Cold Weather Concreting

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GCC
Today’s Discussion Points

- Fundamentals of Cold Weather Concreting (CWC)
- Defining the CWC protection period
- CWC mixes
- Placing/Finishing Procedures
- Durability considerations
- Discussion points of a CWC Plan
- City of Billings Standard Modifications
Cold Weather Concreting (CWC) Objectives

- Prevent concrete freezing at early ages
- Be sure that concrete meets required strength for safe form removal/ loading
- Maintain curing conditions for proper strength development
- Limit rapid temperature changes
- Ensure long term durability even if it means extra $$$
CWC Principles

Concrete protected from freezing until it attains a compressive strength of 500 psi will not be damaged by a single cycle of freezing and thawing.

Where a specified concrete strength is necessary within a few days or weeks, planning and protection may be required.

 Except within heated enclosures, little or no external supply of moisture is necessary.
The temperature of the concrete directly influences the rate of setting and strength gain.

- The chemical reaction that takes place between cement and water is known as hydration.
The rate of hydration is sensitive to the temperature of the concrete

Higher temps = faster rate of reaction
  Faster setting concrete
  Higher early strength gain

Lower temperatures = slower rate of reaction
  Slower setting concrete
  Slower rate of strength gain
What Determines the Onset of Cold Weather
Cold weather exists when the air temperature has fallen to, or is expected to fall below 40 degrees 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.
**Recommended Concrete Temperatures ACI 306**

<table>
<thead>
<tr>
<th>Line</th>
<th>Condition</th>
<th>Thickness of sections, in.:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Less than 12</td>
</tr>
<tr>
<td>1</td>
<td>Minimum temperature of fresh concrete as mixed for weather indicated, F</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>0 F to 30 F</td>
<td>65</td>
</tr>
<tr>
<td>3</td>
<td>Below 0 F</td>
<td>70</td>
</tr>
<tr>
<td>4</td>
<td>Minimum temperature of fresh concrete as placed and maintained, F*</td>
<td>55</td>
</tr>
<tr>
<td>5</td>
<td>Maximum allowable gradual drop in temperature in first 24 hours after end of protection, F</td>
<td>50</td>
</tr>
</tbody>
</table>

- The in-place temperature of the concrete is measured at the surface.
- It is the contractor’s responsibility to maintain the surface temperature of the concrete throughout the length of the protection period.
Length of protection period for concrete placed during cold weather *

<table>
<thead>
<tr>
<th>Line</th>
<th>Service Condition</th>
<th>Protection period at minimum temperature indicated in Table 5.1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Normal- Set Concrete</td>
</tr>
<tr>
<td>1</td>
<td>No load, not exposed</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>No load, exposed</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Partial load, exposed</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>Full load</td>
<td>Refer to Ch. 8 “Protection Period for Structural Concrete”</td>
</tr>
</tbody>
</table>

* The above protection periods pertain to 1 freezing cycle
Cold Weather Mixes

- Reduce the protection period
- Generate heat for curing
- Offset slow rate of hydration
Cold Weather Concrete Mixes

• Additional cement
• Chemical admixtures
  - Chloride and non chloride accelerators
  - Beware of corrosion, discoloration, sulfate and ASR reactions

• Special Cements (Type III, HE)
• SCM usage
Freezing of Fresh Concrete
Effect of Freezing Fresh Concrete

- Water in concrete begins to freeze at 28°F
- As water freezes, it expands 9% in volume
- Up to 50% reduction of ultimate strength can occur if frozen —
  - Within a few hours
  - Before reaching a strength of 500 psi
- Frozen only once at an early age —
  - With curing nearly all strength can be restored
  - Less resistance to weathering
  - More permeable
We must protect the fresh concrete from freezing until the degree of saturation drops below 91.7%.

