Concrete in Practice

What, why & how?

NRMCA

CIP 27 - Cold Weather Concreting

WHAT is Cold Weather?

Cold weather is defined as a period when the average daily temperature falls below 40°F [4°C] for more than three successive days. These conditions warrant special precautions when placing, finishing, curing and protecting concrete against the effects of cold weather. Since weather conditions can change rapidly in the winter months, good concrete practices and proper planning are critical.

WHY Consider Cold Weather?

Successful cold-weather concreting requires an understanding of the various factors that affect concrete properties.

In its plastic state, concrete will freeze if its temperature falls below about 25°F [-4°C]. If plastic concrete freezes, its potential strength can be reduced by more than 50% and its durability will be adversely affected. Concrete should be protected from freezing until it attains a minimum compressive strength of 500 psi [3.5 MPa], which is about two days after placement for most concrete maintained at 50°F [10°C].

Low concrete temperature has a major effect on the rate of cement hydration, which results in slower setting and rate of strength gain. A good rule of thumb is that a drop in concrete temperature by 20°F [10°C] will approximately double the setting time. The slower rate of setting and strength gain should be accounted for when scheduling construction operations, such as form removal.

Concrete in contact with water and exposed to cycles of freezing and thawing, even if only during construction, should be air-entrained. Newly placed concrete is saturated with water and should be protected from cycles of freezing and thawing until it has attained a compressive strength of at least 3500 psi [24.0 MPa].

Cement hydration is a chemical reaction that generates heat. Newly placed concrete should be adequately insulated to retain this heat and thereby maintain favorable curing temperatures. Large temperature differences between the surface and the interior of the concrete mass should be prevented as cracking may result when this difference exceeds about 35°F [20°C]. Insulation or protective measures should be gradually removed to avoid thermal shock.

HOW to Place Concrete in Cold Weather?

Recommended concrete temperatures at the time of

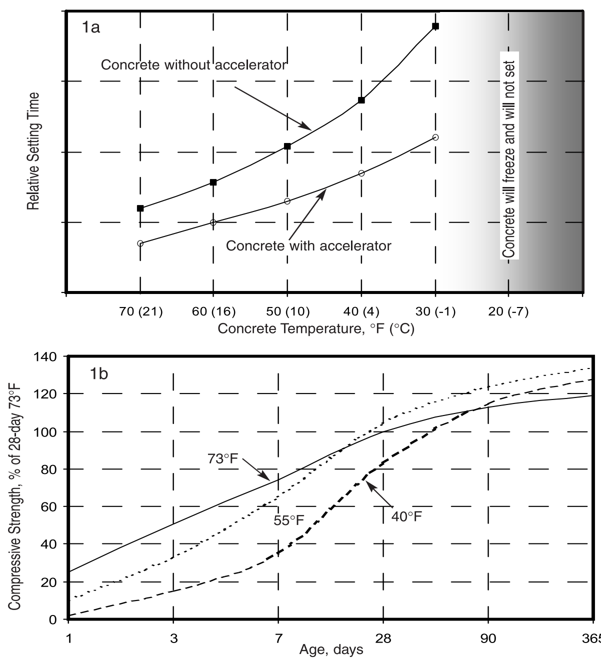

Figure 1 Effect of Temperature on Set Time (1a)

placement are shown below. The ready mixed concrete producer can control concrete temperature by heating the mixing water and/or the aggregates and furnish concrete in accordance with the guidelines in ASTM C 94.

Section Size, minimum dimension, inch [mm]	Concrete temperature as placed
less than 12 [300]	55°F [13°C]
12 - 36 [300 - 900]	50°F [10°C]
36 - 72 [900 - 1800]	45°F [7°C]

Cold weather concrete temperature should not exceed these recommended temperatures by more than 20°F [10°C]. Concrete at a higher temperature requires more mixing water, has a higher rate of slump loss, and is more susceptible to cracking. Placing concrete in cold weather provides the opportunity for better quality, as cooler initial concrete temperature will typically result in higher ultimate strength.

