Evaluation of Testing & Variability of Various Testing Geometries with Recycled Tire Rubber Modified Binder Specifications

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So Why Ground Tire Rubber in Asphalt?

- Used for over 40 years

- Structural Benefits
  - Modification helps to increase viscosity, thereby improving rutting resistance
  - Modification helps to reduce cracking
    - Increases resiliency of mixture
    - Increases asphalt content and film thickness
    - Higher film thickness also provides greater resistance to aging
    - Less aging due to anti-oxidants already in the scrap tire rubber
Performance Specifications

- Current Binder Specifications Evaluated
  - AASHTO M 320
  - AASHTO M 332 MSCR

- Highway agencies are implementing existing binder specs for RTR modified binders.
Variability of RTR Modified Binder

- Do RTR modified binder provide similar variability of testing results as conventional binder?
- Does the new Cup and Bob geometry provide similar variability of test results as the parallel plate geometry.
Experimental Design

- Full M 320 and M 332 classification of binders
  - Compare M 320 to M 332 properties

- One base asphalt with 3 RTR sizes and 4 RTR concentrations.
  - PG 64-22; 60, 30 and 20 mesh RTR
  - 5, 10, 15, and 20% RTR concentrations

- Vary geometries for RTR modified binders
  - Parallel Plate and Cup and Bob
  - Run Triplicate specimens for each sample
RTR Sizes Used in Study

Graph showing the percentage passing through different sieve sizes (mm) for various mesh sizes:
- "20 Mesh" in blue
- "30 Mesh" in red
- "60 Mesh" in green
- "80 Mesh" in purple

The x-axis represents sieve size (mm) ranging from 0 to 1.0, and the y-axis represents the percentage passing ranging from 0 to 100.

Key:
- 20 Mesh
- 30 Mesh
- 60 Mesh
- 80 Mesh
Both geometries can perform the same testing oscillatory, creep and rotational
Geometries Used

- **Parallel Plate**
  - Plate Diameter: 12.5 mm
  - Gap: 2 mm

- **Searle Set (Cup and Bob)**
  - Cup Diameter: 27 mm
  - Bob Diameter: 14 mm
  - Effective Gap: 6.5 mm
PG Continuous grading for blends using different Geometries
Jnr Changes with %RTR and Geometry @ 64C

![Graph showing changes in Jrn 3.2-1kPa with % rubber content for different mesh sizes.

- Blue diamond: 30 mesh
- Green triangle: 60 retest
- Red square: 80 mesh
- Orange circle: 20 mesh C&B
- White diamond: 30 mesh C&B
- Green triangle: 60 mesh C&B
- Red square: 80 mesh C&B]
Change in % Recovery with %RTR and Geometry

- 3.2kPa % Rec
- % rubber
- 30 mesh
- 60 mesh
- 80 mesh
- 20 mesh C&B
- 30 mesh C&B
- 60 mesh C&B
- 80 mesh C&B
Cup and Bob has significantly more particle interaction than Plate-Plate Geometry
30 Mesh COV for RTFOT

$G^* / \sin \delta$ Parallel Plate and C&B

![Graph showing COV $G^* / \sin \delta$ vs. % RTR for 30 M PP and 30 M C&B](image)
30 Mesh COV MSCR Jnr Parallel Plate and C&B

![Graph showing COV Jnr 3.2 kPa vs % RTR for 30 M PP and 30 M C&B]
30 Mesh COV  POV G* sinδ

4mm gap
20 Mesh COV for RTFOT
$G*/\sin\delta$ C&B
20 Mesh COV MSCR Jnr C&B

COV Jnr 3.2 kPa⁻¹

% RTR

20 M C&B
20 Mesh COV POV G* sinδ

4mm gap

% RTR

COV G* sin d

T 315 COV

20 M COV PP
Summary of Variability Study

- For M 320 high temp test Parallel Plate and C&B RTR binders provide similar COV to AASHTO reported results.

