Additives to Impact Performance

Trey Wurst, P.E.
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Chemical warm mix

Surfactant chemistry that improves coating and gives lubricity to asphalt mixtures, allowing placement & compaction at significantly lower production temperatures.
Recycling agents

Asphalt recycling agent used to reactivate oxidized RAP/RAS binder and improve blending with virgin binder.
Binder hardening

Reduced Oxidation with Evotherm

Pen

Virgin AC | After Paving | 2 Years Later
---|---|---
Hot Mix | Evotherm

Evotherm

Ingevity
Aggregate absorption: reduced AC

Evotherm

Hot mix control
Lower emissions

Hot mix

Evotherm
Increased recycled content: Chicago

- Using high amounts of RAP and RAS even in cold temperatures like 25°F
- Reduced equipment wear and tear by lowering the production temperature to 325°F from 365°F (winter production temps)
- Better workability
- **SAVINGS** from lower asphalt content

PG 58-22

37 percent RAP

5 percent RAS
Century Asphalt: no vibrations

Logistical nightmare
- Bridge deck of I–35 in downtown San Antonio, Texas
- Milling, then chip seal, then overlay
- All night paving
- Plenty of freeway intersections and ramps
- Type D mix with PG64–22, 16 percent RAP, 4 percent RAS
- No vibratory rollers allowed on bridges
- Long truck wait times!

Evotherm
- 70°F drop in production temperature
- Excellent workability even with truck delays
- Rollers ran right behind the screed
- 93.5 to 94 densities
More RAP, More RAS
Combination products

Precisely proportioned blend of Evotherm and Evoflex designed to

1. reactivate RAP/RAS binder
2. improve blending between recycled and virgin asphalt
3. provide better coating and workability
4. lubricate the mix
5. enhance compaction efforts
Development of Evoflex additives

Goals

• Thorough blending of the virgin asphalt with the oxidized asphalt
• Softening of the oxidized binder in RAP and/or RAS to allow thorough blending
• Ability to add more recyclables to mixes to offset the reduced stiffness due to lower mixing and compaction temperatures

<table>
<thead>
<tr>
<th></th>
<th>HMA + 20%RAP</th>
<th>EVO + 20%RAP</th>
<th>EVO + 28%RAP</th>
<th>EVO + 35%RAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration (mm)</td>
<td>29</td>
<td>39</td>
<td>32</td>
<td>28</td>
</tr>
<tr>
<td>Viscosity (cP)</td>
<td>25920</td>
<td>16087</td>
<td>16738</td>
<td>23470</td>
</tr>
<tr>
<td>Ductility (mm)</td>
<td>38</td>
<td>79</td>
<td>54</td>
<td>42</td>
</tr>
<tr>
<td>DSR @64C (kPa)</td>
<td>7.35</td>
<td>4.39</td>
<td>5.74</td>
<td>7.56</td>
</tr>
<tr>
<td>MSCR</td>
<td>26</td>
<td>42</td>
<td>37</td>
<td>32</td>
</tr>
<tr>
<td>DSR @ 70C (kPa)</td>
<td>3.48</td>
<td>2.11</td>
<td>2.91</td>
<td>3.59</td>
</tr>
<tr>
<td>BBR -12C</td>
<td>0.394</td>
<td>0.437</td>
<td>0.406</td>
<td>0.393</td>
</tr>
</tbody>
</table>
Evoflex effects on binder properties

![Bar chart showing the effect of Evoflex on binder properties at different PG temperatures.](image-url)

- **PG 64 -22**
  - 0%
  - 1.50%
  - 3%

- **PG 58 -28**
  - 0%
  - 1.50%
  - 3%
Evoflex effects on rutting potential

![Graph showing average rut depth at 20,000 cycles (mm) for different asphalt mixtures with and without Evoflex CA addition.](image-url)
Evoflex effects on binder properties
(low temperature)

More cracking

Creep Stiffness (MPa)

