NCHRP 9-59 Update

September 20, 2017

FHWA Binder ETG

Bozeman, MT

National Center for Asphalt Technology
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Advanced Asphalt Technologies, LLC

"Engineering Services for the Asphalt Industry"

Outline

- Objectives
- Problem
- Theoretical concepts
- Tests
- Materials
- Analysis results
- Remaining work

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NCHRP 9-59 Objective

The primary objective of NCHRP 9-59 is to develop a test or tests that will help to effectively and efficiently control the properties of asphalt binders that contribute to the fatigue resistance of asphalt mixtures

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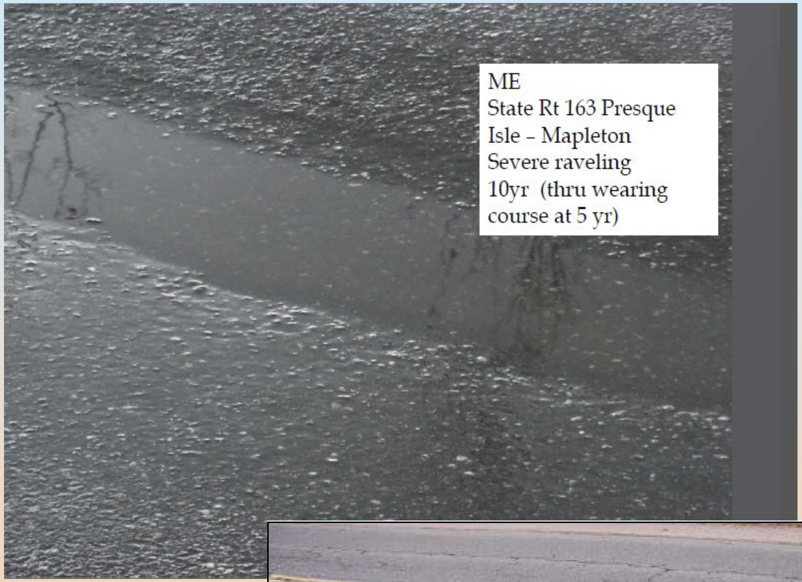
Presentation Objective

- Describe project objectives and important concepts used in testing and analysis
- Provide summary of results to date
- Describe remaining efforts

Problem



Hwy 41 North of Kaladar (1999)

Hesp et al., *Proceedings CTAA*, 2009

Bill Ahearn,
Pamela Marks,
Simon Hesp

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Theoretical concepts

General Failure Theory for Asphalt Binder

$$N_f = \left(\frac{FSC}{\varepsilon_{binder}} \right)^{Ko(90/\delta)}$$

FSC = fatigue strain capacity

$$N_f = \left\{ \frac{FSC}{\left[\varepsilon_{mix} / (VBE/100)\right]} \right\}^{Ko(90/\delta)}$$

Phase angle δ is for the binder, not the mix…

$$D = \sum_{i=1}^{n} N_i \left[\frac{(\varepsilon_{mix})_i}{(VBE/100)} \right]^{Ko(90/\delta)}$$

$$FSC = D^{\delta/(90 \times Ko)}$$

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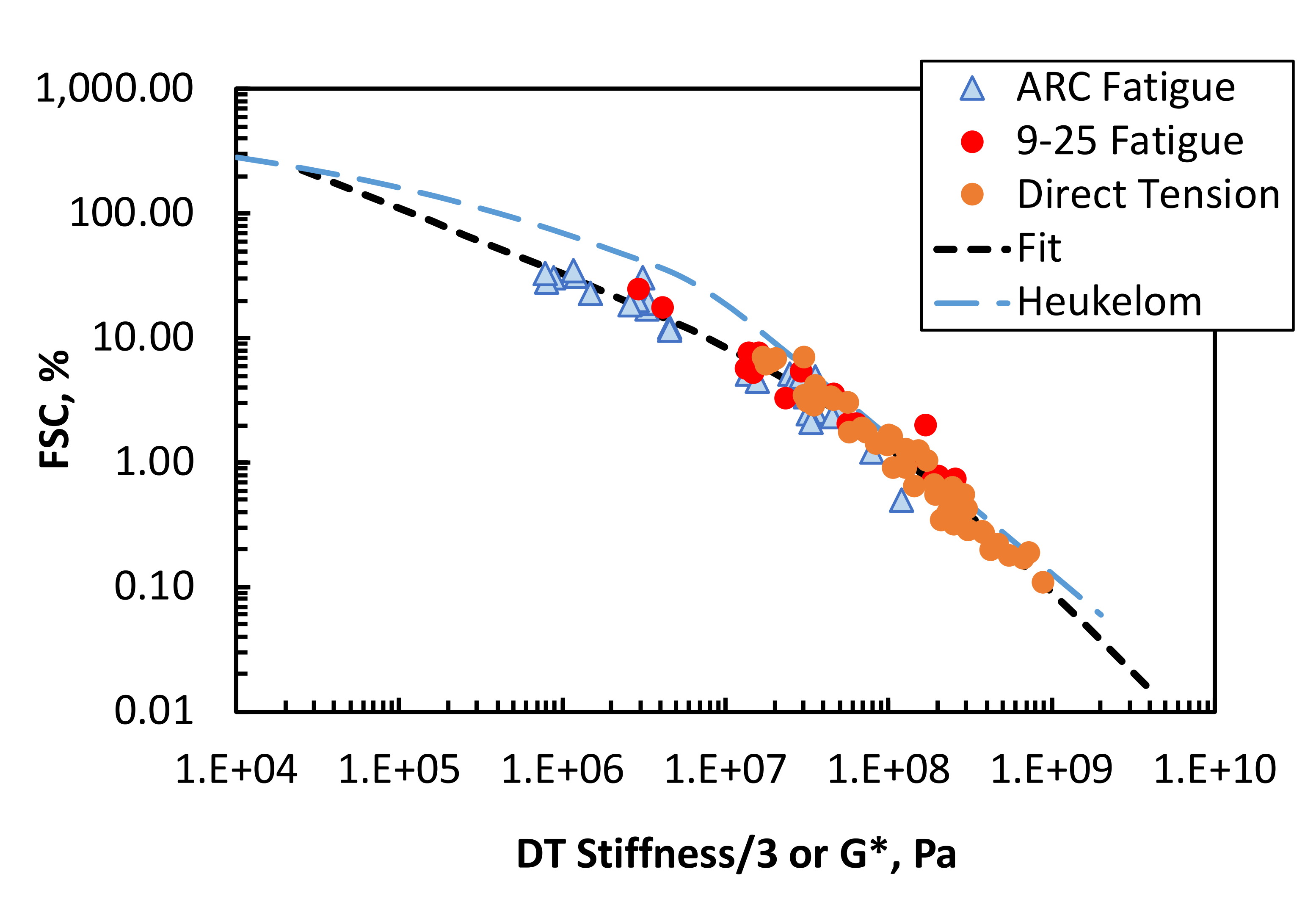
Typical Failure Envelope



