DEVELOPMENT OF RUBBER BINDER SPECIFICATIONS IN CALIFORNIA: PROJECT UPDATE

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Outline

- **AR Specs Overview (ASTM and Caltrans)**
- **California rubber binder performance-related spec**
  - Background
  - 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**

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Asphalt Rubber Binder

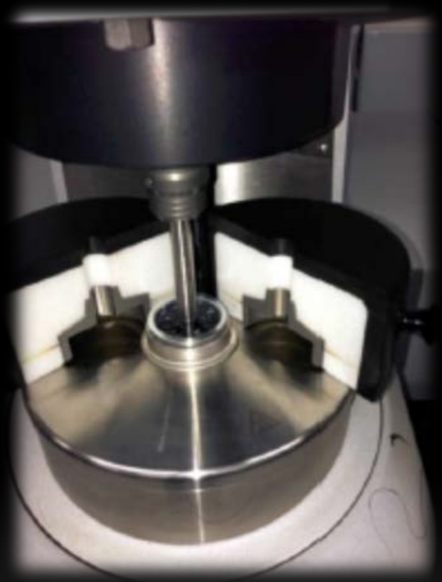
- **ASTM D6114 Definition:**
  - A blend of paving grade asphalt, ground vulcanized recycled tire rubber, and additive, as needed.
  - Must have at least **15% rubber** by weight of total binder
  - No restriction on the amount of natural rubber.

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.

AR Binder High Temp. Testing

- Selecting appropriate testing geometry
  - Concentric cylinder with 7mm 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



Selection of Testing Geometry

Critical factor	Concentric cylinder (CC)	Parallel plate (PP)
Sample trimming	No	Yes
Testing duration	Relatively Long	Short
Testing temperature	High and Intermediate	High and intermediate
Required material	Large volume	Little volume
Standard test method	Not available	AASHTO T315, ASTM D7175
Sample condition	Relatively non-destructive*	---

*** Several tests can be performed on one sample including the viscosity, grading, frequency sweep, and MSCR tests.**

AR Binder Preparation in CA

- 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.

