Investigation of Cold Weather Concrete Long Term Durability

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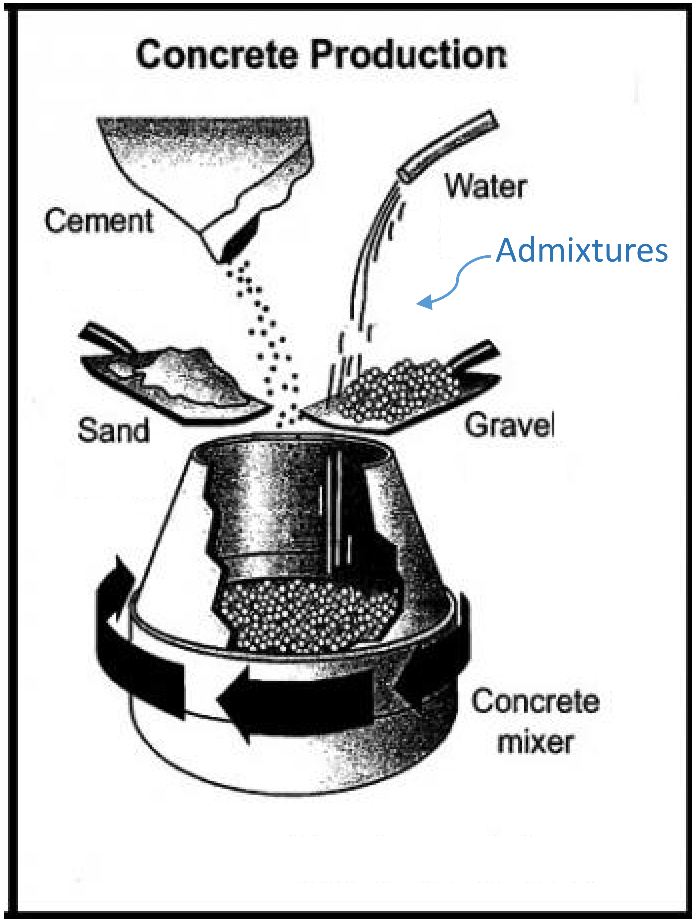
Outline

- Definitions
- Background
- Problem
- Field Investigations
- Data
- Future Work
- Questions & Feedback



Definitions



Concrete: Mixture of cement, aggregates, water, and admixtures

Admixtures: Water Reducer, Corrosion Inhibitor, Air Entrainer, Accelerator, Retarder

CWAS: Cold Weather Admixture Systems

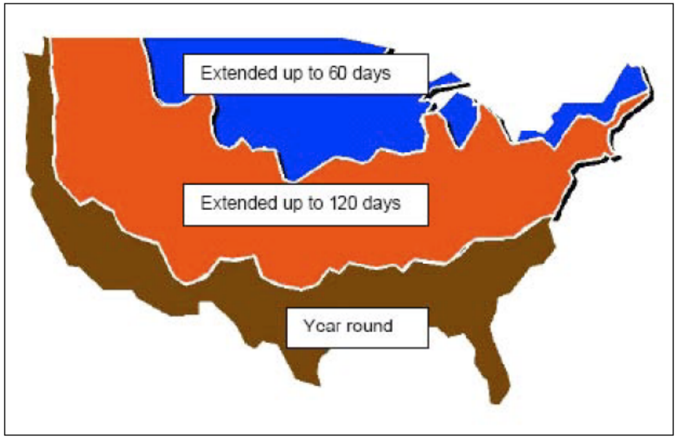
Cold Weather: 40°F (4°C) – ACI 306, UFC 3-250-04, UFC 3-260-02

Background

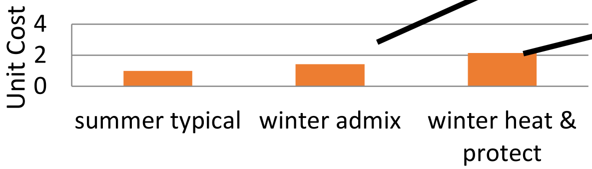
Cold Weather Admixture Systems (CWAS) is a relatively new approach to cold weather concreting that incorporates suites of commercially available chemical admixtures in concrete mixes. When used in combination, these admixtures **depress the freezing point** of the concrete mix water, protect the fresh concrete down to an internal temperature of -5°C, and <u>promote early strength gain</u>.

