Evaluation of the Asphalt Binder Cracking Device (ABCD)

Presented By:

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Northeast States Materials Engineers Association (NESMEA)
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(Somewhere from my house)

Acknowledgements

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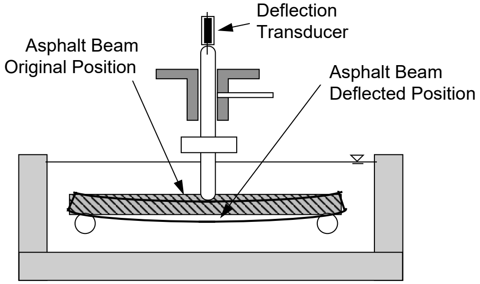
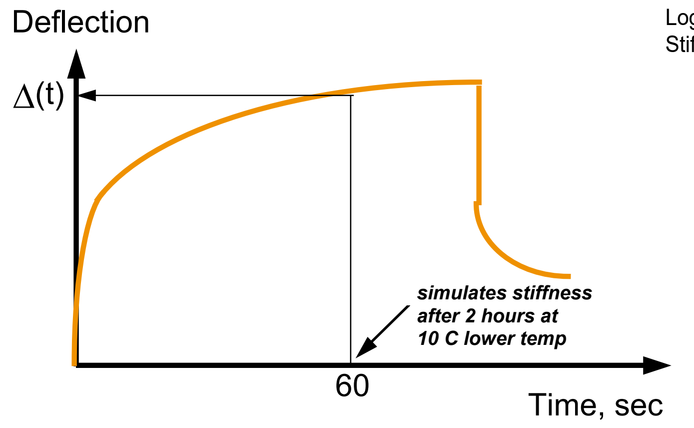
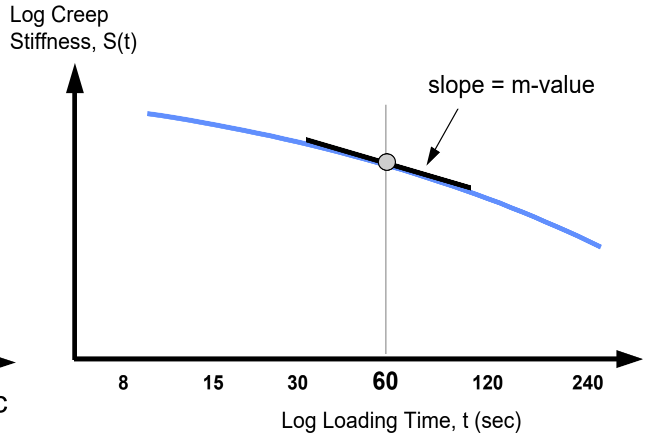
- Rutgers Asphalt Pavement Lab (RAPL) Staff
  - Asphalt Binder: Nick Cytowicz, Chris Ericson
  - Asphalt Mixture: Ed Haas, Drew Tulanowski, Ed Wass Jr.

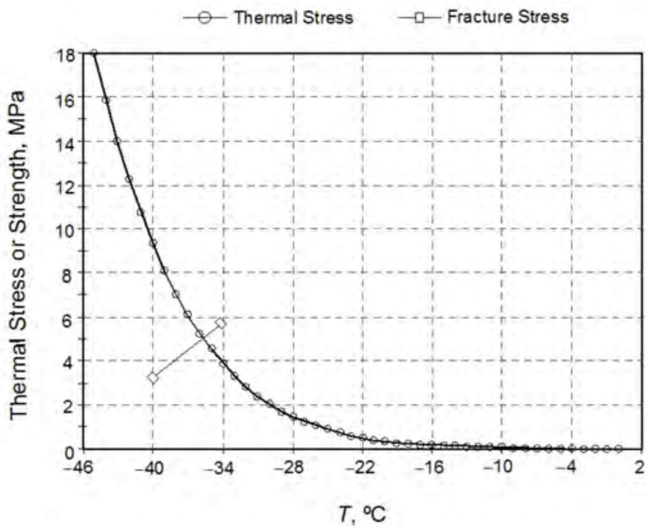
Once Upon a Time in the 1990's…

AASHTO T313



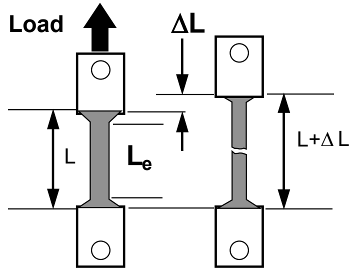




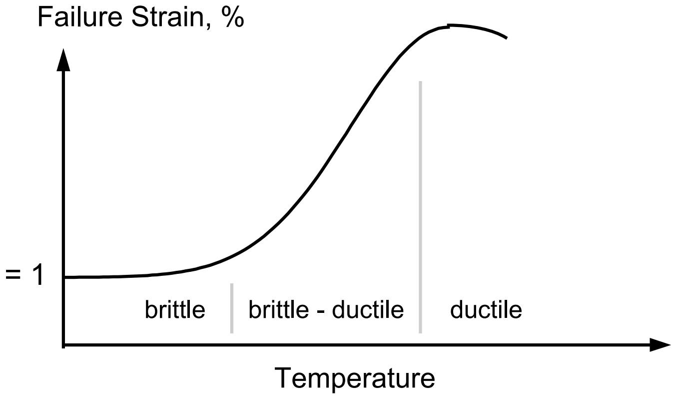


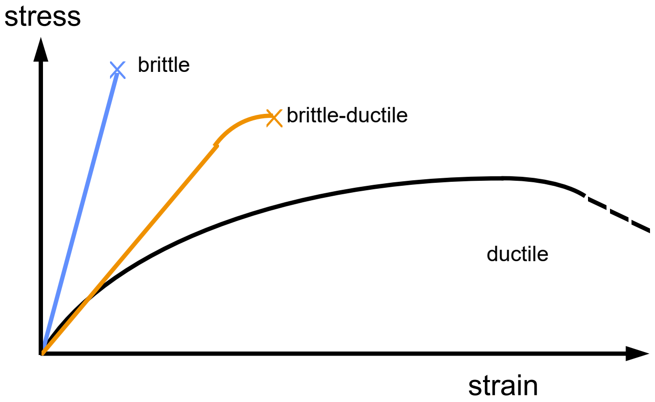
AASHTO R49 (1999)

AASHTO T314



$$\text{failure strain } (\varepsilon_f) = \frac{\text{change in length } (\Delta L)}{\text{effective length } (L_e)}$$



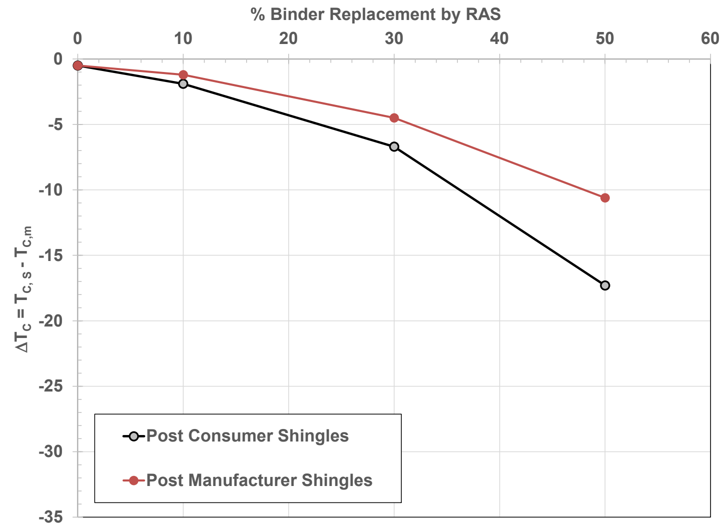


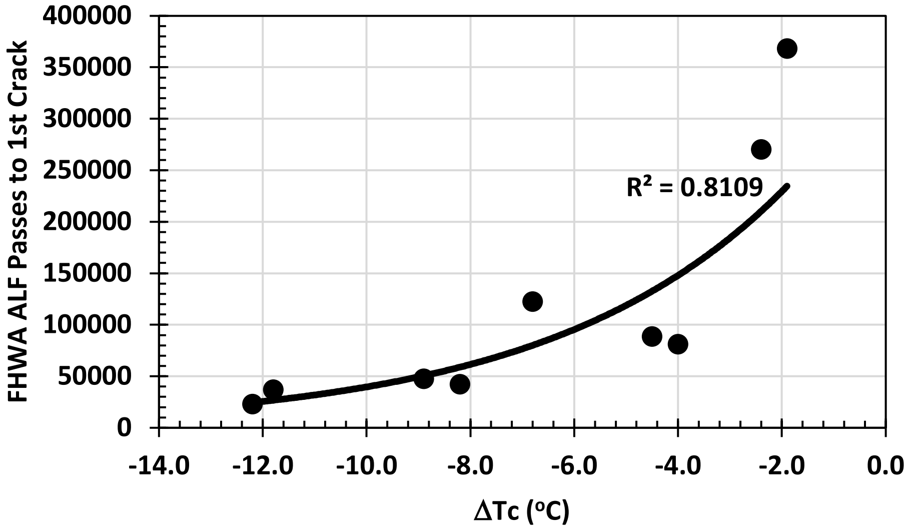
Fast Forward to 2011 - ΔT_c from BBR Testing

