Comparison of Asphalt Binder and Mixture Durability/Fatigue Cracking to FHWA ALF Performance

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Background

FHWA Accelerated Loading Facility (ALF)

- Recently completed High Recycle with WMA Fatigue Cracking Experiment
- Focus on fatigue cracking, temp. controlled at 20°C
  - No high temperature rutting*
- Three year completion
  - 2 years of loading
  - 2 ALF units allow simultaneous loading
- Unmodified binder for all lanes, but 2 different grades
- WMA Technology which does not change PG grade
- 10 kip single wheel = 20 kip equivalent axle
- 4-inch total asphalt thickness

FHWA Accelerated Loading Facility (ALF)

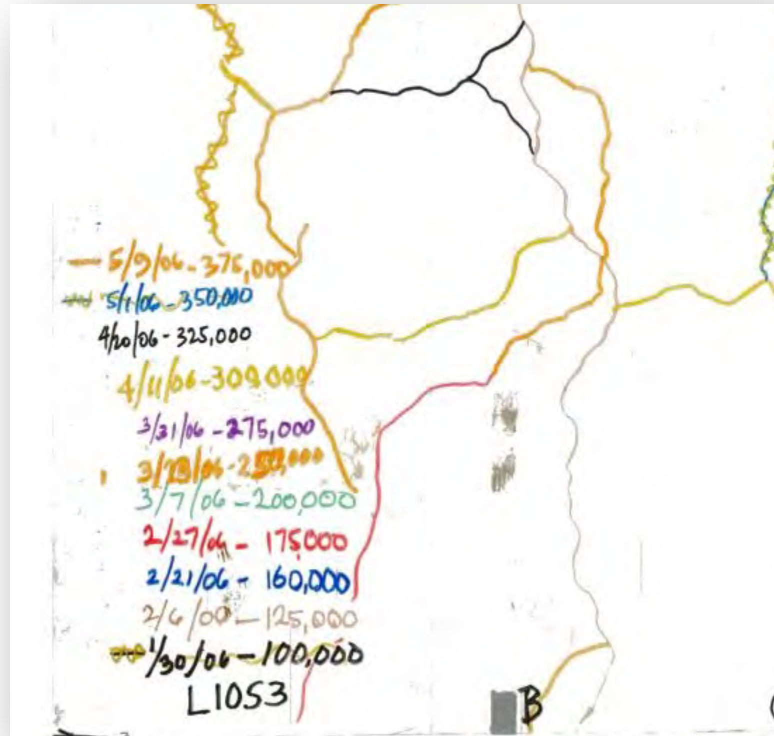
- ALF Loading Conditions
  - Controlled 20°C @ 20mm depth
  - Loading only in one direction
  - Lateral wander
  - 425 Super Single Tire
  - 100 psi inflation
  - 14,200 lb load

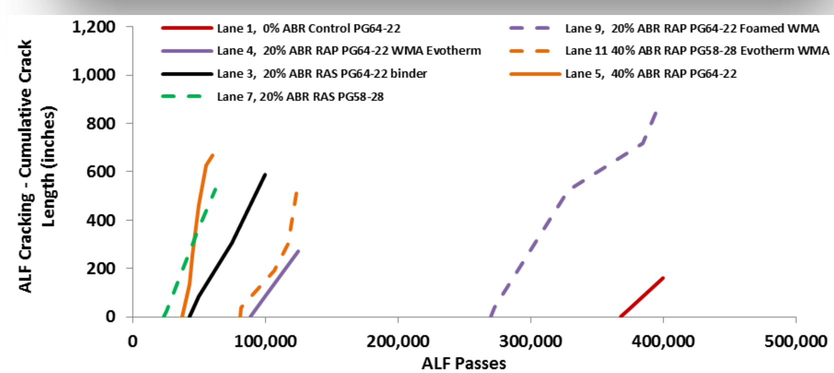
FHWA Accelerated Loading Facility (ALF)

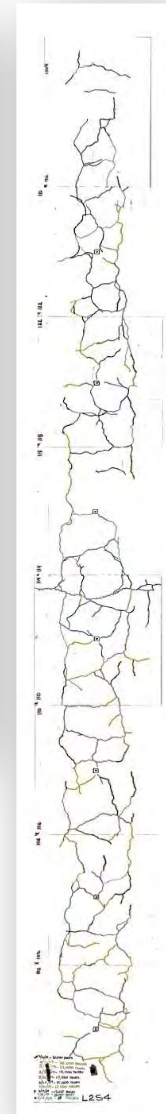
	ALF Lane	% RBR		Virgin Binder PG	WMA Process
		RAP	RAS		
	1	0	-	64-22	-
Re-running	2	40	-	58-28	Water
	3	-	20	64-22	-
	4	20	-	64-22	Chemical
	5	40	-	64-22	-
	6	20	-	64-22	-
	7	-	20	58-28	-
Re-running	8	40	-	58-28	-
	9	20	-	64-22	Water
	11	40	-	58-28	Chemical

FHWA Accelerated Loading Facility (ALF)

- Cracking performance measured and quantified in two indices
  - Number of cycles until 1st Crack observed
  - Cracking Rate







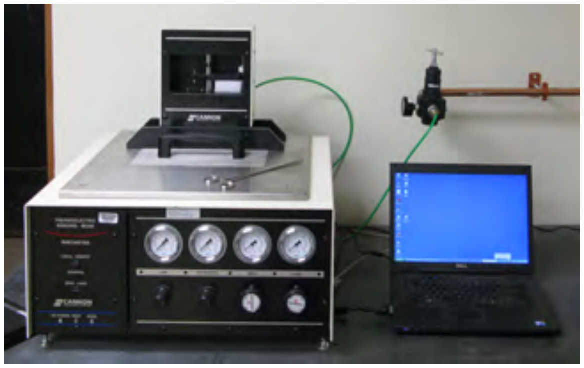
FHWA Accelerated Loading Facility (ALF)

- Question: How well do asphalt mixture and binder tests correlate to field measured fatigue performance?
  - RAP, RAS, WMA
- 10 cores taken from each lane
- Mixture and binder testing conducted on bottom 2 inches of field core to minimize surface aging

Performance Testing – Asphalt Binders

Asphalt Binder Testing

- Asphalt binders recovered using solvent extraction and Rotovapor Recovery
- Binder testing included;
  - PG grading (Intermediate Temp)
  - Master curves
    - Rheological Properties
    - Glover-Rowe Parameter
  - Double Edge Notched Tension (DENT)

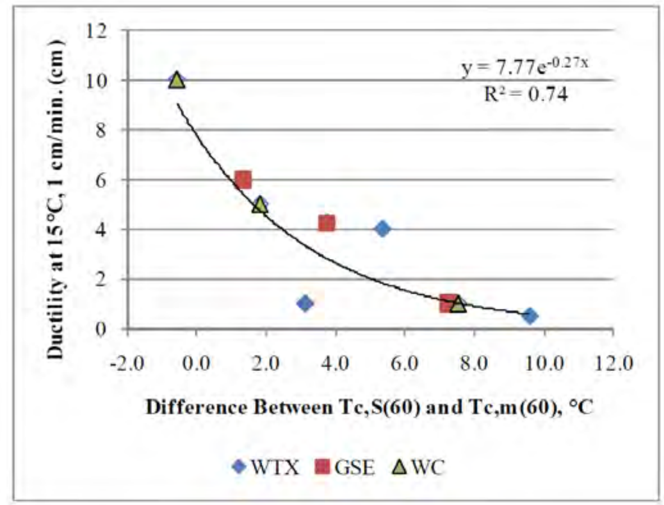


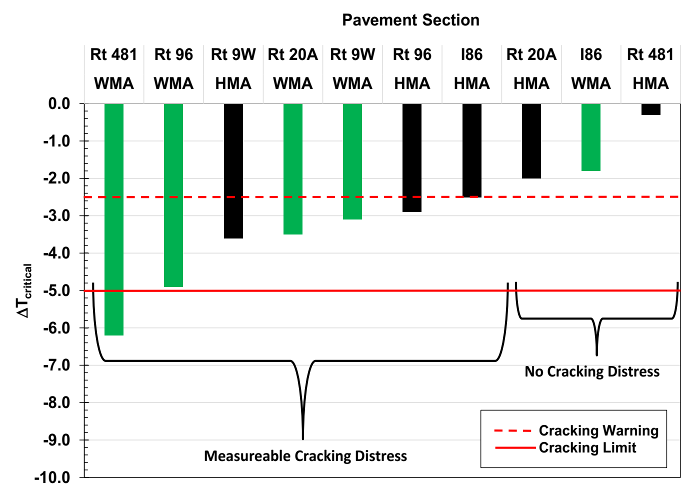
ΔT_c from BBR Testing

- Ductility has always been correlated to fatigue performance of asphalt mixtures and clearly decreases with aging
- 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

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

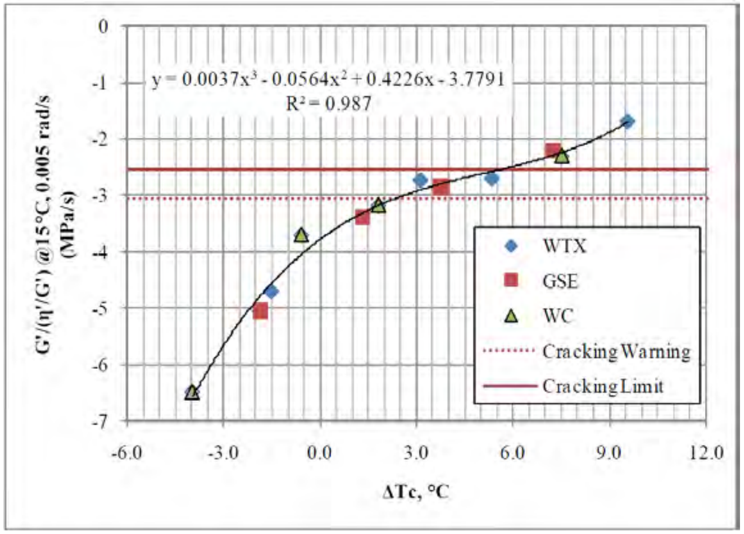
- AAPT (Anderson et al., 2011) showed that the ΔT_c correlated to non-load associated cracking on airfields (i.e. – cracking mainly due to aging), as well as ductility

