Implementation of Performance Specifications for Concrete at the Illinois Tollway

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March 28, 2017
Illinois Tollway System

292-mile system comprised of five tollways

Opened in 1958 as a bypass around Chicago to connect Indiana and Wisconsin

Carries more than 1.6 million vehicles per day

User-fee system

- Only customers who use the Tollway pay for the Tollway
- No state or federal tax dollars used for maintenance and operations
Move Illinois Program

ADDRESS EXISTING SYSTEM NEEDS

JANE ADDAMS MEMORIAL TOLLWAY
$2.5 billion

ELGIN O’HARE WESTERN ACCESS
$3.4 billion

I-294/I-57 INTERCHANGE
$719 million

INTERCHANGES AND OTHER EMERGING PROJECTS

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Performance-Engineered Mix (PEM) Design Specifications
Goals For PEM Designs

**Strength**
- Adequate, but not excessively over-designed

**Durability**
- Freeze/thaw
- Shrinkage
- Chloride penetration resistance
- Alkali-silica reaction (ASR)

**Constructability**
- Batching
- Workability

**Sustainability**
- Increased supplementary cementing material (SCM) usage
- Recycled material
Timeline Of PEM Specifications And Designs At The Tollway

- **2008**: Accelerated (HES) PCC weekend patching mixes
- **2012**: Ternary black rock PCC mixes for composite pavements
- **2013**: Ternary optimized PCC mixes for single-lift pavements
- **2014**: Calcium aluminate (CA) cement overnight patching mixes
- **2015**: Performance-related construction for concrete pavements
# Tollway Mix Performance Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Method</th>
<th>Mix Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength</td>
<td>AASHTO T 22</td>
<td>All</td>
</tr>
<tr>
<td>Flexural strength</td>
<td>AASHTO T 97</td>
<td>Pavement only</td>
</tr>
<tr>
<td>Slump</td>
<td>AASHTO T 119</td>
<td>All</td>
</tr>
<tr>
<td>Plastic air</td>
<td>AASHTO T 152</td>
<td>All</td>
</tr>
<tr>
<td>Length change</td>
<td>AASHTO T 160</td>
<td>All except pavement and CA</td>
</tr>
<tr>
<td>Ring shrinkage</td>
<td>ASTM C 1581</td>
<td>HES, HPC, CA</td>
</tr>
<tr>
<td>ASR</td>
<td>AASHTO T 303</td>
<td>All except CA</td>
</tr>
<tr>
<td>Hardened air</td>
<td>ASTM C 457</td>
<td>All except CA</td>
</tr>
<tr>
<td>Chloride penetration</td>
<td>AASHTO T 277</td>
<td>HES, HPC</td>
</tr>
</tbody>
</table>
Mixture Design And Approval Process

- Design
- Lab Trial Batch
- Field Trial Batch
- Approval

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Case Studies
Jane Addams Memorial Tollway (I-90)
Rebuilding and Widening Project

INTERCHANGE LOCATIONS
1. Irene Road - COMPLETED
2. Genoa Road - COMPLETED
3. Illinois Route 31 - COMPLETED
4. Illinois Route 25 - COMPLETED
5. Barrington Road
6. Roselle Road
7. Meacham Road - COMPLETED
8. Elmhurst Road
9. Lee Street - COMPLETED

LEGEND
- 2013 Work - COMPLETED
- 2014 Work - COMPLETED
- 2014 - 2016 Work - COMPLETED
- Interchange Work
- Toll Plaza Location
- Oasis Location

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High-Performance Concrete (HPC) for Bridge Decks
HPC Concrete Requirements

Proportioning

• Material from approved sources
• ASR
  • Maximum total alkali content contributed by Portland cement ≤ 4 lb/yd³ or test
• Shrinkage
  • 1.5 gal./cy. SRA and < 605 lbs./cy total cementitious or ring shrinkage
• Water/cementitious ratio during production
  • Design – 0.03, + 0.00

Properties

• Compressive strength
  • 4,000 psi at 14 days
• Plastic air
  • Design ± 1.5 percent, minimum 4.0
• Slump
  • 3 – 8 inches
• Freeze/thaw or hardened air (trial batch)
• Slump loss (trial batch)
• Linear shrinkage (trial batch)
• Chloride penetrability (trial batch)
Prairie Material Tollway HPC

