

Placement of Concrete in Cold Weather

An Online Continuing Education Course for Engineers

Course Number: C-1016

Credit: 1 Hour / 1 PDH / 1 CPD

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Introduction:

According to the American Concrete Institute cold weather exists when “for more than three consecutive days the average daily temperature is less than 40 degrees Fahrenheit and the air temperature is not greater than 50 degrees Fahrenheit for more than one half of any 24 hour period.”

In addition to quality control procedures that are routinely necessary to achieve quality concrete placement, there are additional requirements imposed by cold weather. Cold ambient temperatures decrease the rate of setting and increase the likelihood of deficient concrete due to exposure to temperatures below freezing. The rate of setting refers to how quickly the new concrete changes from a fluid to a hard mass. A decreased rate of setting results in increased time the concrete is exposed to the harmful effects of freezing temperatures. A general rule of thumb is that a decrease of concrete temperature of 20 degrees will result in the doubling of the setting time. This slower rate of setting and the accompanying slower rate of compressive strength gain must be accounted for when scheduling work activities. However, the temperature of the concrete should not be higher than allowed by the specifications since high concrete temperatures can cause other undesirable problems such as surface cracking.

The temperature of the concrete as initially mixed should be selected based on weather conditions such as expected ambient temperatures, precipitation, and wind conditions. Other factors to consider are travel time from the plant to the project site and the size and thickness of the concrete placement. The concrete supplier may have recommendations based on the preceding factors. The Quality Control manager and the concrete supplier will have to exercise a degree of judgment in selecting the appropriate mix design temperature for the concrete. If the concrete temperature as placed in the forms is dropping below the acceptable minimum, adjustments will have to be made. The heating of the mixing water or other adjustments may be necessary.

Another factor to consider is the fact that winter days are relatively short in terms of daylight and therefore darkness and rapidly dropping temperatures must be considered.

Preparation for placement:

The placement of concrete should be planned and discussed prior to commencement of work. Typically, the representative of the owner, the Quality Control Manager, a technical representative of the concrete supplier, and the foreman of the concrete crew will meet to discuss placement procedures. The size of the placement, the expected weather conditions, the equipment and materials needed, and the timing of the ready mix trucks should all be discussed and a plan of action adopted. Is the size of the placement reasonable and manageable considering the resources and manpower available? Are overnight temperatures expected to be below freezing? What is the expected high temperature during the next few days? Are the necessary equipment and materials, such as insulated blankets and heating equipment, on site?

The placement plan should identify what work is going to be done, who is going to do it, and when the placement is going to be done to avoid errors due to a lack of communication. Planning should also include a plan of action for emergencies and problems that may arise during

placement. For example, extra vibrators need to be available in the event that the vibrators being used to consolidate the concrete should fail or malfunction. Is a spare generator available for use in case the primary source of power fails? Where should construction joints be placed in the event that the delivery of concrete is interrupted? Temporary lighting should be available in the event that the concrete placement takes longer than anticipated. The technical representative of the concrete supplier should be consulted regarding the selection of a suitable mix design, anticipated travel time, haul routes and distances, and recommendations regarding cold weather practices. Concrete exposed to the elements should be air entrained. Air entrainment increases the durability of concrete. Entrained air will improve the resistance of concrete to the freeze thaw cycle. Entrained air also improves the workability of concrete. The workability of stiff, poorly graded concrete is improved by the use of entrained air. A minimum concrete temperature of 60 degrees Fahrenheit at the time of placement into the forms is generally considered desirable.

In order to meet the minimum concrete temperature requirement, the temperature of the concrete when mixed has to be higher than 60 degrees because of the heat loss from the time of mixing to the time of actual placement into the forms. The concrete supplier may recommend an initial temperature of 70 degrees to compensate for heat loss. A maximum of 85 or 90 degrees is generally specified. The specifications generally stipulate a minimum and a maximum allowable concrete temperature. The temperature of the concrete can be increased by heating the water and the aggregate. However, because of the difficulty of heating aggregate, the heating of mixing water is a more practical solution.

Because setting time is delayed by cold weather, the use of an accelerator may be considered. An accelerator is a chemical admixture that decreases the setting time of the concrete and by decreasing the setting time also indirectly decreases the risk of damage to the concrete due to freezing temperatures. Fresh concrete will freeze if its temperature drops under 25 degrees Fahrenheit and its compressive strength can be cut in half. Such a drastic loss of compressive strength is unacceptable. Admixtures, such as accelerators, are used to modify the characteristics of concrete in response to environmental circumstances such as cold temperatures at the time of the placement or other considerations. Non chloride accelerators can be used when possible corrosion of steel reinforcement is an issue. A misconception with respect to the use of accelerators is that accelerators prevent fresh concrete from freezing. Accelerators will not prevent concrete from freezing and so fresh concrete must be protected from cold weather by heating the ambient surroundings or by the use of insulation. Because of cold weather the substitution of type III cement in lieu of type I should be evaluated. Type III is high early strength cement.

