PENNSYLVANIA HOUSING RESEARCH CENTER

FROST PROTECTED SHALLOW FOUNDATIONS IN PENNSYLVANIA

June 2016 | Emma Dickson, Christopher Hine, and Brian Wolfgang

WHAT IS A FOUNDATION?

The foundation in residential construction is a crucial structural component that is responsible for distributing dead and live loads from above to the ground below. The foundation is also a critical assembly in the overall building enclosure, responsible for controlling heat, air, and moisture flow.

In cold climates, including Pennsylvania, a foundation must take into account the impact of frost penetration in order to function properly. The base of the foundation must extend below the regionally specific frost depth in order to prevent the earth below the foundation from heaving. Heaving occurs when moisture present in soil freezes and expands, thus exerting differential forces on structural components above the soil.

Excavating to an appropriate depth to avoid these issues has been understood for many years. However, builders and design professionals have alternatives, should excavation to this depth be impractical.

WHAT IS A FROST PROTECTED SHALLOW FOUNDATION?

In an effort to reduce the required depth to which foundations and footings must be installed, builders can take advantage of building heat loss and geothermal heating by designing and installing a frost protected shallow foundation (FPSF). Figure 1 shows the interactions between FPSF heat loss and surrounding soil temperatures. Through specific placement of insulation around the perimeter of the foundation, it is possible to raise the soil temperature and frost depth of the surrounding soil. Soil temperature is raised due to the contribution from building heat loss in winter and the accumulation of geothermal heat from below.

Frost protected shallow foundations are most suitable for slab-on-grade construction in cold climates. There are other specific scenarios when this approach may be feasible, including the presence of site and excavation limitations and walk-out basements.

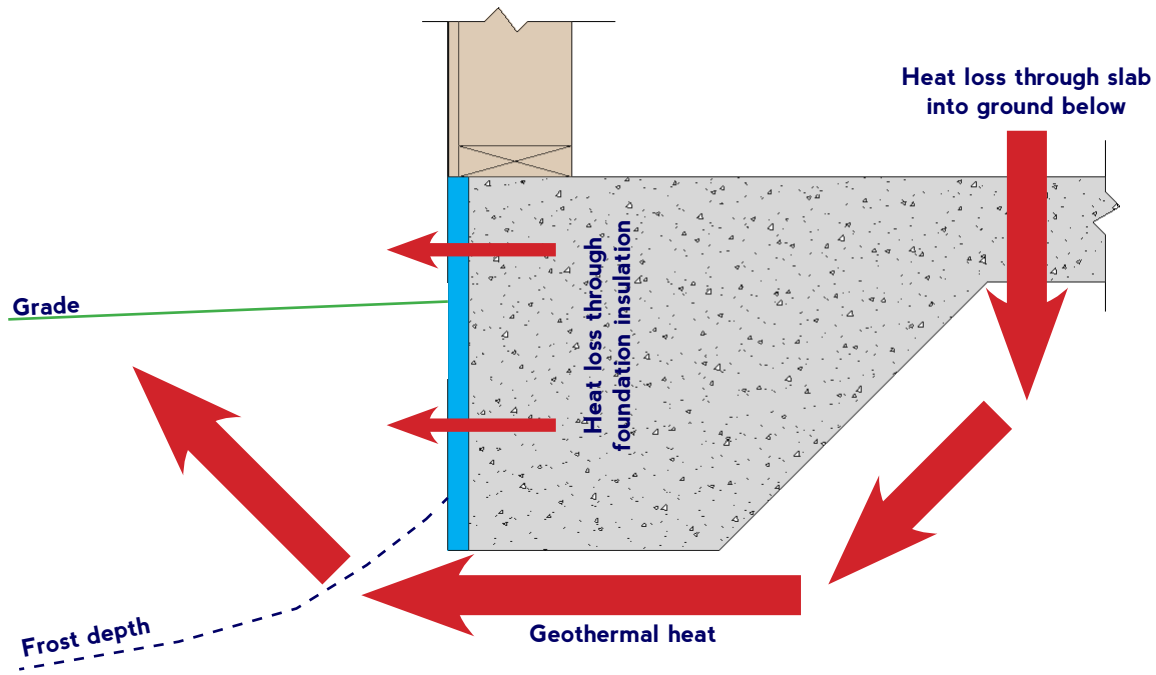

Figure 1: Impact of frost protected shallow foundations on frost depth
Frost depth is raised as it approaches the foundation due to heat loss from the building and geothermal heat from below.

