Successful

COLD WEATHER CONCRETING

COLD WEATHER can lead to many problems in mixing, placing, setting time (see Table 1), and curing of concrete that can have an adverse effect on its properties and service life. This guide has been developed by Master Builders, Inc. to assist the entire construction team (owners, specifiers, contractors, and ready mixed concrete producers) in the design, manufacture, delivery, placement and curing of quality concrete in COLD WEATHER.

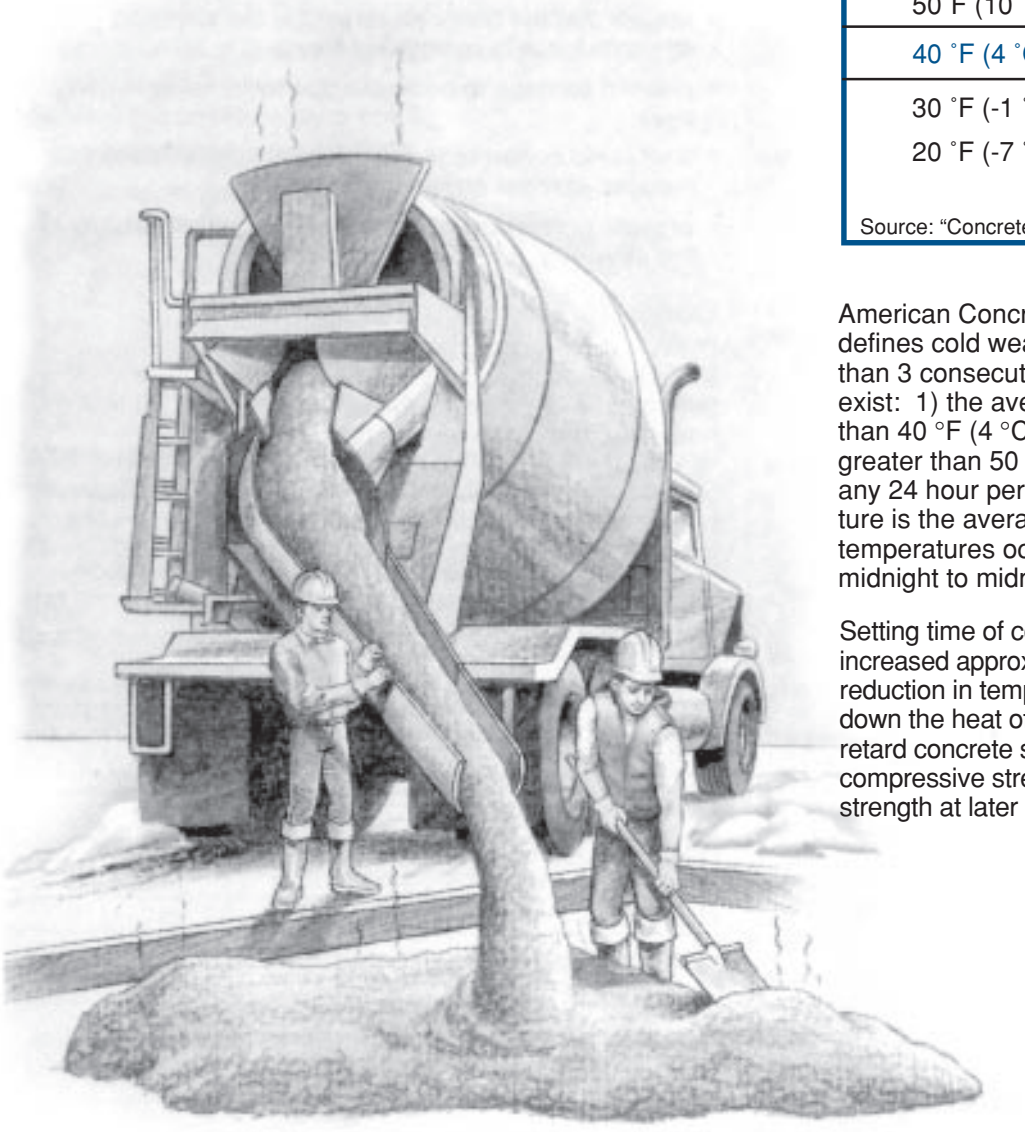


Table 1
Setting Time of Concrete at Various Temperatures

Temperature	Approximate Setting Time
70 ˚F (21 ˚C)	6 Hours
60 ˚F (16 ˚C)	8 Hours
50˚F (10 ˚C)	11 Hours
40 ˚F (4 ˚C)	14 Hours
30 ˚F (-1 ˚C)	19 Hours
20 ˚F (-7 ˚C)	Set does not occur - concrete will freeze

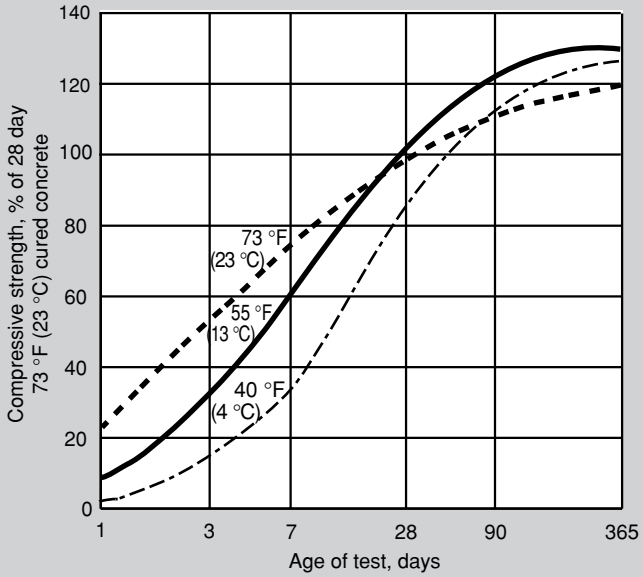
Source: “Concrete Construction”, March,1990

American Concrete Institute (ACI) Committee 306 defines cold weather as a period when, for more than 3 consecutive days, the following conditions exist: 1) the average daily air temperature is less than 40 °F (4 °C) and 2) the air temperature is not greater than 50 °F (10 °C) for more than one-half of any 24 hour period. The average daily air temperature is the average of the highest and the lowest temperatures occurring during the period from midnight to midnight.

