SCHOOL OF
CIVIL AND ENVIRONMENTAL ENGINEERING
College of Engineering, Architecture and Technology

# Effect of Chemical Warm-Mix Additives on Asphalt Binder Rheological and Chemical Properties in the Context of Aging

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## 1. Introduction

- ✓ We need our binder to be
  - "Stiff Enough" at high temperatures
  - "Soft Enough" at low and intermediate temperatures
- ✓ But what happens to the binder at very hot temperatures?
  - Lighter components vaporize (we lose the maltenes)
  - Expedited Oxidation

**Objective of this study:**
Evaluate the impact of different *chemical WMA additives* on binder properties

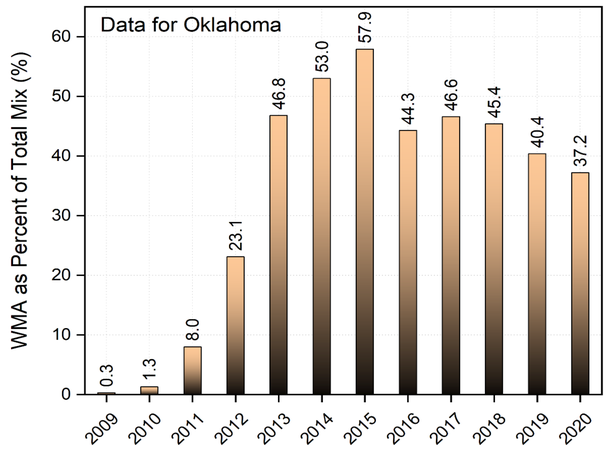
- ✓ Generic Classification by Newcomb (2006)
  - Cold Mix : 68 – 120 F
  - Hot Mix : 280 – 340 F
  - Warm Mix : 220 – 275 F

✓ Chemical additives act on the mixture in *REDUCING* the production and compaction temperature.

**Benefits**
- *Reduced mixture aging*
- *Reduction of emissions*
- *Reduction of energy usage*
- *Reduction of fumes produced in field*

**Challenges**
- *Lack of understanding*
- *Cost of WMA technologies or equipment*
- *Agency restrictions*
- *Difficulty in usage or in design*

## 2. Background




## 3. ODOT SP&R 2288 Scope of Work

➢ The goal of this research project is to help ODOT move towards the implementation of WMA alongside Balanced Mix Design (BMD) as a sustainable paving approach for long-lasting, cost-effective pavement structures.

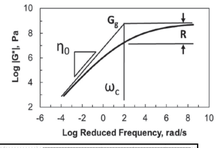
✓ Material selection for test Matrix:

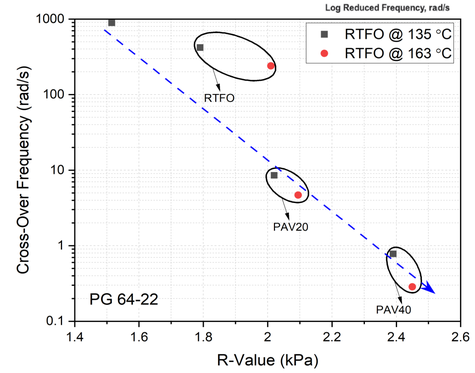
1. **Binder Types and Sources:**
   - PG 76-28 (Holy-Frontier)
   - PG 64-22 from three sources (Trumbull, Lion, AFS)
2. **Mixture Types:**
   - S-4, S-3 (most used)
3. **Aggregate Types:**
   - Limestone, Granite, Sandstone
4. **WMA Chemical Additives:**
   - Focus on liquid Chemical Additives.

## 4. Effect of WMA on Binder Properties

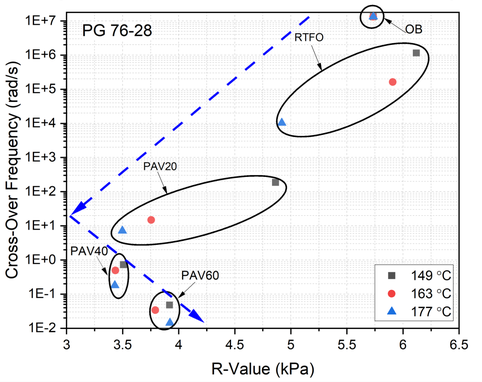
### 4.a) R-Value Parameter Comparison

➢ With aging, R-Value should increase, and Cross-Over Frequency should decrease.

