Laboratory Evaluation:
Wax Additives in Warm-Mix Asphalt Binder

ETG WARM MIX TASK GROUP:
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Objective

Evaluate the effect of wax additives on physical properties and characteristics of asphalt binders and their subsequent performance in mixtures.
Materials

- Asphalt – One (1)
  - Lion Oil PG64-22 Eldorado, AR Refinery (Saudi)

- Wax Additives – Nine (9)
  - Non-Paraffin Wax Additives

- Aggregates
  - Vulcan Barin Quarry Granite, Columbus, GA (Aggregate used on the NCAT Test Track)

- Mix Design
  - 12.5mm Dense Graded SuperPave™ Gyratory
    - ~5.5% Binder
    - ~7.0% Air Voids
**Paraffin and Non-Paraffin Waxes**

**Paraffin Wax**  
Size of molecule \( \text{< } C_{45} \)  
Melting point \( \text{< } 70 \degree \text{C} \)

**Non-Paraffin Wax**  
Size of molecule \( \text{> } C_{45} \)  
Melting point \( \text{> } 70 \degree \text{C} \)

- **natural waxes**
  - animal (e.g. beeswax)
  - vegetable (e.g. Carnauba wax)

- **modified natural waxes**
  - brown coal-derivative
  - mineral oil-derivative

- **partial synthetic waxes**
  - acid waxes
  - ester waxes
  - amid waxes
  - alcohol waxes

- **full synthetic waxes**
  - Fischer-Tropsch-waxes
  - polyethylene-waxes
Selected Additives

- **Paraffin Waxes:**
  - Microcrystalline
    - Astra 3816 Refined Paraffin
- **Non-Paraffin Waxes:**
  - Modified Natural
    - Romonta Normal - Montan
    - Romonta Asphaltan A
    - Romonta Asphaltan B
  - Partial Synthetic
    - Clariant Licomont BS100 – N,N’-ethylenebisstearamide
    - Luxco Pitch – stearic acid pitch
    - Ester Wax - TBD
  - Synthetic
    - Sasobit – Fischer-Tropsch
    - Allied - Polyethylene
Experimental

- Proposed Testing Completed Cooperatively

- Paragon Technical Services, Inc. (PTSi)
- Mathy Technology and Engineering, Inc. (MTE)
- Anderson Asphalt (Dr. Dave Anderson)
- Western Research Institute (WRI)
- Louisiana State University (LSU)
- Federal Highways (FHWA)
- Kraton Polymers (KP)
Experimental – Additive Testing

- **Fourier Transform Infra-Red Spectroscopy (FTIR)** – WRI
- **Gel Permeation Chromatography (GPC)** – WRI/PTSi/KP
  - High Temp GPC – KP
- **Glass Transition (Tg)**
  - Modulated Differential Scanning Calorimetry (MDSC) – WRI/MTE
- **Branching**
  - Nuclear Magnetic Resonance (NMR) – WRI
  - Atomic Force Microscopy (AFM) - WRI
  - Mass Spectroscopy (MS) – WRI
  - X-Ray - LSU
Fourier Transform Infra-Red Spectroscopy (FTIR)
Ten (10) Binders (Control PG64-22 and Nine (9) Wax Modified Binders

Note: Testing other than Tribo-Rheometry and Binder True Grade to be Performed on PAV Aged Binders

- Master Curve Development (DSR) – PTSi
- SuperPave™ True Grade (Through DTT) – PTSi
- Tribo-Rheometry – PTSi/MTE
- Physical Hardening (32 days saturation at -12°C) Bending Beam Rheometry (BBR) - PTSi
- Testing at 1,2,4,8,16 and 32 Days Concurrent with Binder
- Multi-Step Creep Recovery (MSCR) – FHWA
- Binder Stress Sweep Fatigue (Bahia UW Method) – PTSi/MTE
Experimental – Binder Testing (Contd.)

- Ten (10) Binders (Control PG64-22 and Nine (9) Wax Modified Binders

  *Note: Testing other than Tribo-Rheometry and Binder True Grade to be Performed on PAV Aged Binders*

- Glass Transition Tg
- Modulated DSC (MDSC) – WRI/MTE/Anderson Asphalt
- Dilatometric Analysis - Anderson Asphalt
- Fracture Testing – Anderson Asphalt
- Atomic Force Microscopy (AFM) - WRI
- Solid State NMR – (WRI
- X-Ray – LSU
- High Pressure Liquid Chromatography/Gel Permeation Chromatography/Mass Spectroscopy – (HPLC/GPC/MS) – WRI/LSU
Master Curve Development

![Diagram showing temperature and phase lag relationship with G* Pa values]
Tribo-Rheometry

COMPARE NEAT PG 58-28 TESTED AT 3 TEMPERATURES, 125°C, 100°C, & 90°C-GAP 50 µm

viscosity (Pas)

normal force (N)

velocity (rad/s)
Experimental – Mixture Testing

- Ten (10) Mixtures (Control and Nine (9) Modified)
  
  Dense Graded SuperPave™ Gyratory Specimens

- Physical Hardening (32 days saturation at -12°C) Bending Beam Rheometry (Marasteanu UM Method)(BBR) - PTTi
  - Testing at 1,2,4,8,16 and 32 Days Concurrent with Binder
- Sand Cylinder Fatigue (SCF) – MTE
- Glass Transition (Tg) (MTE Method) – MTE
- Fracture Testing – Anderson Asphalt
Physical Hardening - BBR

Zofka, AAPT “Simple Method”, 7/22
Questions?

What’s Over the Hill for Warm Mix?