Insulating blankets are commonly used on slabs, but may also protect formed surfaces, such as this. To be effective, insulation must be kept in close contact with the concrete or surface of the forms.

Cold-Weather Concreting

Protect wet concrete against freezing, and keep it warm until it reaches the desired strength

by Frank Randall

Cold weather makes special problems for concrete placement, especially when temperatures are below freezing. As the temperature drops, the chemical process that hardens concrete slows down. At lower temperatures, concrete sets up more slowly and takes longer to reach a given strength level. If it freezes at an early age, strength loss, increased permeability, and reduced resistance to weathering can result.

To guard against these problems, cold weather concreting practices should:

- prevent damage caused by freezing at early ages
- protect concrete until it reaches necessary strength levels
- allow concrete to cool gradually when protection is removed so that a rapid temperature drop doesn't cause it to crack

To prevent early-freezing damage, the amount of water in the concrete must be reduced before the concrete is exposed to cold weather. This is accomplished by curing the concrete without adding more water. During hydration, internal water-tilled voids are partially emptied as mix water combines with cement. When the concrete reaches a compressive strength of about 500 psi, the water in the voids will be reduced to a safe level. Most properly proportioned concretes placed at 50°F and kept warm will reach 500 psi by the end of the second day after placing. To further protect against cold-weather damage, air-entrained concrete should be used even if the concrete won't be exposed to the weather after the structure is completed.

Table 1 shows how many days air-entrained concrete should be protected. These short periods are allowable only if (1) there is sufficient curing afterwards, to develop the required design strength, and (2) the concrete does not freeze in a saturated condition.

When structures will be fully loaded soon after placing in cold weather, the concrete should be protected until it reaches the required strength. In this case, the formwork should be removed only when the concrete's in-place strength is sufficient—not after some arbitrary time duration. In-place strength can be estimated by testing field-cured cylinders, by maturity tests (relating field-curing temperatures and time to the strength of cylinders cured under standard conditions), or by nondestructive testing of the in-place concrete. Maturity tests and nondestructive in-place tests are considered to be more reliable than results from testing field-cured cylinders.

Good information can be found in *Cold Weather Concreting, ACI 306R-78 (Rev. 1983),* available from the American Concrete Institute, Box 19150, Detroit, Ml, 48219. The publication is a guide for all phases of winter concreting but is not intended for use as a job specification.

Planning

Cold weather is defined as a period when the mean daily temperature drops below 40°F for more than three successive days. When cold weather is expected, thorough and careful planning is needed to avoid problems. Some items on the following list may be controlled by the designer or specifier; others may be the responsibility of the contractor. Nevertheless, the builder should be familiar with all of the items in case the specifier hasn't anticipated cold weather conditions.

1. Select a concrete mix suitable for cold weather. For flatwork, keep the slump less than 4 inches so that bleeding is minimized and set occurs earlier. Use air entrainment. To achieve the needed strength quickly, use a higher than usual cement content, a high-early-strength cement, or an accelerator.

2. Specify the minimum temperature of the concrete as mixed, based on the air temperature and the thickness of sections to be placed. Also specify the minimum concrete temperature allowable during placement and curing, and the temperature drop allowable in the first 24 hours after protection is removed. Recommendations for these temperature limits are given in Table 2.

Table 1, Days of Protection Recommended for Cold Weather Concrete
(For concrete temperatures indicated in Table 2, line 2)

	To protect from damage by freezing		For safe stripping	
Construction and service conditions	Normal [1]	High early strength[2]	Normal[1]	High early strength[2]
1. Not loaded during construction, not exposed to freezing in service	2	1	2	1
2. Not loaded during construction, exposed to freezing in service	3	2	3	2
3. Partially loaded during construction, exposed to freezing in service	3	2	6	4
4. Fully loaded during construction	3	2	(See ACI specifications)	

1 Using Type I or II portland cement. (Adapted from ACI 306R-78)
2 Using Type III portland cement, or an accelerator, or an extra 100 pounds of portland cement per cubic yard.

Table 2. Recommended Temperatures for Cold-Weather Concrete

Condition		Sections less than 12 in. thick	Sections 12 to 36 in. thick
1. Min. temperature (°F) of concrete as mixed in weather indicated	above 30°F	60	55
	0°F to 30°F	65	60
	Below 0°F	70	65
2. Min. temperature (°F) of concrete during placement and curing		55	50
3. Max. gradual temperature drop (°F) allowed in first 24 hours after end of protection		50	40

(Adapted from ACI 306R-78)

In cold weather, buildings should be enclosed while concrete is placed and cured. Canvas tarps are rugged, but translucent polyethylene sheets are sufficiently strong and will admit daylight.

3. Determine what types of production are likely to be required: insulating blankets, insulated wall forms, enclosures, and/or heaters. Have the necessary equipment on hand and in good repair.

4. If concrete slabs are to be placed in heated enclosures, plan to vent heaters and gases from internal combustion engines. The wearing surface of a concrete floor slab exposed to carbon dioxide during the first 24 hours will be chalky and soft after the slab hardens.

5. Also, when using heated enclosures, plan to have fire-fighting equipment on the jobsite and plan to have personnel present to keep the heating units operating continuously.

6. Decide how snow and ice will be removed from forms and how frozen subgrade will be thawed before placing concrete on it. The subgrade can sometimes be thawed acceptably by covering it with insulating material for a few days prior to placing the concrete. But in most cases external heat is needed.

7. Plan reshoring procedures in advance and have them reviewed by the engineer.

8. Decide which method will determine when concrete strength levels are safe for form stripping and reshoring. If maturity methods will be used, make the necessary laboratory cylinder specimens before work begins at the jobsite.

