SPECIAL SEMINAR

Coordinated Technology Implementation Program
Cold Weather Admixture Systems

Presented by Lynette Barna, Force Projection & Sustainment Branch

April 12
1-2:30 PM
Abele Auditorium

A user-oriented, customer-based seminar on CWAS applications

Extending the Season for Concrete Construction and Repair:

Cold Weather Admixture Systems
Putting It Into Practice!

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Acknowledgements

Coordinated Technology Implementation Program webinar sponsor

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Outline

- Background
- Development of Cold Weather Admixture Systems
  - Laboratory testing
- Application of Cold Weather Admixture Systems
  - Field Testing
- Conclusions

Cold Weather Admixture Systems

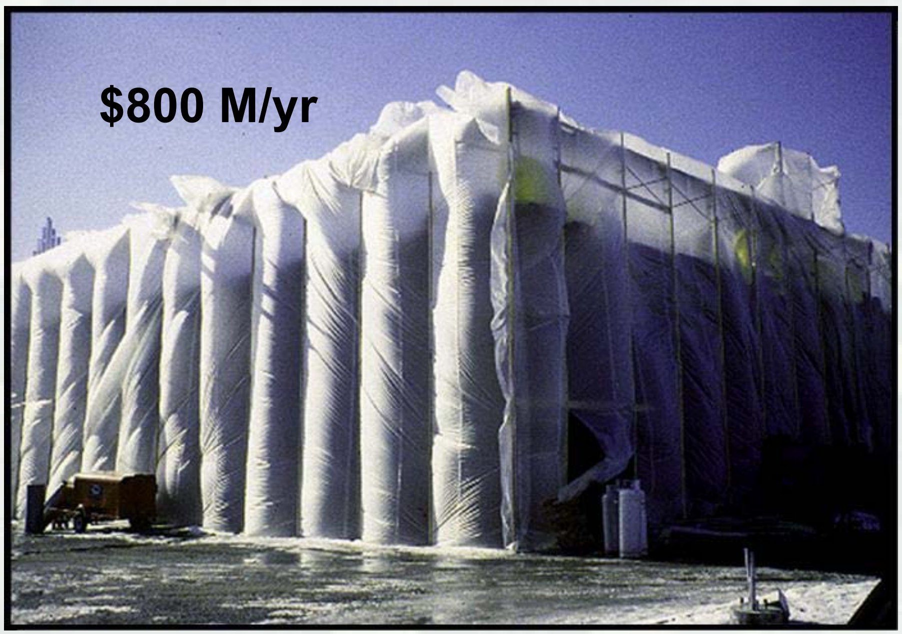
Background

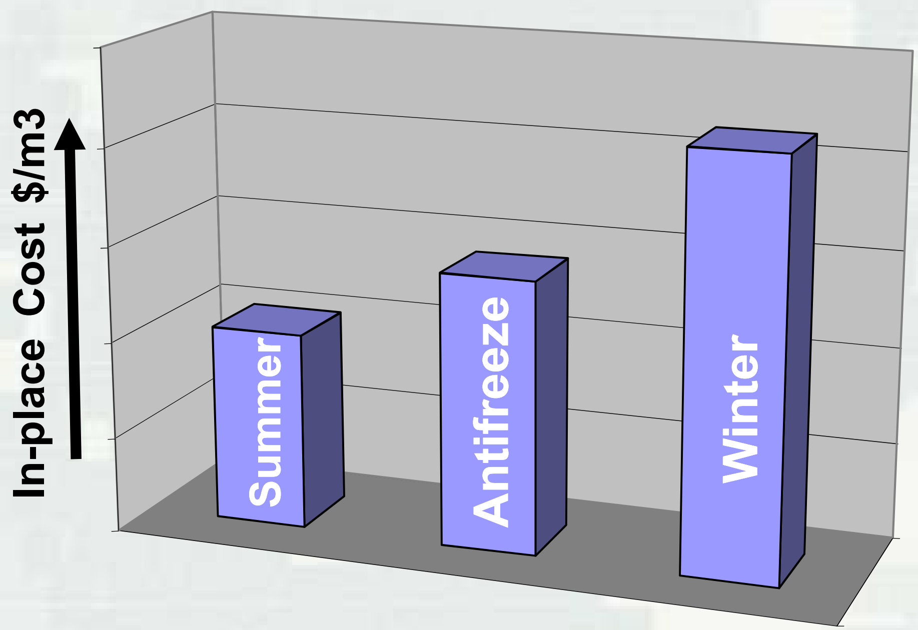
- Problem
  - Cold weather
  - Low temperatures slow hydration rate of fresh normal concrete slows
  - Fresh concrete susceptible to freezing – and damage
  - No single commercial admixture protects concrete below freezing

- Solution
  - Chemical admixture suites depress mix water freezing point
  - Protects fresh concrete to an internal concrete temperature of –5°C (23°F)
  - Promotes early strength gain at temperatures below freezing

Cold Weather Admixture Systems

- Benefits
  - Saves time *and* money *and* energy
  - 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
  - Commercially available admixtures





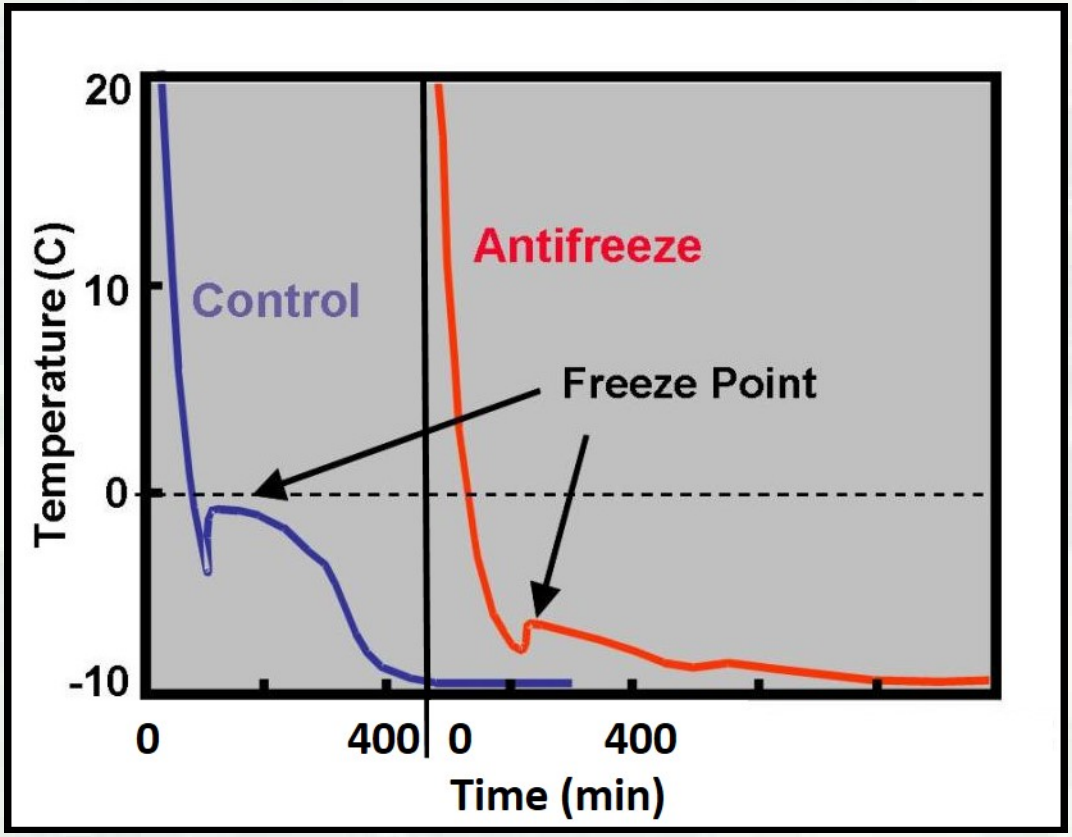
Cold Weather Admixture Systems

Publications

- CRREL technical reports
- Peer reviewed papers and conference presentations
- ASTM C 1622 Standard Specification
- ACI 306 Guide to Cold Weather Concreting
- Website for links to publications
- Public search on:
  CRREL antifreeze concrete

