# COLD CONCRETE: PLAN, POUR, PROTECT & PLACE



CONCRETE CONTRACTOR®

ACI 306R-16 Guide to Cold Weather Concreting and ACI 306.1-90 Standard Specification for Cold Weather Concreting define *cold weather* differently. The Specification document provides a method of how to consider cold weather as *cold weather*; while the Guide provides a description as to why it's important.

Once a contractor understands the definition of cold weather in the concrete process, they can then start to understand the challenges and best practices for cold weather concreting.

According to Sakrete Concrete Expert Dirk Tharpe, when water and portland (hydraulic) cement are mixed, a chemical reaction occurs which releases heat. This exothermic reaction, known as the "heat of hydration," puts the setting of concrete in motion as well as the development of concrete strength. Lower temperatures slow down the cement hydration process, resulting in delayed set times. Concrete will ultimately mature to the designed compressive strength, but lower temperatures will slow the maturity process.

This resource breaks out some of the steps of the concrete process and how they are handled in cold weather. You'll learn more about the four Ps of cold weather concreting: plan, pour, protect, and how to place concrete using calcium chloride when not utilizing structural steel (ACI 332 and 318).

Where both of these definitions indicate towards air temperature, ACI306R-16 continues to explain that the concrete's temperature is what determines the protective measures and what considerations need to be made.

"Maintaining concrete temperature above its freezing point (27° F) until it reaches the minimum strength threshold for durability (500 psi) is mandatory," said James R. Baty II, F.ACI, F.TCA and executive director of the Concrete Foundations Association. Unless the concrete is expected to be subjected to multiple freeze/thaw cycles during the 28-day cycle (or 3,500 psi, whichever comes first), the surface integrity or performance of the concrete should not be damaged after the 500 psi strength is reached.

*This collection of articles was published as informational-use only and not intended to replace official ACI documents.*

## What Is Cold Weather Exactly?

It is vital to know and understand these definitions.

"The conditions of cold weather concreting exist when the air temperature has fallen to, or is expected to fall below, 40 degrees Fahrenheit during the protection period."

*– ACI 306R-16, Guide to Cold Weather Concreting*

"A period when for more than three successive days the average daily outdoor temperature drops below 40 degrees Fahrenheit. The average daily temperature is the average of the highest and lowest temperature during the period from midnight to midnight. When temperatures above 50 degrees Fahrenheit occur during more than half of any 24-hour duration, the period shall no longer be regarded as cold weather."

*– ACI 306.1-90, Standard Specification for Cold Weather Concreting*

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# HOW TO PLAN FOR A COLD WEATHER CONCRETE POUR

**Walking the fine line between not enough and too much detail.**

By Ward R. Malisch, P.E. & Bruce Suprenant, P.E.

**Concrete specifications often require the concrete contractor to submit a cold weather concreting plan. A good plan ties the submittal to cold weather requirements in the specification and can help you to avoid having unnecessary requirements imposed on you. Plan details are the key. Including inadequate detail can result in rejection of the plan but including too much detail can sometimes reduce your cold weather options. The plan should simply describe the means and methods you intend to use in meeting the specification requirements. Submitting the plan and having it approved by the engineer of record provides a written record of your intentions, which can settle a lot of arguments before they start. The only caveat: Don't put anything in the plan that you aren't prepared to do.**

**ACI 306.1-90, is a good starting point for preparing the plan. Section 1.5.1 of this document states: "If required, submit detailed procedures for the production, transportation, placement, protection, curing, and temperature monitoring of concrete during cold weather. In the submittal, include procedures to be implemented upon abrupt changes in weather conditions or equipment failures. Do not begin cold weather concreting until these procedures have been reviewed and accepted."**

**Introduce your plan with:**

*"This Cold Weather Concreting Plan is submitted as required by the Project Specifications and conforms to the requirements established in ACI 306.1-90, 'Standard Specification for Cold Weather Concreting,' available at www.concrete.org."*

**It's a good idea to also include the Standard Specification for Cold Weather Concreting so there are no arguments about when the plan must be followed.**

## PRODUCTION

Discuss the details of cold weather concrete production with your concrete supplier. Some suppliers have a written plan that you can use, but you may want to read the plan, then use only some sections from it in your plan. Describe the means to be used for meeting requirements for the minimum and maximum concrete placement temperatures. These may include heated mixing water or aggregates, or both.

