Mitigating Deicer Damage with Colloidal Silica Enhanced Concrete

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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, ...

- Concrete Enthusiast

- Combined Levels of Testing
Consulting Services
A Technical Representative for Construction Industry

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

Forensics Analysis and Litigation Work
Targeted toward market materials, engineering specifications and project needs.

Educational Seminars
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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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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Colloidal Silica

Defined

Liquid Dispersion of Colloidal Silica Particles

- Liquid Dispersion
- Clear to Milky Appearance
- Surface Area – 80 to 500 m²/g
- Solids Content – 15 to 50%

Colloidal Silica Dispersion

Enhancing Concrete with Newer Technologies

Not Replacing Current Technologies, Enhancing

FOR REFERENCE

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

- Class F Fly Ash
- Colloidal Silica

For Reference

• 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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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

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

• 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

Placement of Nano Engineered Concrete

6 Years Later No Surface Defects / Cracking
Long Term Testing

Mass Loss
**Long Term Testing**

*Compressive Strength*

<table>
<thead>
<tr>
<th></th>
<th>Days in Freeze-Thaw and MgCl Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td><strong>Compressive Strength (psi)</strong></td>
<td></td>
</tr>
<tr>
<td>REF</td>
<td>5000</td>
</tr>
<tr>
<td>WS</td>
<td>6000</td>
</tr>
</tbody>
</table>

*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

ASTM C 779 - Procedure C
Abrasion Resistance of WinterShield Concrete
56 Day Soak in MgCl

Depth of Wear, in

Time, minutes
Long Term Testing
Abrasions Resistance, 90-Days
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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 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, Gigafactory Plans will produce 20 times all the batteries produced in 2013.

3. First year of predicted shortage - 2015