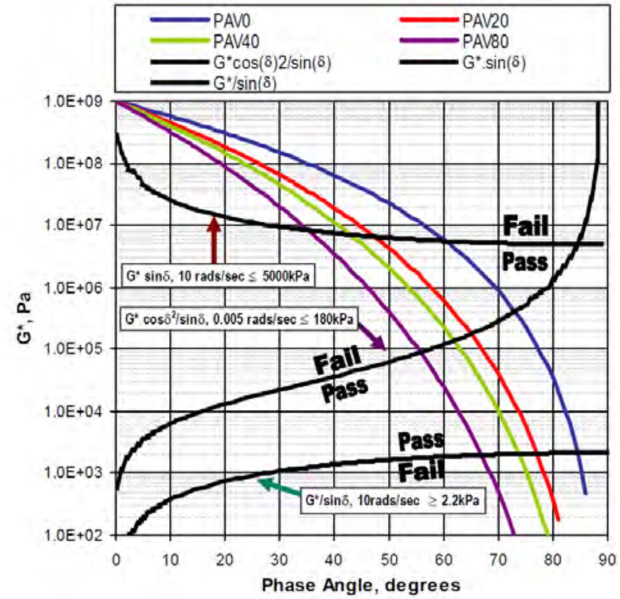




Glover-Rowe Parameter (G-R)

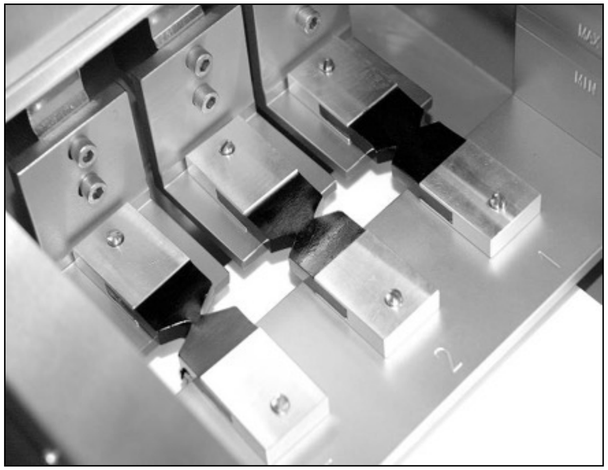
- Due to equipment and material size restraints, Ductility testing may not be available
- Rowe (AAPT, 2011) proposed the DSR master curve analysis to calculate the "Glover-Rowe" parameter
  - As G-R parameter increases, the binder is more prone to fatigue cracking
  - Correlates to both ductility and BBR ΔTc
- Laboratory testing at Rutgers U. has shown the parameter correlates to lab fatigue performance

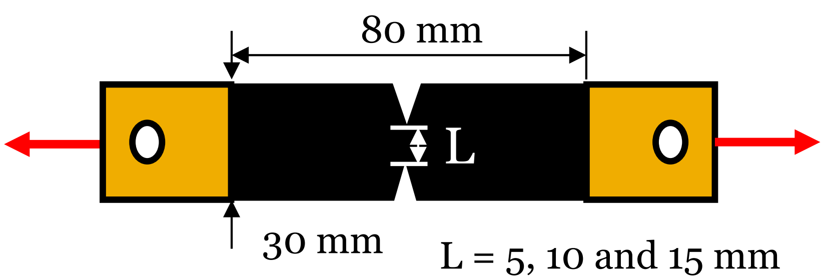




Double Edge Notched Tension (DENT) Test – AASHTO TP113

- Test evaluates the energy required for fracturing ductile materials
  - Test measures the Work of Fracture and Critical Opening Displacement (CTOD)
  - CTOD represents ultimate elongation, or strain tolerance, in the vicinity of a crack (i.e. – notch)
  - As CTOD increases, more resistant to fracturing



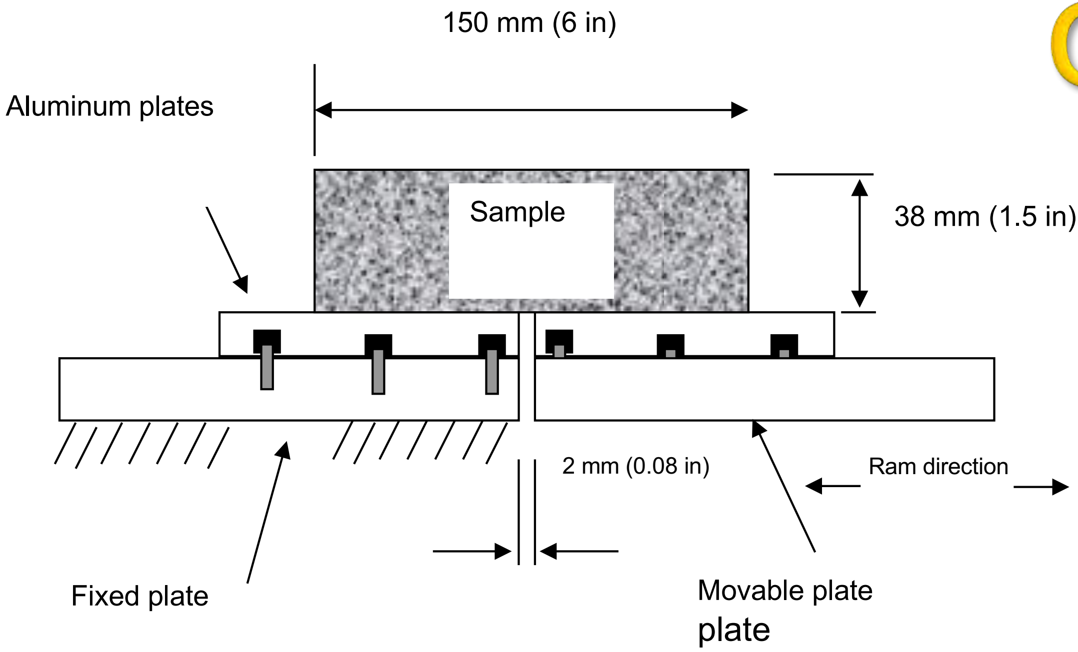


Performance Testing - Mixtures

Mixture Testing

- Due to field cores, test methods limited to evaluated fatigue cracking performance of mixtures
- Three different tests conducted at identical test temperature of 25°C;
  - Overlay Tester
  - SCB - Illinois Flexibility Index
  - SCB – LTRC Procedure

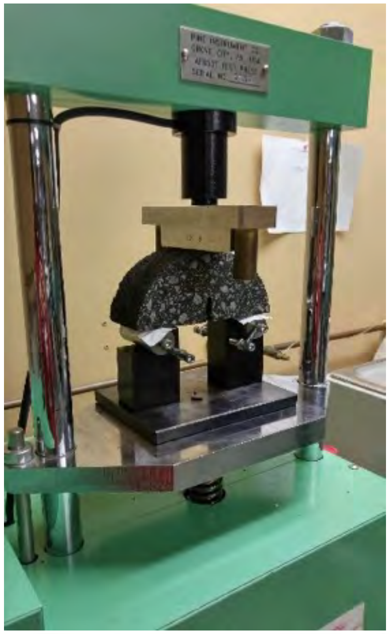
Overlay Tester

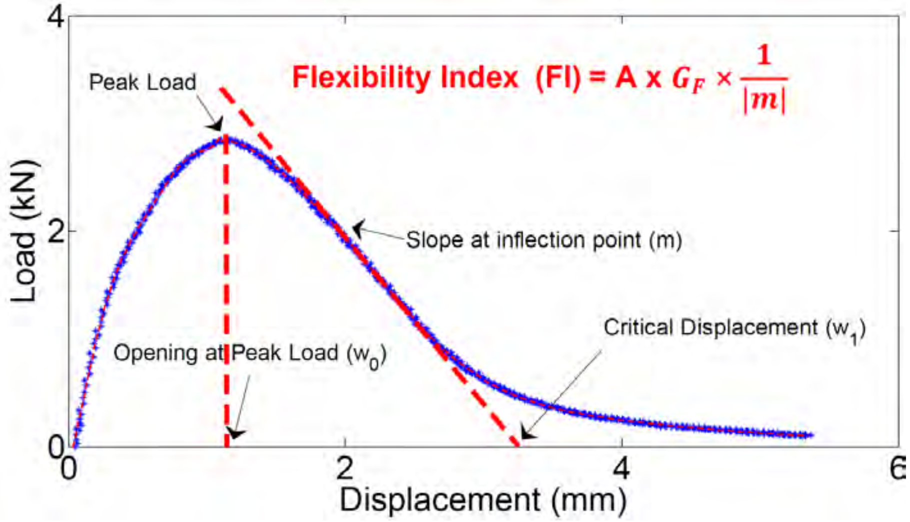


- Sample size: 6" long by 3" wide by 1.5" high
- Loading: Continuously triangular displacement 5 sec loading and 5 sec unloading
- Definition of failure
  - Discontinuity in Load vs Displacement curve

