UAF Sustainable Village

GROUND TEMPERATURE DATA

The University of Alaska Fairbanks Sustainable Village is a demonstration of affordable, low-energy student housing in Interior Alaska and a testing ground for cold climate building and energy research. Two of the four homes, known as the Birch home and the Spruce home, have a super-insulated foam foundation that rests directly on ground with permafrost, referred to as a "raft foundation." At the site, permafrost starts at 5ft - 6ft under the surface and stretches down. The foundations were designed with a thick raft of insulation to slow heat from the homes from leaking into the soil. A first round of temperature sensors were installed underneath the homes in 2012 to allow researchers to monitor ground temperatures throughout the year and ensure the permafrost was staying frozen.

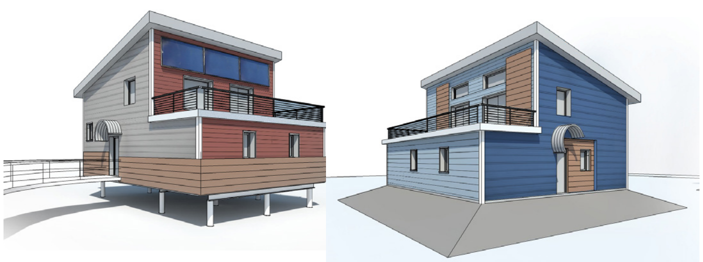


Fig. 1: *Piling foundation versus raft foundation*

The raft foundation was chosen because it is more energy efficient than a raised floor and reduces the cost of building on driven pilings (*see Fig. 1*). It consists of a steel floor structure elevated off of the ground on structural polyurethane spray-foam insulation. The 12"-15" thick foam provides a continuous thermal break between the heated indoor space and the ground.

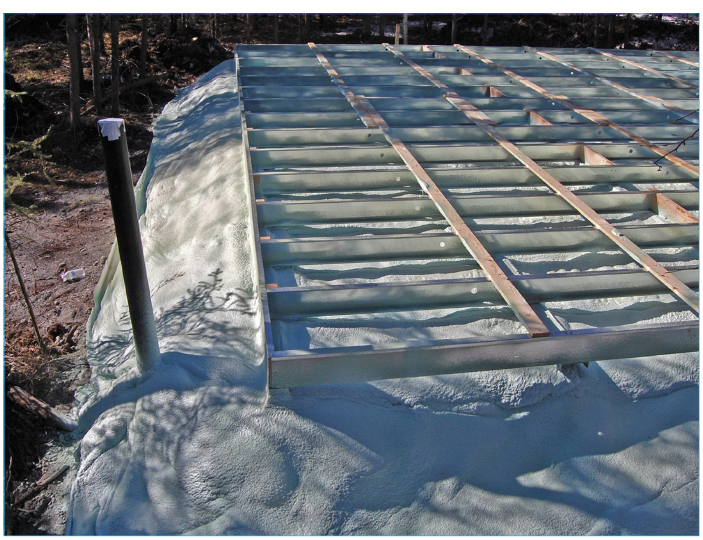


Fig. 2: *Raft foundation during construction with protruding fan pipe*

Fig. 3: *Pipe equipped with in-line fan*

In 2014, researchers installed six temperature strings to replace the original two. Two of the six were placed between the houses to serve as references and one string was placed under each of the four homes, drilled diagonally so that instrumentation could be accessed without going inside the homes. This included a string under each of the two houses with raft foundations and a string under each of the houses with piling foundations. Temperature readings from reference sensors were compared to those placed underneath the Birch and Spruce houses to determine whether the buildings affected the ground temperature outside of natural seasonal cycles (*see Fig. 6 and Fig. 8*).