Setting time of concrete as shown in Table 1 is increased approximately one-third for each 10 °F (5 °C) reduction in temperature. Low temperatures slow down the heat of hydration process and signficantly retard concrete setting time, which results in reduced compressive strength at early ages, and increased strength at later ages (see Figure 1).

degussa.
Construction Chemicals

Figure 1
Effect of Low Temperature on Concrete Compressive Strength



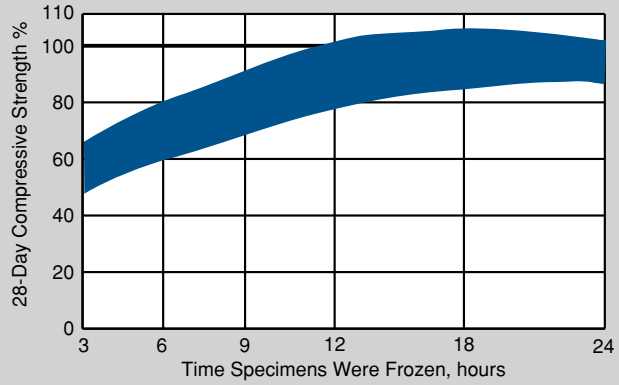
Source: PCA, "Design and Control of Concrete Mixtures"

The benefical impact that low temperatures can have on hardened concrete properties is recognized by ACI Committee 306, and in the ACI 306R report on "Cold Weather Concreting" which states: "One should take advantage of the opportunities provided by cold weather to place low temperature concrete. Concrete that is placed at low temperatures [40 to 55˚F (5 to 13˚C)] is protected against freezing and receives long-time curing, thus developing a higher ultimate strength and greater durability. It is less subject to thermal cracking than similar concrete placed at higher temperatures."

