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Tech Brief:

Cold Weather Concreting for Transportation Agencies

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16. Abstract *An overview of the cold weather admixture systems (CWAS) methodology to mix, place, and cure concrete at or below freezing air temperatures. Benefits, temperature limitations, and applications of CWAS are presented. Adoption of the specifications are recommended. Considerations for contracting, familiarizing the contractors prior to construction, and lessons learned from the demonstration are discussed.*		
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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The Challenge

Placing concrete during periods of cold weather requires extra precautions to protect freshly placed concrete from the damaging effects of freezing temperatures. When temperatures are sufficiently cold, the free water in early-age concrete freezes into ice, causing an increase in volume that damages concrete that hasn't yet gained adequate strength. This can result in loss of compressive strength, cracking, or surface spalling. All too often, projects requiring concrete placement during cold temperatures cannot remain on schedule or come to a halt and cannot be completed. Existing cold weather concrete construction specifications necessitate special planning to address these seasonal variations and call for protective measures, such as temporary heated enclosures, to maintain a suitable curing environment. These additional measures require extra time, money, and energy to supply a heated environment. All of these factors push concrete construction to the warmer times of the year, during which Federal Land Management Agencies (FLMAs) are likely to see increased visitor attendance that adds to congestion.

The Solution

Cold Weather Admixture Systems (CWAS), or *antifreeze* concreting, is an approach to design, mix, transport, place, and cure concrete at or below freezing temperatures without the need for external heat. The chemical admixtures used to place concrete at lower temperatures are cost competitive with conventional winter concreting. Using the antifreeze concreting approach, unlike the conventional method of cold weather concreting, protects freshly placed concrete from freezing down to an internal concrete temperature of 23°F, lower than the current air temperature threshold of 40°F. Below 40°F, hydration in normal concrete is considered insignificant (American Concrete Institute [ACI] 2010), whereas in antifreeze concrete, hydration continues to an internal concrete temperature of 23°F, even when the air temperature is much colder.

Antifreeze concreting extends the concrete construction season because it allows concrete placement later in the fall and earlier in the spring, increasing scheduling alternatives, and enabling timely or even early project completion. It is possible to place antifreeze concrete during the winter, even when air temperatures are near or below freezing.

Although Portland cement concrete (PCC) plays a secondary role in FLMA and other agency transportation infrastructure compared to facilities and dams, PCC is definitely used often enough to make a significant difference when placing concrete. Cold weather concreting is essentially a technology requiring little increased investment, yet it opens up an entire world of possibilities when it comes to scheduling and extending the construction season.

In this demonstration, project teams placed antifreeze concrete at three field sites during the 2017 winter season. The field projects consisted of a concrete pad construction, a sidewalk replacement, and a sign base replacement. As with any construction project, the agencies used existing contracting procedures to select local contractors to perform the construction at each field site and worked with local concrete suppliers. Stakeholders for each field site met for a project kick-off meeting to familiarize themselves with the project and specifications of the antifreeze concrete approach.

The U.S. Army Engineer Research and Development Center Cold Regions Research and Engineering Laboratory (CRREL) developed the technology of designing, mixing, placing, finishing, and curing concrete at or below freezing air temperatures. This technology is made possible by combining specific amounts of particular chemical admixtures that allow PCC to cure when its internal temperature is below freezing. In previous field demonstrations for transportation-related structures, CWAS was used to construct and repair a bridge curbing, a bridge footing, a pavement intersection (Korhonen et al. 2004), an airfield (Korhonen and Seman 2005), and a communications hardstand (Barna et al. 2010). Other features for which CWAS may apply include parking lot sections, foundations, and floors.

To enhance the desired properties, it has become common practice to include chemical admixtures in concrete mixtures. CWAS uses this same idea to achieve concrete capable of resisting freezing air temperatures. The admixtures are commercially available. Within the mixture, these admixture combinations accelerate cement hydration (ASTM International 2006) and reduce the quantity of water needing protection (Korhonen et al. 2004). This is achieved by adding combinations of chemical admixtures to the concrete mixture that depress the temperature of the initial freezing point of the mix water (see Figure 1). The chemical admixtures are commercially available and are listed in the supplemental specification.

