NCHRP 9-59 Update

May 10, 2018

FHWA ETG

Fall River, MA

National Center for Asphalt Technology
NCAT
AUBURN UNIVERSITY

Advanced Asphalt Technologies, LLC

"Engineering Services for the Asphalt Industry"

Outline

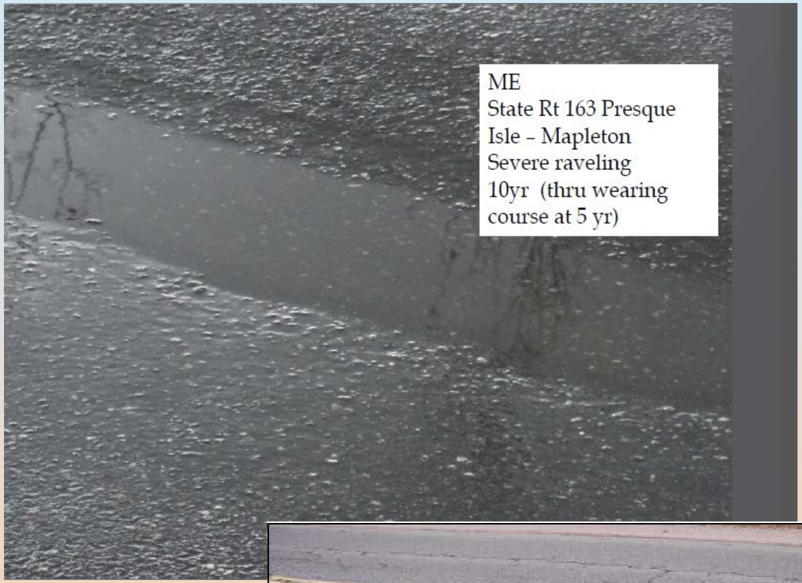
- Introduction
- Materials
- Binder rheology
- Strain capacity, failure envelope
- Mixture vs binder performance
- Delta Tc, GRP, DENT, extended BBR
- Summary, conclusions

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

National Center for Asphalt Technology
NCAT
AUBURN UNIVERSITY

Problem




Hwy 41 North of Kaladar (1999)


Hesp et al., *Proceedings CTAA*, 2009

Bill Ahearn, Pamela Marks, Simon Hesp

National Center for Asphalt Technology
NCAT
AUBURN UNIVERSITY

What is causing these failures?

- Problem binders
  - Excessive brittleness
  - Poor healing
  - Misleading BBR grading
- Delta Tc, R-value, GRP and DENT are all indicators of the same problem

Over last month…

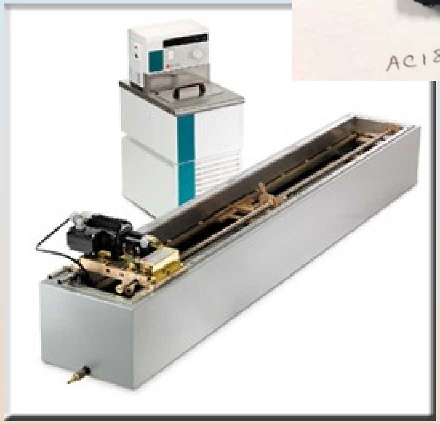
- Further progress made in data analysis since TAI meeting in Savannah
- Slight change in assumed failure envelope significantly improved results
- May be a few more changes as final report is compiled and reviewed…

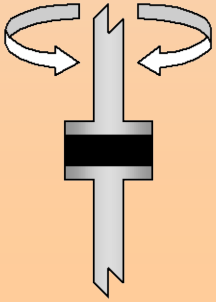
Binders included in NCHRP 9-59

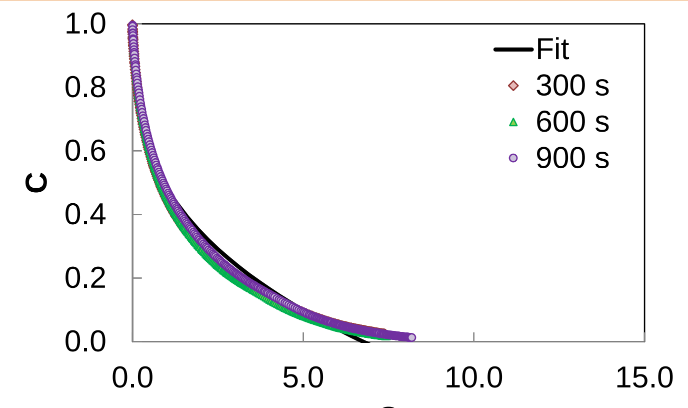
- NCHRP 9-59, 8 polymer modified, 8 non-polymer modified
- 2 REOB, 2 oxidized, 1 PPA
- RTFOT + 40 hour PAV
- SHRP binders, RTFOT aging
- ALF, MNRoad, Westrack binder, miscellaneous aging

Binder Tests

- DSR / master curve
- DSR / linear amplitude sweep (LAS)
- Double-edge notched tension (DENT)
- Various tests from previous research

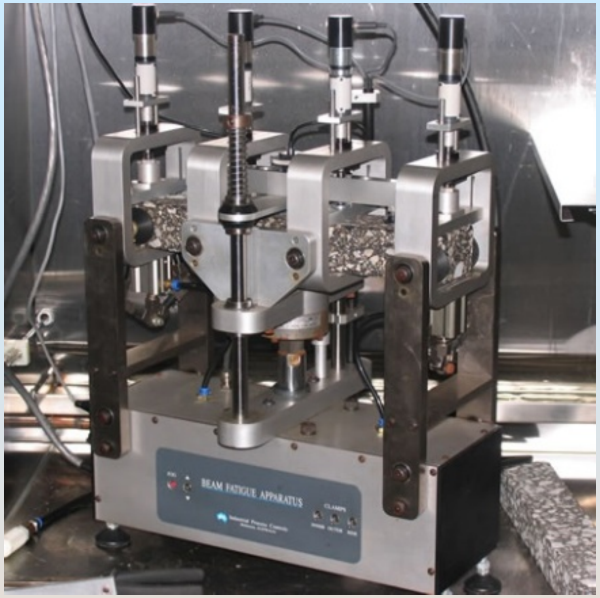




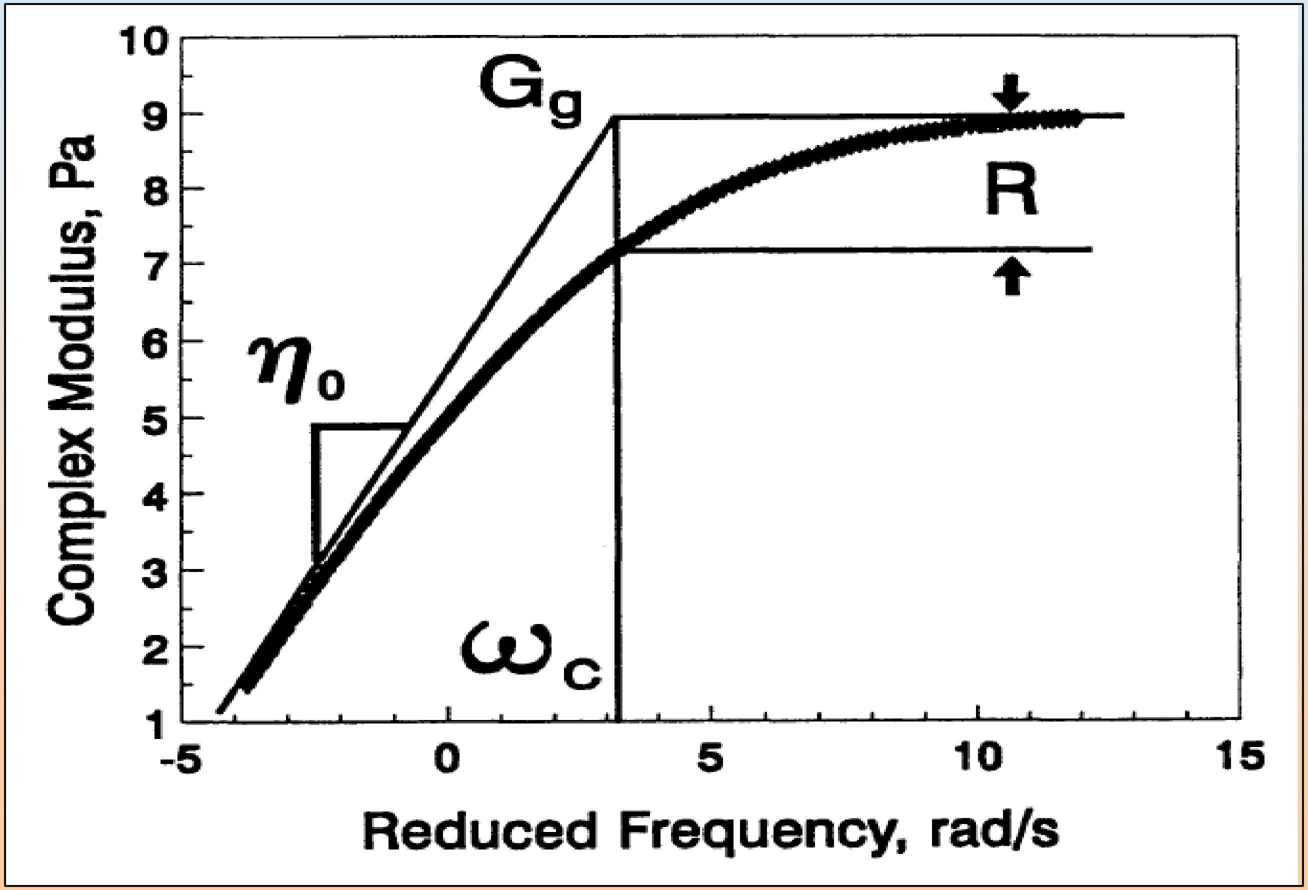


Mixture tests

- Flexural fatigue
- Uniaxial fatigue
- Healing
- Loose mix aging, 95 C for 5 days
- Various tests from previous research



