Cold Weather Concreting In the Spring

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Cold Weather Concreting – In the Spring

Disclaimer

This is not a complete analysis of every material fact regarding exterior concrete flatwork. This information contained herein is provided for use by personnel who are competent to evaluate the significance and limitations of the information provided and who will accept total responsibility for the application of this information. Others should obtain the assistance from a qualified professional before proceeding. The opinions expressed herein reflect the judgement of Ohio Concrete at this date and are subject to change. The information has been obtained from sources Ohio Concrete considers to be reliable, but we cannot guarantee that it is accurate or complete.

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Cold Weather Concreting In the Spring

Learning Objectives:

- Define Cold Weather Concrete
- Provide Specification Guidelines
- Identify Concrete Mixture Adjustments
- Describe Protection and Curing Procedures
- Explain Impacts on Strength Testing

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What defines Cold Weather Concrete Construction ?

- What determines if you are in cold weather conditions
- Sometimes it’s very obvious
- Has to do with temperatures less than 40° F

Definition of Cold Weather Concrete (Old Definition)

ACI 306R-88, (Re-Approved in 2002) defined “Cold Weather” as:

- a period when, for more than 3 consecutive days, the following conditions exist: 1) the average daily air temperature is less than 40°F and 2) the air temperature is not greater than 50°F for more than one-half of any 24-hr period.

ACI 306R-10, (2010) defined “Cold Weather” as

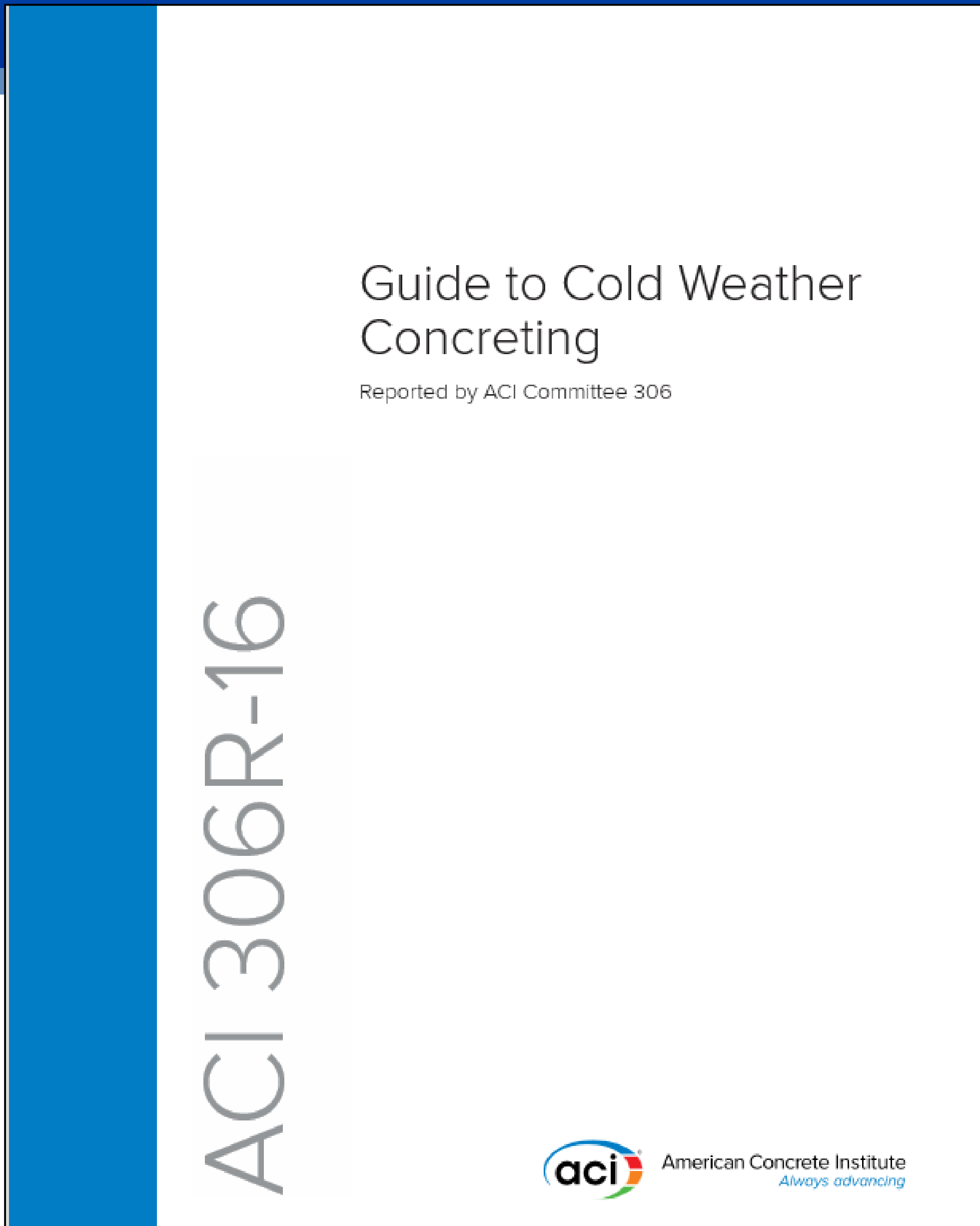
- when the air temperature has fallen to, or is expected to fall below 40°F during the protection period.