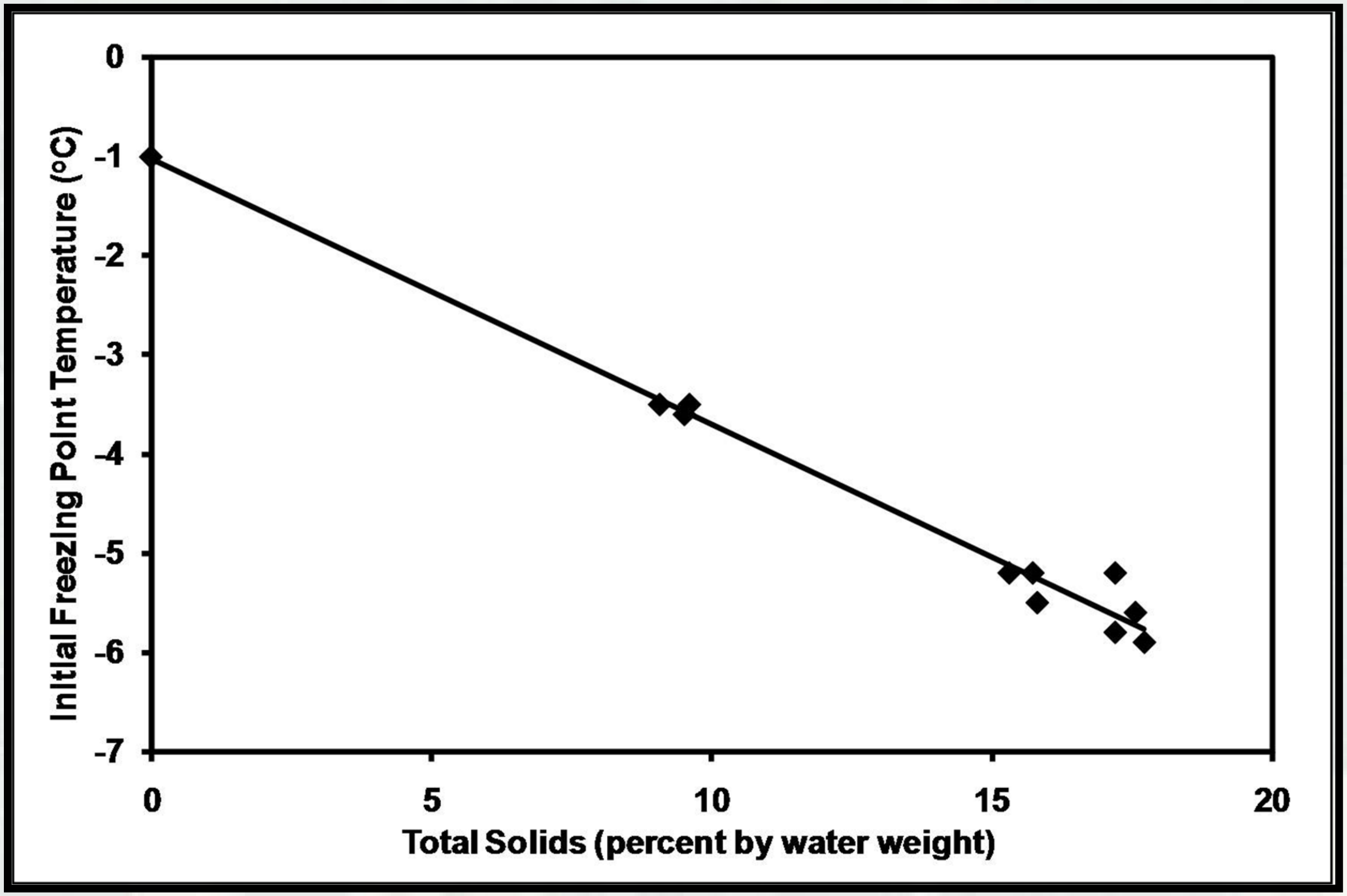
Cold Weather Admixture Systems
“Antifreeze Concrete”

- How Antifreeze Concrete works
  - Combinations of chemical admixtures
  - Accelerates the rate of cement hydration
  - Reduces the amount of water to protect
  - Initial freezing point temperature



Cold Weather Admixture Systems

- Effects of water
  - Relationship between admixtures and mix water content
  - Account for water in admixtures



Laboratory Testing

Cold Weather Admixture Systems

- Performance Requirements for Laboratory Study
  - Dose admixtures within manufacturer's recommended range
  - Ensure workable concrete
  - Protect fresh concrete from freezing down to minimum of –5°C (23°F)
  - Gains compressive strength at –4.5°C (25°F) as good or better than curing at +5°C (40°F)
  - No adverse long-term durability effects
  - Compatible with steel reinforcement
  - Does not promote alkali-silica reaction
  - Accepts air entrainment
  - Does not adversely affect finishability
  - Does not present significant problems with equipment use and cleanup in cold weather

Cold Weather Admixture Systems

- Initial Laboratory Study Objectives
  - Develop antifreeze admixture concrete mixtures using commercially available (off-the-shelf) admixtures
  - To mix, place, finish, and cure concrete at below freezing temperatures
- Scope
  - Type I, Type II, or Type I-II portland cement (ASTM C 150)
  - Cement factor 392 kg/m^3(660 lbs/yd^3) and w-c ratio 0.44
  - Air content 6% (±1.5%) (ASTM C 173)
  - Accept air entrainment (ASTM C 666, ACI 306)
  - Slump 100 mm (4 in.) (ASTM C 143)
  - Admixtures (ASTM C 494 or C 260)
  - Initial freezing point measurement (CRREL method)
  - Unconfined compressive strength testing (ASTM C 39)
  - Several formulations tested in laboratory and used in field
  - Blended cements and SCMs not considered (future study)

Cold Weather Admixture Systems

- Laboratory Mixtures
  - Control

Mixture Component	Quantity
Cement, kg/m^3 (lb/yd^3)	392 [660]
¾ in. aggregate, ssd*, kg/m^3 (lb/yd^3)	1079 [1819]
Sand, ssd, kg/m^3 (lb/yd^3)	801 [1350]
Batch water, L/m^3 (gal./yd^3)	171 [34.7]
Air-entraining admixture, mL/100 kg (fl oz/cwt)	97 [1.49]
Water-reducer, mL/100 kg (fl oz/cwt)	507 [7.78]
Final water-cement ratio	0.436
Target slump mm (in.)	100 ± 25 [4 ± 1]

