Mitigating Deicer Damage with Colloidal Silica Enhanced Concrete

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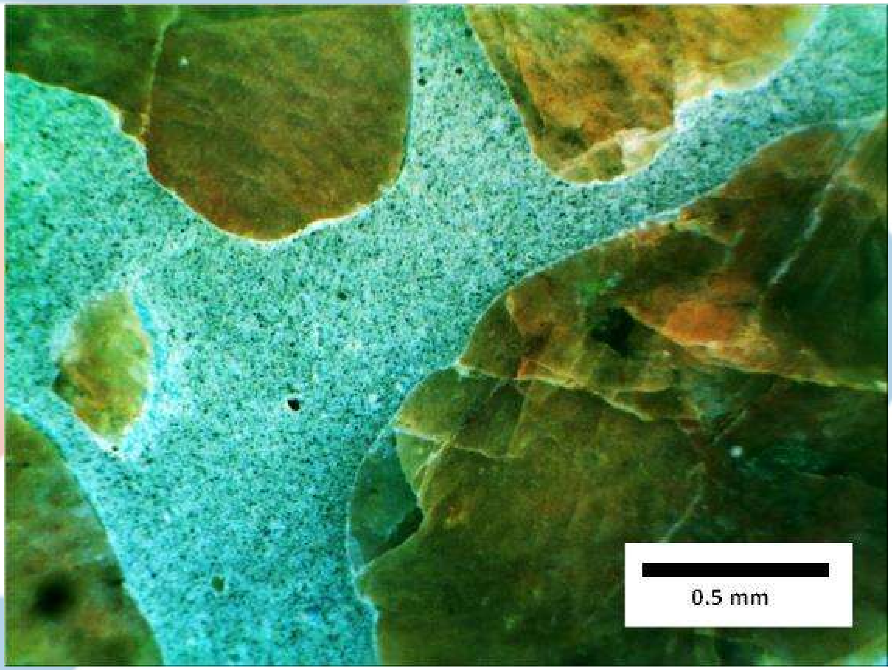
PPRC.org, 2015

Overview

- Background
- **Research Motivation**
- **Colloidal Silica Defined**
- **Analysis**
  - **Deicing Brine Env.**
- The Next Step / Summary
- Questions



Magnified Cross Section of Concrete

Background

- David W. Harris, PhD, PE, …

INTELLIGENT CONCRETE

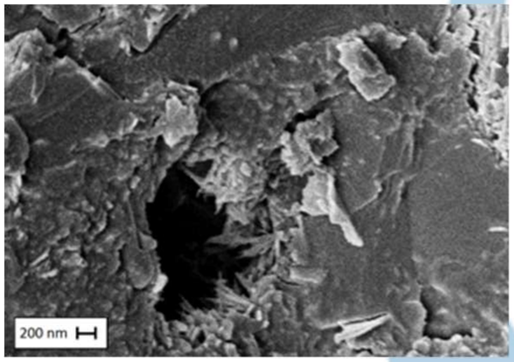
- Concrete Enthusiast

- Combined Levels of Testing

Consulting Services

A Technical Representative for Construction Industry

<u>Research and Development Consulting</u>
Targeted to ensure your emerging technologies are implemented strategically for commercial application.



<u>Forensics Analysis and Litigation Work</u>
Targeted toward market materials, engineering specifications and project needs.

<u>Educational Seminars</u>
From the basic applications to the novel technologies, our educational seminars are designed to educate you to keep your edge in the market.

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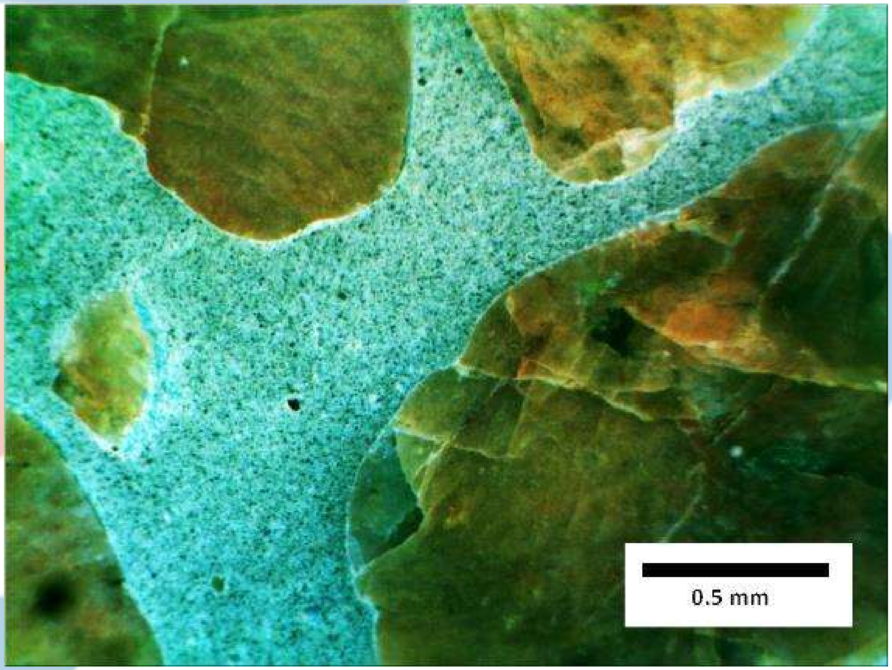