- As asphalt binders age, the relaxation properties (m-value) are negatively affected at greater rate than the stiffness (S)
- The difference between the low temperature cracking grade of m-value and S is defined as the ΔT_c

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

- AAPT (Anderson et al., 2011) showed that the ΔT_c correlated to non-load associated cracking on airfields (i.e. – cracking due to lose of ductility from aging)





ΔT_c from BBR Testing

Asphalt Institute Technical Document

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

October 4, 2019

Asphalt Institute Technical Advisory Committee
2019 ISBN: 978-1-934154-77-9

Agency	ΔT_c Requirement, °C	PAV Aging Duration, hrs.	Status
Florida DOT	$\geq$ -5.0	20	Current
Utah DOT	$\geq$ -2.0	20	Current[2]
PANYNJ	$\geq$ -5.0	40	Current
Vermont DOT	$\geq$ -5.0	40	Current
Maryland DOT	$\geq$ -5.0	40	Current
Kansas DOT	$\geq$ -5.0	40	Current
Ontario MTO	$\geq$ -5.0	20	Current
Texas DOT	$\geq$ -6.0[4]	20	Current[4]
Oklahoma DOT	$\geq$ -6.0	20	2020[3]
Delaware DOT	$\geq$ -5.0	40	2020[3]

[1] Consult Asphalt Institute web site for current asphalt binder specification database (www.asphaltinstitute.org)

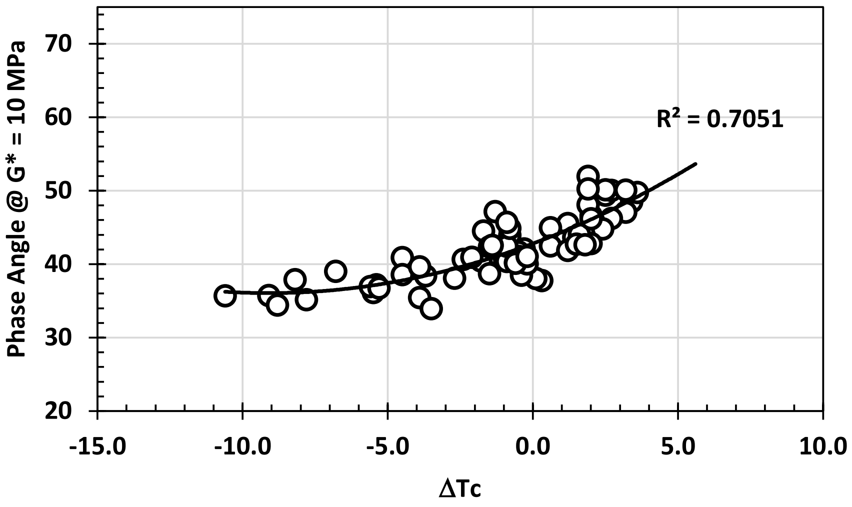
[2] Only applies to binders with $\geq$ 92° C temperature spread; BBR creep stiffness $\geq$ 150 MPa

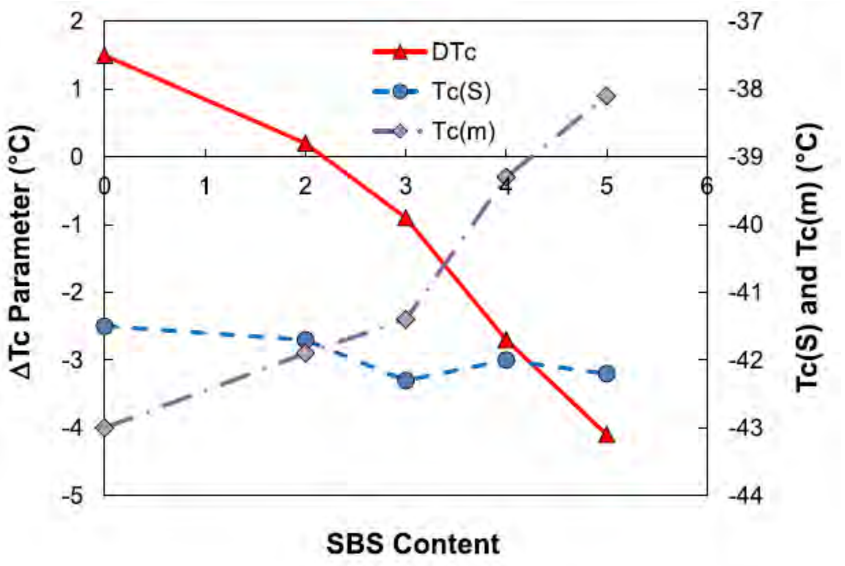
[3] Applies to project tendered for bid beginning 1/1/2020

[4] Only applies to Balanced Mix Design projects. For comparison, TxDOT requirement is shown using ΔT_c computed by $\Delta T_c = T_{c,S} - T_{c,m}$.; actual requirement is $\Delta T_c \leq 6$°C using the equation $\Delta T_c = T_{c,m} - T_{c,S}$. (41)

ΔT_c from BBR Testing

- ΔT_c has shown to provide good relationship to observed field cracking
  - Found to be related to relaxation properties of asphalt binders
  - Sensitive to asphalt binder elements that may accelerate age hardening
- However, some concern over heavily polymer modified binders
  - Asphalt binder phase angle related to ΔT_c (relaxation properties)
  - High PMA reduces δ, which results in poor performance with ΔT_c
- There is a need for a test method that can capture fracture & strain tolerance properties (properties enhanced by polymers)

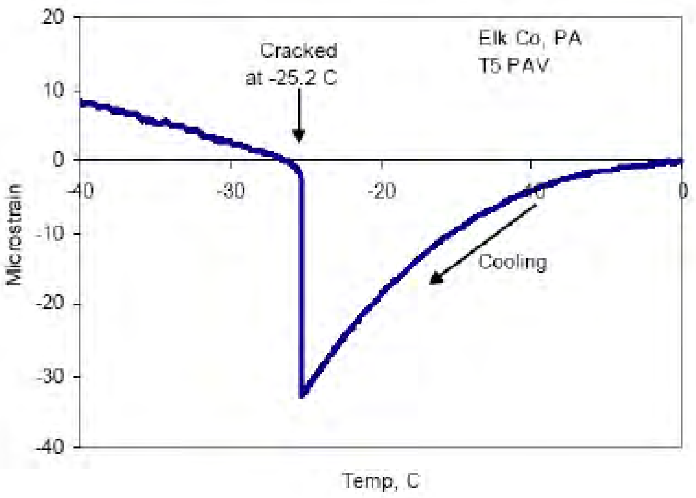




Asphalt Binder Cracking Device (ABCD) – AASHTO T387

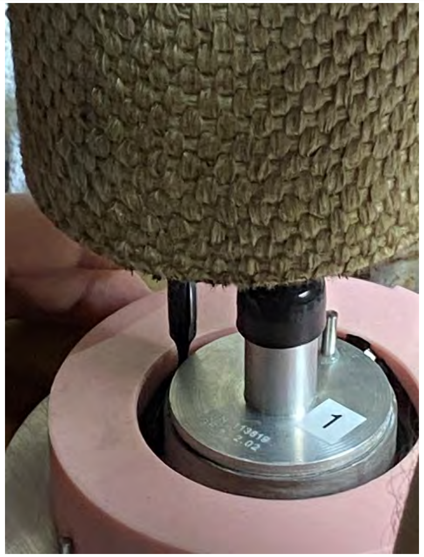
T_{cr} the ABCD Testing

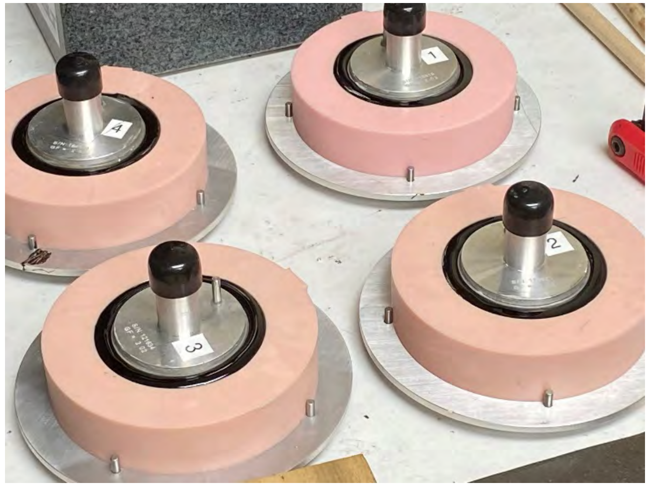
- The ABCD determines the critical cracking temperature due to thermally induced stress
  - Asphalt binder poured between an invar and latex mold to form a ring
  - Chamber cools the specimens at -20°C per hr
  - Strain gauge determines when "cracking" occurs and specimen temperature when this occurs is determined as T_{cr}