* saturated, surface dry

  - Admixture combinations were added to this base mixture

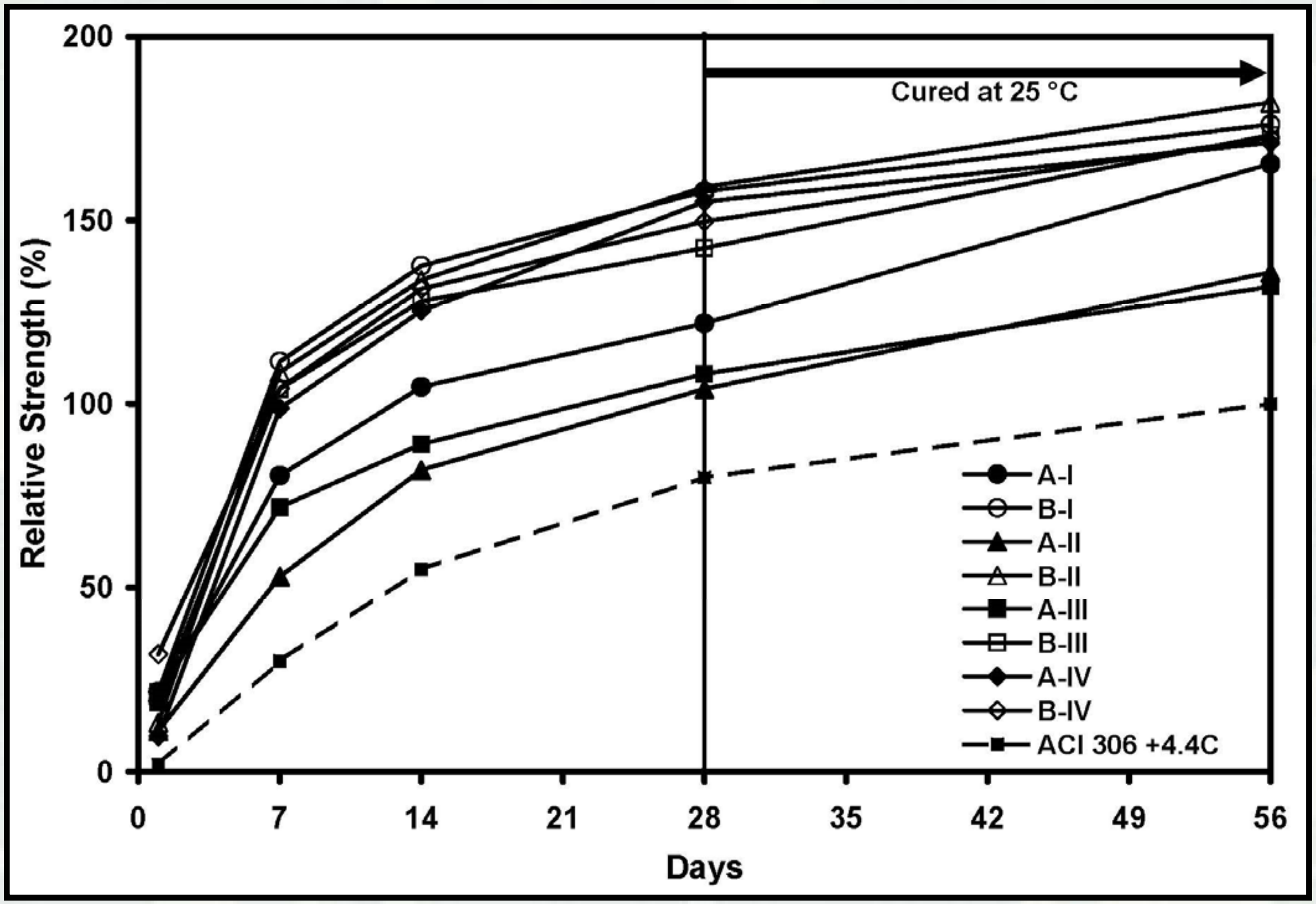
Cold Weather Admixture Systems

- Laboratory Mixtures
  - Chemical Admixtures

Specification Standard		Description
ASTM C 494	Type A	Water-reducing
	Type B	Retarding
	Type C	Accelerating
	Type D	Water-reducing and retarding
	Type E	Water reducing and accelerating
	Type F	High-range water-reducing
	Type G	High-range water-reducing and retarding
ASTM C 260		Air-entraining
(None)		Corrosion-inhibiting
(None)		Shrinkage-reducing

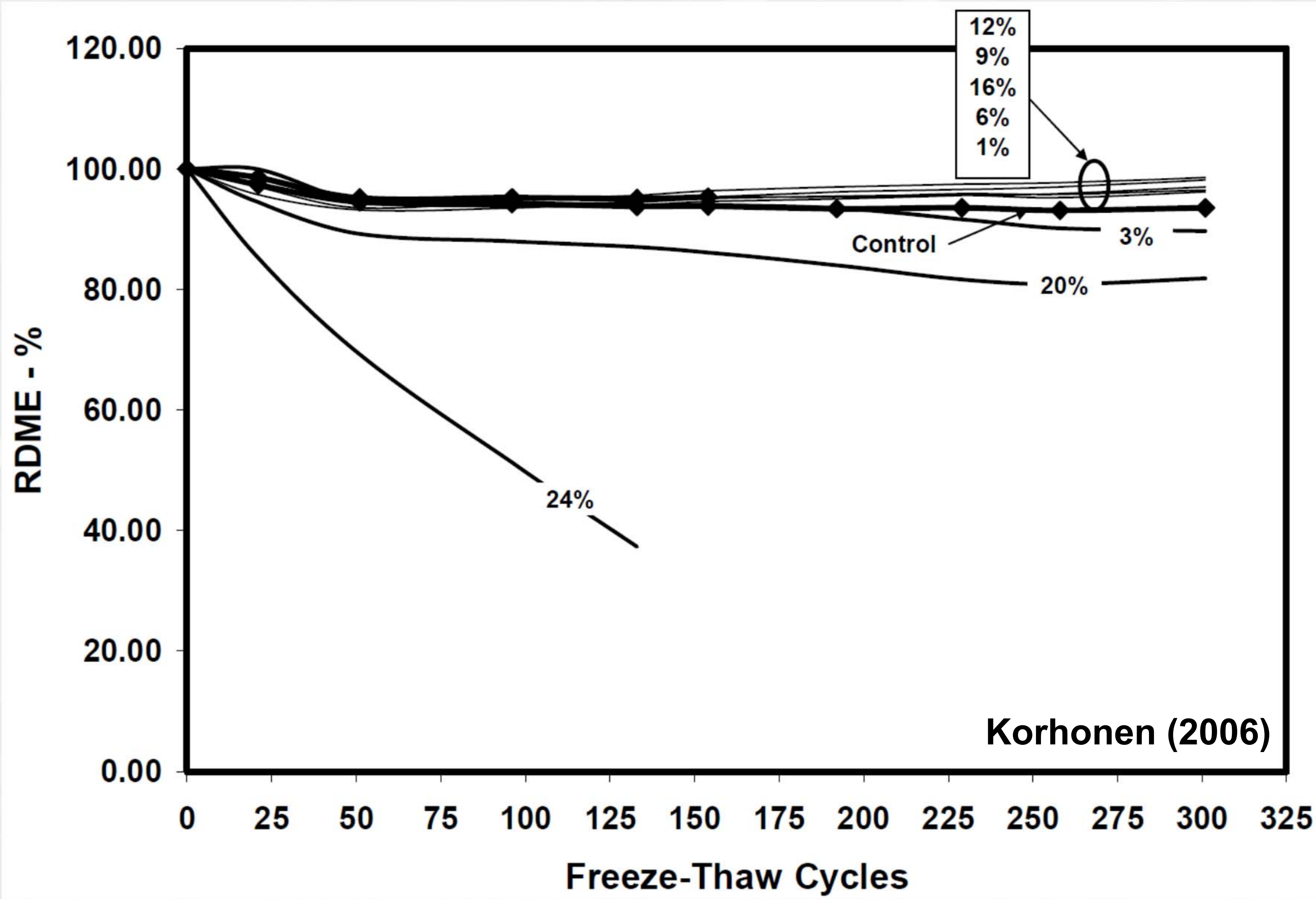
Cold Weather Admixture Systems

- Laboratory Study
  - Compressive strength development
  - Antifreeze concrete cured at 25°F (–4°C)