Benefits

- Structurally comparable to conventional concrete
- Resistant to freezing and thawing
- Predictable to formulate and test for quality
- Cost-competitive with conventional concrete
- Capable of preventing frost damage during cure



Concrete Construction Costs Relative to Summer Typical



Factors: cost of admix(s), ship & handling

Factors: cost of heating, protection, ↓ worker productivity

Problem Definition

Project Objective: quantify the **long term durability** of cold weather admixture systems (CWAS) used in concrete pavements

- Durability – anecdotal vs empirical and materials chemistry-based understanding
- several test sites demonstrate long term durability benefits of CWAS concrete; insufficient empirical evidence nor materials chemistry analyses and rationale to ***comprehensively explain, predict*** CWAS concrete's ***durability*** (resistance to cracking, spalling, other failures caused by repeated freeze-thaw cycles).
- Current standard methods fail to ***predict*** concrete pavements **durability** (ASTM C666)
- Current standard methods governing cold weather concrete admixtures are **vague** and not easily implementable (ASTM C1622)

Field Investigation – Lebanon, NH

Inspected October 2011

Trues Brook Bridge– Poured December 2002

- 34 m of curbing and abutment

Control (October 2011)

Admixture Amended (October 2011)

Field Investigation – Hanover, NH

Inspected: 5-6 April, 2018

Danielle Kennedy, Charles Smith, and Andrew Bernier

CRREL campus concrete bin – Poured February 1994

- 2 Slabs and 3 Walls with 2 CWAS mixtures
- 6 Cores drilled from each slab

Field Investigation – Sault Ste. Marie, MI

Inspected: 19-26 April, 2018

Danielle Kennedy, Charles Smith, Dr. Charles “Chuck” Korhonen

Soo Locks – Poured March 1994

- 6 on grade reinforced concrete slabs
- Bordering water source (St. Mary’s River)

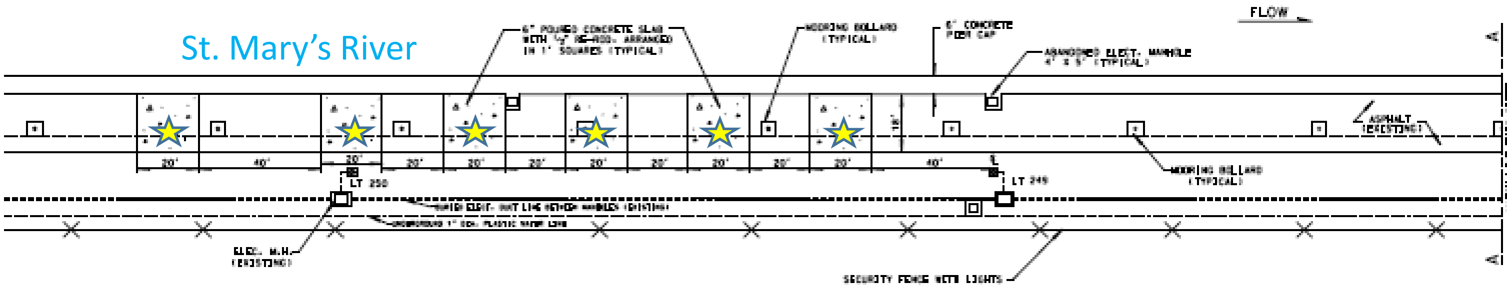
March, 1994

April, 2018

Field Investigation – Sault Ste. Marie, MI

Tasks Completed Onsite

- Visual Inspection



Admixture Amended Concrete

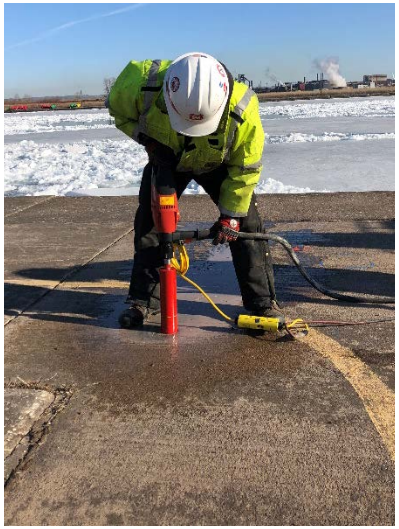
Control Concrete

Field Investigation – Sault Ste. Marie, MI

Tasks Completed Onsite

- Ground Penetrating Radar
- Ultrasonic Pulse Velocity
- Light Weight Deflectometer
- Coring