In sub-freezing weather conditions, setting time, strength development and durability characteristics of concrete that is not protected will be severely affected.
For example, concrete:

- **should not exceed the water-cement ratio limits recommended in ACI 201.2R-92, "Guide to Durable Concrete"**
- **exposed to cycles of freezing and thawing while in a saturated condition or in service, should be properly air-entrained (see ACI 201. 2R-92).**
- **in the plastic state will freeze when the mix temperature falls below 29 °F (-2 °C), and is left undisturbed for sufficient time for ice to form. Once ice has formed, normal hydration will not occur and concrete setting time will be seriously impaired.**
- **that has frozen can experience up to a 50% loss in compressive strength at 28 days (see Figure 2).**
- **that is protected from freezing until it has attained a compressive strength of at least 500 psi (3.5 MPa) will not be damaged by exposure to a single freezing cycle.**
- **should not be allowed to freeze and thaw in a saturated condition before developing a compressive strength of 3,500 psi (24 MPa).**

Figure 2
Effect of Frozen Concrete on 28-Day Compressive Strength



Source: ACI Publication SP-39, "Behavior of Concrete Under Temperature Extremes"

There are established cold weather concreting practices that will ensure satisfactory concrete performance. The objectives of these practices are to:

- **maintain curing conditions that foster normal strength development**
- **assure that the concrete develops the required strength for safe removal of forms**
- **prevent damage to concrete due to freezing at early ages**
- **limit rapid concrete temperature changes to withstand induced thermal stresses**
- **provide protection with the intended serviceability of the structure**

Concrete Temperature Control

During cold weather, the concrete mixing temperature should be controlled so that when the concrete is placed, its temperature is not below the values shown in Table 2 for normal weight concrete.

Table 2
Recommended Concrete Temperatures

Line	Air Temperature	Section size, minimum dimension, in. (mm) <12 in. (300 mm)	Section size, minimum dimension, in. (mm) 12-36 in. (300-900 mm)
Minimum concrete temperature as placed and maintained			
1	–	55 °F (13 °C)	50 °F (10 °C)
Minimum concrete temperature as mixed for indicated air temperature*			
2	Above 30 °F (-1 °C)	60 °F (16 °C)	55 °F (13 °C)
3	0 to 30 °F (-18 ° to-1 °C)	65 °F (18 °C)	60 °F (16 °C)
4	Below 0 °F (-18 °C)	70 °F (21 °C)	65 °F (18 °C)
Maximum allowable gradual temperature drop in first 24 hr after end of protection			
5	–	50 °F (10 °C)	40 °F (4 °C)

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

Source: ACI 306R-88, "Cold Weather Concreting"

The temperature of concrete at the time of placement should always be near the minimum temperatures given in Table 2. Placement temperatures should not be higher than these minimum values by more than 20 °F (11 °C).

High concrete temperatures do not offer significantly longer protection time against freezing because heat loss is more rapid when concrete temperatures are higher than ambient temperatures. High concrete temperatures require more mixing water to attain a given slump, increase the rate of slump loss and thermal shrinkage, as well as the possibility of plastic shrinkage cracking, because moisture loss through evaporation is greater.

Concrete temperature at the time of mixing is influenced by temperature, specific heat and quantity of its ingredients. The approximate temperature of concrete can be calculated from the following equation:

$$T = \frac{0.22\,(TaWa + TcWc) + TwWw + TwaWwa}{0.22\,(Wa + Wc) + Ww + Wwa}$$

where T = temperature of freshly-mixed concrete
Ta,Tc,Tw, Twa = temperature of aggregates, cement added mixing water, and free water on aggregates, respectively.