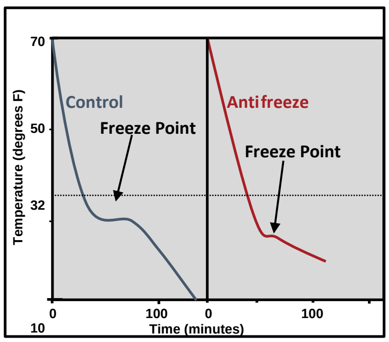


Figure 1. Comparison of initial freezing point temperature for ordinary and antifreeze concrete mixtures (Barna and Korhonen 2012).

CWAS or antifreeze concrete is:

- 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.

The Journey

The selected concrete structures and field sites for this project appear in Table 1.

Table 1. Concrete Structures, Locations, and Agencies

Site No.	Concrete Structure	Site, Location	FLMA
1	Sidewalk replacement (22 yd^3)	Green Mountain National Forest, Rochester Ranger Station, Rochester, VT	U.S. Department of Agriculture (USDA) Forest Service
2	Concrete pad (5 yd^3)	North Hartland Lake, North Hartland, VT	U.S. Army Corps of Engineers
3	Sign base replacement (8 yd^3)	Saint Croix Island International Historic Site, Calais, ME	National Park Service

The agencies used existing contracting procedures for contractor bid package submission. As part of the bid package, the project teams prepared antifreeze concrete specifications for contractors to follow during project construction.

For each field site, representatives from the USDA Forest Service (i.e., the lead FLMA) met with the construction contractor, the material supplier, the project contract supervisor, and the CRREL project team for a project kick-off meeting. As with any pre-construction meeting, this allowed time to view the project location and address aspects of the antifreeze concrete mixture design and construction process following the draft specifications. CRREL tested the initial freezing point temperature of the design mixtures to ensure it met the specification requirements. This demonstration used two concrete mixtures, with the Rochester and North Hartland Lake sites using the same proportions and chemical admixtures. Table 2 lists the general ingredients in the two mixtures.

Prior to construction, workers mixed a trial batch of the design concrete mixture at the batch plant. The trial included simulating the transit time between the plant and the job site by slowly agitating the mix and then releasing it into forms. Because antifreeze concreting is different than conventional cold weather concreting methods, this step familiarized the batch plant and construction contractor with this approach. As antifreeze concrete becomes more widely adopted and material suppliers become more accustomed to the mixtures, this step may not be needed in the future.

Within days of the trial batch, the actual construction occurred during a suitable weather window. Similar to any concrete construction site, a construction contractor designated a materials-testing laboratory, which conducted a standard QC/QA assessment of the material properties of the fresh concrete (i.e., concrete temperature, slump, and air content) and fabricated samples for compressive strength gain testing.

Table 2. Concrete mix components and proportions.

Concrete Mix Components	Rochester and North Hartland Vermont	Calais Maine
Cement (lbs) Type I/II	660	660
Aggregate (lbs) 3/4 inch	1,760	1,640
Sand (lbs)	1,317	1,152
Water (lbs)	267	311.3
Water-cement ratio	0.405	0.47
Air Content	4.5 – 7.0%	6%
Slump (inches)	3 - 5	5
Chemical Admixtures (oz/yd^3)		
Air Entertainment	3	3.3
Full-Range Water Reducer	99	
Mid Range Water Reducer		59.4
High Range Water Reducer		9.9
Retarder	19.8	
Corrosion Inhibitor	768	768
Accelerator	594	660
Workability-Retaining Admixture*	39.6	

Field construction occurred during the 2017 winter months at the Green Mountain National Forest Ranger Station (in January), North Hartland Lake (in February), and Saint Croix Historic Site (in March), when air temperatures at the time of construction were 29°F, 15°F, and 37°F, respectively. Air temperatures within the first 24 hours following placement dropped below 25°F at all three sites. Antifreeze concrete has been successfully placed under similar conditions at previous field sites, and although this was a good test of the material, such frigid conditions are not a requirement. When protective measures are initially called for during the cooler portions of the year, using antifreeze concrete can extend the concrete constructure season. This highlights the flexibility of using antifreeze concrete to tailor the concrete mixture to the forecasted weather conditions.