Binder rheologic type and R value



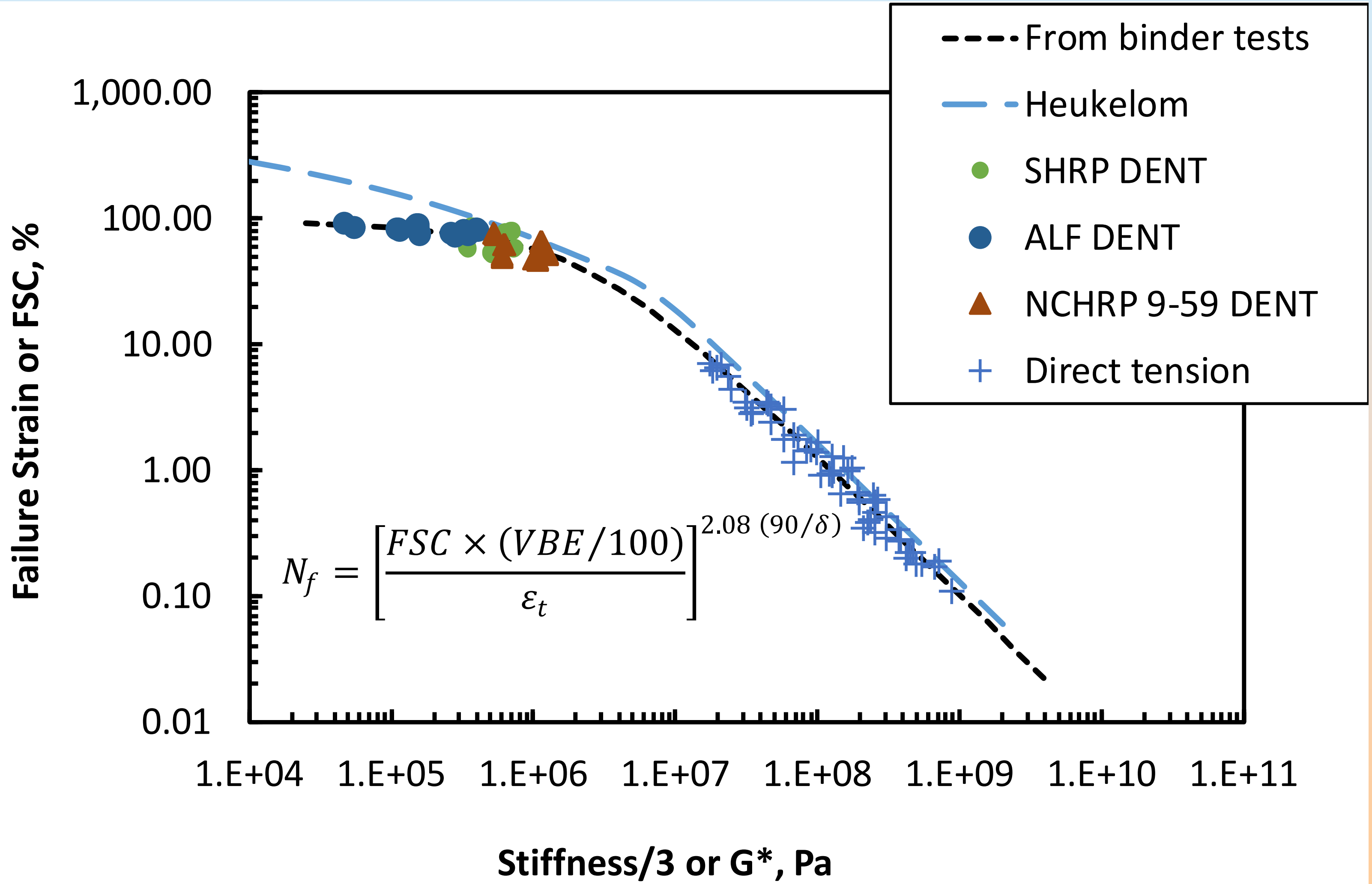
Some notes on R-value

- Polymer modified binders and heavily aged non-modified binders are rheologically complex
- R can be calculated from a DSR point measurement as long as |G*| is about 10 MPa or higher:

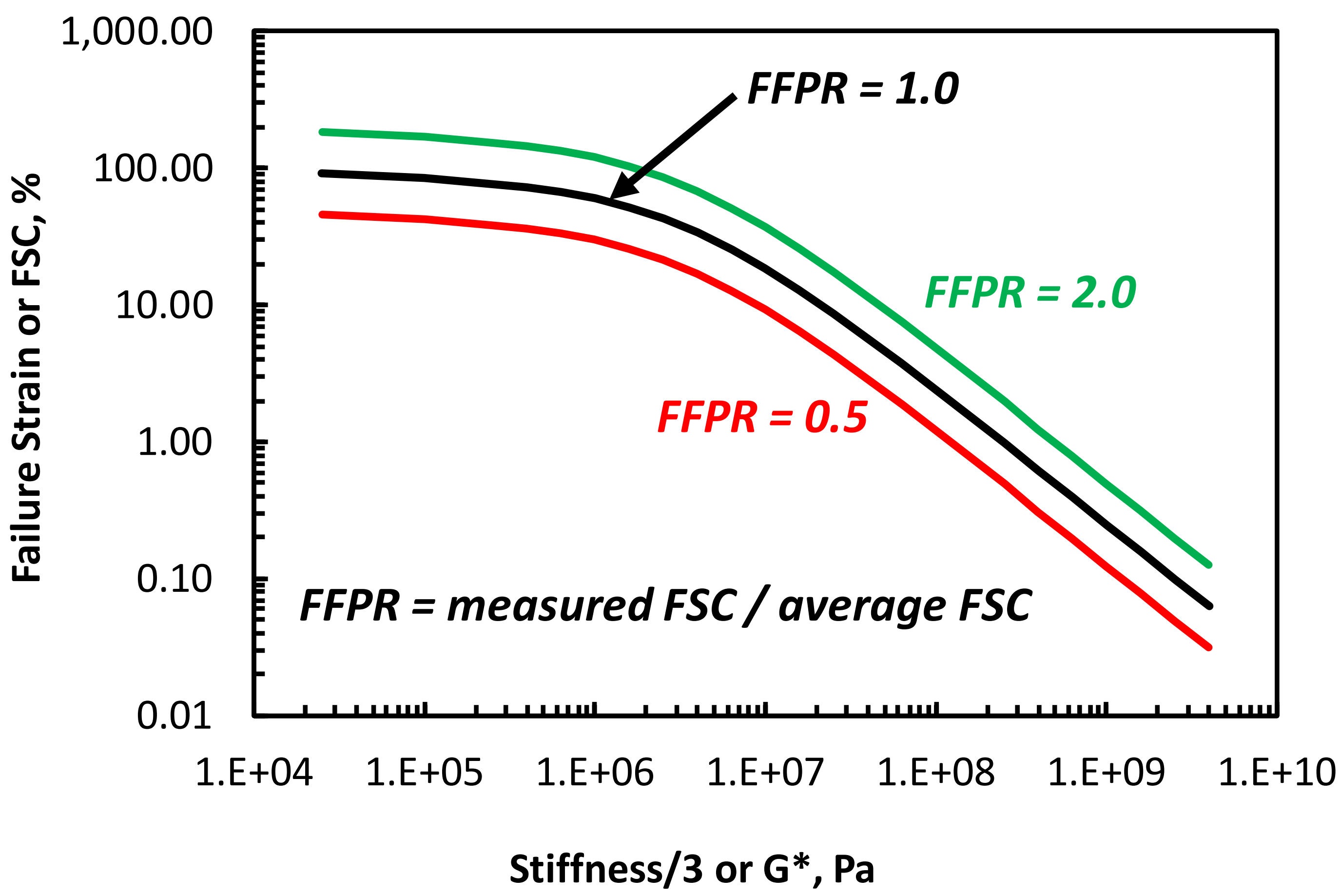
$$R = log(2)\frac{log(|G*|/1 \times 10^9)}{log(1 - \delta/90)}$$

National Center for Asphalt Technology
NCAT
AUBURN UNIVERSITY

Asphalt Binder Failure Envelope



Fatigue/fracture performance ratio FFPR



More on FFPR

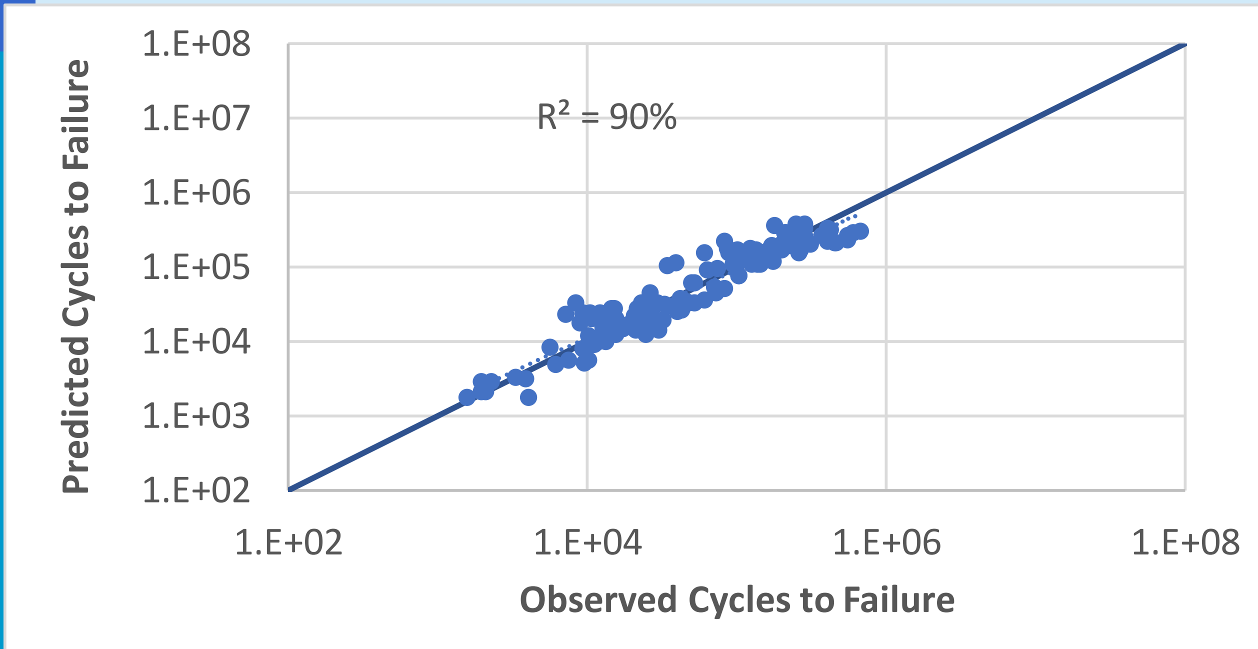
- FFPR is an indicator of inherent fracture and fatigue resistance
- FFPR >> 1 indicate good fatigue performance, FFPR << 1 indicate poor performance
- For the binder studied in NCHRP 9-59, FFPR values ranged from about 0.4 to 2.

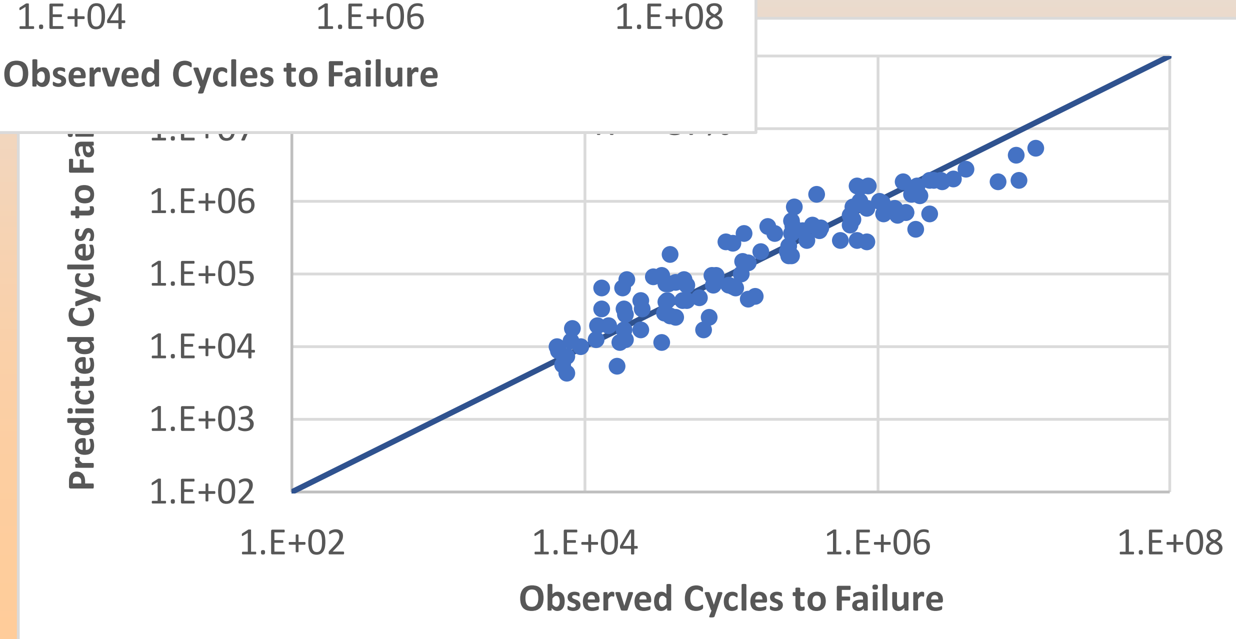
GFTAB model

$$N_f^{\wedge} = \left[\frac{FFPR_i \times FSC^* \times (VBE/100)}{\varepsilon_t}\right]^{k_1(90/\delta)}$$

