

Asphalt Institute DSR-PAV TF Outcomes & Recommendation

June 18, 2019

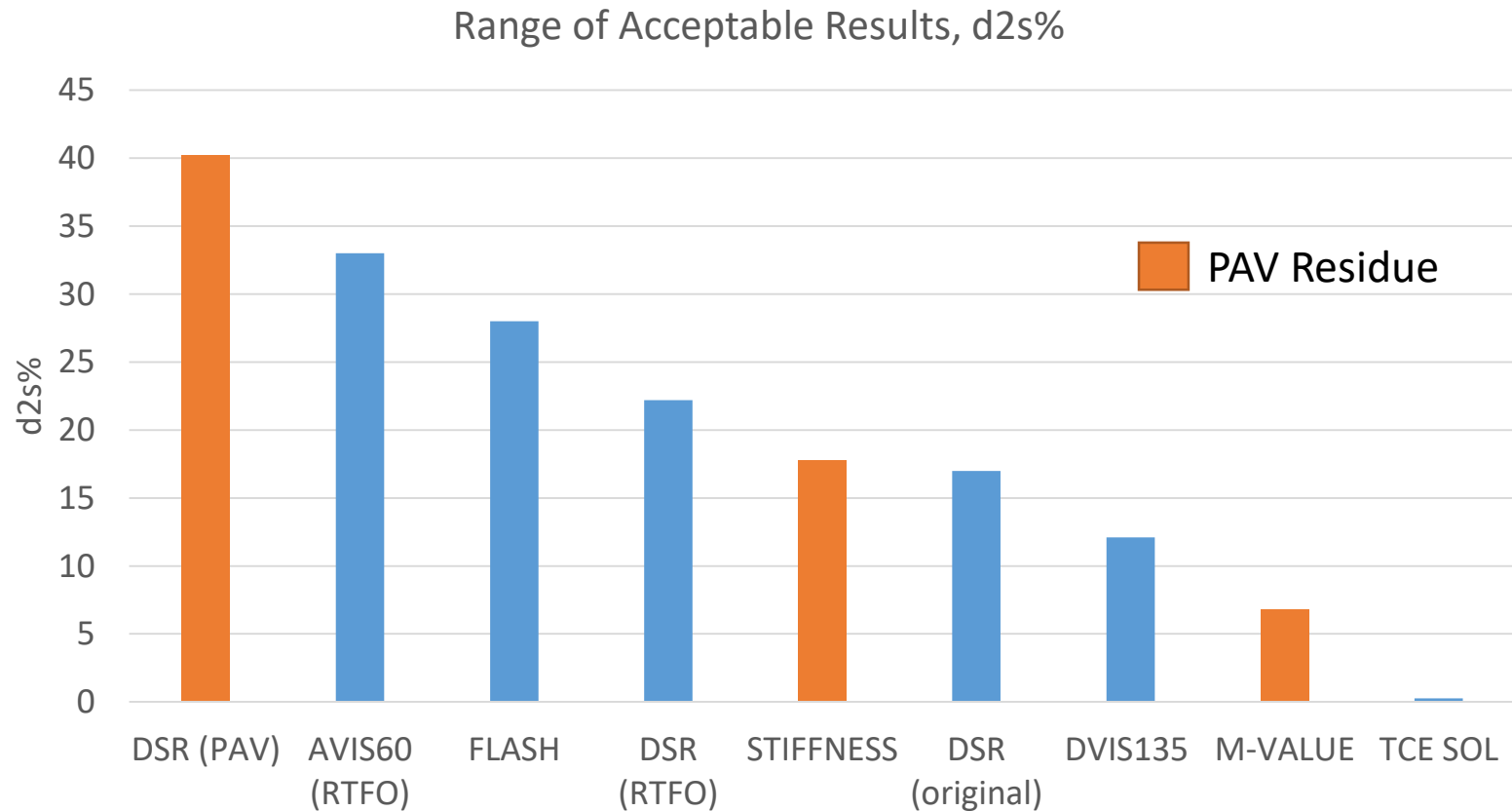
Pavel Kriz (Imperial Oil/ExxonMobil)

Gerry Reinke (Mathy)

Mike Anderson (Asphalt Institute)

