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

ACI Fall 2012 Convention
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FALL CONFERENCE

October 23, 2012 | Toronto, ON

## THE ECONOMICS, PERFORMANCE, AND SUSTAINABILITY OF INTERNALLY CURED CONCRETE

## FIELD PERFORMANCE OF INTERNALLY CURED CONCRETE BRIDGE DECKS IN NEW YORK STATE

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## Learning Objectives

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

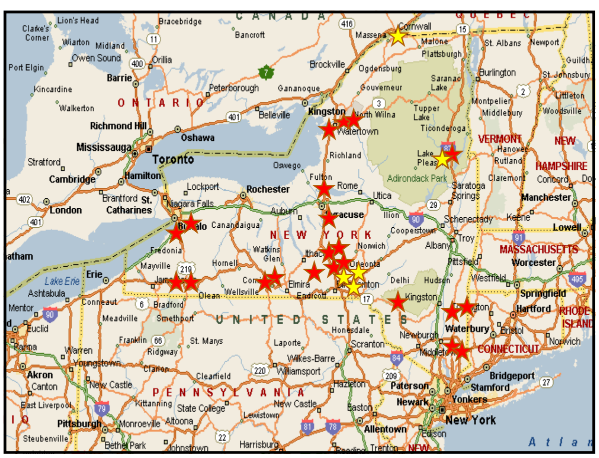
## HISTORY OF IC IN NEW YORK

## 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

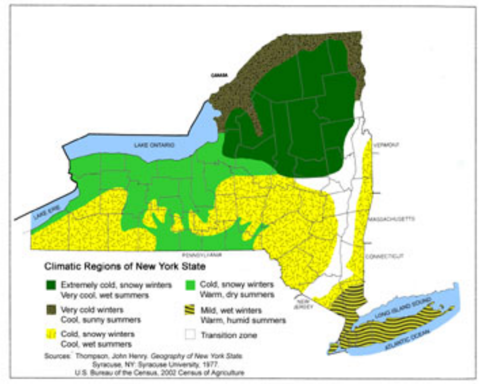
## NYSDOT Internal Curing Study

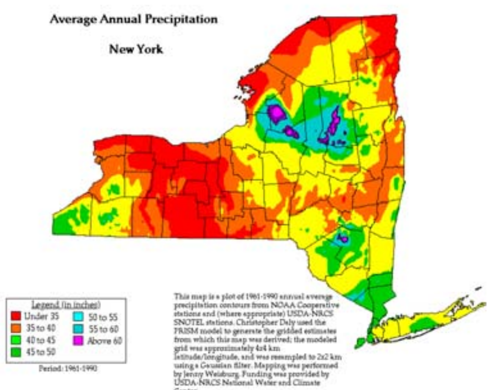
- Main purpose for investigating IC was to reduce cracking
- NYSDOT currently using HPC
- Looking for another tool to improve HPC performance
- 2007 study was developed for IC evaluation
- Multiple structures



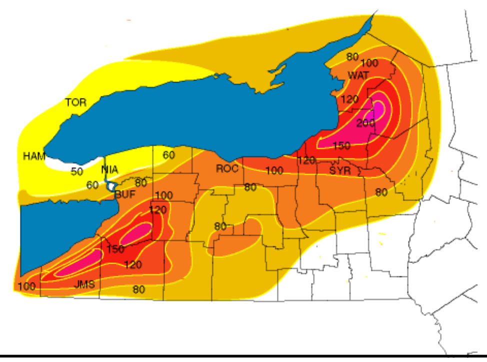

## NYSDOT Study - Variety of conditions

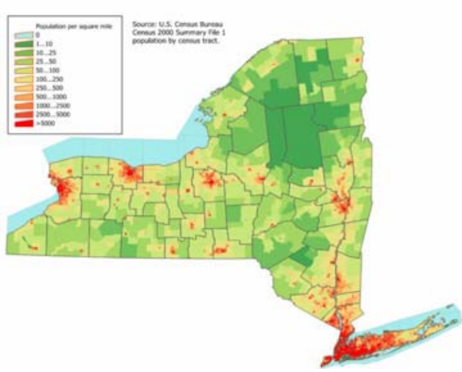
- Bridge type
- Number of spans
- Regions
- Climates
- De-icing chemicals
- Traffic loading
- Time when poured




AVERAGE
SEASON SNOWFALL



MIX DEVELOPMENT

## High Performance Concrete

*Table 1* - Class HP Mix Criteria

| | |
|---|---|
| Cement content (lbs./c.y.) | 500 |
| Fly ash content (lbs./c.y.) | 135 |
| Microsilica content (lbs./c.y.) | 40 |
| Sand percent total aggregate (solid volume) | 40 |
| Designed water/total cementitious content | 0.40 |
| Desired air content (%)<br>Allowable air content (%) | 6.5<br>5.0 - 8.0 |
| Desired slump (inches)<br>Allowable slump (inches) | 4<br>3 -5 |
| Type of coarse aggregate gradation | CA 2 |

**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 determined using actual conditions for fineness modulus and bulk specific gravities (saturated surface dry for aggregate). The proportions shall be computed according to Department written instructions.

