CAPITALIZING GREEN PAVEMENT
A METHOD AND VALUATION

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Presentation Overview

1. Problem
2. Big Ideas
3. Voluntary Carbon Markets
4. Pavement Performance Benchmark
5. Conclusion
Hot-mixed vs foamed asphalt (HMA vs FSB)

1/5: PROBLEM
HMA
HMA

90%

Paved roads in US, Canada, and Europe

Magnum 2006
HMA

90%

Paved roads in US, Canada, and Europe

Magnum 2006

317

Mt produced each year in the U.S.

NAPA 2015
(in metric)
HMA

90% 317 +4

Paved roads in US, Canada, and Europe
Mt produced each year in the U.S.
Other pollutants: CO, NO\textsubscript{2}, SO\textsubscript{2}, various organic compounds

Magnum 2006
NAPA 2015 (in metric)
Truit 2009
HMA

90%  317  +4  3x

Paved roads in US, Canada, and Europe
Mt produced each year in the U.S.
Other pollutants: CO, NO₂, SO₂, various organic compounds
More GHG/$ spent than power and communication lines

Magnum 2006
NAPA 2015 (in metric)
Truit 2009
Truit 2009
# Hot Mix vs Foam Stabilized Base (FSB)

<table>
<thead>
<tr>
<th></th>
<th>HMA</th>
<th>FSB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate</td>
<td>Virgin &amp; Recycled</td>
<td>100% Recycled</td>
</tr>
<tr>
<td>Cost</td>
<td>$$</td>
<td>$</td>
</tr>
<tr>
<td>Mix temperature</td>
<td>High</td>
<td>Low (Ambient)</td>
</tr>
<tr>
<td>Hauling</td>
<td>More</td>
<td>Less</td>
</tr>
<tr>
<td>Use</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Thickness</td>
<td>Standard</td>
<td>A bit more</td>
</tr>
</tbody>
</table>
Interstate Highway Projects

Only eleven states use recycled materials on interstate highway projects

*Image credit: Brian Diefenderfer, PhD, PE, Virginia Transportation Research Council (September 2016)*
FSB Example:
I-64 Highway: Restoration & Widening

Project

- $190 million
- Reconstruction of 7.08 miles (3,000+ trucks/day)
- Addition of a 12ft shoulder

Estimated Impact

- 30 to 50% cost savings
- 50% less greenhouse gasses*
- Fixes deterioration causes, not just symptoms
- Faster than full reconstruction

* initial estimate; I believe actual results will vary
Full Depth Reclamation (FDR)

Recycles materials on-site

1. Pulverize existing asphalt + underlying base (4 to 12 inches)
2. Treat reclaimed material with additives
3. Compact (drum or pneumatic tire roller)
4. Apply a surface layer

Image credit: Brian Diefenderfer, PhD, PE, Virginia Transportation Research Council (September 2016)
Cold Central Plant Recycling (CCPR)

Recycles materials in a central place

- In urban areas, central plants can stockpile RAP from contractors that have excess amounts
- Normally requires hauling/fuel
- Mobile mix plants reduce hauling

*Image courtesy of Global Resource Recyclers Engineering (2017)*
FSB Barriers and Drivers

Barriers

• Business as usual in the U.S.
• Unregulated CO₂ markets
• Equipment / re-tooling
• Training
• No consensus on use or structural performance

Drivers

• Low cost of recycled materials
• Environmental goodwill?
• Q: What goes here?
Voluntary Markets & App

2/5: THE BIG IDEAS
Two Ideas to Drive Adoption

1. Economic
2. Social
Two Ideas to Drive Adoption

1. Economic: Voluntary Carbon Market
2. Social: App
Baselines and Performance Benchmarks for

3/5: VOLUNTARY CARBON MARKETS
Voluntary Carbon Market Projects

1. Projects reduce CO\(_2\) emissions
2. Standard organizations verify reductions and award carbon offset credits
3. Credits are sold at market prices
Voluntary Carbon Market Projects

Two ways to verify emission reductions:

• Project Baselines
• Performance Benchmarks
Baseline Method

Baseline Method

Baseline Project

Voluntary Project

Offset

Baseline

Emissions (CO₂)

Voluntary Market
Baseline Method

Offsets = "Additional" Reductions
Who will buy them?
Baseline Method

- Baseline Project
- Voluntary Project
- For Sale
- Normal Project

Voluntary Market

Organizations with Emission Cap Goals

Actual Emissions

Cap

Emissions (CO₂)
Baseline Method

- Baseline Method
- Emissions (CO₂)
  - Baseline Project
  - Voluntary Project
  - Purchased
  - Sold
  - Greener Project
  - Actual Emissions
  - Cap

Voluntary Market
Organizations with Emission Cap Goals
Baseline Method

Emissions (CO₂)

Baseline Method

Baseline Project

Voluntary Project

Purchased

Sold

Greener Project

Actual Emissions

Voluntary Market

Organizations with Emission Cap Goals

Almost - Buy More!
Many projects are different sizes but technically similar.
How can we capitalize on their similarities?
We can compare different size projects with a rate – a *performance benchmark*: CO$_2$/Project Factor
Project Baseline vs Performance Benchmark
Project Baseline vs Performance Benchmark

Project Baseline

Calculate CO$_2$ emissions for *two* scenarios and their difference

Performance Benchmark

Calculate CO$_2$ for *one* scenario, and compare it to a benchmark rate: CO$_2$ / project factor
Project Baseline vs Performance Benchmark