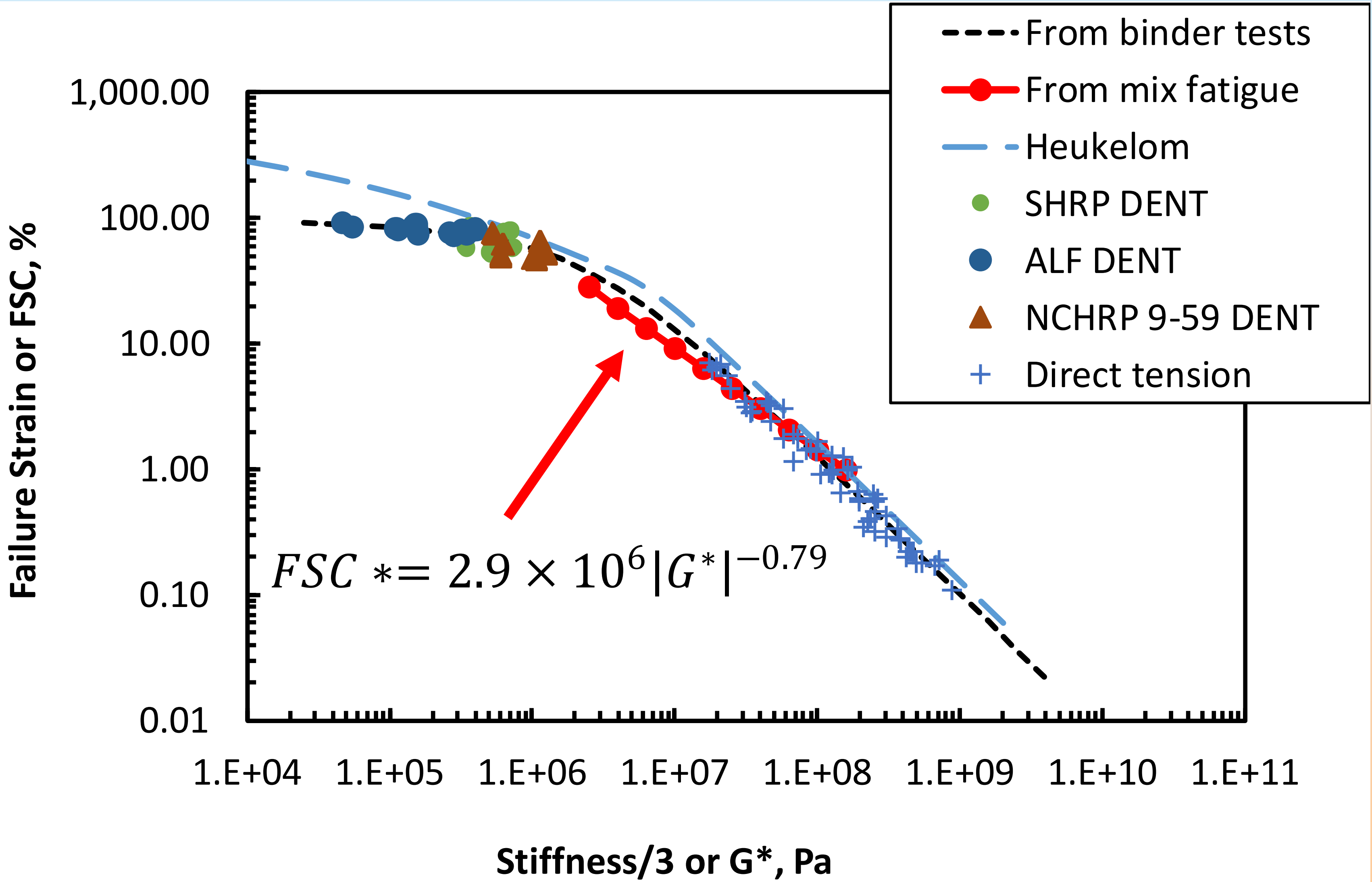
FFPR represents the overall strain tolerance of each binder. FSC is the typical failure strain at any given |G|. K1 was found to be 2.08.*

Results of GFTAB model

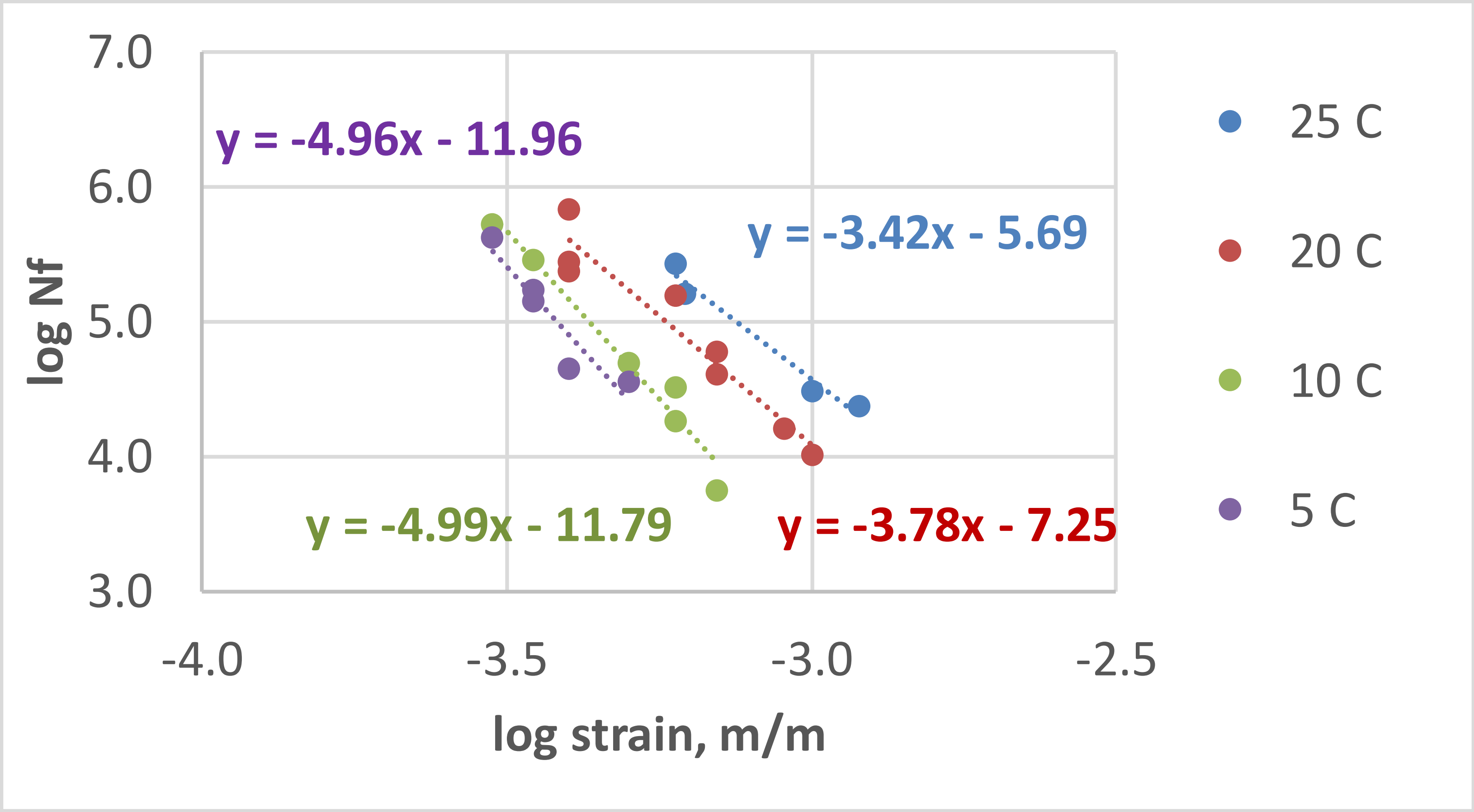




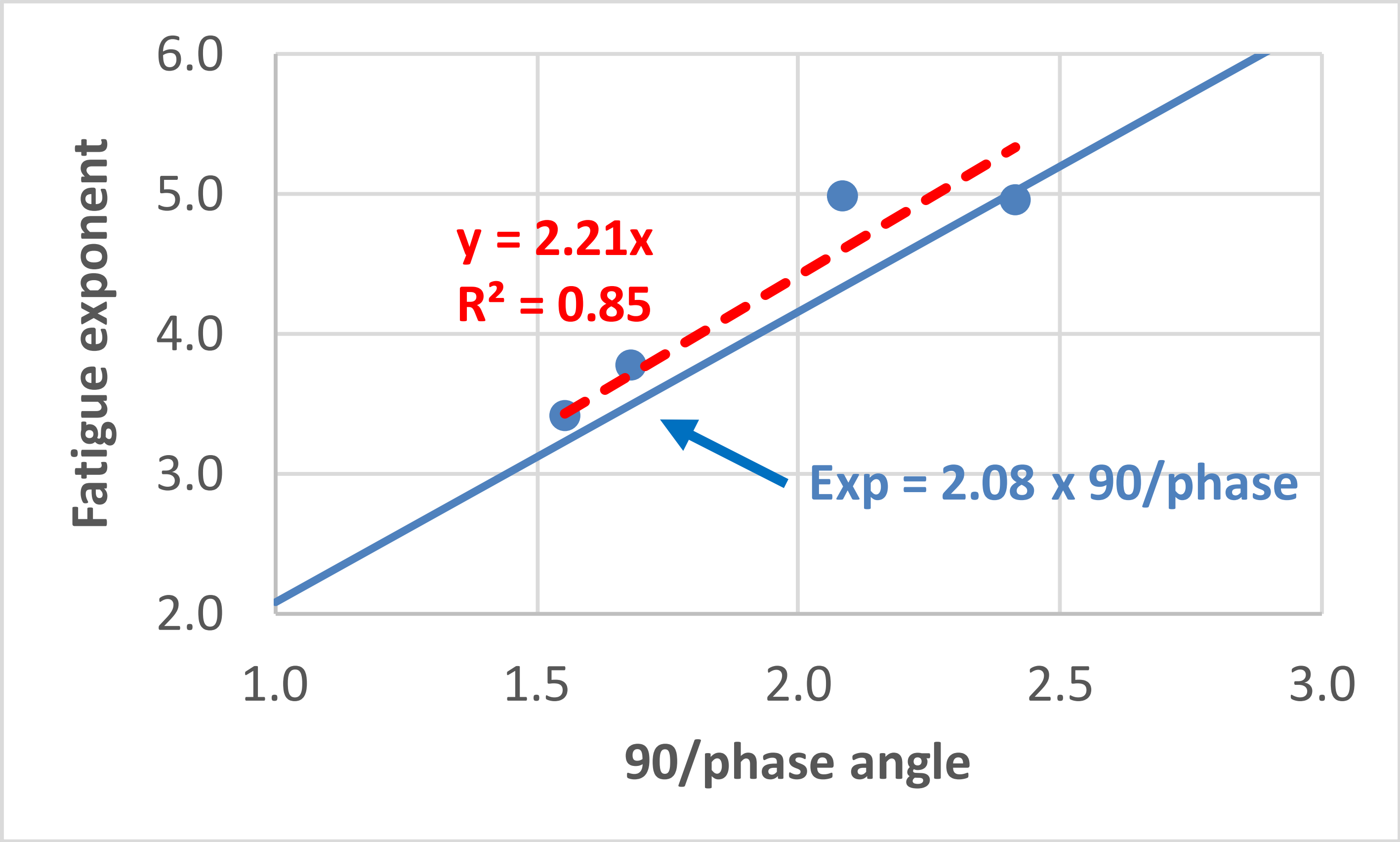
Is GFTAB for real?



