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

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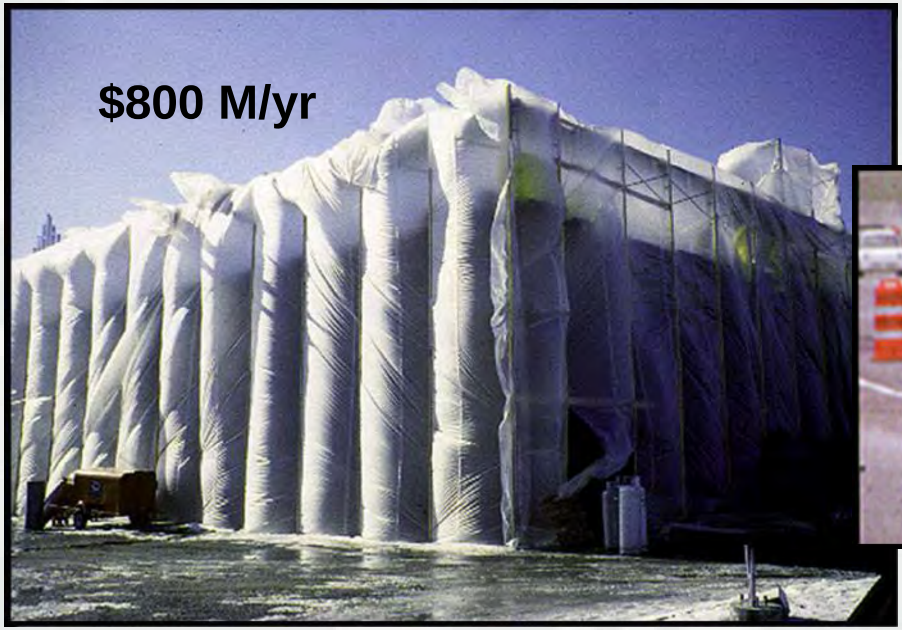
Cold Weather Admixture Systems

