DEVELOPMENT OF ASPHALT RUBBER BINDER SPECIFICATIONS IN CALIFORNIA: PROJECT UPDATE

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Outline

- Background
- Short-term aging
- High temperature tests
- Intermediate temperature tests
- Low temperature tests
- Way forward
Background

- Update on the update given at the September 2014 ETG meeting (Phase 1, lab-produced binder)
- Recap on asphalt rubber in California
  - AB338 (2005) requires Caltrans to use asphalt rubber in at least 35% of all AC placed
    - Asphalt rubber defined as 18-22% CRM by weight of binder
    - CRM is 100% passing #8 (2.36mm)
    - Termed “wet process”, used in gap- & open-graded mixes
    - Binder QC essentially only viscosity (handheld viscometer)
  - “Terminal blend” rubber binder considered in PG-M spec
  - Caltrans 2015 mandate requires that all surface courses placed below 3,000ft are asphalt rubber mixes
- SB1 funding
Background

- Phase 1 study compared concentric cylinder with parallel plate on laboratory-produced AR binders
  - Concern about ratio between rubber particle size and gap influencing the result
  - Plate gap was 1mm or 2mm depending on particle size
  - Limited testing on 3mm and 4mm gaps due to trimming and slump issues
Phase 1 CC vs. PP

All binders

\[ y = 0.9526x + 0.0085 \]

\[ R^2 = 0.9508 \]

250-425µm

\[ y = 0.8851x + 0.0734 \]

\[ R^2 = 0.949 \]

180-250µm

\[ y = 0.9552x + 0.0679 \]

\[ R^2 = 0.9963 \]

425-850µm

\[ y = 1.0544x - 0.1735 \]

\[ R^2 = 0.9497 \]

0.0

0.5

1.0

1.5

2.0

2.5

3.0

3.5

4.0

G*/sinδ - Concentric Cylinder

G*/sinδ - Parallel Plate

Caltrans spec allows particles up to 2,300µm (<2.36mm)
Background

- Phase 2 study on plant-produced binders and mix
  - AR binders tested with 3mm gap on 25mm and 8mm plates
  - Conventional binders tested with 1mm gap on 25mm plates and 2mm gap on 8mm plates
  - Mix testing to interpret rheological properties

- Parallel studies
  - Caltrans/Industry task group study on 3mm parallel plate gap
  - Round robin testing by 16 laboratories completed
  - UCPRC tested with concentric cylinder as well
  - Task group report in preparation

- Caltrans will decide which approach to use
## Phase 2 Experiment Plan

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Number</th>
<th>Progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR binder source</td>
<td>5 (statewide)</td>
<td>Tested 2</td>
</tr>
<tr>
<td>Base binder&lt;sup&gt;1&lt;/sup&gt;</td>
<td>??</td>
<td>Tested 3</td>
</tr>
<tr>
<td>AR mixes&lt;sup&gt;2&lt;/sup&gt;</td>
<td>5</td>
<td>Tested 2</td>
</tr>
<tr>
<td>PM Binders (PG-M spec)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>2</td>
<td>Tested 2</td>
</tr>
<tr>
<td>TR Binders (PG-M spec)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>2</td>
<td>Tested 2</td>
</tr>
</tbody>
</table>

<sup>1</sup> Control testing  
<sup>2</sup> Beam fatigue, SCB, dynamic modulus, flow number, TSRST, etc.
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AR Mixing & Production Temps.

- Temperature when CRM is added to asphalt binder plus extender oil
  - 375°F to 440°F (190°C to 225°C)

- Mix production temperature
  - 375°F and 425°F (190°C to 218°C)
  - Conventional mixes typically between 290°F and 320°F (143°C to 160°C)

- Current RTFO testing temperature (163°C) is based on short-term aging of unmodified binders with no particulates
RTFO Test Method Limitations

- Current method not considered appropriate for AR binder, because:
  - Aging temperature does not simulate AR binder temperature during mix production
  - Aging of the AR binder is non-uniform due to incomplete coating of the bottles
  - Quantity of binder available after aging is often insufficient for DSR and BBR testing
## Proposed Changes

<table>
<thead>
<tr>
<th>Test Parameter</th>
<th>Current</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>163</td>
<td>190</td>
</tr>
<tr>
<td>Duration (minutes)</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>Sample size (g)</td>
<td>35</td>
<td>= to 35 of base binder(^1)</td>
</tr>
<tr>
<td>Oven tilt (°)</td>
<td>zero</td>
<td>zero</td>
</tr>
</tbody>
</table>

\(^1\) 45 grams of AR binder with 20% CRM
Modified RTFO Procedure

163°C  35 g

190°C  45 g
$G^*/\sin(\delta)$ at 64°C
Summary

- Key findings
  - Testing at 163°C does not appear to be appropriate for AR binders due to poor bottle coating; testing at 190°C considered to be more representative
  - Higher binder stiffnesses at 190°C, as expected (increased high PG temperature by up to 9°C)
  - Larger sample volume did not significantly effect results, but did help for DSR/BBR test requirements (can be adjusted to suit)
  - No spillage noted with 45 gram sample (oven not tilted)

- Likely recommendation
  - Dependent on remaining tests, but will probably suggest doing RTFO test at 190°C
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High Temperature Tests