9. Have a pre-pour conference that includes the engineer, contractor, concrete supplier, and inspection agency to ensure that all parties understand and agree upon what is required.

Concrete Production

It's the concrete producer's responsibility to deliver concrete at or near the minimum temperature specified. Making the concrete much warmer than the required temperature doesn't provide proportionately longer protection from freezing since the concrete will just lose heat more rapidly. Furthermore, higher concrete temperatures require more mixing water, increase the rate of slump loss, sometimes cause quick setting, and increase thermal shrinkage and the possibility of cracking.

1. Heat mixing water, then blend hot and cold water to obtain concrete no more than 10°F above the required temperature.

2. When either water or aggregate is heated to over 140°F, combine them in the mixer first, before adding cement, so the temperature of the mix does not exceed 140°F. This prevents quick or flash set of the concrete.

3. If air temperatures are consistently below 32°F consider heating aggregates. They should be heated uniformly since considerable variation in their temperature will noticeably vary the water requirement, rate of hardening, and slump of the concrete. The recommended method is to circulate steam in pipes placed in the storage bins.

4. Steam jets blown into the stockpile can be used to thaw large quantities of frozen aggregate but may cause troublesome moisture variations in the stockpile. Thawing aggregate as far in advance of batching as possible will minimize this problem.

5. When warming stockpiles, cover them with tarps to retain heat.

6. If the air-entraining admixture loses its effectiveness when mixed with hot water, place the admixture in the batch after the water temperature has been reduced by mixing with cooler solid materials.

7. Remember that accelerators such as calcium chloride will not reduce the freezing point of concrete.

Delivery, Placing, and Finishing

Delays in delivery or delays at the jobsite can cause concrete temperatures to drop below the specified minimum temperatures. The producer and contractor should coordinate operations to minimize truck waiting time while assuring a steady supply of concrete. Preparations should also ensure that all surfaces that will contact the newly placed concrete aren't cold enough to cause early freezing or to seriously prolong hardening.

1. Expect heat loss during transit and placement. Compensate for this loss by increasing concrete temperature at the plant. For revolving drum mixers, the temperature drop for a one-hour delivery time is approximately one-fourth the difference between air temperature at the jobsite and concrete temperature *required* at the jobsite. For example, if the concrete must be at least 60°F when delivered and the air temperature is 30°F, the temperature drop during transit would be approximately 0.25 x (60 – 30), or about 8°F. The concrete in this case should be heated at the plant to 68°F.

2. Consider using wind screens to protect slabs from rapid cooling.

3. When concrete is being pumped, run vertical pipelines inside the building if possible to cut down on heat loss through pipeline walls.

4. When using heaters under a formed deck, preheat the forms to melt any ice or snow remaining on top.

5. Do not build up a high temperature under a supported slab to try to keep the top surface warm. Temperature stresses created by this practice can cause cracking. The object is to keep artificial heat as low as possible so that temperature stresses during cooling are low.

Curing and Protection

To keep concrete temperatures as close as possible to values recommended in *ACI 306R-78,* insulation, enclosures, or heaters can be used. Heat from outside sources may not be needed if the heat developed by cement hydration is conserved. To make use of the heat of hydration, use insulating blankets on flatwork or use insulated forms. Heated enclosures are expensive but are very effective. Regardless of the method chosen, take care to prevent excessive moisture loss. Concrete exposed to cold weather is not likely to dry too quickly, but slabs and floors are prone to rapid drying in heated enclosures.

1. Avoid water curing. It produces icing problems and increases the likelihood of the concrete freezing in a saturated condition when the protection is removed.

2. When concrete warmer than 60°F is exposed to air at 50°F or lower in heated enclosures, apply a curing compound to slab surfaces as soon as possible to prevent drying.

3. Delay form stripping as long as possible to help prevent drying and to reduce damage to formed surfaces caused by premature stripping.

4. When insulation blankets are used, choose the proper R-value (thermal resistance) based on thickness of the concrete, ambient temperature, cement content, and whether the concrete is above or on the ground. If wind velocities are greater than 15 miles per hour, increase insulation thickness. Tables to help select the required R-values are given in *ACI 306R-78l.*

5. Place insulation blankets on slabs immediately after the concrete has set sufficiently so that the concrete surface isn't marred.

6. Provide triple thicknesses of insulating materials at corners and edges; these areas are particularly vulnerable to freezing.

7. Wrap protruding reinforcing bars with insulation to avoid heat drain from the warm concrete.

8. When enclosures are heated with forced hot air, provide a fresh-air intake to reduce the carbon dioxide and carbon monoxide.

9. Direct-fired heaters can be used beneath a floor or roof deck, but where heat is supplied to the top of fresh concrete, only indirect-fired or vented heaters should be used for the first 24 hours.

10. Gradually reduce the heat at the end of the heating period to reduce the likelihood of thermal shock.

Testing and Inspection

Testing and inspection normally performed for concrete placed at moderate temperatures should be supplemented by a few additional tasks.

1. Keep records of outside air temperature, concrete temperature as placed, and general weather conditions. Also record temperatures at several points within the enclosure or beneath the insulation and on the concrete surface, corners, and edges. Data recorded should clearly show the temperature history of each part of the structure.

2. Provide curing boxes for test cylinders to keep them at 60º to 80°F until sent to the laboratory.

3. Don't use test results from laboratory-cured cylinders to predict when the field concrete has reached a safe strength for form stripping. Use field-cured cylinders, nondestructive in-place tests, or maturity methods for this determination. ■

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This article is adapted from the September 1984 issue of Concrete Construction, *published by Concrete Construction Publications, Inc., 426 South Westgate, Addison, IL 60101.*