The commonly specified duration of protection period for concrete exposed to freezing is three days, but this can be reduced to two days if the rate of early strength gain is increased by one or more of the following:

- Adding an accelerating admixture
- Using Type III cement, or
- Increasing cement content by 100 pounds per cubic yard

Any combination of these methods is acceptable, so discuss the most economical method(s) with your concrete supplier. If specifications allow the use of calcium chloride as an accelerator, selecting this option is usually the most economical and efficient way to accelerate both setting time and early strength gain. If only non-chloride accelerators are allowed, changing cement content or type may be more economical. Describe the method(s) to be used in your plan.

## TRANSPORTATION & PLACEMENT

Generally, concrete can be produced at a high enough temperature at the plant so no special methods are needed to insulate the concrete truck drum. If the concrete will be placed by crane and bucket, pumping, or conveyor very low air temperatures may necessitate steps to ensure that the placement temperature doesn't drop below the allowable minimum. Scheduling deliveries that reduce truck waiting time is the least expensive way of achieving this goal. In the plan, tie the temperature measurements to the action to be taken if the

A frozen subgrade can sometimes be thawed by covering with insulating blankets, but heating may be required.

placement temperature falls below the specified minimum.

Because concrete must not be placed on a frozen subgrade, means that thawing the subgrade must also be described. In some cases, covering the surface with insulating material for a few days may produce acceptable thawing, but it may be necessary to apply heat. In the plan, describe the methods to be used for insulating or heating the subgrade.

## PROTECTION

Materials for protection may include insulating blankets, enclosures, means for heating enclosures, or a combination of these methods. The number of insulating blankets needed to supply a required R-value must be on hand. The materials used to build heated enclosures must also be on hand: plastic sheeting, lumber, vents, and hardware. Combustion or electric heaters may be needed, and proper venting will then be required for combustion heaters. Wood forms may be left in place for walls or other vertical concrete, but if the forms must be cycled quickly, enough blankets may be needed to cover the concrete for the duration of the protection period.

Describe the proposed protection methods for different temperature ranges. Make sure the plan addresses all concrete elements that might be subject to cold weather, including slabs on ground, walls and columns, and elevated slabs. A separate cold-weather mix may be required for different elements.

## CURING

The plan should indicate the method to be used to prevent concrete from drying during the required curing period. Water curing is generally discouraged because concrete should not be at a high moisture content when it is exposed to freezing temperatures after the protection period. Insulating blankets serve the dual purpose of keeping the concrete warm and preventing moisture loss. Leaving wood forms in place for walls or columns can also be a part of the plan. Indicate if curing compounds will also be used.

## TEMPERATURE MONITORING

Indicate in the plan how temperature will be maintained from the concrete plant to the point of placement. Specifications usually require measuring temperature at the concrete surface at regular intervals to ensure that the concrete gains the strength needed before protection is removed. Your cold weather plan should indicate the general locations of temperature measuring devices having an accuracy of ±2 degrees Fahrenheit and the frequency with which the temperature measurements will be made.

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A thorough plan must also indicate how the concrete temperature will be maintained or protected to the critical waypoints of early-age durability protection (500 psi) as well as target schedule strength requirements such as removal of shoring or loading conditions. When curing and protection are discontinued, specifications also require a gradual decrease in surface temperature to minimize thermal stresses that might cause cracking. Your plan should indicate how you will allow the concrete to cool so the maximum cooling rate isn't exceeded.