## Bentz Equation

$$M_{LWA} = \frac{C_f * CS * \alpha_{max}}{S * \phi_{LWA}}$$

where

$M_{LWA}$ = mass of (dry) LWA needed per unit volume of concrete (kg/m$^3$ or lb/yd$^3$);
$C_f$ = cement factor (content) for concrete mixture (kg/m$^3$ or lb/yd$^3$);
$CS$ = 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

| | |
|---|---|
| Cement content (lbs./c.y.) | 500 |
| Fly ash content (lbs./c.y.) | 135 |
| Microsilica content (lbs./c.y.) | 40 |
| Sand percent total aggregate (solid volume) | 28 |
| Lightweight fines percent total aggregate (solid volume) | 12 |
| Designed water/total cementitious content | 0.40 |
| Desired air content (%)<br>Allowable air content (%) | 6.5<br>5.0 - 8.0 |
| Desired slump (inches)<br>Allowable slump (inches) | 4<br>3 -5 |
| Type of coarse aggregate gradation | CA 2 |

**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 determined using actual conditions for fineness modulus and bulk specific gravities (saturated surface dry for aggregate). The proportions shall be computed according to Department written instructions.

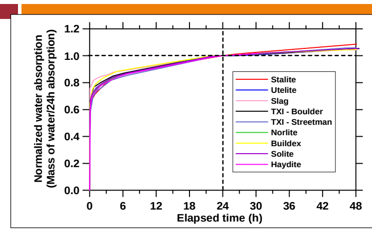
## IC Material Requirements

- 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

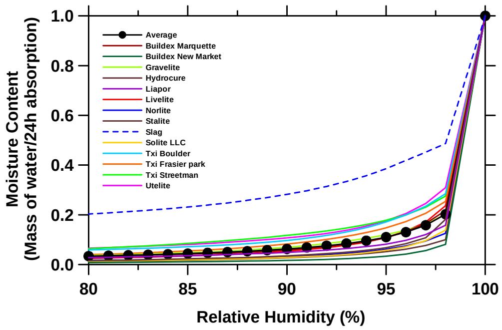
## Absorption Analysis




| Aggregate | SG (OD) | Absorption |
|---|---|---|
| Stalite | 1.51 | 5.9% |
| Haydite AX | 1.4 | 10.4% |
| Solite #10 | 1.62 | 14.4% |
| DiGeronimo - Haydite | 1.4 | 15.7% |
| Fraiser Park | 1.39 | 15.8% |
| Norlite | 1.4 | 16.8% |
| Buildex Marquette | 1.45 | 17.4% |
| Utelite | 1.49 | 19.3% |
| Livelite | 1.04 | 23.1% |

Castro 2010

## LWA Desorption Graph



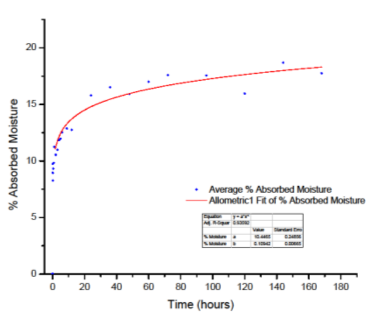

## BATCHING AND PLACING INTERNALLY CURED CONCRETE

## 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

## Aggregate Absorption




## 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 |

## Syracuse, NY Bridge Comparison

| | Concrete Type | 7 day Compressive Strength (PSI) | 14 day Compressive Strength (PSI) | 21 day Compressive Strength (PSI) | 28 day Compressive Strength (PSI) |
|---|---|---|---|---|---|
| Spencer and Butternut Streets Bridges | HPC | 4,727 | 5,917 | 6,077 | 6,309 |
| Court Street Bridge | HPC-IC | 4,859 | 6,222 | 6,570 | 6,976 |
| Percent Improvement | | 2.8% | 5.1% | 8.1% | 10.6% |

Source: NYSDOT

## Interstate 190/Interstate 290
Tonawanda, NY

## Interstate 190/Interstate 290
Tonawanda, NY

| | Class HP | Class HP-IC |
|---|---|---|
| Cement – Blended with 7% Silica Fume | 540 lbs | 540 lbs |
| Fly Ash – Type F | 139 lbs | 139 lbs |
| Fine Aggregate – Natural Sand | 1150 lbs | 813 lbs |
| Fine Aggregate – LWAF 22.0% moisture | 0 lbs | 244 lbs |
| Coarse Aggregate – No. 1 Stone | 674 lbs | 959 lbs |
| Coarse Aggregate – No. 2 Stone | 1,038 lbs | 792 lbs |
| Water | 272 lbs | 273 lbs |
| Air Entrainment - BASF AE-100 | 16.3 oz | 17.7 oz |
| Water Reducer - BASF 100 Xr | 20.4 oz | 26.5 oz |

## Interstate 190/Interstate 290
Tonawanda, NY

| | Class HP | Class HP-IC |
|---|---|---|
| Average 7 day Compressive Strength | 3,040 psi | 3,500 psi |
| Average 28 day Compressive Strength | 4,677 psi | 4,683 psi |
| Average 56 day Compressive Strength | 5,343 psi | 5,417 psi |
| Concrete Density | 140.2 pcf | 135.2 pcf |
| Air Content | 5.5 % | 6.0 % |
| Slump | 5.0" | 4.5" |

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

## 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 194 lbs
- Coarse Aggregate – 1 & 2 Blend 1726 lbs
- Water 273 lbs

## Cicero, NY Bridge Comparison

| | Concrete Type | 7 day Compressive Strength (MPa) | 14 day Compressive Strength (MPa) | 21 day Compressive Strength (MPa) | 28 day Compressive Strength (MPa) |
|---|---|---|---|---|---|
| Bartell Road Bridge | HPC | 22.2 | 17.3 | - | 30.2 |
| Bartell Road Bridge | HPC-IC | 21.0 | 25.9 | 29.4 | 34.8 |
| Percent Improvement | | -5.4% | 49.7% | - | 15.2% |

Source: NYSDOT

## Interstate 87 over Trout Creek
Chestertown, NY

## 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**