Asphalt Binder Cracking Device (ABCD)

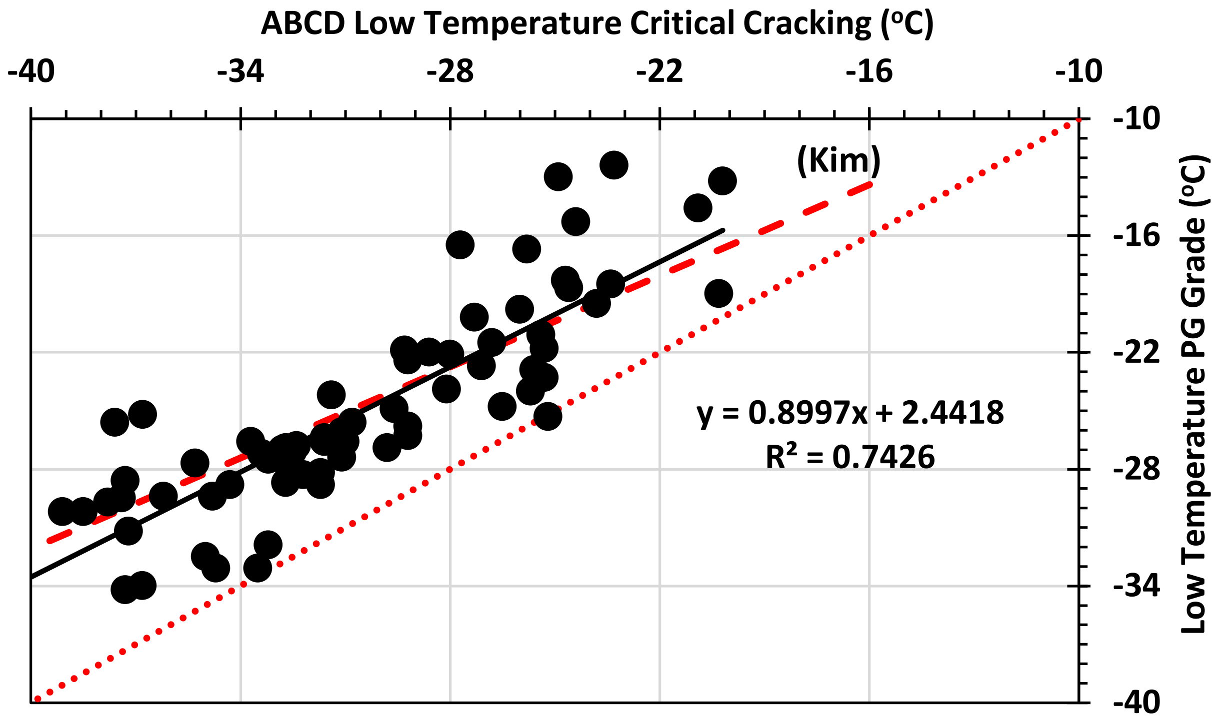
- System utilizes four (4) rings and temperature chamber
  - ≈ 11 grams binder per ring
  - Rings instrumented with thermistor and strain gauge
- Precision/Bias for T_{cr}
  - Single Operator Range of Results
    - Cracking Temp = 2.69°C
    - Fracture Stress = 2.43 MPa
  - Multiple Operator Range of Results
    - Cracking Temp = 3.85°C
    - Fracture Stress = 3.20 MPa