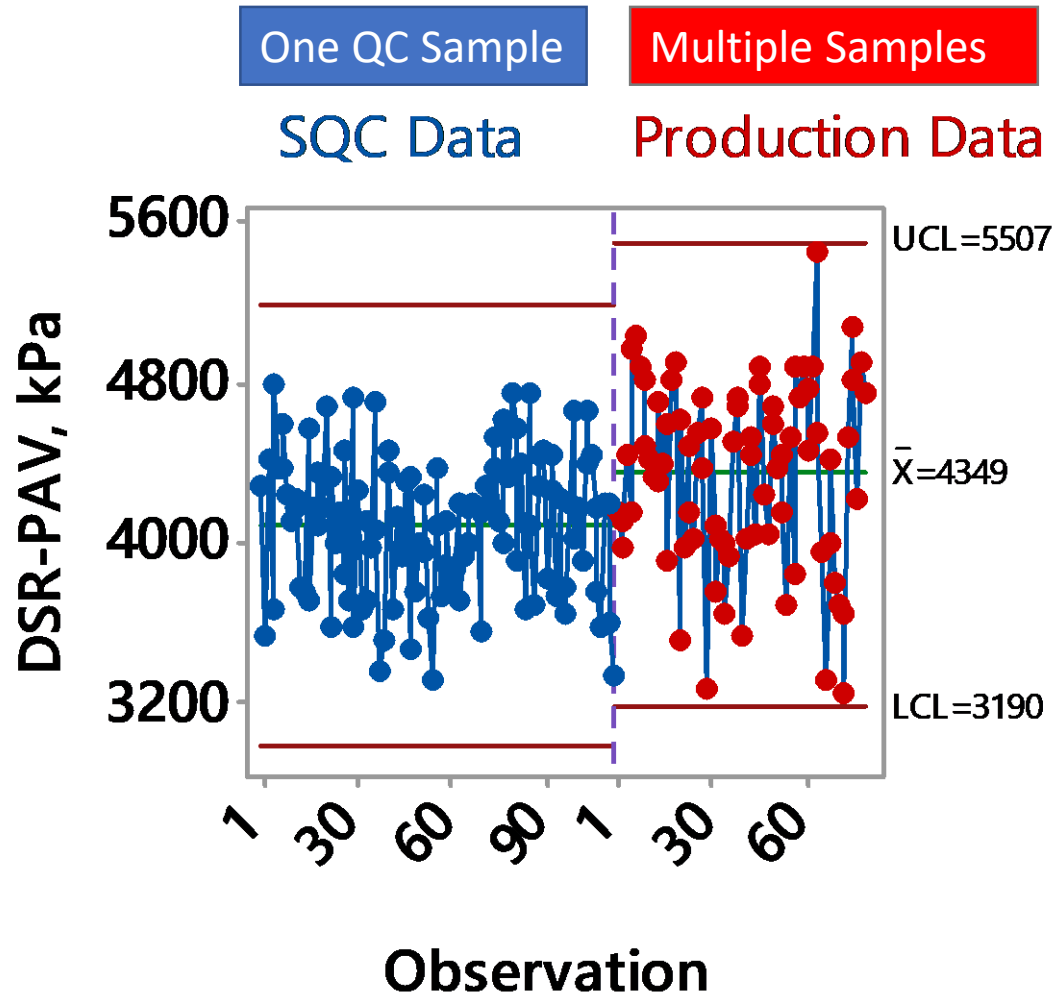
Background & Case for Action

- DSR-PAV is (after DTT) the most variable test SuperPave™



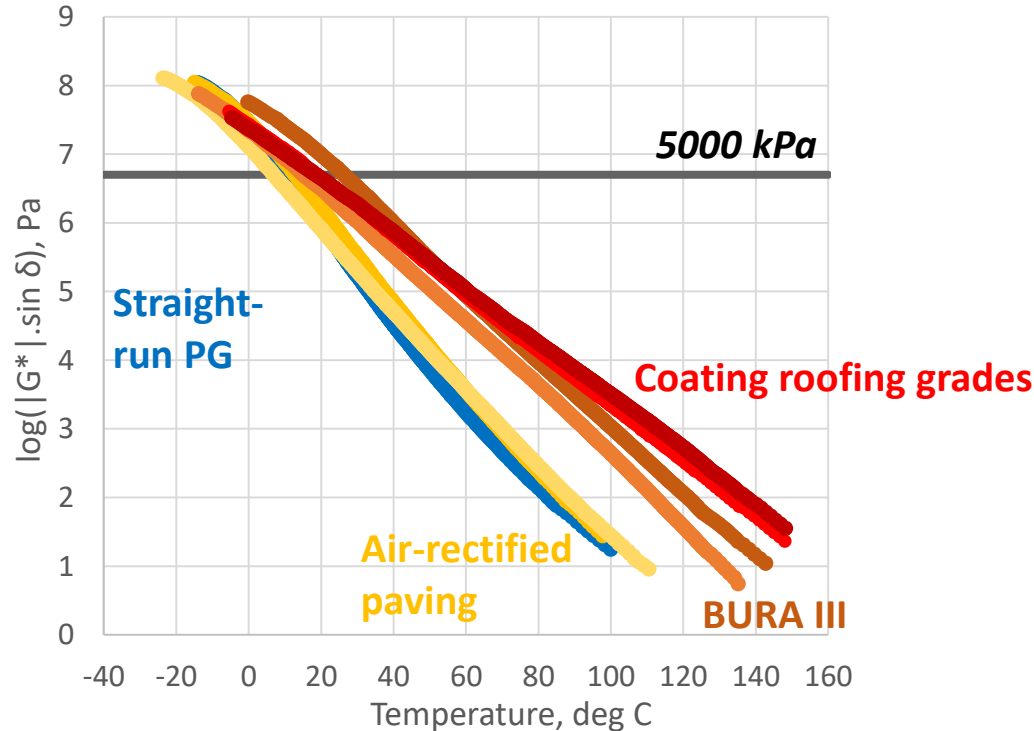
Background & Case for Action

- High test variability = poor performance discrimination



Background & Case for Action

- DSR-PAV cannot discriminate poor performing binders, namely phase instable binders exhibiting high rates of cracking.