Wa,Wc,Ww, Wwa = weight of aggregates, cement added mixing water and free water on aggregates respectively.

The temperature of concrete can be increased 1 °F (0.5 °C) by increasing:

- **cement temperature by 8 °F (4 °C)**
- **water temperature by 4 °F (2 °C)**
- **aggregate temperature by 2 °F (1 °C)**

Of all concrete-making materials, water is the easiest and most practical to heat. The weight of aggregates and cement in a typical cold weather mix is much greater than the weight of water. However, water can store five (5) times as much heat as can solid materials of the same weight.

Concrete Materials

The use of faster setting cements may improve the rate of hardening characteristics of concrete in cold weather. A 10 °F (5 °C) to 15 °F (8 °C) temperature rise per 100 lb (45 kg) of cement occurs from cement hydration. The temperature increase from cement hydration is directly proportional to its cement content.

Type III (high early strength) cement can be used to achieve faster setting time and higher early strength. The principal advantages from Type III cement occur during the first 7 days.

Fly ash and other pozzolans and ground granulated blast-furnace slag are used as partial replacements for portland cement. These materials can be used with accelerating admixtures to obtain desired concrete performance in cold weather concreting.

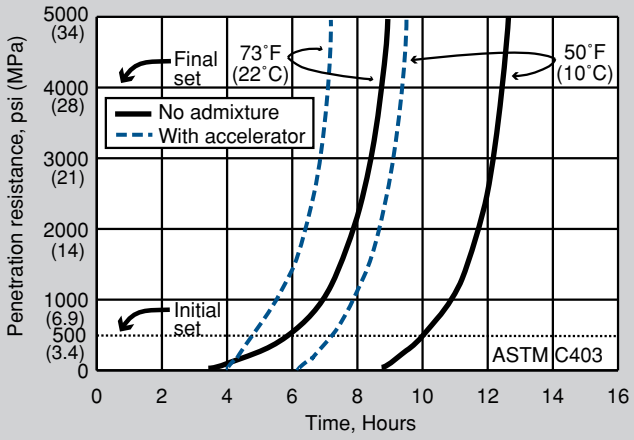
The requirements for good results in cold weather concrete placing and curing are basically no different than that for other seasons. Concrete should be placed where it is to remain and in shallow layers to allow adequate vibration; use wind breaks, cure and protect from moisture loss and freezing.

Chemical Admixtures

Chemical admixtures conforming to ASTM C 494 Types C, accelerating, and E, water-reducing and accelerating; are beneficial for concrete placed during cold weather. Benefits obtained from these admixtures include:

- **lower water demand-minimum 5%**
- **improved workability during placing**
- **faster rate of setting time (See Figure 3)**
- **increased early compressive strength**
- **earlier stripping and reuse of forms**

Figure 3
Effect of Concrete Temperature and Accelerator on Setting Time



Source: Master Builders, Inc.

Master Builders, Inc. offers a complete family of accelerating admixtures (chloride-based and non-chloride) that conform to ASTM C 494 requirements.

Typical performance data is as follows:

Table 3
Typical Performance Data
Concrete & Ambient Temperature 50 °F (10 °C)

Product	ASTM C 494 Designation	Dosage fl oz/cwt (mL/100kg)	Setting Time Acceleration vs. Plain Concrete (hr:min)
POZZOLITH 122 HE[1]	C & E	16 (1,040) 32 (2,080)	– 2:45 – 4:15
POZZUTEC 20[2]	C & E	10 (650) 20 (1,300)	– 3:00 – 4:00
POZZOLITH NC 534[3]	C	13 (850) 26 (1,700)	– 3:06 – 4:43

1 POZZOLITH 122 HE is a chloride-based water-reducing and accelerating admixture
2 POZZUTEC 20 is a non-chloride water-reducing and accelerating admixture
3 POZZOLITH NC 534 is a non-chloride accelerating admixture