<table>
<thead>
<tr>
<th></th>
<th>Stiffness</th>
<th>m-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>PG 64 -22 (-18 C)</td>
<td>300</td>
</tr>
<tr>
<td>1.50%</td>
<td>PG 58 -28 (-24 C)</td>
<td>200</td>
</tr>
<tr>
<td>3%</td>
<td>PG 64 -22 (-18 C)</td>
<td>100</td>
</tr>
<tr>
<td>0%</td>
<td>PG 58 -28 (-24 C)</td>
<td>0%</td>
</tr>
<tr>
<td>1.50%</td>
<td>PG 64 -22 (-18 C)</td>
<td>1.50%</td>
</tr>
<tr>
<td>3%</td>
<td>PG 58 -28 (-24 C)</td>
<td>3%</td>
</tr>
<tr>
<td>0%</td>
<td>PG 64 -22 (-18 C)</td>
<td>0%</td>
</tr>
<tr>
<td>1.50%</td>
<td>PG 58 -28 (-24 C)</td>
<td>1.50%</td>
</tr>
<tr>
<td>3%</td>
<td>PG 64 -22 (-18 C)</td>
<td>3%</td>
</tr>
</tbody>
</table>
North Carolina field trial

- 9.5mm state mix
- PG 64–22 with 15% RAP and 5% RAS (27% binder replacement)
- Mix produced at 275°F
- Roughly 200 tons of each mix
  - Control WMA
  - WMA w/ 1.2% Evoflex CA
  - WMA w/ 0.9% Evoflex CA
- No problems in production and placement
North Carolina pre trial binder evaluation

- RAP and RAS binder was extracted and blended with virgin asphalt in the lab
- 20% RAP and 5% RAS (32% binder replacement)
- RTFO aging of the blend @ 135°C (planned production temperature)
- PAV aging of the blend @ 100°C for 20 hrs
## Effects on unaged binder

<table>
<thead>
<tr>
<th></th>
<th>Unaged Asphalt</th>
<th>Neat AC + RAP + RAS + 0.25% M1</th>
<th>Neat AC + RAP + RAS + 0.25% M1 + 1.2% Evoflex CA</th>
</tr>
</thead>
<tbody>
<tr>
<td><em><em>G</em>/sin - d @ 64C (Pa)</em>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 1</td>
<td>7202</td>
<td></td>
<td>4646</td>
</tr>
<tr>
<td>Trial 2</td>
<td>6897</td>
<td></td>
<td>5187</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>7049.5</td>
<td></td>
<td>4916.5</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>215.7</td>
<td></td>
<td>382.5</td>
</tr>
<tr>
<td><strong>Pass/Fail Temp (C)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 1</td>
<td>81.1</td>
<td></td>
<td>77.1</td>
</tr>
<tr>
<td>Trial 2</td>
<td>80.8</td>
<td></td>
<td>78</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>81.0</td>
<td></td>
<td>77.6</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>0.2</td>
<td></td>
<td>0.6</td>
</tr>
</tbody>
</table>
Effects on low temperature properties

<table>
<thead>
<tr>
<th>Creep Stiffness (Mpa) @ -12C</th>
<th>Neat AC + RAP + RAS + 0.25% M1</th>
<th>Neat AC + RAP + RAS + 0.25% M1 + 1.2% Evoflex CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td>140</td>
<td>141</td>
</tr>
<tr>
<td>Trial 2</td>
<td>144</td>
<td>137</td>
</tr>
<tr>
<td>Mean</td>
<td>142.0</td>
<td>139.0</td>
</tr>
<tr>
<td>SD</td>
<td>2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>m-value @ -12C</td>
<td>0.34</td>
<td>0.349</td>
</tr>
<tr>
<td>Trial 1</td>
<td>0.328</td>
<td>0.349</td>
</tr>
<tr>
<td>Trial 2</td>
<td>0.328</td>
<td>0.349</td>
</tr>
<tr>
<td>Mean</td>
<td>0.334</td>
<td>0.349</td>
</tr>
<tr>
<td>SD</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Dynamic modulus master curve

Low Speed or High Temperature

High Speed or Low Temperature

Reduced Frequency (Hz)