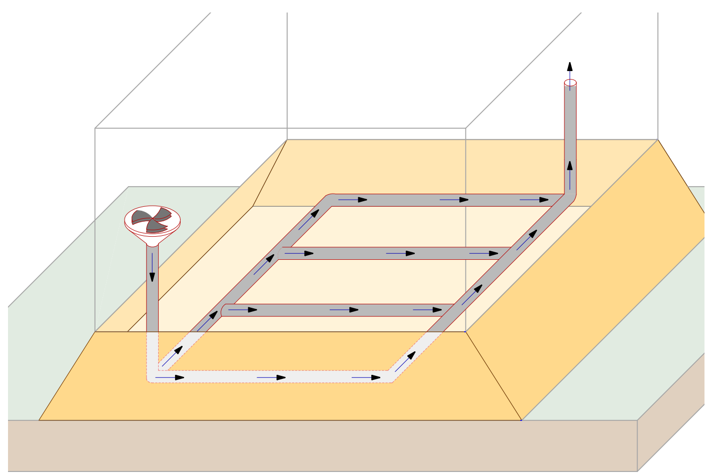
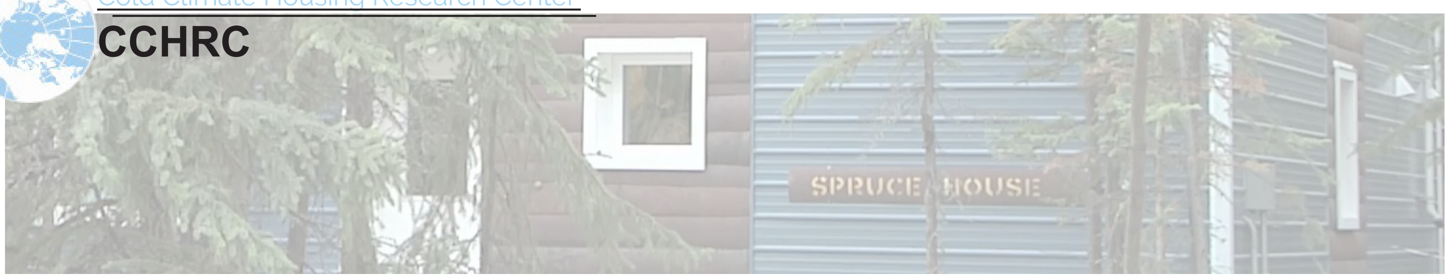


Fig. 4: *Under floor in-line fan circulation system*

A cooling system was installed in each raft foundation to stabilize the soils under the foundation. A small in-line fan circulates cold air through a pipe running throughout the foundation (*see Fig. 2*). The fans were activated in early winter in an attempt to preempt any ground thaw that may have resulted from heat loss through the floor. Fans were turned off in spring, when daily temperatures began to rise above freezing. The fan underneath the Spruce House operated 4 of the 5 past winters, while the Birch House fan operated 3 of the 5 past winters.



Temperature data for the Spruce House, seen in ***Fig. 5,*** reveals warming temperatures between 2ft-4ft during the first 24 months of testing. The rise in ground temperatures can be explained by newly introduced heat transfer from the Spruce House to the ground surface. Additionally, the loss of tree cover onsite (which would have previously reduced solar gains to the ground surface) may have contributed to ground warming.

Prior to construction, permafrost was located at a depth between 6ft - 7ft. After the Spruce House had been constructed, data collected between Sept. 2012 - June 2013 confirmed that permafrost had receded to a depth below 8ft. Data collected during the Dec. 2014 - Sept. 2017 period reveals that frozen ground was regenerated at a depth of at least 7ft by Sept. 2016 at the latest, and persisted until testing concluded.

In 2015 - 2017, the topmost ground temperatures experienced seasonal freeze/thaw cycles as expected, with little difference in ground temperatures between the 2015 and 2016 thaw seasons. It is uncertain whether fan-assisted cooling system assisted in cooling the ground underneath the Spruce House, but evidence suggests the fan system contributed. As seen in ***Fig. 6,*** the ground under the Spruce House was kept cooler than the reference site when the fan was activated, pointing to the success of the cooling system.

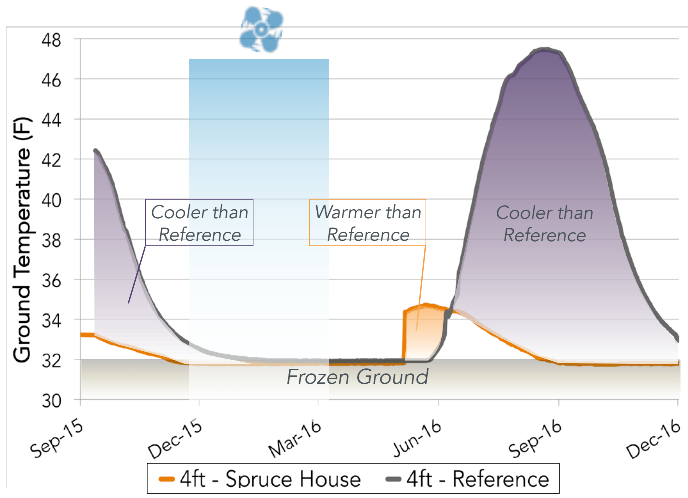


Fig. 6: *Temperature difference between Spruce House and Reference Temperature Strings*

After fan activation, ground temperatures underneath the Spruce House experienced a cooler seasonal freeze/thaw cycle than did the nearby uncovered reference site. Because the fan was the only cooling agent on the ground underneath the Spruce House, it is likely responsible for the cooler temperatures.