- Testing geometry
  - Concentric cylinder with 17mm bob and 6mm gap

- Test methods
  - Binder viscosity (for workability)
  - PG grade
  - MSCR test
  - Frequency sweep test

- Tests on both original and short-term aged binders
CC vs. PP (Unaged at 70°C)

G*/sin(δ) at 70°C

- **CC 17 mm**
- **PP- 25 mm**

![Graph showing G*/sin(δ) at 70°C for different samples.](image-url)
CC vs. PP (RTFO-Aged at 64°C)

G*/sin(δ) at 64°C

- CC 17 mm
- PP - 25 mm
CC vs. PP (RTFO-Aaged at 70°C)

G*/sin(δ) at 70°C

- CC 17 mm
- PP - 25 mm

[Bar chart showing the comparison of G*/sin(δ) at 70°C for CC 17 mm and PP 25 mm across different samples.]

Examples of sample codes:
- 64-16-a
- 64-16-b
- 64-16-c
- 64-28PM-a
- 64-28PM-b
- 64-28TR-a
- 64-28TR-b
- AR-PP-a
- AR-PP-b

Values for G*/sin(δ) at 70°C:
- 2.1, 2.0, 1.5, 1.4, 1.1, 1.1, 2.4, 2.5, 3.3, 3.4, 3.2, 3.3, 2.0, 2.0, 7.7, 10.7, 38.0, 40.8

Sample sizes and conditions:
- CC 17 mm
- PP 25 mm

UCPRC
Summary

- Key findings
  - Difference between CC and PP, as expected on 2 out of 5 samples
  - Difference/variability appears to depend on rubber particle size
- Likely recommendation
  - No recommendation until binder and mix testing is complete
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Intermediate Temperature Tests

- Modified concentric cylinder geometry based on study with Anton Paar
  - Spindle with 10 mm diameter
  - Test temperatures > 16°C (machine limits)
  - Tests are performed on RTFO+PAV aged binder
  - Separate study to check whether PAV test conditions (testing time, temperature, sample size, etc.) need to be adjusted to account for rubber particles
CC vs. PP (Aged)

G*. sin(δ) at 25ºC (kPa)

- CC-10 mm
- PP- 8 mm
CC vs. PP (Percent Difference)

% Difference for $G^*/\sin(\delta)$ at 25ºC

- 64-16-a: 18.6
- 64-16-b: 0.7
- 64-16-c: 4.9
- 64-28PM-a: 4.5
- 64-28PM-b: 13.0
- 64-28TR-a: 11.1
- 64-28TR-b: 4.1
- AR-PP-a: 0.2
- AR-PP-b: 56.4
Summary

- **Key findings**
  - Difference between CC and PP on all binders tested
    - Shrinkage, confinement in CC?
    - Trimming in PP?
  - Further testing required before conclusions can be drawn
  - Refinement of test method may be required

- **Likely recommendation**
  - No recommendation until binder and mix testing is complete
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Low Temperature Tests

- Test method modification
  - Use modified BBR mold to remedy issues associated with pouring the AR binder and preparing a uniformly shaped beam
  - Use revised RTFO test method
Standard Mold
Modified Mold
Modified Mold

Modified mold

Standard mold

Modified mold
Mod. vs. Std. (Creep Stiffness)

<table>
<thead>
<tr>
<th>Test Temp: -6°C</th>
<th>Test Temp: -18°C</th>
<th>Test Temp: -6°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>64-16-a 83</td>
<td>64-16-a 83</td>
<td>64-16-b 105</td>
</tr>
<tr>
<td>64-16-c 97</td>
<td>64-16-c 97</td>
<td>64-28PM-a 160</td>
</tr>
<tr>
<td>64-28PM-a 160</td>
<td>64-28PM-b 160</td>
<td>64-28TR-a 156</td>
</tr>
<tr>
<td>64-28TR-a 156</td>
<td>64-28TR-b 158</td>
<td>64-28TR-b 158</td>
</tr>
<tr>
<td>AR-PP-a 33</td>
<td>AR-PP-a 33</td>
<td>AR-PP-b 26</td>
</tr>
</tbody>
</table>

Creep Stiffness (MPa)

- Modified Mold
- Standard Mold
Modified vs. Std. (m-value)

- Modified Mold
- Standard Mold

Test Temp: -6°C
- 64-16-a: 0.319
- 64-16-b: 0.331
- 64-16-c: 0.399
- 64-28PM-a: 0.371
- 64-28PM-b: 0.316
- 64-28TR-a: 0.319
- 64-28TR-b: 0.318
- AR-PP-a: 0.319
- AR-PP-b: 0.331

Test Temp: -18°C

Test Temp: -6°C
Summary

- Key findings
  - Modified mold much easier to use and it produces better quality specimens than conventional mold
  - Results appear to be realistic

- Likely recommendation
  - Consider modified mold for AR binders
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Way Forward...

- Complete testing of plant-produced AR binders and mixes (3 complete, 2 in progress)
- Compare performance-related properties of mixes with rheological properties of their corresponding binders (3 complete, 2 in progress)
- Evaluate PG grading criteria for AR binders (i.e., what do the numbers mean?)
Thank-you

Photo courtesy Caltrans

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