- 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

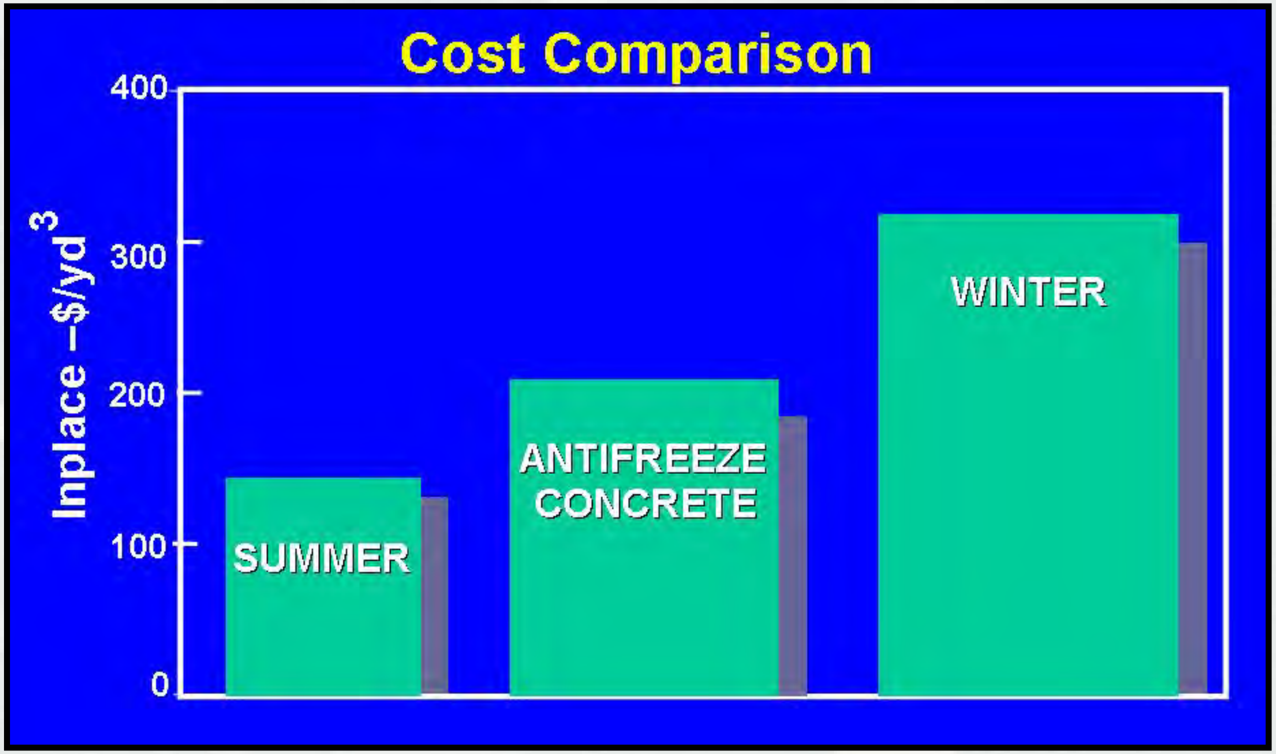
Cold Weather Admixture Systems

- 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)