SCB – Illinois Flexibility Index

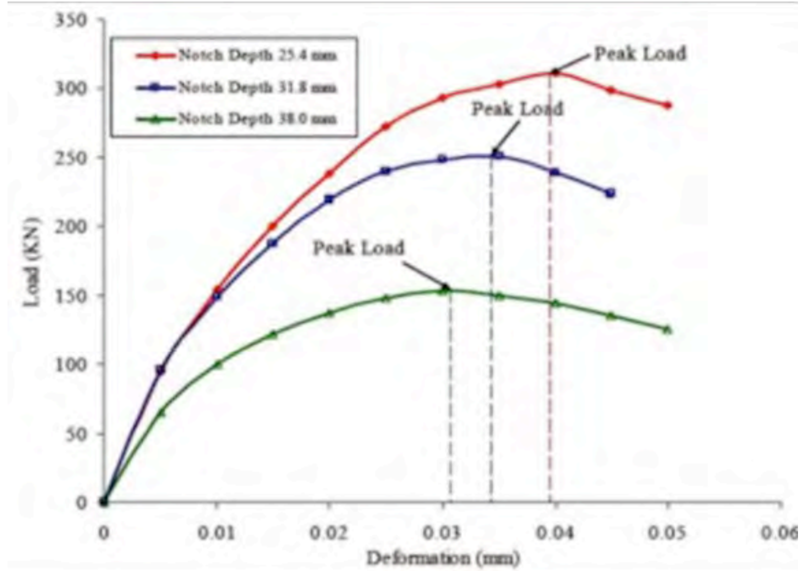
- Semi-circular test specimen
- Set up for a 3 point test with a notch depth of 15 mm
- Deformation rate 50 mm/min
- Analysis uses the fracture energy and slope of post peak curve

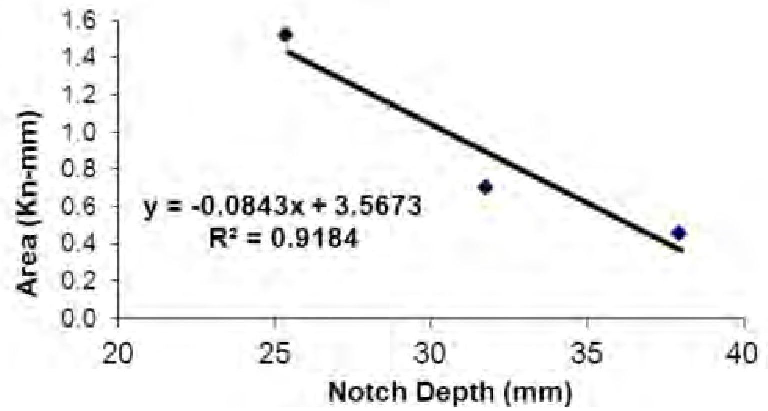




SCB – LTRC Method

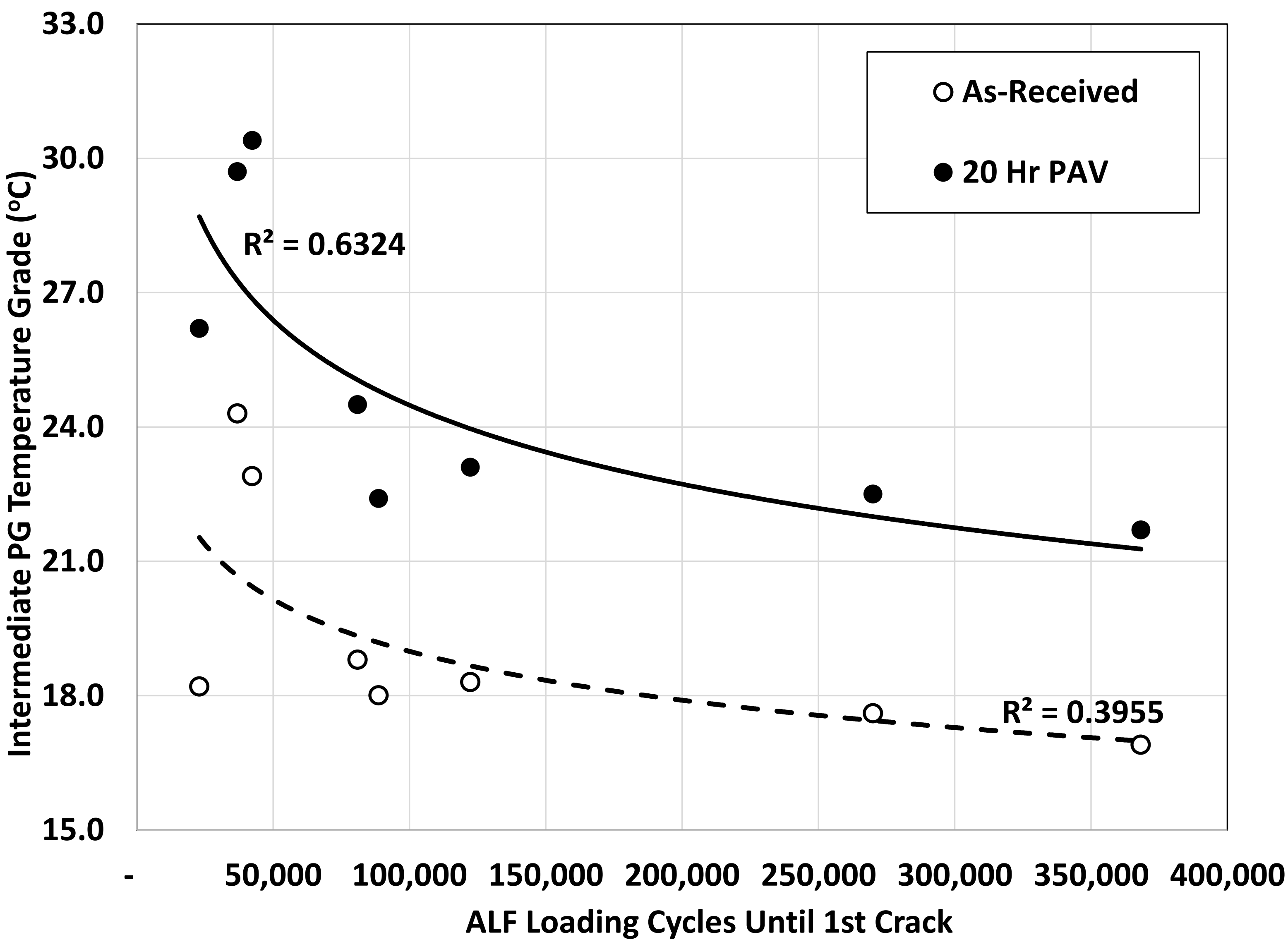
- Semi-circulate test specimen
- Test measures the potential energy at failure for 3 notch depths
- Potential energy plotted vs notch depth to compute Critical Strain Energy (J_c)
- Deformation rate of 0.5 mm/min



