PANYNJ Airfield Fatigue Cracking Study

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NEAUPG Annual Meeting
October 21st and 22nd, 2015
Burlington, VT

Acknowledgements

- Rutgers Staff
  - Chris Ericson, M.S.
  - Darius Pezeshki, M.S.
  - Ed Haas, M.S.
  - Rostyslav Shamborovskyy
  - Ed Wass Jr.
- PANYNJ
  - Casimir Bognacki, Chief of Materials Bureau
  - John Tetar, Asphalt Laboratory Manager

Objective of Study

- Evaluate different runway P401 mixtures for their respective fatigue cracking performance
  - 5 different mixes
  - Different asphalt binders
  - Different field performance
    - 15 years – performing well
    - 6 years – performing poorly
- "Fatigue" asphalt binder testing
- Mixture fatigue cracking tests
- Ultimately – can we find a binder parameter for purchase specification and mixture specification for Quality Control to promote durable asphalt mixtures

Field Observations

- Longitudinal and transverse cracking observed
- Cracking top-down
  - Stops approximately 0.5 to 0.75 inches below surface

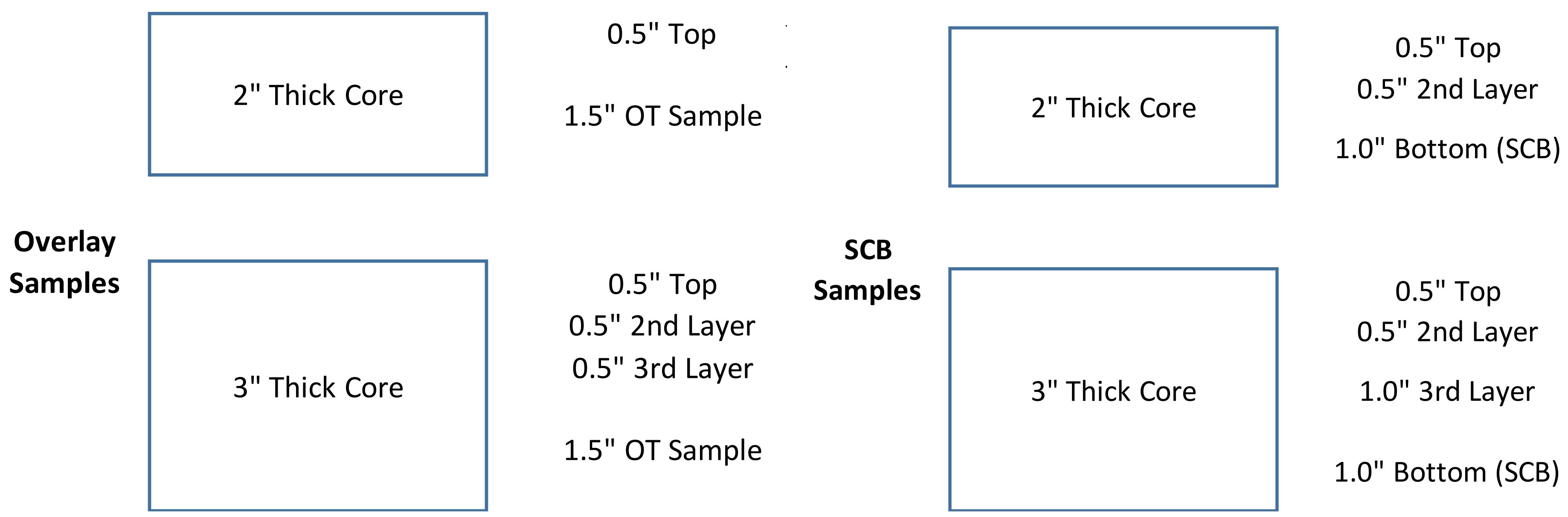
Newark & JFK Runway Fatigue Cracking

Runway	Core Location	Core Thickness	Mix Type	Binder Type	Supplier	Visual Observations	Aggregate Type	Date Placed (Age)	# of Cores
EWR 11-29 (Core Set 1)	Station 38+84, Offset 16 ft, Right of Centerline	2 inches	FAA #3	PG64-22 + 7% Vestoplast	Mt. Hope, Tilcon B Plant	Not performing well; Excessive cracking	Gneiss	9/20/2008 (6 Yrs, 9 Months)	11 (1 cracked)
EWR 11-29 (Core Set 2)	Station 5+99, Offset 63 ft, Right of Centerline	2 inches	FAA #3	PG64-22 + 7% Vestoplast	Mt. Hope, Tilcon B Plant	Not performing well; Excessive cracking	Gneiss	8/9/2008 (6 Yrs, 10 Months)	11 (1 cracked)
JFK 4R-22L (Core Set 3)	Station 39+50, Offset 50 ft, Right of Centerline	3 inches	FAA #3	PG76-22	Willets Pt Asphalt, Flushing, NY	Performing well; No cracking	Trap Rock (from Tilcon, Haverstraw)	9/5/2002 (12 Yrs, 9 Months)	10
JFK 4L-22R (Core Set 4)	Station -12+87, Offset 5 ft, Left of Centerline	3 inches	FAA #3	PG76-28	Willets Pt Asphalt, Flushing, NY	Performing well; Very few cracks	Trap Rock (from Tilcon, Haverstraw)	6/4/2000 (15 Yrs)	10
JFK 4L-22R (Core Set 5)	Station -10+18, Offset 27 ft, Right of Centerline	3 inches	FAA #3	PG76-28	Mt. Hope Rock Products, Flushing NY	Performing well; some cracking	Gneiss	6/4/2000 (15 Yrs)	10

Runway	Binder Type	Asphalt Content	QC Air Voids	QC VMA	QC VFA	Eff AC by Vol (%)	Flow	#200	#200/Eff AC by Vol	Visual Observations	Date Placed (Age)
EWR 11-29 (Core Set 1)	PG64-22 + 7% Vestoplast	5.37	3.4	15.8	78.8	12.4	11.8	4.5	0.36	Not performing well; Excessive cracking	9/20/2008 (6 Yrs, 9 Months)
EWR 11-29 (Core Set 2)	PG64-22 + 7% Vestoplast	5.3	3.5	15.9	77.9	12.4	11	3.9	0.31	Not performing well; Excessive cracking	8/9/2008 (6 Yrs, 10 Months)
JFK 4R-22L (Core Set 3)	PG76-22	5.14	4.9	17	71.1	12.1	13.8	4.4	0.36	Performing well; No cracking	9/5/2002 (12 Yrs, 9 Months)
JFK 4L-22R (Core Set 4)	PG76-28	5.02	4.6	17	72.9	12.4	13.3	4.8	0.39	Performing well; Very few cracks	6/4/2000 (15 Yrs)
JFK 4L-22R (Core Set 5)	PG76-28	5.05	4.6	16.4	72	11.8	14.5	3.7	0.31	Performing well; some cracking	6/4/2000 (15 Yrs)

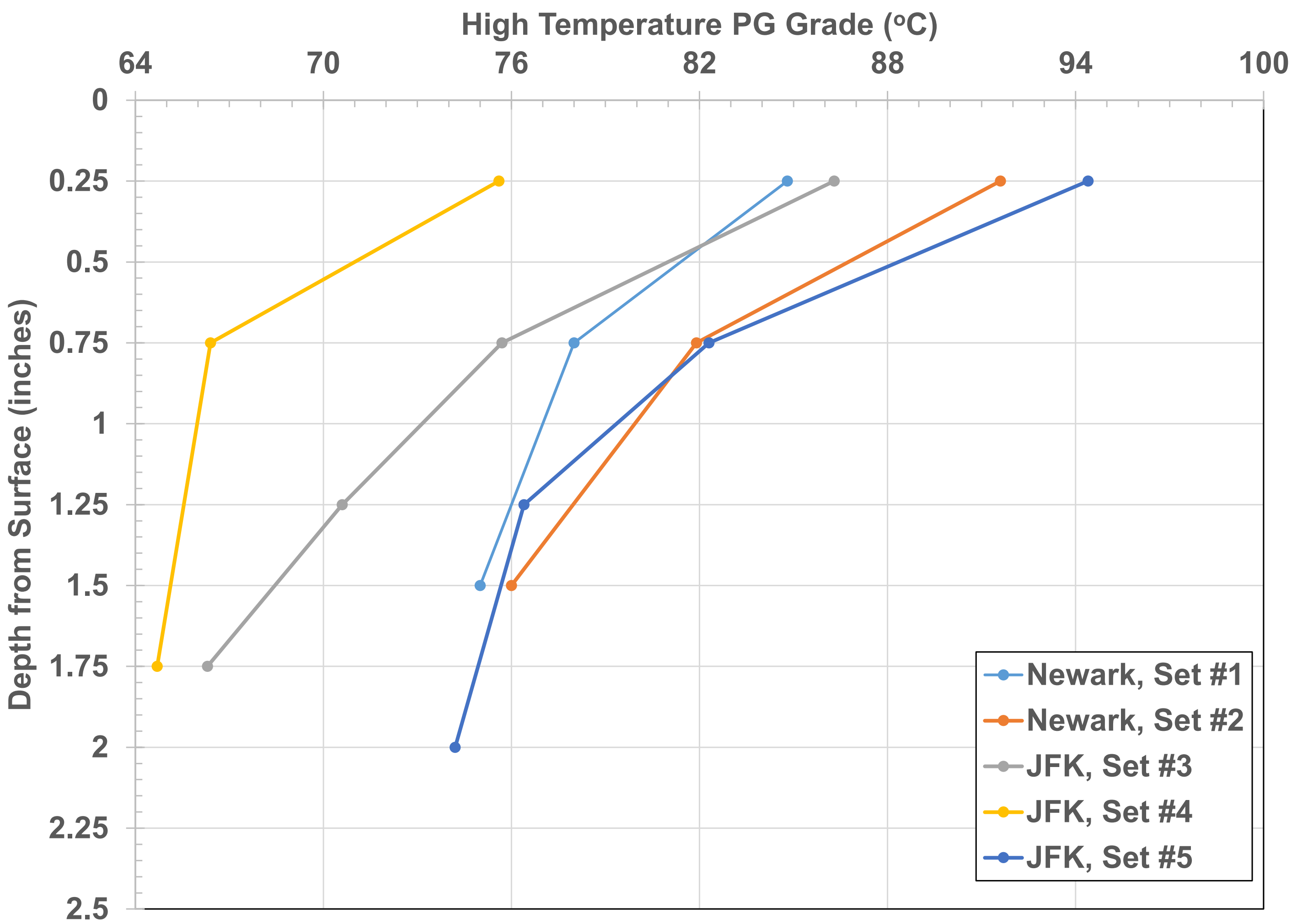
Binder and Mixture Sampling from Field Cores – Approximate Dimensions