ASSUMPTIONS AND LIMITATIONS

- This document does not address unheated buildings or crawlspaces.
- Buildings must maintain minimum average monthly indoor temperature greater than 64°F.
- FPSF insulation requirements may not meet current energy codes; therefore, consult currently enforceable energy code requirements.

FPSF DESIGN CRITERIA

The simplified approach to FPSF design found in the 2009 IRC is based on variables of Air Freezing Index (AFI), insulation R-value, and footing depth.

Air Freezing Index is a value which indicates the intensity of below-freezing temperatures occurring during a given heating season. This value is regionally specific. Table 1 shows varying AFI values for each county in Pennsylvania. All regions within Pennsylvania have an AFI less than 2,000. Many FPSF designs require horizontal insulation extending away from the structure in addition to vertical insulation. In regions with an AFI less than 2,000, however, only vertical insulation is necessary.

Based on the AFI of a specific county in Pennsylvania, Table 1 also lists the minimum footing depth and the vertical insulation R-value. The footing depth shown is the minimum required for meeting the structural intent of preventing frost heave and may be exceeded by the insulation depth requirements from energy code provisions.

Figure 2 shows the depth below grade of a monolithic slab that is designed to meet the FPSF requirements. Again, this depth is a minimum. The insulation shown in Figure 2 must extend to the top of the foundation, including above-grade portions. This insulation must be protected by an appropriate covering.

Table 1 also shows the minimum vertical insulation R-value for FPSF systems. This is the minimum insulation required to direct building heat loss to the surrounding soil in order for FPSF systems to function properly. The insulation specified to meet these requirements must be suitable for ground contact. Typically, expanded polystyrene (EPS) or extruded polystyrene (XPS) is used for this purpose.

As mentioned previously, the insulation required per Table 1 is the minimum amount to be provided in order to ensure the foundation is protected from frost penetration and frost heave in heated buildings. In many instances, this R-value and depth would be exceeded by currently enforceable energy code requirements. In all cases, currently enforceable code requirements and local amendments must be followed.

Table 1: FPSF insulation R-values and footing depths

Air Freezing Index (°F-days)[1]	Minimum Footing Depth, D (inches)	Vertical Insulation R-Value
1,500 or less	12	4.5
2,000	14	5.6

[1]Air Freezing Index by Pennsylvania County

AFI=2000
Berks, Blair, Bradford, Cambria, Cameron, Centre, Clarion, Clearfield, Clinton, Crawford, Elk, Forest, Huntingdon, Indiana, Jefferson, Lackawanna, Lycoming, McKean, Pike, Potter, Susquehanna, Tioga, Venango, Warren, Wayne, Wyoming

AFI=1500 or less
Adams, Allegheny, Armstrong, Beaver, Bedford, Bucks, Butler, Carbon, Chester, Columbia, Cumberland, Dauphin, Delaware, Erie, Fayette, Franklin, Fulton, Greene, Juniata, Lancaster, Lawrence, Lebanon, Lehigh, Luzerne, Mercer, Mifflin, Monroe, Montgomery, Montour, Northampton, Northumberland, Perry, Philadelphia, Schuylkill, Snyder, Somerset, Sullivan, Union, Washington, Westmoreland, York

