Superpave5: Constructing Asphalt Pavement with Road Air Voids Equal to Design Air Voids

Webinar being sponsored by; AFH60, Asphalt Pavement Construction and Reconstruction

Lee Gallivan, Chair
Today’s Webinar Includes

● Three Sessions will cover the following

  ▪ Present the principles of constructing asphalt mixture to the same *compaction* level as the mixture design
  ▪ Describe research to modify design requirements as listed in AASHTO M 323.
  ▪ Describe construction of experimental mixture including production, placement and compaction.
  ▪ Describe the results of the comparison of road cores taken from regular and experimental mixture.
Presenters

- **Gerry Huber, P.E.** – Director of Research, Heritage Research Group, Indianapolis, Indiana (23 years), Asphalt Institute (5 years), Saskatchewan – Highways (10 years)

- **John Haddock, PhD, P.E.** - Professor of Civil Engineering & Director, Indiana Local Technical Assistance Program, Purdue University, Lafayette, Indiana (15 years)

- **Matt Beason, P.E.** - State Materials Engineer (just appointed), Office of Materials Management- Indiana Department of Transportation, Indianapolis, Indiana (8 years)
Questions

- Questions can be posed though anytime using the questions box and I will be monitoring them as they come in but will be answered at the end.

- Follow instructions for your PDH hours.
Laboratory Design at Five Percent Air Voids (Superpave5)

Gerry Huber
Heritage Research Group
Mix Design Historical Perspective

Understand where we have been

To see where we should go
Typical 1900s Pavement

- Surfacing Mix
- Asphalitic Concrete
- Hydraulic Cement
- Stabilized Aggregate
Surface Recipe Design

- **Components (typical)**
  - 78% sand
  - 12% lime
  - 10% asphalt

- **Sand heated to 300° F**
  - Asphalt added
  - Lime added cold
    - Amount adjusted visually

- **Paper Pat Test**
  - Brown paper
  - Mixture dumped on to paper
Surface Mix

- Asphalt Content 11%
- Gradation
  - #10 100
  - #40 87%
  - #80 49%
  - #200 15%
- Air Voids approx. 0%

City Street 1890s
Asphaltic Concrete Mixture

- Asphalt 7.4%
- Air voids 0(?)%
- VMA 13.2%

"Not suitable for Surface Mix"
Hubbard Field Mix Design (1920s)

- Mixture Compacted with rammer
- Specifications
  - Air voids
  - Voids in compacted aggregate
  - Hubbard Field Stability
Marshall Method of Mix Design (1930s)

- Bruce Marshall of Mississippi Department of Highways
  - 1943 joined U.S. Army Corps of Engineers
- Design used for airfields in World War II
  - Post WWII method was “civilianized”
Marshall Mix Design

- Used drop hammer instead of hand rammer
- Air voids calculated
- Stability test
  - Geometry different than Hubbard Field
- No VMA
- No absorption

Added in 1962
Design Air Voids

- Marshall Mix Design
  - Design voids set at 3 to 5%
- Field Compaction
  - “Standard” rolling train used
  - 8% will densify under traffic to 4%
    - “Density at end of life = Design Density”

Construction (8%)

Decreases to

Service Life (4%)
Strategic Highway Research Program

- “Marshall” carried forward
- Design air voids fixed at 4%
- Recommended compaction
  - Set at 92% Gmm
Design Air Voids

- NCHRP Report 573

Construction (8%) decreases to Service Life 5.5%
1959
LCPC visit to Texas

Developed LCPC gyratory compactor
Early Texas Gyratory Compaction

- 1939, Texas Highway Department
  - Philippi, Raines, and Love
- Texas 4-Inch Gyratory Press
LCPC Gyratory Compactor

- Models
  - Texas-type press
  - 1968, 2\textsuperscript{nd} prototype
  - 1973, PCG1
  - 1985, PCG2
LCPC Developed Mix Design Method
Design to 5%
Construct to 5%
Performance Good
Superpave5

- Inspired by LCPC
- Designed in America
Superpave 5

Concept
- Design at 5% air voids
- Compact to 5% (95% Gmm)

Increase:
- Air voids by 1%
- 5% instead of 4%
- VMA by 1%

Aggregate specifications stay same
- Lift thickness stays same
Mix Designs (4% Air Voids)

