Extending the Season for Concrete Construction and Repair

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Concrete Materials and Fresh Concrete Properties
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Outline

• Cold Weather Admixture Systems (CWAS)
• How ‘antifreeze admixtures’ work
• Establishing the Technology (Phase I)
• Defining Engineering Parameters (Phase II)
• Guidance for Optimizing Admixture Dosage Rates (Phase III)
• The Way Forward
Acknowledgements

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Cold Weather Admixture Systems

• Problem
  − The hydration rate of fresh normal concrete slows at low temperatures
  − No single commercial admixture protects concrete below freezing

• Solution
  − Chemical admixture suites depress the freezing point of mix water
  − Protects fresh concrete to an internal concrete temperature of 23°F
  − Promote early strength gain at temperatures below freezing
Cold Weather Admixture Systems

- **Benefits**
  - Saves time and money
  - No external heat required for water & aggregates, or substrate
  - Uses conventional construction practices and equipment
  - Provides an added capability to winter construction
  - Extends the concrete construction & repair season
  - ‘Antifreeze’ admixtures or Cold Weather Admixture Systems (CWAS)

$800 M/yr
Cold Weather Admixture Systems

• Benefits
  − Saves time and money
How Antifreeze Admixtures Work

- Combinations of chemical admixtures
  - Accelerates the rate of cement hydration
  - Reduces the amount of water to protect
  - Approved admixtures
  - No limit

![Graph showing temperature change over time with and without antifreeze admixture. The graph compares the freeze point and temperature changes for a control sample and a sample with antifreeze admixture, indicating the effectiveness of the admixture in delaying freezing.](image)
How Antifreeze Admixtures Work

- Combinations of chemical admixtures
  - Depresses the freezing point
  - Provides liquid water for hydration
  - Resists freezing

![Strength vs. Days Graph](image)
Establishing the Technology

• Phase I
  - Purpose – Establish the feasibility of batching, mixing, placing, and curing concrete in below freezing temperatures
  - Commercially available off-the-shelf chemical admixtures
  - Develop effective concrete formulations

Technical Approach
  - Laboratory investigation
  - Field trials
  - Select effective admixture combinations
    Workability, entrained air, initial freezing point
  - Confirm low-temperature performance
    Compressive strength, freeze-thaw durability, set time, critical maturity
Establishing the Technology

- Phase I – Compressive strength development
  Antifreeze mixtures cured at −4°C
  Compared to ACI 306
  Strength exceeded
Establishing the Technology

- Phase I – Freeze-thaw durability
  Antifreeze mixtures can be durable
Establishing the Technology

• Phase I

Field Trials
- 4 field trials conducted with State DOTs (NH and WI)
- Final demonstration project (Concord, NH)

Technology Transfer
- Final technical report (ERDC/CRREL TR-04-02)
- Guidance manual

Findings
- Eight antifreeze formulations generated
- Antifreeze mixtures workable, transportable, air entrainable
- Verified initial freezing point −5°C
- Compressive strength exceeded standard guidance
- Antifreeze mixtures can be durable
- Field trials proved this a feasible approach
- Developed tools for field use
- One size fits all
Establishing the Technology

- Field trials

Concord, NH (February 2003)

Air temp. = 14°F (Hi 28°F/Lo 0°F)
Concrete temp. = 50°F
West Lebanon, NH (December 2002)

Air temp. = −4°F (at 1030hrs)
Air temp = +14°F (at 1300 hrs)
Establishing the Technology

- Field trials

West Lebanon, NH (Dec 2002)
After 2 years exposure to New England winters

Control (tent and heat section)
Antifreeze Approach
Defining Engineering Parameters

• Phase II
  - Purpose – Freeze-thaw durability of antifreeze concrete mixtures not harmed – in some cases improved
  - Biggest problem – concrete degradation from freeze-thaw cycling exposure in cold regions
  - A better understanding is needed

Background
  - Air entrainment is current approach

Technical Approach
  - Laboratory investigation
    - Freeze-thaw durability testing
    - Verification testing of initial freezing point and compressive strength
Defining Engineering Parameters

- Phase II – Freeze-thaw durability
Defining Engineering Parameters

• Phase II

Findings
− Moderate dosages of admixtures can improve freeze-thaw durability of concrete
− Freeze-thaw durability increases with increasing admixture dosage
− Up to a point
  o Pore space volume fills up
− Mature concrete can have a lower freezing point than either fresh antifreeze concrete or normal mature concrete
  o Antifreeze concrete experiences fewer freeze thaw cycles and lasts longer

Deliverable
− Final technical report (ERDC/CRREL TR-06-8)
Guidance for Optimizing Admixture Dosage Rates

• Phase III
  − Purpose – Develop tools and guidance to specify admixture dosage rates based on forecasted weather conditions
  − Addressing the one-size-fits-all from Phase I
  − Increase economy of antifreeze concrete mixtures
  − Putting it into PRACTICE!

Technical Approach
  − 3 parts
    o Part 1 – Framework development
    o Part 2 – Develop design guidance
    o Part 3 – Computer-based design tool

Deliverable
  − Final technical report – manual or ‘cookbook’
Guidance for Optimizing Admixture Dosage Rates

- **Phase III**
  - Part 2 – Develop design guidance
    - Tailor admixture dosage rates
    - Understand
      - Job site characteristics
      - Climate characteristics
      - Relationship between admixture dosage rates and curing conditions
    - Field data
      - Range of conditions
      - Variety of structures
      - Air temperature
      - In situ concrete temperatures
      - Strength gain with time
Guidance for Optimizing Admixture Dosage Rates

• Phase III
  Part 2 – Develop design guidance

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<th>Date</th>
<th>Location</th>
<th>Work Type</th>
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<td>Hanover, NH</td>
<td>Slab and Wall</td>
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<td>10 December 2001</td>
<td>Littleton, NH¹</td>
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<td>27 February 2002</td>
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<td>12 December 2002</td>
<td>North Woodstock, NH¹</td>
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<td>14 February 2003</td>
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¹ Phase I field sites [FHWA TPF-5(003)]
Guidance for Optimizing Admixture Dosage Rates

• Phase III
  Part 2 – Develop design guidance
  Evaluation tool
    o One-dimensional model
    o Heat transfer principles
    o Finite difference approach
    o Spreadsheet format
The Way Ahead

• Goal
  – Putting it into PRACTICE!

• Future Research
  – Develop the computer tool
  – Validate the computer tool
  – Refine field testing tools
    – Initial freezing point
  – Incorporating supplementary cementitious materials
  – Additional study on micro-pore development
  – Long-life material
    – Durability
    – Long-term field exposure
    – Exposure to salt scaling
Questions?

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