Long Lasting Asphalt Binder Systems and Evolving Binder Specifications

Shane Underwood, Ph.D.
Assistant Professor,
School of Sustainable Engineering and the Built Environment
Co-Director,
The National Center of Excellence on SMART Innovations
Senior Sustainability Scientist,
Global Institute of Sustainability
Objectives

- Identify the factors affecting the sustainability of asphalt binder.
- Name two classes of long-lasting asphalt binder systems.
- Explain the properties of these binder systems that are measured to estimate their longevity.
- Describe the distinguishing characteristic of evolving tests and specifications in asphalt.
Origins of Asphalt

- Modern industrial asphalt cements originate from the fractional distillation of petroleum.

- Factors affecting material properties
  - Nature of the original asphalt source
  - Refinery decisions
  - Terminal/formulation decisions

Sustainability of Asphalt

- Energy requirements and emissions associated with extraction, refining, storage, and transport of crude oil and asphalt.

- Exists as a finite resource
  - Approximately 56 of 131 U.S. refineries produce asphalt (EIA).

- Extending the durability of binder systems to improve the longevity of asphalt pavements
  - Appropriate use of polymers, rubber, and other modifiers in asphalt systems.
Sustainability of Asphalt

- Energy requirements and emissions associated with extraction, refining, storage, and transport of crude oil and asphalt.
- Exists as a finite resource
  - Approximately 56 of 131 U.S. refineries produce asphalt (EIA).
- Extending the durability of binder systems to improve the longevity of asphalt pavements
  - Appropriate use of polymers, rubber, and other modifiers in asphalt systems.
How Asphalt Behaves

Viscosity/Stiffness

Temperature, °C

-15  25  60  135

hard

soft
How Asphalt Behaves
So what helps make a binder system long-lasting?

1. Less temperature sensitivity

Less sensitive to environmental variations

More sensitive to environment variations

Viscosity/Stiffness

Temperature, C

-15  25  60  135

hard

soft
So what helps make a binder system long-lasting?

1. Less temperature sensitivity
2. Right binder for the right application

- Viscosity
- Temperature, C
- Better in a hot climate
- Better in a cold climate
- Hard
- Soft
So what helps make a binder system long-lasting?

1. Less temperature sensitivity
2. Right binder for the right application
3. Elastic binder
So what helps make a binder system long-lasting?

1. Less temperature sensitivity
2. Right binder for the right application
3. Elastic binder
4. UV, oxidation, and moisture resistant
5. Constructable
6. Available in large and stable supplies
Long Lasting Binder Systems

Polymer modified asphalt

- Elastic Type
  - ✔ SB diblock (Dynasol 1205)
  - ✔ SBS (Kraton D1184)
  - ✔ SBR latex (Ultrapave 1156)
  - ✔ Natural latex (Firestone Hartex 104)
  - ✔ Waste rubber (CRM WRF-14)

- Plastic Type
  - ✔ Honeywell Titan 7686
  - ✔ EVA (Exxon Polybilt 103)
  - ✔ polyethylene (Novaphalt)

Long Lasting Binder Systems

- Advantages
  - Long performance history
  - Elastic effect
  - Improved cohesion
  - Many specs designed around stretchy polymers (no mysteries)
  - Favorable co-modifier with sulfur and PPA

- Disadvantages
  - Can be challenging to manufacture
  - Compatibility can be a problem
  - Tougher to handle
  - Not heat stable
  - Challenge to emulsify
  - Relatively expensive
  - Specifications may not capture benefits (or overstate benefits)

Long Lasting Binder Systems

- Rubber modified asphalt
  - On-site blend
    - ✔ Particulate based systems (non-homogeneous)
  - Terminal blend asphalt
    - ✔ Particulate based systems
    - ✔ Non-particulate based systems (TR+ with 8-10% rubber + 1-3% SBS)

Specification and Testing of Asphalt

- Relevant asphalt properties are related to its flow response under loading.
  - Chewing (pre-1880’s)
  - Penetration, ductility, viscosity with and without oxidation (late 1880’s – 1990’s)
  - Viscoelastic modulus across temperatures (oxidized and non-oxidized) (Superpave)

Superpave Specifications

The PG grading system (AASHTO M32) is based on Climate

**PG 70 - 10**

- Performance Grade
- Min pavement temperature (°C)
- Average 7-day max pavement temperature (°C)

Embedded into this grade are assumptions of traffic speed (fast) and truck volume < 3 Million ESALs)
Embedded into this method are experiments that do not apply significant “stretch” to the asphalt system.
Evolving Superpave Specifications

The Modified PG grading system (AASHTO M332) is based on climate and traffic conditions.