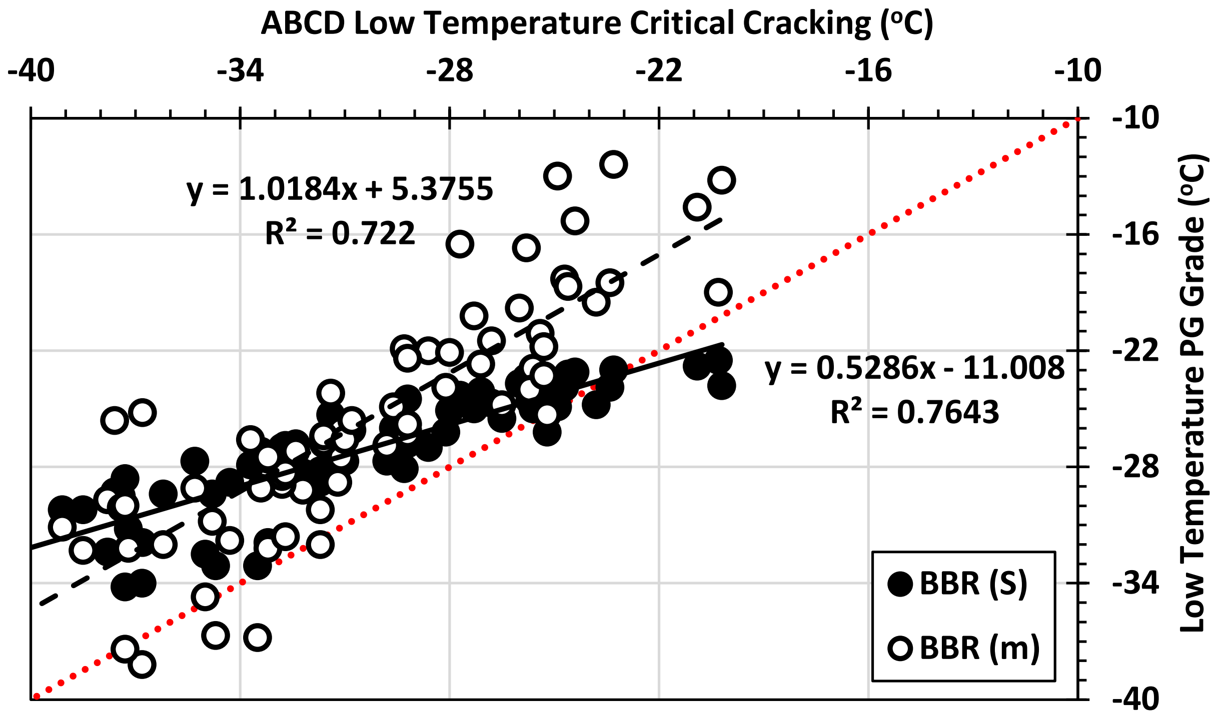




ABCD vs Low Temperature PG

- In general, colder ABCD T_{cr} than low temperature PG

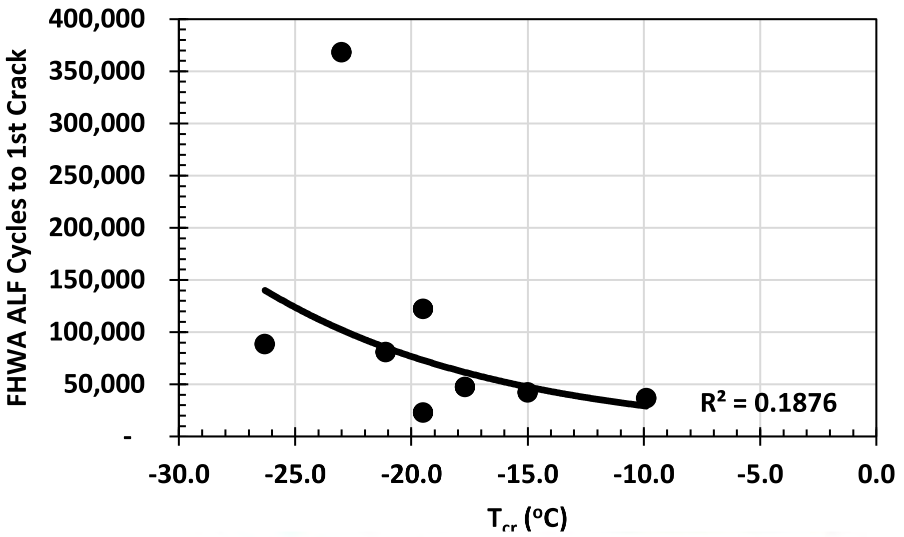


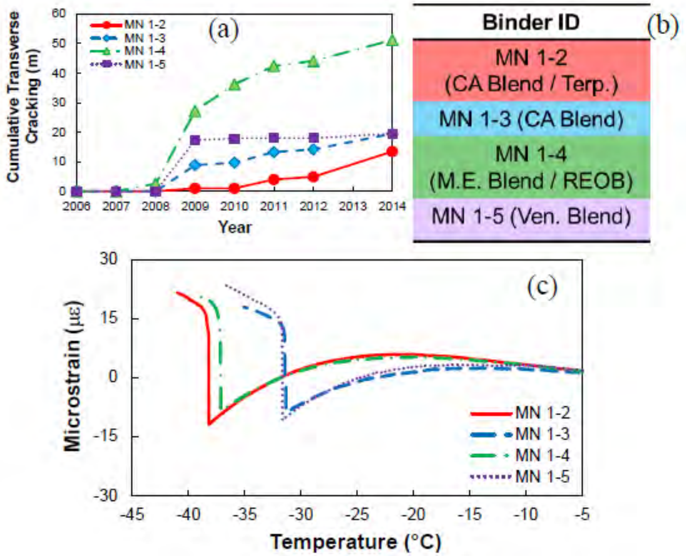


ΔT_f - ABCD Testing

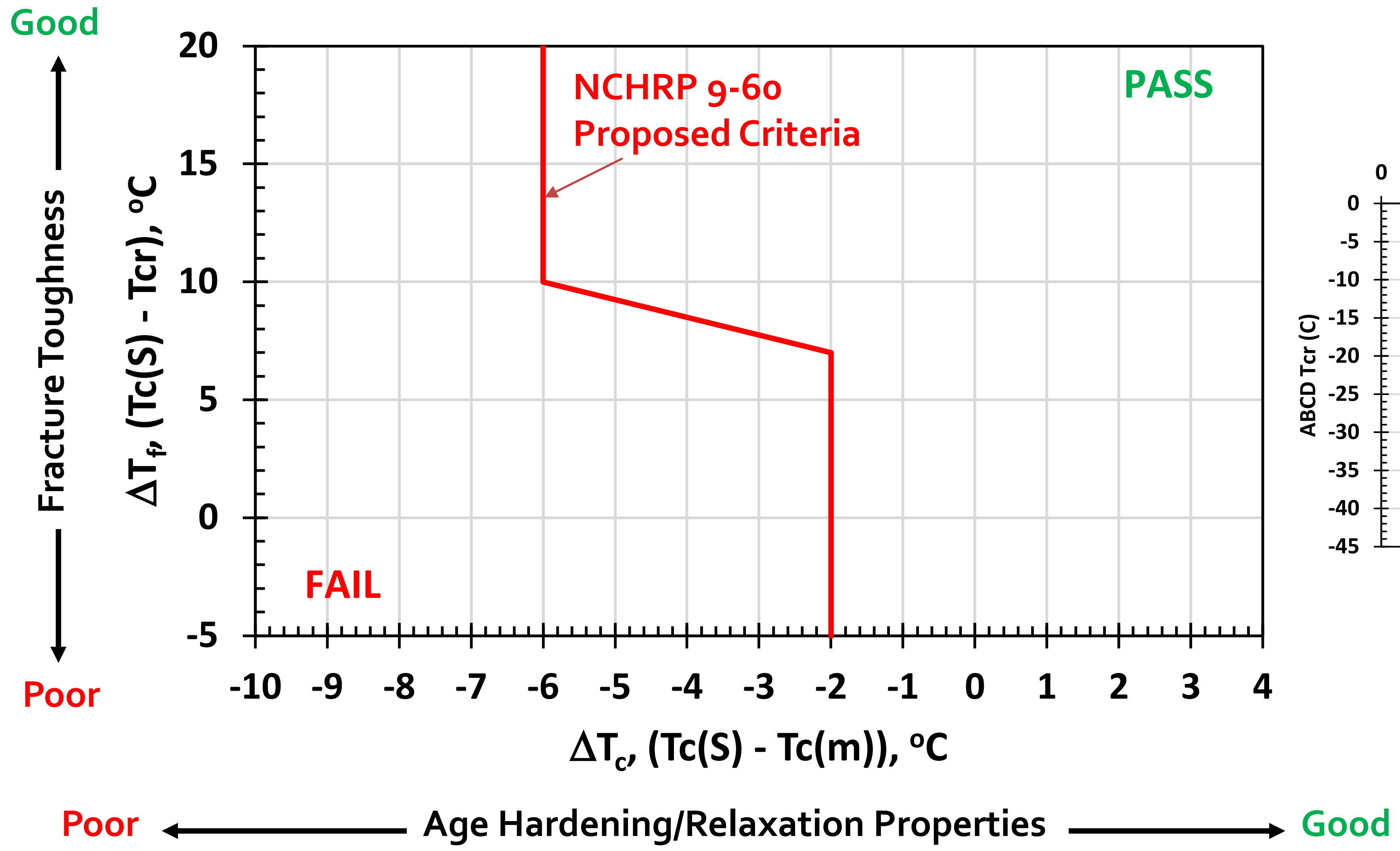
- The T_{cr} parameter by itself may not provide a good correlation to cracking for all binders
  - T_{cr} is a function of fracture strength, which in turn is a function of the stiffness
    - Modifiers like REOB reduces stiffness
- To normalize the impact of stiffness, NCHRP 9-60 researchers recommended ΔT_f

