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Modification of the Rolling Thin Film Oven (RTFO) Test for Realistic Short-term Aging of Asphalt Rubber Binders

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Introduction
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.

Introduction …

- **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.

Introduction
Production of Asphalt Rubber Binder in California

- 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)**.

Introduction
Mixing Temp. for Asphalt Rubber 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."

Problem statement
Limitations of the Current RTFO Test Method

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

- It is not appropriate for asphalt rubber binder, because:

  a) Aging temperature is not simulating asphalt rubber binder temperature during mix production.
  b) Non-uniform aging of asphalt rubber binder. (the RTFO bottles are not fully coated while testing).
  c) It is difficult to obtain sufficient amount of asphalt rubber binder from the bottles after testing.

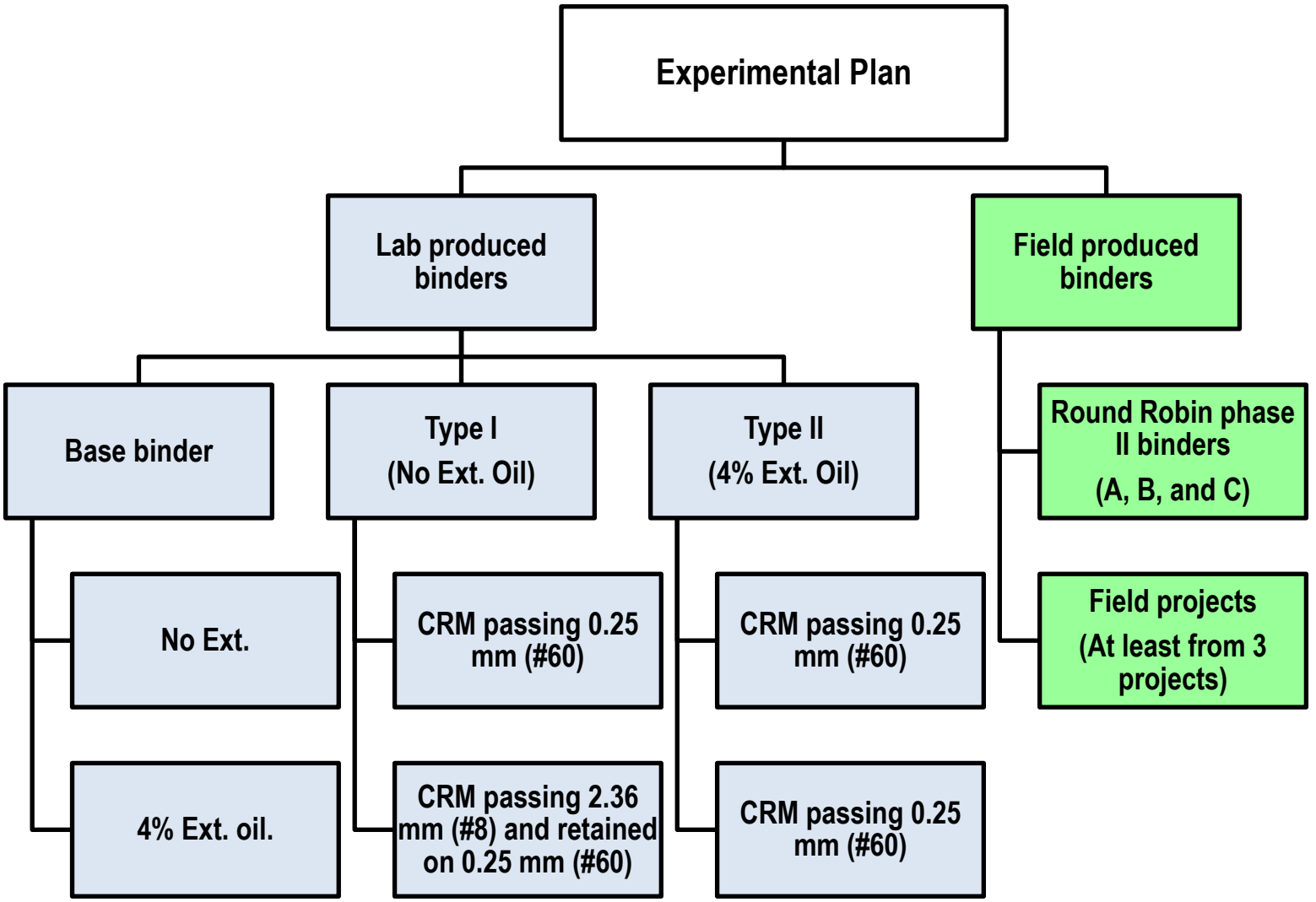
Objective
Realistic Short-Term Aging of Asphalt Rubber Binder

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

Proposed modification for asphalt rubber binder:

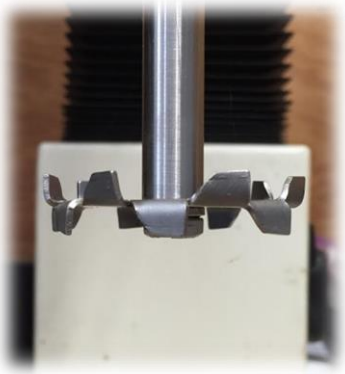
- Increase testing temperature to 190°C to simulate rubberized mix production temperature.
- Modify the amount of binder sample corresponding to 35 g of base binder in each bottle.
- Change testing time ???