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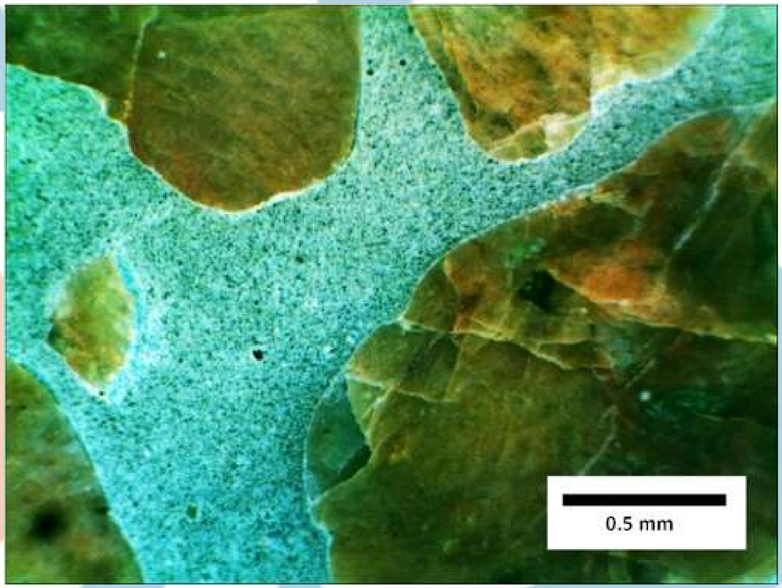
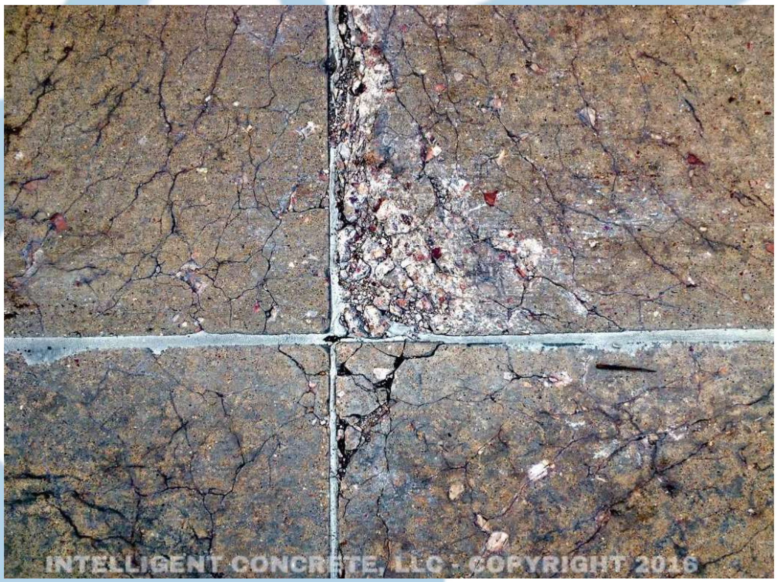
Research Motivation

Solving Today's Problems with Yesterday's Technology





Concrete Durability

- Common Problem w/n Construction
- On-Going Issue
- Enhancement of Concrete Durability Needed

Research Motivation

Deicing Salts and Brines – An Inevitable Dilemma

1. The Increased Use of Salts and Brines
2. More Aggressive Deicing Salts / Brines
3. Inevitable Concrete Breakdown / Reduction in Service-Life
   - Abrasive Wear from Traffic
   - Chemical Impact of Deicing Agents

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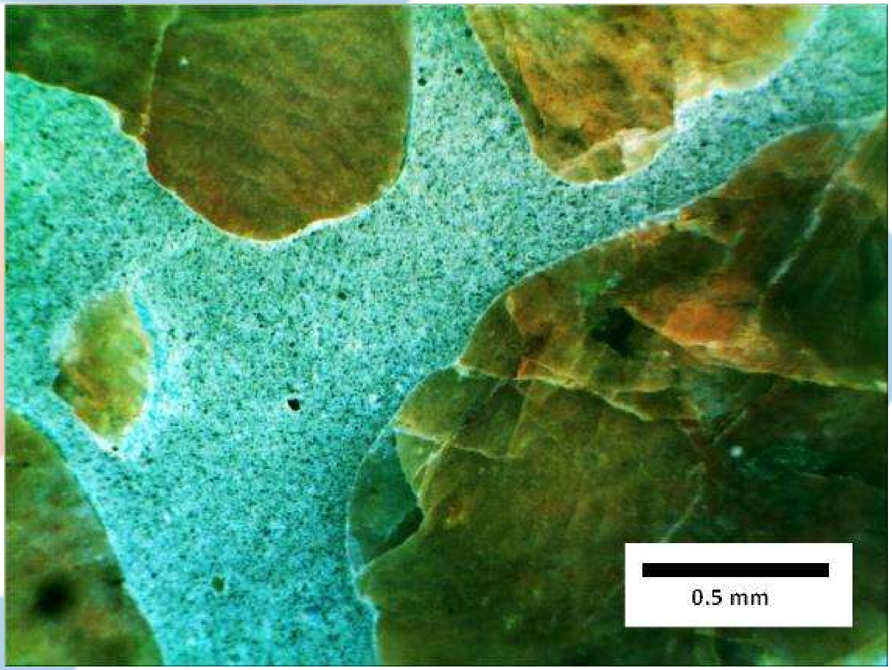

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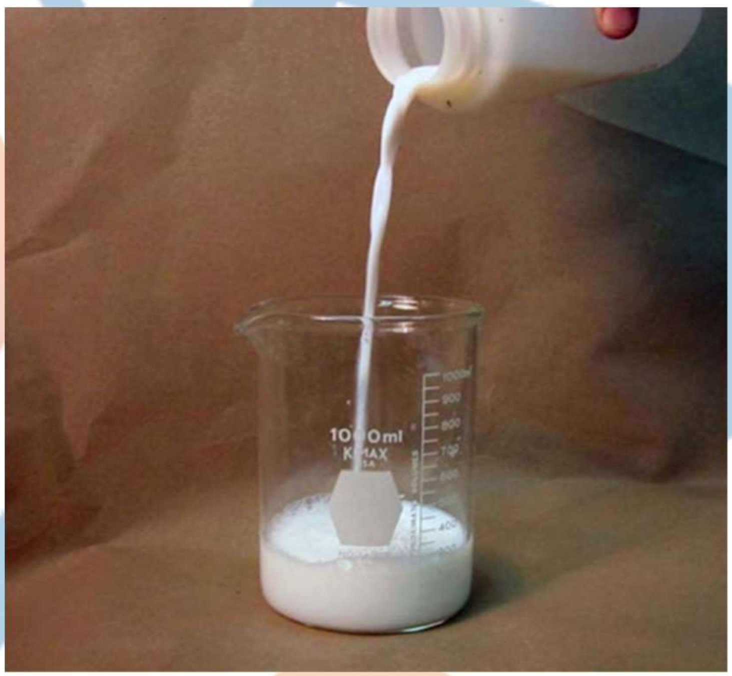
Colloidal Silica

Defined

Liquid Dispersion of Colloidal Silica Particles

- Liquid Dispersion
- Clear to Milky Appearance
- Surface Area – 80 to 500 m^2/g
- Solids Content – 15 to 50%