- Asphalt binder testing conducted every 0.5" to evaluate change in binder properties due to aging
- Asphalt mixture testing conducted at bottom of core to provide "initial" mixture performance

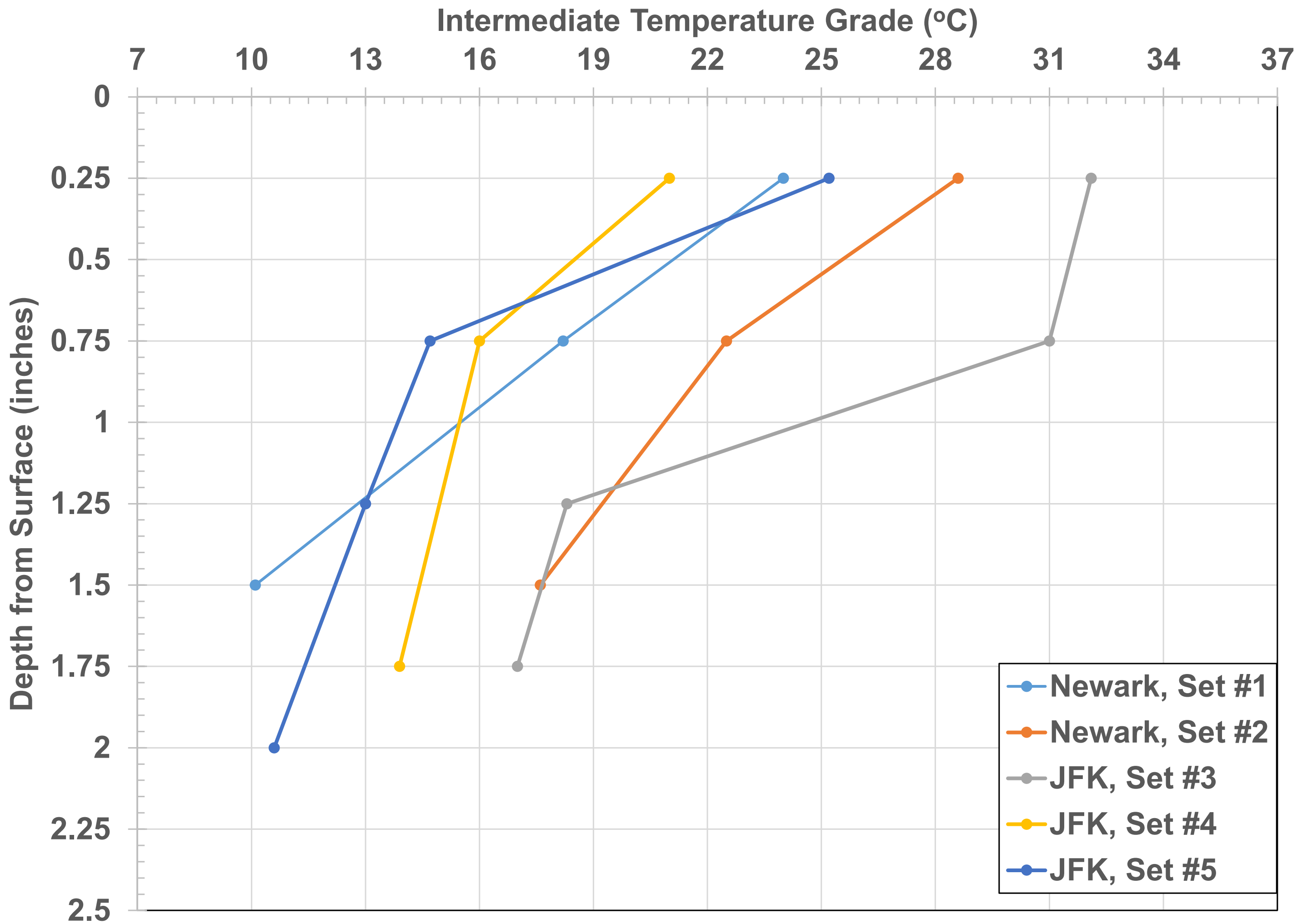


Asphalt Binder Testing & Results

High Temperature PG Grade

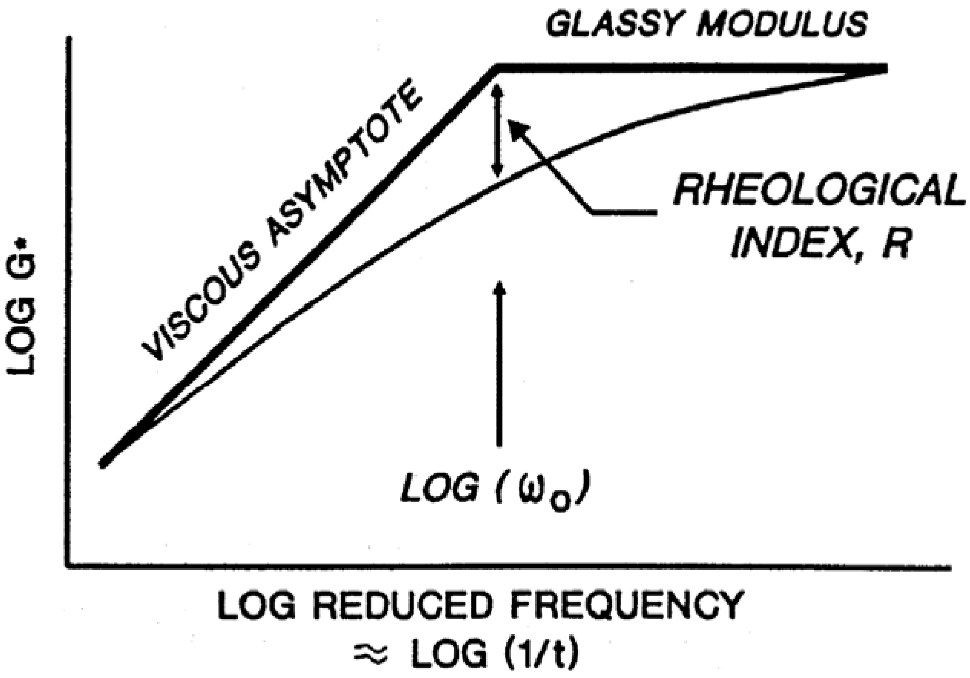


Intermediate Temperature PG Grade

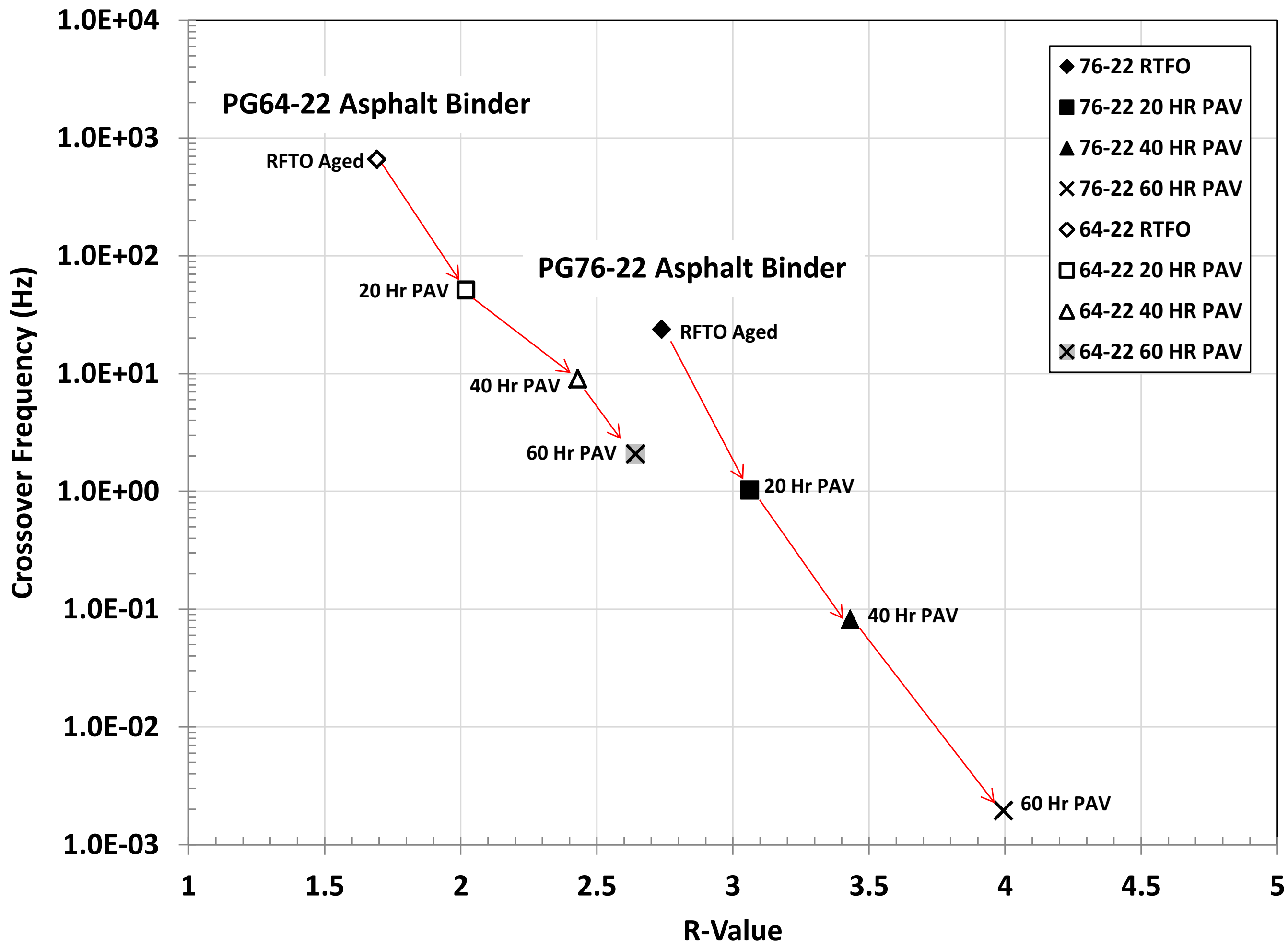


Master Stiffness (G*) Curves - Form of Master Curve (Christensen & Anderson, 2001)

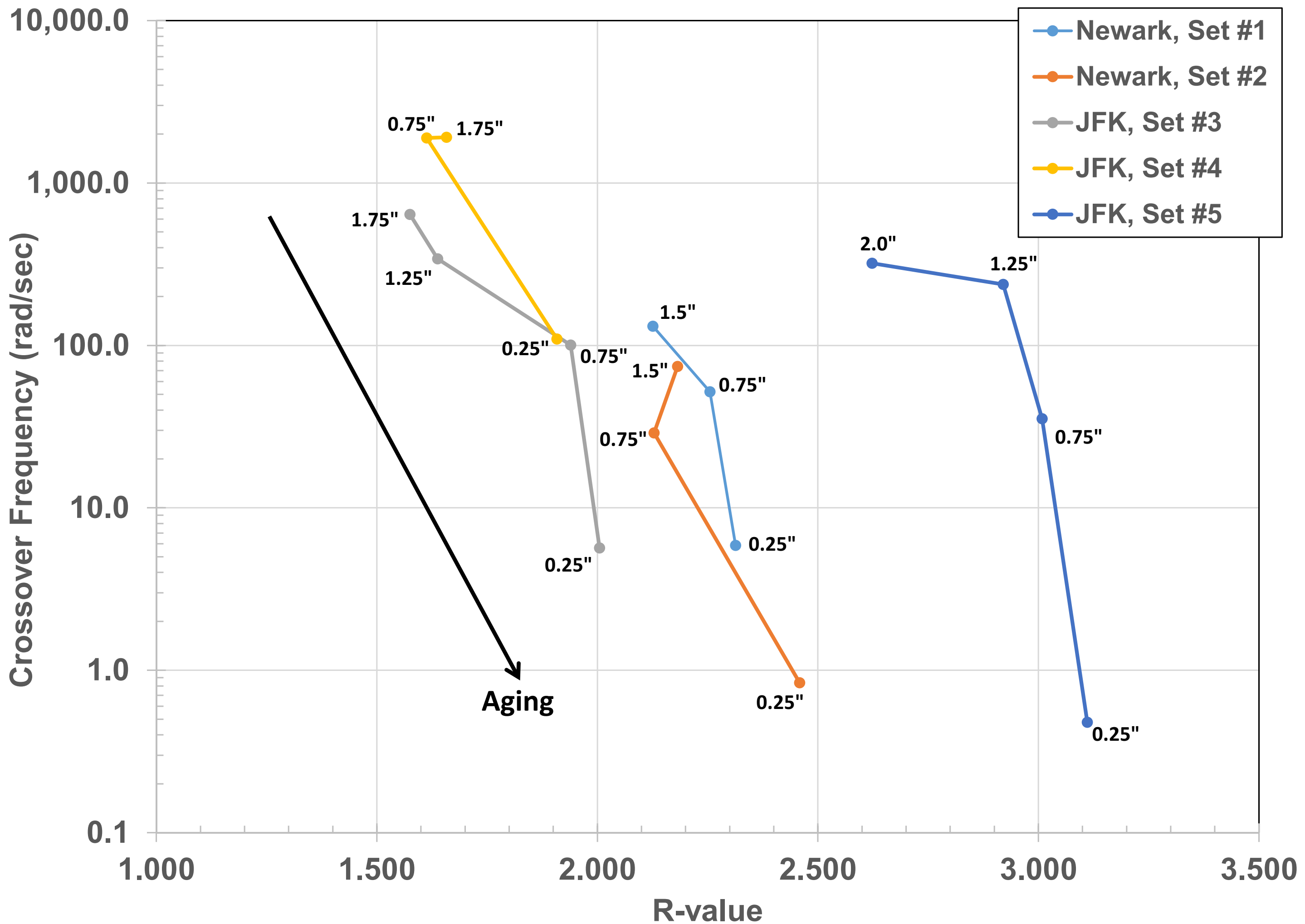