Indicate in your plan the weather services you will monitor to predict local weather changes. Also briefly describe any backup placing and finishing machines, heaters, or other equipment that you'll have on hand in case of breakdowns. A procedure for installing emergency construction joints can also be added.

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# TIPS FOR SMALLER PROJECTS

**Considerations for those smaller projects utilizing bagged concrete or related concrete repair materials.**

By Dirk Tharpe, Sakrete Concrete Expert

**There is a lot more mass in one cubic yard of concrete as compared to the 0.6 cubic feet yield from an 80-pound bag of concrete mix. This means there is a lot less heat generated when mixing bagged concrete as compared to that poured from a ready-mixed concrete truck. Due to the smaller mass being placed, one should expect the set times for bagged concrete placement to actually take longer than the "Concrete Set Time and Temperature" chart indicates in cold weather.**



Before the Pour and Leading Up to the Placement:

- Know the local weather forecast, noting the ambient air temperature, humidity, and wind speeds the day of the job, and the seven-day weather forecast following the pour.
- Prepare the subgrade or prep the concrete to be repaired the day before placement and set the forms.
- Cover the subgrade or area to be repaired with insulating materials to keep the area and forms warm. Remove the insulating materials just before the application of concrete or related materials.
- Choose your winter mix and other materials for the project.
- Store your materials in a dry and warm conditioned area, if possible, as opposed to leaving the materials exposed on the jobsite.
- Never pour concrete or apply concrete repair materials on frozen ground or substrate, or if freezing temperatures will occur within 48 hours.
- Keep an infrared thermometer handy to check surface and material temperatures.
- If the air temperature is too low or the area is experiencing severe inclement weather, delay the placement.

## CHOOSING THE RIGHT MIX

As air temperature drops, so does the ground temperature. In the case of a footing or post hole, you have the soil surrounding the concrete to consider. When pouring a slab, the forms and the stone base come into play. In these scenarios, the jobsite factors all absorb heat from the freshly mixed and placed concrete.

There are three ways to optimize your "winter mix" to help maximize heat of hydration in colder temperatures. Either use a concrete bagged mix with a higher cement content, change to a mix with a more reactive, faster-setting cement, or both.

For those heavier commercial or industrial projects, or you want the best of both worlds, take advantage of higher cement contents, Type III high-yearly cement and special cement blends.

**SETTING TIME OF CONCRETE AT VARIOUS TEMPERATURES**

| TEMPERATURE, °F | APPROX. SETTING TIME, HRS. |
|---|---|
| 70° (21°C) | 6 |
| 60° (16°C) | 8 |
| 50° (10°C) | 11 |
| 40° (4°C) | 14 |
| 30° (-1°C) | 19 |
| 20° (-7°C) | SET DOES NOT OCCUR -(CONCRETE WILL FREEZE) |

The approximate setting time for concrete increases as the temperature drops. Plan ahead.



## CONSIDERATIONS FOR MATERIAL MIXING

Choosing the right mix for cold weather will help the concrete to perform better in lower temperatures, but it does not change the fact that it may still be too cold to "jumpstart" the heat of hydration. Use these strategies to help generate heat to begin the setting process.


When mixing concrete or repair materials, place at the lowest slump possible, i.e., pour a drier mix. This is done by simply adding less water while mixing. Less water means a lower water-to-cement ratio, which will shorten the set time of the concrete, lessen the bleed water on the surface, and result in a stronger, more durable concrete.

Consider adding a flow enhancing admixture to help cut back on the water, while ensuring a looser and easier to place mix.

When setting posts, utilize a fast-setting concrete mix in lieu of conventional concrete, and actually mix the concrete before pouring into the hole.

Use warm water to mix the concrete. Heating water is the most practical and easiest means for increasing concrete temperature. Hot water from the tap generally does not exceed 120 degrees Fahrenheit. This is sufficient to warming the concrete enough to bring about the cement hydration reaction. Do not add boiling water to concrete. This most likely will cause a flash set. Additionally, latex additives to repair products or specialized concrete may melt at temperatures above 180 degrees Fahrenheit.