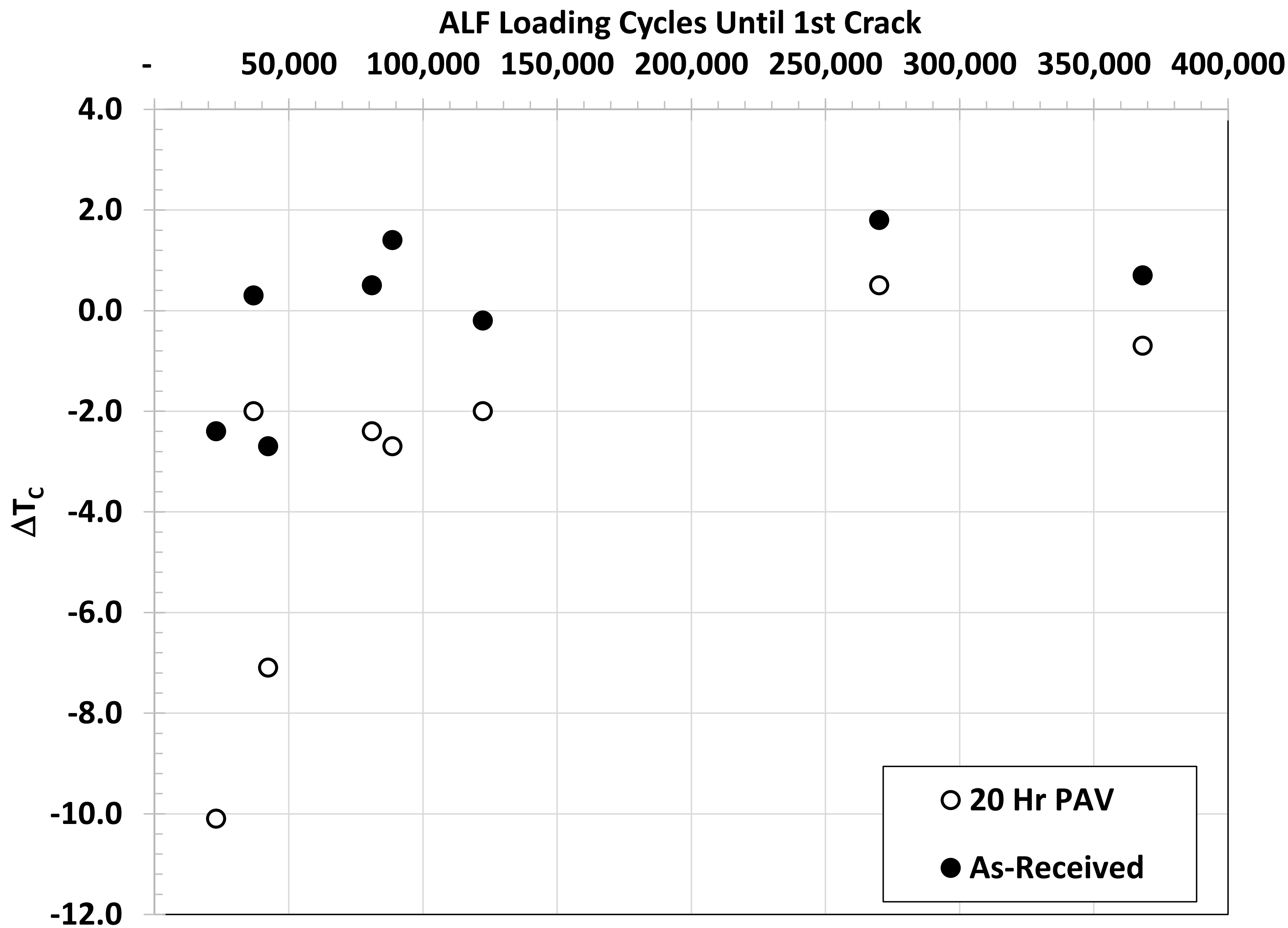


Testing Results – Asphalt Binders

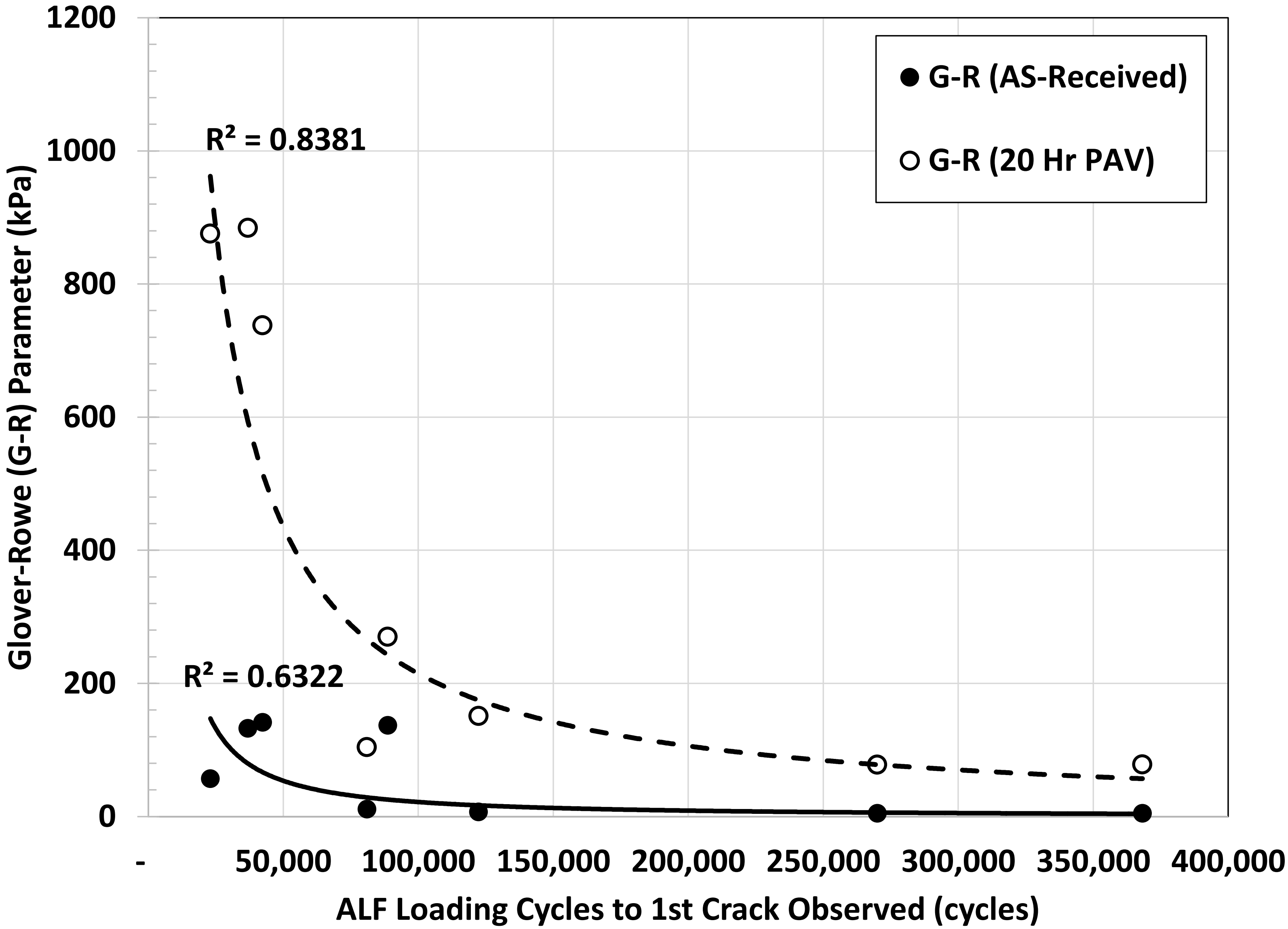
Intermediate PG Grade vs Cycles to 1st Crack