$E^*(\text{ksi})$

- Control
- 0.9% EVOFLEX CA
- 1.2% EVOFLEX CA
Resistance to rutting: HWT

Average Rut Depth (mm) per Cycle

-0.5

-2

-3.5

-5

-6.5

-8

-9.5

-12.5

0  5000  10000  15000  20000

Cycles

Average Rut Depth (mm)

Control  0.9% EVOFLEX CA  1.2% EVOFLEX CA
Overlay test data

Cycles to failure

- **Control**
- **0.9% EVOFLEX CA**
- **1.2% EVOFLEX CA**
Low temperature mix properties

DC(T) Test @ −12°C

CMOD (J/m²)

Control

EVOFLEX CA

EVOTHERM
Missouri field trial

- Surface course 12.5mm mix
- PG 64–22 binder with 19% RAP and 3% RAS
- RAP AC content is 6.0%; RAS AC content is 23.0%
- Sunny, 32°F ambient temperature and windy
- Mostly hand work on driveways and shoulders
- Average mix production temp is 330–340°F
- 30 to 45 minute haul
Missouri field trial

Control Mix

- 0.25% M1
- Total AC is 5.2%; Virgin AC is 3.5% (32.7% replacement)

Evoflex CA Mix

- 0.25% M1
- 1.5% Evoflex CA
- Total AC is 5%; Virgin AC is 3.2% (36% replacement)
- This translated to about 4–5% extra RAP or 0.75% extra RAS or **0.3% savings in virgin AC** without significantly affecting the final binder properties
## Extracted binder properties

### High Temperature Grade

<table>
<thead>
<tr>
<th>% Binder replacement</th>
<th>Control w/M1</th>
<th>M1 w/ 1.5% Evoflex CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>32.7%</td>
<td>36%</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pass fail temp (°C)</td>
<td>81.8</td>
<td>82.3</td>
</tr>
<tr>
<td>Mean</td>
<td>0.42</td>
<td>0.14</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade</td>
<td>76</td>
<td>82</td>
</tr>
</tbody>
</table>

### Intermediate Temperature Grade

| Pass fail temp (°C)   | 24.2         | 24.0                  |
| Inter grade temp (°C) | 25           | 25                    |
| G*/sin(delta) @ 25°C  | 4620         | 4445                  |
| G*/sin(delta) @ 22°C  | 6230         | 6235                  |
| Mean                  | 56.6         | 431.3                 |
| SD                    | 99.0         | 176.8                 |

### Low Temperature Grade

| M–value @ -12c > 0.300 | 0.288        | 0.284                 |
| Stiffness @ -12c < 300 | 171.0        | 181.0                 |
| M–value @ -6c > 0.300  | 0.308        | 0.300                 |
| Stiffness @ -6c < 300  | 92.2         | 100.0                 |
DC(T) test results

DC(T) Test @ -6°C

CMOD (J/m²)

Control

EVOFLEX CA
Kansas field trial

• PG 58–28 mix with 0.3% Evotherm M1
• PG 64–22 mix with 0.3% Evotherm M1 and 3.5% Evoflex CA
• Both mixes contained 32% RAP (34.7% binder replacement)
• Total AC is 4.9%
Resistance to rutting: HWT
Improved resistance to fatigue

The data show the PG 64 mix had a higher cycles to failure than the PG 58 mix at each simulated strain condition.
Evotherm–Flex continuum

0%  15%  30%  50% +

Evotherm®
WARM MIX ASPHALT TECHNOLOGY

EvoFLEX

ingevity
Evoflex RMA Development
Hybrid pellets

GTR, SBS and Ingevity Chemistry

• Solubilize SBS polymer and disperse within GTR matrix

• Predisperse polymer, improves networking efficiency

• Flexible formulation components (custom compound options)

• Additive interaction improves storage stability
How easy is it?

- Easy drop in to existing SBS systems
How is asphalt modified?

- Terminal blend using a Siefer mill
- Plant blend with GTR blend unit
Storage Stability

- Long Term lab testing
- Long Term tank storage
“If you have an opportunity to make things better and you don’t, then you are wasting your time on earth.”

~ Roberto Clemente