Cold Weather Admixture Systems

- Laboratory Study
  - Freeze-thaw durability testing



Cold Weather Admixture Systems

- Initial Laboratory Study Outcomes
  - Verified concrete mixture characteristics
  - Eight antifreeze formulations developed
  - Conducted four field trials and one final demonstration project
- Findings
  - Antifreeze mixtures workable, transportable, air entrainable
  - Verified initial freezing point temperature of 23°F
  - Compressive strength exceeded standard guidance
  - Antifreeze mixtures can be durable
  - Field trials showed this a feasible approach
  - Developed tools for field use
  - One size fits all

Cold Weather Admixture Systems

- Follow-on research study
  - Optimize admixture dosage rates
  - Addressed one-size-fits-all dosage rates
  - Specify admixture dosage rates based on forecasted weather
- Findings
  - Tailor the admixture dosage rates
  - Added economy for the mixtures

Field Testing

Field Testing

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	Bridge curbing
27 February 2002	Rhinelander, WI	Pavement
12 December 2002	North Woodstock, NH	Bridge footing
18 December 2002	West Lebanon, NH	Bridge curbing
14 February 2003	Concord, NH	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

Field Testing

Date	Placement Air Temperature °C (°F)	Overnight Air Temperature °C (°F)	Location	Member
10 December 2001	0 °C (32 °F)	−7 °C (20 °F)	Littleton, NH*	Bridge curbing
27 February 2002	−4 °C (23 °F)	−10 °C (14 °F)	Rhinelander, WI*	Pavement
12 December 2002	3 °C (37 °F)	−3 °C (27 °F)	North Woodstock, NH*	Bridge footing
18 December 2002	−9 °C (16 °F)	−17 °C (1 °F)	West Lebanon, NH*	Bridge curbing
14 February 2003	−15 °C (5 °F)	−25 °C (−13 °F)	Concord, NH*	Sidewalk
25–27 March 2008	−10 °C (14 °F)	−15 °C (5 °F)	Fort Wainwright, AK†	Communications hardstand

* Korhonen et al. (2004)

† Barna et al. (2010)

Field Placement

Prior to job

Trial batch(es)
- slump
- air content
- concrete temperature

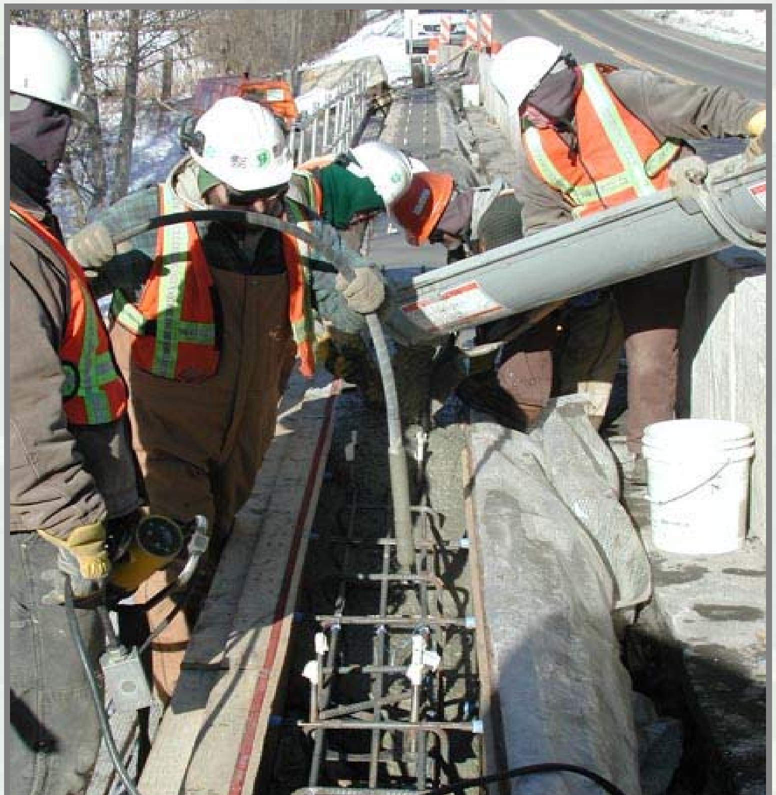
Day of job

Job Supervisor:
- be aware of weather forecast
- consider pre-construction meeting
- close coordination (in the beginning)

Truck Driver:
- avoid excess water
- slow agitation in transit
- use cold water for antifreeze concrete

Crew:
- substrate free of ice and snow
- substrate CAN BE frozen
- place / finish as normal
- cover with vapor barrier to retain moisture

Field Testing the Technology



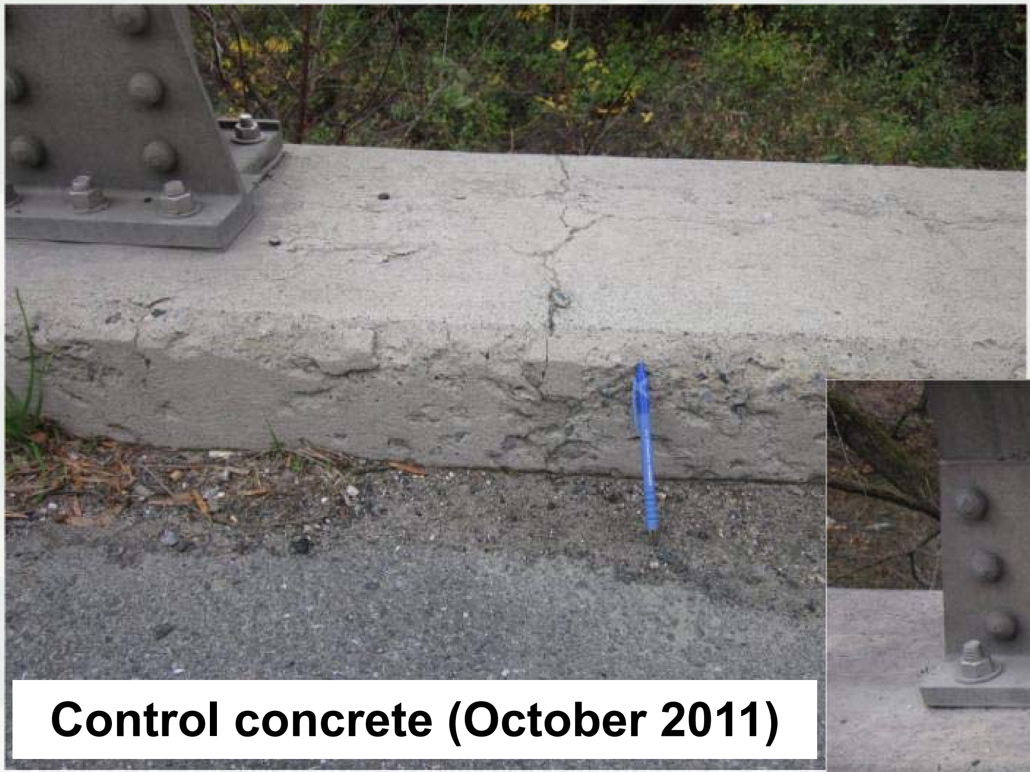
Air temp. = 14°F (Hi 28°F/Lo 0°F)
Concrete temp. = 50°F

West Lebanon, NH (December 2002)

Air temp. = −4°F (at 1030hrs)
Air temp = +14°F (at 1300 hrs)
Concord, NH (February 2003)