Definition of Cold Weather Concrete (New Definition)

ACI 306R-16, defines “Cold Weather” as:

- when air temperature has fallen to, or is <u>expected to fall below, 40°F (4°C) during the protection period</u>;
- <u>protection period</u> is defined as the time recommended to prevent concrete from being adversely affected by exposure to cold weather during construction.

Guide to Cold Weather Concreting ACI 306R-16



Chapter 1- Introduction
Chapter 2- Definitions
Chapter 3- Objectives
Chapter 4- General Recommendations
Chapter 5- Temperature of Concrete

Chapter 6- Preparation
Chapter 7- Protection against freezing
Chapter 8- Protection for Structural Supported Concrete
Chapter 9- Equipment, Materials, and Methods
Chapter 10- Curing Recommendations

Chapter 11- Acceleration of Setting and Strength Development
Chapter 12- References

Standard Specification for Cold Weather Concreting (ACI 306.1-90)

306.1-90 (Reapproved 2002)

P3. Building codes set minimum requirements necessary to protect the public. This Standard Specification may stipulate requirements more restrictive than the minimum.

2.2 -Concrete for slabs and other flatwork exposed to cycles of freezing and thawing in a wet condition during the construction period shall be air entrained as specified in ACI 301 even though the concrete may not be exposed to freezing in service.

However, changes in ACI 306R-16 are not yet adopted into the Standard Specification for Cold Weather Concreting **(306.1-90)**

This document has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

Standard Specification for Cold Weather Concreting (306.1-90)

Reported by ACI Committee 306

Nicholas J. Carino, Chairman*

Fred Anderson*, Peter Antonich, George R. U. Burg, Oleh B. Ciuk, Douglas J. Harvik*, Gilbert Haddad, Jules Houde, David A. Hunt, Robert A. Kelsey, Albert W. Knott, Charles J. Korhonen, William Perenchio*, John M. Scanlon, Michael Shydlowski, Bruce A. Suprenant, J. Derle Thorpe, Valery Tokar, Lewis H. Tuthill*, Harold B. Wenzel, Arthur T. Winters

This Standard Specification gives requirements for cold weather concreting. It includes cold weather requirements for preparations prior to placement of concrete, and protection of concrete.

Keywords: accelerating admixtures; cold weather; compressive strength; construction; curing; formwork; freezing; heating; insulation; maturity; protection; temperature.

FOREWORD

F1. This foreword is included for explanatory purposes only; it does not form a part of the Standard Specification ACI 306.1.

F2. Standard Specifications ACI 306.1 is a Reference Standard which the Architect/Engineer may cite in the Project Specifications for any building project, together with supplementary requirements for the specific project.

F3. Each technical section of Standard Specification ACI 306.1 is written in the Three-Part Section Format of the Construction Specifications Institute, as adapted by ACI and modified to ACI requirements. The language is generally imperative and terse.

F4. Checklists do not form a part of Standard Specification ACI 306.1. Checklists are to assist the Architect/Engineer in properly choosing and specifying any necessary requirements for the Project Specifications.

PREFACE TO SPECIFICATION CHECKLIST

P1. Standard Specification ACI 306.1 is intended to be used by reference or incorporation in its entirety in the Project Specifications. Individual sections, articles, or paragraphs shall not be copied into the Project Specifications, since taking them out of context may change their meaning.

P2. If sections or parts of Standard Specification ACI 306.1 are edited into project specifications or any other document, they shall not be referred to as ACI Standards, since the Standard Specification has been altered.

P3. Building codes set minimum requirements necessary to protect the public. This Standard Specification may stipulate requirements more restrictive than the minimum. Adjustments to the needs of a particular project shall be made by the Architect/Engineer by reviewing each of the items in the Specification Checklist and then including the Architect/Engineer's decision on each item as a mandatory requirement in the Project Specifications.

P4. These mandatory requirements designate the specific qualities, procedures, materials, and performance criteria for which alternatives are permitted or for which provisions were not made in the Standard Specification. Exceptions to the Standard Specification shall be made in the Project Specifications, if required.

P5. A statement such as the following will serve to make Standard Specification ACI 306.1 a part of the Project Specifications.

> Work on ______________ shall conform to all requirements of ACI 306.1, Standard Specification for Cold Weather Concreting, published by the American Concrete Institute, Detroit, Michigan, except as modified by the requirements of these Contract Documents.