Another possible alternative is to increase the amount of type I cement in the mix design. However, the use of type III cement is generally more desirable because of cost. An increased amount of type I cement in the mix design is accompanied by a corresponding increased cost. Either solution is acceptable from the technical perspective. A higher cement content will increase the heat of hydration and decrease setting time. The concrete mix design selected should have the least amount of water possible to reduce setting time. Additionally, the compressive strength of concrete is inversely related to the amount of water in the mix. Higher water content results in lower compressive strength. A measure of this relationship is called the water cement ratio. The water cement ratio is calculated by dividing the weight of water by the weight of cement. Typical water cement ratios are .45 to .50. While the placement of concrete as early in the day as possible is desirable, circumstances may dictate the placing concrete in the afternoon in order to meet minimum ambient temperature requirements in the specifications. Typically, specifications will stipulate that ambient temperature be about 40 degrees Fahrenheit and rising

before concrete placement is allowed. Once all of the preceding factors have been considered and discussed, a mix design and a placement plan can be selected.

Inspection of forms, subgrade, underground plumbing, and reinforcing steel for compliance with specifications should be done at least a day before concrete is ordered. It is advisable that the inspector use a concrete placement check list to determine if the contractor is ready. Forms should be checked for correct elevations. Immediately prior to the placement of concrete the surfaces of the forms should be covered with oil or sprayed with water. Oil will prevent the formation of a bond between the new concrete and the form surface. However, water should be used if the new concrete is to receive a coat of paint or any type of finish requiring a bond with the concrete. Floor slabs and footings should be checked to ensure correct location and dimensions. Floor slabs should be placed in one layer. Otherwise, concrete, such as walls, should be placed in layers not to exceed 12 inches. The limit on layer thickness is to ensure that the concrete is properly consolidated. Equipment to be used during the placement should be checked for proper operation and for adequate quantities to handle the placement. Vibrators should be checked for amplitude and frequency. Portable generators should be checked for operation and for fuel. Items that are to be embedded in the concrete, such as anchor bolts, should be checked for correct location, quantity, and elevation. The bottom of trenches where concrete footings are to be placed should be clean and free of debris. Ice and frozen earth are not acceptable. Reinforcing steel should be clean and free of rust. The ability of reinforcing steel to adhere to new concrete is adversely affected by rust, scale, or other foreign substances. Any reinforcing steel that is coated with concrete splattered during previous placements also needs to be thoroughly cleaned. It is also important that reinforcing steel be properly supported or braced to prevent movement during concrete placement. Spacers can be used to prevent unwanted displacement of reinforcing steel. It is important that the preparation for the placement of concrete be done in a deliberate and careful manner to avoid costly mistakes. The tying of reinforcing steel and other last minute adjustments while the ready mix truck is waiting is a practice that normally leads to mistakes and should be avoided.

Placement:

Concrete temperatures should be checked and recorded for record and control purposes. An acceptable temperature for concrete placement is normally from 60 degrees to 85 degrees Fahrenheit. The temperature of the fresh concrete should be maintained at a minimum of 55 degrees until the compressive strength requirement is met. For transit mixed concrete, the specifications will typically

require that the concrete meet the requirements of ASTM C94. One important requirement of C94 is that a delivery ticket be furnished with each delivery. It is important that the inspector keep a copy of the delivery ticket since the ticket will have important information regarding the time the concrete was batched, amount of concrete delivered, admixtures, air entrainment, any addition of water, and time of arrival at project site. ASTM C94 also establishes limits on the amount of concrete that can be mixed in transit based on the size of the mixing drum.



Reinforcing steel and embedded items should be checked for compliance with specifications before ordering concrete.