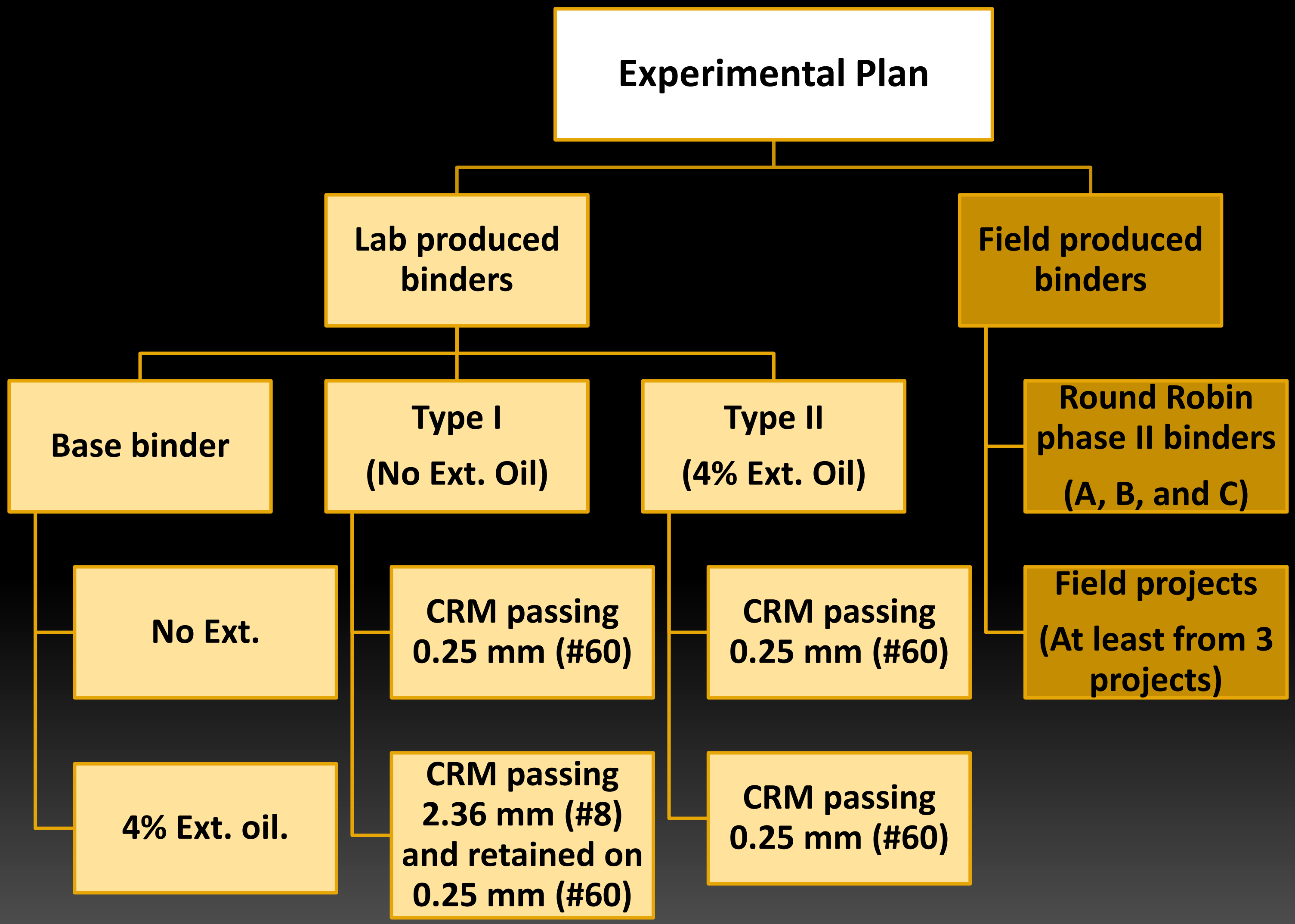
- It is not appropriate for AR binder, because:

  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 ???

Experimental Plan



AR Binder Preparation

- Base binder: PG64-16
- Extender oil: 4% by weight of base binder
- Crumb rubber: 18% by total wt. of binder
- Mixing condition: 195±3°C for 85 min
  - *15 min for adding rubber*
  - *45 minutes at 2000 rpm*
  - *30 minutes at 1000 rpm*

Sample ID: TI-60, T2-60, T1-8, T2-8

Test Methods

Rheology:

High temperature performance-related properties

Concentric Cylinder Geometry

Chemistry:

Degree of oxidation (FTIR measurements)

Degree of volatilization

Improved Coating (uniform aging)

