Colorado Cold Weather Concreting

APWA 2015 Construction Inspection Conference

Presented by:
Kevin Kane, Technical Services Engineer, Holcim (US) Inc.
Cold Weather Concreting

Objectives for today’s presentation:

• Gain better understanding of ACI 306R-10 Guide to Cold Weather Concreting
• Be able to apply good decision making in the field
• Learn new methodologies to ensure success in cold weather concreting
Cold Weather Concreting

Outline for today’s presentation:

• Definitions
• Overview of ACI 306R-10 Guide to Cold Weather Concreting
  – Objectives and Principles
• Effect of Cold Weather on Concrete Properties
• Temperature of Concrete
  – As mixed
  – As placed and maintained
  – Length of protection period
  – Temperature after protection period
• Preparations of Surfaces in Contact with Fresh Concrete
• Methodologies for Cold Weather Concreting
Guide to Cold Weather Concreting

Reported by ACI Committee 306

American Concrete Institute®
Guide to Cold Weather Concreting

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Guide to Cold Weather Concreting

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The committee would like to acknowledge Charles Slinkowski, Mario Garza, and Eric Holck for their contributions to the document.
ACI 306R-10 Guide to Cold Weather Concreting

Objectives of document:

• To prevent damage to concrete from freezing at early ages
• Ensure that the concrete develops the required strength for safe removal of forms
• Maintain curing conditions that foster normal strength development
• Limit rapid temperature changes
• Provide protection consistent with the intended serviceability of the structure
Definitions

Cold Weather – former definition

• A period for more than 3 consecutive days in which the average daily air temperature is less than 40 °F

   and

• the air temperature is not greater than 50 °F for more than one-half of any 24-hour period
Definitions

Cold Weather – new definition

• 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 required to prevent concrete from being affected by exposure to cold weather
Definitions

Curing

- ACI 308 Guide to Curing Concrete

- The process by which concrete matures and develops hardened concrete properties over time as a result of continued hydration of the cement in the presence of sufficient water and temperature.

- The action taken to maintain moisture and temperature conditions in a freshly placed cementitious mixture to allow hydraulic-cement hydration and, if applicable, pozzolanic reactions to occur so that potential properties of the concrete develop.

- The curing period is defined as the time period beginning at placing, through consolidation and finishing, and extending until desired concrete properties have developed.
Principles:

- Concrete that is protected from freezing until it has attained a compressive strength of at least 500 psi will be not be damaged by exposure to a single freezing cycle (Powers 1962). No other protection is needed unless a specific strength must be attained in less time.

Sufficient mixing water has combined with cement during hydration

Degree of saturation is below the critical level (91.7%) at which a single cycle of freezing causes damage

Most well proportioned concrete mixtures reach this strength within 48 hours at 50 °F
ACI 306R-10 Guide to Cold Weather Concreting

Principles:

- Where concrete must attain a specific strength in a few days or few weeks, planning and protection may be required to maintain the concrete temperature.
- Except within heated enclosures, little or no external supply of moisture is required during cold weather curing.
- Under certain conditions, CaCl should not be used to accelerate setting and hardening because of increased chances of corrosion of embedded metals.

Times and temperatures in this guide are not exact values for all situations and should not be used as such. The user should consider the primary intent of these recommendations and use judgment in deciding what is adequate for each particular circumstance.
Objectives of document:

• To prevent damage to concrete from freezing at early ages
• Ensure that the concrete develops the required strength for safe removal of forms
• Maintain curing conditions that foster normal strength development
• Limit rapid temperature changes
• Provide protection consistent with the intended serviceability of the structure
Effect of Cold Weather on Concrete

Plastic Concrete:

- Water demand decreases as temperature decreases
- Air entrainment demand changes as temperature decreases
- Time of set will increase as temperature decreases
Effect of Cold Weather on Concrete

Hardened Concrete:

- Rate of strength gain decreases as temperature decreases
Effect of Cold Weather on Concrete
Effect of Cold Weather on Concrete

ASTM C31 10.1.2 Initial Curing – Immediately after molding and finishing, the specimens shall be stored for a period up to 48 hours in a temperature range from 60 – 80 °F and in an environment preventing loss of moisture from the specimens. For concrete mixtures with a specified strength of 6,000 psi or greater, the initial curing temperature shall be between 68 – 78 °F. Shield all specimens from direct sunlight and, if used, radiant heat devices. Record the temperature using a maximum-minimum thermometer.
Effect of Cold Weather on Concrete

Hardened Concrete:

• 50% reduction in ultimate strength can occur if concrete is frozen before it reaches 500 psi

• Damage can occur if concrete is exposed to multiple cycles of freezing-thawing unless
  – Adequate air void system in paste
  – Aggregate is frost resistant
  – Concrete has attained adequate strength (> 3,500 psi)

• ACI 306R-10 4.6 states “if during construction, but after the protection period, the concrete is likely to be exposed to freezing and thawing while saturated, air entrainment may be necessary even though the concrete will be not be exposed to freezing and thawing in service.”
Effect of Cold Weather on Concrete

Beware of traveling air-entrained concrete floors

Some designers specify air-entrained concrete for interior floors subject to a few freeze-thaw cycles during construction. But be aware that this shifts the risk of surface damage from the designer to the contractor.

BY CAROL A. SATRANITI AND WAYNE R. MULLISH

In the past year, we've heard from many contractors who have been expected to pay for floor slab delamination repairs related to high air-entrained air contents. In all of these cases, the hardened concretes were cast according to ACI 302.5R, "Guide for Concrete Floor and Slab Construction" (Ref. 1), recommendations for air content less than 1% for a floor receiving a heavy traffic load, an contractor liable for the cost of these delamination repairs? And why was air-entrained concrete specified for an interior floor?

The designers' rationale

Under service conditions, most interior slabs don't have a high moisture content or a chance to freeze, so air-entrained concrete isn't needed to ensure a durable floor surface. But what about concrete exposed to freezing during construction?

Non-air-entrained concrete with a moisture content near saturation is susceptible to surface scaling caused by freeze-thaw cycles. In these cases, designers often require interior concrete slabs to be air-entrained if the slabs will be exposed to a cold, wet environment during construction. In addition to requiring entrained air, designers may also specify a lower water-cement ratio and higher compressive strength, which, in some regions, can increase concrete costs by as much as $8 per cubic yard. Designers take these precautions to minimize the owner's risk of a damaged slab surface and the subsequent cost of repairs. If they didn't require air-entrained concrete and the slab was exposed to a freezing construction environment for one winter, scaling could damage the slab surface in areas where water ponded, requiring local repairs. In extreme cases, the slab's surface could scale, requiring a slab surface topping. But owners who opt to use air-entrained concrete to reduce the risk of surface scaling and the cost of any resulting repair may face another threat—the potential for delamination where air-entrained concrete is machine-troweled.

Balancing the risk: scaling vs. delamination potential

Because of the risk of delamination, ACI 302.5R and ACI 301-96, "Specifications for Structural Concrete" (Ref. 2), recommend against incorporating entrained air in lightweight concrete slabs requiring a machine-troweled finish. A field trial (Ref. 3) and our analysis of petrophysical reports related to machine-troweled surfaces for scaling vs. delamination potential.

