Ground Freezing
Cool Technology Keeps Contaminants on Ice

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If you’ve ever had to try to dig a hole in the ground after an extended period of sub-freezing weather, you know how tough frozen soil is. It’s nearly twice as strong as concrete, and nothing passes through it, not water, chemicals or hazardous materials.

Those attributes are the basis for the latest applications of ground freezing, a cool technology for construction shoring, control of groundwater and isolation of subsurface contamination. Wherever soil is loose, soft or wet, ground freezing can create a safe, simple, reliable and surprisingly cost-effective barrier, either as a temporary application or a permanent solution.

Time-Tested Technique
The history of artificial ground freezing and its engineering applications stretches back almost 150 years and across an ocean. Invented by the German scientist F.H. Poetsch in 1863, the technique was reported to have first been used in the coal mining valleys of South Wales. In the United States, the first ground freezing application, to a depth of 30 meters (100 feet), occurred in 1888 for the Chapin Mine Co. in Iron Mountain, Mo. Today, artificial ground freezing is used extensively for groundwater control and excavation support in the underground construction industry and, recently, for environmental remedial applications.

Basic Concepts Still Valid
The concept behind 21st century ground freezing is the same as that developed by Poetsch. When in-situ pore water in the subsurface is frozen, it acts as a bonding agent, fusing particles of soil or rock to create a frozen soil mass with remarkably improved compressive strength and impermeability. While advanced refrigeration technology has refined modern efforts, the core method of achieving the freeze still dates back to Poetsch. Small-diameter, closed-end freeze pipes are inserted into vertical bore holes drilled along the edge of area to be shored or contained. As the cooling agent, typically chilled brine (CaCl₂), is circulated through the pipes, heat is extracted from the soil into the brine solution, causing the ground to freeze around the pipes. The warm brine is returned to the refrigeration plant where it is again cooled. Frozen earth forms around the freeze pipes in the shape of vertical, elliptical cylinders. As the cylinders gradually enlarge, they intersect to form a continuous wall. With heat extraction continued at a rate greater than the heat replenishment, the thickness of the frozen wall will expand with time.

Frozen ground is nearly twice as strong as concrete and is essentially impermeable.

Once the frozen wall has achieved the design thickness, the freeze plant may be operated at a reduced rate to maintain the condition during excavation. Monitoring of conditions during formation and maintenance is accomplished by temperature sensors installed at various levels in monitor pipes located strategically along the frozen wall.

Following excavation, refrigeration is discontinued, allowing the ground to return to its normal state.

While the principle behind the ground freezing process may appear simple, proper execution of the work, particularly at depth, is complex. Successful ground freezing operations require understanding of refrigeration and soil thermal analysis. In addition, understanding of the strength and behavior of frozen earth is vital. The alignment of the freeze pipes is critical to acceptable performance of the ground freezing system. The design, with respect to strength and time of formation, is directly related to the

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spacing between pipes and temperature of the chilled brine solution. If the installed pipes are permitted to deviate too much from the design, unexpected windows or zones of less-than-design thickness can occur.

**Freezing Wall Applications**
Ground freezing is ideal for a multitude of construction and environmental remedial applications. It is effective in almost all soil conditions, including heaving sand, cobbles, peat, clay and bedrock. It provides excellent flexibility for sites with buried utilities, as the freeze pipes can be installed around or beneath existing underground facilities.

Since soil freezing equipment is small, portable and uncomplicated to install, soil freezing can be easily adapted for difficult or remote sites. Power outages during construction are not a problem either, because frozen ground stays frozen for days or weeks without additional chilling, even in the summer. And at between $15 and $25 per square foot, the price of a frozen soil wall is much more attractive than many other options, such as sheet piling with a grout sealing, to provide a shore system and prevent groundwater seeping into the excavation area.

Several factors contribute to the current enthusiasm for ground freezing. Groundwater management and control have become more problematic because of increased regulatory requirements in many states. Often it is not possible to remove and dispose of large volumes of groundwater, even for temporary construction purposes. Construction sites have become more congested and complicated. Often, contractors must work around existing infrastructure such as tunnels, cables, sewer lines and other utilities, prohibiting the use of conventional shoring with sheet piles. A frozen soil barrier, on the other hand, often can be installed without disturbing underground infrastructure or requiring expensive relocation of utilities.

Another factor driving the move toward ground freezing is the presence of contaminated groundwater and soil at many construction sites. Treating and hauling off hazardous materials or contaminated groundwater is a pricey proposition. But a frozen barrier can be installed on a temporary or permanent basis, safely isolating a work area from external contaminants or preventing the migration of contaminants to new locations.

**Summary**
The modern ground-freeze wall is a reliable and effective technology. Its use is worthy of consideration, especially for site conditions in which the excavation area is in the middle of active utility lines and/or next to existing buildings. Implementing a ground freezing wall to provide both earth shoring and groundwater cutoff during construction and soil excavation, including removing the contaminated soil, is also a cost-effective option compared to traditional approaches such as sheet pile and slurry wall.

Ground freezing to provide both earth shoring and groundwater cutoff during soil excavation is a viable and cost-effective option compared to the traditional approach.

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