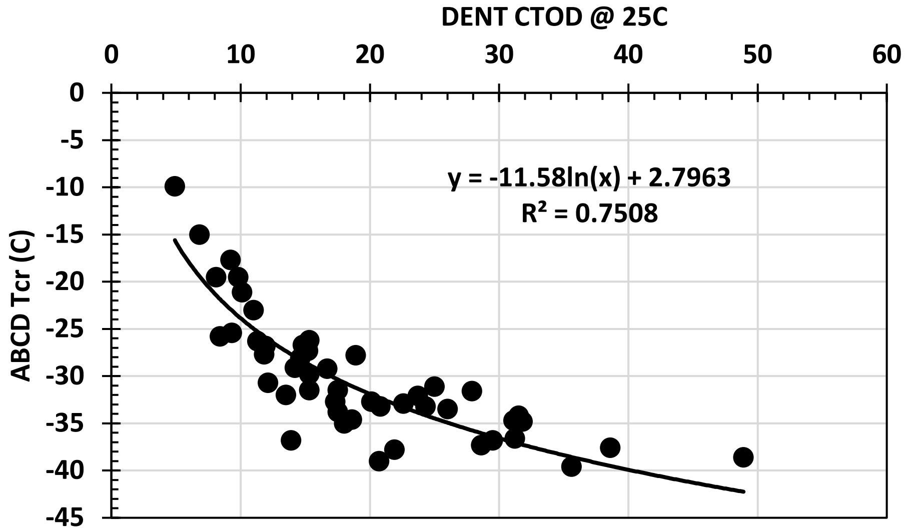
$$\Delta T_f = T_{c,S} - T_{cr}$$





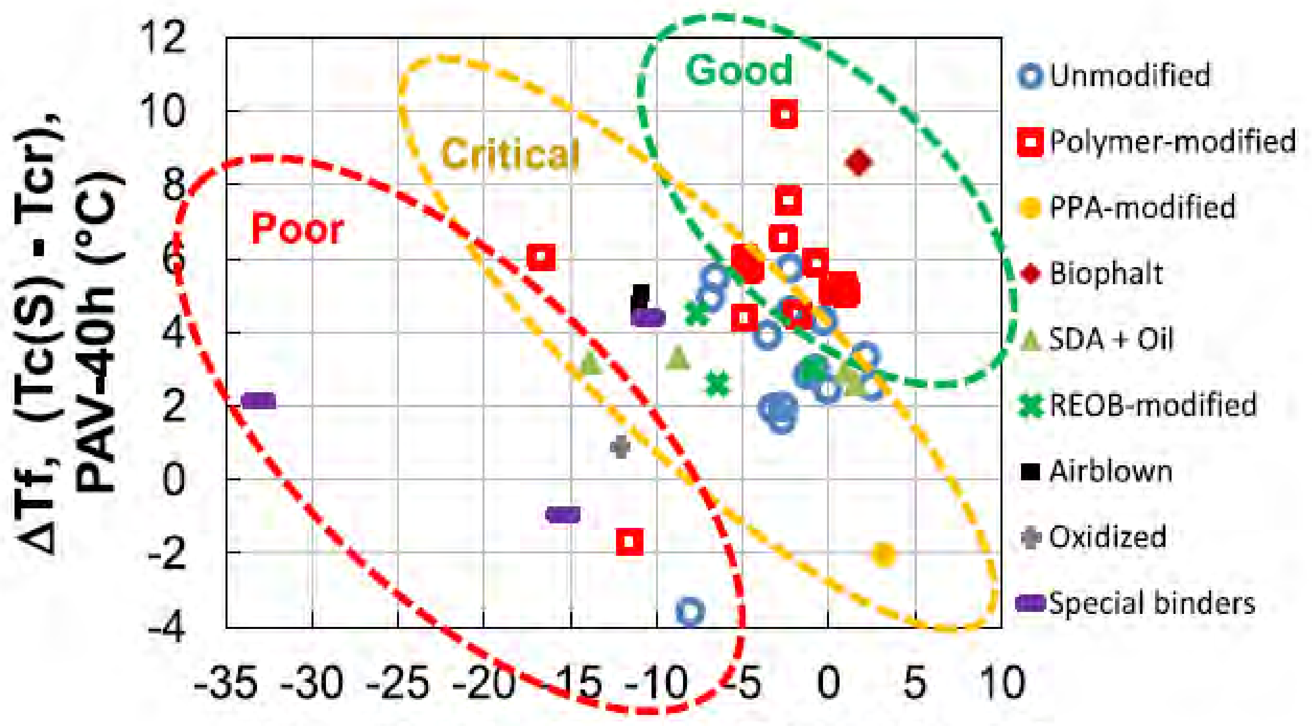
NCHRP 9-60 Approach





NCHRP 9-60 Approach

- As the asphalt industry moves towards Balance Mixture Design, suppliers will turn to the liquid supplier for guidance
- A methodology that better predicts/ranks cracking potential of asphalt binders is critical
  - Rutting is pretty well defined with the high temperature PG grade and Multiple Stress Creep Recovery (MSCR) tests

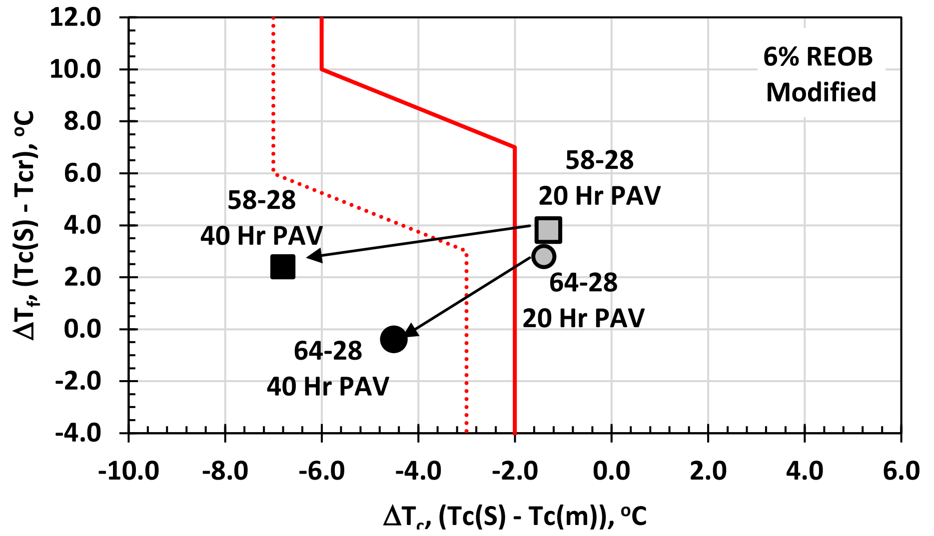


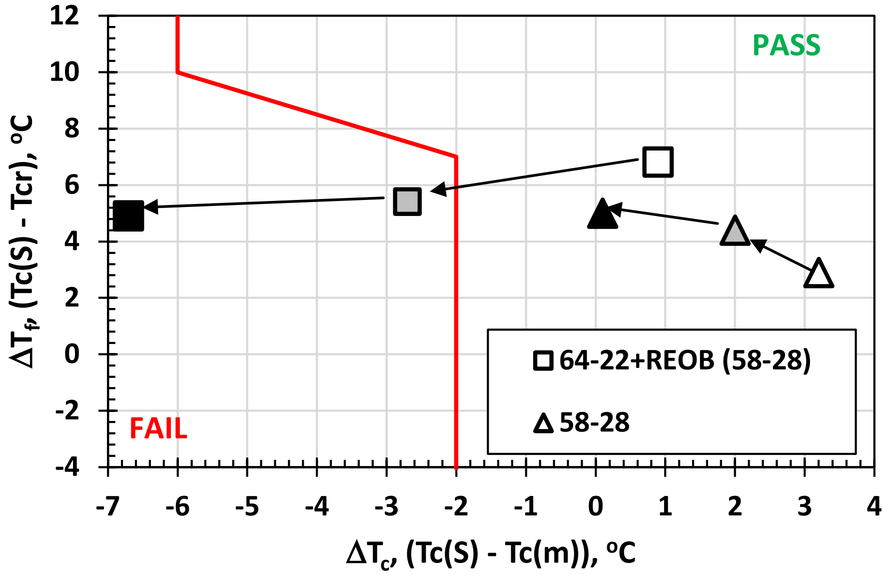
(Elwardany et al., 2020)

Sensitivity to Asphalt Modifiers

Sensitivity to Modifiers - REOB

- REOB used to obtain low temperature grades from stiffer asphalts
  - Small dosages with compatible base can be helpful
  - Higher dosages will drive binder performance to lower left of space
    - Increased age hardening
    - Decrease in fracture strength

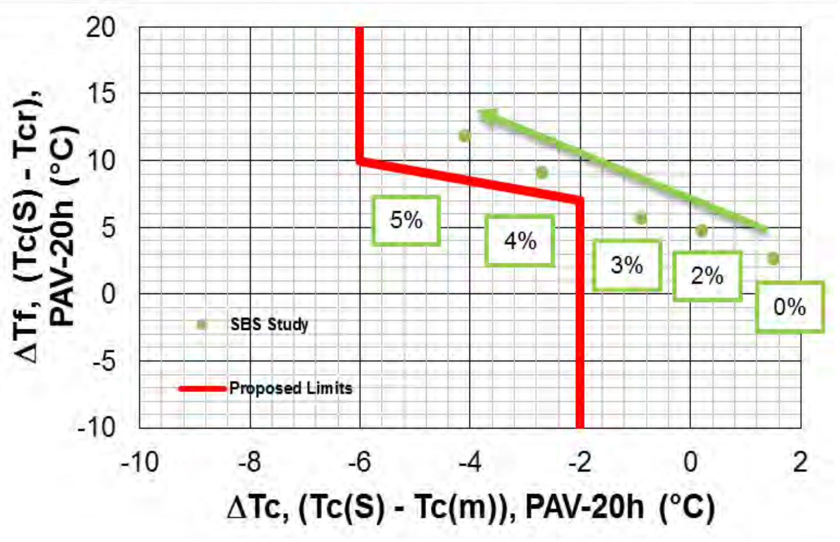


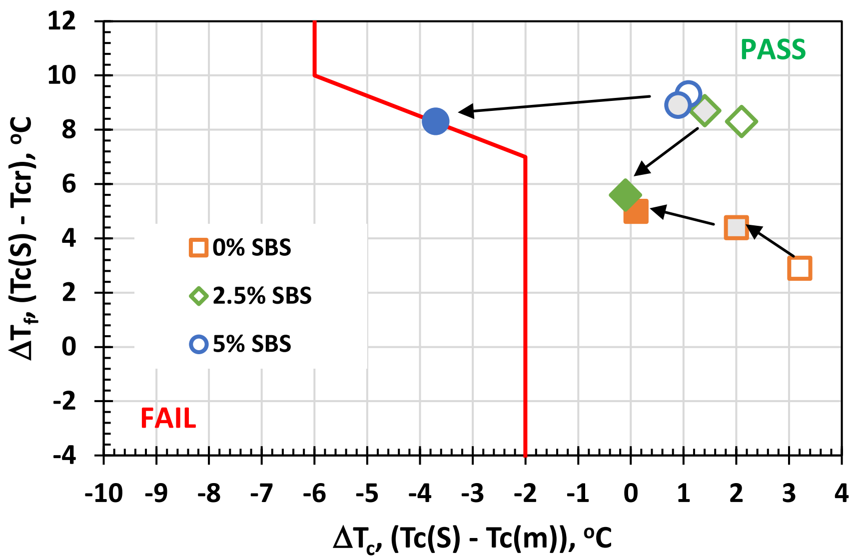


Sensitivity to Modifiers - SBS

- Increase in SBS will improve fracture toughness
  - However, lower resultant phase angles may show more negative ΔTc
- NCHRP 9-60 identified in early studies how SBS performed, resulting in curved area

