DEVELOPMENT OF RUBBER BINDER SPECIFICATIONS IN CALIFORNIA: PROJECT UPDATE

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Outline

- California rubber binder
- High temp. performance-related testing
- Short-term aging of AR asphalt binder
- Long-term aging of AR binders
- Int. temp. performance-related testing
- Low temp. performance-related testing
- Work in progress
- Conclusions
Asphalt Rubber Binder

- **Caltrans Definition:**
  - A combination of asphalt binder, crumb rubber modifier (CRM), and asphalt modifier (i.e., Ext. oil).
  - Must have at least **18 to 22 percent CRM** by weight in total blend.
  - CRM must contain **25.0±2.0 percent high natural crumb rubber**.
  - Only ambient grinding process is allowed for producing CRM. Fiber and metals can be taken out cryogenically.
  - **2% to 6% extender oil** must be used by weight of base binder.
High Temperature Performance-Related Testing
AR Binder High Temp. Testing

- Selecting appropriate testing geometry
  - Concentric cylinder with 6mm gap considered more appropriate than parallel plate

- Selecting test methods
  - AR binder viscosity (for workability)
  - PG grade conv. test
  - MSCR test
  - Frequency sweep test

- Tests must be performed on both original and short-term aged binders
  - Selecting realistic short-term aging test method
## Concentric-Cylinder vs. Parallel Plate

<table>
<thead>
<tr>
<th>Critical factor</th>
<th>Concentric cylinder (CC)</th>
<th>Parallel plate (PP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample trimming</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Testing duration</td>
<td>Long</td>
<td>Short</td>
</tr>
<tr>
<td>Testing temperature</td>
<td>High</td>
<td>High and intermediate</td>
</tr>
<tr>
<td>Required material</td>
<td>Large volume</td>
<td>Little volume</td>
</tr>
<tr>
<td>Standard test method</td>
<td>Not available</td>
<td>AASHTO T315, ASTM D7175</td>
</tr>
</tbody>
</table>
Concentric-Cylinder vs. Parallel Plate

RTFO-aged Binders

G*/sin(δ) at 64ºC

- CC 17 mm
- PP- 25 mm

64-16-a: 4.7 4.5
64-16-b: 3.4 3.2
64-16-c: 2.5 2.4
64-28PM-a: 4.3 4.5
64-28PM-b: 5.8 5.4
64-28TR-a: 5.2 5.5
64-28TR-b: 3.5 3.5
AR-PP-a: 13.0 14.5
AR-PP-b: 58.7 59.4
Concentric-Cylinder vs. Parallel Plate

% Difference for $G*/\sin(\delta)$ at 64°C

- 64-16-a: 1.1
- 64-16-b: 4.4
- 64-16-c: 3.5
- 64-28PM-a: 5.8
- 64-28PM-b: 5.3
- 64-28TR-a: 4.1
- 64-28TR-b: 4.9
- 64-28PM-b: 4.0
- AR-PP-a: 2.4
- AR-PP-b: 6.7
- Original
- RTFO

% Difference for $G*/\sin(\delta)$ at 64°C
Concentric-Cylinder vs. Parallel Plate

Original Binders

G*/sin(δ) at 70°C

CC 17 mm
PP- 25 mm
Concentric-Cylinder vs. Parallel Plate

RTFO-aged Binders

G*/sin(δ) at 70ºC

CC 17 mm
PP- 25...

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

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 2.0 2.0 7.7 10.7 38.0 40.8
Concentric-Cylinder vs. Parallel Plate

% Difference for $G^*/\sin(\delta)$ at 70ºC

- Original
- RTFO
Short-term aging of asphalt rubber binders
When adding CRM, the asphalt binder plus extender oil temperature must be between 190°C (375°F) and 225°C (440°F).

Mixing/interaction duration must be at least 45 minutes.

