The Eco-Efficiency of Chip Seals

2017 WRAPP Pavement Preservation Work Shop
„Going Green“
Ontario, California

Bruce Uhlman, LCACP
Manager, Applied Sustainability
BASF Corporation
February 1, 2017
Our customers what to now more about what we are doing around sustainability as a supplier and what are the environmental impacts/SD benefits of the products we supply to them are
Information to better understand your value chain

Provides a forum to actively engage your customers

Helps grow your business
Understand your value chain

- Feed Stocks
- Manufacturing
- Competition
- Customer
- Consumer
- End of Life

+ Supply Chain Insights

Sustainable Sourcing
Production Efficiencies (Verbund)
Differentiation Potential
Alignment with customer needs
Anticipate Market Developments
Recovery vs. Disposal

Tailored solutions based on customer’s requirements.
BASF has a robust, science based tool box for helping us evaluate the relative sustainability of products and processes over their life cycle.

- Clearly and easily depicts the environmental, social, and economic values and trade-offs between different products.
- Over 600 studies completed globally for diverse products and market applications.
- Following Industry Standards. Methodologies 3rd party validated by TÜV, DNV and NSF. Externally communicated studies verified by NSF in North America.
Ecology (Environment)

- Emissions to Air & Water
- Greenhouse gases
- Waste
- Resource efficiency
- Renewables

- Water
- Human Toxicity
- Land use
- Energy

Holistic Environmental Assessment
Economics

Total Cost of Ownership

Traditional Cost Categories
- Maintenance & Repair
- Labor
- Capital Investment
- Logistics
- Material Costs
- Energy

Non-traditional Cost Categories
- Process Efficiency
- Training
- Durability
- Disposal
- Lost Revenue
Evaluating the full life cycle

Production (cradle to gate)

Basic Raw Materials (cradle)

Recycle / Return (cradle to cradle)

Product Use

Disposal (cradle to grave)
Compare alternatives
Environmental Fingerprint

- Fossil Resources
- Mineral Resources
- Land Use
- Toxicity
- Climate Change
- Summer Smog
- Ozone Depletion
- Acid Rain
- Eutrophication
- Water

Alternatives:
- Alternative 1
- Alternative 2
- Alternative 3
Stakeholder input

How does society and stakeholders feel about environmental impacts?

Talk with stakeholders and conduct interviews

North American Weighting Factors

- Climate Change: 12%
- Ozone Depletion: 9%
- Human Toxicity: 17%
- Eutrophication: 13%
- Summer Smog: 8%
- Resources: 11%
- Land use: 7%
- Water Consumption: 13%
- Acidification: 10%
Compare alternatives
Eco-efficiency

- Eco-efficiency
- Environmental Impact
- Higher
- Lower

Eco-Efficiency Index

Economic impact

Highest Eco-Efficiency, lowest impact

Economic impact dominates

Environmental impact dominates

Lower
Information to support your business strategy

Product Development

Understand Competitive Advantages & trade-offs

Align Solution with Customer Need

Sustainability communications

Advocacy

Eco-certifications

Drive Sales & Increase Added Value
The Eco-efficiency of Chip Seals

A collaborative project by BASF and Colas
Customer Benefit and Alternatives

Customer Benefit

Preventive maintenance of a 1 mile stretch of a 12 foot lane of a rural road to a similar profile and performance using best engineering practices over a 40 year period.

Hot Alternatives

Hot Chip Seal, polymer modified non-emulsified with Ground Tire Rubber (GTR), AC-20-5TR

Cold Products

Polymer modified Chip Seal, emulsified asphalt (CRS-2P) using SBR or SBS polymers

Polymer modified Chip Seal, emulsified asphalt (CRS-2P) using SBR polymers with fiber reinforcement
System Boundaries - Polymer modified asphalt emulsion w/ SBR

Production
- Emulsifier
- Polymer
- Acid
- Water
- Milling
- Aggregate preparation and transport
- Asphalt @ 285 F – 310 F
- Storage, load into truck, transport to site

Use
- Sweep surface
- Spray on Surface
- Drop Aggregate
- Lane Stripping
- Traffic on the road

Disposal
- Old pavement removal
- Transport and Recycling, Disposal

Grey boxes are not considered, since they are the same for all alternatives.
Grey boxes are not considered, since they are the same for all alternatives.
Grey boxes are not considered, since they are the same for all alternatives.
Key Project Assumptions

- Life expectancy data for the alternatives was obtained from a 3rd party (National Center Pavement Preservation) survey of state transportation agencies (17 states responding)
  - 6 years for all alternatives

- Life Cycle costing:
  - Both financial and social discount rates were used
  - Lane rental fees were used to capture the delay costs associated with construction activities
  - Costs for alternatives are industry/national averages and provided by manufacturers.