Experimental Plan



Asphalt Rubber Binder Preparation

- Base binder: PG64-16
- Extender oil: 4% by weight of base binder (VSSI)
- 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 size: ¾ of gallon.



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

Test Methods

Rheology:

High temperature performance-related properties

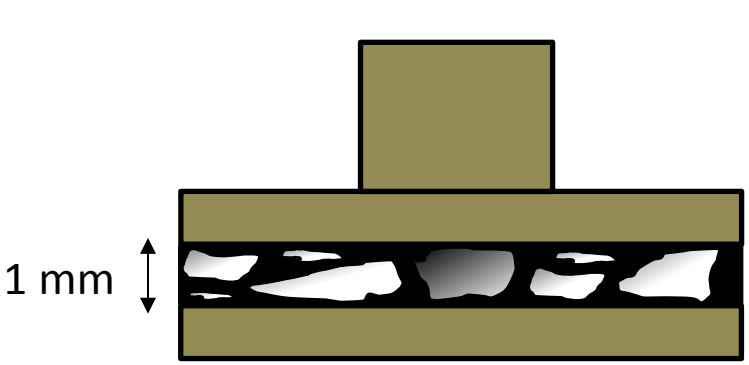
Concentric Cylinder Geometry

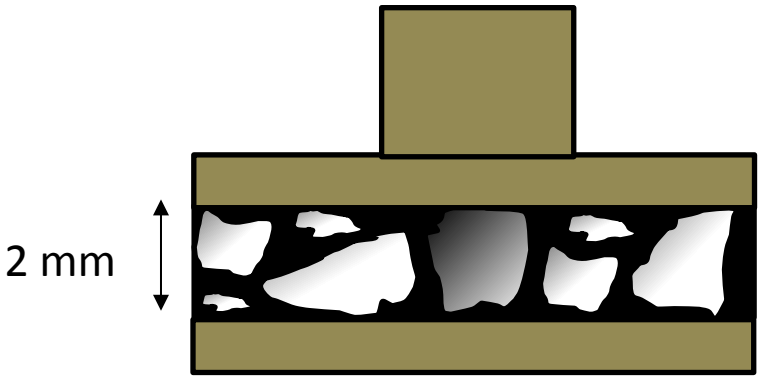
Chemistry:

Degree of oxidation (FTIR measurements)

Degree of volatilization

Selecting Appropriate Testing Geometry
Parallel Plate Limitations



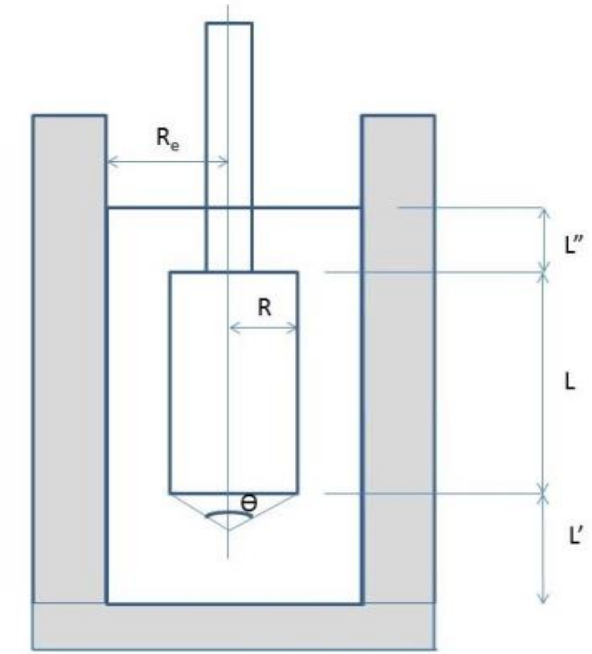


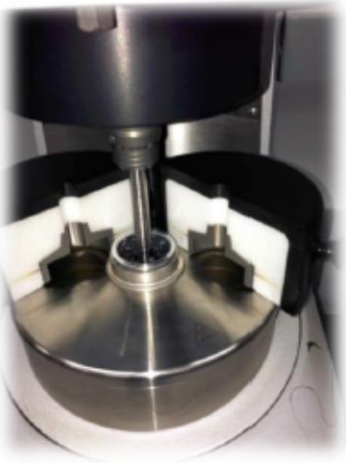
2mm parallel plate geometry is not suitable for binders with particulates as large as 2.00 mm (passing #8).

- ***8mm gap*** *required for 2mm rubber particles (AASHTO T315).*
- *Problems with trimming especially with increased gap.*
- *Result may not be a true representation of asphalt rubber binder rheology.*

Selecting Appropriate Testing Geometry
Proposing concentric cylinder (cup&bob)

- *Gap size: ~**6 mm***
- *Non-linear shear stress distribution*
- *Conversion factor must be determined using a reference material, since it is not just geometry dependent.*



