2010 ANNUAL CONFERENCE

North Eastern States’ Materials Engineers Association

October 5, 2010

Saratoga Springs, NY
INTERNAL CURING OF HIGH PERFORMANCE CONCRETE
Learning Objectives

- What is Internal Curing (IC)
- How does IC work
- Why use IC
- Specifications
- Projects using IC
- Life Cycle Study
2003 FHWA Nationwide HPC survey – Most Common Pavement Distresses

- Early-age deck cracking (57% responses were a 4 or 5=often)
- Corrosion (42% - definitely linked to cracking)
- Cracking of girders, etc. (31%)
- Others (sulfate attack, ASR, F/T, overload, poor construction quality were all below 25% level)
Why we need IC

- In HPC it is not easily possible to provide curing water from the top surface at the rate that is required to satisfy the ongoing chemical shrinkage, due to the extremely low permeabilities that are often achieved in the concrete as the capillary pores depercolate.
What is Internal Curing (IC)?
Internal Curing

- ACI-308 “internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing water.”
- Typically concrete has been cured from the outside in, IC is curing from the inside out. Internal water is supplied via internal reservoirs found in ESCS saturated lightweight fine aggregates.
HOW DOES IC WORK
How IC Works

- HPC is designed to limit the permeability of concrete to reduce chloride ingress. Unfortunately this also limits the ability of externally applied curing water to reach the interior of the concrete.

- IC distributes the extra curing water throughout the concrete microstructure making it more readily available to maintain saturation of the cement paste during hydration, avoiding self-desiccation and reducing autogenous shrinkage.
SEM of Lightweight Aggregate
Visualization of water transport

Blue-ink corona in cement paste around Presaturated Lightweight Aggregate
Paste with w/c = 0.37
Water transport from saturated LWA to drying cement paste
3-D concrete microstructure showing IC

Yellow – Saturated LWA
Red – Normal weight sand
Blues – Pastes within various distances of an LWA
IC Material Requirements

- IC material needs to be able to hold sufficient amount of absorbed water
- Material should not adversely effect strength of concrete
- Will not effect w/c
- Water needs to remain in IC material until needed
- Material should give up water at high RH
EFFECTS OF INTERNAL CURING
Internal RH Results

Mortars with Internal Curing
LWA = saturated lightweight aggregates
SAP = superabsorbent polymer
FSF = control with fine silica fume

$w/cm = 0.35$
Autogenous Deformation Results

\[ \text{Deformation (microstrain)} \]

- \( w/cm = 0.35 \)

- Time (days)

- LWA20
- SAP
- LWA08

Graph showing the deformation over time for different materials with a water-to-cement ratio of 0.35.
Specifications

- Proper amount of water
- 30% replacement of fine aggregate
- Minimum 15% absorbed moisture
- Place under sprinkler for minimum of 48 hours
- Allow stockpiles to drain for 12 to 15 hours immediately prior to use
Specifications

- Calculate absorbed and surface moisture
- Utilize paper towel test
- Adjust pull weights by absorbed moisture only
- Absorbed water does not effect w/c
- Reduce mix water by surface moisture
CASE STUDIES
Court Street Overpass I-81
September 2009
HPC Mix Design
Spencer Street Syracuse, NY

- Cement – Type I: 500 lbs
- Fly Ash: 135 lbs
- Microsilica: 40 lbs
- Fine Aggregate – Natural Sand: 1130 lbs
- Coarse Aggregate – 1 & 2 Blend: 1720 lbs
- Water: 270 lbs
## HPC-IC Mix Design

**Court Street Syracuse, NY**

- **Cement – Type I**: 500 lbs
- **Fly Ash**: 135 lbs
- **Microsilica**: 40 lbs
- **Fine Aggregate – Natural Sand**: 782 lbs
- **Fine Aggregate – Expanded Shale**: 196 lbs
- **Coarse Aggregate – 1 & 2 Blend**: 1720 lbs
- **Water**: 262 lbs
HPC-IC Mix Design
Court Street Syracuse, NY

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## Syracuse, NY Bridge Comparison

<table>
<thead>
<tr>
<th>Concrete Type</th>
<th>7 day Strength (MPa)</th>
<th>14 day Strength (MPa)</th>
<th>21 day Strength (MPa)</th>
<th>28 day Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spencer and Butternut Streets Bridges</td>
<td>32.6</td>
<td>40.8</td>
<td>41.9</td>
<td>43.5</td>
</tr>
<tr>
<td>Court Street Bridge</td>
<td>33.5</td>
<td>42.9</td>
<td>45.3</td>
<td>48.1</td>
</tr>
</tbody>
</table>

