PERMAFROST MITIGATION STRATEGIES 2023

OVERVIEW

Areas of the world underlain with continuous permafrost face unique challenges to infrastructure stability. Changes at the surface can have far-reaching effects on the stability of the soils. This snapshot focuses on strategies to mitigate structural instability in continuous permafrost regions.

Dramatic permafrost thaw poses challenges for any foundation type. Photo from NREL

Building on permafrost has unavoidable challenges and no perfect solution; however, when building or renovating on permafrost, one basic rule should inform all construction decisions: if it's frozen, keep it frozen. Site planning and foundation design should prioritize 1) maintaining the ground at a stable temperature, 2) protecting the vegetation from excessive site disturbance, and 3) taking advantage of winter conditions to keep the ground frozen.

Ignoring best practices risks running up against the laws of physics, some of the effects of which are shown in the image above. Both surface and groundwater define the state of permafrost and, thus, the state of building foundation substrate. Water conducts heat 25 times better than air, has a high heat capacity, and can exert tremendous expansion forces when it freezes in a confined space. When building on ice-rich permafrost, these factors are significant: the soil loses its weight bearing capacity when the ice thaws. In ice-poor permafrost, melting ice will have less effect than on ice-rich, thaw-unstable sites.

SITE PLANNING

Permafrost exists in a very narrow temperature range, which in Alaska is made possible by an insulating layer of tundra that protects it from temperature swings. Once the vegetative layer is disturbed, it does not recover quickly and the permafrost below can warm in summer and begin to thaw. This process can further its degradation and lead to catastrophic destruction (as seen in the image on the right). In more temperate areas of the Arctic, water can seep into tiny crevices and freeze and thaw over successive seasons, causing frost jacking and other problems.

Permafrost vegetation, which can be damaged by construction or even a 4-wheeler, does not recover quickly.

Photo from NIPS (Public Domain)

New construction projects should strive to preserve the integrity of the ground cover and the permafrost. Builders should consider how road access, heavy machinery, and materials staging could affect the site. Site planning should emphasize snow removal and water drainage, including snowmelt diversion/collection and regular pipe and tank maintenance, to ensure that water and wastewater pipes do not leak. During site selection, consider natural drainage and seepage patterns on the site or create slopes for culverts before construction commences (CSA Group, 2019).

COLD CLIMATE HOUSING RESEARCH CENTER

UAF UNIVERSITY OF ALASKA FAIRBANKS

NREL

Funding for this publication was provided by the National Science Foundation Award 1928237 - https://cchrc.org/navigating-new-arctic-ice-rich-permafrost-systems/

Aerial map hanging in the tribal office in Point Lay Photo from NREL

When choosing a site for building, a global view of the area can help pinpoint where ice wedges are to help locate buildings at the high points. Ice wedges can be readily apparent in the polygon formations. Placing buildings on the land between the ice wedges could improve long-term structural performance.

During the winter, a different problem arises from excess snow. Snow is mostly air, and still air is one of the best insulators. In the winter, snow piles (created from plowing or drifting) prevent cold air from reaching the permafrost, thus keeping the ground temperature warmer which, over successive seasons, can raise the ground temperature enough to destabilize the permafrost. Later, during the spring thaw, pooled meltwater will collect solar radiation, raising the ground temperature causing additional disturbance. A site layout that allows snow to pass through and not collect on the building site can help prevent this. When this is impossible, actively move snow to a location where the water can drain quickly and not cause harm elsewhere. Snow collection sites located downstream and away from infrastructure are one possibility.

In the case of existing buildings, certain site conditions can be managed, such as protecting the remaining ground cover and providing adequate water drainage (e.g., away from the structure). Adding fine-grained fill to a site can modify the drainage patterns without further degradation (Perreault, 2016; Connor et al., 2022).

FOUNDATIONS FOR NEW AND EXISTING CONSTRUCTION

Buildings on permafrost are often elevated, as seen in the image on the right, which reduces ground heat transfer and encourages air circulation. Post and pad, piles, and space frames are all options with different strengths and weaknesses. A raised foundation is not always enough to protect the ground; even the best foundation systems will only slow the heat transfer, not eliminate it.

Retrofitting a foundation is usually more expensive and complicated than a new build, but this can vary depending on the approach. For instance, shims, spacers, and even sand-filled 55-gallon drums can help level or restabilize a house. Applying an adjustable foundation to existing piles can be costly and difficult, but not as much as replacing the existing piles.

Space frame with thermosyphons in Atmautluak

Photo from Aaron Cooke, Cold Climate Housing Research Center, Inc

Although gravel pads are not always possible or desirable, using one as a base for the foundation can protect the permafrost from the influence of the house. This option can be highly disruptive but is a viable solution in permafrost settings. Home occupants can help maintain the frozen state of soil under their home by focusing on shading and improved airflow. Additionally, they can:

- Cool the area around the foundation by promoting peat growth to help insulate the soil year-round.
- Allow cold air to reach around and under the foundation by eliminating or minimizing skirting around the foundation, keeping the area under the house free of debris, and removing snow from the area.

