The Effects of Aging on Rheological and Rutting Properties of CRMAs Containing Warm Asphalt Additives

Xin Yu, Jiantao Wu and Yun Liu
Hohai University
P.R. China
Outline

- Introduction
- Experimental Program
- Results and Discussion
- Conclusions and Future Work
- Acknowledgement
INTRODUCTION
Rubber problems

Land filling

Air pollution
CRMAs in pavement

- Environment protection
- Resource saving
- Low noise
- Crack resistance
- Skidding resistance
- Longer fatigue life
- Better high temperature properties
Problems of CRMAs

- Higher Mixing & Compaction Temperatures
  - Higher Emission
  - More Energy
  - Lower Quality
  - Worse Working Condition
Solution to above problems

**REDUCE** Mixing & Compaction Temperatures

**HOW?**

**WMA**

Dose this solution solve all the problems?
One of unknown things

Do those advantages brought by the COMBINATION of crumb rubber and warm additives HOLD WELL under the effects of AGING?
EXPERIMENTAL PROGRAM
Materials

- Base bitumen: PG70-22 (SK)
- Rubber powder: 40 mesh
- Warm additives: Sasobit & Evotherm
- Material combinations:
  - 15R: Rubberized binder (PG70-22 + 15% (mass of binder) crumb rubber);
  - 15R+3S: Rubberized binder with Sasobit (PG70-22 + 15% (mass of binder) crumb rubber + 3% (mass of binder) Sasobit);
  - 15R+10E: Rubberized binder with Evotherm (PG70-22 + 15% (mass of binder) crumb rubber + 10% (mass of binder) Evotherm).
Mixing time

- Temperature sweeps on PG70-22 + 15% (by mass of bitumen) 40 mesh rubber powder;
- Mixing @ 175°C for 15, 30, 45 and 60 minutes;
Mixing time (45 min.)

- Complex modulus (Pa)
- Phase angle (degree)

Graph showing the relationship between temperature and complex modulus/phase angle for different mixing times (15min, 30min, 45min, 60min).
The point of dropping warm additives

- Evotherm is sensitive to the mixing time:
  - Sasobit: mixed at the same as rubber powder (before the 45 min. mixing);
  - Evotherm: mixed after 45 min. mixing with additional 5 min. mixing.
Aging methods

- Short-term aging simulation: TFOT: 163°C for 5h
- Long-term aging simulation: PAV: (at 90°C and 2.1MPa for 20 hours
- Reason for not using RTFOT (problems):
  - large amount of rubber powder sticking on the wall of RTFOT bottle.
Test program

- Original Binder
  - TFOT Aged
    - PAV Aged
  - Rotational Viscosity
    - DSR strain sweep
    - DSR temperature sweep
    - DSR frequency sweep
    - Zero Shear Viscosity
Test program

- Original Binder
  - TFOT Aged
  - PAV Aged

- Rotational Viscosity
  - DSR strain sweep
  - DSR temperature sweep
  - DSR frequency sweep
  - Zero Shear Viscosity
RESULTS and DISCUSSION
Viscosities for binders before aging
Viscosities for binders after TFOT aging

![Graph showing viscosities for binders after TFOT aging]
Viscosities for binders after PAV aging

![Diagram showing viscosity measurements](image)

- Complex viscosity (Pa.s)
- Rotational viscosity (Pa.s)

- 15R PAV CV
- 15R+3S PAV CV
- 15R+10E PAV CV
- 15R PAV RV
- 15R+3S PAV RV
- 15R+10E PAV RV
Linear Strain Range

Results for strain sweep tests at 25°C, 1 Hz

1% strain control was used
Master curves (Sasobit)

- 15R G*
- 15R+3S G*
- 15R phase angle
- 15R+3S phase angle

Complex modulus (Pa)

Phase angle (degree)

Frequency (Hz)
Master curves (Evotherm)

![Graph showing the relationship between complex modulus (Pa) and phase angle (degree) against frequency (Hz). The graph includes various data points and lines for different conditions, such as 15R G*, 15R+10E G*, 15R phase angle, etc.](image)