Machine-troweled surface

Delamination caused by an accumulation of air- and moisture-rich fines

Scaling caused by freezing and thawing of non-air-entrained concrete

Which is more likely—scaling of non-air-entrained concrete exposed to freezing and thawing, but only during construction, or delamination of machine-troweled, air-entrained concrete? Designers, owners, and contractors should consider the question when making decisions on specification requirements for interior concrete floors.
## Temperature of Concrete

ACI 306R-10 Table 5.1

<table>
<thead>
<tr>
<th>Line</th>
<th>Air temperature</th>
<th>Section size, minimum dimension</th>
<th>Minimum concrete temperature as placed and maintained</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt; 12 in. (300 mm)</td>
<td>12 to 36 in. (300 to 900 mm)</td>
</tr>
<tr>
<td>1</td>
<td>—</td>
<td>55°F (13°C)</td>
<td>50°F (10°C)</td>
</tr>
<tr>
<td>2</td>
<td>Above 30°F (−1°C)</td>
<td>60°F (16°C)</td>
<td>55°F (13°C)</td>
</tr>
<tr>
<td>3</td>
<td>0 to 30°F (−18 to −1°C)</td>
<td>65°F (18°C)</td>
<td>60°F (16°C)</td>
</tr>
<tr>
<td>4</td>
<td>Below 0°F (−18°C)</td>
<td>70°F (21°C)</td>
<td>65°F (18°C)</td>
</tr>
<tr>
<td>5</td>
<td>—</td>
<td>50°F (28°C)</td>
<td>40°F (22°C)</td>
</tr>
</tbody>
</table>

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

ACI 306R-10 Table 5.1

ACI 306 4.3 - Concrete temperature during placement should be near the minimum temperatures in Table 5.1. Placement temperatures should not be higher than these minimum values by more than 20°F (11°C). Take advantage of the opportunity provided by cold weather to place low-temperature concrete. Concrete placed at lower temperatures [40 to 55°F], protected against freezing and properly cured for a sufficient length of time, has the potential to develop higher ultimate strength (Klieger 1958) and greater durability than concrete placed at higher temperatures.
Temperature of Concrete

ACI 306R-10 Table 5.1

Table 5.1—Recommended concrete temperatures

<table>
<thead>
<tr>
<th>Line</th>
<th>Air temperature</th>
<th>Section size, minimum dimension</th>
<th>Minimum concrete temperature as placed and maintained</th>
<th>Minimum concrete temperature as mixed for indicated air temperature*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>—</td>
<td>&lt; 12 in. (300 mm)</td>
<td>55°F (13°C)</td>
<td>50°F (10°C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 to 36 in. (300 to 900 mm)</td>
<td>55°F (13°C)</td>
<td>45°F (7°C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>36 to 72 in. (900 to 1800 mm)</td>
<td>50°F (10°C)</td>
<td>40°F (5°C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 72 in. (1800 mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Above 30°F (–1°C)</td>
<td></td>
<td>60°F (16°C)</td>
<td>55°F (13°C)</td>
</tr>
<tr>
<td>3</td>
<td>0 to 30°F (–18 to –1°C)</td>
<td></td>
<td>65°F (18°C)</td>
<td>60°F (16°C)</td>
</tr>
<tr>
<td></td>
<td>Below 0°F (–18°C)</td>
<td></td>
<td>70°F (21°C)</td>
<td>65°F (18°C)</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>70°F (21°C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60°F (16°C)</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>55°F (13°C)</td>
</tr>
</tbody>
</table>

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

- Forms
- Embedded steel
- Subgrade

We do want to allow concrete in contact with these surfaces fall below the recommended ACI 306R-10 Table 5.1 values

Problem: mandatory language versus guidance documents

Example:
- ACI 301-10 5.3.2.1.b …..unless otherwise specified, do not let concrete come in to contact with surfaces less than 35 °F
- ACI 306R-10 6.1…. best practice indicates that all surfaces should be above the freezing temperature of water. However, take care to limit surface temperature to no more than 10 °F greater or 15 °F less than that of concrete to avoid inconsistent setting, rapid moisture loss, and plastic shrinkage cracking
Preparation of surfaces in contact with fresh concrete

Cold Weather Concreting Strategies
Choosing sustainable cold weather protection

by Randy L. Kozikowski, W. Colin McCull, and Bruce A. Suprenant

Regardless of what the different cold weather provisions contained in current ACI committee documents, it’s important to determine what surface and embedment temperatures may be detrimental to concrete. This information can then be used to develop concreting strategies that provide effective, cost-efficient, and environmentally responsible protection of fresh concrete.