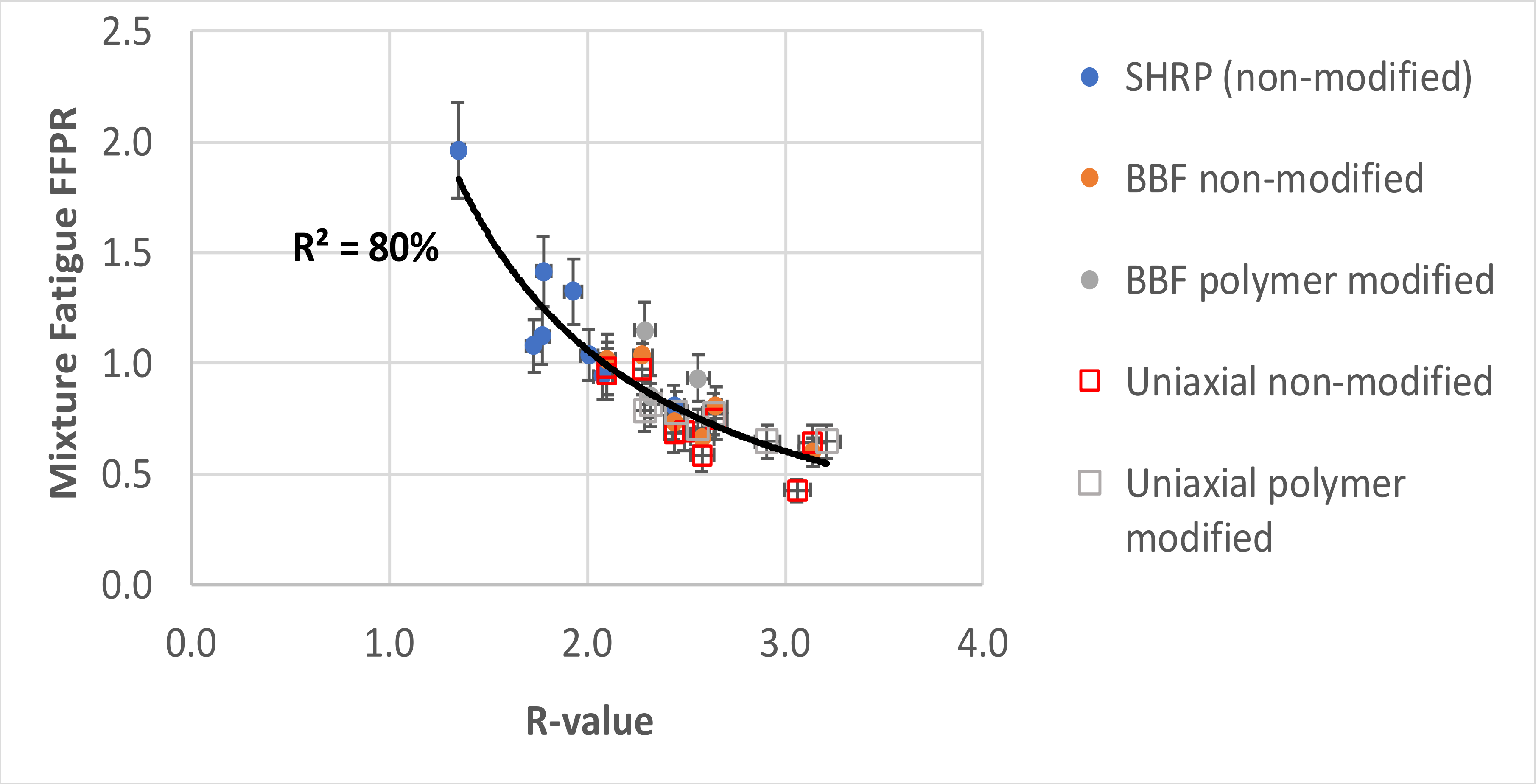
SHRP AAD-1: Fatigue exponents at different temps



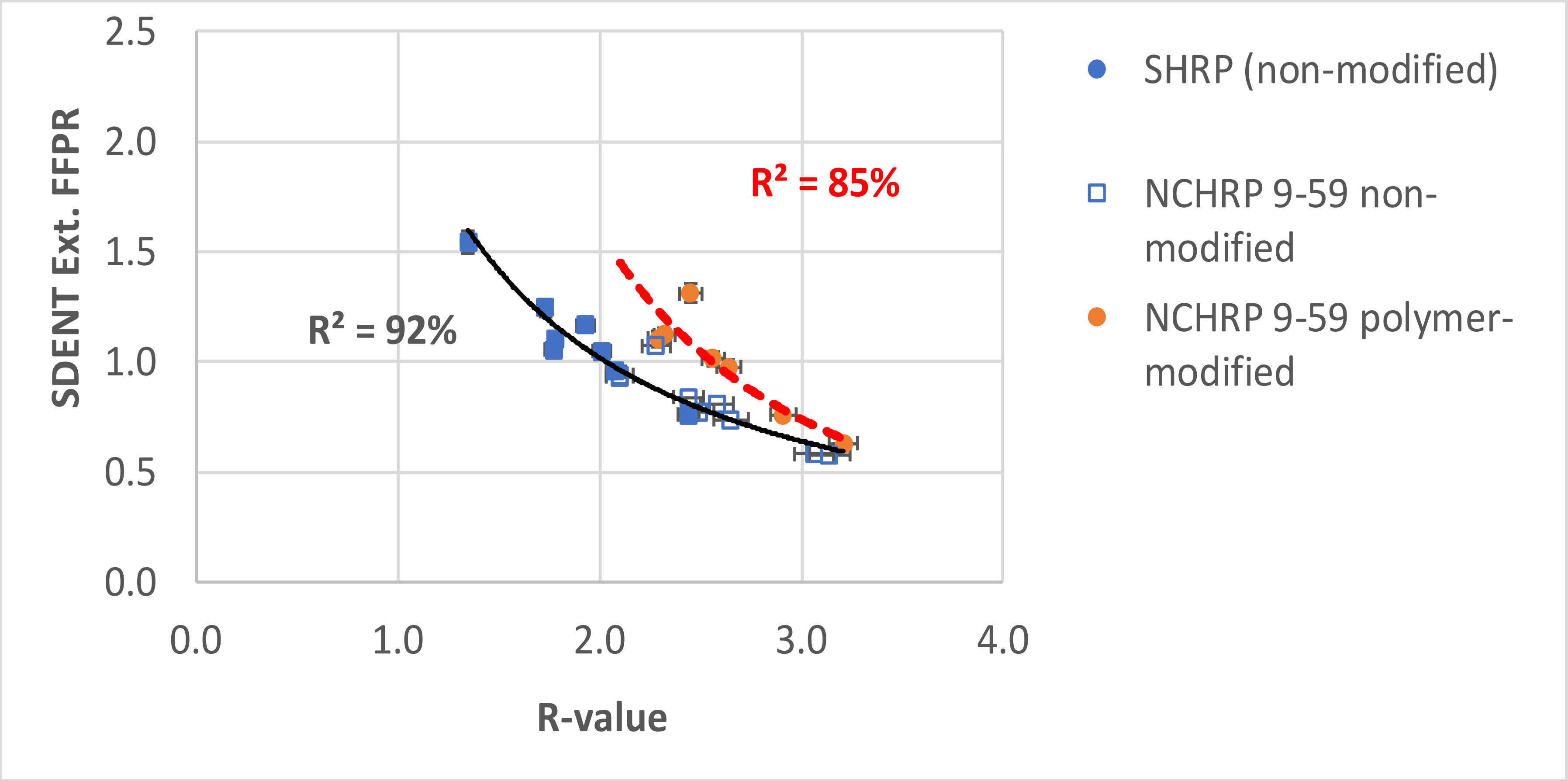
SHRP AAD-1: Fatigue exponent vs. phase angle