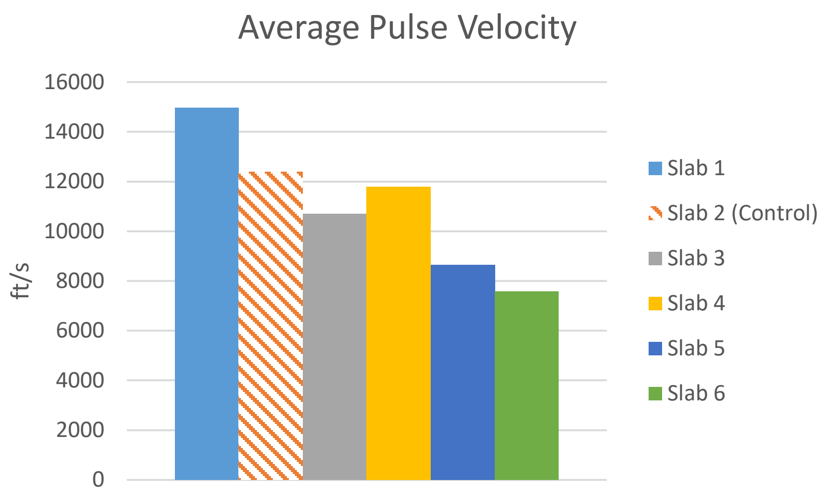



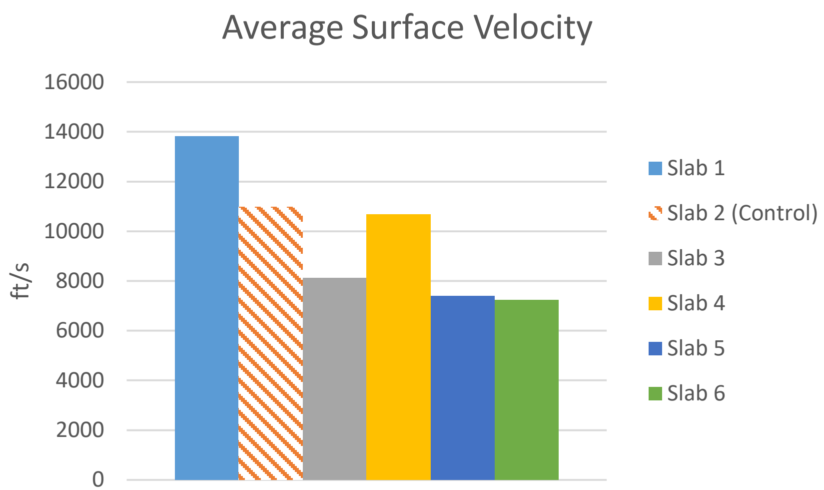
Field Investigation – Sault Ste. Marie, MI

	EY11 Low Slab 1	Control Slab 2	EY11 High Slab 3	Pozzutec 20 Slab 4	Polarset Slab 5	DP Slab 6
Avg. Pulse Velocity (ft/s)	14966	*12385*	10693	11787	8646	7586
Avg. Surface Velocity (ft/s)	13807	*10978*	8113	10681	7393	7243
Elastic Modulus of middle (ksi)	2670	*3517*	6400	6985	4871	1292
Strength Cores (psi) July 1994	7339	*6773*	8050	7840		6672
Hardened Density (lb/ft^3) July 1994	145	*144*	143	146		138
Unit Weight (lb/ft^3)	144	*144*	142	145	143	135