P6. The Standard Specification Checklist identifies Architect/Engineer choices and alternatives. The checklist identifies the sections, parts, and articles of the Standard Specification and the action required by the Architect/Engineer.

*Task force for revision.

Supercedes ACI 306.1-87. Revised by the Expedited Standardization Procedure, effective July 1, 1990. In 1990, the format was revised. The Foreword, Preface, and Specification Checklist were revised. Reference Standards were updated and the sections on Materials and Execution were rewritten and renumbered.

Standard Specification for Cold Weather Concreting (ACI 306.1-90)

ACI 306.1-90

Table 3.2.1 — Concrete temperature

(1)	(2)	(3)
Least dimension of section, in.	Minimum temperature of concrete as placed and maintained during the protection period, F	Maximum gradual decrease in surface temperature during any 24 h after end of protection, F
Less than 12	55	50
12 to less than 36	50	40
36 to 72	45	30
Greater than 72	40	20

Concrete temperatures

Minimum concrete temps during the protection period are shown in column (2)

Temps of concrete as placed shall not exceed the Column (2) by more than 20°F.

The maximum decrease in temperature at the surface of the concrete in a 24-hour period shall not exceed the values in column (3)

Cure and protect concrete from freezing for a minimum of 3 days.

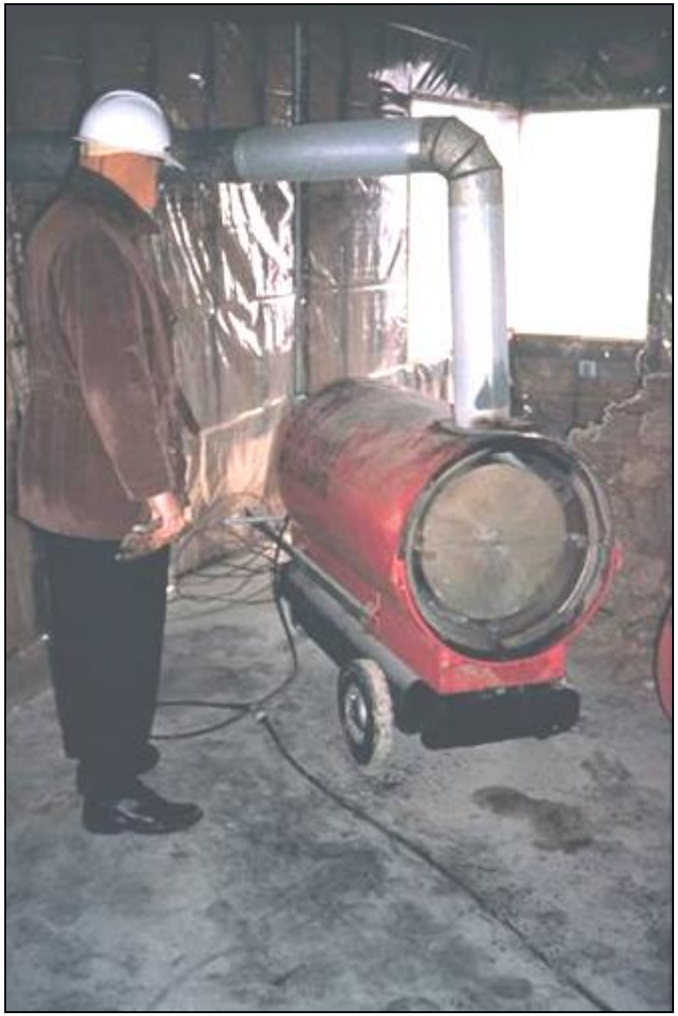
Cold Weather Concreting Objectives

- Prevent damage to concrete due to freezing at early ages
- Assure that concrete develops the required strength so that forms may be safely removed
- Maintain curing conditions to provide normal strength development without using excessive heat
- Limit rapid temperature changes
- Provide protection that is consistent with the intended use of the structure

Cold Weather Challenges

- Slower hydration
  - Retardation of set time
  - Plastic shrinkage crack potential, as surface dries before it’s ready for finishing operations
- Lower early age strength
  - Form removal slowed
- Potential for thermal cracking
- Protect from early freezing

Job site protection: Heated Enclosures



Must Vent CO_2 Exhaust Gas to prevent carbonization resulting in soft dusting surfaces

Dusting

Preparation before placement

- Remove all snow, ice, & never place on a frozen subgrade
- Surfaces in contact with the concrete should be above freezing (32° F).
- Provide insulating blankets on ground several days in advance
- Set up wind breaks

Massive Metallic Embedments

Most embedments including bars, do not need to be heated unless the air temperature is below 10° F (-12°C).

Embedments with a cross-sectional area greater than 4 in² should be heated to above 32° F.

Bars < No.18 ?