Cold Weather Concreting Strategies

Regardless of what the different cold weather provisions contained in current ACI committee documents, it’s important to determine what surface and embedment temperatures may be detrimental to concrete. This information can then be used to develop concreting strategies that provide effective, cost-efficient, and environmentally responsible protection of fresh concrete.
Preparation of surfaces in contact with fresh concrete

Compare / Contrast ACI Committee Documents:

When placing concrete against cold formwork and reinforcing steel surfaces:

1. ACI 306.1-90 - Use the warm concrete to heat forms and reinforcing steel and then maintain the required concrete temperature by protection methods through the prescribed protection period.

2. Required by ACI 301-10 and recommended in ACI 306R-10 - Heat the formwork and reinforcing steel to a minimum of 32 °F, place the concrete, and then maintain the required concrete temperature by protection methods through the prescribed protection period.

3. ACI 306R-10 - Heat the forms and reinforcing steel to within 10 °F less than, but not more than 15 °F more than, the as-placed concrete temperature, and then maintain the required concrete temperature by protection methods through the prescribed protection period.
Preparation of surfaces in contact with fresh concrete

Compare / Contrast ACI Committee Documents:

When placing concrete against cold *massive* embedments:

1. Required by ACI 306.1-90, ACI 301-10, recommended by ACI 306R-10 – heat cold massive embedments (as designated by specifier) to a minimum of 32 °F, and then maintain the required concrete temperature by protection methods through the prescribed protection period.

2. Secondarily recommended by ACI 306R-10 - Heat cold massive embedments (as designated by specifier) to the temperature of the concrete, place the concrete, and then maintain the required concrete temperature by protection methods through the prescribed protection period.
Preparation of surfaces in contact with fresh concrete

Massive embedments are currently classified as steel sections larger than No. 9 bar.
Preparation of surfaces in contact with fresh concrete

What’s the issue?

- Will the concrete warm the steel or will the steel freeze the concrete?
- Contact freezing versus immersion freezing

Concrete placed at 58 °F with No. 18 bar (1% concentration ratio) at -5 °F resulted in steel being warmed to 32 °F within 5 minutes, and equilibrium temperature of 56.6 °F within 220 minutes

Suprenant, Kozikowski, McCall
Preparation of surfaces in contact with fresh concrete

What about cold formwork and reinforcing steel?

- Zero Law of Thermodynamics can predict temperature of concrete cast against cold formwork and reinforcing steel
- Example: If 58 °F concrete is cast against surfaces at -5 °F plywood formwork and No. 18 bar at 5% concentration ratio, the equilibrium temperature will be about 53 °F
Colorado’s Ocean Journey Project: 11/14/1997
Open Blue Tank @ K Line
Preparation of surfaces in contact with fresh concrete

What about cold subgrade?

• ACI 306R-10 6.3 – Concrete should not be placed on frozen subgrade
• ACI 301-10 5.3.2.1.b – Unless otherwise permitted, do not place concrete in contact with surfaces less than 35 F
Maturity Meter for monitoring in-place concrete temperature

East Cherry Creek Water Tank / Bates Engineering
SEMA: Tank Bottom Placement
6500220 2000 psi Maturity

Graph showing temperature (°F) over hours, with lines indicating slab, rim, and ambient temperatures.
Preparation of surfaces in contact with fresh concrete

Compare / Contrast ACI Committee Documents:

When placing concrete against cold formwork and reinforcing steel surfaces:

1. ACI 306.1-90 - Use the warm concrete to heat forms and reinforcing steel and then maintain the required concrete temperature by protection methods through the **prescribed protection period**.

2. Required by ACI 301-10 and recommended in ACI 306-10 - Heat the formwork and reinforcing steel to a minimum of 32 °F, place the concrete, and then maintain the required concrete temperature by protection methods.

