DSR-PAV TF Update
ETG Meeting

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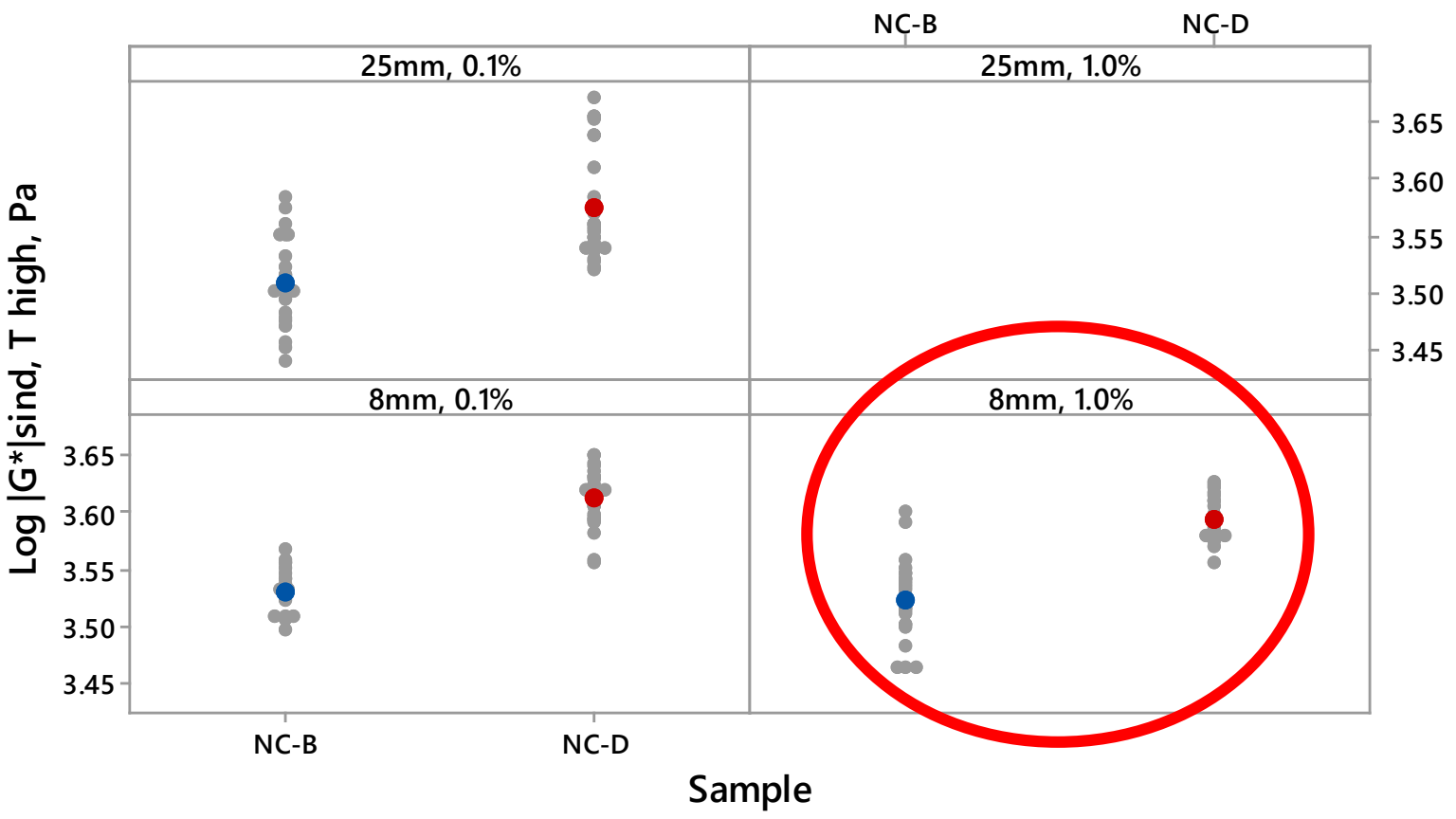
Pavel Kriz (Imperial Oil/ExxonMobil)
Gerry Reinke (Mathy)
Mike Anderson (Asphalt Institute)
Wes Cooper (Asphalt Institute)
David Anderson (Consultant)

