FOUNDATIONS FOR BUILDING ON PERMAFROST

2022

WHAT IS PERMAFROST?

Permafrost is ground common in arctic and subarctic regions that remains frozen for two or more years. The layer of soil above the permafrost that freezes and thaws with annual temperature change is called the active layer, although the name describes not its movement but its ability to support life. Permafrost thickness ranges from several feet to several thousand feet and can be found in soil or bedrock.

WHY DOES THE FOUNDATION MATTER?

Buildings on top of permafrost can be stable as long as the ground remains frozen; however, permafrost is tenuous, and many surface conditions can cause thaw. Permafrost thaw can cause buildings to become unstable. There are two main goals for foundations built on permafrost. The first is to maintain the frozen state of the permafrost. Heat escaping from a building can cause the permafrost underneath to thaw. One way to mitigate this is to separate the underside of the building from the ground to allow cold winter air to circulate under the building and preserve the frozen ground, as shown in the picture below. The second goal of foundations on permafrost is to prevent the building from exceeding the bearing capacity of the soil. Adjustable foundations are a standard recommendation when building on permafrost, as they allow the building to adapt to unpredictable changes in the permafrost.

Elevated Buildings

Photo by Cold Climate Housing Research Center Staff, NREL

COLD CLIMATE HOUSING RESEARCH CENTER

NNA IRPS Ice-Rich Permafrost Systems

UAF UNIVERSITY OF ALASKA FAIRBANKS

NREL

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PILE FOUNDATIONS

Pile foundations are placed deep into the ground. They can be driven into place or sunk into a drilled hole backfilled with soil or concrete. They can either rest on bedrock (end-bearing piles) or transfer the building load to the ground through the frictional resistance force between the pile and the surrounding soil (friction piles). A space is left between the building and the ground, allowing air to circulate. This circulation of cool air above the ground helps keep the permafrost frozen.

ADFREEZE PILES

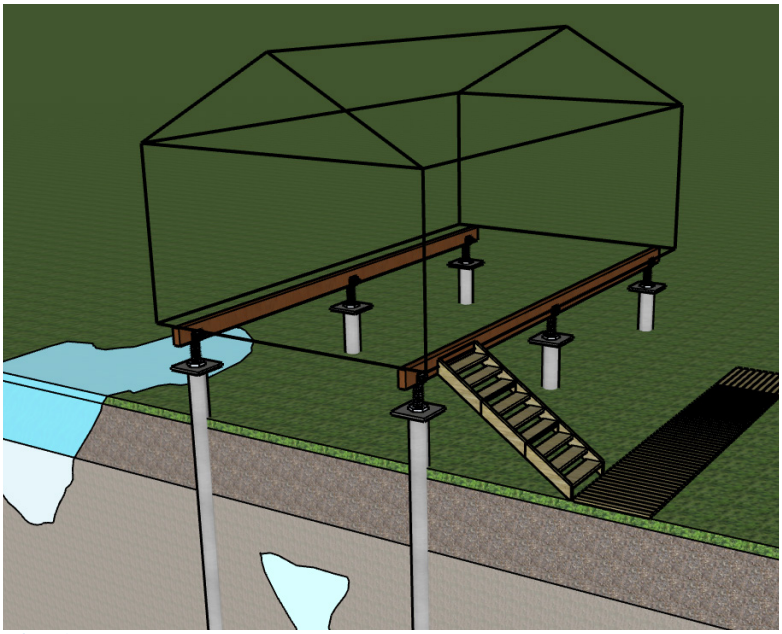
Adfreeze piles are a type of pile design. Adfreezing is the process where ice causes two objects to stick to one another. These piles are embedded and frozen into the permafrost, as shown in the first illustration. The bond between the pile and the surrounding frozen ground allows the pile to transfer the load to the surrounding ground. These piles are used where the permafrost extends to great depths and reaching bedrock is not practical.

HOW IT SUCCEEDS

An engineer must design the pile. The soil type, pile size, and pile material are all important factors. Adfreeze piles are generally used for lighter load buildings and should be installed at ground temperatures below 25° F. Adjustable jacks on top of the piles allow for correction of differential settlement, as seen in the second illustration. Ideally, a fine grained soil pad beneath the home ensures adequate drainage and creates a thermal barrier. Do not remove the vegetation before placing the pad.