**Traffic Dependent Designation**

- **S** = Standard (< 10 Million ESALs at > 45 mph)
- **H** = Heavy (10-30 Million ESALs at > 45 mph or < 10 Million ESALs at 15-45 mph)
- **V** = Very Heavy (> 30 Million ESALs at > 45 mph or 10-30 Million ESALs at 15-45 mph or < 10 Million ESALs < 15 mph)
- **E** = Extreme = > 30 Million ESALs at < 15 mph
New experiments subject materials to higher rotations to activate the polymer network as it would be in service.
MSCR of Asphalt Binder

AASHTO T350

- **Multiple Stress Creep Recovery** test
  - Evaluate resistance to rutting at stress levels “more similar” to pavements.
  - 25 mm DSR sample subjected to pulse of load followed by a recovery period.
  - Response is $J_{nr}$ and a smaller $J_{nr}$ = better performance
LAS Test of Asphalt Binder

AASHTO TP101

- **Linear Amplitude Sweep**
  - Evaluate fatigue performance of asphalt binder
  - 8 mm DSR sample subjected to stepped increase loading pattern
Evolving Specification, M332

<table>
<thead>
<tr>
<th>Performance Grade</th>
<th>PG 64</th>
<th>PG 70</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>Average 7-day max</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pavement design</td>
<td>&lt;64</td>
<td>&lt;70</td>
</tr>
<tr>
<td>temp, °C*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min pavement</td>
<td>&gt;-10</td>
<td>&gt;-16</td>
</tr>
<tr>
<td>design temp, °C*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MSCR, T 350:

- Standard Traffic “S”
  - $J_{\text{cr}}$, max 4.5 kPa
  - $J_{\text{diff}}$, max 75%
  - test temp, °C
  - 64

- Heavy Traffic “H”
  - $J_{\text{cr}}$, max 2.0 kPa
  - $J_{\text{diff}}$, max 75%
  - test temp, °C
  - 64

- Very Heavy Traffic “V”
  - $J_{\text{cr}}$, max 1.0 kPa
  - $J_{\text{diff}}$, max 75%
  - test temp, °C
  - 64

- Extremely Heavy Traffic “E”
  - $J_{\text{cr}}$, max 0.5 kPa
  - $J_{\text{diff}}$, max 75%
  - test temp, °C
  - 64

Traffic grade is dependent on the compliance of the asphalt from MSCR test.
Traffic grade is dependent on the fatigue life of the asphalt binder.

Tested at the same temperature as the existing Superpave system.

<table>
<thead>
<tr>
<th>Performance Grade</th>
<th>PG 64</th>
<th>PG 70</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>Average 7-day max pavement design temp, °C</td>
<td>&lt;64</td>
<td></td>
</tr>
<tr>
<td>Min pavement design temp, °C</td>
<td>≥10</td>
<td>≥16</td>
</tr>
</tbody>
</table>

| LAS, TP101 | Grade “S” | $N_f$ at 2.5 and 5% > 15,000 | | | | | | | | | | |
| Test temp, °C | 31 | 28 | 25 | 22 | 19 | 16 | 34 | 31 | 28 | 25 | 22 | 19 |

| LAS, TP101 | Grade “H” | $N_f$ at 2.5 and 5% > 19,000 | | | | | | | | | | |
| Test temp, °C | 31 | 28 | 25 | 22 | 19 | 16 | 34 | 31 | 28 | 25 | 22 | 19 |

| LAS, TP101 | Grade “V” and “E” | $N_f$ at 2.5 and 5% > 31,000 | | | | | | | | | | |
| Test temp, °C | 31 | 28 | 25 | 22 | 19 | 16 | 34 | 31 | 28 | 25 | 22 | 19 |
Similar high strain evaluations have been proposed for AR.

Primary modifications involves experimental methods incorporating concentric cylinders.
Summary

- Identify the factors affecting the sustainability of asphalt binder.
  - Energy and emissions
  - Finite resource
  - Durability
  - Appropriate use of long-life binders

- Name two classes of long-lasting asphalt binder systems.
  - Polymer modified
  - Rubber modified
Summary

- Explain the properties of binder systems that are measured to estimate their longevity.
  - Viscosity/Stiffness as a function of temperature
  - Elasticity as a function of temperature

- Describe the distinguishing characteristic of evolving tests and specifications in asphalt.
  - Explicit consideration of traffic loads and speed in specification grade
  - Testing at high strains
Thank You

http://pavements-lab.engineering.asu.edu

http://transportationstudies.asu.edu

https://ncesmart.asu.edu/