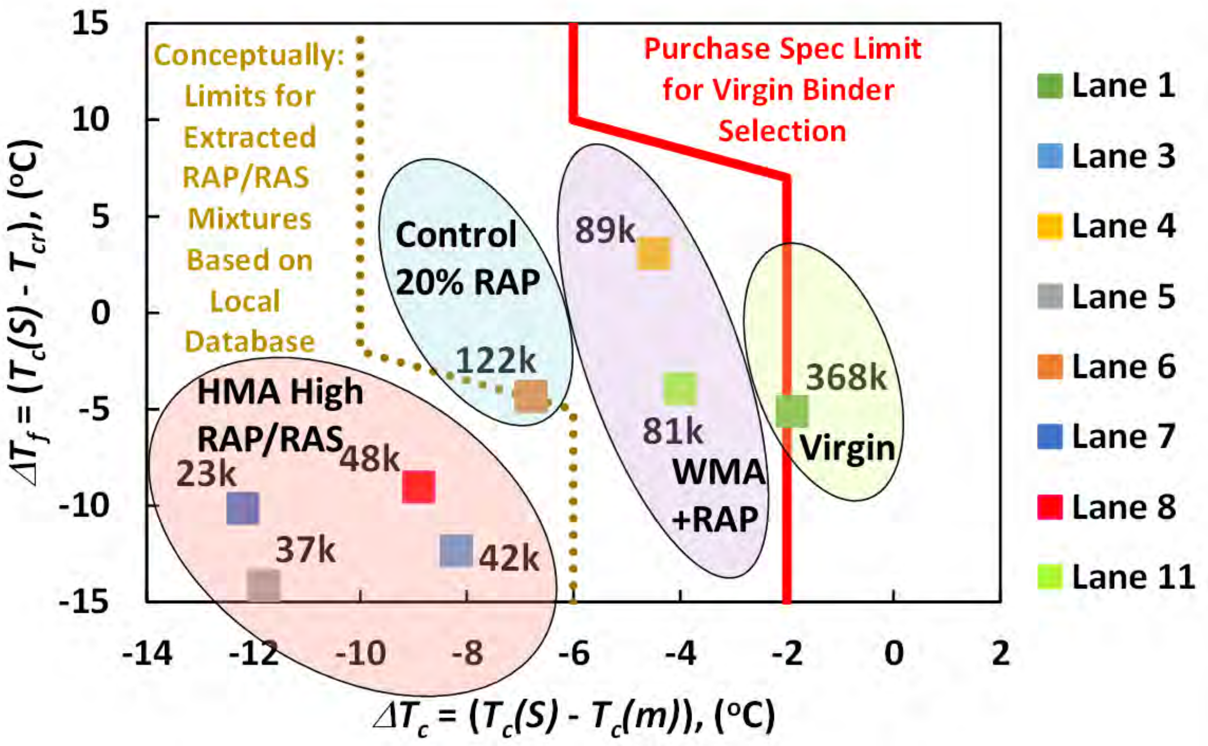
(Elwardany et al., 2020)





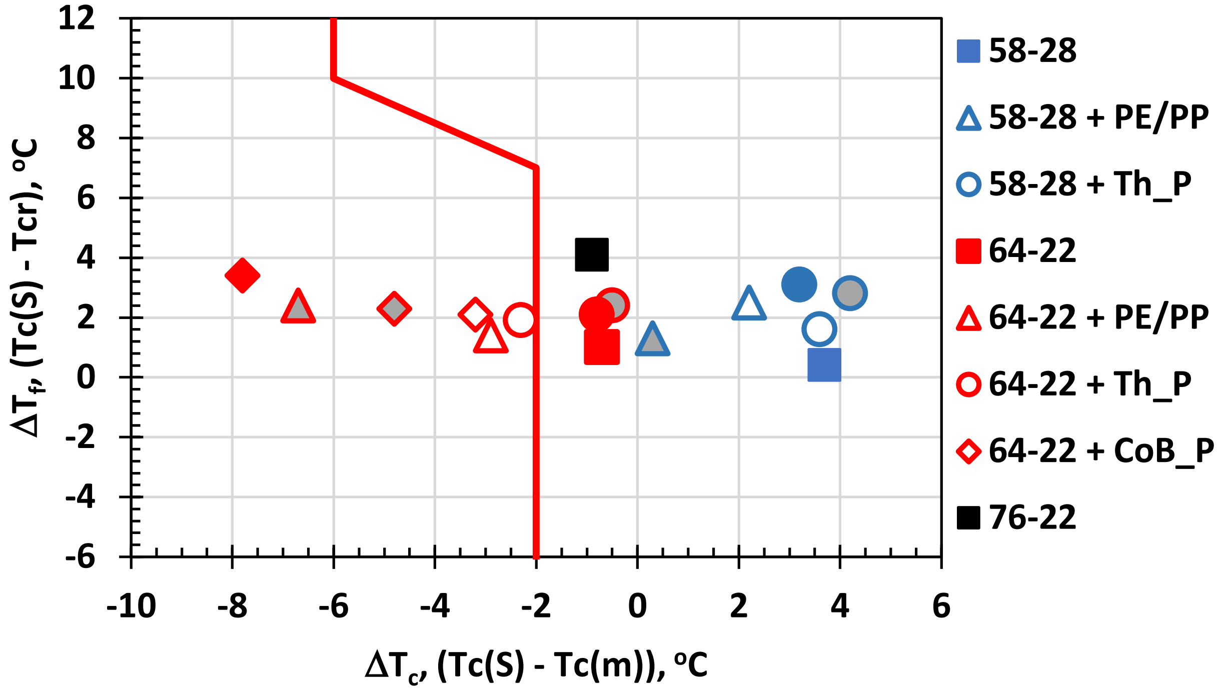
Sensitivity to Modifiers – Recycled Asphalt

- Asphalt binder recovered from top ½" of FHWA ALF
  - Higher recycled content/harder recycled asphalt drives to lower left of space
  - Approach could provide insight into rejuvenator selection



Sensitivity to Modifiers – Recycled Plastics

- Different recycled plastic types high shear milled into a PG64-22 and PG58-28 asphalt binder
  - Differentiates the impact of plastic type & base asphalt binder grade