Warm up metal larger metal embeds

Insulated Concrete Forms

Contractors Be Prepared!

Have plenty of blankets ready

Hydronic Heat System

Hydronic Heat System

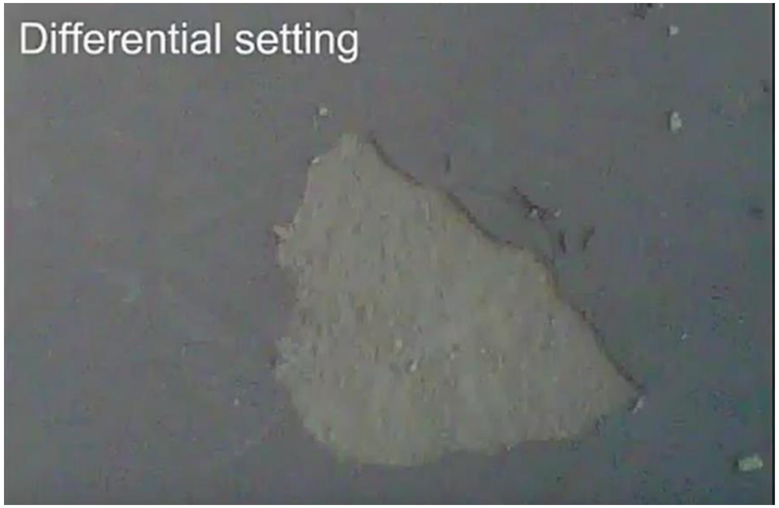
Use system to heat concrete after placement

EFFECTS OF COLD TEMPERATURES ON FINISHING

Concrete on a very cold subbase feels rubbery

The bottom cools rapidly and top remains warm

To reduce this differential set retardation, keep the subgrade covered until the time of concrete placement.

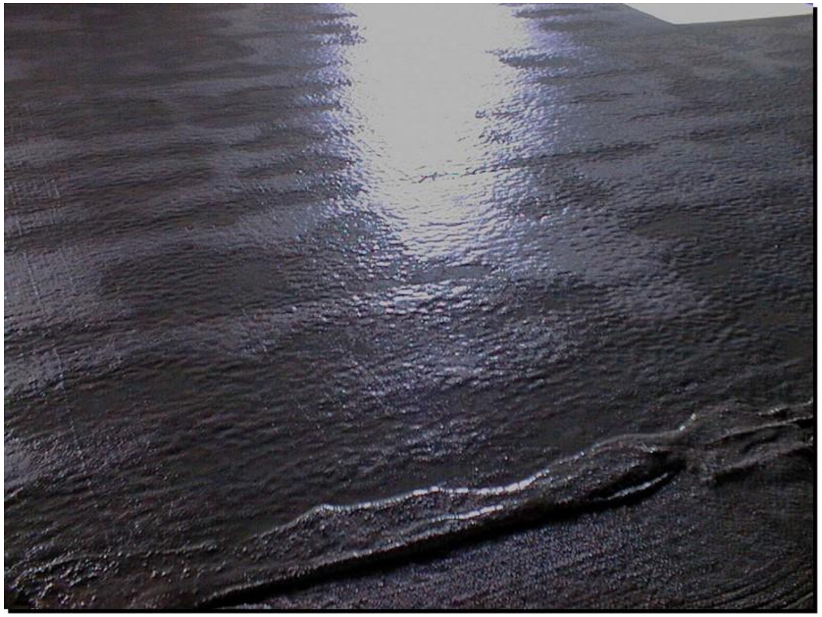


Hard-troweled finished slabs

- For **steel-troweled** floor and slab construction, **air-entrained** concrete should **not** be specified.
- Finishing problems often develop when the total air content >3%
- Addition of air entrainment may lead to finishing difficulties or problems with blisters, delamination, or other surface defects.
- Air entrainment may be necessary for the duration of the project even though the concrete will not be exposed to freezing and thawing in final service condition. (best to use Magnesium trowel)

Finishing air-entrained slabs

- For flatwork in cold weather, lower-slump concrete minimizes excessive bleed water and allows earlier set time.
- During cold weather, bleed water may remain on the surface for extended periods, interfering with or prolonging finishing operations.
- If bleed water is finished into the concrete, the resulting surface will have lower strength and be prone to dusting and deterioration.



EFFECTS OF COLD TEMPERATURES ON FINISHING

Maximum temperature differential between the concrete interior and the concrete surface shouldn't exceed 35°F. Thermal cracks if 30ºF differential between top & bottom surface of concrete

When the concrete materials are heated, the concrete temperatures should be between 50 and 70°F.

Crust forms as the surface dries and cracks may occur

Drying Shrinkage Cracks

Blisters

Bleed water and/or air sealed into concrete

Minimum required strength for concrete to freeze once

- Concrete protected from freezing until it attains a compressive strength of at least 500 psi (3.5 MPa) will not be damaged by exposure to a <u>single</u> freezing cycle.