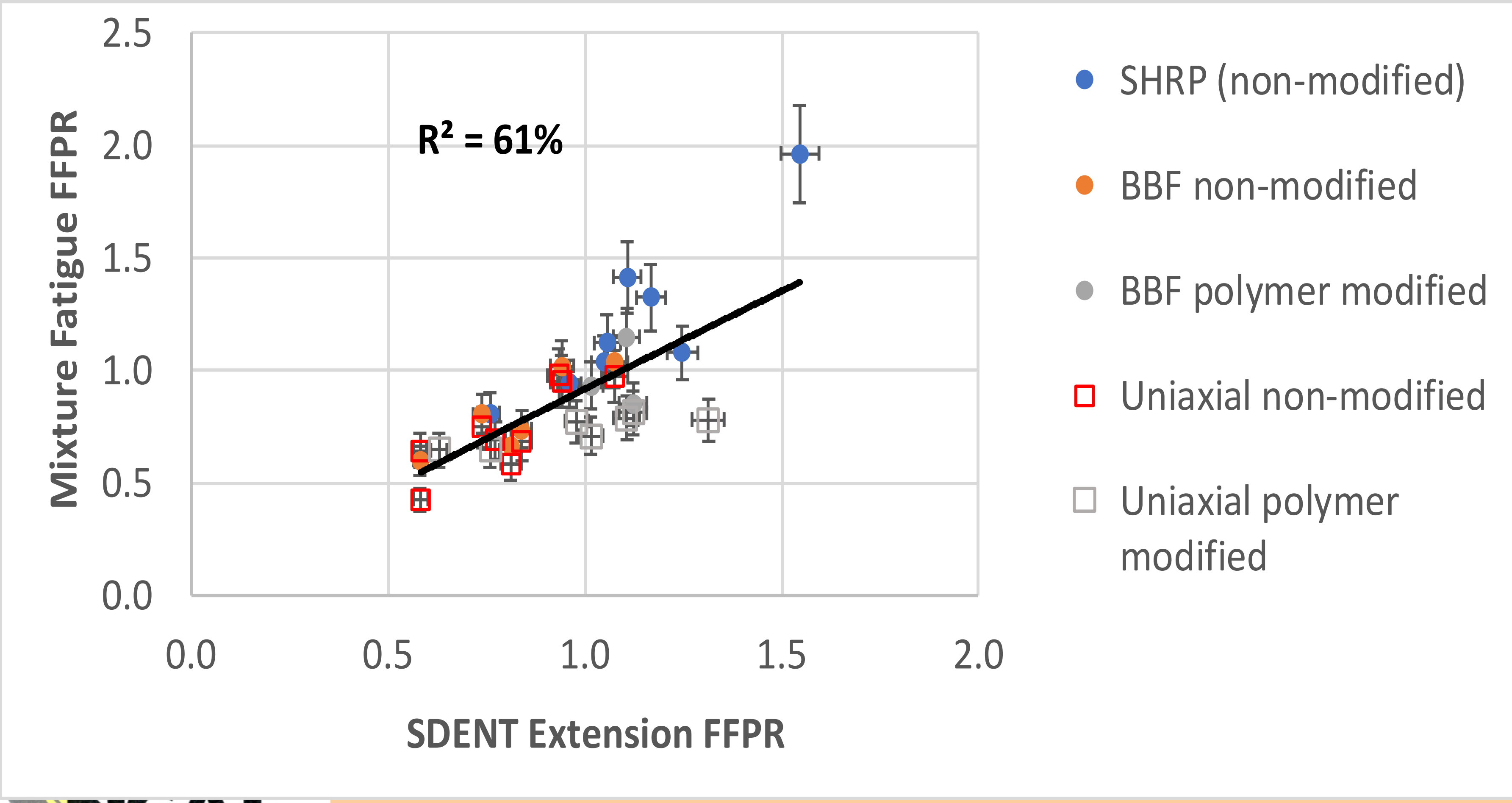
Mixture Fatigue FFPR and Binder R-value



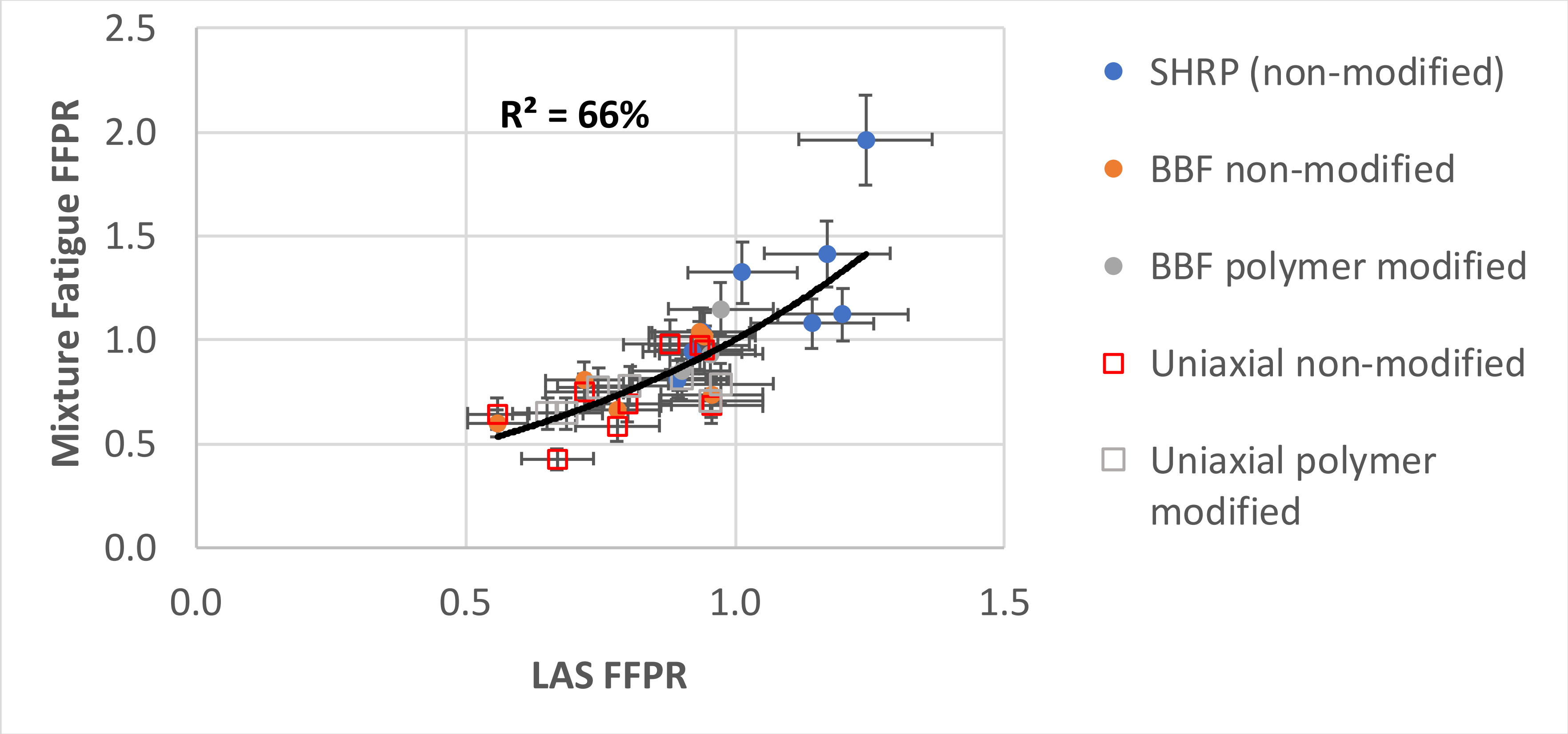
ENT/Extension FFPR and Binder R-value



Mixture fatigue FFPR vs DENT/Extension FFPR

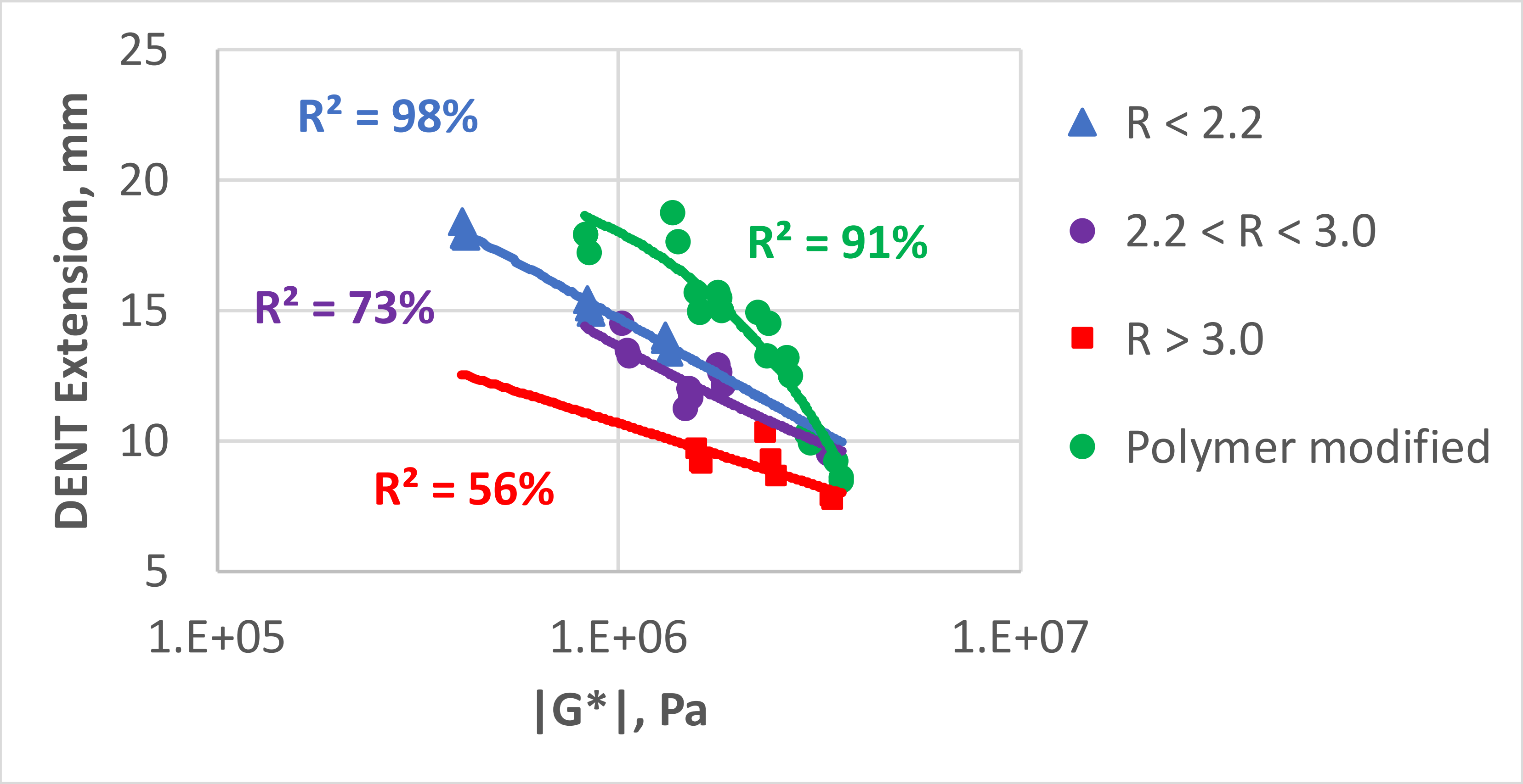


Mixture fatigue FFPR vs LAS FFPR



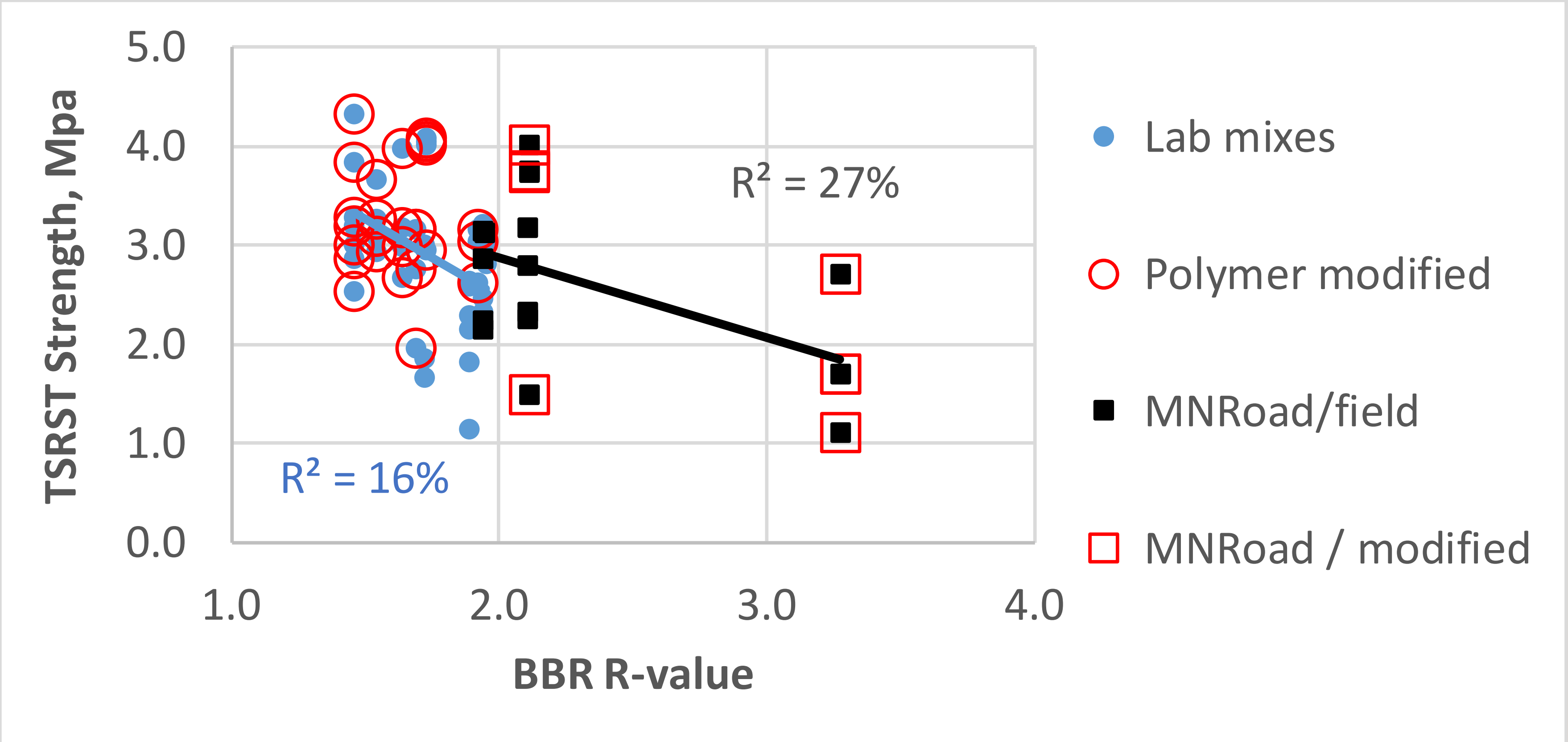
National Center for Asphalt Technology
NCAT
AUBURN UNIVERSITY