<table>
<thead>
<tr>
<th></th>
<th>125 gyrations</th>
<th>100 gyrations</th>
<th>75 gyrations</th>
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</thead>
<tbody>
<tr>
<td>125 gyrations</td>
<td>15.2 VMA</td>
<td>15.4 VMA</td>
<td></td>
</tr>
<tr>
<td>100 gyrations</td>
<td>15.2 VMA</td>
<td>15.4 VMA</td>
<td></td>
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<tr>
<td>75 gyrations</td>
<td>15.3 VMA</td>
<td>15.3 VMA</td>
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</tbody>
</table>

Gradation IS Different!
## Asphalt Content @ 4% Air Voids

<table>
<thead>
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<th>100 gyrations</th>
<th>75 gyrations</th>
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<td>125 gyrations</td>
<td>5.8%</td>
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<tr>
<td>100 gyrations</td>
<td></td>
<td>5.7%</td>
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</tr>
<tr>
<td>75 gyrations</td>
<td></td>
<td></td>
<td>5.7%</td>
</tr>
</tbody>
</table>
Superpave5

Benefit

- Asphalt content stays same
- Higher in-place density
- Lower permeability
- Reduced aging (?)

- No(?) increase in cost
Thank You

Greetings from Billy Bob
Superpave 5: Constructing Asphalt Pavement with Road Air Voids Equal to Design Air Voids

John E. Haddock, PhD, PE
Professor of Civil Engineering
Director, Indiana Local Technical Assistance Program
Purdue University
Background

- Indiana flexible pavements generally reach end of service because of durability issues after 15-20 years
  - Caused in part by oxidized binder
  - Rutting has been significantly reduced
- Reducing permeability decreases rate of binder aging
Concept

- Lower air voids in the field to improve durability
- Do not sacrifice rutting resistance
- Design at 5% air voids, field compact to 5% air voids
- Keep effective binder content the same
- No increase in compaction effort
- Increase pavement in-service life
Objective

- Modify laboratory asphalt mixture design compaction as it relates to field compaction in order to increase in-place durability without sacrificing rutting performance
Scope

- Design 3 standard mixtures
- Re-design each mixture at 5% air voids
  - Maintain effective binder content
  - Use 70, 50, 30 gyrations
- Test all mixtures for dynamic modulus and flow number (anticipated in-service air voids)
# Experimental Matrix

<table>
<thead>
<tr>
<th>Traffic (MESAL)</th>
<th>No. Gyrations</th>
<th>9.5-mm</th>
<th>19.0-mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 3 (3-10)</td>
<td>30</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Category 4 (10-30)</td>
<td>30</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>
Materials

- Coarse aggregates
  - Limestone, dolomite, blast furnace slag
- Fine aggregates
  - Limestone, dolomite, natural sand
- PG 64-22
- No recycled materials
## Category 4, 19.0-mm Designs

<table>
<thead>
<tr>
<th></th>
<th>N100</th>
<th>N70</th>
<th>N50</th>
<th>N30</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_b$, %</td>
<td>4.7</td>
<td>4.7</td>
<td>5.1</td>
<td>5.1</td>
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<tr>
<td>$P_{be}$, %</td>
<td>4.1</td>
<td>4.1</td>
<td>4.1</td>
<td>4.3</td>
</tr>
<tr>
<td>$V_a$, %</td>
<td>4.0</td>
<td>4.9</td>
<td>4.9</td>
<td>4.9</td>
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<tr>
<td>VMA, %</td>
<td>13.6</td>
<td>14.5</td>
<td>14.4</td>
<td>14.9</td>
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<tr>
<td>VFA, %</td>
<td>70.6</td>
<td>66.3</td>
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<td>67.2</td>
</tr>
</tbody>
</table>
Category 4, 19.0-mm

Percent Passing vs. Sieve Size Raised to the 0.45 Power, mm

- N100
- N70
- N50
- N30
## Category 3, 9.5-mm Designs

<table>
<thead>
<tr>
<th></th>
<th>N100</th>
<th>N70</th>
<th>N50</th>
<th>N30</th>
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<tbody>
<tr>
<td>$P_{b, %}$</td>
<td>5.9</td>
<td>5.9</td>
<td>6.0</td>
<td>6.0</td>
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<tr>
<td>$P_{be, %}$</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
<td>4.7</td>
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<tr>
<td>$V_{a, %}$</td>
<td>4.1</td>
<td>5.1</td>
<td>4.9</td>
<td>5.3</td>
</tr>
<tr>
<td>VMA, %</td>
<td>15.0</td>
<td>16.0</td>
<td>15.8</td>
<td>16.3</td>
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<tr>
<td>VFA, %</td>
<td>72.9</td>
<td>67.9</td>
<td>68.9</td>
<td>67.6</td>
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Category 3, 9.5-mm
## Category 4, 9.5-mm Designs

