Outline:

• Why Modify?
• What are Polymers?
• Benefits of SBR in Asphalt Emulsions.
• Impact on Performance of Surface Treatments:
  – Chip Seal
  – Slurry Seal
  – Microsurfacing
• Manufacturing Process with Latex
• Latex
  – Usage
  – Handling
Asphalt Emulsions - Formulation

• Components
  – Asphalt
  – Surfactant (surface active agents, emulsifiers)
  – Water
  – Mechanical energy (colloid mill)

• Other Ingredients
  – Additives (calcium chloride, other agents,...)
  – Modifiers – Polymers
Asphalt Emulsions – Component Distribution

• Dispersion of asphalt in water
  - Water – continuous phase
  - Asphalt – non-continuous or dispersed phase
    - Stabilized by surfactant

• Surfactant → emulsion class.
  - Cationic
  - Anionic
  - Nonionic
Neat Asphalt

- Low Stiffness
- High Temperature
- Cracking
- Bleeding / Rutting

Useful Operating Range
Modified Asphalt

- Low Stiffness: Cracking
- High Stiffness: Bleeding / Rutting
- Low Temperature: Useful Operating Range
- High Temperature:

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**WRAPP**
WESTERN REGIONAL ASSOCIATION for Pavement Preservation
Comparing Neat to Modified Asphalt

- Low Stiffness
- High Stiffness
- Low Cracking
- Medium Useless Operating Range
- High Bleeding / Rutting

Neat Asphalt vs Modified Asphalt
Why use polymers in Asphalt?

• Improve resistance to high temperature permanent deformation and bleeding.

• Increase low temperature flexibility

• Improve fatigue resistance

• Increase tensile strength

• Reduced temperature susceptibility
Concerns with Asphalt Emulsion Application

- Loss of stone under traffic or rain
- Tender in early life
- Bleeding
- Raveling
- Premature cracks
- Deformation
- Early aging
• All conventional Asphalt emulsion may suffer from problems under some circumstances.

• There is a need for better performing Asphalt emulsions.
HOW?

• Better selection of type Asphalt emulsion needed (CRS vs. CMS vs. CSS)

• Better selection of base Asphalt for Asphalt emulsions – Improve Properties with Asphalt Treatment.

• Through modification with polymers
What is a Polymer?

- Made of many (poly) small molecules (monomers)
- Monomers chemically reacted to one another
- Properties are determined by sequence and chemical structure of the monomers.

SB

\[ \text{block copolymer} \]

SBS

\[ \text{multi-block copolymer} \]

SBR

\[ \text{random copolymer} \]
Typical Monomers

Styrene
$M_w \sim 104 \text{ g/mol}$

Butadiene
$M_w \sim 54 \text{ g/mol}$
Polymers for Asphalt Emulsion Modification

- Elastomer — **Styrene-Butadiene Rubber - SBR**
  - Latex form — polymer particles dispersed in water
  - Random monomer addition — typ. 75/25 BD/styrene
  - High molecular weight — 1,000,000 g/mole
    - 13,900 BD “mers”, 2400 styrene “mers”
  - Broad distribution — chains many different lengths
Polymers for Asphalt Emulsion Modification

• Elastomer – **Polyisoprene** – Natural Rubber
  – Latex form – polymer particles dispersed in water
  – Homopolymer of isoprene – harvested from trees
  – High molecular weight – 1,000,000 g/mole
  – Broad distribution – chains many different lengths

![Isoprene molecule](image)

Isoprene

$M_w \sim 68$ g/mol
Polymers for Asphalt Emulsion Modification

- Thermoplastic Elastomers
  - Styrene-BD-Styrene block copolymer – SB-, SBS
  - Monomers blocked in polymer backbone
    - Typically 70/30 BD/styrene
  - Lower molecular weight – 100,000 g/mole
    - 1300 BD “mers”, 288 styrene “mers”
  - Narrow distribution – all chains similar length
Polymers for Asphalt Emulsion Modification

- **Thermoplastic**
  - Ethylene vinyl acetate (EVA) resin
  - Vinyl acetate content ~ 20% to 40%
    - Low Tg, high melt temp due to crystallinity

- **Thermoset**
  - Ground tire rubber (GTR)
  - Mixtures of E-SBR, S-SBR, PBd, natural rubber
    - Depends on tire component
    - Tread, sidewall, innerliner (halobutyl),...
Performance properties vary with...

