The Musts of Successful

COLD-WEATHER CONCRETEING

With a few basic precautions, you can produce high-quality concrete even in severe weather

By Dave Imse, Jerry Krueger, And Neal R. Moss

Before you take a job in the fall or winter, you need to examine how you'll deal with problems like frozen subgrades, extended concrete setting times, slower strength-gain rates, and decreased worker comfort (and efficiency).

All are common to the placing and finishing of ready mixed concrete in cold weather. If you don't address these cold-weather problems, the concrete may freeze before it attains an adequate compressive strength of at least 500 psi, weakening or even destroying your work.

Table 1. Effect of Temperature On Concrete Setting Time

Temperature (°F)	Approximate Setting Time (Hrs.)
70	6
60	8
50	10⅔
40	14⅓
30	19
20	Concrete freezes and doesn't set.

Source: *Concrete Construction,* March 1990.

The American Concrete Institute (ACI) defines cold weather as three successive days in which the average daily air temperature drops below 40°F and fails to rise above 50°F for more than half a day (Ref. 1). To obtain high-quality concrete under these conditions, it's important to take the five general precautions listed below. For more detailed information, consult References 1 and 2.

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Placing and finishing concrete in the bone-chilling winters of Michigan's Upper Peninsula requires careful planning. Knowing what needs to be addressed before you tackle a job like this often means the difference between success and failure.

1. Plan Ahead

Because cold weather can complicate your work, additional planning is required. For example, you should never place concrete on a frozen subgrade. But how will you thaw the subgrade? If you decide to use ground heaters, how many heaters will you need on-site? Will a compactor be needed to reconsolidate the thawed material? Will the weather be cold enough to warrant enclosing and heating the placement area? Be sure to make arrangements for covering, insulating, housing, or heating newly placed concrete before placement.

Make sure all the equipment you need is on-site before you begin to place concrete. It may not be long before concrete temperatures approach

Table 2. Recommended Concrete Temperatures

Line	Air Temperature	Section Size, Minimum Dimension, In.			
		< 12	12 to 36	36 to 72	> 72
Minimum concrete temperature as placed and maintained					
1	—	55°F	50°F	45°F	40°F
Minimum concrete temperature as mixed for indicated air temperature*					
2	Above 30°F	60°F	55°F	50°F	45°F
3	0 to 30°F	65°F	60°F	55°F	50°F
4	Below 0°F	70°F	65°F	60°F	55°F
Maximum allowable gradual temperature drop in first 24 hours after end of protection					
5	—	50°F	40°F	30°F	20°F

Source: Reference 1

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

dangerously low levels. To ease finishing operations in cold weather, you may need additional equipment. Insulating blankets, for example, may be needed to cover the subgrade before the pour. Or wooden floats may be needed to avoid sealing the concrete surface before bleeding stops. Windbreaks or evaporation retarders may also be needed, depending on ambient conditions.

2. Choose Cold-Weather Concrete Mixes

Because cement hydration is slowed in cold weather, the concrete cools quickly, extending setting time by about one-third for each 10°F reduction in temperature (see Table 1) and reducing compressive strengths at early ages. The result: delayed finishing and form stripping.

To expedite your finishing operations and speed form removal and reuse, ready mixed concrete producers usually heat the mixing water or aggregates. You may also want to consider ordering a mix with increased cement content, faster-setting cement, or an accelerating admixture, since these adjustments can speed setting time, increase early and ultimate strength, and reduce the time required for proper curing and protection.

Increasing cement content raises concrete temperature during curing because of the heat produced by cement hydration. And adding cement without increasing water content reduces the water-cement ratio, partially offsetting the lower rate of strength gain during cold weather.

Using Type III (high-early-strength) cement speeds concrete's setting time and strength gain. Ground more finely than Type I or II cement, Type III cement may also contain more tricalcium silicate. Both the fine grind and higher tricalcium silicate content increase the rate at which heat is generated by hydration. Remember, however, that Type III cement may not be available in all local markets, or its use may be limited by the number of silos at the concrete producer's yard.

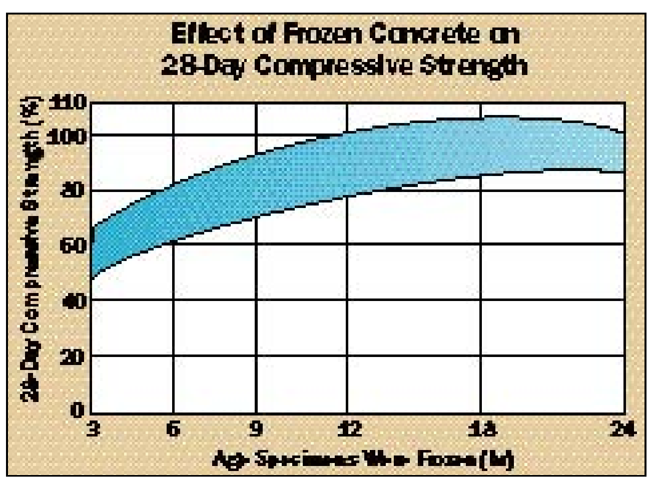
Another way to improve concrete's rate of setting and strength gain is by using chemical admixtures. To accommodate different job requirements, they're available in various classes. If reinforcing steel won't be needed, the most effective mix adjustment is the addition of either calcium chloride or an accelerating admixture containing calcium chloride. If the structure contains reinforcing steel, nonchloride accelerating admixtures are also available, including one type designed for concrete placed in subfreezing temperatures.

