SHRP2 – R21 Composite Pavement Systems – Project Overview

Michael I. Darter & Shreenath Rao

2100 Louisiana Transportation Conference
Baton Rouge, LA
10 January 2011
SHRP2 Long Life Pavements

- Lower life-cycle cost
- Rapid renewal of surface
- Longer time between major renewal activities
- Reduce the total impact on highway users
- Sustainability benefits
R21. Composite Pavement Systems

Sub contractors: University of Minnesota Mn/DOT
University of California at Davis
University of Pittsburg

Key Staff: Darter, Rao, Khazanovich, Von Quintus, Harvey, Signore, Worel, Clyne, Watson, Vandenbossche, Tompkins

Duration: 48 months
Contract: 2007 - 2011
Composite Pavements Constructed
HMA Over New PCC

New Hot Mix Asphalt
(SMA, PMA, Superpave, etc.)

New PCC Layer
(JPC, CRC, RCC, etc.)
Composite Pavements Constructed
Wet On Wet Concrete

New Concrete Surfacing
High Quality PCC/Agg.,
Surface: Exposed Agg. Or
Diamond Grind

New Concrete Lower Layer
(Recycled PCC, Lower Cost PCC)
2008 European Survey of Composite Pavements

- Europe has built **composite pavements** for many years.
- Why?

  ➢ **Excellent asphalt & concrete surface characteristics**
    - High friction
    - Low tire/pavement noise
    - Low splash and spray (porous HMA)
    - Rapid renewal (asphalt)
    - Long life (concrete)

  ➢ **Economical (Yes, believe it or not)**
    - Lower layer: thick and low cost
      (e.g. recycled, low cement, etc.)
    - Upper layer: thin and high quality
      (e.g. hard aggregate, high cement)

  ➢ **Sustainable**
    - Recycled lower PCC layer
    - Lower cost aggregates
    - Rapid renewal of top HMA layer
2008 European Survey of Composite Pavements

- Netherlands
- Germany
- Austria

Report published as an online document

European Survey

• Porous asphalt surface over CRCP
  ▪ Netherlands, Italy, UK project, etc. (low freeze)
• SMA asphalt surface over JPCP
  ▪ Germany (freeze)
• Exposed aggregate concrete (EAC) surface coupled with in-place recycled lower layer placed using two-layer PCC construction
  ▪ Austria, Belgium, Netherlands, Germany, France, etc. (all climates)
European Survey: A12 Netherlands, Porous Asphalt over CRCP

- 11 years oldest
- 40-year design
- 100,000 ADT
- 50-mm (2-in) Porous AC
- 250-mm (10-in) CRC
- 60-mm (2.4-in) ATB

11 years – no reflection cracks!
0.75-in ARFC / 13-in JPCP Composite Pavement
Arizona I-10

EAC used for A1 sections. Why?

- High volume of traffic requires as little maintenance as possible to minimize closure
- Durable texture needed given 6 months per year of salt, plowing, and studded tire use
- Recycling old HMA/PCC layers reduces cost and need for dumping
European Survey: A6 Germany
Upper and lower layers (2008)

PCC Top
- 2in: crushed granite, gap-graded, maximum aggregate size 8 mm
- Cement 430 kg/m$^3$, air content 5%, water/cement ratio 0.45

PCC Bottom
- 10 in: river gravel, maximum aggregate size 32mm
- 350 kg/m$^3$, air content 4%, water/cement ratio 0.40
R21 Composite Test Sections

• European composite sections
  – HMA/CRCP & HMA/JPCP

• US composite sections
  – HMA/CRCP
  – HMA/JPCP

• US special construction
  – Univ. California at Davis sections HMA/JPCP
  – MnRoad (Minneapolis I-94) HMA & PCC / JPCP
## R21: Layout of Test Cells at UCPRC

