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Cold Weather Concreting

1. WHAT is Cold Weather Concreting?

According to the American Concrete Institute, cold weather is defined as a period when for more than 3 consecutive days the average daily temperature is less than 5ºC and the air temperature is not more than 10ºC for more than one-half of any 24 hour period. CSA defines it similarly (see CSA A23.1:19 for more details).
Since weather conditions can change rapidly in the winter months, good concrete practices and proper planning are critical.

2. WHY Consider Cold Weather?

Successful cold weather concreting requires and understanding of the various factors that affect concrete properties.
In its fresh state, concrete freezes if its temperature falls below 4°C. The potential strength of frozen concrete can be reduced by more than 50% and it will not be durable. ACI says concete should be proetected from freezing until a strength of at least 3.5 MPa is attained. CSA says when concrete reaches twice that strength, it should capable of resisting early frost damage. However, exterior concrete flatwork exposed to freeze-thaw cycling and de-icer salts must attain a an ultimate strength of at least 32 MPa in order to ensure its long term durability. CSA A23.1 mandates a curing regime of 7 days at a minimum temperature of 10ºC for concrete subject to these exposure conditions (see CSA A23.1:19). Therefore in cold weather some provision must be in place to ensure that this objective is met.
Concrete at a low temperature has a slower rate of set and strength gain. A rule of thumb is that a drop in concrete temperature of 10ºC will approximately double the set time. These factors should be accounted for when scheduling construction operations, like form removal.

Concrete that will be in contact with water and exposed to cycles of freezing and thawing should be air-entrained. Newly placed concrete is saturated with water and should be allowed to dry after completing the cure period designated in Tables 2 and 19 of CSA A23.1:19 before exposure to freeze-thaw cycling and de-icer salt exposure.

The reaction between cement and water called hydration, generates heat. Insulating concrete retains heat and maintains favourable curing temperatures. Temperature differences between the surface and the interior of the concrete should be controlled. Thermal cracking may occur when the difference exceeds 20ºC. Insulation and protection should be gradually removed to avoid thermal shock

3. HOW to Place Concrete in cold Weather.

Recommended concrete temperatures at the time of placement

Thickness of section, m	Minimum Temperature °C	Maximum Temperature °C
Less than 0.3	10	35
0.3 – 1	10	30
1 - 2	5	25
More than 2	5	20

Source: Table 17-1 Design & Control of Concrete Mixtures (CSA A23.1)

The ready-mix concrete producer and control concrete temperature and furnish concrete to comply. Concrete temperature should not exceed these values by more than 10ºC. Concrete at a higher temperature requires more mixing water, has a higher rate of slump loss, and is more susceptible to cracking. Concreting in cold weather provides the opportunity for better quality, as cooler initial concrete temperature will typically result in higher ultimate strength and improved durability.

In cold weather, slower setting and rate of strength gain of concrete can delay finishing operations and form removal. Chemical admixtures and other materials can be used to offset these effects. Accelerating admixtures conforming to ASTM C494 Types C (accelerating) and E (water reducing and accelerating) are commonly used. Calcium chloride is an effective accelerating admixture, but should not exceed a dosage rate of 2% by weight of cement. Non-chloride, non-corrosive admixtures should be used for prestressed concrete or when corrosion of reinforcement steel or metal in contact with concrete is a concern. Accelerating admixes do prevent concrete from freezing and their use does not preclude the requirements for appropriate curing and protection from freezing.