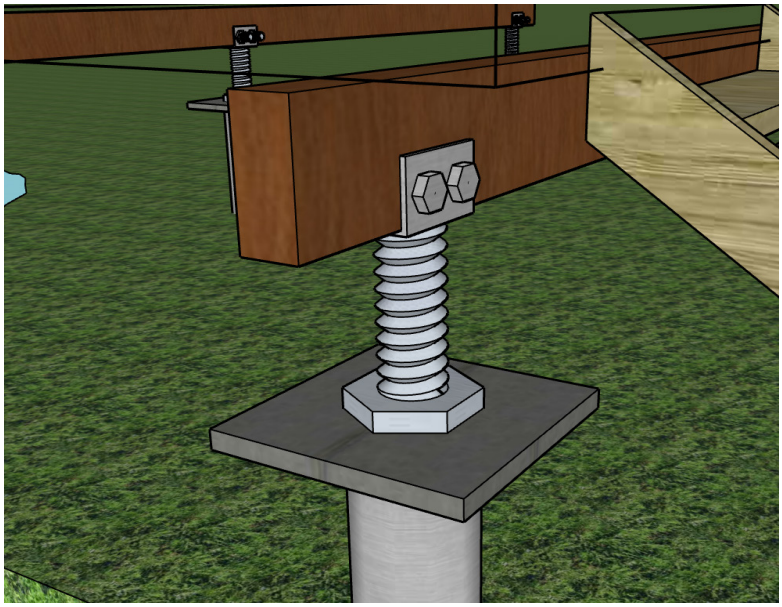
FAILURE POINTS

When major subsidence or frost heave occurs, piles may no longer be adequately embedded in the soil. One mitigation strategy is to divert water runoff away from the foundation. Avoid placing the pile in an ice wedge, but if that is unavoidable, increase the pile length. If possible, remove the top five feet of the ice wedge and backfill it with fine-grained soil to improve drainage and protect the ice wedge from thawing.



Pile Schematic

Illustration by Jessica Biddle, NREL



Pile Detail

Illustration by Jessica Biddle, NREL

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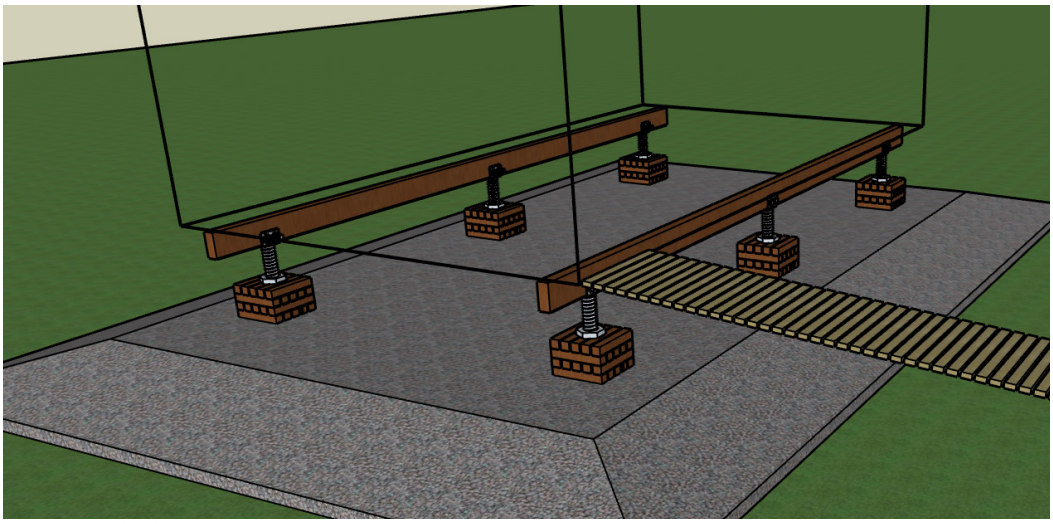
POST AND PAD FOUNDATIONS

Post and pad foundations are generally the most affordable option for building on unstable soil when gravel is available. They consist of a pad, support posts, and a system of rigid beams. Usually constructed from concrete or wood, the pad should be impermeable to water. Often, as shown in the graphic below, the pad is made out of wood cribbing (crosswise stacked wooden elements), which sits upon a built-up gravel pad. Adjustable brackets attach the tops of the pads to the support beams. Steel, wood, or concrete are used to make posts that support the structure. Posts create a gap under the house. This gap has the same effect as the free space with the pile foundations, allowing cold air to circulate, which helps prevent the thawing of the ground. One benefit of the post and pad approach is that adjustments are easier than with other types of permafrost foundations.

HOW IT SUCCEEDS

To ensure that the eventual adjustment is easy and stable, the post and pad should have adjustable brackets on each post and be constructed on top of good bearings soils. You may also want to provide leveling jacks to the system. The house should also have an eave with gutters to help direct rain and water away from the pad.