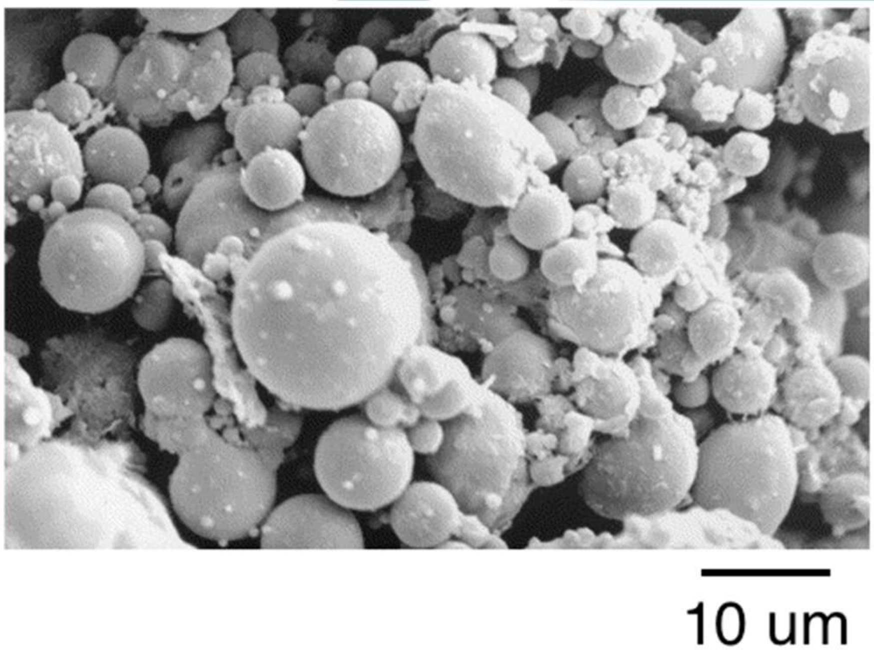


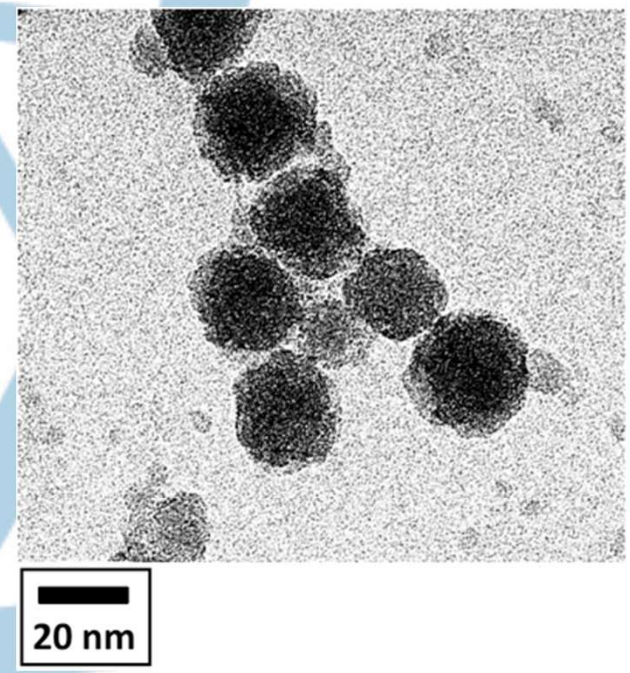
Colloidal Silica Dispersion

- **Green, B. ACI Materials Journal, SP-254-8, 121–132, 2008.**

Enhancing Concrete with Newer Technologies

Not Replacing Current Technologies, __Enhancing__





- **Class F Fly Ash**
- **Colloidal Silica**

FOR REFERENCE

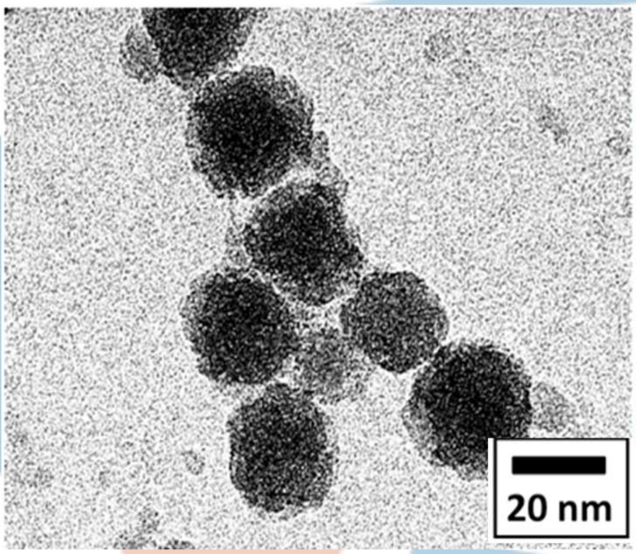
__A strand of hair is approximately 100,000 nm in diameter.__

•Green, B. ACI Materials Journal, SP-254-8, 121–132, 2008.
•Kudyba-Jansen, A., Hintzen, H., Metselaar, R. Materials Research Bulletin, 36, 1215 – 1230, 2001.

Pozzolanic Reaction

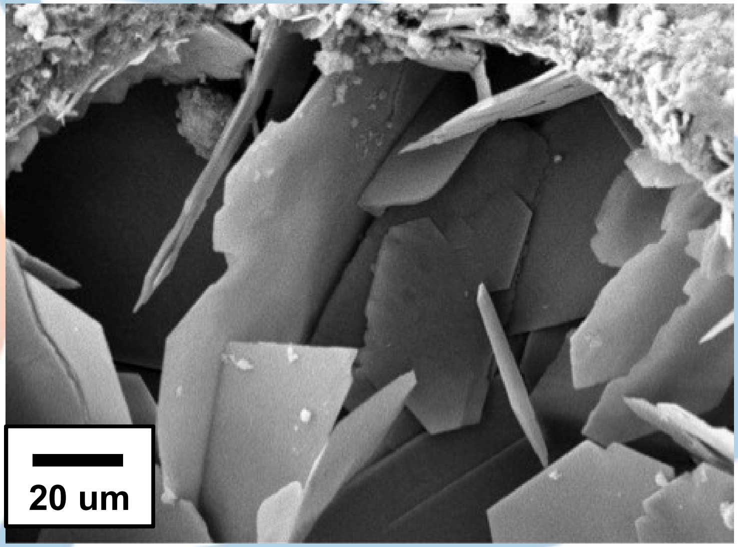
Consuming the Cancer of Concrete

Colloidal Silica (CS)



+

Calcium Hydroxide (CH)



- CS promotes pozzolanic reaction and the development of C-S-H at the expense of CH
- Particle-to-Particle Packing / Void Filling
- Creates an environment not conducive to Chemical and Physical Attack