Aging Temp: 163°C

Aging Temp: 190°C

Pros and Cons of the Proposed Modified RTFO

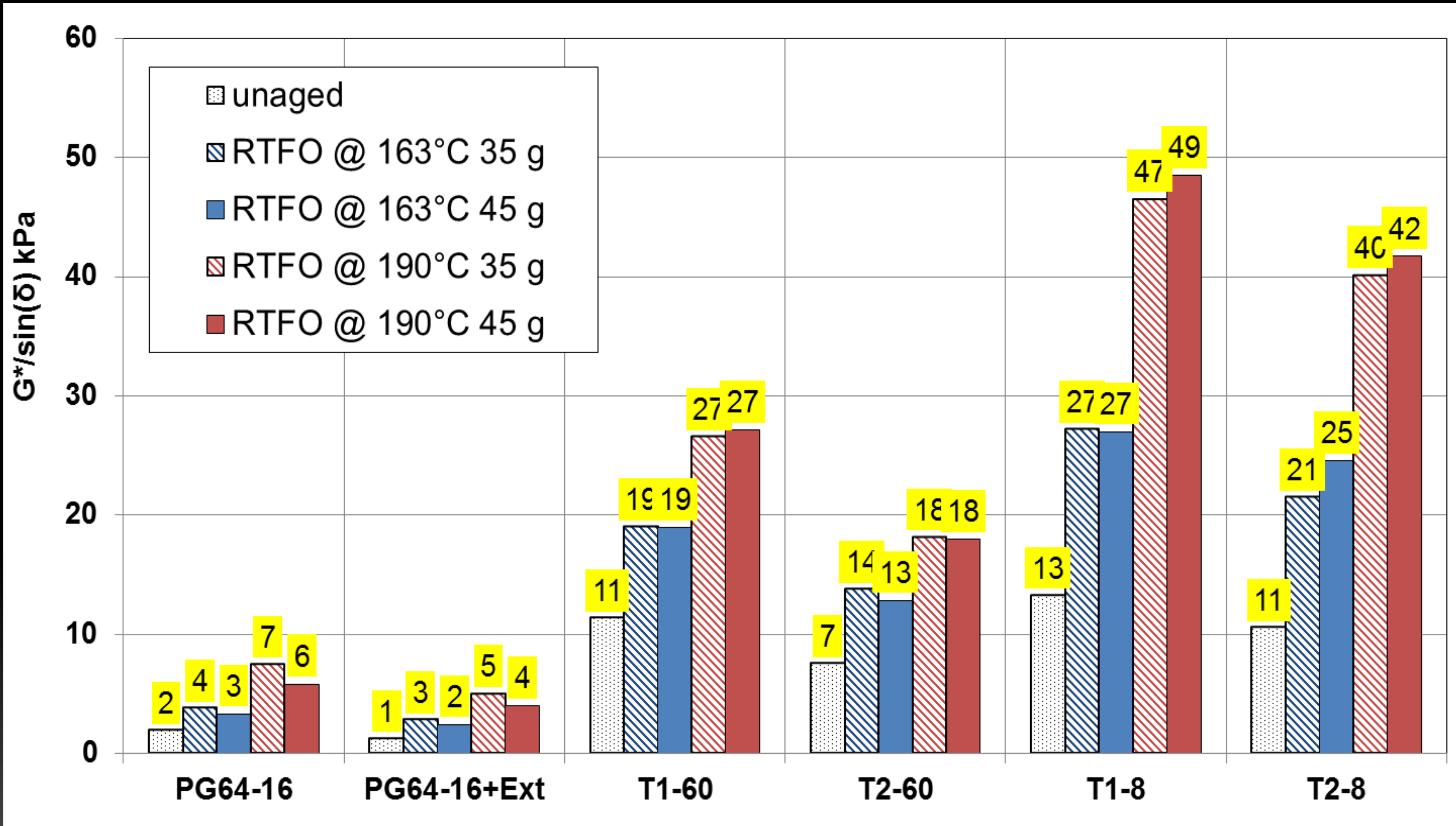
Advantages

- Fully coating of the bottle
- produce more RTFO residue.
- Initial pre-coat of the bottle is much easier.
- Residue is more readily poured out of the glass.
- Easier to scrape the residue.
- produces more RTFO residue.

Disadvantage(s):

