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Cold Weather Concrete

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Tis the Season, make sure you don't get stuck in the cold.

Cold weather concrete construction can present a new set of challenges to the builder, contractor, homeowner and Code Enforcement Official. One of the biggest keys to the successful placement of concrete in cold weather is cooperation between all the parties involved.

By definition (ACI 306), cold weather conditions exist when *"…for more than 3 consecutive days, the average daily temperature is less than 40 degrees Fahrenheit AND the air temperature is not greater than 50 degrees Fahrenheit for more than one-half of any 24 hr. period."*

During cold weather periods, concrete cannot simply be placed, finished and forgotten. In the early stages it must be continuously protected from freezing and repeated freeze-thaw cycles.

Do not place concrete when the temperature is 20 degrees F or less.

To understand the importance of protecting the concrete from cold weather, you must understand the chemistry behind the production and curing of fresh concrete. The setting and strength gain of concrete results from a chemical reaction between the Portland cement and water known as hydration. In order for hydration to take place, the temperature of the concrete must be 40 degrees F. Below 40 degrees F, the hydration process slows and at some point may stop altogether. Further more, the amount of free water in the mix will have a direct relationship to the damaging effects that freezing has on the concrete.

Code requirements IRC

The building code requires that the minimum compressive strength of concrete for footings be 2500 psi, for foundation walls, 3000 psi. The code also specifies that the concrete be air entrained. The total air content (percent by volume of concrete) shall not be less than 5% or greater than 7%.

TABLE R402.2
MINIMUM SPECIFIED COMPRESSIVE STRENGTH OF CONCRETE

TYPE OR LOCATIONS OF CONCRETE CONSTRUCTION	MINIMUM SPECIFIED COMPRESSIVE STRENGTH[a] (f'_c)		
	Weathering potential[b]		
	Negligible	Moderate	Severe
Basement walls, foundations and other concrete not exposed to the weather	2,500	2,500	2,500[c]
Basement slabs and interior slabs on grade, except garage floor slabs	2,500	2,500	2,500[c]
Basement walls, foundation walls, exterior walls and other vertical concrete work exposed to the weather	2,500	3,000[d]	3,000[d]
Porches, carport slabs and steps exposed to the weather, and garage floor slabs	2,500	3,000[d,e]	3,500[d,e]

For SI: 1 pound per square inch = 6.895 kPa.

a. At 28 days psi.

b. See Table R301.2(1) for weathering potential.

c. Concrete in these locations that may be subject to freezing and thawing during construction shall be air-entrained concrete in accordance with Footnote d.

d. Concrete shall be air entrained. Total air content (percent by volume of concrete) shall not be less than 5 percent or more than 7 percent.

e. See Section R402.2 for minimum cement content.

Setting Time of Concrete at Various Temperatures

Temperature	20 Degrees F	30 Degrees F	40 Degrees F	50 Degrees F	60 Degrees F	70 Degrees F
Approximate Setting Time	Set does not occur – concrete will freeze	19 Hours	14 Hours	11 Hours	8Hours	6 Hours

Protection during cold weather
In "cold weather" conditions it is important to protect the concrete from freezing and to maintain curing conditions to ensure adequate strength development. When "cold weather" conditions exist, surface concrete temperatures must be maintained at 55 degrees F for three days. Curing time may be reduced to two days if the cement content is increased by 100 lbs. per cubic yard or Type III Portland Cement is used, or if an approved accelerator is added to Type 1 Portland mix.

Initial set
At low temperatures hydration occurs very slowly. Consequently, low ambient temperatures retard set time and strength gain of concrete. The time for concrete to reach initial set increases as the casting temperature decreases. In cold weather, an approximate 30%to 35% increase in set time can be expected for each 10-degree F drop in ambient temperature.

Workability
Decreases in temperature will also greatly affect the workability of a mix, which is indicated by changes in slump. There is an approximately 0.8-inch increase in slump for every 20-degree F decrease in concrete temperature.

Freezing at early age
The ultimate strength of concrete can be reduced by up to 50 percent if it freezes soon after placement, **usually before 24 hours and before reaching strength of 500 psi.** When the water in the mix freezes, the ice leaves impressions in the paste, disturbing the matrix and increasing porosity. The detrimental effects of cold weather on concrete cannot be refuted. Obviously, you must take precautions to preserve and maintain the integrity of the concrete.