The CRREL project team instrumented each field site with sensors to measure the temperature of the ambient air and the concrete within the structure. To record the measurements, the team connected instrumentation wires to a data collection system that recorded temperature readings every 15 minutes. The instrumentation was part of the Coordinated Technology Implementation Program demonstration to show the actual temperature within the concrete as well as the air temperature.

Rochester Ranger Station. The sidewalk replacement at the Green Mountain National Forest Ranger Station at the Rochester District Office took place in January 2017. Weather conditions at the time of construction, as noted by the material testing laboratory, consisted of partly cloudy skies with an air temperature of 29°F and a constant wind of 25–30 mph. Figure 2 shows the Rochester Ranger Station site prior to (left) and during (right) construction. Transit time from the concrete batch plant in West Lebanon, NH, to the site was approximately 1 hour. Given the lengthy transit time, workers dosed some of the admixtures at the plant and dosed the remainder on site. Once the truck arrived on site, contractors added the remaining admixtures to the mixture, tested the air content and slump, and discharged the mix into the forms. Because there is no bleed water, finishing began immediately after placement. The mixture was stiff, but the contractor was able to put a broom finish on the surface and then covered the concrete with a vapor barrier. Figure 3 shows the recorded temperatures for the ambient air and internal concrete as it cured. Note that the air temperature remained below freezing for nearly 2 days after concrete placement.

Figure 2. Rochester Ranger Station sidewalk before construction (left) and during construction (right). Photos provided by the U.S. Forest Service.

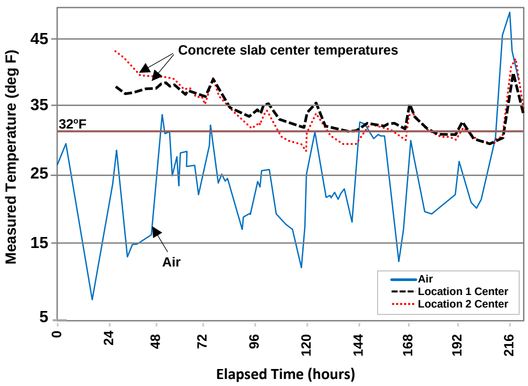


Figure 3. Ambient air and internal concrete temperature measurements for the sidewalk replacement at the Rochester Ranger Station, Rochester, VT.

North Hartland Lake Site. The contractor constructed a concrete pad measuring 10 feet x 10 feet x 8 inches adjacent to a maintenance shed (see Figure 4). The location was level and covered with a mixture of turf and gravel. During spring thaw periods, the location tended to become muddy due to snow melt. Having a concrete pad would alleviate access issues in this area. At the time of construction, the air temperature was 15°F with sunny skies. The transit time from the batch plant to the site was approximately 30 minutes. The contractor placed the concrete in a monolithic pour and covered it with a vapor barrier.

Figure 4. North Hartland Lake Site before (left) and after (right) construction. Photos provided by the U.S. Forest Service.

Saint Croix Island Historic Site. The concrete sign base adjacent to the main entrance of the historic site was in need of replacement (see Figure 5, left photo). Following the installation of piles and setup of the formwork, the cold weather concrete was placed in March 2017 (see Figure 5, right photo). At the time of concrete placement, the air temperature was 37°F, with partly cloudy skies and blustery winds. The concrete supplier was approximately 1 hour away in Machias, ME. The dimensions of the sign base were 16 feet 6 inches x 3 feet x 4 feet, and it was located on a steep slope. Within the base, steel reinforcement and posts were driven to secure the sign columns and attach to the anchor bolts. The concrete was placed in a monolithic pour from a single truck.

After the arrival of the truck on site, workers made final adjustments to the concrete mixture, and tested the slump and the air content. Then, they placed the concrete into the formwork, finished the top, and covered with a vapor barrier.