DENT extension vs G*

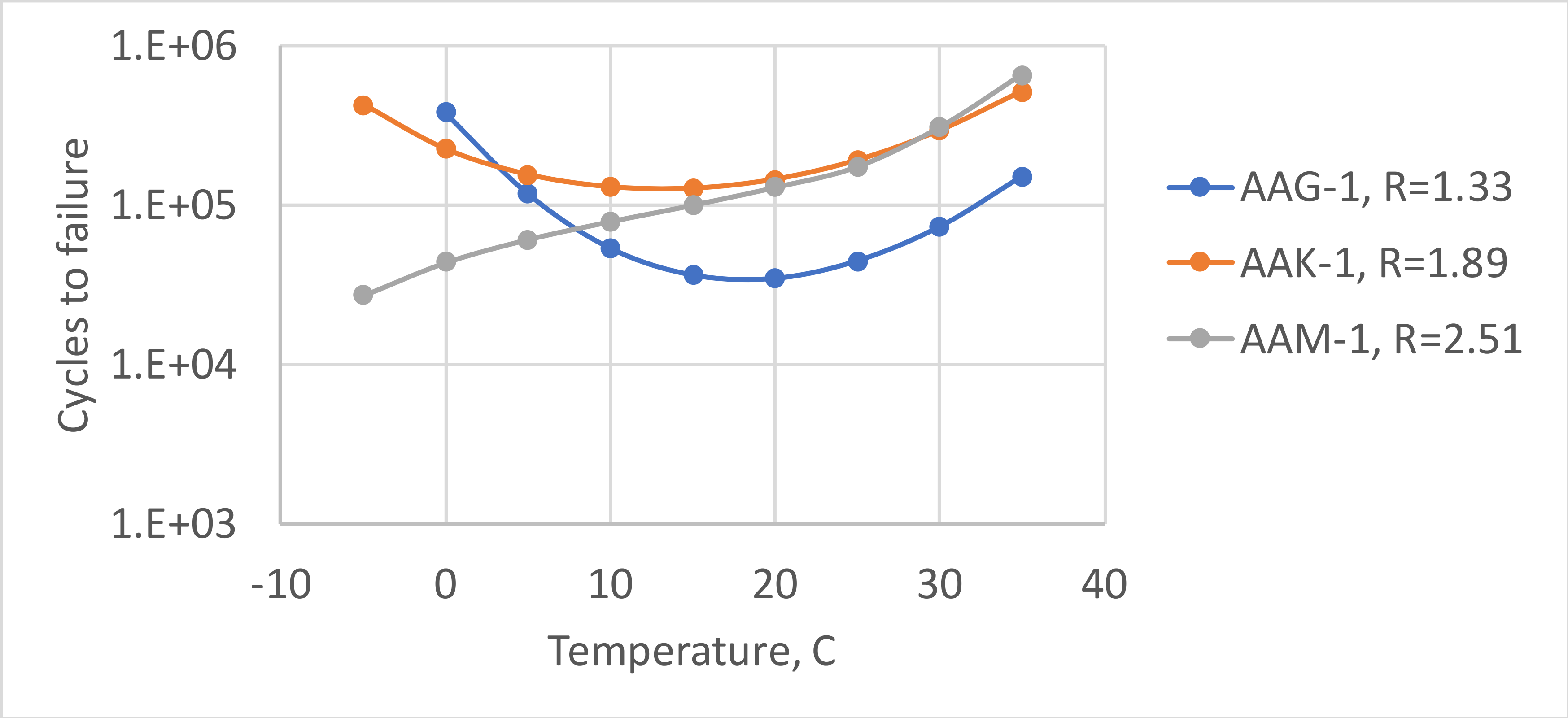


National Center for Asphalt Technology
NCAT
AUBURN UNIVERSITY

NPFS 776: TSRST Strength and R-value



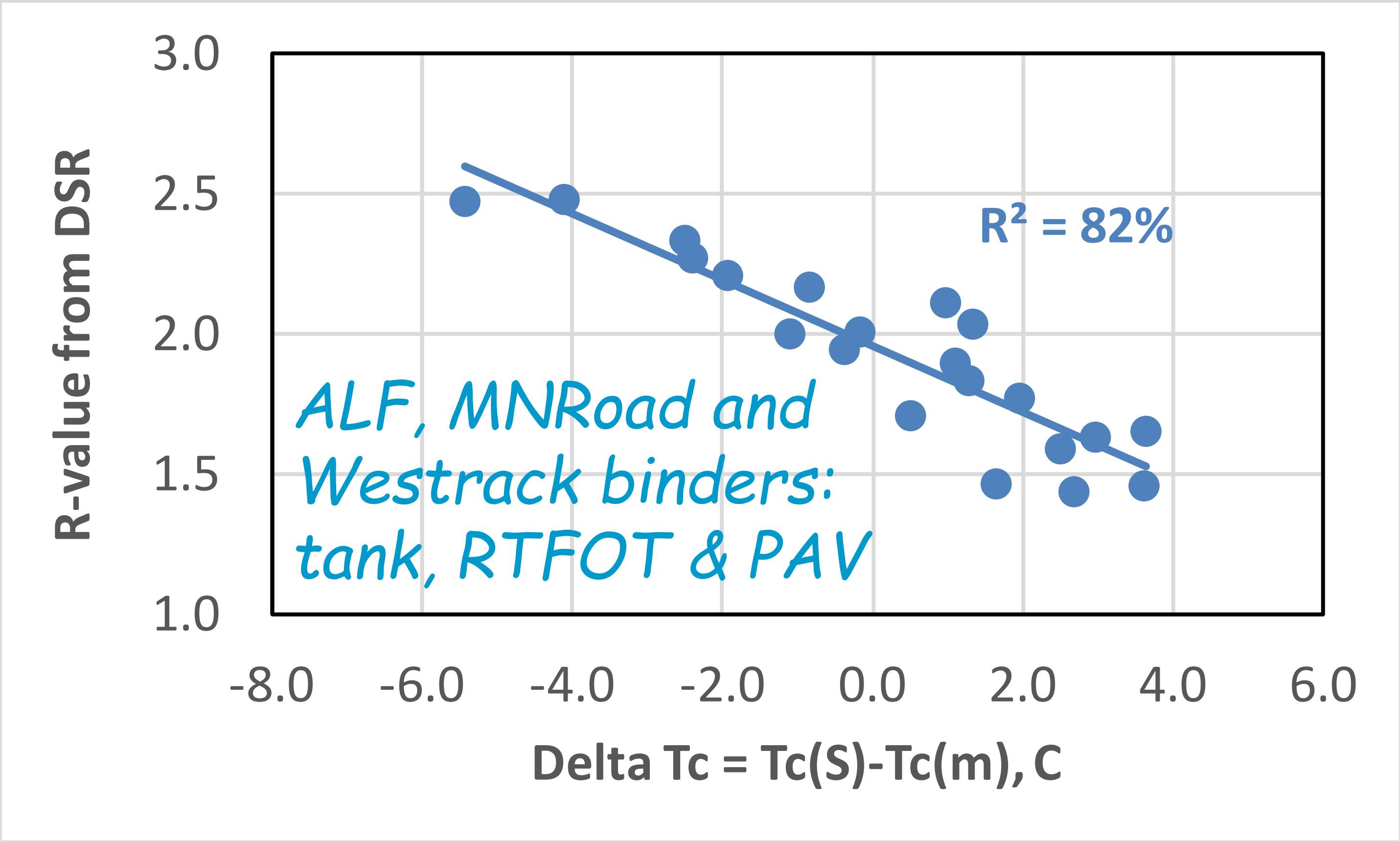
Pavement fatigue life and R-value



Simple LEA analysis with constant sub-base/sub-grade properties, 100-mm pavement

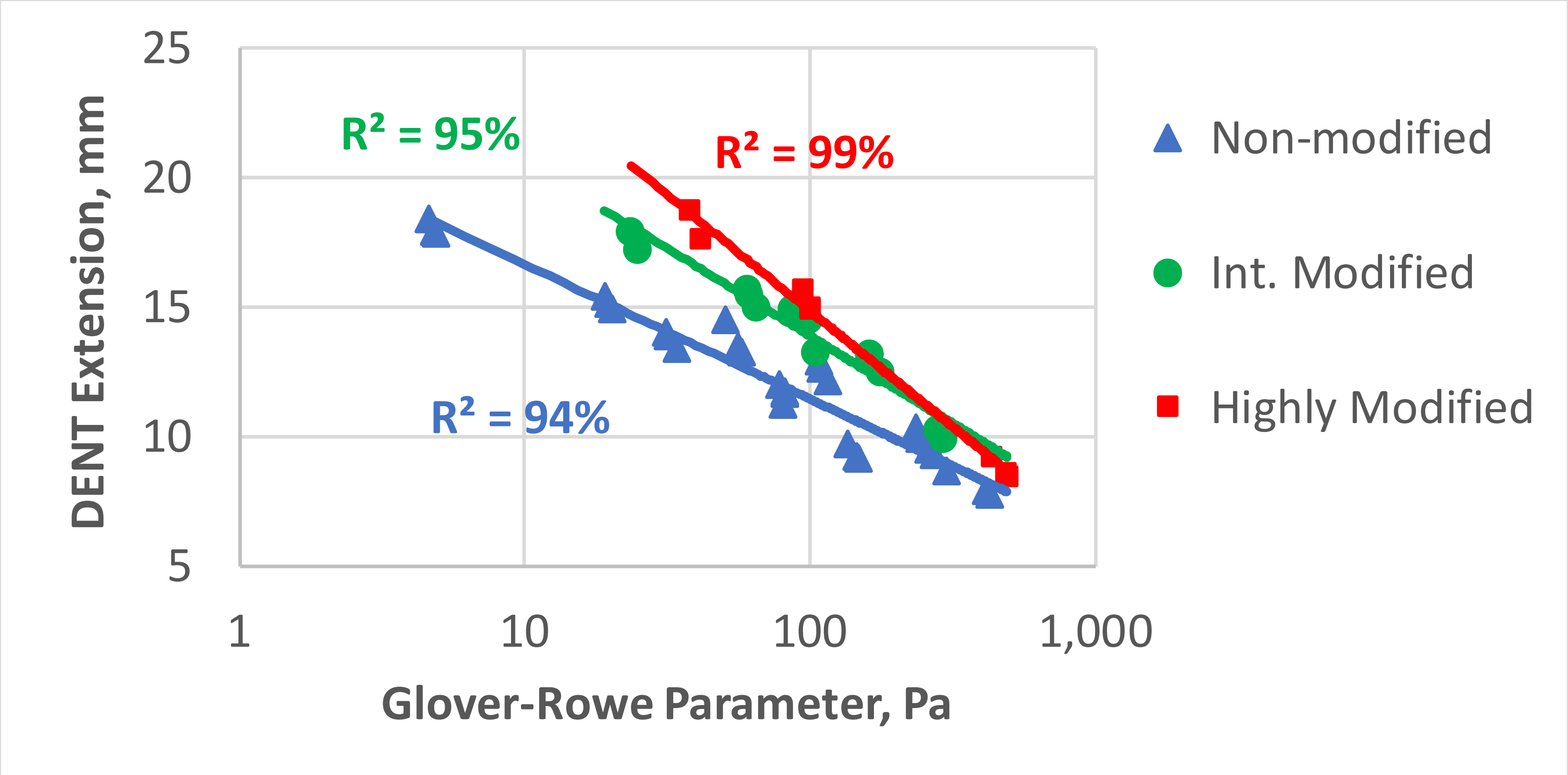
What about ΔTc? Glover-Rowe Parameter? DENT test? Extended BBR/physical hardening?

