CM 420

Temporary Structures

UNIVERSITY OF WASHINGTON

Ground Freezing

Lecture 12

Ground Freezing

- Ground freezing is a process of making water-bearing strata temporarily impermeable and to increase their compressive and shear strength by transforming joint water into ice.
- Freezing is normally used to provide structural underpinning; temporary supports for an excavation or to prevent ground water flow into an excavated area.

Ground Freezing

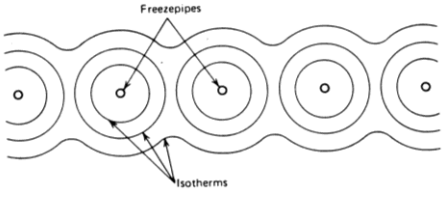
Ground Freezing

- Successful freezing of permeable water-bearing ground affects simultaneously a seal against water and substantial strengthening of incoherent ground.
- No extraneous materials need to be injected and apart from the contingency of frost heave, the ground normally reverts to its normal state.
- It is applicable to a wide range of soils but it takes considerable time to establish a substantial ice wall and the freeze must be maintained by continued refrigeration as long as required.

Ground Freezing

- Ground freezing is used for groundwater cutoff, for earth support, for temporary underpinning, for stabilization of earth for tunnel excavation, to arrest landslides and to stabilize abandoned mineshafts.
- Typically, a row of freezepipes are placed vertically in the soil, and heat energy is removed through them, in a process remarkably analogous to pumping groundwater from wells.

Formation of a freezewall



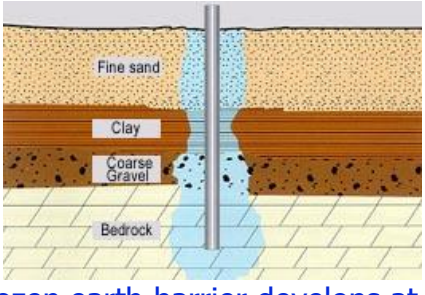
Ground Freezing

Ground Freezing

- When the earth temperature reaches 32°F (0°C), water in the soil pores turns to ice. Then further cooling proceeds.
- With granular soils, the groundwater in the pores freezes readily, and a saturated sand, for example, achieves excellent strength at only a few degrees below the freezing point. Further depression of the temperature produces only marginal increase in strength.
- With clays, however, the ground water is molecularly bonded at least in part to the soil particles.

Ground Freezing

- The design of a frozen earth barrier is governed by the thermal properties of the underlying soils and related response to the freezing system.



Formation of frozen earth barrier develops at different rates depending on the thermal and hydraulic properties of each stratum. Typically, rock and coarse-grained soils freeze faster than clays and silts.

Ground Freezing

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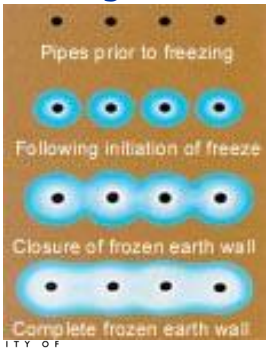
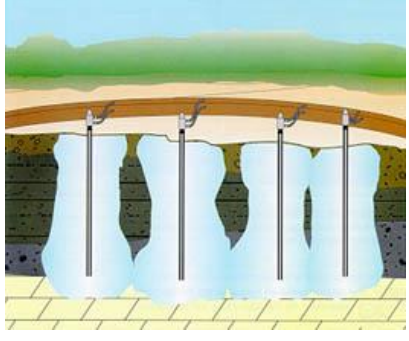
- When soft clay is cooled to the freezing point, some portion of its pore water begins to freeze and clay begins to stiffen. If the temperature is further reduced, more of the pore water freezes and the strength of the clay markedly increases.
- When designing frozen earth structures in clay it may be necessary to provide for substantially lower temperatures to achieve the required strengths.
- A temperature of +20 °F may be adequate in sands, whereas temperatures as low as –20 °F may be required in soft clay.

Ground Freezing

- Referring to the figure on slide #1, the frozen earth first forms in the shape of a vertical cylinders surrounding the freezepipes.
- As cylinders gradually enlarge they intersect, forming a continuous wall.





