Utilization of Fractionated Bio-Oil in Asphalt

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Presentation Outline

- Background
- Bio-oil pilot plant production
- Experimental Plan
- Results
- Conclusions and Future Work
Societal Issues

- Economy
- Transportation fuel pricing
- Job creation
- Infrastructure funding & renewal
- Energy independence
- Climate change
Asphalt Industry
Background & Challenges

- Approximately 68% of GDP utilizes our transportation systems

- About 90% of Nation’s paved highways use asphalt
  - Asphalt pavements and composite pavements
  - Maintenance applications (patching, crack sealing, surface treatments)

- Asphalt is derived from crude petroleum

- Refinery modifications has removed asphalt from the market to produce more transportation fuels
Impacts of Higher Crude Oil Prices

- Higher asphalt & fuel prices reduces the number of infrastructure projects
- Fewer miles driven
  - 50 billion fewer miles from November 2007 to May 2008
  - 11 billion fewer comparing March 2007 to March 2008 (4.3% decrease)
  - 15 billion fewer miles comparing August 2007 to August 2008 (5.6% decrease)
- Decrease in highway tax revenue
- Less asphalt polymers (butadiene) available due to change in polymer production and reduction in tire manufacturing
- Less money for infrastructure projects
Asphalt Industry Market

Nationally

- 500 million tons of hot mix asphalt ($30 billion annually)

- 30 million liquid tons of asphalt ($21 billion annually)

- ~4,000 stationary & 500 mobile hot mix asphalt plants
Bio-economy & Transportation Link

- Market share of bio-energy will become greater percentage of overall energy sector

- Opportunities for utilizing bio-energy co-products exist in asphalt industry
Bio-Energy Components

- Corn Based Ethanol (wet & dry mill)
- Cellulosic Ethanol
- Bio-diesel
- Bio-oil (non-food source)
# Characteristics of Fractionated Bio-Oil

<table>
<thead>
<tr>
<th>Property</th>
<th>Cond. 1</th>
<th>Cond. 2</th>
<th>Cond. 3</th>
<th>Cond. 4</th>
<th>ESP</th>
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<tbody>
<tr>
<td>Fraction of total oil (wt%)</td>
<td>6</td>
<td>22</td>
<td>37</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>pH</td>
<td>-</td>
<td>3.5</td>
<td>2.7</td>
<td>2.5</td>
<td>3.3</td>
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<tr>
<td>Viscosity @40°C (cSt)</td>
<td>Solid</td>
<td>149</td>
<td>2.2</td>
<td>2.6</td>
<td>543</td>
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<tr>
<td>Lignin Content (wt%)</td>
<td>High</td>
<td>32</td>
<td>5.0</td>
<td>2.6</td>
<td>50</td>
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<tr>
<td>Water Content (wt%)</td>
<td>Low</td>
<td>9.3</td>
<td>46</td>
<td>46</td>
<td>3.3</td>
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<td>C/H/O Molar Ratio</td>
<td>1/1.2/ 0.5</td>
<td>1/ 1.6/ 0.6</td>
<td>1/ 2.5 / 2</td>
<td>1/ 2.5 /1.5</td>
<td>1/1.5/ 0.5</td>
</tr>
<tr>
<td></td>
<td>Corn Stover</td>
<td>Oak Wood</td>
<td>Switch Grass</td>
<td></td>
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<tr>
<td>Lignin</td>
<td>82.3</td>
<td>83.9</td>
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<td>Moisture</td>
<td>16.8</td>
<td>15.4</td>
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<td>Solids</td>
<td>0.6</td>
<td>0.6</td>
<td>1.1</td>
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<tr>
<td>Ash</td>
<td>0.3</td>
<td>0.1</td>
<td>0.2</td>
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</table>
Micropyrolyzer GC/MS Analysis of Feedstock Materials

- Oak Wood
- Switch Grass
- Corn Stover
GC/MS Analysis of ESP Fractions

Oak Wood

Switch Grass

Corn Stover
Experimental Plan

- Three asphalt binders
  - 1 local binder (1 polymer-modified, 1 neat binder)
  - 2 well known binders (AAD-1 & AAM-1)
- Three experimental bio-oil fractions
  - Corn Stover
  - Oak Wood
  - Switch Grass
Experimental Plan

- Each asphalt mixed with each bio-oil sample at 3, 6, and 9 percent by weight
- Evaluate rheological properties and determine Tc and performance grade of each blend
Performance Testing