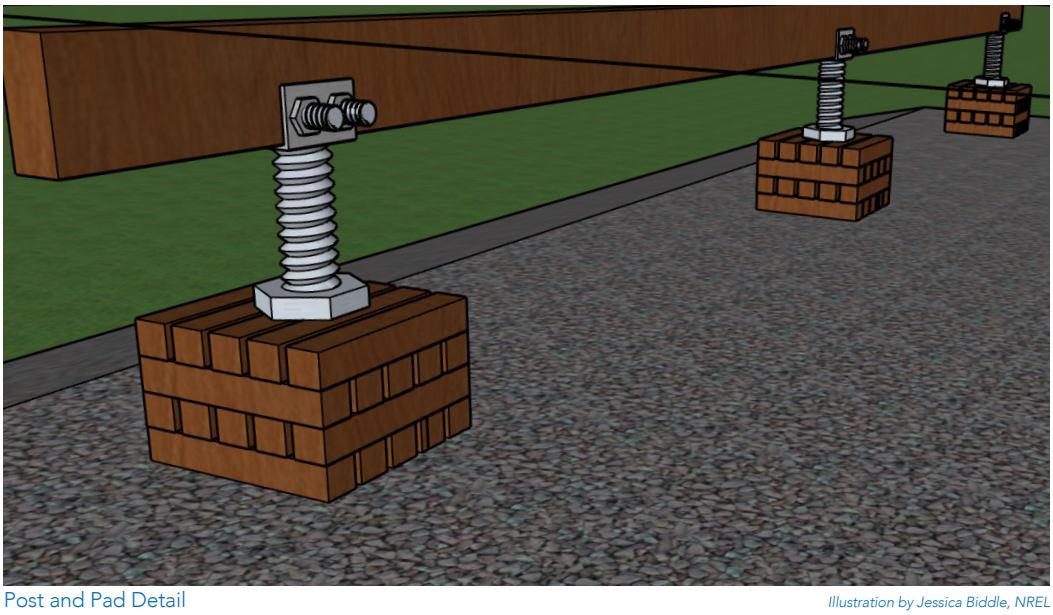


Post and Pad Schematic

Illustration by Jessica Biddle, NREL

FAILURE POINTS

Large lenses of ice in the ground can cause the foundation to settle unevenly. Make sure the cribbing is not placed over a wedge. If this is unavoidable, ensure the cribbing can support the structure's weight as the soil deforms. Re-leveling can also cause stress on the structure. Water is the biggest issue for this type of foundation. Eaves with gutters and downspouts can help mitigate this issue.



Post and Pad Detail

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OTHER FOUNDATION TYPES

SLAB ON GRADE FOUNDATIONS

The house sits on a concrete slab that lies directly on the ground. This type of foundation is difficult to make adjustable. The largest problem with slab-on-grade foundations on permafrost is the heat leaking into the soil and thawing the ground. Adding more insulation to the corners of the building can help mitigate this, but slab-on-grade foundations generally require passive or active refrigeration systems.

FOAM RAFT FOUNDATIONS

This foundation aims to thermally isolate the heated space of the structure from permafrost soils while remaining in physical contact with the ground. If gravel is locally available, the foam raft sits directly on the gravel. If a gravel source is not locally available or is cost-prohibitive, the foam raft is applied onto a geotextile fabric barrier atop the soil. The structure of the foam raft foundation consists of light gauge steel floor joists that are held up off the ground by extruded polystyrene rigid foam spacers so that the top of the joist is the desired height from the ground (up to 18" depending on climate zone). Closed-cell polyurethane spray insulation is then applied from the ground plane up through the joist bay to the top of the floor joists, locking the structure in foam and allowing it to 'float' above the permafrost. The application of the foam raft foundation is seasonally bound in that it must be applied before the active layer above the permafrost has thawed for the summer season. It should also be considered that thawing ice wedges in the vicinity may create a path for water to thaw ice wedges beneath the structure.

Foam Raft *Photo from Bill Tracey, Native Village of Point Lay*

SPACE FRAME FOUNDATIONS

Space frame foundations, also known as Triodetic foundations, have a rigid frame made of either steel or aluminum. The frame cannot sit directly on the tundra as it would sink. Similar to the post and pad foundation, it requires a gravel pad. Space frame foundations use geometry to minimize the material required to support a building, lowering the foundation's cost and weight. Diagonals in the frame create triangles of support. This foundation is also adjustable.

Space Frame *Photo from the Cold Climate Housing Research Center*

SKIDABLE FOUNDATIONS

These homes are built onto metal skids, which have attachment points and can be towed. This design allows the homes to be moved if the ground below becomes unstable.

Skids Detail *Photo from the Cold Climate Housing Research Center*

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

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