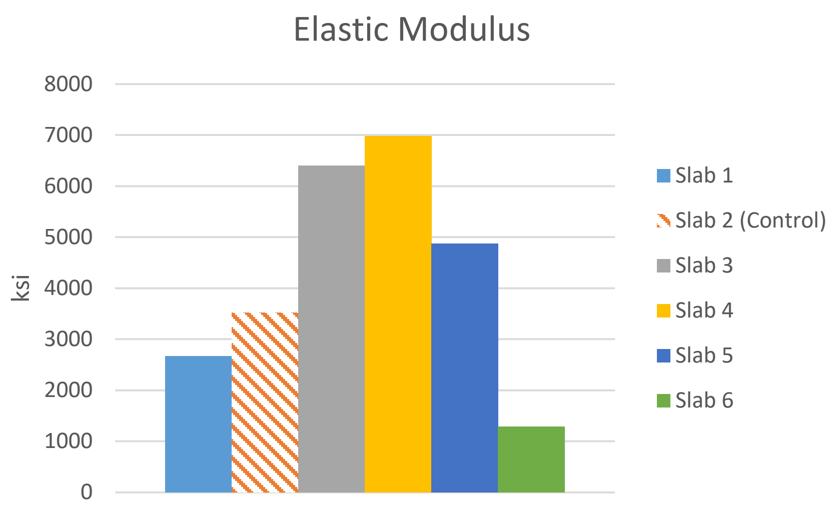
Values highlighted in green are at least 75% of the control value*

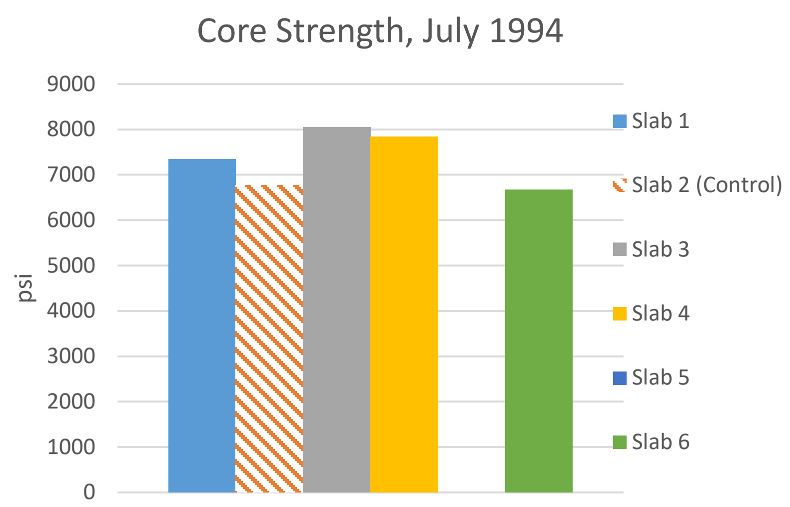
Field Investigation – Sault Ste. Marie, MI