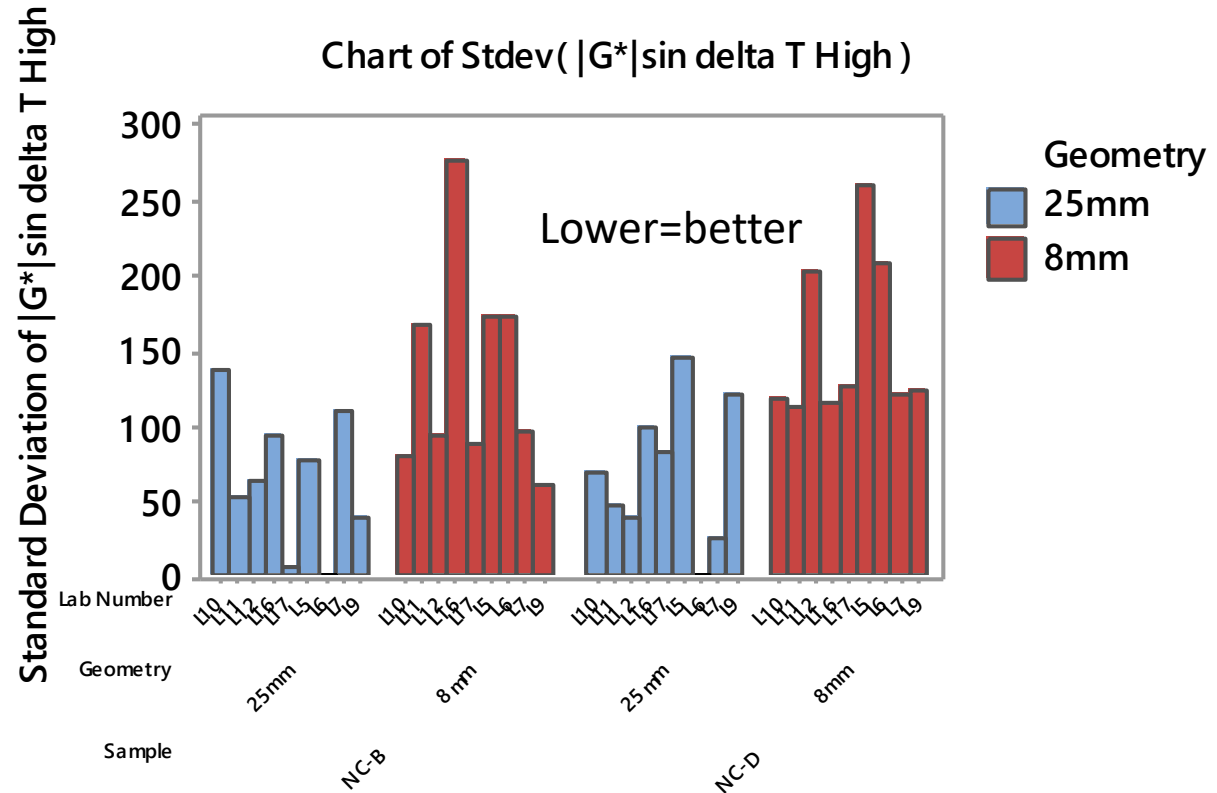
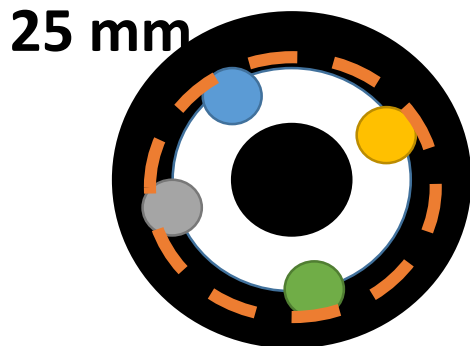
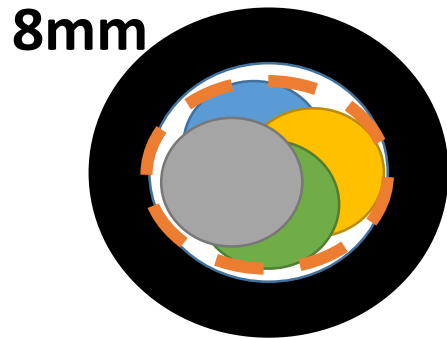


1. Modify T315 test protocol to reduce the test variability to acceptable level
2. Review scientific validity of DSR-PAV parameter $|G^*| \sin \delta$ to assess binder performance
3. Review ability of DSR-PAV test to discriminate poor performers

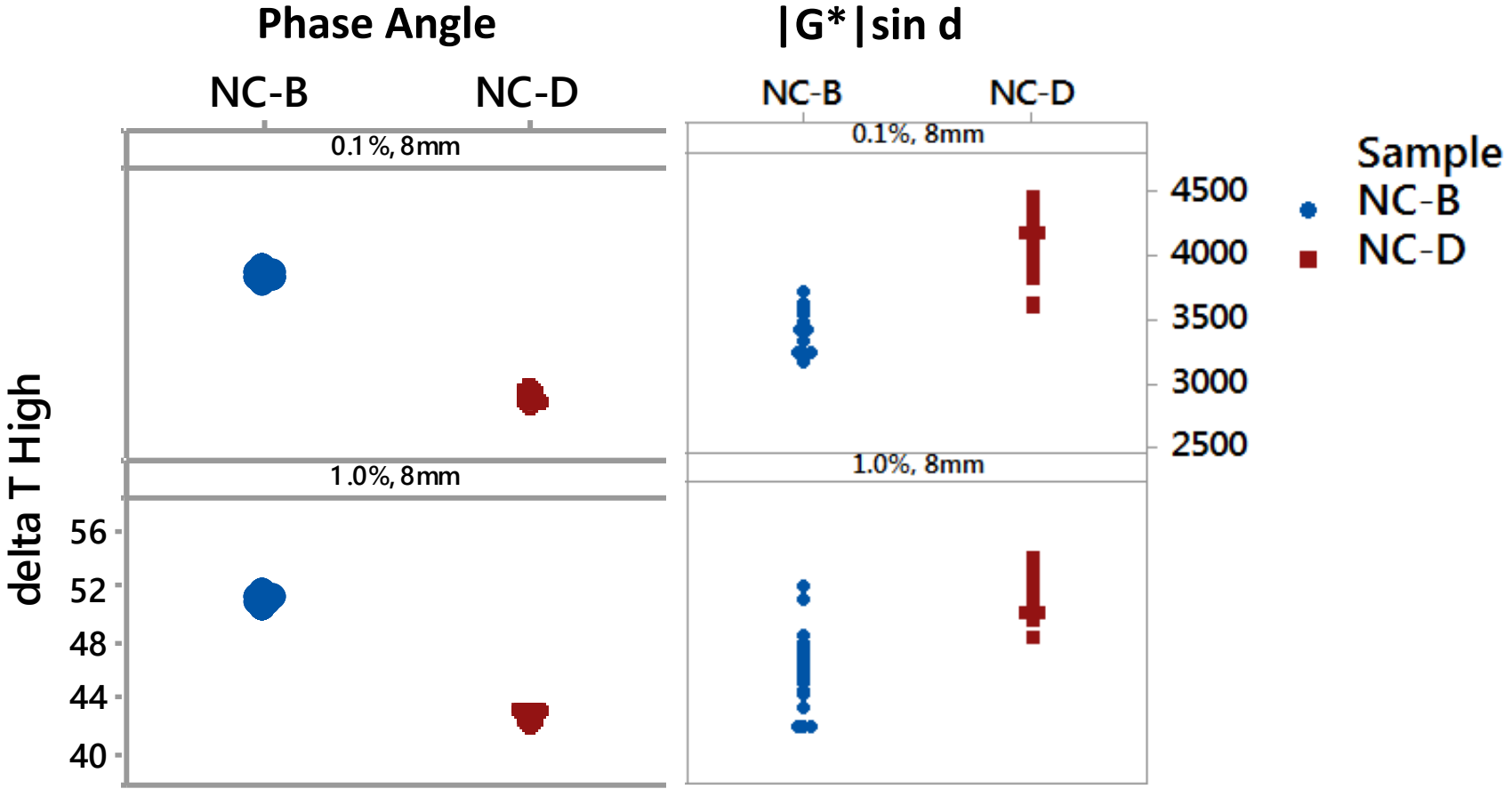
1. Two round robins conducted
 - Stage 1 – thermal equilibrium time
 - Stage 2 – optimal plate size & strain level
2. $|G^*| \sin \delta$ was analyzed for scientific validity
3. Ability of DSR-PAV parameter to discriminate poor performers was tested on 40 binders covering wide range of properties & compositions

