The Economics, Performance, and Sustainability of Internally Cured Concrete, Part 1

ACI Fall 2012 Convention
October 21 – 24, Toronto, ON

William H. Wolfe is a Senior Engineer with the Norlite Corporation, a lightweight aggregate manufacturer located in Albany, New York.
Learning Objectives

- History of Internal Curing (IC) in New York State
- Mix Development
- Batching, placing, and curing
- Projects using IC

HISTORY OF IC IN NEW YORK

Bridges in NYS

- New York has over 17,000 bridges
- Many of these bridges are in need of repair
- NYSDOT is working towards improving life cycle of new structures

NYSDOT Internal Curing Study

- Main purpose for investigating IC was to reduce cracking
- NYSDOT currently using HPC
- Looking for another tool to improve HPC performance
- 2007 study was developed for IC evaluation
- Multiple structures

NYSDOT Study - Variety of conditions

- Bridge type
- Number of spans
- Regions
- Climates
- De-icing chemicals
- Traffic loading
- Time when poured
High Performance Concrete

Table 1 - Class HP Mix Criteria

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement content</td>
<td>500</td>
</tr>
<tr>
<td>Fly ash content</td>
<td>135</td>
</tr>
<tr>
<td>Microsilica content</td>
<td>40</td>
</tr>
<tr>
<td>Sand percent total aggregate</td>
<td>40</td>
</tr>
<tr>
<td>Designed water/total cementitious content</td>
<td>0.40</td>
</tr>
<tr>
<td>Desired air content (%)</td>
<td>6.5</td>
</tr>
<tr>
<td>Allowable air content (%)</td>
<td>5.0 - 8.0</td>
</tr>
<tr>
<td>Desired slump (inches)</td>
<td>4</td>
</tr>
<tr>
<td>Allowable slump (inches)</td>
<td>3 - 5</td>
</tr>
<tr>
<td>Type of coarse aggregate gradation</td>
<td>CA 2</td>
</tr>
</tbody>
</table>

**NOTE:** The criteria are given for design information and the data is based on a fine aggregate fineness modulus of 2.80. The mixture proportions shall be computed according to Department written instructions.

Bentz Equation

\[ M_{LWA} = \frac{C_f \times CS \times \alpha_{MAX}}{S \times \Phi_{LWA}} \]

where
- \( M_{LWA} \) = mass of (dry) LWA needed per unit volume of concrete (kg/m³ or lb/ft³)
- \( C_f \) = cement factor (content) for concrete mixture (kg/m³ or lb/ft³)
- \( CS \) = chemical shrinkage of cement (mass of water/mass of cement)
- \( \alpha_{MAX} \) = maximum expected degree of hydration of cement (0 to 1)
- \( S \) = degree of saturation of aggregate (0 to 1)
- \( \Phi_{LWA} \) = desorption of lightweight aggregate from saturation down to 93 % RH (mass water/mass dry LWA).

30% replacement of fines

High Performance Concrete with Internal Curing

Table 2 - Class HP-IC Mix Criteria

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</tr>
<tr>
<td>Microsilica content</td>
<td>40</td>
</tr>
<tr>
<td>Sand percent total aggregate</td>
<td>28</td>
</tr>
<tr>
<td>Lightweight fines percent total aggregate</td>
<td>12</td>
</tr>
<tr>
<td>Designed water/total cementitious content</td>
<td>0.40</td>
</tr>
<tr>
<td>Desired air content (%)</td>
<td>6.5</td>
</tr>
<tr>
<td>Allowable air content (%)</td>
<td>5.0 - 8.0</td>
</tr>
<tr>
<td>Desired slump (inches)</td>
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</tr>
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**NOTE:** The criteria are given for design information and the data is based on a fine aggregate fineness modulus of 2.80. The mixture proportions shall be computed according to Department written instructions.

**IC Material Requirements**

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

**Internal Curing Materials**

- Three approved expanded shale sources
- Similar absorption and desorption properties
- Allows for same dosage
- Similar strength and relative density

Absorption Analysis

<table>
<thead>
<tr>
<th>Brand</th>
<th>0%</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stalite</td>
<td>0.0</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Utelit</td>
<td>0.2</td>
<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Slag</td>
<td>0.4</td>
<td>0.8</td>
<td>1.2</td>
<td>1.6</td>
<td>2.0</td>
</tr>
<tr>
<td>TXI - Boulder</td>
<td>1.0</td>
<td>2.0</td>
<td>3.0</td>
<td>4.0</td>
<td>5.0</td>
</tr>
<tr>
<td>TXI - Streetman</td>
<td>1.5</td>
<td>3.0</td>
<td>4.5</td>
<td>6.0</td>
<td>7.5</td>
</tr>
<tr>
<td>Norlite</td>
<td>2.0</td>
<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Buildex</td>
<td>2.5</td>
<td>5.0</td>
<td>7.5</td>
<td>10.0</td>
<td>12.5</td>
</tr>
<tr>
<td>Solite</td>
<td>3.0</td>
<td>6.0</td>
<td>9.0</td>
<td>12.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Haydite</td>
<td>3.5</td>
<td>7.0</td>
<td>10.5</td>
<td>14.0</td>
<td>17.5</td>
</tr>
<tr>
<td>Castro 2010</td>
<td>4.0</td>
<td>8.0</td>
<td>12.0</td>
<td>16.0</td>
<td>20.0</td>
</tr>
</tbody>
</table>

 Castro 2010
Prewet LWA

- Proper amount of water
- 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

Soaking Aggregate

Batching

- Bin space
- Batch lightweight first
- Wet sand questions
Batching

- 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

Placing

- Typically pumped
- Finishability similar to HPC
Day of Placement Testing

VS.