Ground Freezing

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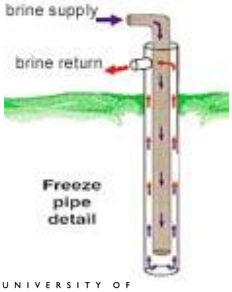
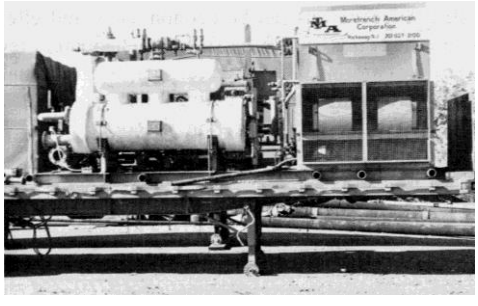
- If the heat extraction is continued at a high rate, the thickness of the frozen wall will expand with time.
- Once the wall has achieved its design thickness, the freeze plant is operated at a reduced rate to remove the heat flowing toward the wall, to maintain the condition.

Freezing Equipment and Methods

- The most common freezing method is by circulating brine (a strong saline solution – as of calcium chloride).
- Chilled brine is pumped down a drop tube to the bottom of the freeze pipe and flows up the pipe, drawing heat from the soil.



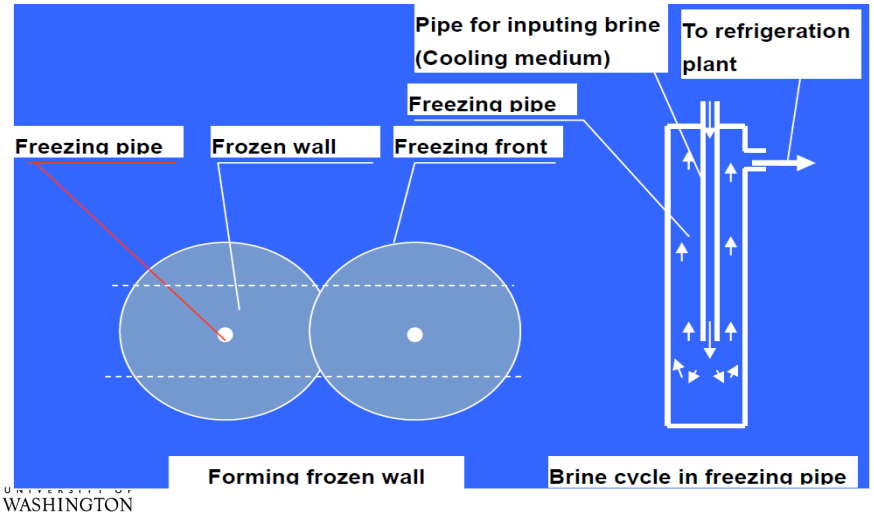
Portable twin 60-ton brine refrigeration unit



Ground Freezing

Freezing Equipment and Methods

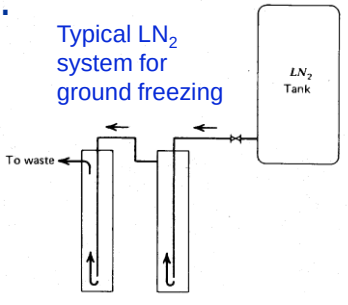
- Freezing Process



Freezing Equipment and Methods

- The liquid nitrogen (LN_2) process has been applied successfully to ground freezing.
- The cost per unit of heat extracted is much higher than with circulated brine. Nevertheless for small, short term projects, particularly in emergencies, the method can occasionally be competitive.
- Because of the extremely low temperature, freezing with LN2 is rapid, and high strengths of frozen clay can be achieved.

Typical LN_2 system for ground freezing



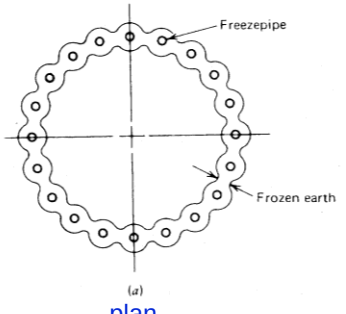
Ground Freezing

Freezing Applications

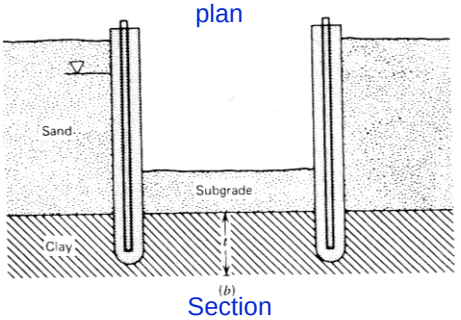
- The freezing method is remarkably versatile, and with ingenuity it can be adapted to a great many project conditions.
- The penetration of a freeze does not vary greatly with permeability, so it is much more effective as a cutoff than grout.
- In stratified soils, cutoff by freezing encounters fewer problems than drainage by dewatering.
- Freezing can perform the dual function of water cutoff and earth support, eliminating sheeting and bracing.