3. ACI 306R-10 - Heat the forms and reinforcing steel to within 10 °F less than, but not more than 15 °F more than, the as-placed concrete temperature, and then maintain the required concrete temperature by protection methods through the **prescribed protection period**.
## Protection Period

ACI 306 Table 7.1 - Length of protection period for concrete placed in cold weather

<table>
<thead>
<tr>
<th>Line</th>
<th>Service Category</th>
<th>Type I or II cement</th>
<th>Type III cement, Chem Accel., + 100 lb Type I,II cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 - no load</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>not exposed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2 - no load,</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>exposed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3 - partial load</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>exposed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4 - full load,</td>
<td>see ACI 306, Chapter 8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>exposed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Protection Period

ACI 306R-10, Chapter 8

- For structural members such as elevated slabs, beams and girders where considerable design strength should be attained before safe removal of forms and shores, provide protection time beyond the minimum given in Table 7.1, as these minimum times do not allow adequate strength gain. Base the criteria for removal of forms and shores from structural concrete on the in-place concrete strength rather than on the specified time duration.
What can happen when things go wrong?

Skyline Plaza, Bailey’s Crossroads, Virginia

- 3/2/1973
- 14 killed, 34 injured
- Collapse of 23rd floor following premature removal of forms
- Concrete placed 2/26 had insufficient strength prior to form removal
- Design engineers and architects were found guilty of negligence
- Lessons: inspections must verify that contractor is properly shoring floors and that concrete is meeting required strength
## Temperature of Concrete

**ACI 306R-10 Table 5.1**

What about temperature drop after end of protection period?

<table>
<thead>
<tr>
<th>Line</th>
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<th>Section size, minimum dimension</th>
<th>Minimum concrete temperature as placed and maintained</th>
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<tbody>
<tr>
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<tr>
<td>1</td>
<td>—</td>
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<td>50°F (10°C)</td>
</tr>
<tr>
<td>2</td>
<td>Above 30°F (−1°C)</td>
<td>60°F (16°C)</td>
<td>55°F (13°C)</td>
</tr>
<tr>
<td>3</td>
<td>0 to 30°F (−18 to −1°C)</td>
<td>65°F (18°C)</td>
<td>60°F (16°C)</td>
</tr>
<tr>
<td>4</td>
<td>Below 0°F (−18°C)</td>
<td>70°F (21°C)</td>
<td>65°F (18°C)</td>
</tr>
<tr>
<td>5</td>
<td>—</td>
<td>50°F (28°C)</td>
<td>40°F (22°C)</td>
</tr>
</tbody>
</table>

*For colder weather, a greater margin in temperature is provided between concrete as mixed and required minimum temperature of fresh concrete in place.*
Colorado’s Ocean Journey Project: 11/14/1997
Open Blue Tank @ K Line
Methodologies for Cold Weather Concreting

Heated Enclosures
Methodologies for Cold Weather Concreting
Methodologies for Cold Weather Concreting
Methodologies for Cold Weather Concreting