Slower setting time and strength gain of concrete during cold weather typically delays finishing operations and form removal. Chemical admixtures and other modifications to the concrete mixture can accelerate the rate of setting and strength gain. Accelerating chemical admixtures, conforming to

ASTM C 494—Types C (accelerating) and E (water-reducing and accelerating), are commonly used in the winter time. Calcium chloride is a common and effective accelerating admixture, but should not exceed a maximum dosage of 2% by weight of cement. Non-chloride, non-corrosive accelerators should be used for prestressed concrete or when corrosion of steel reinforcement or metal in contact with concrete is a concern. Accelerating admixtures do not prevent concrete from freezing and their use does not preclude the requirements for concrete temperature and appropriate curing and protection from freezing.

Accelerating the rate of set and strength gain can also be accomplished by increasing the amount of portland cement or by using a Type III cement (high early strength). The relative percentage of fly ash or ground slag in the cementitious material component may be reduced in cold weather but this may not be possible if the mixture has been specifically designed for durability. The appropriate decision should afford an economically viable solution with the least impact on the ultimate concrete properties.

Concrete should be placed at the lowest practical slump as this reduces bleeding and setting time. Adding 1 to 2 gallons of water per cubic yard [5 to 10 L/m^3] will delay set time by ½ to 2 hours. Retarded set times will prolong the duration of bleeding. Do not start finishing operations while the concrete continues to bleed as this will result in a weak surface.

Adequate preparations should be made prior to concrete placement. Snow, ice and frost should be removed and the temperature of surfaces and metallic embedments in contact with concrete should be above freezing. This might require insulating or heating subgrades and contact surfaces prior to placement.

Materials and equipment should be in place to protect concrete, both during and after placement, from early age freezing and to retain the heat generated by cement hydration. Insulated blankets and tarps, as well as straw covered with plastic sheets, are commonly used measures. Enclosures and insulated forms may be needed for additional protection depending on ambient conditions. Corners and edges are most susceptible to heat loss and need particular attention. Fossil-fueled heaters in enclosed spaces should be vented for safety reasons and to prevent carbonation of newly placed concrete surfaces, which causes dusting.

The concrete surface should not be allowed to dry out while it is plastic as this causes plastic shrinkage cracks. Subsequently, concrete should be adequately cured. Water curing is not recommended when freezing temperatures are imminent. Use membrane-forming curing compounds or impervious paper and plastic sheets for concrete slabs.

Forming materials, except for metals, serve to maintain and evenly distribute heat, thereby providing adequate protection in moderately cold weather. With extremely cold temperatures, insulating blankets or insulated forms should be used, especially for thin sections. Forms should not be stripped for 1 to 7 days depending on the setting characteristics, ambient conditions and anticipated loading on the structure. Field-cured cylinders or nondestructive methods should be used to estimate in-place concrete strength prior to stripping forms or applying loads. Field-cured cylinders should not be used for quality assurance.

Special care should be taken with concrete test specimens used for acceptance of concrete. Cylinders should be stored in insulated boxes, which may need temperature controls, to insure that they are cured at 60°F to 80°F [16°C to 27°C] for the first 24 to 48 hours. A minimum/maximum thermometer should be placed in the curing box to maintain a temperature record.

References

1. *Cold Weather Concreting*, ACI 306R, American Concrete Institute, Farmington Hills, MI.
2. *Design and Control of Concrete Mixtures*, Portland Cement Association, Skokie, IL.
3. ASTM C94 *Standard Specification for Ready Mixed Concrete*, ASTM, West Conshohocken, PA.
4. ASTM C 31 *Making and Curing Concrete Test Specimens in the Field*, ASTM, West Conshohocken, PA.
5. *Cold Weather Ready Mixed Concrete*, NRMCA Pub 130, NRMCA, Silver Spring, MD.
6. *Cold-Weather Finishing*, Concrete Construction, November 1993

Cold Weather Concreting Guidelines

1. Use air-entrained concrete when exposure to moisture and freezing and thawing conditions are expected.
2. Keep surfaces in contact with concrete free of ice and snow and at a temperature above freezing prior to placement.
3. Place and maintain concrete at the recommended temperature.
4. Place concrete at the lowest practical slump.
5. Protect plastic concrete from freezing or drying.
6. Protect concrete from early-age freezing and thawing cycles until it has attained adequate strength.
7. Limit rapid temperature changes when protective measures are removed.