Reconnect from September 2017

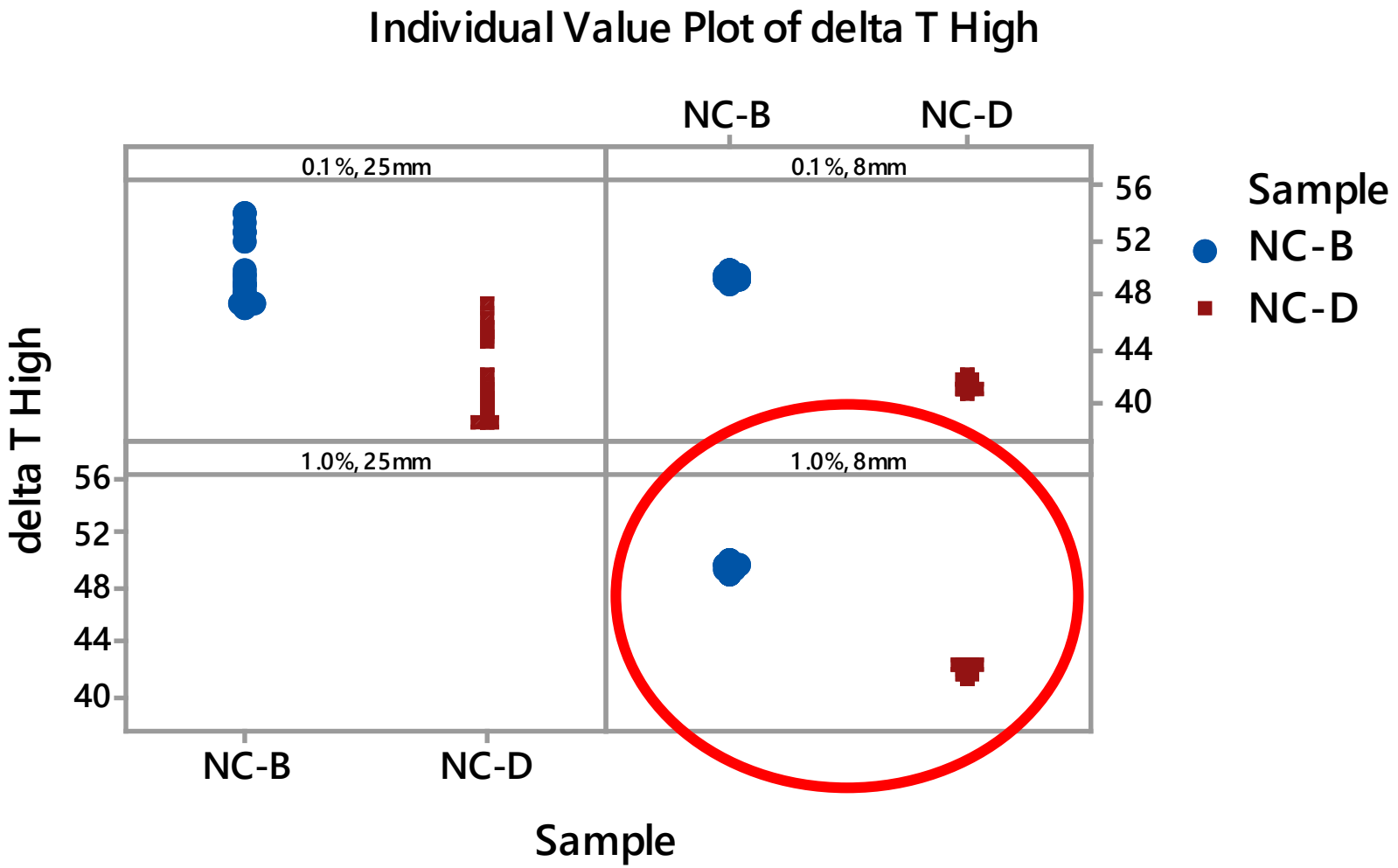
1. Stage 1 Completed → DSR equilibrium time
   - Time to equilibrium is not controlled among different DSRs the same, however its impact on data variability is not dominant
2. Stage 2 Completed → effect of strain magnitude & plate size on variability
   - Modified test setup did not result in desired improvement in test variability – precision improved, however accuracy worsen
   - Current DSR-PAV test is not discriminatory to varying binder qualities, yet it is a limiting specification
   - Phase angle showed as very reliable parameter any lab can measure, and which can discriminate asphalts and temperature changes
   - Data fully support current efforts on finding an alternate property (NCHRP 09-59 and 09-60)