Curing

- Still need surface curing
- Place burlap quickly
- Wet cure 14 days

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**

- **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

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### Syracuse, NY Bridge Comparison

<table>
<thead>
<tr>
<th>Concrete Type</th>
<th>7 day (PSI)</th>
<th>14 day (PSI)</th>
<th>21 day (PSI)</th>
<th>28 day (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spencer and Butternut Streets Bridges</td>
<td>HPC</td>
<td>6,727</td>
<td>8,077</td>
<td>9,288</td>
</tr>
<tr>
<td>Court Street Bridge</td>
<td>HPC-IC</td>
<td>6,690</td>
<td>8,222</td>
<td>9,778</td>
</tr>
</tbody>
</table>

**Percent Improvement**

- **2.8%**
- **5.1%**
- **8.1%**
- **10.6%

Source: NYSDOT

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### Interstate 190/Interstate 290

**Tonawanda, NY**

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### Interstate 190/Interstate 290
**Tonawanda, NY**

<table>
<thead>
<tr>
<th>Component</th>
<th>Class HP</th>
<th>Class HP-IC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement – Blended with 7% Silica Fume</td>
<td>540 lbs</td>
<td>540 lbs</td>
</tr>
<tr>
<td>Fly Ash – Type F</td>
<td>139 lbs</td>
<td>139 lbs</td>
</tr>
<tr>
<td>Fine Aggregate – Natural Sand</td>
<td>1150 lbs</td>
<td>813 lbs</td>
</tr>
<tr>
<td>Fine Aggregate – LWAF</td>
<td>0 lbs</td>
<td>244 lbs</td>
</tr>
<tr>
<td>Coarse Aggregate – No. 1 Stone</td>
<td>674 lbs</td>
<td>959 lbs</td>
</tr>
<tr>
<td>Coarse Aggregate – No. 2 Stone</td>
<td>1,038 lbs</td>
<td>792 lbs</td>
</tr>
<tr>
<td>Water</td>
<td>272 lbs</td>
<td>273 lbs</td>
</tr>
<tr>
<td>Air Entrainment - BASF AE-100</td>
<td>16.3 oz</td>
<td>17.7 oz</td>
</tr>
<tr>
<td>Water Reducer - BASF 100 Xr</td>
<td>20.4 oz</td>
<td>26.5 oz</td>
</tr>
</tbody>
</table>

**Average Properties**

- 7 day Compressive Strength: 3,040 psi
- 28 day Compressive Strength: 4,677 psi
- 56 day Compressive Strength: 5,343 psi
- Concrete Density: 140.2 pcf
- Air Content: 5.5%
- Slump: 5.0"

### Bartell Road Overpass I-81
**Cicero, NY**  **May 2010**

- **Cement – Type I**: 506 lbs
- **Fly Ash**: 135 lbs
- **Microsilica**: 42 lbs
- **Fine Aggregate – Natural Sand**: 797 lbs
- **Fine Aggregate – Expanded Shale**: 154 lbs
- **Coarse Aggregate – 1 & 2 Blend**: 1726 lbs
- **Water**: 273 lbs

### HPC-IC Mix Design
**Bartell Road Cicero, NY**

- **Cement – Type I**: 506 lbs
- **Fly Ash**: 135 lbs
- **Microsilica**: 42 lbs
- **Fine Aggregate – Natural Sand**: 797 lbs
- **Fine Aggregate – Expanded Shale**: 154 lbs
- **Coarse Aggregate – 1 & 2 Blend**: 1726 lbs
- **Water**: 273 lbs
Cicero, NY Bridge Comparison

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<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>Bartell Road Bridge</td>
<td>21.0</td>
<td>23.0</td>
<td>29.4</td>
<td>34.8</td>
</tr>
<tr>
<td>Percent Improvement</td>
<td>-5.4%</td>
<td>49.7%</td>
<td>-15.2%</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: NYSDOT

Interstate 87 over Trout Creek
Chestertown, NY

- 5 span structure on steel girders
- IC deck placed September 13 & 18, 2012
- Deck had no cracks after 4 weeks
- Barrier was HPC without IC – cracked every 4 feet

Conclusions

- Saturated LWA fines can be used to improve concrete properties
- IC can easily be incorporated at batch plant
- IC can help to reduce cracking
- IC has improved concrete strengths
- IC supplements conventional curing
- IC does not effect the finishability of concrete
- IC will help to improve the durability of HPC

Thank You

Questions