West Lebanon, NH

Both bridge curb sections placed during Winter 2002

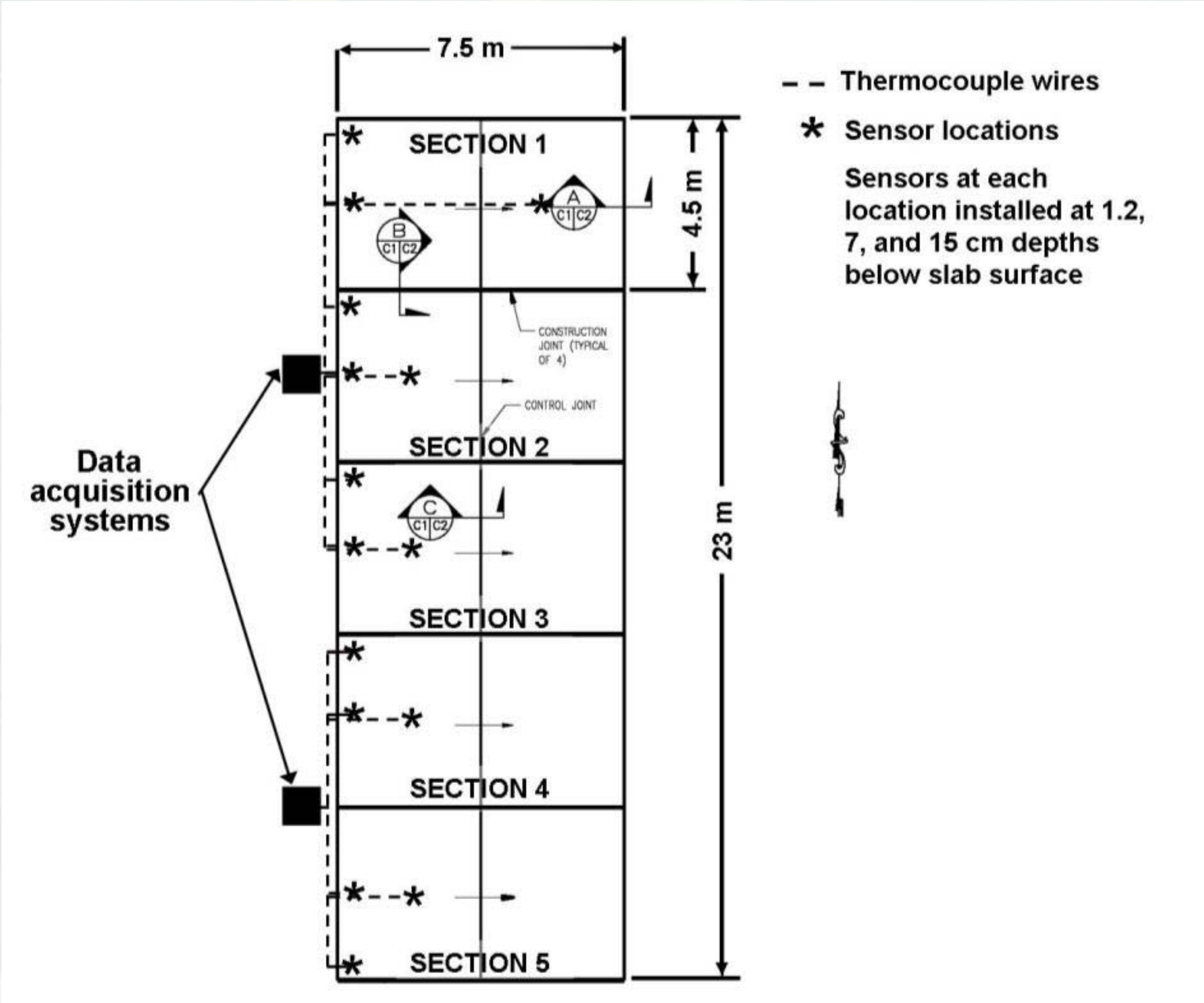


Control concrete (October 2011)

Antifreeze concrete (October 2011)

