Use of Phase Angle for Evaluating Binder Stress Relaxation and Aging Susceptibility

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SuperPave™ Developed for Traditional Asphalts

- SuperPave™ binder specification was developed & field-validated for refinery produced asphalts of 1980s
  - Limited high wax, severely air-blown, cracked stocks
- Chemistry Changes → Recycling & Performance

Crude Oil Production & Selection → Refinery Distillation

Distillation Yield, % vol.

- 100
- 75
- 50
- 25
- 0

Crude Oil Production & Selection

- Synthetics
- Light
- Medium
- Heavy
- Extra Heavy
- Bitumen

Refinery Distillation

- naphtha
distillates
- oils
residuum
Asphalt Yield & Quality

Straight-run Asphalt

Crude

A
D
U

V
D
U

Imperial
Asphalt of Today → Competition for Solvency

- Softeners
- Recyclers
- Lube Extracts
- Cracked Residues
- Waxes
- Aging
- REOB
- SBS/SB/SBR Polymer

**RAP ~20%**
- saturates
- aromatics
- resins
- asphaltenes

**Virgin ~75-80%**

Other non-petroleum additives: Bio-, PPA, WMA…
Screening Phase Instable Binders

• Phase instable asphalt binders are more susceptible to oxidative aging and can lead to phase separation, poor stress relaxation, and cracking

• Today, SuperPave™ uses DSR-PAV $|G^*|\sin\delta$ parameter to screen for binders with high potential for cracking

• Recent work has found that phase instability is demonstrated by more negative $\Delta T_c$, higher aging index & lower phase angle

• It has been found that DSR-PAV $|G^*|\sin\delta$ parameter does not correlate with any of these parameters and does not effectively distinguish binders prone to cracking
\(|G^*|\sin\delta\) does not Differentiate Binders

- DSR-PAV cannot discriminate poor-performing binders, namely phase instable binders exhibiting high cracking rates.
$|G^*|\sin\delta$ does not Correlate to Relaxation

**DSR-PAV Limiting Temperature**

- Compare straight-run Cold Lake PG 64-22 to Cold Lake PG 70-XX softened to PG 64-22 with REOB
The Challenge with $|G^*|\sin \delta$

Two binders, same complex modulus, different phase angle

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

Two binders, same complex modulus, different phase angle

- SuperPave™ intention was to limit high stiffness, brittle binders
- Low phase angle binders are advantaged
- High quality **ductile** binders with high phase angle are disadvantaged.

**Proposed Alternative:** Measure and limit phase angle
Phase Angle Differentiates Binders

- Phase angle can better resolve binders based on quality
Verification with Two Datasets

1) Experimental laboratory blends (37) → Wide range of phase compatibilities; components/methods include:
   • ‘asphaltenes’ fraction (12, 29 & 46 % n-Heptane insoluble)
   • 3 paraffinic oils (viscosity at 60 °C of 0.1, 0.07 & 0.02 Pa.s)
   • 3 straight-run asphalts
   • varying degrees of air-blowing

2) ExxonMobil Asphalt Assay Database (EMAAD): Laboratory prepared straight run asphalts (522)
   • Extremely diverse crude oil origins well beyond suitable asphalt blends
Performance Grade Distribution of Binders
Phase Angle versus Relaxation - $\Delta T_c$

All samples passed DSR-PAV for their respective PG!
Phase Angle versus Relaxation - $\Delta T_c$

![Graph](image-url)

Phase Angle at $|G^*| = 8967$ kPa, °
Phase Angle versus Aging Rate - Viscosity Ratio
Advantages of Phase Angle

1. Measured as part of T315/M320 since dawn of SuperPave™

2. Highly repeatable measurement
   • AASHTO precision for PAV residue (1s/d2s): 0.09°/0.25° and 0.76°/2.11° for single operator & multiple laboratories, respectively
   • 2.11° at 45° is 4.7% for phase angle vs. 40.2% for $|G^*|\sin\delta$

3. When determined at constant magnitude of complex modulus related to morphology/composition and not time/temperature
   • No need for somewhat arbitrary determination of DSR-PAV temperature
Summary

• SuperPave™ is highly sophisticated & functional system

• It has pre-built features at our fingertips we can use to better screen asphalts of today

• Minor modification to M320/M332 can be done easily to improve its selectivity to performance (i.e. replace $|G^*|\sin \delta$)

• Approach is practical & offers fast field validation

• Let’s use what we already have