Findings 1: Test Setup

- 25mm@0.1% strain test improved inter-lab repeatability
- When all labs were considered, data were more dispersed
- Test setup improvements are not viable

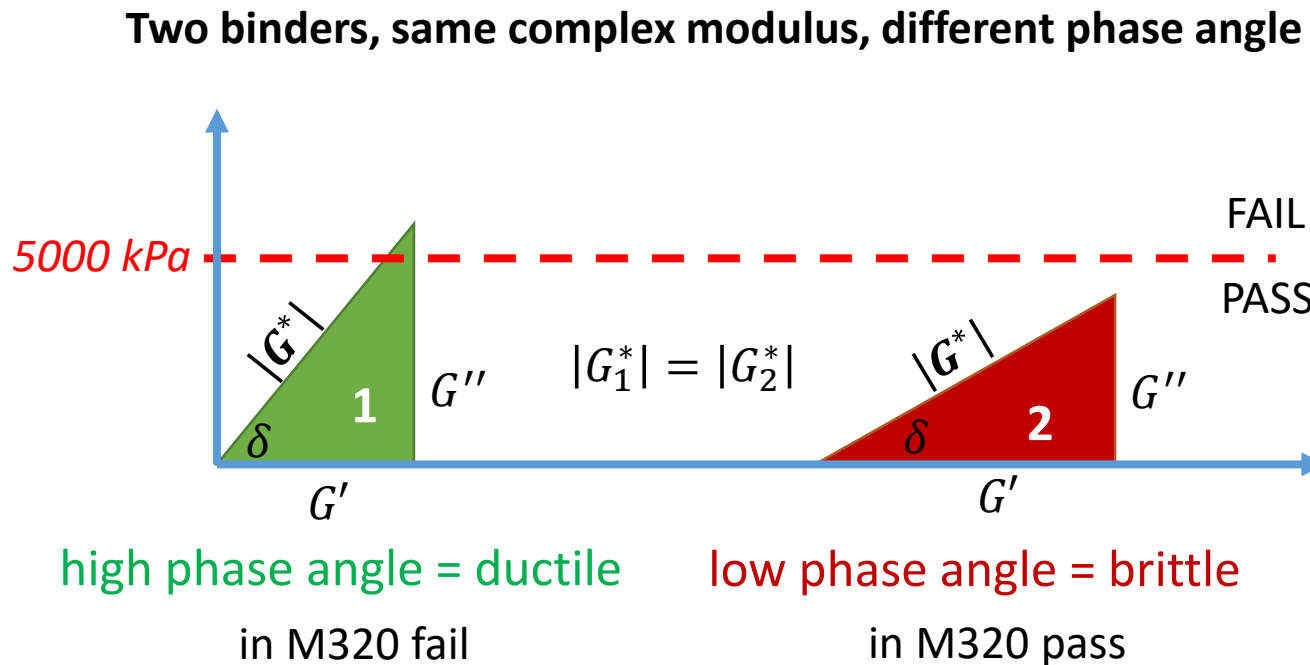


Phase Angle Discriminates Properties



Findings 2: Science Behind DSR-PAV

- Limiting $|G^*| \sin \delta$ ($= G''$) to a maximum limit is benefiting low phase angle, i.e. **brittle** binders
- High quality **ductile** binders with high phase angle are disadvantaged.

