NESMEA

North Eastern States' Materials Engineers Association

2010 ANNUAL CONFERENCE

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INTERNAL CURING OF HIGH PERFORMANCE CONCRETE

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Learning Objectives

- What is Internal Curing (IC)
- How does IC work
- Why use IC
- Specifications
- Projects using IC
- Life Cycle Study

HPC Survey

- 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)?

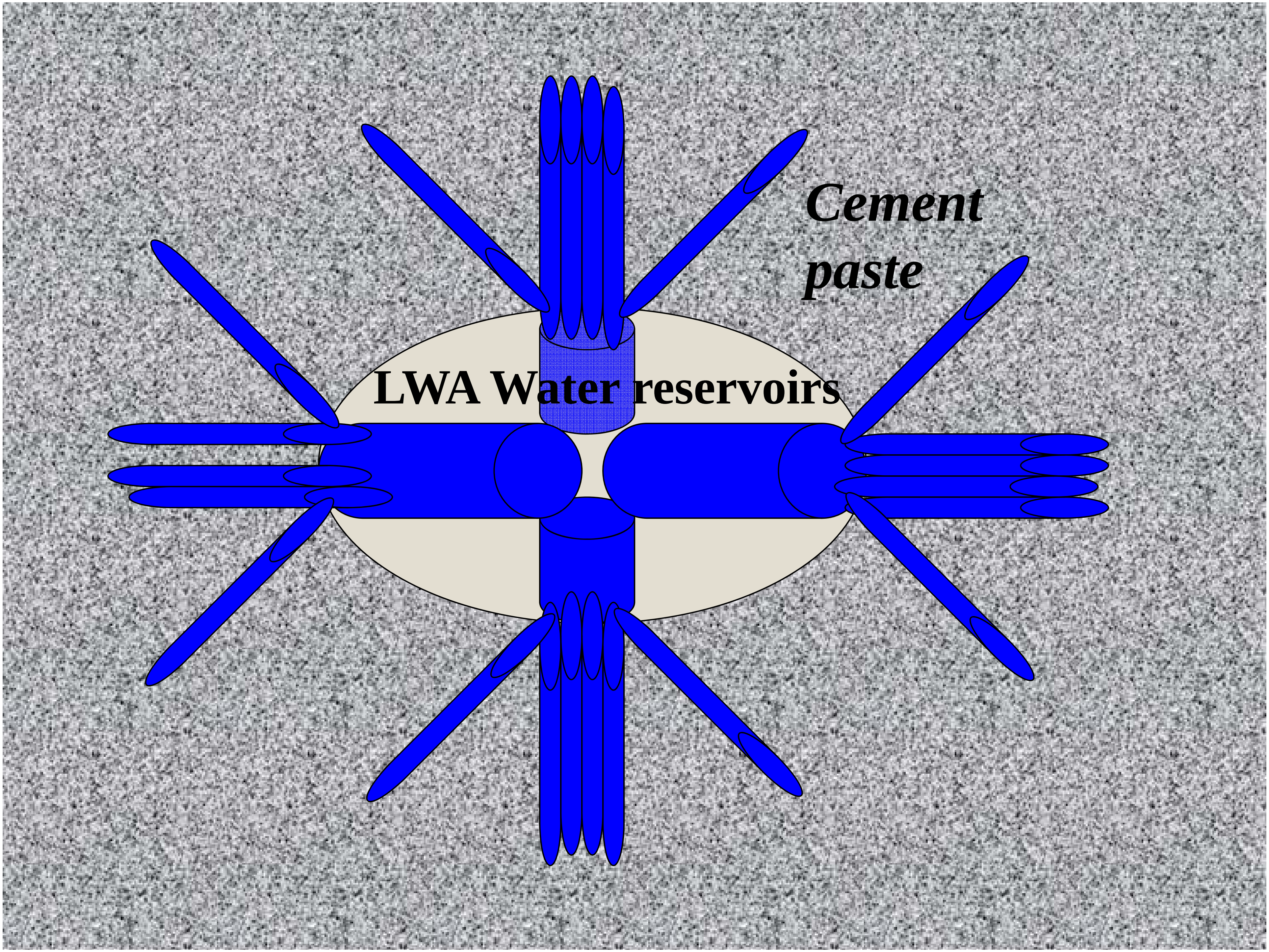
Internal Curing

- 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.

