Internal Curing Concrete New York Experience

Don Streeter
NY Construction Materials Association

Concrete Problems

- Bridges (>25%) are structurally deficient or functionally obsolete
- Highways (>33%) are in poor or mediocre condition
- ASCE 2013 report D+

- Rate methodology changed in 2018
  - Good, Fair, Poor
- ASCE 2025 report C

NY Concrete History of IC

- 1990's High-Performance (HP concrete mixture developed, became the standard concrete mix for structures
- 2008 – Cracking still observed
  - Internal Curing (IC) proposed
- 2013 - Lab and field evaluation program
- 2017 – "HPIC" incorporated into specifications

IC Consideration in NY

- Approached by industry in 2008
  - IC PCC data shown to have:
    - good flexure
    - slightly increased strength
    - lower permeability
  - Consideration for use
    - Pavements
    - Non-wet cured PCC
- Department interest for bridge decks

IC Consideration in NY

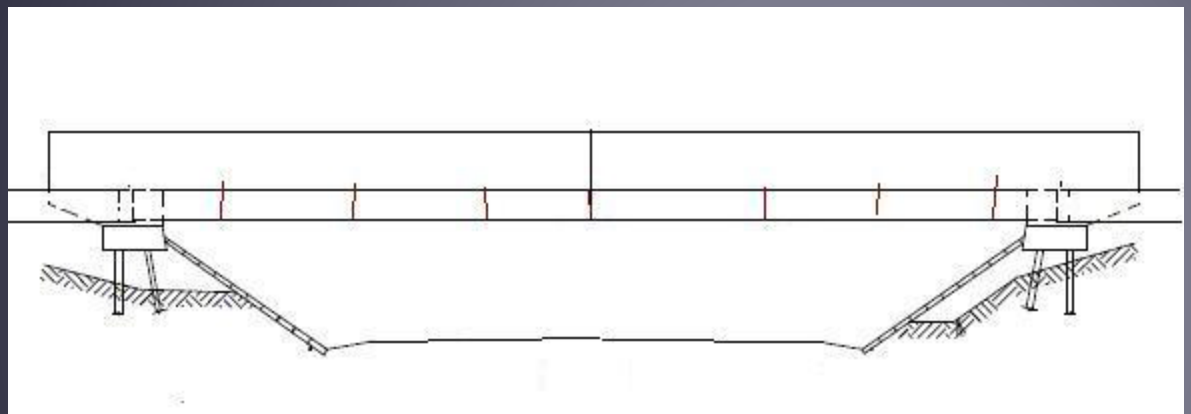
- Bridge Deck TF - cracking concerns
  - Additional characteristic concerns / testing
    - Scaling
    - Freeze / Thaw durability
- Further evaluations performed
  - results comparable to traditional HPC performance

Types of cracks

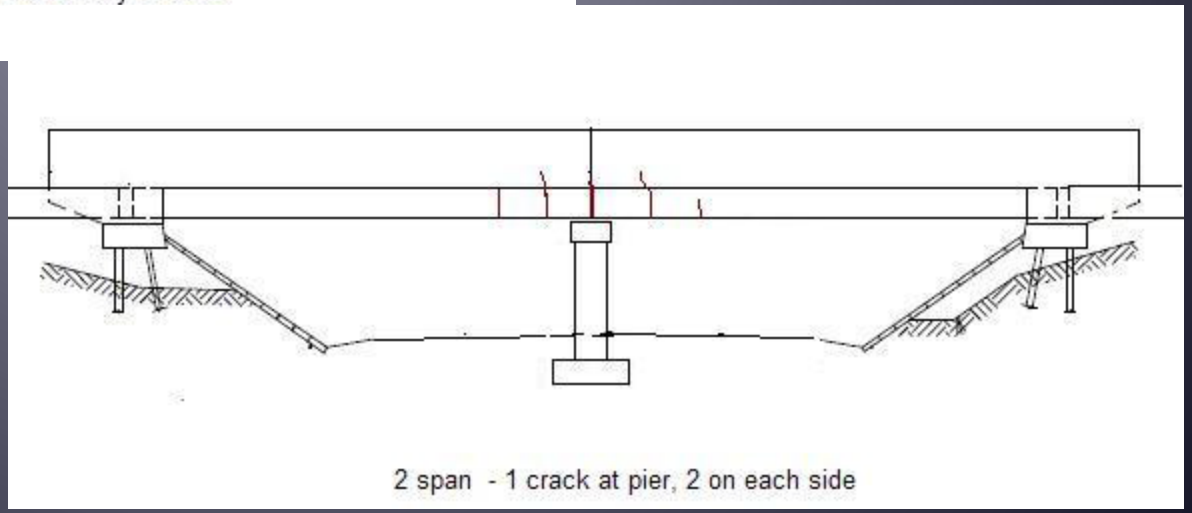
Type	Reaction	Timing	Cause
Plastic	Water leaving concrete before set	First hours / before set	Bleeding and evaporation
Drying	Water leaving concrete after setting	Hours / weeks / months	LT evaporation
Thermal	Concrete temperature change	Hours / weeks / months…	Expansion / contraction as temperatures change
Autogenous	Water consumed by hydration after set	Early days	Self desiccation, especially with lower w/c ratios
Working	Propagation from flexure / movement	Forever	Live loads