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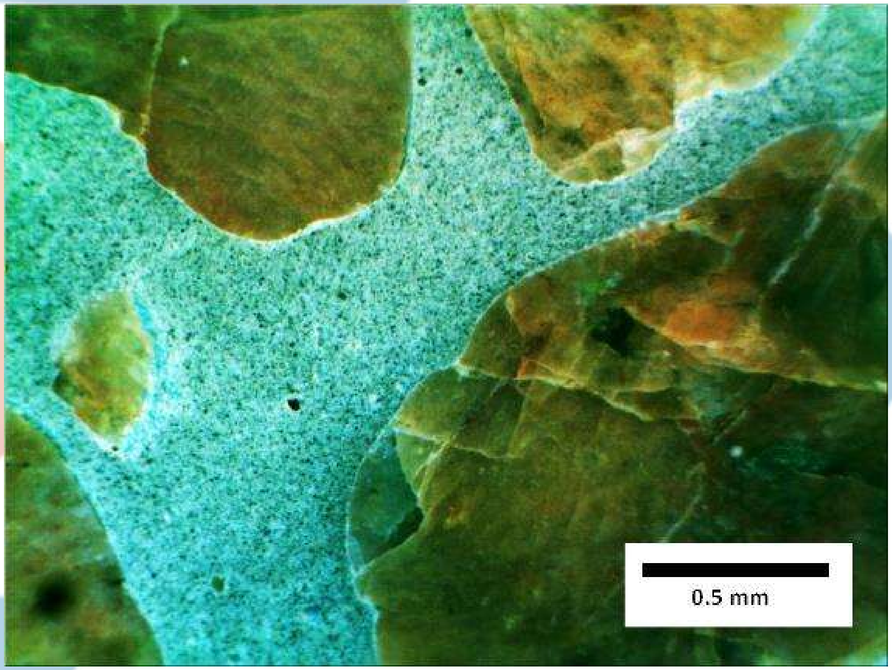
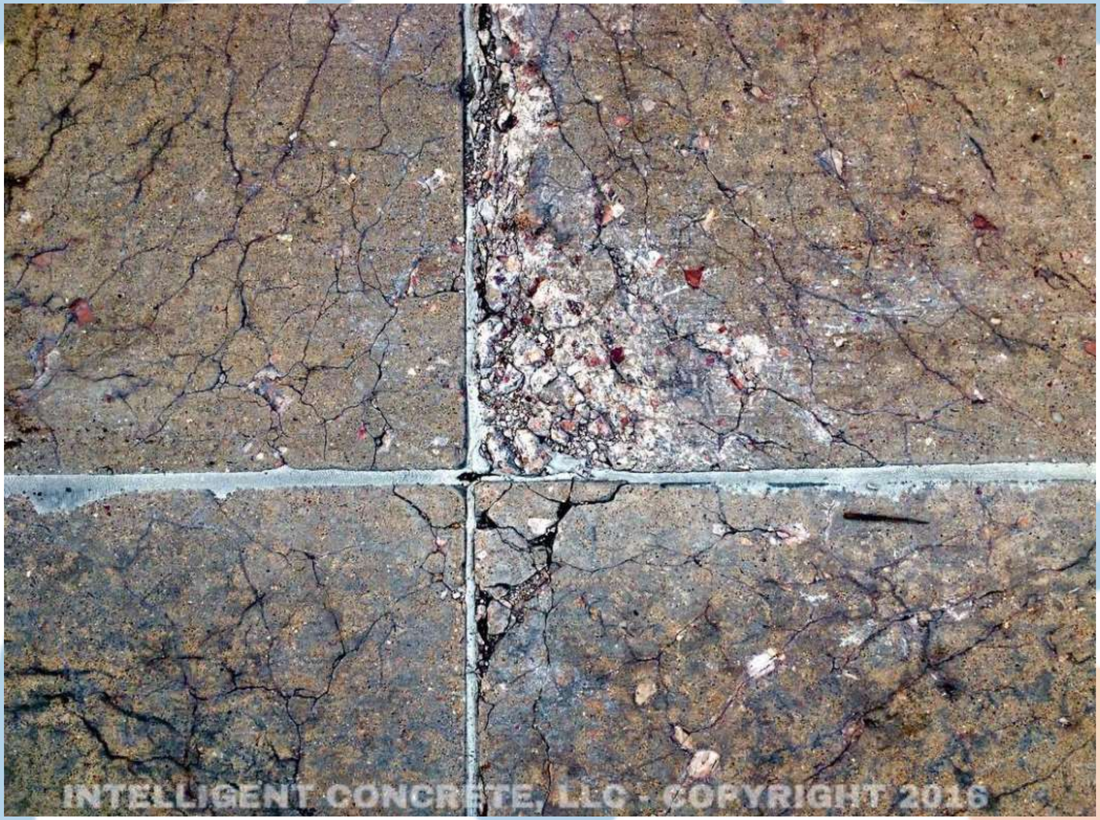


Magnified Cross Section of Concrete

An Analysis on the Impact of Colloidal Silica on Resistance to Deicing Brines

Research and Development Effort with Commercial Concrete Provider in Colorado



Peterson AFB, D-Cracking on the Airfield During Presidential Visit

Long Term Testing

Concrete Mix Design

Materials	BASELINE pcy (fl oz per cwt)
Portland Cement	525 – 555
Class F Fly Ash	70 – 80
Concrete Sand	1220 – 1250
67/57	1710 – 1775
P Gravel	150 – 200
HRWR, Type A and F	(3.0 – 4.0)
Colloidal Silica	(6.0 – 24.0)
Air Entraining Agent	(0.5 – 1.0)
Slump (in)	6.0 – 7.0
Air (%)	4.5 – 6.5

How-To

Colloidal Silica in Concrete

- **Mix Considerations**
  - Use with a w/c above 0.35
  - Use a PCP / PCE style HRWR
    - DO NOT USE A NAPTHALENE/LIGNON/MELAMINE
  - Low-Alkali Cements require a modified Colloidal Silica or a Larger Particle

