April 4, 2022
ICRI 2022 Spring Convention

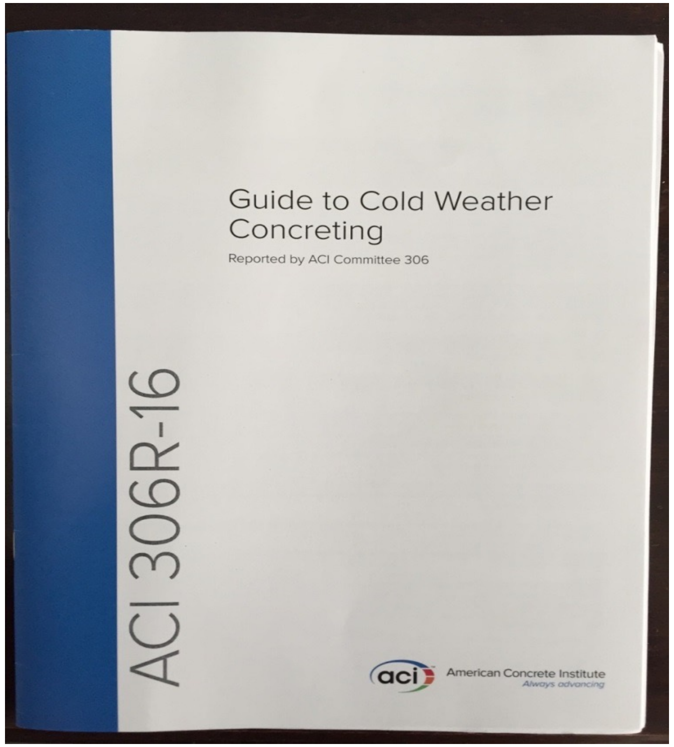
Cold Weather Concrete and Concrete Repair Practices

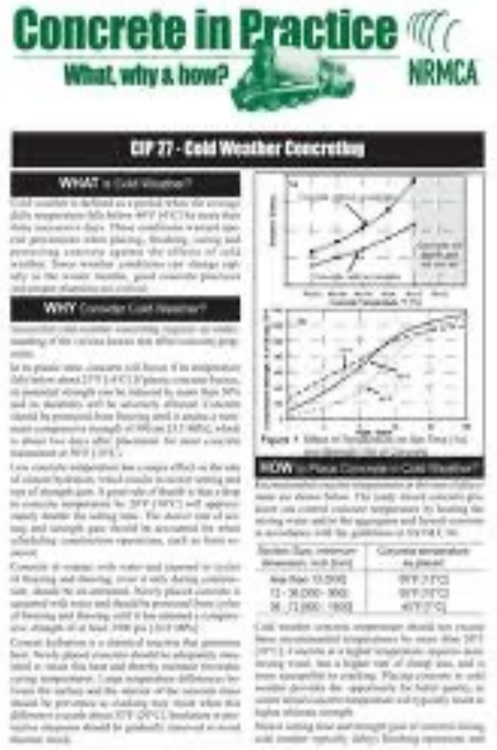
Matt Hansen
National Business Development
Euclid Chemical

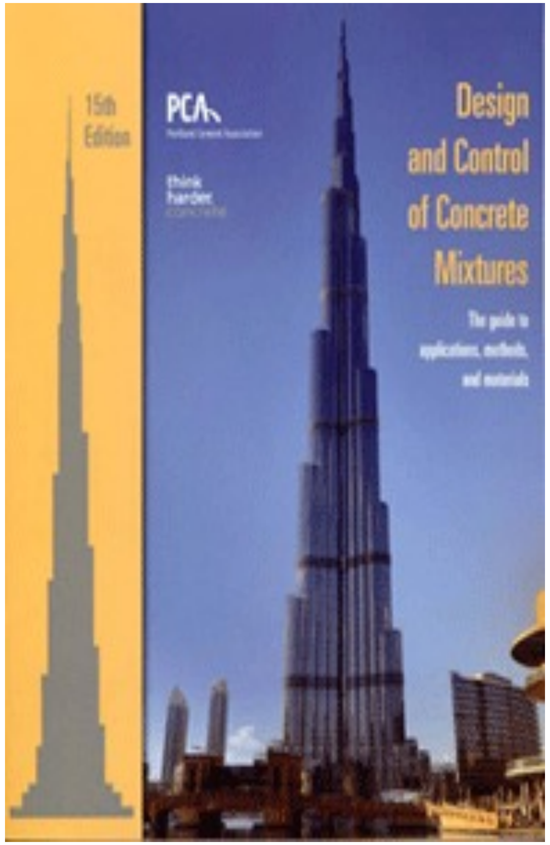
ICRI CONCRETE REPAIR
Restore | Repurpose | Renew

The ideas expressed in this ICRI hosted webinar are those of the speakers and do not necessarily reflect the views and opinions of ICRI, its Board, committees, or sponsors.

