Additives in Asphalt

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Additives in Asphalt - Topics

- Why modify?
- Types of additives
- Selection & verification
- Superpave Implications
- Summary
Why modify?

Improve pavement durability and

Lower life cycle costs
Why Modify?

- Increase serviceable temperature range
  - Stiffen at high temperature
  - Soften at low temperature
  - Improve flexibility at all temperatures
Why Modify?

- Improve asphalt - aggregate bond
- Improve asphalt film thickness
- Reduce:
  - permanent deformation
  - cracking
  - draindown
  - pavement thickness
  - raveling
  - stripping
  - fatigue damage
  - life cycle costs
• 1843 - British patent - polymer modified AC
• 1930’s - Test projects in Europe
• 1950’s - Neoprene Latex in U.S. & Canada
• 1970’s - Wide use of polymers in Europe
• 1980’s - Modified binders increase in U.S.
• 1990’s - SHRP PG specs increase demand
Modifiers

- Polymers
- Asphalt Rubber
- Chemical modifiers
- Fibers & Fillers
- Modification through processing
Types of polymers

- Elastomers (or rubbers)
- Plastomers (or plastics)
• **Elastomers**
  - *Block co-polymers, random polymers, natural & synthetic latex*
  - *Pre-blended or blended at HMA plant*
  - *Used in cold & hot AC paving applications*
Common Elastomers

- **Styrene-butadiene block Copolymers (SB, SBS)**
- **Styrene-butadiene rubber latex (SBR)**
- **Natural rubber latex**
Elastomeric Polymers - Why?

- Temperature Susceptibility
- Strain Recovery
- Tensile Strength at high strains
- Cohesion
- Adhesion
Polymers

- Plastomers
  - Polyethylene & Ethylene Copolymers
  - Preblended or blended at hot mix plant
  - HMA paving applications
Typical Plastomers

• Ethyl vinyl acetate (EVA)
• Polyethylene
• Polypropylene
• Polyolefins
Plastomeric Polymers - Why?

- Temperature Susceptibility
- High modulus
- Tensile strength at low strains
Asphalt Rubber
Asphalt Rubber

- **Wet process**
  - Natural or Synthetic (SBR) rubber
  - Pre-blended or added at HMA plant
  - HMA / OGFC, Chip Seals, SAMI’s

- **Dry process**
  - Added in cold feed at HMA plant
  - HMA paving (e.g. Plus Ride)
Asphalt Rubber

- Performance depends upon
  - process
  - type and size of crumb rubber
  - additives, stabilizers, de-vulcanization
  - application or use- mix/pavement design, climate
Asphalt Rubber - Why?

- Reduced lift thickness
- Temperature Susceptibility
- Elasticity
- Film thickness or durability
- Use of waste material
Chemical Modifiers
Chemical Modifiers

- Anti-stripping agents - amines
- Strong Acids / Bases
- Extender Oils
- Asphalt Extenders
  - Sulfur, Gilsonite
Chemical Modifiers - Why?

• Reduce moisture damage
• Increase AC film thickness
  – Reduce draindown during construction
• Extend PG Temperature Range (Lower costs)
Fillers & Fibers

• Lime
• Mineral fines
• Carbon black
• Waste materials
  – Mineral by-products
  – Polyethylene (HDPE)
  – Sawdust

• Trinidad Lake Asphalt
• Cellulose
• Polymeric fibers
• Synthetic mineral fibers
Fillers or Fibers - Why?

- **Fillers**
  - Stiffen binder - higher mix modulus
  - Lime - anti-strip agent, clay flocculent

- **Fibers**
  - Increase mixture cohesion
  - Prevent draindown during construction for SMA / OGFC
Modification Through Processing
Modification through processing

- Solvent de-asphalting
- Air blowing / Oxidation
- Vis-breaking
- De-waxing
- Caustic washing
Modification through processing - Why?

- Roofing Industry
- Oil crisis of 70’s - gasoline from heavy crudes
- Superpave
  - Extend PG Temperature Range at lower cost
  - Meet “stretch” PG grades
  - Upgrade low quality asphalts
Binder Selection and Modification
Binder / Modifier

Selection & Verification

- Pavement Temperature
- Traffic speed & load
- Pavement Structure
- Application
- Performance Testing
Are the additives effective?