ΔTc and R-value



ΔTc and R-value are directly related, and both indicate rheologic type and strain tolerance

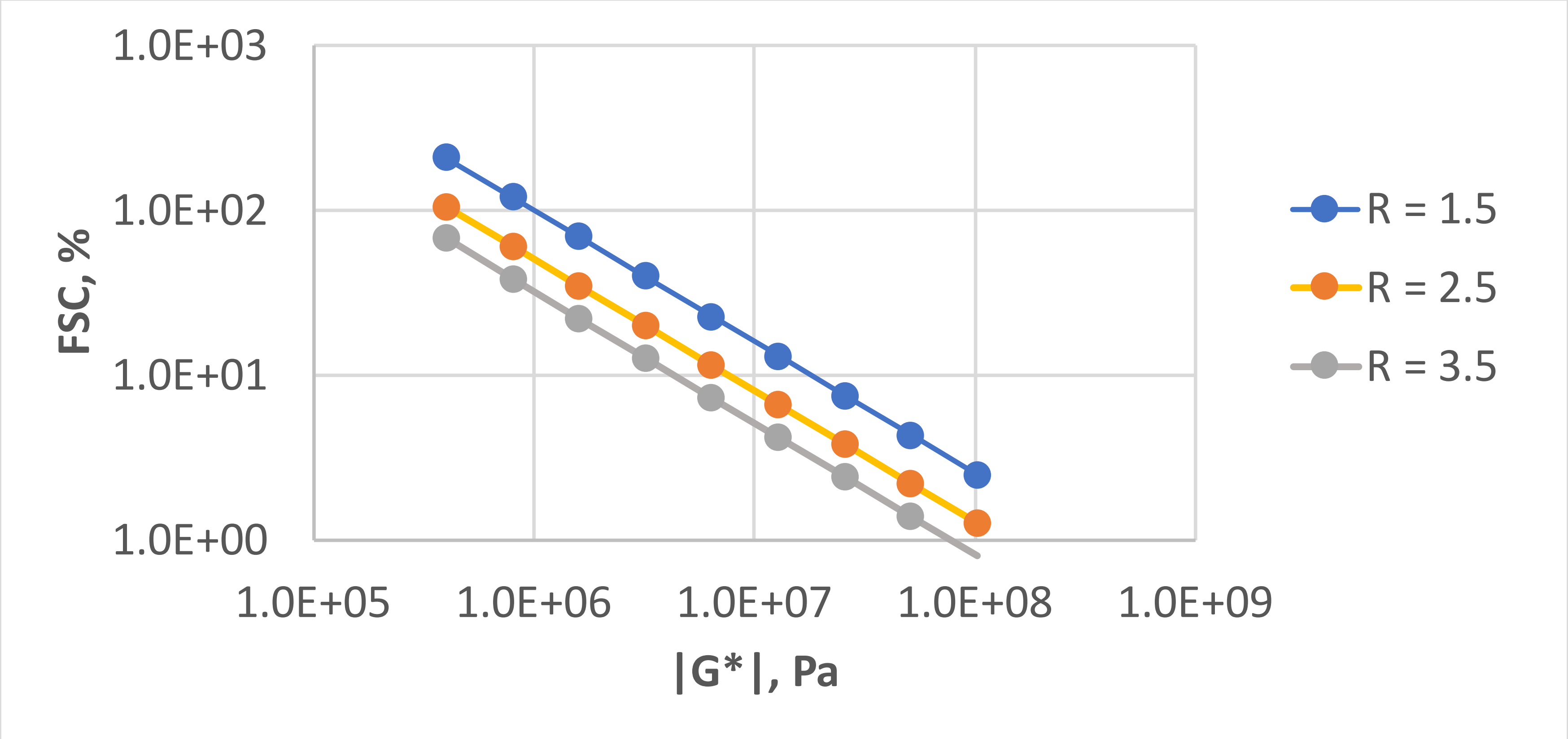
GRP and DENT extension



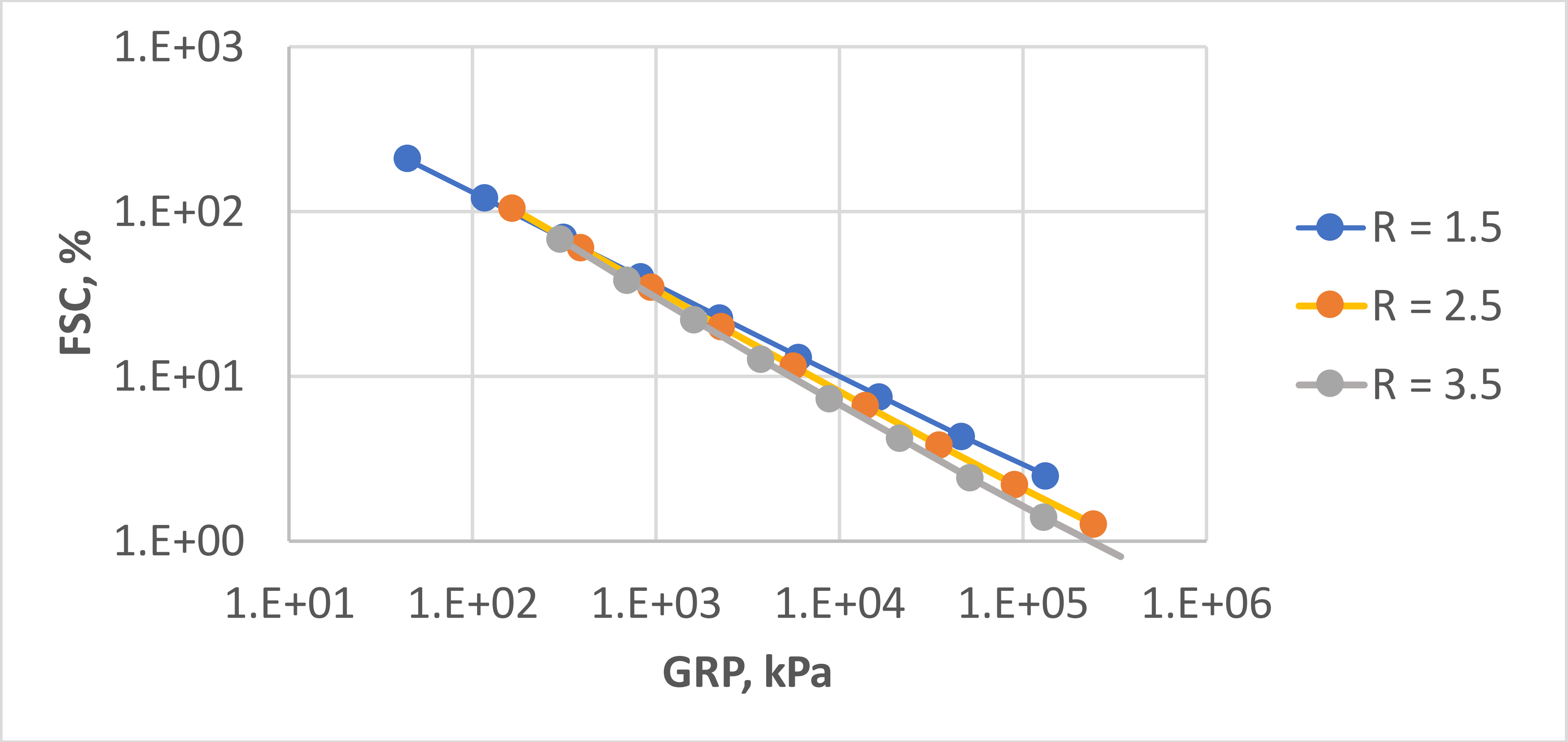
Of all rheological parameters examined, GRP has the best correlation to DENT extension