- Industry avg. data used for compositional data for alternatives.

- Credit (both environmental and cost) given to alternatives for remaining value left in road at end of study timeframe

- Data related to work zone accidents & fatalities obtained from DOT – FHWA data
Key Project Assumptions

- Energy requirements for producing and applying the asphalt alternatives were obtained from:
  - Colas, Life Cycle Analysis, The Environmental Road of the Future, 2003
  - Various manufacturer – industry data

- Energy for grinding tire rubber was considered

- Transportation Impacts consideration:
  - Binder – Fiberglass: 100 km
  - Aggregate: 50 km
  - Disposal – Recycle: 100 km
# Chip Seal Eco-Efficiency Analysis

## Input Data: General Data

<table>
<thead>
<tr>
<th>CUSTOMER BENEFIT:</th>
<th>GTR</th>
<th>Fiber Reinforced</th>
<th>SBR Modified</th>
<th>SBS Modified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Surface</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mi</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Width</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sq. yard</td>
<td>7040</td>
<td>7040</td>
<td>7040</td>
<td>7040</td>
</tr>
<tr>
<td>sq. meter</td>
<td>5886</td>
<td>5886</td>
<td>5886</td>
<td>5886</td>
</tr>
<tr>
<td>Life Expectancy of Road</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>years</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Life Expectancy of Chip Seal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>years</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Number of Road Applications</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>days</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Duration to apply Chip Seal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>days</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Financial Discount Rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>4.80%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social Discount Rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>6.00%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highway Rental Fee</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$/lane-mile-day</td>
<td>$5,000.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane Stripping</td>
<td></td>
<td>$4,455.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work Zone Injuries - Accidents</td>
<td></td>
<td>0.00552</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work Zone Fatalities</td>
<td></td>
<td>0.00009</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Chip Seal Eco-Efficiency Analysis

## Input Data: Compositional Data

### Compositional Data

<table>
<thead>
<tr>
<th>Chip Seal Binder Composition</th>
<th>%</th>
<th>67.6%</th>
<th>67.6%</th>
<th>67.6%</th>
<th>67.6%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Tire Rubber</td>
<td>7.5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bitumen (asphalt cement)</td>
<td>90.5%</td>
<td>67.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polymer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBS</td>
<td>2.0%</td>
<td></td>
<td></td>
<td></td>
<td>2.1%</td>
</tr>
<tr>
<td>SBR</td>
<td></td>
<td>3.3%</td>
<td>3.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emulsifier</td>
<td></td>
<td>0.2%</td>
<td>0.2%</td>
<td>0.2%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td></td>
<td>0.2%</td>
<td>0.2%</td>
<td>0.2%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td>28.7%</td>
<td>28.7%</td>
<td></td>
<td>29.9%</td>
</tr>
<tr>
<td>TOTAL %</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td></td>
<td>100.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pre-coating of Aggregate with asphalt</th>
<th>%</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt by weight</td>
<td>0.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphalt per CB</td>
<td>3549</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Percentages

<table>
<thead>
<tr>
<th></th>
<th>%</th>
<th>0.09</th>
<th>0.089</th>
<th>0.09</th>
<th>0.09</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chipseal binder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiber glass</td>
<td></td>
<td>0.005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate</td>
<td></td>
<td>0.91</td>
<td>0.907</td>
<td>0.91</td>
<td>0.91</td>
</tr>
</tbody>
</table>
## Chip Seal Eco-Efficiency Analysis

### Input Data: Application Rates

<table>
<thead>
<tr>
<th>Application Rates</th>
<th>GTR</th>
<th>Fiber Reinforced</th>
<th>SBR Modified</th>
<th>SBS Modified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chipseal binder</td>
<td>gal/sq. yd</td>
<td>0.35</td>
<td>0.43</td>
<td>0.43</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>lb/gal</td>
<td>1.02</td>
<td>1.01</td>
<td>1.01</td>
</tr>
<tr>
<td>Density</td>
<td>lb/gal</td>
<td>8.51</td>
<td>8.42</td>
<td>8.42</td>
</tr>
<tr>
<td>Rate</td>
<td>lb/sq. yd</td>
<td>2.93</td>
<td>3.62</td>
<td>3.62</td>
</tr>
<tr>
<td>Aggregate</td>
<td>kg/sq. yd</td>
<td>1.33</td>
<td>1.64</td>
<td>1.64</td>
</tr>
<tr>
<td>Density</td>
<td>sq. yd./cu. Yd.</td>
<td>139.00</td>
<td>125.00</td>
<td>125.00</td>
</tr>
<tr>
<td>Rate</td>
<td>lb/cu. Yd</td>
<td>4635.09</td>
<td>4635.09</td>
<td>4635.09</td>
</tr>
<tr>
<td>fiberglass Material</td>
<td>lb/sq. yd</td>
<td>33.35</td>
<td>37.08</td>
<td>37.08</td>
</tr>
<tr>
<td>fiberglass Material</td>
<td>kg/sq. yd</td>
<td>15.13</td>
<td>16.82</td>
<td>16.82</td>
</tr>
<tr>
<td>Road Markings</td>
<td>kg/mile</td>
<td>1794.41</td>
<td>1794.41</td>
<td>1794.41</td>
</tr>
</tbody>
</table>
The biggest contributor to energy consumption for each alternative is the manufacture of the asphalt binder. GTR has the highest impact based on the extra requirements for pre-coating the aggregate as well as higher manufacturing and application temperatures.
Activities related to the production and storage of GTR as well as the pre-coating of aggregate contribute to GTR having the highest GWP. CO₂ emissions from the manufacturing / application of the road markings also is a significant contributor.
The asphalt binder, aggregate, road markings and disposal/transportation modules have the largest impact in the raw material usage category.
GTR has the lowest impact for solid waste emissions. This is directly related to the diversion of tires from landfill and use in the GTR chip seal.
Calculation Factors