Some factors that contribute to cracking:

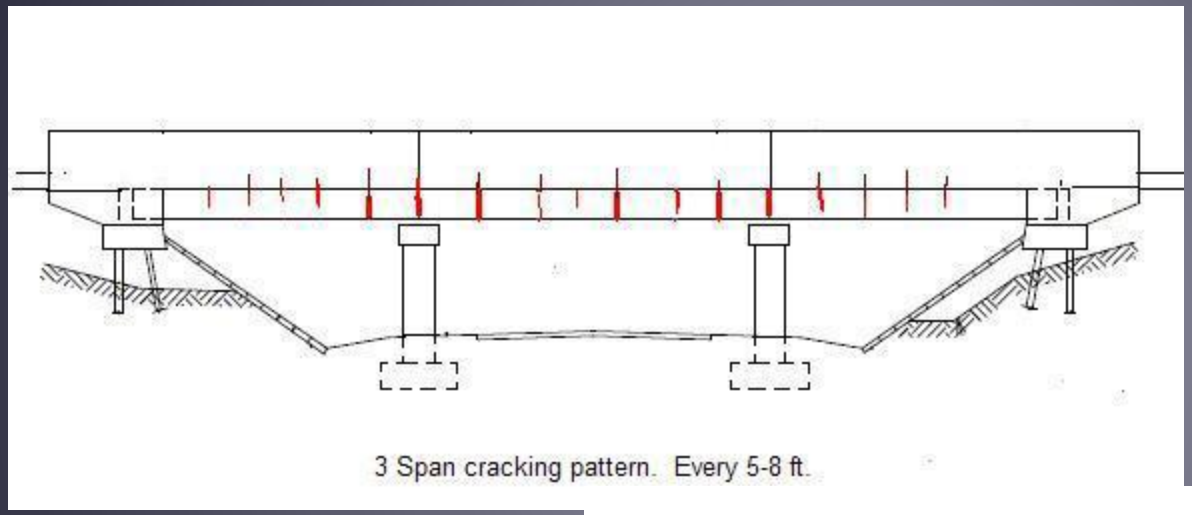
* Span length / width / geometry
* Continuous spans vs. simple span
* Placement (staged vs. continuous)