Calcium chloride is the most common accelerating admixture. Never add more than a 2 percent water-soluble dosage by weight of cement, provided there is no structural steel reinforcement present in the concrete.  ACI 332 and 318 both limit to 0.3 percent maximum percentage when structural steel reinforcement exists. When using bagged concrete or concrete repair materials it is wise to buy a premixed solution of calcium chloride to help meter a correct dosage of the accelerator. Do not add chloride-containing accelerators to concrete that will contain steel reinforcement or that will meet metal. Chloride ions greatly increase the potential for corrosion.

Non-chloride, non-corrosive accelerators are an alternate to chloride accelerators. These are less reactive than calcium chloride, but do not harm embedded reinforcement metals in the concrete. When planning on using a non-chloride accelerator with concrete repair materials or specialized, high performance bagged concretes, mix a test batch. Some non-chloride bases are not reactive with mixes containing a CSA cement.

Never add automotive antifreeze or windshield washer winter formula to concrete. These products do not give “anti-freeze” properties to concrete. That is a construction myth and negatively impacts the durability and ultimate strength of the concrete.


# HOW TO ENSURE YOUR FOUNDATIONS WILL PERFORM

**The Concrete Foundations Association explains how commonly and effectively residential concrete foundations are constructed during the winter.**

By James R. Baty II, F.ACI, F.TCA

**Q. Concrete foundation pours in cold weather will be affected by temperatures in the mid-30s to mid-40s or lower. How should I assure my customers and our building inspectors that the walls will perform as designed?**
– Concrete Contractor (Wisconsin).

**A: There is no denying that the vast majority of basement markets in the U.S. are turning colder; colder to the point of concern from customers, code officials and building inspectors as to what will happen to the concrete during these placements. A wealth of information has been generated in the past decade substantiating the recommended procedures necessary to produce quality foundation concrete during these conditions. Documents such as the CFA Cold Weather Research Report, ACI 332R-06 Guide to Residential Concrete, ACI 332-10 Residential Code Requirements for Structural Concrete, and ACI 306 Guide to Cold Weather Concrete all establish consensus for the contractor to proceed with both caution and confidence under cold weather conditions.**

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CFA member contractors know that in order for cold weather foundation installations to be successful, there are some hard rules to recognize and follow. Most of these are related to the supporting soil condition, but some do affect the concrete and form preparation.

We asked CFA member, Dennis Purinton of Purinton Builders in East Granby, Conn., about his thoughts on cold weather concrete foundations. Purinton is a CFA Board member as well as a voting member on ACI 306 (I am also a voting member on ACI 306). Purinton is also the head of a new task force CFA has formed to research cold weather performance of residential concrete slabs.

**The Four Most Important Things to Remember in Cold Weather Concreting:**

1. Mix design
2. Concrete temperature
3. **Concrete temperature**
4. The correct balance of accelerator to concrete temperature.

*-Dennis Purinton, Purinton Builders*



## WHAT DO THESE MEAN FOR YOU?

The excavation must not be frozen and must also be free of frost. The foundation system is designed based on the strength or rather bearing capacity of the supporting soil. Frozen ground expands and therefore changes its support condition. Once frozen ground has received a structure, that structure is falsely supported by the expanded grade and will experience settlement as the ground thaws.

Concrete must be protected from freezing until it has reached 500 psi. It must be protected from multiple freeze/thaw cycles until it has reached 3,500 psi. The freezing point of concrete is in the neighborhood of 27 degrees Fahrenheit, depending on the concrete mix. Concrete has remarkable strength gain characteristics due to the natural hydration process. Significant research conducted on full-scale wall elements by the CFA has resulted in a more thorough understanding of this performance.

This does not mean that concrete walls will not freeze, as they will and may be below the 500-psi benchmark. Contractors must also understand the behavior of even colder ambient temperatures that may flash freeze concrete or accelerate the temperature drop so that they can plan protection such as blankets and in the most severe cases, auxiliary heat sufficient to meet the strength gain goals.