Once the compressive strength requirement is achieved, insulated blankets can be removed in a manner that will prevent a rapid decline in temperature. An acceptable rate of temperature loss is not more than 2 degrees Fahrenheit per hour. A simple pocket thermometer is handy. The recording of concrete temperatures, ambient temperature, and other weather conditions at the time of placement should be done by the contractor. These duties can become very important in the event that the concrete has to be removed due to exposure to freezing temperatures, unacceptable cracking, cold joints, segregation of aggregate, or failing compressive strength tests. Good documentation helps pinpoint the source of the problem and the liable party. Thorough documentation is an aid to determining if the problem was caused by exposure to cold temperatures, poor workmanship, poor or improper curing, defective curing compound, or faulty concrete because of mixing or batching problems. Samples of concrete should be taken in the frequency stipulated by contract to verify compliance with the slump, compressive strength, concrete temperature, air entrainment and ambient air temperature requirements. Slump is a measure of consistency and workability in concrete. Consistency is determined by comparing the latest batch of concrete with previous batches. Is the concrete consistent with previous batches in terms of air entrainment, temperature, and stiffness of the mix? It is desirable that concrete be consistent from batch to batch. Workability is a characteristic with respect to how easily the concrete can be placed into the forms. Concrete with a relatively higher slump is easier to place than stiff low slump concrete. Workability is effectively obtained by the use of air entrainment and by increasing the amount of fine aggregate. Workability of concrete is decreased by the use of poorly graded aggregates. The preparation and care of concrete cylinders has to be monitored for proper handling procedures. The concrete has to be deposited as closely as possible to the final location. Concrete for slabs on grade should be placed against the forms at one end of the slab with new deliveries placed against the previous batch. Concrete should not be dropped more than 5 feet. Concrete that is dropped from heights greater than 5 feet will segregate. An effective method of placing concrete is to pump the concrete into the forms. Pumping is effective because it places the concrete exactly where it is needed in a minimum amount of time. Concrete should not be dumped in separate piles and then moved to the final location by use of vibrators. This practice tends to cause segregation of the concrete. Excessive vibration of concrete should be avoided. The proper consolidation can be obtained by vibration of concrete from 5 to 15 seconds. Vibration of over 15 seconds will result in the loss of air entrainment. During the placement of concrete into tall sender forms, such as columns, care must be taken to prevent segregation of particles caused by the dumping of the concrete into the form. The use of a tremie or chute may be required or advisable.

After concrete has been placed into the forms, concrete slabs on grade and concrete paving require additional work before curing. First, the concrete surface needs to be screeded to give a level surface at the correct elevation. Screeding is simply the striking off of excess concrete with a straightedge. A 2x4 wood stud is usually moved in a back and forth motion through the fresh concrete to remove humps. Afterwards, screeding the concrete surface is finished with a bullfloat. Large unformed concrete surfaces will require finishing of the surface. However, finishing should not start until surface water has disappeared. Premature finishing will result in a weak, watery, and eventually unacceptable surface and as time goes by the surface will flake and spall. A bullfloat has a flat blade with a long handle and is usually made of aluminum. The long handle allows the worker to reach areas in the middle of the slab. Bullfloating will give a flat even surface. In situations where a hard surface is desired, the floating of the surface is followed by steel troweling. Steel troweling will produce a smooth hard surface. Once the concrete slab is stiff enough to hold the weight of a person, the contraction joints can be sawed as indicated on the plans. Contraction joints provide a selected location for the concrete slab to crack in a predetermined manner instead of a random manner. Contraction joints are also referred to as control joints. Concrete which will remain hidden from view, such as footings, does not need a

finished surface. The main concern with footings and grade beams is the correct location, line and grade. Concrete floors may have a straightness requirement. For ordinary floors the tolerance can be 1/8 inch per 10 feet of length. A gap of 1/8 inch or more would be out of tolerance and therefore unacceptable. Where a level surface is critical, the specifications may state an F number. The F number system consists of two standards. One standard, FF, refers to the bumpiness or waviness in a floor. The second standard, FL, refers to the tilt or inclination of the floor. F numbers are used when the levelness of a floor is important, such as a warehouse. When finishing of the concrete is completed and the surface water has disappeared, the next step is curing.

Curing:

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In practice, curing is essential. Nevertheless, curing must prevent an unacceptable drop in concrete temperature. Fresh concrete must be protected from damage caused by the weather or other sources. The most common method of curing concrete is by moist curing. The surface is kept moist by a continuous fog of moist air or by burlap that has been soaked in water. A fog of moist air is an effective method of curing concrete. Another environmental condition necessary for moist curing is that the ambient temperature be well above freezing. On formed concrete, the wood forms must be kept wet during the curing period. Once the forms are removed, the concrete can be cured with curing compound. Forms must be removed carefully to avoid damaging green concrete. Another moist curing method involves the use of burlap blankets. Burlap is placed on the new concrete as soon as the surface is hard enough to prevent damage