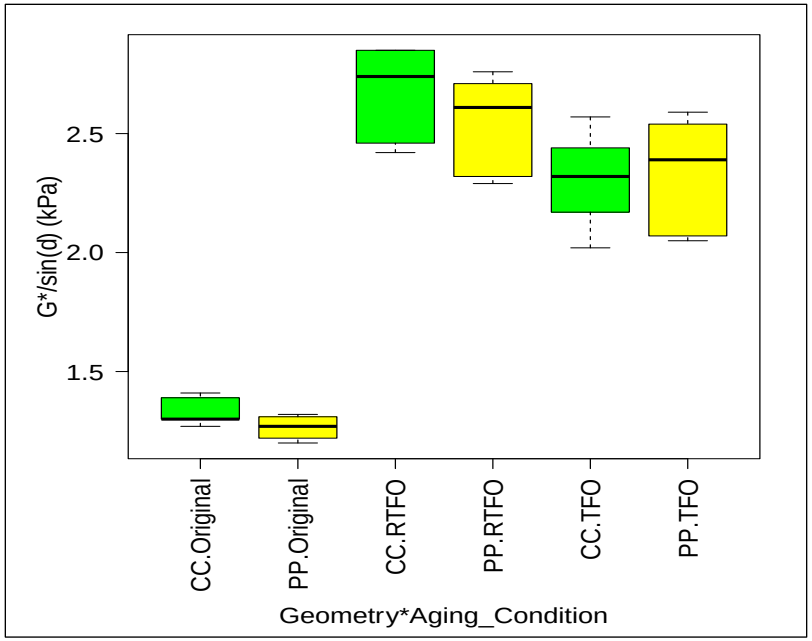


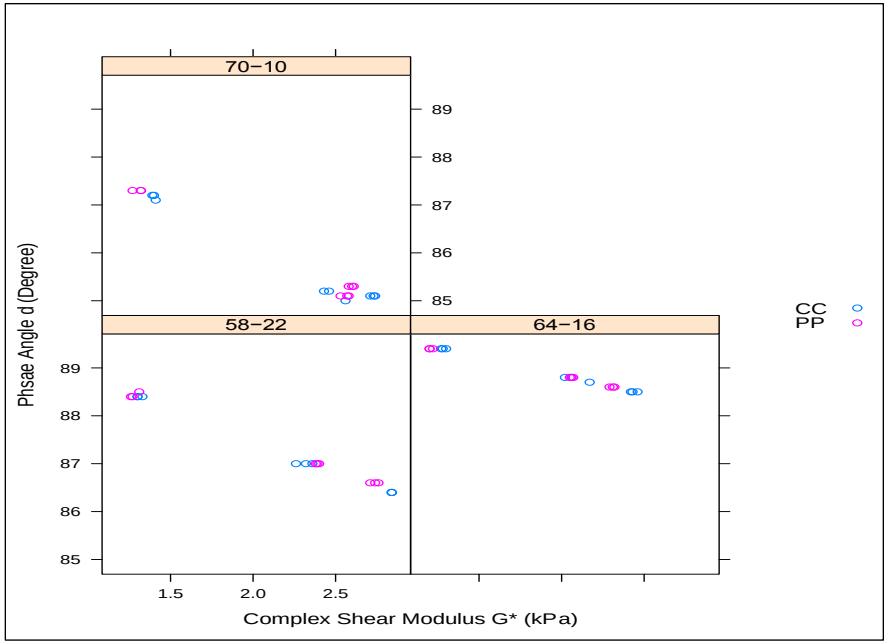
Concentric-Cylinder (CC) vs. Parallel Plate (PP)

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

Comparison of CC and PP for neat binder

Measurements at 64°C



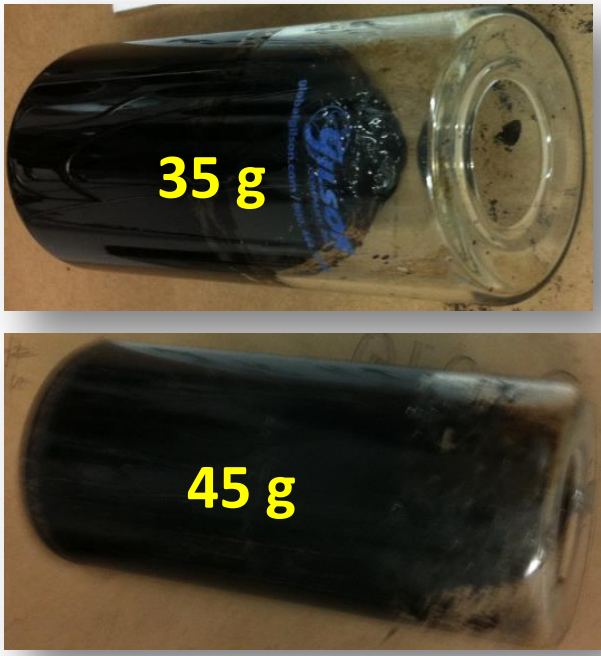


Parameter	Df	Sum Sq	Mean Sq	F Value	Pr (>F)
Geometry	1	0.033	0.033	**1.223**	0.274
Binder type	2	17.15	8.575	315.28	2e-16
Residuals	50	1.360	0.027	-	-