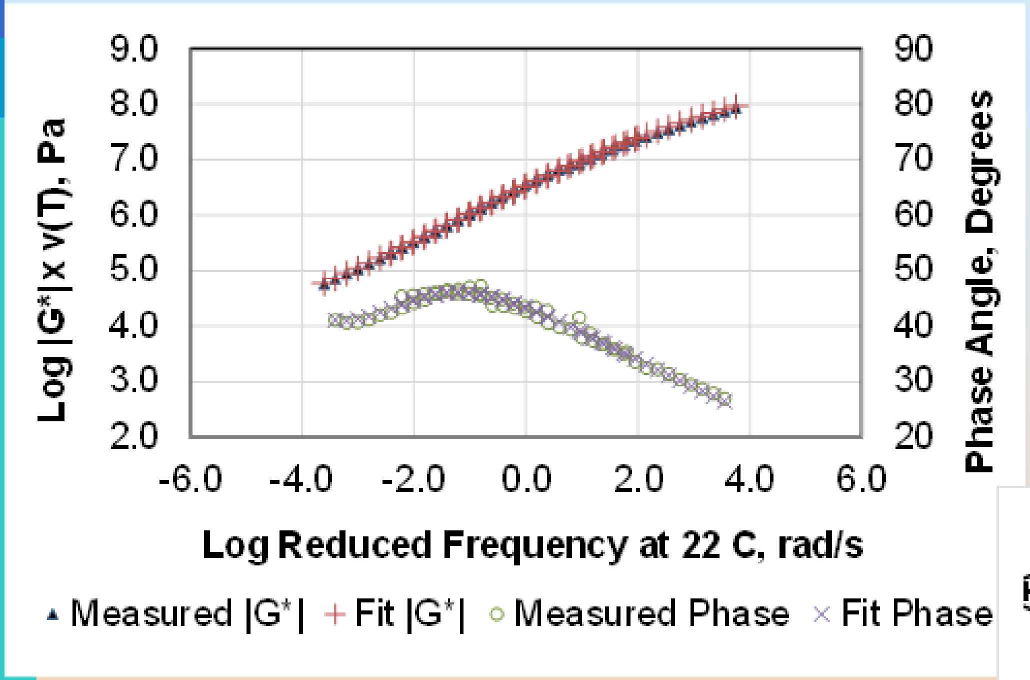
Fatigue/Fracture Performance Ratio, FFPR

$$FFPR = \frac{Measured\ FSC\ or\ \varepsilon^*}{Typical\ FSC\ or\ \varepsilon^*}$$

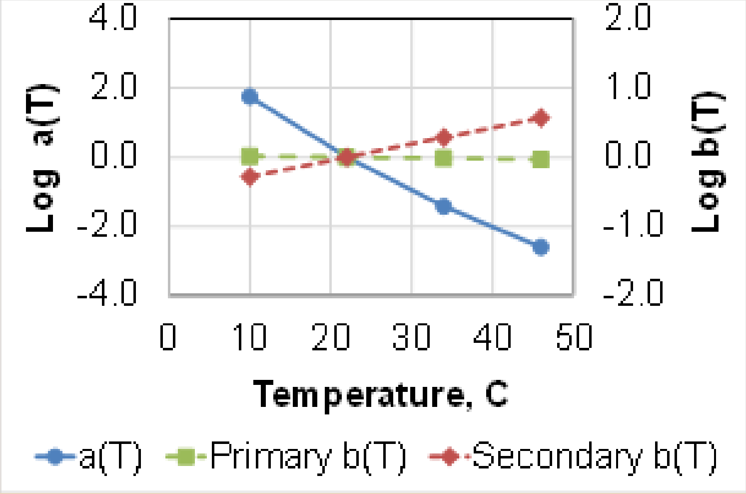
FFPR is simply the ratio of observed to expected failure strain (based upon data for a range of typical binders). Values significantly above 1 are good, below 1 are bad.

Test methods

Dynamic Shear Rheometer

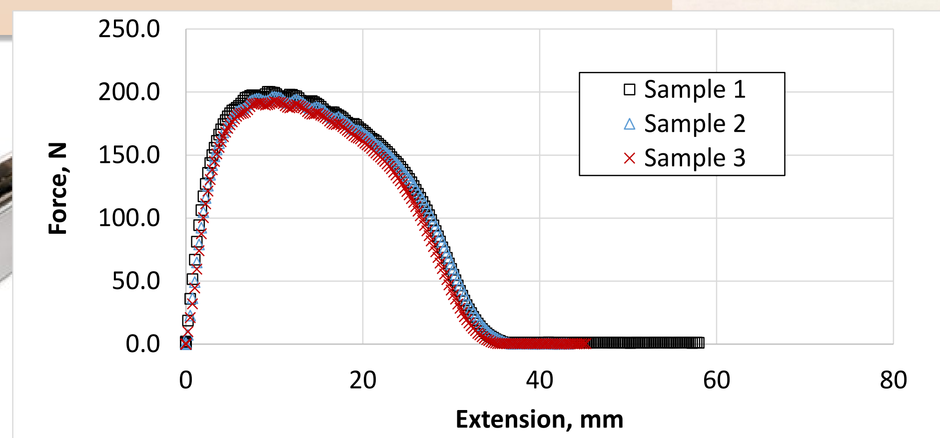


Master curve for PG 76-22

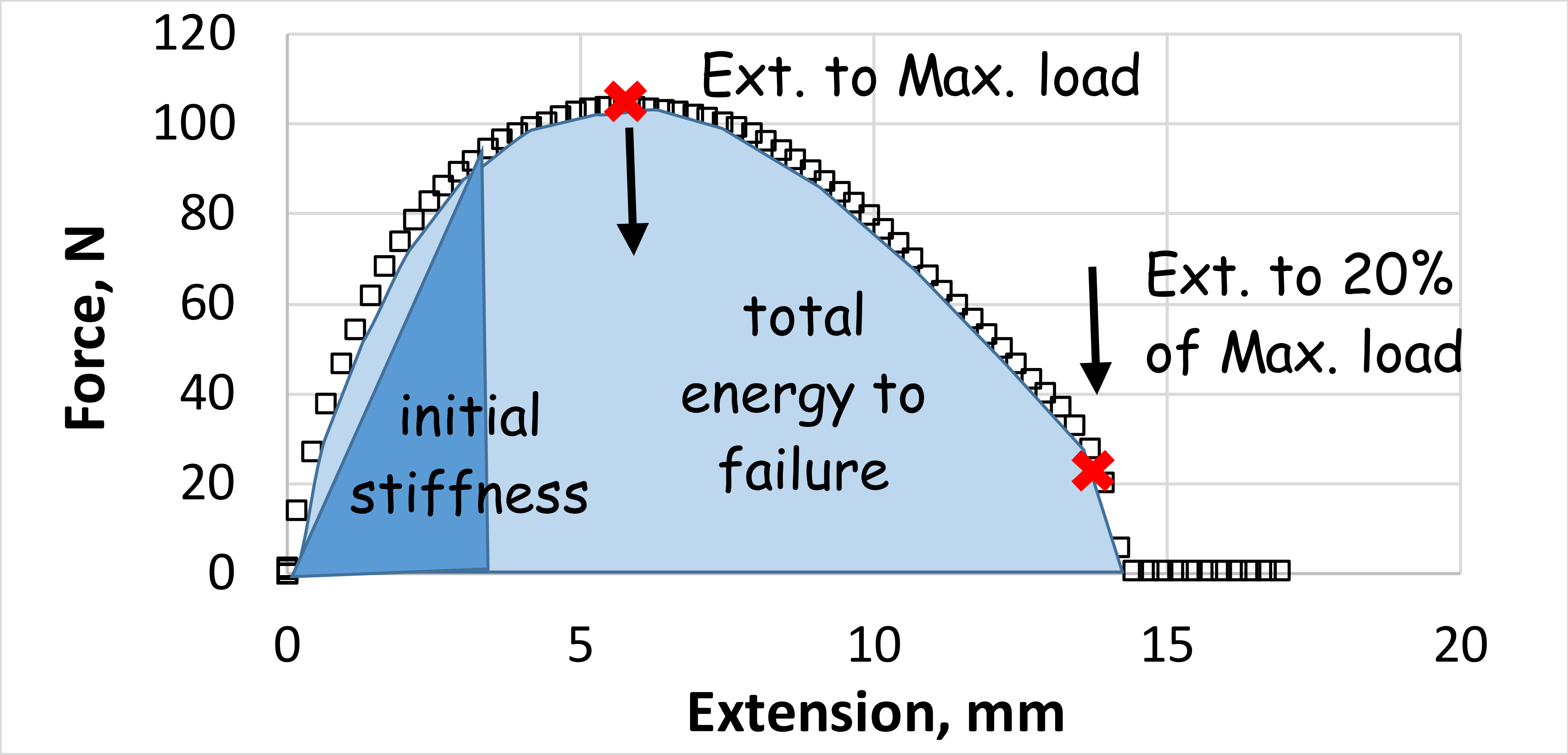


Simplified DENT Test

- Standard ductility batch
- Molds/specimens same as for force-ductility but with double 7.5-mm notch
- 50 mm/min
- Temperature 5 to 25 C