National Center for Asphalt Technology
NCAT
AUBURN UNIVERSITY

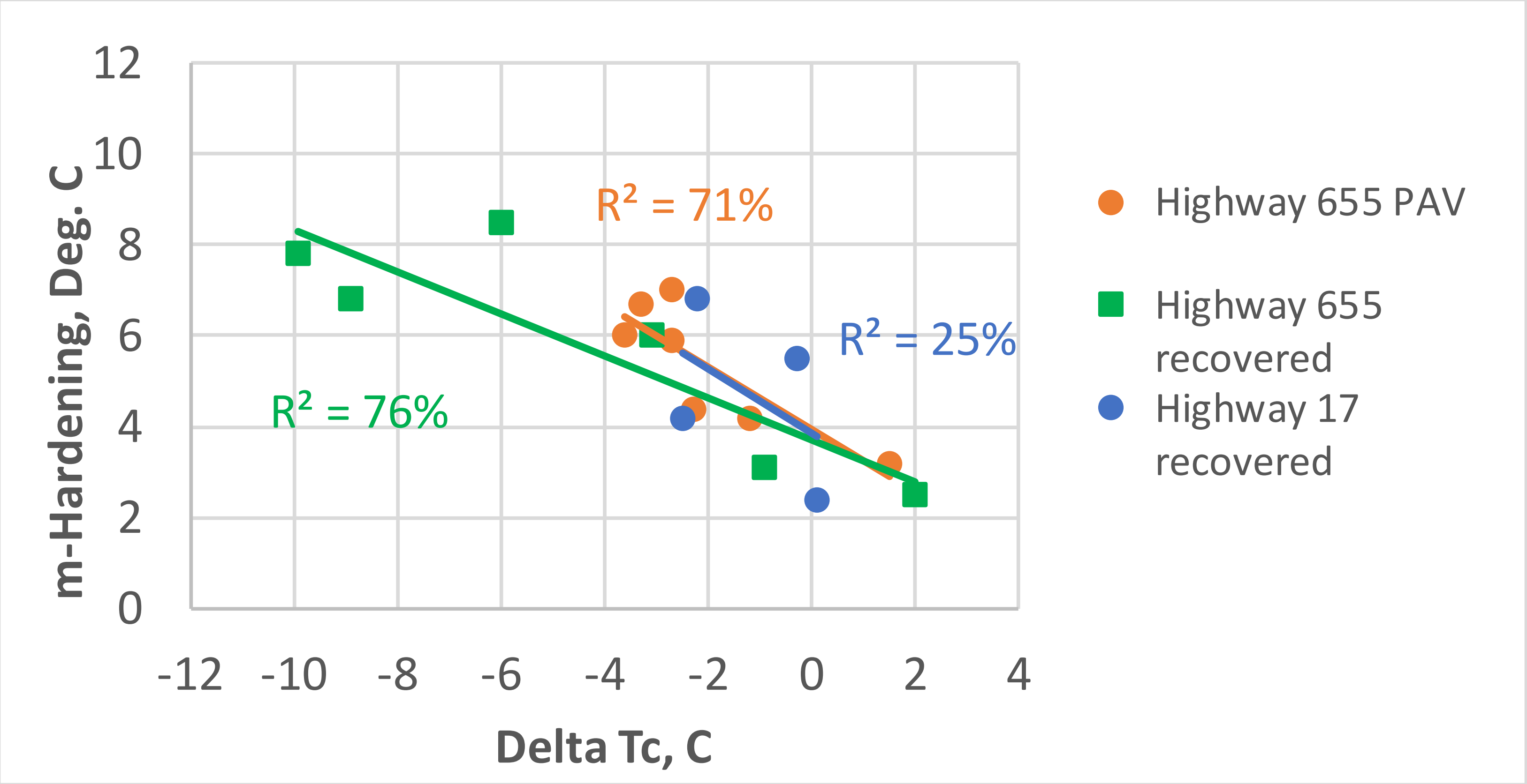
Modulus, R-value and FSC



GRP, R-value and FSC



Extended BBR/ physical hardening



Data from Kanabar, 2010

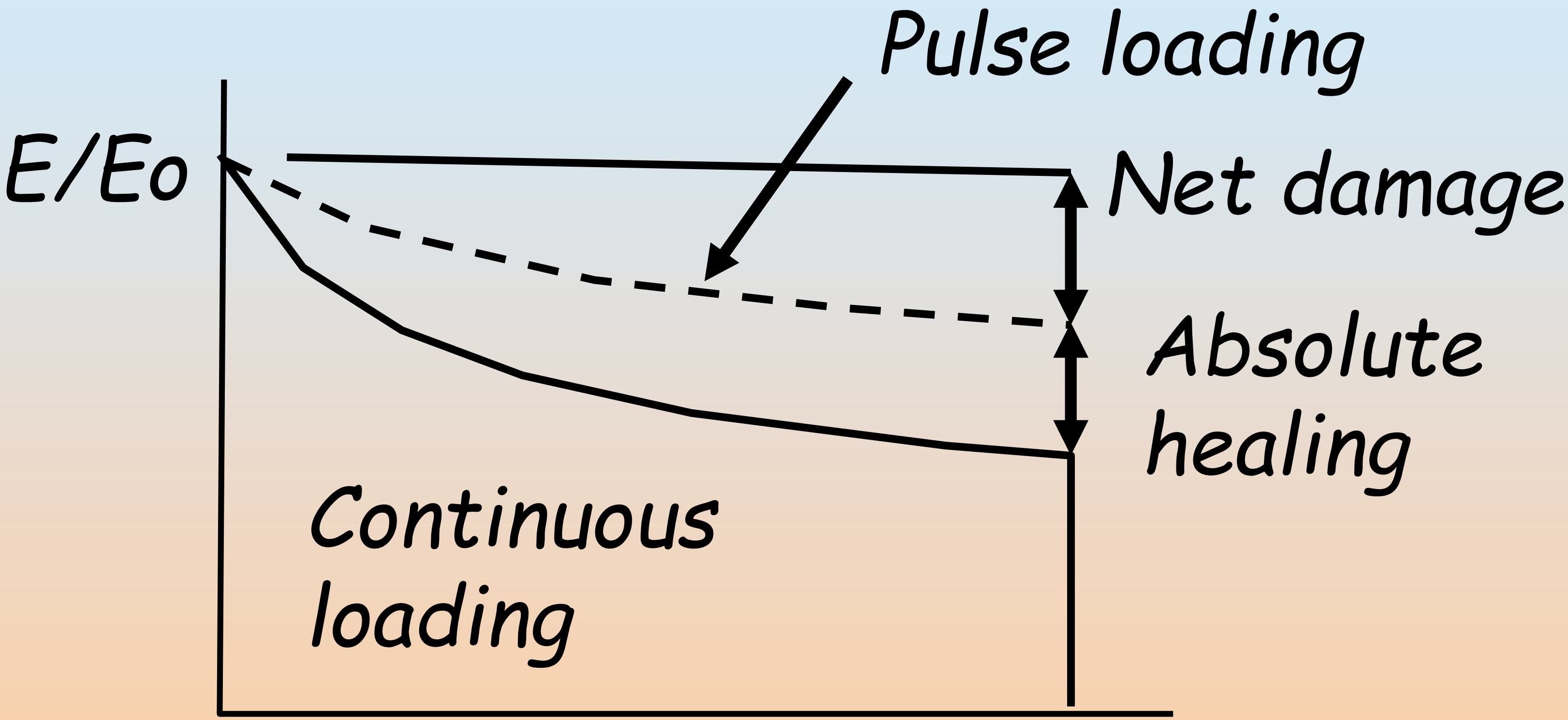
Extended BBR/ physical hardening

- Physical hardening increases with increasing ΔTc / R-value
- For high ΔTc/R the BBR will overestimate m-value
- Not only are these binders brittle, their BBR grades are lower than they should be…

Can we adjust Tc for physical hardening using R?

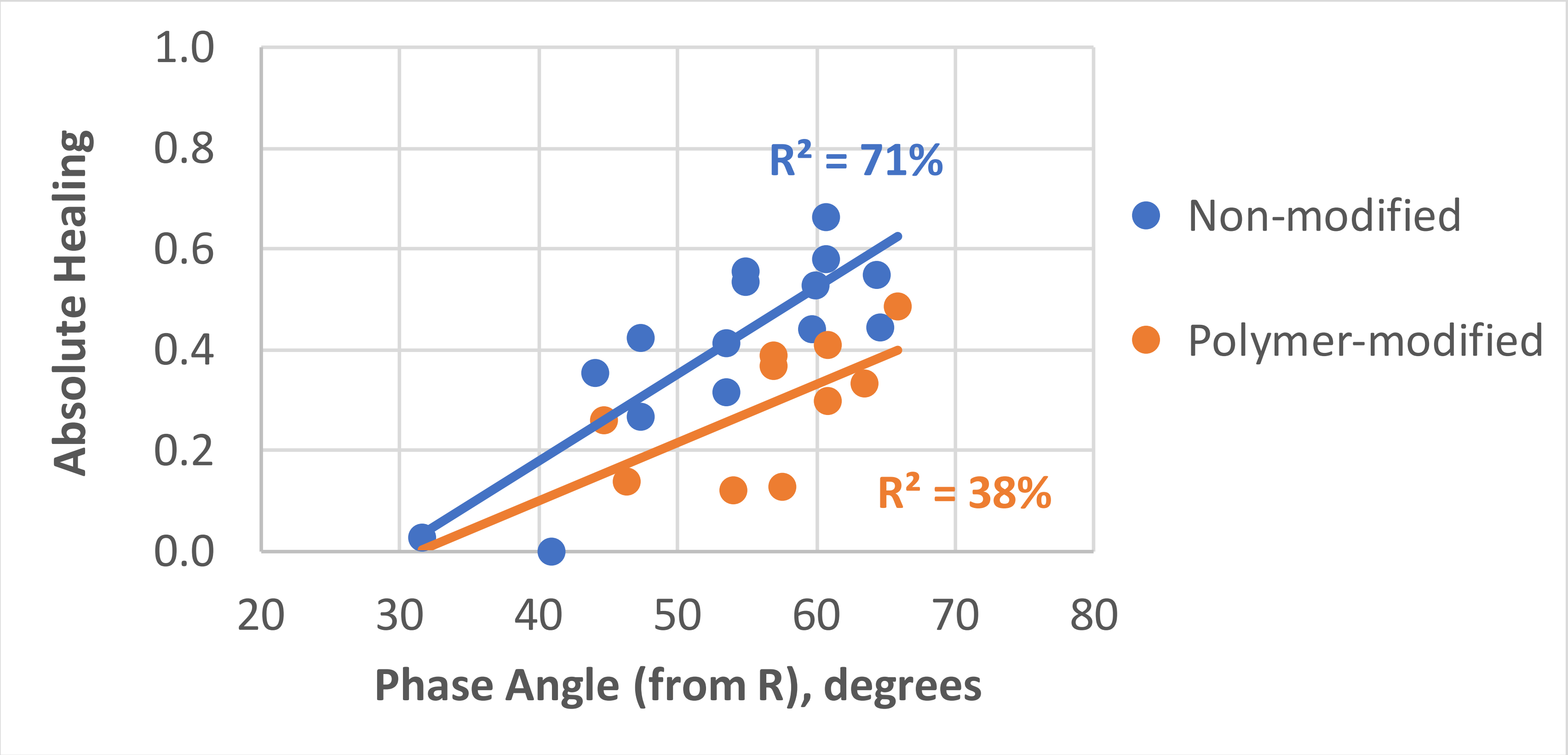
National Center for Asphalt Technology
NCAT
AUBURN UNIVERSITY

Adhesive healing



$$N_f \, [\, (FSC/\varepsilon_t) \times (VBE/100)\,]^{2.08(90/\delta)}$$

Adhesive Healing



Adhesive healing

- Absolute healing increases with increasing phase angle
- Since phase angle at a given modulus decreases with increasing R, binders with high R values will show less healing
- Maximum net damage at 10 to 20 MPa, increases with increasing R

Rheologic type can be specified in several ways

- R-value
  - Calculated from DSR, G* apx. 10 Mpa
  - Calculated from BBR
- DSR minimum phase angle at G* = 10 MPa for example
  - BBR, maximum S at m 0.3, for example
  - BBR, maximum ΔTc

Polymer-modified binders

- High R-values appear to be as bad or worse for the performance of polymer-modified binders as for non-modified ones
- Probably need similar control of R for all binders
  - Level of modification should be controlled primarily through high temperature spec

Summary

- Binders with high R-values are a “triple whammy”
  - Increased brittleness
  - Decreased adhesive healing
  - Errors in BBR grading
- Need to control rheologic type--ΔTc, R-value or some related parameter—to eliminate these problems

(might want a minimum R too)

Remaining work

- Draft final report is being compiled
- Completion of validation testing
- Related work being done as part of NCHRP 9-60 (binder manufacture/pavement performance/specifications) and NCHRP 9-61 (binder aging)

National Center for Asphalt Technology
NCAT
AUBURN UNIVERSITY

Acknowledgements

- NCHRP
- The Project Panel
- Industry suppliers
- Nam Tran and his associates at NCAT
- My associates at AAT