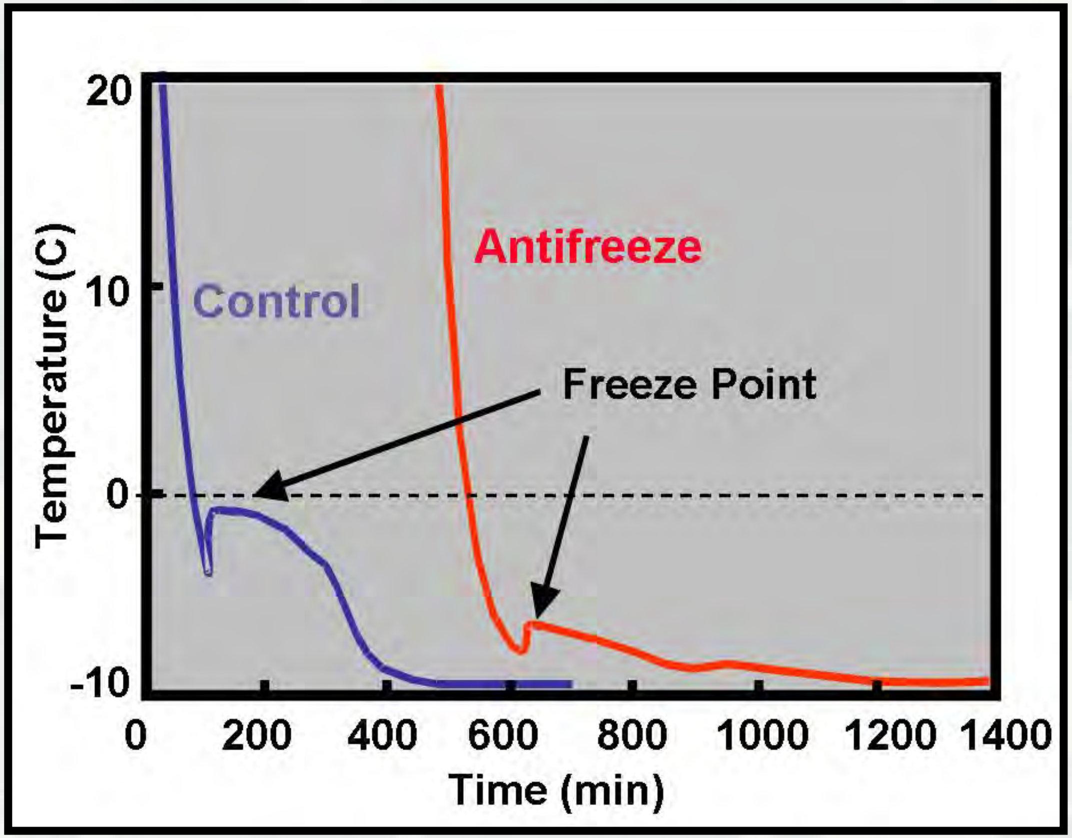
Cold Weather Admixture Systems

- Benefits
  - Saves time and money



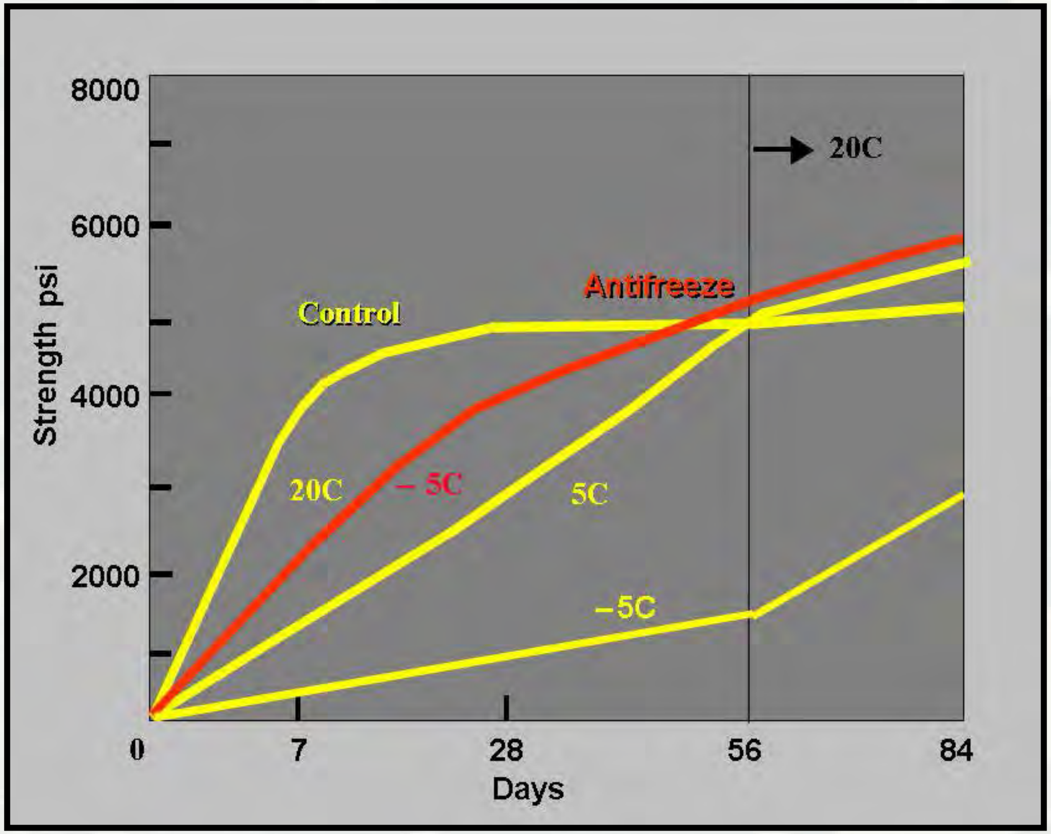
How Antifreeze Admixtures Work

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



How Antifreeze Admixtures Work

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