DENT Test Results



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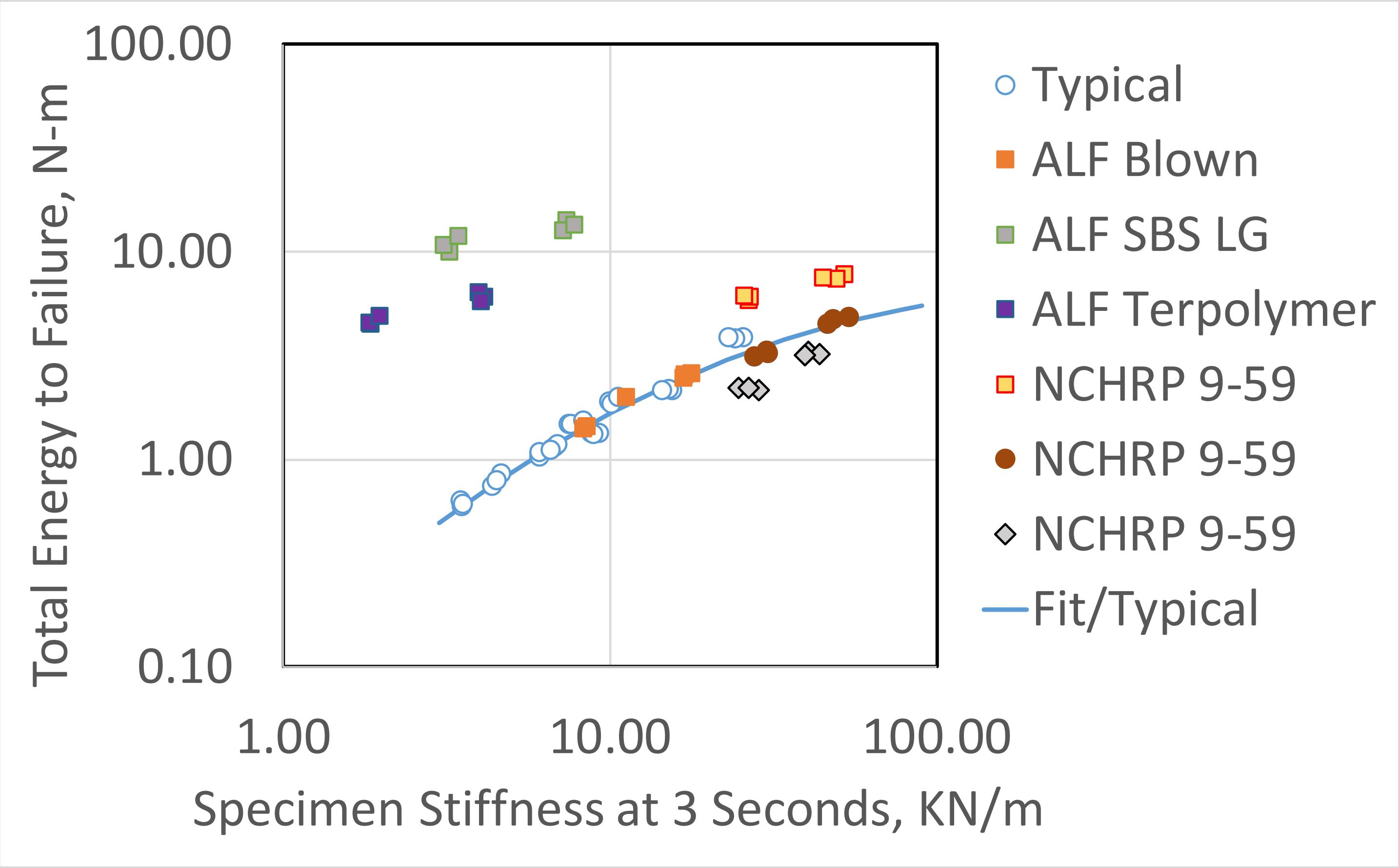
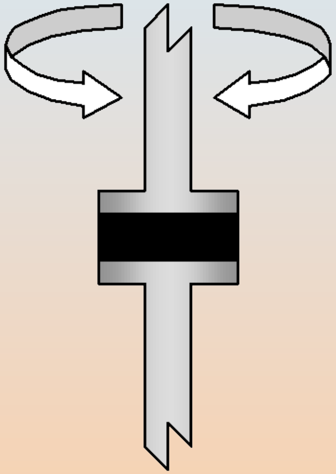
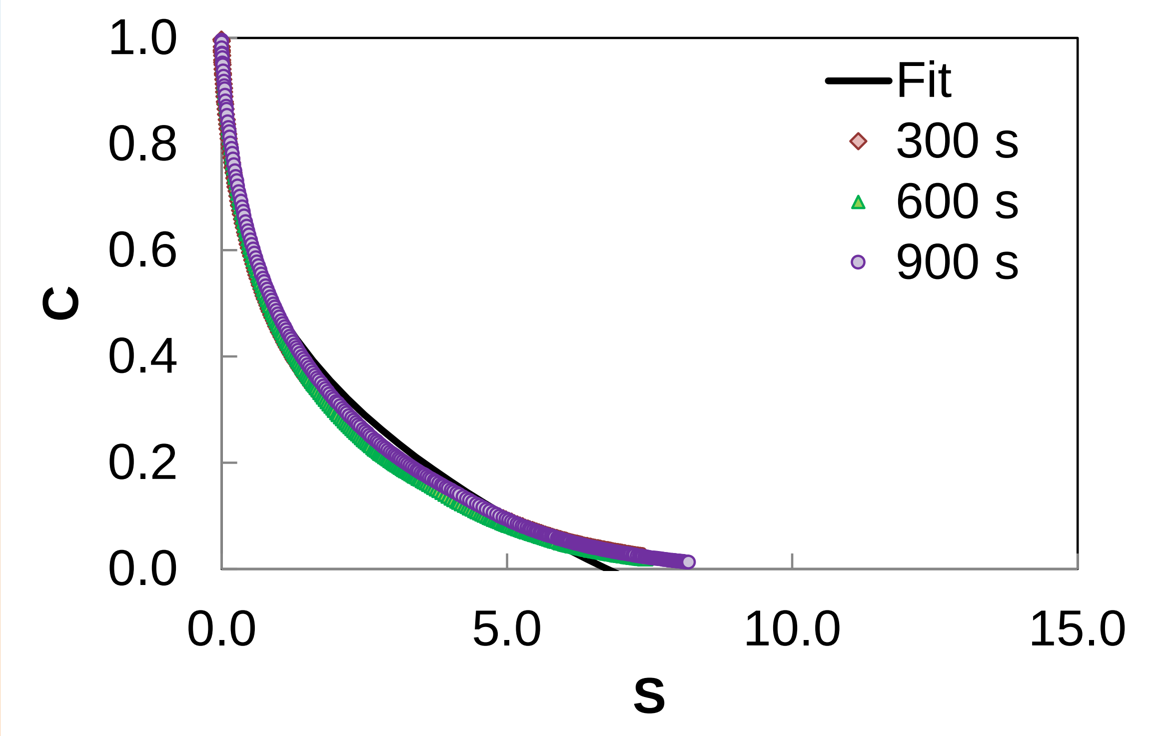
FFPR for DENT Energy to Failure