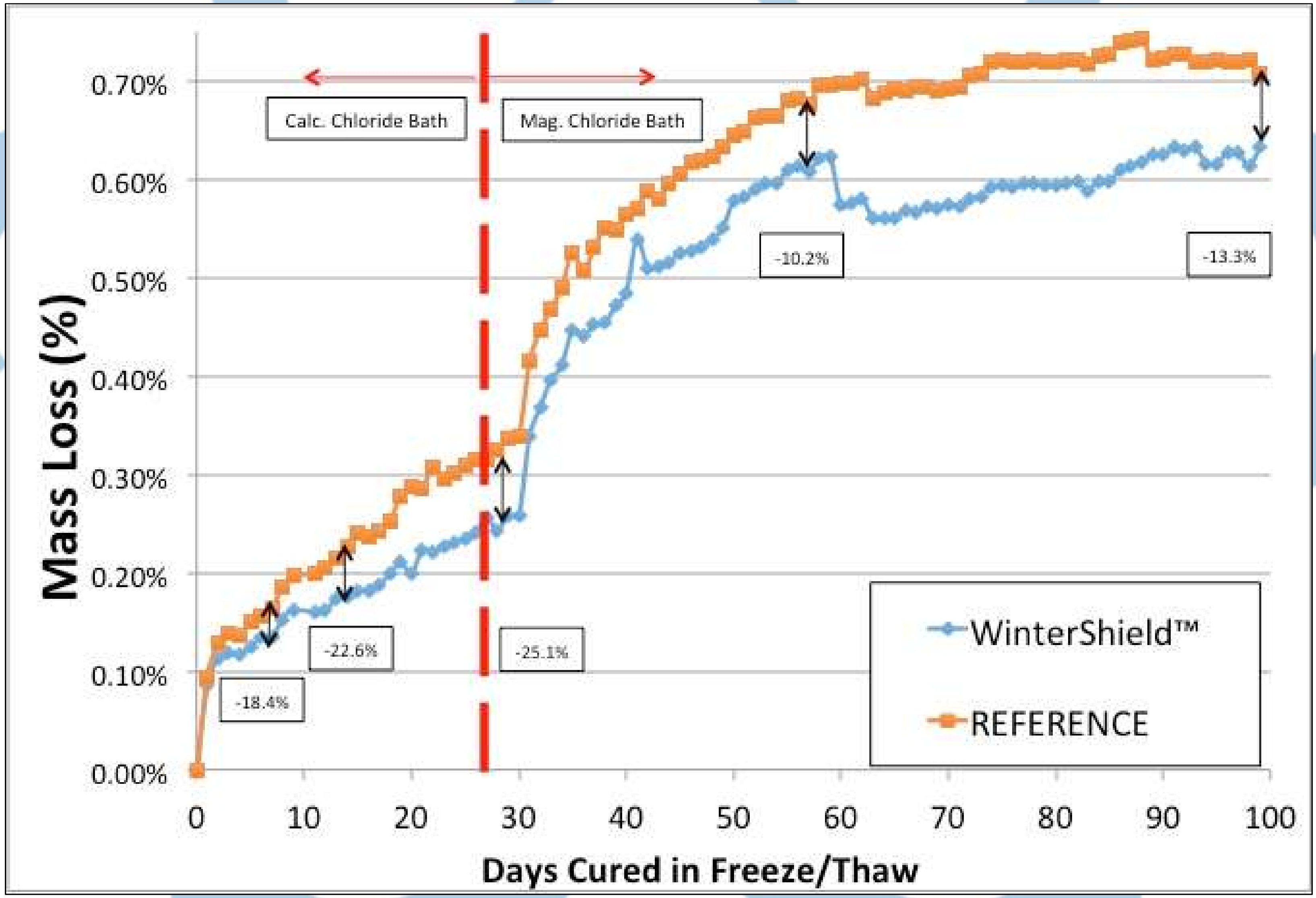
Placement of Nano Engineered Concrete

- **Sequencing**
  - Easily Dispersed at tail end of mixing
  - Dilution before Mixing is needed
  - Fits into the normal critical path of batching concrete to leaving the plant

