DSR-PAV TF Update
ETG Meeting

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1. Stage 1 Completed \( \rightarrow \) 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 \( \rightarrow \) 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

**Individual Value Plot of Log |G*|, T high, Pa**

Panel variables: Geometry, Strain
Phase Angle is a very reliable measurement.

Individual Value Plot of delta T High

Panel variables: Strain, Geometry
Complex, Storage & Loss Moduli

\[ \sigma = \sigma_0 \sin(\omega t + \delta) \]
\[ \sigma = \sigma_0 \cos \delta \sin \omega t + \sigma_0 \sin \delta \cos \omega t \]

\[ \sigma = \gamma_0 \left[ \left( \frac{\sigma_0}{\gamma_0} \right) \cos \delta \sin \omega t + \left( \frac{\sigma_0}{\gamma_0} \right) \sin \delta \cos \omega t \right] \]

**Symbol** | **Modulus** | **Energy** | **Response**
--- | --- | --- | ---
\( G' \) | storage | stored | elastic
\( G'' \) | loss | dissipated | viscous
Science Behind DSR-PAV

\[ \Delta \Delta G'G' = G' + iG'' \]

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

\[ \tan \delta = \frac{G''}{G'} \]

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

low phase angle = brittle

high phase angle = ductile
• 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
Colloidal Stability & Aging Index

- Set of samples of varying phase stability prepared in the lab (by adding oil, asphaltenes, oxidation)
- Are $\Delta T_c$, 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 make sense?

**Low T PG**

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

**High T PG**

|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
COV for Phase Angle about 10x lower

Chart of COV $|G^*|\sin\delta$, %, COV Delta, %

Sample_1
- NC-B
- NC-D

COV $|G^*|\sin\delta$, %
- NC-B: 0.08
- NC-D: 0.04

COV Delta, %
- NC-B: 0.00
- NC-D: 0.01
Phase Angle Measurement is Less Variable

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 $|G^*|$

$$|G^*| \cdot \sin \delta = G''$$
• 5000 kPa limit suggested on very limited data developed from tests on asphalts used in the Zaca-Wigmore Test

Deaco Road 1

Limit Increase

Change to 6 MPa


Figure 13. Analysis of a Zaca-Wigmore Performance Results using $G^*$ sin $\theta$ at 25 °C, 10 rad/s, Pa

Estimated $G^*$ sin $\theta$ at 25 °C, 10 rad/s, Pa

Suggested 3 MPa limit for controlling age-hardening and fatigue

1E+06

1E+05

1E+07

Percent Fatigue Cracking

Log (Number of cycles - Nf)

5.0

5.5

6.0

4.5

4.0