- Master Stiffness (G*) curves generated using frequency sweep in the DSR
- Shape of master curve related to overall stiffness of the asphat binder
- As binders age, increase in stiffening



PG64-22 & PG76-22 in ω_o & R-value Space



Cross-over Frequency (ω_o) – R-value Space

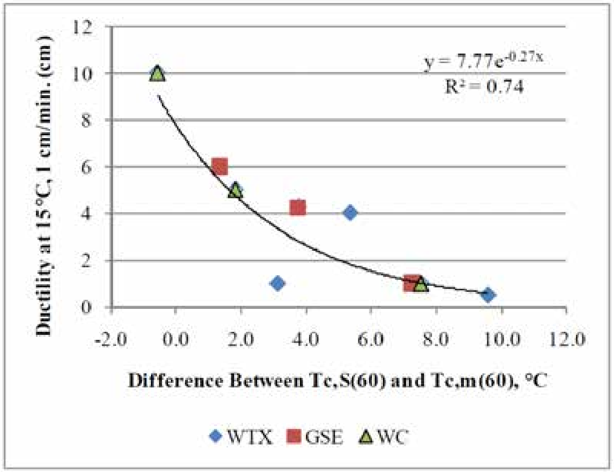


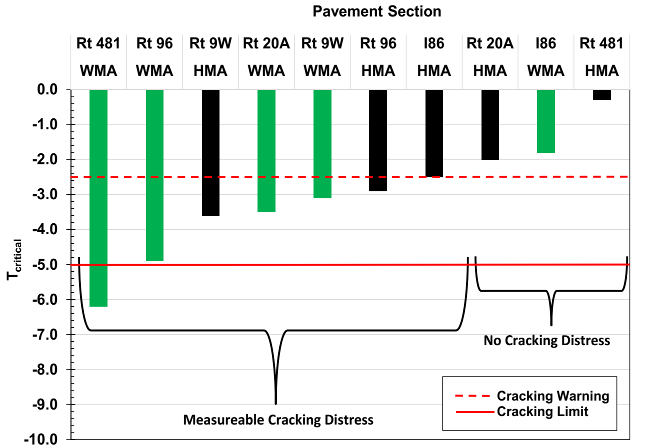
ΔT_c from BBR Testing

- 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

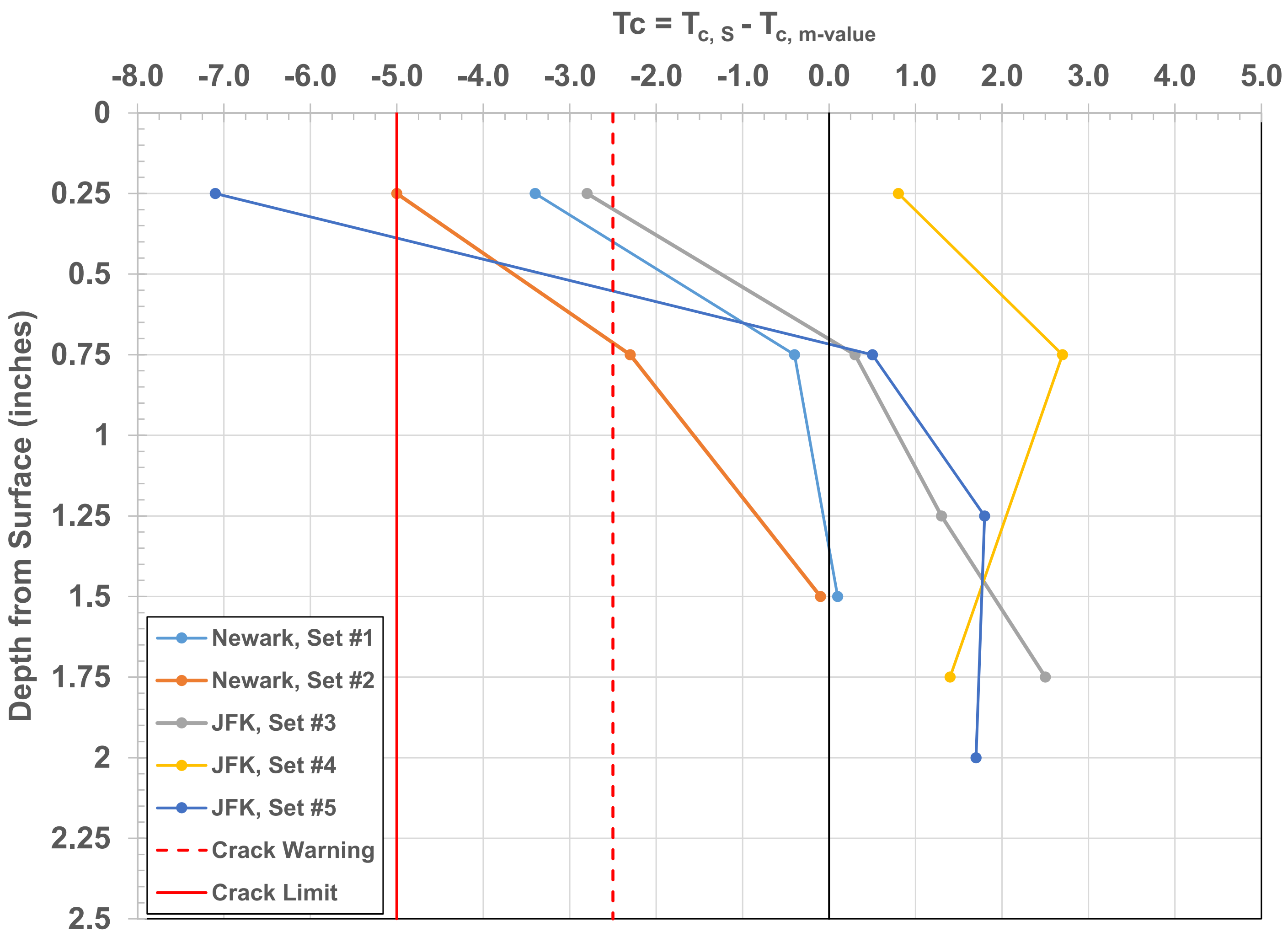
$$\Delta T_c = T_{c,\,S} - T_{c,\,m\text{-value}}$$