- When does this occur? – usually when the concrete reaches 500 psi.
- At 50 degrees F., most concretes will reach 500 psi within 2 days.
- Protect fresh concrete from freezing at least 2 days to avoid damage.
What about repeated cycles of freezing and thawing?
If repeated exposure to freezing and thawing is anticipated...

- 500 psi concrete strength is not sufficient
- The concrete should reach 3,500 psi before being exposed to repeated cycles of freezing and thawing
- Concrete in severe freeze/thaw environments should be air entrained
- Caution is advised where this concrete will receive a hard-troweled finish!
Cold Weather Delays Concrete Setting and Finishing Operations

- As the temperature of the fresh concrete drops, setting or hardening is delayed.
- For every 10 degree drop, the set time is extended about 1/3.
Window of Finishability

ACI 302 Window

Finishing Operations
- Placing
- Screeding
- Bull Float
- Straightedge

Waiting

Concrete Behavior
- Bleedwater Sheen
- Footprint indentation
  - 1" 3/4" 1/2" 1/4" 1/8"
  - Not visible

Finishing Challenges
- Premature Finishing (may result in surface defects)
  - Hitting the gap
- Late Finishing (may not achieve specified flatness or surface finish)

Source: Concrete Construction *The True Window of Finishability*, B. Suprenant, Oct 98
Steel trowels can trap bleed water and air resulting in surface delaminations.
Finishing considerations

- For steel troweled floor and slab construction, air entrained concrete should not be specified.
- If during construction, but after the cold weather protection period, the concrete will be exposed to cycles of freezing and thawing while saturated, air entrainment may be necessary even though the concrete will not be exposed to freezing and thawing in service.
- The addition of air may lead to finishing difficulties.
  > 3% air can lead to finishing problems (ACI 302)
Before concreting....

Don’t Place Concrete on Frozen Subgrades

- May freeze the bottom of the slab
- Pulls heat from the concrete
- Uneven hydration between the surface of the concrete and the bottom causes finishing challenges
Hydronic Systems

Cold-Weather Concreting
After placement...curing

- Proper curing is essential to concrete’s strength and durability
- We need to prevent the loss of moisture from concrete
- We must maintain a favorable concrete temperature for a certain period of time
Curing ?
Curing During Fall Placements

- Membrane forming curing compounds will effectively seal in water for up to 6-8 weeks.
- Concrete remains in a semi-saturated state beyond the protection period.
- Rain/snow, freezing and thawing conditions plus the use of deicing chemicals can damage this “young”, semi-saturated concrete.
The concrete should have a compressive strength of 3500 psi before repeated F/T cycles.

Therefore, new sidewalks and other flatwork exposed to melting snow during daytime and freezing during nighttime should be air entrained and protected from freezing until 3500 psi has been attained.
In the case of Deicers

- The concrete should be allowed to air dry 30 days prior to the onset of F/T cycles and deicers.

- This is difficult to accomplish in practice.

- The industry is now recommending keeping insulating blankets on as long as possible – followed by as long a drying period as possible (2-3 days min.), followed by the application of a concrete sealer.
Cold Weather Concreting Tips

- Know and understand the cold weather specifications
- Protect from early age freezing
- Use cold weather mix design
- Use caution when air entrained and steel troweled concrete is specified
- Anticipate delayed setting and finishing issues
Tips cont.

- Don’t thermal shock the concrete
- Don’t expose new concrete to repeated F/T cycles until it reaches at least 3500 psi
- Don’t expose new concrete to deicing chemicals until it has been air dried for 30 days
- Special attention to acceptance cylinders and to field cured cylinders
Example of a Cold Weather Concreting Plan

1. **Time/Date pour** planned
2. **Temps expected** for the duration
3. What is the **plan for preparation** before the pour – base gravel temp, form temp, etc
4. **Concrete mix** – any admixtures, hot water, minimum concrete temp, etc
5. **Protection/Heating plan**
6. **Plan if concrete temp drops** below acceptable
7. **Cure period**
8. **End of cure period** – plan to gradually lower concrete temp?
Thank You