Design of Illinois Tollway Composite Pavements

William R. Vavrik, Ph.D., P.E.

FHWA Tollway National Open House,
August 20, 2013
Presentation Overview

- Starting in Composite Pavements
- Move to 2-Lift Concrete
- Design of I-90 2-Lift Concrete Pavement
- Life Cycle Cost Analysis & Type Selection
2-Lift Paving is a Forgotten Practice

Popular back in the 50’s, 60’s and 70’s when the Tollway was originally built
2-Lift paving is in our long & recent past

1950’s

2001
Developed with SHRP 2 R21 help
Composite pavements started in 2010

- Asphalt-over-concrete composite ramps
- Strong Concrete Mix
  - 6.5 bag fly ash mix with 20 percent black rock placed
  - Compressive strengths > 3500 psi in three days
  - Flexural Strengths > 650 psi in seven days
I-294 Ramp first composite pavement

- Two HMA/JPC sections of I-94 ramps north of Chicago
- Constructed 2010 using 30% RAP & 20% fly ash in PCC, high quality WMA surface layer, & saw & seal joint over doweled JPC
More Answers Needed

- SHRP R21 Composite Pavement Project Investigated
- Demonstrations Observed
- History of Composites Studied
- History of Black Rock Concrete Studied
- More Research Determined to be Needed
Black Rock Ternary Mixes Researched

- Fractionated Reclaimed Asphalt Pavement (FRAP) as a Coarse Aggregate Replacement in a Ternary Blended Concrete Pavement
Placed 0.7 Mile Trial Reconstruction and Widening Project on I-88 in 2012
Full Implementation Starts in 2013 for I-90 Reconstruction and Widening (62 miles)
$$C_{12} = C_1 + (C_2 \ast FR^{0.25})$$
$$C_{34} = C_3 + (C_4 \ast FR^{0.25})$$

$$FaultMax_0 = C_{22} \ast \delta_{curing} \ast \left[ \log(1 + C_3 \ast 5.0^{E_{Rop}}) \cdot \log \left( \frac{P_{200}}{P_S} \right) \right]^{C_6}$$

$$FaultMax_i = FaultMax_0 + C_7 \ast \sum_{j=1}^{m} DE_j \ast \log(1 + C_5 \ast 5.0^{E_{Rop}})^{C_8}$$

$$\Delta Fault_i = C_{34} \ast (FaultMax_{i-1} - Fault_{i-1})^2 \ast DE_i$$

$$C_0 = DowelDeterioration$$

$$\log(N) = C_1 \left( \frac{MR}{\sigma} \right)^{C_2}$$

$$P.O. = \frac{C_3}{1 + C_4 \cdot Damage^{C_5}}$$

$$cw = C_6 \cdot (cw_i)$$

$$CRK = \frac{100}{1 + C_4 \cdot FD^{C_5}}$$

- C1 - Cracking
- C2 - Spalling
- C3 - Faulting
- C4 - Site Factor

C1 - Punchout
C2 - Site Factor
Total Traffic and Truck Traffic Are Different

- Average Daily Traffic
- Average Daily Truck Traffic

Vehicle Count

Milepost

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

I-39
IL 47
Randall Rd.
Higgins
IL 53
Truck Counts Split In 3 Segments

Milepost

I-39
IL 47
Randall Rd.
Higgins
IL 53

Design

Truck Count

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

0 2,000 4,000 6,000 8,000 10,000 12,000 14,000 16,000

Design

MOVE ILLINOIS

ARA
## Major Traffic Inputs for Pavement Design

- **Lane Distribution**
- **Traffic Volume**
- **Load Spectra**

<table>
<thead>
<tr>
<th></th>
<th>3-Lane</th>
<th>4-Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tollway</strong></td>
<td>70%</td>
<td>70%</td>
</tr>
<tr>
<td><strong>National</strong></td>
<td>60%</td>
<td>45%</td>
</tr>
</tbody>
</table>
Design Trucks – Load Distributions

Current Load Limits
- 12kip
- 34kip
- 34kip

Proposed Load Limits
- 12kip
- 40kip
- 40kip

Proposed Load Limits
- 12kip
- 40kip
- 60kip
Tollway Axle Weight Distribution Does Not Follow National Data