6 Years Later No Surface Defects / Cracking

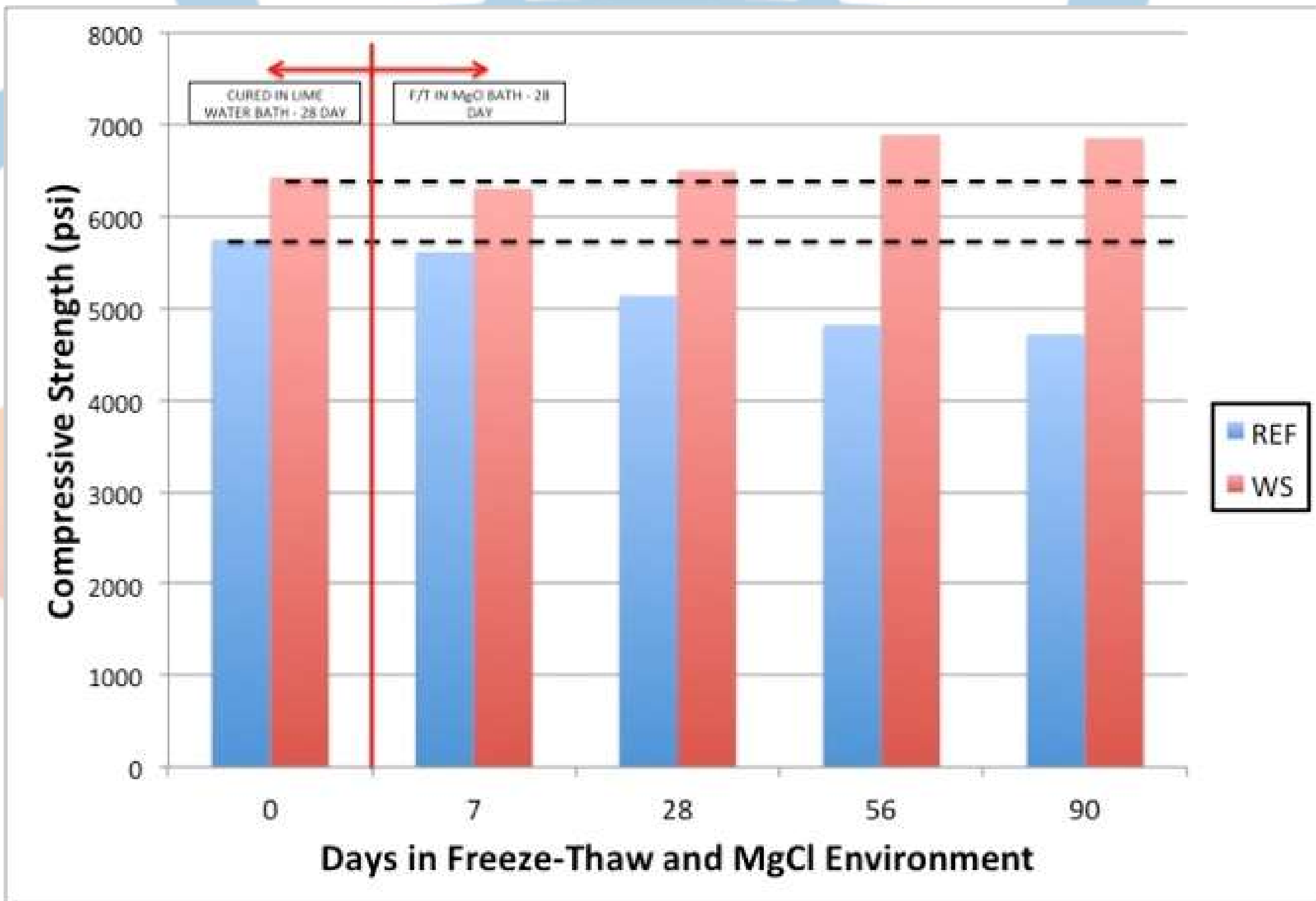
Long Term Testing

Mass Loss



Long Term Testing

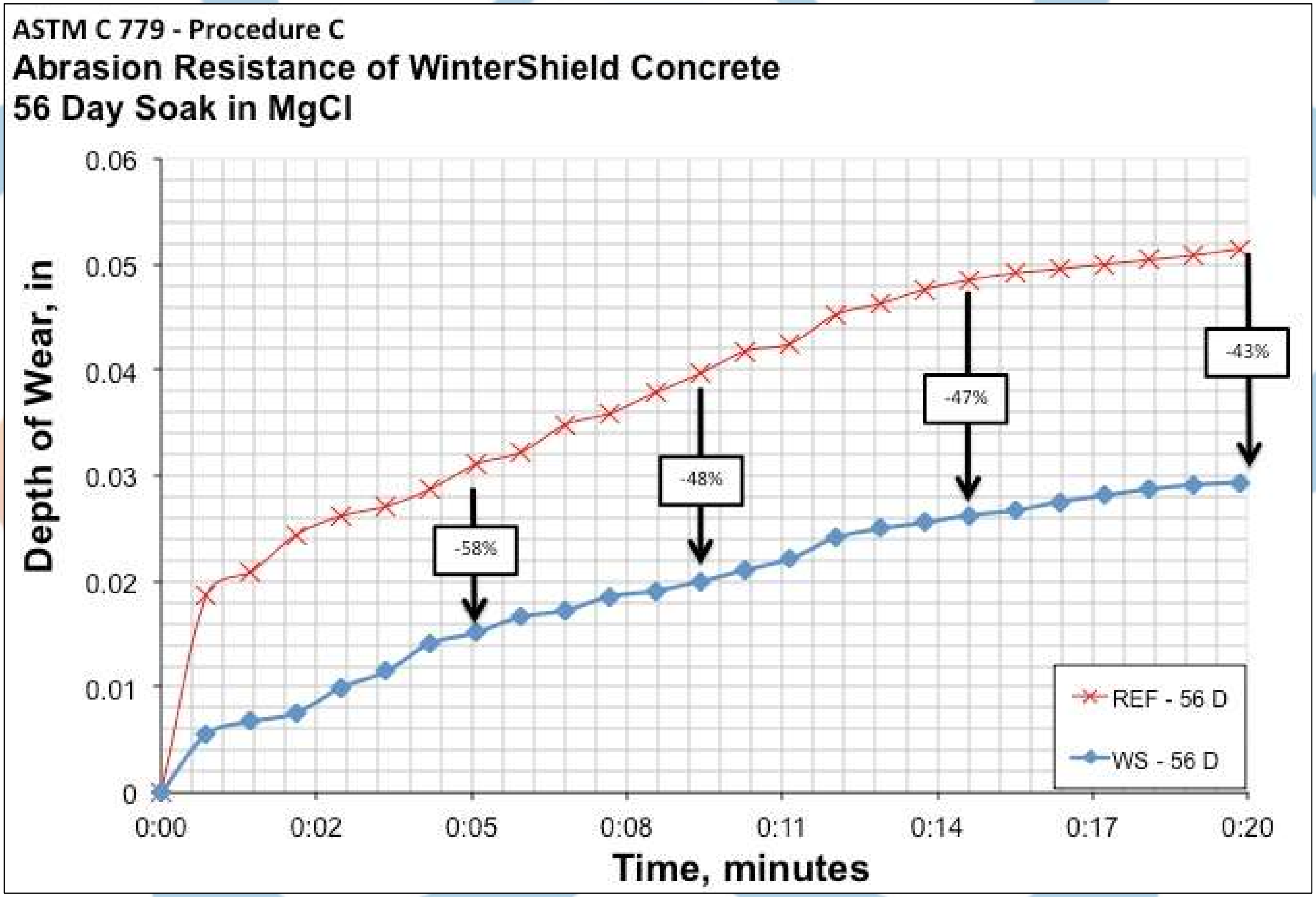
Compressive Strength



** 7 Day WS Cylinders were poorly made with significant flaws that could have had an impact on compressive strength*

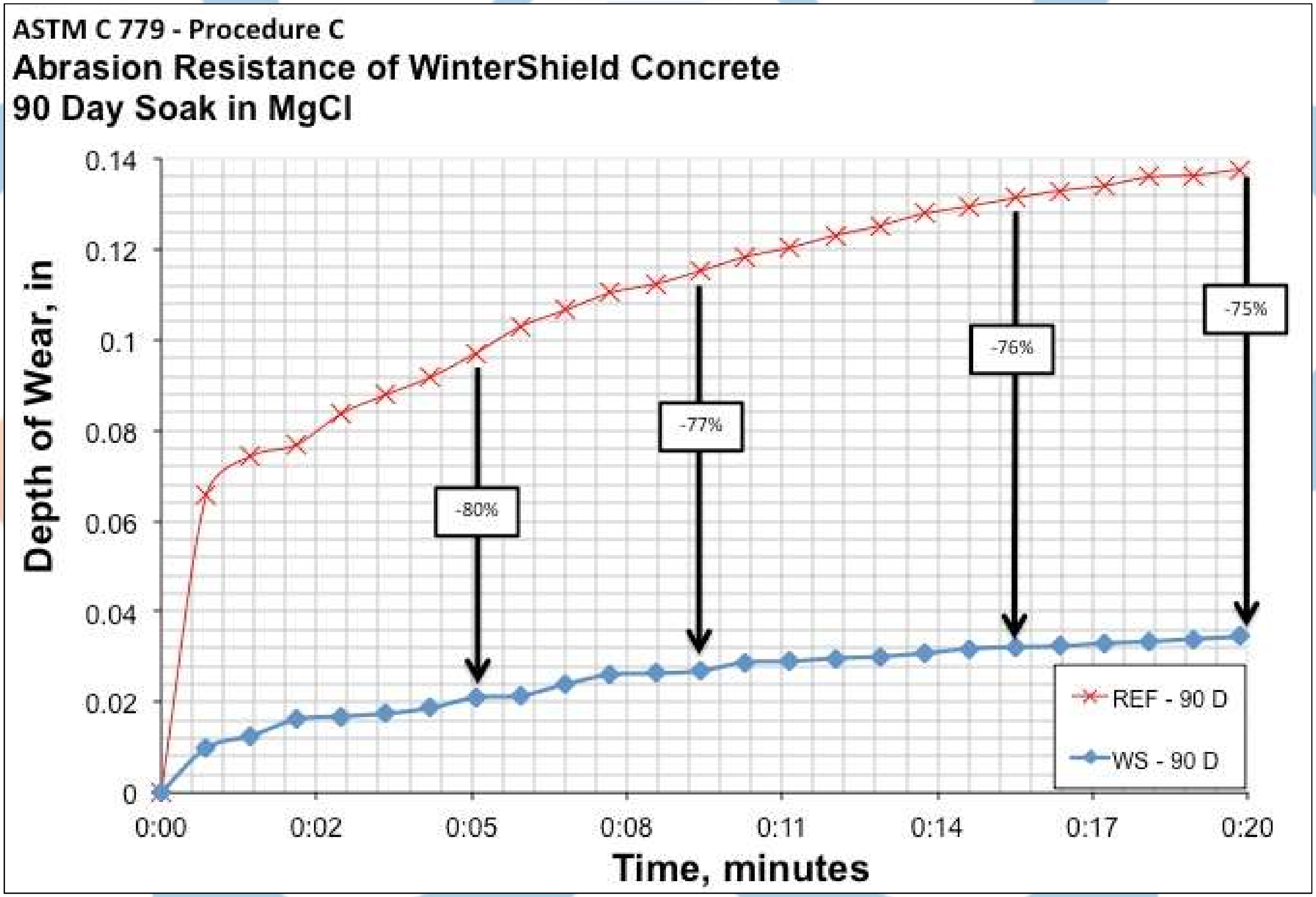
Long Term Testing

Abrasion Resistance, 56-Days



Long Term Testing

Abrasion Resistance, 90-Days



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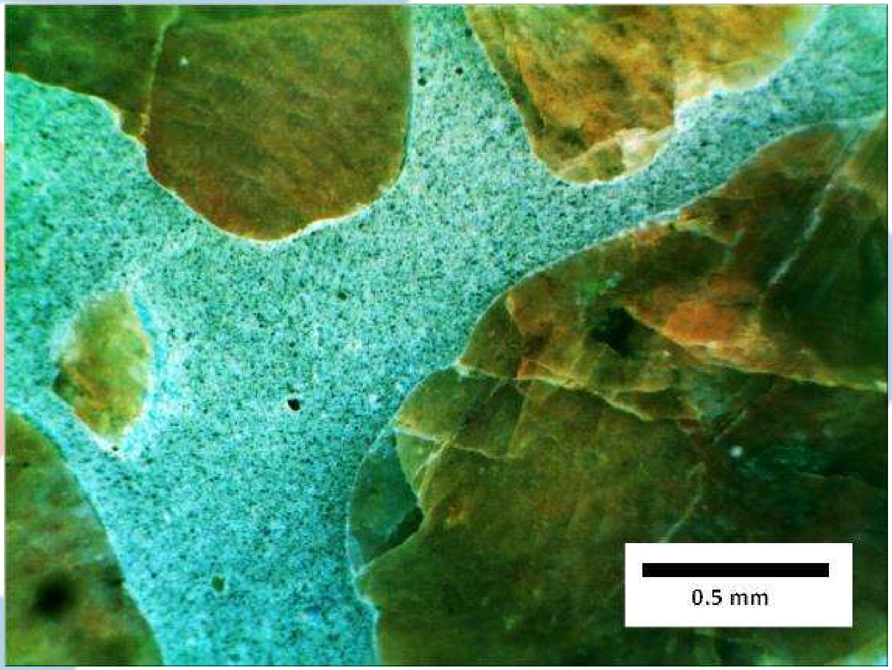