|G*| is a very unreliable measurement



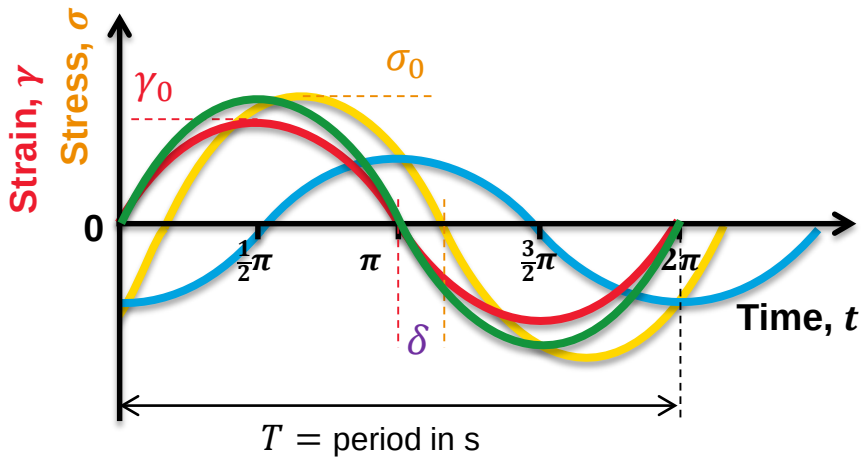
Panel variables: Geometry, Strain

Phase Angle is a very reliable measurement



Panel variables: Strain, Geometry

Complex, Storage & Loss Moduli



$$\omega = \frac{2\pi}{T} = 2\pi f \text{ (analogous to } \dot{\gamma})$$

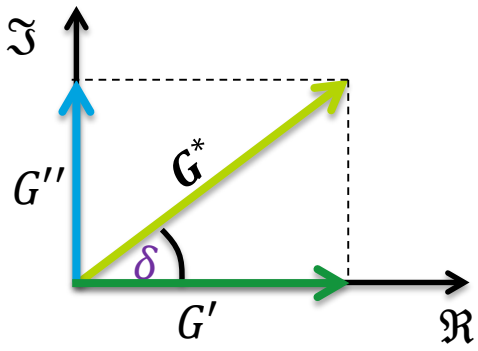
$$\sigma = \sigma_0 \sin(\omega t + \delta)$$

$$\sigma = \underbrace{\sigma_0 \cos\delta \sin\omega t}_{\sigma \text{ in phase with } \gamma} + \underbrace{\sigma_0 \sin\delta \cos\omega t}_{\sigma \text{ out of phase with } \gamma}$$

$$\sigma = \gamma_0 \left[\underbrace{\left(\frac{\sigma_0}{\gamma_0}\right)\cos\delta}_{G'} \sin\omega t + \underbrace{\left(\frac{\sigma_0}{\gamma_0}\right)\sin\delta}_{G''} \cos\omega t \right]$$

Representation in Complex Plane

(σ out of phase γ)
viscous



(σ in phase with γ)
elastic

$$\boldsymbol{G}^* = G' + iG''$$

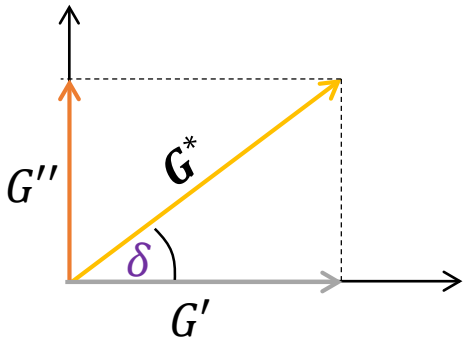
$$|\boldsymbol{G}^*| = \sqrt{G'^2 + G''^2} = \frac{\sigma_0}{\gamma_0}$$

$$\tan\delta = G''/G'$$

symbol	modulus	energy	response
G'	storage	stored	elastic
G''	loss	dissipated	viscous