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

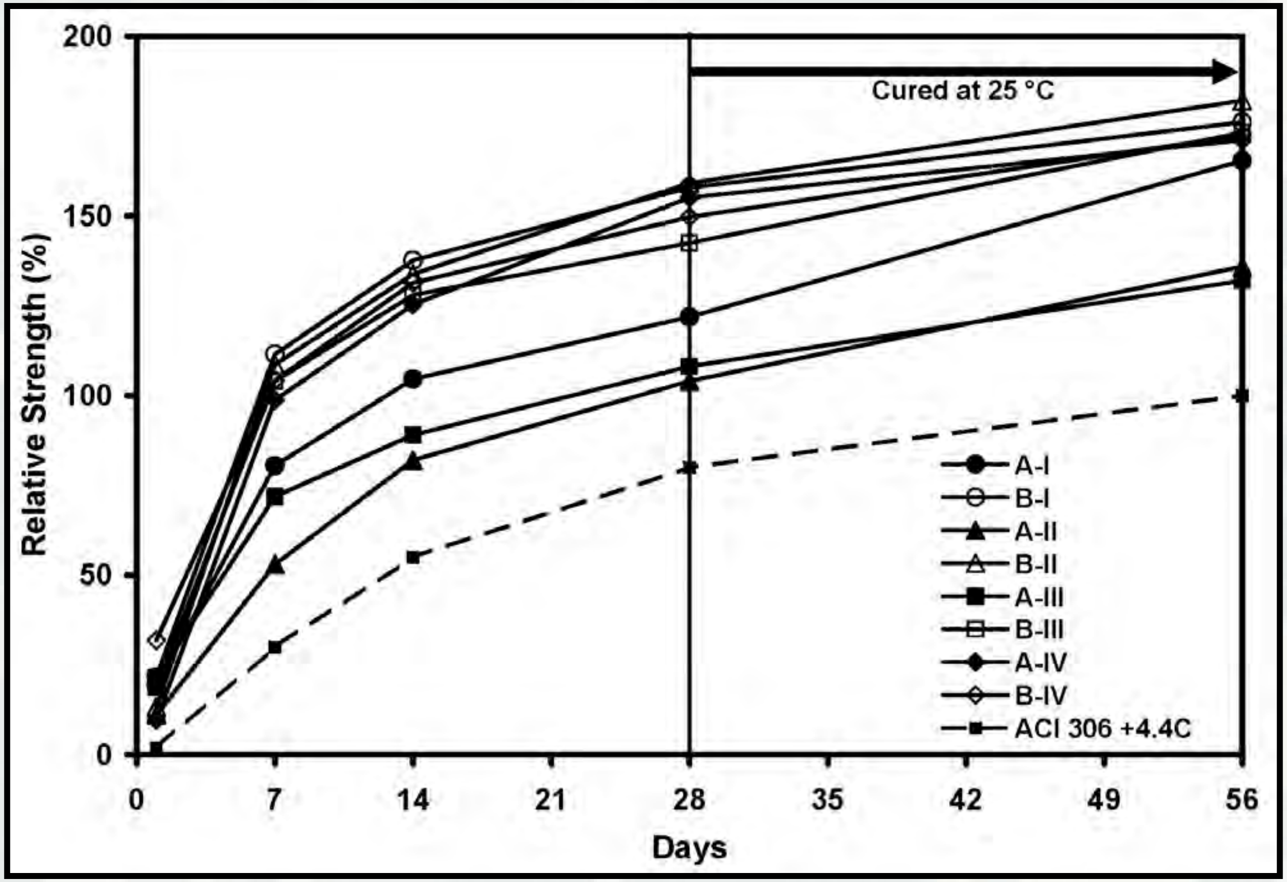
  Technical Approach
  - Laboratory investigation
  - Field trials
  - Select effective admixture combinations

    Workability, entrained air, initial freezing point
  - Confirm low-temperature performance