Mix design must be considered a top priority for successful cold weather concrete. Water-cementitious material ratio is very important for success. Water is required for the hydration process and is consumed by it. However, water is also the culprit for freezing. The higher the water content, the more susceptible the concrete is to early freezing. Cement type is another important decision, such as Type III cement with characteristics of faster strength gain.

Another aspect of the decision process for cold weather concrete is the use of admixtures. Calcium chloride and non-chloride accelerators (NCAs) are proven to be very effective at accelerating the hydration process, generating greater internal heat and thereby strength gain.

The final important decision is temperature at production and delivery. The higher the concrete temperature at delivery time, the more likely 500 psi will be attained in very cold conditions before freezing.



**The CFA Cold Weather Report offers:**

“Contractors should work with their local ready-mixed concrete producer to design concrete mixes that will perform well based on the expected variables for a placement. The mix designs used in this research provide a sound basis for your own mix development but should be used after localized testing.”

*The Concrete Foundations Association Cold Weather Research Report provides data including mix designs for temperature ranges and establishes a research-proven method of predictive behavior with maturity as the best method to ensure cold weather performance. The CFA Cold Weather Report is available for purchase through the online order system at www.cfawalls.org.*

# HOW TO PROTECT CONCRETE DURING COLD WEATHER POURS

Hydronic heaters provide an even distribution of heat to the concrete. Here, a poly sheet covers a slab-on-grade. Hydronic heating tubes were placed on top of the poly and the entire system is being covered with insulated blankets.

**Maintain minimal concrete temperatures to ensure proper strength gain and cure.**

By Kim Basham, PhD PE FACI

**There are three primary objectives for cold weather concreting:**

**Protect the newly placed concrete from early age freezing.**

**If newly-placed concrete freezes, immediate and permanent damage can occur; subsequent curing will not restore the concrete's properties. Damage occurs because water expands nine percent in volume when it freezes. The formation of ice crystals and resulting paste expansion can reduce the compressive strength and increase the porosity of the hardened concrete. Strength reductions up to 50 percent can occur if freezing takes place in the first few hours after concrete placement or before the concrete attains a compressive strength of approximately 500 psi.**

## Protect concrete to ensure adequate strength development.

To protect against early-age freezing, maintain the appropriate concrete temperatures. An accelerated-set concrete can be obtained by including accelerating chemical admixtures; decreasing the water-cementitious material ratio; increasing the cement content; reducing the amount of supplementary cementitious materials; and replacing general use cements with Type III (high-early-strength) cement. Minimum concrete temperatures are a function of the minimum dimension of the section size because the more massive the section, the slower it loses heat.

## Protect concrete from thermal shock and cracking at the end of the protection period.

The rate of concrete hardening and strength gain depends on the temperature of the concrete. Low concrete temperatures decrease the rate of hydration and subsequently retard the rate of strength gain. To ensure newly placed concrete develops the required strength for safe removal

"No load, exposed" means the concrete element will not carry significant loads during the protection period and will be exposed to freezing conditions in service.

of forms, shores and reshores, and safe loading of the structure during and after construction, adequate concrete temperatures must be maintained during the protection or curing period.

## PROTECT FROM EARLY-AGE FREEZING

Newly placed concrete must be protected from early-age freezing until the amount of mixing water or the degree of saturation has been sufficiently reduced by the process of hydration. During hydration, the degree of saturation continually decreases as the mixing water combines with the cementitious materials and the concrete stiffens and hardens. Due to the hydration process, the amount of available mix water to form ice crystals continually decreases so there is less risk of permanent damage if the concrete freezes.

When there are no external sources of water, the critical degree of saturation, a single cycle of freezing, does not permanently damage the concrete if the concrete attains a strength of approximately 500 psi. At specified curing temperatures, well-portioned concrete mixtures should attain this strength within 24 to 48 hours. Therefore, it is critical that newly placed concrete be protected from freezing for the first 24 to 48 hours or until the concrete attains a strength of approximately 500 psi.