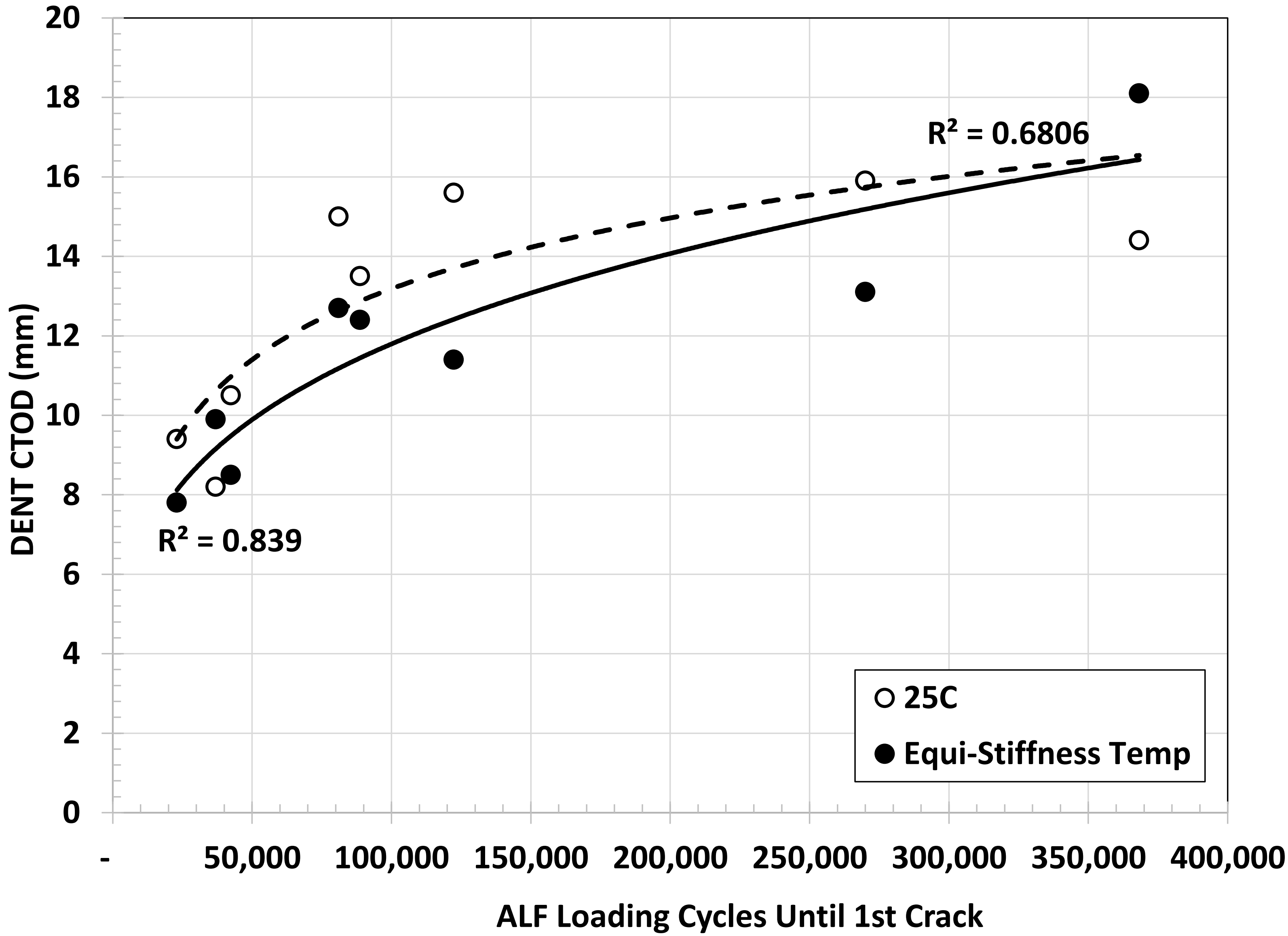
ΔT_C vs Cycles to 1st Crack



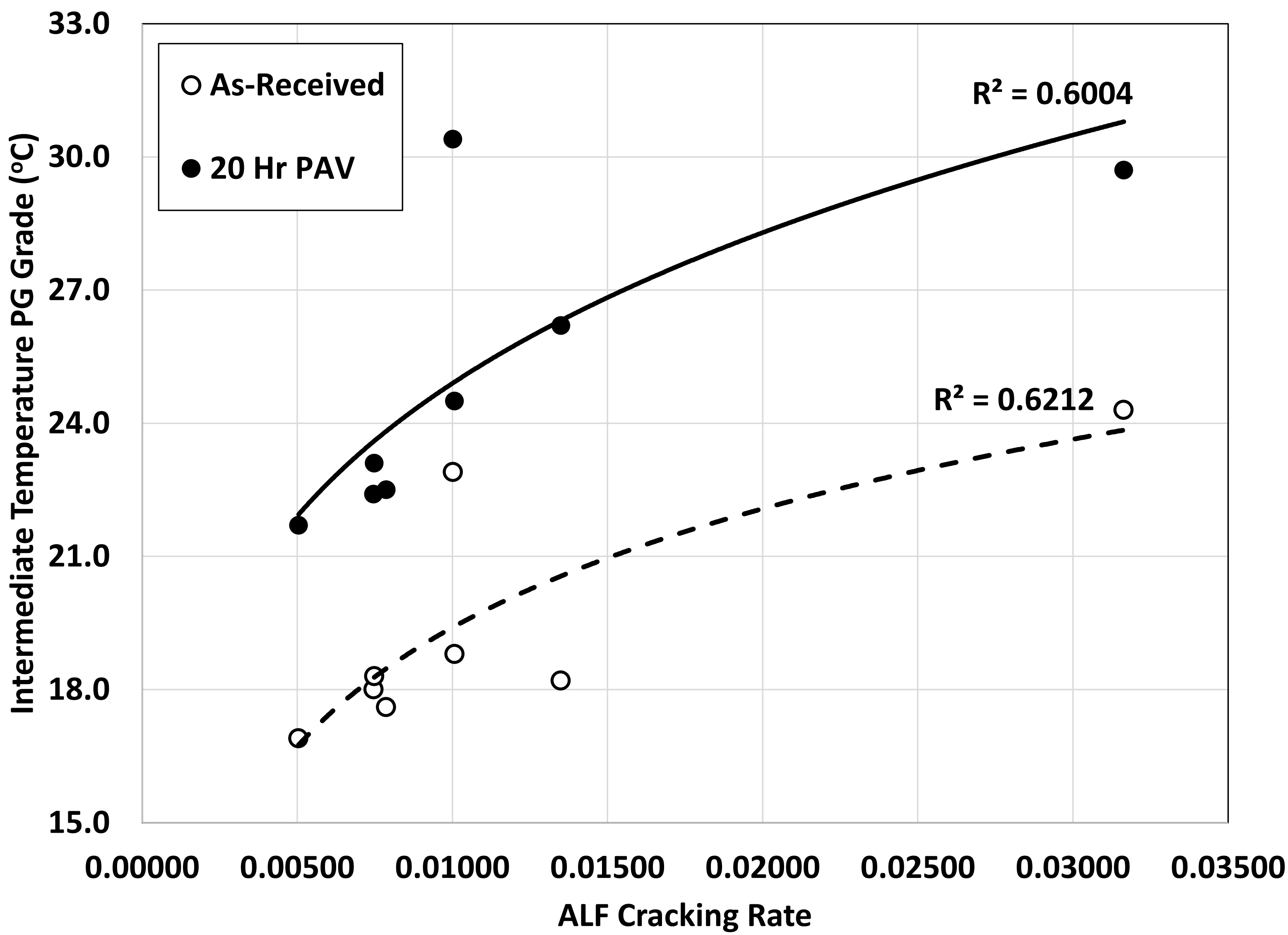
Glover-Rowe Parameter vs Cycles to 1st Crack