- Main Categories
  - Land Use 6%
  - Risk 13%
  - Toxicity 19%
  - Emissions 18%
  - Resources 23%
  - Energy 20%

- Emissions
  - Wastes 22%
  - Water 41%
  - Air 37%

- Air Emissions
  - AP 38%
  - POCP 22%
  - ODP 7%
  - GWP 32%
GTR chip seal scores highest in all categories except toxicity potential. Emulsion based technologies score similar impacts.
Overall Economic Results

<table>
<thead>
<tr>
<th></th>
<th>GTR</th>
<th>Fiber Reinforced</th>
<th>SBR Modified</th>
<th>SBS Modified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chip Seal material Cost</td>
<td>$/yd2</td>
<td>2.37</td>
<td>2.8275</td>
<td>2.262</td>
</tr>
<tr>
<td>Pavement Costs</td>
<td>$/CB</td>
<td>$57,519</td>
<td>$64,642</td>
<td>$54,898</td>
</tr>
<tr>
<td>Striping Material Cost</td>
<td>$/CB</td>
<td>$15,633</td>
<td>$15,633</td>
<td>$15,633</td>
</tr>
<tr>
<td>Lane Rental Fees</td>
<td>$/CB</td>
<td>$15,481</td>
<td>$15,481</td>
<td>$15,481</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$/CB</td>
<td>$91,598</td>
<td>$99,076</td>
<td>$89,318</td>
</tr>
</tbody>
</table>

The installed material costs is the largest contributor to the overall life-cycle costs. The SBR/SBS emulsion technologies have the lowest overall life-cycle cost for this study. Fiber Reinforced has the highest life-cycle costs.
Preventive maintenance of a 1 mile stretch of a 12 foot lane of a rural road to a similar profile and performance using best engineering practices over a 40 year period.

For this study, the SBR/SBS emulsion chip seals are the most eco-efficient.
## Eco-efficiency Portfolio:
### Scenario #1: Increased durability for Fiber Reinforced

<table>
<thead>
<tr>
<th>LIFE CYCLE COSTS</th>
<th>GTR</th>
<th>Fiber Reinforced</th>
<th>SBR Modified</th>
<th>SBS Modified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chip Seal material Cost</td>
<td>$/yd2</td>
<td>2.37</td>
<td>2.8275</td>
<td>2.262</td>
</tr>
<tr>
<td>Pavement Costs</td>
<td>$/CB</td>
<td>$57,519</td>
<td>$56,135</td>
<td>$54,898</td>
</tr>
<tr>
<td>Striping Material Cost</td>
<td>$/CB</td>
<td>$15,633</td>
<td>$13,701</td>
<td>$15,633</td>
</tr>
<tr>
<td>Disposal Costs</td>
<td>$/CB</td>
<td>$2,965</td>
<td>$2,747</td>
<td>$3,306</td>
</tr>
<tr>
<td>Lane Rental Fees</td>
<td>$/CB</td>
<td>$15,481</td>
<td>$13,636</td>
<td>$15,481</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$/CB</td>
<td>$91,598</td>
<td>$86,220</td>
<td>$89,318</td>
</tr>
</tbody>
</table>

**Diagram:**
- Energy Consumption
- Land Use
- Emissions
- Resource Consumption
- Toxicity Potential
- Occupational Illnesses and Accidents
- Environmental burden (norm.)
- Costs (norm.)
We create chemistry

Customers First

Winning Together
For More Information:

Bruce Uhlman, LCACP, CLE
BASF Corporation - Product Stewardship Manager, Applied Sustainability
Tel: (973) 245-7187
Email: bruce.uhlman@basf.com

www.basf.com/sustainability