COLD WEATHER CONCRETE GUIDE FOR STRUCTURAL CONCRETE

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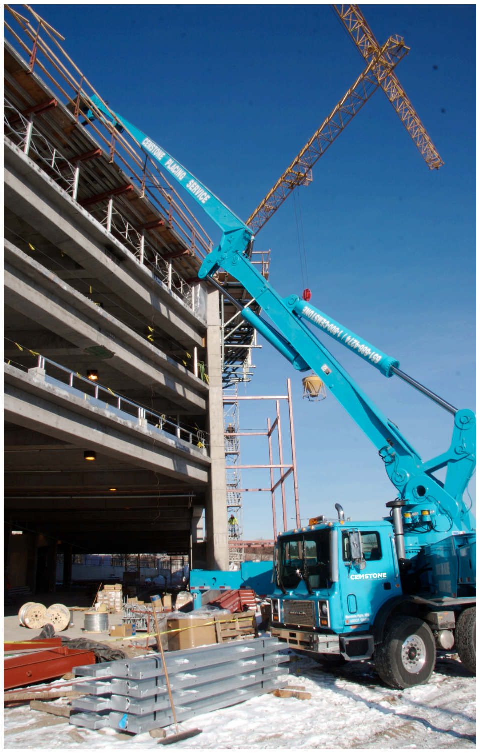
The American Concrete Institute (ACI) 306R-16 "Guide to Cold Weather Concreting" states that cold weather concreting exists when the air temperature has fallen to or is expected to fall below 40°F during the protection period. The protection period is defined as the amount of time recommended to prevent concrete from being adversely affected by exposure to cold weather during construction.

DEVELOPING A COLD WEATHER CONCRETING PLAN

During the fall and winter seasons, ACI 306R-16 recommends that a cold weather concreting plan be implemented for every concrete placement. The goal of this plan is to prevent the concrete from being adversely affected by exposure to cold weather during construction. The time to accomplish this is called the protection period. The following is a list of principles from ACI 306R-16 that should be considered when developing of a cold weather concrete plan:

- Concrete protected from freezing until it attains a compressive strength of at least 500 psi will not be damaged by exposure to a single freezing-and-thawing cycle (Powers, 1962). At 50°F, most well-proportioned concrete mixtures reach this strength within 48 hours.
- Where a specified concrete strength should be attained in a few days or weeks, planning (including mixture proportion alterations and revisions to construction practice) and protection could be required to maintain the concrete temperature needed to attain the specified strength.
- Except within heated protective enclosures, little or no external supply of moisture is recommended during cold weather curing.
- Under certain conditions, calcium chloride ($CaCl_2$) should not be used to accelerate setting and hardening because of increased chances of corrosion of metals embedded in concrete. The use of non-chloride accelerators can be used in place of $CaCl_2$ admixtures.



ACI 306R-16 lists the following objectives when creating a cold weather concrete plan:

- **Prevent damage to concrete due to freezing at early ages.** See Table 1, Line 1 for the minimum concrete placing temperature.
- **Ensure that the concrete develops the recommended strength for safe removal of formwork.**
- **Maintain curing conditions that foster normal strength development without using water as a curing method.** See Table 1, Lines 2-4. In addition, see Table 2 for the duration of the protection period. If the least dimension of the concrete section is larger than 36 in., see Table 5.1 Lines 2-4 of ACI 306R-16.
- **Limit rapid temperature changes.** Avoid cooling the concrete too quickly and minimize temperature differences between the exterior and interior portions of structural members to reduce the likelihood of cracking which can lead to strength and durability issues. See Table 1, Line 5. If the least dimension of the concrete section is larger than 36 in., see Table 5.1 Line 5 of ACI 306R-16.
- **Provide protection consistent with intended serviceability of the structure.** Surfaces, corners and edges need to be protected from freezing, dehydration, and cracking from overheating due to inadequate protection, improper curing, or careless workmanship.