    Compressive strength, freeze-thaw durability, set time, critical maturity

Establishing the Technology

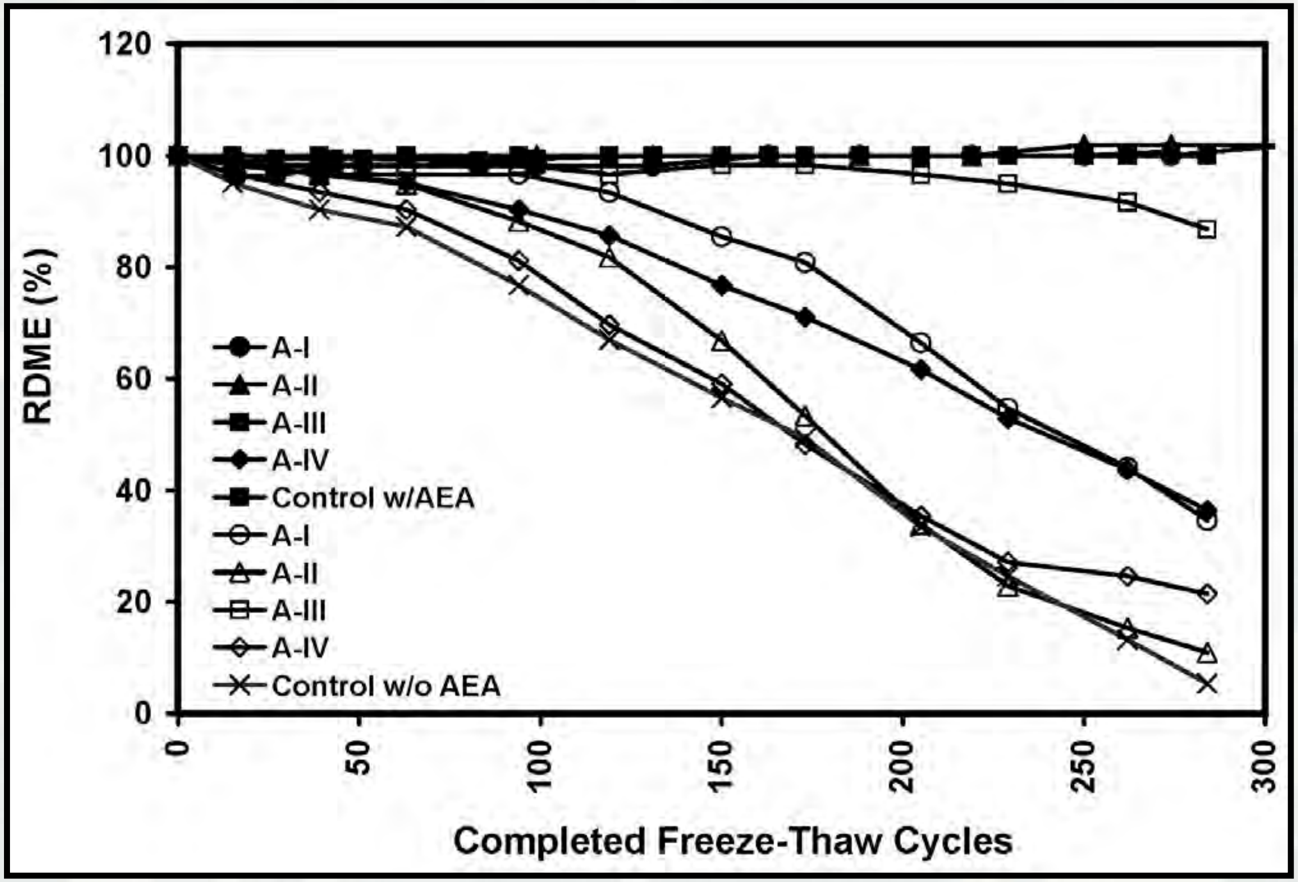
- Phase I – Compressive strength development
  - Antifreeze mixtures cured at −4°C
  - Compared to ACI 306
  - Strength exceeded



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

  - o Final technical report (ERDC/CRREL TR-04-02)
  - o Guidance manual
  - o Web page http://www.crrel.usace.army.mil/projects/coldweatherconcreting/