Magnified Cross Section of Concrete

Summary

Freeze-Thaw Environment

- Mass Loss
  - Reference lost 10-25% more mass than WS
- Compressive Strength (CS)
  - Reduction of CS for Reference over time in F/T and MgCl environment
  - WS samples increased in strength over time in F/T and MgCl environment
- Abrasion Resistance
  - Over time the Reference samples lost resistance to abrasive wear
  - WS samples maintained abrasive wear resistance despite the time in in F/T and MgCl environment

The Next Step

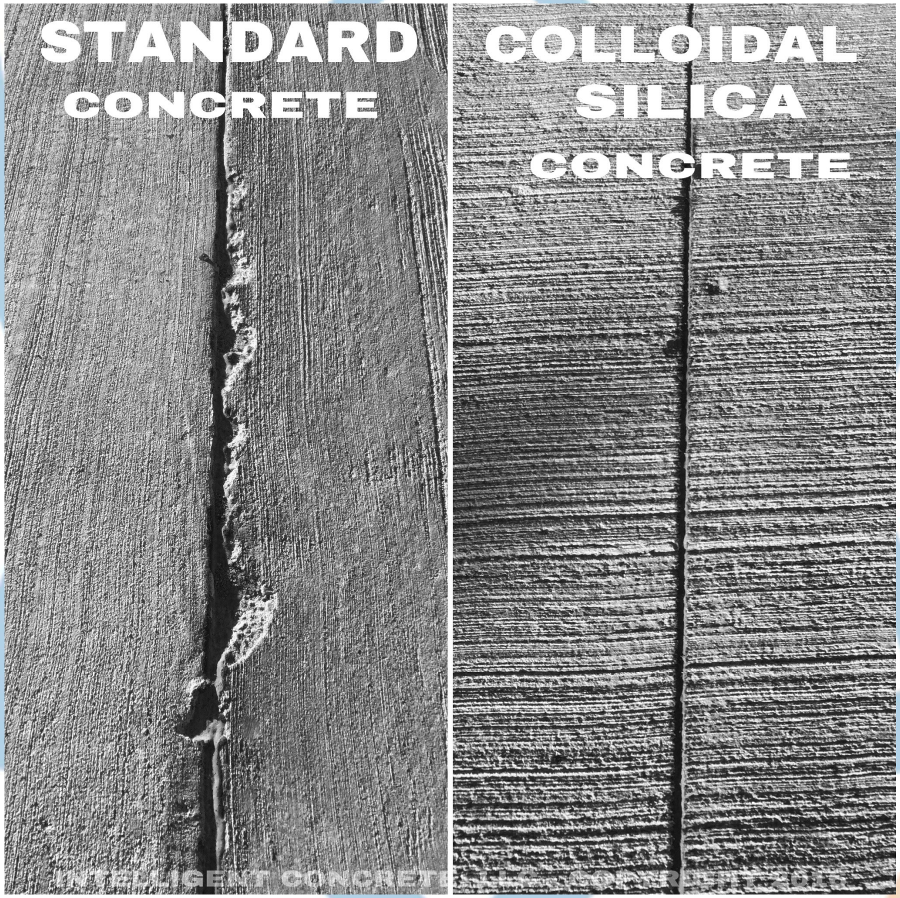
Colloidal Silica Over Time – 6 Year Placement