<table>
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<tr>
<th></th>
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<th>N30</th>
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<tbody>
<tr>
<td>$P_b$, %</td>
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<td>6.4</td>
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<tr>
<td>$P_{be}$, %</td>
<td>4.8</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>$V_a$, %</td>
<td>3.8</td>
<td>4.9</td>
<td>5.0</td>
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<tr>
<td>VMA, %</td>
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<td>16.4</td>
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<tr>
<td>VFA, %</td>
<td>74.9</td>
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<td>69.6</td>
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</table>
Category 4, 9.5-mm
Laboratory Mixture Testing

- Dynamic modulus
- Flow number
Category 4, 19.0-mm
### Category 4, 19.0-mm

<table>
<thead>
<tr>
<th>Gyrations</th>
<th>Average Flow Number</th>
<th>Average Strain at FN ((\mu m))</th>
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<tr>
<td>100</td>
<td>162</td>
<td>23,983</td>
</tr>
<tr>
<td>70</td>
<td>386</td>
<td>18,269</td>
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<tr>
<td>50</td>
<td>348</td>
<td>19,882</td>
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<tr>
<td>30</td>
<td>185</td>
<td>22,090</td>
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</table>
Category 3, 9.5-mm
## Category 3, 9.5-mm

<table>
<thead>
<tr>
<th>Gyrations</th>
<th>Average Flow Number</th>
<th>Average Strain at FN (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100- 7%</td>
<td>91</td>
<td>18,114</td>
</tr>
<tr>
<td>100- 5%</td>
<td>166</td>
<td>18,174</td>
</tr>
<tr>
<td>70</td>
<td>167</td>
<td>17,704</td>
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<tr>
<td>50</td>
<td>163</td>
<td>20,300</td>
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<tr>
<td>30</td>
<td>156</td>
<td>19,204</td>
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</table>
Category 4, 9.5-mm

![Graph showing dynamic modulus versus reduced frequency for different categories (N100, N50, N30). The graph plots dynamic modulus (MPa) on the y-axis against reduced frequency (Hz) on the x-axis. The data points for different categories are represented by different symbols: squares for N100, triangles for N50, and diamonds for N30. The graph indicates a trend of increasing dynamic modulus with increasing reduced frequency for all categories.]
## Category 4, 9.5-mm

<table>
<thead>
<tr>
<th>Gyrations</th>
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<th>Average Strain at FN (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>160</td>
<td>23,983</td>
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<tr>
<td>50</td>
<td>253</td>
<td>20,935</td>
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<tr>
<td>30</td>
<td>211</td>
<td>21,033</td>
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</table>
Category 4, 19.0-mm

Graph showing the relationship between the number of gyrations and $E^*_{\text{@50C}}$ for two different frequencies: $E^*_{\text{@25 Hz}}$ and $E^*_{\text{@10 Hz}}$. The graph highlights a notable feature at around 100 gyrations.
Category 4, 19.0-mm

![Graph showing the relationship between number of gyrations and E* at 6C for different frequencies.](image-url)
Category 4, 19.0-mm

Flow Number

Number of Gyrations
Category 4, 19.0-mm

![Graph showing the relationship Between Number of Gyrations and Strain Flow Number](#)
Conclusions

- Mixtures can be designed at 5% air voids without lowering effective binder content.
- Mixtures designed and tested at 5% air voids can have equivalent dynamic modulus and flow numbers as those designed at 4% and tested at 7% air voids.
- Results suggest if asphalt mixtures were designed at 5% air voids and placed in service at 5% air voids, they could potentially outperform mixtures designed and placed in a more conventional manner.
Recommendations

- Fatigue and low-temperature testing, as well as moisture susceptibility testing, should be completed.
- Future work should include additional traffic levels, mixtures containing RAP, RAS, or both, additional binder grades, aggregate types, mixture sizes.
- Place field projects.
Field Trial 1

- SR-13 near Ft. Wayne, IN
- New overlay, Category 4, 9.5-mm
- Original design, N100, 4%, 7%
- Redesigned, N50, 5%, 5%
- Steel slag and limestone coarse aggregates, limestone and natural sands, RAS, PG 70-22
Field Trial 2