Winter Time Reading:
Cold Weather Concreting…

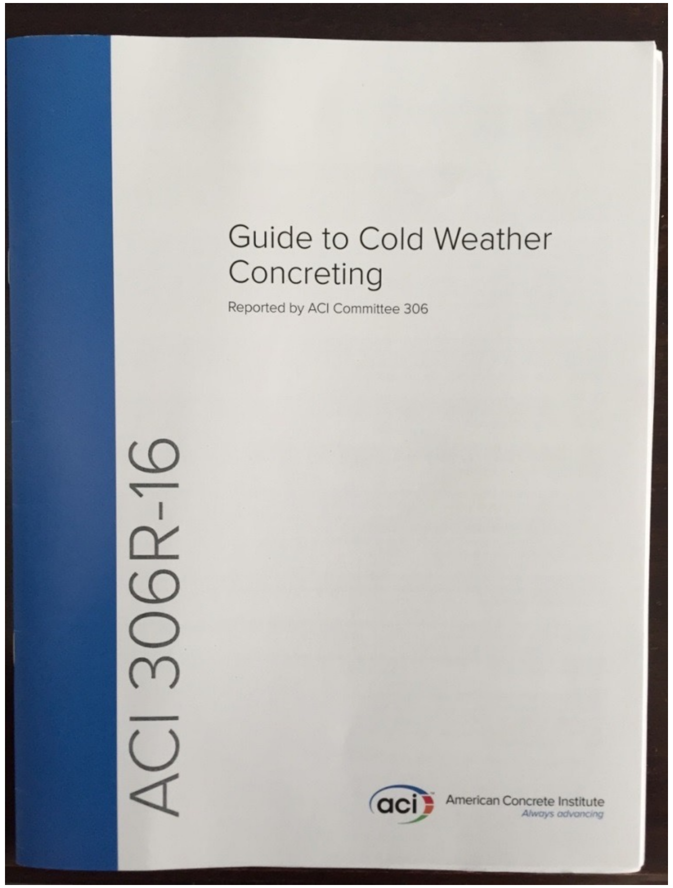






ICRI
CONCRETE REPAIR

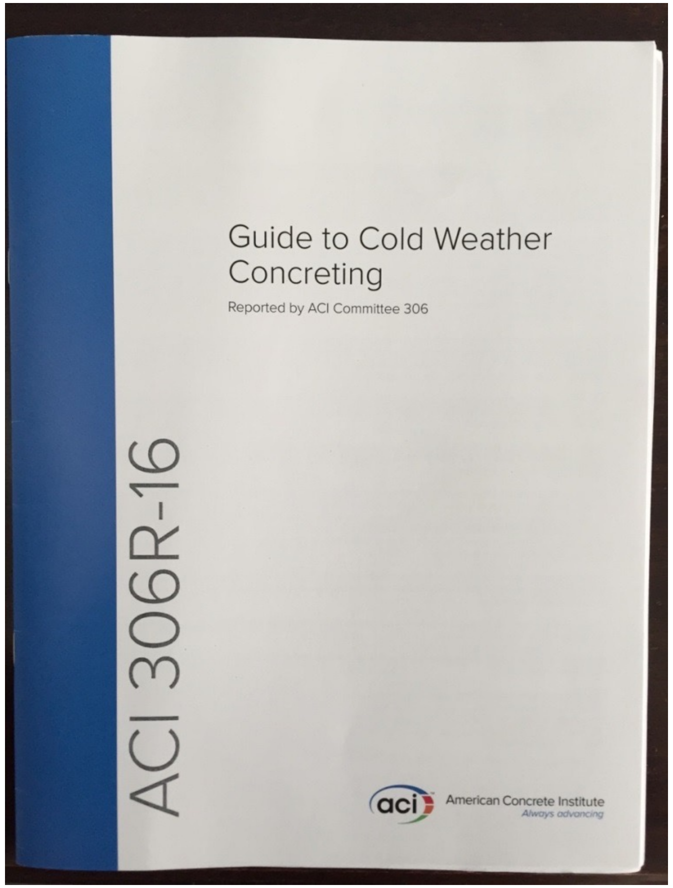
Cold Weather Concrete - Defined



- **cold weather**—when air temperature has fallen to, or is expected to fall below, 40°F (4°C) during the protection period; protection period is defined as the time recom-mended to prevent concrete from being adversely affected by exposure to cold weather during construction.
- Most repair mortar manufacturers recommend against placement of prepackaged repair mortars at temperatures below 40 deg F (4 C).

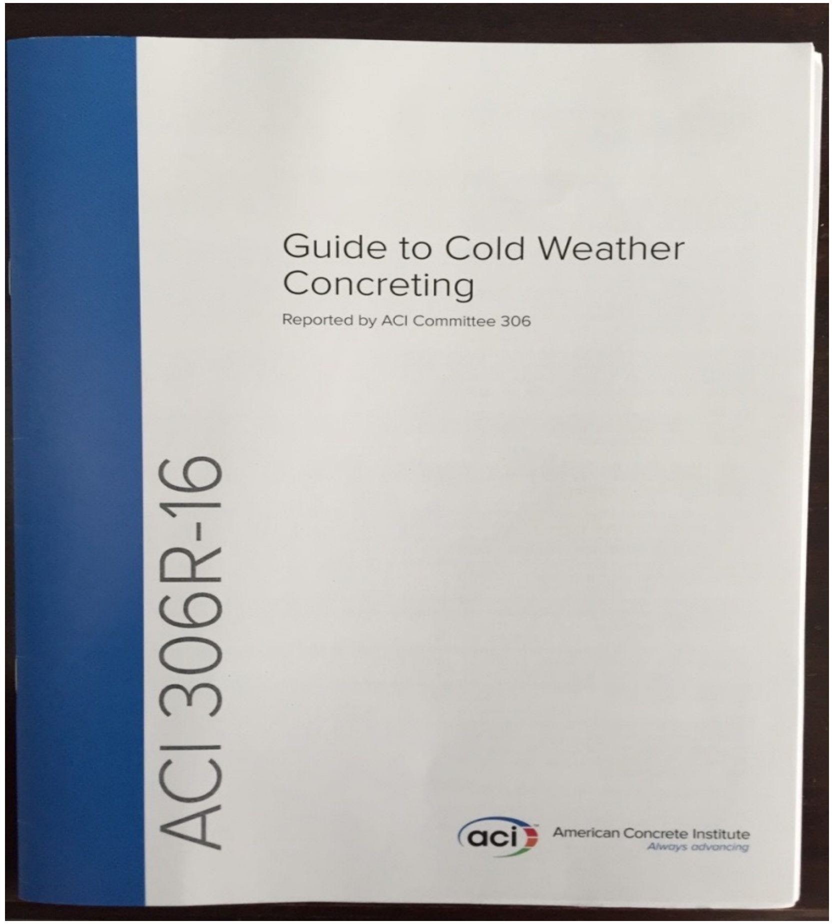
ICRI CONCRETE REPAIR

Objectives



1. Prevent damage due to early age freezing.
   - Critical Saturation
   - Concrete - Minimum 500 psi for single freeze (3500 psi for multiple)
2. Ensure required strength development for safe removal of forms, shores, reshores and for safe loading.
3. Maintain curing conditions without exceeding recommended concrete temperature by more than 20 deg F, and without using water. (Critical Saturation)
4. Limit rapid temperature changes.
5. Provide protection consistent with the durability of the structure during its design life.
   - Short-term gains in construction economy on concrete protection should not be obtained at the expense of long-term durability

Goal of ACI 306



Concrete placed during cold weather will develop sufficient strength and durability to satisfy the intended service requirements when it is properly produced, placed, and protected.

