



Dear Reader,

Welcome to another Technical Mailer from UltraTech Cement Ltd. Every issue carries an article related to Concrete & Construction that we feel would be of value to our clients.

As we are into the colder period of the year, it is pertinent to refresh ourselves about the problems associated with cold weather concreting and the techniques to be adopted to mitigate those problems. This issue is all about "Cold Weather Concreting".

We hope you find the mailer informative and useful. Happy Reading!!



Issue Highlights

- Cold Weather Concreting
- Detrimental effects of Cold Weather on Concrete
- Techniques to minimize the effects of Cold Weather
- Precautions to be taken during Concreting in Cold Weather

Introduction

The production of concrete in cold weather poses peculiar problems, which do not arise while concreting at normal temperatures. In India, severe cold weather prevails for a longer period in Northern, North-East and North-West zones of the country. Cold weather, besides affecting the setting and hardening of the concrete, may also cause damage. If concrete still in plastic state is exposed to very low temperature, ice lenses may form leading to expansions within the pore structure. Hence, it is essential to keep the temperature of the concrete above a minimum value before it is placed in the formwork, while in formwork and after its removal, by adopting special techniques.

Construction engineers should have a general understanding of the possible effects of lower than normal curing temperatures on properties of concrete at early ages and the methods of evaluating and controlling them.

This article contains the problems associated with cold weather and the practices to be followed to overcome the adverse effects of it on concrete. The characteristics of concrete in fresh and hardened state (Strength and Durability) significantly improve by following those practices.

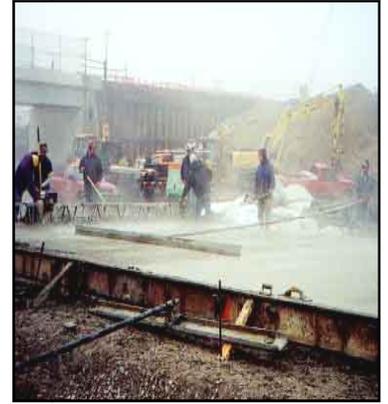
Cold Weather Concreting

Indian Standard defines Cold weather concreting as 'Any operation of concreting done at about 5°C atmospheric temperatures or below¹'.

In context of concreting, ACI defines cold weather as a period when, for more than 3 consecutive days, the following conditions exist:

- The average daily air temperature is less than 5°C and,
- The air temperature is not greater than 10°C for more than one-half of any 24 hour period.

The average daily air temperature is the average of the highest and the lowest temperatures occurring during the period from midnight to midnight.



Effects of Cold Weather on concrete:

Low ambient temperatures affect the properties of the concrete in many ways. These are briefly described below:

- Delayed Setting:** - In cold weather condition the rate of cement hydration is lowered, resulting in delayed setting. For every 10°C reduction in concrete temperature, the setting time of concrete nearly doubles. This results in increasing the period of time that the concrete is vulnerable to damage because of freezing. In addition to this, the time for evaporation of bleed water in low temperatures also increases causing delays in finishing operations and this may add cost. If the concrete is finished prematurely, problems may be experienced with delamination (or flaking) and weak, dusty surfaces. The practice of adding cement or cement/sand mixtures to the surface of the slab to absorb excess water and allow finishing to proceed should be avoided as it will inevitably lead to poor wear resistance.
- Slower Strength Gain:** - At low temperatures, the development of initial strength of concrete is retarded due to low rate of cement hydration compared with the strength development at normal temperatures. The hardening period, necessary before the removal of forms is thus increased and thereby delaying its removal. Though the initial rate of gain of strength is low, the concrete cured at lower temperatures attains higher strengths at later ages. Properly cured and protected concrete will mature to its required strength despite subsequent exposure to cold weather.
- Freezing of Concrete:** - When concrete is exposed to freezing temperature, there is the risk of concrete suffering irreparable loss of strength and other qualities, that is, permeability may increase and the durability may be impaired. Freshly placed concrete is vulnerable to freezing conditions both before and after it has set. If the concrete is frozen and is kept frozen below -10°C, there will be insignificant cement hydration resulting in no strength gain. Therefore fresh concrete must be protected from freezing until adequate strength has been gained. A minimum compressive strength of 3.5 MPa prior to freezing is stated in ACI 306 R as a criterion for preventing frost damage.

As a general rule, concrete must be protected from freezing for at least 24 hours after placement.

If allowed to freeze after setting but before it develops an appreciable strength, the expansion associated with the formation of ice causes disruption and irreparable loss of strength. Concrete can be permanently damaged by the pressures exerted by ice crystal growth if this occurs after the concrete has stiffened but before it has gained adequate maturity. This weakens the paste-aggregate bond and may reduce strength by 30% to 50% for one cycle of freezing. The extent of the damage will depend on its age and strength when frozen.

