INTERNALLY CURED CONCRETE PAVEMENT FOR INTERMODAL FACILITY

HEAVY-DUTY CONCRETE PAVEMENTS, PART 1/2

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Research References and Acknowledgements

Special thanks to
- John Ries, FACI
  - ESCSI
- Victor H. Villarreal, FACI
  - TXI/US Concrete

Villarreal, V., and Crocker, D.A.
“Better Pavements through Internal Hydration - Taking lightweight aggregate to the streets”
Concrete International, Feb 2007
Outline for Presentation

• Details of Intermodal facility with ICC pavement construction
  - Field observations
• Internally cured concrete (ICC) and potential mixture advantages for concrete pavements
  - Mechanical properties
  - Durability
• AASHTO Pavement Design Guide Performance prediction for intermodal facility pavement slabs
Union Pacific Intermodal Facility
Union Pacific Intermodal Facility

Hutchins, TX - ~12 miles from Dallas, TX
Multimodal Facility

360 acre facility
Facility Features

• 365,000 lift capacity and 4,000 parking stalls
• 10-lane automated gate system entrance
• 24-hour, seven-day-a-week operations
• Four loading tracks
• Future expansion
• Paving in 2005, and construction throughout the year

Source: Union Pacific Railroad
www.uprr.com
Multimodal Facility
View of Security/Gate Entry
Facility’s Maximum Traffic Zone
Excellent Performance after 8 years
Two locations with spalls and one slab with cracking – That’s all!
Internally Cured Concrete Pavement
INTERNAL CURING
Internally Cured Concrete

- Use of pre-wet lightweight aggregates (LWA) as partial replacement to coarse/ fine/ coarse and fine fractions
  - For example 30 percent of sand
  - Replace 500 lb of coarse and fine with 300 lb of intermediate size LWA

Physical and mechanical properties favorable for performance

(Castro et al., 2010).
## ICC Mixture and Control Mix Design

<table>
<thead>
<tr>
<th>Material</th>
<th>Control</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement (lb/yd³)</td>
<td>451</td>
<td>451</td>
</tr>
<tr>
<td>Fly ash (lb/yd³)</td>
<td>113</td>
<td>113</td>
</tr>
<tr>
<td>Coarse aggregate (lb/yd³)</td>
<td>1840</td>
<td>1540 {-300lb}</td>
</tr>
<tr>
<td>Intermediate LWA (lb/yd³)</td>
<td>0</td>
<td>300</td>
</tr>
<tr>
<td>Fine aggregate (lb/yd³)</td>
<td>1301</td>
<td>1099 {-200 lb}</td>
</tr>
<tr>
<td>Water (lb/yd³)</td>
<td>242</td>
<td>242</td>
</tr>
<tr>
<td>Water reducer (fl oz/100 lb)</td>
<td>As needed</td>
<td></td>
</tr>
<tr>
<td>AEA</td>
<td>3.0 to 6.0%</td>
<td></td>
</tr>
<tr>
<td>Air content (3-6%)</td>
<td>2 ± 1 in.</td>
<td></td>
</tr>
<tr>
<td>Compressive strength (psi)</td>
<td>4,500</td>
<td></td>
</tr>
</tbody>
</table>

Villarreal, V., et al., 2007
Impact of IC on Concrete Properties – The Basics

Steady and prolonged moisture supply from LWA

Reduced mass from aggregate

Improved hydration products
- Durability benefits
- Lower early age shrinkage
- Reduced stresses from restraint

Enhanced mechanical properties
- Lower unit weight (6pcf)
- Lower elastic modulus (5%)
- Lower CTE (5%)
- Higher strength (5-20%)
Potential Effect of Reduced Shrinkage on Pavement Performance

Reduced early autogenous shrinkage

Permanent Influence
- Effects slab upward curling
- Lowers zero stress temperature

Performance Benefits
- Reduces premature shrinkage cracking
- Affects crack spacing and width in CRCP and rate of crack development
- Affects transverse crack development in JPCP
Potential Impact of Temperature & Moisture On Curling of Slabs

**CONVENTIONAL CONCRETE**
- Increased curl
  - From high moisture gradient through slab
- Moisture gradient
  - High
  - Low