<table>
<thead>
<tr>
<th></th>
<th>HMA Mix 1 – 114 mm</th>
<th>HMA Mix 1 – 64 mm</th>
<th>No HMA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PCC 178 mm</td>
<td>PCC 178 mm</td>
<td>PCC 178 mm</td>
</tr>
<tr>
<td>A</td>
<td>Dowel</td>
<td>Dowel</td>
<td>Dowel</td>
</tr>
<tr>
<td>B</td>
<td>HMA Mix 1 – 114 mm</td>
<td>HMA Mix 1 – 64 mm</td>
<td>No HMA</td>
</tr>
<tr>
<td></td>
<td>PCC 178 mm</td>
<td>PCC 178 mm</td>
<td>PCC 178 mm</td>
</tr>
<tr>
<td></td>
<td>No Dowel</td>
<td>No Dowel</td>
<td>No Dowel</td>
</tr>
<tr>
<td>C</td>
<td>HMA Mix 2 – 114 mm</td>
<td>HMA Mix 2 – 64 mm</td>
<td>No HMA</td>
</tr>
<tr>
<td></td>
<td>PCC 178 mm</td>
<td>PCC 178 mm</td>
<td>PCC 178 mm</td>
</tr>
<tr>
<td></td>
<td>No Dowel</td>
<td>No Dowel</td>
<td>No Dowel</td>
</tr>
<tr>
<td>D</td>
<td>HMA Mix 2 – 114 mm</td>
<td>HMA Mix 2 – 64 mm</td>
<td>No HMA</td>
</tr>
<tr>
<td></td>
<td>PCC 127 mm</td>
<td>PCC 127 mm</td>
<td>PCC 127 mm</td>
</tr>
<tr>
<td></td>
<td>No Dowel</td>
<td>No Dowel</td>
<td>No Dowel</td>
</tr>
</tbody>
</table>

### Measurements
- 178 mm = 7 in
- 127 mm = 5 in
- 114 mm = 4.5 in
- 64 mm = 2.5 in
- 13.7 m = 45 ft
- 3.7 m = 12 ft
R21: UCPRC HVS Testing

[Image of testing setup]

[Graph showing repeated testing results]

Maximum Rut (mm) vs. Repetition for different samples: 612HB, 609HB, 610HB, 611HB.
R21: Construction of HMA/PCC and PCC/PCC Test Sections at MnROAD

• Full-length two-lane test sections constructed at MnROAD in Albertville, MN on Interstate 94.
• Construction in April/June 2010.
• Open to traffic July 2011.
## R21: Experimental Sections at MnROAD

<table>
<thead>
<tr>
<th>Section</th>
<th>Base Course</th>
<th>Interlayer</th>
<th>Surface Course</th>
<th>Subbase Course</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>70</strong></td>
<td>3&quot; 64-34 Saw/Seal</td>
<td>6&quot; PCC Recycle</td>
<td>8&quot; Class 7</td>
<td>Clay 15' Panel 1.25&quot; dowels driving none passing</td>
</tr>
<tr>
<td><strong>71</strong></td>
<td>3&quot; PCC EAC</td>
<td>6&quot; PCC Recycle</td>
<td>8&quot; Class 7</td>
<td>Clay Innovative DG (driving) Convention DG (passing) 15' Panel 1.25&quot; dowels</td>
</tr>
<tr>
<td><strong>72</strong></td>
<td>3&quot; PCC EAC</td>
<td>6&quot; PCC Low Cost</td>
<td>8&quot; Class 7</td>
<td>Clay EAC Surface 15' Panel 1.25&quot; dowels</td>
</tr>
</tbody>
</table>
R21: PCC Mixture Designs MnRoad

• Upper Layer: Exposed Aggregate Concrete (EAC)
  • Granite Aggregate, 0.5-in max. size, gap graded
  • Higher Slump
  • Lower Fly Ash Substitution (15%)

• 2 Lower PCC Mixes (low slump, high fly ash substitution (40-60%))
  • Recycled concrete as coarse aggregate RCA
  • River gravel as coarse aggregate LCA
R21: Four Surface Textures MnRoad