Freezing Applications

- The opposite figure shows a circular excavation supported by a freezewall.



plan



Section

Circular excavation support by a freezewall

Ground Freezing

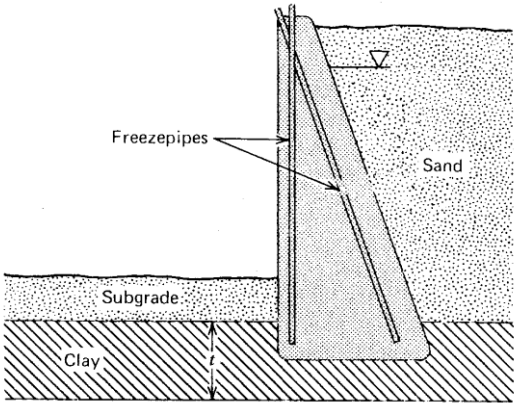
Freezing Applications

- Temporary underpinning of adjacent structure and support during permanent underpinning
- Shaft sinking through water-bearing ground
- Shaft construction totally within non-cohesive saturated ground
- Tunnelling through a full face of granular soil
- Tunnelling through mixed ground
- soil stabilization

Freezing Applications

- Figure below shows an excavation supported by gravity retaining wall of frozen earth. A combination of vertical and inclined freezepipes is typical, to achieve the shape illustrated.

Note in both cases the freezewall toes into an impermeable clay layer below the proposed subgrade.



Ground Freezing

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1. Assembling freeze pipes.

2. Installation of freeze pipes.

3. Application of freeze pipes with electronically controlled refrigeration plant.

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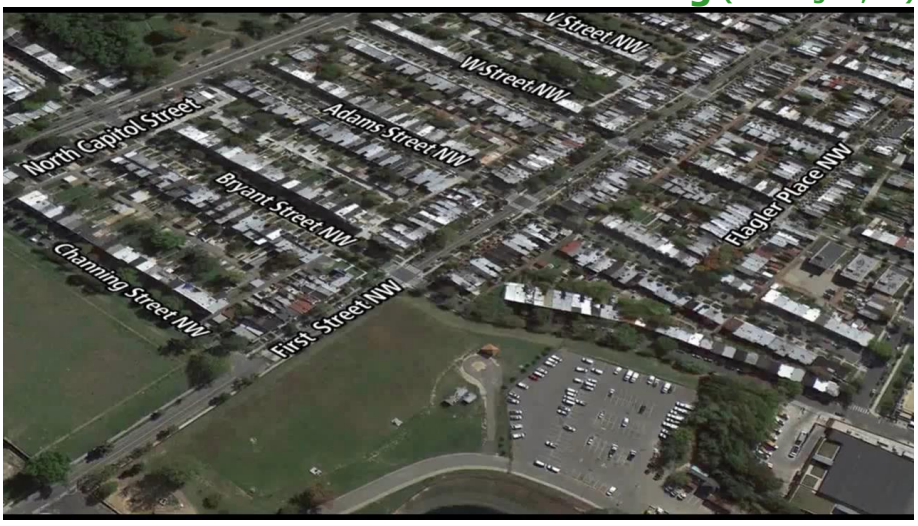
4. Frost development on freeze pipe headers.

5. Excavation following completion of freeze wall.

6. Construction of concrete liner. Once completed, refrigeration can be shut down.

Ground Freezing

First Street Tunnel Ground Freezing (Washington, DC)



The contractor utilized an innovative ground freezing technology to improve ground condition in advance of shaft, adit and near surface construction of the First Street Tunnel Project. By creating a natural gas generated closed loop brine system, the ground was stabilized in advance of excavation. Ground Freezing ensured that the required excavation in the four construction staging areas for this project was fully stabilized.

Northern Boulevard Ground Freezing Support

Ground Freezing