- Concentration
- Molecular weight
- Chemical composition
- Crude source
- Refining process
- Grade of base asphalt
Why SBR?

- Extra performance and durability
- Reduced life cycle cost
- Special techniques not possible with unmodified asphalt emulsions
  - Emulsion chip seals for high volume roads
  - Microsurfacing
  - Improved early strength for cold mixes
Performance Curve - Texas

- Distress Rating vs. Years of Service
- UNMODIFIED: 5.10 YEARS
- MODIFIED: 8.05 YEARS
- 57.8% Increase

57.8% Increase
Performance Curve - Alabama

- UNMODIFIED
- MODIFIED

12.7 Years
8.7 Years

46% Increase
Performance Curve - Colorado

- Years of Service
- Crack Index
- Unmodified Pavement
- SBR Modified Pavement

4.10 Years
6.5 Years
CI = 75
58.5% Service Life Improvement

60.5% Service Life Improvement
Benefits of SBR Latex

• Increased Adhesion
• Toughness at Warm Temperatures
• Flexibility at Low Temperatures
• Resist Deformation
Improvements with SBR

• Raise Softening Point
  – This assists in reducing bleeding & rutting

• Increase Viscosity
  – This allows increased in the thickness of films on the aggregate and hence increases durability. It also helps in deformation resistance and reduced aging.
Improvements with SBR

• Decrease Thermal Susceptibility
  • This gives the effect of a softer binder at low temperatures and a stiffer binder at higher temperatures, that is a better balance of properties

• Increase elasticity
  • This is true for elastomeric polymers. The binder that can recover will resist fatigue induced cracking.
**Improvements with SBR**

- **Increased cohesion and internal strength**
  - This reduces deformation under traffic and increases stone retention

- **Increased low temperature tensile strength and flexibility**
  - This reduces the occurrence of cracks due to reflection or low temperatures
Polymer Modification of Asphalt Emulsions

• Emulsify polymer modified asphalt
  – “Pre-modified” emulsion
  – Polymers – SBS, SB-, EVA
  – Higher mod. asphalt viscosity
    ▪ higher asphalt + mill temp.
  – Exit temp. > 100°C
  – Heat exchanger, back press.

• Polymer inside asphalt droplet
Polymer Modification of Asphalt Emulsions

• Add latex external to asphalt
  – Methods
    • soap batching
    • co-milling – asphalt line
    • co-milling – soap line
  – Polymers – SBR, NR latex
  – Lower asphalt process T
  – No special mill, handling

• Polymer in water phase

• Continuous polymer film formation on curing
Advantages of Latex Polymer Network

- Latex polymer honeycombs remain flexible
- Absorb stresses without permanent deformation
Resistance to High Temperatures:

Latex Polymer added to the Aqueous Phase

- Air dried at Ambient temp for 3 hrs.
- Then at 60 C for 4 hrs. in forced air oven.
- Air dried at Ambient temp for 3 hrs.
- Then at 60 C for 4 hrs. in forced air oven.
- Then subject to 110 C for 2 hrs.
- No Flow observed

Confocal Laser Scanning Microscopy Images:
Binder Requirements for Chip Seal

- Thin Asphalt layer with similar size aggregates, large voids
- Applied on the old pavement as preventative maintenance
  - Need to withstand higher strain-stresses, especially under snow plow operations

“Improved Fatigue Resistance of Asphalt Emulsion Residue Modified with SBR Latex.”
Dr. Koichi Takamura, BASF Corp.
Buildings Designed for Earthquake Resistance

- Absorb mechanical stresses with flexible rubber pads and dissipates as heat.

“Improved Fatigue Resistance of Asphalt Emulsion Residue Modified with SBR Latex.”
Dr. Koichi Takamura, BASF Corp.
**Improved Fatigue Resistance of the SBR Latex Modified Emulsion Residue**

- Schematic of fully cured unmodified and SBR latex polymer modified asphalt emulsion. The unmodified residue would fracture through asphalt droplet/droplet boundaries, but highly flexible, SBR latex films surrounding these droplets absorb these excess stresses through elastic deformation without causing permanent deformation to the bulk asphalt phase.

“Improved Fatigue Resistance of Asphalt Emulsion Residue Modified with SBR Latex.” Dr. Koichi Takamura, BASF Corp.
Physical Properties of SBR Polymer and Asphalt.

- **Latex film:**
  - Flexible at below -30°C and maintains strength at an elevated temperature of above 80°C.
  - Complex Modulus changes only by a factor of 10 between -20 and 80°C.