The Key to Proper Cold Weather Concrete is Managing Risk

Cold Weather Discussion

1. Risks
2. Potential Problems
3. Cold Weather Plan
4. Objectives
5. Goals

Risks of Cold Weather Concrete and Repairs

1. Freezing is the number 1 risk for cold weather concrete and concrete repair mortars.
2. Neglecting protection against early freezing can cause immediate destruction or permanently weakened concrete and repair mortars.
3. The durability of concrete and repair mortars can be significantly reduced

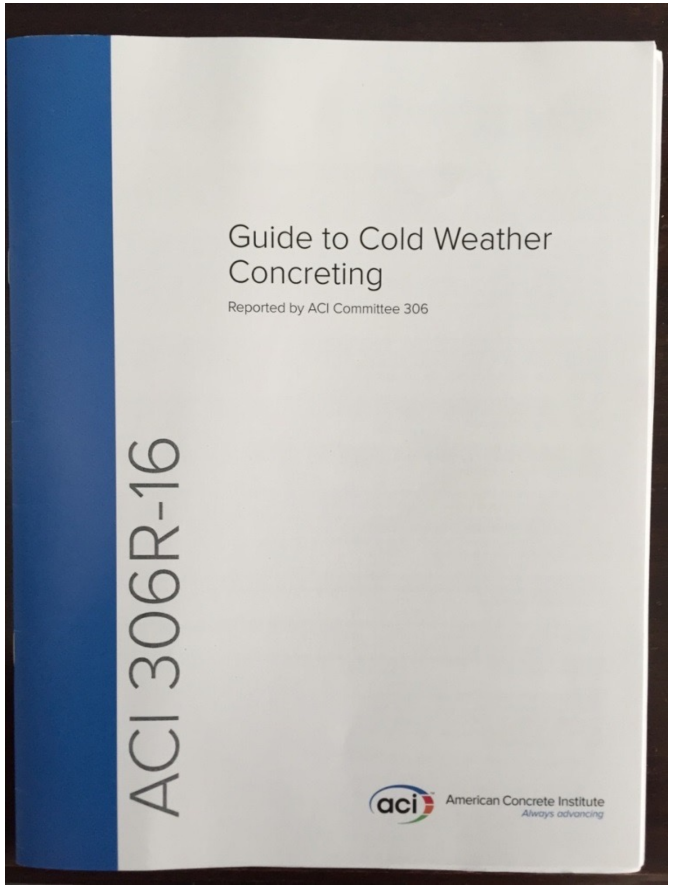
Effect of Freezing – The Race is On

- At a certain point after hydration, the concrete/repair mortar is strong enough to resist freezing
- Very little hydration takes place below 40 ºF
  - True of all concrete and most repair mortars.
  - Chemical reactions of polymers also slow dramatically
- Race Between the hydration of cement (Generates heat as well as strength) and heat loss
  - The thinner the section the faster the heat loss
  - Many repairs involve thinner sections.

ICRI CONCRETE REPAIR

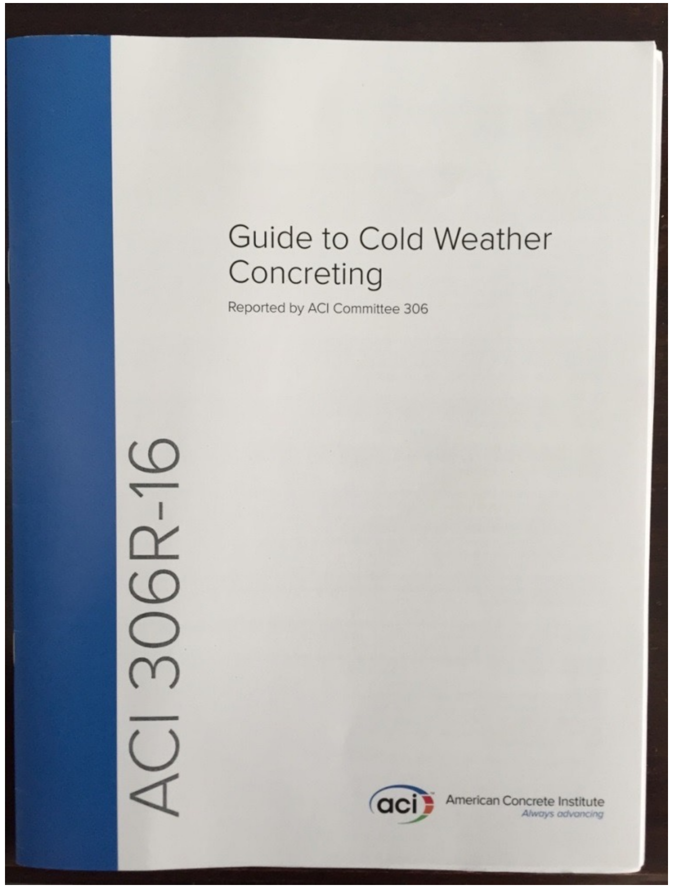
Bladed ice crystals cast in cement paste- concrete froze while still plastic

Critical Saturation - Defined



- Critical saturation is the level at which a single cycle of freezing can cause damage. The degree of saturation falls below critical saturation at the approximate time the concrete attains a compressive strength of 500 psi. (3.5 MPa)
- 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 single freezing-and-thawing cycle. It will mature to its potential strength and will not be damaged, despite subsequent exposure to cold weather. No further protection is necessary unless a minimum strength at a minimum time is specified.

Concrete/Repair Mortar Freezing



- Hydration of the cementitious fraction is needed to develop properties relating to durability, such as strength. If repeated exposure to freezing and thawing is anticipated, reaching 500 psi (3.5 MPa) is not suficient protection. Concrete with a compressive strength less than 3500 psi (24.5 MPa) and exposed to repeated freezing-and-thawing cycles while critically saturated may be damaged. Consider the addition of air entrainment in the concrete (Table 4.1 of ACI 201.2R) and monitoring the concrete strength gain so that 3500 psi (24.5 MPa) is reached before the protection is removed.
- **Concrete intended to provide low permeability or high resistance to chloride ion ingress, identified in the contract documents as being Exposure Class F3, C2, or P1 as deined by ACI 318, should be protected from freezing until the mixture design compressive strength has been achieved.**
- Many prepackaged repair mortars call for higher compressive strength attainment, i.e. 1,000 psi (7 Mpa), or above prior to allowing freeze.