Gaps in data indicate failed sensors. Sensors were also replaced and moved over time to gain a better understanding of where the topmost layer of frozen ground was.

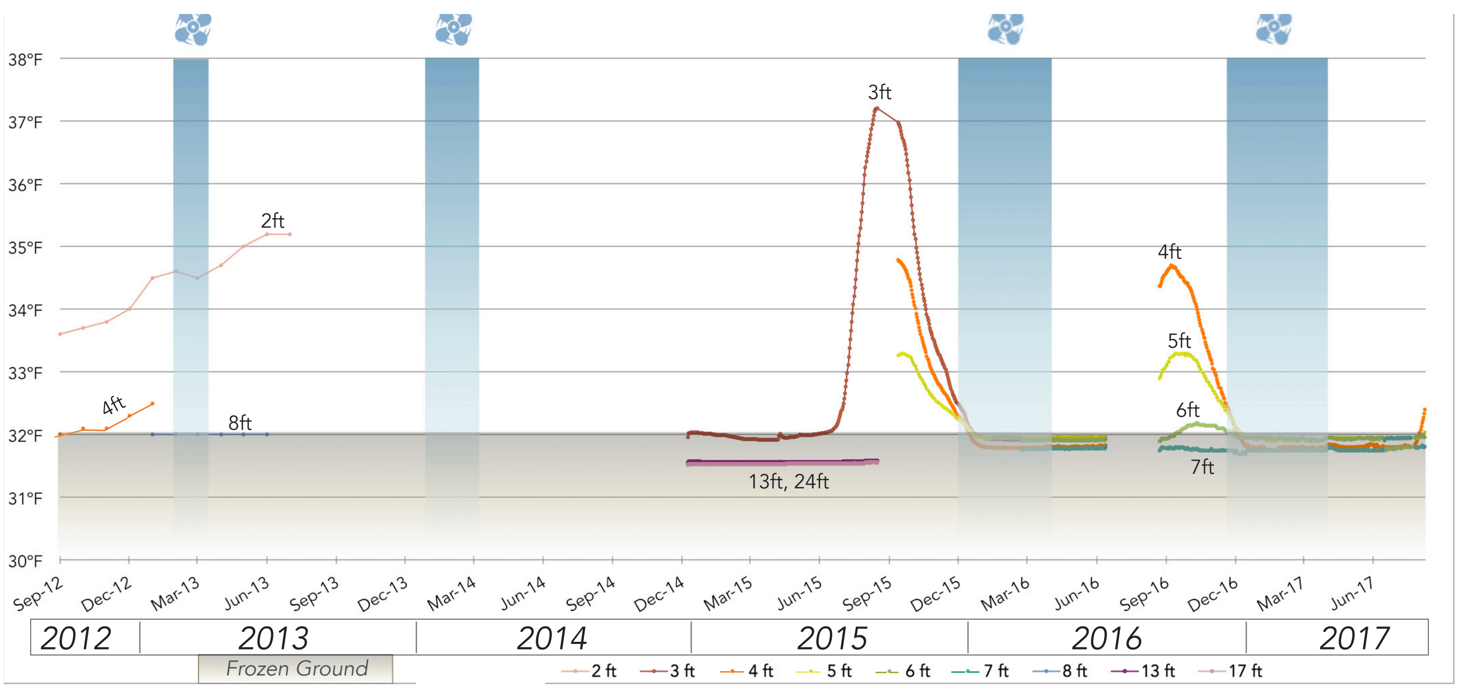


Fig. 5: *Spruce House ground temperature data*

Temperature data for the Birch House, seen in *Fig. 7*, reveals a frozen layer at least 6ft and below during the first 24 months, with a gradual warming and consequent shift of the permafrost layer to around 7ft and below. Similar to the Spruce House, the shift in the permafrost layer can be explained by heat transfer from the Birch House to the ground surface. Additionally, the loss of tree cover onsite that would have previously protected the permafrost may have contributed.