- 15R G*
- 15R+10E G*
- 15R phase angle
- 15R+10E phase angle
- 15R TFOT G*
- 15R+10E TFOT G*
- 15R TFOT phase angle
- 15R+10E TFOT phase angle
- 15R PAV G*
- 15R+10E PAV G*
- 15R PAV phase angle
- 15R+10E PAV phase angle
### Complex Modulus Aging Indices for Different Binders (25°C, 10rad/s)

<table>
<thead>
<tr>
<th>Binders</th>
<th>G* before aging/Pa</th>
<th>After TFOT</th>
<th></th>
<th>After PAV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G*/Pa</td>
<td>Aging Index</td>
<td>G*/Pa</td>
<td>Aging Index</td>
</tr>
<tr>
<td>15R</td>
<td>1,885,000</td>
<td>2,794,000</td>
<td>1.48</td>
<td>4,983,000</td>
</tr>
<tr>
<td>15R+3S</td>
<td>2,394,000</td>
<td>3,501,000</td>
<td>1.46</td>
<td>5,682,000</td>
</tr>
<tr>
<td>15R+10E</td>
<td>967,000</td>
<td>1,869,000</td>
<td>1.93</td>
<td>4,640,000</td>
</tr>
</tbody>
</table>
Rutting properties

- Rutting performance indicators:
  - G*/sinδ :
    - 65°C, 10rad/s
    - data from frequency sweep test
  - Zero Shear Viscosity (ZSV ):
    - Testing mode: oscillation method
    - 65°C, 0.01-100Hz
    - Predicting models: Cross and Carreau
## Testing results

<table>
<thead>
<tr>
<th>Aging stages</th>
<th>Binders</th>
<th>G*/sinδ (Pa)</th>
<th>ZSV (Pa.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cross</td>
</tr>
<tr>
<td>Unaged</td>
<td>15R</td>
<td>10,274</td>
<td>2,516</td>
</tr>
<tr>
<td></td>
<td>15R+3S</td>
<td>12,986</td>
<td>6,680</td>
</tr>
<tr>
<td></td>
<td>15R+10E</td>
<td>5,372</td>
<td>1,662</td>
</tr>
<tr>
<td>TFOT</td>
<td>15R</td>
<td>20,215</td>
<td>8,507</td>
</tr>
<tr>
<td></td>
<td>15R+3S</td>
<td>27,671</td>
<td>14,283</td>
</tr>
<tr>
<td></td>
<td>15R+10E</td>
<td>14,268</td>
<td>6,272</td>
</tr>
<tr>
<td>PAV</td>
<td>15R</td>
<td>30,705</td>
<td>14,642</td>
</tr>
<tr>
<td></td>
<td>15R+3S</td>
<td>49,247</td>
<td>18,460</td>
</tr>
<tr>
<td></td>
<td>15R+10E</td>
<td>29,479</td>
<td>12,318</td>
</tr>
</tbody>
</table>
ZSV ratios

Unaged TFOT PAV

ZSVwarm / ZSVcontrol

15R+3S
15R+10E

Unaged TFOT PAV
CONCLUSIONS and FUTURE WORKS
Conclusions

- At higher temperatures (>100°C), both Sasobit and Evotherm are EFFECTIVE in reducing rotational viscosities of rubberized binders;
- The rutting resistance of rubberized binder can be enhanced by Sasobit, but reduced by Evotherm. In addition, the effects from warm additives on the rutting properties of rubberized binders were observed to be weakened by age hardening;
- The addition of Sasobit MIGHT be able to improve temperature susceptibility of rubberized binders.
Future works

- Similar tests on the binders with different base bitumen are being carried out;
- Tests (aging & rutting) on mixtures are recommended;
- In order to thoroughly investigate aging mechanism of rubberized binders containing warm additives, it is recommended that the techniques such as FTIR and SEM be involved in further studies.
Acknowledge

Thanks to the following organizations for their financial support:

- Department of Transportation, Jiangsu Province;
- The Natural Science Foundation of Jiangsu Province.
Thank You!