- Stresses Due to Temperature Differentials:** - It is a general experience that large temperature differentials within the concrete member may promote cracking and have a harmful effect on the durability. Such differentials are likely to occur in cold weather at the time of removal of form insulations. The extent of cracking may also be increased, as the lower concrete strength may be inadequate to resist the drying shrinkage stresses and /or thermal stresses. The latter may result from the temperature difference between the inside and the (cold) surfaces of the element, particularly in thick sections.
- Repeated Freezing and Thawing of Concrete:** - During construction, it is likely that the concrete will be exposed to cycles of freezing and thawing while it is in a saturated condition. As the temperature of saturated concrete is lowered, the water held in the capillary pores in the hardened cement paste freezes and the expansion of concrete takes place. If subsequent thawing is followed by re-freezing further expansion takes place, so that repeated cycles of freezing and

thawing have a cumulative effect. The compressive strength and the dynamic modulus of elasticity of the concrete get adversely affected due to freezing and thawing. The extent of damage depends on the number of freeze-thaw cycles. More the freeze-thaw cycles, more is the loss in the compressive strength. The new sidewalks and other flatwork exposed to melting snow during day and freezing during night should be air entrained and protected from freezing until a strength of at least 24 MPa has been attained.

Problems resulting from Cold Weather at various stages in the life of Concrete are listed below:

Stage	Effect
● Production	→ Incorporation of frost-bound material
● Transit	→ Cooling of mix
● Placing, finishing and curing	→ Formation of ice crystals in concrete → Increased thermal gradients/increased tendency to thermal cracking → Delayed formwork removal → Slower gain in strength → Greater chance of formwork stripping damage → Bleed water may remain on surface
● Long-term	→ Slower setting → Slower gain in strength → Freeze-thaw damage

Minimizing the effects of Cold Weather on Concrete:

Some of the practical methods to minimize the effects of extreme cold weather on concrete and concreting are as follows:

1. Temperature control of the ingredients:

- The temperature of the concrete can be raised by controlling the temperature of its ingredients. The contribution of each ingredient to the temperature of concrete is a function of the temperature, specific heat and quantity of the ingredients used. The aggregates and mixing water exert the most pronounced effect on temperature of concrete. Of all the concrete making components, mixing water is the easiest to heat. Also it makes more practical sense to do so because water (specific heat is 1.0) can store five times as much heat as can the same mass of cement or aggregate (specific heat is 0.22). At temperatures below freezing, often only the fine aggregates needs to be heated to about 40°C if the mixing water is at 60°C to keep the freshly produced concrete at the required temperature. This is generally accomplished by circulating hot air or steam through pipes embedded in the aggregate stockpile for large jobs and for smaller jobs the heating can be done with the steel drums embedded in heaped aggregates and filled with fire. The heating of aggregates to temperatures higher than 15°C is rarely necessary with mixing water at 60°C.
- The mixing water shall be heated in sufficient quantity under controlled condition so as to avoid appreciable fluctuations in temperatures from batch to batch. At temperature in excess of 40°C either for aggregate or water, these shall be mixed in the mixer first and then cement is to be added to prevent flash set and formation of balls in the mixer.

2. Proportioning of concrete ingredients:

- The type and quantity of cement used in the concrete mix affects the rate of development of compressive strength and rate of increase in temperature of concrete. Additional quantity of Ordinary Portland cement, Rapid-hardening Portland cement or use of accelerating admixtures, when used with proper precautions, helps in development of the required strength in a shorter period. Use of cement which gives earlier and higher heat of hydration is preferable. The cement content in the mix shall preferably be not less than 300 kg/m³.
- It is preferable to use Air entraining admixtures wherever damage to hardened concrete by alternate freezing and thawing during service is anticipated.
- Use of accelerating admixtures (preferably non-chloride admixtures) to the concrete reduces the setting time and accelerates the rate of strength gain by increasing the rate at which the cement hydrates.

- Having less water in the mix ensures lower slump and this reduces bleeding and setting time, and increases the rate of strength gain.

3. Production and Delivery:

- Erect Windbreakers to shield the mixing and batching plants.
- Tarpaulin, plastic sheet and other covering, and insulating materials should be used to protect the mixing unit and the materials
- Transit times to the site should be minimized as significant heat losses can occur.
- Concrete should be delivered to the point of placing at not less than 5°C. Place the concrete quickly and cover the top of the concrete with an insulating material.



