Permafrost

A Building Problem in Alaska

HCM-00754

Introduction

Permafrost is a term used to describe permanently frozen ground. It indicates a thermal condition where the temperature of the rock or soil remains below freezing throughout the year. Permafrost can exist for as few as two years to more than tens of thousands of years. The term "permafrost" was coined in 1943 by S.M. Muller[1].

About one-fifth of the earth's land mass contains permafrost. Almost one-half of the world's permanently frozen ground is in Russia and Siberia, one-third is in Canada, and a large portion is in Alaska.

Constructing buildings in Alaska requires specific knowledge about permafrost and 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 use caution and use the utmost respect when considering building on permafrost.

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 insulating vegetative cover and the climatic conditions of the site.

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. Figure 1 roughly shows the zones of continuous and discontinuous permafrost in Alaska. Future changes in our climate may cause alterations in the depth and distribution of permafrost throughout the circumpolar north.

Terrain Influences

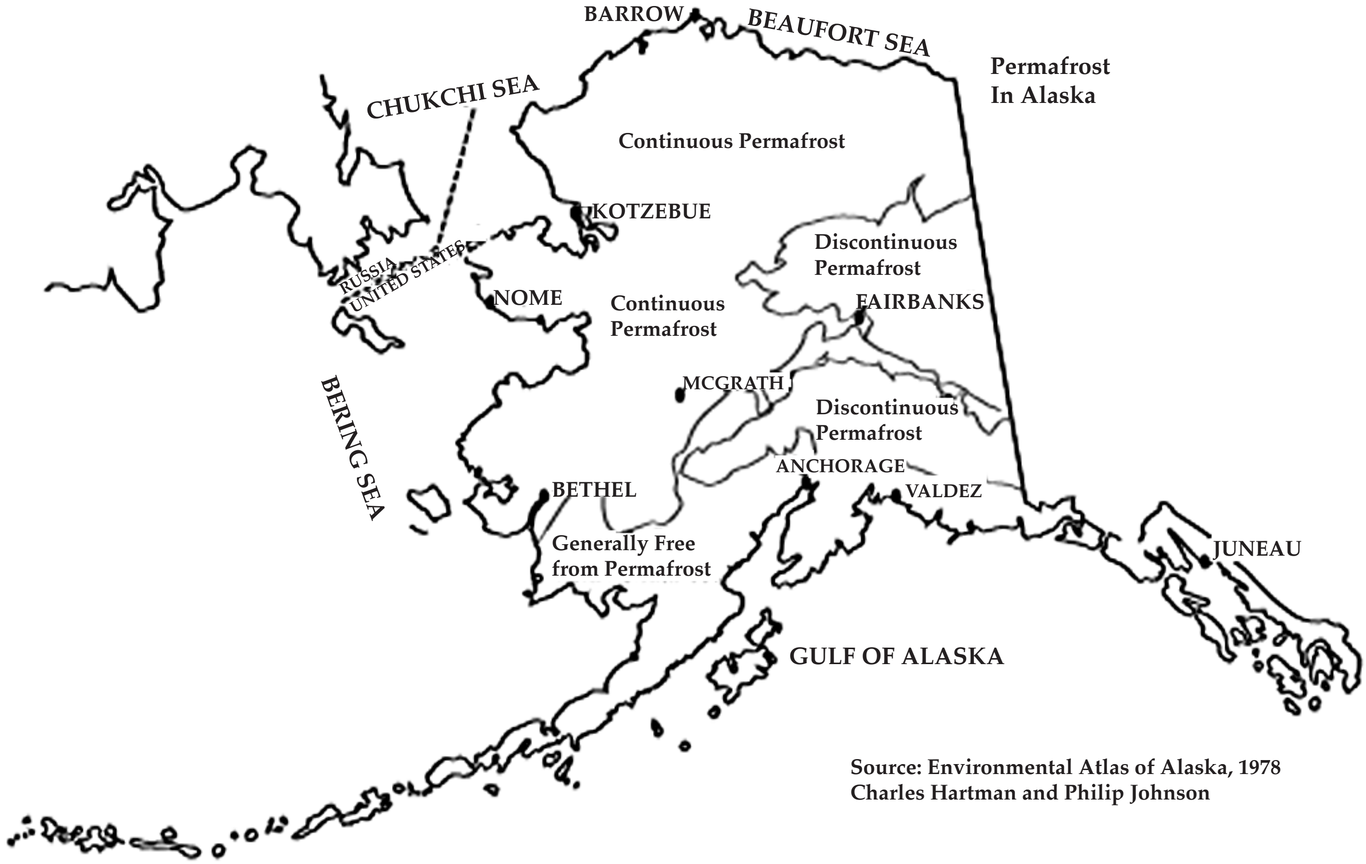
Although climate controls the broad pattern of permafrost, other factors are necessary to explain local variations. Climatic differences alone do not explain variations in thickness and temperature, or discontinuous occurrence at the southern fringes of permafrost and terrain features such as those in 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. Black spruce is often a sign of poor drainage and 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. Permafrost will again prevent drainage and 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 and vegetative layer are often present on the surface of permafrost soils. Moss can be several inches thick and provide two functions. First, it can act as an evaporative cooler, retarding soil thawing, and second, it may also act as insulation that retards heat transfer.