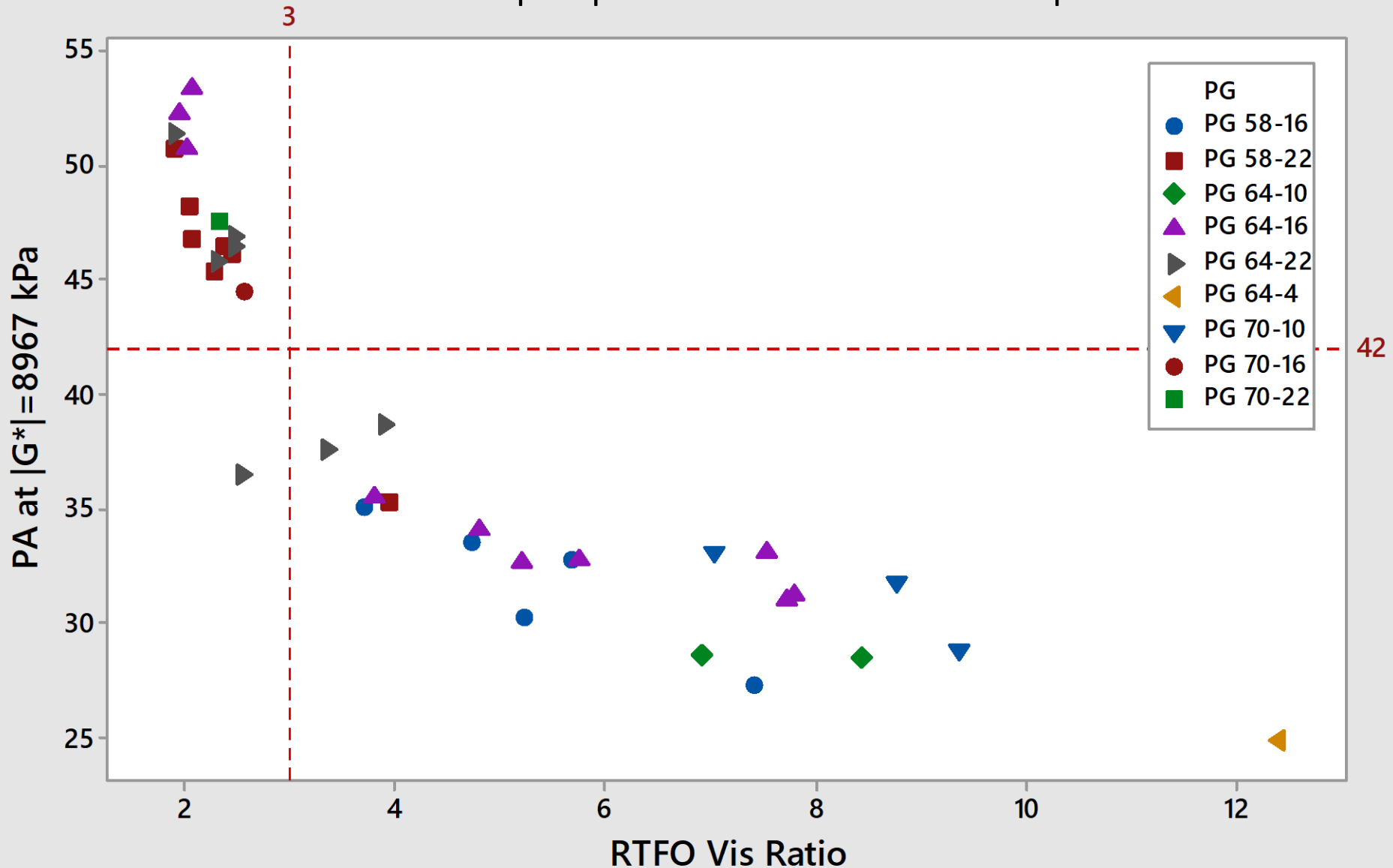


Findings 3: DSR-PAV vs. Binder Performance

- Phase instability is demonstrated in more negative delta Tc, higher aging index & lower phase angle
- These parameters are directly correlated to performance as they represent aging & relaxation rates; critical parameters when cracking is considered
- $|G^*| \sin \delta$ parameter was found not to correlate with any of these parameters, in contrary all samples passed $|G^*| \sin \delta$ limit of 5000 kPa

Phase Angle vs. Aging Rate

- All samples passed DSR-PAV for their respective PG



- Do not alter current AASHTO T315 test protocol
- Specify a parameter at intermediate temperature other than $|G^*| \sin \delta$.
- Support phase angle minimum limit at constant complex modulus value to replace $|G^*| \sin \delta$.
 - This approach utilizes correct science
 - Discriminates poor performers
 - Is practical – uses existing test protocol, labs are familiar with testing & historical data for comparison & validation exist. Best “speed to market” vs. other proposals

AI TAC supports changes to AASHTO M320 and M332 (S-grade) to allow binders with DSR-PAV $|G^*| \sin \delta$ parameter between 5001 - 6000 kPa (as for H, V, E grades), if their phase angle at the intermediate PG temperature is higher than 42 degrees to rectify an impact of a highly variable DSR-PAV test.

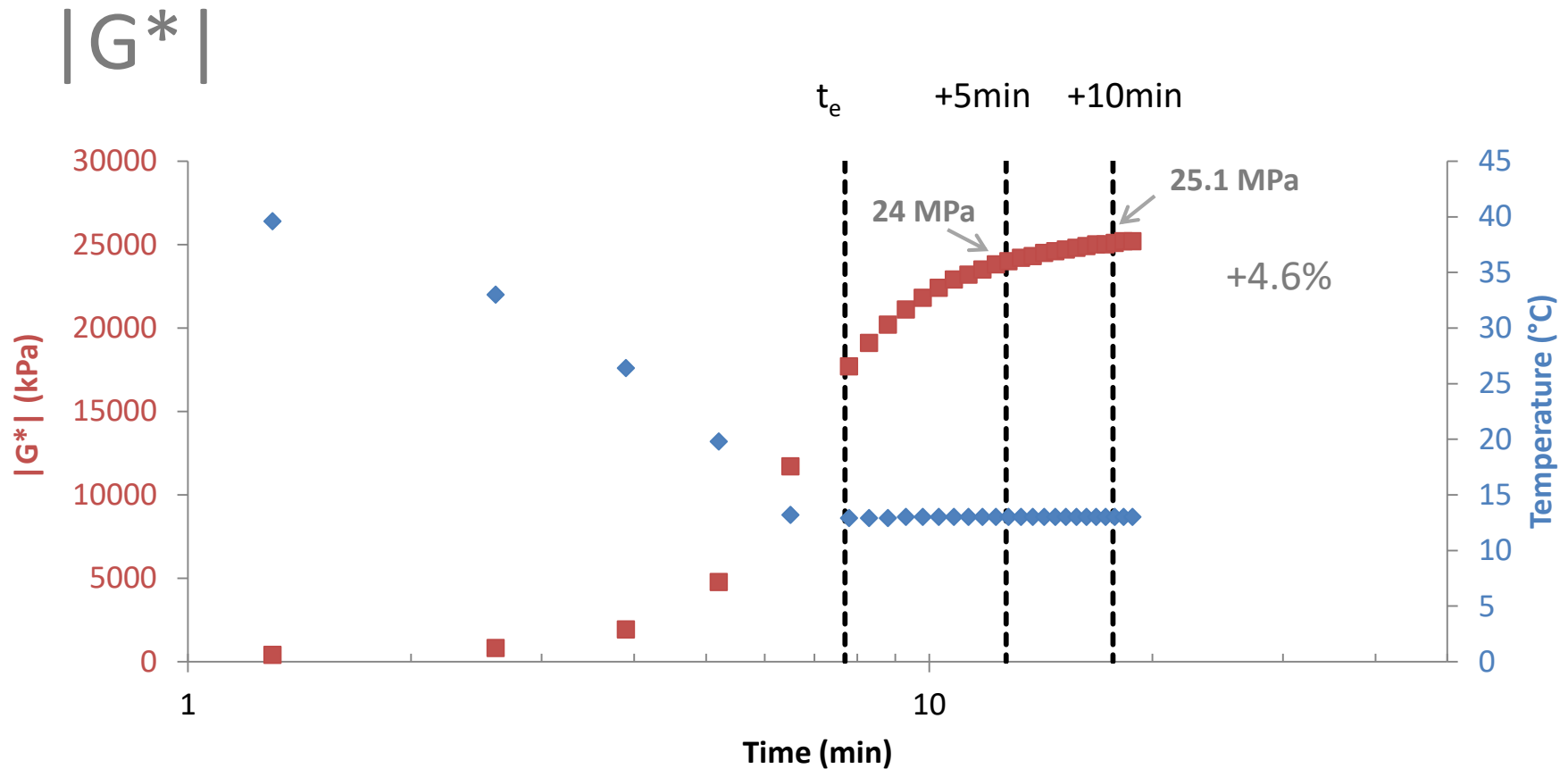
AI TAC supports industry efforts to replace $|G^*| \sin \delta$ parameter with a more repeatable and scientifically correct parameter