In addition to accelerating admixtures, air-entraining admixtures may also be necessary. Using these admixtures is critical if you expect the concrete to be exposed to freeze-thaw cycles while it's in service or in a saturated condition. Saturated concrete shouldn't be allowed to freeze and thaw before it develops a compressive strength of 3500 to 4000 psi (Ref. 2).

3. Maintain Adequate Concrete Temperatures

It's important to maintain adequate concrete temperatures during mixing and placing and in the first 24 hours after placement. If the temperature of undisturbed plastic concrete drops below about 29°F, freezing may occur, reducing the 28-day compressive strength by as much as 50% (see graph).

To prevent early-age freezing, protection must be provided imme-



Source: *Behavior of Concrete under Temperature Extremes*, SP-39, American Concrete Institute.

diately after concrete placement. In some cases, you may only need to cover the concrete with insulating materials and use the natural heat of hydration to maintain the temperature at the recommended levels. Useful insulating materials include polystyrene foam sheets, urethane foam, foamed vinyl blankets, mineral wool or cellulose fibers, blanket or batt insulation, and hay covered with plastic. In more extreme cases, consider building enclosures and using heating units to maintain the desired temperatures.

Table 2 provides ACI's recommended temperatures for concrete as it is mixed, placed, and maintained. Two important points: Keep concrete, subgrade, and ambient temperatures within a range of 20°F, and don't allow concrete temperatures to rise more than 20°F above these minimum values. High concrete temperatures don't significantly protect the material from freezing. In fact, the rate of heat loss is even more rapid when concrete temperatures are higher than ambient temperatures.

Consult Tables 3 and 4 to help determine the proper length of protection time for concrete made with Type I or Type II cement. Note that the use of Type III cement, admixtures, or additional Type I or II cement shortens the concrete-protection period.

Table 3. Length of Protection Period*

		Protection period at temperature indicated in Line 1 of Table 2, days**	
Line	Exposure	Type I or II cement	Type III cement, or accelerating admixture, or 100 lb./cy. of additional cement
1	Not exposed	2	1
2	Exposed	3	2

Source: Reference 1

*Required to prevent damage from early-age freezing of air-entrained concrete.
**A day is a 24-hr period.

Table 4. Length of Protection Period*

		Protection period at temperature indicated in Line 1 of Table 2, days**	
Line	Service category	Type I or II cement	Type III cement, or accelerating admixture, or 100 lb./cy. of additional cement
1	No load; not exposed	2	1
2	No load; exposed	3	2
3	Partial load; exposed	6	4
4	Full load	See Reference 1, Chapter 6.	

Source: Reference 1

*For concrete placed during cold weather.
**A day is a 24-hr period.

4. Maintain Proper Curing Conditions

Proper curing of concrete is critical to normal strength development. Cooler ambient temperatures generally require longer, more carefully controlled concrete curing. You want to ensure that the concrete develops enough strength for safe removal of forms, shores, and reshores, and for safe loading of the structure during and after construction.

Concrete exposed to cold weather is normally unlikely to dry at an undesirable rate, so little or no external supply of moisture is typically required for curing. But this may not be true for concrete within heated protective enclosures. When concrete warmer than 60°F is exposed to air at 50°F or higher, it's important to prevent drying. Using an exhaust steam heater is probably the most effective method, since it provides both heat and moisture. If dry heating is used, be sure to protect exposed concrete surfaces with an impervious covering or a curing compound meeting ASTM C 309 requirements. Monitor combustion heaters carefully. If they're unvented or improperly vented, they can cause carbonation of the concrete, resulting in weak, dusting surfaces.

After removing temperature protection, it's usually not necessary to provide measures to prevent excessive drying as long as the air temperature remains below 50°F, except when concrete is placed in extremely arid climates. If excessive drying is anticipated, concrete can be water-cured when no freezing is expected. Otherwise, use curing compounds or an impervious cover.

5. Limit Rapid Temperature Changes

It's also important to limit rapid temperature changes, especially before the concrete has developed sufficient strength to withstand induced thermal stresses. ACI provides the following maximum allowable drops in temperature during the first 24 hours after the end of the protection period: For concrete that's less than 12 inches thick, the maximum allowable drop is 50°F; 12 to 36 inches thick, 40°F; 36 to 72 inches thick, 30°F; and greater than 72 inches thick, 20°F.

Don't forget that the basic requirements for cold-weather concreting are no different than standard recommended practice: Use a suitable mix, protect the fresh concrete from the elements, and be sure to cure it properly.

Although profitability can be challenged during cold-weather concreting operations, it's not hard to follow the five basic steps described above, all designed to help you better plan your next fall or winter concrete job. Knowing what needs to be addressed *before* you tackle the job will make the difference between successful and unsuccessful cold-weather concreting.

References

1. ACI Committee 306, *Cold Weather Concreting,* ACI 306R-88, American Concrete Institute, Farmington Hills, Mich., 1988.

2. S.H. Kosmatka and W.C. Panarese, *Design and Control of Concrete Mixtures,* 13th ed., Portland Cement Association, Skokie, Ill., 1988.

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The authors recently presented a seminar on cold-weather concreting for Alby University. These free classes are held at Alby Materials' corporate offices in Waterford, Wis. For more information, or for registration forms, call Alby's Bill Hahn at 414-534-5144.

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