COLD CLIMATE HOUSING RESEARCH CENTER
UAF UNIVERSITY OF ALASKA FAIRBANKS
NREL

Funding for this publication was provided by the National Science Foundation Award 1928237 - https://cchrc.org/navigating-new-arctic-ice-rich-permafrost-systems/

- Add insulation to the underside of the house to protect the ground below.
- With the guidance of an expert, install thermosyphons around the building (where conditions allow). Thermosyphons are large, sealed pipes that contain a fluid under a vacuum that evaporates near ground temperature, pulling heat out of the soil and releasing it to the air via condensation at the top of the pipe.
- Prevent rainwater and snowmelt from pooling near or under the house by directing runoff away from the foundation, the site, adjacent buildings, and infrastructure.
- Prevent any water leak from accumulating near the house: this includes hoses and broken pipes or tanks.
- Minimize water pooling by adding fine-grained soil to low-lying areas.

Water pooling in tundra around Point Lay

Photo from Mikhail Kanevskiy, University of Alaska Fairbanks

COMMUNITY SCALE MITIGATION STRATEGIES

By far, infrastructure has the most significant influence on the state of permafrost so planners must consider community-scale mitigation strategies alongside individual home design. Aside from relocation, a handful of community-level mitigation strategies exist for building on permafrost. These strategies are similar to those for individual buildings but are applied at a larger scale. Community layout - both streets and houses - can affect snowdrift patterns. During the warmer months, drainage plans and meltwater retention areas fed by multiple buildings will prevent damaging snow accumulation around buildings (US Army and Air Force 2004). However, it can be challenging to create successful culverts, and they can fail even after careful planning. As seen above, it is critical to move water away into collection sites that do not cause flooding or water contamination issues.

COLD CLIMATE HOUSING RESEARCH CENTER
UAF UNIVERSITY OF ALASKA FAIRBANKS
NREL

Funding for this publication was provided by the National Science Foundation Award 1928237 - https://cchrc.org/navigating-new-arctic-ice-rich-permafrost-systems/

Tundra restoration is a difficult, decades-long process that is only sometimes successful. Communities can limit site degradation by collectively retrofitting buildings to ensure the ground is protected and well-drained. This process could include improving floor insulation in buildings and maintaining skirting around buildings to either allow snow to pass under or keep it out entirely while still allowing enough airflow to keep the temperature low.

Another approach is to create fewer structures by constructing more multi-family buildings: duplexes, fourplexes, and housing clusters that use centralized utilizes. This action reduces the amount of disturbed land and the number of utility connections. Above-ground utilities make service and maintenance more manageable, but even when they are not buried in unstable permafrost, they are still susceptible to the movement of the ground below. Joints are often the weak point, particularly rigid joints that cannot adjust to changing ground conditions. Flexible joints and flexible pylons are two possible solutions.

An example of insulated pipes in Quinhagak. The warmer water in the pipes can cause serious problems if a leak goes unchecked .

Photo from Aaron Cooke, Cold Climate Housing Research Center, Inc

Utility service barrel outside of home in Point Lay. This is not a flexible connection and is subject to breakage.

Photo from Aaron Cooke, Cold Climate Housing Research Center, Inc

During the winter, large snow fences solve the immediate problem of snowdrifts around neighborhoods, but they can cause long-term damage to permafrost by creating massive snow piles on the windward side. Active snow plowing around buildings-in streets and public areas-and the use of snow collection areas are two straightforward but labor-intensive methods of sequestering snow in an area where melting would not further permafrost thaw.

Text References

CSA Group. 2019. Technical Guide: Infrastructure in Permafrost: A Guideline for Climate Change Adaptation. Technical Guide CSA PLUS 4011 :19.
Connor BG, BM Jones, M Kanevskiy, DJ Nicolsky, JL Peirce, VE Romanovsky, and YL Shur. 2023. Permafrost & remote sensing studies: 2022 field report for Point Lay, Alaska. AGC Data Report 23-01, Alaska Geobotany Center, Fairbanks, Alaska.
Perreault, Paul Vincent. 2016. Altering the Thermal Regime of Soils Below Heated Buildings in the Continuous and Discontinuous Permafrost Zones of Alaska. Doctoral Dissertation, University of Alaska Fairbanks.
Shur Y, Jorgenson MT, Kanevskiy MZ. 2011. Permafrost. In: Singh VP, Singh P, Haritashya UK. (eds) Encyclopedia of Snow, Ice and Glaciers. Encyclopedia of Earth Sciences Series. Springer, Dordrecht https://doi.org/10.1007/978-90-481-2642-2_400
US Army and Air Force. 2004. UFC 3-130--04 Foundations for Structures-Arctic and Subarctic Construction, 272.

Images

Many thanks to the Cold Climate Housing Research Center (CCHRC), Aaron Cooke (NREL) and Mikhail Kanevskiy (UAF) for generously providing their images for use in this publication.

Permafrost Resources

Permafrost Tunnel
UAF Geophysical Institute
Informational Video on Permafrost, AWI
Map of Permafrost in Alaska
National Resources Defense Council
National Snow and Ice Data Center
UN Environment Programme

COLD CLIMATE HOUSING RESEARCH CENTER

UAF UNIVERSITY OF ALASKA FAIRBANKS

NREL

Funding for this publication was provided by the National Science Foundation Award 1928237 - https://cchrc.org/navigating-new-arctic-ice-rich-permafrost-systems/