RECOMMENDED CONCRETE TEMPERATURES & CURING DURATION

Table 1 - Recommended concrete temperatures

Line	Air Temperature	Section Size, minimum dimension	
		<12”	12 to 36”
Line	Air Temperature	Minimum concrete temperature as placed and maintained	
1	-	55°F	50°F
		Minimum concrete temperature as mixed for the indicated air temperature*	
2	Above 30°F	60°F	55°F
3	0 to 30°F	65°F	60°F
4	Below 0°F	70°F	65°F
5		Maximum allowable gradual temperature drop in the first 24 hours after end of protection	
		50°F	40°F

* The contractor is responsible for informing Cemstone dispatch if higher concrete temperatures are needed. Additional costs may apply.

* For colder weather, a greater margin in temperature is provided between concrete as mixed and required minimum temperature of fresh concrete in place.

Note 1: For Line 1, maximum placement temperature is minimum temperature in the table plus 20°F (11°C).

Note 2: For Lines 2-4, maximum temperature is minimum temperature in the table plus 15°F (9°C).

Note 3: For larger section sizes, consult Table 5.1 of ACI 306R-16.

Ref. Table 5.1 ACI 306R-16

Table 2 – Length of protection period for concrete placed during cold weather

Service Condition	Protection period at a minimum temperature indicated in Line 1 of Table 1, days*	
	Normal Set Condition	Accelerated Set Concrete
No load, not exposed	2	1
No load, exposed	3	2
Partial load, exposed	6	4
Full load	Refer to Chapter 8 of ACI 306R-16	

* A day is a 24 hour period.

Ref. Table 7.2 ACI 306R-16

PRE-PLACEMENT, TEMPERATURE, HEATED ENCLOSURES CONCRETE MIXTURE, SLAB FINISHING & CURING

RECOMMENDATIONS

PRE-PLACEMENT

- All formwork and subgrade should be free and clear of snow and ice. The temperature difference of the subgrade and fresh concrete should be no greater than 20°F.
- When temperatures are below 10°F, metallic embeds should be warmed prior to placement. Embeds with larger cross-sections (4 in^2 or greater) should be warmed to at least 32°F.
- Use heated enclosures, insulating blankets, insulation or other acceptable means for warming the subgrade and metallic embeds.

TEMPERATURE

- During the spring and fall, not typically defined as cold weather, protect concrete surfaces from freezing for at least 24 hours or until the minimum compressive strength has been reached. See Tables 1 and 2 for recommended protection temperatures and duration.
- When determining a protection plan, the surface temperature of the concrete is the determining factor regardless of air temperature. Therefore:
  - Monitor the surface temperature of the concrete including corners and edges.
  - Monitor the internal temperature to avoid excessive heating.
  - Record the date and time at regular intervals as well as the maximum and minimum temperatures within a 24-hour period.
- Use concrete maturity to determine the in-place compressive strength.

HEATED ENCLOSURES

- Heated enclosures should be waterproof and strong enough to withstand anticipated winds and snow loads.
- Ensure corners and edges are sealed
- Combustion heaters should be vented to avoid exposing surfaces to carbon dioxide (CO_2). CO_2 exposure can lead to crazing and carbonation.

CONCRETE MIXTURES

- The water-cementitious materials ratio (w/cm) should be not exceed the recommendations within ACI 201.2R. All concrete that is subjected to freeze-thaw cycling while saturated in service should have a w/cm ratio no greater than 0.45.
- Air-entrained concrete should not be specified for hard-trowel slab construction.
- Use accelerating admixtures to increase the rate of hydration. Do not use calcium chloride ($CaCl_2$) containing accelerators or admixtures for concrete containing reinforcing steel as this can lead to corrosion. In addition, $CaCl_2$ admixtures can cause the concrete to darken.
- Accelerating admixtures are not anti-freezing agents.
- Limit the use of supplementary cementing materials (SCMs), i.e. fly ash and slag, when early strength development is required.

SLAB FINISHING

- The use of air-entrained concrete is recommended for members that will be exposed to freeze-thaw cycling, when saturated, during construction after the protection period has ended. This applies to members that may not be exposed to freeze-thaw cycling in service.
- Avoid hard-trowel finishing air-entrained concrete (3% or greater) as this can lead to surface blistering or other surface defects. Therefore, air-entrained concrete should not be specified for hard-trowel slab construction.