Appendix

Supporting Data Objective 1

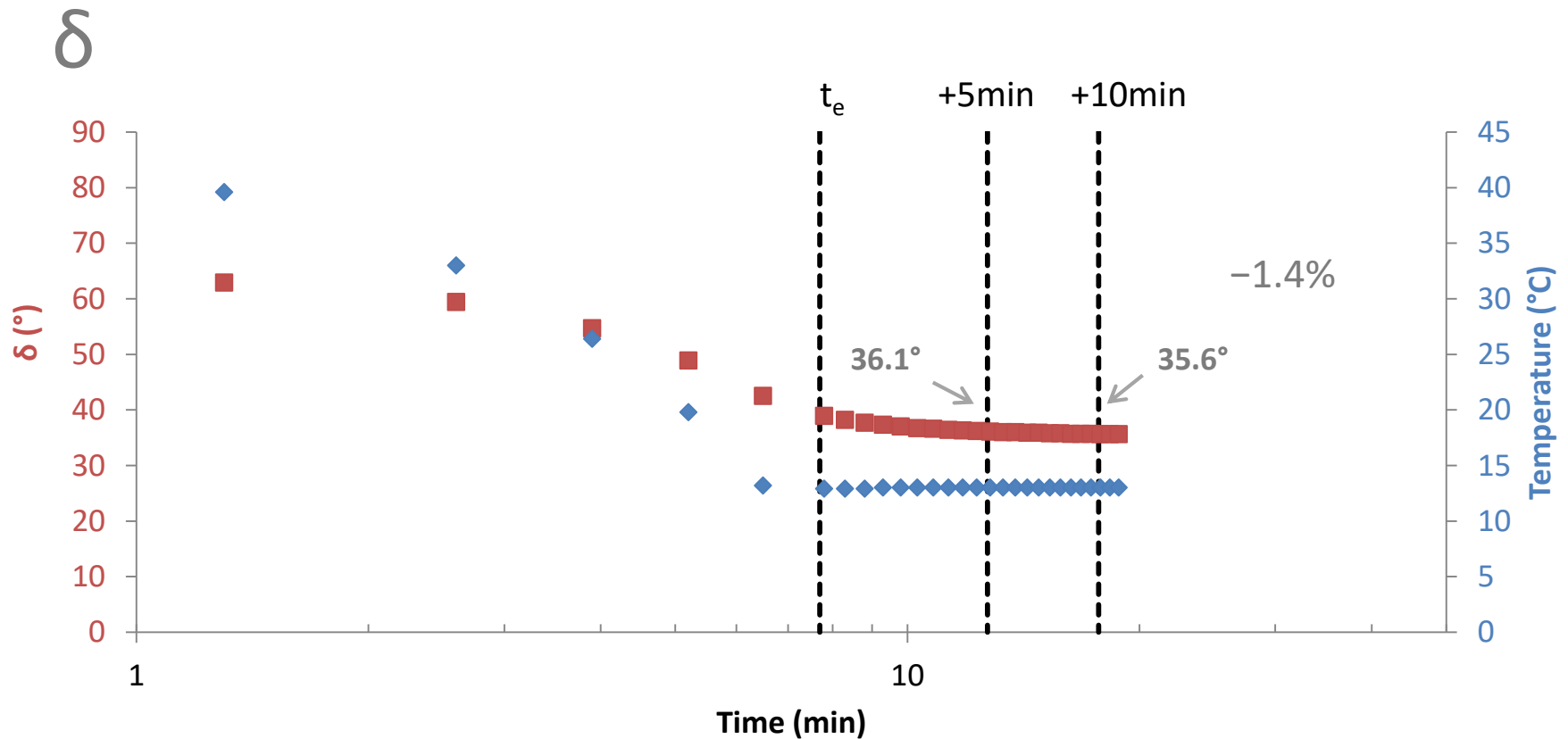
Thermal Equilibrium

1. Thermal Equilibrium is not a significant factor in DSR-PAV variability, however DSR manufacturers should further research it



Thermal Equilibrium

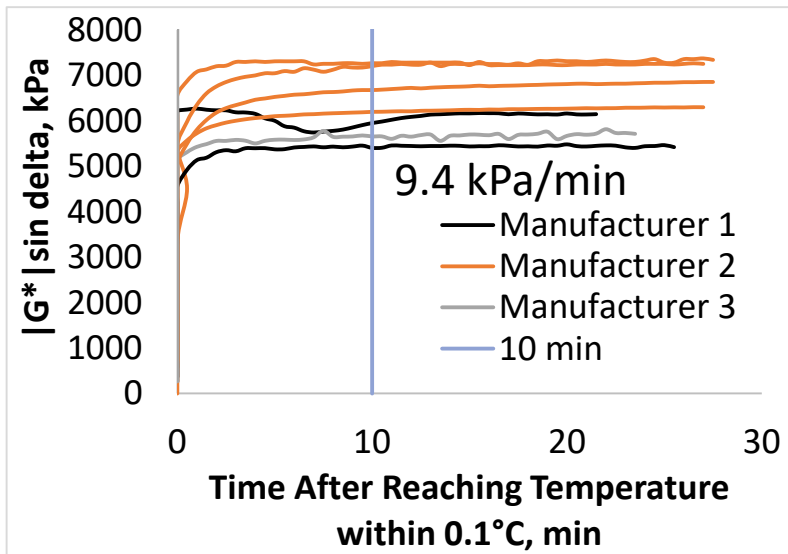
1. Thermal Equilibrium is not a significant factor in DSR-PAV variability, however DSR manufacturers should further research it