ExxonMobil

Science Behind DSR-PAV

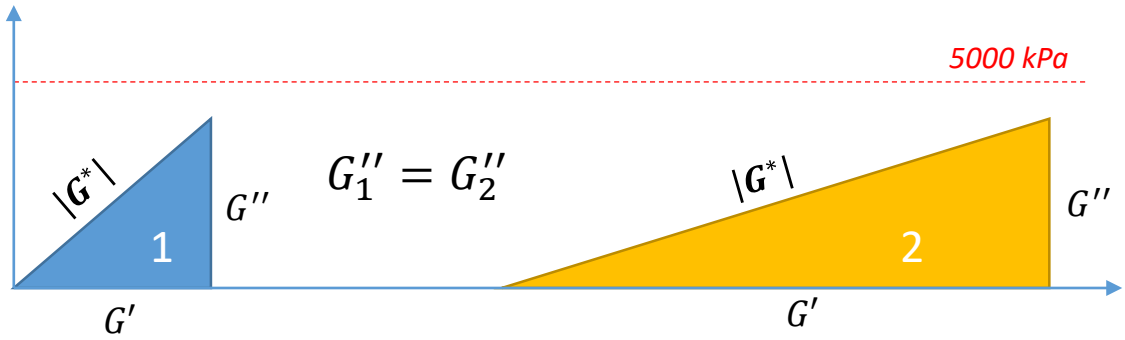


$$\boldsymbol{G^*} = G' + iG''$$

$$|\boldsymbol{G^*}| = \sqrt{G'^2 + G''^2} = \frac{\sigma_0}{\gamma_0}$$

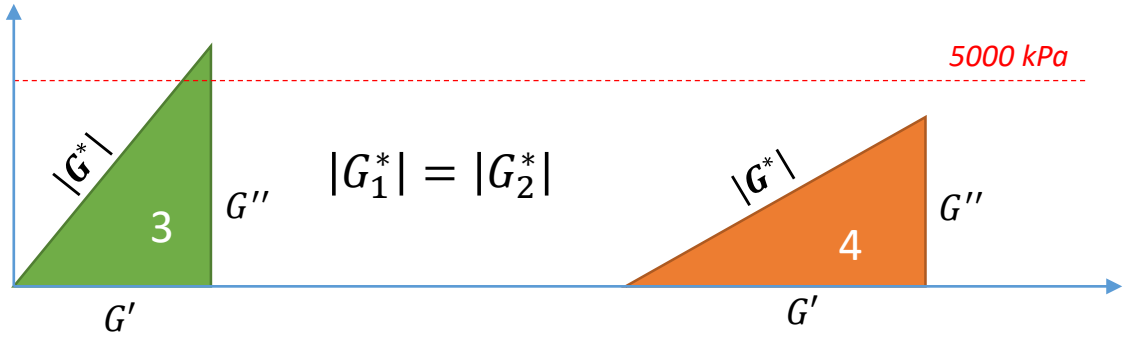
$$\tan \delta = G''/G'$$

$$|\boldsymbol{G^*}| \cdot \sin \boldsymbol{\delta} = |\boldsymbol{G^*}| \frac{G''}{|\boldsymbol{G^*}|} = G''$$



high phase angle = ductile

low phase angle = brittle

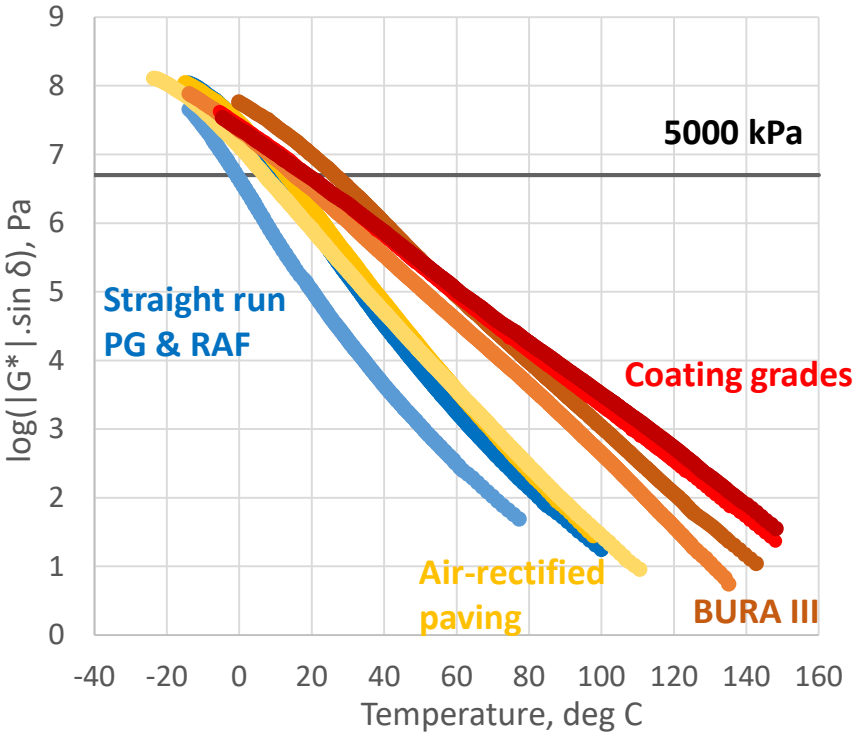


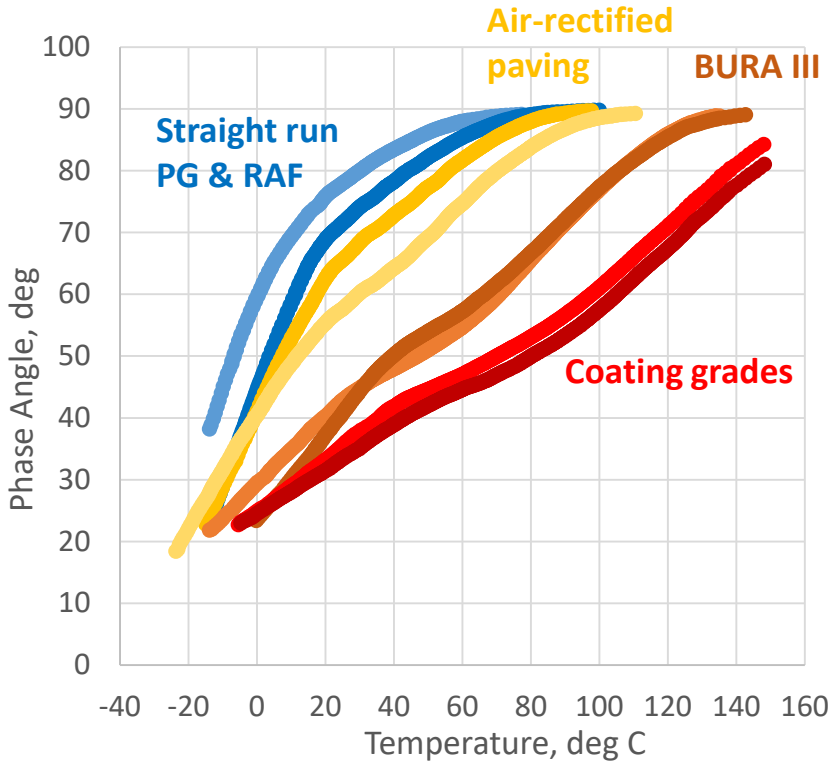
high phase angle = ductile

low phase angle = brittle

DSR-PAV can not capture fundamental differences

- Two asphalts (PG 64 & PG 46) were oxidized to variety of products ranging from 1 PG stiffer paving grade to roofing coating grades
- Phase angle offers clear differentiation between these binders