Source: NYSDOT
Bartell Road Overpass I-81
Cicero, NY  May 2010
<table>
<thead>
<tr>
<th>Material</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement – Type I</td>
<td>506 lbs</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>135 lbs</td>
</tr>
<tr>
<td>Microsilica</td>
<td>42 lbs</td>
</tr>
<tr>
<td>Fine Aggregate – Natural Sand</td>
<td>797 lbs</td>
</tr>
<tr>
<td>Fine Aggregate – Expanded Shale</td>
<td>194 lbs</td>
</tr>
<tr>
<td>Coarse Aggregate – 1 &amp; 2 Blend</td>
<td>1726 lbs</td>
</tr>
<tr>
<td>Water</td>
<td>273 lbs</td>
</tr>
</tbody>
</table>
## Cicero, NY Bridge Comparison

<table>
<thead>
<tr>
<th>Type</th>
<th>7 day (MPa)</th>
<th>14 day (MPa)</th>
<th>21 day (MPa)</th>
<th>28 day (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bartell Road Bridge</td>
<td>22.2</td>
<td>17.3</td>
<td>-</td>
<td>30.2</td>
</tr>
<tr>
<td>HPC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bartell Road Bridge</td>
<td>21.0</td>
<td>25.9</td>
<td>29.4</td>
<td>34.8</td>
</tr>
<tr>
<td>HPC-IC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent Improvement</td>
<td>-5.4%</td>
<td>49.7%</td>
<td>-</td>
<td>15.2%</td>
</tr>
</tbody>
</table>

Source: NYSDOT
NYSDOT Study - Variety of conditions

- Bridge type
- Number of spans
- Regions
- Climates
- De-icing chemicals
- Traffic loading
- Time when poured
Projects in construction or already built

- NY Route 9W over Vineyard Avenue
- NY Route 96 over Owego Creek
- Interstate 81 at Whitney Point Southbound
- Interstate 81 at Whitney Point Northbound
- Court Street over Interstate 81
- Bartell Road over Interstate 81
- Interstate 86 over NY Route 415
- Interstate 84 over Route 6
- Interstate 290 Ramp B over Interstate 190
Projects currently being designed

- Interstate 81 over East Hill Road
- NY Route 17 Exit 90 Ramp over East Branch Delaware River
- NY Route 38B over Crocker Creek
- NY Route 353 over Allegheny River
- Interstate 290 Ramp D Over Interstate 190
- Interstate 87 over Route 9 and Trout Brook
- Interstate 81 Connectors near Fort Drum
# Impact of IC on HPC Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>HPC Concrete w/c = 0.35</th>
<th>HPC-IC Concrete w/c = 0.35</th>
<th>Improvement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC water provided (kg/kg)</td>
<td>0</td>
<td>0.075</td>
<td></td>
</tr>
<tr>
<td>C-S-H content at 28 days</td>
<td>10.2</td>
<td>12.3</td>
<td>21</td>
</tr>
<tr>
<td>Compressive Strength at 7 days (MPa)</td>
<td>45</td>
<td>50</td>
<td>11</td>
</tr>
<tr>
<td>Compressive Strength at 28 days (MPa)</td>
<td>60</td>
<td>65</td>
<td>8</td>
</tr>
<tr>
<td>Water Permeability (m/s)</td>
<td>2.10E-11</td>
<td>1.70E-11</td>
<td>19</td>
</tr>
<tr>
<td>Chloride Permeability (coulumb)</td>
<td>553</td>
<td>415</td>
<td>25</td>
</tr>
<tr>
<td>Freeze/Thaw Resistance (% mass loss)</td>
<td>0.60</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td>Salt Scaling Resistance (% mass loss)</td>
<td>0.46</td>
<td>0.30</td>
<td></td>
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</table>

Source: Cusson & Margeson 2010
## Mix Designs Canadian Study

<table>
<thead>
<tr>
<th>Deck Option</th>
<th>Cracking</th>
<th>Initial Water (kg/cu m)</th>
<th>Cement (kg/cu m)</th>
<th>SCM (%)</th>
<th>LWA (kg/cu m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC</td>
<td>No</td>
<td>140</td>
<td>350</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HPC</td>
<td>Yes</td>
<td>160</td>
<td>450</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>HPC-IC</td>
<td>No</td>
<td>160</td>
<td>450</td>
<td>25</td>
<td>200</td>
</tr>
</tbody>
</table>

Source: Cusson et al. 2010
Life cycle predictions

- NC: 23 years
- HPC: 40 years
- HPC-IC: 63 years
Conclusions

- Saturated LWA fines can be used to improve concrete properties
- IC material should have proper moisture
- IC material should have proper desorption characteristics
- Addition of IC materials do not effect the finishability of concrete
- IC will improve the durability of HPC
For More Information

www.escsi.org

www.norliteagg.com

http://ciks.cbt.nist.gov/lwagg.html
Thank You

Questions