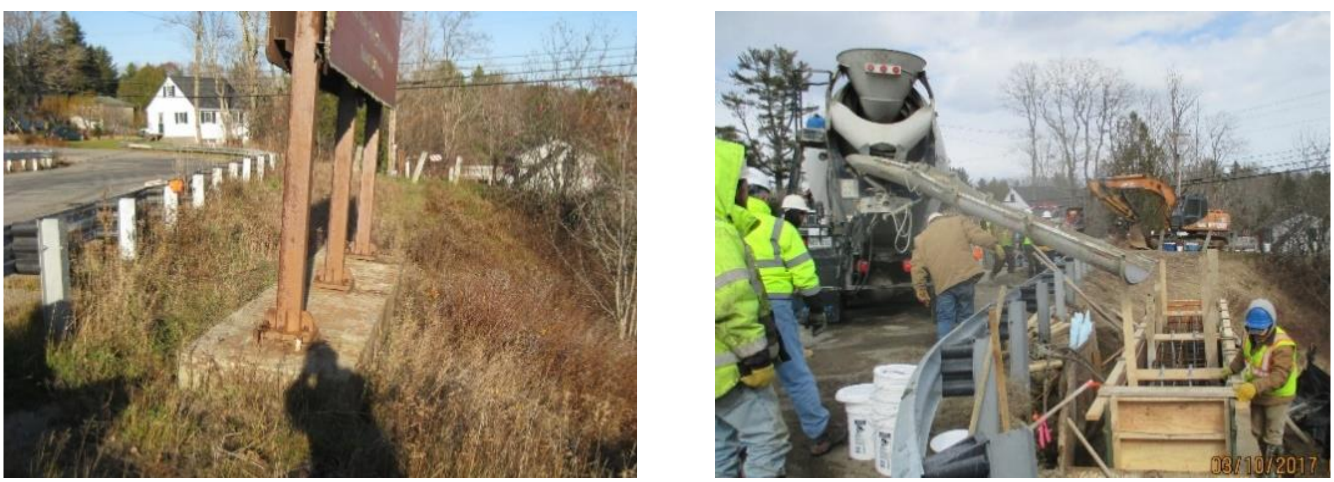
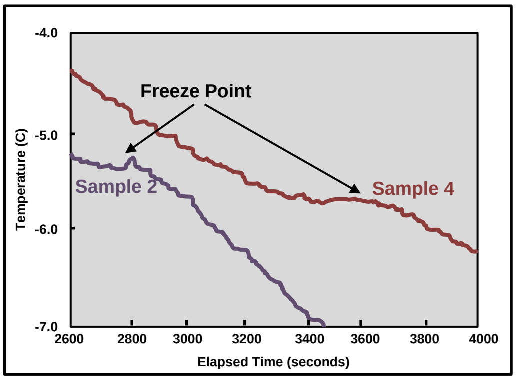


Figure 5. Saint Croix Island Historic Site sign base replacement before construction (left) and during construction (right). Photos provided by the U.S. Forest Service.

The Results

The ability to verify the properties of an antifreeze concrete mixture in the field during construction is an important tool to ensure adequate freeze protection and strength.

During the routine quality control activities at the construction site, CRREL measured the initial freezing point temperature. The initial freezing point temperature is used as a verification tool to ensure that the concrete mixture meets the intended design and that it has the level of freeze protection necessary for the forecasted weather conditions. The measured freezing point temperature curves for the Rochester Ranger Station and the Saint Croix sites are shown in Figure 6. The concrete mixtures used at both sites, which consisted of chemical admixtures from different manufacturers (i.e., Rochester used W.R. Grace & Co.-Conn.; Saint Croix used Master Builders), met the freeze protection criteria. (The freezing point temperature curve for the North Hartland Lake site was omitted because the concrete it received was provided by the same supplier and it used the same mixture as that of the Rochester Ranger Station.)



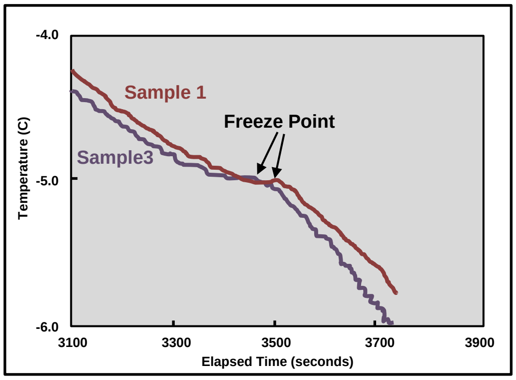


Figure 6. Initial freezing point temperature measurements for the Rochester Ranger Station sidewalk repair (left) and Saint Croix sign base (right).