- 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



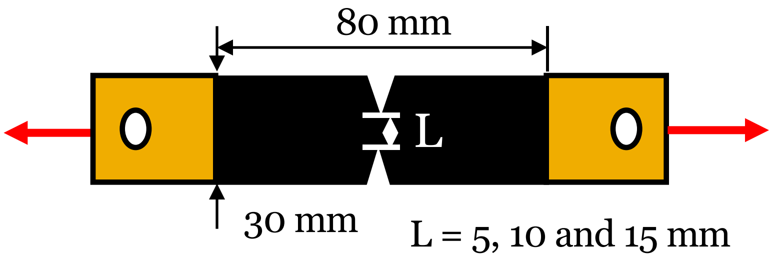


Change in Low Temperature Critical Cracking (ΔT_c)

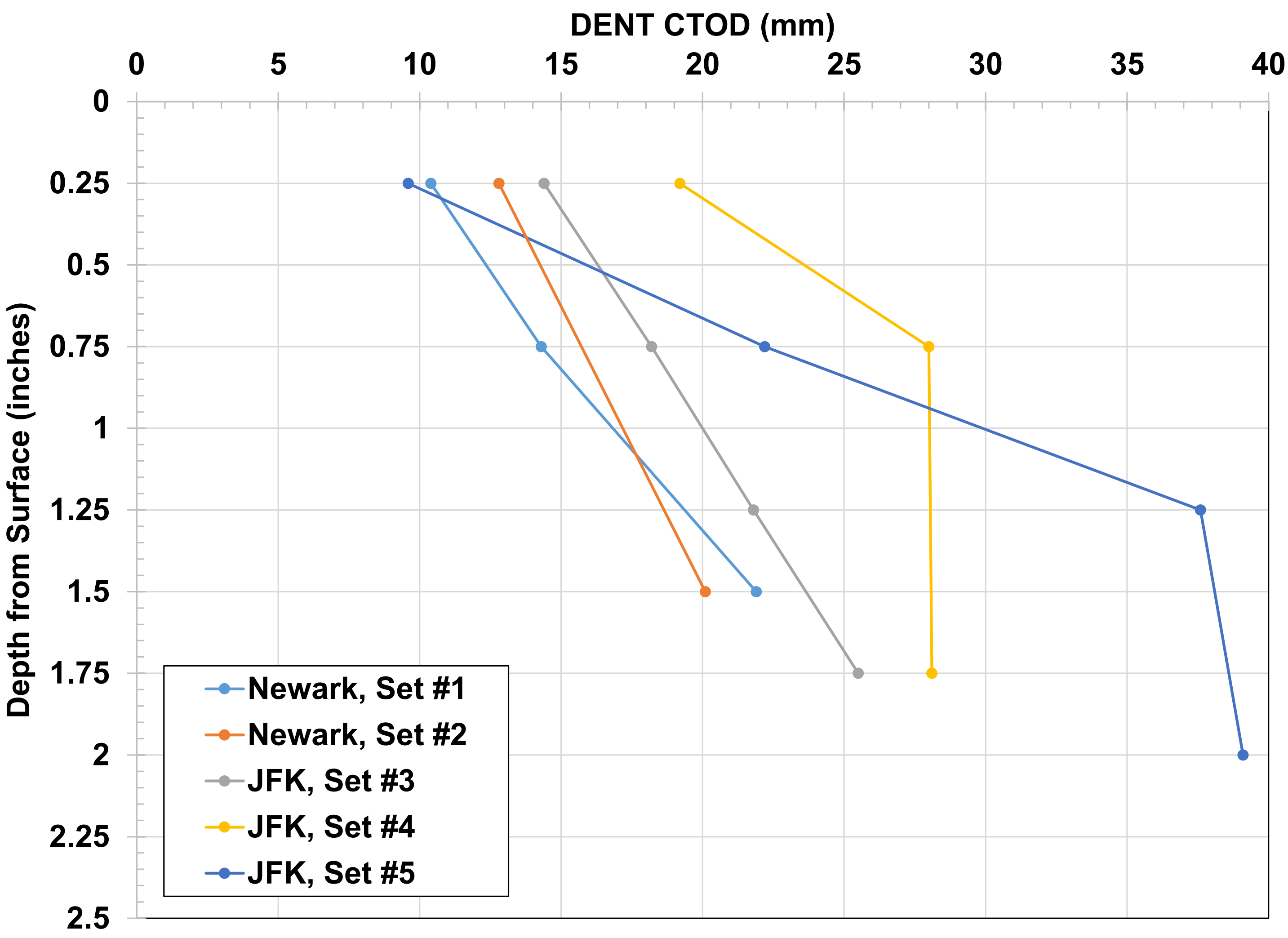


Double Edge Notched Tension (DENT) Test – AASHTO TP113

- 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
- Test has been found to correlate well to field cracking performance at FHWA ALF, as well as laboratory studies at Rutgers U. and TTI

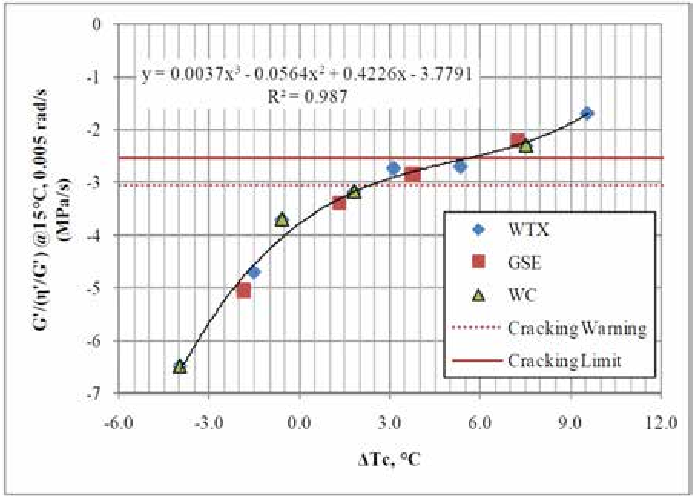


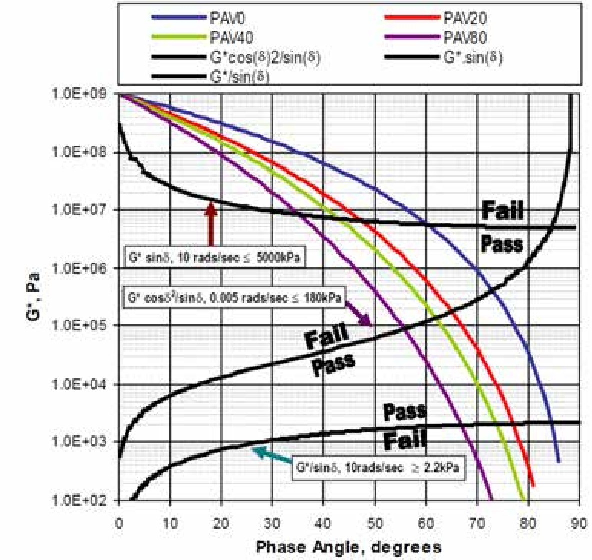
Double Edge Notched Tension (DENT) Test – AASHTO TP113 (20°C)