- Georgetown Road, Indianapolis, IN
- Intermediate layer, Category 3, 19.0-mm
- Original design, N100, 4%, 7%
- Redesigned, N30, 5%, 5%
- Limestone coarse aggregates, dolomite sand, RAS, RAP, PG 64-22
Thank You!
Superpave5 Field Trials

Matt Beeson, PE
State Materials Engineer
Indiana Department of Transportation
INDOT Concerns

- Benefit
- Cost
- Constructability
- Rutting
  - 30 gyrations sounds “scary”
Superpave5 Field Trial #1
Indiana SR 13

- Middlebury, IN
- 1.5” Mill and Fill
- Trial Mix
  - 9.5-mm NMAS
  - 165 lb/yd² (1.5 inches)
Trial Mix

- 9.5 mm
- Steel slag coarse aggregate
- PG 70-22 Binder
- 7% RAS
  - 20.2% Binder Replacement
# QC Volumetric Properties

<table>
<thead>
<tr>
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<th>DMF</th>
<th>Sub-lot 1</th>
<th>Sub-lot 2</th>
<th>Sub-lot 3</th>
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<tbody>
<tr>
<td>%AC</td>
<td>5.2</td>
<td>5.61</td>
<td>5.47</td>
<td>5.45</td>
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<td>5.1</td>
<td>4.8</td>
<td>4.7</td>
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<tr>
<td>VMA</td>
<td>17.0</td>
<td>17.2</td>
<td>16.6</td>
<td>17.2</td>
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## QA Volumetric Properties

<table>
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<th>Superpave4</th>
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<td>Sub-lot 1</td>
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<td>Sub-lot 3</td>
</tr>
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<td>%AC</td>
<td>5.2</td>
<td>5.1</td>
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<tr>
<td>Air Voids</td>
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<td>3.4</td>
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<tr>
<td>VMA</td>
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<td>16.8</td>
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Core Density

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<th>Superpave4</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Sublot 1</td>
<td>Sublot 2</td>
<td>Sublot 3</td>
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<tr>
<td>Gmm</td>
<td>2.750</td>
<td>2.761</td>
<td>2.737</td>
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<td>Core Gmb 1</td>
<td>2.538</td>
<td>2.584</td>
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<td>Core Gmb 2</td>
<td>2.600</td>
<td>2.614</td>
<td>2.646</td>
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<td>%Gmm 1</td>
<td>92.3</td>
<td>93.6</td>
<td>96.3</td>
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<tr>
<td>%Gmm 2</td>
<td>94.5</td>
<td>94.7</td>
<td>96.7</td>
</tr>
<tr>
<td>Air Voids 1</td>
<td>7.7</td>
<td>6.4</td>
<td>3.7</td>
</tr>
<tr>
<td>Air Voids 2</td>
<td>5.5</td>
<td>5.3</td>
<td>3.3</td>
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<tr>
<td>Average AV</td>
<td><strong>5.3</strong></td>
<td></td>
<td><strong>8.2</strong></td>
</tr>
</tbody>
</table>
Superpave5 Field Trial

Georgetown Road
Georgetown Road

- Reconstruction and widening
- Trial Mix
  - 19-mm NMAS
  - 330 lb/yd² (3 inches)
Trial Conditions

- December 12 & 13, 2014
  - Loose samples
  - Cores
- Temperature
  - 34°F to 46°F
  - Light wind
Paving Train
Paving Train
N30 (Superpave5) Mix
N30 (Superpave5) Mix
N30 (Superpave5) Mix
Field Density Quality Control
Research Cores
N30 (5% Air Void) Mix
Plate Sample from Road for QA
Loose Research Samples
Research Samples (N30 and N100)
## QA Volumetric Properties

<table>
<thead>
<tr>
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<th>Superpave5</th>
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<th>Superpave4</th>
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<tbody>
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<td>DMF</td>
<td>Sub-lot 1</td>
<td>Sub-lot 2</td>
<td>DMF</td>
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<td>% Asphalt</td>
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<td>4.76</td>
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<tr>
<td>Gmm</td>
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<td>2.494</td>
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<tr>
<td>Gmb</td>
<td>2.356</td>
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<td>4.0</td>
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<tr>
<td>VMA</td>
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<tr>
<td>%Gmm 2</td>
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<td></td>
<td></td>
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<tr>
<td>Air Voids 2</td>
<td>3.5</td>
<td>3.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What’s Next?

- Promising Concept
  - Constructible
  - Performs in the field
    - No rutting to date
  - Research shows a benefit
- Additional Pilot Projects
  - Various ESAL categories
  - Broader Industry representation
Thank you!