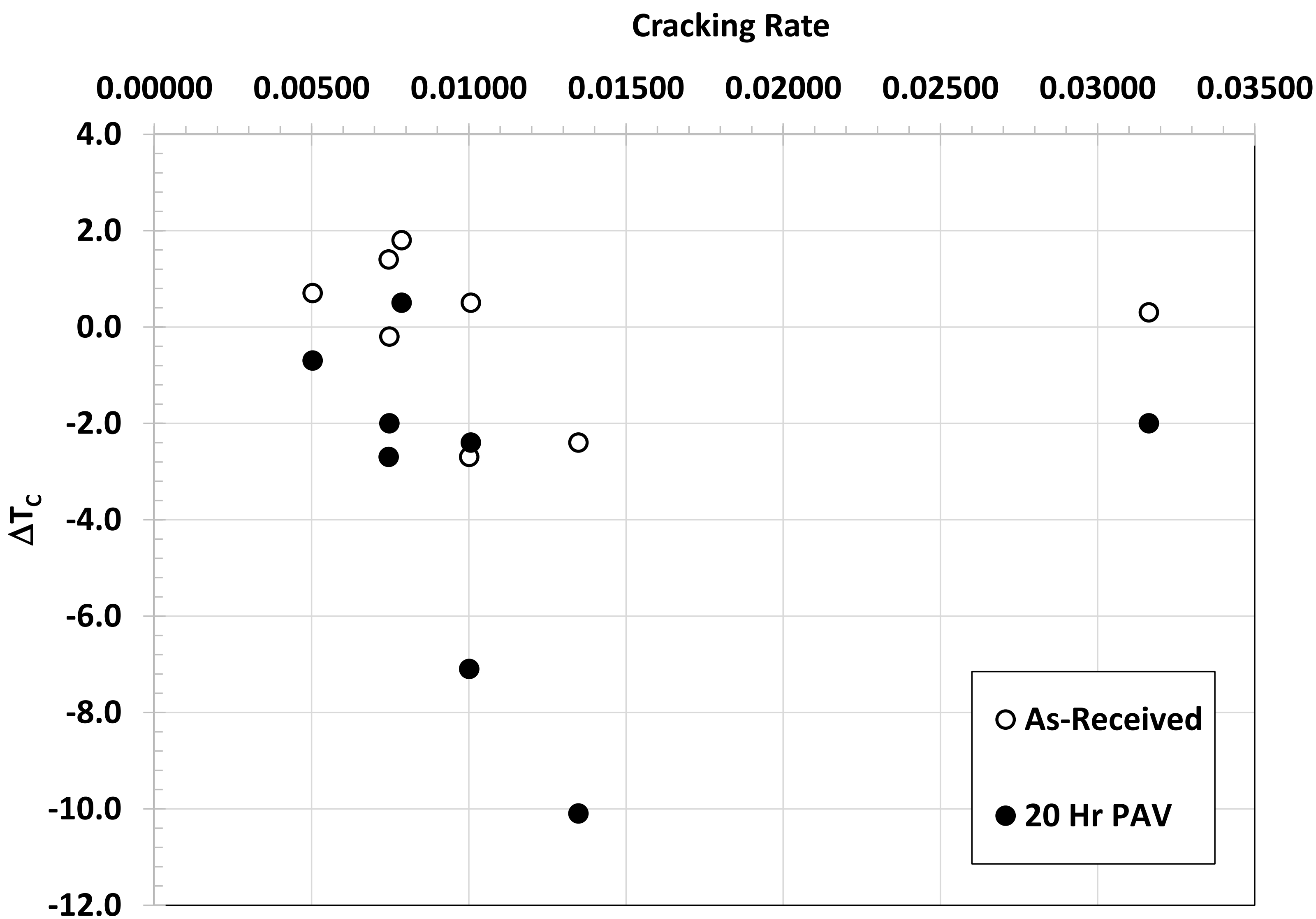
DENT CTOD vs Cycles to 1st Crack



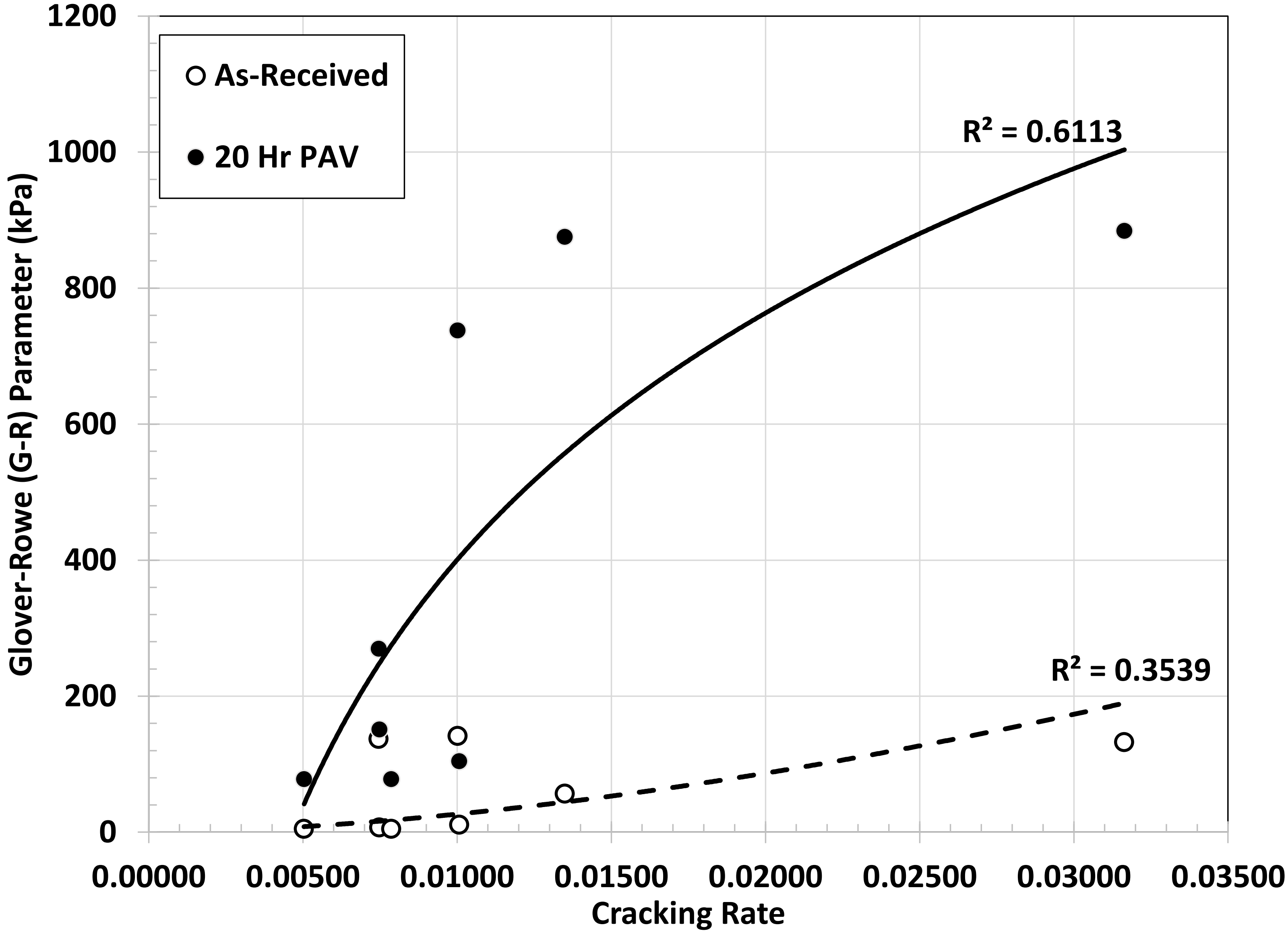
Intermediate Temp PG vs Cracking Rate



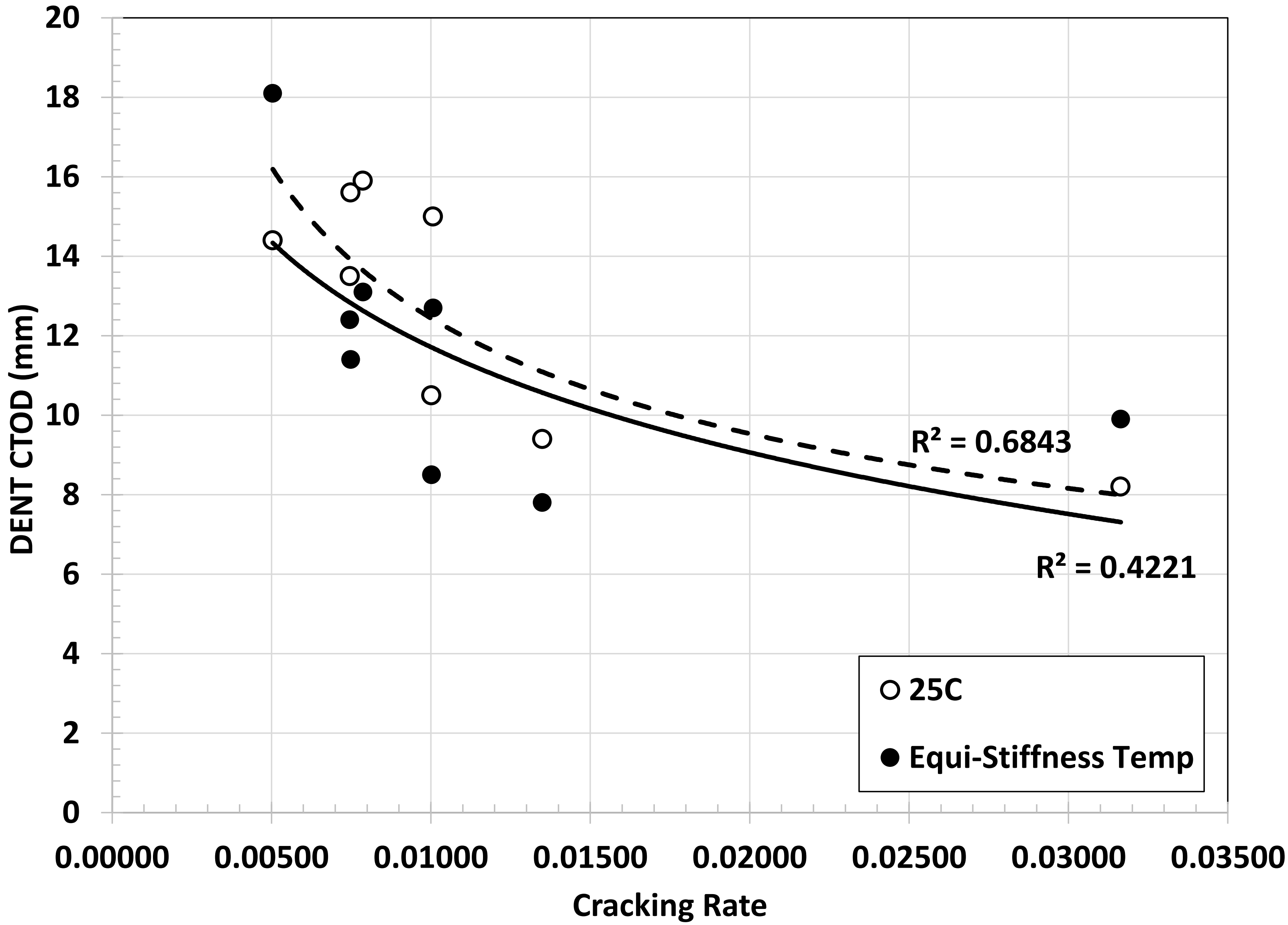
ΔT_C vs Cracking Rate



Glover-Rowe Parameter vs Cracking Rate



DENT CTOD vs Cracking Rate

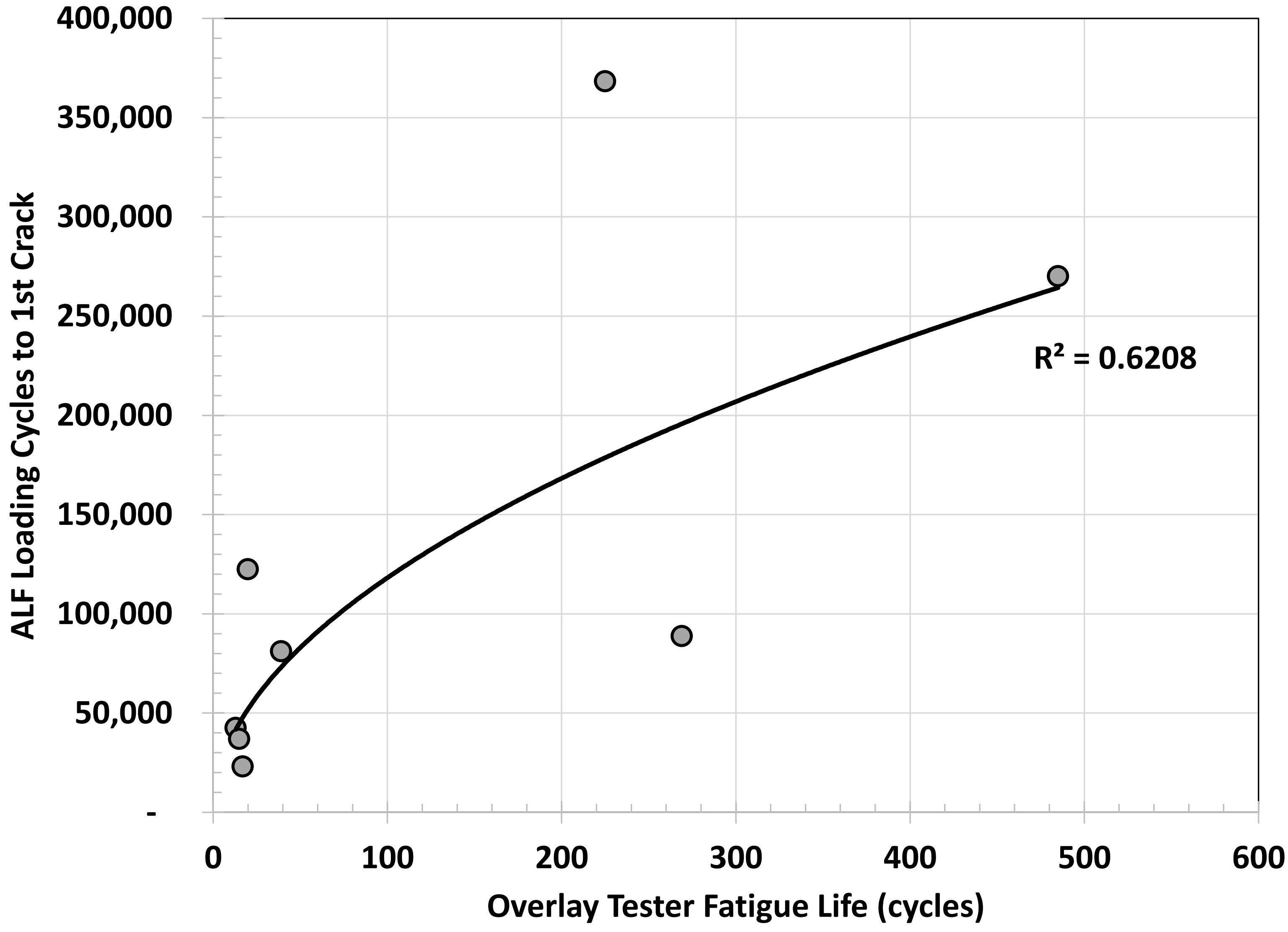


Overview of Asphalt Binder Testing

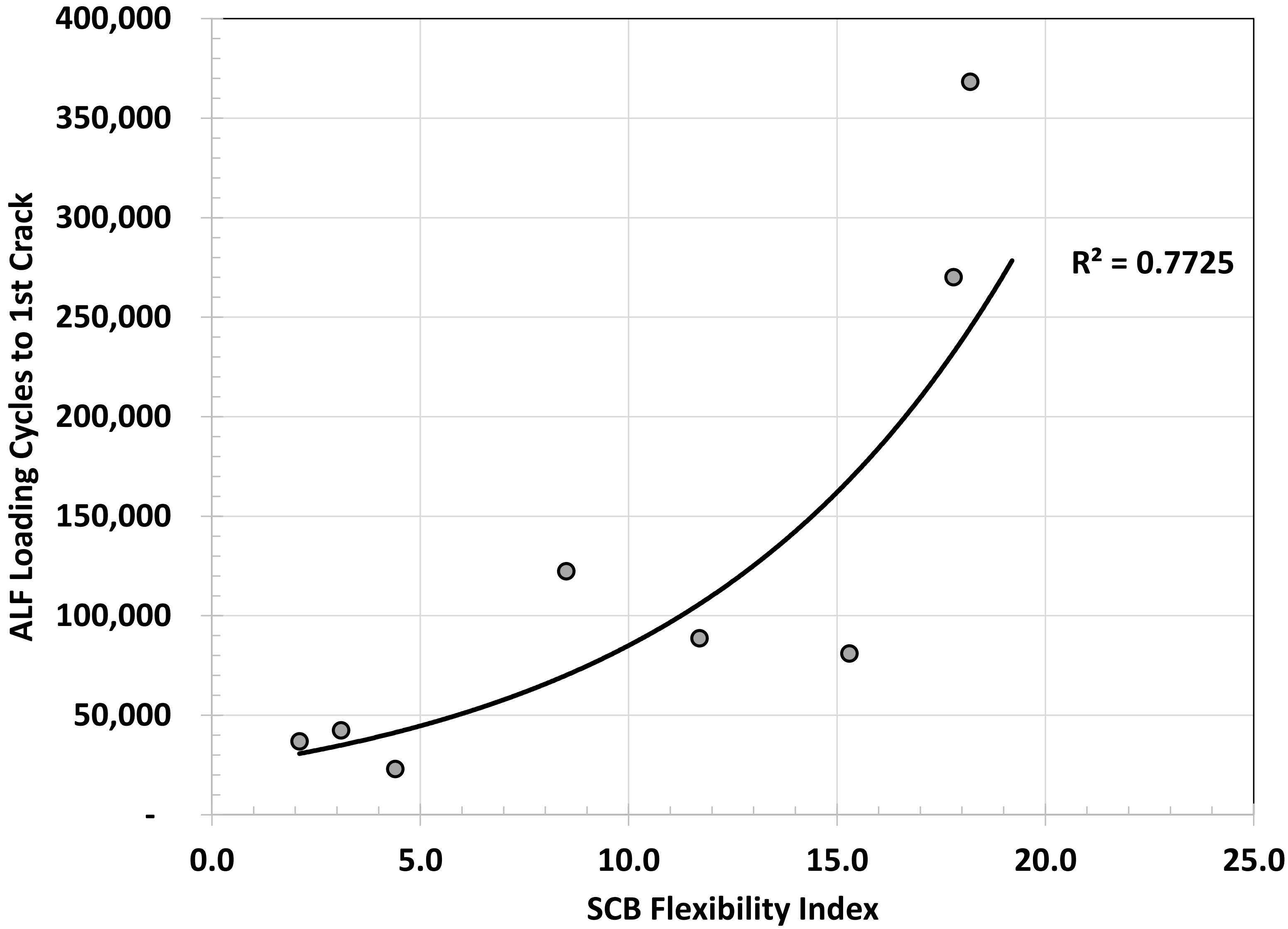
- Glover-Rowe Parameter correlated best with Crack Initiation (Cycles to 1st Crack)
  - DENT CTOD using equi-stiffness temperature also correlated well
  - ΔT_C had moderate correlation – believe it was due to only 20 hour PAV, most likely needed 40 hours to differentiate binders with high recycle contents
- Glover-Rowe and DENT CTOD again provided best correlation to Cracking Rate