- This is about 1-2 days after placement for most concrete maintained at 50F

Effect of Freezing Fresh Concrete

Up to 50% reduction of ultimate strength can occur if frozen before reaching a strength of 3.5 MPa (500 psi)

Ice crystal impression can be seen in the frozen paste

What strength is safe to allow concrete to freeze?

- Newly placed concrete is saturated with water and should be protected from freezing and thawing cycles until it has reached a strength of at least 3500 psi .

Production Control Options w/ Materials & Mixtures

- Use Type III cement (High Early Strength)
- Increase cement amount
- Reduce percentage of SCMs (fly ash, slag cement)
- Reduce water content (lower w/cm) to mitigate problems do to excessive bleed water and delayed set time.
- Use accelerators ($CaCl_2$ if permitted or non-chloride)
- Monitor Air entrained concrete during freezing conditions
- Control temperature loss of fresh concrete
  - Hot water
  - Heated aggregates

Expected temperature loss during delivery

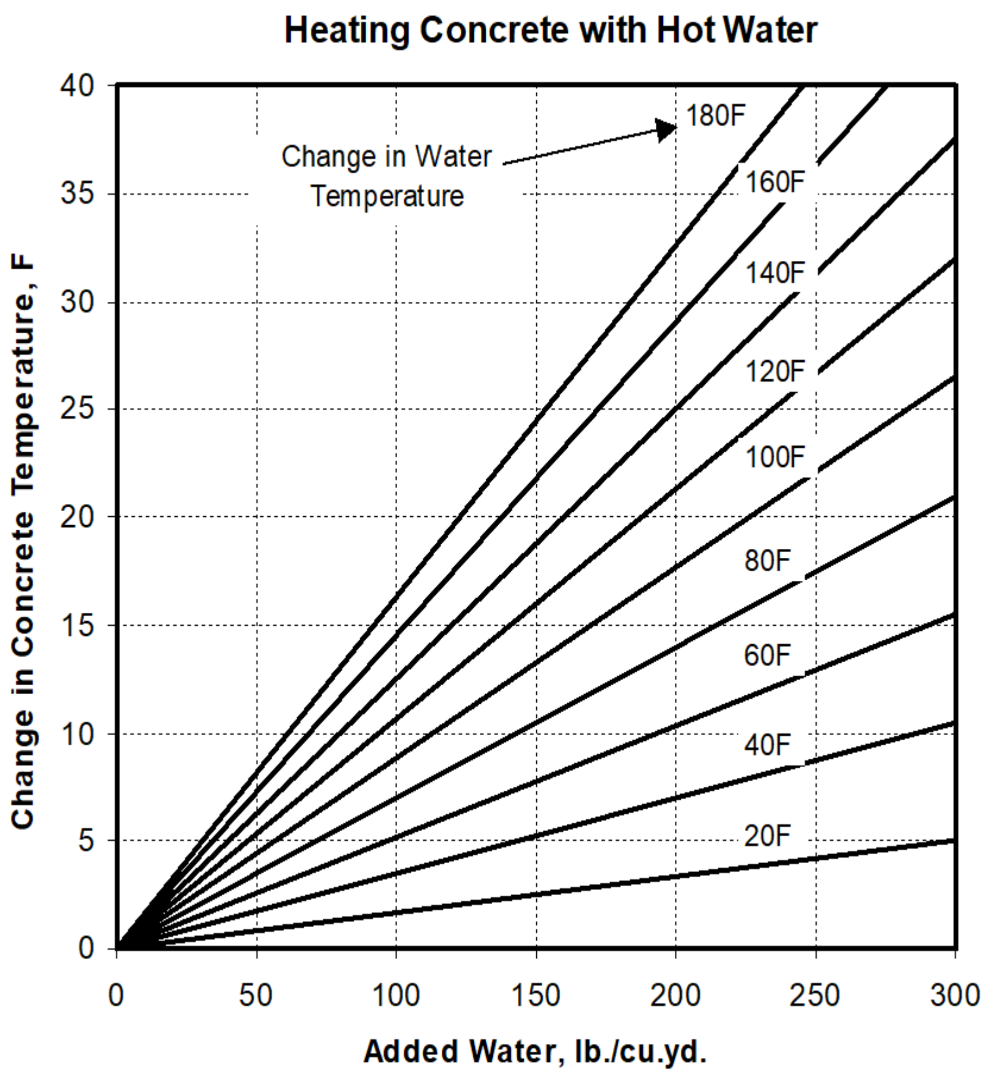
Temperature drop for 1 hour delivery in revolving drum mixers:
T = 0.25 (tr - ta)

tr =50˚F (Temp required at job)
ta =20˚F (Ambient Temp)
∆ =30 (tr - ta)