Insulated forms

Insulating blankets
### Methodologies for Cold Weather Concreting

<table>
<thead>
<tr>
<th>Laboratory I.D.</th>
<th>CONTROL</th>
<th>NC 534</th>
<th>CaCl</th>
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<tr>
<td>1728</td>
<td>1729</td>
<td>1730</td>
<td>1731</td>
</tr>
<tr>
<td>1732</td>
<td>1733</td>
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<td><strong>Proportions</strong></td>
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<tr>
<td>Holcim Type I/II L.A. Cement</td>
<td>564 lb.</td>
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<tr>
<td></td>
<td>564 lb.</td>
<td>564 lb.</td>
<td>564 lb.</td>
</tr>
<tr>
<td>No. 57 1&quot; Coarse Aggregate</td>
<td>1750 lb.</td>
<td>1750 lb.</td>
<td>1750 lb.</td>
</tr>
<tr>
<td>Fine Aggregate</td>
<td>1429 lb.</td>
<td>1429 lb.</td>
<td>1429 lb.</td>
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<tr>
<td>Water</td>
<td>286.8 lb.</td>
<td>285.7 lb.</td>
<td>284.6 lb.</td>
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<td>322N</td>
<td>4 oz/cwt</td>
<td>4 oz/cwt</td>
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<tr>
<td>NC 534</td>
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<td>5 oz/cwt</td>
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<tr>
<td>CaCl</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
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</tr>
<tr>
<td><strong>Physical Properties</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slump</td>
<td>4.50 inches</td>
<td>4.00 inches</td>
<td>4.50 inches</td>
</tr>
<tr>
<td></td>
<td>4.25 inches</td>
<td>3.8%</td>
<td>3.8%</td>
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<tr>
<td>Air Content</td>
<td>4.2%</td>
<td>3.9%</td>
<td>3.8%</td>
</tr>
<tr>
<td></td>
<td>3.4%</td>
<td>64°F</td>
<td>64°F</td>
</tr>
<tr>
<td>Unit Weight</td>
<td>143.9pcf</td>
<td>144.3pcf</td>
<td>144.5pcf</td>
</tr>
<tr>
<td></td>
<td>144.6pcf</td>
<td>145.4pcf</td>
<td>143.3pcf</td>
</tr>
<tr>
<td>Temperature</td>
<td>65°F</td>
<td>64°F</td>
<td>64°F</td>
</tr>
<tr>
<td>Relative Yield</td>
<td>1.037 yd³</td>
<td>1.034 yd³</td>
<td>1.033 yd³</td>
</tr>
<tr>
<td></td>
<td>1.032 yd³</td>
<td>1.027 yd³</td>
<td>1.042 yd³</td>
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<tr>
<td><strong>Initial Set</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Temperature</td>
<td>5 hrs. 5 min.</td>
<td>4 hrs. 10 min.</td>
<td>3 hrs. 45 min.</td>
</tr>
<tr>
<td>Outside Temperature (35°F - 40°F)</td>
<td>10 hrs. 30 min.</td>
<td>7 hrs. 45 min.</td>
<td>5 hrs. 50 min.</td>
</tr>
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<tr>
<td><strong>Compressive Strength</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 day</td>
<td>1810 psi</td>
<td>1650 psi</td>
<td>1560 psi</td>
</tr>
<tr>
<td></td>
<td>1640 psi</td>
<td>1530 psi</td>
<td>2300 psi</td>
</tr>
<tr>
<td>3 day</td>
<td>3600 psi</td>
<td>3400 psi</td>
<td>3490 psi</td>
</tr>
<tr>
<td></td>
<td>3580 psi</td>
<td>3810 psi</td>
<td>4650 psi</td>
</tr>
<tr>
<td>7 day</td>
<td>5090 psi</td>
<td>5270 psi</td>
<td>4990 psi</td>
</tr>
<tr>
<td></td>
<td>5090 psi</td>
<td>5240 psi</td>
<td>5720 psi</td>
</tr>
<tr>
<td>28 day</td>
<td>12/27/00</td>
<td>6380 psi</td>
<td>6460 psi</td>
</tr>
<tr>
<td></td>
<td>6140 psi</td>
<td>6020 psi</td>
<td>7010 psi</td>
</tr>
</tbody>
</table>
Methodologies for Cold Weather Concreting
Methodologies for Cold Weather Concreting

Hydronic heating systems
Methodologies for Cold Weather Concreting

Hydronic heating systems
Methodologies for Cold Weather Concreting

Hydronic heating systems
Maturity Meter for estimating in-place strength

East Cherry Creek Water Tank / Bates Engineering
If the cylinders made 2000 psi in 26 hr, when did the slab make 2000 psi?
M = \text{Sum} \left[ t \left( T + 10 \right) \right]
Maturity Meter for estimating in-place strength