  Findings

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

Establishing the Technology

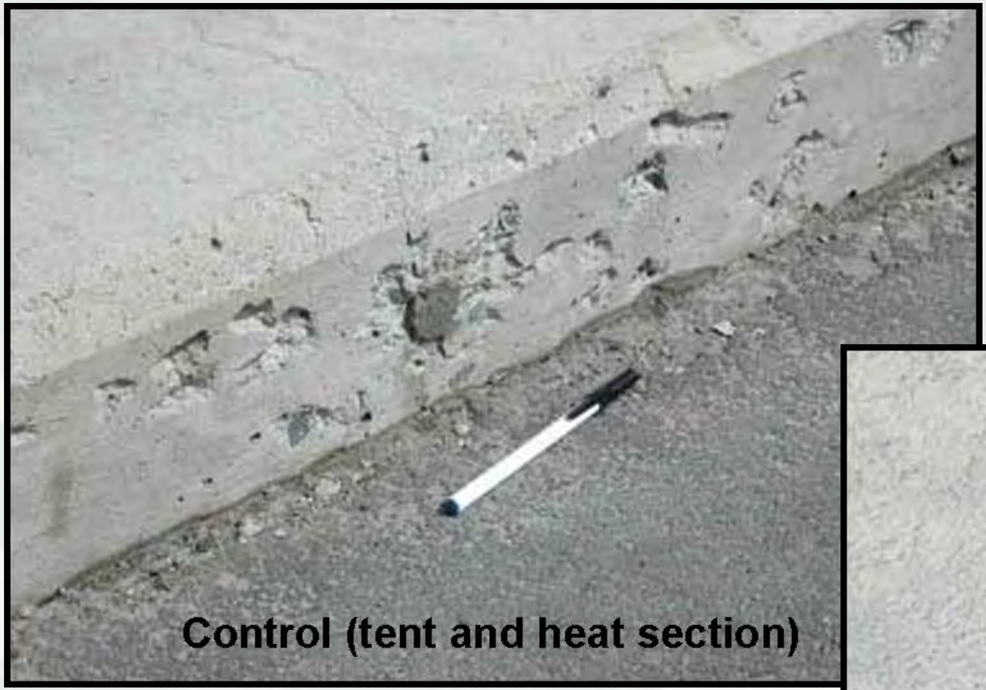
- Field trials

West Lebanon, NH
(December 2002)

Concord, NH (February 2003)

Establishing the Technology

- Field trials



West Lebanon, NH (Dec 2002)

