Effect of Foamed Warm Mix Asphalt on Binder Aging

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Outline

- Background
- Objectives
- Research Plan
- Material Information
- Testing Program
- Test Results
- Conclusions
- Questions
Background
Background

- In recent years, there has been an increased interest in using a new type of asphalt mixtures called warm mix asphalt (WMA)

- Several WMA technologies are available:
  - Chemical and organic additives
  - Foamed asphalt binders
Foamed WMA produced by water injection has received increased interest in Ohio since it requires a one-time plant modification and does not require the use of costly additives.

Over the last seven years, the amount of foamed WMA used in Ohio has increased from approximately 10,000 tons in 2008 to nearly 60% of the total amount of asphalt mixtures produced in the state.
Background

- Key benefits of foamed WMA include:
  - Reduced emissions during production
  - Improved field compaction
  - Improved working conditions
  - Ability to use higher RAP contents

- To date, satisfactory performance has been obtained for pavements constructed using foamed WMA
Background

- However, the wide implementation of this technology requires further investigation of its effects on performance.
- One of the issues that has not been thoroughly studied and might affect the performance and durability of foamed WMA is binder aging.
Objectives of the Study
Objectives of the Study

- Evaluate the short and long-term aging characteristics of foamed WMA and HMA
- Compare the rheological, chemical, and morphological properties of foamed WMA and HMA binders at different stages of aging
Research Plan
Research Plan

- Laboratory Binder Aging
- Laboratory Mixture Aging
- Effect of Extraction and Recovery on Binder Properties
- Field Mixture Aging
- Comparison of Laboratory Binder and Laboratory Mixture Aging
- Comparison of Laboratory Binder and Field Aging
- Comparison of Laboratory Mixture and Field Aging
Material Information
Material Information

- Mix Type: Superpave 12.5 mm
- Aggregate Type: Limestone
- Binder Type: PG 70-22
Testing Program
Laboratory Binder Aging

Physical Tests
- DSR (G*, δ) Int. + High Temp.
  - Unaged
  - RTFO
  - PAV

Chemical Tests
- FTIR
  - Unaged
  - RTFO
  - PAV
- GPC
  - Unaged
  - RTFO
  - PAV
Laboratory Mixture Aging

- HMA (A)
  - Recovered Binders
    - DSR, FTIR, and GPC
  - After Mixing
    - Short-Term 4 hrs @ 135°C
  - Long-Term 5 days @ 85°C

- Foamed WMA (B)
  - Same as (A)
Laboratory Mixture Aging

Mixing and Short-Term Aging

Long-Term Aging

$\text{4''} \ \Downarrow \ \text{6''}$

$7 \pm 0.5\% \ AV$
Overview of Test Procedures
Rolling Thin Film Oven (RTFO)
Pressure Aging Vessel (PAV)
Dynamic Shear Rheometer (DSR)

25 mm

8 mm
Fourier Transform IR Spectrophotometer
Fourier Transform IR Spectrophotometer
Gel Permeation Chromatography (GPC)
Gel Permeation Chromatography (GPC)
Gel Permeation Chromatography (GPC)
Production of Foamed WMA

Foaming Nozzle
Binder Tank
Air Tank
Water Tank
Control Panel
Asphalt Extraction
Asphalt Recovery
Test Results
Binder Aging
DSR
Graph showing the relationship between G*/sin\(\delta\) at 70°C (kPa) and Radial Frequency (rad/sec) for Unaged, RTFO, and PAV.
G*sinδ at 28°C (kPa)

Radial Frequency (rad/sec)

Unaged
RTFO
PAV
FTIR
Mixture Aging
DSR
The graph shows the values of $G^*/\sin\delta$ at 70°C and 10 rad/sec (kPa) for various samples. The values are as follows:

- Unaged HMA: 1.5 kPa
- HMA After Mixing (Blend 1): 2.1 kPa
- WMA After Mixing (Blend 1): 2.4 kPa
- RTFO: 3.7 kPa
- HMA STOA (Blend 1): 5.3 kPa
- WMA STOA (Blend 1): 4.4 kPa
- PAV: 11.0 kPa
- HMA LTOA (Blend 1): 13.0 kPa
- WMA LTOA (Blend 1): 8.0 kPa
$G^*/\sin\delta$ at 70°C and 10 rad/sec (kPa)

- Unaged HMA
- HMA After Mixing (Blend 2)
- WMA After Mixing (Blend 2)
- RTFO
- HMA STOA (Blend 2)
- WMA STOA (Blend 2)
- PAV
- HMA LTOA (Blend 2)
- WMA LTOA (Blend 2)
$G^*\sin\delta$ at 28°C and 10 rad/sec (kPa)

- Unaged HMA
- HMA After Mixing (Blend 1)
- WMA After Mixing (Blend 1)
- RTFO
- HMA STOA (Blend 1)
- WMA STOA (Blend 1)
- PAV
- HMA LTOA (Blend 1)
- WMA LTOA (Blend 1)

Values:
- Unaged: 487 ± 0
- HMA After Mixing (Blend 1): 650 ± 0
- WMA After Mixing (Blend 1): 667 ± 0
- RTFO: 948 ± 0
- HMA STOA (Blend 1): 1387 ± 0
- WMA STOA (Blend 1): 1292 ± 0
- PAV: 2269 ± 0
- HMA LTOA (Blend 1): 2233 ± 0
- WMA LTOA (Blend 1): 1798 ± 0
G* at 28°C and 10 rad/sec (kPa)

- Unaged
- HMA After Mixing (Blend 2)
- WMA After Mixing (Blend 2)
- RTFO
- HMA STOA (Blend 2)
- WMA STOA (Blend 2)
- PAV
- HMA LTOA (Blend 2)
- WMA LTOA (Blend 2)

Graph showing the values of G* in kPa for different conditions.
FTIR
The graph shows the I\(_{\text{C}=\text{O}}\) values for different treatments:

- Unaged: 0.020
- HMA After Mixing (Blend 1): 0.020
- WMA After Mixing (Blend 1): 0.019
- RTFO: 0.025
- HMA STOA (Blend 1): 0.027
- WMA STOA (Blend 1): 0.026
- PAV: 0.036
- HMA LTOA (Blend 1): 0.035
- WMA LTOA (Blend 1): 0.030

The treatments include unaged and various aged conditions such as RTFO, STOA, and LTOA for both HMA and WMA.
GPC
Conclusions

- In general, comparable or slightly higher G*/sinδ and G*sinδ values were obtained using the DSR test for asphalt binders recovered from laboratory-prepared HMA mixtures than those recovered from laboratory-prepared foamed WMA mixtures.
- The conventional DSR test results were consistent with the FTIR and GPC test results.
- This indicates that laboratory-prepared foamed WMA mixtures undergo comparable or slightly lower levels of aging than traditional HMA mixtures.
Conclusions

- The $G^*/\sin\delta$ and $G^*\sin\delta$ values obtained for asphalt binders recovered from short-term oven aged foamed WMA and HMA mixtures were slightly higher than those obtained for the corresponding RTFO-aged binders.

- The $G^*/\sin\delta$ and $G^*\sin\delta$ values obtained for asphalt binders recovered from long-term oven aged foamed WMA and HMA mixtures were not consistently higher or lower than those obtained for the corresponding PAV-aged binders.
Conclusions

- Similar results were also obtained from the FTIR and GPC tests.
- This indicates that the RTFO test procedure results in less aging than the short-term oven aging procedure specified in AASHTO R30, while the PAV test procedure results in comparable aging to the long-term oven aging procedure specified in AASHTO R30.
Questions?