East Cherry Creek Water Tank / Bates Engineering
SEMA: Tank Bottom Placement
6500220 2000 psi Maturity

![Graph showing temperature changes over time for slab, rim, and ambient conditions.](image-url)
6500220 2000 psi Maturity

\[ M = \text{Sum} [t (T + 10)] \]
Methodologies for Cold Weather Concreting

Hydronic heating systems
Methodologies for Cold Weather Concreting

• Monitoring concrete temperature
• ACI 306R-10 Chapter 4.4
• Temperature of concrete at surface determines effectiveness of protection

• Monitor and record:
  – Concrete temperature as delivered
  – Concrete temperature as placed
  – Ambient temperature
  – Concrete corners and edges
  – Record temperatures at regular intervals, not less than twice per day
  – Temperature history of each section of concrete cast
Methodologies for Cold Weather Concreting

Monitoring Temperatures in Concrete Construction Using IR Thermometers

by [Author's Name]

In cold weather concreting, maintaining proper temperature control is crucial to ensure the concrete sets properly and achieves the required strength. Monitoring temperatures is essential to prevent issues such as premature freezing, which can lead to concrete damage. Infrared (IR) thermometers are a valuable tool for this purpose.

**Use of the IR Thermometer**

Object temperature measurement involves the use of IR thermometers to assess the temperature difference between objects and their surroundings. This can be particularly useful in determining if the concrete is at the correct temperature for safe placement and curing.

In cold weather concreting, it is important to ensure that the concrete is placed at the proper temperature to avoid issues like early freezing. IR thermometers can help in this regard by providing real-time temperature measurements, allowing for timely adjustments to the concrete placement process.

**Example Calculation**

To calculate the temperature of the concrete, one would use the IR thermometer to measure the temperature of the concrete surface. This temperature is then compared to the recommended temperature range for placement and curing. If the concrete is too cold, additional heating measures may be necessary to achieve the desired temperature.

**Conclusion**

Monitoring temperatures in concrete construction using IR thermometers is a critical practice in cold weather concreting. It helps ensure that the concrete sets properly and achieves the required strength, minimizing potential issues such as early freezing. Regular monitoring and adjustments can help maintain the integrity of the concrete structure.
Methodologies for Cold Weather Concreting

- In-place concrete temperature prediction models
- Simulate in-place concrete setting behavior based on heat signature of concrete mix, concrete temp, ambient temp, formwork composition, embedded steel

**QUADREL® iTest**

iTest is an online tool for measuring concrete’s heat of hydration and hydration rate versus its curing age. It features our concrete calorimeters for heat hydration, use the heat signature method to simulate thermal crack and fast-track construction management.

Heat signature -- in combination with simulation -- creates a powerful planning tool for optimizing concrete placements. Heat signature helps reduce costs using fast-track construction, provides an argument for value engineering, creates a tool for performance selling of concrete mixes, and aids in troubleshooting.

**Features at-a-glance**
- Alternate curing plans (formwork and insulation types)
- Varying concrete placement temperatures
- Weather (air temperature and wind speed) or imposed curing temperatures (precast)
- Simulating in-place strength to fast-track or thermal cracking speeds
- Simulating in-place setting properties, including criteria for flat-work finishing, saw cutting and slip-forming
Cold Weather Concreting

Outline for today’s presentation:

• Definitions

• Overview of ACI 306R-10 Guide to Cold Weather Concreting
  – Objectives and Principles

• Effect of Cold Weather on Concrete Properties

• Temperature of Concrete
  – As mixed
  – As placed and maintained
  – Length of protection period
  – Temperature after protection period

• Preparations of Surfaces in Contact with Fresh Concrete

• Methodologies for Cold Weather Concreting
Colorado Cold Weather Concreting

APWA 2015 Construction Inspection Conference

Presented by:
Kevin Kane, Technical Services Engineer, Holcim (US) Inc.