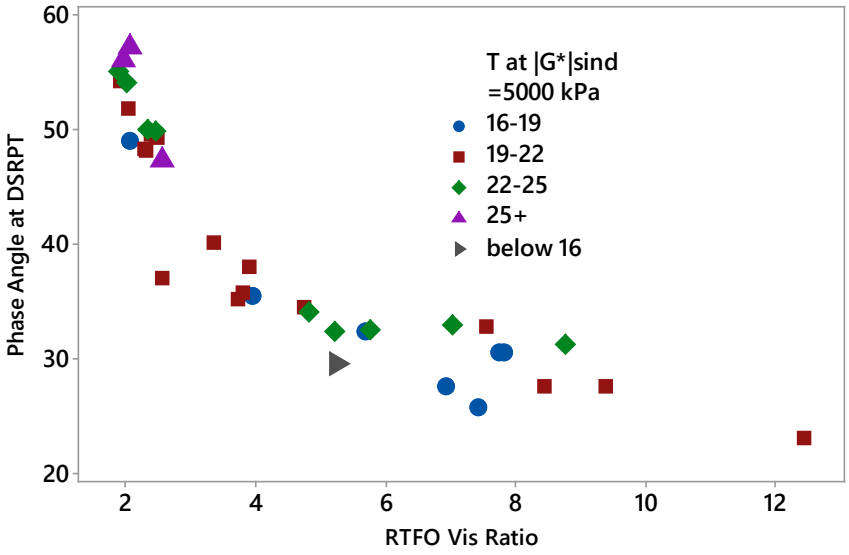


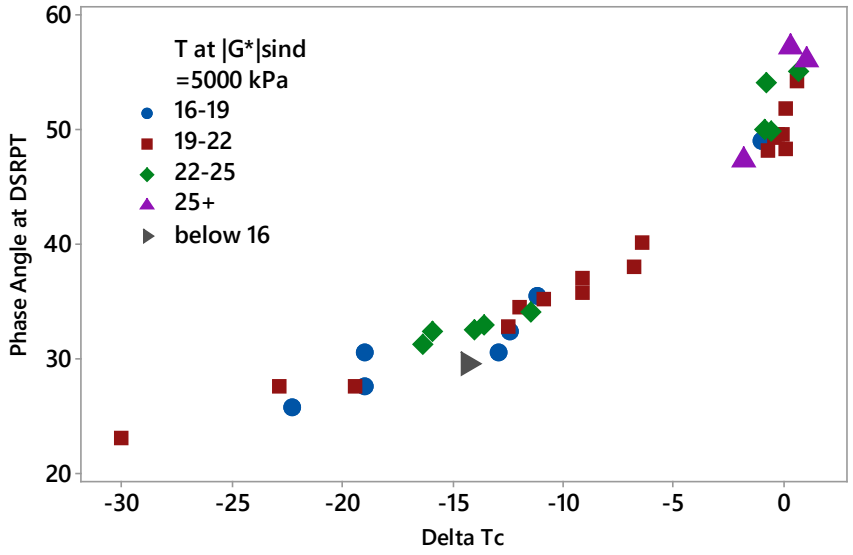


Data from: P. Kriz, et al, Rheological Properties of Simple Bitumen, E&E Congress, Istanbul, Turkey, 2012.

Colloidal Stability & Aging Index

- Set of samples of varying phase stability prepared in the lab (by adding oil, asphaltenes, oxidation)
- Are ΔTc, phase angle & aging susceptibility related to colloidal stability?