Typical LAS test



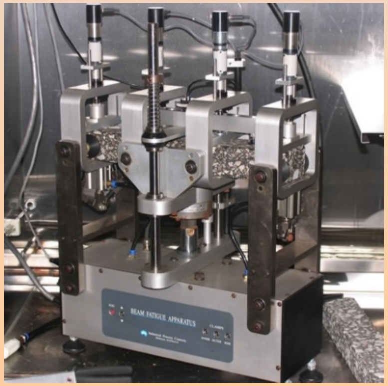


LAS FFPR

- Use GFTAB analysis
- Failure envelope from analysis of 9-59 uniaxial fatigue data
- Calibration factor to account for shear loading and non-constant stresses and strains
- Results in FSC value from which FFPR is calculated

NCHRP 9-59 Mixture Testing

- Uniaxial fatigue (SVECD)
  - Two temperatures
  - Three replicates
- (Texas overlay test)
  - 20°C
  - Three replicates
- Bending beam fatigue



NCHRP 9-59: Laboratory Aging

- Binders: RTFOT + 40 hour PAV
- Mixture: Standard short term aging followed by loose mix aging at 95°C for 5 days.
- Based on data available at the start of the project, which was very limited

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Materials

NCHRP 9-59 Binders

Grade	Modifer/ Additive	Expected Performance
PG 88-22	SBS	good
PG 76-28	SBS	good
PG 76-22	SBS/PPA	good
PG 64-28	SBS	good
PG 70-22	SBR	good
PG 76-22E	SBS	good
PG 58-28	---	moderate
PG 64-22	---	moderate

Grade	Modifer/ Additive	Expected Performance
PG 67-22	---	moderate
PG 70-22	GTR	moderate
PG 70-22	oxidized	poor
PG 76-16	oxidized	poor
PG 58-28	REOB	poor
PG 58-28	REOB	poor
PG 58-34	Terpolymer	good
PG 70-22	PPA	poor

All binder aged in 40 hour PAV at 100°C

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NCHRP 9-59 Mixture Design

- 9.5 mm nominal maximum size
- Blend of granite, limestone and sand
- 6.0 % binder content
- Designed at 4.0 % air voids at 80 gyrations
- Compacted to 7.0 % air voids for most tests

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Analysis and Results

General Method of Analysis

- Model fatigue response
- Include different strain tolerance values (FF{R) for each binder
- Compare these FFPR values to those calculated from binder tests
- Run model using measured binder FFPR values to see if model improves signfiicantly

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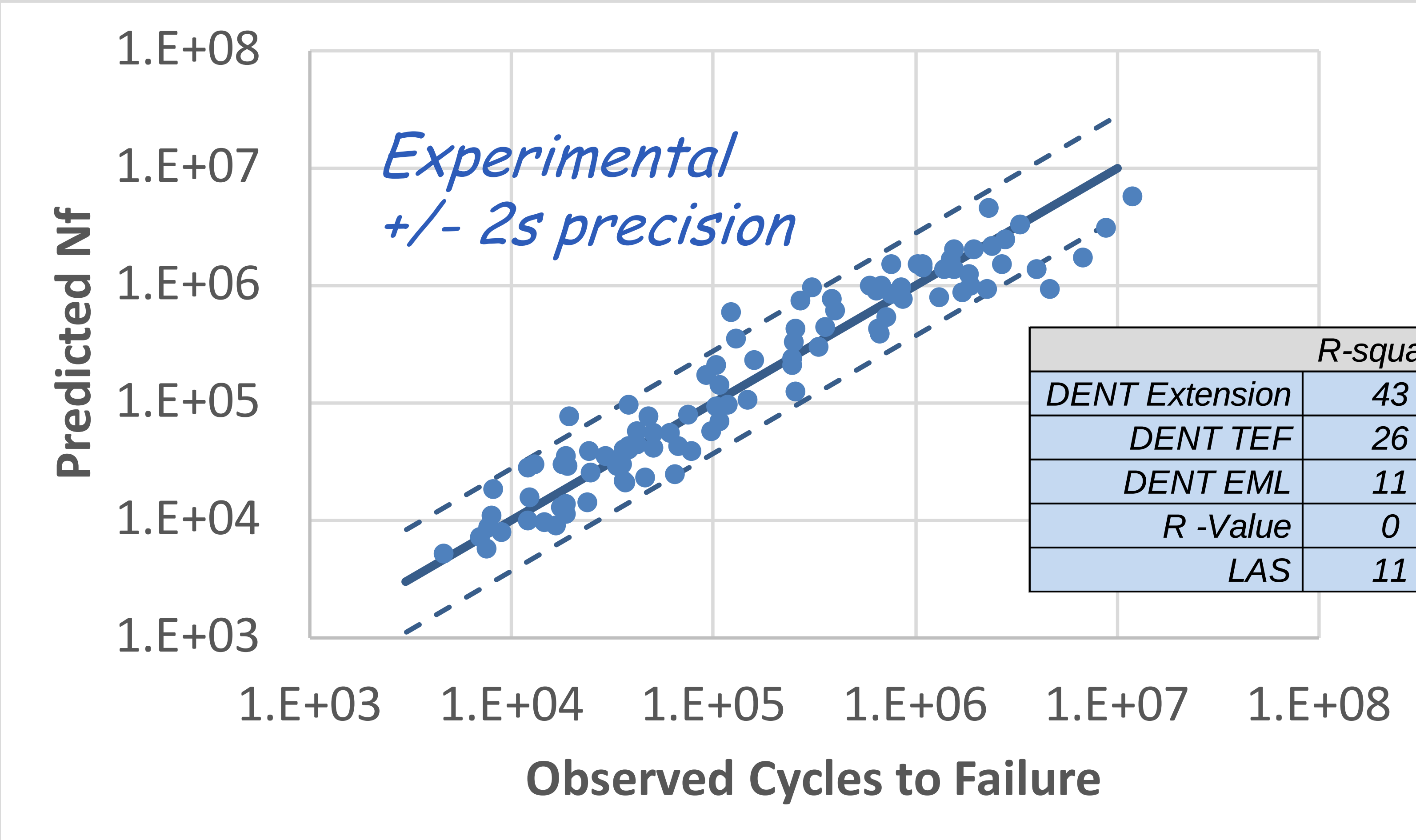
Flexural Fatigue Model

$$LogN_f = K_0 + K_1 \log E^* + K_2 \log\left(\frac{\varepsilon}{FFPR_i}\right) + K_3 \log VBE$$

$FFPR_i$ is different for each binder—the values determined from mix fatigue can then be compared to those determined from binder tests.