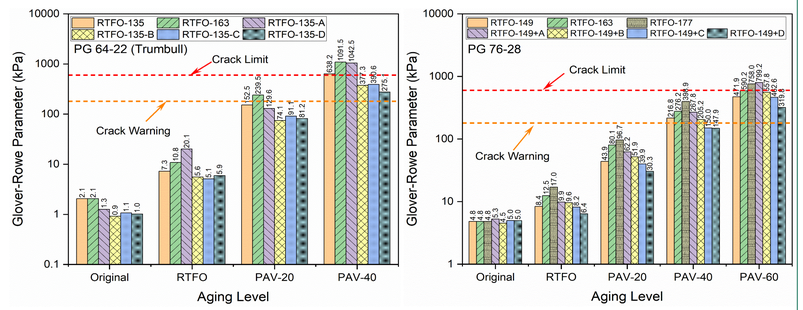



➢ The same trend cannot be seen in PG 76-28. Highly Polymer-Modified Binders can behave Differently



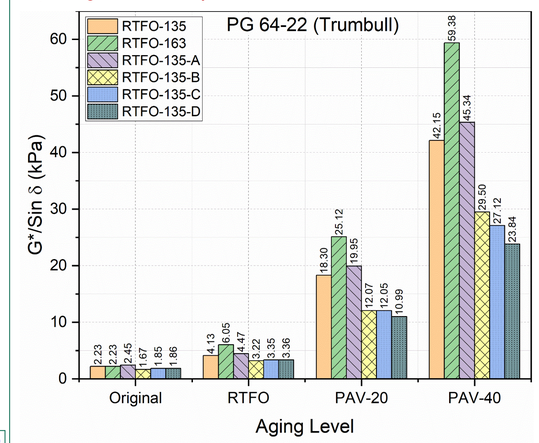

### 4.b) Glover-Rowe Parameter Comparison

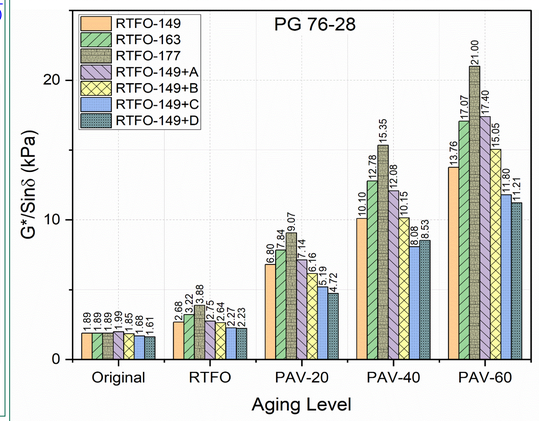



➢ Lower RTFO temperature extends GRP service life.

$$GRP = \frac{G*(cos\delta)^2}{sin\delta}$$

### 4.c) Rutting Parameter Comparison




➢ All CWAs lead to a reduction in the rutting parameter

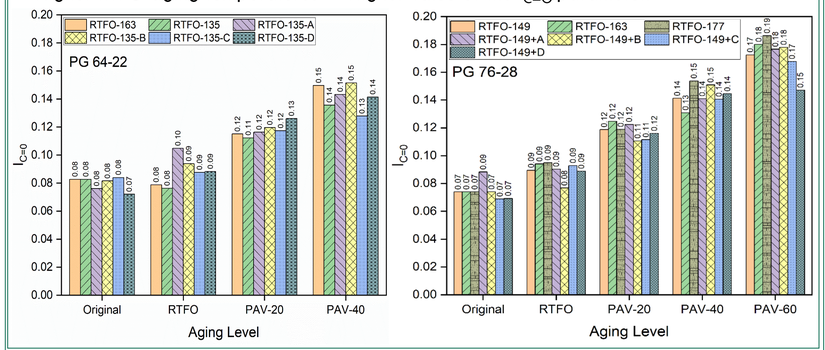
➢ Lower RTFO temperature means less age-hardening.