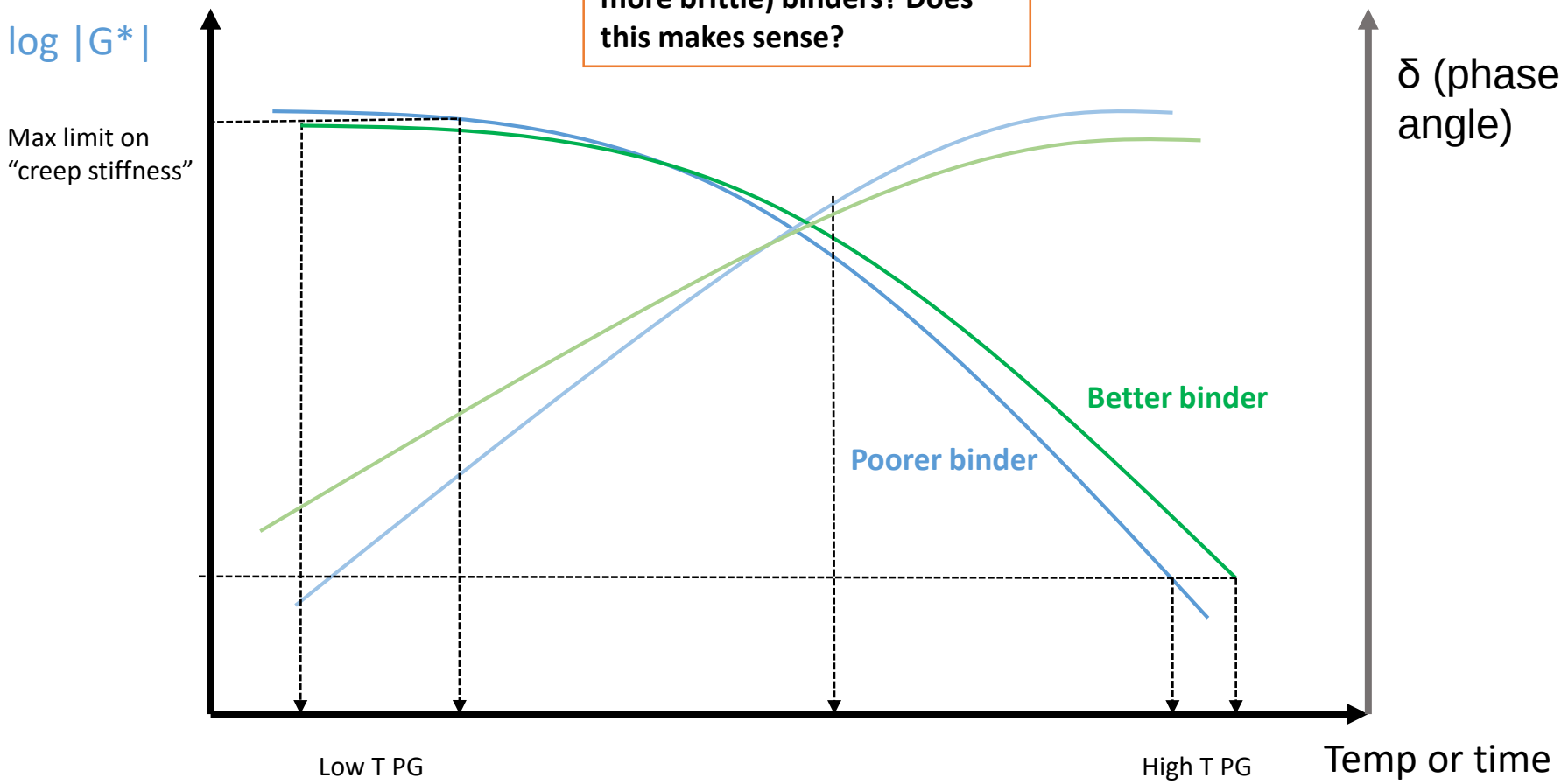
The Proposal

- Short term: Allow good asphalts in the specification
  - For asphalts tested above G”>5000 kPa, review phase angle
  - If phase angle is sufficiently high (e.g. above XX degrees) allow them to pass
  - TF needs help to collect data – field performance & phase angle at intermediate temp. → volunteers?
- Long term: develop a new fatigue parameter to limit fast aging materials and poor phase stable materials (e.g. NCHRP, D. Christensen)
  - There were reasons for aging index & ductility in the specification – Superpave already measures these properties

Appendix

Science Behind DSR-PAV, cont'd

Intermediate PG |G*| sin delta promotes less viscous, more elastic (i.e. more brittle) binders? Does this makes sense?



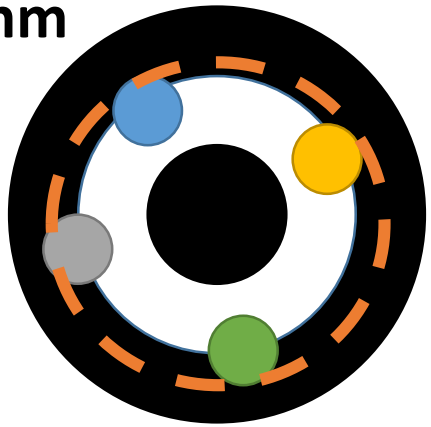
S(t) promotes lower stiffness, m-val more ductile binder to prevent cracking

|G*|/sin delta - Promotes higher stiffness &
More elastic binders to prevent rutting

