Due to project delays, the 42,000-ft² (3900-m²) slab-on-ground floor for a commercial building must now be placed during cold weather. The ground is frozen to a depth of about 16 in. (400 mm). What’s the most economical way to get the frost out of the ground so the concrete floor placement can proceed?

This is a typical problem during cold-weather construction because most specifications have clauses such as “The subgrade shall be free from frost or ice,” or “Do not place concrete on frozen subgrade or on subgrade containing frozen materials.” This means no part of the subgrade can be frozen when concrete is placed on it.

ACI 306.1-90, “Standard Specification for Cold Weather Concreting,” is more lenient. Section 3.1 states:

“Before beginning concrete placement, thaw the subgrade to the depth specified in the Contract Documents.”

This would imply that thawing the subgrade to some predetermined depth might be acceptable. A limited survey of design professionals in the

Hydronic heating is one option for thawing a frozen subgrade. A heated propylene glycol mixture is circulated through hoses that are placed on the frozen subgrade, and then covered with plastic sheeting and insulating blankets. The sheeting keeps the subgrade moist, improving heat conductivity and reducing the time needed for thawing. Insulating blankets prevent heat loss and direct heat into the ground. Photo courtesy of Ground Heaters, Inc.
northern U.S., however, indicates that most specifications don’t allow construction on frozen ground. So what are the options when a project schedule dictates winter concrete placements, but specifications prohibit placing concrete on frozen ground? To answer that question, we first have to ask why frozen ground is a problem.

**EFFECTS OF FROZEN GROUND ON THE CONCRETE AND THE STRUCTURE**

Surfaces that will be in contact with newly placed concrete must not be so cold that they’ll cause early freezing or seriously delayed setting of the concrete. That means contact surfaces must be at least a few degrees higher than the freezing temperature—perhaps 35 °F (2 °C). If the subgrade at greater depths is very cold, newly placed concrete might still be adversely affected even if the ground surface isn’t frozen when the concrete is placed. Table 3.2.1 of ACI 306.1-90 gives the minimum allowable concrete temperature that must be maintained during the protection period. Protection period is defined as the required time during which the concrete is maintained above a specific temperature in order to prevent freezing of the concrete or to ensure the necessary strength development for structural safety. For concrete members with a least dimension less than 12 in. (300 mm), the specific temperature is 55 °F (13 °C).

The greater danger is placing concrete on a frozen soil that isn’t thaw-stable. Many fine-grained soils are susceptible to frost heave. Water accumulates in lenses during freezing and causes the surface to heave. When the ground thaws, it settles and loses bearing capacity. Reduced bearing capacity may cause cracking, and differential heave or settlement after thawing may cause slabs to tilt and crack.

Subgrade freezing can often be prevented by simply covering the ground with insulating blankets or a layer of dry straw covered with a tarp. Other options are heated enclosures or hydronic heaters that are covered with insulating blankets. Dealing with an already frozen subgrade is more difficult, and may be costly.

**GETTING THE FROST OUT**

Methods for dealing with frozen subgrade include:
- Removing and replacing the frozen material with unfrozen fill;
- Covering the frozen subgrade with a tarp and blowing hot air under the tarp;
- Erecting and heating an enclosure; and
- Placing hydronic heating hoses on the frozen subgrade and covering them with insulating blankets.

Before removing and replacing frozen material, some of the other methods may have to be used if the subgrade is frozen so solid that it can’t be easily removed. Also, when any of these methods are used, steps must be taken to ensure that the subgrade won’t freeze again during the protection and curing period. Sometimes the methods used to thaw the subgrade can also be used to prevent freezing after the concrete has been placed.

The choice of any frost-removal options is largely a matter of economics. Heating the air under a tarp or in an enclosure is generally less efficient than placing the heating element in direct contact with the subgrade. That’s because a relatively small percentage of the heat in an enclosure is conducted into the frozen ground.

**GROUND THAWING WITH HYDRONIC HEATERS**

These portable devices are available from several manufacturers. A boiler system heats a propylene glycol mixture that is then circulated through hydronic hoses placed on the frozen subgrade after all surface ice and snow have been removed. Some manufacturers recommend laying a plastic sheet (3-mil minimum thickness) on the ground before the hoses are placed. Others say to place the hoses first, then cover them with the plastic sheet. In either case, the sheet keeps the subgrade moist, improving heat conductivity and reducing the time needed for thawing.

Finally, workers must cover the hoses and plastic sheet with polyethylene-clad insulating blankets. This prevents heat loss and directs heat into the ground. Required blanket thickness, or R-value, depends on the depth of frost to be removed and on ambient conditions. An R-value of 15 h·ft°F/Btu (2.6 m²·K/W) is often recommended, but if the ambient temperature is above 25 °F (−4 °C) and the thickness of the frozen layer is less than 2 ft (0.6 m), an R-value of 10 h·ft°F/Btu (1.8 m²·K/W) may be adequate. Under extreme weather conditions—high winds and very low temperatures—hay bales placed on the blankets can improve the insulating values and help keep the blankets in place.

The required hose spacing also depends on frost depth. For frost depths up to 3 ft (1 m), a hose spacing of 24 in. (600 mm) will thaw about 1 ft (0.3 m) of depth per day under ideal conditions. Compacted soil, or soil that is dry or very wet, will thaw at a slower rate. Dry soil thaws slowly because air conducts heat less efficiently than water, but very wet frozen soil thaws slowly because large amounts of energy are needed to first melt the ice and then heat the water that remains. Hose spacings of 12 in. (300 mm) or even less may be needed under the most adverse conditions.

**WHAT DOES HYDRONIC HEATING COST?**

The cost of ground thawing with hydronic units varies with the type of soil, depth of frost, ambient conditions, and the efficiency of the heating unit. Cost is also affected by whether the heating unit is owned or rented. Soil type affects the cost because coarse-grained soils, such as gravels or sands, don’t hold as much water (or ice) as fine-grained clays and silts. It may take four times as many Btus to melt the ice typically contained in frozen silt as it does to melt the ice in gravel soil. Because of all the variables that must be considered, it’s difficult to give a typical cost. The following example illustrates this point.
One contractor’s project required thawing about 80,000 ft\(^2\) (7400 m\(^2\)) of subgrade into which frost had penetrated up to 4.5 ft (1.4 m). The same system was also used to protect the concrete slab during curing and to keep heat on it until there was no risk that the ground below the slab would freeze after concrete placement. The estimated costs for using four different types of glycol systems varied by a factor of two, with the lowest estimate at about $2.55/ft\(^2\) ($27.40/m\(^2\)) and the highest at $5.00/ft\(^2\) ($53.80/m\(^2\)). Thus, the cost for a given set of conditions varied significantly depending on the type of heating unit used.\(^5\)

**References**


Selected for reader interest by the editors.