During the 2012-2014 post-construction period, the temperature sensor installed "Under Foam" is thought to have been placed directly adjacent to the fan system; potentially responsible for the dramatic temperature fluctuations recorded. Consequently, although a cooling effect is seen underneath the floor correlated to the initiation of the fan-assisted cooling system, the cooling effect of the fan is likely less intense than indicated by temperatures recorded by the sensor.

From 2015-2017, sensors showed that upper ground layers experienced seasonal freeze/thaw cycles, though the ground temperatures during the 2016 thaw period were cooler than in 2015. It is uncertain whether the cooler 2016 temperatures are due to the fan, but ground temperature comparisons between the Birch House and a nearby reference site, as seen in *Fig. 8*, suggest that the fan system is contributing to cooler ground temperatures underneath the Birch House.

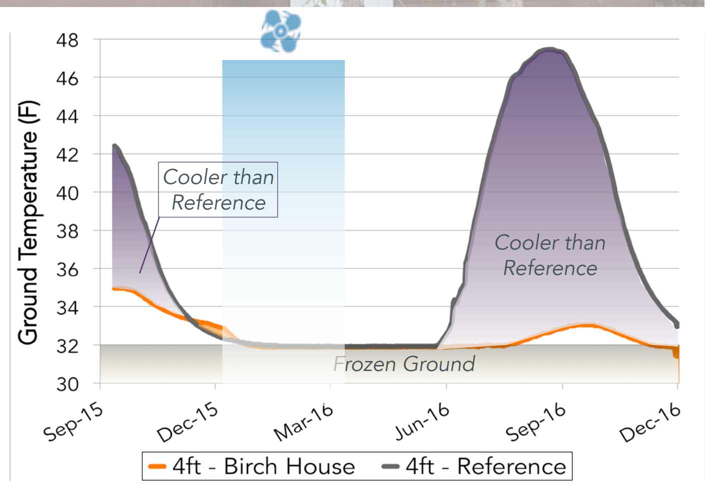


Fig. 8: *Temperature difference between Birch House and Reference Temperature Strings*

After fan activation, ground temperatures underneath the Birch House experienced a cooler seasonal freeze/thaw cycle than did the nearby uncovered reference site. Because the fan was the only cooling agent on the ground underneath the Birch House, it is likely responsible for the cooler temperatures.

In Sept. 2012, the top of the permafrost layer was below 4ft, but receded to a depth not captured by data collection. Between Dec. 2014 - Sept. 2017, frozen ground was regenerated at a depth of at 5ft - 6ft by Mar. 2016, and remained for the duration of data collection.