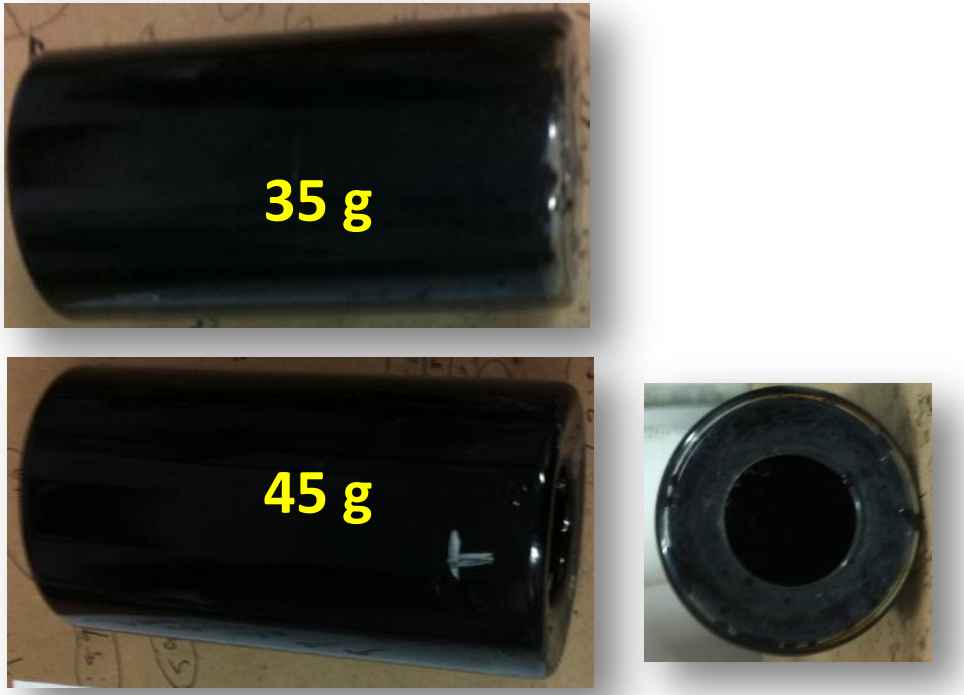
Statistically, there is no significant difference between PP and CC measurements. (95% CI)

Results and Discussion

Results and Discussion
Improvement of RTFO Bottle Coating (uniform aging)



Aging Temp: 163°C



Aging Temp: 190°C

Results and Discussion
Pros and Cons of the Proposed Modified RTFO

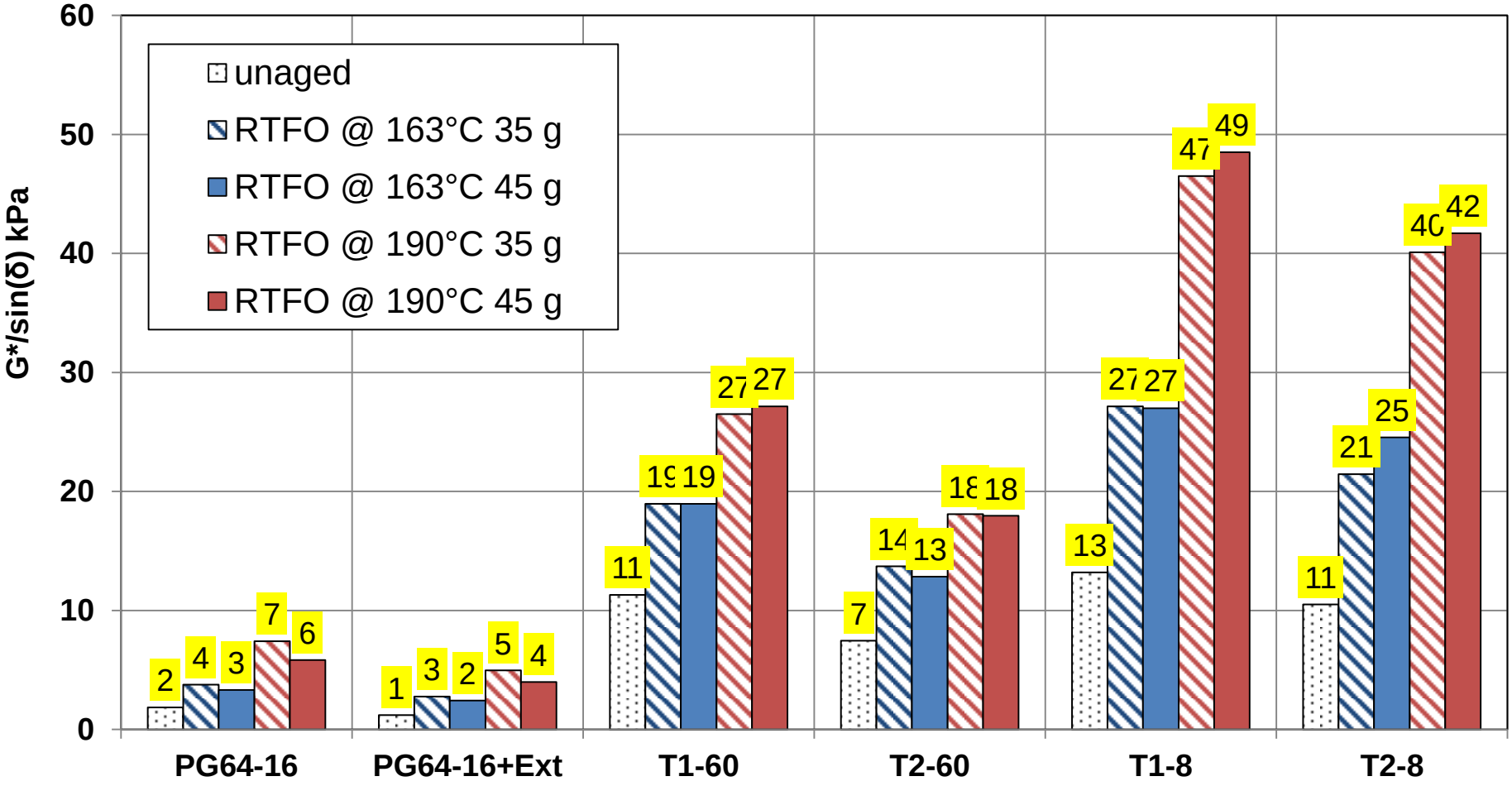
Advantages

- 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.