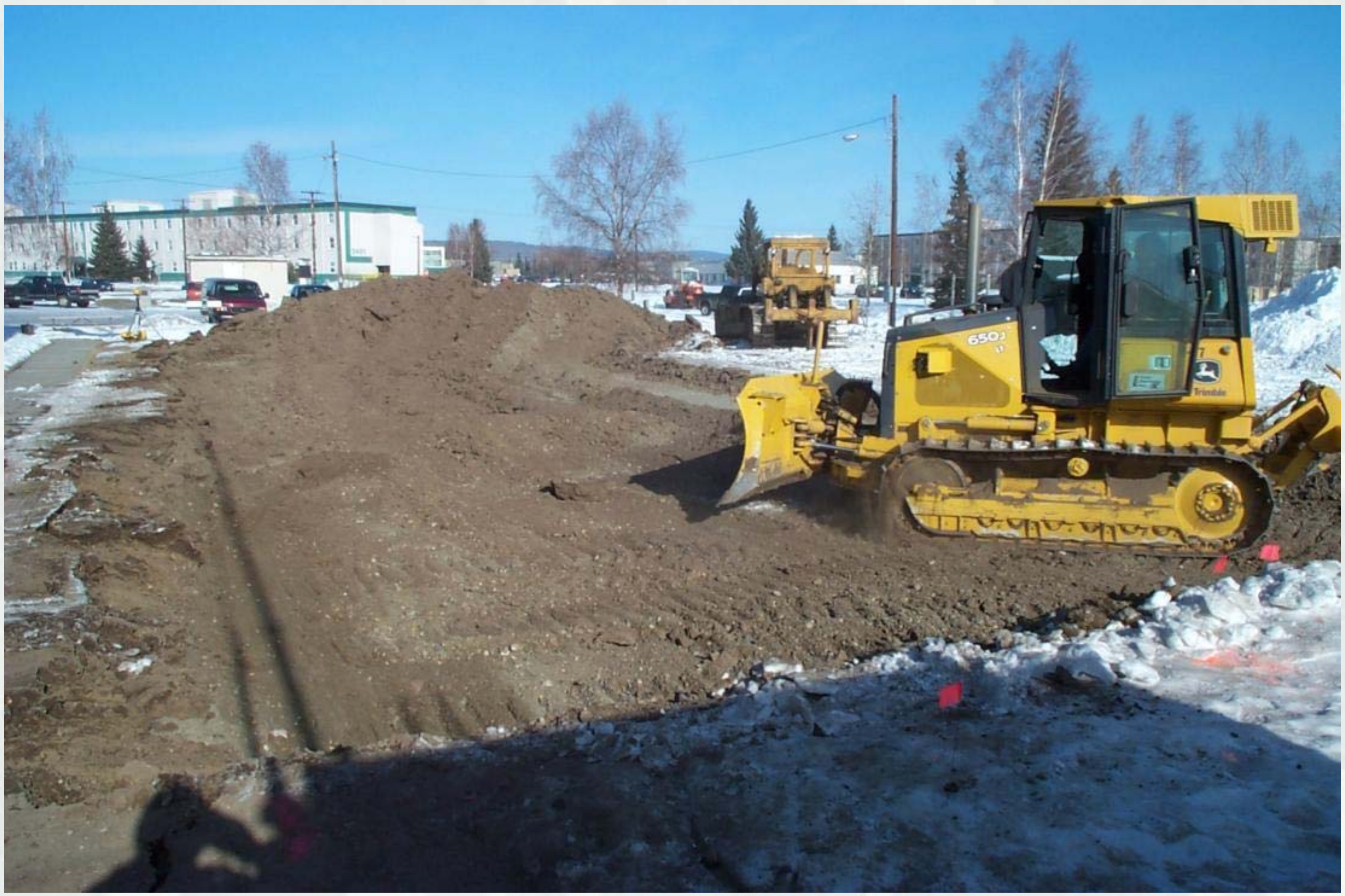
Field Placement

- Ft. Wainwright, Alaska
  - March timeframe
  - Test site layout



Field Placement

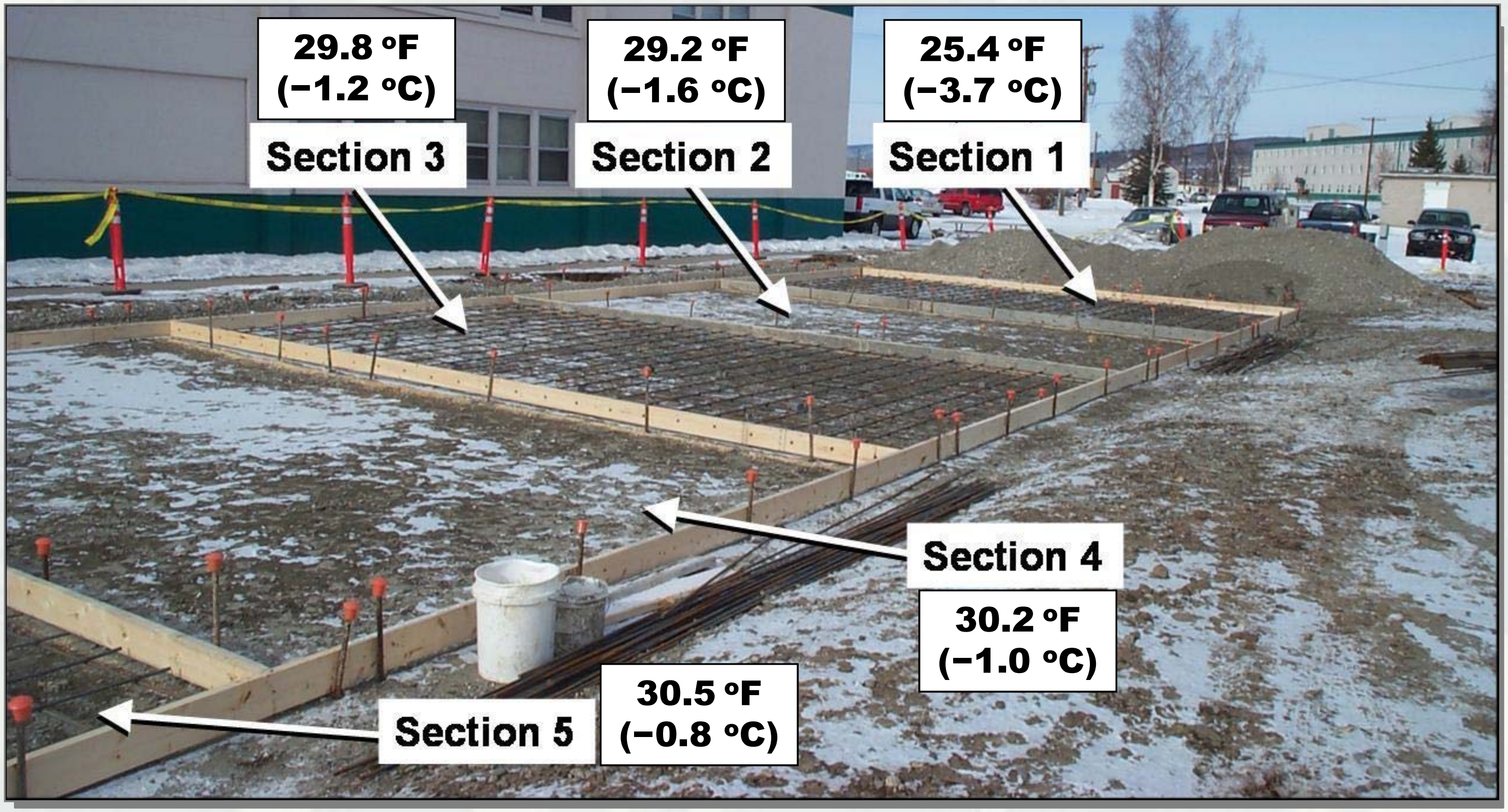
- Ft. Wainwright, Alaska
  - Site preparation 1 week before concrete placement



Field Placement

- Ft. Wainwright, Alaska
  - Five instrumented test sections
  - Varying admixture dosages
  - Frozen substrate

Air Temp = 14°F
Ground Temp = 21°F



Field Placement

Base Concrete Mix

Cement (kg/m^3)	390
Coarse Aggregate (kg/m^3)	1,044
Fine Aggregate (kg/m^3)	800

Field Placement

Admixtures

Test Section	1	2	3	4	5
Water (L/m^3)	94	99.5	119	101	121
HRWR (mL/100kg)	521	456	319	391	261
Water Reducer & Accel (mL/100kg)	4,433	2,934	1,434	2,217	2,223
Corrosion Inhib (L/m^3)	19.8	14.9	7.4	11.4	11.4
Extra Water (L/m^3)	7.9	5.9	2.0		
w/c	0.39	0.39	0.38	0.38	0.47
Total Solids (%)	11.8	8.3	4.4	6.6	5.3