- Exposed Aggregate Concrete (EAC)
- Conventional Diamond Grinding
- Innovative Diamond Grinding
- Conventional (12.5mm) HMA with Saw/Seal joints
MnROAD Recycling and Salvage Operations

RCA Percent Absorption 2.93%
MnROAD Demonstration Slab
MnROAD Paving Wet-on-Wet PCC/PCC

1st Paver: Lower JPCP RCA Layer

2nd Paver: Upper EAC Layer
MnROAD Construction: Two Paver PCC Placement
3-in EAC / 6-in RCA
Exposed Aggregate Concrete Texture

1. Spray Retarder/Curing
2. Brush Surface (Remove)
3. Wire Brush
4. Exposed Aggregate Surface
Exposed Aggregate Concrete Surface MnRoad
R21: Diamond Grinding: Conventional & Next Generation
R21: Next Generation Diamond Grinding
I-94 MnRoad PCC/JPCP Composite (Heavy Truck Traffic)
R21: MnROAD HMA/JPCP (RCA) Construction

- JPCP Placement
- 2 Curing Compound
- 3 Tack Coat
- 4 HMA Placement
R21: MnROAD HMA/JPCP Sawing and Sealing Joints

Sawed & Sealed Trans. Joints
I-94 MnRoad HMA/JPCP
Composite Pavement
R21 Performance Measures

• Smoothness, IRI
• Texture depth
• Noise
• Friction
• Fatigue Cracking (transverse, longitudinal)
• Joint faulting
• Rutting
• Joint reflection cracking (incl. saw/sealed)
# R21 Initial Results: Noise

| Surface                                                        | Sound Intensity Level |
|                                                               |                       |
| HMA                                                            | To be measured        |
| Exposed Aggregate Concrete                                     | 101.7 dBA             |
| Conventional Diamond Grind of EAC                              | 100.4 dBA             |
| Next Generation Concrete Surface (Special grinding) of EAC      | 98.8 dBA              |
## R21 Initial Texture, inches
### ASTM E 965

<table>
<thead>
<tr>
<th>Surface</th>
<th>Texture Depth, in</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA</td>
<td>0.334</td>
</tr>
<tr>
<td>Exposed Aggregate Concrete</td>
<td>0.784</td>
</tr>
<tr>
<td>Conv. Diamond Grind of EAC</td>
<td>1.127</td>
</tr>
<tr>
<td>Next Generation Diamond Grind of EAC</td>
<td>To be measured</td>
</tr>
</tbody>
</table>
# R21 Initial Friction

<table>
<thead>
<tr>
<th>Surface</th>
<th>Friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA</td>
<td>0.656</td>
</tr>
<tr>
<td>Exposed Aggregate Concrete</td>
<td>0.615</td>
</tr>
<tr>
<td>Conv. Diamond Grind of EAC</td>
<td>0.720</td>
</tr>
<tr>
<td>Next Generation Diamond Grind of EAC</td>
<td>0.547</td>
</tr>
</tbody>
</table>
MnRoad Contractor’s Assessment

• Implementation of a 2-layer Composite Paving process would be a viable and competitive alternative to Conventional Paving, if:
  – Class A aggregates aren’t readily available.
    • Long haul times drive the price of the aggregate too high
  – Recycled Concrete could be produced on or near the site.
    • Haul times would have to be cut to minimal levels
    • Would have to produce recycled at about 50% the cost of Class A
  – You were capable of producing and paving at an equal rate to conventional paving.
AASHTO MEPDG Prediction: Inputs

- Traffic: I-94 WIM data
- Climate: Nearest weather stations
- HMA: Test data from MnDOT.
- Concrete: EAC, RCA, LCC test data from FHWA mobile trailer.
- Subgrade: test data from MnDOT & backcalculation of modulus
- Design: joints, dowels, joint spacing, thickness of layers, shoulders
MEPDG Inputs