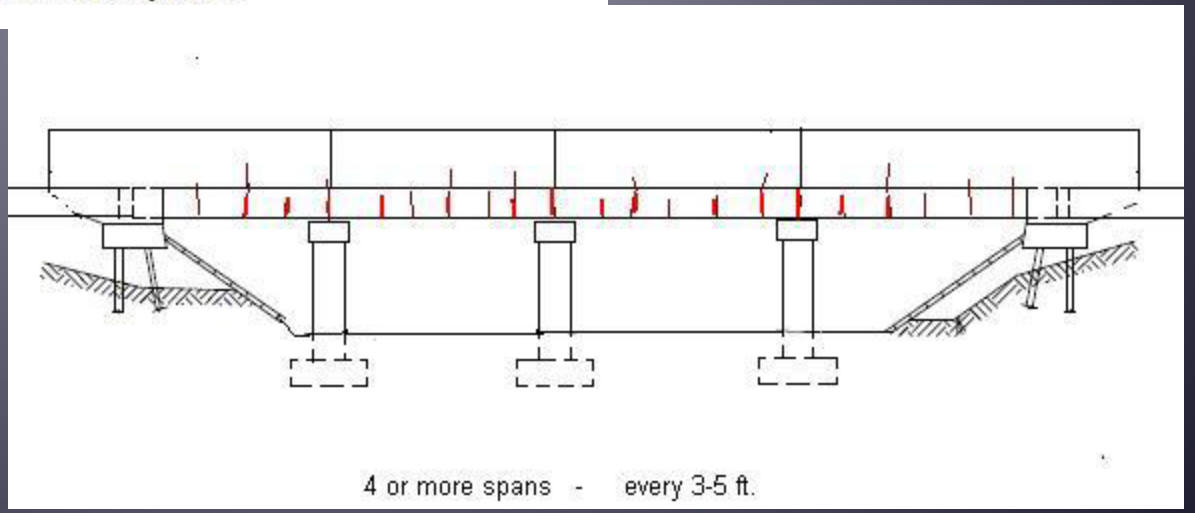
Simple Span (no pier) a crack every 8- 10 ft.



2 span - 1 crack at pier, 2 on each side



3 Span cracking pattern. Every 5-8 ft.



4 or more spans - every 3-5 ft.

Experimental Evaluation

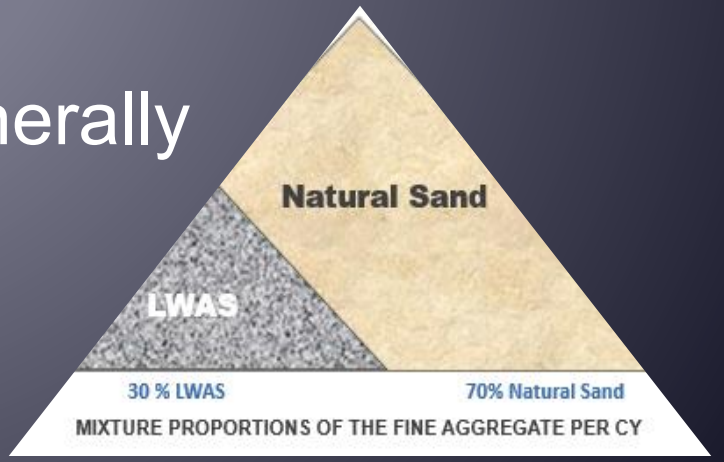
- “Experimental Features” plan developed for FHWA at the time
- 12 projects:
  - up to 20 decks using IC PCC
  - Compare to companion decks of similar size / design
- Measure cracking – use KU research process
  - Focus on early age cracking (typically 60 days)
- Success – 30% reduction of cracking

Standards to use IC

- ASTM C330/C330M – Standard Specification for Lightweight Aggregates for Structural Concrete
- ASTM C1761 - Standard Specification for Lightweight Aggregate for Internal Curing of Concrete
- ACI 308-213R – Report on Internally Cured Concrete Using Prewetted Absorptive Lightweight Aggregate

IC Specification - material

- Use of l-w fine aggregates as a replacement for sand
- 30% substitution by volume
- Contractor designed mix, semi prescriptive
  - Modified HP concrete generally used.



HPIC Specification - mixture

- 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
- Strength 3,000 psi, low or very low permeability

Lab evaluation

- Comparing performance characteristics for different ages of wet curing.
- Evaluated control and IC mixtures
  - Compressive strength
  - Freeze / Thaw
  - Scaling
  - Shrinkage
  - Surface Resistivity

Lab evaluation

- Evaluated 3, 7 and 14 day characteristics
- Samples cast and placed in fog room.