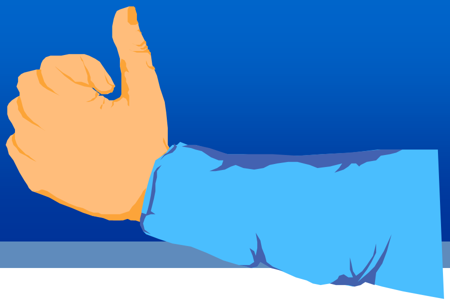
0.25 * 30 = 7.5˚ F temp drop

Must batch concrete at 58°F

Could be 7.5˚ F for 20˚ F ambient



Rules of Thumb:



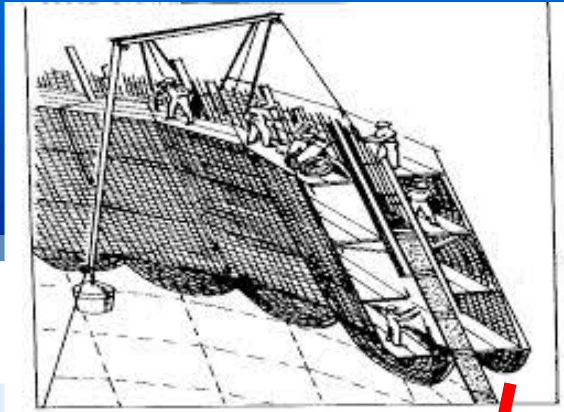
- For every 20°F temperature drop, setting time is doubled
  - A change in temperature from 70ºF to 50ºF will **double** the time it takes for concrete to set
- Warm concrete on cold subgrade gets cold very fast
- Different mixes and materials have very different setting times
- Adding 1 to 2 gallons of water per cy will delay set time by 1/2 to 2 hours

Form Removal

- Based on in-place strength, not time!
- Options include:
  - Field cured cylinders (not very reliable)
  - In-place testing (in-place strength is generally better than field cured cylinders)
  - Pull-out testing, penetration resistance, pulse velocity measurement
  - Maturity testing

Avoid rapid temperature drop when removing blankets (temperature shock)

Maturity Testing (Time & Temperature)



Case History - Willow Island, WV
Cooling Tower Collapse April 27, 1978
Wet Concrete Possible Cause Of 51 …

Protection of Acceptance Samples

ACI Guidelines
Initial cure at 60-80°F
=/> 6000PSI at 68-78°F

Ohio Building Code - Section 1904
Exposure categories and classes.

Concrete shall be assigned to exposure classes in accordance with ACI 318-11, Section 4.2, based on:

- **1. Exposure to freezing and thawing in a moist condition or deicer chemicals;** (F3-Very Severe)
- 2. Exposure to sulfates in water or soil; (S)
- 3. Exposure to water where the concrete is intended to have low permeability; (P)
- 4. Exposure to chlorides from deicing chemicals, salt, saltwater, brackish water, seawater or spray from these sources, where the concrete has steel reinforcement. (C)

OBC SECTION 1905
CONCRETE QUALITY, MIXING AND PLACING

- **1905.6.3 Strength test specimens**. Specimens prepared for acceptance testing of concrete in accordance with Section 1905.6.2 and strength test acceptance criteria shall comply with the provisions of ACI 318-11, Section 5.6.3
- **1905.6.4 Field-cured specimens**. Where required by the building official to determine adequacy of curing and protection of concrete in the structure, specimens shall be prepared, cured, tested and test results evaluated for acceptance in accordance with ACI 318-11, Section 5.6.4.

https://www.com.ohio.gov/documents/dic_bbst_entireOBCJuly2011.pdf

ACI 306R-16

8.2 – Field-cured cylinders

The use of field-cured cylinders <u>is inappropriate </u>and should not be allowed in cold weather concreting.

In-place testing, maturity testing, or both, should be used.

8.3 – In-place testing

A number of techniques are available for estimating the in-place strength of concrete (ACI 228.1R).