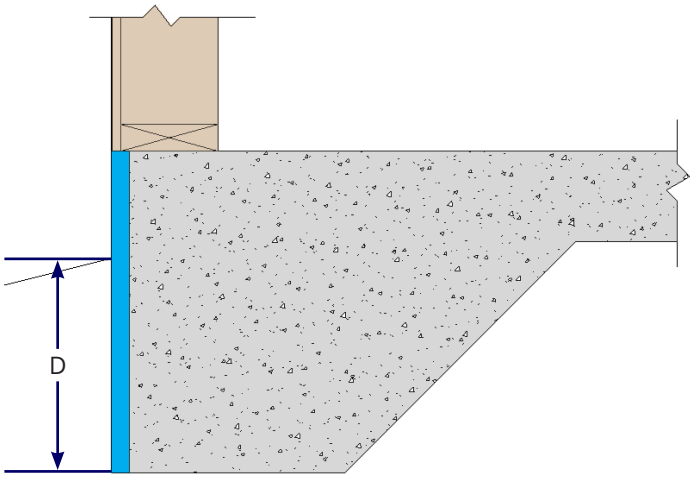

Figure 2: Frost protected shallow foundation depth and insulation placement requirements
Note: Depth below grade = D. Insulation must extend to top of foundation wall. Depth requirements also apply to stem wall construction. Energy code requirements may exceed insulation depth and R-value requirements shown in Table 1.

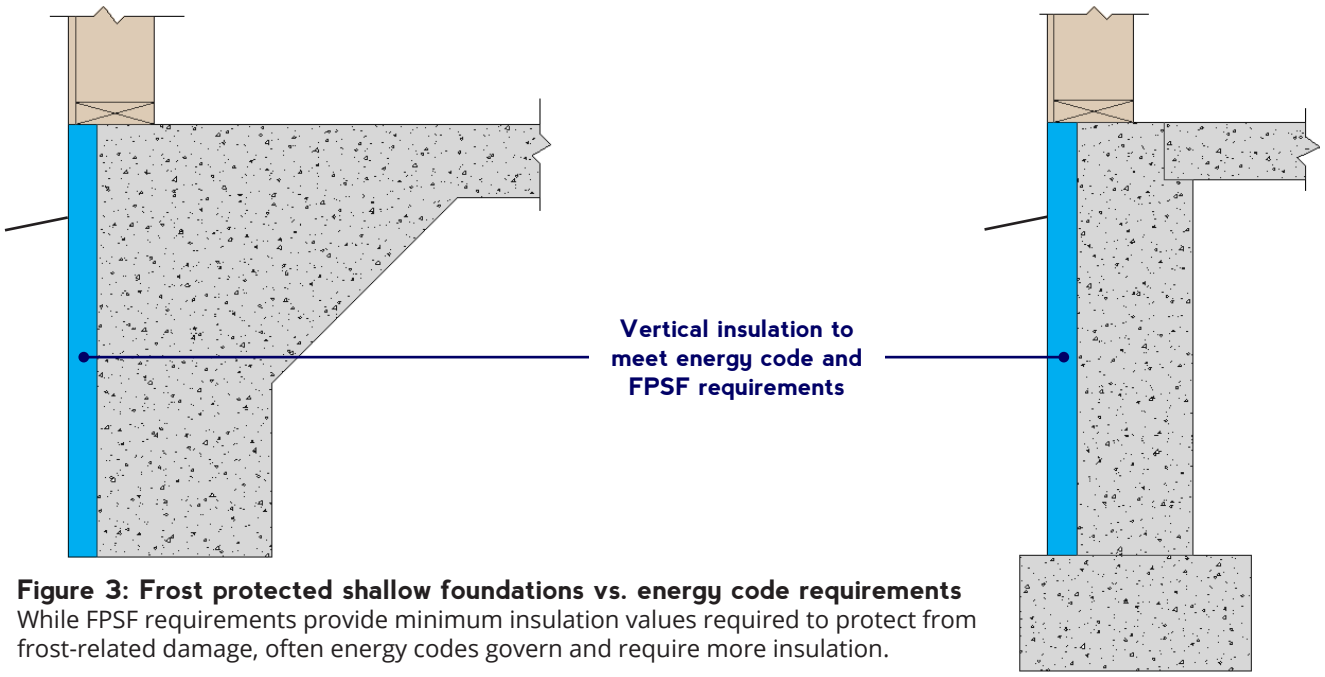

Figure 3: Frost protected shallow foundations vs. energy code requirements
While FPSF requirements provide minimum insulation values required to protect from frost-related damage, often energy codes govern and require more insulation.