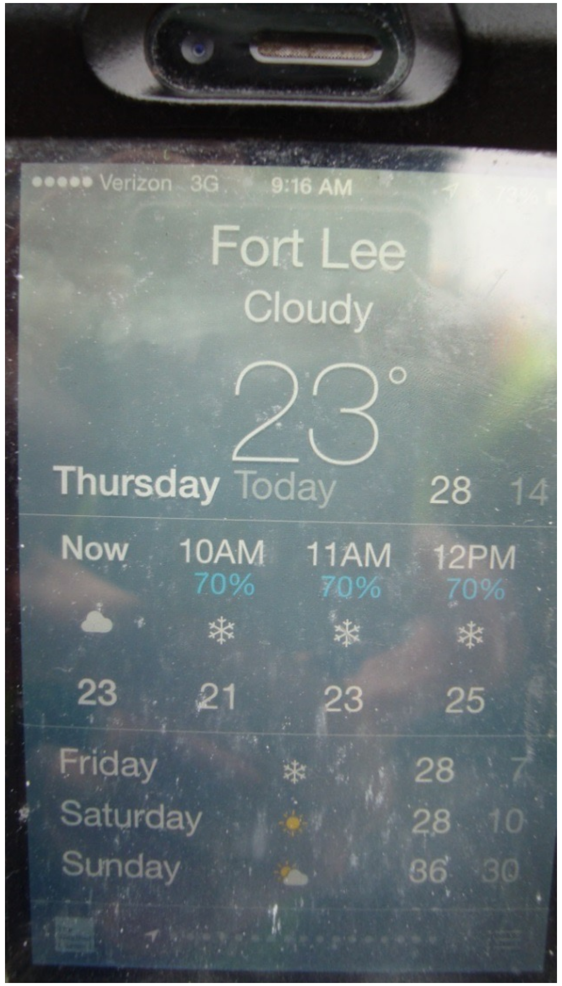
ICRI
CONCRETE REPAIR

Protect the Concrete from Freezing

- Concrete temperature
  - Heating water and aggregates
- Increase cement content
- Type III high early cement
- Set accelerating admixtures
- Insulated covers until 500 psi (2 days at 50 deg F)
- Insulated forms
- Insulated edges and corners
- Heated enclosures

ICRI CONCRETE REPAIR

An Example:



Verizon 3G
9:16 AM
Fort Lee
Cloudy
23°
Thursday Today 28 14
Now 10AM 11AM 12PM
70% 70% 70%
23 21 23 25
Friday 28 7
Saturday 28 10
Sunday 36 30

ThermoWorks
0 20 40 60 80 100 120 140 160 180 200 220
°F

Recommended Concrete Temperatures

ACI 306-16 (Table 5.1)

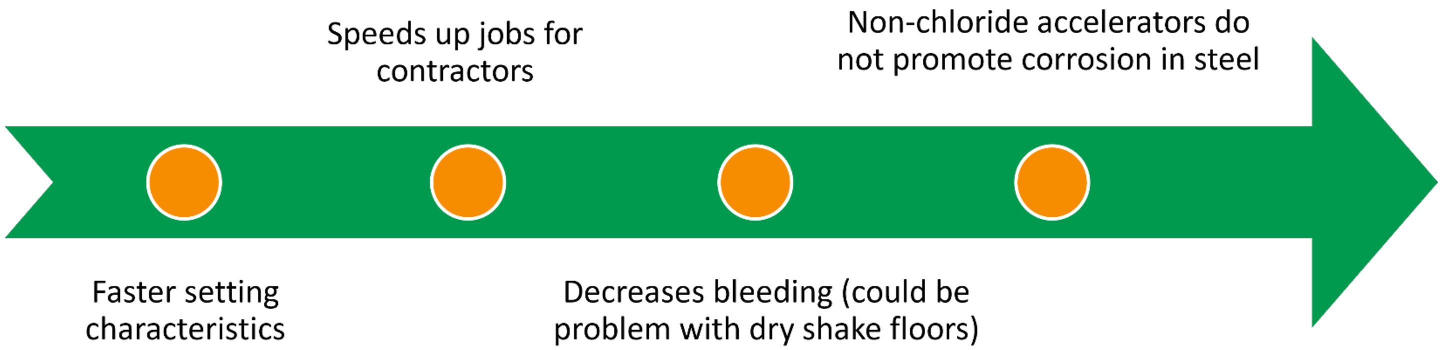
		Section size, minimum dimension			
		< 12 in. (300 mm)	12 to 36 in. (300 to 900 mm)	36 to 72 in. (900 to 1800 mm)	> 72 in. (1800 mm)
Line	Air temperature	Minimum concrete temperature as placed and maintained			
1	—	55 F (13 C)	50 F (10 C)	45 F (7 C)	40 F (5 C)
		Minimum concrete temperature as mixed 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)

SECTION 4.3: The concrete temperature during placement should be near the temperature values in Table 5.1 and should not be higher than these values by more than 20°F (11°C).

SECTION 5.2: While it is difficult to uniformly heat aggregates to a predetermined temperature, mixing water temperature can be adjusted easily by blending hot and cold water to obtain a **concrete temperature within 10°F (5°C) of the recommended temperature**.

Mix Cold Weather Concrete Design Keypoints

- Proper cement content (no SCMs)
- Low W/CM ratio (reduce excess water)
- Water reducing admixtures
- Air entraining admixtures (for freeze/thaw)
- Set accelerating admixtures (non-chloride)



Required for Durability

Concrete exposed to freeze/thaw while saturated requires lower w/cm than required for strength

1. w/cm .50 (4,000 psi) moderate to severe freeze/ thaw
2. w/cm .45 (4,500psi) deicing salts
3. w/cm .40 (5,000 psi reinforced concrete subject to brackish water, sea water or deicing chemicals
4. Air entrainment is also required.

Cold Weather Concrete

KEEP IT SIMPLE!

1. 600# TYPE 1 CEMENT minimum
2. 6% AIR
3. Set accelerating admixture

Why Use Set Accelerating Admixtures in Concrete

1. Reduces initial set
2. Concrete placing cycle is accelerated
3. Improves early strength gain
4. Allows same-day finishing
5. Maintain Schedule
6. Emergency Situations

Set Accelerating Admixtures

Under certain conditions, $CaCl_2$ should not be used to accelerate setting and hardening because of increased chances of corrosion of metals embedded in concrete

ICRI
CONCRETE REPAIR

Set Accelerating Admixtures

- ASTM C494 Type C and E admixtures can be used to accelerate the set of concrete helping it to reach 500 psi sooner.
- Some non-chloride accelerating admixtures can be used to actually lower the freezing point of the water in the mix.
- Work closely with local ready mix producers and admixture suppliers.
- Most repair mortar manufacturers do not recommend adding admixtures to their products.