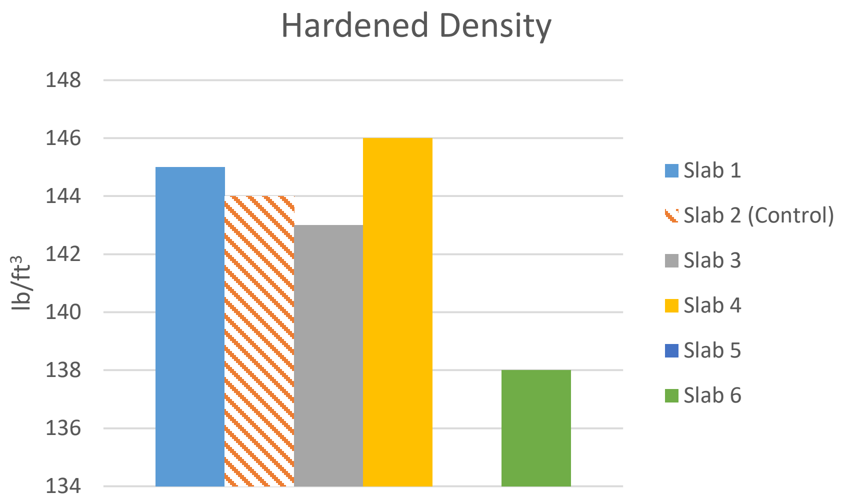


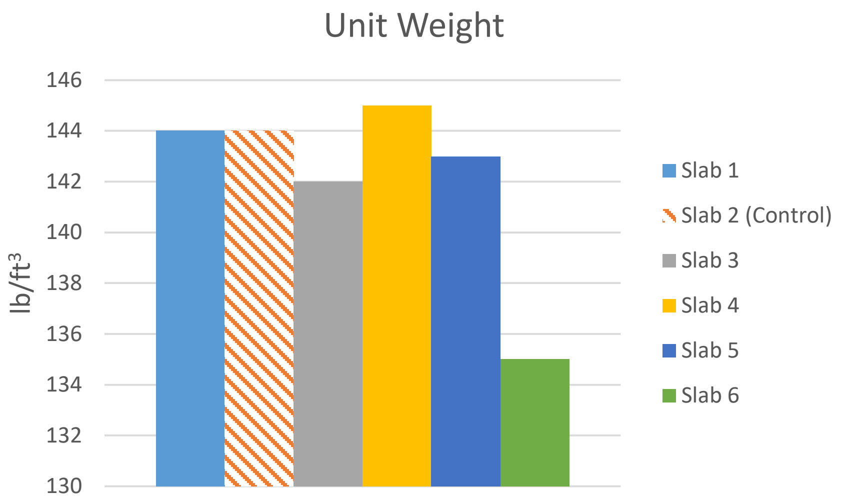
Field Investigation – Sault Ste. Marie, MI





Field Investigation – Sault Ste. Marie, MI





Future Work

Laboratory Investigations:

- Pore Water
  - Chemical analysis
- Hardened properties
  - Strength, Modulus, Air

Field Inspections:

Cold Climate Housing Research Center – Fairbanks, AK

- 2 slabs on grade – Poured March, 2007

Ft. Wainwright – Fairbanks, AK

- 5 slabs on grade – Poured March, 2008

New Specimens

- Placing on Treat Island, ME

Specification Development

Material Characterization

Compress concrete samples with ~ 350,000 pounds

Collect pore water and analyze

- Ion Chromatography (IC)
- Inductively Coupled Plasma Mass Spectrometry (ICP-MS)
- pH

Crush concrete and analyze

- Scanning Electron Microscopy (SEM)
- X-Ray Diffraction (XRD)
- X-Ray Fluorescence (XRF)
- Thermogravimetric Analysis (TGA)

Field Investigation - Fairbanks, AK

17-27 July, 2018

Site 1: Ft. Wainwright – Poured March 2008

- 5 Reinforced cold weather concrete slabs on grade

Varying admixture dosages

Site 2: Cold Climate Housing Research Center – Poured March 2007

- 2 Reinforced cold weather concrete slabs on grade

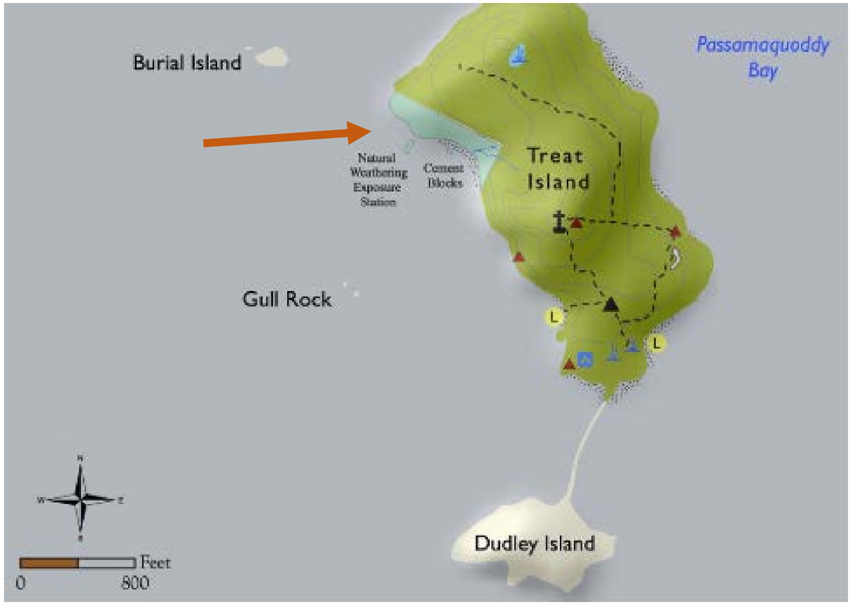
Field Specimens – Environmental Testing

Creating specimens with varying mixture designs

- Admixture dosages
- Water to cement ratio
- Plastic properties

Placing at Treat Island, Maine in August, 2018

- Specimens will endure natural weather exposure for future years
- Inspections annually to determine durability



Conclusion

- Concreting in Freezing Temperatures
- Field Inspections
  - Nondestructive Testing
  - Destructive Testing
- Concrete Analysis
  - Pore Water
  - Strength
  - Modulus
  - SEM, XRD, XRF
- Phase 2
  - Laboratory testing, specification development





Questions & Feedback