When the concrete attains a strength of at least 500 psi, it can tolerate one freeze-and-thaw cycle without damage if the concrete is air-entrained and not exposed to an external water source. For exposure to repeated cycles of freezing and thawing or deicing chemicals, new concrete should attain a strength of at least 3,500 psi, or 4,000 psi. To avoid early-age damage from cold weather, protect the concrete as soon as practicable after placing, consolidation and finishing.

## TEMPERATURE & PROTECTION PERIODS

The minimum concrete temperature as placed and maintained is 55 degrees Fahrenheit for a concrete section with a minimum dimension of 12 inches. The minimum protection periods are one and two days for normal-set and accelerated-set concrete mixtures, respectively. There are minimum concrete temperatures and durations to ensure the mixing water in the newly-placed concrete does not freeze.

As the air temperature decreases, the recommended concrete mix temperatures increase to offset the heat loss between mixing and placing of the concrete. Mix temperature recommendations help ensure the minimum concrete temperatures as placed and maintained are achievable.

## PROTECT TO ENSURE ADEQUATE STRENGTH GAIN

The rate of concrete hardening and strength gain depends on the temperature of the concrete. Low concrete temperatures decrease the rate of hydration and subsequently retard the rate of strength gain. To ensure newly placed concrete develops the required strength for safe removal of forms, shores and reshores, and safe loading of the structure during and after construction, adequate concrete temperatures must be maintained during the protection or curing period.

When there are early-age strength requirements, minimum protection periods need to be determined for the following service conditions:

- No load, not exposed
- No load, exposed
- Partial load, exposed
- Full load

Depending on the load requirements and exposure conditions, it may be necessary to extend the protection period beyond the minimums.

### "No Load, Not Exposed"

means the concrete element will not carry significant loads during the protection period and will not be exposed to freezing conditions in service.

### "No Load, Exposed"

means the concrete element will not carry significant loads during the protection period and will be exposed to freezing conditions in service.

### "Partial Load, Exposed"

means the concrete element will carry loads that are less than the available early-age load capacity during the protection period and will be exposed to freezing conditions in service.

### "Full Load"

Elements that require reshoring to carry construction loads before attaining the specified strength have a service condition of *Full Load* and typically require the contractor to determine in-place concrete strengths.

For example, the service condition for a 6-inch thick, concrete parking lot pavement at a commercial building site that will be exposed

Protect concrete surfaces and corners from cold weather by ensuring all surfaces are covered.

to winter conditions and cast from accelerated-set concrete would be *Partial load*, *exposed* and require a minimum protection period of four days. The minimum concrete temperature of 55 degrees Fahrenheit should be maintained for the four-day protection period.

Methods to maintain the minimum temperatures as placed and maintained include insulation (blankets and boards), heating systems such as electric blankets and hydronic heating systems, unheated or heated enclosures, or a combination of the methods.

Insulation is the most economical means of maintaining adequate cure temperatures because this method takes advantage of the heat of hydration, or the heat generated by the chemical reaction between the cement and water. Depending on the mass of the concrete, cement content and ambient conditions (i.e., air temperatures and wind), insulation can typically maintain adequate cure temperatures by capturing the heat of hydration.

Cover the concrete with blankets as soon as possible to capture as much of the heat of hydration as possible. Capturing the early heat of hydration will help maintain the cure temperature but will also help to promote hydration which in turn produces additional heat. Be sure to protect corners and surfaces since these areas are the most susceptible to early-age freezing and damage.

For extreme winter conditions, sometimes the heat of hydration is not sufficient to maintain adequate cure temperatures and supplementary heat is required. Additional heat can be supplied using electric concrete blankets, hydronic heaters, and heated enclosures. Of course, using supplementary heat increases the cost of cold weather concreting.