Testing Results – Asphalt Mixtures

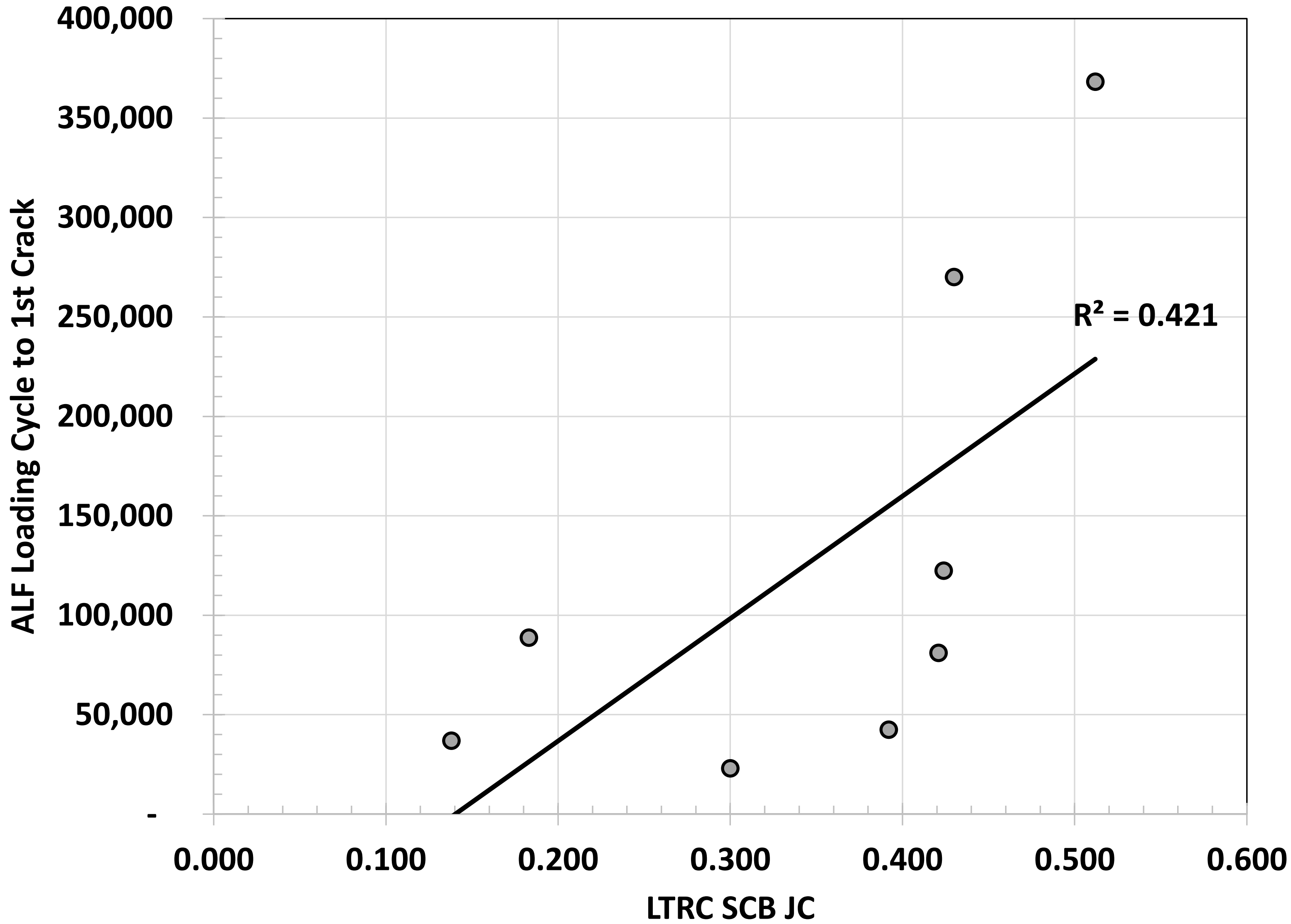
Overlay Tester vs Cycles to 1st Crack



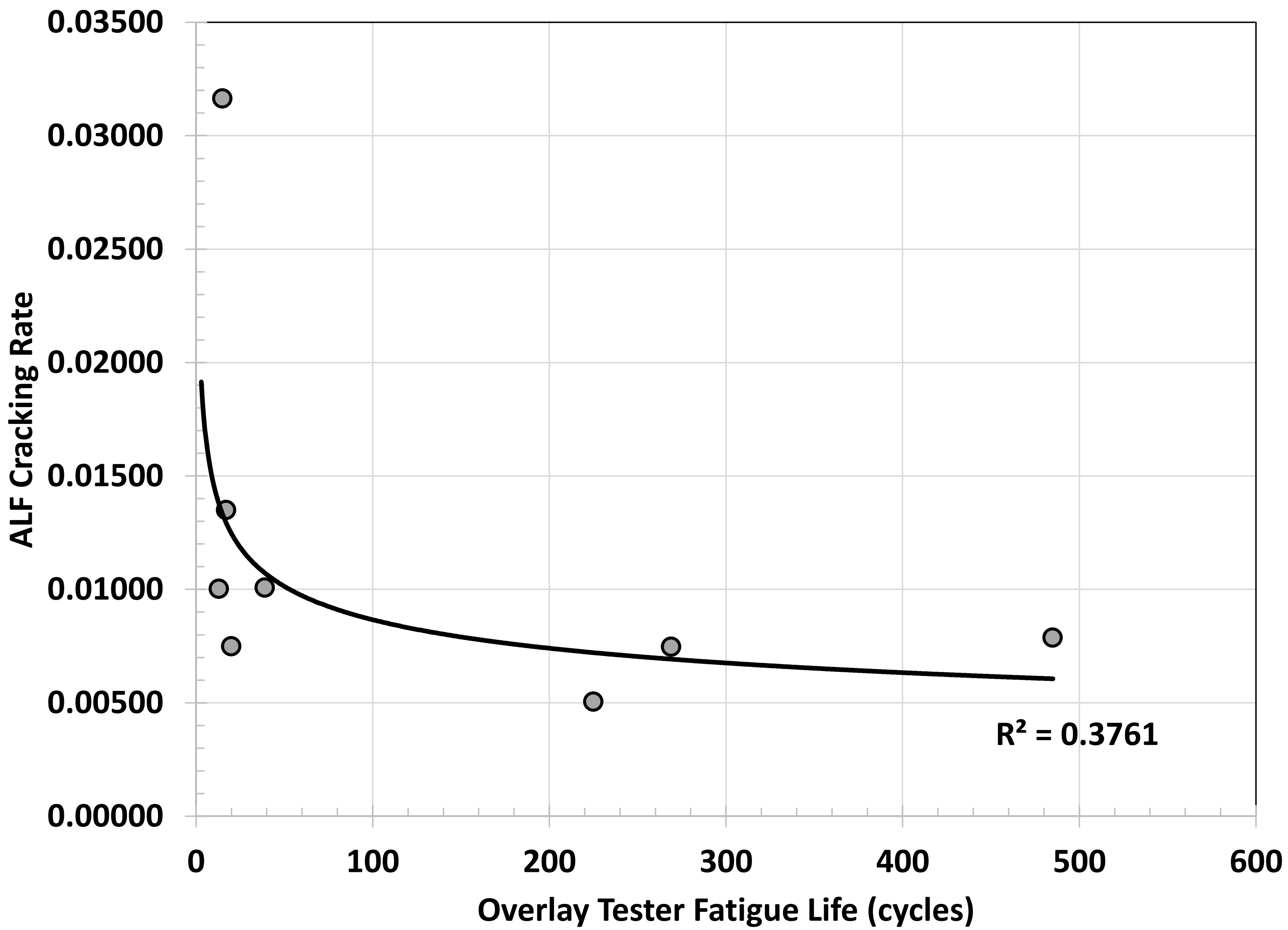
SCB FI vs Cycles to 1st Crack



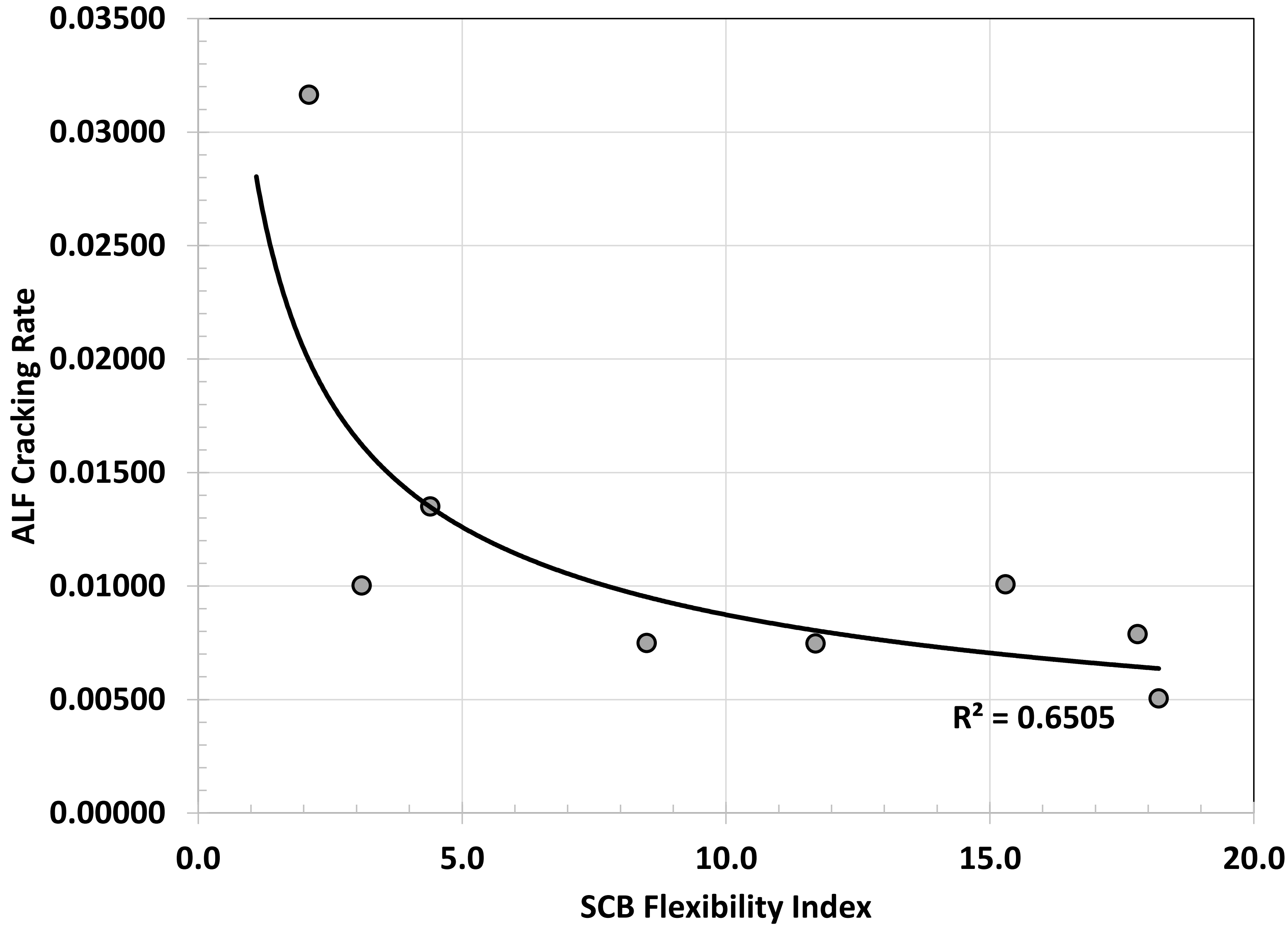
LTRC SCB vs Cycles to 1st Crack



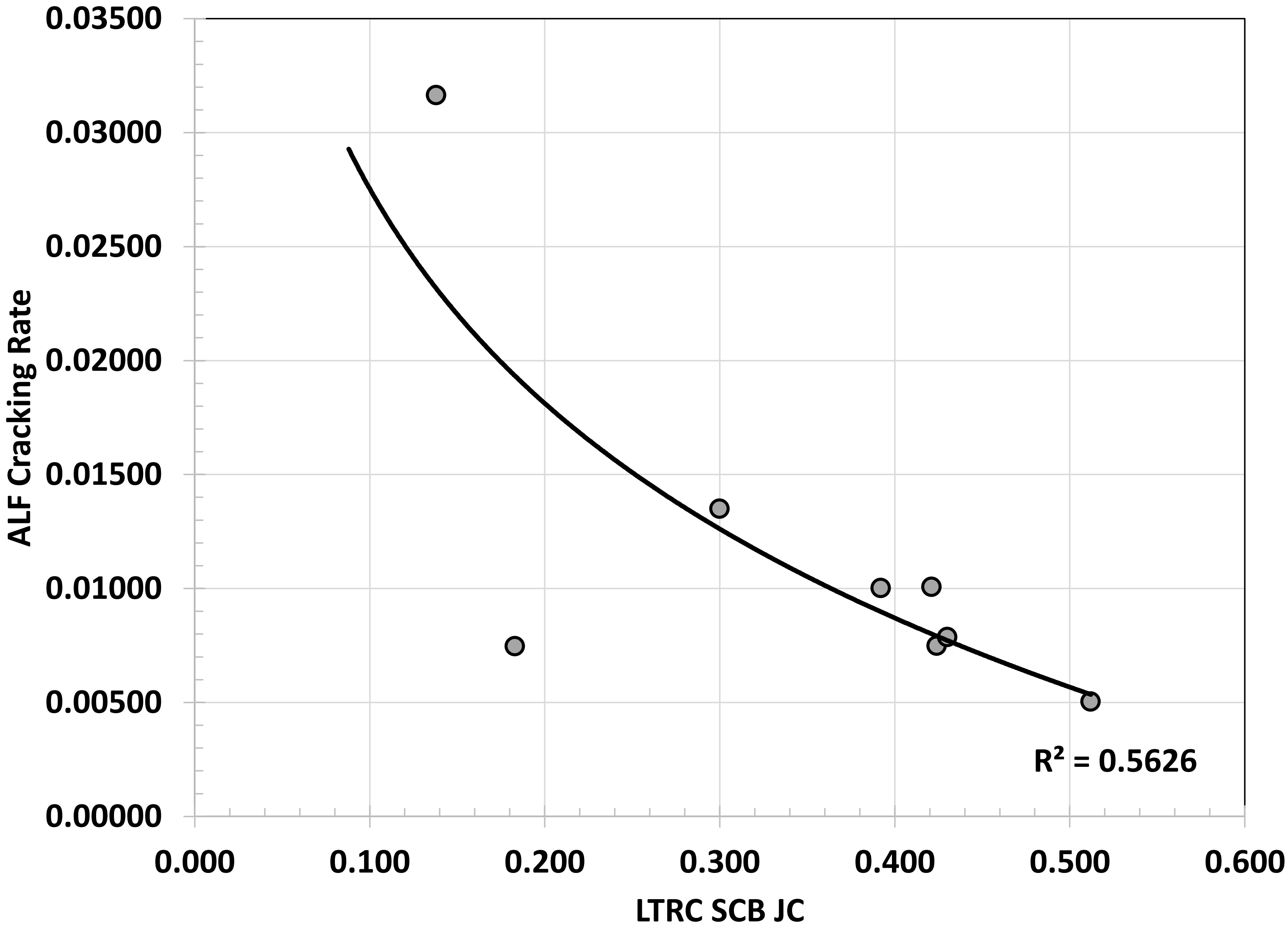
Overlay Tester vs Cracking Rate



SCB FI vs Cracking Rate



LTRC SCB vs Cracking Rate



Overview of Mixture Testing

- SCB Flexibility best correlated to both Crack Initiation (Cycles to 1st Crack) and Crack Growth (Cracking Rate)
  - Overlay Tester good correlation to Crack Initiation
  - LTRC SCB good correlation to Cracking Rate
- Other SCB Flexibility Index benefits
  - Only 3 specimens
  - Typical core thickness
  - Quick test (50 mm/min)
  - Can be run on typical Marshall equipment

Conclusions of Study

- There is an interest by state agencies to have a "fatigue" asphalt binder test for purchase specification, as well as a mixture test to ensure fatigue performance
- Field cores from ALF Fatigue Cracking Experiment was used to evaluate different binder and mixture tests
  - ALF provided different levels of performance for comparison
  - Testing conducted on plant produced materials (cores)

Conclusions on Study

- Asphalt Binder Testing
  - Both Glover-Rowe and DENT CTOD provided good correlations to field cracking performance
    - Glover-Rowe "stiffness" based on correlation to ductility
    - DENT CTOD "fracture" based
  - From practical standpoint, Glover-Rowe requires much less material and can be conducted on current DSR's
    - DENT CTOD requires special equipment and much more material
  - May need to reassess aging condition – collected data suggest ΔT_C should have done better, but perhaps not conditioned enough
  - Additional research needed on appropriate temperatures and loading rates

Conclusions on Study

- Asphalt Mixture Testing
  - SCB Flexibility Index correlated best with both modes of field cracking (initiation and propagation)
  - Current test procedure (AASHTO TP124) can be conducted on research grade servo-hydraulic equipment or Marshall Stability/Flow equipment
    - Deformation rate of 50 mm/min
    - Minimal investment for fixture


Thank you for your time!
Questions?
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