After construction, all test sites experienced seasonal variations over a full year and the project teams revisited the sites during the summer of 2018. The teams did not observe any damage from freeze-thaw exposure at any of the sites. Figure 7 shows the condition of the concrete at the Rochester Ranger Station and Saint Croix Historic sites. The project team recognizes that the follow-up visits occurred early and recommends periodic follow-up visits to monitor the structures.

Figure 7. Rochester Ranger Station sidewalk repair (left) and Saint Croix sign base (right) after post-freezing winter season. Photos provided by U.S. Forest Service.

Curing of compressive strength test cylinders occurred at room temperature and under field conditions. Figure 8 shows results of compressive strength testing for the Rochester Ranger Station sidewalk replacement (left) and for the Saint Croix Historic Site (right). For the room temperature curing condition, the target compressive strength of 3,000 psi was reached within 2 days for both sites. For the field curing condition at both sites, the target compressive strength was achieved in 7 days or less. For comparison, Figure 8 also shows the estimated strength gain of a control concrete mixture using Type I cement and cured continuously at the temperature threshold of 40°F (based on ACI 306). The strength gain of the antifreeze concrete surpassed the control.

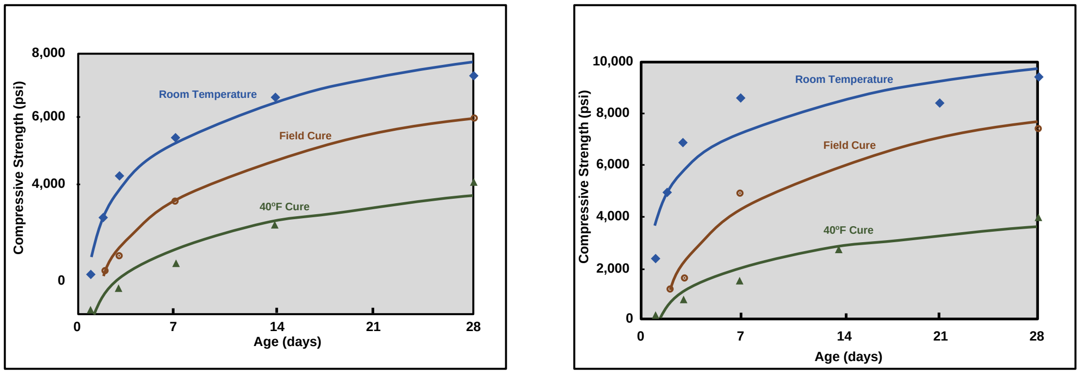


Figure 8. Compressive strength gain with age at room temperature and during field curing conditions for the Rochester Ranger Station sidewalk replacement (left) and Saint Croix Historic Site sign base replacement (right). Included is a comparison of strength gain for normal concrete cured at continuous 40°F (based on ACI 306).

Antifreeze concrete is cost competitive with the conventional winter concrete method (see Figure 9) because the need to construct and heat a temporary enclosure is not needed. However, antifreeze concrete is still more expensive than summer concrete. This cost difference can be overcome through additional savings, such as the inclusion of cement replacement materials and further widespread adoption of the antifreeze concrete approach. Currently, antifreeze concrete formulations are based on Type I, Type II, or Type I/II cements and do not incorporate pozzolans, which are an industry standard.

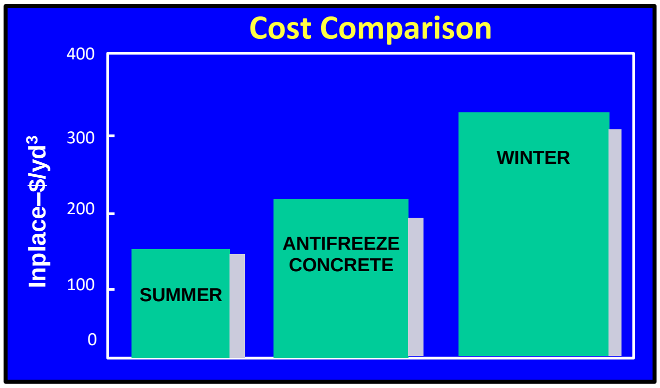


Figure 9. Cost comparison.

