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Cold Weather Concreting 101

The new ACI 306 guide covers the basics and a lot more.

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With proper protection, concrete work can proceed even in the coldest weather.

Credit: Portland Cement Association

Baby, it's gettin' cold outside—again. Are you ready to place concrete so cold weather doesn't damage it and so it can cure in a reasonable amount of time?

The best advice on how to do this is the new ACI 306R-10, "Guide to Cold Weather Concreting." This is the first new version of ACI 306 in more than 20 years and it includes information on new approaches, such as maturity testing and antifreeze admixtures, and clearly written advice on the old standbys, such as enclosures, insulation, supplementary heat, and admixtures.

One significant change is the definition of cold weather. After debating this, the committee settled on simplicity—a great accomplishment for an ACI committee! The old convoluted definition included things such as consecutive days, average daily temperature, and half of any 24-hour period. Instead, the committee focused on the real objective—keeping the concrete from being damaged by the cold and letting it gain enough strength to do its job. So the new definition is:

"Cold weather exists when the air temperature has fallen to, or is expected to fall below 40° F during the protection period. The protection period is defined as the time required to prevent concrete from being affected by exposure to cold weather."

Once the committee agreed on this simplified definition, it set the tone for the rest of the guide. Remember the term "protection period"—it is the basis for much of the advice in ACI 306.

Objective and principles

Concrete work can be accomplished during even the coldest weather as long as the appropriate precautions are taken. The objectives are to prevent damage from early-age freezing (when the concrete is still saturated), to make sure the concrete develops the needed strength, and to limit rapid temperature changes or large temperature differentials that cause cracking. Although there is some cost to all this, it's typically not excessive—certainly not when compared to having your crews sit idle, blowing your schedule, or ending up with damaged concrete.

The guiding principle of cold weather concreting comes from research done by T.C. Powers in 1962. He showed that concrete's water saturation level falls below the critical point (when it will be damaged by freezing) at about the same time it reaches 500-psi compressive strength. If the concrete temperature is kept around 50° F, this will usually happen in about 48 hours. At this point, it is strong enough and dry enough to avoid damage by a single freezing cycle (cyclic freeze/thaw protection requires air-entrained concrete and strength closer to 3500 psi). After that, protection isn't usually required, unless—and this is a big unless—you're not too concerned about how long it will take to achieve further strength gain.

In cases where a specific strength is needed on some schedule, you will need to take additional measures to keep the concrete warm (about 50° F)—such as by adding more cement to the mix, accelerating the mix, insulating the member, or providing heat. For example, if you need to strip forms and expect the concrete to stand on its own or to actually support loads from the floors above, then it will need to be protected longer than 48 hours. For those cases, ACI 306 provides tables that indicate what precautions need to be taken at a given anticipated minimum ambient temperature for different wall thicknesses. These tables show how long the concrete must be protected, how much insulation is needed, and how much cement should be in the concrete. More on this later.

Temperature of fresh concrete

Cement hydration is a chemical reaction. The rate at which that reaction takes place is dependent on temperature. But also, because the reaction is exothermic, concrete generates its own heat during hydration--over the first two or three days. So, if it can be placed at a temperature where the hydration reaction can proceed, and the ambient conditions (whether natural or conditions created with protection) aren't too cold, concrete can keep itself warm.

Table 5.1 in ACI 306 provides the minimum temperatures that should guide your cold weather work. Line 1 indicates the minimum temperature the concrete should reach during the protection period. Note that thicker concrete sections can get a little cooler because they lose heat more slowly, and also because crack prevention is accomplished by minimizing the temperature differential between the center of the section and the outer edges.

TABLE 5.1. RECOMMENDED CONCRETE TEMPERATURES*			
		Section Size, Minimum Dimension (in.)	
Line	Air Temperature (°F)	<12	12–36
Minimum Concrete Temperature, as Placed and Maintained			
1	——	55	50
Minimum Concrete Temperature, as Mixed			
2	Above 30	60	55
3	0 to 30	65	60
4	Below 0	70	65

** This is a compressed and simplified version of Table 5.1 in ACI 306R-10.*
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Lines 2, 3, and 4 are the minimum temperatures as mixed—what the ready-mix producer needs to be concerned with. This temperature increases as ambient temperature decreases to account for the greater amount of heat lost between mixing and placing—but remember that the concrete "as placed and maintained" cannot go below the value in Line 1.

The ready-mix concrete producer has several options for making sure the concrete is at the required temperature when mixed, but the most common is simply mixing the concrete using hot water. In colder weather, aggregate also may be heated.

Maturity meters provide a simple way to determine concrete strength.

Credit: Con-Cure Corp.

Preparation

Chapter 6 of ACI 306 describes measures the contractor must take before placing concrete in cold weather. The basic idea is to not shock the concrete—concrete should feel warm and welcome when it goes into place. Warm up formwork and any embeds, including the reinforcement, and remove snow, ice, and water from the forms. Make sure the ground isn't frozen. This can be accomplished with enclosures, heating blankets, or hydronic heaters. Surfaces should be no more than 15° F colder than the concrete—but also no more than 10° F hotter than the concrete.

Protection

ACI 306 defines protection quite clearly: "Effective protection allows the concrete to gain strength at a normal rate and prevents the concrete from early-age damage by freezing of the mixing water."

That leads to the next important aid in ACI 306, Table 7.1, and back to the term protection period--we told you to remember it! The length of the required protection period depends on whether the concrete is expected to support loads during construction. For example, slabs usually don't need to support loads, while columns, beams, and elevated slabs will have to gain enough strength to support the ongoing work and therefore will need a longer protection period.

TABLE 7.1. LENGTH OF PROTECTION PERIOD DURING COLD WEATHER

Line	Service Condition	Protection Period (days) at Minimum Temperature (Line 1, Table 5.1)	
		Normal-Set Concrete	Accelerated-Set Concrete
1	No load, not exposed	2	1
2	No load, exposed	3	2
3	Partial load, exposed	6	4
4	Full load	see Chapter 8	

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Service condition in this table refers to whether the concrete will be exposed to freezing when in service and to whether it will carry loads during curing. By using the protection period specified here, combined with the minimum temperature in Table 5.1, you can be assured the concrete will be ready to handle the rigors of cold weather. But, as you remove the protection, be careful to let the concrete cool slowly to prevent cracking from thermal shocks.

These minimum protection periods are intended only to protect the concrete from being damaged by the cold. These times do not mean the concrete has gained enough strength to support the loads it will experience when in service. For structural concrete, longer protection periods are needed. There are several ways to determine the strength of the concrete for stripping of forms or removal of shores, including maturity testing.

Maturity testing combines curing time and temperature to indicate the current strength of the concrete. A temperature sensor embedded in the concrete feeds data to a meter that performs the calculations over time and indicates the maturity. Based on a maturity-strength relationship developed in the laboratory for the particular concrete, it's known when the needed strength has been attained. For a more in-depth description of maturity, check out the January 2004 article "Maturity and Strength."