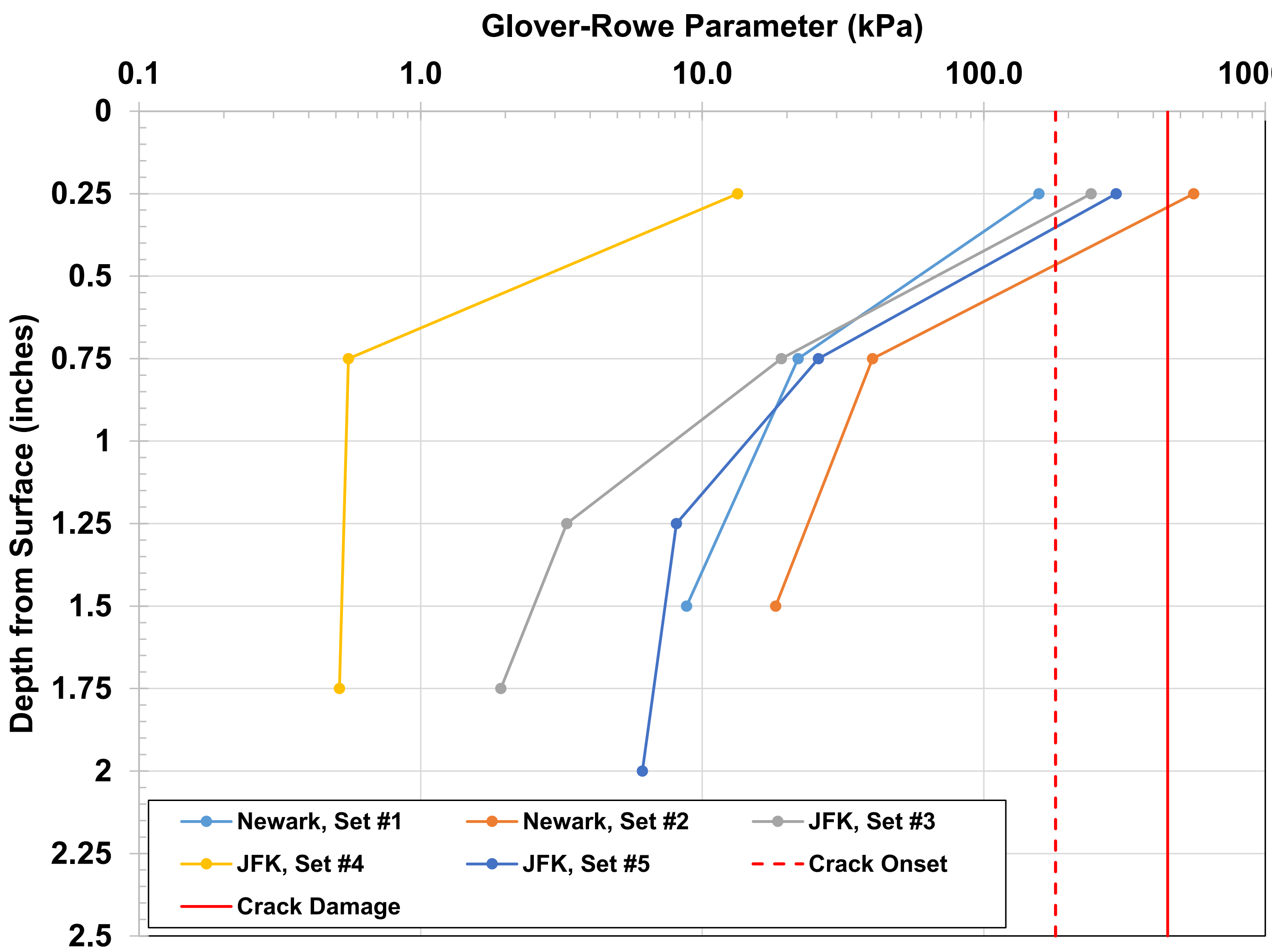
Glover-Rowe Parameter (G-R)

- 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



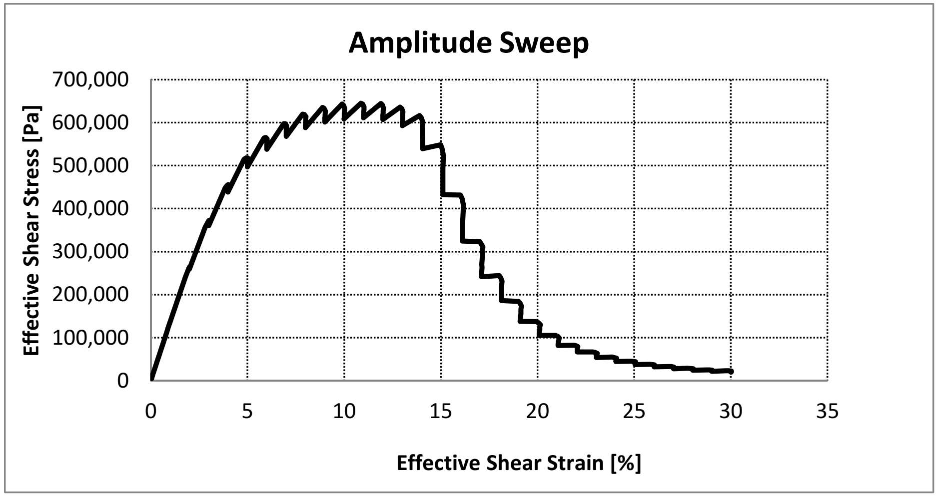


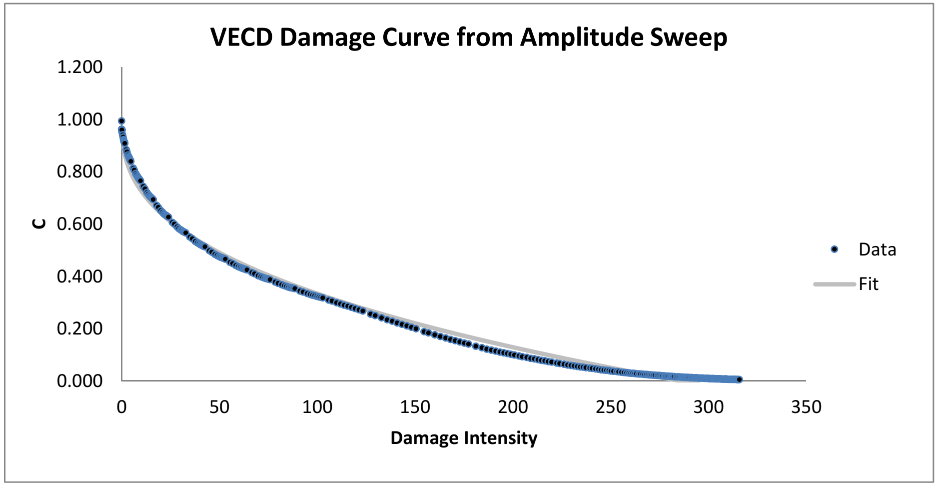
Glover-Rowe Parameter (G-R)



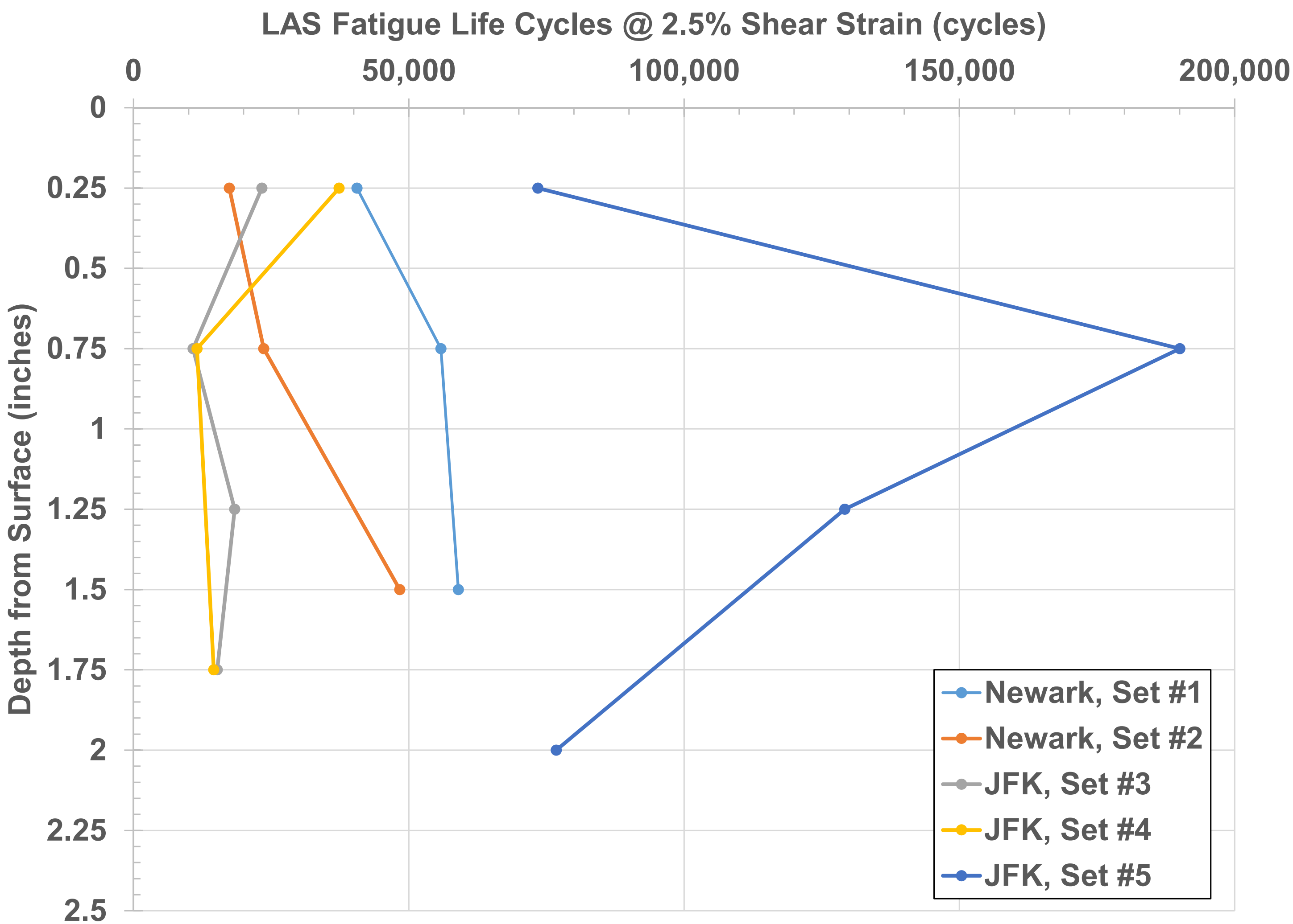
Linear Amplitude Sweep (LAS) – AASHTO TP101