The Implementation

The application of this technology through construction demonstrations has shown the capabilities of placing and curing concrete at freezing and sub-freezing air temperatures. Lessons learned from this demonstration include factoring in transit time, familiarizing the contractor and material supplier on this method, and recording ambient air temperatures. The transit time from the batch plant to the Rochester, VT, and Calais, ME, sites was approximately 60 minutes. Dosing the chemical admixtures at the job site helped offset the lengthy travel time. Familiarity with creating the mixture at the concrete plant, and how it performs on the job site after required additions, is essential. As with any new method, experience is gained through increased use. Finally, temperature conditions applicable for antifreeze concrete may be more moderate than those encountered at the construction sites. This demonstration showed the ability to construct during periods of sub-freezing air temperatures; however, this technology may be used to maintain construction tempo when protective measures would otherwise be required.

CRREL developed the tools to design, mix, transport, place, and cure concrete at air temperatures below freezing. To clarify the antifreeze concrete approach, the resource *Supplemental Specification for Cold Weather Concrete* was prepared and followed to complement the guidance in the primary reference, U.S. Department of Transportation, Federal Highway Administration, Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-14. The bid package included *Supplemental Specification for Cold Weather Concrete*, Section 699 – Minor Concrete Structures (Cold Weather Concrete) and is described in Table 3.

Table 3. Contents of *Supplemental Specification for Cold Weather Concrete*, Section 699 – Minor Concrete Structures (Cold Weather Concrete).

Section	Subject
699.01	Description
699.02	Material
699.02	Hydraulic cement
699.02	Air-entraining admixtures
699.02	Coarse aggregate for concrete
699.02	Fine aggregate for concrete
699.02	Chemical admixtures
699.02	Water
699.02	Pozzolans
699.02	Reinforcing fibers
699.02	Curing material
699.02	Sealants, fillers, and seals
699.02	Reinforcing steel
699.03	Construction requirements
699.03	Concrete composition
699.04	General
699.05	Transit time
699.06	Placing concrete
699.07	Curing concrete

Section	Subject
699.08	Acceptance
699.09	Measurement
699.10	Payment
699.11	Initial freezing point temperature measurement for fresh concrete

To use antifreeze concrete mixtures, complete the following steps:

1. Begin with a concrete mixture for standard weight concrete that is workable and meets the following criteria. (An existing mixture can be modified.)
    a. Cement (i.e., Type I, Type II, or Type I/II) with content between 661 and 802 lb/yd^3.
    b. Aggregates are unheated. Measure the moisture content of each. Coarse aggregate maximum size is less than 1.5 inches.
    c. Regular water to achieve a maximum water-cement ratio of 0.45; cold (or unheated) water is best with a maximum concrete temperature of 50°F.
    d. Air-entraining admixtures are used.
    e. Chemical admixtures are listed in Table 699-2 *Supplemental Specification* (see Appendix A). These admixture types and dosages have performed well and achieved a 23°F initial freezing point temperature.
2. Mix trial batches to establish the optimum admixture dosing sequence for workability properties (i.e., target slump, air content, and working time) and to verify that the mixture produces a 23°F initial freezing point temperature.
3. Use the admixture dosing method that best works with the transit time. For transit times of up to 1 hour, it is recommended to delay adding the accelerating admixture (either some or all) until on site.
4. Test for the following at the job site:
    a. Air content (target 6% ±1.5%).
    b. Slump (target 5 inches maximum).
    c. Mix temperature (50°F maximum).
    d. Initial freezing point temperature (23°F).
    e. Adjust the mixture as necessary to meet criteria. For freeze protection, antifreeze concrete mixtures are sensitive to water content where excess quantities of water will increase the freeze protection temperature.
    f. Antifreeze concrete mixtures can lose slump quickly and be somewhat sticky to finish.
5. Place antifreeze concrete on an ice- and snow-free substrate. It is acceptable if it is frozen.
6. Begin concrete finishing immediately following consolidation and leveling.