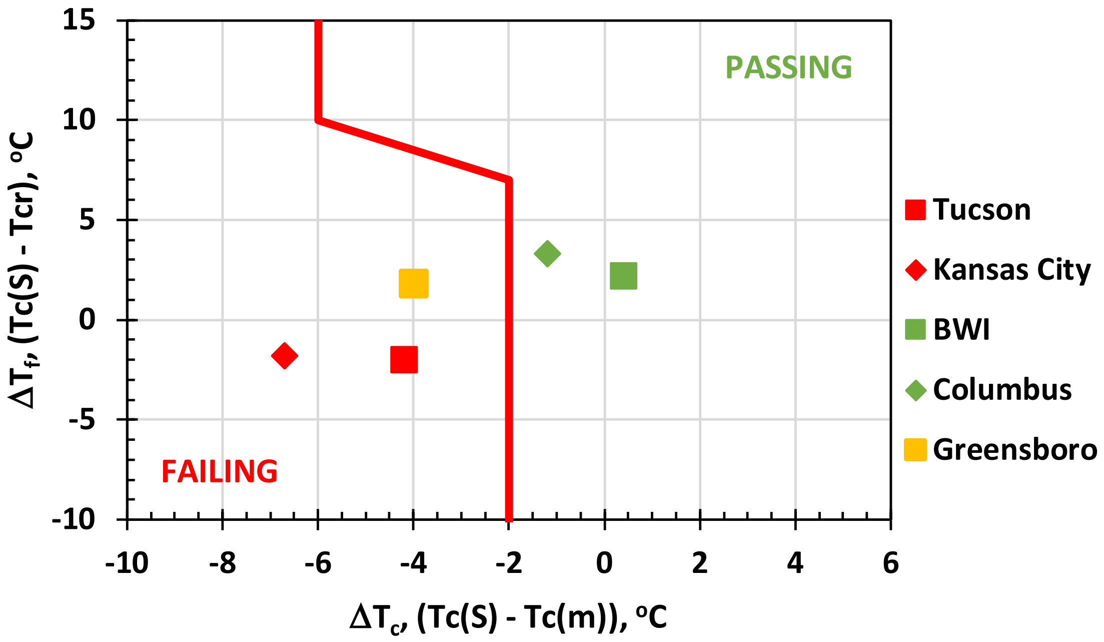


Field Performance

Field Verification

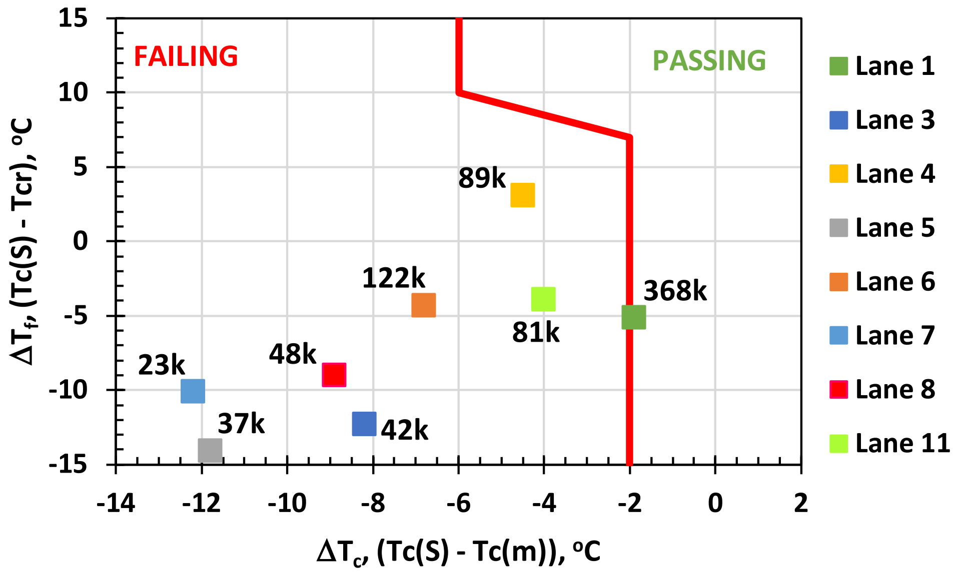
- Multiple pavements noted as having top-down cracking used to help validate tests and proposed criteria
  - Asphalt airfield pavements
    - PANYNJ field engineers observations
    - FAA Extended Pavement Life project
      - Consultant visual distress surveys
  - FHWA ALF Experiment
    - Cycles to 1st Crack
  - NYSDOT Modifier Study

Asphalt Airfield Pavements



Airfield Pavement	Intermediate Temp	ΔTc	ΔTf	Visual Distress
Tuscon	29	-4.2	-2.0	Block, L&T Cracking, PCI = 56 (+/- 20)
Kansas City	22	-6.8	-1.8	Block, L&T Cracking, PCI = 57 (+/- 17)
BWI	25	0.4	2.2	Low Severity Weathering, PCI = 93 (+/- 3)
Columbus	22	-1.2	3.3	No Cracking, PCI = 100
Greensboro	27	-4.0	1.8	Low Severity Weathering/Cracking, PCI = 89 (+/- 2)

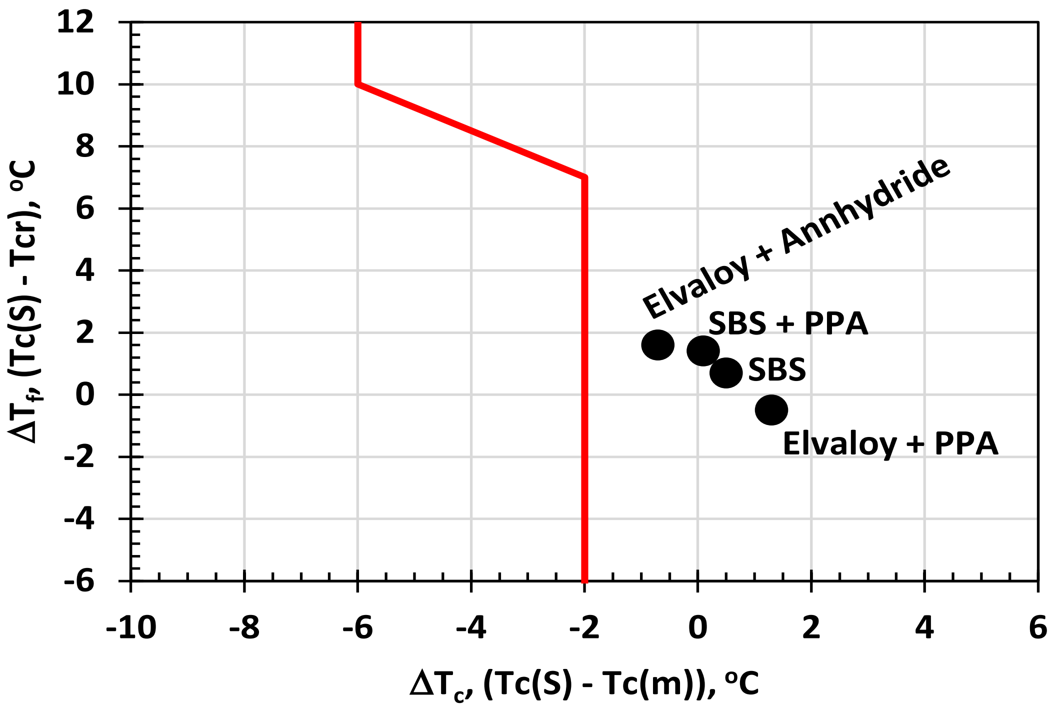
FHWA ALF Sustainability Study



Lane	ΔTc	ΔTf	ABCD Tcr	LT (s)	LT (m)	Cycles to 1st Crack
Lane 1	-1.9	-5.1	-23.0	-28.1	-26.2	368,254
Lane 3	-8.2	-12.3	-15.0	-27.3	-19.1	42,399
Lane 4	-4.5	3.1	-26.3	-23.2	-18.7	88,740
Lane 5	-11.8	-14.1	-9.9	-24.0	-12.2	36,946
Lane 6	-6.8	-4.3	-19.5	-23.8	-17.0	122,363
Lane 7	-12.2	-10.1	-19.5	-29.6	-17.4	23,005
Lane 8	-8.9	-9.0	-17.7	-26.7	-17.8	47,679
Lane 9	-2.4			-25.9	-23.5	270,058
Lane 11	-4.0	-3.9	-21.1	-25.0	-21.0	81,044

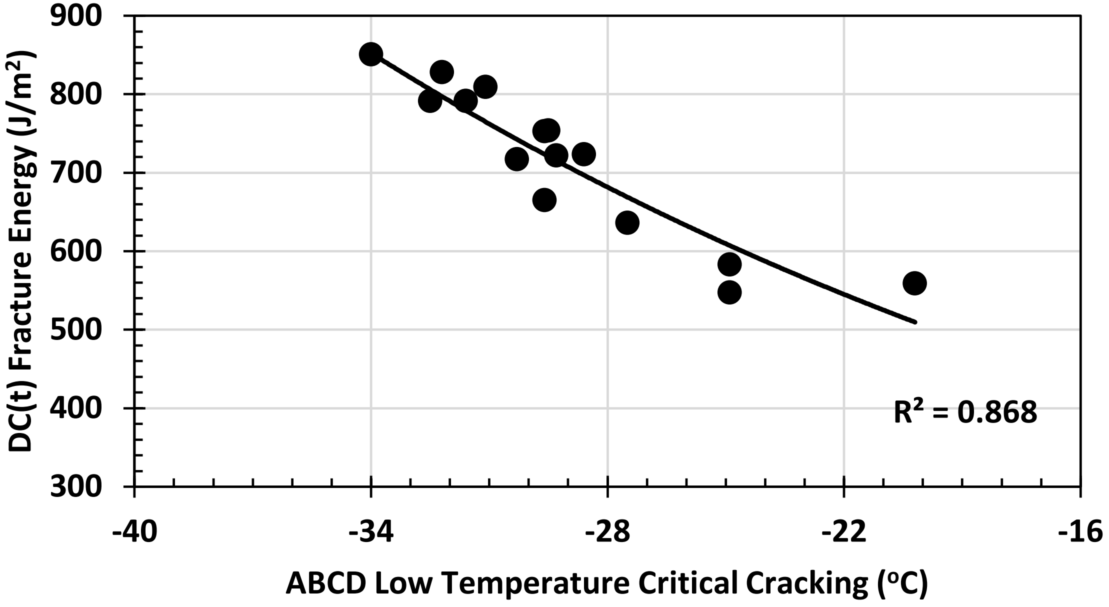
NYSDOT Modifier Study

- NYSDOT evaluated different asphalt modifiers
  - Plant produced and placed in field for evaluation
- NY Rt. 32 SB
  - 9.5mm surface course, 5.7% AC
  - Binders formulated to achieve 76-22
- 5 years of surface life (2020) – no distress observed on any section