Flexural Fatigue Analysis



	R-squared
DENT Extension	43
DENT TEF	26
DENT EML	11
R -Value	0
LAS	11

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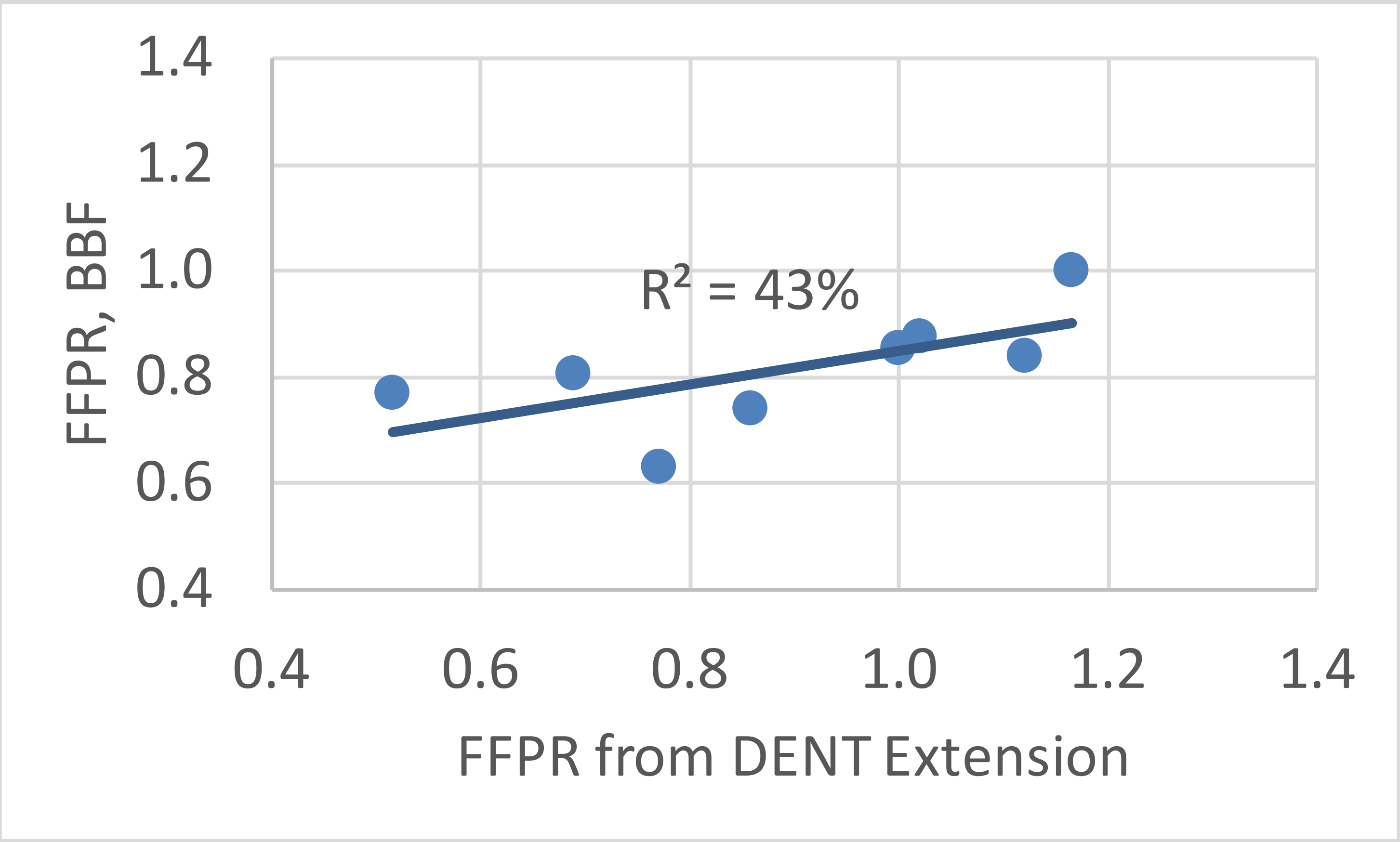
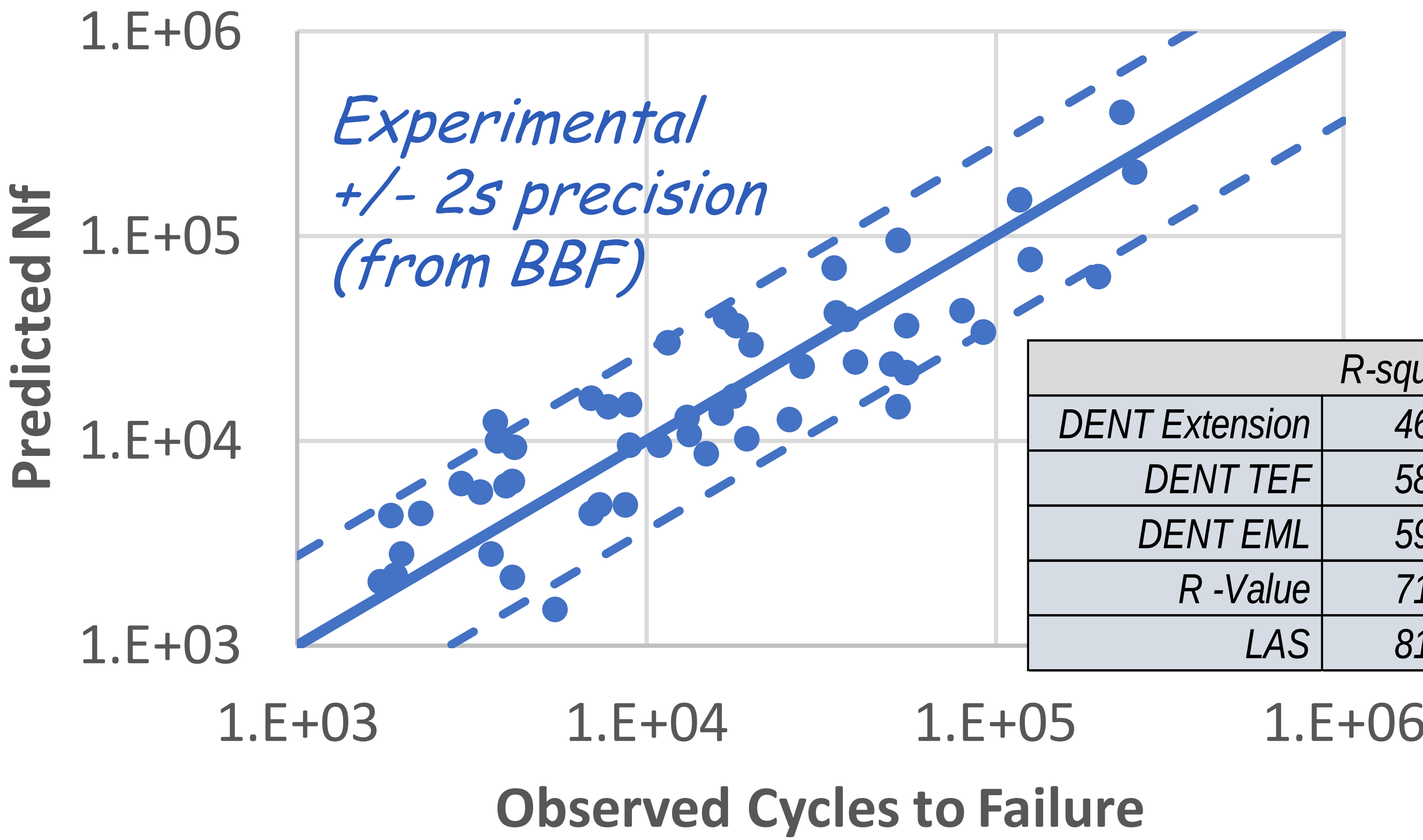
FFPR, Flexural Fatigue vs. DENT Extension