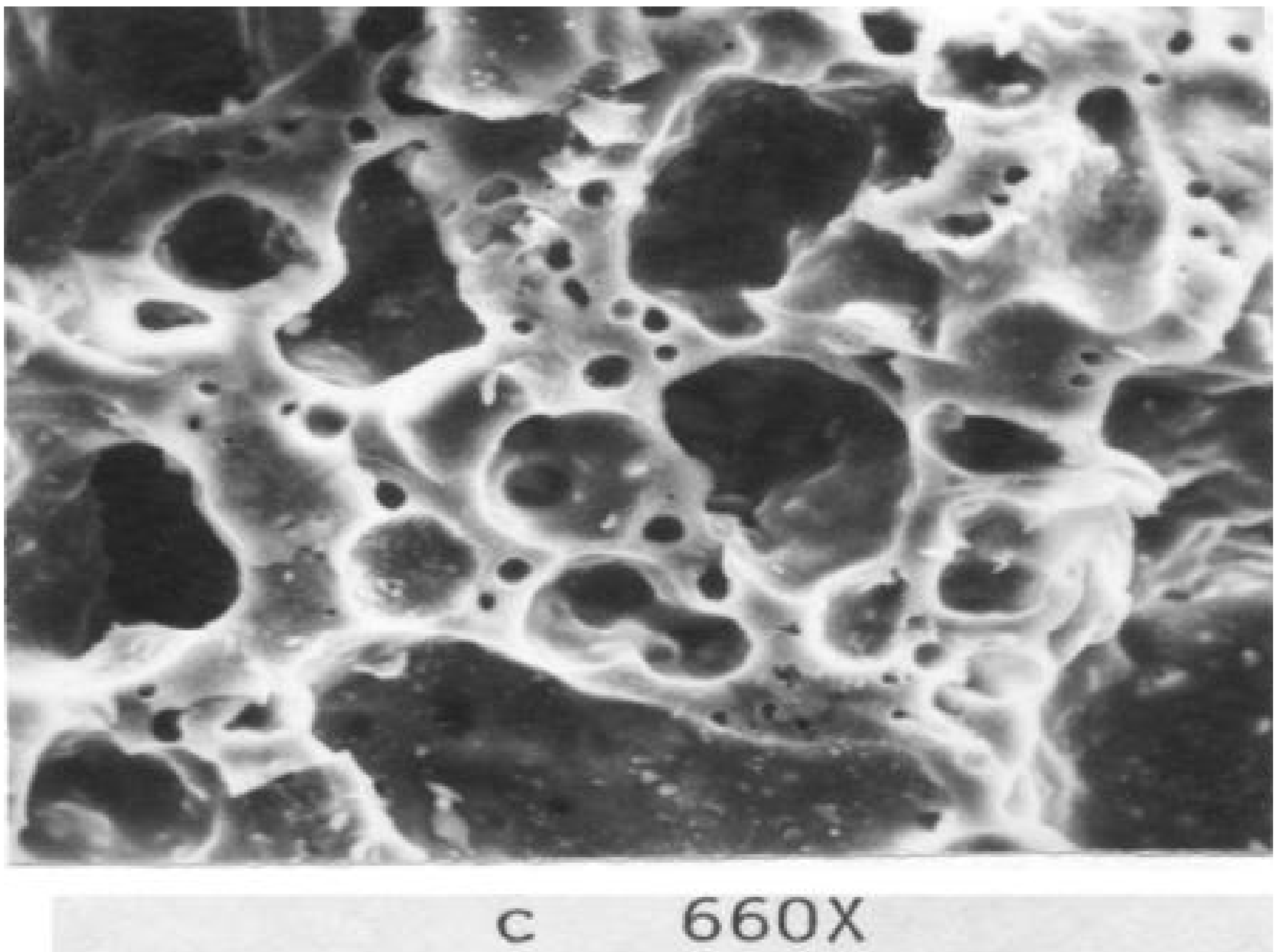
HOW DOES IC WORK

How IC Works

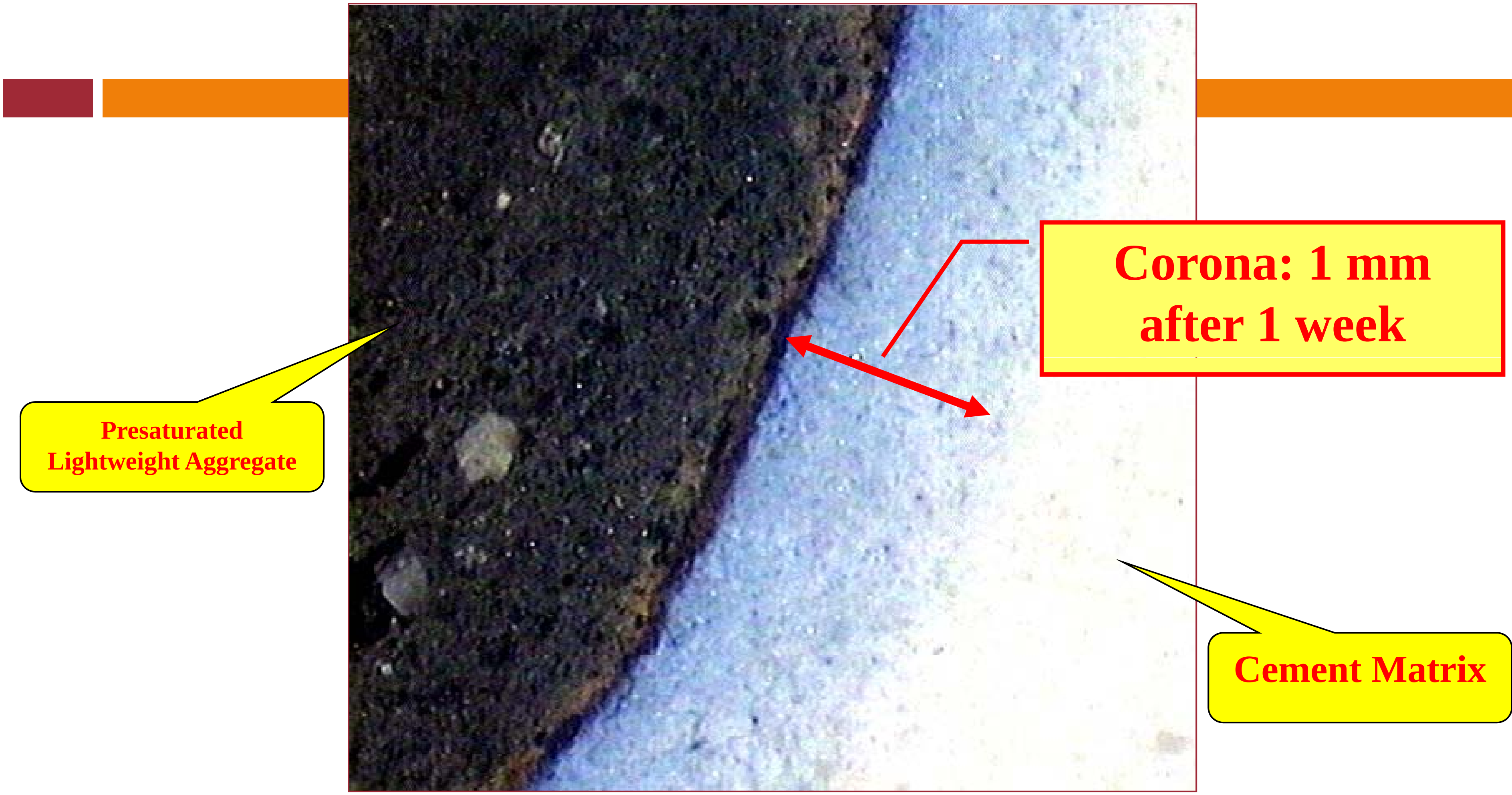
- HPC is designed to limit the permeability of concrete to reduce chloride ingress. Unfortunately this also limits the ability of externally applied curing water to reach the interior of the concrete.
- IC distributes the extra curing water throughout the concrete microstructure making it more readily available to maintain saturation of the cement paste during hydration, avoiding self-desiccation and reducing autogenous shrinkage.


