COOPERATIVE EXTENSION SERVICE
HCM-00754
UNIVERSITY OF ALASKA FAIRBANKS

Permafrost

A Building Problem in Alaska

Introduction

Permafrost, a term coined in 1943 by S.M. Muller, describes ground that has been frozen for more than two years. It indicates a thermal condition where the temperature of the rock or soil remains below freezing throughout the year. It has been estimated that 85 percent of Alaska has permafrost in sub soils to some extent. Permafrost is found primarily on the north side of structures, in lower elevations and at places where there is heavy ground cover. It may appear during excavation as frost in the soil in the middle of summer, or possibly as a thick, solid lens of ice.

Constructing buildings in Western, Interior and Northern Alaska requires awareness of permafrost and knowledge of specialized building techniques. Disturbing permafrost carelessly may cause melting, resulting in uneven foundation settling and disastrous consequences for the building. It is not always possible to safely build on permafrost. Always be cautious when considering building on permafrost. Unfortunately, when looking at building sites, the only way to know if your proposed building location has permafrost is to drill for a soil core sample. If permafrost is found, pilings can be used as a foundation (to avoid heat transfer from the dwelling), floors can be insulated to keep radiant heat upward, and water and sewer pipes can usually be installed above the ground (even with heat tape).

Difference Between Permafrost and Seasonal Frost

People often mistake seasonal frost for permafrost. Permafrost lies under the seasonal frost and remains frozen throughout the summer. Seasonal frost develops over the winter and thaws in the summer. When it occurs over permafrost, seasonal frost is called the active layer. The depth of the seasonal frost active layer varies depending on the duff (insulating vegetative cover) and the climatic conditions of the site. This is partly why it is important — after locating permafrost through drilling — not to remove the organic cover, so as to keep the ground underneath frozen.

Continuous and Discontinuous Permafrost

Permafrost is not necessarily continuous or permanent. Changes in climate and terrain may cause permafrost to thaw and disappear. In arctic zones, permafrost occurs and may extend several hundred feet below an active layer. Permafrost occurs in discontinuous patches in the Tanana Valley near Fairbanks. Changes in the climate can cause alterations in the depth and distribution of permafrost, as we have seen throughout the circumpolar north since the beginning of this century.

Terrain Influences

Although climate controls the broad pattern of permafrost, other factors are necessary to explain local variations. Climatic differences alone do not explain variations in thickness and temperature, or discontinuous occurrence at the southern fringes of permafrost and terrain features such as those in the Fairbanks area. Local variation in climate and soils, vegetation, relief, snow cover and slope aspect appear to control these characteristics.

Surface water influences the distribution and thermal regime of permafrost. Permafrost becomes thinner or disappears entirely underneath large bodies of water like rivers and lakes. On adjacent higher ground, melting permafrost allows surface water to drain through the active layer soils. A lowering water table or permafrost table allows birch and white spruce trees to germinate and mature. As these trees mature, shaded ground may allow permafrost to redevelop. Often, if the permafrost prevents drainage, scrubby black spruce will reappear.

Vegetation affects permafrost in two ways. A heavy mass of dry vegetation may act as insulation and retard heat passing to or from the soil. A heavy moss or vegetative layer can act as an evaporative cooler, retarding soil thawing and acting as insulation that slows heat transfer.

Relief irregularities in the landscape — such as hills and ridges — result in variations in the amount of solar radiation received and reflected at the ground surface. In a discontinuous permafrost zone this means that permafrost occurs on north-facing slopes but not on adjacent south-facing slopes that receive a greater amount of net solar radiation. In continuous permafrost zones, the permafrost tends to be thicker and the active layer thinner, especially on north slopes.

Snow cover influences the exchange of heat between the air and the ground and also affects the distribution of permafrost. A heavy snowfall in the autumn or early winter often slows down frost penetration, soil freezing and the formation of permafrost because the insulating blanket of snow retards heat loss from the ground, while a thick snow cover that persists on the ground in spring will delay thawing of the underlying frozen ground.

Engineering Design Considerations

The same factors that determine the local occurrence of permafrost must be taken into account when designing buildings for permafrost areas.

Temperature change

Permafrost is an excellent foundation as long as it remains frozen; it is very sensitive to temperature changes. Changes to the ground surface, like removing the ground cover, will change the temperature of the ground and can cause the permafrost to thaw and possibly lose its rigidity. A building radically changes the way heat moves in and out of the soil; constructing a building on a permafrost site will affect the permafrost. Buildings are normally heated in the winter and this adds heat to the soil. A building also shades the soil in the summer, preventing exposure to the sun. So, the soil is warm in the winter when it should be cold, and cold in the summer when it should be warm. Make every attempt to keep the soil beneath the building frozen and the permafrost stable. The strategy for alleviating the engineering risks of building on permafrost sites is to build the structure on a pad and post (often called pilings) or an elevated foundation, to insulate the ground and prevent thawing. In addition, adding shading such as vegetation, eaves, gutters, decks, ramps, etc. near this type of foundation is helpful.