ICRI CONCRETE REPAIR

Insulated Covers

- Polystyrene foam sheets
- Urethane foam
- Insulation blankets
- Straw
- Do not use insulation beyond the recommended amount because it could raise the internal temperature of the concrete above recommended levels, which lengthens the gradual cooling period, increases thermal shrinkage, and increases the risk of cracking due to thermal shock.

ICRI
CONCRETE REPAIR

Insulated Covers and Forms

- Corners and edges are particularly vulnerable to cold weather damage.
- Thickness of insulation should be approximately 3 times the thickness recommended for walls and slabs.

Heated Enclosures

Heated Enclosures

- Generally needed for placing operations when the air temperature is lower than –5°F (–20°C)

Heaters

- Direct fired
- Indirect fired
- Hydronic

ICRI
CONCRETE REPAIR

Direct Fired Heaters

- Unless concrete is protected carbon dioxide combines with calcium hydroxide in fresh concrete to create soft dusting surfaces.

Indirect Fired Heaters

- Indirect fired heaters can vent carbon dioxide outside the enclosure.
- Do not blow heat directly on concrete or concrete repair mortars.

Hydronic Heat

- Hydronic heater provide heated water hoses. Combustion units are typically located outside enclosure.

Potential Problems for Concrete and Concrete Repairs in Cold Weather

1. Delayed set times
2. Over/early finishing
3. Frozen sub-grade
4. Ice in bottom of forms
5. Cold formwork and Reinforcing Steel
6. Plastic shrinkage cracking
7. Crazing
8. Thermal shock
9. Hurried and/or poor workmanship

ICRI CONCRETE REPAIR

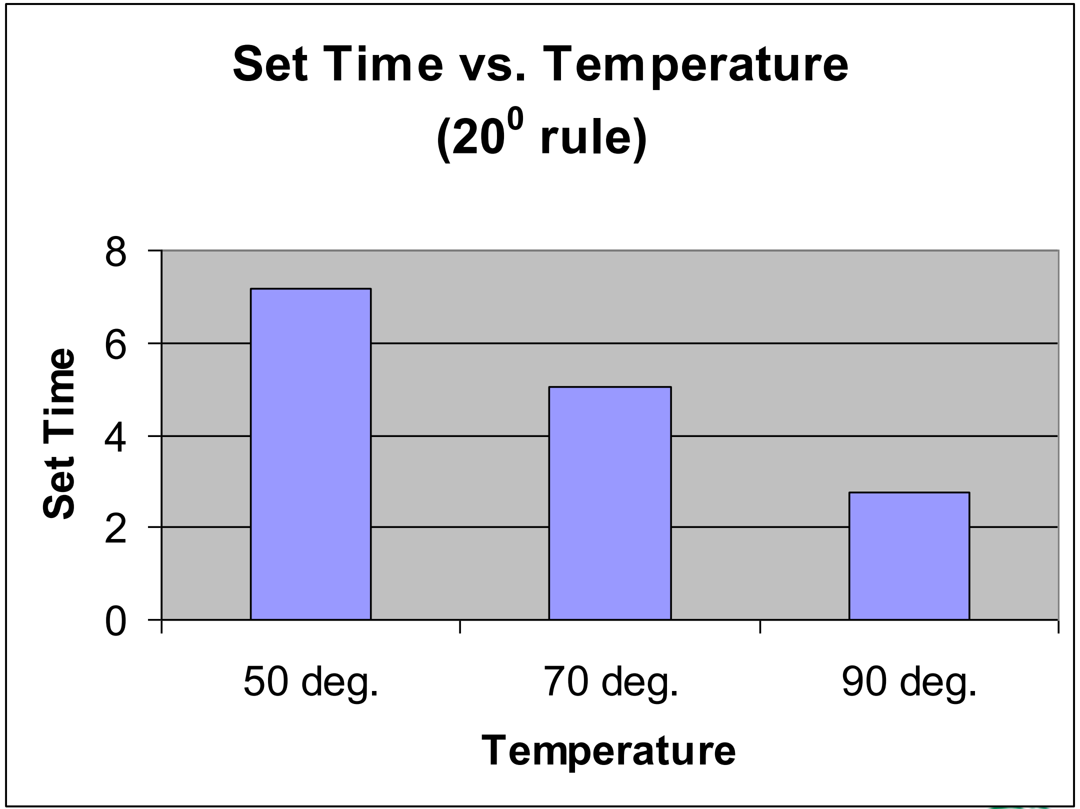
Setting Time of Concrete at Various Temperatures (Delay)

Temperatures	Approximate Setting Time
100 ºF (38 ºC)	2 hours
90 ºF (32 ºC)	3 hours
80 ºF (27 ºC)	4 hours
70 ºF (21 ºC)	6 hours
60 ºF (16 ºC)	8 hours
50 ºF (10 ºC)	11 hours
40 ºF (4 ºC)	14 hours

ICRI CONCRETE REPAIR

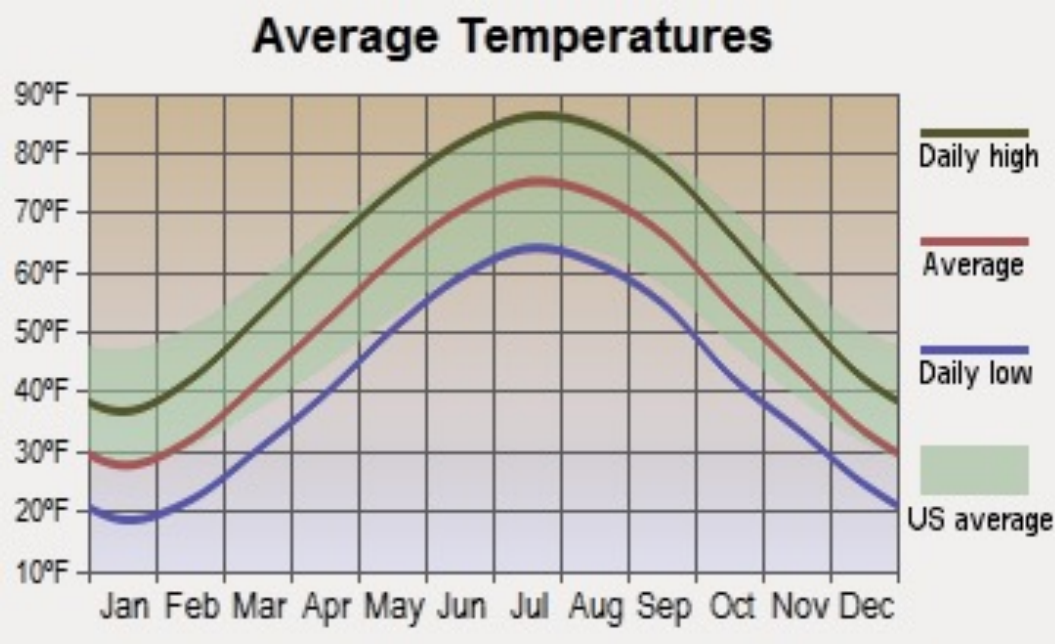
Prepackaged Repair Mortars

- Most repair mortar manufacturers use the 20 deg F rule.
- For every 20 deg F temp change up or down from to 70 deg, set time is either increased (colder) or decreased (hotter) by 50%.