- **Asphalt:**
  - Maintains its desirable properties only at a narrow temperature range 10-60°C.
  - Too brittle at low temperatures.
  - Limited strength at >60°C
  - Complex Modulus changes 100,000 times over the same temperature range of -20 and 80°C.

“Improved Fatigue Resistance of Asphalt Emulsion Residue Modified with SBR Latex.”
Dr. Koichi Takamura, BASF Corp.
SBR Latex Modified Asphalt Emulsion

• Strong Contrast in Physical Properties between Continuous Polymer and Dispersed Asphalt Phases.
  – Rigid Structure from Asphalt
  – Elastic Properties from Polymer Network
Strain Sweep Analysis

- Asphalt emulsion residue with 3% SBR Latex
  - Maintain strength at high strain-stresses

“Improved Fatigue Resistance of Asphalt Emulsion Residue Modified with SBR Latex.”
Dr. Koichi Takamura, BASF Corp.
Benefits of Polymer Modification: 19°C

- 3% SBR Modified Emulsion Residue
- Maintains almost constant $G^*$ at <8% strain
- Withstands repeated stresses at 10% strain
- Recover $G^*$ during 5 minute rest period

“Improved Fatigue Resistance of Asphalt Emulsion Residue Modified with SBR Latex.”
Dr. Koichi Takamura, BASF Corp.
WHAT DO SBR DISPERSIONS DO?

• Form a network in the asphalt

• Will impart the elastic and resistance to flow to the asphalt

• Reduce temperature susceptibility of the asphalt
Chip Seal: Early Strength Development
Curing of Chip Seal Emulsion

- Water in asphalt emulsion wicks the aggregate surface
- Order of migration = Water, latex particles, asphalt drops
Latex Polymer Distribution

- Latex particles migrate together with water!
- Polymer rich regions develop around aggregate

Source: BASF
Chip Seal – CRS-2: Early Strength Development

- Water wicks aggregate surface
- Positive correlation exists between early chip retention vs. aggregate’s water absorption capacity
Aggregate Retention

- Aggregate retention is sensitive to aggregate water absorption
Aggregate Retention:

- “Problem-Free” chip seal operation with SBR modified CRS-2P
Chip Seal: Early Strength Development

% Aggregate Retained

Potential Chip Loss

Aggregate Samples

Data provided by Paragon technical Services
Old Surface Exhibiting Stone Loss and Block Cracking

New (1995) Surface

Cambridge Lane 1995 G Treatment 400+ ADT
Cambridge Lane 1995 G Treatment 400+ ADT Exhibits no sign of Stone Loss or Block Cracking Returning after 4 Years
Chip Seal Summary:

- Polymers Provide Significant Benefits to Chip Seal
  - Faster chip retention with wide varieties of aggregates.
  - Fracture resistance under repeated high strain-stresses.
  - Elastic deformation without permanent damage, even at low temperatures.
Modified Emulsions - Benefits and Uses Of Polymers in Slurry and Microsurfacing
Microsurfacing – Polymer Morphology: Field Application

Texas State Highway 84
- Near Waco, TX
- Paved in 1998
- Samples taken in 2001

“Improved Fatigue Resistance of Asphalt Emulsion Residue Modified with SBR Latex.”
Dr. Koichi Takamura, BASF Corp.
Wet Track Abrasion Loss – ISSA TB-100

SBR latex polymer
- 50% reduction in loss
  - one hour soak
- 67% reduction in loss
  - six day soak
- Surface of mix
  - tougher
  - more abrasion res.
- Adhesion + water resist.
  - improved
Slurry Seal Improvements

• Improved Tear Resistance
• Better Cohesion and Adhesion
• Increased Structural Strength
• Abrasion Resistance
• Bleeding Resistance
• Durability
Microsurfacing Improvements

- Improved Tear Resistance
- Better Cohesion and Adhesion
- Increased Structural Strength
- Abrasion Resistance
- Bleeding Resistance
- Durability
- Deformation Resistance
- Use on higher traffic volume roads
- Thicker applications
Design using Polymer Emulsions

• Will It Mix?
• Will it Set?
• Will it Perform?