Thermal Equilibrium

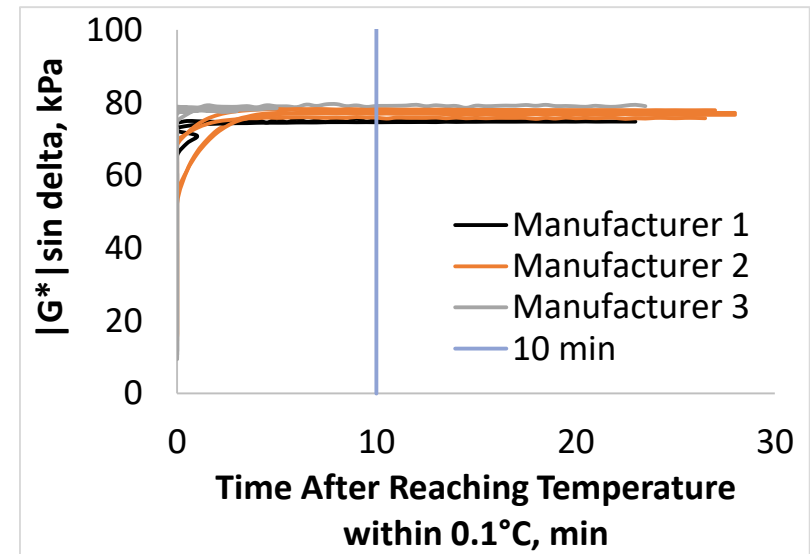
1. Thermal Equilibrium is not a significant factor in DSR-PAV variability, however DSR manufacturers should further research it

NC-D Asphalt



19 °C

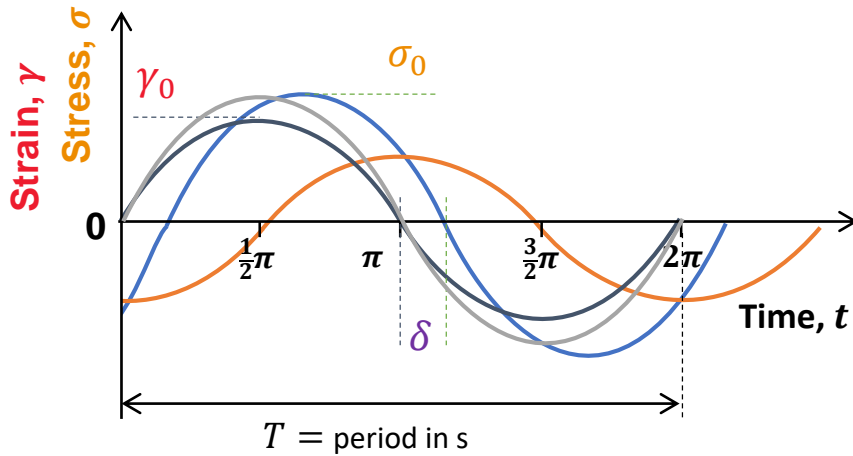
Cannon Standard



13 °C

Supporting Data Objective 2

Complex, Storage & Loss Moduli



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

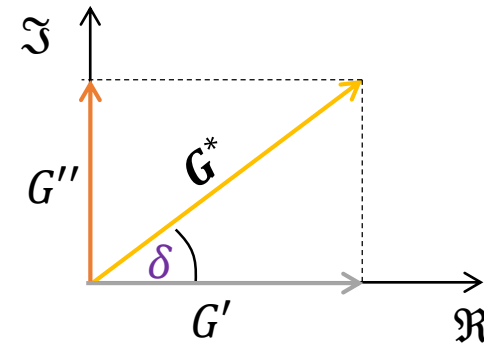
$$\sigma = \sigma_0 \sin(\omega t + \delta)$$