• HMA materials data
  – PG Grade: 64-34
  – Percent asphalt: 5.4 % by weight (assume 10.8% by volume)
  – Percent inplace air voids: 5.5 % measured
  – Density: 148 pcf
  – Gradation of HMA
    • Retained on ¾ in = 0%
    • Retained on 3/8 in = 20%
    • Retained on #4 = 40%
    • Passing #200 = 4.3%
**MEPDG Inputs**

- Concrete: EAC, RCA, LCA test data

<table>
<thead>
<tr>
<th>Test</th>
<th>EAC</th>
<th>RCA</th>
<th>LCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural Strength, psi</td>
<td>854 psi</td>
<td>655 (60%FA)</td>
<td>650 (40%FA)</td>
</tr>
<tr>
<td>Modulus of Elasticity, psi</td>
<td>4.9 M psi</td>
<td>4.9 M psi</td>
<td>5.1 M psi</td>
</tr>
<tr>
<td>Coef. Thermal Expansion</td>
<td>5.6/F</td>
<td>5.8/F</td>
<td>5.4/F</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>0.23</td>
<td>0.25</td>
<td>0.23</td>
</tr>
</tbody>
</table>
# AASHTO MEPDG Prediction

## HMA / RCA

<table>
<thead>
<tr>
<th>Age / Trucks</th>
<th>% Slab Cracking</th>
<th>Rutting, in</th>
<th>Smoothness IRI, in /mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>63</td>
</tr>
<tr>
<td>5 years 3 million</td>
<td>0.3</td>
<td>0.09</td>
<td>94</td>
</tr>
<tr>
<td>10 years 6 million</td>
<td>1.2</td>
<td>0.13</td>
<td>100</td>
</tr>
<tr>
<td>15 years 10 million</td>
<td>2.7</td>
<td>0.17</td>
<td>107</td>
</tr>
</tbody>
</table>

Reflection cracking of transverse joints: controlled by saw and seal & dowels.
## AASHTO MEPDG Prediction
### EAC / RCA

<table>
<thead>
<tr>
<th>Age / Trucks</th>
<th>% Slab Cracking</th>
<th>Joint Faulting, in</th>
<th>Smoothness IRI, in /mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>63</td>
</tr>
<tr>
<td>5 years 3 million</td>
<td>0.8</td>
<td>0.02</td>
<td>82</td>
</tr>
<tr>
<td>10 years 6 million</td>
<td>2.7</td>
<td>0.05</td>
<td>103</td>
</tr>
<tr>
<td>15 years 10 million</td>
<td>5.9</td>
<td>0.07</td>
<td>125</td>
</tr>
</tbody>
</table>
What If Longer Term I-94 Design?

30-year Design: 23 million Trucks

- 3-in HMA / 8-in RCA (Versus 6-in for 15-yrs.)
  - No structural concrete fatigue cracking
  - HMA would need replacement at 8 to 15 years depending on:
    - Saw and seal transverse joints: will these hold up?
    - Rutting of HMA
    - Bonding between HMA & PCC
What If Longer Term I-94 Design?

30-year Design: 23 million Trucks

- 3-in EAC / 8-in RCA (Versus 6-in 15-yrs)
  - No structural concrete fatigue cracking
  - Some joint faulting and roughness.
  - EAC should perform with no problems: good friction, no significant wear.
  - Diamond grinding should perform long term with no polishing (hard aggregate): good friction & texture, low noise.
What are the next steps for R21?

UCPRC and MnROAD Construction and Field Sections

• **UCPRC** - Continue HVS loading and data collection until: Spring/Summer 2011
• **MnROAD** - Monitoring instrumentation and performance data collection (including ride and noise) until: Summer 2011
• **I-294 Ramp Chicago** – HMA / JPCP constructed
• **Other Field Sections** - Field data collection (distress surveys, materials data, IRI, etc.): through Summer 2011
Anticipated R21 products

1. Refined and validated structural & performance models.
2. Design procedures and guidelines (manual, recommended additions to AASHTO MEPDG manual).
3. Construction specifications (combination of MnROAD, UCPRC, Europe, other).
4. Life-cycle cost guidelines & procedures.
5. Composite pavement training materials to aid in implementation.