Mixture Testing – DC(T)

- Current research at Rutgers looking at how the mixture performance results fall within the NCHRP 9-60 approach
  - Asphalt binders recovered from mixture performance specimens



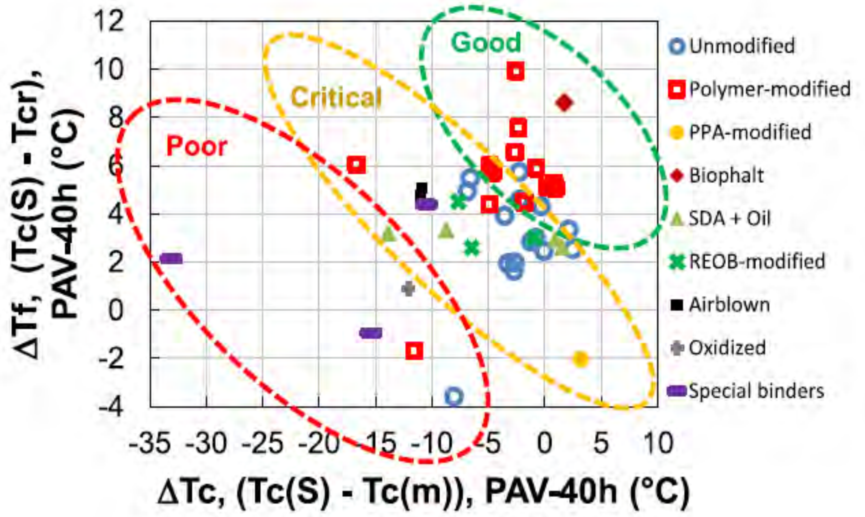
Contents	Project Criticality/Traffic Level		
	Low <10M ESALs	Moderate 10–30M ESALs	High >30M ESALs
Minimum Fracture Energy (J/m^2)@low-temperature PG+10 ° C	400	460	690

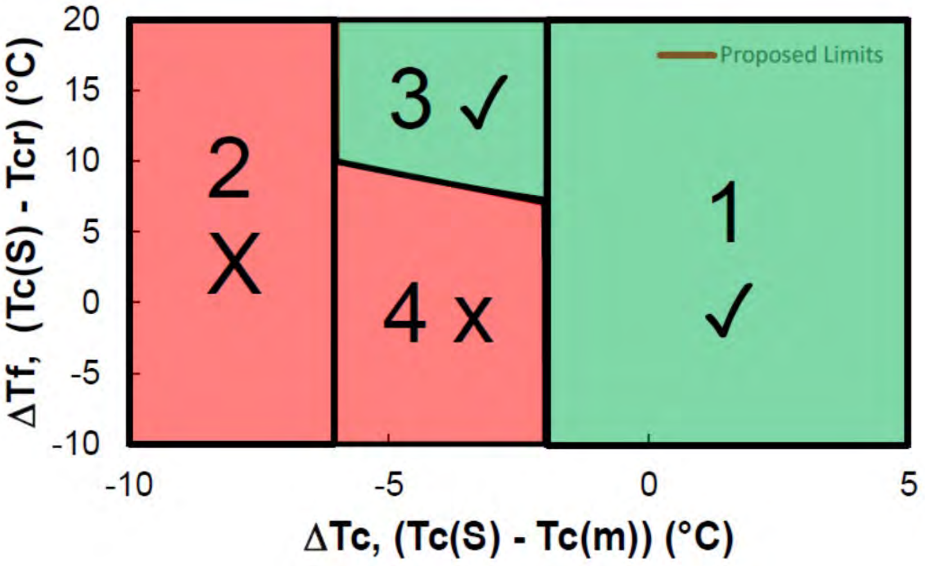
ESAL = equivalent single axle loads.

General Conclusions and Observations

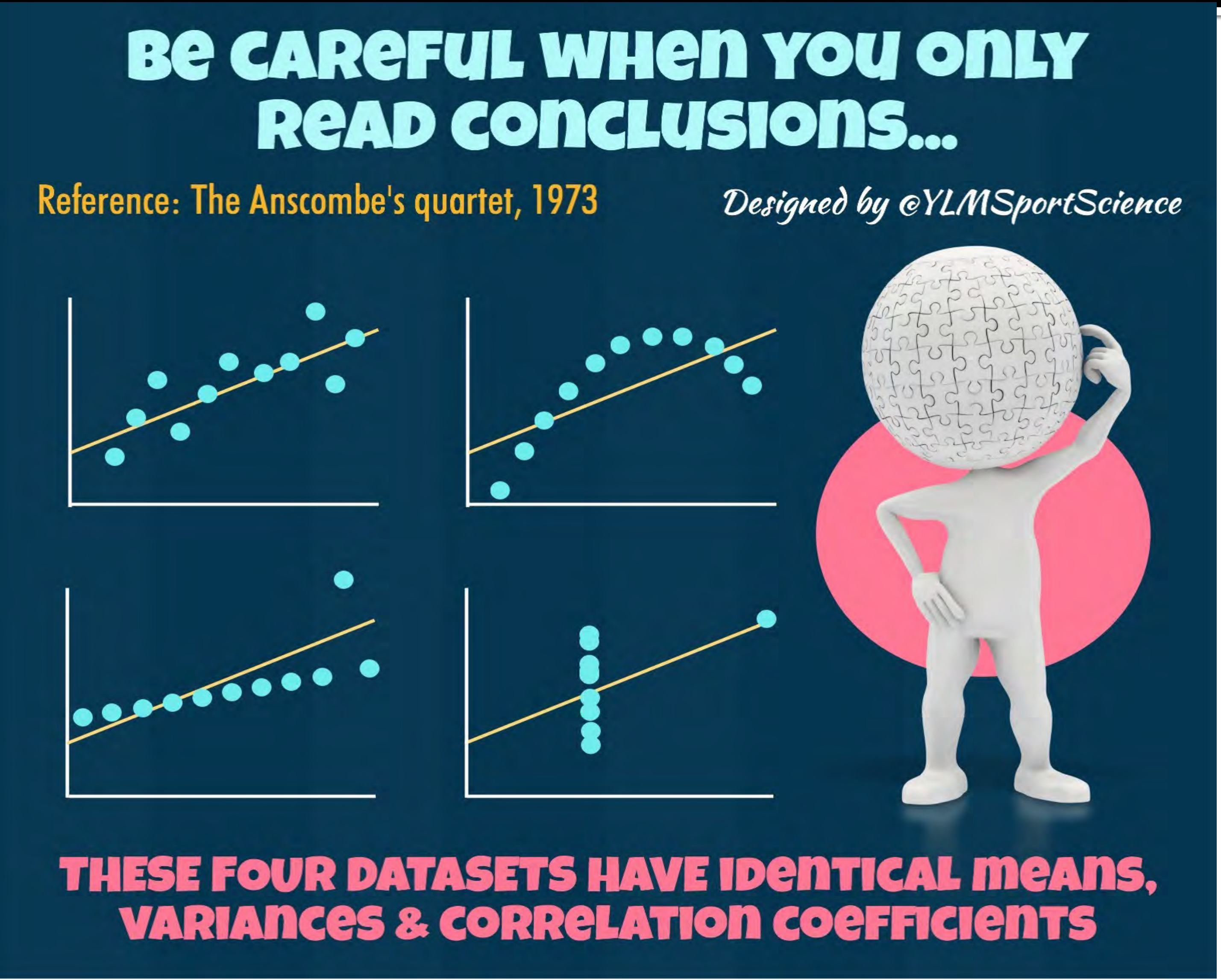
General Conclusions and Observations

- The ABCD test shows promise in characterizing asphalt binders
  - BBR good for stiffness and relaxation & ΔTc
  - ABCD for thermal contraction, strain tolerance, fracture toughness
- Combined with ΔTc, a performance space can be generated that shows good correlation to field performance
  - Support and guidance on asphalt binder selection will be needed as we move into BMD
- NCHRP 9-60 proposed inclusion in grading
  - Determine ΔTc from BBR
  - If -6C < ΔTc < -2C, conduct ABCD to evaluate fracture toughness





Thank you for your time!
Questions?



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