Project Baseline
- For unique projects
- Not scalable
- Expensive to justify the business as usual case

Performance Benchmark
- For similar projects
- Scalable
- Predefined business as usual case: CO₂ / project factor
4/5: PAVEMENT PERFORMANCE BENCHMARK
HMA Study

HMA Plants
(Maryland)

Placement Projects
(Maryland and Virginia)
HMA Emission Categories

Raw Materials
Mix Plant
Hauling
+ Installation

Project Emissions

Quarrying + Processing
Source to Plant + Plant to Job Site
# HMA Emission Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Emissions (kg-CO₂e/t)</th>
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<tbody>
<tr>
<td>Raw Materials</td>
<td>54</td>
</tr>
<tr>
<td>Mix Plant</td>
<td>17</td>
</tr>
<tr>
<td>Hauling</td>
<td>15</td>
</tr>
<tr>
<td>Installation</td>
<td>64</td>
</tr>
</tbody>
</table>

![Pie chart showing the percentage contribution of each category to HMA emissions]

- **Raw Materials**: 36%
- **Mix Plant**: 11%
- **Hauling**: 10%
- **Installation**: 43%
HMA Emission Distribution

121.9 @ LOWER 20%
## HMA Performance Benchmark

<table>
<thead>
<tr>
<th>Project Type</th>
<th>Hauling Distance (miles)</th>
<th>Benchmark (kg-CO₂e/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking Lot</td>
<td>≤ 40</td>
<td>121.9</td>
</tr>
<tr>
<td>Parking Lot</td>
<td>&gt; 40</td>
<td>142.4</td>
</tr>
<tr>
<td>Road</td>
<td>Any</td>
<td>102.9</td>
</tr>
</tbody>
</table>
Structural Performance Adjustment

Directly replacing HMA with all FSB lowers structural performance and provides a poor surface layer.

Traditional Project

Offset Project

Same Granular Base

Same Sub-Base
Structural Performance Adjustment

Replacing HMA with an FSB layer and a small HMA surface layer yields an equal structural performance that is 2% heavier and 25% thicker.

Same Granular Base

Same Sub-Base
FSB Emission Reductions

With the 2% structural performance adjustment:

HMA benchmark
121.9 kg-CO$_2$e/t:

Cold Central Plant Recycling (CPPR)
78.4 kg-CO$_2$e/t
36% Reduction

Cold In-Place Recycling (CIR)
23.3 kg-CO$_2$e/t
81% Reduction
CCPR Total Savings

material savings + offset savings

= total ($/t-material)
CCPR Material Savings (Installed)

HMA 110
FSB 90
Savings 20 ($/t-material)
CCPR Offset Savings

HMA Benchmark 121.9
Adjusted FSB 78.4
Savings 43.5 kg-CO$_2$e/t-material

At a market rate of $9.30 / 1,000 kg-CO$_2$e:
Savings: 0.4 ($/t-material)
CCPR Total Savings

material savings

+ offset savings

= total ($/t-material)
CCPR Total Savings

$20/t material savings

+ $0.4/t offset savings

= $20.4/t ($/t material)
CCPR Contractor Profits

$0.4 offset savings < $20 material savings
CCPR Contractor Profits

$0.4 offset savings < $20 material savings

If a contractor
1. Purchases FSB at $25/t (FOB, material only)
2. Sells it for a 10% profit margin ($2.5)
3. Carbon offset savings ($0.4/t) raise profits 16%
5/5: CONCLUSIONS
Conclusions

• Performance benchmarks developed in this study may be used with or without FSB

• FSB projects generate ~43.5 kg-CO$_2$e/t carbon offset credits

• Replacing HMA with FSB yields ~$20.4/t in savings

• $0.4/t in offset credits can increase contractor material profits (~16%)
What’s Next

• Approve methods
• Launch app
Get Paid
It's like you just planted a small forest, and we want to reward you.

Payback Estimate
$18,008

Carbon Reduction
15,591,377 lb CO₂

Ready Projects
Another project
$32 for 28,003 lb CO₂

Interstate 64
$17,976 for 15,563,375 lb CO₂

Areas
All Traffic - Greenified
199,372.8 yd²

2 in HMA (2893), SN 0.88
2.5 in HMA (2893), SN 1.1
6 in FSB (2901), SN 1.92
6 in Cement Treated Base (CTB), SN 1.2

New Layer
Thickness: 16.5 in
Impact: 17,484 tons CO₂
Structural Number: 5.1
Green Mix: Yes

Edit Layer 3
Summary
SN 1.92
58,317 tons of mix
4,217 tons CO₂

Layer Position
3

Thickness
6 in

Mix Plant to Job Site Distance
3.5 miles

Mix Materials
QUESTIONS?
These didn’t make my presentation, but might be helpful in answering your questions

BACK UP SLIDES
Non-Additionality

What if baseline project emissions decrease or have been overestimated?
Non-Additionality

A "Non-Additional" offset is an offset that should not be awarded.

NEW Biz As Usual

Emissions (CO₂)

Baseline
New Baseline

New Baseline Project
Voluntary Project

Voluntary Market

“Non-Additional Offset”
Offset
HMA Greenhouse Gases and Air Pollutants

Carbon Dioxide (CO$_2$)
Sulfur dioxide (SO$_2$)
Nitrogen oxide (NO$_x$)
Carbon monoxide (CO)
Volatile organic compounds (VOC)
Volatile hazardous air pollutant (HAP)