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland cement</td>
<td>335 lbs./cy.</td>
</tr>
<tr>
<td>Fly ash – class C</td>
<td>90 lbs./cy.</td>
</tr>
<tr>
<td>Slag cement</td>
<td>150 lbs./cy.</td>
</tr>
<tr>
<td>Water</td>
<td>230 lbs./cy.</td>
</tr>
<tr>
<td>Coarse aggregate (CM 11)</td>
<td>1700 lbs./cy.</td>
</tr>
<tr>
<td>Lightweight fine aggregate</td>
<td>395 lbs./cy.</td>
</tr>
<tr>
<td>Fine aggregate (FM 02)</td>
<td>860 lbs./cy.</td>
</tr>
<tr>
<td>Water reducer – type A</td>
<td>4 – 6 oz./cwt.</td>
</tr>
<tr>
<td>Water reducer – type F</td>
<td>1 – 6 oz./cwt.</td>
</tr>
<tr>
<td>Air entrainment</td>
<td>0.4 – 3 oz./cwt.</td>
</tr>
<tr>
<td>Retarder</td>
<td>1 – 6 oz./cwt.</td>
</tr>
<tr>
<td>Shrinkage reducing admixture</td>
<td>0.5 gal./cy.</td>
</tr>
</tbody>
</table>

w/cm – 0.40
Design air – 6.5 percent
Design slump – 5.0 in.
Ternary Optimized (TL) Concrete for Pavement
Slip-Form Class TL Concrete Requirements

Proportioning
- Material from approved sources
- Ternary
  - 35 to 50 percent SCM
- Optimized gradation
  - 2 coarse aggregates
  - Virgin
- ASR
  - Maximum total alkali content contributed by Portland cement ≤ 5 lb/yd³
- Water/cementitious ratio during production
  - Design – 0.03, + 0.00

Properties
- Compressive strength
  - 2,500 psi at 3 days
  - 3,500 psi at 14 days
  - 6,500 psi at 28 days (target)
- Flexural strength (trial batch)
  - 650 psi at 14 days
- Hardened air (trial batch)
  - Spacing factor ≤ 0.008 in.
  - Specific surface ≥ 600 in²/in³
  - Total air content ≥ 4.0 percent
- Plastic air
  - 5.5-8.0 percent
- Slump
  - ¼” slump edge next to adjacent pavement
  - otherwise ½” slump edge
# Terrell Materials Class TL

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland cement</td>
<td>303 lbs./cy.</td>
</tr>
<tr>
<td>Fly ash – class F</td>
<td>98 lbs./cy.</td>
</tr>
<tr>
<td>Slag cement</td>
<td>99 lbs./cy.</td>
</tr>
<tr>
<td>Water</td>
<td>210 lbs./cy.</td>
</tr>
<tr>
<td>Coarse aggregate (CM 11)</td>
<td>1650 lbs./cy.</td>
</tr>
<tr>
<td>Intermediate aggregate (CM 16)</td>
<td>428 lbs./cy.</td>
</tr>
<tr>
<td>Fine aggregate (FM 02)</td>
<td>1186 lbs./cy.</td>
</tr>
<tr>
<td>Water reducer – type A</td>
<td>3 – 5 oz./cwt.</td>
</tr>
<tr>
<td>Air entrainment</td>
<td>0.5 – 3 oz./cwt.</td>
</tr>
<tr>
<td>Retarder</td>
<td>2 – 5 oz./cwt.</td>
</tr>
</tbody>
</table>

- $w/cm = 0.42$
- Design air = 6.5 percent
- Design slump = 1.5 in.
Class TL Combined Gradation
Tarantula Curve

Fine sand: 26 percent
Target: 24 to 34 percent

Coarse sand: 24 percent
Target: > 15 percent

Percent Retained

Sieve No.

#200 #100 #50 #30 #16 #8 #4 3/8" 1/2" 3/4" 1"

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Summary And Future Changes
Performance Vs. Prescriptive

Reduced cement content
• Bridge deck
• Pavement

Increased SCM usage
• More ternary mixtures
• Higher replacement percentages

Focus on durability
• Chloride penetration resistance
• Shrinkage
• Workability
Successes To Date With Performance Specifications

Ternary black rock mixes for composite pavement
• 2013/2014
• Approximately 200,000 cubic yards

Ternary optimized pavement mixes
• 2015/2016
• Approximately 500,000 cubic yards
• Most for performance-related construction specifications

HPC for bridge decks
• Used since 2013 for more than 100 bridge decks
• No placement or finishing issues
• Significantly reduced early age cracking in bridge decks

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Lessons Learned

Stakeholder buy-in
• Agency
• Contractor
• Concrete producer

Material source changes
• Portland cement
• Fly ash
• Aggregate

Constructability
• Contractor risk/reward
New PCC Performance Measures Possibly Coming

Resistivity (bulk) measurements for formation factor
• To replace the chloride penetration test (AASHTO T 277)
• To be a general measure of durability

Super air meter or rapid/easier, hardened air tests
• To replace current hardened air test (ASTM C 457)
• Possibly to replace plastic air tests as well

Box or V-Kelly test for workability (only for designs)
• Box test currently used for trial batches

Service life for bridge decks
• Use chloride penetration resistance or corrosion inhibitor while maintaining crack-resistance to achieve 50-year service life with epoxy coated reinforcement

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Questions?
Thank You