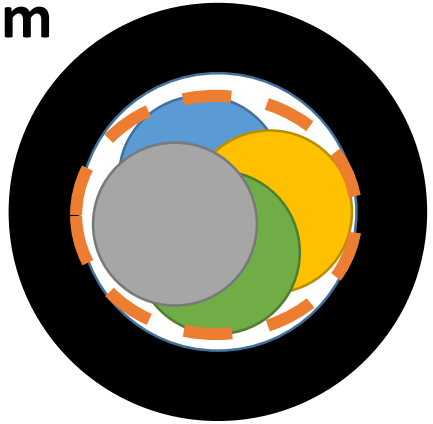
Test Setup - Conclusion

- Very large variability for modulus measurement
- Data from 3 labs had to be excluded from analysis
- Variability increases with increasing stiffness
- 25mm PP at 0.1% showed lower variability for individual labs however larger dispersion among labs

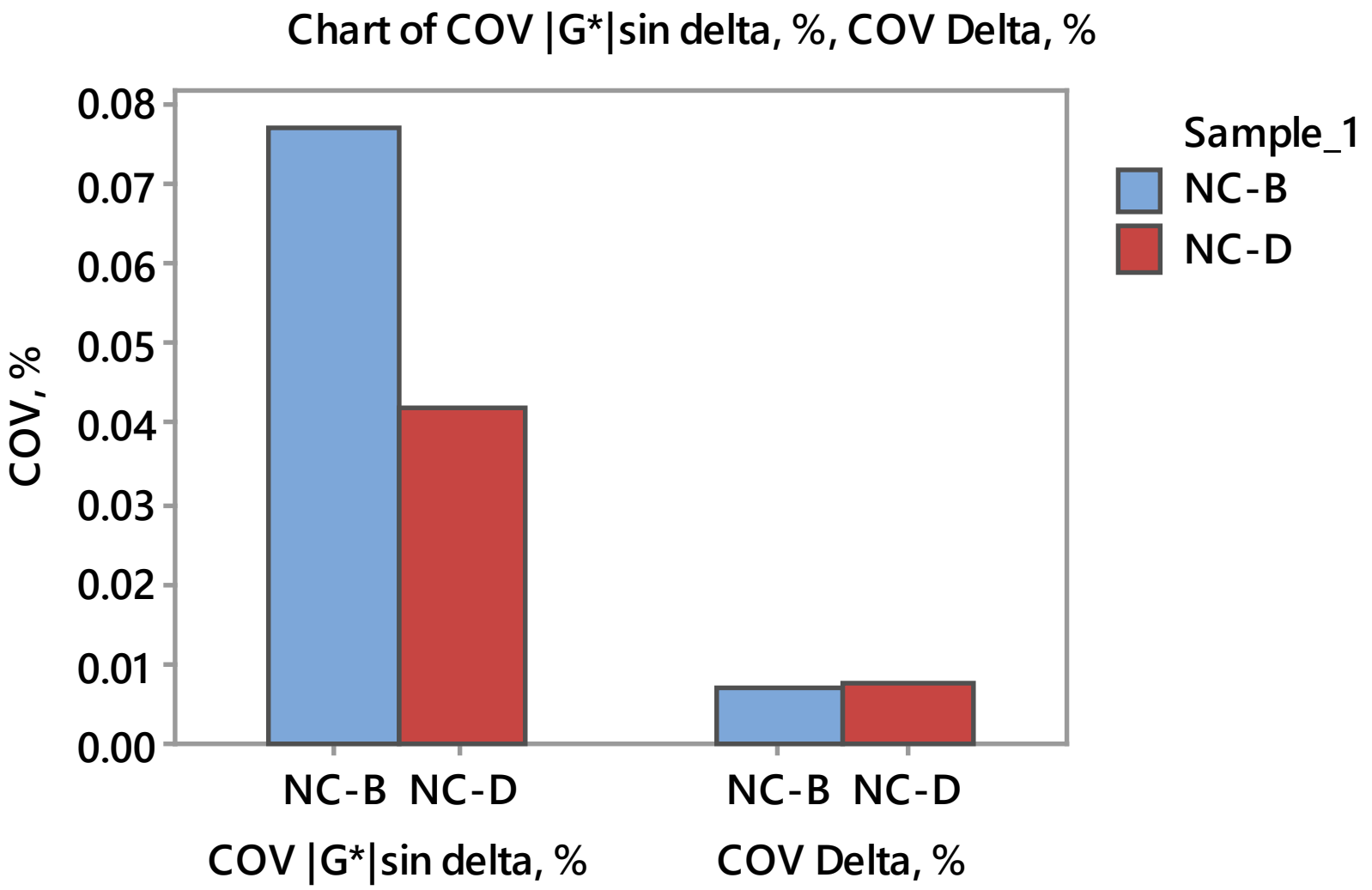
25 mm



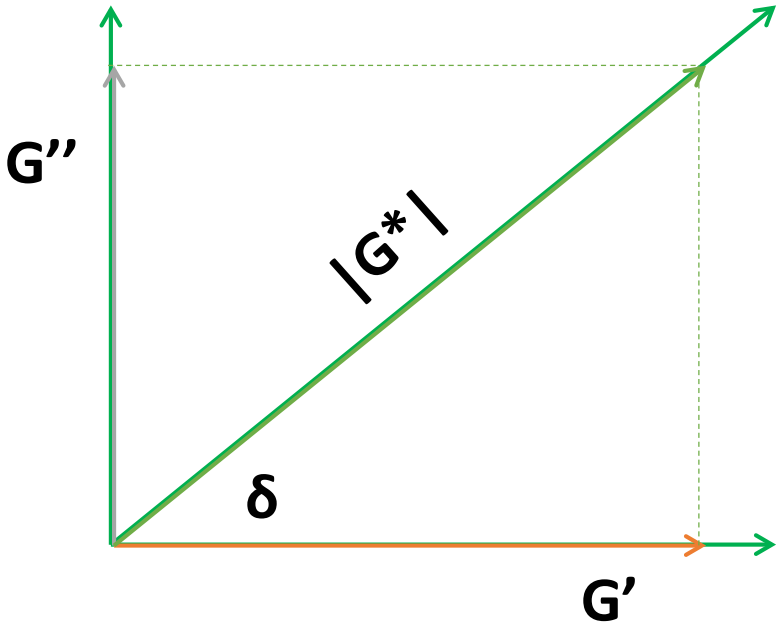
8mm



COV for Phase Angle about 10x lower



Phase Angle Measurement is Less Variable



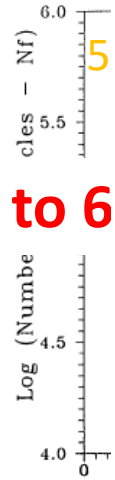
$$|G^*| \cdot \sin \delta = G''$$

Over a narrow range of temperature, G' & G'' change relatively proportionally, thus a change in phase angle would be much less significant than a change in |G*|