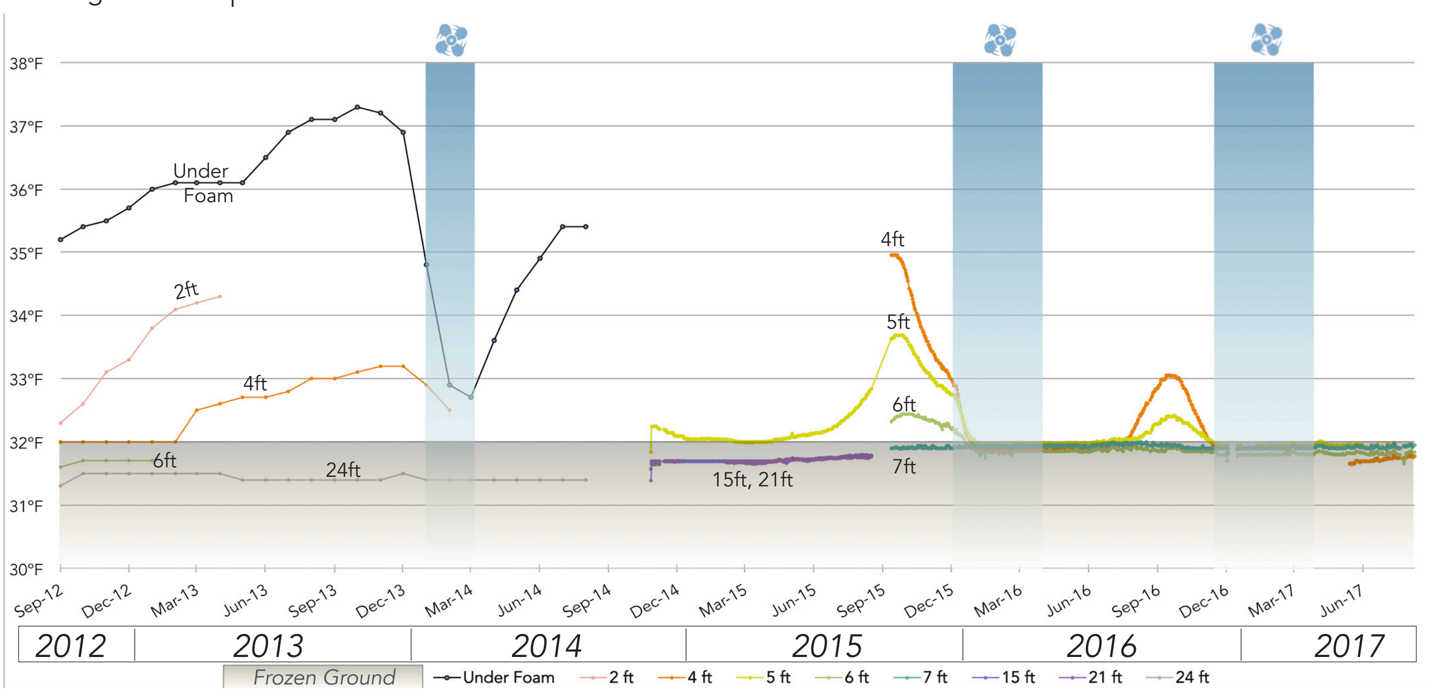


Fig 7: *Birch House ground temperature data*

Summary & Conclusions

In the first 24 months following construction ground temperatures underneath both houses warmed, likely due to initial disruption of the site during construction. Permafrost layers receded below a depth of 6ft during this time, apparently readjusting to new heat sources (heat transfer from houses, increased solar gain, loss of tree cover, etc.). After several prolonged activations of the fan-assisted cooling system during the 2013-2017 period, frozen ground was regenerated at a depth of at least 7ft, and has maintained since Fall 2015.

Comparing ground temperature data between the Spruce and Birch houses reveal consistently lower temperatures underneath the Birch House. This can be explained by the increased solar exposure of the Spruce House, located to the south of, and often shading, the Birch House. The increased solar gains, which are presumably warming the ground around the Spruce House to a higher degree than the Birch House, may also be responsible for a shift seen in the Spruce foundation and consequent drywall cracking inside the home.

During the first data collection period between 2012-2014, sensors were initially installed underground at the center of the building footprints. Conversely, during the second period of data collection from 2015-2017, sensors were installed along the perimeter of the building footprints. It is likely that the sensors placed at the center of the building footprint were predominately affected by heat transfer from the house. The sensors placed around the perimeter of the house, however, were likely affected by heat transfer from the neighboring soils in addition to heat transfer from the house. For this reason, it is possible that sensors placed in the center would read different temperatures than sensors placed along the perimeter, and possibly affect the results of the study. However, the potential temperature differences are assumed to be negligible enough that the larger trends in ground temperature were visible. In future studies of this nature, placing sensors at both the center and along the perimeter of the building footprint would be recommended in order to avoid such issues.

An analysis of the ground temperature data collected post-construction between 2012-2017 supports the conclusion that the fan-assisted cooling systems were successful in maintaining cooler ground temperatures and mitigating the effects of heat transfer from the Spruce and Birch homes to the ground beneath.

Fig. 9: *Birch House Finished Corner*

Although the raft foundations did not fully deter heat transfer from the house to the ground surface, the magnitude of heat transfer was not high enough to incur severe ground thawing, and the fan system was able to restore frozen ground that had been degraded by the presence of the homes. Considering this, the combination of a raft foundation with a fan-assisted cooling system offers a reasonable alternative to piling foundations, assuming that the fan system has been properly designed, and airflow paths remain unobstructed. For anyone considering a raft foundation, it is important to note that **the fan is necessary to maintain soil temperatures underneath the foundation.**

What is perhaps a more important consideration in choosing a permafrost-friendly foundation type is its adjustability. Given the effects of climate change on permafrost, the stability of ground conditions will become more difficult to guarantee over time. Raft foundations have the added advantage of adjustability, in the form of slab-jacking with structural foam. Thus, properly designed raft foundations, with a fan-assisted cooling system and ability to accommodate slab-jacking, are an appropriate foundation for residences resting on permafrost soils.