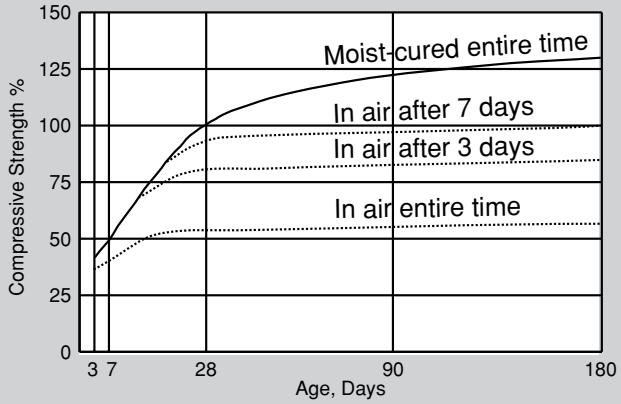
In cold weather, POZZOLITH 122 HE, POZZUTEC 20 and POZZOLITH NC 534 admixtures can be used to obtain accelerated setting time and increased early strength performance. In sub-freezing weather, POZZUTEC 20 admixture can be used to allow concrete placement at ambient temperatures as low as 20 °F (-7 °C) without freezing in its plastic state.

Your Master Builders sale representative will help you select the formulation that best serves your needs.

Curing

Curing is the maintenance of a satisfactory moisture content and temperature in concrete during its early stages so that desired properties may develop (see Figure 4). The minimum recommended curing period is 7 days. Inadequate curing can cause plastic shrinkage cracking and impair strength development and durability.

Figure 4
Effect of Curing on Compressive Strength of Concrete



Source: PCA, "Design and Control of Concrete Mixtures"

Freshly-placed concrete in cold weather must be protected from drying so that adequate hydration can occur. Normally, measures must be taken to prevent evaporation of moisture from concrete.

Methods of curing include the use of:

1. Impervious paper and plastic sheets-white curing sheets.
2. Membrane-forming curing compounds

NOTE: Water curing is not recommended in cold weather.

Control of Plastic Shrinkage Cracking

Polypropylene synthetic fibers (Fibermesh*) reduce formation of plastic settlement and shrinkage cracks. In addition, these fibers:

- **reinforce against plastic shrinkage crack formation**
- **hold cracks together**
- **reinforce against abrasion**
- **are compatible with all surface treatments**
- **will not change required mixture proportions**

Summary

Cold weather concreting difficulties are chiefly caused by low ambient temperatures, and by not protecting concrete from freezing. These conditons adversely affect the quality of concrete since rate of setting is extended, early strength development is reduced and the potential for plastic shrinkage cracking may be increased.

Desired setting time, strength, durability and other properties of concrete can be obtained in cold weather by adhering to the following recommended practices:

- **plan ahead for cold weather concrete placements**
- **use warm concrete ingredients**
- **avoid placing concrete on frozen sub-grade**
- **prevent concrete from freezing**
- **limit rapid concrete temperature changes**

If all precautions and recommended ACI concreting practices are followed, successful cold weather concreting can be achieved.

Master Builders, Inc. has the products and technical expertise to assist the entire construction team (owners, specifiers, contractors, and ready mixed concrete producers) in the design, manufacture, delivery, placement and curing of quality concrete in COLD WEATHER. For further information or assistance, contact your local Master Builders sales representative or our Customer Service Department.

United States
23700 Chagrin Boulevard
Cleveland, Ohio 44122-5554
1-800-MBT-9990
Fax: 216/831-6910

Canada
1800 Clark Blvd.
Brampton, Ontario L6T 4M7
Phone: 800-387-5862
Fax: 905-792-0651

Mexico
Blvd. M. Avila Camacho 80 3er Piso
53390 Naucalpan, Mexico
011-525-557-5544
Fax: 011-525-395-7903

Printed in U.S.A. 6/00
SAP# 112557