- Utilizes cyclic testing in the DSR to evaluate the undamaged and damaged condition of asphalt binders under increased accelerated damage.
- Analysis allows for the determination of asphalt binder fatigue life (cycles) at different shear strain levels
- Comparison to FHWA-ALF and LTPP sections show relatively well correlations

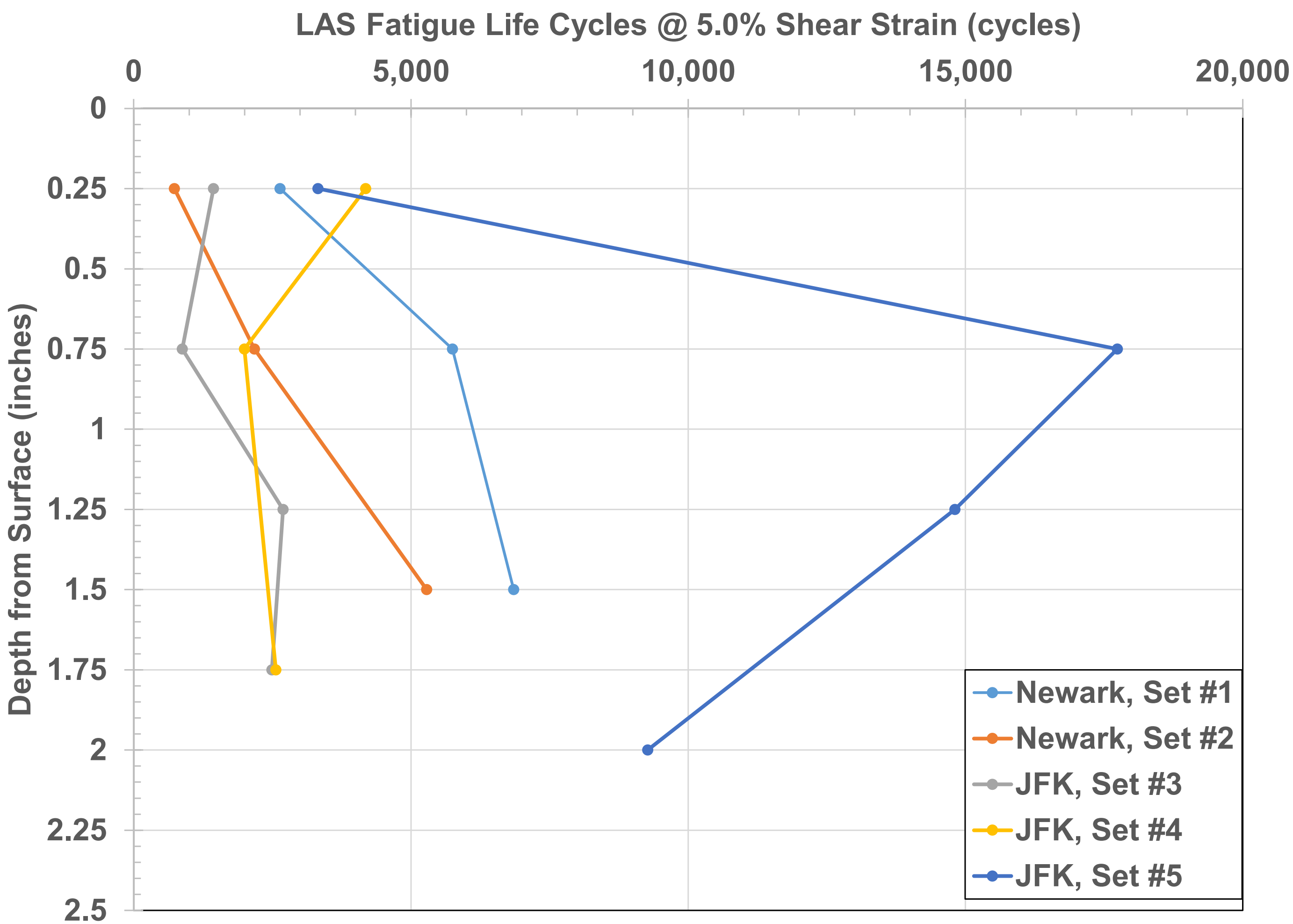




Linear Amplitude Sweep @ 2.5% Shear Strain



Linear Amplitude Sweep @ 5% Shear Strain



Binder "Fatigue" Test - Ranking of Core Sets

0.25" Depth	Tcr	CTOD (mm)	Glover-Rowe	***Average***
Newark, Set #1	3	4	2	***3.0***
Newark, Set #2	4	3	5	***4.0***
JFK, Set #3	2	2	3	***2.3***
JFK, Set #4	1	1	1	***1.0***
JFK, Set #5	5	5	4	***4.7***

0.75" Depth	Tcr	CTOD (mm)	Glover-Rowe	***Average***
Newark, Set #1	4	5	3	***4.0***
Newark, Set #2	5	4	5	***4.7***
JFK, Set #3	3	3	2	***2.7***
JFK, Set #4	1	1	1	***1.0***
JFK, Set #5	2	2	4	***2.7***

1.5" Depth	Tcr	CTOD (mm)	Glover-Rowe	***Average***
Newark, Set #1	4	4	4	***4.0***
Newark, Set #2	5	5	5	***5.0***
JFK, Set #3	1	3	2	***2.0***
JFK, Set #4	3	2	1	***2.0***
JFK, Set #5	2	1	3	***2.0***

Runway	**Binder Type**	**Visual Observations**	**Date Placed (Age)**
EWR 11-29 (Core Set 1)	PG64-22 + 7% Vestoplast	Not performing well; Excessive cracking	9/20/2008 (6 Yrs, 9 Months)
EWR 11-29 (Core Set 2)	PG64-22 + 7% Vestoplast	Not performing well; Excessive cracking	8/9/2008 (6 Yrs, 10 Months)
JFK 4R-22L (Core Set 3)	PG76-22	Performing well; No cracking	9/5/2002 (12 Yrs, 9 Months)
JFK 4L-22R (Core Set 4)	PG76-28	Performing well; Very few cracks	6/4/2000 (15 Yrs)
JFK 4L-22R (Core Set 5)	PG76-28	Performing well; some cracking	6/4/2000 (15 Yrs)

Summary of Binder "Fatigue" Testing

- Both the BBR ΔT_C and DENT CTOD properties correlated to field observations
  - Glover-Rowe provided reasonable comparisons
  - Intermediate PG grade & LAS conflicted to field observations
- "Fatigue" properties of recovered asphalt binder improved with depth
  - At depths > 0.75 inches, appears to be little aging
    - Would change based on in-situ air voids – these mixtures all placed at air voids < 6.5%
- Could bottom portion of 1.5 to 2 inch core be used to develop laboratory to field binder and mixture aging protocols?

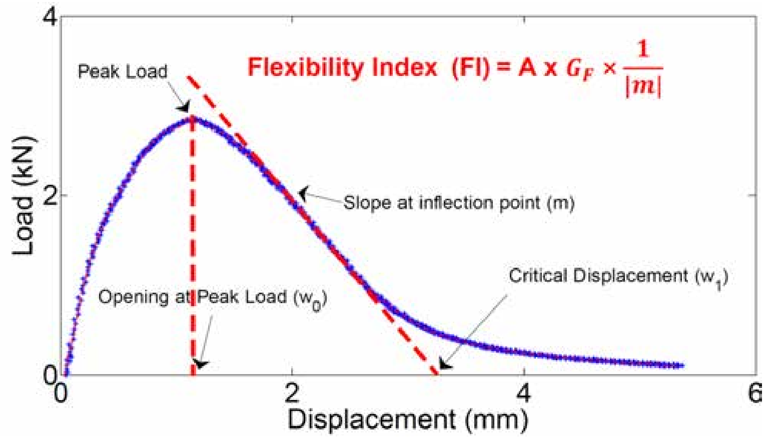
Asphalt Mixture Testing & Results

Asphalt Mixture Testing

- Two fatigue tests conducted on recovered cores
  - Semi-circular Bend (SCB) Test (AASHTO TP105)
  - Overlay Tester (NJDOT B-10; TxDOT TEX-248F)
- Tests chosen based on personal experience and performance correlations in the literature
- Tests also allow thin specimens to be used, which is ideal for either laboratory compacted specimens or field cores
- Test specimens taken away from surface (> 0.75 inches from surface) to obtain asphalt materials that represented close to "original" placement
  - Can the mixture tests predict the resultant field performance?