Prepackaged Repair Mortars

- Most manufacturers recommend minimum of 40 degrees and rising for application of repair mortars.
- Store materials in warm temperatures and mix with warm (Not Hot) water.
- Do not apply to frozen or frost covered surfaces.



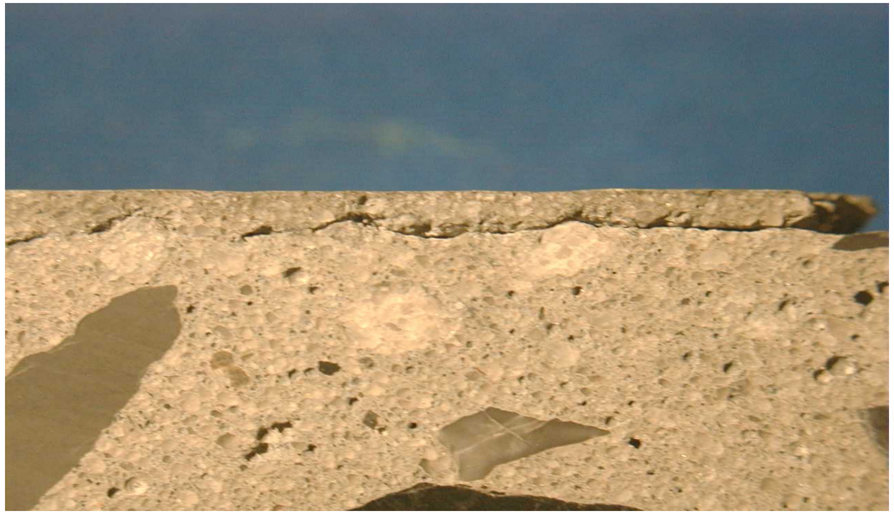
Potential Problems for Concrete and Concrete Repairs in Cold Weather

1. Delayed set times
2. Over/early finishing
3. Frozen sub-grade
4. Ice in bottom of forms
5. Cold formwork and Reinforcing Steel
6. Plastic shrinkage cracking
7. Crazing
8. Thermal shock
9. Hurried and poor workmanship

ICRI CONCRETE REPAIR

Over/ early finishing

1. Because of drying conditions and delayed set, concrete may appear to be ready to finish or, require additional finishing effort
2. Results:
   A. Detrained air in the top ¼”
   B. High potential for scaling



ICRI CONCRETE REPAIR

Potential Problems for Concrete and Concrete Repairs in Cold Weather

1. Delayed set times
2. Over/early finishing
3. Frozen sub-grade
4. Ice in bottom of forms
5. Cold formwork and Reinforcing Steel
6. Plastic shrinkage cracking
7. Crazing
8. Thermal shock
9. Hurried and poor workmanship

Frozen subgrade

Subgrade Has Previously Been Thawed With Hoses, Blankets & Tarps

Elevated Deck Placements

Most Common Application For Freeze Resistant Concrete

Potential Problems for Concrete and Concrete Repairs in Cold Weather

1. Delayed set times
2. Over/early finishing
3. Frozen sub-grade
4. Ice in bottom of forms
5. Cold formwork and Reinforcing Steel
6. Plastic shrinkage cracking
7. Crazing
8. Thermal shock
9. Hurried and poor workmanship

Ice/snow in forms

Preparation Before Concreting

6.2 **Massive Metallic Embedments** –

Most embedments including bars, do not need to be heated unless the air temperature is below 10 F (-12C). Embedments with a cross-sectional area greater than 4 in2 should be heated to above 32deg F. Reinforcing bars smaller than No. 18 in size are not considered massive embedments.

ICRI CONCRETE REPAIR

Repair Surfaces

- All surfaces in contact with repair mortars should be maintained to temperatures between 35 deg F and 90 deg F (2 C and 32 C).

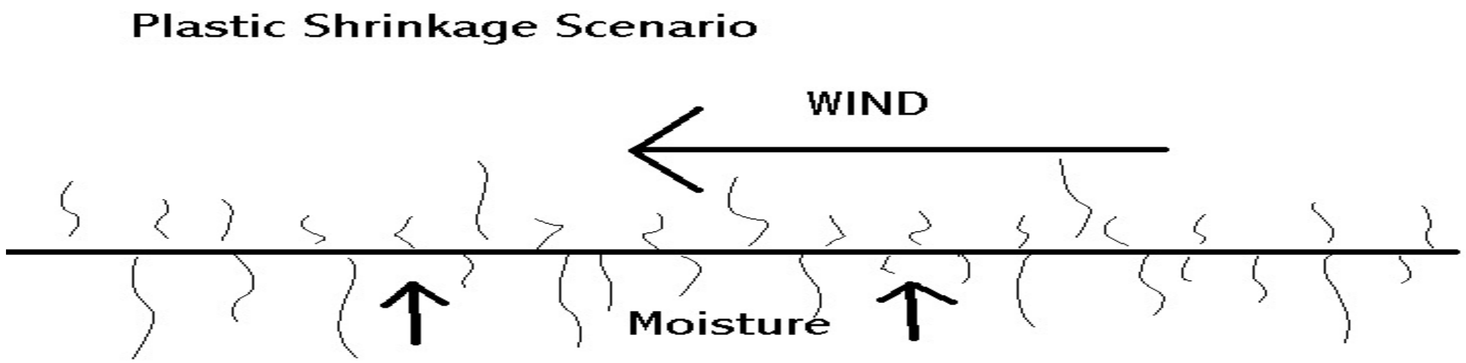
Potential Problems for Concrete and Concrete Repairs in Cold Weather

1. Delayed set times
2. Over/early finishing
3. Frozen sub-grade
4. Ice in bottom of forms
5. Cold formwork and Reinforcing Steel
6. Plastic shrinkage cracking
7. Crazing
8. Thermal shock
9. Hurried and poor workmanship

Plastic Shrinkage Cracking

1. Low relative humidity
2. Wind
3. Absorbent subgrade or formwork
4. Prolonged set times
5. Lack of early protection from drying

WHEN WATER EVAPORATES OFF THE SURFACE TOO RAPIDLY, CRACKING USUALLY OCCURS.