CURING

- Upon completion of finishing, concrete should be protected from drying, i.e. evaporation of moisture should be prevented. Subsequently, since fresh concrete is critically saturated, a drying period must occur after curing and before the concrete is exposed to freezing temperatures.
- When the temperature is predicted to be below 32°F, water curing is not recommended unless the concrete can be protected from freezing. If water curing is used, the concrete is likely to be exposed to freezing and thawing while in a nearly saturated condition after protection removal.
- Additional curing is generally not needed after protection is removed so long as the air temperature remains below 50°F and the relative humidity is above 40%.

ACI 306R-16: GUIDE TO COLD WEATHER CONCRETING

10 COLD WEATHER TIPS YOU NEED TO KNOW FOR STRUCTURAL CONCRETE

01

Concrete can resist the effects of one freeze-thaw cycle as long as it is properly air-entrained, not exposed to an external water source, and has reached a **COMPRESSIVE STRENGTH OF 500 psi.** For well-proportioned concrete mixtures, this is typically within 48 hours of placement when the concrete temperature is maintained at 50 °F.

02

Properly air-entrained exterior structural concrete should not be subjected to multiple freezing and thawing cycles in a saturated condition before developing a **COMPRESSIVE STRENGTH OF 3,500 psi.** If surface defects are a concern, a compressive strength of 4,500 psi needs to be achieved.

03

FROZEN SUBGRADE can cause the concrete to freeze as well as cause finishing and durability issues. The subgrade should be (a) free of snow and ice and (b) have a temperature no greater than 20°F cooler than the concrete being placed.

04

MINIMIZE RAPID TEMPERATURE CHANGES, particularly before the concrete has developed sufficient strength to withstand thermal stresses, which can cause cracking. Gradually remove insulation and other protection methods so that the surface of the concrete temperature decreases no more than 50°F for concrete 12" or less in thickness in a 24 hour period.

05

The use of **HIGH EARLY STRENGTH CONCRETE OR ACCELERATING CHEMICAL ADMIXTURES** is recommended during cooler temperatures to increase the speed of hydration and mitigate free water from freezing. Avoid using calcium chloride as an accelerator if the concrete contains steel reinforcement. Accelerating admixtures must not be used as a substitute for proper curing and frost protection.

06

TEST CYLINDERS for normal strength concrete must be cured according to ASTM C 31 which specifies an initial curing temperature of 60 to 80 °F Cure boxes, blankets or other curing methods must be used in order to comply with ASTM specifications. ASTM C 31 also requires that cylinders must be initially cured in an environment free of evaporation and be stored for no longer than 48 hours prior to being taken to the laboratory for final curing and testing.

07

DO NOT USE UNVENTED HEATERS: Carbon dioxide from unvented fossil fuel heaters can cause carbonation of the concrete. Carbonation can result in craze cracking and a soft, chalky surface that will dust under traffic.

08

Allow ample time for **BLEED WATER** to dissipate before concrete finishing. Trapping or finishing bleed water into the concrete can cause higher water/cementitious materials ratios at the surface and may lead to scaling and/or blistering.