- Specific curing regimes
  - F/T and scaling moist cure for 3, 7, or 14 days then air dried for 24 hrs prior to placing in freezer
  - Resistivity moist cure for 3, 7 or 14 days then air dried until 28 days of age

Lab evaluation - results

- Results
  - Shrinkage, F/T, and scaling - no significant difference between control and IC mixture
  - Strength increased for IC mixture

	Control	IC
3 Day Comp, psi	3050	3430
7 Day Comp, psi	3950	4140
14 Day Comp, psi	4620	5220

Lab evaluation - results

- Results (con't)
  - Surface Resistivity

	Control	IC
3 Day Moist, 25 Day Dry SR, kΩ-cm	21.0	22.4
7 Day Moist, 21 Day Dry SR, kΩ-cm	22.8	24.9
14 Day Moist, 14 Day Dry SR, kΩ-cm	25.7	26.7

  - NYSDOT PEM specs citing >30 kΩ-cm for decks

HPIC PCC

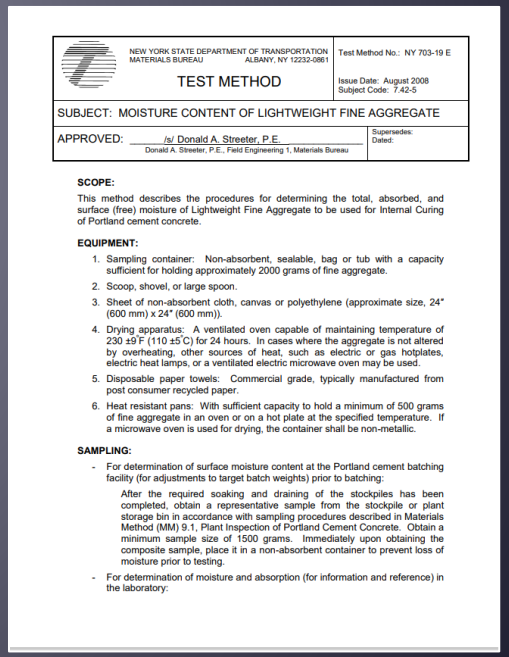
- Experimental use for:
  - Approx 20 decks,
  - concrete barrier,
  - integral pier / deck
- Compare to HP decks
  - Evaluate cracking

HPIC - Construction

- Stockpile establishment
- SSD condition –
  - minimum 15% absorbed moisture
  - place under sprinkler for minimum of 48 hours
  - allow stockpiles to drain for 12 to 15 hours prior to use

HPIC - Construction

- Batching
  - Calculate absorbed and surface moisture
  - Utilize NYSDOT TM 703-19E – Moisture Content of Lightweight Fine Aggregate (Paper Towel test)
  - Adjust batch weights by absorbed moisture only
  - Absorbed water does not effect w/c
  - Reduce mix water by surface moisture content
  - Requires additional bin for plant production



NEW YORK STATE DEPARTMENT OF TRANSPORTATION
MATERIALS BUREAU ALBANY, NY 12232-0861

Test Method No.: NY 703-19 E

TEST METHOD

Issue Date: August 2008
Subject Code: 7.42-5

SUBJECT: MOISTURE CONTENT OF LIGHTWEIGHT FINE AGGREGATE

APPROVED: /s/ Donald A. Streeter, P.E.
Donald A. Streeter, P.E., Field Engineering 1, Materials Bureau

Supersedes:
Dated:

SCOPE:

This method describes the procedures for determining the total, absorbed, and surface (free) moisture of Lightweight Fine Aggregate to be used for Internal Curing of Portland cement concrete.

EQUIPMENT:

1. Sampling container: Non-absorbent, sealable, bag or tub with a capacity sufficient for holding approximately 2000 grams of fine aggregate.
2. Scoop, shovel, or large spoon.
3. Sheet of non-absorbent cloth, canvas or polyethylene (approximate size, 24" (600 mm) x 24" (600 mm)).
4. Drying apparatus: A ventilated oven capable of maintaining temperature of 230 ±9°F (110 ±5°C) for 24 hours. In cases where the aggregate is not altered by overheating, other sources of heat, such as electric or gas hotplates, electric heat lamps, or a ventilated electric microwave oven may be used.
5. Disposable paper towels: Commercial grade, typically manufactured from post consumer recycled paper.
6. Heat resistant pans: With sufficient capacity to hold a minimum of 500 grams of fine aggregate in an oven or on a hot plate at the specified temperature. If a microwave oven is used for drying, the container shall be non-metallic.