Drainage

Permafrost, because it is frozen, is nearly impermeable to moisture. Water that occurs above the permafrost table (the top of the permanently frozen layer) and the active zone on top of this layer is extremely difficult to drain. So, in spite of low rainfall (as in Interior Alaska, for example), poor drainage becomes extremely noticeable. When flying over a permafrost area, the ground surface appears very wet because a thin layer of water is trapped and unable to drain through the underlying permafrost zone. Permafrost consequently limits ground water recharge into the subsurface areas below the permafrost.

Type of soil

Soil type is an important consideration when selecting a building site. Solid rock, gravel and sand normally contain very little ice at freezing temperatures or below. Thawing, therefore, does not result in as much settling with coarse soils as with fine-grained materials. Ice in coarse-grained soils occurs as coatings or films on small particles, stones or boulders, or in soil pores.

Fine-grained soils — such as silt, clay or peat — typically have high ice content. They are susceptible to settling when permafrost melts. These soils are also susceptible to heaving, which occurs when moisture moves to a freezing layer in the soil and moves (heaves) the soil above the freezing zone vertically. (As long as the water in this soil remains frozen, the ice binds material of considerable strength.) When thawed, these soils can change into a soft slurry with very little strength for supporting a building, and foundation failure can result.

Geologic quadrangle maps describe terrain features such as elevation, contours, soil classifications, drainage and permeability of soil, permafrost and susceptibility of soil to frost action, bearing strength of soil, slope stability and suggested use of soils. The USDA Soil Conservation Service is also helpful when seeking information regarding soils.

Ground ice

The riparian soils in Alaska river valleys are nearly always a friable (soft) silt. These soils are commonly some of the worst soils for frost action and heaving. This type of soil combines good water retention characteristics with a high hydraulic conductivity, factors that are necessary for ice lenses to develop. In permafrost areas large masses of clear subterranean ice form. When these ice lenses melt, they often leave large holes in the surface of the ground.

Methods of determining the depth and presence of permafrost

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As a first technique, **rodding** can be a quick way to determine depth to permafrost or the thickness of the active layer. A ¼- to ½-inch sharpened steel rod is driven with a heavy hammer until it will go no further. The rod is then turned by a wrench. If the rod turns easily, it probably hit a stone. If back spring occurs, the rod has probably penetrated wood or permafrost. A sharp clang sound from the rod indicates a stone, a dull clang indicates ice and a dead thud indicates wood.

A more conclusive method for determining the depth to permafrost is to take a **boring with an auger**; this can supply information on ground water levels and types of soils.

Coring, the most accurate method to determine frost characteristics, is the recommended method to use before constructing all commercial and industrial buildings on permafrost. If you have any doubts about soil characteristics, machine core before constructing a home. The cost of boring is minor compared to the cost of repairing foundations that may settle because of thawing permafrost.

Finally, **digging a pit** requires more labor but is a fairly reliable method of determining the active layer depth and allows the character of the permafrost and the soil to be studied.

Foundation selection

Perennial freezing on well-drained, coarse-grained river sand and gravel or bedrock generally has few associated problems. When building on a continuous permafrost zone, particularly with fine-grained soils with high ice content, every effort must be made to preserve frozen conditions. In the discontinuous zone, it may be necessary to remove frozen material that is susceptible to frost action. (See the Foundation chapter of the Alaska Residential Building Manual.) Permafrost may need to be preserved through a combination of insulation and ventilation techniques to keep the integrity of the building intact.

A **gravel pad,** 4 to 6 feet deep, can be used to insulate the active layer. The building can be set on mud sills or other suitable foundation that allows free circulation of air beneath the structure floor. The floor must be insulated to reduce heat transfer from the structure. Some settling must be anticipated and taken into account in the design of the foundation so that it is adjustable.

Wooden piles should be well embedded in the permafrost so that the structure is raised above the ground to permit natural air circulation beneath it and minimize heat flow from the structure to the frozen ground.

To install piles, the permafrost must be melted with a steam jet so that the piles can be set by a pile driver into an augured hole filled with slurry and allowed to refreeze in autumn or early winter. Some piles are fitted with refrigeration coils to hasten the freezing process. The tops of the piles are cut off 4 to 5 feet above ground and built upon, allowing free air circulation beneath the structure floor. Either way, piles should be fitted with a slip-fit casing that will minimize the surface friction on the piles. In lightly loaded structures.

Freezing tubes are filled with a non-freezing liquid and use heat convection — drawing heat from the earth during subzero weather and convecting it to the atmosphere — to keep permafrost from melting.

Whichever option you choose, building foundations should be designed with a uniform weight distribution to prevent damage from heaving action. Foundations should be designed for easy access to realignment and adjustment areas in case minor dimensional changes occur.

Professional services and advice

Individuals considering building construction in Alaska should consult with architects, engineers and contractors who are thoroughly experienced with arctic building problems. The Cold Climate Housing Research Center has reports, videos and podcasts on building in the arctic as well as its "Design Manual for New Foundations on Permafrost" (www.cchrc.org).

www.uaf.edu/ces or 1-877-520-5211

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3-70/ARC/7-18

Revised April 2016