FPSF AND THE ENERGY CODE

In most instances in Pennsylvania, energy code requirements for foundation insulation will govern the insulation in that assembly. For example, in a region with an AFI of 1,500 or less, the footing depth is required to be 12 inches with a vertical insulation R-value of 4.5. However, it is likely that energy codes require R-10 insulation for 2 feet. Figure 3 shows this instance. With energy codes governing, the footing depth would increase to 2 feet and the R-value to 10. This depth, however, is likely to be less than the local frost depth, meaning cost savings are still available.

However, if shallower depth is desirable (for sites with limited excavation or rock, for example), it is possible to meet energy code requirements using horizontal insulation, while meeting FPSF requirements with the minimum depth and R-value of vertical insulation. Figure 4 shows this scenario. It is important to meet all energy code requirements related to slab edge insulation. Additionally, cantilevering wall framing over vertical insulation would require additional consideration to ensure structural stability of the assembly.

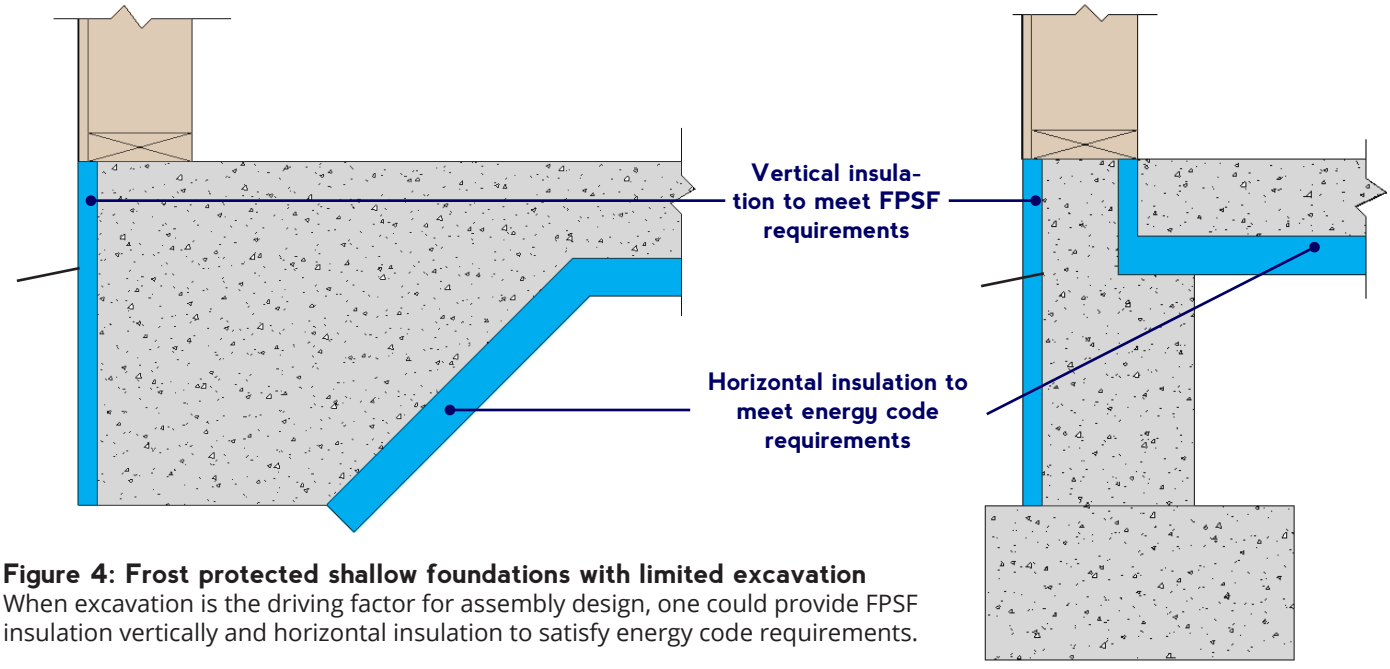

Figure 4: Frost protected shallow foundations with limited excavation
When excavation is the driving factor for assembly design, one could provide FPSF insulation vertically and horizontal insulation to satisfy energy code requirements.