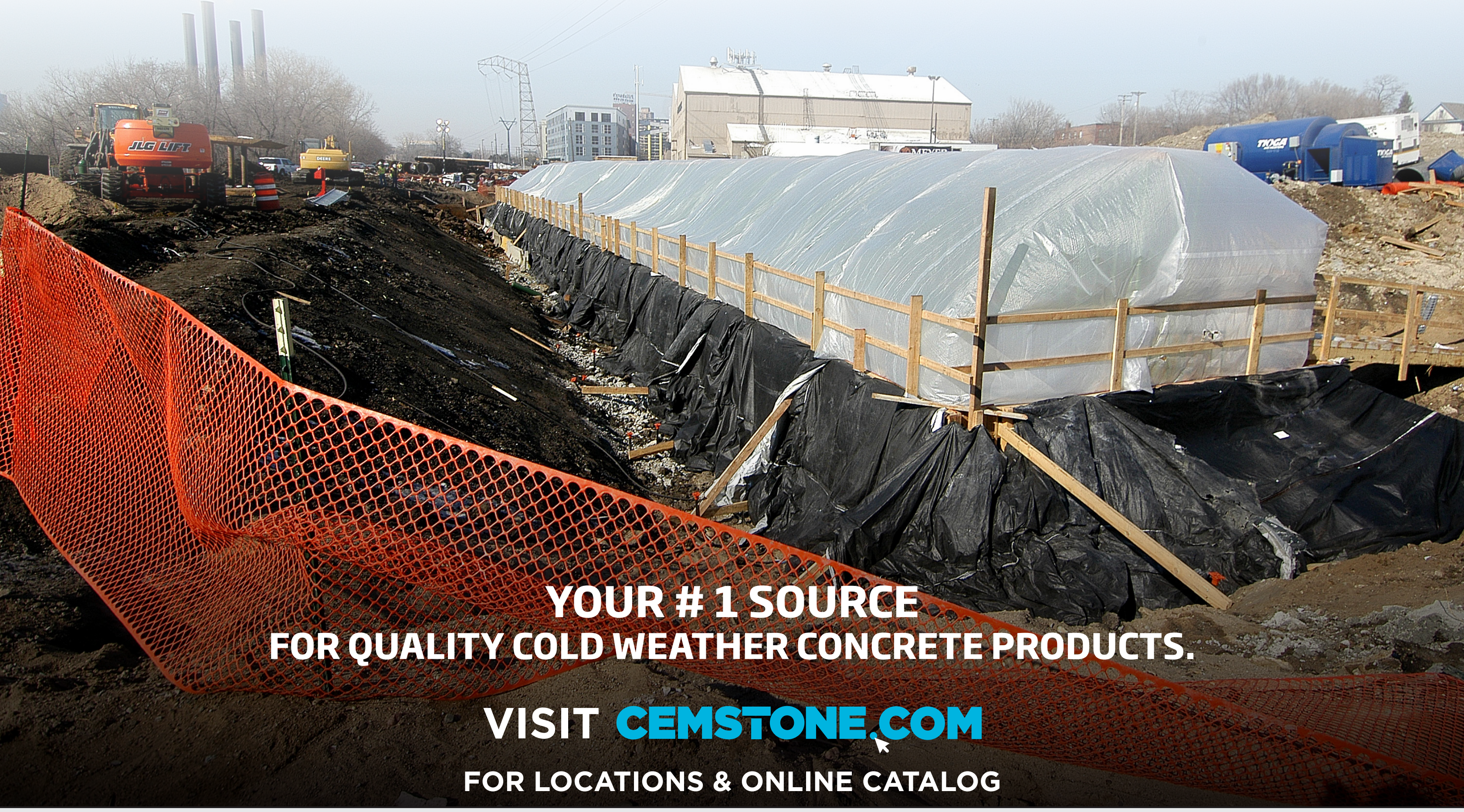
09

PROPER CURING procedures must be followed immediately after finishing is completed, which includes maintaining proper moisture and temperature conditions.

10

MONITOR CONCRETE TEMPERATURES at concrete corners and edges as they are vulnerable to freezing as temperatures are usually more difficult to maintain in these locations.

CEMSTONE SUPPLY



Cemstone Companies are not responsible for concrete failures due to improper cold weather plans, improper placing practices, incorrect mix design selection, inadequate protection, improper curing and/or inadequate maintenance. Please consult Cemstone's Exterior Maintenance Guideline for recommendations on maintaining exterior concrete. For more information on cold weather concreting practices, a copy of ACI 306R-16 is available for purchase at concrete.org. If you have any questions or concerns about a mix design for your project, coarse aggregate selection or admixture packages, please contact your Cemstone Account Representative.

REFERENCE

American Concrete Institute (ACI)
306-16 Guide to Cold Weather Concreting