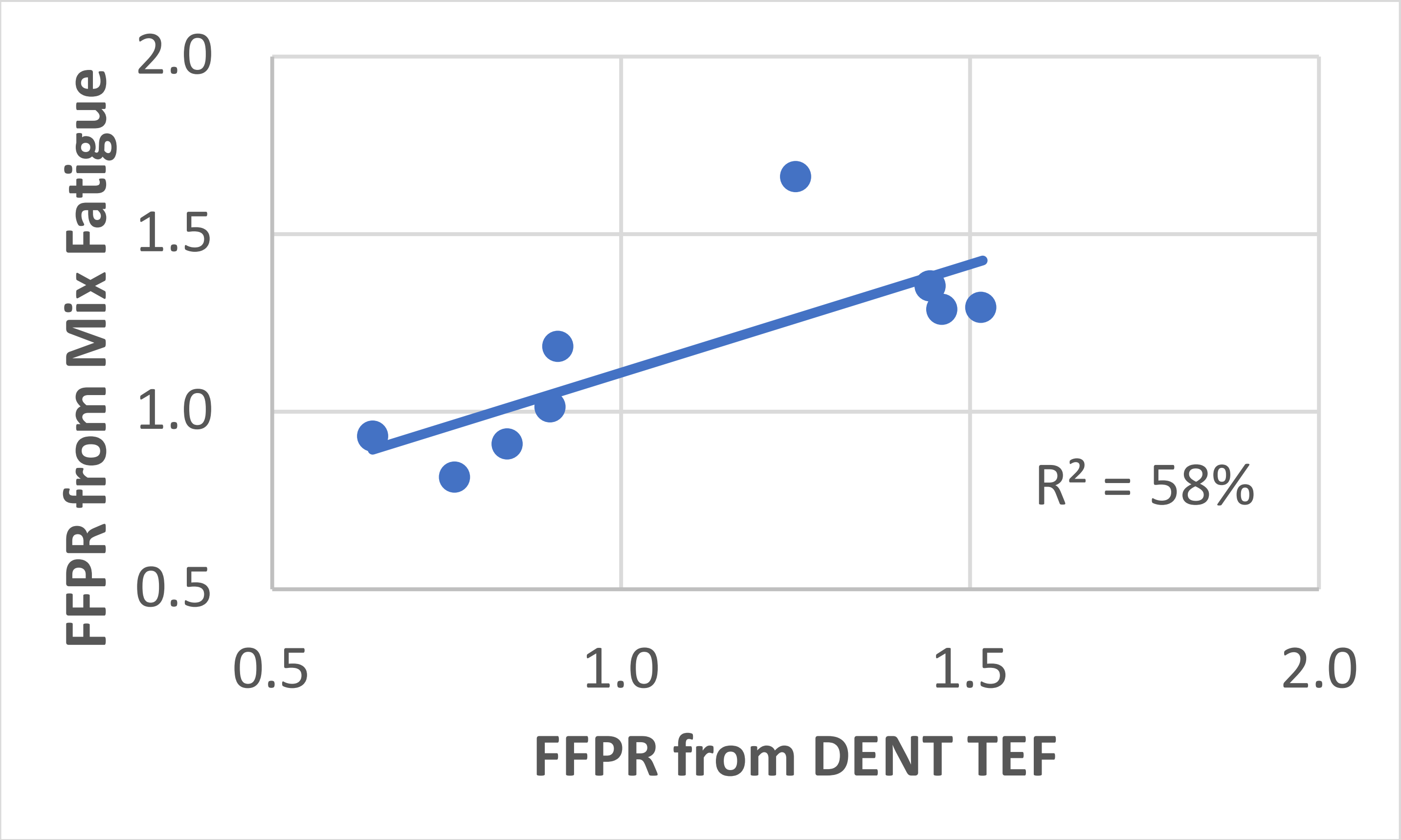


Uniaxial Fatigue Analysis

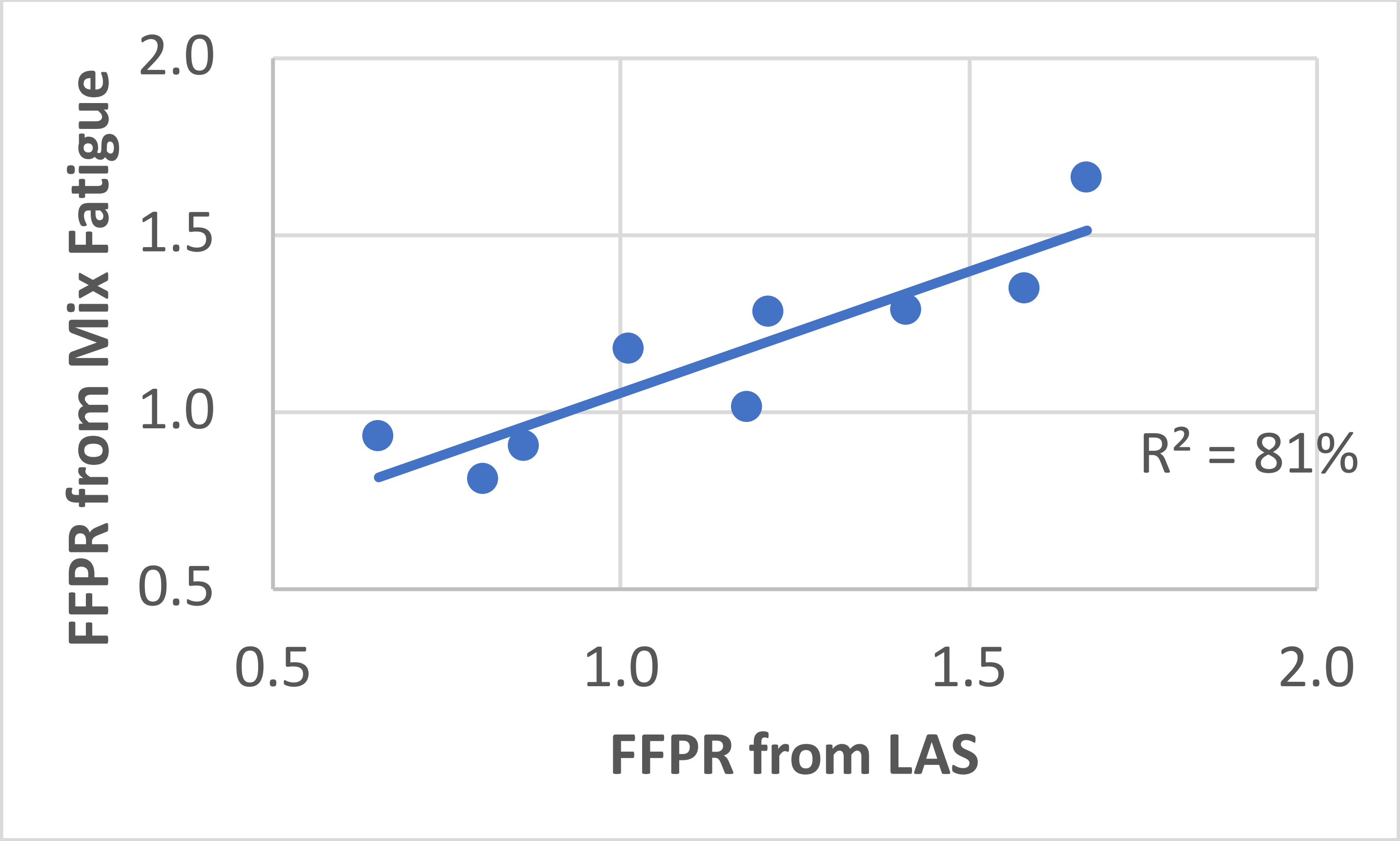


	R-squared
DENT Extension	46
DENT TEF	58
DENT EML	59
R -Value	71
LAS	81

