Potential Mitigation Strategies to Lessen the Impacts of Thawing Permafrost on Community Health and Infrastructure

Rachel Dodd[1] and Jessica Biddle[1]
[1]Cold Climate Housing Research Center – National Renewable Energy Lab

Permafrost Basics

Permafrost is soil that has remained frozen for two or more years. Permafrost encompasses approximately 20% of the land mass of the Northern Hemisphere, and it is inevitable that there are instances where permafrost and infrastructure intersect. Though humans have found ways to build on permafrost in the past, we are now seeing permafrost thaw at an increasing level, which affects the infrastructure that is built on it.

The largest component of permafrost that can cause issues with the built world is water in permafrost because water changes phase within the same temperature range that humans thrive. Water can decrease in size up to 10% of its volume from frozen to thawed states and the tremendous forces it exerts when frozen within confined spaces disappear when it thaws, making it a formidable challenge with regards to roads and buildings.

Permafrost Concerns

Ground Heave: when the ground heaves up as the water in permafrost freezes and expands.

Frost Jacking: ground ice builds up at the base and sides of infrastructure buried within the active layer(the topmost part of the soil that freezes and thaws annually) of permafrost. Water seeps along the solid surfaces then freezes forcing the element up a small amount, and this process can repeat slowly jacking the element out of the soil. This has been seen happening with the post of a foundation.

Subsidence: ground settling is typical of thawing permafrost. Permafrost thaw results in subsidence, which results in the accumulation of water, which results in more heat transfer and accelerates permafrost thaw.

All these issues can have negative impacts on the built environment from unstable foundations, broken stairs, cracked windows, ruptured water and sewer piping, and other health and safety issues. The Cold Climate Housing Research Center conducted a literature review and interviews to document issues from thawing permafrost and identify potential mitigation strategies for existing and new infrastructure built on permafrost.

Mitigation Strategies

Avoid building on Permafrost
The easiest way to avoid the issues that come with thawing permafrost is to avoid building on permafrost either at the community or building level. Though this is not always feasible, if it is an option, it might be worth exploring.

Remove Permafrost:
In discontinuous permafrost, it can be an option to completely remove the permafrost layer then clean non-frost susceptible soils would be used and compacted where the fine-grained permafrost soils were. This can be costly depending on the thickness of the layer of permafrost, but this is a permanent solution when it is an option.

Pre-thaw and Consolidate
This tactic requires that enough heat is allowed to escape the building envelope to ensure that the soils stay thawed. It can be difficult to accurately anticipate the area of thaw that the building would cause, which can cause thaw outside of the pre-thawed area or refreezing at the edges. This is also problematic if the building is unused and unheated for a freezing season, which would allow the ground to refreeze.

Building or Community Relocation
In some cases, this may be the only feasible option, but this is incredibly costly and can bring about many other hurdles such as finding a place to move to.

Keep Permafrost Frozen
When the above strategies are not an option or are too costly, the next way to avoid the issues that come with thawing permafrost is to keep the permafrost frozen. There are several building level strategies that can be used to protect permafrost from thawing.

A building in Point Lay, AK that has been affected by permafrost thaw. Ground subsidence has left the stairs nearly seven feet off the ground, but because the piles have been driven so deep into the permafrost layer that the building is level and intact.

An example of a post and treated wood pad foundation.

Tactics to Keep Permafrost Frozen
Insulate Permafrost:
- Natural vegetative ground cover: leave and protect the natural vegetation that is designed to insulate and protect the permafrost.
- Seasonal Insulation: insulation that is attached to the bottom of the house in the winter and then dropped to cover the ground in the summer.
- Gravel Pad: though to truly insulate the permafrost, it should be 4 to 6 feet in depth.

Control Snow and Water accumulation:
- Proper water drainage: ensure any excess water is directed away from the infrastructure. i.e., don't build in low spots and use permafrost specific foundations.
- Remove snow from around buildings to allow permafrost to fully refreeze in winter months.

Ventilate:
- Air ducts beneath flooring
- Raised foundations

Cooling:
- Passive cooling
  - Thermosyphons
  - Raised foundations
- Active cooling
  - Refrigeration- another mechanical component to the building

Permafrost Foundations
- Piles: drilling steel or treated wood posts deep into the ground often until bedrock is reached. Often a space is left between the building and ground allowing for air circulation, which helps to keep the permafrost frozen
  - Adfreeze piles can be used in situations where the bedrock is too deep.
- Post and Pad: pads placed either directly on permafrost or on a gravel pad on top of permafrost with posts then supporting the structure.
- Foam raft
- Triodetic: three-dimensional matrix of steel tubing that is built directly on permafrost.

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by The National Science Foundation Award 1928237 and The Cold Climate Housing Research Center, Inc. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

Alaska Health Summit
Conference Location - Virtual
January 18th-20th 2022
NREL/PO-5600-81735