SAMPLING:

- For determination of surface moisture content at the Portland cement batching facility (for adjustments to target batch weights) prior to batching:

  After the required soaking and draining of the stockpiles has been completed, obtain a representative sample from the stockpile or plant storage bin in accordance with sampling procedures described in Materials Method (MM) 9.1, Plant Inspection of Portland Cement Concrete. Obtain a minimum sample size of 1500 grams. Immediately upon obtaining the composite sample, place it in a non-absorbent container to prevent loss of moisture prior to testing.

- For determination of moisture and absorption (for information and reference) in the laboratory:

HPIC - Construction

- Plastic Concrete Testing – Type B air pot used (don't need Roll-a-Meter)

HPIC - Construction

- Handling / placing
  - Contractors see no difference in handling , placing or finishing
- Curing
  - Same efforts required

Case Studies / Evaluations

- NY Route 9W over Vineyard Avenue
- NY Route 96 over Owego Creek
- Interstate 81 at Whitney Point
- Court Street over Interstate 81
- Bartell Road over Interstate 81
- Interstate 86 over NY Route 415
- Interstate 84 over Route 6 - overlay
- Interstate 290 Ramp B over Interstate 190 - integral

Case Studies / Evaluations

- 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 - barrier
- Interstate 87 over Route 9 and Trout Brook
- Interstate 81 Connectors near Fort Drum - overlay

Court and Spencer Streets

Court and Spencer Streets

		7 day	14 day	21 day	28 day
	Concrete Type	Compressive Strength	Compressive Strength	Compressive Strength	Compressive Strength
Spencer Street Bridge	HPC	4730 psi	5920 psi	6080 psi	6310 psi
Court Street Bridge	HPC-IC	4860 psi	6220 psi	6570 psi	6980 psi
Percent Improvement		2.8%	5.1%	8.1%	10.6%

Cracking – none for either bridge

I-87 / Rte 9 and Trout Brook

I-87 / Rte 9 and Trout Brook

I-87 / Rte 9 and Trout Brook

Concrete Type	7 day Compressive Strength (psi)	14 day Compressive Strength (psi)	28 day Compressive Strength (psi)	28 day Tensile Strength (psi)	RCP Coulombs	F/T % loss
HPC	4420	5215	5910	569	--	--
HPC-IC	4590	5790	6750	672	383	1.1
% Improvement	3.8%	11.0%	14.2%	18.1%		

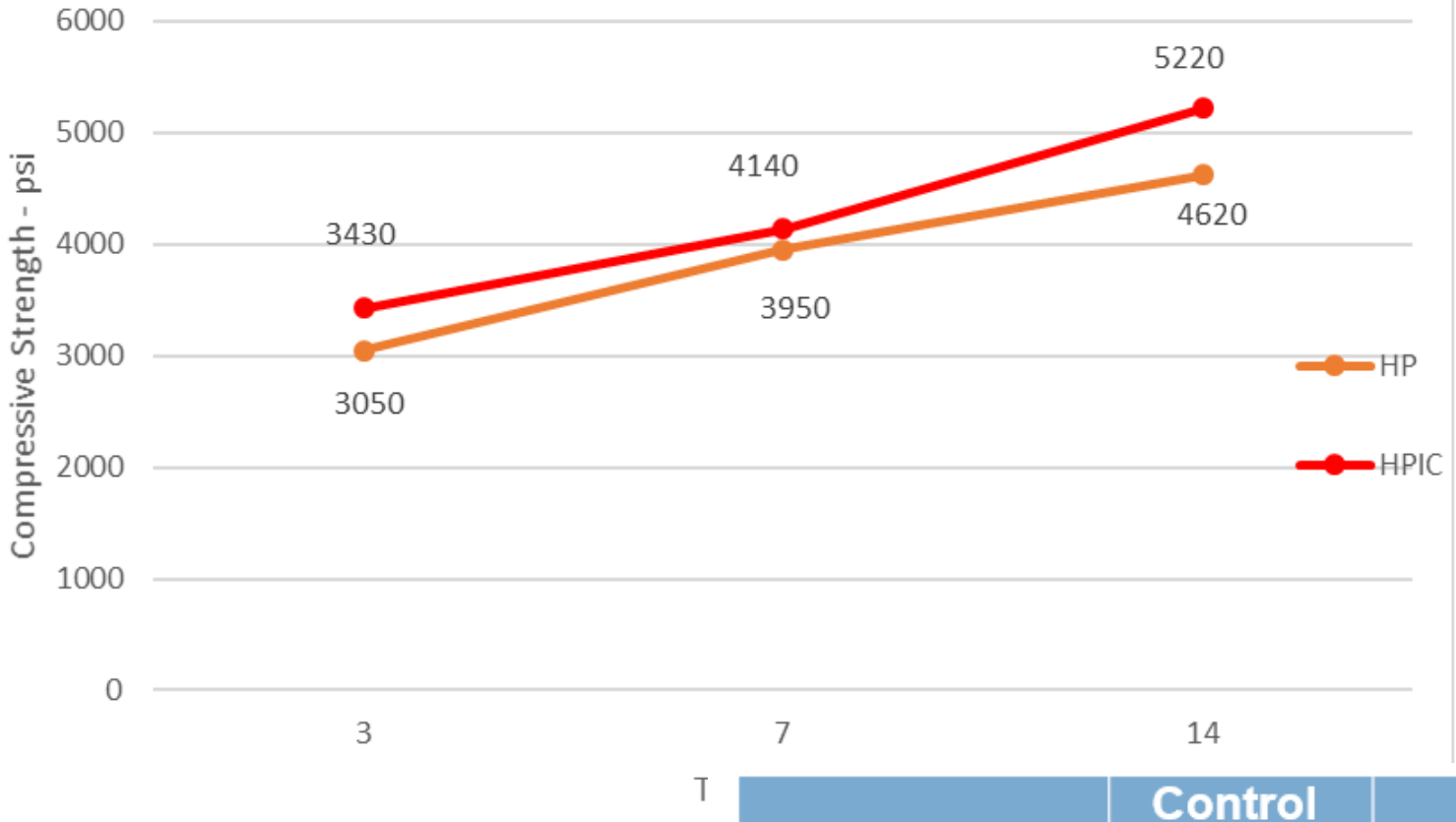
Cracking – no transverse cracking, significant map cracking SB
Barriers – used HPC NB, HPC-IC SB, both show vertical cracking