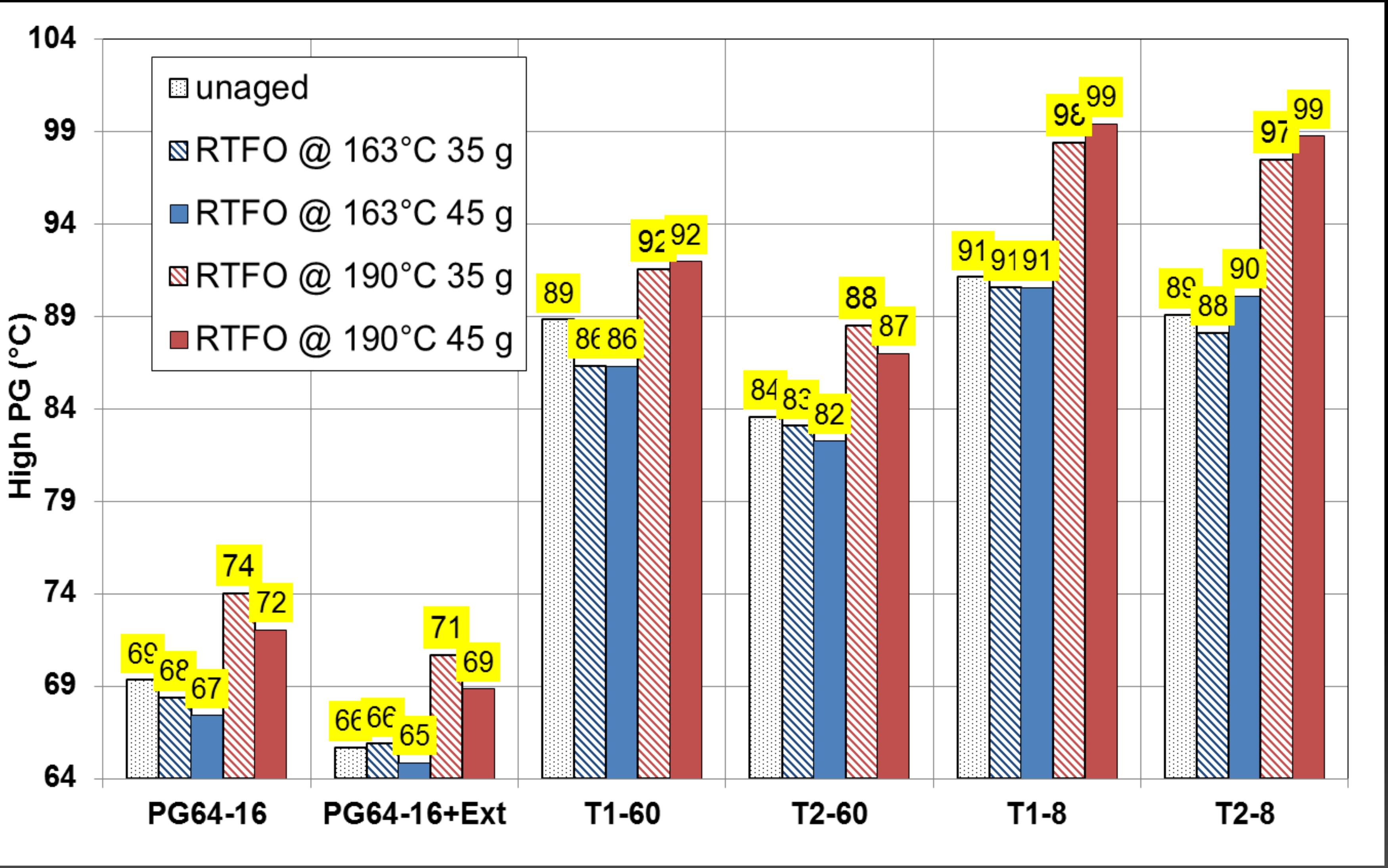
- Extra fumes and smoke while running the test.
- Possible overheating of the binder (procedure will be validated using field produced binders/mixes)

G*/sin(δ) at 64°C



G*/sin(δ) kPa
60
50
40
30
20
10
0
unaged
RTFO @ 163°C 35 g
RTFO @ 163°C 45 g
RTFO @ 190°C 35 g
RTFO @ 190°C 45 g
2 4 3 7 6
1 3 2 5 4
11 19 19 27 27
7 14 13 18 18
13 27 27 47 49
11 21 25 40 42
PG64-16
PG64-16+Ext
T1-60
T2-60
T1-8
T2-8

High PG Limit



AR Binder Int. Temp. Testing

- Using modified concentric cylinder geometry
  - spindle with 10 mm diameter (Testing in progress)
- Using asphalt binder solid torsion bar
  - Sample fabrication is critical. (in progress)
- Tests will be performed on PAV aged binder
- Possible modification of PAV test condition
  - testing time, temperature, and sample size
- Evaluating the effect of rubber particle sizes