7. Securely cover the concrete with a vapor barrier to protect against drying. A plastic sheet or curing compound is sufficient. For plastic, create a smooth wrinkle-free surface. Secure the vapor barrier to prevent movement and wrinkling from wind. In the case of protruding metal, cover with insulation to prevent a heat sink situation with the surrounding concrete. Also, the ends of metal form ties should be insulated.
8. For saw joints, test cuts should leave a sharp, clean edge.

The Wrap-Up

This project successfully constructed three structures using the CWAS (or the antifreeze concrete) approach. At each field site, the air temperatures at the time of placement and during curing were near or below freezing. Artificial heating was not used; instead, workers added combinations of commercially available chemical admixtures to the concrete mixtures to depress the freezing point of the mix water and accelerate cement hydration.

The agencies used existing procedures for contractor bid package submission. While adoption of the antifreeze concrete approach has been gradual, demonstration projects such as these generate more familiarization with the technology.

The *Supplemental Specification for Cold Weather Concrete*, Section 699 – Minor Concrete Structures (Cold Weather Concrete) provides details on implementing antifreeze concrete. Review and adoption of this specification is recommended.

Q&A

Why should I be interested in cold-weather concreting?

When outdoor temperatures dip below 40°F, freshly placed concrete sets up more slowly, takes longer to finish, and gains strength less rapidly. Below 32°F, there is the danger of freezing, which can result in the concrete being destroyed. The only currently approved method for concreting during cold weather is to use thermal protection, such as insulation blankets and heated enclosures, which can more than double the cost of a concreting job. Past estimates have valued that $800 million are spent every year in the United States to protect fresh concrete against freezing. Because it is difficult to thermally protect pavements, virtually no paving is done at temperatures below 40°F. Something needs to be done to allow PCC to be placed in cold weather without the need for heat.

What types of chemical admixtures are used and how are the dosages determined?

The *Supplemental Specification for Cold Weather Concrete* was prepared to augment FP-14 and give specific steps on antifreeze concrete production and placement. The resource gives chemical admixture types and dosage rates from two major manufacturers. All chemical admixtures are commercially available and have met the requirements of ASTM C 494 (Standard Specification for Chemical Admixtures for Concrete).

Are there strength limitations to using the antifreeze concrete approach?

The antifreeze concrete approach, at present, has been used to modify conventional concrete mixtures using Type I/II cement attaining 28-day strengths of 4,000 psi. Future research should consider other types of concrete mixtures that are gaining acceptance.

My agency does very little concreting. Why should I bother?

Consider this an investment that offers another approach for the projects that you do encounter. For example, the product of this project will allow you to handle emergency repairs in cold weather, which is when things typically break down.

My agency currently concretes year-round. Why do I need this new technology?

This technology will allow you to do the same work without the need to build temporary temperature controlling structures or devices around new concrete during freezing weather.

Must the substrate be heated before I place the concrete?

No, provided that the substrate is free of ice and snow and that the substrate temperature is not below the freezing point of the fresh concrete.

Our area is not very cold. Would this admixture be of any benefit to us?

The 23°F capability of the proposed admixture is actually very important to you—it allows concreting year-round, 24 hours a day, without heat.

My area is very cold. Would a 23°F capability do me any good?

The 23°F refers to the internal temperature of the concrete, not that of the ambient air. So, depending on the mass of your concrete, the air temperature could be significantly below 23°F. For example, a few years ago, the Office of Federal Lands Highway placed a 23°F concrete prototype on a frozen substrate while the air temperature was approximately 14°F. The concrete was 6 inches thick and the mix temperature was 38°F. The concrete, at its coldest point, never cooled below 24°F, and it gained strength as rapidly as normal concrete, cured at nearly 50°F. Thicker sections, obviously, could have resisted even colder weather.

The impact on the length of the construction season of a 23°F concrete is the extension of the season by up to 2 months in weather similar to northern Minnesota.

Future work aims to develop admixtures that protect concrete at 14°F or lower. The 23°F was chosen to give everyone a chance to become familiar with this new approach to cold weather concreting without having to work too far outside current practice.

More Information:

https://www.erdc.usace.army.mil/Media/Fact-Sheets/Fact-Sheet-Article-View/Article/476772/cold-weather-admixture-systems/or internet search terms: CRREL antifreeze concrete

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