Cement paste
LWA Water reservoirs

SEM of Lightweight Aggregate



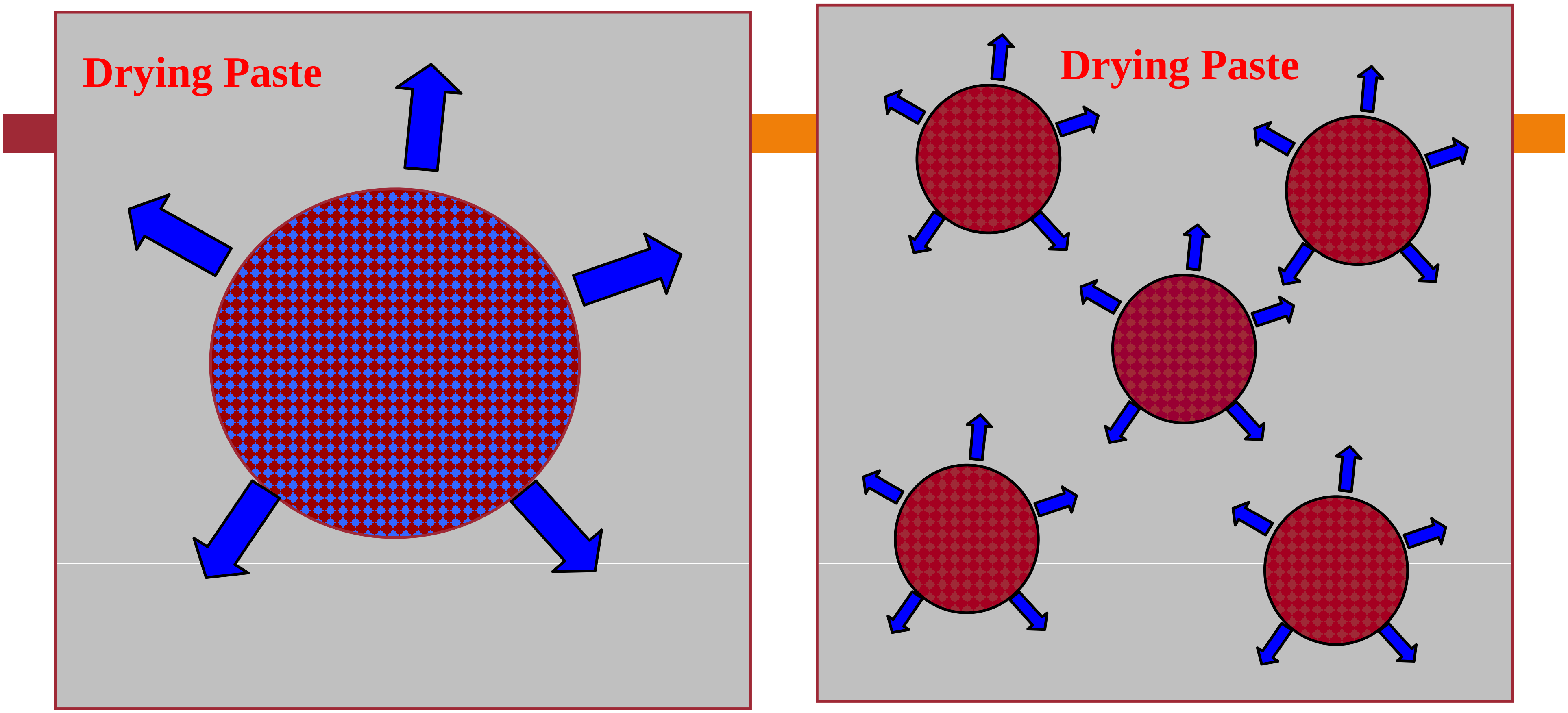
Visualization of water transport



Blue-ink corona in cement paste around Presaturated Lightweight Aggregate

Paste with w/c = 0.37

Availability of water



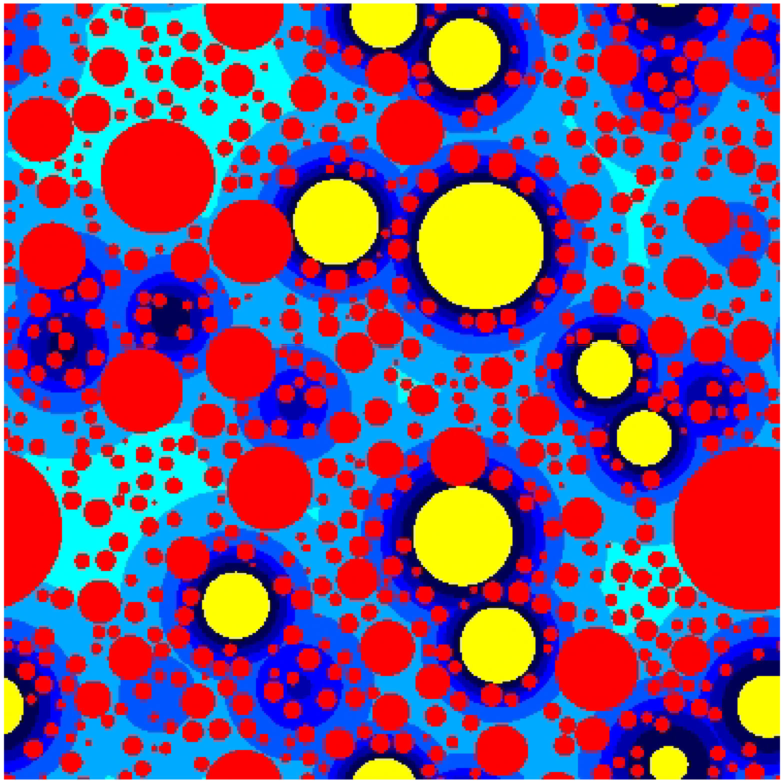