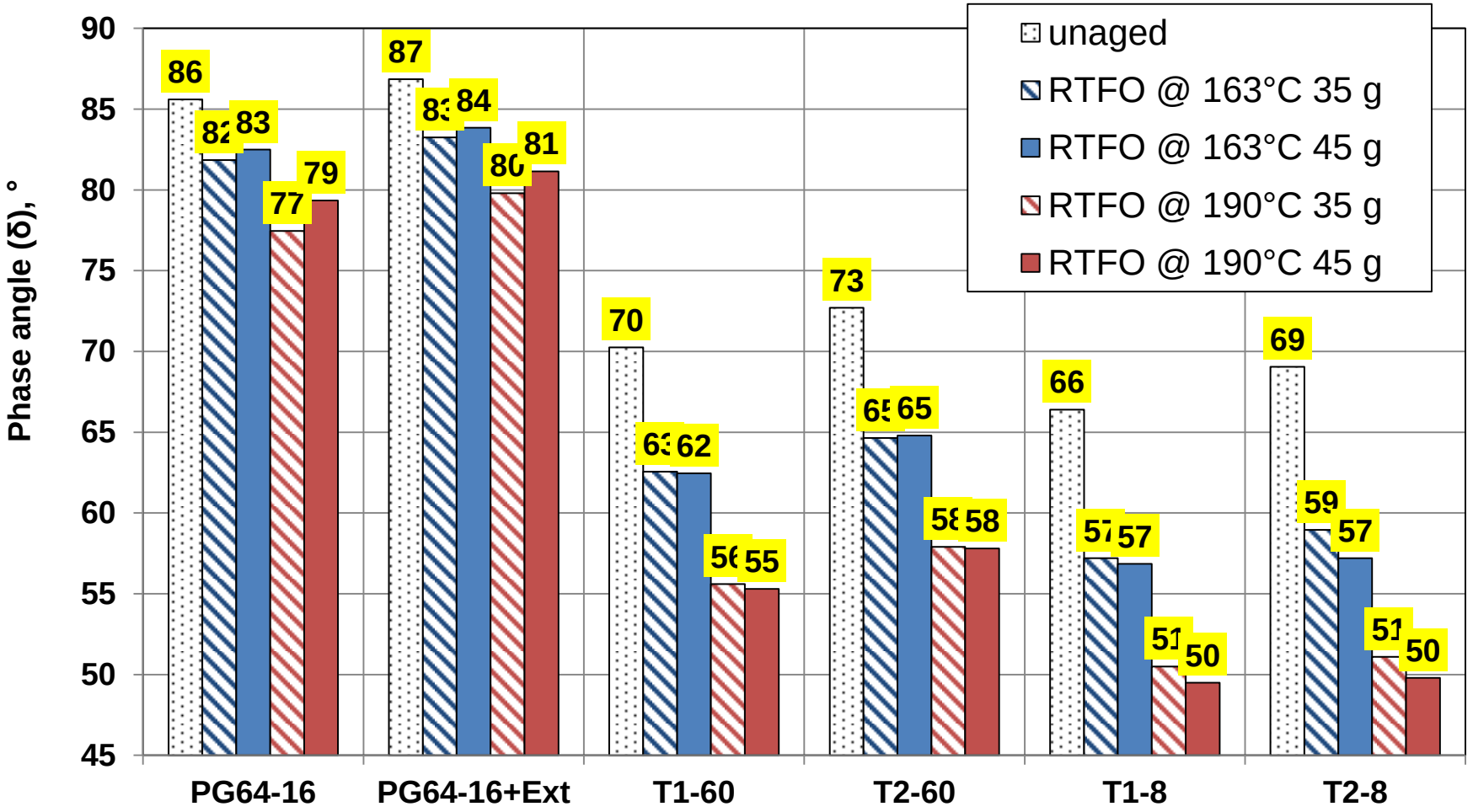
Disadvantage(s):