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 PAV aged binder (considering possible modification)
- Evaluating the effect of rubber particle sizes

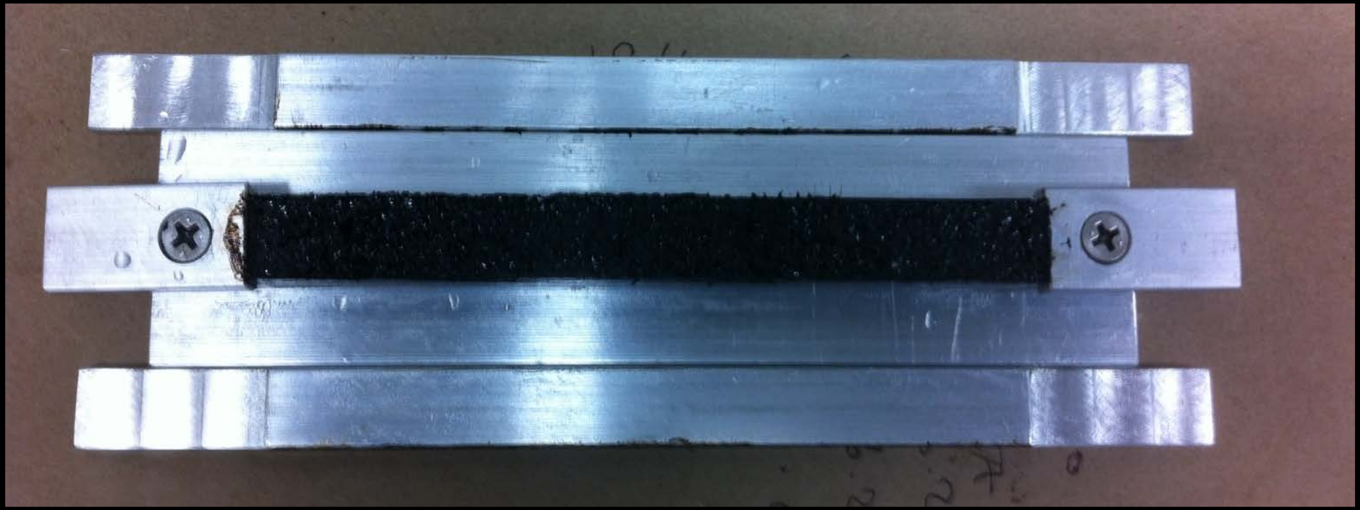
Modified BBR Mold for AR Binder

- 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 Conv. BBR Molds



From Conv. mold

From Mod. mold

Summary of Findings

- Increasing short-term aging temperature resulted in:
  - Increasing binder stiffness
  - reducing phase angle.
- Larger sample size result reduced the aging effect. However, it is not as effective as aging temperature.
- Increasing the aging temperature to 190°C increased the high PG temperature by up to 9°C.
- Using modified BBR mold successfully remedied most of the limitations associated with the AR binder beam preparation.
- Torsion bar fixture and modified bob spindle are promising alternatives for characterizing AR binders at intermediate temp. range.

Work in Progress…

- Analyzing change in chemistry of AR binder by RTFO and PAV aging
  - Quantifying degree of oxidation (Carbonyl and Sulfoxide functional groups)
  - Quantifying degree of volatilization
- Comparing RTFO and TFO test results
- Testing field blended asphalt rubber binders
- Comparing properties of binder in rubberized mix and modified and conventional RTFO aged binders
- Evaluating RTFO test duration, if needed.

Work in Progress

- Evaluating possible changes in PAV aging condition of AR binders (if necessary).
- Testing PAV-aged AR binders using concentric cylinder geometry and torsion bar fixture.
- BBR testing of PAV-aged AR binders using prepared by Conv. and Mod. molds.
- Evaluating the effect of particle size and extender oil on intermediate and low temperature properties.
- Revising grading criteria based on mix test results.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THANK YOU !
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Photo courtesy Caltrans

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