1. Blend asphalt and lignin in a high speed shear mill at 145°C for 15 minutes
2. Evaluate high-temperature rheological properties of unaged blends with a DSR
3. Short-term age asphalt/lignin blends with a RTFO
4. Evaluate high-temperature rheological properties of RTFO aged blends with a DSR
5. Long-term age asphalt/lignin blends with a PAV
6. Evaluate inter-temperature rheological properties of PAV aged blends with a DSR
7. Evaluate low-temperature rheological properties of unaged blends with a BBR
8. Calculate continuous performance grade of mixtures
9. Compare results of different asphalt/bio oil blends
Product Type and Percentage

Unaged High Tc

- AAD-1
- AAM-1
- LPMB
Product Type and Percentage

- None
- Corn Stover: 3%
- Oakwood: 3%
- Switchgrass: 3%
- Corn Stover: 6%
- Oakwood: 6%
- Switchgrass: 6%
- Corn Stover: 9%
- Oakwood: 9%
- Switchgrass: 9%

Fatigue $T_c$

- AAD-1
- AAM-1
- LPMB
Product Type and Percentage
# High Temperature T\(_c\) Means Testing

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Difference in Means (ºC)</th>
<th>LSD 95% Confidence</th>
<th>Tukey 95% Confidence</th>
<th>Bonferroni 95% Confidence</th>
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<tbody>
<tr>
<td><strong>Binder Type</strong></td>
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<tr>
<td>AAD – AAM</td>
<td>-1.39</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>AAD – LPMB</td>
<td>-3.70</td>
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<td>AAM – LPMB</td>
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<td><strong>Bio Oil Content</strong></td>
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<td></td>
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<td>0 – 3</td>
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<td>0 – 6</td>
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<td>0 – 9</td>
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<td>None – Corn Stover</td>
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<td>None – Oak Wood</td>
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<td>Corn Stover – Oak Wood</td>
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<td>Corn Stover – Switch Grass</td>
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<td>+4.59</td>
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## Low Temperature $T_c$ Means Testing

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<th>Tukey 95% Confidence</th>
<th>Bonferroni 95% Confidence</th>
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<tr>
<td><strong>Binder Type</strong></td>
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<td>AAD – LPMB</td>
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<td>AAM – LPMB</td>
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<td><strong>Bio Oil Content</strong></td>
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<td>0 – 3</td>
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<td>0 – 6</td>
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<td>0 – 9</td>
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<td><strong>Bio Oil Source</strong></td>
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<td>None – Corn Stover</td>
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<td>Yes</td>
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<td>None – Oak Wood</td>
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<td>None – Switch Grass</td>
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<td>Corn Stover – Oak Wood</td>
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<td>Corn Stover – Switch Grass</td>
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<td>Oak Wood – Switch Grass</td>
<td>+3.19</td>
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</table>
Conclusions

- The addition of fractionated bio-oil to asphalt binders causes a stiffening effect
  - Binder effects
  - Biomass source of bio-oil
  - Amount of fractionated bio-oil
- The stiffening effect increases the high, int., and low critical temperatures of the asphalt/lignin blends
- The high temperatures are increased more than the low temperatures
- Grade ranges in some combinations are increased by one grade (6°C) and in other combinations no effects
Future Research

- Examination of chemistry & its relationships to rheology
- Examination of reduced production temperatures
- Developing non-petroleum based binder
- Mix performance testing
  - Permanent deformation
  - Fatigue cracking
  - Thermal cracking
  - Moisture susceptibility
- Construction of 5 ton/day pilot plant is underway
- 50 ton/day pilot plant is scheduled to be completed for May 2009
- Field trials
Big Picture

- Economic opportunity
- Integration of green technologies into asphalt industry that is sustainable
- Bio-energy co-products will be regionally produced and “married” with regionally supplied asphalt binders
- The US economy is highly dependant upon transportation infrastructure
Acknowledgements

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- Sam Jones & Kevin Emard, Center for Sustainable Environmental Technologies
Thank You!

Questions?
The Developing Bio-Energy Sector

- Crude oil, asphalt & polymer price increases
- US energy independence
- Sequestering greenhouse gases
- Utilizing bio-energy components to replace crude oil sources
- In the future, the bio-energy sector will become a larger portion of the total energy sector
- Can part of the bio-energy sector be beneficially used in asphalt materials?