Limit Increase

- 5000 kPa limit suggested on very limited data developed from tests on asphalts used in the Zaca-Wigmore Test Road[1]
- Deaco

Change to 6



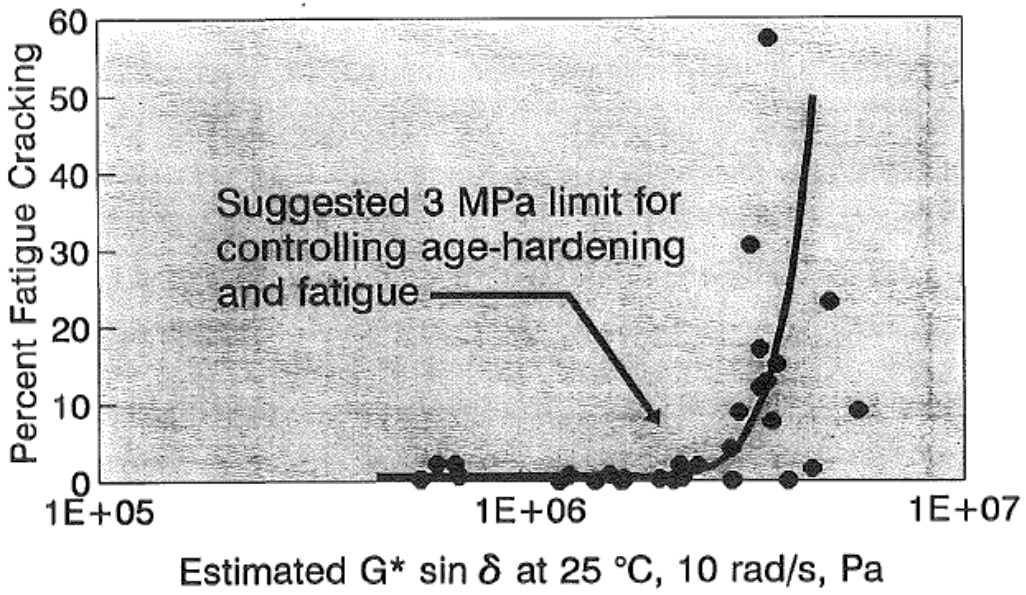
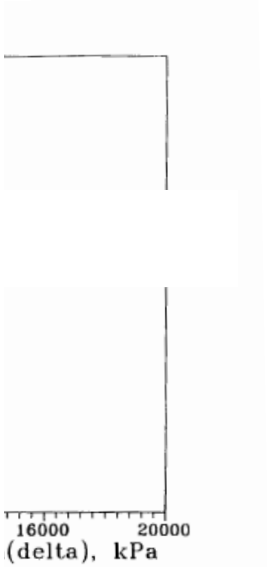


Figure 10.1. Eff
cycles to failure f

Figure 13. Analysis of a Zaca-Wigmore Performance Results using G* sin δ

ween G"



gate source on simulated
cm [6 in.] asphalt layer)

[1]Anderson, D.A. and T.W. Kennedy, "Development of SHRP Binder Specification", J AAPT, Vol. 62, 1993, pp. 481-507.
[2]A.A. Tayebali et al., "Fatigue Response of Asphalt-Aggregate Mixes", SHRP-A-404, National Research Council, Washington, DC, 1994.