4. Placing, Protection and Curing:

- Satisfactory concreting can be achieved for the winter conditions prevailing in India by conserving the heat of hydration of cement with insulations and insulated form works.
- The temperature of the concrete when placing at or near freezing temperature shall be at least 5°C and the temperature after having been placed and compacted is maintained above 2°C until it has hardened thoroughly.
- Ensure that all ice, snow and frost(if any) are removed from surfaces of the formwork and the temperature of all the surfaces of formwork shall be raised as close to temperature of fresh concrete as possible.
- Do not place concrete on a frozen sub grade. Where concrete is to be placed over permanently frozen ground, sub grade material may be thawed enough to ensure that it will not freeze back up to the concrete or it may be covered with a sufficient depth of dry granular material.
- Cover all the concrete surfaces soon after placing in order to retain the heat that helps to prevents freezing. Clean straw mats about 50 mm thick, sacks, tarpaulins, plastic sheeting etc. can be used.
- Provide insulation to the form work, because, during the first 24 hours, hydrating cement generates a significant amount of heat which, if retained within the concrete by insulation, will protect it from freezing. Timber formwork is a reasonable thermal insulator that can be used in moderately cold conditions. Metal formwork offers little or no protection and should be insulated. Some of the insulating materials are saw dust, damp sand, timber insulating board etc.
- For concrete cast in insulated formwork, it is only necessary to cover the member completely in order to maintain sufficient water for the hydration of cement.
- Do not saturate the concrete just released from the insulated formwork with cold water. This can be ensured by covering the concrete members immediately on removal of the formwork with plastic sheet or tarpaulins with proper lapping. The surface temperature of the concrete shall be gradually adjusted to the air temperature.
- **Water curing is not recommended in cold weather** during periods of freezing or near freezing conditions as the loss of moisture from the concrete by evaporation is greatly reduced in cold air conditions.
- Freshly placed concrete in cold weather must be protected from drying so that adequate hydration can occur. Normally, measures such as covering the concrete surfaces with plastic sheets and using membrane forming curing compounds must be adopted to prevent evaporation of moisture from concrete.
- Delay the formwork removal to protect the concrete from frost.



For general guidance, the minimum time limits for stripping formwork when cold weather air temperature is about 3°C and concrete made with OPC are in the table below:

Structural Concrete Members	Min. Time
Beam sides, walls, columns	5 days
Slabs (Props left under)	7 days
Beams Soffits (Props left under)	14 days
Removal of props to slabs	14 days
Removal of props to beams	28 days

Precautions to be taken during Cold Weather Concreting: (As per IS: 7861 Part II)

The severity of the weather determines the precautions to be taken. For this purpose cold weather can be divided into three - categories:

- When the temperature is below 5°C but does not fall below freezing point,
- When frost occurs at night only and is not very severe, and
- When there is severe frost day and night.

Below table summarizes the necessary precautions to be taken under each condition:

Conditions	Precautions to be taken
● At low temperature	<ol style="list-style-type: none">Keep formwork in position for longer duration, or use rapid hardening cement;Cover the top of the concrete with insulating material;Insulate steel formwork; andMake sure that concrete is delivered to the point of placing at not less than 5°C.
● When there is Frost at night	<p>Take all the precautions mentioned for low temperature conditions and also the following:</p> <ol style="list-style-type: none">Insulate all formwork,Make sure that concrete is not placed against frozen sub-grade or against reinforcement or forms covered with snow or ice.Place concrete quickly and insulate.
● When there is severe frost during day and night	<p>Take all the precautions mentioned above and also the following:</p> <ol style="list-style-type: none">Heat the water and, if necessary, the aggregate also.Make sure that concrete is delivered to the point of placing at not less than 10°C, place quickly and insulate; or make sure concrete is delivered to the point of placing at not less than 5°C, place quickly and provide continuous heating to the concrete.

CONCLUSION:

Low ambient temperature during cold weather conditions poses difficulties in concreting operations. In cold weather conditions the concrete shall be protected from freezing. These conditions affect the hydration of cement, setting of concrete, strength gain and durability. The required setting time, strength, durability can be ensured during cold weather conditions by using warm concrete ingredients, by not placing concrete on frozen sub-grade or formwork, by insulating the formwork, by protecting the concrete from drying and by preventing concrete from freezing.

By following the precautions given in this article the problems associated with cold weather can be avoided and successful cold weather concreting can be accomplished.

References:

- IS 7861(Part II) - 1975 (Reaffirmed 1997) - Code of Practice for Extreme Weather Concreting PART 2 Recommended Practice for Cold Weather concreting
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- www.concretenetwork.com



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