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

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

Representation in Complex Plane

(σ out of phase γ)
viscous



(σ in phase with γ)
elastic

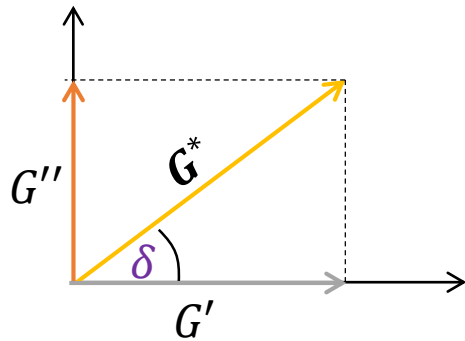
$$G^* = G' + iG''$$

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

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

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

Science Behind DSR-PAV

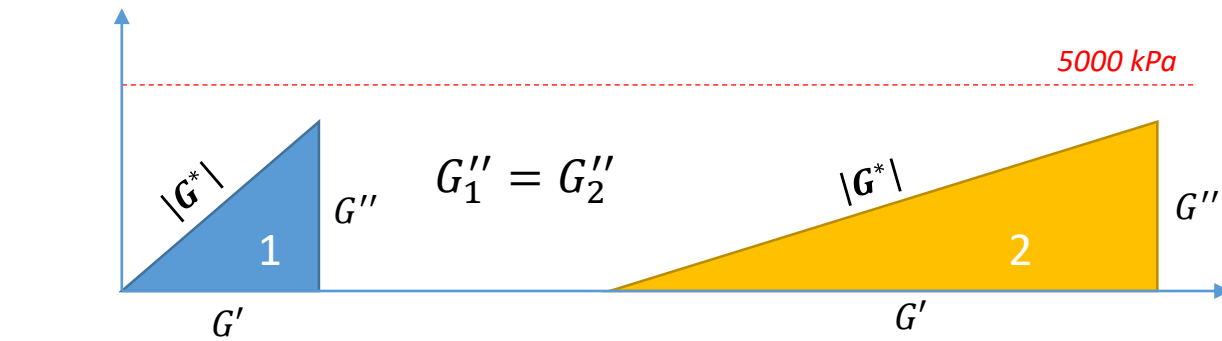


$$G^* = G' + iG''$$

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

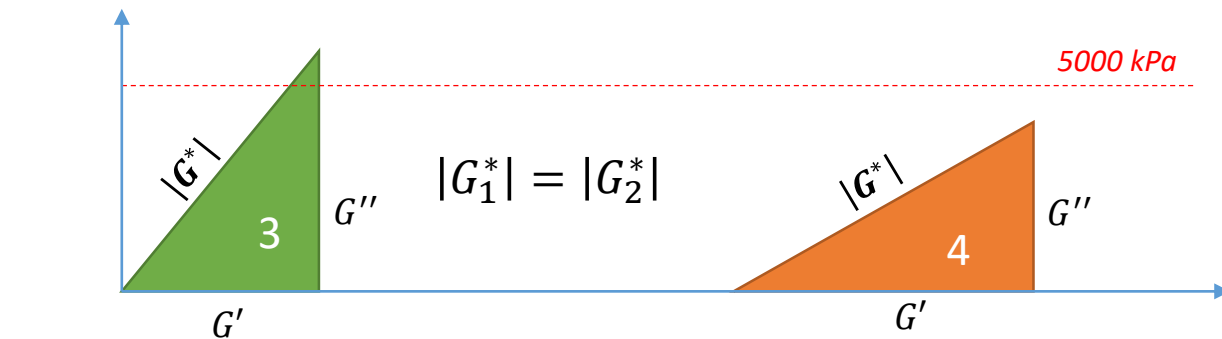
$$\tan \delta = G''/G'$$

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



high phase angle = ductile

low phase angle = brittle



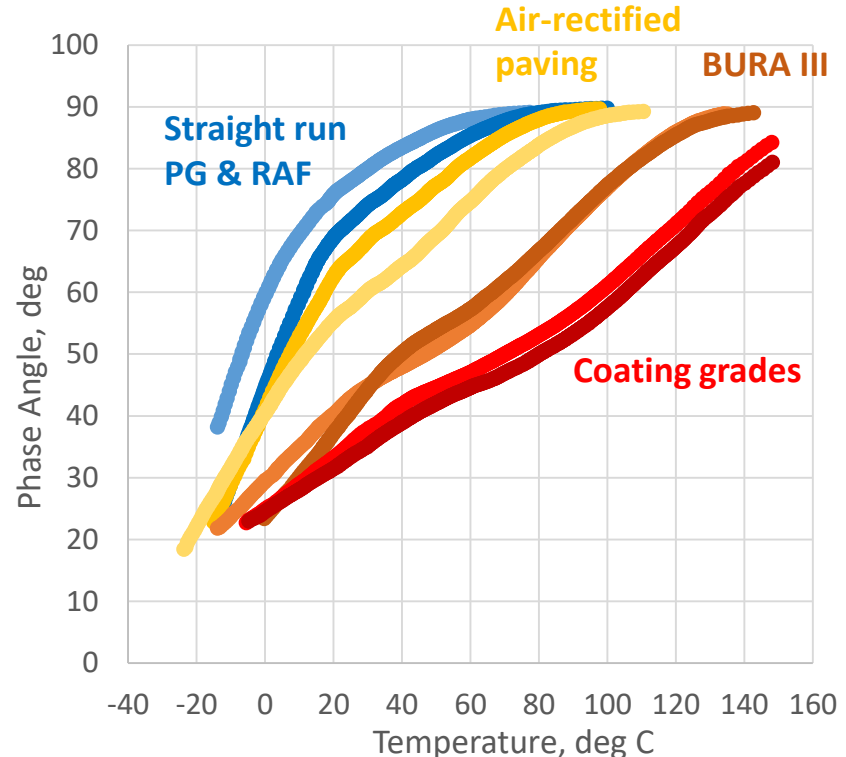
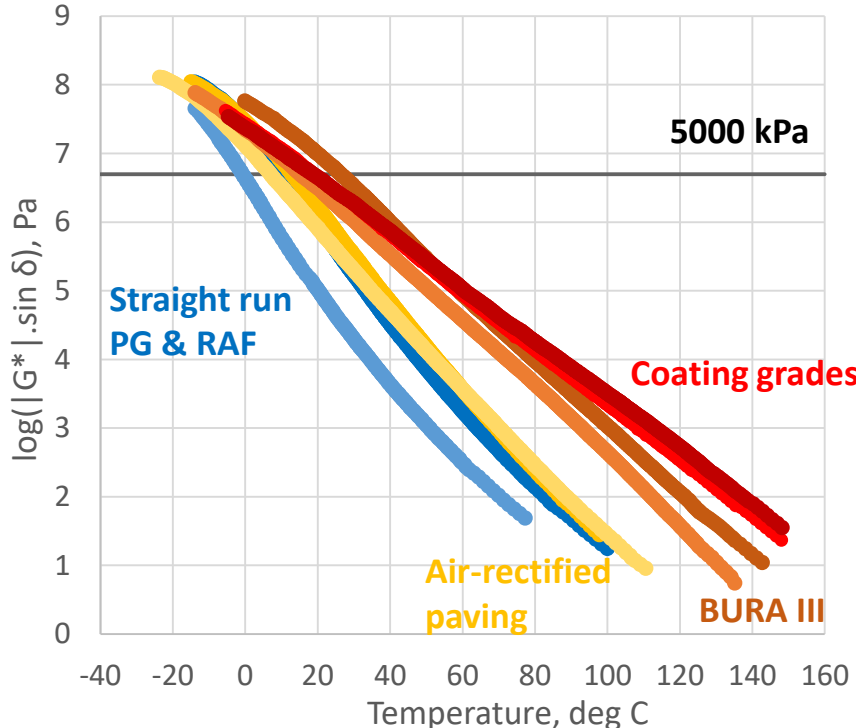
high phase angle = ductile

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.