**Tandem Axle – Class 9**

- MEPDG
- Tollway

**Percent of Axles**

**Weight of Tandem Axle Group (lb)**
Understanding bonding is key

- Lattice Model (PCC/PCC Debonding)
  - R-21 work coupled lattice models with finite element models

- Analysis concluded wet on wet paving had only very low chance if any to debond, matching field surveys & bond testing.
I-90 Concrete Pavement Design Details

- 15’ Slab length
- 1’ Widened slab
- Doweled Joints (1 ½”)

Diagram showing layers of concrete pavement:
- Topping Concrete
- High-recycled Content Concrete
- WMA Base
- Aggregate Cap
- Porous Aggregate
- Compacted Subgrade
Process for Pavement Type Selection

**Agency-based pavement-type selection**

1. Identification of feasible alternatives
2. Development of pavement life cycle strategies
3. Life cycle cost analysis
4. Evaluation of economic and noneconomic factors
5. Agency-based selection of preferred pavement type
6. Design-bid-build preferred pavement type

October 14, 2011
Designs & Life Cycle Strategies

- Designs for current & future traffic

- Pavement Types Evaluated

Jointed Concrete
Continuously Reinforced Concrete
Full Depth Asphalt
Asphalt over CRCP
Asphalt over Jointed Concrete
## Corridor Life Cycle Cost Analysis

### Net Present Value of 50-year Cost of Ownership for the Corridor ($ Millions)

<table>
<thead>
<tr>
<th>Pavement Type</th>
<th>West</th>
<th>Center</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rockford – IL-47</td>
<td>IL-47 to Randall</td>
<td>Randall to O’Hare</td>
</tr>
<tr>
<td>2-Lift Composite Jointed Concrete</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuously Reinforced Concrete</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Depth Asphalt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composite Asphalt/Jointed Concrete</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composite Asphalt/Cont. Reinforced</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Lowest**: Lowest life cycle cost pavement type by section
- **10%**: Life cycle cost within 10% of the low value is generally considered equal and is within the expected variability of costs used in the analysis
Pavement Type Selection Grade Card
Combines Economic and Noneconomic Factors

<table>
<thead>
<tr>
<th>Guide Factors</th>
<th>Tollway Factors</th>
<th>Factor Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial cost</td>
<td>Initial Construction Cost</td>
<td>40%</td>
</tr>
<tr>
<td>Rehabilitation cost</td>
<td>Capital Preservation Cost</td>
<td>40%</td>
</tr>
<tr>
<td>Maintenance Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conservation of materials/energy</td>
<td>“Green” - Recycling Factor</td>
<td>10%</td>
</tr>
<tr>
<td>Sustainability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic during construction</td>
<td>Constructability / Schedule Factor</td>
<td>10%</td>
</tr>
<tr>
<td>Availability of local materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stimulation of competition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance capability</td>
<td>Preference to keep Maintenance yards consistent</td>
<td></td>
</tr>
<tr>
<td>Subgrade soils</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Future needs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental features</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuity of adjacent sections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuity of adjacent lanes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roadway geometrics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise issues</td>
<td>No difference between alternatives</td>
<td></td>
</tr>
<tr>
<td>Local preference</td>
<td>Not considered</td>
<td></td>
</tr>
<tr>
<td><strong>Noneconomic</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Pavement Type Selection Report Card

<table>
<thead>
<tr>
<th>Pavement Type</th>
<th>West Rockford – IL-47</th>
<th>Center IL-47 to Randall</th>
<th>East Randall to O’Hare</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Lift Composite Jointed Concrete</td>
<td>3.16 B</td>
<td>3.21 B</td>
<td>3.02 B</td>
</tr>
<tr>
<td>Continuously Reinforced Concrete</td>
<td>3.00 B</td>
<td>3.00 B</td>
<td>2.99 B-</td>
</tr>
<tr>
<td>Full Depth Asphalt</td>
<td>3.02 B</td>
<td>3.03 B</td>
<td>2.83 B-</td>
</tr>
<tr>
<td>Composite Asphalt/Jointed Concrete</td>
<td>2.43 C+</td>
<td>2.42 C+</td>
<td>2.38 C+</td>
</tr>
<tr>
<td>Composite Asphalt/Cont. Reinforced</td>
<td>2.34 C+</td>
<td>2.36 C+</td>
<td>2.34 C+</td>
</tr>
</tbody>
</table>