Relief irregularities in the landscape — such as hills and ridges — result in a variation in the 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 will slow down frost penetration, soil freezing and the formation of permafrost because the insulating blanket of



snow retards heat loss from the ground. On the other hand, 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 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 piles or an elevated foundation, taking special care to insulate the ground and prevent thawing. (For more information aboutt building on permafrost see UAF Cooperative Extension Service Publications and Permafrost Technology Foundation Publications.)

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 (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 in a number of forms: coatings or films on small particles, stones or boulders, or as ice 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.) Frozen permafrost makes a good foundation as long as it remains frozen. However, 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 are available for some areas of Alaska that 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. Thawing subterranean ice created a spectacular hole at a golf course near Fairbanks — a 15-foot-deep golf trap.

Methods of Determining the Depth and Presence of Permafrost

Determining the conditions of permafrost at a site is made by measuring the depth of the active layer down to the permafrost. There are four methods of locating the depth to permafrost.

Rodding is commonly used as a quick guide for determining 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. The sound of the rod may indicate whether it struck a stone, wood or ice. A sharp clang indicates a stone, a dull clang indicates ice and a dead thud indicates wood.

Auger boring is usually more conclusive in determining the depth to permafrost. Auger boring can also supply information on ground water levels and types of soils.

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.

Machine coring is the most positive method of determining the depth of the active layer, the thickness of the permafrost, and the characteristics of the frozen and unfrozen soil. Machine coring 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.

Foundation Selection

After general site conditions are evaluated, a more detailed investigation is normally required at the specific construction site. Alternatives can be selected when you are sure there is permafrost present.

Perennial freezing on well-drained, coarse-grained river sand and gravel or bedrock can be ignored because it has few associated problems. In 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. (A good discussion of permafrost removal and treatment is given in the Foundation Chapter of the *Alaska Residential Building Manual*. See UAF Cooperative Extension Publications.)

For some types of structures, in either continuous or discontinuous zones, it may not be possible to prevent thawing without special design considerations. Permafrost may need to be preserved through a combination of insulation and ventilation techniques.

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.

Wood piles anchored in the permafrost are considered the most stable foundation for arctic building. The piles should be well embedded in the permafrost and the structure raised above the ground to permit natural air circulation beneath the structure and to minimize heat flow from the structure to the frozen ground.

Piles are driven in place with a pile driver. However, the permafrost must be melted with a steam jet. The piles can be set in an augured hole filled with slurry and allowed to refreeze. Autumn and early winter are the best time to set piles for the next construction season. Piles should remain undisturbed for a year until firmly frozen and anchored in place by the permafrost. Sometimes 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,allowing free air circulation beneath the structure floor.

Thermal piles or freezing tubes can be used to increase the depth, stability and amount of permafrost and for stabilization during warm weather. These devices 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. The power for the convection cycle comes from the warmer soil temperatures in the ground.

Building foundations should be designed with a uniform weight distribution. Lightly-loaded, improperly anchored piles may be pushed out of permafrost by the active layer and heaving action. Piles should be fitted with a slip-fit casing that will minimize the surface friction on the piles. In lightly loaded structures — houses for example — the number of rows of piles and beams should be balanced for uniform load distribution and to minimize uneven floor movement. An improperly designed structure may be costly to realign once it has settled. 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.

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U.S. Geological Survey Quadrangle Maps. Washington, D.C.

UAF Cooperative Extension Service Publications

The following publications related to building construction on permafrost are available from the Cooperative Extension Service office nearest you.

Alaska Residential Building Manual, 7th edition, HCM-00051.

Foundation Retrofit and Rehabilitation, HCM-01555

Glossary of Home Construction Terms, HCM-04759

Small House Construction in Muskeg and Bogs, HCM-01556

Special Considerations for Building in Alaska, HCM-00952

Permafrost Technology Foundation Publications

The following publications related to foundation design and site preparation in the main permafrost areas of Alaska, which primarily includes areas north of the Alaska Range, can be found in greater detail at www.uaf.edu/ces/energy/housing_energy/resources/#frost:

McFadden, Terry. 2001. *A Design Manual for Stabilizing Foundations on Permafrost*. Permafrost Technology Foundation. This manual focuses on the issue of foundations in a state of failure and how to remedy them.

McFadden, Terry. 2000. *Design Manual for New Foundations on Permafrost*. Permafrost Technology Foundation. This manual is perhaps the most useful to those who anticipate building on permafrost land, as it focuses on how to do so correctly the first time, to avoid long-term failures.

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

Art Nash, Extension Energy Specialist. Originally written by Axel R. Carlson, professor of Extension, emeritus.

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