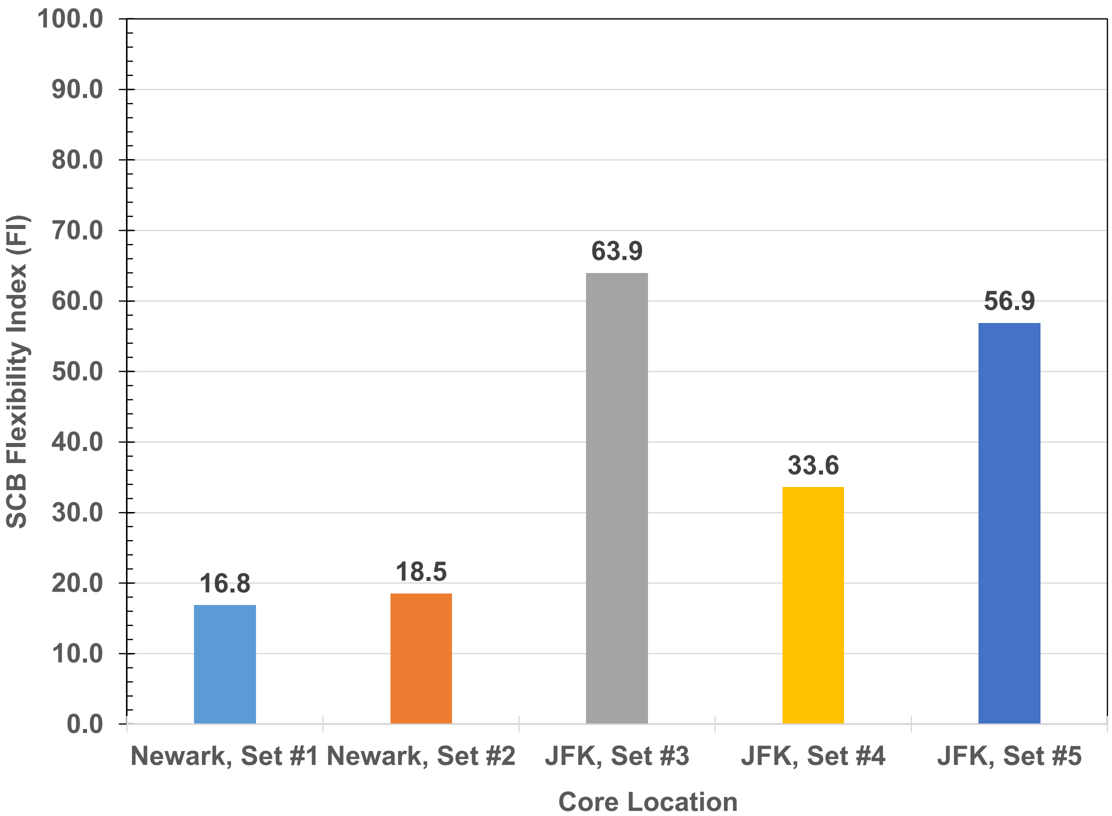
Semi-circular Bend (SCB) Test

- Uses 3-point bending on a semi-circular asphalt sample
- Can use same equipment at AASHTO T283 (50 mm/min)
- Notch cut to initiate cracking
- Test evaluates the energy required to fracture the specimen and propagate a crack at the notch
  - Work of Fracture
- Additional analysis was used to calculate the Flexibility Index (FI)

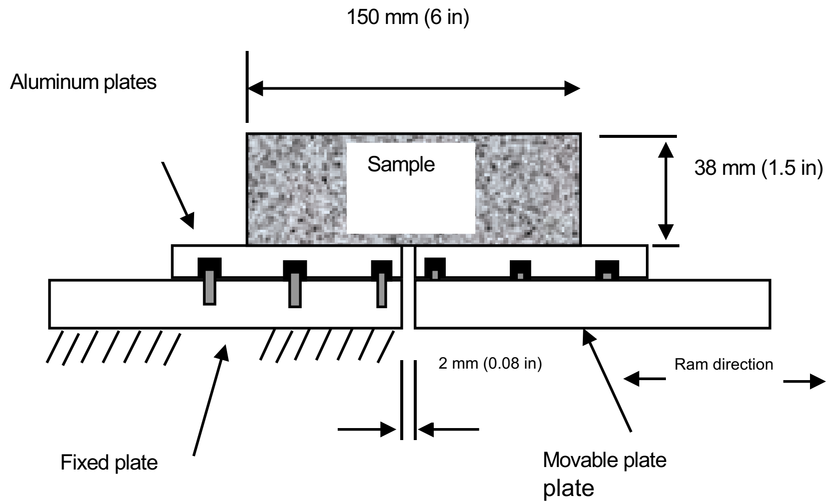


Semi-circular Bend (SCB) Flexibility Index (FI)

- Flexibility Index (FI) shows that Newark Sets #1 and #2 have the worst fatigue resistance
- JFK Set #3 should have best fatigue performance, followed by Set #5 and Set #4



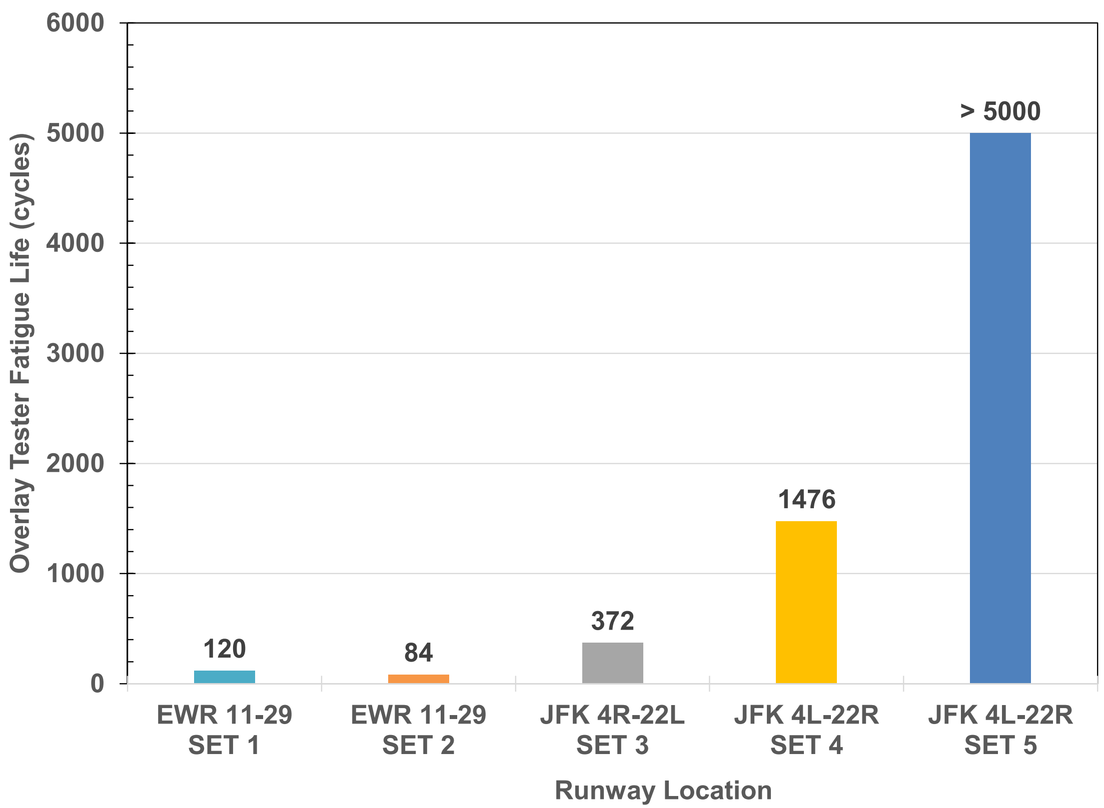
Overlay Tester



- 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

Overlay Tester

- Overlay Tester results indicate that Newark Core Set #1 and #2 should perform the worst.
- JFK Set #5 should have the best fatigue performance, followed by JFK Set #4 and Set #3.



Mixture Ranking of Core Sets

Core Set	SCB Flexibility Index	Overlay Tester	***Average***
Newark, Set #1	5	4	***4.5***
Newark, Set #2	4	5	***4.5***
JFK, Set #3	1	3	***2.0***
JFK, Set #4	3	2	***2.5***
JFK, Set #5	2	1	***1.5***

Runway	**Binder Type**	**Visual Observations**	**Date Placed (Age)**
EWR 11-29 (Core Set 1)	PG64-22 + 7% Vestoplast	Not performing well; Excessive cracking	9/20/2008 (6 Yrs, 9 Months)
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JFK 4L-22R (Core Set 4)	PG76-28	Performing well; Very few cracks	6/4/2000 (15 Yrs)
JFK 4L-22R (Core Set 5)	PG76-28	Performing well; some cracking	6/4/2000 (15 Yrs)

Conclusions

- Asphalt Binder
  - The ΔT_c from the BBR and the DENT CTOD tests appeared to correlate the best to field observations of cracking. Glover-Rowe also showed promise.
  - Results from 0.75" depth and deeper resulted in better correlation to field performance
    - De-icing materials, fuel/oil contamination, residual rubber from tires, etc.
- Asphalt Mixture
  - Both the SCB and the Overlay Tester fatigue cracking performance matched the field performance

Conclusions - continued

- Potential Implementation
  - ΔT_c from the BBR and the DENT CTOD tests can be used as a PG+ specification (specification in addition to current specs) to help insure durability in asphalt binder
    - Need to determine at what aging condition for binder - **RECOMMENDED**
      - 20 Hr PAV may not be enough
      - 40 Hr PAV proposed by some
  - Mixture testing (SCB or Overlay Tester) can be used post-production to ensure the mixture is properly being produced
    - SCB can be run on current asphalt plant equipment using Marshall Compression machine and modified loading head

Potential SCB Plant Implementation – Sample Trimming

(1)

(2)

(3)