Cracking observations

- All IC decks complete and evaluated
- Companion deck investigations completed
- Reduced cracking observed (generalization)
  - Not consistent results for all decks
  - Geometry, number of spans, placement procedures, mix variation (aka strength development) all impact performance

Cure time – Lab Study

- Two batches of concrete (2.5 ft^3)
  - Class HP (control) & HPIC
- Shrinkage – ASTM C157
- F/T – NYSDOT TM 502-3P
  - Using 3% NaCl solution
- Scaling resistance – ASTM C672
- Compressive Strength – ASTM C39
- Surface Resistivity – AASHTO T358



	Control	IC
3 Day Comp, psi	3050	3430
7 Day Comp, psi	3950	4140
14 Day Comp, psi	4620	5220

HP vs. HPIC

- Batching – HPIC requires additional bin
- IC fines need 24-48 hours of saturation with 12 to 15 hours to drain
- Availability – HP most everywhere / HPIC requires producer with additional / extra bin or ability to empty existing bin
- Cost - HP sand $21/ton, IC fines $140/ton

HP vs. HPIC

- Construction Procedures – No Difference with handling, placing, or finishing practices
- Curing Time – HP 14 days / HPIC 7 days
- IC sources limited – costs vary depending on transport distances, trucking expenses, etc.

NY Specifications for HPIC

- Section 557 – Superstructure Slabs, Sidewalks on Bridges, and Structural Approach Slabs
  - Internal Cure required for all Bridge Deck Applications with 7-day cure time requirement for all applications
  - All Mix Design related requirements moved to Materials Procedure 501-2 - Mix Design and Approval Procedure for Performance Engineered Mixtures – Structural Concrete.
- Section 555 – Structural Concrete
  - New pay item option for use for Footing Concrete and Structural Concrete Applications

HPIC Conclusions

- Saturated LW fines can improve concrete properties
- IC material should have proper moisture
- Addition of IC materials
  - Requires added production efforts / expense
  - Does not effect the finishability of concrete
  - Provides better hydration – more efficient use of cement and SCM resulting in
    - Increase strength
    - Reduces cracks and the width of cracks

Thank you

Don Streeter
Vice President – Concrete Division
NY Construction Materials Association

Don@nymaterials.com