- For M 320 intermediate temp test 4mm gap PP RTR binders provided similar COV to AASHTO reported results.
Summary of Variability Study

- For M 332 MSCR high temp test Parallel Plate and C&B RTR binders provide similar COV to AASHTO reported results.

- For M332 MSCR there was some concentration effects. At 20% concentrations the C&B shows very high variability compared to 5 to 15% concentrations.
Jnr vs % Recovery for PMB and rubber blends
Intermediate DSR testing of RTR Binders

- Previous studies indicated that the cup & bob geometry had compliance issues with intermediate DSR testing.
- Large gap sizes needed for larger mesh size rubber.
- Large gap sizes at high temps resulted in sagging of sample, but at intermediate temps it may work.
8 mm plates with 4 mm gap at intermediate temperatures
Intermediate DSR testing

- If particle size is an issue with test results how to develop control to validate gap size results.
  - Torsion bar testing at low and intermediate testing has been used historically.
  - Torsion bar geometry reduces or eliminates particle interaction issues. This can be used as a control to compare to parallel plate testing.
Picture of Asphalt torsion bar loaded in DSR
Torsion bar results compared to Parallel plate 2mm & 4mm Gap

30 mesh GTR 15% GTR PAV residue

- G" vs temp for Torsion Bar
- G" vs temp for 8 mm DSR
- G" 8mm lab 2
- 8 mm PP 4 mm gap

-5 0 5 10 15 20 25 30 35 40 45

temp C

100000
10000
1000
100
10

G" kPa
Torsion bar results compared to Parallel plate 2mm Gap

- Torsion bar test provides higher modulus results than the 2 mm gap parallel plate even for 30 mesh rubber at 15% concentration.

- At higher rubber concentration a larger gap may be needed for accurate results.
Comparison of Intermediate DSR for Torsion Bar and 2 and 4 mm gap

20 mesh GTR 15% GTR PAV residue

G'' vs temp for Torsion Bar
G'' vs temp for 8 mm DSR
G'' vs temp for 8 mm 4 mm gap

temp C
G'' kPa

-5 0 5 10 15 20 25 30 35 40 45
100000 10000 1000 100 10
Torsion bar results compared to Parallel plate 2 and 4 mm Gap

- Torsion bar test provides higher modulus results than the 2 mm gap parallel plate even for 20 mesh rubber at 15% concentration.
- 4 mm gap Parallel plate provides equivalent results to the Torsion bar for 20 mesh RTR.
Comparison of Intermediate DSR for Torsion Bar and 4 mm gap
Change in Intermediate DSR with size and % RTR @ 22°C

![Graph showing the change in Intermediate DSR with size and % RTR at 22°C. The x-axis represents % rubber ranging from 0 to 25, and the y-axis represents G* sinδ ranging from 1000.00 to 4500.00. Different markers indicate different sizes: 30 mesh (diamond), 60 mesh (square), 20 mesh (triangle), 80 mesh (cross), and control (asterisk).]
Effect of CRM on Low Temperature Grade

Low Temp Continuous Grade
All m controlled

Difference between S and M grade temp
All m controlled
Summary Intermediate testing

- The torsion bar provides slightly higher values than the 2 mm gap for 8 mm plates.
- The 4 mm gap also provides slightly higher values than the 2 mm gap even for small RTR sizes.
- 4 mm gap provided very good COV over all sizes and concentration of RTR.
Summary

- The variability of RTR modified binders was very similar to AASHTO reported single lab COV for standard binders.
- The C&B provided similar results to parallel plate geometry.
- At concentrations over 15% RTR the MSCR C&B indicate higher variability.
HWT Test relation to MSCR

- Combined all:
  \[ y = 2.1462x + 3.6023 \]
  \[ R^2 = 0.3604 \]

- Without 80 mesh:
  \[ y = 2.5531x + 2.6697 \]
  \[ R^2 = 0.7723 \]

Graph showing the relationship between HWT rut mm 15000 reps and MSCR 64C, with different gradations and percentages.
Thank You