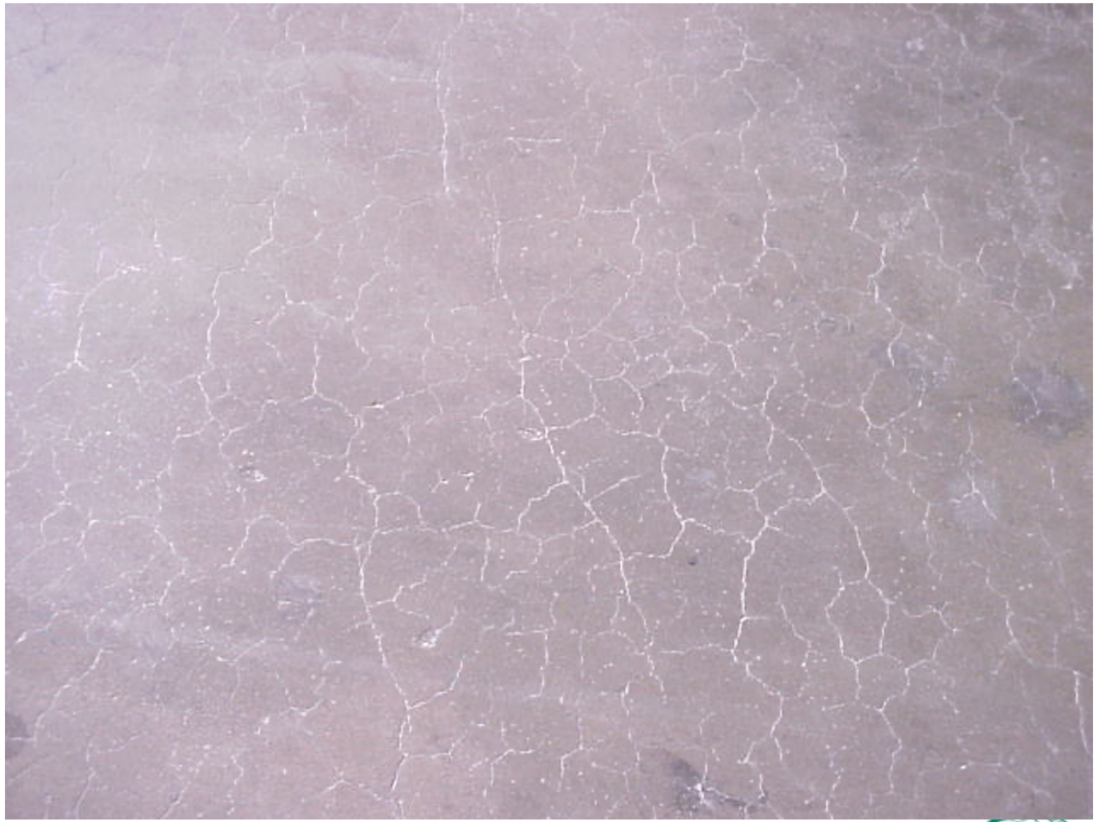


Plastic shrinkage occurs when the rate of evaporation of surface moisture exceeds the rate at which the rising bleed water can replace it.

ICRI
CONCRETE REPAIR

How to avoid plastic (or any other kind of) shrinkage cracks:

1. Accelerate the set (different from high-early concrete)
2. Use micro-fibers in concrete
3. Use low-shrinkage repair mortars
4. Use temporary evaporation control
    1. Use evaporation retarder
    2. use poly/plastic sheeting
5. Cut joints as soon as feasible- DO NOT WAIT!!
6. Use a high quality curing compound, sooner rather than later
7. Use curing/insulating covers
8. Protect & Cure!!



Potential Problems for Concrete and Concrete Repairs in Cold Weather

1. Delayed set times
2. Over/early finishing
3. Frozen sub-grade
4. Ice in bottom of forms
5. Cold formwork and Reinforcing Steel
6. Plastic shrinkage cracking
7. Crazing
8. Thermal shock
9. Hurried and poor workmanship

Rapid Cooling – Thermal Shock

- Rapid temperature drop can result in damage
- Removal insulation slowly over time.

Potential Problems for Concrete and Concrete Repairs in Cold Weather

1. Delayed set times
2. Over/early finishing
3. Frozen sub-grade
4. Ice in bottom of forms
5. Cold formwork and Reinforcing Steel
6. Plastic shrinkage cracking
7. Crazing
8. Thermal shock
9. Hurried and poor workmanship

ICRI CONCRETE REPAIR

Hurried Poor Workmanship

- Freezing cold workers can often rush or make mistakes

ICRI
CONCRETE REPAIR

Issues that often arise in Cold Weather

ACI 306 - 8.2—Field-cured cylinders. Field-cured cylinders intended to be cured with the structure were once widely accepted to represent the lowest likely strength of the concrete. Field-cured cylinders can cause confusion and unnecessary delay in construction. **The use of field-cured cylinders is inappropriate and should not be allowed in cold weather concreting.** This is mainly related to the dificulty in maintaining the cylinders in any approximation of the condition of the structure. In-place testing, maturity testing, or both, should be used instead.