• Have a CLEAR idea why you want to use polymer!!!
Emulsifying Equipment

Source: BAEM, 4th Edition
Manufacturing Process:

Latex may be:

• **Pre-blended** into Soap Batch Tank & Co-Mill

• **Injected & Co-Mill**
  – Injection into soap line or mill
  – Injection into asphalt line
  – Injection into both soap and asphalt line

• Post add
Schematic of Batch Emulsion Plant
Schematic of Batch Emulsion Plant

- asphalt
- emulsion
- latex
- colloid mill
- batch soap tank
- stabilizer
- acid
- emulsifier
- water inlet
Schematic of Batch Emulsion Plant
Schematic of Batch Emulsion Plant

- asphalt
- emulsion
- batch soap tank
- stabilizer
- acid
- emulsifier
- water inlet
- colloid mill
- latex
Schematic of Continuous Emulsion Plant

- asphalt
- solvent
- emulsion
- latex
- emulsifier
- acid
- colloid mill
- dwell tank
- heater
- water inlet
Addition of Latex Summary

• In aqueous phase may cause loss of viscosity
• Must compensate by either raising residue or:
  • Injection of Latex into asphalt line
    – Option of dividing between aqueous phase and injection into asphalt line.
    – Changing distance of injection port
    – Using in-line blender
• Must compensate for pH of latex with additional acid in the soap solution for control of emulsion pH.
Addition Of Latex

Addition into soap

Injection into Mill
What is best?

- Latex is best co-milled into the emulsion: This produces a better dispersion and retards separation. It also avoids pH shock and allows highest treat rates.

Source: Holland, G.
Confocal Laser Scanning Microscopy Images:

The addition of Latex Polymer:

A. Post Added To Emulsion
B. Added to the Solution & Co-Milled
C. Injected into Mill & Co-Milled

Source: Holland, G.
Co Milling effects

SBR Co milled 3um largest

SBR Post added
Largest size 20um

Source: Holland, G
Effect Of Co-milling

Retained stone %

3% Polymer solids on Asphalt, CRS-2 base

Vialit

Temperature Of Test

Source: Holland, G
SBR Latex Polymers Storage and Handling

• Good Shelf Life under proper conditions
• No special type of storage tank required.
• Storage temperatures of 50-100°F (10-38°C)
• Protect from freezing
Plant Needs:

• Piping choice is important.
SBR latex is a dispersion of very small particles in water and the polymer is lighter than water.

- Tendency for the polymer particles to “cream” to the top during long storage time.
- High temperatures will accelerate this creaming.
- Agitation is recommended for storage tanks and for totes.
- Agitated storage tanks recommended
- Latex stored for more than 14 days should be agitated at intervals of once/week for 1-2 hours.
- Low shear “Lightnin” type mixers recommended.
- Rapid agitation to be avoided.
- Totes should be agitated prior to use and after any skins have been removed.
- Never use forced air to agitate Latex.
Container Mixing:

Lightnin

Visco Jet
Tote Mixing

Visco Jet® IBC Tote Tank Agitator (www.viscojet.com)
The exposure of the latex to air will result in a skin forming on the surface.

- Skins will form in storage tank. Keep level of latex above agitation blades.

- Keep all lids and gaskets on drums and totes in place to minimize the exposure to air and skin formation.

- Any skins mixed into the latex will need to be remove using a screen before being used.

- Double screens are good to prevent an interruption in production should skins be present from the storage tank or totes.
Strainers:
**SBR Latex Polymers Storage and Handling**

- **SBR Latex is sensitive to shear.**
  - Use low shear pumps to transfer latex.
  - Do Not Use Gear Pumps

- **Do not contaminate the latex**
  - At no time should water be added to the latex
  - All transfer hoses, lines, pumps should be clean and odor free.
  - If cleaning or flushing must be performed, use soft water. (Hard water will coagulate the latex.)

- **Free falling** of the latex should be minimized when adding to storage or mix tanks to prevent foaming and exposure to air.
Progressive Cavity Pumps with flow meter:
Handling of SBR Latex Summary

- Ideal storage temperature range is 50-100°F.
- Do Not allow to freeze.
- Periodic, mild agitation should be used.
- Use Progressive Cavity or Air Diaphragm Pumps
- Do Not Use gear pumps.
- Prevent contamination.
Conclusions:

• Polymers improve the performance of Asphalt surface treatments allowing application on all types of roads.

• They make micro surfacing possible

• They come in many forms

• Latex is a convenient addition method.

• They are NOT a magic bullet!!
Asphalt emulsion production is as much art as it is science; the art of asphalt emulsions production is in understanding the science and putting it to practical use.

Source: Baumgardner, G., TRB Circular E-C102, Asphalt Emulsion Technology
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THANK YOU

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Questions ??

Initial

After 2 years