Hydronic heaters circulate a heated glycol-water liquid through a system of heat transfer hoses placed on the concrete or forms. Typically, the hoses are covered with concrete insulation blankets to capture and hold the heat.

When using combustion heaters for heating enclosures, ensure proper exhaust ventilation to prevent carbonization of concrete and carbon monoxide safety issues for workers.

Combustion heaters for heating enclosures should be vented and not positioned to directly heat or dry out the concrete. Fresh concrete surfaces exposed to carbon dioxide from unvented combustion heaters can be damaged by carbonation of the concrete. Carbonation occurs when carbon dioxide reacts with cement hydration products creating soft and chalky surfaces. Unvented combustion heaters also produce carbon monoxide. Of course, high concentration levels of these gases are hazardous to workers.

## PROTECT FROM THERMAL SHOCK & CRACKING

At the end of the protection period, gradually remove insulation or other protection so the surface temperatures cool gradually during the subsequent 24-hour period. Otherwise, the surface of the concrete may cool too quickly, creating thermal gradients between the surface and interior portions of the concrete and the resulting thermal stresses can cause surface cracking. Consider leaving insulation in place and slowly reducing sources of heat until concrete temperatures cool to match the average air temperatures.

Preplanning is the key to successful cold weather concreting. When developing your next cold weather concreting plan, consider the three primary objectives: protect the concrete from early-age freezing, protect to ensure adequate strength gain, and protect from thermal shock and cracking.



"Thermal cracking is usually associated with mass concrete but it can also happen to thinner slabs because of temperature differences between concrete ground, and ambient temperatures."
- John Gajda


# ADDING CALCIUM CHLORIDE TO IMPROVE COLD WEATHER CONCRETE POURING

**Calcium chloride is the most effective and least expensive cold weather accelerator for concrete.**

By Ward R. Malisch, P.E. and Bruce Suprenant, P.E.

Calcium chloride is the most effective and least expensive cold weather accelerator for concrete. But its use may be limited by building codes or prohibited by some specifications. Contractors then have to ask one or two questions:

Can we use calcium chloride admixtures?

If so, what is an acceptable dosage?

Fortunately, the International Building Code (IBC) can be used to answer these questions.

ACI 318-11 "Building Code Requirements for Structural Concrete" contains provisions for the maximum allowable amount of chlorides in concrete. But ACI 318 does not govern design and construction of slabs-on-ground unless the slab transmits vertical loads or lateral forces from other portions of the structure to the soil. In accordance with Section 1904 of the 2012 IBC, however, concrete slabs-on-ground must comply with the Chapter 4 Durability Requirements of ACI 318-11.

Thus ACI 318-11 Chapter 4 can be used to determine when and how much calcium chloride can be added to a concrete slab-on-grade.

For prestressed concrete or concrete containing embedded aluminum, ACI 318 does not permit use of calcium chloride or admixtures containing chloride from sources other than impurities in admixture ingredients. Thus contractors can't use calcium chloride for post-tensioned concrete slabs-on-ground or slabs containing aluminum conduit or other aluminum embedment.

## ACI EXPOSURE CATEGORIES & CLASSES

Table 4.2.1 in ACI 318-11 describes the following four exposure categories that affect the requirements for concrete to ensure adequate durability:

- F – freezing and thawing
- S – sulfate
- P – requiring low permeability
- C – corrosion protection of reinforcement

Exposure Category C addresses chloride content limitations. This category is subdivided into three exposure classes defined by the following conditions:

- C0 – concrete dry or protected from moisture.
- C1 – concrete exposed to moisture but not to external sources of chlorides.
- C2 – concrete exposed to moisture and an external source of chlorides from deicing chemicals, salt, brackish water, seawater, or spray from these sources.

Interior slabs-on-ground are usually assigned to Class C0 because they are expected to be dry and protected from moisture in service. Exterior slabs-on-ground are assigned to Class C1 unless they would be subjected to deicing chemicals, in which case they are assigned to Class C2.