During mixing/interaction period the temperature of asphalt rubber binder must be between 177°C (350°F) and 218°C (425°F).
Mixing Temp. for AR Binder

- **Caltrans Section 39-1.08B Mixing**

  “Asphalt rubber binder must be between **190°C (375°F) and 218°C (425°F)** when mixed with aggregate.”

Conventional binder:

  “Asphalt binder must be between **135°C (275°F) and 190°C (375°F)** when mixed with aggregate.”
RTFO Test Method Limitations

- RTFO testing temperature and time is developed based on short-term aging of neat binders.

- It is not appropriate for AR binder, because:
  
  a) Aging temperature is not simulating AR binder temperature during mix production.
  
  b) Non-uniform aging of AR binder. (the RTFO bottles are not fully coated while testing).
  
  c) It is difficult to obtain sufficient amount of AR binder from the bottles after testing.
Realistic Short-Term Aging Condition

- Current RTFO testing condition:
  - Temperature: 163°C.
  - Duration: 85 min.
  - Sample size: 35 g of binder per bottle.

- Proposed modification for asphalt rubber binder:
  - Increase testing temperature to 190°C to simulate rubberized mix production temperature.
  - Modify the amount of binder sample (corresponding to 35 g of base binder in each bottle.)
  - Change testing time ???
$G^*/\sin(\delta)$ at 64°C
Intermediate Temperature Performance-Related Testing
AR Binder Int. Temp. Testing

- Using modified concentric cylinder geometry
  - spindle with 10 mm diameter
  - Binders can be tested at temperature higher than 16°C
  - Tests are performed on RTFO+PAV aged binder

- Possible modification of PAV test condition
  - testing time, temperature, and sample size

- Evaluating the effect of rubber particle sizes
Concentric-Cylinder vs. Parallel Plate

% 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
Low Temperature Performance-Related Testing
AR Binder Low Temp. Testing

- Modification of BBR mold
  - Remedy some of the issues associated with pouring the binder and preparing a uniform shape binder beam
  - Modified mold is proposed!

- Tests will be performed on RTFO+PAV aged binder (considering possible modification)
- Evaluating the effect of rubber particle sizes
Modified BBR Mold for AR Binder

- Conventional BBR mold
  - Requires pre-heating of mold
  - Requires oven conditioning mold after pouring AR binder
  - Requires high amount of AR binder
  - Difficulties in de-molding the specimen
Modified BBR Mold for AR Binder

- **Modified BBR mold**
  - Preheating of the mold is not necessary
  - Oven conditioning is not necessary
  - Sample size is acceptable
  - Sample trimming is easy
  - Demolding is not difficult
Modified vs Standard BBR Molds

From St. mold

From Mod. mold
Modified vs. Standard BBR Mold

RTFO+PAV Aged Binders

Creep Stiffness, MPa

Test Temp: -6°C  Test Temp: -18°C  Test Temp: -6°C
Modified vs. Standard BBR Mold

RTFO+PAV Aged Binders

Test Temp: -6°C

0.319 0.331
64-16-a

0.331 0.369
64-16-b

0.319 0.331
64-16-c

0.319 0.319
64-28PM-a

0.319 0.312
64-28PM-b

0.319 0.319
64-28TR-a

0.319 0.319
64-28TR-b

0.319 0.319
AR-PP-a

0.331
AR-PP-b

Test Temp: -18°C

Test Temp: -6°C
Summary of Findings

- Bob spindle with 17-mm diameter is the proposed alternative geometry for testing AR binders at high temp. range.
- Bob spindle with 10-mm diameter is the proposed alternative geometry for testing AR binders at intermediate temp. range.
- Using modified BBR mold successfully remedied most of the limitations associated with the AR binder beam preparation.
- Increasing RTFO temperature to 190°C increased the high PG temperature by up to 9°C.
Work in Progress…

- Compare RTFO and TFO test results
- Collect field produced AR samples and test them according to the proposed approaches.
- Test rubberized mixes and compare the performance-related properties of mixes with rheological properties of their corresponding binders.
- Evaluate and adjust PG grading criteria for AR binders.
Photo courtesy Caltrans

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