- **Enhanced Pavement Performance**
  - *Stability/Compatibility* of the modifier in AC
  - *Physical properties* of modified binders/mixture
Compatibility
Photomicrographs of the same SBS polymer in 3 different asphalts
Different SBS polymers in the same asphalt

Asphalt A
Polymer A

Asphalt A
Polymer B

Asphalt B
Polymer A

Asphalt B
Polymer C
Physical property characterization of modified asphalt
Specifications and Tests for Modified Asphalts

- Identify presence of specific modifier
  - Task Force 31 (AASHTO, AGC, ARTBA) specs - Types I (SBS), II (SBR) and III (EVA)

- Performance based - blind to modifier type
  - West Coast PBA
  - SHRP’s Superpave PG binder spec

- SHRP+ - PG grade with modifier identifier

- SHRP II? – incorporates tests for modified binders
Tests for Modified Asphalts - and products they favor (PG +)

- **Elastic Recovery** - recovery from deformation (*SBS*)
- **Force Ductility** - strength at elongation (*SBS*)
- **Toughness & Tenacity** - strength measure (*SBR, SBS*)
- **Low temperature ductility** - low temperature behavior (*SBS*)
Elastic Recovery

AC doesn’t recover
SB modified
AC recovers
**Force Ductility**

- **Unmodified AC-20**
- **Same AC-20 With SBS**

Stress vs. Elongation, cm

Strength at elongation given by the polymer
Ductility
Tests for Modified Asphalts - and products they favor (con’t)

• **Ring and Ball Softening Pt** - high temp behavior *(gelled asphalt, oxidation, SBS, SBR, EVA)*

• **% Polymer** (e.g. FTIR, Fourier Transform Infrared) - recipe

• **Separation** – Are the materials homogeneous *(compatible materials)*?
Ring & Ball Softening Point
FTIR - SB(S) Modified AC

![FTIR spectrum with peaks labeled Butadiene and Styrene]

- **Butadiene**
- **Styrene**

**Wavenumber (cm\(^{-1}\))**

**Absorbance**
Separation Test
Separation Test

- Tube cooled
- Cut into thirds
- Tested top & bottom (here, for ring & ball softening point)
Does your state require additional tests?
PG+ specifications

27 states require extra tests (for some grades)

– Elastic Recovery - 17 states
– Separation - 6 states
– Toughness & Tenacity - 5 states
– Phase Angle - 5 states
– Ductility - 3 states
– Force Ductility - 2 states
– Others: Solubility, Sieve, Viscosity, Spot, Smoke, Softening point, Infrared for polymer, APA
Superpave Performance Based Tests

- Developed using unmodified AC’s
  - Dynamic Shear Rheometry
  - Bending Beam Rheometry
  - Direct Tensile Test

- NCHRP 9-10
  - Methodology for modified binders
PG binders

Is spec blind to modifiers?

- **PG for Modified Asphalt (NCHRP 9-10)**
  - **DSR Fatigue parameter** \( (G^* \times \sin \delta) \)
    - No correlation to mixture fatigue
    - Use damage concept based upon dissipated energy ratio \( (DSR) \)
  - **DSR Rutting parameter** \( (G^*/\sin \delta) \)
    - Prefer repeated creep accumulated strain \( (DSR) \)
  - **Binder homogeneity/separation - LAST test**
  - **Mix and compaction temperatures – Zero shear viscosity**
Performance of Modified Mixes
Hamburg Wheeltracking
Same AC-20 unmodified & modified

Deformation, mm

Number of Cycles

Polymer Modified AC-20
AC-20
Permanent Deformation
SST Shear Creep Test, 40°C
FHWA ALF Surface Mixture

Response to Applied Load of 35 kPa for 10 seconds

- PG 64-22 (unmod)
- PG 82-22 (SBS mod)
Thermal Cracking

Indirect Tensile & Bending Beam Predictions

Predicted Cracking Temp, °C

AC PMAC Oxidized PMAC

PG 64-28's PG 76-22's

IDT - Test on Mixture

BBR - Test on Liquid
Durability
Resistance to Fatigue Cycling
Flexural Beam Fatigue Test, AASHTO TP-8

SB Polymer HMA (PG 76-28) - 2,500,000 cycles to failure
Unmodified HMA (PG 64-22) - 250,000 cycles to failure

Cycles to Failure at 500 microstrain
Field Performance
Why Modify?
Performance

AC-20

PMAC
Arizona Experience with CRM
Reduced maintenance costs

George Way, ADOT, 1998
<table>
<thead>
<tr>
<th>Other Field Trials &amp; Life Cycle Cost Comparisons</th>
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<tbody>
<tr>
<td>- Texas: Jones, Kennedy &amp; Torshizi, TRB, 1993</td>
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<tr>
<td>- Michigan: Hawley &amp; Baladi, MDOT, 1996</td>
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<tr>
<td>- California: Reese &amp; Goodrich, AAPT, 1993</td>
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<td>- Kentucky: Blankenship, et. al., AAPT, 1998</td>
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<td>- Canada: Carrick &amp; Fraser, CTAA, 1996</td>
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<td>- Pennsylvania: Anderson &amp; Maurer, TRB, 1999</td>
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<td>- Many others</td>
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Implications

Do the PG specs include the desired properties to ensure field performance?
Summary

• Additives have been used to improve pavement performance

• Additives are used to modify the grade of the asphalt, but the performance of the additives in the mix can vary

• Binder specifications alone do not guarantee good field performance
Summary

- PG binders have reduced **rutting** & **low temperature cracking** failures
- PG binders give more consistent quality, but still need better characterization of modified materials
- Mixture tests are needed to insure that the additive will perform as expected in the field.
Thanks

Any Questions?