After 2 years exposure to New England winters

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

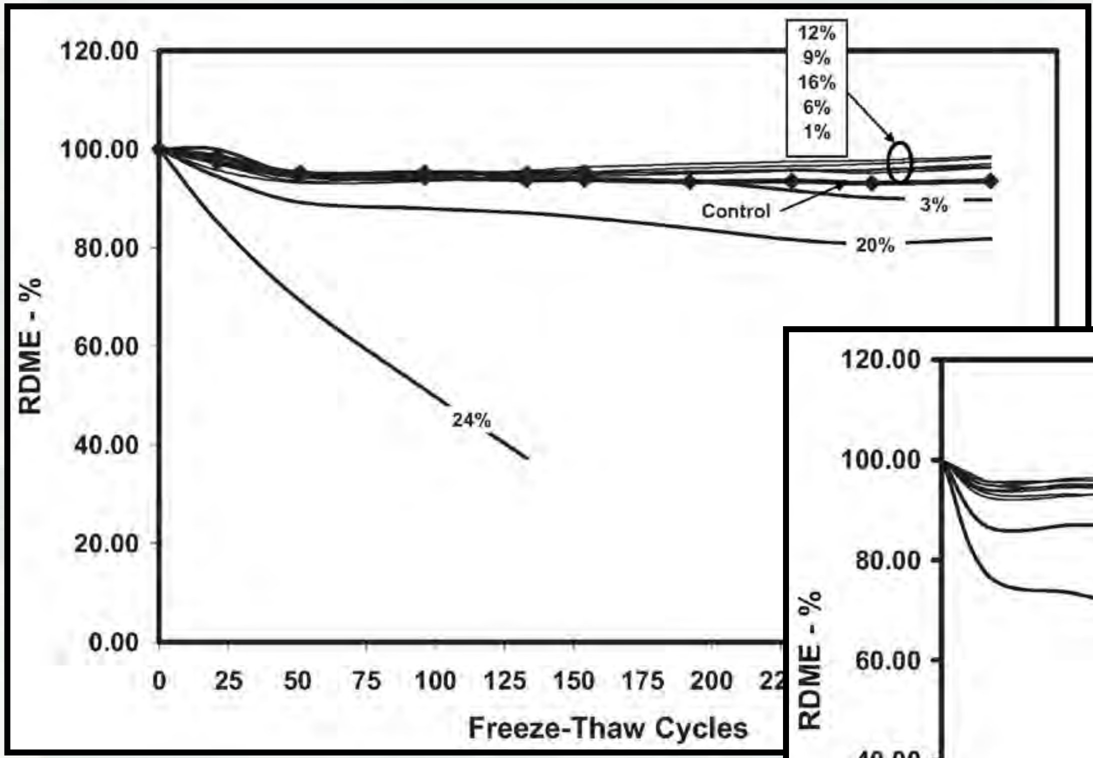
- Air entrainment is current approach

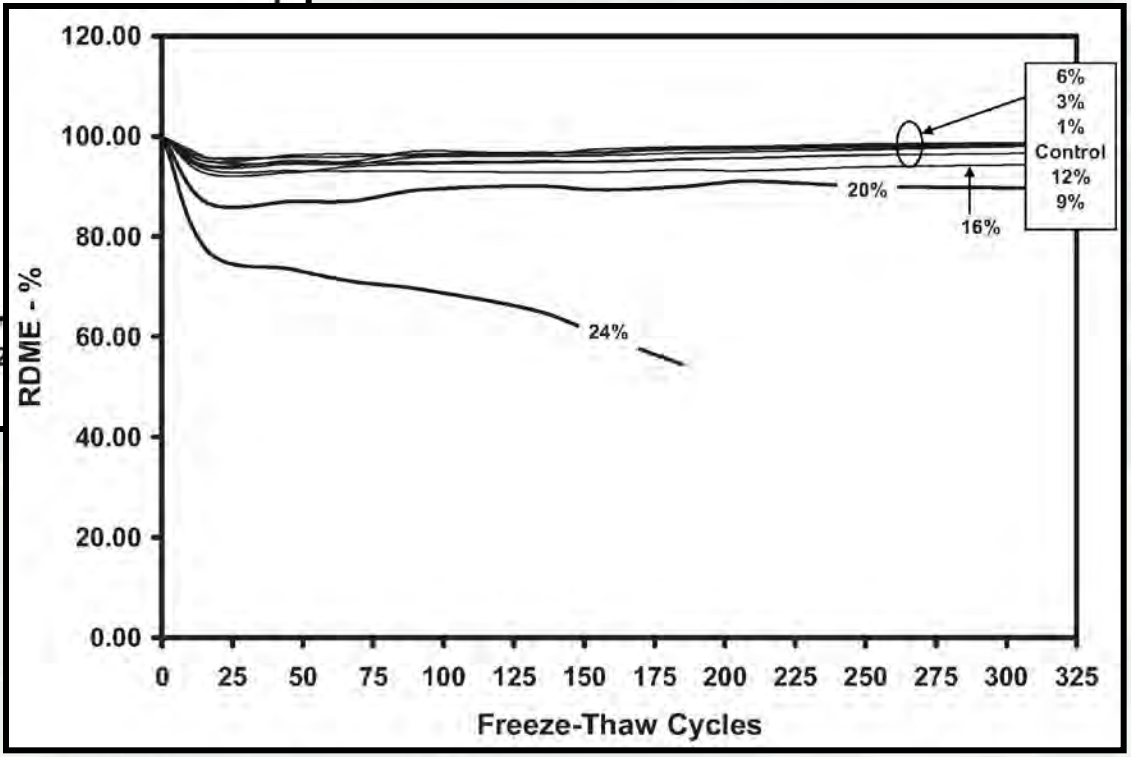
Technical Approach

- 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
    - Pore space volume fills up
  - Mature concrete can have a lower freezing point than either fresh antifreeze concrete or normal mature concrete
    - Antifreeze concrete experiences fewer freeze thaw cycles and lasts longer

  Deliverable

  - Final technical report (ERDC/CRREL TR-06-8)

  http://www.crrel.usace.army.mil/projects/coldweatherconcreting/

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
    - Part 1 – Framework development
    - Part 2 – Develop design guidance ← **We Are Here**
    - 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
    - Insitu concrete temperatures
    - Strength gain with time