8.4 – Maturity testing

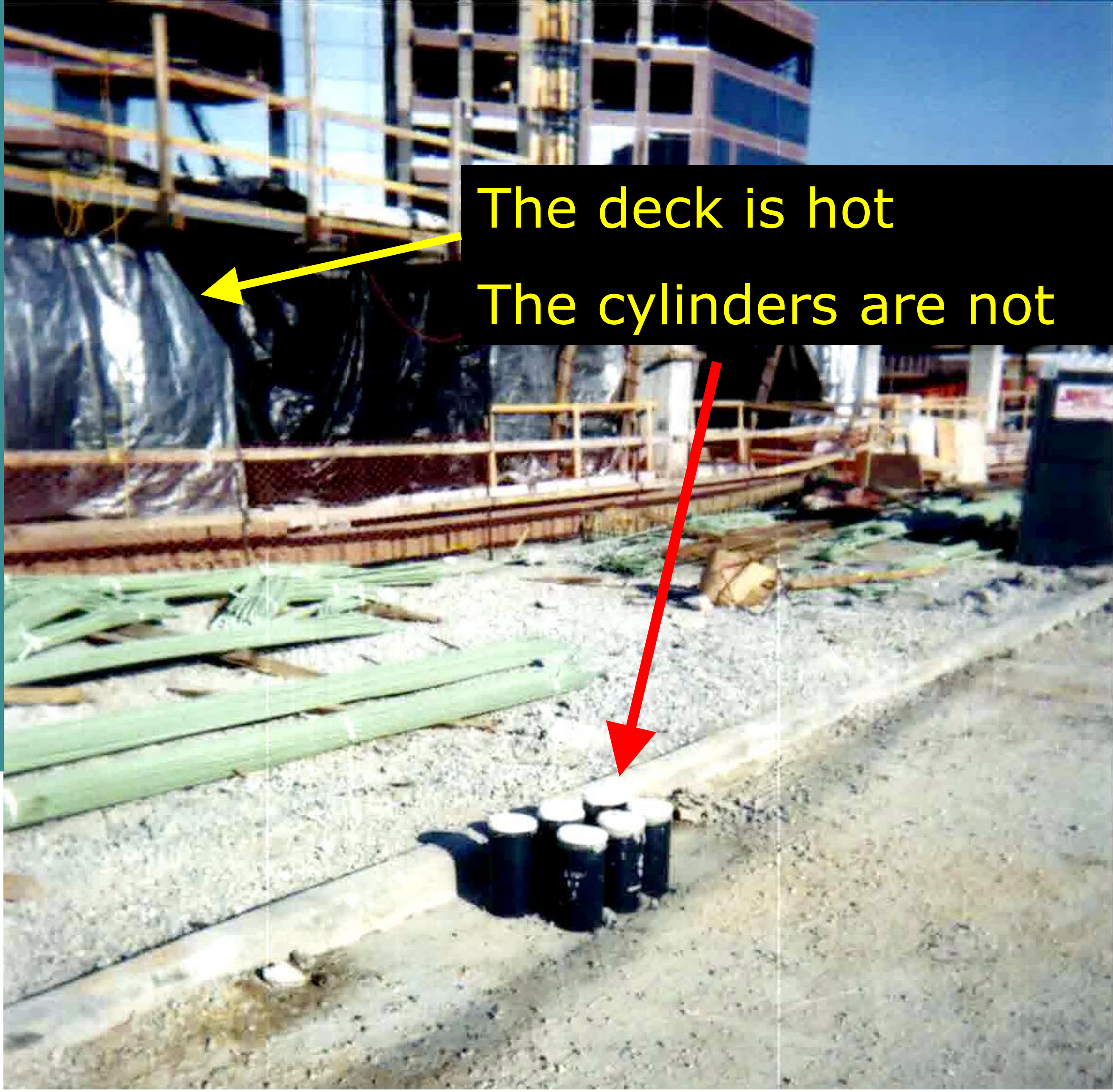
Concrete maturity is based on the concept that the combination of curing time and temperature of the concrete yields a specific strength for a given concrete mixture.

Concrete Cylinders at jobsite.

Date: March 17 2011, 7:30 a.m.

Ambient Temperature at the time the photo was taken: 38º F

Curing conditions of deck: Heated & Covered, with full jacketing.



Field Cure Cylinders ?

Maturity Concept

- $M = \Sigma\,(T - T_o)\,\Delta t$

where

- M = maturity factor, deg-hr
- T = temperature of concrete, deg F (C)
- T_o = datum temperature, deg F (C)

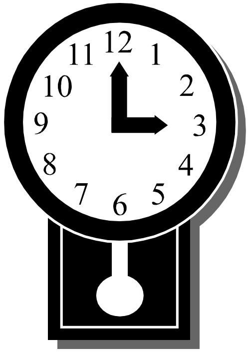
  (approx. 32°F)
- Δt = duration of curing period at temperature T, hr

Example of a Match Cure System

Benefits of Using Set Accelerating Admixtures

The reduction of setting time and the acceleration of strength gain often result in substantial savings due to:

- shorter protection periods
- faster form reuse
- earlier removal of shoring
- and less labor in finishing flatwork



Acceleration may be encouraged by using:

- Type III Portland Cement
- additional cement (normally 20% addition = Type III performance)
- heated materials
- set accelerating admixtures

Chloride and Non-Chloride Accelerators

- Calcium Chloride:
  - The most cost effective accelerator available; provides improved finish in some cases
  - Very effective performance in both powder or solution
  - Dosage based on % by weight of cement (Typ. 1% or 2%, 2% is max)
  - Limitations:
    - 1. It causes corrosion of reinforcing steel in presence of oxygen and moisture.
    - 2. It tends to result in a darker appearing surface