Field Placement

- Ft. Wainwright, Alaska
  - Day Before – trial batch at ready-mix plant

Field Placement

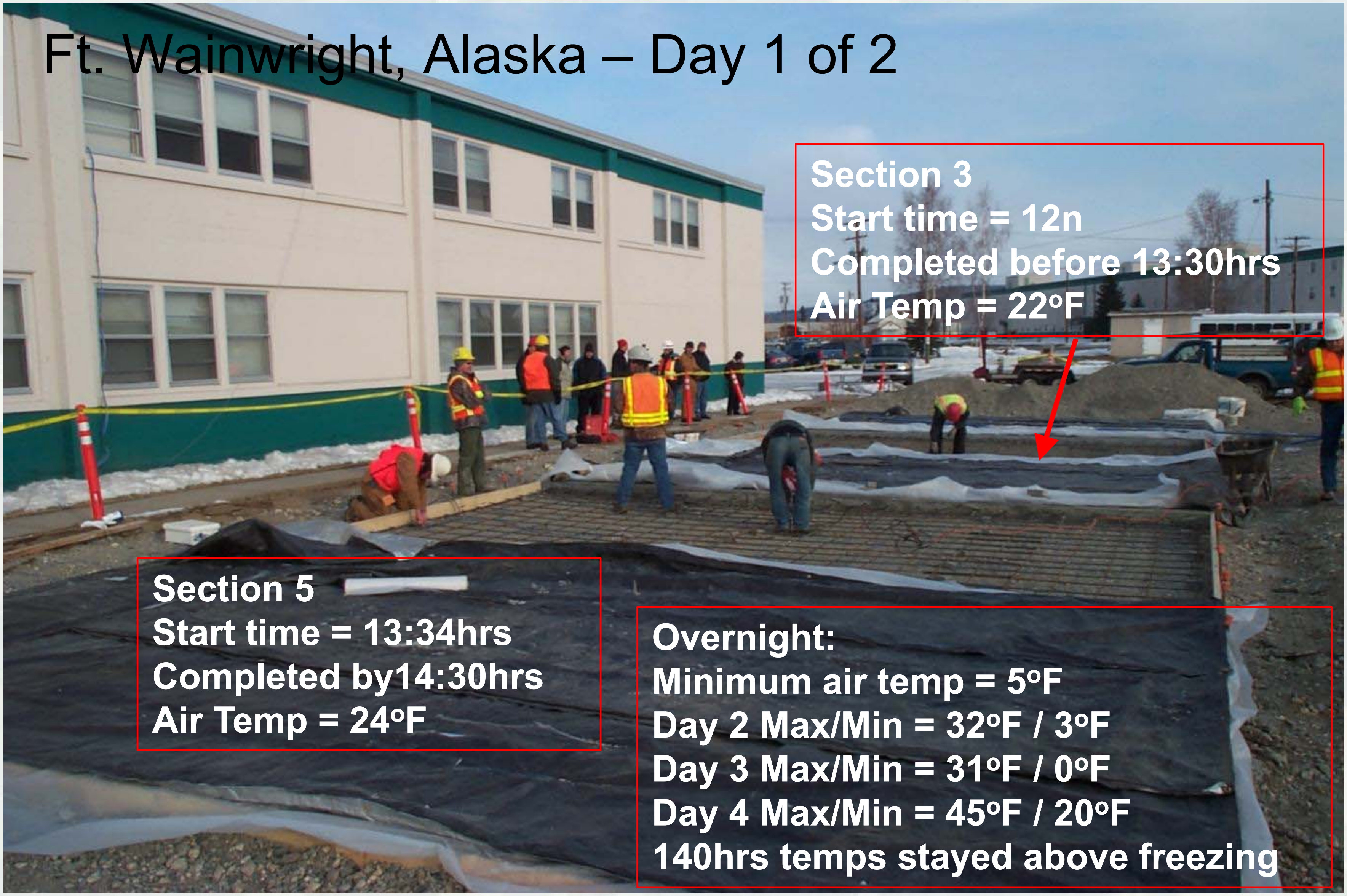
Field Placement

Ft. Wainwright, Alaska – Day 1 of 2

10:30hrs

Field Placement

Field Placement



Field Placement

Ft. Wainwright, Alaska – Day 1 of 2

Concrete mix

28 day compressive strength = 4,000psi

w-c ratio range = 0.34 to 0.47

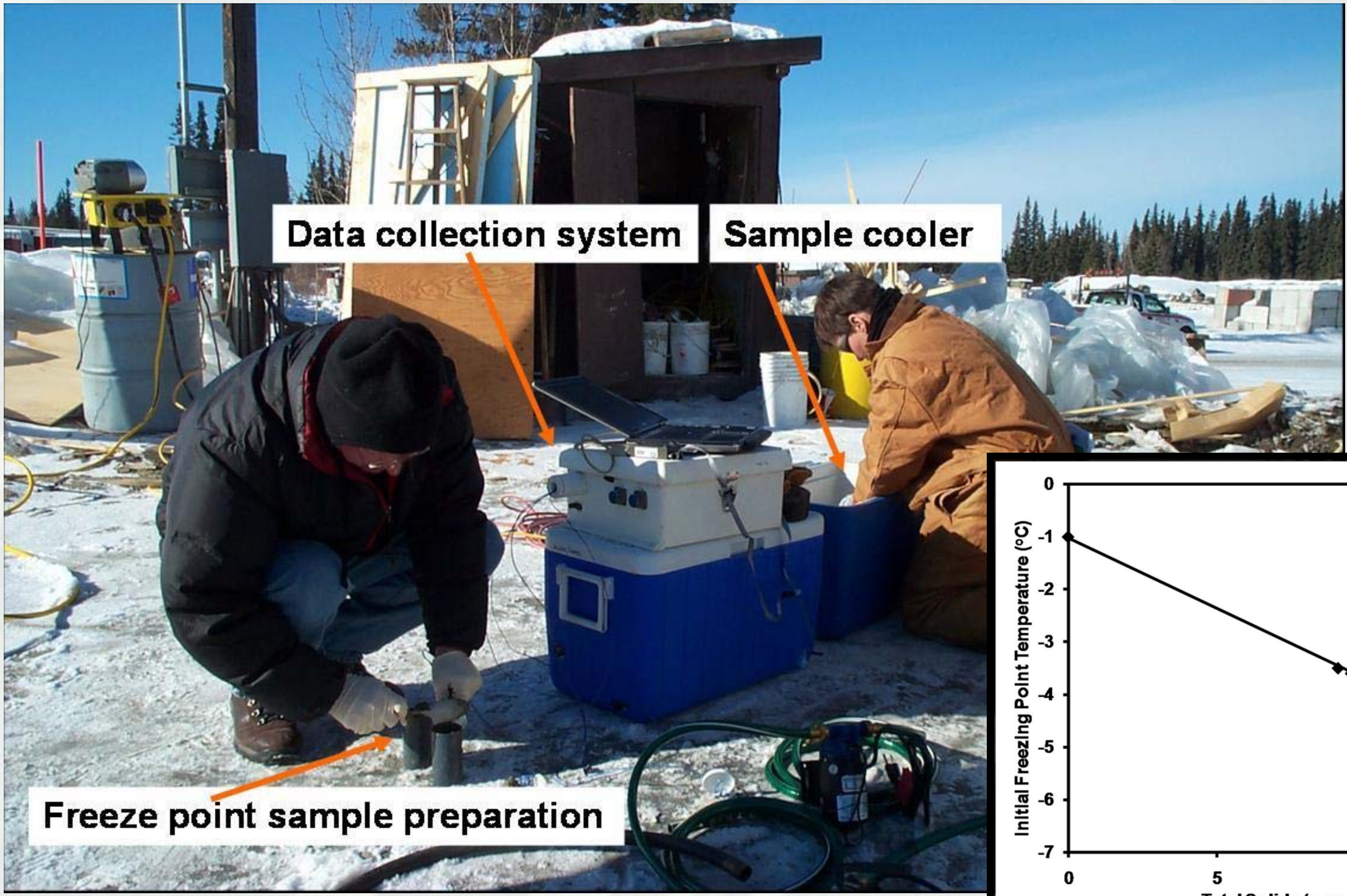
Cement = 658 lb/yd^3 Type I-II

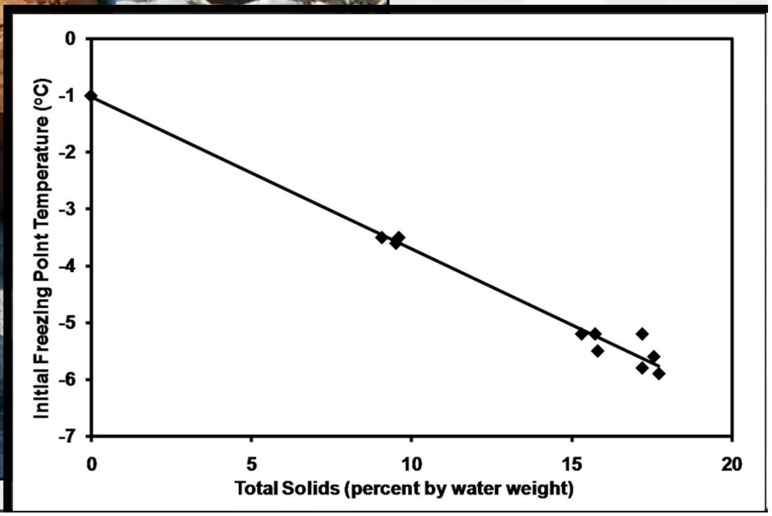
Air content = 5 – 7%

Field Placement

Field Testing

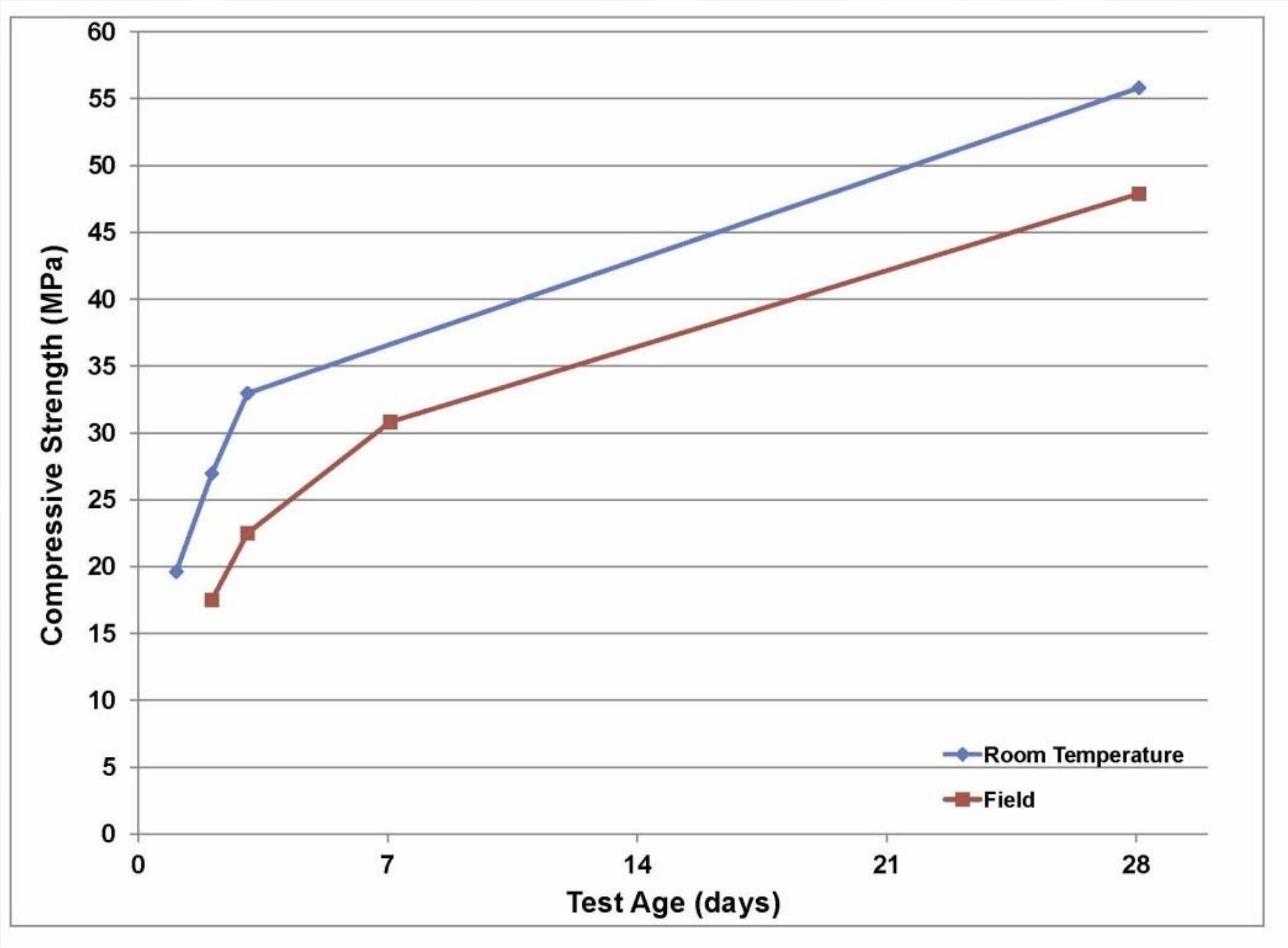
- Measuring initial freezing point temperature
  - Tool to verify water-cement ratio





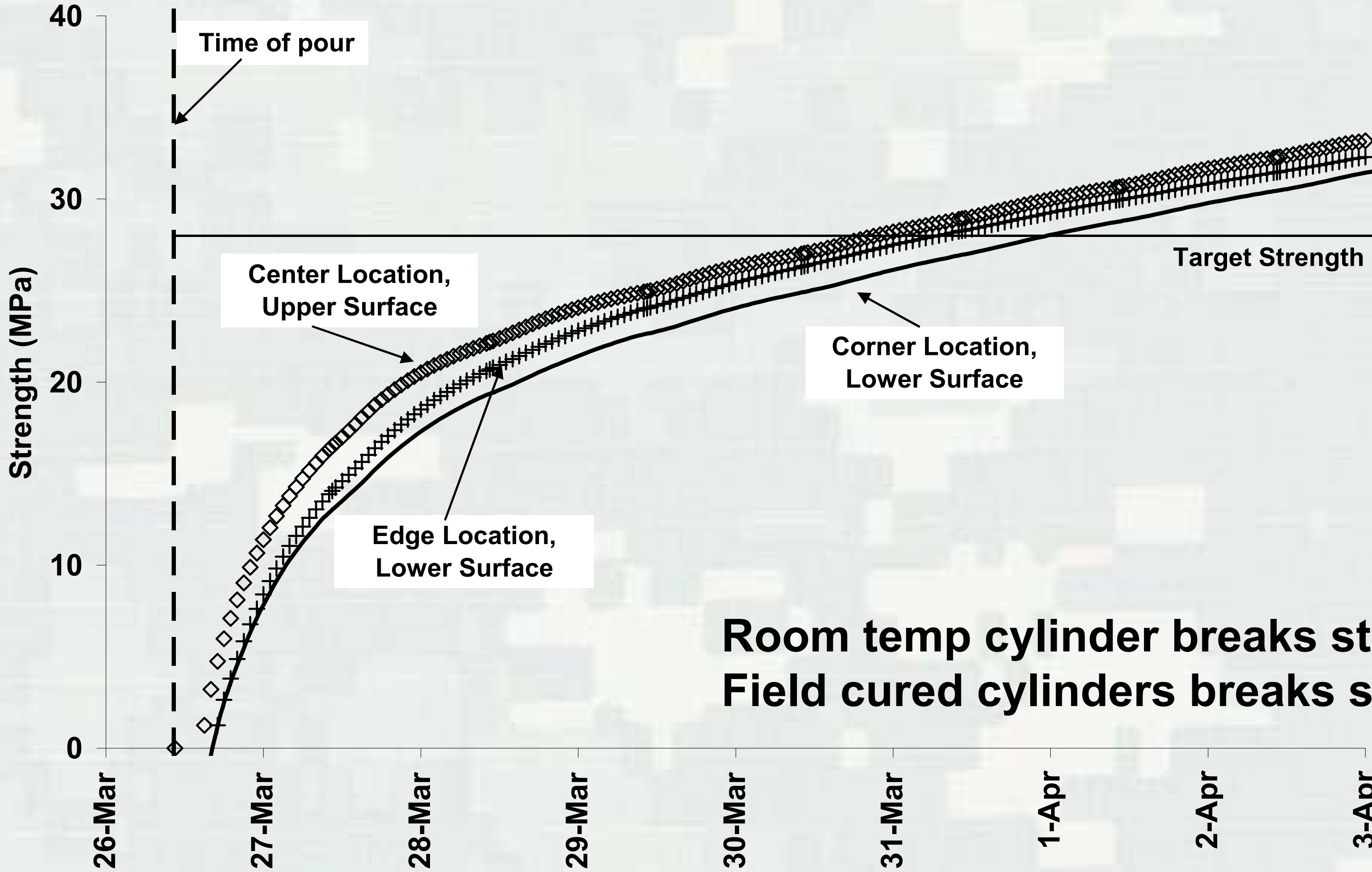
Field Testing

- Compressive strength



Estimating Strength

- Test Section 1



Room temp cylinder breaks start 1 day
Field cured cylinders breaks start 2 days

Field Placement

Conclusions

- Provided a general overview of Cold Weather Admixture Systems
- Provided the background of CWAS development
- Applied the approach in demonstration projects
- Developed tools and guidance to mix, place, and cure concrete at sub-freezing conditions
- Tailor admixture dosage on forecasted weather conditions
- Additional information is available on our website
- Shown the feasibility of using this approach to extend the concrete season
- *Putting It Into Practice!*

Questions?

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