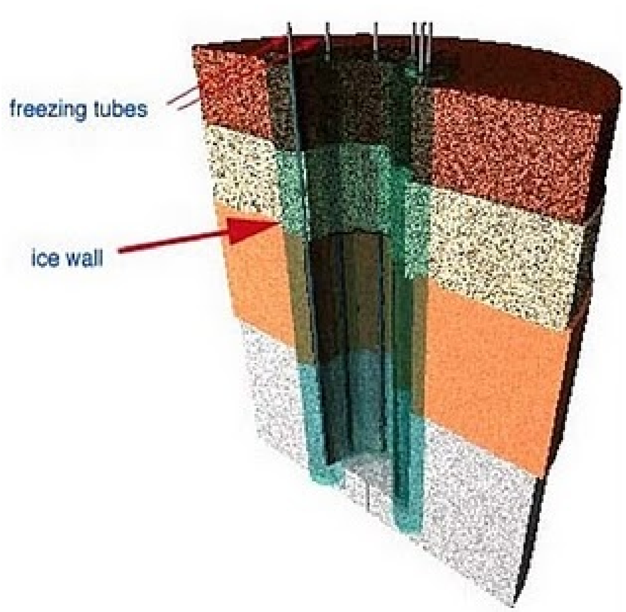
Tech Talk: Ground Freezing to Stop Water Flow and Strengthen Soil

Posted by Heading Out on October 2, 2010 - 8:32pm
Topic: Supply/Production
Tags: ground freezing, ground stabilization, grouting, tech talk [list all tags]

Last time I wrote about grouting of ground in order to either strengthen it, or to stop water flowing through it. Grouting is something that is often carried out during the driving of the tunnel or shaft, so that the effects can be immediately assessed. If the water continues to flow or the cement has failed to do what was desired, then a second set of holes can be drilled, and secondary and subsequent injections can be made until the goal is achieved. It is more common than not to have to make several injections. The alternative, is to immobilize the water, or strengthen the ground before the excavation is started. While this can be attempted with grout, it is more common to use a different idea.

This is ground freezing, and it differs from grouting in many ways. One major difference is that the holes for the process are drilled before the excavation is made, and a second is that the changes to the surrounding soil and rock are temporary since, when all is finished, the ground is thawed and reverts to its original condition (or close). It has the advantage that if the soil/rock is relatively impermeable of has pockets of water not easily accessed by grout injection, if the overall temperature is lowered below freezing, then the water will freeze, even if not directly accessed. This means that the zone around the pipes can be froze, even if the pipes go down through layers with different water content.



Building an ice wall around an excavation. Note that the wall goes down into the stronger formation beneath the areas of concern, to provide a good footing, and that the ice wall does not freeze the material in the middle, which has to be dug out.

So how does it work? There are a number of different ways of going about the process, but I am only going to briefly describe a couple of them. The first is the more conventional approach, using a brine coolant, and the second is more commonly used when, for example, you're refurbishing a road tunnel, and the roof suddenly collapses all the way to the surface. (The injection of liquid nitrogen).


(Photos courtesy of Mott McDonald)

By completely freezing the gravel and other constituents of the roof and tunnel line, it was possible to restabilize and excavate through the area, putting in new supports at the same time.

Ground freezing can effectively form a temporary roof over an excavation, even if very close to the surface. It was used, for example, during the Big Dig, to create a bridge under the railway lines in Boston, while the new tunnel lining was pushed into place beneath it, using hydraulic jacks. It was also used in Vienna, where a subway had to pass relatively closely under existing buildings.


Ice wall as temporary support (image Joe Summers)

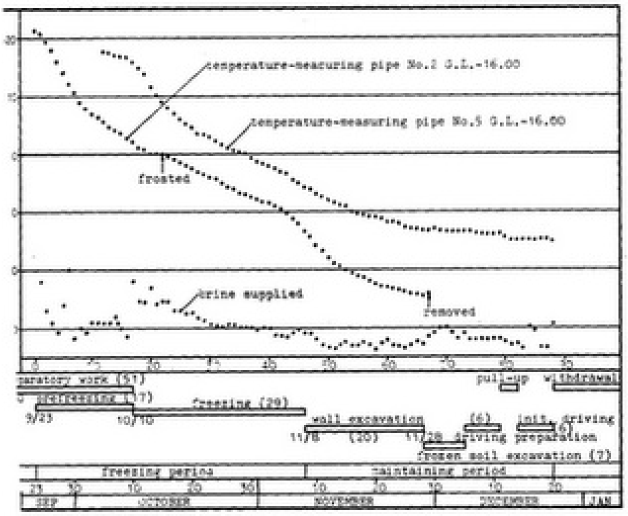
The conventional method of freezing involves inserting two sets of concentric pipes into the ground, inside pre-drilled holes. The outer pipe is sealed at the bottom end, so that as the freezing fluid (typically a chilled brine) is pumped down the inner pipe, and then flows back up the outside, it draws heat from the surrounding rock and soil, lowering the temperature until the water freezes. After circulation the brine returns to the refrigeration plant where it is re-cooled and re-circulated.

It is important to know the chemistry of the water in the ground, since with the wrong combination the water may not freeze at the expected temperature. It is also important that the outer pipe be sealed since if there is any leakage, then the brine may spill into the surrounding rock. At that point it can't be frozen with the system, any longer, and an alternative method has to be used.

