PDHonline Course S129 (1 PDH)

Cold Weather Concreting

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Definition

A period of more than three successive days in which the mean daily temperature drops below 40°F. When temperatures above 50°F occur during more than half of any 24-hour period, the concrete should no longer be regarded as winter concrete. Cold weather concrete (concrete which is placed at temperatures between 40°-50°F) has superior properties to concrete placed in hot weather. If the concrete does not freeze and is cured properly, it reaches a higher ultimate strength, and is more durable and less susceptible to thermal cracking. At lower temperatures, however, concrete sets and gains strength more slowly because the cement does not hydrate as fast.

Air Temperature	Section Size, Minimum Dimension			
	< 12"	12-36"	36-72"	>72"
Minimum Concrete Temperature As Placed And Maintained				
N/A	55°F	50°F	45°F	40°F
Minimum Concrete Temperature As Placed For Indicated Weather				
> 30°F	60°F	55°F	50°F	45°F
0° to 30°F	65°F	60°F	55°F	50°F
< 0°F	70°F	65°F	60°F	55°F
Maximum Allowable Gradual Temperature Drop In First 24 Hour After End Of Protection				
N/A	50°F	40°F	30°F	20°F

Introduction

Concrete freezes in the plastic state when the mix temperature is less than 29°F and the concrete is left undisturbed long enough for ice crystals to form. Once ice has formed, hydration stops and strength development is seriously impaired. Fresh concrete frozen during the first 24 hours can lose up to 50% of its potential 28 day strength. In moderately cold weather, when freezing temperatures are forecast at the job site, all unformed concrete surfaces should be protected from freezing for at least 24 hours after it is placed. Protection from freezing for the first 24 hours does not assure development of the required strength at the specified age when considerably colder weather is expected. For this condition, protection and curing should continue long enough to produce the strength required.

Source: Alliance Formwork

Concrete should not be placed at a temperature lower than that shown in the previous slide. Also, air-entrained, normal weight concrete should be maintained at not less than the temperature listed for the length of time indicated in the table below. The actual temperature of the concrete surface determines the effectiveness of protection regardless of air temperature relative to durability or strength.

Service Category	Protection Recommended At Temperature Indicated / Days			
	From Damage By Freezing		For Safe Strengths	
	Type I or II Cement	Type III, Accelerator Or Extra Cement	Type I or II Cement	Type III, Accelerator Or Extra Cement
No Load Or Exposure	2	1	2	1
No Load, Exposed	3	2	3	2
Partial Load, Exposed	3	2	6	4
Full Load	3	2	Refer to ACI 306	

Heating of Materials

In order for concrete to be placed as close as possible to the minimum recommended temperatures, it is sometimes necessary to heat the components prior to mixing. When aggregates are free of ice and frozen lumps, the desired temperature can usually be obtained by heating only the mixing water, however, when air temperatures are consistently below 32°F it is usually necessary to heat the aggregates. Heating aggregates to temperatures higher than 60°F is rarely necessary in conjunction with mixing water at 140°F. If coarse aggregate is dry and free of frost, ice and lumps, adequate temperatures of fresh concrete can be obtained by increasing the temperature of only sand to no more than 105°F if the mixing water is at 140°F. Overheating of aggregates above 212°F should be avoided and in all cases materials should be heated uniformly.

Source: Steam Engineering

Premature contact of very hot water and concentrated quantities of cement can result in flash set and cement balls in the mixer. When water over 140°F is used it may be necessary to adjust the order in which the components are blended into the mixer to prevent this condition. The anticipated temperature drop for delivery time of 1 hour can be approximated by the following formula for a revolving drum mixer;

T =.25x(concrete temperature required - ambient air temperature)

The required concrete temperature provided at the batch plant will be the value T + that temperature normally maintained at the mixing source. In all cases, the amount of mixing and agitation in the ready mix truck should be minimized in order to help reduce the amount of heat loss during transportation of the concrete.

Source: University of Cape Town

Preparations Before Placing

Assure that all surfaces that are to be in contact with the freshly placed concrete be at a temperature that cannot cause early freezing or serious prolonged hardening. The temperature of these contact surfaces need not be higher than 35°F. All snow, ice and frost must be removed so that it cannot occupy space required for the solid concrete. In all cases, concrete should not be placed on frozen subgrade or surface material.