**CONCRETE WITH INTERNAL CURING**
- Reduced curl due to lower shrinkage (ICC pavement)
- Moisture gradient
  - High
  - Low

**CONCRETE PLACEMENT AND FINISHING STAGES**
- Flat slab at construction
- Built-in temperature gradient (upward curl)

**CONCRETE CURING AND EARLY AGE SHRINKAGE**
- Positive gradient (Zero stress temp)
- Zero gradient

Temperature vs. Depth:
- **CONVENTIONAL CONCRETE**
  - Positive gradient (Zero stress temp)
  - Zero gradient

- **CONCRETE WITH INTERNAL CURING**
  - Reduced curl due to lower shrinkage (ICC pavement)

- **CONCRETE CURING AND EARLY AGE SHRINKAGE**
  - Moisture gradient
    - High
    - Low
Upward Slab Curl Causes Cracking
Transverse Fatigue Cracking (Top-Down) I-80 PA

20-ft Joint Spacing 13-in Slab (5-years)
Photo of Transverse & Longitudinal Top Down Cracking
Plastic Shrinkage Cracks
Interaction Effects – Cannot Isolate Single Cause for Performance Benefits

- Reduced CTE
- Lower unit weight
- Reduced modulus
- Reduced built-in stresses
- Higher strength

Suitable for use when fly ash is incorporated in mix design

Depends on
- Range of temperature changes in local climate
- Traffic level and traffic characteristics
- Slab thickness
- Aggregate type
AASHTOWare
Pavement M-E Analysis
– Dallas Intermodal ICC Pavement
Project Analysis Details

• Assume about 240 trucks per day per lane
  - Class 9 trucks single trailer trucks

• Pavement Structure
  - 8.5 inch JPCP
  - 12 inch aggregate base on subgrade

• Construction through several months (all seasons)
  - Measured zero curling in the slab with string line

• 60-yr analysis period
### Concrete Inputs (Measured & Estimated)

<table>
<thead>
<tr>
<th>Inputs (or Calculated Values)</th>
<th>Control</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit weight, pcf</td>
<td>145</td>
<td>137</td>
</tr>
<tr>
<td>CTE, $x 10^{-6}$ in/in/°F</td>
<td>4.8</td>
<td>4.3</td>
</tr>
<tr>
<td>Compressive strength, psi</td>
<td>5130</td>
<td>6070</td>
</tr>
<tr>
<td>Elastic modulus, psi</td>
<td>4,127,000</td>
<td>4,123,000</td>
</tr>
<tr>
<td>Permanent deltaT</td>
<td>-10F</td>
<td>-10F</td>
</tr>
<tr>
<td>Ultimate shrinkage, $x 10^{-6}$ in./in.</td>
<td>611</td>
<td>592</td>
</tr>
<tr>
<td>Calculated by program</td>
<td></td>
<td></td>
</tr>
<tr>
<td>w/cm ratio</td>
<td>0.43</td>
<td>0.43</td>
</tr>
<tr>
<td>Base layer</td>
<td>12” crushed stone aggregate</td>
<td></td>
</tr>
<tr>
<td>Subgrade</td>
<td>AASHTO A-7-6</td>
<td></td>
</tr>
</tbody>
</table>
Predicted Performance, Transverse Cracking

- 8.5-inch JPCP - CONTROL
- 8.5-inch JPCP - ICC

ICC JPCP predicts one-half or less cracking over 60-years (Note: No concrete durability problems were noted during the field survey at 7 years age. No upward curling was measured on several slabs).
Predicted Performance, Faulting and Roughness

- **8.5-inch JPCP - CONTROL**

- **8.5-inch JPCP - ICC**
Other Field Project
ICC Pavements in DFW area

SH121 CRCP

Residential street
Conclusions

• Changes in mixture properties with small replacement of normal weight aggregates with prewetted aggregates, i.e. ICC
  - Changes in properties are favorable for pavement performance
• M-E analysis validates excellent performance observed on field
  - ICC properties are within the range of values applicable for M-E analysis
  - Long-term projections seem reasonable
  - Will reduce initial construction costs if proper inputs for ICC are used in design
• ICC used in a heavy-duty pavement application has shown excellent field performance and is validated with M-E analysis
THANK YOU.

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