It is generally smart also, particularly when digging near the surface, to make sure that there aren't any pipes (such as water and sewer) that can act as heat sources during the process. There can be embarrassing results if one of these (particularly the latter) is undetected, and the surrounding ground collapses as the shaft is then dug.


Hole in an ice wall (arrow) note that it depends on how the ground is being dug out, how fast this is detected.

Brine operations generally take a considerable time, and there is a project schedule so that you can get an idea (depending on the depth and size of the hole) of what might be involved in such an operation. Remember that the ice wall has to be kept cold during the excavation, but that keeping the central material unfrozen makes it easier to dig out. Cement poured against a frozen wall, if properly designed, will set as planned, since the heat of hydration overcomes the surrounding heat loss.



This requires, obviously, a lot of preplanning. Where there is an emergency this is not possible, and thus the use of faster freezing methods, such as the injection of liquid carbon dioxide, or nitrogen, into the ground, in order to freeze and stabilize it more rapidly.

There are two ways of making the injection. There is the dual-pipe approach where the nitrogen is in a closed circuit, and then there is the simpler process where a lance is, simplistically, pushed into the ground and the resulting gas percolates upward from the end. That is a little less precise, given that the gas moves through the ground following the path of least resistance, but it does have the advantage of being quick, and generally effective in stopping an imminent disaster. Relative to the months of a brine installation the work [takes a week or so] (depending on size).

> Copper freeze pipes with a standard diameter of 2" (54 mm) are installed, at an average distance of 2" (54 mm) On the inside, downpipes with diameters of ½" (10–12) mm are installed.

LIN is fed into the pipes through insulated supply lines. The LIN vaporizes, with 1 kg of LIN extracting about 200 kJ of energy from the surrounding soil, cooling and freezing it. The vaporized cold nitrogen (i.e., exhaust gas) extracts another 100 kJ from the ground. After about one week, this process forms a frozen wall with a diameter of about 1 m. This so-called "establishing phase" lasts four to seven days, and about 300 - 500 gal (1,500–2,500 l) of LIN is used to freeze 1 cubic yard (0.75 m^3) of soil.

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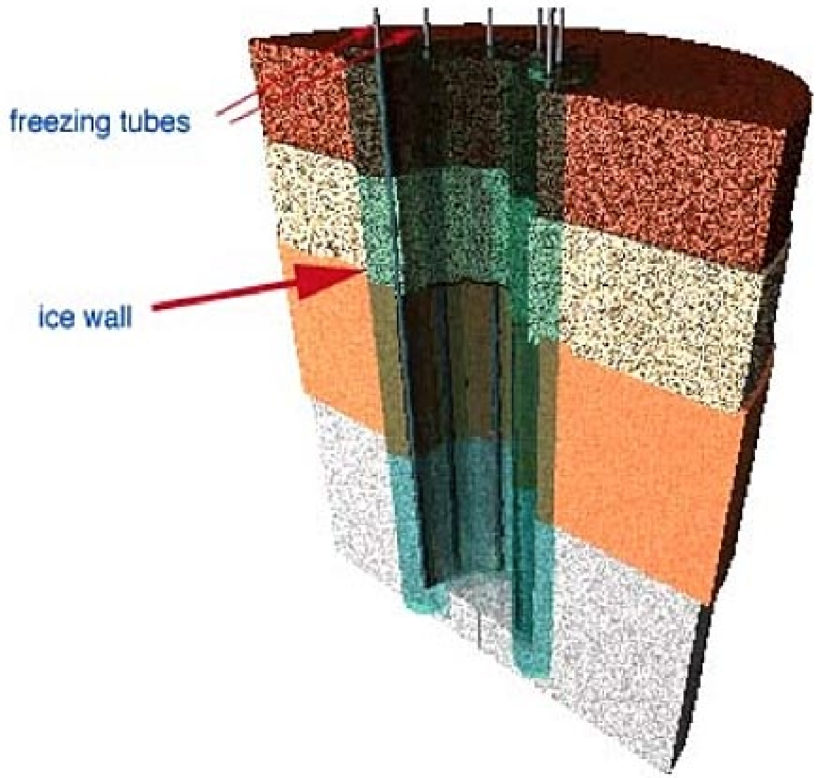

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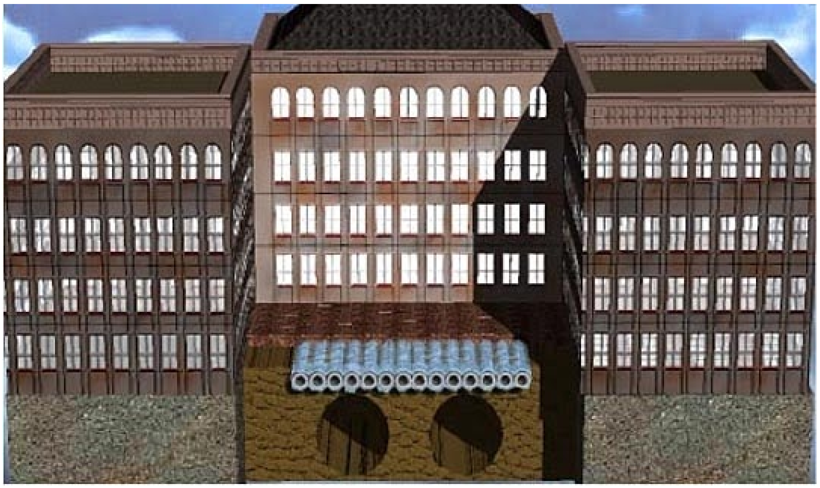

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