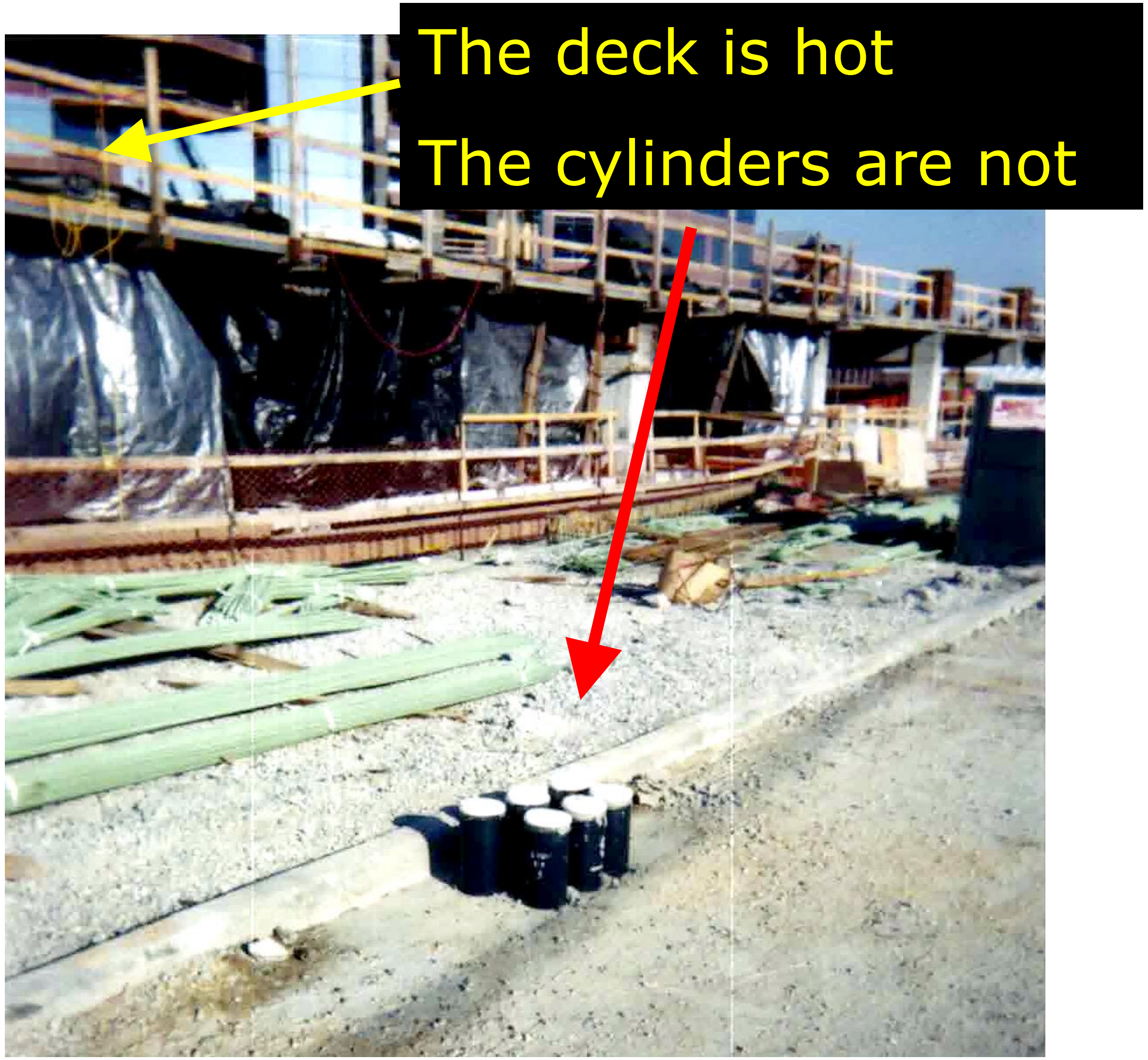
ICRI CONCRETE REPAIR

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.



Curing!

Chapter 10: Curing Recommendations and Methods

- Measures should be taken to inhibit evaporation of moisture from concrete. Freshly placed concrete is vulnerable to freezing when it is critically saturated. Therefore, concrete should be allowed to undergo some drying before being exposed to temperatures below 32 F (0^C)
- Avoid curing methods that add water to the surface.except in heated enclosures.
- 10.2 - If the relative humidity is less than 40 percent inside the enclosure, it is necessary to add moisture to the air to maintain at least 40 percent relative humidity, and inhibit desiccation of the exposed surface.

ICRI
CONCRETE REPAIR

What To Do When The Show Must Go On?

1. You have a Critical Placement!
2. The Weather does not Cooperate!
3. The Concrete Placement is critical to the Time Line of Construction!
4. There is no Easy Method for Winter Protection!
5. What Is Your Option????????
6. **Create a plan

Basic Recommendations – Level I

1. No single mix answer.
2. Selection of a few mix designs supported by maturity testing to confirm local performance.
   - Some repair mortars are more friendly to cold applications than others.
3. Pour earlier in the day – solar gain on concrete mass
4. Type III cements over Type I for performance
5. Set accelerating admixtures
6. Slower strength gain in cold weather – use caution when removing support.

Cold Weather Concreting Plan

1. Contingencies
   a. For equipment failure
   b. Abrupt changes in weather

Cold Weather Concreting Plan

1. Curing
    a. Insulating blankets, leave forms in place, curing compounds
2. Temperature Monitoring
    a. From plant to point of placement
    b. In place
    c. Frequency and location of T monitors
    d. Rate of T decrease to minimize thermal cracking

ICRI CONCRETE REPAIR

Cold Weather Concreting Plan

1. Transportation & Placement
   1. Schedule deliveries to minimize truck waiting times
   2. Tie temperature measurements to action if temps drop below allowable minimum
   3. Means for thawing, heating or insulating subgrade and forms
2. Protection (Different for different temp ranges)
   1. Blankets, enclosures (lumber, plastic sheeting, vents, hardware), means of heating (vents, fuel)

ICRI CONCRETE REPAIR

Pre-Placement Meeting

1. Timing – Not the day before
2. Goals of the meeting
    1. Clear – expectations and goals
    2. Clear – process and procedures.

- 3. This is Contractor's Day.
- 4. Specification overview
    1. Have the difficult conversation!

ICRI CONCRETE REPAIR

Pre-Placement Meeting

1. Attendees
   a. Owner
   b. Design Engineer
   c. General Contractor – Supt or PM
   d. Concrete Supplier
   e. Testing Agency
   f. Foreman – All concrete trades
   g. Other Suppliers – Pump, admix, fiber, etc.

Planning

1. Plan ahead!
2. Suppliers & Consultants – model the plan
3. Understand the goals
4. Mix Design
   a. Have options!
5. Monitor
   a. Temperatures
   b. Maturity
   c. Tie temperature measurements to action if temps drop below allowable minimum

Plan Components

1. Concrete temperature during mixing and placing,
2. Temperature loss during delivery
3. Preparation for cold weather concreting
4. Estimating strength development,
5. Methods of protection,
6. Curing requirements,
7. Admixtures for accelerating setting and strength gain and antifreeze admixtures.

Questions?

Matt Hansen
Euclid Chemical
952-567-1563
mhansen@euclidchemical.com

EUCLID CHEMICAL

ICRI
CONCRETE REPAIR