- On-Going DEIC Problem with Few Viable Solutions
- Limitations on Matured Technologies
- Quality Aggregate Supply is Dwindling
- Colloidal Silica Lab Use
- Colloidal Commercial Success
- **Communicating to PEs / CMs**
  - **CDoT, FAA, Commercial, Residential, …**

Placement of Nano Engineered Concrete

6 Years Later No Surface Defects / Cracking

Questions



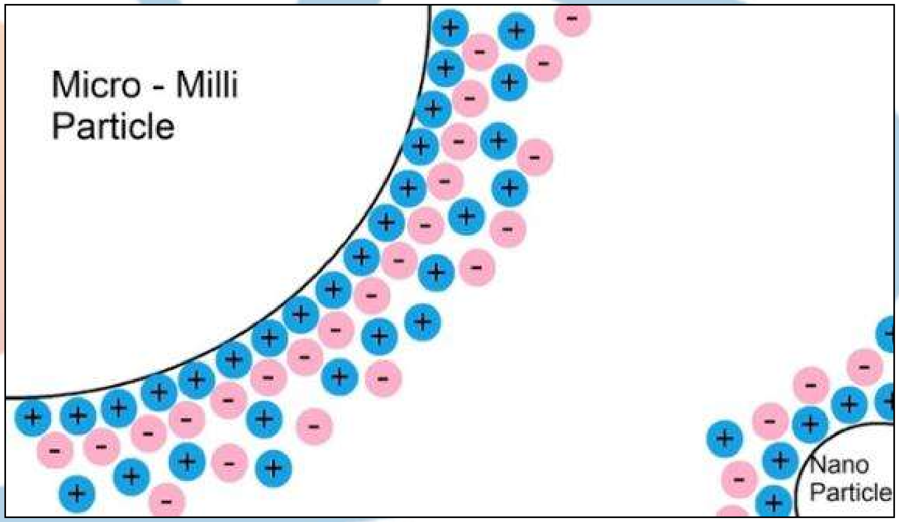
Test Section at Denver International Airport after 6 weeks, 2016

“Our Biggest Problem, We are Solving Today’s Problems with Yesterday’s Technologies” – WB, 2012

Colloidal Dispersion of Nano Silica

What is so special about a Nano Silica?

1. Free Silica Surface Area Pozzolanic Reaction
2. Accelerated Cement Dissolution
3. Heterogeneous Nucleation



- Increases Tendency for C-S-H Development
- Consumes CH

How to Use CS in Concrete?

Survey for Use of Cembinder in Concrete

Questions Asked:

1. What is the Concrete use?
   a. Slump
   b. Air
   c. Strength
   d. Physical / Chemical Attack Resistance
2. What are the Concrete constituents?
   a. Cement Type
   b. SCM
   c. Admixtures
3. What is the Concrete mix design?

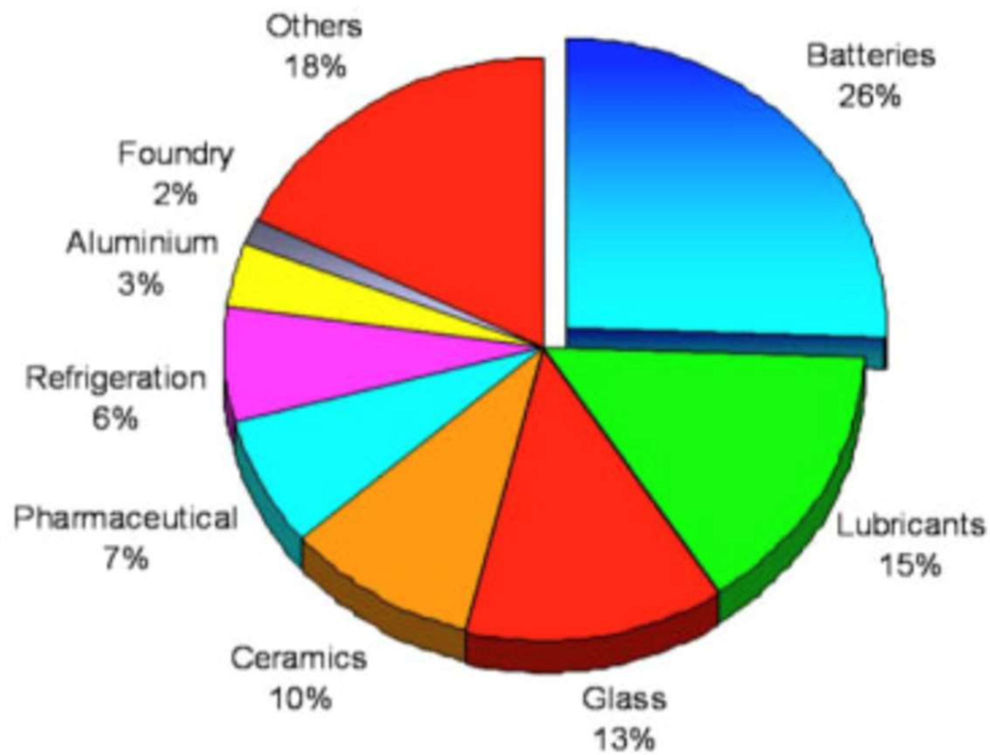
Lithium Shortage

Demand for Lithium Batteries

1. Demand for ALL lithium chemicals used in batteries will increase by 50%+

2. By 2020 Tesla Motors, Gigafacotry Plans will produce 20 times all the batteries produced in 2013.

3. First year of predicted shortage - **2015**



- Maverick, T. Gigafactory Plans May Lead to Lithium Shortage. www.WallstreetDaily.com. 18 November 2014.
- Battery Institute. Update 16 March 2015. Report BU-308: Availability of Lithium.