### 4.d) Carbonyl Index Comparison

$$I_{C=0} = \frac{Carbonyl\ Peak\ Area\ (1700\ cm^{-1})}{Peak\ Area\ (\sum 2000\ and\ 600\ cm^{-1})}$$

➢ For the Carbonyl Index, the wavelength range of [1650-1820] is used.

➢ Higher RTFO aging temperatures → Higher value of the $I_{C=O}$ parameter.

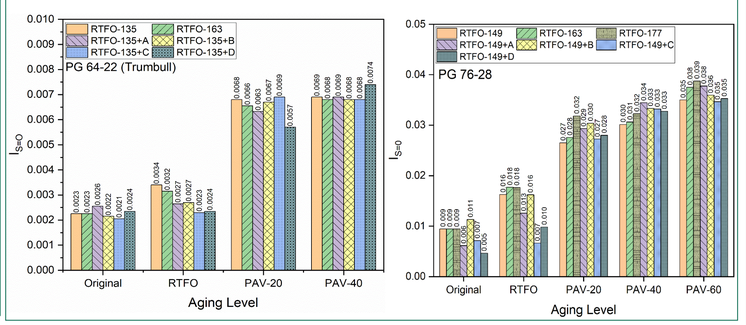



### 4.e) Sulfoxide Index Comparison

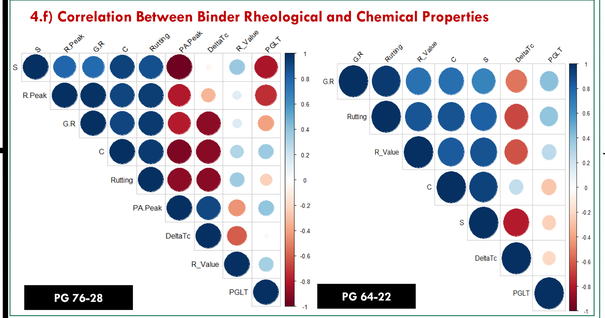
$$I_{S=0} = \frac{Sulfoxide\ Peak\ Area\ (1030\ cm^{-1})}{Peak\ Area\ (\sum 2000\ and\ 600\ cm^{-1})}$$

➢ For the Sulfoxide Index, the wavelength range of [1000-1050] is used.

➢ Higher RTFO aging temperatures → Higher value of the $I_{S=O}$ parameter.




### 4.f) Correlation Between Binder Rheological and Chemical Properties




## 5. Conclusion & Summary

✓ **Reducing the RTFO temperature significantly improves the long-term performance of binders (Based on Rheological and Chemical Properties)**

- ❑ PG 64-22: 163 °C → 135 °C
- ❑ PG 76-28: 177 °C → 163 °C → 149 °C

✓ **Generally adding chemical additives will show better performance of asphalt binders**

## 6. Future Plan of Research

➢ **Mechanistic analyses and performance prediction of pavement sections with/without a combined WMA-BMD technology will be performed using AASHTOWare Pavement ME Design (PMED) and FHWA FlexPAVE.**

➢ **Perform Life Cycle Assessment:**
- **Promote the use of WMA technology to reduce the temperatures and emissions during asphalt mixture production.**


- **Sustainable Engineering Design Criteria:**
  - Function
  - Cost
  - Safety
  - Impact on people (Society)
  - Impact on the planet (Environment)

Carbon Offsets

- Explore the use of carbon offsets to reach net zero emissions
- Explore the potential use of carbon offsets to monetize and incentive industry practice that reduce GHG emissions



**6. Acknowledgement**

The authors would like to thank Ingevity for their help in this study. The help of all ODOT partners is greatly acknowledged.

Ingevity
OKLAHOMA Transportation