FPSF WITH HEATED SLABS

In Figures 3 and 4, common scenarios were outlined regarding the comparison of FPSF and energy code requirements. Another scenario that is common in Pennsylvania would involve the inclusion of heating elements in the slab adjacent to the FPSF. Energy codes typically require the additional placement of insulation under heated slabs. Since FPSF systems rely on heat loss from the building to raise the surrounding soil temperature, there is a practical limit to the amount of insulation that can be placed under the slab before this heat loss is no longer contributing to this effect. In general, under slab insulation should be limited to R-10 in order to provide an appropriate FPSF. Figure 5 shows this scenario. In this case, R-10 insulation is required for energy code provisions, but this insulation must be placed vertically on the outside of the foundation with R-5 insulation placed under the heated slab.

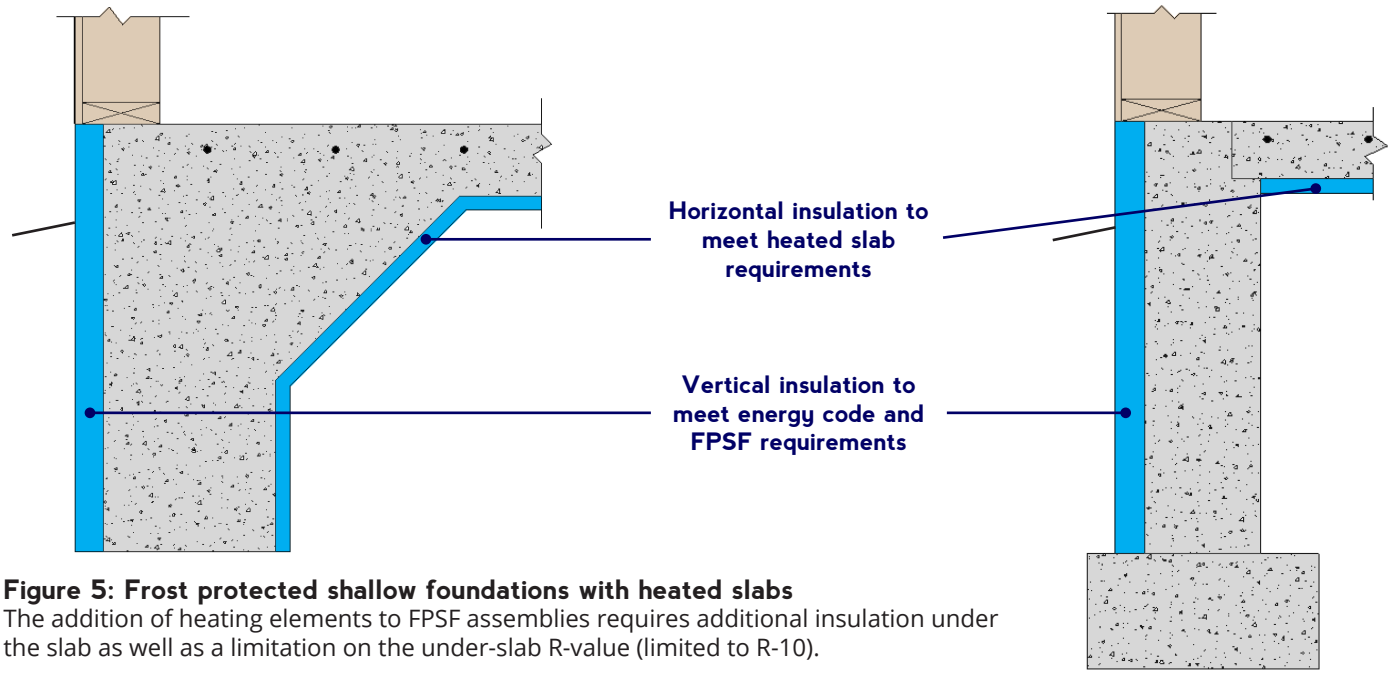

Figure 5: Frost protected shallow foundations with heated slabs
The addition of heating elements to FPSF assemblies requires additional insulation under the slab as well as a limitation on the under-slab R-value (limited to R-10).

SUMMARY

Frost protected shallow foundations are a feasible and code-approved alternative to traditional deep foundations in Pennsylvania. However, the nuances of this approach, including the stringency of energy codes, leave this as a niche option for a specific set of scenarios. It is important to understand the assumptions and limitations to this approach in order to provide a durable and energy-efficient foundation assembly.

REFERENCES

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