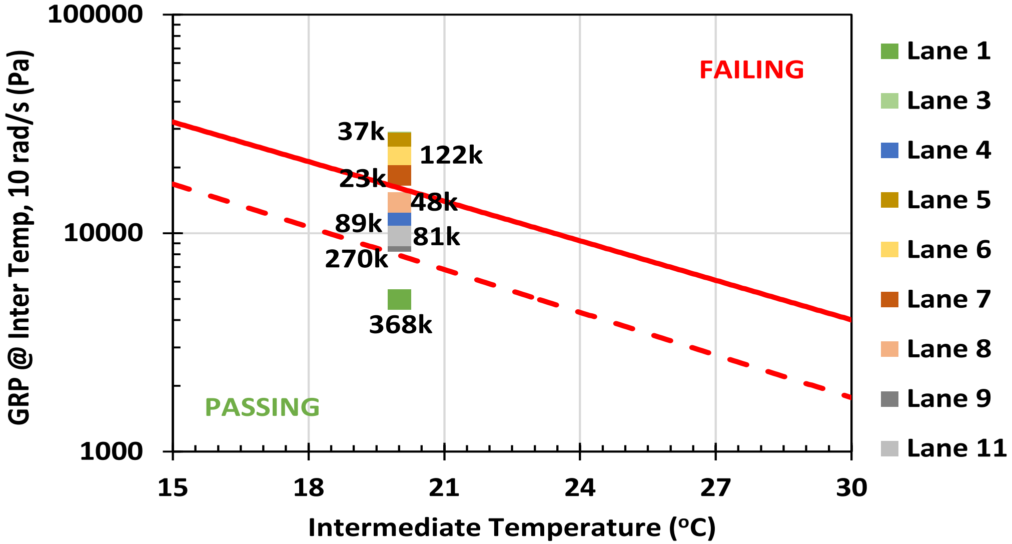




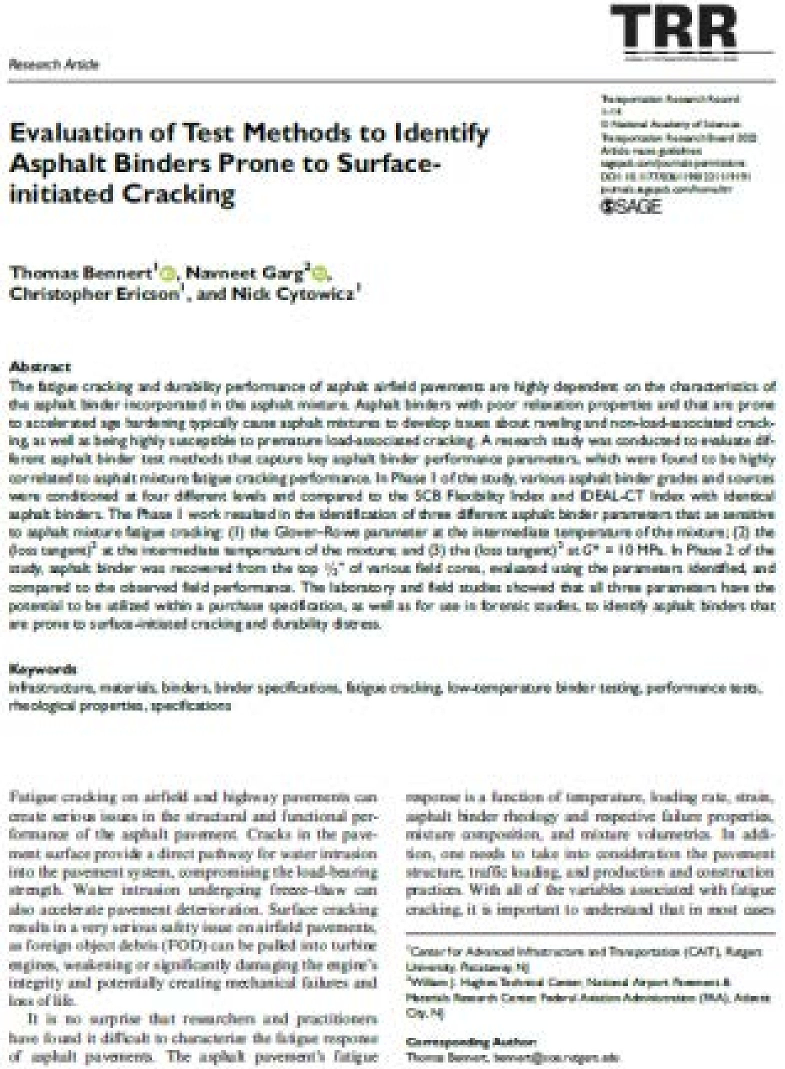


G-R Intermediate Temp Criteria?





Temp (C)	Warning	Limit
15	16760	32258
17	12416	24429
19	9198	18500
22	5865	12192
25	3740	8035
27	2770	6085
35	834	2001



TRR

Research Article

Evaluation of Test Methods to Identify Asphalt Binders Prone to Surface-initiated Cracking

Thomas Bennert[1], Navneet Garg[2], Christopher Ericson[1], and Nick Cytowicz[1]

Abstract

The fatigue cracking and durability performance of asphalt airfield pavements are highly dependent on the characteristics of the asphalt binder incorporated in the asphalt mixture. Asphalt binders with poor relaxation properties and that are prone to accelerated age hardening typically cause asphalt mixtures to develop issues about raveling and non-load-associated cracking, as well as being highly susceptible to premature load-associated cracking. A research study was conducted to evaluate different asphalt binder test methods that capture key asphalt binder performance parameters, which were found to be highly correlated to asphalt mixture fatigue cracking performance. In Phase 1 of the study, various asphalt binder grades and sources were conditioned at four different levels and compared to the SCB Flexibility Index and IDEAL-CT Index with identical asphalt binders. The Phase 1 work resulted in the identification of three different asphalt binder parameters that are sensitive to asphalt mixture fatigue cracking: (1) the Glover–Rowe parameter at the intermediate temperature of the mixture; (2) the (loss tangent)^2 at the intermediate temperature of the mixture; and (3) the (loss tangent)^2 at G* = 10 MPa. In Phase 2 of the study, asphalt binder was recovered from the top ½" of various field cores, evaluated using the parameters identified, and compared to the observed field performance. The laboratory and field studies showed that all three parameters have the potential to be utilized within a purchase specification, as well as for use in forensic studies, to identify asphalt binders that are prone to surface-initiated cracking and durability distress.

Keywords

infrastructure, materials, binders, binder specifications, fatigue cracking, low-temperature binder testing, performance tests, rheological properties, specifications

Fatigue cracking on airfield and highway pavements can create serious issues in the structural and functional performance of the asphalt pavement. Cracks in the pavement surface provide a direct pathway for water intrusion into the pavement system, compromising the load-bearing strength. Water intrusion undergoing freeze–thaw can also accelerate pavement deterioration. Surface cracking results in a very serious safety issue on airfield pavements, as foreign object debris (FOD) can be pulled into turbine engines, weakening or significantly damaging the engine's integrity and potentially creating mechanical failures and loss of life.

It is no surprise that researchers and practitioners have found it difficult to characterize the fatigue response of asphalt pavements. The asphalt pavement's fatigue response is a function of temperature, loading rate, strain, asphalt binder rheology and respective failure properties, mixture composition, and mixture volumetrics. In addition, one needs to take into consideration the pavement structure, traffic loading, and production and construction practices. With all of the variables associated with fatigue cracking, it is important to understand that in most cases

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