Calcium Chloride Admixture

Non-chloride accelerators

- Type E (ASTM C494)
- May contain a small amount of calcium chloride
- More expensive than calcium chloride
- Will not darken surface
- Not as effective as $CaCl_2$
- 2% Non-chloride is about 1 gal / cu yd of water replacement

To prevent early age freezing

- Provide protection immediately after concrete placement
- Don’t allow concrete to freeze when saturated
- Set accelerators are not used as substitute for proper curing and protection

Table 5.1 – Recommended concrete temperatures

Table 5.1—Recommended concrete temperatures

		Section size, minimum dimension			
		< 12 in. (300 mm)	12 to 36 in. (300 to 900 mm)	36 to 72 in. (900 to 1800 mm)	> 72 in. (1800 mm)
Line	**Air temperature**	**Minimum concrete temperature as placed and maintained**			
1	—	55°F (13°C)	50°F (10°C)	45°F (7°C)	40°F (5°C)
		Minimum concrete temperature as mixed for indicated air temperature*			
2	Above 30°F (–1°C)	60°F (16°C)	55°F (13°C)	50°F (10°C)	45°F (7°C)
3	0 to 30°F (–18 to –1°C)	65°F (18°C)	60°F (16°C)	55°F (13°C)	50°F (10°C)
4	Below 0°F (–18°C)	70°F (21°C)	65°F (18°C)	60°F (16°C)	55°F (13°C)
5	—	**Maximum allowable gradual temperature drop in first 24 hours after end of protection**			
		50°F (28°C)	40° (22°C)	30°F (17°C)	20°F (11°C)

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

Note 1: For Line 1, maximum placement temperature is minimum temperature in the table plus 20°F (11°C).

Note 2: For Lines 2-4, maximum temperature is minimum temperature in the table plus 15°F (9°C).

Table 7.2 - Length of protection period for concrete

	Service Condition	Normal Concrete	Accelerated Set Concrete
At minimum temperatures in line 1	Not exposed	2 days	1 day
	Exposed	3 days	2 days

Removing thermal protection CAUTION !

- Remove curing blankets slowly
- Do not “shock” the concrete
- Allow it to acclimate to the cold temperatures
- Slide 2x4s under the blankets to allow some air circulation for a day or two

What is Curing?

Definition:

maintenance of a satisfactory moisture content and temperature in concrete for a suitable period of time immediately following placing & finishing so that the desired properties may develop…*offer ample condition for hydration to occur*

Minimal Requirements

Time: 3-7 days
Temp: 50-100 F
Moisture: Saturated at all times

Caution on Curing Compounds

- Not suggested after about October 1st
- Seals the excess moisture in the concrete
- Will actually cause scaling if excess water in the concrete freezes
- Use blankets instead

ODOT 2016 CMS Placing Concrete Paving

Item 451.07

When the air temperature is 35 °F (2 °C) or below, ensure the concrete has a temperature of between 50 and 80 °F (10 and 27 °C) at the point of placement.

When the air temperature is greater than 35 °F (2 °C) before placing, maintain a concrete temperature of not more than 95 °F (35 °C).

Do not place concrete on any surface that is frozen or has frost.

Contractor Communication

Communicate to the Ready Mixed Supplier:

- Design Strength and early age strength requirements
- Air Entrainment, Agg Size, W/C ratio, slump
- Exposure condition and ambient temperatures
- Required set time - need for accelerators
- Section Thickness – dictates minimum concrete temp as placed
- Placement method –slump modification admixtures
- Producer assumes the contractor will have proper cold weather protection and concrete curing

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Resources

- American Concrete Institute, *ACI 306R-16 Guide To Cold Weather Concreting*
- American Concrete Institute, *ACI C873-15 Compressive Strength by Cast-In-Place Molds*
- American Concrete Institute, *ACI 228*
- National Ready Mixed Concrete Association, *Concrete in Practice (CIP) 13, Concrete Blisters and (CIP) 20, Delamination of Troweled Concrete Surfaces*, (CIP) 27 Cold Weather Concreting, (CIP) 42 Thermal Cracking of Concrete (www.nrmca.org);
- International Code Council, *2012 International Building Code*;
- Ohio Concrete, *Technical Tips for Residential Concrete, #4 Cold Weather Concreting*
- Ohio Concrete, *Industry Recommendation for Exterior Concrete Flatwork,* 2014
- *The Contractor's Guide to Quality Concrete Construction*, An ACI / ASCC Manual
- *Design and Control of Concrete Mixtures*, Portland Cement Association, Skokie, IL, 16th Edition, 2016

Thank you for Listening !

Questions??

Upcoming Future Webinars

- Stay tuned for future webinars by Ohio Concrete
  - We welcome suggested topics

Your opinion matters!

Please take a moment to complete the brief survey following today's presentation to help us improve future webinars.

THANK YOU!