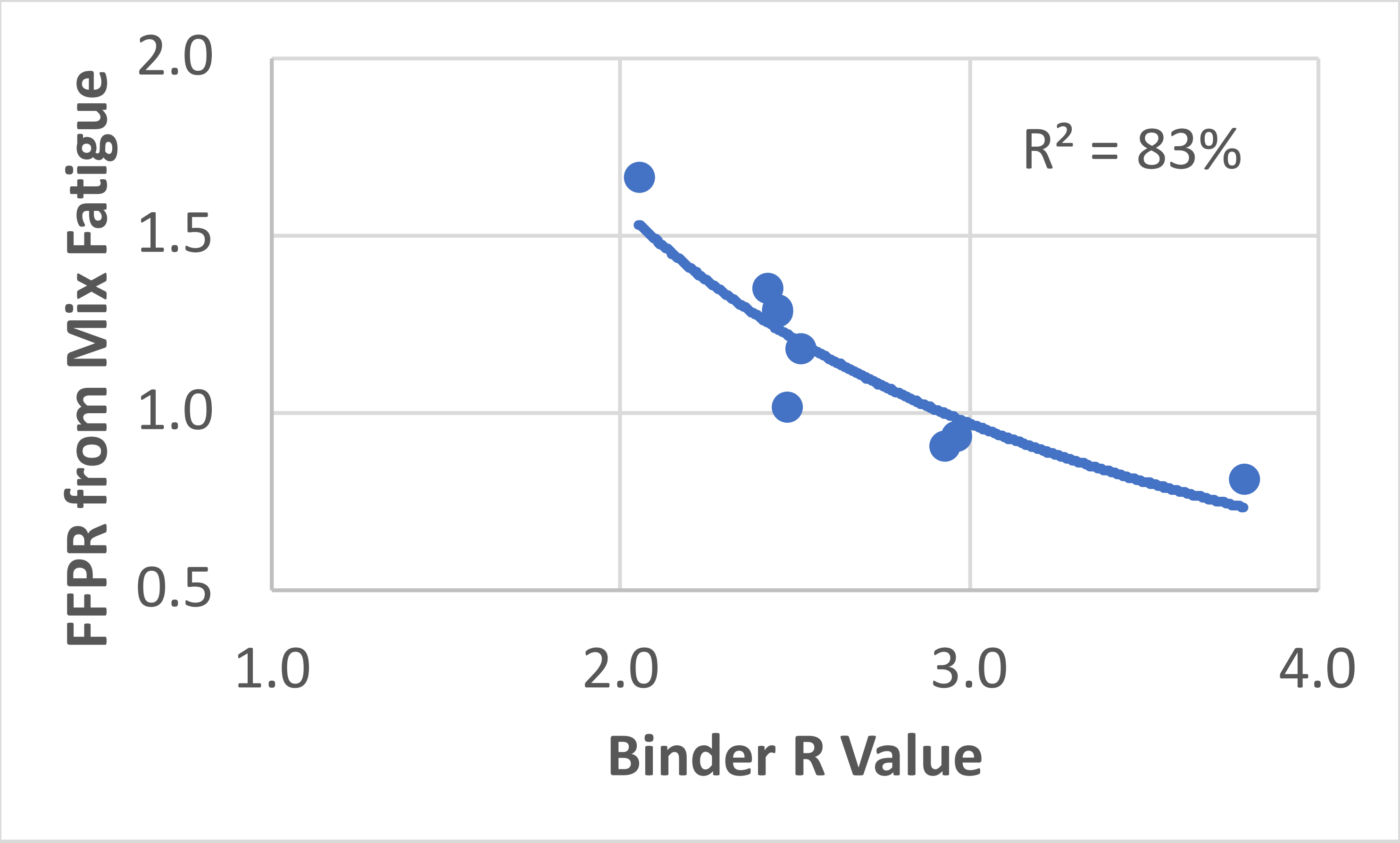
Mix Uniaxial FFPR vs FFPR from DENT Energy to Failure



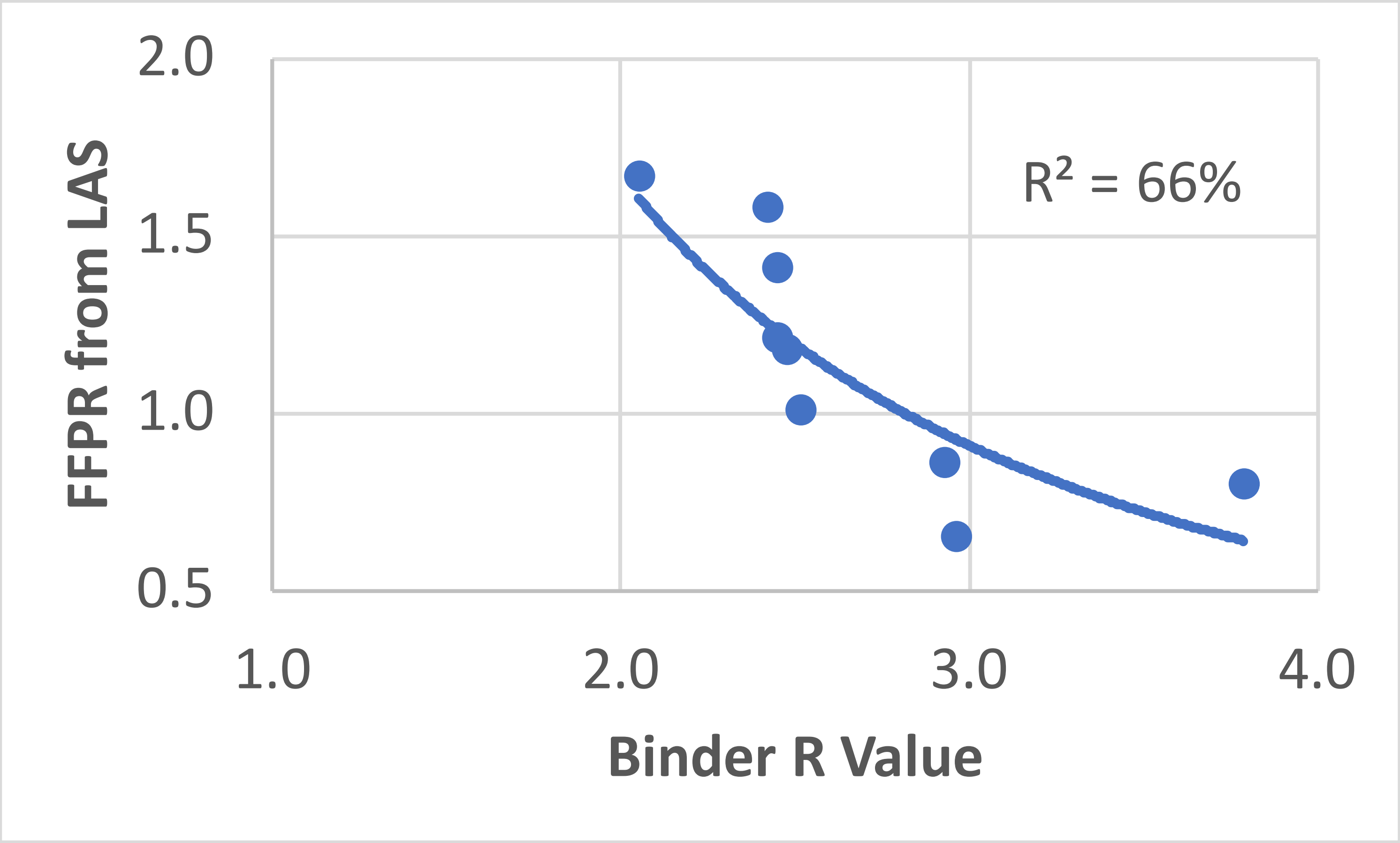
Mix Uniaxial FFPR vs FFPR from Binder LAS



