Effects of Foaming on Performance of Binders Modified with (PPA) Additive

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Objectives & Roles of Research Team

- **Objective:** Foaming is widely used for WMA production. Investigate the effect of foaming on the performance of PPA modified binders.

- **Why so many authors? Real contributions:**
  - Olga and Rene made the plan
  - Cris and Raquel conducted testing and analysis
  - Henry paid for the “beers”
  - Hussain is presenting!
  - No one wants to answer questions...
Materials:

- **Asphalt Binders:**
  - Flint Hills PG 64-22 and Valero PG 64-16.

- **Polyphosphoric Acid (PPA):**
  - ICL- Concentrations of 0.8% and 1.5%.

- **Water**
# Test Methods and Conditions:

<table>
<thead>
<tr>
<th>Property</th>
<th>Test</th>
<th>Details/ Test conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability</td>
<td>Viscosity</td>
<td>• Same as below</td>
</tr>
<tr>
<td>Performance Grading (HT)</td>
<td>DSR - Continuous Grading</td>
<td>• Unfoamed asphalt binders</td>
</tr>
<tr>
<td></td>
<td>MSCR Test @ 64 C</td>
<td>• Foamed and cured for 2 and 24 hrs at 135°C</td>
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<tr>
<td></td>
<td>Linear Amp. Sweep (LAS) @ 25 C</td>
<td>• Foamed and cured for 2 and 24 hrs at room temp</td>
</tr>
<tr>
<td></td>
<td>• BBS @ 22 C</td>
<td>• Foamed/ unfoamed asphalt binders</td>
</tr>
<tr>
<td></td>
<td>• Mixture T283 ITS at 25 C</td>
<td>• 24 h curing at 135°C</td>
</tr>
</tbody>
</table>

**July 10, 2012**
Wirtgen WLB-10 Laboratory Foaming Plant

Water added = 2.2-2.3%
Temp = 160 °C
Bitumen Bond Strength Test

\[ POTS = \frac{(BP \times Ag) - C}{A_{ps}} \]

- \( Ag \) = contact area of gasket with reaction plate (mm\(^2\))
- \( BP \) = burst pressure (kPa)
- \( A_{ps} \) = area of pull stub (mm\(^2\))
- \( C \) = piston constant
BBS Test – Typical Results

- Maximum Pull Off Pressure
- Cohesive Failure
- Adhesive Failure

Graph showing pull off pressure versus time for dry and moisture conditioned samples.
Linear Amplitude Sweep Test
Progression of Fatigue Fracture

Increasing loading duration

Image analysis used to determine crack length

Source: Hintz 2012

\[ N_f = A \cdot \gamma^B \]
Continuous PG Grading Un-foamed, Neat and RTFO- Flint Hills Binder

True Grade, °Celsius

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>True Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>FH neat OB</td>
<td>PG 70</td>
</tr>
<tr>
<td>FH +08 PPA</td>
<td>PG 76</td>
</tr>
<tr>
<td>FH +1.5 PPA RTFO</td>
<td>PG 70</td>
</tr>
<tr>
<td>FH +1.5 PPA RTFO</td>
<td>PG 76</td>
</tr>
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</tbody>
</table>
Continuous PG Grading Un-foamed, Neat and RTFO – Valero Binder
Foaming Results - Viscosity - FH Curing at Room Temperature ~ 23°C
Foaming Results - Viscosity - FH Curing at $135^\circ C$
Foaming Results - Viscosity - Valero
Curing at 135°C
Recovery of Continuous Grade Flint Hills binder - @ Room Temp (22-23 C)
Results - Continuous Grade Valero Binder at Room Temperature

Conditioning at Room Temperature

- Valero 64-16 Neat
- Valero 64-16 + 0.8% PPA
- Valero 64-16 + 1.5% PPA

True Grade (°)

- Unfoamed
- Foamed, 0 h
- Foamed, 2 h
- Foamed, 24 h
Results-Continuous Grade Valero Binder at 135°C

Conditioning at 135°C

- Valero 64-16 Neat
- Valero 64-16+0.8%PPA
- Valero 64-16+1.5%PPA

- True Grade (°C)
  - Unfoamed
  - Foamed, 0 h
  - Foamed, 2 h
  - Foamed, 24 h

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Fatigue – LAS Results
Foamed + Cured 24 hrs @ 135 + RTFO