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

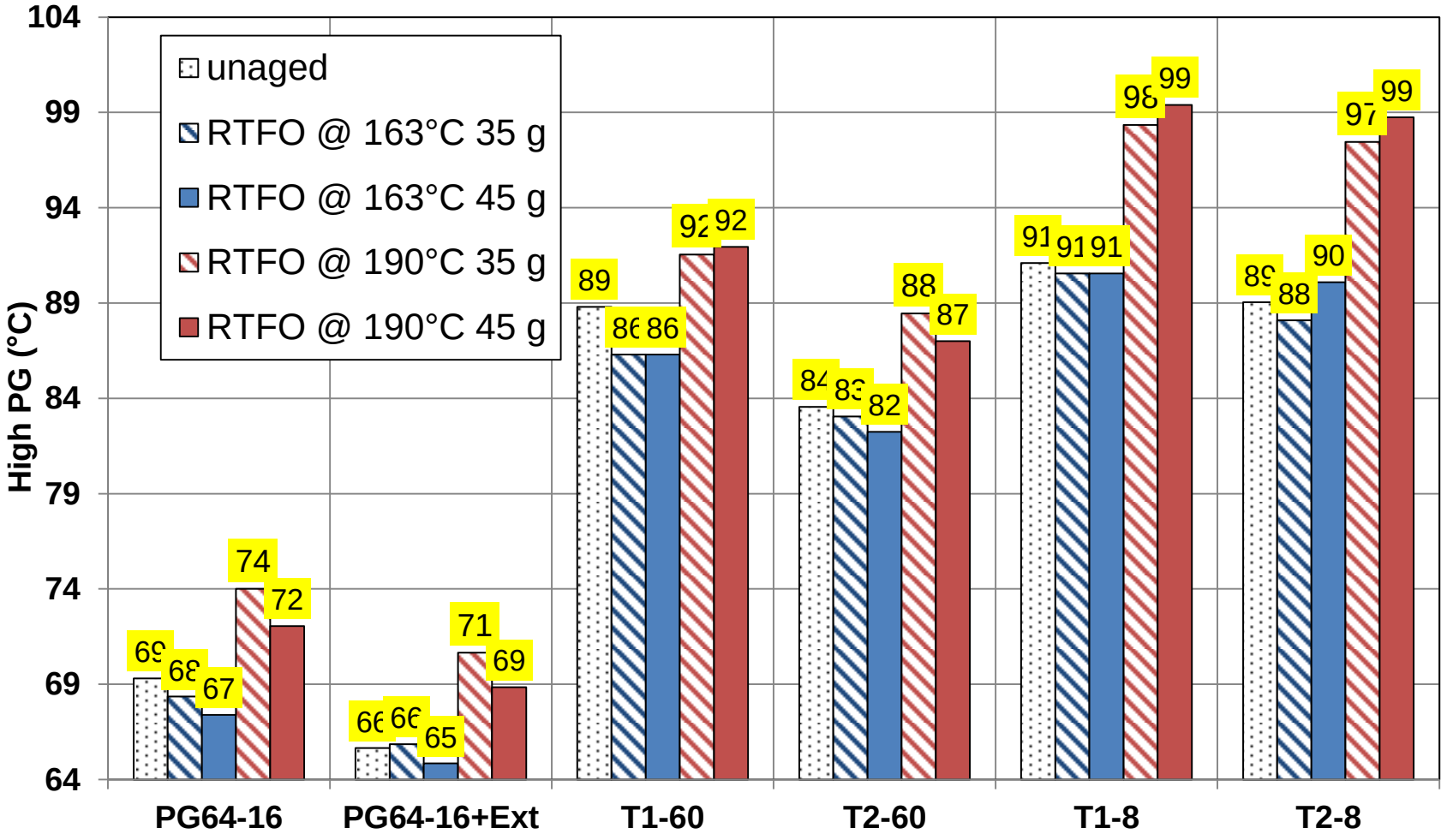
Results and Discussion
G*/sin(δ) at 64°C



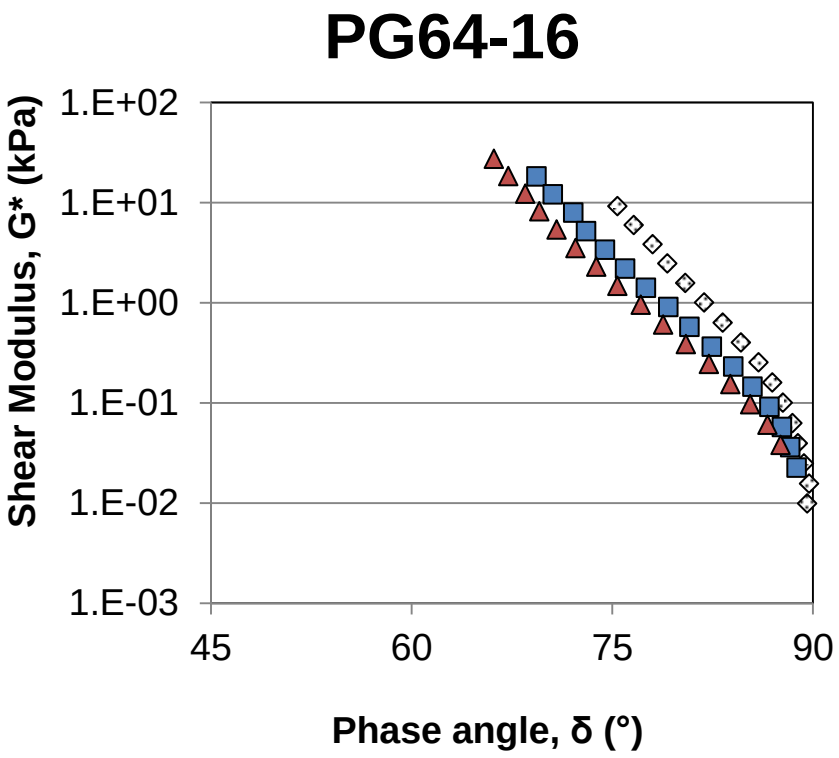
Results and Discussion
Phase angle at 64°C