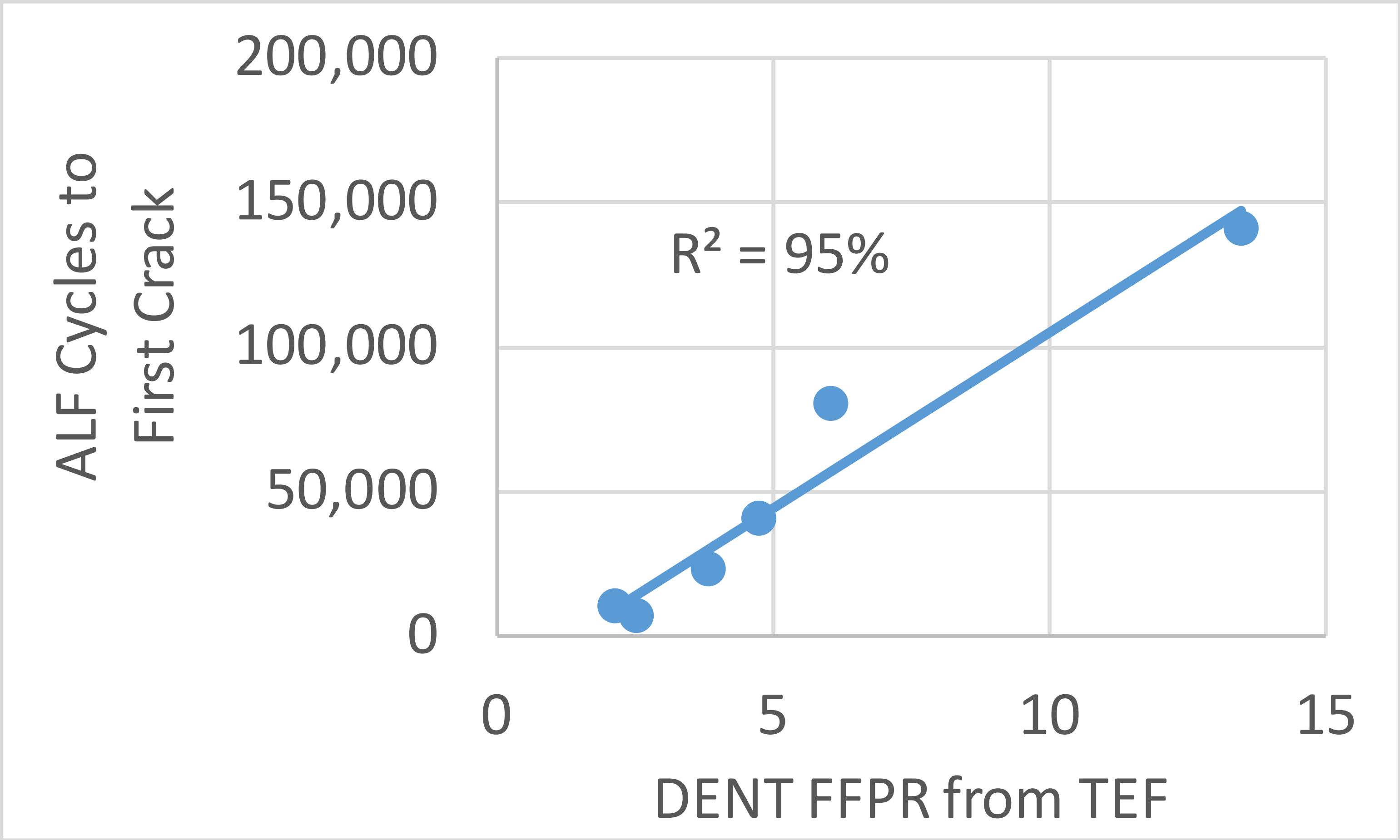
Mix Uniaxial FFPR vs Binder R-Value



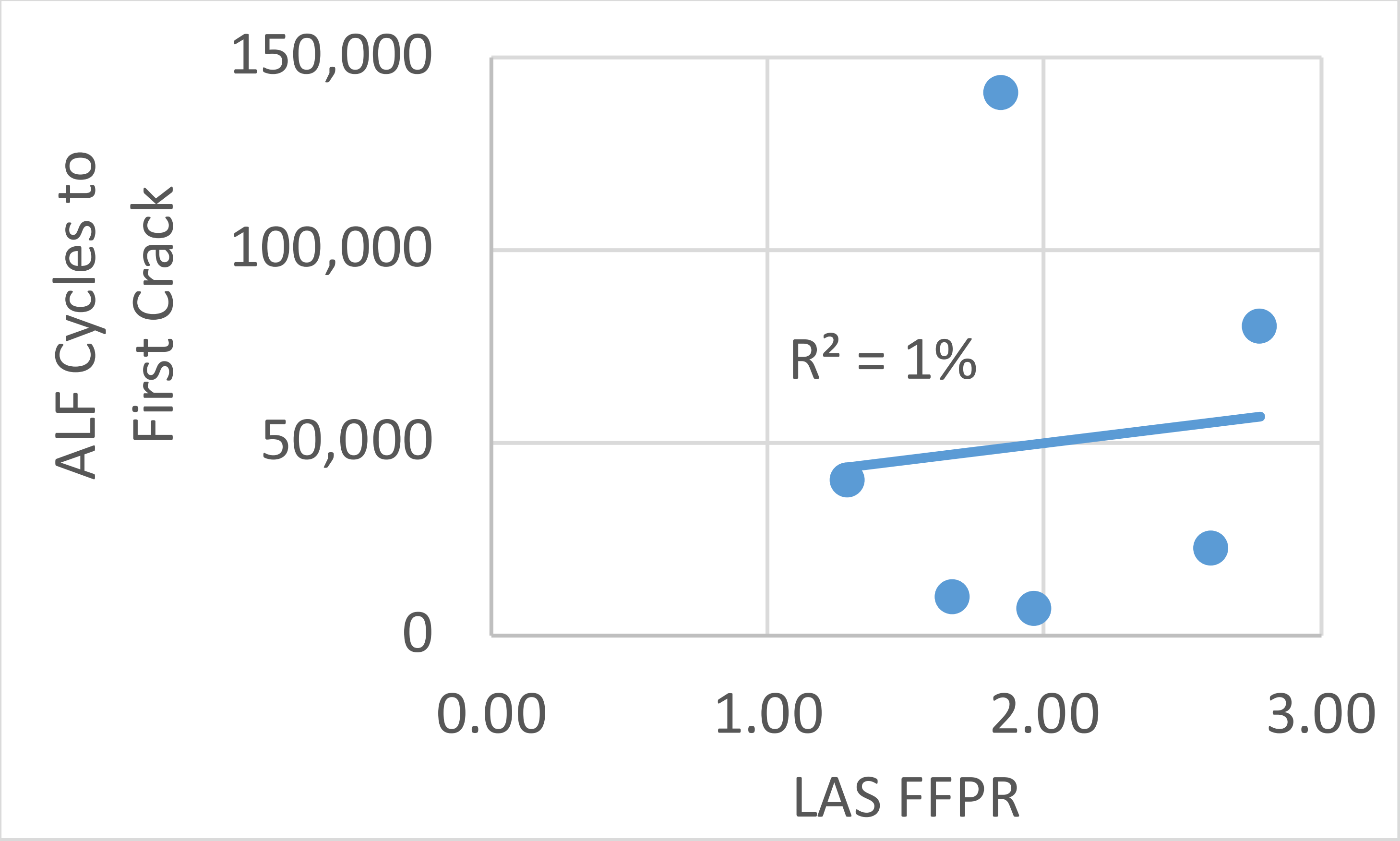
LAS FFPR vs Binder R Value



ALF Fatigue Experiment and DENT Test Data



ALF Fatigue and FFPR from LAS Test



Healing experiment

- The healing experiment conducted in NCHRP 9-59 shows that at phase angles below about 40 degrees, there is little healing; at phase above about 70 degrees, healing is nearly complete
- We have found several studies where there are good correlations between field performance and phase angle supporting this observation

In conclusion…

Preliminary Findings

- Substantial evidence suggests DENT test is a reasonably good predictor of fatigue and fracture performance
- Conflicting evidence on effectiveness of LAS test
- Phase angle appears to relate well to adhesive healing, which in turn appears to be a significant factor in field performance

Remaining work

- Complete uniaxial testing
- Refine analysis and select final test methods
- Finalize validation binders and perform validation testing
- Draft and Final Reports in 2018

Acknowledgements

- NCHRP
- The Project Panel
- Industry suppliers
- Nam Tran and his associates at NCAT
- My associates at AAT, including Ray, Don, and Bob