Guidance for Optimizing Admixture Dosage Rates

- Phase III

  Part 2 – Develop design guidance

Date	Location	
17–18 February 1994	Hanover, NH	Slab and Wall
15–17 March 1994	Sault Ste. Marie, MI	Pavement
10 December 2001	Littleton, NH[1]	Bridge curbing
27 February 2002	Rhinelander, WI[1]	Pavement
12 December 2002	North Woodstock, NH[1]	Bridge footing
18 December 2002	West Lebanon, NH[1]	Bridge curbing
14 February 2003	Concord, NH[1]	Sidewalk
18 February 2004	New York, NY	Streets and sidewalks
23 February 2004	Grand Forks AFB, ND	Airfield pavement
7 February 2007	Juneau, AK	Pre-cast work
27 March 2007	Fairbanks, AK	Slabs on grade
25–27 March 2008	Ft. Wainwright, AK	Communications hardstand

[1] Phase I field sites [FHWA TPF-5(003)]

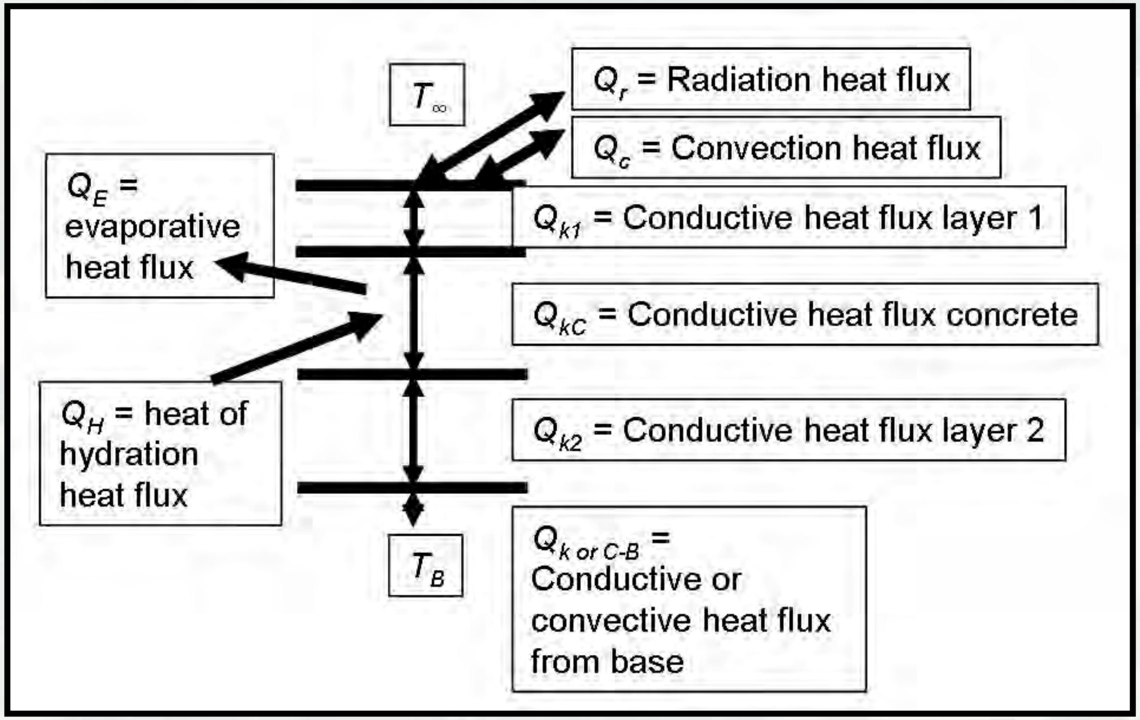
Guidance for Optimizing Admixture Dosage Rates

- Phase III

Part 2 – Develop design guidance

Evaluation tool

- One-dimensional model
- Heat transfer principles
- Finite difference approach
- 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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