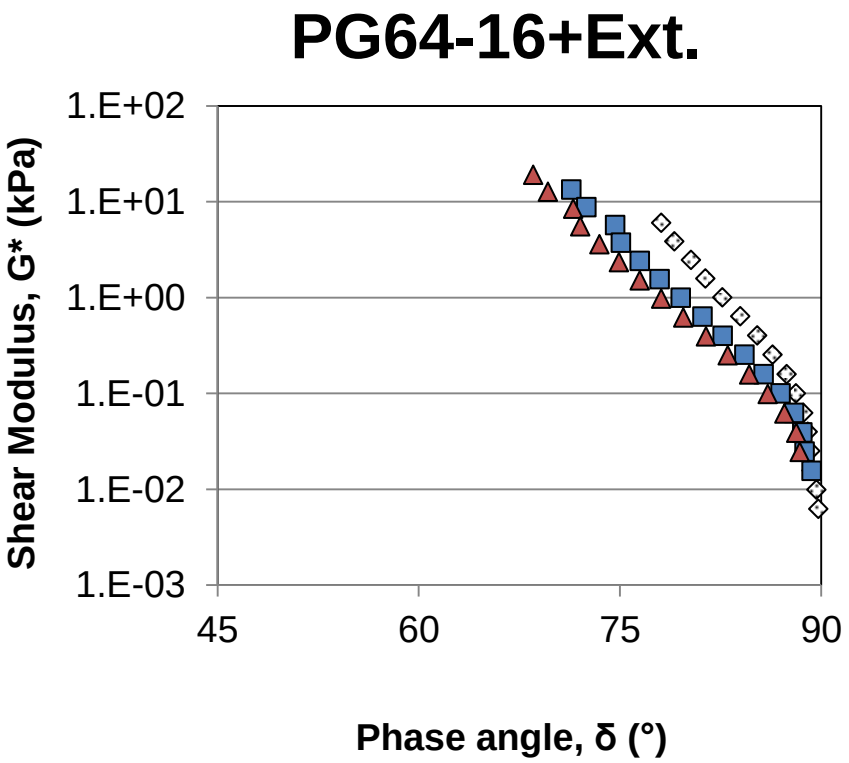


Results and Discussion
High PG Limit



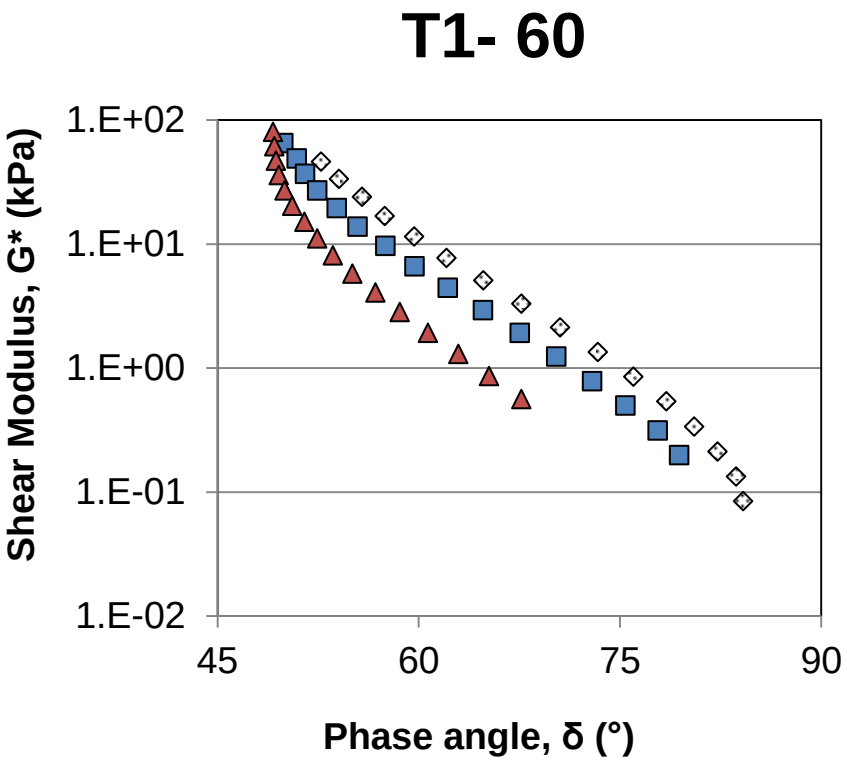
Results and Discussion
G* vs δ relationship at 64°C (block diagram)