FH log % Strain vs. log # Cycles

1.5 % PPA
0.8 % PPA
Neat

Favorable Trend
Longer fatigue life

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Fatigue – LAS Results – Valero
Foamed + Cured 24 hrs @ 135 + RTFO

Nf35 - Cycles to 35% damage

1.5 % PPA
0.8 % PPA
Neat

Favorable Trend
Longer fatigue life

VAL log % Strain vs. log # Cycles
MSCR Results
Foamed + Cured for 24 hrs @135 C + RTFO

![Bar chart showing MSCR results for different samples.]
Effects on Bond Strength with Aggregates - dry

0 hours - Dry

Pull-off Strength (MPa)

- UNFOAMED
- FOAMED

FH64-22 Neat
FH64-22+0.8%PPA
FH64-22+1.5%PPA
VAL64-16 Neat
VAL64-16+0.8%PPA
VAL64-16+1.5%PPA

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Effects on Bond Strength – Wet (96 h at 40 C)

96 hours - Wet

- UNFOAMED
- FOAMED

Pull-off Strength (MPa)

FH64-22 Neat
FH64-22+0.8%PPA
FH64-22+1.5%PPA
VAL64-16 Neat
VAL64-16+0.8%PPA
VAL64-16+1.5%PPA

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Results-Bond Failure and Effect of Moisture – Foamed Binders

Neat Binder
FH 64-22
Dry

Neat Binder
FH 64-22
Wet 96 hrs

Modified Binders

FH 64-22 + 0.8 PPA – Wet 96 hrs

FH 64-22 + 1,5 PPA – Wet 96 hrs
Results-Bond Failure and Effects of Moisture – Foamed Binders
Results-Mixture’s Indirect Tensile Strength & Moisture Effects

![Graph showing tensile strength data for different conditions and mixtures.]

- **Neat**
  - TSR = 0.32 – 0.34
- **0.8% PPA**
  - TSR = 0.73 – 0.76
Conclusions- Viscosity

- **Effect of PPA on Viscosity:**
  - 0.8% of PPA caused only minor increase in viscosity.
  - 1.5% of PPA increased viscosity by ~ 0.31 - 0.44 Pa.s.

- **Effect of Foaming on Viscosity:**
  - Foaming reduced viscosity of PPA modified binders slightly more than the base binders, in particular when 1.5 % PPA was used.
  - Curing for 24 h at 135 C caused PPA binders to recover.
  - When storing at room temperature, the recovery takes longer time.

- In all cases the margins of change are small and not important considering the limit of 3.0 Pa-s.
Conclusions- PG grades

- Effect of Foaming on PG True Grade (TG):
  - Foaming does not have significant effect on the high temperature TG of base binders (effect is less than 1.0 C).
  - However the initial effect on TG of PPA-modified is significant.
  - For the binders modified with 0.7-0.8 % PPA, the effects are less than 2.0 C and there is a clear recovery of the grade after 24 h conditioning at 135 C or at room temperate.
  - Conditioning at room temperature shows less recovery, but there appears to be a trend that higher temperature storage could expedite this.
  - For the binders modified with 1.5% PPA, the initial effects on TG are higher (2-6 C reduction in grade). Conditioning at 135 for 24 h can cause almost full recovery of the grade before foaming.
Conclusions – Bond strength and moisture effects

- Effect of Foaming on Binder’s Bond to Aggregates:
  - Foaming cause a minor reduction in initial-dry bond strength with aggregates.
  - All samples containing PPA however show significantly higher bond strength after 96 hours of wet conditioning.
  - Failure modes after moisture conditioning were mainly cohesive for PPA binders, which indicates bond at the aggregate-binder interface is greater than the cohesive strength of the foamed binders.
Conclusions – Fatigue and Rutting of binders

- Foaming did not affect fatigue and rutting performance of PPA binders.
- Fatigue life of PPA modified foamed binders are equal or better than base binder.
- Also, the rutting resistance as measured by the Jnr compliance at 3.2 kPa is much better of the PPA binders than the base binder.
Acknowledgments

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• Presentation posted at UWMARC.org
  - Questions: please e.mail me bahia@engr.wisc.edu