Methods of protection

- For footings, an acceptable method of protection from freezing during the curing process is to cover footings with 12 inches of straw. The straw shall be held in place with tarps or polyethylene sheeting.
- For foundation walls, insulated blankets may be used.
- After the initial curing period, it is recommended that the concrete be kept dry (protected from the elements) for at least two or three additional days before it is exposed to freezing conditions.
- Remove the heat protection in a manner that ensures the temperature of the concrete will not drop faster than more than 40 degrees Fahrenheit in 24 hours.

Control mixing temperature
The colder the ambient temperature, the more difficult it is to maintain a constant concrete temperature. Concrete temperature can be increased by heating the aggregates and/or heating the mix water. Typically, it is difficult to heat aggregates evenly. Store aggregates underground or in a building, if possible, so that heating mixing water will be sufficient. However, since the temperature of concrete affects the rate of slump loss and the efficacy of various admixtures, use caution when increasing concrete mixing temperature. When using heated mixing water, the water temperature should be the same from batch to batch to ensure consistency and performance predictability.

Surfaces in contact with concrete
Obviously, all surfaces in contact with concrete should be protected from freezing for at least 24 hours before placement, including embedded items. Embedded items, especially reinforcement, at temperatures below freezing can cause localized freezing of concrete. Embedded items should be kept indoors for as long as possible. It all begins with being well prepared – monitor weather conditions and know when cold weather will strike.

Inspection practices

1. Inspectors shall approve only the foundation elements that are going to be poured that same day.

2. The inspectors will be checking to ensure that the sub grade is not frozen and whether the proper protection components are on site at the time of inspection when daily temperatures are below 32° F or forecasted to drop below 32° F within the next 24 to 48 hours. The minimum time period for which the concrete must be protected against freezing is as follows:

- When pouring conventional concrete during "cold weather" conditions, the concrete shall be protected from freezing for at least **72 hours (3 days).**
- When pouring concrete utilizing approved accelerators, Type III Portland Cement, or where the cement ratio is increased 100 lbs. per cubic yard; the concrete shall be protected from freezing for at least **48 hours (two days).**

*When pouring conventional concrete during "non-cold weather" conditions, protection from freezing shall be maintained for at least **24 hours**.

3. If footings were required to be protected from freezing, foundation walls should not be allowed to be poured for at least 48 hours. **Exception:** If protection from freezing can be maintained for the period specified above the wall may be poured after 24 hours has elapsed from the time of the original footing pour.

4. At the inspector's discretion, concrete drivers batch tickets may be reviewed for the purpose of determining the time the concrete truck left the plant, strength of the concrete, percent of air entrainment or any special additive that may have been added to the concrete.

When this procedure mandates protection of footings and walls, the inspector shall give only a partial approval on the initial inspection. Final approval will be given only when it can be established that proper procedures have been taken to protect the concrete from freezing. If the inspector believes that the concrete has not been properly protected as described above or per another approved method, the inspector shall require that the concrete be tested in order to ensure that proper strength of the concrete has been developed.

Below are some general tips to help insure the successful placement of concrete in cold weather.

- Make sure the concrete mix has been proportioned for cold weather placement, which can include heating the aggregates, using hot water in the batching process, and using accelerating admixtures.
- Remember that accelerators are not antifreeze agents; they simply shorten the set time and can accelerate the strength gain of the concrete.
- DO NOT use calcium chloride (or agents containing chlorides) in any amounts as an accelerator **in steel reinforced concrete.**
- Do not place concrete on frozen ground. Remove all snow, ice, and frost from the areas to receive concrete. **Protect the footing sub-surface soil from freezing prior to placement.**
- The temperature of embedded items should be above freezing when coming into contact with fresh concrete. This includes rebar, wire mesh and anchor bolts.
- Always cure the concrete after finishing and protect it from freezing. It is advisable to maintain the in-place temperature at 50 degrees F or greater until required strength has been attained. Use insulating blankets, heaters, insulated forms, **loose straw (minimum 12 inches deep) sandwiched between a waterproof cover such as polyethylene** or other appropriate methods. Edges and corners tend to be more susceptible to freezing so pay extra attention to these areas.
- Hydration is a chemical reaction which produces its own heat, the above methods are intended to reduce this heat loss and allow the hydration to continue.
- If combustion heaters are used make sure the exhaust is vented out and away from the concrete to reduce the risk of carbonation which occurs when carbon monoxide from the exhaust forms carbonic acid, which can react with the fresh concrete to form a soft dusty surface when it cures.
- Place concrete earlier in the day to gain the advantage of the thermal heat gain produced by the sun in daylight hours.