Source: The Concrete Producer

Protection

Since most of the heat of hydration of hardening cement is developed during the first three days, no outside heat source may be required to maintain the correct concrete temperature during this period as long as the heat is retained through the use of insulating blankets on unformed surfaces. Normally measures must be taken to prevent excessive evaporation of moisture from concrete. During the winter, however, when the air temperature is below 50°F, atmospheric conditions in most areas will not cause undesirable drying. In addition, new concrete is vulnerable to freezing in a saturated condition and therefore should be allowed to undergo some drying before being exposed to freezing weather. Unformed surfaces are prone to drying in heated enclosures. When concrete warmer than 60°F is exposed to air at 50°F, it is essential that measures be taken to prevent drying. It is also advantageous to retain forms until the end of the required minimum protection period, or even longer when possible to provide both insulation and moisture retention capabilities.

Source: Wacker Neuson

The criteria for the removal of formwork for loadbearing elements should be based on the in-situ strength of concrete as verified through the testing of concrete samples rather than some arbitrary time duration. Strength-maturity calculations can be made, however, to aid in the estimation of the anticipated concrete strength. Formulas for the calculation of a maturity factor are provided in ACI 306. Fresh concrete exposed to carbon dioxide gas resulting from exposure to the use of salamanders or other heating devices that exhaust fuel gases directly into an enclosed area, may result in carbonation of the concrete surface. Carbonation results from the reaction of the combustion gases with the calcium hydroxide in the cement to form calcium carbonate thereby reducing the durability of the surface.

Source: Godwin Formwork Solutions

Acceleration of Strength

The use of high-early strength cement (Type III) or the use of additional cement to a standard mix, may be used to develop the level of strength required in a shorter period. The use of calcium chloride as an accelerating agent is strictly prohibited except for special conditions because the presence of residual chlorides in the concrete will result in accelerated corrosion of the embedded reinforcement. Type E chemical water-reducing admixtures have been found to accelerate strength gain at ambient temperatures of 50°F and below. However, some Type E admixtures contain small percentages of calcium chloride and should be avoided. Although air-entrainment admixtures are not considered an accelerator, it is recommended that any concrete that will be exposed to freezing in a saturated condition during construction should be properly air entrained even though it will not be exposed to freezing in service.

Source: Lafarge

Recommendations for Cold Weather Concrete

Cold weather is defined as a period when one or more than three (3) consecutive days of the following conditions exist:

- The average daily air temperature in less than 40°F.
- Air temperature is not greater than 50°F for more than ½ a day.

Objective:

- To prevent damage to concrete due to freezing at early ages.
- It is important to note that concrete that is protected from freezing until it has attained a compressive strength of at least 500 psi will not be damaged by exposure to freezing per the American Institute of Concrete (ACI). Most well-proportioned concrete mixtures reach this strength during the second day.
- Assure that the concrete develops the required strength.
- Maintain faster than normal strength curing conditions so that it is safe for removal of forms, removal of shores and for safe loading.
- Limit rapid temperature change.
- Provide protection consistent with intended serviceability of the structure.

Preparation before Concreting:

- Temperature of surfaces in contact with fresh concrete must be above freezing or about 35°F and preferably not more than 10°F higher than the maximum placement temperatures.
- Removal of snow and ice via hot air jets can be used to remove frost.
- Condition of sub-grade; concrete should not be placed on frozen sub grade

- If the minimum dimension is less than (<) 12 inches (Slab):
  - Air temperature **ABOVE 30°F**……Concrete mix 60°F
  - Air temperature **0 - 30°F**……..Concrete mix 65°F
  - Air temperature **BELOW 0°F**…….Concrete mix 70°F

And the maximum allowable gradual temperature drop is the first 24 hours after end of protection is 50°F

- If the minimum dimension is 12 – 36 inches:
  - Air temperature **ABOVE 30°F**……Concrete mix 55°F
  - Air temperature **0 - 30°F**……..Concrete mix 60°F
  - Air temperature **BELOW 0°F**…….Concrete mix 65°F

And the maximum allowable gradual temperature drop is the first 24 hours after end of protection is 40°F

Protection against freezing and protection for concrete not requiring construction supports:

Protection to prevent early age freezing must be provided immediately after concrete placement and should include arrangements for covering, insulating, housing, or heating before placement

Length of protection period:

- Footing and Substructures……2 days (Type I or II cement)
- Slabs, Walls……..3 days (Type I or II cement)

NOTE:

It is the Contractor's responsibility to follow the American Concrete Institute's (ACI) recommendation for cold weather concreting.