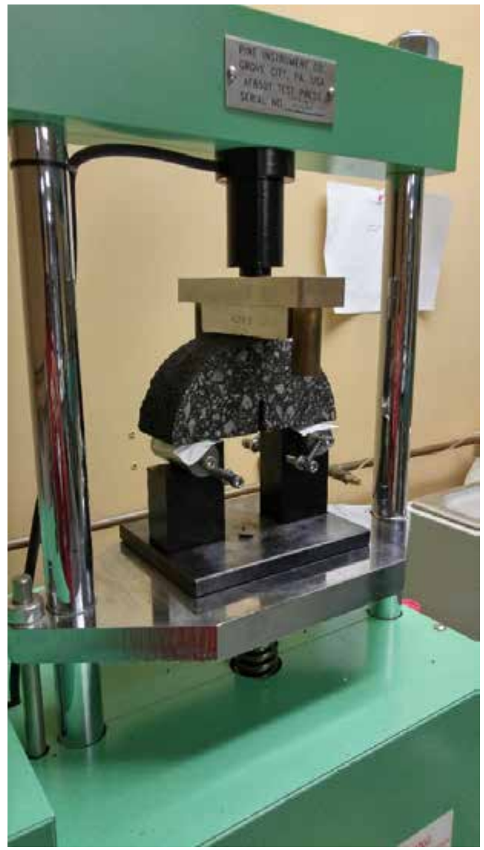
Potential SCB Plant Implementation – Cutting Notch

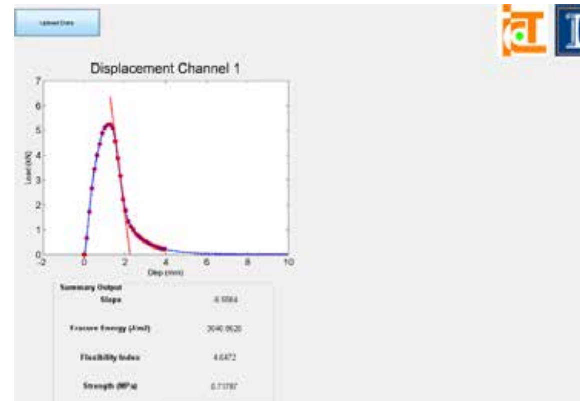
(1)

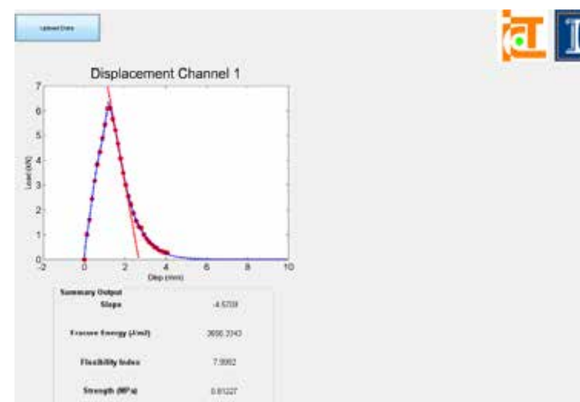
(2)

(3)

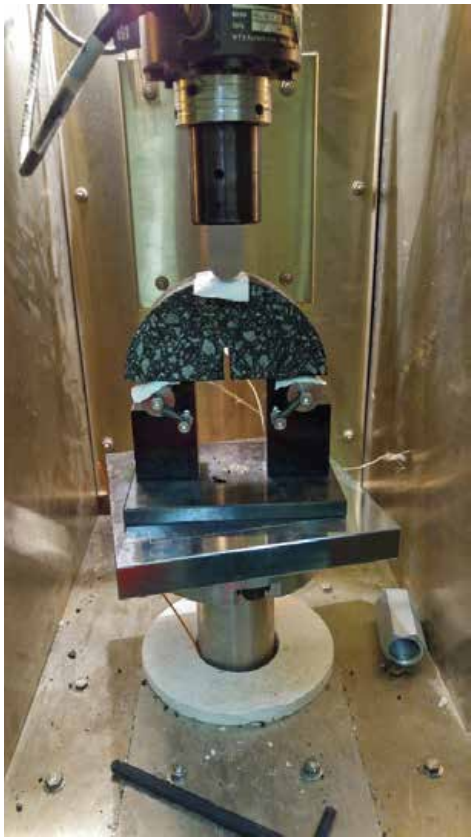
Potential SCB Implementation – Marshall Press

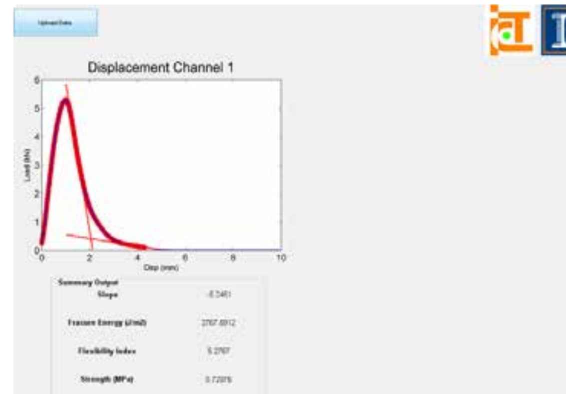


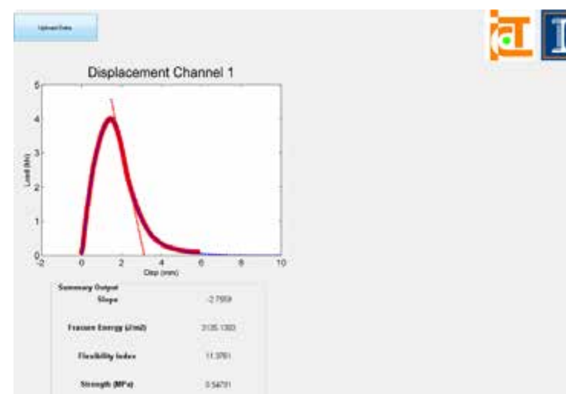




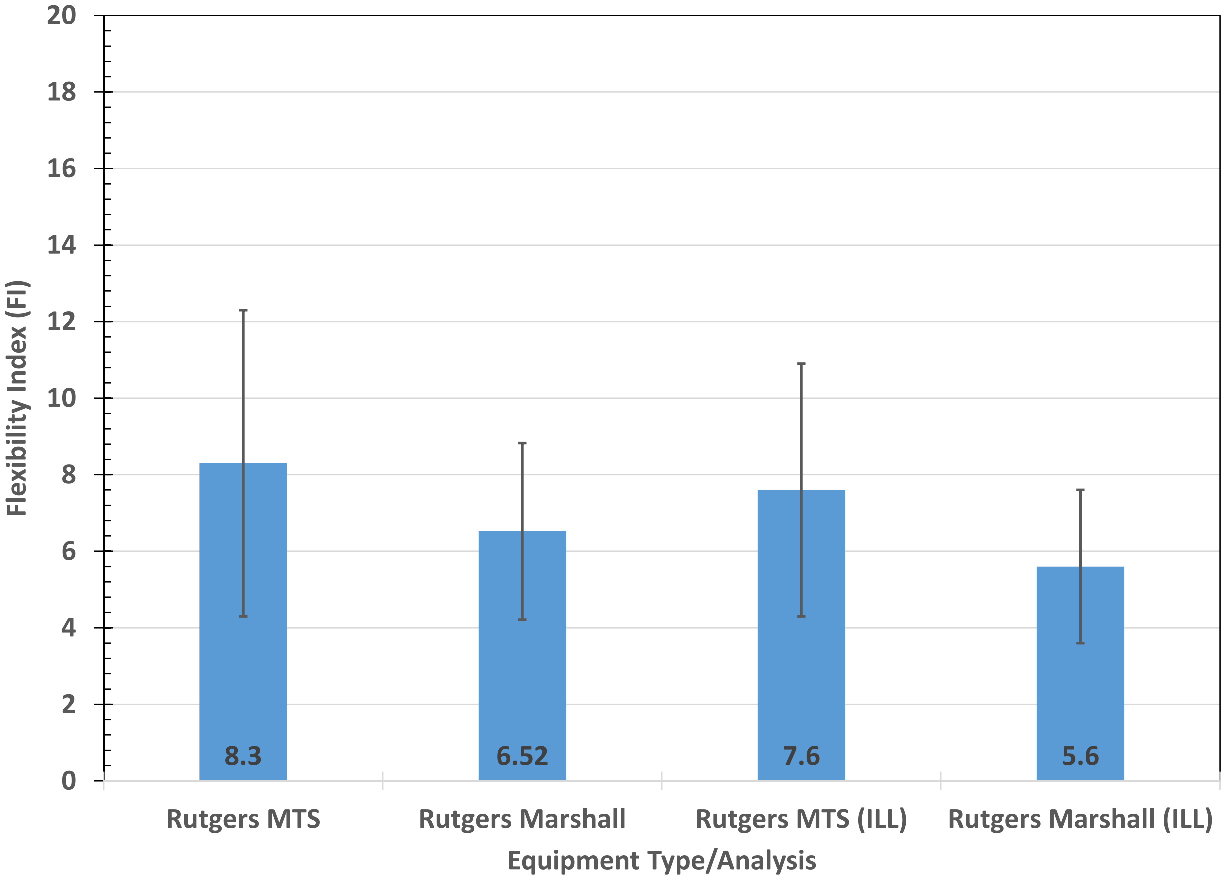
Potential SCB Implementation – Rutgers MTS







Comparison of Rutgers MTS & Marshall Press



Potential SCB Implementation - Needs

- Wet saw for preparing samples
- 3 point loading fixture
- Rounded loading head for line load (modified Lottman too wide)
- Conditioning test specimens – tests conducted at 25°C and used environmental chamber
  - QC lab could use a water bath and place specimen in sealed, plastic bag
- Questions to be answered:
  - Criteria – what is pass/fail?
    - Study's field cores would indicate Flexibility Index > 20 ~ 25
  - What type of test specimen? QC sample? Compacted to target air voids?
  - Should test specimens be long-term aged?


Thank you for your time!
Questions?
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