Maximum allowable amounts of chlorides in concrete decrease as the Classes increase from C0 to C2.

Water-soluble chloride ion (Cl-) content in concrete is expressed as a percent by weight of cement and is limited to a maximum amount by ACI 318. The water-soluble chloride ion content contributed by ingredients including water, aggregates, cementitious materials, and admixtures is determined in concrete mixtures at ages between 28 and 42

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days. Testing is done in accordance with ASTM C1218 "Standard Test Method for Water-Soluble Chloride in Mortar and Concrete."

The maximum allowable water-soluble chloride ion (Cl-) content for differing Exposure Categories in reinforced concrete, percent by weight of cement, is shown below:

- C0 – 1.00%
- C1 – 0.30%
- C2 – 0.15%

## HOW MUCH CALCIUM CHLORIDE CAN BE ADDED?

Because the concrete ingredients from different suppliers contain different levels of chlorides, it is not easy to calculate the amount of a chloride admixture that can be added while staying below the water-soluble chloride ion limits. A guide, which should be confirmed, is that about two percent calcium chloride by weight of cement can be added for class C0 exposure and about 0.5 percent can be added for C1 exposure. Rarely can any calcium chloride be added to concrete that will be subjected to C2 exposure.

These guidelines, however, need to be verified by the ready-mixed concrete producer. Be sure to get, in writing, information related to the amount of water-soluble chloride ion from all sources. This information can be submitted with your request to add calcium chloride.

ACI also prohibits the use of calcium chloride when soil or ground water contains enough sulfate to be classified as S2 or S3. Check the project specifications to determine if the concrete mix has a sulfate requirement. If it does, don't use calcium chloride.

## REINFORCED OR UNREINFORCED SLAB-ON-GROUND

The limits on chloride content in concrete are intended to protect reinforcement from damage due to corrosion. If a slab-on-ground contains no reinforcement, chloride limits in the Code don't apply. However, there is some disagreement within the concrete industry as to the definition of reinforcement. For instance, should dowels at joints in a slab-on-ground or steel fibers be considered as reinforcement and be subject to chloride limitations? What about anchor bolts or other embedded items? These issues should be discussed with the engineer of record or brought to his/her attention in the submittal.

## MAKING THE REQUEST TO USE CALCIUM CHLORIDE

Make sure to submit a request for approval to use calcium chloride. If you believe the slab contains no reinforcement, make that point and indicate that no Code requirement is applicable. If the slab contains reinforcement, the submittal should acknowledge that IBC requires that ACI durability requirements be met. Also include the Exposure Class that you believe the slab-on-ground falls into — either a C0 or C1 — and the applicable chloride limit. Then add documentation by the ready-mixed concrete producer that with the chloride ions contributed by other mixture ingredients, concrete at the requested calcium chloride dosage rate meets that chloride limit requirement.

Finally, attach the ASCC Position Statement #31 "Acceptable Use of Calcium Chloride in Concrete." This document addresses economy and timely completion by stating that blanket restrictions on any use of calcium chloride in reinforced concrete increases cost to the owner and may also result in slowed progress when some of the project will be built during cold weather. ■

*Access and download ASCC Position Statements through ASCConline.org/concrete-technical-resources/position-statements.*

## REFERENCES


American Concrete Institute 306R-16 "Guide to Cold Weather Concreting"

American Concrete Institute 306 "Guide to Cold Weather Concrete" (this document was replaced by 306R-16)

American Concrete Institute 306.1-90 "Standard Specification for Cold Weather Concreting"

American Concrete Institute 318-11 "Building Code Requirements for Structural Concrete"

American Concrete Institute 332R-06 "Guide to Residential Concrete"

American Concrete Institute 332-10 "Residential Code Requirements for Structural Concrete"

American Society of Concrete Contractors Position Statement #31 "Acceptable Use of Calcium Chloride in Concrete"

Concrete Foundations Association "Cold Weather Research Report"


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***Thank you to all the authors that have contributed their insights for the industry.***

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