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References:
1. *Cold Weather Concreting*, ACI 306R, American Concrete Institute, Farmington Hills, MI
2. *Design and Control of Concrete Mixtures, 8th Edition 2011*, Cement Association of Canada, Ottawa Ontario.
3. CSA A23.1:19 *Concrete Materials and Methods of Concrete Construction*, The CSA Group, Toronto ON Canada.
4. CSA A23.2-3C-19, *Making and Curing Concrete Compression and Flexural Test Specimens*, The CSA Group, Toronto, ON Canada.
5. *Cold-Weather Finishing*, Concrete Construction, November 1993.
6. *CIP-27 Cold Weather Concreting*, NRMCA with permission, Silver Spring, MD, www.nrmca.org
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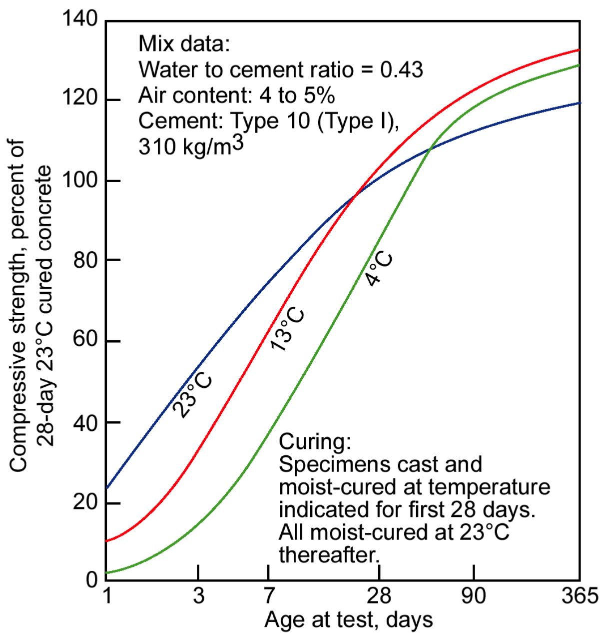
Effect of Low Temperature on Strength

Rate of setting and strength gain can be increased by increasing the cement content of a concrete mix or by using a Type HE cement. The quantity or fly ash or slag in concrete may be reduced for a similar effect. However, this may not be possible if a minimum quantity of SCM is required for durability such as for sulphate resistance or mitigation of ASR. The selected solution should be economical and not compromise on the required concrete performance.



Source: Fig 17-6 Design & Control of Concrete Mixtures

Concrete should be placed at the lowest practical slump. Adding water to achieve slump can delay setting time and prolong bleeding, thereby impacting finishing operations. Adequate preparation should be made prior to concrete placement. Have a pre-pour meeting and develop an action plan:

- Arrange for covering, insulating, housing or heating
- Have protection and curing equipment and materials on hand
- Schedule work so concrete placing can occur with the least delay
- Have sufficient manpower available
- Plan on proper curing.

On site: Concrete should never be placed on frozen ground as this may be the cause of settlement, set delays and frozen concrete. Snow and ice should be removed and the temperatures of surfaces and metallic embedments in contact with concrete should be above freezing. This might require insulating or heating subgrades and contact surfaces prior to placement. Thaw frozen ground; alternatively, excavate ground before freezing, then insulate. Corners and edges are most susceptible to heat loss.

Fossil-fuel heaters in enclosed spaces should be vented for safety reasons and to prevent carbonation of newly placed concrete surfaces, which causes dusting. Concrete poured on cold ground may also be more susceptible to "crusting" under these protection conditions as the top surface dries out before the underlying layer sets.
Water curing is not recommended when freezing temperatures are imminent. Use membrane forming curing compounds or impervious paper and plastic sheets for concrete slabs. Note that the latter curing method may result in a discontinuity of colour of the final concrete surface.

Forming materials, except for metals, maintain and evenly distribute heat and may provide adequate protection moderately cold weather. In cold temperatures, insulating blankets or forms should be used, especially for thin sections such as residential foundation walls and footings. Forms should not be stripped for 1 – 7 days, depending on rate of strength gain, ambient conditions, and anticipated loading on the structure. Field cured cylinders or nondestructive methods should be used to estimate in-place concrete strength prior to stripping forms or applying loads. Removal of protective measures and formwork should not cause thermal shock to the concrete. When the outside air temperature is below -5° Celsius: cool concrete gradually before removing insulation and exposing concrete surface to freezing outside air temperatures, to avoid thermal shock. Cool at rates of 1 °C/hour for sections over 1 m^3; 3°C/hour for thinner sections.

Concrete test specimens used for acceptance of concrete should be carefully managed. In accordance with CSA, concrete test cylinders should be stored in insulated containers, which may need temperature controls, to ensure they are maintained at 20+/- 5°C for the first 28+/- 8 hours. A minimum/maximum thermometer must be placed in the curing box to maintain a temperature record of curing test specimens at the jobsite. (see CSA A23.2-3C for full details).

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