Coarse aggregate **Fine aggregate**

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

10 mm by 10 mm



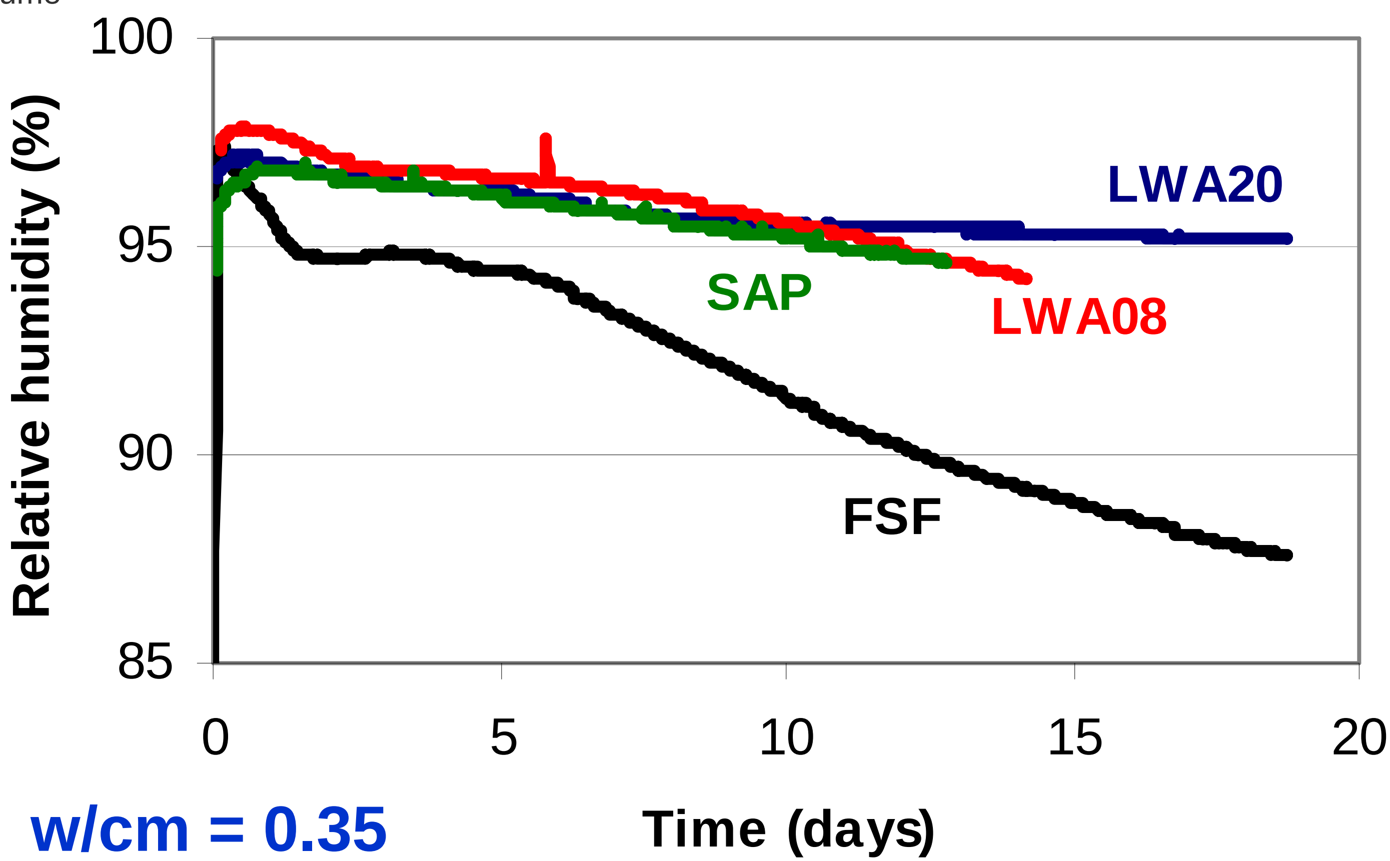
IC Material Requirements

- 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

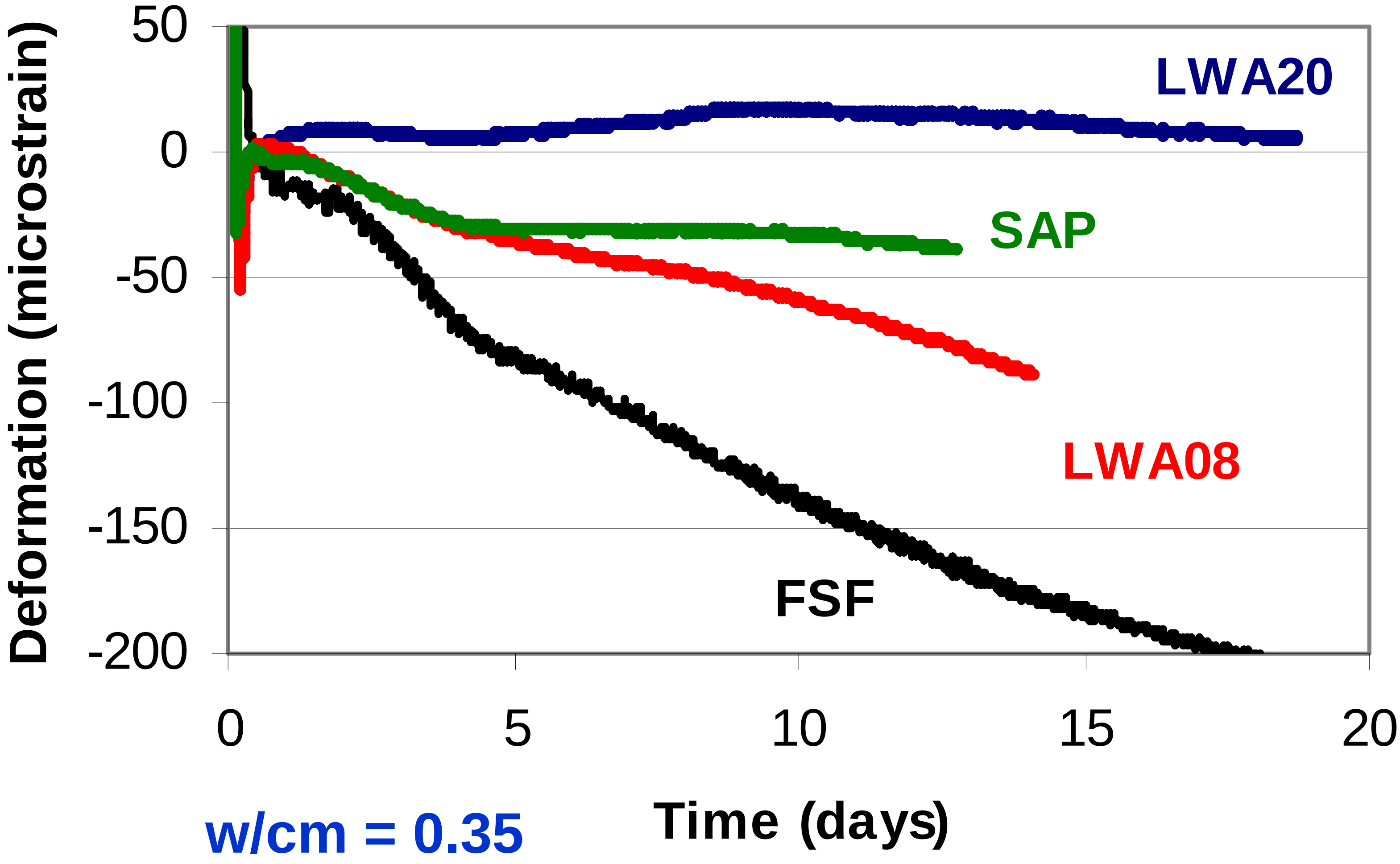
Internal RH Results

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



w/cm = 0.35

Autogenous Deformation Results



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

Cement – Type I	500 lbs
Fly Ash	135 lbs
Microsilica	40 lbs
Fine Aggregate – Natural Sand	782 lbs
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Water	262 lbs


BID-WELL
3600

Syracuse, 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)
Spencer and Butternut Streets Bridges	HPC	32.6	40.8	41.9	43.5
Court Street Bridge	HPC-IC	33.5	42.9	45.3	48.1
Percent Improvement		2.8%	5.1%	8.1%	10.6%