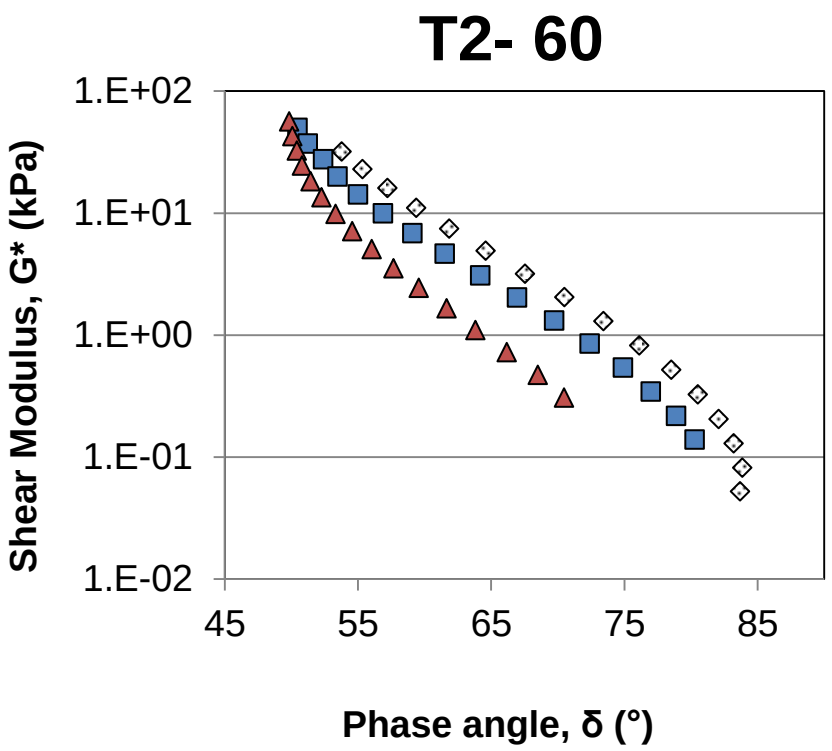




◇ Unaged ■ RTFO (163°C_85min_35g) ▲ Mod. RTFO (190°C_85min_45g)

Results and Discussion
G* vs δ relationship at 64°C (block diagram)





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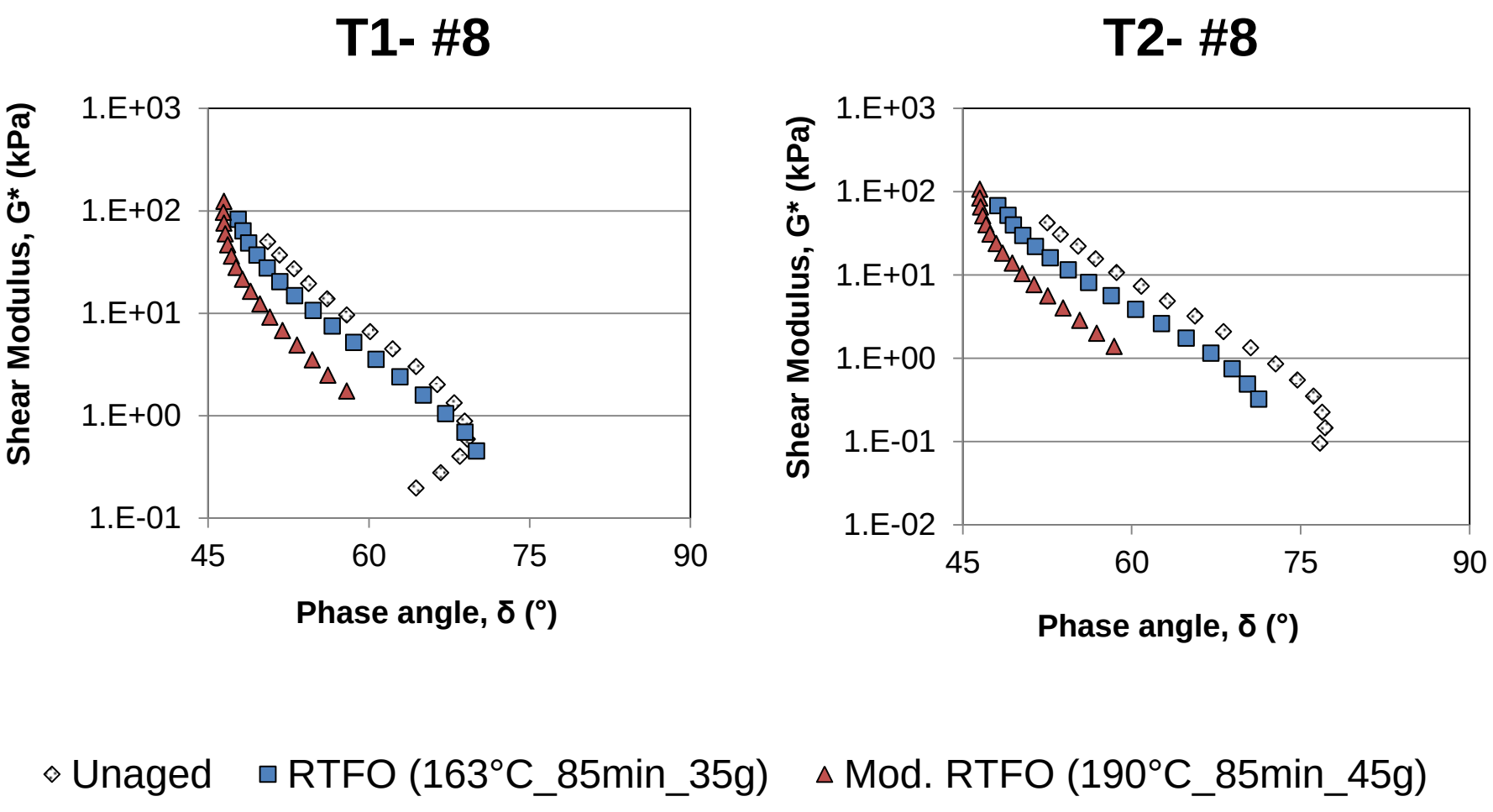

Summary of Findings

- As expected, 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.

Work in Progress…

- Analyzing change in chemistry of asphalt binder
  - 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.

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Thank you for your attention!