Source: NYSDOT

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

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

LIFE CYCLE

Impact of IC on HPC Properties

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

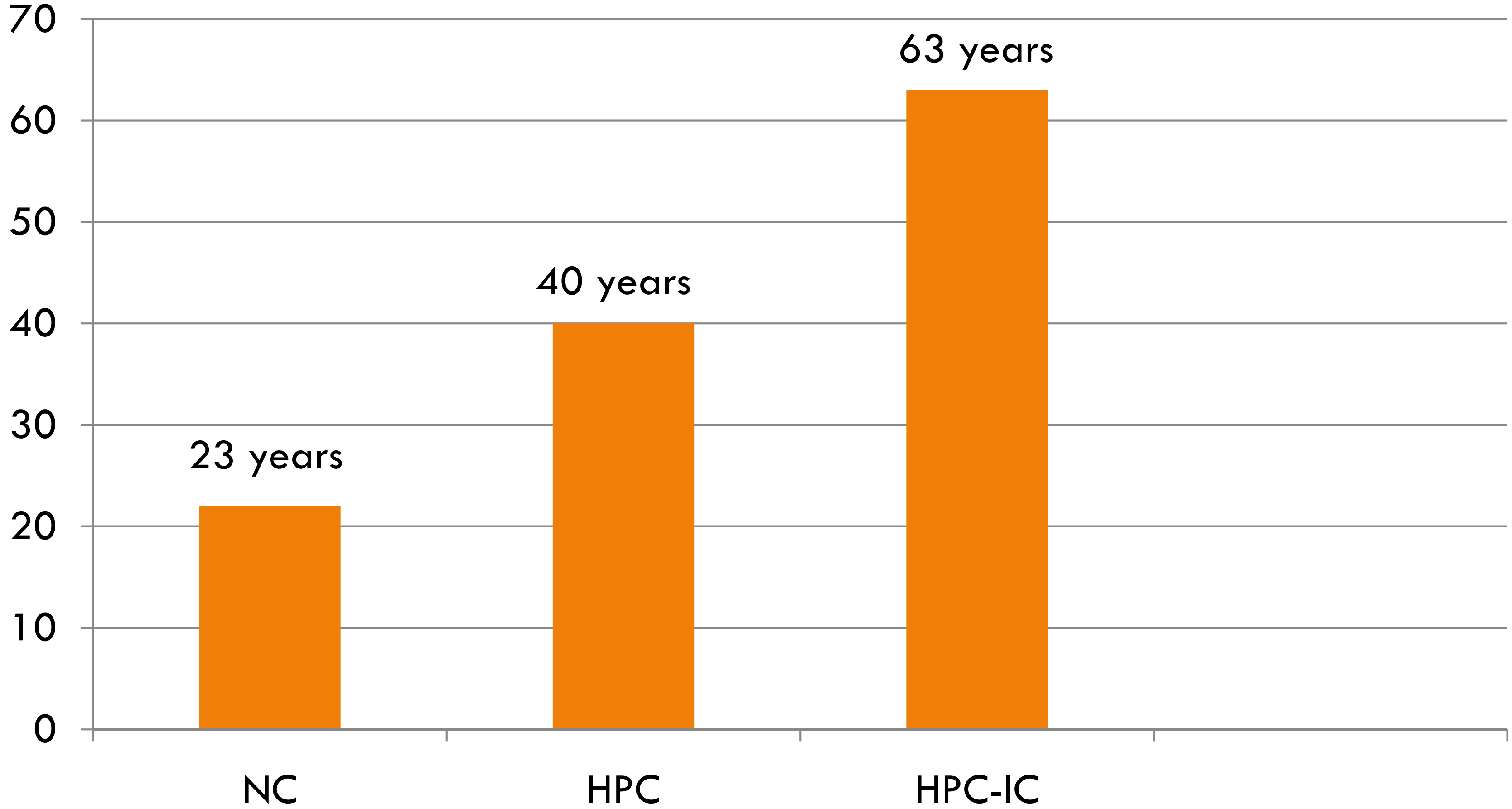
Source: Cusson & Margeson 2010

Mix Designs Canadian Study

Deck Option	Initial Cracking	Water (kg/cu m)	Cement (kg/cu m)	SCM (%)	LWA (kg/cu m)
NC	No	140	350	0	0
HPC	Yes	160	450	25	0
HPC-IC	No	160	450	25	200

Source: Cusson et al. 2010

Life cycle predictions



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

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Thank You

Questions